BIOGAS: Economics, Efficiency, Chemistry

Part 1 - Chemistry

right solutions.
right partner.

Darlene Hoogenes-Stastny
National Air Quality, ALS Canada Ltd

Biogas - definition

What ?
- mixture of gases →rich in methane,
- produced by the breakdown of organic matter in the absence of oxygen

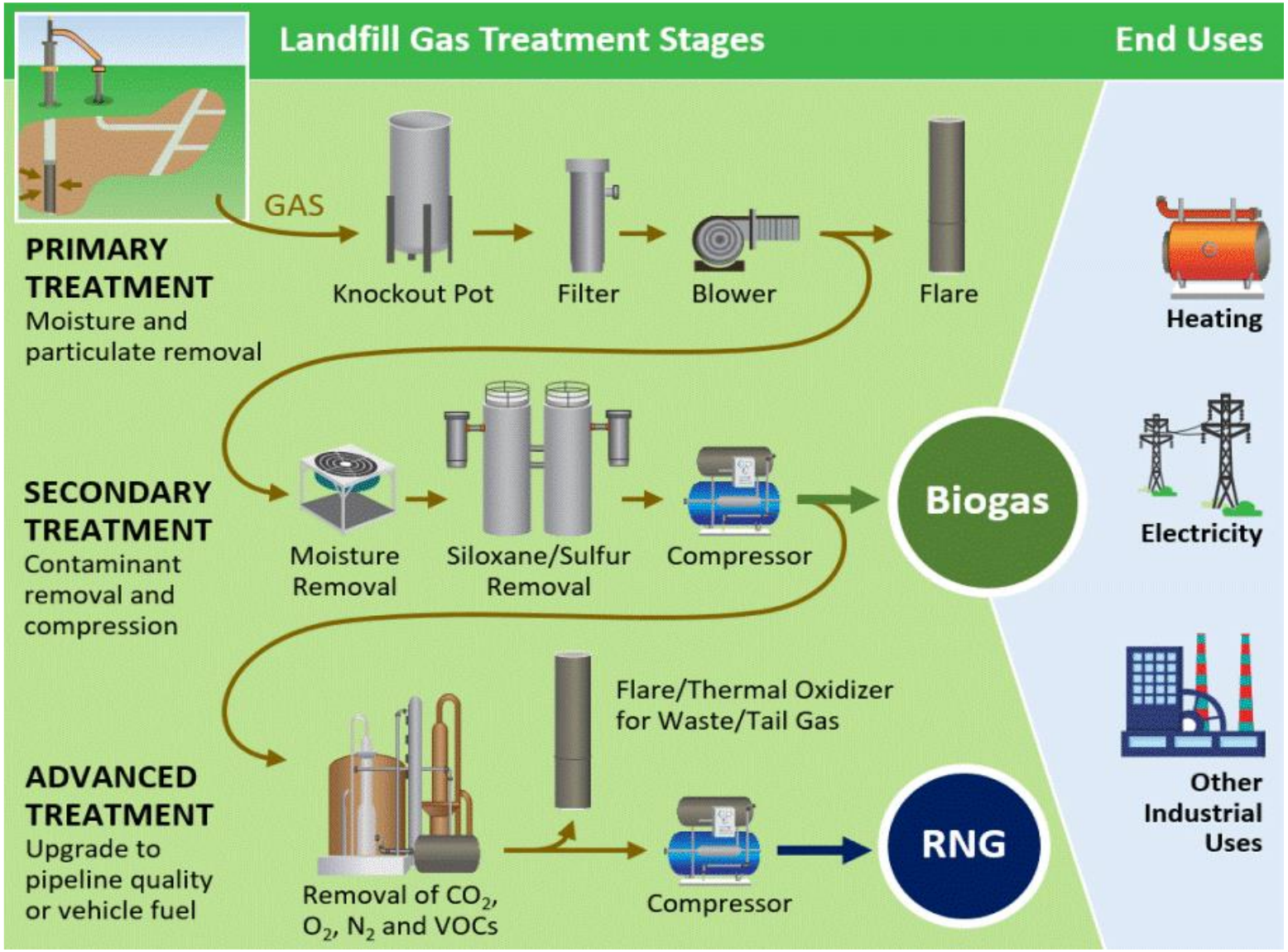
Where?
- It may be produced in anaerobic digestion facilities, but it is also present in landfills

Why?
- Capturing landfill gas or diverting organic waste to produce biogas reduces greenhouse gas emissions
- Raw biogas typically contains 45-65% methane and can be upgraded or refined to remove impurities such as moisture, particulate matter, siloxanes, hydrogen sulfide, volatile organic compounds (VOCs), carbon dioxide, oxygen, and nitrogen

How does RNG relate?
- Renewable Natural Gas (RNG) refers to biogas that has been upgraded to >90% methane content, although most RNG is upgraded to 96-98% methane for use as a fossil natural gas substitute, for injection into existing natural gas distribution pipelines

To determine economic viability and efficiency, biogas composition must be determined

BIOGAS & RENEWABLE NATURAL GAS from landfill gas



Chemistry Associated with Biogas Testing

- Fixed Gases
- Volatile Organic Compounds
- C1-C5 light hydrocarbons
- Siloxanes (linear and cyclic)
- Ammonia
- Sulfurs/Mercaptans
- More ??

Fixed Gases

- Includes: Methane, O2, N2, CO,CO2 (optional: Hydrogen/Helium)
- Best Sampled into Canister for hold time and stability
- Method : EPA 3C – modified/ASTM D1946
- Instrumentation : GC-TCD

- soil vapour
- vapour probes
- landfill gas
- monitoring well head space
- short term samples (< 1hr)

Volatile Organic Compounds

- Includes various VOC compounds – *lists and reporting limits vary*
- Sampling into canister provides best hold time (30 days) and stability
- Method: EPA TO-15 modified
- Instrumentation: GC-MS

C1-C5 Light Hydrocarbons

- Best Sampled into Canister for hold time and stability
- Method : EPA TO-3 modified
- Instrumentation GC-FID

C1-C5-FID-WT

CANISTER		**RL Units**	**RL Units**
Parameter	**Synonym**	**%**	**ppm(V)**
BUTANE	Butane	0.0002	2
ETHANE	Ethane	0.0002	2
ETHENE	Ethene	0.0002	2
METHANE	Methane	0.0001	1
PENTANE	Pentane	0.0002	2
PROPANE	Propane	0.0002	2
PROPYLENE	Propene	0.0002	2

Siloxanes: linear & cyclic

- Sampled onto a thermal desorption (TD) tube
- Method reference: EPA TO-17 modified
- Instrumentation : TD- GC/MS

