Things to Digest about Digesters

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But first, a quick poll

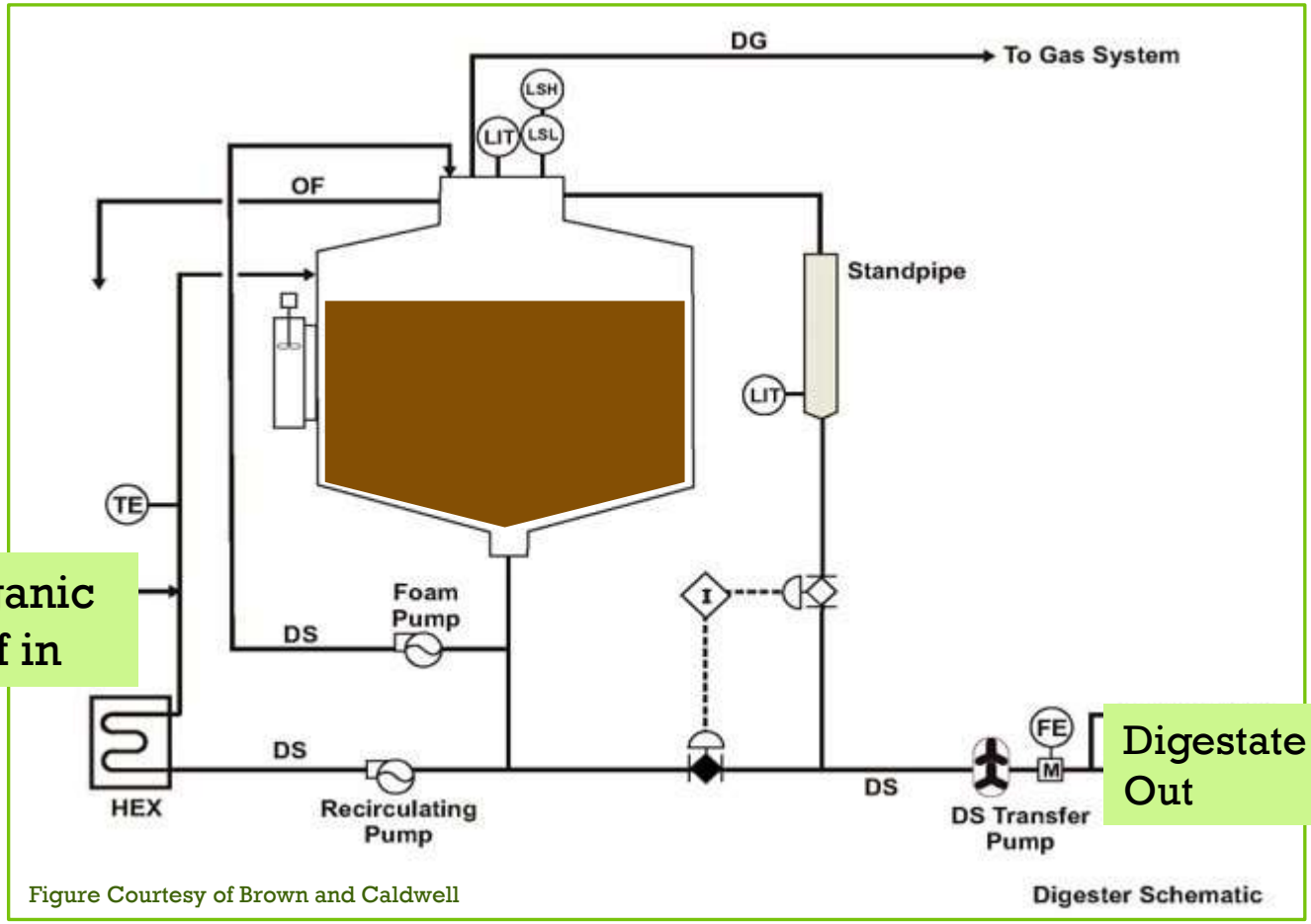
- What questions do you still have about digesters even after these workshop(s)?

