

Low Carbon Renewable Natural Gas (RNG) from Wood Wastes *Update*

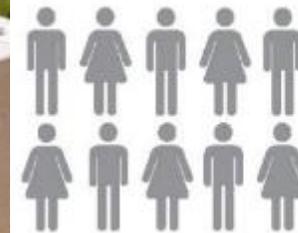
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GTI Overview

Serving the Energy Industry Since 1941

- > Independent, not-for-profit research, technology development and deployment organization
- > Areas of research include energy production and conversion, delivery and end-use
- > Technology development focus on improving efficiency and reducing emissions
- > Research Facilities
 - 18-acre campus near Chicago
 - laboratories in Agoura Hills, CA and Davis, CA
 - pilot and demo facilities worldwide
- > GTI California offices in Davis, Woodland Hills
 - Over 100 employees in California including subsidiaries



RESEARCH & DEVELOPMENT



PROGRAM MANAGEMENT



TECHNICAL/ ANALYTICAL



CONSULTING



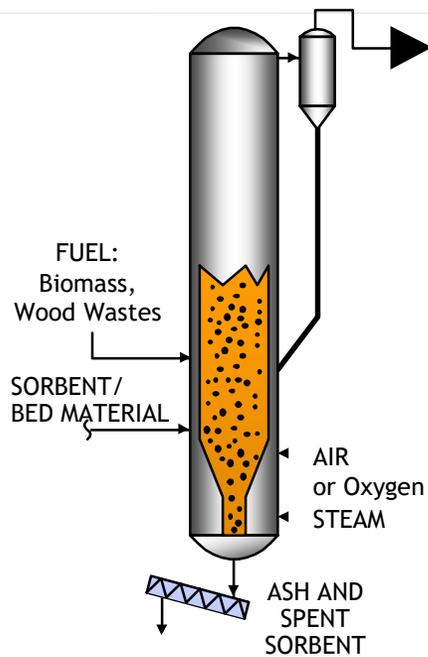
TRAINING

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!

GASIFIER



- > 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):

CO (carbon monoxide)

H₂ (hydrogen)

(CO/H₂ ratio can be adjusted)

By-products:

CO₂ (carbon dioxide)

Solids (minerals from fuel)

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*

What We Learned From the Stockton Site, the Engineering Design, and Other Post Project Assumptions

- > Plant could convert 945 tons/day of wood wastes
- > Plant could produce approximately 3 BCF/yr of RNG
- > Configuration in the base case yields a CI of 16.8 gCO₂eq/MJ
- > Stockton not likely the best site for the first commercial facility (pipeline capacity issues and space is very tight)
- > 1st commercial plant likely to produce all its own electricity (lowers CI from 16.8 to approximately 3-7 gCO₂eq/MJ)
- > All in capital cost is \$340 million ±30%
- > The production cost for RNG is in the range of \$13-15/MMBtu.
 - The potential availability of transportation fuel and CO₂ reduction incentives/credits, would likely result in an RNG price in the range of \$18-\$26/MMBtu
 - Revenues would provide for cost of financing, investment and ROI

What's Happening Now



*GTI created a for profit subsidiary called **SunGas Renewables***

***SunGas** is working to bring down the cost of a wood waste to renewable fuels production facilities*

***SunGas** is investigating opportunities in California and elsewhere for the production of low carbon fuels including RNG, hydrogen and liquid transportation fuels*

Who are we?

Harnessing
Clean Energy
From the Sun

www.sungasrenewables.com



- SunGas Renewables takes the sun's energy that is stored in organic wastes and their byproducts — principally woody biomass — and converts it into renewable fuel at high efficiency, while simultaneously reducing the adverse environmental impacts of these waste streams
- Founded 2019 as a subsidiary of GTI

Summary of SunGas Biomass Gasification Systems

- > Bubbling Fluidized Bed gasifier developed for multiple feedstocks
- > Applications for power, chemicals, and fuels have been tested
- > Downstream gas conditioning developed to provide high-purity syngas
- > Commercial reference in operation since 2006 for combined heat and power with over 90% efficiency
- > Integrated biorefinery configuration demonstrated wood to gasoline production over 1000 hours of operation producing 10,000 gallons of gasoline
- > Commercial systems have been designed for Fischer-Tropsch diesel and Renewable Natural Gas production

Technology developed over 40 years to handle waste biomass materials from agricultural residues to wood wastes to refuse-derived fuel.

Thousands of hours of testing and over a decade of reference commercial operations provide technical confidence in the GTI-developed direct bubbling fluidized bed gasifier.





SunGas Renewables Activities

- > Further Plant Design Refinements (1000 tons and 300 tons of biomass per day)
- > Renewable hydrogen production plant design being developed (lower cost than electrolyzers)
- > Engagement on RFS pathway for gasification of wood waste to RNG
- > Responding to several project developers regarding feasibility studies for SunGas Gasification for biofuel production (gaseous and liquid fuels)
- > New alliance being developed with global engineering firm to provide engineering design services for SunGas gasification systems for renewable bio-fuel (gaseous and liquid) production facilities



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 $\frac{3}{4}$ 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.