Incineration of Biosolids Provides a Pathway for Maximum Phosphorus Recovery – A German Approach

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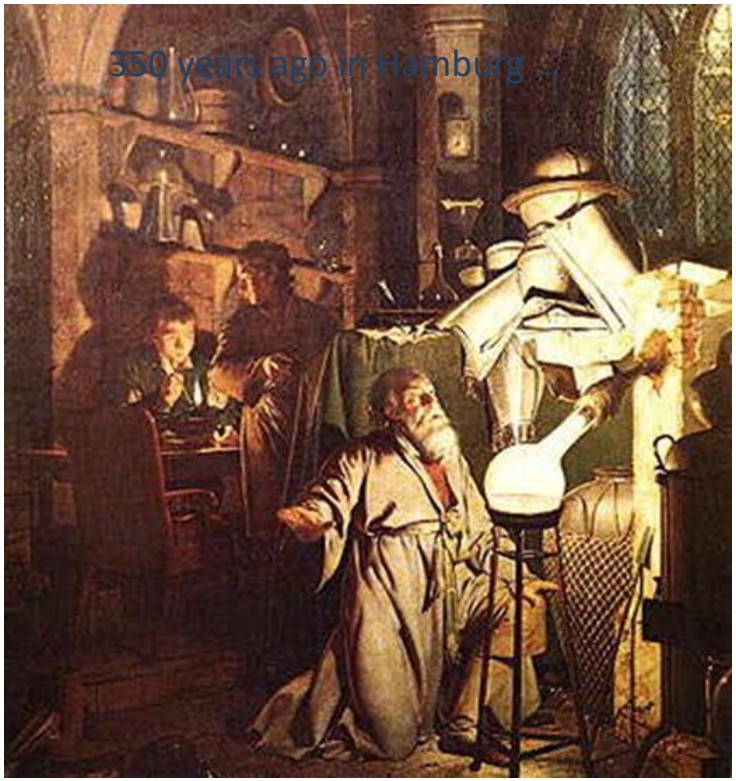
February 4, 2021

Agenda

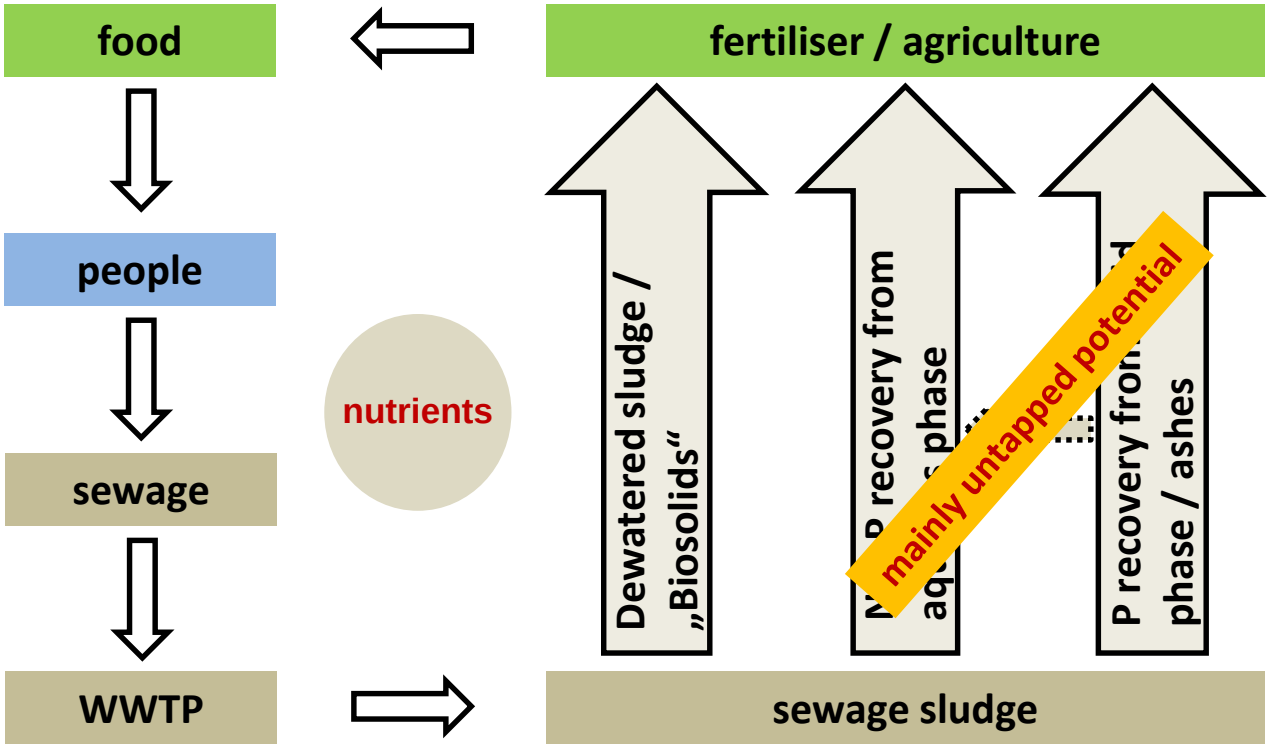
- New Regulations and their Impact
- Emerging Phosphorus Recovery Technologies
- Value Chain and Market Considerations



Henning Brand discovering phosphorus in 1669 in Hamburg (Joseph Wright)

Nutrient Recovery & Recycling

Challenge: Enabling techn. alternatives to complement /compensate traditional route!



