Partitioning and fate profiles of per- and polyfluoroalkyl substances (PFAS) in biosolids:

Part 1 - Differences in biosolids quality between two treatment plants

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Florida Water Environment Association | BIOSOLIDS COMMITTEE

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What are PFAS?

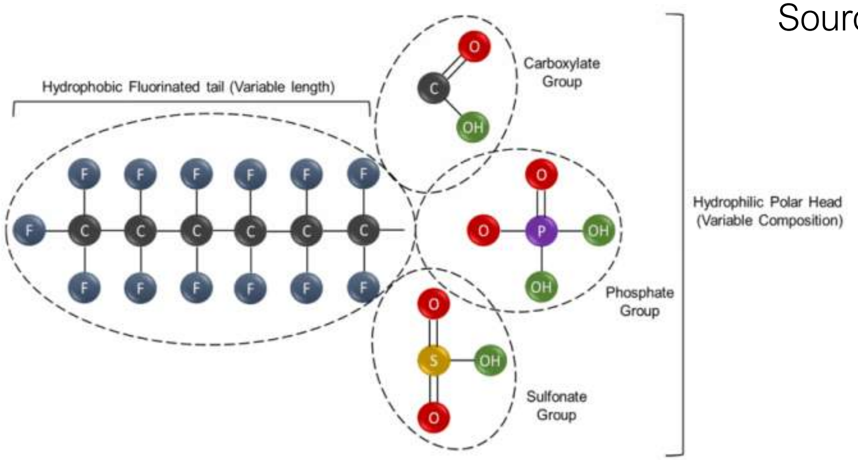
- Synthetic chemicals used in variety of industrial and consumer products
- Persistent in nature and widespread presence in the environment
- Composed of strong C-F bond (130 kcal/mol)
- Resistance to heat, oil, stains, grease and water.
- Show adverse health effects to animals and humans (potential carcinogenic).

Source: Pinellas.gov/pfas

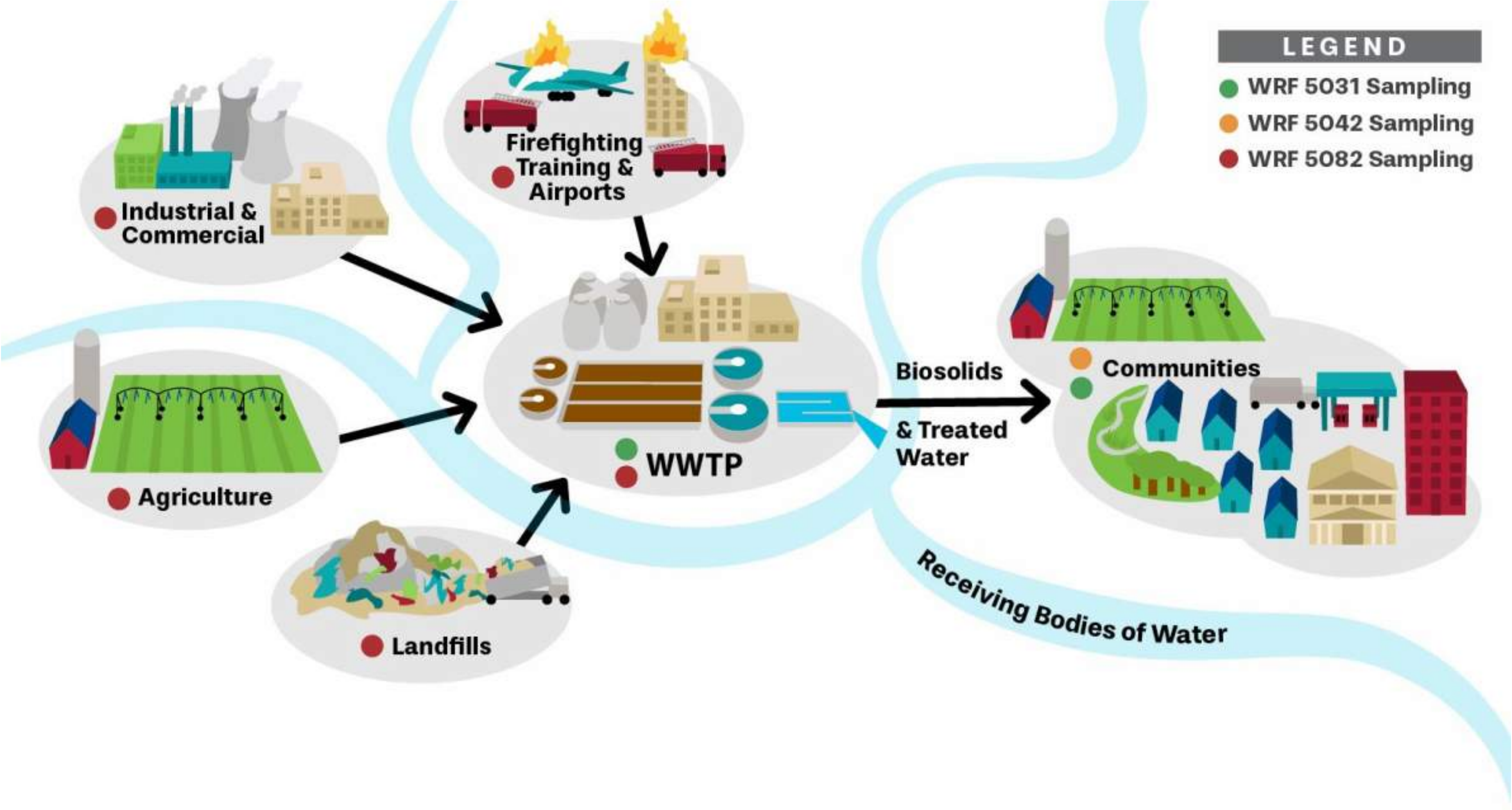
kidney & testicular cancer

infertility & low birth weight

thyroid & heart issues



Sources of PFAS in Biosolids



- About 7.18 million tons per year (6.51 million kg/year) biosolid produced at wastewater treatment plants.
- 60% land-applied
- 20% landfilled
- 20% incinerated
- Land application of biosolids can result in uptake of perfluoroalkyl acids into edible crops

- MCL in drinking water for PFOA and PFOS: 4 ppt, but no MCL for soil/biosolids

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Objectives of the project

- Conduct sampling of biosolids after dewatering and drying processes at two Miami-Dade wastewater treatment plants (South District and Central District Wastewater Treatment Plants).
- Analyze biosolids samples for PFAS content and component profile; determine the prevalent PFAS compounds.
- Conduct leaching experiments to evaluate the release of PFAS from biosolids under site-specific conditions.
- Estimate time dependent solubilization and the release characteristics of the PFAS homologues from biosolids.
- Further scientific understanding of PFAS originating from biosolids as a source in the environment, potential exposure pathways for human health and ecological effects.

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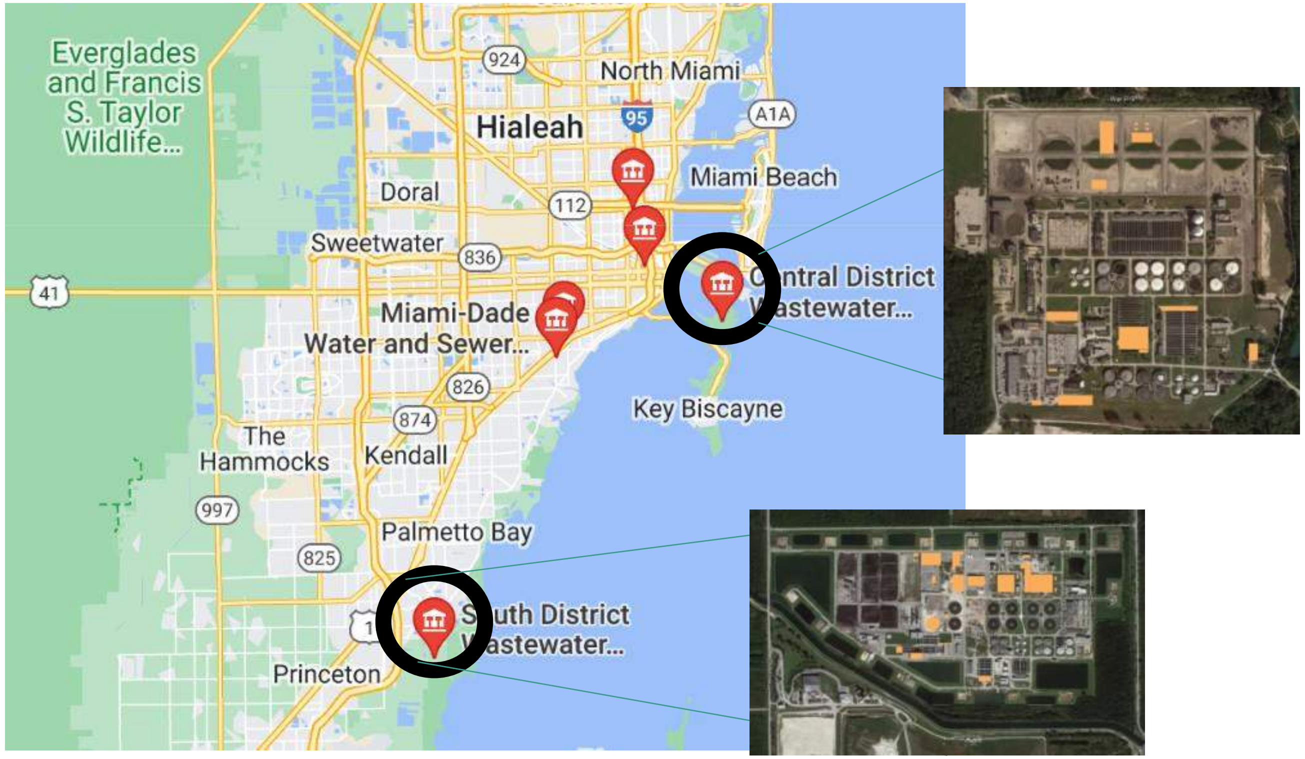
Sampling Biosolids at WWTPs

- **Central District Wastewater Treatment Plant**
  - MDWASD's oldest and largest plant with a treatment
  - Capacity: 143 million gallons per day (MGD)
  - Ave daily flow: 101 MGD
  - Effluent discharged via outfalls

- **South District Wastewater Treatment Plant**
  - Wastewater Treatment Water Reclamation plant
  - Receives leachate from South Dade Landfill
  - Capacity: of 112.5 MGD
  - Ave daily flow: 93.2 MGD
  - Effluent discharged via injection wells



1 Thickened Sludge → 2 Digested Sludge → 3 Dewatered Sludge → 4 Biosolids for Land Application

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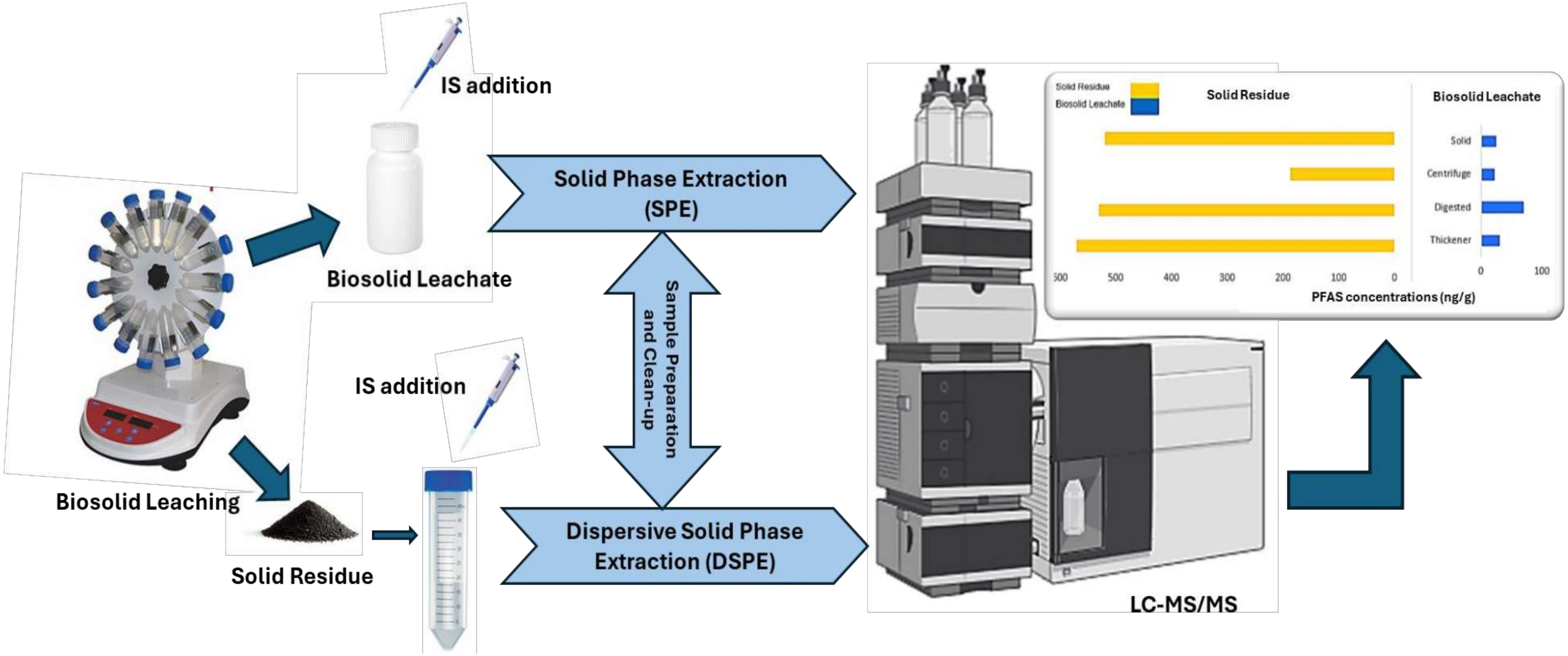
Methodology- PFAS leaching and analysis



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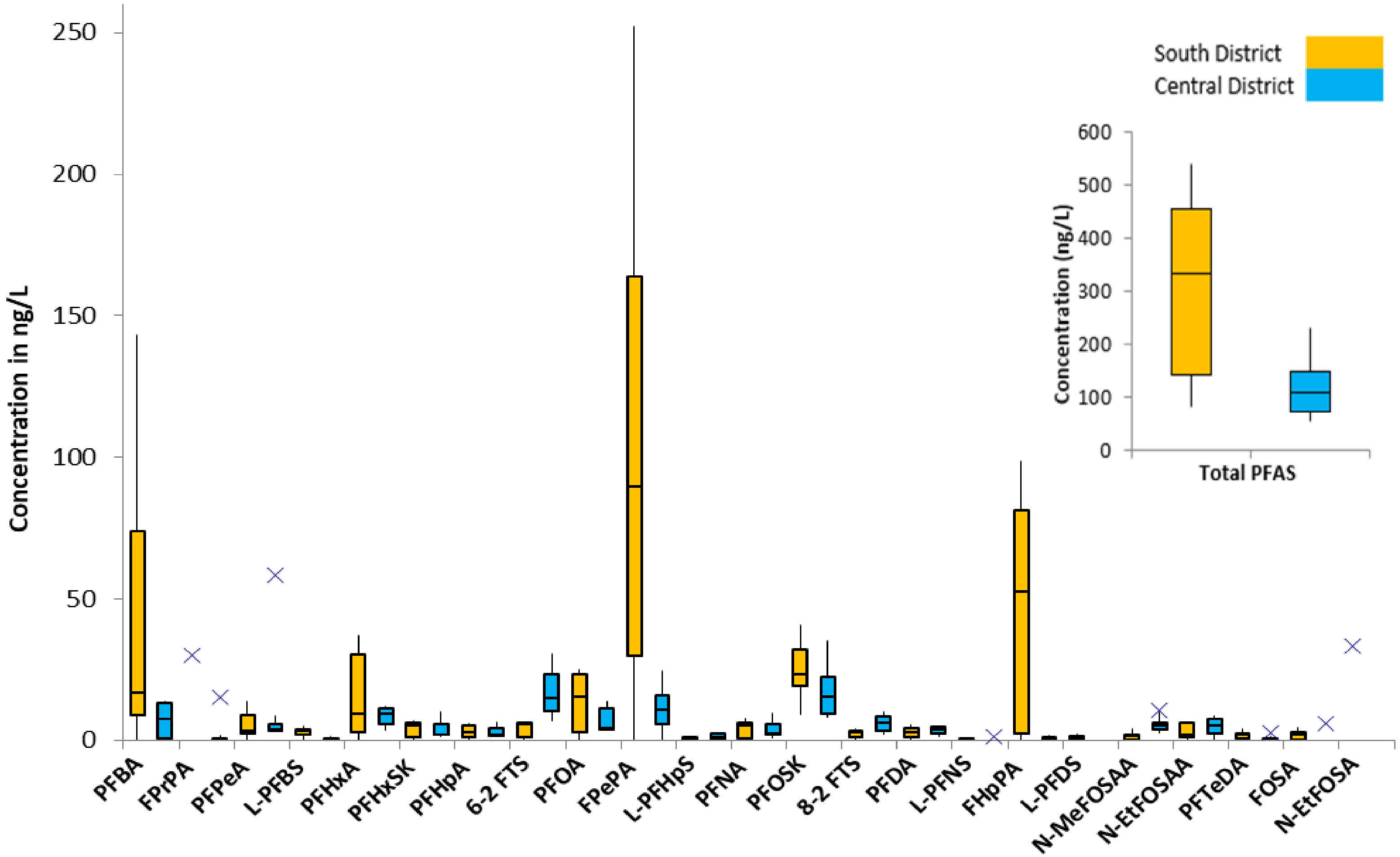
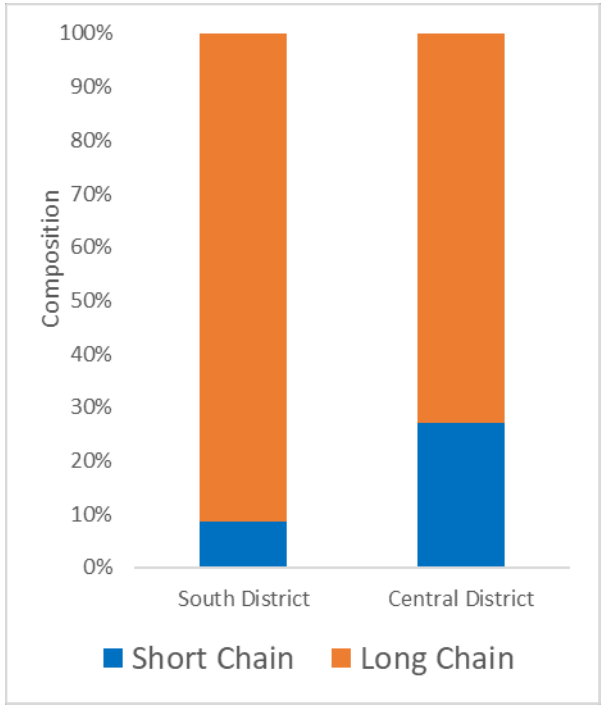
PFAS composition in Leachate





Concentration (ng/L) of PFAS concentration in biosolid leachates from SDWWTP and CDWWTP

Predominant PFAS in biosolid leachates: PFBA, PFHxA, PFOA, FPePA, PFOS, and FHpPA

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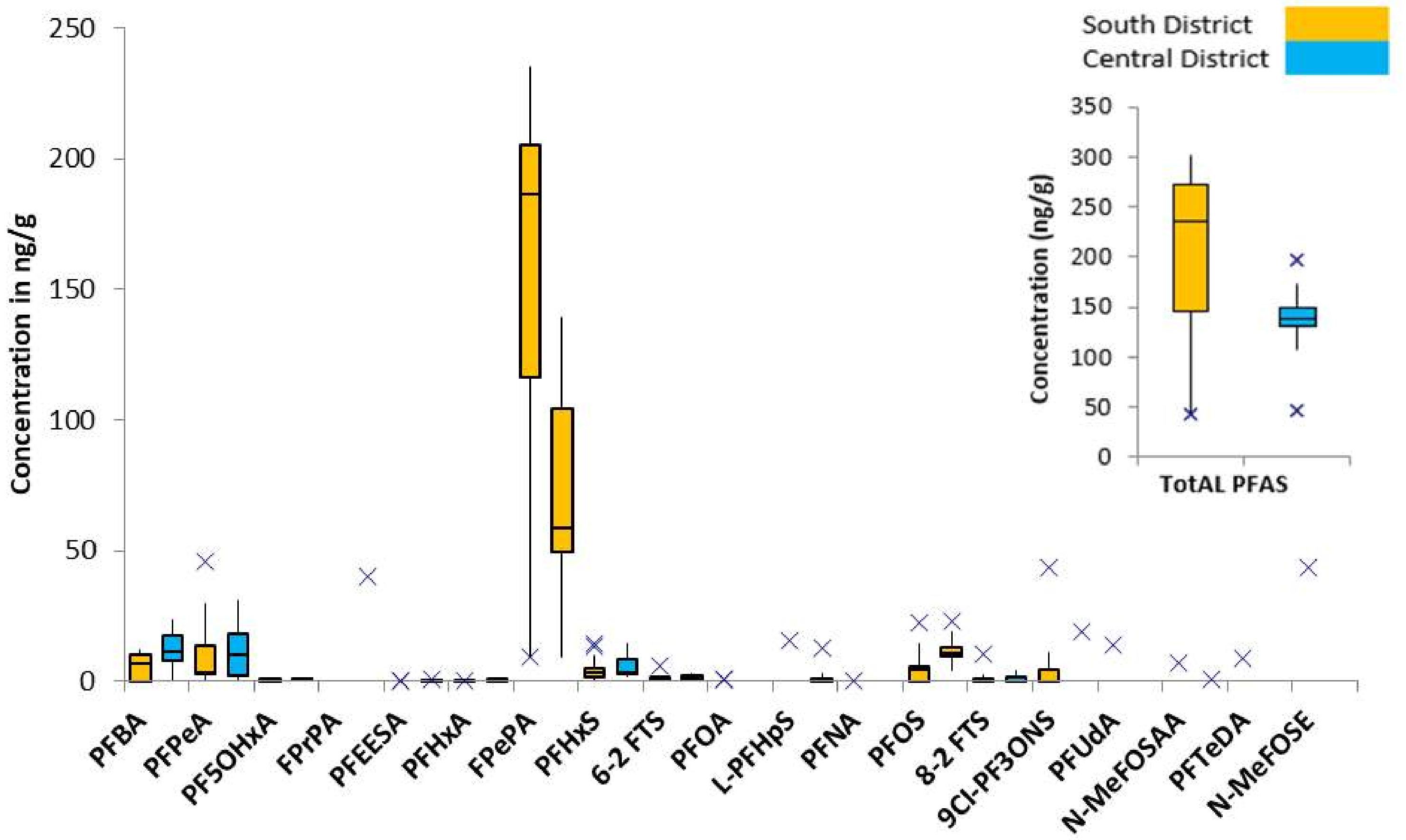
PFAS composition in solid residue



Concentration (ng/g) of PFAS concentration in the solid residues from SDWWTP and CDWWTP

Predominant PFAS: PFBA, PFPeA, FPePA, PFHxS, and PFOS- detection frequencies (DF) between 54 and 100%, except PFOS with 35% DF in CDWWTP.

SDWWTP exhibits a greater overall PFAS concentration at p < 0.10 in biosolids (817.17 ng/g) and leachates (1135.3 ng/L) compared to the CDWWTP (399.88 ng/g in biosolids and 359.962 ng/L in leachates).

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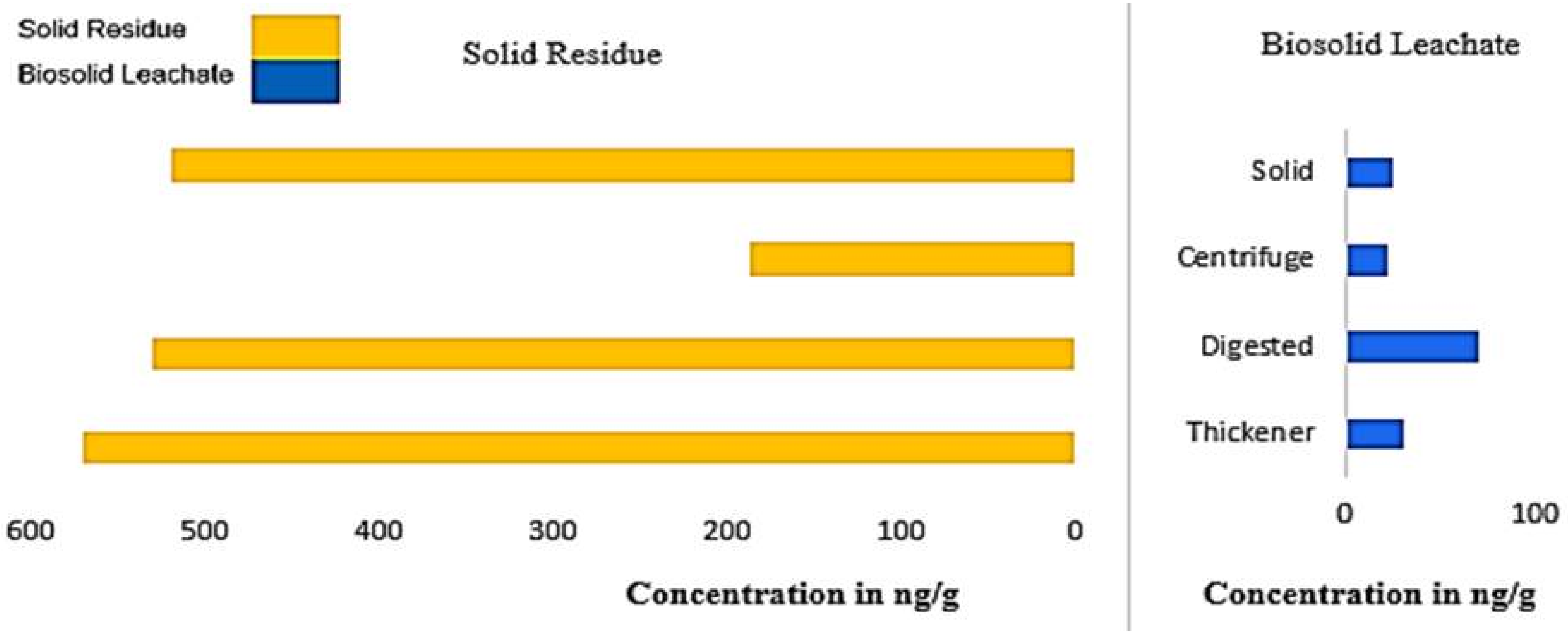
∑PFAS in the different treatment stages



∑PFAS in Biosolids Leachates and the Solid Residue in (ng/g) at different treatment stages of SDWWTP.

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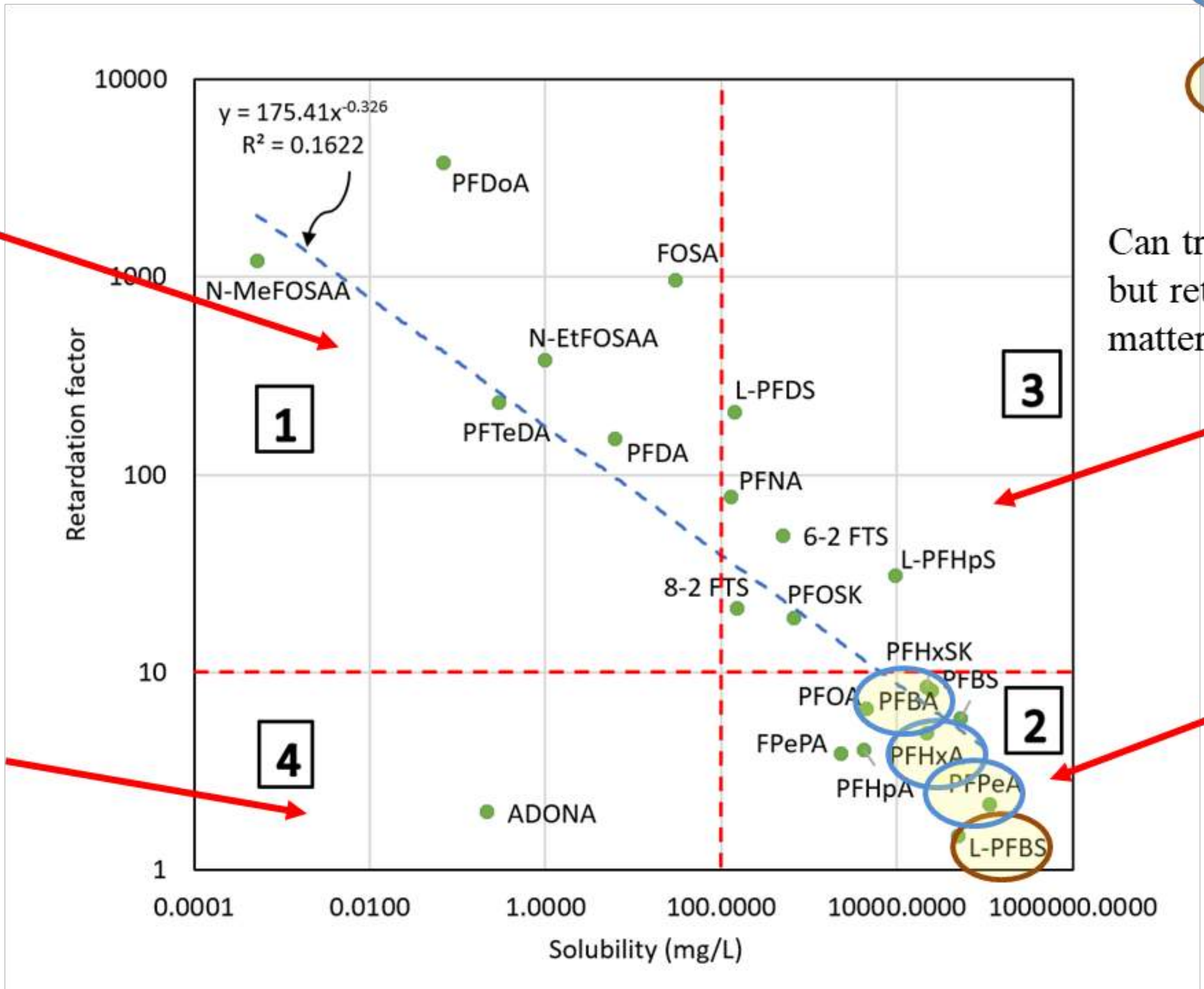
PFAS Partioning in Biosolids

High conc in leachate

High conc in solid residue

High accumulation tendency in soil

Slow transfer to aqueous phase



Can transfer to aqueous phase but retained by the soil organic matter during transport

High solubility and high mobility

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Prioritization of PFAS in Biosolids

Compound	Biosolids Leachates				Solid Residue			
	CDWWTP		SDWWTP		CDWWTP		SDWWTP	
	Average Concentration (ng/L)	DF	Average Concentration (ng/L)	DF	Average Concentration (ng/g)	DF	Average Concentration (ng/g)	DF
FPePA	11.25	89	122.42	83	73.64	100	149.22	100
PFBA	7.05	89	39.87	67	10.96	90	11.68	88
PFHxA	8.37	100	14.64	78	-	-	-	-
PFOA	7.20	100	12.13	78	-	-	-	-
PFOS	17.77	100	25.00	100	4.94	88	11.35	53
FHpPA	0.49	78	46.01	33	-	-	-	-
PFPeA	5.4	100	13.01	89	5.84	88	12.22	63
PFHxS	6.60	100	4.94	88	-	-	-	-

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Take Home Messages

1. **Distinct differences in PFAS composition** in biosolids between the South District (receives landfill leachate), and the Central District plants (domestic wastewater).
2. Biosolids from both plants have a predominance of **long-chain PFAS**, but biosolids collected from CDWWTP had a higher proportion of short-chain PFAS than SDWWTP.
3. The majority of **PFAS become associated with the organic solids** produced during aeration, ultimately ending up in the thickened sludge.
4. Digested sludge exhibited higher concentrations of PFAS. As volatile solids decompose, some PFAS are released into the water phase and removed during dewatering by centrifugation.
5. The leachate from the samples collected at the **CDWWP has significantly lower** PFAS levels than those from the SDWWTP.
6. The leachate samples collected at different times indicate that PFAS would leach rapidly. The leaching tests led to the **highest PFAS concentrations after 1 day**.

Partitioning and fate profiles of per- and polyfluoroalkyl substances (PFAS) in biosolids:

Part 2 - Effect ionic content and protein content

Dr. Yelena Katsenovich, Dr. Natalia Quinete, Dr. Berrin Tansel, Joshua Ocheje, Maria Mendonza Manzano, Zariah Nasir

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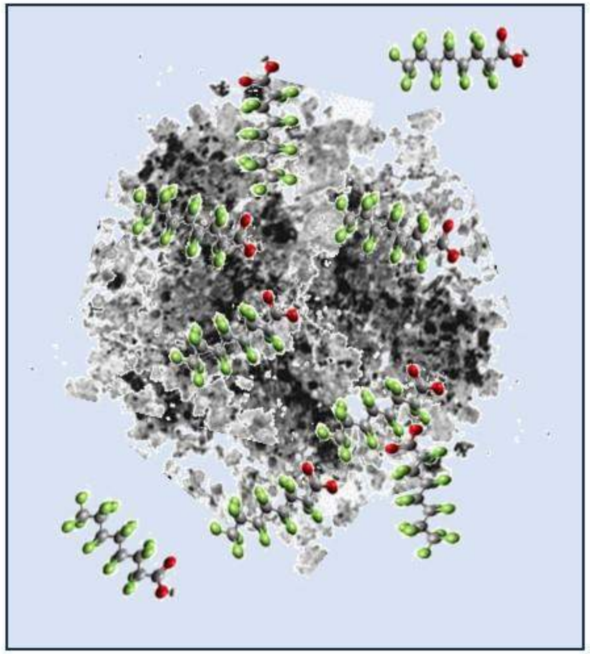
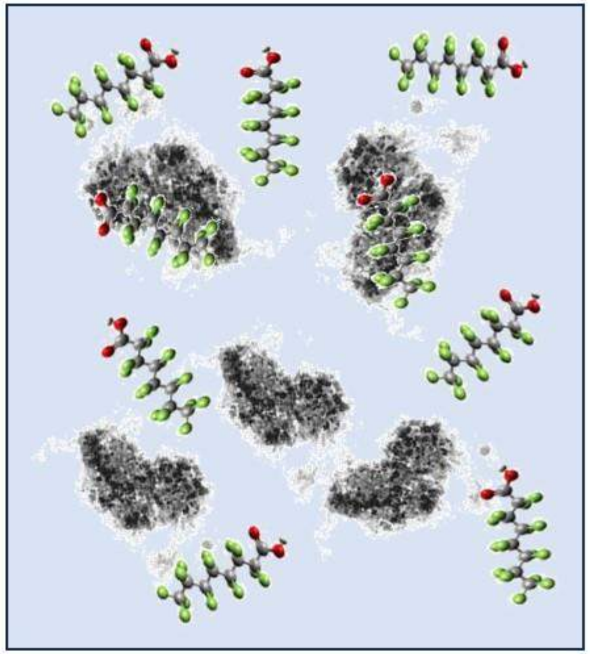
What is the fate of PFAS during wastewater treatment?

Thickened sludge



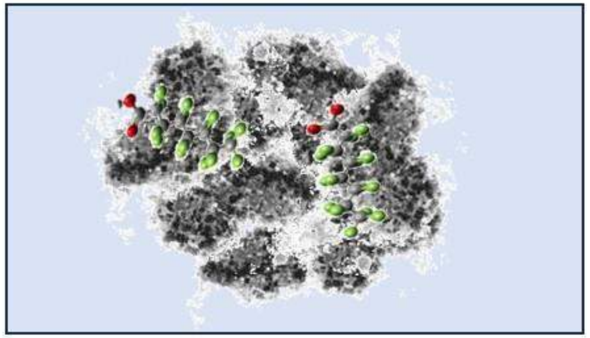
PFAS sorbed by solids forming during activated sludge process.

Digested sludge

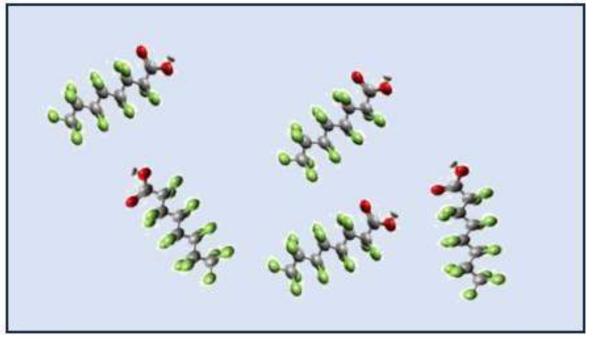


Some PFAS are released back to water phase as volatile solids decompose.

Centrifuged biosolids



Cake solids have less PFAS.



Some PFAS removed with supernatant.

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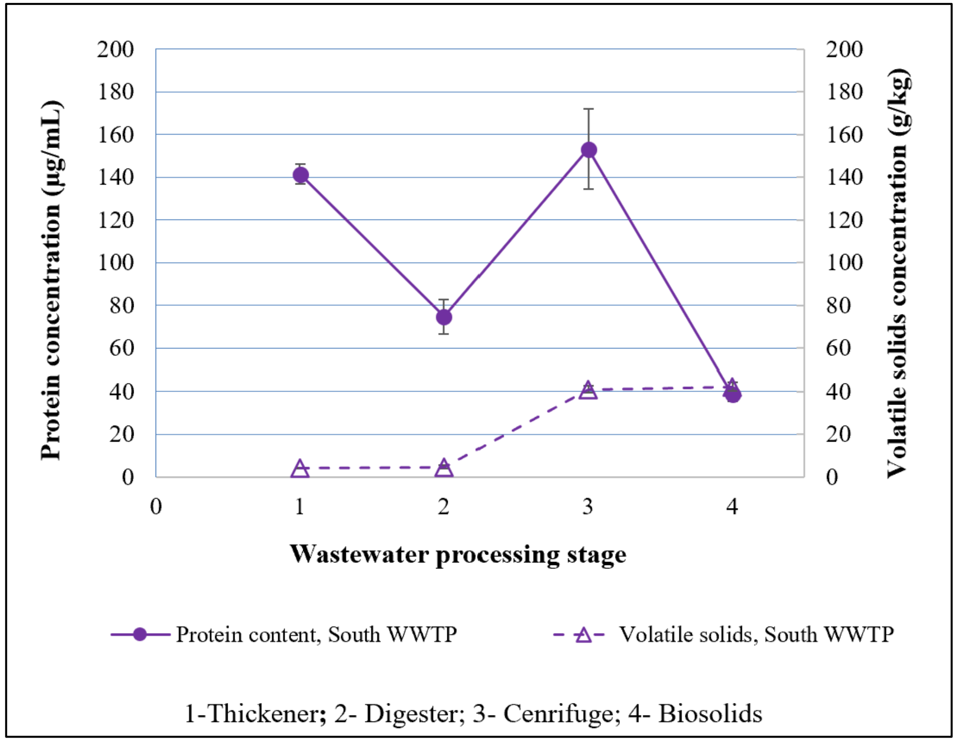
Protein content of biosolids

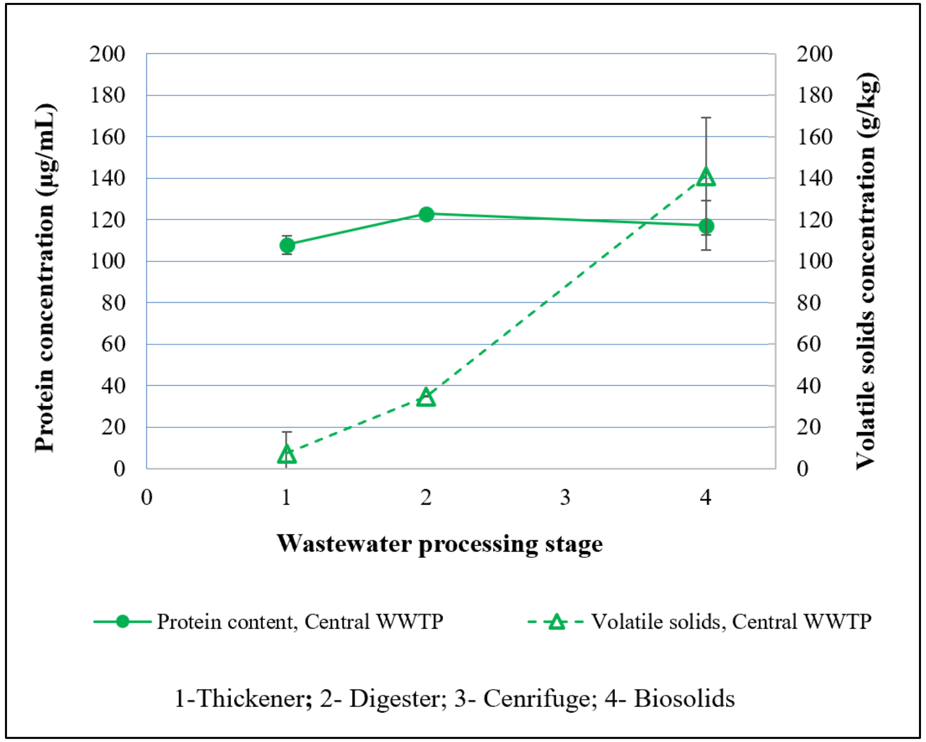
Biosolids are organic fertilizers that can provide phosphorus to agricultural soil.

Since protein is a component of the organic fraction in biosolids, protein levels can affect PFAS fate.

South District



Central District



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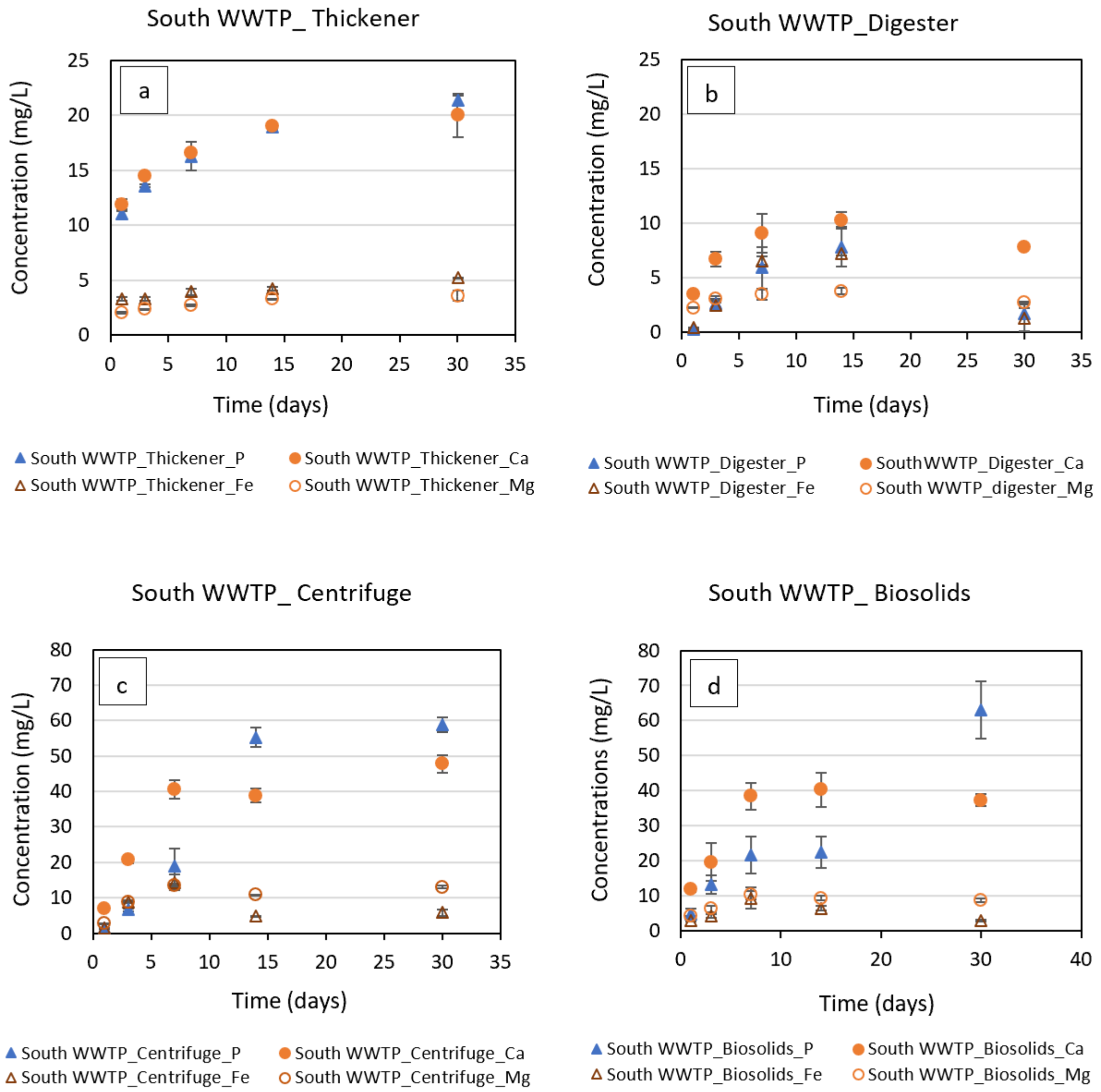
Ionic content of biosolids – P, Fe, Ca, Mg

South District

It has been reported that higher concentrations of iron are required to affect the mobility of PFAS or induce iron-mediated decompositions (Behnami et al, 2024).



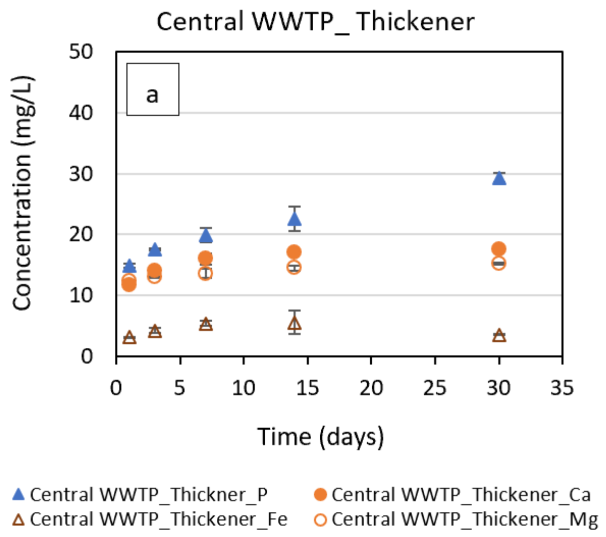
Behnami, A., Benis, K.Z., Pourakbar, M., Yeganeh, M., Esrafili, A., Gholami, M. 2024., Biosolids, an important route for transporting poly- and perfluoroalkyl substances from wastewater treatment plants into the environment: A systematic review. Science of the Total Environment, 925. doi: 10.1016/j.scitotenv.2024.171559.

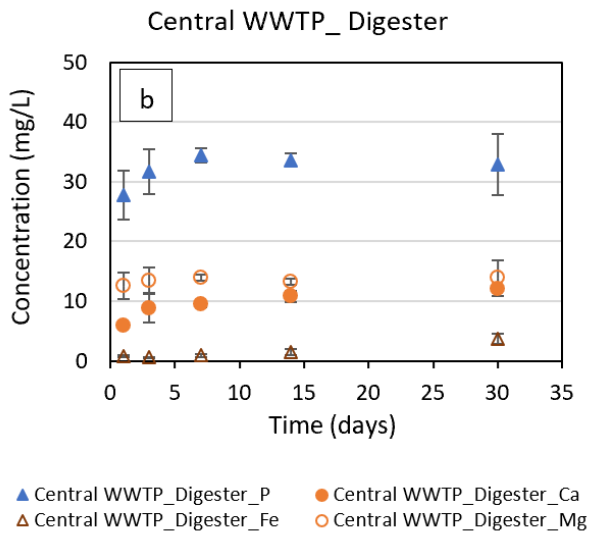
Ionic content of biosolids – P, Fe, Ca, Mg

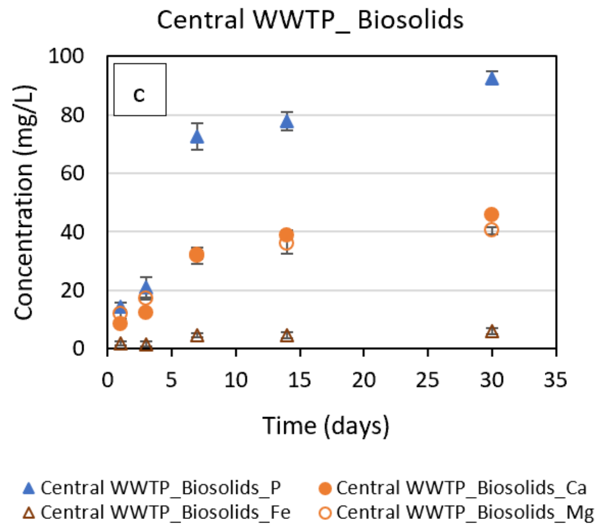
Central District

- The phosphorus (P) concentration in leachate samples from the SDWWTP ranged from 11 mg/L to 60 mg/L, which was lower than the values from the CDWWTP which ranged from 15 mg/L to 92 mg/L.

- The iron levels in the leachate ranged from 1.5 mg/L to 5.5 mg/L from both wastewater treatment plants.

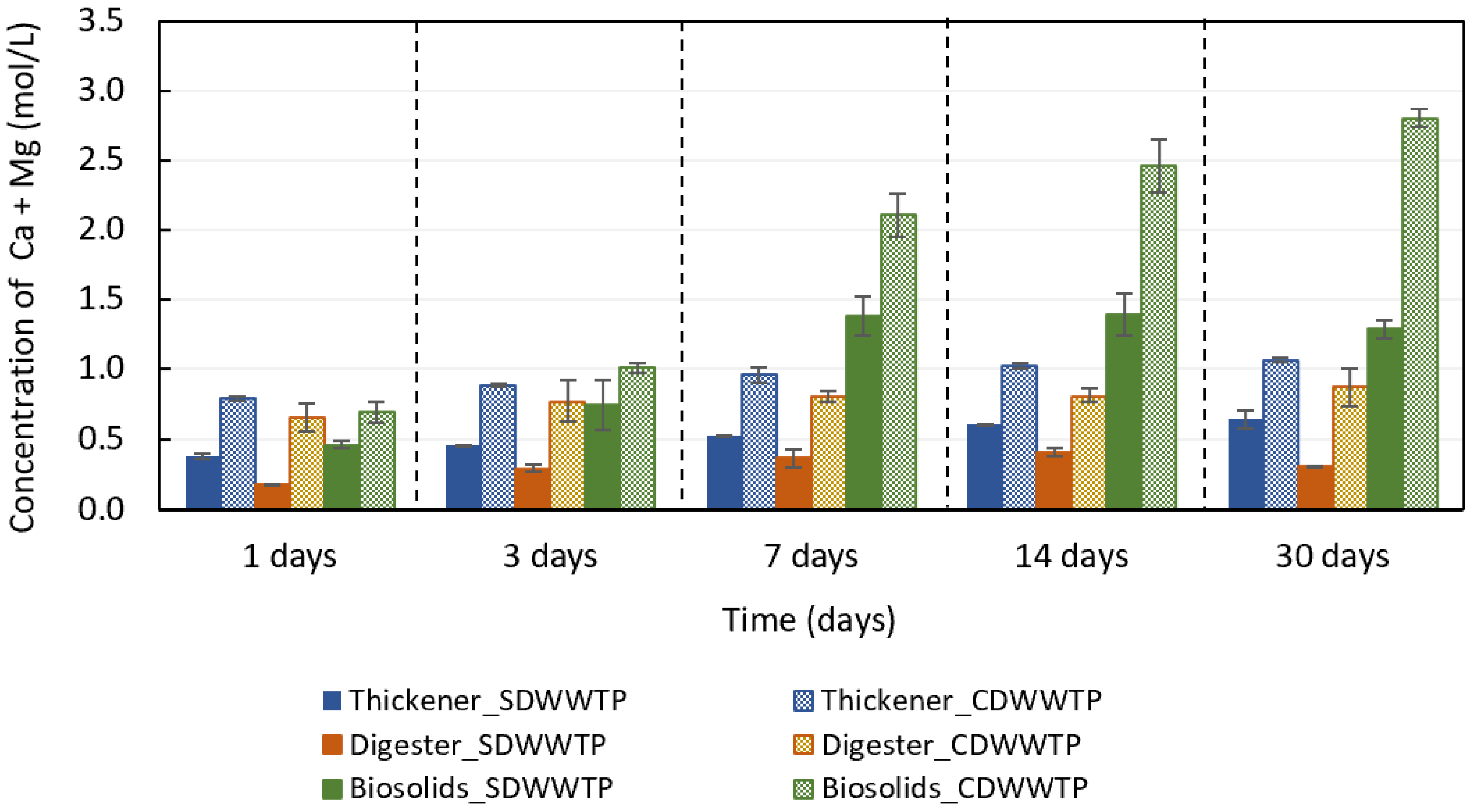






Combined concentrations of Ca and Mg

- The presence of divalent cations such as Mg^{2+} and Ca^{2+} has been shown to enhance PFAS adsorption on biosolids.
- Previous studies have indicated that polyvalent cations exhibit stronger interactions with the interfacial layer, thereby increasing the adsorption of PFAS on biosolids.



Batch test leachate of the samples from the South District and Central District wastewater treatment plants

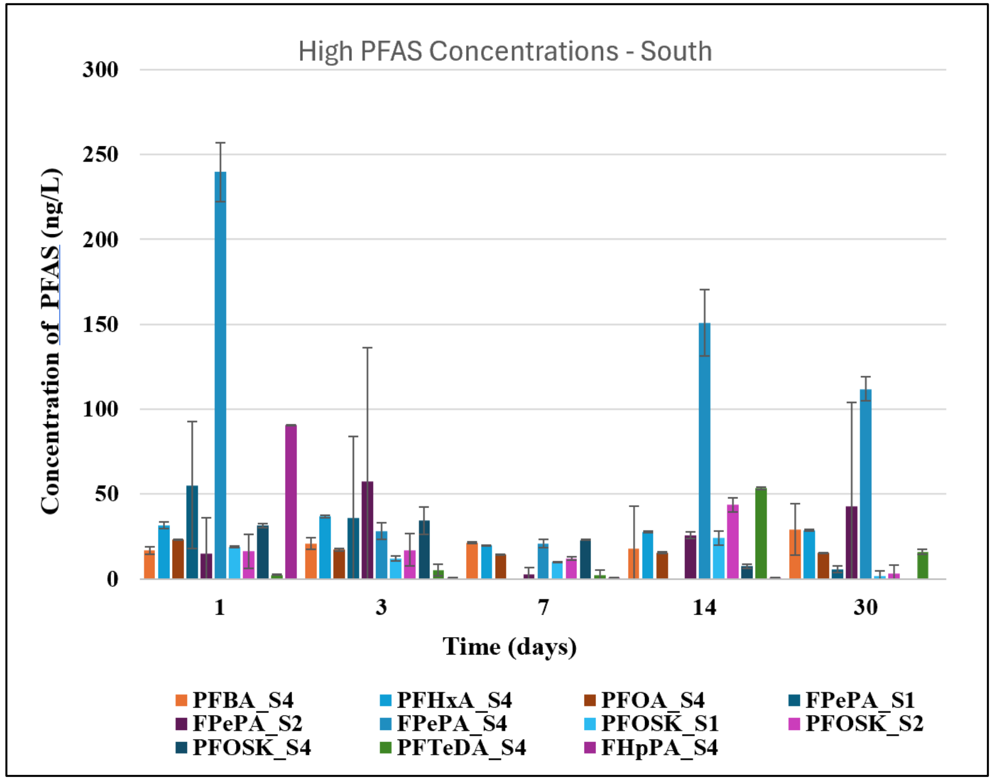
Ionic content of biosolids –P, Fe, Ca, Mg

What we learned

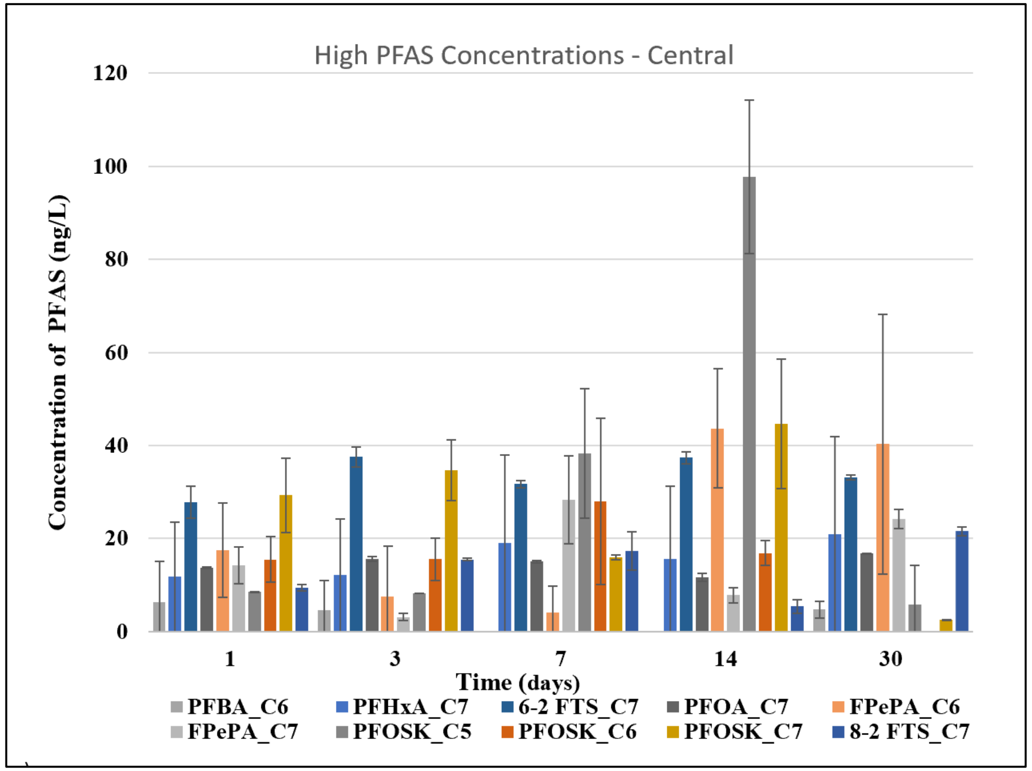
- The phosphorus (P) levels in leachate samples from the SDWWTP ranged from 11 mg/L to 60 mg/L, which was lower than the values from the CDWWTP which ranged from 15 mg/L to 92 mg/L.
- The iron levels in the leachate ranged from 1.5 mg/L to 5.5mg/L for both wastewater treatment plants.
- The combined concentrations of Ca^{2+} and Mg^{2+} in SDWWTP leachate samples were consistently 1.6 to 2.8 times lower for SDWWTP leachate samples compared to those from CDWWTP.

PFAS leaching from biosolids over time

South District



Central District



Batch test leachate of the samples from biosolids

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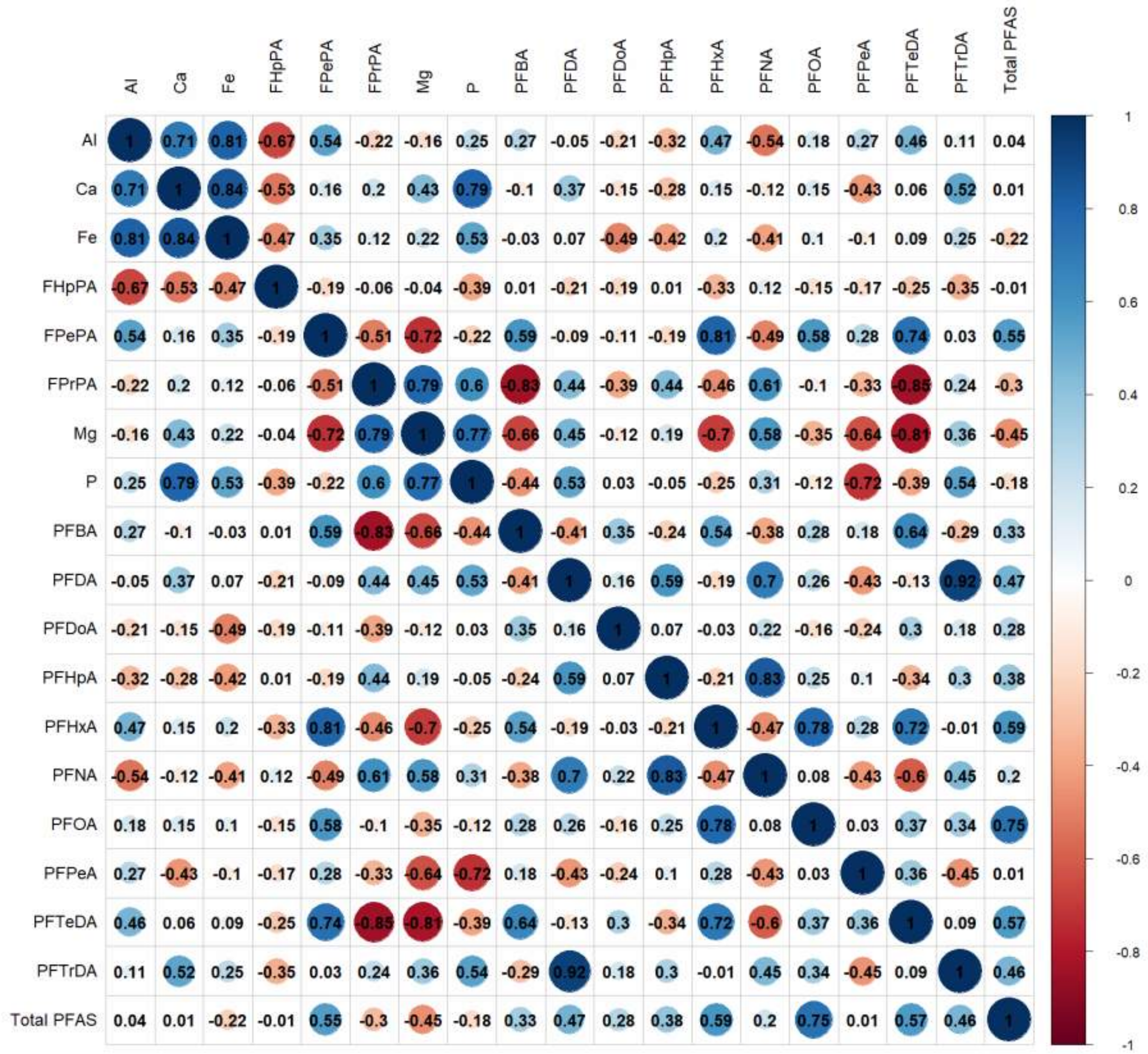
Correlations between PFAS leaching and ionic concentrations

Statistical Spearman correlations between leached metals with perfluoroalkyl carboxylic acids (PFCAs) and fluorotelomer carboxylic acid (FTCA) levels in leachates from biosolids.

- **dark blue - strong positive correlation**
- **dark red - strong negative correlation**



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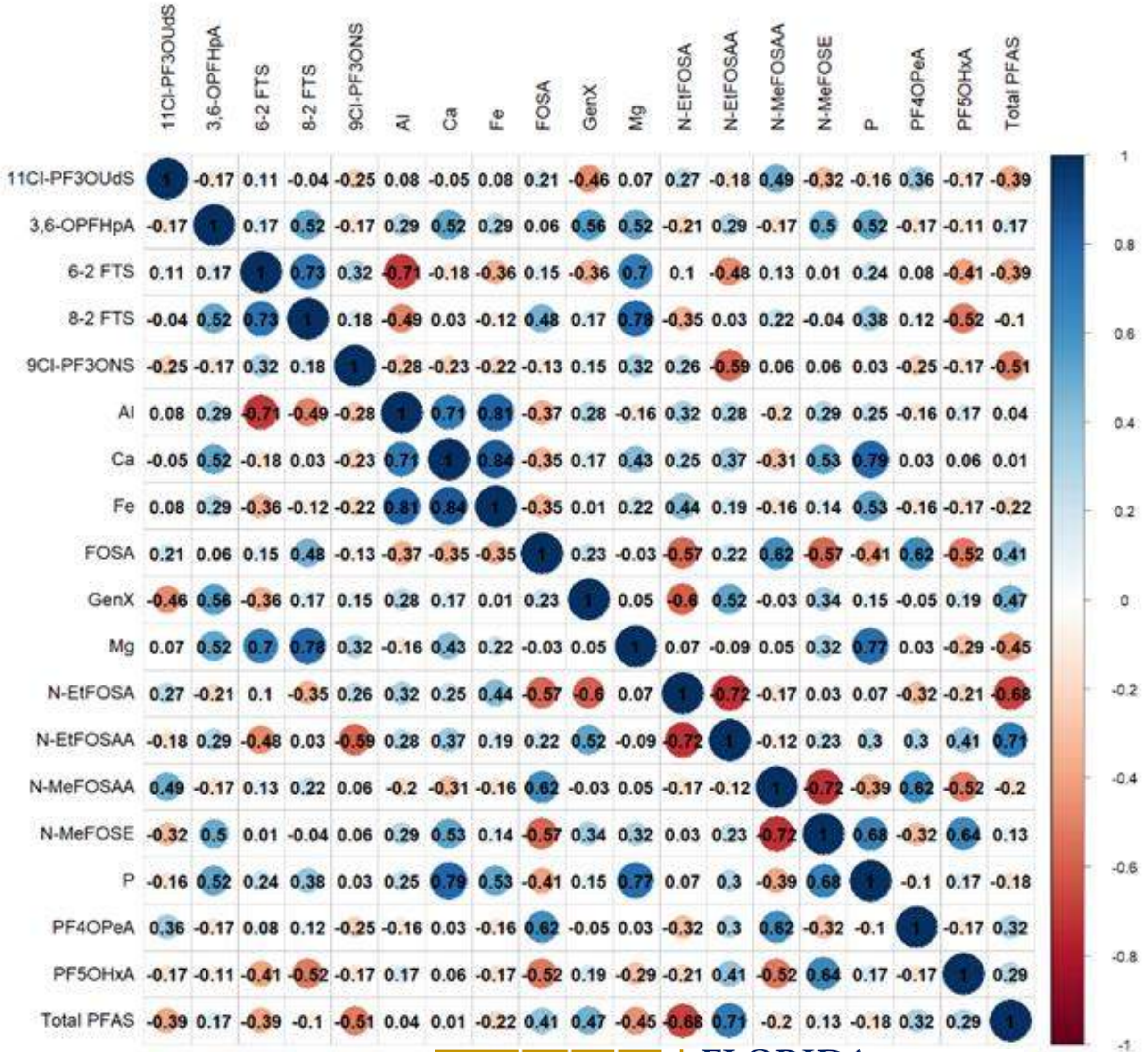
Correlations between emerging PFAS leaching and ionic concentrations

The emerging perfluorosulfonates 6-2 FTS and 8-2 FTS, N-methylperfluorooctane sulfonamidoacetic acid, N-MeFOSE, and 3,6-perfluoro-1-hexanol phosphate acid, 3,6 -OPFHpA, showed a moderate correlation with phosphorus in the leachates (R^2= 0.38-0.68) across tested solids.

Mg leaching correlated with P and showed a moderate to strong correlation with 6 -2 FTS, 8-2 FTS, and 3,6 -OPFHpA for all tested solids.



Take Home Messages

1. Biosolids provide phosphorus to agricultural soil. Since protein is a component of the organic fraction in biosolids, protein levels can affect PFAS fate.

2. The strongest correlation was observed between long-chain PFCAs (C_8–C_{14}), such as perfluoro-1-nonanoic acid (PFNA), and P (R^2=0.76) and Mg leaching (R^2=0.83) followed by PFPeA correlated with P (R^2=0.66) and Mg leaching (R^2=0.67). This phenomenon could be attributed to the microbial degradation of organic matter leading to the release of water-soluble P and Mg.

3. The emerging fluorotelomers sulfonates 6-2 FTS and 8-2 FTS, N-methylperfluorooctane sulfonamidoacetic acid, N-MeFOSE, and 3,6-perfluoro-1-hexanol phosphate acid, 3,6 -OPFHpA, showed a moderate correlation with phosphorus in the leachates (R^2= 0.38-0.68) across tested solids.

4. Mg leaching correlated with P and showed a moderate to strong correlation with 6 -2 FTS, 8-2 FTS, and 3,6 -OPFHpA for all tested solids.

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FIU Institute of Environment
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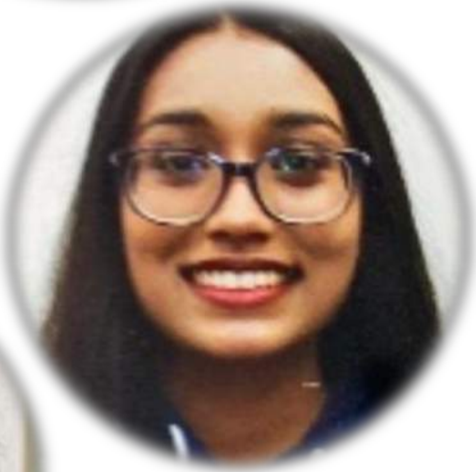
HINKLEY CENTER FOR SOLID AND HAZARDOUS WASTE MANAGEMENT



Thank you for your attention!

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Florida Water Environment Association | BIOSOLIDS COMMITTEE

Biosolids Handling & Disposal

Regulations May Require a Paradigm Shift for Biosolids Management in Florida

July 2024

carollo

Today's Agenda

- Current challenges for biosolids management
- Regulatory framework for biosolids
- PFAS in biosolids and regulatory update
- Current state of biosolids in Florida
- Solar Drying—A potential untapped sustainable solution for volume reduction?
- PFAS treatment approaches and knowledge gap
- Potential Strategies for biosolids management
- Q&A

01

Current Challenges for Biosolids Management

Biosolids Handling and Disposal

- **Biosolids Management Regulations:** Has become more and more stringent and will continue to…
- Biosolids are a beneficial ‘resource’
  - Contains nutrients and organic matter to support plant growth…essential for beneficial reuse
  - Has high energy content ~8,000 Btu/lb (2.3 kWh/lb) on a dry weight basis

THE BIG QUESTION:

Can we get rid of the biosolids while harnessing the energy?

Current Challenges and Strategies for Biosolids Management

Typical Dewatered Biosolids
~18–22% dried solids

~78–82% water by weight

Water adds significant volume and weight to transportation.

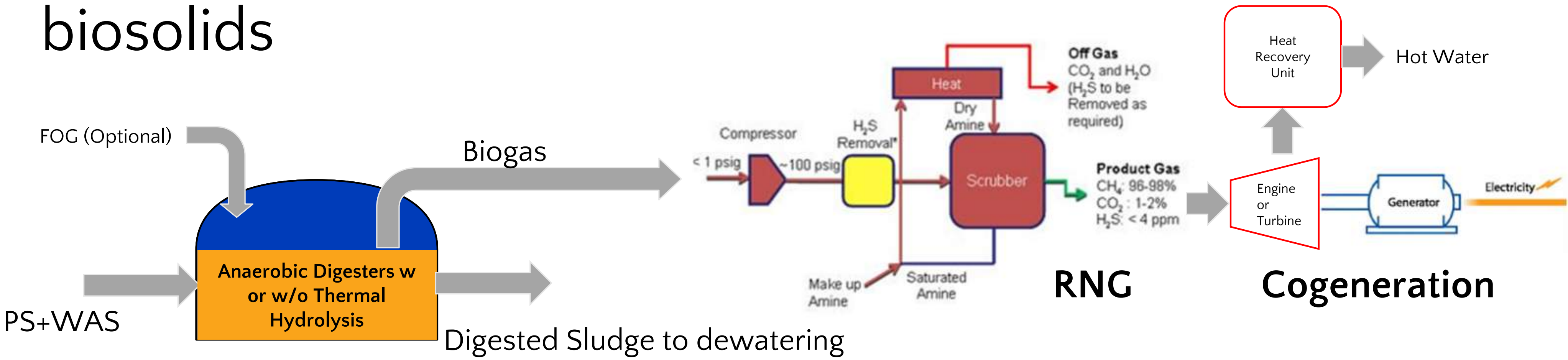
Sufficient pathogen reduction necessary to make it suitable for beneficial use.

Strategies/ Solutions

Elements for long-term sustainability of biosolids disposal:

- **Tier 1 Approach:** Volume Reduction
- **Tier 2 Approach:** Pathogen Reduction—Produce Class A/AA for Beneficial Use
- **Tier 3 Approach:** Energy Recovery

Traditional approach to harness energy from biosolids



Limitations of Traditional Approach of harnessing energy from biosolids

- **Digested sludge needs to be disposed**
- **In Florida, very few WWTPs have anaerobic digestion (AD) due to:**
  - Most FL WWTPs require AWT treatment with stringent effluent N and P limits
  - To preserve influent C for N & P removal, primary clarifiers (PCs) are not desired
  - Without PCs, biogas production is limited
  - AD generates high N & P loading in the recycle stream and requires further treatment
  - If Bio-P removal is happening at the plant, AD can cause struvite issues

02

Regulatory Framework for Biosolids

Florida Biosolids Regulations

New regulations have resulted in significant restrictions of land application of Class B biosolids.

Concerns about excess phosphorus in sensitive surface waters is creating public pressure and legislation that will potentially restrict recycling of biosolids as soil amendment

- In Florida, biosolids are classified as “Class AA,” “Class A,” or “Class B.” The classes are based, in part, on the degree of pathogen reduction.
- Class B biosolids receive the least amount of treatment.
- Class AA biosolids may be distributed and marketed like other commercial fertilizers with few further restrictions.

Effective July 1, 2022, biosolids land application site permits shall comply with two key provisions of section 403.0855, F.S.,—the requirement for all biosolids land application sites to be enrolled in a Florida Department of Agriculture and Consumer Services Best Management Practices program and the prohibition on the land application of biosolids on soils with a seasonal high-water table within 6 inches of the soil surface or depth of biosolids placement.

Florida Biosolids Regulations

- Based on FDEP Statement of Estimated Regulatory Costs (SERC), amendments to 62-640, FAC will cause a **75%** reduction in land application rates
- Utilities will likely change course to
  - **Disposal of Class B biosolids at landfills or**
  - **Transport of Class B biosolids long distances (North FL or South Georgia)**
  - **Conversion of Class B biosolids to Class AA**
- Expect impacts to the Class AA market (supply and demand)

03

PFAS in Biosolids and Regulatory Update

EPA PFAS Roadmap is Leading to Biosolids Guidance in 2024

Ongoing

Evaluating and developing technologies for reducing/destroying PFAS

Restrict industrial PFAS discharges

Surveying of PFAS occurrence in water and wastewater systems

Fall 2021

National PFAS testing strategy

Spring 2022

Proposed CERCLA designation for PFAS

Fall 2022

Analytical method for 40 PFAS (EPA 1633) published

Winter 2022

NPDES permitting requiring pretreatment programs to including source control and best management practices

Spring 2023

Drinking water MCLs announced

Fall 2023

Issue updated guidance on destroying and disposing of PFAS

Fall 2024

Designated as hazardous under CERCLA, April 2024

Publish finalized human health ambient water quality criteria for PFAS

Winter 2024

Finalized risk assessment for PFOS/PFOA in biosolids

Serves as basis for determining whether regulation is appropriate and any subsequent biosolids standards to benefit the **environment** and **human health.**

States Are Taking Action to Identify the Extent of PFAS in Biosolids

Michigan – Tiered approach.
PFOS > 100 ppb: land application not allowed.
PFOS > 20 ppb; source control required and limited land application.
PFOS < 20 ppb: no restrictions.

Vermont –
Sampling/reporting of biosolids req'd. Similar data assessment as Michigan studies. Monitoring of imported biosolids.

Maine – Ban on land app/biosolids due to PFAS concern.

Minnesota –
Proposing study of solids levels and PFAS fate/transport after land application.

Wisconsin -- Tiered approach like Michigan.

Illinois – Bill proposing ban like Maine

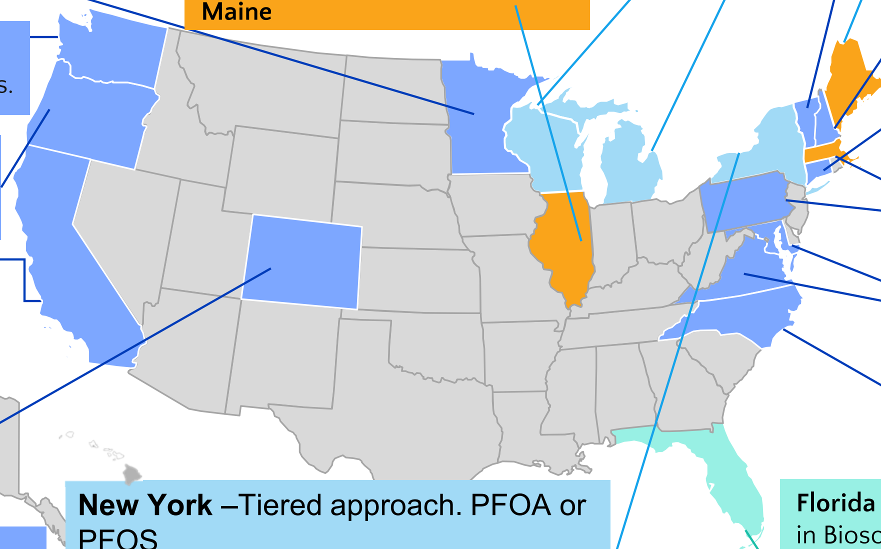
New Hampshire –
Solids monitoring required. General interim best management practices guidance for solids developed.

Connecticut –
Ban on on land app/biosolids due to PFAS concern

Washington –
PFAS monitoring in biosolids.

Oregon –
Voluntary PFAS testing in solids by some larger utilities.

California –
Sampling and reporting required.



Massachusetts/Pennsylvania –
PFAS testing required for solids in permit renewal process.

Virginia and Maryland–
Considering sampling/reporting Michigan's studies.

North Carolina –
Biosolids monitoring at targeted facilities.

Colorado --
PFAS monitoring in biosolids req'd;
PFOS > 50 ppb requires source investigation.

New York –Tiered approach. PFOA or PFOS
> 50 ppb: land application not allowed until < 20 ppb
> 20 ppb: 1 year to reduce to <20 ppb
< 20 ppb: land app allowed

Florida – Following EPA's efforts to conduct risk assessments for PFAS in Biosolids….to be completed by end of 2024
CS/SB 1692: Preventing Contaminants of Emerging Concern from Discharging Into Wastewater Facilities and Waters of the State – **Bill did not pass (March 8, 2024)**

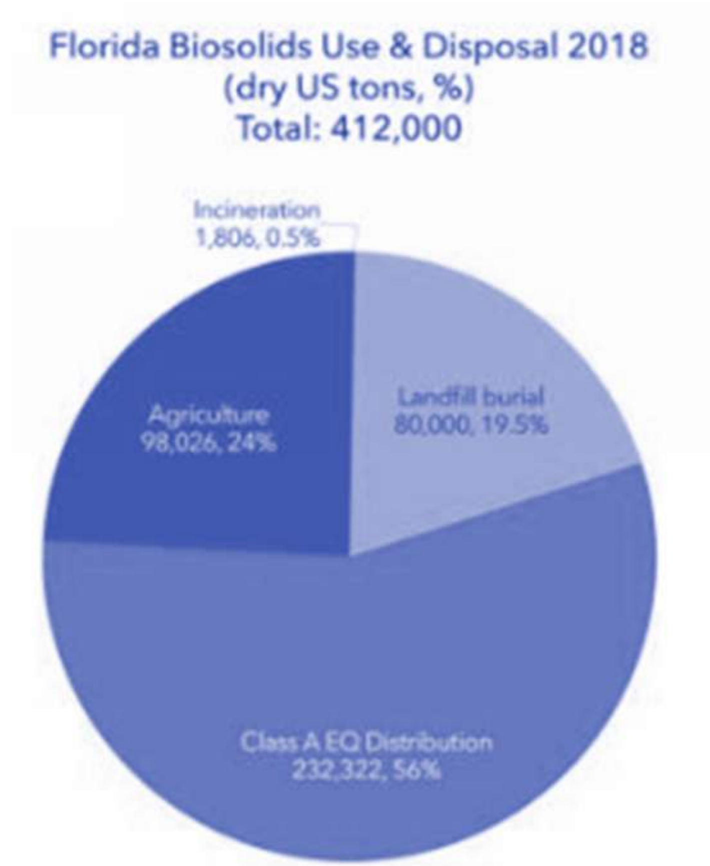
Not intended to be comprehensive due to ongoing changes.

04

Current State of Biosolids – Florida

Current State of Florida Biosolids

- About 412,000 dry tons of biosolids are produced in Florida each year, according to National Biosolids Data Project.
- The state DEP reports that 232,322 dry tons of Class AA biosolids were produced at about 40 plants in the state in 2018.
- Less than 1% of Florida's biosolids (about 1,800 dry tons, according to the National Biosolids Data Project) are used to fuel so-called 'waste-to-energy' facilities.



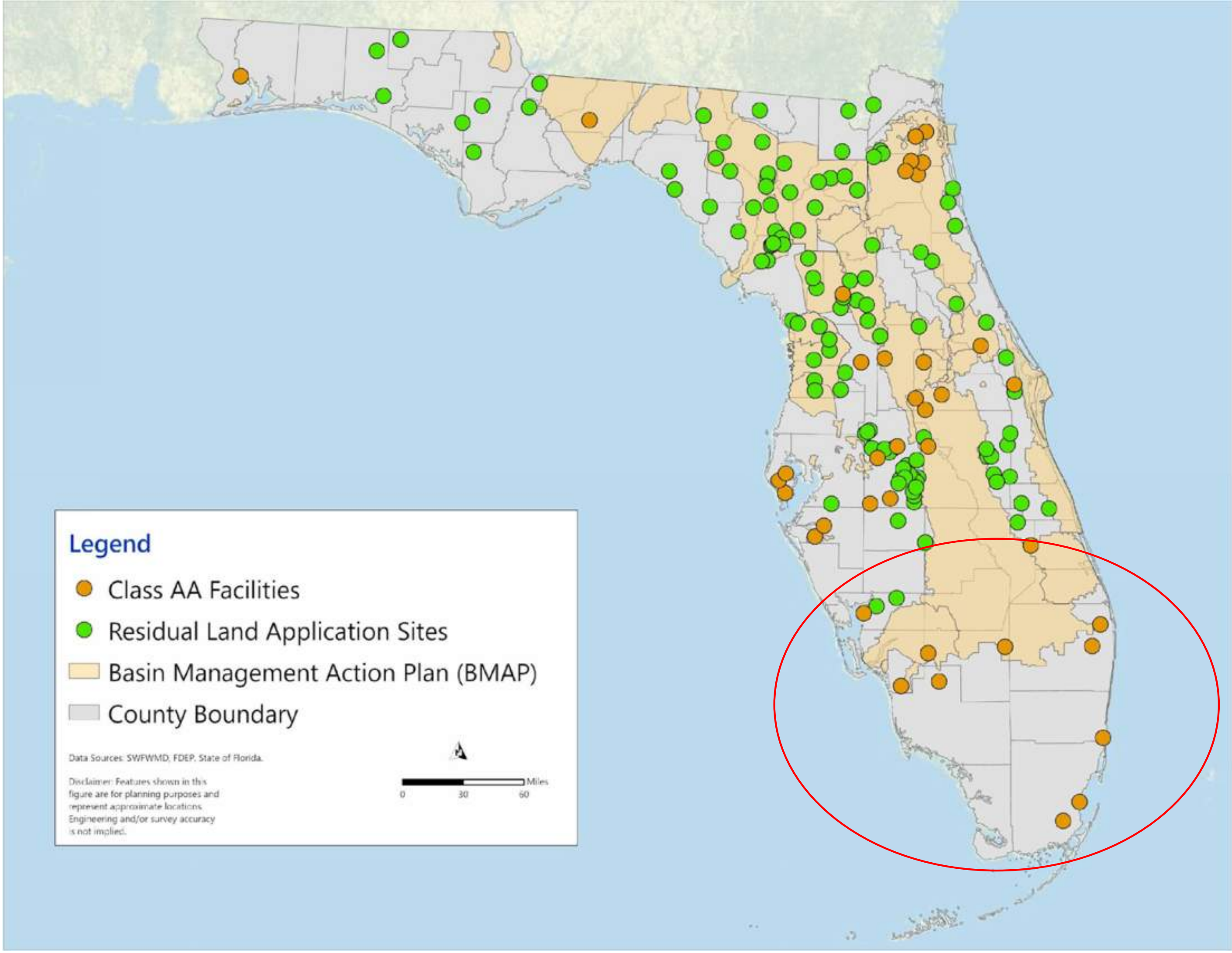
Source: National Biosolids Data Project 2018

Majority of the small to medium sized Florida Utilities contract with 3rd party haulers/vendors for un-stabilized biosolids for further treatment and disposal.

