REINHOLD ENVIRONMENTAL Ltd.

2017 APC & Wastewater Round Table & Expo Presentation

July 17 & 18, 2017 in Charlotte, NC / Hosted by Duke Energy

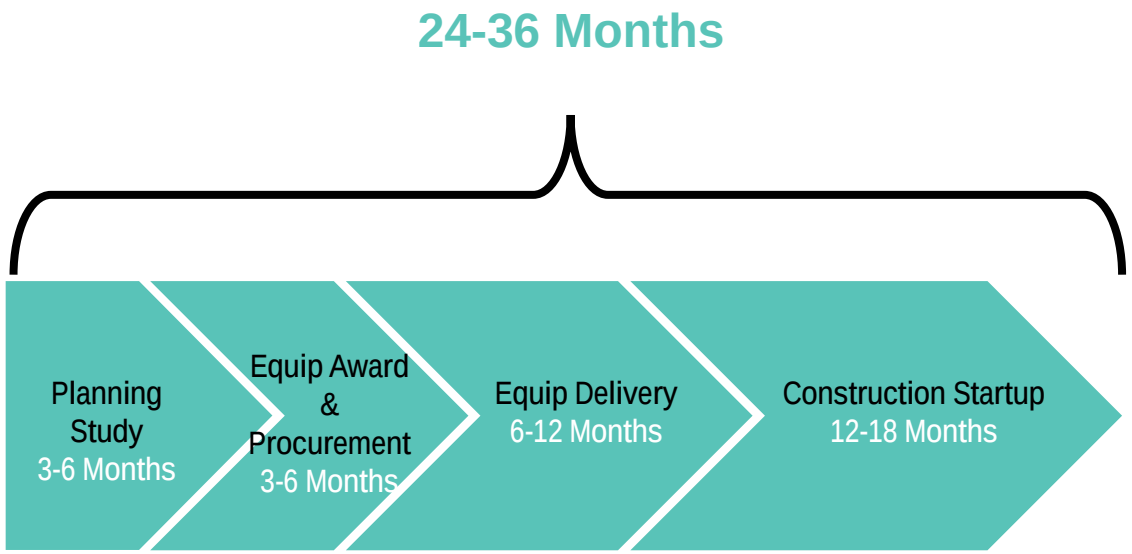
Emerging Technologies for ELG Compliance

