

**Renewable Natural Gas  
via  
Catalytic Hydrothermal  
Gasification  
of Wet Biomass**

**October 2009**

**Genifuel**

# **Overview of Gasification Process**

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- **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**
- **Process developed over 30-year period at Pacific Northwest National Laboratory, a DOE National Lab**
- **Genifuel has licensed process**

# Bench-Scale Gasifier

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## **Overview of Gasification Process (cont.)**

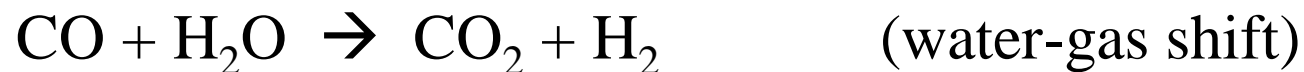
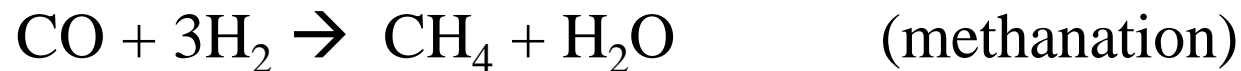
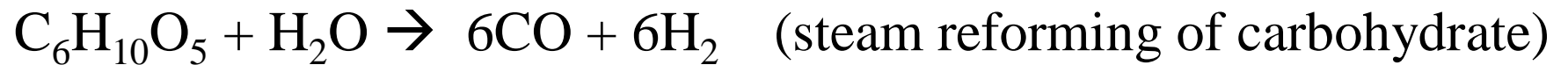
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- **Catalytic Hydrothermal Gasification (CHG) is *not* the same as thermal pyrolysis gasification**
  - CHG produces Renewable Natural Gas (RNG)—a mixture of methane with small amounts of hydrogen and ethane
  - Thermal pyrolysis produces syngas—a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

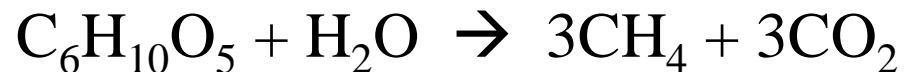
# CHG Chemistry

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Partial equations:



The overall stoichiometry is then:



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**

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- **Feedstock is heated and pumped to 350°C and 21MPa (app. 20 atm/3,000 psi)**
  - Conditions are just below supercritical water
- **Held briefly in filter tank to precipitate certain inorganics and liquefy feedstock**
- **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**

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- **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, 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% CO<sub>2</sub> by volume**
- **Separate out CO<sub>2</sub> to get pipeline natural gas**

# **Advantages of CHG Process**

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- **CHG compared to anaerobic digestion (methane)**
  - Higher yields—greater conversion of organics
  - No sludge left over
  - 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

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- **While any organic material can be used, aquatic biomass is ideal**
  - Material is soft and wet, easy to make into slurry
- **Can convert algae-oil “bottoms” after lipid extraction into additional fuel—no waste**
- **Other wet feedstocks are also good—wastewater solids, animal waste**
- **Woody biomass is more difficult and expensive to prepare into slurry**
  - High lignin content makes it harder to process

# Aquatic Feedstocks

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- **Algae is a perfect feedstock, but with entirely different approach than oil producers**
  - The goal is highest biomass production at lowest possible cost
  - Do not need or want monocultures of oil producers, simplifying growth in outdoor ponds
  - Want indigenous types which are large, robust, fast-growing, and easy to harvest--filamentous species are perfect
  - Usually mixtures of algae, cyanobacteria, diatoms
  - Can use marine algae

