P-REX

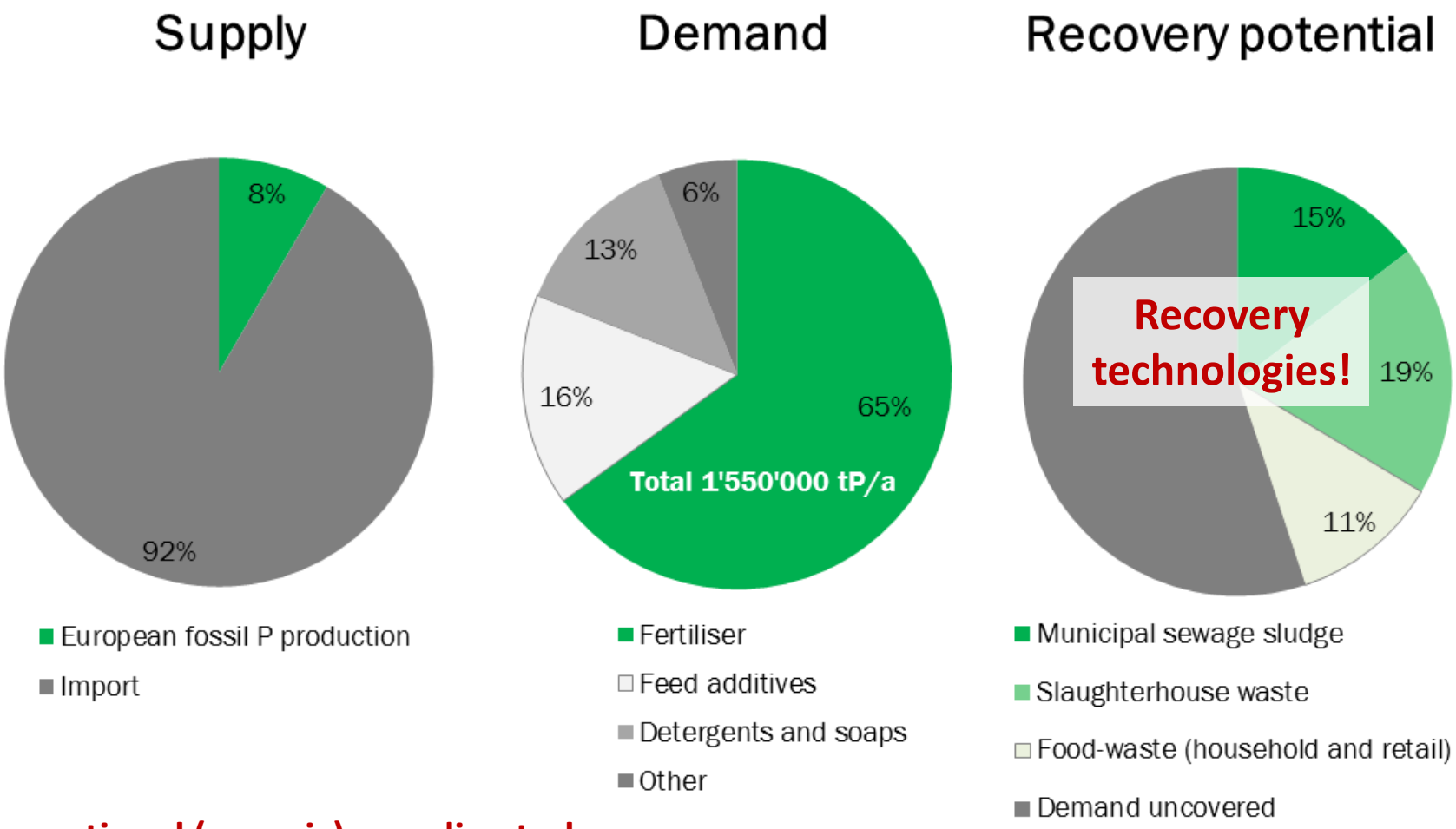
Performance of nine technologies for phosphorus recovery from wastewater

Overview from the European P-REX project

Anders Nättorp, Jan Stemann
FHNW, University of Applied Sciences and Arts Northwestern Switzerland
Christian Remy, Christian Kabbe
KWB, Berlin Centre of Competence for Water
Verena Wilken, IASP
Hannes Herzel, *BAM* Federal Institute for Materials Research and Testing

PHOSPHORUS RECYCLING
FROM PROTOTYPE TO MARKET

How do we get a safe mineral P supply?