Patricia Scroggin, PE

Regional Global Practice Manager

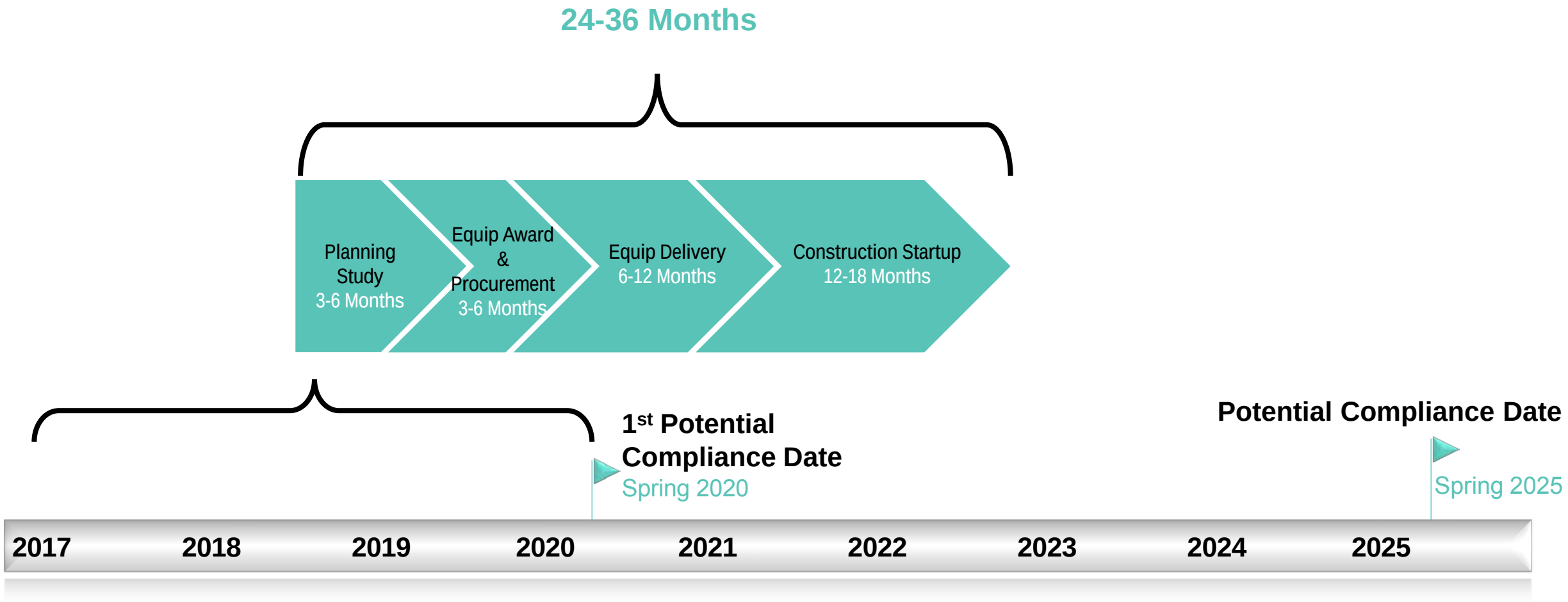
Burns & McDonnell

Published Compliance Timeline



2017 2018 2019 2020 2021 2022 2023 2024 2025

Published Compliance Timeline



“Traditional” ELG Compliance Technologies - FGD

Physical/Chemical and Biological

- GE ABMet
- Moving bed biological
- Large, concrete structures
- Demonstrated at 5+ sites

Zero Discharge (Thermal)

- Aquatech, GE (RCC), HPD Veolia and GEA
- Falling film evaporators and crystallizers
- Expensive materials of construction
- Demonstrated at 3 sites

The times, they are a-changing….

2016 Technologies

- Phys/Chem followed by:
- Biological (2 vendors)
- Thermal (3 vendors)
- Developing
  - Bypass evaporation (1 vendor)
  - ZVI (1 vendor)
  - Membranes (2 vendors)
- Deep Well Injection
  - (poor history)

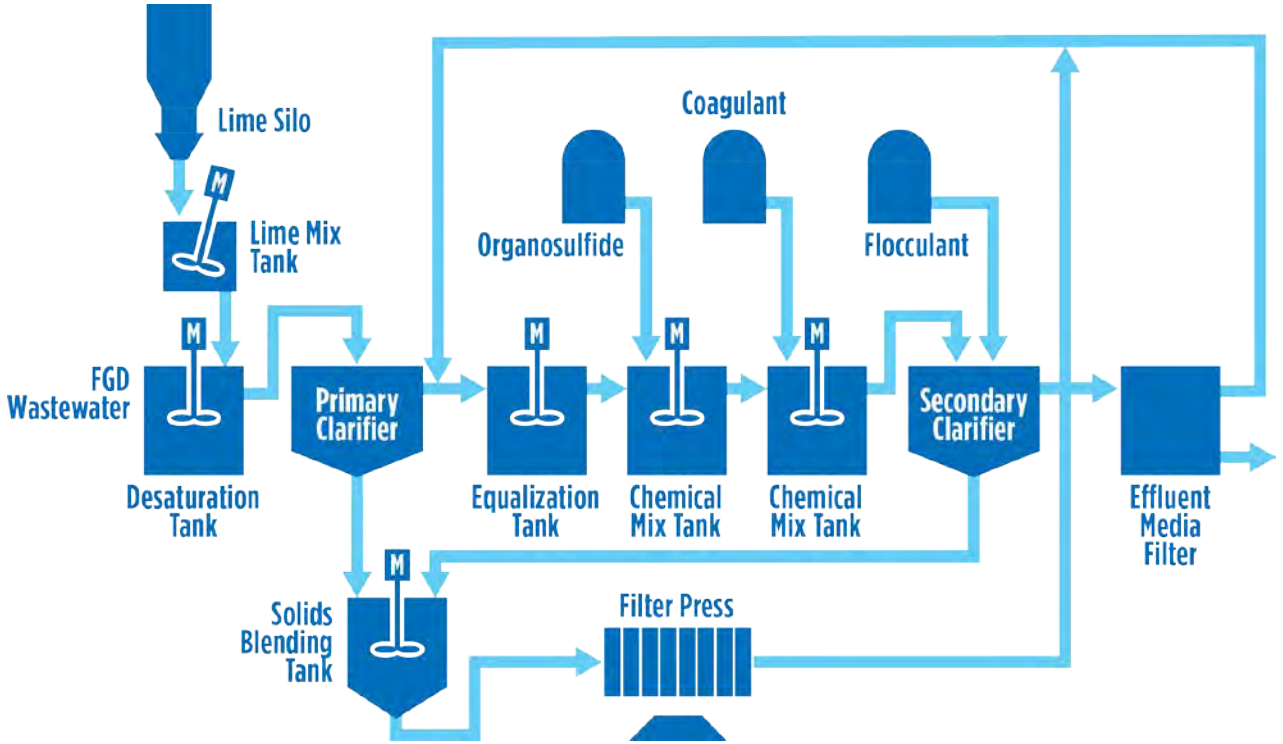
2017 Technologies

- Phys/Chem (pretreatment to a number of technologies)
- Biological (up to 6 vendors)
- Thermal (up to 5 options)
- ZVI (2 or 3 options)
- Membranes (3 or 4 options)
- Bypass evaporation (3 vendors)
- Deep Well Injection
  - (improving potential)

