DOE Office of the Biomass Program: Efforts to Accelerate Deployment and Commercialization of Advanced Biofuels

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OUTLINE

- Overview of DOE Biomass Program: Mission and Goals
- Current Directions
- Conversion Technologies and Feedstock Pathways
- Update on the Integrated Biorefinery Portfolio

BIOMASS PROGRAM Mission and Goals

Advancing Presidential Objectives

Science & Discovery - Maintaining our leadership position

Economic Prosperity – Job Creation

Climate Change – GHG Reduction

Clean, Secure Energy – Energy Security



The Program supports the four key tenets of the Office of Energy Efficiency & Renewable Energy (EERE) Office's Strategic Plan:



Promote the use of diverse, domestic and sustainable energy resource

Establish a domestic bioindustry

Reduce carbon emissions from energy production and consumption

To meet both EISA and Department of Energy (DOE) goals, the Biomass Program is focused on developing, demonstrating, and deploying biofuel, bioproducts, and biopower technologies in partnership with other government agencies, industry and academia.

Renewable Fuel Standard (RFS2)

The 2007 Energy Independence and Security Act (EISA) sets aggressive goals for reducing the nation's dependence on foreign sources of energy and reducing greenhouse gas emissions from the transportation sector by establishing a goal of 36 billion gallons of renewable transportation fuels to by 2022.

The U.S. Department of Energy Biomass Program is focused on the development of all of the green items outlined in this chart.



15 BGY Cap on Conventional (starch) Biofuels

The Program, within the DOE EERE umbrella, is focused on forming cost-share partnerships with key stakeholders to develop, demonstrate, and deploy technologies for advanced biofuels production from lignocellulosic and algal biomass.



BIOMASS PROGRAM Current Directions

Replace the Whole Barrel!

Products Made from a Barrel of Crude Oil (Gallons) in 2009



- America's transportation sector relies almost exclusively on refined petroleum products, accounting for over 70% of the oil used.
- Oil accounts for 94% of transportation fuel use, with biofuels, natural gas, and electricity accounting for the balance.
- Nearly 9 million barrels of oil are required every day to fuel the 247 million vehicles that constitute the U.S. light-duty transportation fleet.
- Only about 40% of a barrel of crude oil is used to produce light duty petroleum gasoline.
- For the industry to be as effective as possible, it needs to focus on research, development, demonstration, and deployment of a range of technologies to displace the entire barrel of petroleum crude.
- Reducing dependence on oil will require developing technologies to replace other fuels, such as diesel, jet, heavy distillates, and a range of bio-based chemicals and products.



JET FUEL



Biomass-based jet blendstocks

- Technologies
 - Catalytic conversion, deoxygenation, upgrading, etc.

• Partners or Tasks

- GTI, UOP, PNNL, or;
- IBR demonstrations
- Targeted R&D
- Challenges
 - Aromatics
 - Tight fuels specifications
 - Blending and engine compatibility





Gasoline



Other Products

GASOLINE



Biomass-based gasoline blendstocks

- Technologies
 - Fermentation, catalysis, etc.
 - Ethanol versus renewable hydrocarbon blendstocks?

• Partners or Tasks

- POET, ADM, Abengoa, etc
- IBR demonstrations
- Targeted R&D

Challenges

- Alcohols as a replacement fuel (ie E85) versus blendstock (ie E10 and E15).
- Long term LDV government policy
- Distribution of alcohols: infrastructure considerations

Feedstock supply







Gasoline





OTHER PRODUCTS



- Technologies
 - Fermentation, separations, catalytic conversion
- Partners
 - Myriant
- Challenges
 - Market saturation: High value, low volumes







Gasoline



Other Products

BIOMASS PROGRAM: Conversion Technologies and Feedstock Pathways

Thermochemical Approaches to Fuel





Biological Approaches to Fuel





Biomass Conversion Pathways



Biomass Conversion Pathways



BIOMASS PROGRAM: Update on the Integrated Biorefinery Program

Integrated Biorefinery Status

- Investments broadened to include more hydrocarbon fuels, diverse biomass feedstocks, and geographical diversity: Over \$1B in DOE investments in 29 IBR projects.
 - » 11 hydrocarbon fuels \$326M
 - » 16 cellulosic ethanol \$766M
 - » 1 butanol \$30M
 - » 1 succinic acid \$50M

Projects face challenges getting off the ground

- Financial issues are root cause of construction delays
- Technology, feedstock, off-take agreements, and regulatory uncertainty
- Developments in securing DOE or USDA Loan Guarantees are expected to move several of these biorefineries forward; 2 awards in December, 2011

