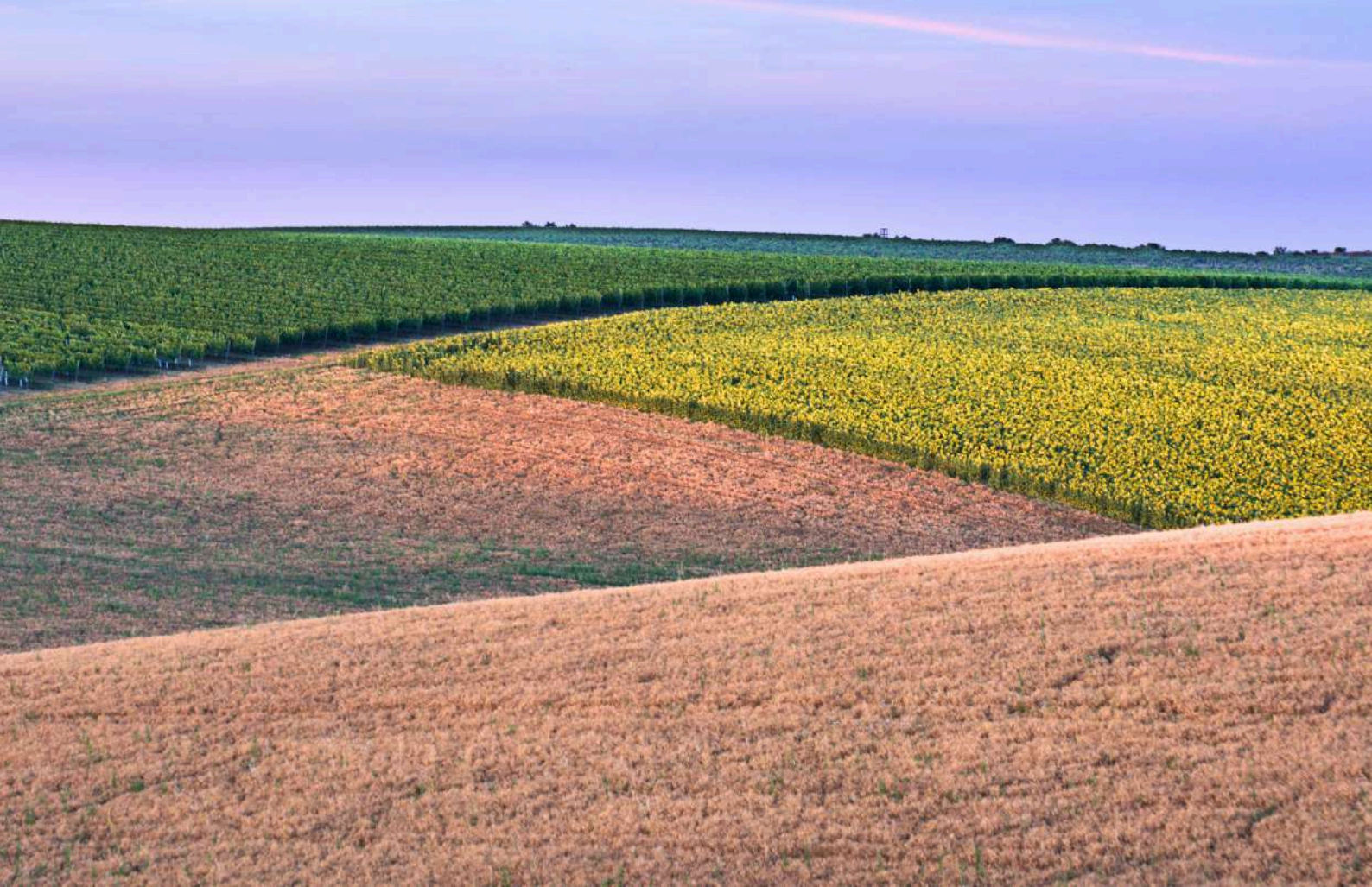




Green growth: from waste to bio-based fertilisers



WHITE PAPER

**FEB
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The European agricultural model faces a major challenge: ensuring food security while reducing dependency on imported synthetic fertilisers and mitigating fertilisation environmental footprint. The geopolitical instability and the depletion of non-renewable resources have exposed the vulnerability of the current system. Meanwhile, the urgency to restore soil health and achieve the EU's climate neutrality targets calls for a new paradigm, one that redefines waste not as an end, but as a beginning.

In this respect, bio-based fertilisers (BBFs) might emerge as a tangible solution for this transition. They can be extracted from waste and waste waters, applying liquid/solid separation systems and also, novel nutrient recovery and reuse technologies, and therefore, they can close nutrient loops, reduce greenhouse gas emissions, and foster a circular bioeconomy. However, their implementation still faces significant regulatory, economic, and social barriers. These include the absence of a common legal definition, fragmented governance across Member States, limited market access, and a persistent lack of awareness among farmers. **The WalNUT Project** addresses these challenges by integrating scientific knowledge, technological innovation, and policy analysis. Through five pilot plants across the European Union (EU), the WalNUT Project demonstrated practical nutrient recovery pathways to reach for sustainable fertilisation. Beyond technology, the project generated valuable data to build recommendations to support policymakers, administrations, and stakeholders in implementing BBFs as part of a resilient and circular agricultural model.

This **White Paper** consolidates the WalNUT Project findings, and offers actionable recommendations and opportunities for the BBFs implementation:

- Establishing a clear and harmonised EU definition for BBFs.
- Creating an official European BBFs Observatory for transparency and market monitoring.
- Developing financial incentives and tax schemes to bridge the cost gap with synthetic fertilisers.
- Ensuring the true circularity of BBFs through standardised assessment tools.
- Supporting long-term agronomic validation through coordinated long-term studies.
- Promoting awareness and technical training programs to foster social acceptance.
- Reinforcing the BBFs value chain and work on its development.

Each recommendation is designed to align policy with practice, and transform research results into concrete governance tools.

Together, they form a coherent roadmap to unlock the potential of BBFs within the EU fertiliser Product Regulation and the Common Agricultural Policy, while contributing directly to the objectives of the Green Deal, the Farm to Fork Strategy, and the EU Soil Strategy for 2030.

With a scientific and technical groundwork, the next step depends on policy. A coordinated, informed, and ambitious response from policymakers can turn the current challenges into opportunities for innovation and sovereignty in nutrient management. The path toward circular fertilisation is clear, what remains is to act decisively to make it real.



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Current state of agricultural fertilisation in the EU

Agricultural fertilisation is a fundamental component to ensure food security worldwide. With regard to nutrient consumption in the EU, the latest report by Fertilisers Europe [1] states that **while organic fertilisers contribute significantly to phosphate and potash consumption, mineral fertilisers remain crucial, especially for nitrogen (N) supply.**

That document indicates that synthetic fertilisers remain central to nutrient supply, providing around half of N inputs (8.7 million tons), alongside comparable contributions from organic sources (8.3 million tons). Similarly, mineral fertilisers account for a significant share of phosphorus (P) and potassium (K) supply, contributing 2.0 million tons of phosphate (P_2O_5) and 2.2 million tons of potash (K_2O), complemented by higher inputs from organic sources.

Synthetic fertiliser production in the EU dropped in 2022 due to the energy crisis following the Russian invasion of Ukraine, which drove up natural gas prices. Rising transport costs and geopolitical instability lead to supply constraints for critical raw materials (such as phosphate rock).

At the same time, environmental concerns have reinforced the EU's commitment to reduce the impacts of fertilisation across the entire value chain.

Synthetic fertilisers are associated with high greenhouse gas (GHG) emissions and resource depletion during production (particularly through the energy-intensive Haber–Bosch process and phosphate mining) [2]. In addition, some phosphate fertilisers may contain potentially toxic elements, such as heavy metals [3].

In practice, inefficient application of both organic and synthetic fertilisers can lead to environmental problems, such as nutrient losses through runoff and leaching causing eutrophication and biodiversity loss, and nitrous oxide emissions as addressed by the Nitrates and Water Framework Directives [4, 5], Council Directive 91/676/EEC, and Directive 2000/60/EC.

In response to these challenges, the EU promotes higher fertilisation efficiency and nutrient recovery from waste streams, aiming to reduce nutrient losses by 50% and fertiliser use by at least 20% by 2030, in line with the Green Deal and the Circular Economy Action Plan [6, 7].

Thus, the EU's current focus is to intensify efforts to treat nutrient-rich waste streams as valuable secondary raw materials, thereby adding value to waste, closing nutrient cycles and promoting independence from external sources for valuable nutrients. **This is where the crucial role of bio-based fertilisers (BBFs) comes in.**

What are bio-based fertilisers?

The new EU strategies and policies are now committed to a novel approach for agricultural production and fertilisation, based on a broader perspective aligned with natural cycles within agriculture, and with the new paradigm of a circular bio-based economy. The new perspective has taken shape in the **Farm to Fork (F2F) Strategy**, a fundamental component of the **European Green Deal** [8, 6].



Figure 1: F2F scheme [8].

To ensure the supply of key nutrients while avoiding the impacts associated with fertilisation, the F2F Strategy recommends more efficient fertilisation practices.

To accomplish it, the strategy aims at reducing nutrient losses while ensuring no deterioration in soil fertility, so the overall goal is to achieve healthy soils with near-zero contamination and a much lower dependence on chemical inputs [6, 8].

To reach these targets, the EU will work with the Member States (MS) to develop the nutrient load optimisation. This concept implies a balanced fertilisation and a sustainable nutrient administration, specifically N and P, throughout monitoring their life cycles.

To enhance nutrient optimisation, the European Commission (EC) aims to implement, with the MS, integrated nutrient management action plans. The EC will work with the MS to facilitate fertilisation and sustainable agricultural practices (especially in areas with intensive livestock exploitations), and the recycling of organic waste into renewable fertilisers. The EU expects that bio-waste will replace up to 30% of the currently used synthetic fertilisers [9], since the transition from a fossil-based to a circular bio-based economy requires the recovery of nutrients from waste streams [10].

Bio-based fertilisers (BBFs) can be considered as the fertilising products derived from organic waste nutrient recovery techniques [11], but there are many other definitions, depending on the source, and so, an official definition of BBFs is still **under discussion**.

The **WaINUT Project** has proposed to define **BBFs as fertilisers derived from biomass using the nutrient recovery and re-use technologies (physical, thermal, chemical and/or biological, excluding anaerobic digestion and composting), in order to concentrate nutrients from the initially treated biomass and hence improve its nutrient efficiency** [12].

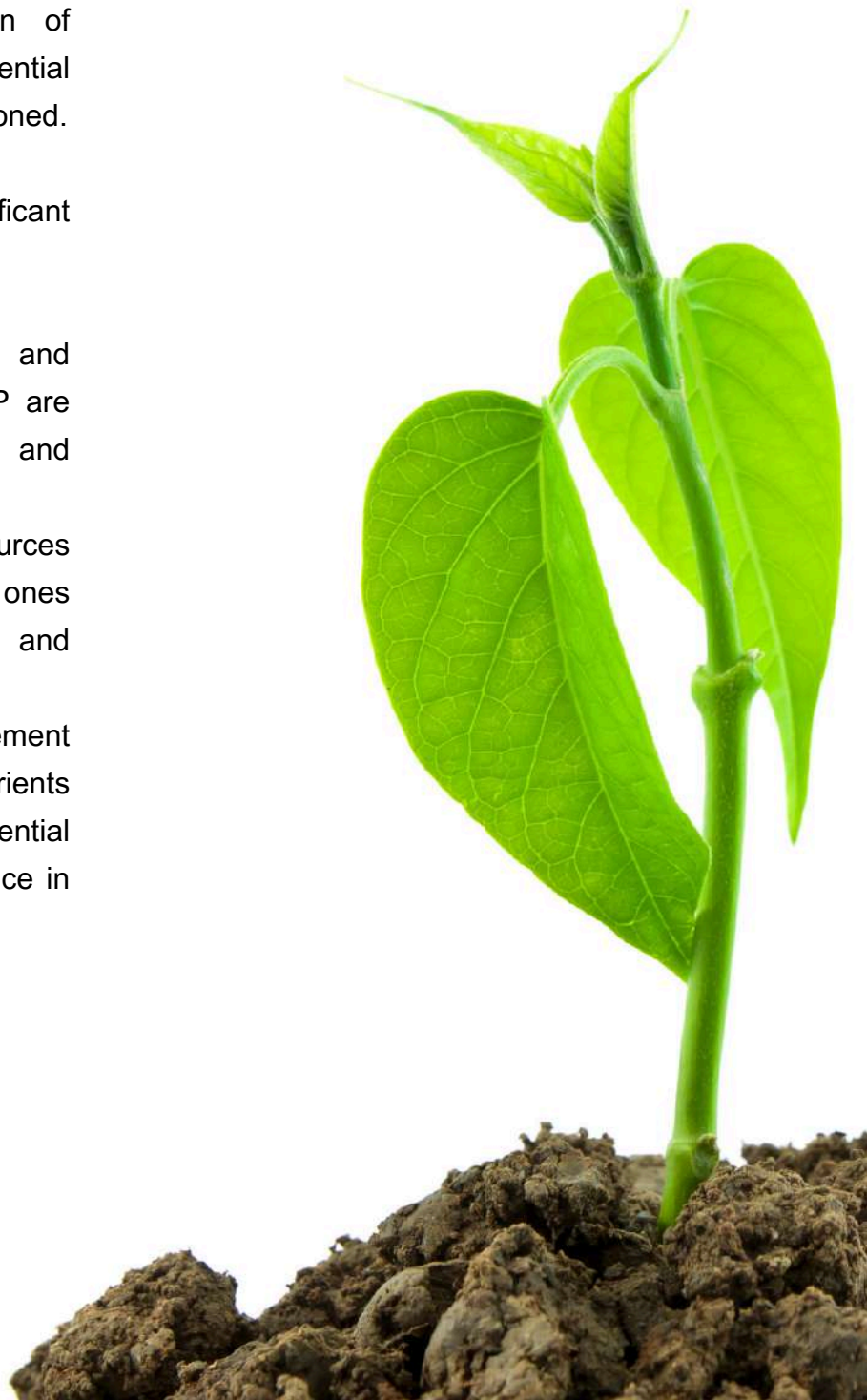
BBFs are emerging as promising secondary raw materials extracted from waste streams in different processes of valorisation. These waste streams can be very varied and come from very different sources, such as the agro-industries, food or urban waste water treatment plants (WWTPs), and thus, may include manure, sewage sludges, brine, etc. [13 - 15].

Synthetic fertilisers are not inherently negative, but, they present associated environmental and economic problems that need to be considered. Similarly, the handling and application of organic fertilisers also present potential environmental problems, as already mentioned.

In contrast, BBFs may offer some significant environmental advantages, such as:

- A decrease in potential water and atmospheric pollution, since N and P are recovered from the waste streams and thus, their leaking is minimised.
- A reduction in depletion of finite resources and harmful emissions, such as the ones related to mining, manufacture and transportation of synthetic fertilisers.
- Potential improvement in the management and application of concentrated nutrients from renewable sources, and potential similar or better agronomic performance in many cases [2, 16].

