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BIOMASS RESEARCH & DEVELOPMENT BOARD

An Investigation Into Expanding the Bioeconomy

Biomass Research and Development Technical Advisory Committee

June 5, 2014

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What is the Bioeconomy?

"The biological sciences are adding value to a host of products and services, producing what some have labelled the "bioeconomy". From a broad economic perspective, the bioeconomy refers to the set of economic activities relating to the invention, development, production and use of biological products and processes."

OECD: The Bioeconomy to 2030: Designing a Policy Agenda, 2009

"A bioeconomy is one based on the use of research and innovation in the biological sciences to create economic activity and public benefit."

White House Bioeconomy Blueprint, 2012

"The United States is a world leader in technology and agricultural prowess, which puts it in a powerful position to capitalize on the vast potential of bio-based alternatives to petrochemicals. The potential markets are huge, given the importance of petrochemicals in industrial economies."

Unleashing the Power of the Bio-economy, 2013

For the purpose of this presentation, the "Bioeconomy" is the economic activities associated with the production, harvest, transport, conversion, and use of biomass for biopower, bioproducts, and biofuels.

The Challenge and The Opportunity

The Challenge

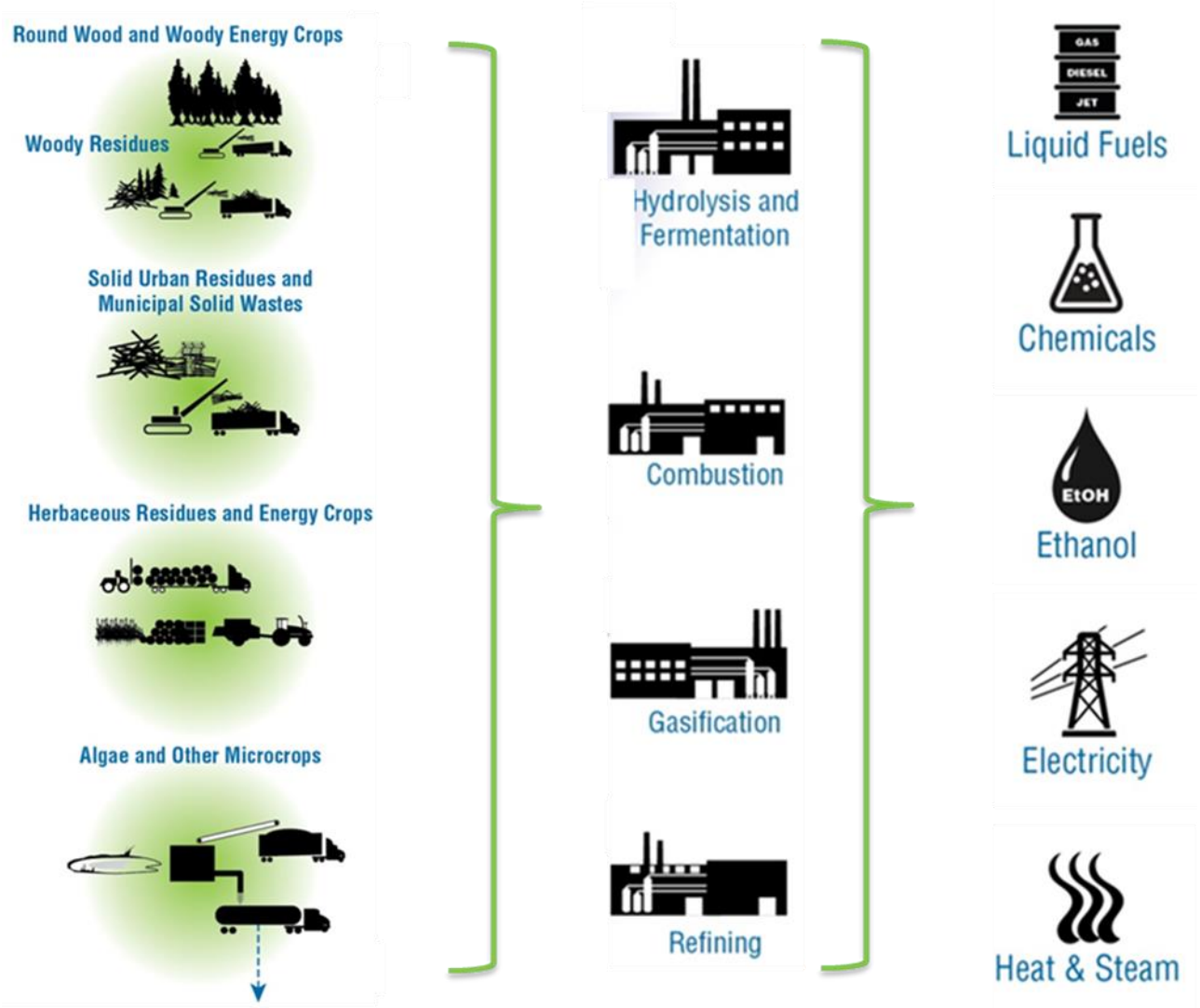
- More than 13 million barrels of fuel are required every day to fuel the U.S. transportation sector.[1]
- 67% of petroleum consumed in the U.S. is in the transportation sector – at a commercial value of $350 billion; only 7% of petroleum consumption is in the chemicals and products sector – at a commercial value of $255 billion.[2]

