European Sustainable Phosphorus Platform

SCOPE NEWSLETTER

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ESPP workshops on phosphorus as a Critical Raw Material and on White Phosphorus (P_4)

This newsletter summarises the two ESPP workshops on Phosphate Rock and on White Phosphorus (P_4),as Critical Raw Materials, Brussels and online, 19th-20th November 2025, during the EU Raw Materials Week (18th-20th November 2025).

The ESPP workshops examined the increasing criticality of phosphates and P_4 for the EU, from agricultural uses to strategic industrial applications, gathering around 100 participants in Brussels and over 200 online, including industry experts, stakeholders, researchers and policy makers.

The first workshop focused on phosphates as a central agricultural input, listed as a Critical Raw Material ("Phosphate Rock") under the EU Critical Raw Materials Act (2024/1252), examining quantitative needs, supply security, nutrient use efficiency and recycling, and the implications for EU agricultural sovereignty and the future Common Agricultural Policy 2028–2034.

The second workshop explored white phosphorus (P_4), also listed as a Critical Raw Material (as "Phosphorus") but not as a Strategic Raw Material, despite its essential role in the "Strategic" sectors: fire safety, batteries, semiconductors, renewable energy technologies, defence and aerospace. Discussions highlighted the EU's strong dependency on a very limited number of global suppliers of P_4 and raised questions about whether current EU policy frameworks sufficiently reflect its strategic importance.

Phosphate Rock - an EU Critical Raw Material, key to food security and agriculture resilience

Robert van Spingelen, ESPP, opened the meeting by framing the discussion around the criticality of nutrients in agricultural inputs, food production and agricultural sovereignty. He highlighted the links between farm nutrient use efficiency, nutrient recycling and nutrient supply security, stressing **the importance of closing nutrient loops to reduce dependency on external inputs and strengthen the resilience of the agri-food system**.

Nutrient supply, use and losses in the EU

Allan Pickett, Fertecon – S&P Global Energy, highlighted the complexity of the phosphorus value chain and Europe's structural dependence on imports. Phosphate rock is mainly processed via wet processes into phosphoric acid for production of fertilisers, animal feed and industrial uses. Maybe 1% of phosphate rock is processed via the thermal route producing elemental phosphorus (P_4) and so its derivatives. While thermal phosphoric acid was once dominant for industrial uses, it has largely been replaced by wet-process routes followed by acid purification.

Around 78% of the phosphate rock mined annually is used in fertilisers, which underpin global food production. Animal feed phosphates account for about 11%, with another 11% used in industrial and phosphorus-dependent chemicals. Europe does have some identified phosphate rock resources, including one active mine in Finland and a total of around 18 projects, but most are unlikely to become commercial due to low grade rock or small scale, raising the question of how much consumers are willing to pay for supply security.

Despite limited mining, Europe has a significant phosphate processing industry, with around 73 production sites, just over half focused on fertilisers and around 15 producing animal feed phosphates, giving Europe a substantial economic and industrial stake in secure raw material supply. However, globally Europe remains a small player in phosphate rock production, which is dominated by Asia, the Americas and Eurasia. Today, most phosphate rock and fertilisers used in Europe are imported from Africa, especially Morocco, with additional supplies from countries such as South Africa, Egypt, Algeria and Tunisia.

Since the war in Ukraine, Russia has largely stopped supplying phosphate rock to Europe, but Rus**sia remains today a major supplier of phosphate fertilisers to the EU**. The EU response included new tariffs on Russian phosphate and nitrogen imports, starting in July 2025 and increasing progressively. While limited trade could theoretically continue until 2027, tariffs from 2028 onwards would effectively end imports. Even recently, around 40% of EU phosphate fertiliser imports came from Russia, underlining the scale of the challenge. Options for Europe in the future are:

- continuing to rely on imports, that will remain necessary but come with growing geopolitical risks,
- investing in European resources despite moderate rock quality,
- expanding recovered phosphorus streams, especially from sewage sludge ash, which represents a significant long-term opportunity, though progress depends on regulatory, economic and social acceptance factors,
- investing outside the EU, particularly in regions such as the Middle East and North Africa, which may offer shorter-term solutions.

Kimo van Dijk, Wageningen University & Research (The Netherlands), explained that **around 90% of phosphate mined is used in the food chain** (fertilisers, animal feed, food additives), with the remaining 10% for non-food applications. Using the reserves-to-production (R/P) ratio, the world's currently exploitable phosphate rock reserves correspond to at least c. 150 years, increasing to over 1 000 years when considering the broader resource base ('resources' are known deposits whereas 'reserves' are those considered today technico-economically exploitable).

Presenting EU phosphorus flow data (based on van Dijk et al. 2016), he showed that about 60% of phosphorus inputs to the EU food system (which includes crop and animal production, food processing, non-food production and consumption) are imported, mainly as mineral fertilisers. Major end-point losses occur at the consumption stage, mainly food (around 50% of total losses), largely via wastewater (sewage sludge going to incineration then landfill) and biodegradable waste (where P ends up in landfill), followed by food processing losses (around 30%, notably Cat.1 meat and bone meal again going to landfill). Although leaching and runoff represent a smaller share (around 7%), they have a disproportionate impact through eutrophication. Phosphorus use efficiency varies strongly across the system, from about 70% in crop production to only 21% at the consumption stage, and around 77% of phosphorus inputs still originate from mined phosphate rock. (the remainder comes from imports of organic products such as food products and animal fodder, fisheries, other imported products …).

For nitrogen, about four to five times more nitrogen enters the EU as fertiliser than in animal feeds, compared to phosphorus where fertiliser inputs are only about three times higher than animal feeds. Nitrogen recycling and residual flows are lower than for phosphorus because a large share is lost to the atmosphere through volatilisation and emissions.

On average, the EU food system delivers twice as much phosphorus to consumers as is actually consumed as intake per person and the consumed amount is twice as much compared to dietary P intake requirements per person, indicating **significant food waste and scope for improvement through dietary choices and waste reduction**.

Current recycling captures only around 30% of the theoretical technical phosphorus recycling potential in the EU (not taking into account manure, where phosphorus is considered to be generally returned to the field) with strong differences between Member States. According to recently updated data, the potential phosphorus recoverable from the three largest (non-manure) 'waste' flows, namely sewage sludge, biodegradable solid waste, and meat & bone meal is around 400 000 tonnes (t) P/year. By comparison, mineral fertiliser use in 2019 was 1.1 million tonnes (Mt) P meaning that recycling from these waste streams could potentially replace about one third of mineral fertiliser. Manure in the EU contained 2016 around 1.7 Mt P, but this is considered to generally return to fields.

