
# Resource Recovery from Biosolids - Phosphorus and Energy

Wednesday October 31, 2018

1:00 – 2:30 PM ET

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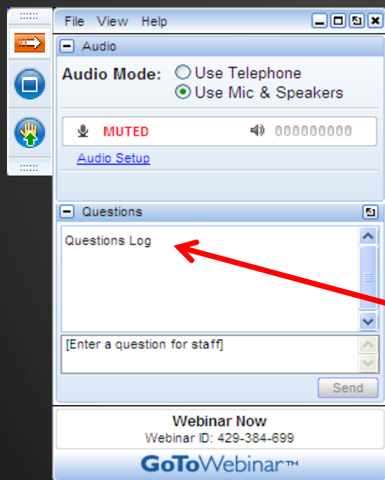
# How to Participate Today




- **Audio Modes**
  - Listen using Mic & Speakers
  - Or, select "Use Telephone" and dial the conference (please remember long distance phone charges apply).
- **Submit your questions using the Questions pane.**
- **A recording will be available for replay shortly after this webcast.**

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# Today's moderator

**Peter Brady**
**Alpine Technology**

ALPINE TECHNOLOGY, INC.
AUTOMATION/OPTIMIZATION CONTROLS

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# Today's speakers

- Dr. Christian Kabbe
  - Phosphorus Recovery and Recycling in Europe – Why?
  - Phosphorus Recovery and Recycling goes Global – How?
- Greg Homoki
  - Energy Recovery for Sludge Incineration

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# Our next speaker

**Dr. Christian Kabbe**
**Isle Utilities Germany**

isle

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# Phosphorus Recovery & Recycling in Europe

Why?

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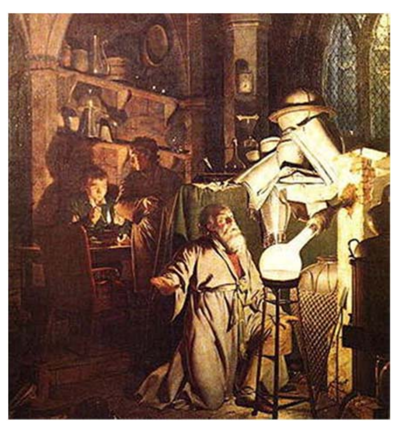
# Agenda

01 Why? Background

02 Nutrient recovery – How and where?

03 Market issues

04 Outlook



*Joseph Wright of Derby: Henning Brand discovering phosphorus in 1669*

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**Phosphorus**
Life's bottleneck! Limits the biomass potential of the planet!
*Isaac Asimov 1959*

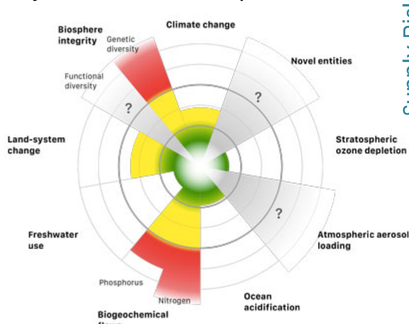
1. **Phosphorus is essential to life, non renewable**
   - **Phosphate rock limited availability**
2. **Geostrategic dependency of EU on few countries**
   - **EU import dependency 92% of fossil based P (Germany 100%)**
   - **Phosphate rock on EU list of 20 Critical Raw Materials since 2014**
   - **$P_4$ at CRM list since 2017**
3. **Environmental impact of active phosphorus (surplus coming from waste)**

*P-REX Policy Brief (2015)*

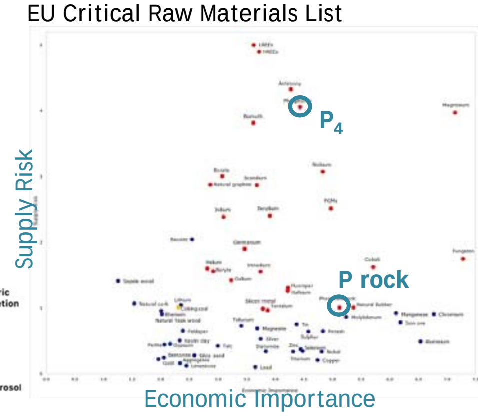


# Why Phosphorus - global?

Planetary boundaries concept

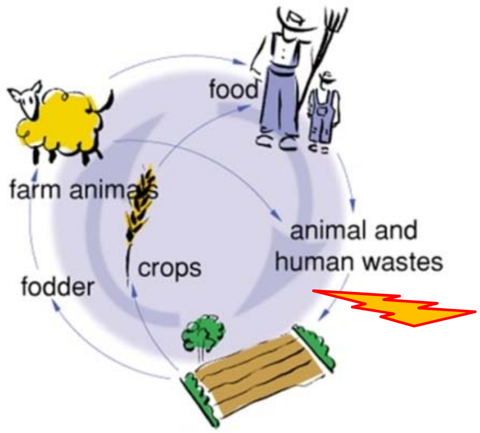



EU Critical Raw Materials List




https://www.stockholmresilience.org/research/planetary-boundaries/planetary-boundaries/about-the-research/the-nine-planetary-boundaries.html

# The broken cycle




90% fertilizer animal feed

**263 million tons fossil P rock**
**(global mining 2017, USGS 2018)**

- Increase crop yield
- Compensate dissipation and losses

Adapted from: http://www.nhm.ac.uk/research-curation
/research/projects/phosphate-recovery/ceep11.htm

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# Relevant renewables

| [kton P/year] | Total | Recycled | Potential |
|---|---|---|---|
| Sewage sludge | 297 | 115 | 182 |
| Biodegradable solid waste | 130 | 38 | 92 |
| Meat & bone meal | 128 | 6 | 122 |
| **Total** | **427-555** | **153-160** | **274-396** |
| **Manure recycling =** | **1 736** | | |
| ***Mineral fertiliser use =*** | ***1 448*** | | |

Van Dijk & Oenema "Overview of phosphorus flows in wastes in Europe", 2013, Fertilisers Europe seminar, 6 Feb. 2013. Updated Van Dijk et al. 2015

Sewage (sludge) is the second most relevant renewable P source in Europe!