There are ~130 FDEP approved land application sites, some of which are expected to stop accepting biosolids.

Very few FDEP approved land application sites in South Florida which has almost 30% of the population of the state

Class B biosolids from South Florida (estimated to be >30% of all biosolids that is land applied) is therefore putting pressure on disposal in Central and North Florida



Current State of Florida Biosolids

Thermal Drying Facilities (Class AA Biosolids)

» JEA
» Tallahassee
» Palm Beach County
» Largo
» Bonita Springs
» Wellington
» Pinellas County
» Manatee County

Manatee County Thermal Drum Dryer

Thermal Drying provides both Pathogen destruction and significant volume reduction… less material to dispose.

Current State of Florida Biosolids


City of Orlando Bioset Reactor

Lime Stabilization (Class AA Biosolids)

» Orlando Conserve II
» Hollywood
» Immokalee

Lime Stabilization while destroying pathogens, adds 10–15% additional volume… more material to dispose.

Current State of Florida Biosolids

Composting (Class AA Biosolids)

- » Charlotte County
- » Lee County and Ft. Myers
- » Punta Gorda

Composting also while destroying pathogens, adds ***>10–15% additional volume****…so even more material to dispose.*

Charlotte County BioRecycling Center. Photo courtesy of Synagro.

Current State of Florida Biosolids

Solar Drying Facilities

» Pasco County *(patented process by Merrell Bros. includes a pasteurization step with belt drying following Solar Drying to produce Class AA product)*

» Sanford

» Cocoa Beach

» Okeechobee Utility Authority

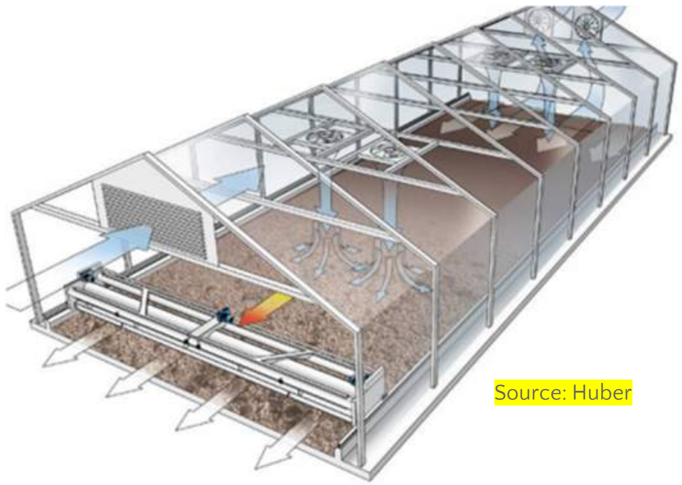
Solar Drying provides volume reduction…if followed with belt drying provides for pathogen reduction …less material to dispose.

05

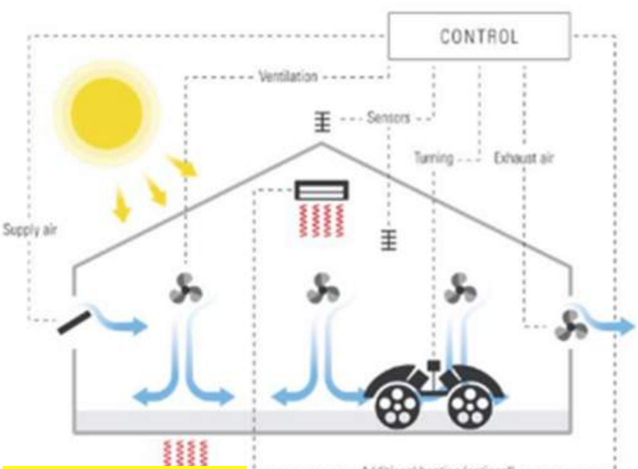
Solar Drying – An untapped solution for biosolids management?

Harnessing Solar Energy to Dry Biosolids

- Solar drying comprises of
  - » Polycarbonate or tempered glass greenhouses with aluminum or galvanized steel frames
  - » Supply and Exhaust fans (automated control based on meteorological parameters like temperature, solar radiation, relative humidity)
  - » Automated sludge turning/mixing mechanism moving on guiderails
  - » Automated sludge feed and removal mechanisms
  - » Odor control equipment (biotrickling filters and polishing with carbon if required)
  - » Overall, an easy to operate and maintain drying technology…less O&M costs

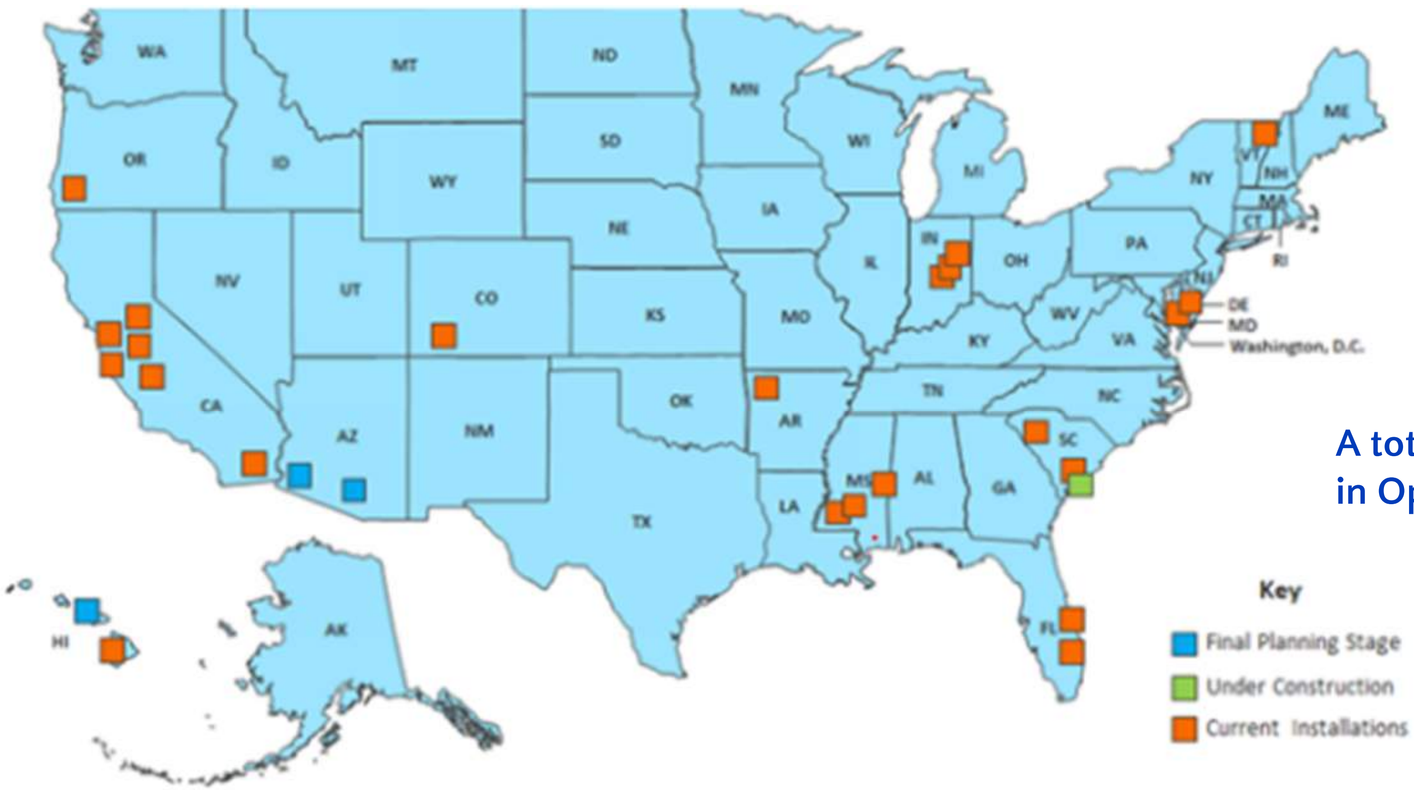


Source: Huber



Source: Thermo-Systems

Solar Drying of Biosolids – US Current Installations



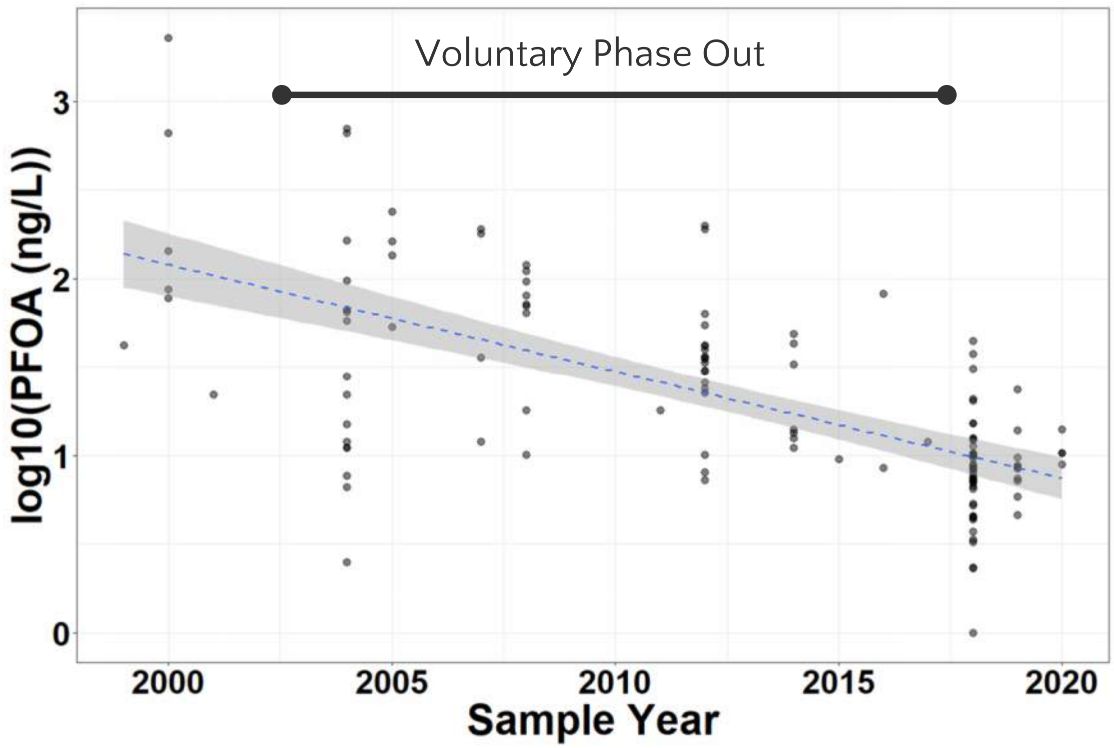
A total of ~30 Solar Dryers in Operation in US

Solar Drying of Biosolids in Florida – Evaporation of Water ~ 0.52 lb/sf/d to 1.04 lb/sf/d
Solar Drying Area = ~ 0.5 to 1.2 acres/mgd (achieve ~60 to 75% dried product)

06

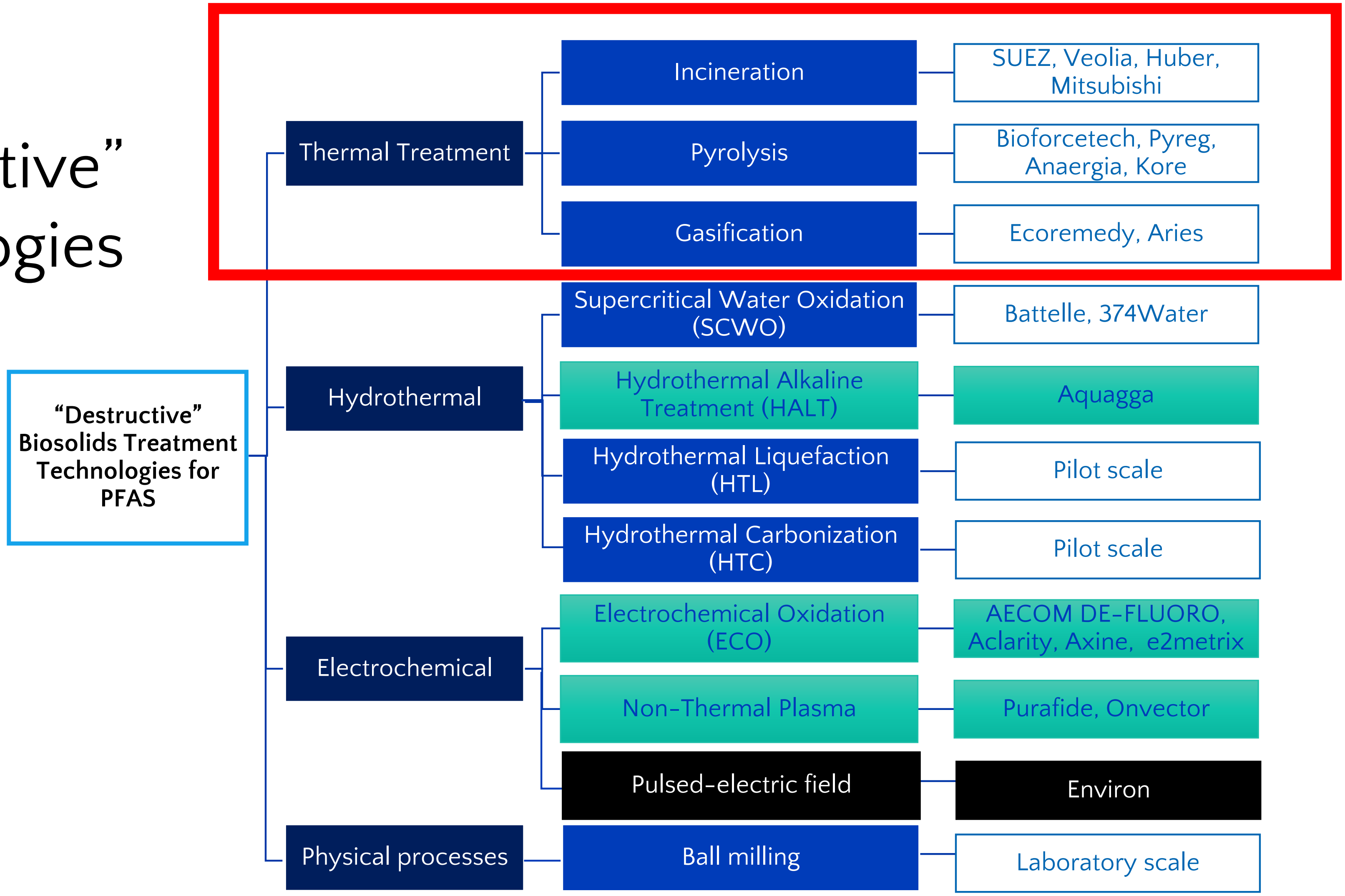
PFAS Treatment Approaches and Knowledge Gaps

Good News! Source Control and Phase Outs Have Led to Decreased PFOA Concentration in Effluent and Biosolids

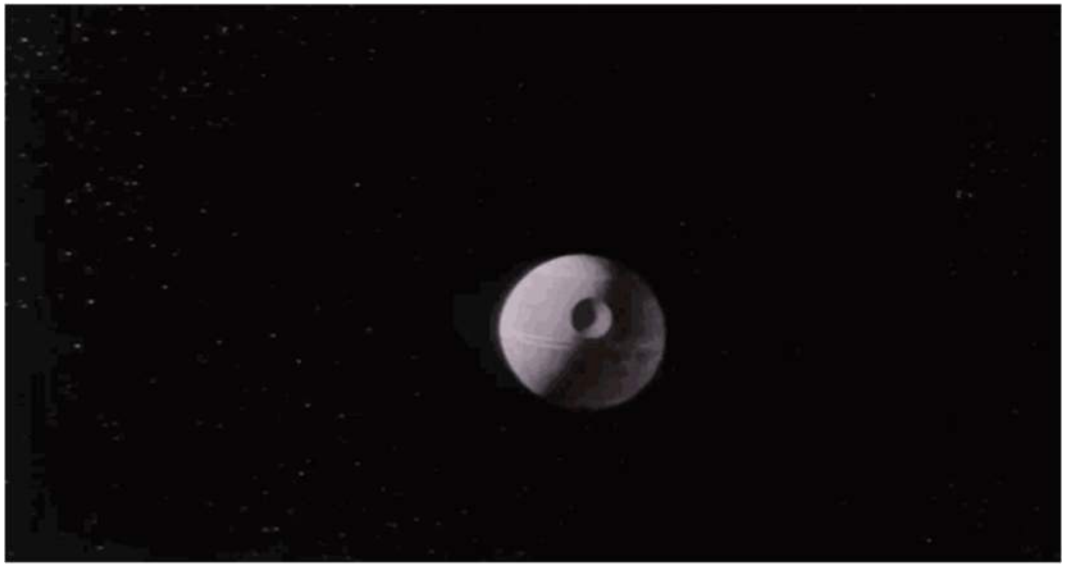


Source: Thompson, K. A. et al. 2022. ACS ES&T Water, 2(5), 690–700.

PFAS “Destructive” Technologies



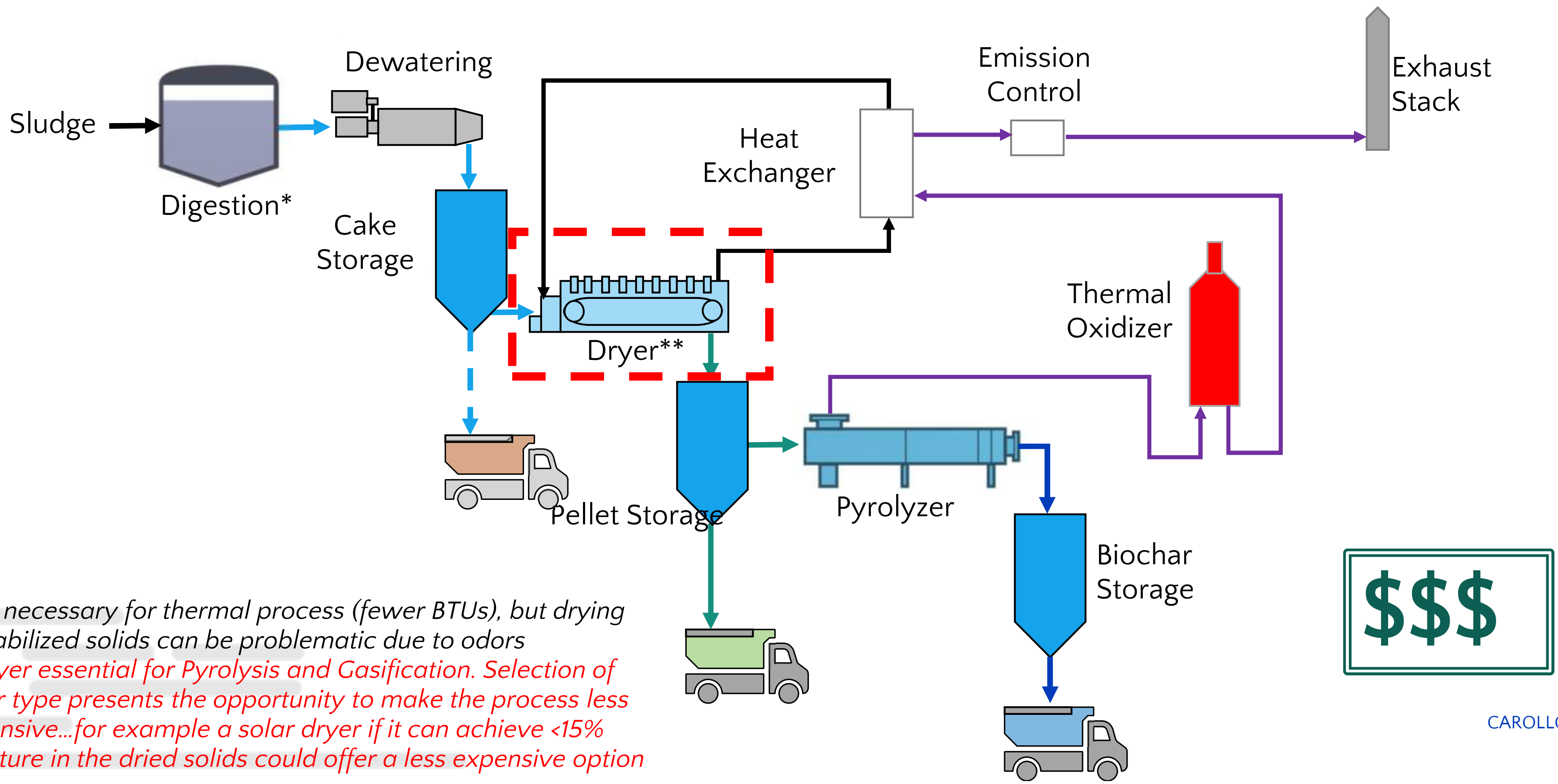
Complete PFAS destruction or mineralization requires > 1000 °C



Knowledge gap Incineration/Pyrolysis/Gasification – PFAS destruction

	Biosolids Incineration	Pyrolysis	Gasification
Air/Oxygen Requirement	> Stoichiometric amount	None	< Stoichiometric amount
Temperature	700°C - 900°C	300°C - 950°C	700°C – 1,000°C
Products	Heat Ash Exhaust (CO_2, H_2O)	Heat Biochar, Tar Hydrogen rich synthetic gas (syngas)	Heat Sometimes char Syngas
Full-Scale Installation **(Biosolids)**	Many	1 Operating (CA)..shut down due to dust issues	1 Constructed (WA)
Support equipment	Dryer (not essential)	Dryer	Dryer
Removal efficiency	Only 1 study done recently (WRF 5111) investigating 2 installations. Bottom Ash is free of PFAS. Both MHF and FBF reported 95% removal	There is promising data from WRF 5211 reporting >99% removal of PFAS, but there also transformation of PFAS compounds. Complete	No data published on PFAS. WRF 5211 will conduct sampling and report on this.

Thermal Processing Requires Many Important Ancillary Elements



*Not necessary for thermal process (fewer BTUs), but drying unstabilized solids can be problematic due to odors
**Dryer essential for Pyrolysis and Gasification. Selection of dryer type presents the opportunity to make the process less expensive…for example a solar dryer if it can achieve <15% moisture in the dried solids could offer a less expensive option

Elements for long-term sustainability of biosolids disposal in Florida:
√ Tier 1 – Volume Reduction
√ Tier 2 – Energy Recovery
√ Tier 3 – Beneficial Use

07

Potential Long-Term Strategies for Biosolids Management

Volume Reduction using Solar or Thermal Dryers + High Temperature Pyrolysis (HTP) Waste to Energy

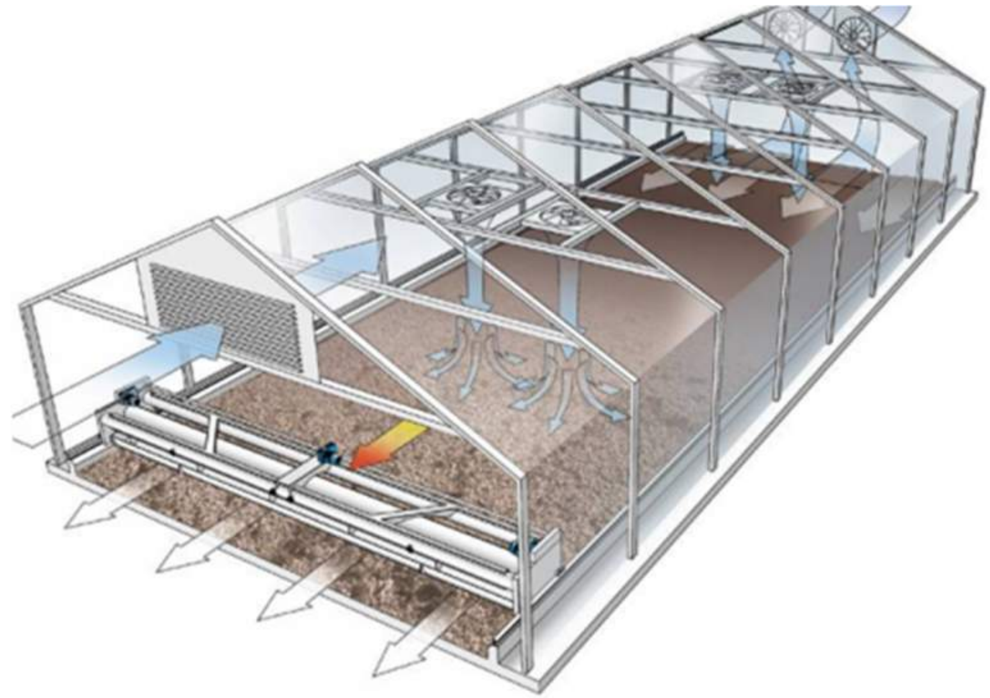
Regionalization for Biosolids Management

Adjoining utilities can work together using interlocal agreements:

- **Study, pilot, plan, design and construct the most cost effective, long-term sustainable solution.**
- **Share costs and spread risks**
- **Either self operate and maintain or hire a 3rd party**

Build a Pilot Scale Solar Dryer Greenhouse – Bridge the knowledge gap….Optimize Solar dryers to achieve Class A/AA biosolids

- Build a greenhouse with tempered glass, and aluminum frames on a pilot scale basis to operate for a 12-month period. Add supplemental heat if available.
- Investigate SRT to achieve up to 85% cake dryness (<15% moisture)..ideal for Pyrolysis/Gasification
- Test for pathogens to see if it can achieve Class A/AA requirements



Solar dried product ~85% DS can be burned in an HTP to produce Biochar and Recover Energy

Dewatering at WRF

Haul Dewatered Cake to a Central Solar Dryer Facility

Centralized Solar Dryer Facility located nearby and potentially at a Landfill

If Product is 60+% Dried

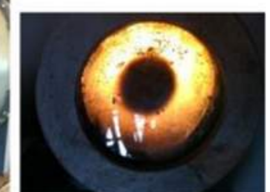
Centralized Thermal Dryer Facility

Syngas/Heat

Dried Biosolids (85%+)

If Product is 85+% Dried

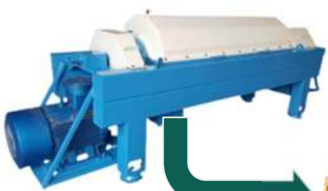
High Temperature Pyrolysis



Energy Recovery

If Solar Drying can only achieve 60% dried solids, the dried product can be tested for use as landfill cover or burn in a cement kiln or other industries that could use this as fuel. The product can also be further dried using a thermal dryer (85% dried product) and converted to Biochar in a Pyrolysis process

Thermal Drying to ~85% DS followed by an HTP to produce Biochar and **Recover Energy**



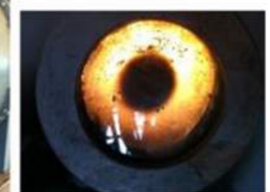
Dewatering at WRF

Haul Dewatered Cake to a Centralized Thermal Dryer Facility

Syngas/Heat

Centralized Thermal Dryer Facility

High Temperature Pyrolysis



Energy Recovery

~18% dried solids → **~ 85% Reduction** → ~95+% dried solids

Belt or Thermal Drum Drying for producing Class A Biosolids…product can be easily disposed.
The process can use either NG or Landfill gas (if centrally located at nearby landfill).
If PFAS becomes an issue, HTP process can be added on at a later stage

Thank you.

Open for Questions, comments, and suggestions.

Sudhan Paranjape, PE
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sparanjape@carollo.com

GETTING A BIOSOLIDS PROJECT ACROSS THE FINISH LINE

ENGAGING ELECTED OFFICIALS FOR INFORMED DECISION-MAKING

MEGAN ROSS, PE, MPA, ENV SP

Florida Water Environment Association | BIOSOLIDS COMMITTEE

Southeast Biosolids Association

Summer Seminar
July 18, 2024
Miami, FL

OVERVIEW

1 Policy Definition

2 Project versus Policy

3 Decision-Making and Decision-Makers

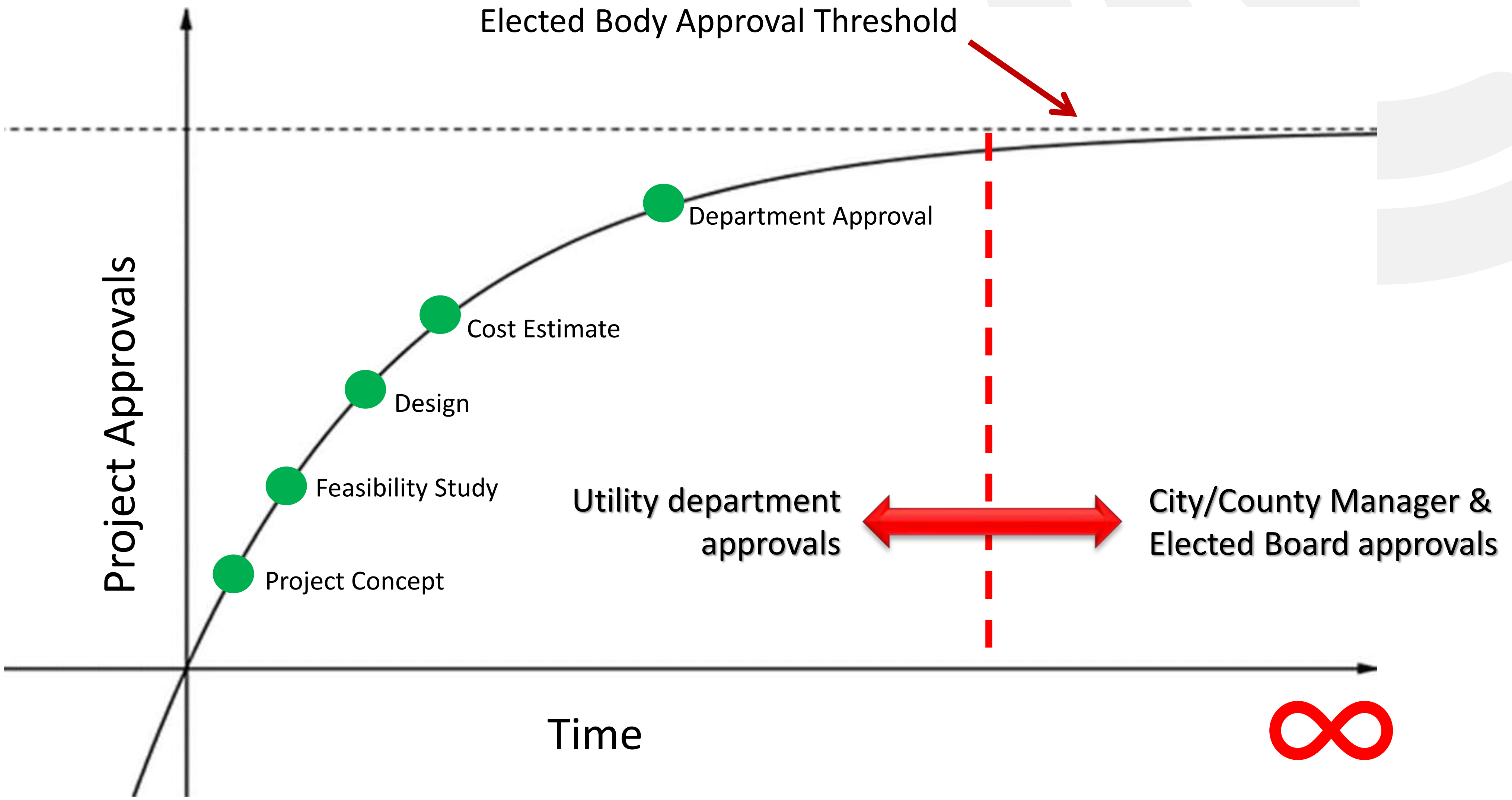
4 Complexities of Biosolids Management

5 Kraft Policy Process

6 Alternatives Evaluation

7 Case Study: Pinellas County Private Sewer Lateral Policy

WHY DO PROJECTS FAIL TO GET APPROVED?

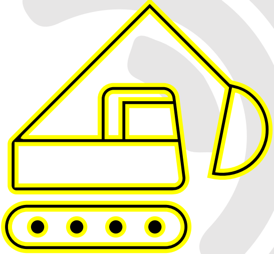


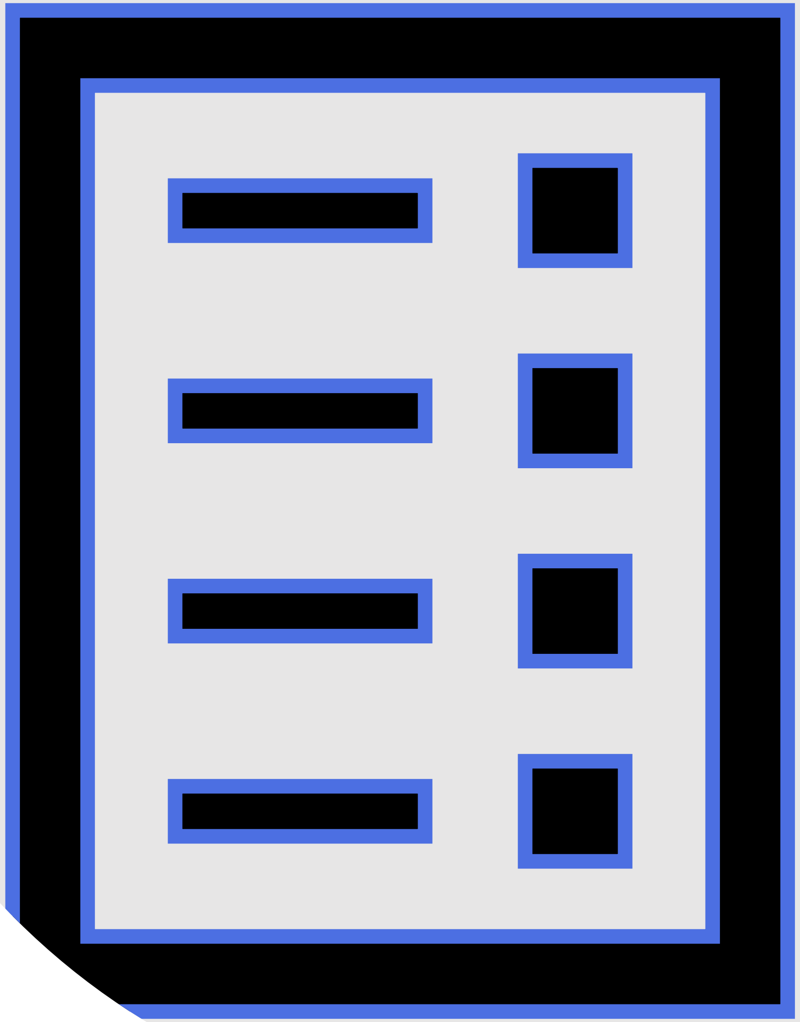
WHAT IS PUBLIC POLICY?

- A decided set of elements like laws, regulations, guidelines, and actions
- To solve or address **relevant** and **real-world problems**, guided by a conception and often implemented by programs.
- These policies govern and include various aspects of life such as **education, health care, employment, finance, economics, transportation**, **environment** and all over elements of society.
- The implementation of public policy is known as **public administration**.

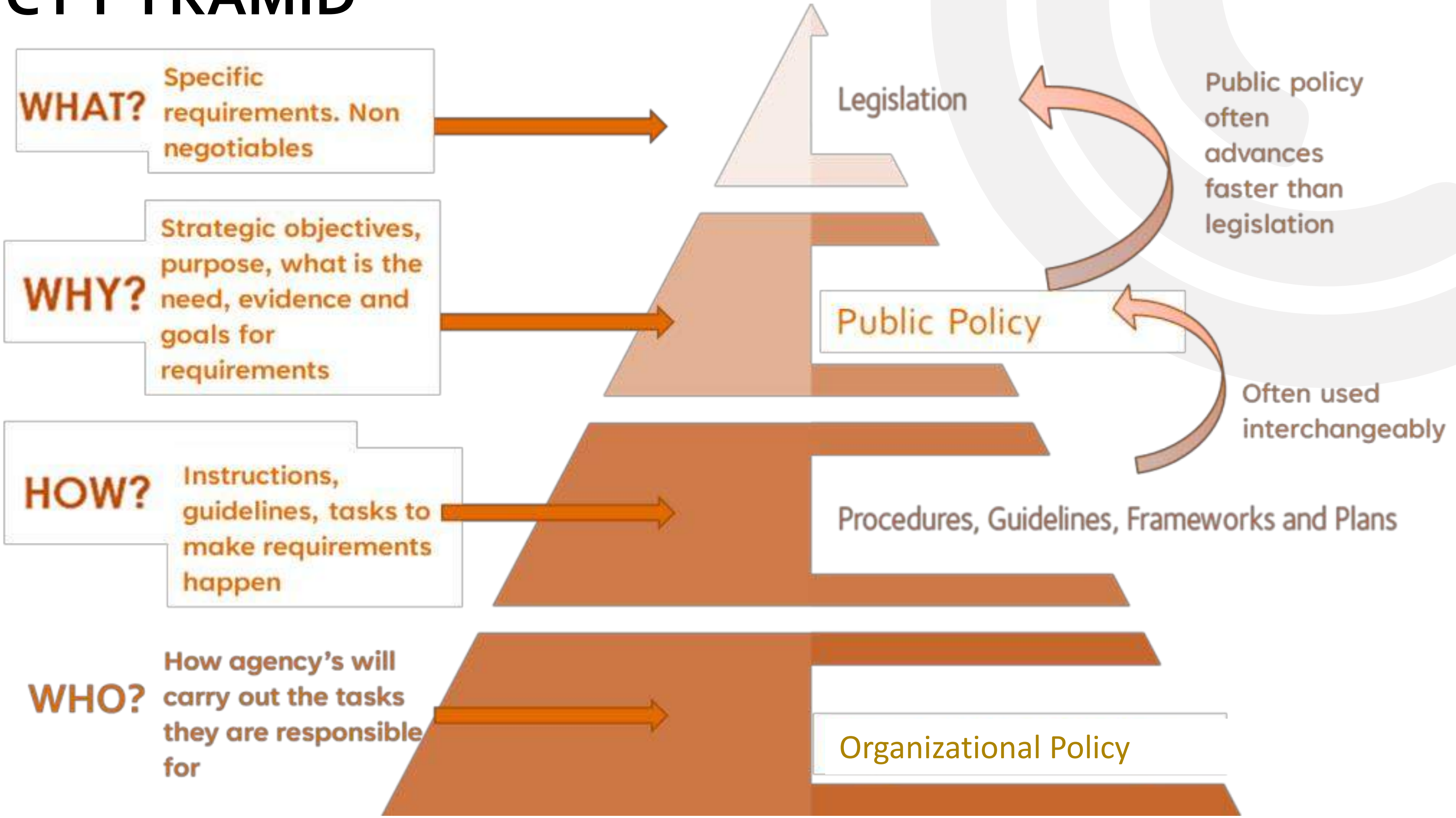
WHAT IS A PROJECT?

- A **project** is a **set of tasks** that must be completed within a **defined timeline** to accomplish a specific set of **goals**
- An organizational initiative to achieve certain outcomes within a **timeframe** and a **budget**.
- A series of **tasks** that need to be completed to reach a **specific** outcome.
- A unique, **transient endeavour**, undertaken to achieve planned objectives, which could be defined in terms of outputs, outcomes or benefits.





POLICY PYRAMID



IS YOUR PROJECT A POLICY DECISION?

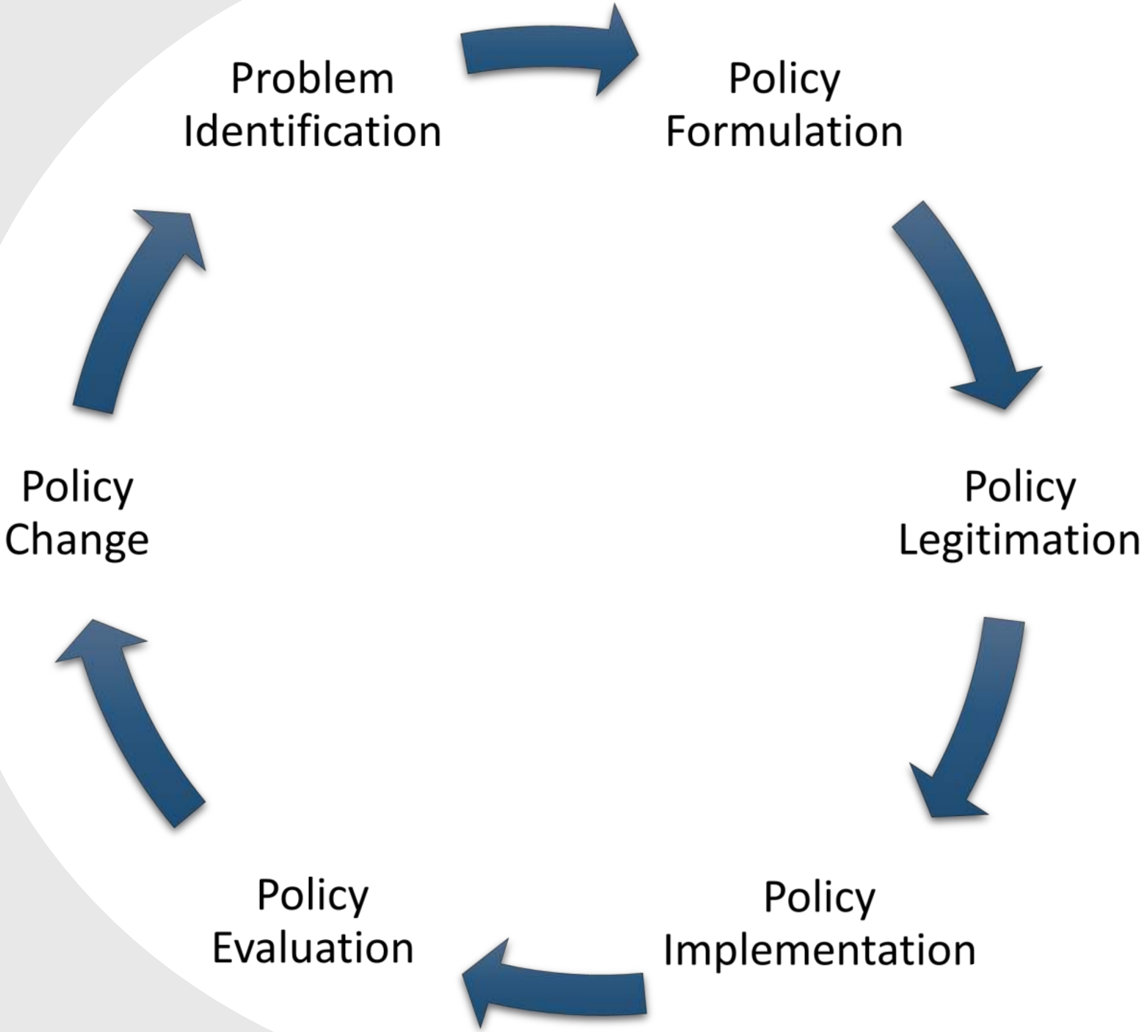
PROJECT	POLICY
Being done to continue meeting current laws and regulations	Require a change in law or regulation
Maintain the same or similar operating costs	Increase costs compared to what you are currently doing
Maintain the same financing or funding, not new	Require additional financing or grant funding
Results in no change to environmental impact	Impact the environment, positively or negatively
Replace/upgrade infrastructure to continue the same services	Impact service levels currently provided to the public
No significant or ongoing impact to stakeholders	Impact stakeholders significantly (business, nonprofits, community groups)
Involve typical easements or access to complete	Involves private property
Only involve county/municipal land	Involve land/property acquisition
No change to operating paradigm	Involve considering privatization or P3
Requires no change to how facility is governed	Require a change in governance structure
No other county/municipality involved	Involve another county or municipality
Typical media or public interest anticipated	Significant media or public attention

IS YOUR PROJECT A POLICY DECISION? EXAMPLES

PROJECT	POLICY
Replacing/upgrading a water or wastewater treatment plant	Converting to potable reuse
Upgrading your current biosolids facility	Converting from land application to pelletizing/solar drying/composting
Upgrading a force main	Expanding sewer services to new communities
Replacing a leaking service line	Replacing a lead service line
Implementing process improvements	Implementing PFAS removal treatment
Implementing an I/I abatement program	Implementing a private sewer policy to address I/I

COMPLEXITIES OF BIOSOLIDS

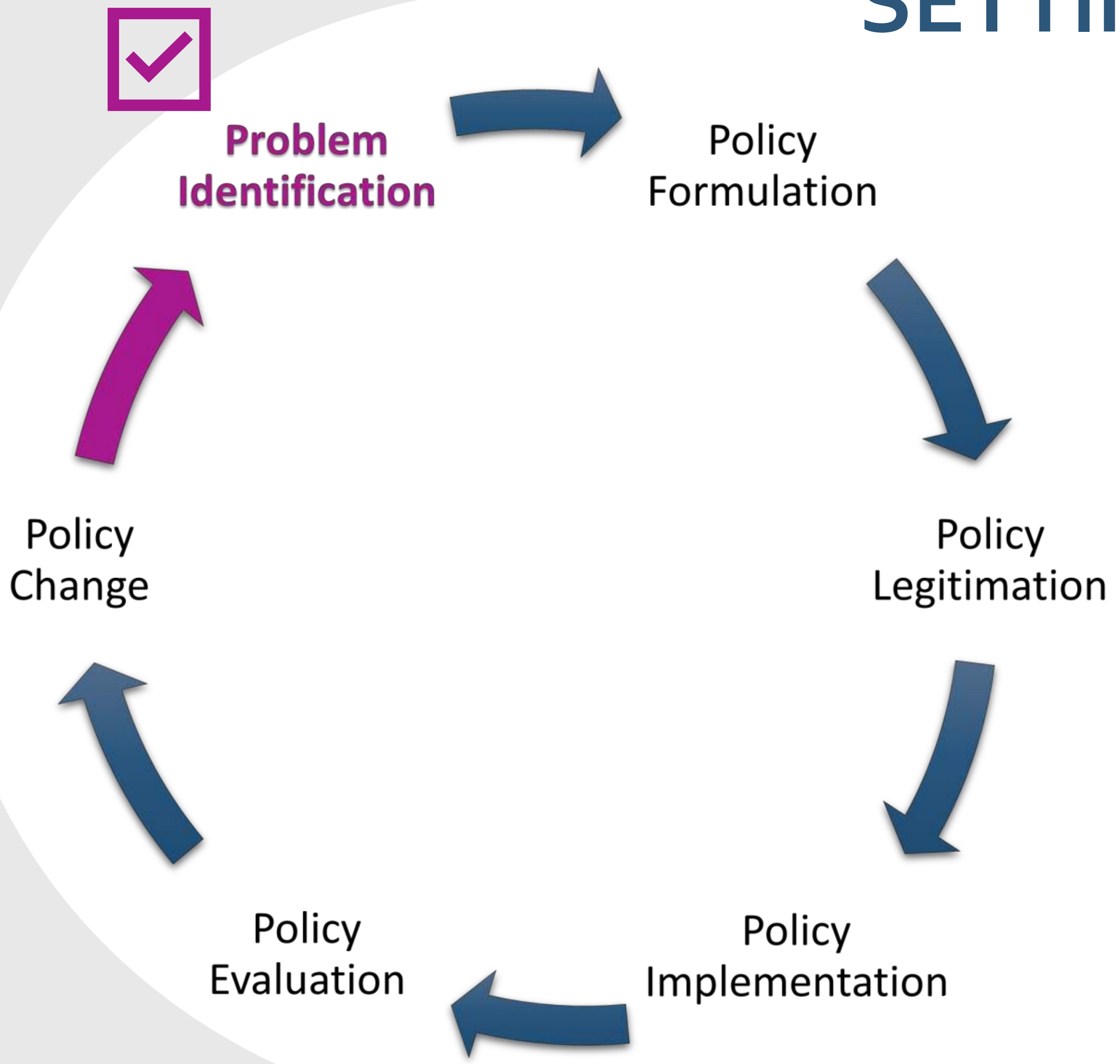
- Operational
- Regulatory (state and federal)
- PFAS
- Clean Waterways Act
- Land Application Restrictions
- Decision is based on more than just cost, sustainability and environment are factors
- Solid Waste sometimes involved



KRAFT POLICY PROCESS

6-STEP PROCESS CYCLE

"SETTING THE TABLE"

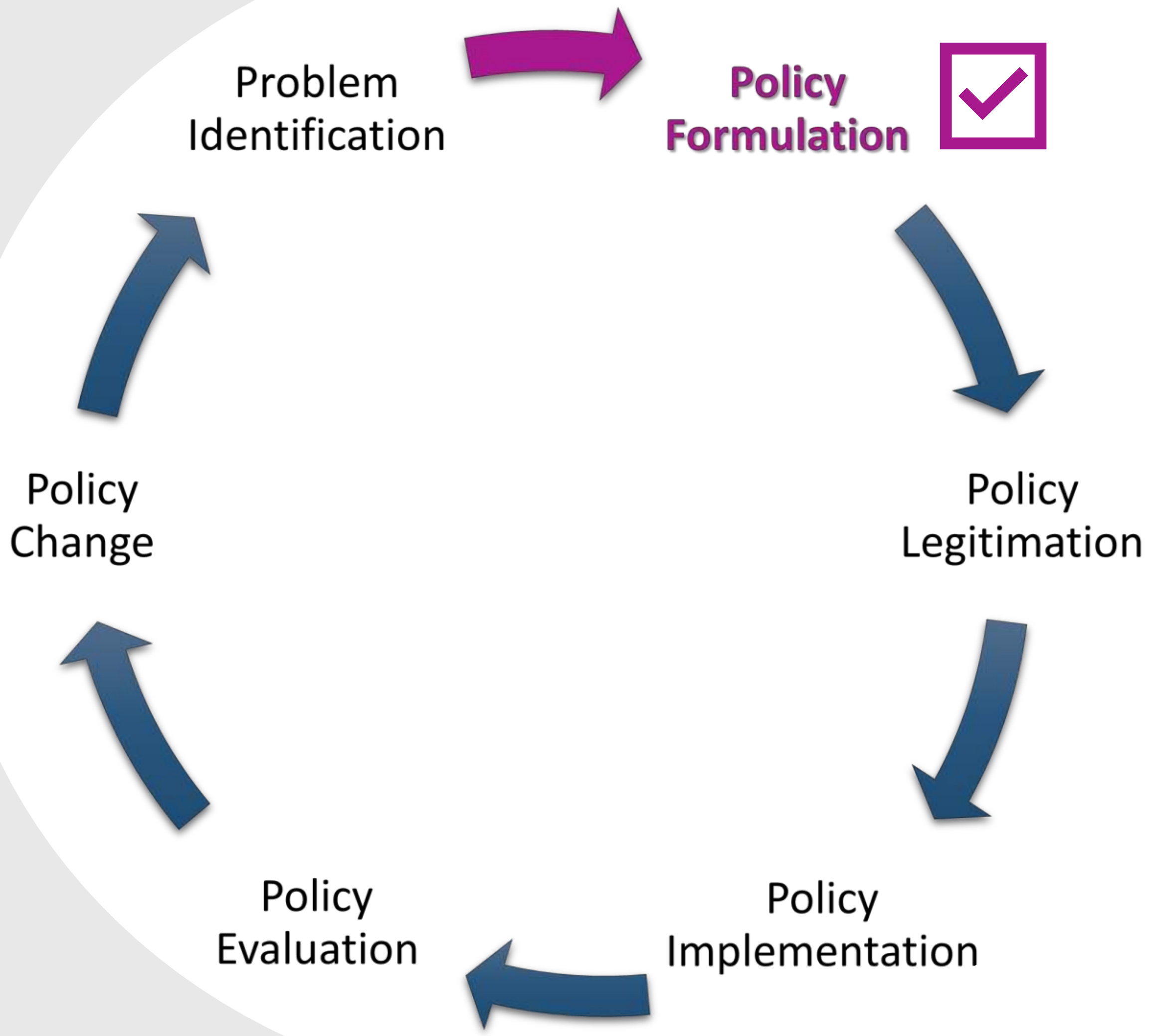


- **RECOGNITION OF A PROBLEM**
- **DEFINITION OF WHAT THE PROBLEM**

QUESTIONS:

- WHAT IS HAPPENING?
- WHY IS IT HAPPENING?
- WHAT IS THE MAGNITUDE OF THE PROBLEM? (COST, POLLUTION, COMPLIANCE, ETC.)
- WHAT IS THE CONTEXT SURROUNDING THE PROBLEM? (HISTORY, PAST SOLUTIONS, WHY THEY DIDN'T WORK)

DEVELOPING SOLUTIONS



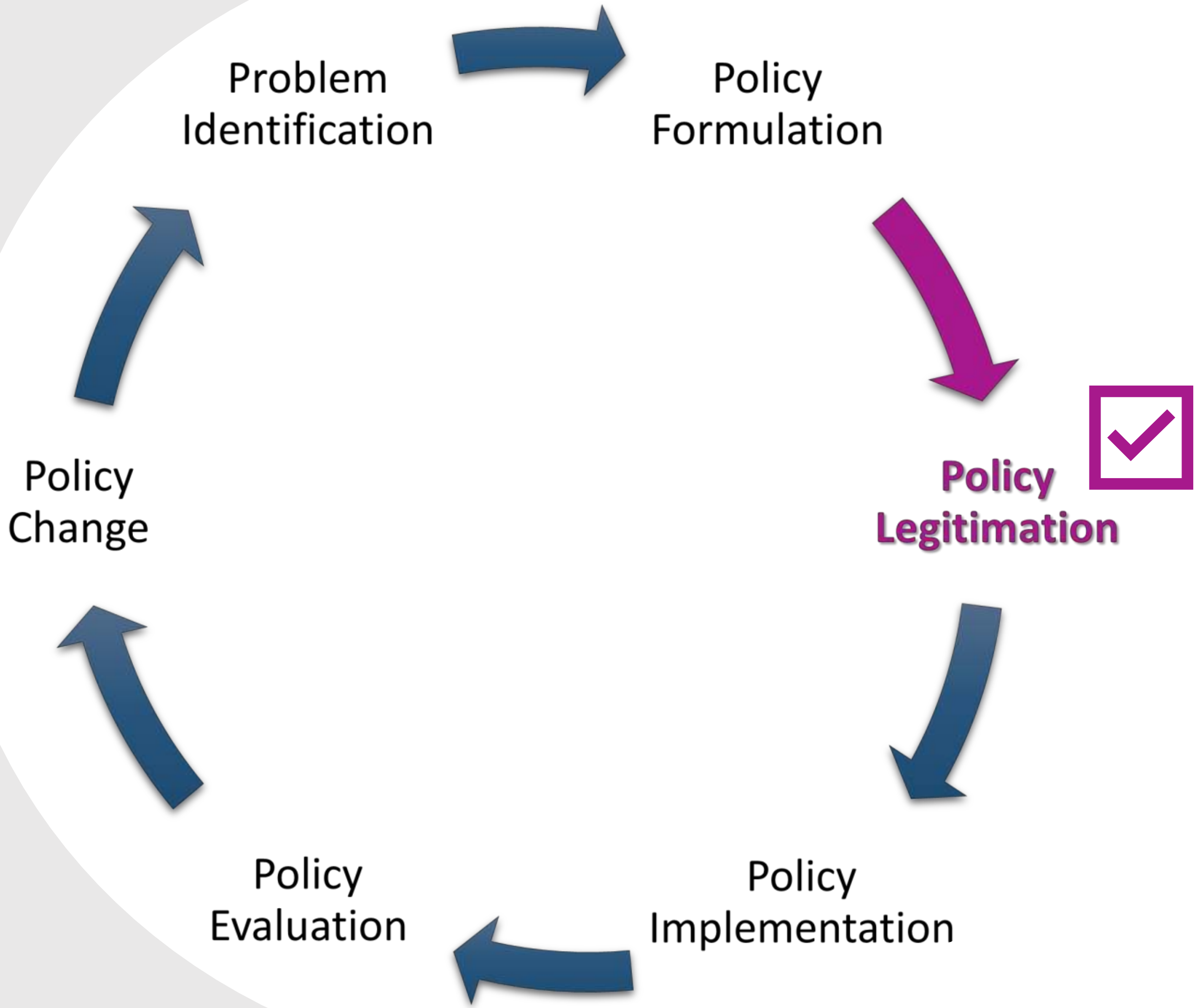
- **DEVELOPMENT OF A POLICY**
- **SEEKS TO REMEDY THE IDENTIFIED PROBLEM**

[redacted]UESTIONS:

- WHAT ARE ALTERNATIVES TO ADDRESS THE ISSUE?
- WHAT IS THE COST?
- WHAT IS THE EFFECTIVENESS?
- WHAT IS THE POLITICAL FEASIBILITY?
- WHAT IS THE SUSTAINABILITY?

NOTE: ONE ALTERNATIVE MAY BE TO CONTINUE DOING WHAT YOU ARE CURRENTLY DOING

IS THE POLICY AN "OVERREACH"

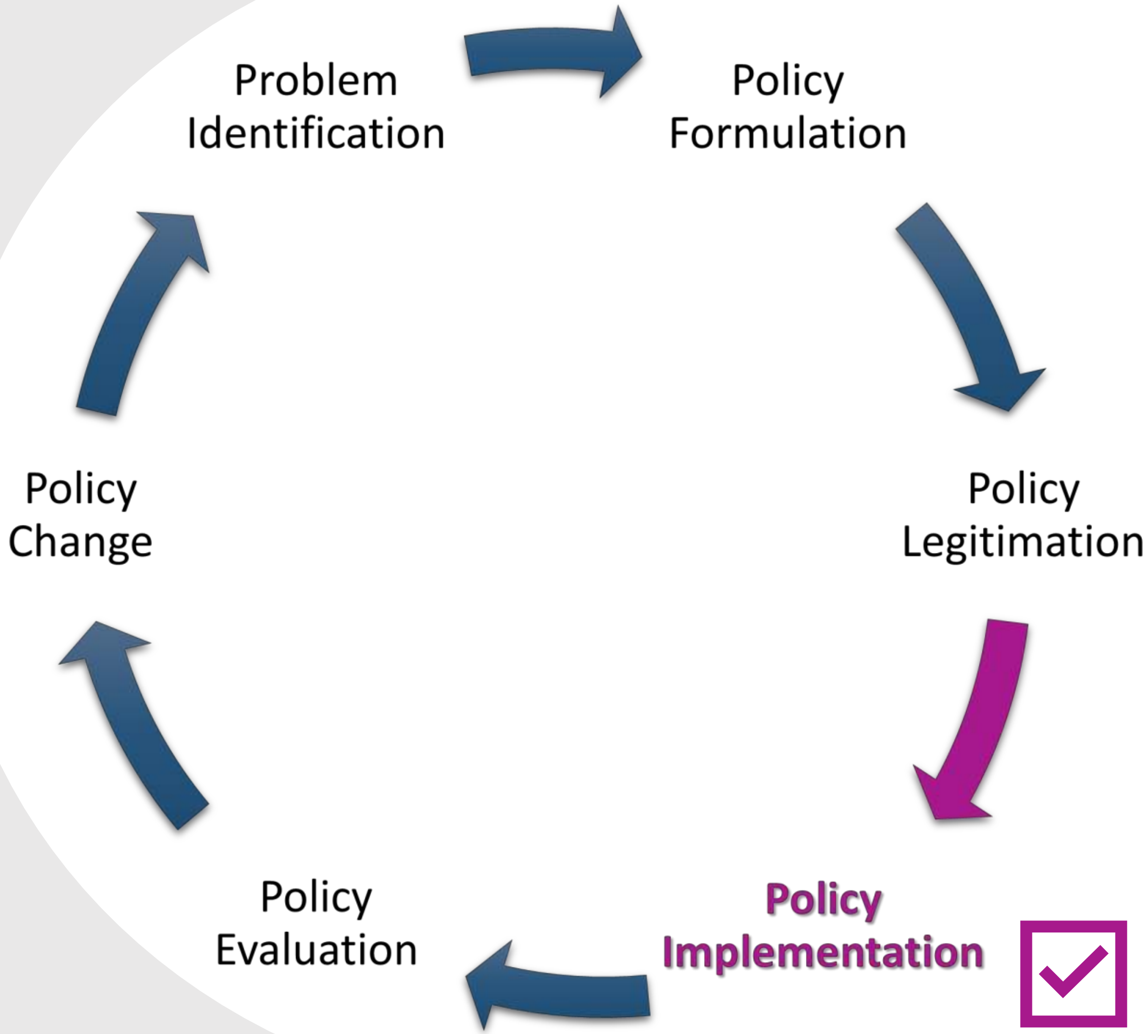


- **THE DETERMINATION OF AUTHORITY FOR GOVERNMENT TO ENACT THE POLICY**
- **LEGAL CHALLENGES**
- **PUBLIC PERCEPTION**

QUESTIONS:

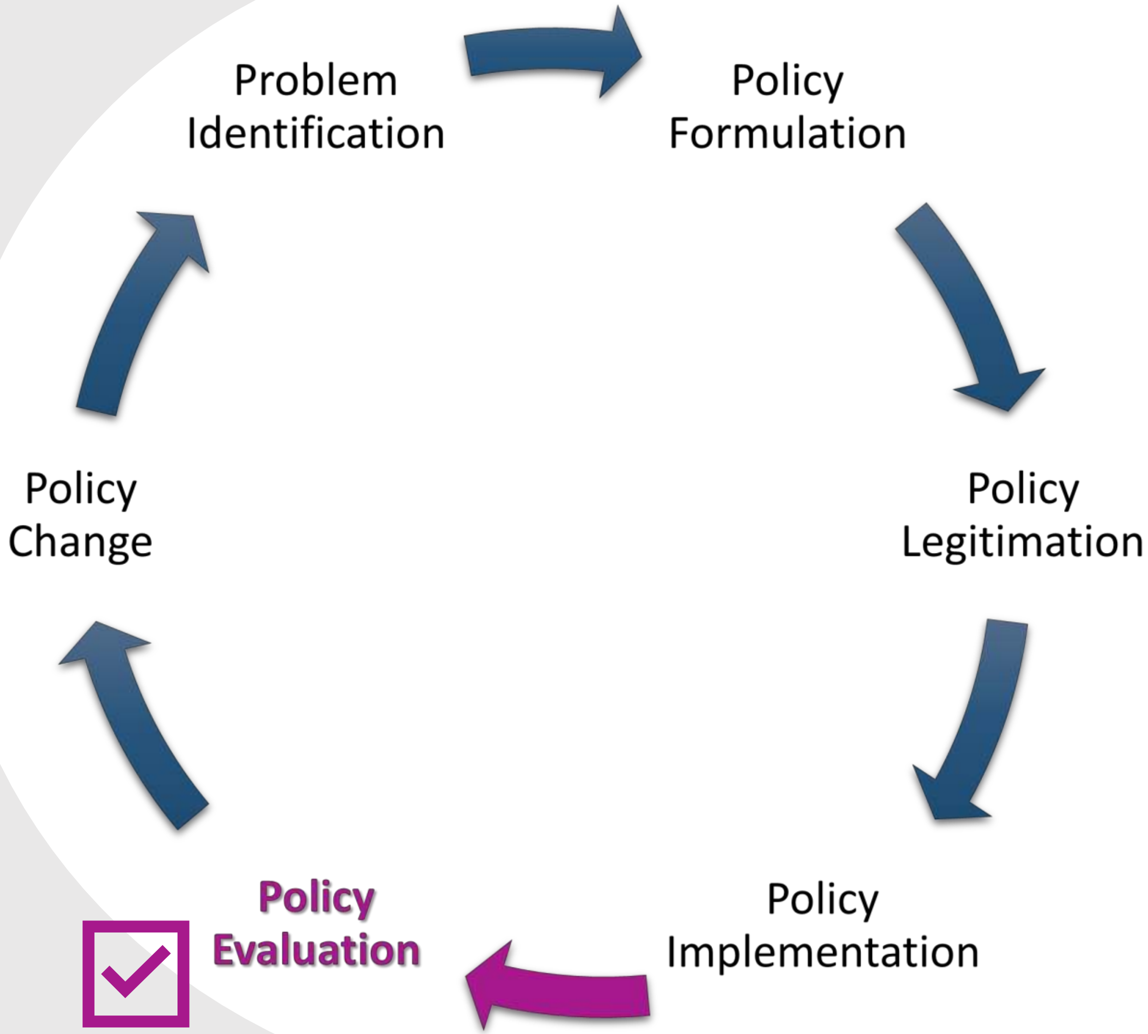
- WILL THIS RESULT IN SIGNIFICANT LEGAL CHALLENGES?
- WILL THE PUBLIC GENERALLY ACCEPT THE POLICY?
- ARE STAKEHOLDER GROUPS AFFECTED?

HOW WILL IT GET DONE?



- **EXECUTION OF THE POLICY (PROJECT) AFTER THE LAW OR PROGRAM IS ENACTED**
- **ENFORCEMENT**
- **DESIGN, CONSTRUCTION, OPERATION**
- QUESTIONS:
- INCREASED STAFFING?
- INCREASED BUDGET?
- PUBLIC OUTREACH?
- HOW WILL THE PROJECT BE PROCURED?
- HOW WILL THE PROJECT BE EXECUTED?

HOW IS IT WORKING OUT?

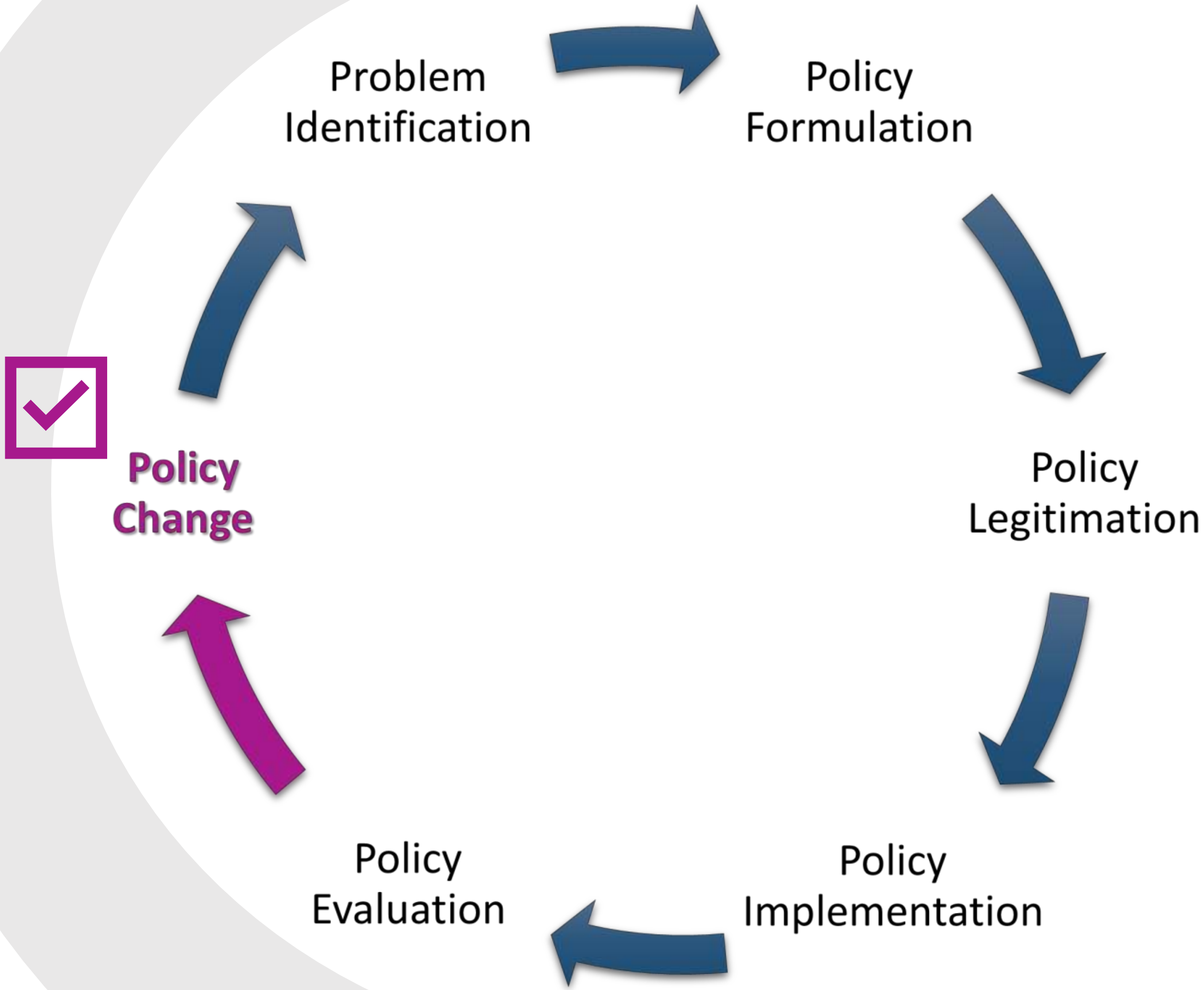


- **STUDY OF THE EFFICACY OF THE POLICY OR PROJECT IN SOLVING THE ORIGINAL PROBLEM**

QUESTIONS:

- IS IT SOLVING THE PROBLEM?
- IS IT THE SAME COST AS ANTICIPATED?
- HAS THERE BEEN CHANGES IN CONTEXT?
- UNANTICIPATED REACTIONS FROM PUBLIC OR STAKEHOLDERS?

IS A CHANGE NEEDED?



- **NEW INFORMATION IS OBTAINED AND EVALUATED**
- **CHANGE OR MODIFICATION TO THE EXISTING POLICY**

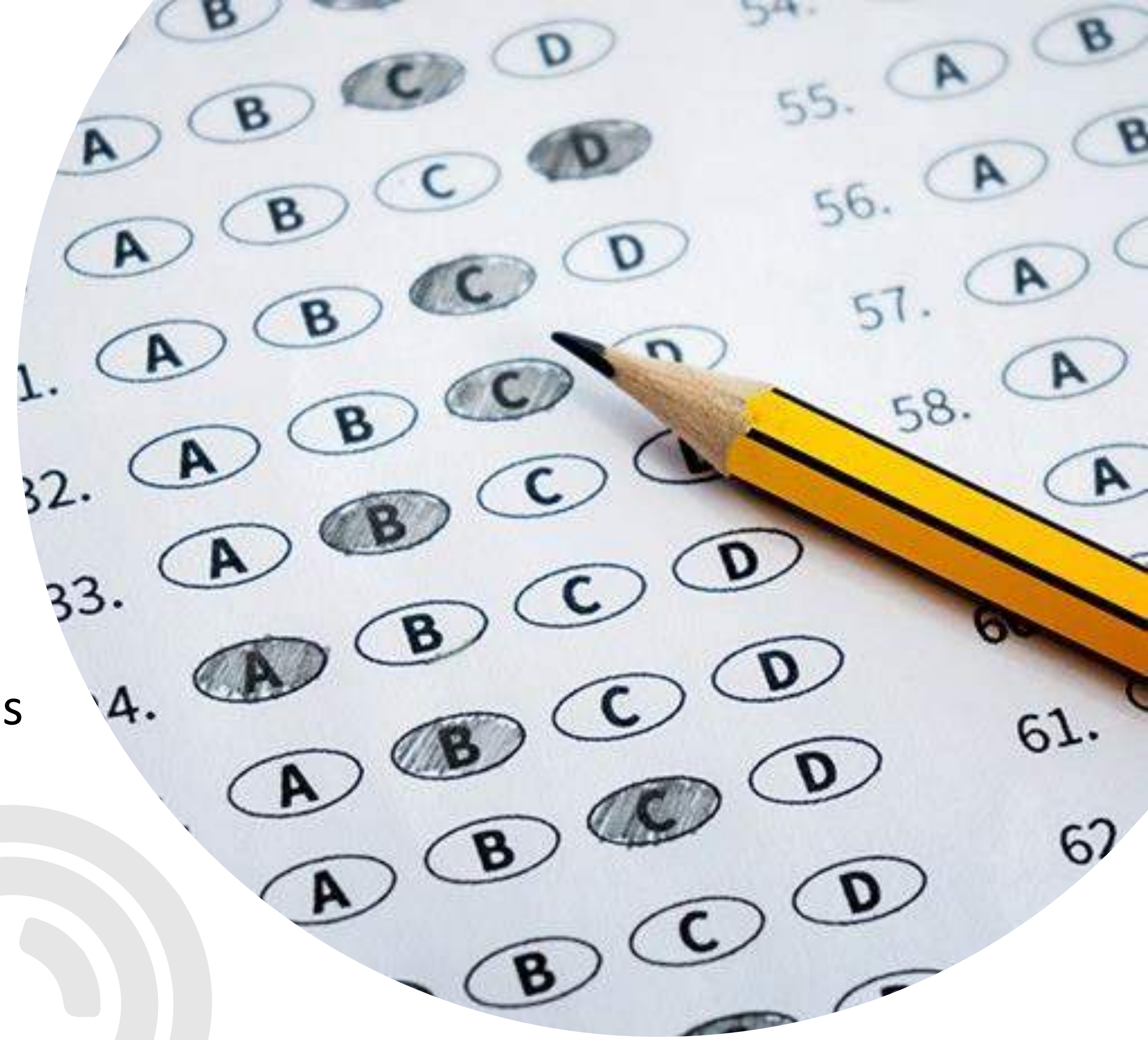
[redacted]

QUESTIONS:

- ARE THERE ADJUSTMENTS NEEDED BASED ON THE EVALUATION?
- IS THE POLICY NEEDED ANYMORE?
- MINOR OR MAJOR CHANGES?

ASSESSING ALTERNATIVES

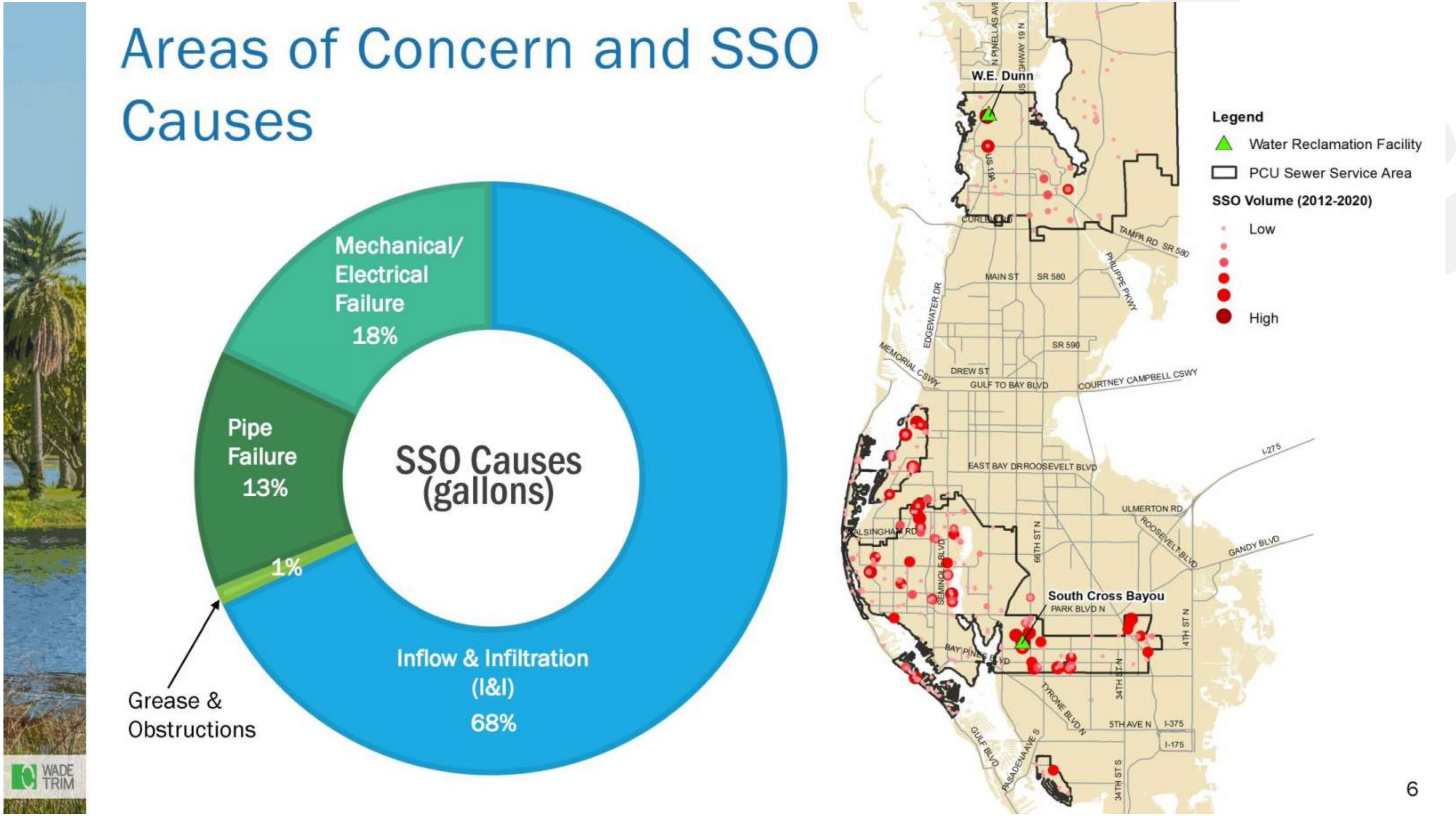
- Takes away a binary choice (Yes or No) which can create a split decision
  - Taking sides based on party affiliation
  - No “right or wrong”
- Enables a broader and more productive discussion
- Places the decision in the hands of officials (give them the power that they want)
- Narrows the focus to a limited set of options
- Provides the data needed to make an informed decision



CASE STUDY – PRIVATE SEWER LATERAL POLICY

DATE	PUBLIC MEETING	APPROACH AND OUTCOME
May 6th, 2021	First Board Work Session	Present Policy Alternatives with analysis. Included public outreach video & draft ordinance language. Resulted in the removal of one alternative
December 2nd, 2021	Second Board Work Session	Presented the remaining alternatives again. Included specific details regarding implementation. Resulted in consensus to proceed.
February 22nd, 2022	Public Hearing	Presented a review of the alternatives again for public hearing purposes. Resulted in unanimous approval.

MAY 6TH WORK SESSION – PROBLEM IDENTIFICATION



MAY 6TH WORK SESSION – ALTERNATIVES ANALYSIS

Private Sewer Lateral Policy Options Summary

The tiles shown below summarize the key considerations of the private sewer lateral policy options that are presented in this document. The subsequent pages provide detailed information regarding each policy option.

REBATE

- Incentive based
- County funded
- PCU customers only
- Increased public education

POINT OF SALE

- Countywide
- Increases buyer awareness
- Impacts sales process

PERMITTING

- Integrated into existing process
- Requires defined criteria
- Adds permitting step and cost

FIND-AND-FIX

- Cost advantage with County projects
- Problem area focused
- PCU customers only
- Private property access

Point of Sale (POS)

Policy Definition

Through the point of sale (POS) option, an inspection of the private sewer lateral is required as part of any property title transfer within Pinellas County. Repairs will be required if the private lateral does not meet applicable building codes. Deadlines to conduct inspections and repairs will be established by the County, most likely to occur soon after closing.

Magnitude

Pinellas County real estate data from 2019 and 2020 showed an average of 20,400 residential sales countywide. Approximately 40% are condominium units and approximately 6,800 are within the Pinellas County Utilities (PCU) service area. The number of laterals impacted each year will depend on factors such as real estate market activity and the number of single-family home sales versus condominium sales.

Effectiveness

This option has the potential to result in a significant number of private sewer lateral inspections and repairs. This may provide a measurable inflow and infiltration (I&I) reduction at water reclamation facilities, however, localized benefits may be delayed due to the widespread location of home sales. While customers are improving private laterals, PCU may be addressing the adjacent public portions of the laterals and sewer mains. Performing this work simultaneously will increase overall effectiveness of I&I reduction.

Cost/Affordability

The cost and impact to the County to implement this option is expected to be low. The County will need administrative staff to track title transfers, inspection status, and repairs. The Building Department may need additional resources to conduct post-construction inspections. The affordability impact to the property owner could be high, depending on the extent of necessary repairs.

Variations

Each variation to the POS option informs the seller of statutory disclosure requirements (i.e., they must inform the buyer of any known issues related to the property's private sewer lateral). All variations could include a rebate component (see rebate policy option).

1. **Require Inspection Prior to Closing:** The seller must complete the inspection prior to closing to ensure the buyer is aware of the private lateral's condition. Any necessary repairs could be done after title transfer but would still be subject to the mandated deadline.
2. **Require Inspection & Repair Prior to Closing:** The seller is responsible for inspection and repair of the private lateral prior to closing. This variation would likely have the greatest impact on the process due to the time needed for repair. This would reduce the County's involvement because enforcement would have occurred by the time the sale of the home was complete, requiring no further action from the County.
3. **Seller & Buyer Determine Conditions:** The seller and buyer will jointly agree on timing and terms of payment for inspection and repair, but the buyer will be responsible for meeting County-mandated deadlines.
4. **Fully Voluntary POS Option:** Private lateral inspections are voluntary. The County increases public awareness that the private lateral is the property owner's responsibility and sellers are required by state law to disclose any known issues.