SILOXANES-GCMS-WT			
	Typical sampling volumes 0.05 to 1L		
TD Tube	*Volume = 0.05L for ug/m^3 calculation*	RL Units	RL Units
Parameter	**Synonym**	**ng**	**µg/m^3**
DECAMETHYLCYCLOPENTASILOXANE	D5(CVMS)	10	200
DECAMETHYLTETRASILOXANE	MD2M(LVMS)	10	200
DODECAMETHYLCYCLOHEXASILOXANE	D6(CVMS)	10	200
DODECAMETHYLPENTASILOXANE	MD3M(LVMS)	10	200
HEXAMETHYLCYCLOTRISILOXANE	D3(CVMS)	10	200
HEXAMETHYLDISILOXANE	MM(LVMS)	10	200
OCTAMETHYLCYCLOTETRASILOXANE	D4(CVMS)	10	200
OCTAMETHYLTRISILOXANE	MDM(LVMS)	10	200

- Released into biogas through decomposition process -→anaerobic digestion
- Combustion of biogas releases silicon- this combines with free oxygen to form mineral deposits on surfaces – causing pitting and abrasive wear on landfill equipment

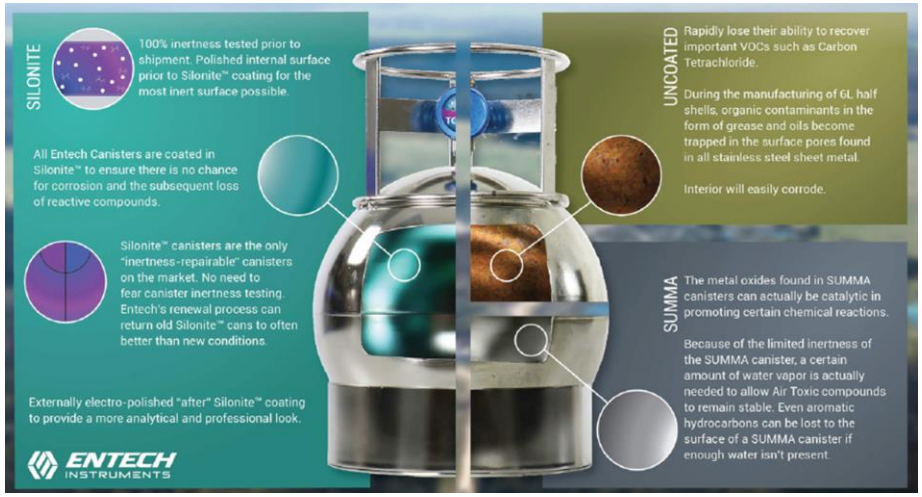
Ammonia – NH_3

- Sampled onto an SKC tube (SKC 226-10-06) with low-flow pump
- Method reference: NIOSH 6015 modified
- Instrumentation : VIS (spectrophotometry)

- Ammonia is formed during anaerobic digestion, it is important that its concentration in biogas remain below 0.1mg/Nm^3 (Persson et al., 2006)
- High concentrations of NH_3 in biogas can combust and lead to formation of nitrous oxide
- Controlling NH_3 can be done by maintaining lower pH and temperature as well as adjusting the C/N ratio of feed stock (Kaparaju, Rintala, The Biogas Handbook, 2013)

Sulfurs and Mercaptans

- Best Sampled into Canister for hold time (7 days) and stability
- Method : ASTM D5504 modified
- Instrumentation GC-SCD



CANISTER		RL Units	RL Units
Parameter	Synonym	ppb(V)	µg/m³
BUTYL(N) MERCAPTAN	n-Butyl mercaptan	4	14.8
BUTYL(T) MERCAPTAN	Butyl(t) mercaptan	4	14.8
CARBON DISULFIDE	Carbon Disulfide	2	6.2
CARBONYL SULFIDE	Carbonyl sulfide	4	9.8
DIETHYL DISULFIDE	Diethyl disulfide	2	10.0
DIETHYL SULFIDE	Diethyl Sulfide	4	14.8
DIMETHYL DISULFIDE	Dimethyl disulfide	2	7.7
DIMETHYL SULFIDE	Dimethyl sulfide	4	10.2
2,5-DIMETHYLTHIOPHENE	2,5-Dimethylthiophene	4	18.4
ETHYL MERCAPTAN	Ethyl mercaptan	4	10.2
ETHYL METHYL SULFIDE	Ethyl Methyl Sulfide	4	18.4
2-ETHYLTHIOPHENE	2-Ethylthiophene	4	18.4
HYDROGEN SULPHIDE	Hydrogen Sulfide	4	5.6
ISOBUTYL MERCAPTAN	Isobutyl Mercaptan	4	14.8
ISOPROPYL MERCAPTAN	Isopropyl Mercaptan	4	12.5
METHYL MERCAPTAN	Methyl mercaptan	4	7.9
2-METHYLTHIOPHENE	2-Methylthiophene	4	16.1
3-METHYLTHIOPHENE	3-Methylthiophene	4	16.1
PROPYL MERCAPTAN	Propyl mercaptan	4	12.5
TETRAHYDROTHIOPHENE	Tetrahydrothiophene	4	14.4
SEC-BUTYL MERCAPTAN + THIOPHENE	sec-Butyl Mercaptan + Thiophene	6	21.5
TOTAL REDUCED SULFUR (22) AS H2S	Total Reduced Sulfur (22) as H2S	4	5.6

Types and Sizes of Canisters

6L silonite canister with TWA sampler

1.4L silonite canister

1.4L silonite canister with short-term grab sampler

1L glass bottle vac & components

Sampling Times

6L Canister

Flow Controller is a :

- TWA (time weighted average) Sampler
- Options for sampling times:
  - 1 hour
  - 4 hours
  - 8 hours
  - 12 hours
  - 24 hours

1.4L Canister

Flow Controller is a:

- Grab (short term) Sampler
- Options for sampling times:
  - 4 minutes
  - 10 minutes
  - 20 minutes
  - 60 minutes

- add'l option: no flow restrictor-instant fill)

1.0L Canister

aka Bottle Vac

- Flow Controller is Grab (short term) Sampler
- Options for sampling times:
  - 3 minutes
  - 7 minutes
  - 14 minutes
  - 40 minutes

