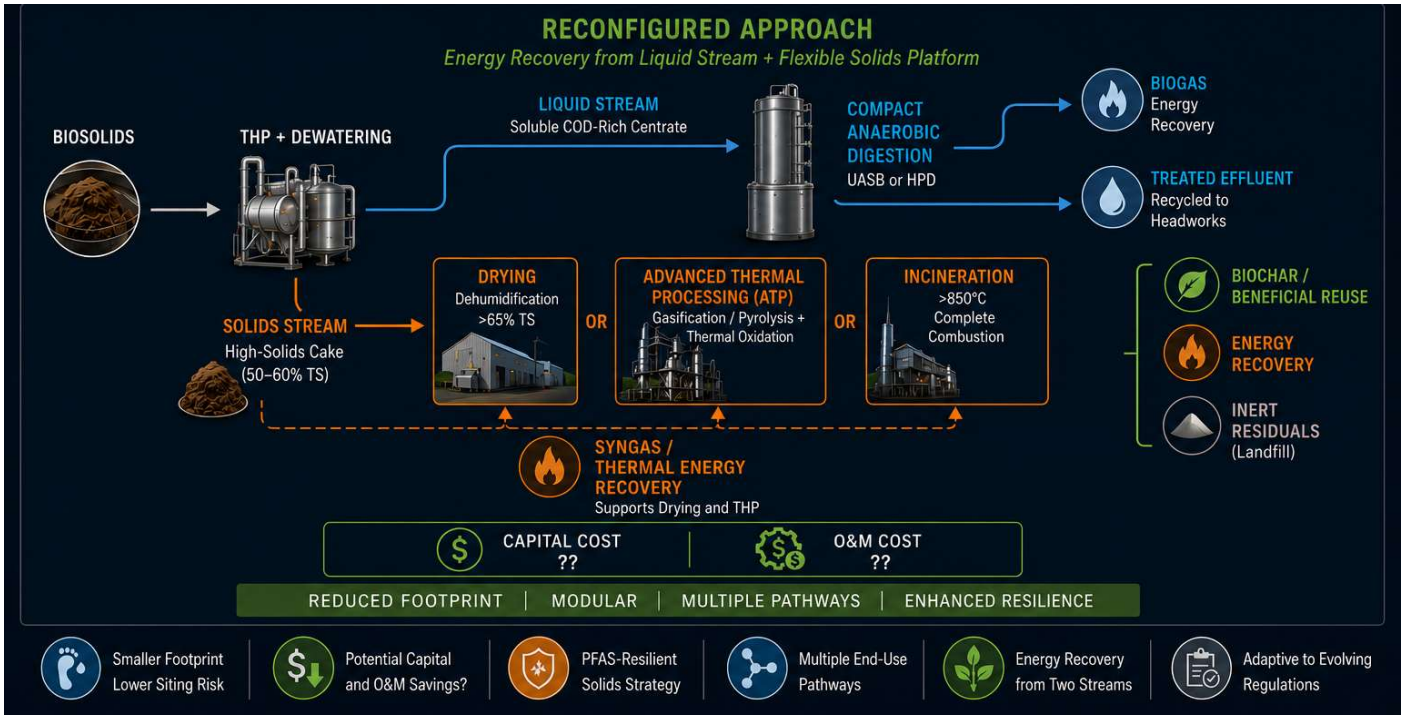

Reconfiguring Anaerobic Digestion for Cost, Risk, and Regulatory Resilience

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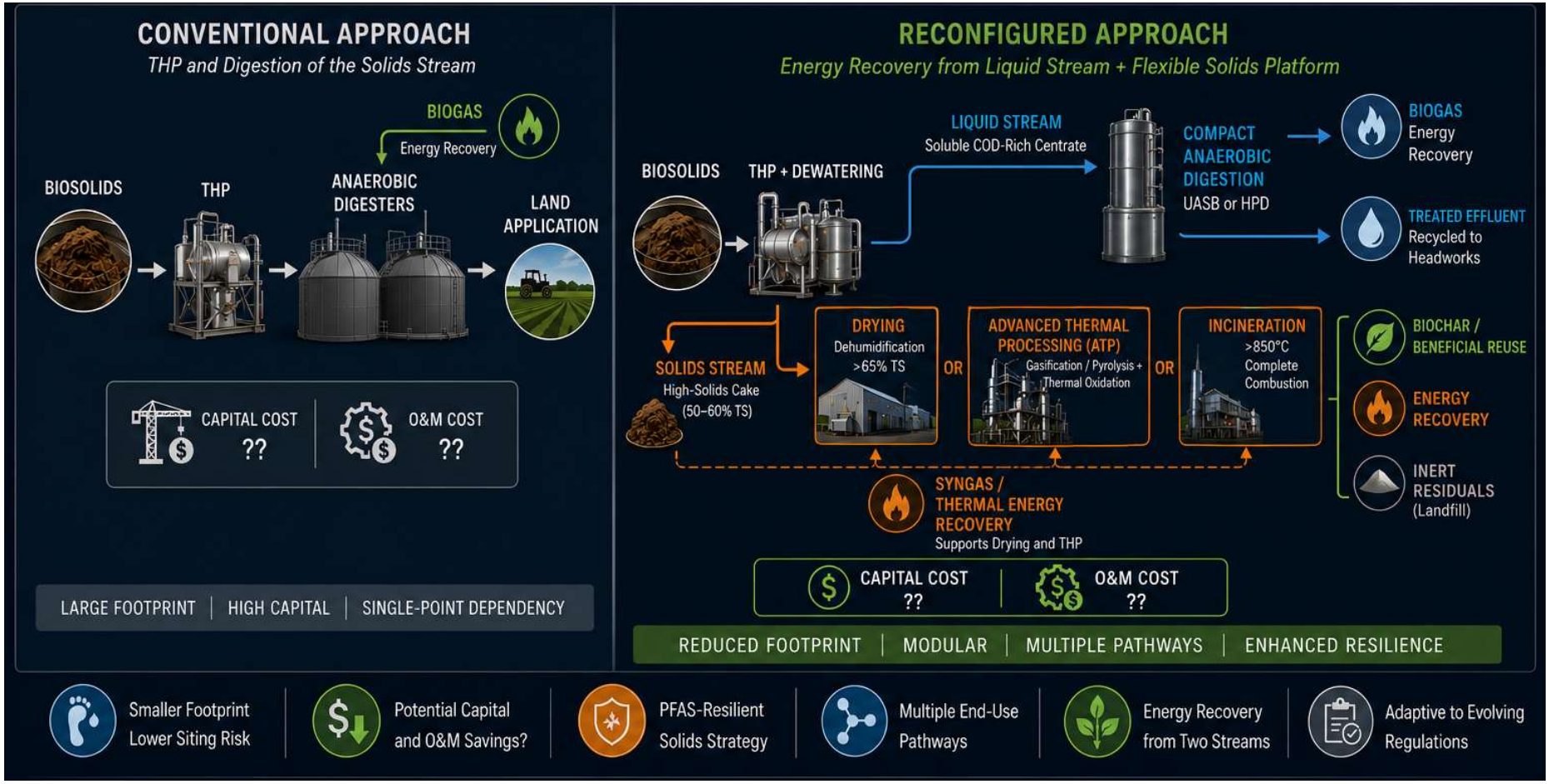
June 9, 2026