The Potential

- Biomass is a leading renewable resource with the potential to provide drop-in replacements for the 11 million barrels per day of petroleum fuels consumed in 245 million existing light and heavy duty vehicles on the road and specifically for air transportation needs (an additional 1 million barrels/day) utilizing existing infrastructure. [1]
- The United States could produce more than 1 billion tons of sustainable biomass resources that can provide fuel for cars, trucks, and jets; make chemicals; and produce power to supply the grid.
- By 2030, there is the potential to develop terrestrial biomass resources to displace 30% of U.S. current petroleum usage. This does NOT take into account algae.[3]

[1] Energy Information Administration, 2012 Energy Review, U.S. Department of Energy, 2013
[2] Frost, John, Redefining Chemical Manufacture, *Industrial Biotechnology*, Spring 2005 (numbers are assumed to be annual figures for 2004)
[3] Update to the Billion-ton Study, U.S. Department of Energy, 2011

The Bioeconomy Concept



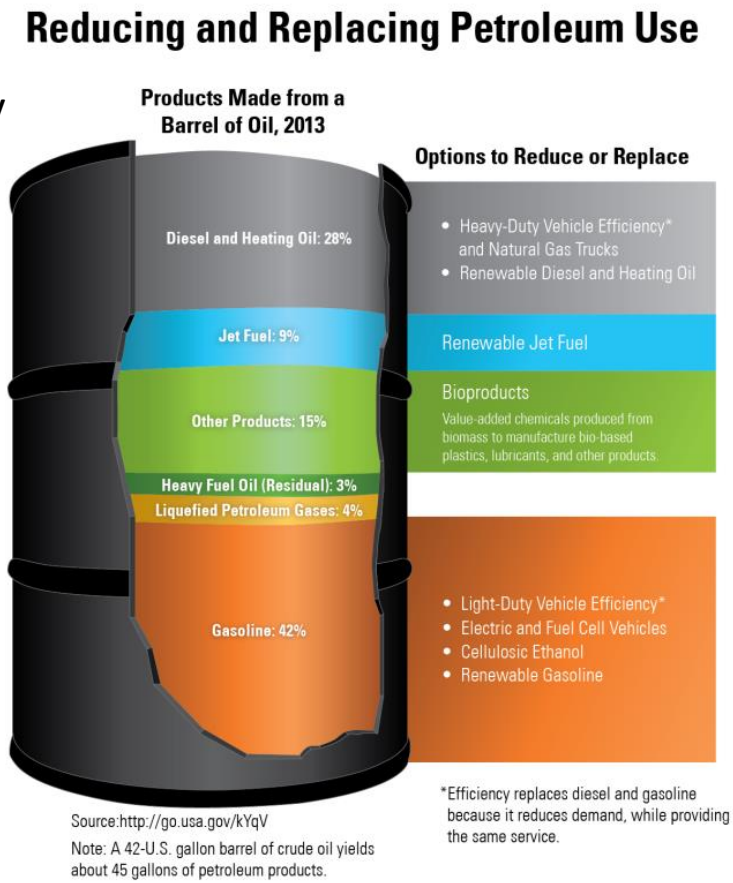
- Revenue and economic growth
- Broad spectrum of new jobs
- Rural development
- Advanced technologies and manufacturing
- Reduced emissions and Environmental Sustainability
- Export potential of technology and products
- Positive societal changes
- Investments and new infrastructure

The Baseline Bioeconomy

- Biofuels
  - Ethanol based
  - Policy driven
- Biopower
  - Mostly wood wastes and wood
  - Historically industrial heat, steam, and electricity
- Bioproducts

Bioeconomy Parameter	Current
Biomass Utilization	200 million DMT
Biopower Production (EIA)	30 billion kWh
Biofuels Production	15 billion gallons
Bioproducts Production	2.5 billion pounds
Direct Revenue	$40 billion
Total (Direct + Indirect) Revenue	$100 billion
Direct Jobs	150,000
Total (Direct + Indirect) Jobs	480,000
Estimated CO_2e Reduction	35 million tons

Estimates are 2011 and based on various assumptions and sources that may not be consistent with other published sources.



What Drives the Bioeconomy (transportation)?

Photo by Yige http://goo.gl/auhZS5

Photo by John H Gray http://goo.gl/HX3Jnm

Photo by Arria Belli http://goo.gl/jeyytW

What Drives the Bioeconomy (products and more)?

Photo by Secretlondon http://goo.gl/Wlpg26

cryotech.com

Why Expand the Bioeconomy?