Policy support to sustainable nutrient management

Stephanos Kirkagaslis, DG Agri, European Commission, presented on nutrient management under the new CAP 2028–2034. He highlighted the Vision for Agriculture and Food (19 February 2025) as a guiding document, calling for improved nutrient management at farm level, enhanced nutrient circularity, and territorial approaches to address nutrient hotspots, particularly from livestock farming, supporting extensification in high-density areas. The Vision also emphasises that reducing dependence on fertiliser imports benefits both farmers and the environment, incentivising circular solutions such as manure and digestates.

The current CAP (total budget 386 billion €) supports nutrient management through conditionality, requiring compliance with statutory requirements and good agri-environmental standards. Farmers meeting conditionality can access eco-schemes and agri-environment-climate commitments (voluntary commitments). This is supported by farm advisory services and knowledge exchange and innovation networks such as the EIP-Agri operational groups.

The new CAP proposals (July 2025) are embedded in the new Multiannual Financial Framework (MFF) 2028–2034 proposal, which reaches 2 trillion € overall. Within this MFF, 865 billion € are allocated to the new National and Regional Partnership Fund (NRPF), a single fund covering cohesion and regional policy, the CAP, the Common Fisheries Policy, as well as defence and security. Around 300 billion € are ring-fenced for farmers, of which 293.7 billion € is secured for farmers' income support, while 6.3 billion € are reserved for crisis and market disturbance measures. Member States may top up agricultural support from within the same fund by allocating resources from non-allocated parts, enabling additional funding for innovation, territorial cooperation, and EIP-AGRI activities. The distribution of the €293.7 billion income support between Member States would follow allocation keys aligned with those used under the current CAP, providing continuity despite the new governance structure.

The new CAP proposal introduces a "green architecture": farm stewardship (corresponding to a reshaped conditionality in the current CAP) with statutory management requirements and protective practices. Member states can adapt protective practices territorially to address specific conditions and nutrient hotspots. Key elements include recommendations by the Commission to Member States to identify challenges and provide guidance on e.g. circularity, bioeconomy, resource efficiency, digitalisation, and the green transition. Support measures under the new CAP include Agri-Environmental and Climate Actions (AECAs), with a transition payment for e.g. soil protection, nutrient management, water quality, carbon sequestration, or climate adaptation, as well as support for investments, knowledge sharing, innovation, digital tools, and advisory services.

While the names and budget allocations are updated, the new CAP continues to support sustainable nutrient management. The core responsibility remains with Member States, that need to provide support and adapt protective practices to the conditions of their territories. Reducing dependencies on imports remains a priority, with focus on low-carbon and recycled nutrients, and more efficient use of nitrogen and phosphorus.

Tobias Eriksson, Ragn-Sells (Sweden), presented the UN Global Partnership on Nutrient Management (GPNM). Launched in 2009 at the United Nations headquarters, it serves as a global platform connecting governments, international agencies, researchers, and donors to optimise nutrient use worldwide. It aims to reduce excess nutrients where they cause pollution and improve access to nutrients in areas with poor soils or limited food production, by fostering international cooperation, knowledge sharing, technical support, and policy guidance, engaging stakeholders from farmers to policymakers to raise awareness on sustainable nutrient management, food security, and healthy ecosystems.

GPNM received funding for two projects, Global Nutrient Cycling and the International Nitrogen Management System (INMS), and released two publications: "Our Nutrient World" (2013), which documented rapid human nutrient use and environmental impacts, laying the foundation for global nutrient efficiency strategies, and "Our Phosphorus Future" (2022), which focuses on phosphorus and introduces the 50:50:50 goal: halve phosphorus pollution and double recycling by 2050.

The UNEP Executive Director report to UNEA 7 (United Nations Environment Assembly), highlighted current gaps, including the **absence of an integrated global assessment of nitrogen and phosphorus use, and emphasised rising political awareness but limited coordinated action**, calling for a global working group and formal collaborative platform for sustainable nutrient management.

UNEA8 will take place Nairobi, from 6 to 10 December 2027.

Eriksson also presented EasyMining technologies, including Ash2Phos, which recover phosphorus from incinerated sewage sludge for use in fertilisers and animal feed. Current EU regulations classify such recovered phosphorus as waste, preventing sale for feed, so the recovered product will initially be sold to Canada, where regulations allow its use.

Fertiliser industry responses to supply risks and sustainability challenges

Tiffanie Stephani. Yara produces organic, organo-mineral, and mineral fertilisers, industrial solutions, and operates the only European phosphate rock mine in the EU, located in Finland. The illegal invasion of Ukraine by Russia affected fertiliser flows and emphasised import dependency in Europe. Eurostat data show that total urea imports increased, driven by high natural gas prices in Europe that made domestic nitrogen-based fertiliser production more expensive, with **a growing share of imports from Russia, peaking in 2022–2023, and currently remaining about 10% above pre-war levels.**

She identified several risks related to this import trend:

- moral and ethical concerns as fertiliser imports supported the Russian war efforts in Ukraine;
- market distortion due to large price differences in feedstocks (natural gas, 10 times more expensive in Europe than Russia);
- dependency of farmers and the broader food system on imported inputs from unreliable trade partners;
- potential weaponisation of food and energy, all compounded by reduced European production capacity.

In July 2025, the EU introduced a tariff mechanism with an import threshold (2.7 Mt for N&P fertilisers in 2025) to stabilise the market. This tariff will increase over three years, and when the threshold is reached, tariffs would come to the highest level. As of November 2025, 17% of the limit had been used, reflecting front-loading before July 2025 and showing that the market can respond fast to policy signals, and that the mechanism is already supporting resilient supply, and protection against unfair competition.

She outlined three pathways through which the fertiliser industry can support diversification and improve nutrient use efficiency:

- at policy level, upcoming EU initiatives, including the Circular Economy Act (expected in 2026) and the reviews of the Animal By-Product Regulation and the Fertilising Product Regulation could create a more enabling framework for the use of by-products and for nutrient recovery from food industry residues, manure, sewage sludge and ashes, while ensuring sufficient regulatory flexibility for innovation;
- at farm-level, nutrient efficiency can be improved through the uptake of complementary solutions such as biostimulants, fertigation, digital tools and precision farming, which can reduce nutrient losses while delivering both economic and environmental benefits;
- finally, through the Common Agricultural Policy, which continues to incentivise sustainable nutrient management.

