Jacobs In the kNOW

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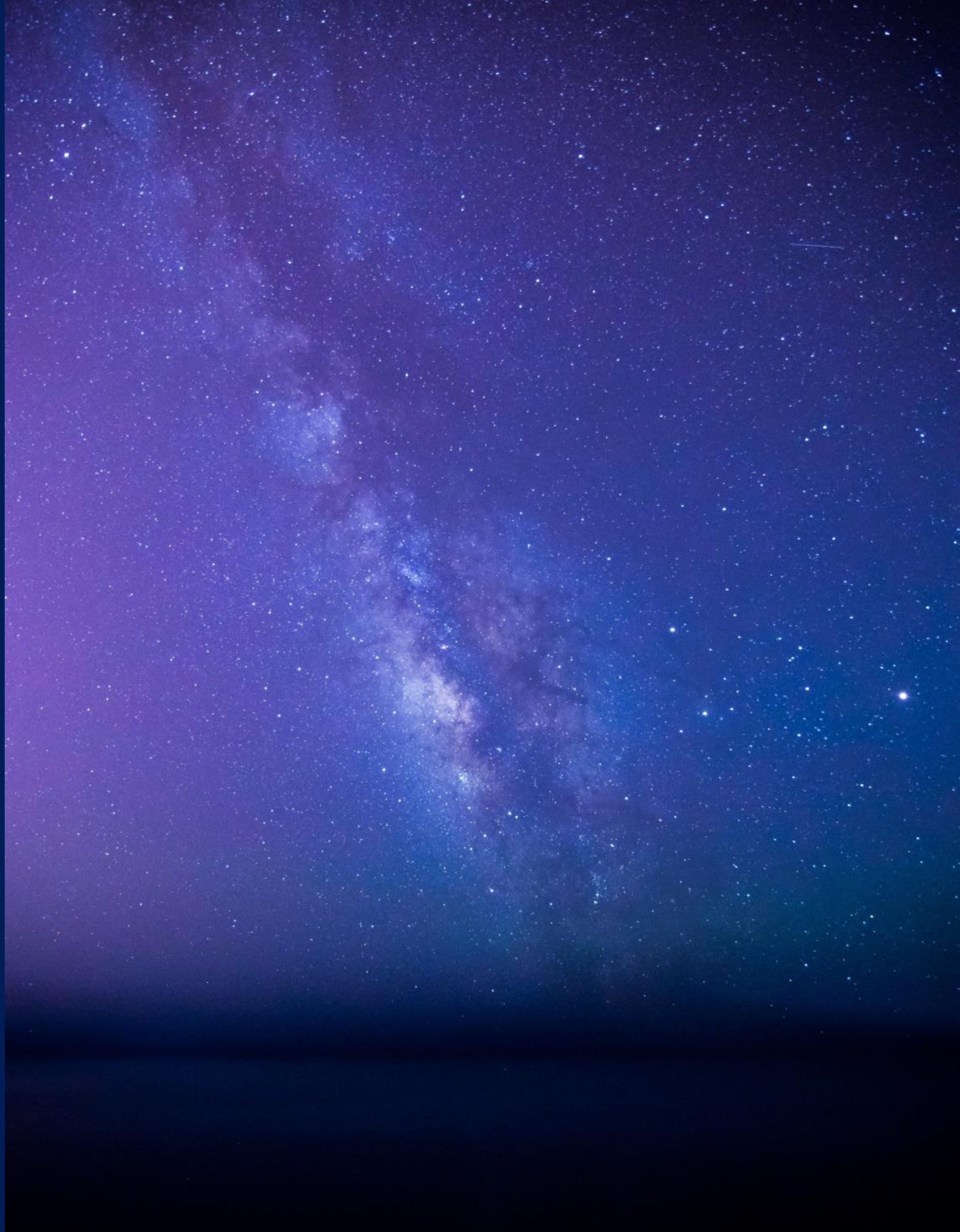
We encourage you to submit questions in the chat.

Jacobs

Challenging today.
Reinventing tomorrow.



Jacobs

Challenging today.
Reinventing tomorrow.

Closing the loop: Biosolids treatment for maximum resource recovery and carbon neutrality

In the kNOW Webinar Series

May 2, 2023

Agenda

Introductions

Adaptive System Planning

Advanced Digestion

Thermal Technologies

Resource Recovery Opportunities

Live Q&A

Introduction

Colin Newbery

About Jacobs In the kNOW webinars

Introduction

Delivers the latest information on the hottest topics trending in the water sector. Each webinar includes case studies and firsthand experiences with the featured topics presented by the foremost water industry experts.

The webinar series was launched to provide a platform to connect with the water sector, share innovations and offer professional development credits.

Visit: www.jacobs.com/webinars/in-the-know

Identifying Smarter Solutions to Infrastructure Challenges Using Optimization

Infrastructure projects are becoming more challenging as we address aging infrastructure, capacity issues, climate change, population growth and conflicts with other existing infrastructure. Optimization technology employs sophisticated algorithms, enhanced computation and automation to assist water utilities in finding solutions to these complex infrastructure problems that maximize benefits and minimize costs. In this webinar, we will present examples from Anglian Water's Strategic Pipeline Alliance, a CSO Long-Term Control Plan and others with our partner Optimatics.

Climate Change: How Should Water Utilities Respond to the IPCC's Call to Action?

While we respond to other pressing global challenges, climate change remains one of the biggest threats to life on this planet as we know it. As anchor institutions embedded in nearly every community, water systems have an opportunity to accelerate our progress, playing an even bigger role in delivering decarbonization and resilience measures against climate change. In this webinar we will present the key findings of the recent IPCC AR6 'Physical Science Basis' report of greatest relevance to the Water sector. We will help identify the potential vulnerabilities and make practical recommendations for resilience actions that can be taken to pro-actively manage them.

The Water Sector and Hydrogen: Green for Go

This "In the kNOW" webinar examines hydrogen from the perspective of the water sector as a potential producer and user of hydrogen. We identify pathways for hydrogen production at Water Resource Recovery Facilities, highlighting synergies and trade-offs with day-to-day treatment, and exploring hydrogen's possible contribution to the water sector's Net Zero carbon emissions targets.

Speakers

Meet our presenters

Facilitator

Colin Newbery, P. Eng

Jacobs Technical Director,
Water Asia

Speakers

Peter Burrowes, P. Eng

Jacobs Senior Fellow
Technical Engineer, Biosolids
and Resource Recovery, Canada

Gokul Bharambe

Jacobs Technical Director,
Biosolids and Resource
Recovery, ANZ

Our speakers

Meet our presenters

Peter Burrowes

- 47 years experience
- Global leadership in Process Engineering at Jacobs
- SME in thermal and biological treatment of organic wastes
  - Anaerobic digestion (AD)
  - Thermal and chemical/thermal pre-treatment prior to AD
  - Composting
  - Thermal drying
  - Incineration
  - Gasification
  - Pyrolysis
  - Hydrothermal Liquifaction

Gokul Bharambe

- 18 years of experience
- Technical Director – Resource recovery, ANZ
- Expertise in:
  - Adaptive system planning, Options assessment, Concept Design, Detailed design, commissioning
  - Anaerobic digestion
  - Advanced Digestion
  - Co-digestion
  - Resource Recovery

Adaptive System Planning

Development of World Cities

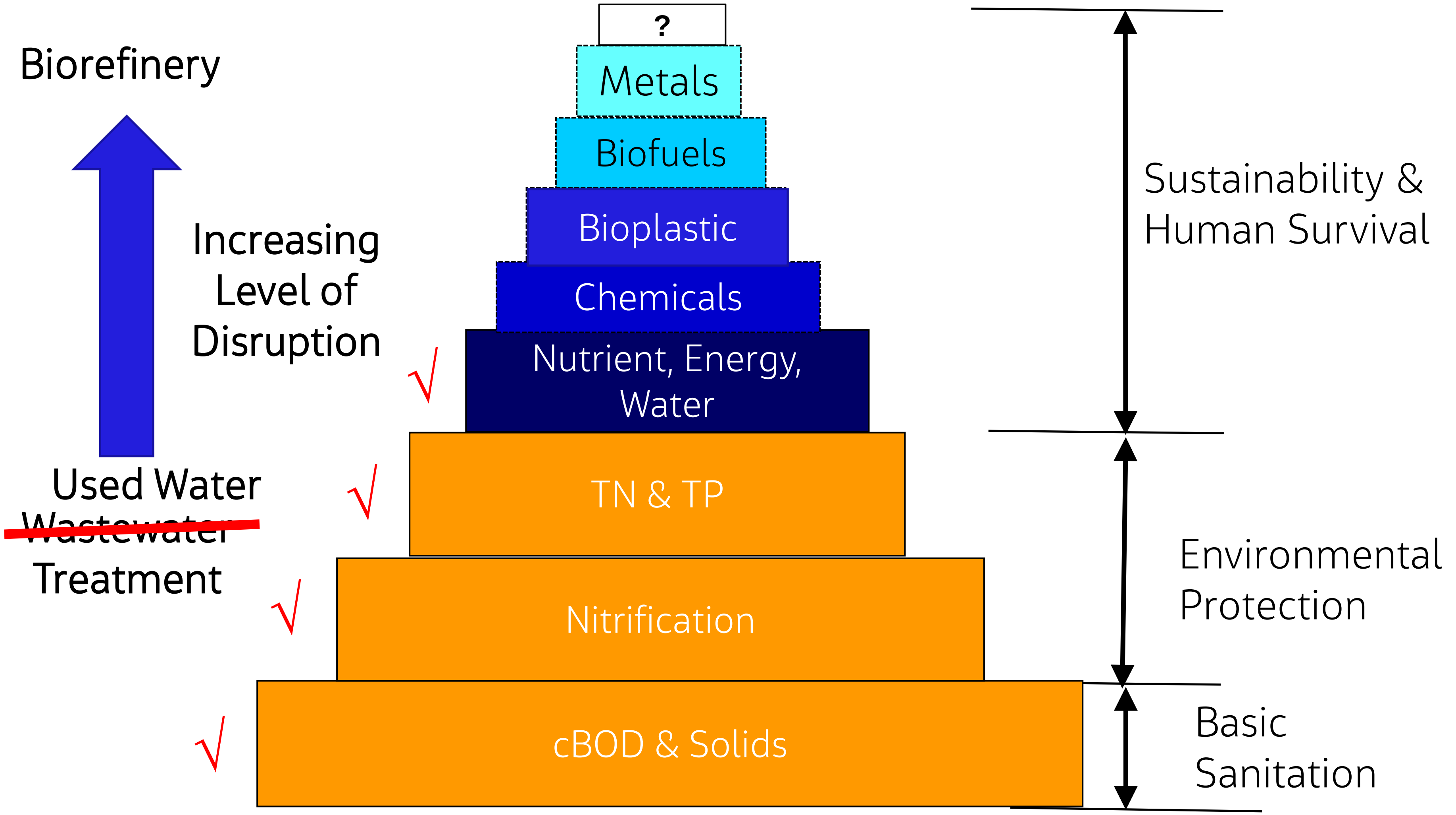
Münchener Rück
Munich Re Group

Development of World Cities

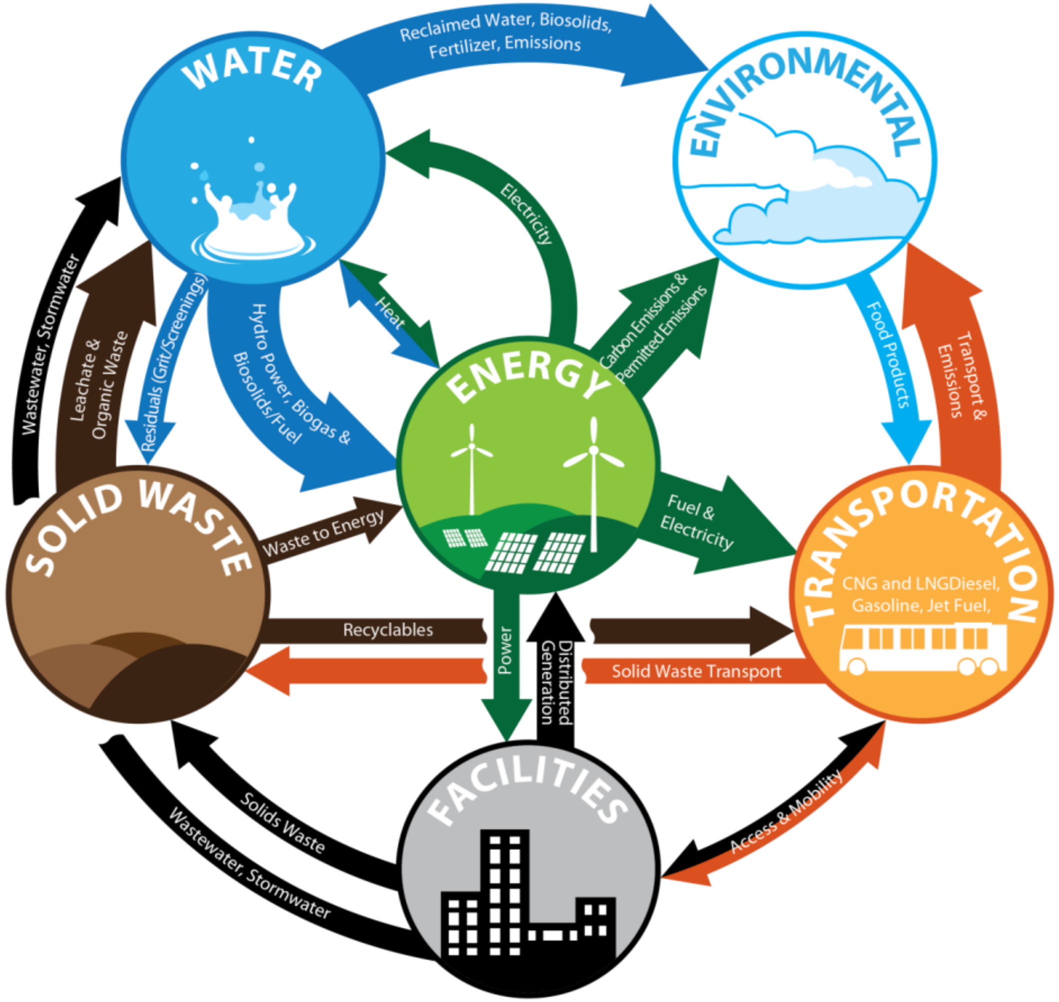
Development of World Cities

Münchener Rück
Munich Re Group

Disruptive Approaches are Needed to go from Treatment to Product Recovery



Solids Processing is an integral part of a Circular Economy



Biosolids

Nutrients

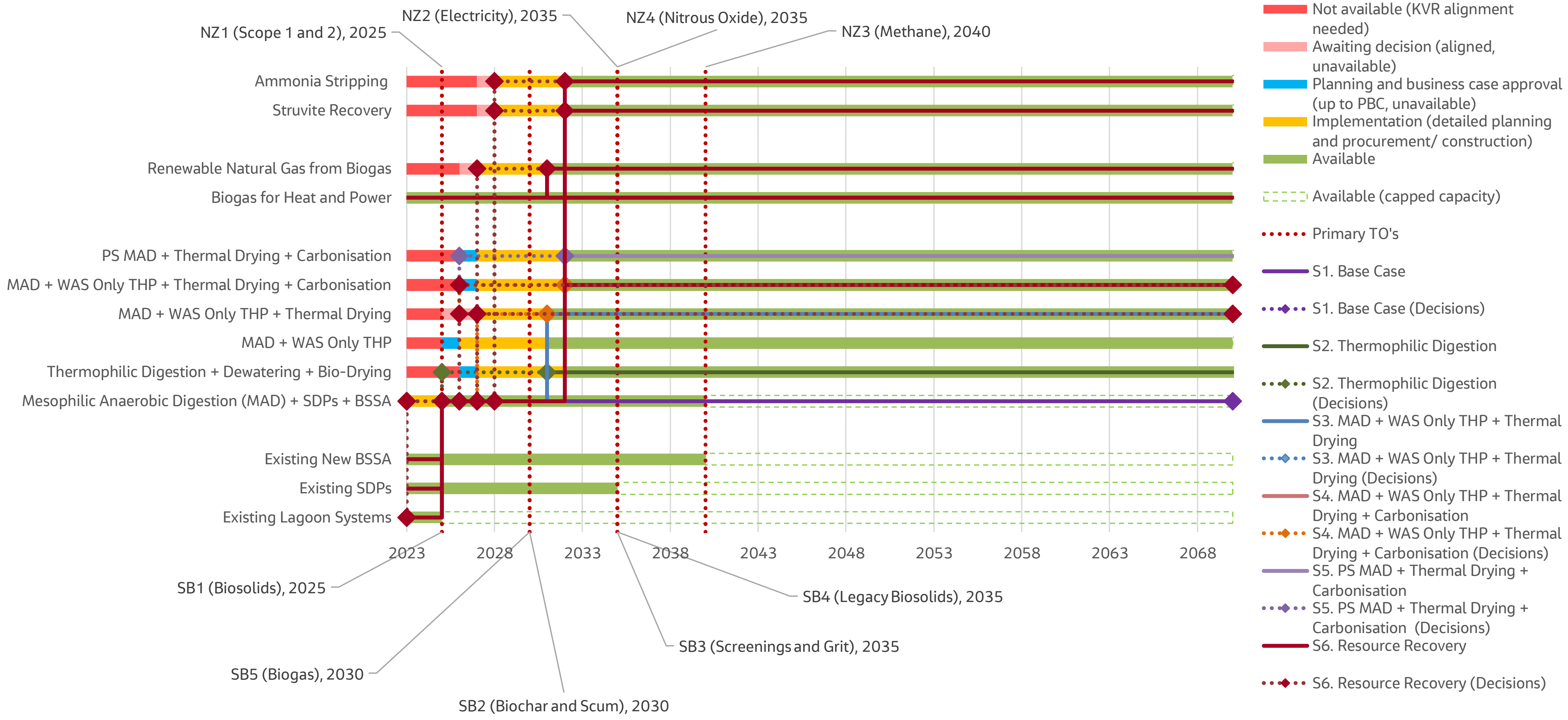
Energy

Water

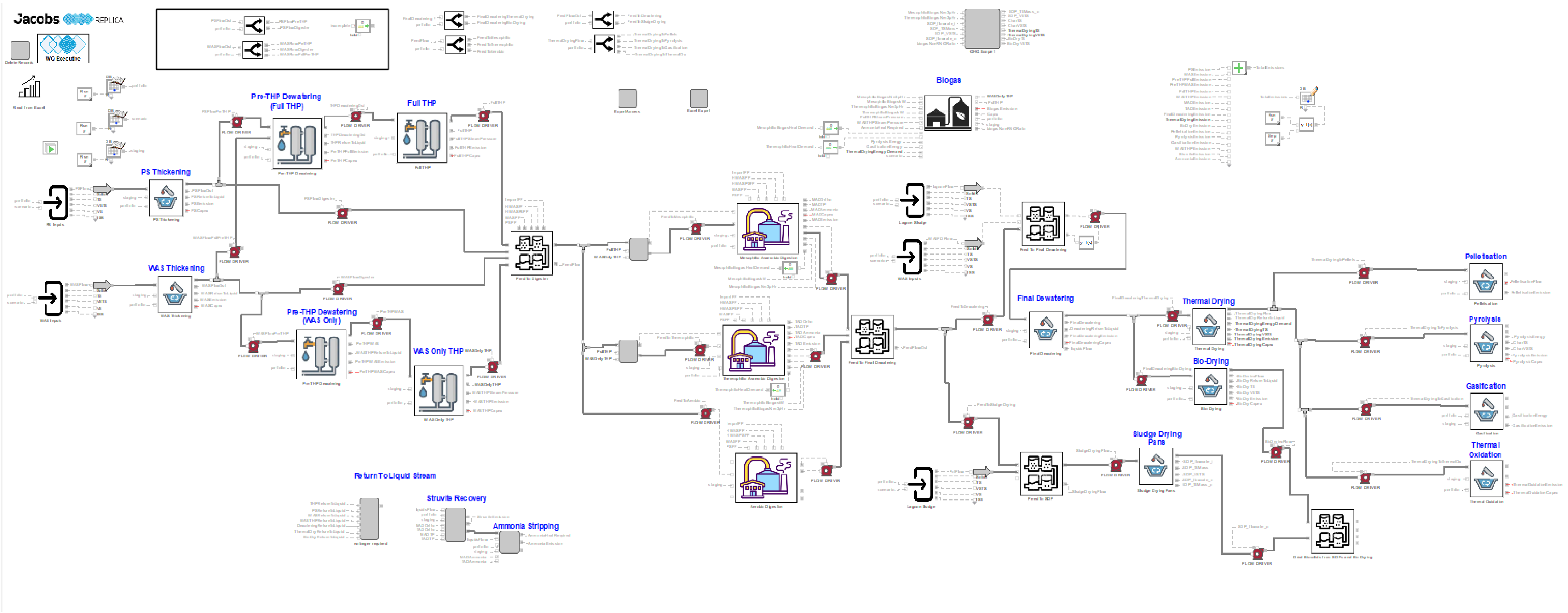
Biosolids Adaptive System Planning: Decision Making by Balancing Multiple Objectives

Economic Feasibility	• Circular Economy (Waste to Resource) • Revenue (Waste receiving, Value of resources) • Cost (Capital, Operating, Life Cycle Cost) • Adaptability to changing economic conditions
Environmental Sustainability	• Regulatory Requirements (Current, Future) • Resource Recovery (Biosolids, Nutrients, Energy, Water) • Produce more biogas and less biosolids (Reduce energy demand) • Market (Organic waste receiving, Biosolids, Energy)
Infrastructure Operations	• Reliability & Redundancy, Flexibility • Operation & Maintenance Ease • Maximize use of existing assets
Socially Acceptable	• Self Reliant (Less Dependent on Utilities) • Odor and Noise Control • Aesthetics • Reduced Truck Traffic

