Phosphorous Recovery from Wastewater: Current Practices and Future Opportunities

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Jacobs
Challenging today.
Reinventing tomorrow.

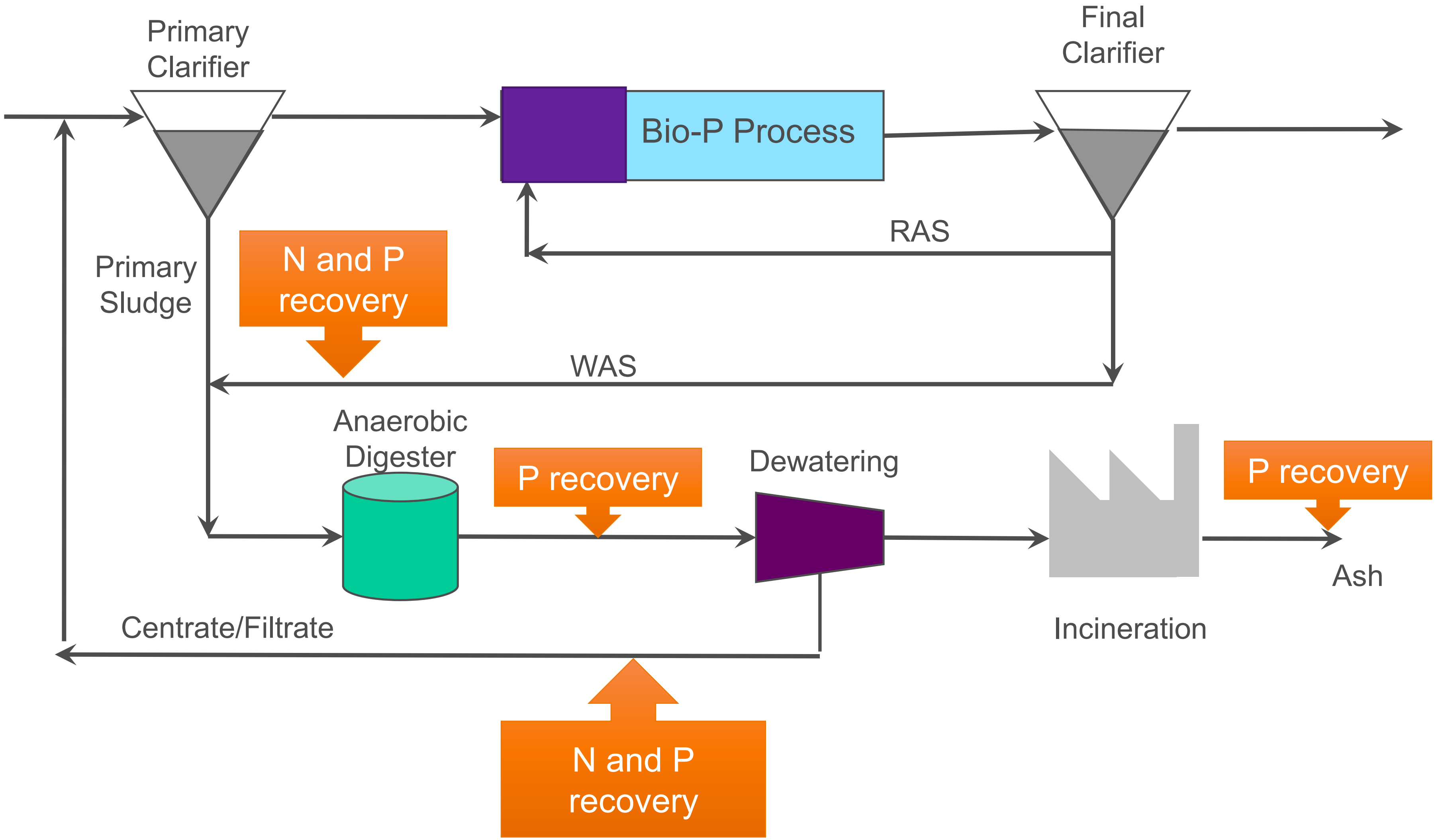
Why Do We Need Nutrient Recovery Capability in WRRF's?

- Complements nutrient removal
- Represents resource recovery
- Highly marketable end-product
- Contributes to sustainable nutrient management
- Provides factor of safety for Bio-P
- Minimizes impact of sidestream loads
- Reduces chemical consumption (sidestream treatment)
- Reduction in sludge quantity and hauling costs
- Minimizes nuisance struvite formation
- Reduces P content of biosolids
- Improves biosolids dewaterability
- Higher sludge cake %TS
- Reduces polymer demand

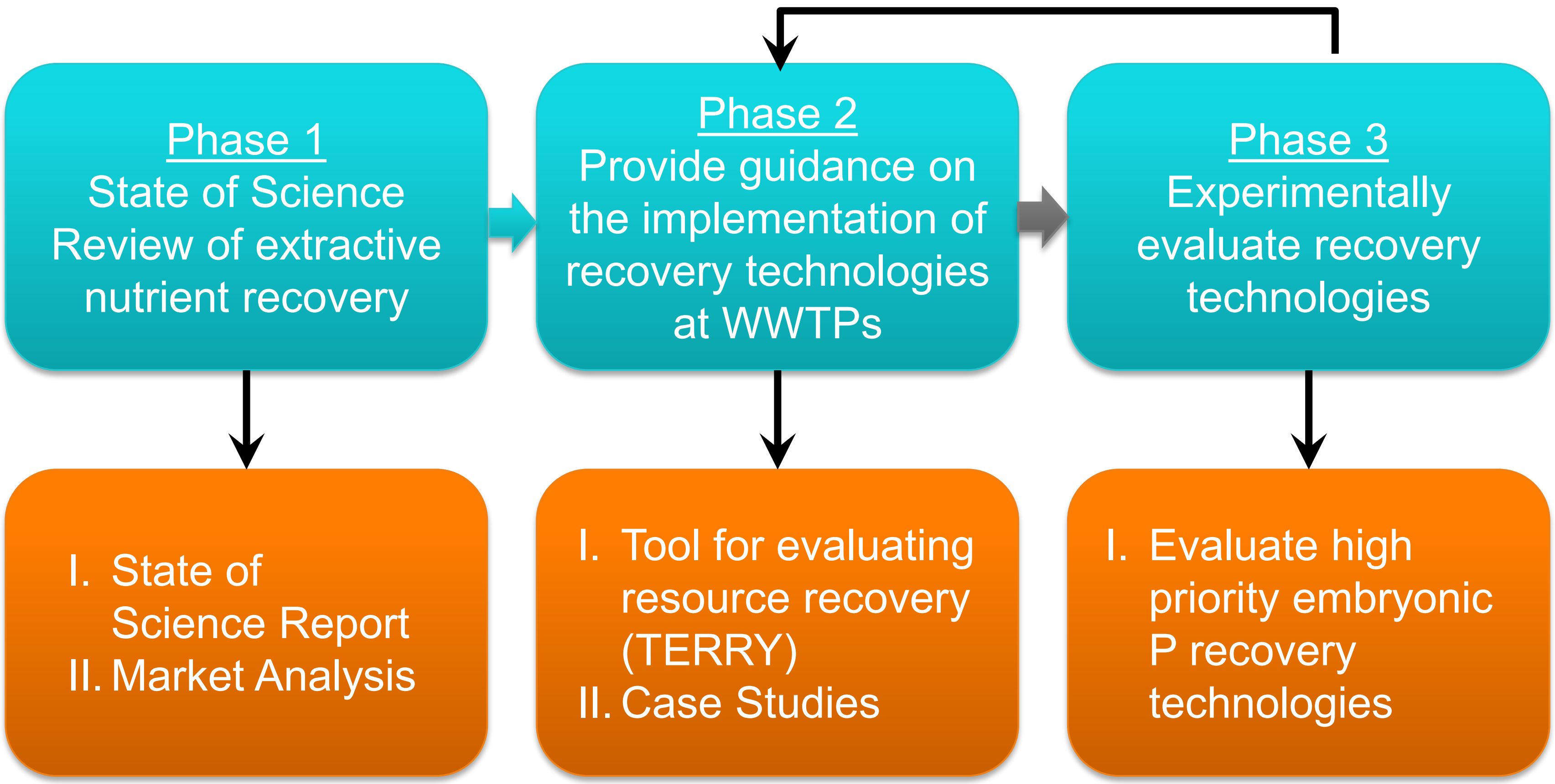
What is Nutrient Recovery?

