Environmental impact assessment of phosphorus recovery technologies from sewage sludge

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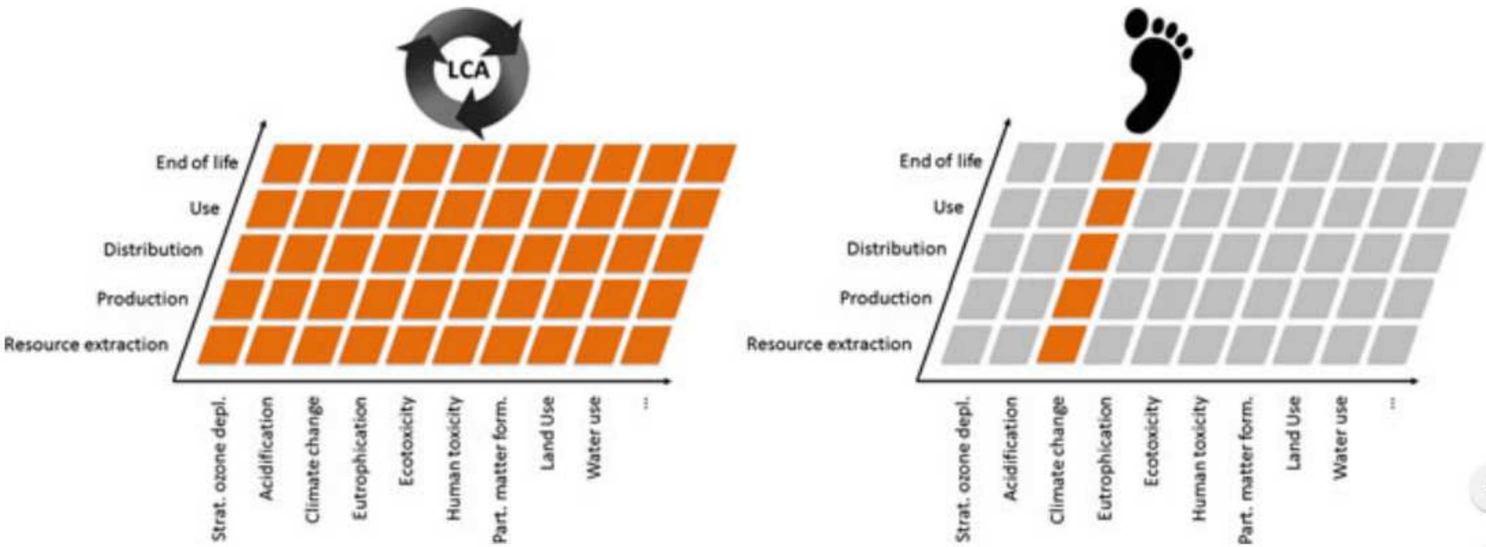
What is Life Cycle Assesment (LCA)?

- Standardization: ISO 14040 and 14044 (2006)
- « LCA addresses environmental aspects and potential environmental impacts (e.g. use of ressources an the environmental consequences of releases) throughout a product's life cycle from raw material acquisition through production, use, end-of life treatment, recycle and final disposal (i.e. cradle-to-grave) ».



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Introduction to LCA methodology

Goal & Scope	Primary data ← Partners Generic data ← Ecoinvent 3.7 (CH)	ecoinvent SimaPro

Life Cycle

Fonctionnal unit (FU)
Boundaries

Inventory

	Flows	Quantities
Inputs	Water	m³
	Fuel	kg
	Electricity	kg
	etc	…
Outputs	CO_2 (air)	kg
	Hydrocarbons (air)	kg
	Waste water (water)	kg
	HCl (water)	kg
	Cadmium (soil)	kg
	etc	…

Impacts assesment

Potential environmental impacts

- Climate change
- Eutrophication
- Fossil ressources scarcity
- Mineral ressources scarcity
- …

Method → ReCiPe 2016

LCA applied to phosphorus recovery technologies

- Issue: Inclusion of the wastewater treatment plant as a sludge producer in the LCA