Advantages

- Requires minimal effort for the County and PCU
- Buyers and sellers of private property drive the responsibility for inspection and repair
- Depending on the housing market, a significant number of laterals could be inspected each year

Disadvantages

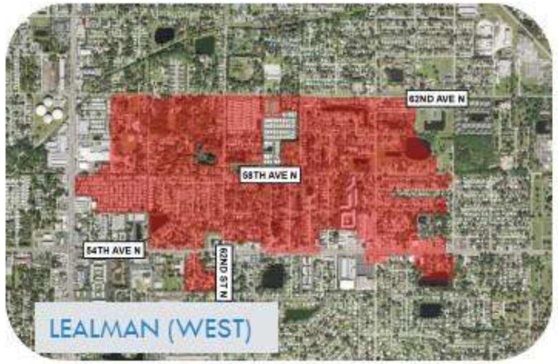
- Consensus must be reached between PCU, the real estate industry, other sewer system owners, and plumber/contractors on relevant program components
- May affect the sales process and increase effort required by real estate professionals
- Added cost from inspection and potential repair to be reconciled between the buyer and seller

DECEMBER 2ND WORK SESSION

Find and Fix Policy – Preliminary Priority Areas

<u>Policy Summary:</u>

- ✓ Estimated I&I Reduction: 25% to 55% by addressing private laterals
- ✓ 36 Miles of Pipeline Rehabilitation
- ✓ 3300 Private Laterals
- ✓ Public Rehab: 3.6 Miles per year
- ✓ Cost Avoidance: $25M to $50M+ for additional flow attenuation storage and pumping



Policy Component	Policy Administration	Annual Costs
Private Laterals	Approx. 340 Per Year	$957,000
Public Lines and Laterals	Approx. 19,000 LF Per Year	$3,223,000
Public Outreach	Mailers, Social Media, etc.	$20,000
Temporary Easements	One FTE	$58,000
Engineering Services	Design/Bid/CM Services	$800,000
	Total Estimated Annual Cost	$5,058,000

5

ON YOUR MARK, GET SET, GO!

- Get on the agenda (utility director)
- Prepare alternatives (attorney review)
- Present to council/board
- Assess feedback (utility director)
- Narrow down & add detail
- Get across the finish line!

*Update board periodically as the project progresses to keep all informed.

THANK YOU

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(352) 262-9878

FIND ME ON LINKEDIN!

BIOSOLIDS RULE IMPLEMENTATION UPDATE

Maurice Barker
Division of Water Resource Management
Wastewater Management Program
Florida Department of Environmental Protection

Florida International University | July 18, 2024

AGENDA

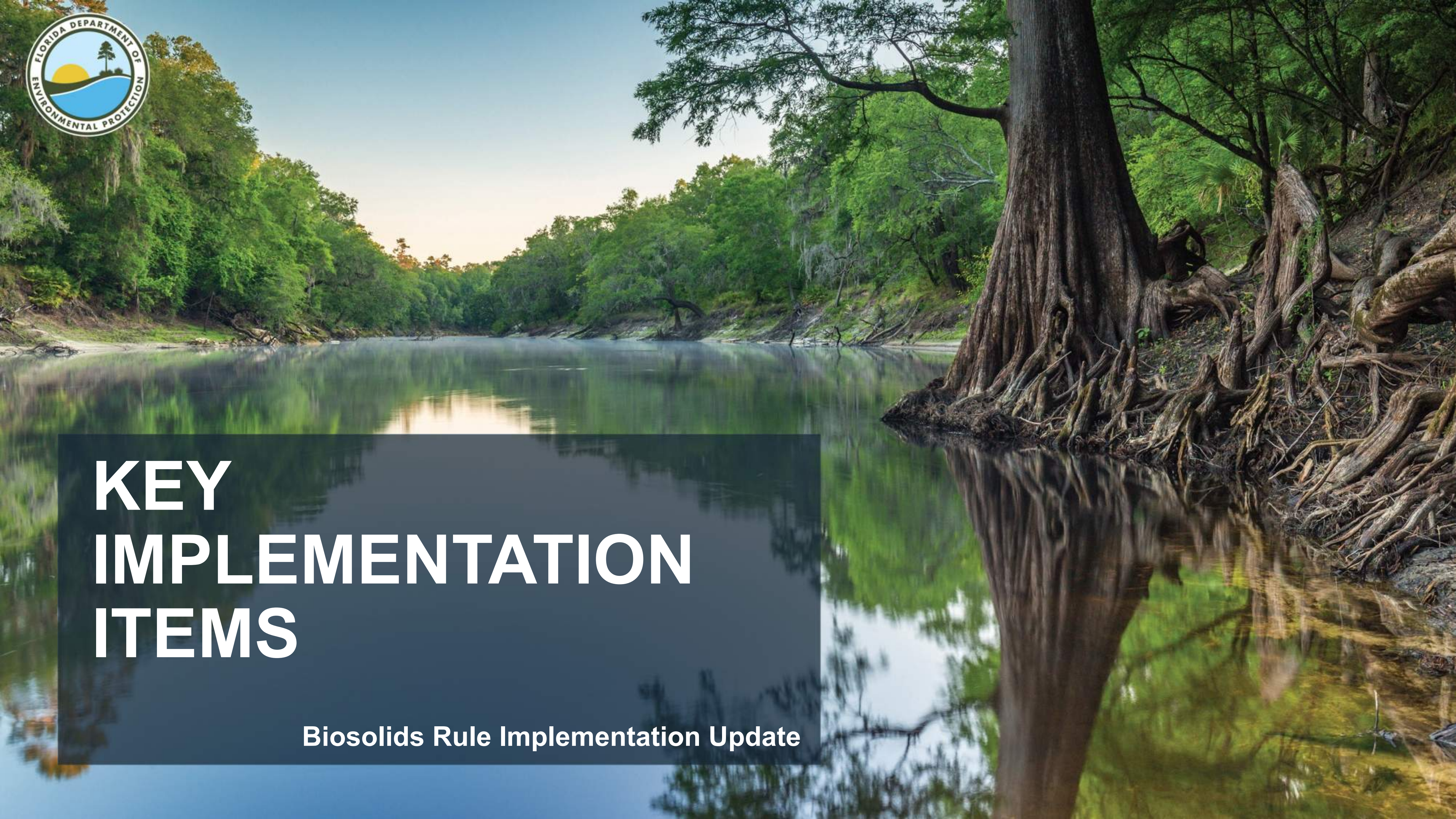
- Review of the 2021 revisions to the biosolids regulations.
- Key implementation items.
- Future.
- Questions.

REVIEW OF 2021 BIOSOLIDS REQUIREMENTS

Biosolids Rule Implementation Update

2021 RULE PROVISIONS

- New prohibition on land application on soils with a seasonal high-water table (SHWT) within six inches of the soil surface or depth of biosolids placement.
- Requires site enrollment in a Florida Department of Agriculture and Consumer Services (DACS) best management practices (BMP) program.
- Facilities must monitor for water extractable phosphorus (WEP).
- Nutrient management plans (NMPs) shall include a nitrogen (N) based rate for each zone and a phosphorus (P) based rate; neither rate can be exceeded.
- Septage application rates.
- Revised method to determine allowed application rates that accounts for biosolids P solubility and the soil phosphorus storage capacity index.
- New soil fertility testing requirements; annual monitoring.
- Ground water monitoring; surface water monitoring.
- All permits for sites were required to meet the requirements of the rule by June 21, 2023.



KEY IMPLEMENTATION ITEMS

Biosolids Rule Implementation Update

SEASONAL HIGH-WATER TABLE

- **Section 403.0855, Florida Statutes (F.S.), prohibits land application on soils with an SHWT within six inches of the soil surface or depth of biosolids placement.**
- Primarily affects sites in Southeastern Florida based on SHWT values in previous permit applications submitted 2013-2020.
  - Some old application forms provided SHWT values to exact inches.
  - Some old applications forms just noted “<2 ft” or “0 to 2 ft” for the SHWT since anything less than two feet required piezometers; these permittees will need to update the SHWT values.
- Some site permittees have elected to remove all the acreage with a shallow SHWT.
- The statute allows a permittee to propose a water quality monitoring plan and a NMP that will provide the Florida Department of Environmental Protection (DEP) reasonable assurance that no water quality violations will occur if they apply.

BMP REQUIREMENT

- **Section 403.0855, F.S., requires all permitted biosolids land application sites to be enrolled in the DACS BMP program or be within an agricultural operation enrolled in the program for the applicable commodity type.**

- DACS BMP website: https://www.fdacs.gov/Agriculture-Industry/Water/Agricultural-Best-Management-Practices.

- DACS has been working to enroll sites.
  - Some landowners have not attended the enrollment meetings.
  - Some sites don't appear to fall under a specific BMP crop program (silviculture, disposal of mowed clippings, pasture questions, etc.).

WEP MONITORING

- **Facilities must monitor for WEP using the "Universal Water Extractable P Test for Manure and Biosolids."**
  - Measures the initial solubility of P in the facility's biosolids.
  - Discharge monitoring report (DMR) parameter B0011 (phosphorus, sludge, water extractable, dry weight [as P] in percent).
  - WEP/Total P = percent water extractable phosphorus (PWEP); PWEP is needed by sites to prepare new NMPs.
- **Some labs did not initially offer WEP monitoring.**
  - As a "new" method, no labs were certified; DEP recognizes that labs need time to get certified and will accept results until labs are certified.
  - The WEP method is comprised of a water extraction followed by inductively coupled plasms (ICP) analysis of P; labs can get certified for ICP analysis of P.

NMP APPLICATION RATES

- **NMPs must now determine a P-based rate in addition to determining an N-based rate; neither rate can be exceeded.**
  - Seeing lower overall application rates, since P-based rates are usually lower.
    - Base P rate in the regulations for pasture is around 17 lbs. P/acre/year. At a N-based rate of 240 lbs./acre/year, about 120 lbs. P/acre/year would potentially be applied.
    - Sites can use a combination of the biosolids WEP values and the soil phosphorus storage capacity index (CI) values to adjust the P rate to higher levels; many existing sites have negative CI values that do not allow adjusting the P rate.

- **Still working to revise some NMPs, primarily for larger sites.**
  - Some sites claimed “native phosphatic soils” where native phosphatic soils are not known to exist.
  - Some sites may be able to take deeper soil samples for the CI, but the samples can’t go into the SHWT.

SEPTAGE NMP APPLICATION RATES

- **Septage is limited to one of three basic rates.**
  - 40,000 gallons/acre/year if the rate is N-based and no grease.
  - 30,000 gallons/acre/year if the rate is N-based but the septage management facility accepts grease.
  - 12,000 gallons/acre/year if the rate is P-based.

- **Septage rates must be P-based if the soil phosphorus storage CI is less than zero.**
  - Some septage sites have used the option to test the soil deeper than six inches (but not into the SHWT) to try to get a positive CI.
  - If the CI is less than zero, ground water monitoring will be required at the septage site.

CAPACITY INDEX (CI)

- **The CI is a relative measure of the soil's ability to hold phosphorus.**
  - CI is based on soil fertility testing results for the Mehlich 3 extractions of iron (Fe), aluminum (Al) and P – see the rule definition for the math formula.
  - The University of Florida's Institute of Food and Agricultural Sciences (UF/IFAS) laboratory has several soil fertility test analysis options, but the "Phosphorus Index Test" provides soil CI.
- **Most site permitting to date has shown negative CI results for the top six inches of soil for existing septage and biosolids sites.**
  - Some sites have used the rule option to test the soil deeper than six inches (but not into the SHWT) to try to get a positive CI.
  - Deeper sampling cannot go past the SHWT.

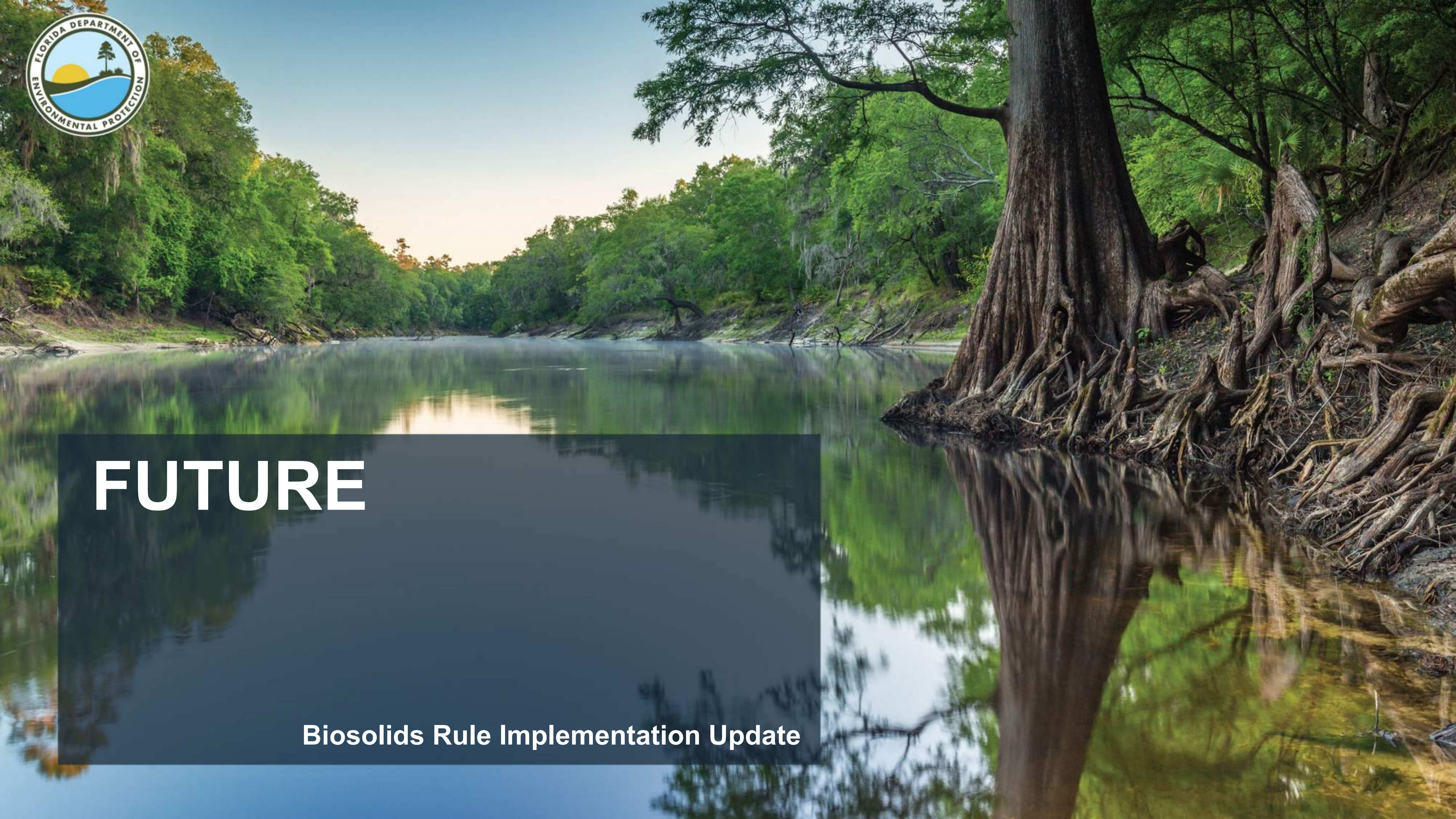
GROUND WATER MONITORING

- **Ground water monitoring is required in any of the following situations.**
    - The application rate is 160 lbs. of Total N acre/year or more.
    - The application rate is 40 lbs. of phosphorus pentoxide (P_2O_5) acre/year or more.
    - The CI is less than zero (negative); this is the only situation where septage sites will need to conduct ground water monitoring.

- **At 5% Total N and 2.5% Total P, one ton of biosolids will supply about 100 lbs. of Total N and 50 lbs. of Total P (equivalent to 115 lbs. of P2O5).**

SURFACE WATER MONITORING

- **Surface water monitoring is required in the following scenario.**
  - The biosolids application zone is bordered or crossed by waters of the state and the application zone is located within 1,000 feet of waters of the state, excluding wetlands.
- **If the permittee is not required to monitor, DEP may conduct monitoring.**
- **DEP is in the process of approving NMPs for sites that will have to implement surface water monitoring.**
- **Expected to reduce allowable acreage at some sites; one site removed the acreage within 1,000 feet of a surface water.**



FUTURE

Biosolids Rule Implementation Update

TRENDS

- As identified in the Statement of Estimated Regulatory Costs for Chapter 62-640, Florida Administrative Code (F.A.C.).
  - Allowed application rates are dropping.
    - Many existing sites have negative capacity index results and the pastures on the sites would typically be limited to 40 lbs. P_2O_5 per acre per year (about 0.3 dry tons of biosolids per acre).
    - Land application at Florida sites decreased from about 96,000 dry tons in 2021 to about 63,000 dry tons in 2023.
  - 57 sites have become inactive since 2018, including about 20 septage sites.
  - Interest is increasing in producing Class AA biosolids.
    - Three new composting facility permits were issued in the past five years.
    - Volume of Class AA biosolids products distributed and marketed by Florida facilities was up to about 270,000 dry tons of biosolids in 2023, from about 228,000 dry tons in 2021.

NMP REVISIONS

- Need to resolve issues related to revising NMPs for many large sites.
  - If the sites were to follow a P-based rate, the sites do not have enough approved acreage to apply the amount of biosolids currently land applied – would need four to ten times the amount of land.
  - Existing alternate use and disposal options, such as landfilling or sending to a Class AA biosolids treatment facility, are limited and can't handle the excess volume.
  - In early 2024, one facility had a temporary backlog of 400 to 600 loads of biosolids but was ultimately able to arrange enough additional capacity at other facilities.
  - Working with several stakeholders to resolve the issues.

PFAS

- U.S. Environmental Protection Agency (EPA) activities.
  - Currently conducting a risk assessment to determine if and what regulations may be needed for per- and polyfluoroalkyl substances (PFAS) in biosolids (scheduled for completion by the end of 2024).
  - Published a proposed information collection request in the Federal Register – proposing to require monitoring and reporting of PFAS in biosolids from 200-300 wastewater facilities.
- PFAS lawsuits.
  - Five Texas farmers are suing Synagro for PFAS contamination.
  - Public Employees for Environmental Responsibility (PEER) filed a lawsuit on behalf of two of the Texas farmers against EPA for failure to regulate PFAS under the Clean Water Act.
  - News articles indicate more lawsuits may be filed in the future.

THANK YOU

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Division of Water Resource Management
Wastewater Management Program
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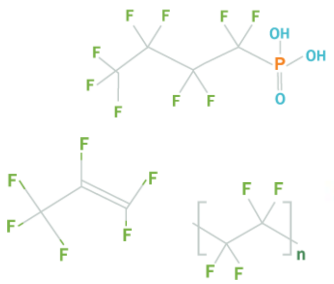
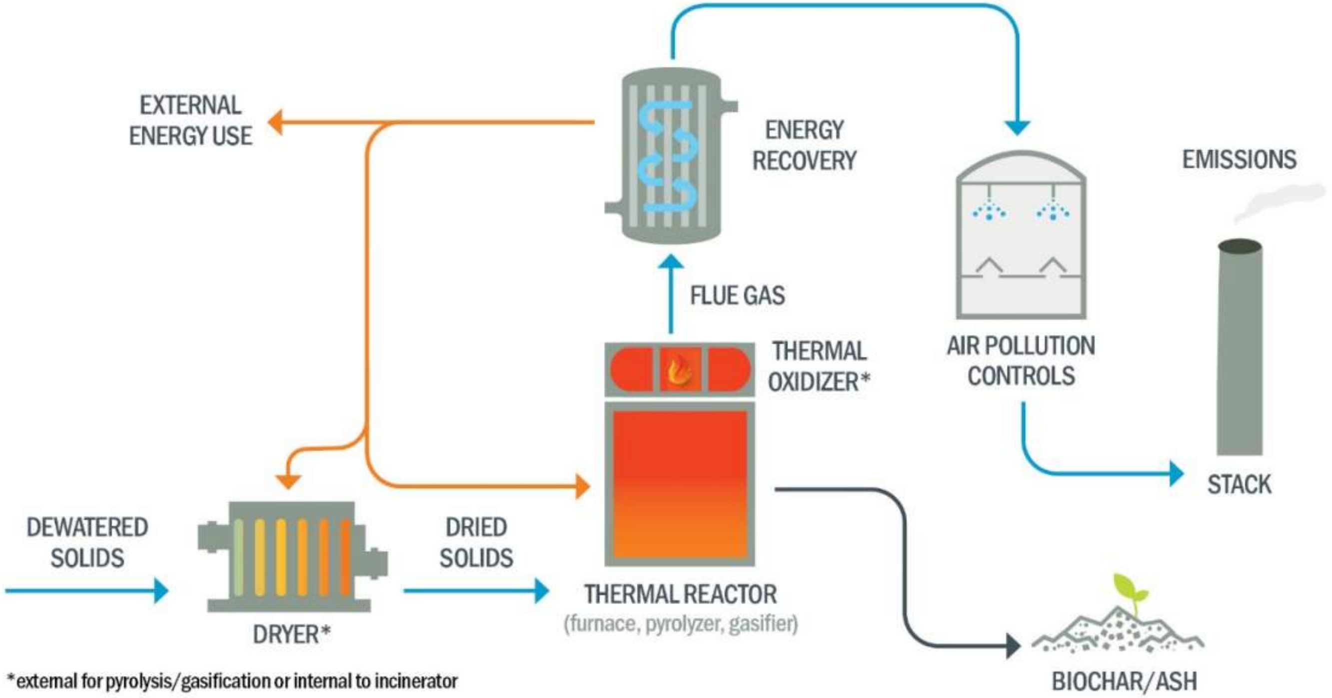
July 18, 2024

Fate of PFAS through Incineration, Pyrolysis, and Drying – Research Based Results





Winchell, L.J., Ross, J.J., Brose, D. A., Pluth, T. B., Fonoll, X., Norton Jr., J.W., Bell, K.Y. High-temperature Technology Survey and Comparison among Incineration, Pyrolysis, and Gasification Systems for Water Resource Recovery Facilities *Water Environ. Res.*
http://dx.doi.org/10.1002/wer.10715

Florida Water Environment Association | BIOSOLIDS COMMITTEE

Brown AND Caldwell

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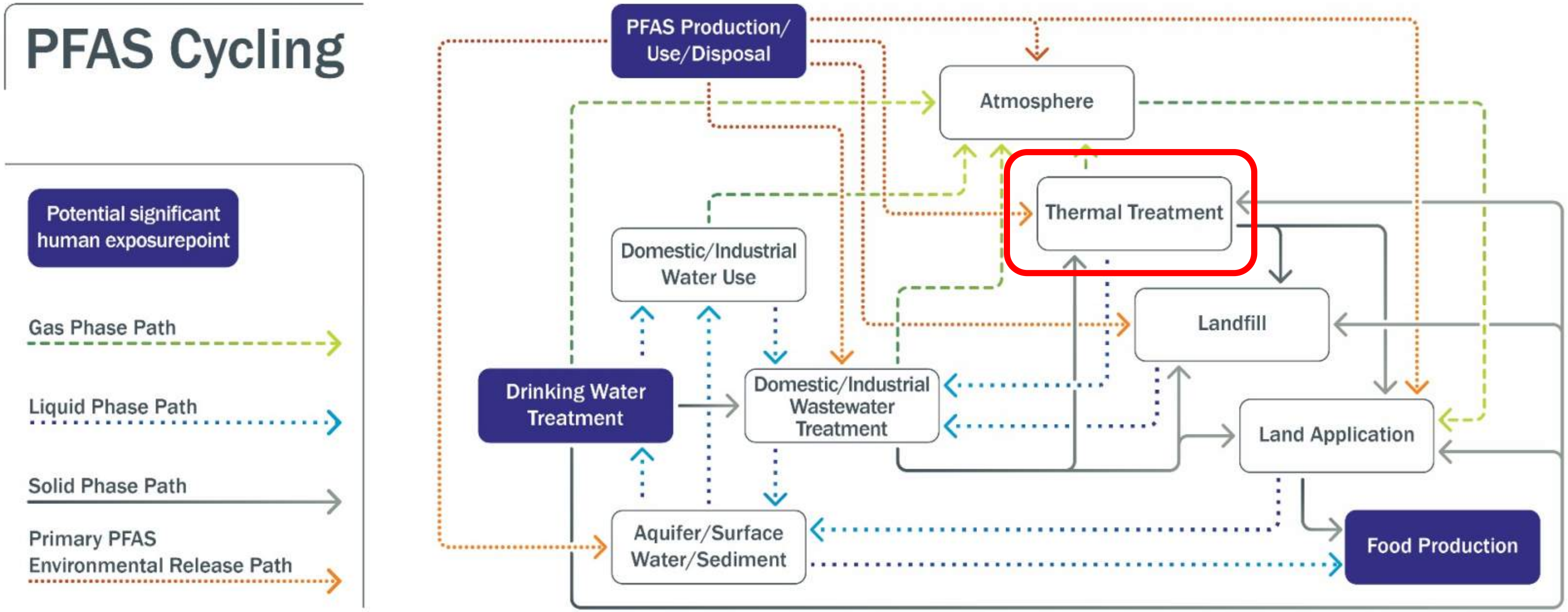
Interrupting the PFAS environmental cycle



Winchell, L. J., Wells, M. J. M., Ross, J. J., Fonoll, X., Norton, Jr., J. W., Kuplicki, S., Khan, M., and Bell, K. Y. (2021). Per- and Polyfluoroalkyl Substances (PFAS) Presence, Pathways, and Cycling through Drinking Water and Wastewater Treatment: A State-of-the-art Review. Journal of Environmental Engineering. https://doi.org/10.1061/(ASCE)EE.1943-7870.0001943.

Thermal treatment offers the only established PFAS destruction process for biosolids

PFAS thermal destruction requirements

Guidance typically based on lab-scale data or guidelines for hazardous waste and does not consider:

- Fuel chemistry unique to sludge
- Turbulence
- Residence time
- Oxidation conditions

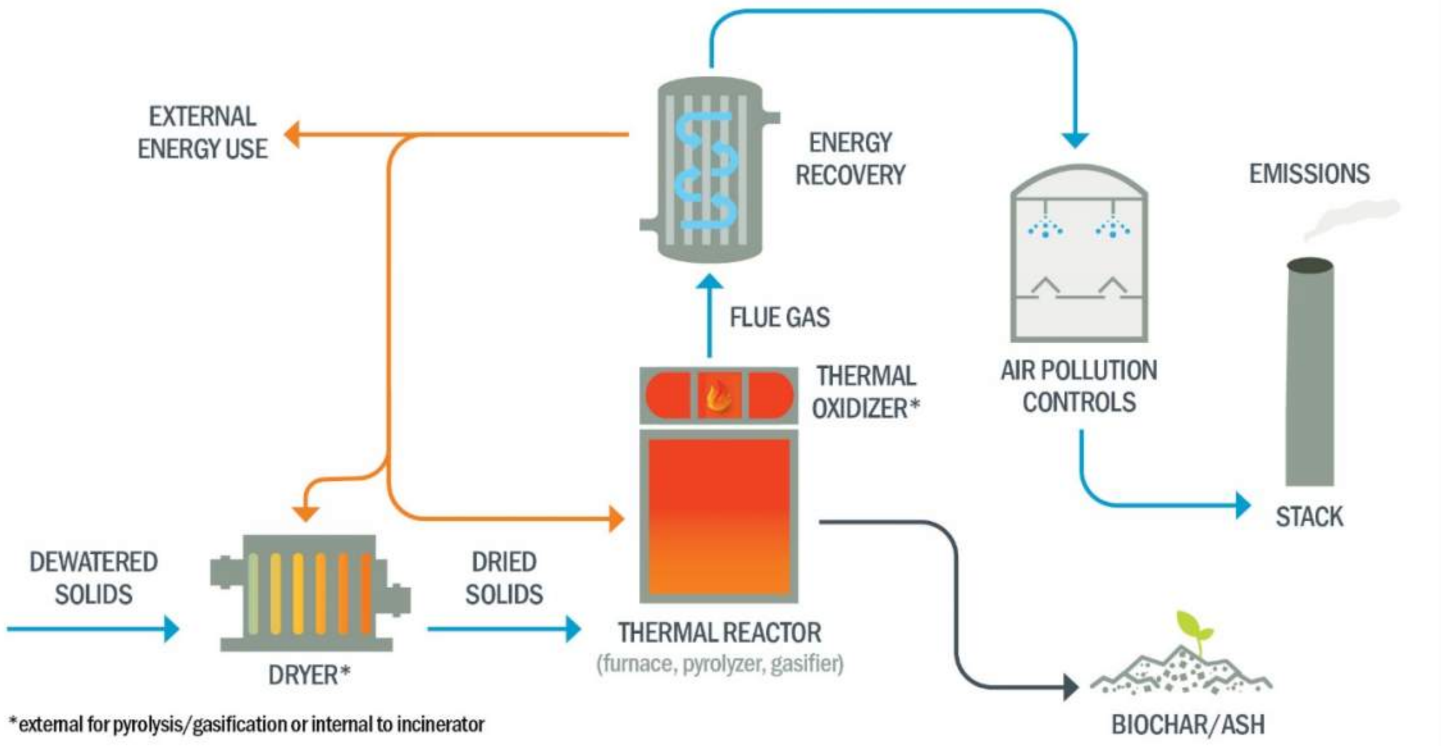
Table 3. Recent guidance and literature basis for PFAS thermal destruction

SOURCE	TEMPERATURE NOTED	COMMENTARY
Pancras et al. (2016)	1,000–1,200°C	High-temperature incineration is required for complete PFOS degradation
Kucharzyk et al. (2017)	1,000°C or greater	High-temperature incineration is required to destroy PFAS adsorbed to spent activated carbon
USEPA (2020c)	1,000°C	Studies found PFOA is removed to nondetect levels using laboratory-scale combustion experiments
UNEP (2019a)	1,100°C	Combustion at hazardous waste incineration process parameters (2 s residence time at temperature) is the most appropriate way to handle PFOS waste
Ross et al. (2018)	1,100°C	High temperatures are required for destruction of gas-phase PFAS
ITRC (2020)	1,000°C or greater	PFAS destruction can be achieved at high temperature

Winchell, L.J., Wells, M.J., Ross, J.J., Fonoll, X., Norton Jr., J.W., Bell, K.Y. (2021). PFAS Thermal Destruction at Wastewater Treatment Facilities: A State of the Science Review. *Water Environ. Res.* http://dx.doi.org/10.1002/wer.1483

Mature thermal destruction processes

- Incineration (combustion) offers the only thermal process with historical track record
- Pyrolysis/gasification emerging
- Others further behind
  - Hydrothermal liquefaction
  - Hydrothermal carbonizaton
  - Supercritical water oxidation
  - Smoldering



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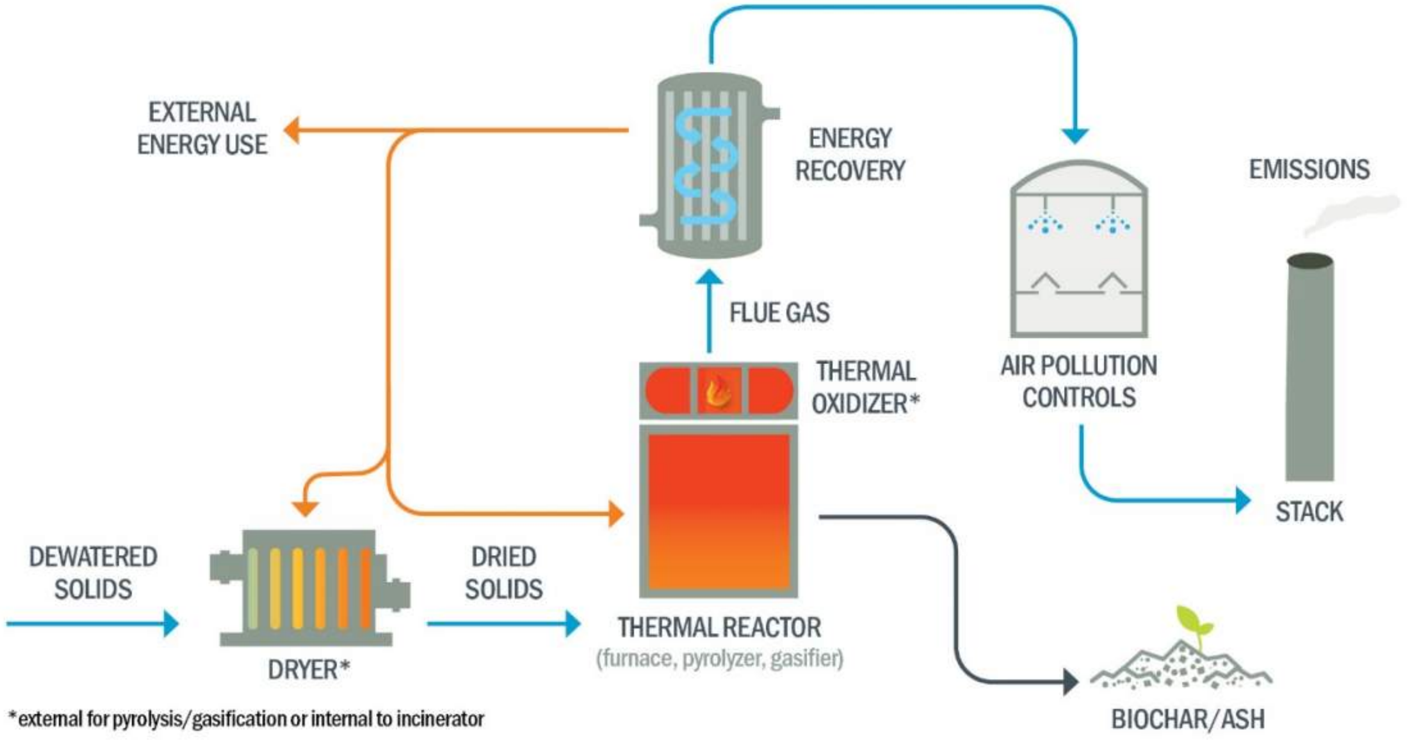
Incineration



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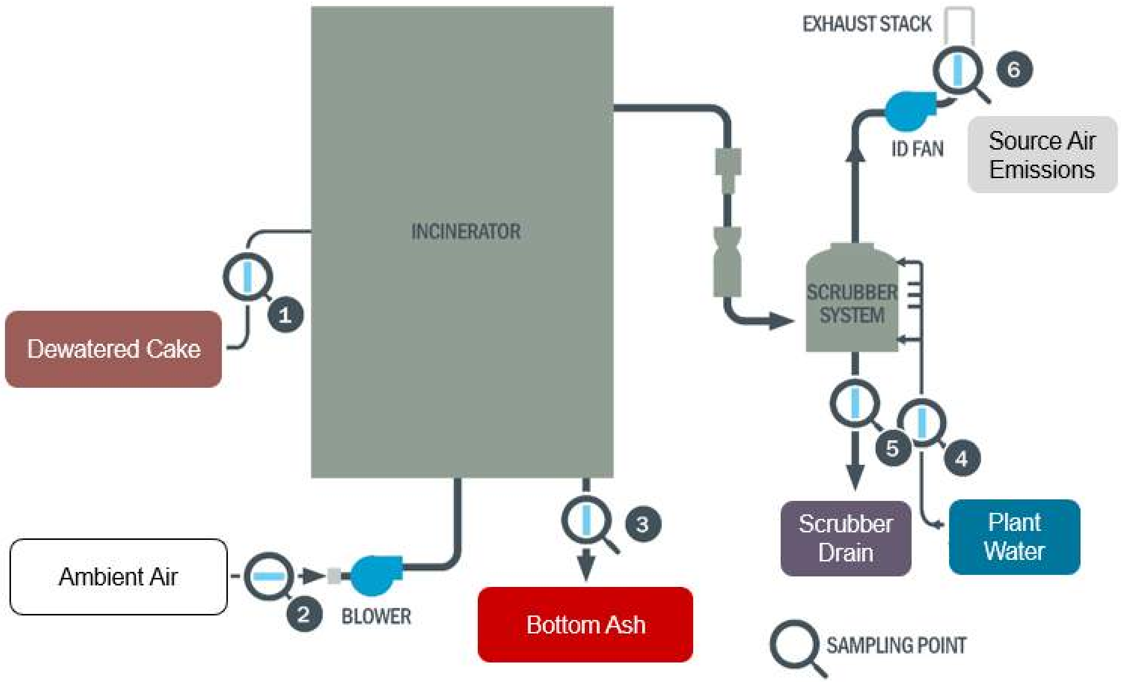
WRF Tailored Collaboration 5111: “Existing” Incineration

- FBF and MHF, one each
- Sampled inputs/outputs
- Evaluating results and drafting report
- Data published in Water Environment Research

Winchell, L. J., Wells, M. J.M., Ross, J. J., Kakar, F., Teymouri, A., Gonzalez, D. J., Dangtran, K., Bessler, S. M., Carlson, S., Fonoll, X., Norton Jr., and Bell, K. Y. (2024) Fate of PFAS Through Two Full-Scale Sewage Sludge Incinerators. Water Environment Research. https://onlinelibrary.wiley.com/doi/10.1002/wer.11009



Final report: Fall 2024

Incinerator Emissions (mg/d, MHF/FBF)[a]

Family	PFAS chain length	Effluent[b]	DSS	Stack[c]
PFCA	PFBA — 4	41.8 / 42.8	– / –	0.369 / –[e]
	PFPeA — 5	59.3 / 39.1	– / 0.475	0.115 / –[e]
	PFHxA — 6	77.1 / 66.2	0.866 / 3.66	0.0474 / –[e]
	PFHpA — 7	20.1 / 11.9	– / –	–[f] / –
	PFOA — 8	40.0 / 46.7	0.744 / 3.29	0.0244 / –
	PFNA — 9	– / –	– / –	– / –[e]
	PFDA — 10	– / –	1.08 / 5.80	– / –
	PFUnA — 11	– / –	– / 0.850	– / –
	PFDoA — 12	– / –	– / 2.82	– / –
	PFTeDA — 14	– / –	– / 0.623	– / –

Family	PFAS chain length	Effluent[b]	DSS	Stack[c]
PFSA	PFBS — 4	– / 77.7	– / –	– / –
	PFHxS — 6	38.5 / 15.6	– / –	– / –
	PFOS — 8	101 / 29.2	21.7 d / 11.8	0.0177 / –
	PFDS — 10	– / –	0.642 / –	– / –
FASA	FOSA — 8	– / –	– / 0.830	– / –
	NMeFOSA — 8	– / –	– / 0.450	– / –
FASAA	NMeFOSAA — 8	– / –	2.19 / 11.5	– / –
	NEtFOSAA — 8	– / –	1.53 / 11.2	– / –
FASE	NMeFOSE — 8	– / –	1.43 / 10.8	– / –
	NEtFOSE — 8	– / –	– / 14.5	– / –
FTSA	6:2 FTS — 8	46.7 / 26.0	– / 0.532	0.0995 / –
	8:2 FTS — 10	– / –	1.27 / –	– / –
	10:2 FTS — 12	– / –	1.16 / –	– / –

DSS = dewatered sewage sludge
– = result less than reporting limit, screened during quality control.
a. Normalized to 0.907 DMT/d of DSS and 3.785 ML/d of effluent.
b. Assumed same targeted PFAS levels as wet scrubber supply.
c. Stack emissions normalized by average stack flow per DMT/d.
d. Two samples of DSS from the MHF site yielded reportable results.
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	PFOS	[illegible]	[illegible]	.0177 / –
	PFDS	[illegible]	[illegible]	– / –
FASA	FOSA	[illegible]	[illegible]	– / –
	NMeFOS	[illegible]	[illegible]	– / –
FASAA	NMeFOS	[illegible]	[illegible]	– / –
	NEtFOSAA — 8	– / –	1.53 / 11.2	– / –
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PFCA detections at stack, FBF samples contaminated

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	NE[illegible]	[illegible]	[illegible]	[illegible] / –
FASE	NM[illegible]	[illegible]	[illegible]	[illegible] / –
	N[illegible]	[illegible]	[illegible]	[illegible] / –
FTSA	6[illegible]	[illegible]	[illegible]	[illegible]95 / –
	8:2 FTS — 10	– / –	1.27 / –	– / –
	10:2 FTS — 12	– / –	1.16 / –	– / –

Where present in all three samples,
≈ order of magnitude decline:
effluent → DSS → stack

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	…AA — 8	– / –	2.19 / 11.5	– / –
	…AA — 8	– / –	1.53 / 11.2	– / –
	…SE — 8	– / –	1.43 / 10.8	– / –
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	8:2 FTS — 10	– / –	1.27 / –	– / –
	10:2 FTS — 12	– / –	1.16 / –	– / –

Stack emissions favor smaller PFAS, DSS larger

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Incinerator Emissions (mg/d, MHF/FBF)[a]

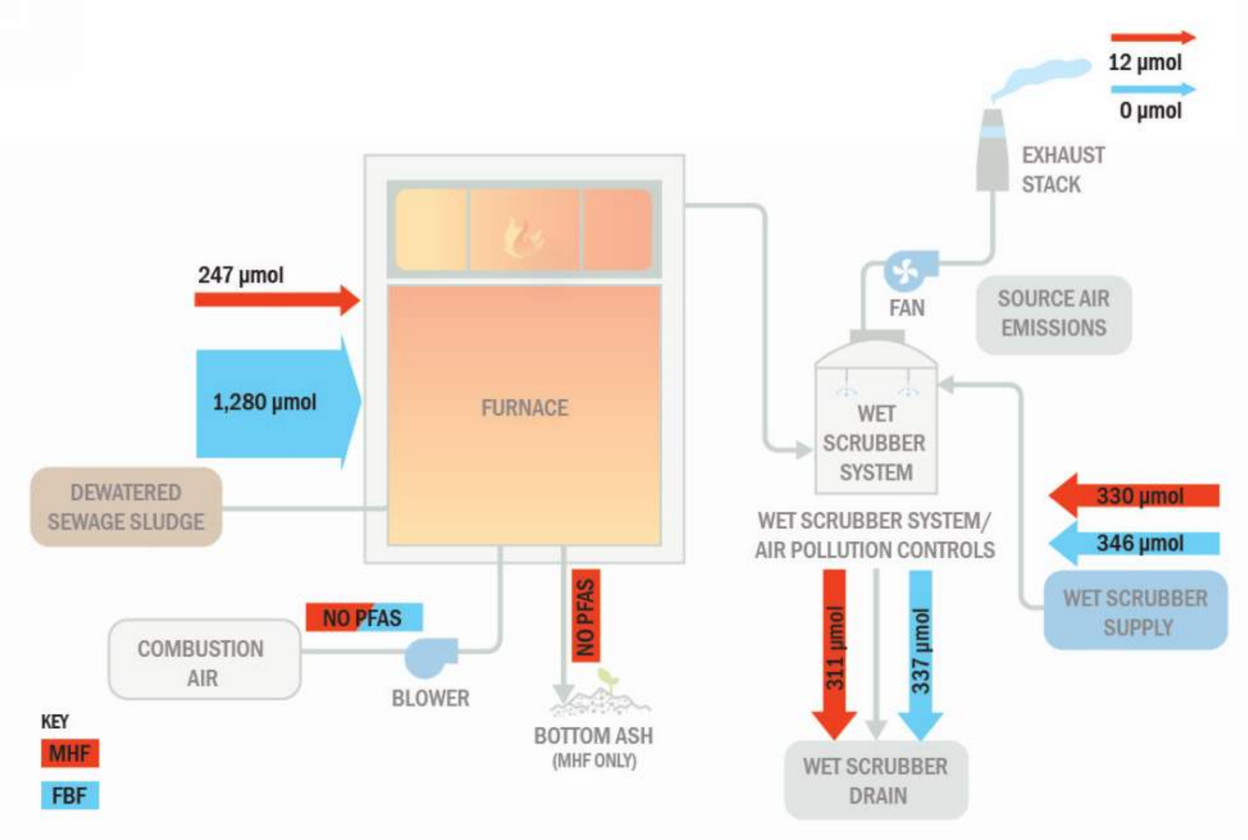
	Measured Emission (µg/DSCM)			State Requirements (µg/cubic meter)[a]			
PFAS	Run 1	Run 2	Run 3	MI[b]	MN[c]	NY[d]	TX[e]
PFBA	0.0205	0.0211	0.0251	—	10	—	—
PFHxA	0.00343	0.00143	0.00373	—	0.5	—	—
PFOA	0.00105	0.00137	0.00200	0.07	0.063	0.0053	0.005
PFBS	Q	Q	Q	—	0.3	—	—
PFHxS	Q	Q	Q	—	0.34	—	—
PFOS	0.00115	0.00112	0.000937	0.07	0.011	—	0.01
6:2 FTS	0.00421	0.00381	0.0100	1	—	—	—

— = Not applicable.
Q = Data screened during quality control.
a. Threshold values represent most stringent criteria listed.
b. Michigan Department of Environment, Great Lakes, and Energy (2023).
c. Minnesota Department of Health (2023).
d. New York State Department of Environmental Conservation (2020).
e. Texas Commission on Environmental Quality (2023).

MHF meets current state requirements

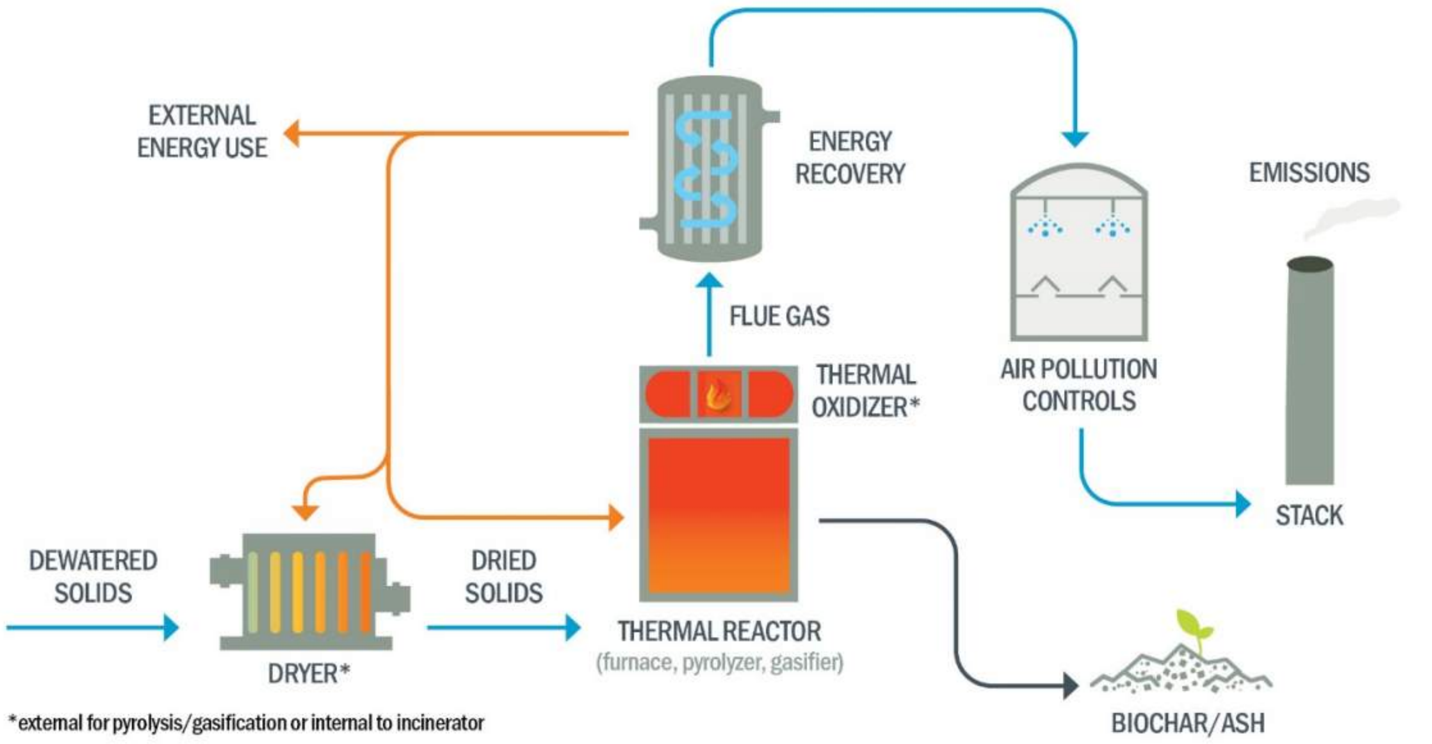
WRF 5111 Highlights

- MHF emitted reportable amounts from stack
- Five percent of the MHF sludge molar PFAS load was reported in the stack
- Ash is PFAS "free"
- MHF and FBF wet scrubber water streams accumulated nonpolar fluorinated organics and fluoride from the furnace exhaust
- Ultra-short volatile PFCs measured at the stack represented 0.5%–4.5% of the estimated facility greenhouse gas emissions



Winchell, L. J., Wells, M. J.M., Ross, J. J., Kakar, F., Teymouri, A., Gonzalez, D. J., Dangtran, K., Bessler, S. M., Carlson, S., Fonoll, X., Norton Jr., and Bell, K. Y. (2024) Fate of PFAS Through Two Full-Scale Sewage Sludge Incinerators. Water Environment Research. https://onlinelibrary.wiley.com/doi/10.1002/wer.11009

Pyrolysis



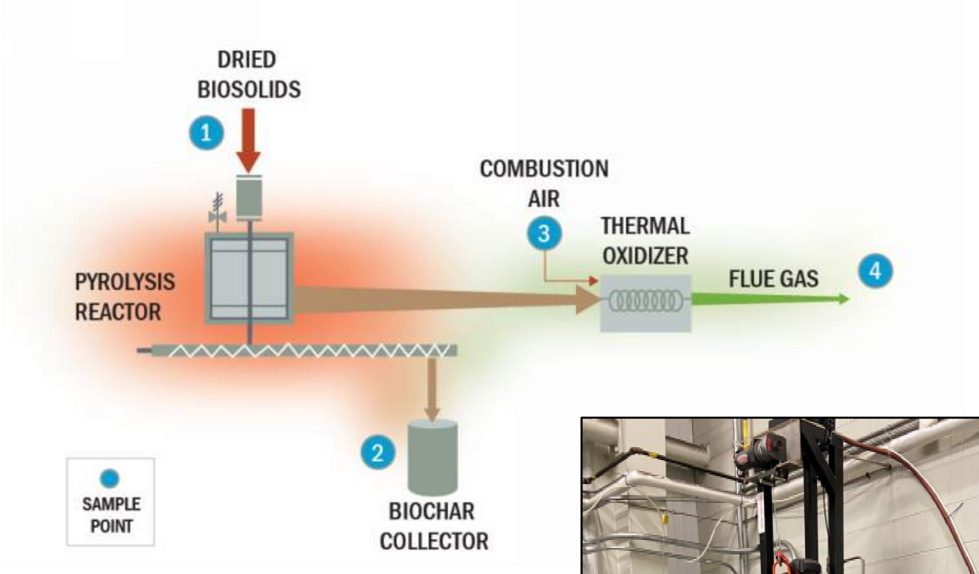
Winchell, L. J., Ross, J. J., Brose, D. A., Pluth, T. B., Fonoll, X., Norton, Jr., J. W., and Bell, K. Y. (2022a). High-temperature Technology Survey and Comparison Among Incineration, Pyrolysis, and Gasification Systems for Water Resource Recovery Facilities. *Water Environment Research*, 94. https://onlinelibrary.wiley.com/doi/10.1002/wer.10715

Pyrolysis/Gasification/Thermal Oxidation Research

Process	Study	Findings/Status
Pyrolysis	Kim et al (2015)	No change in biochar PFAS at 300°C and 700°C
	Xia et al (2020)	99.9% reduction of PFOA/PFOS on GAC at 700°C
	Kundu et al (2021)	Non-detect in biochar at 500–600°C
	Williams et al (2021)	84.4–95.6% removal from efficiency from biochar and off-gas
	McNamara et al (2022)	Undetectable in biochar, collected in condensable liquid from off-gas
Thermal oxidizer	Focus Environmental (2020)	99.99% reduction at 980°C at 0.75–1.2 seconds
	Barr (2022)	PFOA and PFOS reduction of 92% and 75%, respectively, at 980°C and 0.75–1.2 seconds
Gasifier and thermal oxidizer	Loganholme City Council (2021)	94% destruction and removal efficiency with thermal oxidizer operating at 800–850°C for 2 seconds
Pyrolysis and thermal oxidizer	Thoma et al (2022)	Non-detect in biochar, possible fluorinated products in flue gas, but unreliable data to support conclusions
	WRF 5107	Full-scale evaluation capturing condensable and using engine for thermal oxidation after off-gas cleaning
	WRF 5211	Lab scale study currently underway
	WEF	BC study discussed later

WEF Study

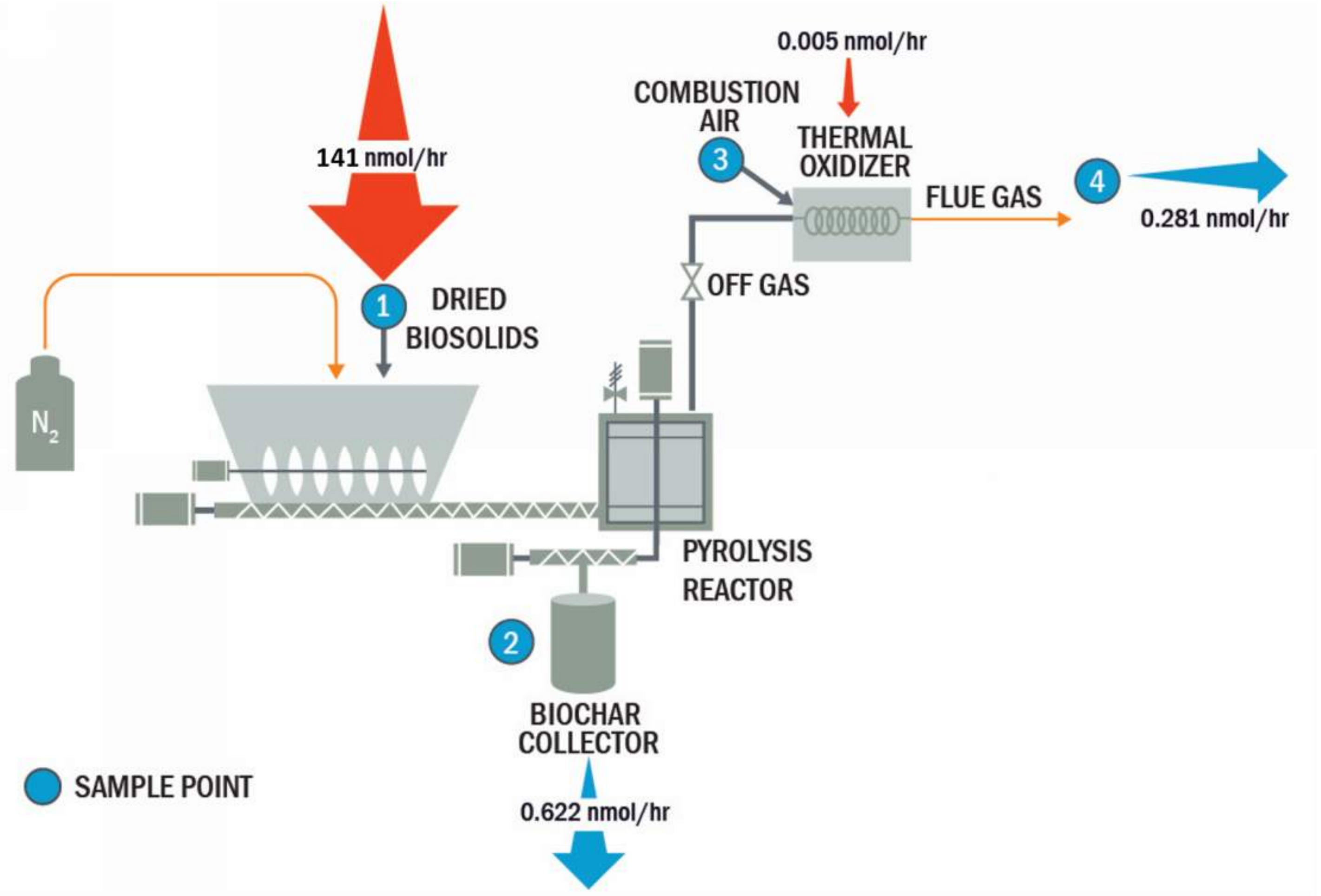
- Characterize the fate of PFAS through both a lab scale pyrolysis system and a full-scale system - equivalent?
- Publishing preliminary lab-scale results



https://www.wef.org/resources/pressroom/press-releases2/wef-press-releases/research-explores-option-for-destruction-of-pfas/

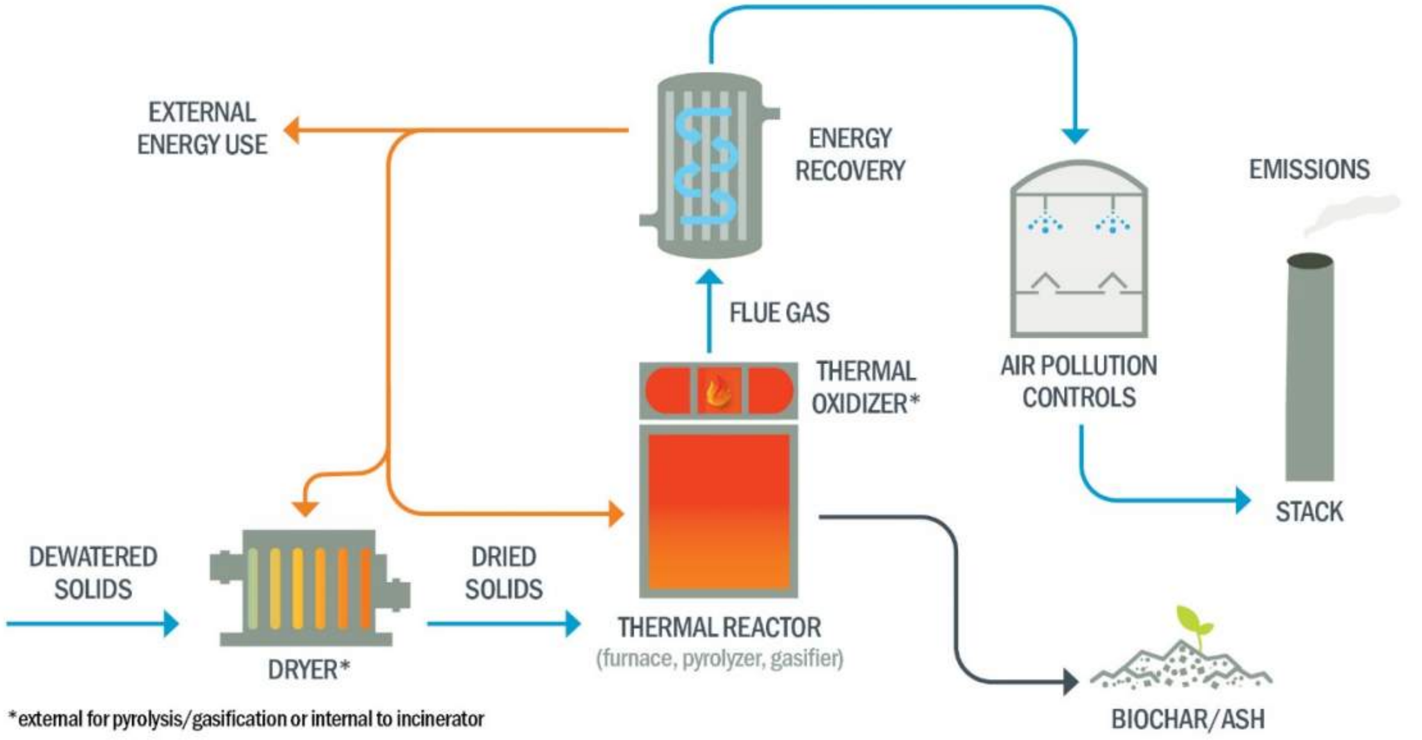
Pyrolysis Results

- 0.44% of PFAS in biosolids stayed in biochar
- 0.20% of PFAS in biosolids left after thermal oxidation
- DRE ≈ 99.4%
- Flue gas emissions shift toward small chains compared to biosolids PFAS



Winchell, L. J., Cullen, J., Romero, M. L., Kakar, F., Bronstad, E., Wells, M. J. M., Klinghoffer, N., Berruti, F., Bell, K. Y. Fate of Biosolids Bound PFAS Through Pyrolysis Coupled with Thermal Oxidation for Air Emissions Control. In review.

Drying



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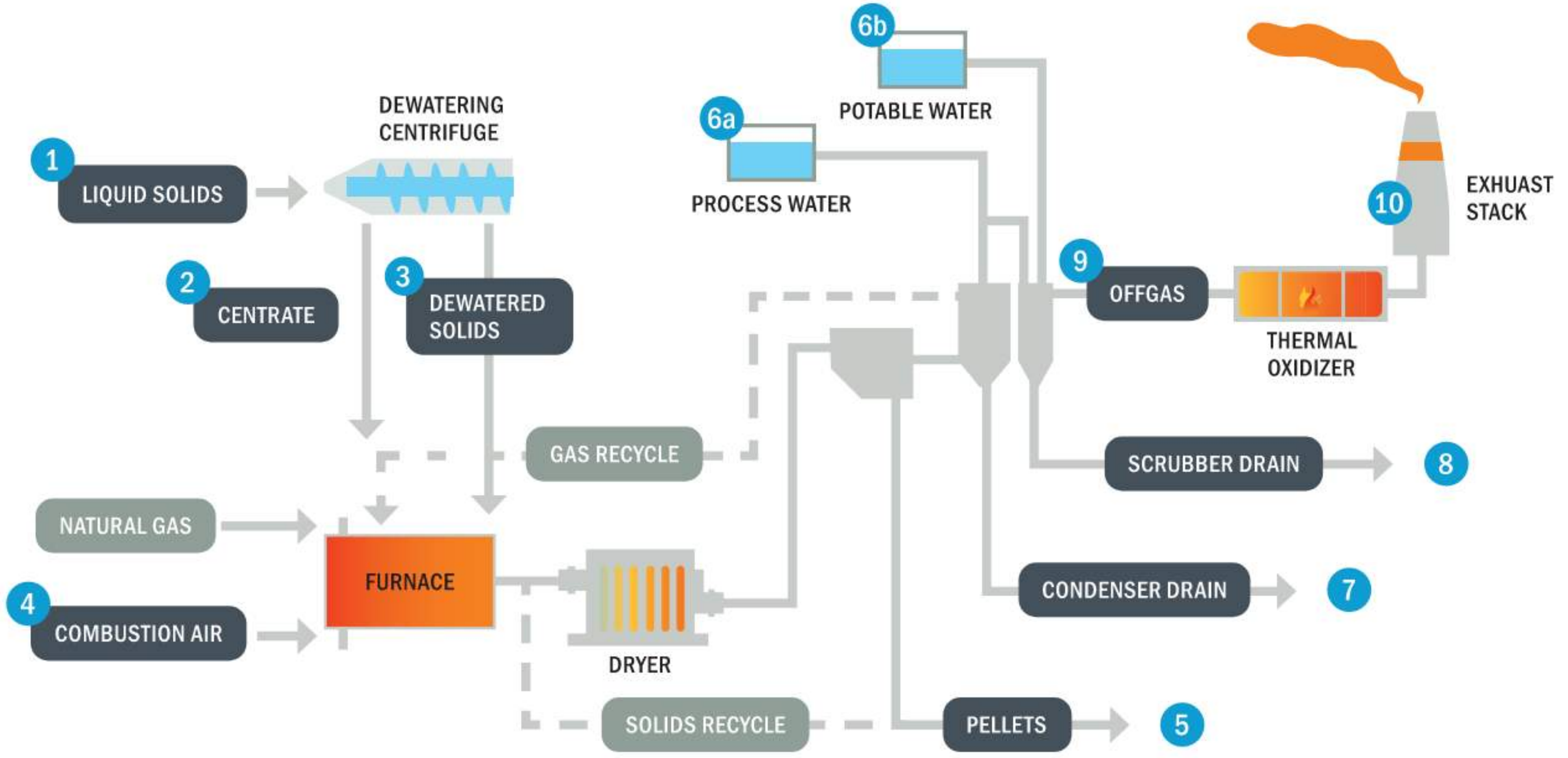
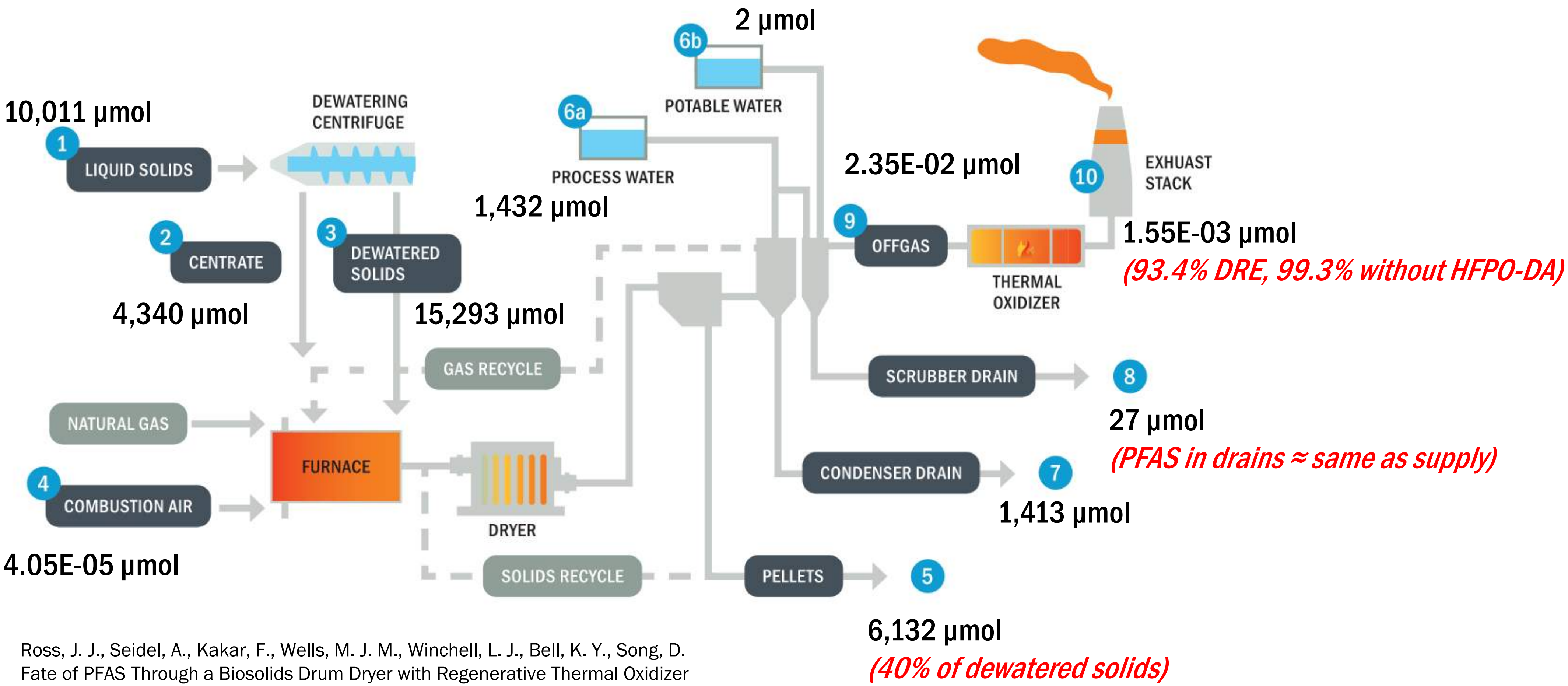
Thermal Drying Study

- Synagro and BC partnered to evaluate a full-scale rotary drum dryer
- Sampling of solids, liquids, and gas streams
- Dryer details:
  - Pelletizes ~15 dtpd
  - 340–450°C
  - Polycyclone
  - Saturator
  - Venturi Scrubber
  - RTO (815°C for ½ second



Thermal Drying Results



Ross, J. J., Seidel, A., Kakar, F., Wells, M. J. M., Winchell, L. J., Bell, K. Y., Song, D. Fate of PFAS Through a Biosolids Drum Dryer with Regenerative Thermal Oxidizer Emissions Control. In review.

QUESTIONS?

it's about connecting

Florida Water Environment Association | BIOSOLIDS COMMITTEE

Brown AND Caldwell : essential ingredients®

Teaming Wastewater Utilities: The Intersection of a long-term Partnership and Solving Today's Byproduct Disposal Challenges

July 18,2024

Florida Water Environment Association | BIOSOLIDS COMMITTEE

Ray Schauer
Director, Facility Contract Operations
Solid Waste Authority of Palm Beach County

SWA SOLID WASTE AUTHORITY of Palm Beach County

Saving South Florida's Environment Using A Tri-County Biosolids Pelletization Facility

Florida Water Environment Association

Solid Waste Authority of Palm Beach County

November 14, 2001

SOLID WASTE AUTHORITY

Tri-County Participating Utilities

<u>Palm Beach County Utilities</u>

- Palm Beach County Water Utilities Department
- South Central Regional Wastewater Treatment Facility
- City of Boca Raton
- Village of Wellington
- Village of Royal Palm Beach
- City of South Bay
- Seacoast Utilities

<u>Martin And St. Lucie County Utilities</u>

- Martin County Utilities
- City of Stuart
- St. Lucie County Utilities
- Port St. Lucie Utilities
- Fort Pierce Utilities Authority
- Loxahatchee River District
- South Martin Regional Utility

Update on the Palm Beach County Regional Biosolids Pelletization Facility

Ray Schauer
Director, Facility Contract Operations
Solid Waste Authority of Palm Beach County

Florida Water Environment Association

March 23, 2005

Participating Utilities

- Palm Beach County Water Utilities Department
- South Central Regional Wastewater Treatment Facility
- City of Boca Raton
- Village of Royal Palm Beach
- SWA/Seacoast Utilities
- Loxahatchee River Environmental Control District

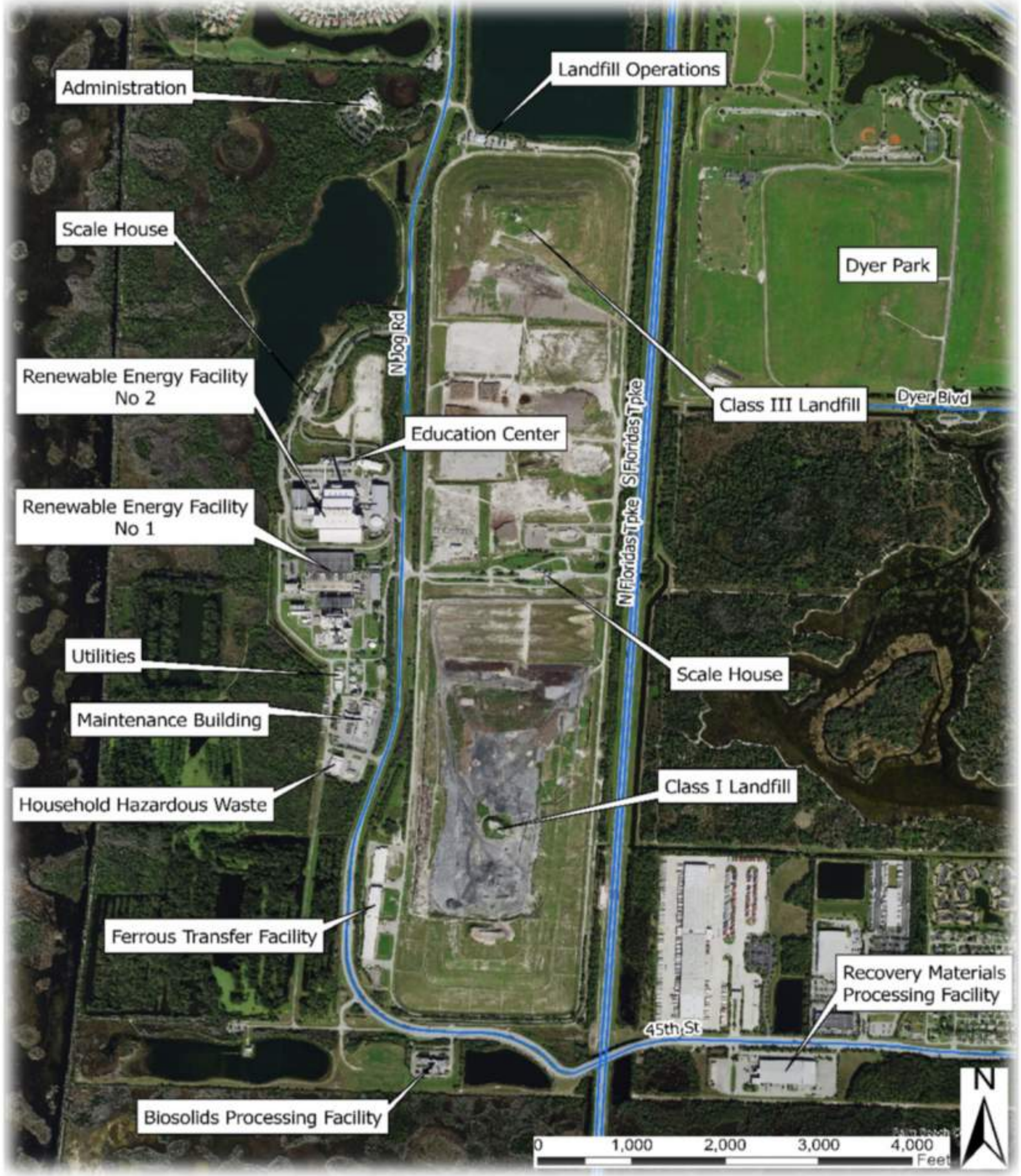
PROJECT DRIVERS

- Utilities throughout Palm Beach County were land applying biosolids
- Suitable land application sites keep getting farther away, increased hauling costs
- Future of Class B biosolids in question with revisions to Ch. 62-640 F.A.C.
- Senate Bill 392 (now FS. 373.4595) – Lake Okeechobee Basin restrictions

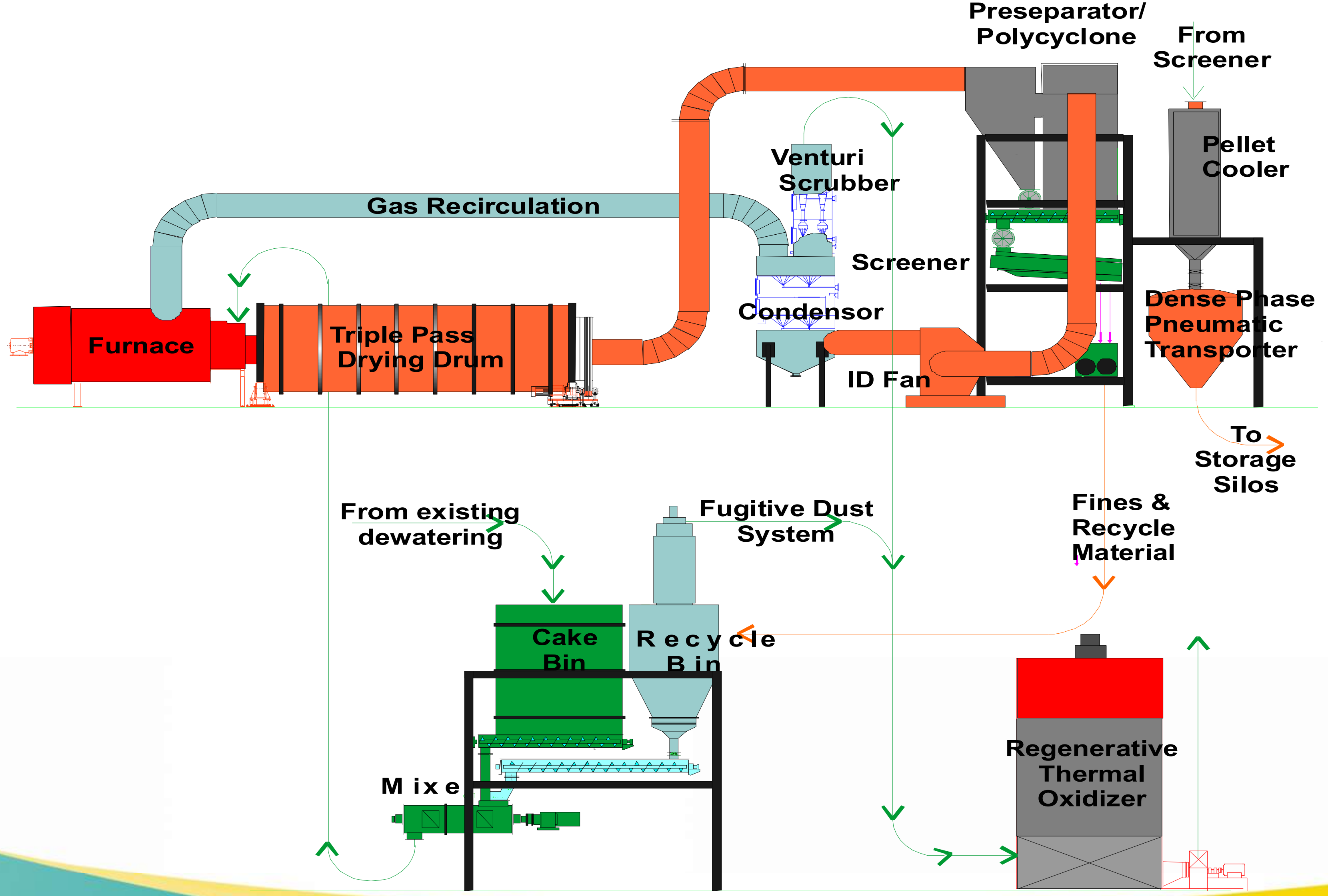
Agenda

- Biosolids Processing Facility(BPF) Description
- Interlocal Agreement Development
- Where Are We Now?
- Where Are We Going?

1,300 acre SWA Resource Recovery Campus



BPF Process Schematic



Biosolids Processing Facility (BPF)

- Developed on a design-build-operate (DBO) basis
- Guaranteed annual throughput 189,900 wet tons per day (15% solids average)
- Maximum 600 wet tons per day (Title V Permit max 675 wtpd)
- Development and Capital Cost (all in) $37,062,230 (2009 dollars)
- $3,173,500 received in grant funding
- Achieved Commercial Operation August 10, 2009
- Current Tipping Fees
  - 0 to 91,250 wtpy - $40.33/ton
  - 91,250 to 104,000 wtpy - $20.56/ton
  - > 104,000 wtpy - $18.07/ton

Biosolids Processing Facility (BPF) cont.

- Pass-Through Costs at $43.96/ton
  - Electric
  - Potable Water
  - Wastewater
  - Chemical Solutions
  - Gas
    - Landfill gas O&M
    - Natural gas supplement
  - Administrative Costs

Utility Partnership

- East Central Regional Wastewater Treatment Facilities Operation Board
- South Central Regional Wastewater Treatment Facility
- City of Boca Raton
- Palm Beach County Water Utilities Department
- Loxahatchee River Environmental Control District
- Seacoast Utility Authority (Solid Waste Authority)

Interlocal Agreement(ILA)

- SWA retaines100% ownership of the BPF. Partners own a percent of the BPF processing capacity based on their prorate share.
- Stipulate terms and conditions on developed on a phased approach consistent with project development, ultimately included;
  - Development/Capital Cost Share (engineering, permitting, procurement, design and construction etc.)
  - Commitment to Supply Biosolids (Put-or-Pay)
  - Biosolids Quality Specifications
  - Delivery Schedule including max TPD consistent with O&M Agreement Requirements
  - Ability to Sale of Excess Capacity
  - Processing Fee (annual reconciliation based on actual costs incurred)
  - End of Term

Where Are We Now?
Developing Regulatory Issues

- Two new provisions to the Florida Statutes became effective July 1, 2022 that affect land application sites
- Amendments to Chapter 62-640, F.A.C. to minimize migration of nutrients into waterbodies
  - Mainly affects Class A and Class B
  - Class AA must be analyzed monthly for water soluble phosphorus
- House Bill 1405 passed in May 2023
  - Creates biosolids grant program for projects that implement innovative technologies and solutions for biosolids disposal
  - Construct, expand, upgrade, or retrofit facilities that produce Class AA biosolids

Where Are We Now?
Partner's Needs

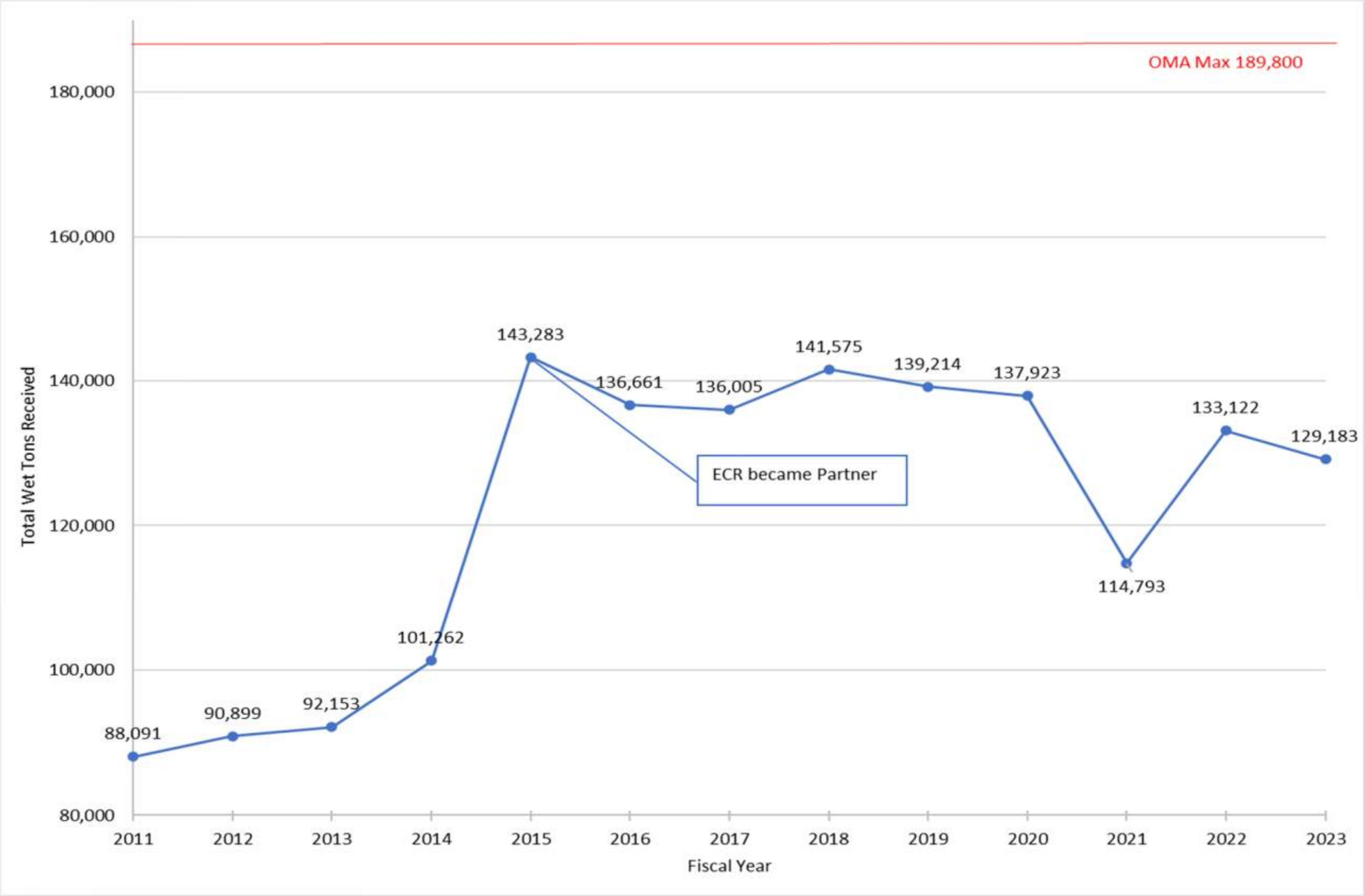
Facility	PBCWUD	SCRWWTDB	Boca	LRD	SWA/Seacoast	ECR	Total
Current Contract Minimum Annual (wet tons/year)	16,261	13,459	9,371	8,176	11,288	32,695	91,250
Current Contract Maximum Annual Delivery (wet tons/year)	33,822	27,996	19,492	17,006	23,478	68,005	189,799
2029 Projection (wet tons/year)	**28,263**	**27,144**	**14,849**	**12,458**	**13,200**	**48,323**	**144,237**
2049 Projection (wet tons/year)	**33,664**	**31,007**	**21,441**	**13,574**	**13,200**	**60,797**	**173,683**
Percent Solids	16.8%	17.6%	14.7%	15.0%	18.1%	18.3%	17.2%
2029 Projection (dry tons/year)	**4,757**	**4,772**	**2,181**	**1,865**	**2,393**	**8,829**	**24,797**
2049 Projection (dry tons/year)	**5,666**	**5,451**	**3,150**	**2,032**	**2,393**	**11,108**	**29,799**

1. SCRWWTDB and LRD projections end at 2045.

2. Percent solids is based upon the daily deliveries data provided by SWA and NEFCO from June 2022 to June 2023.

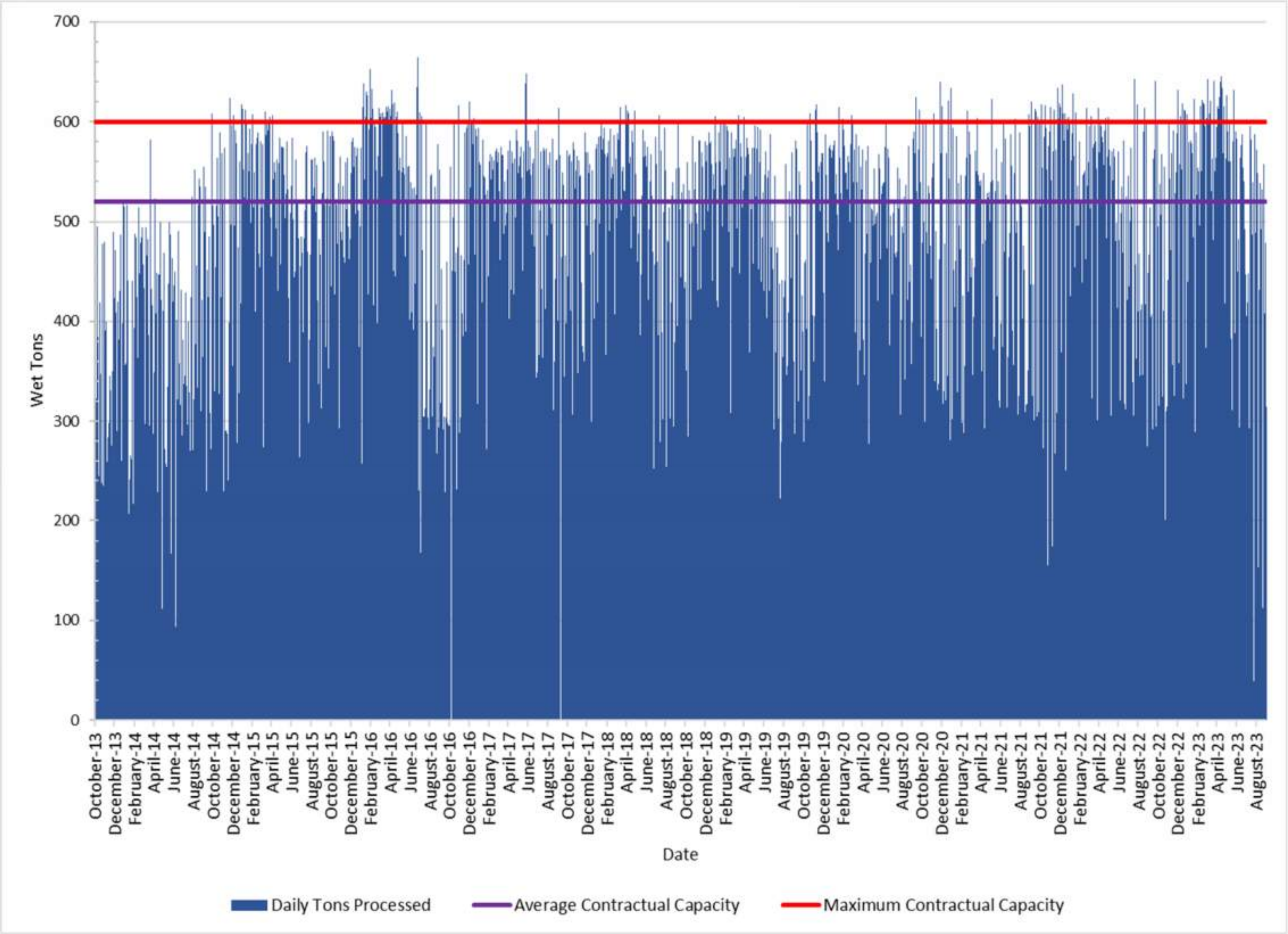
3. Boca indicated they did not project an increase, but a conservative estimate would be 10% increase to contracted amount by 2049. Therefore, a three-year average was utilized for the 2029 projection and the 2049 projection was a 10% increase of the current maximum.