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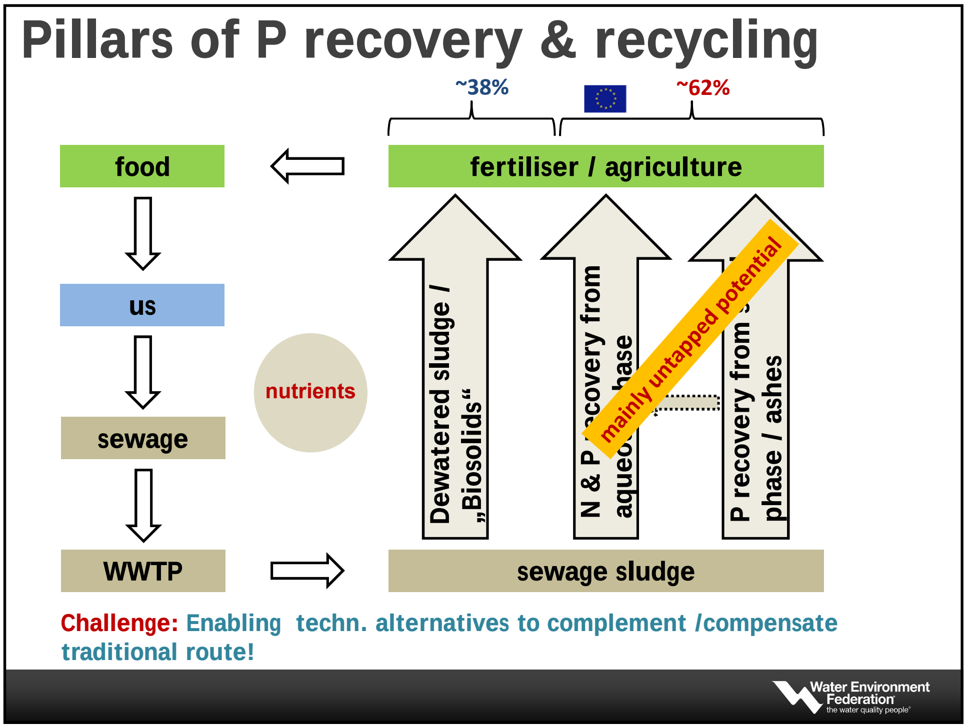
Pillars of P recovery & recycling
~38%
~62%
food
fertiliser / agriculture
us
nutrients
sewage
WWTP
sewage sludge
Dewatered sludge / „Biosolids“
N & P recovery from aqueous phase
P recovery from solid phase / ashes
mainly untapped potential
Challenge: Enabling techn. alternatives to complement /compensate traditional route!
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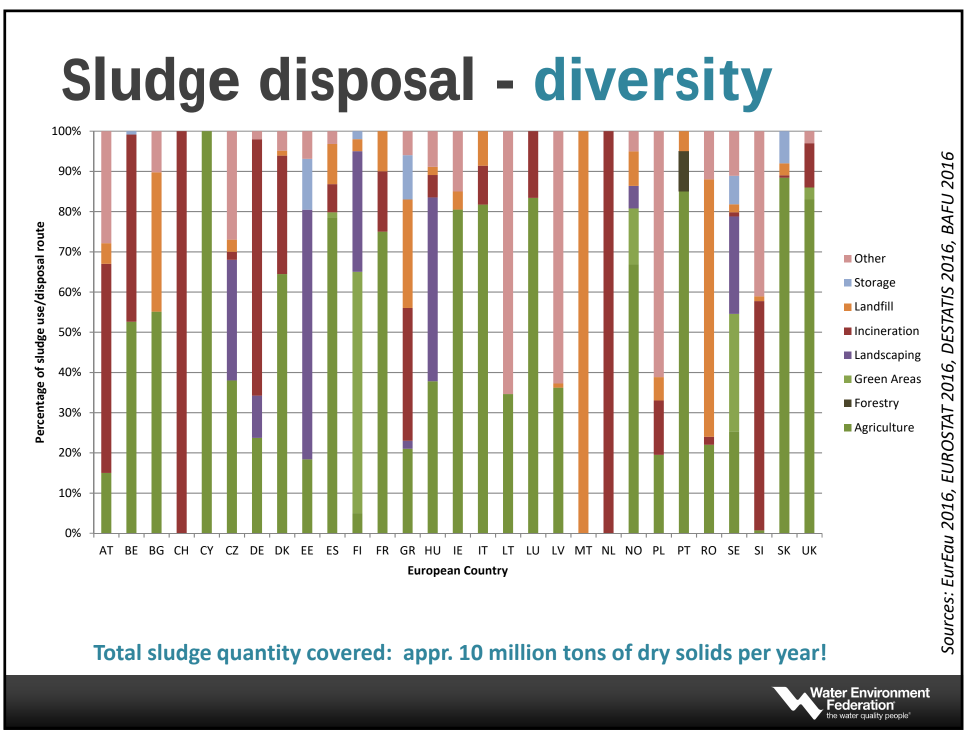
Sludge disposal - diversity
Percentage of sludge use/disposal route
European Country
AT BE BG CH CY CZ DE DK EE ES FI FR GR HU IE IT LT LU LV MT NL NO PL PT RO SE SI SK UK
Other
Storage
Landfill
Incineration
Landscaping
Green Areas
Forestry
Agriculture
Total sludge quantity covered: appr. 10 million tons of dry solids per year!
Sources: EurEau 2016, EUROSTAT 2016, DESTATIS 2016, BAFU 2016
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# The wind of change