- **Major Motivations**
  - Energy security
  - Environmental quality
  - Economic opportunity
    - U.S. job creation
    - U.S. revenues
- **Other Reasons**
  - Reinvest in our "working lands" heritage
    - Bring marginal agricultural soils and land back into production
    - Provide market incentives for forest restoration and management
    - Keep working farms and woodlots productive
    - Support the rural community
  - Provide additional environmental benefits
    - Give farmers more conservation options
    - Improve ecological systems across the landscape
    - Restore forests

Key Considerations to Expand Bioeconomy

- What needs to be accomplished to get a self-sustaining, profitable bioeconomy for advanced biofuels and bioproducts and biopower in the United States?
- What are the major hurdles that will need to be addressed in growing the bioeconomy over the next 5 years? 10 years? 30 years?
- How can the bioeconomy build off the lessons learned from the corn ethanol industry and the emerging RFS to arrive at a robust bioeconomy?
- What are barriers and how do we reduce barriers to commercialization for sufficient critical mass where markets forces pull the bioeconomy instead of policy?
  - How should we address an effort to grow the bioeconomy in the current economic environment that builds on the RFS?
  - How would government-facilitated tours, workshops, or matchmaking of financiers with new technologies be received?
- What technology advances are needed to grow the bioeconomy for biofuels? For bioproducts and biopower technologies needed to enable biofuels?

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Expanding the Bioeconomy
- An Analysis of the Potential -

Biomass Research and Development Technical Advisory Committee

June 5, 2014

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Senior Advisor, CNJV
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Analysis Working Group

Analyzing the Future Bioeconomy

- The analysis is a collaborative effort involving the Analysis Interagency Working Group (Analysis IWG) of the Biomass R&D Board.

- The analysis is a general assessment of the potential expansion of the bioeconomy and is subject to additional changes and impacts from policy, technology, and market dynamics that were not considered.

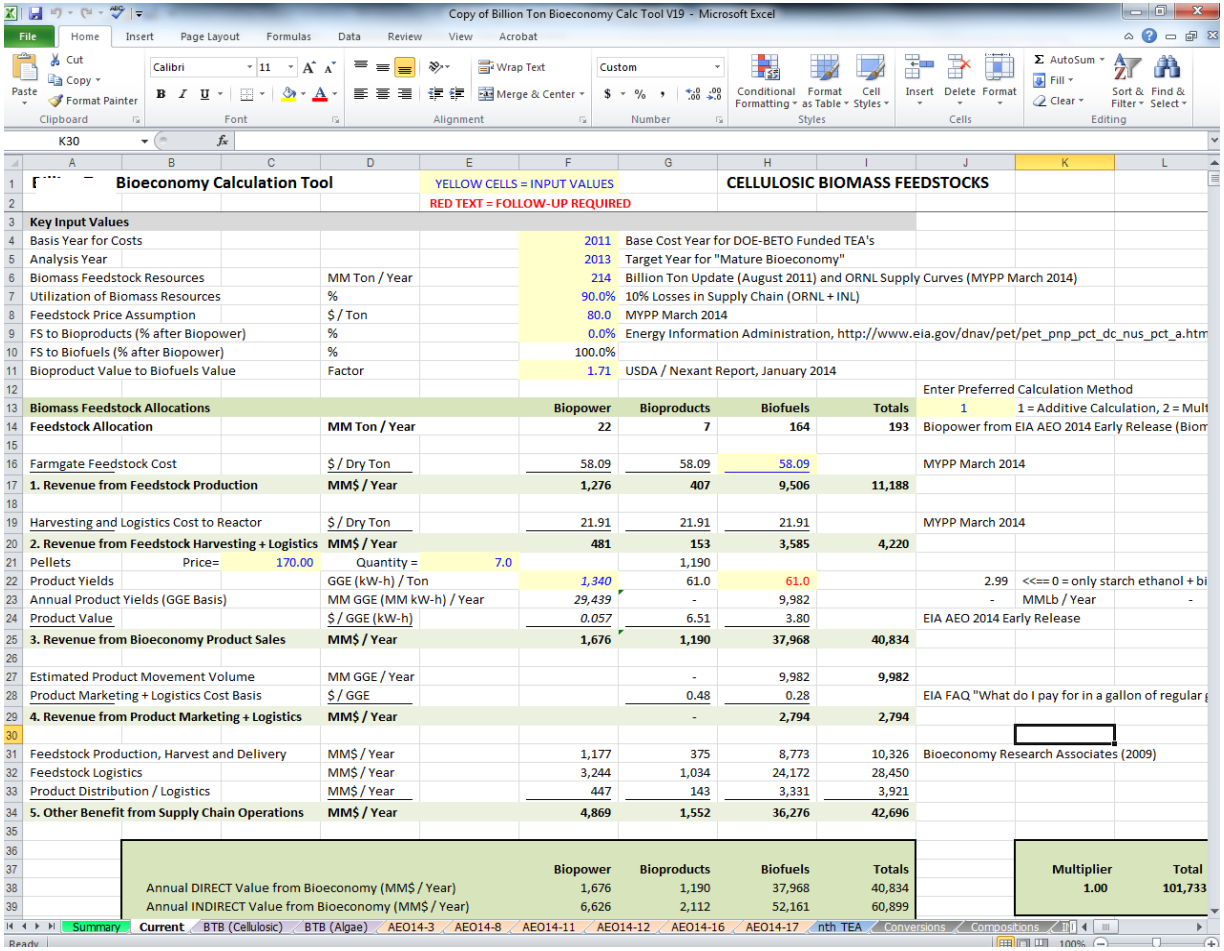
- This is a first-order analysis with continued improvements expected to be made based on additional inputs, other perspectives, feedback and increased information collected from interested stakeholders.

