

Biomass Gasification R&D Activities in North America



**IEA Task 33 Workshop
Christchurch, NZ**

Richard L. Bain

Apr 14, 2011

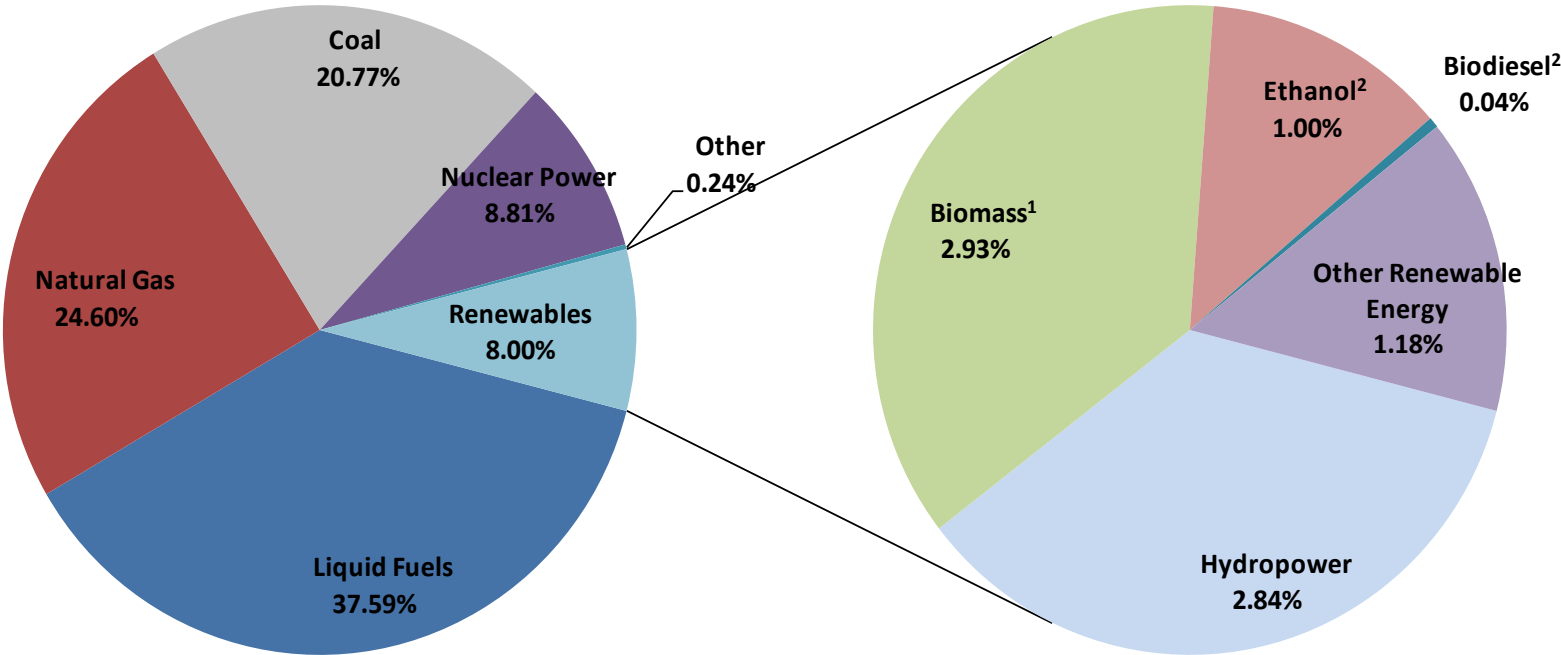
Presentation Outline

- **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



¹ Biomass modified to include biogenic MSW and landfill gas included in other/other renewables in AEO

² Ethanol and biodiesel taken from Liquid Fuels in AEO

Total U.S. 2009 Primary Energy Consumption = 100 Exajoules

Current Biofuels Status

Biodiesel – 2.85 billion gallons/yr nameplate capacity (April 2011)¹

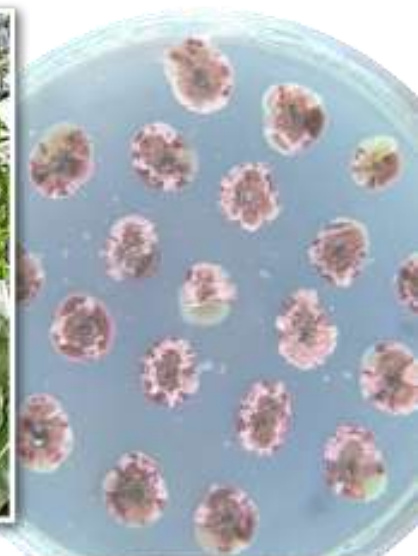
- Mar 2011 Rack Price – 478.06 cents/gal

Corn ethanol

- 218 commercial plants²
- 14.554 billion gal/year nameplate capacity
- 11.987 billion gal/yr. production²
- Additional 0.27 billion gal/yr planned or under construction
- Mar 2011 Rack Price – 270.48 cents/gal

Key DOE Goals

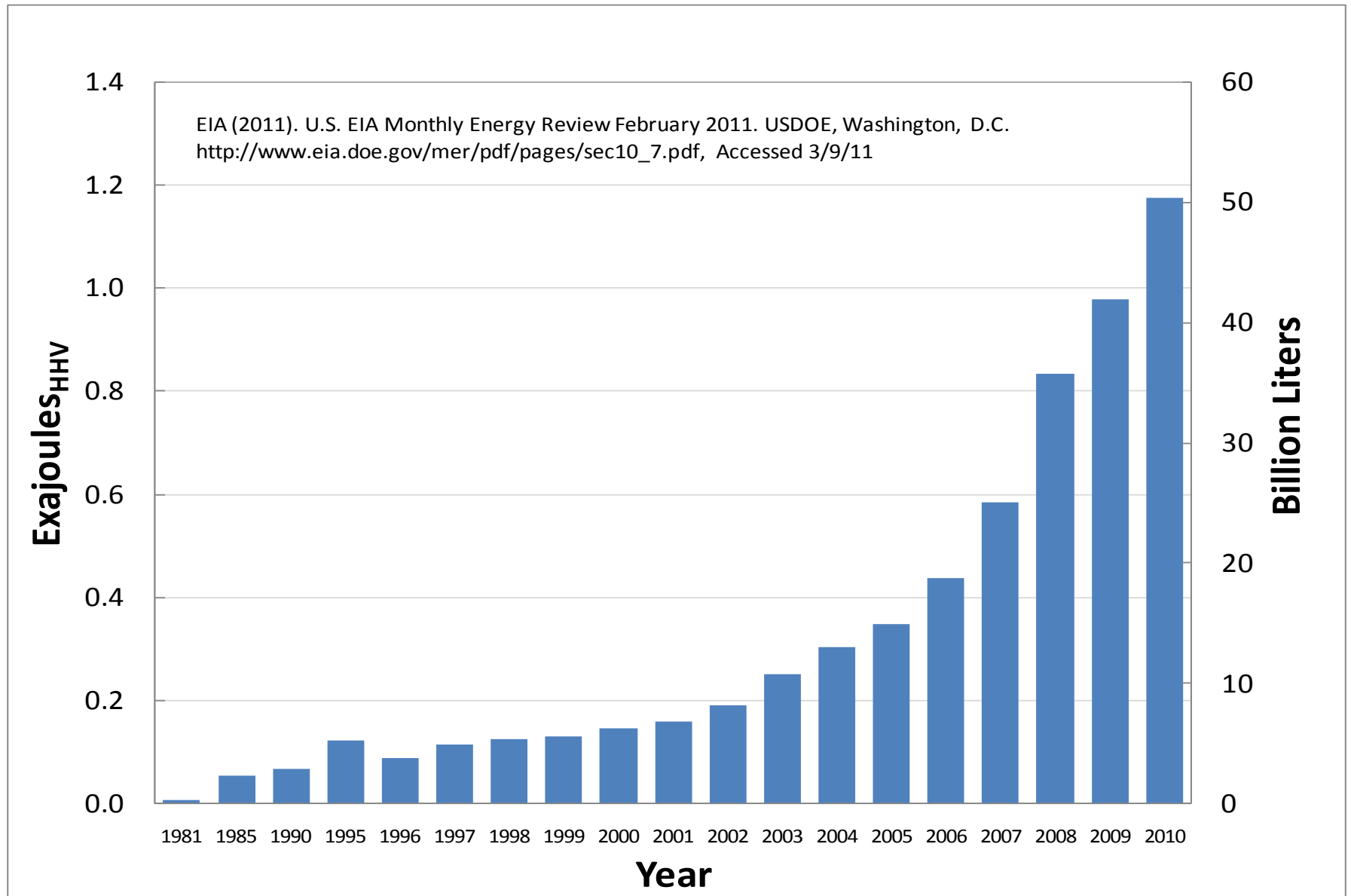
- 2012 goal: cellulosic ethanol \$1.51/ETOH gallon
- 2022 goal: 36B gal Renewable Fuel; 21B gal “Advanced Renewable Fuel”– 2007 Energy Independence and Security Act
- 2030 goal: 60 billion gal ethanol (30% of 2004 gasoline)