Long-term security for disposal route

Concerns

Acceptance

Monitoring Cost

Hygiene

Contaminants

Heterogenity

Uncertainties

Transparency

Surplus manure

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# Pressure or motivator

- 2017 – new fertilising ordinance (DÜV) limits nutrient … s applied to land and acutely reduces sludge disposal capaciti… explosion!
- new fertiliser ordinance (DÜMV) sets strict… criteria (less sludge conform) – monitoring cost
- 2017 – new sewage sludge ordi… KlärV) enters into force
  - 2023 – all WWTP have to subm… anagement concepts considering P recovery
  - 2029 – P recovery obli… WTP above 100,000 p.e. (ban from land application)
  - 2032 – P recov… r all WWTP > 50,000 p.e.
    - Even … P have to recover P, if no land application possible
    - O… : P recovery to deplete below 20 g P/kg DS or at least by 50%
    - … mal-pretreatment recoverable separate storage of ash/concentrate
    - … overy process with >80% recovery rate

Sludge mono-incineration is favoured and will double in coming years!
Sludge disposal cost have already been doubled regionally last year!

1 p.e. = 100 GPD

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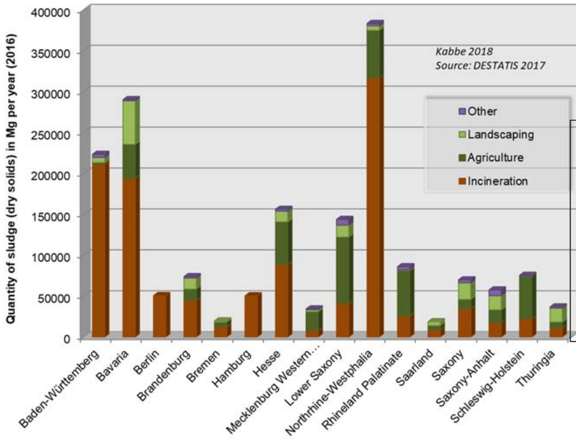
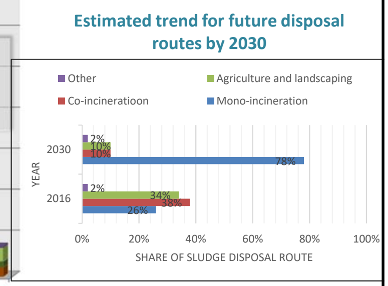
# The wind of change




**Total municipal sludge quantity: 1.77 million tons of dry solids per year (2017)!**

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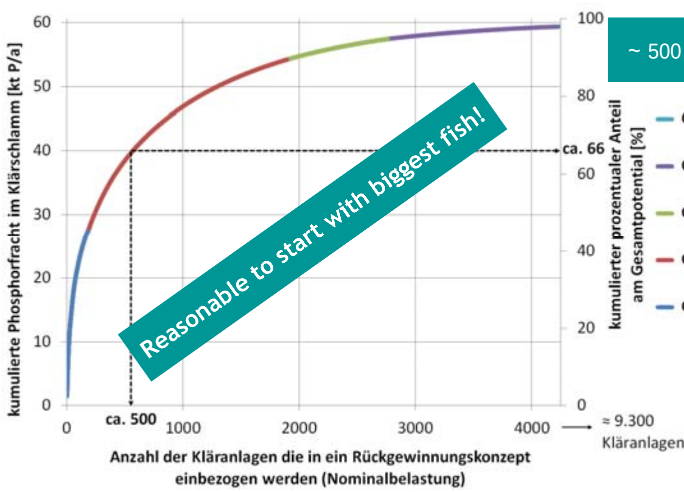
# Catching the big fish




*Source: Kraus 2016*

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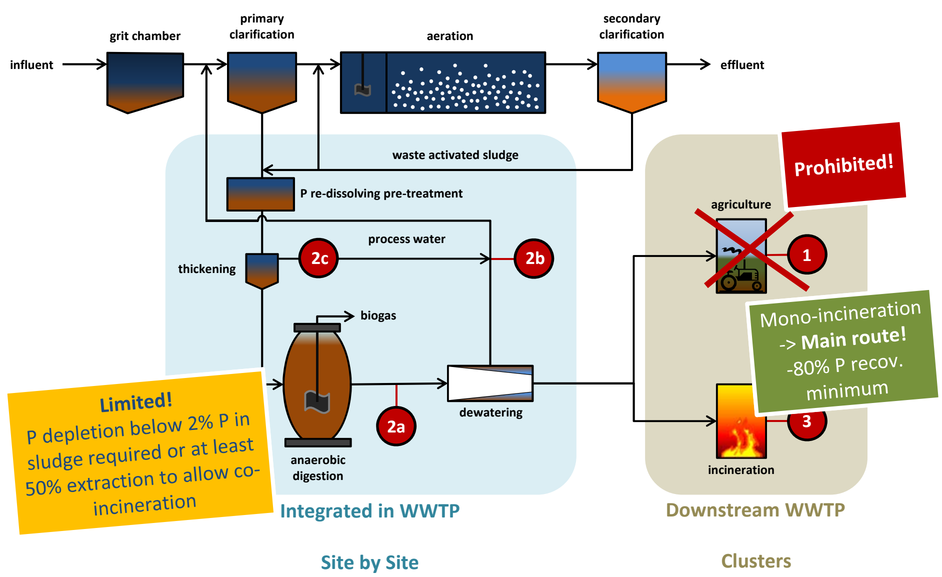
# WWTP bigger 50,000 p.e.




Wisdom just written on paper will be dust one day;

Only the wisdom applied will shape our future!