- The bioeconomy analysis is based on the Billion Ton Update (U.S. Department of Energy, 2011) and recent POLYSYS model runs from Oak Ridge National Laboratory for biomass availability at a selected cost with transportation and preprocessing costs added to supply curves.

- The bioeconomy analysis provides results for only 2030 (discrete analysis).

Description of Analysis Tools

- The analyses were completed using a wide range of analytical tools.
- Primarily an EXCEL® spreadsheet used to complete the primary calculations and to present and maintain the data.
- The spreadsheet tool was reviewed by the Analysis IWG and other agency personnel.



Copy of Billion Ton Bioeconomy Calc Tool V19 - Microsoft Excel

1	Bioeconomy Calculation Tool		YELLOW CELLS = INPUT VALUES			CELLULOSIC BIOMASS FEEDSTOCKS		
2			RED TEXT = FOLLOW-UP REQUIRED					
3	**Key Input Values**							
4	Basis Year for Costs			2011	Base Cost Year for DOE-BETO Funded TEA's			
5	Analysis Year			2013	Target Year for "Mature Bioeconomy"			
6	Biomass Feedstock Resources	MM Ton / Year		214	Billion Ton Update (August 2011) and ORNL Supply Curves (MYPP March 2014)			
7	Utilization of Biomass Resources	%		90.0%	10% Losses in Supply Chain (ORNL + INL)			
8	Feedstock Price Assumption	$ / Ton		80.0	MYPP March 2014			
9	FS to Bioproducts (% after Biopower)	%		0.0%	Energy Information Administration, http://www.eia.gov/dnav/pet/pet_pnp_pct_dc_nus_pct_a.htm			
10	FS to Biofuels (% after Biopower)	%		100.0%				
11	Bioproduct Value to Biofuels Value	Factor		1.71	USDA / Nexant Report, January 2014			
12							Enter Preferred Calculation Method	
13	**Biomass Feedstock Allocations**			**Biopower**	**Bioproducts**	**Biofuels**	**Totals**	1 = Additive Calculation, 2 = Mult
14	**Feedstock Allocation**	**MM Ton / Year**		**22**	**7**	**164**	**193**	Biopower from EIA AEO 2014 Early Release (Biom
15								
16	Farmgate Feedstock Cost	$ / Dry Ton		58.09	58.09	58.09		MYPP March 2014
17	**1. Revenue from Feedstock Production**	**MM$ / Year**		**1,276**	**407**	**9,506**	**11,188**	
18								
19	Harvesting and Logistics Cost to Reactor	$ / Dry Ton		21.91	21.91	21.91		MYPP March 2014
20	**2. Revenue from Feedstock Harvesting + Logistics**	**MM$ / Year**		**481**	**153**	**3,585**	**4,220**	
21	Pellets Price= 170.00	Quantity =	7.0		1,190			
22	Product Yields	GGE (kW-h) / Ton		*1,340*	61.0	61.0		2.99 <<== 0 = only starch ethanol + bi
23	Annual Product Yields (GGE Basis)	MM GGE (MM kW-h) / Year		*29,439*	-	9,982		- MMLb / Year -
24	Product Value	$ / GGE (kW-h)		*0.057*	6.51	3.80		EIA AEO 2014 Early Release
25	**3. Revenue from Bioeconomy Product Sales**	**MM$ / Year**		**1,676**	**1,190**	**37,968**	**40,834**	
26								
27	Estimated Product Movement Volume	MM GGE / Year			-	9,982	**9,982**	
28	Product Marketing + Logistics Cost Basis	$ / GGE			0.48	0.28		EIA FAQ "What do I pay for in a gallon of regular
29	**4. Revenue from Product Marketing + Logistics**	**MM$ / Year**			-	**2,794**	**2,794**	
30								
31	Feedstock Production, Harvest and Delivery	MM$ / Year		1,177	375	8,773	10,326	Bioeconomy Research Associates (2009)
32	Feedstock Logistics	MM$ / Year		3,244	1,034	24,172	28,450	
33	Product Distribution / Logistics	MM$ / Year		447	143	3,331	3,921	
34	**5. Other Benefit from Supply Chain Operations**	**MM$ / Year**		**4,869**	**1,552**	**36,276**	**42,696**	
35								
36								
37				**Biopower**	**Bioproducts**	**Biofuels**	**Totals**	**Multiplier** **Total**
38	Annual DIRECT Value from Bioeconomy (MM$ / Year)			1,676	1,190	37,968	40,834	**1.00** **101,733**
39	Annual INDIRECT Value from Bioeconomy (MM$ / Year)			6,626	2,112	52,161	60,899	

Summary | Current | BTB (Cellulosic) | BTB (Algae) | AEO14-3 | AEO14-8 | AEO14-11 | AEO14-12 | AEO14-16 | AEO14-17 | nth TEA | Conversions | Compositions

Description of Analysis Tools (cont.)