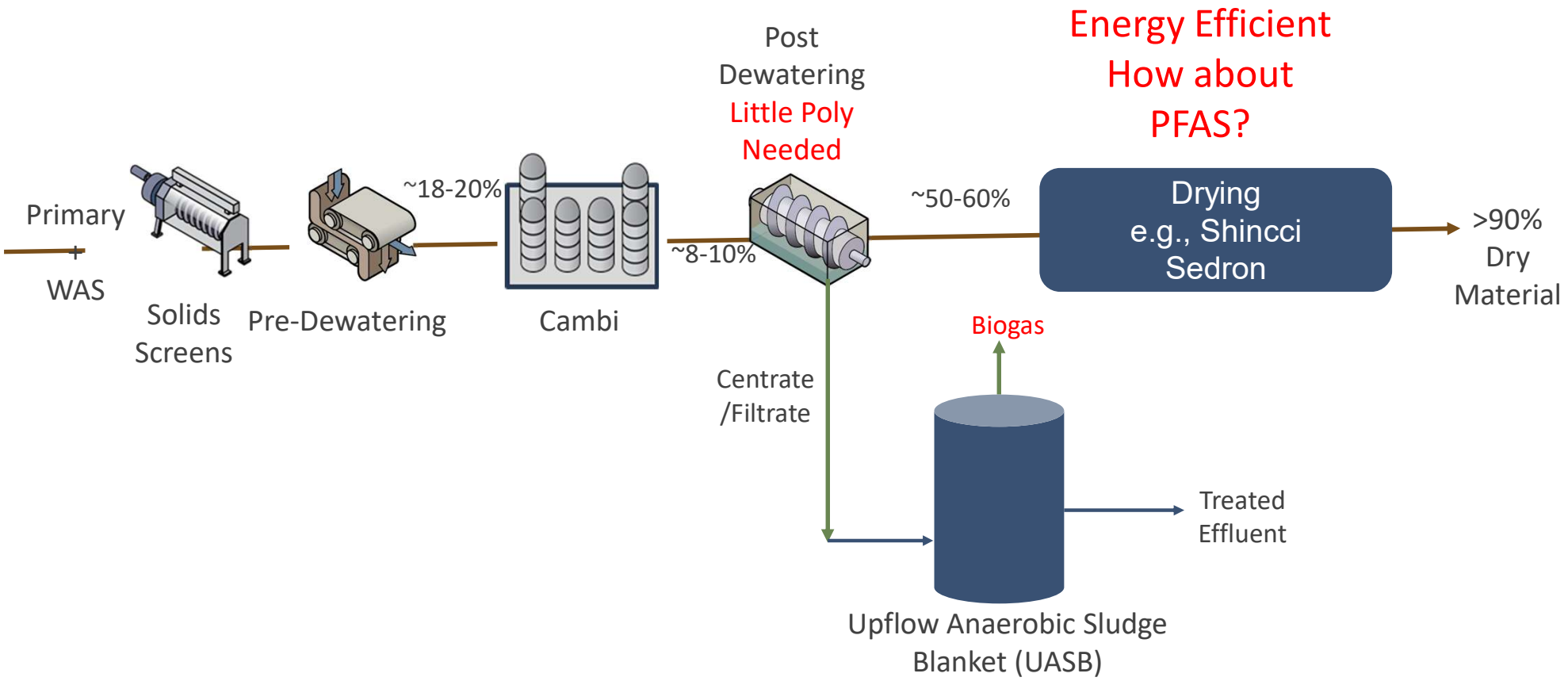
MIDWEST BIOSOLIDS ASSOCIATION

3rd Annual Conference

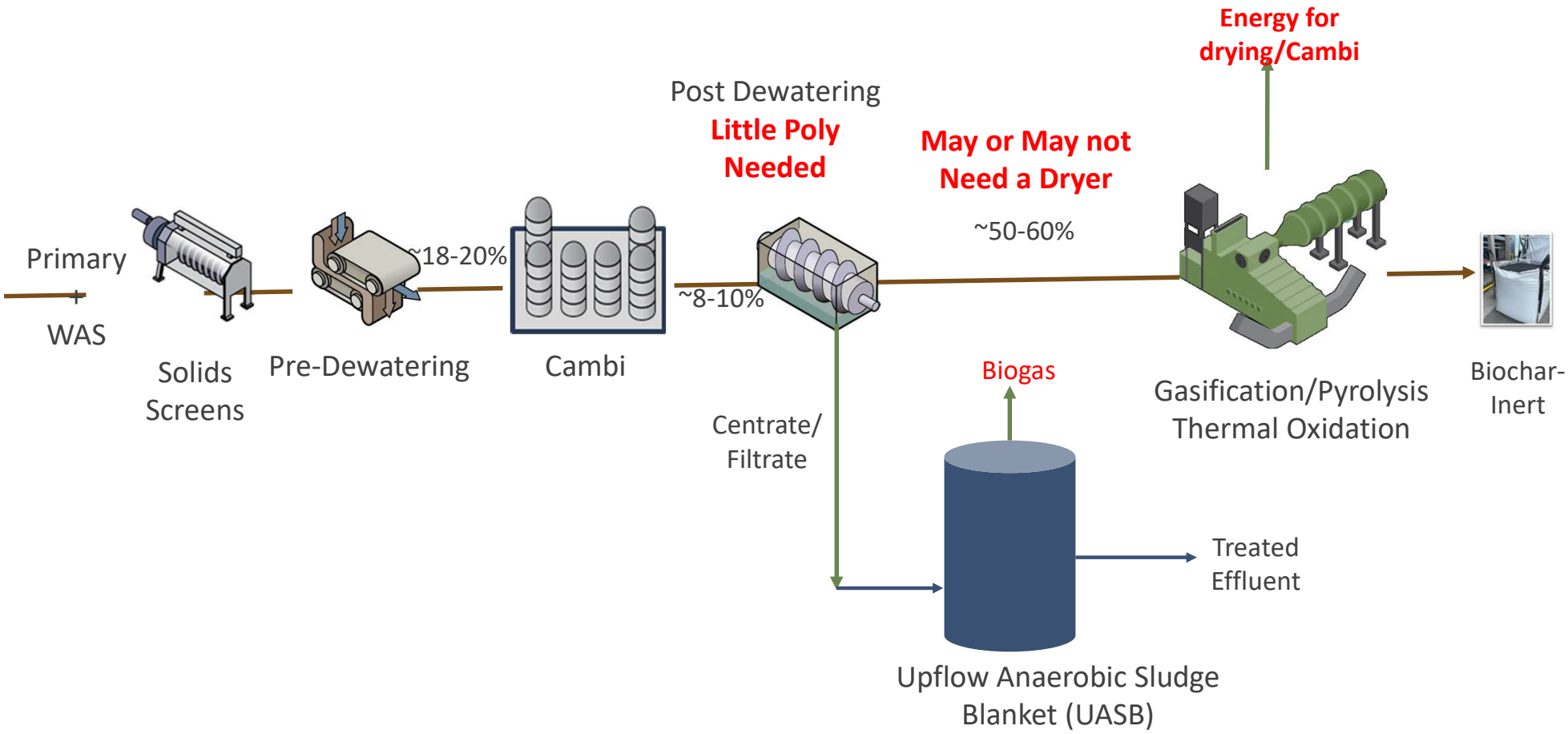
Reconfiguring where and how we recover energy creates a more resilient future



