P-REX

Performance of nine technologies for phosphorus recovery from wastewater

Overview from the European P-REX project

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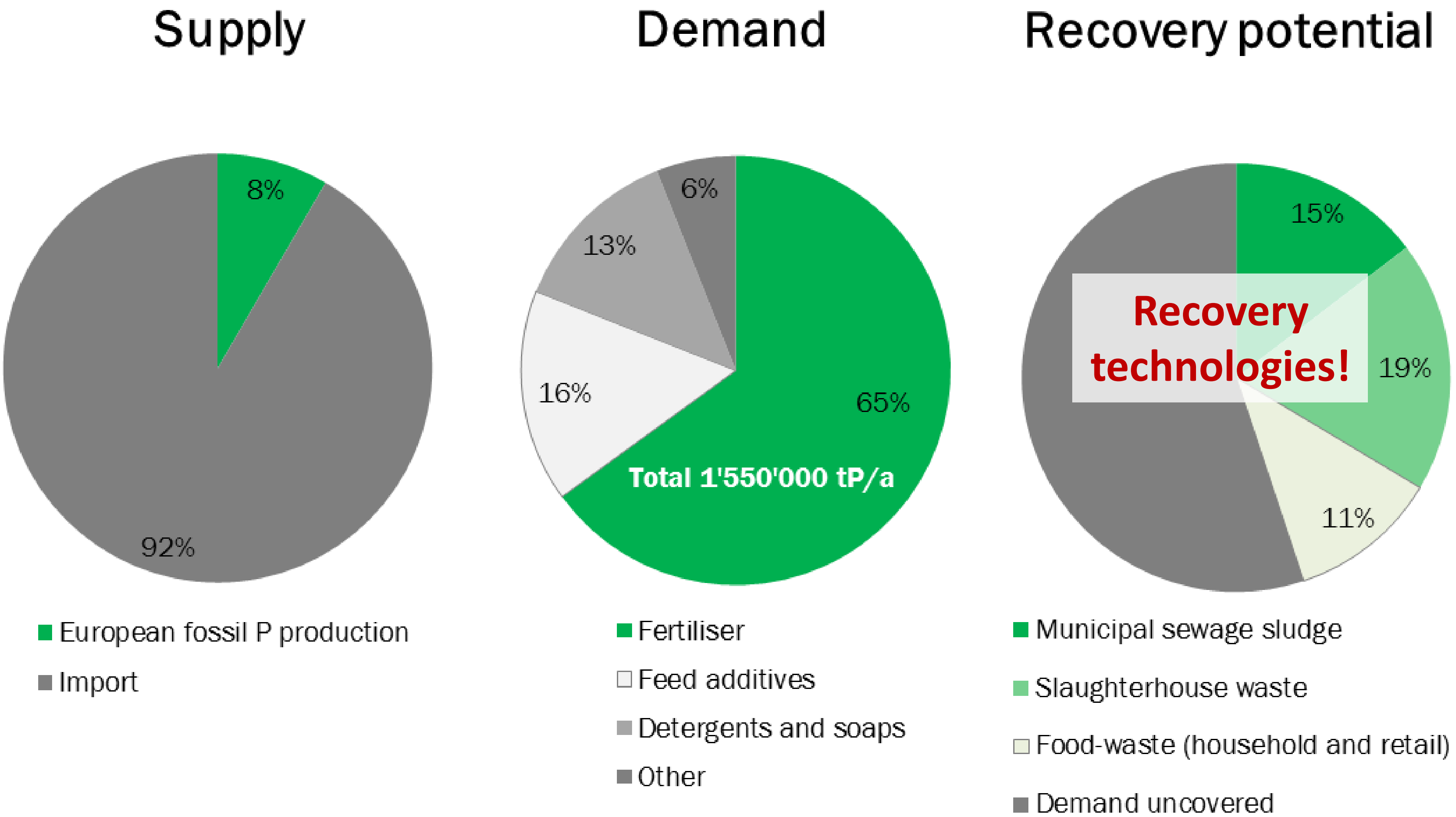
PHOSPHORUS RECYCLING
FROM PROTOTYPE TO MARKET

How do we get a safe mineral P supply?



