Regulatory framework - Part 1

Deliverable D4.1

INNOVATIVE DECISION-MAKING TOOL FOR DEFINING THE MOST SUITABLE MANURE MANAGEMENT STRATEGIES TO ACHIEVE A SUSTAINABLE LIVESTOCK FARMING SYSTEM DURING THE WHOLE VALUE CHAIN

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NUTRITIVE

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1. Executive summary

Deliverable 4.1, developed within the framework of the Nutritive project, represents a key step in understanding the complex legislative landscape governing livestock manure management. The primary focus of the work was a comprehensive mapping and study of current European regulations, designed to identify existing weaknesses and inconsistencies in the regulatory framework, such as the fragmentation of rules, the lack of quantified emission targets, and the insufficient integration of emerging pollutants.

To translate these identified gaps into actionable data, the core critical issues were re-elaborated into a structured technical questionnaire. This analytical tool consists of 40 specific questions, organized into distinct thematic areas, covering legal frameworks, technical standards for storage and application, monitoring protocols, and incentive schemes. This modular approach ensures a holistic evaluation of how different jurisdictions handle the environmental and health challenges associated with manure.

Furthermore, this document outlines the adopted strategy for data collection and dissemination. The approach aims to gather high-quality information from case studies in several European countries and insights from China. By distributing the questionnaire to key institutional and technical stakeholders, the project seeks to map national and regional specificities, distinguishing between mandatory requirements and voluntary incentives. The evidence collected through this process will provide the necessary knowledge base for the subsequent development of the Nutritive Decision Support System (DSS) and for formulating future policy recommendations aimed at a more harmonized and sustainable regulatory approach.

2. Introduction

Livestock farming is a key sector that involves 40 % of the total agricultural activity in Europe. representing a total value for products equal to € 170 billion. However, there is an increasing concern due to livestock farming's contribution to environmental pollution since it generates more than 1.4 billion tonnes/year of manure leading to significant greenhouse gases (GHG) and air pollutants emissions (NH3, NOX) as well as to soil and water contamination caused by hazardous manure chemicals and biological contaminants (called here emerging contaminants). In this context extensive effort has been carried out for years to assess the detrimental effects of farming systems and to develop abatement methods to be implemented. However, despite major advancements, many fundamental issues are beyond the scope of existing legislation.

The main objective of NUTRITIVE is to develop a decision-making tool (DSS, decision support system) able to define the most efficient and sustainable (in its three pillars: environmental, economic, and social) manure management strategies for a given livestock farm limiting manure air emissions as well as soil and water contaminants. This will allow for the formulation of technical guidelines and recommendations that will support policy makers with enhanced knowledge to establish requirements for future European policies.

To fulfil this objective, the project is divided into six work packages (WP): WP1 Up-to-date inventory; WP2 Novel management strategies/technologies investigation; WP3 Modelling and Life Cycle Assessment (LCA); and WP4 Guidelines formulation; WP5 Communication, dissemination, and exploitation; WP6 Management (Figure 1).

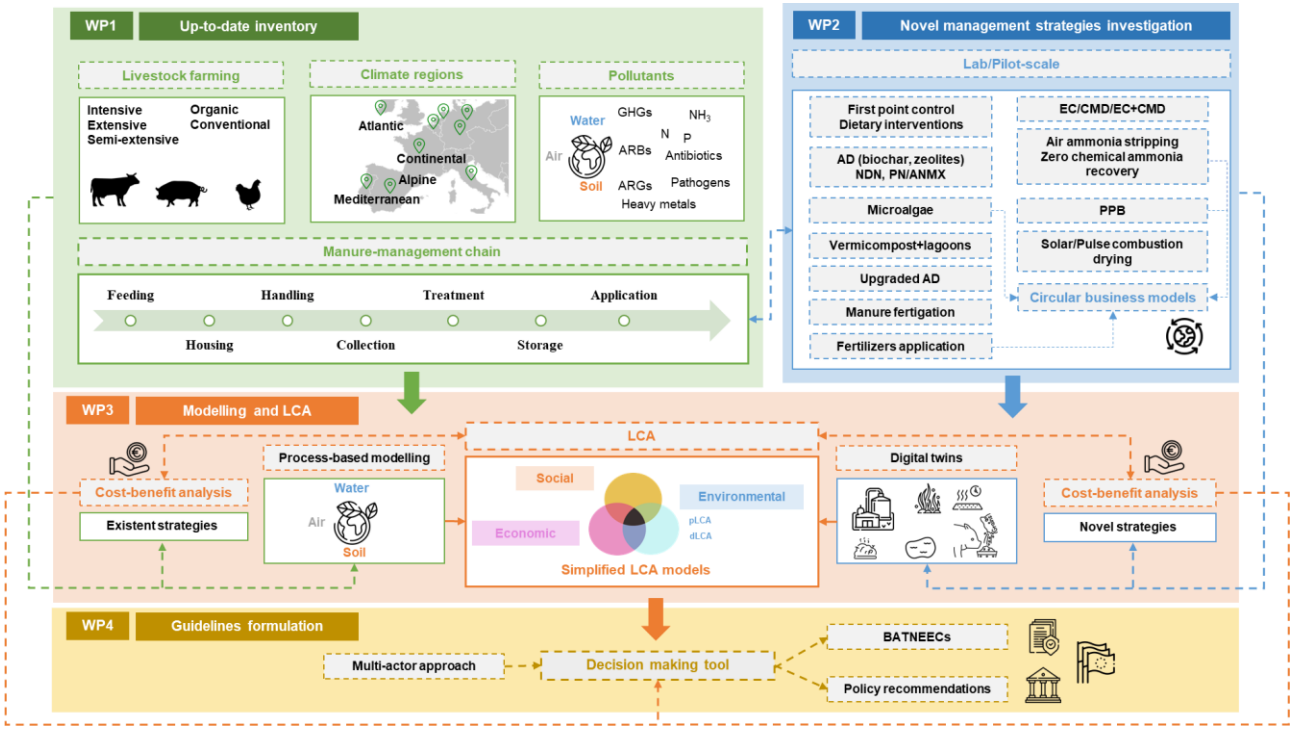

Figure 1. NUTRITIVE methodology.

NUTRITIVE anticipates a wide spread of the project outcomes, with the synthesis of the consortium as a baseline: 22 partners (4 Chinese) from 8 different countries across Europe, covering 6 climatic regions (2 Chinese ones), representing the whole supply chain experts, from animal feed to soil application.

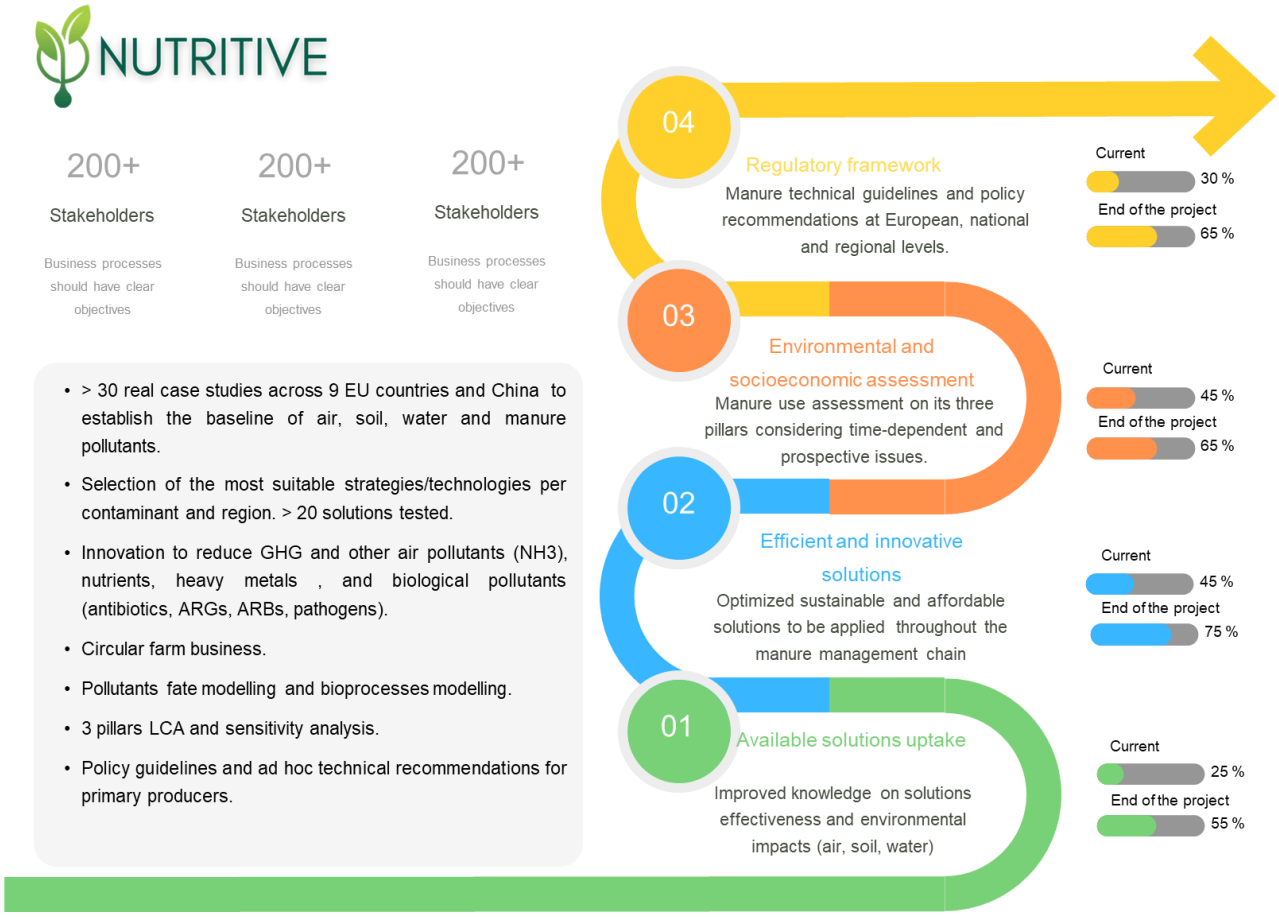

Figure 2. NUTRITIVE overview.

Task 4.1. is about European, national and regional regulations affecting manure management. An analysis of current regulatory frameworks affecting manure management will be carried out. The state-of-the-art will be updated and further detailed at European, national and regional levels to identify (un)successful policies, while taking into account differences in agro-ecological conditions, livestock species, and production systems. Sustainability synergies and trade-offs in agri-environmental regulations and directives that affect manure management will be considered. Various sustainability aspects are envisaged in this literature search, including gaseous emissions, soil preservation, water quality, animal health, welfare, and productivity, and human health. Attention will be paid to the potential multitude, multidimensionality, and (lack of) complexity of agri-environmental regulations, which can lead to clashes during implementation. The need for improved monitoring of current agri-environmental policies or stronger restrictions regarding certain pollutants will be evaluated. Moreover, the need for harmonised policies and/or environmental quality thresholds will be discussed at different spatial scales based on WP1 and WP3 outcomes.

3. Nutritive Technical Report on EU Regulatory Framework

This section introduces the foundational activity of Task 4.1. The primary objective of this phase was to conduct a systematic reconnaissance of the European legislation that directly or indirectly governs livestock manure management. The analysis focused on the main legislative acts impacting various environmental matrices (air, water, soil) and emerging issues (processed products, health):

- Directive (EU) 2016/2284 (National Emission Reduction Commitments Directive - NEC)
- Regulation (EU) 2021/1119 (European Climate Law)
- Water Framework Directive (WFD) 2000/60/EC
- Nitrates Directive 91/676/EEC
- Regulation (EU) 2019/1009 on EU Fertilising Products
- EU Soil Strategy for 2030
- Directive 86/278/EEC on Soil Protection (Use of Sewage Sludge in Agriculture)
- Animal By-products and Derived Products Regulation (EU) 1069/2009/EC
- Antimicrobials, Resistance, and Environmental Persistence in Regulation (EU) 2019/6.

This mapping exercise allowed for the delineation of a regulatory framework characterized by the fragmentation and overlap of instruments. The crucial outcome of this preliminary analysis was the identification, for each thematic area, of the regulatory gaps and areas where EU legislation is still generic or lacks binding and quantifiable requirements. These gaps formed the logical and structural basis for the creation of the Regulatory Analysis Questionnaire (or Questionnaire on Manure Management) used for the subsequent phase of regional data collection.

The complete and detailed text of the: Nutritive Technical Report on EU Regulatory Framework is included in this Deliverable report as **Annex 1**.

4. Questionnaire on Manure Management within European and National Regulatory Framework

Based on the regulatory gaps identified during the analysis of the EU framework, Regione Lombardia proceeded with the formulation of a detailed Regulatory Analysis Questionnaire. This instrument served as the first formal attempt to translate the critical issues and areas of uncertainty raised by the Nutritive Technical Report into a set of precise, actionable questions.

To ensure a thorough and qualitative analysis of diverse national and regional regulations, the questionnaire was deliberately structured using open-ended questions. This methodology was crucial for capturing local specificities and allowed European partners to fully describe the specific measures adopted at their respective national/regional levels, including legislative acts, quantitative limits, and operational protocols.

The questionnaire was divided into six interconnected thematic areas (Air, Climate, Water, Soil, Derived Products, and Health) to align with key EU environmental policies. This comprehensive approach was designed to cover the entire lifecycle and environmental impact of manure management.

Subsequently, the Regulatory Analysis Questionnaire was condensed into a Reduced Version with the primary goal of streamlining the document for partner submission. This strategic choice was adopted to significantly lighten the data collection workload across different national and regional contexts, while still maintaining the core reference points for the critical issues within the various thematic areas. The structure and content of the Reduced Questionnaire are fully based on the previous, extended version, ensuring complete methodological consistency.

To ensure maximum uniformity and accuracy in responses, this reduced version includes an Explanatory Introduction on the compilation modalities, emphasizing that responses are considered relevant only if they concern a binding and specific regulatory requirement for manure management, thus distinguishing legal obligations from mere incentives or recommendations.

The extended Questionnaire and the Reduced Version are provided in this Deliverable as **Annex 2** and **Annex 3**, respectively.

The Reduced Version, which also includes the detailed answers elaborated for the Lombardy Region case study to serve as a comprehensive compilation example for the partners, is provided as **Annex 4**.

5. Methodology for Data Collection and Country Selection

The core activity of Task 4.1 is the compilation and analysis of the Regulatory Analysis Questionnaire across selected European countries and regions. The approach is structured to ensure both high data quality and broad geographical coverage, while balancing allocated partner workload (person-months).

The selection strategy is structured in two distinct phases:

- Phase 1. The initial compilation and detailed analysis are assigned to the three partners with dedicated person-months, who will be responsible for data collection and analysis within their respective territorial contexts:
    - Italy, Regione Lombardia - Focusing on the highly intensive livestock area of the Po Valley, serving as the pilot example
    - Ireland, TEAGASC
    - Spain, Galicia Region (AGACAL)
- Phase 2. To maximize the impact and general validity of the results, the analysis will be extended to 7 additional countries, leveraging in-kind support from other project partners without additional budget transfer.

Regione Lombardia and AGACAL will lead the data collection effort for these extension cases. This involves:

- Providing the questionnaire template and technical support to the in-kind partners
- Receiving existing regulatory documentation and key information from the in-kind partners

- **Final Compilation:** Regione Lombardia and AGACAL will subsequently **compile the questionnaire** for these extension countries based on the documentation and data provided by the in-kind partners

Initial targets for this phase include:

- Belgium (EV ILVO, VITO, DETRICON)
- France (ENSMP, ARMINES)
- Germany (ATB)
- Netherlands (TU DELFT)
- Portugal
- Denmark
- China (XIHUA, SICHUAN)

The completion of the questionnaire is based on a strict set of criteria to ensure that the analysis focuses solely on *binding* regulatory provisions:

1. Mandatory Nature: Responses must strictly refer to mandatory and binding legal instruments (Laws, Decrees, Action Programmes, etc.), explicitly separating mere recommendations, incentives, or voluntary guidelines.
2. Specificity and Quantification: The measures cited must be specific to manure management (or livestock effluents) and must include quantifiable limits, specific technologies, or measurable reduction targets, distinguishing them from generic agricultural regulations.

All data collected through the questionnaires will be systematically analysed to identify areas where national/regional regulations successfully integrate or exceed EU requirements (strengths) and areas where gaps and regulatory uncertainties still persist (gaps).

The complete analysis, comparison, and synthesis of all regulatory frameworks from both phases, including the identified strengths and gaps, will be presented in the **Deliverable D4.2** (Regulatory Framework - Part 2) at **Month 30** of the project.

The inclusion of the Chinese case study involves a dedicated methodological approach: to ensure practical implementation, the questionnaire initially developed for the European countries has been previously shared with the Chinese partners to be progressively adapted to their specific regulatory and operational context. In line with the contributions of other in-kind partners, China is providing the necessary documentation and data required for its compilation. Significant progress has already been achieved regarding the air-related sections of the framework, as it is possible to see in **Annex 5**. The same operational procedure will be maintained to collect and analyse data concerning the other thematic areas of the questionnaire. This adaptation process is supported by regular meetings between the European and Chinese teams to monitor progress, resolve methodological issues, and ensure alignment between the different regulatory systems. It is noted that this process will require a higher degree of complexity, specifically in decoupling certain queries from the context of European Union regulations. China's involvement is strategically significant, as a non-European perspective offers a broader outlook on manure management approaches, enhancing the global relevance and robustness of the project's findings.

ANNEX 1

Nutritive Technical Report on EU Regulatory Framework

Summary

Introduction

The Complex European Regulatory Framework and Manure Management: An In-Depth Technical Analysis

The sustainable management of manure is a crucial challenge for European agriculture, with direct impacts on water quality, soil health, antimicrobial resistance, and the transition towards a circular economy. The European Union has developed a **complex and articulated regulatory framework** to address these issues, through directives and regulations that, although with specific objectives, deeply intersect in the regulation and impact of manure management.