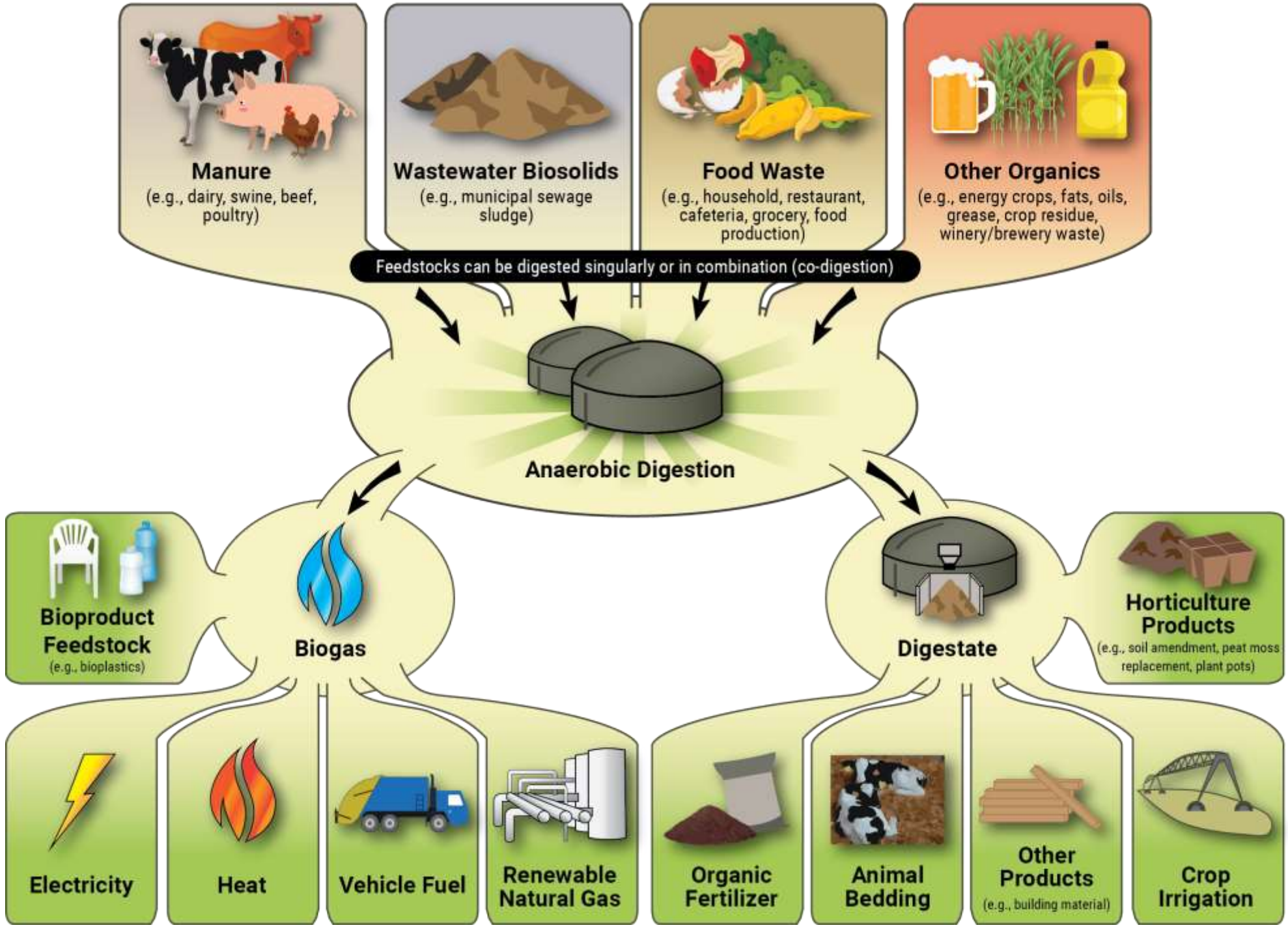
A Quick Baselining Glossary

- Biogas: Mostly a mix of methane (CH_4) and carbon dioxide (CO_2) that is generated by bacteria when they anaerobically decompose organic matter.
- Upgraded biogas or Renewable Natural Gas (RNG): biogas that has scrubbed of everything that is not methane, and is now molecularly identical to NG
- Anaerobic: In the absence of oxygen.
- Organic: Not capital "O" USDA-certified organic. Small "o", carbon-based material.
- Anaerobic Digester: You. You are an anaerobic digester. More on this later.
- Covered Lagoon: An anaerobic treatment system that can produce biogas
- Digestate: The (valuable and nutritive) solids that come out of the digester after processing.
- Co-digestion: The mixing of different feedstocks to a digester. Usually this means adding food waste and/or FOG to a poop-processing digester.
- FOG: Fats, Oils, and Grease

