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Creating an Alternative Governance for Phosphorus Circularity Through Framings That Strengthen Intersectoral Policy Coherence in the EU: Constraints and Implementation Possibilities

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Abstract: Phosphorus' availability and pricing is critical for the entire food system. Transformative phosphorus governance is required to reduce the European Union's fertiliser vulnerability. At the same time, the EU's governance approach is constrained by multiple problem definitions and missing salient framings that could make phosphorus recovery a priority of the EU's decision-making agenda. The article addresses this policy gap by gathering and discussing different institutional and stakeholder framings that could inform a transition to a transformed phosphorus governance. We combine triangulated methods (framing as an analytical heuristic, semi-structured expert interviews, document analysis, and conference observations) with Kingdon's three streams of agenda-setting as a conceptual framework to identify alternative intersectoral framings of phosphorus sustainability. Our findings suggest that the window of opportunity filled by the EU's Fertiliser Affordability Communication supports a decarbonisation pathway that fails to emphasise the potential of emergent framings supporting phosphorus recovery. We analyse these framings and suggest that a new window of opportunity for their elevation on the EU's decision-making agenda is opening with the inauguration of a new European Commission. We propose five alternatives that apply powerful spillover framings to implement phosphorus governance that is synchronous with the commission's sectoral priorities. We believe that an extension of the EU's current environmental policy along these pathways can potentially contribute to phosphorus sustainability.

Keywords: framing; phosphorus; renewable; circular; strategic; transformation; governance

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1. Introduction

The global phosphorus challenge is framed increasingly through the exhaustibility and discrete availability of phosphate rock (85% of which is concentrated in just five countries), the embeddedness of 72% of all phosphorus in animal feed and livestock rearing, soil phosphorus deficits at 30–32%, chemical fertiliser overapplication at 30–40% leaching into water bodies and triggering toxic eutrophication, and its persistently low recycling rates [1–4].

Around 80% of phosphorus is used in food production [5], and 80% of that amount is lost between crop farming and food consumption [6]. Despite phosphorus' non-substitutability for food security [7], its governance does not reflect the increasing demand for Lithium Iron Phosphate (LFP) batteries and microchips [8–10]. Global trade has improved phosphorus' accessibility, but is increasingly contributing to its wasteful use and susceptibility to price shocks, making a transition to local crop–livestock system integration and accelerated nutrient recycling a necessity [11,12]. Nutrient recovery processes are also important for advancing sustainability, as they can offset 50–70% of phosphorus lost along the supply chain [13]. In addition, the projected 0.6–1.5% increase in fertiliser demand cannot be met solely by decarbonising fertilisers' chemical synthesis [13].

Neither critical advances in circularity nor phasing out carbon-intensive products and industries rest at the centre of the transition to phosphorus sustainability. Instead, phosphorus governance is trapped in technocratic recycling targets that receive little political attention [14]. Few demonstration plants in the EU showcase the potential of recovery technologies [15], regardless of estimations that 15–17% of phosphate rock can be substituted with recycling [16,17]. While the EU cannot overcome its import reliance on mined phosphate rock (84%) (the EU has phosphate mines in Sokli and Siilinjärvi, Finland, and new mines with significant reserves (70bn tons) were found in south Norway (Bjerkreim–Sokndal); however, currently there is no evidence regarding their economic feasibility) and processed phosphorus (100%) through its substitution with other elements, it can achieve better resilience to market shocks by exploiting and recycling underutilised phosphorus streams [12,18]. The problem is that phosphorus management has been largely left to markets [19] and the EU formally governs the element through obligations for a 20% reduction in chemical fertiliser application and a 50% increased fertiliser use efficiency [20–23]. These targets have the potential to reduce the eutrophication caused by phosphorus leaching and are echoed by a range of United Nations biodiversity and chemical governance frameworks [24].

However, these top-down regulatory approaches suffer from poor enforceability and do not reflect inefficiencies across the phosphorus supply chain, which would remain unregulated [22], as phosphorus extraction, fertiliser production, animal feed growing, livestock rearing, and food consumption may happen outside the EU [25]. Key challenges such as climate change and the scramble for obtaining funding for decarbonisation also remain unaccounted for [26–29]. These approaches do not direct efforts towards advanced chemical recycling or nature-based solutions. Such targets allow only for small technical changes and leave the strategic direction of phosphorus governance ambiguous [14,30–33]. In contrast, the governance of nitrogen has benefitted from nitrogen oxide's recognisable framing as an acidifying greenhouse gas that damages public health, which has appealed to high-level politics and driven substantial research into its climate effects [34–37]. Although phosphorus acid is produced with sulfuric acid derived from the processing of fossil fuels [38], there is more public awareness of nitrogen, due to the direct usage of natural gas in its synthesis [35,39].

The EU's record of framing entrepreneurship in environmental policy could be explained through the usage of market mechanisms that encourage reforms in exporting counterparties [40–42]. For example, the inclusion of fertilisers in the EU Carbon Border Adjustment Mechanism (CBAM) could trigger not only emission accounting in companies, but also the adoption of emission taxation or allowances' trading in third countries [43]. Innovative patterns of governance can also be promoted in multilateral formats such as the G7 and G20 [44,45]. Although the EU has a modest influence in reciprocating its internal framings in other multilateral organisations, improving its internal policy coherence is key to consolidate these efforts [46]. Multiple policy sectors in the EU have relevance to phosphorus, and their objectives can serve as the backbone for a more coherent phosphorus governance that makes the best use of the EU's existing instruments (see Figure 1).

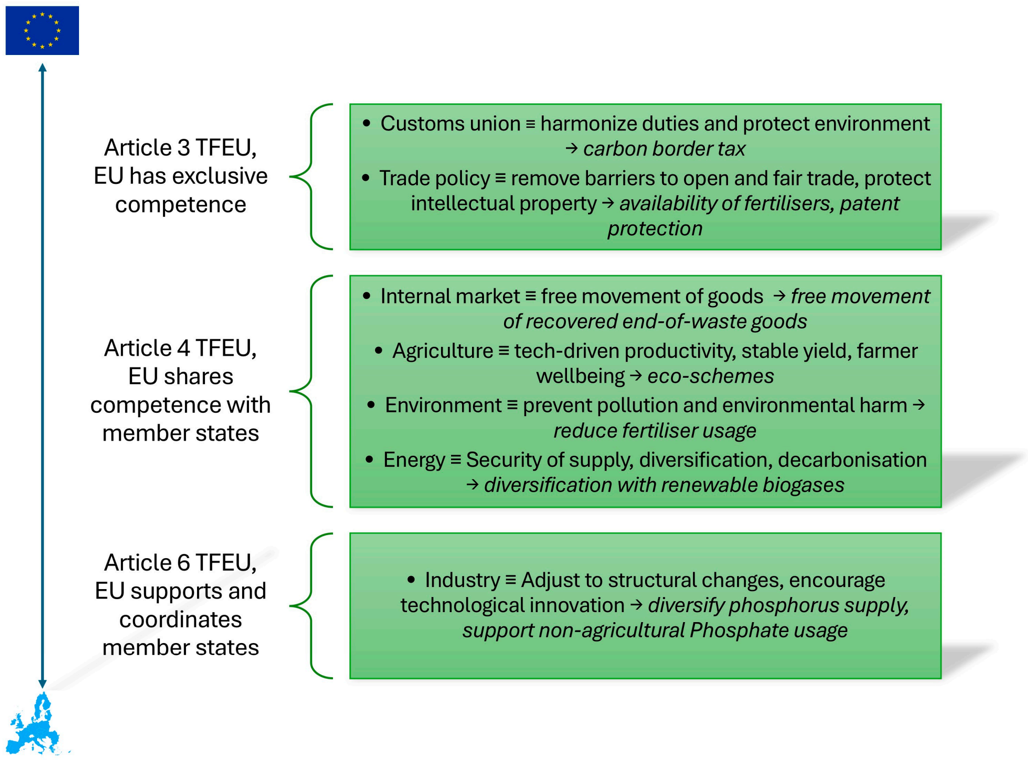

Figure 1. Division of competencies in the EU, sectoral policy objectives, and relevance to phosphorus. The arrow represents the spectrum between exclusive legislative competence exercised by the EU as a federal entity in the sectors above (depicted by the EU flag) and its complementary legislative competence exercised in the sectors below (depicted by the EU map).

Addressing this policy gap by reformulating the existing phosphorus framings may have ramifications for the holistic understanding of the global phosphorus challenge. In this paper, we bridge a research gap by gathering and discussing the alternative institutional and stakeholder perspectives across EU policy sectors to inform this process of governance transformation.

We do so by asking the following questions:

1. What intersectoral framings can emerge to inform a more coherent phosphorus governance?
2. What dynamics and vested interests in the EU constrain the advancement of these framings on the political agenda?

We answer these questions by (1) discussing the related institutional framings and those elevated by stakeholders as feedback towards the existing agenda in the EU and (2) identifying powerful spillover framings that can trigger intersectoral learning through participant observation at stakeholder conferences and analysing the reasons for their limited potential.

2. Conceptual Framework

Traditionally, governance is seen as the formal and informal interaction between institutions steering "hybrid and multi-jurisdictional" phenomena [47] and stakeholders shaping institutional designs and objectives [48]. Governance innovation may contribute to the creation of new markets to alter technology trajectories and point the way forward through times of political uncertainties via borrowing or extending a proven principle in a new policy field, context, or jurisdiction [49]. For example, EU missions were conceived to address the failures of the economic growth paradigm and redirect growth and technological innovation towards solving societal challenges, such as restoring soils and adapting to climate change [50–52].

Due to the frictions between the regulatory momentum propagated by the European Commission and member states' struggle to constrain this process, in the EU, this innovation process often happens through softer modes of governance based on the voluntary adoption of guidelines, benchmarks, and best practices [53]. It typically involves modes of multi-level negotiation, which allow transformative governance coalitions to form, and subsequently change, the direction of policy [54]. Still, this complex multi-level governance process often results in piecemeal solutions.