This detailed technical analysis examines the main **relevant European regulations**, including the **Nitrates Directive (91/676/EEC)**. For each regulation, the original objectives, strengths, and, above all, the specific **criticalities and weaknesses in relation to manure management** will be explored, highlighting the **operational and scientific gaps** that require further intervention to ensure a truly integrated and effective approach. The aim is to provide a technical overview that sheds light on the complexities and opportunities for improvement on the path towards more sustainable manure management, in line with the EU's environmental ambitions.

Air quality

Directive (EU) 2016/2284 (National Emission Reduction Commitments Directive - NEC)

Directive (EU) 2016/2284, known as the NEC Directive, sets national emission reduction commitments for Member States for five key atmospheric pollutants: sulfur dioxide (SO2), nitrogen oxides (NOx), non-methane volatile organic compounds (NMVOCs), ammonia (NH3), and fine particulate matter (PM2.5), with deadlines in 2020 and 2030. The objective is to significantly reduce the harmful effects of air pollution on human health and the environment. Member States must develop National Air Pollution Control Programmes (NAPCPs) to outline the policies and measures to achieve these commitments. Ammonia (NH3) emissions are particularly relevant for agriculture and, consequently, for **manure management**. The Directive encourages Member States to consider applying Best Available Techniques (BAT) and promote the adoption of low-emission agricultural techniques.

While the NEC Directive represents a crucial step for air quality, its criticisms regarding manure management stem from its **top-down, national commitment-based approach**, which can lead to variability in implementation at the farm level and insufficient granularity in targeting specific manure-related emission sources.

Lack of Specific and Quantifiable Targets for Different Stages of Manure Management

The Directive sets national percentage reduction commitments for NH3. Although agriculture is responsible for approximately 90-95% of total NH3 emissions, the Directive does not impose specific reduction targets for individual stages of manure management (e.g., housing, storage, spreading) or for specific livestock sectors. This delegates to Member States the choice of the "most cost-effective" measures, often without a homogeneous approach.

- **Undifferentiated Targets by Source:** For example, no specific reduction targets (e.g., 40% by 2030 compared to 2005) are set for NH3 emissions from covers on liquid manure storage facilities, or a 75% reduction target for emissions generated during manure spreading. This lack of granularity allows Member States to focus on "easier" or less impactful measures on manure management.
- **Adoption of BAT and Low-Emission Technologies:** While mentioning the adoption of BAT (such as those described in the BREF documents for intensive rearing of pigs and poultry - IRPP BREF), the Directive does not impose a binding obligation for a minimum percentage of farms (e.g., 80% by 2025) to adopt low-emission techniques for liquid manure application (e.g., direct injection or band spreading). The adoption of these techniques can reduce NH3 emissions by 60-90% compared to broadcast spreading, but their diffusion remains variable due to the lack of specific mandates or targeted incentives.

Uncertainty and Limitations in Monitoring and Reporting Real Manure Emissions

Verifying actual emission reductions at the farm level for diffuse sources like manure is complex, and national inventory methods present significant uncertainties.

- **Uncertain Emission Factors (EFs):** National emission inventories are based on Emission Factors (EFs) that often have high uncertainty, estimated around ± 30-50% for NH3 from spreading, due to variability in climatic factors, manure characteristics, and agricultural practices. The Directive does not impose the obligation of direct on-site emission monitoring by sampling (e.g., through eddy covariance systems or inverse dispersion techniques) in a representative number of farms to calibrate and validate the EFs, reducing the accuracy of estimates.
- **Lack of Small-Scale Data:** Reporting is predominantly at national or regional levels. There is no requirement for systematic collection of georeferenced and quantitative data on specific manure management practices (e.g., type of housing, storage duration, application technology, incorporation times) at the individual farm level. This data deficiency prevents a precise and targeted evaluation of interventions and a more accurate quantification of emission reductions attributable to specific practice changes.

Insufficient Integration with a Holistic Approach to Nutrient Management and the Circular Economy

The Directive focuses on NH3 as an atmospheric pollutant but does not explicitly promote an integrated approach that links ammonia emission reduction to broader sustainable nutrient management or circular economy principles.

- **Manure Treatment Technologies:** No specific targets are set for the adoption of manure treatment technologies (e.g., anaerobic digestion, solid-liquid separation, acidification) which, in addition to reducing NH3 (e.g., slurry acidification can reduce NH3 emissions from storage by 40-70% and from spreading by 30-50%), contribute to more efficient nitrogen and phosphorus management. The lack of such specific targets or incentives limits the diffusion of practices that simultaneously improve air quality and nutrient management.

- **Cross-Media Effects:** Measures for NH3 reduction can have unintended effects on other environmental compartments. For example, rapid incorporation of manure to reduce NH3 can, under certain soil conditions, increase N2O (nitrous oxide) emissions, a potent greenhouse gas. The Directive does not include a requirement for quantitative assessments of cross-media effects or for defining synergistic mitigation targets that consider all pollutants (air, water, soil) resulting from manure management.

Obligation to Develop National Air Pollution Control Programmes (NAPCPs): Platform for Technical Implementation

NAPCPs (Article 6) are not merely administrative documents; they mandate a thorough **technical assessment** of agricultural emission sources and mitigation measures. This implies:

- **Detailed Identification of NH3 Sources from Manure:** Requires the disaggregation of NH3 emissions based on different manure management stages (housing, storage, processing, spreading) and different types of livestock (pigs, cattle, poultry). This analysis provides a technical mapping of critical emission points and opportunities for specific interventions (e.g., identification of regions or livestock types with the highest emissions, measurable in tonnes of NH3/year).
- **Evaluation of Available Measures:** NAPCPs require a review of existing and potential policies and measures, including agricultural ones, to reduce NH3 emissions. This involves a **technical evaluation** of the effectiveness of different manure management technologies and practices (e.g., stable ventilation systems, rapid manure removal systems, phase separation, anaerobic digestion). Each measure has a quantifiable NH3 abatement potential (e.g., low-emission ventilation in pig stables can reduce emissions by 20-30%).

Promotion of Best Available Techniques (BAT) and Low-Emission Agricultural Techniques: Guiding Technical Standards

While not a universal mandate, the reference to BAT (e.g., from BREF documents, particularly the IRPP BREF) and the promotion of low-emission techniques (Article 7, Annex III) establish a **technical benchmark of excellence** for manure management. This drives towards:

- **Adoption of Advanced Spreading Technologies:** The Directive encourages the use of techniques that reduce contact between manure and air during spreading. These are specific technologies that require investment in advanced machinery:
    - **Trailing hose/shoe:** Reduces NH3 emissions by 60-70% compared to broadcast spreading.
    - **Direct injection into soil:** The most effective technique, with NH3 reductions exceeding 90%. The pragmatic implication is that Member States are incentivized to create subsidy programs or technical support for the adoption of these machines.
- **Advanced Storage Management:** Technical solutions for covering slurry storage pits are promoted. Floating or fixed covers (e.g., foils, membranes, straw bales) are technical solutions that reduce NH3 emissions from storage by 60% up to 90% (for hermetic fixed covers).

The NEC Directive is fundamental for air quality, but to improve its effectiveness in manure management, regulatory integrations are needed that introduce **more specific and quantifiable emission reduction targets** for different stages of manure management, requirements for more detailed emission monitoring and the adoption of low-emission technologies, and a more holistic approach that integrates NH3 reduction with circular nutrient management and the mitigation of cross-media effects.

Regulation (EU) 2021/1119 (European Climate Law)

Regulation (EU) 2021/1119, the "European Climate Law," provides the legal basis for the EU's commitment to achieve **climate neutrality by 2050** and sets an intermediate target of at least a **55% net reduction in greenhouse gas (GHG) emissions by 2030**, compared to 1990 levels. Although the law does not directly regulate specific agricultural practices, it imposes a general legal obligation on all sectors, including agriculture and, indirectly, **manure management**, to contribute to these ambitious climate goals.

Lack of Direct Regulatory Specificity and Granular Targets for Manure Management

The Climate Law defines GHG reduction targets at the overall EU and national levels but does not include direct and detailed regulatory provisions on how livestock farms should manage manure to reduce emissions. This absence of a "technological mandate" or "mandatory best practices" at the EU level for the livestock sector leaves a regulatory gap.

- **Absence of Specific Emission Intensity Limits:** The law does not impose, for example, maximum CH4 emission intensity limits (e.g., g CH4/kg of protein produced or per unit of manure stored) for different manure management systems. This means there's no binding technical requirement for farms to achieve a certain emission efficiency.
- **Lack of Mandatory Abatement Targets for Phases:** No mandatory and quantifiable abatement targets are defined (e.g., a minimum 70% reduction of CH4 emissions from slurry storage) for new or existing manure management facilities. The absence of such benchmarks makes it difficult to enforce the widespread adoption of low-emission technologies like gas-tight covers (which can reduce CH4 by over 80%).

Strong Reliance on Inconsistent National Implementation and Variable Ambition of National Energy and Climate Plans (NECPs)

While National Energy and Climate Plans (NECPs) are the implementation vehicle, the Climate Law does not prescribe the minimum ambition level or the specific technical measures that Member States must adopt for manure management. This can lead to inconsistent strategies and uneven progress across the EU.

- **Variability in Treatment Obligation:** There is no binding EU-level target for the percentage of manure to be treated with anaerobic digestion (AD) or other advanced technologies. Some Member States may not have any obligation, while others might incentivize, but not mandate, the treatment of a small percentage (e.g., <10% of total manure), missing the opportunity to reduce CH4 by 50-80% and produce bioenergy.
- **Uncertainty on the Diffusion of Low-Emission Technologies:** The adoption of low-emission spreading technologies (e.g., direct injection, band spreading) that significantly reduce N2O and CH4

emissions (e.g., N2O reductions of up to 50% for injection compared to surface spreading) depends on national incentives, which are optional. There is no EU target that mandates, for example, that 50% of liquid manure be applied with low-emission technologies by a certain date.

Challenges and Uncertainties in Monitoring, Reporting, and Verification (MRV) of Diffuse Manure Emissions

The Climate Law does not provide detailed technical methodologies or enforcement mechanisms for the MRV of diffuse agricultural emissions at the farm level, making precise attribution and verification of reductions from manure management difficult.

- **High Uncertainty of Inventories:** The emission factors (EFs) used in national inventories for CH4 and N2O from manure management show significant uncertainties (e.g., ± 30-60% for CH4 from storage, ± 50-100% for N2O from soils after application). The law does not require the implementation of higher-resolution monitoring programs (e.g., through field sensors, flux chambers, or micrometeorological techniques) on representative farm samples, which could reduce these uncertainties and provide more robust data on the actual effectiveness of measures.
- **Lack of Verifiable Farm-Level Data:** There is no mandate for the systematic and verifiable collection of data at the individual farm level on specific manure management practices (e.g., volumes stored, storage times, temperatures, composition of treated manure, GPS data on spreading). This gap makes it difficult to directly correlate emissions with practices and, consequently, attribute reductions to specific interventions.

Limited Consideration of Cross-Media Effects and Environmental Trade-offs

As a climate law, the primary focus is on GHGs. This can lead to neglecting or not adequately addressing potential negative cross-media effects on other environmental compartments (water, air – non-GHG) resulting from measures implemented to reduce GHGs from manure.

- **Integrated Nutrient Management:** An integrated technical assessment approach that simultaneously considers the impact of manure management strategies on all key pollutants (e.g., reduction of CH4 and N2O but also NH3, prevention of nitrate and phosphorus leaching) is not explicitly required. For instance, some measures to reduce CH4 (e.g., pit covers) can increase costs or management complexity without guarantees of co-benefits on other pollutants if not integrated into an overall plan.
- **Risk of Pollution Transfer:** Measures aimed at reducing one type of emission can sometimes increase another. For example, rapid incorporation of manure into the soil to reduce NH3 emissions (a non-GHG air pollutant) could, under certain moisture and soil conditions, favor N2O emissions. The Climate Law does not provide an explicit technical framework for quantifying and managing these trade-offs, risking suboptimal solutions from an overall environmental perspective.

While the European Climate Law provides the political impetus and ultimate objectives, its criticalities lie in the **lack of direct technical and operational prescriptions on manure management**, the **reliance on potentially inconsistent national implementation**, the **challenges of MRV for diffuse emissions**, and the **limited integration of cross-media effects**. Overcoming these criticalities will require more specific regulations and targeted funding for advanced technical solutions in the livestock sector.

Water quality

Water Framework Directive (WFD) 2000/60/EC

The Water Framework Directive (WFD) 2000/60/EC establishes a framework for Community action in the field of water policy, with the main objective of achieving "good ecological status" and "good chemical status" for all EU waters (rivers, lakes, transitional, coastal, and groundwater) by specific deadlines (generally 2015, with possibilities for extension). The Directive requires Member States to:

- Identify river basin districts.
- Characterize river basin districts to assess water status.
- Monitor water status.
- Define "environmental objectives" for each body of water.
- Develop and implement "river basin management plans" (RBMPs) and "programmes of measures" (PoMs) to achieve these objectives.
- Promote sustainable water use and protect aquatic ecosystems. The WFD adopts an integrated approach that considers all pressures on water bodies, including diffuse pollution sources (such as those from agriculture), which are directly relevant to **manure management**.

Despite the WFD being an ambitious and comprehensive piece of legislation for water protection, its weaknesses in relation to manure management stem from its nature as a high-level framework directive, which grants discretion to Member States, and from the challenges in managing diffuse pollution.

Difficulty in Quantifying and Attributing Diffuse Pollution from Manure

The WFD explicitly aims to reduce diffuse pollution from agriculture. However, quantifying the precise contribution of manure to nutrient loads (nitrogen and phosphorus) and contaminants (e.g., veterinary drug residues, pathogens) in water bodies is scientifically and technically complex. Although the Directive requires the identification of significant pressures (Article 5) and the establishment of monitoring networks (Article 8), the direct attribution of specific water quality problems to manure management practices (compared to other fertilizers, soil erosion, etc.) remains a challenge. This makes it difficult to design precisely targeted and quantitatively effective "Programmes of Measures" (PoMs) for manure.

This complexity leads to PoMs that can be generic rather than specifically optimized for manure. For example, while promoting "basic measures" such as those provided by the Nitrates Directive (Art. 11, para. 3, point (a)), the WFD does not prescribe how to measure the specific impact of manure application methods (e.g., surface spreading vs. injection) on runoff or nutrient leaching. It also does not set quantitative targets for reducing pollution from manure distinct from other agricultural sources, hindering the implementation of targeted manure management strategies.

Variability in Implementation and Application of Programmes of Measures by Member States

The WFD provides a regulatory framework but grants Member States considerable flexibility in designing their River Basin Management Plans (RBMPs) and Programmes of Measures (PoMs) (Article 11). This flexibility

can lead to significant disparities in the ambition and effectiveness of measures, particularly regarding diffuse agricultural pollution. Some Member States may prioritize other sectors or implement less stringent measures for manure management, resulting in insufficient progress towards water quality objectives.

The effectiveness of measures directly related to manure, such as restrictions on spreading periods, storage capacity requirements, or the promotion of specific application techniques, heavily depends on national interpretation and application within the PoMs. For instance, a PoM might generically state the need to reduce nutrient runoff but may lack quantitative enforcement mechanisms (e.g., regular inspections or penalties linked to specific non-compliances in manure application) that would lead to a measurable reduction (e.g., 20% reduction) in nitrogen or phosphorus loads from manure in specific water bodies.

Lack of Specific Quantitative Targets for Contaminants Not Included as "Priority Substances" and Directly Linked to Manure

The WFD identifies "priority substances" (Annex X) for which environmental quality standards (EQS) must be met. However, it does not explicitly list or provide specific quantitative targets for a wider range of contaminants that can originate from manure, such as veterinary medicinal product residues (antibiotics, hormones) or pathogens (bacteria, viruses). While requiring the prevention of pollution from "other pollutants" (Art. 1, para. 2, point (d)), the lack of specific EQS for manure-related contaminants makes their control less direct and measurable.

This is a critical gap. For example, although the WFD requires good chemical status, it does not set specific quantitative limits for the concentration of oxytetracycline (a common veterinary antibiotic) in surface waters, which could largely derive from manure runoff, nor specific targets for the reduction of *E. coli* or *Salmonella* directly linked to manure in agricultural runoff. This limits the ability to design and apply PoMs that specifically target these emerging concerns.

Instrumental Limitations in Quantifying and Attributing Manure Pollution

Despite the WFD aiming to control diffuse pollution, its effectiveness is limited by the difficulty of specifically quantifying the contribution of manure to pollutant concentrations (nitrates, phosphates, pathogens, pharmaceutical residues) and distinguishing that contribution from other agricultural or non-agricultural sources. Conventional monitoring techniques often do not discriminate the exact origin.

- **Specific Markers:** PoMs rarely mandate the use of advanced molecular or isotopic markers (e.g., stable nitrogen isotopes $\delta^{15}N$ and $\delta^{18}O$ to differentiate nitrates from manure/synthetic sources; host-specific genetic markers like *Bacteroidales* to identify fecal contamination of animal origin) that could precisely attribute specific pollutant loads to manure. This prevents a quantitative estimation of the percentage contribution of manure to the total N or P load in a water body, making it difficult to optimize measures.
- **Predictive Modeling:** PoMs do not always require the application of complex hydrological-agricultural models (e.g., SWAT, DAISY) calibrated with specific data on manure management (type, quantity, timing, and application methods) to accurately predict the impact on runoff and leaching. Without these models, setting quantifiable reduction targets (e.g., -15% N leached from manure per hectare) is based on less accurate estimates.

- **Manure Nitrogen Use Efficiency (NUE):** Impact predictions do not account for the variability of manure NUE (often less than 50-60% for organic N in the first year), which leads to an N surplus in the soil and potential leaching, even when respecting the 170 kg N/ha limit of the Nitrates Directive.