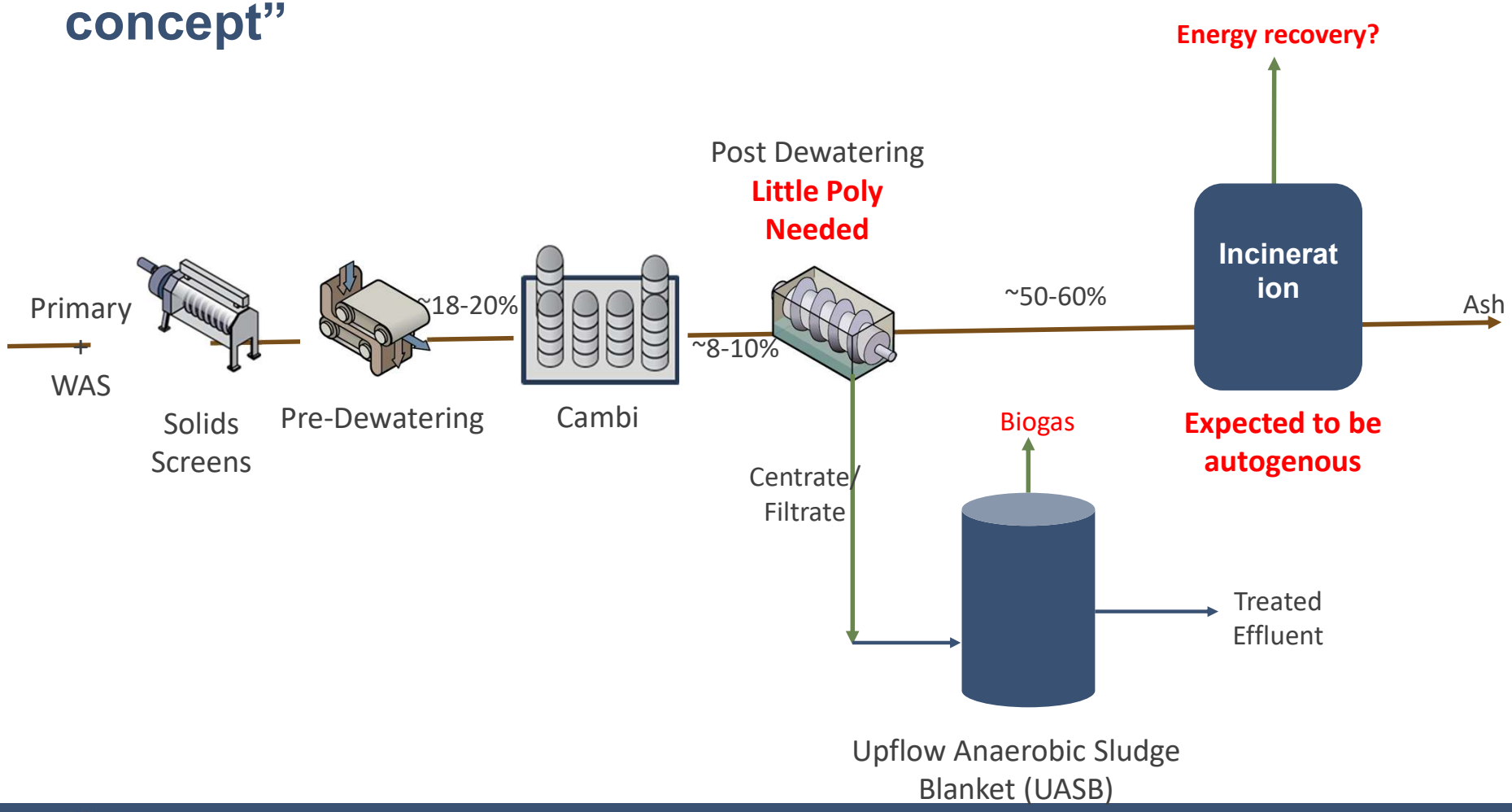
Using thermal drying



Using gasification/pyrolysis

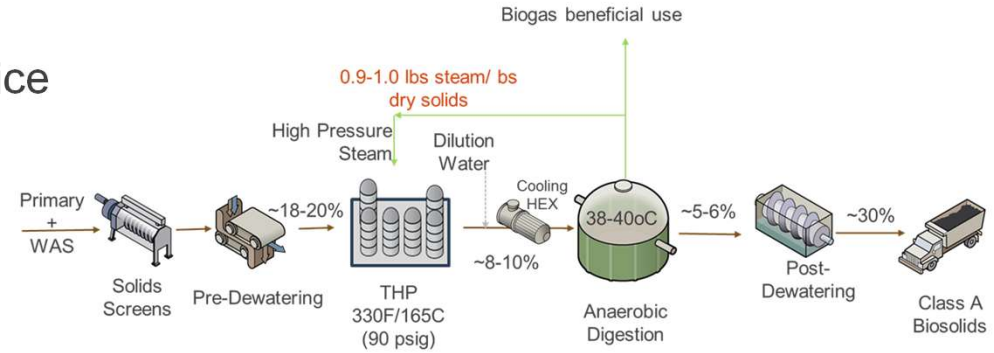


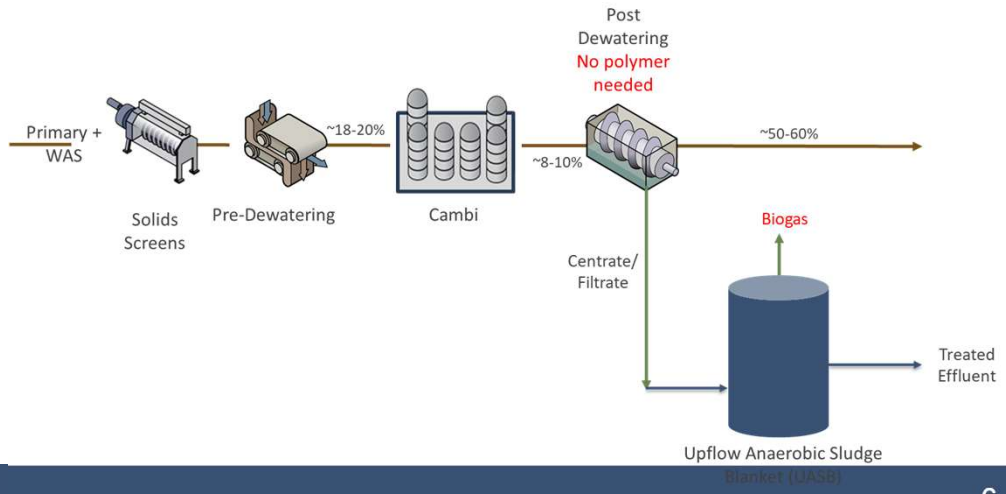
Using incineration at the end, this is the “good old Zimpro concept”



Objective: Does the process have a merit?

- Compare new concept to THP-Digestion practice
- Use green facility concept
- Use three sizes of 10, 25 and 50 MGD
- Plants have primary and WAS (50:50)
- Conduct energy and mass balance for both systems
- Compare in terms of
  - **Conceptual cost**
  - **Footprint**
  - **Energy demand/recovery**
- End treatment
  - **Use gasification/pyrolysis**
  - **Use thermal drying**



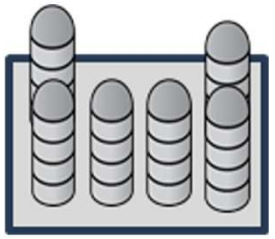


What to compare?
Proceeding components to post THP are same

	Conventional THP	New Concept
Post Dewatering: Centrifuges	After digestion 30% cake	After THP 55% cake
Digestion (Sizing, cost, footprint and biogas production)	After THP	USAB
~~Drying to 90%~~ ~~Using Shincci Drying as a surrogate~~	~~Start from 30%~~	~~Start from 60%~~
Drying gasification (sizing, cost and footprint) Use Ecoremedy as a surrogate	Start from 30%	Start from 55%