# Our next speaker

**Greg Homoki**
**Schmidtsche Schack**

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# Energy Recovery for Sludge Incineration

Greg Homoki
Senior Advisor
Arvos Schmidtsche Schack LLC

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## Energy Recovery for Sludge Incineration

**Agenda**

- Overview of Energy Recovery
- Air Preheaters
- Waste Heat Boilers & Economizers
- Thermal Oil Heaters
- Plume Suppression Heat Exchanger
- Gas Preheater for Mercury Control
- Benefits

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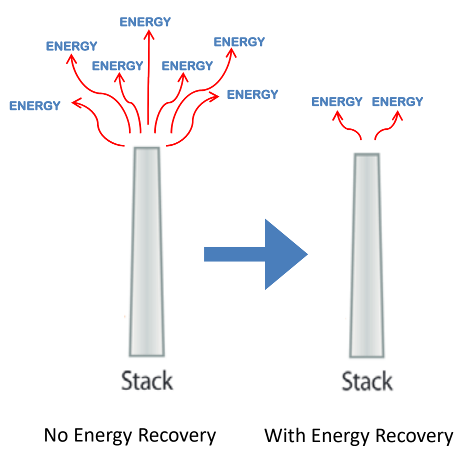
## Energy Recovery for Sludge Incineration




- Every stack that exhausts hot flue gas to the atmosphere represents irretrievable thermal energy.
- In a typical sludge incinerator operating at 1400 to 1600°F, heat loss can be significant.

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# Energy Recovery for Sludge Incineration

**SLUDGE QUALITY**

- Sub-Autogenous
  - Requires auxiliary fuel.
  - Typical of older units with lower air
- Autogenous
  - No auxiliary fuel required.
  - Typically achieved with higher air preheats, ~1200°F and well dewatered sludge.
- Super-Autogenous
  - Requires removal of heat
  - Bed temperatures are too high requiring removal of energy, otherwise, leads to:
    - Higher NOx & SOx
    - Molten Ash / Clinkers

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# Energy Recovery for Sludge Incineration

**Forms of Indirect Waste Heat Recovery**

- Recuperation
  - Heat is returned to the combustion process.
  - Preheating combustion air with flue gases.
  - The most common and economical form of heat recovery.
- Secondary Recovery
  - Uses the heat in the flue gases for other purposes.
  - Preheating an external medium.
  - Power generation; space heating; hot oil heating; plume suppression; gas reheating

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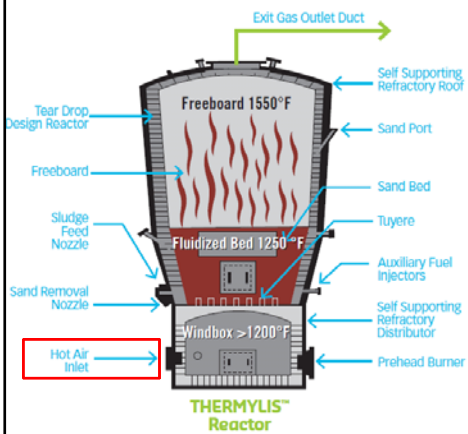
# Air Preheaters




Courtesy of Suez

## Air Preheater Operation

- Fluid bed operates at 1500°F to 1600°F during normal operation.
- Air preheat ranges from 1000°F to 1200°F.
- Flue gases still contain about 40% water vapor by volume.



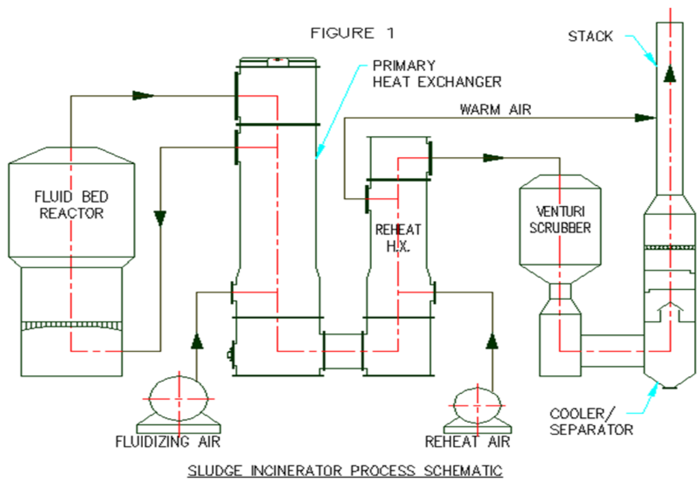
# Air Preheaters

**Table 1: Typical composition of wet flue gas (volume basis)**

| | |
|---|---|
| Nitrogen | 45-55% |
| Oxygen | 4-6% |
| Carbon dioxide | 6-10% |
| Water vapor | 35-45% |
| Sulfur dioxide | 0-1000 ppm |
| Hydrogen chloride | 0-1000 ppm |
| Acid dew point[a] | 125-300°F (50-150 °C) |

[a] Add 100°F (56 °C) safety factor for design.

# Air Preheaters

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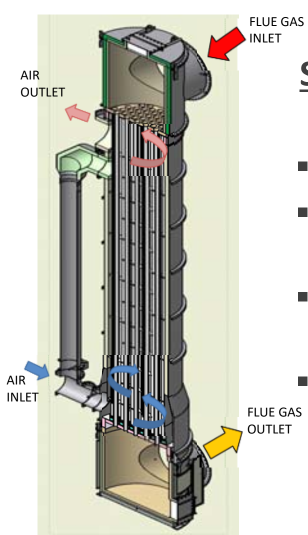
# Air Preheaters




## Schack® Flue-Gas-Through-the-Tubes (FGTT) Air Preheater

- Hot, dirty flue gas flows through the tubes.
- Minimizes erosion - particulate flow is parallel to the tube wall.
- Minimizes fouling - vertical tubes offer little or no area for ash to accumulate.
- Combustion air passes over the tubes in multiple passes.

