

# Biomass Gasification R&D Activities in North America



**IEA Task 33 Workshop  
Christchurch, NZ**

**Richard L. Bain**

**Apr 14, 2011**

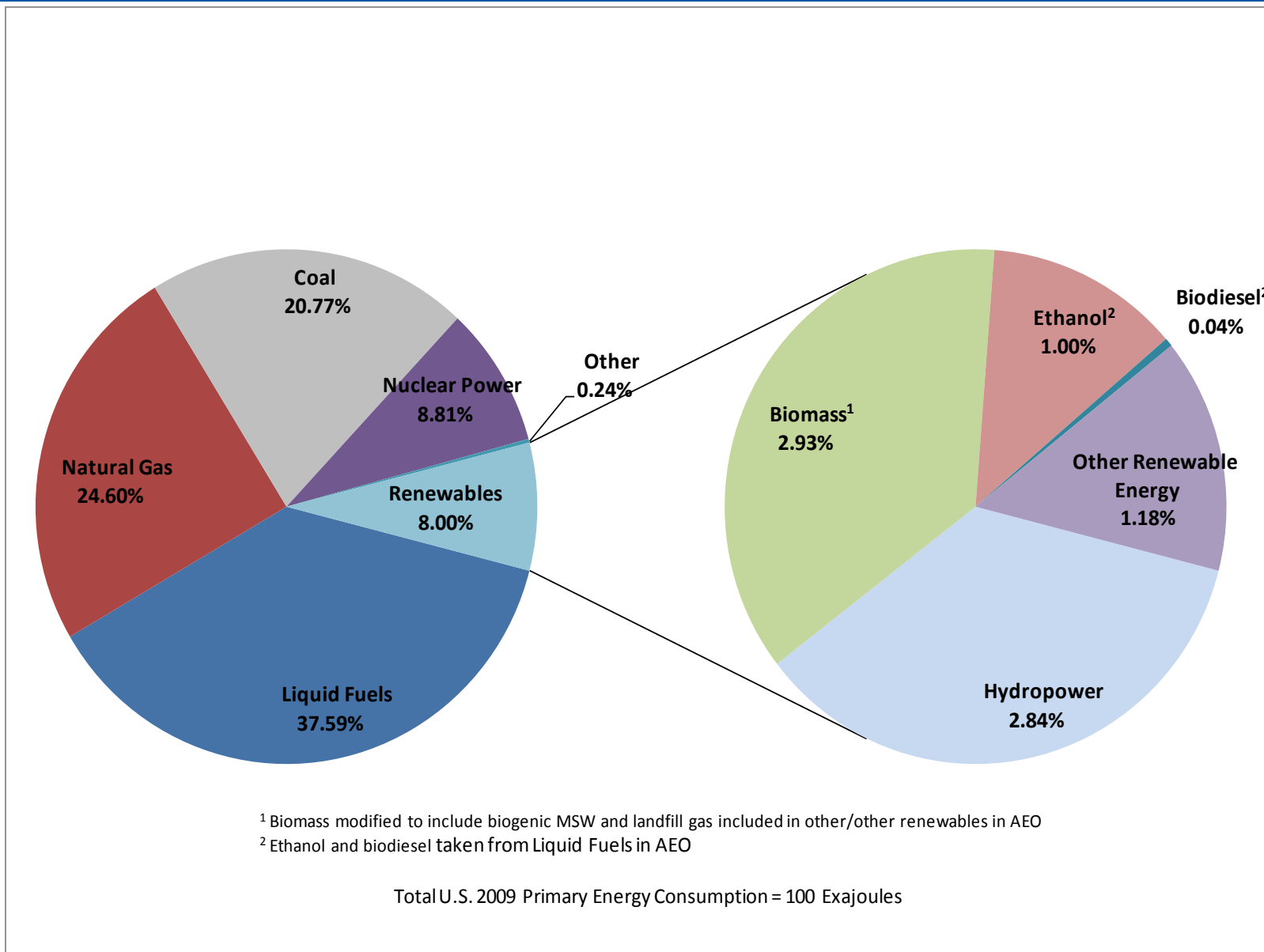
# Presentation Outline

- **Biopower and Biofuels Status**
- **Biomass Resource Potential**
- **U.S. Gasifier Developers**
- **USDOE Projects**
- **Gasification Technologies**
  - **Canadian Developers**
  - **U.S. Developers**



Photo Credit: Chariton Valley RC&D

# U.S. Primary Energy Consumption in 2009



# Current Biofuels Status

## Biodiesel – 2.85 billion gallons/yr nameplate capacity (April 2011)<sup>1</sup>

- Mar 2011 Rack Price – 478.06 cents/gal

## Corn ethanol

- 218 commercial plants<sup>2</sup>
- 14.554 billion gal/year nameplate capacity
- 11.987 billion gal/yr. production<sup>2</sup>
- Additional 0.27 billion gal/yr planned or under construction
- Mar 2011 Rack Price – 270.48 cents/gal

## Key DOE Goals

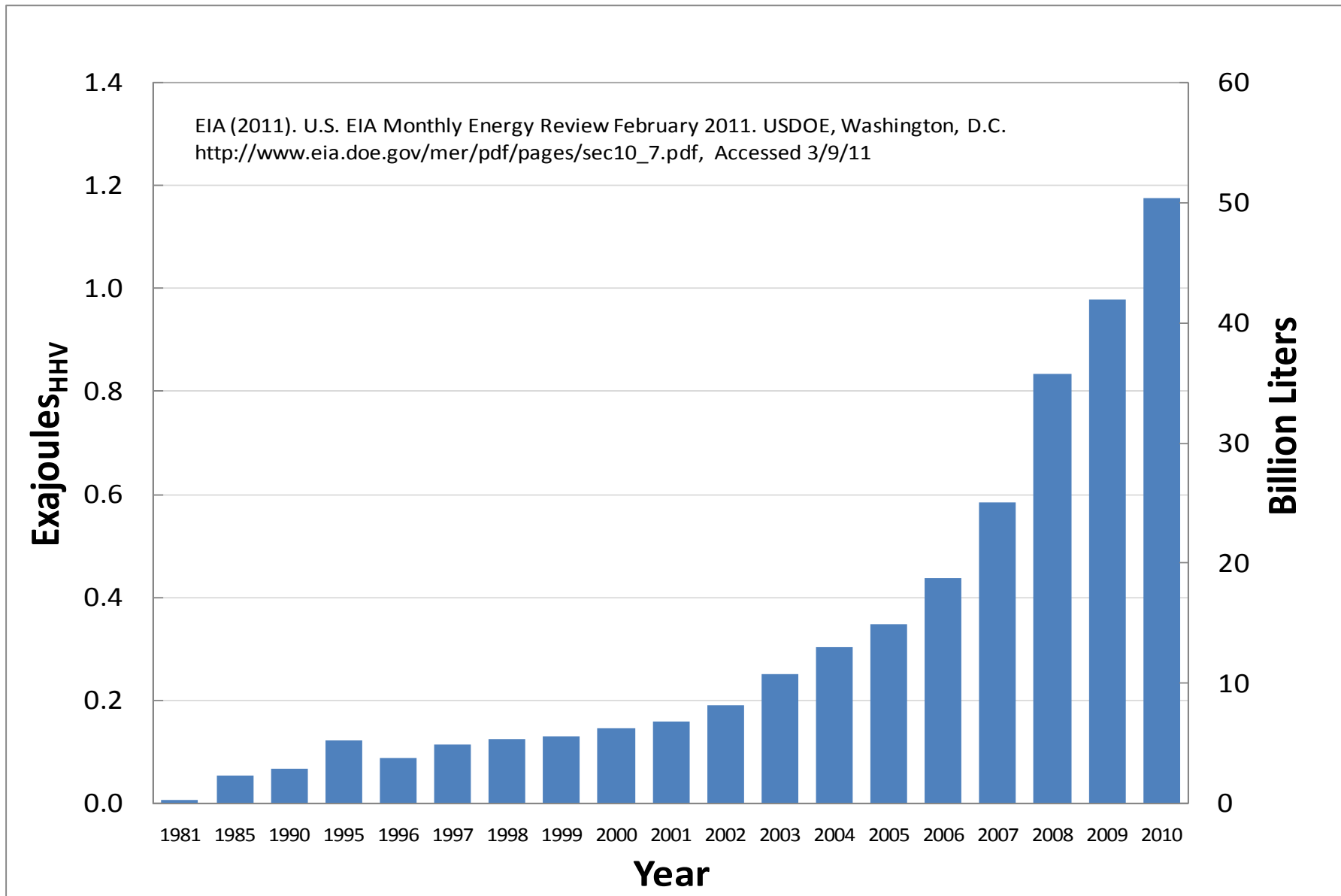
- 2012 goal: cellulosic ethanol \$1.51/ETOH gallon
- 2022 goal: 36B gal Renewable Fuel; 21B gal “Advanced Renewable Fuel”– 2007 Energy Independence and Security Act
- 2030 goal: 60 billion gal ethanol (30% of 2004 gasoline)