Inadequate Harmonization and Lack of Specific Data in the Implementation of Programmes of Measures (PoMs)

The discretion granted to Member States in formulating PoMs (Article 11) has led to inconsistent implementation. Manure-related measures often lack technical specificity and robust mechanisms for verifying effectiveness.

- **Monitoring of Application Compliance:** There is no standardized requirement for quantitative monitoring of manure spreading practices compliance. For example, the frequency of on-farm inspections (currently <5% in many regions) is insufficient to verify adherence to spreading ban periods or the use of low-emission techniques. This leads to estimated ammonia (NH3) losses exceeding 30% of total N in liquid manure during surface spreading.
- **Operational Data Reporting:** Standardized and georeferenced reporting on the quantities of manure produced, treated (e.g., digestate, compost), and applied to land at the individual farm level is not mandatory. This gap prevents an accurate evaluation of the effectiveness of PoMs in promoting the shift from raw manure to treated manure (e.g., a target of 20% of anaerobically digested or composted manure by 2030) to improve effluent quality and reduce emissions.

Absence of Environmental Quality Standards (EQS) for Emerging Contaminants and Microorganisms in Manure

The WFD sets EQS for "priority substances" (Annex X), but not for a wide range of emerging contaminants or microorganisms of health concern that can result from manure management. This is a significant gap in water protection.

- **Veterinary Medicinal Product (VMP) Residues:** The WFD does not establish EQS for specific VMPs (e.g., tetracyclines, sulfonamides, diclofenac) or their metabolites that are excreted and persist in manure, subsequently reaching waters. Concentrations of VMPs in manure can range from ng/g to µg/g, and their subsequent runoff can lead to concentrations in surface waters in the order of ng/L, contributing to AMR.
- **Antimicrobial Resistance Genes (ARGs):** There are no EQS for ARGs or resistant bacteria. Manure is a hotspot for the spread of ARGs. The lack of quantitative thresholds (e.g., number of copies/mL or colony-forming units/mL for specific ARGs like *bla*CTX-M or *mcr*-1) limits the ability to assess and manage this risk in waters.
- **Pathogens and Fecal Indicators:** Although the WFD aims to reduce pollution, no specific limits or reduction targets are imposed for indicators of fecal contamination such as *E. coli* or *Enterococci* of livestock origin in surface waters affected by agricultural runoff (e.g., a 90% reduction target for ruminant-specific *E. coli* near agricultural discharge points). This is particularly relevant for the safety of recreational and drinking waters.

The WFD provides a solid foundation for water protection. However, to effectively address issues related to manure management, **regulatory and operational integrations are needed that include more precise attribution methodologies, binding quantitative targets for manure pollution reduction, more rigorous compliance monitoring mechanisms, and the introduction of EQS for emerging contaminants specific to the livestock sector.**

Nitrates Directive 91/676/EEC

The Nitrates Directive 91/676/EEC is a fundamental legislative instrument of the European Union, aimed at preventing and reducing water pollution (surface and groundwater) caused by nitrates of agricultural origin. The Directive requires Member States to identify polluted or at-risk waters (Article 3, paragraph 1), designate Nitrate Vulnerable Zones (NVZs), and draw up and implement mandatory Action Programmes (PoAs) for these zones (Article 5). A cornerstone of these PoAs is the maximum limit of **170 kg of nitrogen from manure per hectare per year** in NVZs (Annex III, point 2, letter a)).

Despite its crucial role, the application of the Nitrates Directive presents technical and operational criticalities, particularly evident in the context of manure management:

Ineffectiveness of the 170 kg N/ha Limit and Optimization of Nitrogen in Manure

The limit of 170 kg of total nitrogen from manure per hectare per year, while being a reference, is often insufficient to prevent significant nitrate leaching, especially in high-intensity production systems or on soils with reduced retention capacity. The Directive focuses on nitrogen input but not sufficiently on the dynamics of nitrogen release from manure into the soil and its utilization efficiency by crops.

- **Effectively Available Nitrogen:** The limit refers to total nitrogen, not considering the fraction actually available to crops, which varies from 20-60% in the first year for organic N depending on the type of manure, treatment, and climate. Unstabilized manure (e.g., raw slurry) releases nitrogen more rapidly, increasing the risk of leaching if crop demand is exceeded or during heavy rainfall events.
- **Lack of Dynamic Nutrient Balances:** The Directive does not impose the obligation for detailed nutrient balances at the individual plot level, which would consider in real-time the actual crop demand, manure mineralization, and losses. This leads to an estimated average over-fertilization of 15-25% of nitrogen in many agricultural areas.
- **Inter-annual Variations:** The Directive does not provide agile mechanisms to modulate the 170 kg N/ha limit based on climatic variations (e.g., excessive rainfall or drought) or expected yields, which directly influence N uptake by crops and, consequently, the risk of N leaching from manure.

Technical Deficiencies in Manure Storage and Application Management

The Directive's requirements (Annex III) on storage capacity and application methods are often interpreted and implemented sub-optimally, leading to significant nutrient losses and environmental impacts.

- **Ammonia (NH3) Emissions:** The Directive promotes the adoption of "application techniques that minimize losses" (Annex III, point 2, letter d)), but implementation is often lacking. Surface spreading of liquid manure without immediate subsequent incorporation can cause volatilization losses of am-

monia (NH3) exceeding 30-50% of ammoniacal N within a few hours of application. NH3 then contributes to N deposition in sensitive ecosystems and PM2.5 formation.

- **Inadequate Storage Capacity:** Despite the requirement for sufficient storage capacity for periods when spreading is prohibited (Annex III, point 1, letter a)), in many farms, the capacity is less than the theoretically required 6 months, forcing spreading during suboptimal periods (e.g., saturated soils), increasing the risk of dissolved N and P runoff by 20-40%.
- **Manure Treatment:** The Directive promotes manure treatment (e.g., anaerobic digestion, composting) but does not impose quantitative targets for the percentage of manure to be treated or for the reduction of specific pollutants (e.g., N, P) through such processes. This limits the adoption of technologies that could stabilize N, reduce volume, and concentrate nutrients, facilitating their management.

Inadequacy of Monitoring and Compliance at the Operational Level

Water status monitoring and the effectiveness of PoAs (Article 6) are often insufficient to provide detailed feedback on specific agricultural practices, including manure management. The Directive lacks rigorous compliance verification mechanisms at the individual farm level.

- **Frequency of Field Controls:** The frequency of compliance inspections on farms to verify manure management practices (e.g., recording of applied quantities, spreading periods, correct equipment calibration) is often low, typically less than 2-5% of farms/year. This reduces deterrent effectiveness and data collection on actual implementation.
- **Manure Composition Data:** Periodic analysis (e.g., at least annually or every 500 m³ of manure produced) of the chemical composition of manure (total N, ammoniacal N, P2O5, K2O) at the farm level is not a stringent requirement. Without this specific data, the calculation of applied N doses is based on average tabular values, which can deviate from reality by as much as +/- 20-30%.
- **Specific Impact Indicators:** Water monitoring focuses on nitrates but does not include more specific indicators of manure impact such as dissolved organic nitrogen (DON) or specific microbial markers of animal origin (e.g., *E. coli* or *Enterococci* of bovine/swine origin), which could provide a more direct indication of manure losses.

Poor Optimization of Manure Nitrogen and Insufficient 170 kg N/ha Limit for Leaching Prevention

The 170 kg N/ha limit refers to total nitrogen, ignoring the release kinetics and actual availability for crops, which vary drastically depending on the type of manure and treatment. This can lead to an imbalance between applied nitrogen and actual crop demand, resulting in significant leaching.

- **Nitrogen Fractions and Mineralization:** Manure contains both highly available Ammoniacal Nitrogen (NH4+-N) and slowly mineralizing Organic Nitrogen (Org-N). In liquid bovine manure, NH4+-N can represent 50-70% of total N. If manure application is not synchronized with the crop's peak uptake phases, NH4+ can rapidly nitrify to NO3- and leach. The Org-N mineralization process is equally crucial; only 20-40% of Org-N is generally available in the first year, but the Directive does not require a dynamic estimation or a specific effectiveness coefficient that goes beyond often generic tabular values.

- **Real Nitrogen Balance:** There is no obligation to use Decision Support Systems (DSS) or advanced nutrient balance models that integrate real-time data (e.g., pre-sowing soil analysis, weather forecasts) to optimize the N dose from manure and achieve a manure Nitrogen Use Efficiency (NUE) greater than 70%. Currently, the actual NUE from manure in many agricultural practices can be even less than 40-50%, resulting in an average surplus of 30-50 kg N/ha/year contributing to pollution.
- **Risk Prediction:** The Directive does not impose the use of predictive leaching risk models (e.g., based on simulated water and nitrogen balances) that consider specific soil characteristics (e.g., organic matter content > 4%, sandy texture) and manure type to adjust the dose and timing more precisely than the simple 170 kg N/ha limit.

Technical Inefficiencies in Manure Storage and Application, with High Nutrient Losses

The measures provided for manure storage and application, if not adequately implemented or supported by specific technologies, lead to significant nitrogen and phosphorus losses to the environment.

- **Storage and Emissions:** Many manure storage facilities are not adequately covered or sealed. Open lagoons can generate NH3 volatilization losses of 40-60% of ammoniacal N during the storage period. The absence of a stringent requirement for mandatory covering of slurry pits (e.g., >60% reduction in NH3 emissions) is a gap.
- **Outdated Application Techniques:** The persistence of surface broadcast or splash-plate spreading is critical. These techniques can cause NH3 volatilization losses of up to 80-90% of ammoniacal N within 24-48 hours if the manure is not immediately incorporated (within 4 hours). The introduction of a strict obligation for direct injection (NH3 reduction >90%) or band spreading (NH3 reduction >60%) for liquid manure in all NVZs is a missing pragmatic requirement.
- **Phosphorus Losses and Runoff:** Inadequate storage and application can increase the risk of dissolved reactive phosphorus (DRP) runoff. Storage basin ruptures or application overload on saturated or frozen soils can release hundreds of kg of P per hectare in a single event, causing eutrophication. The Directive does not impose specific practices or technologies for quantifiable reduction (e.g., 25% reduction) of DRP from manure.

Insufficiency of Monitoring and Compliance Verification at Field Level

The monitoring and compliance verification system is often too aggregated and not sufficiently focused on individual agricultural practices to identify specific sources of manure pollution.

- **Frequency and Quality of Manure Analysis:** Periodic and frequent analysis (e.g., quarterly or for every 1000 m³ of manure produced) of the chemical composition of manure (total N, ammoniacal N, P2O5, K2O, Dry Matter) at the individual farm level is not a standardized requirement. Dependence on average tabular values can lead to calculation errors in applied dosages of +/- 20-30%, rendering fertilization planning ineffective.
- **Traceability and Digital Recording:** The lack of a mandatory digital and georeferenced recording system for manure applications (e.g., use of GPS on agricultural machinery to track date, time, volume/surface applied) prevents timely verification of compliance with PoAs and direct correlation with

water quality monitoring data. Currently, verification often relies on paper records or declarations, with an estimated accuracy of less than 70%.

- **Risk-Based Field Controls:** Field inspections to verify compliance with manure management measures are often too sporadic (inspection rate less than 5% of farms/year). A more intensive risk-based control system (e.g., 10-15% of farms in NVZs with prior non-compliance) for storage and spreading practices would be necessary.

To improve the effectiveness of the Nitrates Directive in a more sustainable manure management context, **reforms are essential that go beyond the mere quantitative N limit.** These should include **dynamic and precise nutrient balances, obligations and incentives for the adoption of advanced storage and application technologies (with quantifiable reduction targets), and a more granular, technologically advanced, and frequent field monitoring and compliance verification system.**

Soil preservation

Regulation (EU) 2019/1009 on EU Fertilising Products

Regulation (EU) 2019/1009 sets out rules for the making available on the market of EU fertilising products, expanding harmonization beyond just inorganic fertilizers to include recycled and organic materials, with the aim of promoting the circular economy. The regulation amends Regulation (EC) No 1069/2009 and Regulation (EC) No 1107/2009.

The Regulation classifies fertilising products into Product Function Categories (PFCs) and Component Material Categories (CMCs), each subject to specific safety and quality requirements. Attention is paid to the containment of contaminants such as cadmium and impurities derived from organic waste.

Despite the intention to promote the use of organic materials, the Regulation presents some critical issues in **manure management**:

Definition and Determination of the "Endpoint" for Manure-Derived Products (CMC 10)

The regulation states that products derived from Regulation (EC) No 1069/2009 (including manure-based materials) are not subject to the requirements of that regulation once they have reached an "**endpoint in the manufacturing chain**." However, the determination of this endpoint is complex and must follow the procedures laid down in Regulation (EC) No 1069/2009. The Commission must carry out an assessment to verify the possibility of establishing such an endpoint.

The lack of a clear and timely definition of the "endpoint" for treated manure (e.g., compost, digestate) slows down the integration of these materials into the harmonized fertilising product market. Until the endpoint is reached, the product remains subject to the administrative burdens of Regulation (EC) No 1069/2009. This limits the free movement and the economic incentive for the large-scale production of manure-derived fertilizers, hindering the efficient utilization of these nutrients.

Standardization and Specificity of Quality Requirements for Processed Manure

The regulation introduces CMCs for derived materials, such as CMC 11 for by-products under Directive 2008/98/EC, which includes compost (CMC 3) and digestate (CMC 4 and 5). While limiting contaminants, the Regulation does not provide specific quantitative standards for all **potential pollutants** present in manure, such as antibiotic residues or pathogens, which are not always eliminated during treatment.

Manure is a heterogeneous material that can contain veterinary medicinal product residues and pathogens. Although the regulation establishes safety and quality requirements, the absence of stringent quantitative standards specific to the biological and chemical safety of manure-derived fertilizers can entail environmental and health risks. This reduces the confidence of producers and farmers, limiting the large-scale adoption of such products.

Optional Harmonization and Market Fragmentation

Regulation (EU) 2019/1009 allows for optional harmonization. Non-harmonized products can be placed on the internal market in accordance with national law.

While optionality is useful for local markets, it leads to regulatory fragmentation. Different national regulations for manure management and fertilizer production can create **technical and administrative barriers** for operators intending to commercialize treated manure transnationally, reducing the efficiency of nutrient transfer from surplus areas (e.g., areas with high livestock density) to those with deficits.

EU Soil Strategy for 2030

The "EU Soil Strategy for 2030" (Commission Communication COM (2021) 699 final) is a policy document that aims to achieve a good state of soil health by 2050. It recognizes soil as a vital resource for food production, regulation of water and carbon cycles, biodiversity, and the provision of ecosystem services. The strategy identifies the main processes of soil degradation (erosion, loss of organic carbon, contamination, salinization, compaction, loss of biodiversity) and proposes a future legally binding instrument for soil health restoration, setting restoration targets. The Strategy promotes sustainable soil management practices, including nutrient and organic matter management, elements directly linked to **manure management**.

While strongly promoting soil health and sustainable practices, the Strategy presents weaknesses related to manure management, primarily due to its programmatic and not yet regulatory nature:

Lack of Immediate Binding Targets and Specific Quantitative Measures for Soil Health (with impact on optimizing manure application).

The Strategy sets a long-term vision for "healthy soils by 2050" and proposes a future legally binding instrument. However, in its current form as a "Communication," it does not impose specific, directly applicable, and quantitative **targets for soil management** that prescriptively dictate how manure should be managed to contribute to soil health. No percentages are specified for the annual increase in soil organic carbon (SOC) or for the improvement in nutrient retention efficiency resulting from manure application.

The absence of legally binding targets and immediate quantitative metrics for increasing SOC, nutrient retention, or improving soil microbial biodiversity reduces direct incentives for farmers to optimize manure application for long-term soil health benefits. This could maintain the emphasis on short-term productivity rather than on a holistic approach that fully values manure as a source of stabilized organic matter.

Generality in the Principles of "Sustainable Nutrient Management" and "Circular Economy" without Implementation Details for Manure.

The Strategy emphasizes sustainable nutrient management, loss reduction, and the transition to a circular economy, including the recycling of organic matter from waste and wastewater (Chapter 2.2). However, these are high-level strategic statements.

Although manure is a key element for nutrient recycling and organic matter, the Strategy does not include operational details or specific quantitative requirements for its management. For example, it does not define minimum standards for manure pre-treatment to improve nutrient availability, reduce pathogen load, or decrease residual contaminants. Nor are quantitative targets set for increasing the percentage of **treated manure** (e.g., digestate, compost) compared to raw manure applied to land. This lack of specificity can limit the translation of strategic principles into concrete and effective agricultural practices for manure management.

Emphasis on Research and Knowledge Gaps (indicating the current lack of data and operational tools on the impact of manure on soil).

The Strategy recognizes the need for more research, data, and a better understanding of soil processes and the impact of agricultural practices. It calls for improved monitoring and indicators of soil health.

This admission implies the existence of knowledge gaps regarding the precise and long-term impacts of different manure management practices (e.g., raw vs. treated manure, application methods and frequencies) on specific soil health indicators (e.g., microbial diversity, water retention capacity, carbon sequestration). Without robust quantitative data and evaluation tools derived from such research, it is difficult to prescribe optimal manure management practices that can ensure measurable and verifiable improvements in soil health across different soil types and agricultural systems.

The EU Soil Strategy for 2030 provides an ambitious and necessary vision for soil health, valuing the role of organic matter and nutrient cycling. However, its main "weakness" lies in the **absence of immediate, legally binding, and highly quantitative targets, and specific operational methodologies for manure management.** These elements would be essential for translating strategic principles into tangible and measurable improvements in soil health at the farm level.