Long-term security for disposal

Acceptance

Hygiene

Contaminants

Heterogenity

Concerns

Uncertainties

Monitoring Cost

Surplus manure

Transparency

German Regulatory Drivers

- **Phosphorus recovery**
  - Phosphorus necessary nutrient for fertilizer and modern agriculture
  - Phosphate supply sources limited, dependent on imports
  - Biosolids untapped renewable source

- **Reduce biosolids land application**
  - Nutrient runoff from biosolids/manure contributes to eutrophication
  - Biggest concern in areas of concentrated food production
  - Farmer will prefer manure to biosolids if regulations force choice

New German Regulations (2017)

- Manure ordinance (DÜV, GER) limits nutrient loads applied to land and acutely reduces sludge disposal capacities
- Fertilizer ordinance (DÜMV) sets stricter quality criteria (less biosolids conform) – monitoring cost increases
- Sewage sludge ordinance (AbfKlärV) requires phosphorus recovery
  - For large WRFs (>50,000 p.e.), if > 2% P in sludge
    - Recovery 50% of P from sludge, or reduce to sludge < 2% P, or
    - Incinerate with P recovery of >80% from ash
    - For >100,000 p.e., starts in 2029, for >50,000 p.e., starts in 2032

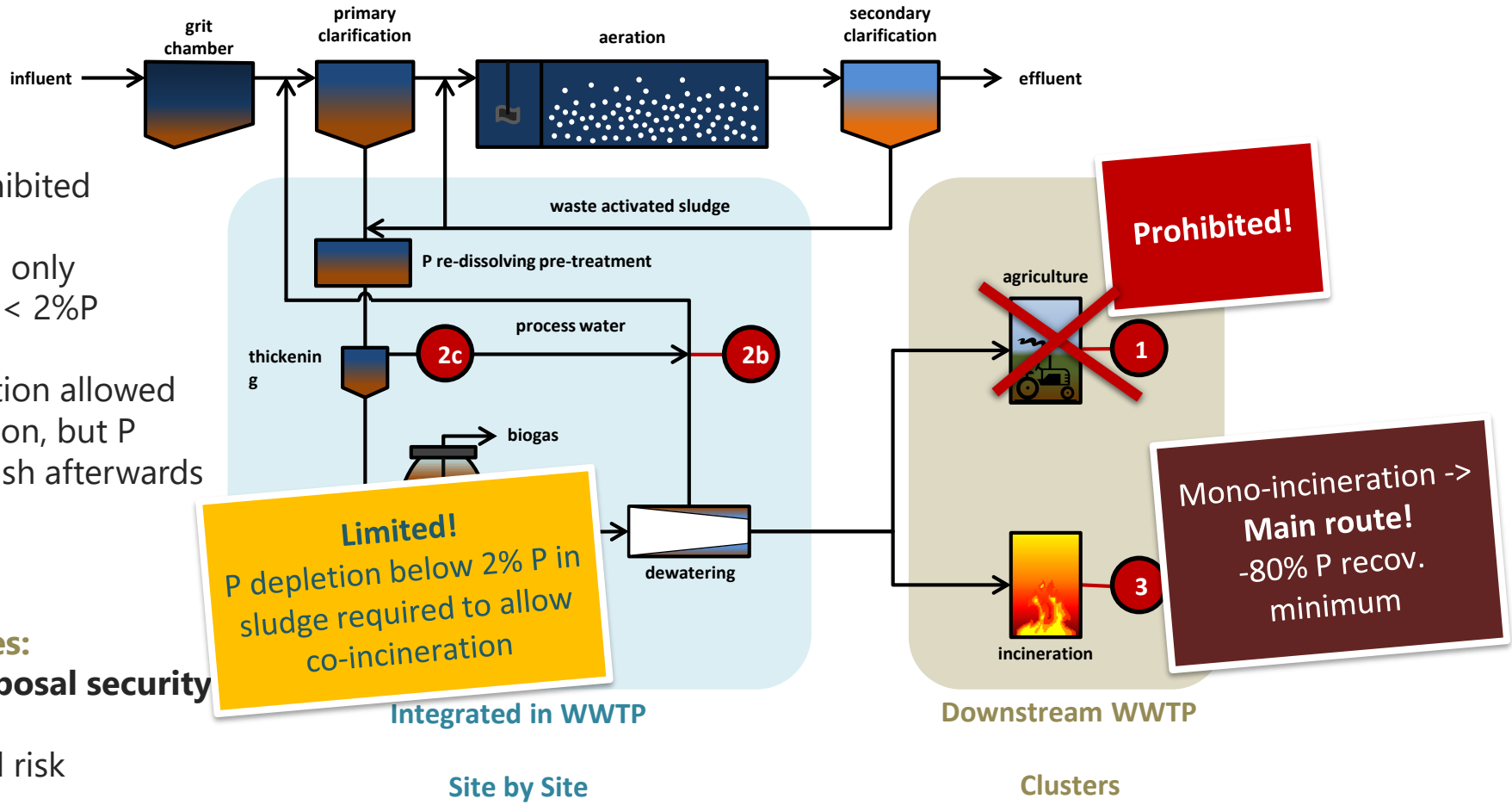
P Recovery & for WRFs > 50.000 p.e.