As BBFs are associated with nutrient recovery through waste valorisation, some of them can be considered derived from **renewable biomass-resources**. In this case, this origin also implies that some BBFs may offer agronomic advantages, such as growing media or soil improvers [12, 17, 13].



How are bio-based fertilisers obtained?

As seen from the definition proposed by the WaINUT Project for BBFs, according to their characteristics, BBFs can be considered fertilisers derived from biomass and waste streams that are treated to concentrate nutrients. Depending of the treatment process the resulting BBFs may present an organic or a mineral form.

It is important to highlight that, also according to the BBFs definition proposed by the WaINUT Project, **the traditional organic fertilisers**, such as manure, sewage sludge, digestate or composted agricultural residues, **can be considered apart from BBFs**. Their use is very old and well-known, and lately, they have been recognised for their alignment within the principles of circularity, and promoted as an essential part of agricultural sustainability [18].

Additionally, they play an important role in fostering ecosystem services for crop production, due to their capacity for enhancing biodiversity and soil health. High yields have also been reported for most crops, including tomatoes, rice and cereals [18, 19].

However, traditional organic fertilisers **present some issues**: the organic input can vary considerably depending on the organic source, and the nutrient content/imbalance of the amount of nutrients as needed by plants, would require careful management to ensure balanced soil fertility, avoid nutrient losses and

nutrient surplus, (which would lead to environmental issues). Also, heavy metals and other contaminants can be incorporated to the soil [2, 19].

Since **traditional organic fertilisers**, among other biomass sources, **are also considered waste streams**, they might be excellent candidates for nutrient recovery treatments for the production of BBFs.

As mentioned, depending on the treatment system, BBFs can present a mineral or organic form. Figure 2 provides an example of the paths to obtaining BBFs according to the WaINUT Project principles and the most common techniques.

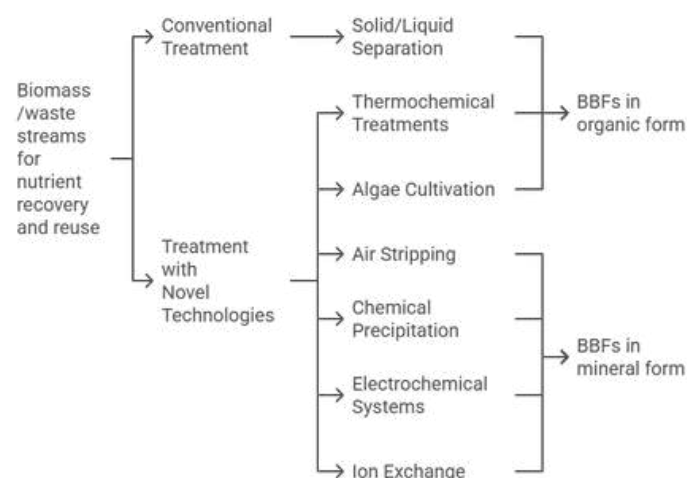


Figure 2: WaINUT example of BBFs obtention pathways.

These techniques will be briefly described in the following pages.

Traditional techniques for bio-based fertiliser obtention

A CONVENTIONAL TREATMENT EXAMPLE: solid / liquid separation

Solid / liquid separation is a mechanical and/or chemical process usually applied on waste streams (such as manure or digestate) to divide the stream in two different phases: a liquid and a solid one. This separation is usually done using equipment like screw presses or centrifuges. Particularly, centrifugation is a form of mechanical separation, but more advanced than other simple methods such as sieves, filters or decanters and its main advantage lies in its efficiency and ability to operate continuously with large volumes. The separation is usually done to facilitate storage, management and transportation [20, 21].

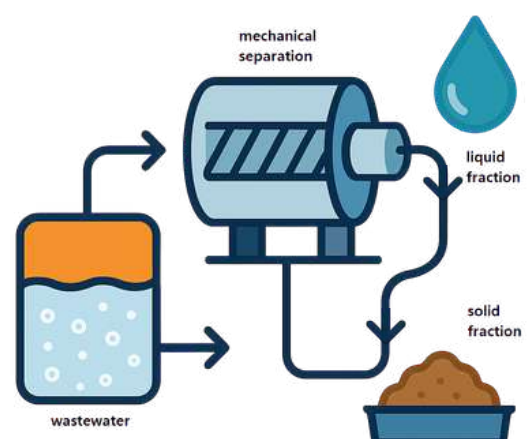
The process aims to apply the mechanical separation to transform thick organic waste streams to obtain two fractions:

- A **solid fraction**: which is organic matter- and nutrient-rich, and that contains most of the P.
- A **liquid fraction**: rich in available N for plants.

Therefore, the process results in a **liquid fraction which can be used for fertigation and the solid fraction can be used for soil amendments or composted**.

This characteristic could make it interesting for the fertilisation programmes to adjust the nutrient ratios.

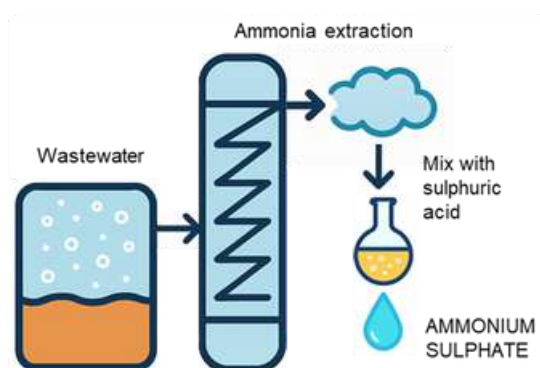
Furthermore, this technique can be a **first step in waste treatment and valorisation**, suitable for combining with the subsequent application of innovative technologies for nutrient recovery, such as those that will be presented in the next section [21, 22]. Although this technique uses much energy, its performance can vary depending on the raw material; it also requires investment and maintenance costs. However, the technique's advantages can outweigh these drawbacks: it offers greater nutrient efficiency, better storage and transportation, and new opportunities of BBFs recovery adapted to different agricultural needs [21].



Novel techniques for bio-based fertilisers obtention

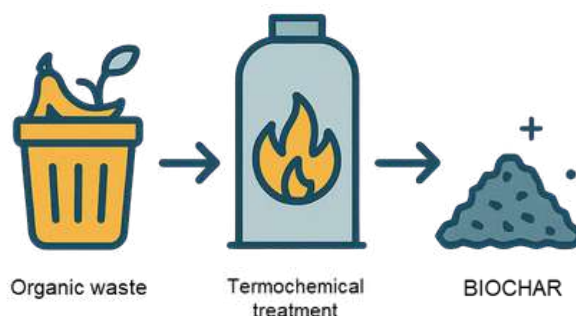
SIX EXAMPLES OF INNOVATIVE TECHNOLOGIES FOR NUTRIENT RECOVERY

1) Air stripping is a process where ammonia is stripped from waste streams through an air column at high temperatures, and later combined with nitric or sulfuric acid to produce **ammonium nitrate or sulphate**, valuable N fertilisers. This method not only captures N efficiently but also helps in odour control and reduces N emissions into the atmosphere.



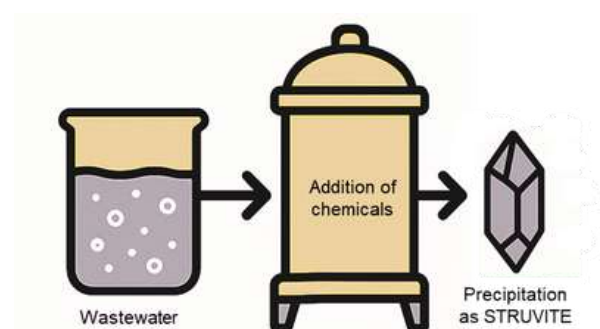
Air stripping **stands out for its high efficiency in N recovery** and for generating a stable fertiliser, **ammonium sulphate**, suitable for many crops. Its maturity level or “**technology readiness level**” (TRL), is close to 9, which means that it is a **system successfully tested in a real environment**. It is already applied at industrial scale in the EU, particularly in biogas plants and agroindustrial WWTPs. This technology is expected to continue expanding through integration with existing processes, contributing to a more circular and low-emission agriculture. This process would result in a **BBF in mineral form** (Figure 2) [22].

2) Thermochemical treatments, such as **pyrolysis and gasification**, can also convert organic waste into **biochar**. The composition of biochar may vary depending on the waste. All biochar, like the plant-based biochar, is rich in organic matter and is used in soil amendments. Animal bone biochar is rich in P, so it can be used for soil amendments and also as fertiliser.



Biochar stands out for its ability to **improve soil health and sequester carbon** while acting as a **slow-release fertiliser**. It also may enhance nutrient retention and water-holding capacity, promoting long-term soil fertility. Its **TRL is around 8–9**, reflecting successful large-scale demonstrations in the EU often linked with **waste valorisation** and **discarded biomass**. Biochar technology use is expanding due to its versatility, environmental benefits, and alignment with circular-economy goals that close nutrient and carbon loops in agriculture. This technique would result in a **BBF in organic form** (Figure 2) [22].

3) Chemical precipitation is a process where magnesium is added to a reactor, and there it interacts with the ammonium and phosphate contained in the waste waters, precipitating and forming a solid mineral called **struvite**. This mineral can be used directly as a slow-release fertiliser, providing essential nutrients to plants over time.

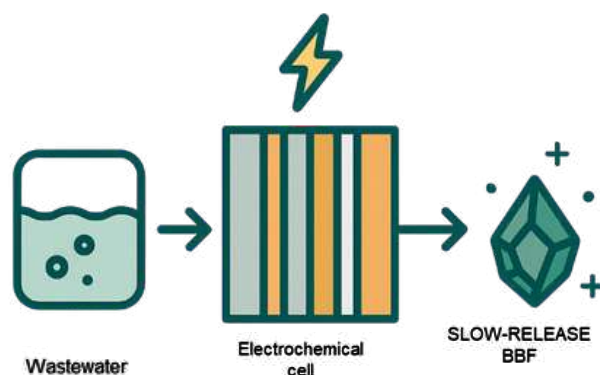


Struvite precipitation is a **well-established and well-known technology for P recovery, generating a high-purity, slow-release fertiliser** rich in magnesium, ammonium, and phosphate. It may reduce sedimentation in pipes, and it may improve operational efficiency in WWTPs.

With a **TRL close to 9**, it has been widely tested and implemented across the EU, particularly in urban and agroindustrial facilities. Its versatility to be combined, for example, with biostimulants or additives that aid in P release makes it an attractive option for potential manufacturers.

The **adoption of struvite precipitation techniques is expected to grow** due to its agronomic value, regulatory alignment, and its ability to transform waste into a marketable product. This technique would result in a **BBF in mineral form** (Figure 2) [22].

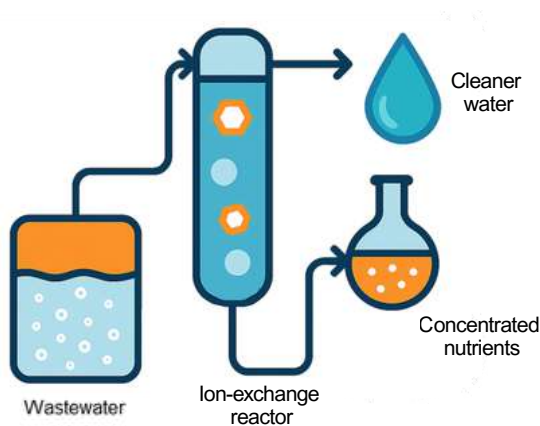
4) Electrochemical systems are also a novel option to recover nutrients, specially P. Electrodialysis and the electrodialytical method use electricity to separate interesting ions from waste waters and concentrate them into solutions for further precipitation and use as slow-release fertilisers.



Any effort to recover P, a critical raw material in the EU, deserves attention. In this case, advances are being made in innovation to complement other methods such as struvite precipitation, which increase recovery efficiency. In this sense, electrodialytical methods may **represent an emerging pathway for nutrient recovery**, that would enable the production of clean, customizable nutrient solutions that can be further transformed into slow-release P-rich fertilisers. With a **TRL around 6–7**, these systems have shown promising results in pilot-scale applications, and ongoing research is accelerating their refinement. Their **potential lies in their precision, low chemical input, and integration into modular treatment setups**, offering an innovative solution for circular and efficient nutrient use. This technique would result in **BBFs in mineral form** (Figure 2) [22].

5) Ion exchange is a technique that allows the capture of nutrients dissolved in water, such as ammonium or P, using special materials called ion exchange resins.

First, nutrient rich waste water is passed through an **exchange column, where the ions of interest (such as nitrates, phosphates, or ammonium) adhere to the resin**. It works as if the column selectively "filters" the useful nutrients. When the **resin becomes saturated**, it is cleaned with a regenerating solution (such as brine or acid), which releases the trapped nutrients in a concentrated form ready to be processed or precipitated to form BBFs.



Ion exchange offers a selective and efficient method to recover nutrients like ammonium and phosphate from waste water.

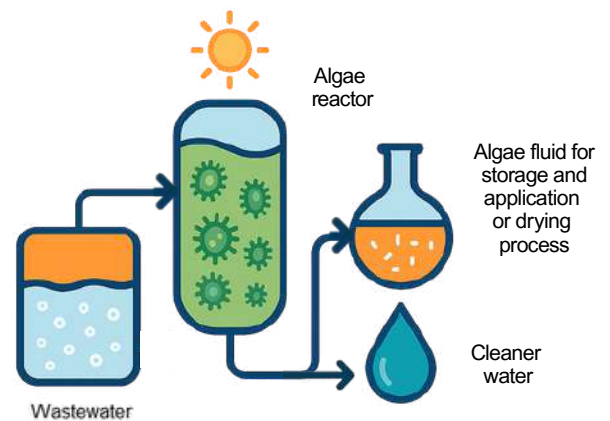
Its **TRL is around 7–8**, with successful pilot and demonstration cases across Europe. The method is gaining attention for its precision, adaptability, and potential integration into decentralised or modular treatment systems, paving the way for innovative nutrient loops and more sustainable farming practices.

According to the diagram in Figure 2, this technique would result in **BBFs in mineral form** [22].

6) Phototrophic algae are organisms known for their **ability to capture nutrients present in waste water**, such as N and P, which are essential for plant growth.

In these systems, nutrient-rich waste water is introduced into an illuminated bioreactor, where the algae grow by feeding on these compounds, thanks to sunlight or artificial light. As the algae develop, they absorb the polluting nutrients, transforming the waste water into a cleaner medium and generating nutrient-rich biomass.

This biomass can be harvested and processed to produce slow-release BBFs.