- Accumulation step to increase N content > 1000 mg N/L and P content > 100 mg P/L
- Release step to generate low flow and high nutrient stream
- Recovery step produces high nutrient content product

Potential Locations for Nutrient Recovery at Water Resource Recovery Facilities (WRRFs)

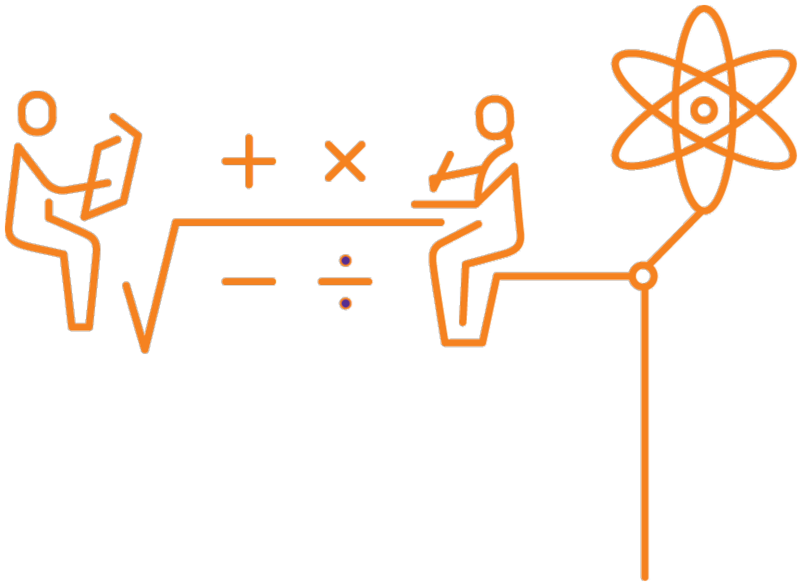


The WERF Nutrient Recovery Project



WERF Project Team

- Project Team led by:
  - Hazen and Sawyer
  - CH2MHILL (now Jacobs)
- Utilities: 20
- National & international experts
  - Universities & research organizations
    - USA
    - Australia
    - Europe
    - Japan
- Technology providers: 6



WERF NTRY3R13: Objectives & Project Team

Water Environment Research Foundation



Principal Investigators/Project Team
Wendell O. Khunjar, Thomas Worley-Morse
(Hazen and Sawyer)
Sam Jeyanayagam (CH2M HILL)
Kevin Gilmore, Brian Zuidervliet (Bucknell Univ.)


Technical Advisory Committee
Paul Pitt (Hazen and Sawyer)
Glenn Daigger (CH2M HILL)
Mark van Loosdrecht (TU Delft)

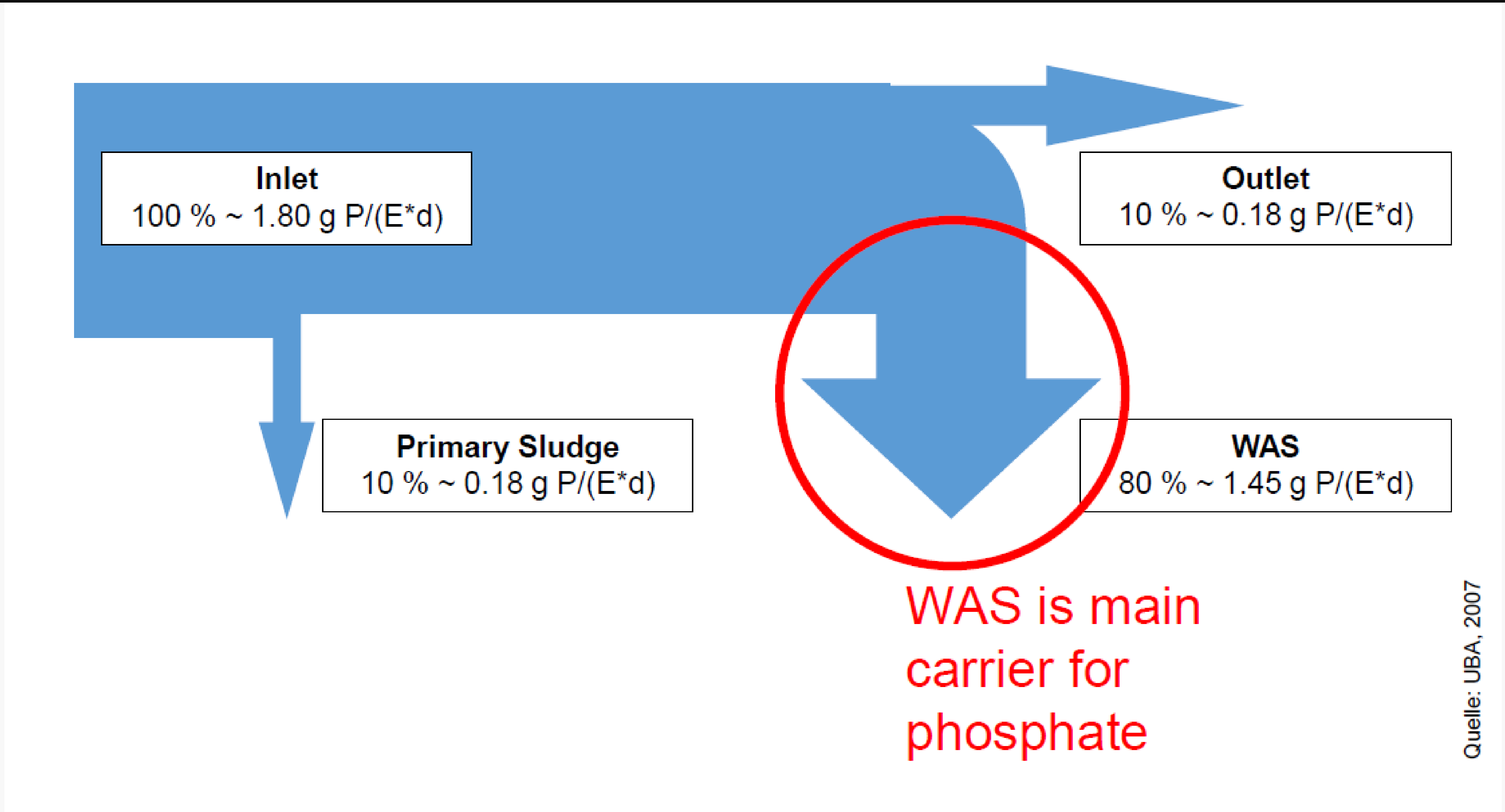
Quality Assurance and Control
Ron Latimer (Hazen and Sawyer)
Julian Sandino (CH2M HILL)
Todd Williams (CH2M HILL)

Objective 1
Develop an inventory of technologies capable of recovering carbon-based and other non-nutrient commodity products from wastewater

Objective 2
Characterize the market potential and financial climate for selected non-nutrient commodities

Objective 3
Prioritize resource recovery needs for future research and development

Phosphorous flows and concentrations in a WRRF



Waste activated sludge from a BNR facility contains approximately:

- 12% nitrogen
- 5% phosphorus

Can be recovered as struvite

It has Taken us 6,000 years to realize that our poop is priceless!