Since experimental evidence alone is unlikely to solve the global phosphorus challenge [14], we employ framings as an analytical heuristic device to explore the shifting and often unknown definitions of complex problems [55]. Framing is a socially constructed interpretation of an occurrence [56]. Framing analysis explores how intentional formulations of choice problems can shift an actor's preferences [57]. Framing has inspired strategies for alignment through the amplification of beliefs or extension of objectives [58], and is the device that defines a problem, its causality, and remedies [59]. In public policy, competing framings are supported by sponsors and serve as prototypes that inform the reframing of an existing controversy [60]. The reframing dialogue may involve strategies such as incorporating inferior issues and accommodating differences by excluding incompatibilities [61]. In the EU, decision frames are usually a result of consensual decision-making that presents policy options neutrally; however, institutions or actors may be interested in emphasising a policy direction [62,63]. The framing of policy choices can therefore exemplify the vested economic interests of stakeholders interested in capturing the institutional agenda [64–66]. Beyond embellishing, incumbent stakeholders may also be interested in employing framing as a heuristic device to obscure inconvenient aspects of a problem.

To summarise, we understand framings as the core objectives of a discourse that defends a policy option [60], and an embodiment of power relations [67]. We also take note of existing critiques of framing theory and focus on using a particular unit of analysis (EU Laws), as well as exposure to more than a single experimental context [68]. Since socio-political processes are dynamic and may involve the conscious and strategic unfolding of frames or exhibit transformation weaknesses over time, we also investigate the entirety of the EU's legislative programme, the Green New Deal [69]. To further improve reproducibility, we do not explore the idiosyncratic effects of legal framings in persuading and directing the masses. Instead, we analyse the limitations of existing policy objectives in the EU and propose reframings derived from relevant strategies and laws [61].

We base our analysis on Kingdon's three streams theory [70], a well-established concept for researching agenda-setting, which has not been previously used in phosphorus research. The concept suggests that the reframing of the decision-making agenda is contingent upon the identification of circumstances as problems that require attention, as well as policy entrepreneurs' alignment across the following three streams: problems, policies, and politics:

1. Problems: There are many alternative problem definitions developed outside of government that compete to attract attention and become recognisable issues [70,71]. Problems may be constructed through frames that suit the governance actors' preference for solutions, which are proposed at high-profile focusing events or after a crisis has drawn the attention of policymakers [72]. Frames may be supported by negative feedback on existing policy (e.g., shifting effects) or indicators [73];
2. Policies: Solutions to the problem such as policy recommendations may be based on feedback on existing policy and are diffused in a discussion between authoritative sponsors and the policy officials who evaluate them [70]. In the case of the EU, the

EU Commission is a gatekeeper, which provides technically feasible solutions and the routes for policy review [74,75]. In its action, it can be affected by foreign policy or competing priorities among different directorates [76,77]. The sponsors are expert policy communities with sufficient resources, access to, and understanding of EU policy making [78,79];

3. Politics: The influence of government agendas is realised through organised advocacy by powerful interest groups, significant swings in national mood, or alterations to the composition of the government [70]. In the EU, there is oftentimes no common European position on policy choices across member states [74,78]. The biggest opportunity for influence lies in the election of a new European Parliament and new office of the Commission, but it may include Council Presidencies, parliaments' right to legislative initiatives, political resolutions by the EU Parliament, or prime ministers, as well as political spillovers [74,75,78,79].

Framing can be used as a manipulation tactic to advance a problem formulation that sets out a policy solution [80–82]. While some early conceptual debates differentiate between an epistemic community of recognised experts and an advocacy coalition comprising a variety of stakeholders, more recent perspectives suggest the definition expert policy entrepreneurs, who work across the three streams to bring an issue to the attention of high-level officials [70,79,83,84]. Based on the above, we developed the framework illustrated in Figure 2.

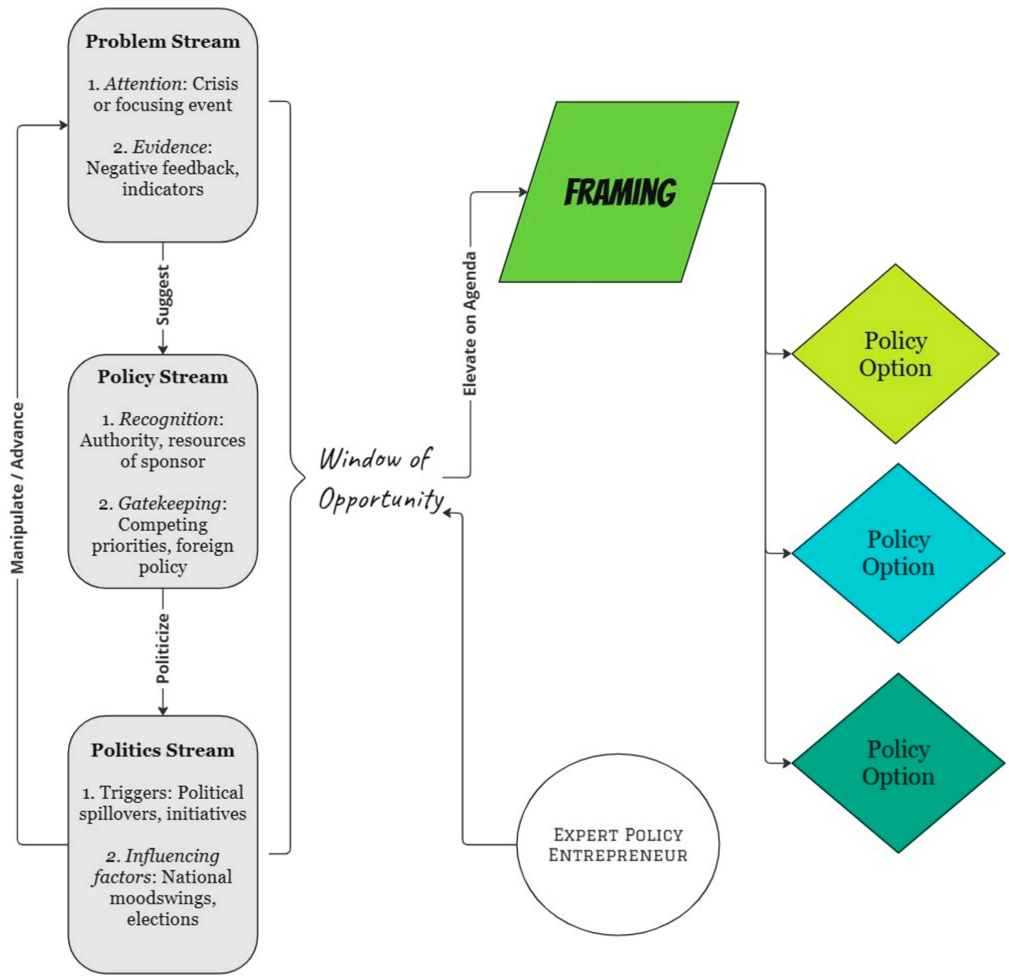

Figure 2. The interactions between the three streams that produce a policy window and a representation of how policy entrepreneurs elevate framings that suggest policy options.

Ontologically, we take a critical realist stance over the intractable nature of reality that can be described by a theory, but that requires critical examination to generate knowledge. Epistemologically, due to the siloed understanding of the phosphorus problem, we object to the current realist and positivist understanding of and focus on the subjective and pluralist reality of the object of study—phosphorus framings as interpretive devices embraced by relevant actors based on their interests, backgrounds, and worldviews [85,86]. We use the conceptual framework to engage in critical theoretical inquiry into existing assumptions defined by hegemonic power relations and advocate for a new framing [87,88].

3. Methodology

3.1. Research Method

To address the research questions and to build upon previous conceptual groundwork in phosphorus framing for governance change [14], we carried out thirty semi-structured interviews with phosphorus experts. To analyse the data, firstly, we applied inductive coding to interview transcripts to identify framings in the feedback provided by stakeholders (see Figure 3).

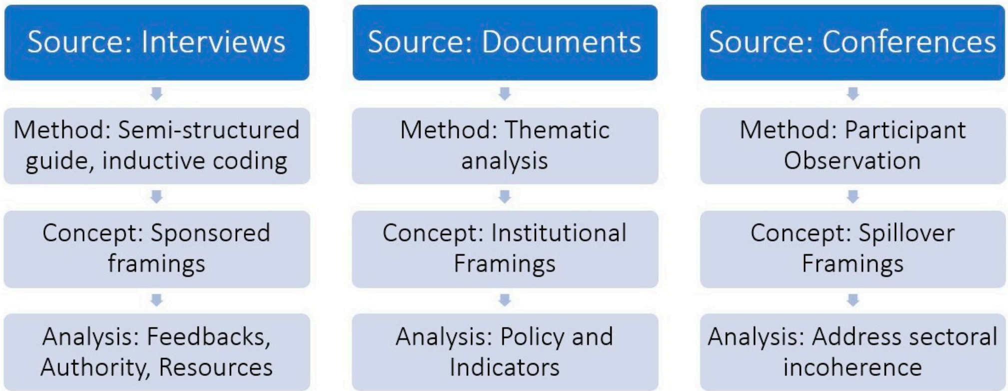

Figure 3. Triangulation of empirical sources and methods.

Secondly, we combined these data with a thematic document analysis of relevant EU strategies and laws aimed at identifying institutional framings in the EU that are applicable to phosphorus [89]. We then categorised and labelled the framings shaped by stakeholders of pphosphorus governance, on the one hand, and relevant EU institutional framings, on the other hand, into general framings that can speak to high-level policymakers and, subsequently, synthesised them into recognisable, overarching meta-framings [69,70].

Thirdly, we triangulated the method and data sources by applying participant observation at three stakeholder conferences, through which we identified framings that could induce political spillover effects formally shaped by the vertical division of powers in the EU and open a window for policy change based on learning across sectoral policies [90,91].