THP or equivalent

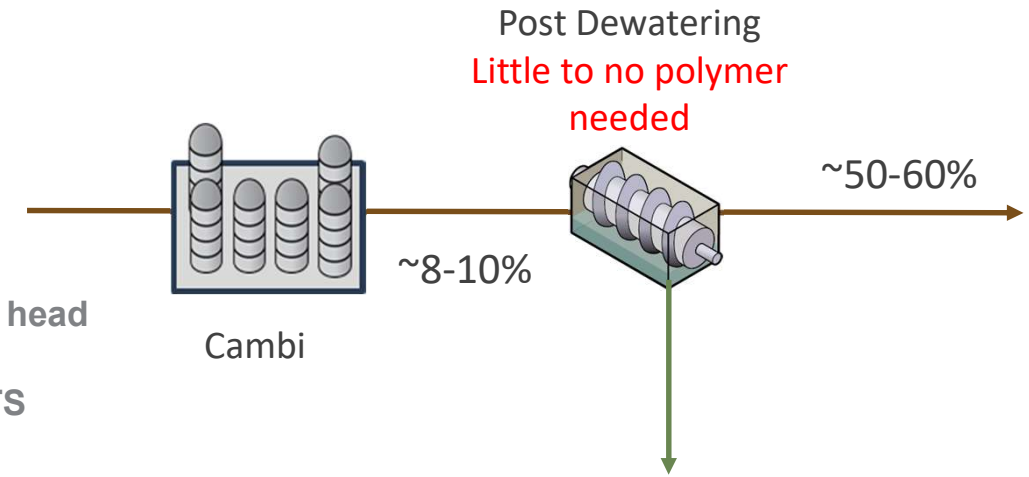
- Use Cambi systems
- Operating conditions
  - **More continuous system**
  - **Pump and continuous system**
- Input solids
  - **18-20%**
- Output solids
  - **8-10%**
- Same sizing/cost for both systems



THP
330F/165C
(90 psig)

Post THP Dewatering (VOWASA Experience)

- Input solids
  - **Centrifuge directly from flash tank**
  - **Small polymer consumption 5 lb/dt compared to 25 lb/DT for Cambi**
  - **COD solubilization if ~ 20-30%**
- Cake solids
  - **~50-60% cake out of the, large**
  - **Assume sludge heat content is 1,000 BTU/lb**
  - **Heat content in the cake**
- Centrate stream characterization
  - **In smaller systems, e.g., cruise ships, centrate to head of plant**
  - **Experience in cruise ships that centrate is ~ 4% TS without polymer**
  - **sCOD estimates**
    - *10,000 mg COD/L +10000x%DS in centrate*
  - **Ammonia content 2000 -2500 mg/l: assumed 2,000 mg/L**



Other assumptions

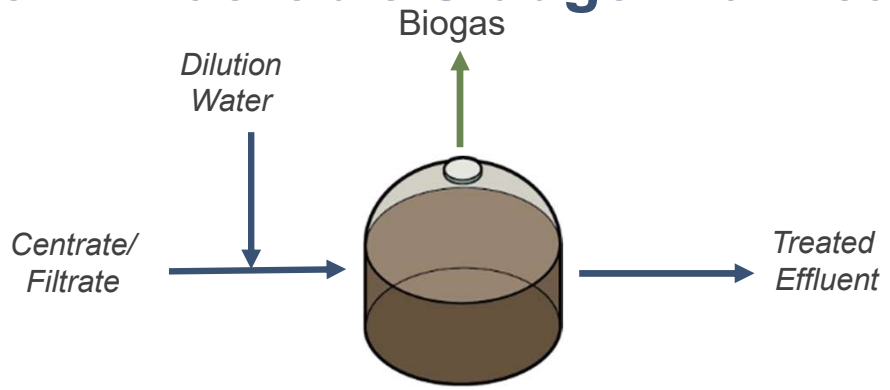
Parameters	Values	Resources/References
Specific Enthalpy of Saturated Steam @ 330F and 90 psi, BTU/lb	1,186	Calculated
Heating Value of Raw Sludge, BTU/lb dry solids	10,000	Fonts et al. 2012; Fytili and Zabaniotou 2008
Cambi THP Steam Injection, lb per lb dry solids	1.0	Calculated and verified by technology provider
Energy Content of sCOD, kJ/g sCOD	13.9	Shoener et al. 2014; Bantacut and Aulia 2019
sCOD conversion in UASB,%	80%	Provided by UASB vendor
Thermal Energy Recovery on Gasification	Heat Recovery Steam Generator	Assumed
Thermal Energy Recovery Efficiency, %	80%	Param and Jianu 2020

Post dewatering comparison: centrifuge

	THP-Digestion	THP-Dewatering
Cake	30%	55%
Centrate	Requires separate sidestream treatment for ammonia	Goes to USAB for biogas production
Polymer	25 lb/DT	5 lb/DT
Operation	Conventional	Hot dewatering experience
Hydraulic loading, gpm	90	90
Solids loading, lb/hour	1,300	1,300

Digestion of centrate using Upflow Anaerobic Sludge Blanket (UASB) Reactor

- Tested granular based
  - **Pacques system**
- HRT: 1.5 days!
  - **High organic loading 20 kg/L**
  - **SRT is high**
- Dilution of THP filtrate necessary to reduce COD to 20,000 mg/L
- sCOD removal is ≥ 80%



Upflow Anaerobic Sludge Blanket (UASB)