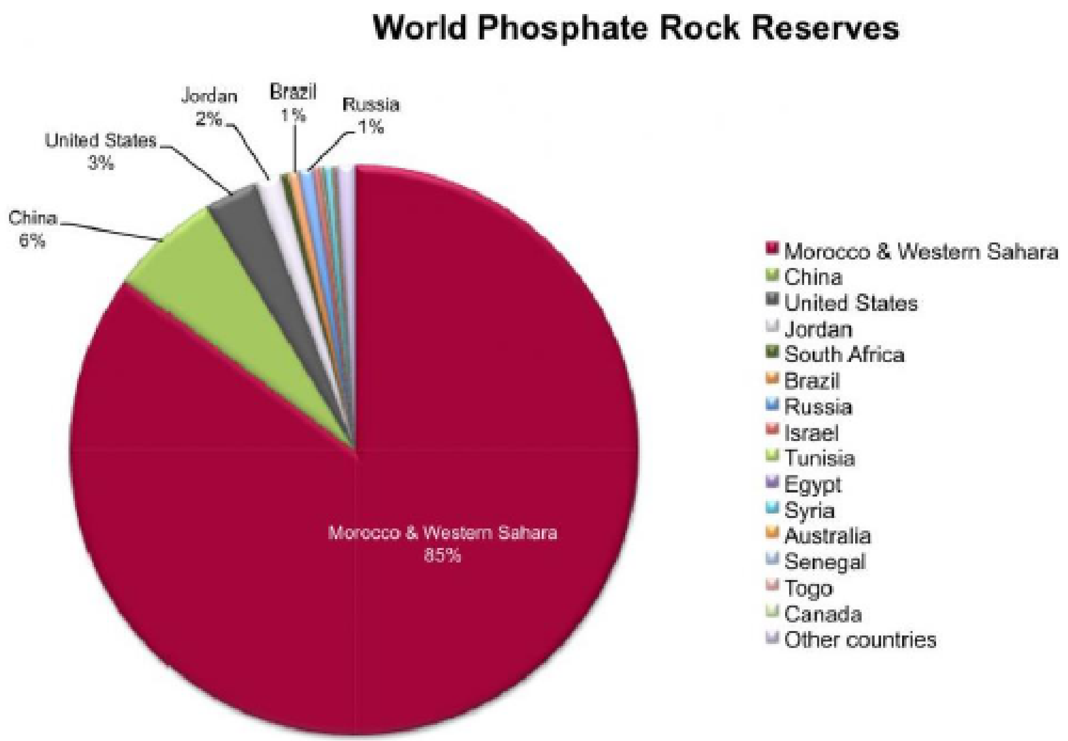
Benefits of Nutrient Recovery

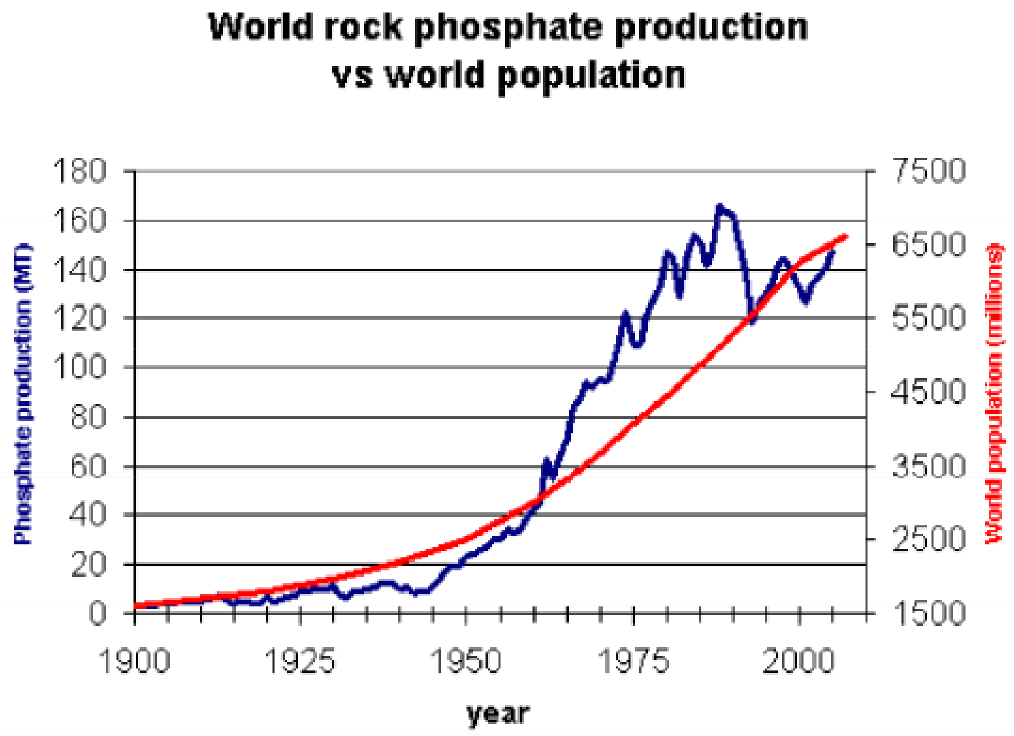
- Lowers energy use and greenhouse gas emissions associated with fertilizer production.
- Minimizes struvite scaling.
- Stabilizes Bio-P performance by reducing sidestream loads.
- Lowers biosolids P content – higher land application rates.
- Recovers N &P as struvite, a slow-release fertilizer.
- Enhances biosolids dewaterability.
- Creates a modest revenue stream.
- Aligns with the ‘plant of the future’ vision.

Why is Phosphorous Recovery from WRRF's so Important?

Phosphate:

- Limited resource (30 - 300 yrs)
- Direct correlation to phosphate production and world population