Applying these spillover framings to the sponsored and institutional framings allows us to employ the definition of institutional innovations as anticipating uncertainty by borrowing or extending a proven principle into a new policy field [49]. Thus, we are also able to address inter-sectoral controversies rooted in variable policy design [86,92]. Our expectation is that reframing towards more coherent governance will make phosphorus a recognisable problem and provide new advocacy tools to stakeholders working in environmental policy.

We answer the first research question by analysing the authority and access to resources of sponsored framings providing feedback on existing policy and indicators, and which spillover framings may trigger the opening of an intersectoral policy window of opportunity [14,70,91].

We answer the second research question by analysing which framings with substantial authority and resources have influenced the institutional agenda, and whether these advance a problem definition that serves vested interests. Manipulative definitions may include conceptual recycling of circularity [93], a linear fossil economy [94], defending existing structures [95], or dealing with crises through the allocation of capital to their expert community [96].

Lastly, to apply the conceptual framework, we identify the possibility to open a policy window that can address the EU's vulnerability to external shocks by elevating long-term, capital-redistributive, experimentation-oriented framings that can induce radical change in phosphorus governance through intersectoral learning [12,91,96].

3.2. Data Collection

The qualitative empirical data were collected in 2022–2023 in three phases:

a. *Semi-structured interviews*: This sponsorship scoping phase [97–100] consisted of 30 in-depth interviews with experts based on an interview guide focusing on institutional fragmentation, actors' visions for a circular phosphorus economy, and potential institutional innovations (see Table 1 and Annex I, Appendix A). The experts were recruited at the European Sustainable Phosphorus Conference (ESPC4), the biannual landmark event of the European Sustainable Phosphorus Platform (ESPP), which drives the regulatory debate on phosphorus in the EU.
b. *Document Analysis*: The European Commission search engine was used to generate a scoping snapshot of phosphorus-related documents in May 2023 through the search word: "phosp*". To improve the transferability of the findings [101], the focus of the analysis was shifted to strategies and laws of relevance to the recovery and the end-uses of phosphorus (see Figure 4 and Annex II in Supplementary Materials) and the EurLex/EU Parliaments' Legislative Train, while the search strings were expanded to "phosp*, fertiliser, nutrient, resource". The political objectives of each document were extracted while paying attention to the themes that emerged (i.e., energy and climate).
c. *Participant Observation*: Besides observations of the industry at the ESPC4, we made further non-participant observations of policymakers at two annual stakeholder conferences organised by the EU: Green Week 2023 and Sustainable Energy Week 2023. Ultimately, we transcribed the collected field notes into observed spillover framings [102] (See Annex II).

3.3. Data Analysis

The analysis focused firstly on the extraction of framings from the empirical qualitative data. This was carried out inductively for the collected interviews and resulted in "actors, barriers and innovations" as codes that informed the sponsored framings. The key words and core objectives of EU strategies and laws were used to identify the policies and indicators and derive institutional framings. Lastly, field notes from conferences were organised into spillover framings and supplemented with online quotes provided by the organisers. These three framing types were organised into general framings that can speak to high-level policymakers and grouped thematically into identifiable meta-framings.

Table 1. Interview participants.

Nr.	Role and Occupation	Organisation Type	Level	Sector
1	Circular Economy Director	Company	European	Fertilisers
2	Sustainability Director	Company	European	Waste Management
3	Policy Officer in the Biogas Industry	Association	European	Biogas
4	Anonymized	SME	National	Nanomaterials
5	Anonymized	SME	European	Fertilisers and Biogas
6	Head of Fertiliser Department	Association	National	Building Materials and Steel Slag
7	Scientific Manager	Consultancy	National	Fertilisers
8	Project Manager	Association	Macro-region	Agriculture and Environment
9	Anonymized	Research	National	AI
10	Anonymized	Research	National	Agriculture and Waste
11	Anonymized	EU Institution	European	Fertilisers
12	Director General	Association	European	Fertilisers
13	Anonymized	Association	Macro-region	Environment
14	Researcher	Research	National	Agriculture
15	Anonymized	Association	National	Fertilisers
16	Senior Policy Officer, EurEau	Association	European	Water Utilities
17	Anonymized	Company	European	Remote Sensing
18	Anonymized	Ministry	National	Institutions
19	Anonymized	Consultancy	European	Systems and Biobased Innovation
20	Anonymized	Company	National	Vivianite and Batteries
21	Anonymized	Platform	National	Phosphorus
22	Manager	Platform	National	Phosphorus
23	Project Manager	Tech Centre	National	Water Innovation
24	Natural Resources Associate, Systemiq	Consultancy	European	Systems and Resource Management
25	Policy Officer, Environmental Civil Society Organisation	Civil Society Organisation	European	Fertilisers
26	Anonymized	Association	European	Specialty Chemicals
27	Anonymized	Association	National	Resource Recovery from Wastewater
28	Anonymized	EU Institution	European	Circular Economy
29	National Research Centre INIA-CSIC	European Partnership	National	Innovation Partnership
30	Manager	Company	European	Chemical Industry

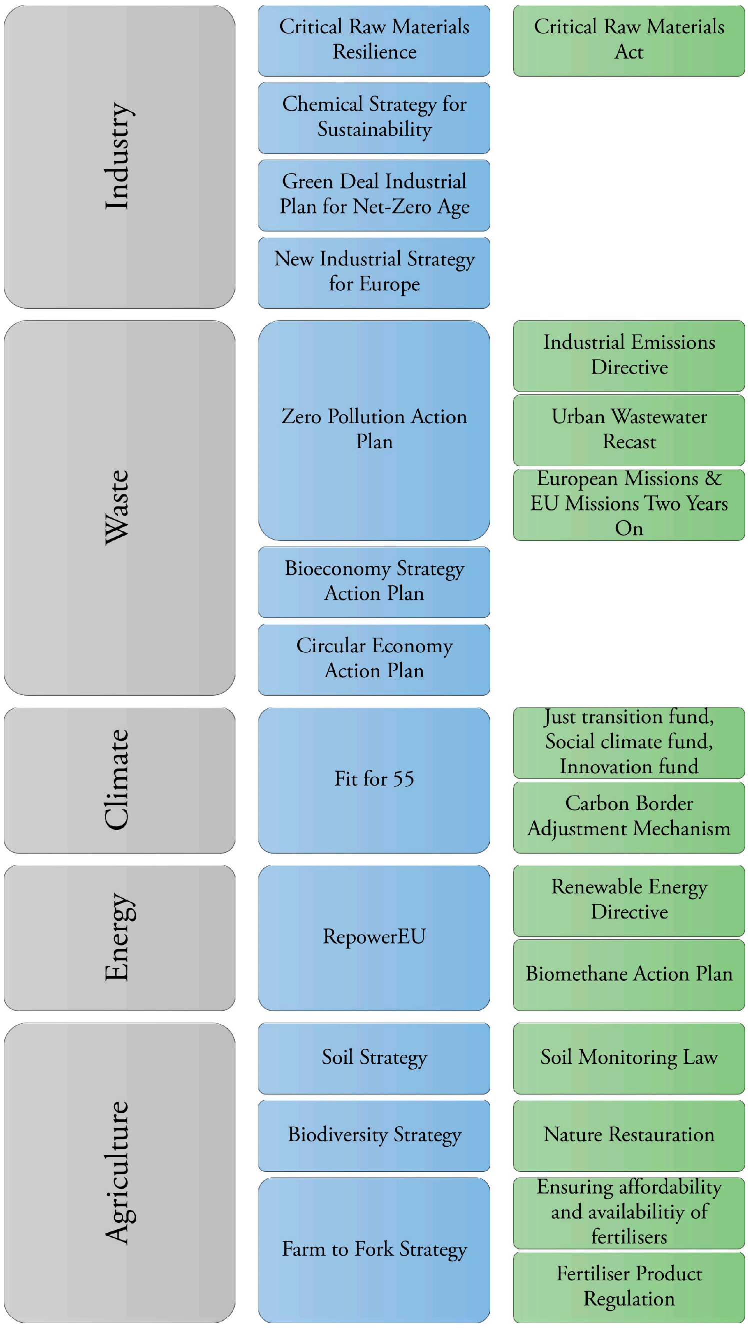

Figure 4. Reviewed sectors (shaded grey), strategies (shaded blue), and laws (shaded green).

4. Results

Description of Meta-Framings

We present the framings derived from the empirical material in Table 2 and describe how they align with the overarching meta-framings (see Annex II for the original dataset). Figure 5 shows the pathways that sponsors have used to progress their framings.

Table 2. The overarching meta-framings comprise accessible general framings, which were developed based on the sponsored, institutional, and spillover framings obtained from the triangulated qualitative data.