These systems produce algal biomass that can be used directly as a BBF or processed into tailored products. **The TRL is around 6-7**, showing promising pilot-scale operations. This system involves waste water treatment and biomass production, making this process a multifunctional and nature-based solution. Of all the technologies described above, this is the only one that is biologically based, meaning it uses microorganisms to function and recover nutrients. Following the diagram in Figure 2, this technique would result in **BBFs in organic form** [23].

Main advantages of bio-based fertilisers



Environmental and agronomic

- Protection of soil health and biodiversity (specific to BBFs in organic form), and avoidance of potentially toxic elements.
- Minimisation of the depletion of non-renewable resources.
- Avoidance of the GHGs emissions related to the synthetic fertilisers' production, transport and application, by closing nutrient cycles.
- Tailor-made formulations allow BBFs to adapt to diverse soils, crop types, and local nutrient needs.
- Slow-release profiles and soil-enhancing properties support efficient nutrient uptake and long-term fertility.



Economic

- Implication in waste valorisation associated to waste management.
- Possibility of being produced within the EU, reducing the dependence on external supply of synthetic fertilisers, meaning more control over food security.
- Opportunities for nutrient exchange among different European regions.
- Potential to obtain economic returns from waste streams.
- Potential to be combined with existing waste treatment technologies already implemented in the WWTPs (biorefinery approach).



Social

- New forms of fertilisation possibilities adapted to crop requirements.
- Additional options so farmers can decide what products best suit their needs.
- Contribution to the sustainable development goals (SDG), such as Goal 2 (zero hunger, promoting sustainable agriculture for food security).
- New bussines models and rural jobs opportunities.

Legal Framework

The policy framework for fertilisers in the EU covers different legal areas. For example, waste legislation used to focus on waste disposal or storage. It then shifted to considering the needs of waste management and treatment. Today, it focuses on the recovery of the remaining value, from energy to substances such as nutrients.

For this, it is necessary to **regulate the different types of waste streams**, and with them, **how the recovered substances will be considered**. To address the complexity of this challenge, the **EU takes into account many different points of view**, aiming to set an example with innovative regulations and strategies.

Table 1. Main relevant legal texts and strategies related to fertiliser use at the EU level. Adapted from Kurniawati *et al.* [24].

Policy Area	Norm	Type	Relation to the use of fertilisers
Common Agricultural Policy (CAP)	Cross Compliance (C/2022/3390)	Regulation	To maintain organic matter level in soils, limit nutrient losses.
Soil Policy	EU Soil Strategy for 2030 (COM/2021/699)	Strategy	To adopt soil protection measures and restore soils to their healthy state (nutrient balance and organic matter content).
Animal exploitations	Animal By-Products Regulation (EC) No 1069/2009	Regulation	Animal by-products (bones, waste, etc.), should be processed to avoid transmitting diseases to humans or animals, and treated.
European Green Deal (COM/2019/640)	Farm to Fork (COM/2020/381)	Strategy	To reduce nutrient losses (ensuring that there is no deterioration in soil fertility), and a reduction of the use of fertilisers by at least 20% by 2030.
Circular Economy	Zero waste program for Europe (COM/2014/398) & 1st and 2nd Actions Plans (COM/2015/614 and COM/2020/98)	Strategy	To increase sustainable waste management, and improving waste treatment, to extract all the high value-added products from waste water flows. To develop the Integrated Nutrient Management Action Plan, reviewing the waste water and sewage sludge directives, and to assess the natural means of nutrient removal.
Waste Policy	Sewage sludge Directive (86/278/EEC)	Directive	To increase the amount of sewage sludge used in agriculture (ensuring that heavy metals in soil and sludge do not exceed set limits).
Water Policy	The Nitrates Directive (91/676/EEC)	Directive	To reduce the eutrophication caused by N with an agricultural origin.

The new EU Fertiliser Product Regulation

To adapt to the current needs and to reflect changes in recent years regarding waste valorisation, the EU has approved a new norm: the **REGULATION (EU) 2019/1009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL**, of 5 June 2019, laying down rules on the making available on the market of EU fertilising products and amending Regulations (EC) No 1069/2009 and (EC) No 1107/2009 and repealing Regulation (EC) No 2003/2003 [25].

This Regulation (EU) 2019/1009 is **more commonly known as the New EU Fertiliser Product Regulation (FPR)**, and is a key norm that organises the commercialisation of fertiliser products in the EU. As a regulation, it is a binding legislative act, and therefore it must be applied in its entirety across the EU. All MS should refer to it when developing their own regulations at any level.

The FPR is the **new legal basis for the regularisation of all fertilisers**, organic and mineral. **It has also opened the door for a single market, in particular to fertilisers made from recovered waste and by-products available in the EU.** It promotes green and circular alternatives to natural gas and mined raw materials for fertiliser production.

Given its importance, hereunder have been summarised its most important points, including key definitions, the objectives of the regulation, and also its advantages and **disadvantages, such as loopholes and possible overlaps with other regulations.**

Two important **definitions according to the FPR** are (30/12/2025 consolidated version):

- Fertilising product: means a substance, mixture, micro-organism or any other material, applied or intended to be applied on plants or their rhizosphere or on mushrooms or their mycosphere, or intended to constitute the rhizosphere or mycosphere, either on its own or mixed with another material, for the purpose of providing the plants or mushrooms with nutrient or improving their nutrition efficiency.
- EU fertilising product: means a fertilising product which is CE marked when made available on the market; (Figure 3).



Figure 3. EU certified fertilising product example.

According to the **FPR**, the fertilisers must meet specific requirements to be marketable in the EU, according to two main categories:

1. **Product Function Category (PFC)**
2. **Component Material Category (CMC).**

The **PFC regulates** fertilisers, liming materials, soil improvers, growing mediums, inhibitors, plant biostimulants and fertilising product blend in the Annex I of the FPR.

An EU fertilising product should consist solely of component materials complying with the requirements for one or more of the CMCs listed in the FPR. The **component materials, and the input materials used to produce fertilisers** must not contain any of the substances for which maximum limit values are indicated in Annex I of the norm.

The FPR differentiates **several CMC categories**:

- CMC 1: Virgin material substances and mixtures.
- CMC 2: Plants, plant parts or plant extracts.
- CMC 3: Compost.
- CMC 4: Fresh crop digestate.
- CMC 5: Digestate other than fresh crop digestate.
- CMC 6: Food industry by-products.
- CMC 7: Micro-organisms.
- CMC 8: Nutrient polymers.
- CMC 9: Polymers other than nutrient polymers.
- CMC 10: Derived products within the meaning of Regulation (EC) No 1069/2009.
- CMC 11: By-products within the meaning of Directive 2008/98/EC.
- CMC 12: Precipitated phosphate salts and derivatives.
- CMC 13: Thermal oxidation materials and derivatives.
- CMC 14: Pyrolysis and gasification materials.
- CMC 15: Recovered high purity materials.

The Commission Delegated Regulation (EU) 2022/973 establishes agronomic efficiency and safety criteria for the use of by-products in EU fertiliser products, supplementing the FPR and ensuring that their use does not pose risks to human health, the environment, or soil health [26]. This includes strict limits for contaminants, purity requirements, and labelling standards.

This regulation complements the FPR by developing specific criteria for by-products included in Category Component Materials, as it has been described previously.

This opens the door for new BBFs developed in recent years to be marketed on equal terms with other traditional products.

In the Regulation 2022/973 by-products are divided into two categories:

- those that provide nutrients or improve nutritional efficiency;
- those used as technical additives to improve the quality or safety of the fertiliser.

All these substances must follow also the Regulation (EC) No 1907/2006, of Registration, Evaluation, Authorisation and Restriction of Chemicals (**REACH Regulation**, [27]), which regulates the risks related to chemical substances for human health and the environment. In CMCs where REACH registration is required by FPR EU 2019/1009 (i.e. substance used as fertiliser) then stricter legal requirements apply; for instance, the substance (imported or manufactured), must be registered according to the REACH specifications, even for amounts below one tonne.

The main aim of the FPR is to ensure that fertilisers marketed in the EU are safe, effective and environmentally friendly, while promoting innovation and the use of recycled materials on their production. To achieve this, the norm establishes a regulatory basis for:

- Establishing harmonised conditions to make fertiliser products available in the EU's common market.
- Promoting the use of recycled and organic materials, as a basis for the production of fertilisers, according to the circular economy principles by transforming waste into raw materials as nutrients for crops.
- Boosting circular bioeconomy by reducing the dependency on nutrients from third countries.
- Endorsing the production of fertilisers with reduced cadmium content.

The FPR offers a comprehensive perspective of products and scenarios, with a diverse approach for end users, producers and also, operators.

The key points of the FPR are:

1. It provides rules for free movement in all CE marked fertilising products across the EU. Now the fertilising products would include those derived from recycled bio-waste and nutrients.
2. It includes recovery rules for bio-waste transformed into composts and digestates.
3. It updates the requirements for inorganic CE marked fertilisers.
4. It introduces harmonised requirements for all CE marked fertilising products regarding:

- Quality: minimum nutrient and organic matter content, neutralising values that are specific to each category of fertilising products;
- Safety: maximum limits for heavy metals (also Cd), organic contaminants, microbial contaminants and impurities for each category;
- Labelling: with specification of the actual nutrients content and their forms; allowing the farmers to choose and dose the fertilisers depending on the crops needs.

5. It modernises the “declaration of conformity” and “conformity assessment procedures” for manufacturers of fertilising products for the EU market.

6. It offers new borderlines between fertilisers and Plant Protection Products, to avoid overlap between plant bio-stimulants and plant growth regulators.

7. It enables derived animal-by-products to move freely on the single market as fertilisers.

The FPR has been in force since 16 July 2020, however, at the time of writing this White Paper, possible amendments are being discussed such as the proposal for digital labelling for fertiliser products.

The modifications to the FPR are in the hands of technical committees and working groups within the European Commission. These groups are usually made up of representatives from MS, industry experts, representatives of farmers, expert advisory boards, NGOs, etc., who debate topics such as digital labelling and fertiliser sustainability.

These discussions can last several months or even years, depending on the complexity of the proposed changes and the level of consensus among interested parties.

This process includes technical consultations, committee meetings, legal reviews, and possible adjustments in response to feedback received. The duration also depends on the political priorities of the European Commission and how the proposals align with other ongoing legislative initiatives.

Therefore, **there is still room for improvement for the FPR, since there are some challenges to be considered [24].**

The most **significant limitations detected so far are listed as follows [10, 13, 24, 28, 29]:**

1. Lack of clear definitions: the FPR does not present a clear definition about what is a "bio-based fertiliser." This can lead to different interpretations across MS, creating inconsistencies in market access and regulatory compliance.

2. Overlapping or possible conflicts with other regulations. For instance:

- *Waste Framework Directive (2008/98/EC)*: Governs waste management and recycling. If bio-based fertilisers are derived from waste, this directive might apply, complicating compliance.
- *Animal By-Products Regulation (EC) 1069/2009*. If BBFs are derived from animal by-products, additional safety and handling regulations may apply.

- *REACH Regulation (EC) No 1907/2006*, since the bureaucracy associated with complying with the requirements of the standard can be complex and time-consuming.
- *Nitrates Directive (91/676/EEC)*, which limits the amount of N applied per ha.

3. Barriers/inconsistencies with MS regulations:

The legal barriers/inconsistencies between EU and the MS could be classified as:

- Variable national standards: while the EU provides overarching regulations, the implementation can vary significantly among MS.
- Divergent certification requirements: certification processes and requisites can differ from one country to another.

4. Approval and notification procedures.

- Lengthy approval processes.
- Complex notification requirements.

5. Certification processes, which could be often complex and time-consuming.

6. Limited scope of the positive list under Component Material Category (CMC) 7:

This positive list has opened the door for microbial plant bio-stimulants containing *Azospirillum*, *Azotobacter*, *Rhizobium*, and mycorrhizae. *Trichoderma* is not included.

The list will be expanded through Delegated Acts, and other mechanisms are currently being proposed.

Despite these issues, the new legislation FPR with the complement of the Commission Delegated Regulation (EU) 2022/973 opens a precedent to promote the closure of nutrient cycles and to increase the extraction of N and P from waste and waste water flows.

In the end, with the new norms it will be easier to:

- Establish fair competition for all fertilising goods at the EU level, to boost industry access to the internal market.
- Preserve national laws for products restricted to domestic markets to prevent any disruptions to the market.
- Raise the bar for environmental and health protection by limiting the amount of pollutants found in fertilisers and additives across the EU.

The final policy will establish a fair, affordable, transparent, and adaptable regulatory environment to help EU farmers to get the new products they need.



Objectives of this White Paper

The advantages of BBFs are many and varied, and the circular economy has been promoted for several years now. So, why are BBFs not already a reality available to farmers?

A simple answer might be that they are still very new products and just need more time to establish as an alternative.

However, it is necessary to look more deeply into the implications associated with their development, to consider how the different challenges, gaps and barriers affect them, and how they might be addressed individually but also collectively, to propose practical solutions that can be applied in the real world.

The BBF concept and characteristics have already been outlined. In the next chapters the main challenges for BBFs will be described, and then the **WalNUT Project will be presented as one of the drivers of the solutions for these challenges.**

Finally, the White Paper will present and explain several practical **recommendations** and **opportunities** for stakeholders and policy makers, in order to help the implementation of these new fertilisers.

The dissemination **of the knowledge** and the findings of research projects, such as the WalNUT Project, **is key to ensuring that society can benefit from the discoveries made.** The advancement of new lines of innovation and the exploration of new economic and environmental perspectives depend largely on the efforts and the findings of the R&D initiatives.

One way to contribute to the dissemination of knowledge generated through research is the use of white papers, which bring ideas and recommendations closer to the general public.



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To study the problems related to BBF development, the latest relevant publications were consulted, as were also relevant EU projects and experts along the value chain.

This section presents four most challenging areas for BBFs implementation:

1. Definition.
2. Characteristics.
3. Markets.
4. Costs.

1. DEFINITION

There is currently no binding, universally accepted legal definition of “bio-based fertiliser” within EU law. The updated FPR establishes PFCs and CMCs, but does not clearly distinguish BBFs as a standalone class. This creates legal ambiguity and regulatory fragmentation across European MS.

Without a formal definition, BBFs face inconsistent classification and are often excluded from subsidies, standards, or trade across borders.

Therefore, definition of BBFs is still a subject of debate. **It is generally accepted that BBFs should be materials coming from waste streams, usually biological, but not always (e. g. brine from desalination), with enough bioavailable nutrients to be used as fertilisers. However, it is commonly accepted that these materials must undergo some transformation process to extract or concentrate nutrients, thus optimising their fertilising capacity.** This treatment can be done through different technologies but the key

must be their **circularity (upcycling)**, that is, obtaining valuable materials from waste streams that are capable of reducing negative environmental impacts compared to fossil-based synthetic fertilisers [28, 30].

In addition to the lack of a clear common definition, there are also **misconceptions** about what BBFs are. They are often confused with biofertilisers and biostimulants. **Biofertilisers** can be considered as a mixture of microorganisms (primarily bacteria, fungus, or cyanobacteria) that improves soil quality and plant growth and development when applied to plants or soil [31].

