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California
Energy Commission

Renewable Natural Gas Research & Development

Energy Research and Development Division

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IEPR Workshop on Renewable Natural Gas
August 31, 2021

Overview

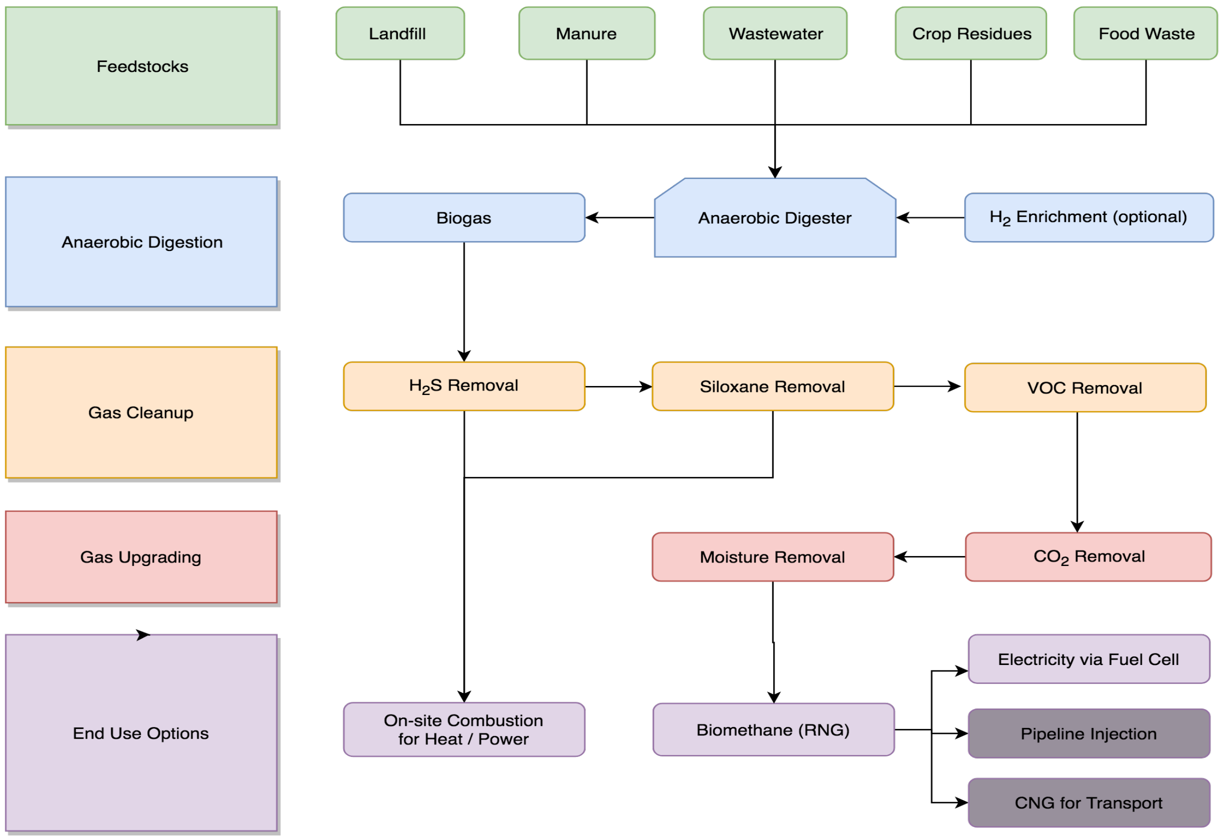
- Renewable natural gas definition
- "Most common" feedstock and conversion pathway
- Three examples of different facilities and applications
- Emerging renewable gas production
- RNG in decarbonized future
  - Resource estimates and projections
  - Select takeaways from an E3 study
  - Revisiting challenges and technological development needs

Defining Renewable Natural Gas

- Renewable natural gas (RNG) could be any of several low-GHG substitute fuels to fossil natural gas. For today's purposes, RNG will refer to biomethane which is a purified form of biogas.