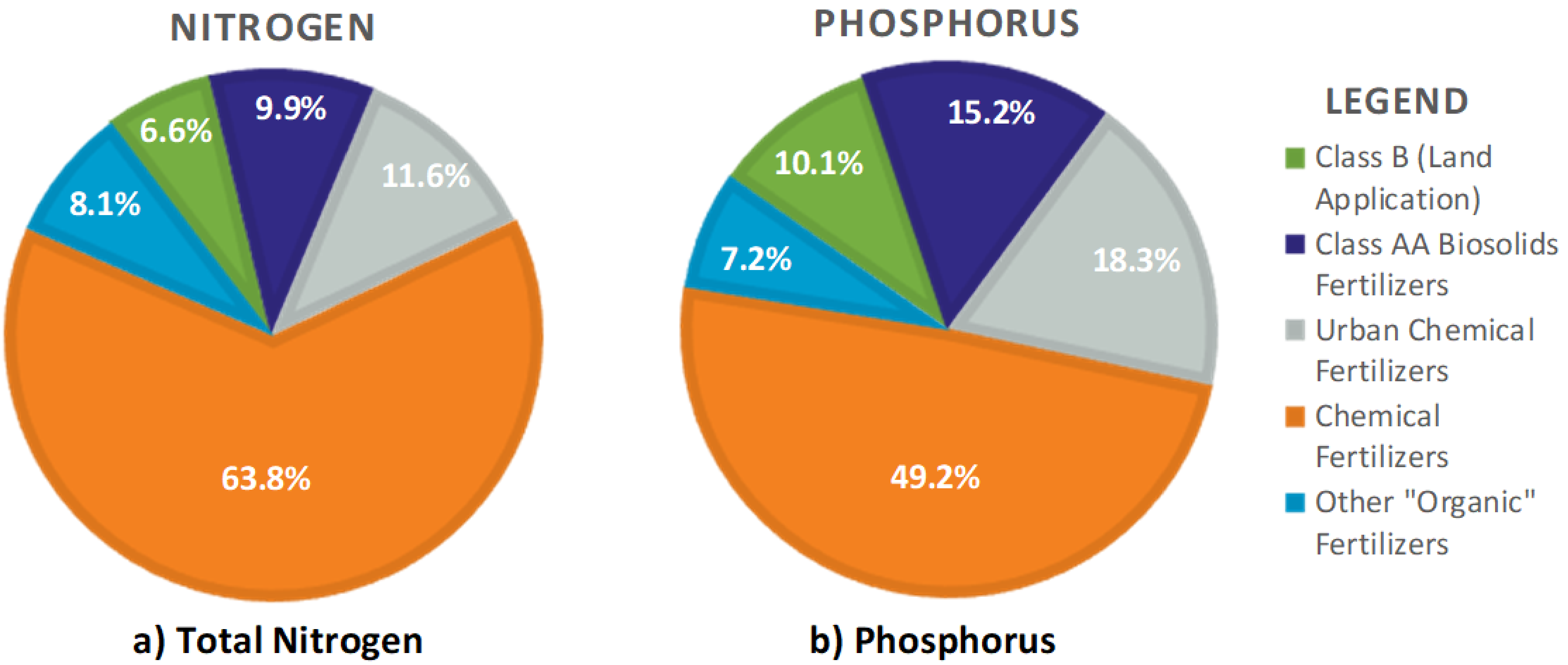
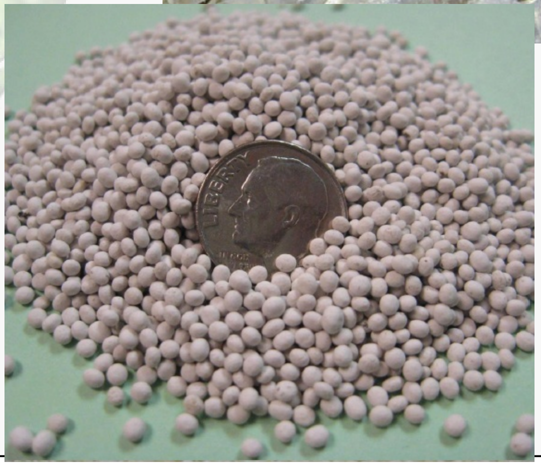


Figure 1. Florida's Agricultural Total Nitrogen and Phosphorus by Source/Use Category

Source: J. Willis, 2019

What is Struvite?

- Struvite is Magnesium Ammonium Phosphate ($MgNH_4PO_4$)
  - Like kidney stones
- Historical perspective
  - First observed in sewer systems in 1845 in Hamburg, Germany
  - Named after geologist Gottfried von Struve
  - Value as a fertilizer dates back to 1857
- Forms readily when:
  - Molecular ratio of Mg:N:P is 1:1:1
  - pH around 9.0.
- Often an O&M nightmare at plants with anaerobic digesters:
  - Anaerobic digestion releases the necessary ‘raw materials’
  - Turbulence drives out CO_2 resulting in pH rise & struvite scaling



Recovery from Wastewater Requires a Three-Step Framework

Accumulation → Release → Extraction

Accumulation

- **Bio-P**
- Algae
- Purple non-sulfur bacteria
- Adsorption/Ion exchange
- Chemical precipitation
- NF/RO

Release

- **Anaerobic digestion**
- Aerobic digestion
- Thermolysis
- WAS release
- Sonication
- Microwave
- Chemical extraction

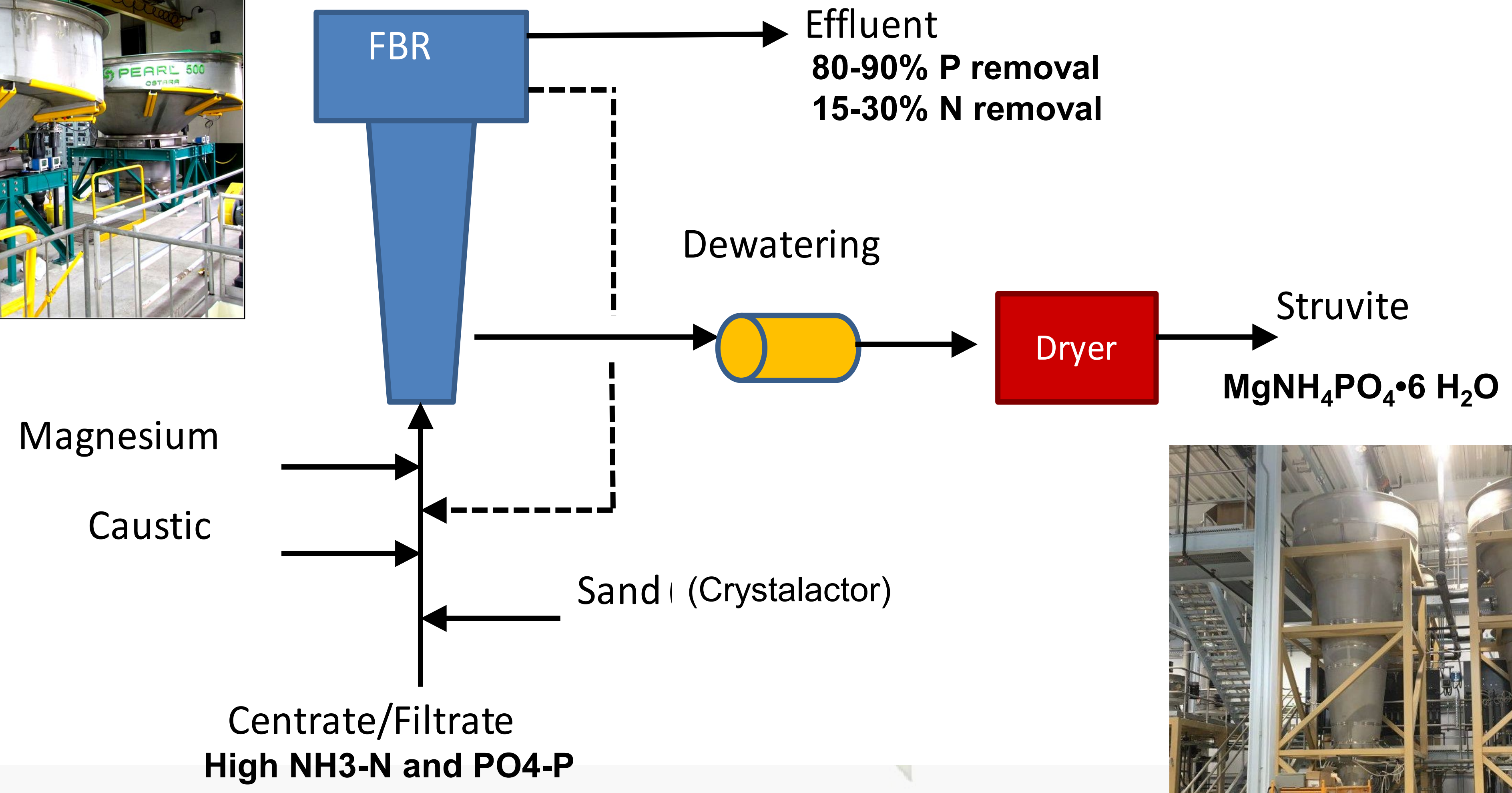
Extraction

- **Chemical crystallization**
- Electrodialysis
- Gas permeable membrane and absorption
- Gas stripping
- Solvent extraction