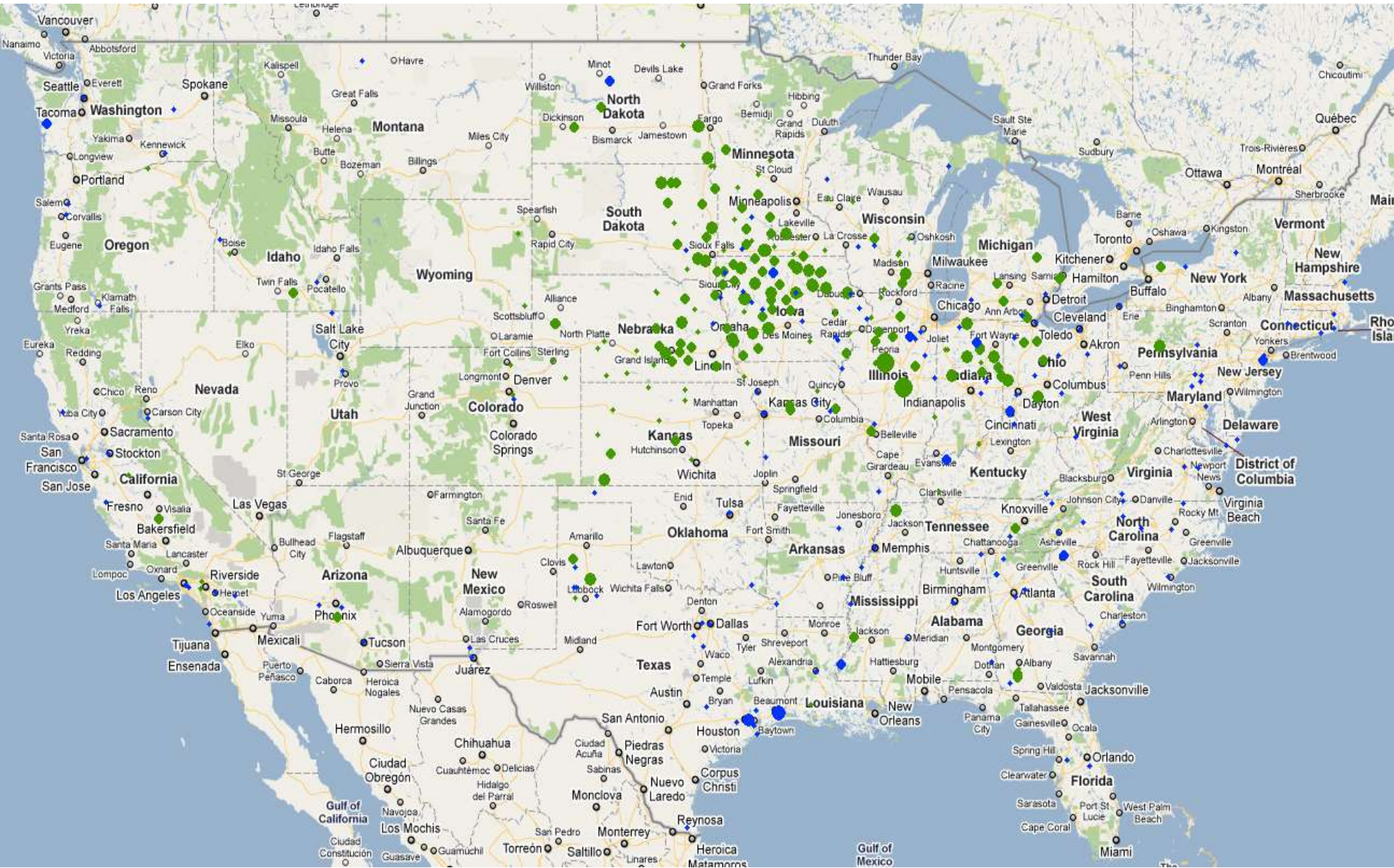
Updated Apr 2011

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



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

2022 - 22 GW

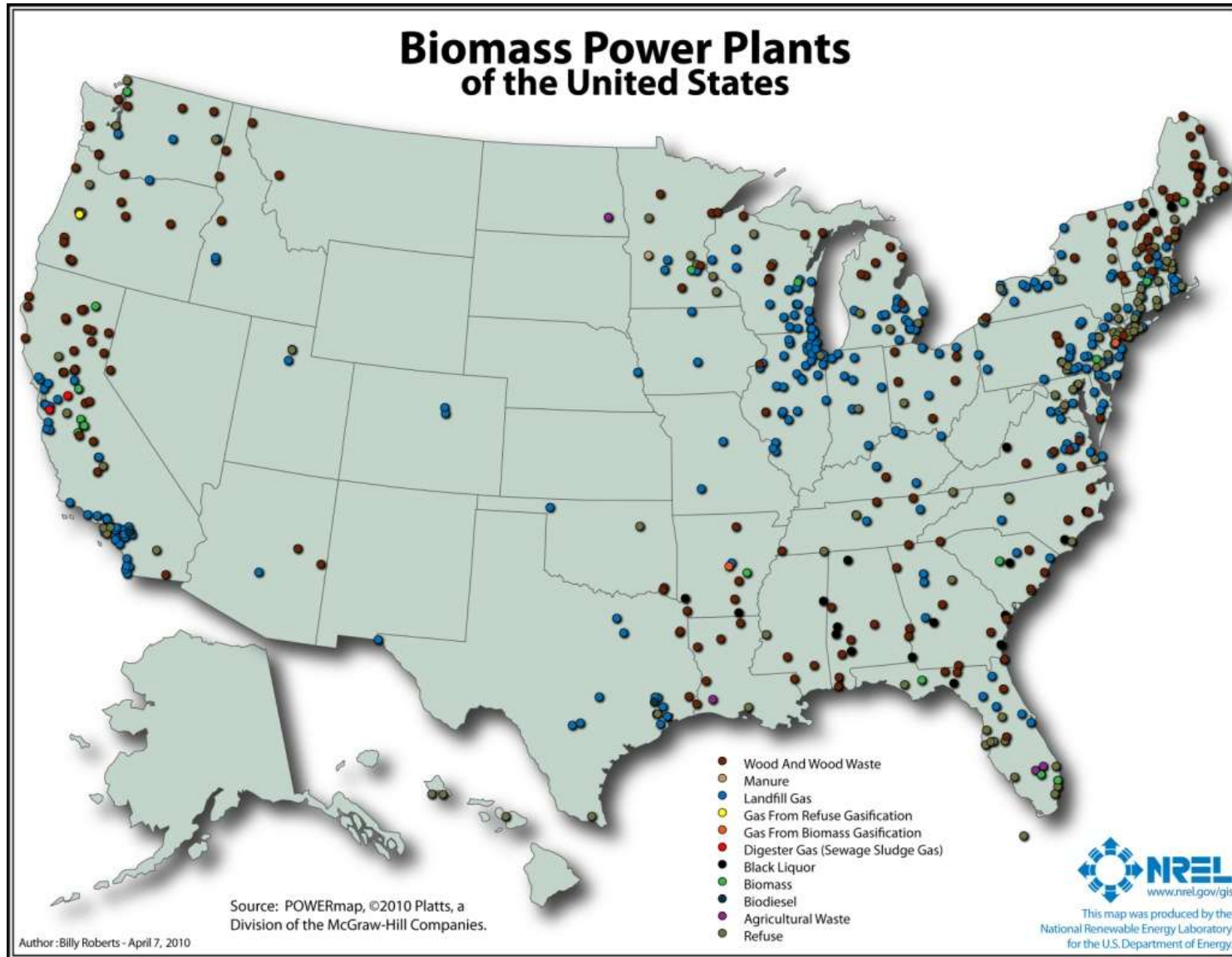
2035 - 48 GW

2050 - 91 GW

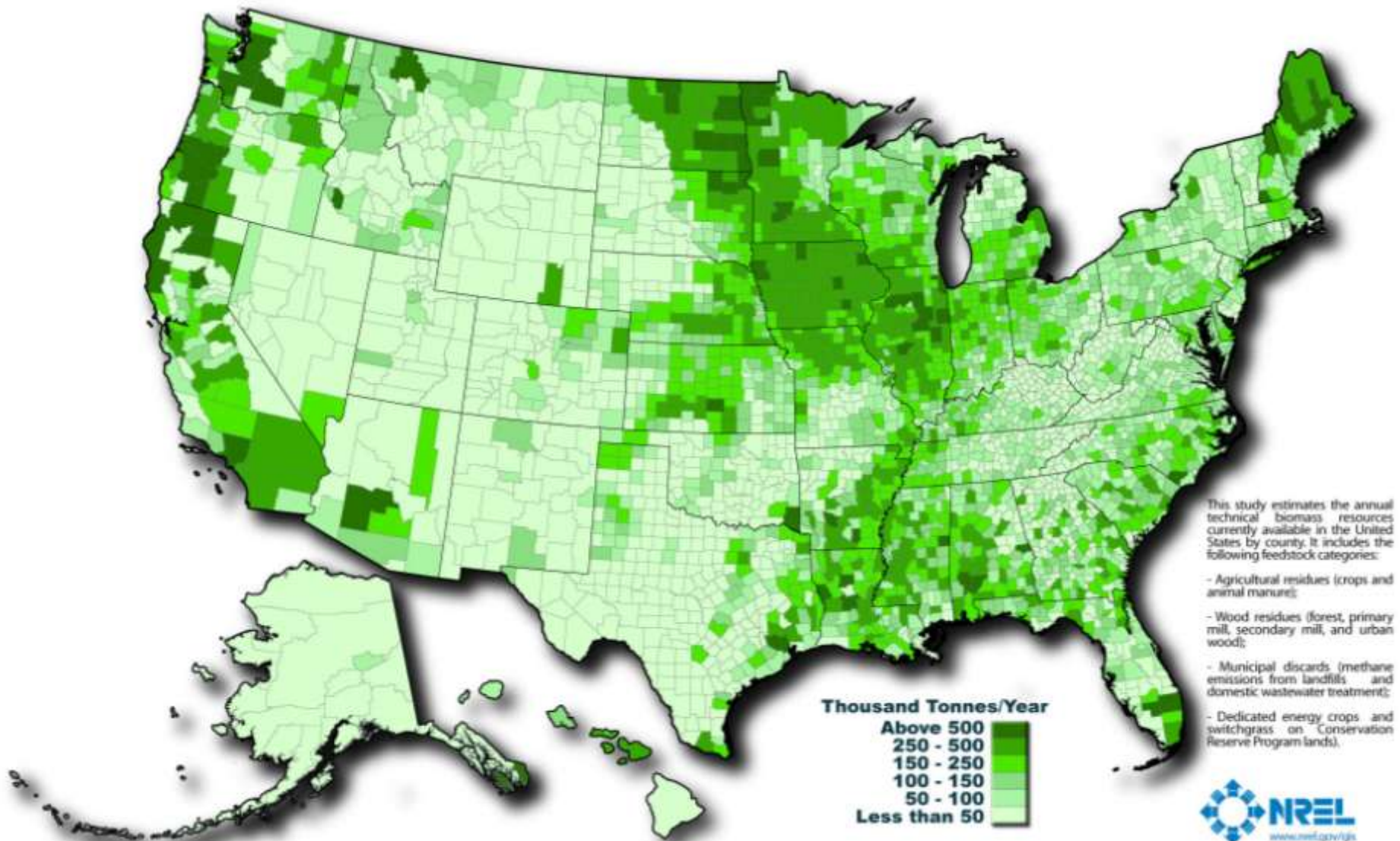