Digestion and UASB comparison

	THP- Digestion: Anaerobic Digesters			THP-Dewatering: UASB Reactors		
	10 MGD	25 MGD	50 MGD	10 MGD	25 MGD	50 MGD
Gallons	484,000	1,210,000	2,420,000	45,000	91,000	178,700
Footprint, ft^2	17,000	23,000	42,000	5,900	6,600	7,400
Comparison	**~3x**	**~3.5x**	**~5.7x**			
Biogas, cfm	83 **(~2.4x)**	208	415	35	90	175
Capital Cost*	$37M	$69M	$128M	$12.3M	$12.5M	$15.5M
	~3x	**~5.5x**	**~8.3x**			

**Estimated total project cost for digester or UASB reactor plus control building cost estimate escalated to include engineering contingency (30%), contractor overhead, profit, mobilization (30%), and owner's allowance (5%)*

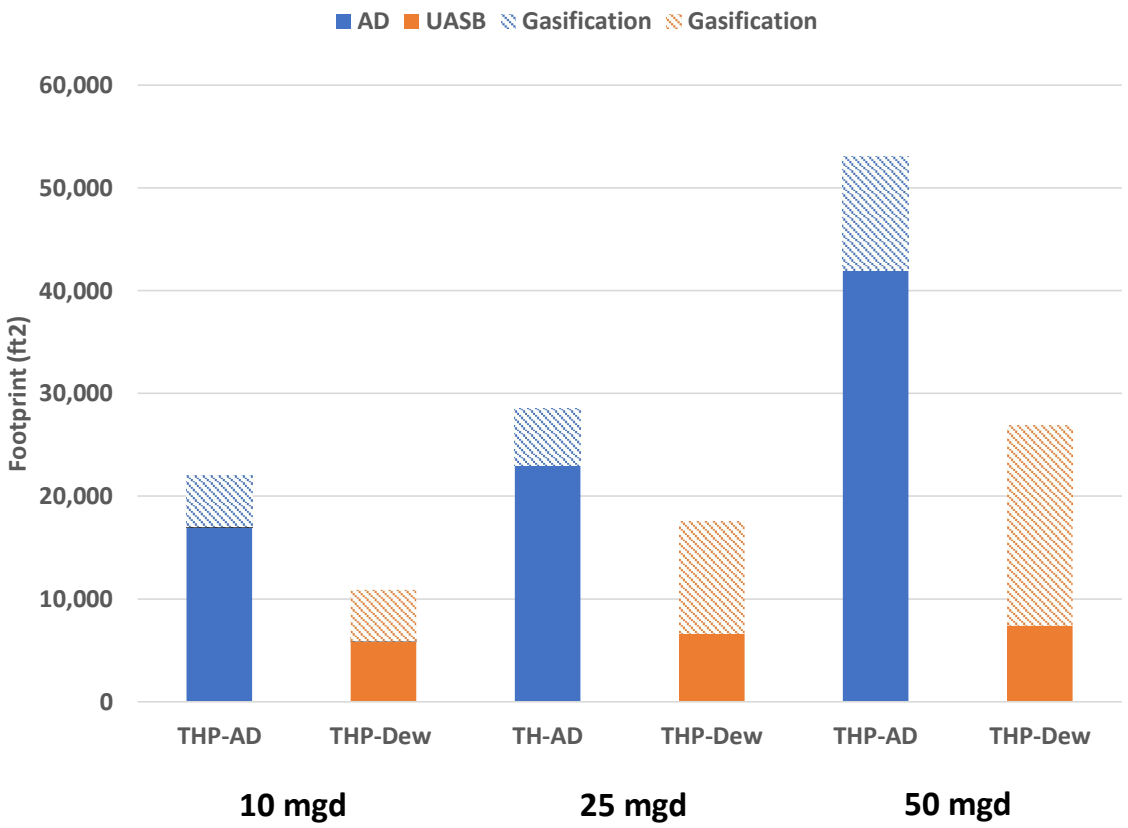
Gasification comparison: Ecoremedy

	THP- Digestion			THP-Dewatering		
	4.5 dtpd	**11.1 dtpd**	**22.5 dtpd**	**8.6 dtpd**	**21.4 dtpd**	**42.9 dtpd**
	30%			55%		
Units	1	1	2	1	2	3
Footprint (sf)	5,000	5,500	11,000	5,000	11,000	19,500
Energy Excess (mmbtu/year)	9,600	23,500	47,800	47,100	117,300	235,000
CAPEX Cost*	$40M	$60M	$110M	$50M	$110M	$230M
ECR Equipment	$13.5M	$20M	$40M	$16.5M	$40M	$87M
No. of Units and Model	1 x ECR-442	1 x ECR-642	2 x ECR-642	1 x ECR-542	2 x ECR-642	3 x ECR-752

**Includes estimates for ECR Equipment, Gasification Building, Mechanical and Electrical Upgrades, Conveyance from dewatering to gasification, Piping and Valving in gasification building, Engineering Contingency, Contractor Overhead, Profit & Mobilization, and Owner's Allowance; does not include potential major electrical upgrades, additional pumps, piping, and storage.*

