Renewable Natural Gas via Catalytic Hydrothermal Gasification of Wet Biomass

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Genifuel

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
- 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:

$C_6H_{10}O_5 + H_2O \rightarrow 6CO + 6H_2$ (steam reforming of carbohydrate)

$CO + 3H_2 \rightarrow CH_4 + H_2O$ (methanation)

$CO + H_2O \rightarrow CO_2 + H_2$ (water-gas shift)

The overall stoichiometry is then:

$$C_6H_{10}O_5 + H_2O \rightarrow 3CH_4 + 3CO_2$$

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. 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

- **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_2 by volume**
- **Separate out CO_2 to get pipeline natural gas**

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Advantages of CHG Process

- **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

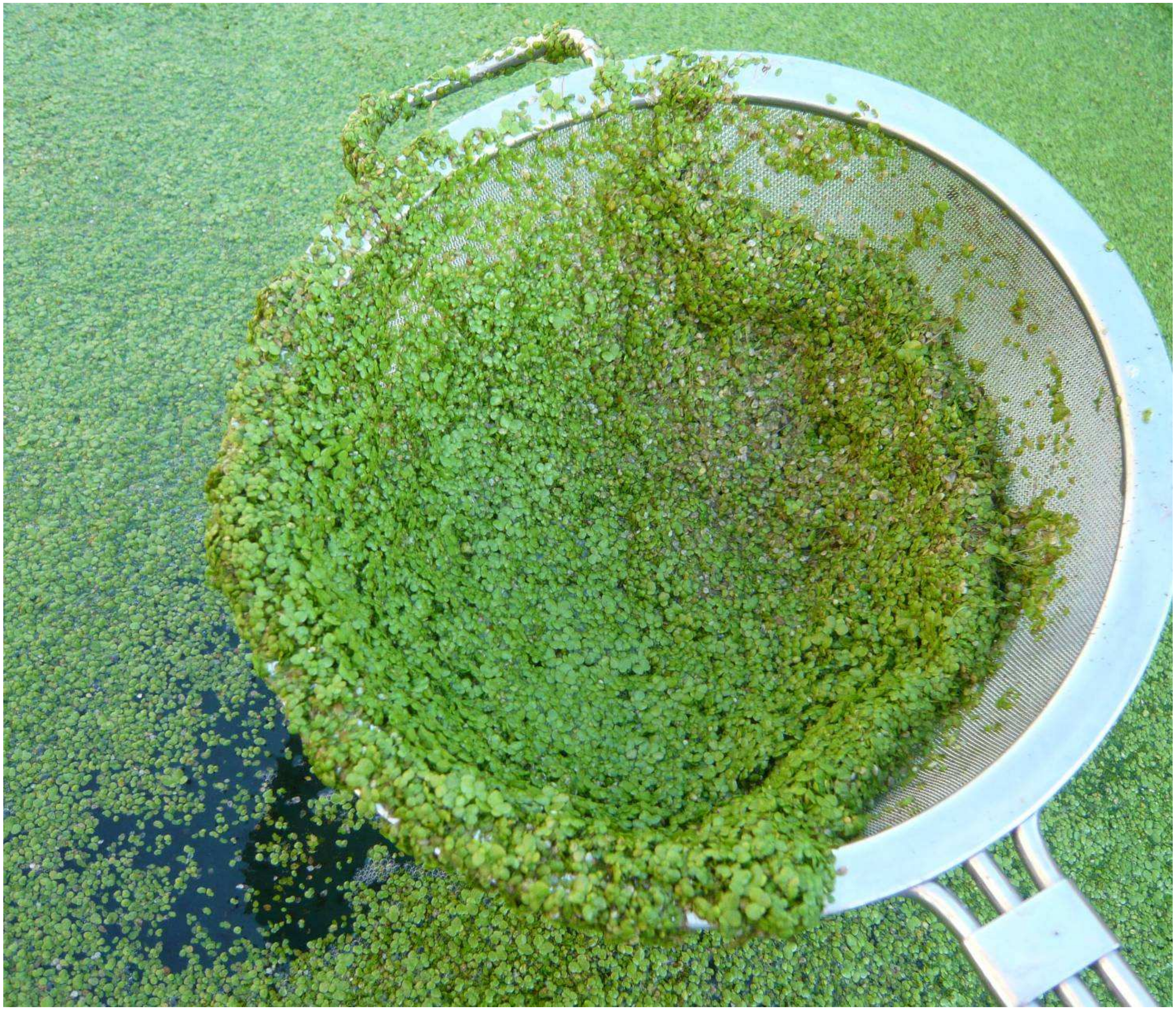
- **While any organic material can be used, aquatic biomass is ideal**
  - Material is soft and wet, easy to make into slurry
- **Can convert algae-oil “bottoms” after lipid extraction into additional fuel—no waste**
- **Other wet feedstocks are also good—wastewater solids, animal waste**
- **Woody biomass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

Aquatic Feedstocks

- **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

Duckweed (non-algae)—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 product gas very similar to natural gas**
- **CO_2 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)

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

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Status and Conclusion

- Engineering in progress for 2,000 m^3/d pilot plant operational in Q2 2010
- Small commercial unit of either 4,000 m^3/d or 8,000 m^3/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