Meta-Framing	General Framing	Source			
		Key Sponsors	Interviews: Sponsored Framing	Documents: Institutional Framing	Conferences: Spillover Framing
Fertiliser Self-Sufficiency	Import fertilisers	Farmers, Chemical Industry, Politicians, EU Institutions	Resistance to recovered fertilisers	Import phosphates, subsidise transition to ammonia (Fertiliser Affordability Communication)	Incorporate Recovery Technologies in FPR
	Scale-up recovery technology	Tech Centre, SME, EU Institutions	Standardise risk management to fast-track end-of-waste status	"One Health" approach to risk for people, animals, and environment (Biodiversity strategy, Soil strategy) "One Substance, One Assessment" (Chemical strategy for sustainability) Synergies from cross-sectoral demand (New industrial strategy for Europe)	
	Assign value to recovered fertilisers	Tech Centre, National Association, Consultancy	Assign value to recovered fertiliser to reduce leakage to third countries	Optional end-of-waste harmonisation across member states of the EU (Fertiliser Product Regulation)	Prevent unfair competition through CBAM
Decarbonisation	Farming sufficiency through service provision	Civil Society, Chemical Industry, Tech Centre	Sufficiency approach to farming, remote sensing, and deep learning	Chemicals-as-Service (Chemical strategy for sustainability)	
	Create modules for nutrient recovery from organic waste	Chemical Industry, SME, EU Association, Consultancy, EU Institutions	Wastewater utilities as modular (easy disassemble, repair, and reuse) resource plants of the future	Soils are a recycling machine (Soil strategy) Circularity reduces import dependency (Critical Raw Materials Act)	Warfare-driven destruction of wastewater plants
	Biogas is a rural industry, recovered phosphorus can be used in energy storage	EU Association, Civil Society, Ministry, Corporation	Anaerobic digestion brings biogas industry to rural areas, recovered phosphorus in e-vehicle batteries	Fully substitute Russian fossil fuels with hydrogen and ammonia (RePowerEU, Fertiliser Affordability Communication, Methane Regulation)	Hydrogen limits deployment of renewables
System Change	Design change-oriented regulation	Corporation, Ministry, Phosphorus Platform, Tech Centre, Consultancy	Design change-oriented regulations (tax virgin materials, extend efficiency with wellbeing, finance nature restauration and R&D) connecting high-level objectives with individual goals	Innovate for climate-neutral competitiveness and fairness of the transition (Fitfor55)	Reduce amount and frequency of legislation, focus on implementation
	Use market instruments to select energy-relevant phosphorus recovery solutions	EU Association, Ministry, EU Institution	Devise market pull instruments that support phosphorus recovery frontrunners	Use state aid, critical resource clubs, regulatory sandboxes with energy focus (Industrial Plan for Net Zero Age)	Abandon technological neutrality
	Advance phosphorus recovery as instrument to phase out fossil fuels and mitigate climate change	SME, EU Institution	Add emission factors for recycling to move away from mining and imports of raw materials	Equivalent carbon pricing for imports and domestic products to avoid carbon leakage (Carbon Border Adjustment Mechanism)	Use regulatory sandboxes to phase out fossil fuels

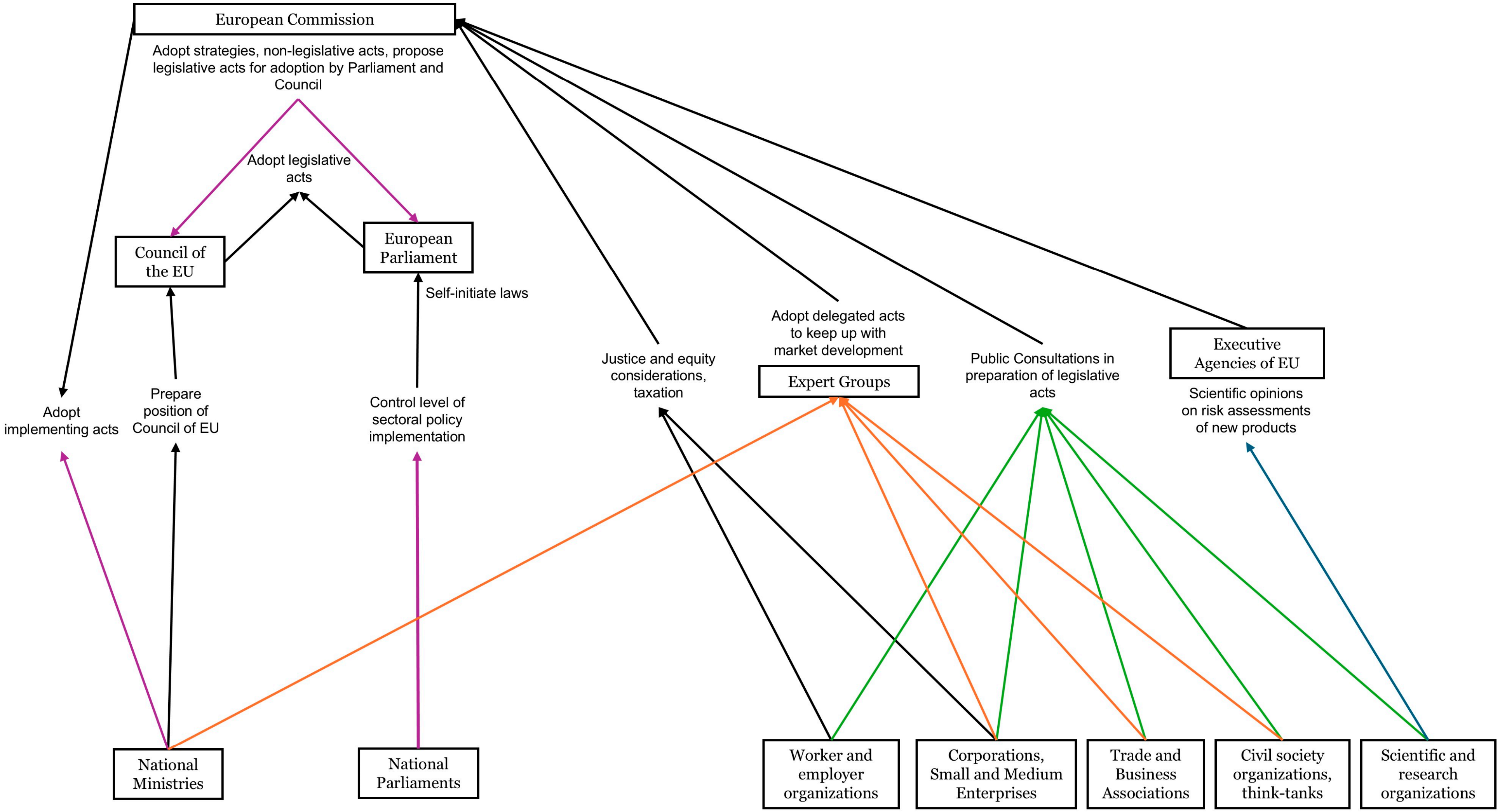

Figure 5. Representation of the pathways for elevation of sponsored framings to the decision-making agenda that was developed through the collected results.

1. **Fertiliser Self-Sufficiency** can be seen as the friction between linear markets dependent on domestic production and imports versus a recovery-focused paradigm. This meta-frame encompassed three general framings:
    - Import fertilisers: This is based on the institutional framing in the EU's communication on ensuring the availability and affordability of fertilisers, which allows gas subsidies and imports of Russian fertiliser as a means to avoid market disruptions. The framing sponsored by farmers and the chemical industry does not endorse recovered fertilisers coming from sludge. The spillover framing is a response by the EU commission that focuses on expanding the scope of recovery technologies included in the Fertiliser Product Regulation;
    - Scale-up recovery technology: This is based on several institutional framings proposing the standardisation of risk assessment carried out before the approval of new products across EU agencies. These are relevant as recovered phosphorus comes from a range of inputs and may be synthesised into a range of products though chemical processes. The sponsored framing aligns with this proposal as it criticises the burdensome testing and approvals of end-of-waste status pursuant to Fertiliser Product Regulation (FPR). Although no spillover framing was identified at the conferences, the EU Industrial Strategy potentially includes it in the framing economies of scale created by synergistic demand from civic and defence industries. This was omitted as it is outside the methodology's scope;
    - Assign value to recovered fertilisers: This is premised on the institutional framing for optional EU-wide harmonisation of end-of-waste status of substances pursuant to FPR, and the sponsored framing that in the absence of such harmonisation, recovered fertilisers are designated for export to third countries outside the EU and should instead be ascribed value. The spillover framing suggests that an option lies in seeing recovered fertilisers as a means to substitute the (Russian) carbon-intensive fertilisers, which are allowed in EU as a means to avoid market disruptions.
2. **Decarbonisation** can be seen as the contribution phosphorus circularity can make to achieving net-zero emissions and was composed of three general framings:
    - Farming sufficiency through service provision: This is built on the alignment between the institutional framing of providing chemicals (and resources) as services and the sponsored framings demanding moving to a sufficiency approach in farming (via less livestock) and usage of remote sensing and deep learning for precision fertilisation and monitoring eutrophication. There was no spillover framing in support of this general framing;
    - Create modules for nutrient recovery from organic waste: This is built on the institutional framing of soils as a recycling machine promoting regenerative circularity and the idea that circularity reduces import dependency, enhanced by the sponsored framing that criticised the restrictive legal status of utilities and proposed their reframing as resource plants built with modules allowing easy disassembly, repair, and reuse. The destruction of wastewater plants as critical infrastructure in Ukraine (Avdiivka) was selected as relevant spillover framing, as it was used by policymakers to attract attention to phosphorus-driven eutrophication and greenhouse gas emissions;
    - Biogas is a rural industry, recovered phosphorus can be used in energy storage: This is built as an alternative to the institutional framing of prioritising hydrogen and ammonia as substitutes for fossil fuels and fertilisers. The sponsored framing suggests instead that public investment should be channelled towards rural anaerobic digestion for biogas and the simultaneous synthesis of recov-

ered phosphate from dewatered sludge or remaining digestate in the case of manure. This sponsored framing was defended through the idea that it supports farmer livelihoods because remaining digestate can be used to regenerate soils, and that recovered phosphorus (as vivianite) can be used as a cathode in LFP batteries. The spillover framing suggests that the hype around hydrogen restricts investments in renewable energy, and that it should be limited to hard-to-abate industries (e.g., steel and marine transport).

3. **System change** can be explained as the necessity to design instruments that are defined by established sectoral siloes and that translate system-wide objectives to individual responsibilities. It comprises three general framings:
    - Design change-oriented regulation: This is built through the institutional framing that innovation should focus on climate neutrality as a means to achieve competitiveness and redistributing revenues to ensure fairness of the transition for those excessively reliant on fossils, but not having the means to phase them out, and the sponsored framing that suggests several implementing directions (tax virgin materials, extend efficiency with wellbeing, and finance nature restauration and R&D), as well as to define individual goals. The spillover framing suggests that the current amount and frequency of legislation is resulting in regulatory fatigue and that future legislation needs to focus on implementation;
    - Use market instruments to select energy-relevant phosphorus recovery solutions: This is based on the institutional framing that renewable energy and energy storage technologies should be supported with regulatory experimentation in the form of sandboxes, less restrictions on using state aid, and advancing critical resource clubs to achieve net-zero. The sponsored phosphorus framing suggests that even if high recovery rates are achieved, there must be market instruments that can pull recovered phosphorus into the market (e.g., blending obligations). The spillover framing suggests that technology neutrality should be abandoned and instead the EU should bet on pathways that are competitive in a net-zero scenario;
    - Advance phosphorus recovery as an instrument to phase out fossil fuels and mitigate climate change: This is based on the institutional framing that carbon taxation is one of the instruments ensuring a fair level playing field between domestic producers aiming to decarbonise and external counterparts that may engage in unfair practices. It was complemented by the sponsored framing criticising the lack of internationally accredited emission factors for phosphate recovery. The spillover framing suggests that regulatory experimentation should focus on technologies enlisted in the net-zero industry act (biogas, battery storage, and hydrogen) that can phase out fossil fuels.