There is potential to increase nutrient use efficiency in Europe by up to 20%, provided farmers are supported with appropriate fertilisers, practices and advisory services.

Nicolas Willaume, ICL, discussed how by-products and waste streams can be transformed into fertilisers to strengthen European phosphorus autonomy, in the context of the Critical Raw Materials Act. According to Eurostat, Europe has used around 1.1 Mt P/y fertilisers over the past decade (with a decline in 2022–2023), with most phosphorus imported from outside the EU.

Regarding waste streams, sewage sludge contains a relatively limited amount of phosphorus (c. 0.3 Mt P/year) compared to total use, while manure represents a much larger potential (c. 1.5 Mt P/year). However, valorising these streams faces major challenges, notably geographical and temporal mismatches, quality variability, and logistic constraints, as nutrients are often generated in surplus regions and at times that do not match crop demand. For instance, manure production is concentrated in intensive livestock regions with nutrient surpluses, while demand lies elsewhere. Because manure is dilute and costly to transport, it is often applied locally, exacerbating environmental pressures. While current policy discussions often focus on reducing livestock densities, processing technologies could convert manure into concentrated, transportable, and more balanced fertiliser products, turning manure into an efficient nitrogen and phosphorus resource.

On sewage sludge, he noted that on average 34% of EU sludge is directly applied to agriculture, with strong national differences, while around 31% is incinerated. ICL operates a facility in Amsterdam that converts sewage sludge incineration ash into P, PK and NPK fertilisers, illustrating the technical feasibility but also the challenges. These include ash management, competition for ash use, and logistical mismatches, as incinerators produce ash continuously while fertiliser production is demand-driven, creating storage and transport constraints that would benefit from EU-level support.

He concluded that the EU has untapped nutrient potential in manure, sewage sludge and by-products, which could cover a larger share of EU phosphorus demand, reduce import dependency and close nutrient loops. Key barriers to a better valorisation of these nutrients include complex and fragmented regulation, limited market access for innovative recycled fertilisers, and the classification of secondary raw materials as waste.

European and extra-European primary resources

Zineb Jabri, OCP (Morocco). OCP manages the world's largest phosphate reserves, with approximately 50 billion t in Morocco (USGS data), representing 68% of global reserves totalling 74 billion t. Most of the reserves are located in the north of Morocco (the Khouribga mine alone holds 43% of Morocco's reserves). In 2024, OCP Group has achieved installed production capacities of 47.5 Mt of phosphate rock, 8 Mt phosphoric acid and 14 Mt of customised fertilisers.

While there is no imminent scarcity, the company recognises phosphate rock to be a finite and strategic resource.

As the long-term custodian of phosphate rock reserves, OCP Group places responsible stewardship at the heart of its mission – ensuring phosphate is available globally, not only for food security (fertilisers, animal feed) but also for emerging sectors such as energy, batteries, all within a sustainability-driven framework.

Stewardship spans the entire value chain:

- Conserving the resource, including advanced mining techniques such as reverse flotation to recover high-quality phosphate from lower-grade ores;
- Producing sustainably, through efficient manufacturing, logistics, and circular economy practices;
- Using phosphate efficiently in agriculture, tailoring nutrients to soil and crop needs and helping farmers avoid overuse;
- Creating value by transforming phosphate not only into fertilisers but also into specialty products supporting emerging technologies.

Efficient use is central to global food security. Phosphate supports yield improvements to meet growing food demand with limited arable land, especially in Africa, where closing yield gaps could reduce cropland expansion. Globally, 46% of soils are P-limited, highlighting the need for 4R (right source, right rate, right time, and right place) nutrient management. This approach can improve yields, and contribute to restoring soil health and to carbon sequestration, opening pathways to carbon-credit mechanisms.

OCP Group's ambition is backed by its US$13 billion Investment Plan (2023-2027), which accelerates the shift to a low-carbon, resource-efficient industrial model. The plan aims to scale up green hydrogen and green ammonia, expand solar and wind capacity, and deploy seawater desalination to secure non-conventional water for all of the Group's operations.

In parallel, the Group is developing specialty chemicals such as fluorine and intermediates for lithium iron phosphate (LFP) batteries, unlocking new strategic applications for phosphate.

OCP aims for carbon neutrality by 2030–2040, and aims to turn responsible custodianship into a model of competitive, sustainable industrial transformation for Morocco, Africa and global partners.

Will Myles. Norge Mining is a Norwegian critical raw materials company holding 32 extraction licenses in southwest Norway. **Norge Mining recently concluded a pre-feasibility study for 4.6 billion t resource consisting of igneous rock** containing phosphate (around 39% P_2O_5, naturally low in cadmium and uranium), ilmenite (c. 45% TiO_2) and magnetite (c. 67% Fe). The low contaminant levels of igneous phosphate were highlighted as an advantage for both fertiliser and industrial applications. The project foresees most output destined for fertiliser markets. Given the scale of investment, the timeline extends beyond 2030. The company's plans for P_4 were also presented. In Europe, P_4 currently comes mainly from Kazakhstan and Vietnam, creating significant supply-chain risks, including long rail routes through Russia. To address this, Norge Mining is considering developing a P_4 plant in Italy, at a coastal site near Brindisi (Puglia). The location offers access to green energy, industrial land and skills, and efficient import/export logistics. The project would create local jobs and re-establish P_4 production in Europe, improving security of supply for downstream industries. An additional benefit of using their clean igneous phosphate is that the resulting slag is uncontaminated, allowing potential use in construction and aggregates. The company is currently studying feasibility using the classical thermal process and energy costs remain a key challenge in Europe.

P_4 (white phosphorus) a 'Strategic' Raw Material for Europe ?

P_4 (white phosphorus) is included in the EU Critical Raw Materials Act (CRM Act 2024/1252), under the vocabulary 'Phosphorus', separately from and in addition to the CRM 'Phosphate Rock', but is not today recognised by the EU as a 'Strategic Raw Material'. The CRM 'Phosphorus' refers to phosphorus in the specific form of elemental phosphorus ('white' or 'yellow' phosphorus), produced by reduction from phosphatic materials in furnaces – and also in effect to the P_4 derivate chemicals which are used as 'vectors' for P_4, such as PCl_3, PMIDA (N-(phosphonomethyl)iminodiacetic acid), phosphine (PH_3), …

P_4 (itself or via its derivates) is today non-substitutable for:

- synthesis of many organophosphorus chemicals: there is at present no industrial chemical pathway, other than via P_4, to organophosphorus chemicals with P oxidation state -3 to +3,
- specific applications, for example silicon doping for semiconductors and photovoltaics (P oxidation state -1 required) or synthesis of specialised metal alloys (P oxidation state -3 required),
- production of some organophosphorus chemicals with P oxidation state +5*, because of practical obstacles to synthesis from phosphoric acid (e.g. water release in esterification for production of phosphate esters),
- production of organophosphorus chemicals with P oxidation state +5* for applications where zero water content is required, e.g. phosphate flame retardants for electronics,
- phosphoric acid (P oxidation state +5*) for semiconductor etching, 'molecular' levels of purity are required.