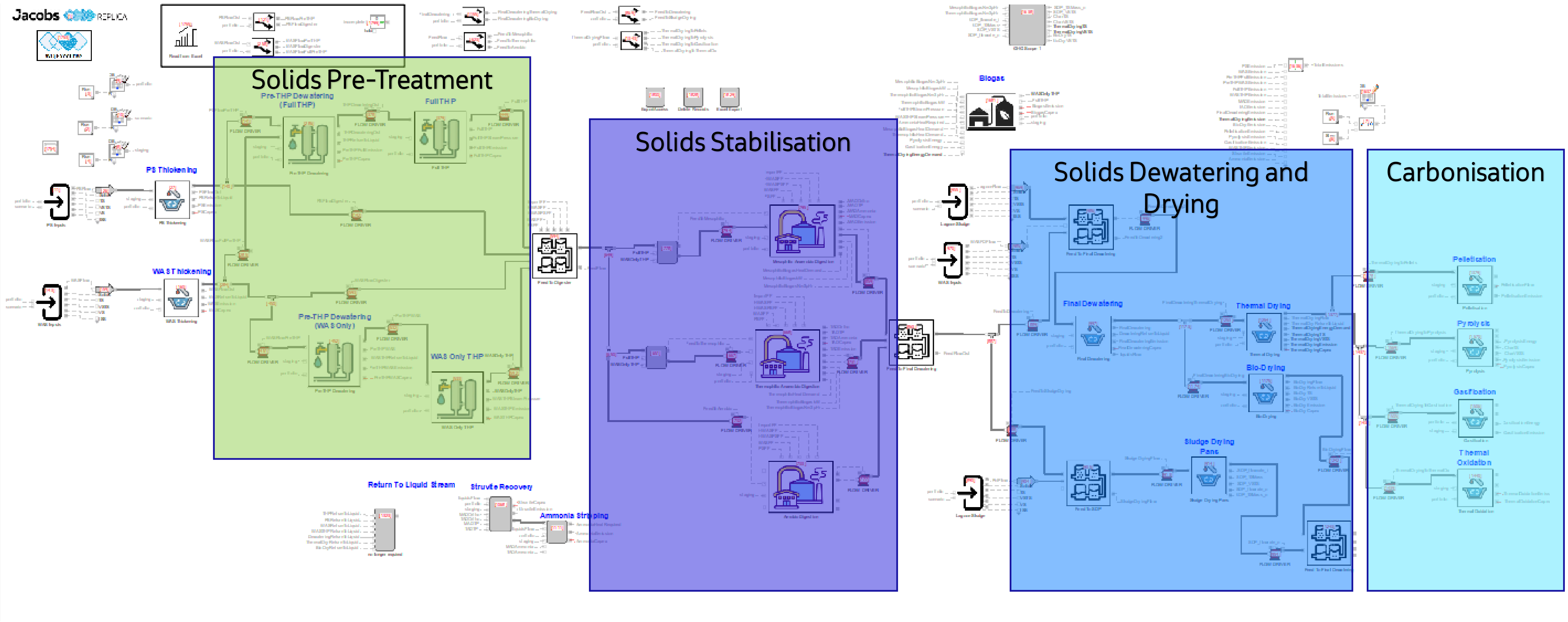
Adaptive System Planning - example



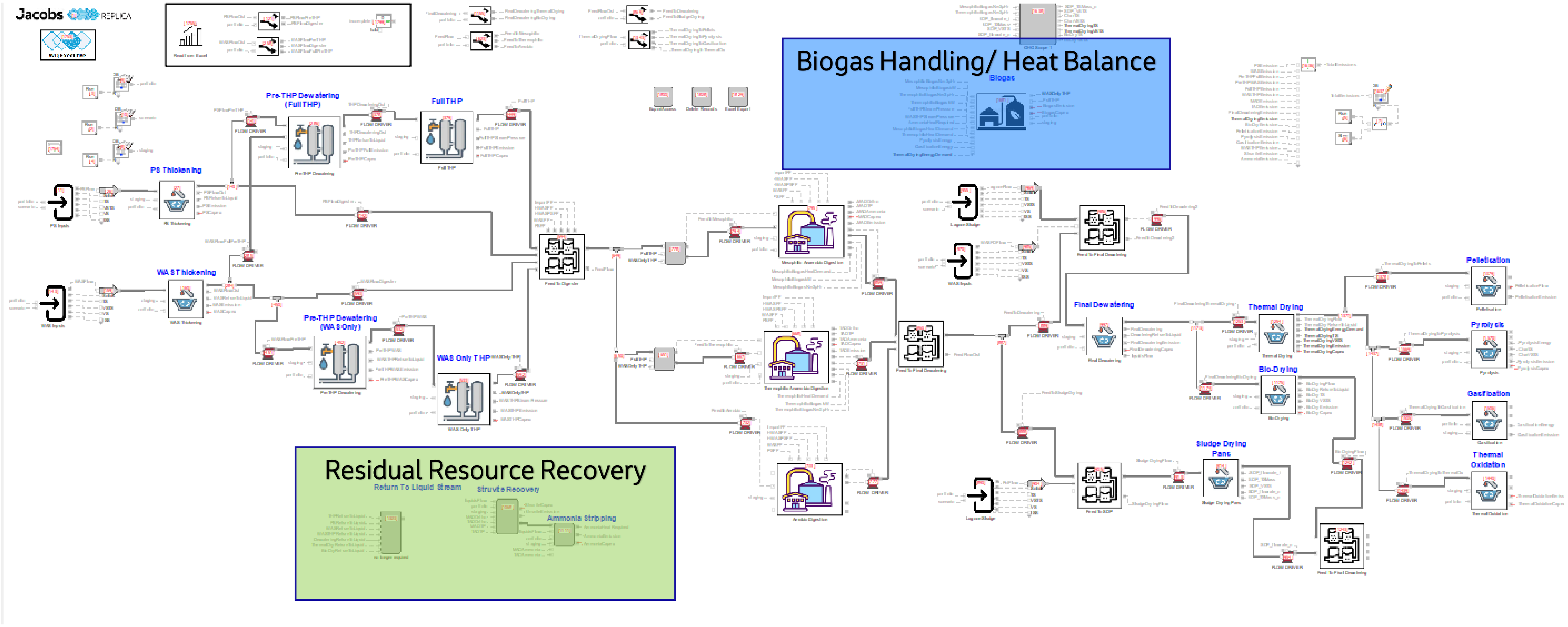
Adaptive System Pathway – solids handling model



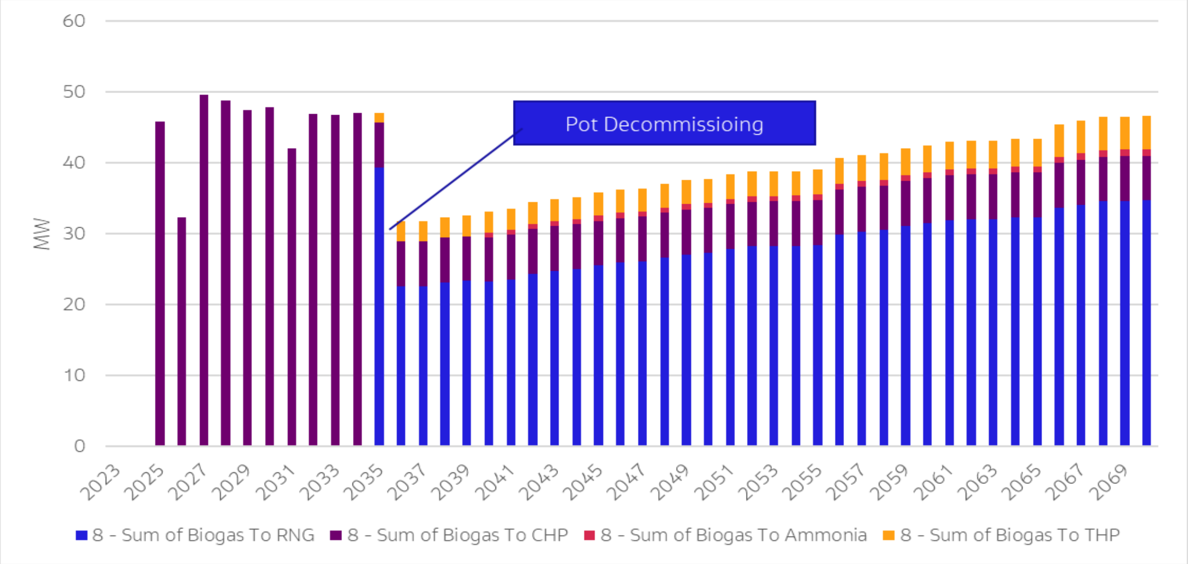
Adaptive System Pathway – solids handling model

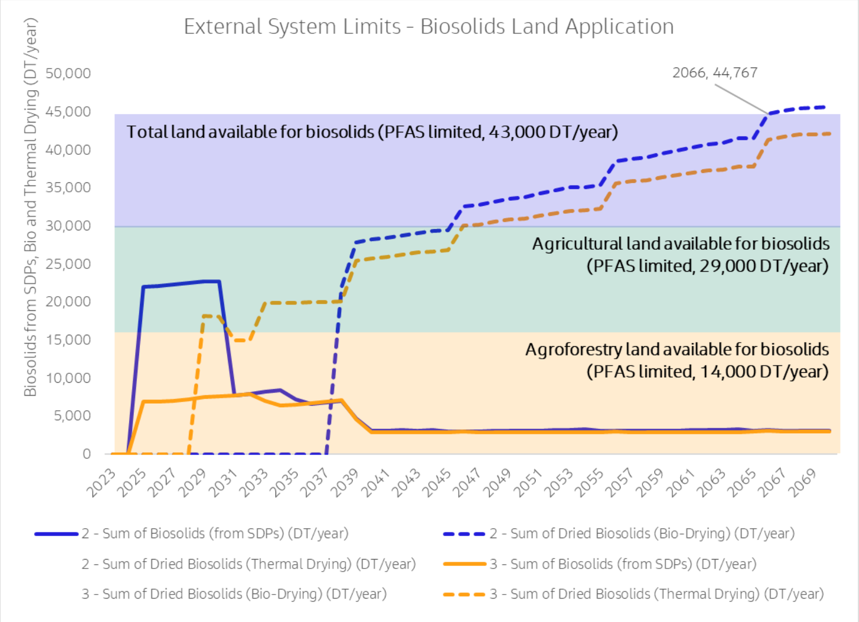


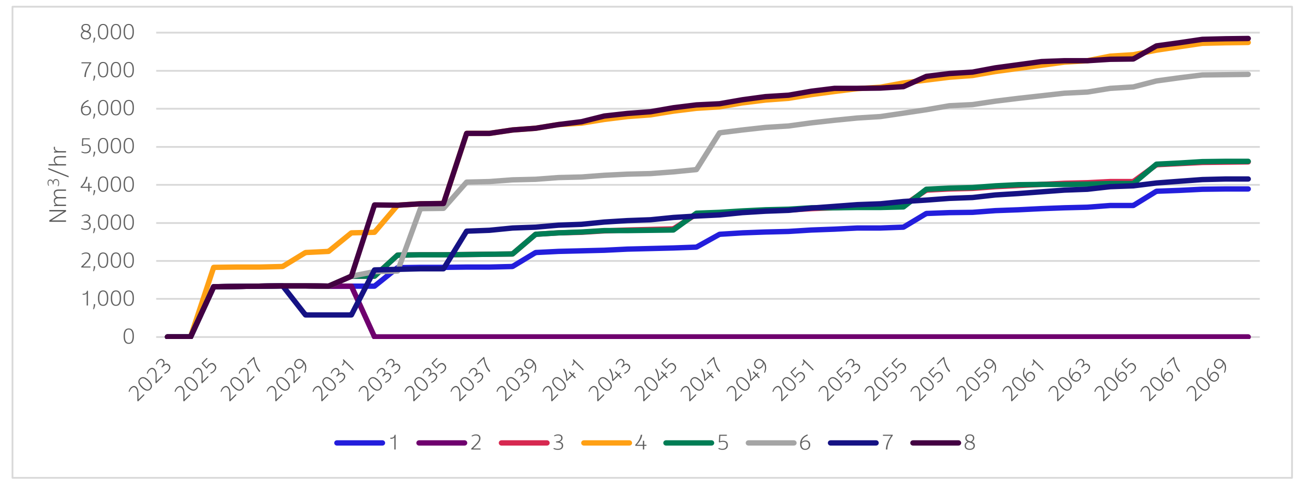
Adaptive System Pathway – solids handling model

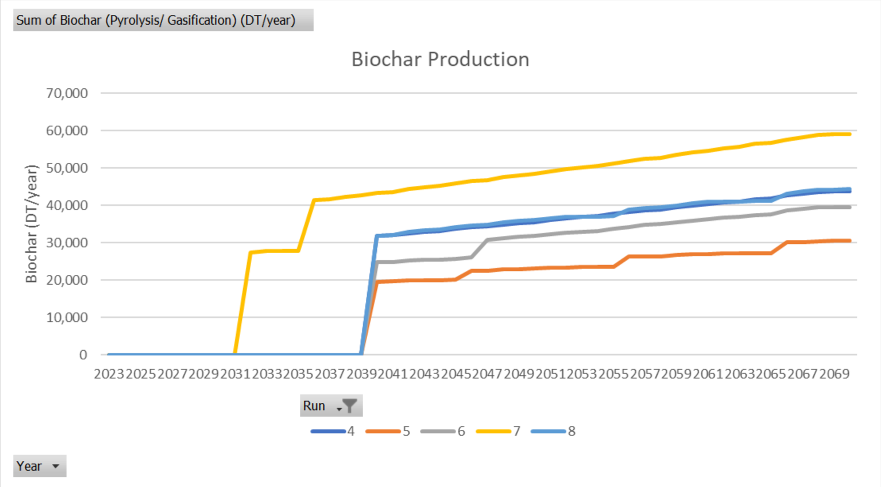


Adaptive System Planning Outcome - Examples









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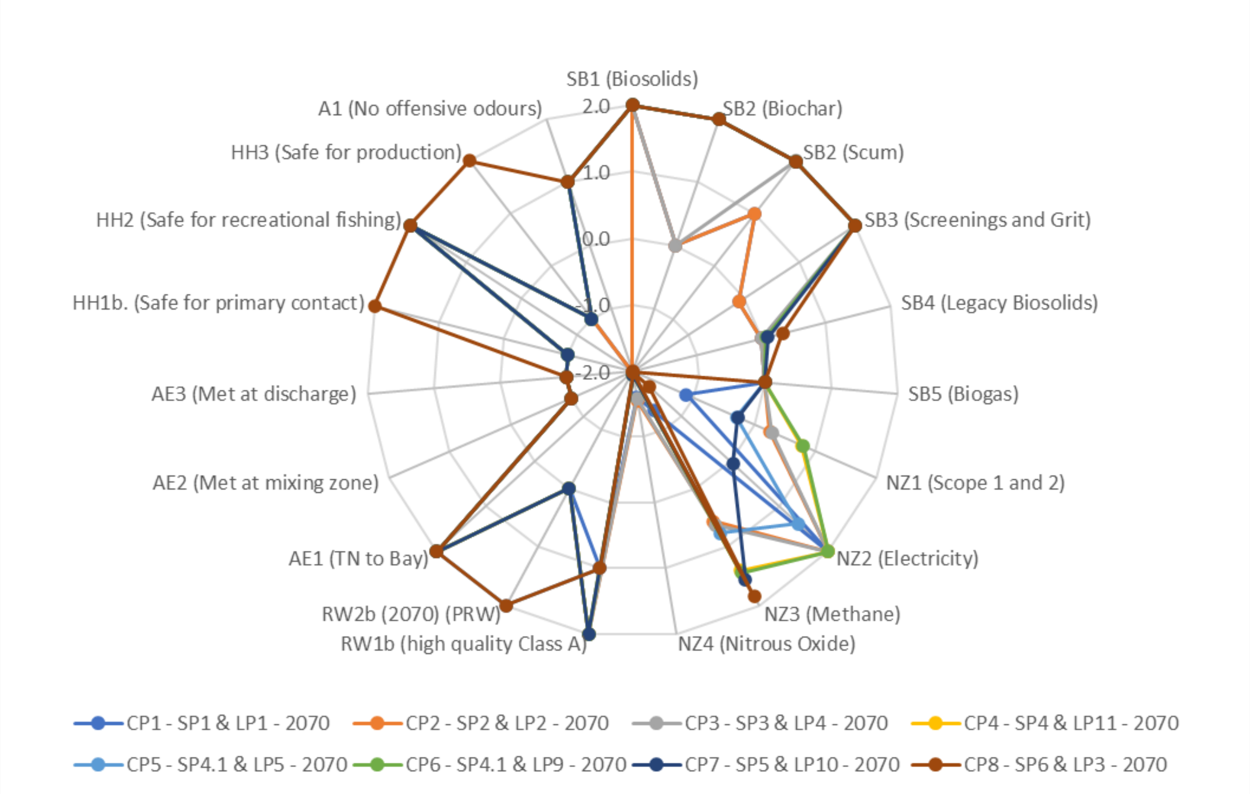
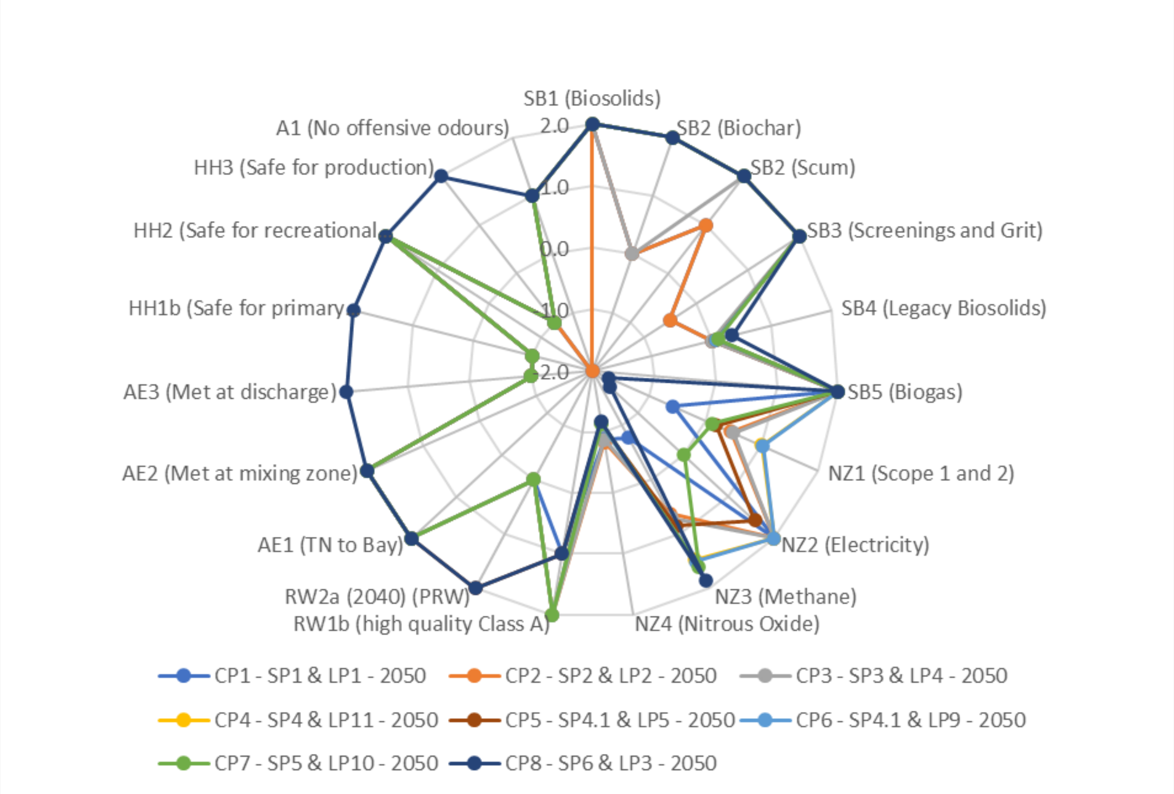
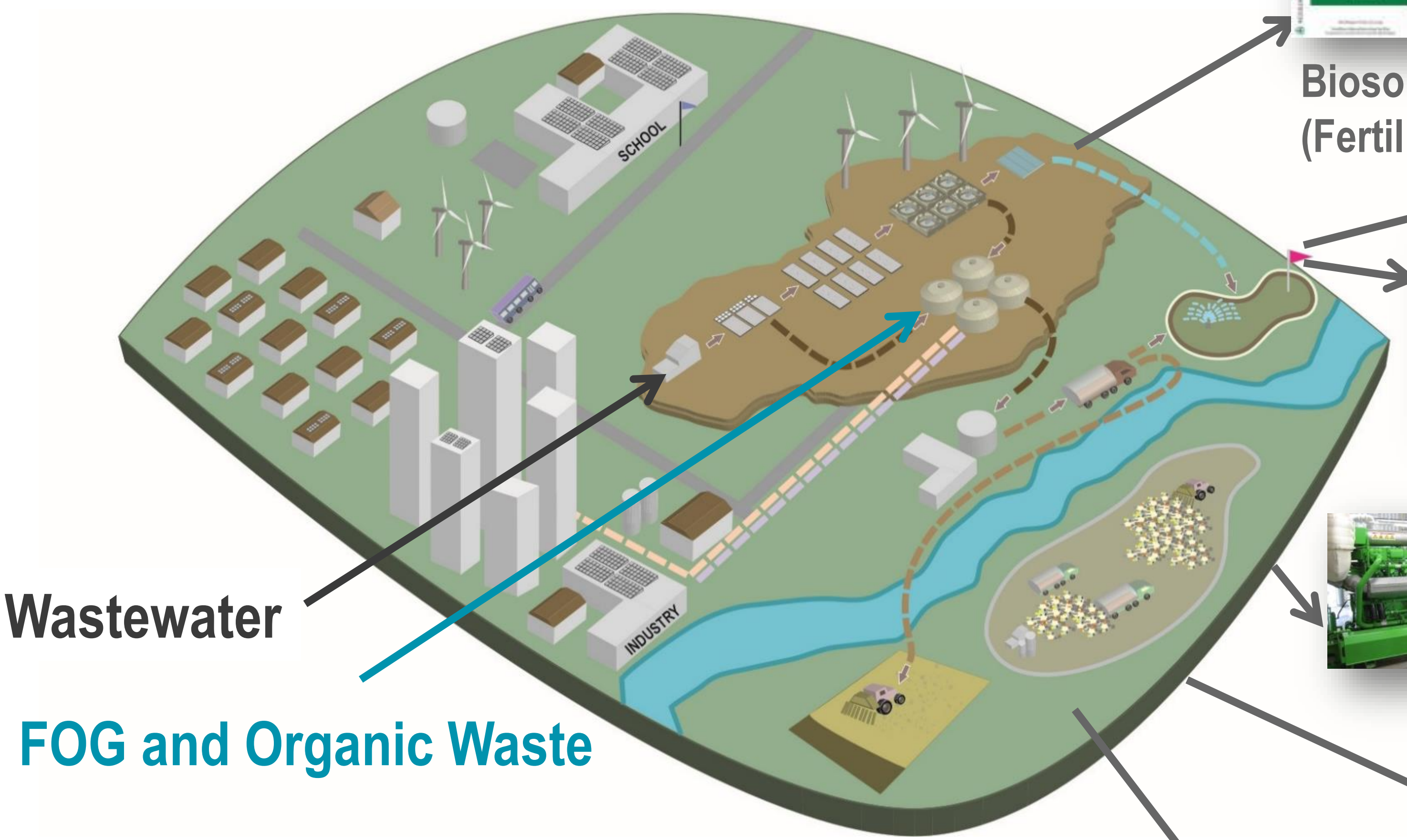