5. Discussion

This section discusses the framings through Kingdon's three streams concept to identify constraints to and opportunities for the advancement of alternative phosphorus recovery framings.

The Fertiliser Affordability and Accessibility Window

From the institutional framings, we learn that the EU's Green Deal is a legislative programme and a public investment framework with the objective of decarbonising the EU's economy through support for technological advances that require fewer resources, reduce greenhouse gases, and promote renewable energy technologies and resource circularity. Besides supporting green growth, the strategy acknowledges the importance of digitalization and makes fiscal transfers towards those that are most affected and have fewer resources for adaptation (such as energy-poor households, coal regions, and less developed member states). When it comes to phosphorus recovery, two relevant factors have undermined its role in such a transformation.

Firstly, within its common agricultural policy (CAP) the EU is mandated (see Figure 1) to pursue yield productivity, market stability, and wellbeing-oriented living standards. The external shock of the war in Ukraine increased the prices of fertilisers and, by extension, food production. Hence, to pursue its mandate within the agricultural sector, the EU has tapped into the "Import Fertilisers" general framing, associated with the removal of tariffs and the expansion of the scope of the Fertiliser Product Regulation in line with emerging feedstocks and recovery technologies. However, this has strengthened the position of the domestic agrochemical industry, which also required further support for its decarbonisation. Thus, there are two other emerging general framings related to emergent recovery technologies that build on standardising risks assessments and overcoming the arbitrary application of end-of-waste status across member states. However, the fertiliser self-sufficiency paradigm is dominated by competition between domestic chemical industries and imported fertilisers supplied by carbon-intensive third countries. This is especially evident in the UN-brokered Black Sea Grain deal, which promotes Russian fertilisers and raw materials for ammonia production in exchange for unobstructed shipping of Ukrainian grains [103]. The EU also reduced customs tariffs on fertiliser inputs to improve the affordability of domestically synthesised nitrogen [104].

Secondly, the war on Ukraine triggered a substantial shift towards investment in renewable energy and storage to increase the energy system's resilience. The priority has been replicated in RepowerEU, the EU Methane Regulation, the Green Deal Industrial Plan for the Net-Zero Age, as well as, notably, the Fertiliser Communication. Hydrogen has been set out as a political priority due to its possible synthesis via water electrolysis, while other energy recovery pathways (framed in policy circles as "clean molecules") have been included in the technology neutral pathway advanced by the EU fertiliser industry [105,106]. They include the anaerobic digestion of biogas containing 50–75% methane, 25–50% carbon dioxide, and traces of nitrogen and hydrogen sulphide [107]. The biogas/biomethane can be split into hydrogen through (steam) methane reforming, and carbon dioxide and the process can be reversed via the methanation of carbon dioxide captured from industrial installations and hydrogen [108]. While these opportunities can act as drivers for nutrient recovery that precedes the anaerobic digestion of biomass, they have not received significant political attention.

These factors contextualised the limited inclusion of the fertiliser self-sufficiency and decarbonization meta-framings in the problem definition and the policy responses outlined in the communication. More precisely, the "Import Fertilisers" general framing is used to present food security in relation to domestic industry's dependence on natural gas:

- *"In summer 2022, gas accounted for up to 90% of the variable production cost of the ammonia production in the EU";*
- *"The global scarcity of fertilisers is primarily caused by the high price of natural gas which is necessary for the production of nitrogen fertilisers".*

This cost rationale has been used to defend several policy responses that can improve conditions for EU industry and ensure a stable fertiliser supply (improved access to natural gas, improved market transparency through a fertiliser market observatory, supporting the nitrogen industry's transition to ammonia, supporting hydrogen, and trade diversification).

Secondly, the Fertiliser Communication mentions the strategic objective of a 50% reduction in losses and the structural solution of accelerating the transition to sustainable food production and innovative technologies without jeopardising affordability. There are, however, several issues with these policy responses. Noticeably, the communication proposes *improved access to organic and recovered fertilisers*, which corresponds to the general framing of "scale-up recovery technology"; however, without mentioning the difficulties related to achieving end-of-waste status. There is also a noticeable emphasis on the target of achieving 25% organic fertilisers as a way to reduce emissions and substitute mineral fertilisers. However, as the formulations do not mention recovered fertilisers in this transition, they fail to make use ofthe general framing "assign value to recovered fertilisers".

In the absence of the mentioned integrated nutrient management plan (INMP), which was meant to implement the strategic objectives of loss reduction, crop diversification management practices reducing nutrient use (precision agriculture machinery, agro-ecological methods such as diversification, rotation with plant proteins, usage of catch crops, and organic farming), as well as the rollout of the Farm Sustainability Tool For Nutrients (EU's remote sensing platform), these objectives are suggested as possibilities that can be financed through the national CAP strategic plans. However, since CAP is a shared competence (Figure 1), all of them remain voluntary. This undermines their consolidation under the general framing "farming sufficiency through service provision". Applying sufficiency as an ethno-social concept of wellbeing to the biophysical realm of agriculture requires removing the CO_2-intensive excesses that do not contribute to human need [109] and that can slash 72% of phosphorus demand if meat is phased out [3]. However, such actions are contentious, as 46.5% of direct payments, which constitute 72% of the total CAP funding, are oriented towards (non-dairy) grazing livestock [110,111]. Research suggests that economic policies may be the answer to reduce phosphate loading from livestock; however, this has only been tested with a cap-and-trade phosphate rights system in the Netherlands, which had limited results [22,112,113]. Another possibility to reduce phosphorus loading and increase productivity lies in decreasing livestock density and rotating land uses within integrated crop–livestock systems [114,115]. However, the EU's fertiliser industry, represented in the study, suggested rather that the efficiency rationale of the Zero Pollution and Farm to Fork strategies (50% less losses and 20% less chemical fertiliser) can be implemented via precision application aided by remote sensing. Effectively, even if consolidated, the "farming sufficiency through service provision" general framing would still lack a redistributive focus towards carbon emission-offsetting practices.

Lastly, actions for achieving resilience are mostly designated for the purchase (855 million euro) and storage (450 million euro) of chemical fertilisers. Despite the available funding of 9 billion euros in Horizon Europe, only 185 million are mobilised for fertiliser research. Resilience can also be achieved via the scaling-up of emergent circularity solutions contributing to decarbonization, outlined in the "create modules for nutrient recovery from organic waste" and "biogas is a rural industry, recovered phosphorus can be used in energy storage" general framings. Although stakeholders support EU-wide obligations for phosphorus recovery from wastewater that can drive the scaling-up of nanotechnology-based adsorption modules, German and Austrian national laws [116,117] prefer incineration, as health hazards reduce options and limit the possibility for a harmonised EU-wide approach towards recovery. However, prioritising certain pathways in respect of subsidiarity can streamline funding and consolidate efforts.

Secondly, biomethane gas has been mentioned as an income possibility for rural areas, but not as a driver for recovery. Instead, it is presented only as a driver for organic agriculture, which is emphasised as a CO_2-reduction possibility. This limits the researchers and farmers' attention only to recovery technologies allowed as organic fertilisers, such as struvite, instead of exploring others with lower technological readiness, but with relevance for energy systems' resilience, such as vivianite.

> *"Using vivianite as fertiliser could be a serious contender in some niche markets. Even more compelling is the fact that vivianite could be a perfect raw material for Lithium-Iron-Phosphate batteries, which do not require cobalt."* [118]

This is a missed opportunity, as vivianite recovery from manure could be included in National CAP Strategic Plans, and as much more funding is made available for compensations and investments in renewable energy sources, such as biogas through the temporary crisis framework and the cohesion funds (180 billion euro). Lastly, the communication sets out a long-term target of green hydrogen's competitiveness, expected to be reached vis à vis potentially rising natural gas prices. These uncertain long-term projects undermine the already existing potential of wastewater treatment to provide renewable nutrients and biogases and contribute to human wellbeing by reducing health hazards and greenhouse gas emissions.

Notably, these projects reflect the official positions of the EU nitrogen fertiliser industry, which sets out two ammonia decarbonisation pathways: one based on electrolysis for green hydrogen and the capture of CO_2 from air, and a more technology-neutral pathway inclusive of biogases and carbon capture and storage [105,106]. While the substitution of natural gas with recovered biogas in the steam methane reforming process of hydrogen production is the most cost-effective solution in the report, this is presented through coupling with organic fertilisers, and not emphasised as driver for their recovery in general. Instead, the EU nitrogen industry has explicitly tapped into ammonia as a decarbonised replacement of natural gas in power generation and marine shipping. Effectively, this has neutralised biogas as a political priority, and instead allowed ammonia to be emphasised in the EU's communication as a diversification pathway for Russian gas imports.