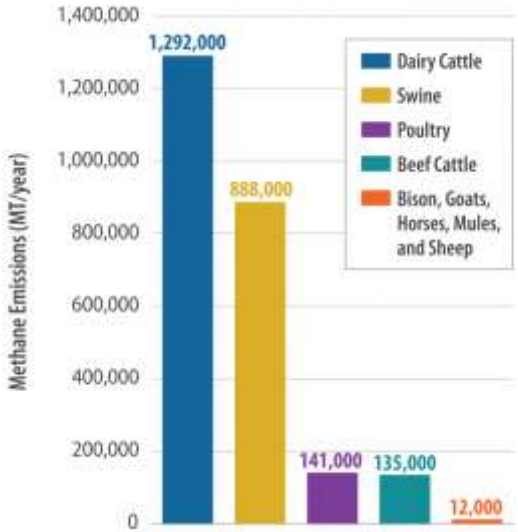
Anaerobic Digester

or, the biomimicry of your gut

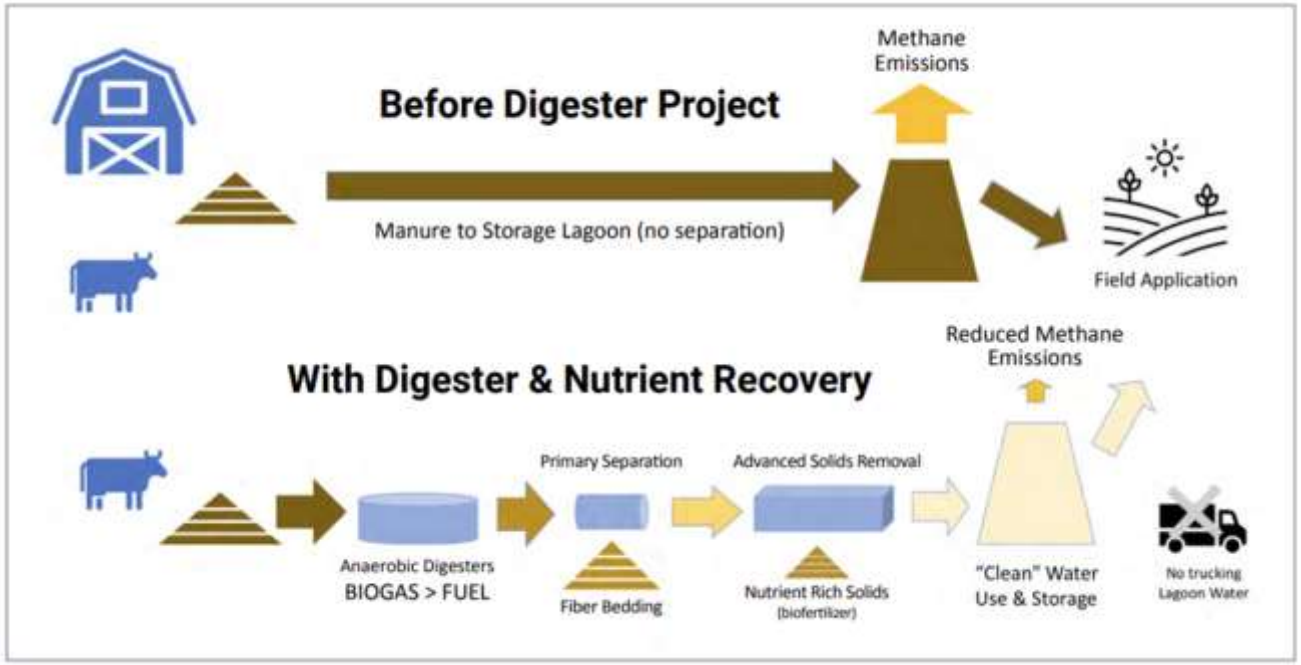



Manure
(e.g., dairy, swine, beef, poultry)
Wastewater Biosolids
(e.g., municipal sewage sludge)
Food Waste
(e.g., household, restaurant, cafeteria, grocery, food production)
Other Organics
(e.g., energy crops, fats, oils, grease, crop residue, winery/brewery waste)
Feedstocks can be digested singularly or in combination (co-digestion)
Anaerobic Digestion
Bioproduct Feedstock
(e.g., bioplastics)
Biogas
Digestate
Horticulture Products
(e.g., soil amendment, peat moss replacement, plant pots)
Electricity
Heat
Vehicle Fuel
Renewable Natural Gas
Organic Fertilizer
Animal Bedding
Other Products
(e.g., building material)
Crop Irrigation

Why such an interest in dairy digesters now?



Source data: U.S. EPA GHG Inventory of Greenhouse Gas Emissions and Sinks: 1990-2018.