Over 143M Wet Tons Processed



Daily Tons Processed

Number of days over 520 wtpd – 889 days
Number of days over 600 wtpd – 159 days

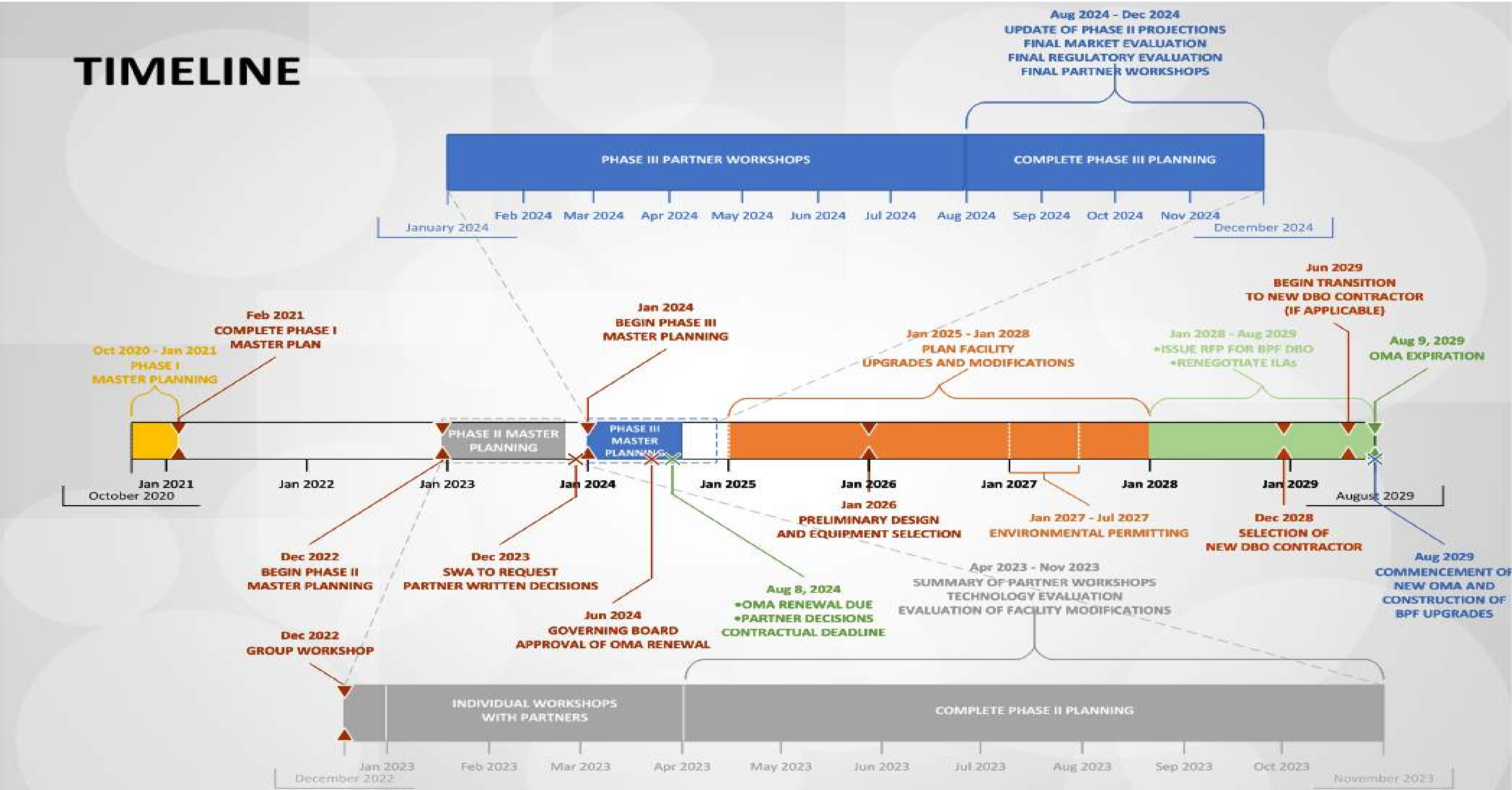


Where Are We Now?
BPF Major Equipment Replacement/Rehabilitation

Equipment/Component	Remaining Useful Life	Upgrade Required
Furnace (refractory and burner housing)	10 years (Train No. 1 and No. 2)	Rehabilitation/Repairs
Dryer Drums	8 years (Train No. 1 and No. 2)	Replacement
Dryer Ductwork Repair	N/A	Rehabilitation/Repairs
Main Fan	12 years (Train No. 1 and No. 2)	Overhaul
Cyclone Separators	2 years (Train No. 1), 5 years (Train No. 2)	Replacement
Receiving Bin Screw Conveyor	7 years (Train No. 1 and No. 2)	Replacement
Recycle Conveyor (screw and troughs)	7 years (Train No. 1 and No. 2)	Replacement
Pug Mill Mixer (shell and paddles)	8 years (Train No. 1 and No. 2)	Replacement
Pellet cooler (plates and housing)	8 years (Train No. 1 and No. 2)	Replacement
Recycle Bin	7 years (Train No. 1 and No. 2)	Rehabilitation/Repairs
Impingement Tray Scrubber/Condenser	15 years (Train No. 1 and No. 2)	Rehabilitation/Repairs
Heat Exchanger	5-7 years (Train No. 1 and No. 2)	Replacement
Cooling Tower	5-7 years (Train No. 1 and No. 2)	Replacement or upgrade with single chiller system.
Regenerative Thermal Oxidizers (RTOs)	6 years (Train No. 1 and No. 2)	Replacement - New technology will need to be evaluated with improvements to the ability to maintain.
RTO Fan (impeller and housing)	10 years (Train No. 1), 5 years (Train No. 2)	Replacement with potential upgrades
Nitrogen Generator	5 years	Replacement - There is no redundancy so that may want to be considered in the future.
Building Roof	6 years	Replacement
Variable Frequency Drives (VFD)/Instrument Replacement	N/A	Replacement
Programmable Logic Controller (PLC)/SCADA Upgrades	N/A	Upgrades to hardware and software
Switchgear	7-8 years	Replacement
Motor Control Centers	7 years (both units)	Replacement

SWA SOLID WASTE AUTHORITY of Palm Beach County

Where Are We Going?



Where Are We Going?
Technology Evaluation

Screening Criteria	Incineration	Pyrolysis	Gasification	Supercritical water oxidation	Hydrothermal liquefaction
Development Status	5	4	4	3	3
Typical application Scale	5	3	4	1	2
Proven system/ technology	5	4	4	4	3
Ease of operation and maintenance	3	3	3	3	2
Reliability	4	3	3	2	2
Ability of construct	3	3	3	3	3
Ability to integrate into existing BPF, minimize outages during construction	2	4	4	1	2
Product Use	3	4	3	3	3
Water and Air Impacts	2	4	3	4	4
Permitting Impacts	2	4	4	4	3
End-use management and control	4	3	3	4	2
Quality of resulting gas, liquid or solid product	4	4	4	4	3
Ability to destroy emerging contaminant such as PFAS	3	4	4	5	4
Total	**45**	**47**	**46**	**41**	**36**

SWA SOLID WASTE AUTHORITY of Palm Beach County

Where Are We Going?
Technology Evaluation

Evaluation Criteria	Pyrolysis		Gasification	
	Discussion	Score	Discussion	Score
Capital Costs	Budgetary capital costs for pyrolysis would range between $20 and $35 million per train.	2	Can be similar to pyrolysis, but specific vendors will have to be contacted to establish cost.	2
O&M Costs	1 to 2 additional staff would be required. Increased electricity, water and wastewater usage would result from the pyrolysis system.	2	Similar to pyrolysis	2
Integration with BPF	The current BPF rotary drum dryers and pelletized biosolids integrate well with a pyrolysis system. Conveyors could be added to feed the pellets to a pyrolysis system.	4	The current BPF rotary drum dryers and pelletized biosolids integrate well as drying would be a first step. Conveyors could be added to feed the pellets to a gasification system.	4
Permitting	Any new technology will require complex permitting as the BPF resides on a PPSA site. In addition, the site has PSD and Title V Air Operation permits.	3	Any new technology will require complex permitting as the BPF resides on a PPSA site. In addition, the site has PSD and Title V Air Operation permits.	3
Active Full-Scale Facilities in the U.S.	4 facilities (1 active, 3 in development)	3	4 facilities (2 active, 2 in development)	3
End Use Products and Markets	Biochar can be beneficially reused. Syngas can potentially be beneficially reused.	4	Residuals can be beneficially reused. Syngas can be used to generate energy.	4
	Total	**18**	**Total**	**18**

SWA SOLID WASTE AUTHORITY of Palm Beach County

Where are We Going?
Alternative Options

Implementation Year:	2030	2031	2032	2033-2036	Total
Alternative	Costs (2023 Present Value)	Costs (2023 Present Value)	Costs (2023 Present Value)	Costs (2023 Present Value)	(2023 Present Value)
Alternative 1 - Rehabilitate, Upgrade, and Continue Operation	$12,600,000	$12,500,000	$2,100,000		$27,200,000
Alternative 1 - Maintenance and Storage Building	$2,600,000				$2,600,000
Alternative 1 - Storage and Receiving Area Modifications	$5,000,000				$5,000,000
Total Alternative 1	$20,200,000	$12,500,000	$2,100,000		$34,800,000
Alternative 1 - Rehabilitate, Upgrade, and Continue Operation	$12,600,000	$12,500,000	$2,100,000		$27,200,000
Alternative 1 - Maintenance and Storage Building	$2,600,000				$2,600,000
Alternative 1 - Third Train	$25,000,000	$25,000,000			$50,000,000
Total Alternative 1 with Third Train	$40,200,000	$37,500,000	$2,100,000		$79,800,000
Alternative 2A - Rehabilitate and Add a New Technology	$42,600,000	$42,500,000	$2,100,000		$87,200,000
Alternative 3 – Terminate Operations	$5,550,000				$5,550,000
Alternative 4 - Three-Year Contract Extension (Rehabilitation and Replacement)	$2,500,000	$7,400,000	$3,300,000	$16,600,000	$29,800,000
Alternative 4 - Maintenance and Storage Building				$2,600,000	$2,600,000
Alternative 4 - Storage and Receiving Area Modifications				$5,000,000	$5,000,000
Total Alternative 4	$2,500,000	$7,400,000	$3,300,000	$24,200,000	$37,400,000

Where are We Going?
Next Steps

- Further develop the preferred approach(es) for the upgrade of the BPF's operating capacity to address frequent transient peaks based on discussions with SWA, NEFCO, and the Partners after the December 2023 vote.
- Further determine permitting requirements for BPF upgrades, modifications, and/or expansions.
- Begin development of design criteria.
- Determine if some equipment rehabilitation/replacement can begin prior to 2029 for potential cost savings.
- Continue to monitor rulemaking in Florida.
- Continue to monitor regulations on emerging contaminants and the EPA PFAS roadmap to determine impacts to biosolids regulations and markets.

SOLID WASTE AUTHORITY of Palm Beach County

THANK YOU!!
Questions?

Florida Water Environment Association | BIOSOLIDS COMMITTEE

Team of Hundreds Delivering Comprehensive Biosolids and Energy Processing Solution

Stantec

Florida Water Environment Association | BIOSOLIDS COMMITTEE

FWEA Biosolids Conference - Miami
July 18th, 2024

David Socha, PE (Stantec)
Jamey Steffen, PE (Archer Western)

Project Organizational Chart

FACILITIES OWNER
LOUISVILLE MSD

PROJECT FEDERAL FUNDING (WIFIA)
EPA

TECHNICAL ADVISOR
Hazen

PDB – TEAM LEAD
WALSH

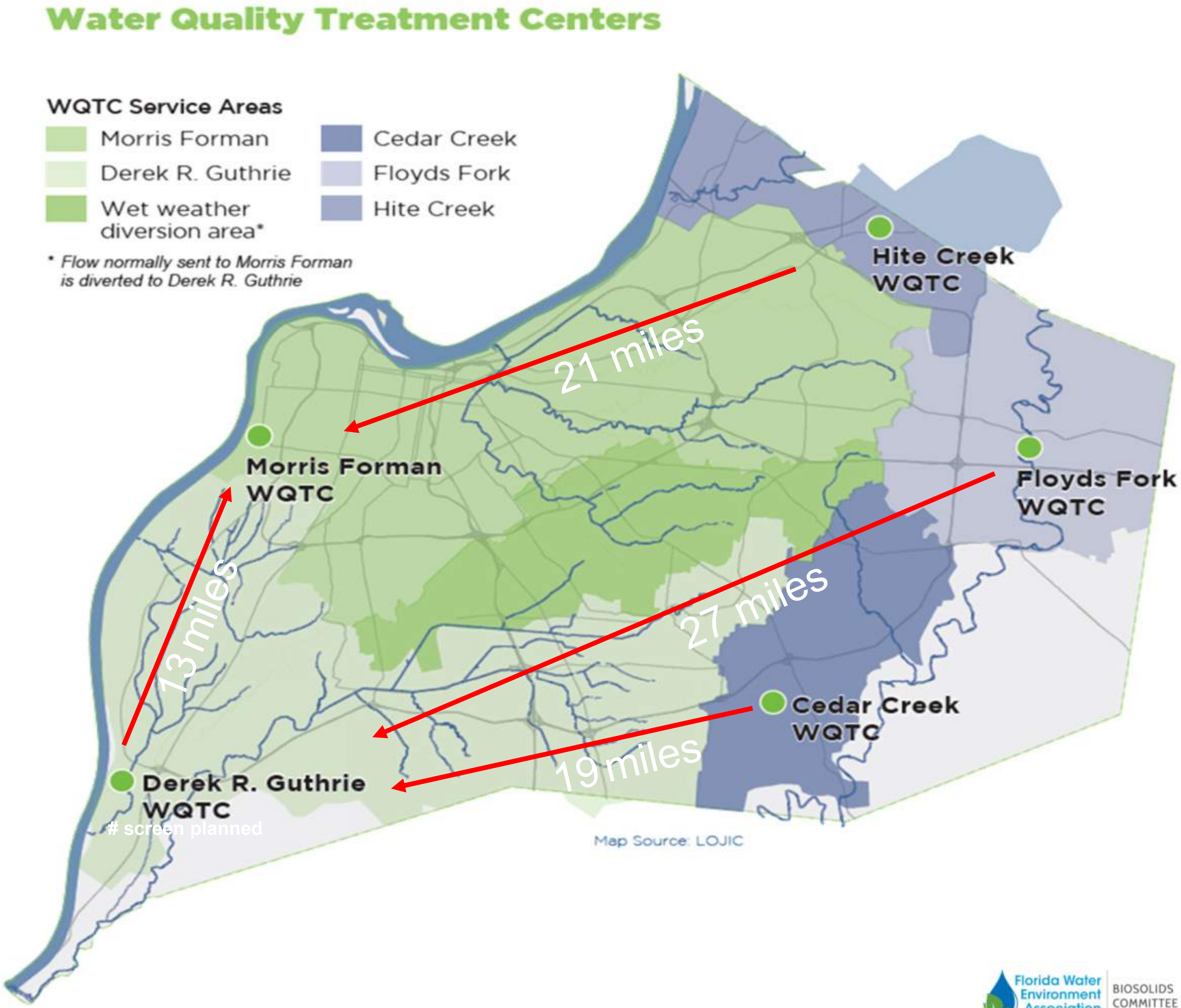
DESIGN AND PRE-CONSTRUCTION
Stantec
Cornerstone
Shrewsberry
Magna
Strand
VS Engineering
C2

CONSTRUCTION AND START UP
Trades and Skills
e.g. ESI
Subcontractors
Design Team

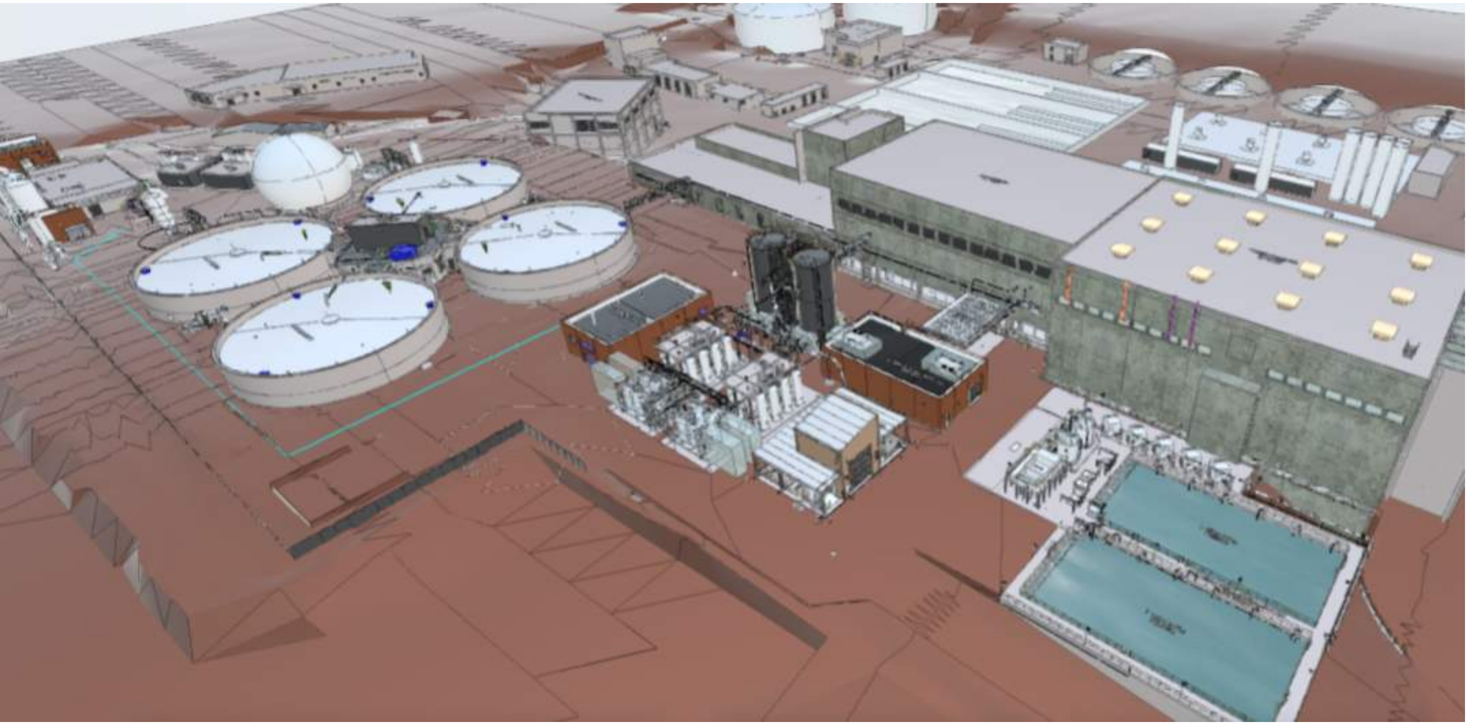
Progressive Design Build

- **Stage 1:** MSD and Walsh/Stantec Team collaborate
  - "Open Book"
  - Guaranteed Maximum Price (GMP) agreement
  - Early works packages (EWP) for equipment procurement
  - Design advanced to 60+%
- **Stage 2:** 100% Design, Procurement and Construction
  - Construction is Fixed Price and ESDC "Open Book"
  - Includes commissioning, training, and O&M manuals
  - Final details developed during Phase 1

A Regional Biosolids Solution

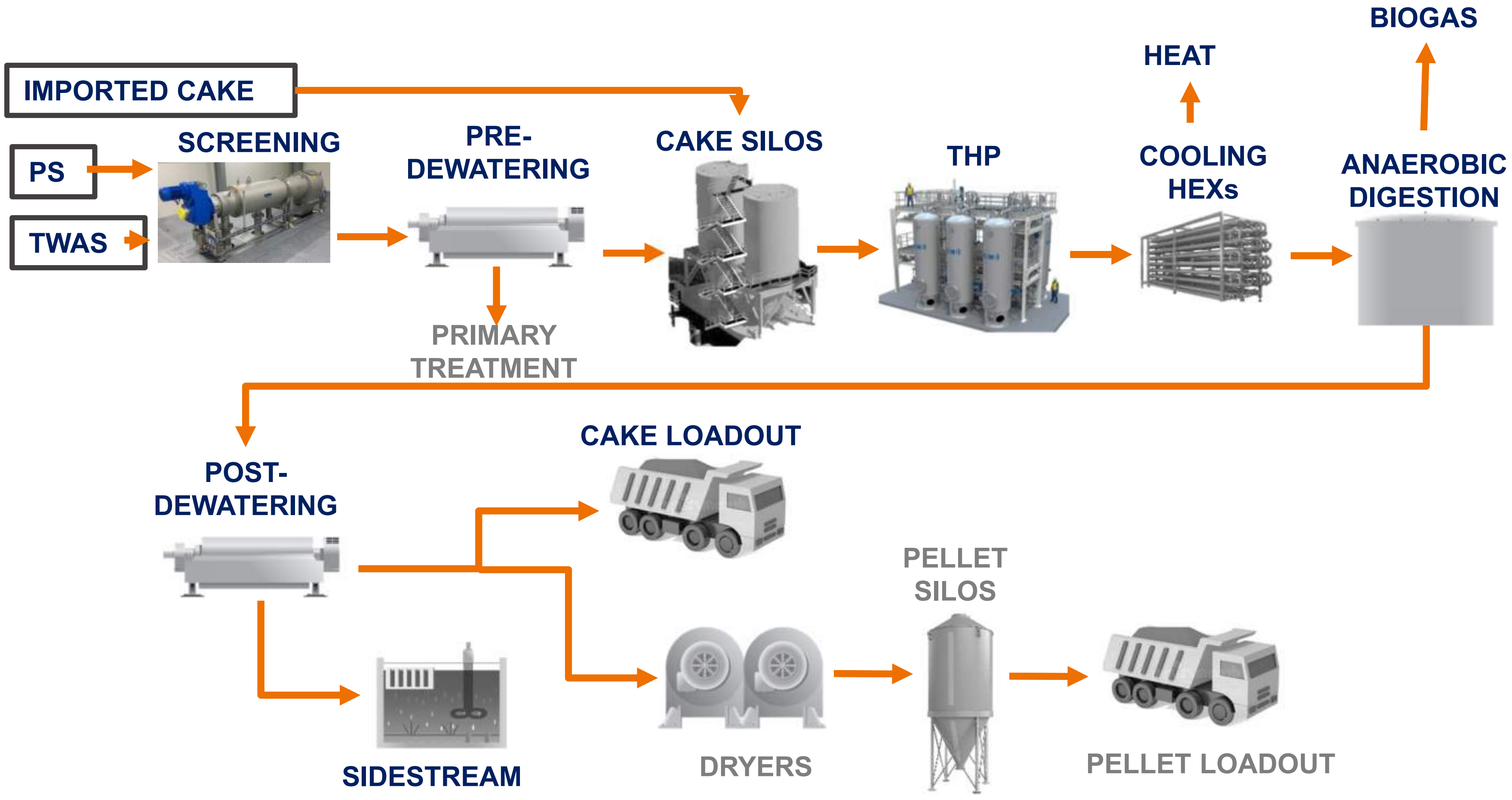


Morris Forman WQTC Biosolids Processing Solution



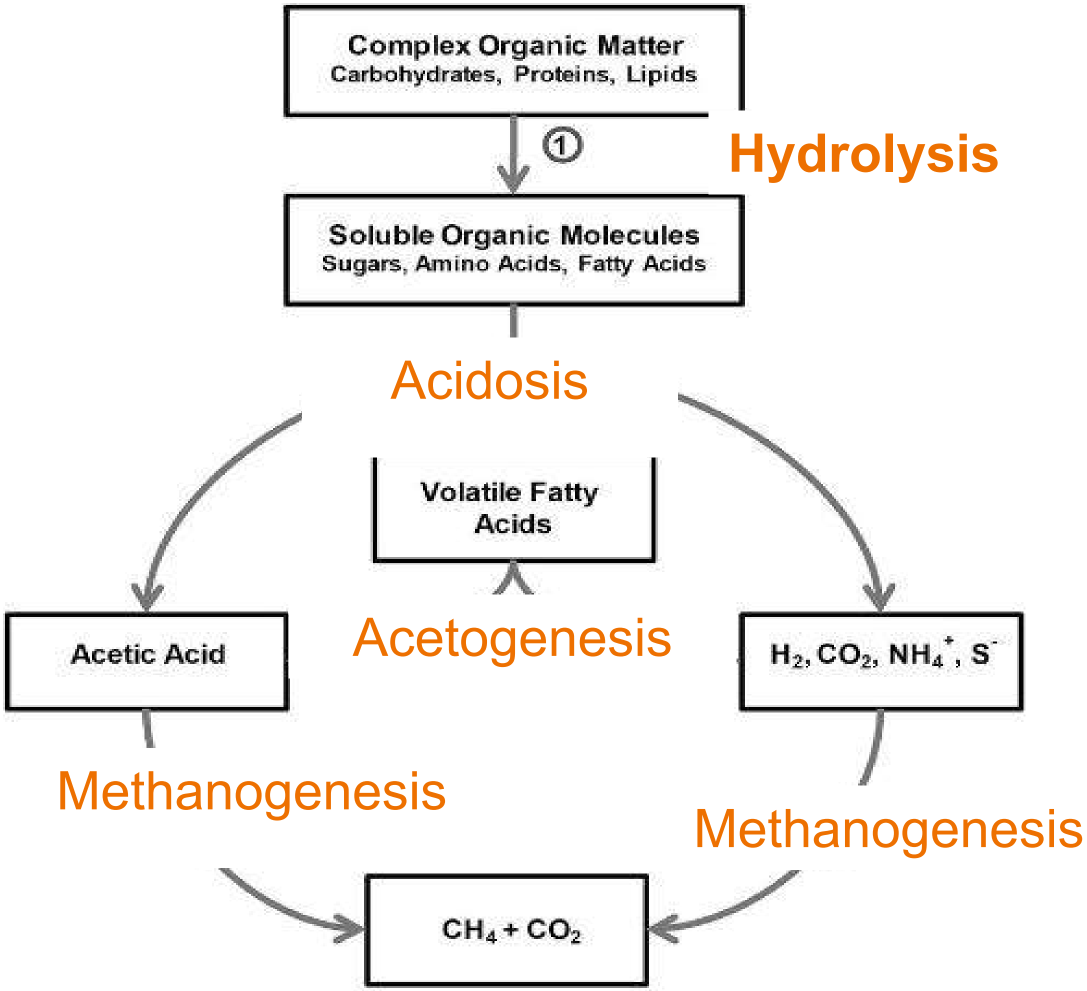
- 184 dtpd (Max Month) Waste to Energy Biosolids
- Thermal Hydrolysis Pretreatment (THP)
- RNG likely future project
- Upgrade Digesters
- Ancillary Processes
- Tight site

General Scope



Thermal Hydrolysis Pretreatment

Anaerobic Digestion Pathway

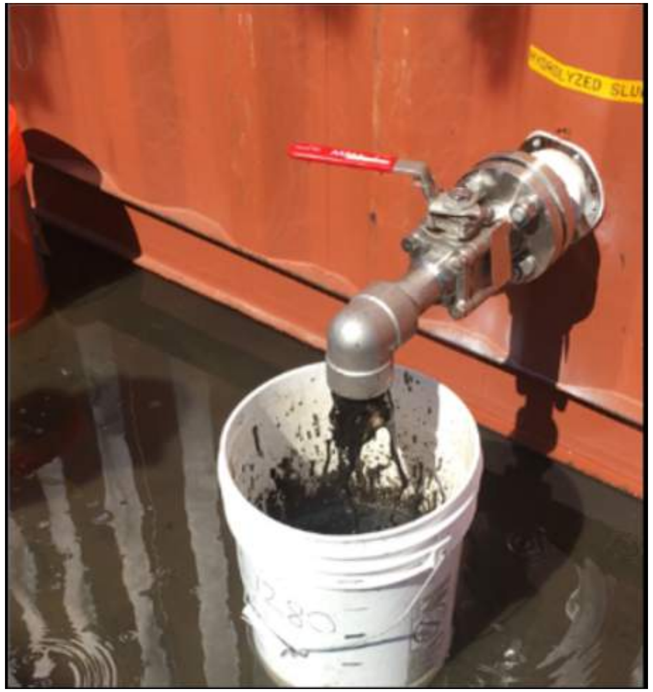


THP Impact on Sludge

16+%
sludge

THP

320 - 330ºF
~100 PSI+



Hydrolyzed
Sludge

THP Kills Pathogens & Intensifies Digestion

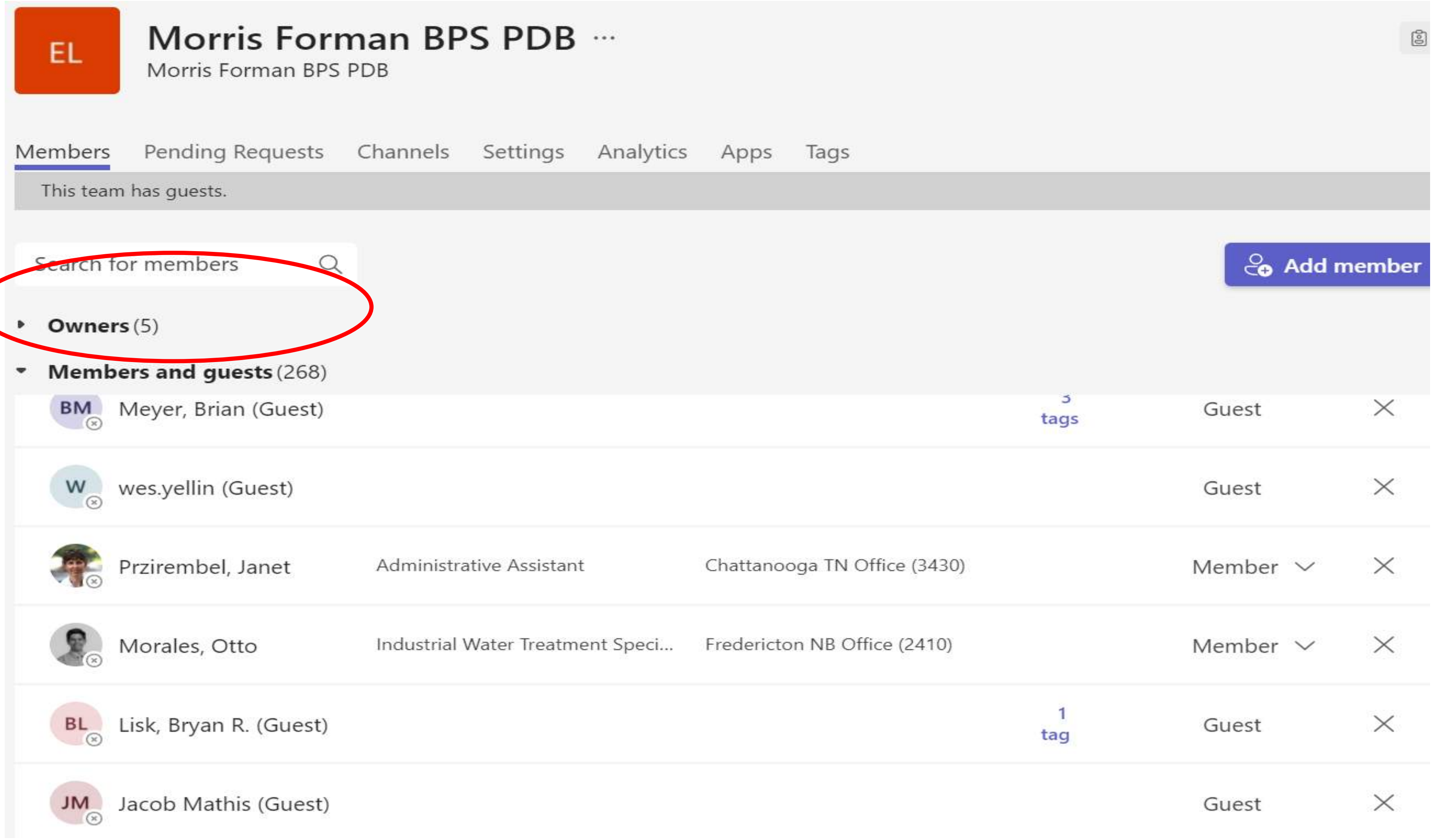
	Conventional AD	THP + AD
Hydraulic Retention Time (HRT)	15 – 20 days (min 15 days for Class B)	10 – 15 days (no min for Class A)
Organic Loading Rate (OLR)	0.1 – 0.2 lb VS/ ft^3-d	0.3 – 0.4 lb VS/ ft^3-d
Digester Feed Solids Concentration	3 – 6% TS	8 – 12% TS
WAS Volatile Solids Reduction	45 – 55%	60 – 65%

THP Benefits

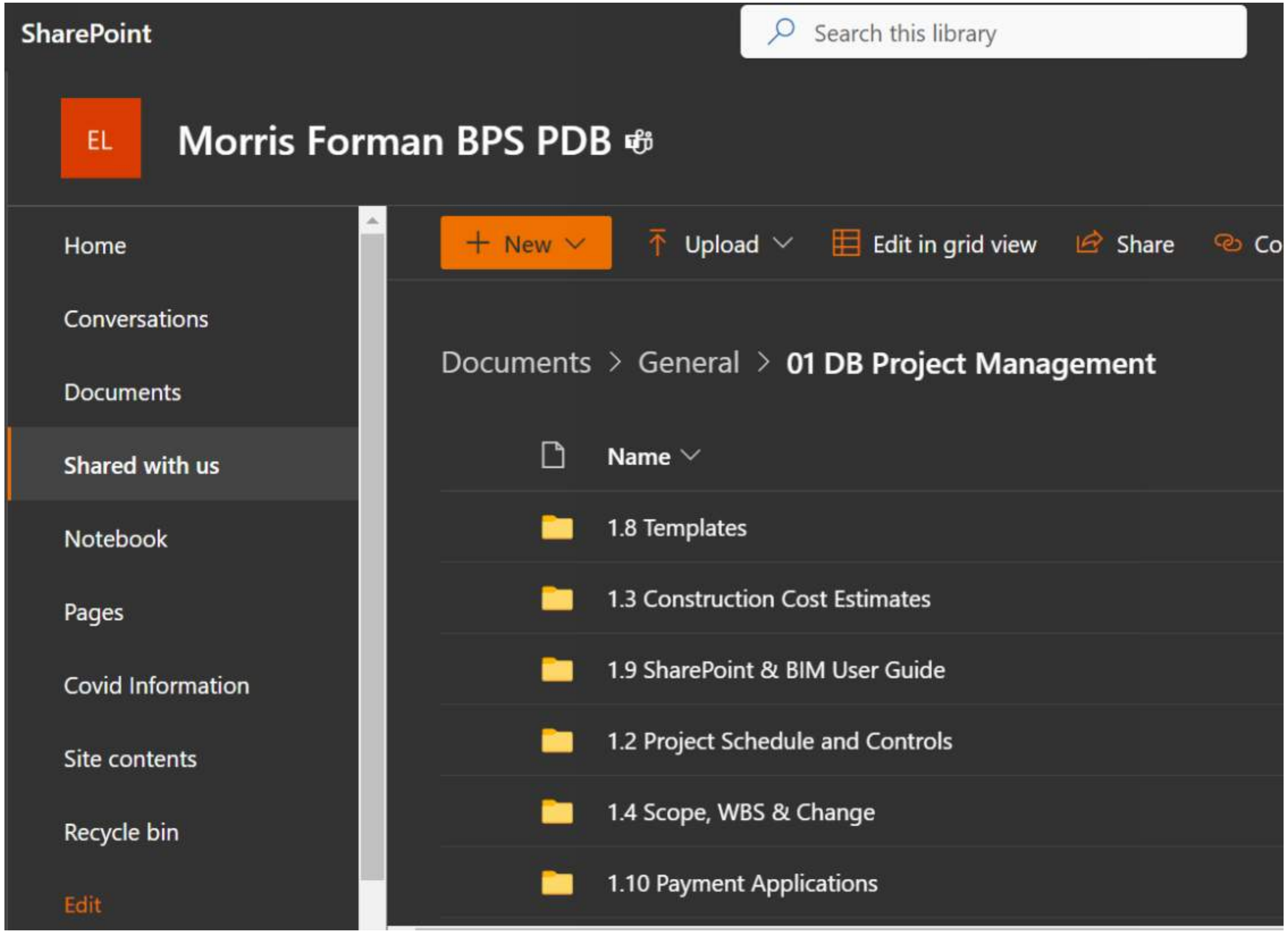
- Class A Biosolids
- Shorter Retention
- Higher Loading
- Higher VSR for WAS
- More biogas
- Lower viscosity
- Drier cake

Morris Forman WQTC BPS

EVERYONE involved in project hosted on Teams/ SharePoint



"All Work All the Time" in collaborative space



Three Early Major Decisions

1

Biogas use options

a) CHP with biosolids only,
b) Add high-strength waste
c) RNG

2

In parallel:
choose best
THP location

3

Choose best location for CHP (if being used)

How Decisions Are Made

1. ID DECISIONS TIMELINES AND STAKEHOLDERS
2. IDENTIFY OPTIONS
3. DETERMINE DECIDING FACTORS
4. INFORM STAKE-HOLDERS
5. MEET TO MAKE DECISIONS
6. PUBLICIZE DECISIONS

"Deciding Factors Used" Used

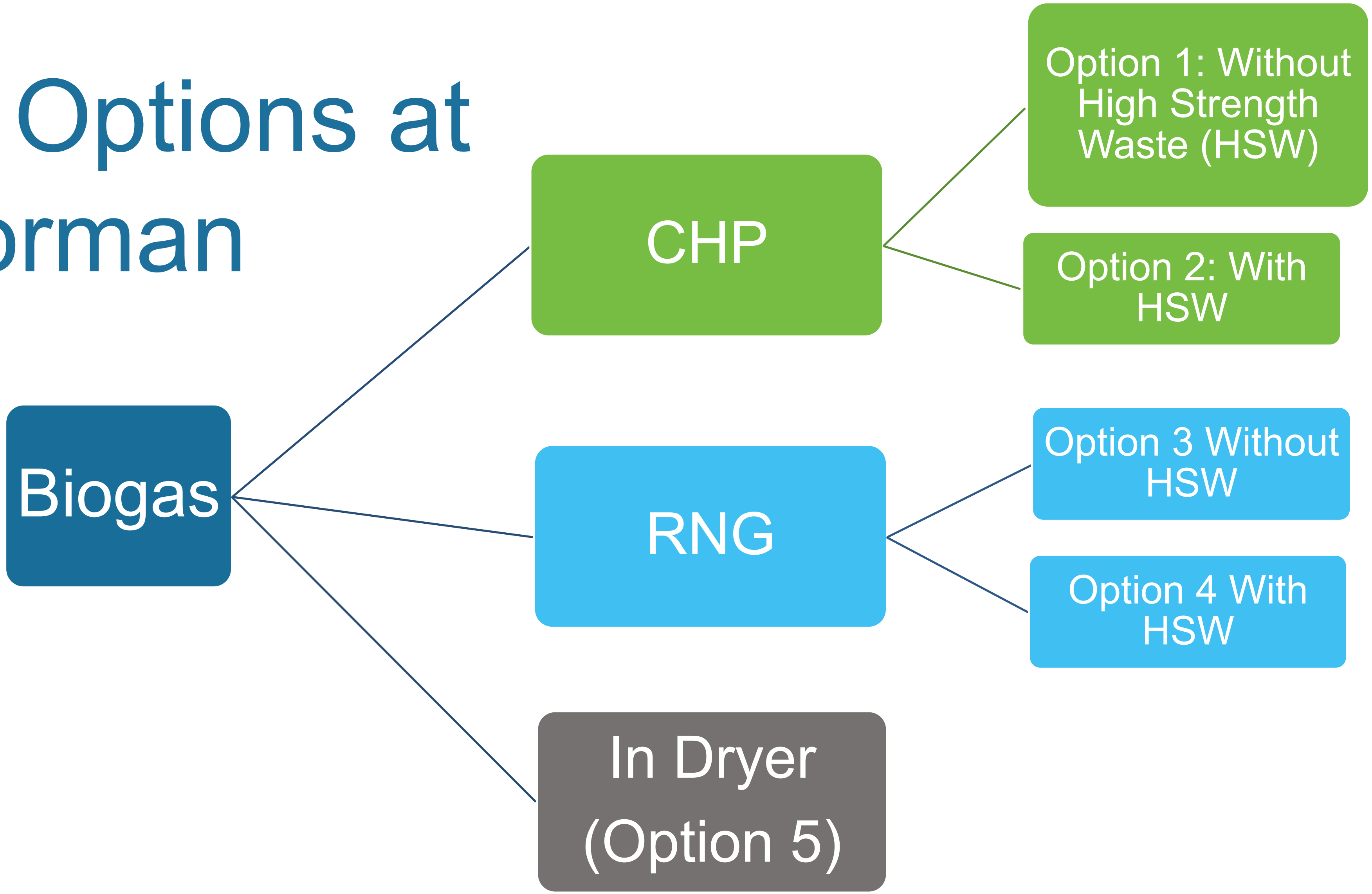
Life-Cycle Cost

Non cost O&M

Non cost Risk

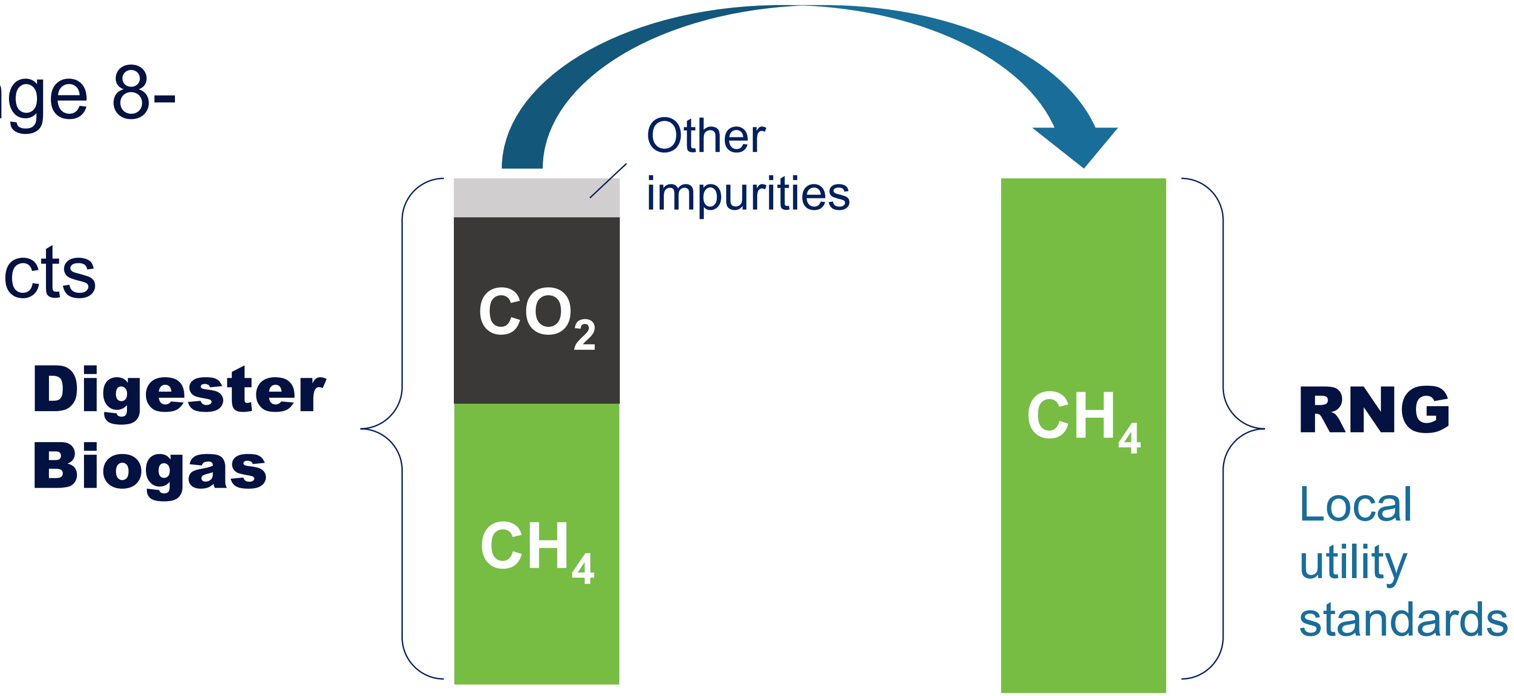
Non cost Miscellaneous

Gas Use Options at Morris Forman



RNG Considerations

- Environmental credits (e.g. RINs)
- High $ Value
- Volatile: 4-fold price change 8-years
- Many complicated contracts
- Simpler O&M than CHP but still significant
- Air emissions lower



Non-Cost Factors Considered (total 60%)

Primary Criteria (PC)	Weights	Subcriteria (SC)	Weights
Non-Cost O&M	35%	Ease of Maintenance	30%
		Safety	15%
		Reporting/Documentation Requirements	10%
		Operational Simplicity	15%
		Operational Flexibility / **Reliability**	20%
		Availability of Spares / Chemicals/ Consumables	5%
		After Market Support	5%
		Subtotal	100%
Non-Cost Risk	15%	Chance of fouling	5%
		Footprint impacts	25%
		Constructability/Schedule Risk	15%
		Permit/Emissions	5%
		Proven Technology (relative strength to each other)	50%
		Subtotal	100%
Non-Cost Misc	10%	Community benefits	10%
		Sustainability/Reputation	50%
		Terms and Conditions issues	40%
		Subtotal	100%

Overall RNG Appears Most Favorable in Louisville

	CapEx Cost	$32,307,619	$43,604,762	$18,412,619	$27,663,810	$1,147,857
	OpEx Cost	$23,647,937	($12,470,206)	($57,843,135)	($49,318,419)	$49,541,192
	Lifecycle Cost	$55,955,556	$31,134,556	($39,430,516)	($21,654,610)	$50,689,050
Primary Criteria	**Weights**	**Option 1 (CHP w/o HSW)**	**Option 2 (CHP with HSW)**	**Option 3 (RNG w/o HSW)**	**Option 4 (RNG with HSW)**	**Option 5 (Dryers)**
Sub Total Non-Cost Score	60%	53%	48%	40%	35%	57%
Lifecycle Cost Score	40%	8%	9%	40%	25%	10%
Total Score	**100%**	**61%**	**57%**	**80%**	**60%**	**67%**

RNG Best in base case

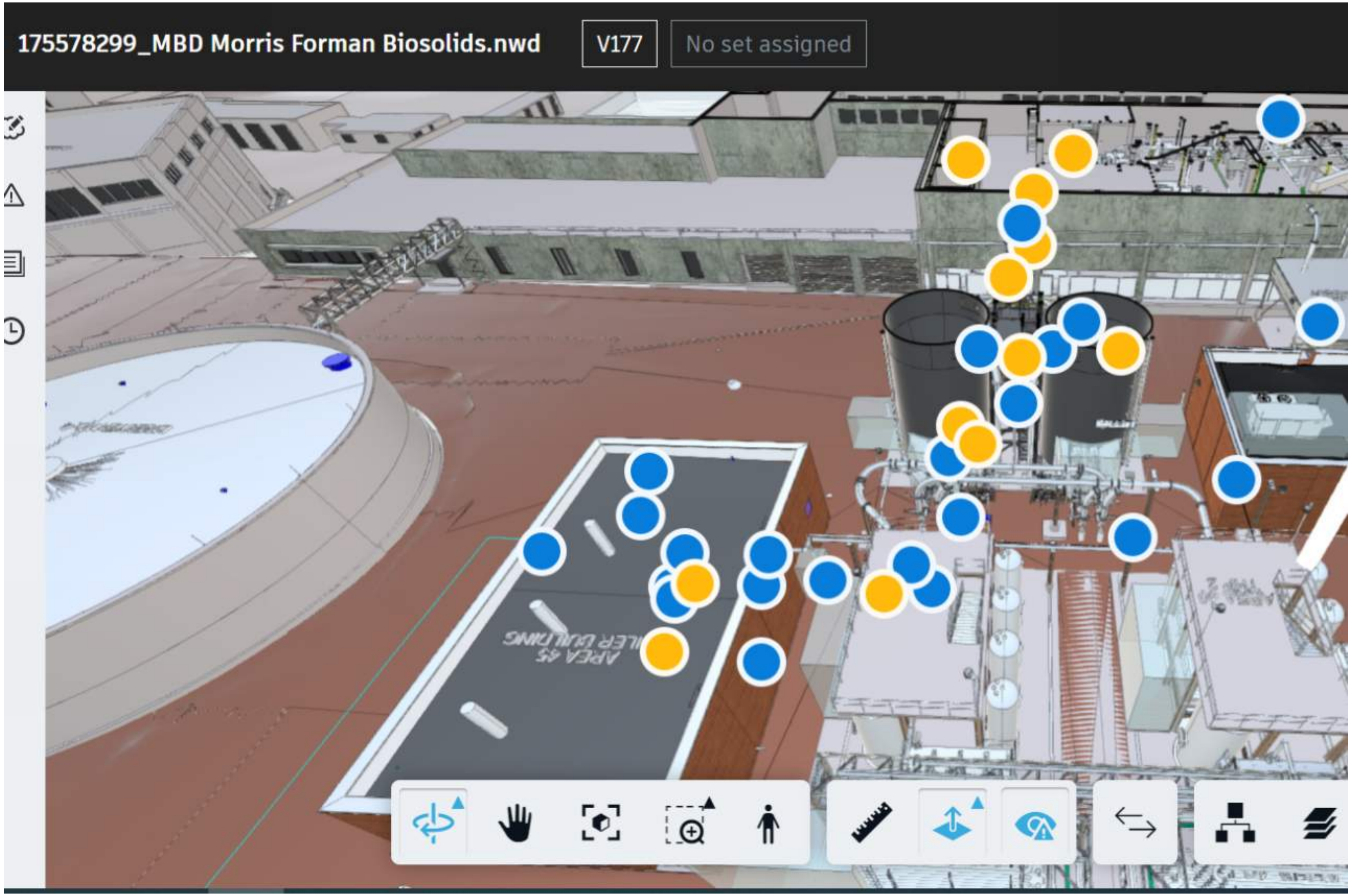
Note: "Do Nothing" was easiest option

- Considered scenarios such as variability possible in RIN, NG and power markets.
- MSD decided to change to pursuing RNG instead of CHP

3D Model

For Communication

ACC Issues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V177
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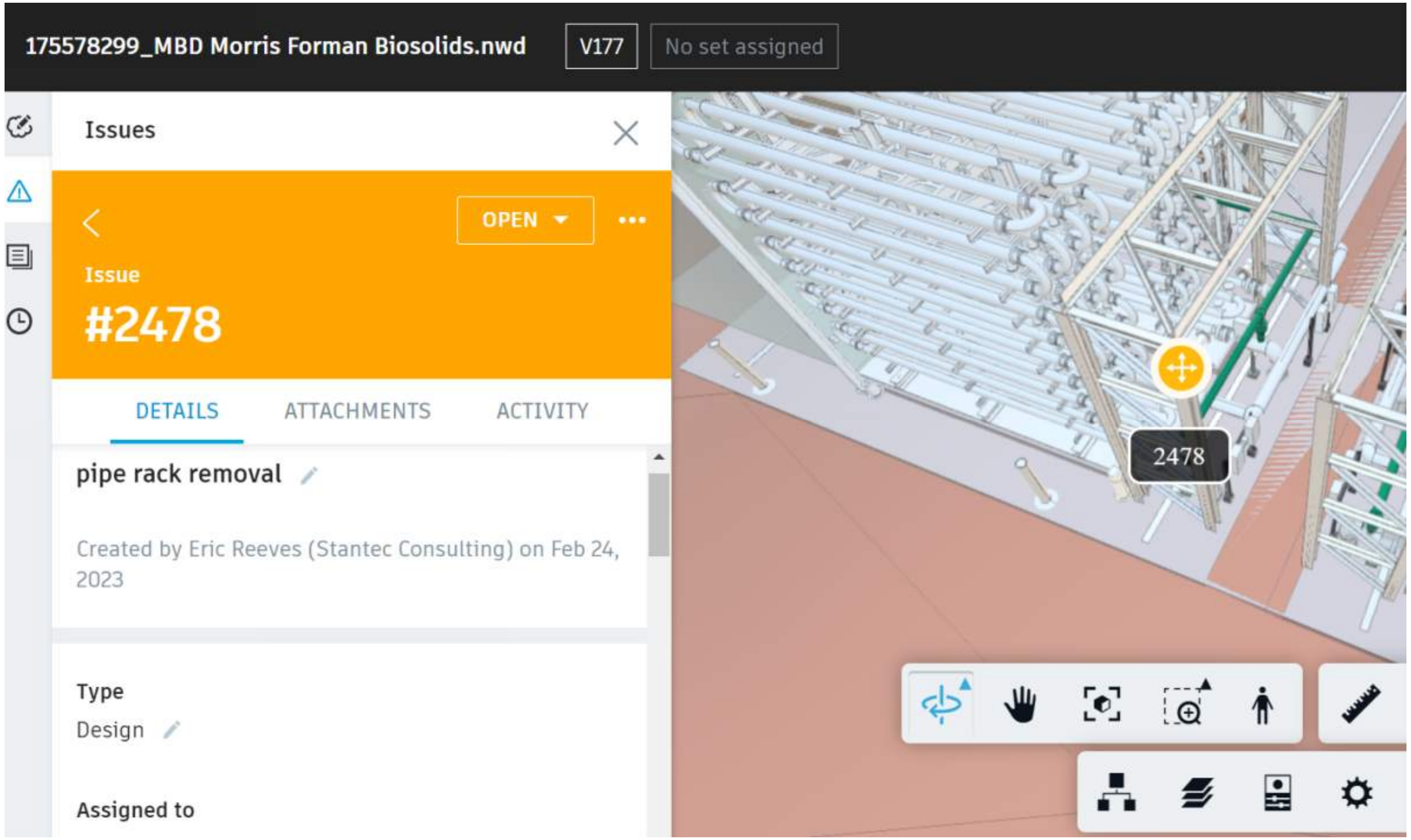
AREA 45
BOILER BUILDING

Communication Tool, To do List, and QC ALL IN ONE



Examples of Major Changes

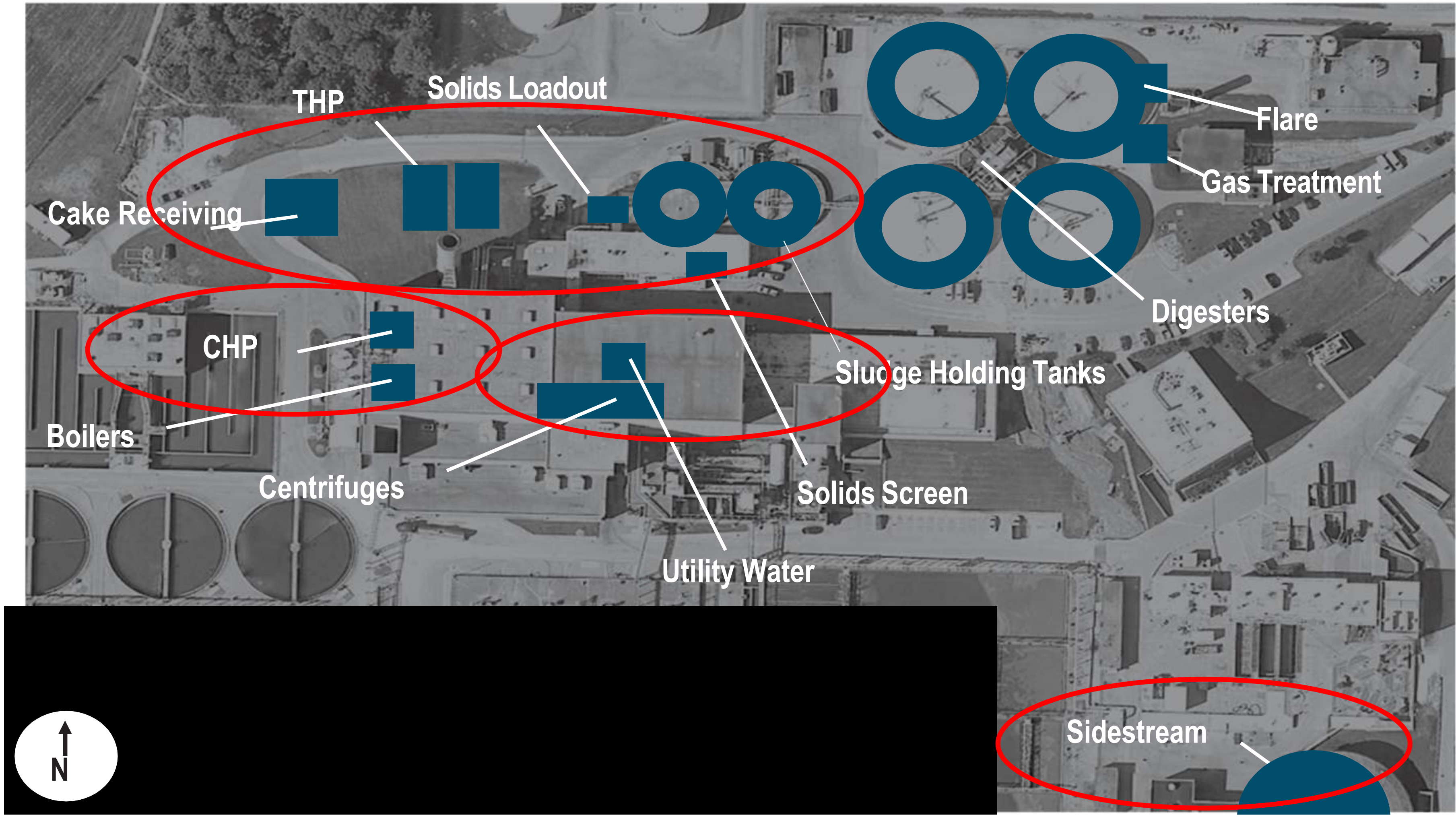
- Reuse of buildings and tanks changed after 30%
- Modifications at both 30% and 60% to increase odor control
- Sidestream vendor selected after 30% allowing detailing in that area
- Process water expanded at 30% to save $200k/month in costs

No need for change orders or delays with any of this progression.

Challenges for Cost Management

- Very tight site
- Inflationary period (2021 and 2022: COVID-19, Supply Chains, and Ukraine)
- Very busy market
- Strong commitment to XBE involvement
- Limited competition for some key elements

Major Changes Since Original Concept (most everything!)



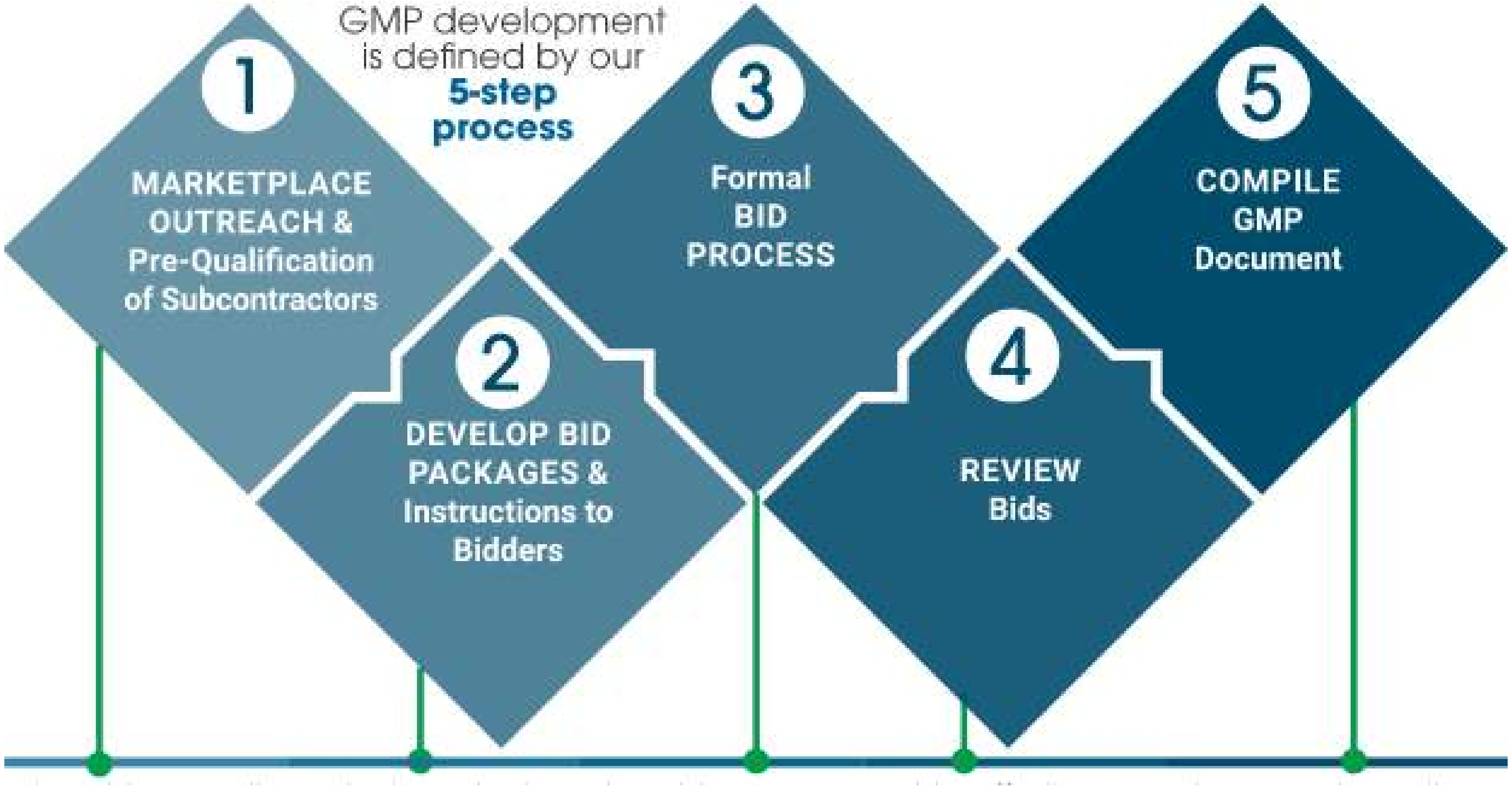
Progression of Cost Estimate

- RFP - $190M
- Initial scope - $285M
- 30% Estimate – $245M
- GMP - $256M

Major Value Engineering Savings

- Single bay with mechanical redundancy for cake receiving - $5M
- Not demolishing bio-roughing towers - $4M
- Simplification of dewatering/conveying - $2M
- Material selection for cake feed silos - $4M
- CHP changing to RNG use - $25M
- Reusing Solids Receiving Tank - $5M

Guaranteed Maximum Price (GMP) Development



Morris Forman WQTC BPS Final

Questions?

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BIOSOLIDS COMMITTEE

Hazen

Florida Water Environment Association | BIOSOLIDS COMMITTEE

Renewable Natural Gas: Project Drivers and Case Studies

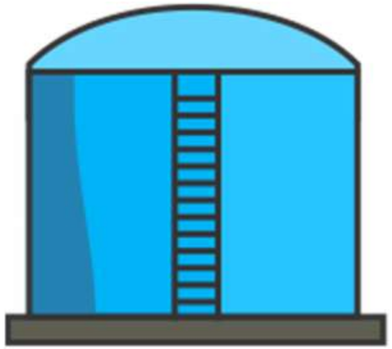
Presented by: Elizabeth Keddy, PE, LEED AP

2024 FWEA Biosolids Seminar, July 18, 2024

Presentation Outline

- Biogas Utilization Alternatives
- Renewable Natural Gas (RNG) Overview
- Funding Opportunities
- Case Studies
  - **~10 MGD**
  - **~25 MGD**
  - **~50-70 MGD**
  - **~60-100 MGD**
- Public-Private-Partnerships (P3)
- Next Steps

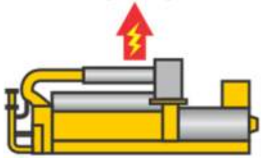
Typical Digester Gas to Energy Technologies



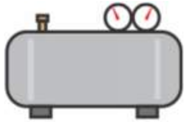
Anaerobic Digester

Digester Gas

Lots of Interest



Combined Heat and Power (Combustion)
40% Electricity
45% Heat Recovery

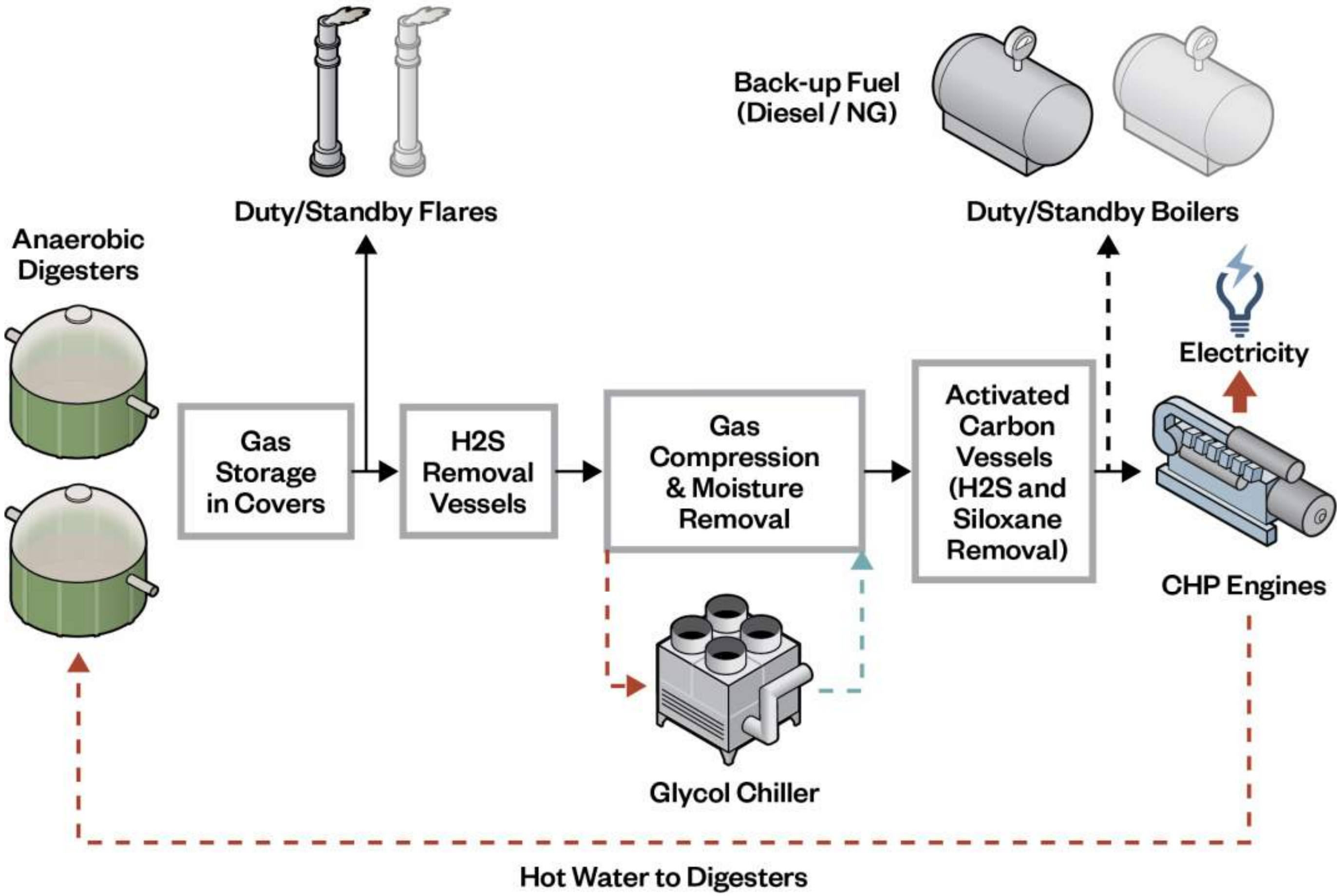


Thermal Systems (Combustion)
80% Heat Recovery

Renewable Natural Gas (Conversion)
85% - 97% Fuel Conversion

Flare Gas (Combustion)
0% Energy Recovery

Combined Heat and Power – Process Flow Diagram



Combined Heat and Power – Typical Equipment

H2S Removal Vessels

Siloxane Removal Vessels

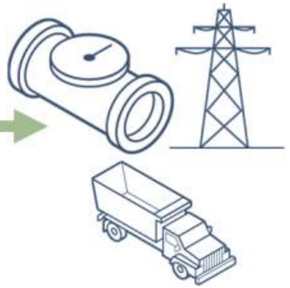
Reciprocating Internal Combustion Engine (RICE) Generator

What is Renewable Natural Gas (RNG)?

- RNG is biogas converted to natural gas standards
- **RNG and natural gas have the same chemical makeup after treatment**

Parameter	Typical Raw Biogas	Typical Natural Gas Requirements
Moisture	Saturated	Dry
Carbon Dioxide	35% - 70%	3% Max
Methane	**40% - 60%**	**98%**
Oxygen-Nitrogen	0.5-4%	1-3% Max
H2S	5-10,000 ppmv	4 ppmv Max
Siloxanes	0-1.5 ppmv	Non-Detect
VOC	0-9,000 ppmv	Non-Detect
BTU	400-600 BTU/SCF	980 BTU/SCF

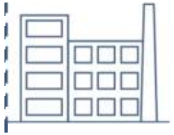
Trend – Evolving Bioenergy Markets & Pathways



End Use "Market"

Offset Energy: You are your "own customer"

Renewable Fuels: RINs, LCFS & "eRINs"



Energy Utilities: Voluntary and Mandated Portfolio Requirements

Blue Chip Corporations: Voluntary Sustainability Commitments

Bioenergy Resource

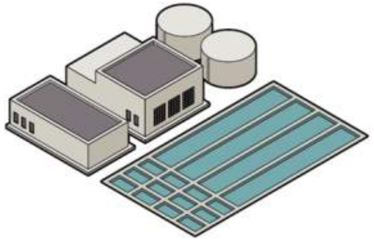
- Biogas
- Organic Matter
- Nutrients

Transformation

- Electricity
- Thermal Energy
- Renewable Natural Gas
- Other Fuels/Resources

"Physical" Pathway

- Electrical Connection
- Pipeline
- Other Products

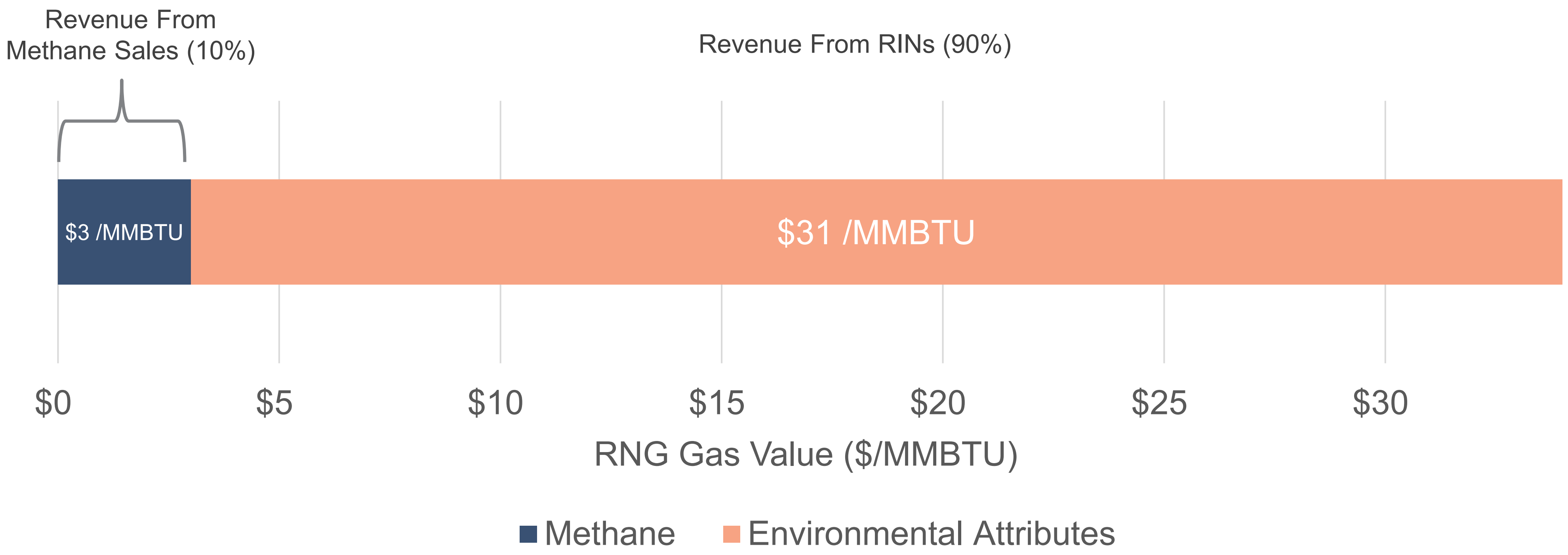


Water Utility

"Contractual" Pathway

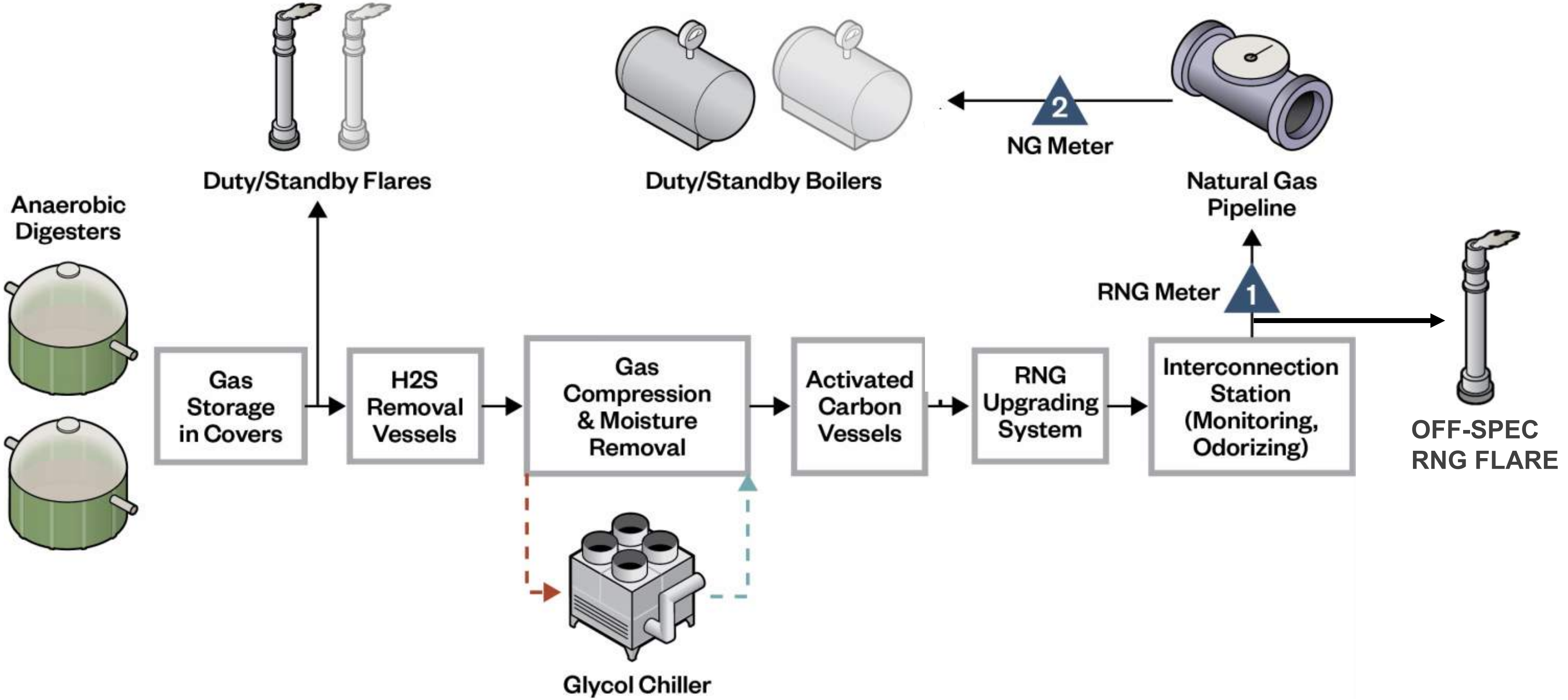
- Power Purchase Agreement
- Offtake and Purchase Agreement
- Interconnection Agreement

Typical Renewable Natural Gas (RNG) Revenue Breakdown: Methane Sales and RINs



RNG's NPV is highly sensitive to RIN prices

Renewable Natural Gas – Process Flow Diagram



RNG Upgrading Technologies (CO_2, N_2, O_2 Removal)

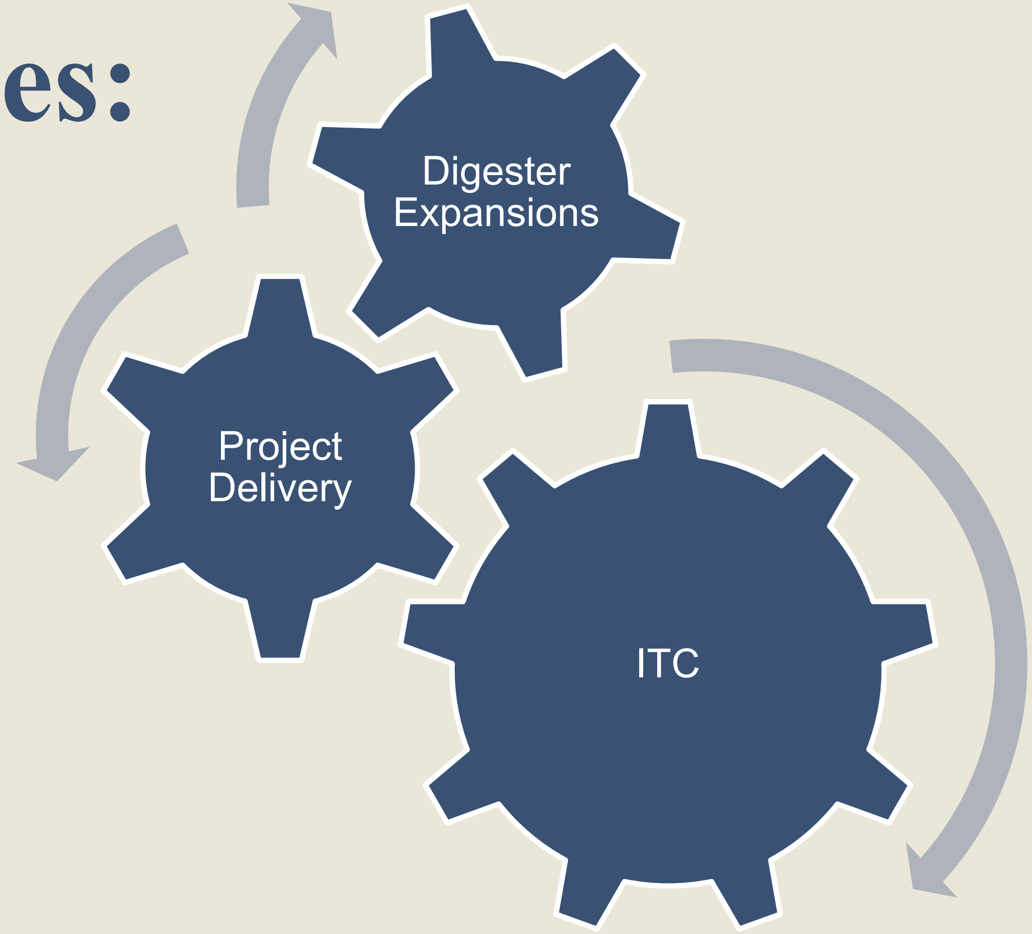
RNG Upgrading Membranes

- Solvent (Amine) Scrubbing
  - **CO_2 dissolved into chemical solution**
  - **Chemical solution heated to remove CO2**
  - **Also effective at H2S removal**
- Water Scrubbing
  - **CO_2 dissolved into water at high pressure**
  - **CO_2 released under low pressure**
- Pressure Swing Adsorption (PSA)
  - **System alternates between cycles of adsorption and desorption**
  - **CO_2, N_2, O_2 adsorbed at high pressure into media while CH4 passes through**
  - **Depressurized to remove CO_2, N_2, O_2 from media**
- Membranes (Single- or Multi-pass)
  - **Gas is pressurized and forced through membrane filter that acts as a sieve**
  - **CH_4 molecules pass through pores in membrane while larger molecules are discharged with tail gas**

Typical RNG Upgrading Technologies

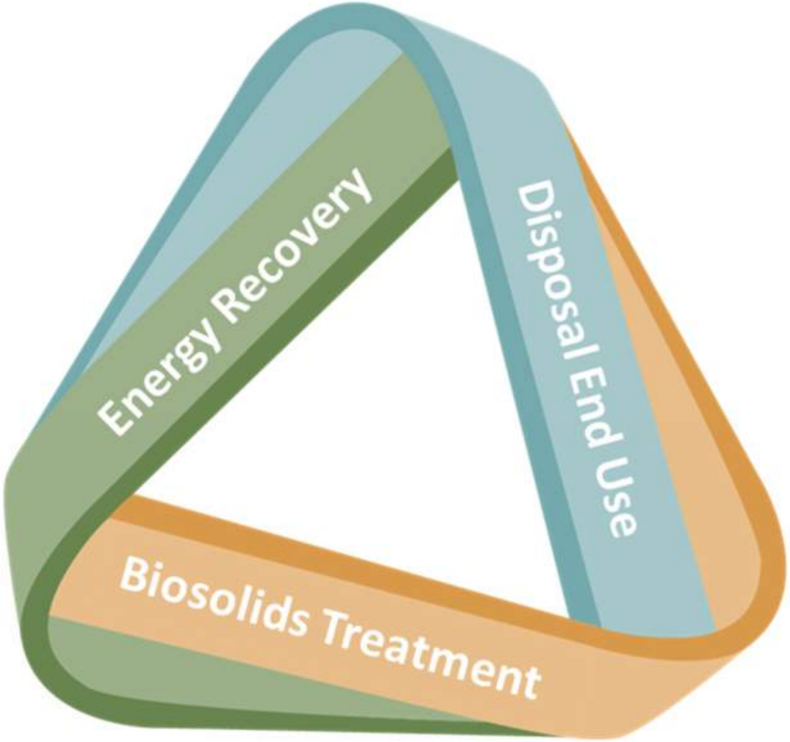
Technology	Appx. Scale (Typ.)	Footprint	Methane Recovery	Removes O_2	Removes N_2	Heat Required	Operating Pressure (Energy Consumption)	Tail Gas Treatment Typical
Solvent/Amine Scrubbing	1,000 to 5,000+ SCFM		>99%	No	No	Yes	1 psig	No
Water Scrubbing	50 to 3,000 SCFM		97-99%	No	No	No	150 psig	No
Pressure Swing Adsorption	800 to 5,000+ SCFM		90-95%	Yes	60-80%	No	120 psig	Yes
Single-Pass Membranes	50 to 400 SCFM		90-95%	Some (Up to 50%)	Minimal	No	200-250 psig	Yes
Triple-Pass Membranes	200 to 5,000+ SCFM		>99%	Some (Up to 50%)	Minimal	No	200-250 psig	No

Funding Incentives: Investment Tax Credits (ITCs)



Big Picture Trend – “The New Energy Transition”

- **Funding for low/neutral carbon energy projects**
- Mandates for renewable energy
- Markets and pathways for renewable energy
- Decentralized Energy Production
- New Low Emission Technologies
  - **Energy Storage, Electrification, Solar, Hydrogen**



Inflation Reduction Act (IRA)

Passed August 2022

Expands tax credits to new sources of renewable energy

- Biogas Property
- Hydrogen
- Storage
- Zero emissions energy systems

Provides "direct payment" of tax credits to tax exempt entities.