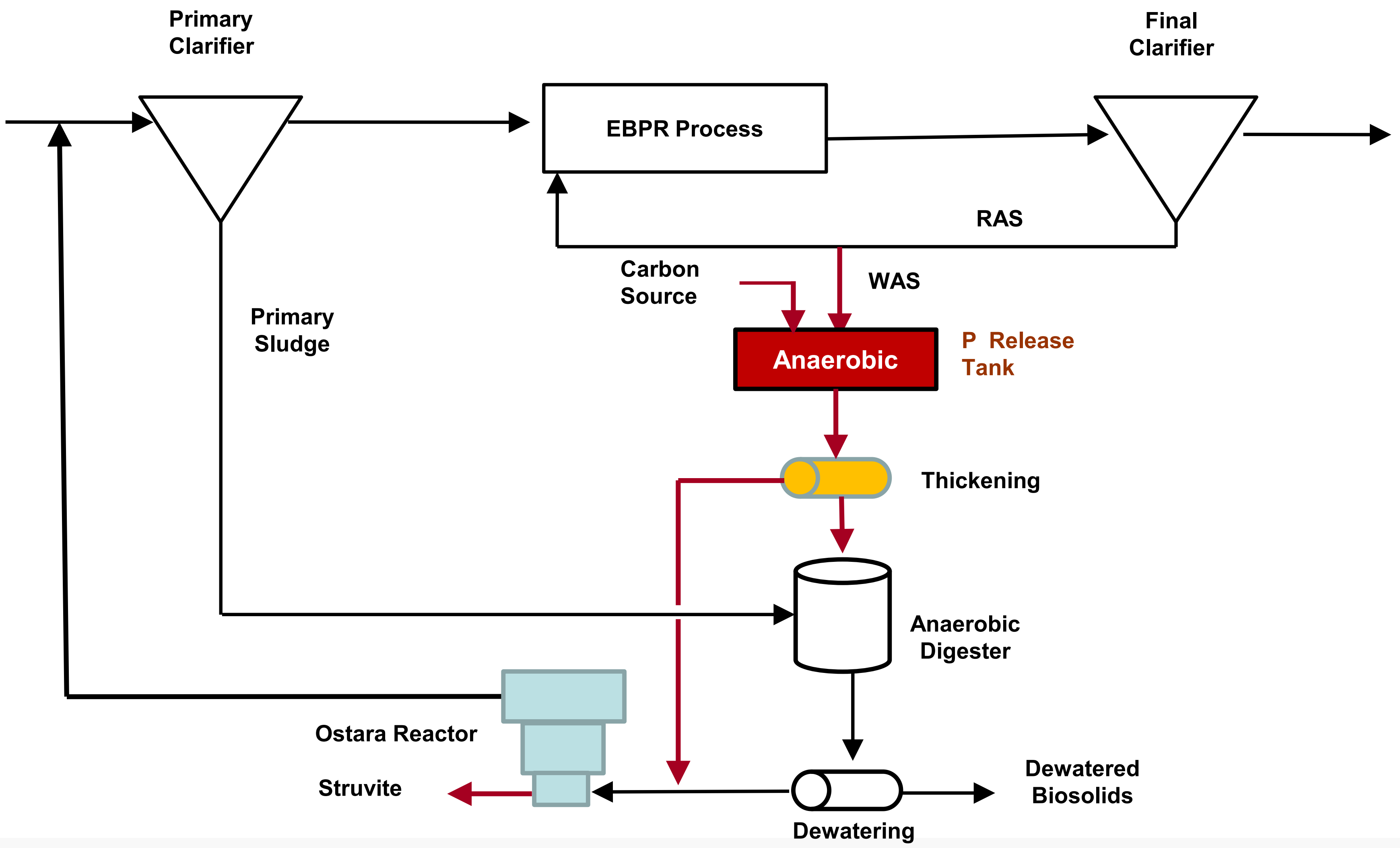
Proven P Recovery Technologies

Feature	Ostara Pearl®	Multiform Harvest	NuReSys	Phospaq	Crystalactor	Airprex
Type of reactor	Fluidized Bed Reactor (FBR)	FBR	Completely Stirred Tank Reactor (CSTR)	CSTR	FBR	CSTR
Point of Recovery	Centrate/Filtrate	Centrate/ Filtrate	Centrate/ Filtrate; digested sludge	Centrate/Filtrate	Centrate/Filtrate	Digested sludge
Recovery efficiency	80-90% P 10-40% NH3-N	80-90% P 10-40% NH3-N	>85% P 5-20% N	80% P 10-40% NH3-N	85-95% P for struvite 10-40% NH3-N > 90% P for calcium phosphate	80-90% P 10-40% NH3-N
Full-scale installations	10	2	7	3	4	3

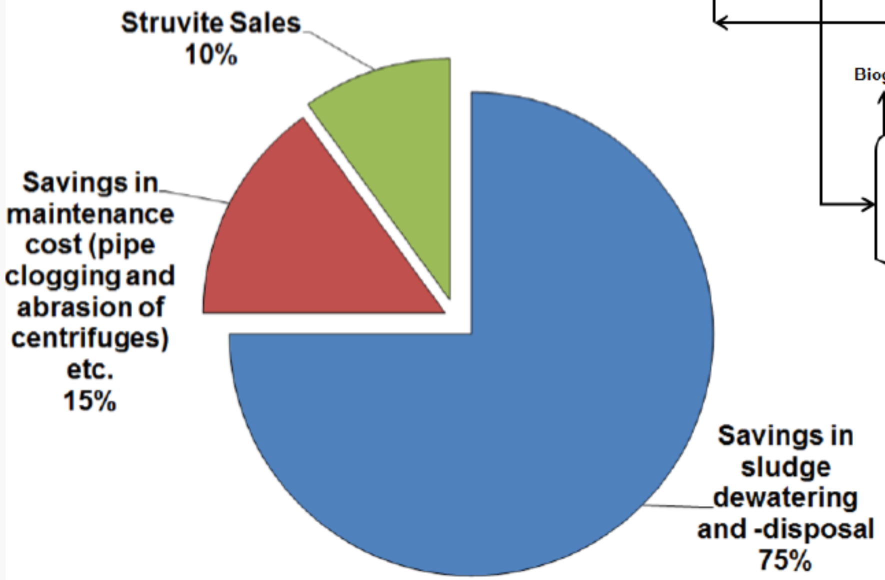
Fluidized Bed Reactor (Ostara, Multiform Harvest, Crystalactor)

