



The 2016 Billion-ton Report: Towards Commercialization

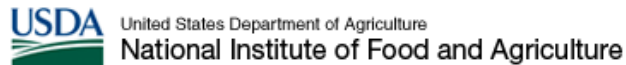
The webinar starts at 2:00 PM(Eastern Time)

Presenter(s): Matthew Langholtz & Rebecca Ann Efroymsen, Oak Ridge National Laboratory

Moderator: Helene Cser, NCSU Extension Forestry



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October 21, 2015



A banner image showing a large industrial facility with tall chimneys and a complex network of pipes and walkways under a blue sky with light clouds. A green semi-transparent box on the left contains the text 'Webinar Portal FOR BIOENERGY'.

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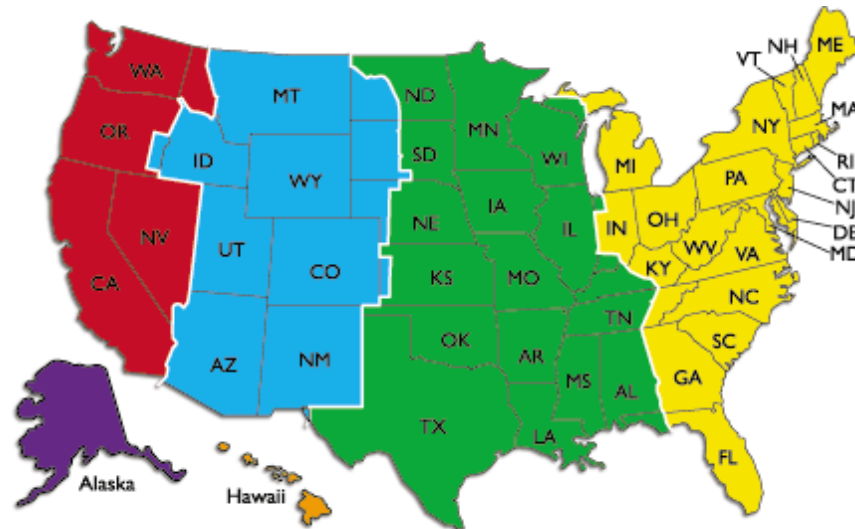
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Matthew Langholtz



Dr. Matthew Langholtz's primary research interests are in biomass resource economics, short-rotation woody crops, and bioenergy from forest resources. He has worked on short-rotation woody crop economics, valuation of non-market externalities, and developing biomass supply curves for the southeast US. His current research involves biomass feedstock supply and demand, and sustainable forest management approaches to providing bioenergy feedstocks. Background includes agroforestry extension in Latin America with the US Peace Corps, and production of herbaceous and woody cellulosic biomass crops in the Gulf South. He has a BS in Forestry from Oklahoma State University, and a Masters of Forestry and PhD in Forest Economics from the University of Florida. He is currently in the Bioenergy Program of the Environmental Sciences Division at Oak Ridge National Lab in Oak Ridge, TN.

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Rebecca Efroymsen



Rebecca Efroymsen is a senior scientist at the Center for BioEnergy Sustainability at Oak Ridge National Laboratory. Her work includes identifying environmental and socioeconomic sustainability indicators for algal biofuels, evaluating sustainability effects of current and future national potential biomass supply, evaluating best practices for bioenergy, and developing a causal analysis framework for bioenergy and land-use change. She developed conceptual ecological risk assessment frameworks for several agencies, with topics including wind energy development, petroleum exploration and production, wastewater treatment systems, and managing rare species and their habitats. She was a member of the National Research Council Committee on the Sustainable Development of Algal Biofuels. She was recently Editor-in-chief of the journal *Environmental Management*. She is a fellow of the American Association for the Advancement of Science. She has a B.A. in biology from La Salle University, and an M.S. and Ph.D. in environmental toxicology from Cornell University.

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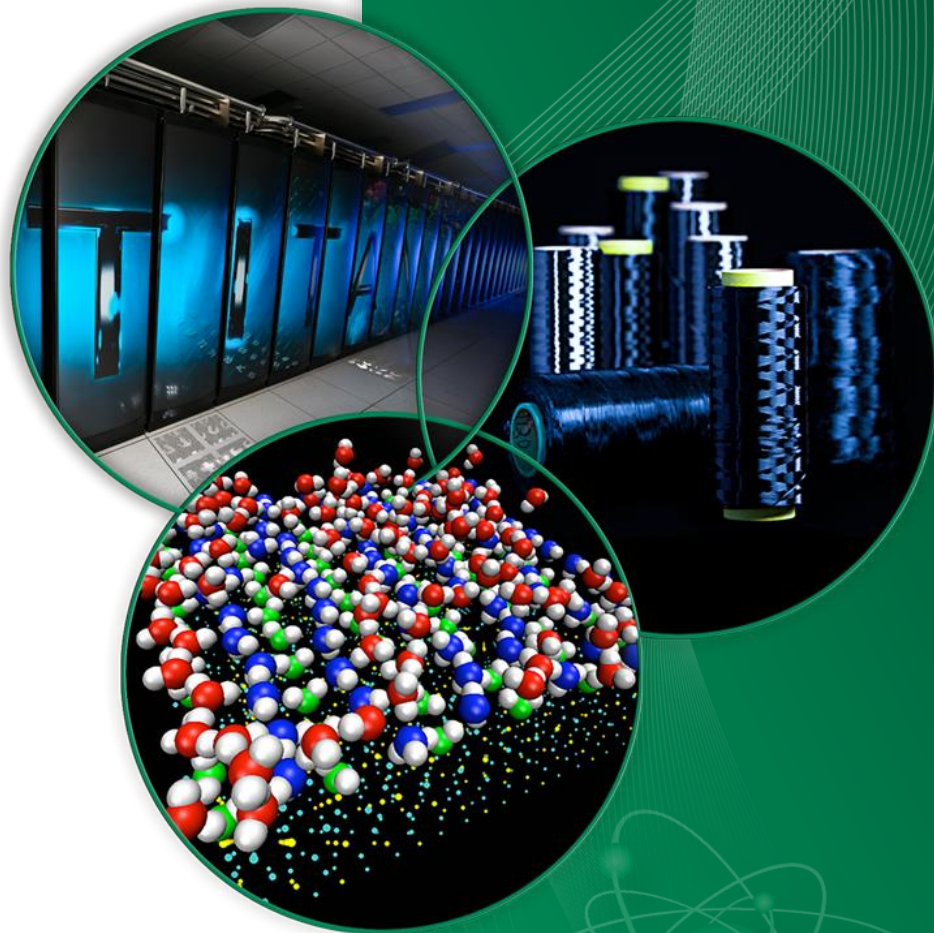


U.S. Biomass Resource Potential

National Bioenergy Day 2015

2015 SREF Webinar Series,
Tuesday October 20th 2015

Matt Langholtz and Rebecca
Efroymson, Oak Ridge National
Lab



Contributors

Oak Ridge National Laboratory

Robert D. Perlack*
Laurence M. Eaton
Anthony F. Turhollow
Matt H. Langholtz
Craig C. Brandt
Lynn L. Wright
Robin L. Graham
Mark E. Downing
Jacob M. Kavkewitz
Anna M. Shamey

Idaho National Laboratory

David J. Muth
J. Richard Hess
Jared M. Abodeely

Kansas State University

Richard G. Nelson

State University of New York

Timothy A. Volk
Thomas S. Buchholz
Lawrence P. Abrahamson

Iowa State University

Robert P. Anex

CNJV LLC

Bryce J. Stokes*

University of Tennessee

Chad Hellwinckel
Daniel De La Torre Ugarte
Daniel C. Yoder
James P. Lyon
Timothy G. Rials

USDA Agricultural Research Service

Douglas L. Karlen
Jane M. F. Johnson
Robert B. Mitchell
Kenneth P. Vogel
Edward P. Richard
John Tatarko
Larry E. Wagner

University of Minnesota

William Berguson
Don E. Riemenschneider

Texas A&M University

William L. Rooney

USDA Forest Service

Kenneth E. Skog,
Patricia K. Lebow
Dennis P. Dykstra
Marilyn A. Buford
Patrick D. Miles
D. Andrew Scott
James H. Perdue
Robert B. Rummer
Jamie Barbour
John A. Stanturf
David B. McKeever
Ronald S. Zalesny
Edmund A. Gee

USDA National Institute of Food and Agriculture

P. Daniel Cassidy

USDA Natural Resources Conservation Service

David Lightle

University of Illinois

Thomas B. Voigt

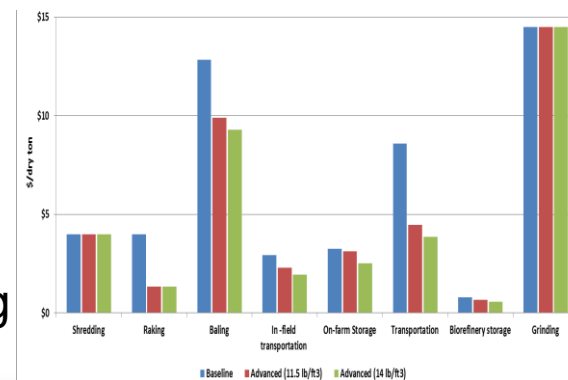
* Co-leads

What does ORNL do?

