Pacific West
BIOMASS
CONFERENCE & TRADE SHOW
a Biorefining and Biomass Power & Thermal event

CHG:
Today's Lowest-Cost Biofuel Process

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Genifuel

Overview of Gasification Process

- **Catalytic Hydrothermal Gasification (CHG) is a wet process (up to 90% water) which produces methane in a single step**
- **Feedstock is any organic material made into slurry**
- **Reactions are fast (< 1 hour) and complete (>99%)**
- **Process developed over 30-year period at Pacific Northwest National Laboratory (PNNL), a DOE National Lab, by Doug Elliott and others**
- **Genifuel is licensed for commercialization**
- **Member of NAABB consortium to gasify algae**

Energy from CHG Gas Production

- **Gas produced is mostly methane and carbon dioxide; no nitrogen, sulfur or siloxanes**
- **Gas can be burned directly as medium-heat fuel**
  - App. 24 MJ/m^3 (620 BTU/ft^3)
  - Engines, turbines, and fuel cells can accept this gas
- **Alternatively, can remove CO_2 to get pure methane (renewable natural gas or RNG)**
  - App. 38 MJ/m^3 energy content (1020 BTU/ft^3)
- **Gasifier is compact and can be co-located at the feedstock source to reduce transport of wet stock**

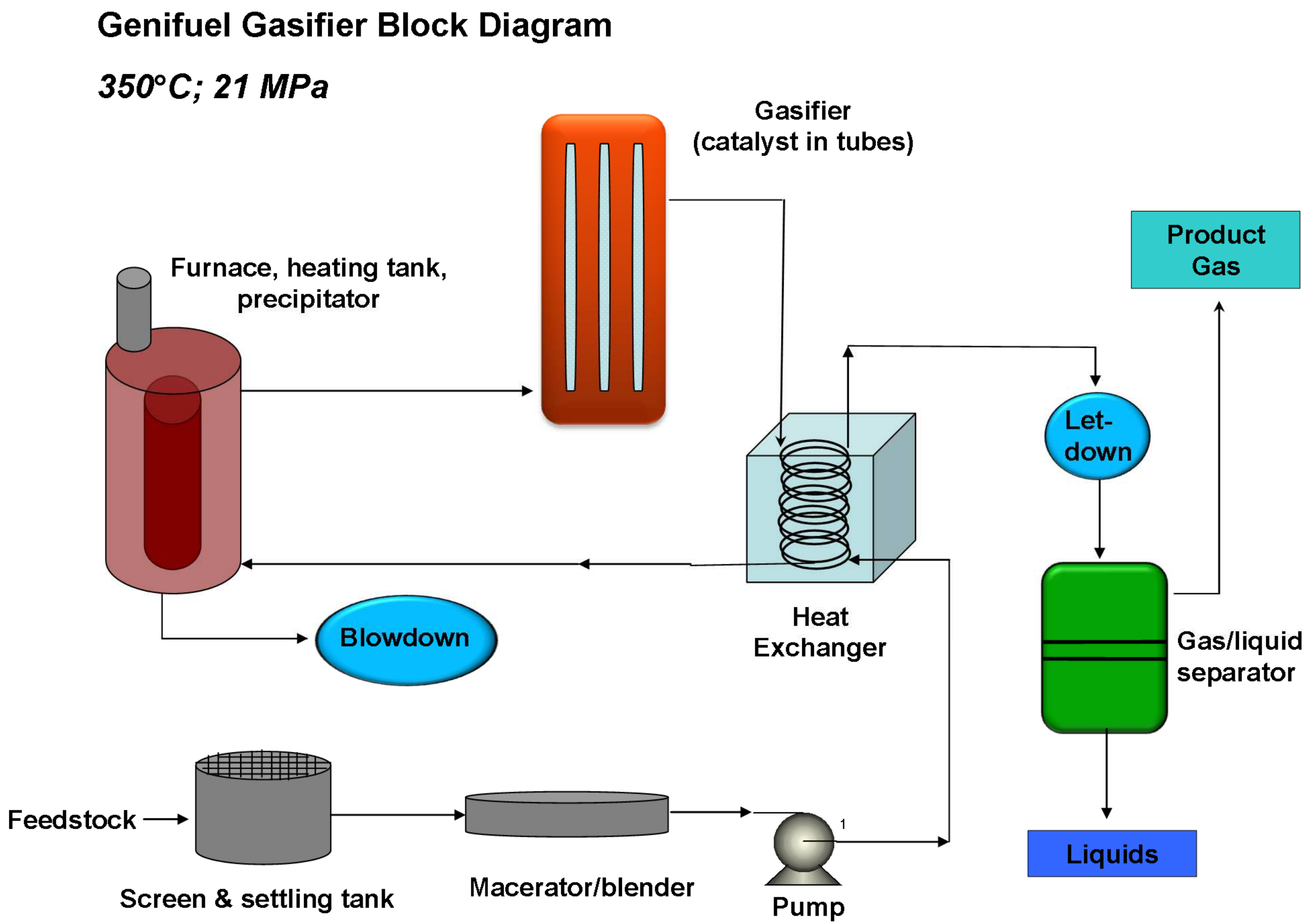
Feedstocks

- **In the wet slurry, water carries the solids and is also a reactant**
- **Operation at 21 MPa (3,000 psi) and 350ºC (660ºF)**
- **Solids in slurry can be between 1% and 40%, but optimum range is between 10% and 20%**
  - Feedstocks in this range flow well, can be pumped easily, and allow for better sizing of machinery

Feedstocks (cont.)