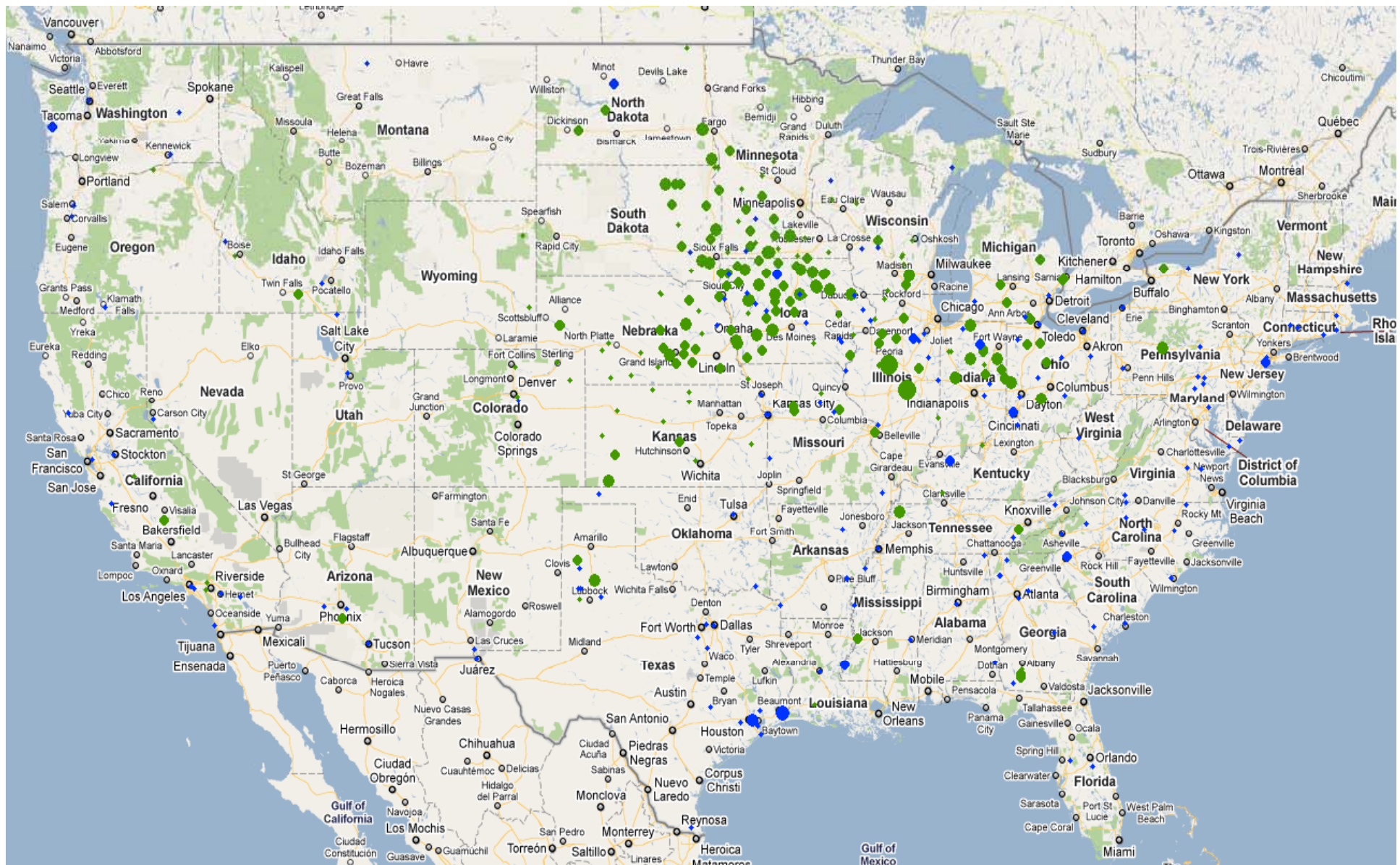
Updated Apr 2011

Sources: 1- National Biodiesel Board, 2 - Renewable Fuels Association, all other information based on DOE and USDA sources

# Historical U.S. Ethanol Production



# Existing Biofuels Facilities



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# Biopower Status

**2010 Capacity – 10.5 GW**

- **5.6 GW Electric Power Sector**
- **5.2 GW End Use Generators**

**2010 Generation – 55TWh**

**Cost – 0.08 – 0.12 USD/kWh**

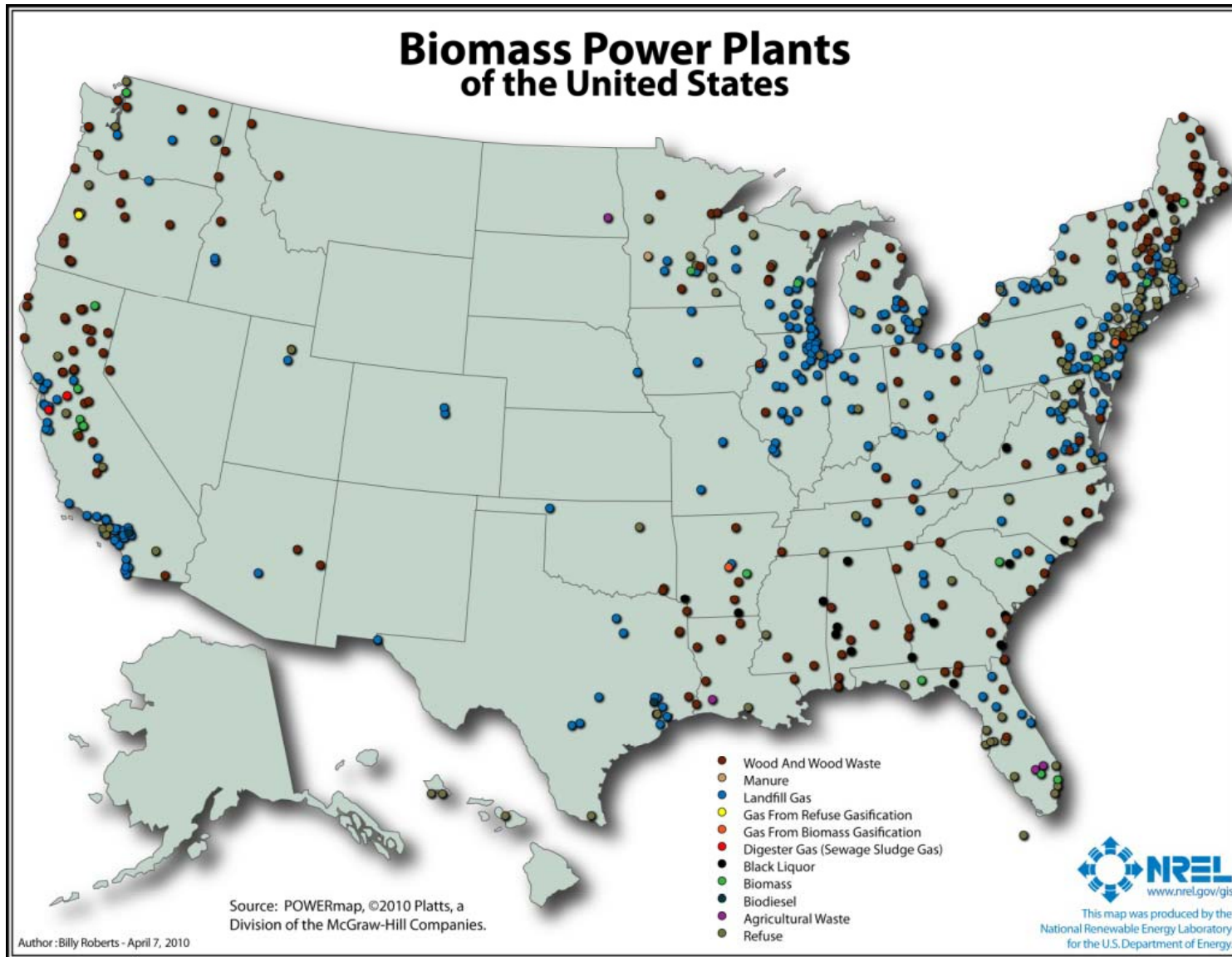
**Potential – Electric Sector**

<b>2022 -</b>	<b>22 GW</b>
<b>2035 -</b>	<b>48 GW</b>
<b>2050 -</b>	<b>91 GW</b>



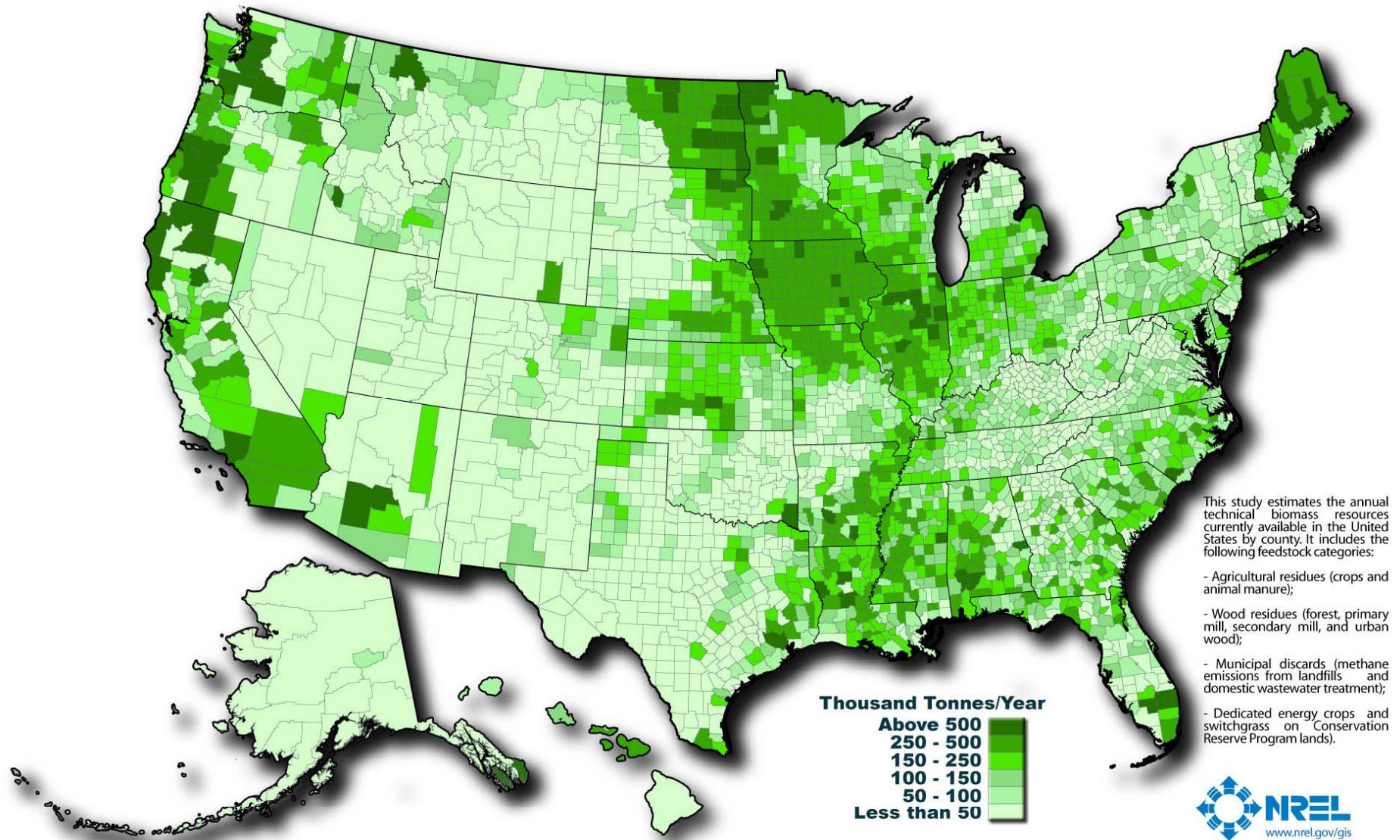
Sources: DOE EIA Annual Energy Outlook, Table A16 (year-by-year) , NREL Renewable Electricity Futures Study (2010) – **Preliminary Data**  
EIA Form 860 (Capacity), EIA Form 923 (Generation)