Summary Comparison

Estimated differential footprint

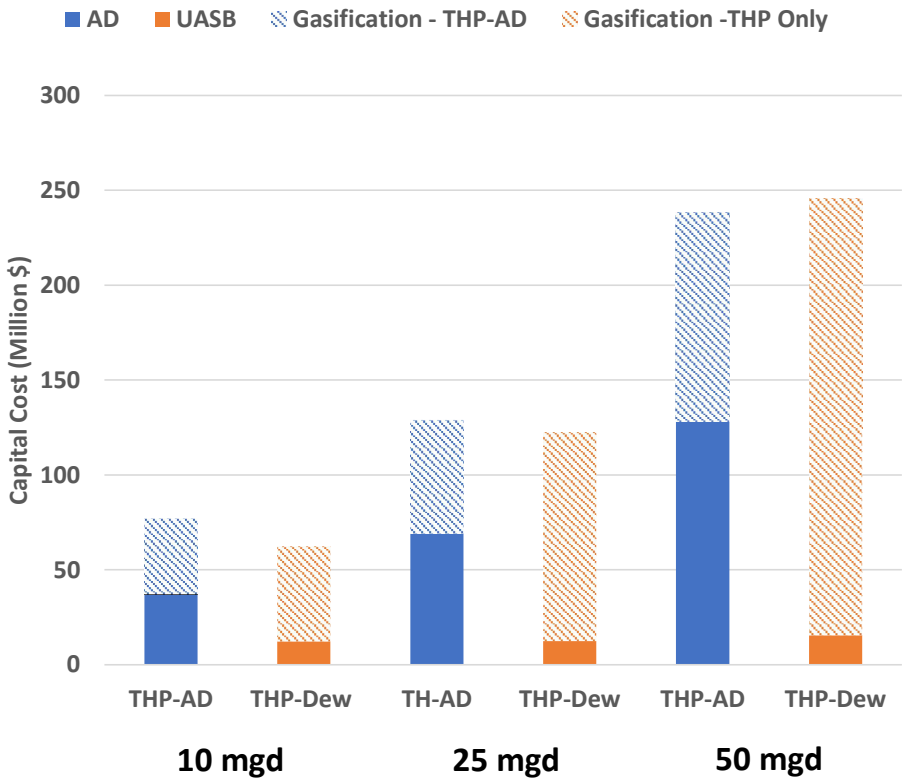


THP-Dewatering scheme has a smaller footprint than THP-AD.

**Absolute footprint would also include screens, pre- and post-dewatering, and Cambi system (all processes that are common to both trains)*

Estimated differential CAPEX costs Need to be further reviewed

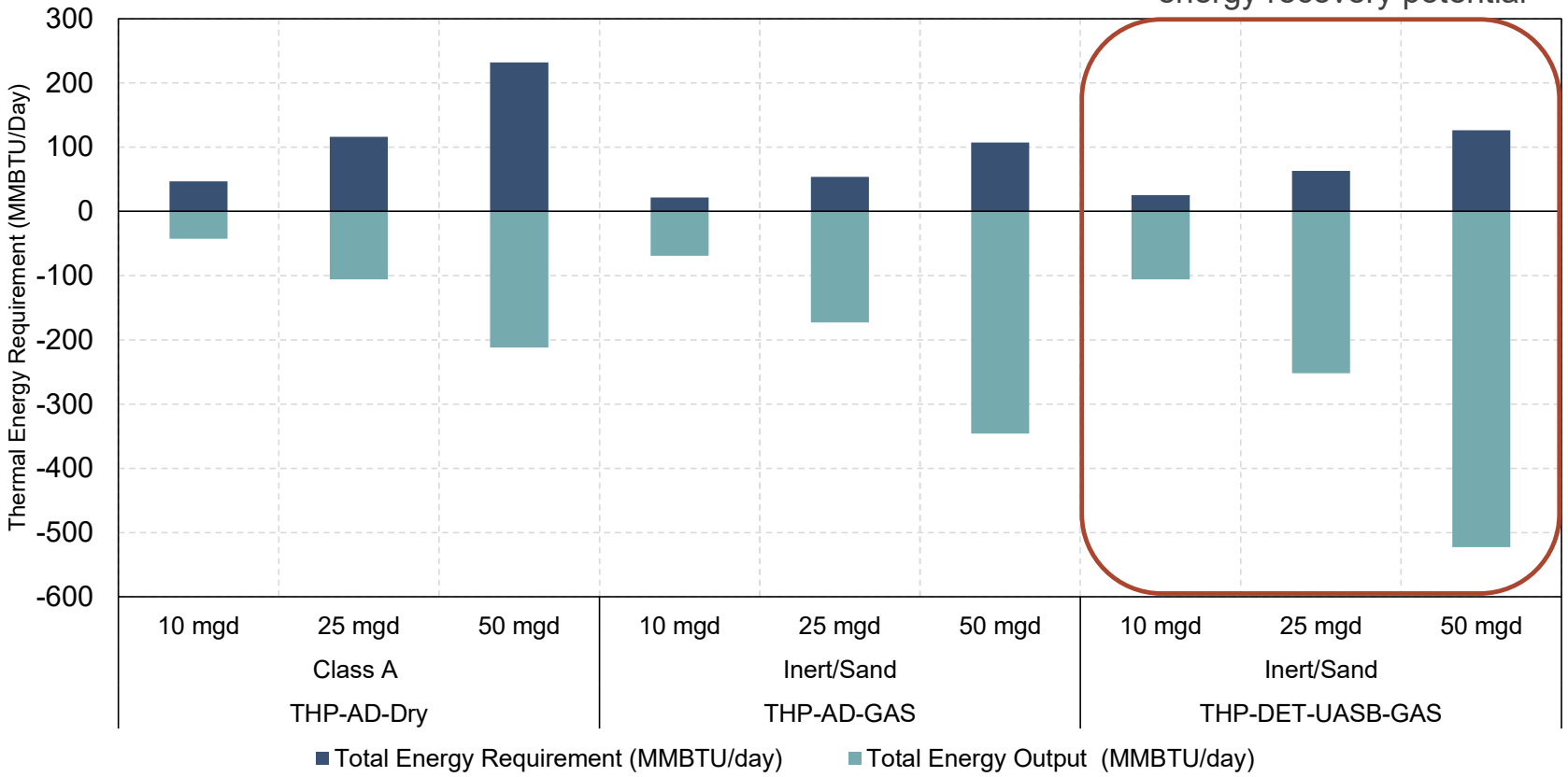
- THP-Dewatering results in more sludge to gasification, more units needed → increases gasification CAPEX costs



**Absolute costs would also include screens, pre- and post-dewatering, and Cambi system (all processes that are common to both trains)*

Summary table comparing the systems energy

New Scheme shows substantially higher energy recovery potential



Note: This is the energy balance at steady state and does not include start up energy requirements.