Phys-Chem Treatment with Organosulfide

- **Step 1 for most options**
- Removes metals/solids
- May remove hardness
- ***Not:***
  - Selenium
  - Nitrate
- Multiple vendors
  - Equipment
  - Chemicals

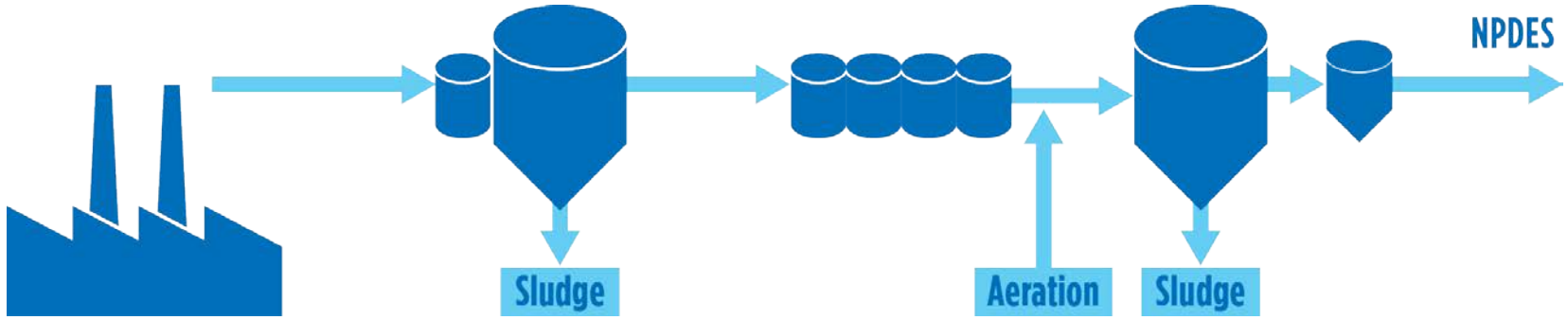
- **Effluent polishing required**
  - Biological
  - Thermal
  - Other/developing



Zero Valent Iron

- Phys-chem process replaces bacteria
  - Uses zero valent iron to reduce arsenic, selenium and mercury
- Full scale
- Pilot on FGD @ Water Research Center
  - 2 pilots completed, 2 running/starting up

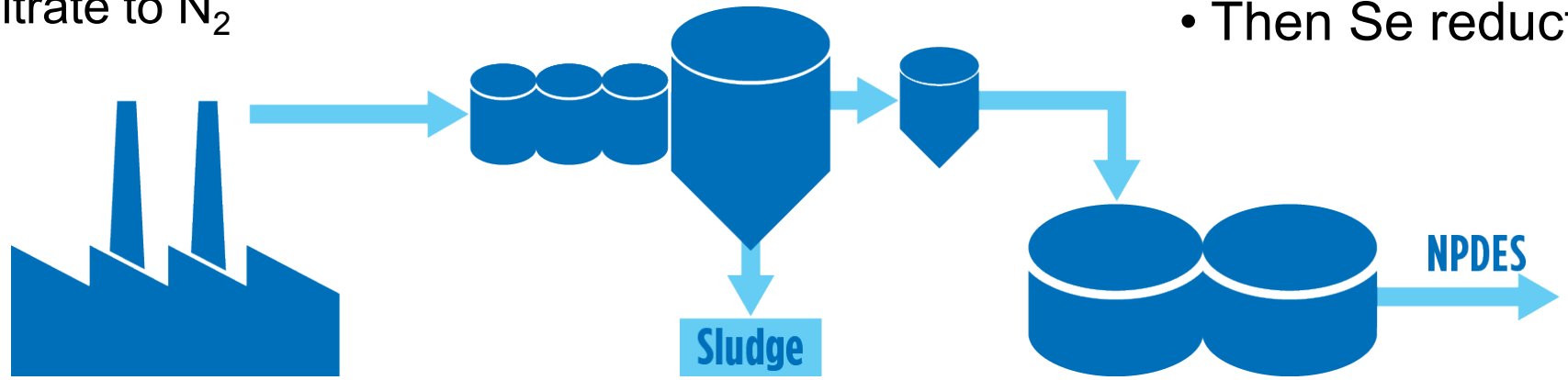
- Limited number of vendors
- In pilot testing
  - Nitrate removal
  - Guarantees
- High reagent use = high sludge
  - May be better suited for polishing



Biological Treatment

- Most established
- EPA's Technology Basis
- Currently in use at several facilities
- Bacteria convert:
  - Selenate or selenite to elemental Se
  - Mercury to insoluble salts
  - Nitrate to N_2