# U.S. Existing Biopower Plants





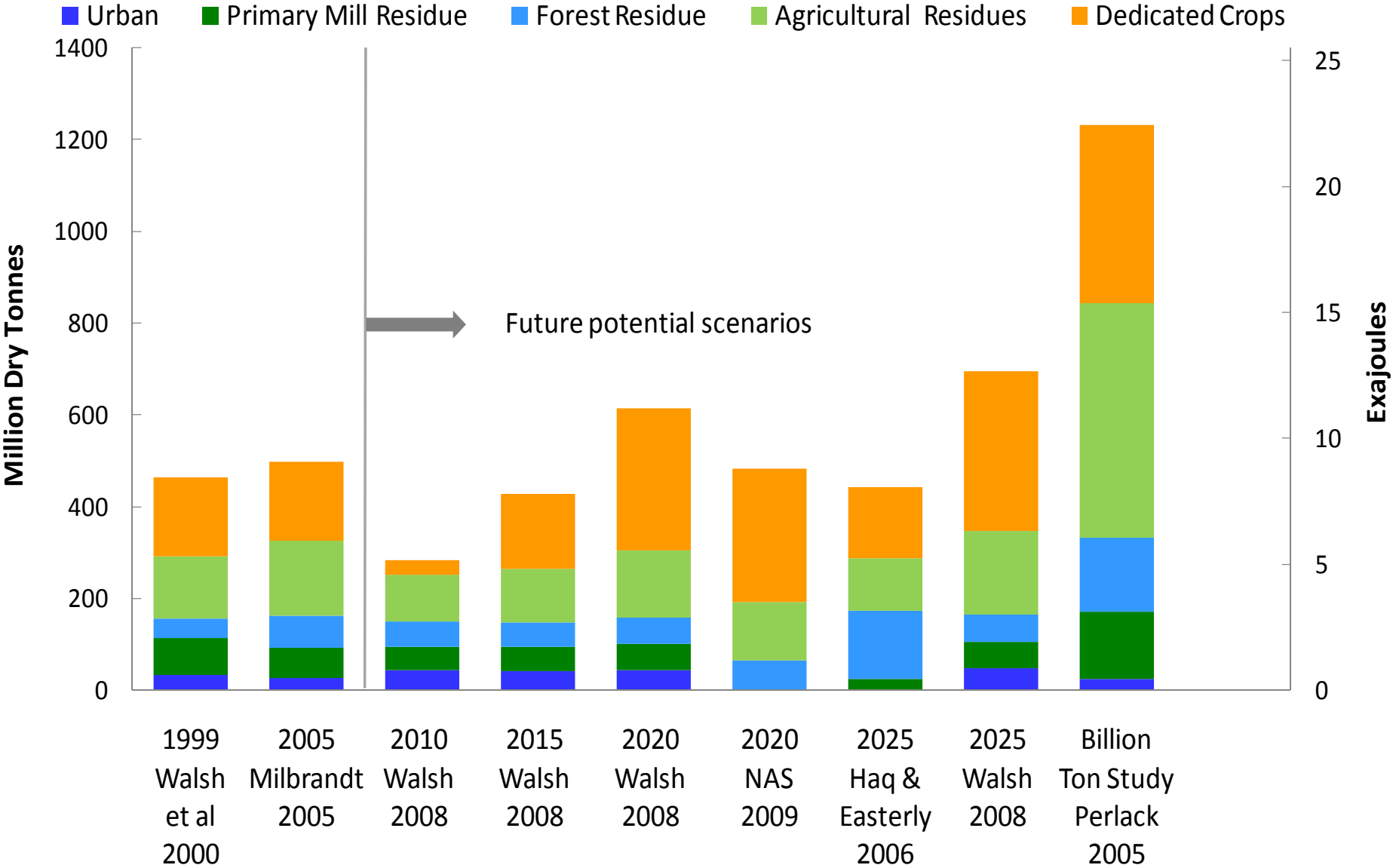
# U.S. Biomass Resource



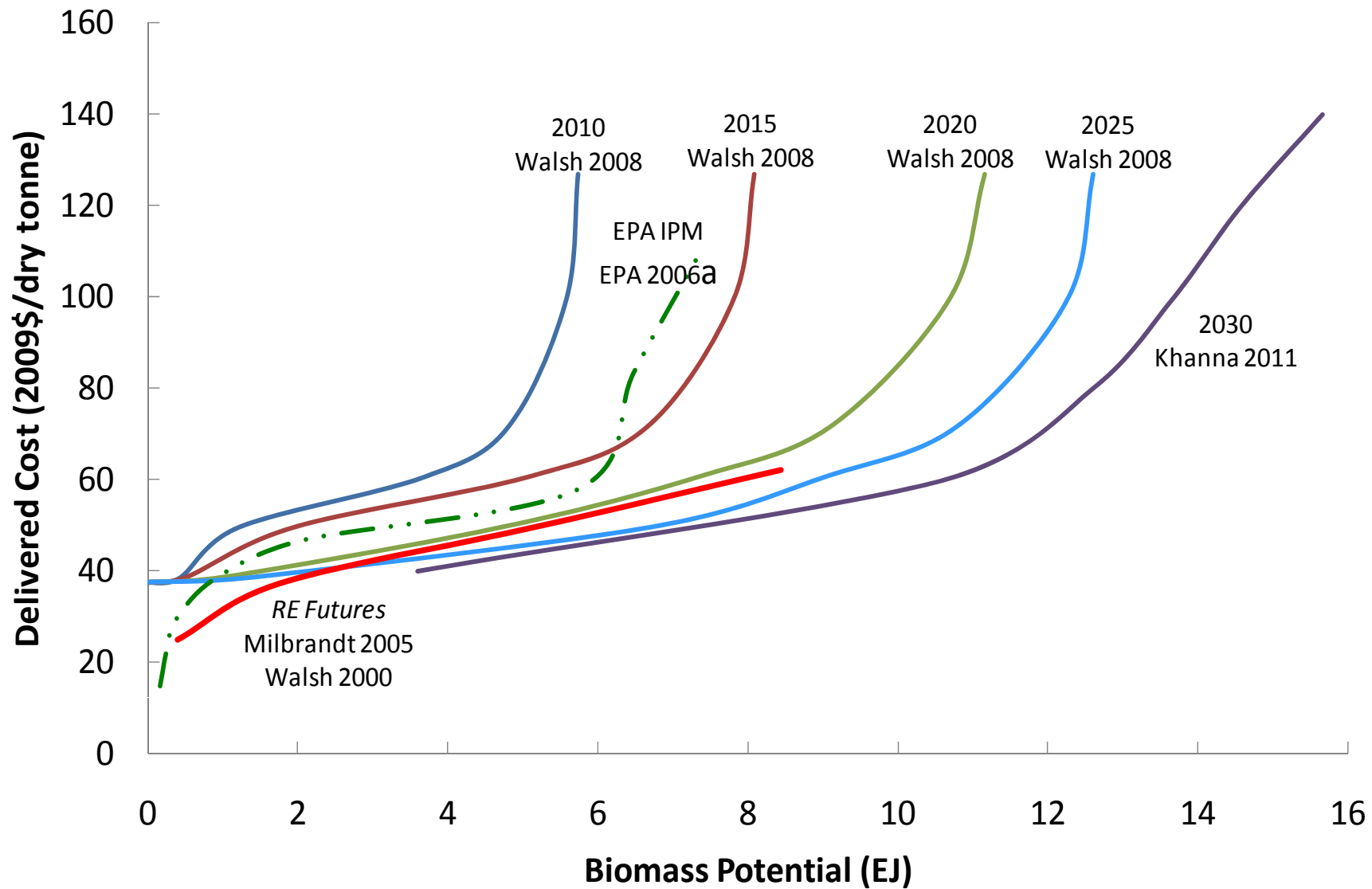
Author: Billy Roberts - October 20, 2008

This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy.  
See additional documentation for more information at <http://www.nrel.gov/docs/fy06osti/39181.pdf>

# U.S. Biomass Resource Potential Scenarios



# U. S. Biomass Supply Curve Scenarios



# U.S. Biomass Gasifier Developers

Organization	Gasifier Type	Scale				Status
		kg/hr	Tonnes/d	kWt	kWe	
Adaptive Arc	plasma					Pilot
Advanced Alternative Energy Corp.						?
Bioten Power & Energy Group	DD-var					Pilot
Bioconversion Technology, LLC	Mixed	25			1000	Demo
Biomass Gas & Electric, LLC	Indirect - dual CFB					Design
Black and Veatch	Dry ash entrained flow					?
Carbona Corp	FB				5000	Start-up
Chiptec	UD					OP
Clear Fuels	Dry ash indirect					pilot design
Clenergen						?
Community Power Corp	DD	35			25	OP
Cratech						OP
Diversified EnergyCorp	MM					Demo
EERC, ND	CFB, DD					pilot
Thermogenics	DD-var	455-2730				Pilot
Emergy Energy Co.	Mixed UD/DD		10			Const.
Energem Technologies	BFB - O2					pilot /Comm. Const
Energy Products of Idaho	FB				6-50 MWe	OP
Energy Quest, Inc. / Syngas International						?
Foster Wheeler	CFB					Comm
FrontLine Bioenergy, LLC	FB					Comm
GAZOGEN	FB				100	OP
Genoray Advanced Technologies, Ltd.	FB					?
GTI Flex-Fuel Gasification	FB	375-750				Pilot

# U.S. Biomass Gasifier Developers

Organization	Gasifier Type	Scale				Status
		kg/hr	Tonnes/d	kWt	kWe	
GTS Duratek						OP
Gulf Coast Energy	IND					Pilot
Hamilton Mauer International/MIFGA (HMI, Inc.)	UD					?
HTI - Heat Transfer International	UD					?
ICM Inc.	Air-blown Auger		136 - 181			Demo
InEnTec	Plasma					Pilot
Intellergy - Rockwell	rotary kiln					?
Mississippi Ethanol	IND-E		40			?
Nexterra	UD					OP
Pearson Technologies	IND-E		27.3			OP
Powerhouse Energy	Inductively heated					pilot
Primenergy, LLC	Mod-UD		27.3			OP
PRME	Mod-UD					OP
Range Fuels	2-stage indirect		>100			shut down
Red Lion Bioenergy						OP
Rentech	Indirect: Dual CFB		320			design
Simeken, Inc.						?
Taylor Biomass						Design
Thermo Technologies LLC	IND	250 TPD				OP
Thermochem	IND	1,800-				OP
TRI (Commercial Arm of Thermochem)						Pilot
Viresco						pilot
Vista International Technologies						?
West Biofuels	Indirect		5			pilot
Westinghouse Plasma	Plasma					OP
Ze-Gen	Molten Salt		ca. 10			?