Supply

Demand

Recovery potential

Recovery technologies!

Conventional (organic) recycling today
147 kt in sewage sludge and
1700 kt in manure recycled

Sources: P-REX policy brief
Van Dijk et al "Phosphorus flows and balances of the European Union Member States
http://www.sciencedirect.com/science/article/pii/S0048969715305519

Overview P-REX

- FP7 European Research and demonstration project
- Period: 2012-2015
- 15 Partner from 8 countries
- 4.4 million € (EU: 2.9 million €)

Overall Objective: EU-wide implementation of phosphorus recovery and recycling from wastewater considering regional conditions

Presentation

- Demonstration and technical assessment of recovery processes
  - Process properties
  - Fertilizing potential and contaminants of recovered materials

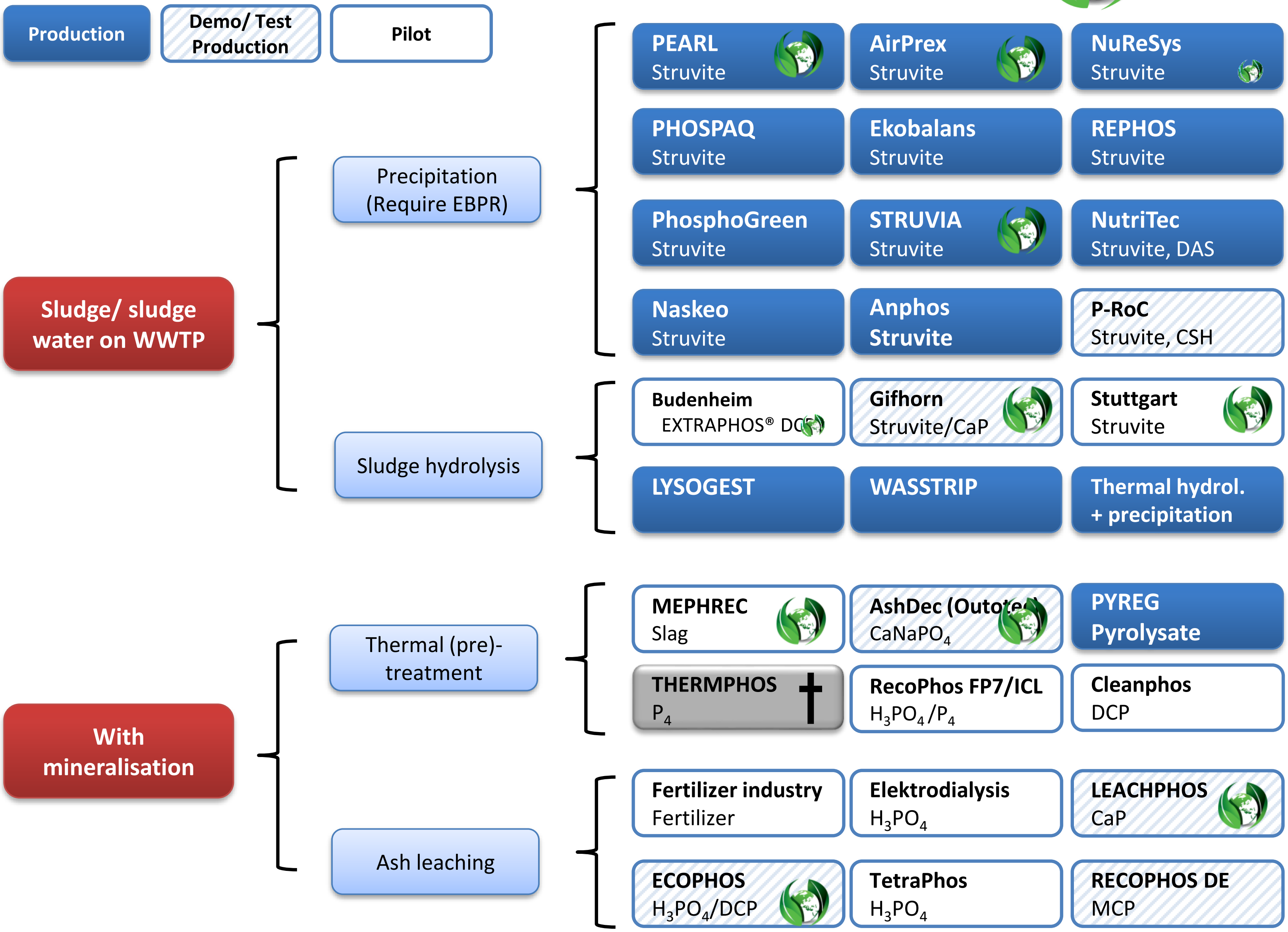
- Environmental impact and costs in relation to valorization of sewage sludge in agriculture and mineral fertilizers