  - Single vendor
    - With FGD **full scale** installations
    - Others under contract
  - More are developing
  - May require polishing
- Theme:
  - Nutrient/nitrate reduction
    - Then Se reduction

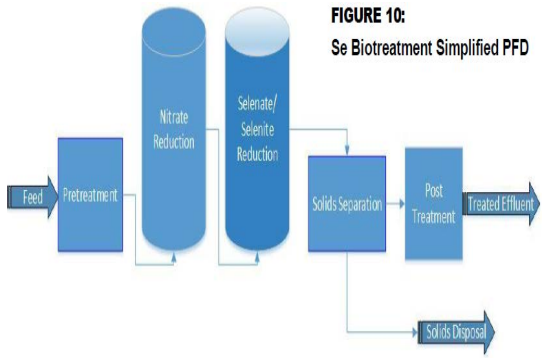


Biological – Industry Cross-Over and New to Market

Frontier Water – SeHAWK

- Modular
- Fiberglass construction
- Upflow and downflow bioreactors followed by microfiltration
- Mining/CCR pond dewatering

Further Developments in Bio

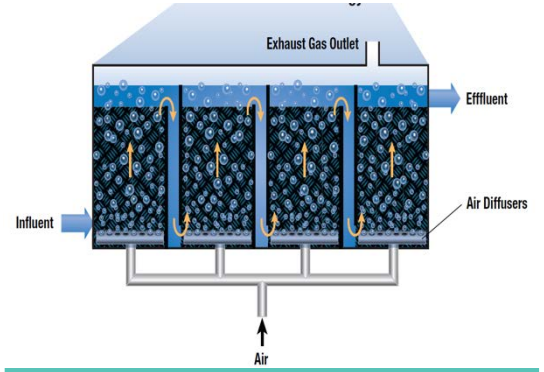


Envirogen

- FBR
- Focused on selenium

Veolia AnokKaldnes

- Moving bed bioreactor



UOP Xceed

- Selenium focus
- Refinery experience
- 50+ installations

Doosan LENA/MBBR

- Moving bed
- In development
- Single pilot on mining

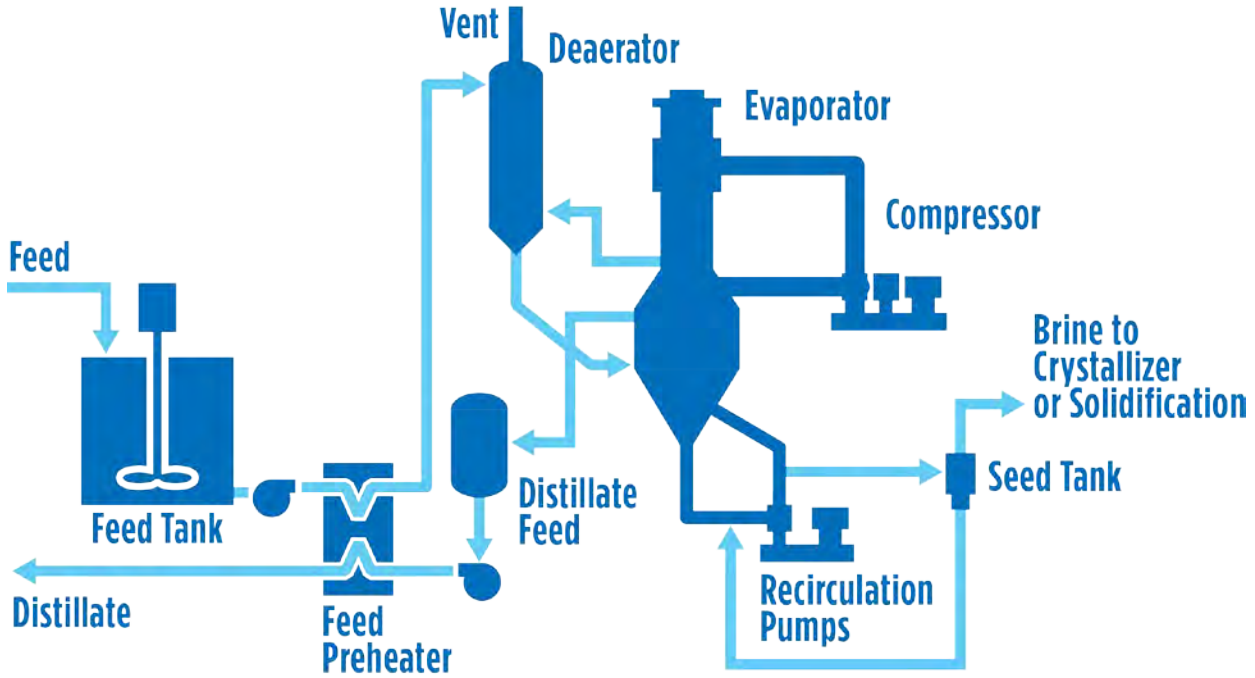
Biological Treatment – Quick Pilot Update