Directive 86/278/EEC on Soil Protection (Use of Sewage Sludge in Agriculture)

Directive 86/278/EEC aims to protect the environment, particularly the soil, from pollution caused by the use of sewage sludge in agriculture. It sets limits for heavy metal concentrations in the receiving soil and in the sludge itself, as well as defining usage methods to prevent harmful effects on soil, vegetation, animals, and humans. The Directive specifies analysis parameters (pH, cadmium, copper, nickel, lead, zinc, mercury, chromium) and sampling methods for soil and sludge.

Directive 86/278/EEC presents significant limitations and a reduced connection to manure management, mainly due to its specific scope and date of adoption.

Exclusive Scope on Sewage Sludge, Not Manure.

The Directive is explicitly focused on "sewage sludge." Its entire regulatory framework, from definitions to limits and monitoring requirements, was designed for this specific type of material. Manure is neither mentioned nor directly regulated by this Directive.

This is the most significant criticality. The Directive does not directly address manure management. Therefore, potential risks associated with heavy metals, organic contaminants, or other pollutants present in manure are not subject to the specific limits or monitoring requirements of this Directive. The regulation of heavy metals in manure, although often present at lower levels than in sludge, falls under other, more recent and broader regulations (e.g., Regulation (EU) 2019/1009 on EU Fertilising Products).

Outdated Contaminant List and Potentially Insufficient Limits.

Having been adopted in 1986, the list of heavy metals (cadmium, copper, nickel, lead, zinc, mercury, chromium) and the related maximum permissible limits (Annexes IB and IC) may not be up to date with current scientific knowledge on environmental risks. Crucially, the Directive does not consider the presence of emerging contaminants, such as microplastics, or residues of organic pollutants (e.g., veterinary medicinal product residues), which are relevant for organic materials applied to soil.

While the heavy metal content in manure is generally lower than in sludge, the absence of limits or consideration for antibiotic residues, antimicrobial resistance (AMR) genes derived from the excretion of veterinary medicinal products, or microplastics (which can come from animal feed or bedding), represents a significant gap. If this Directive were to be broadly applied to organic amendments, its list of contaminants and limits would be inadequate to cover current issues related to manure.

Focus on "Input Control" Rather than "Process Control" or Risk Assessment for Manure Quality.

The Directive focuses primarily on controlling maximum heavy metal concentrations in sludge and soil. It adopts an "input control" approach.

For manure, especially in the context of circular economy objectives and more recent regulations (such as Regulation (EU) 2019/1009), there is a growing need for "process control" (e.g., ensuring effective treatments like anaerobic digestion or composting) and "risk assessment" that considers not only heavy metals but also pathogens and AMR. The framework of this Directive does not provide specific methodologies or requirements for the treatment processes of organic materials like manure to ensure their overall safety and quality beyond basic heavy metal limits.

In summary, Directive 86/278/EEC is a fundamental piece of legislation for the use of sewage sludge, but it has minimal direct relevance or impact on manure management due to its specific scope. Its limitations, if hypothetically applied to manure, would include an outdated list of contaminants and a narrow focus on heavy metals alone, neglecting a wider range of issues (pathogens, AMR, organic pollutants) relevant to modern manure management practices.

Human health & animal health, welfare, and productivity

Animal By-products and Derived Products Regulation (EC) 1069/2009/EC

According to Regulation (EC) No 1069/2009, manure is indeed classified under **Category 2** animal by-products. This categorization indicates an intermediate level of health risk. The overall objective of this regulation is to prevent or minimize risks to public and animal health arising from ABPs, as well as to safeguard the safety of the food and feed chain.

The regulation provides various valorisation and disposal options for Category 2 materials, including manure, if health risks are adequately controlled. Permitted uses include:

- **Manufacture of organic fertilizers and soil improvers:** Manure can be used to produce organic fertilizers. If Category 2 materials (such as meat and bone meal) are used in these fertilizers, they must be mixed with a component (e.g., an inorganic or indigestible substance) and permanently marked to prevent their direct use as feed. Such mixing is not necessary if the composition or packaging of the products, particularly those intended for the final consumer, prevents improper use as feed. Manufacturing must take place under conditions suitable for preventing risks to public and animal health.
- **Composting or conversion into biogas:** Manure can be composted or converted into biogas. This process can occur after pressure sterilization and permanent marking of the resulting material. However, for manure, digestive tract content, milk, milk products, colostrum, and eggs/egg products, conversion into biogas or compost can also occur without prior processing, if the competent authority deems that they do not present risks of spreading serious transmissible diseases.
- **Direct application to land:** Manure, as well as digestive tract content (separated), raw milk, colostrum, and derived products, can be applied to land without prior processing, provided that the competent authority deems that there are no risks of spreading serious transmissible diseases. This practice is considered safe if the manure is "adequately treated to prevent the transmission of diseases during their use on land."

Contrary to the statement in the abstract that "no limits are set for these pollutants, neither mitigation strategies are suggested," it is important to note that Regulation (EC) No 1069/2009 establishes conditions and technical requirements for the handling, treatment, processing, and storage of ABPs, including process parameters (time, temperature, pressure) for treatment methods other than pressure sterilization, and parameters for conversion into biogas or compost. These are direct measures for mitigating health risks.

Ineffectiveness of Official Controls and Lack of Compliance

Official controls on manure management as an ABP (Category 2) are not always sufficiently robust, leading to non-compliant practices that increase risks. Specifically:

- **HACCP Plans:** On farms or at manure treatment plants (e.g., biodigesters), HACCP principles or equivalents for manure management (storage, treatment, transport) may be inadequate or not applied correctly. This is crucial for preventing the persistence of pathogens (bacteria, viruses, parasites) and the spread of antimicrobial resistance (AMR) carried by manure.

- **Specific Audit Protocols for Manure:** The Commission (through implementing acts) should impose detailed audit protocols for establishments managing or treating manure, requiring verification of 95% compliance of critical control points (CCPs) identified in HACCP plans. This includes measuring temperature, hydraulic retention time (HRT) in anaerobic digesters, and sanitization for dedicated sections.
- **Risk-Based Environmental Monitoring:** Introduction of the obligation for an environmental sampling program (e.g., surfaces, runoff water) with tests for indicator pathogens (e.g., *Enterobacteriaceae*, with a limit of <100 CFU/g) and for antimicrobial resistance genes (e.g., via qPCR for specific genes like *bla*CTX-M or *mcr*-1) in 10% of high-throughput manure processing plants, with a mandatory mitigation plan in case of detection.
- **Separation and Storage:** Incorrect separation of manure from other ABPs or food products, and inadequate storage (e.g., lack of impermeabilization, insufficient capacity), increase the risk of environmental contamination (soil, water) and diversion. Considering (16) and Article 21, paragraph 1, point (a) requires the prevention of cross-contamination and storage under hygienic conditions.
- **Traceability:** The traceability of manure, from producer to final user or treatment plant, is often lacking, hindering risk management in case of contamination. Article 21, paragraph 1, point (c) and Article 22 impose traceability and record-keeping.

Logistical, Technical, and Economic Challenges in ABP Processing and Management

The management and valorization of manure as a resource (e.g., for energy or fertilizers) face significant obstacles:

- **High Logistics Costs:** Manure has a high-water content and density, making its long-distance transport economically unfeasible. This limits delivery to centralized treatment plants.
- **Inefficiency in Processing:** Manure treatment technologies (e.g., anaerobic digestion, composting, drying) require significant investments and complex processes to ensure pathogen reduction and nutrient stabilization, as required for Category 2 material intended for land use (e.g., Annex V, Chapter II of Regulation (EU) No 142/2011, which implements 1069/2009, establishes standard processing methods). The quality of the resulting digestate or compost can be variable, affecting market acceptance.
- **Lack of Robust Markets for Derived Products:** Despite the potential, the market for digestate, compost, or fertilizer from treated manure is not always developed, making the economic sustainability of treatment plants difficult.
- **Risk of Diversion and Misuse:** The co-location of ABP and human food production lines, or poor segregation of materials, can create opportunities for the diversion of ABPs into the food chain, posing a safety risk.

Need for Greater Regulatory Clarity and Harmonization of Interpretations

Although Regulation 1069/2009 and its implementing regulation (EC) No 142/2011 provide detailed rules, practical application for manure can differ among Member States. This manifests in:

- **Definition of "End Point":** The determination of when treated manure ceases to be an ABP and becomes a "derived product" no longer subject to the strict health rules of Regulation 1069/2009 can be interpreted differently, creating uncertainty for operators.
- **Specific Hygiene and Treatment Criteria:** Although Regulation 142/2011 specifies processing methods for Category 2 material, the practical application and validation of these processes (e.g., pathogen reduction) can vary, leading to different safety levels for treated manure. Article 24, point (a) of Regulation 1069/2009 refers to requirements for establishments treating ABPs.

Inadequate Management of Microbiological and Chemical Risks (Pathogens and Contaminants)

Regulation (EC) No 1069/2009 has as its primary objective the prevention of risks to public and animal health arising from animal by-products. However, critical issues remain in the effective management of pathogens (bacteria, viruses, prions, parasites) and chemical contaminants (e.g., veterinary drug residues, heavy metals, dioxins) throughout the entire ABP production and processing chain:

- **Lack of Specific Limits for Pathogens:** Regulation (EC) No 1069/2009 classifies manure under Category 2 (intermediate health risk). It allows for direct application to land without prior processing, provided that the competent authority deems that they "do not present risks of spreading serious transmissible diseases." While it refers to "adequately treated to prevent the transmission of diseases," the regulation itself does not set explicit numerical limits for specific pathogens or contaminants in manure intended for land use. The definition of "adequately treated" is left to further implementing measures or the assessment of the competent authority.
- **Insufficient Validation of Processing Procedures:** Although the Regulation prescribes specific processing methods for different ABP categories, control authorities have found weaknesses in verifying the effectiveness of these treatments. This can lead to processes that do not guarantee sufficient reduction of pathogen load or degradation of chemical contaminants.
- **Persistent Risk of Cross-Contamination:** Despite segregation rules, the risk of cross-contamination between different ABP categories or between ABPs and products intended for human/animal consumption (e.g., feed) persists due to inadequate operational practices, insufficient cleaning, and disinfection of equipment and transport vehicles.
- **Limited Monitoring of Chemical Contaminants:** Although the focus is often on pathogens, the presence of veterinary drug residues or other chemical contaminants in ABPs, especially those intended for reuse (e.g., as fertilizers or fuels), is not always sufficiently monitored with specific parameters and adequate frequencies.
- **Emergence of New Pathogens or Contaminants:** The regulatory framework and control protocols may not be sufficiently agile to respond rapidly to the emergence of new zoonotic pathogens or new chemical contaminants that can be transmitted through ABPs.

Incentives for Technological Innovation and Localized Logistics

Creation of a dedicated EU funding program within Horizon Europe, for the development and implementation of innovative technologies for ABP treatment. Priority for solutions that:

- Reduce the volume of transported ABPs through pre-treatment (on-site concentration, dewatering).
- Reduce manure volume through efficient solid-liquid separation or drying, cutting logistical costs.
- Increase biogas production or enable nutrient recovery in more stable and concentrated forms (e.g., slow-release fertilizers).
- Increase the energy efficiency of processing (e.g., heat recovery systems).
- Ensure a **logarithmic reduction of pathogens (e.g., 5-log reduction of *Salmonella*)** in processed products with reduction indicators.

Harmonization and Strengthening of Sampling and Validation Procedures

Define, through delegated acts, standardized protocols for the validation of ABP processing procedures, specifying critical parameters (e.g., temperatures, times, pressure for pathogen reduction) and microbiological analysis methods (e.g., ISO 6579 for *Salmonella*, ISO 16649 for *E. coli*) with quantitative detection limits. The goal is to ensure an equivalent risk reduction level (>5 log reduction) across the EU.

- Introduction of the obligation to use continuous monitoring systems (e.g., temperature and humidity sensors) and rapid tests (e.g., PCR or ELISA with a detection limit of 0.05% for unauthorized animal proteins) to verify the absence of cross-contamination.
- Implement a risk-based sampling and testing program for products derived from ABPs, with increased frequency of controls for specific pathogens (e.g., *Clostridium botulinum* for ABP silages) or contaminants (e.g., dioxins, PCBs, antibiotic residues) based on the risk category and the destination of the product.
- Define quantitative maximum limits (e.g., ng/kg or µg/kg) for specific chemical contaminants in products derived from ABPs, in line with feed or fertilizer standards, with a detected non-compliance rate of less than 1%.
- Incentivize (e.g., with targeted EU funding up to 50% of costs) the adoption of advanced decontamination technologies (e.g., irradiation, ozone treatments, advanced filtration) for higher-risk ABP categories or to improve the safety of final products, with the goal of achieving zero detection of specific pathogens (e.g., *E. coli* O157:H7) in post-treatment samples.

Clarity on End-of-Waste Criteria and Harmonization of Post-Treatment Controls

Uncertainty about when treated manure ceases to be an ABP can lead to insufficient or unharmonized controls on "derived products," increasing risks if these still contain pathogen residues, antibiotics, or resistance genes.

- **Definition of Performance-Based "End Point" Criteria:** The Commission should adopt delegated acts establishing specific and measurable end-of-waste criteria for treated manure, based on:

  - **Hygiene Limits:** Maximum permissible concentrations of specific pathogens (e.g., *Salmonella* absent in 25g, *E. coli* <100 CFU/g) in finished products.
  - **Residue Limits:** Possible introduction of maximum limits for antibiotic residues or quantification of resistance genes (e.g., copy number/gram) based on the intended use (e.g., agricultural use).
- **Harmonized Post-Treatment Control Programs:** Oblige Member States to implement post-treatment control programs (e.g., analysis of digestate or compost) with a minimum quarterly frequency for each plant, verifying compliance with end-of-waste criteria. Results should be uploaded to a centralized EU database to allow for harmonized monitoring and trend identification.

Antimicrobials, Resistance, and Environmental Persistence in Regulation (EU) 2019/6

Regulation (EU) 2019/6 on veterinary medicinal products recognizes and addresses **Antimicrobial Resistance (AMR)** as an emerging global health threat, adopting a "One Health" approach that integrates human, animal, and environmental health. The European Medicines Agency (EMA) plays a central role in coordinating this strategy.

Objectives and AMR Control Measures

The regulation is structured to mitigate the development and spread of AMR and promote the prudent use of antimicrobials (AM) in animals. Key provisions include:

- **Strict Use Restrictions:**
  - **Prohibition of Systematic Use:** AMs must not be used to promote growth or compensate for poor hygiene and animal husbandry practices (Art. 107, para. 1, points b), c)).
  - **Conditional Prophylaxis:** Prophylactic administration is limited to exceptional cases, for individual animals or small groups with a very high risk and serious clinical consequences; for antibiotics, it is restricted to individual animals (Art. 107, para. 3).
  - **Controlled Metaphylaxis:** Metaphylaxis is allowed only in the presence of a high risk of disease spread and the absence of adequate alternatives (Art. 107, para. 4).
- **Classification and Prescription Discipline:** Antimicrobial veterinary medicinal products are subject to veterinary prescription (Art. 34). The veterinarian is the guarantor of prudent use, based on resistance data, epidemiology, and risk factors (Recital 58).
- **Antimicrobials Reserved for Human Use:** The Commission may reserve specific AMs exclusively for the treatment of human infections, prohibiting their placing on the veterinary market (Art. 37). This decision is based on scientific recommendations from EMA, EFSA, WHO, and OIE.
- **Monitoring and Data Collection:** The regulation explicitly acknowledges the "lack of sufficiently detailed and comparable data on antimicrobial resistance at Union level" (Recital 60). To address this, it requires Member States to collect data on the volume of sales and use of AMs in animals, with particular attention to food-producing animals (Art. 57, para. 1). EMA coordinates the analysis of these data and publishes an annual report.

Evolution, Environmental Persistence, and Mitigation Strategies

Regulation (EU) 2019/6 is detailed on the need to understand and manage the environmental impact of AMs:

- **Benefit/Risk Balance Assessment:** The concept of "benefit/risk balance" (Art. 38) explicitly includes "risks of undesirable effects on the environment" and "risks related to the development of resistance."
- **Environmental Risk Assessment (ERA):**
    - **Mandatory:** An ERA is required for all new marketing authorization applications (Art. 8, para. 1, point h); Annex II, point 3.1.1).
    - **Two-Phase Structure:** Phase I (Assessment of the degree of environmental exposure to the product, its active substances, and other constituents - Annex II, point 3.1.2) and Phase II (Assessment of the effects of the active residue on specific ecosystems (soil, water, air, aquatic systems, non-target organisms), considering the extent of exposure and the physico-chemical, pharmacological, and toxicological properties of the substances - Annex II, point 3.2).
    - **GMOs:** For veterinary medicinal products containing or consisting of Genetically Modified Organisms (GMOs), the ERA must comply with Directive 2001/18/EC (Annex II, point 3.1.3).
    - **Generics:** Competent authorities may require environmental safety data for generic veterinary medicinal products if the reference medicinal product was authorized before October 1, 2005, and is identified as potentially harmful to the environment (Art. 19, para. 2, point b)).
- **Reporting of Environmental Incidents:** Any environmental incident observed following the administration of a veterinary medicinal product (e.g., a significant increase in soil contamination or high concentrations in water) must be reported as a suspected adverse event and recorded in the Union pharmacovigilance database (Art. 117, para. 2, point d)).
- **Waste Disposal:** Member States are obliged to ensure the adoption of appropriate systems for the collection and disposal of veterinary medicinal product waste (Art. 118, para. 1, point c)).
- **Future Review:** The Commission is required to submit a report (by January 28, 2022) on a feasibility study concerning a review of active substances (monographs) and other alternatives for the environmental risk assessment of veterinary medicinal products, with a possible legislative proposal (Art. 32, para. 5).

Manure Management in the Context of Regulation (EU) 2019/6

The critical link between the Veterinary Medicinal Products Regulation and manure management lies primarily in the **environmental risk assessment and management of active substances and their metabolites excreted by animals, which can contaminate manure and, consequently, the environment.**

Antimicrobials administered to animals are partially excreted unaltered or as active metabolites in feces and urine. These residues end up in **manure**. The presence of antibiotics and their metabolites, combined with resistant bacteria, in manure (whether stored or spread on land) creates a reservoir and a vector for the spread

of AMR in the environment. Environmental microorganisms can acquire resistance genes, which can then transfer to other bacteria, including those pathogenic to humans and animals.