Provides uncapped credit opportunities

- No limit on the amount of projects and credits
- Estimate the energy tax credits will cost the federal government 400 billion to 1 trillion USD over the life of these credits

AUGUST 15, 2022

BY THE NUMBERS: The Inflation Reduction Act

BRIEFING ROOM ▸ STATEMENTS AND RELEASES

The Inflation Reduction Act will lower costs for families, combat the climate crisis, reduce the deficit, and finally ask the largest corporations to pay their fair share. President Biden and Congressional Democrats have worked together to deliver a historic legislative achievement that defeats special interests, delivers for American families, and grows the economy from the bottom up and middle out.

Here's how the Inflation Reduction Act impacts Americans by the numbers:

Two Basic Types of Tax Incentives

ITC – Investment Tax Credit (IRC Section 48, 48C, 48E)	PTC - Production Tax Credit (IRC Section 45, 45Y, 45Z)
One time credit based on the investment made for qualified and eligible projects. "Direct Pay" option allows tax exempt entities to received benefit.	Annual payments based on the renewable energy generated, sold or consumed by eligible projects Paid over the first 10 years of operation. Tax exempt entities eligible.

Can Not "Double Dip"

Overview of Available Tax Credits

Eligible Energy Technology	Tax Credit Type and I.R.C. Section	Credit Structure	Timeline & Milestones
Electricity Production • CHP, Fuel Cells • Solar, Wind • Geothermal	§48 Energy Credit ITC	§48: 6%-50% of Eligible Project Costs *	Start Construction by **12/31/2024**
	§45 Renewable Electricity PTC	§45: $0.0055 - $0.0335/kWh for 10 years *	
<u>Biofuel Production</u> • ***Qualified Biogas Property*** • RNG	§48 Energy Credit ITC	§48: 6%-50% of Eligible Project Costs *	Start Construction by **12/31/2024**
	§45Z Clean Fuel PTC	§45Z: $1.12-$5.60/MMBTU for RNG **sold by end of <u>2027</u>**	
<u>Electricity Production</u> • Net Zero GHG Electricity Technologies (Solar, heat recovery/ORC, wind, etc.)	§48E Clean Electricity ITC	§48E: 6%-50% of Eligible Project Costs *	Start Construction **2025-2032**
	§45Y Clean Electricity PTC	§45Y: $0.0055 - $0.0335/kWh for 10 years *	
GHG Reduction • 20% GHG Reduction of an industrial facility	§48C Advanced Energy Projects	30% of Eligible Project Costs *	Next competitive round opens soon

*Depending on Prevailing Wage & Apprenticeship, Domestic Contents, and Energy Community bonuses

ITC and PTC Construction Start Timelines

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
CHP (Electricity)	48 ITC / 45 PTC		48E ITC / 45Y PTC Clean Electricity							
RNG (BioFuels)	48 ITC									
	45Z Clean Fuels PTC									
Anaerobic Digestion	48 ITC									
	48C (20% GHG Reduction)									

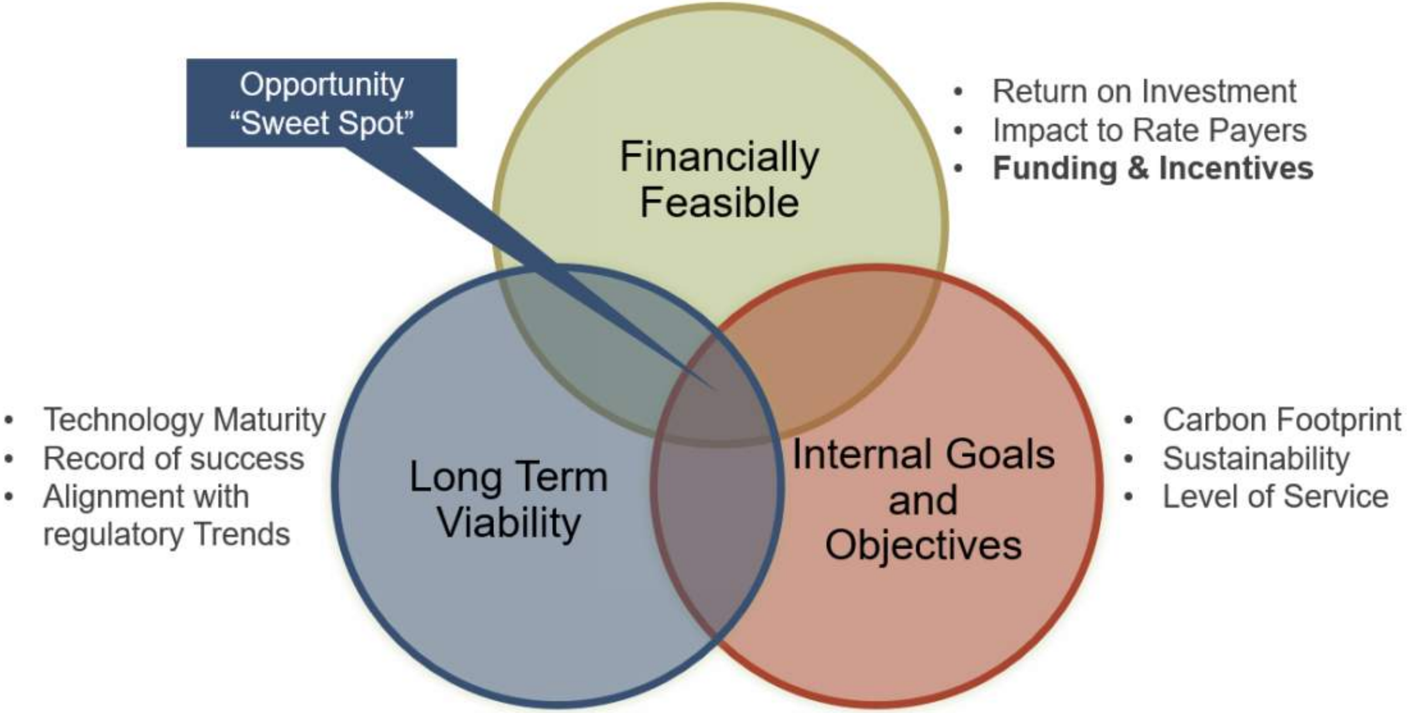
Confirmed (green)

Further IRS Guidance Needed / Not Guaranteed (grey)

*Qualified projects that are currently underway and meet the 2024 construction deadline qualifies for these credits

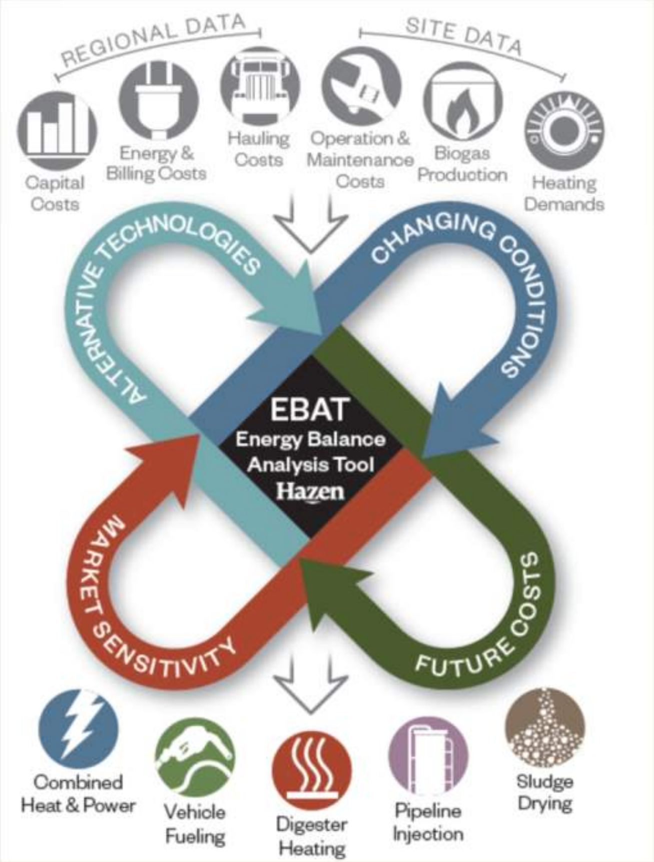
Long Term Planning Considerations

- Section 48 ITC Window is closing very quickly. Will be very difficult to develop new qualifying projects.
- Tax credits are always evolving
- GHG reduction credits will likely be viable through the "New Energy Transition"
    - Net Zero Emissions by 2050
- Tax Credits are obtained after project is in service
- Incentives and funding are just a part of the overall planning picture

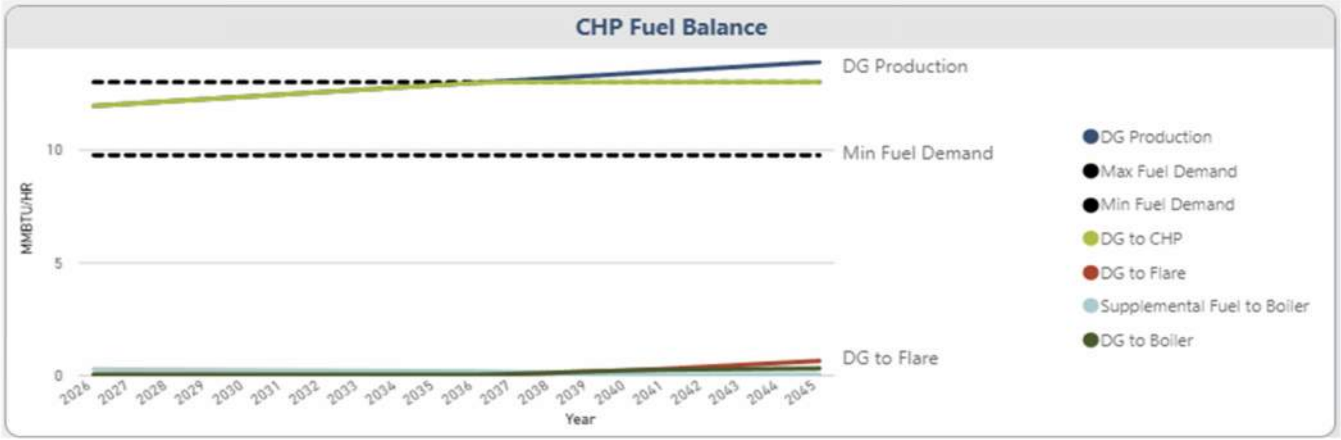


Focus on future zero emission technologies

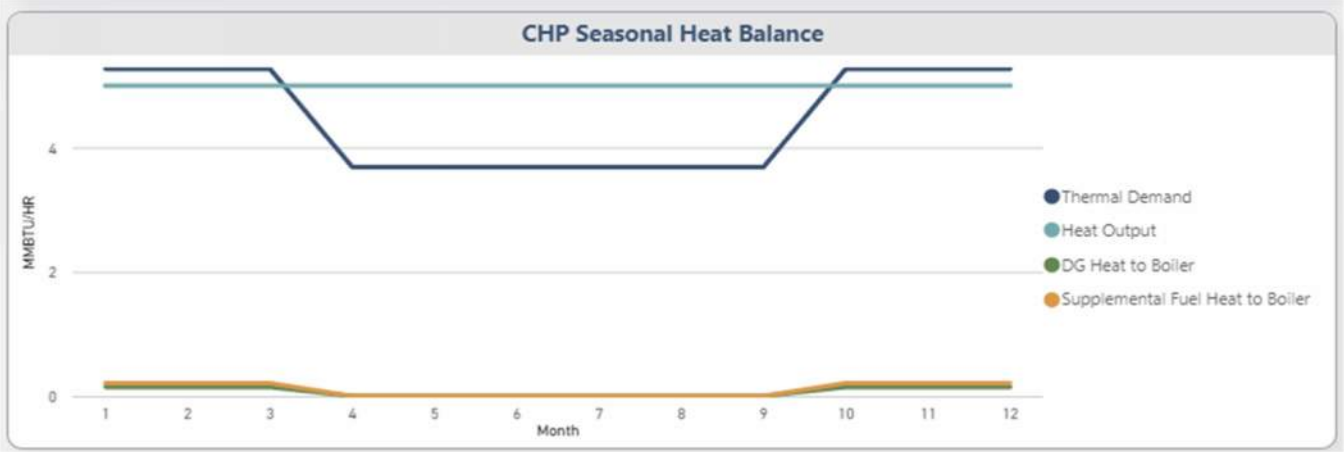
Case Studies

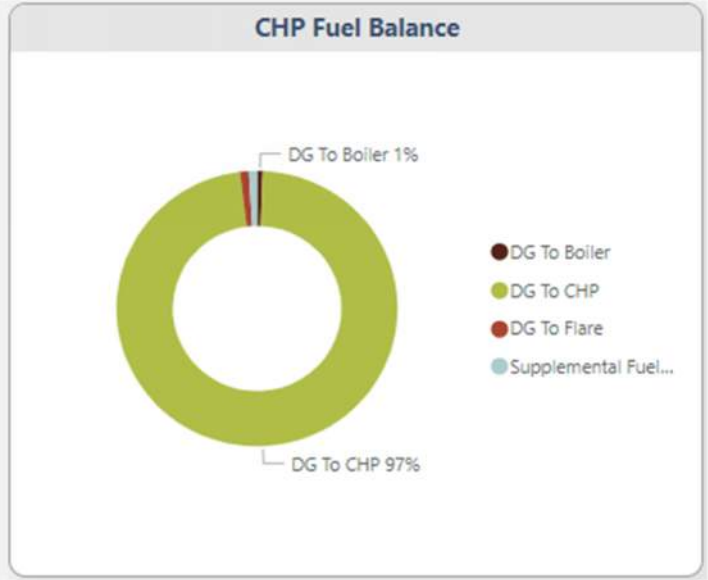


Combined Heat and Power (CHP) - Fuel and Heat Balance

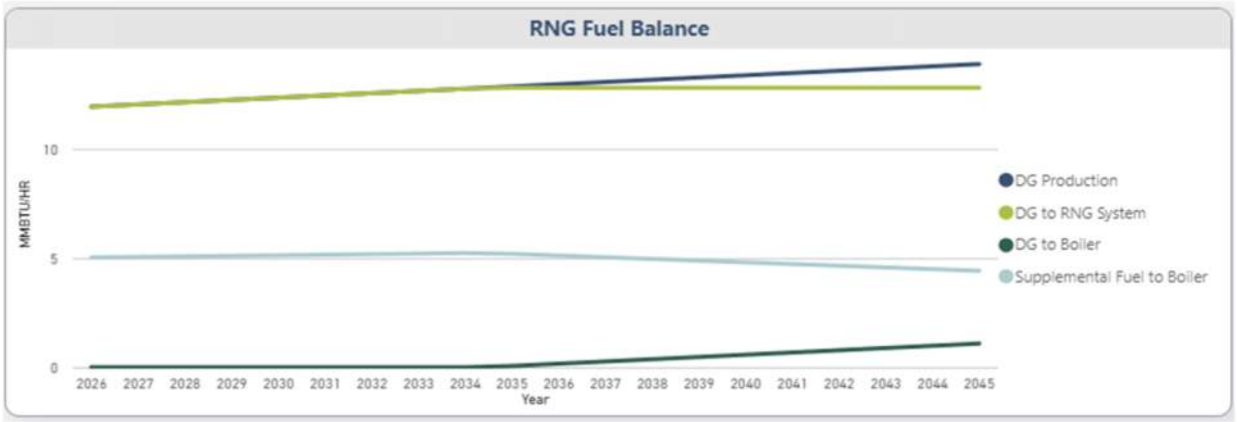


- CHP Rating: 1,560 kW
- Thermal Efficiency: 43%
- Electrical Efficiency: 41%
- CHP Uptime: 90%

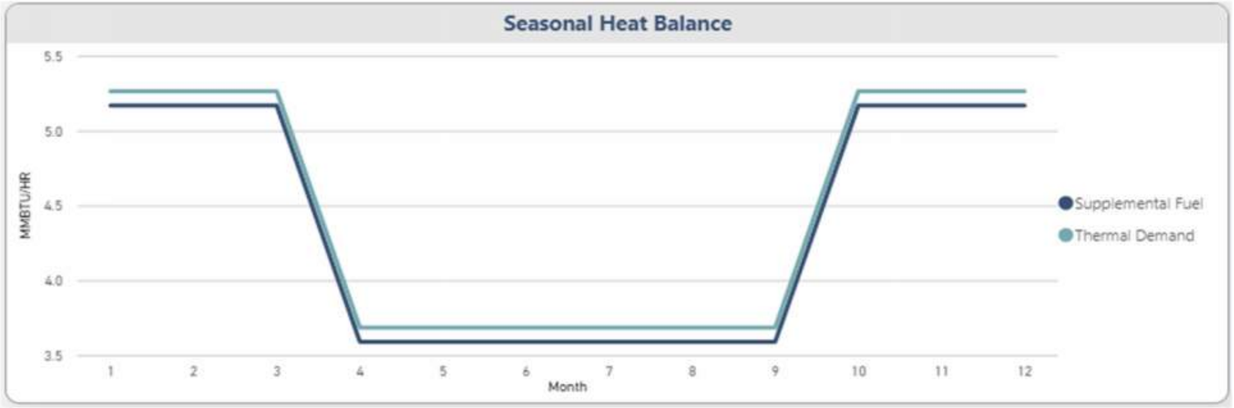


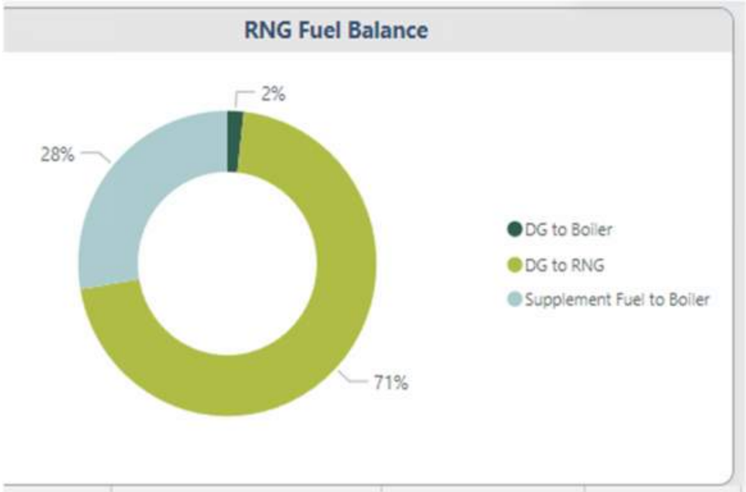


Renewable Natural Gas (RNG) - Fuel and Heat Balance

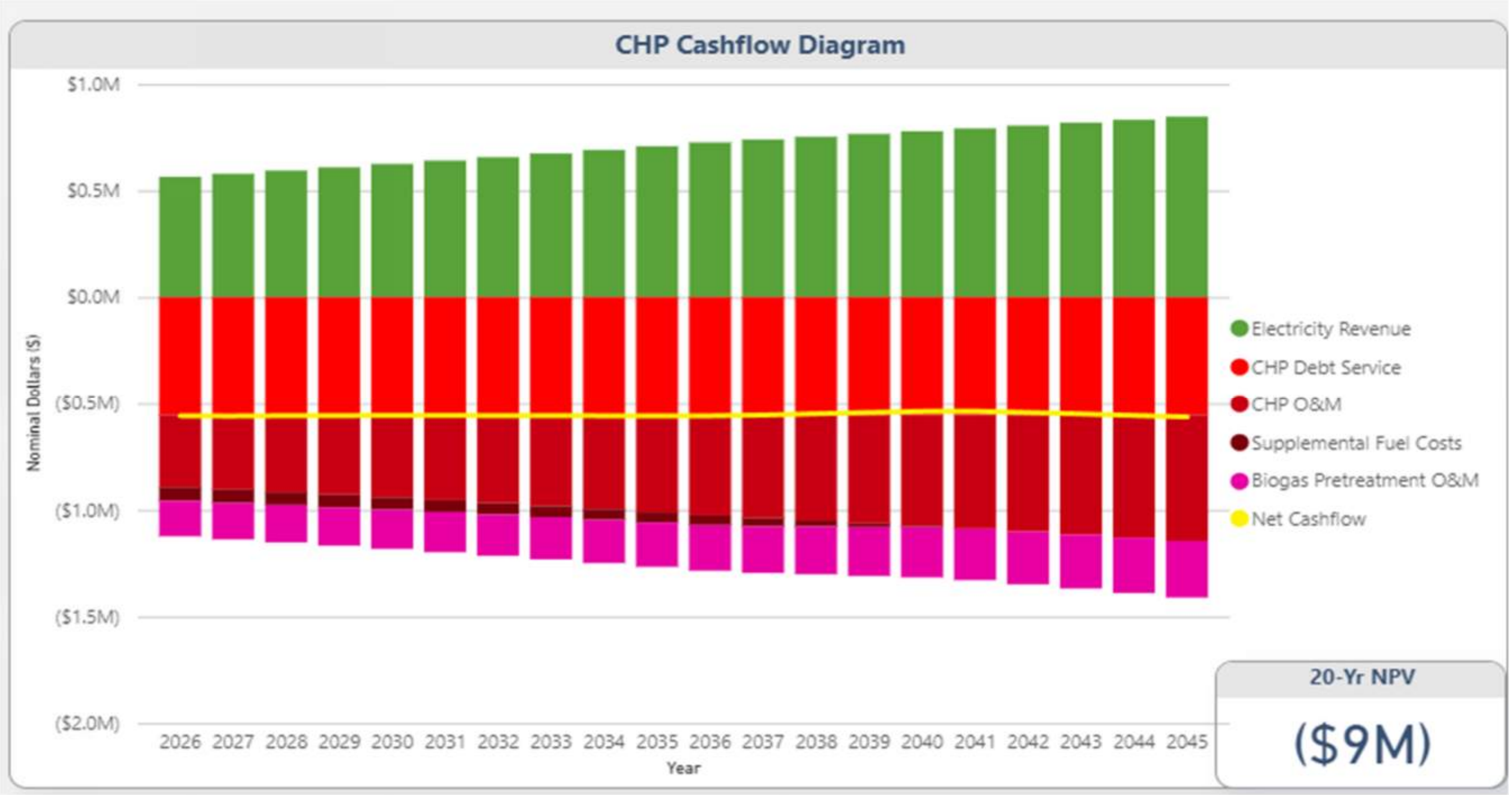


- RNG System Capacity: 400 SCFM
- RNG Efficiency: 99% (assuming Triple Pass Membrane)
- RNG Uptime: 90%



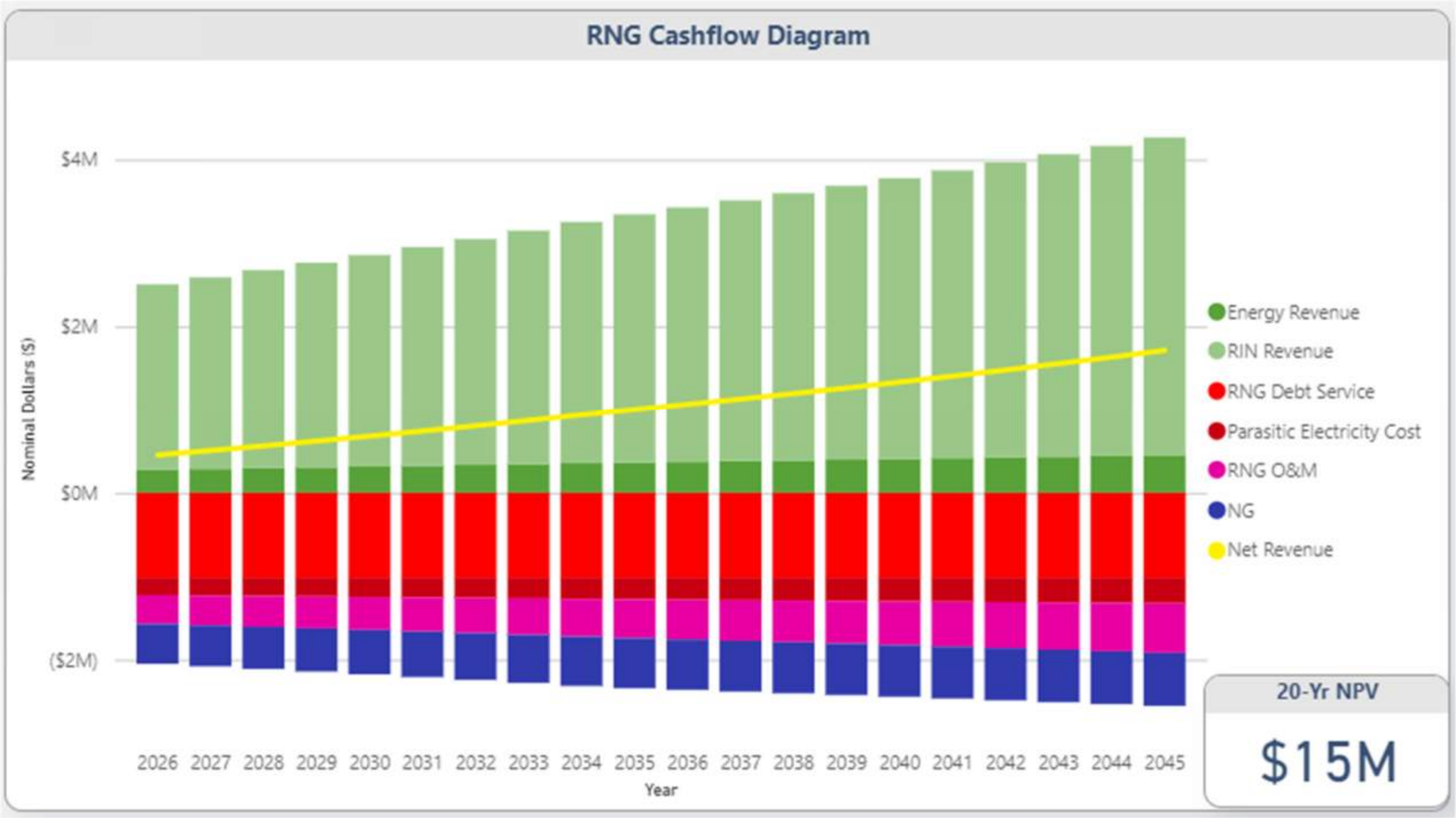


Combined Heat and Power (CHP) - Cash Flow Diagram



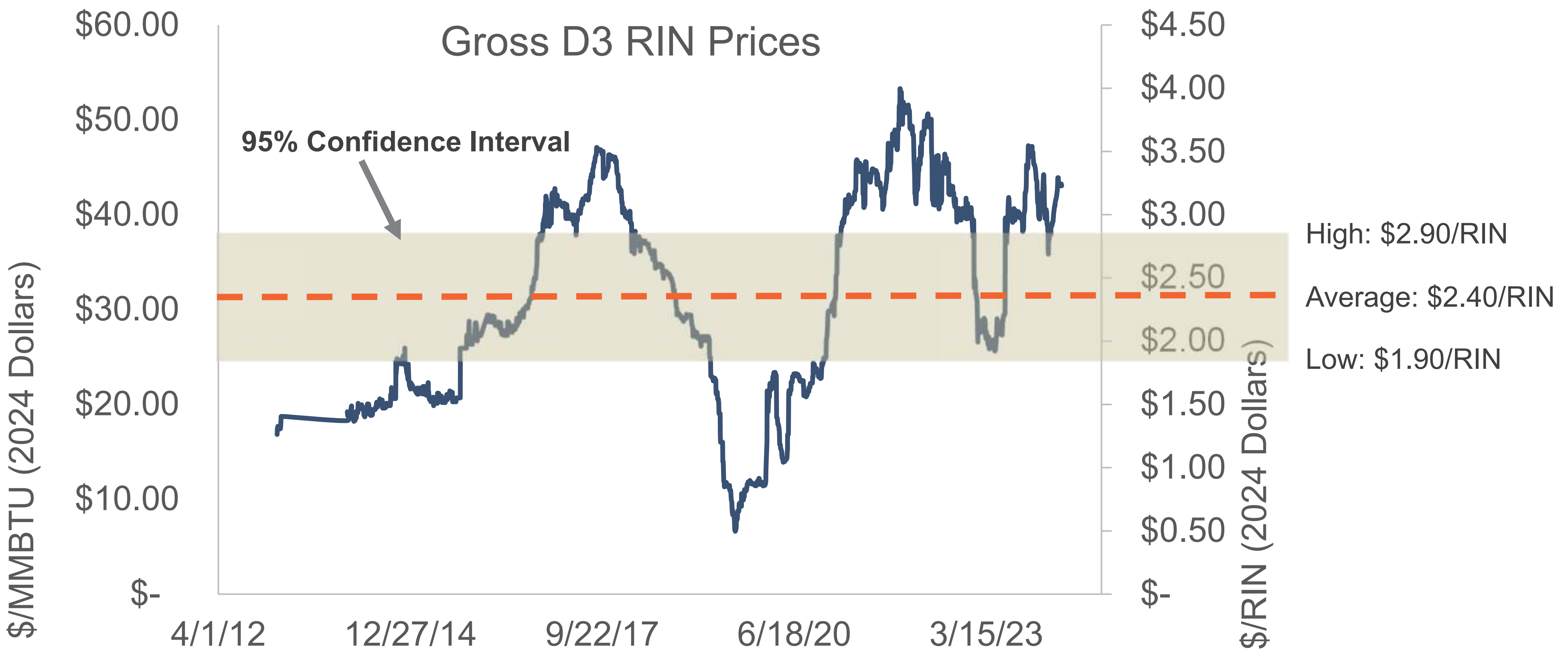
Note: Cashflow diagram assumes capital cost is amortized over 20-years at 1% interest rate (SRF Loan Funding)

Renewable Natural Gas (RNG) - Cash Flow Diagram



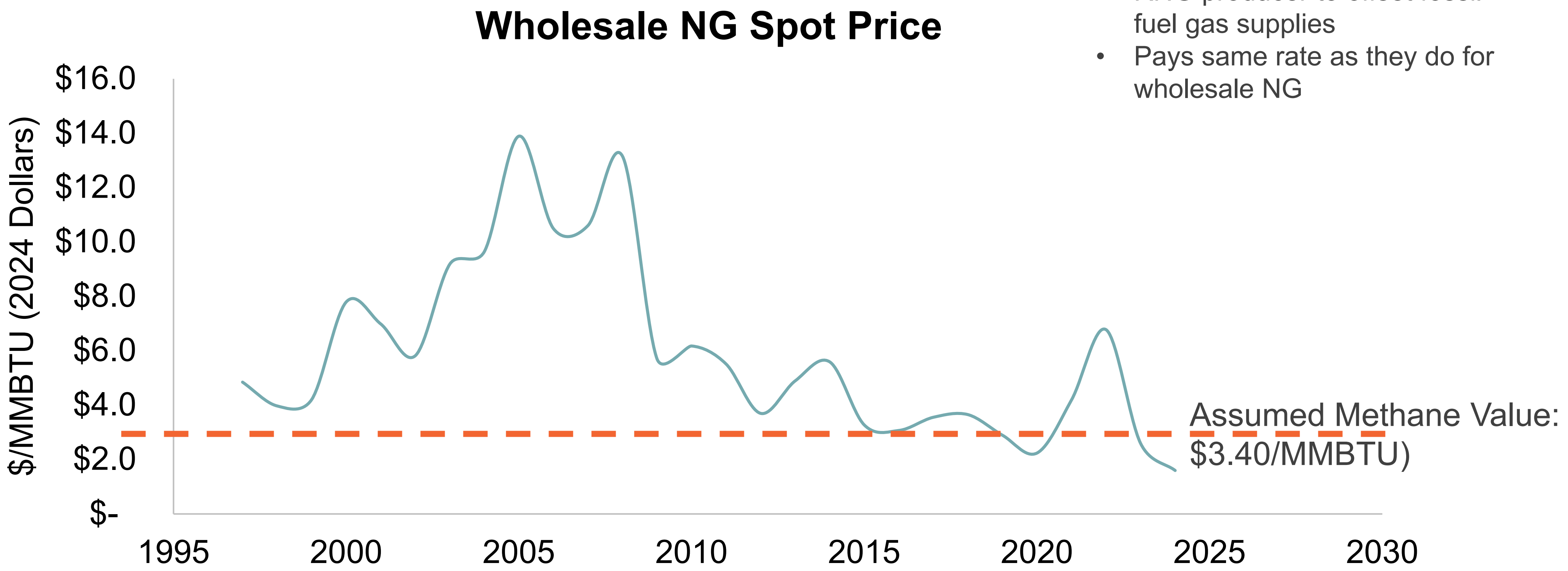
Note: Cashflow diagram assumes capital cost is amortized over 20-years at 1% interest rate (SRF Loan Funding)

Revenue – D3 RINs



Revenue – Methane Sales to Natural Gas Utility

- Gas Co purchases gas from RNG producer to offset fossil fuel gas supplies
- Pays same rate as they do for wholesale NG



EIA Data

Summary of Case Studies (20-Year Net Present Value)

WWTP Size	~10 MGD	~25 MGD	~50-70 MGD	~60-100 MGD
Raw Biogas	55-100 scfm	95-120 scfm	375-435 scfm	575-800 scfm
CHP Size	180 KW	360 KW	1560 KW	2 x 1200 KW
CHP NPV	$3.5-4M	$2.6-3.5M	$7-10M	$40-60M
RNG NPV	$0-2M	$2.2-3.9M	$13-16M	$25-33M

Public-Private-Partnerships (P3)

P3 Partnerships Have Many Forms

Private Operations and Maintenance

- Private party O&M only
- Facility financed, built and owned by public utility

Design Build Operate Maintain (DBOM)

- Private party designs, builds operates and maintains facility
- Financed and owned by public utility

Design, Build Finance, Own, Operate and Maintain (DBFOOM) (P3)

- Private party has full project delivery, operations and maintenance responsibility
- Public utility has no financial, operational and maintenance responsibilities

Key Considerations

- Risk vs reward appetite
- Capital dollars availability and allocation
- O&M responsibilities
- Availability of resources
  - Specialty skills – RIN management
- Time sensitivity and urgency

Considerations Before Pursuing a P3 Partnership

Understand True Value and Risks	Regulatory Landscape &Trends	Alignment With Biosolids Long Term Plan	Know the “Pitfalls”
• Revenue and Return on Investment • O&M/Performance Risks • Capital at Risk • Market Volatility • Reliance on FOG/HSW codigestion to meet financial objectives	• Evolving markets & pathways (i.e. eRIN Pathway) • Funding Opportunities • Evolving Regulations (PFAS, emissions, organics recycling, etc.)	• Future Biosolids Processing (i.e. dryers, gasification, etc.) • Co-digestion Process Impacts • Impacts from Biosolids Hauling/Disposal Costs	• Unrealistic Proposals • Equitable Allocation of Revenue and Risk • Unclear Roles and Responsibilities • Transparency and “Off Ramps” During Development

“Stack the deck in your favor”

Florida Laws Governing P3 Contracts

Section 255.065 of the Florida Statutes

- A public entity may partner with a private entity to develop a project that serves a public purpose. A wastewater facility or related infrastructure is specifically defined as a qualifying project. The intent of the Florida law is to expedite cost-effective projects, encourage private financing of public facilities, and provide flexibility to public and private entities contracting for the provision of public services.
- A public entity may receive unsolicited proposals, or may solicit proposals, through a process defined in Section 255.065 of the Florida Statutes.
- Either the public entity or private entity may finance the project. As of July 1, 2024, the private entity may own the project if there are public benefits apart from ownership. The private entity must develop or operate and maintain the project, or reimburse the public entity for maintenance of the project or other services provided to the private entity. The comprehensive agreement must set forth the manner in which any revenue is applied and the negotiated portion of the revenue returned to the public entity.
- P3 comprehensive agreements must have safeguards in place to 1) prevent additional costs or service disruptions if the public entity terminates the agreement, and 2) allow the public or private entity to add capacity to the project.

Typical Division of Responsibilities for RNG Under a DBFOOM P3 Contract

Private Partner	Public Utility
- Design, Construct and Own - Operate and Maintain - Permitting, Approvals - Property Agreements, Easements - Raw Gas Supply & Quality Monitoring - Minimum System Performance Guarantee - Gas Environmental Attribute & Commodity Marketing - Management and Disposal of Gas Processing Wastes, Condensate - Environmental Remediation	- Own, operate and maintain raw biogas conveyance infrastructure to RNG facility. - Operate digesters in accordance with best industry practices. - Provide accurate biogas production data during project development phase. **Gas characteristics, production and variation limits.** - Maintain open lines of communication with P3 entity on near term conditions or potential plant changes that may impact biogas supply. - Provide site space and access for RNG facility. - Maintain a safe working environment for P3 staff.

Typical RNG Project Development Steps for P3 Delivery

Initial Feasibility
Understand the project value and risks

- Overall feasibility evaluation (understand value, risks & delivery alternatives)
- Initial pipeline interconnection evaluation
- Alignment with long term biosolids strategies
- Life Cycle Cost Assessment
- **(3-6 months)**

Preliminary Engineering
Basis for RFP

- 10-20% design development for PPP proposals
- Layout, major equipment, design criteria, cost, etc.
- RNG interconnection coordination with gas company (conditioning, volume, offtake monitoring)
- **(4-8 months)**

RFQ/RFP – *PPP solicitation and selection*

- Define operating conditions – gas production, co-digestion limitations, gas storage, performance requirements, roles and responsibilities, etc.
- Agreement parameters – i.e. Ownership, roles and responsibilities, O&M requirements
- Provide 10-20% design documents if RFP includes a binding financial proposal
- Experience, internal capabilities, financial stability, RNG ownership history, references
- **(6-12 months)**

Memo of Understanding
Document project needs and intentions

- Document initial negotiations and what makes a successful project
- Develop and integrate **"off ramps"** as possible
- Define performance metrics
- **(2-3 months)**

Final Agreement
Expansion of the MOU

- Expand the MOU
- Project cost and profit-sharing framework
- Finalize roles and responsibilities, address cost runs, build in specific check points
- **Define all off ramps. (4-8 months)**

Next Steps for Case Study Projects

~10 MGD 55-100 scfm	~25 MGD 95-120 scfm	~50-70 MGD 375-435 scfm	~60-100 MGD 575-800 scfm
• NO GO (b/c no AD)	• GO RNG (w/new AD ~ $10M ITC) • **No P3** • RNG in design now • Gas Co	• GO RNG • Evaluating P3 delivery depending on revenue share	• GO RNG (w/major AD ~ $20M ITC) • Prefer P3 but ITC may require ownership • Gas Co

Hazen

Florida Water Environment Association | BIOSOLIDS COMMITTEE

2024 FWEA Biosolids Seminar, July 18, 2024

Questions/Discussion?

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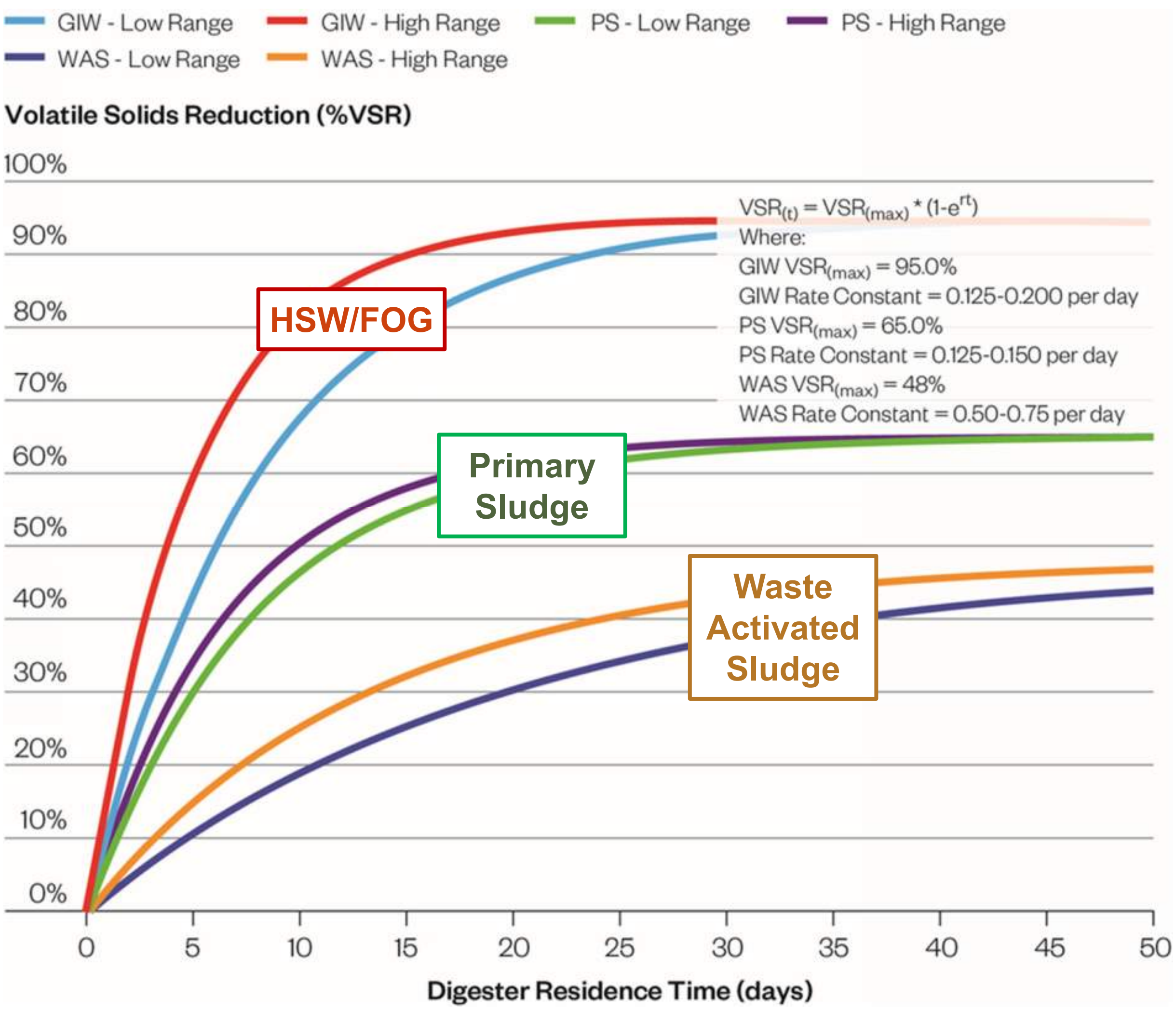
Bullpen

Basics and benefits of anaerobic digestion

- Thickened sludge stored, mixed and heated in tanks for 15 days or greater at 95 to 100 deg-F
- A **portion of the volatile solids are converted to biogas** in a multi-step biological process in the absence of oxygen (anaerobic)
- % of volatile solids destroyed (converted to biogas) is a function of solids retention time in digester and feed material
- Benefits:
  - **Reduces hauled solids quantities**
  - **Reduces annual dewatering and disposal costs**
  - **Potential recovery of biogas for beneficial use**



How is the "Start of Construction" Established?

Construction Start Can Be Established In Two Ways

1 - Physical work of a significant nature	2 - Safe Harbor

1 - Physical work of a significant nature

- Work performed to manufacture, construct, or produce property for use in the facility
- Includes physical work such as:
  - **Excavation for the foundation,**
  - **Pouring of concrete pads and/or foundations,**
  - **Off-site manufacture of components for energy facilities.**
  - **Other similar physical installations.**
- Excludes activities such as planning, designing, securing financing, exploring, obtaining permits, surveys, site clearing, etc.

2 - Safe Harbor

- Point at which "five (5) percent or more of the total cost of the facility" has been paid or incurred.
- "Total cost of the facility" is defined as "all costs properly included in the depreciable basis of the facility"
  - **Includes machinery, equipment and structures integral to the activity of the energy property.**
  - **Includes soft costs like architect and engineering fees, permits, and other expenditures that are necessary to put an energy property asset into service.**
  - **Excludes the cost of land, building or facilities that aren't considered "integral" or "Energy Property".**

What is "Qualified Biogas Property"??? (Section 48)

1. Must convert biomass into a gas that is >= 52% methane, **OR** concentrate the gas to >= 52% methane
2. **Gas must be captured for sale or productive use**
3. Qualified biogas property includes any property which is part of such system which cleans or conditions such gas.

- A unit of Qualified Biogas Property is the full system that accomplishes the three (3) bullets above
- Does not include non-integral property: buildings, unrelated electrical, flare, etc.

Examples of "Qualified Biogas Property" (Partial List)

System Component	Converts biomass into gas >= 52% methane	Captures such gas for sale or productive use	Energy Property
Digester tanks	x		Yes
Digester covers	x	x	Yes
Mixing system	x		Yes
Heating system	x		Yes
Sludge transfer pumps	x		Yes
Sludge piping	x		Yes
Digester gas system (storage, conveyance)		x	Yes
Emergency flare			Maybe[1]
Electrical & I&C for above systems	x	x	Yes
Access roads			Maybe[2]
Buildings, Lighting, HVAC, etc.			No
RNG Upgrading	x	x	Yes

[1] Safety components are being considered by IRS/DOE
[2] On-site roads that provide access for equipment to operate and maintain the system and, therefore, its functionality (2023-25539.pdf (federalregister.gov))

Critical ITC Requirements to Consider

AD and RNG

1. Meet construction start deadline
2. Max duration limits
    - **Automatically four (4) years**
    - **If longer than four (4) years, must maintain a continuous program of construction**
3. RNG system ownership considerations:
    - **3rd party ownership – RNG must be completed and operational by the end of the digester project**
    - **Self-ownership – must demonstrate continuous program of construction**
4. Must have beneficial use of DG

FLORIDAPOLY

Florida Water Environment Association | BIOSOLIDS COMMITTEE

Linking Biosolid Biochar’s Adsorption Capacity with Physiochemical Properties: A Promising Substitute of Activated Carbon for PFAS Adsorption

Yudi Wu, Ph.D.

Florida Polytechnic University

Biosolid in Florida

- Three types of biosolid: **class A, AA and B**
- **Two-third** of biosolid produced in Florida are treated to Class B
- Class B biosolid has limited land application and other beneficial usages

Common practices of biosolid disposal

- **Land application**
- **Surface disposal**
- **Incineration**

FDEP Approved Biosolids Land Application Locates in Lower Suwannee Basin

No.	Name	Applicable Acreage	Application Rate (Dry Tons/Year)	Starting Year	Biosolids Source
1	Chason Site	23.14	60-100	2017	City of Madison WWTP
2	Jasper Cat Creek Site	44	128	2013	City of Jasper WWTP
3	Live Oak	*	*	*	Live Oak City of WWTP
4	Raymond Howard	176.4	80.4	2017	Raymond Howard's Septic
5	Rolling R Ranch K				
6	Rolling R Ranch RAF	222.30 (approved) 76.9 (applied)	45.9	2010	Edgewater WRF, Orange Park WWTF, etc.
7	Stephenson Septage	147.4 (approved) 49.3 (applied)	6.05	2016	OSTDS of Dixie County
8	Smith Septage	17	22.4	2017	Smith Septage Management Facility
9	Trenton	*	*	*	Trenton WWTF
10	Corbin Agricultural Site	*	*	*	
11	Jones	14.8	19.4	2016	Jones SMF
12	Graham Site #2	25.8	14.4	2010	City of Chiefland
13	Graham Site #1				
14	Graham Site #3	46.4 (approved) 11.3 (applied)	11.3	2016	City of Chiefland
15	Graham Site #4	40.5	0	2016	City of Chiefland
16	Jones Septage	58.5	39.2	2021	OSTDS City of Chiefland

Biosolid is a renewable resource

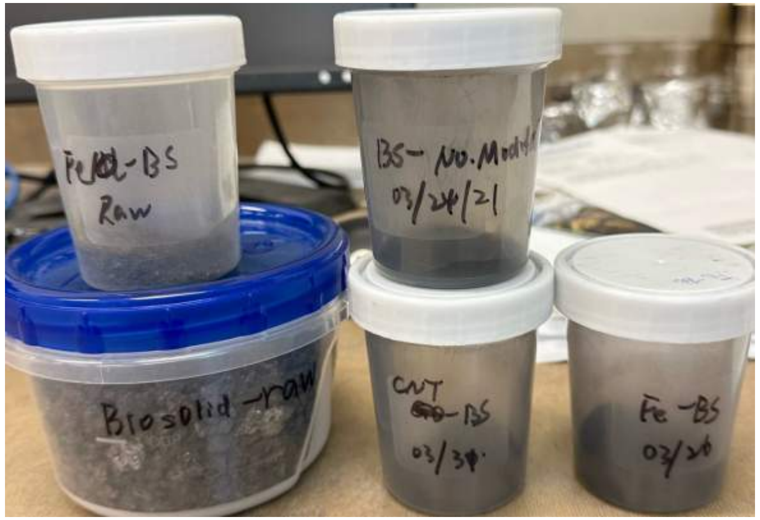
When it is in the right place…

Biosolid is most beneficial in agricultural application

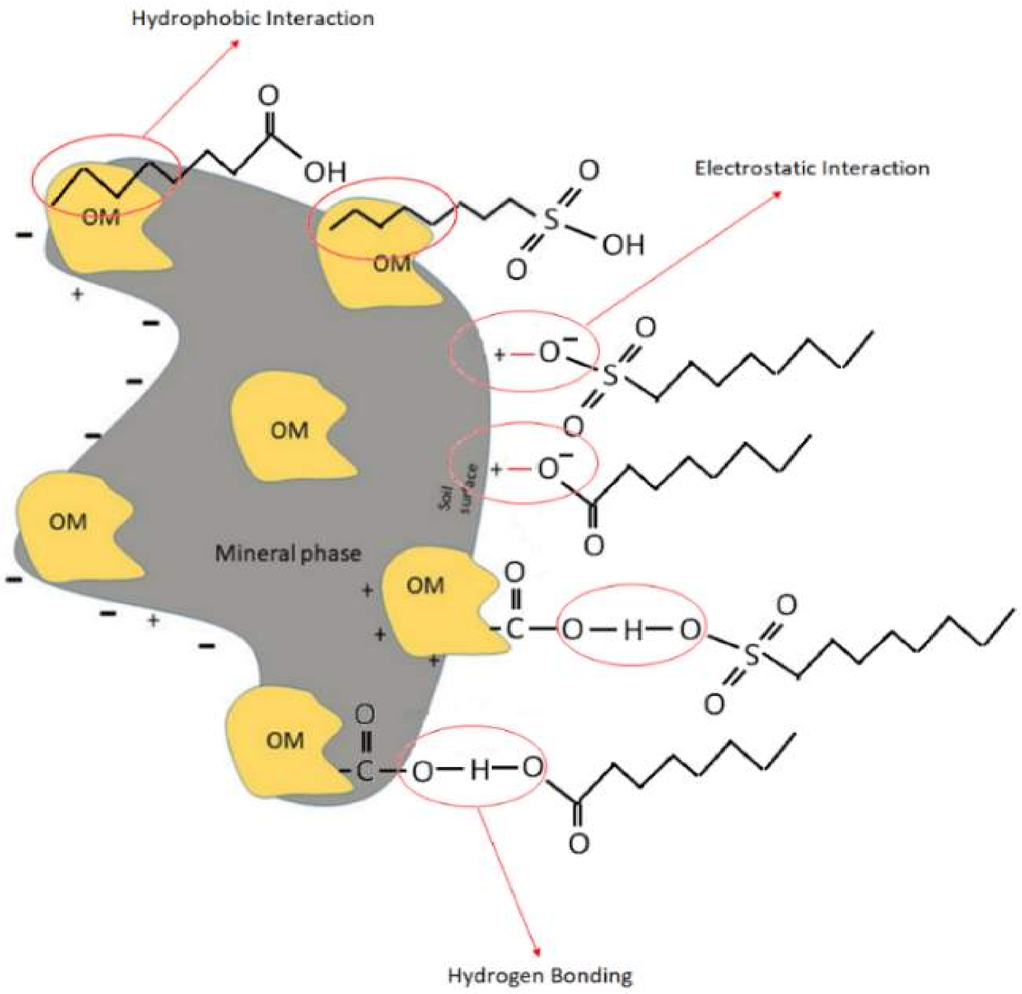
If limited heavy metal, pathogen, organic matters contamination

Biosolid could be a beneficial to PFAS adsorbent

Because the existence of metal, ~~pathogen~~, and organic carbon



Adsorption mechanism



Hydrophobic Interaction:

$$\Delta G_{adh} = (\gamma_{ps} - \gamma_{pl} - \gamma_{sl})A$$

Electrostatic Interaction:

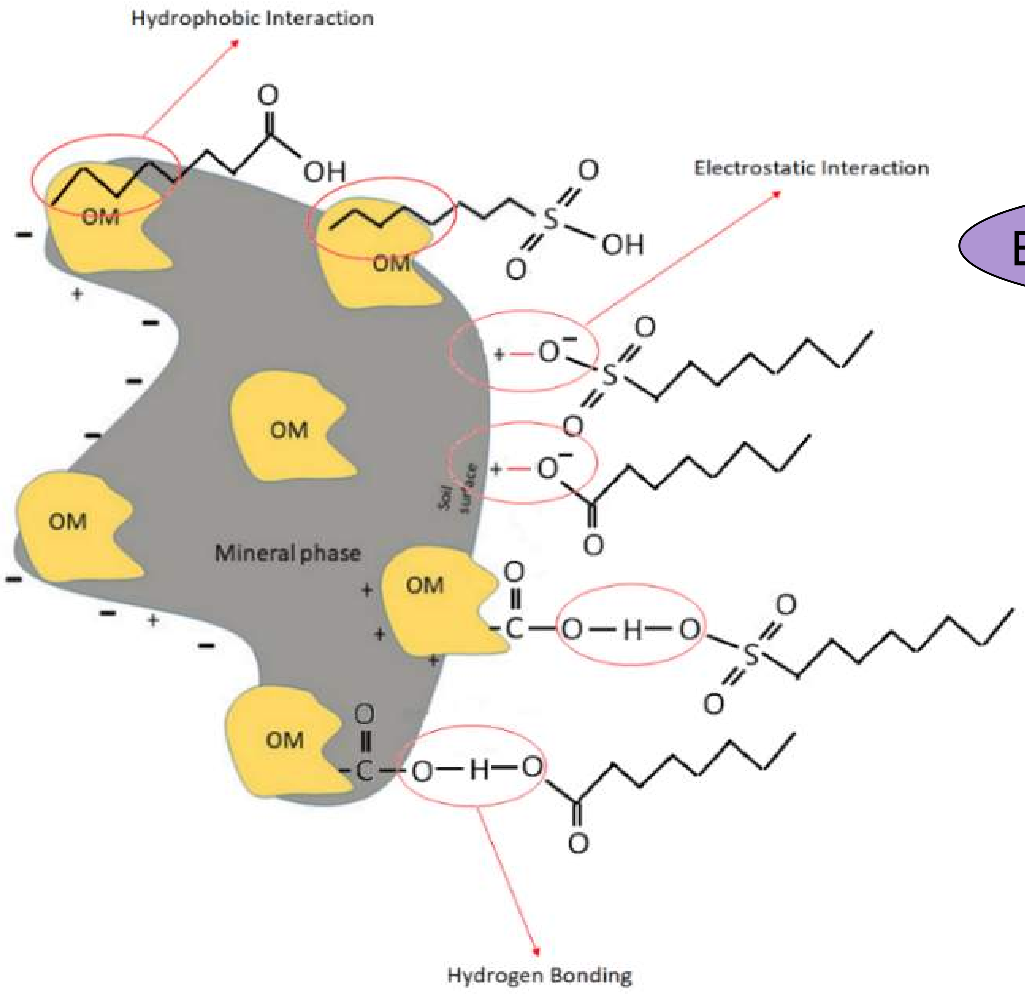
$$F^{el} = kT\sum_i (C_i(z) - C_{i,\infty}) - \frac{\varepsilon\varepsilon_0}{2}\left(\frac{d\psi}{dz}\right)^2$$

Hydrogen Bonding:

$$AH(H_2O) + H_2O \overset{K^0_{AH}}{\Longleftrightarrow} H_3O^+(H_2O) + A^-(H_2O)$$

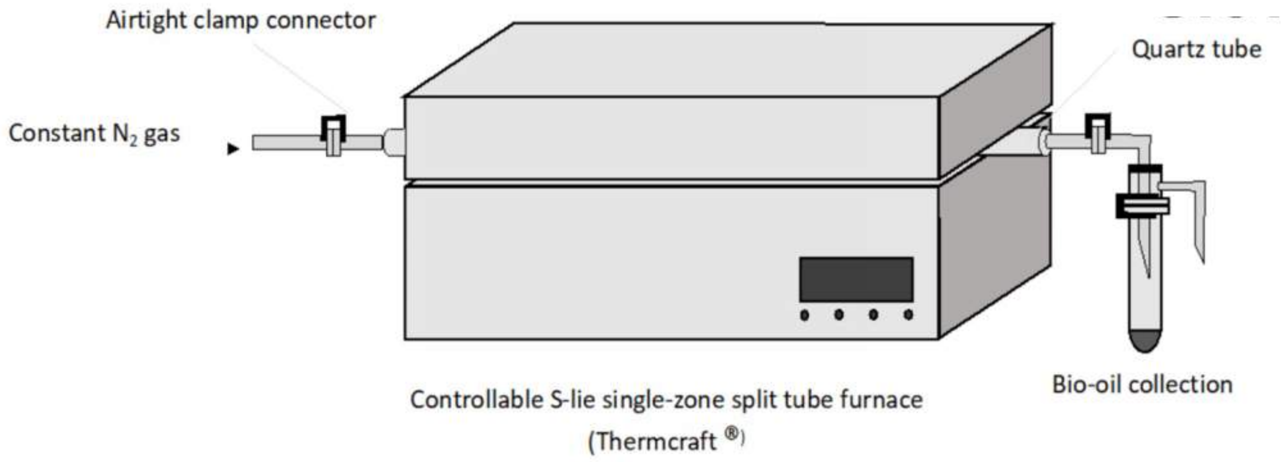
$$BH^+(H_2O) + H_2O \overset{K^0_{BH^+}}{\Longleftrightarrow} H_3O^+(H_2O) + B(H_2O)$$

What leads to high adsorption capacity?



- TOC
- Functional groups
- Elemental composition
- Zeta potential
- Pore size and volume
- Pyrolysis Temperature
- DOM
- Ionic Strength
- pH

Biosolid biochar production



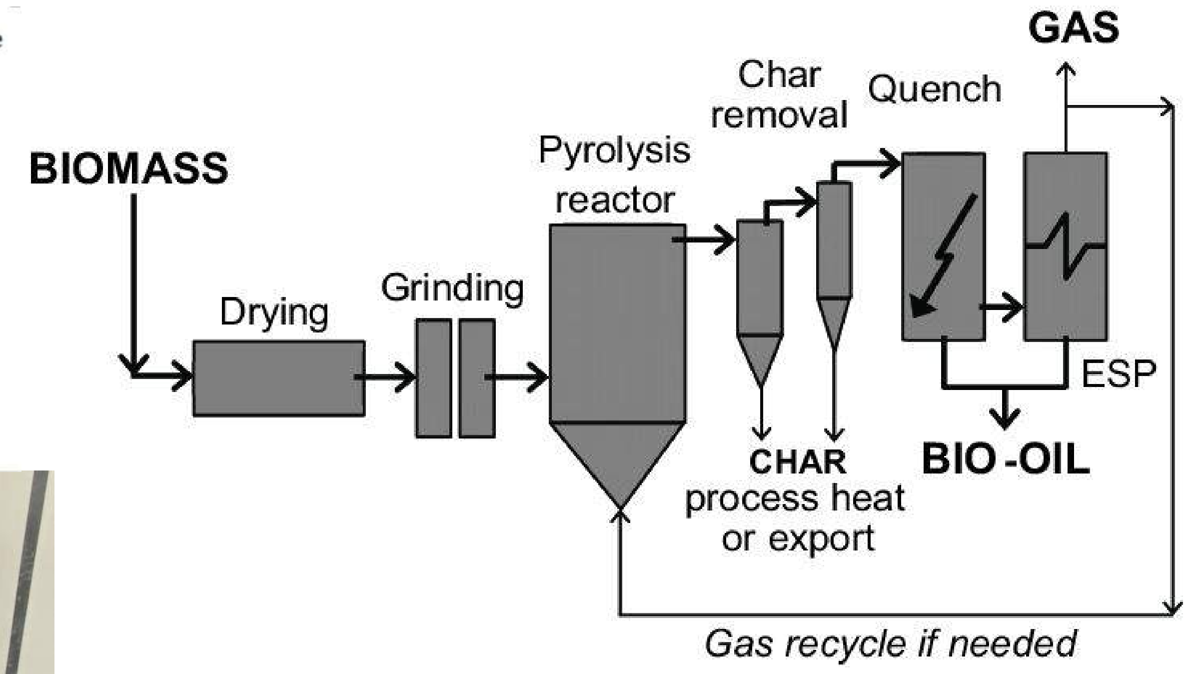


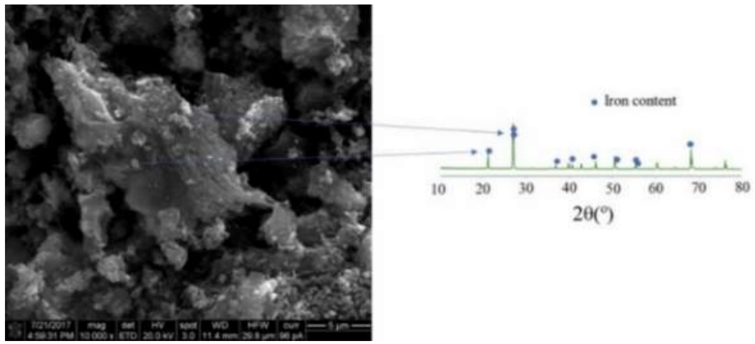
Figure source:
https://www.civilsdaily.com/news/what-is-pyrolysis/

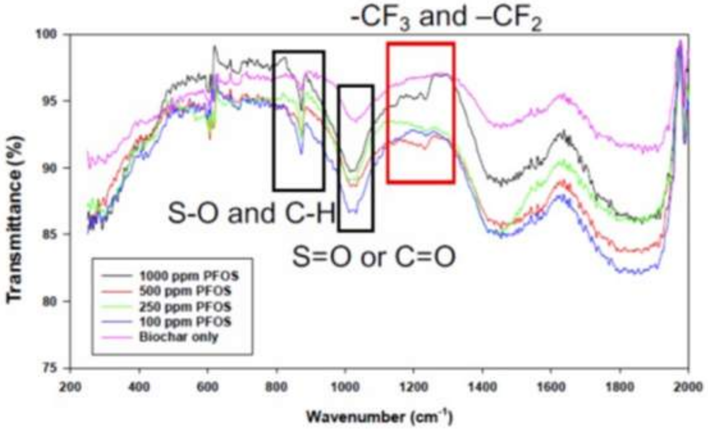
Engineered biochar production

- Biochar to be produced using switchgrass (SG), water oak (WO), and biosolids (BS)
- To enhance PFAS adsorption, biochar to be engineered by 1) Fe_2O_3 impregnation (Fe), 2) coating with graphene oxide, and 3) coating with carbon nanotubes (CNT)

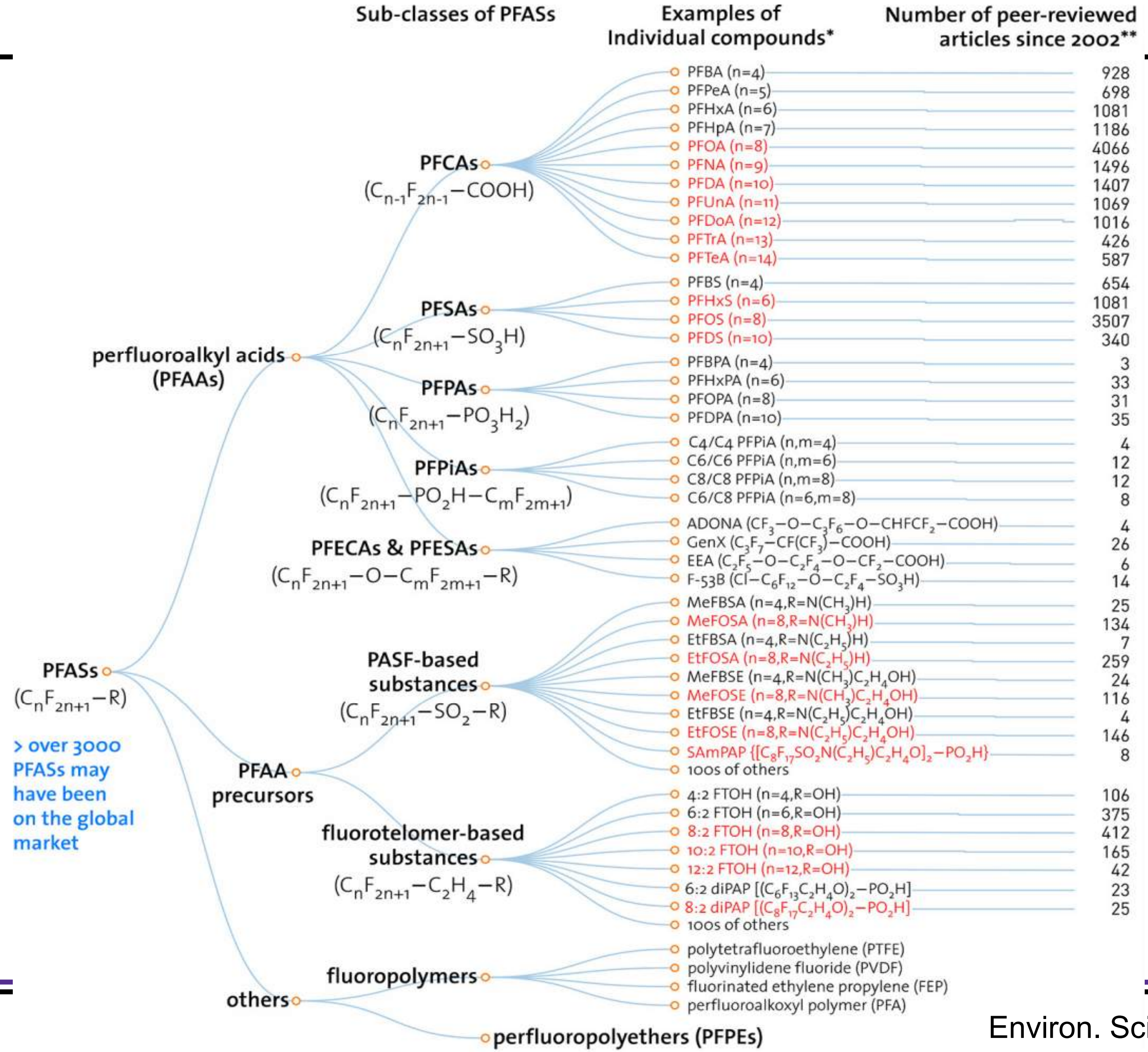
Split Tube Furnace

Biochar



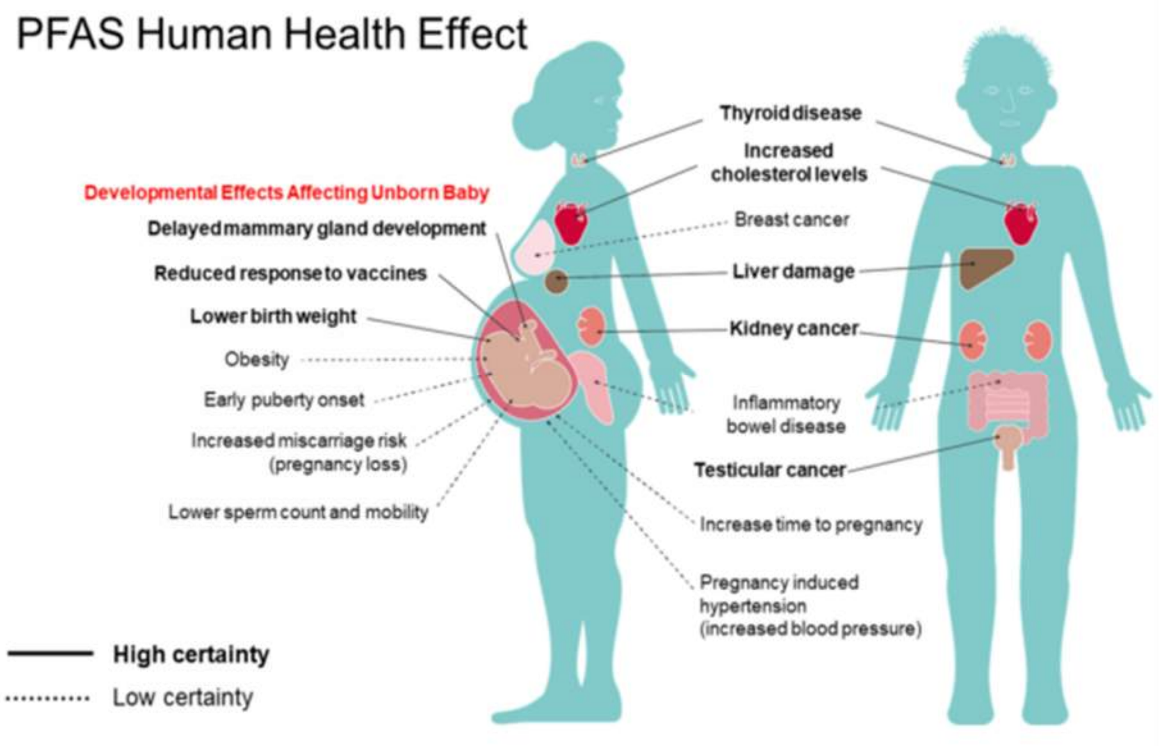


What is PFAS?



Environ. Sci. Technol. 2018, 52, 5, 3325

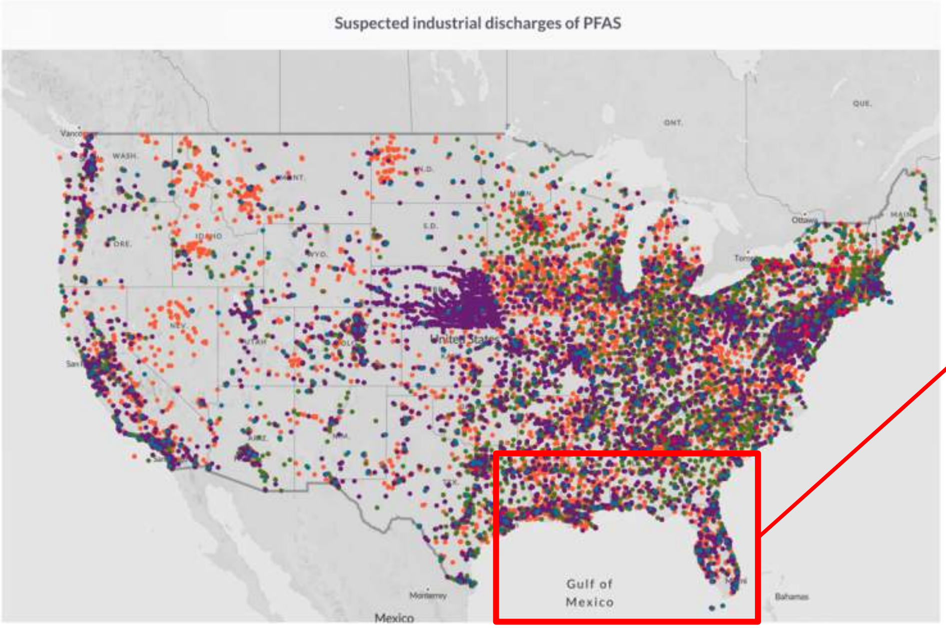
What are major concerns of PFAS?

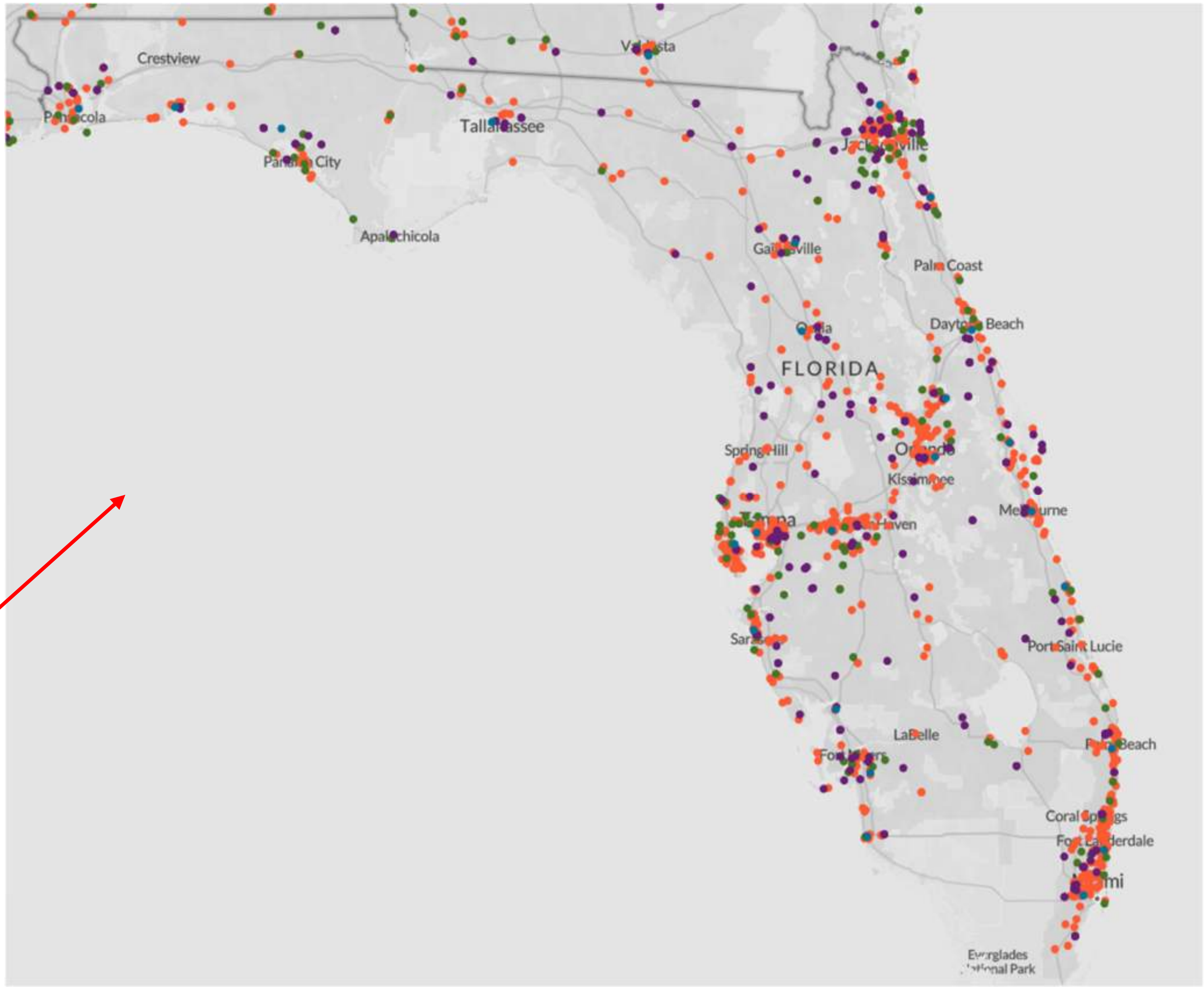


- Pervasive, persistent, and bioaccumulative
- Exposed to PFAS in a variety of Ways
- Measurable level in 98% American bodies
- Associated with adverse health effects
- September 6, 2022, EPA designated PFOA and PFOS as “hazardous substances” under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), also known as the Superfund.

PFAS in discharge

- Known users of PFAS
- Suspected users of PFAS
- Airports previously required to use AFFF
- Landfills and waste disposal facilities
- Sewage and waste treatment plants





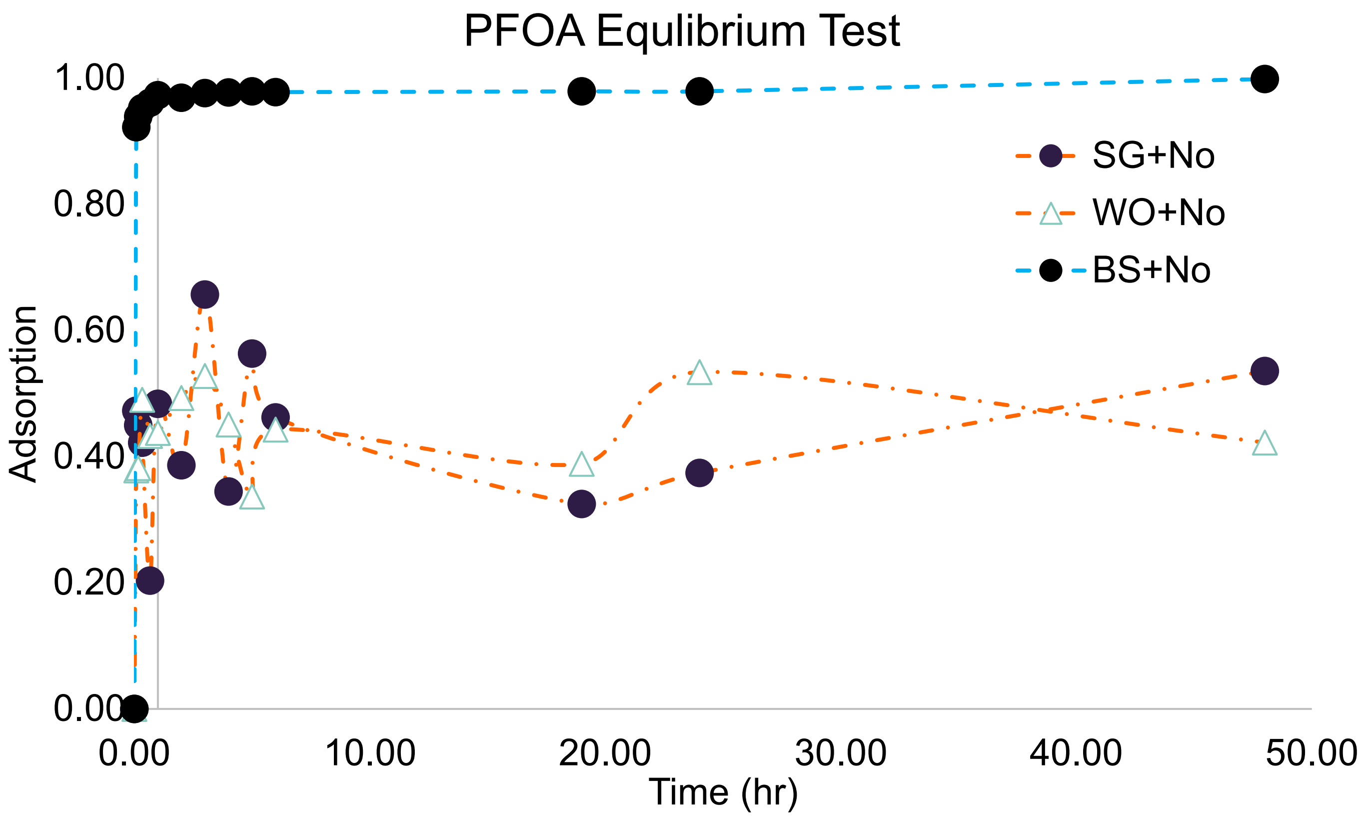
2024, Environmental Working Group.