- Other models and tools used in the analyses were:
  - POLYSYS – Policy Analysis Framework (POLYSYS) provides a comprehensive economic characterization of the US agricultural sector and is calibrated to the USDA Long Term Forecast (i.e. Baseline) [USDA OCE, 2014]. POLYSYS was utilized by Oak Ridge National Laboratory to generate supply curves.
  - Biomass Logistics Model – Feedstock logistics and pre-processing costs were provided by Idaho National Laboratory's model (INL , 2014).
  - Bioeconomy AGE – (Air emissions, Greenhouse gas emissions, and Energy consumption) was developed by Argonne National Laboratory to estimate the energy and environmental impacts of the bioeconomy as compared to a business-as-usual, baseline case. (Internal model based on and relying on the GREET model).

Determining Biomass Availability in 2030

- Based on the Billion Ton Update modified to use the 2013 USDA Long Term Forecast.
- Modified biomass supply curves to include transportation, preprocessing, and storage/handling.
- Used an average cost of $80 per dry ton to the throat of the convertor based on DOE-BETO Multi Year Program Plan targets.
- Included all feedstock types as well as “currently used” and “potential.”
- Applied a 10% loss factor.

Feedstock Basis for Current and Target Bioeconomy

Projected Feedstock Quantities	(Million Dry Tons/Year)	CURRENT	TARGET
Agricultural Residues	Corn Stover		241.9
	Wheat Straw		45.2
Energy Crops	Herbaceous Energy Crops		108.6
	Woody Energy Crops		54.6
Forest Resources	Pulpwood		50.5
	Logging Residues and Fuel Treatments		87.8
	Other Forestland Removals		3.7
	Urban and Mill Wood Wastes		43.4
Algal Biomass	Algal Biomass		50.0
SUB-TOTAL: Biomass Resources Presented in DOE-BETO MYPP		**-**	**685.6**
Currently Allocated Feedstocks	Starch to Ethanol	76.0	88.0
	Oils to Biodiesel	2.0	4.0
	MSW Sources (Ag)	7.0	11.0
	MSW Sources (F)	14.0	20.0
	Fuelwood	38.0	106.0
	Mill Residue	32.0	42.0
	Pulping Liquors	45.0	58.0
SUB-TOTAL: Currently Allocated Biomass Resources per Billion Ton Upda		**214.0**	**329.0**
Secondary Agricultural Resources	Animal		58.9
	Orchard		5.5
	Cotton, Rice and Cane		19.9
SUB-TOTAL: Secondary Biomass Resources per Billion Ton Update		**-**	**84.4**
TOTALS		**214.0**	**1,099.0**

$80 per ton average feedstock cost to conversion reactor.

Average (blended) feedstock cost is calculated by solving for a marginal cost applied to a quantity-price curves for each feedstock category from the POLYSYS model. The marginal price corresponding to $80 per ton average is approximately $103 per ton.

Biomass Allocations Assumptions

- Biomass allocations based on cited sources where possible.
- The first allocation category for biomass is losses through the supply chain, 10% based on estimates from National Laboratories.
- The second allocation category for biomass is for biopower, which was based on projections from the Energy Information Administration's 2014 Annual Energy Outlook.
- The basis for the next allocation, biomass resources for bioproducts and biochemicals, is rooted in the objective for the bioeconomy to displace products from the "entire barrel of crude oil," and analysis from three consistent references* to support the assumption that 4.5% of total biomass should be allocated to the production of higher-value biochemical products and intermediates.
- The remaining biomass is allocated to biofuels.

Estimated and assumed biomass allocations in million dry tons.

Feedstock Allocation	CURRENT	2030
Losses in Supply Chain	21	110
Biopower	22	60
Bioproducts / Biochemicals	7	59
Biofuels	164	870
Total Feedstock Supply	**214**	**1,099**

*bioproduct/biochemical allocations discussed further on slides 9-10

Biofuels Product Allocation

The bioeconomy contributions to the fuel mix in the table below represent the base case biofuels allocation, which assumes a 10% ethanol blend limit in motor gasoline.