2029/32+

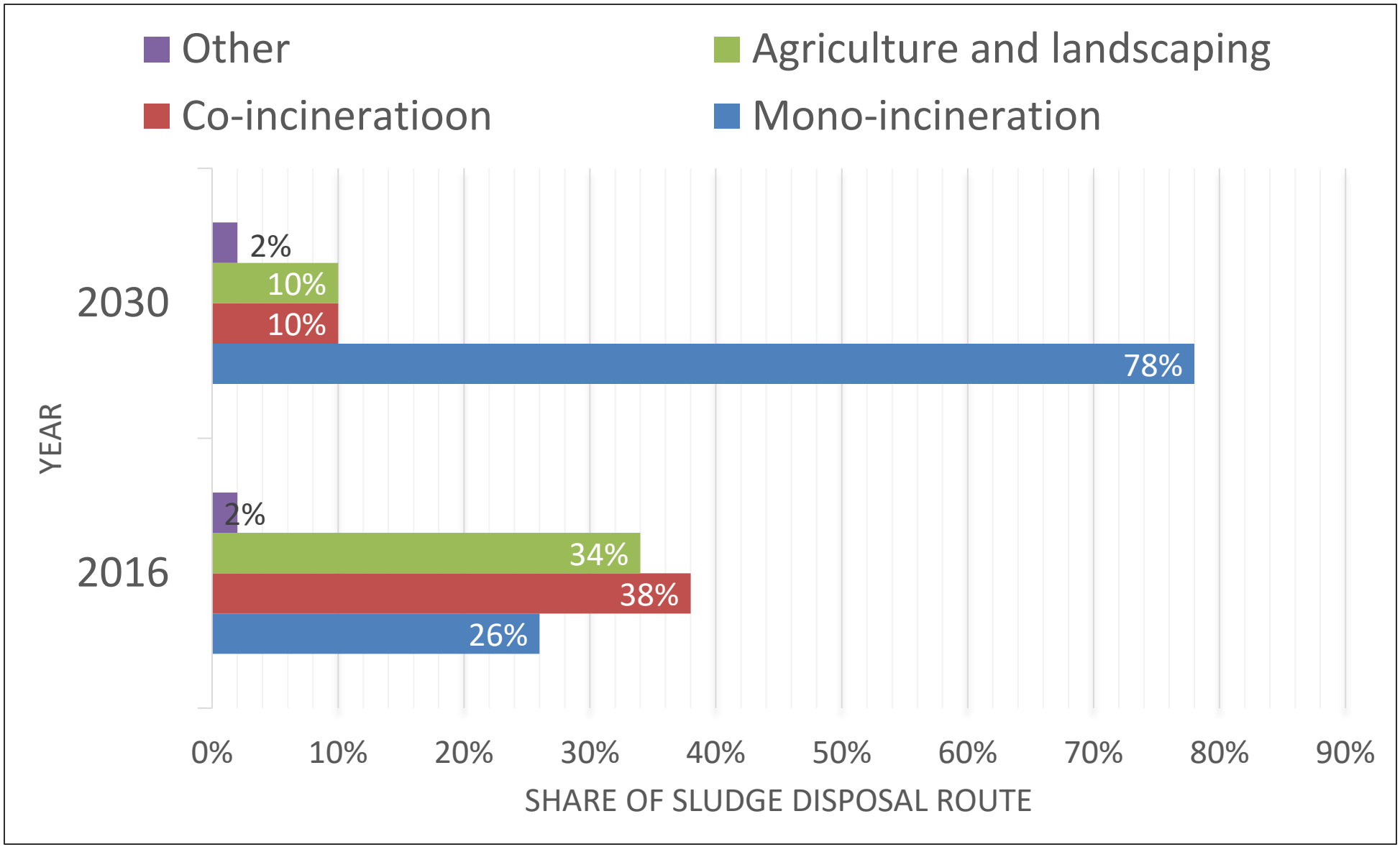
- Land appl. prohibited
- Co-incineration only for sludge with < 2%P
- Mono-incineration allowed without restriction, but P recovery from ash afterwards required

Priority for utilities:

- **Long-term disposal security**
- Cost control
- Lowest financial risk



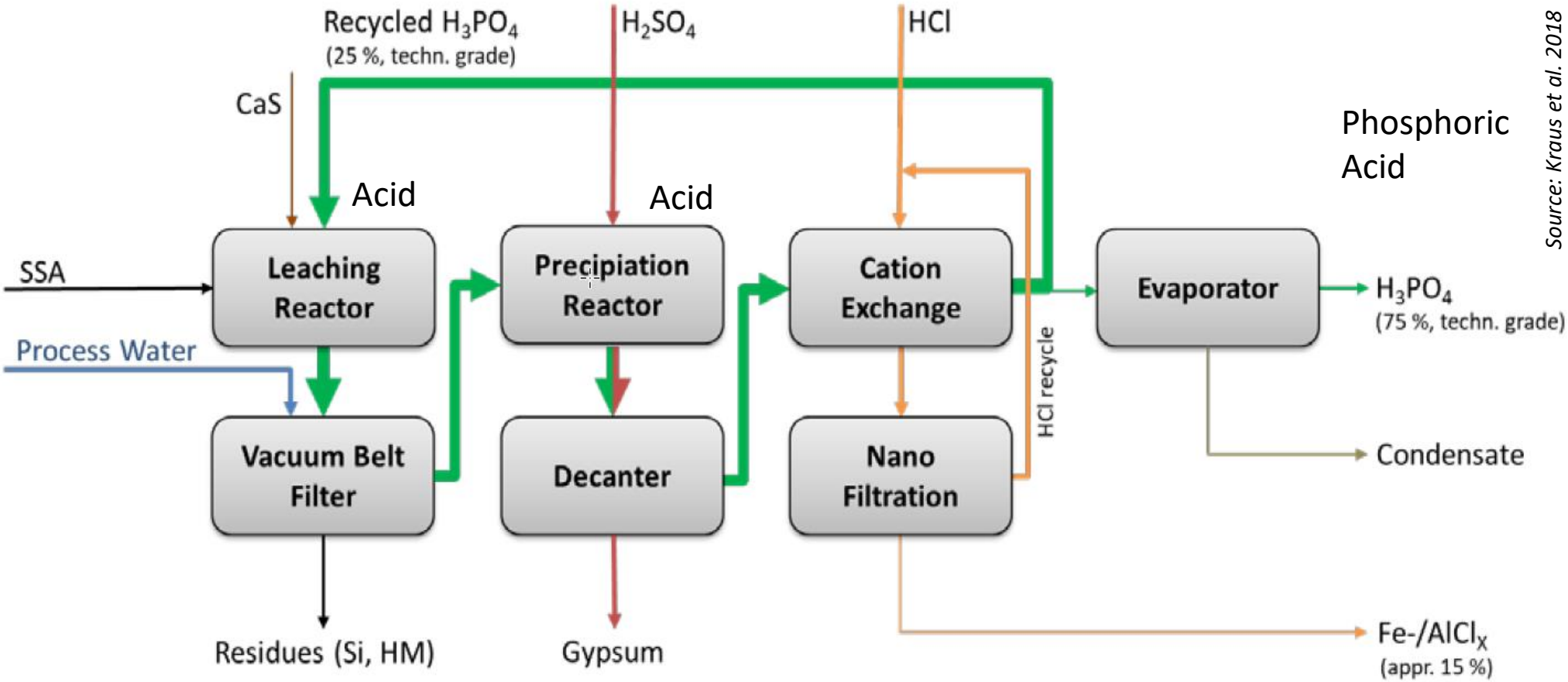
German Biosolids Use/Disposal Options



Regs Driving Technology Development

Name / Company	Process Description	Product(s)	Development Stage
TetraPhos® / Remondis Aqua (Germany)	Acid leaching, filtration, acid precipitation, ion-exchange, and evaporation	High-grade phosphoric acid	Pilot, full-scale in construction
Ash2®Phos / Easy Mining (Sweden)	Acid leaching, alkaline precipitation of phosphorus, additional dissolution/precipitation	Calcium phosphate, additional products with more stages	Pilot tested, full-scale in preparation
METAWATER / METAWATER (Japan)	Alkaline leaching, separation, alkaline precipitation, drying and granulation	Calcium hydroxyapatite (HAP)	2 full-scale facilities in operation since 2010 and 2013
AshDec® / Outotec (Finland)	Thermochemical calcination using sodium sulfate, reducing agent, and heat	Phosphorus pentoxide (20-35%) in ash matrix	Pilot tested, full-scale in preparation
PHOS4green / Glatt Seraplant (Germany)	Suspension, with added phosphoric acid, water, and nutrients, granulation, drying and cooling	Various phosphate and complex fertilizers based on added nutrients	Pilot tested, full scale in construction

