REINHOLD ENVIRONMENTAL ®

2022 Reinhold/PCUG Round Table Presentation

Hosted by Duke Energy in the Charlotte Sheraton/Le Meridien Hotel, Charlotte, NC on June 27-28, 2022

Renewable Natural Gas 101

Benjamin Chu / June 28, 2022

Southern Company

Agenda

- What is Renewable Natural Gas (RNG)?
- How is it made?
- What is the market for it?
- What are some challenges it presents?
- What is Southern Company doing with it?

What is Renewable Natural Gas (RNG)?

What is Renewable Natural Gas?

- Renewable natural gas (RNG) is a pipeline-quality biogas that has been upgraded to be fully interchangeable with conventional natural gas.
- It can be injected into natural gas transmission or distribution pipelines.
- End uses include
  - Thermal applications
  - Electricity
  - Vehicle fuel
  - Bio-product feedstock

What is Renewable Natural Gas?

Waste-To-Energy

- The process of generating energy in the form of electricity and/or heat from the primary treatment of waste or the processing of waste into a fuel source.

Wood and Wood Waste

Biological

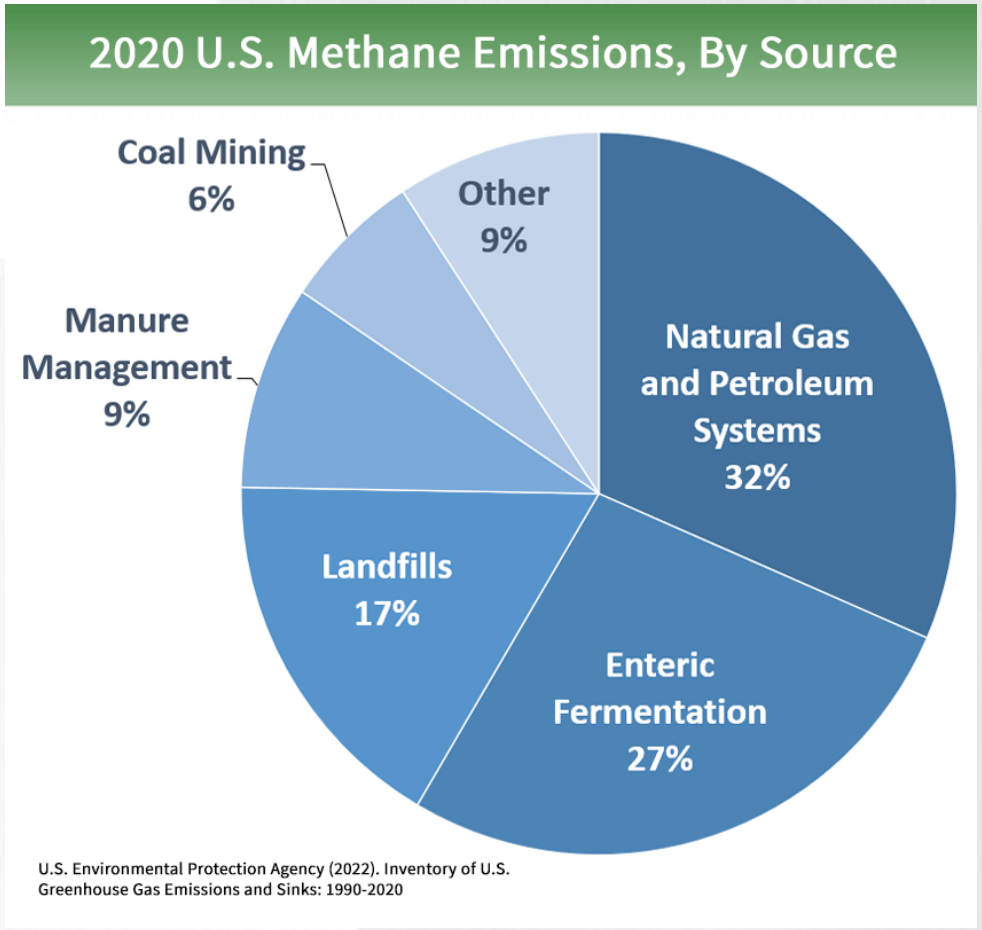
What is Renewable Natural Gas?

History of Biogas Production

- Biogas may have been used for heating bath water in Assyria as early as the 10th century BC
- Anaerobic digestion (AD) of solid waste may have been applied in ancient China
- Modern attempts to harness AD of biogas during mid 1900s
- Commercial use of biogas in China in 1921
- Sewage treatment gas fed to public gas supply in Germany in 1920
- First large agricultural biogas plant – Germany, 1950
- High oil prices in 1970s motivated alternative energy research, biogas technology adoption

What is Renewable Natural Gas?

Municipal Solid Waste (MSW)

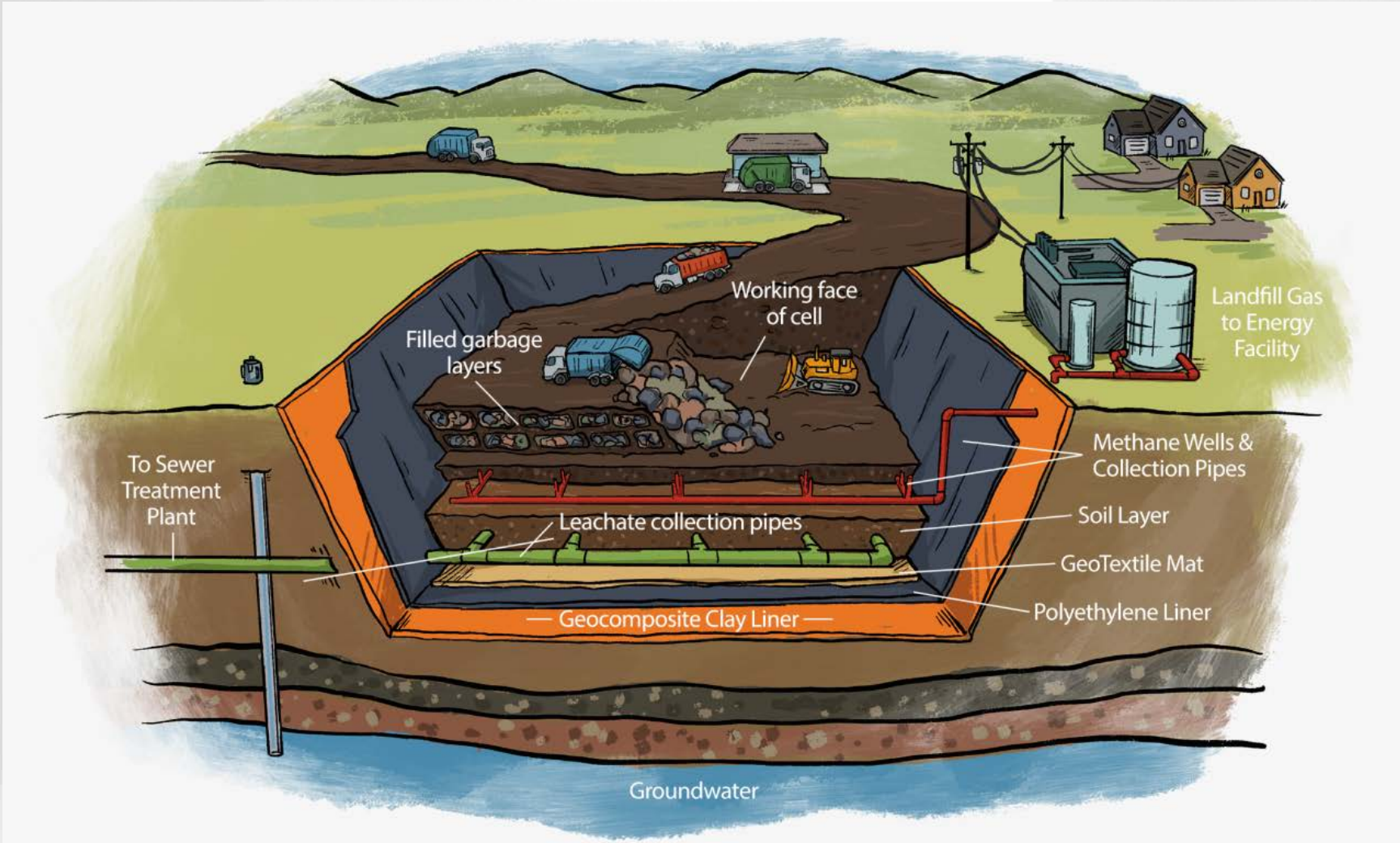


How is RNG Made?

Landfills

Landfills

Landfill Diagram

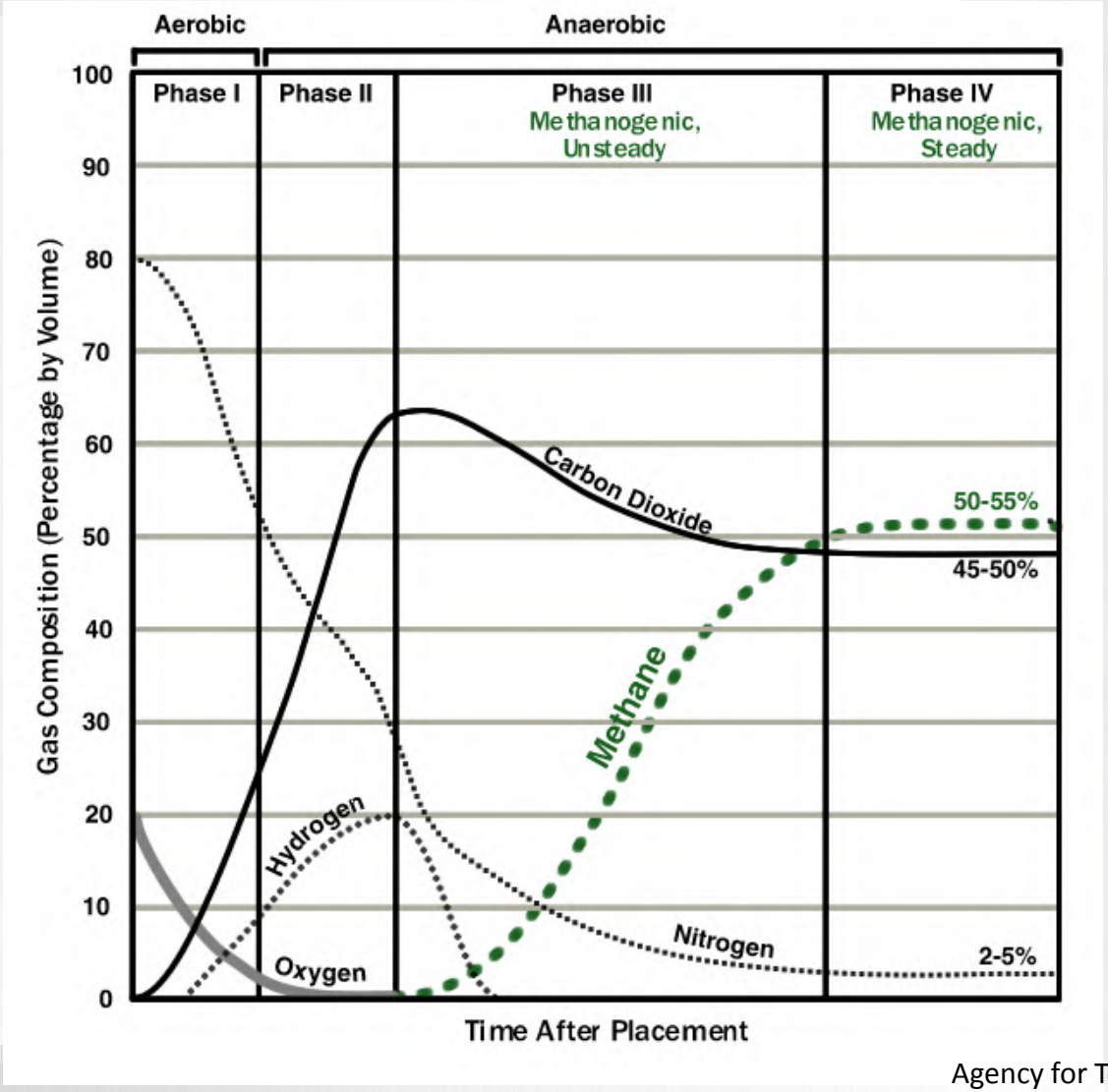


Wasatch Integrated Waste Management District

Landfill Gas Production

- Three processes form landfill gas
  - Bacterial decomposition
  - Volatilization
  - Chemical reactions
- Raw landfill gas
  - Typically 45-60% CH_4
  - 40-60% CO_2
  - small amounts of nitrogen, oxygen, sulfides, other contaminants
- A medium-sized landfill might be 2000-3000 scfm

Four Phases of Bacterial Decomposition of Landfill Waste



Agency for Toxic Substances and Disease Registry

What conditions affect landfill gas production?