- Two methodological approaches:
  - System expansion
  - Avoided burden

System expansion and avoided burden

	System expansion		Avoided burden	
Reference scenario	Wastewater treatment	Mineral P production	Wastewater treatment	
	Treatment of 100 m³ containing 0.8 kg P_2O_5	Production of 0.8 kg P_2O_5 as TSP	Treatment of 100 m³	
Phosphorus recovery scenarios	Wastewater treatment + P-recovery	Mineral P production	Wastewater treatment + P-recovery	Avoided mineral P production
	Treatment of 100 m³ + recovery of X kg P_2O_5	Production of 0.80 – X kg P_2O_5 as TSP	Treatment of 100 m³ + recovery of X kg P_2O_5	Avoided production of X kg P_2O_5 as TSP

With X < 0.80 kg and depending on the recovery process

System expansion

- Multifunctional: Wastewater treatment **and** P-fertilizer production

- Functional unit: Treatment of 100 m³ of wastewater **and** the production of 0.8 kg of P_2O_5

→ P_2O_5: from mineral production in the reference scenario and from phosphorus recovery technologies from sludge in others

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Avoided burden

- Monofunctional: Wastewater treatment

- Functional unit: Treatment of 100 m³ of wastewater

→ Environmental impacts of water treatment **minus** impacts of **avoided** P_2O_5 mineral production

LIÈGE université

Main assumptions

- Sludge used by the demonstrators:
  - Same sludge for all (no “local” specificity*)
  - P content = average German digested sludge (6.5 to 7 % of P_2O_5 in dry matter)

- Inventory data:
  - Sludge production (from the water treated in the WWTP) (common data*)
  - Yield of the demonstrator :
    - Mass sludge in (the demonstrator)
    - Mass P_2O_5 out

  → kg P_2O_5 recovered (OUT)/kg sludge (IN)

  → Example for EuPhoRe process:
    - 100 m³ of wastewater treated → 60.5 kg digested sludge (DM 20%)
    - 76.65 kg sludge DM20% treated for 1 kg P_2O_5 recovered

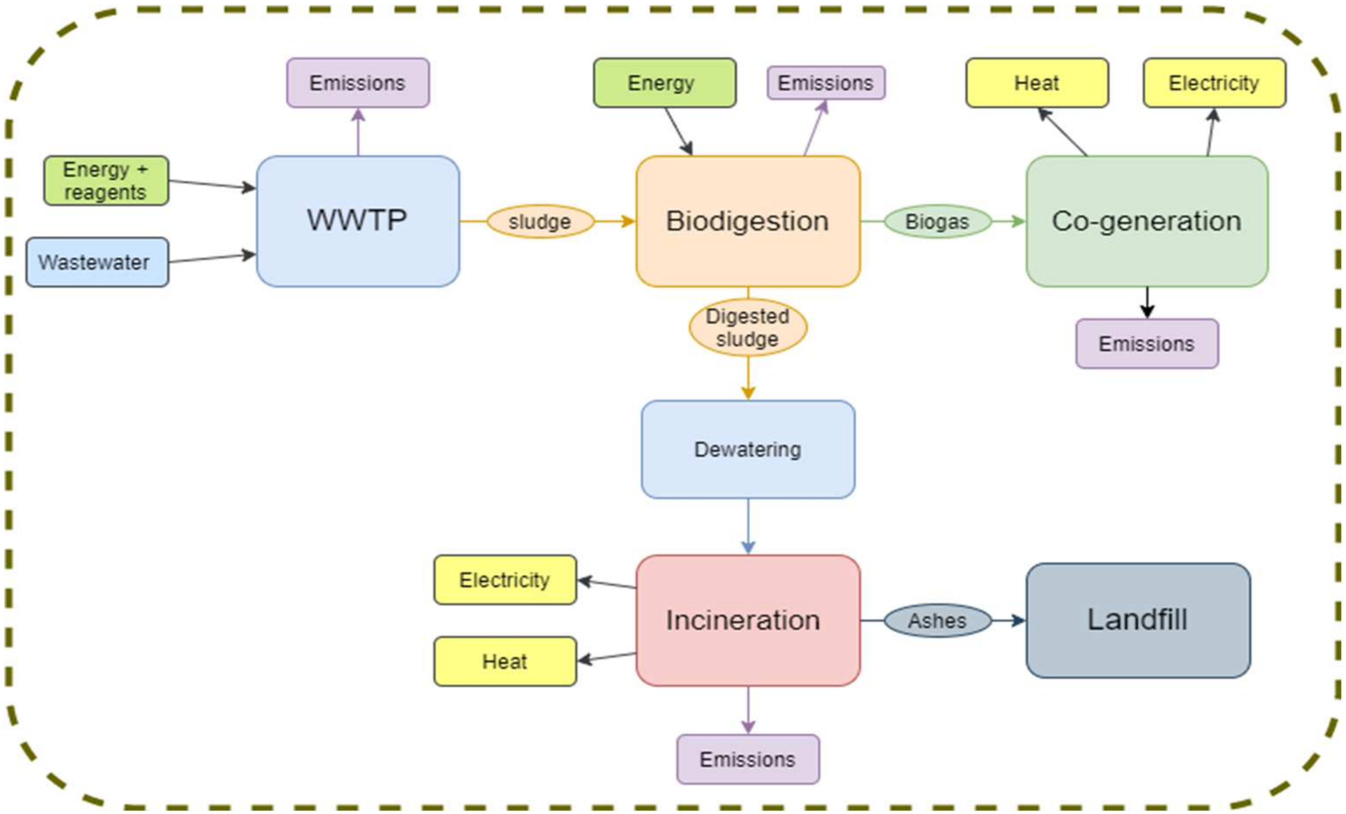
    → 100 m³ of water in the WWTP = 0.79 kg P_2O_5 recovered