Sources: DOE EIA Annual Energy Outlook, Table A16 (year-by-year) , NREL Renewable Electricity Futures Study (2010) – Preliminary Data
EIA Form 860 (Capacity), EIA Form 923 (Generation)

U.S. Existing Biopower Plants



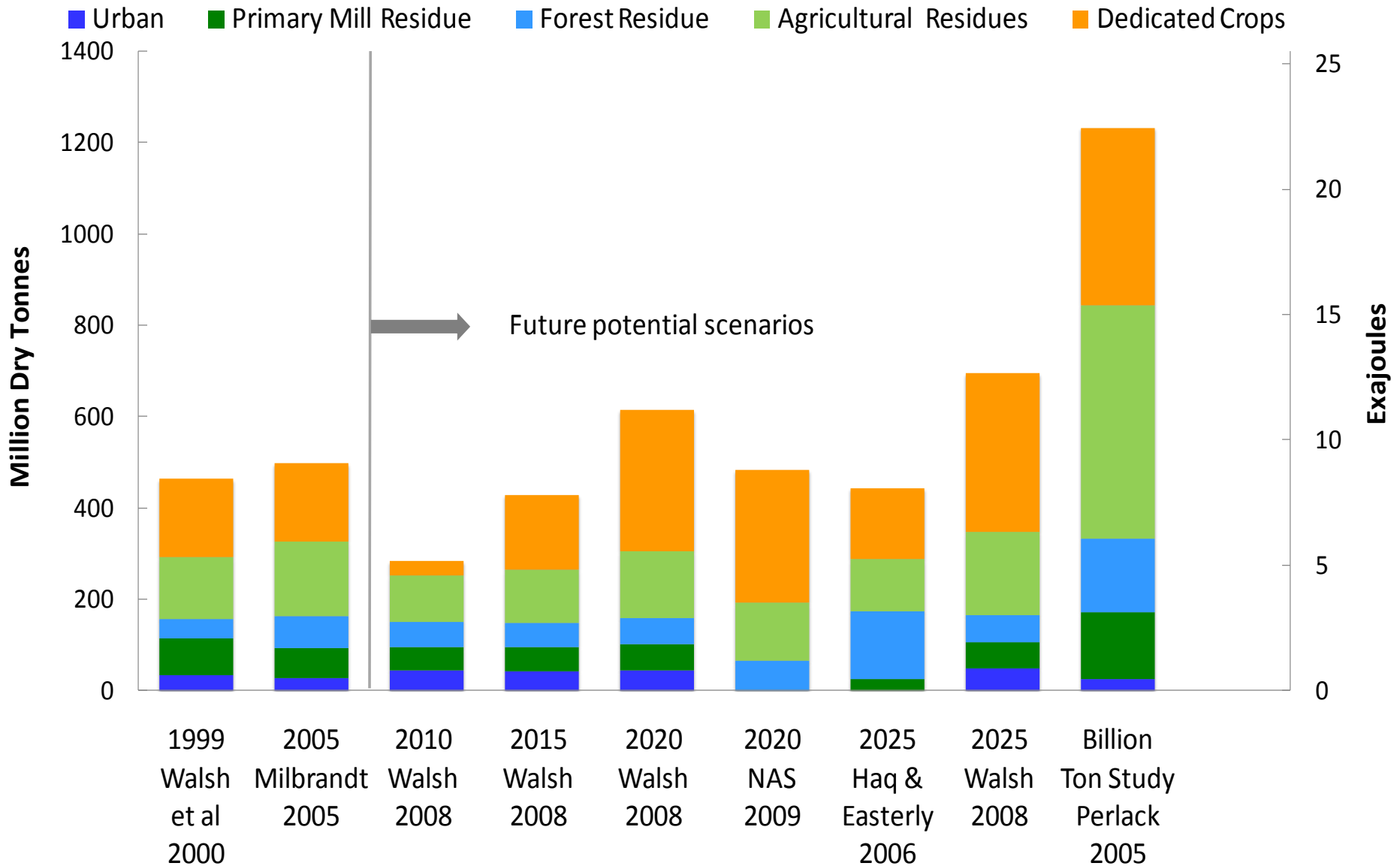
U.S. Biomass Resource



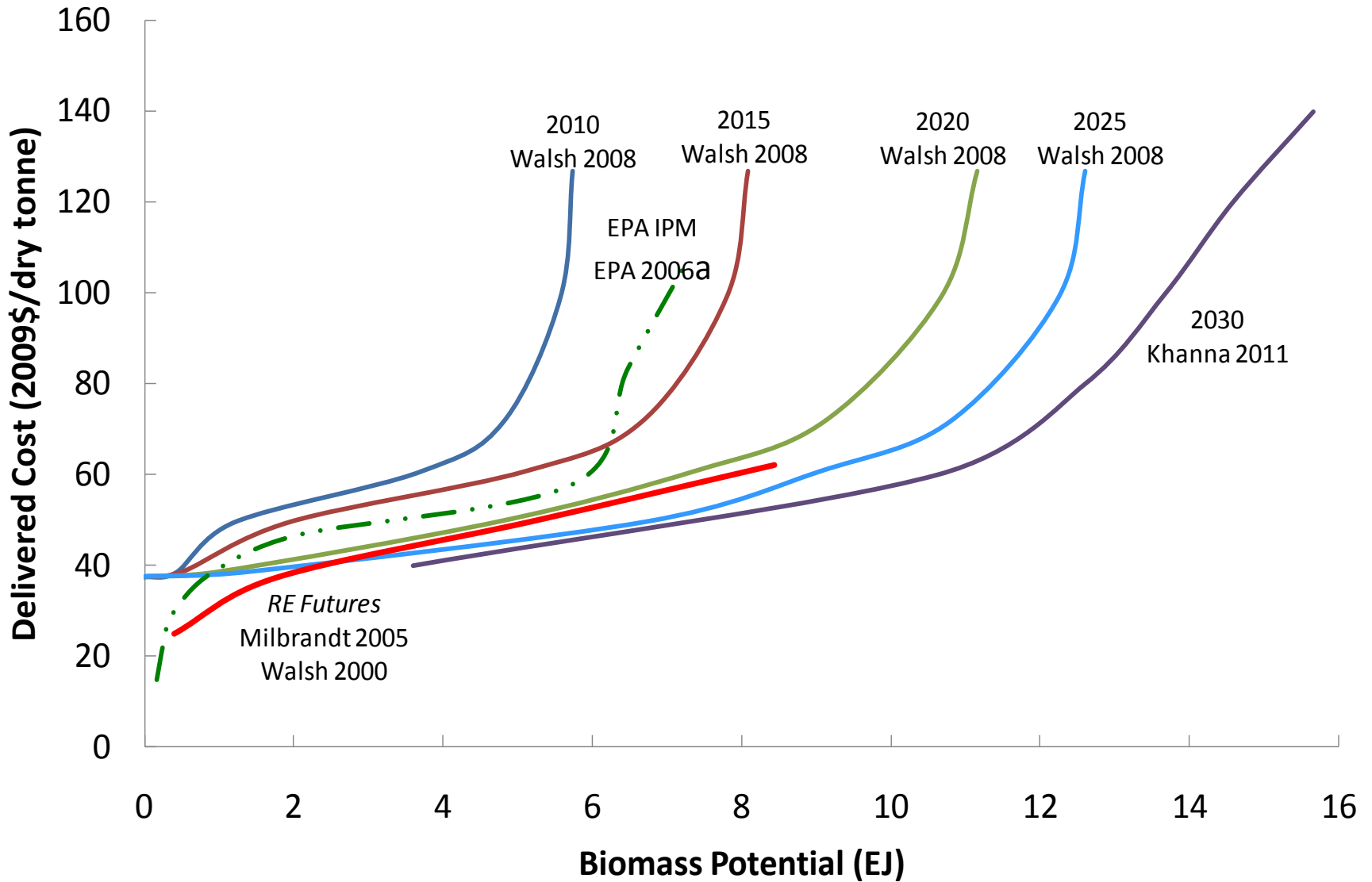
Author: Billy Roberts - October 20, 2008