- AB 3163 (Salas, Chapter 358, Statutes of 2020) expanded the definition of biomethane to include:
  - Methane produced from an organic waste feedstock that meets the standards for injection into a common carrier pipeline.
  - Methane produced from the anaerobic decomposition of organic material, including codigestion.
  - Methane produced from the noncombustion thermal conversion of any of the following materials, when separated from other waste: agricultural crop residues; bark, lawn, yard, and garden clippings; leaves, silvicultural residue, and tree and brush prunings; wood, wood chips, and wood waste; nonrecyclable pulp or nonrecyclable paper materials; livestock waste; and municipal sewage sludge or biosolids.

Anaerobic Digestion Pathway to Renewable Natural Gas



Source: J. Loeb/REAG-CEC

Example 1: Food Wastes and Green Wastes Biogas-to-Electricity

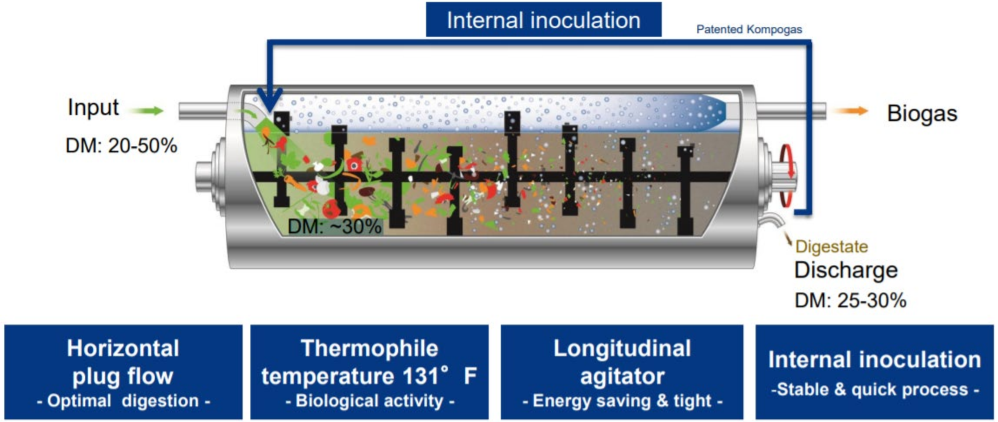


Diagram of horizontal plug-flow digester (Credit: HZIU Kompogas)

Example of green waste feedstock (left) and digestate (right). (Credit: HZIU Kompogas)

> Uses local food wastes and green wastes

- Ave. of 100 tons per day; 36,500 tons per year (TPY)

> Produce renewable electricity for power purchase agreement

- Average 733kW, 85% capacity factor

> Create value-added fertilizer by-products

- 13,000 TPY of solid fertilizer
- 1.6 million gallons of liquid fertilizer

Example 1: Food Wastes and Green Wastes Biogas-to-Electricity

Results by the End of Project Term:

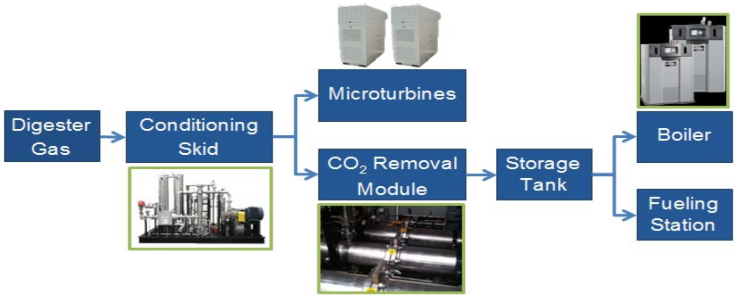
- Fast construction and first generator for BioMAT
- Exported 2,058,698 kWh of renewable electricity
- Processed 31,261 tons of organic feedstock
- Reduced GHG emission by 5151 MTCO2e
- Produced 7,679 tons of solid fertilizer/compost and 1.5 million gallons of liquid fertilizer