Digester Types

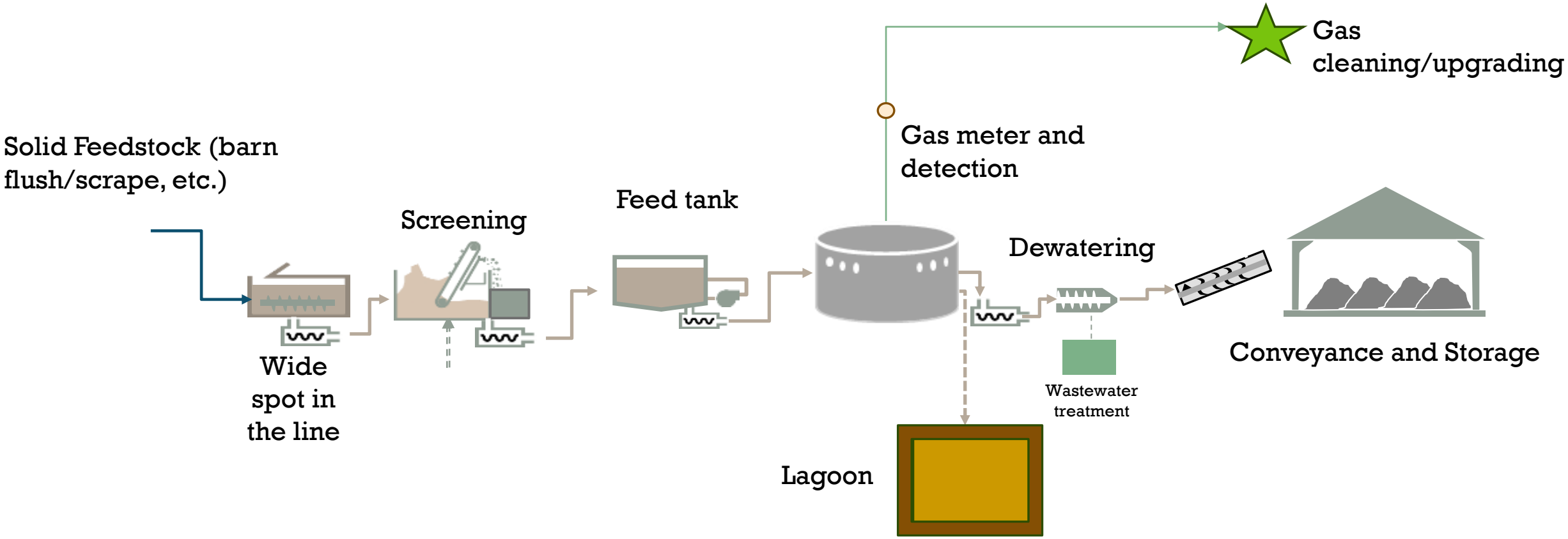
But: what are your goals?

Solids stabilization?
Methane reduction?
Biogas production?

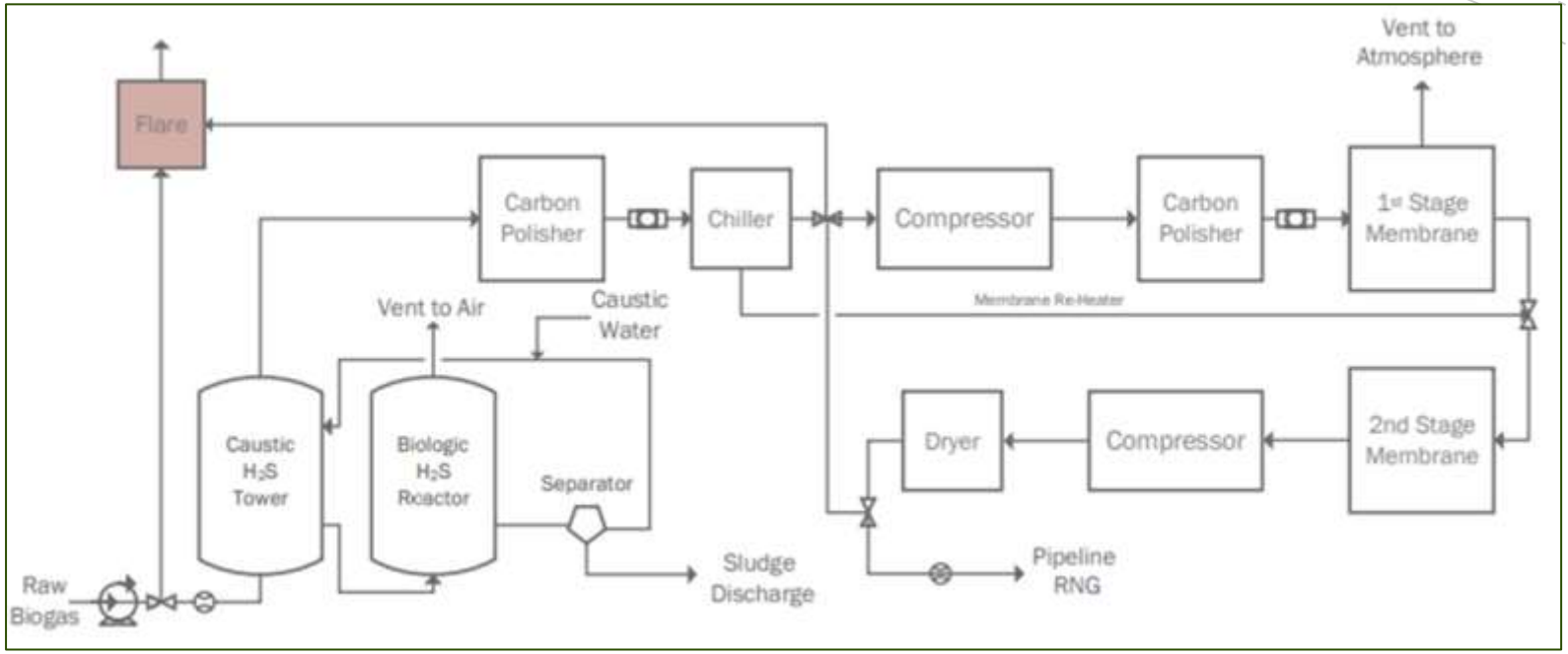
Source data: U.S. EPA GHG Inventory of Greenhouse Gas Emissions and Sinks: 1990-2018.