• Forward-looking approach to the success of the IBRs

- The 1-2 yrs of IBR delays have a silver lining during this time additional R&D and integrated piloting has been conducted which has significantly reduced technology scale up risks, enabled better LG applications and attracted more equity partners.
- Once LGs are secured, more commercial scale biorefineries can initiate groundbreaking activities and commence operations to support RFS2 goals

Integrated Biorefinery Status

# IBR at Scale / DOE\$s / Cost Share	Description	Feedstocks	Fuel/Product	
2 R&D, \$6m 80-20%	R&D and a preliminary engineering design	Woody Biomass, Ag Residue, and Algal Oil	Gasoline, Diesel, Jet Fuel, and Specialty Chemicals	
12 Pilots, \$278m, 80-20 %	Processes min. 1 dry tonne per day biomass to verify the techno-economic and environmental performance of integrated technologies.	Algae, Energy Crops, Forest Resources, and Ag Residues	Cellulosic Ethanol, Gasoline, Diesel, Jet Fuel, Specialty Chemicals and BioPower	
9 Demos, \$370m 50-50 %	Processes min. 50-70 dry tonne per day biomass to verify the techno-economic and environmental performance of integrated technologies.	Algae, Energy Crops, Forest Resources, Ag Residues, and Sorted MSW	Cellulosic Ethanol, Butanol, Diesel, Jet Fuel, Specialty Chemicals, and BioPower	
6 Commercial, \$518m 60-40 %	Processes min. 700 dry tonnes per day biomass for first-of-a- kind or "beta" commercial facility.	Ag Residues, Forest Resources, Sorted MSW	Cellulosic Ethanol, Diesel Jet Fuels, Specialty Chemicals, and BioPower	

DOE OBP - Integrated Biorefinery Map



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

2007 Commercial-Scale Biorefineries

Performer	Location	DOE Award*	Feedstock Type	Conversion Technology	Fuel / Capacity**
Bluefire	Fulton, MS	\$87.6M	Wood Wood Waste Sorted MSW	Biochemical- Concentrated Acid Hydrolysis	19M gals ethanol/yr
Poet	Emmetsburg, IA	\$100M	Corn Cob	Biochemical	25M gals ethanol/yr & 7MW power
Range Fuels	Soperton, GA	\$76.2M	Wood Waste	Gasification + Mixed Alcohol synthesis	20M gals per yr mixed alcohols
Abengoa	Hugoton, KS	\$100M	Agricultural Residues	Biochemical	25M gals ethanol/yr & 18MW power
Mascoma	Kinross, MI	\$75M	Woody Biomass	Biochemical	40M gals ethanol/yr & 17MW power
Flambeau River Biofuels LLC	Park Falls, WI	up to \$80M	Forest Residues and Wood Waste	Thermochem to Fischer-Tropsch	9M gals FT Liquids/yr and 50M lbs of FT wax & biopower

Projects in GREEN are now in construction

2008 Demonstration-Scale Biorefineries

Performers	Location	DOE Award*	Feedstock Type	Conversion Technology	Fuel / Amount
Lignol Innovations	Grand Junction, CO	Up to \$50M	Woody Biomass	Biochemical- Organisolve	2.5M gals ethanol/yr
NewPage	Wisconsin Rapids, WI	Up to \$50M	Woody Biomass	Thermochemical- Fischer-Tropsch	5.5M gals FT Liquids/yr
Pacific Ethanol	Boardman, OR	\$30M	Wheat Straw, Stover, Poplar Residuals	Biochemical- Biogasol	2.7M gals ethanol/yr
RSA	Old Town, ME	\$33.9M	Hemicellulose from Wood	Biochemical- Pentose Extraction	2.2M gals of Ethanol or Butanol
Verenium Biofuels Corp.	Jennings, LA	\$14.9M	Energy Cane and Sugar Cane Bagasse	Biochemical Process	1.5M gals ethanol/yr