- add'l option: no flow restrictor-instant fill

Canister DO's and DON'Ts

DO's

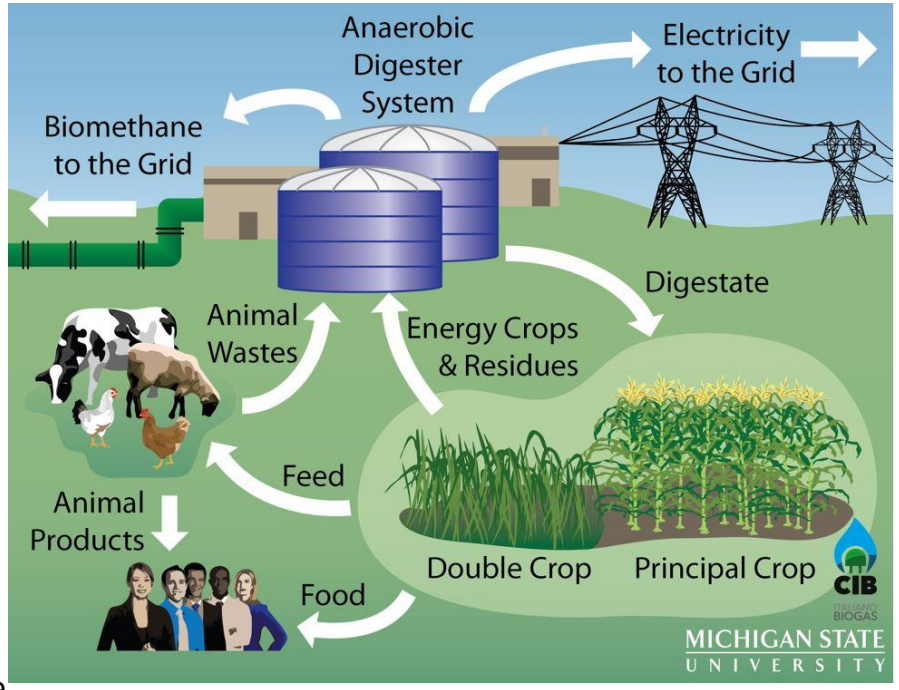
- Check the vacuum on the canisters with the independent pressure gauge–record it
- Connect Swagelok fittings (tighten with a wrench.. GENTLY) and tubing to the end of the flow controller before connecting the flow controller to the canister
- Keep canisters dry , away from extreme heat and cold
- Return canisters promptly, rental is for 2 weeks, please allow time for shipping and to meet hold times
- Take care of the equipment, do not remove or bend parts (damaged equipment is invoiced)

DON'Ts

- Start sampling without checking the canister vacuum first
- Connect the flow controller (TWA or Grab) to the canister until you are ready to sample
- Put ice in the cooler with the canisters or get water in them
- Hold onto canisters if your project is delayed more than 2 weeks, or hold onto canisters after sampling
- Remove parts or use wrenches on quick connects

Other BIOGAS chemistries

- Metals
- Heating Value/Wobbe Number
- Polynuclear Aromatics and Semi-Volatiles
- Pesticides
- PCBs



Biogas plant in Malaysia

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Community Focused Anaerobic Digestion

ESAA Environmental Summit

April 12th-14th 2023

Presented by: William Selten

Anaerobic Digestion Benefits

- Diverting organics from landfill
- Sustainable management of organic waste
- Renewable energy production
- Organic fertilizer production
- Promoting circular economy
- Contained process (limiting odour)
- Reduction of greenhouse gas emissions

Feedstocks

Municipal organic waste (household green bin waste)

Sludge from wastewater treatment plants

Farm waste

Industrial waste (food industry)

Commercial waste (supermarkets & restaurants)

Organic content from MBT

Industrial Anaerobic Facilities

- Usually specialize in one type of feedstock, typically large facilities & city owned (Ex. Disco Road)
- Cities are moving away from composting organics due to:
  - energy production and use
  - odour issues
- Anaerobic digestion is an all-enclosed process with little risk of odour issues

Toronto Disco Road, SSO Processing

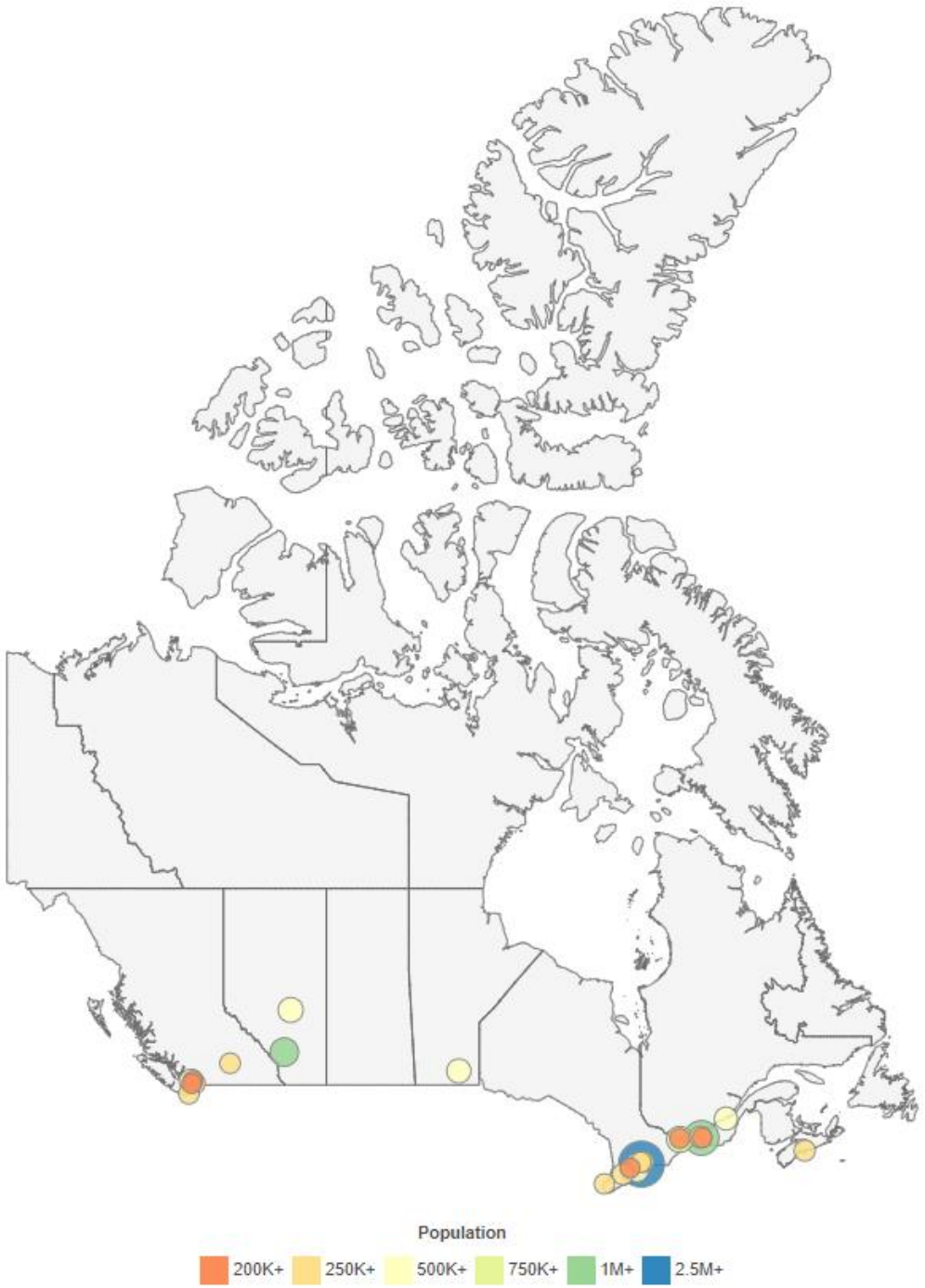
- City Owned
- Built in 2014
- $75m to construct
- Industrial facility
- Processes 75,000 tpy of municipal waste (green bin waste)