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

DOE Integrated Gasification Biorefinery Projects



http://www1.eere.energy.gov/biomass/integrated_biorefineries.html

DOE Integrated Gasification Biorefinery Projects



an initiative 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 100 short ton (90 metric ton) 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 slowly generated in the surrounding counties and allowed to be landfilled each day. By converting this waste into renewable fuels, the



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

by over 99% and of the waste that 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 biorefinery is located. Furthermore, of this municipal-waste energy remaining for conversion into renewable fuels for 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

Gasification Technologies



Nexterra Energy Corporation

Johnson Controls Inc.
University of South Carolina

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

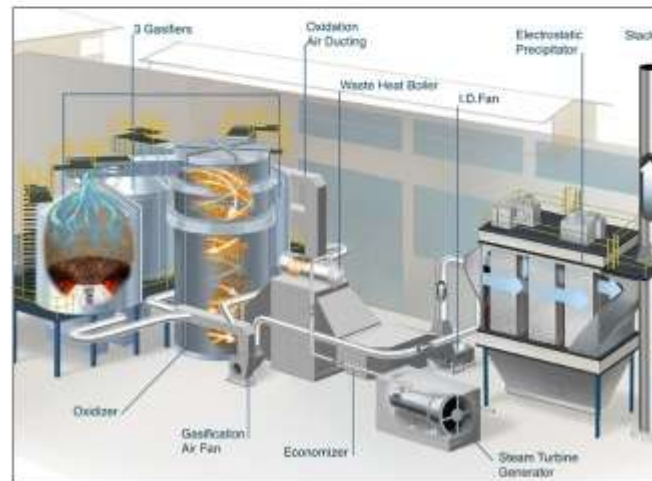
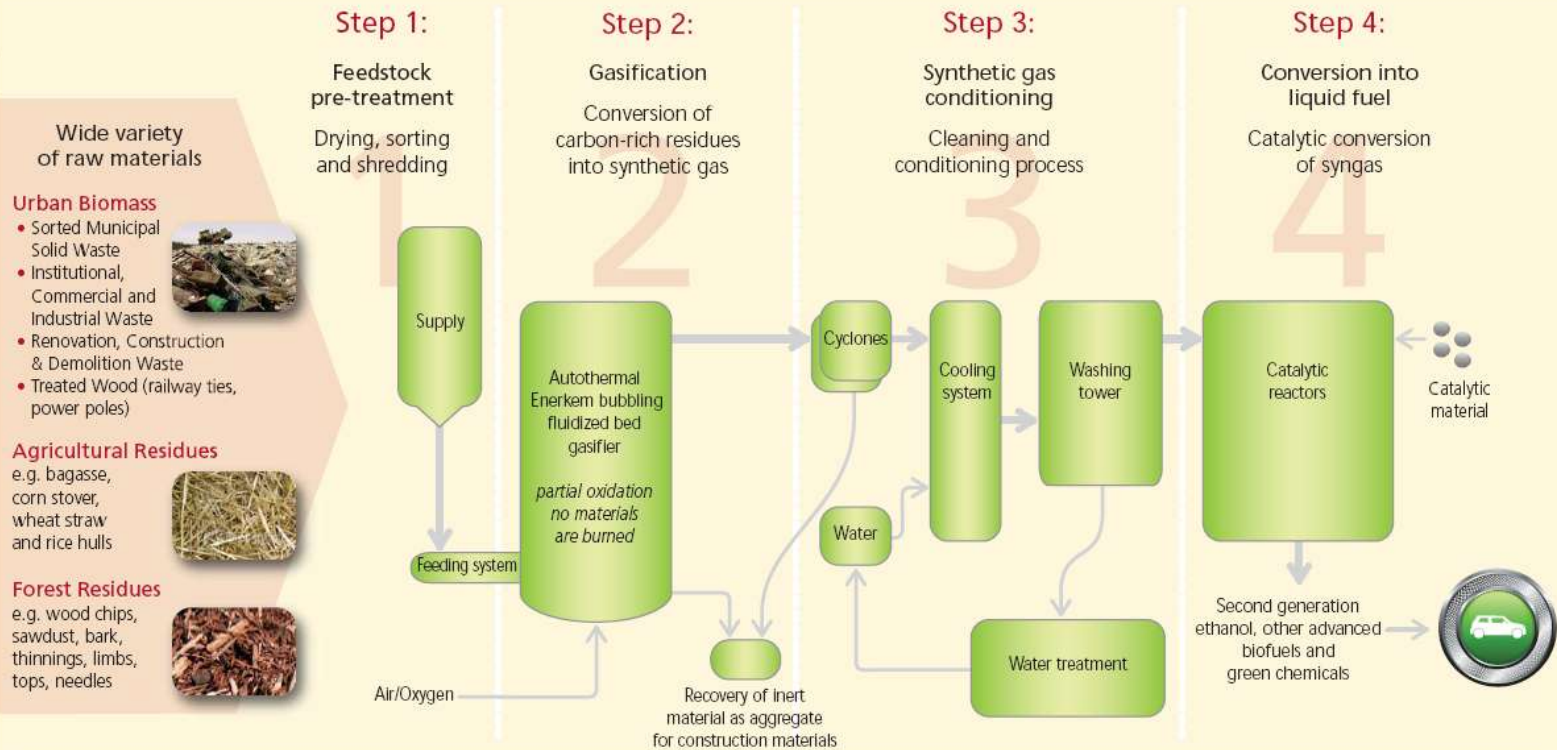


Illustration of Nexterra's gasification system at USC



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.

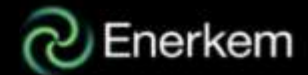
Enerkem uses an environmentally friendly process:

- 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.