- Biomass supply forecast and analysis:
 - ✓ Including billion ton studies (2005, 2011, 2016)
 - ✓ Feedstock supply and logistics
- Sustainability
 - ✓ Defining and measuring
 - ✓ Short-rotation woody crops
 - ✓ Water quality and diversity
 - ✓ Algae
- Biochemical conversion
 - ✓ Catalytic upgrading
 - ✓ Bioconversion of lignin derivatives to fuels
- Thermochemical conversion
 - ✓ Membranes
 - ✓ Catalysts
 - ✓ Materials degradation
 - ✓ Hydrogen
- Fire standards codes and prevention in biorefineries
- Strategic analyses
- Cookstoves – combustion/materials durability relationships for improved low-cost cook stoves
- Carbon fiber – Carbon Fiber Technology Facility, using carbon fiber in vehicles for increased fuel efficiency



Photo credit: Steve Thomas

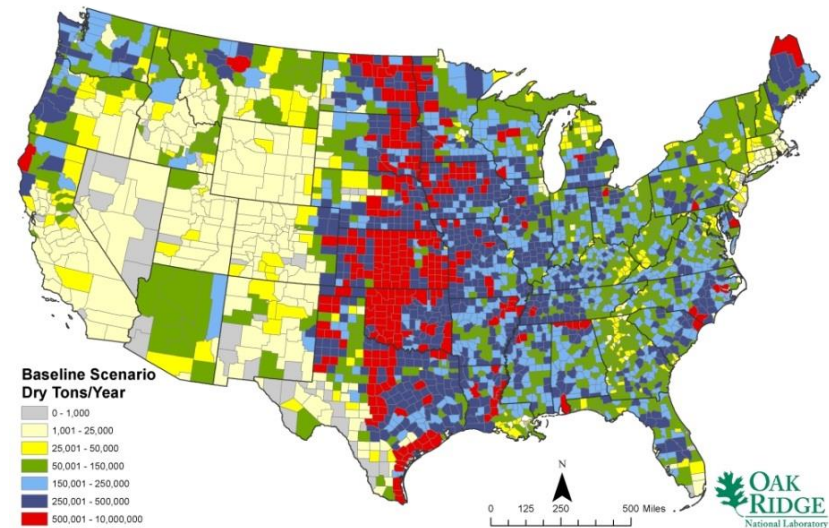
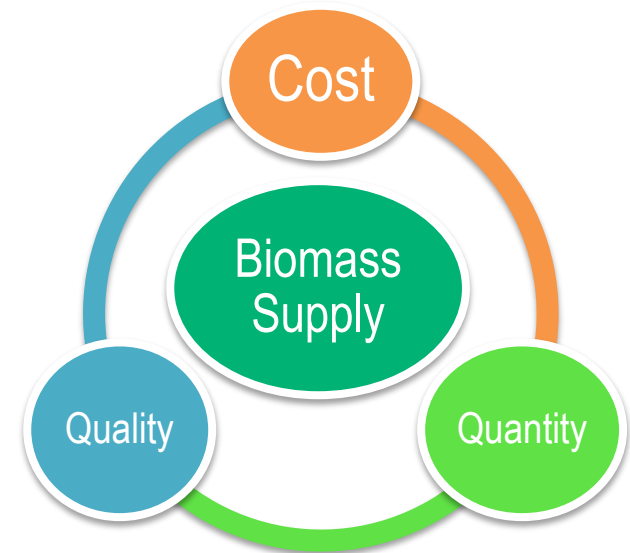


Outline

- **Biomass resource analysis objectives.**
- **National resource assessments to date.**
- **2011 Billion-ton Update summary.**
- **2016 Billion-ton Report preview**
- **www.bioenergykdf.net**

Resource Analysis Objectives

- In order to realize an advanced biofuels industry, we need a **significant sustainable supply of biomass**
- Goal: Provide timely and credible estimates of feedstock supplies and prices to support
 - the development of a bioeconomy; feedstock demand analysis of EISA, RFS2, and RPS mandates
 - the data and analysis of other projects in sustainability, logistics, conversion, etc.



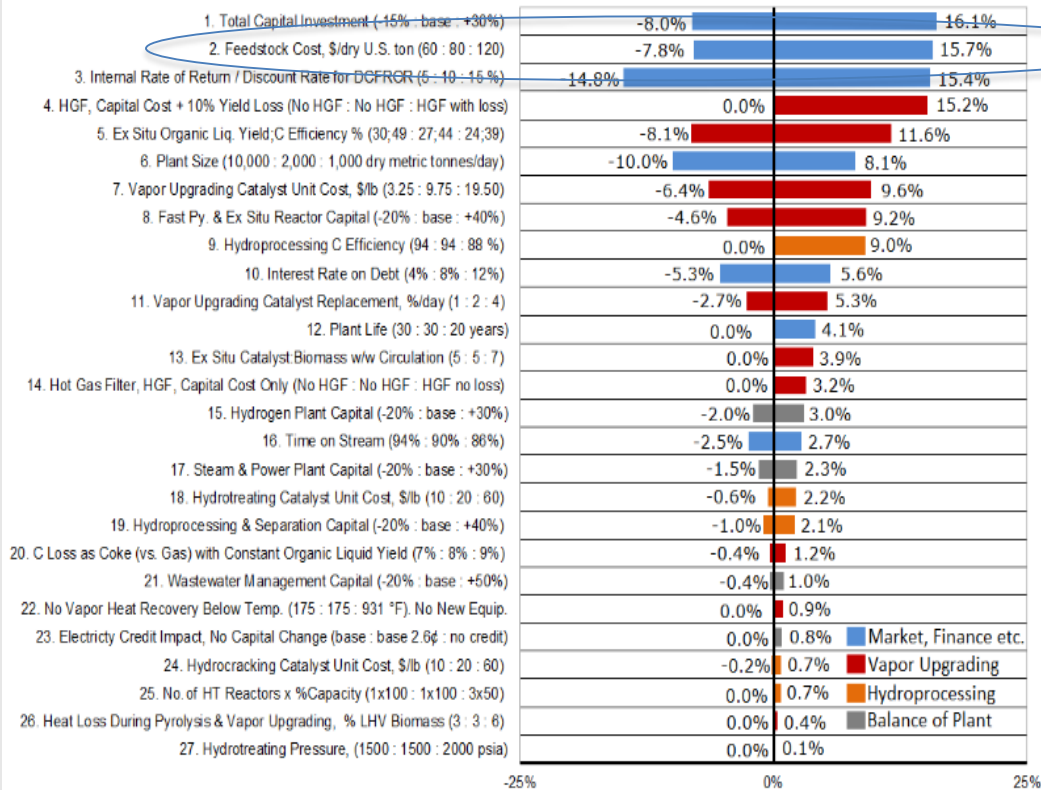
Economics of Biomass and Conversion

- Feedstock cost is 2nd largest source of cost variability in 2014

Thermochemical Minimum Fuel Selling Price (-7.8% to +15.7%)

- In Biochemical and Thermochemical process design cases (Technoeconomic Analysis), feedstocks costs consistently account for about 1/3 of Minimum Fuel Selling Price (MFSP)

Relevance – Scenarios and Sensitivity



Example of sensitivity studies for *ex situ* case

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

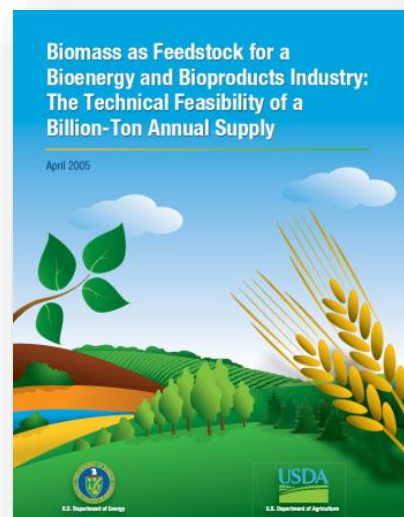
Cost variability = RISK

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

History and Accomplishments

Billion-Ton Study (BTS), 2005

- **Technical assessment** of agricultural and forestry systems to supply low-valued biomass for new markets
- Identified adequate supply to displace **30%** of petroleum consumption; i.e. physical availability



Billion-Ton Update (BT2), 2011

- Quantified potential **economic availability** of feedstocks for 20-year projection
- Publicly released **county-level supply curves** for 23 candidate feedstocks through Bioenergy Knowledge Discovery Framework.