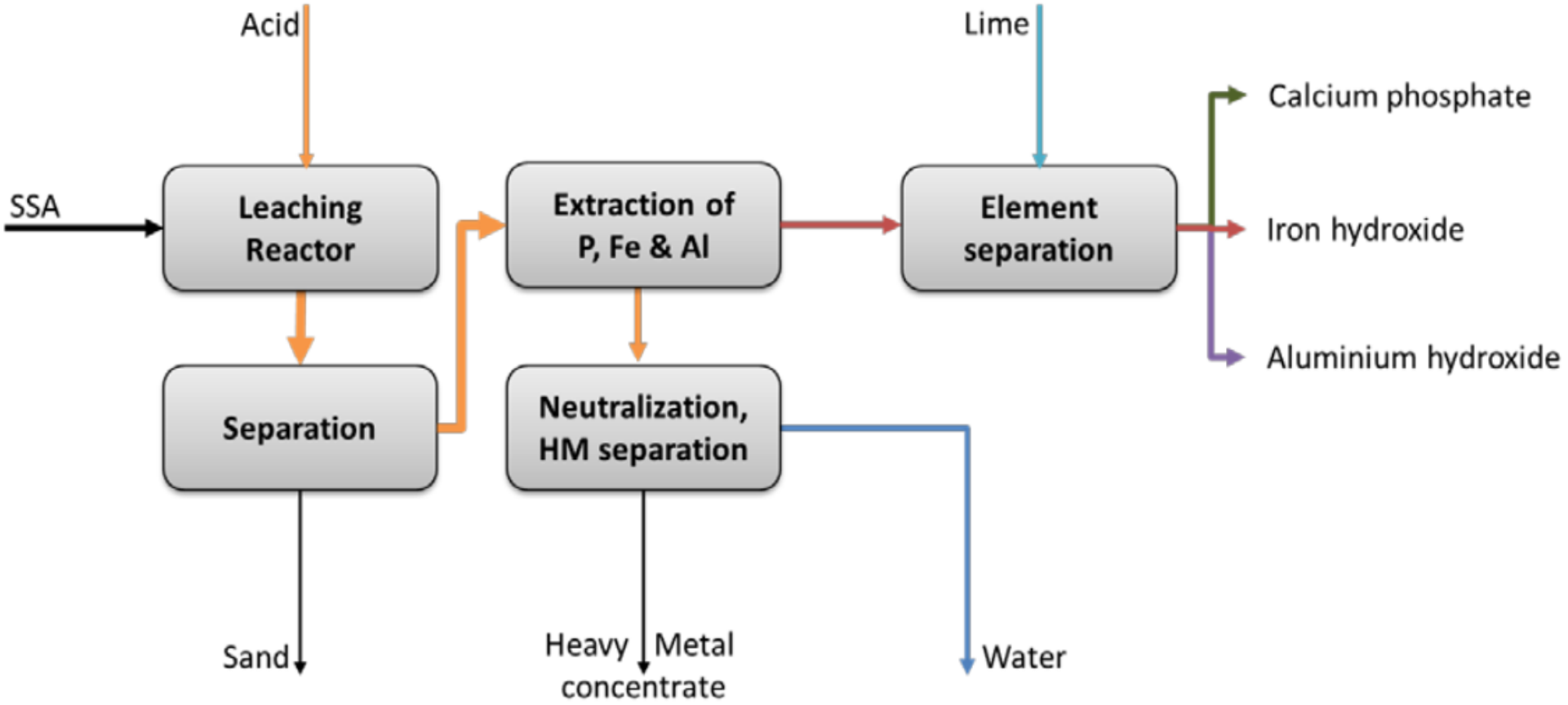
Tetraphos®



Source: Kraus et al. 2018

- ✓ Flexible low-grade inputs
- ✓ Commercial products (H_3PO_4), need evaporation
- ✓ Heavy metal-decontamination by IEX
- ✓ Successfully piloted
- ✓ Full-scale under construction (Hambug 20 kt ash/a)
- – Evaporation requires heat

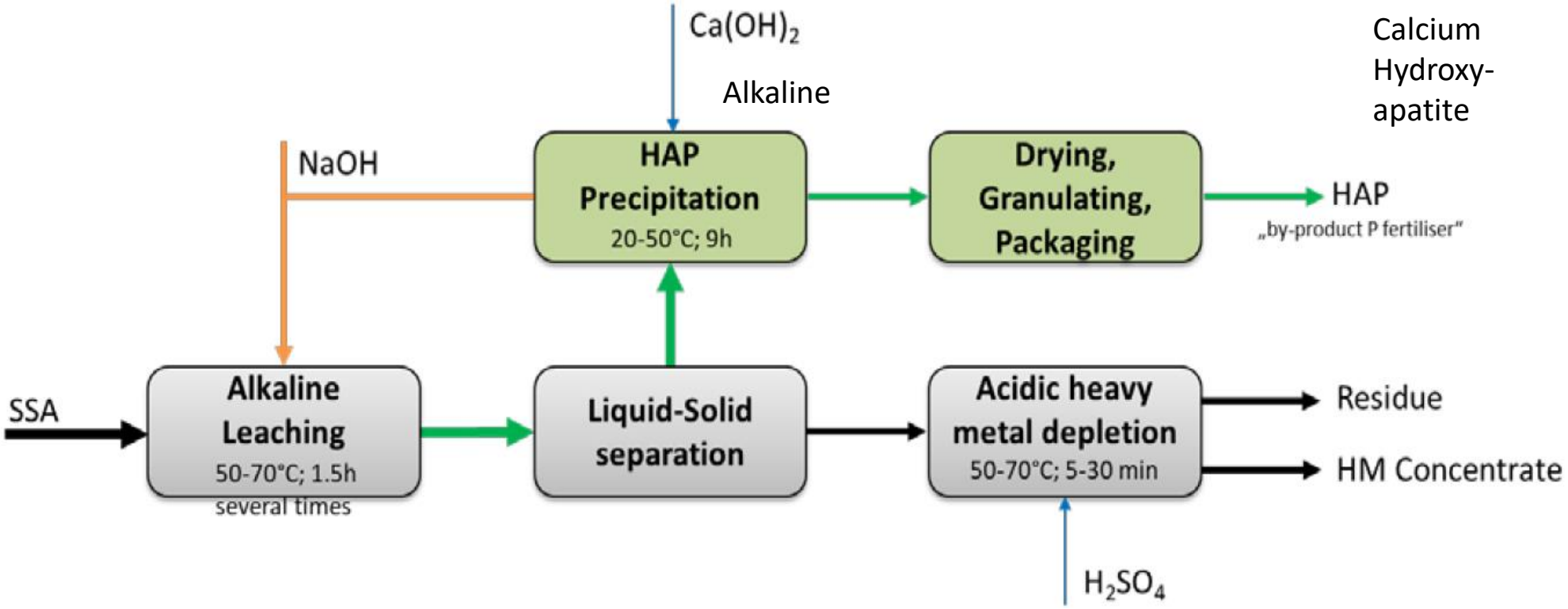
Ash2®Phos



- ✓ **Flexible low-grade inputs**
- ✓ **Commercial P products**
- ✓ **Independent of Fe/Al and ash moisture**
- ✓ **Heavy metal decontamination**
- ✓ **Low energy input, successfully piloted**
- ✓ **Full-scale in Sweden and Germany in prep.**