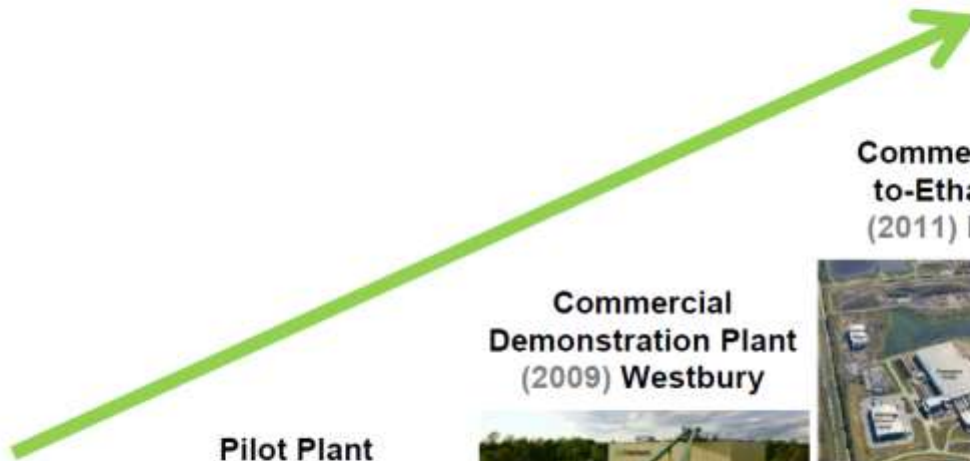




Leading developer and producer
of advanced fuels and green chemicals
from waste



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

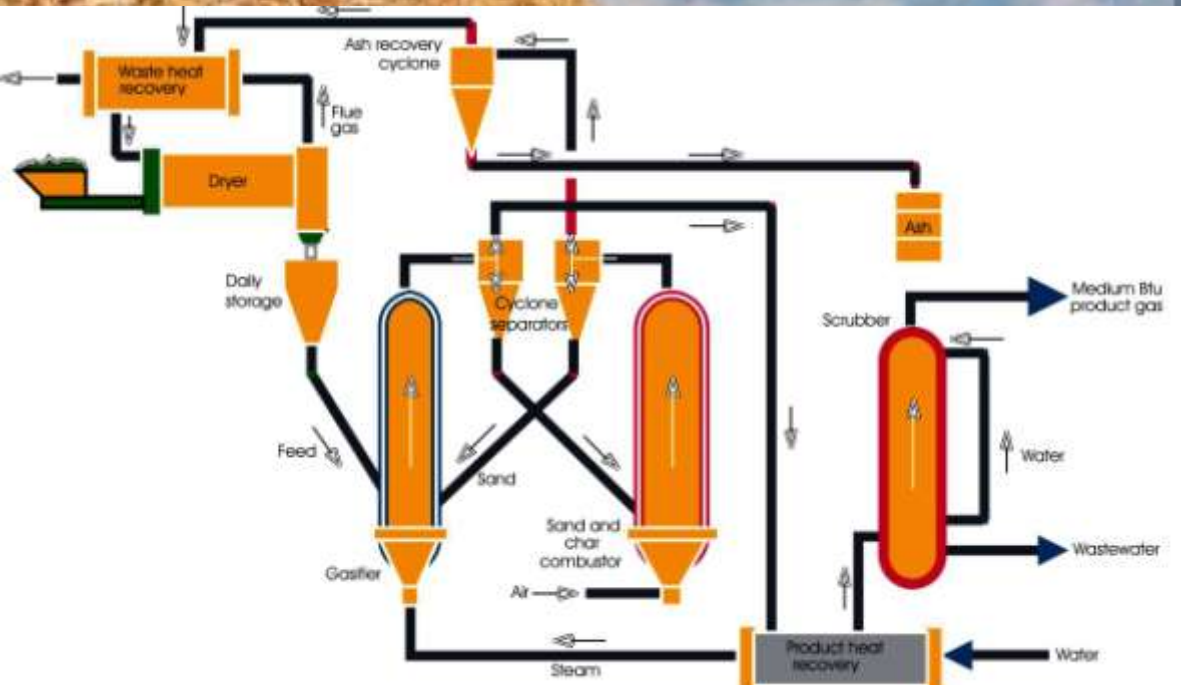


Commercial Waste-
to-Ethanol Plant
(2012) Pontotoc,
Mississippi

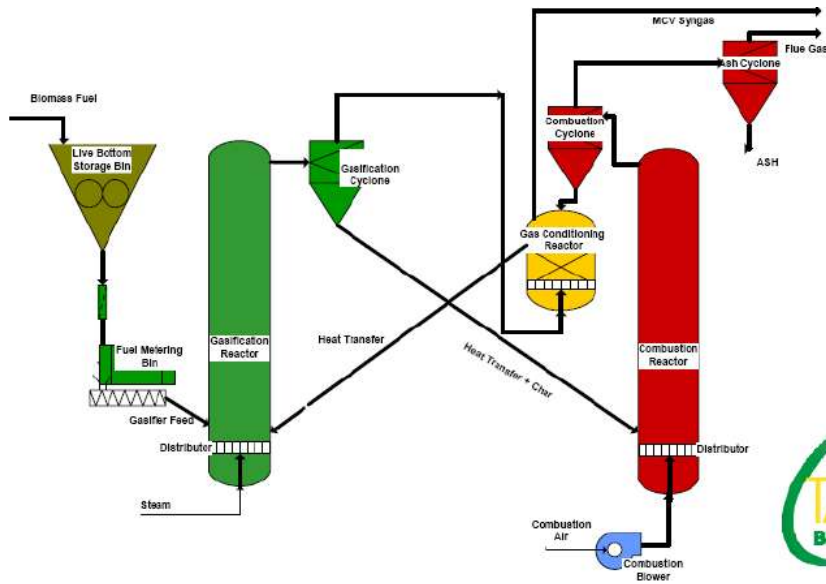
FERCO GASIFIER- BURLINGTON, VT

350 TPD

Technology now owned by Rentech



Taylor Biomass Energy, LLC



- **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**

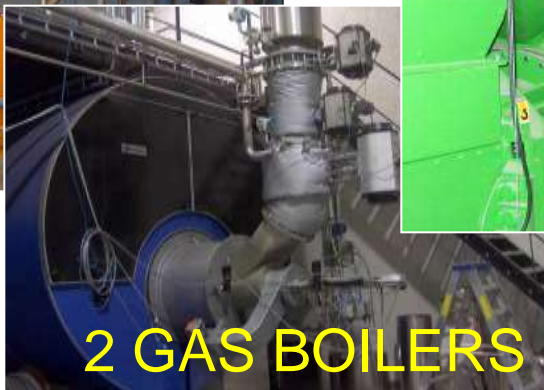
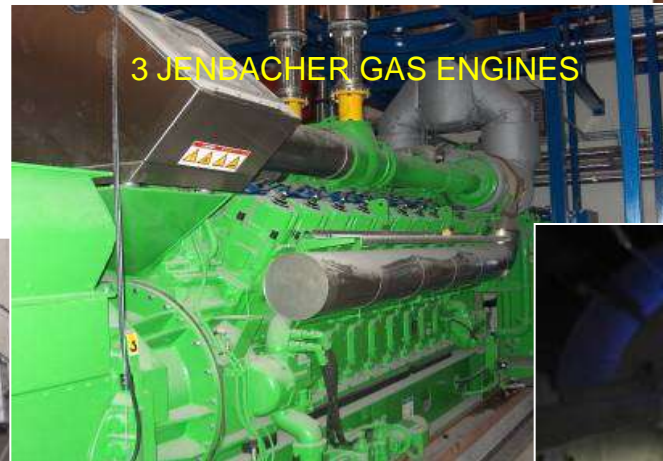
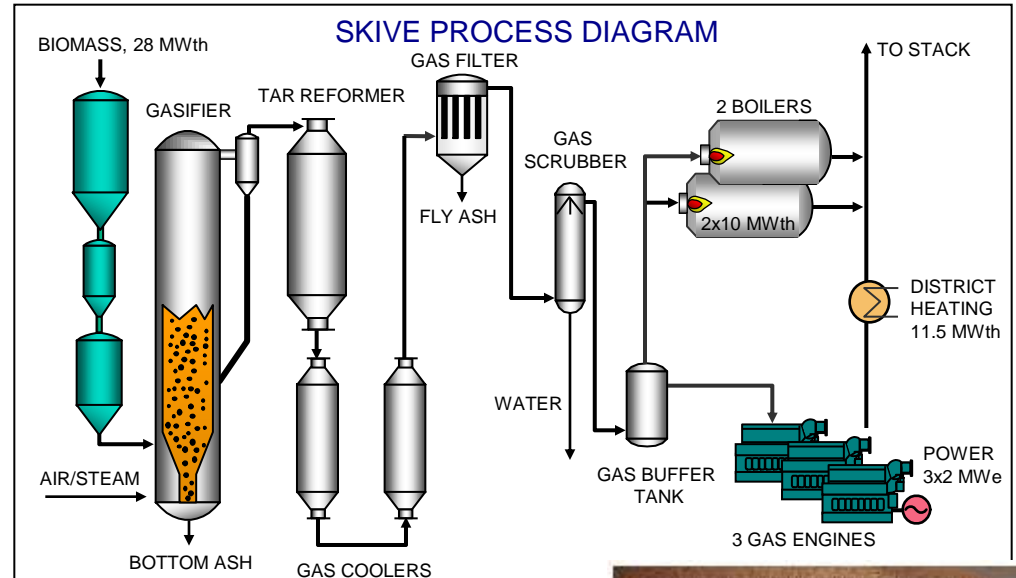
- Synthesis to FT liquids

HYDROGEN	45 - 48
CARBON MONOXIDE	15 - 20
METHANE	10 - 13
CARBON DIOXIDE	18 - 20
ETHYLENE	1 - 3
ETHANE	0 - 1
NITROGEN	trace
HHV	14 - 17 MJ/Nm³