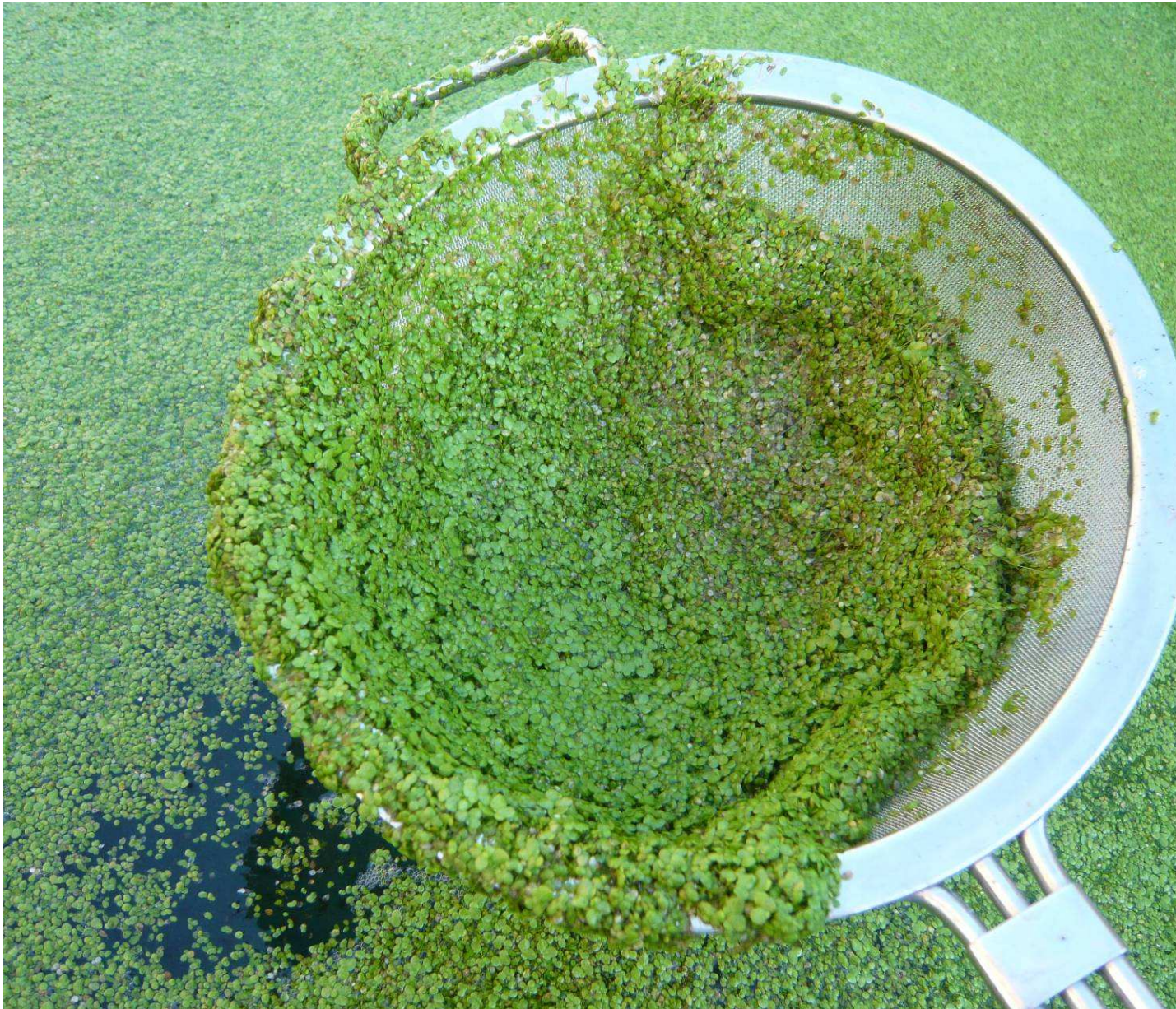
# *Cladophora* or *Ulva* “Nuisances” Perfect for Gasification

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# Duckweed (non-algae)—Easy to Harvest

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# 10% Slurry of algae, cyanos, duckweed



# Resource Recovery

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- **Heat is recovered to heat incoming feedstock**
- **CO<sub>2</sub> is separated from product gas leaving product gas very similar to natural gas**
- **CO<sub>2</sub> dissolved in the condensate is recycled to the aquatic growth medium, accelerating growth of the biomass and reducing local emissions to nearly zero**
- **Other nutrients can be recycled**

# Energy Cost for Renewable Natural Gas Compared to Biodiesel (Q4 2009)

	<u>RNG</u>	<u>Algae B100</u>	<u>Soy B100</u>
<b>COST</b>	<b>\$12/MCF</b>	<b>\$30/gal</b>	<b>\$3/gal</b>
<b>BTU Content</b>	<b>1,020,000</b>	<b>118,300</b>	<b>118,300</b>
<b>COST/ 100,000 BTU</b>	<b>\$1.18</b>	<b>\$25.36</b>	<b>\$2.54</b>

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# Status and Conclusion

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- **Engineering in progress for 2,000 m<sup>3</sup>/d pilot plant operational in Q2 2010**
- **Small commercial unit of either 4,000 m<sup>3</sup>/d or 8,000 m<sup>3</sup>/d will be installed by end of 2010**
- **Initial use will probably be for CNG-powered vehicles in urban areas**
- **Can also be used in combined-cycle electricity generation with conventional technology**
- **Compared to other biofuels, RNG is probably the cheapest and cleanest alternative available**