- **Wide variety of wet feedstocks are usually available in large quantities**
- **Algae is an ideal feedstock material—easy to make into slurry**
  - Lipid-extracted algae (LEA) can be used, giving a second fuel stream in addition to lipid-based fuels

Simplified Process Diagram



Skid-Mounted Gasifier Test Unit

CHG Pilot Plant Design

- **Current design for Pilot Plant will gasify 10 metric tons of wet biomass/day at 15% solids**
  - Follow-on design will be 10x larger
- **This size will produce 500 m^3 (18,000 ft^3) of net methane (after 10% internal use) per day**
  - This amount of methane will power a 100 kWe generator 24 hours/day
  - Or could store gas and generate 200 kWe for 12 h/d
- **At 30 $g/m^2/d$ productivity, algae feedstock would require 4.5 ha (11 acres) of ponds to supply feed**

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CHG Value Addition to Algae Biofuels

- **If harvest 2 t/d dry algae with 25% lipids, then:**
  - Lipid production is 500 kg/d, or 143 gal/d
  - Lipid-Extracted Algae (LEA) is 1.5 t/d dry mass
- **CHG will yield 500 m^3/d net product methane from 1.5 t/d dry LEA mass**
- **Value of the products:**
  - Lipid value @ $3.00/gal = $429/d
  - Methane yields electricity @ $0.12/kWh = $261/d
- **Therefore, CHG increases biofuel value by 60%**

CHG Energy Bonus to Algae Biofuels

- **For same conditions as previous slide:**
- **Algae oil produces 143 gallons of biodiesel**
  - Energy content = 16.9 million BTU's
- **Remaining algae biomass (LEA) produces 500 m^3 of net methane**
  - Energy content = 18.0 million BTU's
- **Therefore gasification of algae biomass more than doubles energy production from harvested algae**

Cost of CHG Methane vs. Algae Lipids

- **Cost of biodiesel from algae**
  - Now: $30 - $300 per gallon (hard to get real data)
  - 3-5 years: $10 per gallon
  - 5-10 years: $3 per gallon
  - Note: Some algae biodiesel companies forecast a shorter timeframe for their cost reductions
- **Cost of CHG Methane**
  - Now: App. $1 per GGE (gallon of gasoline equivalent)

Scope of Algae Biofuels

- **If algae were used to produce 5% of US liquid fuel use, then would need to produce:**
  - 5% x 200 billion gallons per year = 10 billion gal/y
  - This is roughly the scope of corn ethanol production
- **If algae productivity is:**
  - Algae growth 30 $g/m^2/d$ average for full year
  - Lipid fraction is 25% of the algal mass
- **Then**
  - Would need 1.2 million hectares or 3 million acres of algae ponds (4,700 square miles of ponds).

Feedstocks

- Beer fermentation bottoms
- Corn ethanol fermentation bottoms
- Food processing plant wastes
- Algae fuel residuals (lipid-extracted algae)
- Water weeds from remediation programs
- Dairy wastes (manure, processing wastes)
- Wastewater solids
- Many others

CHG World Feedstocks Electricity Production in TWh*

FEEDSTOCK	WORLD	USA
Cattle Manure	280	18
Dairy Cow Manure	140	9
Pig Manure	112	7
Food Proc. Waste	382	67
Algae Bottoms	254	57
Wastewater Solids	21	8
Beer Bottoms	10	2
Other**	18	7
TOTAL	**1,218**	**175**

* TWh is terawatt hours. Terawatt = 1 x 10^{12} watt; assumes 42% efficiency

** Other includes barley ethanol bottoms, water plant remediation, etc.

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CHG Potential Output in Perspective

- **Worldwide CHG production could equal (2010):**
  - 8.2% of fossil natural gas production
  - 6.3% of electricity production
  - 3.5 times the electricity produced by wind
- **Like wind, the source of energy (feedstock) is free, or in many cases even less since it avoids costs of disposal and/or environmental cleanup of wastes**
- **CHG power is base load and dispatchable--higher value than wind power**
- **Production is highly distributed throughout world**

Other Gasification Technologies

- **Two existing technologies also provide alternate forms of gasification**
  - Anaerobic Digestion (Biogas)
  - Thermal Gasification to Synthesis Gas (Syngas)
- **Both differ in significant ways from CHG, with CHG offering a number of process advantages**
- **Additional advantage of CHG is that plant nutrients in the feedstock are recovered and can be recycled for new growth (i.e. fertilizer)**

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CHG Compared to Anaerobic Digestion

COMPARISON	CHG	AD
Organic Conversion	>99%	40-50%
Dwell Time	< 1 hour	20-40 days
Material Remaining	Almost none	50-60% of feedstock
Quality of Effluent	Sterile	Not Sterile
Size	Small	Very Large
Operation	Consistent, Stable	Hard to Balance

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CHG Compared to Syngas Gasification

COMPARISON	CHG	SYNGAS
Feedstock	Wet	Dry
Temperature	350ºC	850ºC
Gas Produced	Methane (CH_4, CO_2)	Syngas (H_2, CO, CO_2)
Tars	No	Yes
Size	Small	Large
Energy Yield	90%	60%

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CHG Conclusion

- **Best method available today to make renewable fuel or electricity from wet biomass**
- **Makes substantial contribution to energy balance**
- **Based on more than 30 years of well-documented development and tested with many feedstocks**
- **Performance will be documented through NAABB consortium**