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# Air Preheaters

## Design

- Typical Tube Materials: Alloy 20, Alloy 625, Stainless Steel.
- Tube Lengths: Vary, as long as 30 feet +.
- Pipe Sizes: Range from 2-1/2 to 8 inches.
- Number of tubes: Built with as many as 199.

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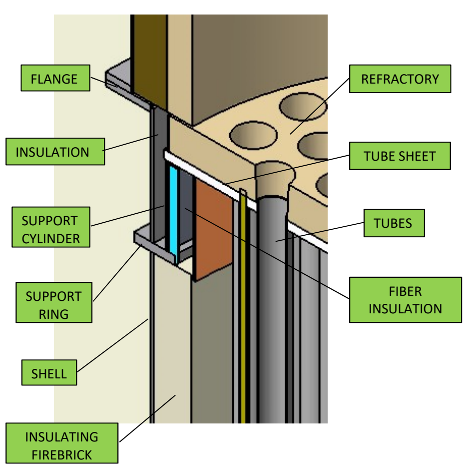
# Air Preheaters




## Tube Sheet Support

- Support element is in compression, not tension.
- Tube sheet will not fall.
- Damage tolerant design minimizes leakage.
- Thicker not always better!

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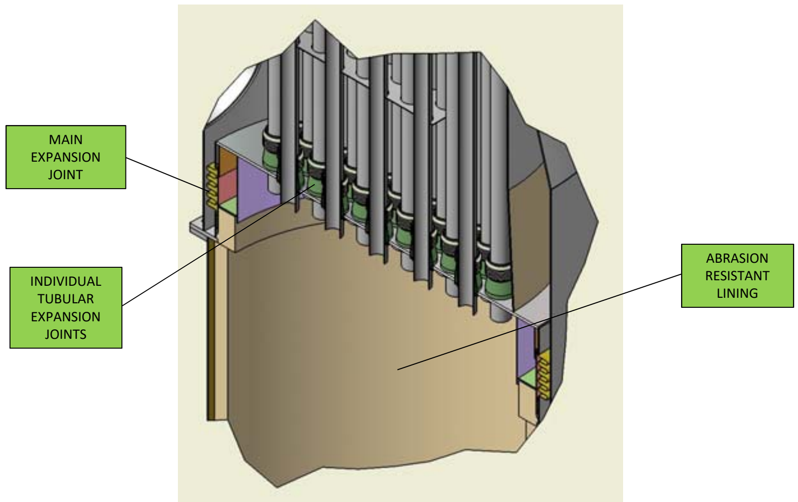
# Air Preheaters

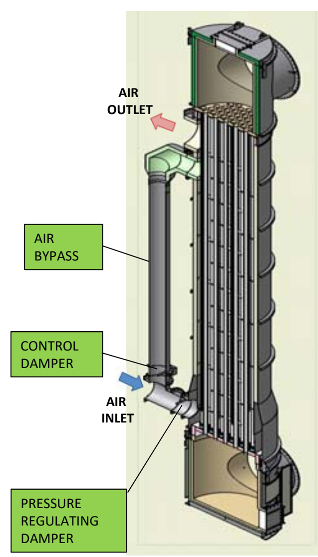





# Air Preheaters

## Air Side Inter-stage Bypass

- Cold, inlet air is bypassed around a portion of the heating surface.
- Mixed with the hotter preheated air.
- 100% of the air flow is maintained in the hot end.
- Partial bypass reduces the air temperature & results in longer life.
- Optional pressure regulating damper provides greater turndown.



## Secondary Heat Recovery

- Waste Heat Boilers (WHBs) & Economizers
- In Bed Surface Coils
- Thermal Oil Heaters
- Plume Suppression Heat Exchanger
- Gas Preheater for Mercury Control



## WHB's & Economizers

- Usual flue gas inlet temperatures > 1000°F
- Typical dust loadings of 3 grains/scf and higher.
- Boiler exit temperature and feedwater inlet temperature must be maintained above acid dew points.
- Common boiler sizes in this service:
  - 5,000 to 50,000 lb/hr steam at 60 to 600 psig.

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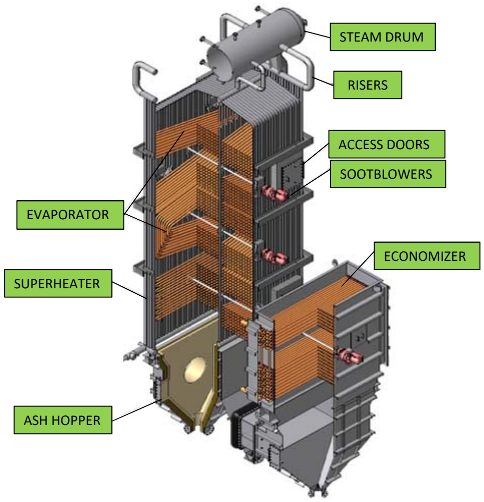
## WHBs & Economizers




### Water Tube WHB Design

- Hot waste gases are in contact with the outside surfaces of the boiler tubes.
- Fouling can be handled with on-line cleaning such as sootblowing.
- Ash is collected in hoppers.
- Higher pressure operation of > 300 psig.

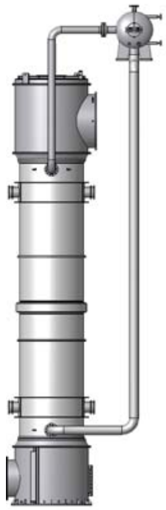


## WHB's & Economizers

Water Tube WHB Installations (Recent)

| Location | Equipment Description | # of Trains | Steam/Water Operation (ea) |
|---|---|---|---|
| Bilbao, Spain | Economizer, Evaporator, Superheater | 1 | 9,900 lb/hr 788°F |
| Hartford MDC Hartford, CT | Economizer, Evaporator, Superheater | 2 | 13,200 lb/hr 600°F |
| NEORSD Cleveland, OH | Economizer, Evaporator, Superheater | 3 | 15,500 lb/hr 750°F |
| Duffin Creek Toronto, ON | Economizer, Evaporator, Superheater | 2 | 16,200 lb/hr 700°F |
| MCES St. Paul, MN | Economizer, Evaporator, Superheater | 3 | 21,825 lb/hr 700°F |

## WHB's & Economizers



- Fire Tube WHB Design
  - Hot waste gases are inside the tubes with water on the shell.
  - Self cleaning design (like FGTT Air Preheater).
  - Low pressure operation up to 400 psig.