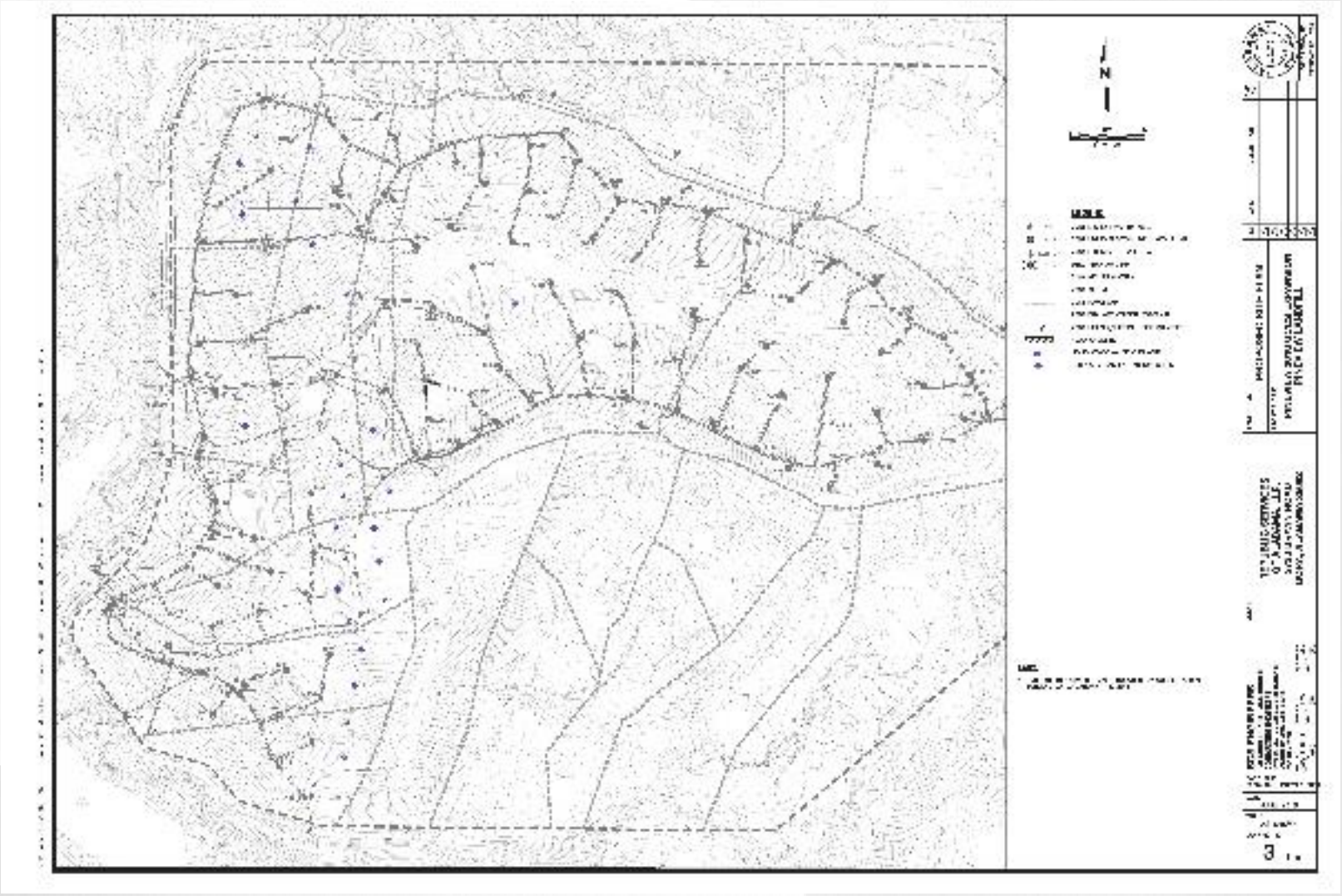
- Rate and Volume of LFG depend on
  - Refuse
    - » Composition
    - » Age
  - Environmental factors
    - » Presence of oxygen in the landfill
    - » Moisture content
    - » Temperature

How Does Landfill Gas Move?

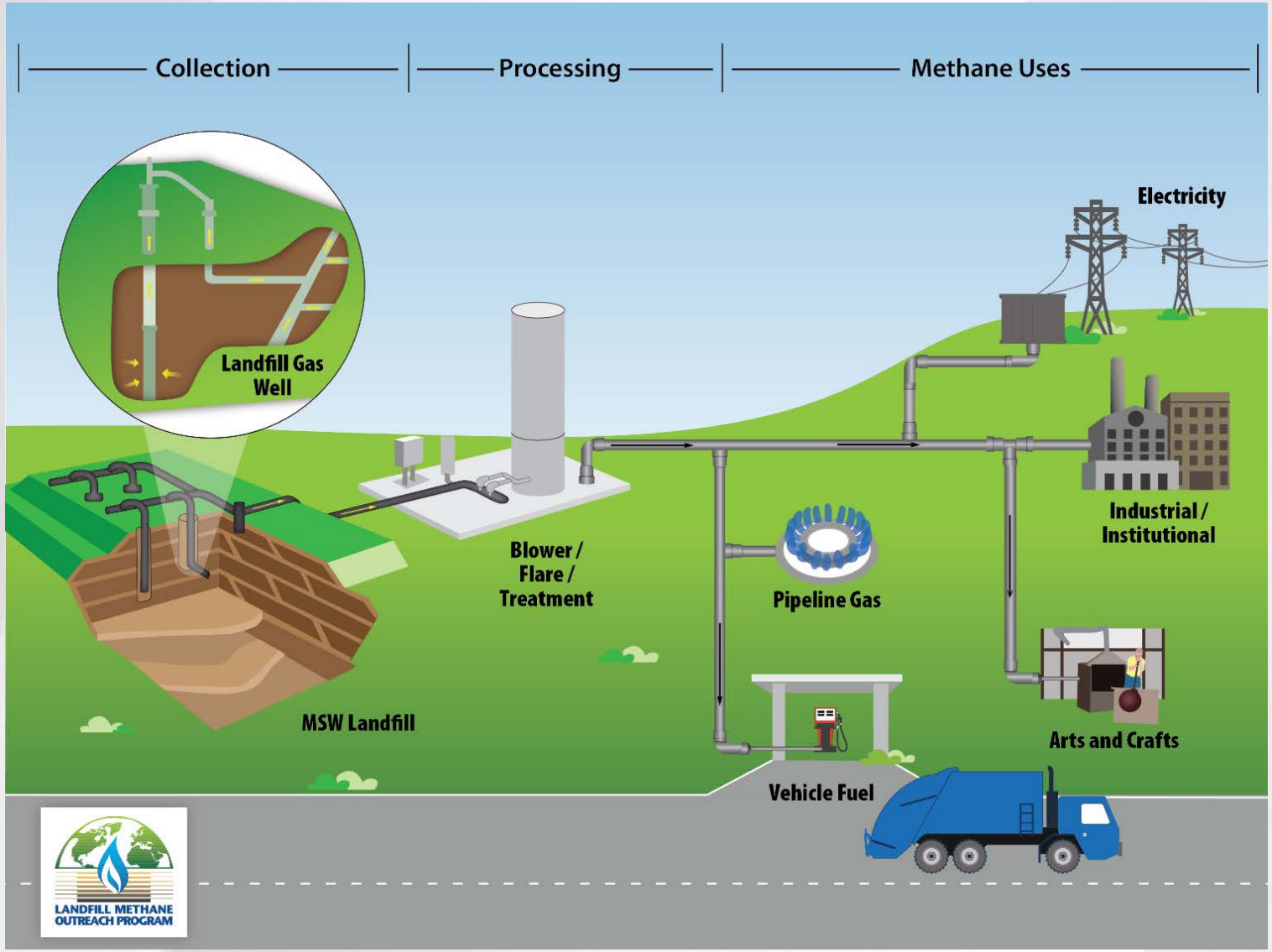
- Diffusion
  - High to low concentration, diffusion out to surrounding areas
- Pressure
  - High to low pressure (convection)
- Permeability
  - High permeability = more movement
  - Dry, sandy soils are highly permeable
  - Moist clay less permeable
  - Landfill covers are often low-permeability soils, like clay
  - Gas in a covered landfill is more likely to move horizontally

Landfill Gas Collection System Design

- Collection Wells
- Collection Headers
- Water Management



Landfill Gas Upgrading Plant



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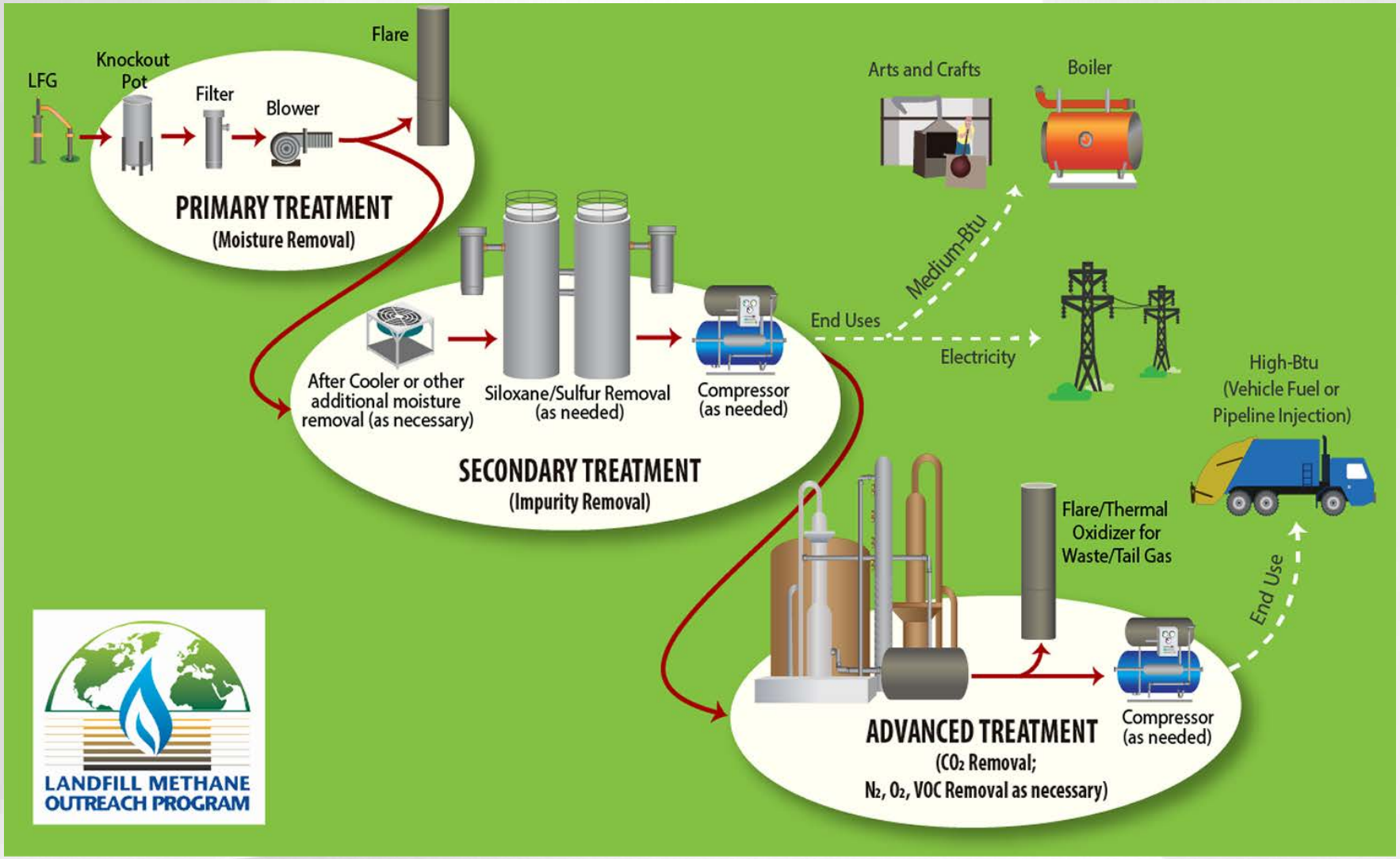