- GE ABMet
  - Multiple pilots
  - Longest history
- Frontier SeHawk
  - Multiple pilots
  - 6 pilots on FGD
  - 6 for mining
  - Up to 250 gpm
- Envirogen FBR
- Veolia AnoxKaldnes
  - MBBR
  - 1 pilot on FGD
- UOP Xceed Bioreactor
  - Se removal at refineries
  - No current FGD pilots
  - 50+ other installations
- Doosan LENA/MBBR
  - MBBR
  - 1 pilot on mining

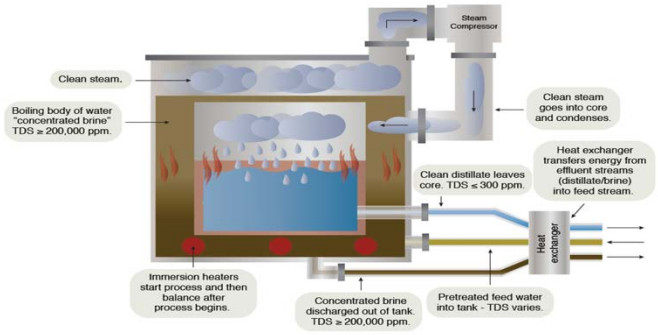
Thermal Evaporator/Crystallizer

- Established technology
  - In use at Merrimack, Duke, others
- Produces low TDS reusable waste stream

- High parasitic power
- Expensive
- Operator-intensive

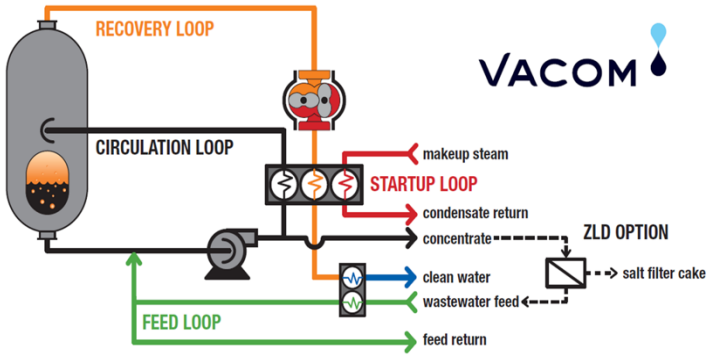


Thermal – Push for Modularization



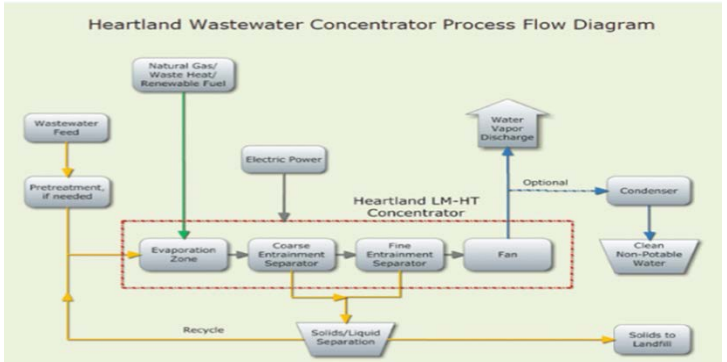
Avara

- Modular
- Produced water/fracking industry
- Pilot in progress with EPRI



Vacom

- Modular
- Mining/auto industry
- FC crystallizer
- Piloted at Water Research Center and one utility



Heartland

- Single step concentration
- Large scale demonstration – multiple year pilot at Iatan
- 2 additional EPRI pilots

Membranes – Low Cost Alternatives

Kleenwater

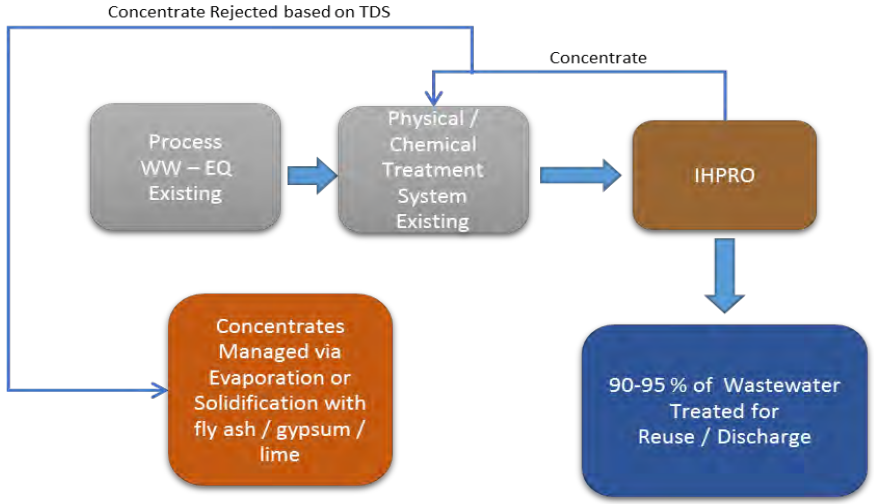
- Multi-state high pressure reverse osmosis
- 80-85% recovery
- Softening pretreatment