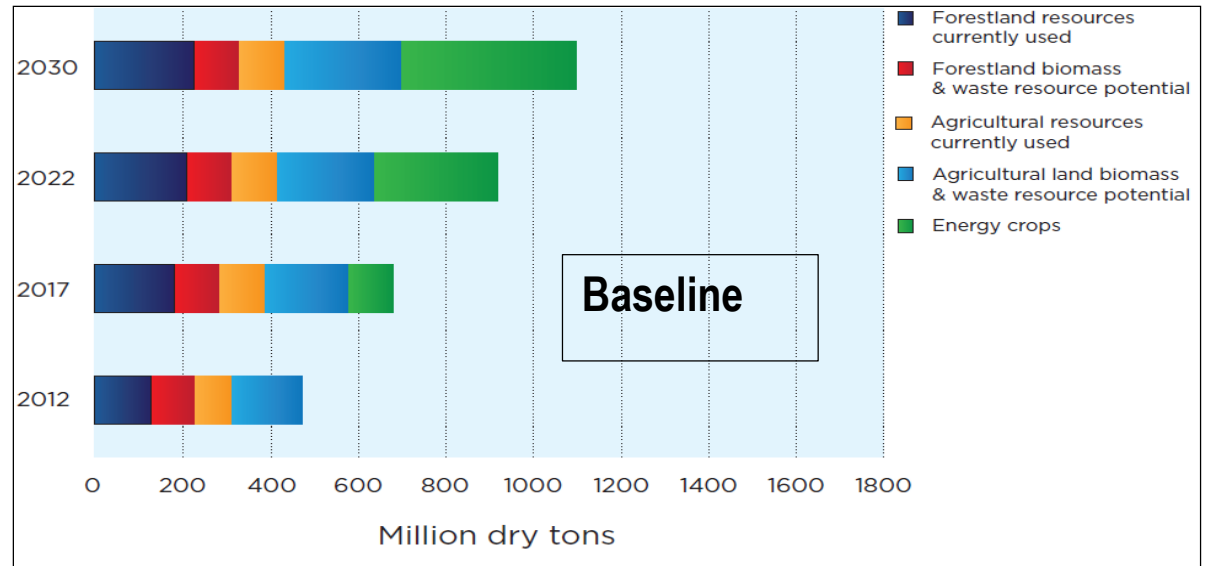
Preamble to the 2011 Billion-ton Update

- Resource assessment – not demand estimates
- Excluded algal feedstocks
- Included “major” feedstocks
- Costs were only to roadside/farmgate
- No specified product end use or conversion process
- Raw material in form as described with **losses only up to roadside**
- Does not represent full cost or actual, usable tonnage at facility

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

Baseline scenario

- 2012 combined resources from forests and agricultural lands total about 473 million.
- By 2030, estimated resources increase to nearly 1.1 billion dry tons.



High-yield scenario

- By 2030, total resource ranges from 1.4-1.6 billion dry tons annually.
- No high-yield scenario was evaluated for forest resources.

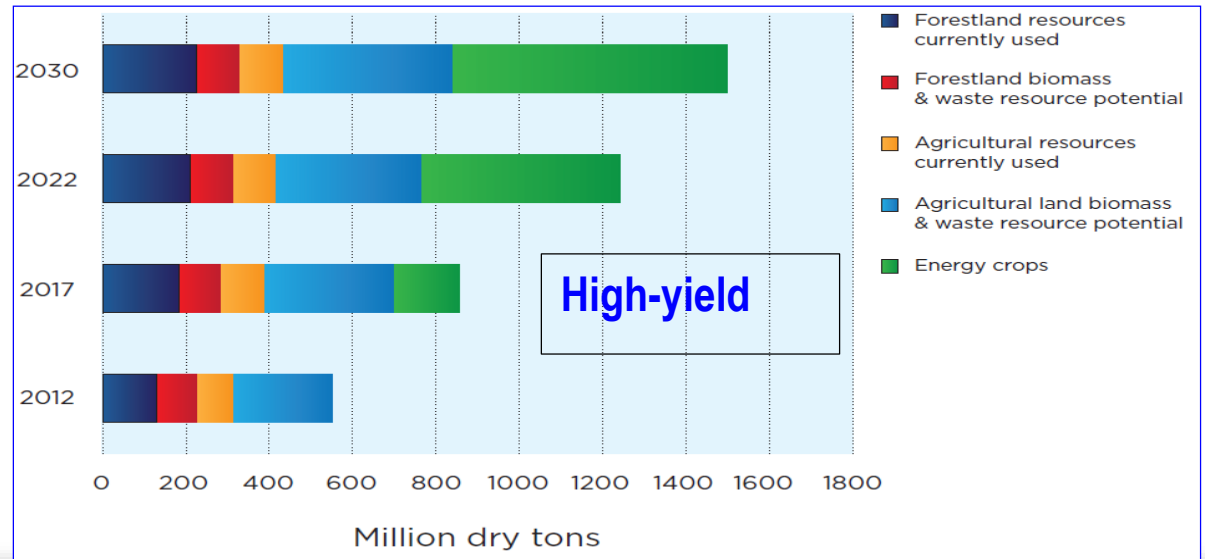
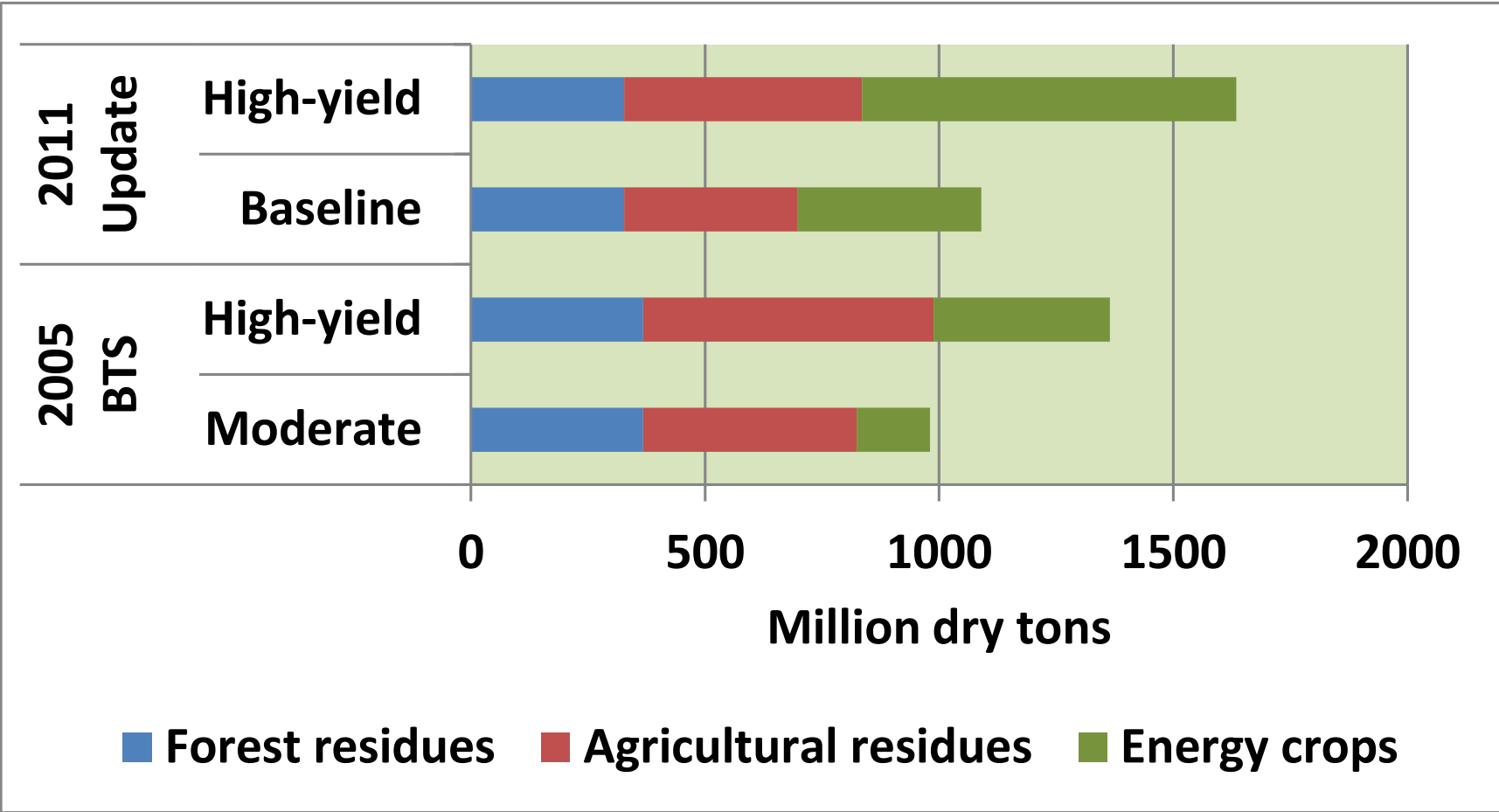