LFG Process Components

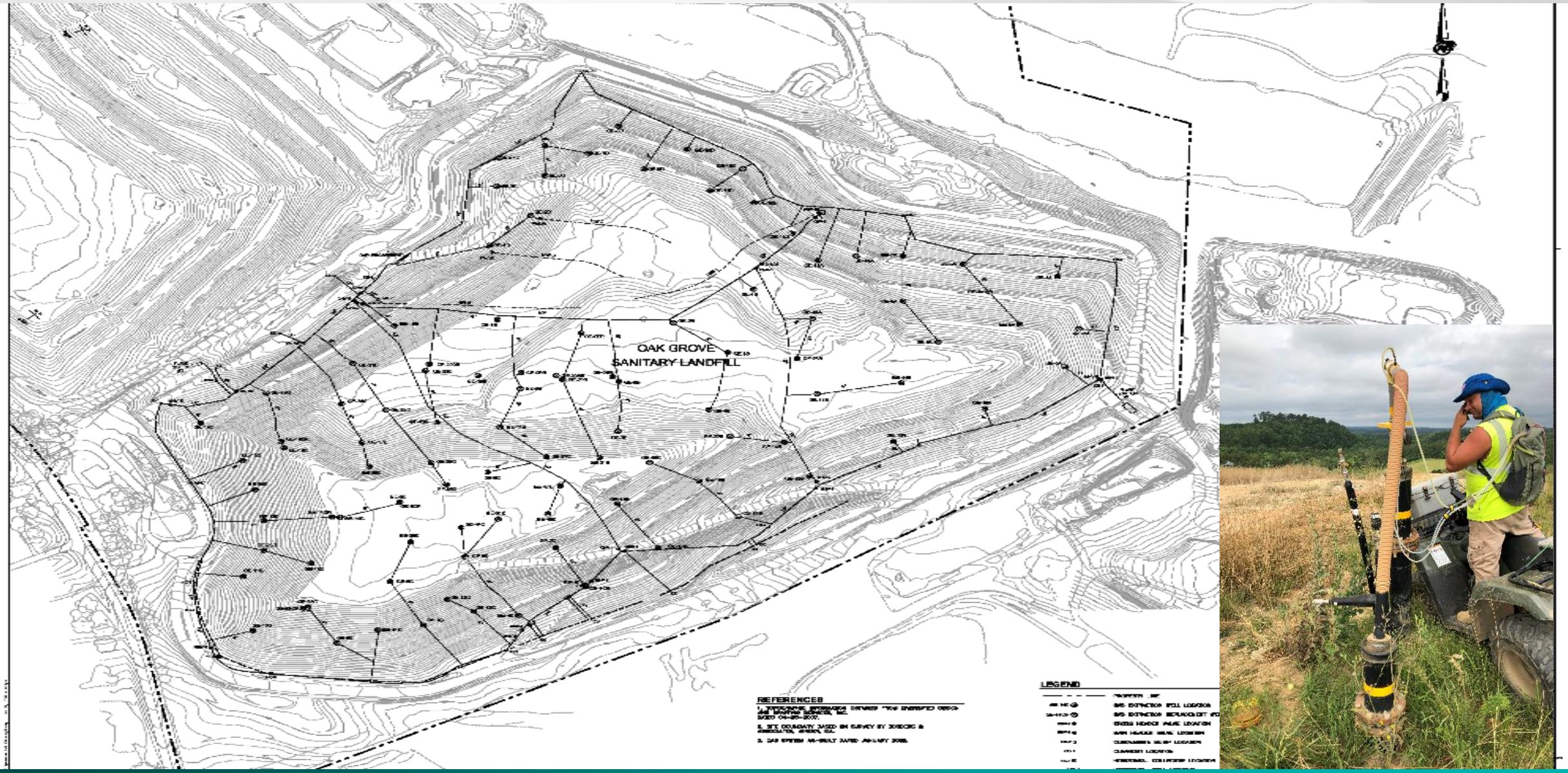
Hydrogen Sulfide Removal

Dehydration

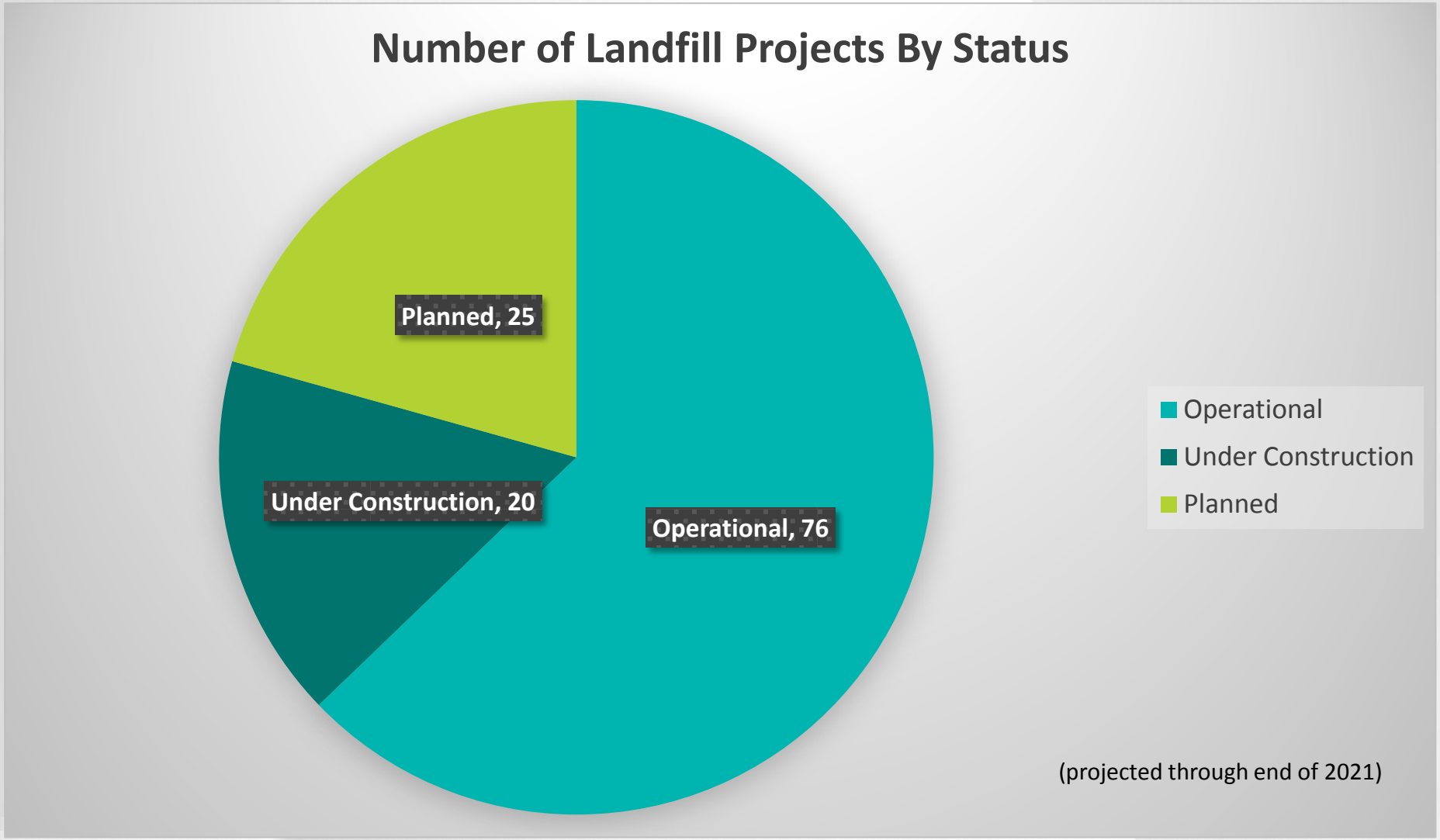
Inlet Gas Compression

Membrane filters

Wellhead Sampling and Tuning to Improve Gas Quality

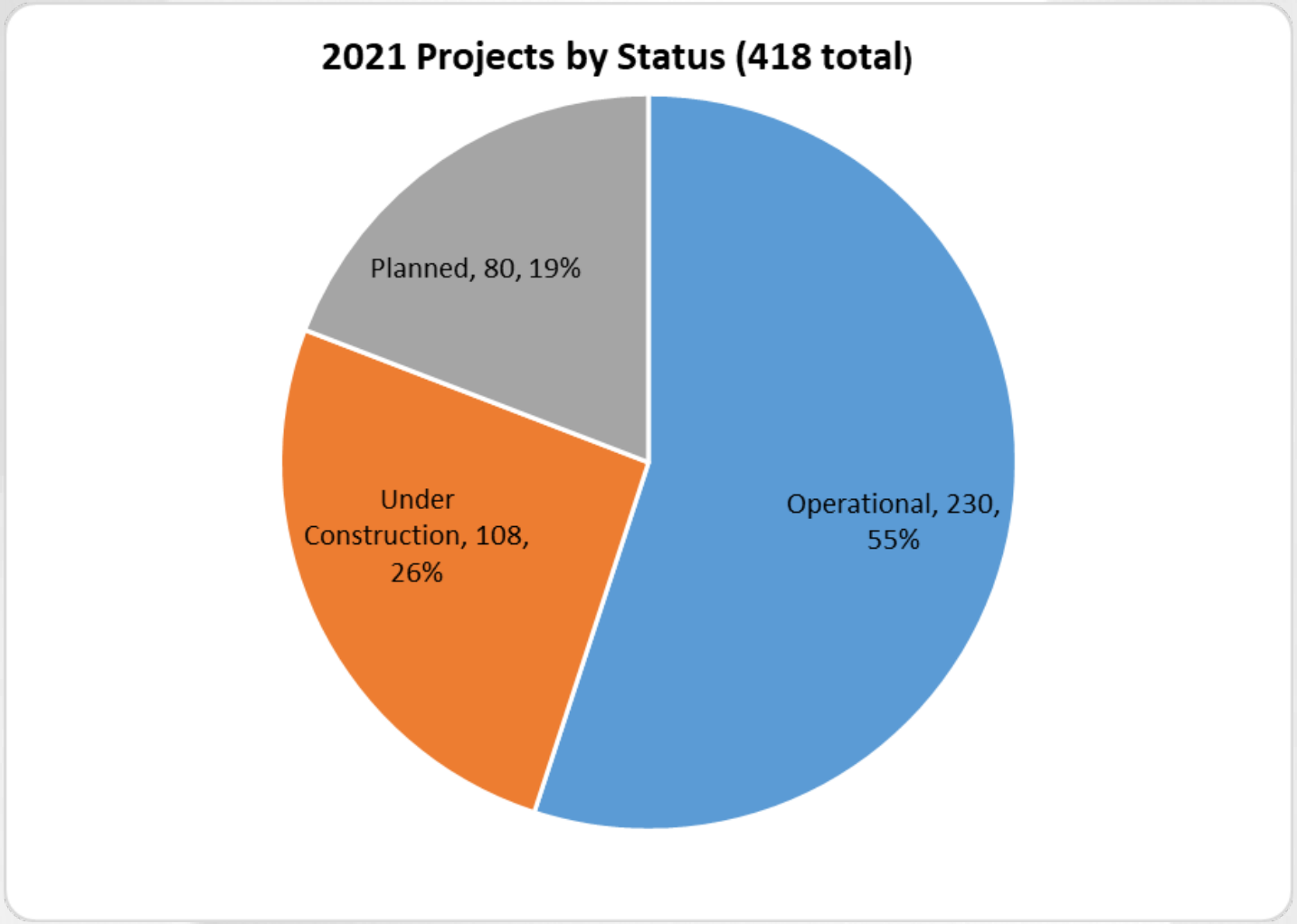


U.S. Landfill Gas Projects



Argonne National Laboratory RNG Database

RNG Projects by Type and Status



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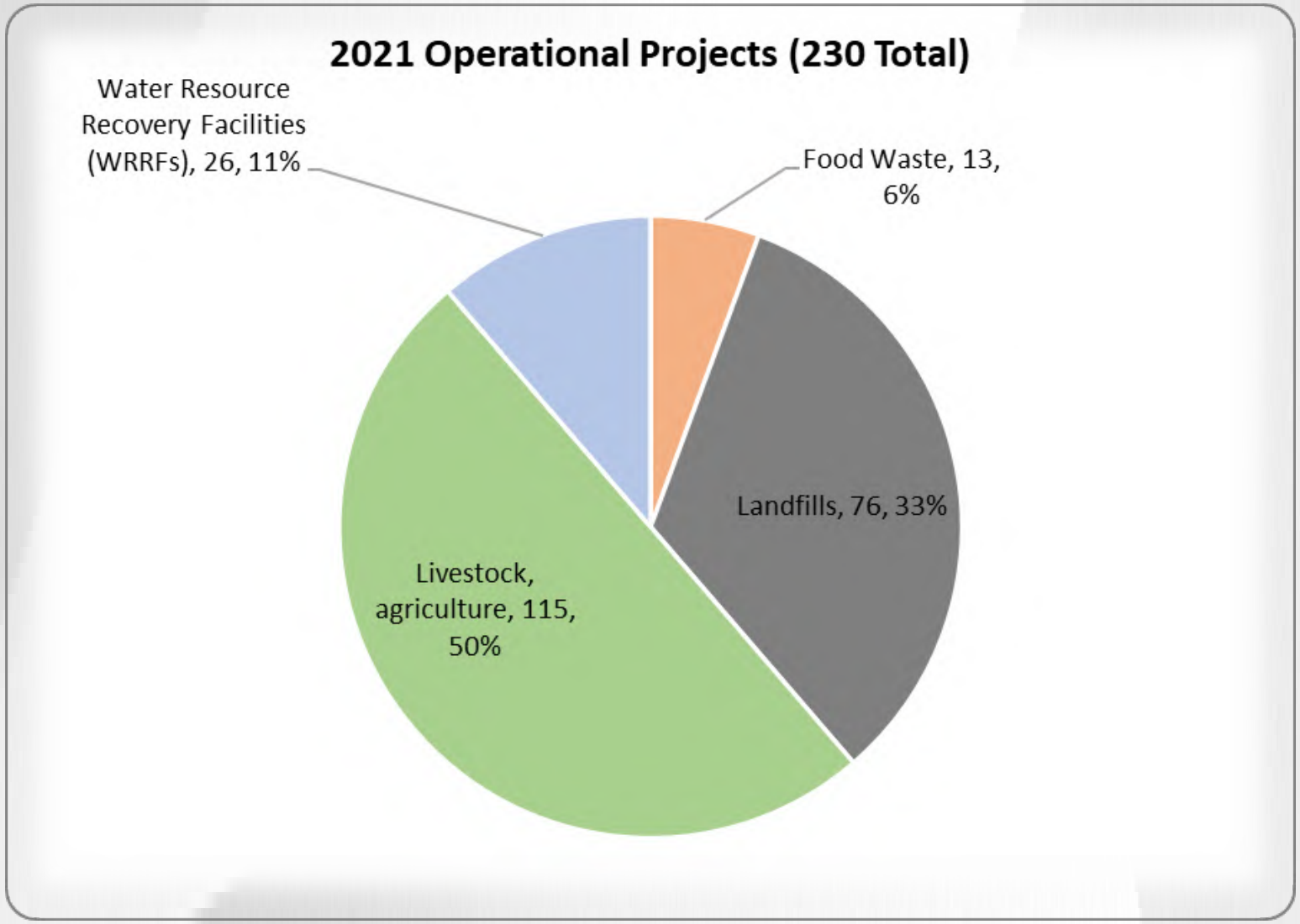

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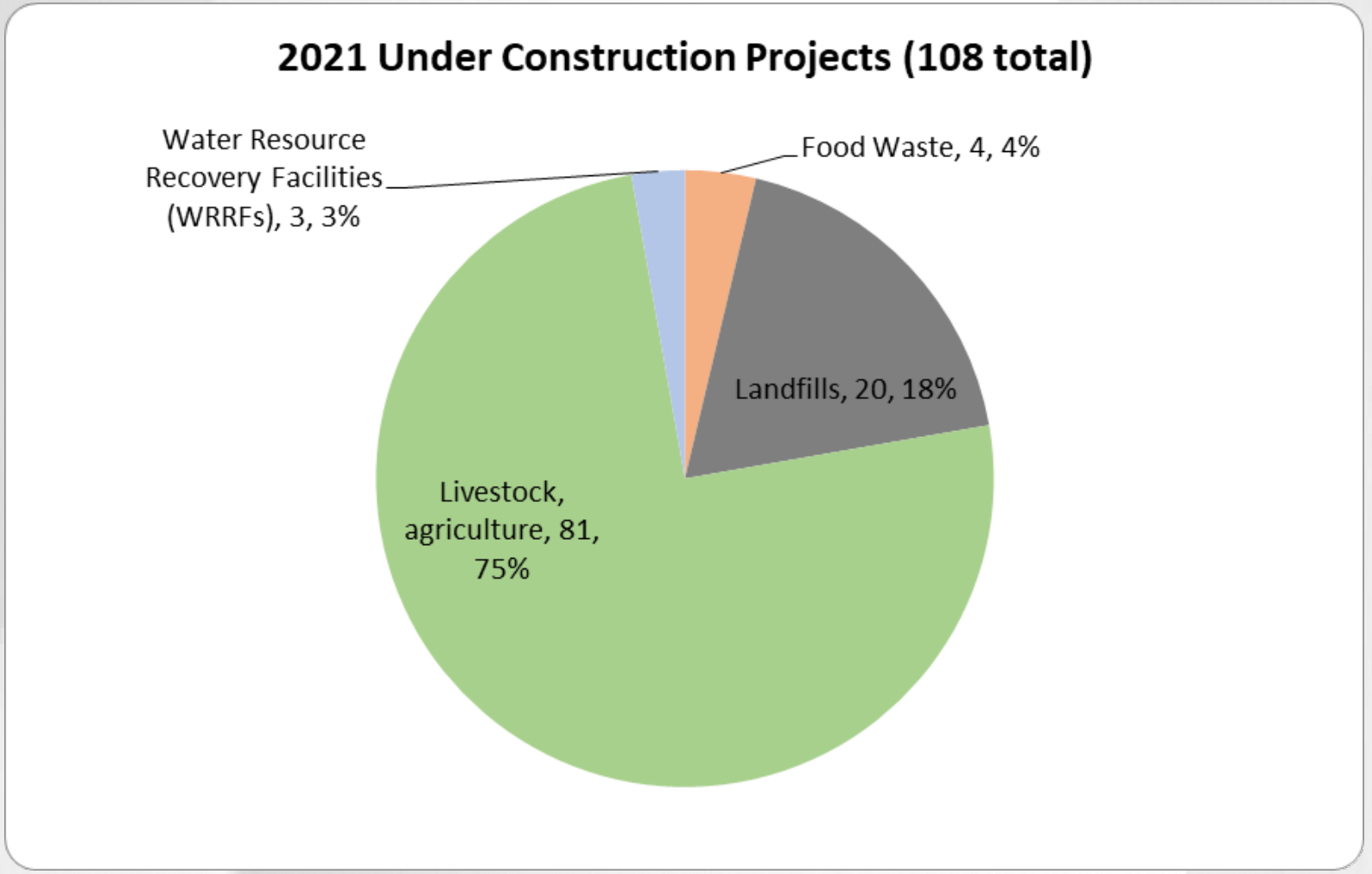