Biostimulants can be defined as substances or microorganisms capable of improving the properties of the soil and/or its microbiota, and which do not necessarily have any nutrient content [32].

Some authors even consider biofertilisers a subcategory of biostimulants [32].

Therefore, there is still a lot of work to refine the definitions related to BBFs. Also, parallel definitions have even been proposed, such as “circular fertilisers” or “nutrient-recovery-based” [28, 33], to highlight those fertilisers that are produced from nutrients recovered from recycled waste, by-products and waste waters.

The WaNUT Project has proposed its own definition of BBFs, as seen before, and it is expected that a general agreement will be reached soon.

2. CHARACTERISTICS

In the case of fertilisers, demand may exceed supply, and this could mean BBFs aren't necessarily dismissed by producers or users. However, there are indeed some reservations on their composition (formula), and so, how they will work.

Firstly, BBFs still face distrust from final consumers and farmers due to fears of contamination, odor, or are still perceived as “dirty”, and their acceptance is specially low for edible crops [28].

Also, both potential producers of BBFs and farmers are concerned about the quality of the products, where quality is associated with the amount of nutrients bioavailable for the crops. By their nature, waste streams show a particular **heterogeneity**, so nutrient recovery technologies must be adapted to work towards achieving a **certain composition of N, P and K**, which entails its own challenges. Even so, **technical requirements would not be as much of a problem as investment or operational costs**. In the same way, users may demand more transparent labelling that shows the origin of the components; for example, if a certain percentage of the fertiliser product has been recovered from a waste stream, which one and by what means, etc., [28, 30, 34]. This type of information can be included in the specifications of EU fertilising products (Figure 4) and it could be interesting for potential certifications.

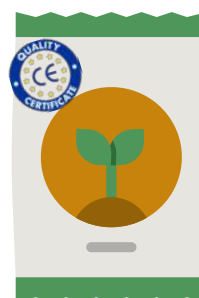


Figure 4: Example of a potential certified BBF product.

This can be especially important in the case of agricultural practices that have particular specifications or standards (such as organic farming), which need to prove their sustainability throughout the entire supply chain of their products [28, 30, 34].

Another concern is associated with the origin is the **type of presentation of the product**.

Neither farmers nor producers are willing to change the **production methods, storage or application systems**, so that the **presentation formats of the BBFs must be as similar as possible to those that already exist**, such as liquid ammonium sulphate for fertigation [28, 30, 34].

3. MARKETS

According to the information collected by the WalNUT Project, most potential producers of BBFs agree that one of the biggest challenges is the **limited access of BBFs to established markets for their commercialisation** [29].

The potential producers can be considered mostly the WWTPs, but for that, a change in social perception is needed, in a way that final users, farmers and even consumers, may start perceiving these plants not as waste water processing facilities but as biorefineries.

Biorefineries would be one more piece in a complex network of stakeholders that also includes farmers (as bio-waste producers but also as fertilisers buyers), food industries, government organisations, researchers in the agri-food sector and the final consumers, among others [30].

For the success of BBFs in the market, it is necessary to put all these agents parties in harmony so that their interests would be complementary and aligned.

In the same way, **public opinion about BBFs** may differ from one EU country to another. However, trust is greater when the potential advantages BBFs may involve are clearly described, and when their recovery processes are well explained, as this disassociates the concept of waste from biological insecurity.

In parallel with the **labelling** initiatives for clarification on their composition, **providing information** about the environmental benefits, the potential improvement of soil properties, and their ability to be combined with biofertilisers or biostimulants results in a positive perception of the BBFs by the public.

In this regard, many research projects have made significant efforts to create online knowledge transfer platforms, information exchange platforms, and even platforms for inter-stakeholder trading of BBFs.

According to this initiatives, the WalnUT Project developed its own platform (Figure 5), to improve and increase knowledge on nutrient recovery from EU waste water streams.

The users can register for free and select their role, then, the platform will help them to find best possible match for their needs, and guide them on the dashboard through the potential transactions.



Figure 5: WalNUT Project platform front page.

Many authors have commented that **highlighting the qualities and advantages of the BBFs** would help to achieve greater acceptance among producers and users, and that it would open the door to markets. Since BBFs are associated with a lower environmental impact than fossil-based synthetic fertilisers, it is expected that in the medium term they would become more interesting, as more environmental policies are expected to be developed [13, 28, 30, 35].

4. COSTS

BBFs costs are a critical factor that will determine their market viability and long-term adoption by the agricultural sector [11, 34].

As it has been described, BBFs appear to be a good solution for the agricultural challenges and the uncertainty related to resources. They are a promise for closing nutrient loops, reducing GHGs emissions while maintaining soil health and lowering dependency on imported synthetic fertilisers. However, after a decade of innovation and policy momentum, BBFs remain a niche market, often priced above or equal to the synthetic fertilisers, and still far from being a real option for final users.

The BBFs costs plight: why BBFs still struggle to compete?

It has been proposed in literature that the core of the problem is not only the high production costs, but also the **fragmented structure of the BBF value chain**. Since BBFs are products derived from substances extracted from waste streams (such as sewage sludge, brine, digestate, manure, food residues, etc.), each one may present its own variability, handling challenges, and regulatory barriers. Transforming these substances into consistent, safe, and nutrient-dense fertilisers requires energy, infrastructure, and monitoring, all of which add costs before the product even reaches the market.

Economies of scale play a decisive role in production costs.

Conventional synthetic fertiliser producers operate on a global scale with stable feedstocks and well-established logistics. In contrast, the BBF production is decentralised and reliant on small or medium-scale facilities, often located near waste water sources. This can be a disadvantage if there is no comprehensive management plan for its integrated distribution. Transporting hefty water-rich materials such as digestate or sludge can exceed the value of the nutrients they contain. As a result, **logistics and pre-treatment often represent a large share of total costs**, particularly in regions lacking coordinated waste management systems or local application markets. In line with this, the **energy intensity of some recovery processes** (such as air stripping, conventional pyrolysis, HTC, or even electrodialysis), further increases operational expenditure. In many cases, these technologies would remain at pilot or demonstration scale (TRL 5–7), and so they won't benefit from optimisation or mass production. The **challenge is compounded by regulatory uncertainty**, where many products still require national authorisation or compliance with additional standards such as REACH among others. This multi-layered legal environment slows investment and adds compliance costs that synthetic fertilisers do not face, and can involve **costs for administrative procedures or legal support**. Another cost dimension emerges from **market perception**. Farmers usually focus on productivity and affordability when it comes to making decisions; therefore, they might prioritise reliability, nutrient concentration, and price [10, 11, 13, 34].

Several studies suggest that, for the BBFs acceptance, the price of BBFs should be reduced by 30% to 65% approximately, and therefore incentives or cost reduction in the value chain should be considered [11, 13, 34].

To address these issues, each year, new projects emerge offering new solutions, with technological refinement, better process integration, and supportive policy design that can narrow the cost gap. **It could be said that the high costs issues might be not permanent, and it would reflect a transition phase where technologies are evolving, regulation is catching up, and supply chains are still forming.** It is essential to understand where costs are highest and how they differ across technologies to identify how innovation and policy should intervene together [28].

Analysing cost drivers of BBFs obtention to transform challenges in opportunities

In all cases, there is variability associated with geography and the type of waste management. In the next pages, the costs of the previously presented techniques for BBFs obtention are briefly described.

Mechanical **solid/liquid separation** can be considered cost-effective, but its profitability is related to local factors and scale. It might present high capital costs (CAPEX) and also significant operational costs (OPEX), but both could be balanced due to some options, such as the reduction of the expenses of dewatered

solids, nutrient management flexibility, and potential revenue from concentrated BBFs. This technique may enhance the nutrient management strategy, improve nutrient efficiency, and reduce long-term costs associated with traditional waste management [36].

Air stripping shows promising recovery efficiencies, yet it is energy-intensive and requires acid consumption, corrosion-resistant materials, and careful process control. Its competitiveness improves when it is co-located with biogas facilities, where waste heat and biogenic CO₂ can be used to enhance stripping efficiency. These systems are already operational in some full-scale plants, but scaling them further demands process automation, modular design, and integration into regional nutrient markets to offset operational costs [37, 38].

Biochar carries high capital costs for reactors and emission-control systems, and its profitability may depends on the valuation on carbon credits and the potential production of bio-oil and syngas. Market uptake is further slowed by regulatory ambiguity: while some biochars are now included under the EU's component material categories, many still lack standardised testing for stability or agronomic efficiency. Despite this, biochar remains one of the few options that can generate negative emissions and add long-term soil carbon, giving it strong potential if carbon markets and certification schemes mature [39, 40].

Struvite precipitation is often presented as the flagship technology for P recovery. While it offers a highly pure, slow-release fertiliser, the process demands intense chemical control, magnesium dosing, and post-treatment for market acceptance. The capital costs of reactors, pumps, and chemical reagents can be substantial, particularly for small waste water plants. Moreover, the quantity of P recovered could be considered low in relation to the WWTP's total nutrient load. Integration with existing waste water infrastructure can reduce costs, but large-scale deployment would remain dependant on P prices and recovery operational costs [41, 42].

In the case of **ion-exchange** technologies (using synthetic resins or natural adsorbents such as zeolites), they may recover nutrients like ammonium and phosphate through selective capture. Their appeal lies in flexibility and modularity. Therefore, they are suitable for different waste water types and easy to integrate into the existing treatment lines. However, their economic feasibility is largely defined by regeneration costs and chemical use.

Natural zeolites are less expensive but also less selective and require frequent reactivation; synthetic resins achieve higher recovery rates but are prone to fouling and demand costly maintenance. Overall, ion exchange remains one of the most adaptable but cost-sensitive options: is technically capable of producing concentrated nutrient solutions, although it still needs further advances in regeneration efficiency and material longevity to become truly competitive [43, 44].

Electrodialytic systems might be considered as an innovative technology to concentrate nutrients using electric fields rather than chemicals. Their advantage lies in selectivity and compactness but they are limited by electricity demand or membrane cost. With the rise of the renewable options, the energetic environmental profile may improve, however, economically they remain suited mainly to high-value niche applications or coupling with other processes. The future cost reductions could rely on advances in membrane durability, energy improvements and hybrid configurations that can combine nutrient concentration with, for example, desalination or water reuse [45, 46].

For the option of **algae cultivation**, the main economic challenge may be balancing nutrient uptake efficiency with the energy and operational costs of cultivation, harvesting, and drying of the algae. Phototrophic systems require large surface areas and light control to achieve sufficient light exposure. Also, since light penetration in the ponds limits growth, algal cultures are typically diluted, which dramatically increases harvesting and dewatering costs. In the same way, cost-effectiveness drops in winter or at high latitudes. Even in favourable scenarios, the steps of harvesting and drying the biomass are very energy intensive. So, although these algal phototrophic systems might be ecologically interesting, they are economically fragile. On a positive note, the heterotrophic/mixotrophic option can reach positive cost-benefit ratios, when integrated into circular industrial settings (like agro-food waste water treatment) [47, 48].

Looking for solutions

The cost barrier may seem too big but it is not insurmountable; it reflects a system in **transformation**.

As the **technology matures and production scales increase, unit costs may decrease accordingly**, as it has already happened in the past with other environmentally preferable options, such as renewable energies. In any case, **political support** through investments, price fixing, recognition of environmental value, and other measures is fundamental. Also, by improving communication and training on BBFs, along with efforts to strengthen value chains, the trust of the markets could increase.

These steps are part of a **cycle that can begin with any of the main stakeholders, and expand to the rest, to demand high-quality, environmentally sustainable products** that are not only circular but also may guarantee supply without depending on external sources.

The idea of this interconnection gave rise to the concept of the **biorefinery**, which has already been mentioned. It has been highlighted in the used literature the potential of integrated biorefineries to mitigate costs through resource symbiosis. By aligning fertiliser recovery with energy production, feedstock valorisation, and by-product reuse, biorefineries distribute costs across multiple value streams.

The various approaches for solutions outlined above will be developed further in the Recommendations section.

Changing the BBFs narrative: their versatility as a strategy

Cost variability among BBFs obtention technologies could be perceived as a weakness, which would be easily explained given that the BBFs sector lacks uniformity or economic predictability.

However, this perspective can be changed and this variability can be one of the greatest strategic strengths of BBFs: it might reflect their **versatility, as diversity of context and adaptability of design**, rather than inefficiency. Each nutrient recovery technology alternative may respond to specific local conditions: some could thrive where biogas plants generate heat and CO₂ for stripping systems; others can be applied where waste water rich in P can use precipitation techniques to obtain crystalline products; while others can apply HTC or pyrolysis to produce carbon rich bio-based fertilisers.

This variety of technological options means that BBFs are not constrained by a single industrial model, and they can be applied depending on the waste streams necessities and conditions, from large municipal facilities or small agroindustrial cooperatives. This flexibility could be used as an advantage over centralised fertiliser production, where instead of one uniform solution, BBFs offer diverse context-specific pathways, capable of adapting to feedstock variability and regional market needs. In this sense, circular nutrient recovery technologies could be considered part of a single concept: the sustainable solution for the future of fertilisation.

In one way or another, the described challenges will affect the different stakeholders involved in the production, promotion, and use of BBFs. **The implications that each one of these challenges have for the main BBFs stakeholders, are described below.**

1. TECHNOLOGY PROVIDERS

Technology providers (as tech or industrial engineering companies) play a strategic role in nutrient recovery, since they design, implement, and scale technical solutions that recover N, P and the other key elements from waste flows. However, they face multiple structural and market related barriers that limit their ability to establish themselves in this emerging field.

For instance, with vague regulatory frameworks and little certainty of agronomic acceptance, suppliers cannot estimate consistent sales volumes or clear return on investment. This discourages funding actions on R&D, or on the production of technologies on an industrial scale. Also, many technologies are in the demonstration or pilot phase, which limits access to structural public financing (beyond European projects) and private loans; in addition, they may face high certification and validation costs. Also, compared to other environmental technologies (renewable energy, water treatment, etc.), nutrient recovery is not yet perceived as a priority sector, which slows down the integration into innovation policies or green strategies.

Related to that, technology developers lack direct communication channels with agricultural users or fertiliser manufacturers, and also with R&D programs and researchers, making the novel technologies difficult to adapt to real market needs and to operate at full scale.

2. POTENTIAL PRODUCERS

The WWTPs may be one of the direct sources of recoverable nutrients, so their active participation is essential. However, their role is limited by technical, economic, and regulatory challenges that hinder their transition from "waste managers" to "resource producers", as potential biorefineries.

For example, the current framework does not compensate for nutrient recovery as an environmental service, which discourages investment in additional technologies beyond conventional treatment. And if the facilities consider the installation of nutrient recovery technologies, they may find that the costs (both CAPEX and OPEX) of those technologies (such as air stripping or struvite precipitation), are not offset by the economic value of the recovered products (as BBFs). On the other hand, although some processes are recognised by the EU Regulation 2019/1009 (e.g., composting, anaerobic digestion), many plants do not know whether the product they generate can legally be marketed as fertiliser. There is a lot of confusion about the differences among by-products, waste/s, secondary raw materials, processed material, and EU fertiliser.