Recovery processes for

→ improvement of quality of waste streams

→ tapping unused potentials

Processes in Europe



Production

Demo/ Test Production

Pilot

Sludge/ sludge water on WWTP

Precipitation (Require EBPR)

PEARL Struvite

AirPrex Struvite

NuReSys Struvite

PHOSPAQ Struvite

Ekobalans Struvite

REPHOS Struvite

PhosphoGreen Struvite

STRUVIA Struvite

NutriTec Struvite, DAS

Naskeo Struvite

Anphos **Struvite**

P-RoC Struvite, CSH

Sludge hydrolysis

Budenheim EXTRAPHOS® DCP

Gifhorn Struvite/CaP

Stuttgart Struvite

LYSOGEST

WASSTRIP

Thermal hydrol. + precipitation

With mineralisation

Thermal (pre)-treatment

MEPHREC Slag

AshDec (Outotec) $CaNaPO_4$

PYREG **Pyrolysate**

THERMPHOS P_4 †

RecoPhos FP7/ICL H_3PO_4/P_4

Cleanphos DCP

Ash leaching

Fertilizer industry Fertilizer

Elektrodialysis H_3PO_4

LEACHPHOS CaP

ECOPHOS H_3PO_4/DCP

TetraPhos H_3PO_4

RECOPHOS DE MCP

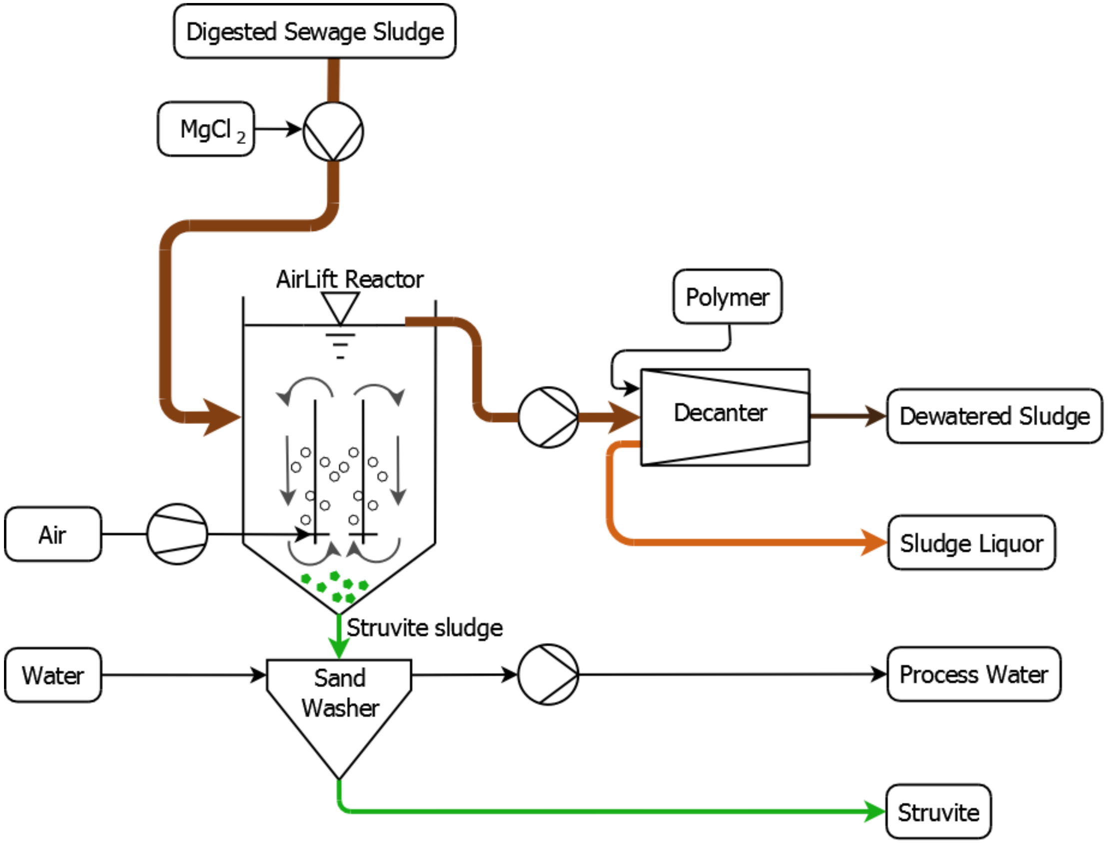
The assessed processes

Scenario	Process name	Data quality
Sludge Precipitation	Airprex™	Commercial production
Liquor precipitation 1	Pearl®	Commercial production
Liquor precipitation 2	Struvia™	Pilot
Sludge leaching 1	Gifhorn	Test production
Sludge leaching 2	Stuttgart	Pilot
Sludge metallurgic	Mephrec®	Pilot
Ash leaching 1	LeachPhos	Test production
Ash leaching 2	Ecophos	Commercial P rock. Pilot ash. No technical assessment in P-REX.
Ash thermo-chemical	Ashdec	Test production