Thus, phosphorus stakeholders' propositions within the decarbonisation meta-framing have been sidetracked from the communication's foci on energy system resilience and fertiliser decarbonisation. Seen from Kingdon's conceptual interpretation, the Ukraine crisis has acted as a trigger for the moving of the fertiliser issue towards a globally recognisable **problem**. However, the EU's policy response has paid asymmetric attention to the feedback of its own nitrogen fertiliser industry, which has adeptly interpreted the coupled natural gas and fertiliser commodity price shocks. This affordability paradigm applied internally is also not reciprocated in its external cooperation, where the EU's communication supports agro-ecological methods and uses its development cooperation portfolio of instruments (DeSIRA: Development of Smart Innovation through Research in Agriculture, GCCA+: Global Climate Change Alliance+) to support the scaling-up of farmers' climate-relevant agro-ecological innovations, either by connecting them with research and private sector agri-value chains or with carbon markets. These efforts echo COP27's Agricultural Innovation Mission for Climate that supports the inclusion of climate-smart agriculture in the nationally determined contributions to climate change mitigation [119]. Importantly, nutrient recycling is one of the principles of agro-ecology [120], yet the EU's internal target of 25% organic agriculture has superseded most recovery-focused formulations in the Fertiliser Communication. As a result, similarly to the nitrogen industry's decarbonisation programme, recovered fertilisers have not been assigned CO_2 and gas dependence reduction properties.

The Green Deal Industrial Plan for the Net-Zero Age, the Fit-for-55 climate strategy, and the CBAM regulation provide several system change propositions that could address the aspects undelivered by the EU's Fertiliser Communication. A key aspect raised by high-level consultancies hosting previous EU commissioners and national ministries is the necessity to design change-related regulations that ensure the delivery of the EU's climate objectives through impactful measures that make use of advances in sustainability. In the same way that steel can be substituted with wood to achieve a change in system design, so can recovered fertilisers. Most of these actions would certainly rely on active spending to shift the growth towards emergent solutions. However, the key problem to achieving these objectives is that these ideas (see Table 2) are not supported by knowledge communities with sufficient access to EU institutions as gatekeepers, or are lacking non-technical boundary spanners that can translate technical expertise in a way that speaks to the EU's high-level priorities. EU institutions' representatives have been markedly in favour of using market instruments such as high taxes on landfilling and pollution; however, the ESPP has mostly devised regulatory propositions for pull actions [121]. At the same time, bottom-up innovations such as regulatory sandboxes with an energy focus and permissible supply-side actions such as state aid for scaling-up strategic projects have not been borrowed by phosphorus communities, as these lie outside of their usual sectoral scope. Lastly, SMEs that have become interested in implementing phosphorus recovery besides their nitrogen recovery activities have suggested that the EU has not paid sufficient attention to developing emission factors for recovery from different streams (e.g., fish waste in aquaponics) that can be used to defend supply-side actions.

From Kingdon's prism, we can therefore say that in the **policy** stream, the EU has recognised the EU nitrogen industry's ammonia decarbonisation pathways, while cautiously postponing emergent alternatives. Its gatekeeping has focused on energy policy rationales in line with the necessitated decoupling from Russia. The fact that ammonia is currently produced via grey hydrogen steam methane reforming and that green hydrogen constitutes only 0.13% of the supply [122,123] is expected to be reversed by gas market pricing in the future. In the meantime, carbon capture and the storage of nitrogen plants will remain the preferred retrofitting strategy [124], despite ammonia being hazardous, requiring energy for conversions and more land and water than other pathways [39,125]. When it comes to ascribing value to recovery, the EU has also made the choice to do so only for organic fertilisers. Notably, these decisions have been made to the detriment of the emergent alternatives described in the decarbonisation meta-framing.

The **politics** of these decisions can be positioned in the socio-institutional space through the "regulatory" fatigue from the EU's legislative programme that has affected multiple stakeholders. Most notably, these are the farmers, whose protests watered down science-backed policy targets for nature restauration through 10% non-commercial land use, the abolishment of chemical pesticide (glyphosate) reduction targets that were the same as those for fertilisers, and removing nutrient plans and eco-schemes' conditionality from CAP [126,127]. Nitrogen has also received higher attention than eutrophication from phosphorus during these protests, due to the specifics of Dutch loading with nitrogen. Lastly, farmers' discontent with rising prices has reinforced chemical industries' case for subsidies as a tool to address the commodity price shocks, in neglect of warnings that profits that are already centralised by the chemical industry and additional supply of chemical fertiliser will slow the shift to alternatives [128,129]. We depict the three streams and policy choices made in the EU's Fertiliser Communication in Figure 6.

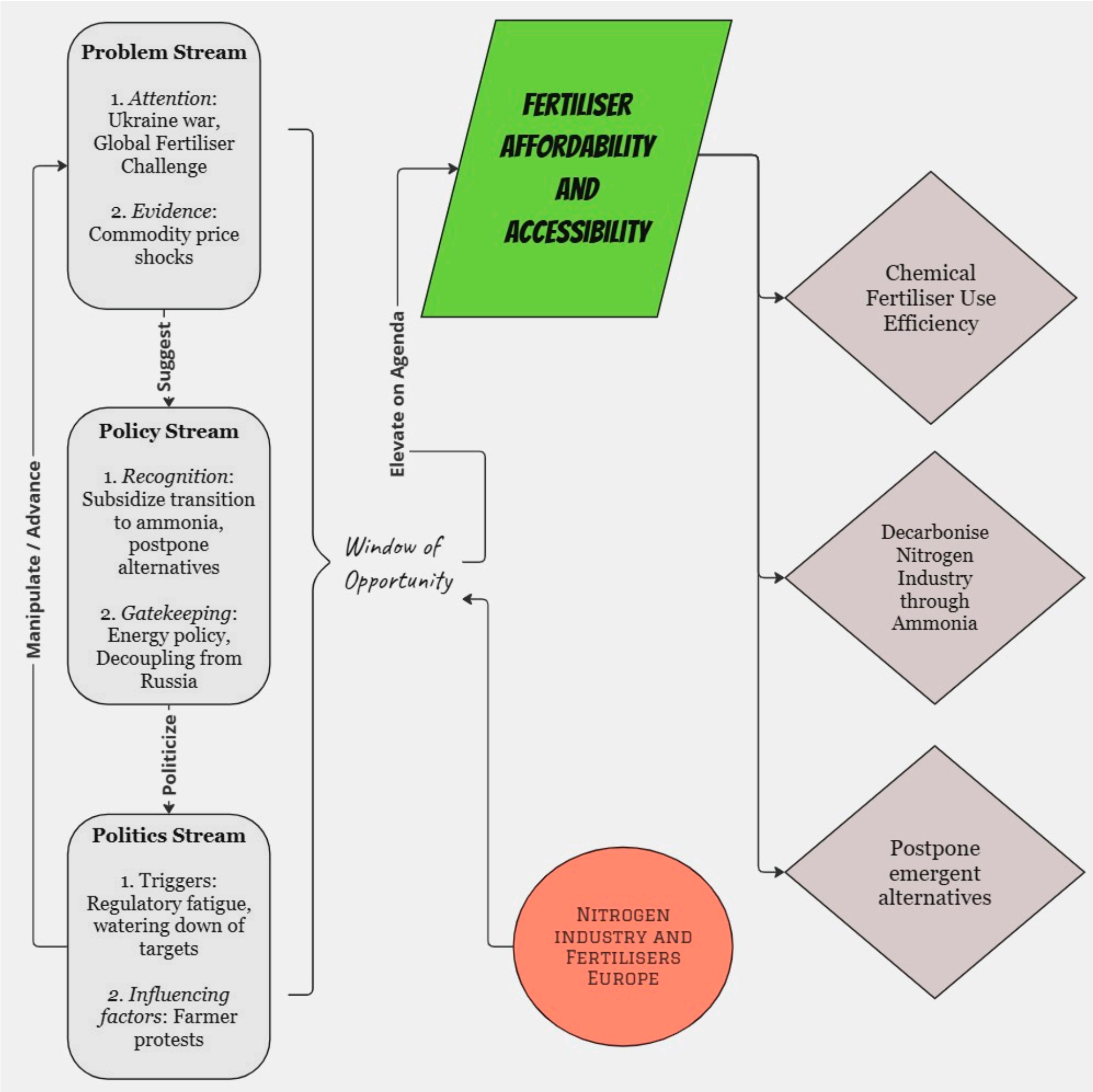

Figure 6. The fertiliser affordability window depicting the current situation.

The window of opportunity opened by the EU elections (2024–2029)

The Fertiliser Communication was adopted as a soft law instrument meant to steer actors in multi-level systems through allocating responsibilities and monitoring prescriptive non-binding targets that promote actors' learning alongside the "open method of coordination" [130]. Soft law initiatives, formally labelled Team Europe, function as a mobilising factor when a clear political objective and targets are provided, and such is necessary for nutrient recovery. However, in contrast to critical raw materials (CRM), the EU has yet to adopt an act specific to nutrients. This has been acknowledged by the strategic dialogue on agriculture completed in 2024, which sets out autonomy, the usage of human waste, and closing phosphates cycles as priorities for INMP [131]. The forthcoming updates of the CAP, the expected Circular Economy Act, and the EU's CBAM implementing the overarching priorities of quality of life and competitiveness outlined in the Commissions' work programme for 2024–2029, are further possibilities for embedding nutrient recovery in the existing governance [132]. The updated climate aspirations (90% emission reduction by 2040) also support the creation of a single market for circular raw materials such as phosphorus, decarbonising agriculture strategy through mitigation technologies and focusing on supply-side investments in climate solutions [133,134]. The new European Commission and parliament and the advent of a new Green Deal Industrial Plan have shifted the priorities on the decision-making agenda. Nevertheless, the right combination of salient spillover framings may still open windows of opportunity for the elevation of hitherto postponed alternative intersectoral framings.