# DOE Integrated Biorefinery Projects

## Biomass Program *Integrated Biorefinery Platform*

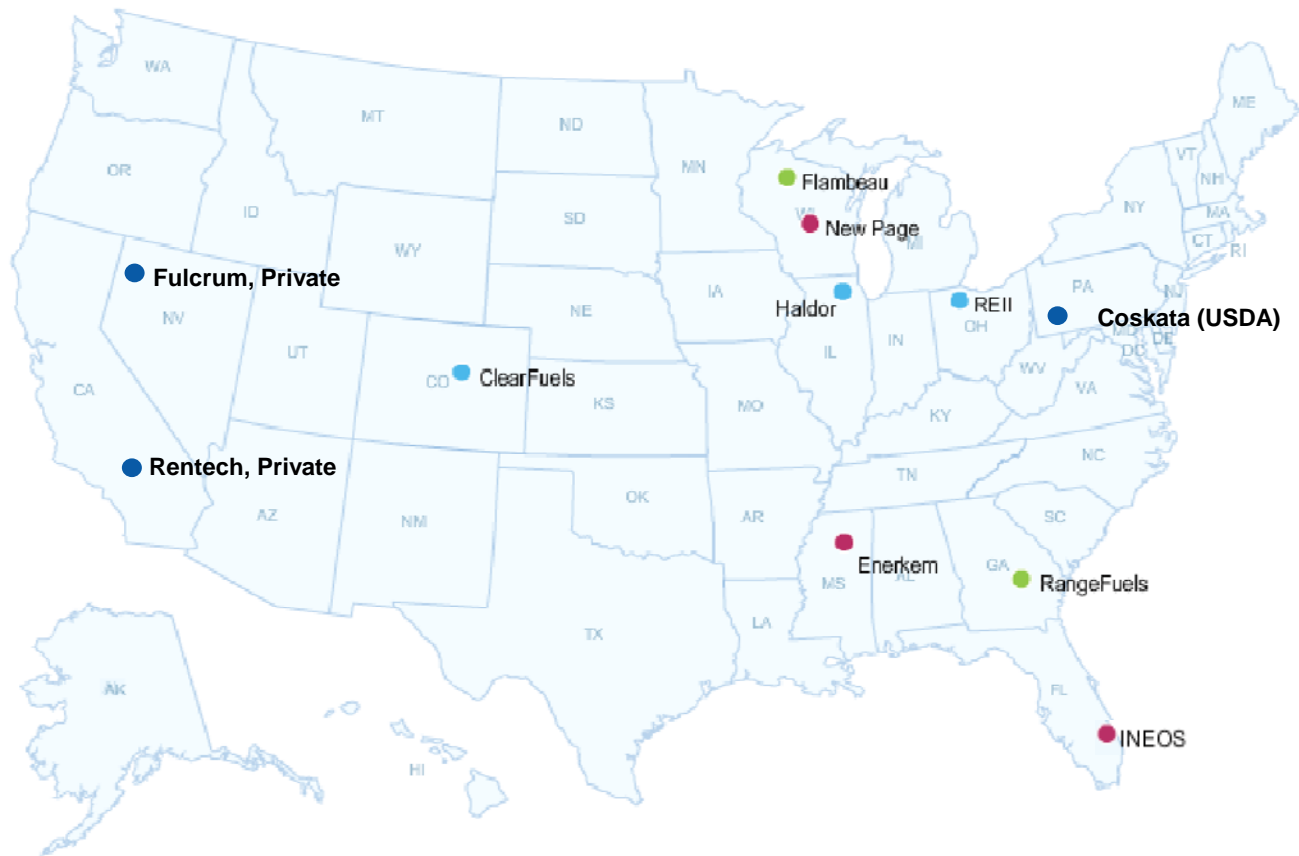
### IBR PROJECTS

Click on the project locations to see more information and locations are approximate



[http://www1.eere.energy.gov/biomass/integrated\\_biorefineries.html](http://www1.eere.energy.gov/biomass/integrated_biorefineries.html)

# DOE Integrated Gasification Biorefinery Projects



[http://www1.eere.energy.gov/biomass/integrated\\_biorefineries.html](http://www1.eere.energy.gov/biomass/integrated_biorefineries.html)

# DOE Integrated Gasification Biorefinery Projects

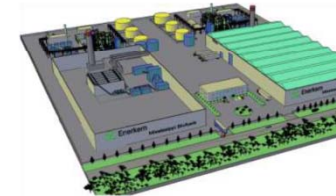


U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy | Biomass Program

### Enerkem to use Sorted Waste as Feedstock in Biorefinery

Enerkem's biorefinery in northern Mississippi will convert heterogeneous (mixed) sorted municipal solid waste into ethanol.

Enerkem will build a 300 short tons (300 metric tons) per day biorefinery in Pontotoc, Mississippi that will produce 10 million gallons of ethanol per year from the post-recycling municipal solid waste. Because the project is located on a portion of a regional landfill, feedstock for the project is already generated in the surrounding counties and delivered to the landfill each day. By converting this waste into transportation fuels, the



CAPTION: 3D Rendering of Enerkem's Pontotoc, Mississippi Biorefinery

by over 90% and at the same time extracts all useful energy from the waste used as feedstock. Enerkem has been developing its technology platform since 2001, and has built and operated both a large pilot plant in Sherbrooke, Quebec, Canada, as well as a demonstration-scale plant (50 tons per day) in Westbury, Quebec.

landfill on which the facility is located. Furthermore, the commercial-scale plant will remove remaining bar commercialization of the technology throughout the U.S.

- ★ Range Fuels, USDA Loan Guarantee
- ★ Enerkem and INEOS Conditional USDA Guarantees;
- ★ Coskata has conditional USDA Loan Guarantee for project in Boligee, AL

[http://www1.eere.energy.gov/biomass/integrated\\_biorefineries.html](http://www1.eere.energy.gov/biomass/integrated_biorefineries.html)



# Gasification Technologies

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# Nexterra Energy Corporation



### JCI/USC Gasification System

**Customer:**  
Johnson Controls Inc. -  
University of South Carolina  
**Location:**  
Columbia, South Carolina  
**Facility Type:**  
University  
**Application:**  
Cogeneration plant to provide heat  
and power for university.  
**Scope of Work:**  
Supply only of gasification system

### Highlights

**Start-up:**  
Q4 2007  
**Capacity:**  
60,000 lbs/hr of high pressure  
steam for district heating  
**Power:**  
1.38 MW of electricity power  
generation  
**Fuel:**  
Wood residue (hog fuel)  
**Fuel moisture content:**  
25 - 55%

### Process

3 gasifiers convert wood  
biomass to combustible syngas.  
Syngas is burned in the oxidizer.  
The hot flue gas is directed  
through heat recovery steam  
generator to produce steam.  
Steam sent to a back pressure  
turbine to produce electricity.  
Turbine exhaust steam is  
distributed to campus heating  
system.



Gasifiers and metering bins at USC plant

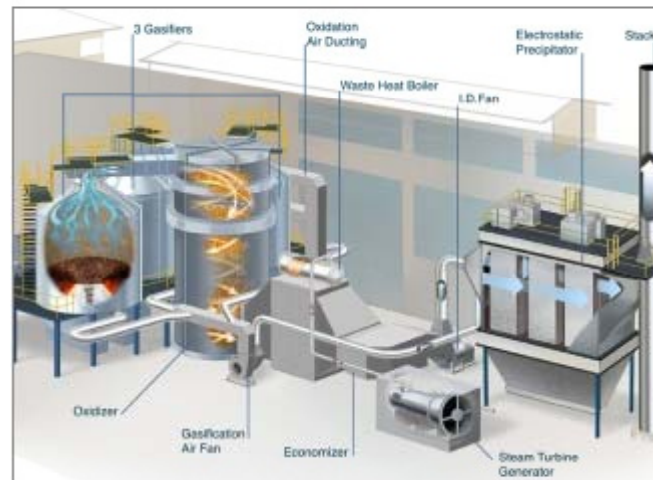
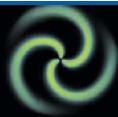


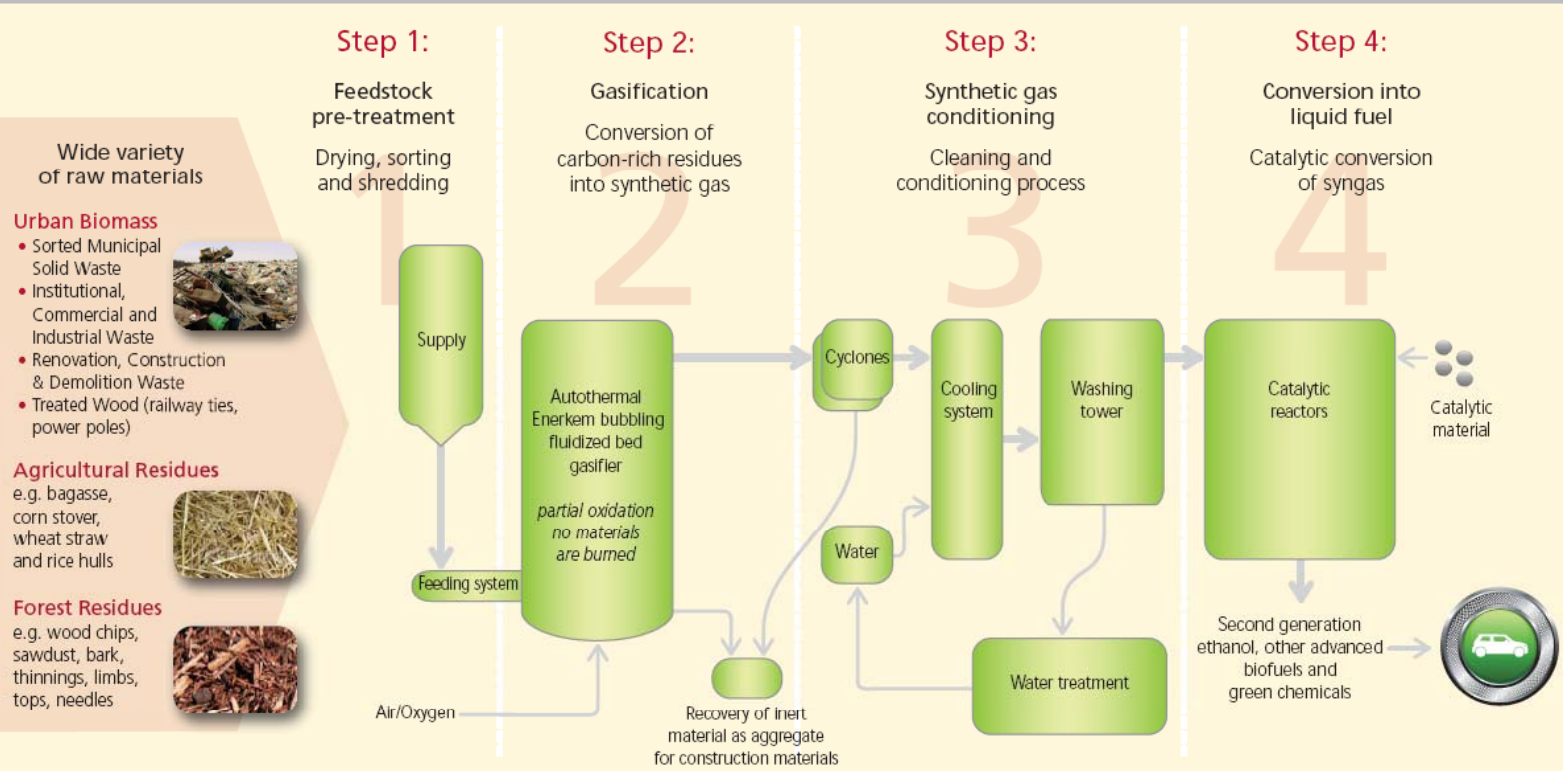
Illustration of Nexterra's gasification system at USC

Credit: <http://www.nexterra.ca/>



# Enerkem converts waste and residuals into advanced biofuels

## A Unique Gasification and Syngas to Biofuels Technology



### Enerkem promotes sustainable development:

- Uses the non-recyclable portion of our waste and creates value from our forest and agricultural residues.
- Produces 360 litres (95 gallons) of ethanol from one tonne of waste (dry base).
- Reduces greenhouse gases by using raw materials that would otherwise produce methane when landfilled and by replacing gasoline produced from petroleum.