Partial data on Budenheim, Crystalactor, Nuresys

AirPrex process

Sludge precipitation



Digested Sewage Sludge

$MgCl_2$

AirLift Reactor

Polymer

Decanter

Dewatered Sludge

Sludge Liquor

Air

Struvite sludge

Water

Sand Washer

Process Water

Struvite

precipitation reactor, several full scale plants

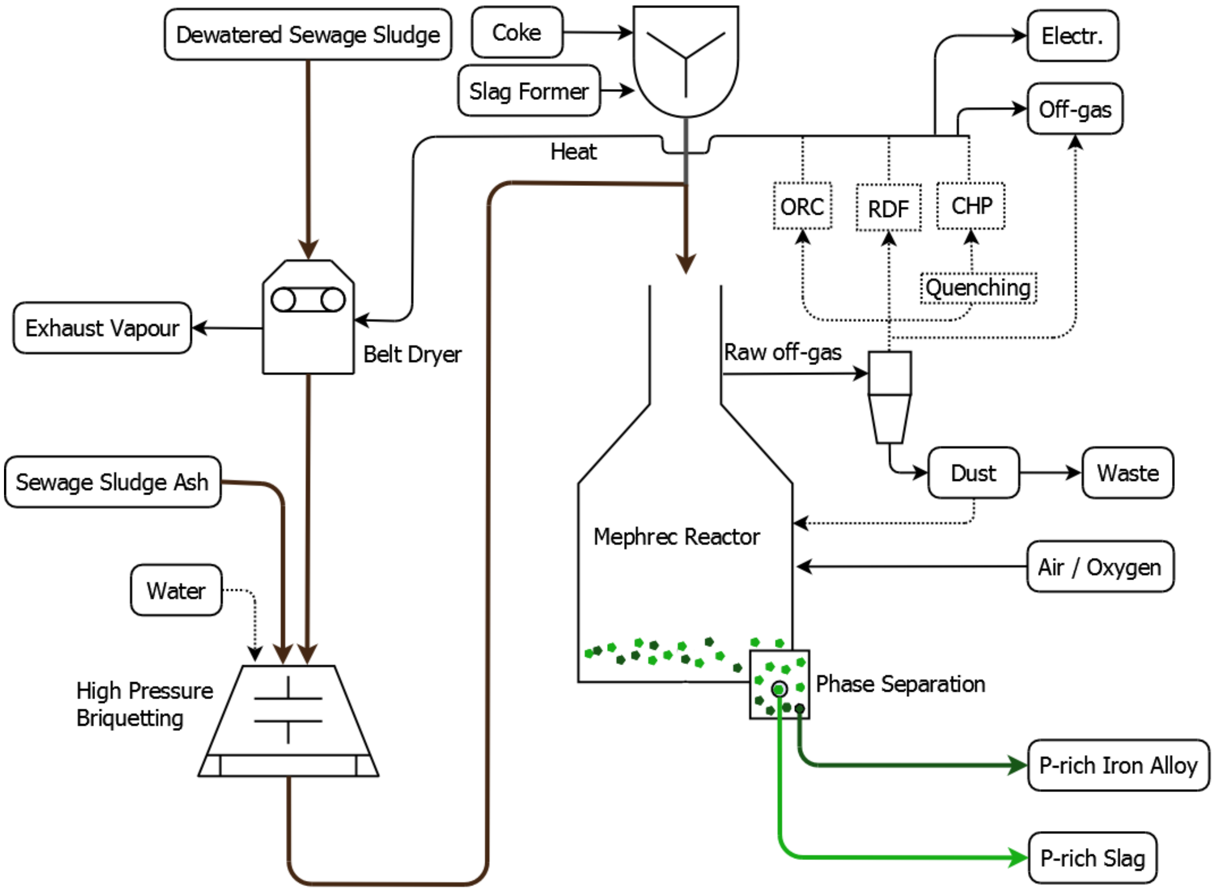
[CNP]

product

[CNP, BWB]

Sludge metallurgical treatment

Mephrec



Pre-Pilot trial 2008
1.5 t briquettes

KRN Mephrec

Pilot plant 07/2016 to 10/2017, Nürnberg, Germany:
0.5 t/h briquette
1000 h operation time
6.7 M€

www.nuernberg.de

Summary technologies

- **Mineral outputs**
- **Purification, concentration and/or increase in plant availability**
- **Product grade**
    - 20%-30% P_2O_5 on DM in struvite from sludge and sludge liquor
    - Lower for metallurgic and thermochemical treatment. Higher for ash leaching
- **Process yield (% of P in sludge)**
    - ~10% precipitation
    - ~50% sludge leaching
    - 70-100% dry sludge or ash based

.

Fertilizer potential of recovered materials

- Recovered Materials are often only sparely water soluble
- Fertilizer potential using
  - Solubility in neutral ammonium citrate
  - Pot trials for «relative agronomic efficiency» (RFE) compared to Triplesuperphosphate (TSP)

Pot trials

- 7 recovered materials

- References: ash, sludge Chem-P and EBPR, TSP

- Two years with one P application for short and longer term availability
- Two soils different in pH-value
- Maize plant height and mass development
- Exact tests: nutrient adjustments and replications