Advanced Digestion

High Performance Solids Processing is at the Heart of Resource Recovery from Wastewater



Wastewater

FOG and Organic Waste

Biosolids, Nutrients, Energy, Water (BNEW) Recovery Facility

Biosolids
(Fertilizer, Fuel)

Ammonia
Recovery

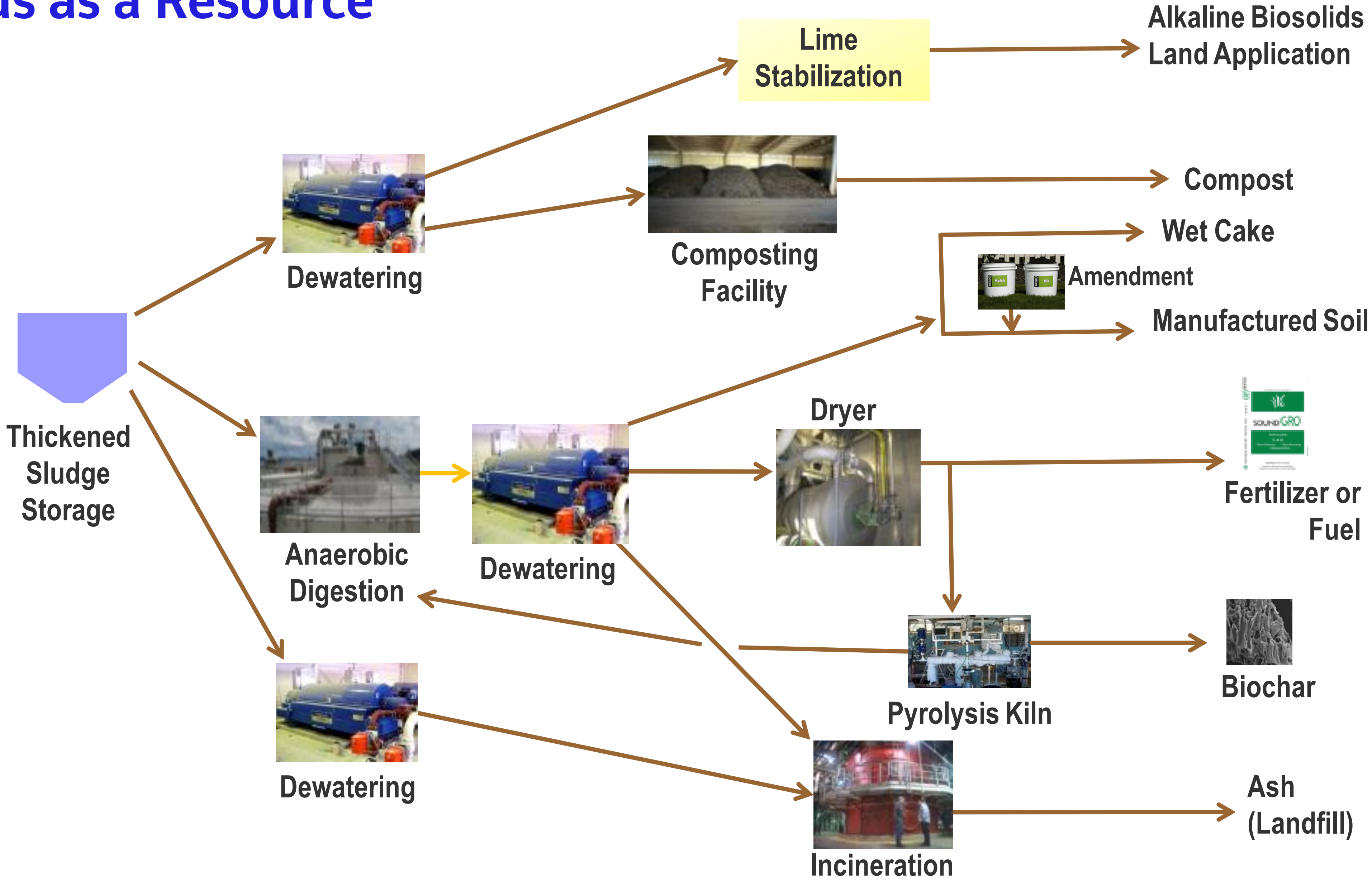
Phosphorus
(Fertilizer)

Energy
(Heat, Power, Fuel)

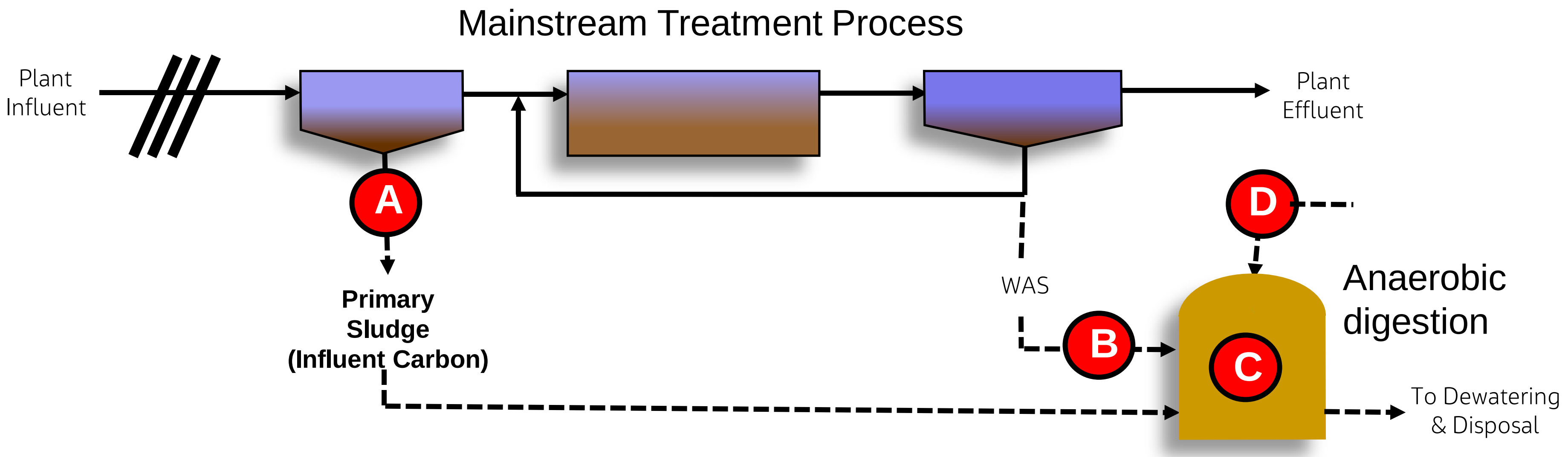
Water
(Reclaimed)

Biomethane

Biosolids as a Resource

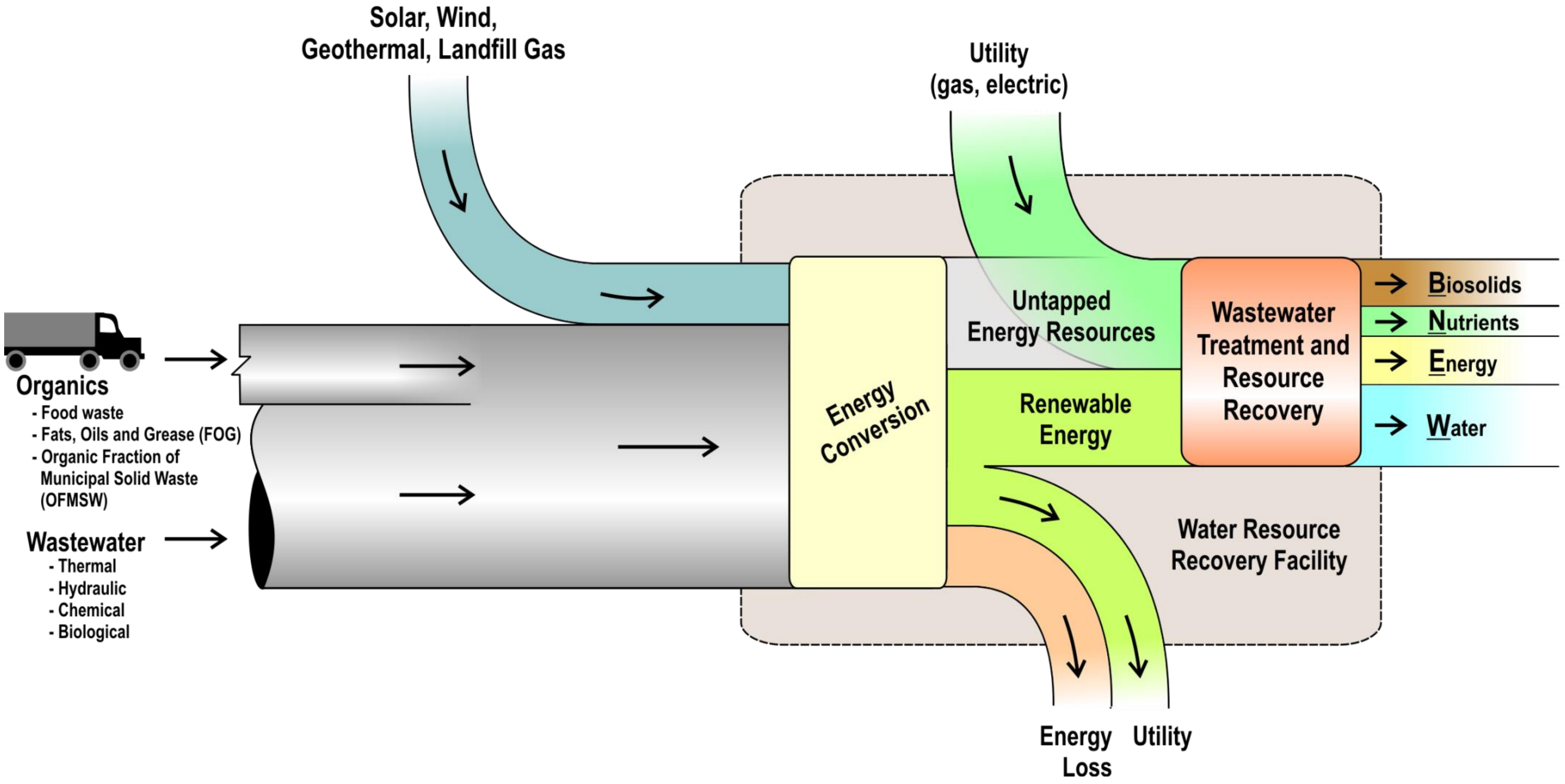


Anaerobic Digestion is a Major Route for Recovering Energy from Influent Carbon



A Carbon Diversion	B WAS Biodegradability	C Advanced AD	D External Carbon Source
Chemically Enhanced	Thermal Hydrolysis	Acid Hydrolysis	FOG Wastes
A-B Process	Thermo-chemical Hydrolysis	Mesophilic Digestion	Food Wastes
	Micro Hydrolysis Process	Thermophilic Digestion	High Strength Waste
		Phased Digestion	

Energy Conversion and Resource Recovery



Future of Anaerobic Digestion

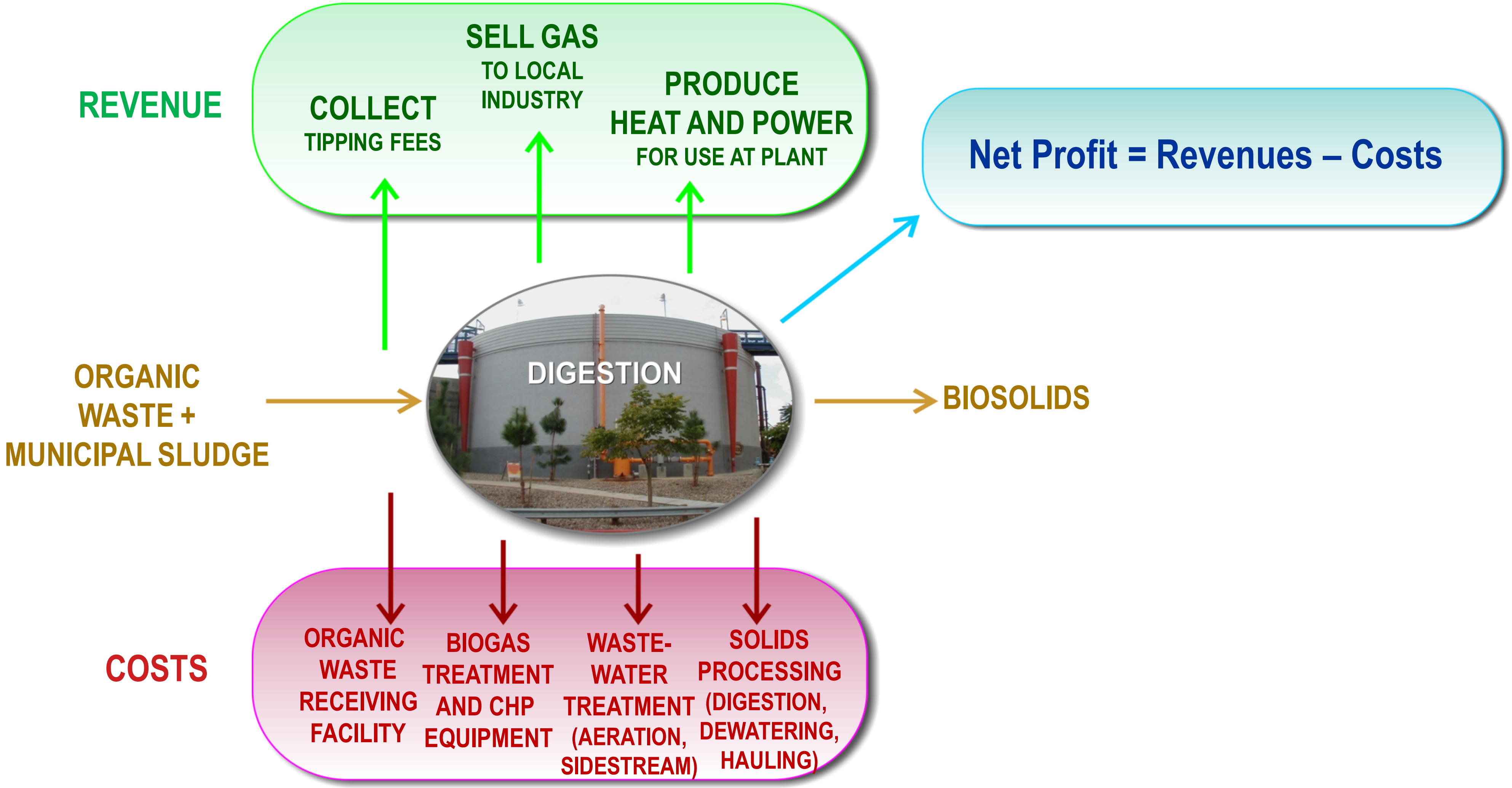
- High Performance (mesophilic, thermophilic)
- Hydrolysis (thermal, microbial)
- Co-Digestion
- Digestion combined with thermal process
- Anaerobic side-stream treatment
- Anaerobic full-stream treatment

Co-digestion

- Simultaneous digestion of two or more substrates
- Why co-digest?

Parameters	Food Waste	Sewage sludge (Conventional)
Micro-nutrients	↓	↑
Buffer capacity	↓	↑
Digestibility	↑	↓
Percent solids	↑	↓
Carbon : Nitrogen	Carbon source	Ammonia toxicity

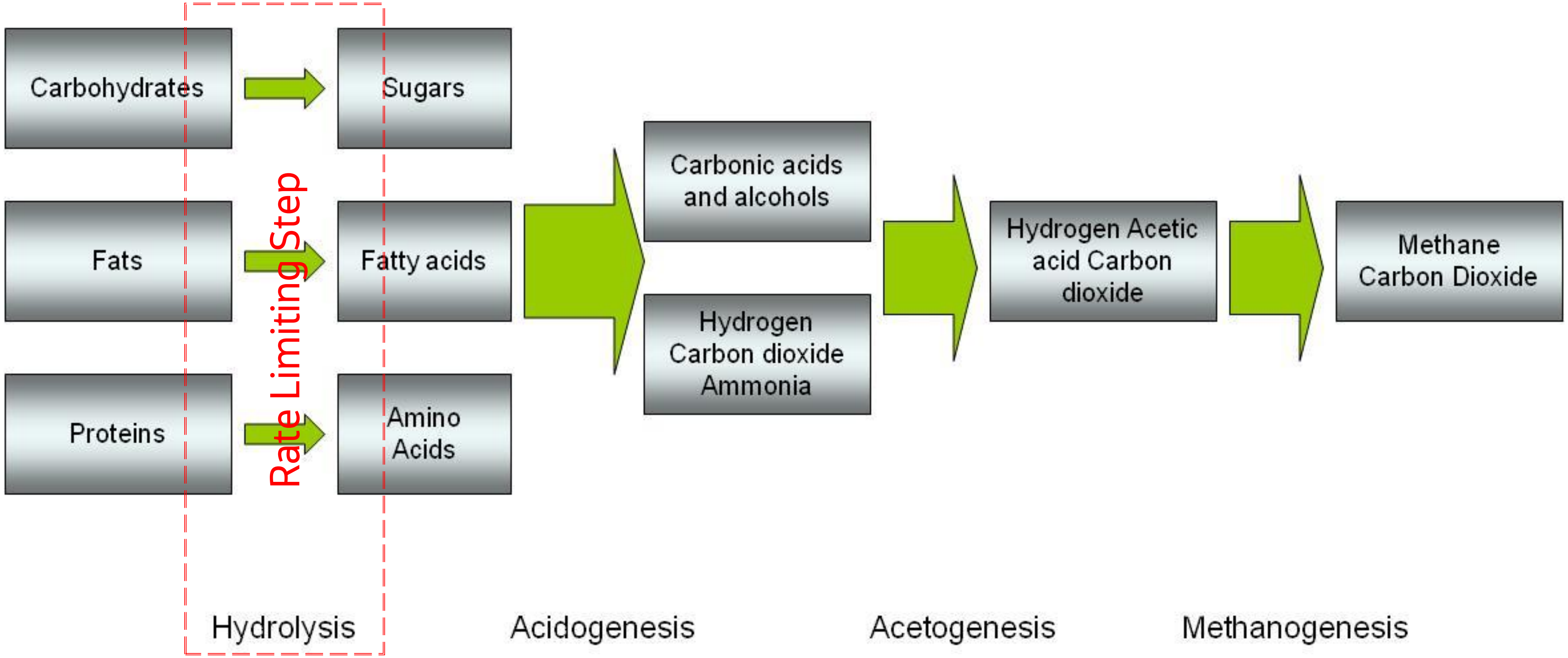
Profitable Operation from Co-Digestion



Advanced Digestion Technology Selection Drivers

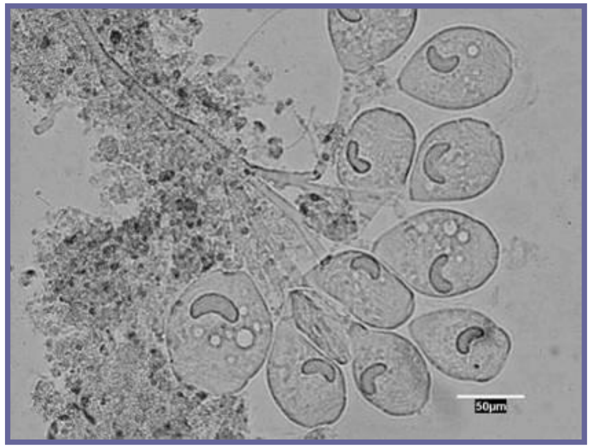
- Process Intensification
- Increase in VSD and Biogas production
- Ease of implementation
- Maturity of Technology
- Non Proprietary or Proprietary with multiple vendors
- Operability
- Scale
- Improved Dewatering Performance