Lack of Sufficient Guidelines and Clarifications for Environmental Risk Assessment (ERA)

Environmental Risk Assessment (ERA) is mandatory for veterinary medicinal products. However, its application for substances excreted in manure is particularly complex. The lack of specific and harmonized guidelines on how to model and quantify the environmental fate and effects of these substances in the manure cycle (storage, treatment, land spreading, runoff, and leaching into water) can lead to:

- **Underestimation of Exposure Risk:** Difficulty in accurately predicting Predicted Environmental Concentrations (PECs) in manure, soil, and surface/groundwater after manure application. This is due to factors such as variability in degradation, soil adsorption, and the impact of climatic conditions.
- **Ineffective Mitigation Measures:** Without a clear understanding of exposure pathways through manure, proposed measures (e.g., waiting periods before manure spreading, treatment requirements) may not be sufficient to reduce the risk to acceptable levels.

Strengthening of Environmental Risk Assessment (ERA) Guidelines Specific to Manure

Current ERA guidelines are often too generic to address the complexities of the fate and behaviour of active substances in the manure cycle. There is a lack of a standardized methodology for quantifying the loss of active substances during different manure phases (e.g., pit or heap storage, anaerobic digestion, phase separation) and their subsequent behaviour in agricultural soil.

The Commission/EMA should publish new ERA guidelines, with a deadline by Q4 2026, which include:

- **Detailed Predictive Models for Manure:** Development of standardized mathematical models to predict foreseeable concentrations in manure, incorporating variables such as excretion rate (unchanged drug/metabolite), thermal and microbial stability in manure, storage times, and the removal efficiency of different manure treatment technologies (e.g., anaerobic digestion, composting).
- **Field Test Protocols for Soil Fate:** Requirements for conducting specific field studies to assess the fate (adsorption, degradation, leaching) of active substances and their metabolites in soil after manure spreading, under various pedoclimatic conditions. These studies should aim to quantify the **reduction of antibiotic concentration by X%** within a certain period in the soil.
- **Ecotoxicological Risk Thresholds for Manure/Soil Environment:** Definition of quantitative risk thresholds (e.g., PNEC - Predicted No Effect Concentration) for specific soil organisms (e.g., earthworms, soil microflora) and for ecosystem functionality (e.g., biogeochemical cycles) directly exposed to residues through manure.

Reinforced Integration with the Nitrates Directive (91/676/EEC) and the Animal By-products Regulation (EC) No 1069/2009

There is an operational disconnect between the management requirements for veterinary medicinal products (Regulation 2019/6) and manure management practices regulated by other legislation (Nitrates Directive for

nitrogen, Regulation 1069/2009 for the classification and treatment of ABPs, including at-risk manures). This fragmentation can lead to gaps in the control of active substances and AMR in manure.

Specific Solutions

- **Mandatory Coordination Clause (Delegated/Implementing Act):** Introduce a clause in Regulation 2019/6 or an implementing act that makes it mandatory to integrate environmental risk mitigation measures derived from veterinary medicinal products (identified in the ERA) into Member States' Nitrates Directive Action Programmes and into standardized operating procedures (SOPs) for the management of animal by-products (Regulation 1069/2009), particularly for livestock farms.
- **Harmonization of Sampling and Analysis Protocols:** Develop joint and standardized protocols (e.g., based on ISO/CEN) for manure sampling and analysis, which include both Nitrates Directive parameters (nitrogen, phosphorus) and veterinary medicinal product residues (AMs, antiparasitics) and the presence of resistance genes. The goal is to achieve **15% coverage of high-risk farms** (e.g., large pig/bovine farms) in Nitrate Vulnerable Zones (NVZs) with such annual sampling.
- **Incentives for Multi-Benefit Manure Treatment Technologies:** Incentivize, through CAP and LIFE funds, the adoption of manure treatment technologies (e.g., anaerobic digestion, advanced composting, phase separation with specific post-treatment) that not only reduce nitrogen losses but are also validated for the **removal or inactivation of specific veterinary medicinal product residues (with a minimum efficiency of 70% for high environmental risk substances)** and the **reduction of the resistance gene load (e.g., >3 log reduction)**.

Conclusion

The detailed analysis of various EU legislations reveals a **fragmented yet interconnected regulatory landscape** governing manure management. While each directive and regulation addresses specific environmental and health concerns—from nutrient pollution and soil degradation to public health risks from animal by-products and antimicrobial resistance—they often operate in silos. This can lead to **operational inefficiencies, enforcement challenges, and a lack of holistic synergy** in tackling the multifaceted impacts of manure.

Key weaknesses highlighted across the board include:

- **Insufficiently precise and dynamic quantitative targets** for environmental outcomes.
- **Outdated contaminant lists and limited scope** in older directives that don't account for emerging pollutants like antibiotic residues or microplastics.
- **Gaps in monitoring and compliance verification** at the farm level.
- **Lack of harmonized methodologies** for assessing environmental risks and validating treatment processes, particularly for manure.

- **Economic and logistical barriers** that hinder the widespread adoption of advanced manure treatment technologies.

Moving forward, a more **integrated and proactive regulatory approach** is essential. This would involve:

- **Harmonizing definitions and "endpoint" criteria** for treated manure across different regulations.
- **Developing robust, scientifically validated guidelines** for environmental risk assessment that specifically address manure's complex pathways for pollutants and pathogens.
- **Setting clear, measurable, and binding targets** for manure treatment efficiency and environmental outcomes.
- **Incentivizing and supporting technological innovation** for manure processing, focusing on solutions that offer multiple benefits (e.g., nutrient recovery, energy generation, and pollutant reduction).
- **Strengthening monitoring, data collection, and compliance verification** through digital tools and risk-based inspection protocols.

Ultimately, achieving truly sustainable manure management requires moving beyond single-issue regulations toward a **comprehensive and synergistic framework** that recognizes manure not merely as a waste product, but as a valuable resource whose careful management is vital for the health of our environment and agricultural systems. This proactive evolution of EU policy will be key to unlocking the full potential of manure in a circular economy, protecting precious natural resources, and mitigating the growing threat of AMR.

ANNEX 2

Questionnaire on Manure Management within the European and National Regulatory Framework

Objective: To assess if and how national regulations of individual Member States integrate and specify the provisions of the European regulatory framework on manure management, particularly where European directives have gaps.

Directive (EU) 2016/2284 - National Emission Ceilings (NEC)

Manure emission reduction plans

1. Does your national legislation require livestock farms (especially larger ones or those in critical areas) to develop and implement mandatory plans for reducing ammonia emissions from manure management?
2. If yes, does this include the specification of particular technologies and implementation timelines?
3. Are there specific and quantifiable NH3 reduction targets for the different stages of manure management, which go beyond the overall national ceilings imposed by the NEC Directive?
4. If yes, which stages (housing, storage, and spreading) are involved?
5. Are there specific and quantifiable NH3 reduction targets for particular livestock sectors, which go beyond the overall national ceilings imposed by the NEC Directive?

National emission factors, monitoring, and transparency

6. Does your national inventory system use country-specific emission factors for manure management?
7. If yes, are they regularly updated to reflect national practices and technological innovation, going beyond the default IPCC factors?
8. Does your national legislation require direct on-site monitoring of manure emissions (e.g., through eddy covariance systems) to calibrate and validate emission factors, thereby reducing uncertainty in estimates?
9. Are there specific mechanisms in place to verify the effective adoption and proper functioning of low-emission manure management techniques on farms (e.g., field checks, remote sensing)?
10. If yes, how is this data integrated into emission inventories?
11. Is there a systematic collection of georeferenced and quantitative data on specific manure management practices at the individual farm level to improve the accuracy of emission estimates?
12. If yes, what specific practices are investigated? (e.g., type of housing, duration of storage, application technology, data on manure composition).
13. Are farm-level or regional data on manure management practices and related ammonia emissions systematically collected and made publicly available (anonymized if necessary) to increase transparency and monitor progress?

Support for the adoption of treatment technologies and low-emission practices

14. Do your national regulations establish specific targets for the adoption of manure treatment technologies for a more holistic approach to nutrient management and the circular economy?
15. If yes, what treatment technologies are being adopted? (e.g., anaerobic digestion, solid-liquid separation, acidification).
16. Does the national implementation of the Common Agricultural Policy (CAP) or Rural Development Programs incentivize or mandate the adoption of manure management practices that reduce ammonia emissions, beyond the requirements of cross-compliance?
17. Is there a binding national obligation, beyond the simple encouragement provided by the NEC Directive, to adopt low-emission techniques for slurry application (e.g., direct injection, band spreading, shallow incorporation into crops, or other)?
18. If yes, does it provide for a minimum percentage of farms that must adopt such techniques?

Assessment of Cross-Media Effects

19. Does your legislation require quantitative assessments of the cross-media effects of ammonia emission reduction measures (e.g., how NH3 reduction might influence N2O emissions or nitrate losses into water)?

Regulation (EU) 2021/1119 - European Climate Law

Specific and quantifiable targets

20. Does your national climate strategy or legislation establish binding quantitative targets for the reduction of greenhouse gas emissions specifically from manure management?
21. If yes, are the targets disaggregated by gas type (CH4, N2O)?
22. If yes, are the targets disaggregated by specific management stages (e.g., housing, storage, spreading)?
23. Are there maximum limits on CH4 emission intensity (e.g., per unit of livestock product)?
24. Are there mandatory manure emission abatement targets at the national level?

Promotion of low-emission technologies

25. Beyond optional incentives, does your national regulatory framework include mandatory support schemes or direct regulatory drivers to ensure widespread adoption of low-emission manure management technologies?
26. If yes, are mandatory support schemes or direct regulatory drivers aimed at specific low-emission manure management technologies (e.g., anaerobic digesters, storage pit covers, low-emission application techniques)?
27. Is there a binding national target for the percentage of manure to be treated with anaerobic digestion or other advanced technologies, beyond what is recommended at the EU level?
28. Is there a binding national target for the percentage of liquid manure to be applied with low-emission technologies (e.g., direct injection, band spreading, or other)?

Monitoring, Reporting, and Verification (MRV) at the farm level

29. Does your national MRV (Monitoring, Reporting, Verification) system require the systematic and verifiable collection of data at the individual farm level on manure management practices and related emissions to improve the accuracy of the national greenhouse gas inventory for the livestock sector?
30. Are advanced methodologies used to reduce uncertainties in national inventories of diffuse emissions from manure?
31. If yes, what are they? (e.g., emission models specific to the national context, direct monitoring).

Integrated assessment of cross-media effects

32. Does your national legislation explicitly require an integrated technical assessment approach that simultaneously considers the climate impact of manure management solutions along with their effects on air quality, water quality, and soil health, in order to avoid the transfer of pollution between environmental compartments?
33. Does your national legislation explicitly require an integrated technical assessment approach that simultaneously considers the climate impact of manure management solutions in relation to all key pollutants (e.g., CH4, N2O, NH3, nitrates)?

Role of National Energy and Climate Plans (NECP)

34. Do your Integrated National Energy and Climate Plans (NECPs) translate EU climate targets into concrete, binding measures for manure management to reduce greenhouse gas emissions?
35. If yes, do they provide for specific financial allocations?

Water Framework Directive 2000/60/EC (WFD)

High-granularity monitoring and detailed attribution of manure pollution

36. Does your national legislation require the implementation of high-granularity monitoring or modelling approaches to more precisely quantify and attribute diffuse pollution specifically from manure management in water bodies?
37. If yes, what high-granularity monitoring or modelling approaches are used? (e.g., collection of data at the individual farm level on manure application, advanced hydrological models, other).
38. Does your national legislation incentivize the implementation of these high-granularity monitoring or modelling approaches?
39. Does your national regulatory framework include specific methodologies to accurately quantify and attribute the contribution of manure to nutrient and contaminant loads in water bodies, distinguishing it from other agricultural sources?
40. Does your legislation mandate the use of advanced molecular/isotopic markers for the precise attribution of manure pollution sources and the prediction of their impact?
41. Does your legislation mandate the use of complex hydrological-agricultural models for the precise attribution of manure pollution sources and the prediction of their impact?

Data transparency, reporting, and compliance

42. Are there standardized requirements for the quantitative monitoring of manure spreading practice compliance at the individual farm level?
43. Are there standardized requirements for reporting operational data at the individual farm level?
44. Are there national requirements for the standardized reporting of operational data related to manure management practices that feed into the WFD reporting cycle and improve transparency and verification?
45. If yes, what are they? (e.g., quantities produced, treated, and applied; types of treatment).

National water quality objectives and strategies

46. Given the flexibility of the WFD, does your national legislation establish binding quantitative targets for the reduction of specific pollutants derived from manure in water bodies, beyond the general objectives of good ecological and chemical status?
47. If yes, which ones? (e.g., phosphorus, organic carbon, emerging contaminants).
48. Are there quantitative objectives or specific environmental quality standards (EQS) for emerging contaminants from manure that are not included as "priority substances" at the EU level?
49. If yes, which ones? (e.g., veterinary drug residues, pathogens, antibiotic resistance genes).
50. Do your River Basin Management Plans (RBMPs), beyond generic measures, contain specific quantitative targets for reducing manure pollution?
51. Do your Programmes of Measures (PoMs), beyond generic measures, contain specific quantitative targets for reducing manure pollution?
52. Does your national regulatory framework include a risk-based approach that identifies specific areas or farms with a high potential for water pollution related to manure, leading to the application of more targeted measures or more stringent monitoring requirements in those areas?

Integrated management measures and practices

53. How does your national legislation ensure the integrated management of pollutants derived from manure with other sources of agricultural pollution within the scope of achieving WFD objectives?
54. If yes, which ones? (e.g., synthetic fertilizers, pesticides).
55. Does your national legislation mandate the adoption of specific Best Management Practices (BMPs) for manure application and storage, directly linked to improving water quality, going beyond general recommendations within action programs?

Financial and technical support

56. Does your national framework provide specific financial or technical support to farmers for the adoption of manure management practices that directly contribute to achieving WFD objectives, particularly for the reduction of diffuse pollution?

Nitrates Directive 91/676/EEC

Nitrogen management and nutrient balances

57. Does your national legislation introduce dynamic and precise plot-level nutrient balances to optimize nitrogen use from manure, going beyond the static 170 kg N/ha/year limit?
58. Does your national legislation mandate the adoption of farm-level or plot-level nutrient balances that account for the nitrogen actually available to crops from manure (and not just total nitrogen)?
59. If yes, do they consider factors such as crop type, soil and climate conditions, and timing of application?
60. How does your national regulatory framework differentiate and incentivize the application of treated manure (e.g., digestate, compost) compared to raw manure in relation to the 170 kg N/ha/year limit, considering its potentially different nutritional and environmental characteristics?

Storage and application techniques

61. Are there specific and quantifiable obligations (e.g., minimum reduction percentages) for the adoption of advanced storage technologies (e.g., airtight covers) to reduce nutrient losses?
62. Are there specific and quantifiable obligations (e.g., minimum reduction percentages) for the adoption of advanced manure application technologies (e.g., direct injection) to reduce nutrient losses?
63. Does your national regulatory framework establish minimum quantitative requirements for manure storage capacity that are explicitly aimed at reducing nutrient losses?
64. If yes, what are they? (e.g., minimum compulsory storage days, requirements for specific types of covers or gas-tight structures to prevent ammonia volatilization).
65. Are there specific obligations for the adoption of low-emission manure application techniques (e.g., direct injection, band spreading or trailing hose for slurry, immediate incorporation into the soil for solid manures), or are they only recommendations?
66. If there are obligations, are there specific timelines or targets for their adoption?
67. If yes, what specific timelines or targets are adopted?

Data collection, monitoring, and farm-level compliance

68. Does your regulatory framework provide for a more rigorous and frequent system of monitoring and verifying compliance at the individual farm level?
69. If yes, does the system include periodic analysis of manure composition and digital recording of applications?
70. Does your national legislation use specific mechanisms to ensure rigorous, frequent, and detailed verification of compliance at the individual farm level regarding manure application?
71. If yes, what are they? (e.g., mandatory digital recording of spreading activities, monitoring through satellite technologies, increased frequency of on-farm inspections for high-risk farms).
72. Does your national regulatory framework require periodic and mandatory analysis of manure composition (including available nitrogen, phosphorus, dry matter) at the farm level?
73. How is this data used to optimize nutrient application planning?
74. Have specific indicators of manure impact been implemented in water monitoring?
75. If yes, which ones? (e.g., dissolved organic nitrogen, microbial markers of animal origin).

76. In addition to nitrate concentrations, does your national water quality monitoring program incorporate specific indicators directly linked to manure pollution to more fully assess the effectiveness of action programs?
77. If yes, which ones? (e.g., specific forms of phosphorus, dissolved organic carbon, or microbial indicators of animal fecal origin).

Research and development

78. Does your national legislation include specific provisions or funding mechanisms to promote research, development, and adoption of advanced manure treatment technologies (e.g., anaerobic digestion, nutrient recovery technologies) that go beyond the minimum requirements of the directive?

Regulatory framework

79. How does your national legislation explicitly integrate the objectives and measures of the Nitrates Directive with those of other directives (e.g., NEC Directive for ammonia emission reduction) to minimize nutrient losses across different environmental compartments?

Directive 86/278/EEC on Soil Protection

National constraints on the presence of contaminants

80. Since Directive 86/278/EEC focuses exclusively on sewage sludge, does your national legislation establish binding limits for heavy metals and emerging contaminants in animal manure when it is applied to agricultural land?
81. If yes, which emerging contaminants are limited? (e.g., veterinary drug residues, microplastics, antibiotic resistance genes).