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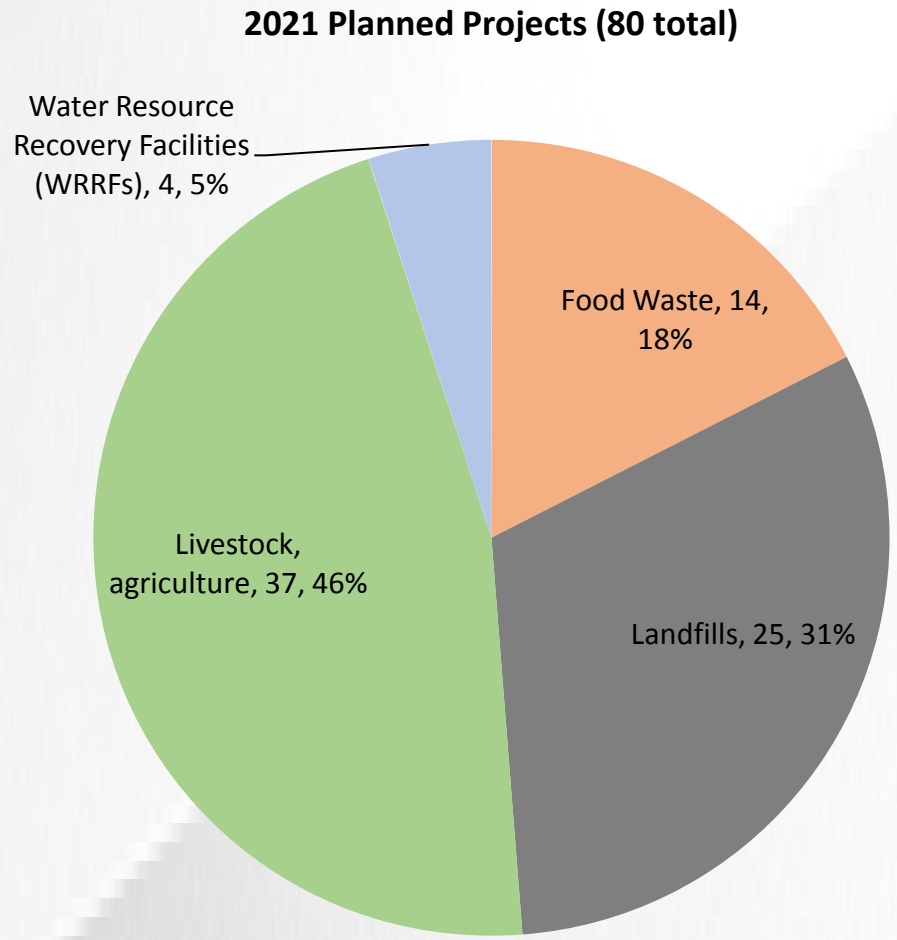


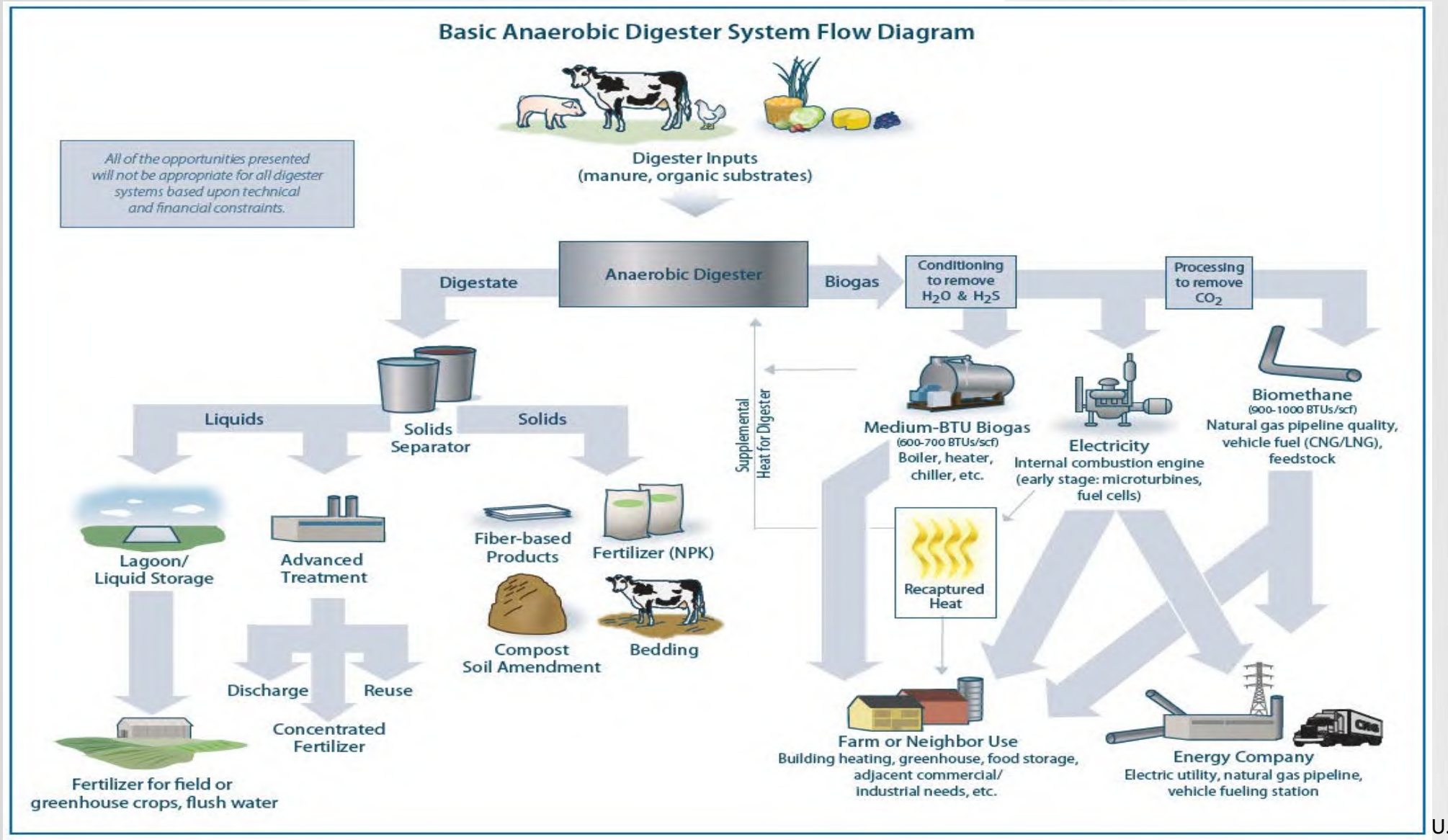
Argonne National Laboratory RNG Database

Anaerobic Digesters

- 317 operational projects in the US (Sept 2021)
  - 265 Dairy
  - 45 Hog
  - 8 Poultry
  - 8 Beef

