European Commission

SCIENCE FOR POLICY BRIEF

The next-generation of sustainable fertilisers: a win-win solution

HIGHLIGHTS

→ Fertiliser prices are soaring due to surging input costs and supply disruptions as Russia and Belarus are major suppliers of fertilisers

→ Fertilisers derived from nutrient-rich waste streams can replace expensive chemical fertilisers and improve security of supply

→ Next-generation fertilisers have a lower energy intensity, create less greenhouse gases and reduce eutrophication of surface waters

SUBSTITUTION OF MINERAL FERTILISERS

Why are alternatives needed?

Nutrients are essential for crop productivity and food production. The three most important macronutrients are nitrogen (N), phosphorus (P) and potassium (K), that currently mostly come in the form of chemical fertilisers. However, the **production of chemical, inorganic fertilisers is energy-intensive**. The production of synthetic nitrogen fertiliser alone consumes about 1% of world's energy [1]. The second main nutrient in fertilisers – phosphorus – is based on a finite mineral supply of phosphate, the majority of which is located in only a handful of countries, whose resources may be depleted within 50-400 years [2]. In 2020, phosphorus was included in the EU's critical raw material list, which is currently being revised.

Russia is the biggest exporter of fertilisers to the EU (nearly 13% of total consumption), followed by Belarus (4% of total consumption) [3]. In 2020, EU imports of potash peaked, and more than half was sourced from Russia and Belarus [4]. Due to the current geopolitical and economic situation, fertiliser prices have risen nearly 30% since the start of 2022, following an 80% surge last year [5]. **Supply of all three main nutrients (NPK) has been affected by surging input costs [3], disruptions caused by the war in Ukraine and export restrictions in China** [5].

From a resource use perspective, chemical fertilisers are extremely inefficient: only 15-20% of industrial converted nitrogen reaches consumption [6] and less than 5% of human-derived phosphorus ends up in the food system [7]. Over the past century, **human activities have increased the surplus of nitrogen in soils** from 20 to 138 Tg/a and **the surplus of phosphorus** from 0 to 12 Tg/a [8]. This causes nutrient runoffs, which lead to **eutrophication and more than 400 reported dead zones in water systems around the globe since the 1960s** [9]. The environmental cost of all nutrient pollution in Europe is estimated to be EUR 70-320 billion per year [10].

Therefore, in addition to diversification and alternative import sources, **next-generation fertilisers can play a crucial role not only in filling the supply gap, but also in improving circularity, sustainability and regional economies**.

The benefits of next-generation sustainable fertilisers

Recycling and the recovery of nutrients from food waste, the animal food chain, sewage and other bio-products rich in nutrients, can replace expensive chemical fertilisers and improve security of supply. The European Commission has set a goal of 30% reduction of non-renewable resources in fertiliser production [11]. The **new EU regulation on fertilisers** opens the Single Market for organic fertilisers as of 2022. **This will boost further development and use of organic and waste-based fertilisers**.

The potential of recovery from waste streams in the EU alone represents about 18-46% of the nitrogen currently applied to EU crops and 43% of the mineral-based phosphorus applied to crops [12]. **Closing the loop improves circularity and mitigates losses to the environment**, thus enabling reduction of eutrophication of surface waters.

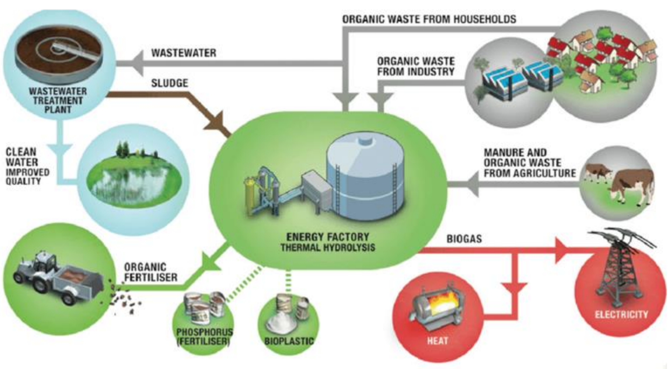
Organic fertilisers have smaller carbon footprints, reducing greenhouse gas emissions by an average 78% for nitrogen and 41% for phosphorus [13]. An EU project, B-Frest, developing advanced bio-based fertilisers, also claims to cut energy and water consumption, while achieving a 10% improvement in crop yield, thanks to bio-stimulants with microbial and non-microbial additives in their innovative fertilisers [14].

