

**CHG:**  
*Today's Lowest-Cost Biofuel  
Process*

**February 2011**

**Genifuel**

# **Overview of Gasification Process**

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- **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**

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- **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<sup>3</sup> (620 BTU/ft<sup>3</sup>)
  - Engines, turbines, and fuel cells can accept this gas
- **Alternatively, can remove CO<sub>2</sub> to get pure methane (renewable natural gas or RNG)**
  - App. 38 MJ/m<sup>3</sup> energy content (1020 BTU/ft<sup>3</sup>)
- **Gasifier is compact and can be co-located at the feedstock source to reduce transport of wet stock**

# Feedstocks

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- **In the wet slurry, water carries the solids and is also a reactant**
- **Operation at 21 MPa (3,000 psi) and 350°C (660°F)**
- **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.)**

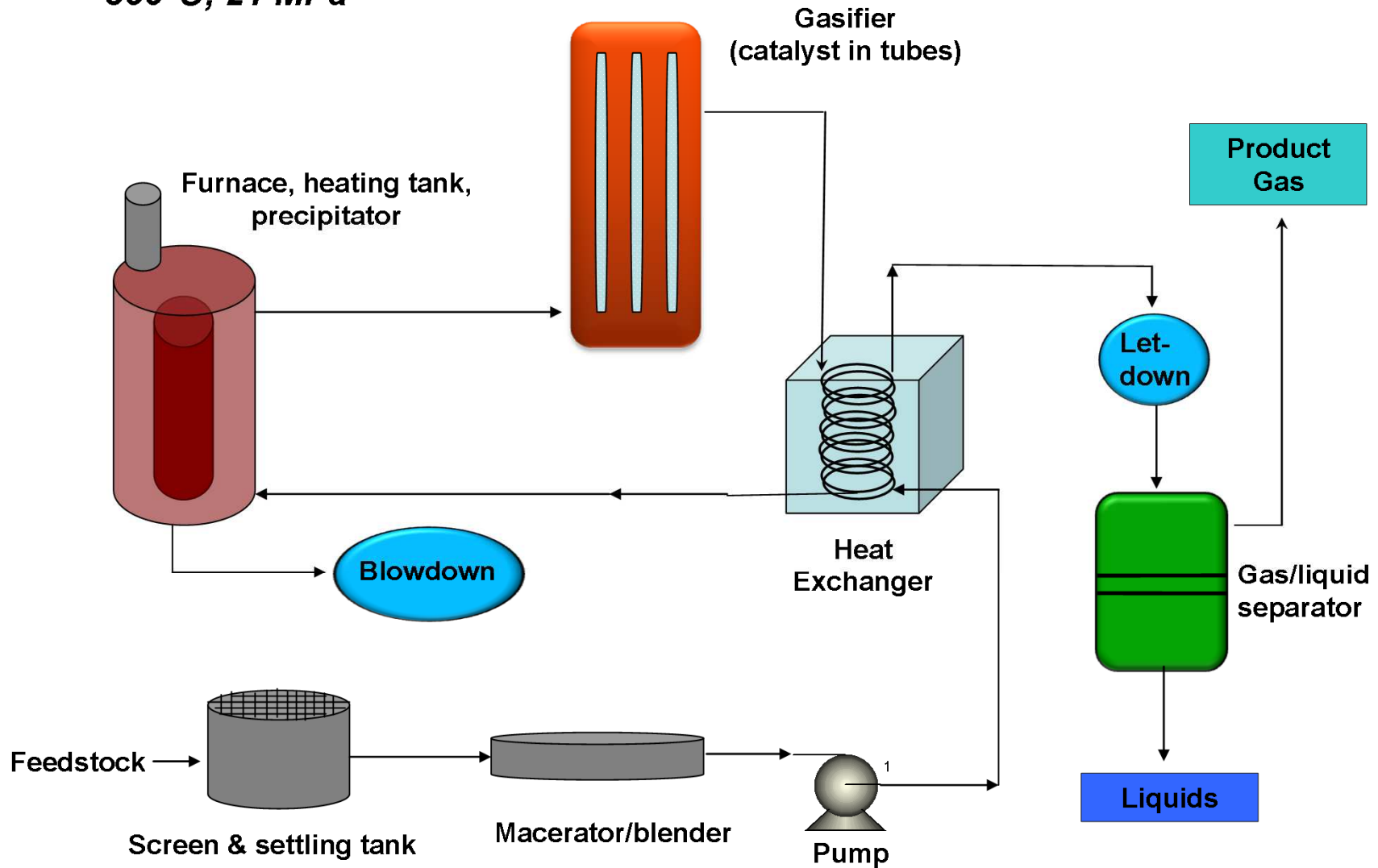
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- **Wide variety of wet feedstocks are usually available in large quantities**
- **Algae is an ideal feedstock material—easy to make into slurry**
  - Lipid-extracted algae (LEA) can be used, giving a second fuel stream in addition to lipid-based fuels