U.S. EPA

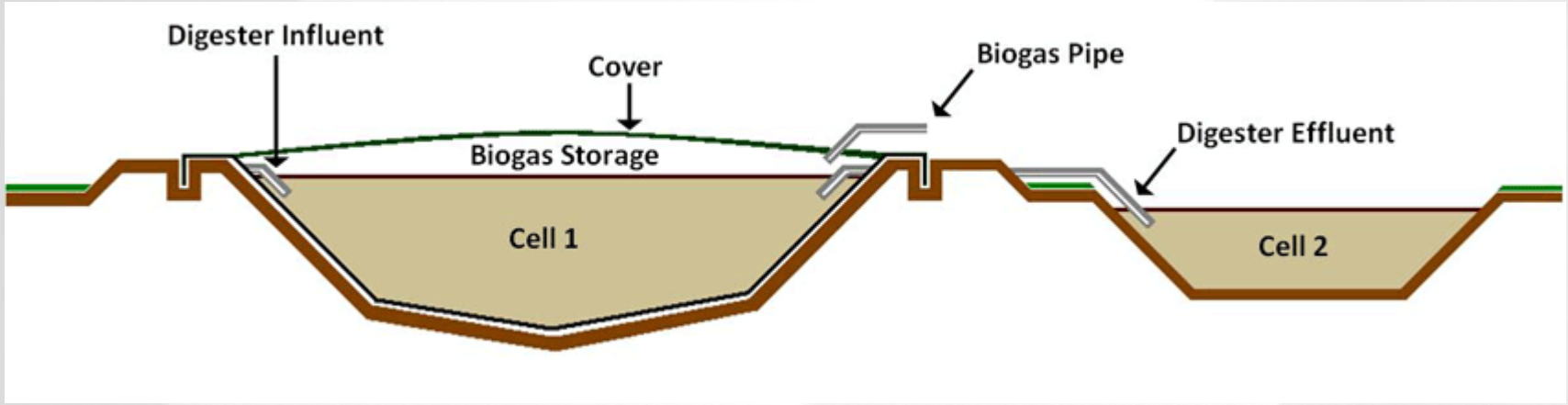
Anaerobic Digesters



U.S. EPA

Anaerobic Digester Types

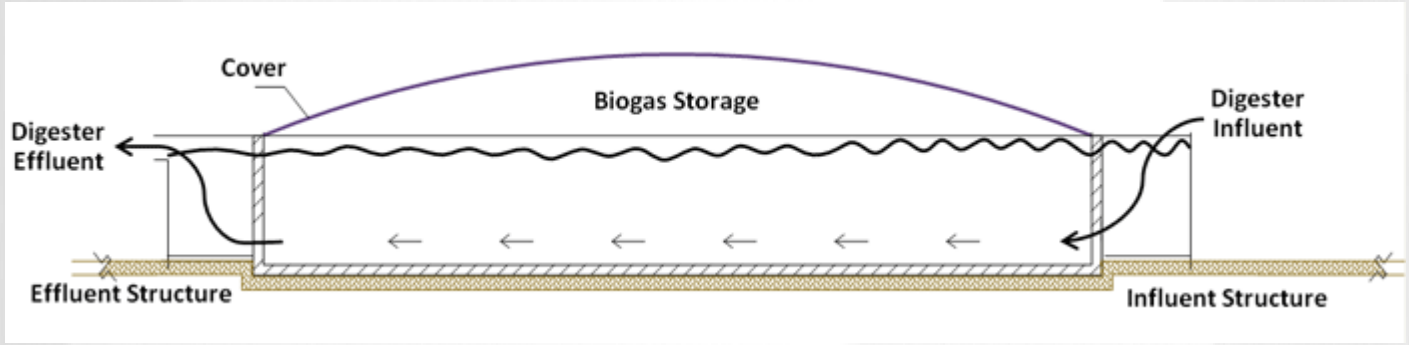
Covered Lagoon



U.S. EPA

Anaerobic Digester Types

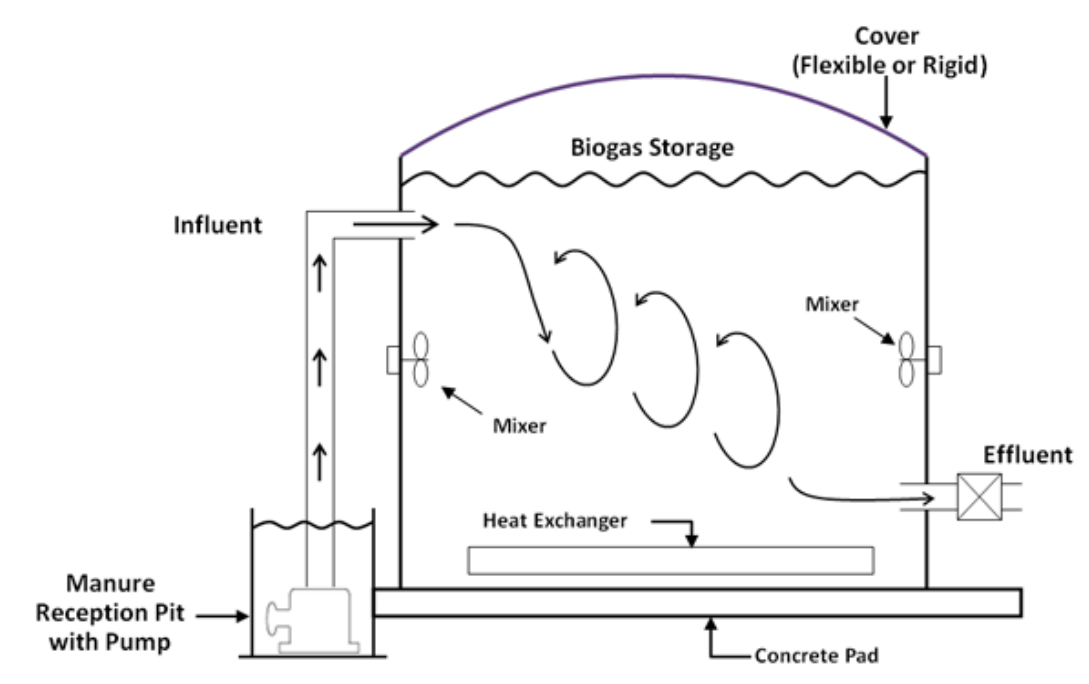
Plug Flow



U.S. EPA

Anaerobic Digester Types

Complete Mix

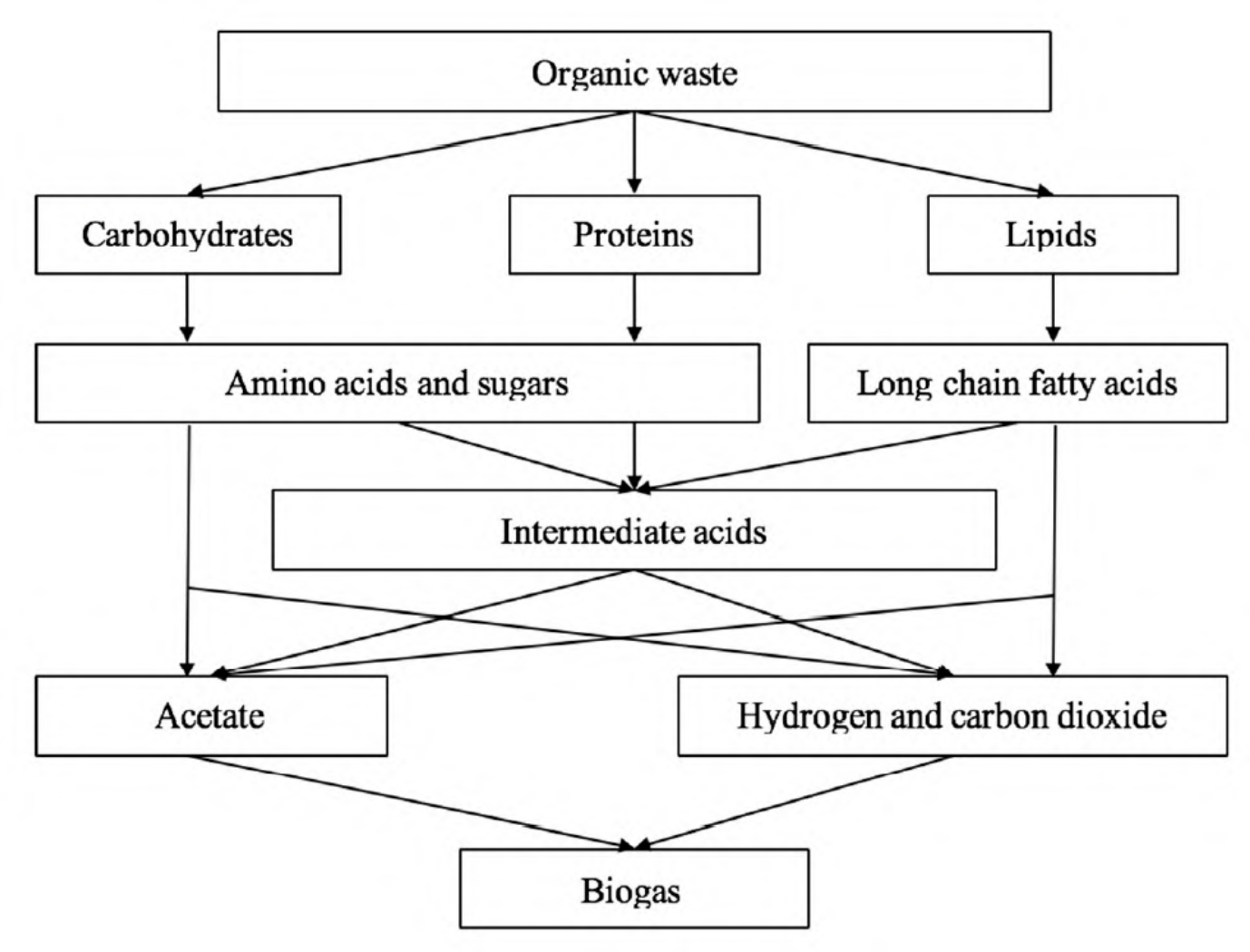


U.S. EPA

Anaerobic Digestion Pathways

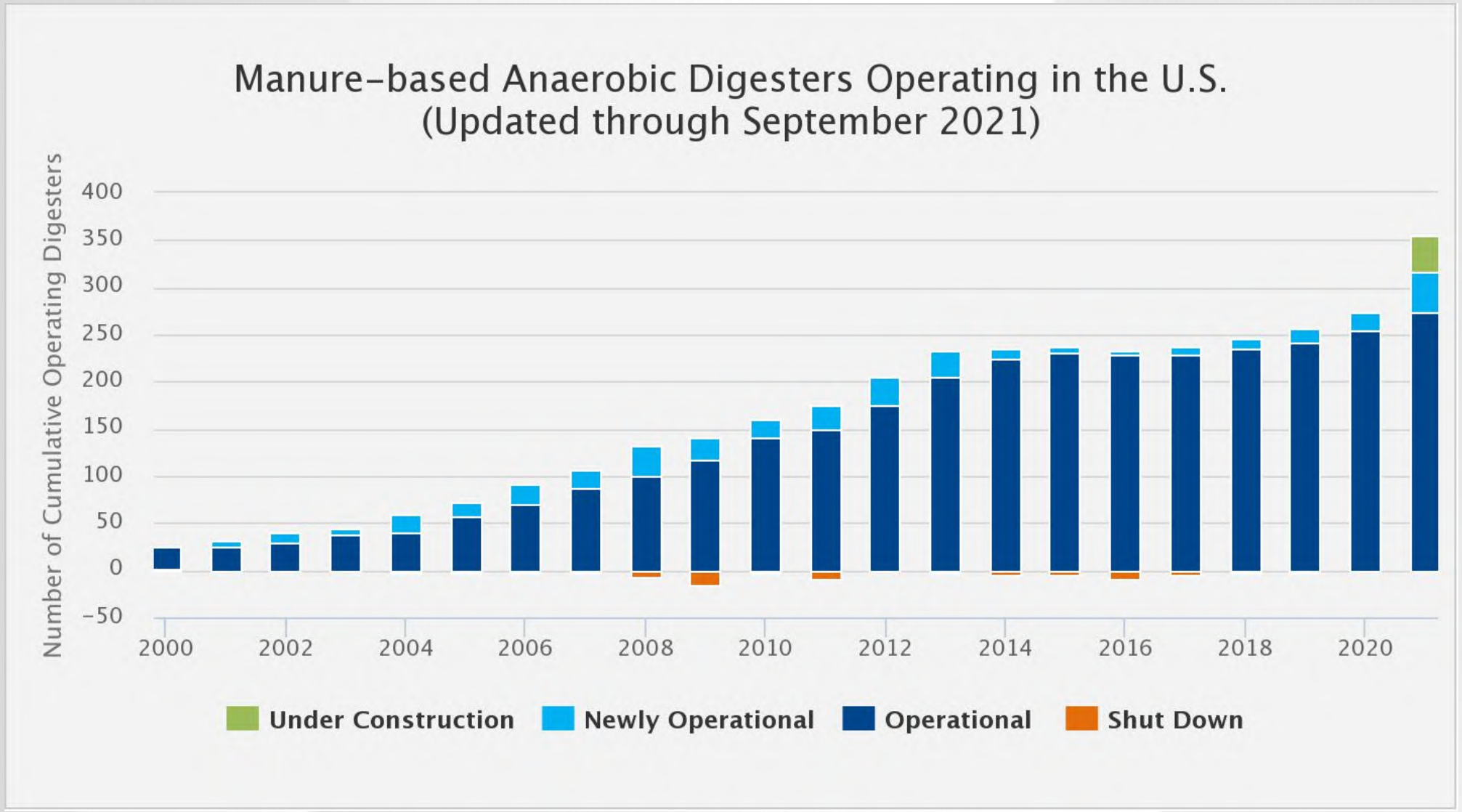
Stages of Anaerobic Digestion

1. Hydrolysis
2. Acidogenesis
3. Acetogenesis
4. Methanogenesis



Meegoda, 2018.

Anaerobic Digesters by the Numbers



U.S. EPA

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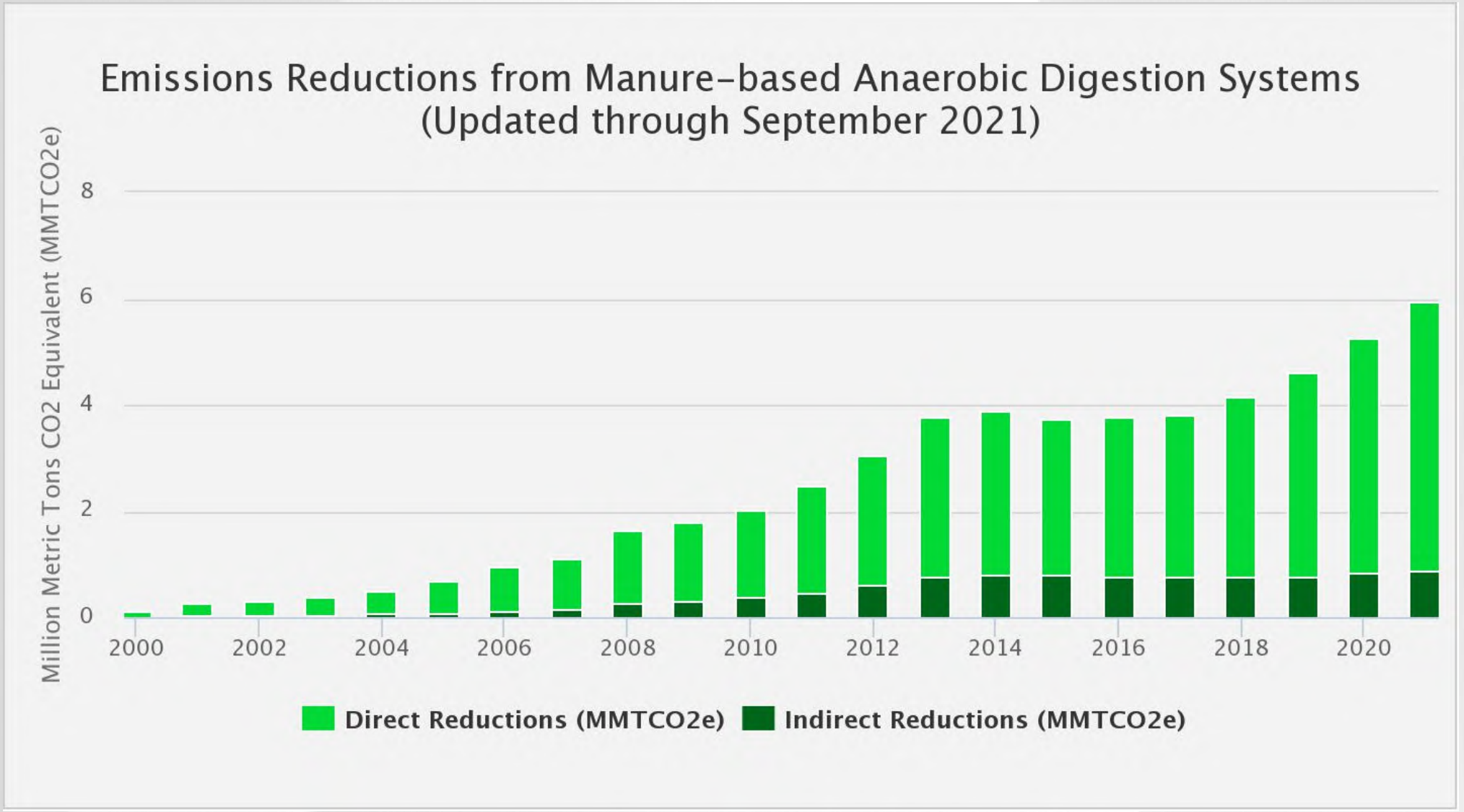

U.S. EPA

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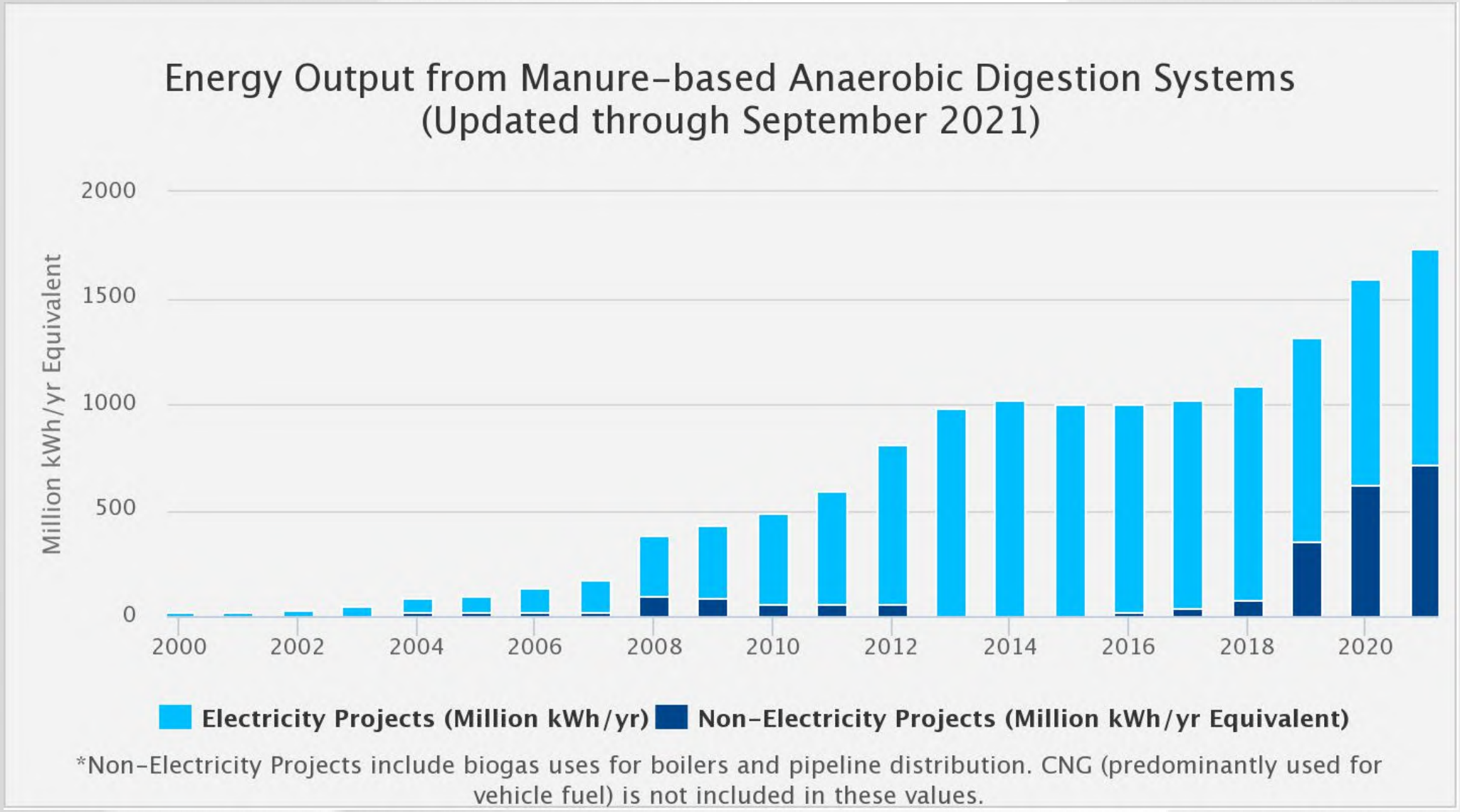

