Feedstocks for the Bioeconomy

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Relevance of Resource Assessment

1. Total Capital Investment (15% - base - +30%)	-8.0%	16.1%
2. Feedstock Cost, \$/dry U.S. ton (60 : 80 : 120)	-7.8%	15.7%
Internal Rate of Return / Discount Rate for DCFROR (5 : 10 : 15 %)	-14.8%	15.4%
4. HGF, Capital Cost + 10% Yield Loss (No HGF : No HGF : HGF with loss)	0.0%	15.2%
5. Ex Situ Organic Liq. Yield;C Efficiency % (30;49 : 27;44 : 24;39)	-8.1%	11.6%
Plant Size (10,000 : 2,000 : 1,000 dry metric tonnes/day)	-10.0%	8.1%
7. Vapor Upgrading Catalyst Unit Cost, \$/lb (3.25 : 9.75 : 19.50)	-6.4%	9.6%
8. Fast Py. & Ex Situ Reactor Capital (-20% : base : +40%)	-4.6%	9.2%
9. Hydroprocessing C Efficiency (94:94:88 %)	0.0%	9.0%
10. Interest Rate on Debt (4% : 8% : 12%)	-5.3%	5.6%
11. Vapor Upgrading Catalyst Replacement, %/day (1:2:4)	-2.7%	5.3%
12. Plant Life (30 : 30 : 20 years)	0.0%	4.1%
13. Ex Situ Catalyst:Biomass w/w Circulation (5 : 5 : 7)	0.0%	3.9%
14. Hot Gas Filter, HGF, Capital Cost Only (No HGF : No HGF : HGF no loss)	0.0%	3.2%
15. Hydrogen Plant Capital (-20% : base : +30%)	-2.0%	3.0%
16. Time on Stream (94% : 90% : 86%)	-2.5%	2.7%
17. Steam & Power Plant Capital (-20% : base : +30%)	-1.5%	2.3%
18. Hydrotreating Catalyst Unit Cost, \$/lb (10 : 20 : 60)	-0.6%	2.2%
19. Hydroprocessing & Separation Capital (-20% : base : +40%)	-1.0%	2.1%
20. C Loss as Coke (vs. Gas) with Constant Organic Liquid Yield (7%: 8%: 9%)	-0.4%	1.2%
21. Wastewater Management Capital (-20% : base : +50%)	-0.4%	1.0%
22. No Vapor Heat Recovery Below Temp. (175 : 175 : 931 °F). No New Equip.	0.0%	0.9%
23. Electricty Credit Impact, No Capital Change (base : base 2.6¢ : no credit)	0.0%	0.8% Market, Finance etc.
24. Hydrocracking Catalyst Unit Cost, \$/lb (10 : 20 : 60)	-0.2%	0.7% Vapor Upgrading
25. No. of HT Reactors x %Capacity (1x100 : 1x100 : 3x50)	0.0%	0.7% Hydroprocessing
26. Heat Loss During Pyrolysis & Vapor Upgrading, % LHV Biomass (3 : 3 : 6)	0.0%	0.4% Balance of Plant
27. Hydrotreating Pressure, (1500 : 1500 : 2000 psia)	0.0%	0.1%
-2	5% 04	% 25%

Example of sensitivity studies for ex situ case

% Change to MFSP from the ex situ base case (\$3.31/GGE)

http://www.energy.gov/sites/prod/files/2015/04/f21/thermochemical_conversion_dutta_210302.pdf



Comparison of 2005 BTS with 2011 BT2

Comparison of 2030 at \$60/dry ton with the 2005 BTS





Resource Assessments

Billion-Ton Study (BTS), 2005

- <u>Technical potential</u> of agricultural and forestry systems to supply biomass
- Identified supply to displace 30% of petroleum consumption; i.e. physical availability

Billion-Ton Update (BT2), 2011

- Economic potential of feedstocks
- Data via Bioenergy Knowledge Discovery Framework

2016 Billion-Ton Update (BT16), 2016

- Economic potential
- Two volume approach
 - 1. Economic Availability of Biomass Feedstocks
 - 2. Environmental Effects of Select Scenarios









2016 Billion-Ton Report

	Grower payment, stumpage price, procurement price	Farmgate price, roadside price	Delivered Cost		
	Production	Harvest	Delivery and Preprocessing		
Example operations:	Site preparation, planting, cultivation, maintenance, profit to landowner	Cut and bale, rake and bale; fell, forward, and chip into van	Load, transport, unload		
Format:	In the field or forest, dispersed	Baled or chipped into van roadside	Comminuted to < ¼ inches (conventional) or pelleted (advanced)		
Chapters: (3) At the Roadside, Forestland Resources; (4) At the Farmgate, Agricultural Residues and Biomass Crops; (5) Waste Resources; and (7) Microalgae					

Chapters (2) Currently Used;



Enhancements of the BT16

Modeled crop yields





Interactive visualization



Adding algae and other energy crops



Enhanced Energy Crop Potential Yield

Average Annual Yield Potential, 1981 - 2010

Energycane

Herbaceous Energy Crops



0-year Average (dry tonslacro



0-year Average Yie (dry tonslacre)