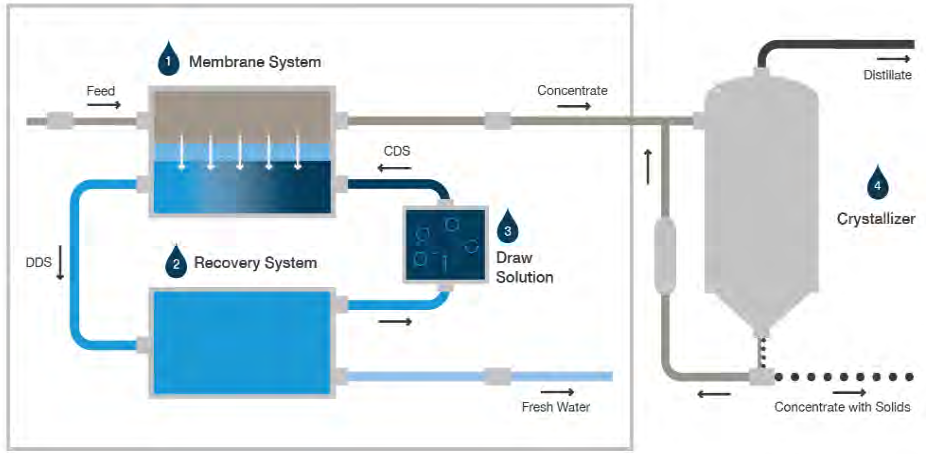
VSEP

- Vibrating, vertical RO
- Pure water

Oasys

- Forward osmosis
- Low pressure
- Up to 90% recovery
- Chinese installation on FGD

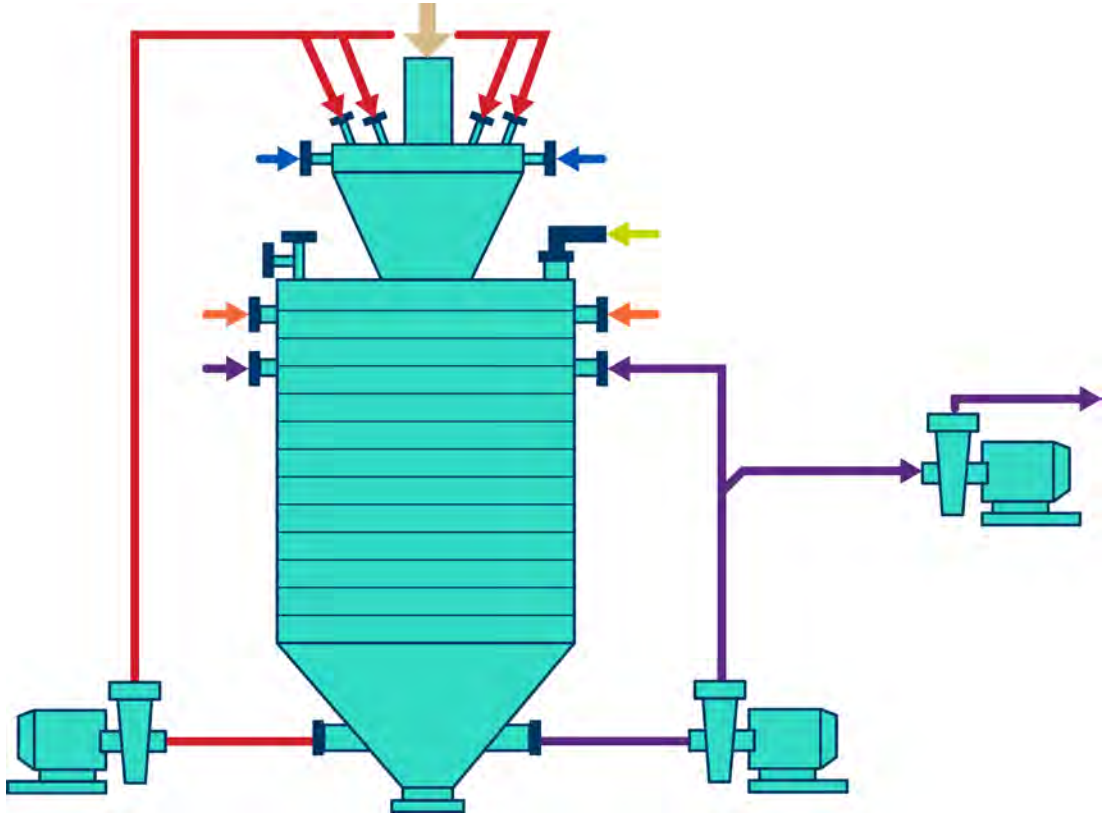




Membranes – Pilot Status

- Oasys - Forward Osmosis
  - Full scale installation in China
  - EPRI pilot
    - 90% recovery
    - ELG compliant
- VSEP©
  - Pilots completed at WRC
- EDR/RO
  - Electro-dialysis reversal followed by RO
  - Similar to EDI
  - Pilots on mine water showing promise