Oshawa Project 3D Overview

- Under construction
- Privately owned
- $100m+ to construct
- Industrial facility
- Flexibility to process various feedstocks
- Designed to process 200,000 tpy of organic waste

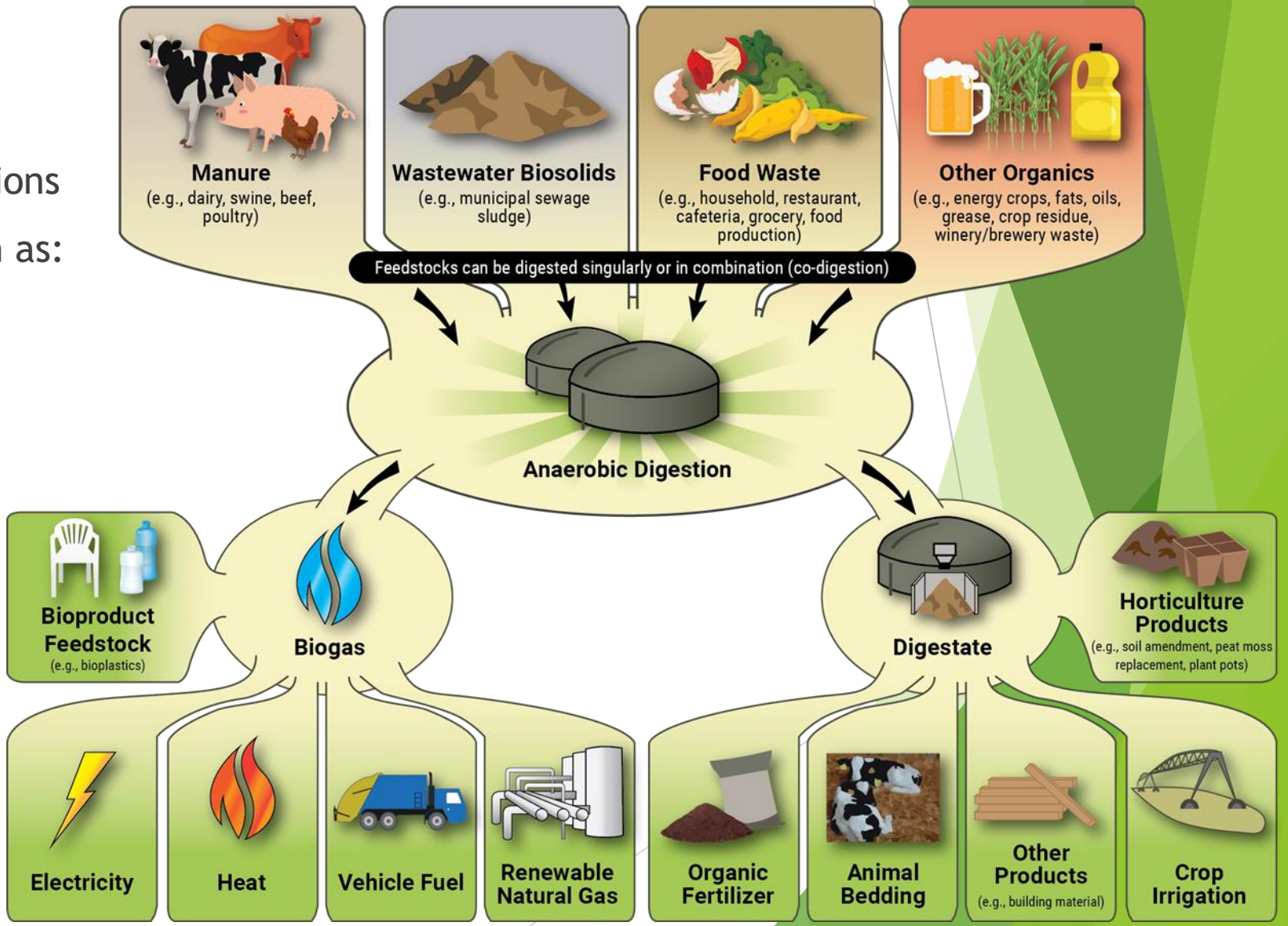
Anaerobic Digestion Demographic

- Large facilities only work well in large urban environments
- A large scale facility will need approximately half a million people to serve in order for the design to be feasible if using one waste source.
- 82% of Canada's population live in larger cities
- 7 million living outside large population areas



Community focused Small Scale-Digester

- Added flexibility
- As little as 1 tonne per day
- Focus on smaller areas/populations
- Various types of feedstock, such as:
  - SSO
  - ICI
  - Farm waste
  - WWTP sludge
  - Pubs & restaurants



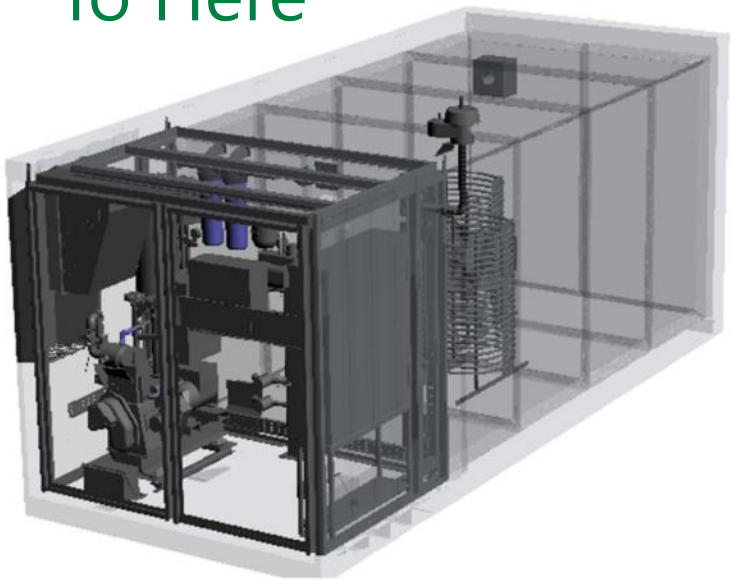
Local Importance

- Process locally sourced organic waste
- Economic benefits
  - RNG production
  - Organic fertilizer production
- Educational concept
- Regenerative cycle
- Local jobs
- Reduce costs
- Reduce emissions