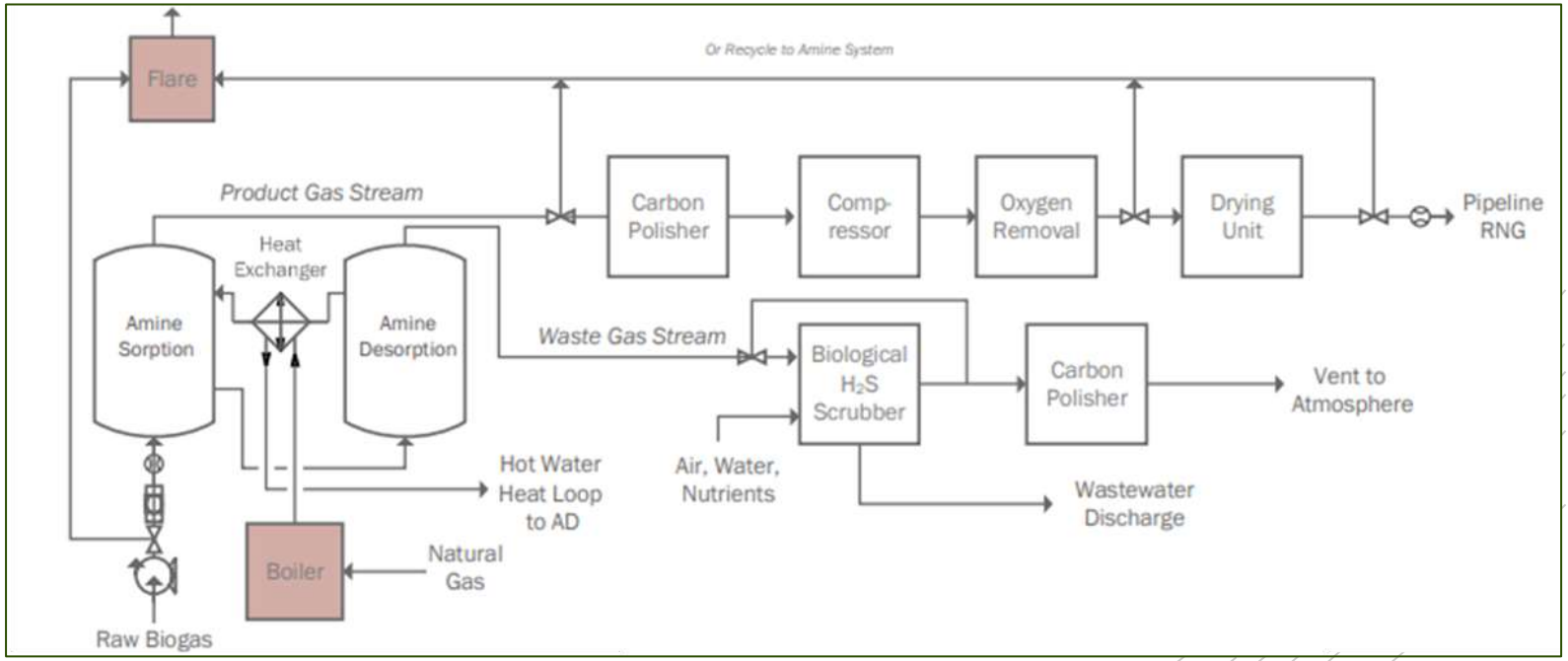
So now, the Things to Digest

Before we even get to the gas part….



Gas upgrading is going to be a big part of your project





Figures Courtesy of Regenis

Questions to ask: "On Farm"

- Who is maintaining this system on what schedule?
- What are the dairy's responsibilities for O&M?
- Who is managing the digestate? How?
- What happens if the gas quality or quantity changes?
- What happens if the digestate quality or quantity changes?
- What happens if the digester fails? Who is responsible for figuring out what happened and restarting it?
- Who is commissioning the digester and the gas upgrading system?
- How long after startup do we have before we have to contractually make gas?

