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2026 Wisconsin Section Operations Seminar

February 26, 2026

Energy Recovery from Digester Gas – Technologies, Markets, and Trends

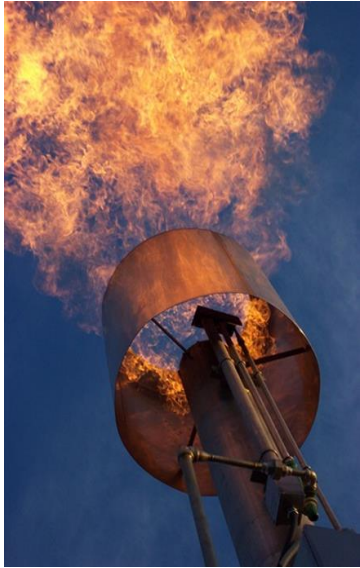
Randy Wirtz, Ph.D., P.E., Strand Associates, Inc.®



Agenda for Today

- Digester Gas Reuse Alternatives
- Digester Gas Use Technologies and Processes
- Markets and Financial Viability
- Trends and Innovation
- Advanced Biosolids Processes and Energy Recovery
- Primer on U.S. Carbon Markets (related to advanced processes)

Digester Gas Reuse Alternatives



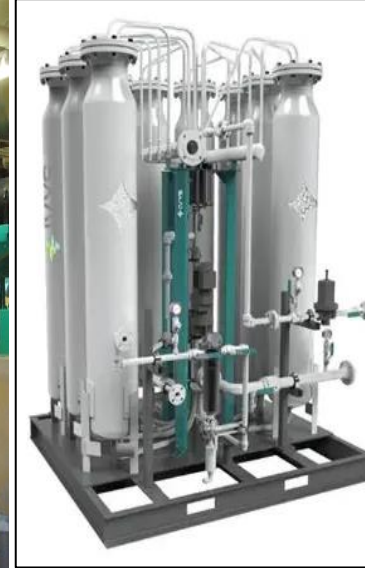
Flare



Process Heat



Cogeneration



**Renewable
Natural Gas**



**Green
Hydrogen**

Source: Bing Images



Fuel Cells

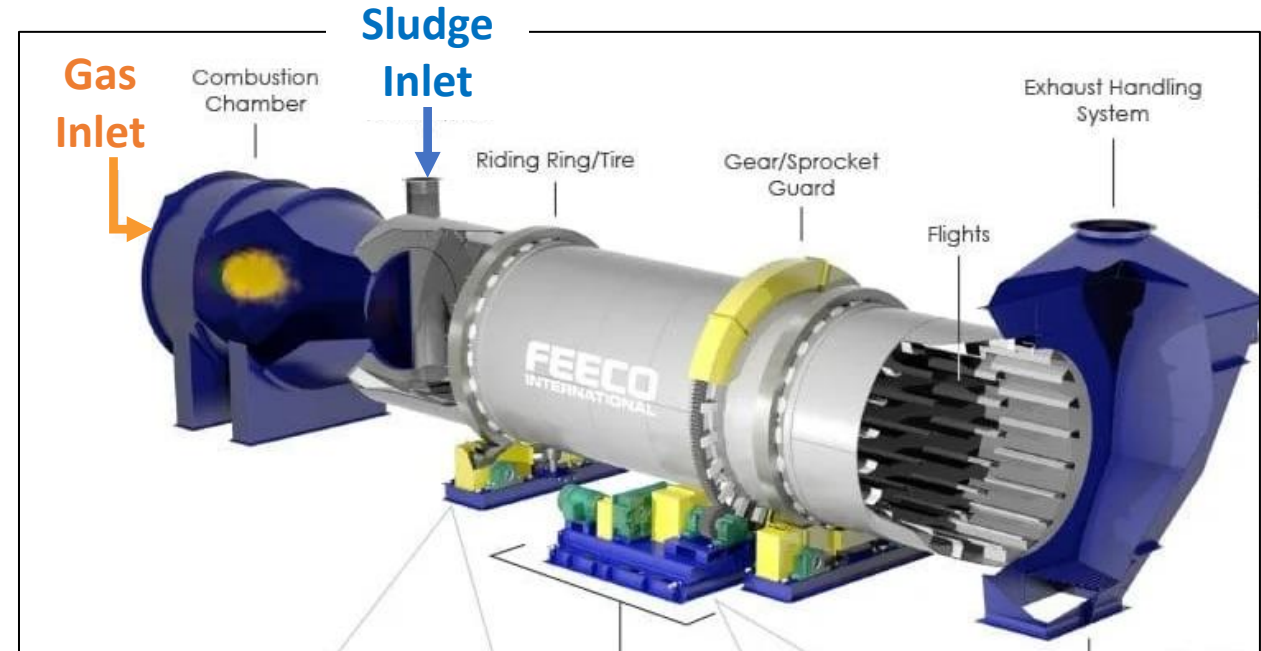
Process Heating with Digester Gas



**Indirect Hot Water Boilers
Typical at WWTPs**



**Indirect Thermal Fluid
Heater Used with
Many Dryers**



**Direct Combustion Used with Some Dryers
(e.g., rotary drum, some belt dryers)**

Internal Combustion Engines and Microturbines – Cogeneration

Pros:

- > 85% energy recovery possible (heat + electricity)
- Politicians (and you) may feel green & sustainable!

Cons:

- **High maintenance costs and downtime**
 - Strand review: **\$0.02 to \$0.09/kWH** for maintenance
- Selling to the grid (~ \$0.02-\$0.03/kWH) won't pay for the required maintenance
- Significant staff time required

Note: In Strand's experience, microturbines are even more problematic than IC engines.



Fond du Lac biogas engine



Dubuque microturbines

Cogeneration (*continued*)

Consider when:

- High electrical costs > \$0.10/KWH
- You can use all of the electricity on-site
- No or limited access to natural gas pipeline
- **Federal eRIN pathway** is approved
- **Green hydrogen** is in your future



A Note Regarding the Federal eRIN Pathway

- Renewable Fuel Standard: eRIN pathway proposed in December 2022
- Rule was expected to be finalized by June 2023 and go into effect early in 2024
- No updates since 2023
- Current administration unlikely to push for further electrification incentives



Renewable Natural Gas Has Become Mainstream (in a hurry)

- Since 2022, RNG production facilities in North America doubled from 281 to 570.
- Significant investment from private equity.
- Significant mergers and acquisitions as companies position themselves to capture opportunities.



Dane County Rodefild Landfill RNG Facility

Renewable Natural Gas (*continued*)

- The vast majority of operating and planned RNG facilities are at landfills and agricultural facilities (manure, crop residue, etc.)
- About half of the RNG produced is used in the transportation sector (federal RFS program).
- Current RNG capacity is < 1% of total U.S. natural gas supply but has the potential to meet 5–20% of demand.