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

STATUS OF UPM BTL PROJECT

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**

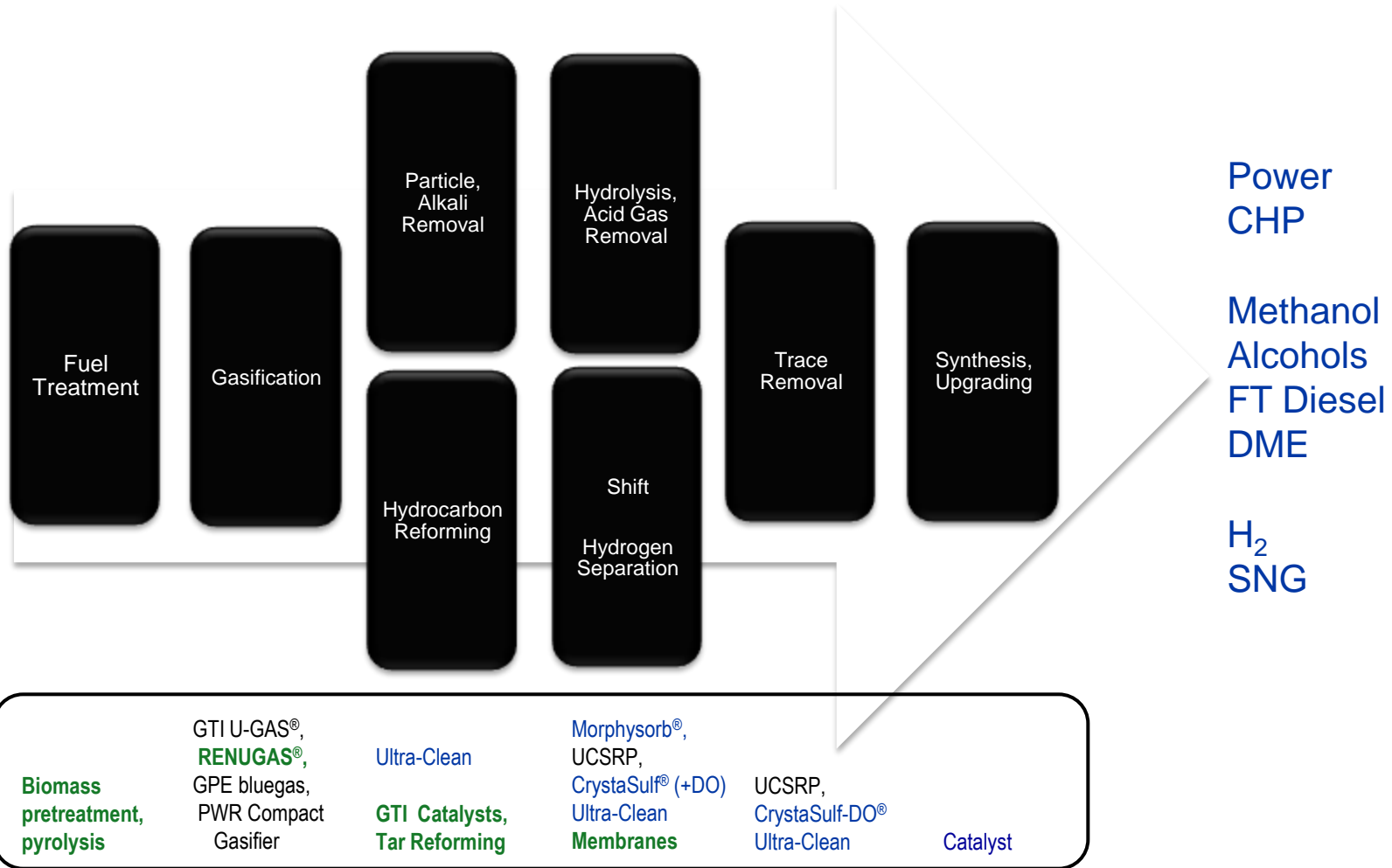


GTI Biomass Gasification Activities

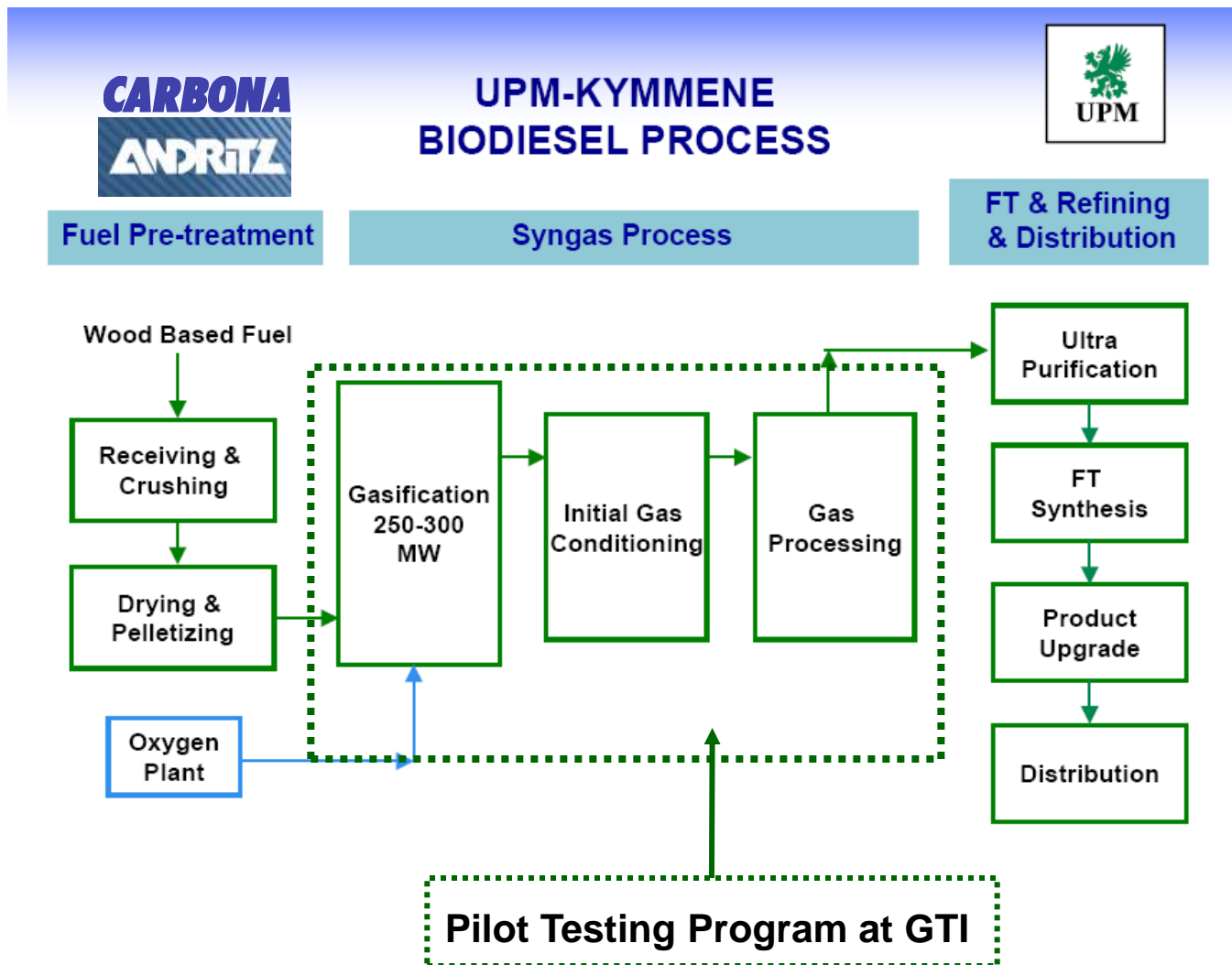


- 2nd generation biofuels
 - Laboratory & pilot-scale tests for Andritz/Carbona and UPM F-T project
 - maximum feed rate of biomass (O₂-blown, 25 bar) is 40 tons/day
- Syngas cleanup
 - Warm-gas cleanup train
 - Engineered catalysts
- H₂ production
 - Membrane reactor system
- Biomass pretreatment
 - Hydrothermal process

GTI Synthesis Gas Process



2nd Generation Biofuel Production from Wood by Fluidized Bed Gasification and F-T



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



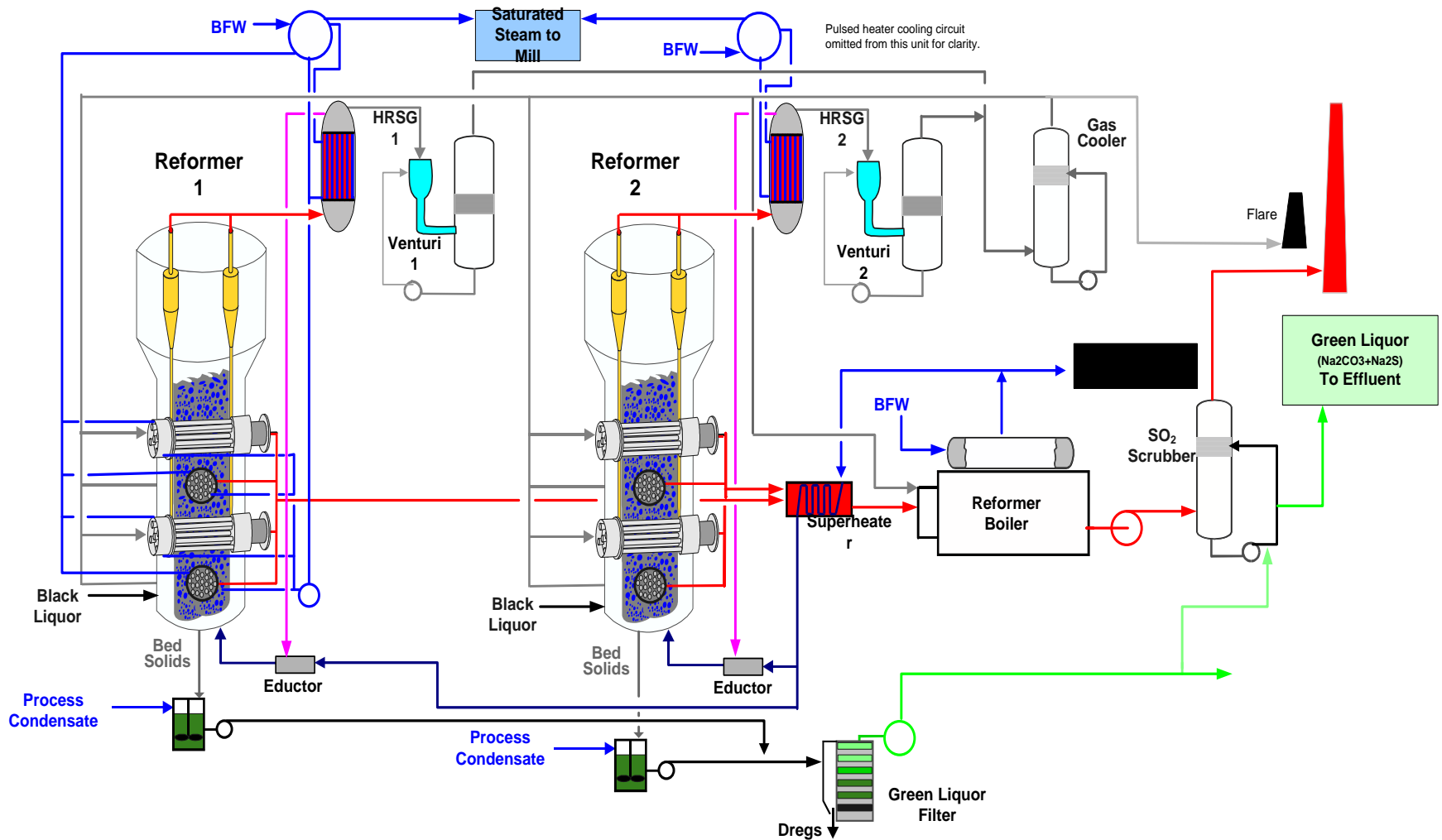
TRI BL gasifier (top left) at Norampac's Trenton, Ontario plant