Woody Crops







Manuscript in preparation by SGI Field Trial and Resource Assessment Teams

Average Annual Yield Potential, 1981 - 2010 Lowland Switchgrass

Credit: Oregon State University PRISM Climate Group



BT2-Table ES1: Current and Potentially Available Feedstocks, \$60/dt_____

Feedstock	2012	2017	2022	2030		
		Million dry tons				
Baseline scenario						
Forest resources currently used	129	182	210	226		
Forest biomass & waste resource potential	97	98	100	102		
Agricultural resources currently used	85	103	103	103		
Agricultural biomass & waste resource potential	162	192	221	265		
Energy crops ^a	0	101	282	400		
Total currently used	214	284	312	328		
Total potential resources	258	392	602	767		
Total – baseline	473	676	914	1094		
High-yield scenario (2%–4%)						
Forest resources currently used	129	182	210	226		
Forest biomass & waste resource potential	97	98	100	102		
Agricultural resources currently used	85	103	103	103		
Agricultural biomass & waste resource potential ^b	244	310	346	404		
Energy crops	0	139–180	410-564	<u>540–79</u> 9		
Total currently used	214	284	312	328		
Total potential	340	547–588	855-1009	1046–1305		
Total high-yield (2-4%)	555	831-872	1168-1322	1374–1633		



2011 U.S. Billion-Ton Update: <\$60/dt







Near-term Potential

www.bioenergykdf.net

• **2012**

Baseline scenario

• \$60 dry ton⁻¹







Author: Laurence Eaton (eatonim@ornl.gov)- December 4, 2012.



2011 Billion-ton Results

www.bioenergykdf.net

• 2017

Baseline scenario

• \$60 dry ton⁻¹



327 x 10⁶ dt



Author: Laurence Eaton (eatonim@ornl.gov)- December 4, 2012.



2011 Billion-ton Results

www.bioenergykdf.net

• 2022

Baseline scenario

• \$60 dry ton⁻¹



529 x 10⁶ dt



Author: Laurence Eaton (eatonim@ornl.gov)- December 4, 2012.



Advancing Resources

Key Assumptions





Advancing Resources

- Crop improvement
- Advanced logistics
- Precision agriculture

Supply push

		2015	2017	2020 Production Level	2022	2025	2030	2035	2040
	\$30			ase then 10 dUSqMEe 📕 10-100 dUS	gMile 100-500 dt/SqMile	500-1000 dz/SqMile	CCC-5000 dVSqMin		
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nd	\$50	C. 1990	C. 399	C W		CINY	C. C. C.	C. C.	CALC!
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- Conversion
- Bioproducts
- International markets

14 ABLC 2016



Advancing Resources



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15 ABLC 2016

Farmgate: National Supply Curves

2013 Feedstock Supply and Price Projections and Sensitivity Analysis: Langholtz MH, Eaton LM, Turhollow A, Hilliard MR. 2013 Feedstock Supply and Price Projections and Sensitivity Analysis. BioFPR [Internet]. 2014;8(4). http://onlinelibrary.wiley.com/doi/10.1002/bbb.1489/abstract



Feedstock Supply and Price Projection



BT16 Delivered Supplies: (preliminary, do not cite, values redacted)





BT16 Volume 2: Environmental sustainability indicators

	Indicator		Indicator		
Soil quality (ANL, USFS)	1. Total organic carbon (TOC)2. Total nitrogen (N)3. Extractable phosphorus (P)	Greenhouse gases (ANL)	12. CO_2 equivalent emissions (CO_2 and N_2O)		
	4. Bulk density	Biodiversity (ORNL)	13. Presence of taxa of special concern		
Water quality and quantity (ANL, ORNL, USFS)	5. Nitrate loadings to streams (and export) 6. Total phosphorus (P) loadings to		14. Habitat area of taxa of special concern		
	streams	Air quality	15. Tropospheric ozone		
	7. Suspended sediment loadings to	(NREL)	16. Carbon monoxide		
	8. Herbicide concentration in streams (and export)		17. Total particulate matter less than 2.5 µm diameter (PM _{2.5})		
	9. Storm flow				
	10. Minimum base flow 11. Consumptive water use (incorporates base flow)		18. Total particulate matter less than 10 µm diameter (PM ₁₀)		
	Addition: Water yield		Possible additions: VOCs, SO _x , NO _x , NH ₃		
McBride et al. (2011) <i>Ecological</i> Indicators 11:1277-1289		Productivity (ORNL)	19. Aboveground net primary productivity or Yield		

Summary

- Resource assessments indicate vast national biomass resource potential, ~1.0-1.5 billion tons/yr.
- Future biomass utilization is a function of supply and demand interactions.
- Resource assessments can help evaluate impacts of supply push and market pull and inform strategies to increase biomass utilization.
- Future research should advance from "how much is there" to "how can it happen".





Upcoming Event

- Bioenergy 2016, July 12-13
 Washington, DC
- 2016 Billion-ton Report
 - Interactive data visualizations
 - Expanded feedstock cost and supply data



- Sun Grant Regional Feedstock Partnership Synthesis Report
 - Seven field trial teams and national laboratory analysis of field trial data validate input data in supply projections



Thank you!

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Key Points

- U.S. bioeconomy potential is enormous, yet difficult to quantify
- Many assumptions on crop/residue yield, grower contracts, traditional crop demand, among many others
- Resource assessments serve multiple industries, stakeholders
- Growth of bioeconomy is limited by availability of feedstocks



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Quality: Biomass vs. Feedstock

- There is a lot of biomass, but not all biomass is the same
 - Between feedstocks and within a feedstock
- The quality of field-run biomass is impacted by:
 - inherent species variability
 - production conditions
 - differing harvest, collection, and storage practices
- Conversion processes desire consistency
- Variability can be with respect to ash, sugars, particle morphology, and moisture, for example





National Crop Yield and Variability Modeling



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Adaptability Woody and Herbaceous of Bioenergy Crop



FIG. 4. Map of recommended biofuel feedstock plantings in the United States (updated from Wright [1994]).

>110 Trials in Sun Grant Regional Feedstock Partnership



Integrated Resource Assessment and Analysis



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