Table ES-1: Current and Potentially Available Feedstocks

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	540–799
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

Comparison of 2005 BTS with 2011 BT2

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



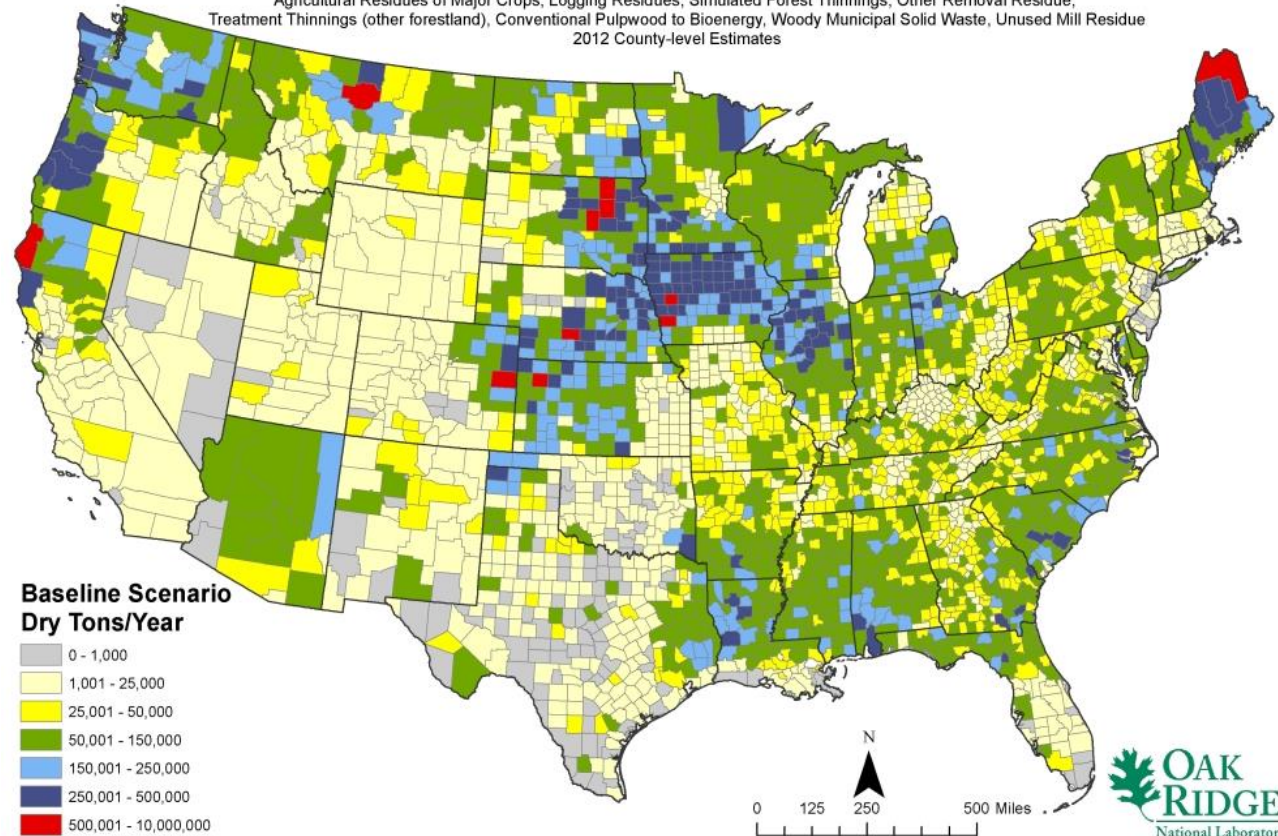
Near-term Potential

- 2012
- Baseline scenario
- \$60 dry ton⁻¹

201 x 10⁶ dt

Currently Available Biomass Resources

Includes all potential primary agricultural resources and primary and secondary forestry resources excluding Federal Lands (when available) at \$80 per dry ton or less: Agricultural Residues of Major Crops, Logging Residues, Simulated Forest Thinnings, Other Removal Residue, Treatment Thinnings (other forestland), Conventional Pulpwood to Bioenergy, Woody Municipal Solid Waste, Unused Mill Residue
2012 County-level Estimates

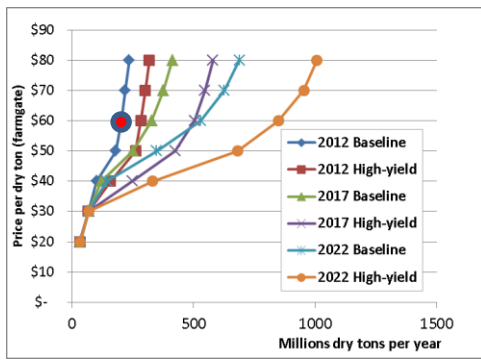


Baseline Scenario Dry Tons/Year

- 0 - 1,000
- 1,001 - 25,000
- 25,001 - 50,000
- 50,001 - 150,000
- 150,001 - 250,000
- 250,001 - 500,000
- 500,001 - 10,000,000



Source: U.S. Department of Energy, 2011. U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry. R.D. Perlack and B.J. Stokes (Leads), ORNL/TM-2011/224, Oak Ridge National Laboratory, Oak Ridge, TN. 227p. Data Accessed from the Bioenergy Knowledge Discovery Framework, www.bioenergykdf.net. [December 4, 2012].
Author: Laurence Eaton (eatonlm@ornl.gov)- December 4, 2012.