In relation with this, there is a lack of technical knowledge and operational experience. Operating mechanical solid/liquid separation machinery and the novel nutrient recovery technologies requires specialised training and even an understanding of advanced chemical, physicochemical, or biological processes. Many WWTPs (specially medium and small sized) may not have a qualified workforce, or the resources to incorporate new treatment lines.

From an other perspective, many technologies depends on the quality of the treated waste (nutrient content, contaminants, etc.) to be successful. However, WWTPs in many cases do not control the origin of their waste, or receive highly variable flows, which compromises the consistency and quality of the final BBF product. Even so, if the BBFs were produced, WWTPs, might face tasks outside their usual mission: labelling, storage, transportation, contact with farmers or distributors. Furthermore, they may be in charge of sales, taxes, legal liabilities, etc. Many public and even private plants are likely not willing to take on such tasks.

3. RESEARCH CENTRES

Research centres can be defined as different types of institutions and facilities that group investigators with a common background or specialisation, whose task is focused on advancing research projects for innovation.

Research projects are developed to improve EU policies, or to answer to a particular necessity of the society finding novel solutions.

Research projects show a holistic and a cross-sectoral vision that integrates technology, economics, politics, and a social dimension. However, they are usually conditioned by their completion date, and their progress can be lost or forgotten since there is not an official European protocol to collect, process, compile and distribute the information, as a way to avoid redundancy and omissions regarding the conjunctural research already done.

For instance, Gudek *et al.* [49] assessed how the tools for stakeholder engagement work in the Horizon Europe R&I projects framework. They found that it might be positive to dedicate more resources on improving the engagement tools already created, instead of promoting the creation of new ones in new projects, which often repeat the features and functions, and only differ in the logo. Furthermore, these authors indicated that usually the impact of the European research projects (as results and tools), is apparently designed to last as long as the project is completed. Monitoring the impact of the project beyond the finalisation date is a responsibility usually delegated to project leaders, but its reach over time lasts only a few years.

Thus, research projects have a short-term profile, which influences the way they are managed and, above all, the way they relate to other projects, stakeholders, and especially the target audience.

How does this affect the development of BBFs? In some cases, due to the limited amount of time to develop a project (2 to 4 years), the research focus only on a specific part of the

value chain (e.g., recovery efficiency, emissions, acceptance, etc.), without connection to the next or previous steps.

For their part, researchers are often not integrated into regulatory or certification processes, despite the critical role they play.

In this respect, there is a lack of a consolidated culture of practical dissemination, co-creation, and applied advisory tools. Much research remains in academia and does not reach farmers, manufacturers, or policymakers in useful formats. There is a limited institutional recognition of the role of researchers in the circular agricultural transition, and as generators of useful evidence to be used for innovation and public policies.

4. POLICYMAKERS AND PUBLIC ADMINISTRATION

In addition to issues related to the lack of an official BBF definition, there are also problems related to high sectorial and competence fragmentation in MS.

Responsibilities regarding agriculture, waste, water, and the circular bioeconomy are often distributed among different administrations, and even among different administrative levels.

This can generate inconsistencies, bottlenecks, and delay the advancement of policies of interest to BBFs. It can even lead to duplication of efforts and budgets, and management conflicts. Beside all of this, policymakers and legislators might find themselves lacking clear tools, aggregated data, or understandable cost-benefit analyses, to make significant strides and take decisions.

This could be explained because there are not always effective channels or official ways of communication between science and public policy. Therefore, more dissemination would be essential.

It is important to remember that public policies often favour previously established policies usually due to institutional inertia, lobbying, or concerns about food security. Promoting a structural shift towards BBFs can be seen as a political risky decision so it might be managed with scientific data and consensus.

Finally, it can be stated that it might be a lack of visibility of the strategic role of BBFs. Although they fit with the objectives of the main European strategies for sustainability (such as Green Deal Farm to Fork, European Soil Health Act, etc.), BBFs are not yet positioned as a key tool in the European policies. For the moment, BBFs continue to be seen in political bodies as a marginal or experimental solution, rather than as a structural part of the future agri-food model. Therefore, it's important to perceive them as the seeds of a paradigm shift.



5. FARMERS AND FINAL USERS

Farmers are the final decision makers on whether or not to apply a fertiliser products on their farms, and what products it would be. Their perception, confidence, and experience with fertilisers will determine if BBFs are going to be integrated into routine agronomic management or relegated to "marginal options." However, despite their key role, they are not always recognised as such, and are given a secondary role [11, 34].

Many farmers might be still mostly unaware of BBFs performance in the field, optimal dosage, and compatibility with crops or machinery. The studies consulted suggest that doubts remain regarding their top priorities: whether crops will maintain the same productivity, and the associated costs. In this regard, it is estimated that in many cases they have not received information on field yield results or usage systems. Furthermore, potential exchange platforms are not yet widely known. Thus, there is still insufficient dissemination about BBFs and their potential.

Also, the composition and the application methods among different BBFs creates uncertainty. Furthermore, as many BBFs come from waste water or agroindustrial wastes there is a concern about safety issues, health and odor.

Many potentially interested farmers may lack access to advisors trained in fertilisation practices or yields related to BBFs; this could be an example of the disconnection between research and field work [28, 34].

New approaches, such as regenerative agriculture, may offer a new point of view, where improved soil health, biodiversity, and agronomic resilience are important objectives, beside high productivity.

Access to training, apps and advisors on BBFs can make a difference for BBFs development. With the leadership of pioneering farmers, circular value chains may become a reality, and that will be explored in the following Recommendations section.

SYNTHETIC FERTILISER MANUFACTURERS

Synthetic fertiliser manufacturers should be viewed as potential crucial collaborators who can bring significant value to the BBFs implementation. They already have the means to produce standardised and certified fertilisers, and, in the end, it is simply a matter of replacing a chemical compound from a fossil source with a renewable one. This would be the case, for example, of struvite or ammonium sulfate, both pure BBFs chemical compounds (without organic components) that can adapt to established manufacturing processes. Replacing nutrients from non-renewable sources with sustainable ones can pave the way to greater sustainability for this sector.

However, they also face major barriers that should be considered, such as a clear political structure, a consistent and sufficient supply of nutrients with known concentrations, or concerns about consumer perception about the final products.

Objectives of the WaINUT Project

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Expected impacts of the WaINUT Project

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All these challenges can be addressed with determination and a scientific basis.

Although BBFs appear as a promising alternative to minimise external dependence on synthetic fertilisers and their environmental issues, their development is still conditioned. Many EU research projects have addressed this reality, and among them the **WalNUT Project** emerge to respond to the BBFs challenges.

The WalNUT Project is focused on the potential of waste streams as source of nutrients, to mitigate the soil nutrient imbalance and to increase the fertilisation efficiency. **The WalNUT Project aim** is to close the waste water cycles for nutrient recovery, **to redesign the value and supply chain of nutrients from different waste and waste streams, creating new solutions for nutrient obtention and contributing to the bio-circular economy and sustainability in the European agricultural sector.**

The WalNUT Project also set various sub-objectives and highly specific goals:

- Establish a definition of BBFs, and clarify their benefits, detailing their components, mechanisms of action and environmental advantages over the synthetic options.
- Bring the concept of BBFs and how they are obtained closer to end users so they can make informed decisions when choosing them over less sustainable synthetic alternatives.
- Promote R&D in BBFs so that, through innovation, safe and effective products adapted to user needs are generated.
- Analyse the main barriers (legal, commercial, etc.) of the BBFs and to propose recommendations for their acceptance, not only on the market but also by the end users.
- Develop five case studies to show the agricultural yields and the potential impacts, and to ensure profitable agricultural practices that protect the environment and improve soil quality.



In order to support a strong and resilient agri-food industry, WalNUT's goal is in line with the EU Green Deal agenda as well as the EIP's focus on agrifood and raw materials. WalNUT's contribution in this respect has been:

- The proposal of twelve technologies that have been verified as five novel solutions evaluated at the appropriate scale to provide a new generation of safe, sustainable, and commercial fertilisers based on by-products.
- The reduction of EU external dependency and depletion concerns by substituting traditional, non-renewable synthetic fertilisers with renewable nutrients, particularly P.
- The increase in resource efficiency by balancing nutrient concentrations within or between regions.
- The minimisation of the environmental effects associated with GHGs emissions, the manufacture of synthetic fossil fuel-based fertilisers, and the dispersion of nutrients found in waste flows.

- The presentation of new business models that will work with other economic sectors, developing wealth and good jobs in rural areas.
- The outline of a coherent policy framework for the sustainable production and use of BBFs.

For several years, the project has brought together experts in technology, legislation, agronomy, the circular economy, and social perception from across the EU, to identify barriers, demonstrate solutions, and propose a realistic and applicable framework for action.

Through five pre-industrial-scale pilot plants, WalNUT has implemented advanced technologies to recover N, P and other nutrients, generating BBFs that have been analysed, tested, and validated under real-world field conditions. The plants are located in different European countries, and they operate with different waste waters flows, to recover valuable nutrients. They will be presented in the next chapters.



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The **WalNUT Project** has opted for an **integrated approach**; from the research, analysis, and social investigation carried out in the project, valuable information has been generated and its highlights are the following:

- A nutrient flow analysis and a nutrient transfer model.
- A nutrient imbalance analysis.
- An analysis of the main gaps and barriers for BBFs development.
- An official harmonised protocol for the characterisation of waste streams.
- Inventory and integrated assessment of the EU regulations related to production and application of BBFs.
- Study of the twelve novel technologies for BBFs production; design, construction, installation and operation of the five pilot plants.
- Farmer BBFs application manual.
- Performance of BBFs in pot trials and field trials.
- Business plans for WalNUT's technologies and products.
- Life cycle assessment of these novel technologies, to compare the potential environmental impacts with the usual fertilisation practices.

This White Paper compiles the knowledge generated in all the project's steps, and translates the results into:

- **Structured Recommendations**, with the aim of transferring the potential of BBFs into real-world policy and agricultural practice.
- **List of Opportunities** for policymakers, potential BBFs producers and final users, to create the conditions for BBFs implementation and use.

In the following pages, the *Recommendations* section aims to solve the listed problems and it will be presented with a specific structure:

- a) presentation of the problem to be addressed;
- b) description of the key recommendation;
- c) explanation of how the recommendation could be implemented;
- d) main stakeholders involved;
- e) proposed success indicator.

After the *Recommendations*, different *Opportunities* are presented for each of the stakeholders in the BBFs value chain, along with the most important advantages that these possibilities can offer when investing in BBFs.

The recommendations were validated through expert interviews and a partner workshop. Seven BBFs specialists provided insights on regulation, technical challenges, market readiness, and social acceptance.

A Delphi-inspired focus group with project partners reviewed and refined the recommendations, ensuring a multidisciplinary perspective on legal, economic, and social issues.

Recommendations

1. OFFICIAL DEFINITION OF BBFs

As it has been pointed out, at this time, **there is no single, recognised and legal definition at the European Union level for BBFs.**

This creates several issues, where it is possible to highlight, among others: legislative confusion, uncertainty for manufacturers regarding the classification of their products and obstacles to their marketing.

Although Regulation (EU) 2019/1009 legislates about the EU fertilisers, it does not include a specific definition of BBFs, which prevents the creation of clear and coherent norms to promote their use.

The [key recommendation](#) would be to formulate and include a consensus-based definition of BBFs in Regulation (EU) 2019/1009, building on the previous work carried out by EU Projects.

The recommended definition for BBFs in this White Paper is the consensus-based technical definition presented by the WaINUT Project, and as it has been previously shown (in page 6), it proposes the use of nutrient-recovery and re-use (NRR) technologies (physical, thermal, chemical, and/or biological, excluding anaerobic digestion and composting) to get nutrients from biomass that has already been treated. This would help to make the waste more nutrient-efficient.

To reach an official definition, it is recommended to convene a formal inter-project group with representatives from WaINUT, FERTIMANURE, LEX4BIO, Sea2Land and Rustica projects, and also the European Sustainable Phosphorus Platform (ESPP) plus standardisation bodies, to agree on a technical and operational definition by the end of 2027 at the latest. Then, draft a joint proposal to be submitted to the European Commission's Directorate General for Internal Market, Industry, Entrepreneurship and SMEs (DG GROW), requesting its inclusion as an official definition in Regulation (EU) 2019/1009 (particularly in Article 3 and Annex I). Subsequently, submit the proposal for public consultation, along with other technical changes to the FPR, and establish clear timelines (synthesis and publication of the review in 2026 - 2027), with the aim of having the definition enter into force by 2027.

Key actors would be:

- For **TECHNICAL CONSENSUS AND PROPOSAL: H2020 EU sister Projects** to WaINUT, which will provide technical knowledge and practical evidence. Also, technical platforms (such as ESPP) and fertiliser associations, participating in expert groups. These projects have already generated operational technical definitions of BBFs, based on (i) nutrient content, (ii) degree of transformation and concentration; (iii) the exclusion of materials (such as raw compost).

Furthermore, the ESPP may act as a neutral platform for dialogue between science, industry, and government.

- **For ACCEPTANCE AND REGULATION:**

European Commission (DG GROW and DG AGRI). For its side, DG GROW (as Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs) is directly responsible for Regulation (EU) 2019/1009 on EC fertiliser products. It coordinates the technical expert groups that review the CMCs and other regulatory definitions. It has the legislative power to introduce a new definition of BBFs or expand the scope of the Regulation. On the other hand, the DG AGRI (Directorate-General for Agriculture and Rural Development) is key to align the definition with the CAP approaches. It can promote the recognition of BBFs as eligible inputs in agri-environment measures, eco-schemes, or payments for sustainable practices. Therefore, it would be expected they work to accept and integrate the technical definition of BBFs, facilitating its use.

- **For STANDARDISATION AND APPLICATION:** CEN / other European standardisation bodies. Firstly, the CEN (European Committee for Standardisation) as responsible for developing and publishing harmonised standards, would contribute with the validation of characterisation, quality, and traceability tests for BBFs, and also with the inclusion of new protocols for recovered materials in fertiliser standards.

It would be expected that standardisation bodies would likely produce a harmonised standard to accompany the legal definition of BBFs for manufacturers, certifiers etc., to be used as a reference.

- **For DISSEMINATION AND FIELD USE:**

Firstly, **MS**, whose national authorities must align with the definition to ensure uniform application. They are responsible for implementing Regulation 2019/1009 at the national level, overseeing: (i) the EU certification and labelling of fertiliser products.; (ii) consistency with other national regulations (waste, plant health, water, etc.). Then, they will validate and adopt the proposed definition ensuring a consistent and operational interpretation across all member countries. Secondly, **fertiliser manufacturers and associations** (such as Fertilisers Europe), that will use a clear legal definition to: (i) adapt their formulation processes; (ii) apply for EU certifications; (iii) position BBFs products with safety, quality, and marketing guarantees. It is expected that they may participate in the public consultation, support the agreed definition, and adjust their product lines to the new legal framework.