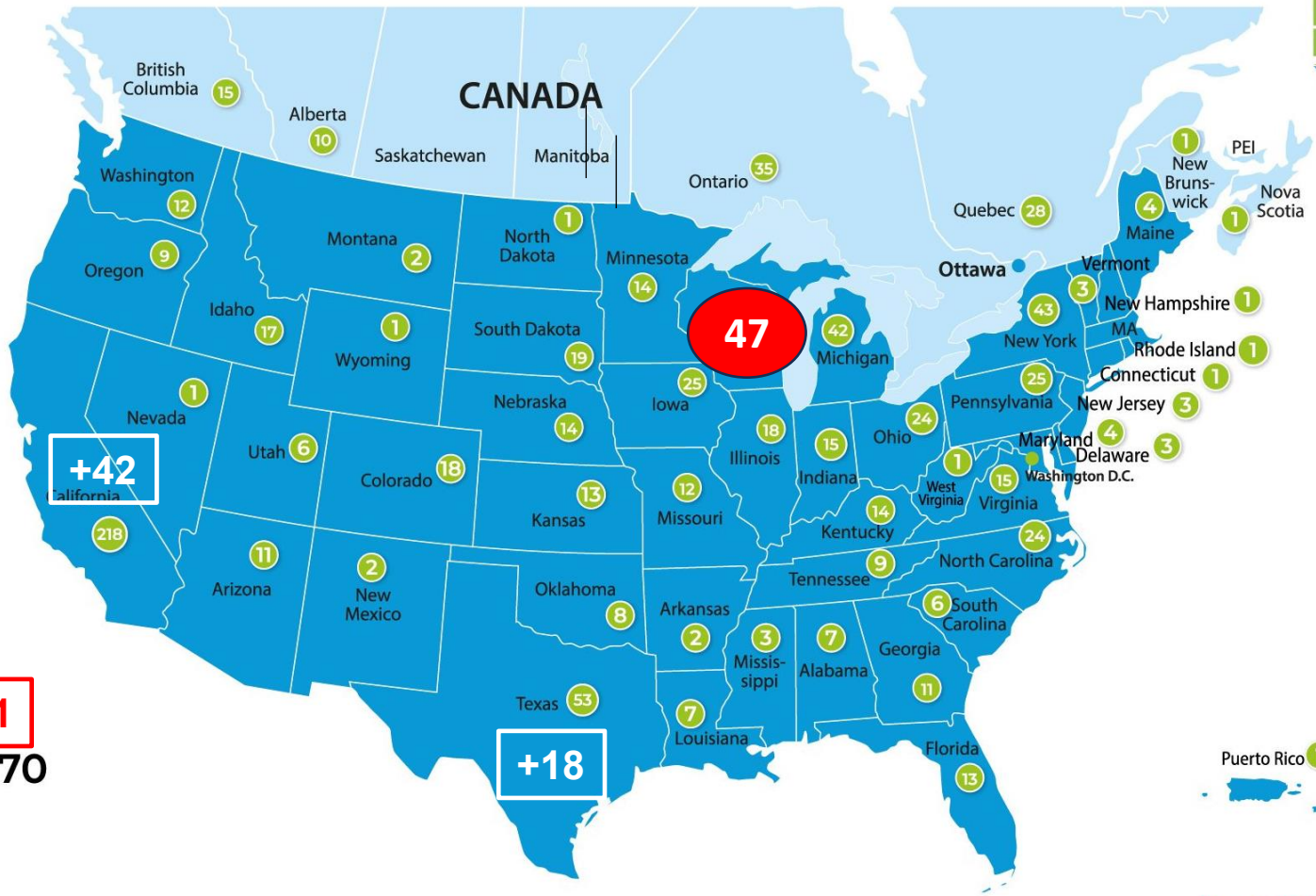


Typical RNG Skid for Outdoor Installation (Source: SysAdvance)

Renewable Natural Gas – U.S. and Canada (2024)



2024



RNG Facilities

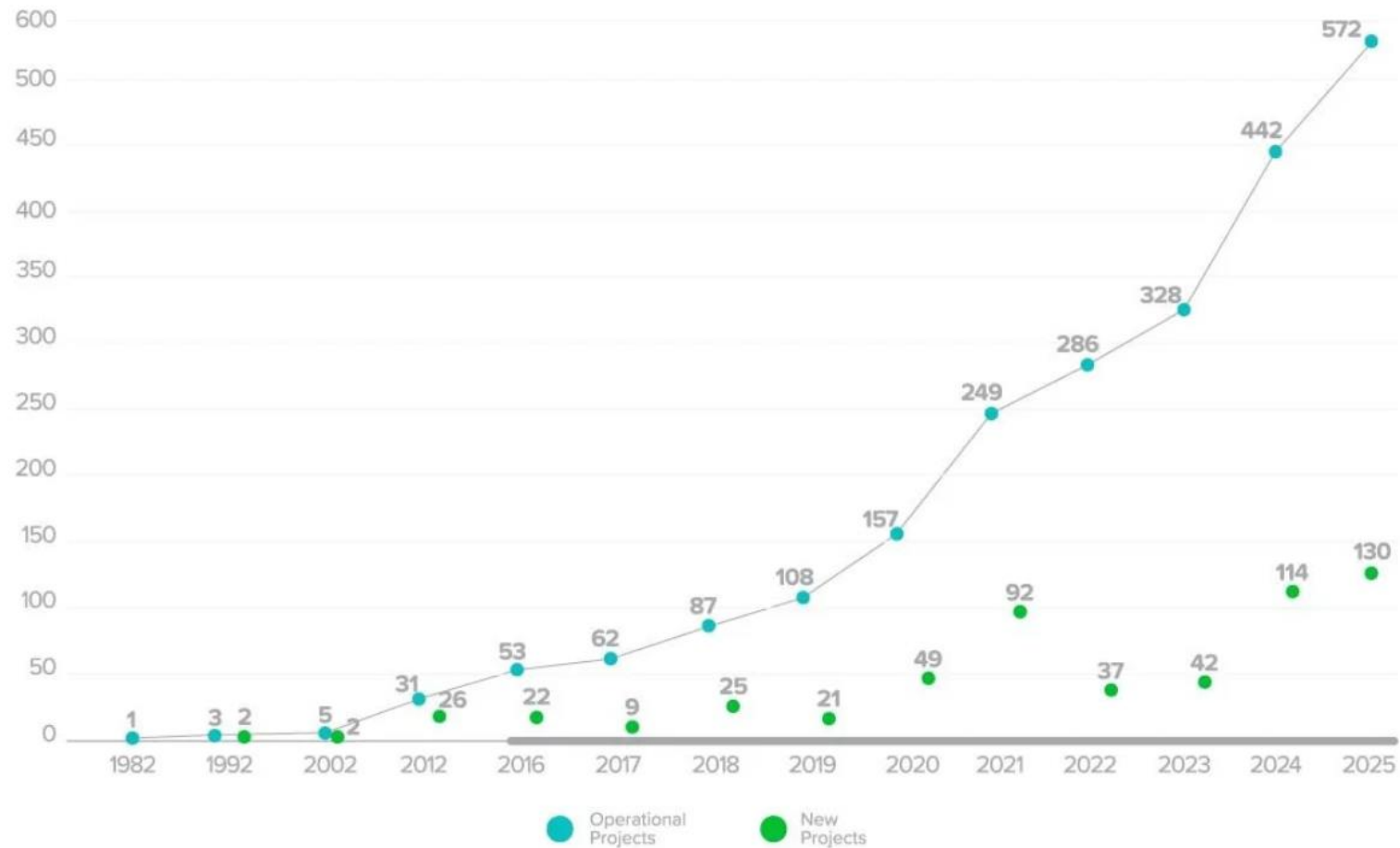
Operational: 442 **+161**
 Under Construction: 170
 Planned: 285
 Total: 897 **+140**