PFOA adsorbent efficiencies

Sorbent types	Sorbate: Sorbent Ratio (Bench Test)	PFOA concentration	*Maximum adsorption capacity q_e	Removal efficiency
Powered Activated Carbon	0.25 g: 100 mL	5 - 40 mg/L	39.85 µmol/g	0.99
Powered Activated Carbon	0.01 g: 100 mL	20 - 250 mg/L	390 µmol/g	-
Granular Activated Carbon	0.01 g: 100 mL	20 - 250 mg/L	670 µmol/g	-
Anion-Exchange Resin	0.01 g: 100 mL	20 - 250 mg/L	2920 µmol/g	-
Polyaniline Emeraldine Salt Nanotubes	0.02 g: 100 mL	25 - 300 mg/L	3987. 25 µmol/g	-
H_3PO_4 - Activated Carbon	0.15 g: 100 mL	0.125 - 1 mg/L	139.83 µmol/g	0.90
KOH - Activated Carbon	0.15 g: 100 mL	0.125 - 1 mg/L	190.55 µmol/g	0.95
Chemically Activated Maize Tassel	0.1 g: 100 mL	0.025 mg/L	920 µmol/g	-
Biosolid Biochar	2 g: 100 mL	0.36 - 24 µg/L	N/A	0.2 to 0.9
Amino-Functionalized Graphene Oxide Aerogel	0.1 g: 100 mL	10 mg/L	3803.70 µmol/g	0.99
Granular Activated Carbon	0.05 g: 100 mL	1 mg/L	86.2 µmol/g	0.72
Softwood-derived Biochar	0.05 g: 100 mL	1 mg/L	52.06 µmol/g	0.60

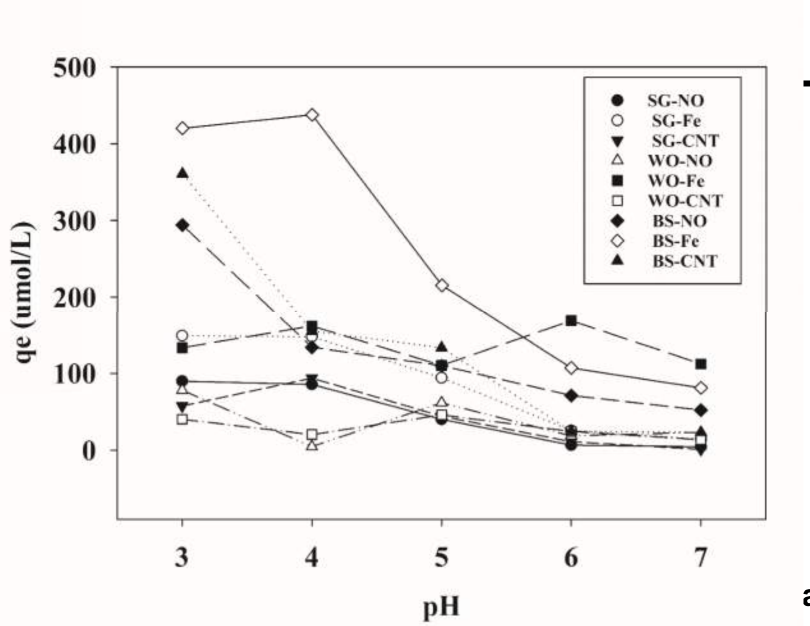
Environ. Sci.: Water Research & Technology, 7 (3) (2021), 638-649; Environ. Sci. Pollut. Control Ser., 24 (14) (2017), 13107-13120; Environ. Sci. Technol., 52 (11) (2018), 6300-6308; J. Hazard Mater., 169 (1) (2009), 146-152; Water Res., 42 (12) (2008), 3089-30; Water, Air, Soil Pollut., 231 (9) (2020), 485 Environ. Technol., 42 (12) (2021), 1798-1809; Sci. Total Environ., 783 (2021), 147041; Colloid. Surface., 479 (2015), 60-67

Biosolid biochar-PFAS adsorption



	Isotherm parameter	
	Q_m (μmol/g)	R^2
BS+No	194.00	0.97
BS+Fe	469.65	0.61
BS+CNT	236.40	0.92

Impacts of water chemistry



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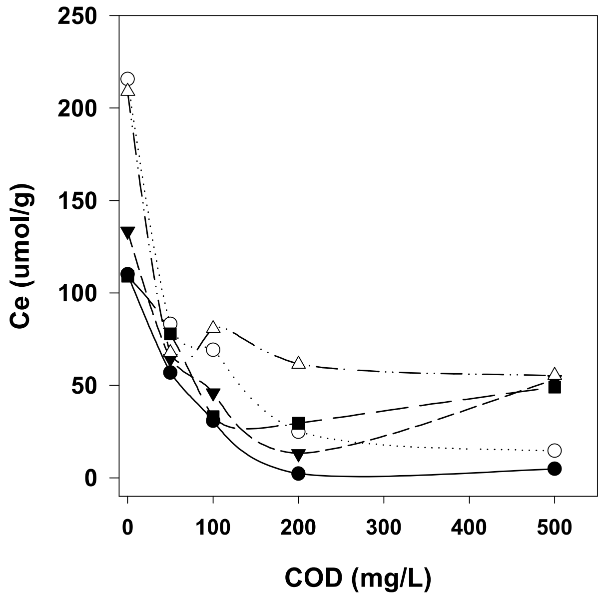
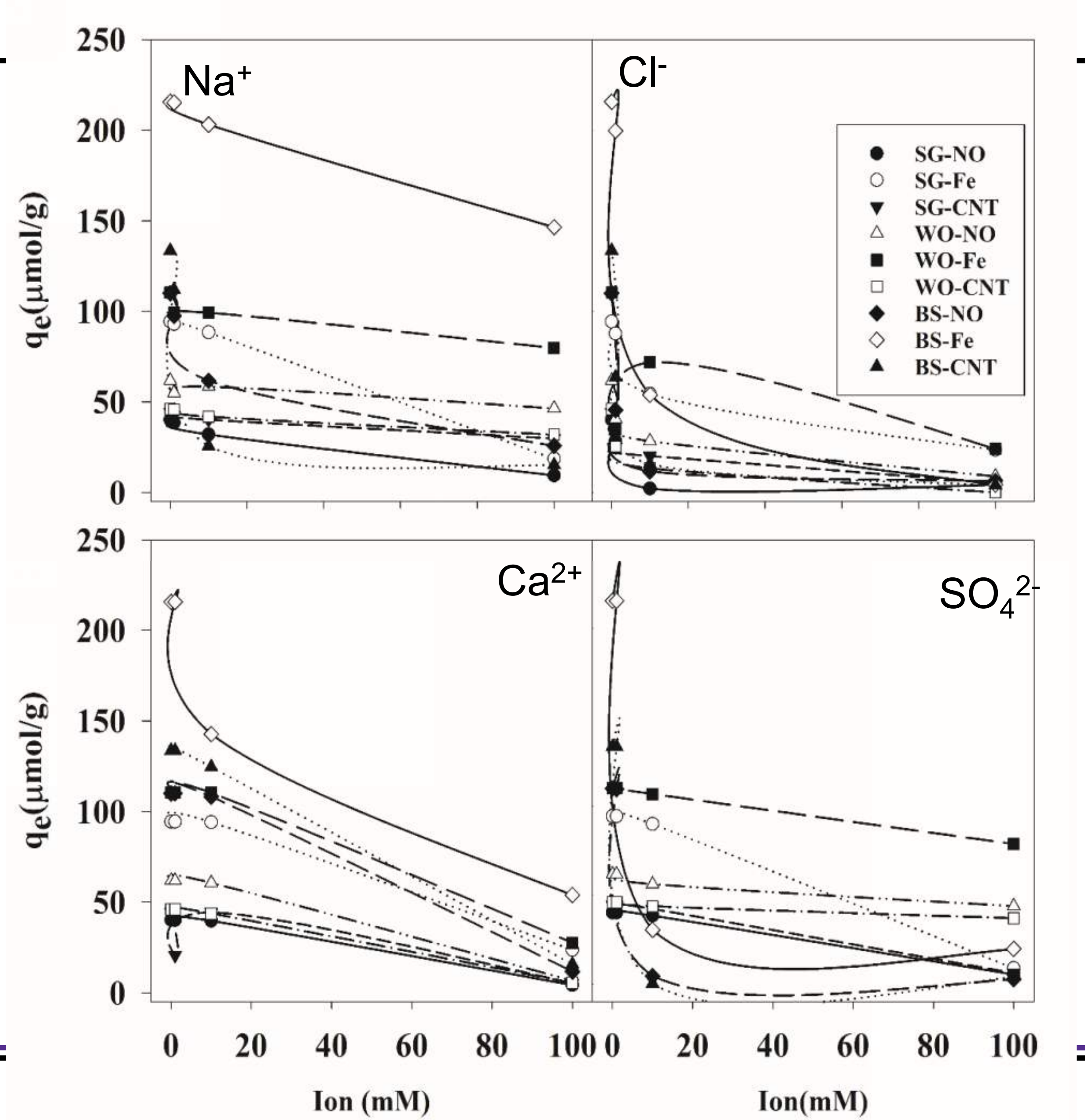
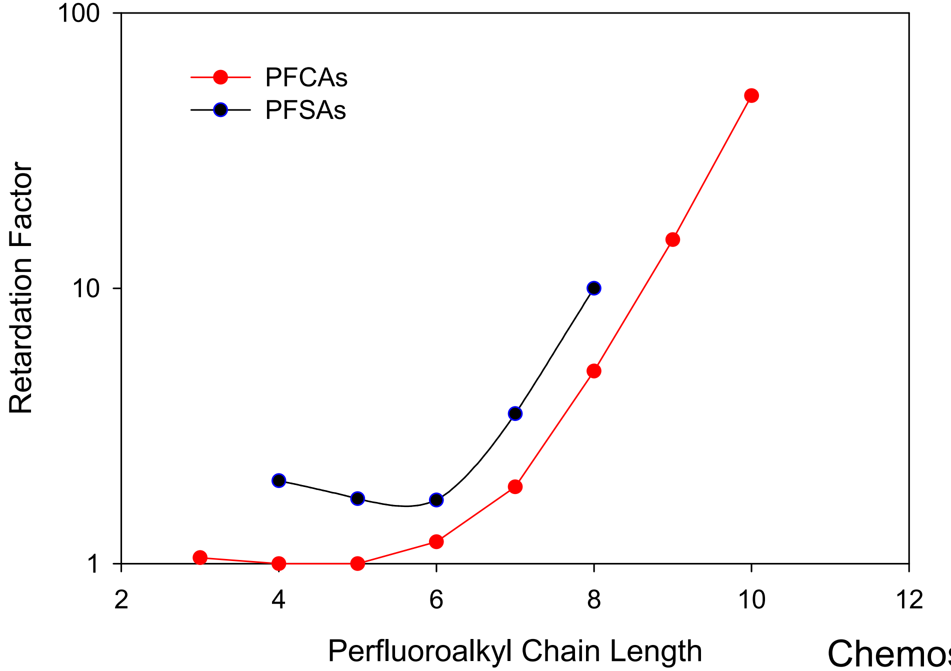




Journal of Cleaner Production, 2022, 340, 130742.

PFCAs vs PFSAs : PFAS transport

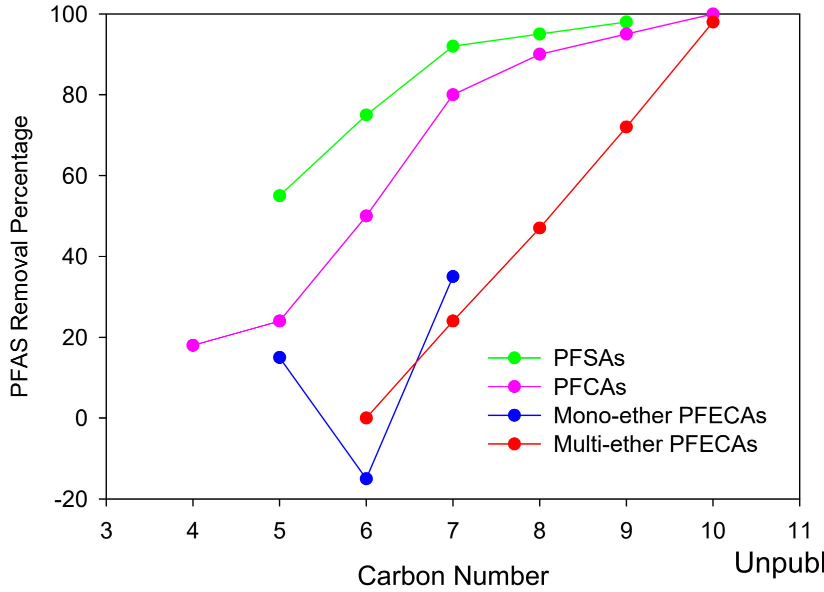
- Perfluorosulfonic acids (PFSAs) to retain to a greater extent than perfluorocarboxylic acids (PFCAs) of equal C-F chain-length
  - PFSAs to transport to a lesser extent
  - PFSAs to display a greater retardation
- Retardation to increase with C-F chain-length for both PFCAs and PFSAs



Chemosphere, 2022, 303, 135160

Adsorption of PFASs with C-F Replacement

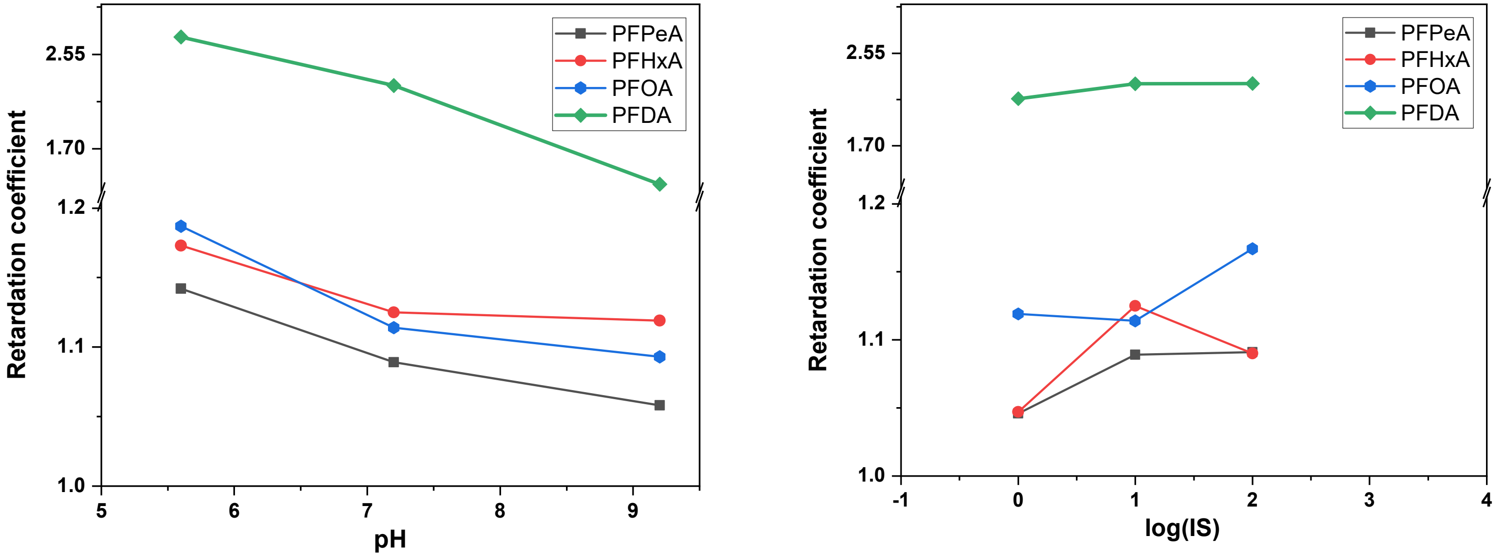
- Replacement of CF_2 group with ether oxygen atom to decrease affinity of PFASs
- Perfluoroalkyl ether carboxylic acids (PFECAs) to exhibit lower adsorption than those of PFCAs and PFSAs of the same chain length
- Replacement of additional CF_2 groups with ether groups to have minor affinity change among PFECAs



Unpublished data

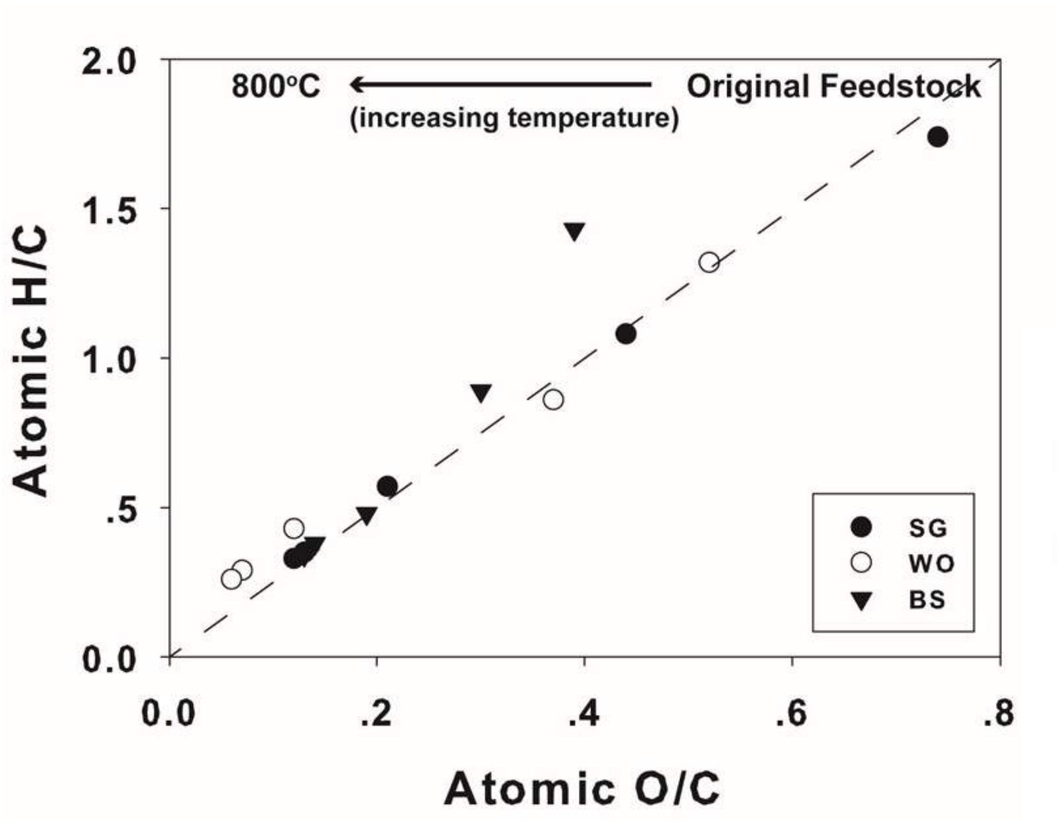
Impacts of water chemistry: PFAS transport

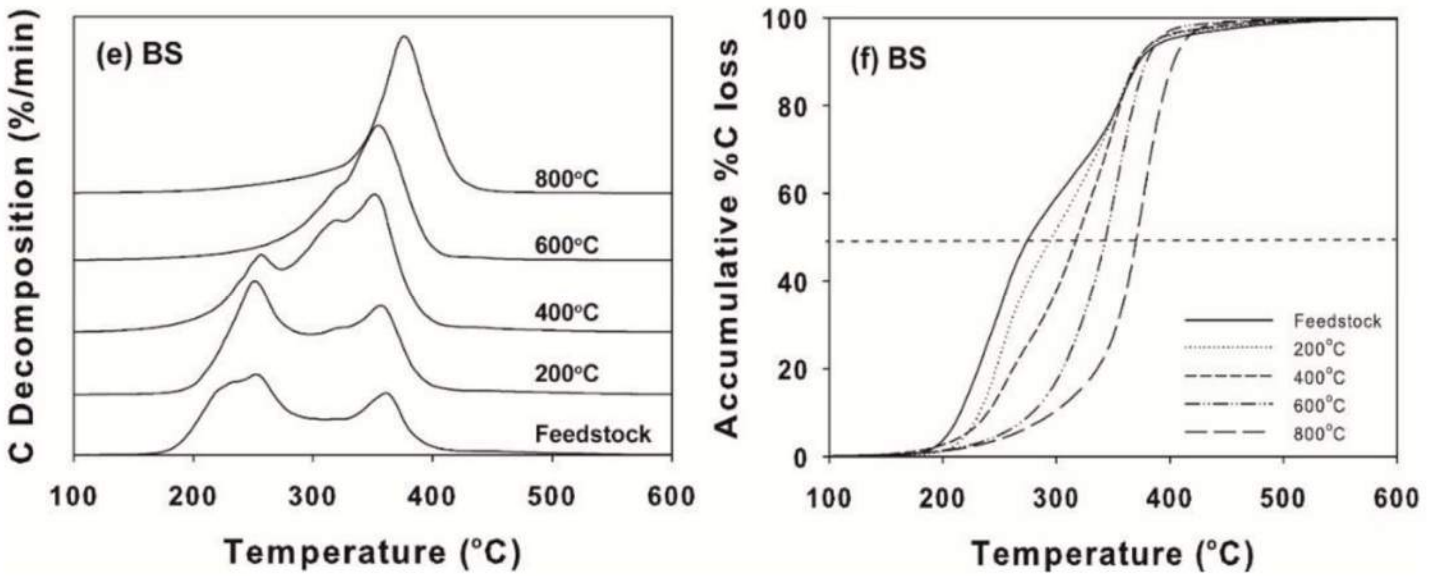
- Chain length to have limited impact on PFCA transport when C-F chain length < 8, such as PFPeA (5), PFHxA (6), and PFOA (8) under various pH and ionic strength conditions
- pH and ionic strength to have significant effect for C-F chain >8 such as PFDA (10)
- Divalent cation of Ca^{2+} to inhibit both short-chain and long-chain PFCAs, more pronounced for long-chain ones



Unpublished data

Biochar characterization





BS: Biosolid

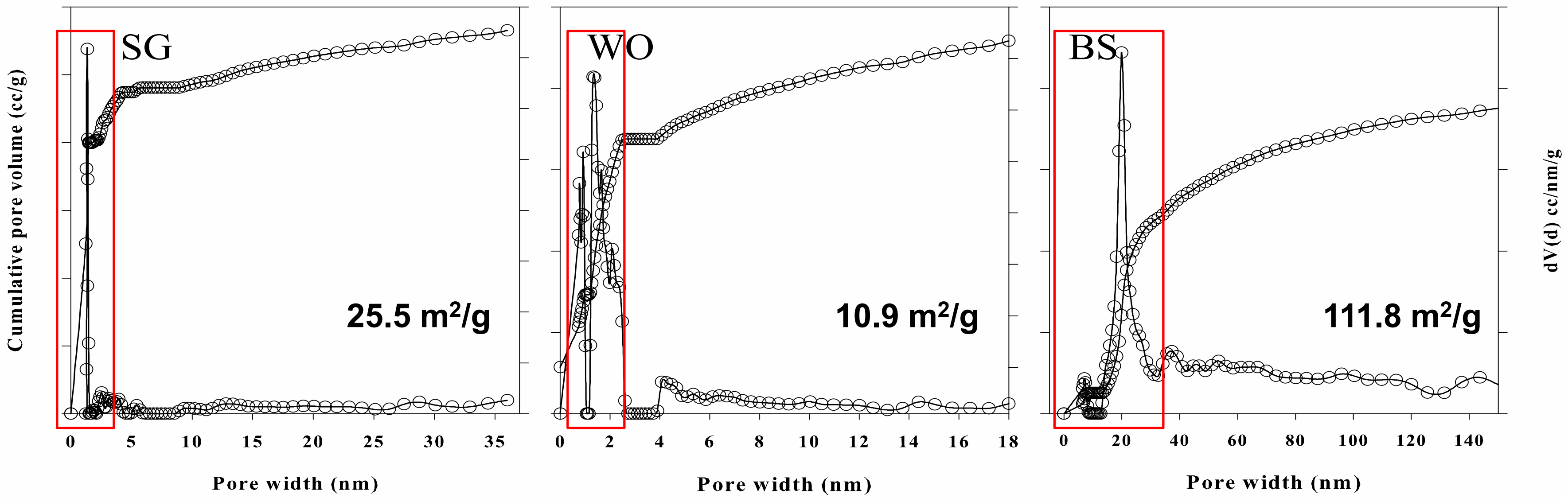
Waste Management, 2018, 78, 198-207
(credit to Simeng)

Biochar characterization

	C (%)	N (%)	H (%)	O (%)	SSA (m²/g)	n (nm)
BS+No	56.0	10.4	0.03	33.6	111.78	4.15
BS+Fe	59.1	11.0	0.02	29.4	52.30	4.15
BS+CNT	57.0	11.9	0.02	28.0	147.12	3.96

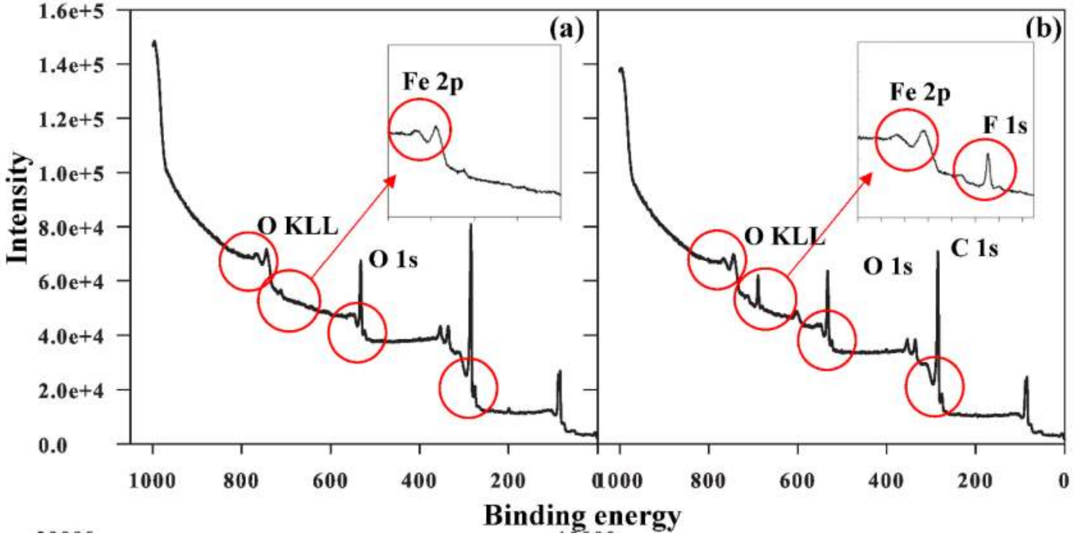
SSA: Specific surface area
n: Pore size

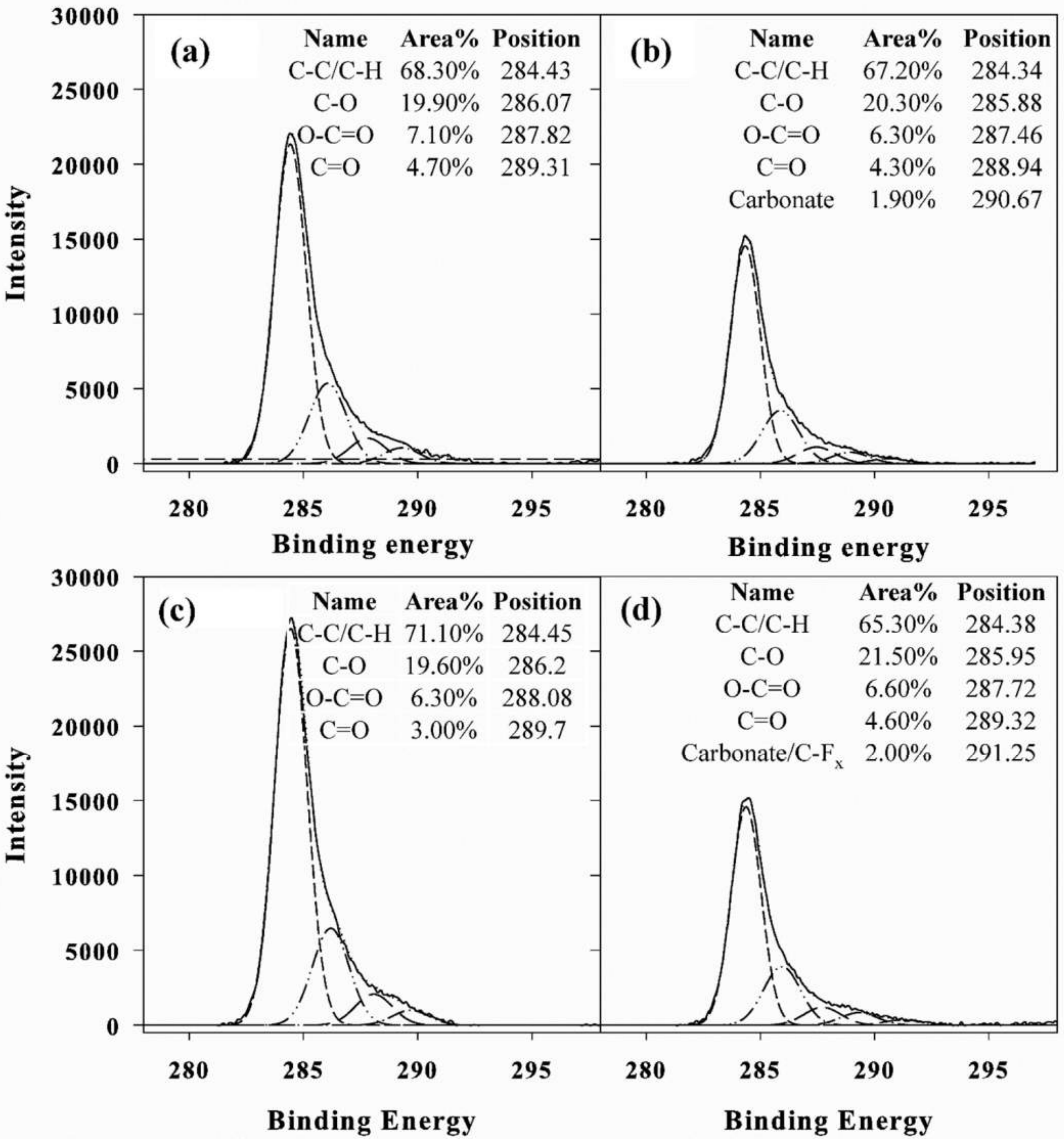
Pore size distribution curves of SG, WO, and BS biochar



Journal of Cleaner Production, 2022, 340, 130742.

PFAS adsorption to engineered biochar





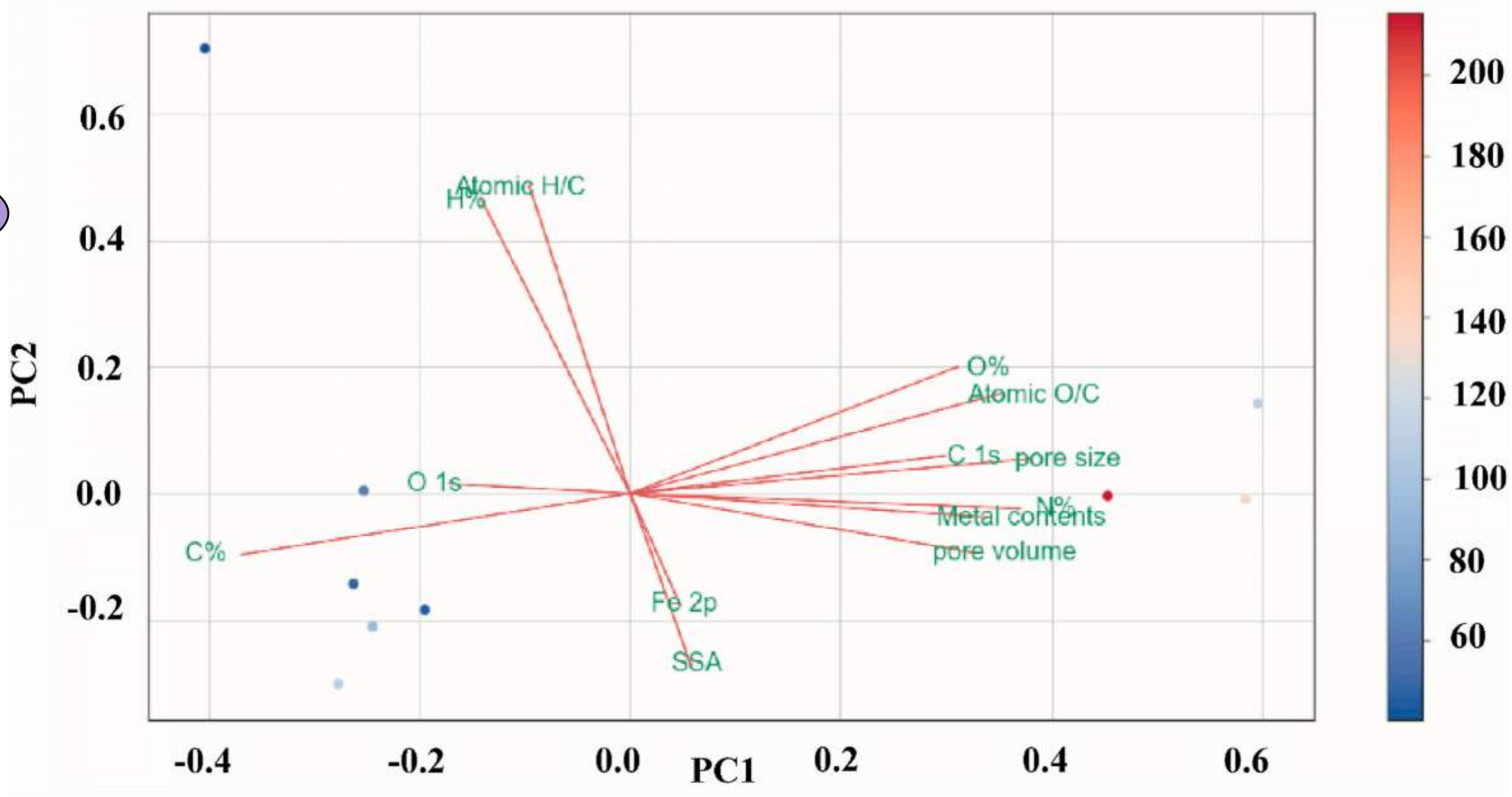
Journal of Cleaner Production, 2022, 340, 130742.

What leads to high adsorption capacity?

Functional groups

Elemental composition

Pore size and volume



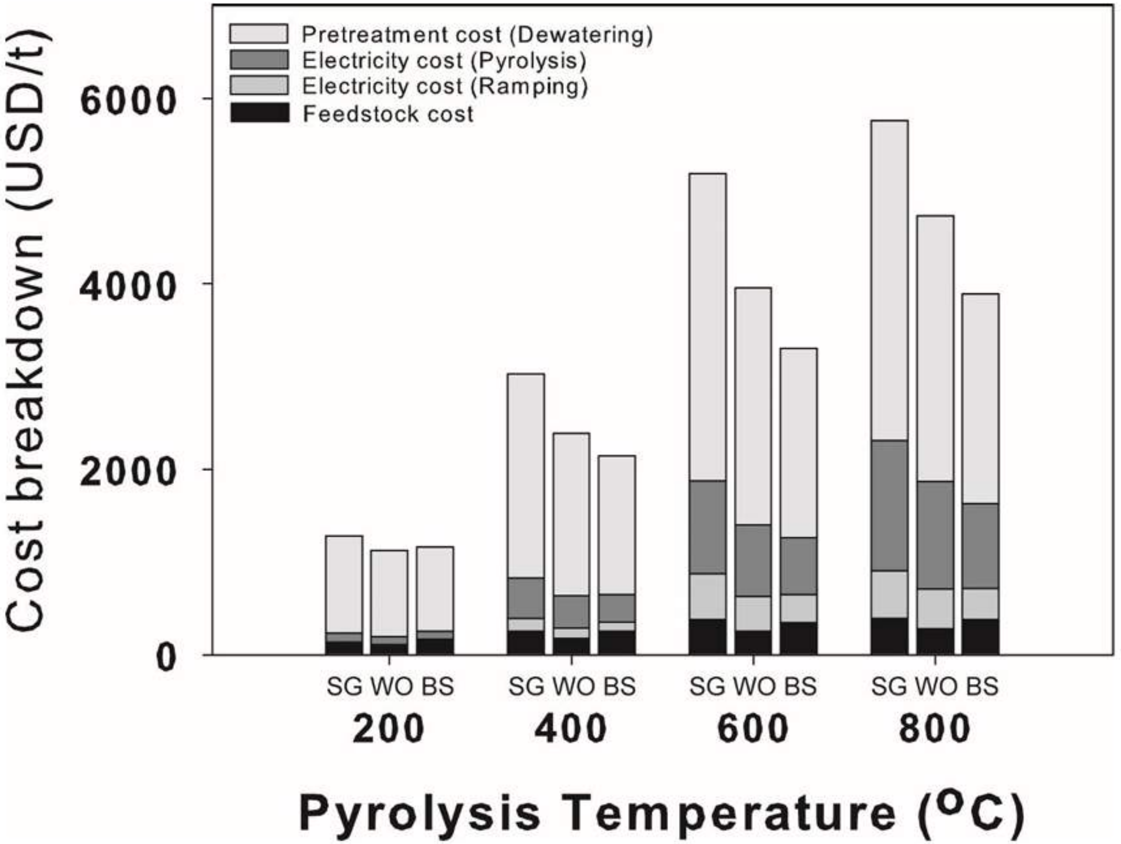
Journal of Cleaner Production, 2022, 340, 130742.

Cost analysis

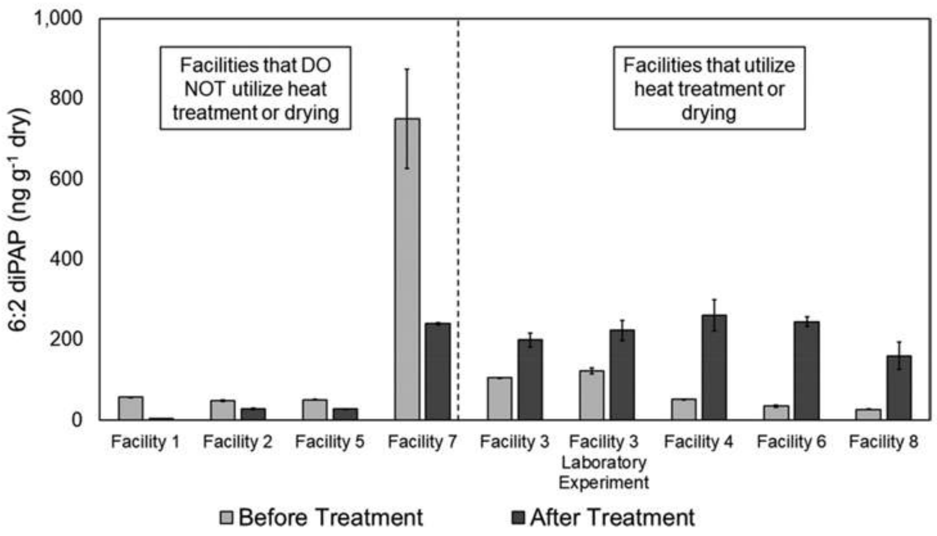
$$Total\ cost = \frac{P_{t=60^oC} \times \Delta t_{dry}}{M_{biochar}} + \frac{\sum P_{t=i}\,\Delta t_{ramp} + P_{t=desired} \times \Delta t_{pyr}}{M_{biochar}} + \frac{C_{feedstock}}{Y_{biochar}\theta_{feedstock}}$$

Waste Management, 2018, 78, 198-207
(credit to Simeng)

$M_{biochar}$ is the mass of biochar produced;
$P_{t=60^oC}$ (kW) is the required power for pretreatment;
$P_{t=i}$ (kW) is the required power for the temperature *i* °C;
$\Delta t_{dry}, \Delta t_{pyr}$, Δt_{ramp} are the time for drying, ramping and pyrolysis;
$C_{feedstock}$ is the unit cost of feedstock (USD/t), typically 65 USD/t for SG, 45 USD/t for WO, and 60 USD/t for BS;
$Y_{biochar}$ is the yield of biochar;
$\theta_{feedstock}$ is the water content of the feedstock.



PFAS in biosolid-preliminary results



Environment, Science and Technology, 2023, 57, 3825-3832

PFAS Types		Biosolid Biochar			Raw Biosolid		
		Fe-BS	CNT-BS	BS-No-Modified	BS-Raw-R1	BS-Raw-R2	BS-Raw-R3
PFCA	PFBA	U	U	U	2.30	3.64	U
	PFPeA	U	U	U	U	U	U
	PFHxA	U	U	U	U	U	U
	PFHpA	U	U	U	U	U	U
	PFOA	U	U	U	U	U	U
	PFNA	U	U	U	U	U	U
	PFDA	U	U	U	U	U	U
	PFUnA	U	U	U	U	U	U
	PFDoA	U	U	U	U	U	U
	PFTriA	U	U	U	U	U	U
	PFTreA	U	U	U	U	U	U
PFSA	PFBS	5.38	U	U	U	11.70	U
	PFHxS	U	U	U	U	U	U
	PFOS	U	U	U	0.31	U	1.23
	4:2 FTS	U	U	U	U	U	U
	6:2 FTS	U	U	U	0.03	0.34	U
	8:2 FTS	U	U	U	U	U	U
	PFPeS	U	U	U	U	U	U
	PFHpS	U	U	U	U	U	U
	PFNS	U	U	U	U	U	U
	PFDS	U	U	U	U	U	U
	N-EtFOSAA	U	U	U	U	U	U
	N-MeFOSAA	U	U	U	U	U	U
	PFOSA	U	U	U	U	U	U

U: under detection limits (in a range of 10 ppb)

Unpublished data

Case study:
Apply biochar in landfill treatment train

Feasible and effective PFAS treatment in landfill?

Cost-effective?

Large volume?

PFAS precursor?

Remediation residual?

Complicated water matrix?

Short-chain PFAS?

Remediation

via **Solar Photocatalysis**, **Advanced Oxidation/Reduction**
Aqueous PFAS Destruction or Solid Thermal **Incineration**
Non-Thermal Plasma Degradation

Management

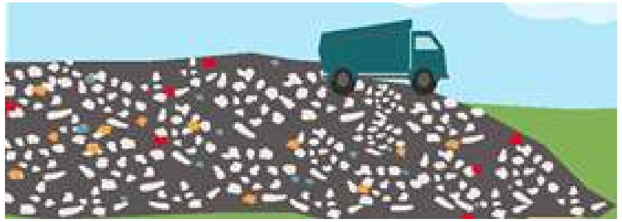
PFAS Remediation **Residuals**

PFAS in landfill

Landfill leachate	PFOA (nmol/L)	PFOS (nmol/L)
US[1]	2.42	0.20
Florida[2,3]	3.63 (600 ng/L)	1.13 (550 ng/L)
Michigan[4]	2.87	0.57
North Carolina[5]	2.01	0.48

Total PFAS concentration in the leachate is 31000* ng/L

*averaged number from three selected Florida landfill

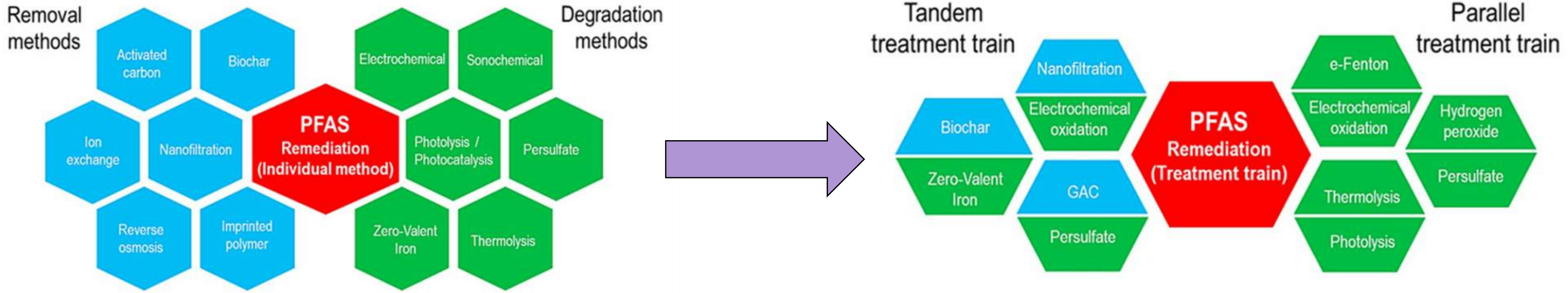


- Widely spread in **closed (31 ng/L)** and **active** landfills (**up to 12,800 ng/L**).
- Estimated mass flux of $\sum_{26}$PFAS released from landfills was **36.8 g/ha-yr[1]**.
- **97%** of PFAS was found in leachate[1].
- PFAS from landfill will be leased for **over 40 years[1]**.
- Highly concentrated: **more than 10 times** than the paired WWTP influent

[1]Data by March 2024

Waste Management, 2024, 175, 348-359
Environ. Sci.: Water Res. Technol., 2020,6, 1300-1311

PFAS – What is current issues



Journal of Hazardous Materials, 2020, 386, 121963

Remediation

via **Solar Photocatalysis**, **Advanced Oxidation/Reduction**
Aqueous PFAS Destruction or Solid Thermal **Incineration**
Non-Thermal Plasma Degradation

Management

PFAS Remediation **Residuals**

Ideally…Selective adsorption

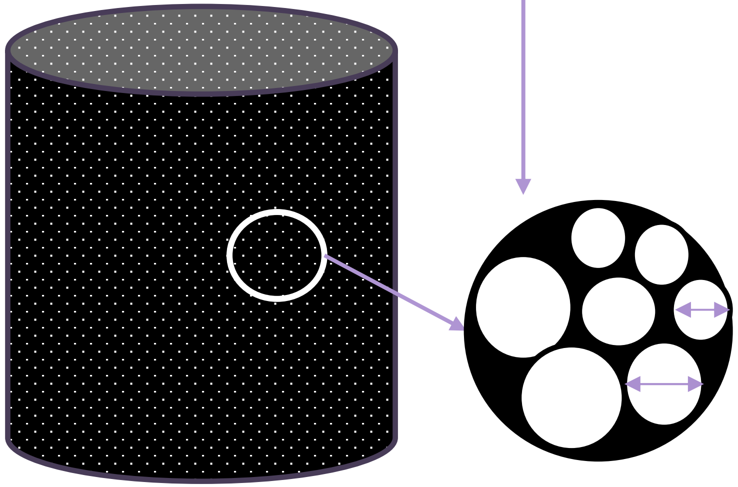
Biosolid

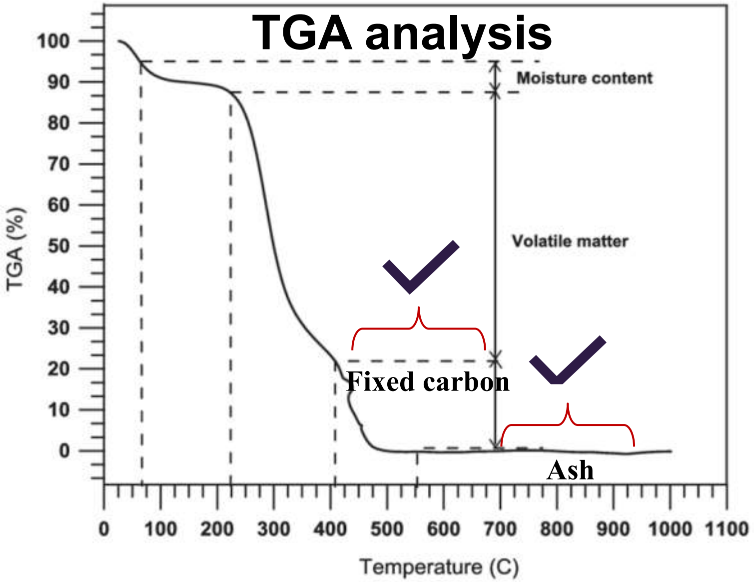
Pyrolysis

Activation

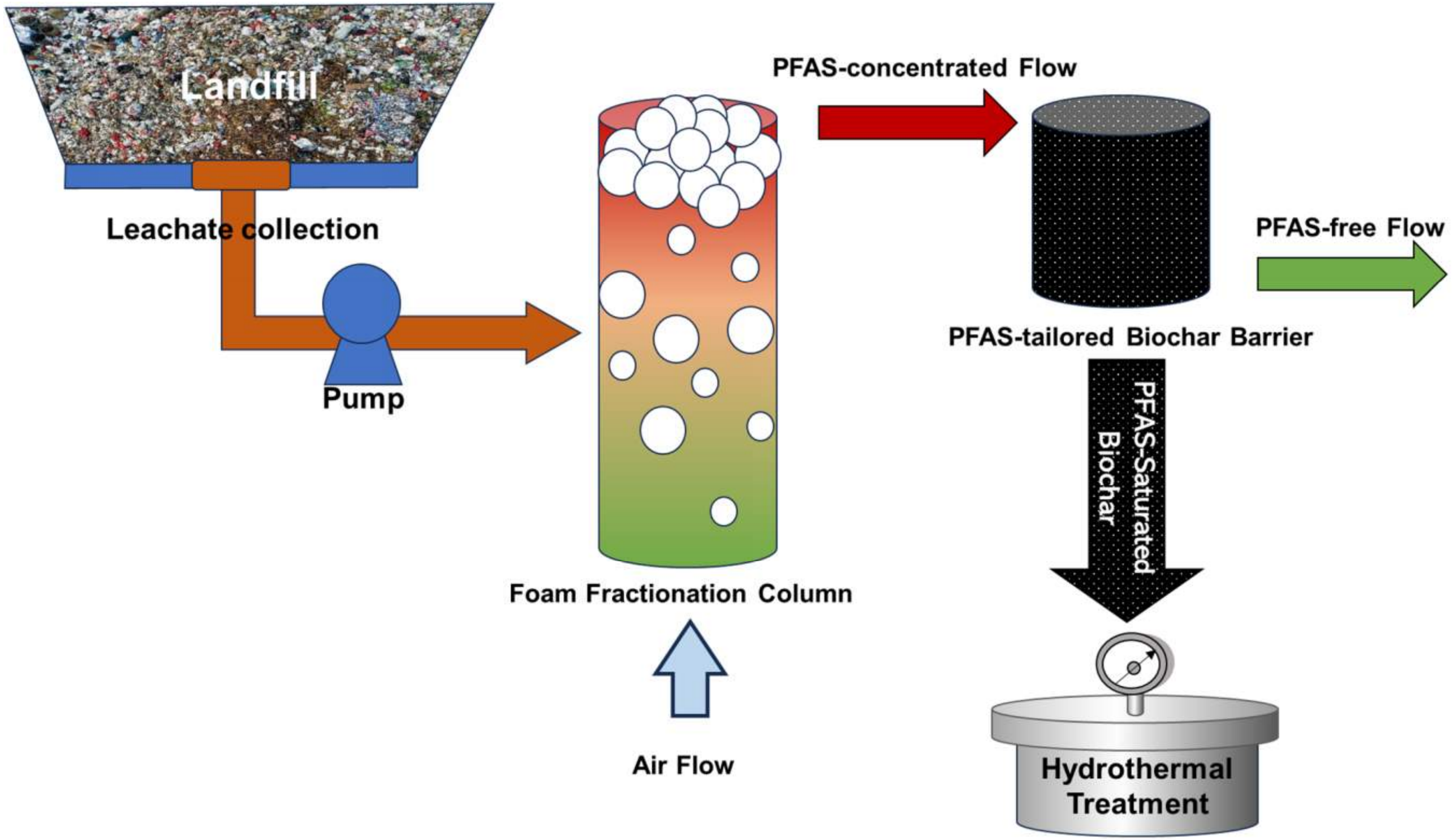
Size Design

Pore size (nm)

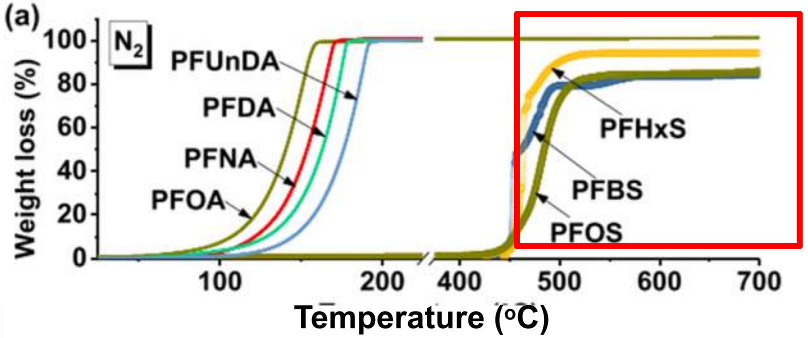




Mass balance of the treatment train (on-going)

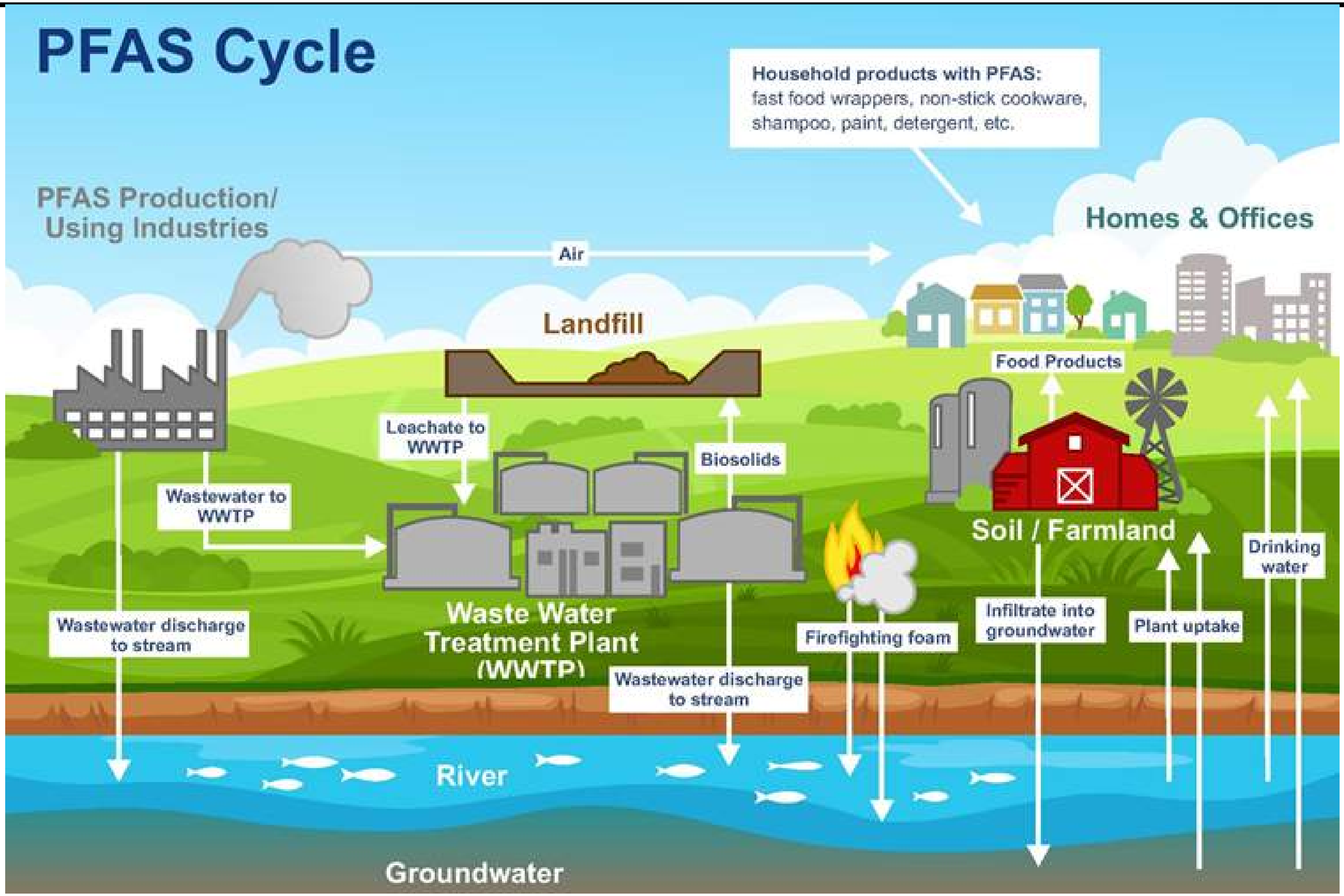


TGA analysis of PFAS destruction on **Spent Granular Activated Carbon**



Environ. Sci. Technol. Lett. 2020, 7, 5, 343–350

Questions?


PFAS Cycle
Household products with PFAS:
fast food wrappers, non-stick cookware, shampoo, paint, detergent, etc.
PFAS Production/ Using Industries
Air
Homes & Offices
Landfill
Food Products
Leachate to WWTP
Biosolids
Wastewater to WWTP
Soil / Farmland
Drinking water
Waste Water Treatment Plant (WWTP)
Infiltrate into groundwater
Wastewater discharge to stream
Firefighting foam
Plant uptake
Wastewater discharge to stream
River
Groundwater

FLORIDAPOLY

Acknowledgement

Sponsors:

Hinkley Center for Solid and Hazardous Waste Management

Florida Water Environment Association | Biosolids Committee

EREF | Environmental Research & Education Foundation™
Lighting the way towards a more circular economy

Collaborators: Dr. Gang Chen (FAMU-FSU COE), Dr. Simeng Li (CalPoly), and Lin Qi (Ph.D. Candidate)

Florida Agricultural & Mechanical University — Head, Heart, Hand, Field — 1887

Florida State University — Vires, Artes, Mores — 1851

CalPoly Pomona

HARVEST
TECHNOLOGY

University Hohenheim

- 26 diploma thesis
- 3 doctorate thesis
- 7 R&D projects:
  - wastewater sludge
  - renewable energy sources

University Stuttgart

- 7 diploma thesis
  - wastewater sludge
  - Biomatter waste
- 150 scientific publications

Active Solar Dryer™

Small WRF
1.000 – 30.000 PE

Drainage Dryer
Electr. Mole

Storage Dryer
Electr.Mole

THERMO-SYSTEM
INDUSTRIE- & TROCKNUNGSTECHNIK GMBH

solar

Medium WRF
10.000 – 200.000 PE

SolarBatch
Electr. Mole

SolarFlow
SludgeManager

SolarPlus
Solar + supp. heat

SmartDry
Belt dryer

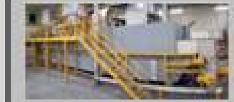
solar

Supp.Heat

Large WRF
> 200.000 PE

SolarBatch
Electr. Mole

SolarPlus
Solar + heat



SmartDry
Belt dryer

BlueDry
Solar+thermal drying

OpenBed
for arid climate

solar

Supp. Heat

Active Solar Dryer™ Thermo-System®

- Market – Leaders for solar & waste heat drying
- Over 200 installations world wide
- More than 400 Tilling Devices in operation

<u>We Offer Drying Solutions For:</u>

- Sludge / Biosolids
- Biowaste
- Timber
- Fire wood for Kiln

THERMO-SYSTEM
INDUSTRIE- & TROCKNUNGSTECHNIK GMBH

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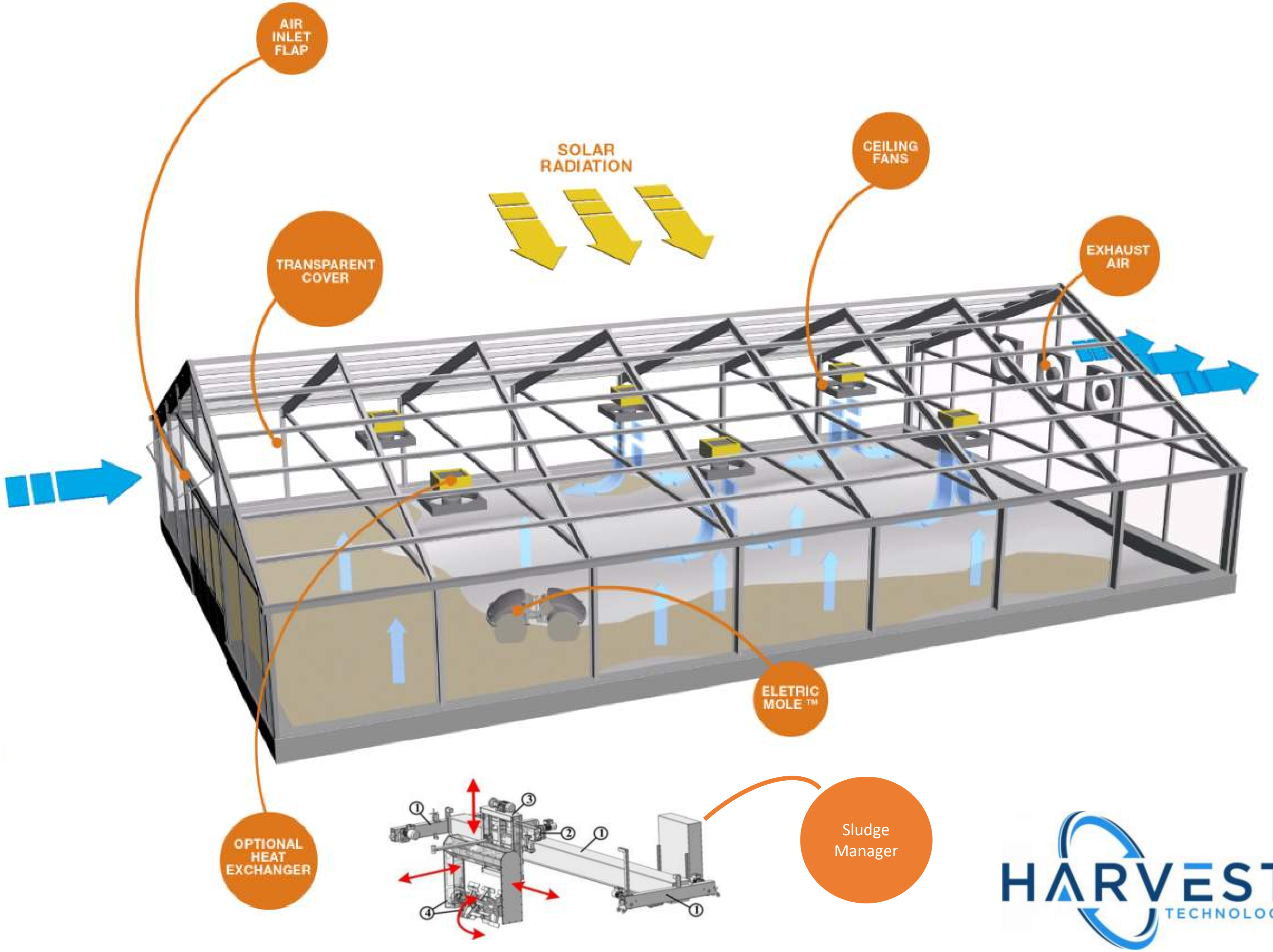
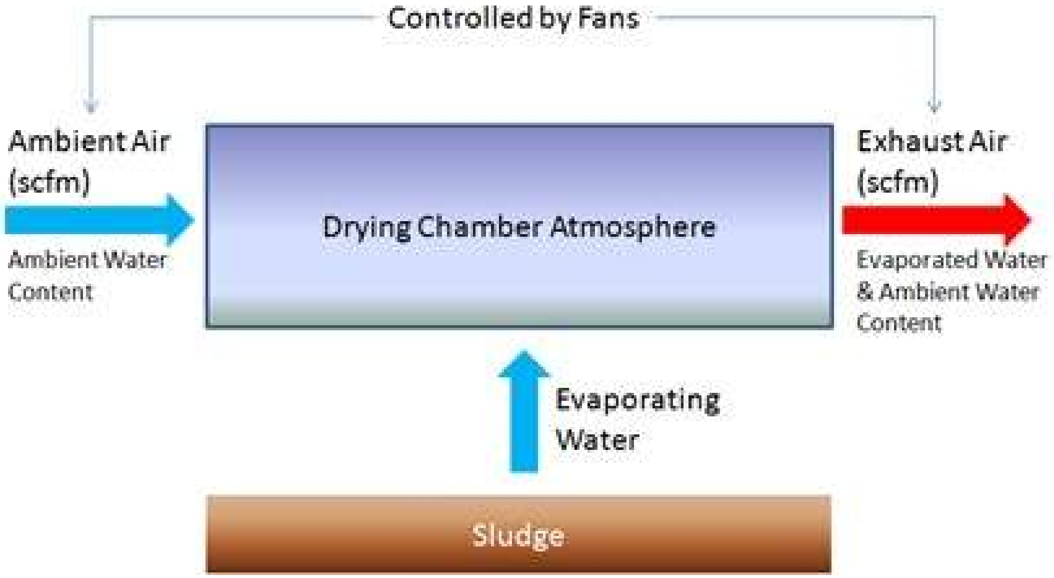
TECHNOLOGY

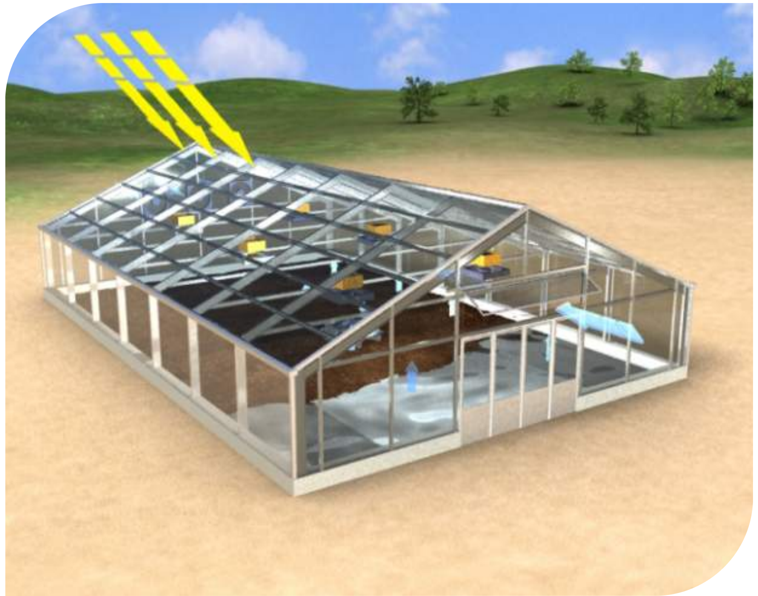
SolarBatch™
SolarFlow™
Operated
System



The Principle of Solar Drying

- Effective use of ambient conditions
  - Solar radiation
  - Ambient air
    - Air temperature & relative humidity
- Best possible "conditioning" of the biosolids
  - Mixing & turning
    - Avoid dry surfaces & anaerobic conditions
  - Optimize structure of the biosolids
    - Increase surface area
- Manage environment inside the drying chamber
  - Heat gain, heat loss & weather protection
    - Drying chamber
  - Air exchange
    - Exhaust fans & air flap
  - Air speed & distribution
    - Internal fans
  - Biosolids conditioning
    - Turning Device





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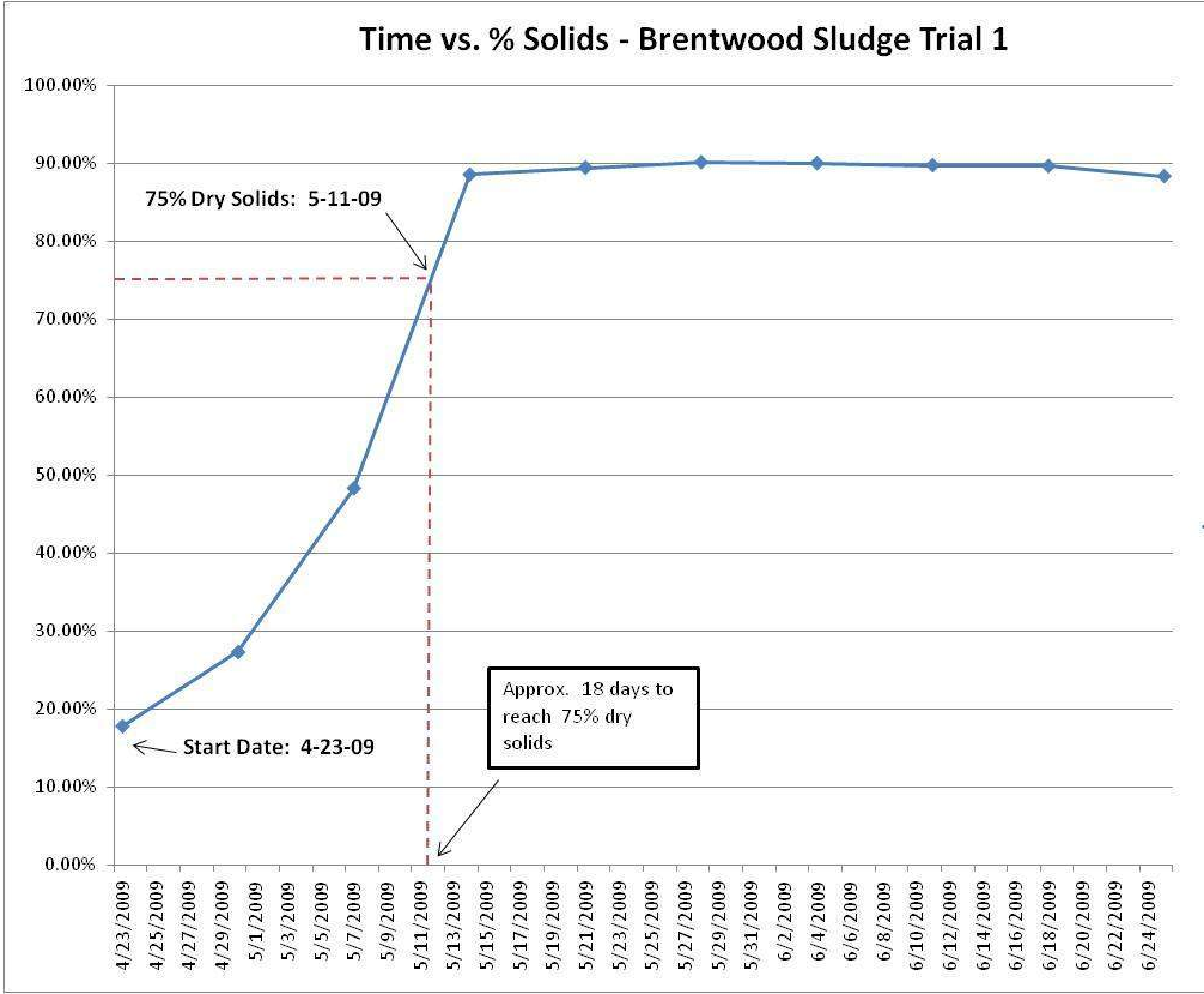
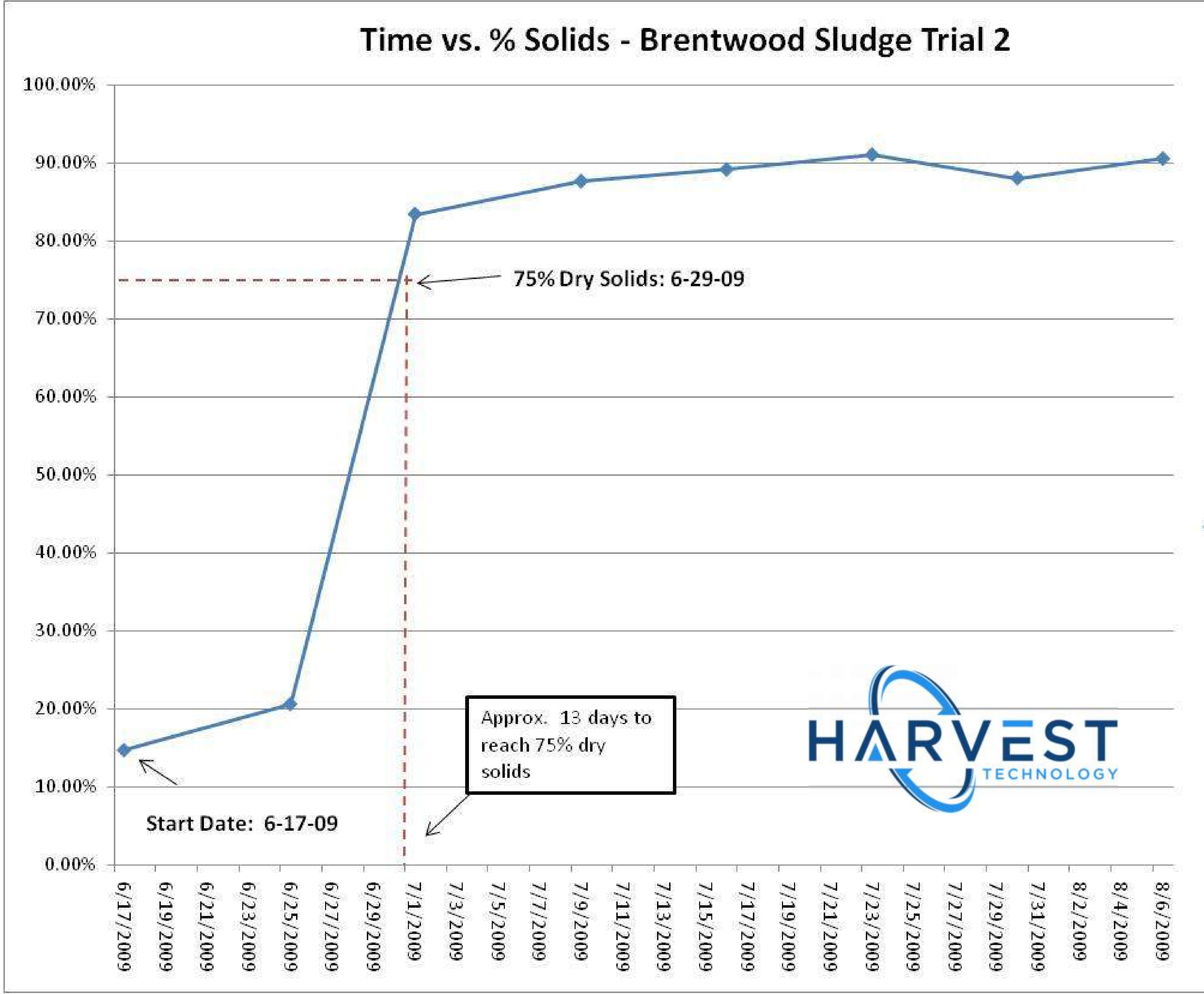
HARVEST
TECHNOLOGY

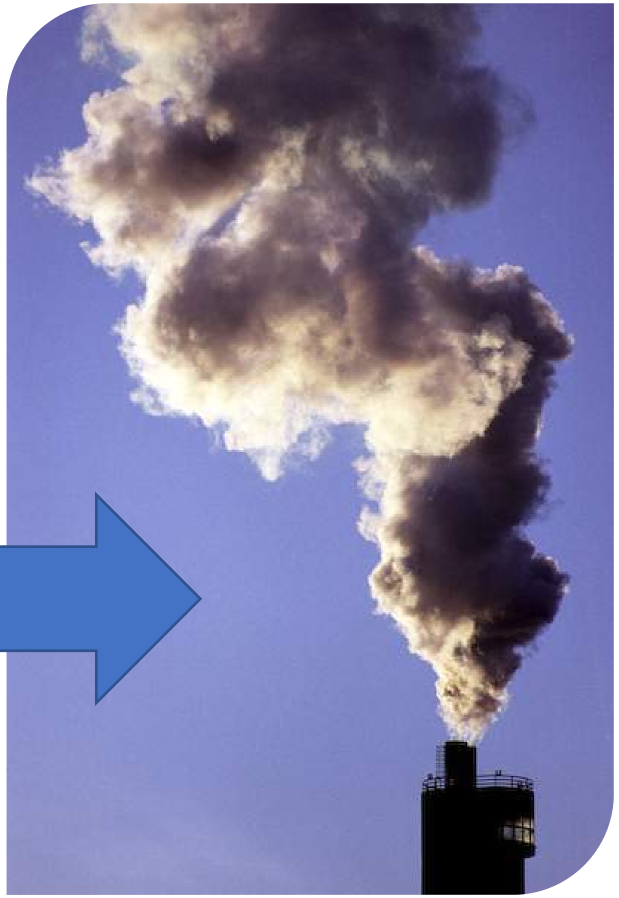



Time vs. % Solids - Brentwood Sludge Trial 2
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
75% Dry Solids: 6-29-09
Approx. 13 days to reach 75% dry solids
Start Date: 6-17-09
6/17/2009
6/19/2009
6/21/2009
6/23/2009
6/25/2009
6/27/2009
6/29/2009
7/1/2009
7/3/2009
7/5/2009
7/7/2009
7/9/2009
7/11/2009
7/13/2009
7/15/2009
7/17/2009
7/19/2009
7/21/2009
7/23/2009
7/25/2009
7/27/2009
7/29/2009
7/31/2009
8/2/2009
8/4/2009
8/6/2009
HARVEST TECHNOLOGY

The Concern with drying Sludge / Biosolids

- It requires lots of energy!
  - 90 – 130 kWh per ton of water evaporated (depending on temperature level/moisture content)
  - Thermal Energy Requirement
    - Natural Gas
    - Heating Oil

CO_2 Production

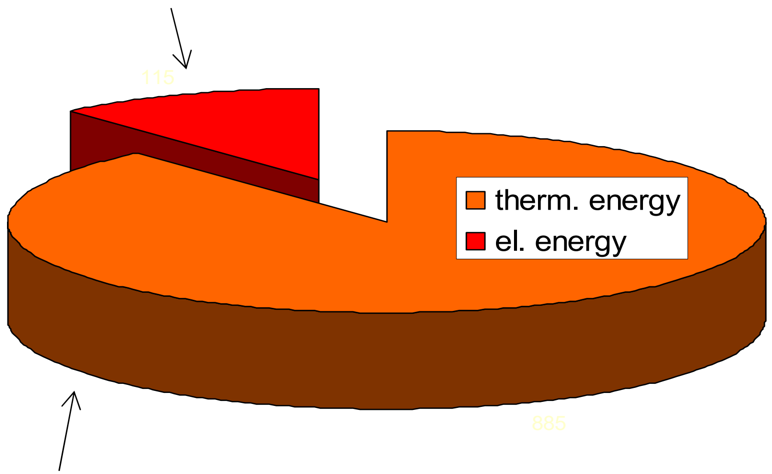


- Energy is typically derived from the burning of fossil fuels

! 1,000 kWh from Stuttgart University research on high temperature dryers !