The Scale Down => Local Organics to Energy

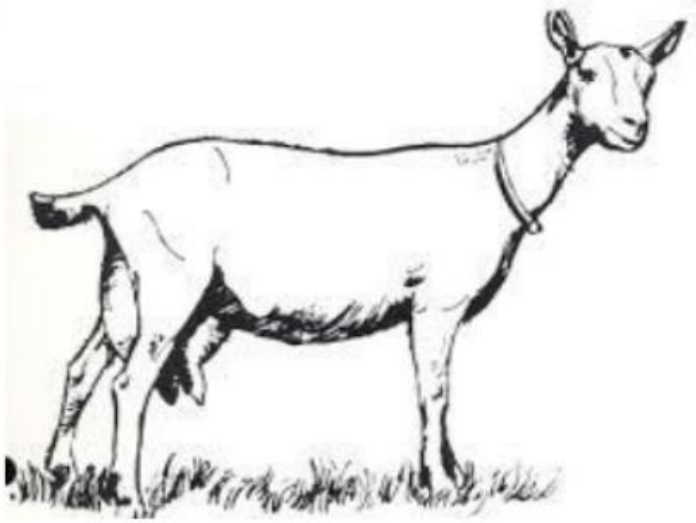
It's About Going From Here

To Here



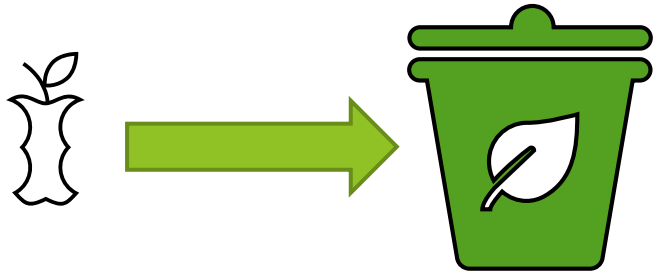
Algoma Orchards – Pilot (Canada)

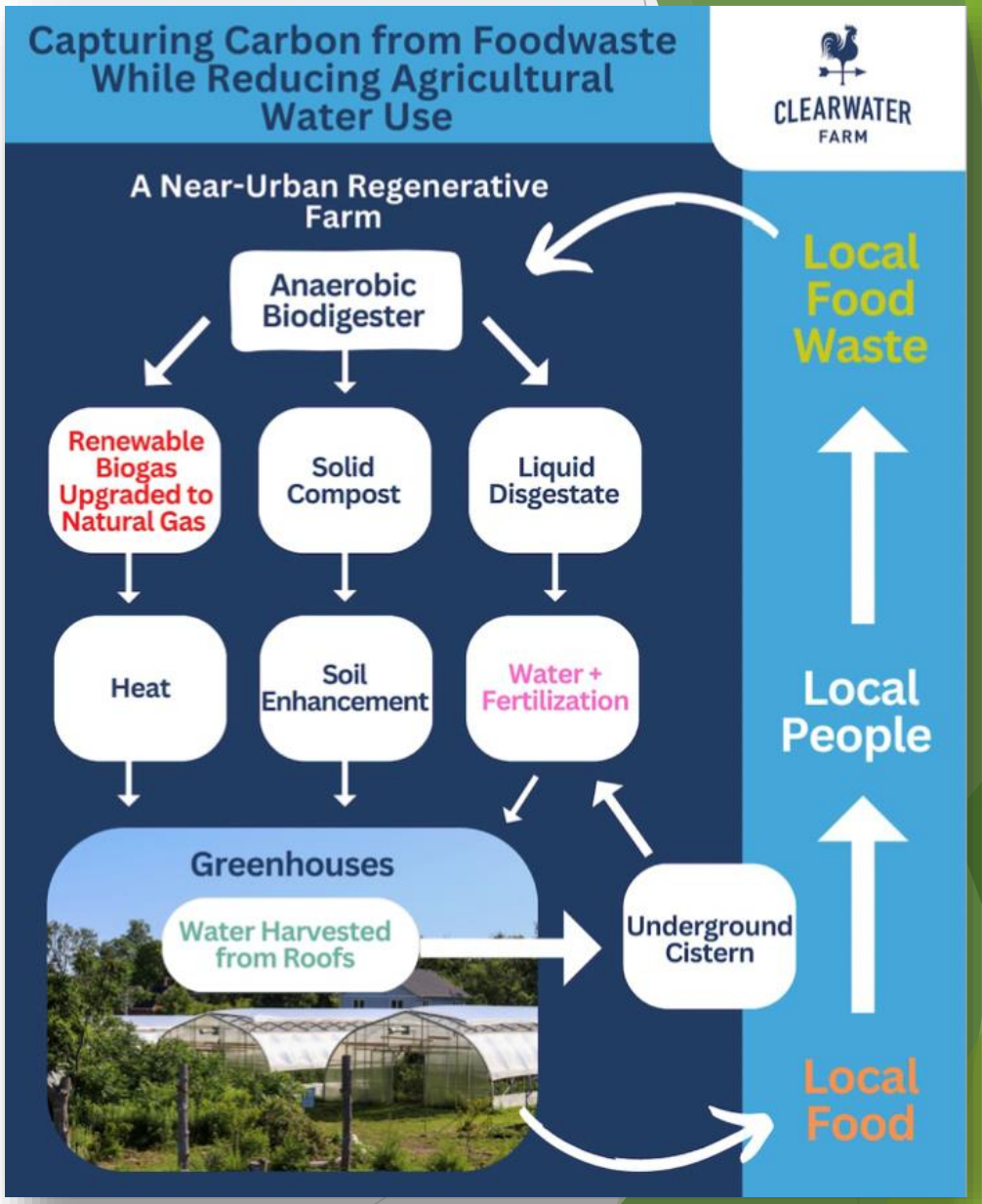
Mariposa Dairy Limited – Pilot (Canada)



Ontario Water Centre Project

- Small-scale anaerobic digestion
- Locally sourced organic waste & manure
- Processes 1-3 tonnes of organic waste daily
- RNG production and upgrading
- On-site CNG (compressed natural gas) re-fueling station
- Organic fertilizer production
- 100% grant funded
- Educating 3,000 Children each year
- Non-profit organization





Applications

- Small & remote communities
- Work camps
- Remote industrial facilities
- Commercial facilities
- Large institutions

Example: Jasper

- Year-round population: around 5,000
- 3,000 tonnes of food waste (SSO & ICI)
- 36,000 tonnes of biosolids
- 28,000 GJ of energy produced
- Can provide 230 households with renewable natural gas
- 15% of Jasper's total households
- Reduction of composted material

Promoting Circular Economy

- Community involvement
- Sustainable practices
- Responsible waste management done locally
- Reducing pollution
- Circulating products and materials
- Restoring natural systems
- Creating value from waste

Thank you!