Other Tools in the Toolbox

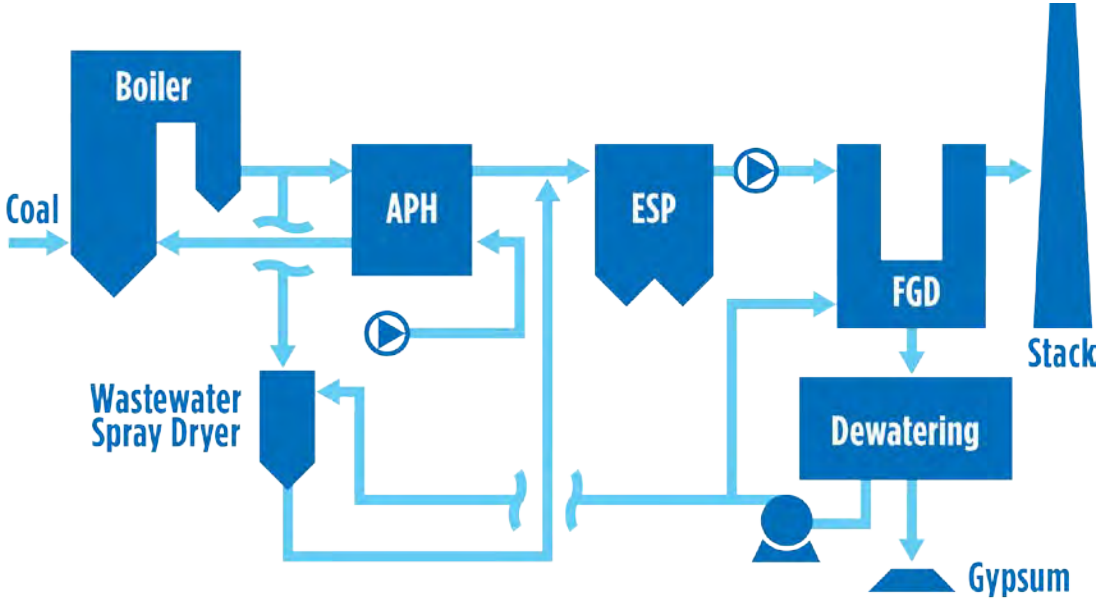


NAES	Air Heater Bypass Evaporators	Deep Well Injection
• Dense slurry • Zero discharge • Belgium installation	• Multiple vendors • Domestic installation	• Site specific geology • State by state permitting • Pretreatment required

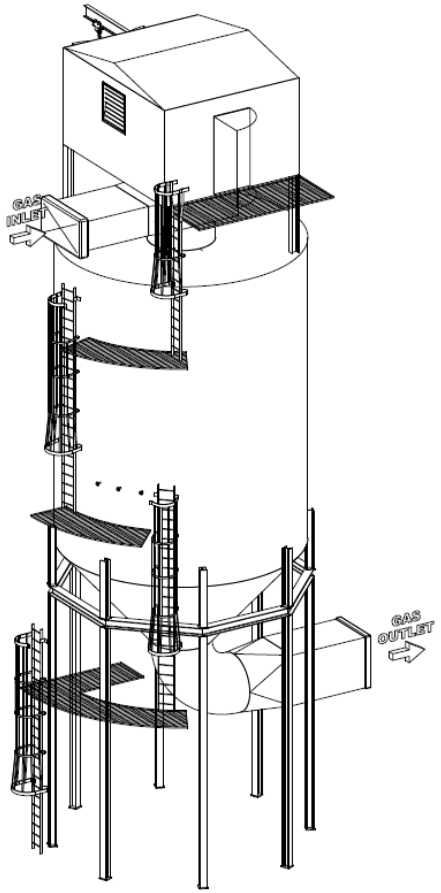
Evaporation into Flue Gas

- Installations in progress
  - Commercial in 2017
- Spray dryer technology is well understood in other applications
- Uses “spare” heat to dry FGD wastewater

- No wastewater discharge
- Impact to baghouse
- Materials of construction
- Full scale operation achieved in 2017