Updated December 2024

Source: RNG Coalition



OPERATIONAL RNG FACILITIES IN NORTH AMERICA



RNG Value: D3 vs. D5 RINs

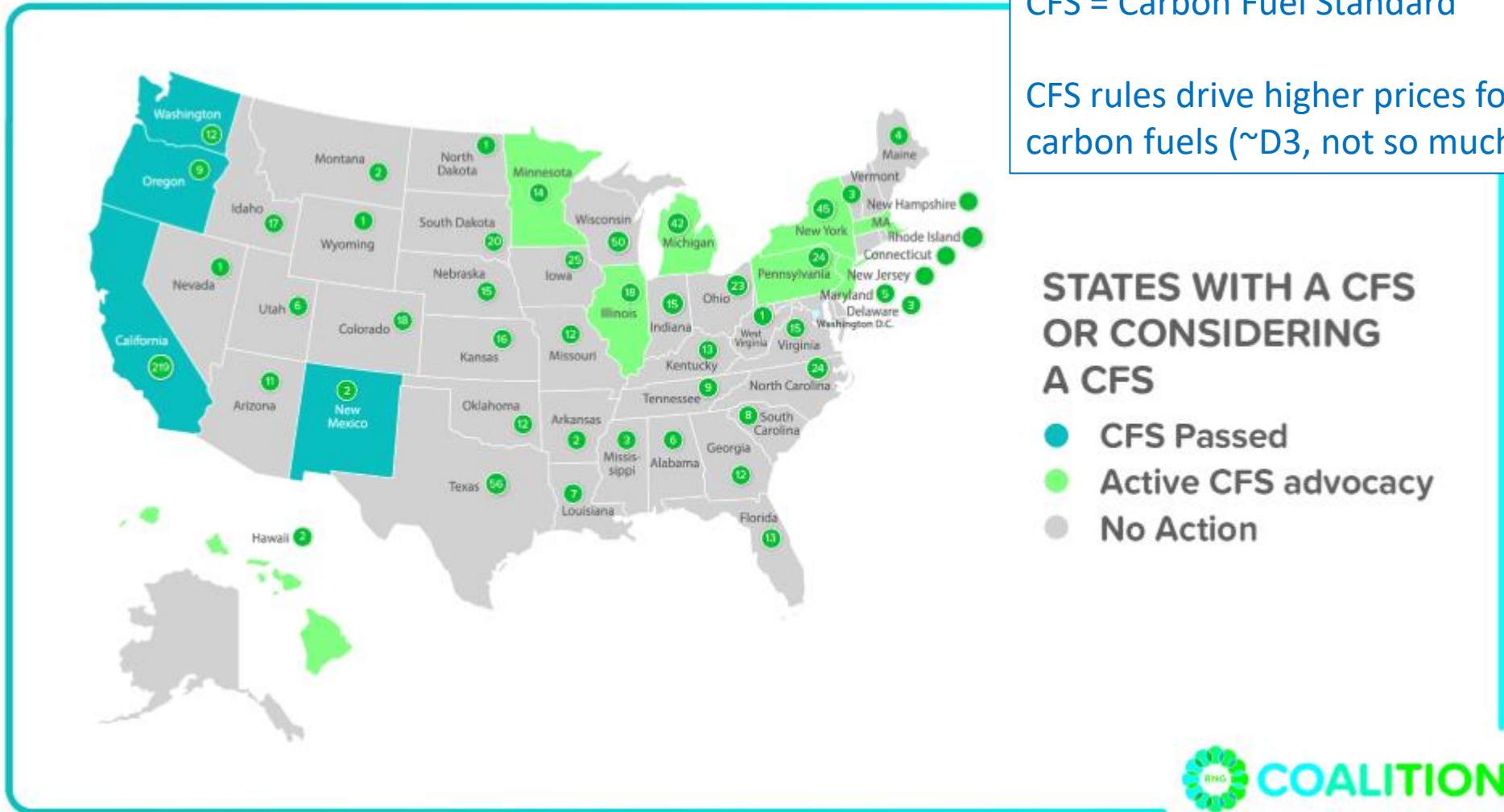
- RIN = Currency of the Federal Renewable Fuel Standards (RFS) program
- Municipal WWTPs produce D3 RINs (high value) from sludge digestion and D5 RINs (lower value) from hauled waste digestion.