Newest TRI PDU in Durham, NC

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

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)

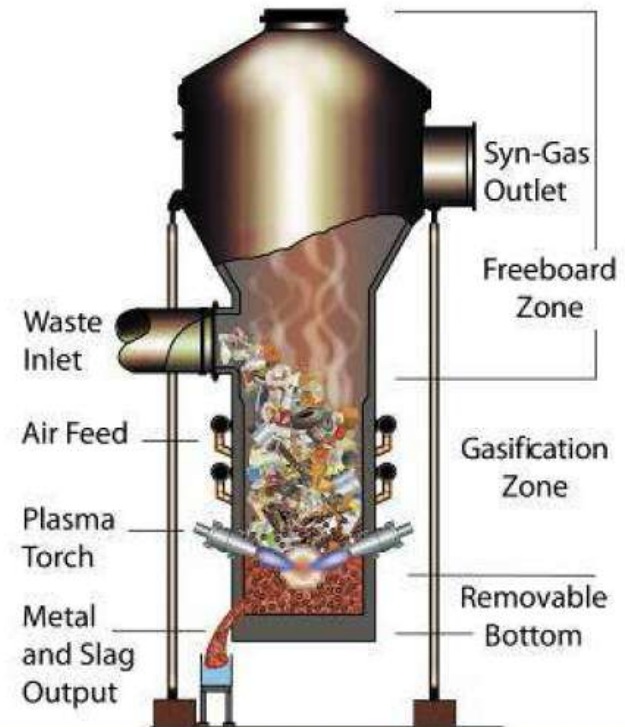


Alter NRG Gasifier

- 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

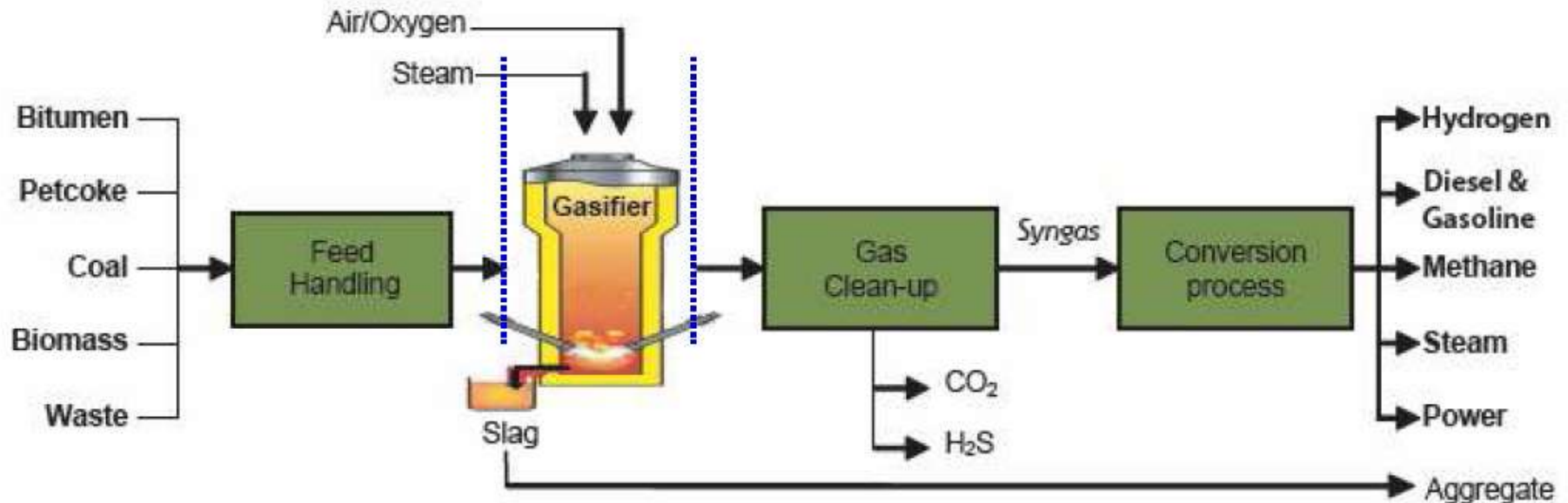
Alter Nrg Plasma Gasifier



Harnessing the Power Of Plasma

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

- 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

Commercial Installation in Benson, MN



- **Bubbling Fluid Bed:** air or oxy/steam
- **Pressure Operation:** up to 5 bar
- **Gas Conditioning:** high efficiency filtration; tar reforming development
- **Capacity:** up to 70 MW_{th} per train



Frontline System

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

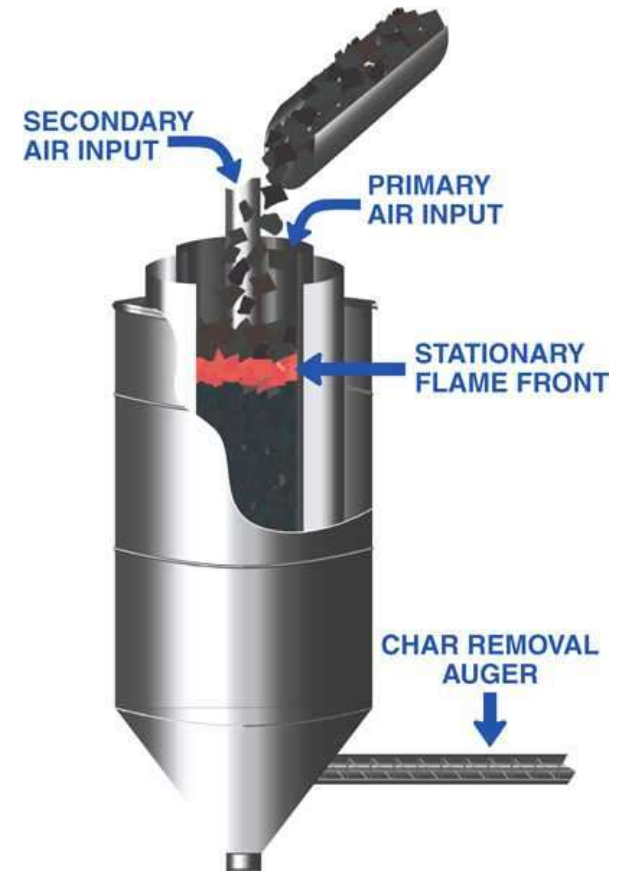
- Novel filtration: removes alkalis and PM, protects downstream boilers and catalytic/biological processes
- Proprietary Tar cleanup: allows multi-burner applications

Upgradeable for Syngas production

- Add oxy/steam system for syngas production

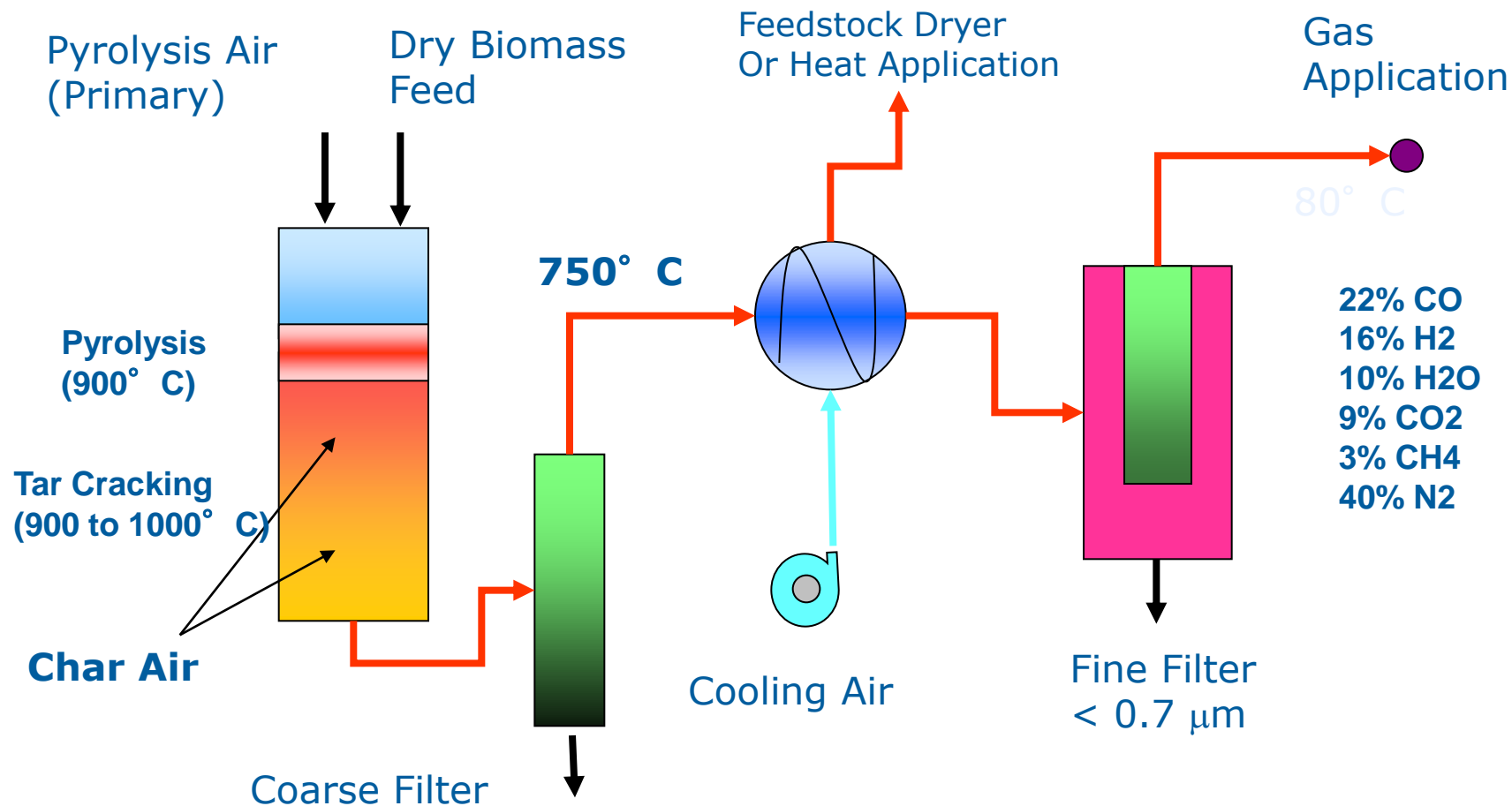
DOE and the USDA Forest Service have supported development Community Power Corporation's BioMax Modular Biopower System