### Enerkem uses an environmentally friendly process:

- Energy self-sufficient since the chemical reactions in the gasification process produce most of the energy and heat needed.
- Requires little use of water and allows for its reuse in a closed circuit. With certain feedstocks, the process is a net producer of water.
- Compact and decentralized facilities located near feedstock supply.

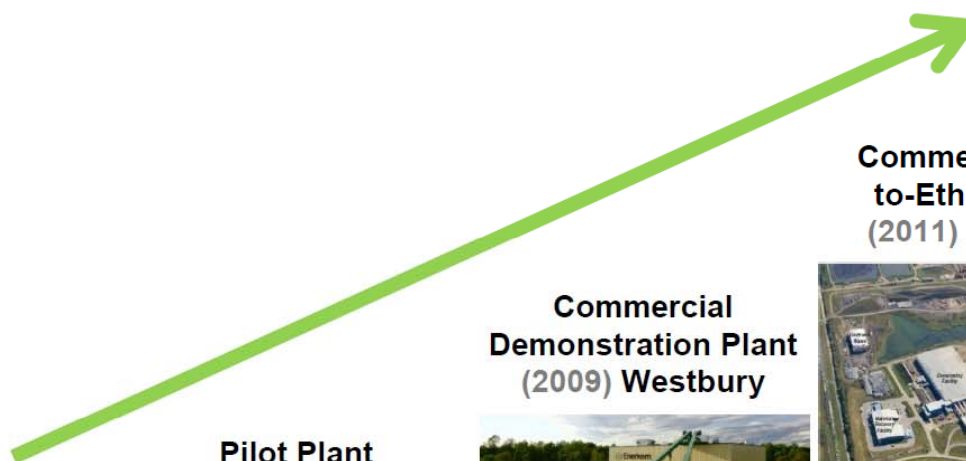




Leading developer and producer  
of advanced fuels and green chemicals  
from waste



## Rigorous Path to Commercialization



**R&D Center  
(1999)  
Sherbrooke**

**Pilot Plant  
(2003)  
Sherbrooke**

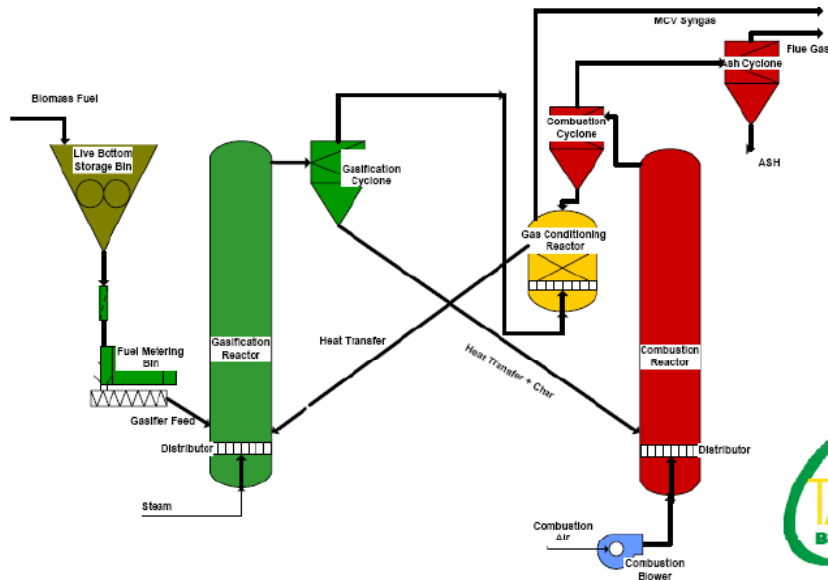
**Commercial  
Demonstration Plant  
(2009) Westbury**

**Commercial MSW-  
to-Ethanol Plant  
(2011) Edmonton**

**Commercial Waste-  
to-Ethanol Plant  
(2012) Pontotoc,  
Mississippi**



# Taylor Biomass Energy, LLC



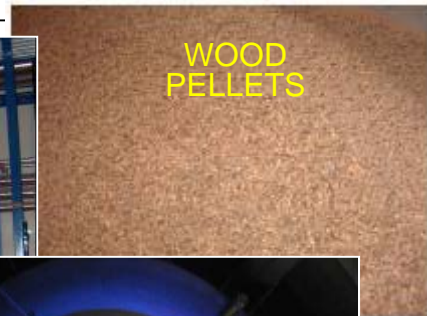
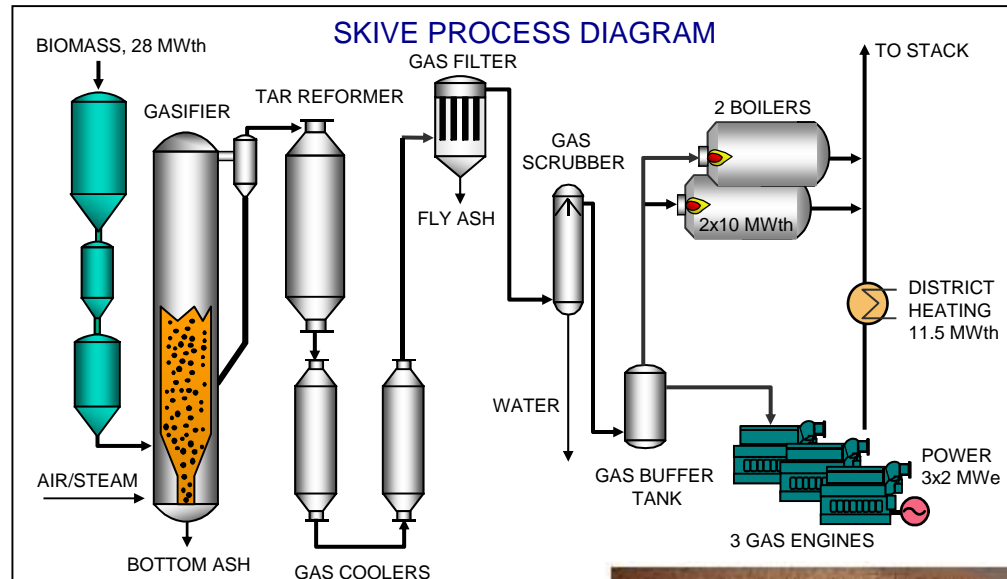
<i>HYDROGEN</i>	<i>45 - 48</i>
<i>CARBON MONOXIDE</i>	<i>15 - 20</i>
<i>METHANE</i>	<i>10 - 13</i>
<i>CARBON DIOXIDE</i>	<i>18 - 20</i>
<i>ETHYLENE</i>	<i>1 - 3</i>
<i>ETHANE</i>	<i>0 - 1</i>
<i>NITROGEN</i>	<i>trace</i>
<i>HHV</i>	<i>14 - 17 MJ/Nm<sup>3</sup></i>

- **Montgomery, NY**
  - MSW + C&D Material
  - Modular gasification facility
  - Process systems for liquid fuel + hydrogen production
  - 24 MW Combined Cycle system
  - Sell green energy to NY grid
- **Alberta, Canada**
  - 24 MW Combined Cycle system
  - Hog fuel / residuals
- **Maryland**
  - Synthesis to FT liquids

Source: Paisley, M. (2009) Biomass Conf & EXPO, April 28-30, Portland, ORE

# Carbona: SKIVE GASIFICATION CHP-PLANT, DENMARK

## 6 MWe and 12 Mwth



Status: >1000 hours with engines  
April 2009

Source: Carbona

February 2009

# STATUS OF UPM BTL PROJECT

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## ***Biomass to liquids development***

- ❑ **Route:**
  - ❑ ***FB-gasification***
    - ❑ ***Fischer Tropsch synthesis***
  - ❑ ***Product upgrade***
- ❑ **UPM strengths:**
  - ❑ ***Access to raw material***
  - ❑ ***Mill integration***
  - ❑ ***Close to core business***

## ***Current status***

- ❑ **Exclusive alliance with Andritz/Carbona**
- ❑ **Piloting in Gas Technology Institute facility in Des Plaines, IL**
- ❑ **Commercial scale plant engineering ongoing & EIA initiated**
- ❑ **Site selection process ongoing**
- ❑ **Wood supply chain & logistics survey ongoing**





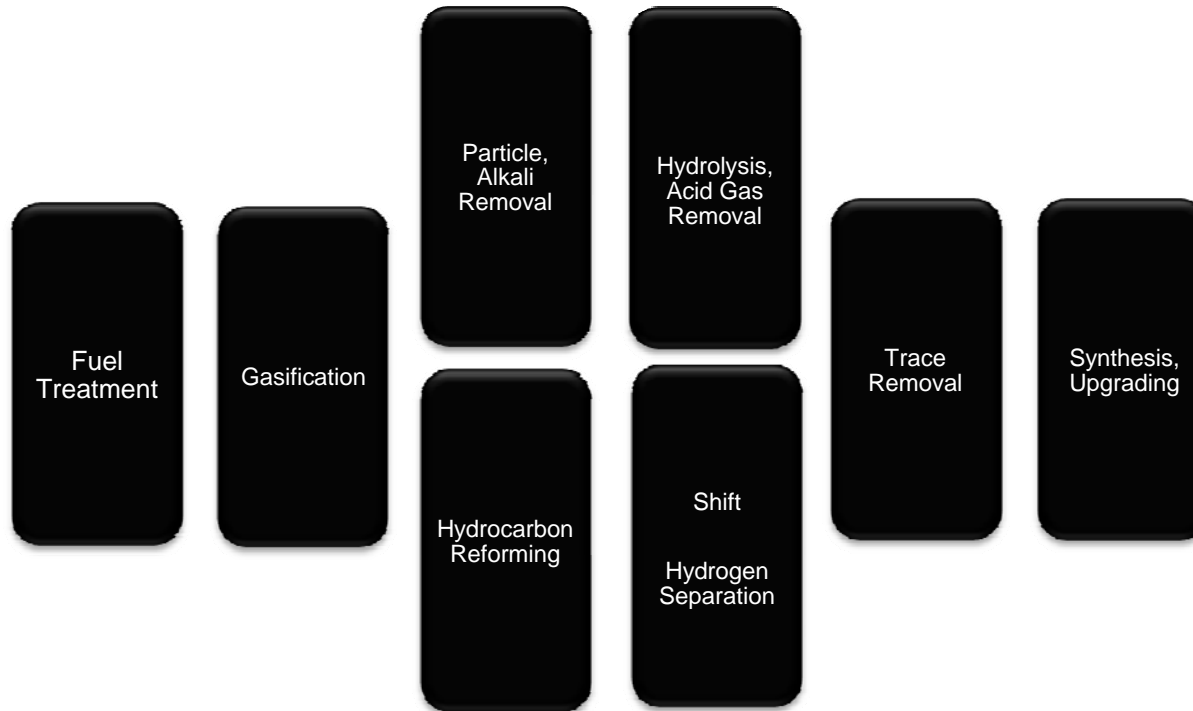
# GTI Biomass Gasification Activities



- 2<sup>nd</sup> generation biofuels
  - Laboratory & pilot-scale tests for Andritz/Carbona and UPM F-T project
  - maximum feed rate of biomass (O<sub>2</sub>-blown, 25 bar) is 40 tons/day
- Syngas cleanup
  - Warm-gas cleanup train
  - Engineered catalysts
- H<sub>2</sub> production
  - Membrane reactor system
- Biomass pretreatment
  - Hydrothermal process