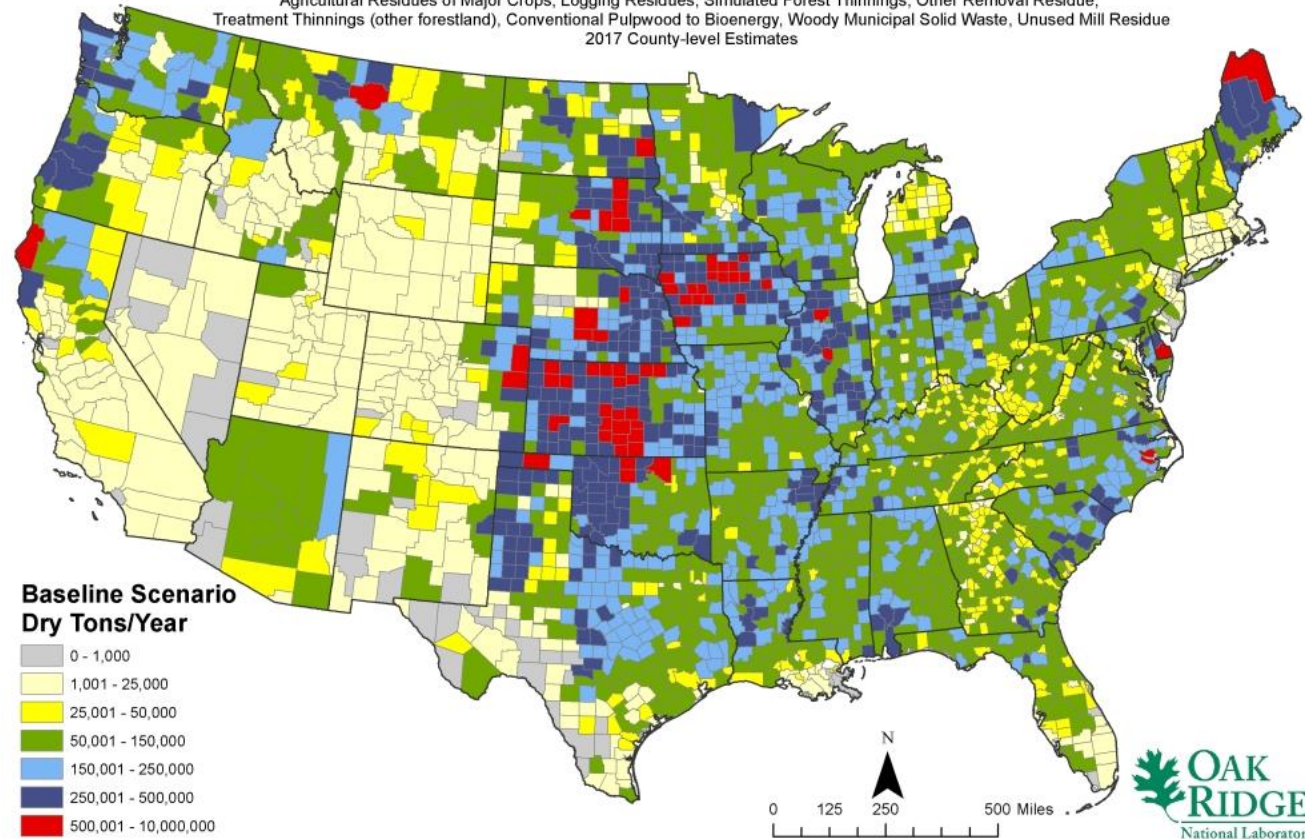
Billion-ton Results

- 2017
- Baseline scenario
- \$60 dry ton⁻¹

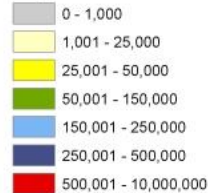
327 x 10⁶ dt

Potentially Available Biomass Resources

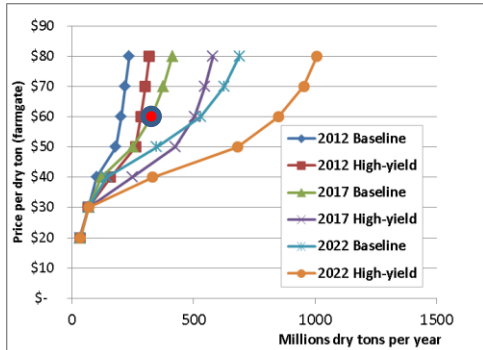
Includes all potential primary agricultural resources and primary and secondary forestry resources excluding Federal Lands (when available) at \$80 per dry ton or less:
 Agricultural Residues of Major Crops, Logging Residues, Simulated Forest Thinnings, Other Removal Residue, Treatment Thinnings (other forestland), Conventional Pulpwood to Bioenergy, Woody Municipal Solid Waste, Unused Mill Residue
 2017 County-level Estimates



Baseline Scenario Dry Tons/Year



Source: U.S. Department of Energy, 2011. U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry. R.D. Perlick and B.J. Stokes (Leads), ORNL/TM-2011/224. Oak Ridge National Laboratory, Oak Ridge, TN. 227p. Data Accessed from the Bioenergy Knowledge Discovery Framework, www.bioenergykdf.net. [December 4, 2012].
 Author: Laurence Eaton (eatonlm@ornl.gov)- December 4, 2012.



2016 Billion-Ton Report-Additions

- **Characterization of delivered supplies:** feedstock mixes, prices, comparison of logistics scenarios.
- **Additional sensitivity analyses** and specified-demand scenarios.
- **Interactive visualization** of biomass supplies, costs, types, and spatial distribution.
- **Additional crops:** Miscanthus, energy cane, poplars, and eucalyptus.
- Biomass **crop yields** derived from empirical model of 30-year climate average.
- Development and application of **POLYSYS forest module** for primary forest resources.
- Supplies and prices of **algae** from co-located production systems.
- **Two-volumes:** Volume 1, economic availability of feedstocks; Volume 2, environmental effects of select scenarios.

2016 Billion-Ton Report-Comparisons

	2005 BTS	2011 Update	2016 Update
Spatial scale	National estimates—no spatial information	County-level estimates with aggregation to state, regional and national levels	County-level estimates with regional analysis of potential delivered supply
Cost analyses	No cost analyses—just quantities	Supply curves by feedstock by county, costing at the farmgate/forest landing	Costing both at the farmgate/forest landing and at the biorefinery delivery point.
Land management change	No explicit land-management change modeling	Land-management change modeled for energy crops	Land-management change modeled and assessed for soil carbon impacts
Time horizon	Long-term, inexact time horizon (2005; ~2025 and 2040–50)	2012–2030 timeline (annual time step)	2016– 2040 timeline (annual time step)
USDA projections	2005 USDA agricultural projections; 2000 forestry RPA/TPO	2010 USDA agricultural projections; 2010 FIA inventory and 2007 forestry RPA/TPO	2015 USDA agricultural projections; 2012 USDA Census
Crop residue modeling	Crop residue removal sustainability addressed from national perspective; erosion only	Crop residue removal sustainability modeled at soil level (wind and water erosion, soil carbon)	Crop residue considered in scenario of <i>integrated landscape management</i>
Environmental constraints and impacts	Erosion constraints to forest residue collection	Greater erosion plus wetness constraints to forest residue collection	Volume 2 will feature robust analysis of environmental sustainability
Data reporting format	No external data	County-level data as a function of farmgate price and scenario	County-level data, plus on-line companion data available for interactive visualization linked to select figures and tables

2016 Billion-Ton Report-Forest Resources at Roadside (in progress)

Goal: Dynamic stand inventory incorporated in forest resource analysis.

Resources: Logging residues and forest thinnings.

Additions to the 2016 Report:

- **Market assessment:** US Forest Products Model (USFPM)/Global Forest Products Model (GFPM), USDA Forest Service (changes in bioenergy demand growth, housing starts, silvicultural intensity, paper and paperboard demand, external biomass demand)
- **Future market scenarios:** Subregional Timber Supply Model (SRTS), North Carolina State University
- **National Economic Availability:** Forest Sustainable and Economic Model (ForSEAM), University of Tennessee

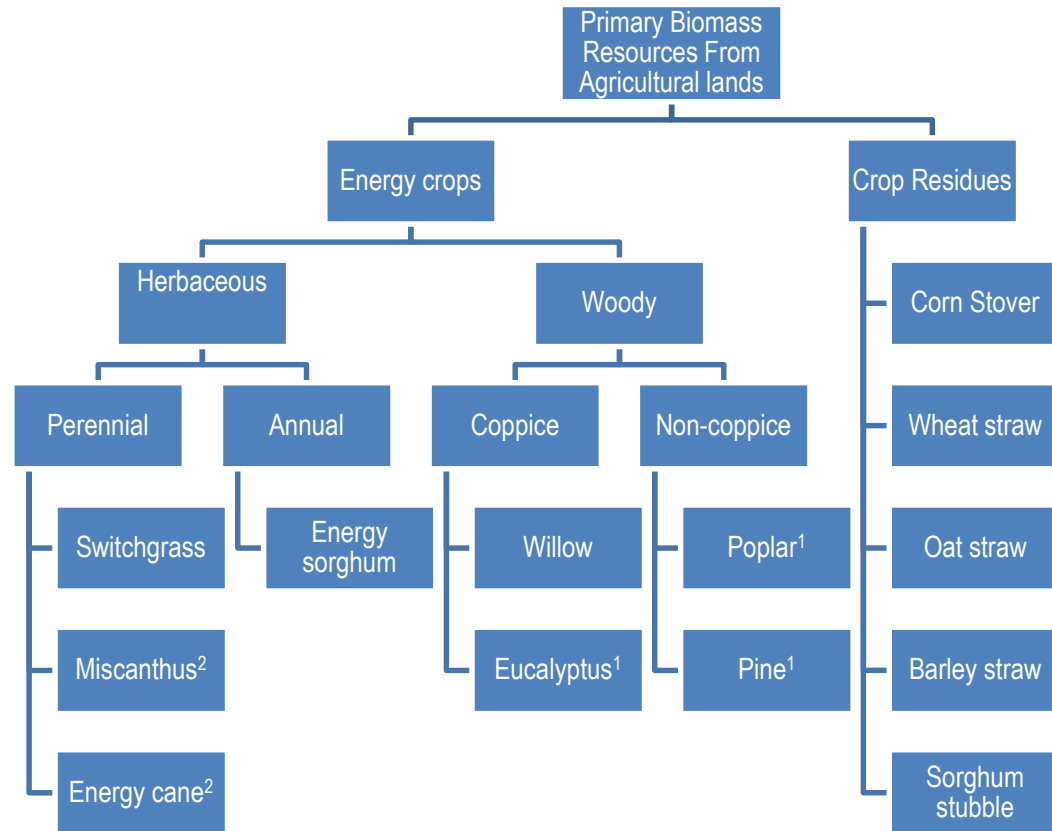
2016 Billion-Ton Report-Agricultural Resources at Farmgate

Goal: Update assessment, advance analysis of market scenarios.