Sample Lessons Learned:

- Need for education to support diversion
- Feedstock contamination impacts wear of equipment
- Lower food waste percentages in feedstock stream lowers biogas yields

High-solids anaerobic digestion system designed to meet the organics diversion goals of San Luis Obispo County. (Credit: HZIU Kompogas)

Example 2: Wastewater Biogas-to-Energy System



Simplified schematic of the biogas energy recovery system

Photograph of microturbines, gas cleanup system and digester

(Credit: Las Gallinas Valley Sanitary District)

- Pre-commercial biogas energy recovery system at a small wastewater treatment plant
- Biogas provide renewable electricity, heat, and transportation fuel
- Utilizes a biogas cleanup skid, microturbines, hydronic boiler, and CNG refueling station
- New system replaces aging internal combustion engine and diesel-fueled vehicles with cleaner, more efficient technologies.

Example 2: Small Scale Wastewater Biogas-to-Energy System

Results from the First 12 Months of Operation:

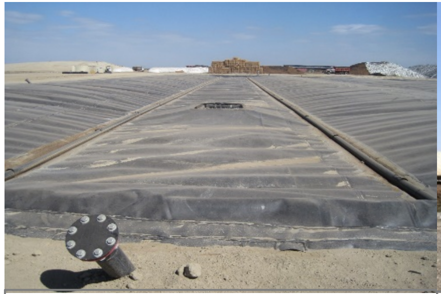
- Average of 33 scfm of biogas production
- Produced 7,700 MMBtu of conditioned digester gas
- Produced 520 DGE of RNG
- Generated ~438,265 KWh of renewable electricity
- Overall system efficiency of 60%

Some Lessons and Opportunities:

- Need for accurate biogas use study
- Verify quantity and quality of digester gas
- Unique engineering and construction challenges
- Knowledge of equipment functionality and selection
- Demonstrated a wide range of possibilities for larger size facilities

Time-fill RNG Station (*top picture*) and Fast-fill CNG station (*bottom picture*).
(Credit: Las Gallinas Valley Sanitary District)

Example 3: Dairy Manure Biogas-to-Energy Systems



Digester Cover Installation
(Hub-and-Spoke Project)

H2S Sponge scrubber
(Biogas Storage Project)

Location of Digester Projects

CHP Cooling Tower & Chiller
(CHP Project)

Three different strategies :

Biogas Storage Project: Two cell digester for producing and storing biogas and generating electricity at times of peak demand

Hub-and-Spoke Project: 1 central hub dairy; 11 nearby spoke dairies transport biogas to hub to process, clean, and generate electricity

CHP Project: Improved energy efficiency by capturing waste heat from power generation system and using for absorption chiller to chill milk

Credit: CalBio / ABEC #2 LLC, ABEC #3 LLC, and ABEC #4 LLC

Example 3: Dairy Manure Biogas-to-Energy Systems

Estimated Impacts of Each Dairy Digester Project:

- 7 - 8 million kWh of electricity exported over 12 months
- 10k - 21k metric tons of CO_2 equivalent reduced per year
- Reduce hydrogen sulfide prolongs engine-generator life
- 20 full time jobs during construction, and 125 at hub-and-spoke cluster
- $120,000/month net income, with 7- to 8-year payback period

Key Lessons and Opportunities:

- Business model breakthrough in dairy bioenergy operation
- Technology improvements resulted to Increased biogas production and electricity generation
- 20-year utility contract and incentives is key to bioenergy economics
- Use and optimization of the air injection system
- Explore improved solids separation methods
- Expanding on-farm use of waste heat from generators