Questions to ask: "Off Farm"

- Who is designing the system?
  - How many dairy digesters have they done?
  - How many co-digesting dairy digester systems have they done?
- What pro-forma inputs are being used?
  - Gas quality and quantity
  - Value of the gas
  - Digestate quantity and quality
  - Value of the digestate
- What kind of contract is in place for feedstock procurement? For how many years? What quality?
- If part of a "co-op" or hub and spoke mode, how are nutrients getting redistributed?
- How much of the market value of the gas is coming back to the dairy?
- What happens if the value of the gas drops below or doubles what was in the proforma? How does this reflect what gets back to the dairy?

The care and feeding of your digester **will** affect gas quality and quantity.

I can talk about this all day.
Please reach out if you have any questions:

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Back pocket

Biomethane in California Common Carrier Pipelines: Assessing Heating Value and Maximum Siloxane Specifications

An Independent Review of Scientific and Technical Information

A Commissioned Report prepared by the California Council on Science and Technology, 2018

Gas Composition	Source of Gas			
	WWTP	Landfill	Animal/ Agricultural Waste	Municipal Waste
Methane (CH4, vol. %)	55-70% [1] 60-67% [3] 59.6% [6] 60% [7]	45-60% [1] 47-62% [3] 35-65% [4] 44% [5] 45% [7]	50-70% [1] 55-58% [3] 60-70% [4] 68% [7]	50-60% [2]
Carbon dioxide (CO2, vol. %)	30-45% [1] 33-38% [3] 39.1% [6] 33% [7]	35-40% [1] 32-43% [3] 15-50% [4] 40.1% [5] 32% [7]	30-50% [1] 37-38% [3] 30-40% [4] 26% [7]	34-38% [2]
Nitrogen (N2, vol. %)	<2% [3] 0.9% [6] 1% [7]	0-3% [1] 1-17% [3] 5-40% [4] 13.2% [5] 17% [7]	0-3% [1] 1-2% [3] 1% [7]	0-5% [2]
Oxygen (O2, vol. %)	None [1] <1% [3] 0.2% [6] 0% [7]	0-2% [1] <1% [3] 0-5% [4] 2.6% [5] 2% [7]	<1% [3] 0% [7]	<1% [2]
Heating Value (BTU/scf)	500-640 [1]	410-550 [1]	450-650 [1]	450-550 [2]

[1] (Lampe, 2006), [2] (Bailón Allegue & Hinge, 2012), [3] (Rasi, 2009), [4] (Persson, Jonsson, & Wellinger, 2006), [5] (Jaffrin, Bentounes, Joan, & Makhlouf, 2003), [6] (Osorio & Torres, 2009), [7] (Favre, Bounaceur, & Roizard, 2009)

https://www.cpuc.ca.gov/-/media/cpuc-website/files/uploadedfiles/cpuc_website/content/utilities_and_industries/energy/energy_programs/gas/natural_gas_market/biomethane-report.pdf

For the anaerobic digestion process, what are some minimum laboratory tests that should be performed?

a) Feed Sludge

- Total solids
- Volatile solids
- pH

b) Primary Digesters

- Volatile acid
- Alkalinity
- pH
- Ammonia and total Kjeldahl nitrogen
- Temperature
- Physical characteristics