April 13 2023

Presented by: William Selten
wselten@egreens.ca

TETRA TECH

Bio Gas Overview

Peter Klaassen P.Eng, MBA

April 13, 2023 Jasper Summit

esaa Environmental Summit

Company Overview

TETRA TECH

TETRA TECH SNAPSHOT

WORKS IN
100+
COUNTRIES

7
CONTINENTS

Publicly traded on NASDAQ as
TTEK

$4.5 billion
ANNUAL REVENUE

WORKS ON
100,000
PROJECTS
ANNUALLY

550 OFFICES WORLDWIDE

ENR RANKINGS

#1	Water
#1	Environmental Management
#1	Water Treatment/Desalination
#1	Hydro Plants

22,000 CLIENTS

27,000 EMPLOYEES

What we do

TETRA TECH

WATER

- Coastal and Marine Resources Management
- Drinking Water
- Groundwater
- Stormwater
- Wastewater Treatment
- Water Resources

ENVIRONMENT

- Air Quality
- Greenhouse Gas
- Environmental Compliance
- Environmental Management
- Permitting
- Remediation
- Waste Management
- Technological Risk Assessment

INFRASTRUCTURE

- Airports and Aviation
- High Performance Buildings
- Communications
- Dams, Reservoirs, and Levees
- Ports, Harbors, and Waterfront
- Transportation

RESOURCE MANAGEMENT

- Industrial
- Mining and Minerals
- Oil, Gas
- Pulp and Paper
- Aeronautics
- Bioenergy
- Biofuels
- Clean Technologies

ENERGY

- Conventional Generation
- Energy Efficiency
- Nuclear
- Offshore Energy
- Renewable Energy
- Transmission and Distribution
- Utilities and Market Analytics

INTERNATIONAL DEVELOPMENT

- Economic Growth
- Education
- Energy
- Environment
- Health
- Governance
- Infrastructure
- Land Rights
- Water

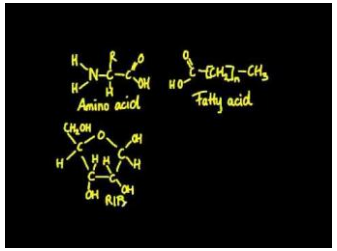
What is BioGas & How is it formed?

BioGas composition

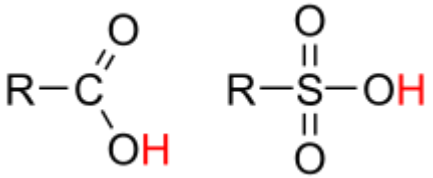
Methane CH_4	55 – 65 %
Carbon Dioxide CO_2	35 – 45 %
Hydrogen H_2	0 – 1 %
Carbon Monoxide CO	0 – 3 %
Oxygen O_2	0 – 2 %
Nitrogen N_2	0 – 1 %

AD Methane Production

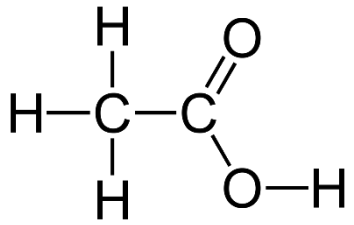
Carbohydrates
Proteins
Fats



Sugars
Amino Acids
Fatty Acids



Organic Acids
Alcohol
H_2, CO_2, Ammonia



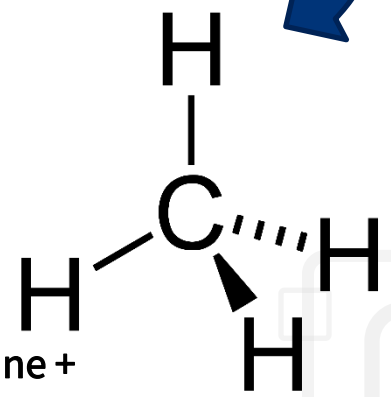
Acetic Acids
CO_2, H_2

Hydrolysis

Acidogenesis

Acidogenesis

Methanogenesis



Methane +
H_2, CO_2 + others

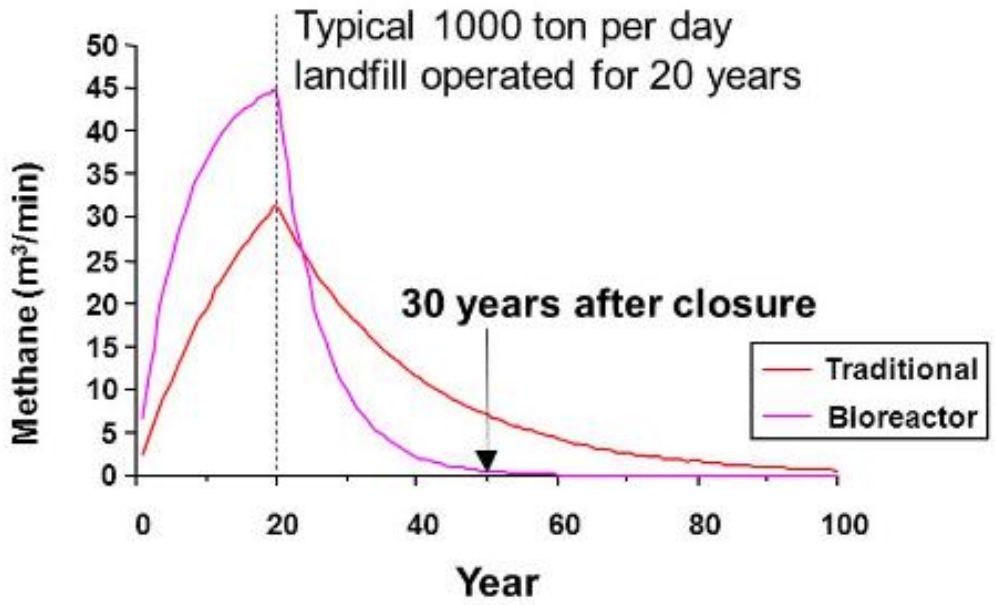
Renewable
Natural Gas

Where does BioGas come from?


ААНННННН!

Landfills

- Bio Gas generated from organics in waste
- Gas Collection System typically installed in larger landfills
- 75% Gas collection is considered good
- Typically flared in past or if large enough, electrical generation



Dedicated AD Facility

- Composition of Waste is important
- SSO and ICI organics
- High solids
- Typically good quality digestate

Types of AD Technologies

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Low-solids (TS <15%)

High-solids (TS > 15%)