Risk assessment and contaminant monitoring

82. Does your national framework require a comprehensive risk assessment for the application of manure to agricultural land that considers not only nutrients but also potential contaminants (e.g., pathogens, organic pollutants)?
83. If yes, does this assessment also consider their long-term effects on soil health and the food chain?
84. Does your national soil monitoring program include regular testing for contaminants (e.g., heavy metals, emerging contaminants) in soils that regularly receive manure applications, to track accumulation and potential risks?

National quality standards

85. Are there national quality standards or specific certification schemes for manure to ensure its safety and suitability for agricultural application?
86. If yes, do they also cover treated manure used as a soil improver?

EU Soil Strategy 2030

Binding national targets

87. Does your national soil health strategy or legislation establish direct targets or limits for specific manure application practices?
88. Does your national soil health strategy or legislation establish direct targets or limits for application rates aimed at improving soil health, going beyond general good agricultural practices?
89. If yes, which ones? (e.g., increasing organic matter, reducing nutrient leaching into the soil, improving soil biodiversity).
90. Are these direct targets or limits legally binding?

Monitoring of specific parameters and data collection

91. Does your national soil monitoring program include specific parameters related to manure application to assess its long-term impact on soil health?
92. If yes, what parameters does it include? (e.g., heavy metals from manure, specific organic pollutants, the response of soil microbial activity to manure).
93. Does your national framework require or incentivize the collection of data at the individual farm level on manure application (quantities, types, methods)?
94. Does your national framework require or incentivize the collection of data at the individual farm level on the impact of manure on soil health indicators?
95. If yes, is this data used to inform soil management decisions and monitor progress towards soil health objectives?

Incentives for the use of manure-derived soil improvers

96. Are there national incentives or regulatory frameworks in place to promote the use of highly processed and quality-controlled products derived from manure as soil improvers to enhance organic matter and fertility?
97. If yes, what highly processed products are promoted? (e.g., compost, digestate biochar).

Regulation (EU) 2019/1009 on EU Fertilising Products (FPR)

Regulation of unprocessed manure

98. Since unprocessed manure is not directly covered by the FPR as an EU fertilising product, does your national legislation regulate the quality, safety, and nutrient content of unprocessed manure when it is applied directly to land or traded between farms?
99. Are there national standards or guidelines for quality control and environmental risk assessment of unprocessed manure used in agriculture?

Specific quality criteria for manure-derived products

100. Does your national legislation establish chemical quality and safety criteria for manure-derived fertilising products that go beyond those specified in the Component Material Categories (CMCs) of the FPR? This question refers to emerging chemical contaminants, such as veterinary drug residues and microplastics.
101. Does your national legislation establish biological quality and safety criteria for manure-derived fertilising products that go beyond those specified in the Component Material Categories (CMCs) of the FPR? This question

refers to emerging biological contaminants, such as antibiotic residues, specific pathogens, and antibiotic resistance genes.

102. If yes, which manure-derived fertilising products are subject to quality and safety criteria? (such as compost, digestate, processed manure).
103. Are there specific national criteria for the end-of-waste status for manure-derived products?
104. If yes, do these criteria facilitate market placement as fertilisers by preventing classification as waste even after processing?

Market placement and monitoring of derived products

105. Does your national system ensure effective monitoring and enforcement of the FPR requirements for manure-derived fertilising products once they are placed on the market?
106. If yes, does this include verification of their declared composition, safety, and compliance with quality standards?
107. Are there national traceability mechanisms for manure-derived fertilising products, from production to application, to ensure compliance and monitor potential environmental impacts?
108. Does your national legislation address market fragmentation due to optional harmonization, creating a more homogeneous framework for the cross-border marketing of treated manure?

Incentives for innovation and manure valorisation

109. What national policies, financial incentives, or regulatory frameworks are in place to promote and support the research, development, and adoption of innovative technologies for transforming manure into safe and high-quality fertilising products compliant with the FPR?

Cross-compliance

110. Does your national legislation ensure the harmonious integration and coherence between the FPR requirements for manure-derived fertilising products and other national laws derived from relevant EU directives, to avoid regulatory overlaps or gaps?
111. If yes, which directives and regulations are taken into consideration? (e.g., Nitrates Directive for nutrient limits, Animal By-Products Regulation for animal health, Water Framework Directive for water protection).

Regulation (EU) 2019/6 - Antimicrobials, Resistance, and Environmental Persistence

National monitoring of VMPs and AMR in manure

112. Has your national legislation implemented detailed predictive models to assess the predicted environmental concentrations (PECs) of veterinary medicinal product (VMP) residues in manure, soil, and water after manure application?
113. Does your national legislation require or incentivize the systematic monitoring of veterinary medicinal product (VMP) residues (in particular antimicrobials) in raw animal manure intended for soil application?
114. Does your national legislation require or incentivize the systematic monitoring of genes/bacteria responsible for antimicrobial resistance (AMR) in raw animal manure intended for soil application?

115. Does your national legislation require or incentivize the systematic monitoring of veterinary medicinal product (VMP) residues (in particular antimicrobials) in treated animal manure intended for soil application?
116. Does your national legislation require or incentivize the systematic monitoring of genes/bacteria responsible for antimicrobial resistance (AMR) in treated animal manure intended for soil application?
117. Are there national thresholds or limits for the presence of specific VMP residues or AMR indicators in manure used as fertilizer?
118. Does your national legislation provide for harmonized protocols for manure sampling and analysis?
119. If yes, do these protocols include both the parameters of the Nitrates Directive and veterinary drug residues and the presence of antibiotic resistance genes?
120. Has your regulatory framework defined specific and measurable end-of-waste criteria for treated manure?
121. If yes, are these criteria based on hygienic limits, residue limits, and the quantification of resistance genes?
122. In the case of end-of-waste, are harmonized post-treatment control programs foreseen?

Treatment requirements for VMP/AMR reduction

123. Does your national regulatory framework impose mandatory requirements for specific manure treatment technologies that have been proven effective in reducing VMP residues and/or AMR (genes/bacteria) before the manure is applied to agricultural land?
124. If yes, for which manure treatment technologies are the mandatory requirements imposed? (e.g., anaerobic digestion, composting, thermal treatment).
125. Does your national regulatory framework provide incentives for specific manure treatment technologies (e.g., anaerobic digestion, composting, thermal treatment) that have been proven effective in reducing VMP residues and/or AMR (genes/bacteria) before the manure is applied to agricultural land?
126. If yes, for which manure treatment technologies are incentives provided? (e.g., anaerobic digestion, composting, thermal treatment).
127. Are there national standards or verification methods to confirm the effectiveness of such manure treatments in reducing these contaminants?

Environmental risk assessment and management

128. In addition to the initial environmental risk assessment (ERA) during the authorization of VMPs, does your national legislation require post-marketing environmental monitoring?
129. In addition to the initial environmental risk assessment (ERA) during the authorization of VMPs, does your national legislation require specific risk management measures for VMP residues and AMR arising from manure application?
130. If yes, are there more restrictive specific management measures in vulnerable areas (e.g., near water bodies)?
131. Are there national guidelines or mandatory practices for farmers to minimize the environmental spread of VMP residues and AMR through manure application?
132. If yes, what guidelines or mandatory practices exist? (e.g., specific timings, methods, or site restrictions).

Data collection related to VMP/AMR in the manure value chain

133. Does your national system include verifiable mechanisms for collecting and analysing data on the actual concentration and environmental fate of VMP residues and AMR determinants in manure?

134. Does your national system include verifiable mechanisms for collecting and analysing data on the actual concentration and environmental fate of VMP residues and AMR determinants in water bodies and soils that receive manure applications?

135. How is this data used to inform national policies and risk assessments related to VMPs and AMR in the agricultural sector?

Integration of national strategies

136. Does your National Action Plan and strategy on Antimicrobial Resistance specifically integrate manure management practices as a key component to prevent the development and spread of AMR in the environment?

137. Are there concrete objectives or measures related to manure treatment or application within this strategy?

138. Does your legislation mandatorily integrate environmental risk mitigation measures from veterinary drugs (identified in the ERA) into the Nitrates Directive Action Programmes and standard operating procedures for animal by-products?

ANNEX 3

Reduced Questionnaire on Manure Management within the European and National Regulatory Framework

Introduction and Instructions for Completion

This document is a **Questionnaire on Manure Management within the European and National Regulatory Framework**, designed to assess the extent to which national (or regional, where competency is delegated) regulations in Member States specify, integrate, and, where necessary, address the gaps in EU directives concerning the management of livestock effluents.

Completion is required by the Authority responsible for implementing and specifying EU directives within its territory (National or Regional/Local level).

Method of Completion and Focus of Responses

Please answer each question based on **formal binding legislative provisions in force** (e.g., Laws, Decrees, Action Programmes, Regulations, Guidelines) and not merely on recommendations or incentives.

Specifically, the assessment should focus on two key criteria:

- **Mandatory Nature:**

  Determine whether the requirements, emission reduction plans, or adoption of specific technologies are **mandatory and binding** for livestock farms (particularly larger ones or those in critical areas, such as Nitrate Vulnerable Zones - NVZ, moving beyond mere encouragement or financial support.

- **Specificity and Quantification:**

  Verify whether the objectives, limits, and monitoring mechanisms are **specific and quantifiable** solely for manure management (distinguishing it from other agricultural sources) and if they go beyond basic minimum requirements at the EU level. This includes the presence of thresholds for new contaminants or advanced monitoring methods on the farm or in the environment.

Recipient Entity

1. Does the entity (recipient) of this questionnaire operate at the national level or at a sub-national/sub-federal level (e.g., provincial, regional, or equivalent administrative jurisdiction)?

Directive (EU) 2016/2284 - NEC

2. Does the national legislation impose mandatory plans for the reduction of NH3 emissions from manure management (with specific technologies/timelines) for livestock farms (especially larger ones or those in critical areas)?
3. Are there specific and quantifiable NH3 reduction targets that go beyond the NEC ceilings, disaggregated by management phases (housing, storage, spreading) and/or by specific livestock sectors?
4. Does the national inventory system use country-specific emission factors (updated and beyond IPCC factors) and require direct on-site monitoring of manure emissions for calibration/validation?
5. Are mechanisms in place to verify the effective adoption and correct functioning of low-emission techniques, such as the systematic collection of georeferenced data at the individual farm level on specific manure management practices (e.g., type of housing, application technology, manure composition) to improve emission estimates?
6. Does the normative establish specific targets for the adoption of treatment technologies (e.g., anaerobic digestion, acidification) and/or make the adoption of low-emission techniques for slurry application mandatory (e.g., direct injection)?
7. Does the legislation require quantitative assessments of the cross-media effects of NH3 reduction measures (e.g., impact on N2O or nitrate losses to water)?

Regulation (EU) 2021/1119 - European Climate Law

8. Does your national climate strategy or legislation establish binding quantitative targets for the reduction of GHG emissions (such as CH4, N2O) specifically from manure management, disaggregated by gas or by management phases, or maximum CH4 emission intensity limits?
9. Does the regulatory framework include mandatory support schemes or direct regulatory drivers to ensure widespread adoption of low-emission manure management technologies (e.g., anaerobic digesters, storage covers)?
10. Is there a national binding target for the percentage of manure to be treated with advanced technologies (e.g., anaerobic digestion) and/or for the percentage of liquid manure to be applied with low-emission techniques?
11. Does the MRV system require the systematic and verifiable collection of data at the individual farm level on manure management practices and related GHG emissions, using advanced methodologies (e.g., specific models, direct monitoring) to reduce uncertainties in national inventories?
12. Does the legislation explicitly require an integrated technical assessment approach that simultaneously considers the climate impact of manure management solutions along with their effects on air, water, and soil quality and in relation to all key pollutants?
13. Do the National Integrated Energy and Climate Plans (PNIEC) translate EU climate targets into concrete measures, binding for manure management, providing specific financial allocations?

Water Framework Directive 2000/60/EC

14. Does the legislation require the implementation of high-granularity monitoring or modelling approaches (e.g., farm-level data, advanced models, molecular/isotopic markers) to accurately quantify and attribute diffuse pollution specifically from manure management in water bodies, distinguishing it from other agricultural sources?
15. Are there standardized requirements for on-farm monitoring/reporting of operational data (e.g., quantities, treatment types) related to manure spreading and management practices that improve transparency and verification in the WFD reporting cycle?
16. Does the legislation establish binding quantitative targets for the reduction of specific manure-derived pollutants in water bodies (e.g., phosphorus, emerging contaminants) and/or specific Environmental Quality Standards (EQS) for emerging contaminants (e.g., veterinary drug residues, pathogens) not included as "priority substances" at the EU level?
17. Do the River Basin Management Plans (RBMPs) and Programmes of Measures (PoMs) contain specific quantitative targets for the reduction of manure pollution?
18. Does the regulatory framework include a risk-based approach that identifies areas or farms with a high potential for water pollution related to manure, leading to the application of more stringent measures or monitoring requirements?
19. Does the legislation make the adoption of specific Best Management Practices (BMPs) for manure application and storage mandatory, directly linked to improving water quality, and does it provide specific financial or technical support for their adoption?

Nitrates Directive 91/676/EEC

20. Does the legislation introduce dynamic and precise nutritional balances at the plot level that account for the nitrogen actually available from manure for crops (considering crop type, pedoclimatic conditions, and timing of application), going beyond the static limit of 170 kg(N)/ha/year?
21. Does the regulation differentiate and incentivize the application of treated manure (e.g., digestate) compared to raw manure in relation to the 170 kg(N)/ha/year limit?
22. Are there specific and quantifiable obligations for the adoption of advanced storage technologies (e.g., airtight covers) and application technologies (e.g., direct injection) for manure to reduce nutrient losses?
23. Does the regulation establish minimum quantitative requirements for manure storage capacity (e.g., minimum mandatory storage days) and/or specific obligations for the adoption of low-emission application techniques (with specific timelines or targets)?
24. Does the regulation provide for a more rigorous and frequent system for monitoring and verifying compliance at the individual farm level (e.g., digital registration, more frequent inspections)?
25. Does the regulation require mandatory periodic analyses of manure composition (including available nitrogen and phosphorus) at the farm level and their use to optimize nutrient application planning?
26. Does the national water quality monitoring program incorporate specific indicators directly linked to manure pollution (e.g., specific forms of phosphorus, microbial markers of animal origin) in addition to nitrate concentrations to assess the effectiveness of action programs?
27. How does the national legislation explicitly integrate the objectives and measures of the Nitrates Directive with those of other directives (e.g., NEC) to minimize nutrient losses across different environmental compartments?

Soil Protection (Directive 86/278/EEC and EU Soil Strategy 2030)

28. Does the national legislation establish binding limits for heavy metals and for emerging contaminants (e.g., veterinary drug residues, microplastics) in animal manure when applied to agricultural land?

29. Does the national framework require a full risk assessment for the application of manure to agricultural land that considers, besides nutrients, also potential contaminants and their long-term effects on soil health and the food chain?
30. Does the national soil monitoring program include regular testing for contaminants (e.g., heavy metals, emerging contaminants) in soils that receive manure applications, and specific parameters related to manure application (e.g., microbial activity) to assess long-term impact?
31. Does the national soil health strategy or legislation establish direct, legally binding targets or limits for specific manure application practices or rates, aimed at improving soil health (e.g., increasing organic matter)?

Regulation (EU) 2019/1009 on Fertilising Products (FPR)

32. Does the national legislation regulate the quality, safety, and nutrient content of untreated manure when applied directly to land or exchanged between farms (e.g., national standards or guidelines)?
33. Does the regulation establish chemical and biological quality and safety criteria (e.g., contaminants, antibiotic resistance genes) for fertilising products derived from manure that go beyond those specified in the Component Material Categories (CMCs) of the FPR, providing specific national end-of-waste criteria?
34. Are there national quality standards or specific certification schemes for manure (including treated manure) to ensure its safety and suitability for agricultural application?
35. Are national incentives or regulatory frameworks in place to promote the use of highly processed and quality-controlled products derived from manure (e.g., compost, biochar from digestate) as soil conditioners?
36. Does the national system ensure effective monitoring and enforcement of the FPR requirements for manure-derived fertilising products placed on the market (e.g., verification of composition and safety) and provide national traceability mechanisms?

Antimicrobials, Resistance, and Environmental Persistence (Regulation (EU) 2019/6)

37. Does the national legislation require or incentivize the systematic monitoring (in raw and treated manure) of veterinary medicinal product (VMP) residues and genes/bacteria responsible for antimicrobial resistance (AMR)?
38. Are there national thresholds or limits for the presence of specific VMP residues or AMR indicators in manure used as fertilizer, and does the regulation provide harmonized protocols for sampling and analysis that include both Nitrates Directive parameters, drug residues, and AMR?
39. Does the regulatory framework impose mandatory requirements or provide incentives for specific manure treatment technologies (e.g., anaerobic digestion, composting) that have been proven effective in reducing VMP residues and/or AMR (with national verification standards)?
40. Does the legislation require post-marketing environmental monitoring or specific risk management measures for VMP residues and AMR resulting from manure application (e.g., mandatory guidelines/practices for farmers on timing/site restrictions), and does the National Action Plan on AMR specifically integrate manure management practices?

ANNEX 4

Reduced Questionnaire on Manure Management within the European and National Regulatory Framework: Regione Lombardia case study

Introduction and Instructions for Completion

This document is a **Questionnaire on Manure Management within the European and National Regulatory Framework**, designed to assess the extent to which national (or regional, where competency is delegated) regulations in Member States specify, integrate, and, where necessary, address the gaps in EU directives concerning the management of livestock effluents.

Completion is required by the Authority responsible for implementing and specifying EU directives within its territory (National or Regional/Local level).

Method of Completion and Focus of Responses

Please answer each question based on **formal binding legislative provisions in force** (e.g., Laws, Decrees, Action Programmes, Regulations, Guidelines) and not merely on recommendations or incentives.