Drivers Promoting RNG's Future – States' Low Carbon Fuel Standards

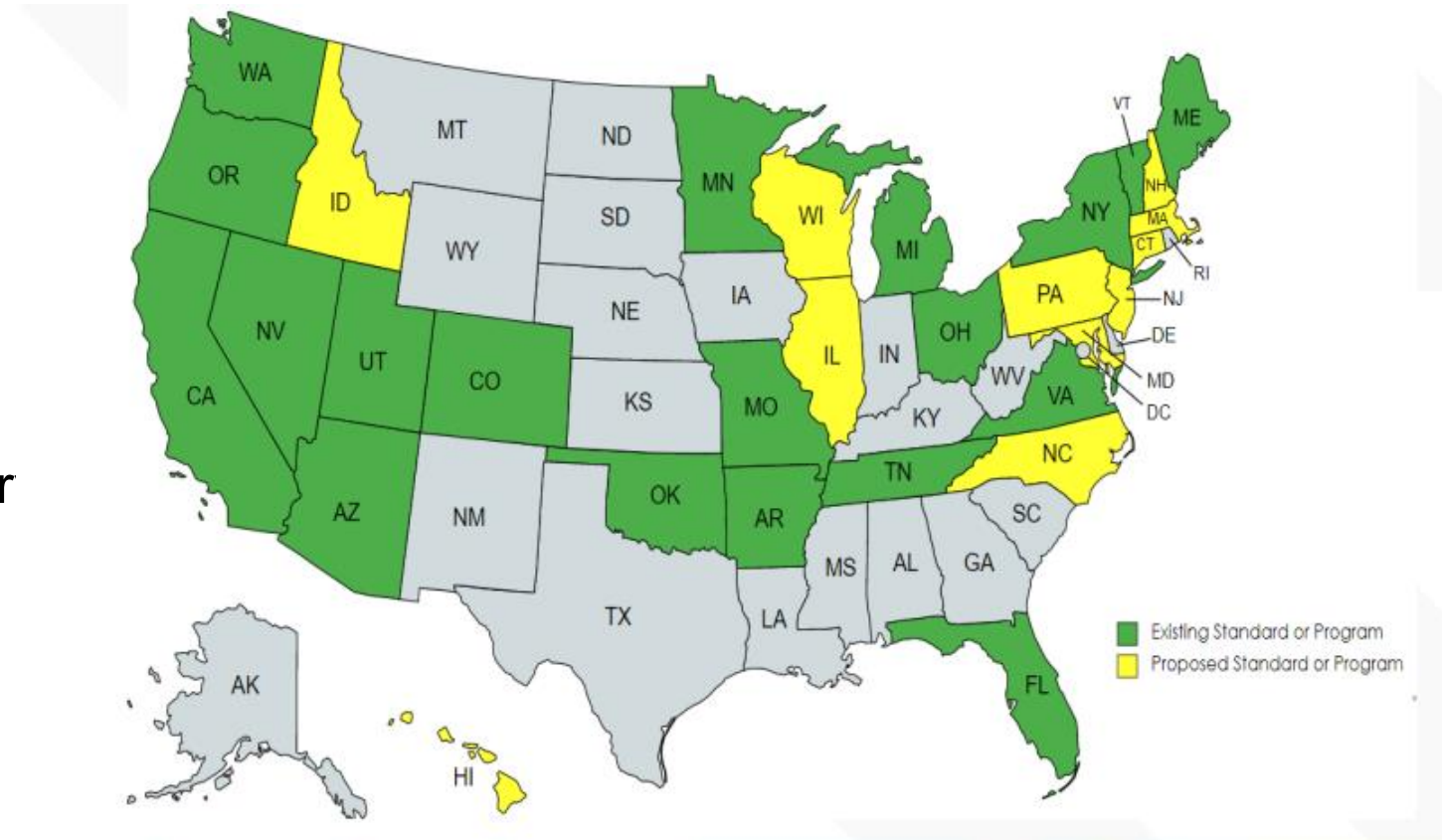
CFS = Carbon Fuel Standard

CFS rules drive higher prices for low carbon fuels (~D3, not so much D5)



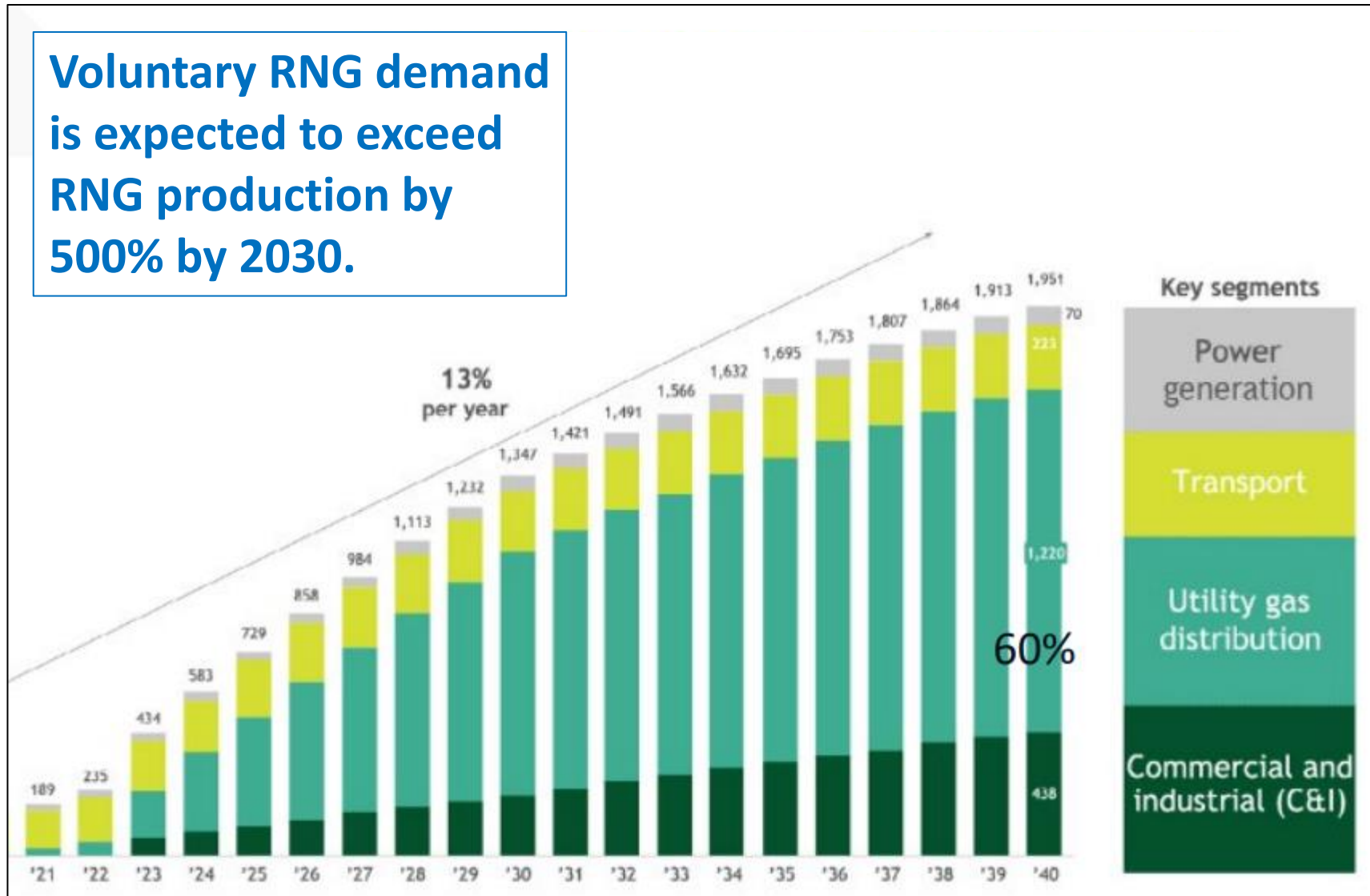
Drivers Promoting RNG's Future – Utilities' Cost Recovery

- Many states have voluntary or mandatory cost recovery rules for energy efficiency investments by utilities.
- Allows utilities to promote/invest in RNG development without the associated risk.
- Wisconsin has proposed cost recovery rules.



Drivers Promoting RNG's Future – Voluntary Markets

Voluntary RNG demand is expected to exceed RNG production by 500% by 2030.



D3 vs. D5 RINs – EPA Update

Recent changes allow D3 and D5 fractions to be calculated based on:

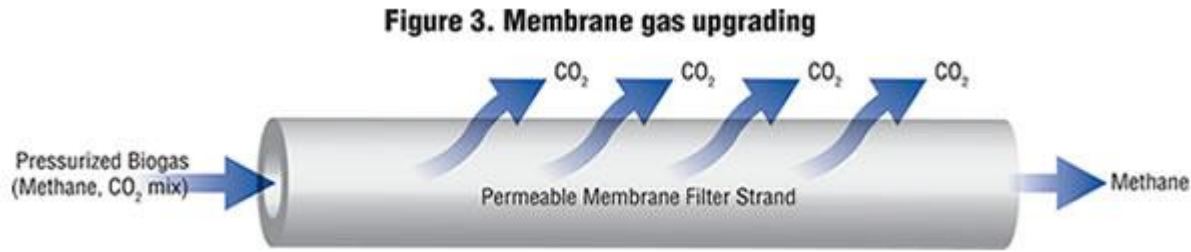
- **Prescriptive Option:**

- Default standard feedstocks – known conversion factors
- Anticipated D3 value = ~40-60% of actual