Results fertilizer potential

Process	Material	RFE Y1 (average pH 5&7) %	RFE Y2 (average pH 5&7)	Solubility in NAC+ H2O %	RFE,Y1, RFE,Y2 and NAC ≥80%?
Sludge precipitation 1	Struvite	110	91	94	YES
Liquor precipitation 1	Struvite	72	90	94	NO*
Sludge leaching 2	Struvite	95	93	96	YES
Sludge metallurgic	Slag	23	33	6	NO
Ash leaching 1	CaP	80	95	95	YES
Ash thermochem Na2CO3	Ash	93	86	99	YES
MgCl2	Ash	47	48	28	NO**
Sewage sludge ash	Ash	31	41	16	NO
Sewage sludge, chem-P	Sludge	53	67	95	NO
Sewage sludge, EPBR	Sludge	87	102	90	YES
TSP	TSP	100	100	92	YES

*Die off of plants in two pots and limited growth in another two at pH 5 first year. >80% RFE at pH 7.

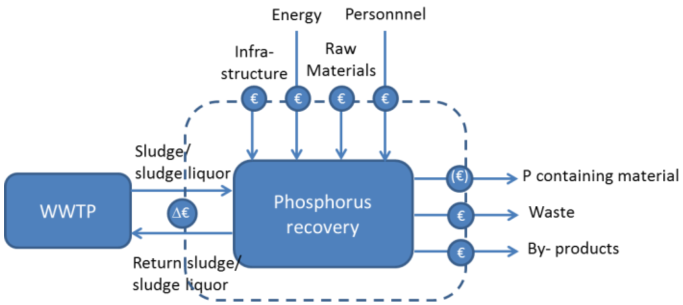
** >80% RFE at pH 5

Contaminants in recovered materials

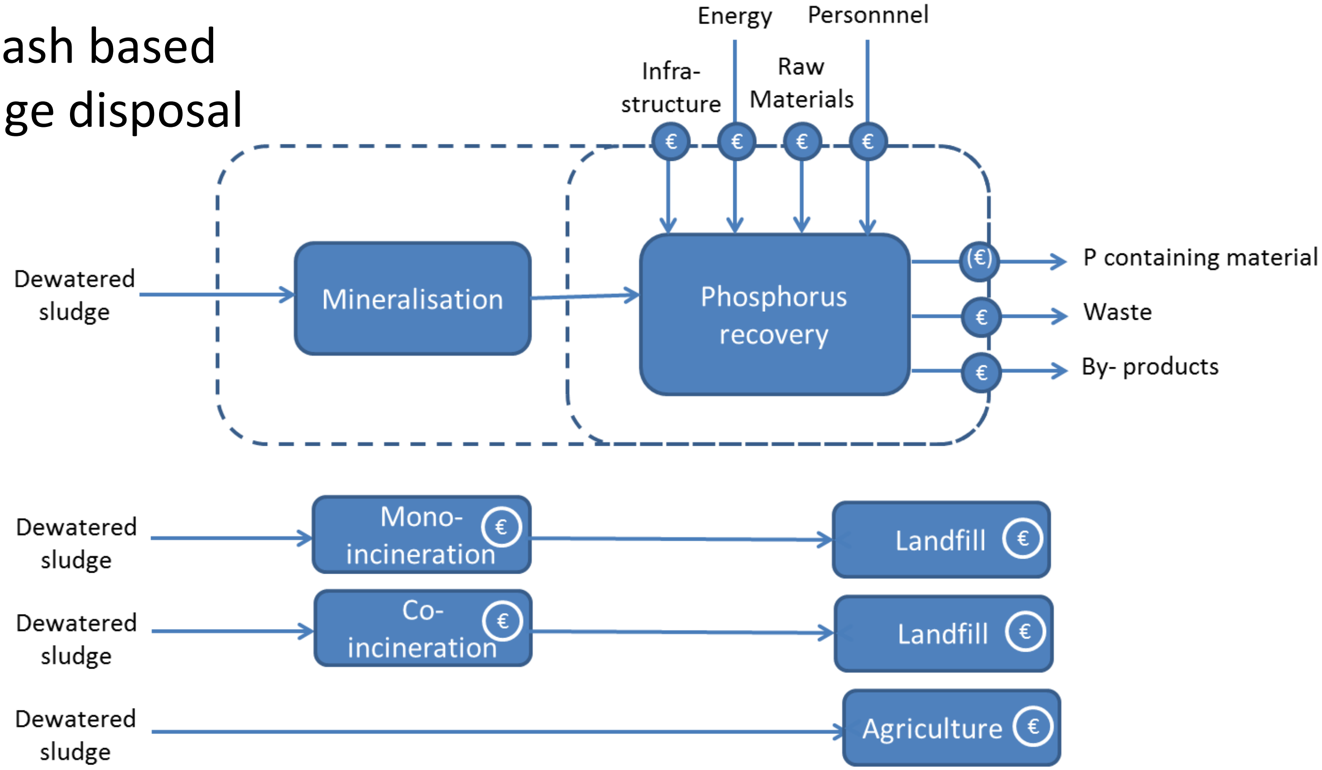
- Contaminants limited in German fertilizer regulation measured
- PCDD/F, dl-PCB, PAH, As, Cd, Cr, Cu, Hg, Ni, Pb, Zn
- All recovered materials fulfill the strict German fertilizer regulation with regards to heavy metals.
- Organic contaminants measured only for struvite and are within German limits
- Risk assessment based on the measured contents shows risk for exceeding Zink and Cadmium acceptable limits for ground water and Zink acceptable limits for soil organisms.