Main assumptions

- Bio-availability of phosphorus in P-material: Considered equivalent to the bioavailability of TSP for all processes
- Legal aspects: Important but not taken into account
- Other potential nutrients in the P-materials: Not taken into account

Reference system : boundaries

- Functional unit: 100 m³ of wastewater treated

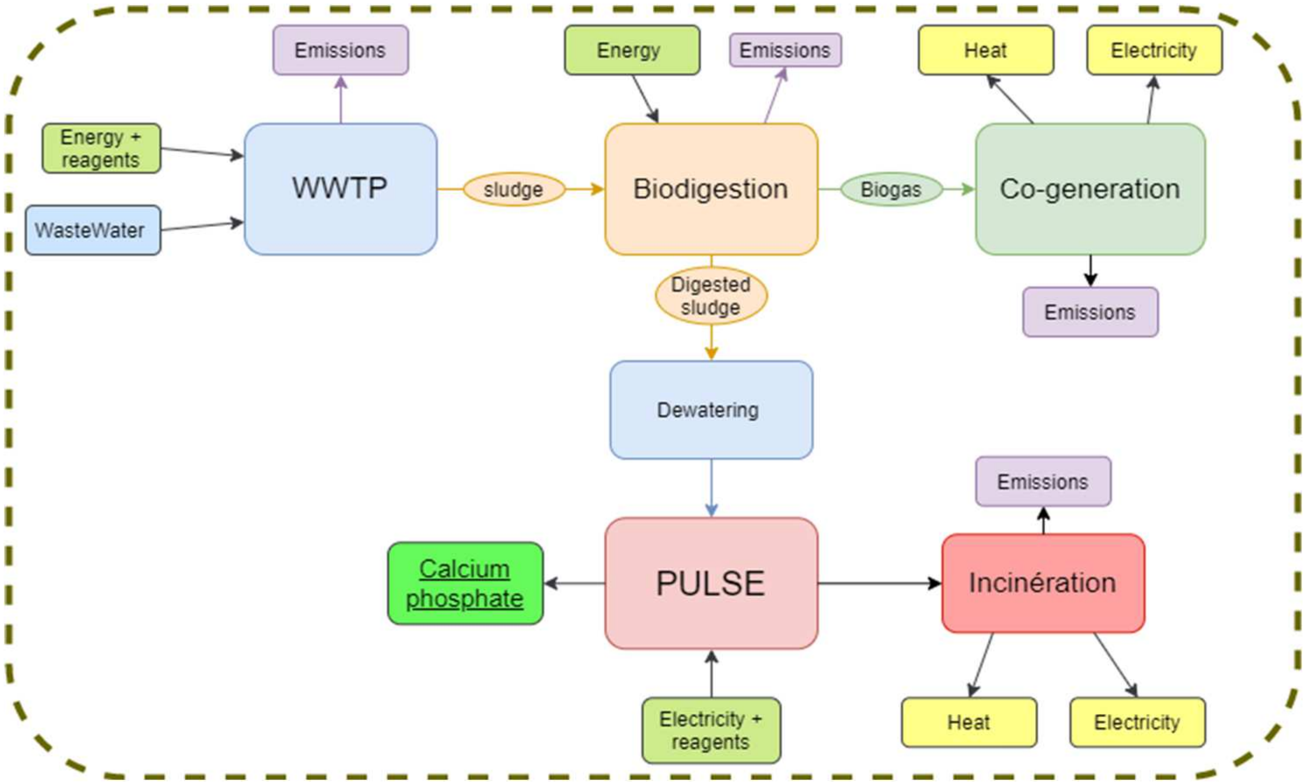


Reference system: main results

- Significant deleterious impact of the wastewater treatment plant (WWTP):
  - Direct emissions (to air – biological treatment)
  - Chemicals
- GWP: 47,08 kg CO_2 eq / 100 m^3