- **Non-Prescriptive (Site-Specific) Option:**

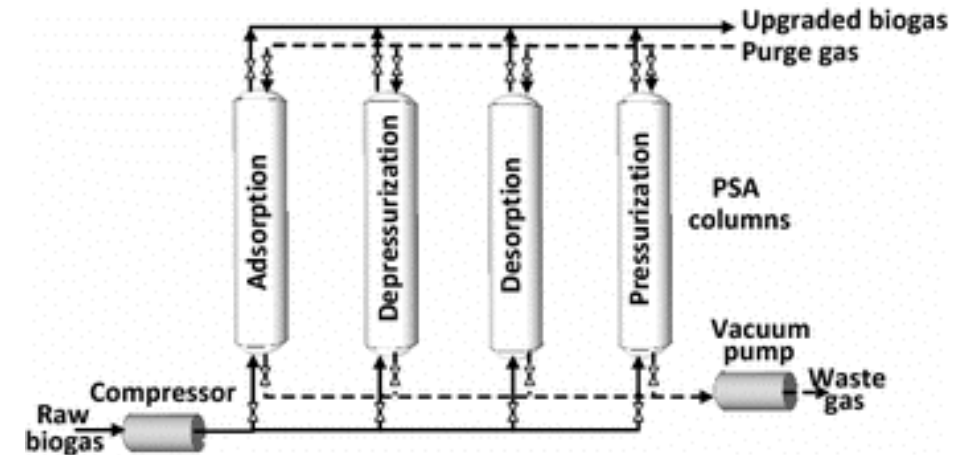
- Operate the digesters without the added feedstock to define D3 gas production
- Then operate with added feedstock – additional gas is considered D5
- Anticipated D3 value = 80-90%+ of actual
- **Potential significant reduction in monitoring cost, both up-front and ongoing**
- Guidance is limited at this time

Renewable Natural Gas – CO₂ Removal Technologies



Source: biocycle.net

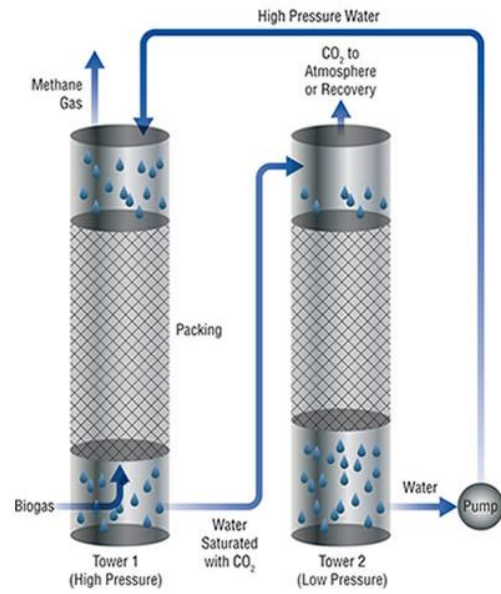
- Membranes
 - Molecular size separation
 - CO₂ is smaller than CH₄



Source: researchgate.net

- Pressure Swing Adsorption (PSA)
 - CO₂ adsorption at high pressure
 - CO₂ desorption at low pressure
 - Multiple tanks operating in batch mode

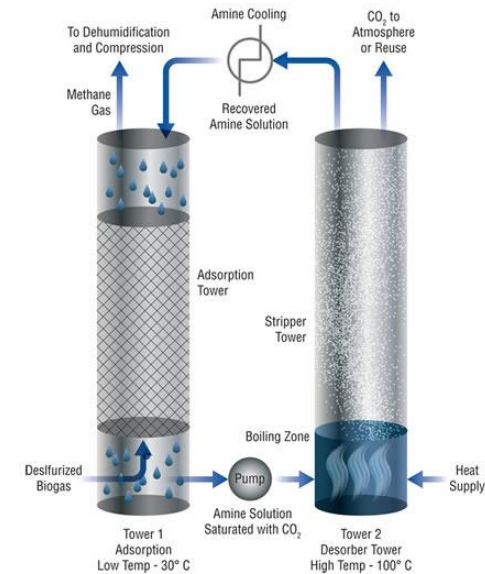
Renewable Natural Gas – CO₂ Removal Technologies (*cont.*)



Source: *biocycle.net*

- Water Wash/Water Scrubbing
 - CH₄ is not soluble in water
 - High-pressure reactor column followed by a depressurization tower

Figure 8. Amine upgrading system process flow diagram



Source: *biocycle.net*

- Amine Scrubbers
 - CO₂ scrubbing with amine solution
 - CO₂ off-gassing or recovery through heating

Example RNG Installations



Unison Containerized Membranes



Guild PSA



SysAdvance Containerized PSA

Strand's Recent/Current RNG Projects

- Critical Issue: Pipeline access – location and utility cost
- Size definitely matters in the renewable energy market

Project ID	Raw Biogas Flow (scfd)	Ownership	Capital Cost	Approx. Payback w/o IRA Funding (years)	Moving Forward?
1	1,200,000	Private	\$15 MM	5-7	Yes
2	600,000	WW Utility	\$12 MM	5-7	Yes
3	250,000	WW Utility	\$10 MM	8-12	Yes
4	230,000	WW Utility	\$10 MM	10-15	Yes
5	150,000	WW Utility	\$8 MM	10-15	No
6	150,000	WW Utility	\$15 MM	>60	No
7	70,000	WW Utility	\$6 MM	>50	No

Renewable Natural Gas – Pros and Cons vs. Cogeneration

Pros:

- Typically (much) higher revenue
- Less maintenance (?)

Cons:

- More complex to monetize
- Market fluctuations and long-term economics concerns
 - Voluntary markets have matured

Consider when:

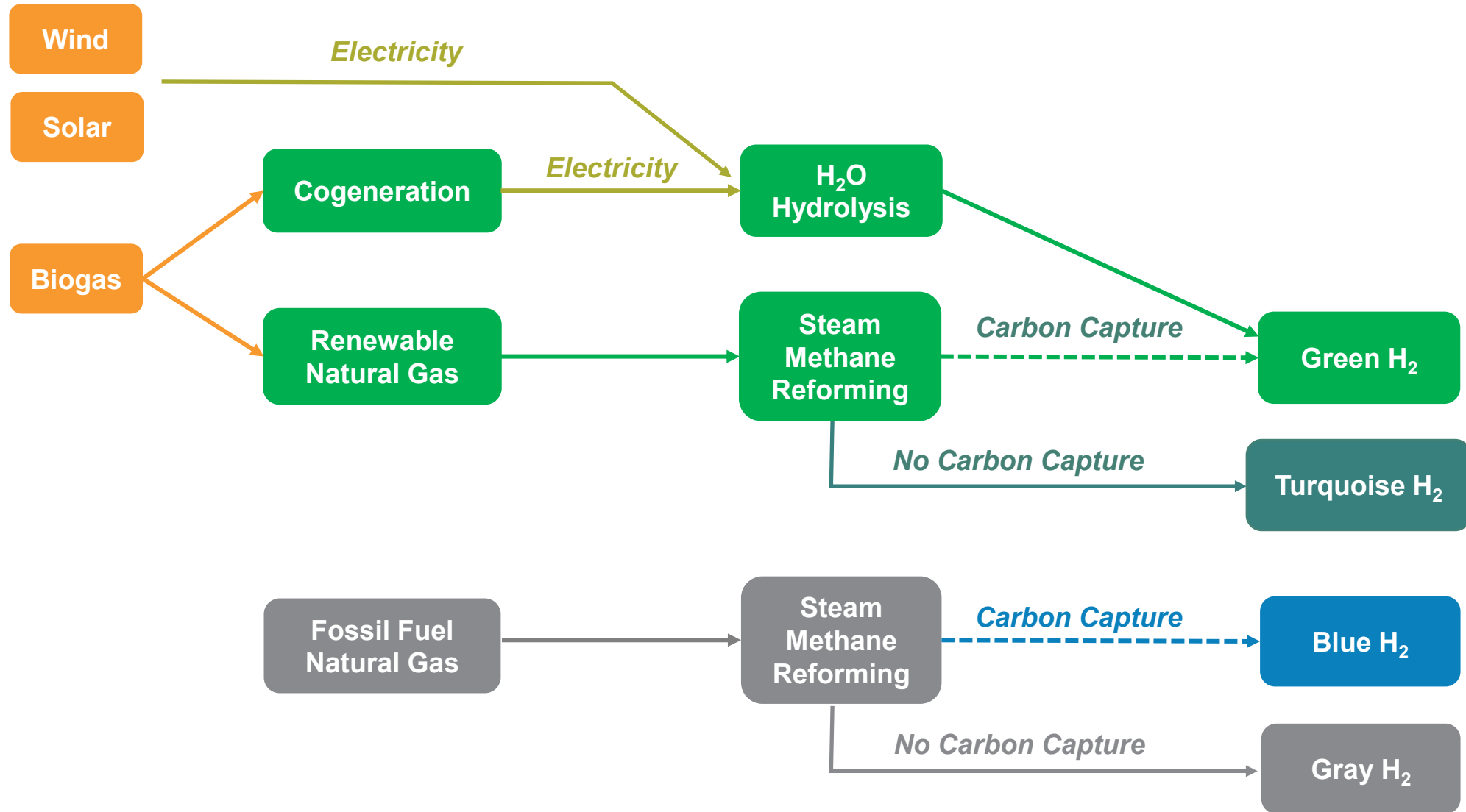
- Digester gas production > 400,000 CFD, possibly as low as 200,000 CFD
- “Low cost” access to natural gas pipeline
- Electrical costs are low
- You need to replace your cogen system
- You’d like to capture carbon (now or in the future)
- You have some level of risk tolerance