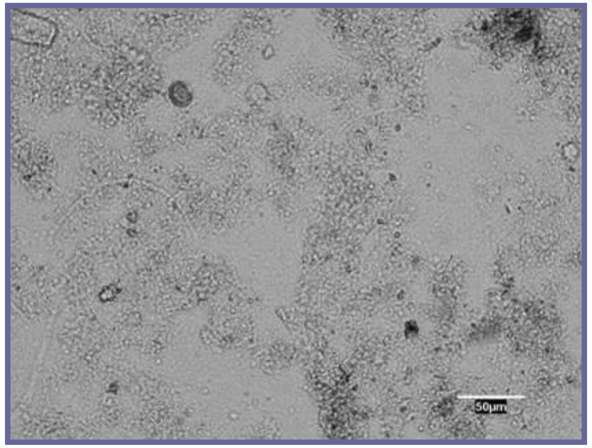
Why Hydrolysis

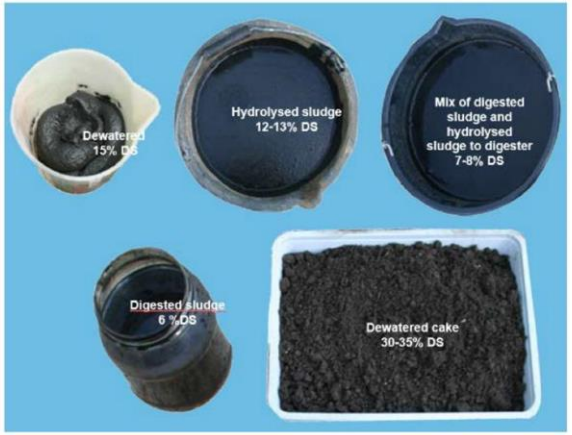


Hydrolysis process – key Mechanism

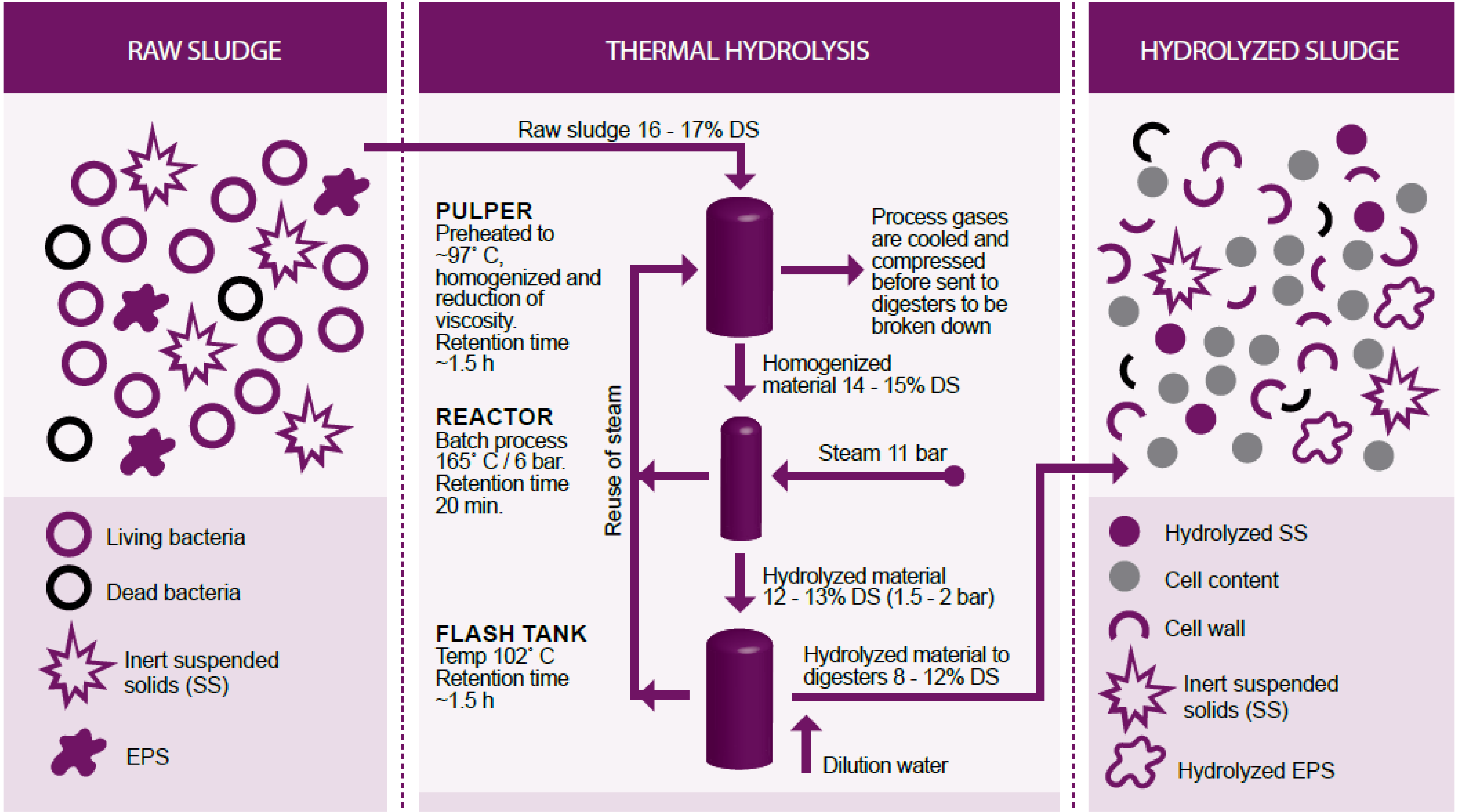
- Focused on floc disintegration and cell lysis
- From cell wall damage to full cell disruption depending on energy intensity
- Increased digestion rates & stability
- Increased volatile solids reduction (VSr)
- Increased biogas production
- Reduced solids for dewatering & reuse/disposal
- Several mechanisms: Physical, thermal, biological







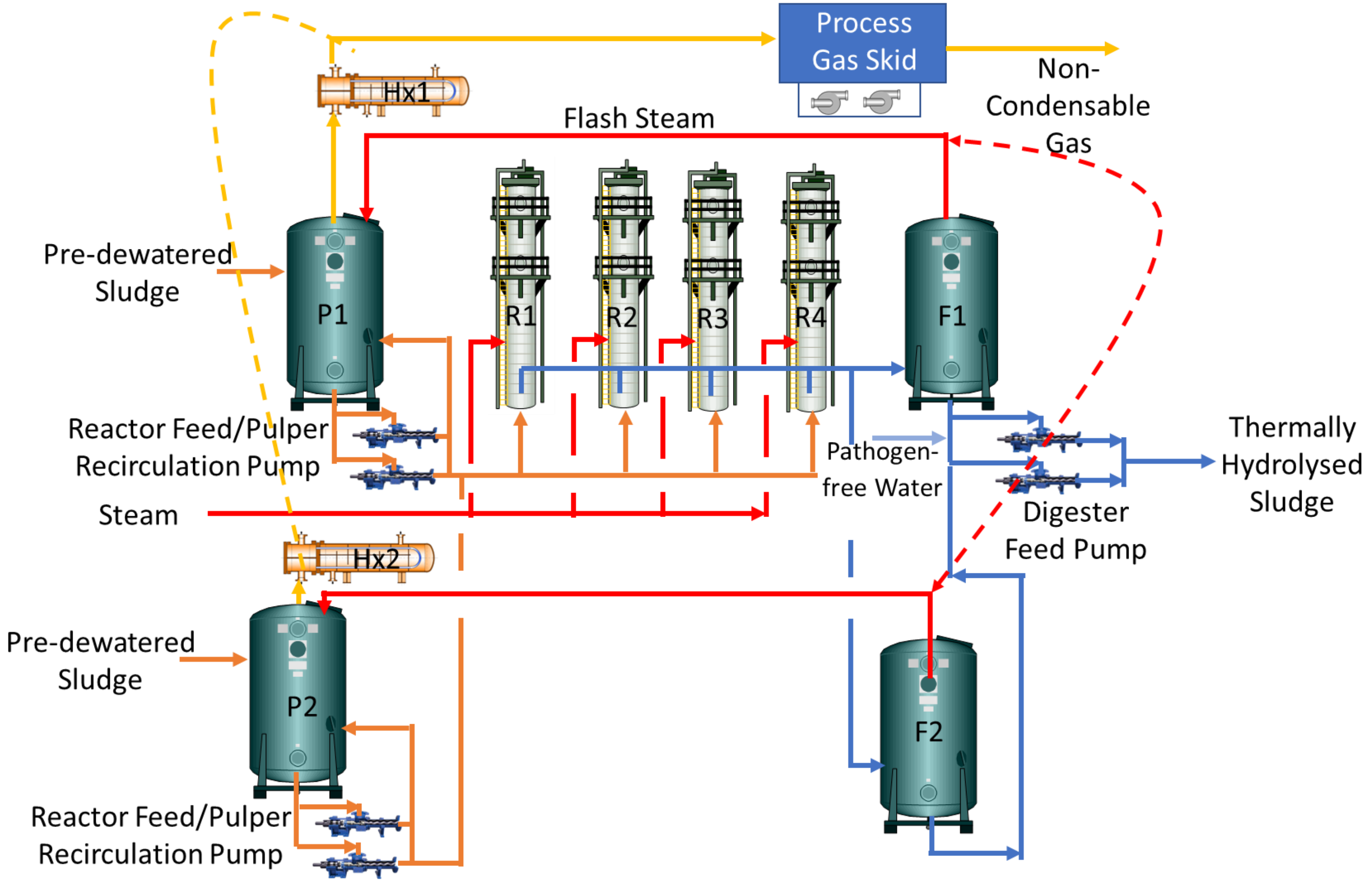
Thermal Hydrolysis-Mechanism



Benefits of Thermal Hydrolysis

- Allows significantly increased loading to digester
- Lower viscosity liquid sludge (easier to pump)
- Improved volatile solids destruction & digester biogas increase
- Improved dewatering performance
- Reduce quantity of solids requiring further handling
- Lower odor product without pathogen regrowth
- Full THP can produce Class A Biosolids

2 pulper 2 flash Tank design- Woodman Point



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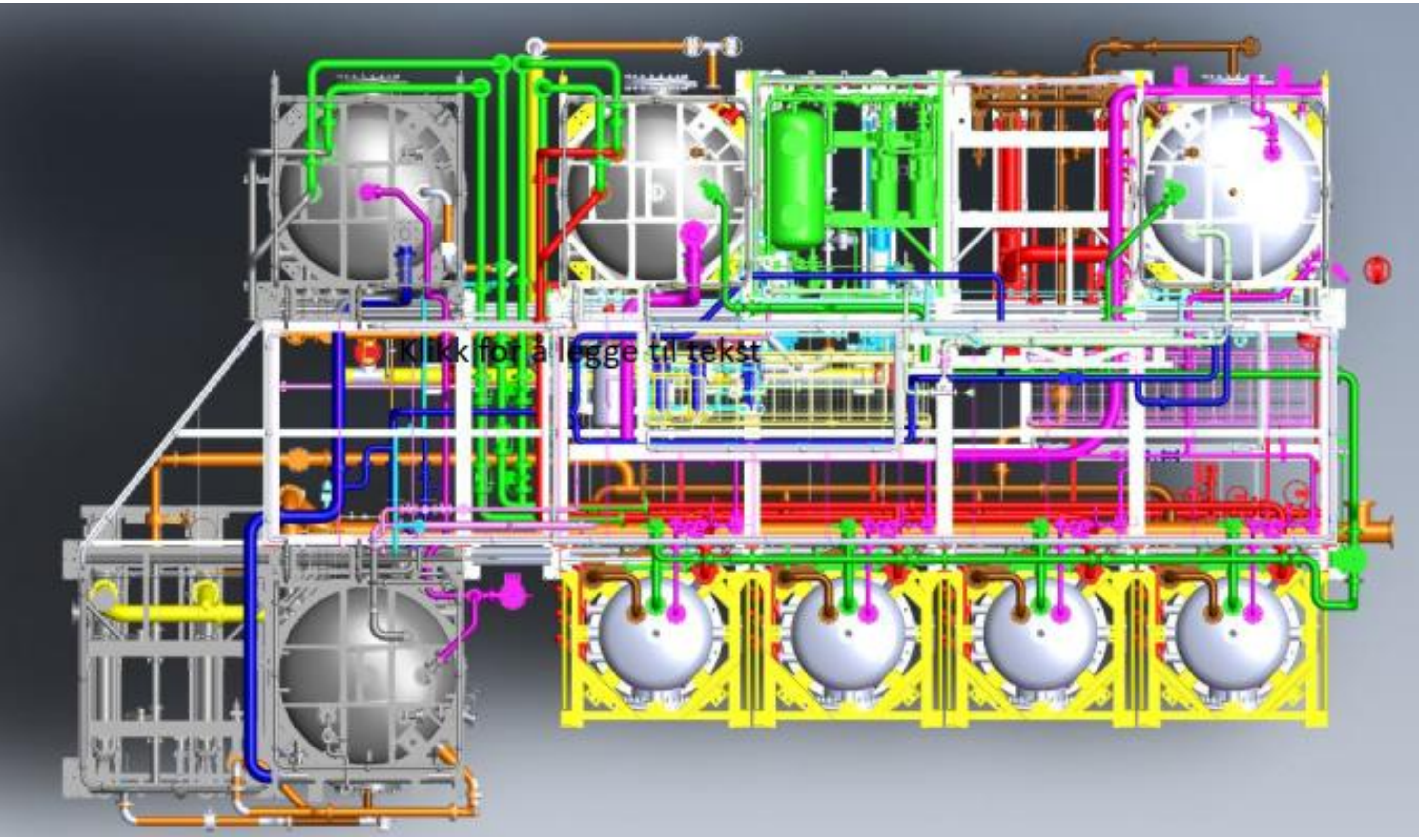
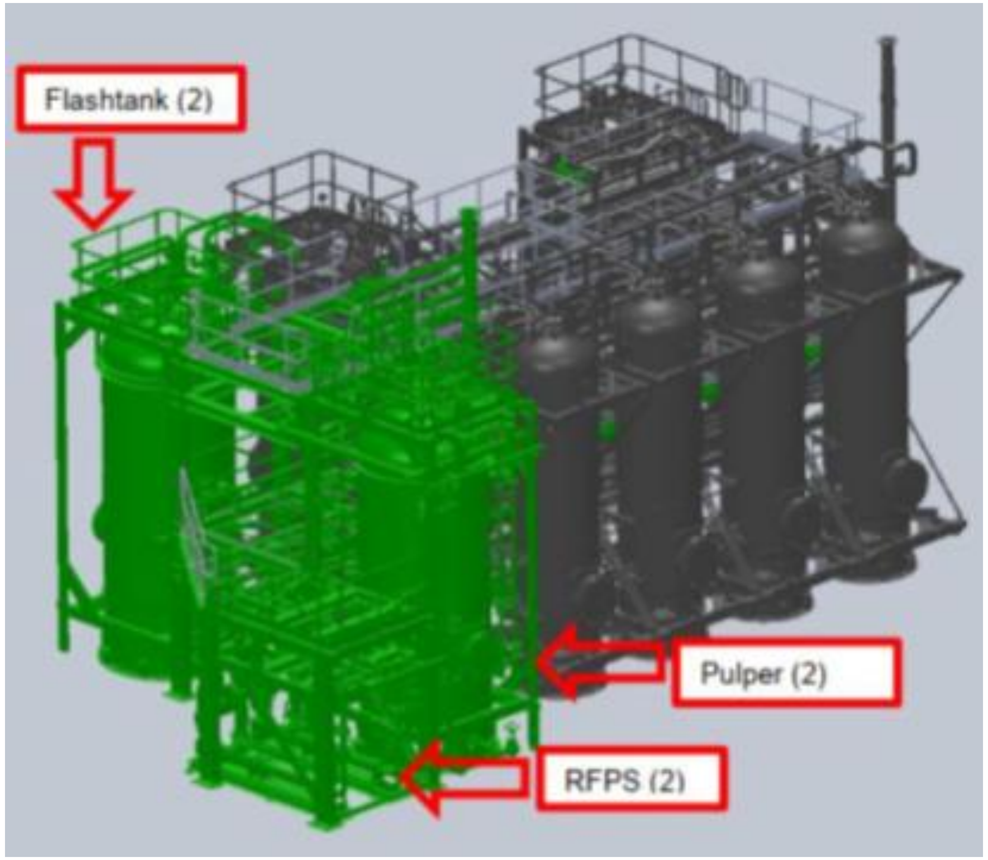
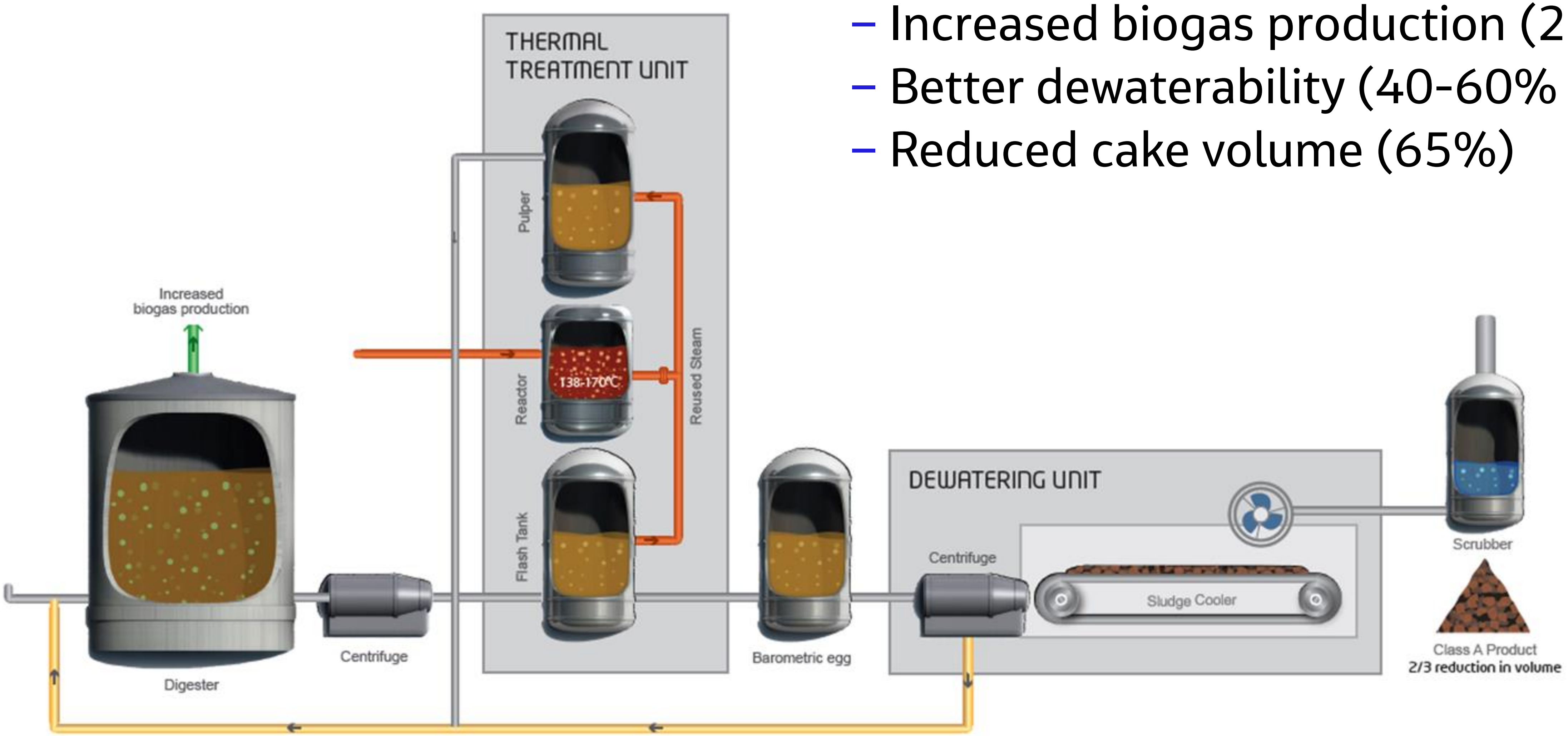


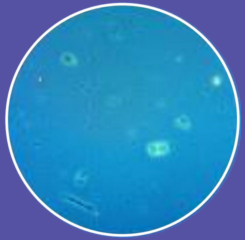


Solids Stream THP

- SolidStream® (after digestion)
  - Increased biogas production (20-30%)
  - Better dewaterability (40-60% DS)
  - Reduced cake volume (65%)



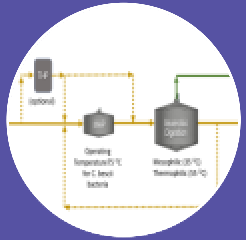
Enhancing Anaerobic Digestion Performance with the Microbial Hydrolysis Process (MHP) using C. bescii.



What is the Microbial Hydrolysis Process (MHP) and *C. bescii*?

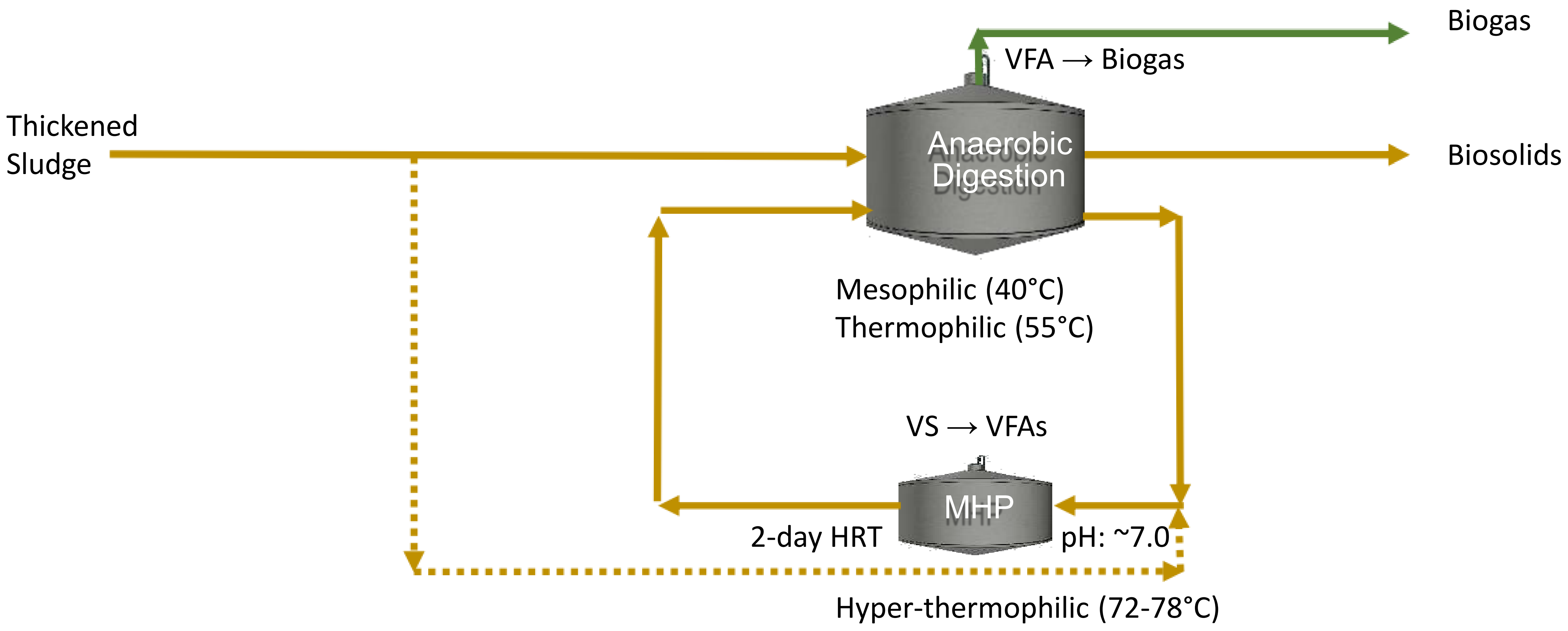
Where and how did we test MHP using *C. bescii*?