## WHB's & Economizers

Economizer

- Flue gas exiting recuperator still has considerable sensible heat.
- Water-tube construction is conventional approach, although the fire-tube design has also been utilized.
- Schack® Fire Tube Economizer

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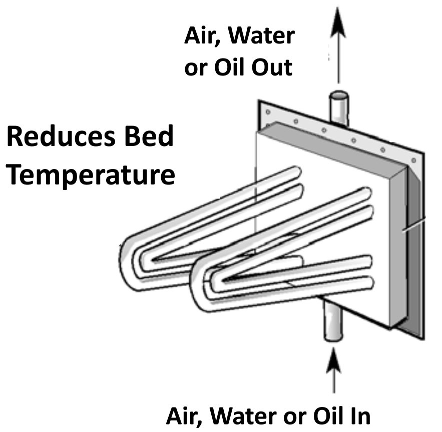
## In Bed Surface Coils

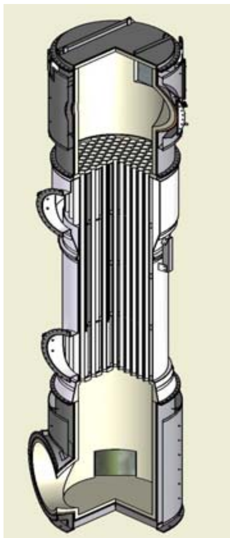





## Thermal Oil Heaters

- Can be 'water-tube' or 'fire-tube' design.
- Preheat thermal oil for sludge drying, ORC, etc.
- Various thermal fluids may be utilized.
- Bare tubes with low gas velocities (water-tube).
- Vertical tubes with high gas velocities (fire-tube).

## Plume Suppression



- Simplified FGTT Air Preheater design.
- Preheat clean exhaust gases or plume suppression air to eliminate steam plume.
- Typical materials are Alloy 20 or stainless steel.

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## Gas Reheater for Mercury Control

- Preheat clean exhaust gases for the mercury capture system.
- Typical materials are stainless steel.
- Radiant double shell design with clean gas bypass for temperature control.

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## Conclusions

- Direct reduction in plant energy costs (and possible capital costs).
- Reduction in spray cooling requirements, reducing the volume flow through downstream equipment.
- Air preheating is the most common and cost effective means of heat recovery, but…….
- Secondary waste heat recovery offers additional opportunities for renewable **"green"** energy.

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## Phosphorus Recovery & Recycling goes global

How?

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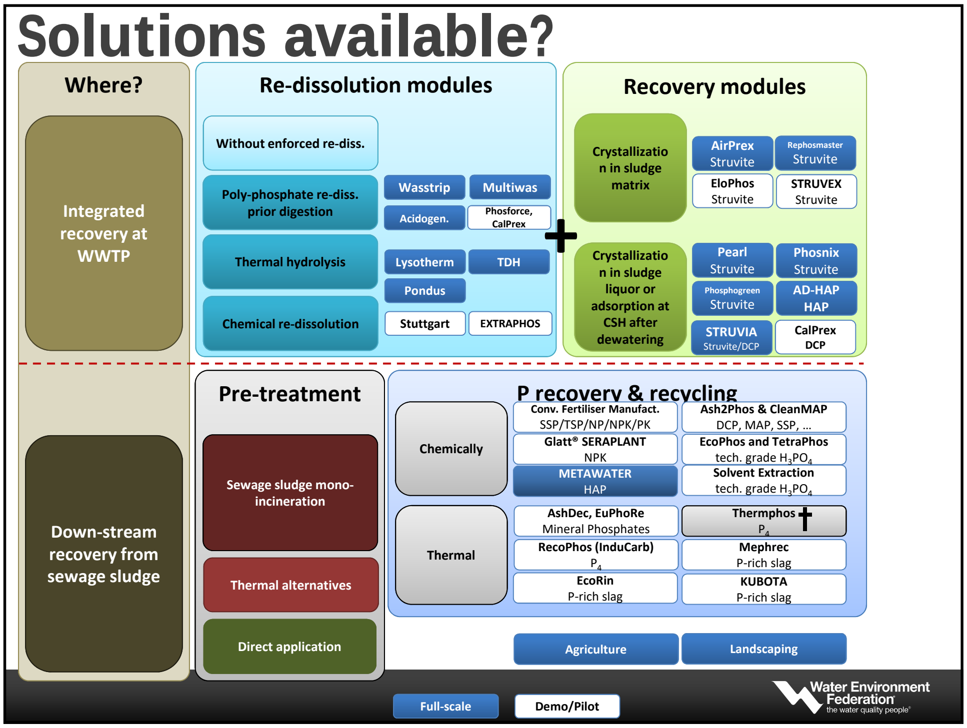
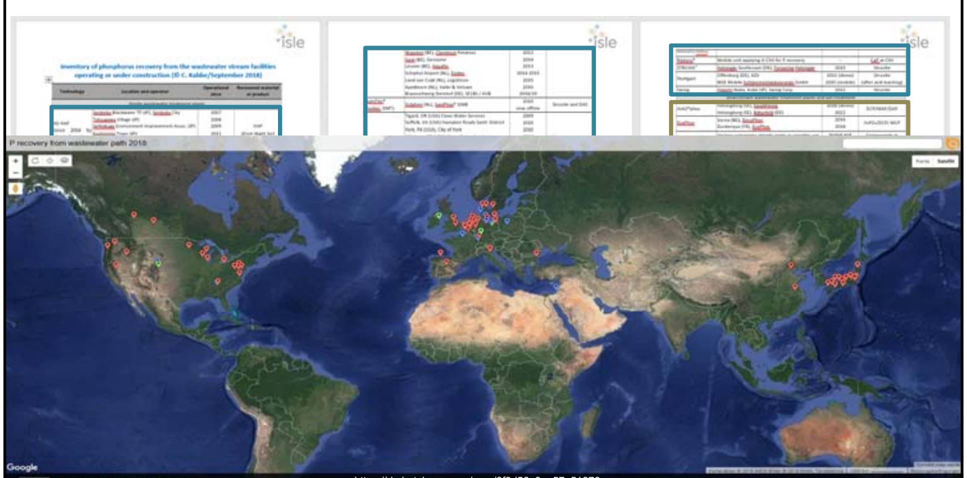