Projects in GREEN are now in construction; Orange Projects are Complete

2009 ARRA Pilot Scale Biorefineries

Project	Feedstock	Technology 1° Product		Scale (gal/yr)	Class
Algenol	Algae	Closed Ponds Ethanol		100,000	Pilot
Solazyme	Sugar/Hydrolysates	Heterotrophic Algae	Algal Oil to Biodiesel or Renewable Diesel	300,000	Pilot
American Process Inc.	Hardwood Hydrolysate	Biochemical	Ethanol	894,000	Pilot
Renewable Energy Inst. Inc.	Rice Hulls & Forest Residues	TC Gasification	RE Diesel	625,000	Pilot
Haldor Topsoe	Wood Waste	TC Gasification	RE Gasoline	345,000	Pilot
ADM	Corn Stover	Biochemical Ethanol		25,800	Pilot
ICM	Corn Fiber, Switchgrass, Energy Sorghum	Biochemical	Ethanol	345,000	Pilot
ClearFuels/Rentech	Wood Waste, Bagasse	TC Gasification	RE Diesel, RE Jet	151,000	Pilot
Zeachem	Hybrid Poplar, Stover, Cobs	BC/TC Hybrid	Ethanol	250,000	Pilot
Amyris	Sweet Sorghum	Biochemical	RE Diesel	1,370	Pilot
Logos/EdenIQ	Corn Stover, Switchgrass, Wood Waste	Biochemical	Ethanol	50,000	Pilot
UOP	Forest Residues, Corn Stover, Bagasse, Switchgrass, Algae	TC-Pyrolysis	RE Gasoline, RE Diesel	60,000	Pilot

Projects in GREEN are now in construction; Blue Projects are operational

2009 ARRA Demo Biorefineries

Project	Feedstock	Technology	1° Product	Scale (gal/yr)	Class
Sapphire	Algae	Open ponds	Oil	1,000,000	Demo
Enerkem	MSW, Forest Residues	st Residues TC Gasification		10,000,000	Demo
Ineos	MSW	Hybid/TC Ferm	Ethanol	8,000,000	Demo
Myriant	Sorghum	Biochemical	Succinic Acid	30,000,000 lbs/yr	Demo

2009 ARRA R&D Biorefinery Projects

Project	Feedstock	Technology	1° Product	Scale (gal/yr)	Class
Elevance	Algae oil, Plant oil, Animal oil	Chemical- Metathesis	RE Diesel, RE Jet	NA	R&D only
Gas Technology Institute	Wood Waste, Corn Stover, Algae	TC-Pyrolysis	RE Gasoline, RE Diesel	NA	R&D only

Projects in GREEN are now in construction; Blue Projects are operational

Integrated Biorefinery Volumetric Projections by Project

Project (State)	Fuel Type	Scale	2010	2011	2012	2013	2014
Bluefire (MS)	Cellulosic Ethanol	commercial				18.900	18.900
Abengoa (KS)	Cellulosic Ethanol	commercial				25.000	25.000
Poet (IA)	Cellulosic Ethanol	commercial				25.000	25.000
Mascoma (MI)	Cellulosic Ethanol	commercial				40.000	40.000
Flambeau (WI)	FT diesel and waxes	commercial					7.700
RangeFuels (GA)	Mixed alcohol	commercial		2.500	2.500	20.000	20.000
RSA (ME)	Biobutanol	demonstration				1.300	1.300
NewPage (WI)	FT diesel and waxes	demonstration				4.600	4.600
Pacific Biogasol (OR)	Cellulosic Ethanol	demonstration				2.700	2.700
Lignol (OR)	Cellulosic Ethanol	demonstration				1.800	1.800
Verenium (LA)	Cellulosic Ethanol	demonstration	1.400	1.400	1.400	1.400	1.400
INEOS (FL)	Cellulosic Ethanol	demonstration			8.000	8.000	8.000
Enerkem (MS)	Cellulosic Ethanol	demonstration				10.000	10.000
Sapphire (NM)	Jet fuel and diesel	demonstration			1.000	1.000	1.000
Solazymes (PA)	Biodiesel and renewable diesel	pilot				0.300	0.300
Alpena (MI)	Cellulosic Ethanol	pilot		0.760	0.760	0.760	0.760
ICM (MO)	Cellulosic Ethanol	pilot		0.260	0.260	0.260	0.260
Logos/EdenIQ (CA)	Cellulosic Ethanol	pilot			0.050	0.050	0.050
ADM (IL)	Cellulosic Ethanol	pilot			0.026	0.026	0.026
Zeachem (OR)	Cellulosic Ethanol	pilot			0.250	0.250	0.250
Algenol (FL)	Cellulosic Ethanol	pilot			0.100	0.100	0.100
REII (OH)	Diesel	pilot			0.625	0.625	0.625
Amyris (CA)	Diesel	pilot		0.001	0.001	0.001	0.001
UOP (HI)	Diesel, gas, jet fuel	pilot			0.060	0.060	0.060
Clearfuels (CO)	FT diesel and jet fuel	pilot		0.151	0.151	0.151	0.151
Haldor Topsoe (IL)	Green gasoline	pilot				0.345	0.345
	Cumulative Capacity in N	lillion Gals / Year	r 1.400	5.072	15.183	162.628	170.328

Projects in **GREEN** funded through the American Reinvestment and Recovery Act.



THANKS!