Wet AD

Plug Flow

Dry AD

Food waste

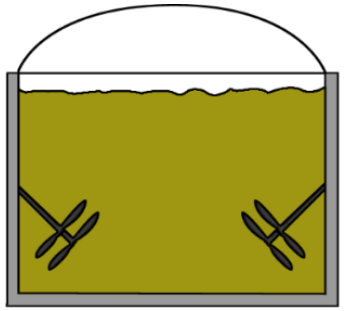
Green waste

Complete Mix / CSTR

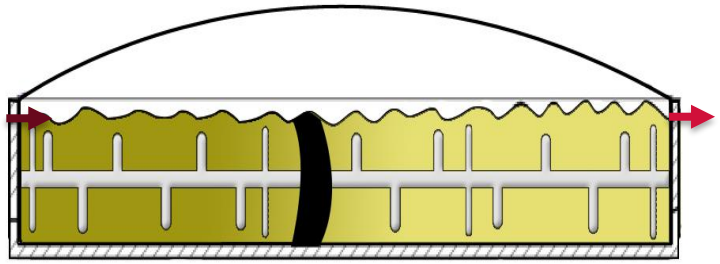
Continuous Dry AD

Batch Tunnel

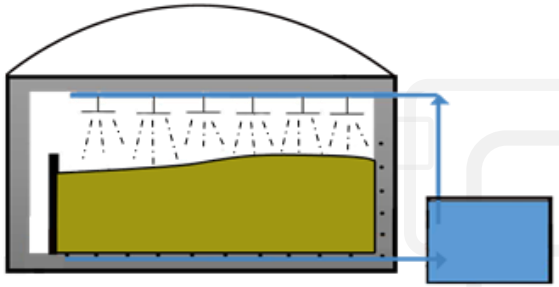
Low-Solids Wet AD



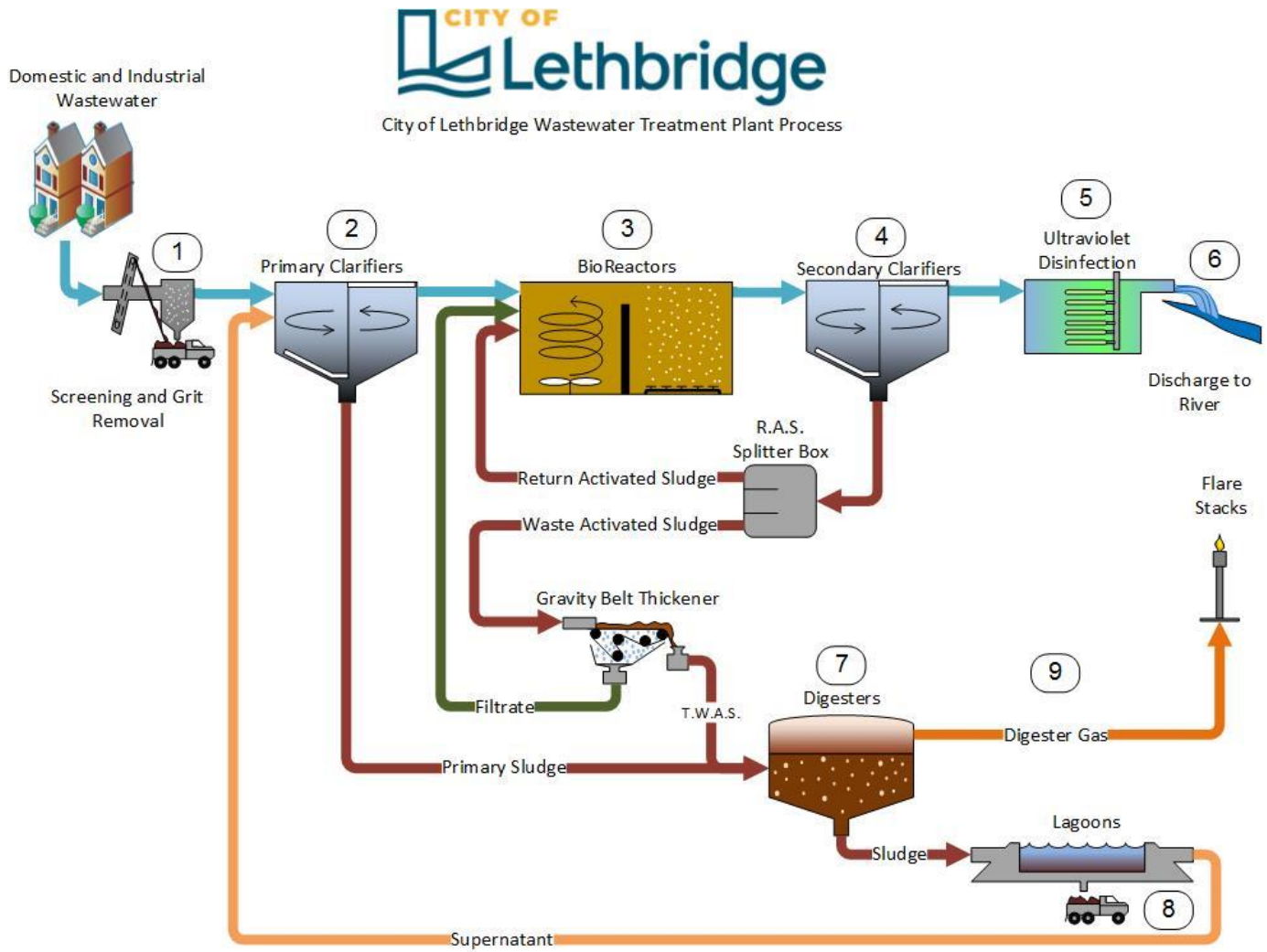
Horizontal Plug Flow



Percolate Bunker

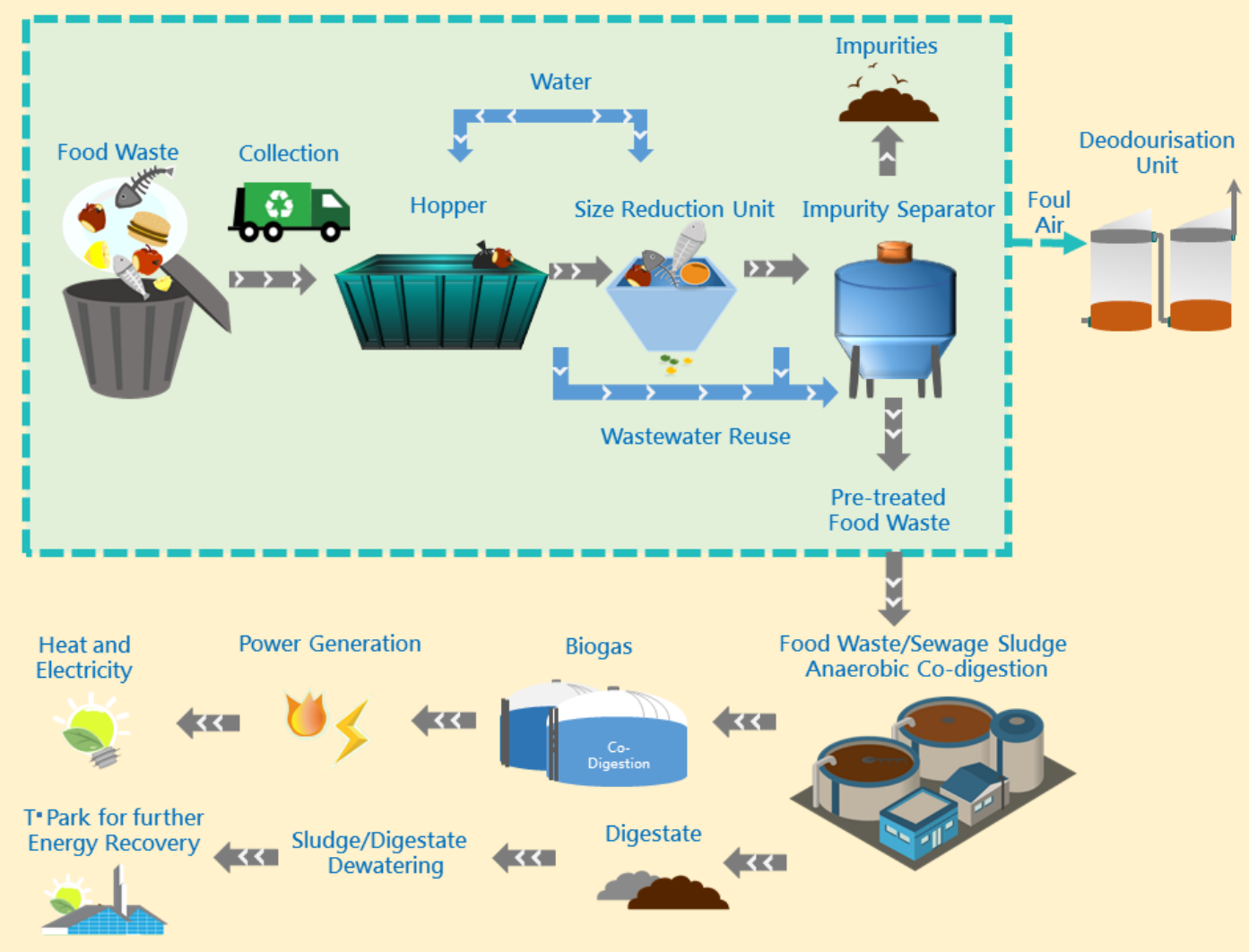


Waste Water Treatment Facility



- Low Solids (5%) Bio
- Gas Generation lower due to Low Solids
- Typically flared

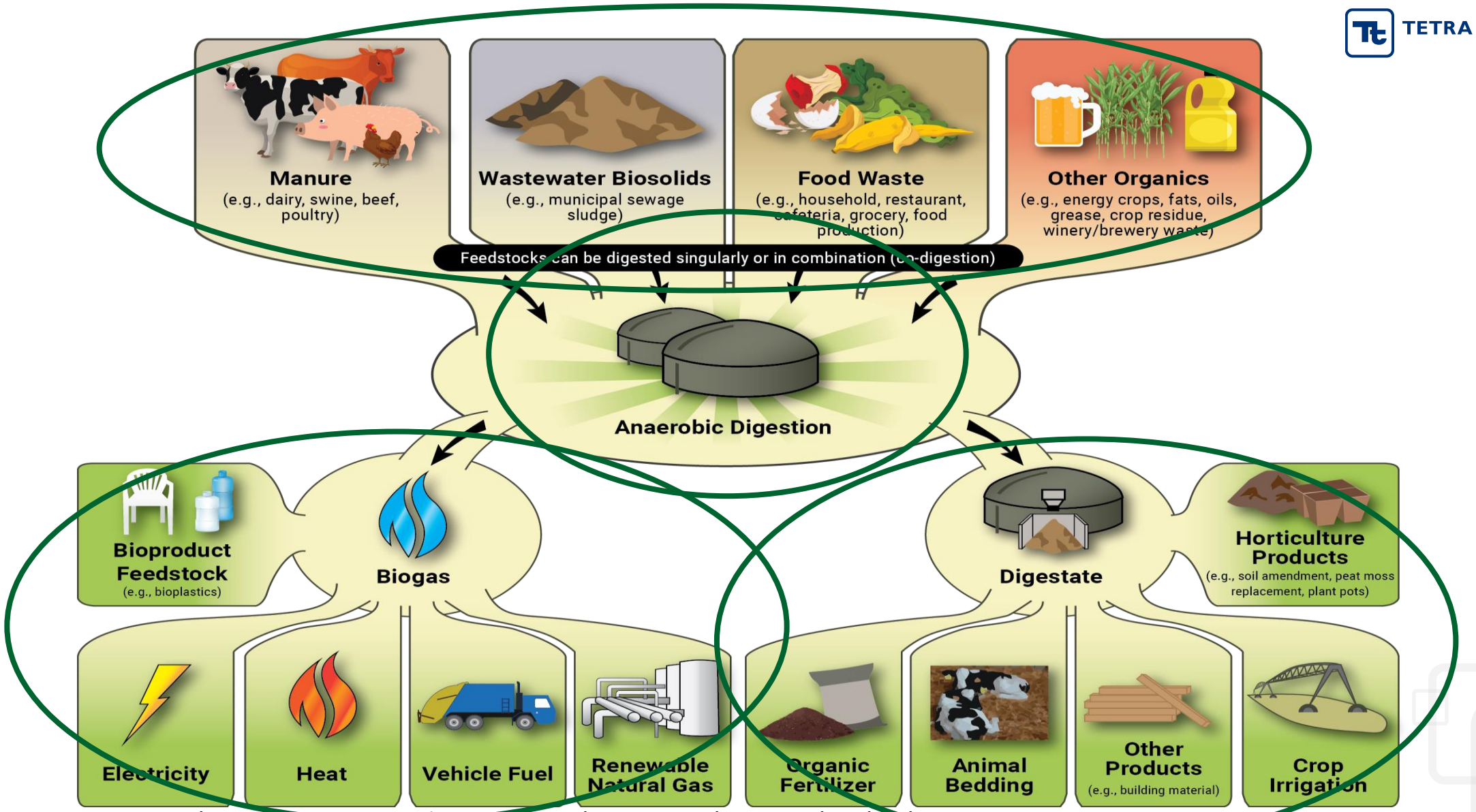
Co Digestion



- Curbside and ICI Organics blended with Waste Water Digestate
- (High Solids with Low Solids)