# Global implementation




More than 100 full-scale plants operational world-wide! > 80 recover Struvite (> 60 are municipal)

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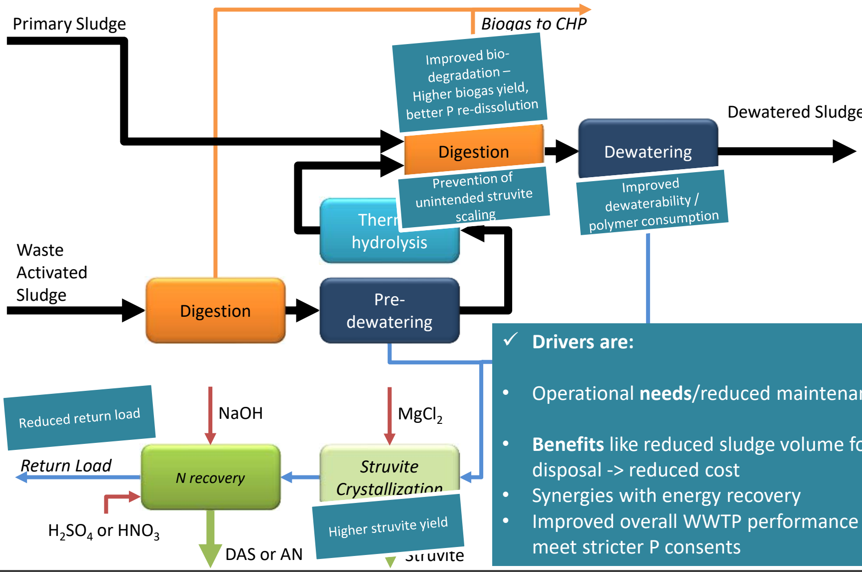
# C, N & P recovery cascades




✓ **Drivers are:**

- Operational **needs**/reduced maintenance
- **Benefits** like reduced sludge volume for disposal -> reduced cost
- Synergies with energy recovery
- Improved overall WWTP performance to meet stricter P consents

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## Challenges and keys to Success and Sustainability?

Only technologies, yielding **homogenous products** or raw materials, **independent from input material quality** and mutually meeting both criteria, **energy efficiency** and **resource efficiency** will have a chance for wide-spread application under sustainability aspects.

***Keys:***

✓ Heavy metal depletion (high quality products)
✓ Moderate energy (and chemicals) consumption (cost)
✓ Market for "known" recovered P (commercial products) (real value and price)


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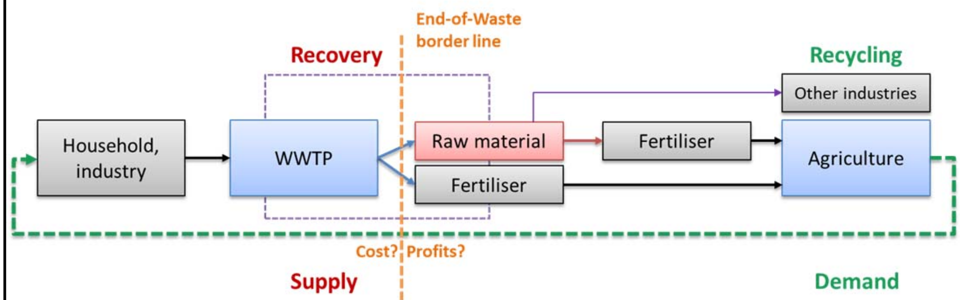
## No Recycling without Value Chains




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

Commodities

- Sludge – organic fertiliser
- Struvite – NP fertiliser in some MS (proven good fert. eff.)
- DCP – approved P fertiliser (component)
- Ash – generally barely plant available, rather raw material – processing needed
- MAP/DAP – main N&P components in fertiliser production (commodities)
- MGP / $P_4$ – commercial products with broad application (commodities)

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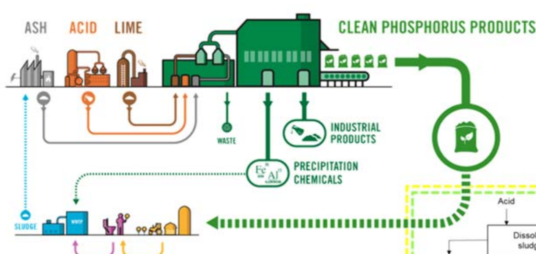
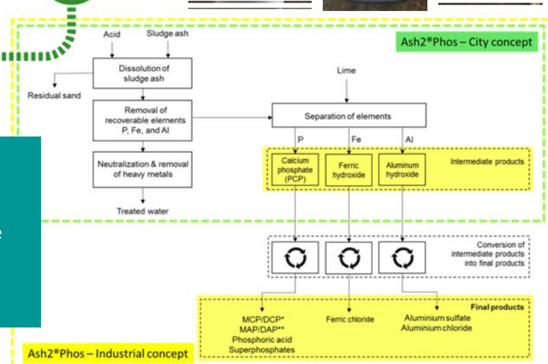
## Ash2®Phos




* mono/di-calcium phosphate (feed phosphate), mono/di-ammonium phosphate (fertilizer)

- ✓ Flexible low-grade inputs
- ✓ Commercial HQ P products
- ✓ Commercial HQ by-products
- ✓ Independent of Fe/Al and ash moisture
- ✓ Heavy Metal decontamination
- ✓ Robust and simple!!!
- ✓ Substantially reduces waste!