# Simplified Process Diagram

## Genifuel Gasifier Block Diagram

*350°C; 21 MPa*



# Skid-Mounted Gasifier Test Unit



# CHG Pilot Plant Design

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- **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<sup>3</sup> (18,000 ft<sup>3</sup>) of net methane (after 12% 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

# **Feedstocks**

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- **Beer fermentation bottoms (brewer's spent grain)**
- **Ethanol fermentation bottoms (fuel production)**
- **Food processing factory wastes**
- **Algae fuel residuals (algae after lipid extraction)**
- **Water weeds from remediation programs**
- **Dairy wastes (manure, processing wastes)**
- **Wastewater solids**
- **Many others**

# CHG World Feedstocks

## Millions of cubic meters/y methane

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FEEDSTOCK	WORLD	USA
Cattle Manure	60,972	3,857
Dairy Cow Manure	30,486	1,929
Pig Manure	24,389	1,543
Food Proc. Waste	83,000	14,625
Algae Bottoms*	55,125	12,469
Wastewater Solids	4,617	1,660
Beer Bottoms	2,216	391
Other**	4,000	1,500
<b>TOTAL</b>	<b>264,805</b>	<b>37,974</b>

\* Assumes algae production to supply 5% of liquid fuels

\*\* Other includes barley ethanol bottoms, water plant remediation, etc. Also includes corn ethanol bottoms not sold as DDG

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# CHG World Feedstocks

## Millions of MCF (MMBtu)/y methane

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FEEDSTOCK	WORLD	USA
Cattle Manure	2,152	136
Dairy Cow Manure	1,076	68
Pig Manure	861	54
Food Proc. Waste	2,930	516
Algae Bottoms*	1,946	440
Wastewater Solids	163	59
Beer Bottoms	78	14
Other**	141	53
<b>TOTAL</b>	<b>9,348</b>	<b>1,340</b>

\* Assumes algae production to supply 5% of liquid fuels

\*\* Other includes barley ethanol bottoms, water plant remediation, etc. Also includes corn ethanol bottoms not sold as DDG

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# CHG World Feedstocks

## Electricity Production in TWh\*

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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
<b>TOTAL</b>	<b>1,218</b>	<b>175</b>

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

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

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# **CHG Potential Output in Perspective**

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- **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**

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- **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)**

# **CHG Compared to Anaerobic Digestion**

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<b>COMPARISON</b>	<b>CHG</b>	<b>AD</b>
<b>Organic Conversion</b>	<b>&gt;99%</b>	<b>40-50%</b>
<b>Dwell Time</b>	<b>&lt; 1 hour</b>	<b>20-40 days</b>
<b>Material Remaining</b>	<b>Almost none</b>	<b>40-70% of feedstock</b>
<b>Quality of Effluent</b>	<b>Sterile</b>	<b>Not Sterile</b>
<b>Size</b>	<b>Small</b>	<b>Very Large</b>
<b>Operation</b>	<b>Consistent, Stable</b>	<b>Hard to Balance</b>

# CHG Compared to Syngas Gasification

<b>COMPARISON</b>	<b>CHG</b>	<b>SYNGAS</b>
<b>Feedstock</b>	<b>Wet</b>	<b>Dry</b>
<b>Temperature</b>	<b>350°C</b>	<b>850°C</b>
<b>Gas Produced</b>	<b>Methane (CH<sub>4</sub>, CO<sub>2</sub>)</b>	<b>Syngas (H<sub>2</sub>, CO, CO<sub>2</sub>)</b>
<b>Tars</b>	<b>No</b>	<b>Yes</b>
<b>Size</b>	<b>Small</b>	<b>Large</b>
<b>Energy Yield</b>	<b>90%</b>	<b>60%</b>

# **CHG Conclusion**

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- **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**