Environmental and cost assessment

- Sludge and sludge water based processes, on WWTP



- Dried sludge and ash based processes, in sludge disposal



Results life cycle assessment

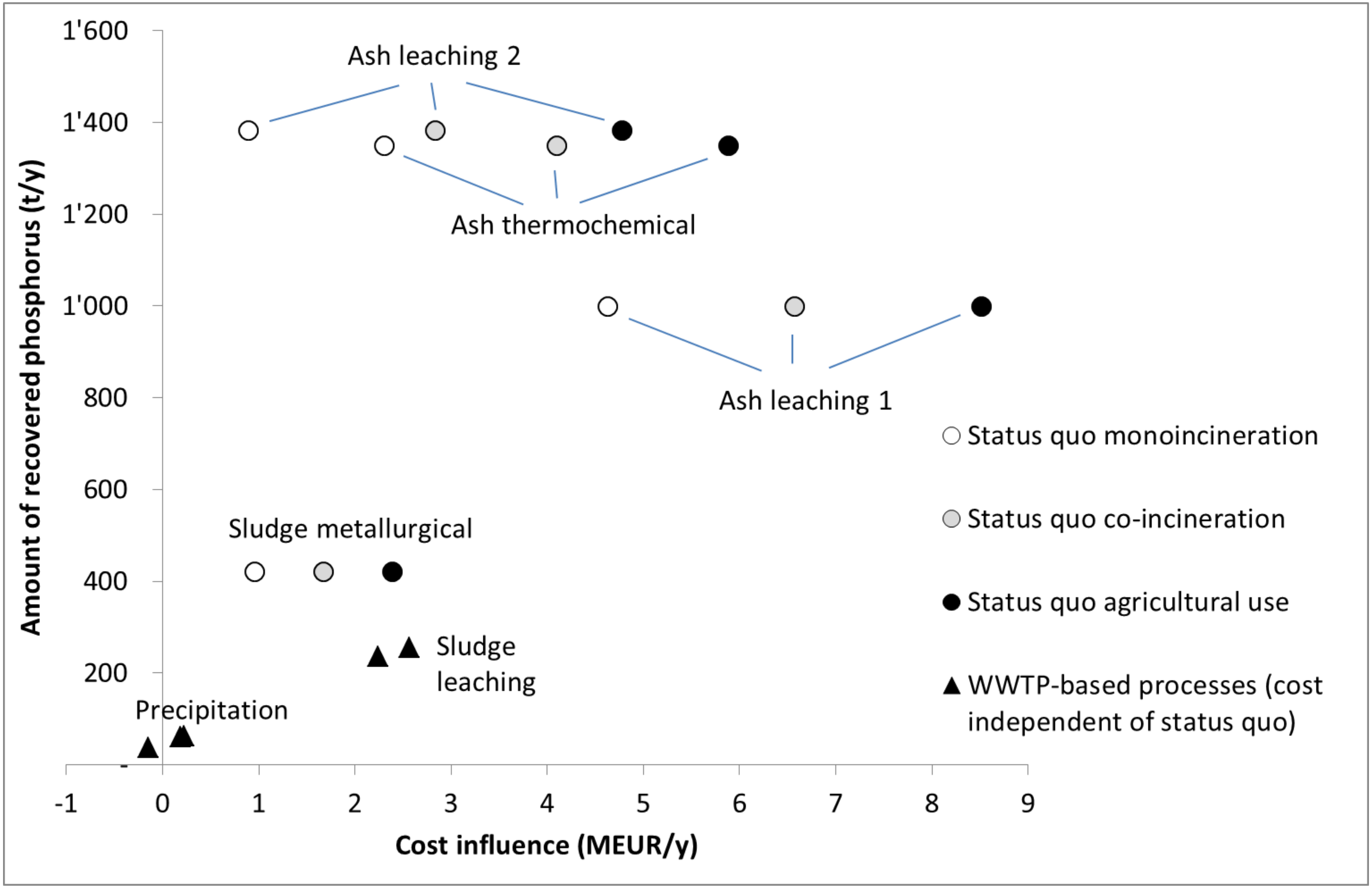
Environmental impacts of P recovery from 1 Mio pe WWTP