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

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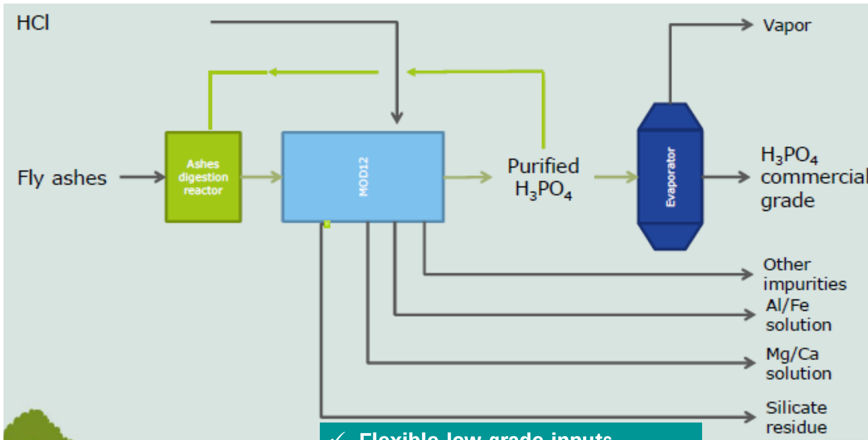
# EcoPhos®




- ✓ Flexible low-grade inputs
- ✓ Commercial products ($H_3PO_4$)
- ✓ By-products (Metal salts)
- ✓ Independent from Fe/Al content
- – Evaporation

*Source: ECOPHOS, R. de Ruiter 2014*

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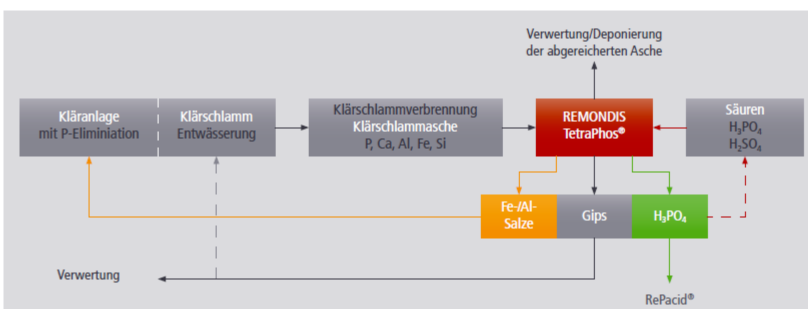
# TetraPhos®





*Source: Remondis, 2015*

- ✓ Flexible „low-grade“ inputs
- ✓ Commercial products ($H_3PO_4$)
- ✓ By-products
- ✓ HM-decontamination
- – Evaporation

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# SeraPlant / Glatt®

Suspend

Ash + $H_3PO_4$ + other nutrients

Granulate

Spray granulation

Sell

Customized product

- ✓ **Robust and simple**
- ✓ **Zero waste**
- o **Customized, commercial fertiliser?**
  - – **No HM depletion!!! (only dilution)**
  - – **Limitation to premium ashes**

*Source: SERAPLANT*

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## Sludge Incineration Germany


- Currently appr. 668 kt DS mono-incineration capacity 2017 (municipal sludge)
- After 2029/32 at least 1.200.000 Mg DS capacity needed to comply with sludge reg (Ecoprog 2017) … likely more
- Most new capacities between 2022 and 2027 (already +600 kt DS in prep. announced)

-> future SSA quantity > 500.000 Mg/a (>45.000 Mg P/a)

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# Sludge, biosolids and recyclates?

- **Advantages** of commercial recovered P recyclates are:
  - ✓ Defined/adjustable composition and fertilising efficiency (even precision farming)
  - ✓ Reduced contamination (health & safety, soil hygiene)
  - ✓ Reduced nutrient losses to environment (avoid eutrophication)
  - ✓ Are known in the market (demand, less bureaucratic burden)
  - ✓ Create real value (not just disposal)
  - ✓ Increase versatility of application (higher market potentials)

- **Challenges** for recovered P recyclates
  - Still missing level playing field (virgin vs. secondary materials, question of origin)
  - Investments (capex) often only made if real need
  - Progress often needs legislative „motivation“ or pressure

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# Wrap up and Outlook

- Key driver for P recovery is regional nutrient surplus in industrial countries (not scarcity) – directly linked to population and lifestock density (waste per territory)
- Sewage sludge already is and will be more & more pushed out of land application by farm residues in Europe (trend towards incineration in more and more countries)
- New regulations can foster P recovery innovation and replication
- Site-by-site P recovery on-site WWTP needs to be linked with operational needs and benefits and will play a limited complementary role (Short ROI)
- Ash-based route can recover highest P quantities, but needs proper infrastructure (CAPEX)
- Known materials easier to integrate in market! Recyclates need to fit into existing markets, not the other way around!
- Phosphorus must not be considered in isolation (N, C …) … also synergies with other wastes like manure etc? Tap synergies! Water sector can become frontrunner!!!

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# Questions?

*Panel Contact Information*

Peter Brady – pbrady@alpinetechnology.com
Christian Kabbe – christian.kabbe@isleutilities.com
Greg Homoki - greg.homoki@arvos-group.com

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