RECONFIGURING ANAEROBIC DIGESTION

FOR COST, RISK, AND REGULATORY RESILIENCE

Moving Energy Recovery from the Solids Stream to the Liquid Stream

RECONFIGURED APPROACH

Energy Recovery from Liquid Stream + Flexible Solids Platform

BIOSOLIDS

THP + DEWATERING

LIQUID STREAM
Soluble COD-Rich Centrate

COMPACT ANAEROBIC DIGESTION
UASB or HPD

BIOGAS
Energy Recovery

TREATED EFFLUENT
Recycled to Headworks

SOLIDS STREAM
High-Solids Cake (50–60% TS)

DRYING
Dehumidification
>65% TS

OR

ADVANCED THERMAL PROCESSING (ATP)
Gasification / Pyrolysis + Thermal Oxidation

OR

INCINERATION
>850°C
Complete Combustion

BIOCHAR / BENEFICIAL REUSE

ENERGY RECOVERY

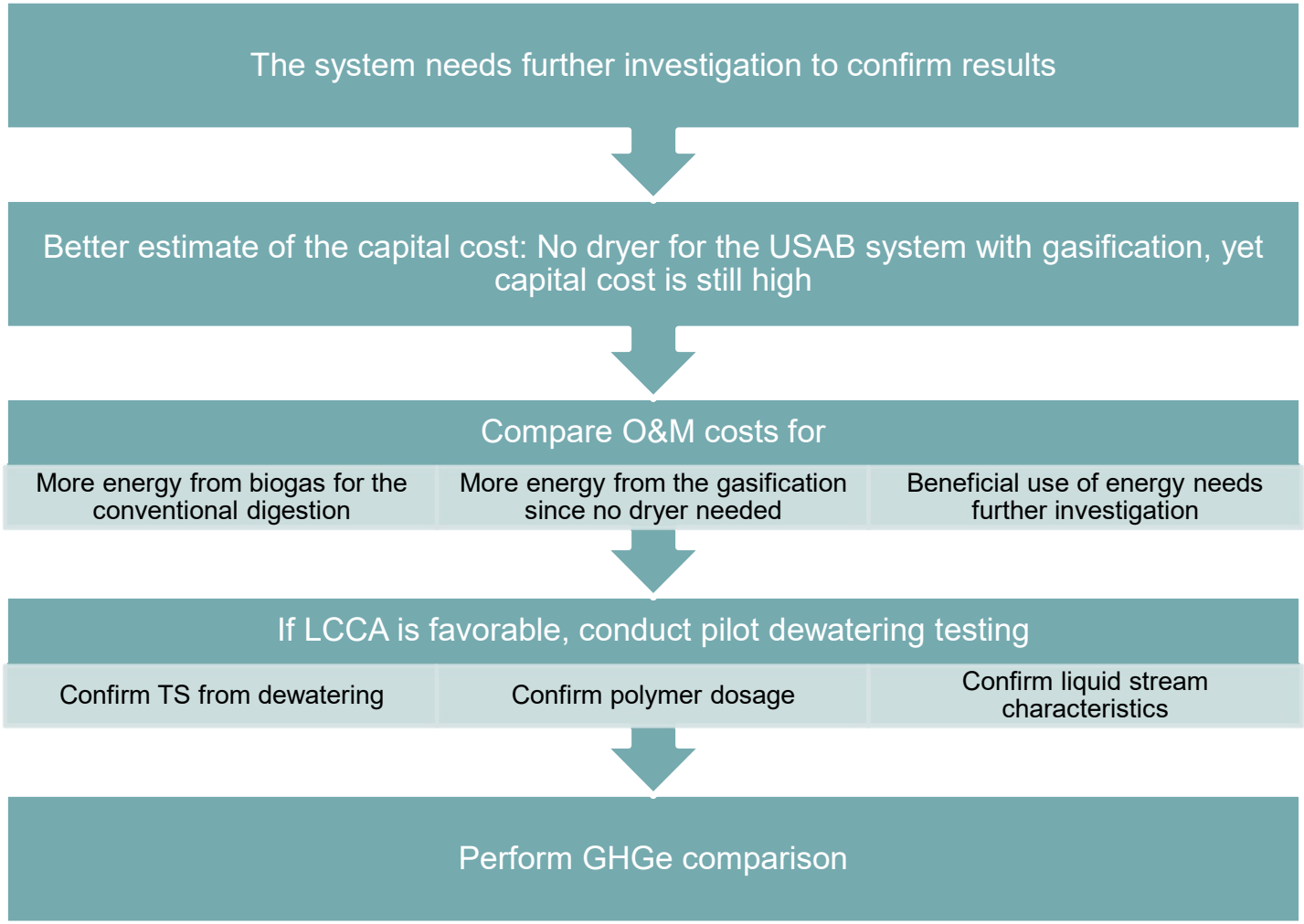
INERT RESIDUALS
(Landfill)

SYNGAS / THERMAL ENERGY RECOVERY
Supports Drying and THP

CAPITAL COST	O&M COST
??	??

REDUCED FOOTPRINT | MODULAR | MULTIPLE PATHWAYS | ENHANCED RESILIENCE

Key Takeaways and what's next



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