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

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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. 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% CO_2 by volume**
- **Separate out CO_2 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. 1/5th 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

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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

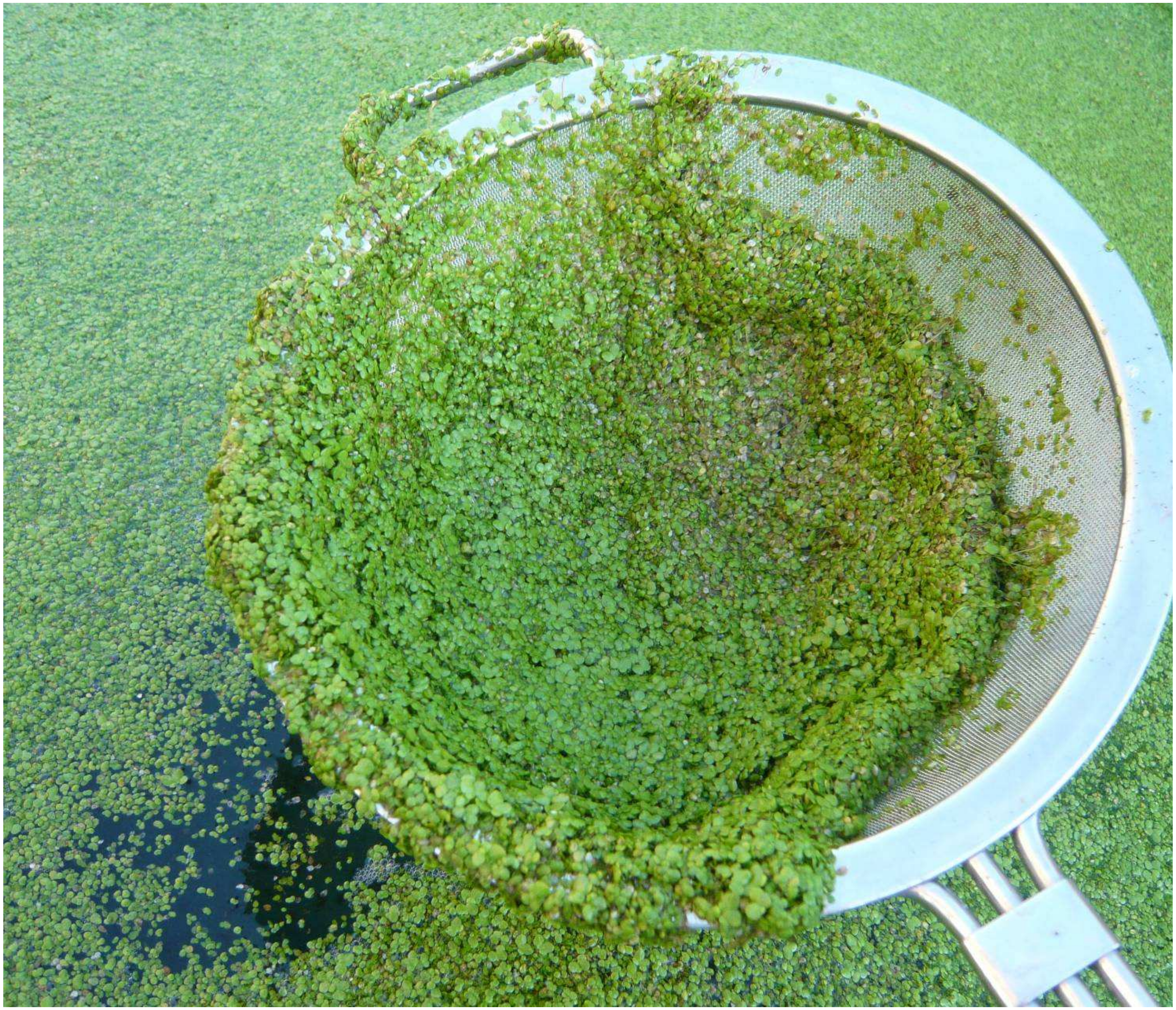
- **Things which are generally considered weeds, nuisances, or problems**
- **Some reasons why:**
  - Because they grow fast, are robust, and cosmopolitan (i.e. grow wherever conditions are right), or
  - Because they have to be disposed of (wastewater solids), or
  - Because they can generate a revenue 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)

	RNG	Algae B100	Soy B100
COST	$10/MCF	$30/gal	$3/gal
BTU Content	1,020,000	118,300	118,300
COST/ 100,000 BTU	$.98	$25.36	$2.54

Status and Conclusion

- Now engineering 2,000 m^3/d pilot plant for Q3 2010; demonstration unit of 8,000 m^3/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

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