Specifically, the assessment should focus on two key criteria:

- **Mandatory Nature:**

  Determine whether the requirements, emission reduction plans, or adoption of specific technologies are **mandatory and binding** for livestock farms (particularly larger ones or those in critical areas, such as Nitrate Vulnerable Zones - NVZ, moving beyond mere encouragement or financial support.

- **Specificity and Quantification:**

  Verify whether the objectives, limits, and monitoring mechanisms are **specific and quantifiable** solely for manure management (distinguishing it from other agricultural sources) and if they go beyond basic minimum requirements at the EU level. This includes the presence of thresholds for new contaminants or advanced monitoring methods on the farm or in the environment.

Recipient Entity

1. **Does the entity (recipient) of this questionnaire operate at the national level or at a sub-national/sub-federal level (e.g., provincial, regional, or equivalent administrative jurisdiction)?**

The Lombardy Region, through the Regional Action Programme (D.g.r. 16 December 2024-n. XII/3634 - PdA 2024-2027), is the authority that implements and specifies EU directives in its territory, particularly in Nitrate Vulnerable Zones (NVZ).

Directive (EU) 2016/2284 - NEC

2. **Does the national legislation impose mandatory plans for the reduction of NH3 emissions from manure management (with specific technologies/timelines) for livestock farms (especially larger ones or those in critical areas)?**

The Additional Measures (MA) for NH3 emission reduction are made mandatory by the Regional Action Programme (D.g.r. n. XII/3634) for farms in NVZs and/or with a livestock load exceeding 40 LSU. These measures include the mandatory covering of slurry storage and the adoption of Low Emission Techniques (BAT) for spreading, with precise deadlines. Emission reduction stems not only from the Regional Nitrates Action Programme but also from the "Air Quality Sectoral Plans" (e.g., Po Valley Basin).

3. **Are there specific and quantifiable NH3 reduction targets that go beyond the NEC ceilings, disaggregated by management phases (housing, storage, spreading) and/or by specific livestock sectors?**

No. Specific, quantifiable reduction targets for NH3 for individual management phases or specific livestock sectors (beyond the overall NEC ceiling) are not set. However, the mandatory Additional Measures (BAT adoption) are naturally disaggregated by management phase (storage and spreading) and are sector-specific based on the effluent type produced.

4. **Does the national inventory system use country-specific emission factors (updated and beyond IPCC factors) and require direct on-site monitoring of manure emissions for calibration/validation?**

Partially. The National Inventory (ISPRA) uses country-specific (Tier 2/3) emission factors. However, direct on-site monitoring of NH3 emissions at the farm level is not a mandatory requirement for the calibration or validation of the national inventory, but may be admitted in specific circumstances (e.g., in derogation).

5. **Are mechanisms in place to verify the effective adoption and correct functioning of low-emission techniques, such as the systematic collection of georeferenced data at the individual farm level on specific manure management practices (e.g., type of housing, application technology, manure composition) to improve emission estimates?**

No. Although the Fertilization Register requires recording the application technique, there are no systematic, mandatory mechanisms to verify the correct functioning of BAT or the systematic collection of georeferenced data at the individual farm level for the explicit purpose of improving NH3 emission estimates.

6. **Does the normative establish specific targets for the adoption of treatment technologies (e.g., anaerobic digestion, acidification) and/or make the adoption of low-emission techniques for slurry application mandatory (e.g., direct injection)?**

The use of low emission spreading techniques (BAT) is mandatory for slurry in NVZs and in specific periods. Advanced treatment technologies (anaerobic digestion, acidification) are strongly incentivized (e.g., PNRR, PSR) but their adoption is not rendered mandatory by the Regional Action Programme.

7. **Does the legislation require quantitative assessments of the cross-media effects of NH3 reduction measures (e.g., impact on N2O or nitrate losses to water)?**

Yes, at the strategic level. Such assessments are required within the Strategic Environmental Assessment (SEA/VAS) of the regional plans to ensure that NH3 reduction measures do not negatively impact other compartments (e.g., increasing N2O emissions or nitrate leaching). This is not an obligation for the individual farm.

Regulation (EU) 2021/1119 - European Climate Law

8. **Does your national climate strategy or legislation establish binding quantitative targets for the reduction of GHG emissions (such as CH4, N2O) specifically from manure management, disaggregated by gas or by management phases, or maximum CH4 emission intensity limits?**

Binding quantitative targets are set at the national level (PNIEC) but are aggregated for the entire Agriculture sector. There are no binding, disaggregated targets or limits specifically for manure management (e.g., a maximum CH4 intensity limit).

9. **Does the regulatory framework include mandatory support schemes or direct regulatory drivers to ensure widespread adoption of low-emission manure management technologies (e.g., anaerobic digesters, storage covers)?**

Partially. The obligation to cover slurry storage (driven by the Nitrates/NEC Directives) is a direct regulatory driver that also mitigates CH4. The widespread adoption of other key technologies (e.g., anaerobic digestion, which reduces CH4) is promoted through financial incentives (PNRR, PSR, biomethane incentives) rather than direct obligations within the PdA.

10. **Is there a national binding target for the percentage of manure to be treated with advanced technologies (e.g., anaerobic digestion) and/or for the percentage of liquid manure to be applied with low-emission techniques?**

There is no binding target for the percentage of manure to be treated. However, the obligation to apply liquid manure with low-emission techniques (BAT) in NVZs (driven by Nitrates/NEC) effectively sets a binding target for the application method.

11. **Does the MRV system require the systematic and verifiable collection of data at the individual farm level on manure management practices and related GHG emissions, using advanced methodologies (e.g., specific models, direct monitoring) to reduce uncertainties in national inventories?**

The MRV system (PUA/Register) collects basic data on practices necessary for GHG estimates. However, the collection of advanced data (e.g., direct monitoring of GHG or advanced modelling for GHG reduction) is not a mandatory requirement at the individual farm level.

12. **Does the legislation explicitly require an integrated technical assessment approach that simultaneously considers the climate impact of manure management solutions along with their effects on air, water, and soil quality and in relation to all key pollutants?**

The principle of integrated assessment is required within the Strategic Environmental Assessment (SEA/VAS) of the regional plans to ensure the effectiveness of measures and prevent negative trade-offs (e.g., between NH3 and N2O). This is not a formal requirement for the individual farmer adopting a single measure.

13. **Do the National Integrated Energy and Climate Plans (PNIEC) translate EU climate targets into concrete measures, binding for manure management, providing specific financial allocations?**

The PNIEC defines strategies that result in both binding measures (via the PdA) and financial support (PNRR, incentives for biomethane and efficient technologies) aimed at promoting low-climate-impact effluent management.

Water Framework Directive 2000/60/EC

14. **Does the legislation require the implementation of high-granularity monitoring or modelling approaches (e.g., farm-level data, advanced models, molecular/isotopic markers) to accurately quantify and attribute diffuse pollution specifically from manure management in water bodies, distinguishing it from other agricultural sources?**

RBMPs use modelling for diffuse pollution, but the specific attribution to manure, distinguishable from mineral fertilizers, using high-granularity methods (e.g., isotopic/molecular markers) is not a standardized and mandatory requirement for the individual farm.

15. **Are there standardized requirements for on-farm monitoring/reporting of operational data (e.g., quantities, treatment types) related to manure spreading and management practices that improve transparency and verification in the WFD reporting cycle?**

The Agricultural Utilization Plan (PUA) and the Fertilization Register are standardized requirements. They oblige the farm to record quantities, effluent type, parcel, date, and application technique, which supports compliance verification and indirectly the WFD reporting (Nitrates Directive).

16. **Does the legislation establish binding quantitative targets for the reduction of specific manure-derived pollutants in water bodies (e.g., phosphorus, emerging contaminants) and/or specific Environmental Quality Standards (EQS) for emerging contaminants (e.g., veterinary drug residues, pathogens) not included as "priority substances" at the EU level?**

Partially. Phosphorus (P) is regulated through PUA and spreading restrictions. No binding quantitative targets or specific EQS are set for emerging contaminants (e.g., VMP, Veterinary Medicinal Products) in water bodies derived specifically from manure application.

17. **Do the River Basin Management Plans (RBMPs) and Programmes of Measures (PoMs) contain specific quantitative targets for the reduction of manure pollution?**

RBMPs and PoMs establish measures and targets for reducing pollution from agricultural and livestock sources in general, often coinciding with the Nitrates Directive measures. The targets are generally aggregated and qualitative (improving the status of water bodies), not disaggregated and quantitative solely for the *manure* component.

18. **Does the regulatory framework include a risk-based approach that identifies areas or farms with a high potential for water pollution related to manure, leading to the application of more stringent measures or monitoring requirements?**

The identification of Nitrate Vulnerable Zones (NVZs) is the primary risk-based approach. Farms in NVZs are subject to more stringent measures (PUA, N limits, storage obligations) than those in non-vulnerable zones.

19. **Does the legislation make the adoption of specific Best Management Practices (BMPs) for manure application and storage mandatory, directly linked to improving water quality, and does it provide specific financial or technical support for their adoption?**

The Nitrates Directive measures (e.g., spreading prohibition periods, minimum storage capacity, application techniques) are essentially mandatory BMPs in NVZs. Financial support (e.g., PSR - Rural Development Programme) is provided for the adoption of more efficient technologies.

Nitrates Directive 91/676/EEC

20. **Does the legislation introduce dynamic and precise nutritional balances at the plot level that account for the nitrogen actually available from manure for crops (considering crop type, pedoclimatic conditions, and timing of application), going beyond the static limit of 170 kg(N)/ha/year?**

The Agricultural Utilization Plan (PUA) is mandatory in NVZs. It calculates Efficient Nitrogen (Ne), which is dynamic and considers the application technique and crop needs. This is done while maintaining the 170 kg(N)/ha/year limit as the ceiling for Total Nitrogen from livestock effluents.

21. **Does the regulation differentiate and incentivize the application of treated manure (e.g., digestate) compared to raw manure in relation to the 170 kg(N)/ha/year limit?**

The 170 kg(N)/ha/year limit applies to total N. There is no differentiation in the limit itself. However, the coefficients of agronomic efficacy in the PUA may be better for treated effluents, and specific treatments (e.g., digestate separation) are incentivized for export and better nutrient management.

22. **Are there specific and quantifiable obligations for the adoption of advanced storage technologies (e.g., airtight covers) and application technologies (e.g., direct injection) for manure to reduce nutrient losses?**

The PdA imposes:

- mandatory covering for slurry storage to reduce N losses to air (NH3).
- mandatory use of BAT for spreading, aiming to reduce N losses to air and water.

23. **Does the regulation establish minimum quantitative requirements for manure storage capacity (e.g., minimum mandatory storage days) and/or specific obligations for the adoption of low-emission application techniques (with specific timelines or targets)?**

The Regional PdA establishes a **minimum storage capacity of 180 days (6 months)** for effluents in NVZs. Low-emission techniques (BAT) are also **mandatory** in specific periods and zones, with deadlines imposed by Air Quality Sectoral Plans.

24. **Does the regulation provide for a more rigorous and frequent system for monitoring and verifying compliance at the individual farm level (e.g., digital registration, more frequent inspections)?**

Partially. The system is made rigorous by the obligation to present the PUA and maintain the Fertilization Register. Controls are carried out based on risk criteria. However, systematic, high-frequency verification of on-site compliance with application techniques is not standardized as routine monitoring.

25. **Does the regulation require mandatory periodic analyses of manure composition (including available nitrogen and phosphorus) at the farm level and their use to optimize nutrient application planning?**

Farms above a defined livestock threshold (e.g., 40 LSU) and located in NVZs are subject to the mandatory periodic analysis (at least annual) of effluents (slurry/manure) to accurately determine N and P content for use in the PUA.

26. **Does the national water quality monitoring program incorporate specific indicators directly linked to manure pollution (e.g., specific forms of phosphorus, microbial markers of animal origin) in addition to nitrate concentrations to assess the effectiveness of action programs?**

No. Standard monitoring focuses on Nitrates and Total Phosphorus (P). The use of microbial markers or specific P forms to unequivocally attribute pollution to the livestock source is not a standardized or routine requirement in water body monitoring under the PdA.

27. **How does the national legislation explicitly integrate the objectives and measures of the Nitrates Directive with those of other directives (e.g., NEC) to minimize nutrient losses across different environmental compartments?**

The integration is formal and operational. Measures for NH3 reduction (NEC Directive) have been incorporated into the Nitrates Action Programme (PdA Regional) as Mandatory Additional Measures (e.g., covers and spreading BAT). This ensures that anti-nutrient (Nitrates) and air pollution (NH3) measures are synergistic and managed by the same regulatory instrument.

Soil Protection (Directive 86/278/EEC and EU Soil Strategy 2030)

28. **Does the national legislation establish binding limits for heavy metals and for emerging contaminants (e.g., veterinary drug residues, microplastics) in animal manure when applied to agricultural land?**

Yes, limits for heavy metals are established by national law (e.g., DM 5/98). No, no binding limits are set for emerging contaminants (e.g., VMP) in raw manure applied to soil.

29. **Does the national framework require a full risk assessment for the application of manure to agricultural land that considers, besides nutrients, also potential contaminants and their long-term effects on soil health and the food chain?**

A comprehensive, formal risk assessment including long-term effects of emerging contaminants is not required for raw manure application at the farm level. Risk assessment is implicit only for heavy metals and required for highly processed materials (e.g., sludge, digestate).

30. **Does the national soil monitoring program include regular testing for contaminants (e.g., heavy metals, emerging contaminants) in soils that receive manure applications, and specific parameters related to manure application (e.g., microbial activity) to assess long-term impact?**

There is no mandatory, regular soil monitoring program that includes testing for emerging contaminants or specific long-term impact parameters (like microbial activity) at the farm level.

31. **Does the national soil health strategy or legislation establish direct, legally binding targets or limits for specific manure application practices or rates, aimed at improving soil health (e.g., increasing organic matter)?**

No, the PdA focuses on limiting N and P to protect water. While the use of effluents benefits organic matter, the legislation does not establish direct, legally binding targets or limits on application rates specifically for soil health purposes (beyond the 170 kg(N)/ha/year limit).

Regulation (EU) 2019/1009 on Fertilising Products (FPR)

32. **Does the national legislation regulate the quality, safety, and nutrient content of untreated manure when applied directly to land or exchanged between farms (e.g., national standards or guidelines)?**

Nutrient content (N and P) is strictly regulated by the Nitrates Directive/PUA. However, no formal national standards for the chemical or biological quality of raw, untreated manure exist, apart from existing heavy metal limits.

33. **Does the regulation establish chemical and biological quality and safety criteria (e.g., contaminants, antibiotic resistance genes) for fertilising products derived from manure that go beyond those specified in the Component Material Categories (CMCs) of the FPR, providing specific national end-of-waste criteria?**

Fertilising products derived from manure that do not fall directly under the FPR must comply with national End-of-Waste (EoW) criteria. These criteria establish more rigorous safety and quality limits (e.g., for heavy metals and hygiene) for specific processed materials (e.g., compost).

34. **Are there national quality standards or specific certification schemes for manure (including treated manure) to ensure its safety and suitability for agricultural application?**

Mandatory standards exist for EoW products and conventional fertilisers. Voluntary certification schemes also exist for treated manure/digestate (e.g., linked to biomethane production) that ensure quality and traceability for agricultural use.

35. **Are national incentives or regulatory frameworks in place to promote the use of highly processed and quality-controlled products derived from manure (e.g., compost, biochar from digestate) as soil conditioners?**

Strong national incentives (e.g., PNRR, biomethane incentives, PSR) promote the installation of anaerobic digestion and treatment plants, indirectly encouraging the production and use of quality-controlled derived products as soil conditioners.

36. **Does the national system ensure effective monitoring and enforcement of the FPR requirements for manure-derived fertilising products placed on the market (e.g., verification of composition and safety) and provide national traceability mechanisms?**

Monitoring and enforcement are ensured by relevant authorities (ICQRF, Regions, ASL) for products placed on the market. Traceability is required both by FPR requirements and national EoW regulations.

Antimicrobials, Resistance, and Environmental Persistence (Regulation (EU) 2019/6)

37. **Does the national legislation require or incentivize the systematic monitoring (in raw and treated manure) of veterinary medicinal product (VMP) residues and genes/bacteria responsible for antimicrobial resistance (AMR)?**

Systematic monitoring of VMP and AMR in manure is not a legal obligation for the farmer under the PdA. It is, however, a focus of the National Action Plan on AMR (PNACC) and is implemented through studies, research, and pilot programs.

38. **Are there national thresholds or limits for the presence of specific VMP residues or AMR indicators in manure used as fertilizer, and does the regulation provide harmonized protocols for sampling and analysis that include both Nitrates Directive parameters, drug residues, and AMR?**

Currently, there are no binding national thresholds or limits for VMP residues or AMR indicators in manure applied to agricultural land. Consequently, no mandatory harmonized protocols for analyzing these specific indicators exist.

39. **Does the regulatory framework impose mandatory requirements or provide incentives for specific manure treatment technologies (e.g., anaerobic digestion, composting) that have been proven effective in reducing VMP residues and/or AMR (with national verification standards)?**

There are no mandatory requirements for adopting specific treatments for VMP/AMR reduction. Technologies are strongly incentivized (e.g., PNRR, energy incentives) also for their hygienic benefits, which include reducing the risk of AMR spread.

40. **Does the legislation require post-marketing environmental monitoring or specific risk management measures for VMP residues and AMR resulting from manure application (e.g., mandatory guidelines/practices for farmers on timing/site restrictions), and does the National Action Plan on AMR specifically integrate manure management practices?**

Partially. The National Action Plan on AMR (PNACC) *integrates* effluent management into its One Health strategy. However, these have not been translated into specific mandatory measures (e.g., site restrictions or additional timings beyond the Nitrates PdA) for farmers to manage VMP/AMR risk.