P_4 is not needed to produce Purified Phosphoric Acid (e.g. Food Grade, for food additives or beverages, Battery Grade, for LFP battery cathode material) as these qualities can today be achieved by purification of MGA (Merchant Grade Acid for wet process from phosphate rock).

P_4 it is not today included in the sub-list of 'Strategic' Raw Materials in the EU CRM Act 2024/1252. In this Act, 'Strategic' Raw Materials are those necessary for "Strategic Technologies", defined in the Act as green transition (in particular renewable energies), digital, defence and aerospace. See Meeting Conclusions below.

This workshop, with nearly one hundred participants in Brussels and online, 20th November 2025, brought together nearly all the key industry players in P_4 chemistry and use in Europe: Clariant, Filo Chemical, ICL, Italmatch, Lanxess, Perimeter, Prayon. The workshop discussed the different uses of P_4 and its derivates, with the aims of identifying where they are necessary for 'Strategic Technologies', why the EU today faces supply risks, and what are future perspectives.

**The oxidation state of biological organophosphorus chemicals is +5, e.g. DNA, ATP/ADP, phospholipids, certain proteins and amino acids.*

Full explanation: see ESPP's SCOPE Newsletter n°136.

P_4 relevant upcoming events

18th CRU Phosphates & Potash 2026
Paris, 13-15 April 2026

This is "the" annual world P and K industry & technology meeting place, covering the whole industry value chain. ESPP presentation, with Willem Schipper, on P_4 markets, uses, supply and projects.

http://events.crugroup.com/phosphates/home

25th ICPC
Montpellier, 5-8 July 2026

International Conference on Phosphorus Chemistry.

ESPP-ICPC joint session on P_4. Call for abstracts open to 3rd April 2026. Possible research into route to organophosphorus chemicals without the P_4 furnace route. P_4 chemistry. P_4 uses and applications.

https://icpc25.sciencesconf.org/?lang=en

P_4 and Strategic Technologies

Willem Schipper, phosphate industry consultant, presented the chemistry of P_4, its derivates and its uses, showing why it is non-substitutable in a range of industry applications and technologies.

Less than 2% of phosphate rock in the world is today processed to P_4. In some places in the world, P_4 is still used in applications where it could be replaced by chemicals derived from purified phosphoric acid (from phosphate rock via the 'wet acid' route), for example for food phosphate additives (food-grade quality can today be achieved by wet acid purification). Such non-essential use of P_4 is disappearing worldwide because of energy costs and climate emissions of P_4 furnaces.

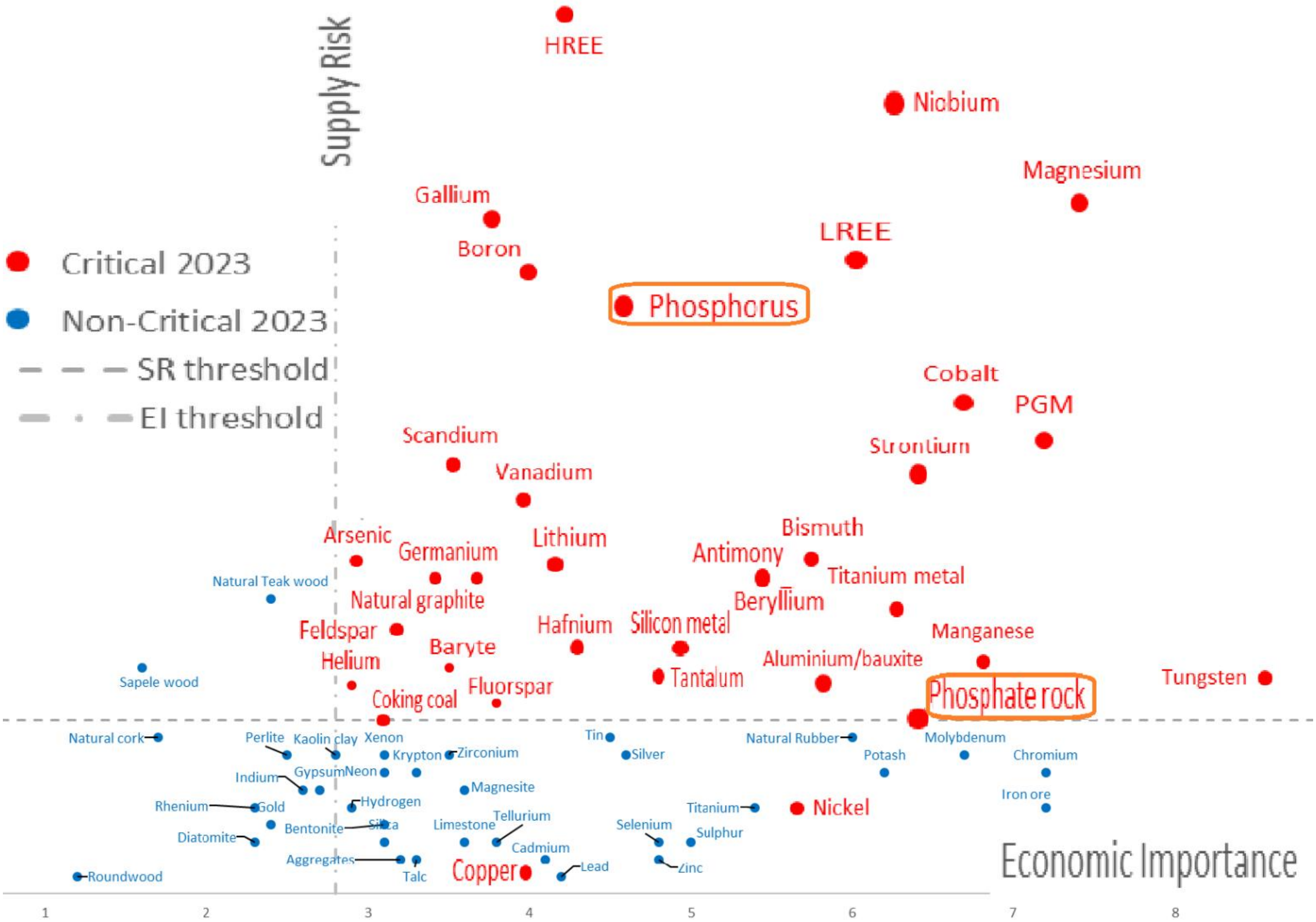
P_4 shows as a priority in EU criticality assessment of raw materials (see below). It is essential in e.g. fire safety (electronic and electrical systems, data cables, insulation, biobased materials, aerospace …), batteries, semiconductors, photovoltaic panels, crude oil extraction, aviation hydraulic fluids, metallurgy, chemicals.