- Detrimental impacts of the dewatering phase: Electricity
- Beneficial effect of cogeneration and incineration: Energy production

PULSE system: boundaries

- PULSE: Chemical-extraction process from sludge
- Functional unit: 100 m³ of wastewater treated – avoided mineral production of TSP (1.56 kg)



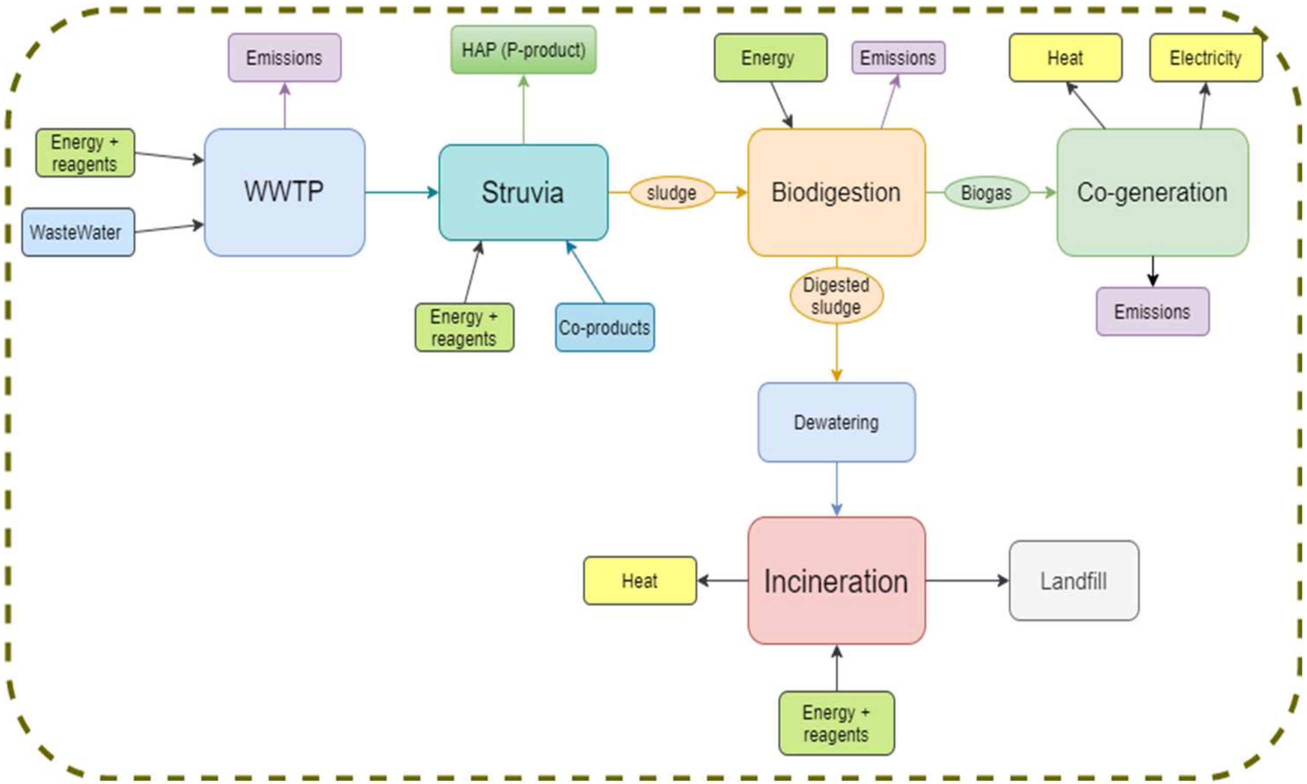
PULSE system: main results

- Environmental benefit on the category of mineral resource depletion: Avoided TSP production
- Impacting process steps: Drying, organic solvent regeneration (base consumption) and process waste treatment
- Eco-design advices: Solar dryer, optimization of solvent regeneration