In the **problem stream**, we can expect that framings tapping into the resilience, autonomy, and competitiveness of the EU's economy will be attracting policymakers' attention. Considering that LFP technologies may be on the rise, the problem definition must analyse supply chain inefficiencies also through the growing intersectoral demand for phosphorus, so that policy responses address the market dynamics that may otherwise hinder food security. The 2024–2029 cycle dynamics outlined above present a possibility to rethink phosphorus circularity as a climate mitigation strategy applied not only to organic fertilisers (which are subject to stricter regulatory approvals), but also to technical and advanced chemical recovery of nutrients from organic wastes such as manure and wastewater. Such a paradigm could position recovery against the linear production of fertilisers that is dependent on fossil fuels. One key target that can mobilise stakeholders can be found in the CRM Regulation, which recommends 25% recycling targets for strategic materials with non-agricultural use [135]. It must be emphasised that the currently reported rate of 17% phosphorus circularity in the EU's documents relates only to the direct application of manure and sludge in agriculture and stifles the momentum for the advanced technical and chemical recycling of organic wastes [18]. As the completion of the single market for recovered resources is increasingly seen through the prism of industrial policy (see Figure 1), the 12% industrial circularity in the EU compared to the viable 34% achieved by the Netherlands should also be emphasised [136]. Overall, to set out higher recycling targets, stakeholders must position their actions in line with the definition of strategic raw materials that relates to the twin green and digital transformation, and not that of proneness to supply disruptions, which defines resource criticality.

In the **policy stream**, institutional gatekeepers are expected to prioritise the long-term goals of agriculture, energy system resilience, accelerating their decarbonisation through public investment in carbon footprint reduction, and employing trade policy tools to defend new business models [137,138]. However, as seen in the analyses above, the linear production of fertilisers has more authoritative sponsorship and resources, and may centralise these funds. While the food industry prefers primary phosphates, research and development support could focus on scaling-up recovery technologies that substitute technical grade P-acid, as these have higher returns on investment and may bring authoritative sponsors (e-vehicle manufacturers, microchip industry). Since the EU does not have its own primary production of phosphorus, advancing chemical recycling could be incorporated into climate policy, not only as public investment in mitigation but also as corporate carbon offsetting. To avoid the leakage of these recovered resources as exports, measures must be taken towards completing the single market of end-of-waste products. Lastly, the policy of reducing losses by 50% and chemical fertilisers by 20% should include sufficiency measures in agriculture that reduce fertiliser demand by reorienting phosphorus towards plant and dairy protein.

Within the **politics stream,** the national mood towards decarbonisation will continue to play a central role. Therefore, policy responses should find a balance between EU-centred priorities such as competitiveness and providing appropriate incentives to particularly vocal groups such as farmers [139]. The funds outlined in Fitfor55 climate strategy for 55% emission reduction by 2030 defined different levels of granularity for their redistribution, and would dictate more support for rural regions and weaker groups affected by the transition. Since it is expected that geopolitical challenges may persist, circularity may continue to be justified as decoupling from strategic competitors [140]. The emergent intersectoral alternatives (with limitations in Table 2) postponed as a response to the

Ukraine crisis could be elevated on the EU's policy making agenda by selective coupling with the high-level priorities outlined by the Commission and the Council. We present five non-prescriptive combinations that were limited by the scope of our data collection below (see Figure 7).

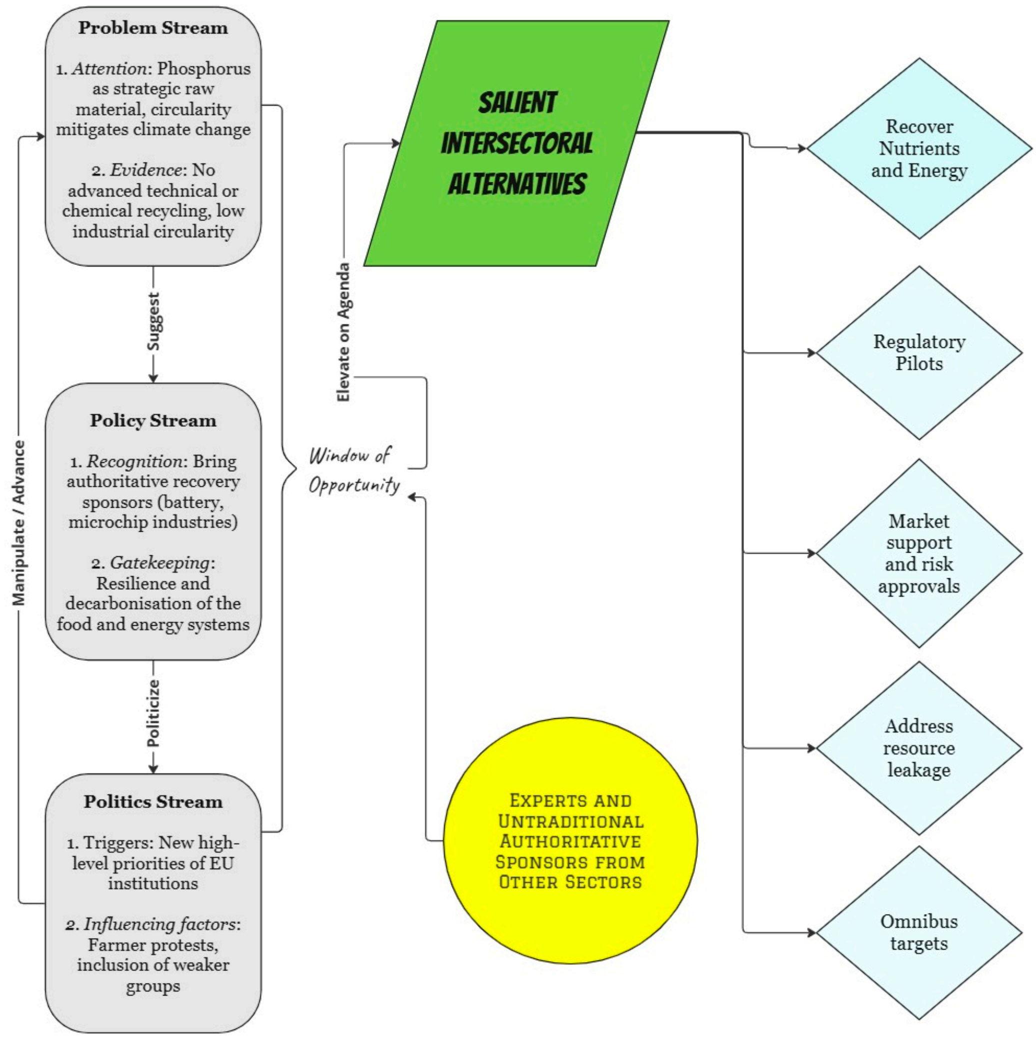

Figure 7. The window after the 2024 European Elections.

Alternative intersectoral framings of phosphorus

We identify five emergent intersectoral framings of phosphorus that trigger policy learning and whose salience could be enhanced though spillover framings:

1. **Recover Nutrients and Energy:** The "Hydrogen limits deployment of renewables" spillover can be used to scale-up phosphorus recovery through vivianite precipitation for potential usage in LFP batteries, while simultaneously digesting organic wastes anaerobically to synthesise biogases containing small amounts of hydrogen [141] and returning the remaining digestate to replenish soil organic matter [118,142]. This holistic sustainability solution could address decoupling from fossil fuels, as it could satisfy 14–32% of the energy share in the EU [143], produce a slow-release fertiliser with 8–16% improved phosphate uptake [144], and replenish soil matter. As such, it can defend phosphorus' understanding as a strategic raw material subject to 25% recovery obligation in the CRM Regulation. Additionally, the "Warfare-driven destruction of wastewater plants" can be used to advance the demonstration of repairable nano-adsorption modules, which can be used both in rural areas to treat

manure and in urban areas to threat wastewater. They would be eligible for financial support from the ETS/CBAM-powered Innovation Fund, as well as from private sector financing in accordance with EU taxonomy for sustainable investment. If cross-border, significant in size, and incorporating priorities from multiple sectoral strategies (e.g., AI optimisation), such projects could be eligible under the Important Project of Common European Interest scheme to create innovative business ecosystems for batteries and hydrogen value chains [145]. Lastly, such modules can be used in the EU's development cooperation;

2. **Regulatory pilots:** The "Use regulatory sandboxes to phase out fossil fuels" spillover can be used to test regulatory pilots in the derogation of existing laws under the net-zero industries act [146], which enlists batteries for storage and biogas synthesis as priorities [147]. These bottom-up solutions are expected to play a central role in technological scaleups under the forthcoming European Innovation Act [148]. Similarly to living labs, they bring added value by collecting evidence on demand reduction, recovered fertiliser acceptance, and upscaling potential [149]. Quantitative evidence on reduced fossil fuel imports and mitigated greenhouse gas emissions could be used to justify impact or venture capital investment in such biowaste industries [150]. At the same time, such pilots are underused in sustainability. While 57 countries have adopted sandboxes in Fintech [151], in the EU, these are mostly limited to renewable energy [152]. Since phosphorus recovery models are constrained by end-of-waste status [153], their application could focus on goal-focused sandbox models that can allow a shift from restrictive ex ante precautionary principles to ones applied before demonstration [154]. As wastewater plants may be legally restricted to produce fertiliser, biogas, or electricity, the testing of new technologies could focus on turning them into energy plants, resource mines, or other legally compatible formulations. Secondly, to enable soil regeneration, digestate or other organic byproducts can be tested regulatorily as amendment solutions, sequestering carbon via enhanced plant growth. Alternatively, if the income of farmers is a priority, regulatory testing could focus on collaborative production and consumption models, where manure is provided to digesters in exchange for fertilisers or energy. In consideration of the "farming sufficiency through service provision", pilots could also focus on redistributing capital from carbon markets by redirecting manure from dairy livestock or biochar towards alternative proteins such as pulses. These models could use blockchain to verify emissions and ensure payments. If successful, such pilots could be used to promote ex post risk approvals of agri-value chain innovations through trade agreements [155];
3. **Market Support and Risk Approvals**: The spillover "Abandon technological neutrality" could be used to scale-up recovery technologies relevant to the energy system. They may require both relaxed state aid rules as well as amending existing regulatory instruments to achieve a market pull effect. Stakeholders in the study have expressed support for EU-wide recovery and blending obligations, but a fuller list is compiled by the ESPP [121]. The valorisation of wastes is further impeded by the lack of regulatory harmonisation of contamination thresholds and stricter risk criteria in some member states, which impede intra-EU trade [156–158]. Currently, struvite is the only technology whose market feasibility is studied by the Joint Research Centre of the EU and that is regulated as an organic fertiliser, but such information is missing for vivianite and biochar [159,160]. These processes are subject to strict veterinary (and phytosanitary if traded in third countries) control, but could benefit from borrowing the institutional approaches to risk harmonisation across sectors outlined in the results. While relevant predominantly for different EU agencies, successful standards could be promoted at

the multilateral level though cooperation with the FAO-WHO Codex Alimentarius. Such measures could lay the foundation of resource recovery clubs;