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

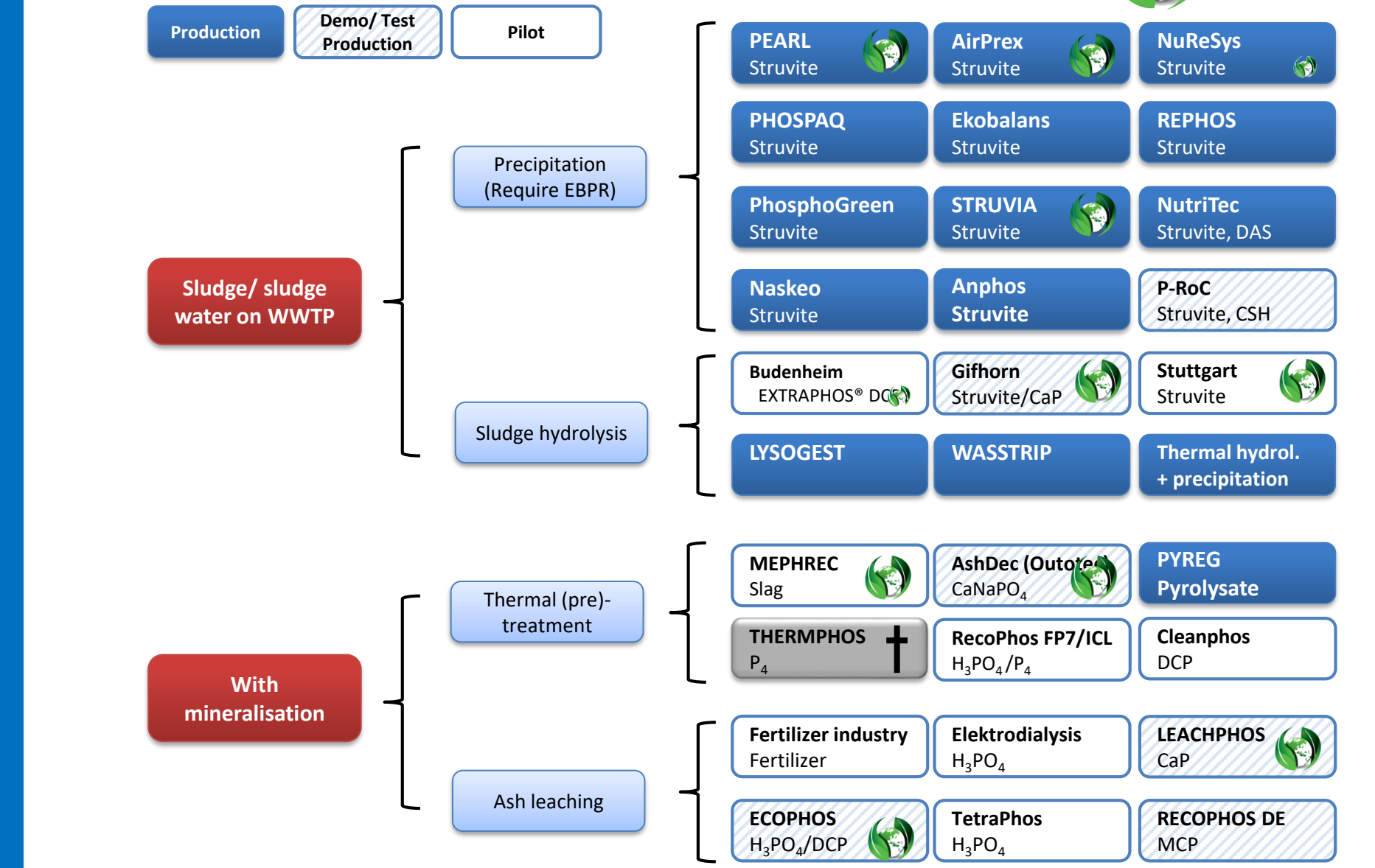
Recovery processes for

➔ improvement of quality of waste streams

➔ tapping unused potentials

Processes in Europe

P-REX

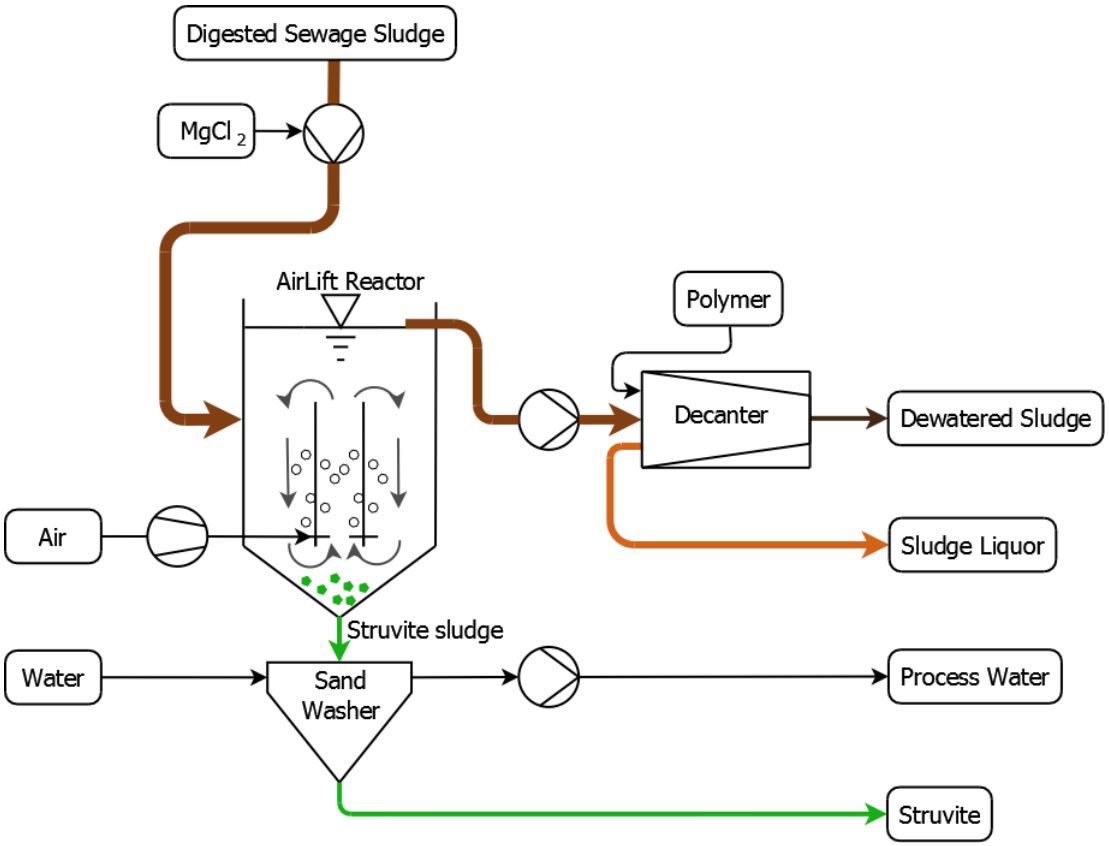