Projected fuel demands for 2030 and potential fuel mix from target bioeconomy

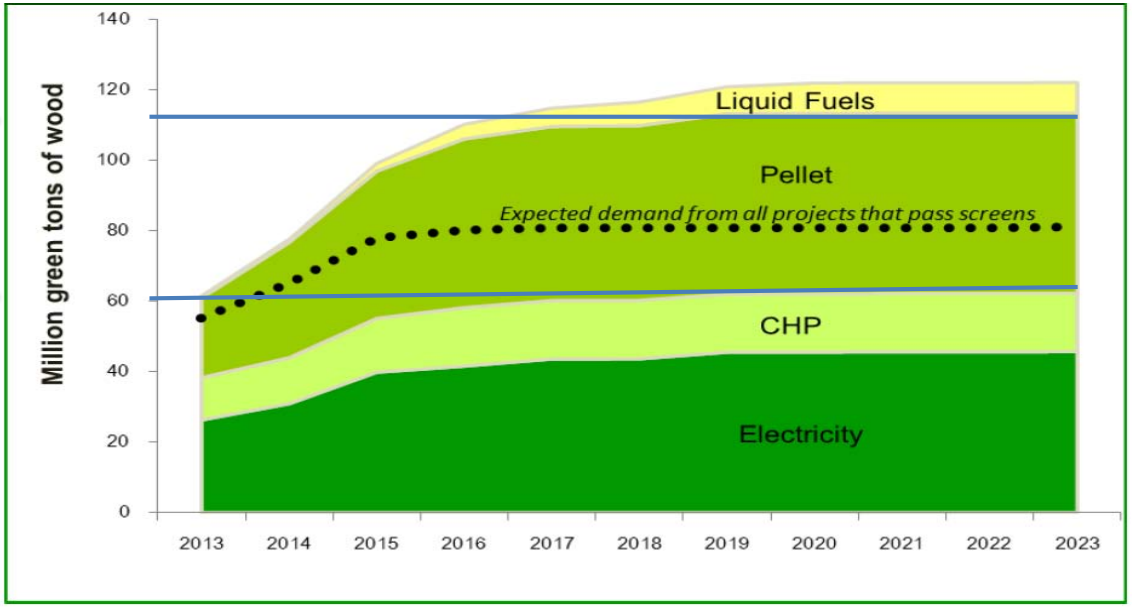
Note: These scenarios do not state or imply BETO strategy or the strategy of the agencies involved.

Projected Fuels in 2030	**All Transportation Fuel Totals** (Million Gallons / Year)	**Renewable Fuels from Bioeconomy** (Million Gallons / Year)	**Potential Portion of Biofuels in Market** (Volume % of Market)
Total Motor Gasoline + E85 (assumes 10% ethanol in motor gasoline and 85% ethanol in E85)	109,500 Motor Gasoline: 104,700 + E85: 4,900	36,400	33.8 %
---Ethanol component (E10+ E85)	14,600	14,600	100.0 %
---Naphtha component (Fossil +Renewable)	94,900	21,800	23.0 %
Jet / Aviation Fuels	23,800	5,500	23.0 %
Diesel Fuel / Heating Oil	69,300	15,900	23.0 %
Total Transportation Fuels	**202,600**	**57,800**	**28.5 %**

- Bio-diesel from oils based on EIA projection for 2030.
- Starch ethanol from corn to meet ethanol contributions to motor gasoline up to 10 volume % and projected demands for E85.
- Cellulosic ethanol to meet the motor gasoline blending limit beyond the contribution from starch ethanol.
- Fossil-fuel equivalent hydrocarbons or drop-in blendstocks for gasoline (non-ethanol fraction), jet / kerosene fuels and diesel / home heating fuels in volumetric ratios consistent with projected demands from EIA.

Estimated Wood Use by Announced Facilities

66% of 52 million green tons is 34 million green or 17 MM dry tons



Basis for allocating biomass to pelletized wood products

		CHP	Thermal	Liquid Fuel	Pellet	Total	Total that pass screens	Wood use of all projects gtons	Wood use of projects that pass screens	Additional announced that pass project screens	Additional announced pass project screen clean chips	Additional announced pass project screen clean chips
	Number of projects, announced and operating							dt			%	dt
North	57	23	8	10	88	186	135	18,227,712	12,650,725	3,750,000	76%	2,850,000
South	38	21	10	21	69	159	91	34,261,377	21,613,503	10,600,000	89%	9,434,000
West	33	17	2	5	40	97	64	8,823,736	6,196,898	1,450,000	54%	783,000
Total	128	61	20	36	197	442	290	**61,312,825**	**40,461,126**	15,800,000		**13,067,000**
	Source: FORISK 2013											
									Pulpwood harvest (south, TPO 2009)			59,000,000
									Pulpwood harvest (nation, RPA 2007)			**74,000,000**
									Logging residues (nation, RPA 2007)			83,250,000

66% passed screen

Maximum Biochemicals in 2030 Based on Petrochemical Capacity

- Total refinery capacity is 228.6 billion gallons per year[1] (~1,500,000 billion pounds)

Reference	% Specialty Products (SP)	Calc'd Petrochemical Market Size (Billion Pounds per Year)
B. Shanks (ISU) Note: Original source from DOE-BETO not identified / no longer available.	3.4 % of Crude	43.1
EIA US Refinery Yield[2]	4.1% of Crude	51.9

[1]Based on 760 million gallons per day and capacity utilization rate of 82.4%

[2] EIA "U.S. Refinery Yield". http://www.eia.gov/dnav/pet/pet_pnp_pct_dc_nus_pct_a.htm.