The potential for EU industry and regional economies

There are various promising recovery technologies and novel fertiliser products being developed. **Horizon 2020-funded project NUTRIMAN created an overview of more than 100 innovative market-ready solutions across Europe**. The technologies that are already readily available to recover fertilisers and energy from waste streams include: (1) anaerobic digestion of wet matter with the added advantage of producing biogas; (2) aerobic composting of dewatered matter, which allows for the mineralisation of nitrogen, phosphorus and also carbon, which improves the bioavailability of the resulting fertiliser; (3) pyrolysis of dried matter designed to retain carbon in the form of biochar which also retains phosphorus content; and (4) incineration of dried matter to produce ash for the extraction of phosphorus (though nitrogen and carbon are lost to the atmosphere) [15].

Manure is the single largest waste flow of nutrients and is already an established circular economy example. However, there are still significant opportunities to reduce process losses and gas emissions, through better treatment and recovery technologies. In addition to nutrients, **solid fraction of manure can be valorised into biogas, syngas, bio-oil, bio-hydrogen, methanol, and hydrochar depending on the chosen technology** [16]. Biomethane plays an important role in fuel diversification and the reduction of natural gas imports from Russia. REPowerEU aims to boost the production of biomethane to 35 bcm by 2030 [17]. **Manure-based biorefineries coupling nutrient and energy recovery offer economic benefits to farmers and the diversification of their income sources**. Figure 1 shows one example of conventional wastewater treatment plant remodelled into biorefinery, which is able to carry out several mutually beneficial processes indicated and produce in result both energy and fertilisers.

Figure 1. The biorefinery concept in Billund, Denmark.



Source: Nielsen, P.A. 2017. Microbial biotechnology and circular economy in wastewater treatment. Microbial Biotechnology 10(5).

Sewage is another important source of nutrients. There is still room for improvement in the recovery of nitrogen, with ammonia stripping, for example. Encouraging anaerobic digestion can also generate biogas. Higher recovery rates for phosphorus (70-90%) can be obtained from sewage sludge ash mono-incineration. However, **further investment is needed in technical improvement** [12].

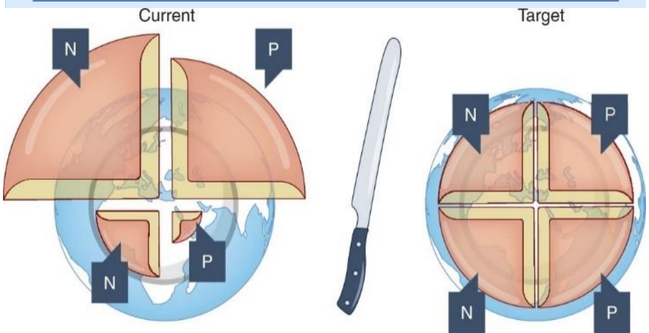
Municipal and food chain waste offer another important source for nutrients. The EU creates approximately 173 kg of food waste per person per year [18]. **As much as a quarter of all fertiliser use in Europe is lost through food waste** [19]. The challenge here is the separation and collection of the fraction of waste which is organic. Technically, the recovery of phosphorus is not difficult. Nevertheless, the main priority here is to prevent the incidence of waste in the first place.

In June 2022, the Commission launched a public consultation on the Integrated Nutrient Management Action Plan, which aims to tackle nutrient losses by 50% by 2030 and stimulate markets for recovered nutrients [10].

Box 1: The North-South dimension

Global **resource use is disproportionate**, exemplified in Figure 2. Just 10% of the world's croplands account for 32% of the global nitrogen surplus and 40% of the phosphorus surplus, **Western Europe being one of the nutrient hotspots** [20 and 21]. At the same time, depletion of soil quality, land degradation and low supply and availability of fertilisers pose major challenges to food security in developing countries, especially in sub-Saharan Africa. Africa accounts for only 3% of the world's fertiliser consumption [22]. One innovative proposal is to facilitate redistribution of accumulated nutrients in Europe through the reversal of logistics used to ship rock phosphate from Africa to Europe [23].

Figure 2. Unequal distribution of nutrients globally



Redistribution of nutrients accumulated in the Global North would counteract the transgression of the planetary boundaries while improving food security in the Global South.

Source: Kahiluoto, et al, 2021. Global nutrient equity for people and the planet. Nature Food, 2 (857-861).

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DISCLAIMER

This is based on preliminary assessment made in the context of the European Climate Neutral Industry Competitiveness Scoreboad (CIndECS), a project between JRC and DG GROW.

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