What were our findings?

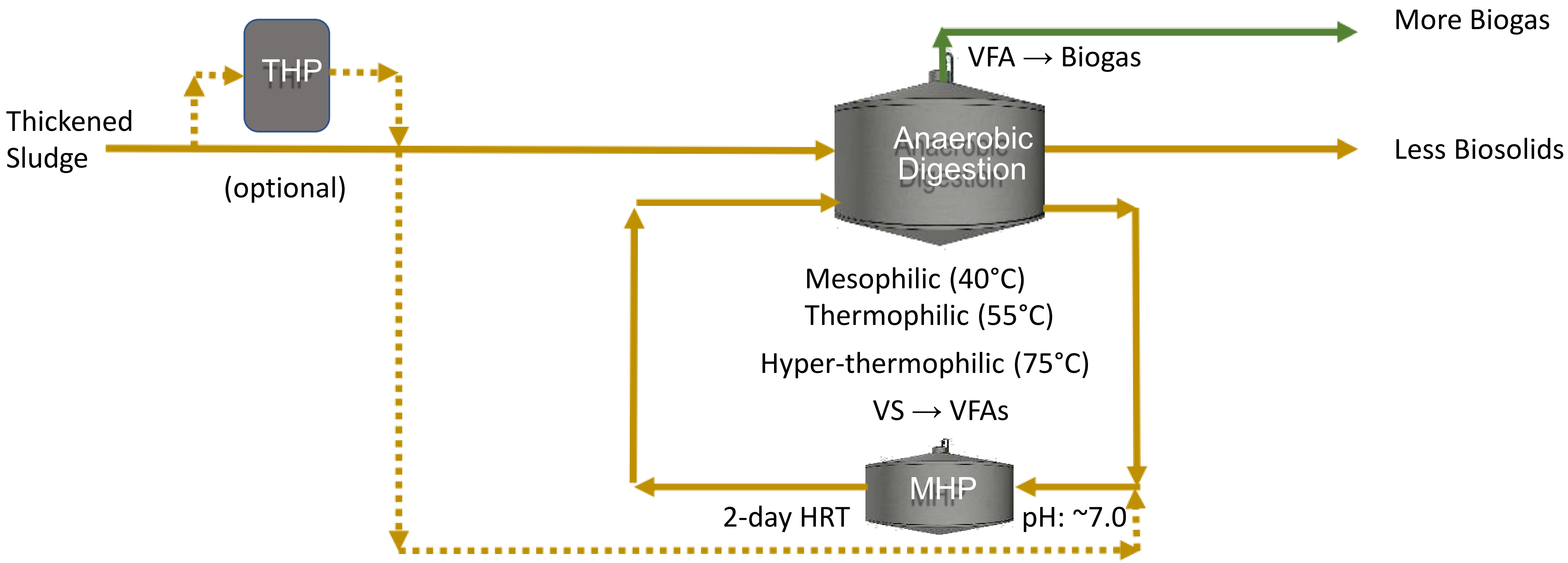


How can this be applied at full-scale?

Anaerobic Digestion enhancement with the Microbial Hydrolysis Process (MHP) using C. bescii bacterium.

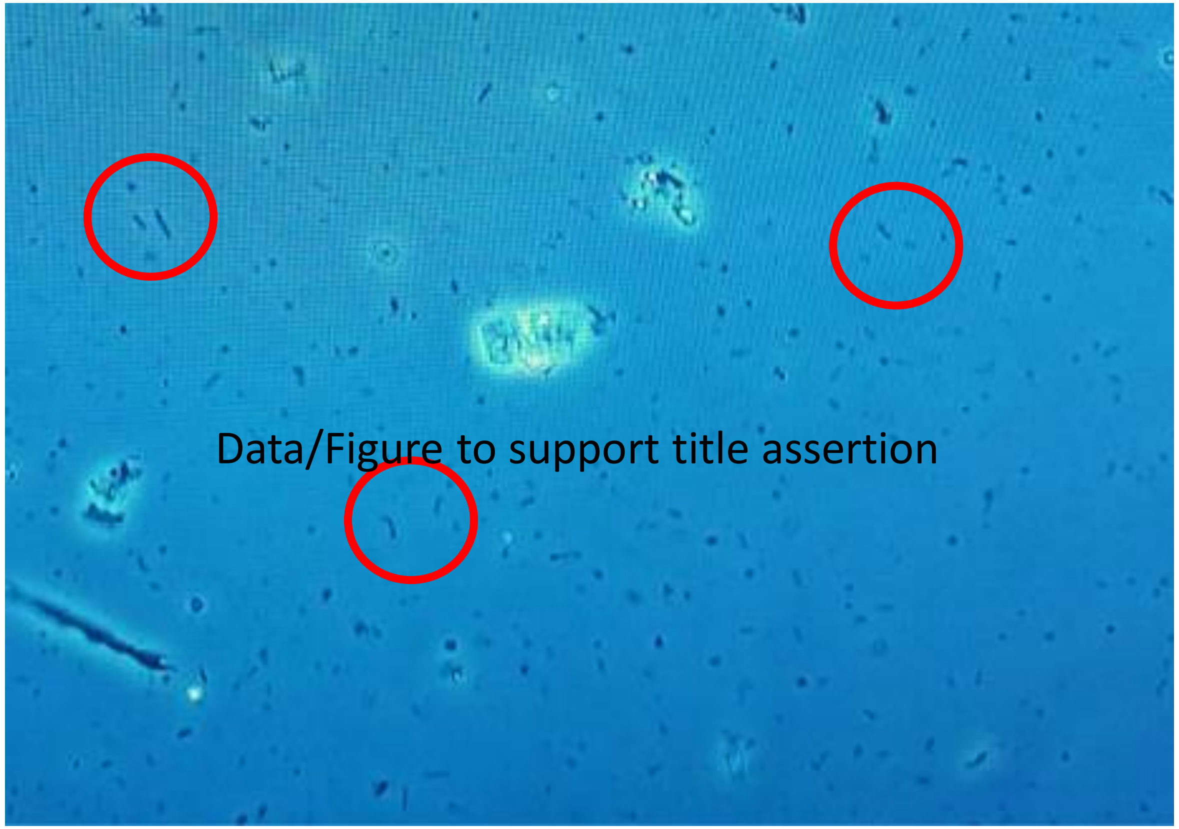


MHP is compatible with all AD processes, including the thermal hydrolysis process (THP)



C. bescii is a hyper-thermophilic anaerobic bacteria that is capable of hydrolysing recalcitrant organic materials.

- Caldicellulosiruptorbescii (C. bescii) was isolated in a geothermally heated freshwater pool in Russia in 1990
- Thrives at 75°C
- Hydrolyzes cellulose and other recalcitrant organic material like waste activated sludge



C. bescii **bacteria under a microscope**

MHP using C. bescii has been tested at both lab-and pilot-scale

Lab Scale

10-L Digesters and 5-L Hydrolysis Tanks

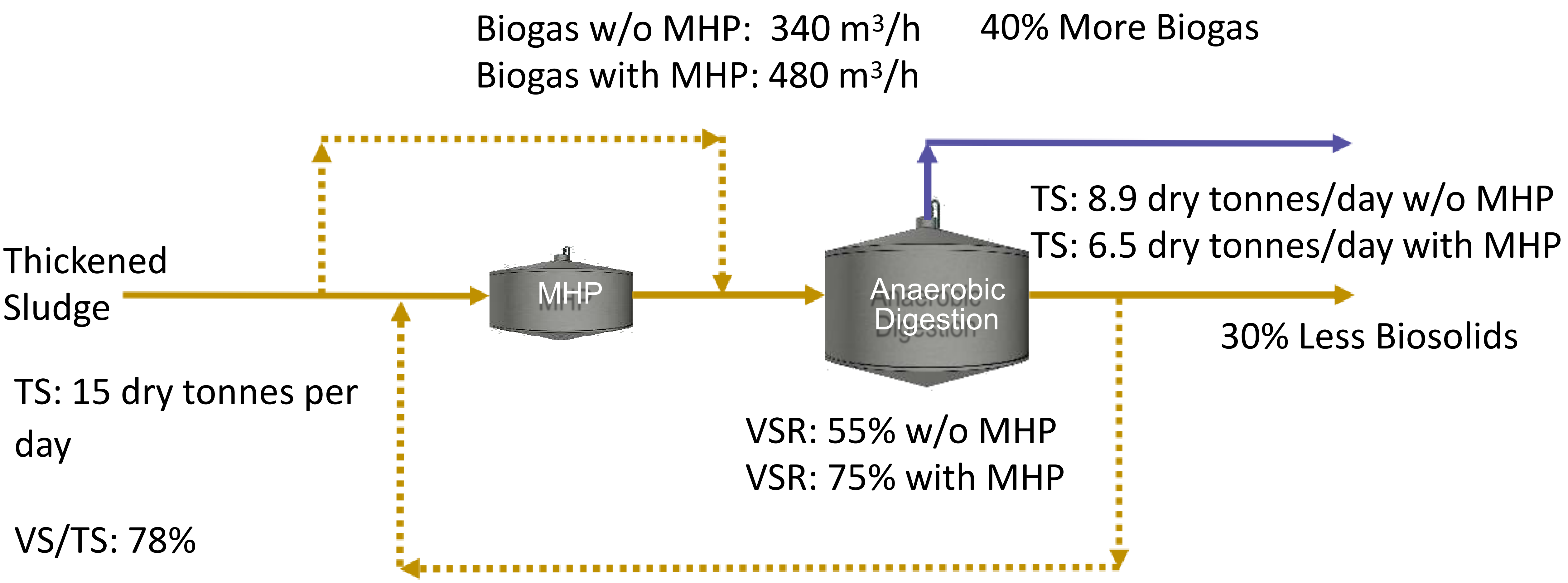
Pilot Scale

1200-L Digesters and 500-L Hydrolysis Tank

In summary, the addition of MHP increased anaerobic digestion performance from good VSR (~60%) to great VSR (>75%).

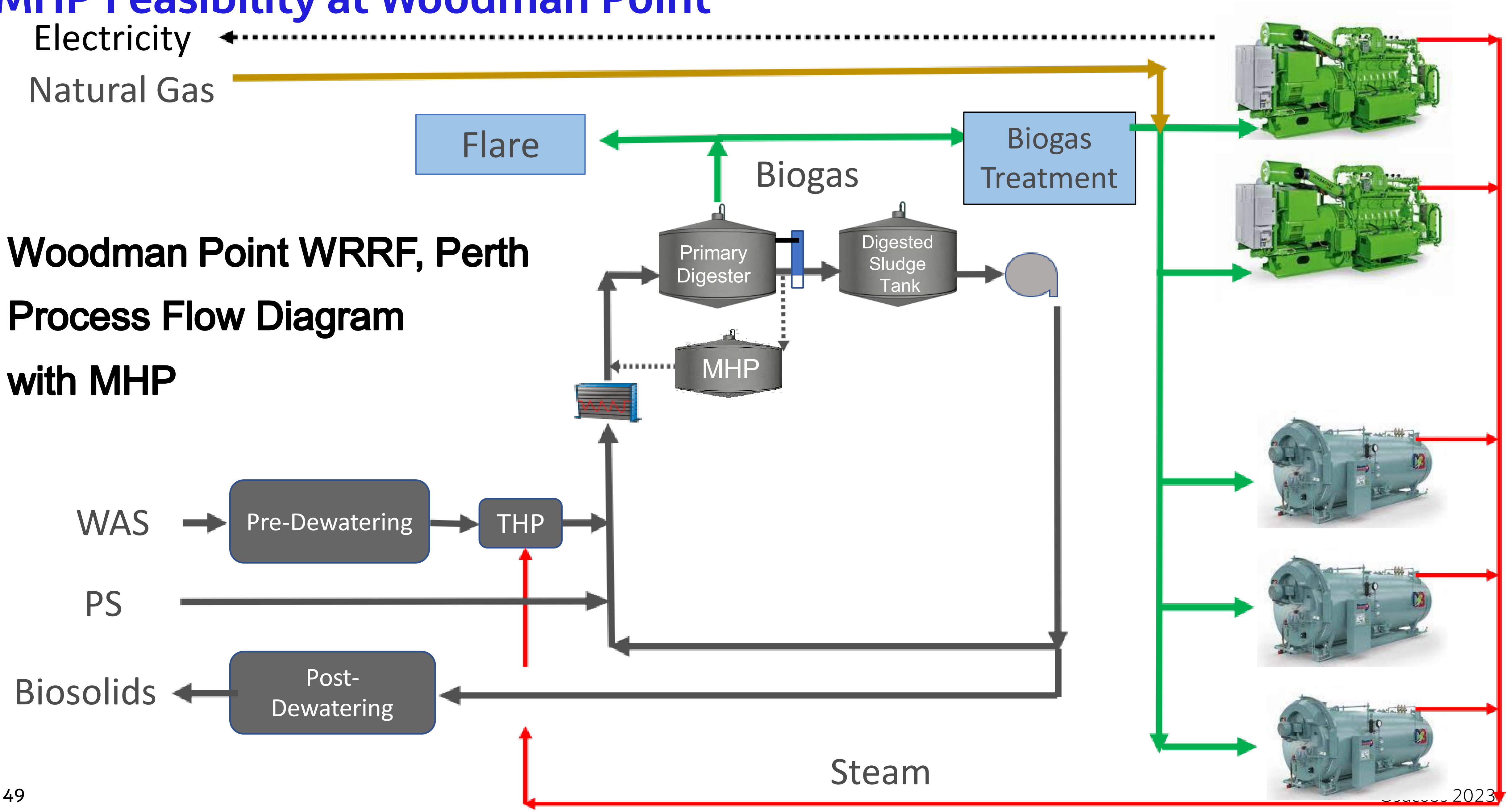
Facility	Digestion	Existing Performance VSR	Method	Control Performance VSR	Test Performance VSR
Gresham WWTP Gresham, OR	Mesophilic AD with FOG	60%	Lab-scale	70% Attributed to C. bescii in control	80%
Encina Wastewater Authority WPCF Carlsbad, CA	Mesophilic AD	60%	Lab-scale	71% Attributed to long retention time	77%
Clinton River WRRF, operated by Oakland County WRC; Pontiac, MI	THP Mesophilic AD	58%	Pilot-scale	65% Attributed to solids settling in control	75%

For a conventional AD system at a 300,000 PE WRRF: Applying MHP can result in a total value of 450,000 $/yr



MHP Feasibility at Woodman Point

Woodman Point WRRF, Perth
Process Flow Diagram
with MHP



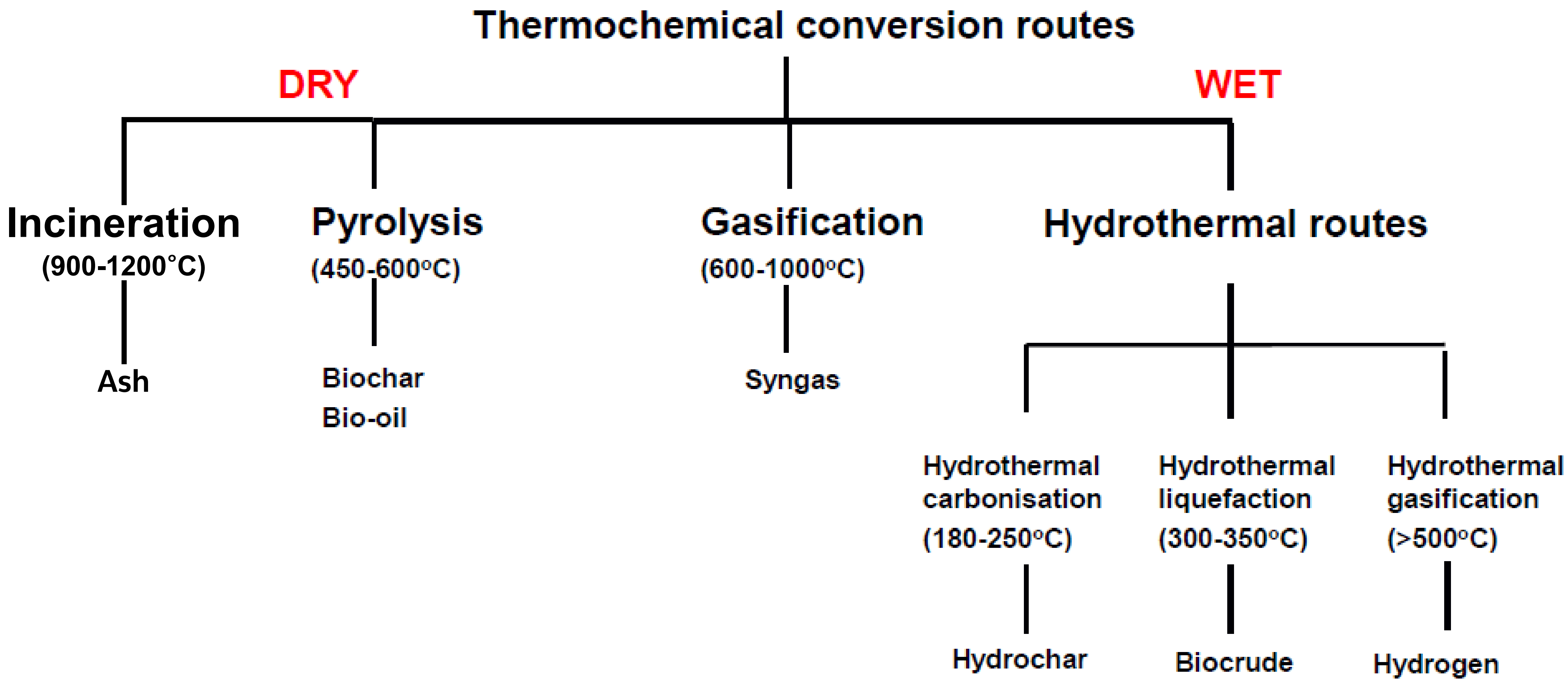
Thermal Processes

Applications and benefits

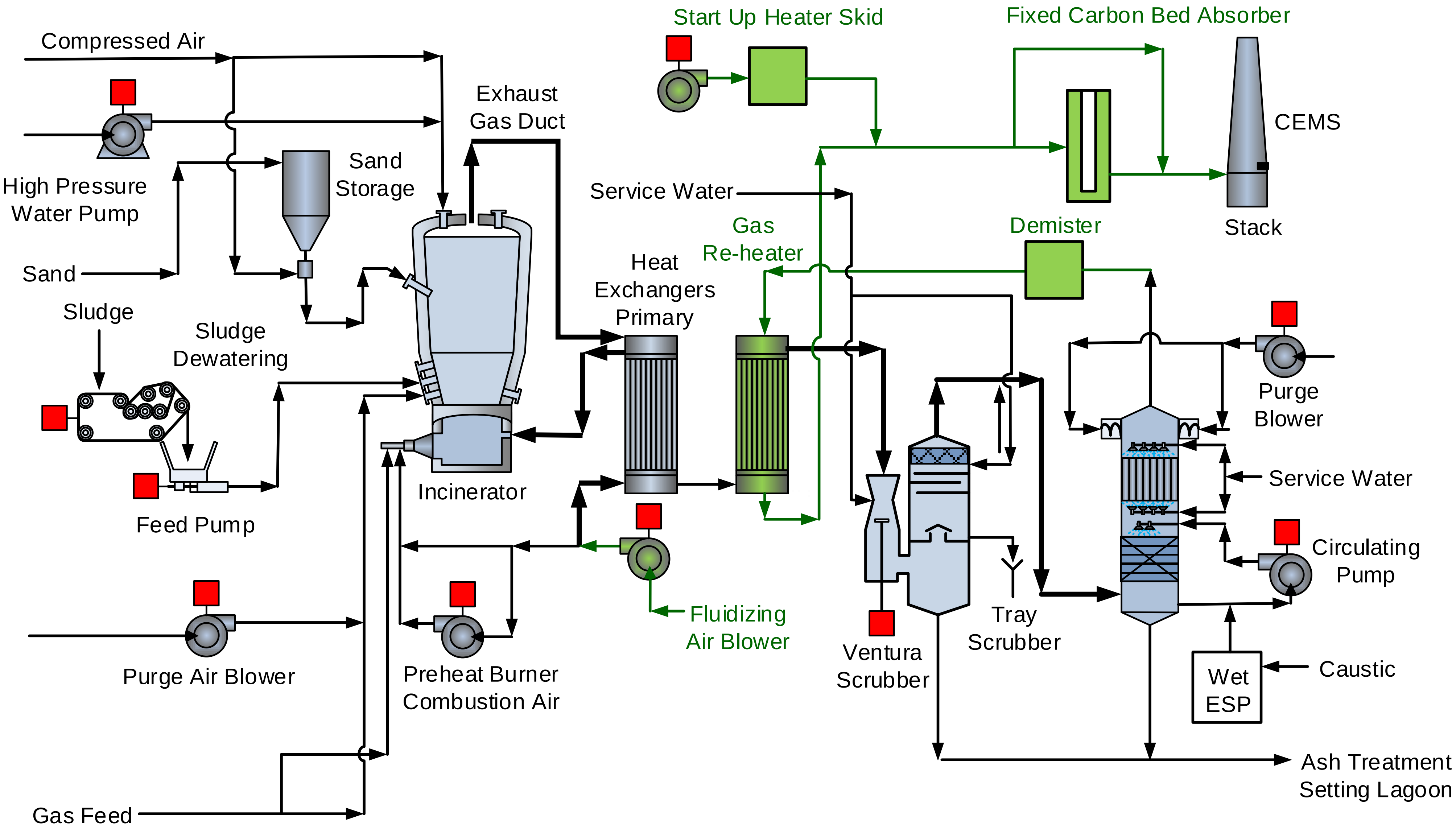
Why Choose Thermal Technologies

- To reduce the quantity of biosolids produced
- To recover and utilise thermal energy
- To produce an alternate product
- To produce Class A product
- To destroy PFAS