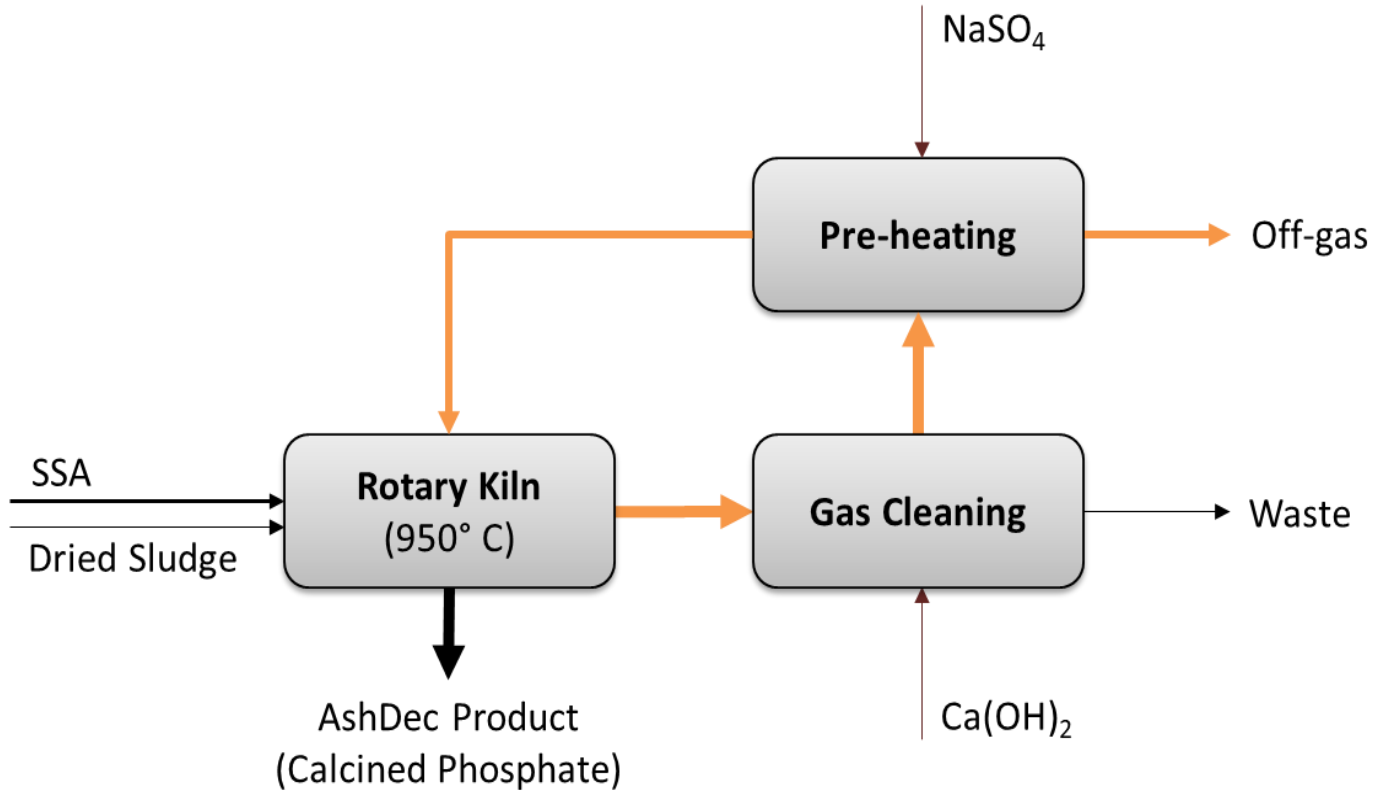
Source: http://www.easymining.se/our-technologies/ash2phos/

METAWATER



- ✓ **Marketable P product**
- ✓ **Recycled process inputs**
- ✓ **Minimum waste products**
- ✓ **Heavy metal decontamination**
- ✓ **Full-scale in operation for 10 years**