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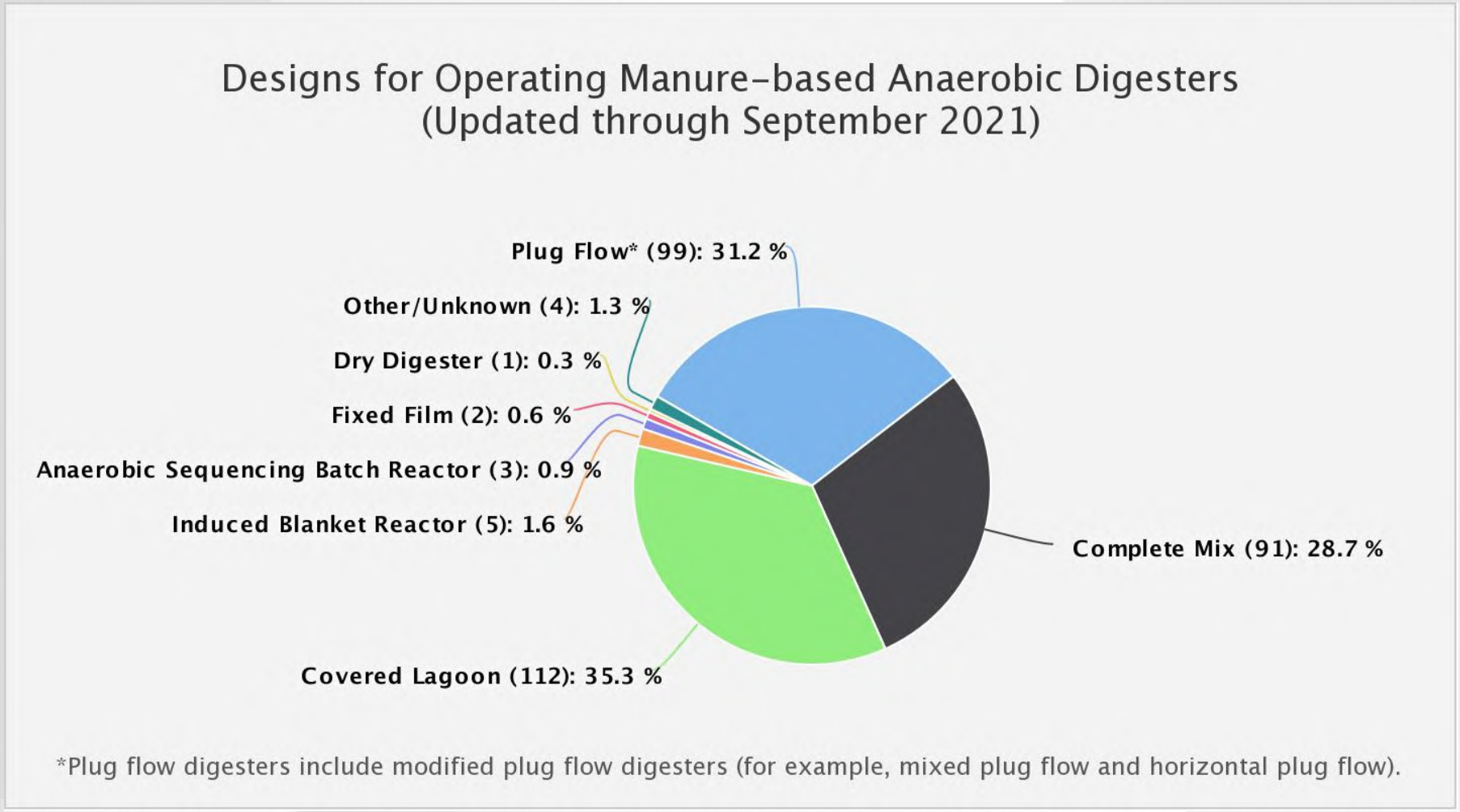

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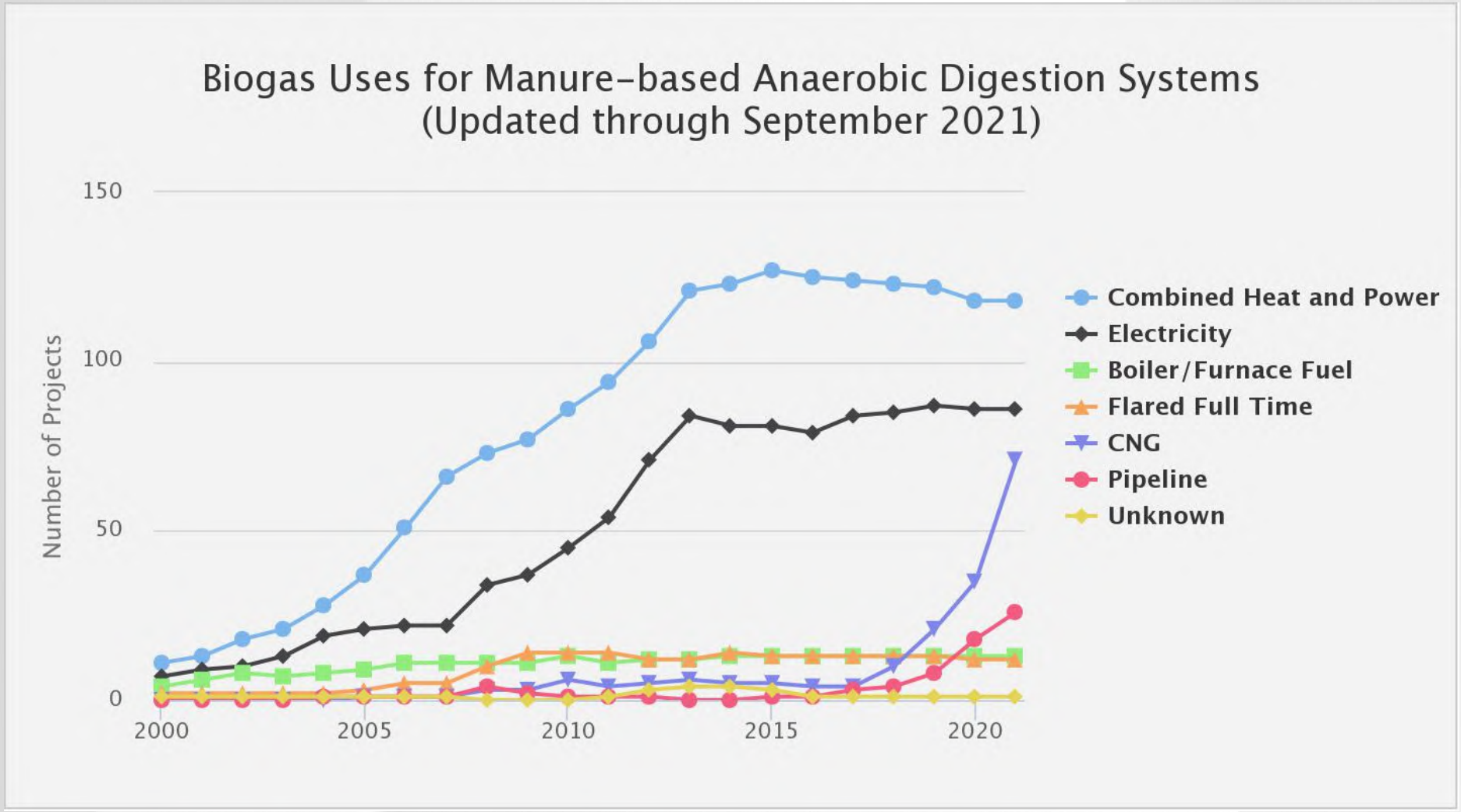

U.S. EPA

What is the Market for RNG?

What is the Market for Renewable Natural Gas?

- **Reduce Greenhouse Gas Emissions**
  - Municipal solid waste (MSW) landfills are the third-largest human-generated source of methane emissions in the United States
  - Many of the technologies and practices that reduce methane emissions also reduce associated emissions of volatile organic compounds (VOCs), odors, and other local air pollutants.
- **Benefit the Community and Economy**
  - Create jobs associated with the design, construction, and operation of energy recovery systems.
    - » LFG projects involve engineers, construction firms, equipment vendors, and utilities or end users of the power produced.
    - » Much of the project costs are spent locally for drilling, piping, construction, and operational personnel.

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What is the Market for Renewable Natural Gas?

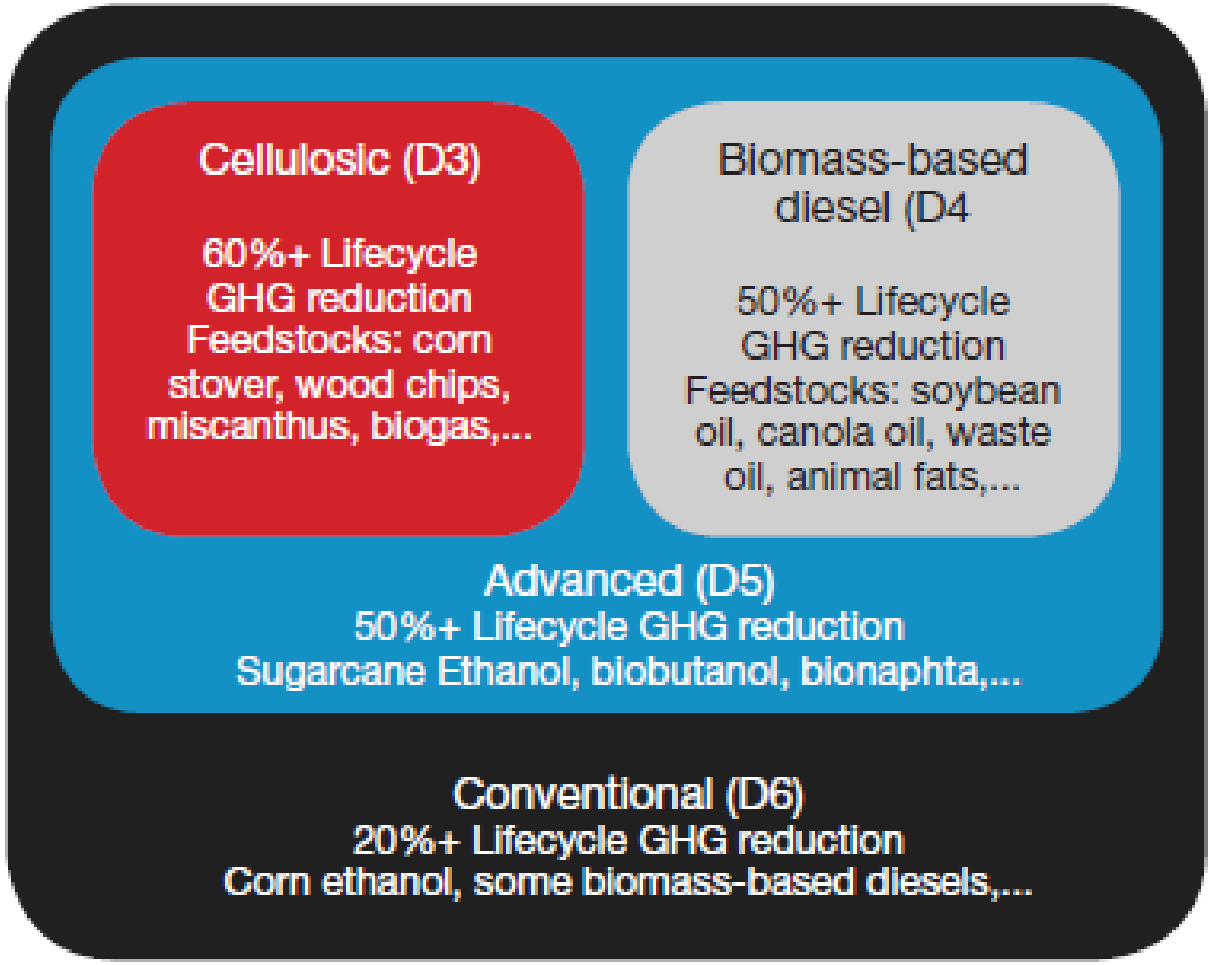
The oil and gas industry pays premium prices for renewable energy in order to meet the obligations of the Renewable Fuel Standards (RFS)

To generate a RIN

- Volume of fuel
- Pathway
- Origin
- Feedstock and amount
- Production date

Mechanics of the Renewable Fuels Standard

What are some types of RINS?



Source: EPA

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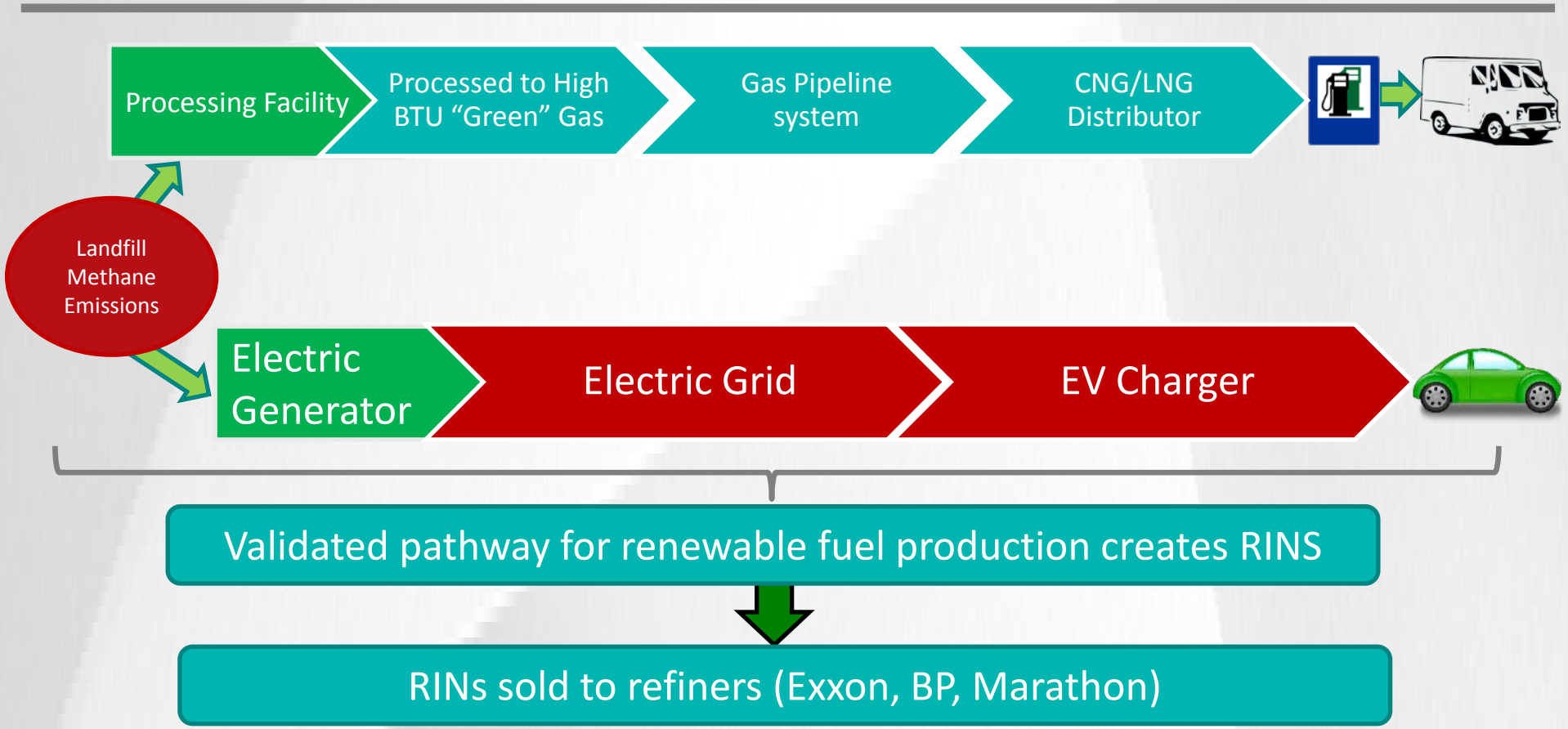
What is the Market for Renewable Natural Gas?