Different Combustion Technologies

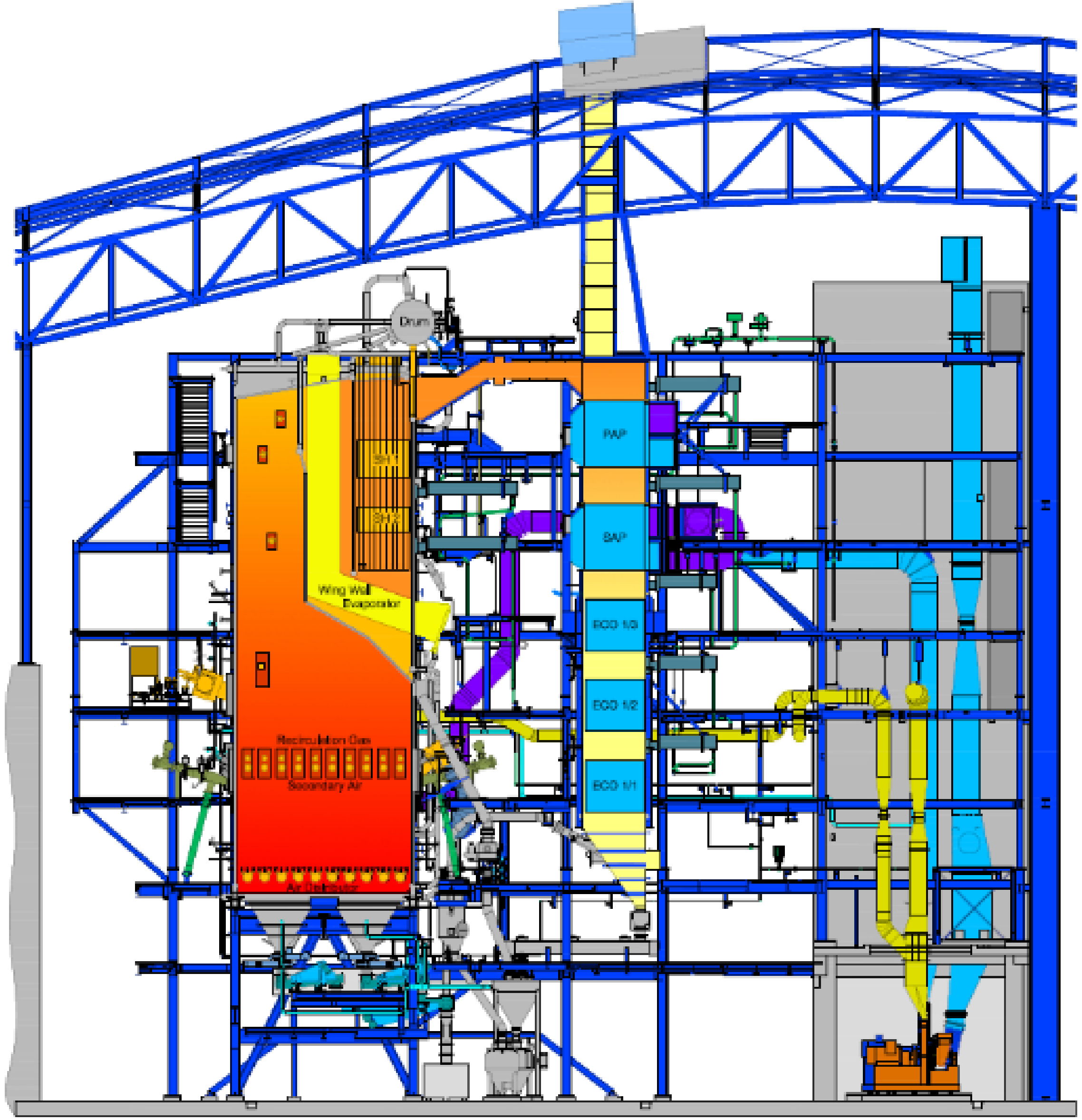


Incineration / Thermal Oxidation

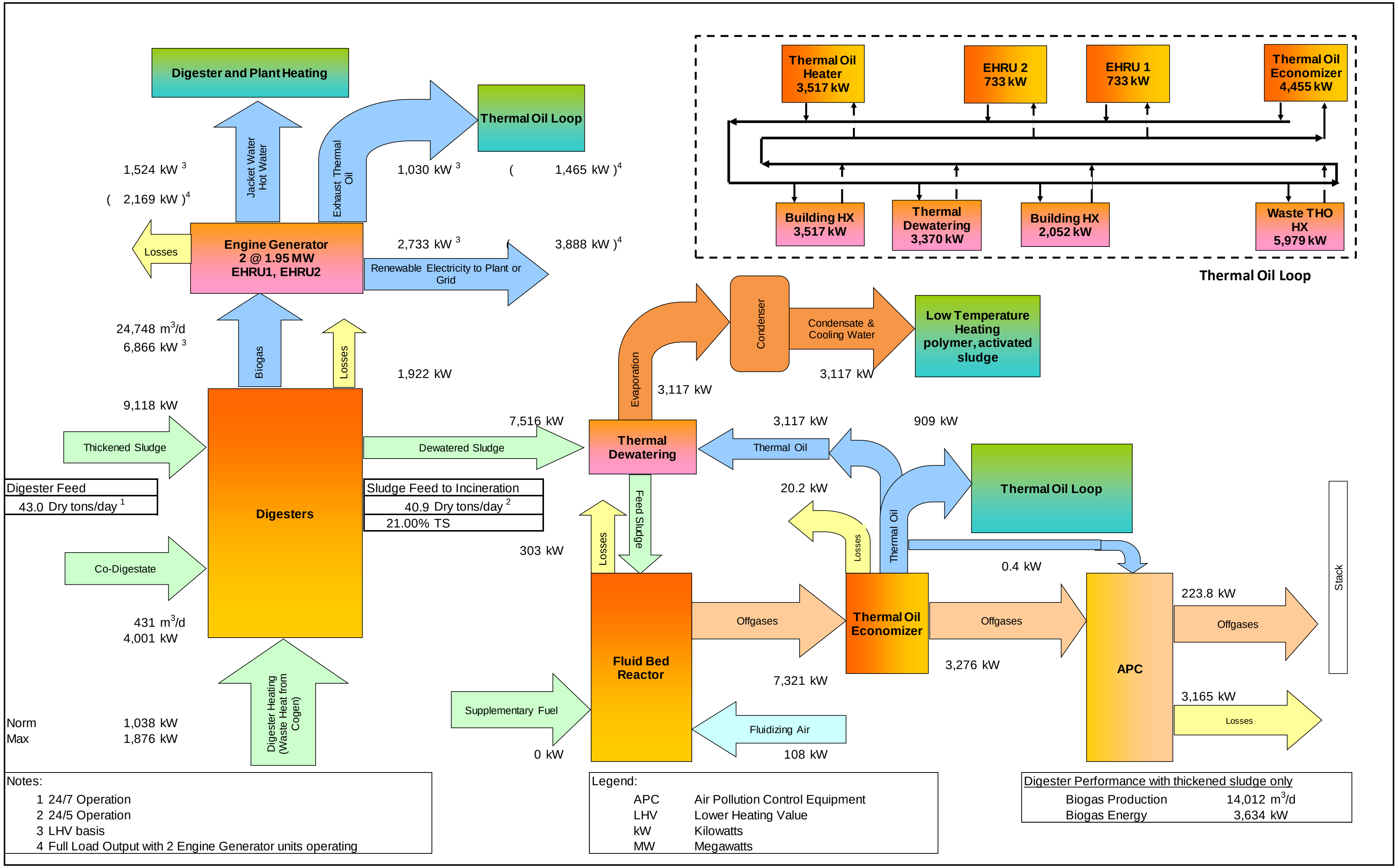


Bubbling Fluidized Bed Boiler – Hong Kong Example: Technical Data

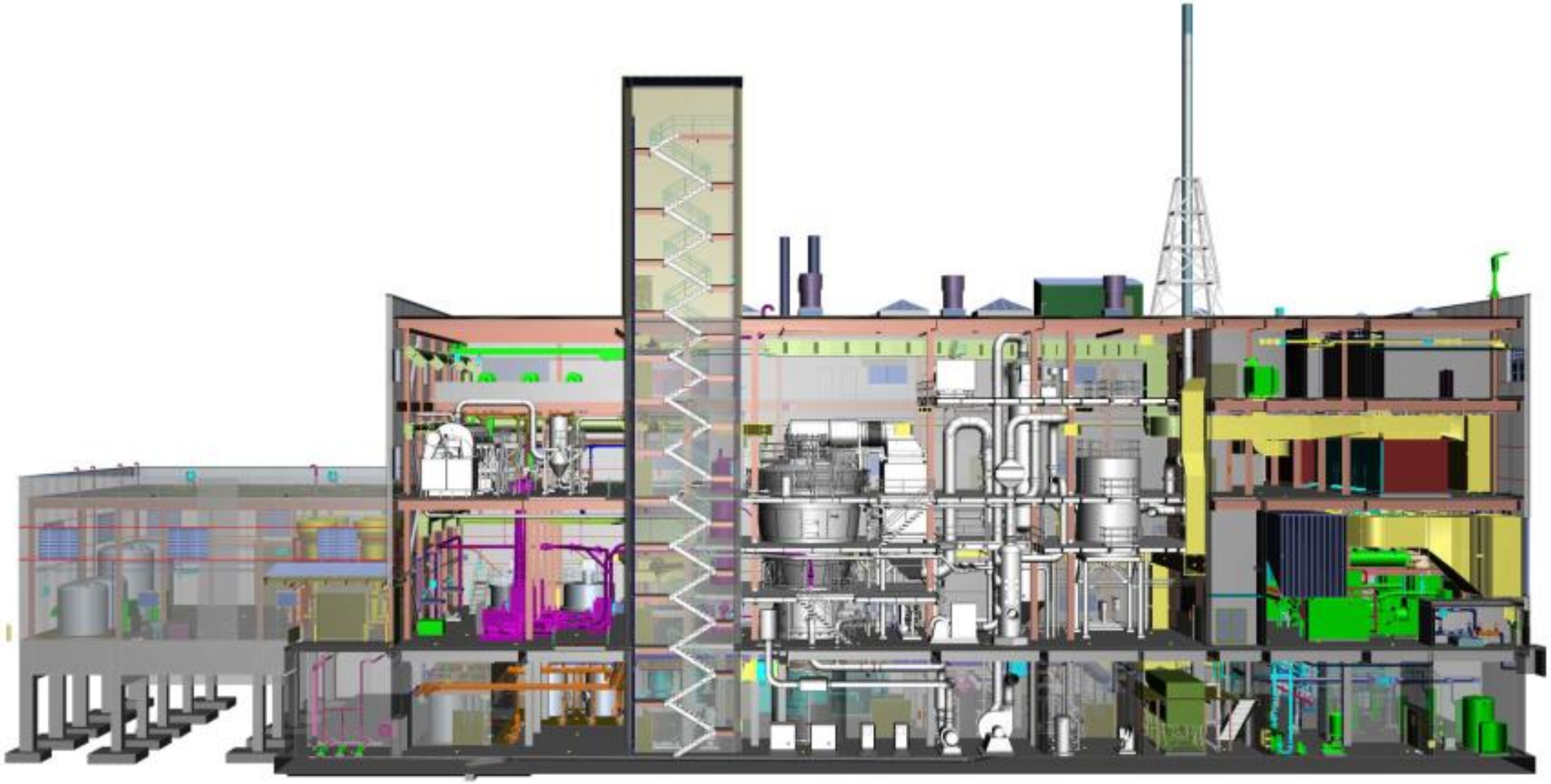
Technical data of the steam boilers	
Type of construction	Bubbling fluidized bed boiler, EcoFluid AC
Number	4
Fuel	Sewage sludge
Heating value range Hu	3.0 – 5.8 MJ/kg
Self-sustained combustion	as from approx. 3.5 MJ/kg, depending on load
Fuel heating capacity ea.	27.5 MW max.
Sludge throughput ea.	23 t/h max.
Steam output ea.	31.3 t/h max.
Steam temperature	383°C
Steam pressure	42 bar
Feed water temperature	130°C
Flue gas temperature	200°C



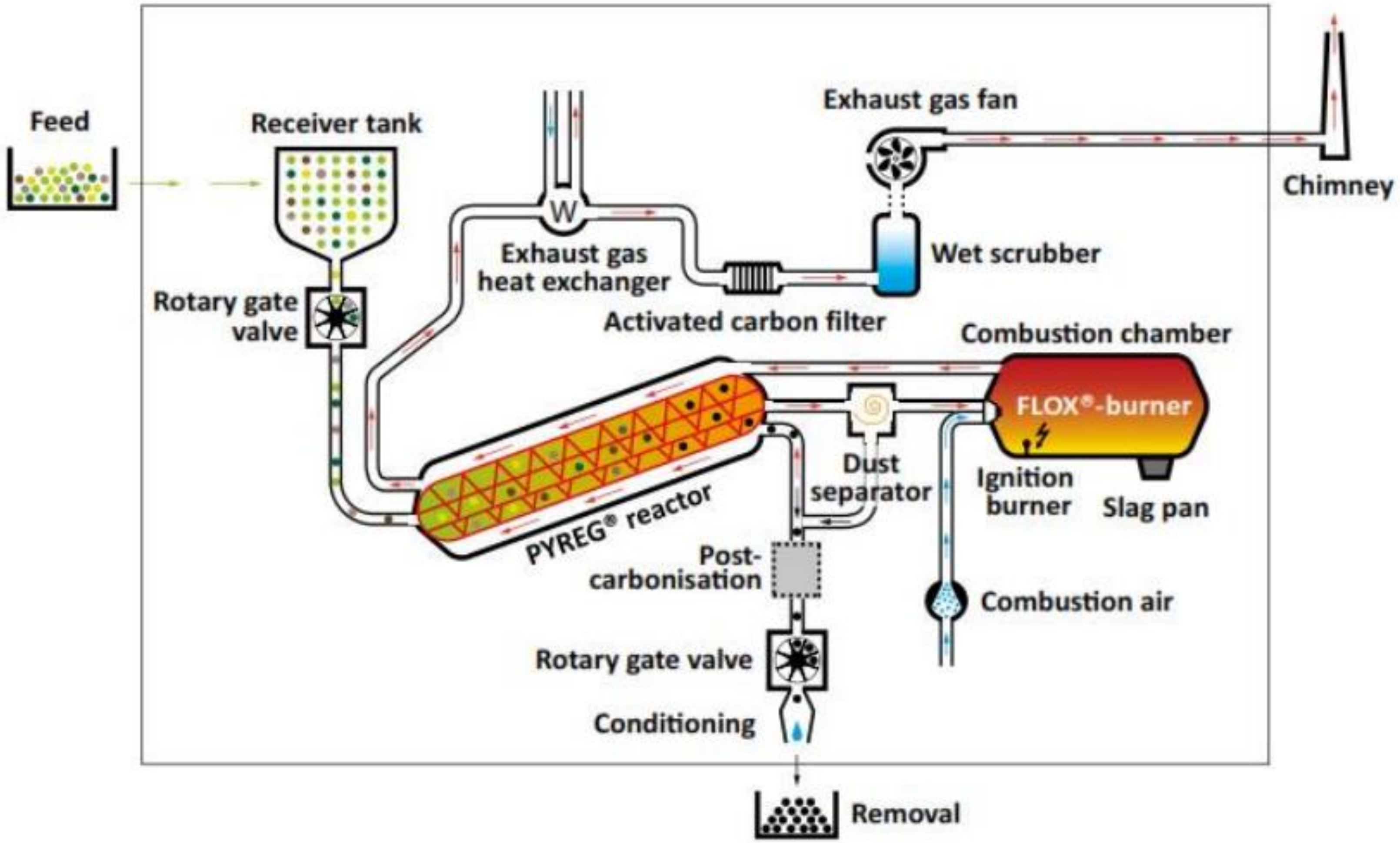
Typical Energy Balance
R2E2 – 2035 Maximum Month Load



Green Bay's R2E2 BioThermal System with Anaerobic Digestion and Incineration

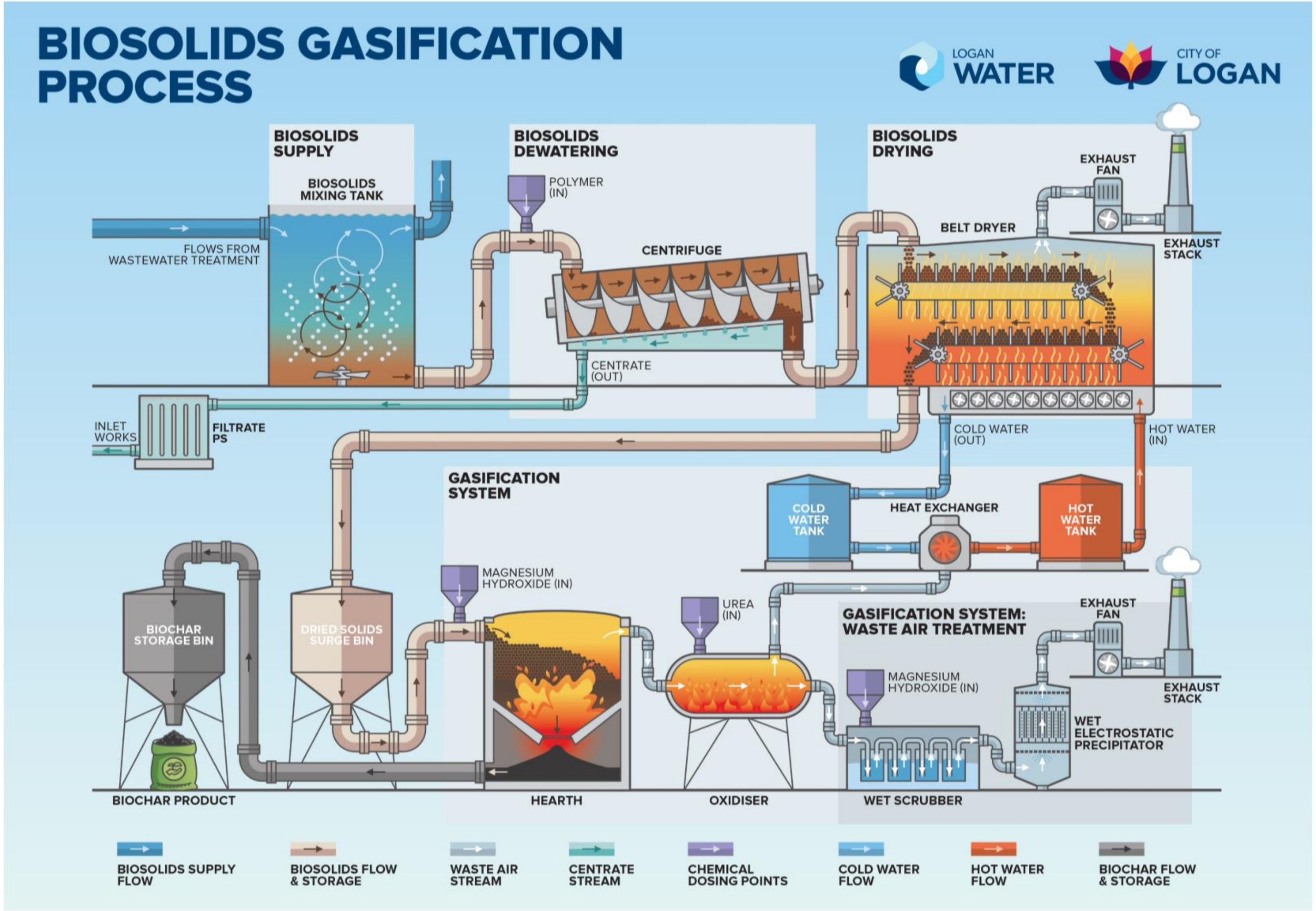


Pyrolysis Process



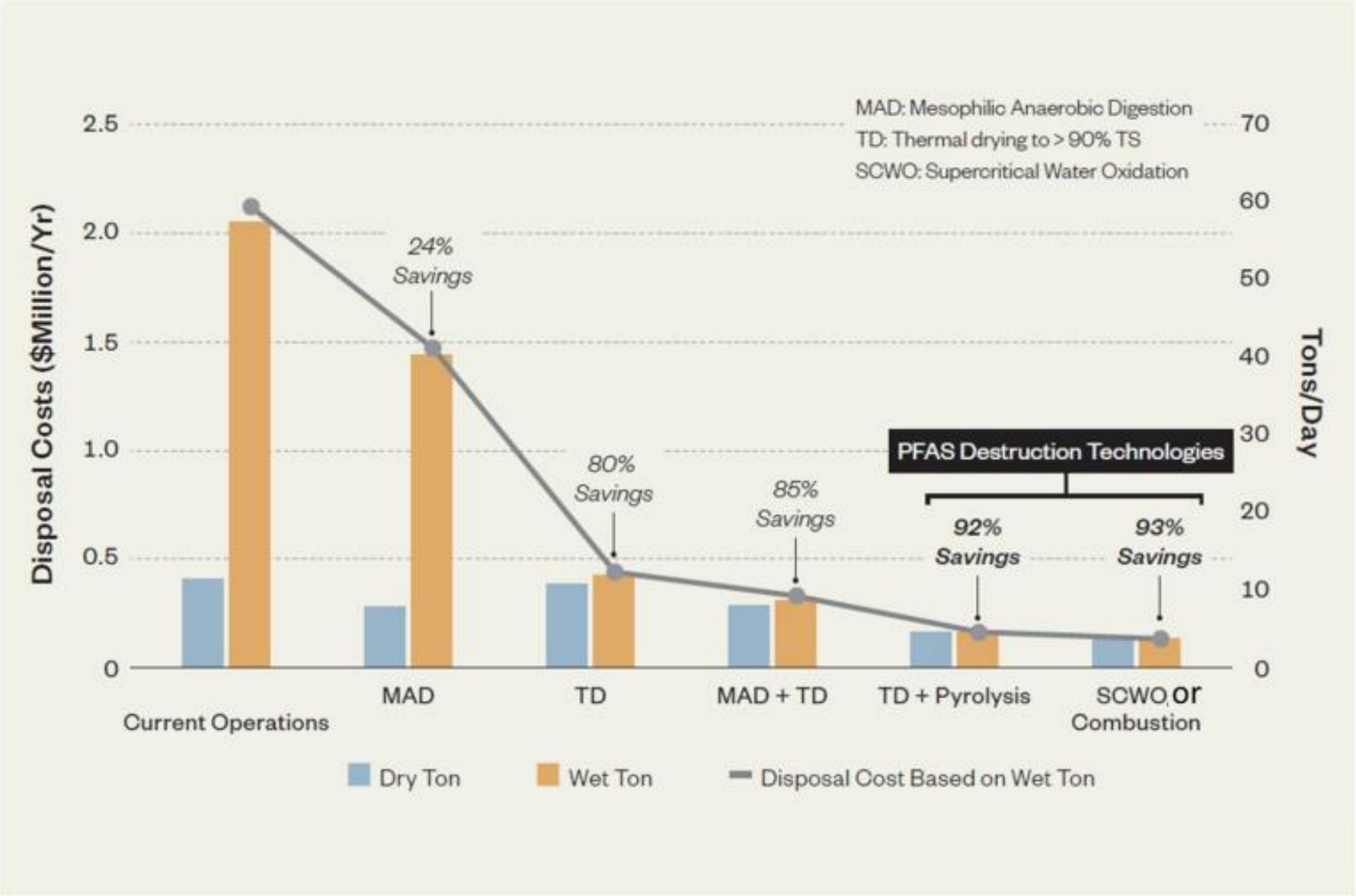
- Thermal conversion of carbon-based materials, in absence of air or oxygen into syngas and biochar
- It requires an indirect source of heat

Gasification Process



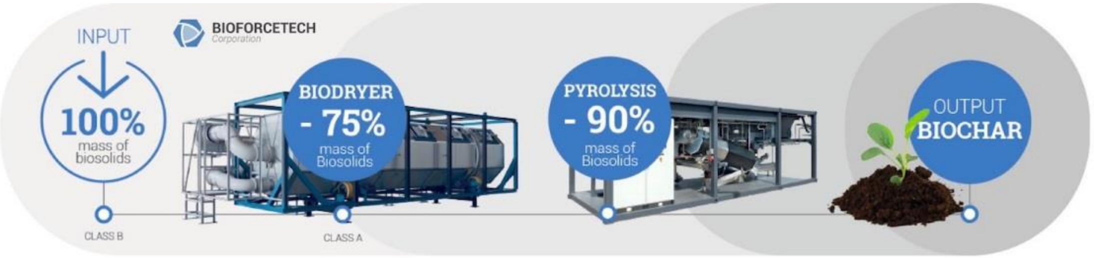
- Thermal conversion of carbon-based materials, with a limited supply of air or oxygen (sub-stoichiometric), into syngas and biochar
- It requires a direct source of heat that is generated by the partial oxidation of a small amount of the carbon-based material

PFAS Destroying Technologies Significantly Reduce Hauling and Beneficial Use Costs!