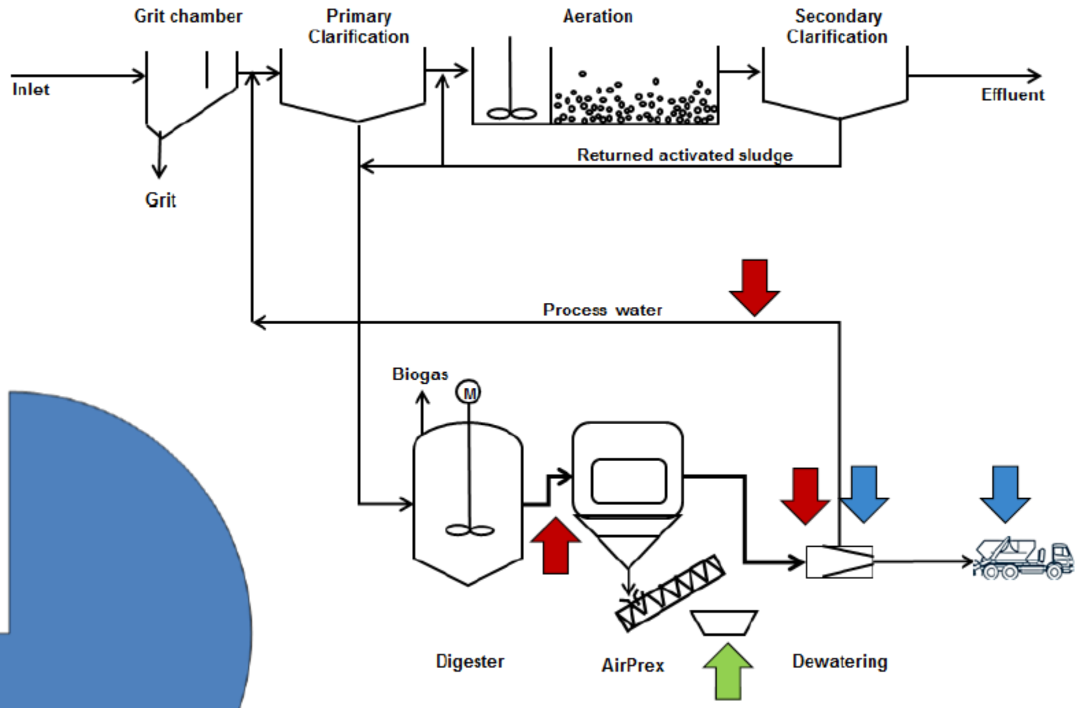


Waste Activated Sludge Stripping to Recover Internal Phosphate (WASSTRIP®)



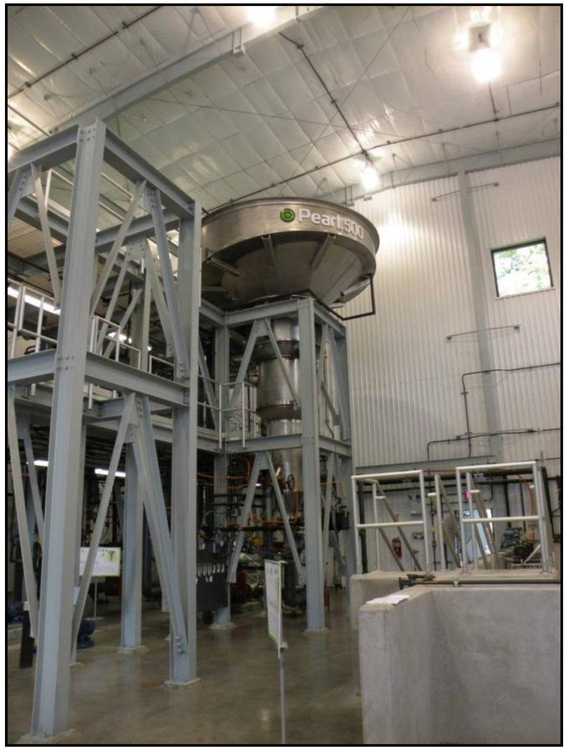
AirPrex
Struvite Recovery from Digested Biosolids





WERF Deliverables

- Final WERF report including TERRY released August 2015
- User manual and tutorial
- Who do we envision using TERRY?
  - Utility managers, research and development personnel
  - Consultants
  - Regulators



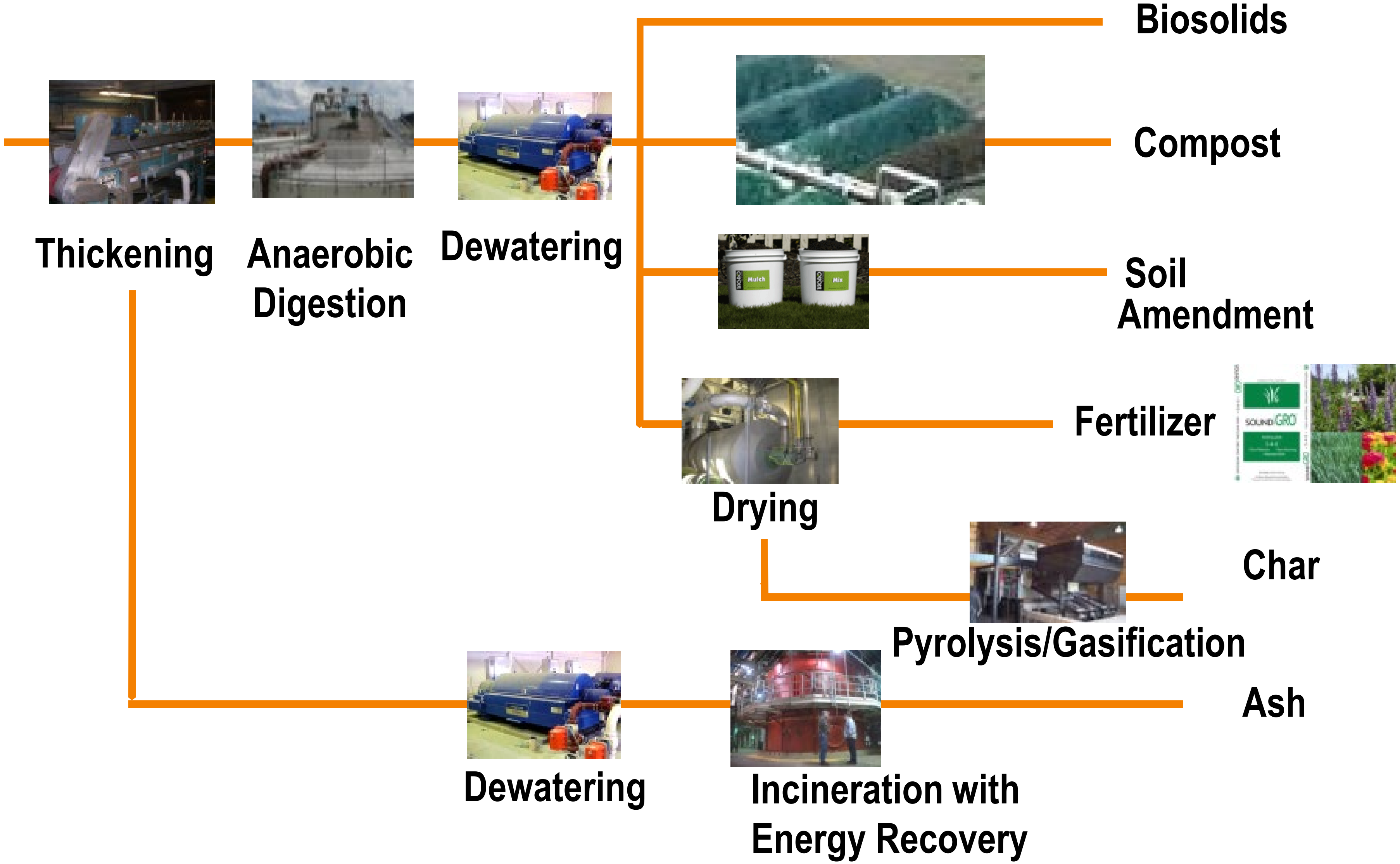
Tool for Evaluating Resource Recovery (TERRY)