Credit: CalBio / ABEC #2 LLC, ABEC #3 LLC, and ABEC #4 LLC

Emerging Method for Upgrading Biogas to RNG

❑ Efficient Biogas Upgrading Technology Based on Metal-Organic Frameworks (MOF)

Sample of composite MOF pellets for exposure testing (top); tableted MOF adsorbent (bottom-left); Slipstream testing apparatus at the biogas site (bottom-right)

- A solid-state amine scrubbing technology for biogas upgrading
- Sorbent material (called metal organic framework or MOF) tested over long-term repeated cycling.
- Removed CO_2 down to ≤2% for 1000+ cycles without capacity loss
- 38% reduction in OpEx, 14% reduction in CapEx vs. standard chemical scrubbing system
- New technology will enhance biomethane with increased efficiency and reduced the cost

Credit: Mosaic Materials, Inc. (Grant Recipient)

Exploring the Potentials of Woody Biomass to RNG

Production of Renewable Natural Gas and Value-Added Chemicals from Forest Biomass Residues

- Catalytic upgrading of syngas to RNG.
- Lower wholesale cost of RNG with low carbon intensity of less than 15 grams CO2eq per MJ.

West Biofuels Catalytic Synthesis Reactor System

Source: West Biofuels, LLC

Renewable Syngas Methanation

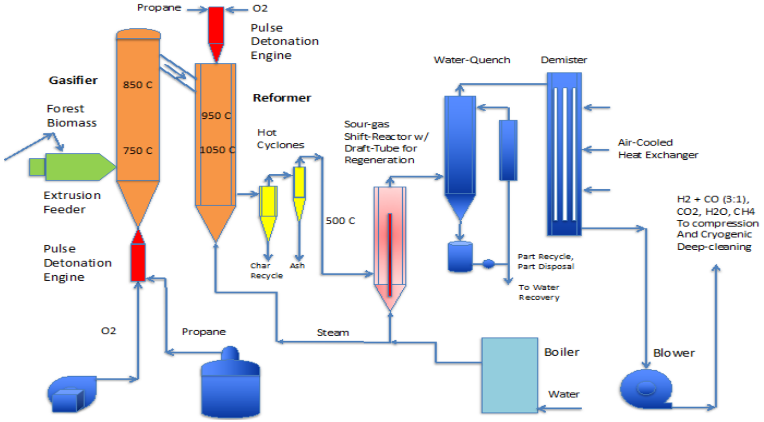


Diagram of Gasifier and Syngas Methanation System
Source: Taylor Energy

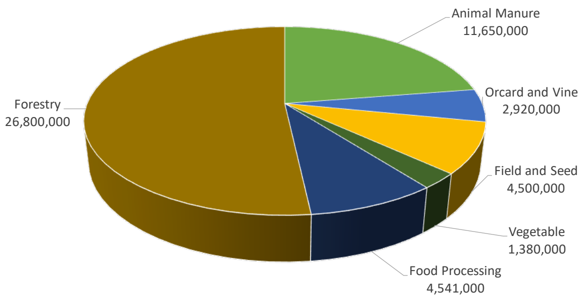
- An autothermal-gasification process designed to convert forest-biomass into renewable natural gas.
- Gas shift methods, cryogenic deep-cleaning and methanation while producing RNG with 990-1150 BTU/scf and with low sulfur content.

RNG in a Decarbonized Future

❑ Different Estimates of Biomass Resource Potentials

- Biogas potential from animal manures, landfill gas, anaerobic digestion of food, leaves and grass from MSW disposal stream, and wastewater treatment plants = *93 billion cubic ft/year*
- Gross resource – 78 million bone dry tons per year (BDT/y)
- Available on a technically sustainable basis – 35 million BDT/y

California Gross Biomass Resource Potential (BDT/yr), 2013 data



Source: California Biomass Collaborative, UC Davis. https://biomass.ucdavis.edu/wp-content/uploads/CA_Biomass_Resource_2013Data_CBC_Task3_DRAFT.pdf