4. **Address resource leakage:** The "Prevent Unfair Competition through CBAM" spillover can be used to address not only the leakage of carbon to third countries, but also the leakage of recovered phosphorus happening because of the optional harmonisation of end-of-waste status across the EU's member states. The current scope of CBAM includes phosphate rock and mixed fertilisers, and would tax the carbon content of otherwise freely imported primary fertilisers. Among the most affected by this action would be Russia, which is also the biggest exporter of phosphates into the EU [43,161]. Currently, CBAM revenues go into the EU's Innovation Fund, but could be used both to reinvest in recovery infrastructure and the carbon accounting of output products coming from it to justify further investments. Emissions accounting for recovered resources as a connection with CBAM can be promoted at the G7 Alliance and G20 Dialogue on resource efficiency to build integrated climate and circular economy clubs and diffuse the practice in upstream markets. The impact of these measures could be high, as while CBAM may trigger the adoption of emission trading in 36–58 countries [162], connecting the instrument with recovery may communicate its priority to 110 countries that have adopted circular economy measures [163];
5. **Omnibus targets:** The "Reduce amount and frequency of legislation, focus on implementation" spillover can be used to design change-oriented regulations that cumulate unrelated targets by connecting them with overlapping high-level objectives related to climate neutrality, resilience, competitiveness, wellbeing, and restauration. Examples related to phosphorus recovery include mitigated emissions, recovery obligations, connections with energy neutrality, net income gains, and restored soil biomass. While the current FPR suggests a CE mark only for fertilisers approved across member states, the EU has a much more potent labelling competence within the CAP. It could allow the embedding of similar targets under an omnibus "true cost of food" labelling that would improve the visibility of socio-environmental considerations and act as a behavioural nudge for individual responsibility. It is expected that consumer choices related to recovered fertilisers may lead to a 4–7% reduction in climate change and could be verified through funding targeting EU Missions [164].

It must be noted that these combinations are subject to the limitations of the collected interviews and observations, respectively, sponsored and spillover framings. We attempt to improve the study's relevance by outlining other emergent recovery pathways in the section below. Nevertheless, the identified institutional framings can be used to replicate the study. Their framings reveal a multitude of high-level objectives adopted during the EU Green Deal, which have been updated with those hitherto established for the 2024–2029 working programme of the EU. We can expect that in the long-term, the affordability rationale will be complemented by or substituted with one related to climate mitigation. Health and wellbeing concerns would also be important in defending the costs of non-action. During the study, we also learned that the resilience of agricultural and energy systems will remain highly relevant. Stakeholders and environmental activists interested in phosphorus could use these rationales to defend their scaling-up efforts, and widely speaking, resource recovery. We believe that a major window of opportunity has opened with the inauguration of a new European Commission. The five measures outlined above could also contribute to strategic environmental goals such as reducing fossil fuel usage and replicating nutrient recovery as a priority in third countries through CBAM [127,138].

Other considerations

Wastewater is expected to grow by 50% by 2050. It contains five times more energy than what is required to treat it, yet more than 80% of it is untreated [165]. Full nutrient recovery can satisfy 6.8% of the global phosphorus demand, 14.4% of nitrogen, and 18.6% of potassium, bring 13.6 billion USD investment returns, and power 239 million households [166]. Besides their nutrient and energy recovery potential, investments in wastewater contribute to carbon neutrality by limiting carbon dioxide, nitrous oxide, and methane emissions, and their monitoring is key to select mitigation strategies in comparable contexts [167–169]. Such measurements can also be used to unlock climate mitigation funding from carbon taxes, credits, or sustainable investments. These, in turn, should focus on a transition towards nutrient recovery and data generation through monitoring of the process.

In principle, there are biological, chemical, and bioelectrochemical processes for nutrient concentration in sludge [170]; however, most plants focus on phosphorus removal and discharge limits instead of its recovery [171–173]. Advancing recovery is also important, as despite the illegality of discharge in the EU, sewage overflow, clogging and breakage, and salinity-induced corrosion due to rainfall variations may still lead to eutrophication [174–176].

Among the more advanced recovery techniques is struvite precipitation, which may contain ammonium salts, but is less bioavailable and captures only up to 40% of phosphorus [170,177,178]. Due to the obtained results, we focused on the magnetic recovery of vivianite as a highly suitable pathway for several member states, which can achieve up to 70% phosphorus recovery, but is currently in its demonstration phase [179,180]. Another pathway worth investigating is the pyrolysis or hydrothermal carbonisation of dewatered sewage sludge to produce biochar, which has decontamination and nutrient retention properties, can sequester carbon, and act as an amendment in soils, but may be less suitable as a fertiliser [181]. These recovery pathways should be considered based on local economic conditions and the economic implications of selecting either anaerobic digestion for biogas or dewatered sludge pyrolysis to produce biochar [182,183]. Lastly, high amounts of phosphorus can be recovered after sludge incineration, but this technique bears low bioavailability and low energy recovery [184–186].

6. Conclusions

This article expands the sectoral scope of analysis to overcome the siloed understanding of phosphorus governance, and makes several contributions to the literature.

Firstly, it fills a methodological gap by applying the three streams conceptual framework for agenda-setting and employing framing as an analytical heuristic in phosphorus research. Secondly, it critically analyses the shift to non-binding soft governance tools cumulated in the EU's communication on the accessibility and affordability of fertilisers to inform stakeholders of the EU's actions. The document was adopted in response to the commodity price shocks exacerbated by the Ukraine crisis and the identification of the global challenge of fertiliser affordability. The EU's response consisted of providing gas subsidies to stabilise fertiliser prices and replicating the preferred decarbonisation pathways of the nitrogen agrochemical industry, without emphasising the potential of emergent phosphorus recovery technologies that can be combined with the anaerobic digestion of biogases. This centralised revenues in linear production and postponed the transition to a circular economy of organic wastes that can strengthen the food system's resilience and contribute to the resilience of the energy system.

Thirdly, the article outlines the inauguration of the new European Commission as a policy window for elevating the emergent phosphorus governance framings that can create a more coherent, intersectoral, and transformative governance.

Lastly, we propose five bottom-up alternatives developed through stakeholder-sponsored framings and salient spillover framings that can trigger this transformation though policy learning, better integration with related sectoral strategies, and laws promulgated as part of the EU Green Deal. They focus on recovering fertilisers and energy-relevant outputs, which can improve the understanding of phosphorus as a strategic raw material and thus increase the obligatory rates of recovery it is subject to. To strengthen the case for scaling-up, we also suggest using sandboxes as bottom-up regulatory pilots, supply-side investment and market pull support tools, harmonised risk approaches, addressing the leakage of recovered resources in third countries, as well as using omnibus targets to assign individual responsibilities. We believe that these can serve to inform stakeholder efforts and replicate recovery as a priority in third countries. To improve the relevance of the study, we also suggest other recovery pathways that are worth exploring, such as biochar.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su17041478/s1.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

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Appendix A

Annex I. Interview Guide

SYSTEM FRAGMENTATION

1. How would you describe the current phosphorus system?

1.1. Do you recognize any problems/challenges in your (partners') work related to phosphorus recovery? What is their nature, what do they stem from? (or) Have you been subjected to duplicating or conflicting stimuli, objectives, regulations, requirements, certifications, etc. related to phosphorus recovery and innovation?

1.2. Do you believe (the current) regulatory frameworks (e.g., EU fertilizer Regulation, CE Action Plan) are helpful for increasing recovery and innovation? (or) Has the lack of regulation or stimuli targeting innovation helped you in particular instances?

2. Who would you "call" if you wish to propose changes in the way phosphorus recovery is done?

2.1. Would it be a business association, non-governmental organization, body of your government or an EU institution?-

2.2. Do you feel sufficiently empowered to change the decision-making agenda? Do such events help you channel demands for policy improvements to decision-makers?

3. Could you enlist any organizations that support you in your work with Phosphorus recovery?

3.1. Which of your collaborators have central importance in brokering innovative technology to decision-makers or challenging existing rules?

3.2. Are these exchanges contractual or rather more informal? Do any of them resort to connections in other influential networks of actors to maximize these efforts?

CIRCULAR PHOSPHORUS ECONOMY

4. Have any of them helped you achieve a (more radical) vision of circular economy in your work?

4.1. What innovative phosphorus futures would look like within a circular economy? Which Phosphorus recovery activity should be prioritized?

4.2. How could policy act as enabler of innovative circular business models which are based on phosphorus recovery?

5. Do you think phosphorus circularity could lead to new business models (beyond fertilizers)?

5.1. Do you believe added circular value within these can help accelerate phosphorus recovery?

5.2. What can improve the demand for recovered Phosphorus?

INSTITUTIONAL INNOVATIONS

6. Have you noticed any institutional innovations that have overcome hindrances to phosphorus recovery and upscaling to novel products?

6.1. How did they come into being? Have technological and infrastructural capacity, particular European strategies or major events outside the EU been their driver?

6.2. What could potentially bring such them into being?

7. Would you like to see a fast-track authorization for phosphorus recovery for novel circular products?

7.1. Would you rather see economic stimuli for phosphorus recovery or improved technology and infrastructure?

7.2. Would you rather prefer a guidance document that prioritizes recovery models in a taxonomy?

8. If you had a chance to propose a policy (including, but not limited to legislative change) that maximizes the best practices of your work what it would be and to whom you would like to propose it?

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