Gasification Technologies and
Low Carbon Renewable Natural Gas (RNG) from Wood Wastes

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California Issues Need Solutions

> Local air quality continues to be exacerbated by black carbon and conventional air pollutants produced from open burning of agricultural wastes and from forest fires.

> Aggressive mandates for GHG and CO₂ emission reductions in all energy sectors is creating an expanded need for low and zero carbon fuel for transportation as well as for residential, commercial and industrial energy consumers.

> More options needed for storable renewable energy – ready when needed.

> Low and zero carbon fuel options to provide dispatchable power generation.

> More and nearer term reduction of conventional and GHG emissions from the heavy duty vehicle sector.

> Reduction of conventional pollutants in economically disadvantage areas.

> Biomass power plants that process wood wastes to produce electricity continue to close, there is now more wood wastes in California than places to have it processed, thus, leading to open burning of agricultural wastes in the San Joaquin valley and rampant forest fires throughout the State every year.
What is Gasification? How Can it Help!

> Thermal conversion of wood waste with a limited supply of air or oxygen, into a synthetic gas, or syngas.

> It’s not combustion; there’s no burning. Gasification uses only a fraction of the oxygen that would be needed to burn the material.

> An ash/slag remains as a residual – Little to no un-reacted carbon char remains.

Products (syngas):  By-products:
CO (carbon monoxide)  CO₂ (carbon dioxide)
H₂ (hydrogen)  Solids (minerals from fuel)
(CO/H₂ ratio can be adjusted)

Gasification of wood wastes to produce renewable natural gas (RNG) can:
> Reduce production of black carbon statewide
> Produce a very low or negative carbon fuel
> Provide an easy to store energy source
> Produce RNG, to power dispatchable renewable electricity
> Substantially lower GHG emissions in the heavy-duty transportation sector today
> Reduce criteria pollutants by 99% (compared to existing biomass power plants)
> Provide processing for millions of tons of California wood waste every year
Example of Using Existing Infrastructure to Optimize the Energy Value of Biomass

**Issue**
- Capital-intensive projects improve economics by increasing scale.
- Biomass has a low energy density and is disperse.
- Need to aggregate large amounts of biomass sustainably.

**Option**
- Piggy-back – go to the biomass (forest industry).
- Use the biomass at maximum conversion efficiency.
- Make a fungible product for a vast market.
- Use existing infrastructure to get the product into the economy.
Project Structure

> Funding provided by California Air Resources Board, Southern California Gas, Pacific Gas and Electric, Northwest Natural and Sacramento Municipal Utility District

> RNG technology team of world experts in gasification, gas clean-up, and conversion technologies.

- GTI : *Leader in biomass conversion and syngas processing, developer of commercial gasification technology*

- Black & Veatch : *Leading global engineering & construction firm* - 10,500 employees worldwide

- ANDRITZ : *Global supplier of equipment and services including gasification systems* – 25,000 employees worldwide

- Haldor Topsoe : *World leader in catalyst production and methanation* – 2700 employees

- Stockton Biomass Power Plant (DTE Energy Services) : *DTE Energy Services provides biomass power and RNG production throughout North America*
The RNG process

- Dry the biomass with waste heat
- Feed dry biomass to gasifier
- Remove tars and dust
- Shift to get $\text{H}_2:\text{CO}$ ratio $= 3:1$
- Compress to pipeline pressure
- Remove acid gases including $\text{CO}_2$
- Convert syngas to methane
- Remove remaining moisture
Final RNG Product Composition

<table>
<thead>
<tr>
<th>Component</th>
<th>Composition</th>
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<tbody>
<tr>
<td>Methane</td>
<td>95 - 97%</td>
</tr>
<tr>
<td>CO</td>
<td>10 ppm</td>
</tr>
<tr>
<td>CO₂</td>
<td>0.6 - 0.9%</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>1.0 – 1.5%</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>1 – 2%</td>
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</table>

NO ISSUES WITH POTENTIALLY PROBLEMATIC TRACE CONSTITUENTS
Final RNG Composition can be Changed with Adjustments to the Methanation Process
# Lifecycle Carbon Intensity (CI)