Source: GTI

# GTI Synthesis Gas Process



Power  
CHP

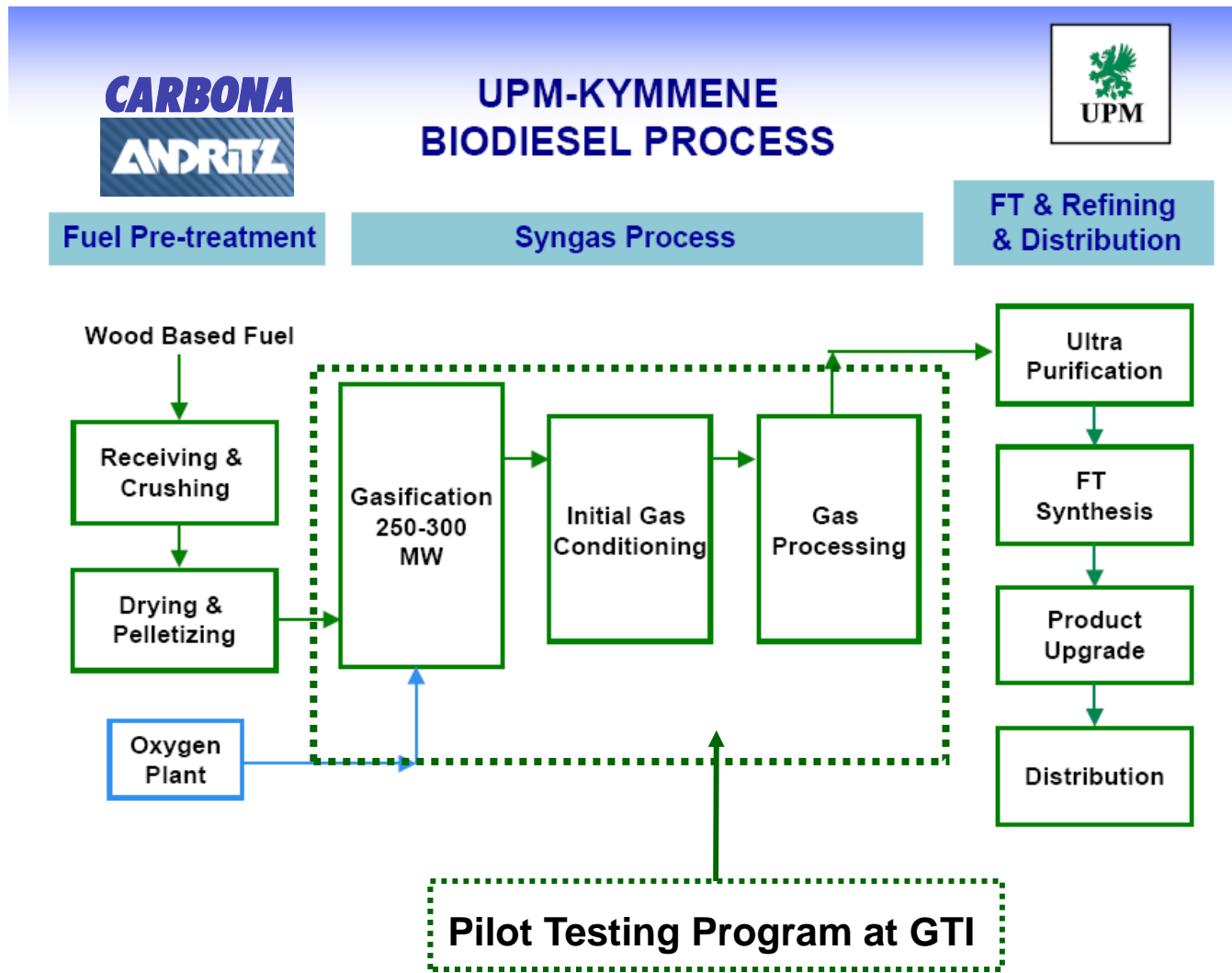
Methanol  
Alcohols  
FT Diesel  
DME

H<sub>2</sub>  
SNG



Source: GTI

# 2<sup>nd</sup> Generation Biofuel Production from Wood by Fluidized Bed Gasification and F-T



Source: GTI

# TRI Technology and Projects



TRI's core technology is deep fluidized bed, indirectly-heated, steam reforming of biomass

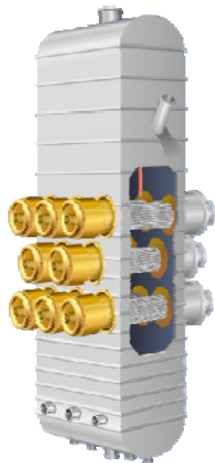
- Biomass undergoes evaporation, pyrolysis, and gasification in our system; tars are recovered and gasified

TRI's black liquor gasifier has been commercially operational for six years (Trenton, Ontario)

Two separate DOE "Small-Scale Biorefinery Projects" are employing TRI technology

- NewPage, Wisconsin Rapids, WI; 500 dry tons per day biomass to FT fuels and tail gas. Class 10 study underway (\$30 million award, 2008)
- Flambeau River Biofuels, Park Falls, WI; 1000 dry tons per day biomass to FT fuels. Class 30 completed (\$30 million award, 2008)

State-of-the-art 4 dry ton per day solid biomass pilot plant at Carbon-2-Liquids (C2L) Center, Durham NC



Highly-scalable TRI reformer design:  
number of PulseEnhanced™ heaters is  
adjusted within same reformer vessel to  
meet required throughput level