Green Hydrogen – The Future of Renewable Energy (?)



Source: www.fst.com

Hydrogen Production Pathways



H₂ in the United States

- Uses:
 - Petroleum refining – #1
 - Chemical production – #2
 - **Fuel-cell** driven forklifts, buses, fleets

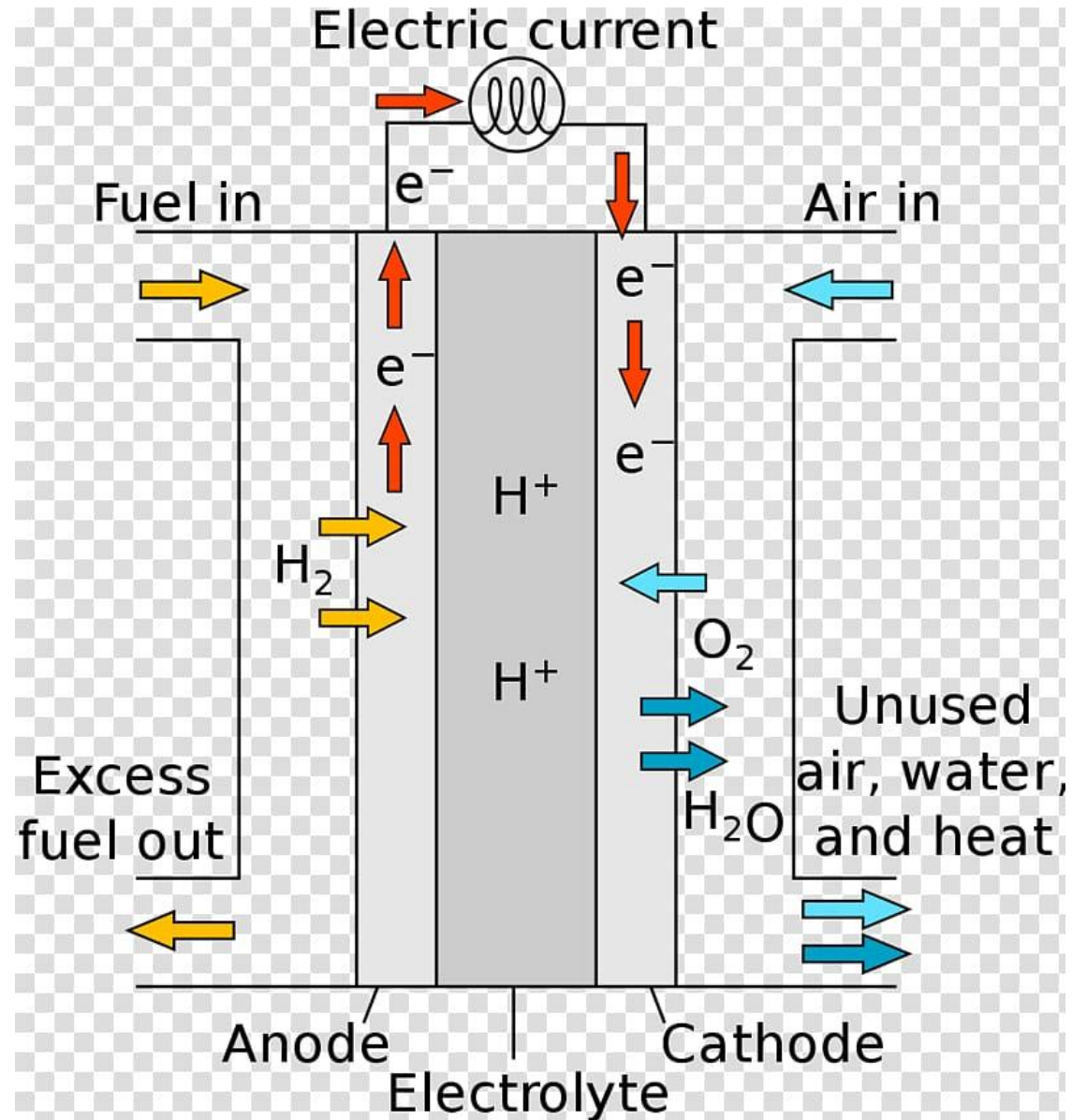
Consider when:

- Significant biogas + local H₂ demand
- You have nothing better to do with your money!

Fuel Cell for Cogeneration



Source: Fuel Cell Energy



Fuel Cell History and Advancements

- First recorded mention in 1838
- Several installations on digester gas 10-15 years ago, but problems with gas quality
- Recent advancements allow digester gas to be used directly following sulfur, siloxane, and moisture removal (similar to RNG gas treatment)
- Consistency is the key:
 - Stable gas flows
 - Stable gas composition



Source: Fuel Cell Energy

Fuel Cells – Installations (Recent)



Riverside, CA

Generating electricity and heat for a water quality control plant.



Tulare, CA

Generating electricity and heat for a wastewater treatment plant facility.



San Bernardino, CA

Generating electricity and heat for a water reclamation plant.

Source: Fuel Cell Energy

Fuel Cells – Why Consider?