The assessed processes

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

Sludge precipitation



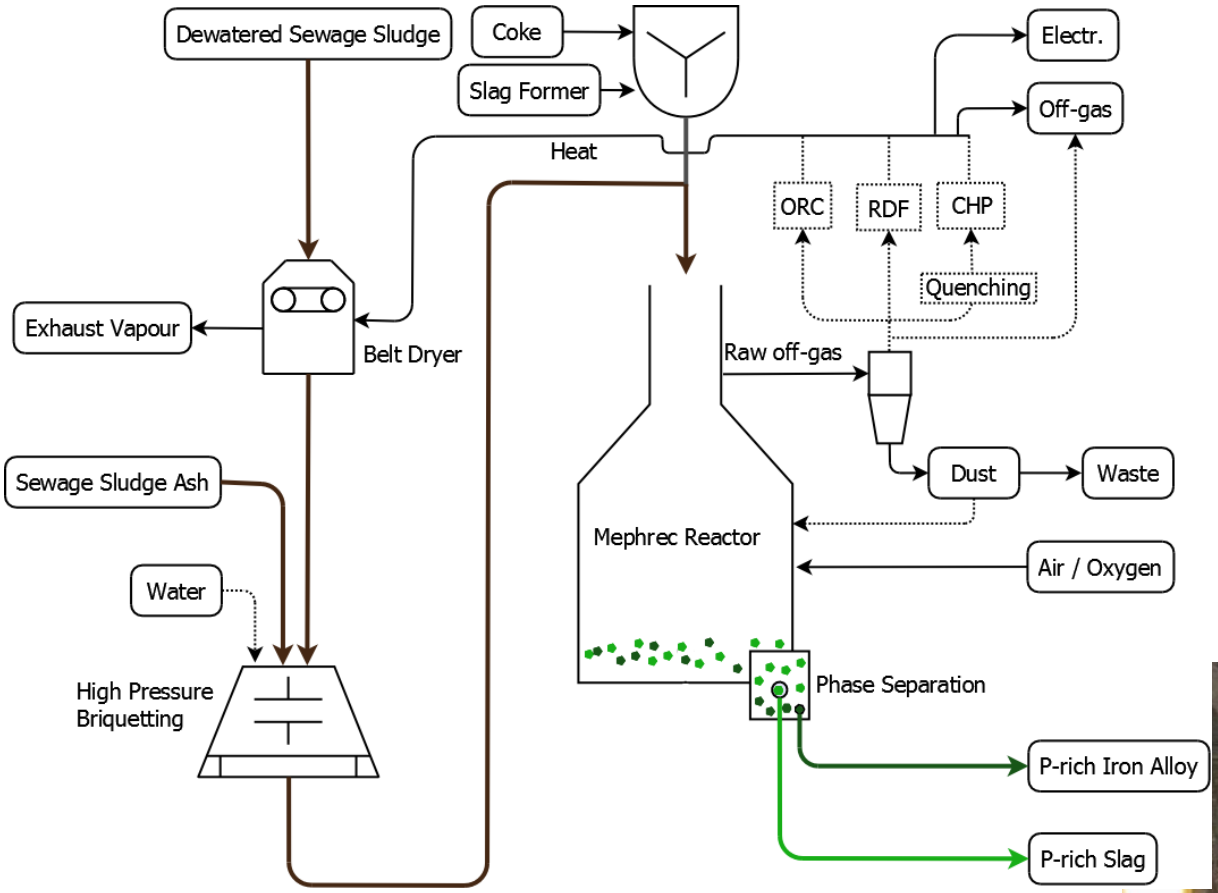
precipitation reactor, several full scale plants

[CNP]

product

[CNP, BWB]

Sludge metallurgical treatment



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

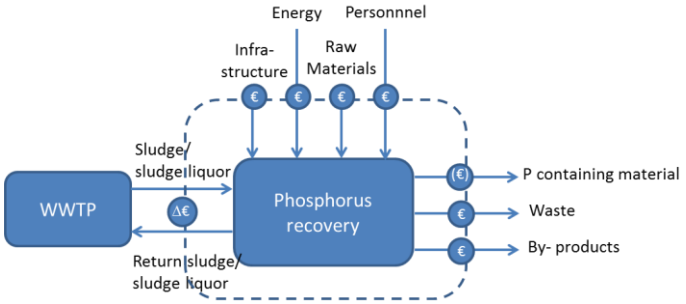
*Die off of plants in two pots and limited growth in another two at pH 5 first year. >80% RFE at pH 7.
** >80% RFE at pH 5