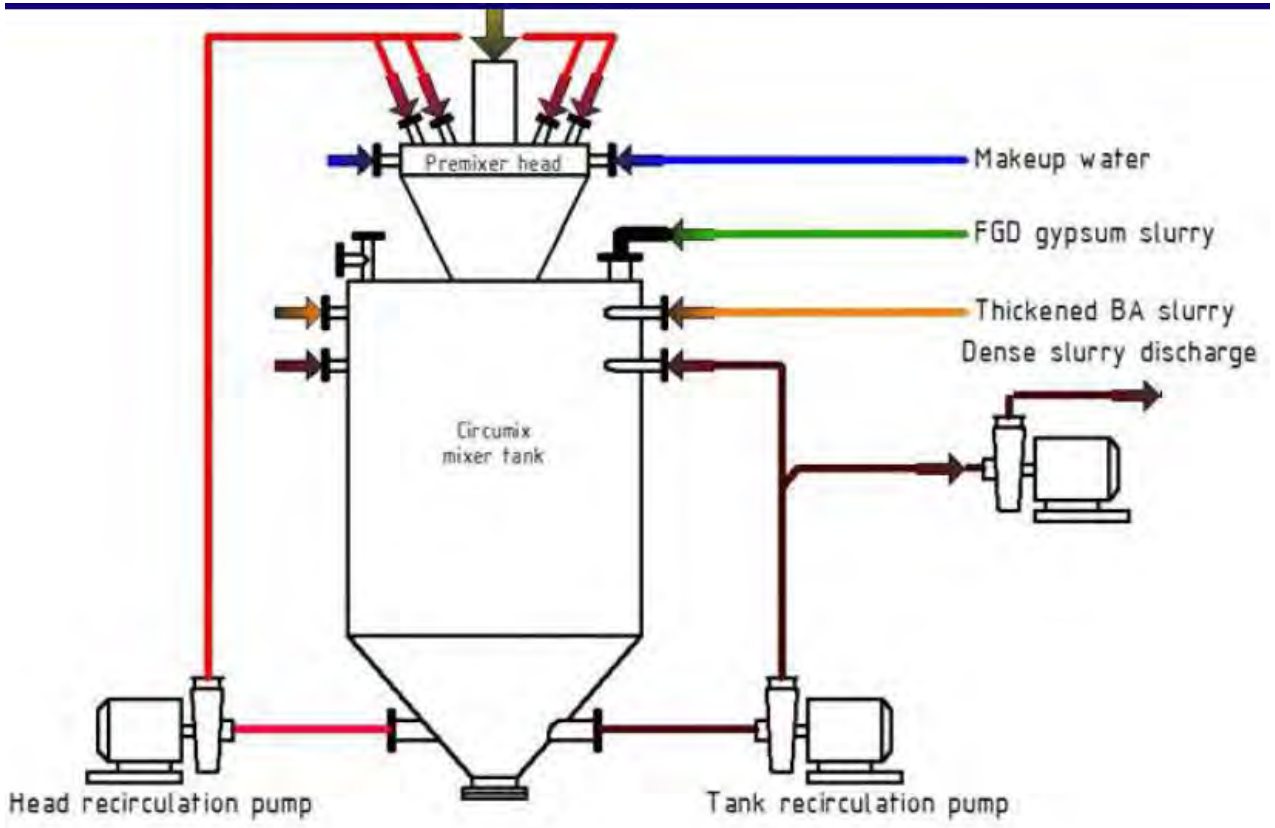
Evaporation into Flue Gas



- **Suppliers**
  - **Alstom**
  - **B&W**
  - **Mitsubishi**
  - **Lechler**
  - **Etc.**
- **Design Considerations**
  - **Multiple Unit Sites**
  - **Load Following Conditions**
  - **Outages**
  - **Isolation Dampers/Online Maintenance**

Slurry or Paste Systems

- NAES Dense Slurry Systems
  - Full scale operation in Belgium
  - Pilots available for demonstration



Deep Well Injection

- Class I deep wells common for some industries
  - No hazardous waste
  - Not like Class II wells
- State or EPA lead
  - ~2 year permitting and construction
    - ~ 1year for permit to construct
    - Another year or more to
    - Construct test well, do formation compatibility test, submit report, and obtain operating permit
  - Test well is “the well”
- FGD CaSO4 chemistry
  - Reverse solubilities
  - Flash precipitation
  - Particle size limitations
  - Defined during compatibility test

Future Solutions

- **Innovation**
  - **Flue Gas Solutions**
  - **Post FGD Volume Reduction**
  - **ZLD alternatives**
  - **Polishing Techologies**
  - **Modularization**

The race is on!

Questions?

Patricia M. Scroggin, PE
pscroggin@burnsmcd.com

Regional Practice Manager, Energy
Burns & McDonnell

BURNS McDONNELL℠