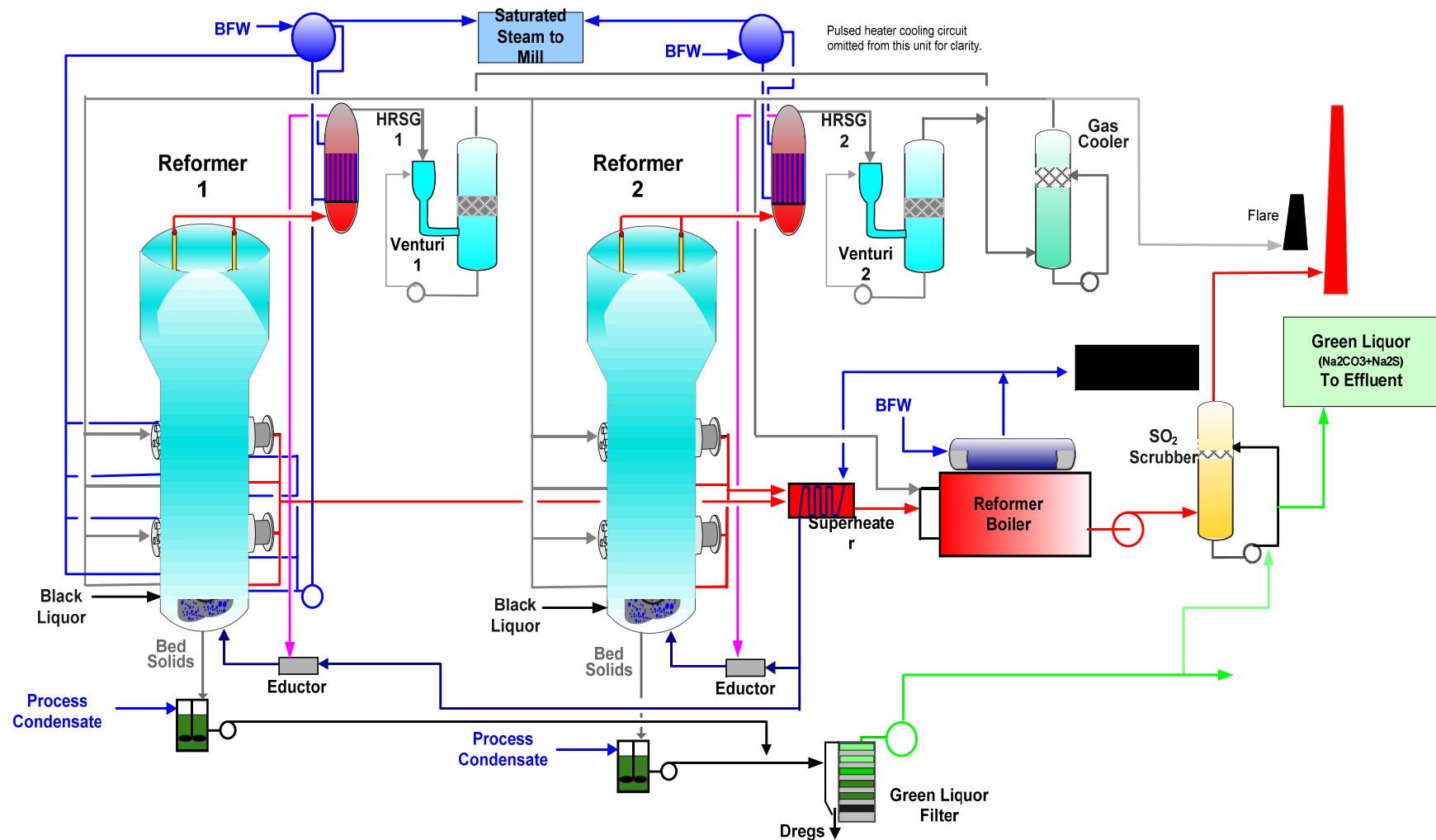


TRI BL gasifier (top left) at  
Norampac's Trenton, Ontario plant



Newest TRI PDU in Durham, NC

## Black Liquor Steam Gasification



# TRI Technology and Projects



# Coskata – Project Lighthouse

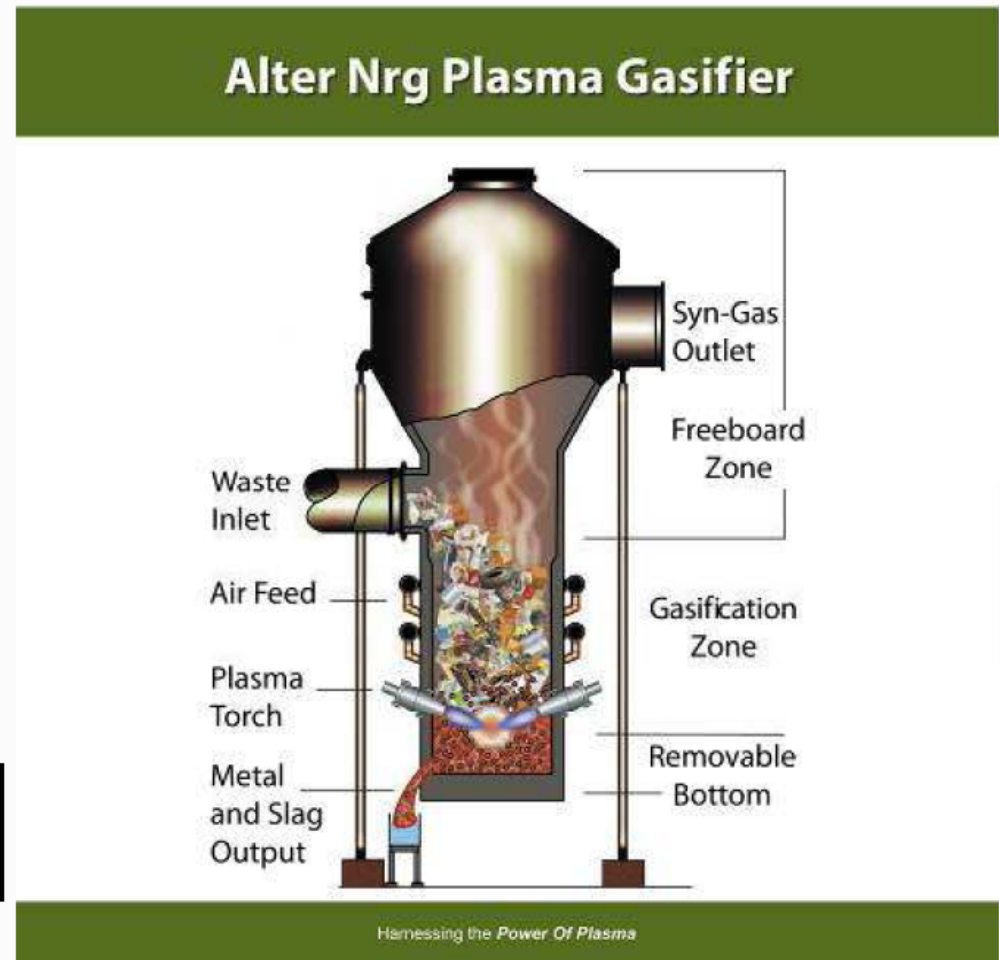
- Semi-commercial demonstration
- Located in Madison, PA
- Partnership between Coskata and Alter NRG
- Technology
  - Gasification Westinghouse Plasma Gasifier
    - Now owned by Alter NRG
  - Coskata – Syngas fermentation to ethanol
- Scale – 50,000 gal/yr ethanol
  - 100 gal/ton
  - Pine chips
- Status – Successful startup announced (Oct 2009)



# Alter NRG Gasifier

- The Proprietary Alter Nrg Plasma Gasifier (PG) design is based on the Iron-Melting Cupola Furnace
  - Proven in harsh operating environments
  - Refractory lined steel vessel
    - Lower section is water cooled
  - Able to generate high operating temperature, reducing gas velocities
  - Ash produced as vitreous non-leaching slag
- Typical reactor capacities vary by feedstock:

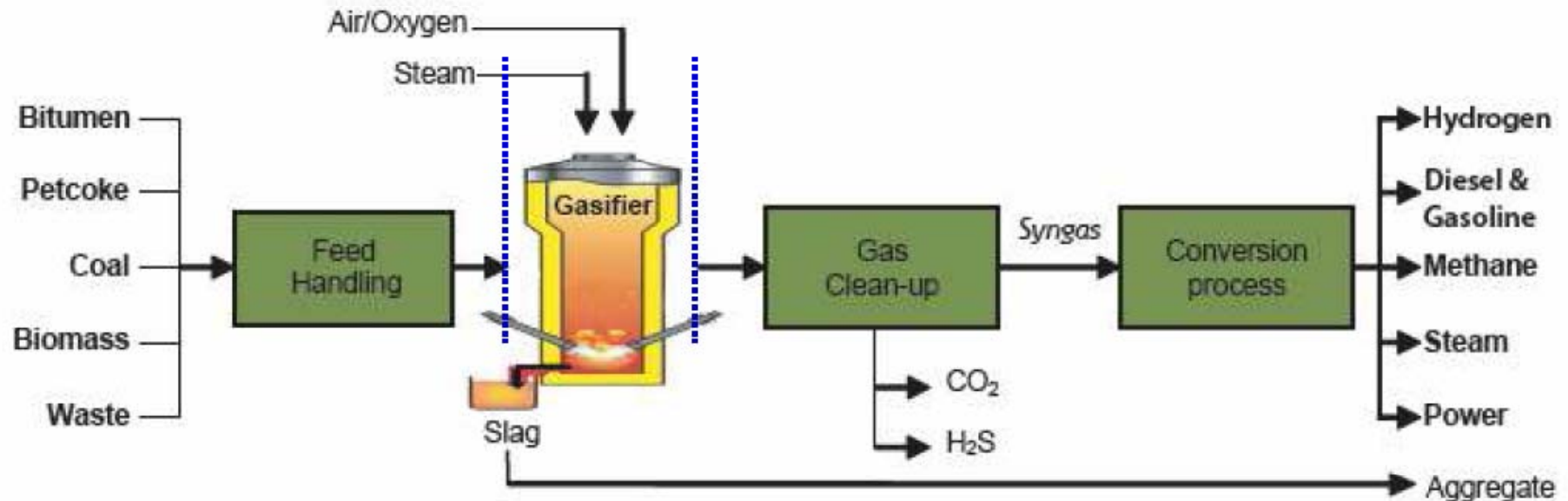
MSW	500-750 tpd
Biomass	500-750 tpd





# Alter NRG Simple Process Schematic

Wide Variety of Feedstocks → Flexible Process → Wide Variety of Products



Low \$ Cost

Gasifier

High \$ Value

# Other Plasma/Plasma Assisted Gasifier Developers

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- Inentech Chemicals, Idaho & Florida
  - <http://www.inentec.com/>
  - Projects:
    - Dow Corning, Midland, MI – industrial wastes
    - Richland, WA – sorted MSW 1 tpd)
    - Inactive - Iisuka, JP; Kapolei, HI
- Adaptive ARC, Carlsbad, CA
  - <http://www.adaptivearc.com/>

# Frontline Bioenergy, LLC, Ames, Iowa



# Frontline System

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## Bubbling Fluid Bed

- Fuel flexibility: corn stover, straw, grasses, tramp material
- Robust performance, isothermal: minimal clinkers, bed recycle

## Moderate pressure operation

- Greater throughput: single unit, allows shop-built components
- Benefits for Biomass-to-liquids: avoid first stage compression

## Gas Conditioning

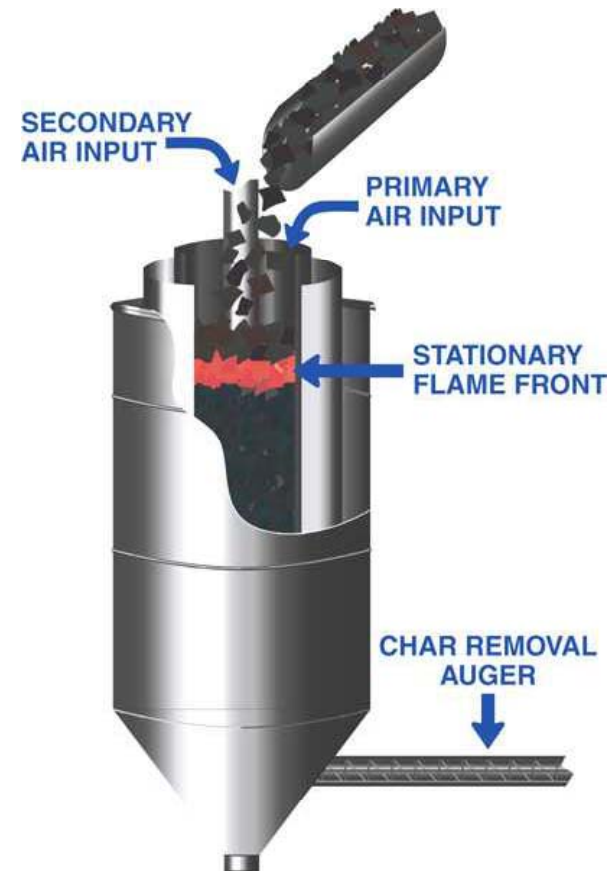
- Novel filtration: removes alkalis and PM, protects downstream boilers and catalytic/biological processes
- Proprietary Tar cleanup: allows multi-burner applications

## Upgradeable for Syngas production

- Add oxy/steam system for syngas production
-

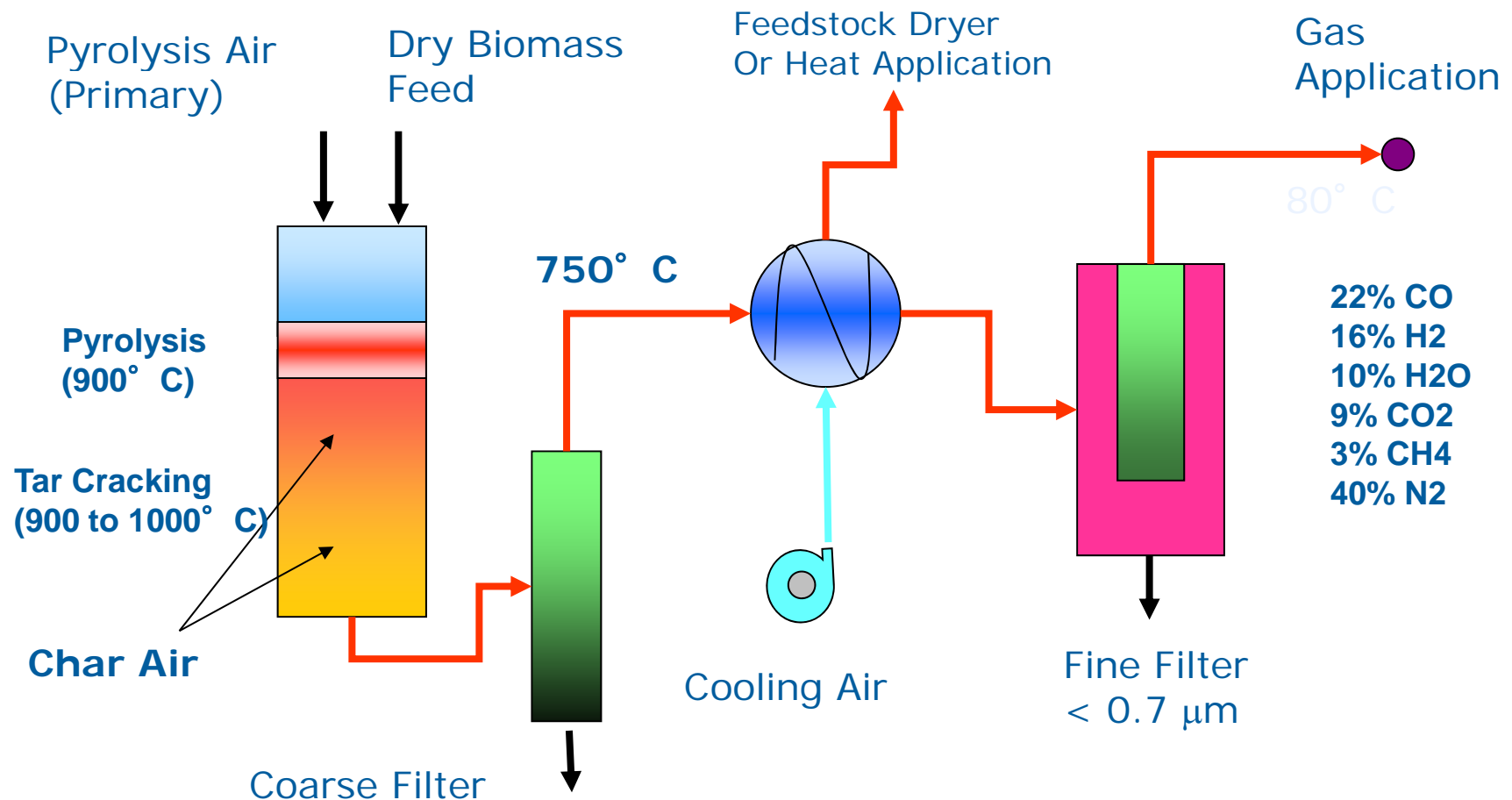
# DOE and the USDA Forest Service have supported development Community Power Corporation's BioMax Modular Biopower System