- Can potentially use existing WWTP to process both streams

Mixed Waste Processing

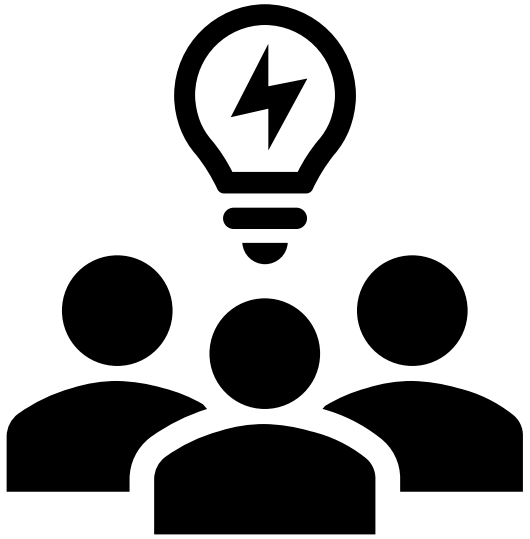
Bio Gas Processing and Marketplace



Source: https://www.epa.gov/agstar/anaerobic-system-design-and-technology

RNG Fueling Station

Market Dynamics



- Increased demand for RNG
  - Fortis, Energir (Canada), RIN in US, Ontario in future
  - Organic bans to Landfill
  - 5% (plus) RNG in pipeline
  - Prices have almost doubled over last 2-3 years
- Electrical Generation (in Canada) demand is low
- GHG Credits (Federal)

Questions? Comments?

TETRA TECH

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