Scope	2011 Billion-Ton Update	2016 Billion-Ton report
USDA Baseline	2010 USDA Baseline assumed, extrapolated from 2020 to 2030	2015 USDA Baseline assumed, extrapolated from 2025 to 2040
Energy crop types	Perennial herbaceous, annual herbaceous, coppice SRWC, non-coppice SRWC	Switchgrass, Miscanthus, energy cane, energy sorghum, poplar, and willow
Energy crop yields	Regionally assigned yields based on literature	Modeled yields based on Regional Feedstock Partnership PRISM results
Pasture intensification	One acre of management-intensive grazing assumed capable of replacing forage production displaced by one acre of pasture converted to energy crops	1.5 acres of management-intensive grazing assumed capable of replacing forage production displaced by one acre of pasture converted to energy crops
Farmgate prices	Flat nominal prices	Flat real (inflation-adjusted) prices based on the Producer Price Index for Crude Materials for Further Processing
Operational constraints	All crop residues available after sustainability retention coefficients are met are assumed operationally available	Operational availability is assumed 50% in 2014 increasing linearly to 90% in 2040 (cross reference xx), not exceeding sustainability retention coefficients
Geographic range of energy crops on pasture land	East of the 100th meridian	To account for precipitation, pastureland values from the 2012 USDA census were considered to constrain the conversion of pastureland to energy crops in counties where the 30 year average annual precipitation is 25 in. or less
Nutrient replacement costs	Costs of nutrients for 1 dry ton/acre of energy crops included	Costs of nutrients for energy crops applied on a per dry ton basis

2016 Billion-Ton Report-Agricultural Resources at Farmgate

Goal: Update assessment, advance analysis of market scenarios.



¹Poplar, eucalyptus, and pine are newly added feedstocks to the billion-ton reporting. They were generalized in the 2011 BT2 as 8-year rotation, short-rotation woody crops under single-stem management.

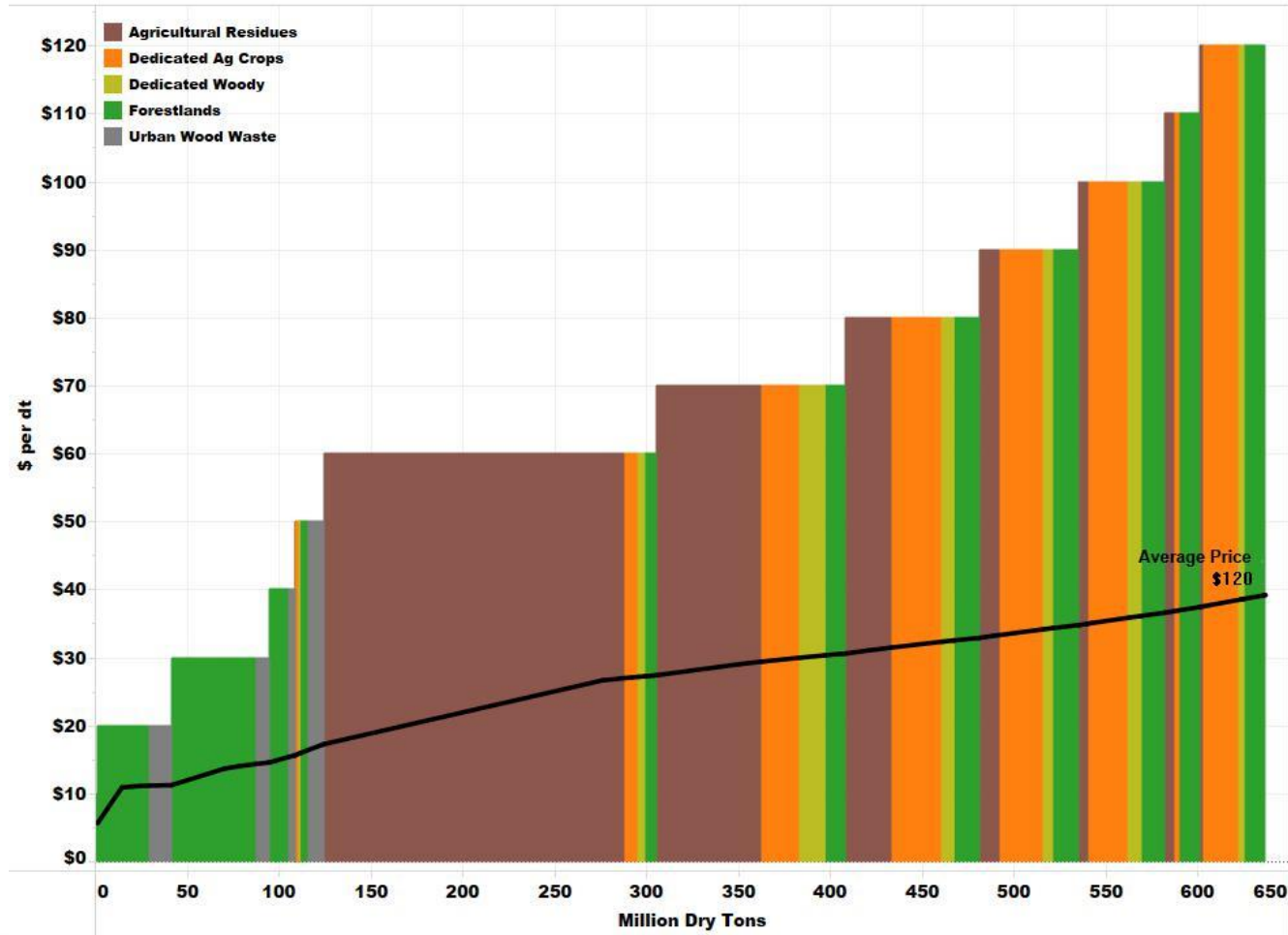
²Energy cane and Miscanthus are newly added feedstocks to the billion-ton reporting. They were generalized in the 2011 BT2 as perennial grasses, along with switchgrass.

Farmgate: National Supply Curves

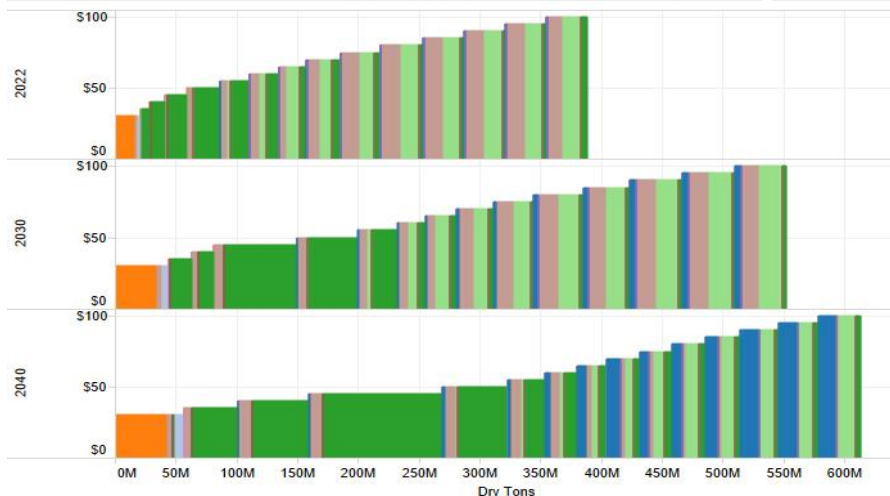
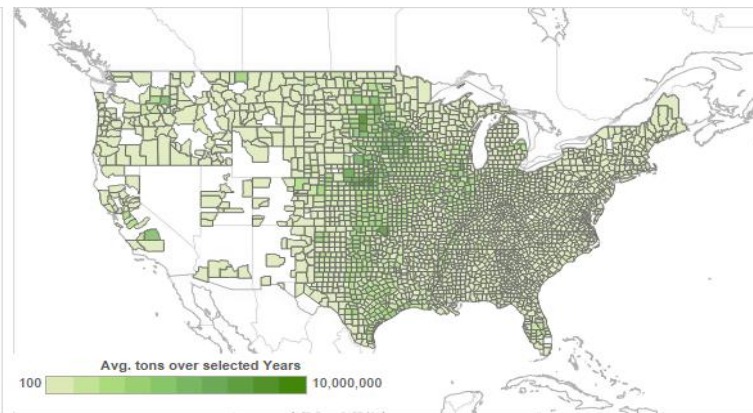
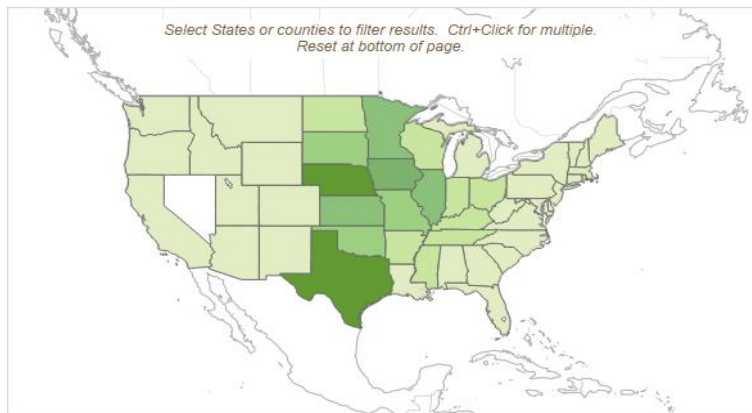
2013 Feedstock Supply and Price Projections and Sensitivity Analysis: Langholtz MH, Eaton LM, Turhollow A, Hilliard MR.
2013 Feedstock Supply and Price Projections and Sensitivity Analysis. BioFPR [Internet]. 2014;8(4).
<http://onlinelibrary.wiley.com/doi/10.1002/bbb.1489/abstract>