Struvia™ system: boundaries

- Struvia™: Combination of bio-acidification and precipitation of hydroxyapatite

- Functional unit: 100 m³ of wastewater treated – avoided mineral production of TSP (0.54 kg)

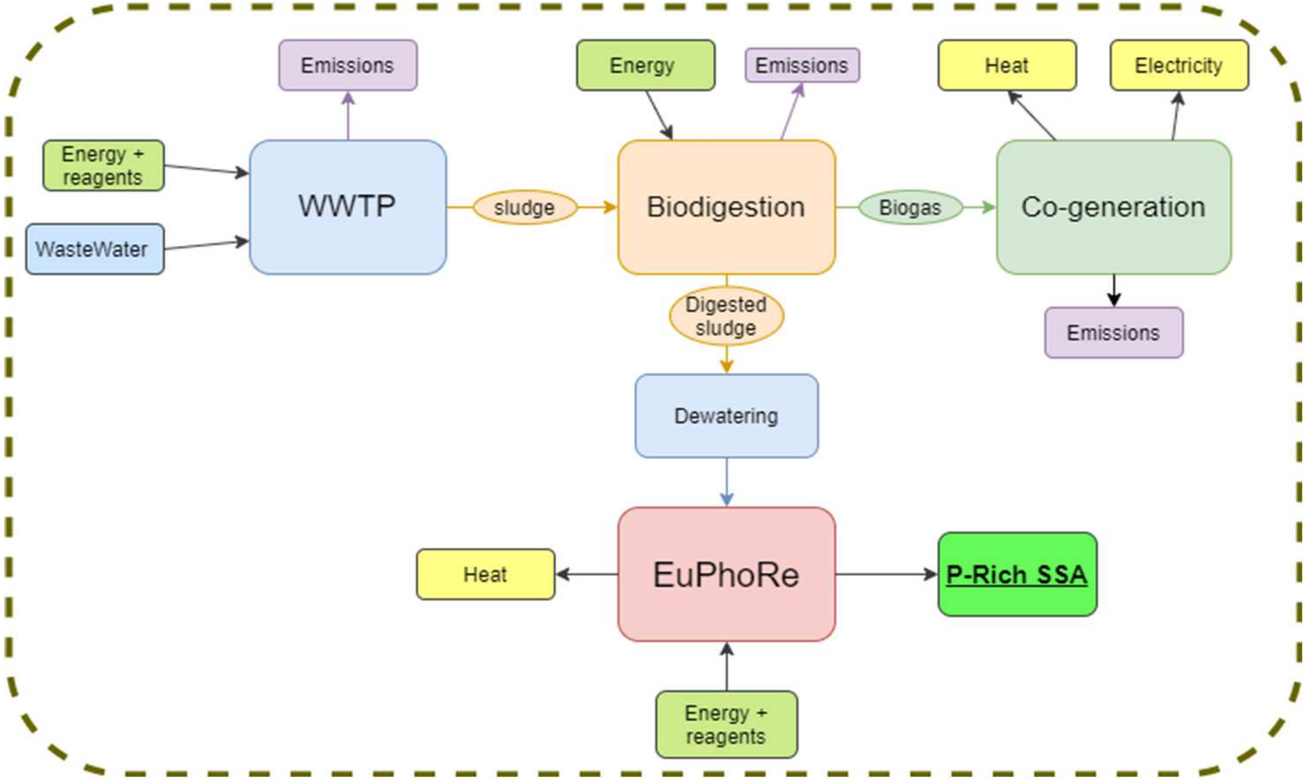


Struvia™ system: main results

- Environmental benefit on categories of mineral and fossil resource depletion
- Low impact of the Struvia™ process + increased benefit from cogeneration
- Impacting process steps: Electricity and polymers use
- Eco-design advices: Optimization of the solid/liquid separation