c) Digested Sludge

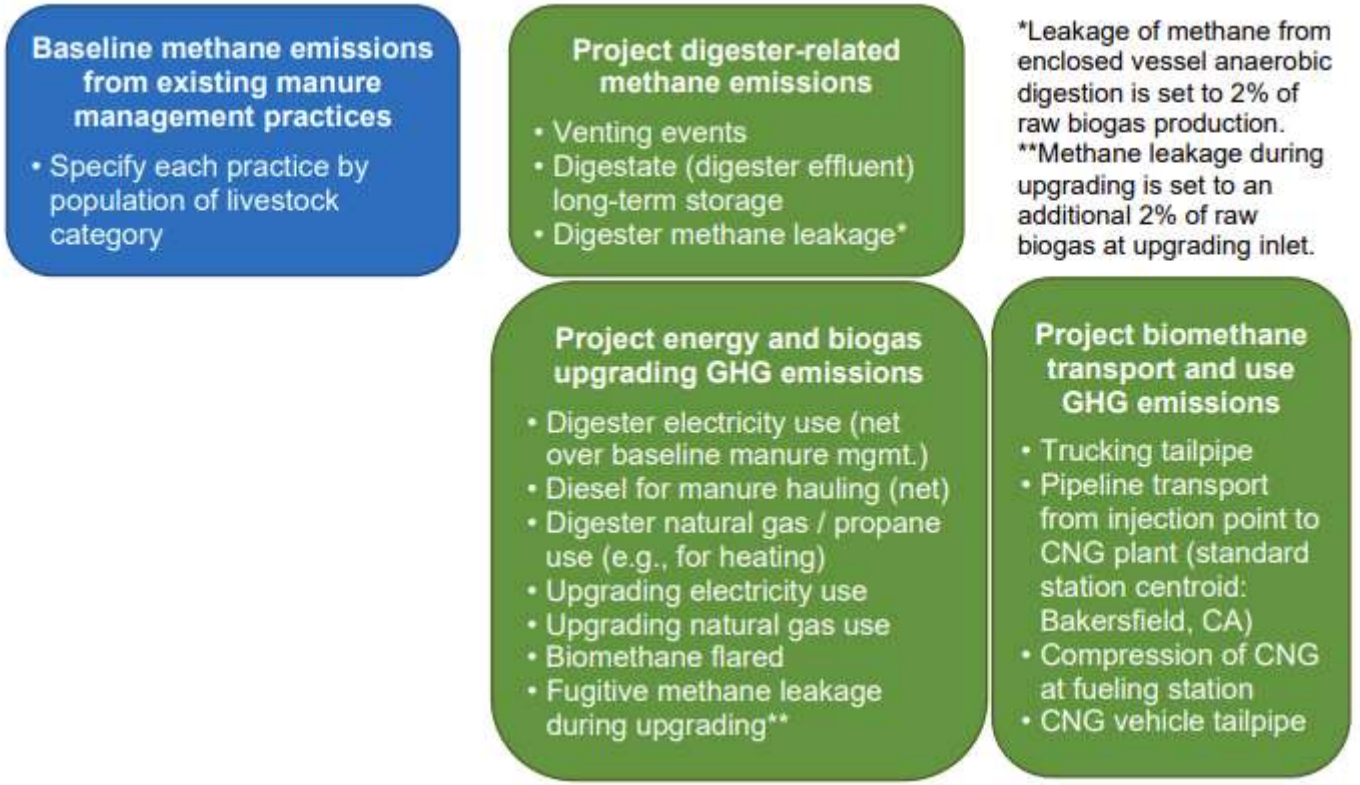
- Total solids
- Volatile solids
- Physical characteristics

d) Digester Gas

- Methane and carbon dioxide composition

C I or, Carbon Intensity Score

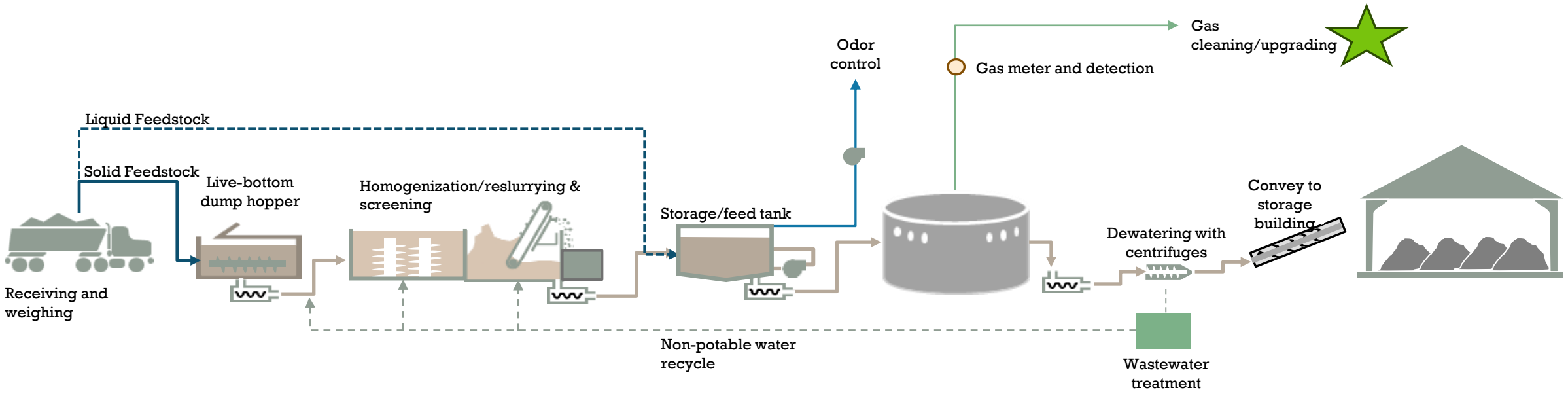
- CI score quantifies the life cycle GHG emissions per unit of transportation fuel energy