Feedstock Supply and Price Projection
2022 USDA Baseline Projection, Million Dry Tons

These supplies and prices were generated September 2014, 100% off woody resources (i.e., not intergrated harvesting operations)



BT16 Farmgate: Pending interactive visualization (preliminary results, do not cite)

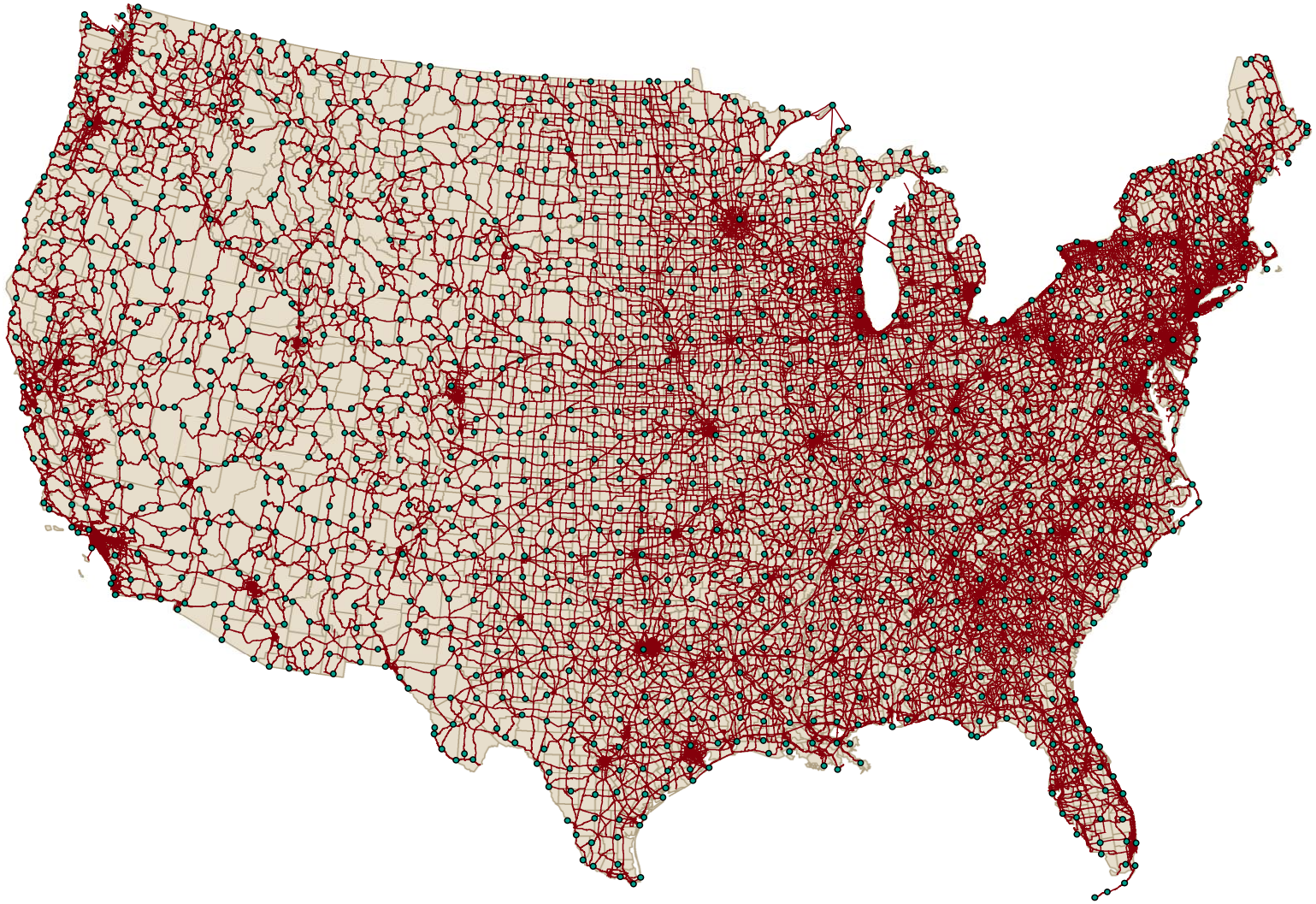


	2017	2022	2030	2040
Switchgrass		116,547,162	184,747,571	288,717,747
Cpcwood		131,791,440	146,786,868	74,552,886
Miscanthus		109,008,323	138,317,711	84,194,745
Corn-strw	8,387,605	24,209,584	43,559,666	52,986,447
Biomass sorghum		3,133,188	31,313,181	101,960,934
Wheat-strw	2,322,085	3,302,095	6,789,460	9,175,833
Npcwood			399,665	521,039
Cane		451,461	277,434	549,274
Barley-strw	10,021	112,642	159,624	636,643
Sorghum-stbl	14,703	37,490	56,316	320,504
Oats-strw	6,236	7,415	13,697	17,391
Grand Total	10,740,650	388,600,801	552,421,193	613,633,442

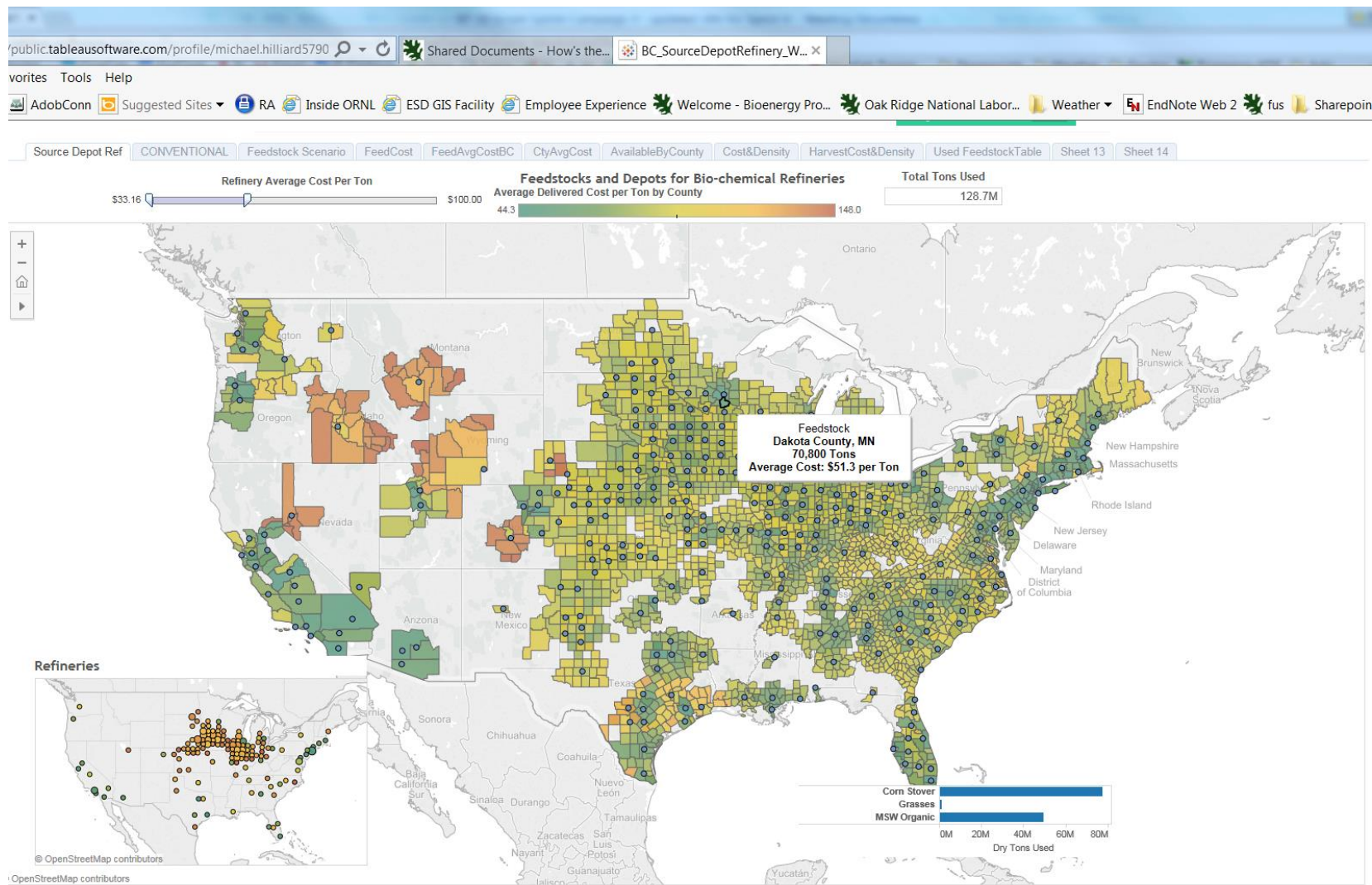
Click on a column, row or entry to filter results. Ctrl+Click to select multiple years or feedstocks.