Biochar from Bioforcetech Corp.

- One set of samples 2019, confirmed in 2020
- Pyrolysis at 1100°F (600°C)
- We know soil sampling needs to be above 1000°C for destruction of PFAS



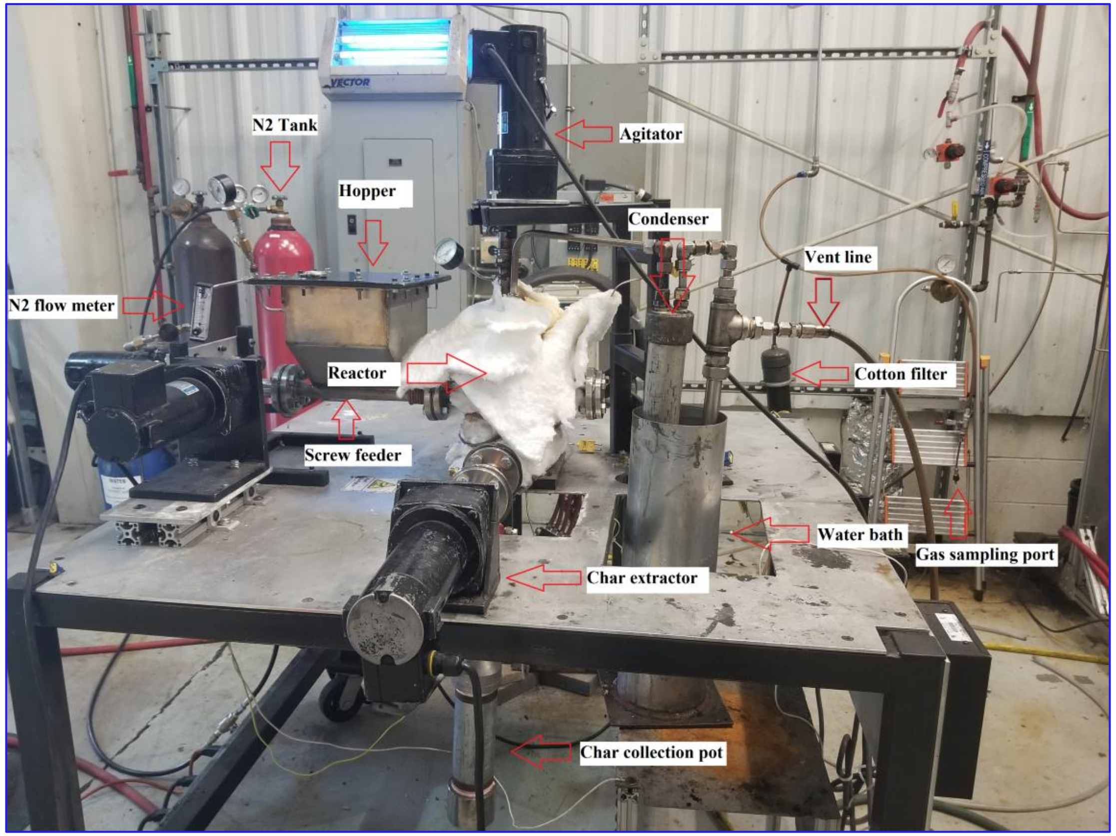
Compound Name	Dry Biosolids (ng/g)	Biochar (ng/g)
PFBA	7.03	Not Detected
3:3 FTCA	ND	Not Detected
PFPeA	5.94	Not Detected
PFBS	2.3	Not Detected
4:2 FTS	ND	Not Detected
PFHxA	33.7	Not Detected
PFPeS	ND	Not Detected
HFPO-DA	ND	Not Detected
5:3		
PF		
AD		
PF		
6:		
PFOA	89.1	Not Detected
PFHpS	ND	Not Detected
7:3 FTCA	40	Not Detected
PFNA	5.3	Not Detected
PFOSA	ND	Not Detected
PFOS	26.3	Not Detected
9Cl-PF3ONS	ND	Not Detected
PFDA	11.3	Not Detected
8:2 FTS	5.68	Not Detected
PFNS	ND	Not Detected
MeFOSAA	23.5	Not Detected
EtFOSAA	19.6	Not Detected
PFUnA	3.39	Not Detected
PFDS	ND	Not Detected
11Cl-PF3OUdS	ND	Not Detected
10:2 FTS	ND	Not Detected
PFDoA	5.85	Not Detected
MeFOSA	ND	Not Detected
PFTrDA	ND	Not Detected
PFTeDA	2.44	Not Detected
EtFOSA	ND	Not Detected
PFHxDA	ND	Not Detected
PFODA	ND	Not Detected
MeFOSE	17.1	Not Detected
EtFOSE	ND	Not Detected

PFOA =89.1 &
PFOS = 26.3

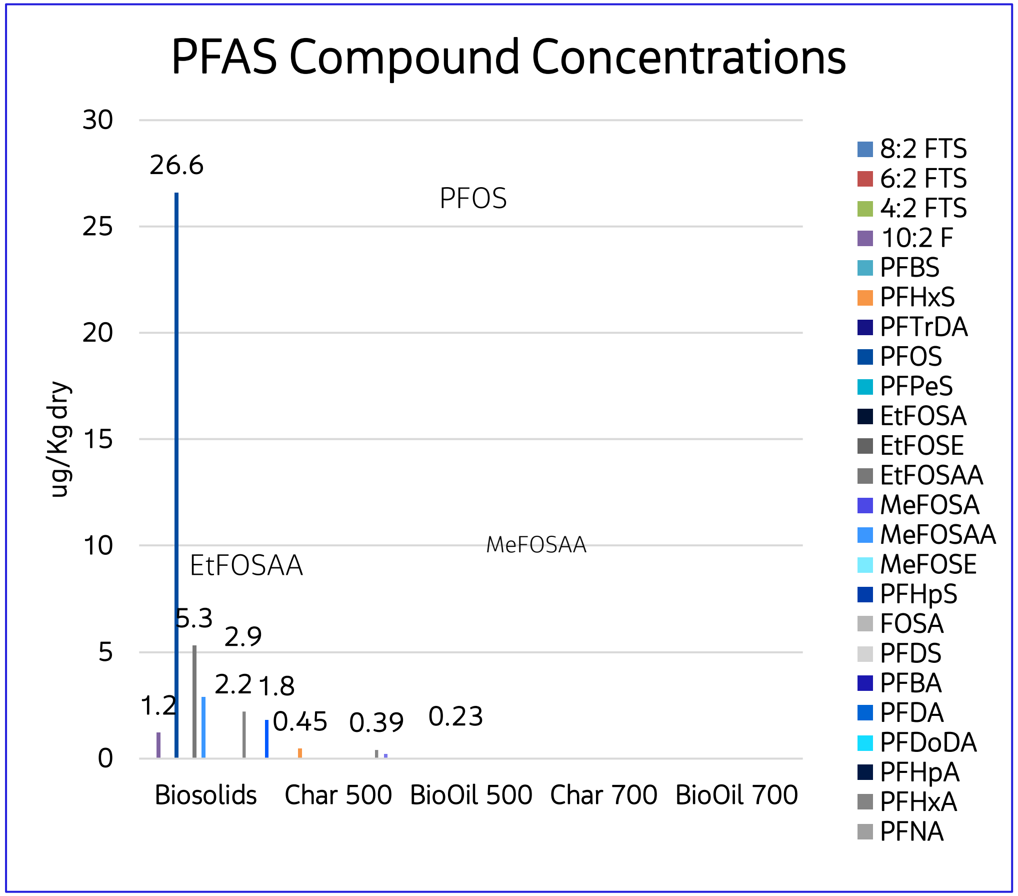
All ND
@ 2ppb

Jacobs and CharTech Bench Scale Pyrolysis Testing in 2020

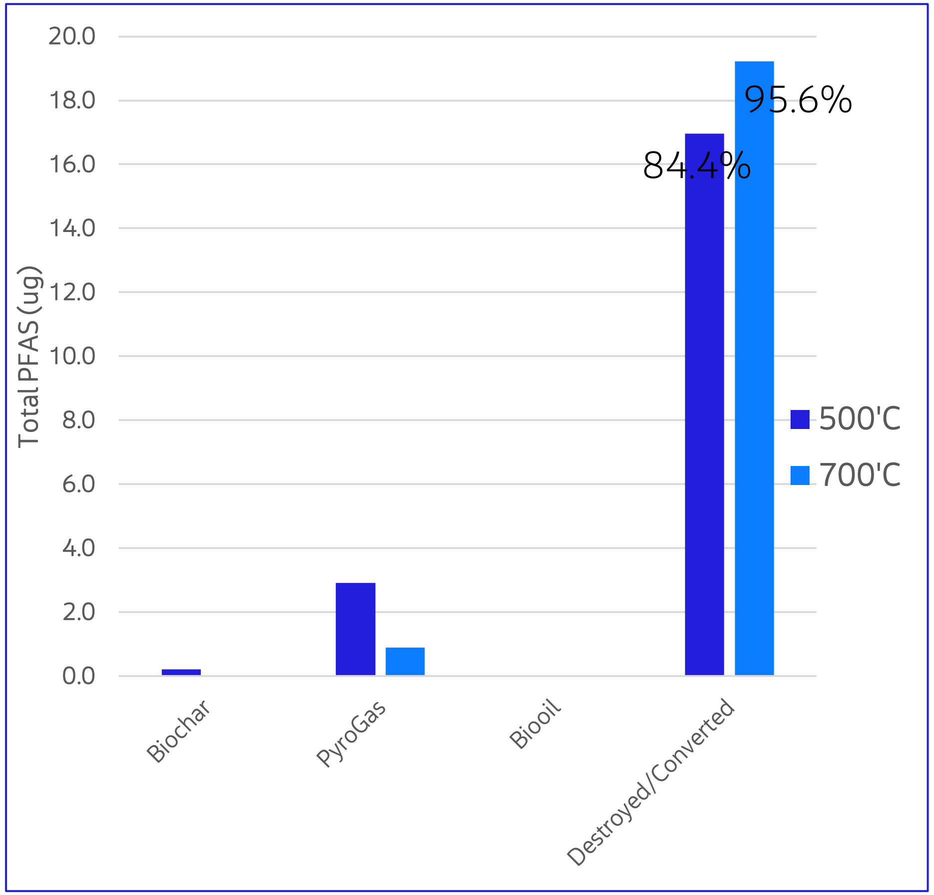
- A continuously-fed bench-scale pyrolysis kiln unit (known as “Baby MFR”) processing 500g dried biosolids at 500°C and 700°C
- Bench study completed at ICFAR (Western University Institute for Chemicals and Fuels from Alternative Resources)
- Biosolids were previously dewatered and subsequently dried in a batch thermal dryer to approximately 95 percent solids
- Biosolids processed in pyrolysis reactor for 20 minutes



PFAS Testing Results Before and After Pyrolysis



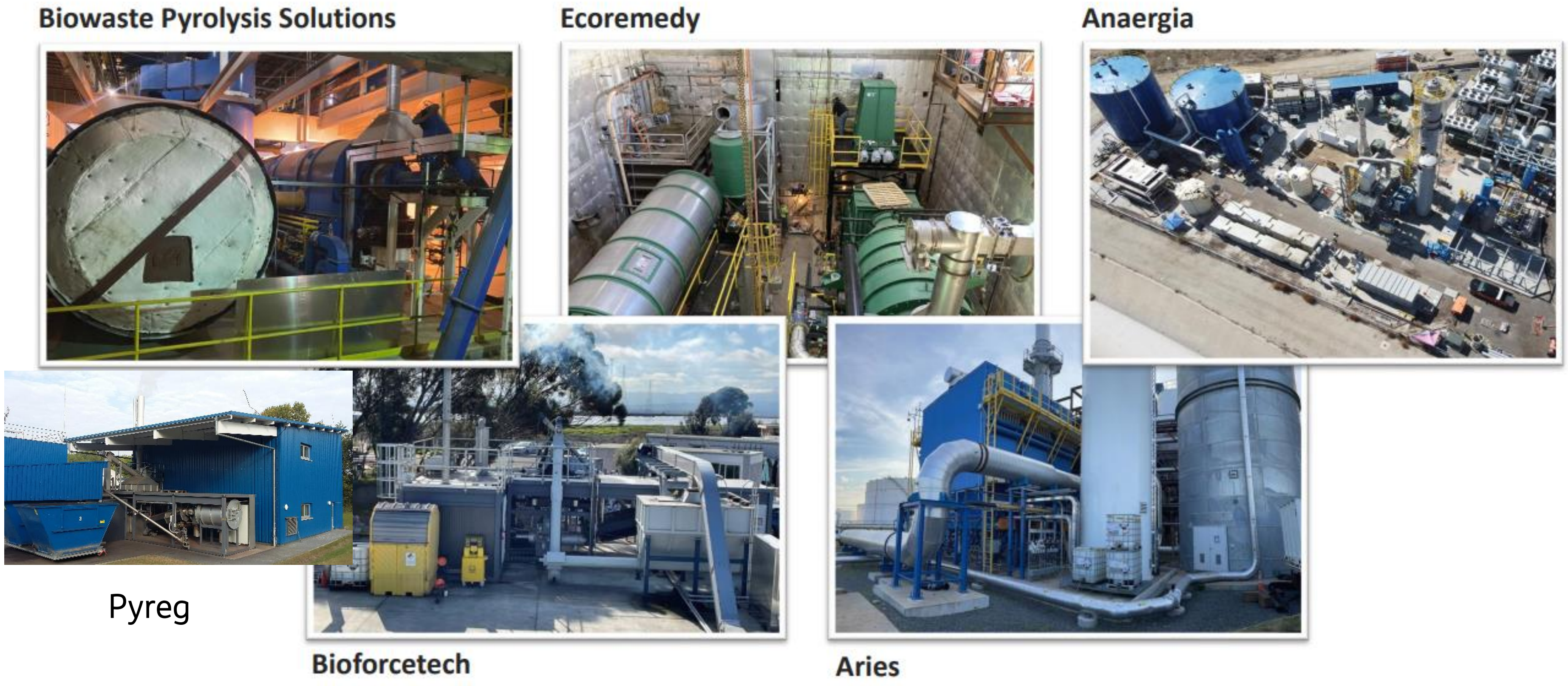
PFAS Mass and % Reductions out of 20 ug PFAS in biosolids



Gasification / Pyrolysis Facilities in Various Stages of Implementation

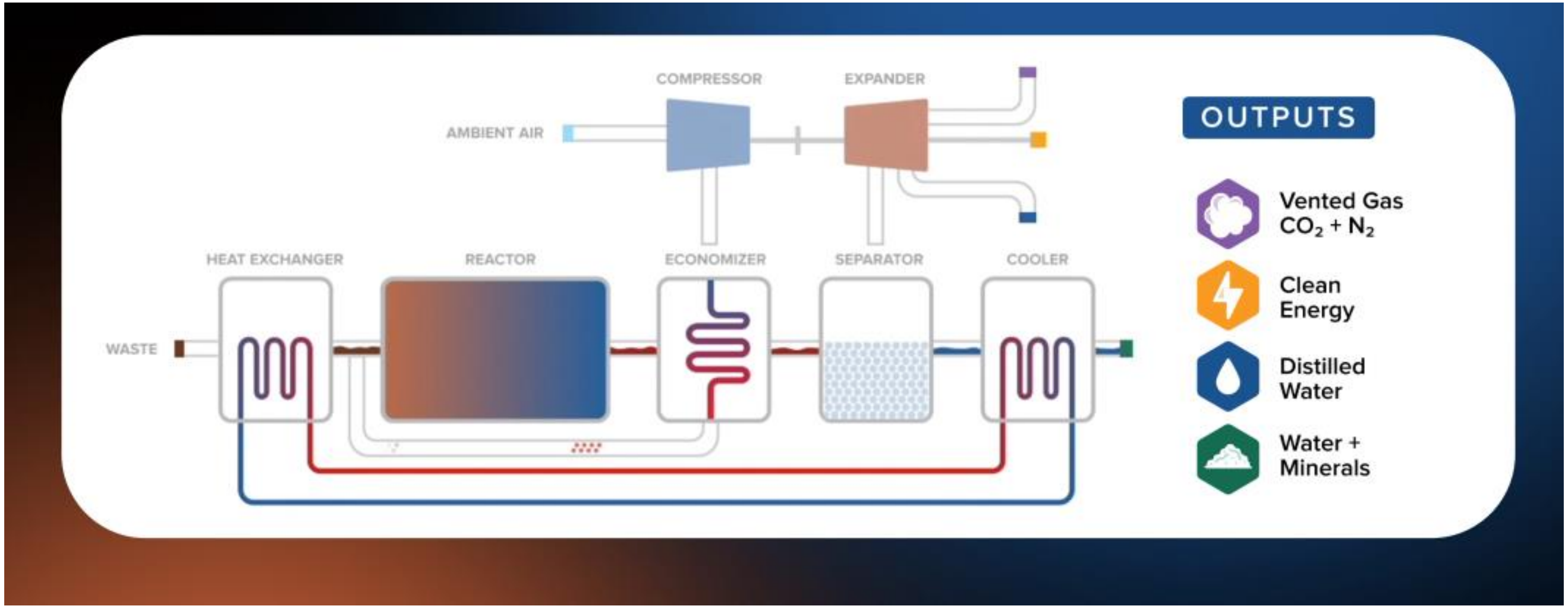
Facility	Vendor	Drying / Thermal Process	Size (Wet tonne/day)	Status
Silicon Valley Clean Water, CA, USA	Bioforcetec (Pyreg)[1]	Biodrying / Pyrolysis	20	Operating Since 2017
Ephrata, PA, USA	Bioforcetec (Pyreg)[1]	Biodrying / Pyrolysis	20	Construction 4Q, 2022
Loganholme, Australia	Pyrocal	Thermal drying / Gasification	90	Commissioning phase
Unkel, Germany	Pyreg	Thermal Drying / Pyrolysis	NA	2015
Homburg, Germany	Pyreg	Thermal Drying / Pyrolysis	NA	2016
Hammenhög Sweden	Pyreg	Thermal Drying / Pyrolysis	NA	2019
Trutnov Czech Republic	Pyreg	Thermal Drying / Pyrolysis	NA	2020
Lorsbach Germany	Pyreg	Thermal Drying / Pyrolysis	NA	2021
Kleve Germany	Pyreg	Thermal Drying / Pyrolysis	NA	Q4 2022

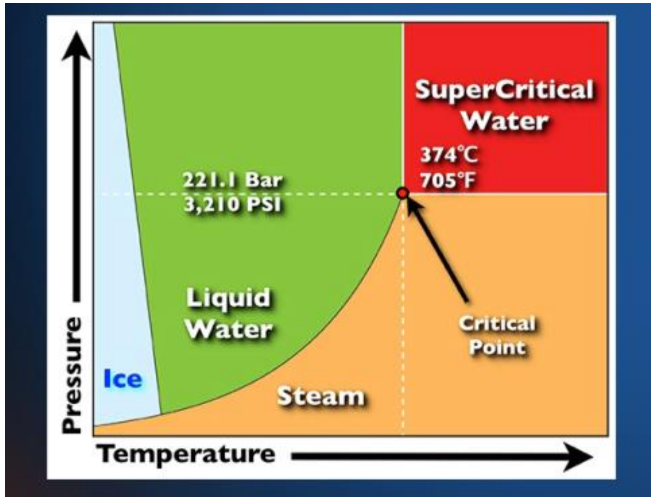
Pyrolysis / Gasification Suppliers

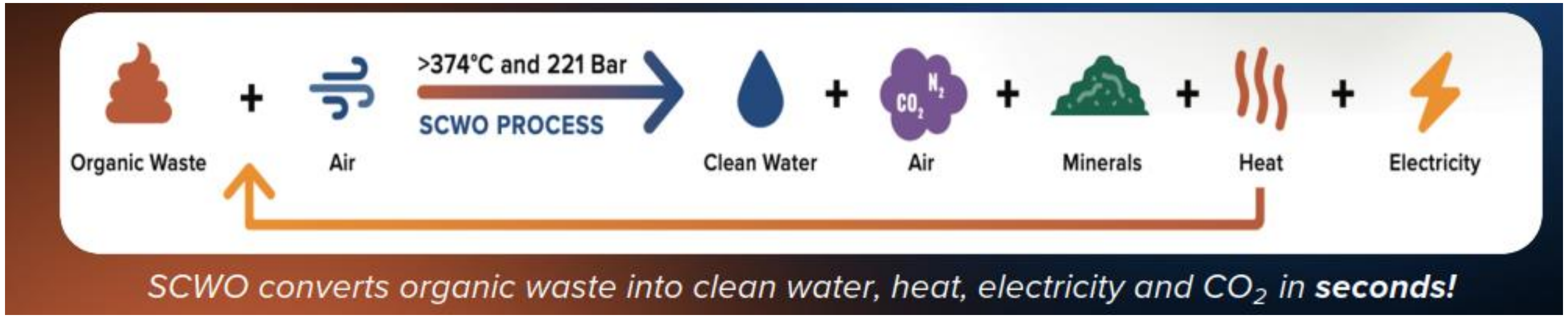


Pyreg

Supercritical Water Oxidation







Pilot at Durham, NC (ESTCP Project to treat AFFF)
https://www.youtube.com/watch?v=AQMSnRyih48