ANNEX 5

Reduced Questionnaire on Manure Management within the European and National Regulatory Framework: China case study (Focus on Air Emissions)

Introduction and Instructions for Completion

This document is a **Questionnaire on Manure Management within the European and National Regulatory Framework**, designed to assess the extent to which national (or regional, where competency is delegated) regulations in Member States specify, integrate, and, where necessary, address the gaps in EU directives concerning the management of livestock effluents.

Completion is required by the Authority responsible for implementing and specifying EU directives within its territory (National or Regional/Local level).

Method of Completion and Focus of Responses

Please answer each question based on **formal binding legislative provisions in force** (e.g., Laws, Decrees, Action Programmes, Regulations, Guidelines) and not merely on recommendations or incentives.

Specifically, the assessment should focus on two key criteria:

- **Mandatory Nature:**

  Determine whether the requirements, emission reduction plans, or adoption of specific technologies are **mandatory and binding** for livestock farms (particularly larger ones or those in critical areas, such as Nitrate Vulnerable Zones - NVZ, moving beyond mere encouragement or financial support.

- **Specificity and Quantification:**

  Verify whether the objectives, limits, and monitoring mechanisms are **specific and quantifiable** solely for manure management (distinguishing it from other agricultural sources) and if they go beyond basic minimum requirements at the EU level. This includes the presence of thresholds for new contaminants or advanced monitoring methods on the farm or in the environment.

Recipient Entity

1. **Does the entity (recipient) of this questionnaire operate at the national level or at a sub-national/sub-federal level (e.g., provincial, regional, or equivalent administrative jurisdiction)?**

The responses have been prepared based on the latest legislative provisions and technical guidelines currently in force in China.

Directive (EU) 2016/2284 - NEC

2. **Does the national legislation impose mandatory plans for the reduction of NH3 emissions from manure management (with specific technologies/timelines) for livestock farms (especially larger ones or those in critical areas)?**

Yes, mandatory accounting requirements exist at the national level, with detailed governance measures at the local level. Effective March 1, 2026, the Ministry of Ecology and Environment's "Technical Guidelines for Ammonia Emission Calculation in Large-scale Livestock Farms (Trial)" (HJ1434-2025) was formally implemented nationwide. This is a mandatory national environmental standard applicable to large-scale pig farms with annual output of 500 head or more (other livestock species follow the same standards). The accounting boundary covers the entire chain including pig house feeding, manure storage, and manure treatment. These guidelines are fully integrated with the current pollution discharge permit system and environmental tax collection management, making ammonia emission reduction a statutory compliance requirement for large-scale livestock farms. In key air pollution prevention and control areas such as Beijing-Tianjin-Hebei and surrounding regions, clear ammonia emission reduction targets have been set (e.g., 5% reduction by 2025 compared to 2020). Article 9.1.4 of the "Sichuan Province Livestock Breeding Pollution Prevention and Control Technical Guidelines (Trial)" (Chuan Agriculture Letter [2017] No. 647) clearly stipulates that livestock farms may adopt various odor treatment methods including physical, chemical, and biological deodorization, providing a technical basis for ammonia emission reduction. Article 37 of the "Yunnan Province Air Pollution Prevention and Control Regulations" explicitly classifies large-scale livestock breeding as a source of odorous gases, requiring the installation of purification devices or other measures to prevent odorous gas emissions. Meanwhile, Yunnan Province conducts regular law enforcement inspections on pollution prevention facilities construction and operation of large-scale livestock farms through the "random inspection and public disclosure" mechanism.

3. **Are there specific and quantifiable NH3 reduction targets that go beyond the NEC ceilings, disaggregated by management phases (housing, storage, spreading) and/or by specific livestock sectors?**

Yes, there are quantitative accounting parameters by management phase and livestock species, but no mandatory phased total emission reduction targets. China has not yet established national-level phased ammonia emission reduction targets similar to the EU NEC Directive. However, the latest accounting technical guidelines provide very specific quantitative emission parameters and recommended reduction rates by phase (housing, liquid/solid manure treatment) and by livestock species (pigs, dairy cattle, beef cattle, laying hens, broilers). For example, the guidelines clearly specify annual nitrogen excretion for different livestock species (e.g., 10.95 kg per pig per year) and the proportion of ammonia emissions to nitrogen loss at each stage. For farms adopting emission reduction technologies, the guidelines provide reduction rates for different technologies (e.g., 30% reduction rate for liquid manure covered storage technology), providing a basis for precise quantification of emission reduction effects. Sichuan Province's "Sichuan Province Livestock Breeding Pollution Discharge Standards (Draft for Comments)" further standardizes emission limits. Although technically capable of phase-specific accounting, policies have not yet established phased mandatory emission reduction targets similar to the NEC Directive.

4. **Does the national inventory system use country-specific emission factors (updated and beyond IPCC factors) and require direct on-site monitoring of manure emissions for calibration/validation?**

Yes, the national accounting system uses localized parameters and provides on-site monitoring method options. Both the national greenhouse gas inventory and ammonia emission accounting systems use localized parameters adapted to national conditions. The "Technical Guidelines for Ammonia Emission Calculation" provide localized correction coefficients based on extensive domestic measurement data, with coefficients for different emission nodes corrected according to county-level average annual temperature zones (<10C, 10-20C, >20C). The guidelines provide three accounting methods: mass balance method, emission factor method, and on-site monitoring method. For large-scale farms with monitoring capabilities, the on-site monitoring method can be selected for precise accounting, providing a direct means for calibrating and verifying emission factors. The "Technical Guidelines for Pollution Reduction and Carbon Mitigation in Large-scale Livestock Farms" issued by the National Animal Husbandry Service requires all regions to actively coordinate with development and reform, ecological environment, and statistics departments to jointly carry out basic work such as carbon emission statistical accounting for animal husbandry, providing technical support and services for livestock enterprises to enter the carbon trading market, carry out carbon footprint quantification, and obtain carbon labelling certification. Article 7 of the "Sichuan Province Livestock Breeding Pollution Prevention and Control Technical Guidelines (Trial)" provides reference tables for daily manure excretion of different livestock species (e.g., pig manure 2kg/day, urine 3.3kg/day), providing basic data support for localized parameters.

5. **Are mechanisms in place to verify the effective adoption and correct functioning of low-emission techniques, such as the systematic collection of georeferenced data at the individual farm level on specific manure management practices (e.g., type of housing, application technology, manure composition) to improve emission estimates?**

No, a systematic farm-level data verification mechanism for the purpose of verifying low-emission technology operation has not yet been established. Although China regulates pollution prevention facilities and manure treatment methods of livestock farms through the "Pollution Discharge Permit Management Regulations" and the National Livestock Manure Resource Utilization Information System, the core objectives of these mechanisms are pollution prevention compliance inspection and resource utilization rate statistics, rather than specifically verifying the operational effectiveness of low-emission technologies or improving ammonia emission estimates. Currently, a systematic monitoring system for the operational efficiency of low-emission technologies (such as storage covers, injection fertilization) has not been established, nor are farms required to provide georeferenced data for dynamic calibration of emission models. Ammonia emission estimates still mainly rely on the emission factor method rather than dynamic verification based on real-time farm operational data. Yunnan Province's "random inspection and public disclosure" plan lists "large-scale livestock breeding pollution prevention and control" as an inspection item, including "whether supporting pollution prevention facilities are in place and the status of manure resource utilization." However, this is a compliance inspection, not a data collection mechanism aimed at improving emission estimates. An enforcement case in Dayao County, Chuxiong Prefecture showed that ecological environment departments use drone inspections to discover farms storing waste in pits without anti-seepage measures and impose penalties according to the "Yunnan Province Ecological Environment Administrative Penalty Discretionary Rules," indicating that law enforcement inspections have become normalized.

6. **Does the normative establish specific targets for the adoption of treatment technologies (e.g., anaerobic digestion, acidification) and/or make the adoption of low-emission techniques for slurry application mandatory (e.g., direct injection)?**

Low-emission technologies are mandated through regulations, while advanced treatment technologies are mainly guided through incentives. The "Regulations on the Prevention and Control of Pollution from Large-scale Livestock Breeding" stipulate that livestock farms must construct manure storage, comprehensive utilization, and harmless treatment facilities

adapted to their breeding scale, otherwise they may not be put into production or use. The "Technical Guidelines for Pollution Reduction and Carbon Mitigation" issued by the National Animal Husbandry Service clearly require farms using dry manure removal processes to minimize solid manure entering liquid manure as much as possible; liquid manure storage facilities may be covered with lids, films, or sheds; manure application should use injection fertilization or soil covering after application. Article 5.2.1 of the "Sichuan Province Livestock Breeding Pollution Prevention and Control Technical Guidelines (Trial)" requires that livestock farms (communities) should adopt dry manure removal processes and take effective measures to promptly transport manure and manure residue to storage or treatment sites, not to be discharged mixed with urine and sewage. It also requires that the total volume of storage facilities shall not be less than the total amount of manure produced by the farm during the maximum interval for supporting agricultural and forestry crop production fertilizer use.

7. **Does the legislation require quantitative assessments of the cross-media effects of NH3 reduction measures (e.g., impact on N2O or nitrate losses to water)?**

Yes, national technical guidelines have incorporated cross-media impact considerations. The "Technical Guidelines for Pollution Reduction and Carbon Mitigation in Large-scale Livestock Farms" explicitly propose the principle of "adhering to coordinated promotion," coordinating the promotion of collaborative carbon reduction throughout the livestock breeding industry chain, strengthening the research and promotion of collaborative emission reduction technologies for greenhouse gases and odorous gases, and gradually building a coordinated governance path for pollution reduction and carbon mitigation in animal husbandry under the "dual carbon" goals. The guidelines provide collaborative emission reduction effect data for various technologies: Low-protein diet technology: For every percentage point reduction in feed crude protein content, total nitrogen excretion in manure and urine can be reduced by 5%-10%, and nitrous oxide emissions from house manure storage, manure treatment, and manure field application can be reduced by about 10%. Optimized liquid manure storage technology (pH < 5.5): Can reduce methane, nitrous oxide, and ammonia emissions by 60%, 60%, and 50% respectively. Manure covered field application technology (injection fertilization): Compared with sprinkler irrigation, can reduce greenhouse gas and ammonia emissions by 10%-20% and 40% or more respectively. Article 4.2 of the "Sichuan Province Livestock Breeding Pollution Prevention and Control Technical Guidelines (Trial)" provides recommended values for suitable livestock carrying capacity per unit area of arable land under different planting patterns (e.g., 3 pigs/mu/year), providing a quantitative basis for assessing cross-media nitrogen impacts.

Regulation (EU) 2021/1119 - European Climate Law

8. **Does your national climate strategy or legislation establish binding quantitative targets for the reduction of GHG emissions (such as CH4, N2O) specifically from manure management, disaggregated by gas or by management phases, or maximum CH4 emission intensity limits?**

No, there are currently no mandatory quantitative emission reduction targets specifically for manure management by phase or by gas type. The Nationally Determined Contributions targets and the carbon peak and carbon neutrality "1+N" policy system provide general directions for greenhouse gas emission reduction in the agricultural sector but have not yet established mandatory quantitative limits specific to manure management segments, disaggregated by gas type or management phase, like the EU. Related work (such as CCER methodologies) focuses more on providing accounting bases for voluntary emission reduction projects rather than setting mandatory emission caps. The Ministry of Agriculture and Rural Affairs has clarified that by 2030, on the basis of ensuring stable and safe supply of livestock and aquatic products, breeding production efficiency will be significantly improved, and the average feed consumption per unit of animal product in standardized large-scale breeding will decrease by more than 7% compared to 2023. The "Ten Measures for Promoting High-quality Development of Animal Husbandry in Sichuan Province" proposes to "support the upgrading of facilities and equipment in large-scale farms and promote the resource utilization of livestock breeding waste with fo-

cus on integrated planting and breeding," and clarifies specific fiscal subsidy and reward standards. However, these are incentive measures rather than mandatory emission reduction targets.

9. **Does the regulatory framework include mandatory support schemes or direct regulatory drivers to ensure widespread adoption of low-emission manure management technologies (e.g., anaerobic digesters, storage covers)?**

Yes, through a combination of regulatory mandates and market incentives. The "direct regulatory driver" mainly comes from the "Regulations on the Prevention and Control of Pollution from Large-scale Livestock Breeding," which mandates the construction of manure storage and treatment facilities, which themselves can achieve methane and ammonia emission reduction. For more advanced technologies such as anaerobic digestion, promotion is mainly through "mandatory support programs" such as the Greenhouse Gas Voluntary Emission Reduction Project (CCER), which provides carbon credit income for biogas utilization projects, as well as tax incentives and electricity price subsidies. The "Ten Measures for Promoting High-quality Development of Animal Husbandry in Sichuan Province" explicitly "supports the upgrading of facilities and equipment in large-scale farms" and stipulates that "for animal husbandry equipment eligible for agricultural machinery purchase subsidies, all eligible equipment shall be subsidized," increasing the loan interest subsidy rate for the pig industry by 0.5 percentage points on the original basis. These measures provide financial support for the promotion of low-emission technologies. The "Notice on Strengthening and Optimizing Facility Agricultural Land Management" jointly issued by Yunnan Province Department of Natural Resources, Department of Agriculture and Rural Affairs, and Forestry and Grassland Bureau explicitly include "manure treatment" facilities in the scope of breeding facility land, providing land security for farms to construct manure treatment facilities.

10. **Is there a national binding target for the percentage of manure to be treated with advanced technologies (e.g., anaerobic digestion) and/or for the percentage of liquid manure to be applied with low-emission techniques?**

No, there are no mandatory national targets for manure treatment technology adoption rates, but there are overall utilization rate targets. The Ministry of Agriculture and Rural Affairs has announced that the target for comprehensive utilization of livestock manure in 2025 is over 80%. National policies encourage comprehensive utilization methods such as manure field application, biogas production, and organic fertilizer manufacturing, but have not set nationwide mandatory indicators such as "proportion of manure that must use anaerobic digestion" or "percentage of liquid manure using low-emission application technologies." As a major animal husbandry province, Sichuan ranks first nationally in pig slaughter volume. Although no specific technology adoption rate targets have been set at the provincial level, the province promotes high-quality development of animal husbandry through county-wide implementation approaches.

11. **Does the MRV system require the systematic and verifiable collection of data at the individual farm level on manure management practices and related GHG emissions, using advanced methodologies (e.g., specific models, direct monitoring) to reduce uncertainties in national inventories?**

Yes, there are strict requirements for specific projects and record-keeping requirements for general large-scale farms. General large-scale farms need to regularly report waste generation and utilization to environmental protection departments. The "Technical Guidelines for Ammonia Emission Calculation" require the establishment and maintenance of complete records including feed use, manure generation and treatment, and monitoring data. For projects participating in the carbon market, the Monitoring, Reporting, and Verification (MRV) system has extremely high requirements, requiring daily recording of key data or automatic real-time monitoring by instruments. Anju District in Sichuan requires farms (households) to establish manure treatment and utilization records to ensure complete and authentic recorded information. It establishes a "list system + responsibility system + cancellation system" and organizes third-party institutions to evaluate and accept rectification effects. In enforcement practice in Chuxiong Prefecture, Yunnan, ecological envi-

ronment departments use drone inspections, on-site sampling, and monitoring to verify farm pollution discharge, with monitoring reports serving as direct evidence for administrative penalties.

12. **Does the legislation explicitly require an integrated technical assessment approach that simultaneously considers the climate impact of manure management solutions along with their effects on air, water, and soil quality and in relation to all key pollutants?**

Yes, there are clear requirements at the planning and EIA stages. The "Regulations on the Prevention and Control of Pollution from Large-scale Livestock Breeding" require that when formulating animal husbandry development plans and livestock breeding pollution prevention and control plans, environmental carrying capacity must be considered comprehensively, and pollution prevention targets, tasks, and measures must be clarified. When conducting environmental impact assessments for new, renovated, or expanded farms, analysis must focus on waste types and quantities, comprehensive utilization and harmless treatment plans, and impacts on water bodies, soil, and other environments. This reflects the need to comprehensively consider the impacts of manure management solutions on climate change, air, water bodies, soil, and other environmental media at the decision-making level. Article 10 of the "Yunnan Province Air Pollution Prevention and Control Regulations" explicitly states that "this province implements a total quantity control system for key air pollutant emissions," and Article 11 stipulates that if air quality improvement targets are not met, the provincial ecological environment authority shall summon the principal responsible person of the government for a talk. EIA approvals require farms to strictly implement "rain and sewage separation" drainage systems and key anti-seepage treatment for wastewater pools and composting rooms, reflecting the concept of multi-media integrated prevention and control.

13. **Do the National Integrated Energy and Climate Plans (PNIEC) translate EU climate targets into concrete measures, binding for manure management, providing specific financial allocations?**

Yes, through national strategic planning translated into concrete measures and financial support. China's "dual carbon" goals and their implementation opinions constitute the top-level design. The Ministry of Agriculture and Rural Affairs' annual priorities for animal husbandry and veterinary work clearly identify promoting livestock breeding pollution prevention and control, manure resource utilization, and green and low-carbon transformation of the breeding industry as core tasks. These strategies are implemented through specific regulations (such as the "Regulations on the Prevention and Control of Pollution from Large-scale Livestock Breeding"), technical standards (such as ammonia accounting guidelines), and financial arrangements (such as the National Development and Reform Commission and Ministry of Agriculture and Rural Affairs' county-wide livestock manure resource utilization projects, PPP projects, tax incentives, electricity price subsidies, etc.). The "Ten Measures for Promoting High-quality Development of Animal Husbandry in Sichuan Province" clarifies specific fiscal incentive policies: for beef cattle (including yak) breeding farms (households), the provincial finance provides incentives at the standard of 300 yuan per head; for cities (prefectures) exceeding pig, cattle, and sheep slaughter targets, the provincial finance provides incentives at the standard of 50 yuan per head for pigs, 200 yuan per head for cattle, and 30 yuan per animal for sheep for the excess portion.