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RNG Market

Sources, Potential, and Costs
**TERMS**

» Biogas – methane from renewable sources but not necessarily pipeline quality

» Biomethane– biogas that has been further processed to pipeline quality

» RNG – Biomethane that has been compressed and injected into a pipeline for use to replace natural gas

» Formed anaerobically (no oxygen) from renewable sources such as:
  • Animal manure
  • Wastewater Treatment Plants (WWTP)
  • Landfill Gas (LFG)
  • Forestry & Crop waste
    - Can also be through gasification or pyrolysis

  • Potentially from crops; but such isn’t usually classified as renewable by California
NATURAL GAS USE

» Source:
• California Energy Demand 2020 - 2030 Baseline Forecast - Mid Demand Case
Usage is 12,000 MM Therms
• A little over half by buildings; will electrification reduce?
• Transportation could consume more

Technical potential is capturing every feasible methane molecule

See Slide in appendix for sources
Anaerobic digesters are used to process and sterilize waste from:
- Manure from dairies and swine farms
- Wastewater Treatment Plants (WWTP)
- Municipal Organic Waste (e.g., food scraps and lawn clippings)

Heating content of biogas often much lower than RNG
DAIRIES

» Source: EPA and LCFS

» 889 Dairies with Over 500 Cows

» Some in industry think minimum herd size is more like 1,500-2,000
  • Current average is over 5,000 cows for digester sites

» ~100 more in construction
**WASTEWATER TREATMENT PLANTS**

- Required to flare

- Facilities with an Anaerobic Digester (AD) have 10x the average design flow as those without

- Known uses of biogas are largely generation

- Difference ‘Has AD’ vs ‘Known to be Using Biogas’ is largely due to unknown uses
Larger Landfills (>450k tons) are required to collect methane and destroy it.

Siloxanes (compounds from breakdown of plastics) need to be removed.

Sulfides (particularly H₂S) also need removals.
LANDFILLS

» Source: EPA LMOP (Landfill Methane Outreach Program) and LCFS

» Candidate:
  • Accepting waste or closed five years or less
  • At least one million tons of waste (note >450k tons require gas collection)

» Future Potential:
  • Landfill is open but does not meet criteria for Candidate status yet

» Low Potential:
  • Landfill is closed and
  • Does not meet criteria for Candidate status;
  • or other site-specific information.
BIOMASS

» Source: University of California Woody Biomass Utilization Group

» Most used for generation

» Current driver likely the BioMat Feed-In-Tariff generation program (more this afternoon)

» SB 1440 (Biomethane) may drive more towards pipeline injection
CURRENT SOURCES

» Using LCFS historical data as a proxy
IN VS OUT OF STATE SOURCES

» Based on CARB LCFS Pathways
• Proxy for RNG Supply

<table>
<thead>
<tr>
<th>Source</th>
<th>In State</th>
<th>Out of State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landfill Gas</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Dairy Manure</td>
<td>10%</td>
<td>90%</td>
</tr>
<tr>
<td>Swine Manure</td>
<td>10%</td>
<td>90%</td>
</tr>
<tr>
<td>Wastewater</td>
<td>10%</td>
<td>90%</td>
</tr>
<tr>
<td>Urban Landscaping Waste (n=1)</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>HSAD Food &amp; Green Waste (n=2)</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Food Scraps/Waste (n=1)</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Other Organic Waste (n=1)</td>
<td>100%</td>
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RNG Market: Sources, Potential and Costs
EXPECTED COMMODITY COSTS
From 2019 AGF Report

» Nationwide estimates

» Based on bottom-up estimates

» Only commodity, not transportation

» Actual contract pricing likely to vary with source and term

<table>
<thead>
<tr>
<th>Source</th>
<th>Cost ($/MMBtu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landfill</td>
<td>$13.00</td>
</tr>
<tr>
<td>WWTP</td>
<td>$16.75</td>
</tr>
<tr>
<td>Biomass</td>
<td>$22.85</td>
</tr>
<tr>
<td>Dairy</td>
<td>$25.50</td>
</tr>
<tr>
<td>MSW</td>
<td>$30.75</td>
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What would have been done in the absence of a program (the counterfactual)?

- Venting – methane released to the atmosphere
- Flared – methane destroyed by burning

THE SOURCE MATTERS FOR CARBON

<table>
<thead>
<tr>
<th>Source</th>
<th>LCFS Bio-CNG Average Carbon Intensity (gCO2-e/MJ)</th>
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<tbody>
<tr>
<td>Swine Manure Vented</td>
<td>-347</td>
</tr>
<tr>
<td>Dairy Manure Vented</td>
<td>-309</td>
</tr>
<tr>
<td>Waste Water Flared</td>
<td>19</td>
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<tr>
<td>Wastewater Sludge Flared</td>
<td>37</td>
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<tr>
<td>Landfill Gas Flared</td>
<td>45</td>
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<tr>
<td>North American Fossil NG</td>
<td>79</td>
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<tr>
<td>N/A</td>
<td></td>
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RNG Market: Sources, Potential and Costs

VERDANT
Both LCFS and RFS are variable->risk

Dairy has significant differences

One long-term RNG contract price estimate is $18/MMBtu
- Actual pricing will vary based on term, location, source, etc.
SUMMING IT UP

» Dairies have significant potential in both production and carbon reduction

» Landfills and Wastewater plants provide lots of volume
  • SB 1383 could drive this up

» Biomass could be another large source

» Policies can influence
QUESTIONS?

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stephan@verdantassoc.com
www.verdantassoc.com
THANK YOU
BIOMASS PROCESSING

» Collection can be significant barrier

Gasification:

» Can also process through digestion
SOURCES

» Potential:
  • UC Davis: Jaffe et al., June 2016
  • EFI: Energy Futures Initiative; Pathways for Deep Decarbonization, May 2019
  • AGF: American Gas Foundation, Renewable Sources of Natural Gas, December 2019
    Also costs
  • CEC Tech: Rob Williams and Stephen Kaffka, UC Davis, presentation to the CEC on January 30, 2017

» $18/MMBtu RNG: Supporting letter by ENERGY VISION 138 East 13th Street New York, NY 10003 for Reply Comments of Southern California Gas Company (U904g) to Assigned Commissioner’s Ruling Seeking Comments on Implementation of Senate Bill 700 and Other Program Modifications in CPUC Rulemaking 12-11-005 (Filed November 8, 2012)