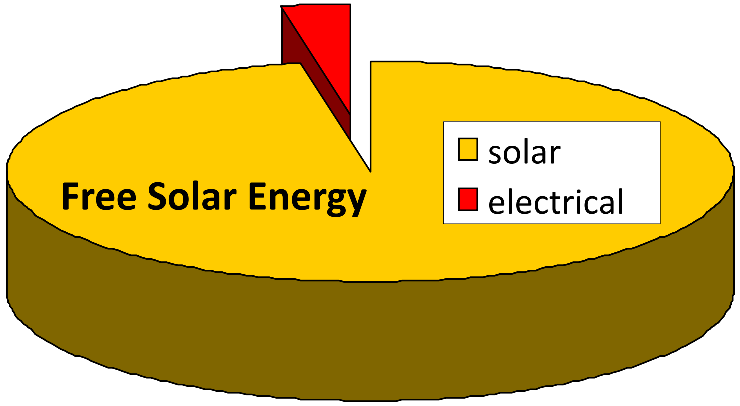
Energy Consumption – drying Biosolids

90 – 130 kWh_{el} / ton H_2O evaporated



3.1 Million BTU/ ton H_2O evaporated

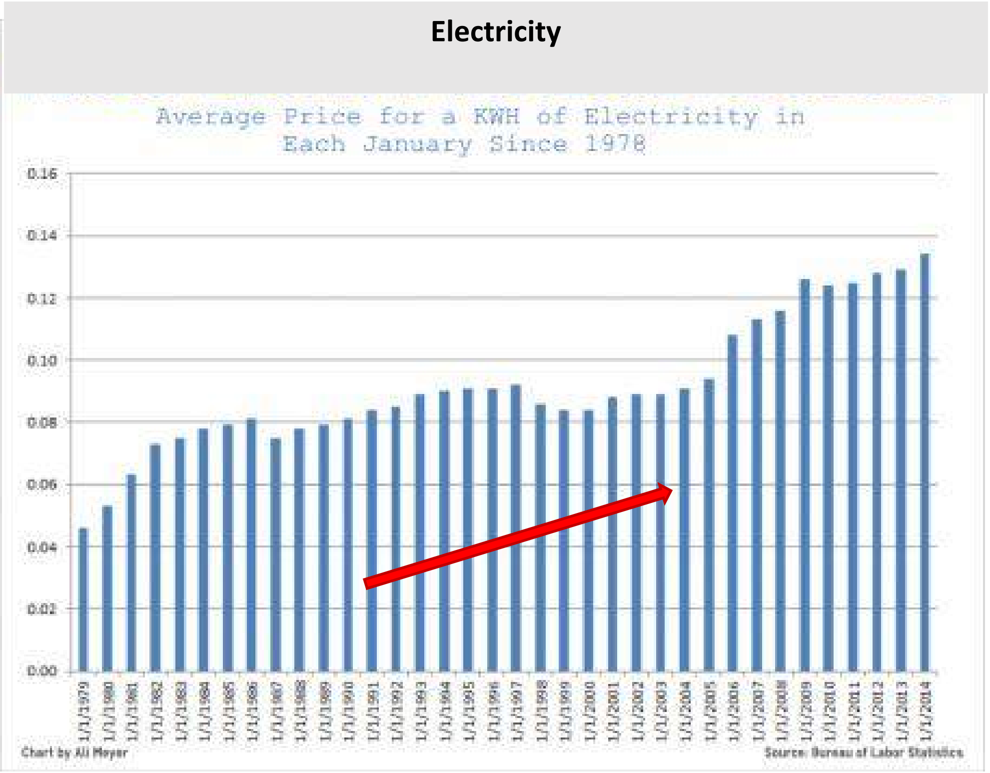
25 – 35 kWh_{el} / t H_2O evaporated

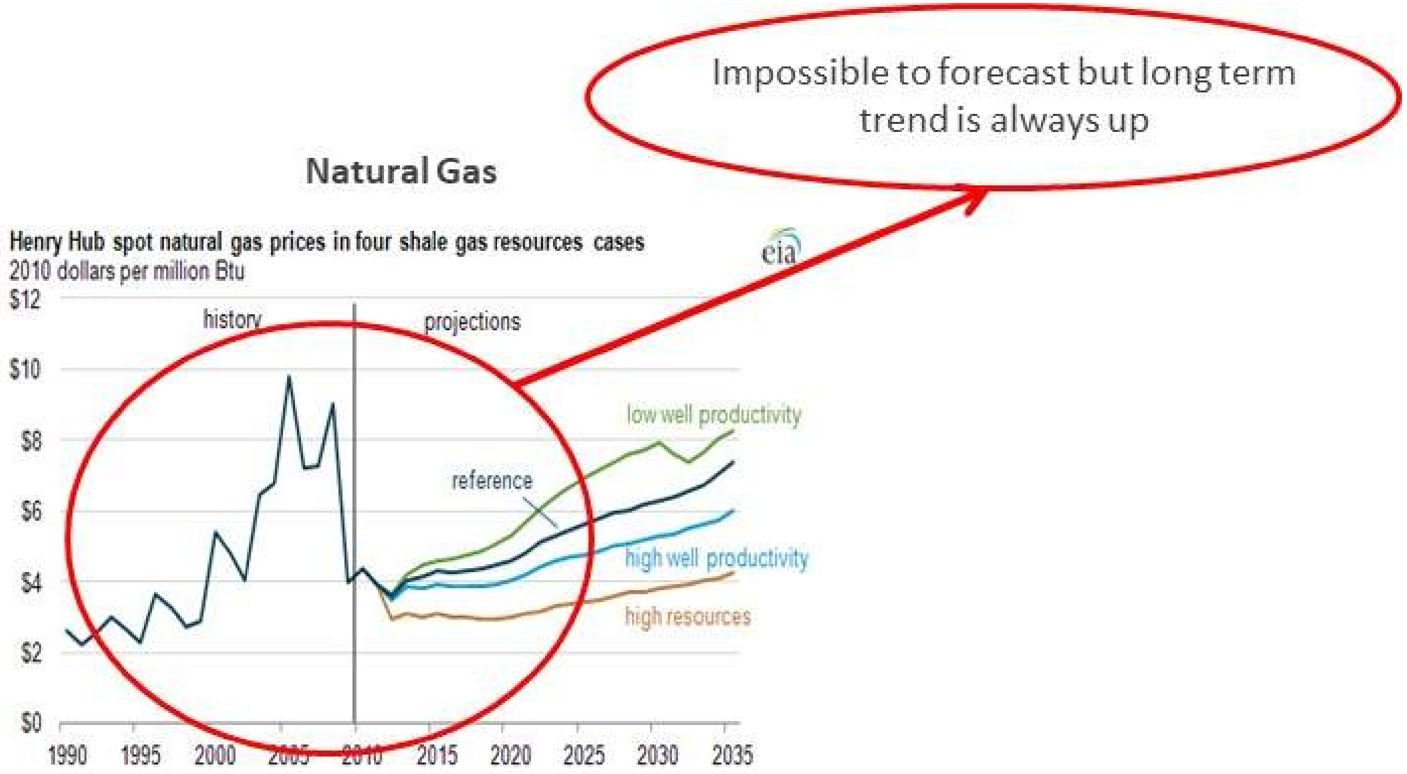


Thermal Dryers vs Active Solar Dryer™

The Concern with drying Sludge / Biosolids

- It requires lots of energy!





Why Solar Drying

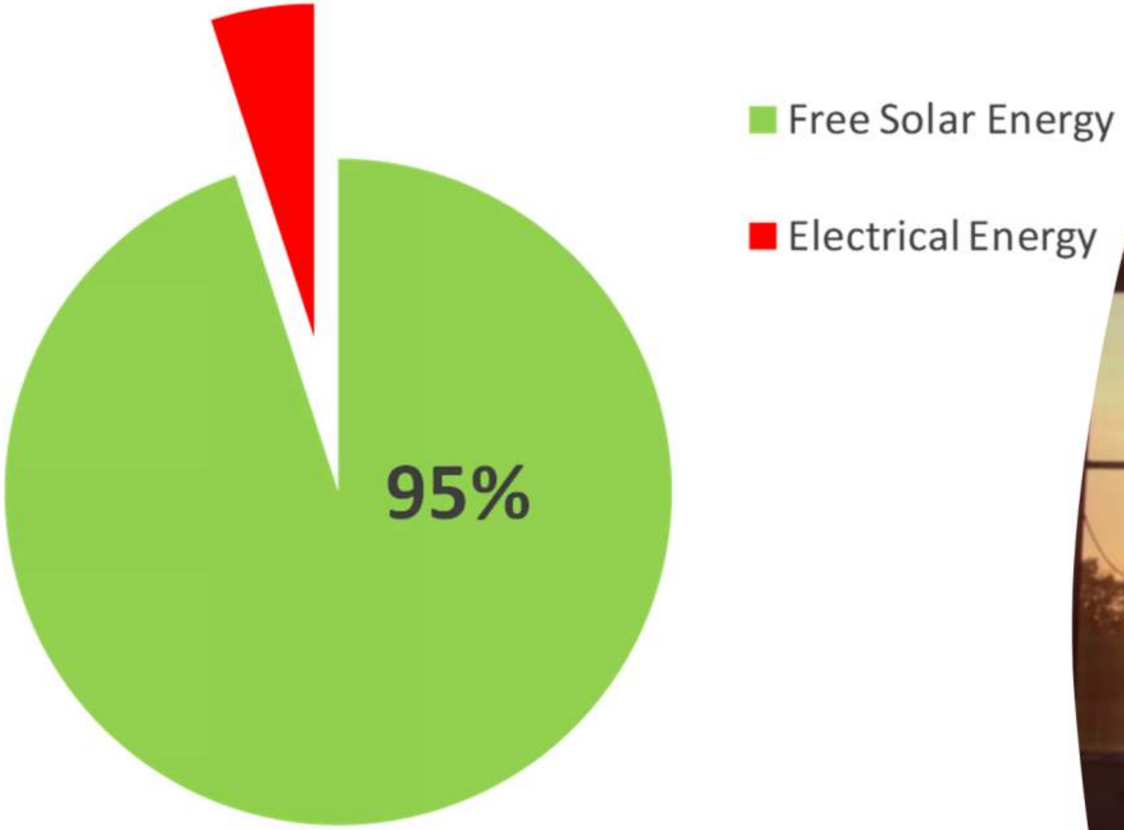
Comparison to Gas Fired Dryers

HARVEST TECHNOLOGY

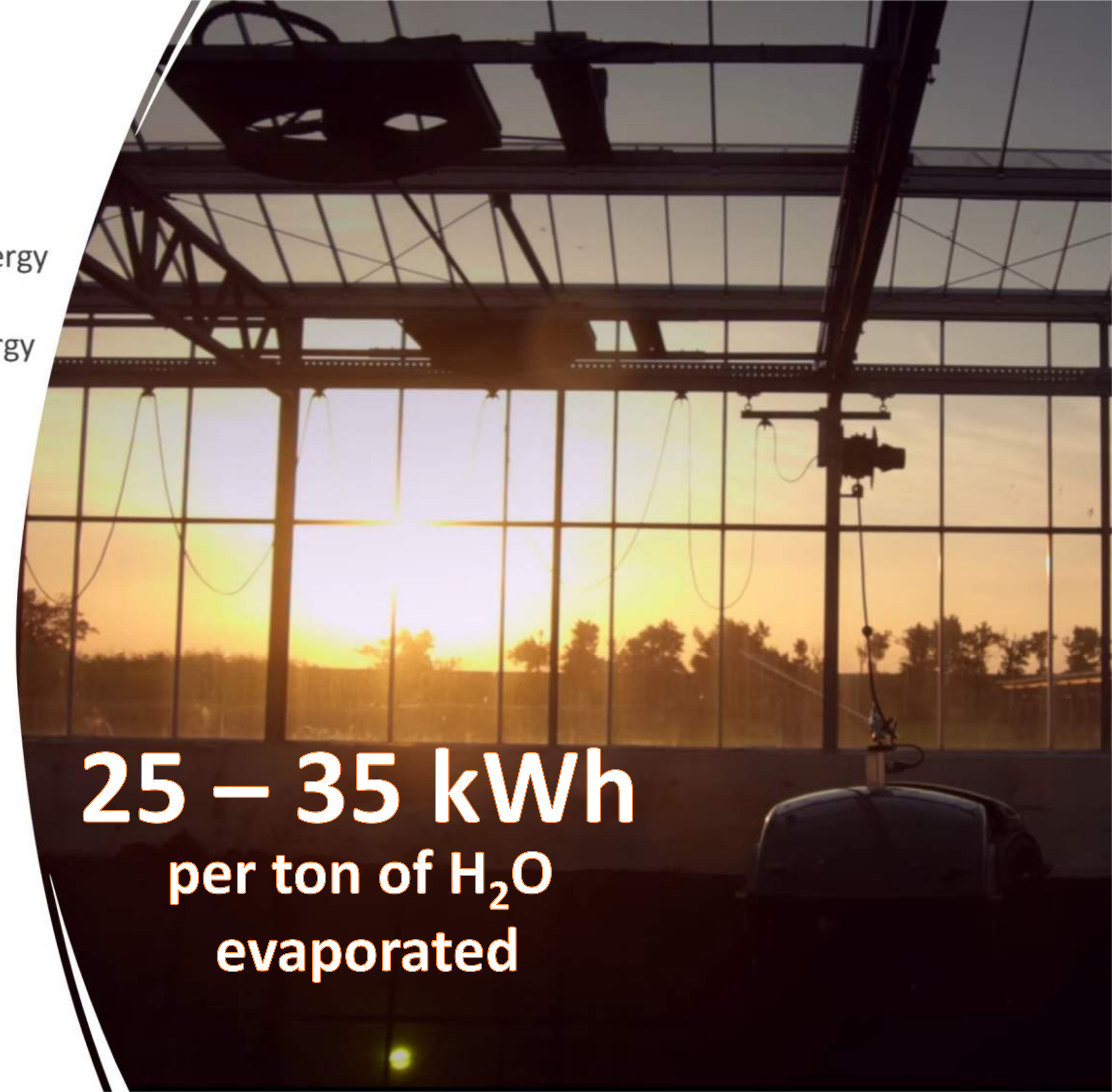
- Lower energy costs (example 10 MGD)

Thermal Energy Consumption	**Gas Fired**	**Solar**
Consumption per ton of water evaporated [BTU]	3,100,000	3,100,000
Price per million BTU's	$4.00	$0.00
Cost per ton of water evaporated	**$ 18.6**	**$0.00**
Electrical Energy Consumption		
Consumption per ton of water evaporated [kWh]	100	30
Cost per kWh	$ 0.10	$ 0.10
Cost per ton of water evaporated	**$ 10.00**	**$ 3.00**
Total energy cost per ton of water evaporated (today's cost)	**$28.60**	**$3.00**
Example 10 MGD Plant		
Total amount of sludge to be dried [tons/yr]	18,000	
Initial dry solids [% ds]	20%	
Final dry solids [% ds]	75%	
Water to be evaporated [tons/yr]	14,400	
Cost per ton of water evaporated	$28.60	$3.00
Annual Energy Costs	**$411,840**	**$43,200**

$368,640 Annual Savings at Current Price Level



Source: LFU / LFW Report Fuessen

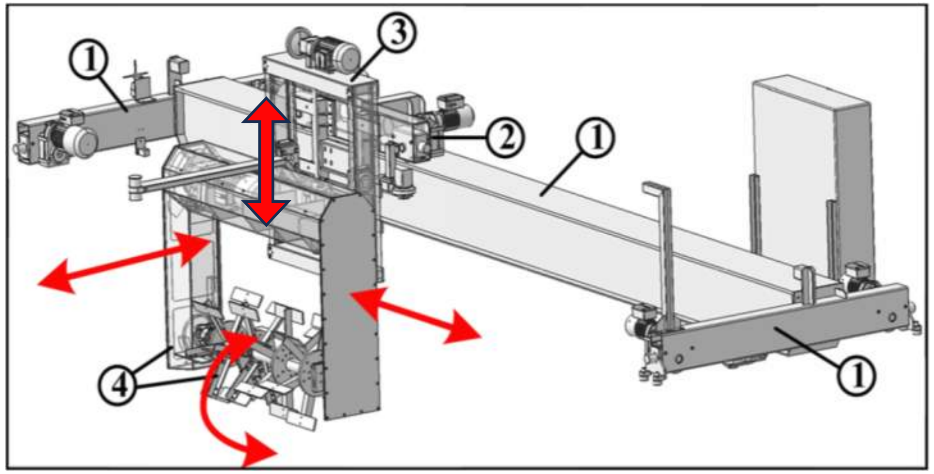


25 – 35 kWh

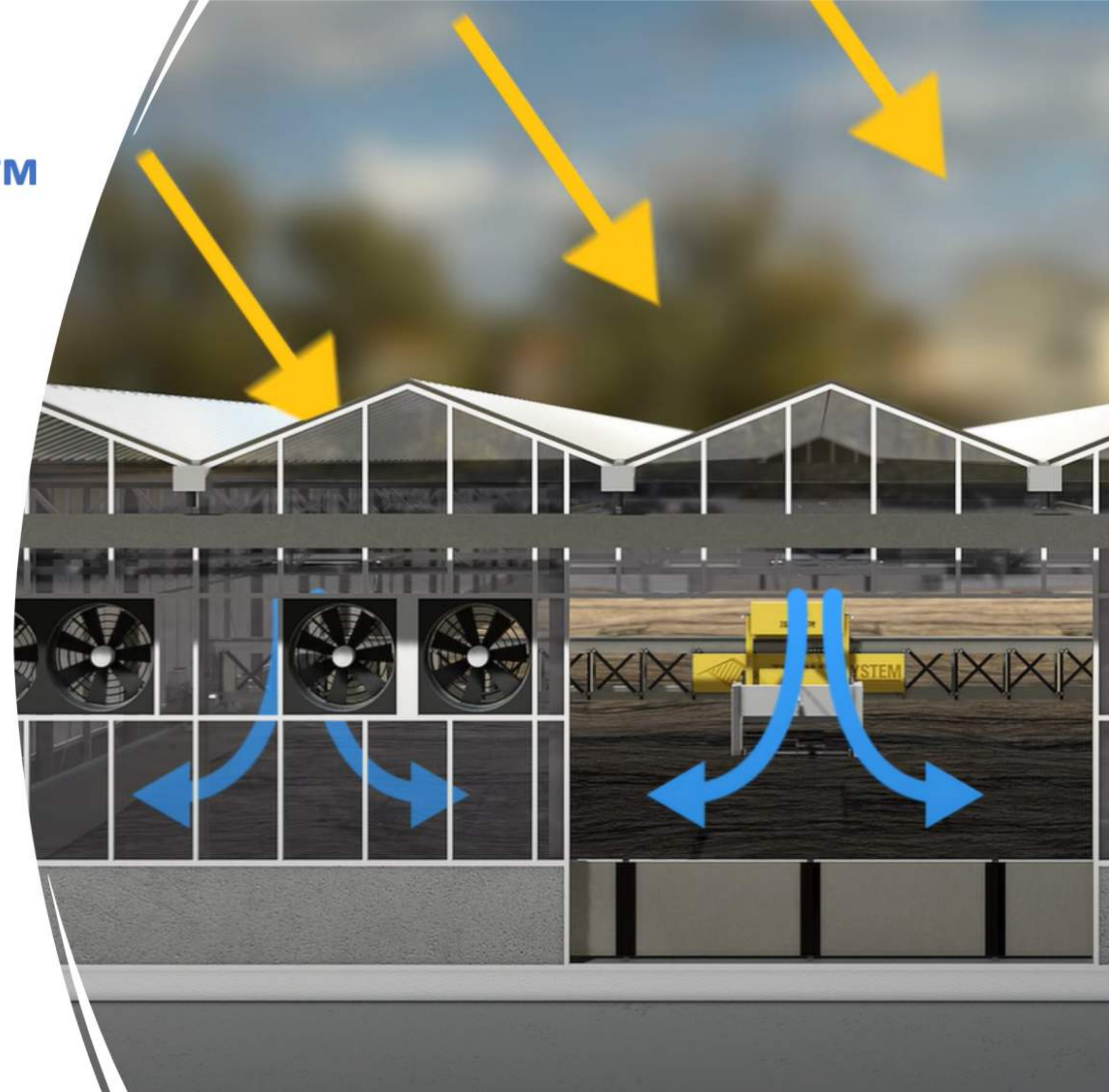
per ton of H_2O evaporated

HARVEST TECHNOLOGY

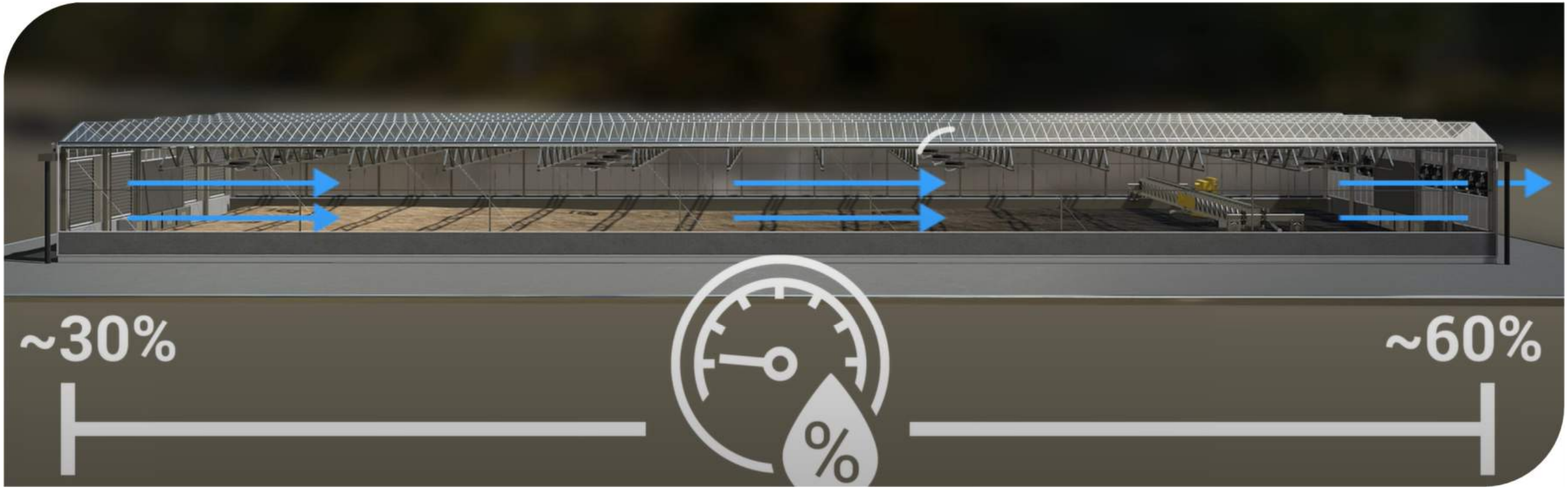
Solar Drying with SludgeManager™



Tilling Device: SludgeManager™



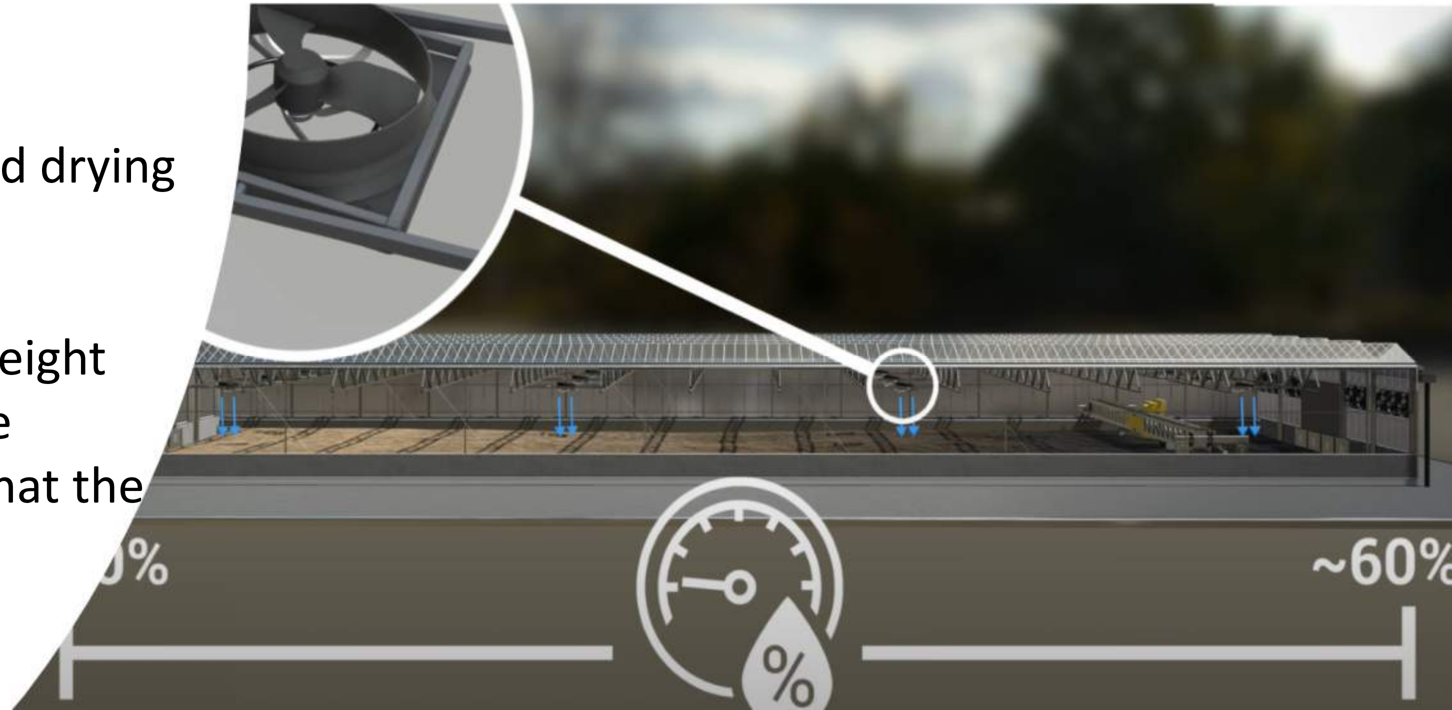
Solar Drying | Continuous Operation
SolarFlow™ with Counter Biosolids / Air Flow



Solar Drying
Continuous Operation

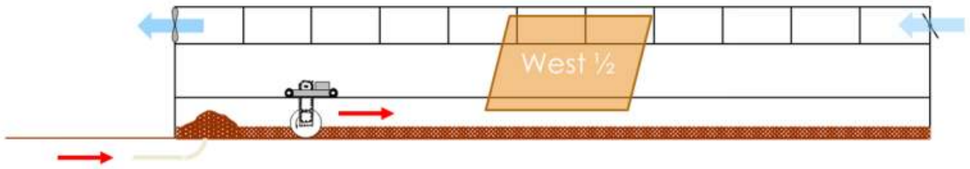
<u>Features & Benefits:</u>

- fully automated loading, drying and discharge process
- Point-to-point transport of the biosolids
- Effortless biosolids handling even in the sticky phase
- Durable and low-maintenance technology
- Suitable for chamber widths of 30ft to 60ft and drying areas of up to 33,000 ft² per Tilling Machine
- AHC® (Automatic Height Control) automatic height mapping system ensures that the tilling device automatically adjusts to uneven ground and that the filling level of the hall is even

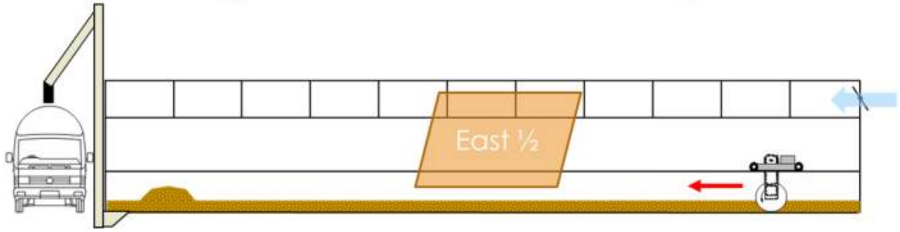


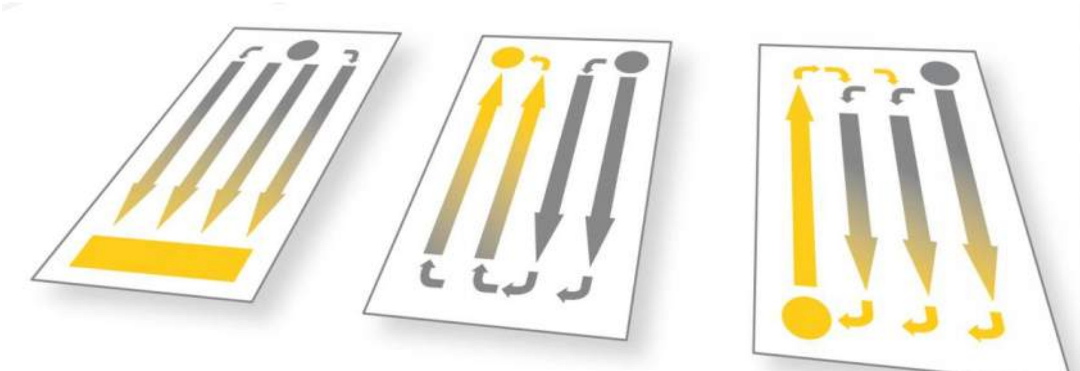
Solar Drying SludgeManager™

Biosolids loading at 15 - 28 %d.s. *fully automated*



Biosolids unloading at 75 - 90% d.s. *fully automated*

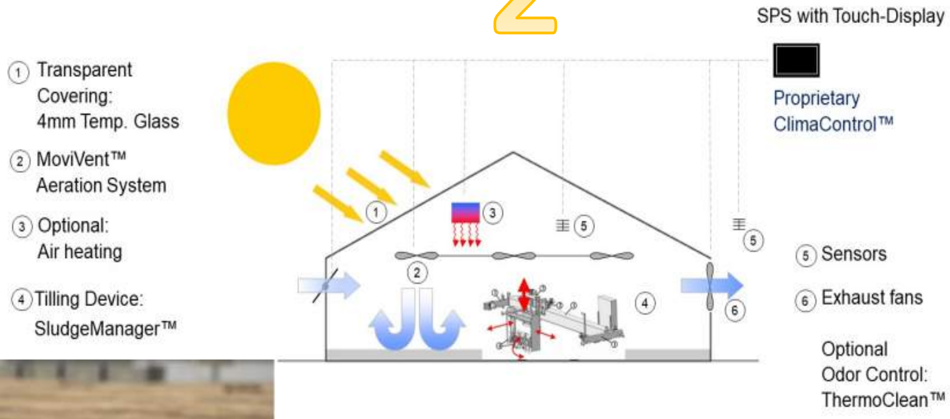




SolarFlow™ with SludgeManager™

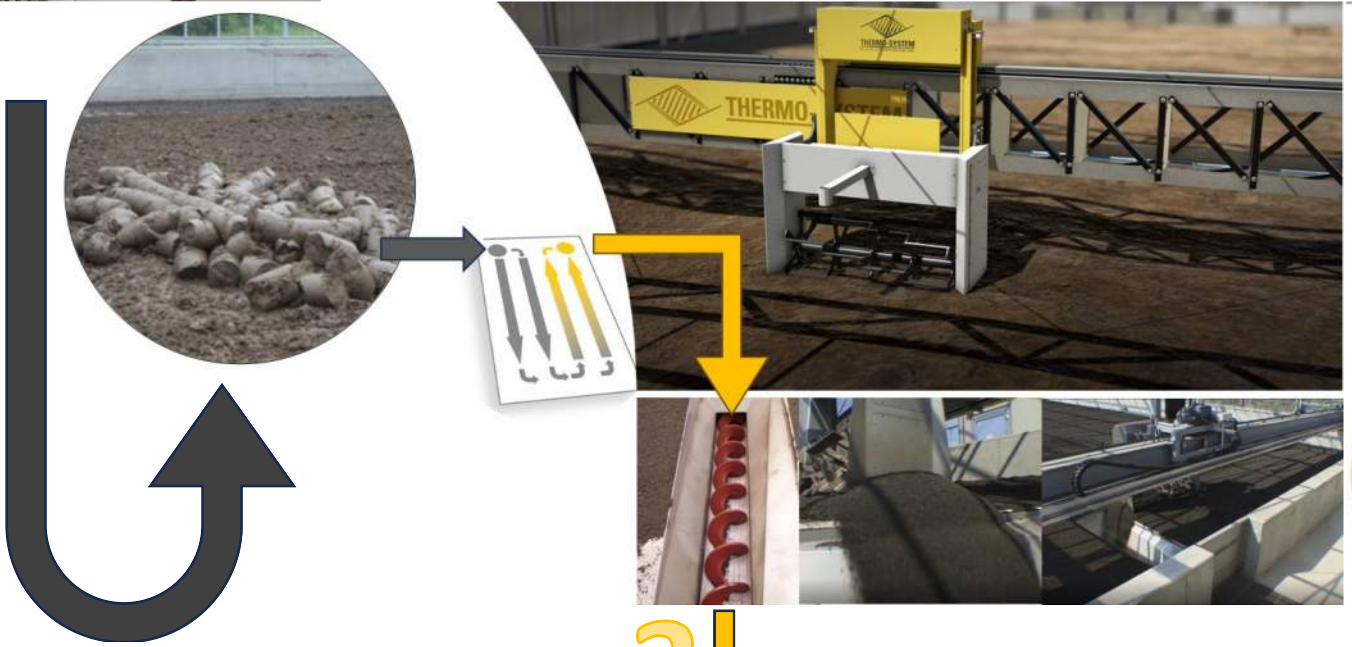
1. Automated Feed
2. Automated solar drying with ClimaControl™
3. Automated Discharge

2

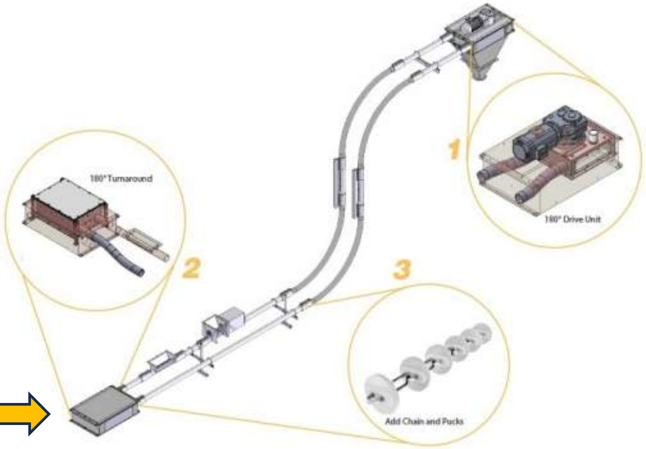


Single Biosolids Loading Point

1



Tubular Drag Conveyors by Chain-Vey®



3

Single Biosolids Discharge Point

HARVEST TECHNOLOGY



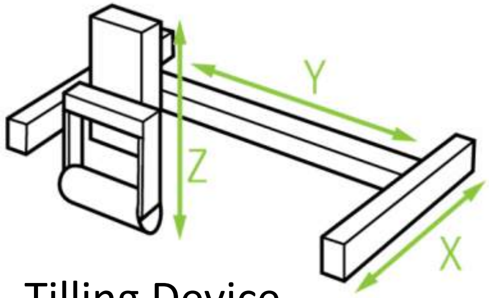


THERMO-SYSTEM® Active Solar Biosolids Dryer

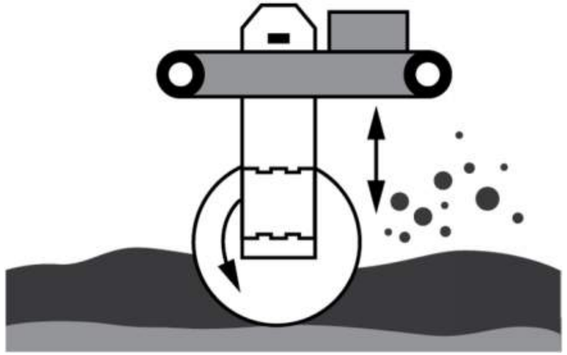
Site Visit: Rödental

THERMO-SYSTEM® Active Solar Biosolids Dryer

Site Visit: Rödental



Tilling Device
MOVABLE IN 3 AXES
X = longitudinal
Y = transverse
Z = vertical



AHC® - AUTO. HEIGHT CONTROL
(height mapping of the drying area, height mapping of the sludge for level determination)

THERMO-SYSTEM® Active Solar Biosolids Dryer

Site Visit: Rödental

HARVEST TECHNOLOGY

THERMO-SYSTEM® Active Solar Biosolids Dryer

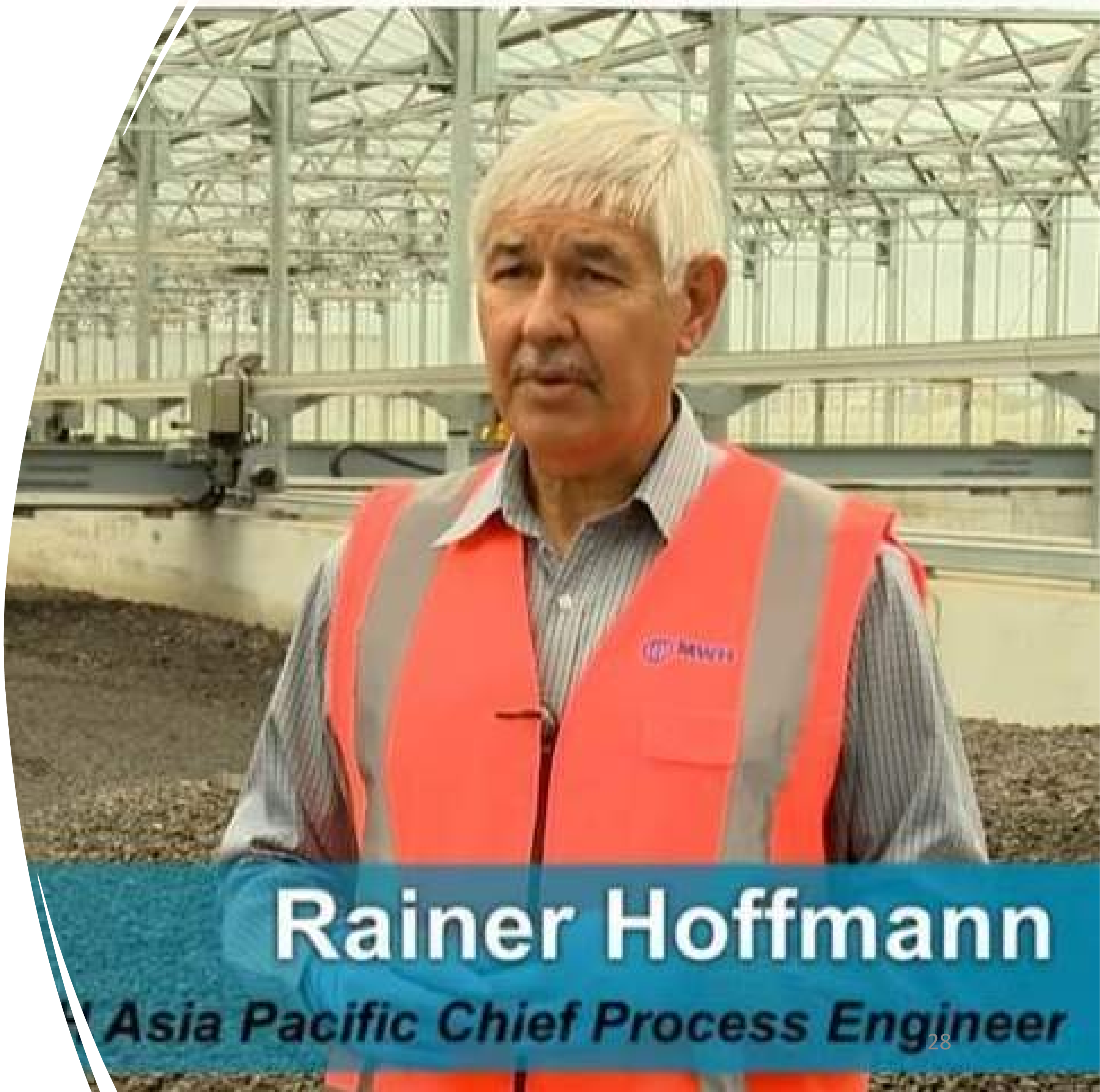
Site Visit: Rödental

HARVEST TECHNOLOGY


MWH Global Produces New Zealand's First Municipal Solar Sludge Drying Facility
MWH

Solar Drying Continuous Operation

"The operational experience with the solar drying facility in New Zealand is very positive and the operator input has been minimal. The Solar Drying Facility is a fully automated system that is robust and reliable and has a low energy requirement of about 206 kWh/t dry solids to dry the dewatered sludge from 18 % dry solids to over 70 % dry solids." – Mr. Rainer Hoffmann STANTEC/MWH Asia Pacific Chief Process Engineer at Christchurch, New Zealand – referring to the -> SludgeManager™



THERMO-SYSTEM – Air treatment







THERMO-SYSTEM® Active Solar Biosolids Dryer

Exhaust Air Treatment System

Integrated Airwasher — *ClimaControl™ System*

Expected Performance

Max air flow: 150,000 m³/h

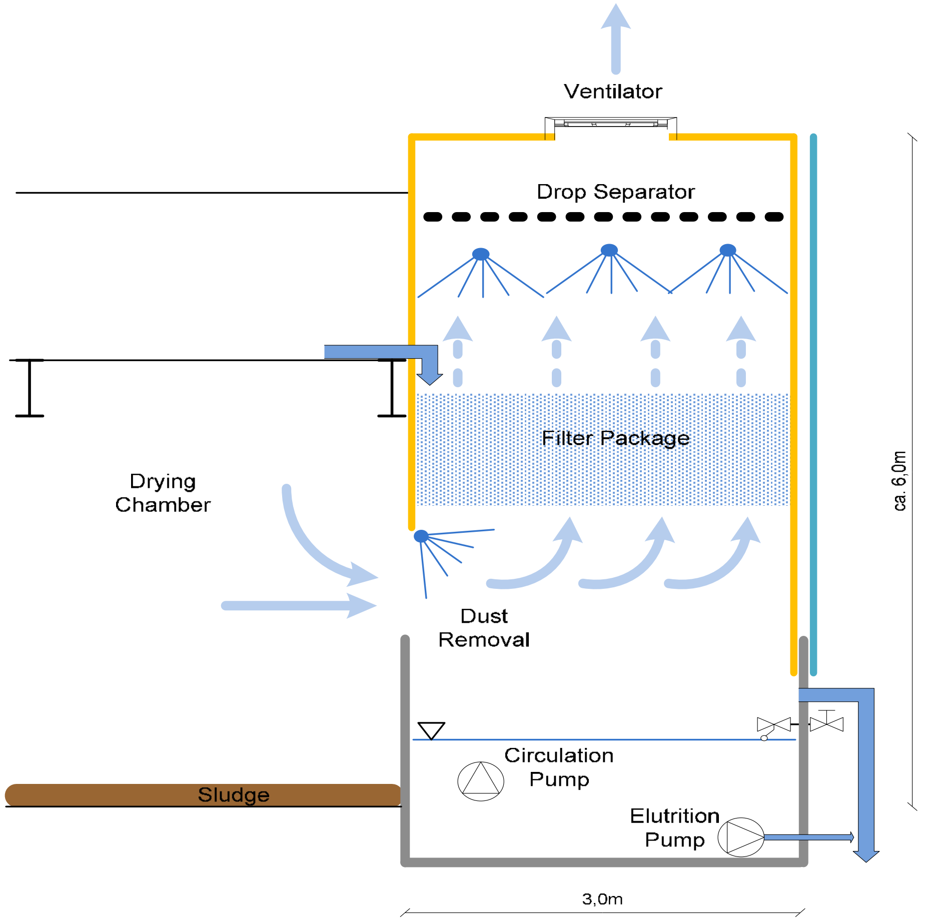
Pressure Drop: 20 – 100 Pa

Dust reduction*: 80 – 95 %

Odour reduction*: 60 – 75 %

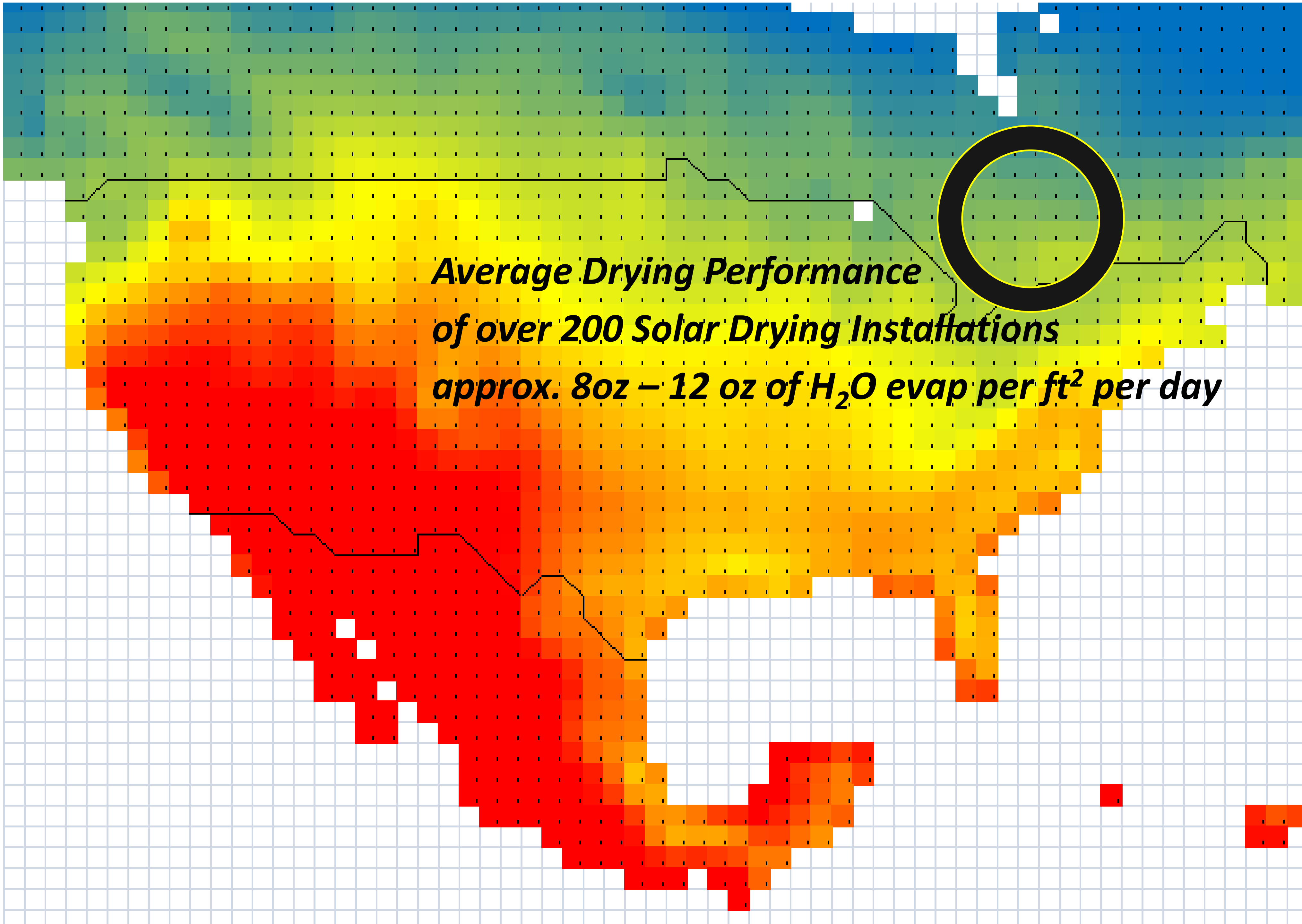
NH_3-reduction*: 60 – 90 %

*under standard conditions of operation and typical pollution loads

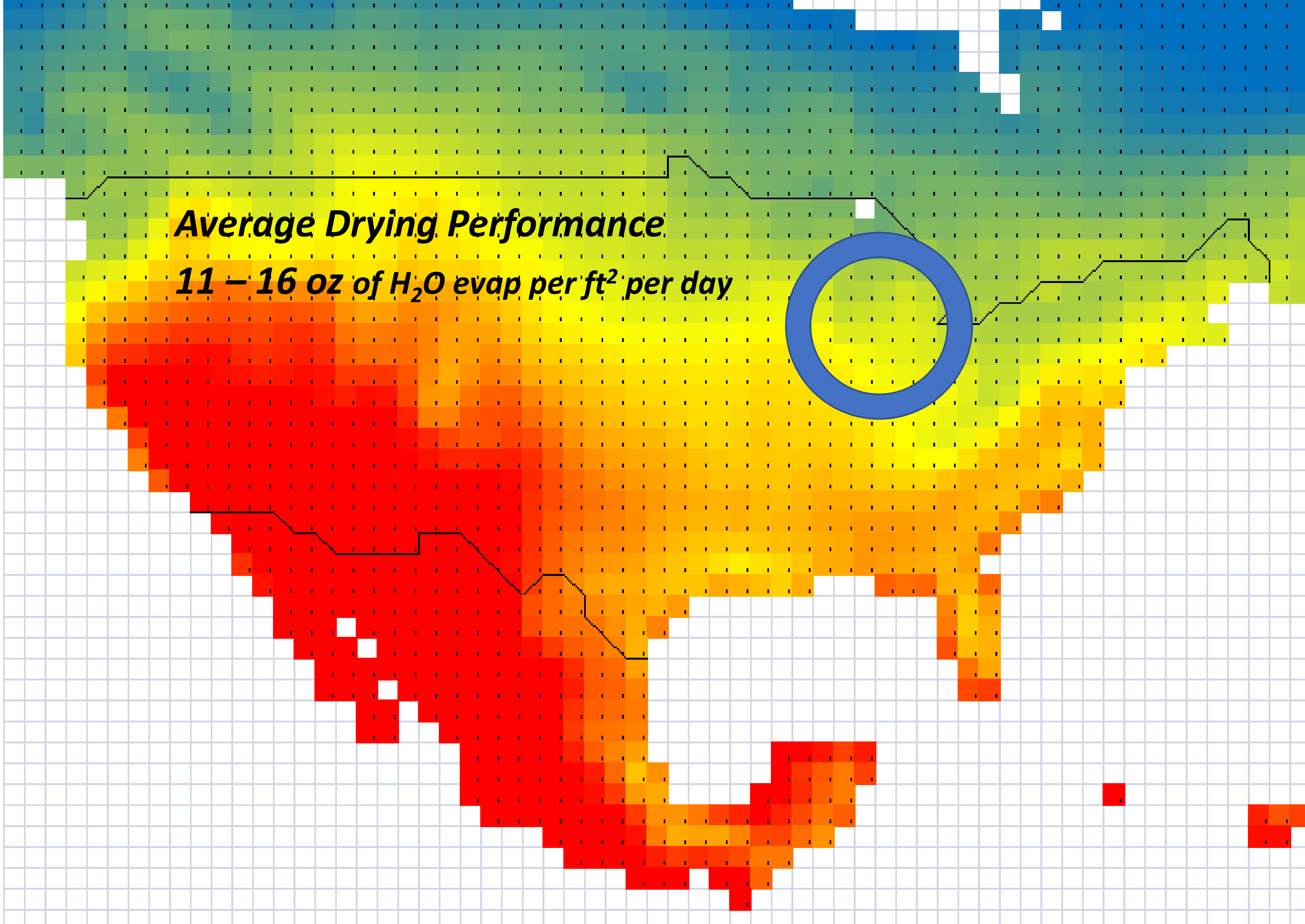



USA 23
EUROPE 148
CHINA 9
MENA 11
INDIA
SRI LANKA 7
SOUTHEAST ASIA 2
LATIN AMERICA 4
AUSTRALIA
NEW ZEALAND 2

THERMO-SYSTEM®
Active Solar Dryer™

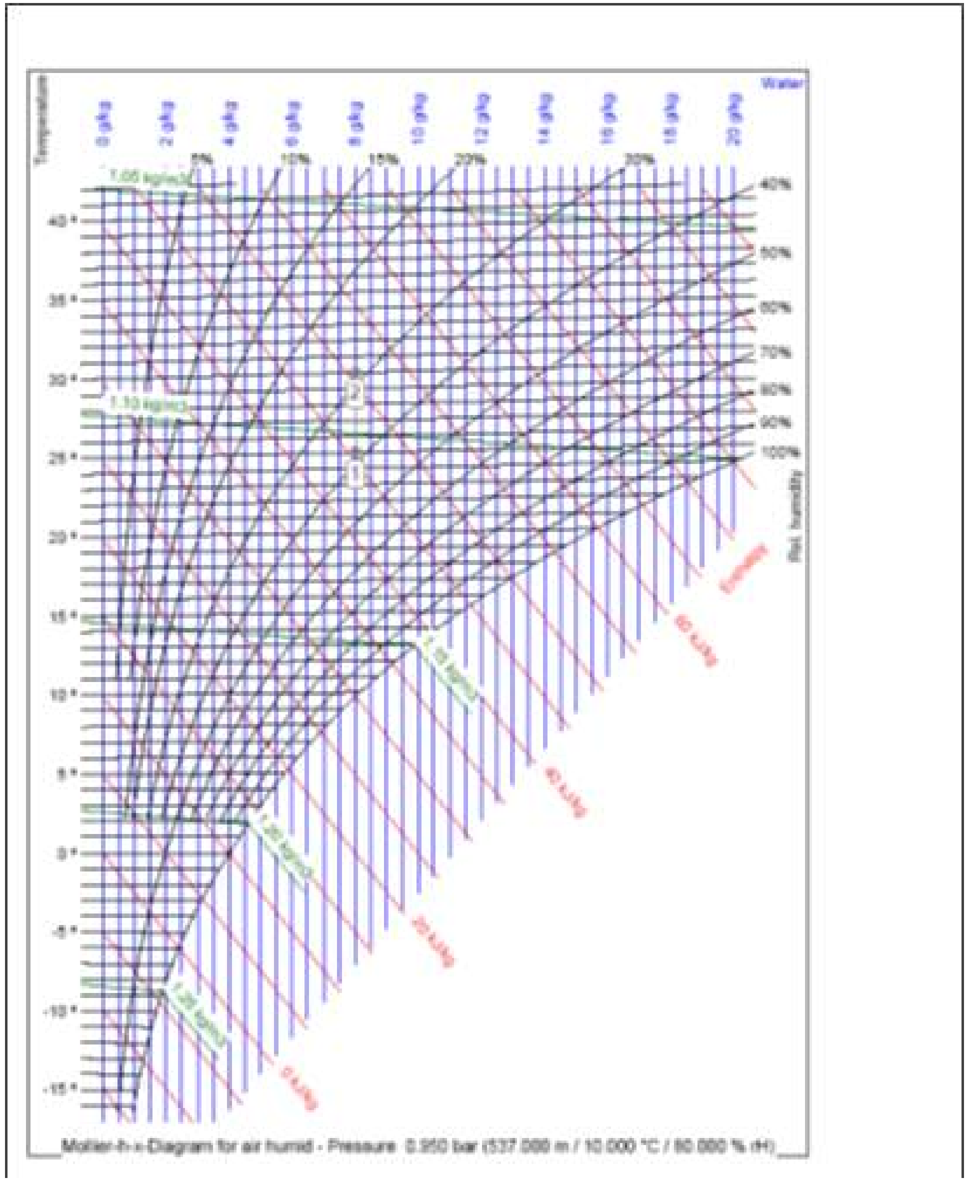


THERMO-SYSTEM®
Active Solar Dryer™



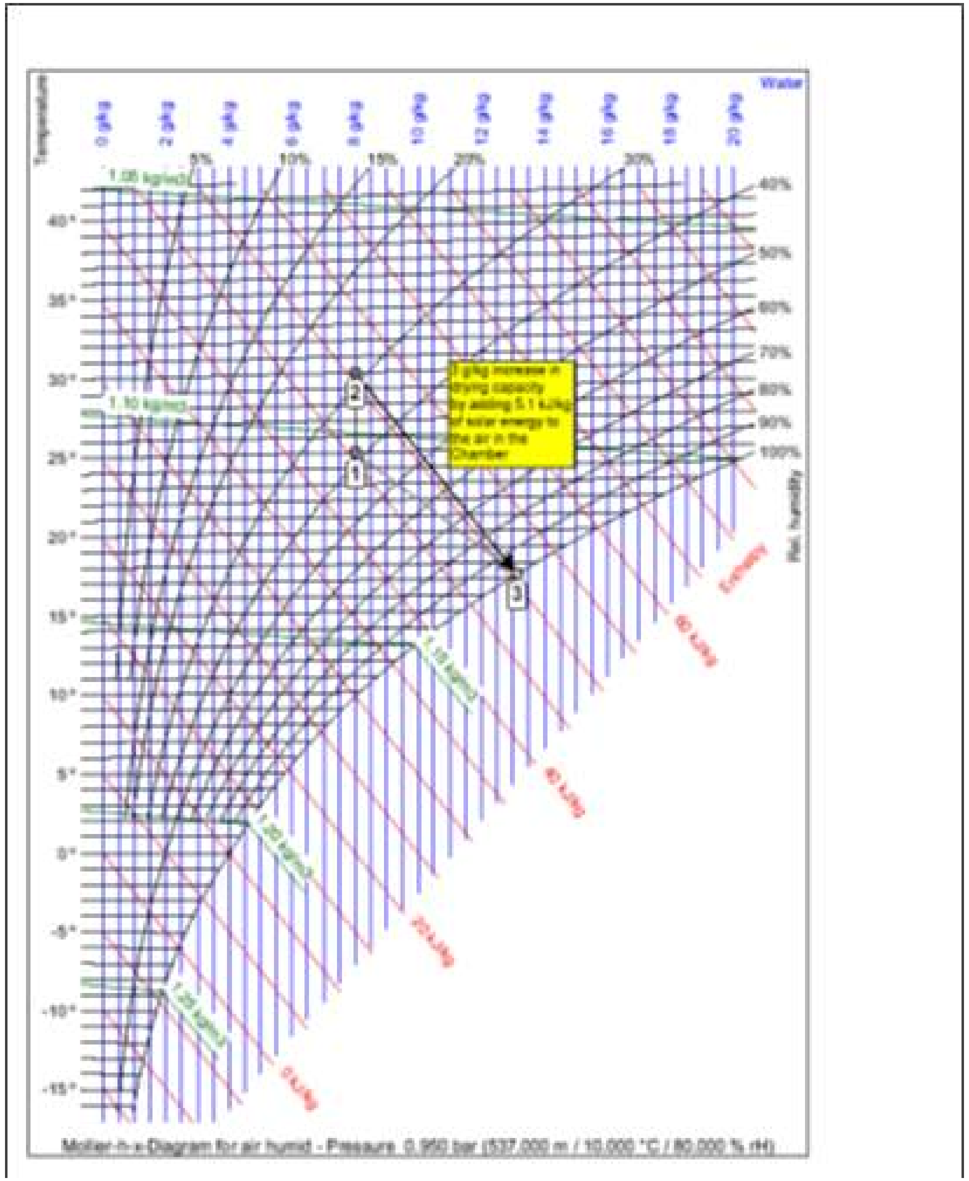
Mollier Diagram

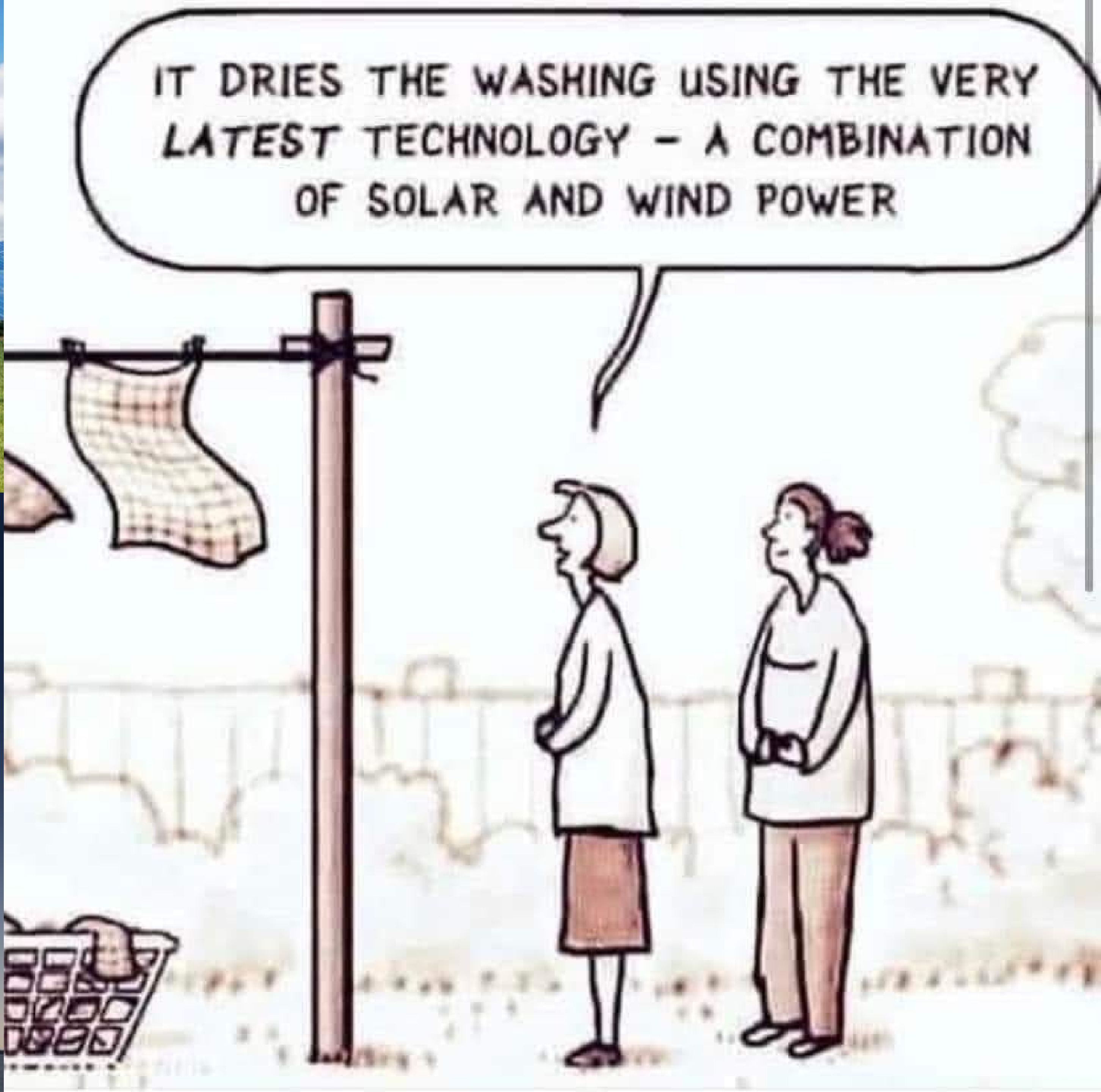
- Describes all the properties of air at different humidities
  - Enthalpy
  - Temperature
  - Relative & Absolute Humidity
  - Density
- Humidity
  - Absolute Humidity – mass of water per mass of dry air. Expressed as grams of water per kg of dry air
  - Saturation – the maximum amount of water air can hold
  - Relative Humidity – the ratio of Absolute Humidity and Saturation Humidity



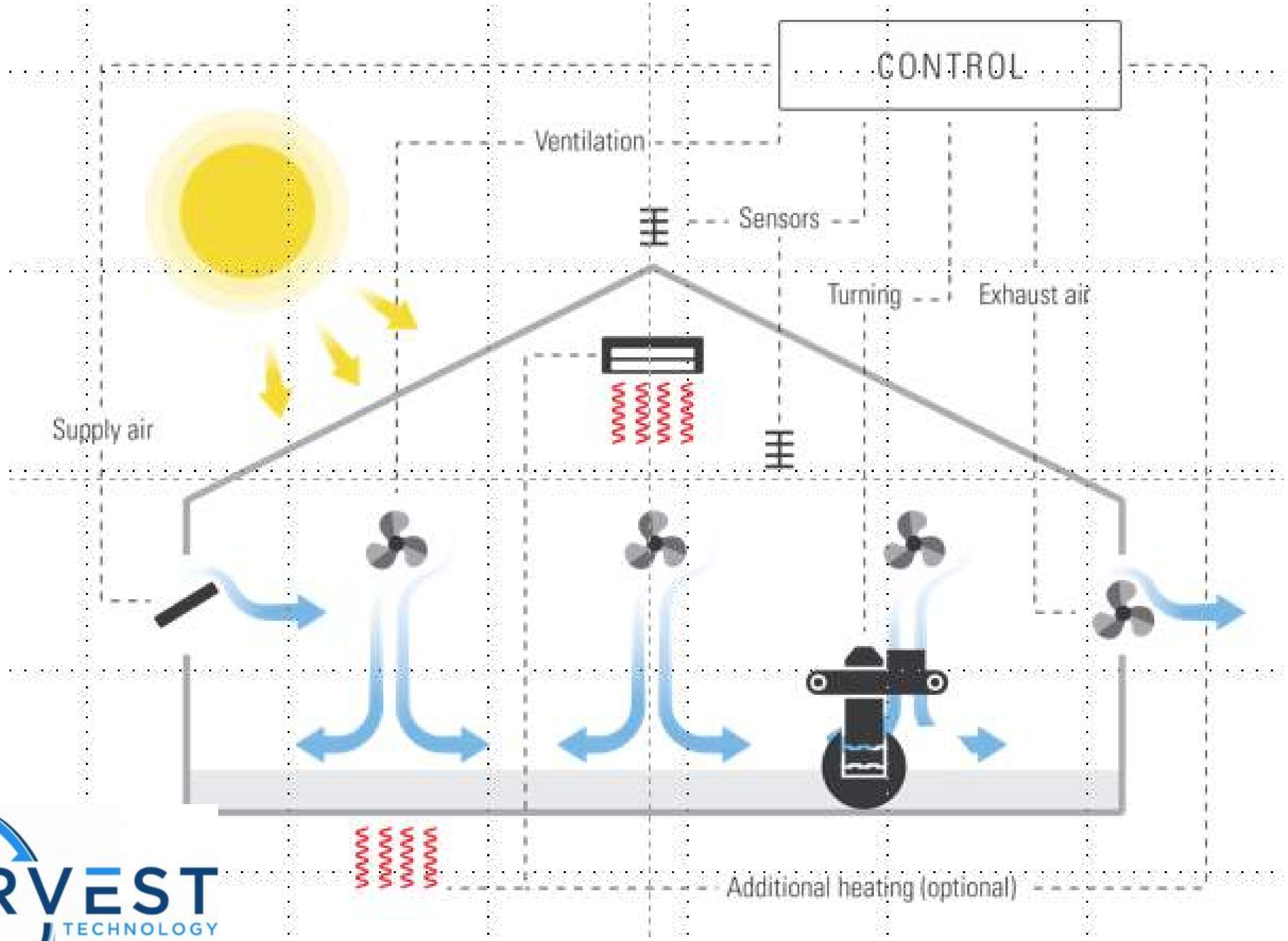
Mollier Diagram

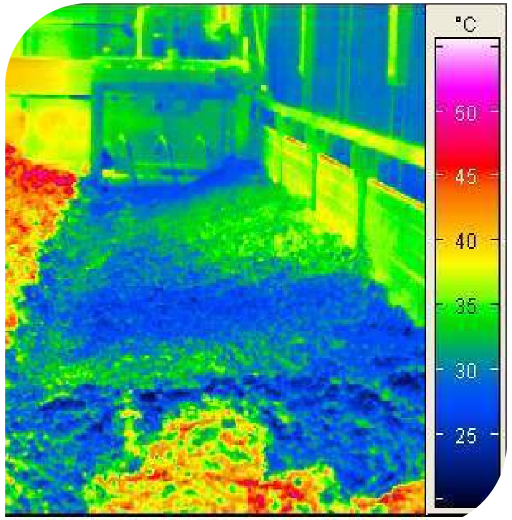
- By increasing the air temperature, you increase the drying potential of the atmosphere
- Evaporation rate is proportional to difference between humidity and saturation
    - Low relative humidity results in faster evaporation
    - Slow evaporation at high relative humidity



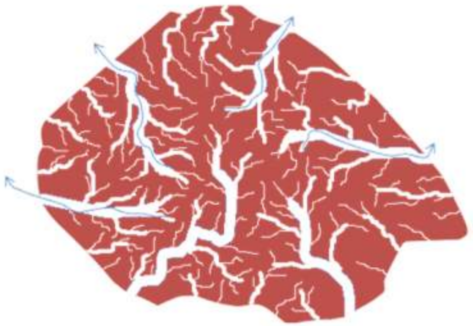

IT DRIES THE WASHING USING THE VERY LATEST TECHNOLOGY - A COMBINATION OF SOLAR AND WIND POWER

Symphony of all Components

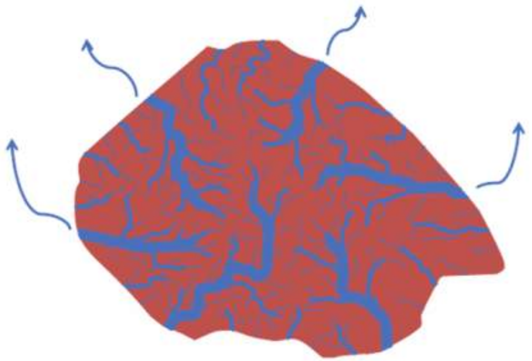




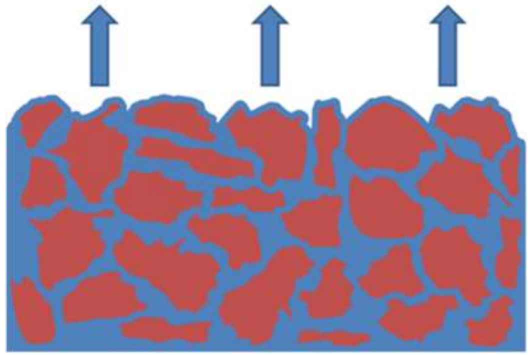
HARVEST TECHNOLOGY



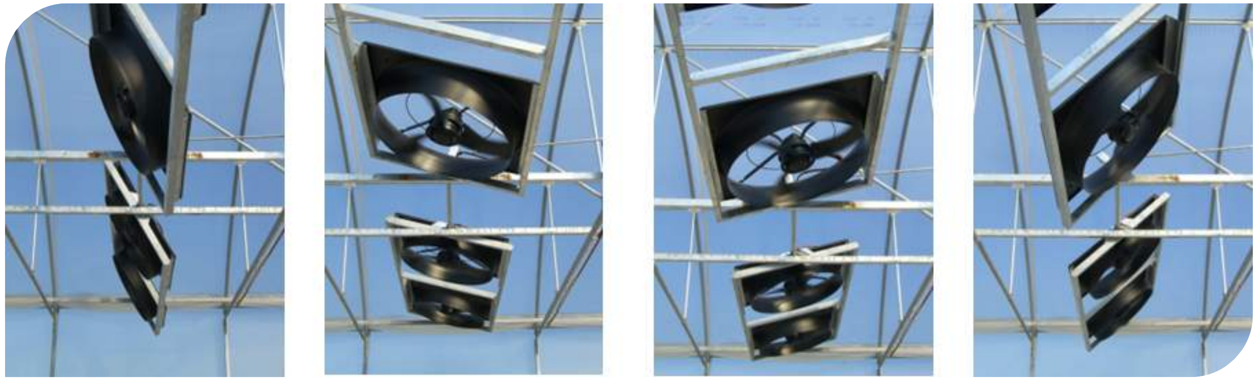
Adsorption Drying
60%DS to 90%DS
Water bonded to the surface
Vapor transported through pores
Requires energy to expand the gas

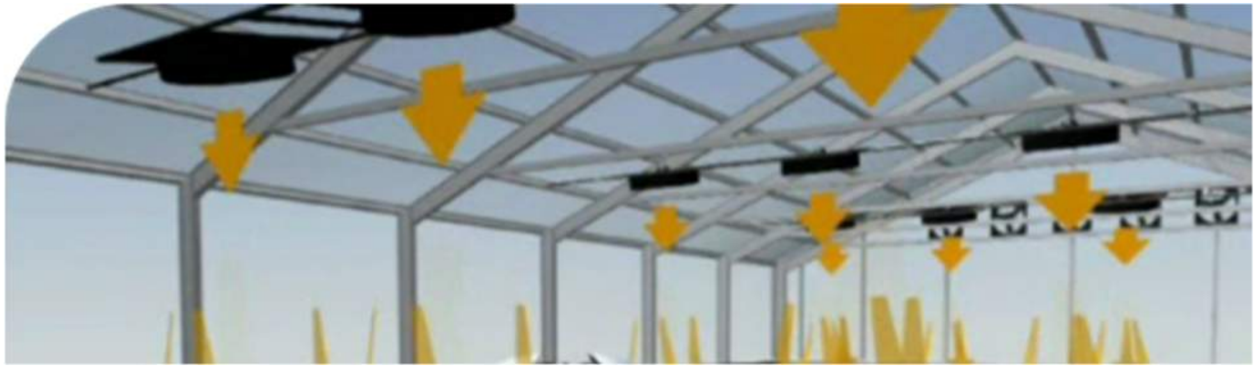


Capillary Drying
45%DS to 60%DS
Water inside the pores
Evap only occurs at the pore exits
Requires energy to expand the liquid

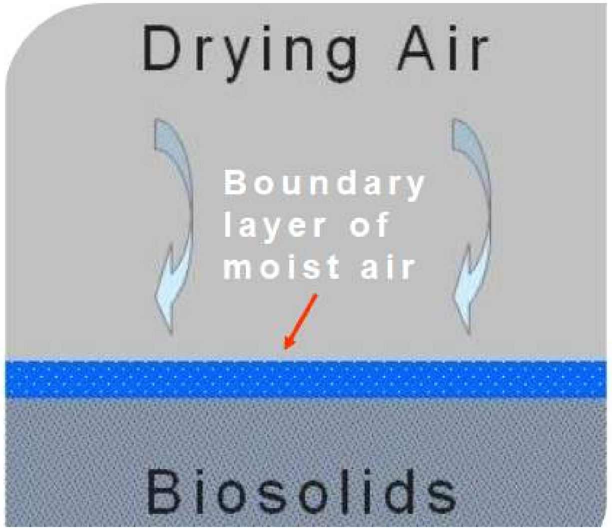


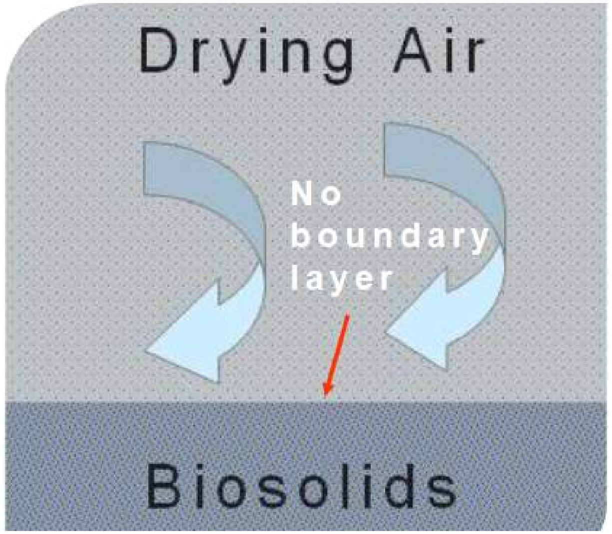
Bulk Drying
Up to 45%DS
Lots of loose water
Easy to Dewater/Evap





Natural Convection *Forced Convection*





Tilling, ONLY = Putty

TILLING ALONE

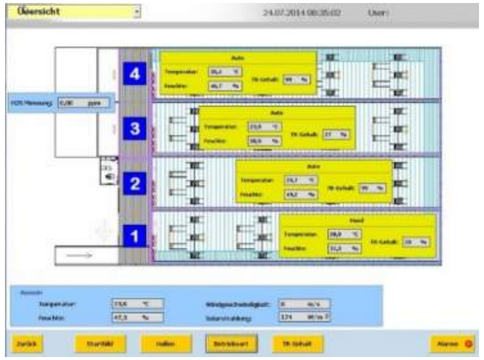
Thermo-System have performed extensive research with the University of Hohenheim to assure the correct tilling frequency to avoid thixotropic conditions.

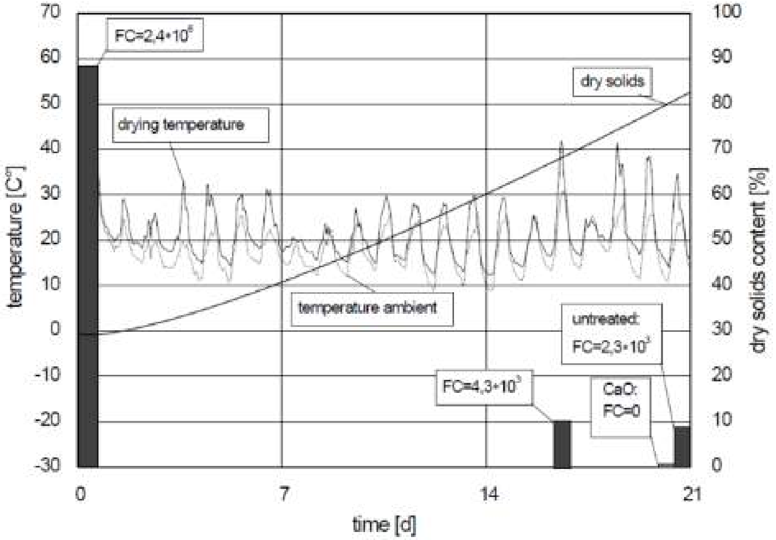
HARVEST TECHNOLOGY

Solar Drying and Class A with Automoated Dryer System

Process Guarantee & Experience

- Class A is only guaranteed with a PLC controlled **batch** process
  - A continuous process does not allow for efficent climate control during all stages of biosolids drying
    - The inactivation of Helminth Ova requires a defined drying regime during the drying process
  - Contamination with pathogens cannot be avoided if the same mixing device is turning dry as well as wet biosolids in the same cycle
    - One turning cycle typically starts in the wet biosolids zone and ends in the dry bioolids zone
- Harvest Technology with the Thermo-System is the only supplier to provide a year round Class A performance guarantee
  - Experinence in different climatic zones throughout the US





HARVEST TECHNOLOGY

Solar Drying and Class A

EPA 40 CFR Part 503

- Vector attraction reduction (VAR) criteria
  - 12 options to meet the specified critaria
    - Option 7: Dry biosolids with no unstabilized solids to at least 75% solids
    - Option 8: Dry biosolids with unstabilized solids to at least 90% solids
- Pathogen reduction criteria
  - 6 alternatives to meet the criteria
    - Alternative 4: Biosolids treated in unknown processes

1. Fecal Coliform < 1,000 MPN / g

or

1. Salmonella < 3 MPN / 4g

and

2. Viruses < 1 PFU / 4g

and

3. Viable Helminth Ova < 1 / 4g

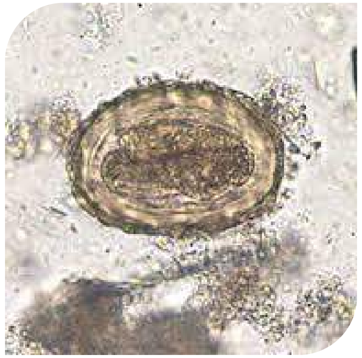
(Measured at time of disposal)

(Measurements can be a representative sample of multiple batches)

Solar Drying and Class A

Helminth Ova

- Selected by the EPA due to its resistance to environmental conditions
- Due to increased hygenic conditions in the US not always present in sludge
- Helminth eggs have several layers of resistant walls to protect the embryo while it develops
- Can surrive for may years in dry soil
- **Drying by itself does not kill Helminth Ova!**
- Any Class A process needs to be designed to safely kill/inactivate Helminth Ova in order to guarantee Class A consistently

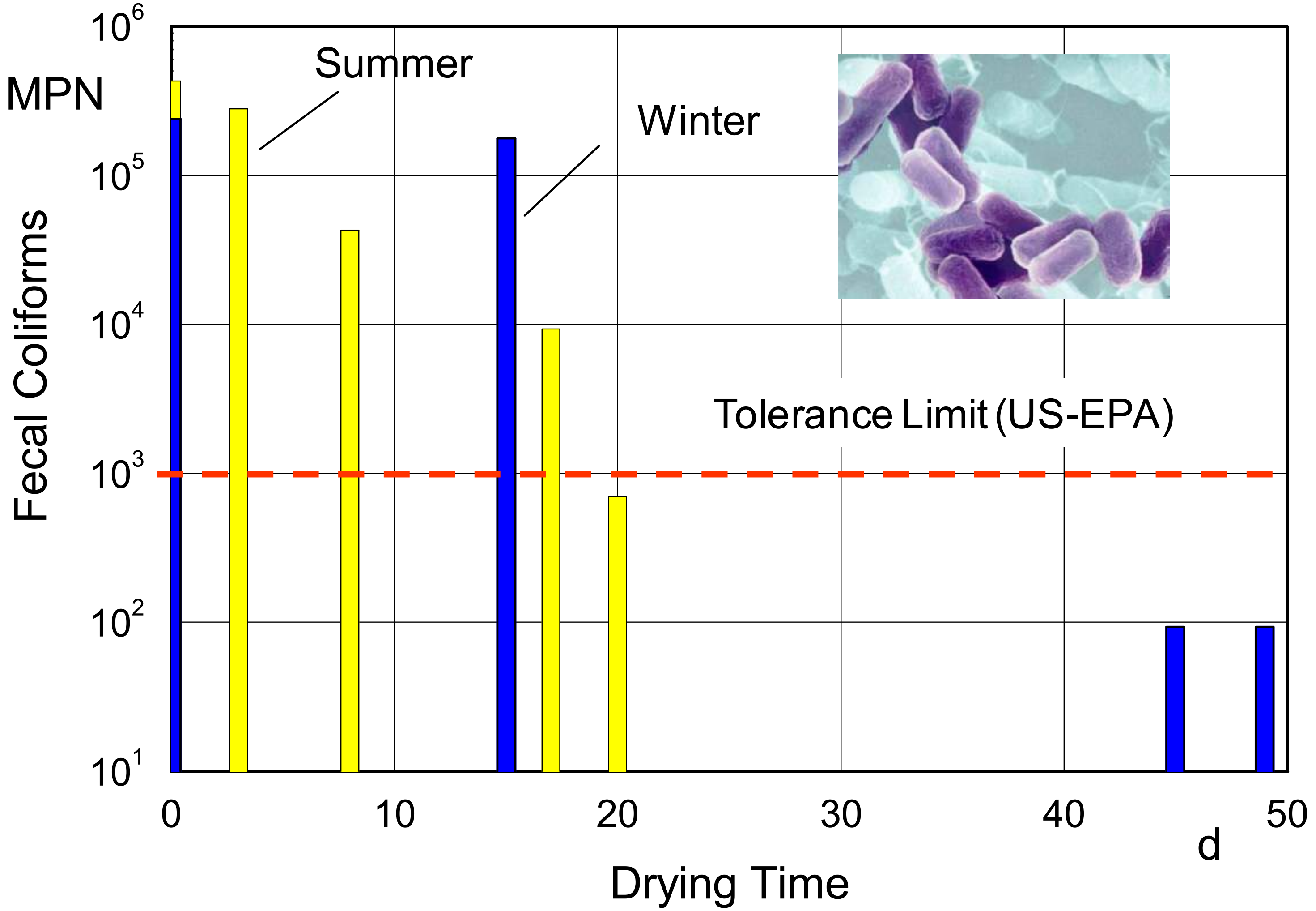


Thermo-System have performed extensive research to assure that Helminth Ova is always being deactivated during the solar drying process.

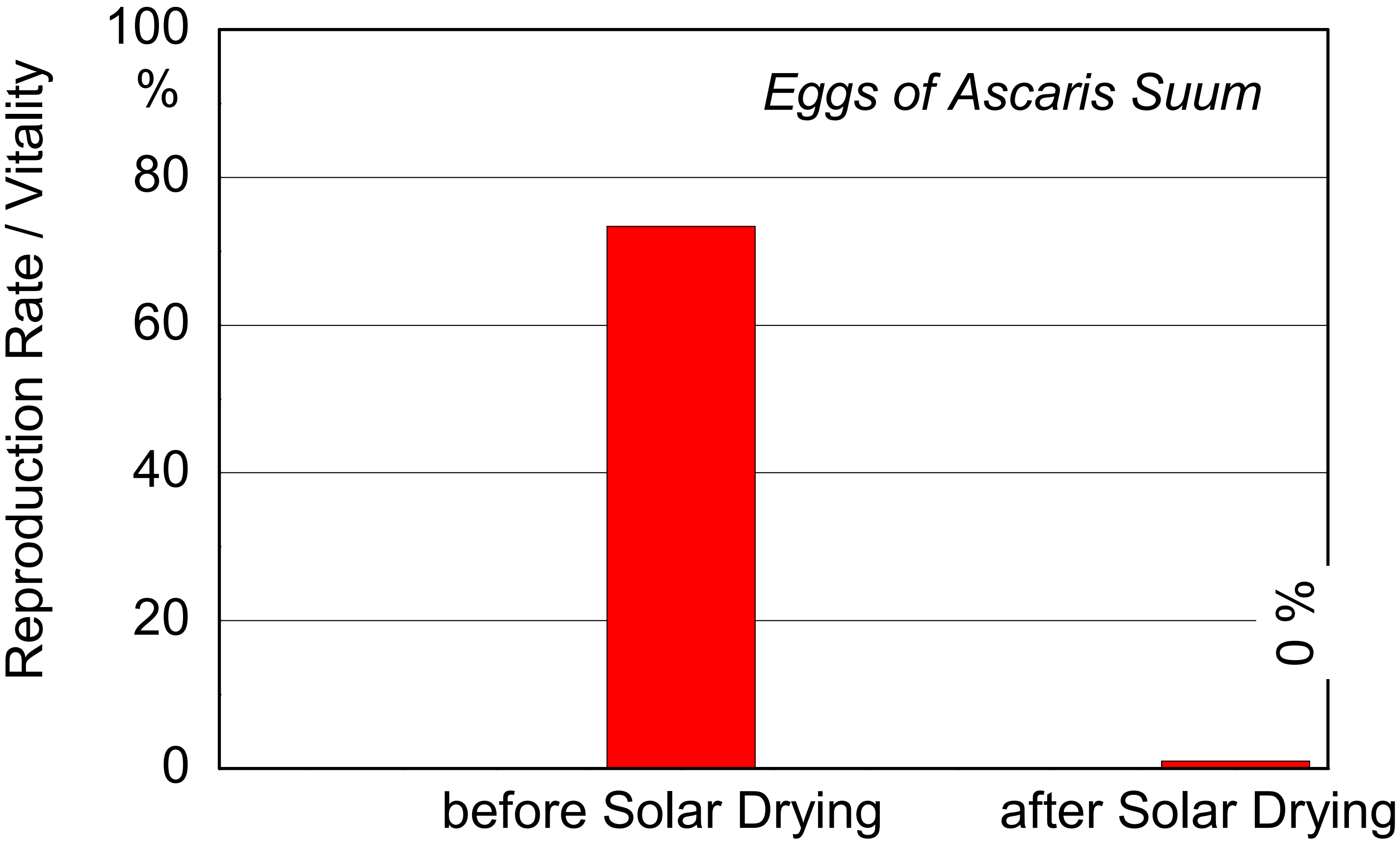
One of the sites used to research the behavior of Helminth Ova is Keowee Key, SC where thickened sludge is dried to 75% ds. Keowee Key is producing Class A biosolids since 2002.