- Produces electricity, heat, and water from hydrogen or other C_xH_{2x+2} (such as CH_4)
- Much lower air pollutants
- Higher electrical efficiency than internal combustion engine CHP – Up to 60%
- Potential of 85%+ overall energy recovery

Battery Storage for Entire WWTP

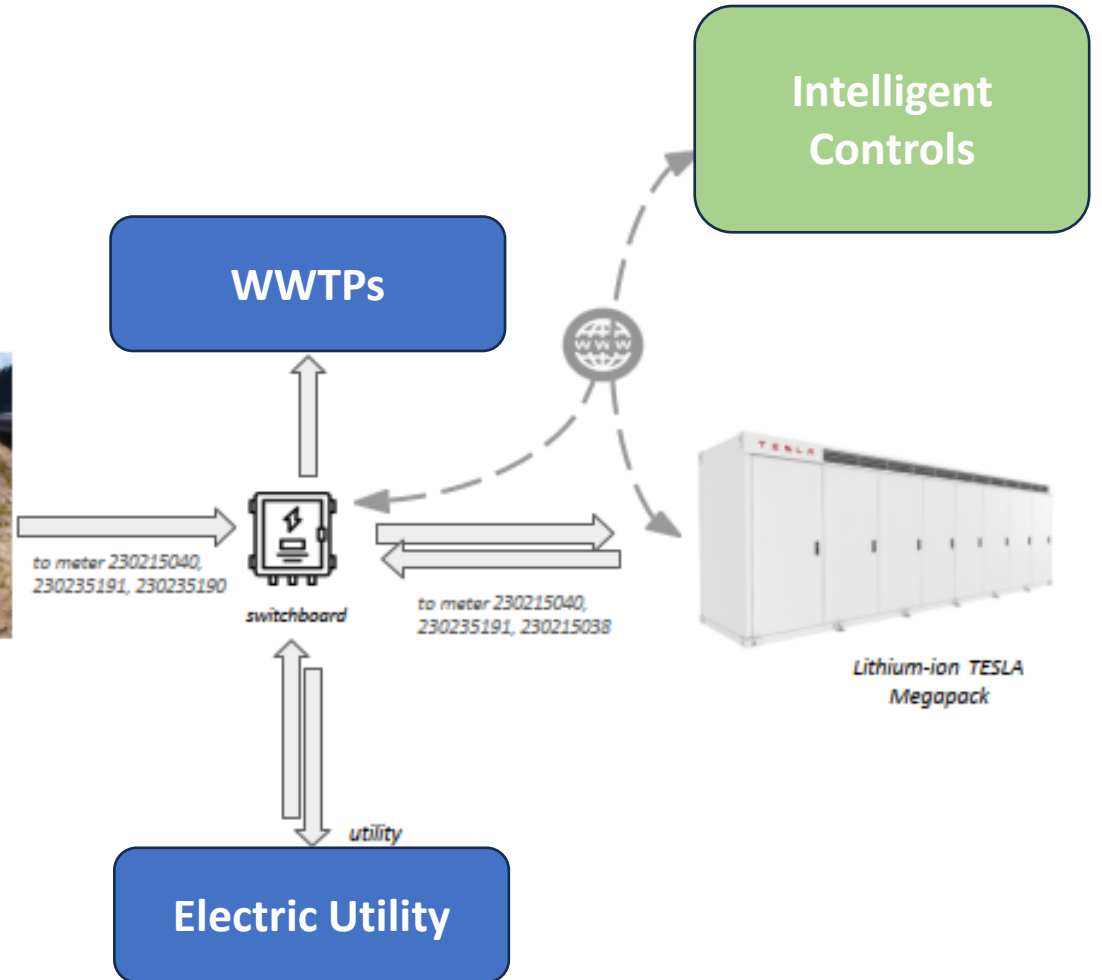


Battery Storage (Illinois WWTP)

- Site has 2.3 MW of solar fields
- Installing 4 Tesla lithium-ion battery
 - 1 @ 979 kW
 - 2 @ 530 kW
- Charge batteries and use during peak grid demands (auto-controlled)
- Battery Cost ~ \$6.3 million
- Rebates ~ \$5.2 million
- Annual Savings:
 - ~\$90,000/year on utility bill (~8%)
 - ~\$270,000/year on “grid stability” credits