Europe and the world market are today dependent on only two suppliers: Vietnam and Kazakhstan. Malaysia also has a P_4 furnace, but is seems to be not producing any significant amount for some time. China and the USA have significant production but do not export. The EU's last P_4 furnace (Thermphos, The Netherlands) closed in 2012.

Willem Schipper presented the wide 'family tree' of different chemistries derived from P_4 and how these map into tens of different industry uses and applications (available to participants in slides).

He underlined some of the **key uses where P_4 / derivates are non-substitutable to enable Strategic Technologies and/or sectors of industry essential for society,** including:

- Electrolytes of different types of lithium-ion batteries (large automotive and energy storage lithium-ion and lithium-iron-phosphate LFP batteries, small electronics NMC or NCA lithium ion batteries, lithium-polymer pouch cells, …): $LiPF_6$ (see also the presentation by Prayon below);
- Solar panels: n-doping of silicon (via the P_4 derivative: phosphine);



Results of the European Commission 2023 EU criticality assessment "Study on the Critical Raw Materials for the EU 2023"

- Fire safety in electronics and electrical equipment, aviation hydraulic fluids, and many other applications;
- Catalysts and ligands (e.g. metal-phosphine catalysts);
- Oil drilling and extraction: scale prevention;
- Nickel plating (e.g. machine parts);
- Lubricant additives;
- Pharmaceuticals;
- Metal extraction (cobalt, nickel, both CRMs);
- Crop protection;
- Industrial water-cooling system protection (phosphonates).

Adrian Beard, Clariant, explained that P_4 derived chemicals are essential to ensure fire safety in modern society, in particular in Strategic Technologies.

Flammable polymers (plastics and thermosets), composites and bio-based materials are ubiquitous in "strategic technologies" (see the EU Strategic Technologies for Europe Platform): such as renewable energies, batteries, information technology, the bio-economy.

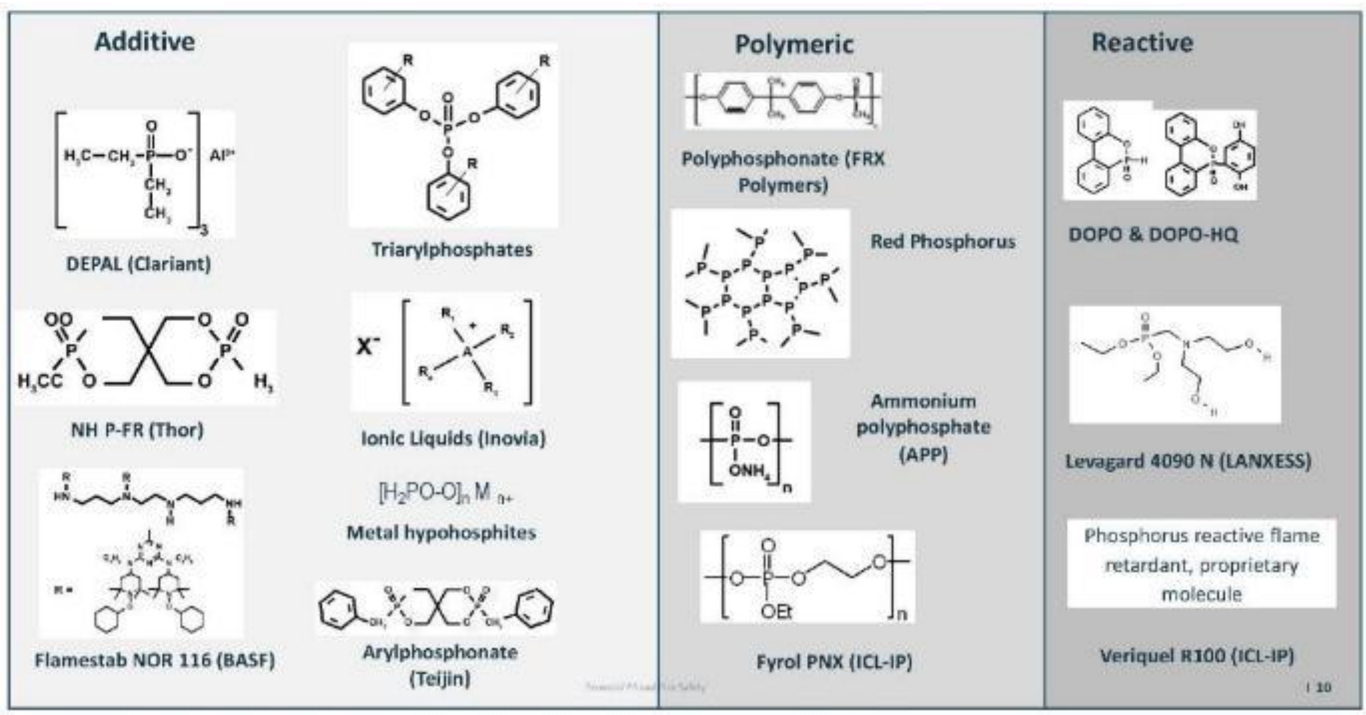
Phosphorus flame retardants reduce fire risk through two mechanisms: release (under heat) of gas radicals which quench fire reactions, and formation of protective char layer preventing fire from attacking the material. They can achieve low smoke and low fire gas corrosivity specifications required for aviation, railway/metro or data centres.

There is a wide range of chemistries of phosphorus-based flame retardants (see below), enabling compatibility with specific polymer and different material performance requirements, such as electrical insulation, strength, flexibility, temperature resistance. These flame retardants include additive compounds, reactive chemistries (react into the synthetic or bio-based polymer matrix) and polymeric compounds, both organophosphorus and inorganic phosphates.