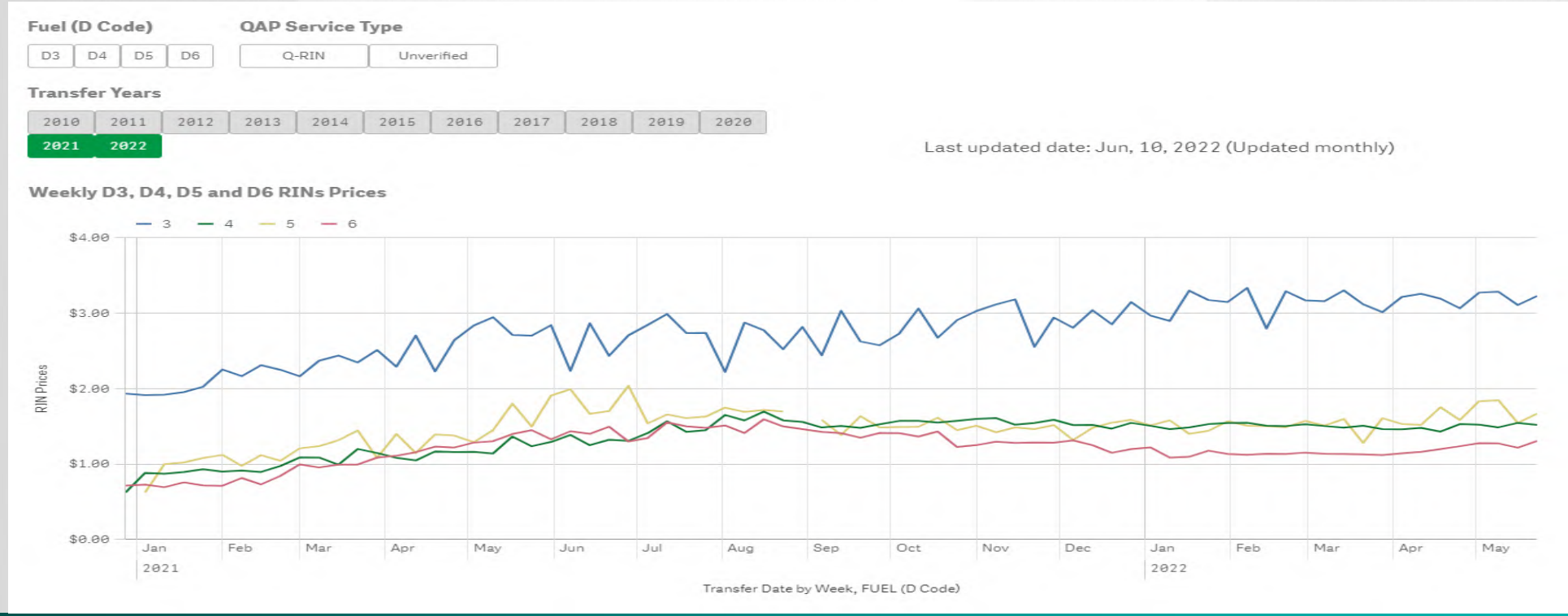
What does a pathway look like?



What is the Market for Renewable Natural Gas?

RINS

- If validated, 11.727 RINS/decatherm
- Volatile since it is based on market forces
- Fluctuates based on changing federal policy - RFS



U.S. EPA

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What is the Market for Renewable Natural Gas?

RINS:

- On 5/23/22, a D4 RIN had a value of $1.48
- By definition, 11.727 RINS = 1 MMBTU
- So, 1 MMBTU of biogas used as transportation fuel for CNG/LNG had a value of $17.36 on 5/23/22
- A 1,000 MMBTU/day RNG facility generates $17,356/day in RIN value alone

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What is the Market for Renewable Natural Gas?

LCFS

- Low Carbon Fuel Standard (California)
- Managed and enforced by the California Air Resources Board
- Purpose: Reduce the average carbon intensity (CI) of California transportation fuels by 20% by 2030.
- CI of a fuel – the amount of GHG emissions associated with is production, transportation, and consumption
- CI of retailed fuels
  - Reduced
  - Or credits purchased as an offset
- 1 LCFS credit = 1 metric tonne of CO_2 reduced

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What is the Market for Renewable Natural Gas?

LCFS

- LCFS credits fluctuate based on changing fuel production pathways - lower carbon intensities (CI)
- Mainly committed to dairy
- Codigestion (dairy manure + food waste/other) gas doesn't qualify

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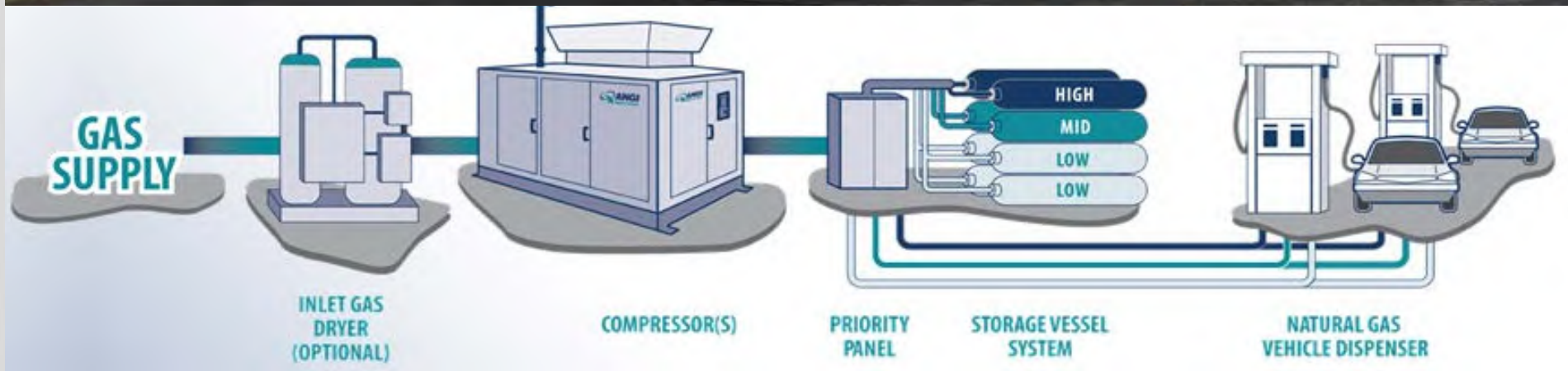
What is the Market for Renewable Natural Gas?

- Since 2014 UPS has added over 3,000 CNG/LNG vehicles to its fleet.
- It is now the largest user of Renewable Natural Gas (RNG) in the U.S. transportation sector.

- Waste Management recently opened its 100th CNG station in Oklahoma City
- Now operates 6,000 CNG trucks, the largest heavy duty CNG fleet in US

What is the Market for Renewable Natural Gas?



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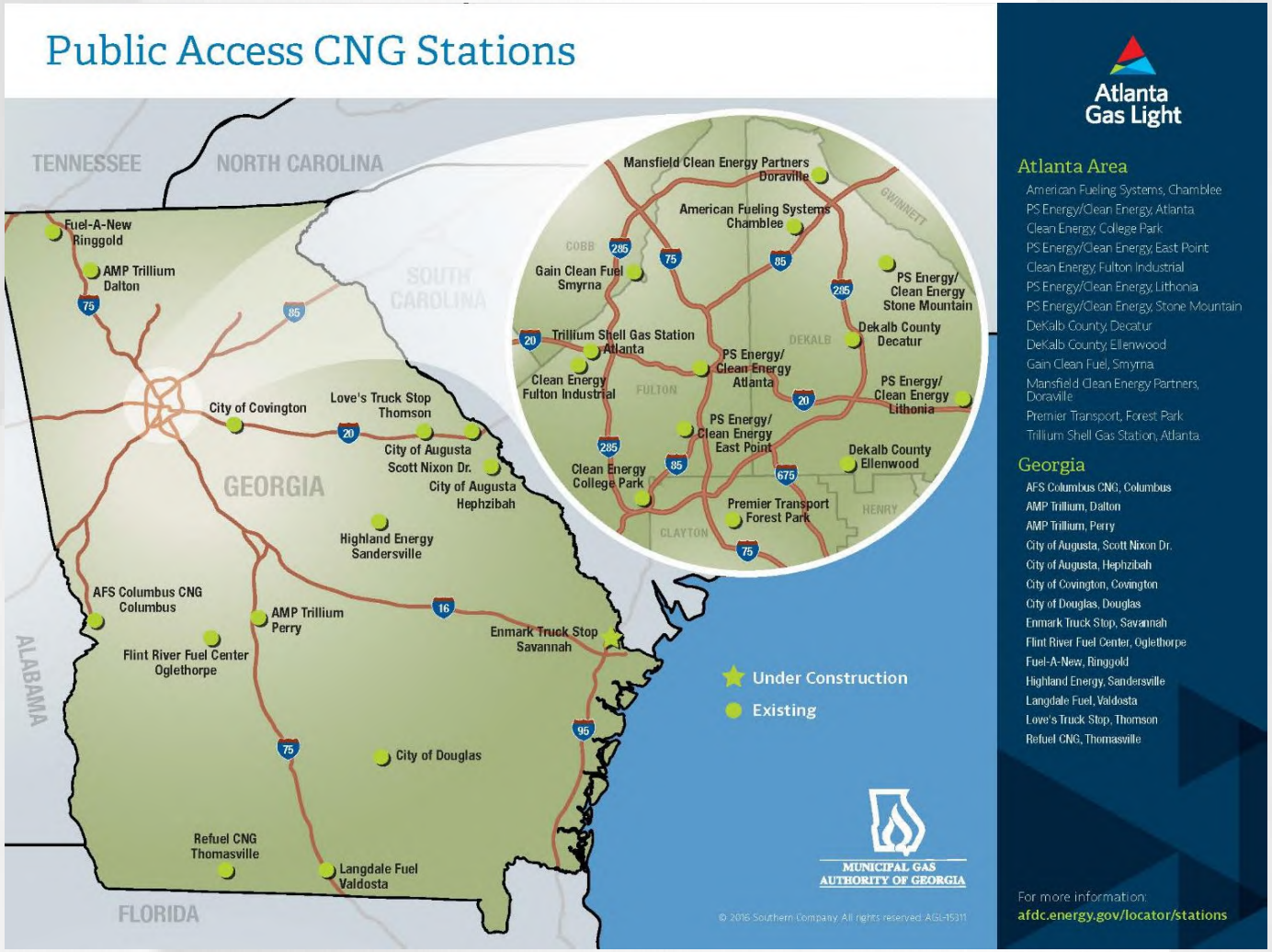


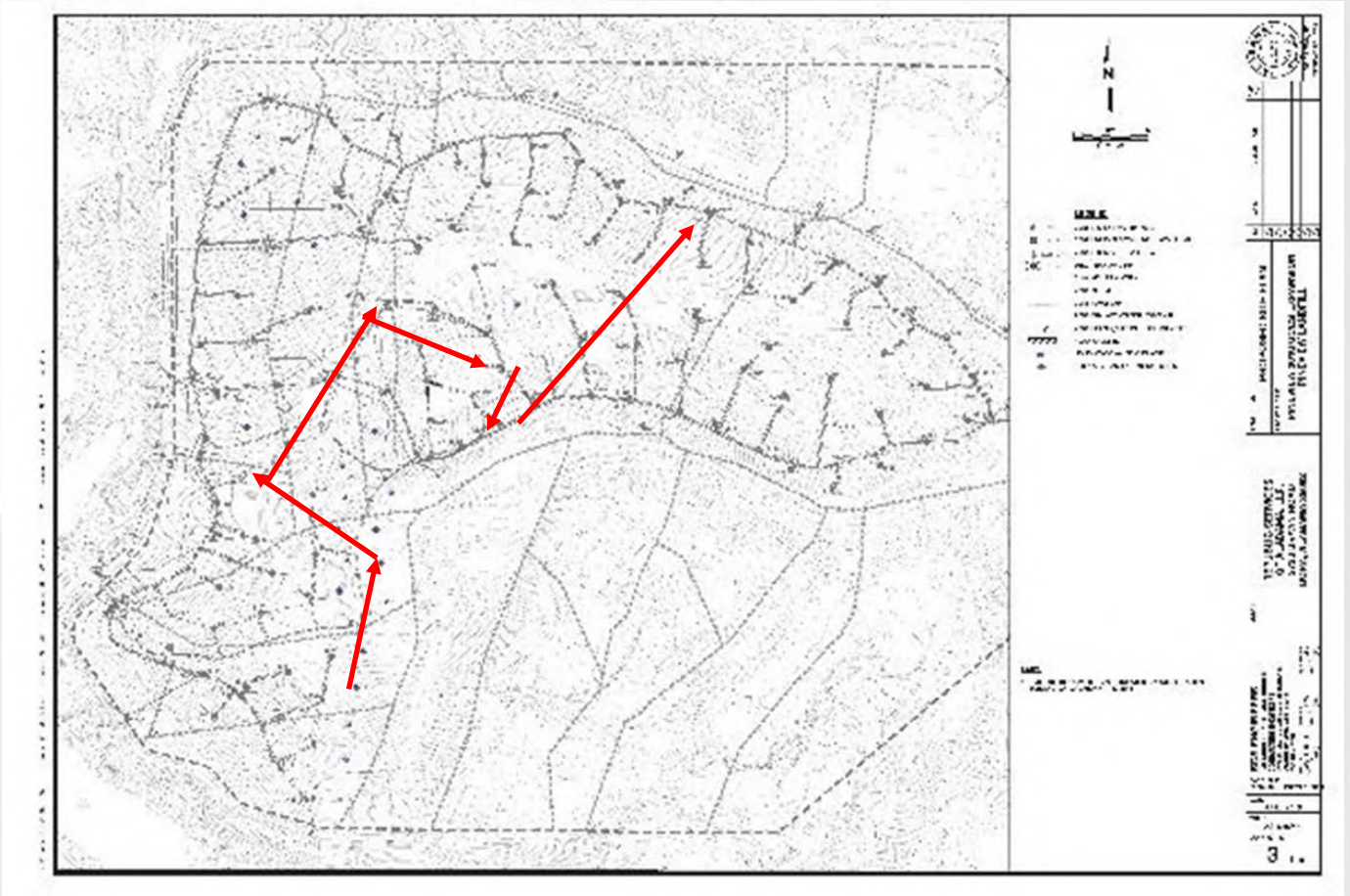
What are some challenges RNG presents?