- User friendly Excel tool
  - High level evaluation of site-specific feasibility of implementing extractive nutrient recovery
  - Used by several major US and Canadian utilities

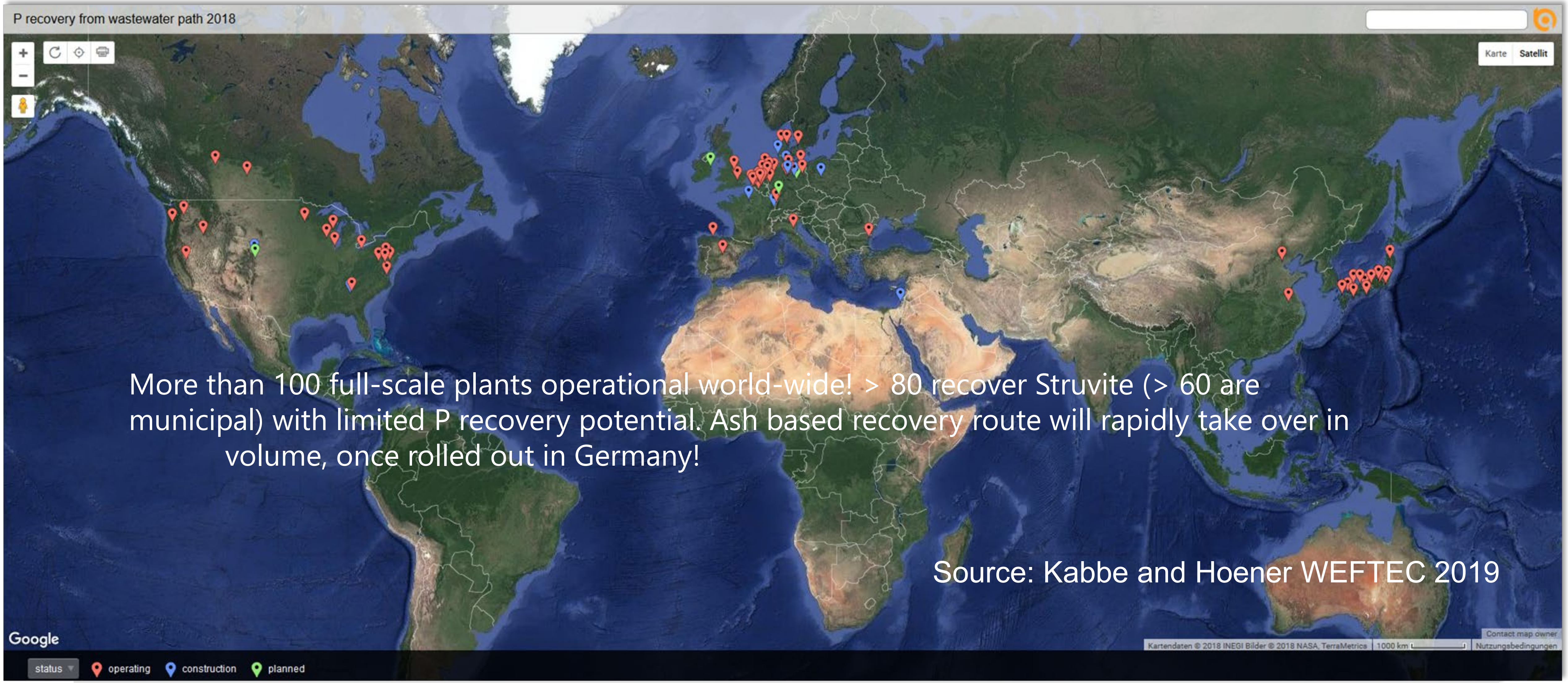
- Allows
  - Net present worth comparison of struvite recovery & chemical sidestream P treatment
  - Business case evaluation taking into account 13 criteria such as:
    - Cost
    - Technology performance
    - Environmental/ socials impacts
    - Technology maturity
    - Plant-wide impacts
  - Payback analysis
  - Technology factsheets available within the tool so that technology options can be compared