Phosphorus flame retardants are thus an essential tool to ensure fire safety of strategic technologies. This is dependent on P_4 derived chemistries, today non-substitutable for the organophosphorus flame retardants. P_4 is also used, via derivates, to produce specific grades of inorganic phosphate flame retardants for use in polymers where zero-water is required to ensure performance and polymer compatibility, in particular for electrical and electronics applications.

Bio-based flame retardants are today being developed. Biological molecules (such phytate) can contain significant levels of phosphorus, with fire protection effects, but pose issues of limited stability (in temperature, humidity) not compatible with use in technical materials. Properties can be improved by chemical modification, often using P_4 derivates to react.

Europe has a history of industrial phosphorus chemistry innovation (see photos), developing from roots with inorganic phosphates a century ago to specialist P_4-based chemistries for innovative technologies today.



Some examples of phosphorus-based flame retardants (source: pinfa and Clariant).


Knapsack phosphorus chemistry site, near Cologne, Germany, 1908 and today (photos: https://commons.wikimedia.org/w/index.php?curid=8706462 and Clariant).

Maxime Castes, European Semiconductor Industry Association (ESIA), underlined that **P_4 is essential for semiconductor, microchip and electronics component production,** but that the European Commission does not seem to yet be aware of this.

The EU today produces around 10% of global microchips, with specific strengths in chips for automotive and health technology applications. The global chip market is growing at >10%/year and is expected to be around 1 trillion Euros by 2030. The EU is a significant user (purchaser) of microchips, in particular taking a quarter of automotive chips.

P_4 derivate chemicals, in particular phosphine (PH_3), are necessary to "dope" silicon, that is to introduce phosphorus atoms which have one more electron in the outer shell than does silicon (5 vs. 4), so giving the electron gate and transmission behaviours necessary for transistors or photovoltaics. Phosphorus can be substituted by other elements to bring this functionality (arsenic, antimony …) but they result in different properties.

Phosphine (PH_3 derived from P_4) is used to produce compound semiconductors, such as gallium phosphide or indium phosphide, vital for opto-electronics, such as optical sensors, LEDs (light emitting diodes) and laser diodes.

Extreme purity P_4-derived "thermal" phosphoric acid is necessary for microchip production (circuit etching). Some substitution is possible by other acids.

P_4 is also essential for other 'Strategic Technologies' (beyond microchips), including both liquid electrolytes in all types of battery today, and also future solid-state electrolytes (LiSP).

The European Commission's 2023 Impact Assessment for the Critical Raw Materials Act 2024/1252 refers to semiconductors a number of times, linking to gallium and silicon, but does not recognise the relevance of P_4. Gallium and silicon are classed as "Strategic Raw Materials" in the CRM Act, phosphorus (P_4) is not.

The European 'Chips Act' ("Strengthening Europe's semiconductor ecosystem …" 2023/1781 amending 2021/694) art. 24 Emergency Toolbox could possibly also enable actions on input raw materials for chip production.

The criteria for assessment of "Strategic" Raw Materials in the CRM Act 2024/1252 are difficult to appreciate. It does seem certain that P_4 is essential for semiconductors, which are a Strategic Technology as defined by the Act, and which have significant and growing global demand. However, it is difficult to estimate the quantities of P_4 needed for semiconductor manufacturing and the impact of use in semiconductors on global P_4 supply chains.

The question must be raised as to whether the EU should have a key manufacturing industry such as semiconductors, which is essential for major user sectors (transport, health, defence), dependent on imported P_4?

Rovena Preka, ENEA (Italian National Agency for New Technologies, Energy and Sustainable Economic Development), updated on the SCRREEN3 project.

The SCRREEN 1, 2 and 3 projects (202 – 2027) are funded by the EU to develop knowledge on and identify Critical Raw Materials, with total EU funding of around 9 million Euros. SCRREEN3 is led by the French Geological Research Office (BRGM) and SCRREEN 1 and 2 were led by the French Atomic Energy Authority (CEA). ENEA is leading the network of experts and one work package related to factsheets.

The SCRREEN projects have developed a methodology for defining criticality of materials, based on supply risk and economic importance, published here (2024). There is however no published methodology for assessing which materials are 'Strategic' under the CRM Act 2024/1252 but the factors to be taken into account are specified in Annex I of the Act.

SCRREEN is currently working to engage a list of experts on criticality assessment and on the different Critical Raw Materials (CRMs) and other 'candidate' materials, to update the SCRREEN2 'Fact Sheets' on these materials, and to collect information and data to support the process of reassessing the lists of Critical and Strategic Raw Materials (the CRM Act requires that these lists be updated by May 2027).

Currently the factsheets of Phosphate Rock and Phosphorous, which are grouped under "Industrial and Construction materials" work package, are under revision, though not yet published on the website.

Regarding the situation in Italy, the Ministry for Environment and Energy Security has promoted the National Phosphorus Platform, identifying ENEA as manager of the platform, aiming to achieve the self-sufficiency for the phosphorus cycle on national basis and in coordination with European policies.

The Platform includes phosphorous cycle stakeholders (research centres and academy, public and private institutions, companies and associations, civil society). Its approach is based on the principles of the circular economy, therefore on the closure of the cycle on the entire value chain: from primary production to recovery from secondary sources. It is divided into 4 working groups (WP) that address the issue from different points of view; WP1 Management and Promotion; WP2 Technologies and Best Practices; WP3 Legislation; WP4 Market and Policies. The Platform works in connection with Italian Platform for Circular Economy.

ESPP noted that 'Phosphate Rock' and 'Phosphorus' (P4) have been inadequately taken into account and confused in previous SCRREEN factsheets (SCRREEN2 see ESPP eNews n°74), apparently partly because based on the inappropriate methodology and flow models developed by Deloitte for the European Commission in 2016 (see ESPP SCOPE Newsletter n°119). ESPP notes that SCRREEN3 is moving to hopefully now address correctly 'Phosphate Rock' and 'Phosphorus' (P_4), and in particular to distinguish between end uses which do require P_4 (e.g. electrolytes for all types of lithium battery, fire safety, silicon doping for semiconductors and photovoltaics, hydraulic fluids for aviation and aerospace …) and uses which do not require P_4 (food phosphates, LFxP battery cathodes …)

Purified phosphoric acid

Alain Germeau, Prayon, presented the increasing demand for purified phosphoric acid (PPA) for lithium iron phosphate (LFP) battery cathodes and other applications.