AshDec®

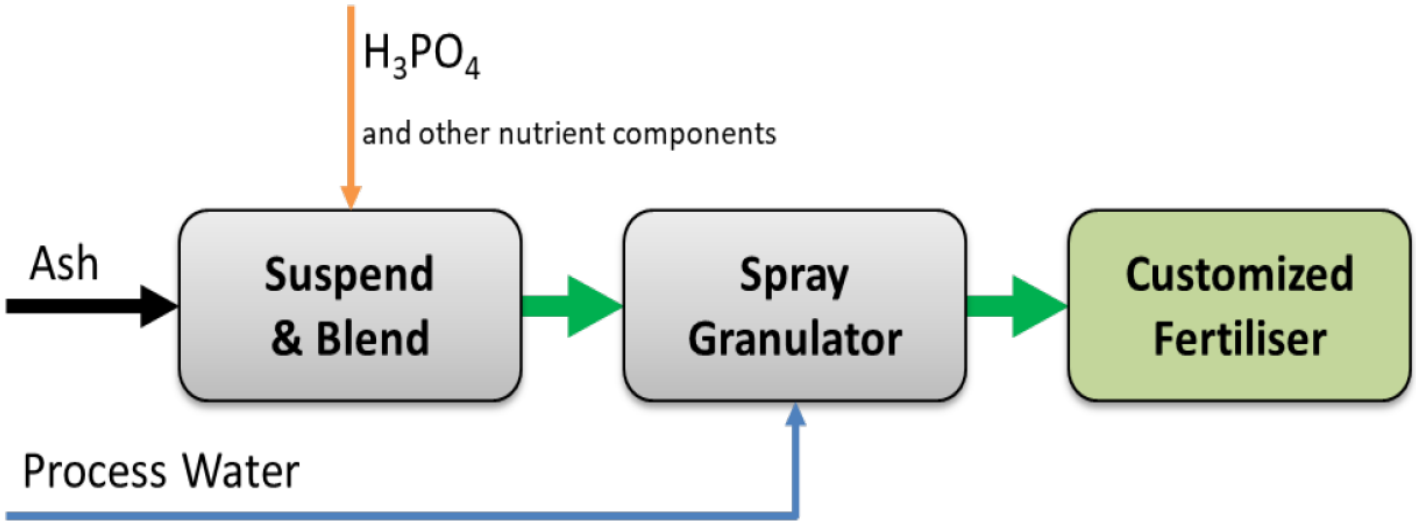


Source: adapted from Kraus et al. 2018

- ✓ Increases plant availability of P
- ✓ Depletes heavy metals (but not remove)
- ✓ Full scale plant in preparation
- – Heat input and exhaust gas cleaning
- – No definable P product/intermediate

Glatt® PHOS4green

Source: Kabbe and Rinck-Pfeiffer, 2019

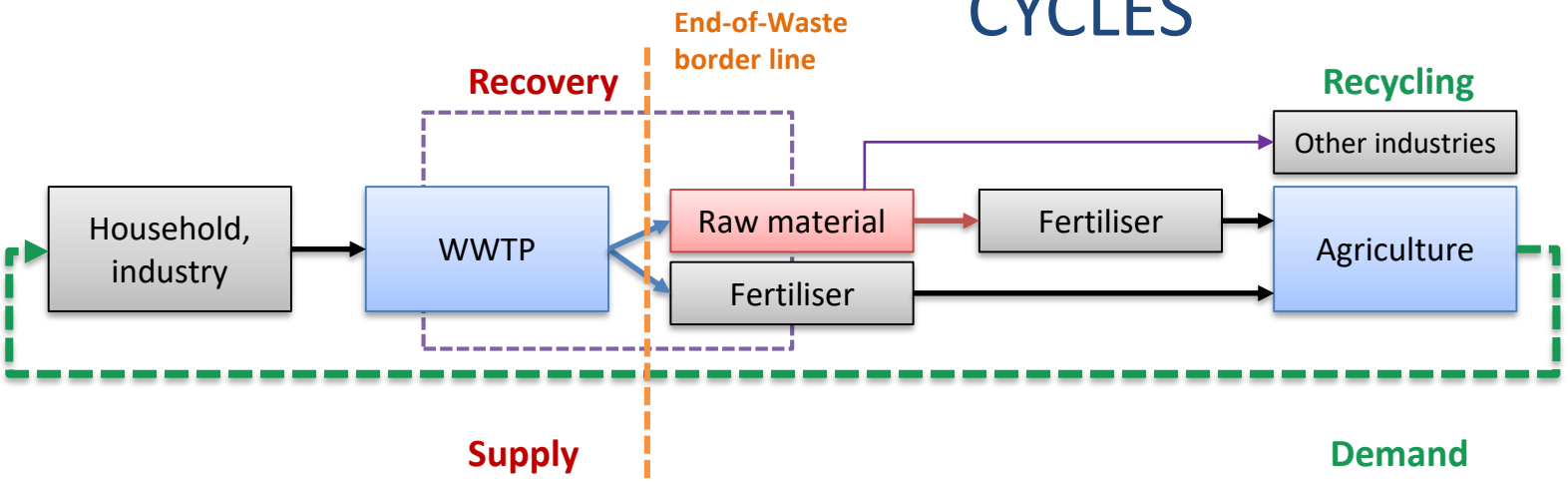


https://www.phos4green-glatt.com/home.html

- ✓ Robust and simple (only few steps)
- ✓ Proven components
- ✓ Zero waste, no disposal cost
- ✓ Customized, commercial fertilizer
- ✓ Full scale facility in construction
- – No heavy metal depletion (only dilution)
- – Limited to premium ashes
- – Consumes P (acid) to recover P