A **coordinated effort** may ensure that the definition of BBFs is technically sound, legally feasible.

The impact indicator might then be the definition included in the FPR before the end of 2027; with its effective implementation in all MS by the end of 2028.

2. EUROPEAN BBFs OBSERVATORY

The lack of a European repository with up-to-date and accessible information on the availability, composition, prices, agronomic characteristics, and quality of BBFs, hampers decision-making by authorities, investors, agricultural managers, and producers. This means market fragmentation, mistrust, and obstacles to the development of informed policies. According to multiple European projects, the lack of structured data is a barrier slowing the adoption of BBFs.

The key recommendation would be to establish an official *European BBFs Observatory*, to centralise and disseminate rigorous data on availability, quality, prices, certifications, use cases, and impact. This observatory would act as a **single source of reference for all stakeholders, enhancing the visibility, comparability, and transparency of the BBFs market.**

How can this be put into practice? Since the EC has already promoted similar initiatives for synthetic fertilisers, creating the EU Fertilisers Observatory and the Agri-Food Data Portal to monitor prices and availability, a dedicated module for BBFs can leverage this infrastructure with marginal implementation costs and generate immediate value for decision-makers (politicians, companies, farmers). Data centralisation facilitates informed policymaking, and the monitoring of the impact of the potential improvements.

The European BBFs Observatory may foster transparency and comparability among BBFs, help improve policy design and implementation to achieve the targets set for preventing nutrient losses and recovering them through valorisation.

It will strengthen collaboration between public and private actors.

The actors **involved** would be:

- **DG AGRI** and **DG ENV** (European Commission): responsible for the Data Portal and the EU Fertilisers Market Observatory, and for their integration into the CAP.
- **Horizon EU projects** (such as the mentioned WaINUT sister projects): as they will provide data and real-life cases.
- **BBFs producers and manufacturers**: will provide data on composition, price, and market status.
- **Agricultural advisors and cooperatives**: will use the database to guide decisions in the field.
- **Researchers and technology centres**: might provide analysis, validation, and advise for technical labelling.
- **Circular Bio-based Europe Joint Undertaking (CBE JU)**.

From all of these stakeholders involved, the EC (through the DG AGRI) is the institutional actor with the greatest capacity to lead the creation of the European BBFs Observatory, specially integrating it into the mentioned existing structures.

The EC might coordinate the use of open data platforms for agriculture that already include synthetic fertilisers, so it can expand the structure without creating a new one from scratch.

The **main impediments** to this actor's involvement is the lack of an official definition of BBFs and the resulting legal basis. Furthermore, the fact that, although it has the technical capacity, the EC usually needs a formal request to prioritise the development of this module.

If these issues are addressed, the implementation of this Observatory may take around two years (for design of the BBFs specific module, technical integration, the structuring of key fields —composition, origin, CE status, price, etc.—, launching, and promotion, etc.), however, it is estimated that **its integration into existing platforms** (EU Farmbook, the EU Fertilisers Market Observatory or the Agri-Food Data Portal) **as starting points**, might leverage existing infrastructure and minimise costs, so this timeframe can be reduced by half for a first functional version.

This Observatory is expected to not only inform but also transform, by driving structural changes in the EU fertiliser model. In this regard, a new BBFs Platform is close to being built, to address the needs of different industries and involve several countries. This might **accelerate technical development, guarantee user-oriented formats, and facilitate the immediate incorporation of real data and sectoral contacts**, avoiding duplication and ensuring the continuity of the knowledge generated.

The BBFs Observatory should be designed and developed as a comprehensive digital center, not just a knowledge base, but also a hub for active data curation, integration, and usability. It would support continuous learning, innovation, and policy development.

In this respect, the transformative potential could be focused on taking concrete actions towards launching proposals and new initiatives related to the BBFs. Specifically, it can function as an advisory and knowledge-sharing hub. This is directly related to two other recommendations, such as *Enhance social acceptance and technical capacity for BBFs*, and *Creation of a collaborative BBFs Network*, which will be presented in the following pages.

All stakeholders could participate, not only to seek solutions and data, but also to share their experiences and explore potential collaborations.

Centralising data makes it easier to create well-informed policies, spot gaps in technology, and track how well recommendations (like incentive systems and quality improvements) are working.

An impact indicator could be the **set-up of the operational platform with a module for BBFs within the EU Fertilisers Observatory by 2028**, in line with the implementation of the official BBFs definition.

Another indicator could be **at least 70% of active producers registered on the database within the first two years of operation.**

3. ECONOMIC INCENTIVES FOR BBFs

Many sources found that BBFs costs are in **general higher than that of conventional synthetic fertilisers. However, a great variability has been found regarding potential production costs**, derived from the diversity of waste water flows, the geographical perspective, the scale and the legality involved. **This makes it necessary to conduct more precise techno-economic analyses (TEAs)**, at the European level, and also tailored to specific cases, **to avoid falling into simplistic statements and concluding that “BBFs are simply more expensive”**.

This might seem a difficult task, but as in the previous recommendations, it can be addressed with political will and a solid scientific basis.

Fertiliser purchases account for up to 12% of arable crop farmers' input expenditures, with an average of 6% [50]. However, these percentages may increase in the future if food security is threatened by an uncertain geopolitical context. **If the price of fertilisers is not offset, farmers will not use them, and the circular transition will not be viable.** Therefore, this might be one of the most important and urgent challenges to address: **“how to close this cost gap to ensure the real adoption of BBFs?”**

The key recommendation can be summarised as: enhance of the establishment of subsidies, carbon credit schemes, and tax incentives, to promote BBFs obtention and use.

The design of a comprehensive package of economic incentives may include:

- 1) **Direct subsidies** per ton of BBF produced or applied, aligned with common mitigation and recycling goals.
- 2) **Tax credits or reductions** (VAT, corporate tax) for synthetic fertiliser manufacturers that incorporate a minimum of BBFs in their formulas.
- 3) **Carbon and nature credits**, linked to the European certification scheme (CRCF), recognising the positive impacts of BBFs use on emissions and biodiversity.
- 4) **Priority in green public procurement (GPP)** for products that contain at least the recommended minimum of BBFs.

How can this be put into practice? Below some specific directions are presented:

a) Direct subsidies by:

- Enabling support lines within the new CAP (2027-2034) for BBF producers.
- Defining technical criteria (EU certification) that determine the funds.
- Establishing clear quantitative ratios: for example, €100 of economic support per ton of recovered P or N.

In this case the main actors involved would be the EC (DG AGRI, DG CLIMA), and national management agencies. A recommended timeframe would be two years after the official BBFs definition adoption.

b) Tax reductions by:

- Reducing or exempt VAT for fertilisers with ≥15% recycled nutrients.
- Applying corporate tax breaks to manufacturers that achieve ≥20% recycled formulation.

In this case the main actors involved would be the EC (DG TAXUD, DG AGRI), and national finance ministries. It could be desirable to implement these measures no later than one year after the approval of the BBFs definition.

c) Carbon credits by:

- Using the EU's Carbon Removals and Farming (CRCF) system to certify regenerative practices in the field, including BBFs.
- Enabling a special module for BBFs in voluntary schemes and incorporate it as a valid methodology. This will allow their use to generate additional income and facilitate their economic viability.

The key actors for this would be the EC (DG CLIMA, DG AGRI, the Joint Research Centre (JRC)), the European Environment Agency (EEA) and certification bodies. An estimated timeframe would be three years after the approval of the BBFs official definition, to elaborate the mechanisms, with a full integration by 2030.

d) Green Public Procurement (GPP):

- Establishing clauses in public tenders (parks, infrastructure, recreational areas, Erasmus+, etc.).
- Requiring a minimum of for example 20% BBFs in commercial fertilisers.

Main actors might be the EC (DG ENV) and public entities, and the deadline could be 2030. The **actors will be interconnected**, so fluid communication is recommended, apart from their specific tasks, such as:

- DG AGRI / DG CLIMA (EC) would design and implement subsidies, credits, etc.
- CAP and DG TAXUD and Finance Ministers may define tax incentives for the recovered nutrients.

- Certification bodies and JRC validation of CRCF may create methodologies for BBFs obtention and application
- Manufacturers of fertiliser would work for the integration and development of hybrid fertilisers.
- BBF potential producers could provide data to the database, and campaign to receive the subsidies.
- Farmers and cooperatives can use the BBFs in the field, being beneficiaries of carbon credits, and CAP subsidies.
- Public authorities and municipalities may implement the use of BBFs on public lands.

Initiatives of this type would not start from scratch. For example, in the publication “Ensuring the availability and affordability of fertilisers” [50], the authors **stated that the CAP would fund sustainable farming practices, such as “recycled fertilisers made from manure, processed, sewage sludge and biowaste”, or “nutrient management”**. Therefore, it can be inferred that the basis on which to build a policy of subsidies, investment and tax benefits already exists, and can serve as a starting point for developing future policies and strategies for the benefit of the BBFs. The recommended **impact indicators** could be:

- Tax reduction integration in the CAP subsidies plans by 2030.
- A 30% reduction cost in BBF in average, per kg of nutrient recovered (N, P or K) by 2030.
- An increase on credits generated, by the creation of at least 10 MtCO₂eq of credits linked to BBFs and circular agriculture by 2030.

4. ENSURING THE CIRCULARITY OF BBFs

Although BBFs are presented in many cases as circular alternatives to conventional synthetic fertilisers, **their current development model remains, in many cases, linear**: (i) nutrients are recovered from waste streams (ii), they are transformed into concentrated or isolated products, (iii) then transported long distances and even applied without contextualised agronomic control. This brings to mind the classic model where raw materials are extracted, transformed into products that are consumed or applied, resulting in waste. In this case, the only thing that would change is the source, which goes from being extractive to recovered. Recycling nutrients is important, but by itself it does not imply circularity. **Thus, without a true assessment and monitoring of circularity, BBFs can fall into repeating the patterns of the old linear system**, instead of following the principles of circularity and the closing of nutrient cycles. To ensure true circularity, it would be desirable for BBFs to comply with its principles throughout the entire value chain. To the best of our knowledge, there are no standardised indicators or regulatory requirements to demonstrate their functional, economic, or ecological circularity; and this is where this recommendation comes in.

The key recommendation would be to develop an standardised EU system for assessing and monitoring the circularity of BBFs, based on existing indicators and life cycle methodologies.

This will allow stakeholders to:

- Measure the complete traceability of the nutrients: from the source residue to its agronomic destination.
- Calculate the use efficiency (Nutrient Use Efficiency (NUE)) associated emissions (N_2O , NH_3), and soil improvement (soil organic matter, biodiversity).
- Integrate circularity indicators from different perspectives (technical, territorial, and/or economic).
- Assess the usefulness of a "verified circularity seal" to differentiate truly regenerative BBFs.

This recommendation is primarily focused on highlighting the value of circularity within waste valorisation and **to prevent greenwashing**. It is believed that this would be a key suggestion when it comes to promote a minimum content of recovered nutrients in fertiliser formulations, especially in public procurements. This would ensure greater transparency and contribute to the quality and trust in the value of BBFs.

How can this be put into practice?

- a) Using known frameworks such as the Life Cycle Assessment (LCA), or the Ellen MacArthur Foundation's Material Circularity Indicator (MCI).
- b) Using available digital tools to offer key data about BBFs processes, and obtain a circularity index. This can be performed online, on platforms already described, and integrated into the proposed BBFs Observatory. In this way, farmers can consult an indicator scale, which also might help producers to promote and achieve their environmental goals.

c) Considering the creation of a complementary label associated with the circularity indicator, which can be easily used in public procurement, assigning tax incentives, etc.

The **key actors** in this case could be:

- DG ENV / DG AGRI / DG RTD for the regulatory and methodological development.
- JRC for technical validation and calculation of LCA indicators.
- Circular economy and BBFs platforms, for dissemination, tool testing and indicator generation, by calculating circularity of the products.
- Farmers / cooperatives, for consultation and informed decision-making based on circularity.

The proposed **impact indicators** are:

- At least 70% of BBFs analysed according to circularity criteria by 2030.
- At least 50 products with a “*Circular Verified*” label by 2030.
- Inclusion of products with high circularity scores in tenders and subsidies before 2030.
- At least a 25% reduction in unnecessary transport and logistics emissions in certified BBFs by 2030.

This recommendation offers a **pioneering and transformative approach**, and aims to strengthen the environmental legitimacy of the EU sustainable fertilisation vision.

The objectives of the F2F strategy and the Green Deal [6, 8] are clear: a reduction in the nutrient losses that will lead to a reduction of use of fertilisers by 20% by 2030, all while ensuring agricultural productivity. To this end, it is possible to measure the NUE on crops, but it would be essential to ensure that the applied nutrients that remain in the soil for use are not lost.

In this regard, circularity indicators, which have already begun to be studied [51, 52] will allow to ensure that their use is in line with EU objectives. Furthermore, circularity indicators for BBFs could consider the entire value chain, and reveal the environmental advantages of BBFs: such as their capacity to replace fossil-based synthetic fertilisers, the GHGs emissions reduction, their capacity for waste valorisation or closing of nutrient cycles (soil mass balances).

This new recommendation proposes moving from narratives to figures, from principles to actions. Measuring the circularity of BBFs will allow all stakeholders to distinguish real solutions from empty rhetoric, and will give new strength to those that are truly regenerating the European agricultural system.



5. SUPPORT LONG-TERM AGRONOMIC VALIDATION

Although it has been stated that BBFs can improve soil fertility, nutrient efficiency and present similar productivities than synthetic fertilisers [10, 13], many BBFs trials have lasted less than two years, which does not allow for the assessment of cumulative effects on soil, yield, or emissions. Also, the trials (laboratory and field), may not reflect all the diversity of soils, climates, and agricultural practices found in the EU. Data often belong to specific projects, which prevents relevant comparisons and meta-analyses. With this, scientific results do not reach farmers or technicians in a practical, visual, and easily applicable form.

This lack of evidence reduces the confidence of farmers, institutions, and public purchasers and compromises their widespread incorporation into technical and financial support systems.

The key recommendation would be to establish a coordinated system for long-term, full-scale agronomic validation.

How could this be accomplished? The recommended initiatives are:

a) Funding multi-year trials, allocating specific resources under Horizon Europe and the CAP for projects with a minimum duration of 4–5 years.

b) Creating a European network of demonstration plots ("Living Labs") that analyse productivity, soil, water, and emissions using BBFs:

- over diverse agricultural environments (irrigated and dryland, loamy, calcareous, acidic, intensive, extensive soils, etc.);
- coordinating trials with common protocols (yield, soil health, water retention, N₂O/CO₂ emissions, organic matter content, etc.).

c) The inclusion of BBFs in major agricultural research programs (Horizon Europe, EJP SOIL, ERA-NET). For instance, promoting the incorporation of BBFs as a key aspect of sustainable agriculture research projects, and supporting more research projects about the implementation of BBFs (such as the transformation of many technologies from TRL 5 to TRL 9).

d) The creation of accessible repositories with open data, fact sheets, and real-life testimonials (as was previously proposed in the European BBFs Observatory).