P_4 is today essential for all lithium-ion batteries (from hand-held electronics to energy storage), for $LiFP_6$ in the electrolyte, as well as for fire safety of battery membranes, polymer structure and casings, cables and insulation.

Prayon uses P_4 to produce electronic grade phosphoric acid only (used for microchip etching).

Prayon produces Purified Phosphoric Acid (PPA) by multi-stage purification of 'wet route' phosphoric acid (produced by attacking phosphate rock with sulphuric acid, as for fertilisers) for applications such as:

- lithium iron phosphate ($LiFePO_4$) for LFP battery cathodes
- food additive phosphates, e.g. to extend shelf life of food products and so reduce food waste, to replace sodium in leavening agents for health reasons
- drinking water treatment
- a range of industrial applications requiring high purity, including ceramics, personal care products, inorganic phosphate flame retardants, chemicals.

Phosphate cathodes are today widely used in LFP (lithium iron phosphate) batteries, which represent over 60% of global cathode material sales. Cathode material makes up around 1/5 to 1/3 of battery production costs. Phosphate cathode materials are also used in other battery technologies, including Lithium Manganese Iron Phosphate (LMIP), vanadium, cobalt, sodium-ion, some solid-state electrolyte technologies and in cathode coatings.

Global demand for purified phosphoric acid is expected to more than double in the next ten years. New purification capacity will be needed. If capacity investment is not made in Europe, then the continent risks being excluded from battery technologies by lack of this key raw material.

Prayon also emphasises the importance of materials recycling from end-of-waste batteries. Currently this is hindered by barriers in EU waste regulations.

John Passalaqua, First Phosphate, presented the company's **project for an igneous phosphate rock mine at Bégin-Lamarche in Sagueany-Lac-Saint-Jean, Quebec, Canada**.

Exploitable reserves of some 250 Mt of igneous phosphate rock have been identified. The site is 70 km from the Port

Saguenay deep sea port, currently under expansion with Canadian Federal Government investment. The region has an industrial tradition, bringing infrastructure and competence, but centred on aluminium and forestry which are in decline, so that First Phosphate is seen as an opportunity.

First Phosphate aims to use the mined anorthosite igneous phosphate rock to produce phosphoric acid. The igneous rock has around 6 – 8 % P content, but low heavy metal levels, facilitating production of Purified Phosphoric Acid and of a clean gypsum which can be valorised. Only around 5% of world phosphate rock deposits are igneous.

There are only five significant producers of Purified Phosphoric Acid outside China, plus several smaller plants. Global Purified Phosphoric Acid demand is expected to more than double over the coming decade. No new plants have come online in recent years (one site has made considerable capacity extension).

First Phosphate's aim, working with Prayon, is to integrate through to production of lithium iron phosphate, for LFP battery cathode active material (CAM). First tests have shown successful LFP 18650 battery cell production with Ultion Technologies and Nouveau Monde Graphite.

The total investment in the mine, infrastructure, phosphoric acid purification and lithium iron phosphate plants is estimated at under 1.5 billion Euros, enabling a production potential of around 700 kt/y of LFP CAM (for 350 GWh), sufficient for around half of Noth American EV production.

The current objective is to start industrial phosphate rock production in year 2029 with LFP production potentially sooner using feedstock from other producers.

Innovation for P_4

Arnout D'Haese, Gent University, and **Quentin Van Haecke, Aquafin**, presented the **Spodofos process to react phosphate-containing materials (in particular sewage sludge incineration ash) with low-quality, low-value aluminium scrap to produce P_4.**

Once started, the process needs little external energy input (relying on the embedded energy in the aluminium scrap) but operates at high temperatures (1 600 °C) to ensure that generated slag stays liquid in the reactor. The iron in input materials (significant in sewage sludge incineration ash) is converted to ferrophosphorus, with specific characteristics which could enable sale to replace ferrosilicon in Dense Medium Separation. Phosphorus losses to ferrophosphorus may be lower than in traditional P_4 furnaces because of the higher operating temperature. The remaining aluminium – silica – calcium slag, depending on the cooling process, can offer cement properties so may also find a market. See STOWA technical and economic analysis summarised in ESPP eNews n° 99.

The process has to date been tested at 1 kg batch scale (TRL5) and a 100 kg input ash / hour (TRL6) pilot is under construction with the aim of testing 4 hours continuous operation.

ThermusP's Spodophos project is in cooperation with SNB, Lanxess, STOWA, Gouda Refractories – Shiagawa, GMB, Aquafin and Urban Mine.

Shingo Ishihara, Tohoku University, Japan, presented the **RinPhos process to produce P_4 from concentrated phosphoric acid, using energy and activated carbon or bio-based coke as input**.

The objective is to use waste phosphoric acid, because the process is tolerant of high levels of impurity in the acid. Impurities are not removed with the P_4. The reactor is heated to around 1 000 °C (lower temperature than a P_4 furnace using phosphate rock as input). Very little waste is generated: mainly ash generated from the bio-coke or activated carbon. Heavy metals that do not volatilize at 1000 °C remain in the ash residue, whereas more volatile metals are transferred to the off-gas and are separated by controlled P_4 condensation and downstream gas cleaning.

In addition to net energy input (electricity, coke) needed to reduce phosphoric acid to P_4, RinPhos will need energy to concentrate available waste phosphoric acid to 85% (65% P_2O_4). Overall estimated total electricity consumption for RinPhos is claimed to be significantly lower than that of traditional electrothermal P_4 furnaces. The endothermic reduction of phosphate to P (removal of oxygen) requires the same energy, energy is not lost to solid slag (as in traditional P_4 furnace) but chemical reaction water and acid dilution water will need to be removed.

The project has been initially supported by the University and by Japan Ministry funding, and now has further support of Sumitomo Group (fertilisers, minerals, chemicals …), regional government and several other companies. To date the process has been laboratory tested in a 3m high pilot producing 1 - 12 kg/day of P_4 (photos). The aim is to construct and operate by 2027 a 1 tonne P_4/day test plant before scaling up to commercial scale of maybe 3 000 to 10 000 tP_4/year.

Kirill Nikitin, University College Dublin, presented the **SINFERT project, which aims to produce $POCl_3$ from solid inorganic phosphates by deoxychlorination.**

The $POCl_3$ (phosphorus oxychloride) could be used to produce fertilisers, highly pure phosphoric acid, or potentially more interesting organophosphorus chemicals. $POCl_3$ has P in oxidation state +5 (the same as for inorganic phosphates and biological organic phosphate compounds such as DNA).