Source: SERAPLANT

NO RECYCLING WITHOUT VALUE CHAINS TO PRODUCTS CYCLES

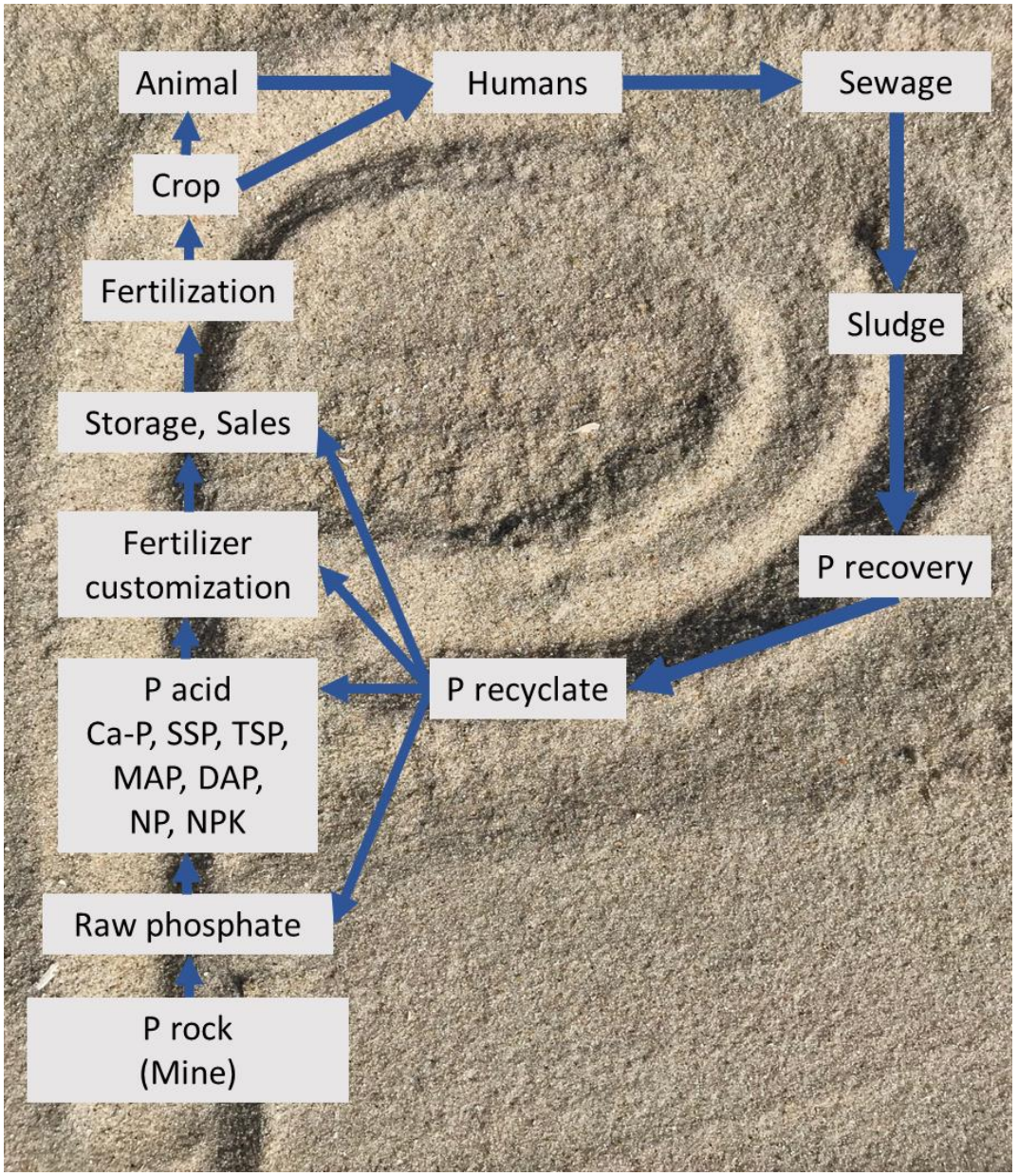


Waste, raw material or product? -> Question of volume, homogenity and still of origin!

Commodities

- Sludge/biosolids – organic fertiliser, but rather undefinable, heterogenious matrix
- Struvite – NP fertiliser in some MS (interesting for organic farming!) - definable
- SSP, TSP, DCP – approved P fertiliser (components, defined)
- Ash – barely plant available, rather raw material – processing needed, undefinable
- MAP/DAP – main N&P components in fertiliser production (defined commodities)
- MGP / P_4 – commercial products with broad application (defined commodities, corrosive!)

Closing the Loop at Several Hubs



P Materials and Market Considerations

Phosphate		Physical form	CAS number, hazard	Raw material	Fertilizer	Market share of fertilizer in Germany
Calcium phosphate	P acid (H_3PO_4)	liquid	7664-38-2, corrosive	X		
	Apatite (Ca-P)	solid	1306-05-4	X	X	2%
	SSP (Ca-P) (and PK from SSP) TSP (Ca-P)	solid solid solid	8011-76-5, corrosive, irritating 65996-95-4, corrosive, irritating	X X	X X X	0,5% (7.5%) 5%
	MAP (mono-ammonium phosphate) DAP (di-ammonium-phosphate)	solid solid	7720-76-1, irritating 7783-28-0, irritating	X X	X X	5% 56.5%
	"mixed acid route" NP NPK	solid solid	various, customized end products		X X	4% 7.5%
	„nitro-phosca route" NP NPK	solid solid			X X	4.5% 7.5%

Source: Kraus et al. 2018

Emerging Technology Summary

- Multiple technologies emerging in German market to recover >80% P from ash
- Wet chemical extraction processes which remove heavy metals will meet regulations
- Low grade inputs, low energy are advantages
- Time/market will determine which are most effective
- Utilities interested in resource recovery can track the development and benefit from experience

North American Beneficial Ash Use

- Past efforts to use ash in construction products, only partially successful due to limited scale
- Growing experience of using ash for nutrient value
  - California facility, ash used as component in fertilizer
  - Ohio plant, ash used to enhance soil products
  - Minnesota utility sponsoring research demonstrating nutrient benefits for crops

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