Beneficial Use of Biosolids

Technologies producing higher quality products and recovering more energy



GLOBAL IMPLEMENTATION OF P RECOVERY

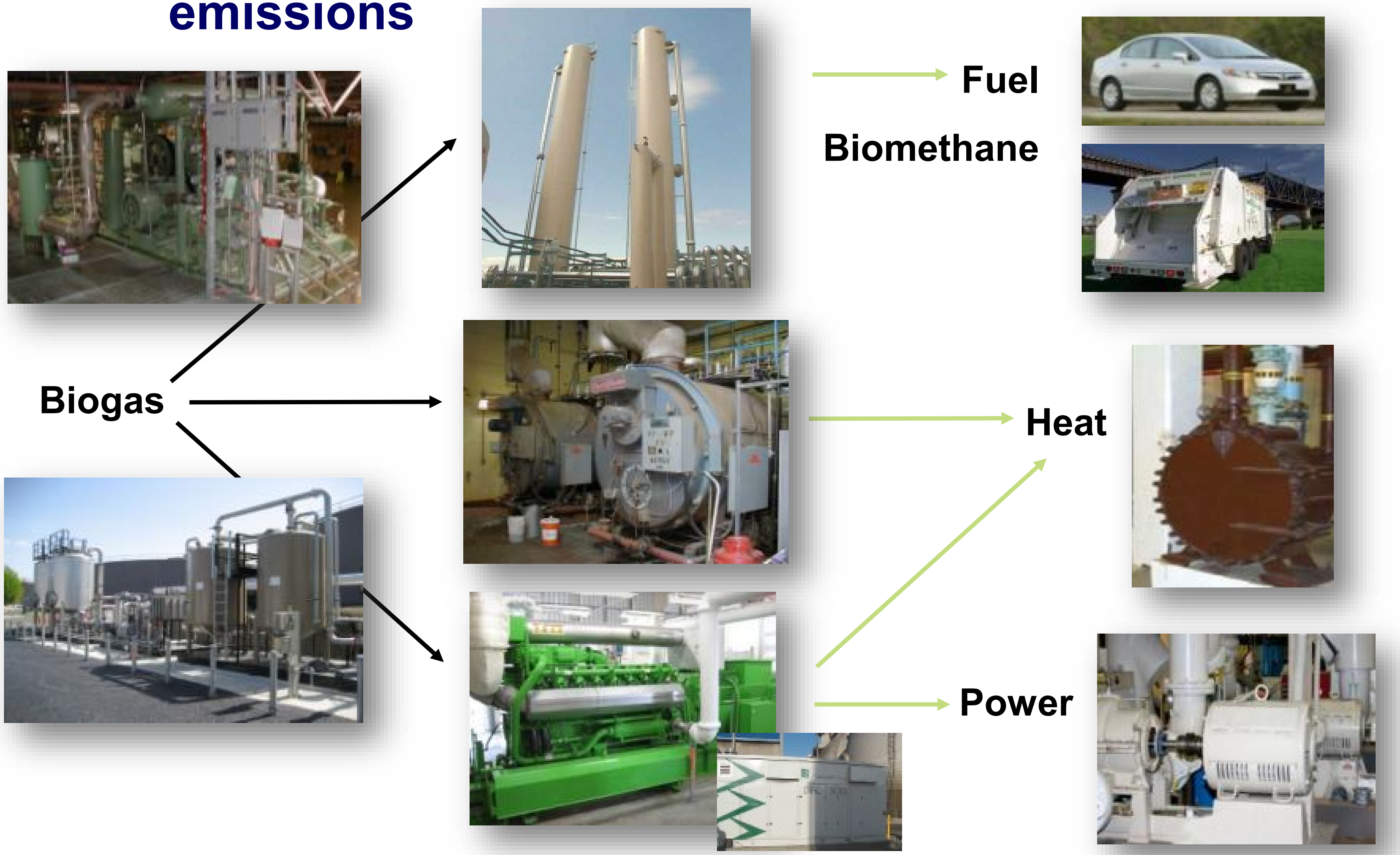


More than 100 full-scale plants operational world-wide! > 80 recover Struvite (> 60 are municipal) with limited P recovery potential. Ash based recovery route will rapidly take over in volume, once rolled out in Germany!

Source: Kabbe and Hoener WEFTEC 2019

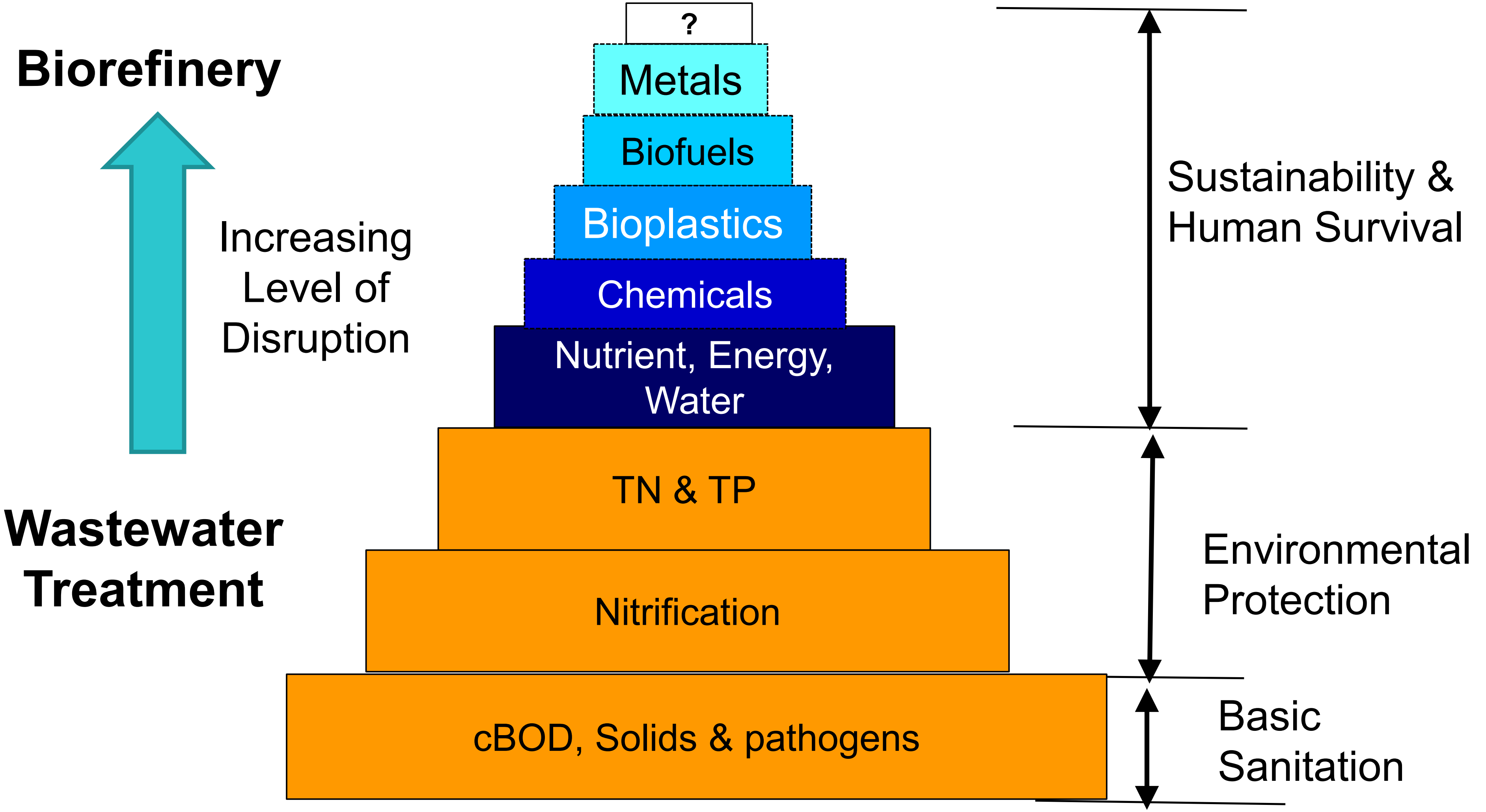
Beneficial Use of Biogas

Technologies with greater efficiencies and lower emissions



Engines, Turbines, Fuel Cells

Disruptive Approaches are Needed to go from Treatment to Product Recovery



What does the WRRF of the future look like?

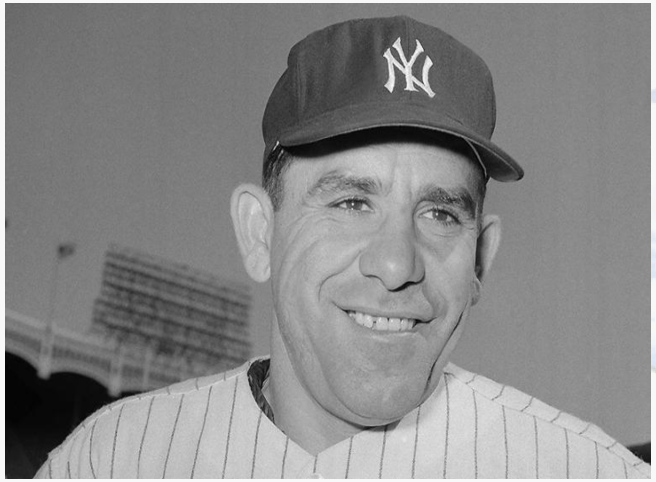
Key attributes of a WRRF of the future:

- Operate as a production center/biorefinery
  - Water factory
  - Energy factory
  - Resource (nutrient and organics) factory
    - Fertilizer manufacturing facility for example
- Carbon neutral; energy self-sufficient
- Centralized and decentralized systems
- Highly automated
- Increasingly resilient
- Doing more with less (intensification)
- In a highly regulated environment

Some summary thoughts…

- Leadership must articulate a vision for the future – ***be bold!***
- Consider non-traditional approaches to bridge gaps – ***dare to disrupt!***
- Utility staff must be involved, empowered, motivated, and accountable – ***seek buy in!***
- Know where are you starting from – ***develop a baseline!***
- Implement changes incrementally, reassess frequently, and have a contingent plan – ***no regrets!***
- Involve the community you serve – ***communicate!***
- Learn from others; share results – ***collaborate!***

Make a Plan….



Yogi Berra

"You've got to be very careful if you don't know where you are going, because you might get there."

"In theory there's no difference between theory and practice. In practice there is."

Courtesy: Glen Daigger

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QUESTIONS?

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