$POCl_3$ is today a widely traded P_4 derivate (100 – 150 kt/y estimated global trade), used in current industrial pathways to produce some chlorinated and non-chlorinated (tri-organo) phosphate esters (some flame retardants, aviation hydraulic fluid fire safety, lubricant additives, starch modification, crop protection chemicals …). These phosphate esters (P oxidation state +5) can "chemically" be produced from phosphoric acid (without P_4) but this not industrial practice because of difficulties in removing esterification water, resulting in high energy use, interference with catalysts, low yields and difficult production conditions.

Based on both old (1900's) and recent (2025) research, work is currently underway to produce, from the $POCl_3$, (tri-organic) phosphine oxides (P oxidation state -1) which can currently only be obtained via P_4 and which can be used as intermediates for production of other organophosphorus chemicals, such as phosphites (phosphinates) and phosphonates (both P oxidation state +3).

To date, there is no known feasible route to convert $POCl_3$ to phosphine (PH_3 – oxidation state -3) which is used for doping silicon in semiconductors and photovoltaics (see above).

To date, the DOC process has been tested in the SINFERT project at laboratory (gramme) scale, using secondary raw materials including sewage sludge and bone meal ashes. Vivianite (iron(II)phosphate recovered from sewage treatment) has also been tested with up to 90% P-recovery. Scale up to 1 kg batches is completed with Almac Ltd. The project is supported by Research Ireland, the EU, Sawn Meats and ICL.

Christian Schmidberger, University of Stuttgart, and **Carlos Galeano, Italmatch**, updated on the **Flashphos EU Horizon R&D project, which aims to demonstrate production of P_4 from dried sewage sludge**.

The project is currently starting up a pilot plant of capacity 250 kg/h dried sewage sludge input. To date successful tests of drying, grinding and gasification of sewage sludge have been made (see ESPP eNews n°94). FlashPhos represents a technical refinement of the EU-funded RecoPhos project (2012-2015, see SCOPE Newsletter n°136), using a two-stage thermal process. First, dried and ground sewage sludge is flash-oxidised. Second, the material is reduced using coke to produce P_4. The process is designed for high-efficiency separation: iron is recovered as ferrophosphorus, heavy metals are concentrated in an offgas stream, and calcium silicates and other elements are incorporated into a glassy slag. The Flashphos consortium includes Italmatch Chemicals and nearly twenty research organisations and engineering companies. The aim is to now establish a consortium of European P_4 industry operators to take the project from pilot to full scale.

Meeting conclusions

Approximately, ESPP estimates, based on collated expert opinions, that **Europe's need for P4 and derivate chemicals is of the around 60 - 100 ktP/y** (expressed as tonnes-P/year), which is around half of the annual P_4 production of Kazakhstan plus Vietnam. This represents the use of P_4 and derivates in industrial processes in Europe, it does not include P_4 derived chemicals embedded in imported articles (e.g. phosphorus flame retardants in imported plastic compounds, microchips or electronics goods).

P_4 it is not today included in the sub-list of 'Strategic' Raw Materials in the EU CRM Act 2024/1252. In this Act, 'Strategic' Raw Materials are those necessary for "Strategic Technologies", defined in the Act as "*green and digital transitions as well as for defence and aerospace*".

Some of the tools installed by the CRM Act are applicable to all "Critical" Raw Materials: incentivise technological progress and resource efficiency, facilitation of site permitting, monitoring of CRM flows, trade and prices, identification of steams with significant recycling potential, possible environmental footprinting and certification.

Important CRM Act tools are however only applicable to "Strategic" Raw Materials: fixing policy recycling and supply targets, establishing European 'strategic stocks' and "Strategic Projects". Strategic Projects aim to develop supply of Strategic Raw Materials, either within the EU or from countries outside the EU, and can include facilitating permitting, investment funding, joint purchasing and offtake agreements (which might otherwise be limited by competition law).

The European Commission has also launched the "Critical Chemicals Alliance" (see ESPP eNews n°102) which aims to identify and map critical chemical molecules and production sites and to facilitate relevant investments at these sites. ESPP has been admitted by the European Commission as a member of this Alliance and will participate at its first meeting at the Chemelot chemicals hub, Geleen, The Netherlands, 13th January 2026.

Participants at the meeting agreed that the EU Critical Raw Material termed "Phosphorus" - P_4 should be identified as a "Strategic Raw Material" (in the CRM Act 2024/1252 update, May 2027), because:

- it is non-replaceable for the "Strategic Technologies" (defined in this act): digital, renewable energies, aerospace
- user sectors have high economic value and export potential
- EU supply is at risk, because 100% on imports from only two countries Kazakhstan (1 company) and in Vietnam (8 companies).

This confirms the Declaration (2023) signed by 25 companies and organisations calling for Elemental Phosphorus (P_4) and Purified Phosphoric Acid (PPA) to be both be on the EU list of "Strategic Raw Materials".

Information on P_4's essential role in Strategic Technologies seems to be not taken into consideration by the EU and by SCRREEN (see European Semiconductor Industry Association presentation above). Despite repeated inputs by ESPP and others to the SCRREEN process from 2013 through to 2022, the SCRREEN2 2023 Factsheets failed to distinguish between P_4 (CRM "Phosphorus") and "Phosphate Rock", with both mixed up in one single Factsheet, resulting in errors (such as stating for P_4 production that Morocco and Russia are the main EU suppliers). See ESPP comments and input on this page www.phosphorusplatform.eu/regulatory, in particular ESPP preliminary input to SCRREN3 (26_5_2025) and ESPP letter concerning SCRREEN2 (29_9_2022).

ESPP expects this absence of understanding and confusion will be reduced now that SCRREEN work on both "Phosphorus" and "Phosphate Rock" are led by ENEA, who also operate the Italian Phosphorus Platform.

Proposed actions to follow the workshop should include:

- ✓ Update the 2023 Declaration calling for P_4 and Purified Phosphoric Acid to be added to the list of "Strategic" Raw Materials in the CRM Act update, May 2027
- ✓ Develop information on Strategic Technology uses of P_4 and its derivates (green, digital, aerospace, defence). Data on quantities used and economic value of dependent industry sectors. Possible substitutes where these exist. Uses not to date listed in the 2023 Declaration
- ✓ Identify and engage with downstream user industries (federations, companies)
- ✓ Update (text) and garner further support for the 2023 Declaration
- ✓ Develop information on alternative pathways to P_4 derivate chemistries
- ✓ Structure applied R&D in Europe into P_4 chemistry, handling and applications

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