These initiatives would scientifically validate the benefits of BBFs and establish a solid foundation for their institutional and commercial adoption.

The **main actors in this case** would be:

- EC (DG AGRI / DG RTD), to design of CAP and Horizon programmes financing lines.

- EJPs (EJP SOIL) and ERA-NETs for methodological coordination, call for Living Labs.
- Research technical institutes, and universities, for technical management of trials, soil analysis and results.
- Agricultural associations and cooperatives for plot selection, local participation, dissemination.
- Farmers and technicians, for the application of BBFs, data recording, advisory services, testimony, etc.
- Producing and certifying companies, to supply products, guarantee quality, participate in control, etc.

In this case, the **impact indicators** proposed are:

- At least two field trials in 25 MS, to last at least 5 years (preferably 10) from the moment the BBFs Observatory is created, or from 2030. This could be particularly interesting for those with a strong agricultural sector, such as France, Spain, etc.).
- An annual publication with comparative results, success stories, and practical recommendations, in the context of the a European BBFs Observatory so that the results are known as widely as possible.

- At least 50 training courses/webinars delivered through the CAP Network and training organisations, to promote the use of BBFs; also, at least 60% of agricultural technicians and advisors qualified for BBFs trainings.
- The inclusion of the BBFs in the fertilisation plans (through digital tools or other systems), in pilot areas after 3 years following the field trials implementation.

Experience in agricultural innovation demonstrates that local pilots and participatory research are the foundation for technology transfer and increased adoption in real-world practices. According to a FAO report on agroecological innovation, demonstration systems can transfer knowledge more quickly than purely scientific models [53]. Also, in the report about the costs and benefits of transitioning to a more sustainable agriculture in the EU, by the IEEP, more research has been requested in order to see the potential impacts during the transition [54]. A circular agricultural transition requires robust empirical tools, and this recommendation seeks to develop the ecosystem for testing, dissemination, and ongoing analysis.

By promoting this recommendation the BBFs implementation moves from hypotheses to practice, offering regionally diverse and replicable evidence with BBFs in full-scale crops. This might create a solid foundation of scientific authority, user trust, and political legitimacy. It is a real lever for circular BBFs to become a field decision, not just a promising theory.

6. ENHANCE SOCIAL ACCEPTANCE AND TECHNICAL CAPACITY FOR BBFs

Despite progress in regulatory and technical domains, the widespread adoption of BBFs remains hindered by a limited social acceptance and insufficient agronomic knowledge among farmers and technicians.

Surveys and interviews conducted within the WalNUT Project and related initiatives reveal a pervasive lack of awareness regarding BBFs: what they are, how they function, and their tangible benefits. This knowledge gap undermines trust and visibility, impeding the integration of BBFs into mainstream agricultural practices.

The key recommendation would be to develop a multi-tiered European programme to promote awareness, build technical capacity, and foster community engagement.

How can this be done? Key actions may include:

- a) Development of outreach materials, such as:
 - Multimedia content (videos, infographics, podcasts) based on Living Lab results.
 - Digital platforms and traditional media.
- b) Demonstration activities: such as demo-days and field visits facilitated by reference users (both from public or private sectors), and showcases of BBFs advantages and performances.

c) Integrated training programmes as modules about BBFs in the a agricultural advisory systems (e. g. CAP Network, national programs, etc).

d) Implementing and improving strategic communication campaigns in new BBFs projects (or similar initiatives on R&D), to improve the public image of circular fertilisers.

The objective would be to create an informed community committed to circular fertilisers, facilitating adoption through knowledge, experience, and trust. Each one of these elements can rely on different dissemination channels, both digital (MOOCs, apps, social networks, webinars, newsletters, etc.), and analogical (newspapers, magazines, specialised journals, etc.). These channels must be appropriate for their intended audience, taking into account the social and geographical context.

Some examples of the recommendation put into practice would be:

- Include BBFs training modules in the fertilisation trainings for CAP advisors and farmers, considering specifications of use in the digital Farm Sustainability Tool for nutrients (FaST) to help farmers to create customised nutrient management plans, while technical experts from the public or private sector, would act as soil health advisors.
- Certify training for technicians in the use and diagnosis of BBF potential. Use these training courses as eligibility criteria for accessing subsidies or tax incentives.

- Establish “peer learning” networks in agricultural cooperatives and networks.
- Organise information campaigns in the media, networks, even with the involvement of professional communication partners.
- Organise "BBFs Days" at agricultural fairs or industry conferences related to fertilisation and soil health and nutrition, including clear messaging and quantified data (performance, costs, carbon savings).

Another **key recommendations is to focus on end users as groups, not just as individuals**. This would determine the means with which to dynamically reach them, using media that are familiar to them in the areas they already frequent (for example, at cooperative or company meetings, at annual producer-member meetings, etc.). The proposals when promoting BBFs should be presented in their own terms and relatable. **BBFs can be shown as a sustainable viable alternative that complements the experience and knowledge of the veteran farmers, and serves an incentive for new users who will be the future of the sector.**

The **main actors** in this case might be:

At European level:

- EC (DG AGRI / CAP network coordinate training modules and fund workshops)
- European projects and EJP / ERA-NET networks Create and distribute technical and audiovisual material.

At national/regional/local level:

Agricultural training institutions, associations and cooperatives for reference users, etc.

The **impact indicators** proposed for this recommendation are:

- At least 60% of farmers surveyed in pilot regions should be familiar with BBFs two years from the initiative's launch.
- At least 10 certified training sessions for technicians per country annually, between up to 2030.
- At least 25 demonstration days per year across the EU by 2030.
- At least 70% of demonstration day attendees report increased trust and willingness to adopt BBFs.
- Monitoring the use of BBFs in pilot areas: at least 20% adoption within 3 years since the application of the BBFs pilot trials.

Co-creation with end-users and practical training are decisive [53, 54] and so, the approach that could be used for similar sustainable initiatives like BBFs acceptance, may be equally effective. Furthermore, **it is important to take into account the local identity, and to design the training modules according to it, instead of imposing external or foreign models.**

In other words, **it is highly recommended to foster honest and robust communication with the community, avoiding marketing.**

Expected results would include greater trust in BBFs thanks to greater user awareness, and more availability of technicians and advisors to offer fertilisation plans aimed at maintaining agricultural productivity.

7. CREATION OF A COLLABORATIVE BBFs NETWORK

One of the major barriers identified is neither technical or regulatory, but structural: **the value chain appears to be fragmented and disconnected**. This leads to siloed industries and unclear business models, where stakeholders (from technology developers and WWTPs, policymakers, researchers to the end users) operate in isolation, without a clear understanding of how things work or how synergies can be created.

In the worst case, stakeholders are **unaware of the potential of working together, resulting in missed opportunities for collaboration** and, at times, duplication of efforts. As knowledge sharing is enhanced by the proposed recommendations above, and the European BBF Observatory offers support from the digital realm by gathering all the necessary information and assistance, it is necessary to create a collaborative hub on the ground.

The key recommendation would be to develop a Collaborative BBFs Network, comprised of regional platforms and coordinated by a central digital infrastructure, with the aim of strengthening connections across the entire value chain, aligning interests, and creating a stable cooperation framework to foster innovation, scalability and trust.

How can this be implemented? The following measures can be highlighted:

a) Building **BBFs Regional Hubs** as centers to develop personal connections and offer digital tools, **driven by neutral entities** (such as research institutes, technology centres, regional agencies, or CAP platforms). These hubs may promote professional facilitators trained in cross-sectoral collaboration, for example with:

- Activities such as stakeholder mapping, common agendas, symbiosis agreements or shared logistics trials.
- An annual circular innovation forum.

b) Promoting **multi-stakeholder regional platforms** to facilitate dialogue, matchmaking, and joint ventures. This **could be integrated into the European BBF Observatory or another type of digital hub**. Here, mapping tools can be developed to visualise nutrient flows, stakeholder roles, synergies, identify gaps, etc. Also, the concepts already discussed will gain strength, as well as any new ones that may arise within: Interactive maps of actors (companies, projects, institutions), a matchmaking system between supply and demand, a repository of contract templates, legal guides and financial tools, a potential technical forum, and a living library with results from projects, studies, and events.

c) Working to promote fundraising, such as:

- Specific lines within Horizon or other EU Projects, between WWTPs, cooperatives, and manufacturers.
- Local BBFs-CAP alliances for testing novel BBFs as a progressive replacement for synthetic fertilisers.
- Innovation development programmes between universities and startups.

Collaboration would be based on the principles of R&D in the EU, and which are highlighted in the Green Deal [6], such as transparency, open access and mutual benefit, and equitable access to advances and results.

All of this can be overseen by actors already involved in the value chain, such as research institutes, or R&D foundations, **eliminating cost overruns and problems with the distribution of responsibilities**. Therefore, the **main actors would be placed in different stages of the value chain, and developing their fundamental parts** (Figure 6):

- Regional and local authorities: they could coordinate BBFs Regional Hubs in collaboration with the end users (cooperatives, associations, etc.), to help adapting circularity policies to territorial strategies. They are the driving force connecting producers, farmers, and innovation centers.
- Technology centres, universities, and innovation agencies, may act as facilitators of the network, organising training, and supporting companies in the validation and development of new products.
- Treatment plants, manufacturers, and agricultural cooperatives, may work to generate BBFs, validate them in the field, and share information on logistics, quality, and demand.
- Farmers and agricultural advisors (CAP Network, EIP-Agri), would represent the practical level of application, to test the functioning of the Collaboration Hubs, testing the products, evaluate agronomic results, and share experiences.

The European Coordination Committee (DG AGRI / DG ENV / JRC) could provide technical support and regulatory coherence, ensuring the connection between regional nodes and the European BBFs Observatory or an equivalent platform.

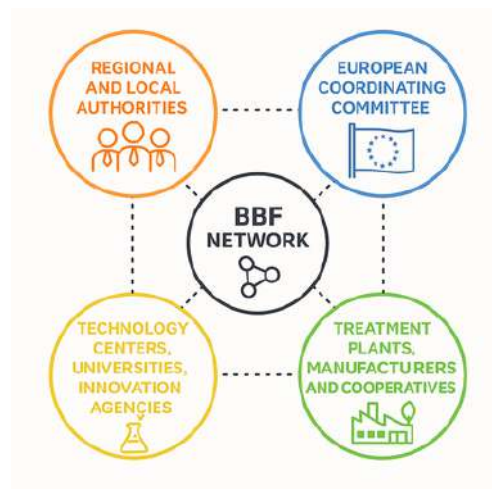


Figure 6: Collaborative BBFs Network conceptualisation.

The following impact indicators can be proposed:

- At least 10 active and coordinated regional Collaboration Hubs in the Network within two years from the recommendations launch.
- Cross-sector participation of at least 5 types of stakeholders (industry, agriculture, government, research, and civil society) per hub.
- At least 50 intersectoral collaboration agreements signed and operational by 2030.

A strong value chain acts as the backbone of any successful system. In the case of BBFs, its circularity might be linked to boosting the circularity of the key actors, so, this recommendation proposes a strategy opportunity to reshape EU's fertilisation model.

It can be concluded that **there is a strong synergy between all aspects involved in the implementation of the BBFs, and with it, a great synergy between the recommendations.**

An **official definition of BBFs** and their characteristics included in **all legal texts** will act as **basis to clear the concept of BBFs in all frameworks**. With this, the **creation of an official European BBFs Observatory** may accommodate the findings on the promoted field trials, feeding the online platform with validated data and real-life cases.

This will serve as **scientific basis** to endorse the benefits of BBFs and their advantages against the synthetic fossil-based fertilisers. The **European BBFs Observatory** will also help as a **channel for communication among the different stakeholders**, from researchers to policymakers, farmers and potential producers, nurturing the exchange of ideas between very different but interdependent sectors, and also enhancing industrial synergy.

This digital tool could be complemented by the **Collaboration BBFs Network** and the BBFs Regional Hubs, to disseminate and to enhance **the long-term studies** about BBFs performance. This will allow to generate various connections and knowledge, that would **strengthen the trust that farmers and consumers, accelerating the much needed economic impulse for BBFs.**

All these recommendations have been compiled thanks to the knowledge generated in European projects, in the WaNUT Project itself, and a large number of studies carried out over the years.

Furthermore, they are **based on the opinions of experts in the field, gathered through valuable interviews** that have allowed us to convey the perspectives of those most closely involved with the challenges of BBFs and their development. **Some examples of these important conversations can be seen on the following page.**



The quotations* that follow present insights shared by experts in the BBFs field, whose contributions have enriched and supported the contents of this document.



“There is the need of a circular economy approach engaging all the stakeholders in the value chain. There are barriers at each step of the chain which need to be dealt with in parallel and simultaneously with a holistic approach, not a compartmentalised approach. Consumers are not the main barrier but could be an important driver by favouring products grown with the right fertilisers.”

Interviewee: Caterina Batello.

Area of expertise: Member of the Board of Agroecology Europe.



“At the moment mineral fertilisers are easier to use. The price of BBFs is still too high, net of all the price fluctuations in the fertilisers market.”

Interviewee: EC officer from DG Agriculture and Rural Development.

Area of expertise: DG AGRI Unit F.2 - Research and Innovation.



“Creating a network between different actors that produce BBFs could be a solution to the issue of flexibility in the development of new BBFs. There is the need to adapt the production and operational process to enhance a transformation industry.”

Interviewee: Laura Mejias Torrent.

Area of expertise: Environmental Science and Technology, Circular economy, (University of Catalonia, Spain).



“Engaging farmers in BBFs projects is important, to spread trust to neighbour farmers, enlarging the involvement. Peer-to-peer knowledge exchange is useful and effective. Drivers [of BBFs use] include: peer learning and exchanges, pioneer farmers experimenting, small clusters forming out in several areas in the EU, innovation lighthouses”.

Interviewee: Expert in Environmental Sustainability Aspects.

*The semi-structured interviews were carried out between April and June 2025 following a pre-established interview protocol designed for the WaiNUT Project. They were conducted individually via online meetings and lasted approximately one hour.

Opportunities

WITH AN EU BBFs OBSERVATORY

The creation of an official European BBFs Observatory within the European Fertilisers Observatory, will help **all researchers have a common reference when analysing the state-of-the-art of nutrient recovery BBFs** and reviewing the literature and the latest advances in the field. Also, it would act as a **collaborative digital landscape that enhances knowledge transfer, bridging the gap between research, industry, and policy**. It may foster the creation of public-private partnerships, innovation contracts, and immediate references for buyers, producers, and technicians, foster the creation of new bussiness models.