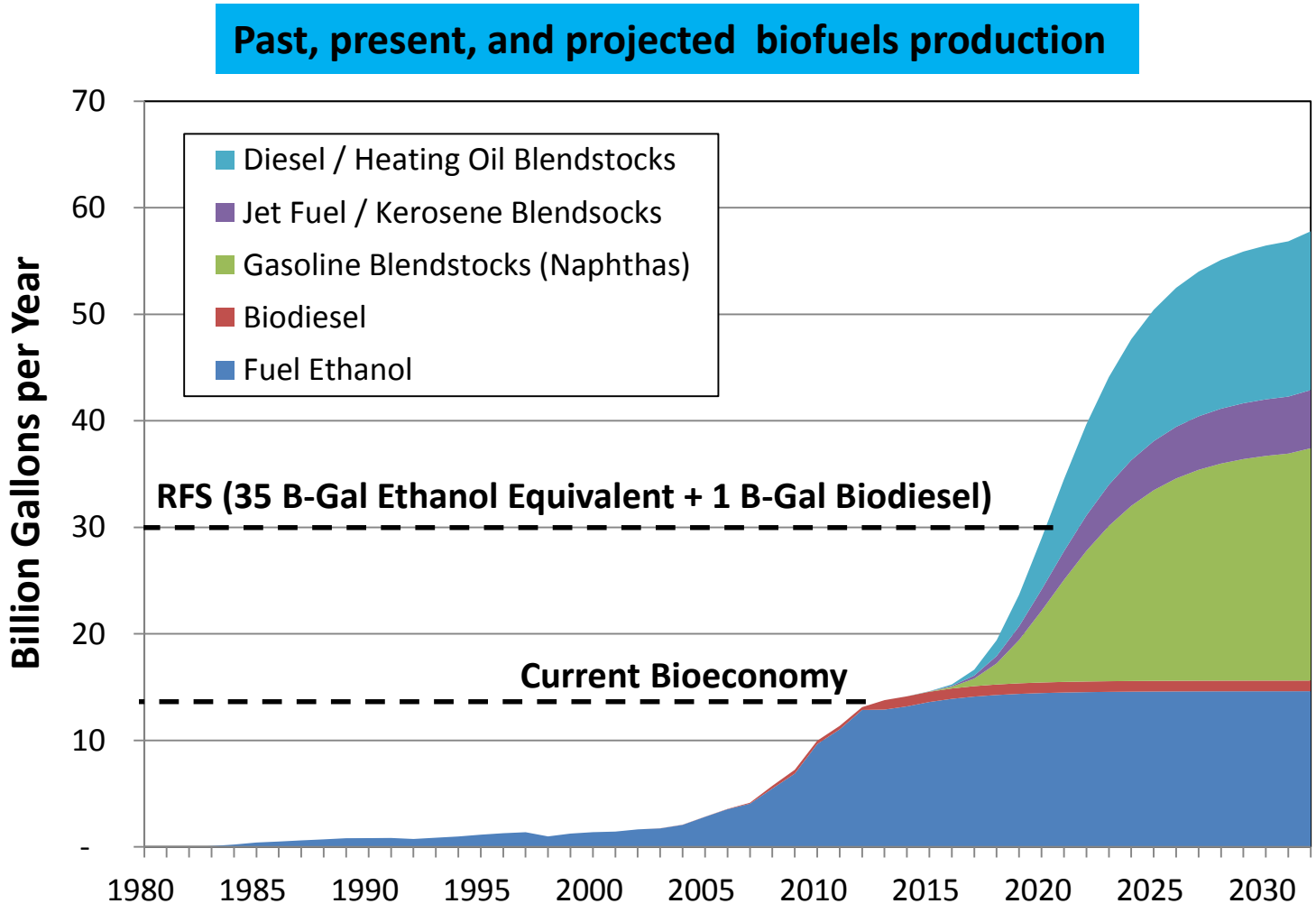
Biochemicals Allocation Summary

Reference	Potential Biochemicals (Billion Pounds)	% of Calc'd Market	Direct Value (Billion $)
1 – Nexant / USDA (conservative growth 2022 – 2030)	13.8	26% – 32%	11.1
2 – Shanks (ISU) (3.4 % of Crude / 4.6% of Fuels + SP)	14.2	27% – 33%	11.4
3 – EIA U.S. Refinery Yield (4.1% of Crude / 4.5% of Fuels + SP)	13.8	26% – 32%	11.1

Assumptions:

1. Can not expect to displace a significant portion of petrochemical because of value to refinery (could cause negative Big Oil response)
2. Framed new biochemical potential as new capacity economically competitive based on the Nexant Report (USDA 2014) – about 14 billion pounds.