Challenges: RNG Grid Injection

- Interchangeability: The ability to substitute one gaseous fuel for another in a combustion application without materially changing operational safety, efficiency, performance or materially increasing air pollutant emissions.
- Injection flow vs. baseline flow.

- Planning
- Metering and control
- Instrumentation and control
- Gas measurement
- Custody transfer

Challenges: Maintaining Wellfield Performance



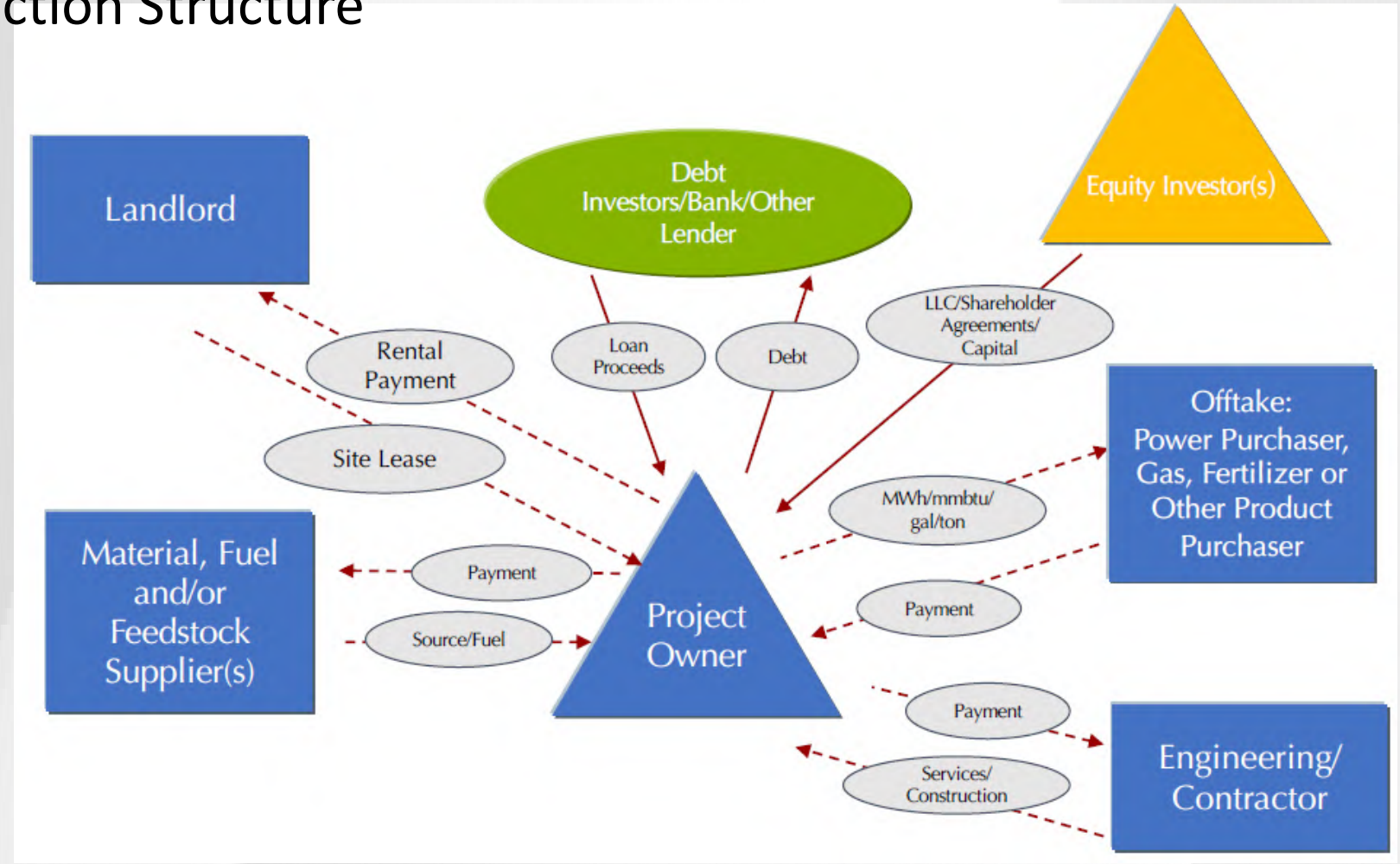
Challenges: Profitability

Finite Renewable Natural Gas Supply

- Farms and landfills with large potential gas volumes are most profitable; most have been developed or will be developed soon
- Smaller site profitability – little to none
- Most sites medium to small
  - Dairy farms - 80% are considered small < 3000 heads of cattle
    - » 60 scfm!
  - Landfills – medium to small range from
    - » 2000-3000 scfm

Challenges: Multiple Parties with Multiple Interests

Simple Transaction Structure



Lamb, 2021

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Challenges: Utility Companies – RNG Pipe Dreams?

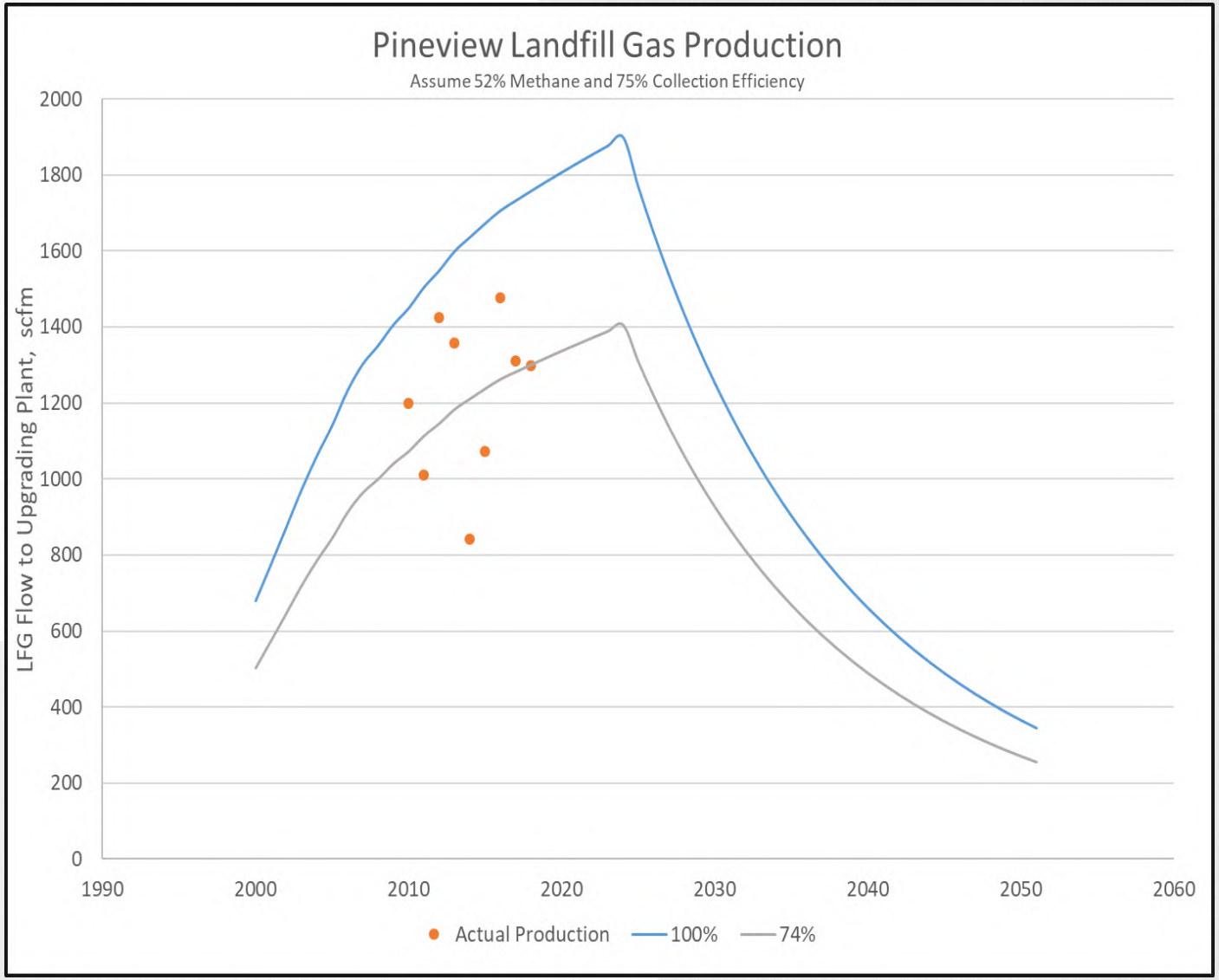
Strengths	**Weaknesses**
• Make, move, sell energy • Access to capital • Natural gas pipeline infrastructure	• Business model adaptation • Need high ROR • Regulated Markets
Opportunities	**Threats**
• GHG reduction • Large customer base • Service territory	• Finite renewable gas supply • Private equity • RNG policies favor the transportation industry

What is Southern Company doing with RNG?

Landfill Gas Project Development

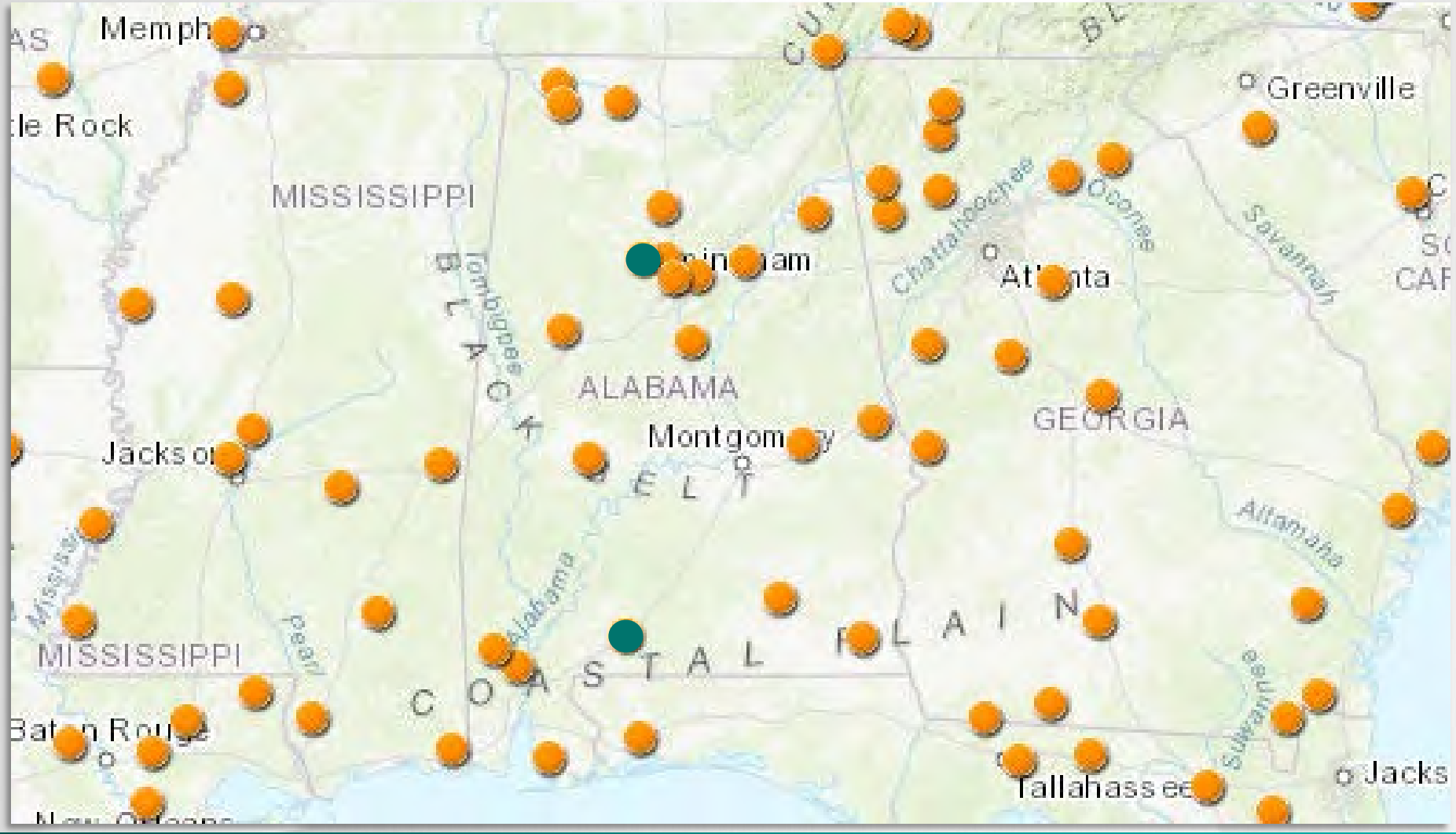
- **Disposal Rates**
  - 30,000 to 400,000 tons per year
- **Types of Waste Accepted**
  - Municipal Solid Waste (MSW)
  - Construction and Demolition (C&D)
- **Gas Generation Rates**
  - Methane Generation Potential, L_o
  - Rate Constant, k

$$Q_{CH_4} = L_o R (e^{-kc} - e^{-kt})$$



Landfill Gas Project Development

Many opportunities within our traditional footprint



RNG Potential

- Carbon offsets
  - Gas production vs. Carbon Offsets
- Hydrogen production through electrolysis

Nicor Gas Renewable Gas Interconnect Pilot

- Any RNG producer can enter into an interconnect agreement with Nicor Gas to deliver RNG through the company's distribution system
- RNG producer and Nicor negotiate benefits and GHG offsets
- Gauge interest, develop insights into economic and environmental benefits
- Permanent interconnect can follow
- An allowance from Nicor Gas of no more than $16 million to help offset the capital costs of interconnection

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Questions?

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Southern Company