5, 15, 50 kW systems



Credit: Community Power Corp

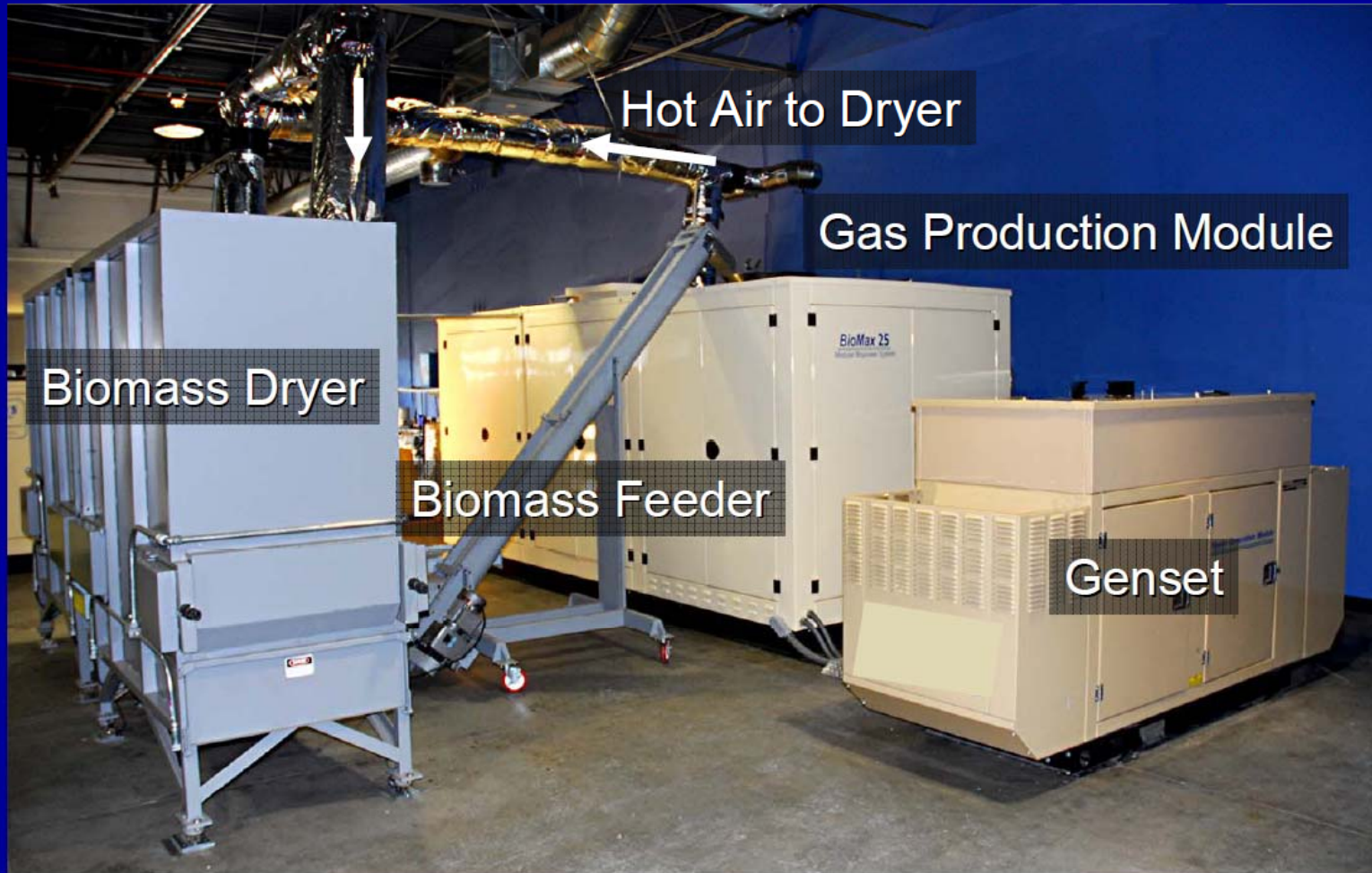
# CPC's Process Schematic



**70% of Biomass Energy = Chemical Fuel**  
**15% of Biomass Energy = Recoverable Heat, Gas Cooling**

# Community Power Corporation, Littleton, Colorado

## Today: BioMax™ – Modular Bioenergy Systems From 25 to 100 (kWe)



# Community Power Corporation, Littleton, Colorado

## CPC's BioMax Has Extensive Field Experience

### 18 BioMax Sites

- Walden, CO
- Reno, NV
- Madison, WI
- Starkville, MS
- Grand Forks, ND
- Mt. Wachusett, MA
- Miami, FL
- El Salvador (#1)
- El Salvador (#2)
- West Lafayette, IN
- Minneapolis, MN\*
- Winters, CA
- Auburn, AL
- Missoula, MT
- Alexander, LA
- Edmonton, Canada\*
- Detroit, MI\*
- US Army\*

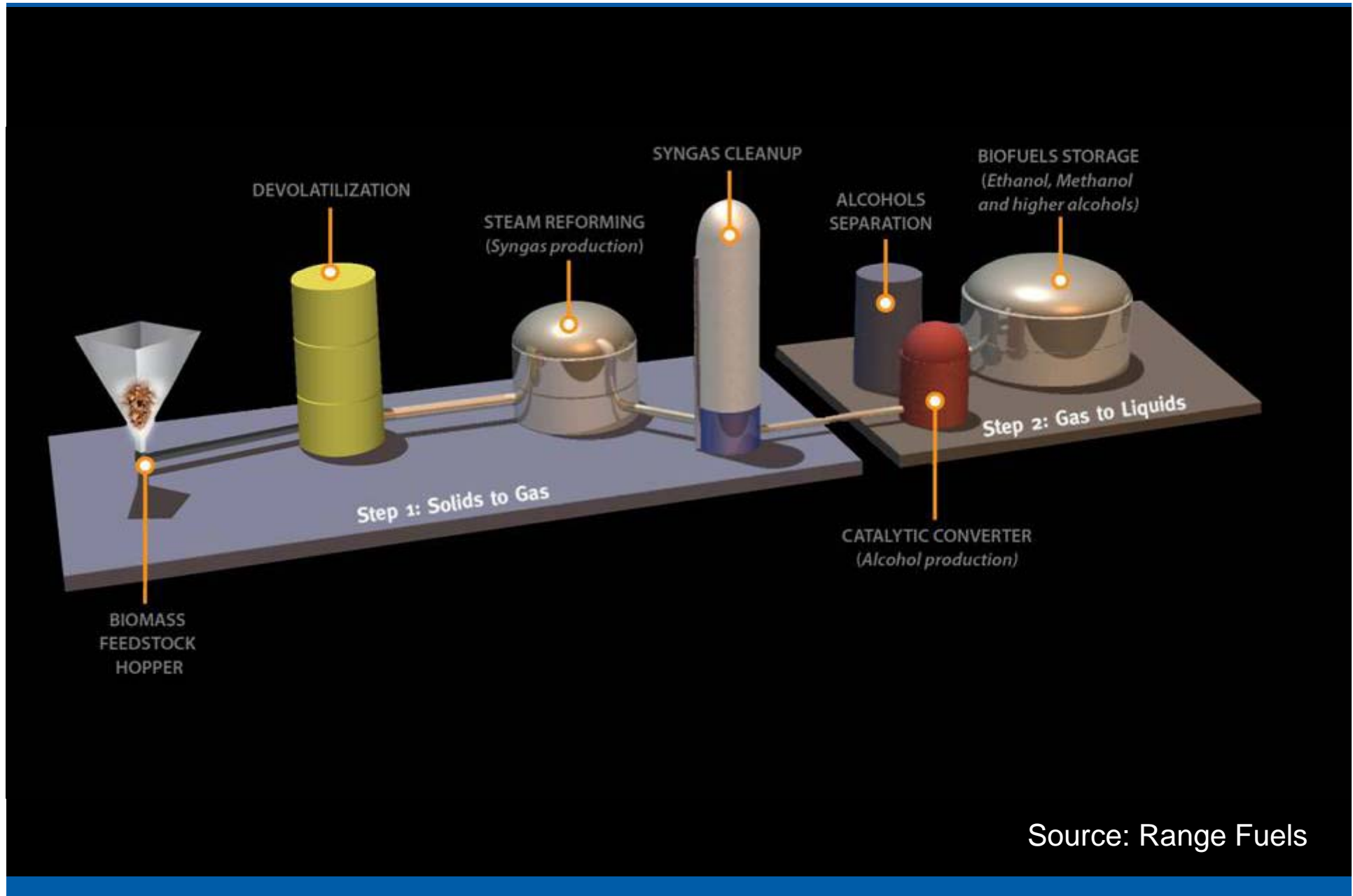
\* Installation pending



**Prototype Tactical Biorefinery**  
 Mobile encampment feeding waste to energy (gaseous fuels and ethanol)  
 US Army/Baghdad  
 Contractors: Community Power Corporation, Purdue University, Defense Life Sciences  
 May 2008



# Range Fuels' Thermo-chemical Conversion Technology



Source: Range Fuels

# University of California & West Biofuels: Thermochemical Conversion of Biomass to Mixed Alcohols

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Research Team: University of California (San Diego, Davis, and Berkeley), West Biofuels LLC.  
Location: Woodland Biomass Research Center, Woodland, CA 95776  
Contact: Professor Robert Cattolica, PI, UCSD, email: rjcat@ucsd.edu



- 5 ton/day dual-fluidized bed gasifier based on “Pyrox Process”
- Producer Gas – 500 BTUs/ft<sup>3</sup>
- Atmospheric Pressure
- Air blown combustor
- Auto-stabilizing: Bed Level Temperature
- Auto-regeneration of catalyst
- Minimizes replenishment of bed material and catalyst
- Extensive Testing on MSW in Japan (MITI) for power production  
3 units each 150 tons/day  
7 year demonstration  
1983 -1989
- Status: In Start-up

Source: University of California, San Diego

# Gulf Coast Energy, Inc

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**Process:** Ethanol production via biomass steam reforming, gas cleanup, mixed alcohol synthesis, alcohol distillation

**Gasifier:** Indirect entrained flow using natural gas as fuel

**Status:** 4.5 tpd pilot unit

**Location:** Livingston, AL



# Questions