Constituent	Where does it come from?	How much is in biogas?	Why is it a problem?
Methane!	Bacterial byproduct of anaerobic decomposition	Ranges from 40%-70% by volume	Not a problem at all!
Carbon Dioxide	Bacterial byproduct of anaerobic decomposition	Ranges from 25-55% by volume	Significantly reduces the heating value
Water Vapor	Warm wet feedstocks	~ 5-10% by volume depending on temperature and pressure	Combines with other constituents (hydrogen sulfide, e.g.)to produce corrosive conditions and lowers engine efficiencies
Hydrogen Sulfide	Bacterial conversion of other sulphurous compounds in the feedstock	Varies considerably based on pH and feedstock: can get as high as 1,000s of ppm	Biologically converted with water to produce sulfuric acid, which corrodes equipment
Siloxanes	Personal care products	1-25 mg/L but depends on the feedstock	When combusted, results in hard deposits on pipes, valves, pistons, spark plugs, etc.
Ammonia	Bacterial conversion of organic nitrogen in feedstocks	Contingent on feedstock, pH and temperature in the reactor; higher in digesters taking food waste	Can dissolve in water vapor to produce corrosive liquids, and at high levels upsets the methane-producing bacteria
Oxygen	Usually accidentally introduced through ancillary equipment or in situ treatments	~ 1-2% by volume	Can react with other constituents in the gas to result in corrosive conditions
Nitrogen	Usually accidentally introduced through ancillary equipment	Depends on size and volume of leaks	Reduces BTU value of gas, adds to “inerts”

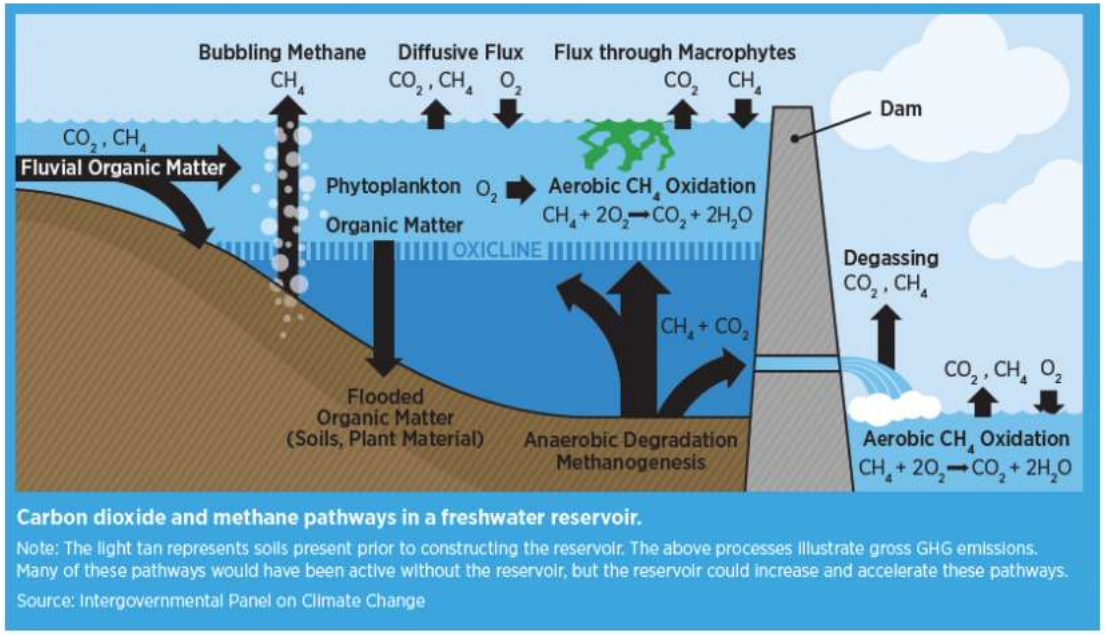
Biogas to RNG

Constituent	Removal Technology/Process
Water Vapor	Piping design Chillers Driers
Hydrogen Sulfide	*Oxygen dosing* *Ferric salts* Iron sponge Adsorption (activated carbon, e.g.) Gas scrubbers (biological, water, solvent/amine)
Siloxanes	Adsorption (activated carbon, e.g.)
Ammonia	Feedstock management pH management in the digester Removing water vapor
Nitrogen	Collection system maintenance (Membranes) Pressure Swing Adsorption (PSA)
Oxygen	Collection system maintenance Pressure Swing Adsorption (PSA)
Carbon Dioxide	Water scrubbers Chemical scrubbers Pressure Swing Adsorption (PSA) Membrane separation


Liquid Feedstock
Solid Feedstock
Live-bottom dump hopper
Homogenization/reslurrying & screening
Odor control
Storage/feed tank
Gas meter and detection
Gas cleaning/upgrading
Dewatering with centrifuges
Convey to storage building
Receiving and weighing
Non-potable water recycle
Wastewater treatment

Biogas Happens.

Inventor harvests methane gas from ditches and ponds to power his moped



Carbon dioxide and methane pathways in a freshwater reservoir.

Note: The light tan represents soils present prior to constructing the reservoir. The above processes illustrate gross GHG emissions. Many of these pathways would have been active without the reservoir, but the reservoir could increase and accelerate these pathways.

Source: Intergovernmental Panel on Climate Change