5, 15, 50 kW systems



Credit: Community Power Corp

CPC's Process Schematic

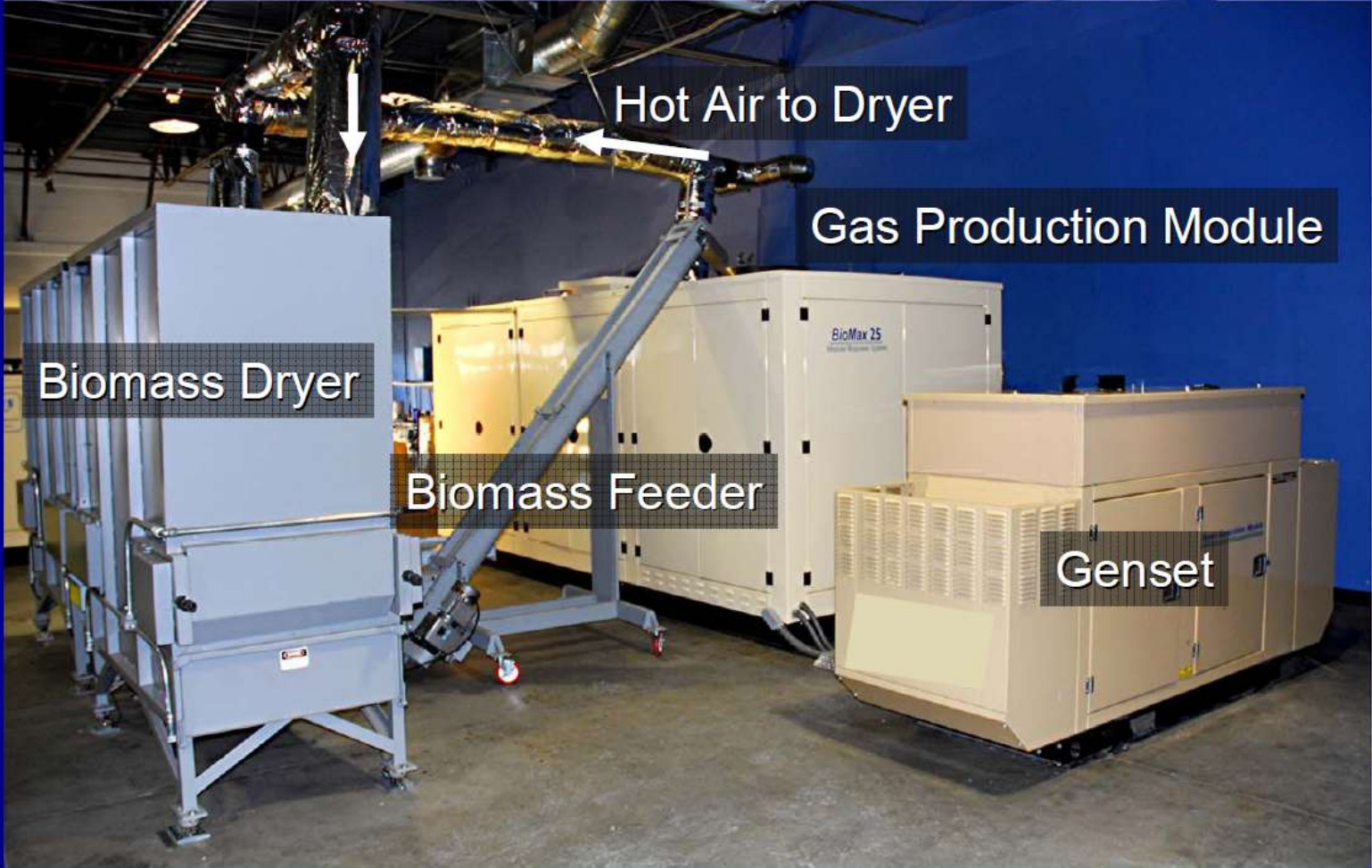


70% of Biomass Energy = Chemical Fuel

15% of Biomass Energy = Recoverable Heat, Gas Cooling

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*

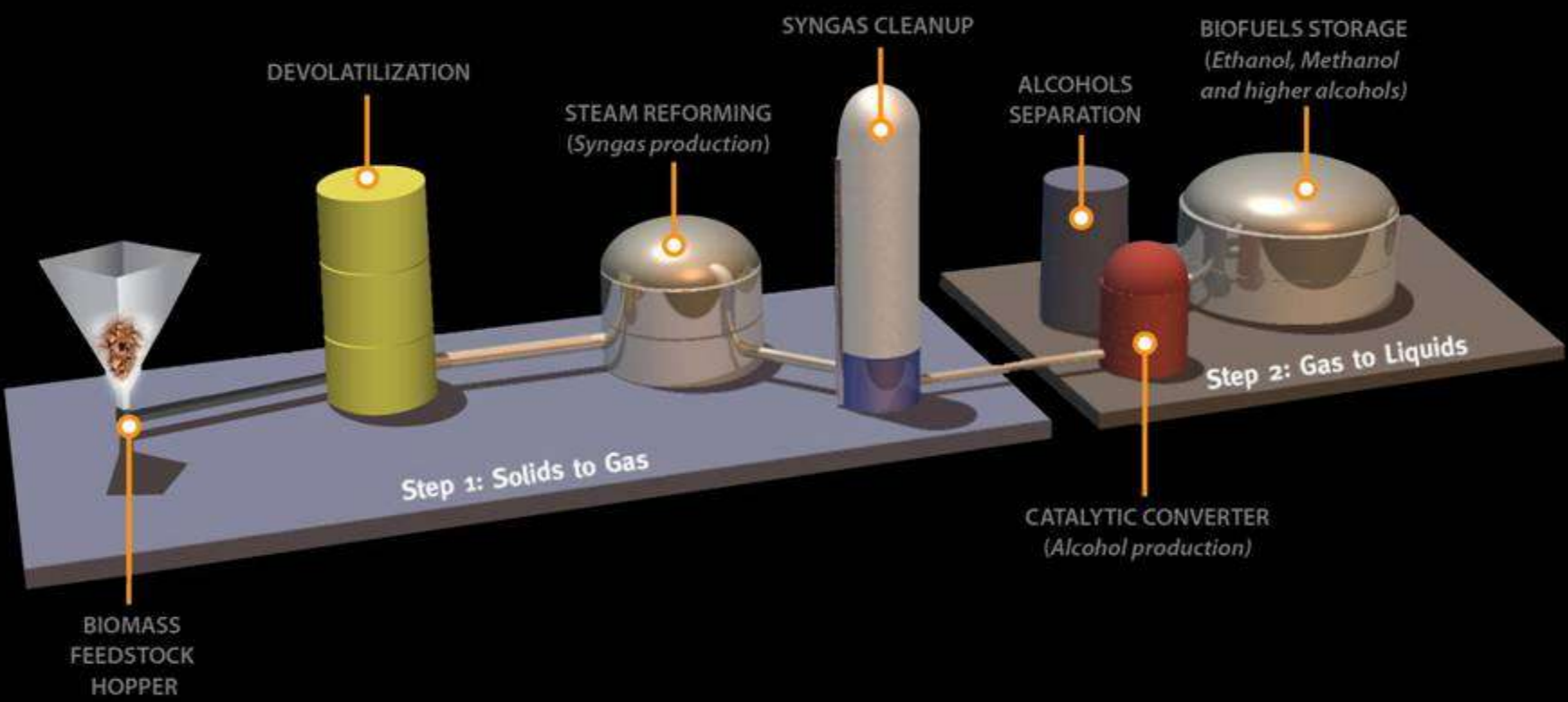


* Installation pending



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



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

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/ft³
- 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

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

