Renewable Natural Gas via Catalytic Hydrothermal Gasification of Wet Biomass

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Biofuel With A Difference

- Most biofuel development today is focused on liquid fuels, especially ethanol and biodiesel
- Catalytic Hydrothermal Gasification (CHG) directly produces a gas—natural gas
- Process is simple and fast, and is the most efficient way to produce biofuel available today—lowest cost and least environmental impact per unit of energy produced
Overview of Gasification Process

- Catalytic Hydrothermal Gasification (CHG) is a wet process which produces renewable natural gas in a single step
- Reactions are fast and quite complete
- Catalyzed by ruthenium catalyst in fixed bed
- Process developed over 30-year period at Pacific Northwest National Laboratory, a DOE National Lab
- Genifuel has licensed process
Bench-Scale Gasifier
Overview of Gasification Process (cont.)

- Catalytic Hydrothermal Gasification (CHG) is not the same as thermal pyrolysis gasification
  - CHG produces Renewable Natural Gas (RNG)—a mixture of methane with small amounts of hydrogen and ethane
  - Thermal pyrolysis produces syngas—a mixture of carbon monoxide and hydrogen
  - CHG feedstock is processed wet, in the form of a slurry of 5% to 25% solids
CHG Chemistry

Partial equations:

\[ \text{C}_6\text{H}_{10}\text{O}_5 + \text{H}_2\text{O} \rightarrow 6\text{CO} + 6\text{H}_2 \]  
(steam reforming of carbohydrate)

\[ \text{CO} + 3\text{H}_2 \rightarrow \text{CH}_4 + \text{H}_2\text{O} \]  
(methanation)

\[ \text{CO} + \text{H}_2\text{O} \rightarrow \text{CO}_2 + \text{H}_2 \]  
(water-gas shift)

The overall stoichiometry is then:

\[ \text{C}_6\text{H}_{10}\text{O}_5 + \text{H}_2\text{O} \rightarrow 3\text{CH}_4 + 3\text{CO}_2 \]

Note: Feedstocks contain many molecular structures, including carbohydrates, proteins, etc. The actual gas products will usually contain a small amount of hydrogen and ethane as well as methane and carbon dioxide.
CHG Gasifier Is Simple and Economical

• Feedstock is heated and pumped to 350°C and 21MPa (app. 200 atm/3,000 psi)
  – Conditions are just below supercritical water
• Held briefly in filter tank to precipitate inorganics and liquefy feedstock, then passes through fixed catalyst bed
• Output flows through heat exchanger (to heat incoming feedstock) and water/gas separator
• Dwell time is only a few seconds
Characteristics of CHG Process

• Works with almost any organic material, as long as it can be made into a water slurry
• Converts >99% of organics with most feedstocks
• No tars or oils, very little ash
• Very efficient—almost all heat is recovered in heat exchanger to heat incoming feedstock
• Output is a directly usable medium-BTU fuel—62% natural gas and 38% CO₂ by volume
• Separate out CO₂ to get pipeline natural gas
Advantages of CHG Process

• CHG compared to anaerobic digestion (methane)
  – Higher yields—greater conversion of organics
  – Much less sludge left over (app. 1/5\textsuperscript{th} as much)
  – Much, much faster
  – Physically smaller

• CHG compared to pyrolysis (syngas)
  – Lower temperatures
  – Handles high water content easily with no drying
  – Directly produces methane, with many uses
Feedstocks for CHG

• While any organic material can be used, aquatic biomass is ideal
  – Material is soft and wet, easy to make into slurry

• Other wet feedstocks are also good—e.g. wastewater solids

• Woody biomass is more difficult and expensive to prepare into slurry
  – High lignin content makes it harder to process
Typical Aquatic Feedstocks

• Freshwater algae--mixes of algae, cyanobacteria, diatoms
• Filamentous species are good—easy to harvest
• Algae “bottoms” left after oil extraction
• Other fast-growing aquatic species
• Marine algae
  – Ulva (filamentous)
  – Seaweeds (e.g. kelp)
Aquatic Feedstocks

• Algae is a good feedstock, but with entirely different approach than algae oil producers
  – The goal is highest biomass production at lowest possible cost
  – Do not need or want monocultures of oil producers, simplifying growth outdoors
  – Want indigenous types which are large, robust, fast-growing, and easy to harvest--filamentous species are perfect
Short Summary of Feedstocks

• Things which are generally considered weeds, nuisances, or problems

• Some reasons why:
  – Because they grow fast, are robust, and cosmopolitan (i.e. grow wherever conditions are right), or
  – Because they have to be disposed of (wastewater solids), or
  – Because they can generate a revenue side-stream
Cladophora glomerata:
A “Nuisance” Perfect for Gasification
Ulva in Large Quantities
Other Water/Marsh “Nuisances”
Duckweed—Easy to Harvest
10% Slurry of algae, cyanos, duckweed
Resource Recovery

- Heat is recovered to heat incoming feedstock
- CO$_2$ is separated from product gas leaving final gas very similar to natural gas
- CO$_2$ dissolved in the condensate is recycled to the growth ponds, accelerating growth of biomass and reducing local emissions
- Other nutrients (nitrogen, potassium, micronutrients, etc.) flow through in effluent water and are recycled to growth water, reducing both local emissions and fertilizer costs
## Energy Cost for Renewable Natural Gas Compared to Biodiesel (Q4 2009)

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<th>RNG</th>
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<th>Soy B100</th>
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Status and Conclusion

- Now engineering 2,000 m³/d pilot plant for Q3 2010; demonstration unit of 8,000 m³/d next
- Initial use for CNG-powered vehicles in Asia and urban areas in US
- Can sell RNG into natural-gas pipelines to be used as chemical feedstock or in electricity generation to meet RPS
- Compared to other biofuels, RNG is the cheapest and cleanest biofuel available per unit of energy