Contaminants in recovered materials

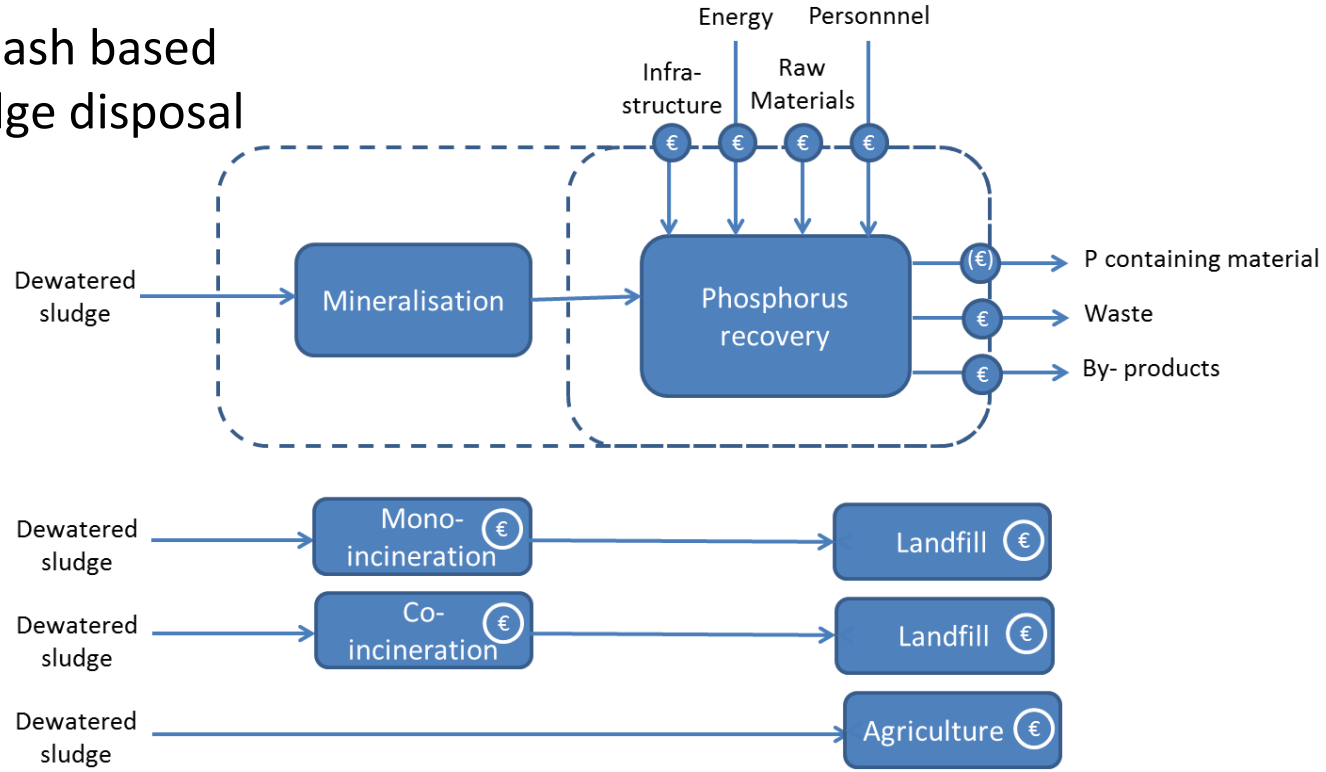
- Contaminants limited in German fertilizer regulation measured
- PCDD/F, dl-PCB, PAH, As, Cd, Cr, Cu, Hg, Ni, Pb, Zn
- All recovered materials fulfill the strict German fertilizer regulation with regards to heavy metals.
- Organic contaminants measured only for struvite and are within German limits
- 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