In recent years, numerous European projects funded under H2020 and Horizon Europe (such as the WaINUT sister Projects, FERTIMANURE, SEA2LAND or LEX4BIO, among others), have generated a wealth of technical, regulatory, and agronomic knowledge on BBFs.

These projects have repeatedly reached similar conclusions: the lack of a BBF legal definition, the importance of creating economic incentives, and the urgency of improving social acceptance. However, **this repetition of diagnoses in successive projects points to a disconnection between knowledge and action [49]**. Also, it has been stated that there is a limited implementation of responsible research and innovation in H2020 initiatives, so it may result in inconsistency with existing goals or economic objectives [55].

Thus, the recommended European BBFs Observatory would **channel the observations and the research results**, to take measures to translate technical consensus into effective regulatory, commercial, and policy progress for a more sustainable agriculture. Also, it could **lead the way to coordinate the work already done**, which is essential for the EU to move towards a more circular, secure, and resilient fertiliser system.

All of this, aligned with the expected “Institutional changes towards responsible research and innovation” of all H2020 projects.



WITH ECONOMIC INCENTIVES

According to the consulted sources, an economic boost for BBFs implementation would represent an opportunity in two areas: it might help to revise the agricultural model, and in the other, it might improve the creation of new business models aligned with circular values.

In detail:

a) Revision of the agricultural model:

A report about the costs and benefits of the transition to a more sustainable agricultural model in EU [54], concluded that, given the experimental nature of adopting sustainable techniques, it is crucial to allow farmers to test them out without incurring losses due to production uncertainty. This is specially important for smaller farms, so, insurance plans or multi-year conversion assistance can help reduce the risk of the shift (from traditional exploitations to sustainable ones). For example, national public insurance funds could provide public revenue to assist farmers throughout their transition phase, funded by taxes on synthetic fertiliser and phytopharmaceutical industries.

In this context, the economic incentives recommended for BBFs would be aligned with a more sustainable agriculture for the EU, which will reduce the dependence on synthetic fossil-based fertilisers, buffer the effects of the upcoming extreme weather events, and ensure food safety.

b) New bussiness models/products:

Beyond their environmental and agronomic potential, the BBFs may involve a **new generation of business models rooted in cooperation, innovation, and shared value**. The creation of opportunities can go far beyond fertiliser production, as they can become the new models where agriculture, industry, and public services work in real applied circularity. For instance, WWTPs and agro-industries can be transformed from waste managers into resource producers, and farmers can become not just consumers but partners in nutrient recovery cycles by their optimised fertilisations plans and practices.

It is worth mentioning the well-known **industrial symbiosis**, where by-products from one process serve as inputs for another, reducing costs and emissions. Also, **logistical collaborations, such as shared storage, distribution networks, and co-branding strategies** would make BBFs more visible and accessible to new markets. The new field for **digital tools** can create value-added services (such as nutrient passports or carbon credit platforms), rewarding transparency and circular performance. **Start-ups** specialising in nutrient analytics or eco-certification may emerge, or cooperatives managing regional BBFs hubs, even **alliances between traditional fertiliser manufacturers and emerging circular technologies**. These new hybrid ventures embody the **shift from competition to collaboration, replacing the linear extract-and-discard mindset with a regenerative, partnership-based economy** [29].

WITH TRULY CIRCULAR BBFs

The recommendation for greater circularity in BBFs may represent an **opportunity to move from symbolic recycling to measurable regeneration**.

By assessing how nutrients flow (from their recovery to their effective reuse in soils), the EU can ensure that BBFs truly close the loop. This shift promotes territorial nutrient cycles, strengthens local value chains, and stimulates collaboration between municipalities, industries, and farmers. This approach also encourages the life cycle perspective, and opens the door to innovation in traceability and digital monitoring tools, transforming circularity from a concept into a verifiable, value-driven reality.

WITH THE LONG-TERM AGRONOMIC VALIDATION

In this case, the field validation of BBFs in long-term trials might generate a collective empirical knowledge base.

This will make it easier to seek and found agreements and collaborations among farmers, scientists, and producers, increasing the sector's competitiveness.

It enables the rapid integration of study results and their translation into real day-to-day improvements. For example, by expanding databases that will serve as the basis for agricultural **digitalisation tools** (fertiliser management apps (Sativum app, predictive services, etc.) for general advice.

WITH TRAINING AND AWARENESS

This can promote the creation of new professional profiles, such as “soil nutrition advisors” (in Spain, already recognised in RD 1051/2022, [56]).

At the European level, it could be an opportunity to create or recognise similar roles will be created in all MS. These roles might facilitate communication among stakeholders, and especially with end users.

Greater educational content can be shared with higher education institutions, which would help increase circularity values.

FINALLY...

Each recommendation proposed addresses a gap and/or barrier for BBFs, but also offers a broader view about the related opportunities that might appear with their implementation. That would turn a promise of circularity into an agricultural reality, with measurable economic, environmental, and social effects.

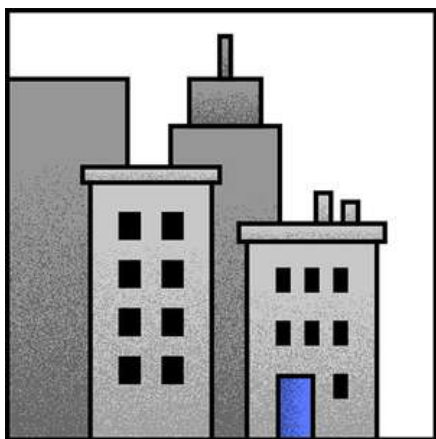
The offered approach is not just about “problem-solving”, but about a strategic moment to transform the European fertility model, to empower the EU independence, revitalise the rural areas and build knowledge networks with real human, economic, and political value.

How is the WalNUT Project contributing to these opportunities? The WalNUT Project's **case studies** are presented below in the summary charts. They show details of the pilot plant technologies developed and how they compare to the basic nutrient recovery technologies presented earlier. Other information can be found on the website and in the project's factsheets

While conventional systems such as air stripping, struvite precipitation, or biochar production have demonstrated technical maturity, the **WalNUT technologies showcase their evolution through integration, hybridisation, and adaptation to specific waste streams**. This section highlights how advanced nutrient recovery can move from single-process solutions to multifunctional, circular systems ready for real-world application.

These explanatory summaries also complement the technical information already detailed in other WalNUT deliverables, where each pilot plant is described in depth. To avoid unnecessary repetition, this section focuses instead on the comparative perspective, highlighting the distinctive characteristics and innovative value of each pilot plant technology within the broader nutrient recovery landscape.

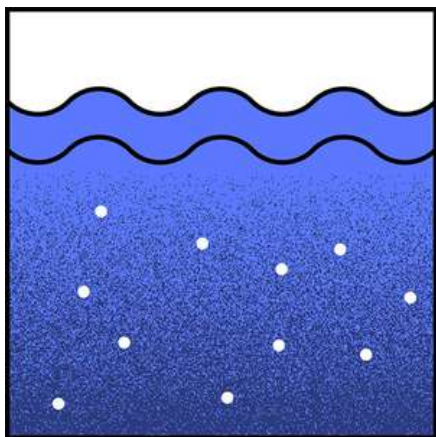
BELGIUM – URBAN WASTE WATER – HRAS & ION EXCHANGE SYSTEM



This pilot combines high-rate activated sludge (HRAS) with adsorption and ion-exchange to recover nutrients from municipal waste water. Compared for example to conventional biological treatment, it may enhance nutrient selectivity and minimizes energy use.

The system achieves faster biomass turnover and higher N and P recovery. This technology may lead to better effluent quality and lower operational costs. Its integration in urban WWTPs represents a practical step toward circular, low-emission water management in densely populated areas.

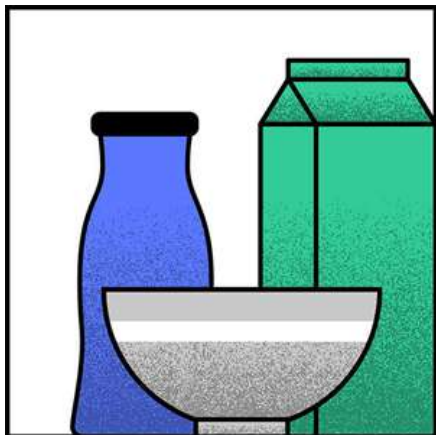
GREECE – DESALINATION BRINE – CHEMICAL PRECIPITATION, NF & MED



This pilot targets nutrient and salt recovery from seawater desalination brine using chemical precipitation, nanofiltration (NF) multiple-effect distillation (MED), and selective crystallisation. Unlike base processes such as struvite precipitation, it handles high-salinity matrices, turning a waste stream into valuable resources.

Anticipated improvements include reduced brine discharge and generation of reusable minerals. The combination of membrane and thermal methods positions this pilot as a breakthrough in valorising saline effluents under Mediterranean conditions.

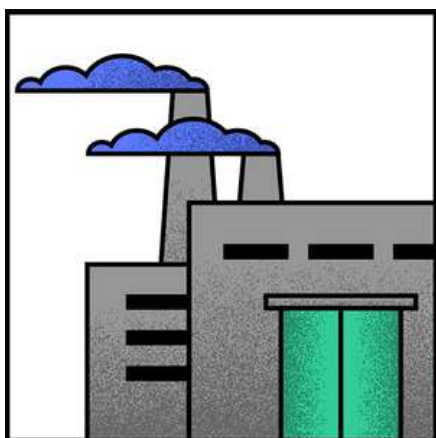
HUNGARY – DAIRY INDUSTRY – PYROLYSIS & FERMENTATION PLATFORM



In this pilot, high-temperature pyrolysis is applied to obtain animal bone biochar, which is biotech formulated and compost integrated to get BIO-NPK-C, a compound BBF, and a commercial product.

Compared with plant-based biochar for composting, it may offer higher nutrient retention and pathogen elimination. The expected advances include multifunctional products acting as soil improvers and biostimulants. This integration of thermal and biotechnological processes showcases a circular model for nutrient recovery in the agri-food sector.

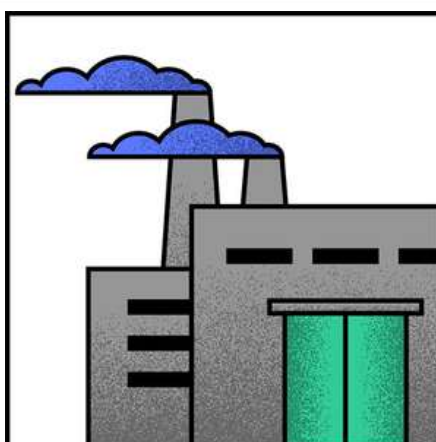
SPAIN – INDUSTRIAL WASTE WATER – HYBRID MICROALGAL SYSTEM



This system couples photoautotrophic and heterotrophic microalgae cultivation to recover N and P from industrial effluents. Compared with traditional photobioreactors, it might achieve higher productivity and resilience under variable conditions.

Anticipated benefits include stable nutrient removal, valuable algal biomass for fertiliser production, and CO₂ mitigation. The approach represents a new generation of biological treatment, aligning nutrient recovery with carbon capture and industrial symbiosis.

SPAIN – INDUSTRIAL SLUDGE REJECT WATER – FILTRATION, ION EXCHANGE & HFMC



This pilot integrates filtration, ion-exchange, and hollow fibre membrane contactors (HFMC) to treat nutrient-rich reject water from sludge dewatering.

Compared with single-step air stripping or ion exchange, it might enhance ammonia recovery efficiency and product purity.

Expected improvements include compact modularity and energy savings. The system demonstrates how coupling advanced separation processes can yield high-quality ammonium salts and close nutrient loops within waste water treatment facilities.

This section aims to make the key ideas of this White Paper easier to navigate. It gathers the most common questions about BBFs, and each answer offers an overview and points toward the sections where the topic is explored in depth.

1. What are bio-based fertilisers (BBFs)?

At the moment, there is no official definition, but BBFs can be considered fertilisers derived from waste streams and/or biomass, which are treated to extract valuable nutrients such as N and/or P, among others, using concentration and recovery techniques.

2. How do BBFs differ from conventional synthetic fertilisers?

Unlike synthetic fertilisers, BBFs come from waste (which can be considered a renewable source) that can be valorised to close nutrient loops and reduce dependence on imported raw materials.

3. Are BBFs already used in European agriculture?

Yes, though their use is still limited. Several EU-funded projects, including WalNUT, are testing their large-scale application and assessing their agronomic performance.

4. What is the main barrier for BBFs adoption?

There are significant barriers, such as a lack of economic incentives or awareness among potential users; however, the main obstacle is regulatory uncertainty. New EU policies, such as Regulation (EU) 2019/1009, are helping bridge the gap.

5. What environmental benefits do BBFs offer?

They reduce reliance on fossil-based synthetic fertilisers and minimise nutrient losses, while improving soil quality.

6. What are the main nutrient recovery techniques?

They range from solid/liquid separation to cutting-edge methods such as air stripping, struvite precipitation, ion exchange, biochar production, and phototrophic algae cultivation.

7. What is the TRL (Technology Readiness Level) of novel BBF technologies?

Most range between TRL 6 and 9, meaning they are already demonstrated or close to commercial deployment.

8. How does the WalNUT Project contribute to this field?

WalNUT pilots integrated advanced technologies for nutrient recovery across diverse waste streams, testing innovative approaches that enhance efficiency and scalability.

9. Are there economic opportunities linked to BBFs?

Yes, BBFs can open new markets for circular bio-based products, create new business models, foster local value chains, and reduce production costs for farmers over time.

10. Where can I find more technical information?

Complementary details and pilot data are available in [WalNUT deliverables](#), and on the project website: www.walnuthproject.eu.

A way forward...

This White Paper has stayed true to the essence of the WalNUT Project objectives to offer a space to identify challenges, connect evidence, and translate knowledge into practical, actionable insights.

It was developed in scientific rigor and collective experience, and aims to bridge the gap between innovation and implementation, and between research findings and real policies, that can shape a more sustainable agricultural future.

Rather than continuing the BBFs discussion these pages seek to offer a way to work for solutions. The content offers a common ground for decision-makers, scientists, and practitioners to meet, question, and act; to reflect not only individually but collectively, and how putting knowledge into practice begins by walking the path and asking all interested parties to accompany it. The work presented here is not a definitive answer, but a compass pointing toward systems where circularity, soil health, and efficient resource use are no longer ambitions but realities.

... and a call to action:

Therefore, now is the moment to move beyond acknowledgement and into transformation.

The science is ready, the tools exist, and the urgency is undeniable. Each recommendation in these pages is an invitation to design policies that reward circular thinking, to fund pilot projects that prove feasibility, to cultivate trust between institutions and innovators.

This could be the turning point where regulation keeps pace with aspirations, and where the EU leads to turn waste into worth and potential into action.

**THE CIRCULAR FUTURE WILL NOT WAIT:
IT BEGINS WITH EVERY DECISION MADE TODAY.**



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