Table A-1: California Biomass Availability for Different Data Sources (Millions of Dry Tons per Year)

Biomass Type	CEC/UC Davis*: 2013 resource	CCST[5]: 2050 resource, baseline scenario	CCST: 2050 resource, high-biomass scenario	E3 assumptions: 2040 resource
Wastes & Residues	31.0	36.1	77.1	28.0
Energy crops	*Not included*	*4.5*	*45.7*	*Not included*
Total Excluding Energy Crops	31.0	36.1	77.1	28.0
Total including assumptions about imported biomass from rest of U.S.	*Not included*	*Not included*	*Not included*	43.3

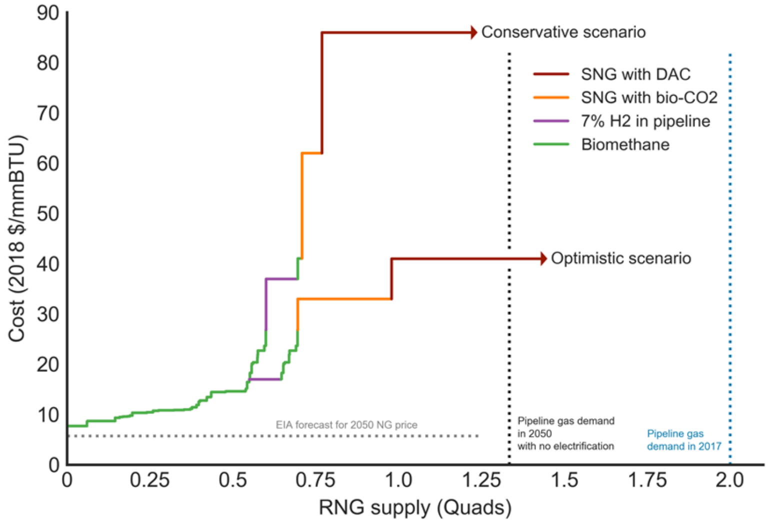
*Does not count landfill or wastewater treatment gas, which are not listed in dry tons. As with the previous table, numbers from the Bioenergy Association of California (BAC) document prepared by Rob Williams of UC Davis are used, which are based on prior CEC work. However, the numbers in the BAC document for agricultural waste biomass availability are slightly lower than what is listed in the CEC reports (8.7 million vs 12.1 million dry tons).

Source: E3, 2019. California Energy Commission. Publication Number: CEC-500-2019-055-F. https://www.ethree.com/wp-content/uploads/2021/06/CEC-500-2019-055-AP-G.pdf

RNG in a Decarbonized Future

❑ Select Takeaways from the E3 2019 Study

- Millions of gas customers remain on the gas system through 2050.
- Use of fossil fuels like natural gas will need to decrease by 80 percent or more by 2050.
- Any scenario that meets California's climate policy goals uses some amount of renewable natural gas
- Biomethane is limited in availability based on sustainable sources of biomass feedstock.
- Reserve the inexpensive portions of biomethane for energy-intensive sectors of economy that do not have efficient, electrified substitutes readily available.



California RNG Technical Potential Supply Curve in 2050, Assuming All Biomass Is Directed to RNG (Source: E3, 2019. CEC-500-2019-055-F)

RNG in a Decarbonized Future

❑ Revisiting Select Lessons Learned and Development Needs

- Feedstock supply quality, availability, and cost, including process and management scale and logistics
- Improving efficiency of biogas clean-up and upgrading technologies
- Improving processes for managing wastes and co-products, e.g. solids separation
- Performance validation for emerging RNG production technologies, e.g. woody feedstock to RNG
- Cost and efficiency improvements for RNG downstream equipment

Other considerations:

- High capital cost of process equipment (e.g., digester, clean-up and upgrading)
- Relatively low RNG yields vs high availability and low cost of fossil natural gas
- Gas quality requirements for pipeline and onsite use
- Training and education