Bioeconomy Transportation Fuels: Past, Present, and Future



Source: "International Energy Statistics – Biofuels Consumption." Energy Information Administration (2014). Retrieved April, 2014 from http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=79&pid=79&aid=2. Projections are based on target bioeconomy fuel product volumes and application of Gompertz growth profiles from current bioeconomy volumes.

Summary of 2030 Bioeconomy

Revenue (Economic Output)

2030 Bioeconomy (2011 US $)	Product Quantity (MM Units per Year)	Product Value ($ / Unit)	Direct Output or Revenue (MM$ / Year)
Biopower	91,519 MM kW-h	0.067	$6,130
Biochemicals	16,451 MM Lbs	0.80	$13,350
Bioproducts (pellets)	17.0 MM Tons	170	$2,890
Biofuels	57.8 MM Gallons	2.80	$162,160
Total Direct Output or Revenue			$184,530

2030 Bioeconomy (2011 US $)	Direct Output (MM$ / Year)	Economic Multiplier	Total Output (Direct + Indirect) (MM$ / Year)
Biopower	$6,130	2.66	$16,320
Biochemicals	$13,350	2.66	$34,710
Bioproducts (pellets)	$2,890	2.66	$7,690
Biofuels	$162,160	2.66	$431,800
Totals	$184,530	2.66	$490,520

Summary of the 2030 Bioeconomy

Creation of Jobs

2030 Bioeconomy	Direct Full Time Positions	Multiplier	Total Jobs Supported
Biopower	19,900	3.20	63,680
Biochemicals / Bioproducts	31,100	3.20	99,520
Biofuels	427,500	3.20	1,368,000
TARGET Bioeconomy Jobs	478,500		1,531,200
Less CURRENT Bioeconomy Jobs	- 149,000	3.20	- 476,800
New Jobs with TARGET Bioeconomy Development	329,500		1,054,400

Summary of the 2030 Bioeconomy

Displacement of Revenue to Oil Imports

Current (2013) Net Petroleum Imports	7.36 MM Barrels / Day
Average Petroleum Import Cost	$107.34 / Barrel
Current (2013) Revenue to Petroleum Imports	$288,395 MM / Year
2030 Bioeconomy Direct Economic Output	$184,530 MM / Year
Bioeconomy Direct Output : Revenue to Petroleum Imports	64.0%

Air emissions, GHG emissions, and Energy consumption (AGE) Calculator

- Best available data for life-cycle fuel consumption and air emissions, including greenhouse gases, in developing estimates of total energy consumption and air emissions.
- Argonne National Laboratory's GREET™ model was the data source for fuel yield and life-cycle energy consumption for conventional fuels and biofuels.
- In the case of biochemicals, AGE makes use of a new GREET module developed to analyze biochemicals produced from either corn stover or algae as compared to conventional products.

Biofuels, biochemicals, conventional fuels, and biopower feedstocks included in AGE

Biofuels	Biochemicals	Conventional Fuels	Feedstocks to Biopower
Corn Ethanol	Polyethylene	Gasoline	Forest residue
Sorghum Ethanol	Succinic acid	Diesel	Corn stover
Cellulosic Ethanol		Jet	Sugarcane residue
Sugarcane Ethanol			Switchgrass
Biodiesel			Miscanthus
Renewable Gasoline (pyrolysis)			Poplar
Renewable Diesel (pyrolysis)			Willow
Renewable Jet (Fischer-Tropsch / pyrolysis)			Pine

AGE Estimates

AGE Outputs

- Fossil Energy Consumption
- Petroleum Consumption
- GHG Emissions

AGE Analysis Results

Analysis Parameter	Current Bioeconomy	Target Bioeconomy
GHG emissions reduction (million tons CO_2e)	35 (1%)	500 (10%)
Fossil energy reduction (Quadrillion Btu)	0.6 (1%)	4.6 (9%)
Petroleum reduction (Quadrillion Btu)	1.0 (4%)	5.5 (24%)

Direct Land Use Change

Approximately 26 million acres would be converted from cropland and pasture to energy crops in achieving the target bioeconomy. Use was restricted to direct cropland change from conventional crops or idle land to energy crops or from pastureland to energy crops. This constraint was used to assure that the conventional product demands, including livestock, are met.

The land use change for the 2030 bioeconomy would be energy crops planted on cropland and pasture land totaling about 26 million acres by 2030. This is less than 3% of the approximately 1 billion acres of cropland, pastureland, and rangeland in the U.S.

The U.S. can sustainably produce the Billion Tons of Biomass estimated while meeting the demands for food, feed, and fiber in the nation.

Land use change (LUC) analysis results for bioeconomy

Category	Land Type	Million Acres
Herbaceous Energy Crops	Cropland	13.6
	Pasture	5.0
Woody Energy Crops	Cropland	3.0
	Pasture	4.3
Total (Herbaceous + Woody Energy Crops)	Cropland	16.6
	Pasture	9.3
	Total LUC	25.9

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