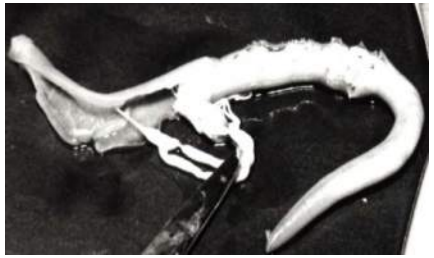
Extensive research was also carried out by our partners Thermo- System and the University of Hohenheim in Stuttgart, GER. The research & testing in Europe was performed in the laboratory as well as in operating plants.

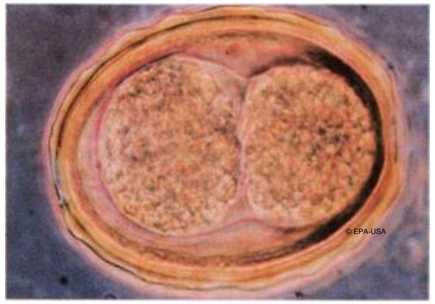
Solar Drying and Class A

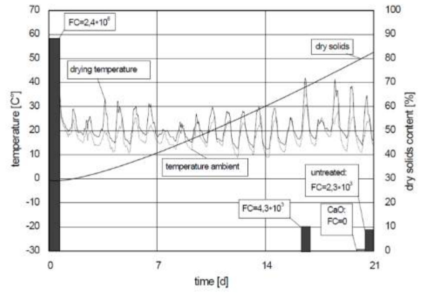


Solar Drying and Class A

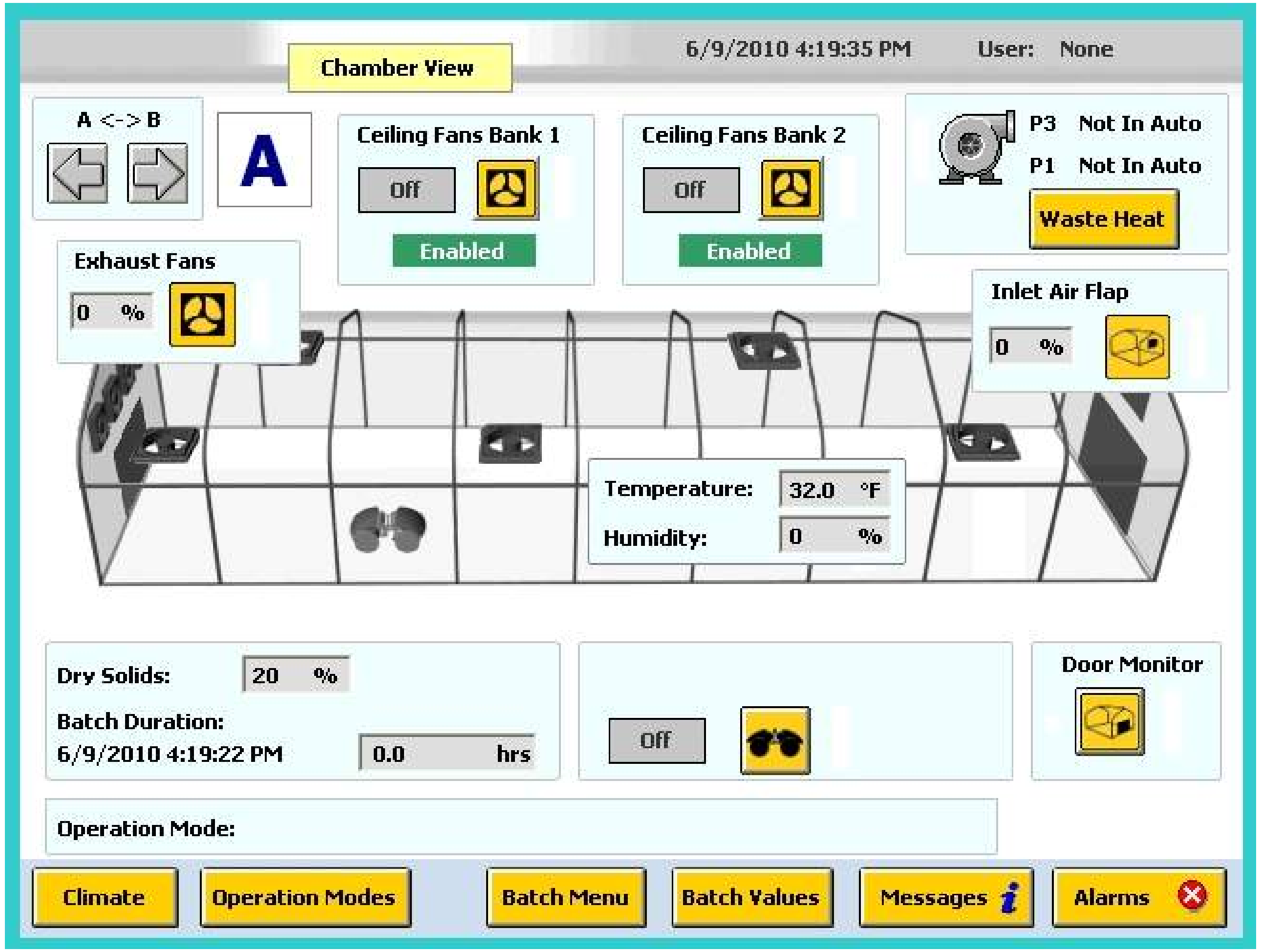


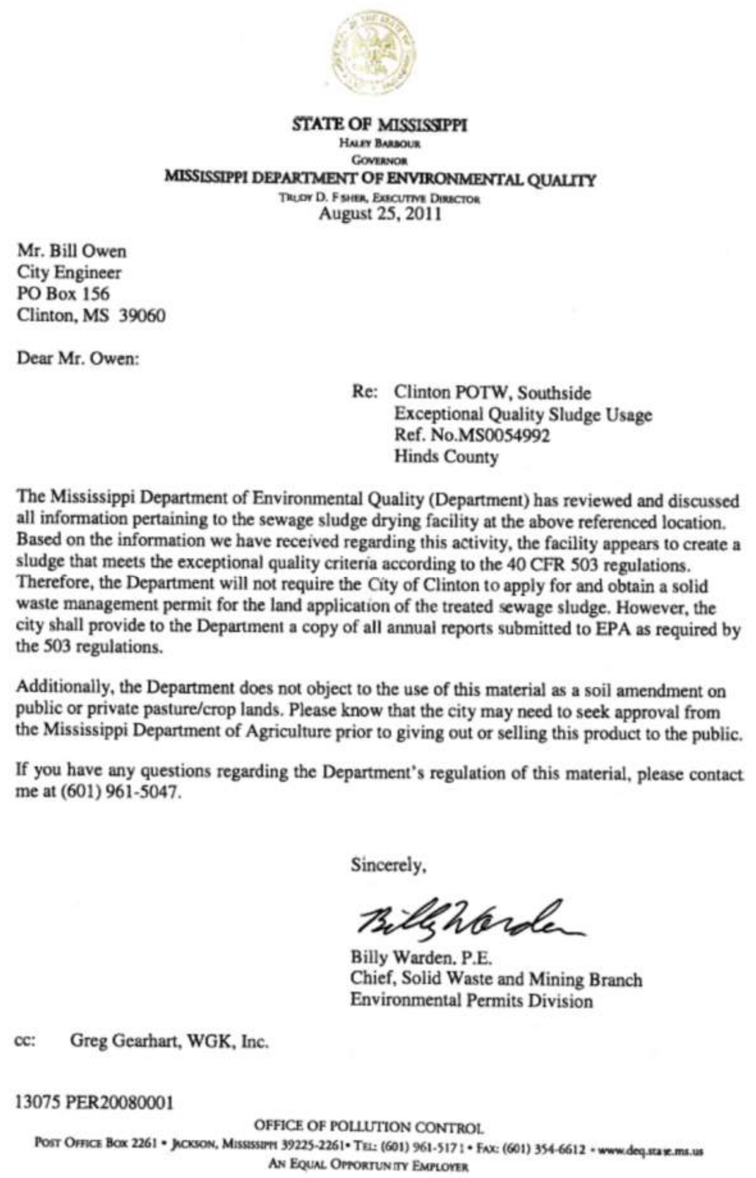






Solar Drying and Class A with Automated Dryer System





STATE OF MISSISSIPPI
HALEY BARBOUR
GOVERNOR
MISSISSIPPI DEPARTMENT OF ENVIRONMENTAL QUALITY
TRUDY D. FISHER, EXECUTIVE DIRECTOR

August 25, 2011

Mr. Bill Owen
City Engineer
PO Box 156
Clinton, MS 39060

Dear Mr. Owen:

Re: Clinton POTW, Southside
Exceptional Quality Sludge Usage
Ref. No.MS0054992
Hinds County

The Mississippi Department of Environmental Quality (Department) has reviewed and discussed all information pertaining to the sewage sludge drying facility at the above referenced location. Based on the information we have received regarding this activity, the facility appears to create a sludge that meets the exceptional quality criteria according to the 40 CFR 503 regulations. Therefore, the Department will not require the City of Clinton to apply for and obtain a solid waste management permit for the land application of the treated sewage sludge. However, the city shall provide to the Department a copy of all annual reports submitted to EPA as required by the 503 regulations.

Additionally, the Department does not object to the use of this material as a soil amendment on public or private pasture/crop lands. Please know that the city may need to seek approval from the Mississippi Department of Agriculture prior to giving out or selling this product to the public.

If you have any questions regarding the Department's regulation of this material, please contact me at (601) 961-5047.

Sincerely,

Billy Warden, P.E.
Chief, Solid Waste and Mining Branch
Environmental Permits Division

cc: Greg Gearhart, WGK, Inc.

13075 PER20080001

OFFICE OF POLLUTION CONTROL
POST OFFICE BOX 2261 • JACKSON, MISSISSIPPI 39225-2261 • TEL: (601) 961-5171 • FAX: (601) 354-6612 • www.deq.state.ms.us
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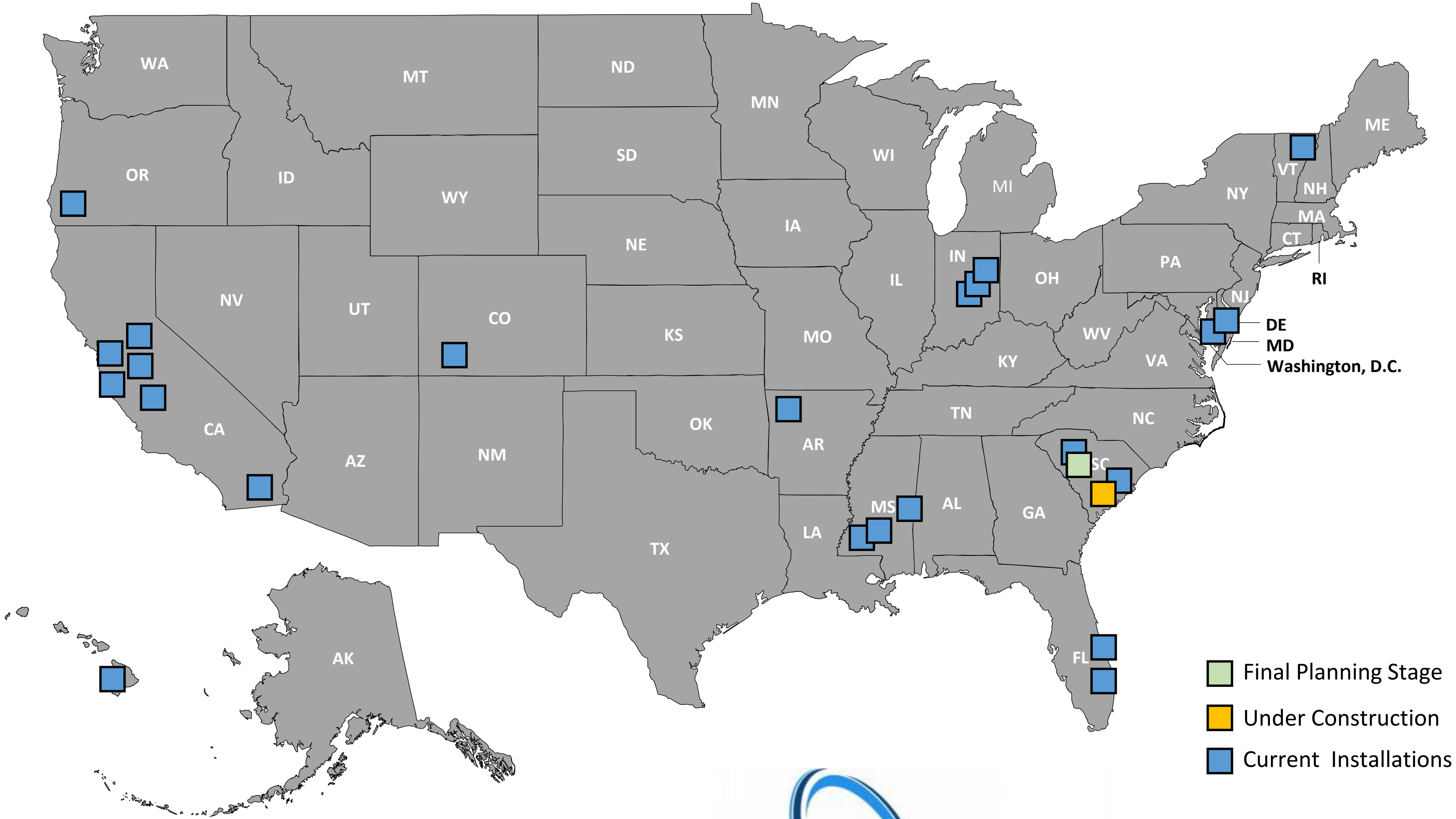
>20 Installations USA & growing

THERMO-SYSTEM®
Active Solar Dryer™



HARVEST TECHNOLOGY

THERMO-SYSTEM®
Active Solar Dryer™

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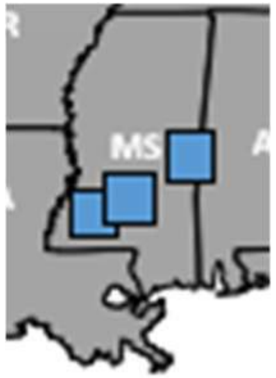


THERMO-SYSTEM®
Active Solar Dryer™

THERMO-SYSTEM®

Active Solar Dryer™

- ***Palma de Mallorca, Spain***

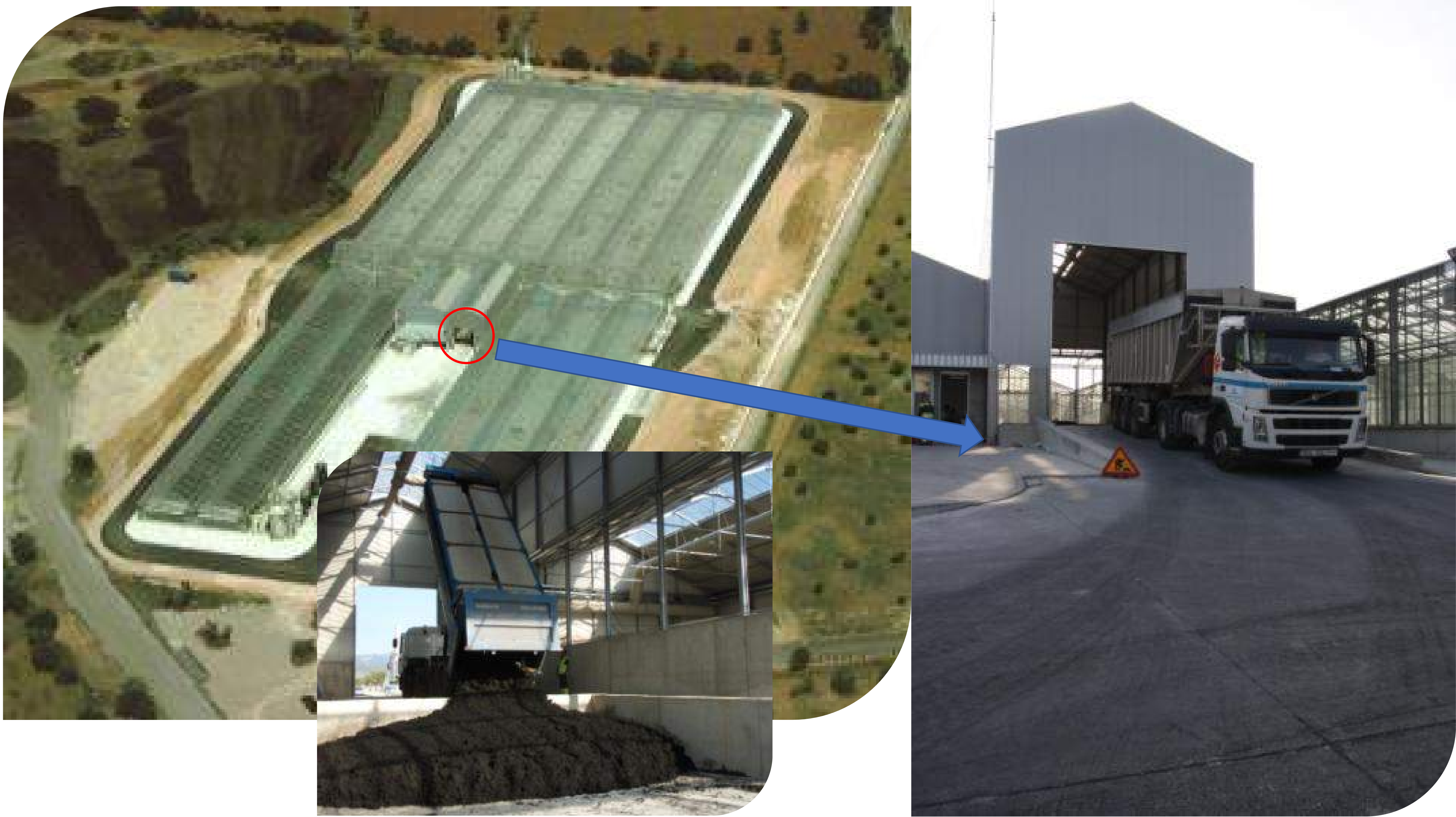
- equivalent 40 MGD Plant
- receives different types of biosolids
- 33,000 tons per year throughput
- Footprint: 4.4 acres
- 12 Chambers

REGIONAL DRYING FACILITY

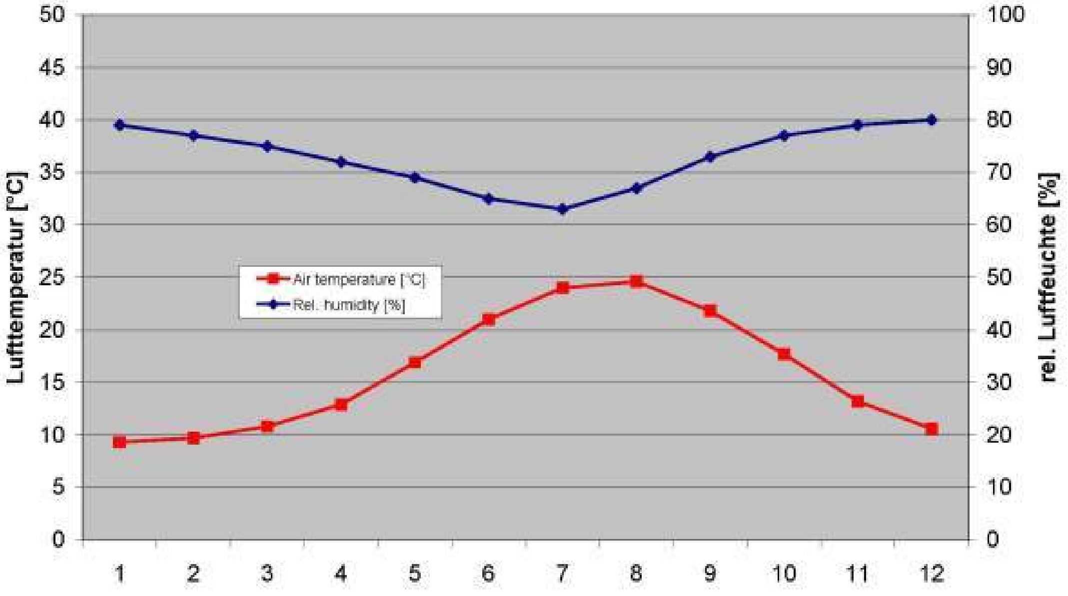
HARVEST TECHNOLOGY

THERMO-SYSTEM®
Active Solar Dryer™

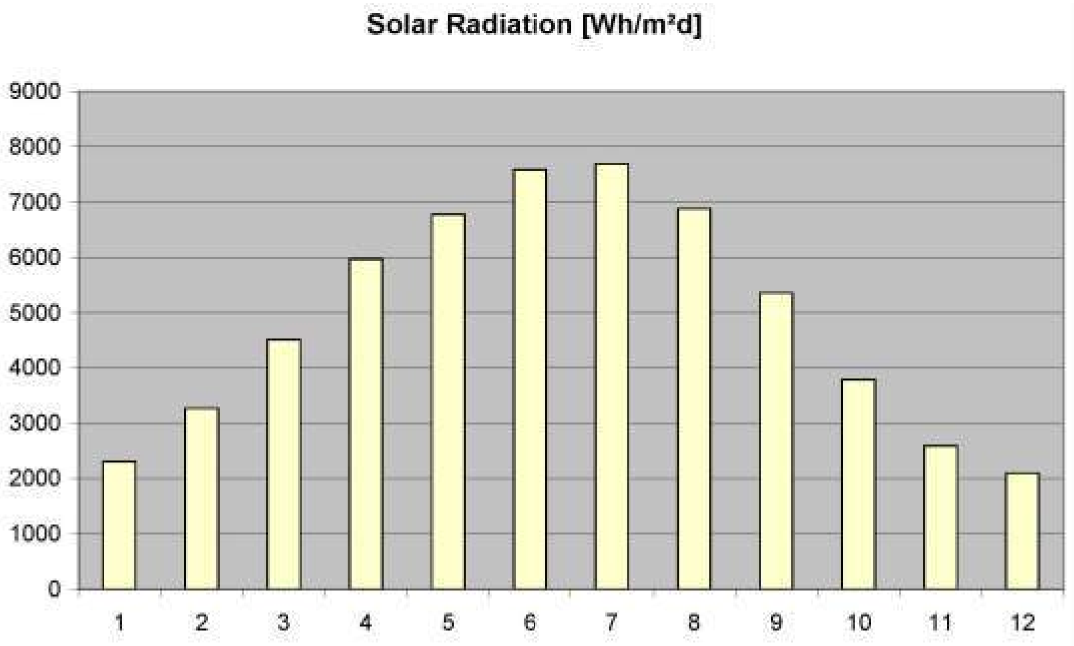
Biosolids Handling inside Dryer Facility



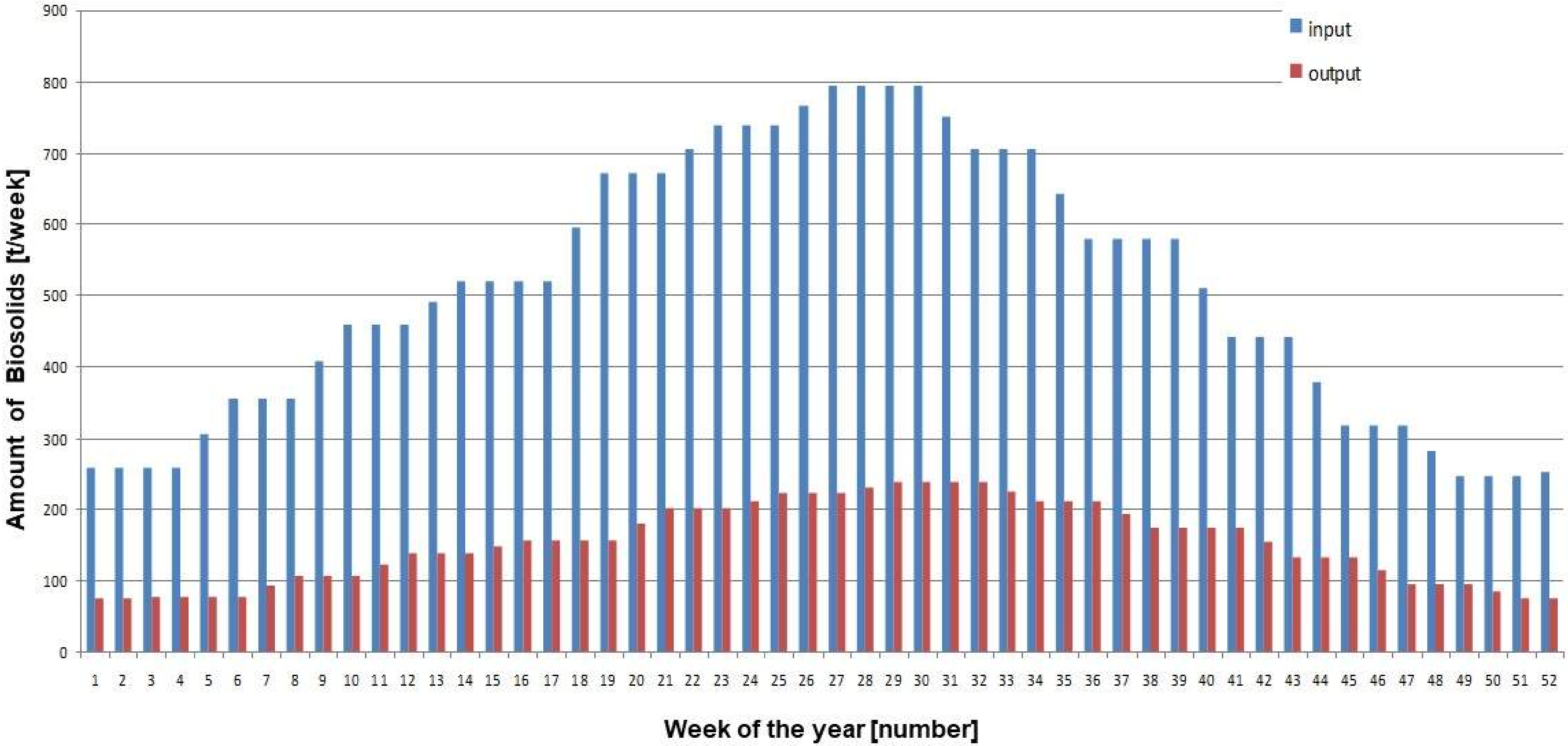
Climatic Data

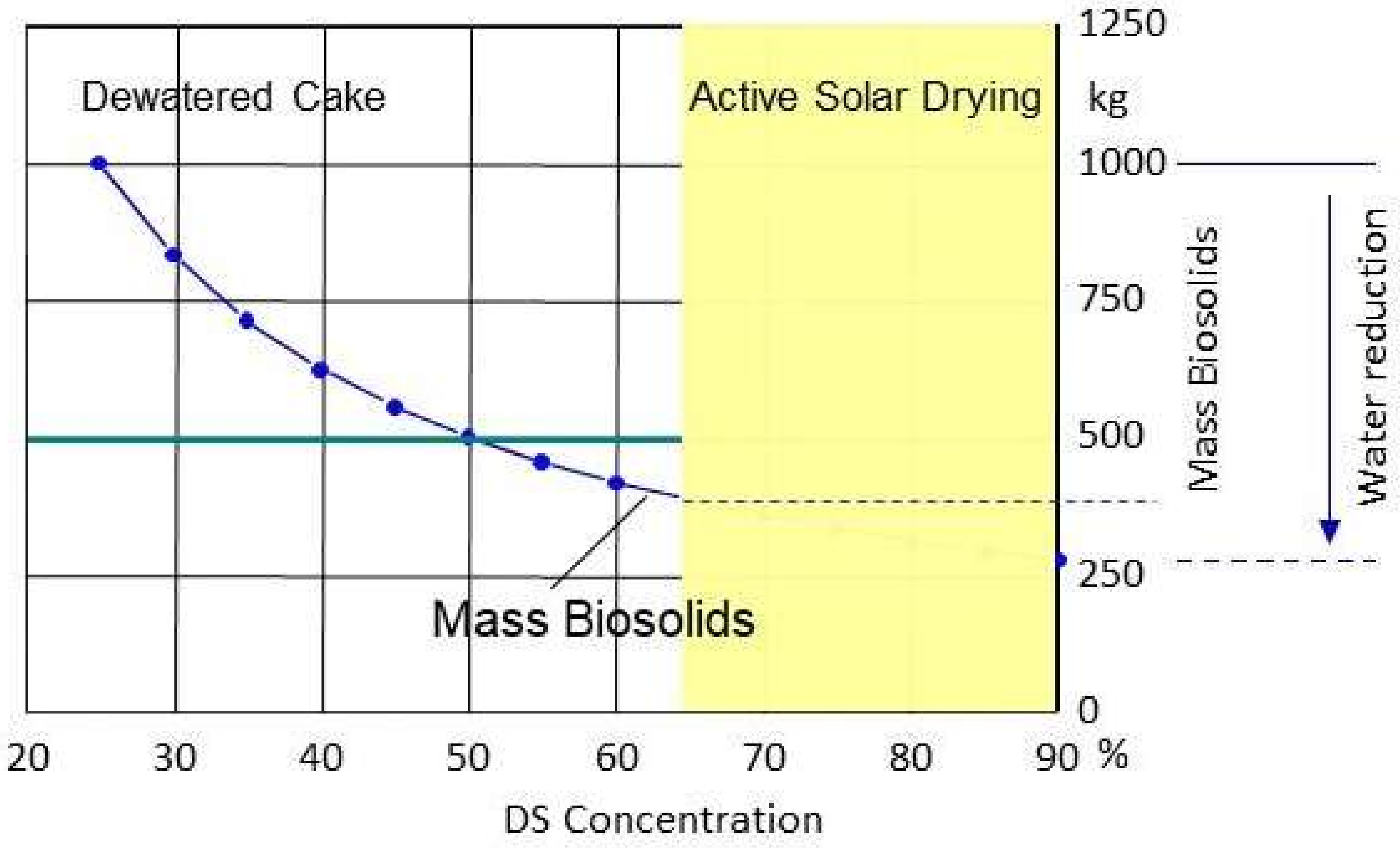


2008 Data Set

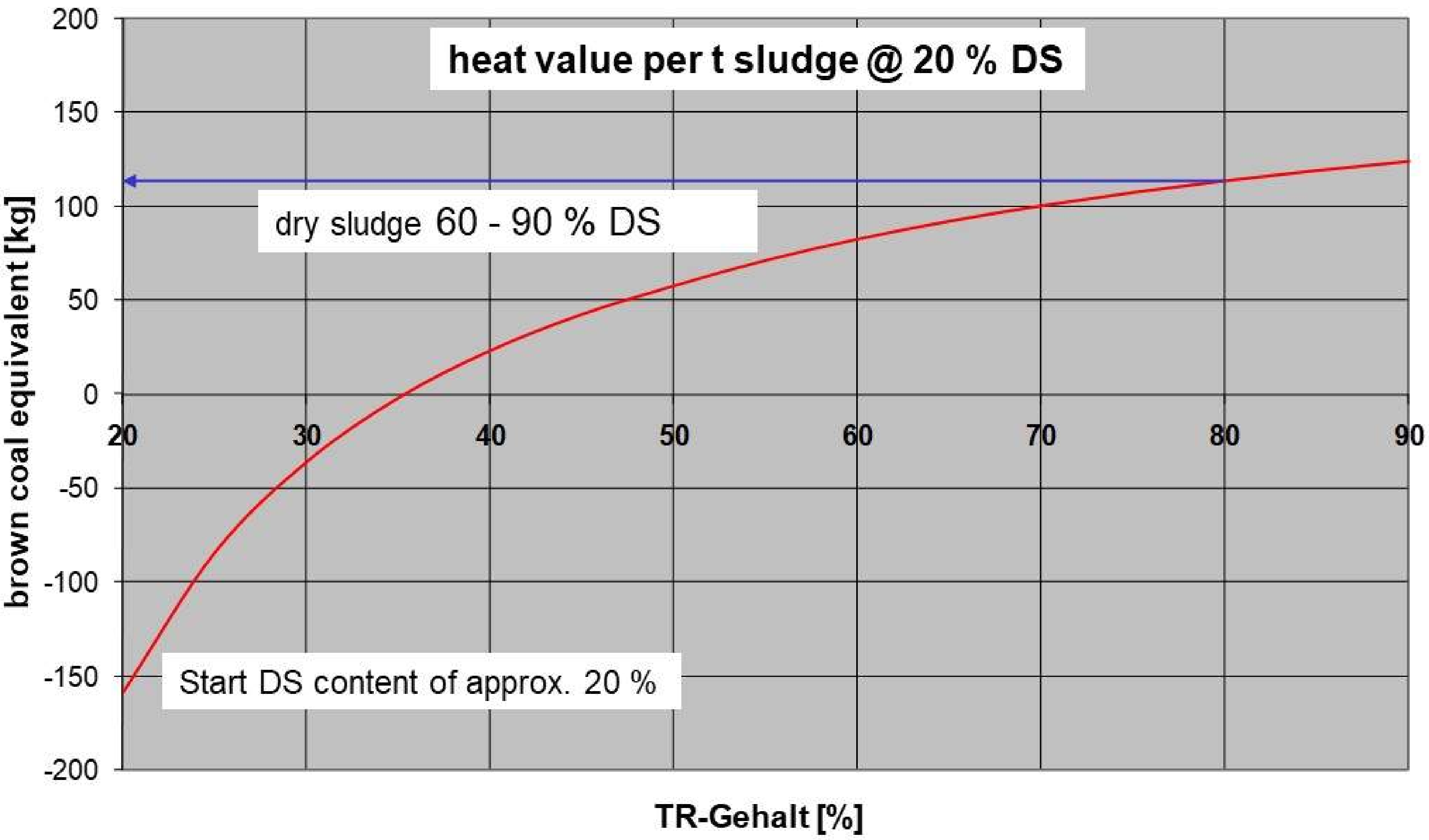


Biosolids Input (15-25 % DS) and Biosolids Output (65-75% DS) on a Weekly Basis

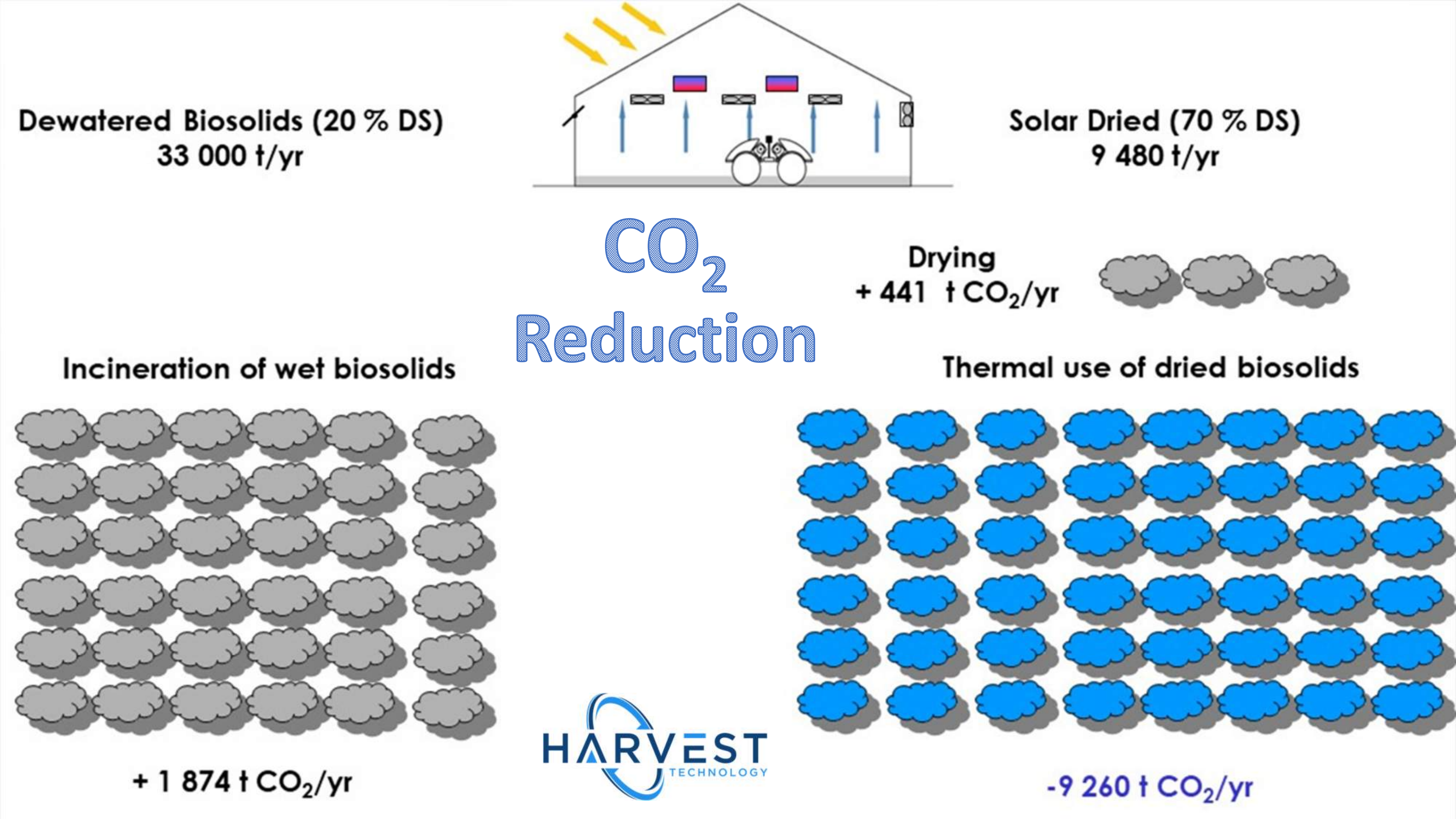




Dewatered Cake
Active Solar Drying
1250
kg
1000
750
500
250
0
Mass Biosolids
Water reduction
Mass Biosolids
20
30
40
50
60
70
80
90
%
DS Concentration



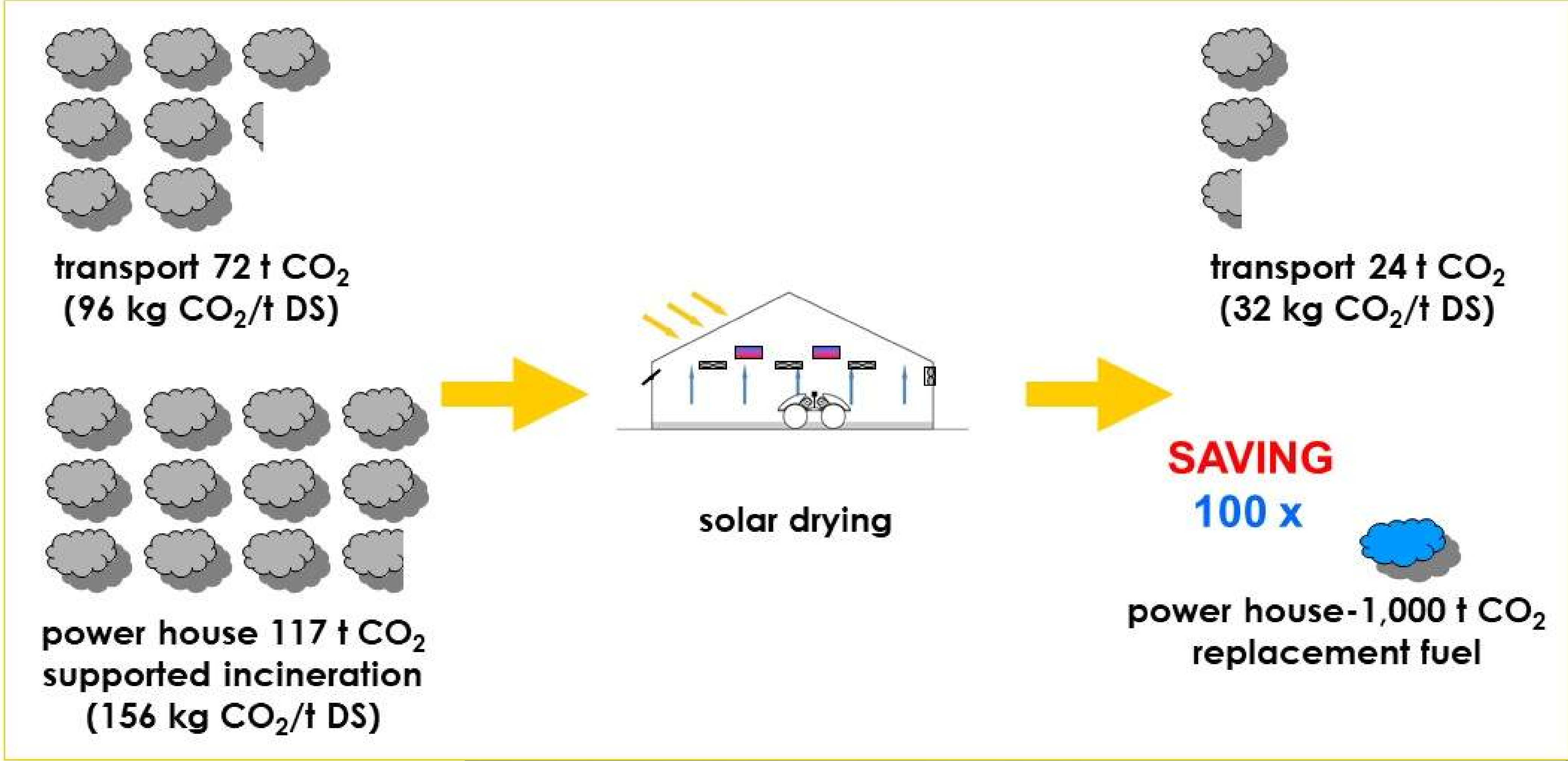
➔escalation of the heat value (~raw brown coal)


Dewatered Biosolids (20 % DS)
33 000 t/yr
Solar Dried (70 % DS)
9 480 t/yr
CO2
Reduction
Drying
+ 441 t CO2/yr
Incineration of wet biosolids
Thermal use of dried biosolids
+ 1 874 t CO2/yr
HARVEST
TECHNOLOGY
-9 260 t CO2/yr

Type of Drying Facility	Unit	Conventional Dryer	Solar Dryer
Location		Data from Literature	Palma de Mallorca, Spain
Area	ft^2	(smaller)	215,280
Annual Throughput Capacity	tons	(TBD/open)	33,000
Initial Dried Solids Concentration	% ds	hypothetically: 20-30	15 – 20
Final Target Dried Solids	% ds	>80	60 – 70
Evaporation of H_2O	t/yr	(TBD/open)	22,928
Natural Gas / Thermal Energy	BTU	Constantly required	None / Solar Radiation
Temperature of Heating Fluid	°F	<400	None
Temperature of Drying Process	°F	<300	<125
Thermal Energy Demand	kWh/t H_2O	<1,300	Solar Radiation
Electrical Energy Demand	kWh/t H_2O	<120	<35
Final Use of Biosolids		(all options open)	Fuel Supplement Coal-Fired Power Plant
Class A		Yes	Optional
CO_2 Emissions	t CO_2/t H_2O	240	23
Total Drying Costs	US$/t H_2O	130	40

HARVEST TECHNOLOGY

Reduction in CO_2- emission (e.g. 40,000 PE)



Case Study Renningen, Germany

SludgeReformer™

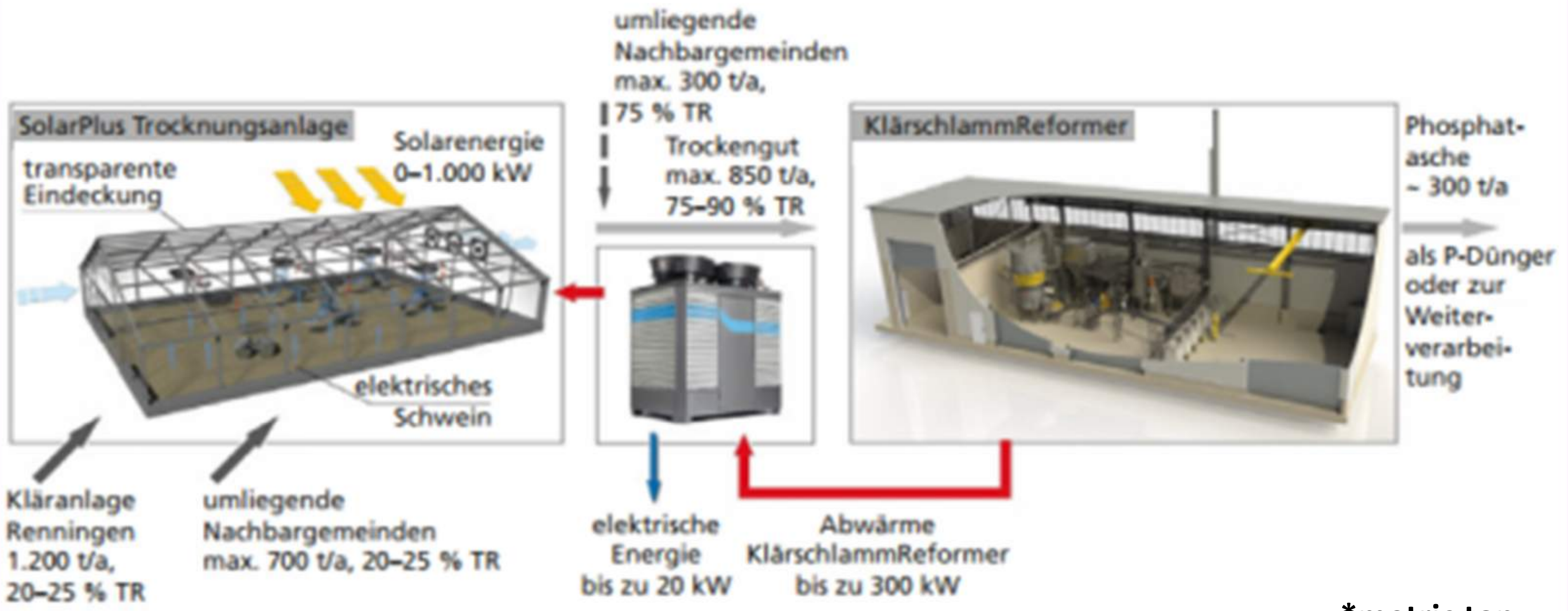
From Lab-Scale to Piloting

Type P-1: Throughput 45 lbs/hr at 70% ds

Type P-2: Throughput 220 lbs/hr at 70% ds

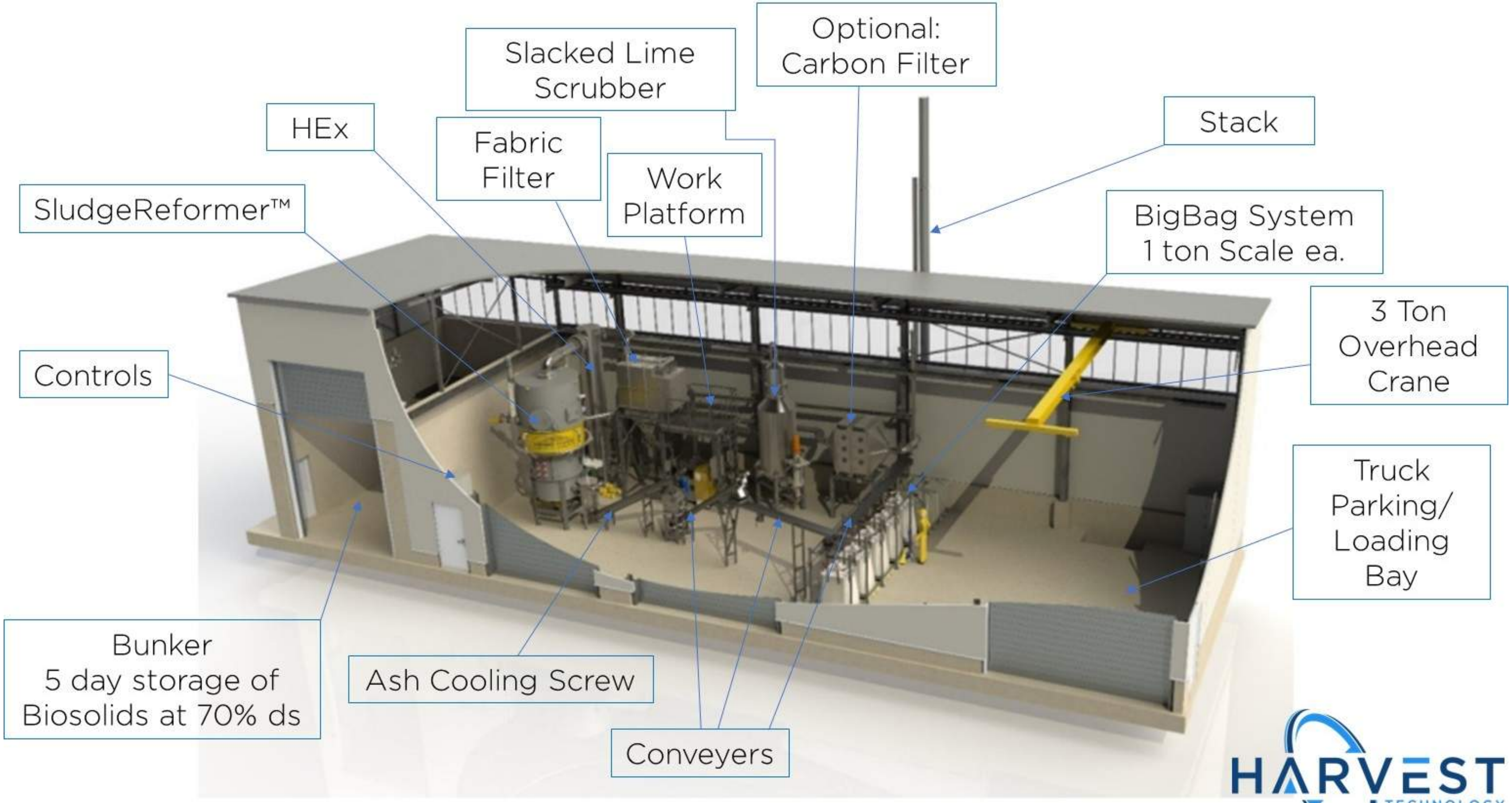
Case Study Renningen

SludgeReformer™ Installation Renningen, Germany		
Biosolids Input (dry basis)	937	tons per year
Dried Solids Concentration	70	% ds
Organic Content post A.D.	˜60	%
Ash Amount (out)	275	tons per year
Nominal Fuel Throughput	330	lbs per hour
Combustion Heat Output	1.1	MMBTU/hr
Exhaust Gas Cleaning	Three (3)	Steps/Phase
ORC Turbine Electr. Power	68,300	BTU/hr (output)
Wasteheat To Solar Dryer	683,036	BTU/hr
Area of Reformer Building	3,230	ft^2



*metric ton

Renningen Anaerobic Digestion 1.5 MGD
20,000 PE (population equivalent)



Slacked Lime Scrubber
Optional: Carbon Filter
HEx
Fabric Filter
Work Platform
Stack
SludgeReformer™
BigBag System 1 ton Scale ea.
3 Ton Overhead Crane
Controls
Truck Parking/ Loading Bay
Bunker 5 day storage of Biosolids at 70% ds
Ash Cooling Screw
Conveyers

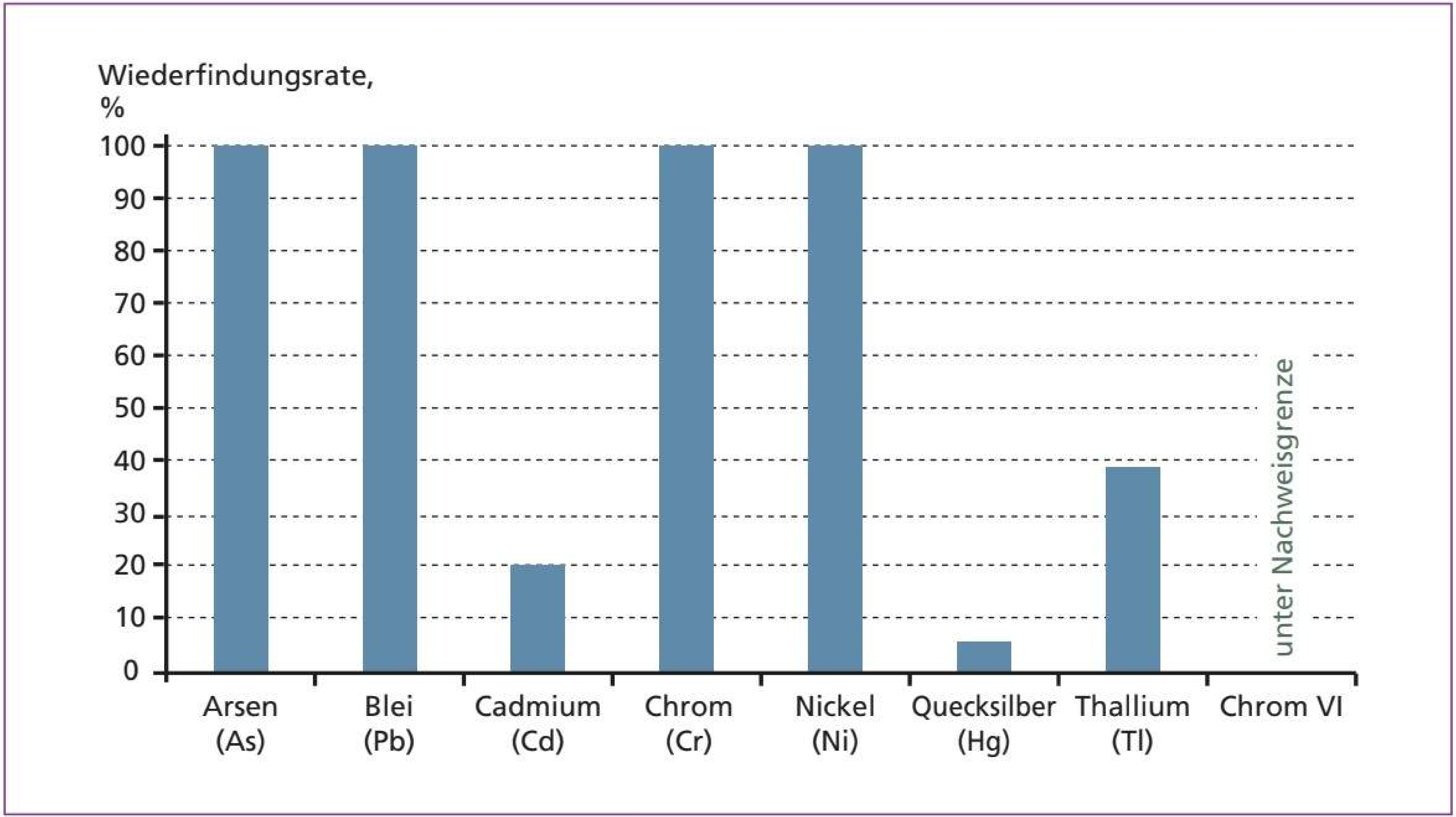
Dewatering to Drying to Ash

dewatered biosolids at 22% ds

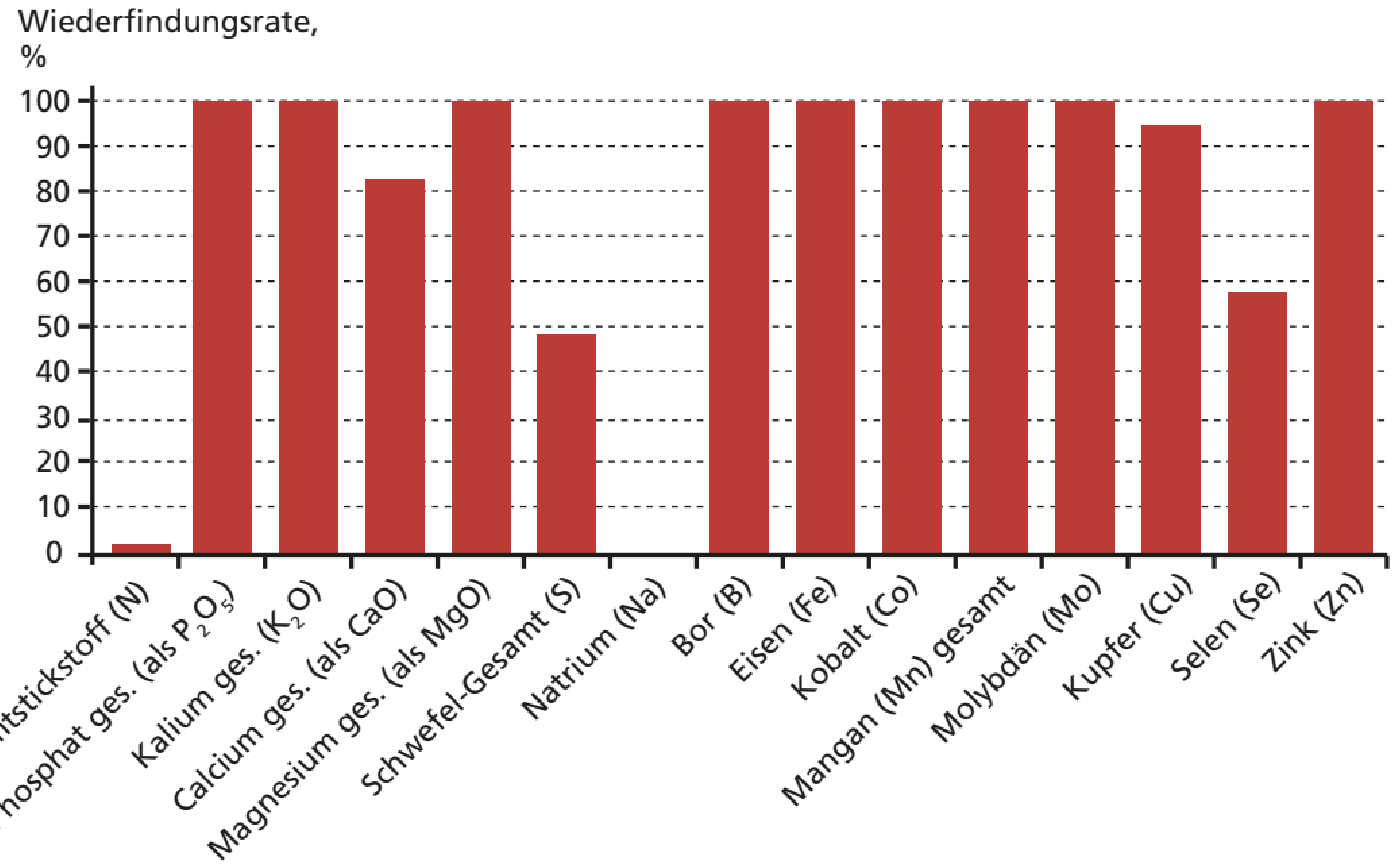
dried biosolids at 80% ds

ash from the Reformer

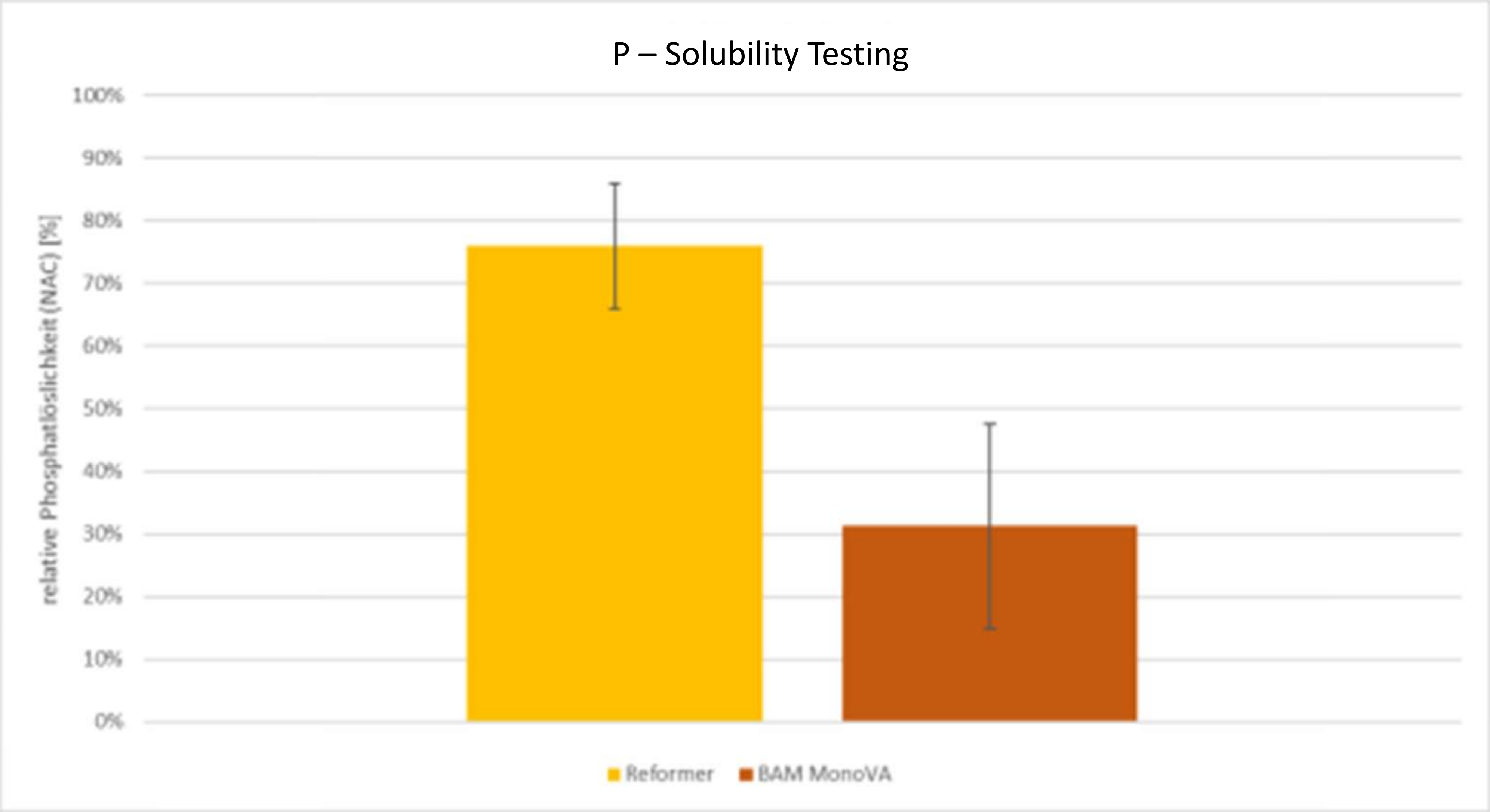
Heavy Metals



Elements



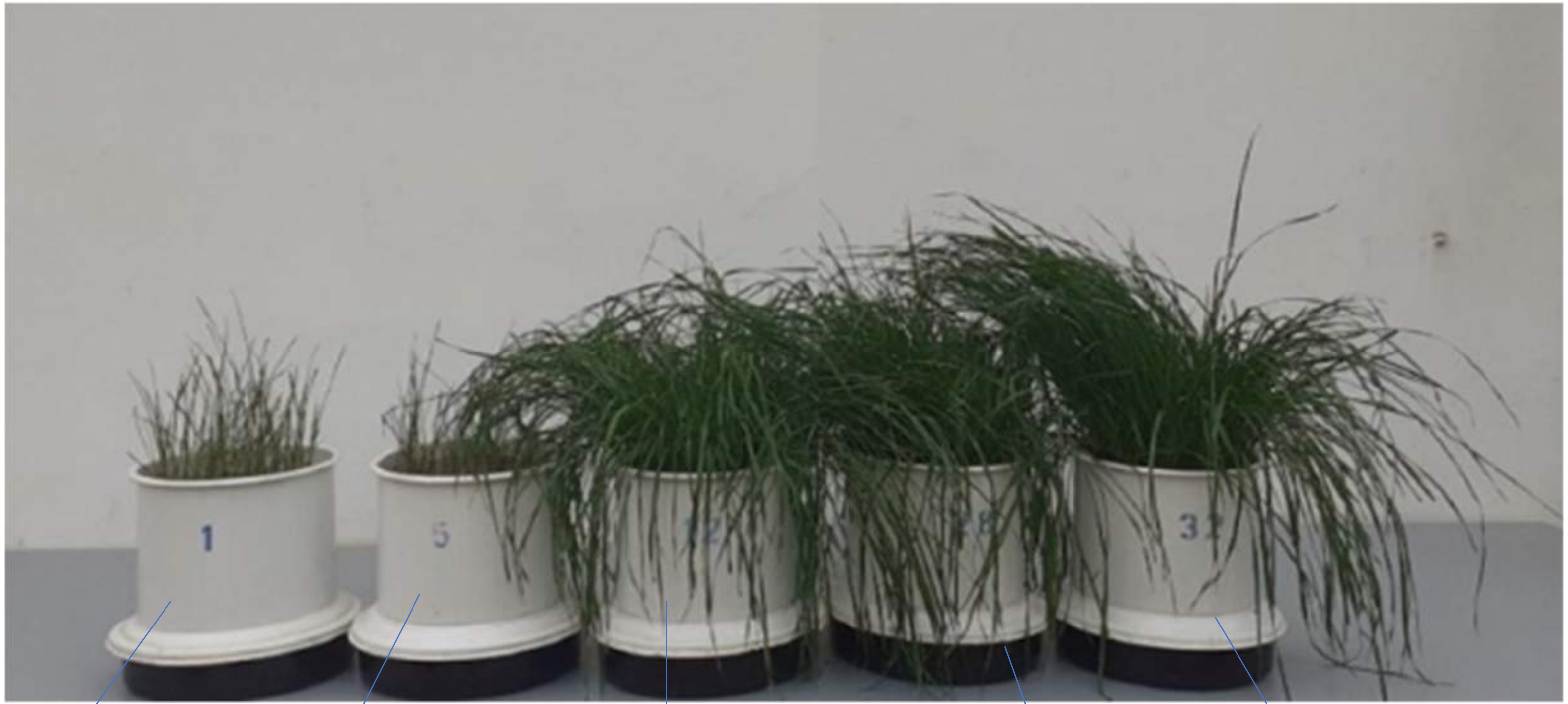
Wiederfindungsrate, %
100
90
80
70
60
50
40
30
20
10
0
Gesamtstickstoff (N)
Phosphat ges. (als P2O5)
Kalium ges. (K2O)
Calcium ges. (als CaO)
Magnesium ges. (als MgO)
Schwefel-Gesamt (S)
Natrium (Na)
Bor (B)
Eisen (Fe)
Kobalt (Co)
Mangan (Mn) gesamt
Molybdän (Mo)
Kupfer (Cu)
Selen (Se)
Zink (Zn)



Comparison of the neutral ammonium citrate solubility (NAC) of ash from the SludeReformer and typical mono-incineration ash

Growth of Welsch Weidelgrass / Ryegrass

[Technical University of Mittelhessen 2020]



PO Raw

Phosphate

Ca(H2PO4)2 triple superphosphate

Sludge Reformer Ash Test 1

Sludge Reformer Ash Test 2

SludgeReformer™

Type 3: Throughput 770 lbs/hr @ 70% ds

330 lbs/hr

SludgeReformer™ Type 1: 330 lbs/hr at 70% ds

HARVEST TECHNOLOGY

Air Handling and Bagging

Active Solar Dryer™

Sludge Reformer

Proof of Concept

1.000 t/yr

25% DS
75% Water
dewatered

333 t/yr

70% DS
30% Wasser
After ASD

125 t/yr

Ash

Heat Recycling

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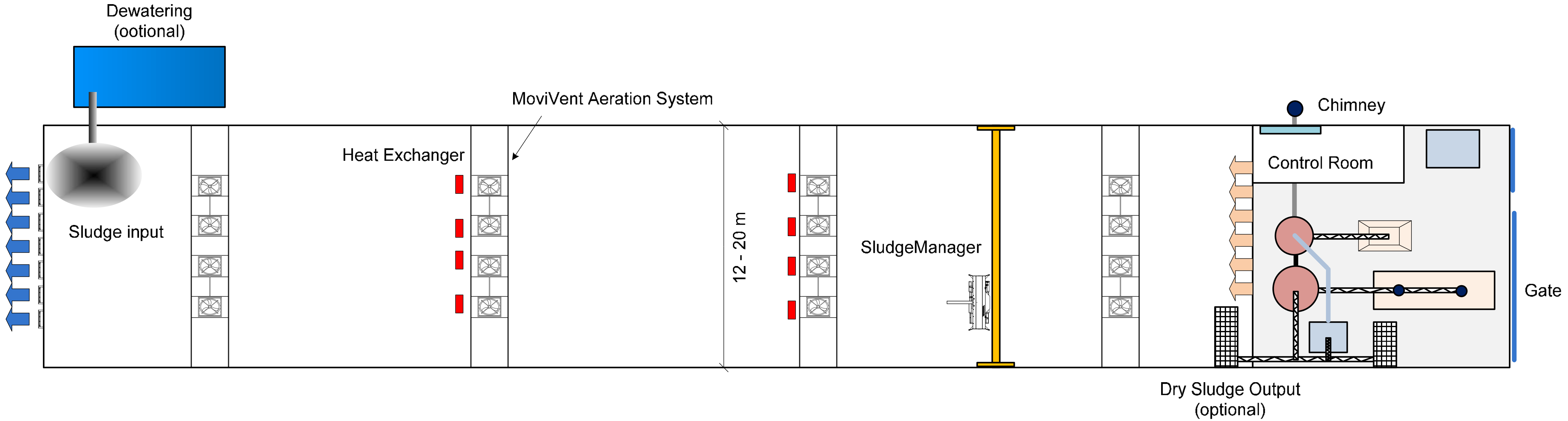
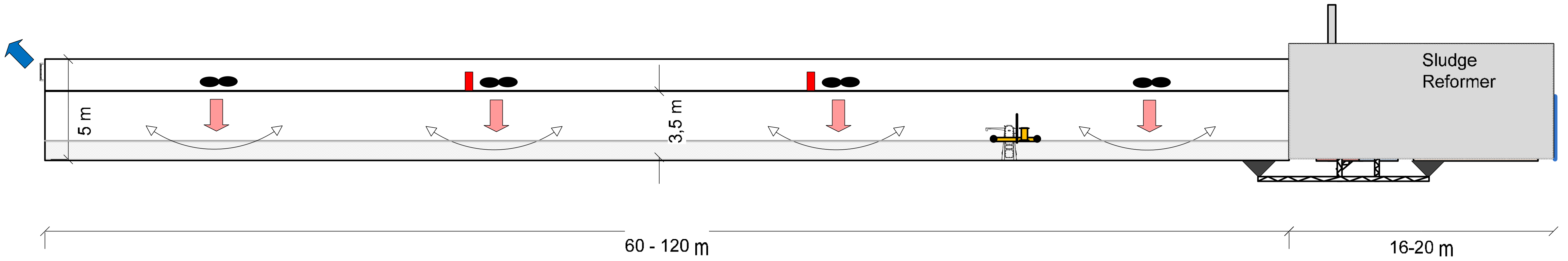
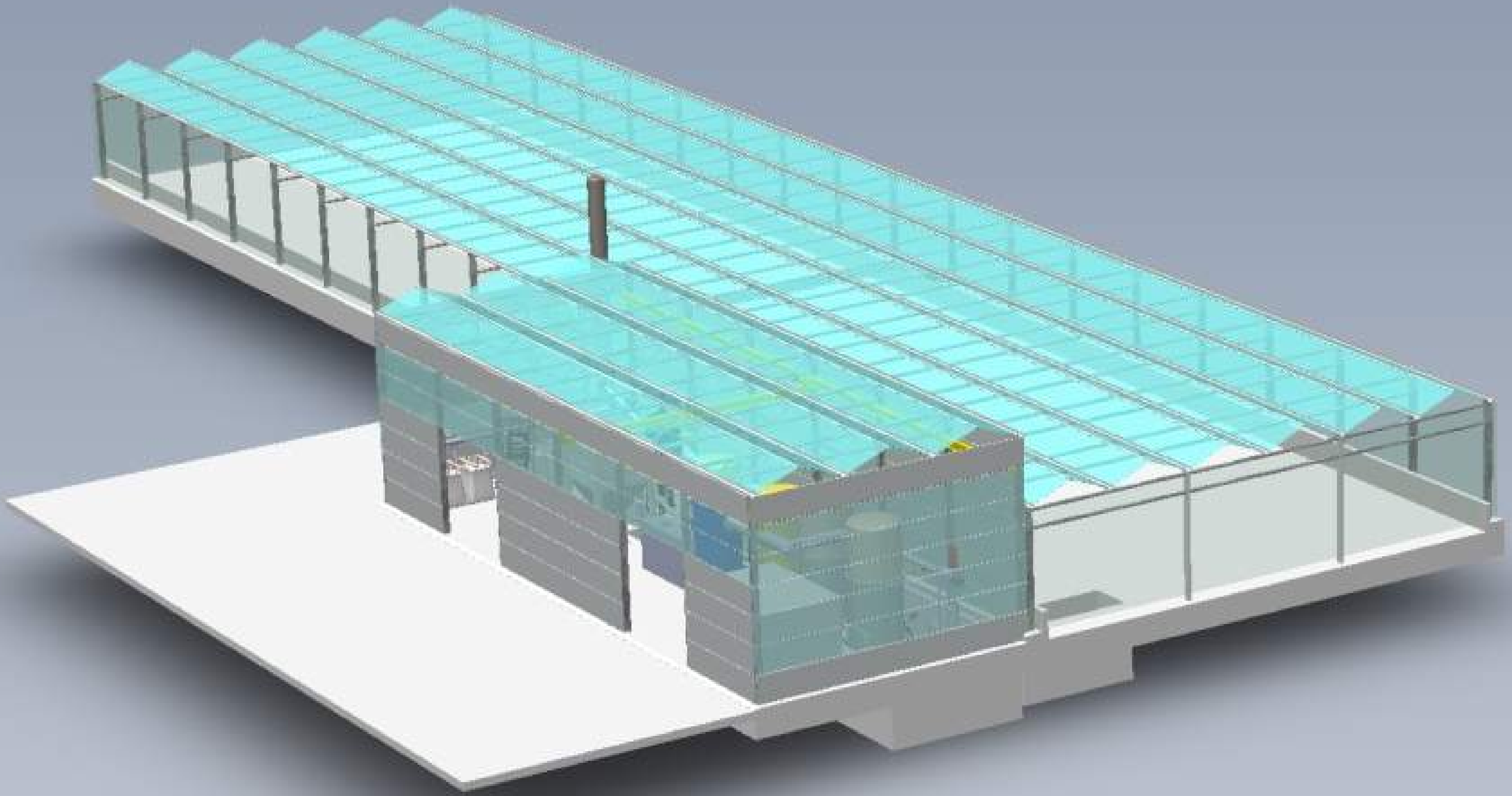
Future Design Option

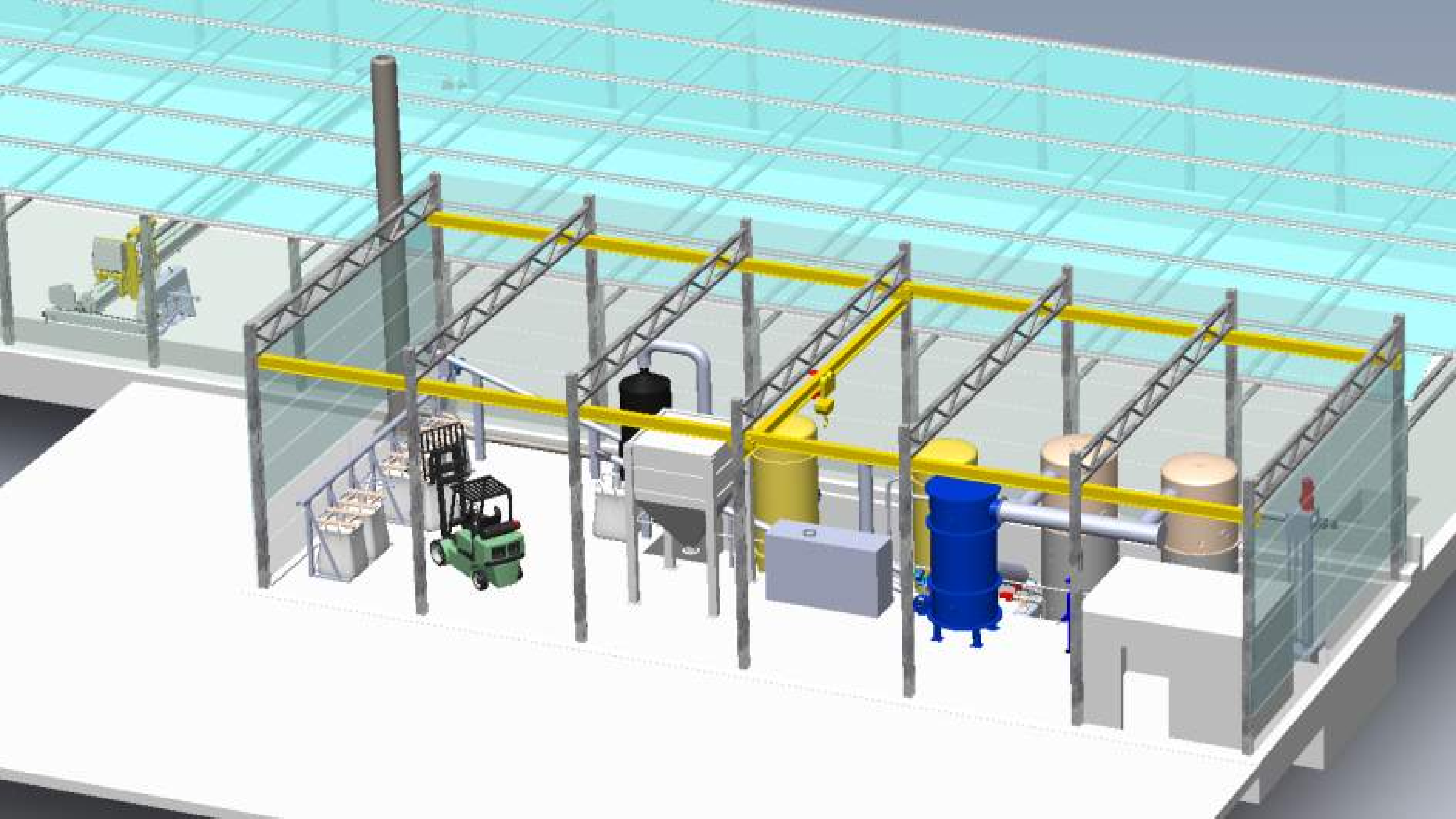
Top View

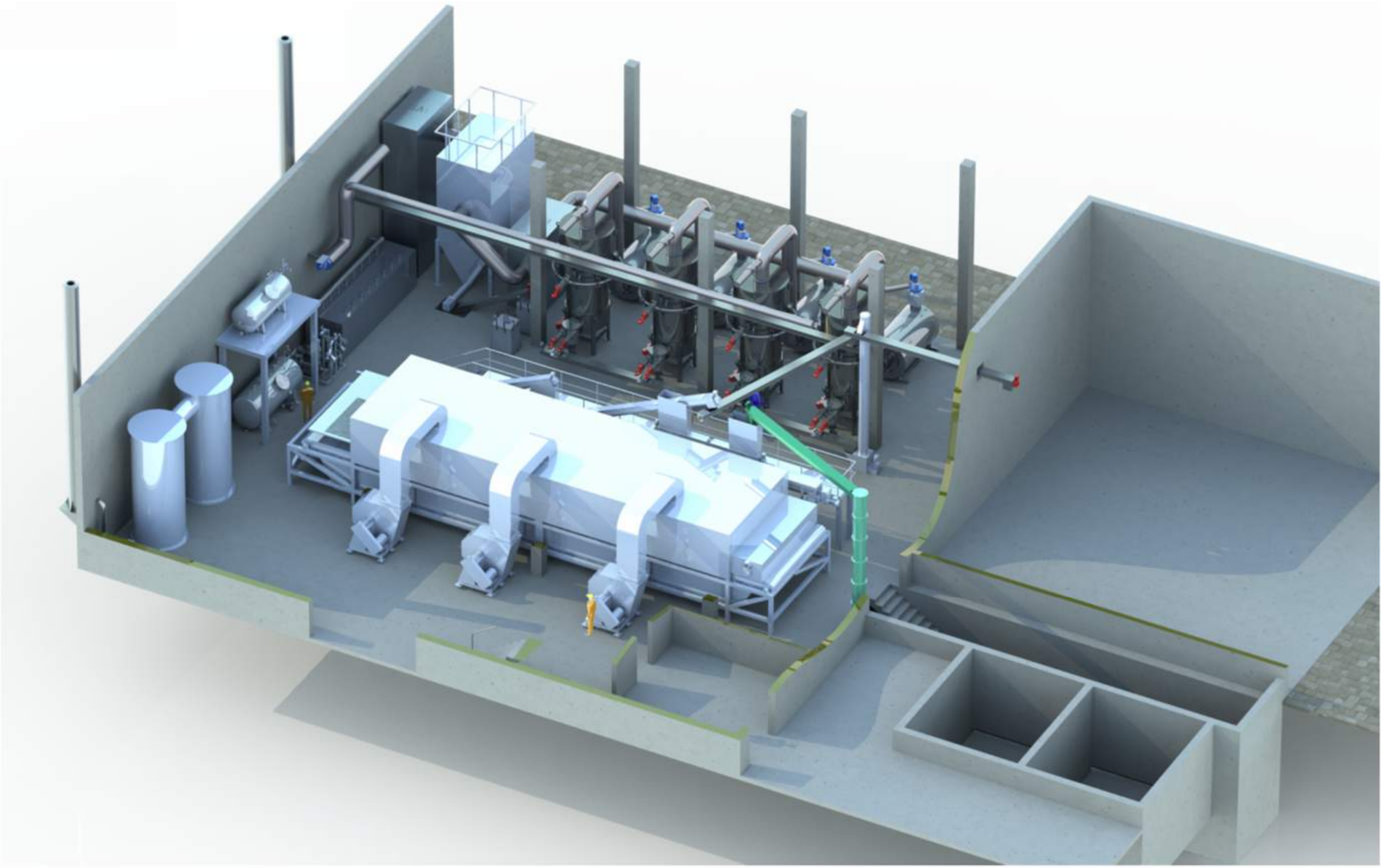


Side View







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