EuPhoRe® system: boundaries

- EuPhoRe®: Thermo-chemical process
- Functional unit: 100 m³ of wastewater treated – avoided mineral production of TSP (1.64 kg)



EuPhoRe® system: main results

- Potential environmental benefit for the categories of climate change, fossil and mineral resources scarcity → Favorable impact of the EuPhoRe® process

- Beneficial impacts of EuPhoRe® process: Recovered heat + significant avoided TSP production

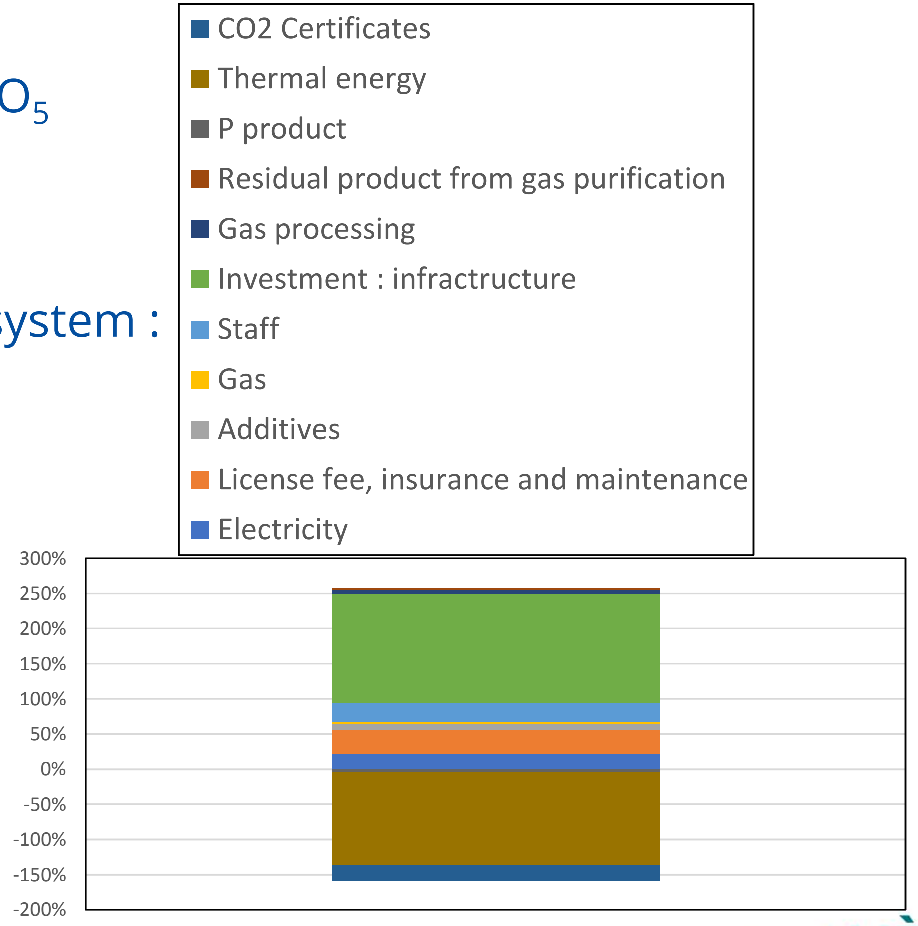
- Impacting points of the EuPhoRe® process: Electricity and additives

EuPhoRe® process: cost analysis

- EuPhoRe® P-material selling price : 0.05 € / kg P_2O_5
- TSP price (03.2021): 0.87 €/ kg P_2O_5

- Treatment cost of 1 ton of sludge by EuPhoRe® system : 135 – 145 €/t DM
- Average incineration cost: 200 - 400 €/t DM

→ Economic interest of the process for sludge valorization



Conclusions

- Advantage on **mineral resource scarcity** category for all recovery technologies: Phosphorus recovery

- Potential environmental advantage for EuPhoRe® and Struvia™ processes

- Identification of impactful steps for each process
  → **Eco-design advices**

- Two methodological approaches in LCA: Same conclusion

Take home message…

Local production of phosphorus: feasible!

→ Saving world's phosphorus mineral resources

→ Reduction of European dependence on phosphorus importing countries

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Thank you for your attention