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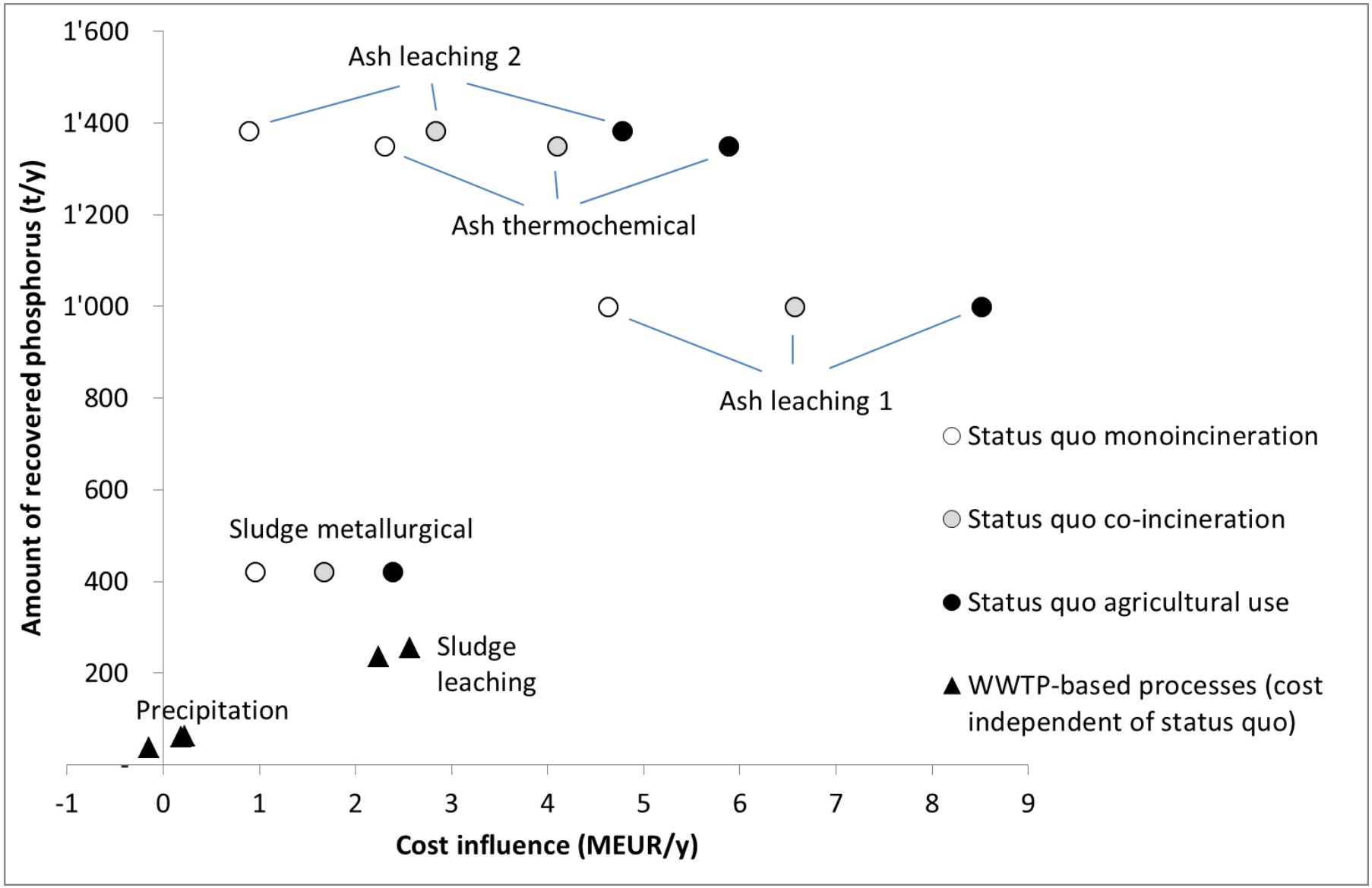
Environmental impacts of P recovery from 1 Mio pe WWTP

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

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Thank you for your attention!

Contact: anders.naettorp@fhnw.ch

Project coordinator: christian.kabbe@kompetenz-wasser.de

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

This project has received funding from the European Union's Seventh Programme for Research, Technological Development and Demonstration under Grant Agreement no. 308645.

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