<table>
<thead>
<tr>
<th>Cases</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>Design case of GTI's RNG production / 2.9 BCF of RNG</td>
</tr>
<tr>
<td>Case 1</td>
<td>Base case with carbon capture and sequestration / 2.9 BCF of RNG</td>
</tr>
<tr>
<td>Case 2</td>
<td>Maximum RNG by combining CO(_2) with H(_2) generated from an electrolyzer using renewable electricity (power-to-gas) 7.3 BCF of RNG</td>
</tr>
<tr>
<td>Case 3</td>
<td>Replacing the ASU with an electrolyzer; byproduct H(_2) is used to produce additional RNG (power-to-gas) /4.1 BCF of production</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cases</th>
<th>Base†</th>
<th>Case 1</th>
<th>Case 2‡</th>
<th>Case 3‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feedstock transportation and treatment</td>
<td>6.47</td>
<td>6.47</td>
<td>0.995</td>
<td>1.45</td>
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<tr>
<td>Gasification</td>
<td>8.43</td>
<td>8.43</td>
<td>0.0321</td>
<td>0.0468</td>
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<tr>
<td>Residual transportation</td>
<td>0.0850</td>
<td>0.0850</td>
<td>0.0410</td>
<td>0.0599</td>
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<tr>
<td>Syngas cleanup</td>
<td>5.99</td>
<td>5.99</td>
<td>0.0349</td>
<td>0.0572</td>
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<tr>
<td>RNG production</td>
<td>0.0418</td>
<td>0.0418</td>
<td>0.00737</td>
<td>0.00907</td>
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<tr>
<td>Miscellaneous‡</td>
<td>3.54</td>
<td>3.54</td>
<td>0.686</td>
<td>0.807</td>
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<tr>
<td>Electricity displacement*</td>
<td>-8.60</td>
<td>-8.60</td>
<td>0</td>
<td>0</td>
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<tr>
<td>RNG transportation</td>
<td>0.856</td>
<td>0.856</td>
<td>0.856</td>
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<tr>
<td>Carbon capture</td>
<td>0</td>
<td>-77.4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Carbon Intensity (CI)</strong></td>
<td>16.8**</td>
<td>-60.6</td>
<td>2.65</td>
<td>3.29</td>
</tr>
</tbody>
</table>

**GREET MODEL (performed by Argonne)**

†Miscellaneous include water treatment, sour water stripping, cooling water systems, thermal oxidizer, etc.

*There is co-produced electricity, which indirectly reduce GHG emissions by displacing CA electricity.

† CA electricity grid is used.

‡ Renewable electricity is used.

**California GREET® 3.0 CI = 17 gCO2e/MJ**
Emissions Profile Compared to Biomass Power Facilities

Source of biopower data: Assessment of the Emissions and Energy Impacts of Biomass and Biogas Use in California, Provided to the California Air Resources Board by Marc Carreras-Sospedra, Professor Donald Dabdub University of California, Irvine; in collaboration with Robert Williams California Biomass Collaborative, January 14, 2015
What We Learned From the Stockton Site, the Engineering Design, and Other Post Project Assumptions

- Plant would convert 945 tons/day of wood wastes
- Plant would produce approximately 3 BCF/yr of RNG
- Configuration in the base case yields a CI of 16.8 gCO$_2$eq/MJ
- Stockton not likely the best site for the first commercial facility (pipeline capacity issues and space is very tight)
- 1$^{st}$ commercial plant likely to produce all its own electricity (lowers CI from 16.8 to approximately 3-7 gCO$_2$eq/MJ)
- All in capital cost is $340 million ±30%
- The production cost for RNG is in the range of $13-15/MBtu.
Benefits and Opportunities

Material quantities in the tens of billions of cubic feet per year of RNG can be produced using commercially available technologies.

Wood waste to RNG, compared to biomass power, reduces criteria pollutants by approximately 99% and produces a very low carbon fuel.

This plant alone could displace approximately 170,000 tons of CO₂ vehicle emissions each year (equal to offsetting the emissions from 400 million vehicle miles, or consuming 15 million gallons of gasoline).
What New Policies are Needed for Wood Waste to RNG plants to be built in California

- Definition of Renewable Methane being considered by CPUC should include RNG produced from gasification of wood waste
- Ensuring that renewable methane production facilities can get approval for connection to the natural gas pipeline system and can receive all the incentives for connection and benefits that biomethane receive now.
- Need to revise California’s Health and Safety Code definition of “biogas” to allow the gas from gasification of organic waste into the state’s pipelines. Right now, H&S Code section 25420 limits pipeline biogas to the gas from anaerobic digestion, which doesn’t work on wood waste and therefore excludes ¾ of California’s potential biogas production (all urban wood waste and most agricultural and forest waste). The definition should be revised to include gasification of organic material allowed under Public Resources Code section 40106, which are non-digestible organic wastes.
- Pipeline biogas incentives, like the incentives for interconnection adopted pursuant to AB 2313 (Williams, 2016) should also be available for the RNG or hydrogen from gasification of wood waste.
- Need to revise Public Resources Code section 40117 to clarify that gasification of wood waste and other organic material that would otherwise go to a landfill counts as waste “diversion” – right now, gasification does not qualify as waste diversion unless it is zero emission of any kind. We do not hold anaerobic digestion or any other technology to this standard. It should be revised at least for organic waste gasification.
- The carbon intensity of RNG from forest and agricultural waste should include avoided emissions from burning and wildfires.