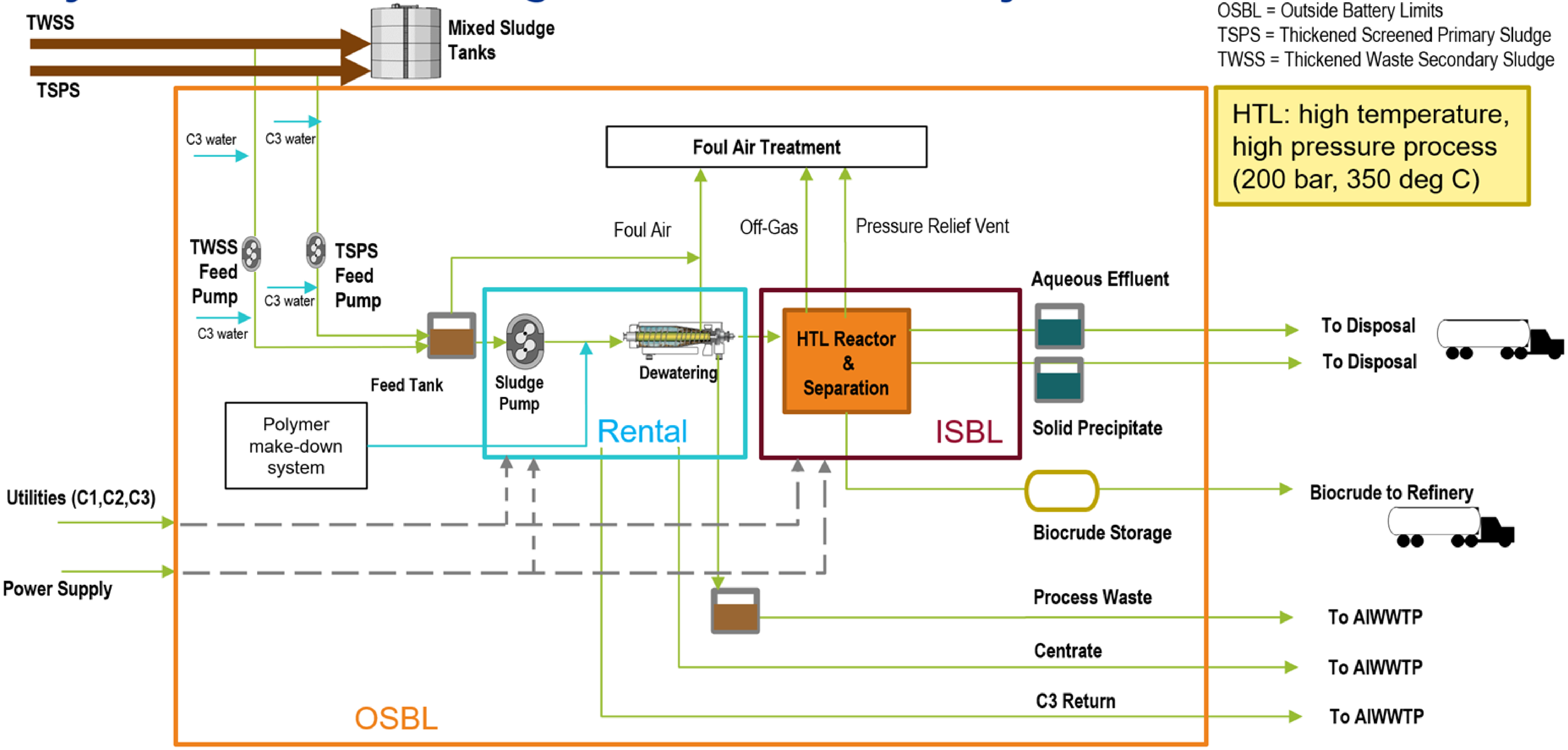
Sludge to liquid biofuel

Leveraging existing infrastructure to create low-carbon fuel

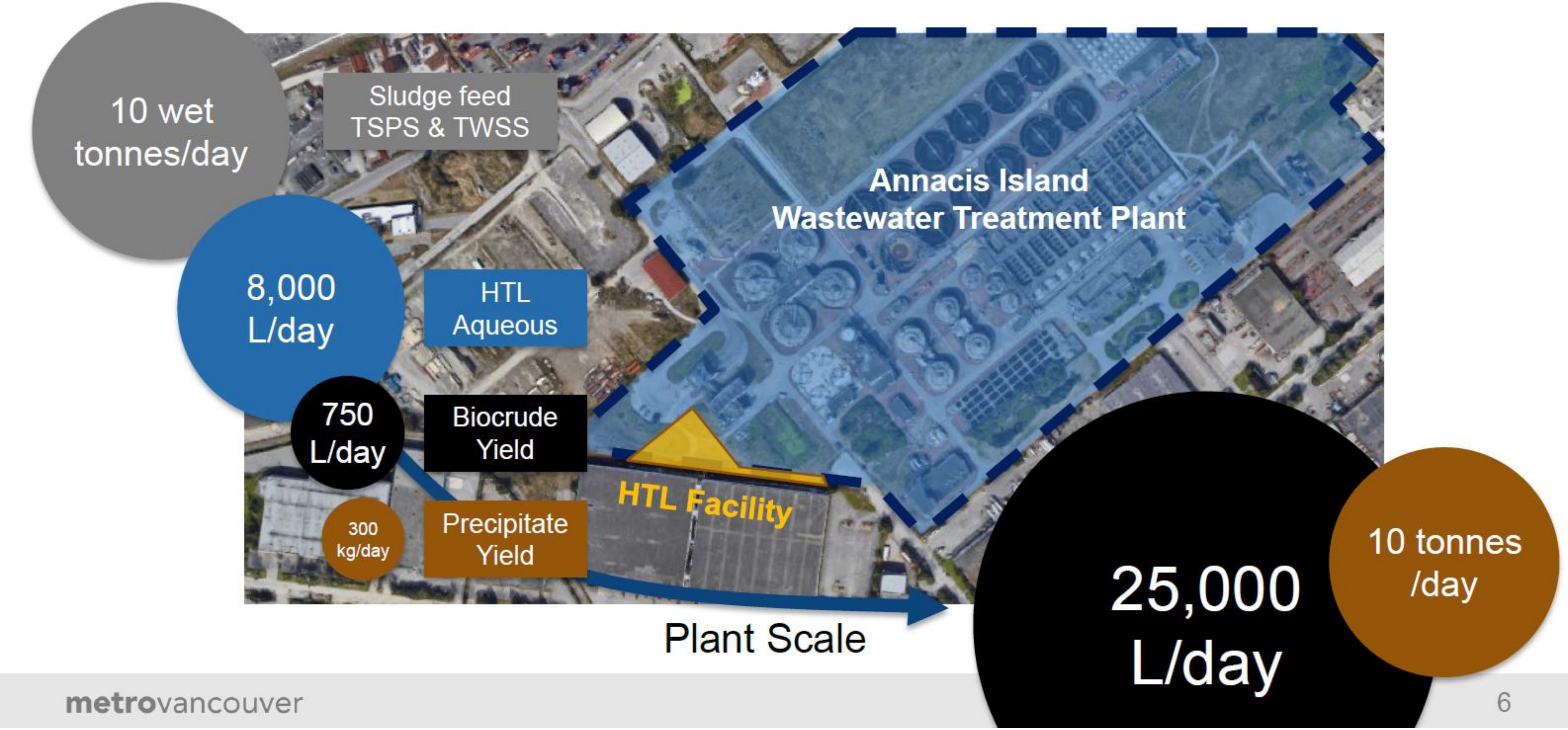
Hydrothermal Processing Demonstration Facility

Legend:
ISBL = Inside Battery Limits
OSBL = Outside Battery Limits
TSPS = Thickened Screened Primary Sludge
TWSS = Thickened Waste Secondary Sludge

HTL: high temperature, high pressure process (200 bar, 350 deg C)



Hydrothermal Processing Demonstration Facility



Resource Recovery

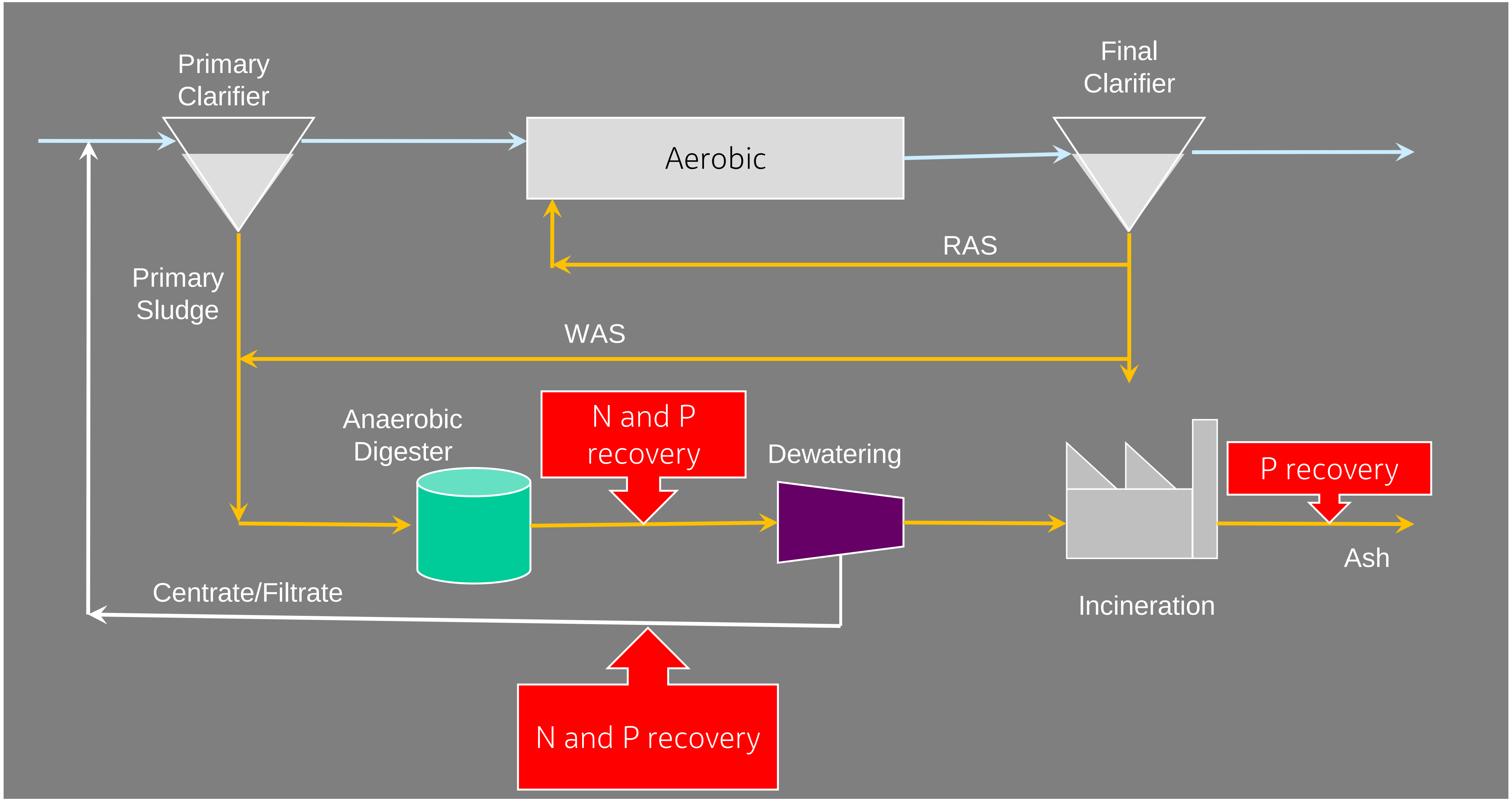
Resource Recovery

- P recovery – Ostara, from Ash
- Ammonia recovery – impact on N_2O emissions
- Biomethanation
- Degassing – fugitive methane emission reduction

Benefits of Nutrient Recovery

- Helps WWTPs meet discharge limits:
  - Effluent recovery
  - Reduced sidestream loading
- Produces a sustainable and beneficial byproduct
- Revenue generation for a utility from sale of the fertilizer product
- Controls and mitigates scaling or fouling of equipment from detrimental precipitation
- Alleviates negative impact of EBPR sludge on dewaterability
- Controls the nutrient content of biosolids

Nutrient Recovery at WWTPs



Convert Problem into Opportunity

Struvite Recovered as a <u>finished</u> product

P Recovery

Feature	Ostara Pearl®	NuReSys	Phospaq	Crystalactor	Airprex
Type of reactor	Fluidized Bed Reactor (FBR)	Completely Stirred Tank Reactor (CSTR)	CSTR	FBR	CSTR
Point of Recovery	Centrate/Filtrate	Centrate/Filtrate; digested sludge	Centrate/ Filtrate	Centrate/Filtrate	Digested sludge
Recovery efficiency	80-90% P 10-40% NH3-N	>85% P 5-20% N	80% P 10-40% NH3-N	85-95% P for struvite 10-40% NH3-N > 90% P for calcium phosphate	80-90% P 10-40% NH3-N
Full-scale installations	22	9	3	4	13

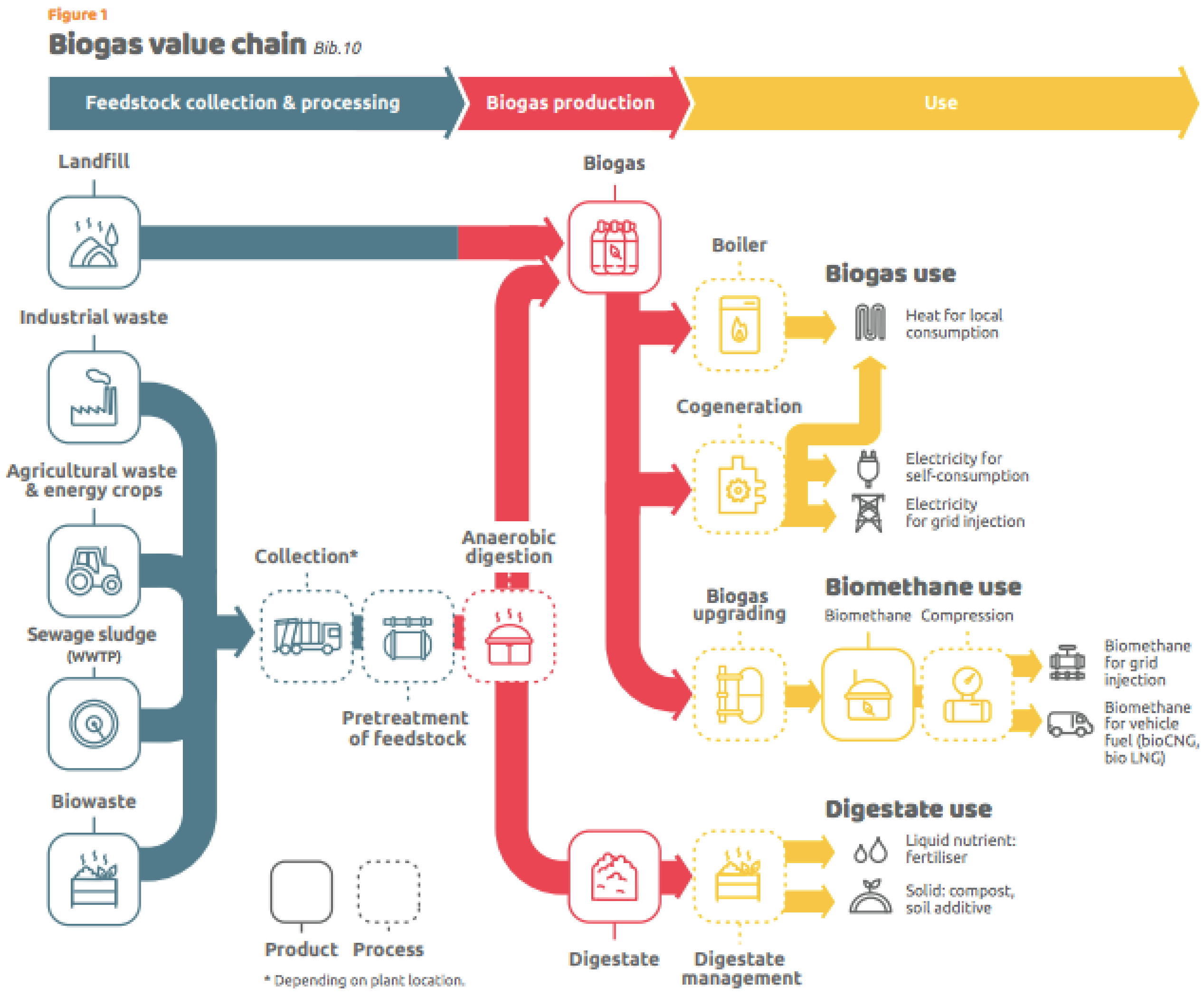
Ammonia Recovery

- Steam Stripping / Thermal stripping
- Membrane Ion exchange
- Membrane separation
- Air stripping – increasing pH

Organics Group:
Thermal stripping ammonia recovery

Biomethanation

- Produces high-value product
- Replaces natural gas with renewable energy
- Multiple vendors available
- Widely applied in the Europe
- Multiple Technologies available:
  - Water Wash
  - Pressure Swing Adsorption
  - Membrane separation

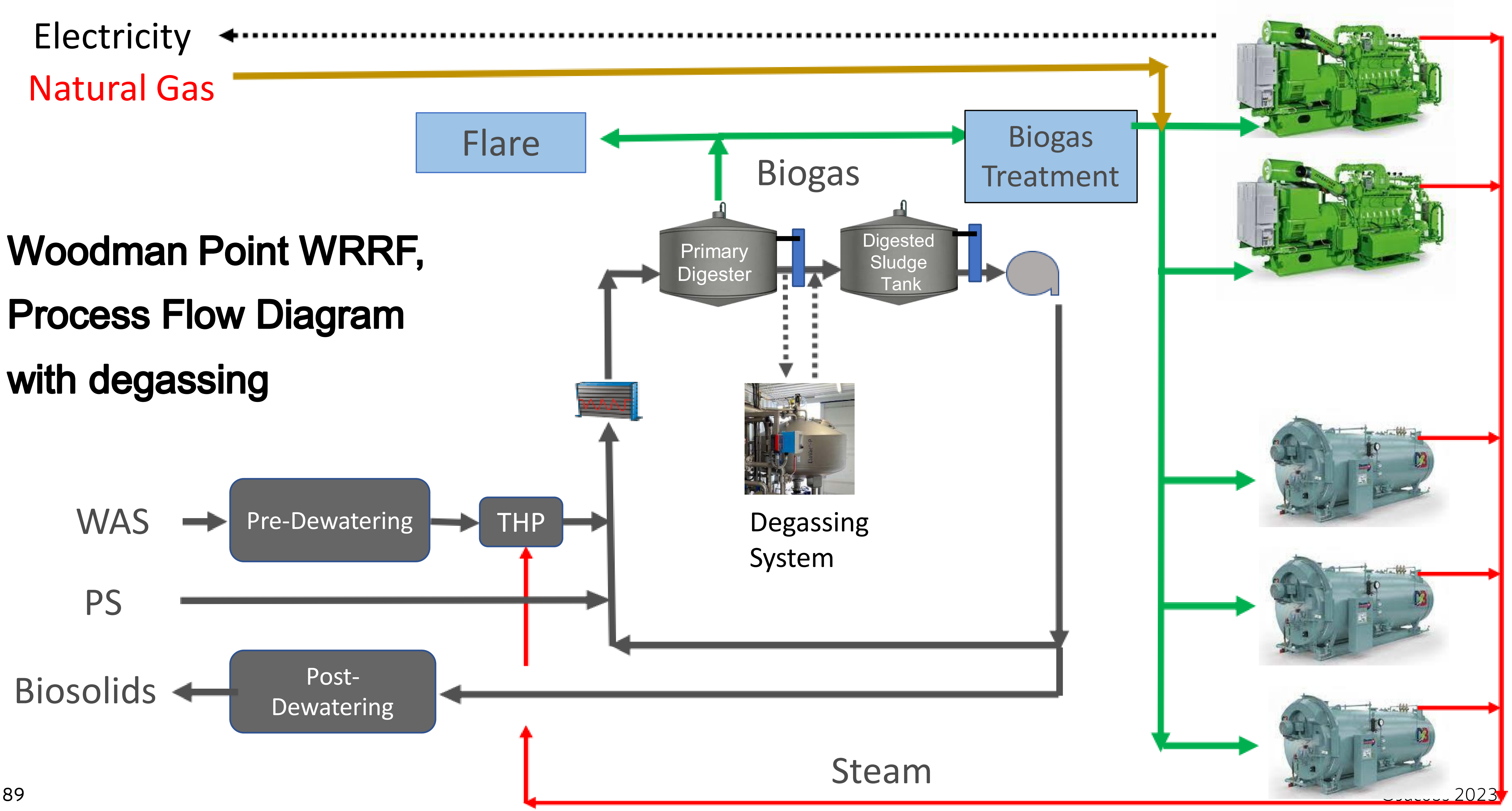


https://arena.gov.au/blog/biogas-time-to-start-cooking-with-renewable-gas/

Degassing of Digested Biosolids

- Recovery of methane
- Additional biogas for co-generation and reduces fugitive methane emission
- Can remove struvite, resulting in Improved dewatering

Woodman Point WRRF, Process Flow Diagram with degassing



Q & A

Jacobs

Challenging today.
Reinventing tomorrow.