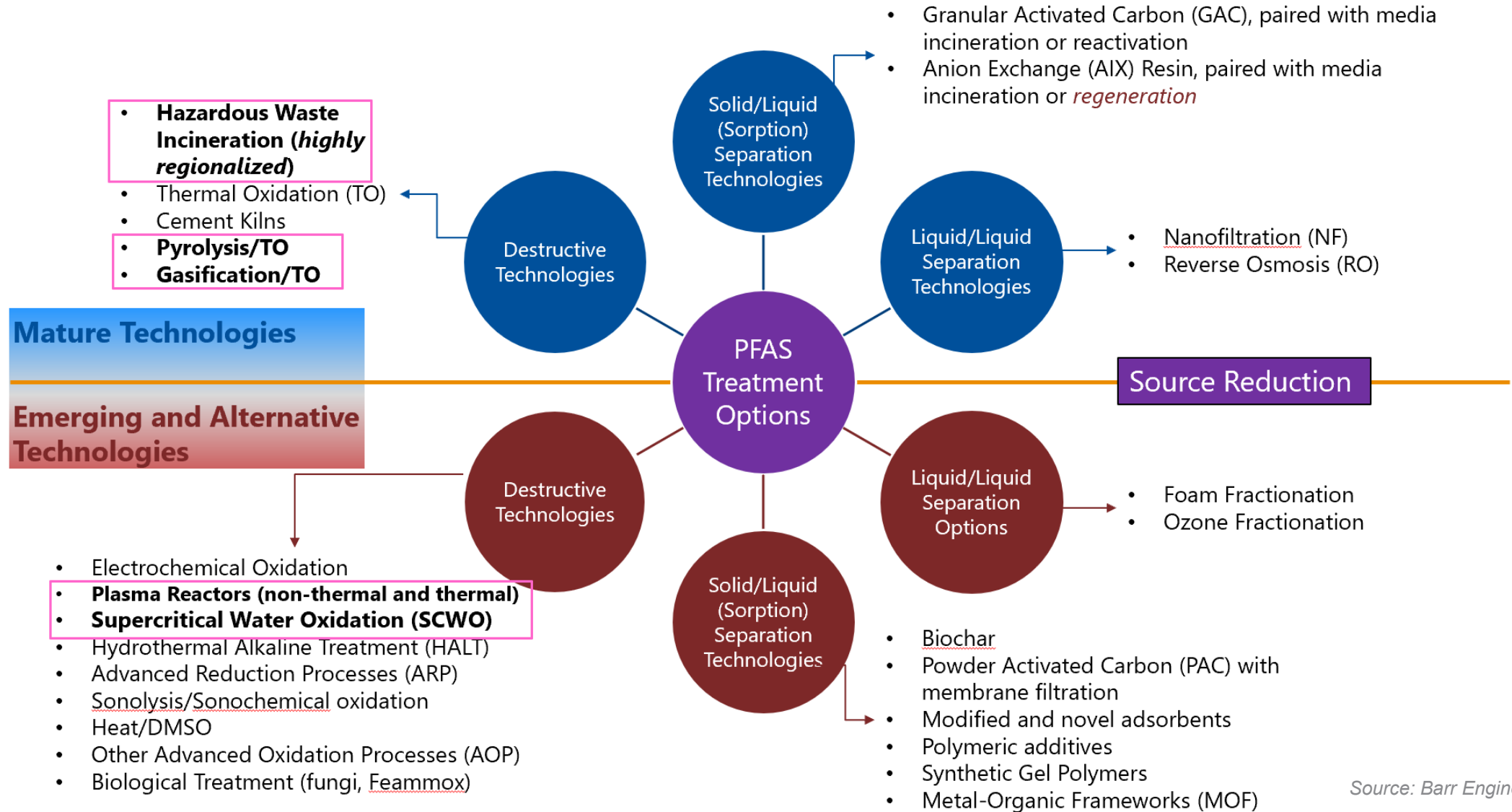


Ground Mounted Fixed



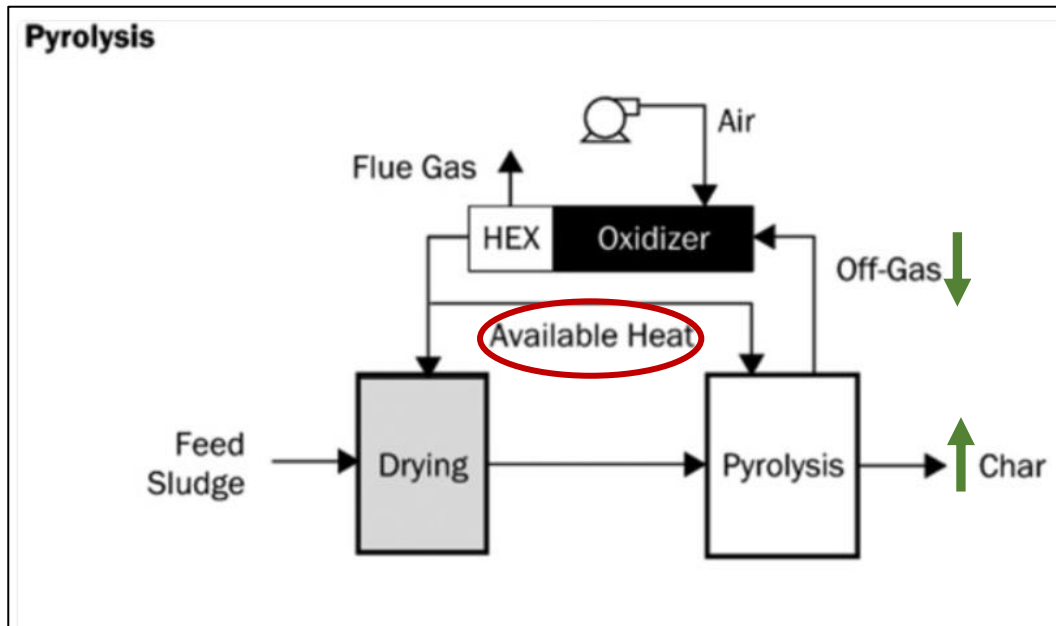
Source: Fuel Cell Energy

Energy Efficiency with Advanced Biosolids Processes

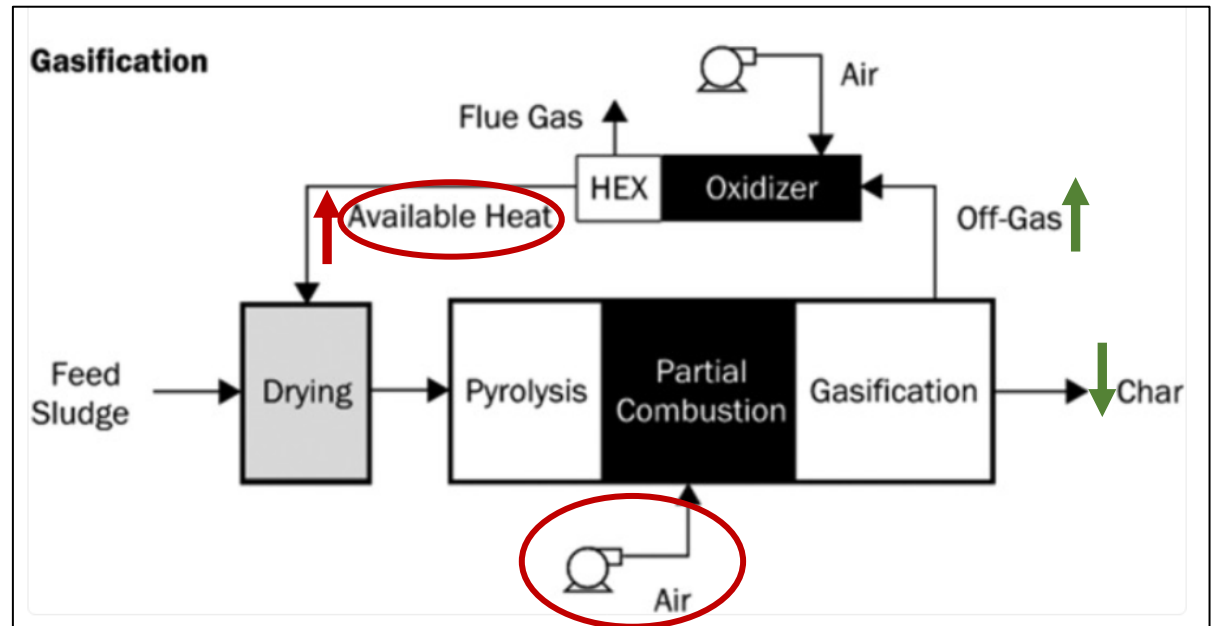


Source: Barr Engineering

Sludge Destruction Technologies Offset Dryer Heat Loads



- No air/oxygen combustion (endothermic)
- Lower-temperature systems (300-700°C)
- Maximizes char (reuse; carbon sequestration)
- Lower energy recovery (40-60% of dryer heat load)
- Good PFAS destruction with thermal oxidizer (?)



- No air/oxygen combustion (exothermic)
- Higher temperatures (700-1,200°C)
- Maximum volume reduction = more gas to burn
- Higher energy recovery (~80-90% of dryer heat load)
- Higher PFAS destruction (?)

Pyrolysis/Gasification



Monetizing Carbon

- The U.S. has no official (regulatory) carbon market.
- Some states (CA, OR, WA, and 9 NE states) have regulatory “cap and trade” markets.
- The voluntary carbon market is expected to grow from \$2 billion in 2022 to **\$40 billion** by 2032; some estimates are much higher.
- Biochar from pyrolysis and gasification effectively ties up carbon it into a stable form resists decomposition for centuries.
- Monetization is via CO₂ Removal Certificates (CORCs), which are focused on engineered carbon removal.
- CORCs are issued by Puro.earth and other carbon verification companies to provide a standard for engineered credits.
- Example 10 MGD WWTP: CORC value estimated at \$200,000 (low estimate) annually based on preliminary proposals received by Strand.



Final Thoughts

- Exciting time to have biogas and biosolids!
- Internal combustion engine CHP is viable but maintenance intensive
- RNG development and investment is growing very quickly, largely because of high values and available natural gas infrastructure
- The energy economy **seems** to be slowly moving towards hydrogen, and renewable electricity is seen as the main pathway to **green H₂**. Viability seems like it is a long way in the future.
- Fuel cells are technically viable but still very expensive and relatively unproven.
- Advanced sludge processes may have a payback (?).



Thank you for your attention!
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