Pathways	**Fossil energy demand**	**Eco-toxicity (USE-tox)**
Unit per a	*[Mio MJ]*	*[Mio CTU]*
Sludge disposal	*-46*	*9.6*
Sludge precipitation	-9,5	0,9
Liquor precipitation 1	-5,0	-1,0
Liquor precipitation 2	-4,8	-0,9
Sludge leaching 1	24,1	-2,0
Sludge leaching 2	51,6	10,0
Sludge metallurgic, integr.	-26,0	38,6
Ash metallurgic	-14,5	38,9
Ash leaching 1	2,7	147,0
Ash leaching 2	-6,1	-9,6
Ash thermo-chemical, integr.	-12,6	421,6

Baseline

Mono-incineration

Results cost assessment, standard size plants 1 or 2.5/2.7 Mio PE



Summary of environmental and cost assessment

- **Impact dependent on the process and existing infrastructure, e.g. mono-co-incineration**
- **Environmental assessment**
  - Scenarios for P recovery have different environmental profiles, some can realize P recovery with overall environmental benefits.
  - Assessment result depends on the method used, e.g. Ecotox
- **Cost assessment**
  - Bad news: Cost influence per kg P mostly higher than mineral fertilizer cost
  - Good news: Costs influence per PE <3% of wastewater disposal cost

Conclusion

- **P-REX shows applicability**
  - Technologies for P-recovery from sewage sludge are applicable already today
  - Recovery and recycling with costs of less than 3% of wastewater disposal cost
  - Environmental gain by recovery shown and improvement of the phosphorus supply security is obvious
- **Where to apply**
  - Where concerns regarding the sludge quality and logistics exist: to purify, concentrate, make plant-available and improve storage properties
  - Where nutrients contained in sewage sludge are wasted today

➔ Turning waste phosphorus into a real replacement for mineral phosphorus imports!

Source: P-REX policy brief

P-REX

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Thank you for your attention!

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We would like to thank all involved project partners
and other contributors

Download at www.p-rex.eu and soon at https://zenodo.org/ :
Technical Factsheets for processes
Reports on processes, recovered materials, environmental impact and more
P-REX policy brief

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