Delivered Supplies: Potential Facility Locations

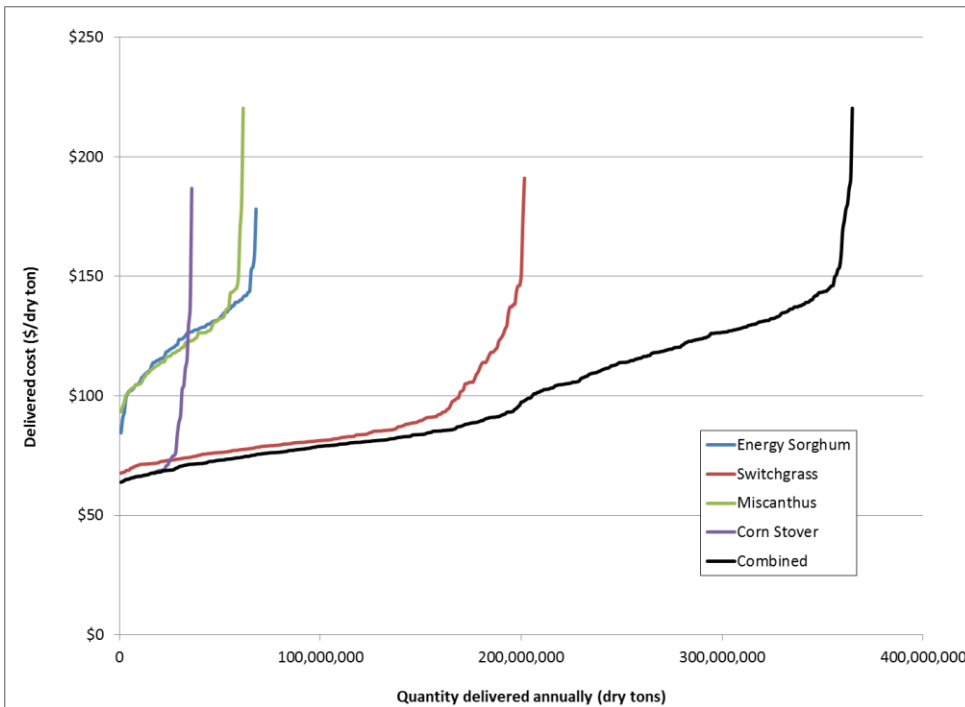
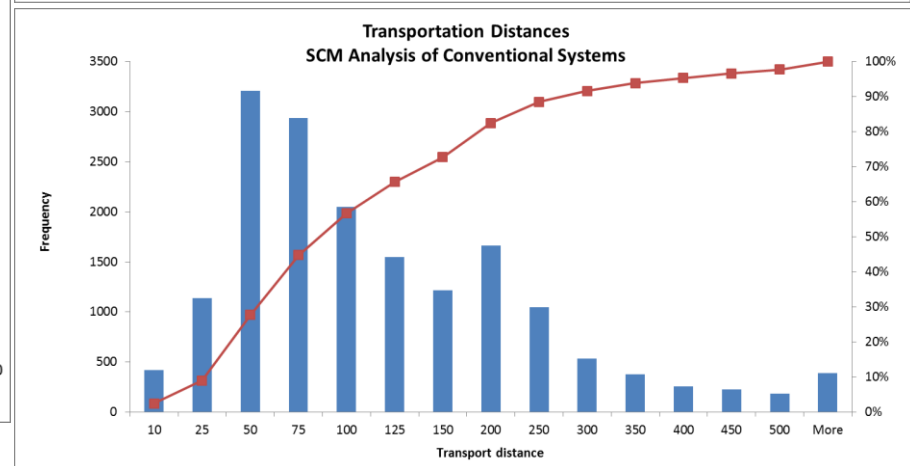
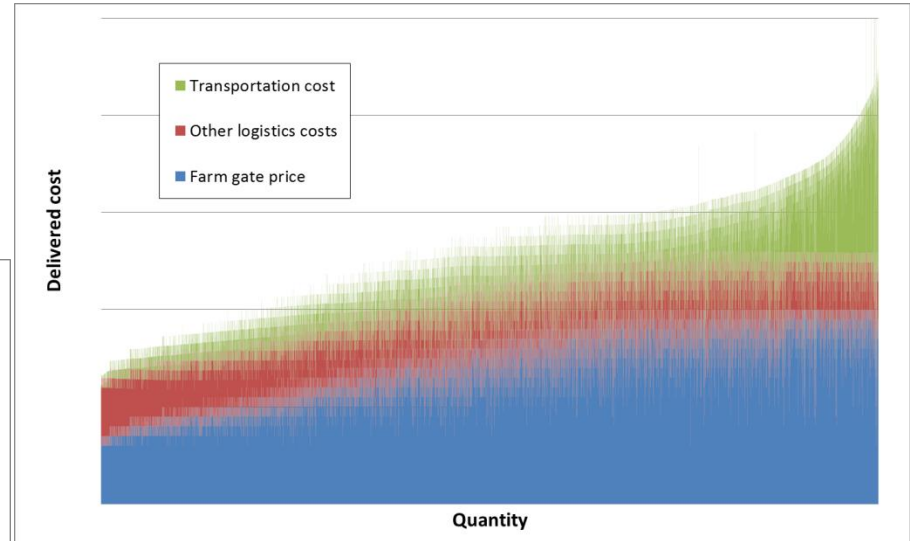


BT16 Delivered Supplies: (preliminary, do not cite)

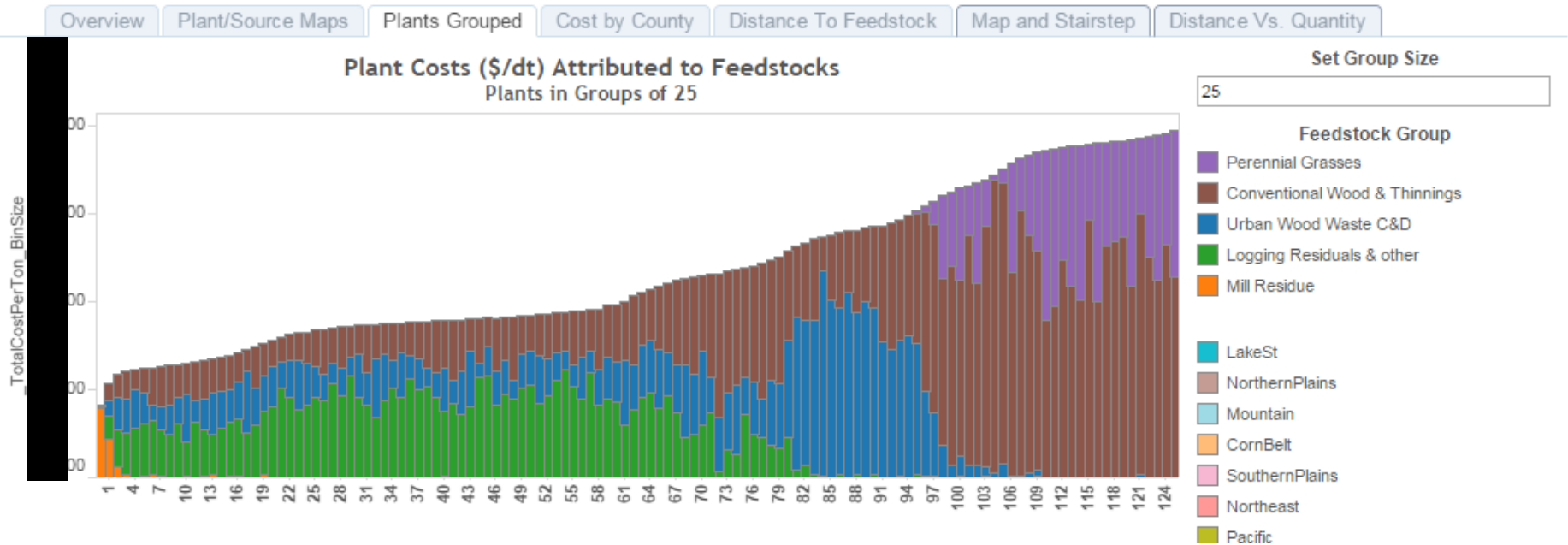


BT16 Delivered Supplies (preliminary, do not cite)

Costs to deliver corn stover, switchgrass, energy sorghum, and miscanthus to the biorefinery.

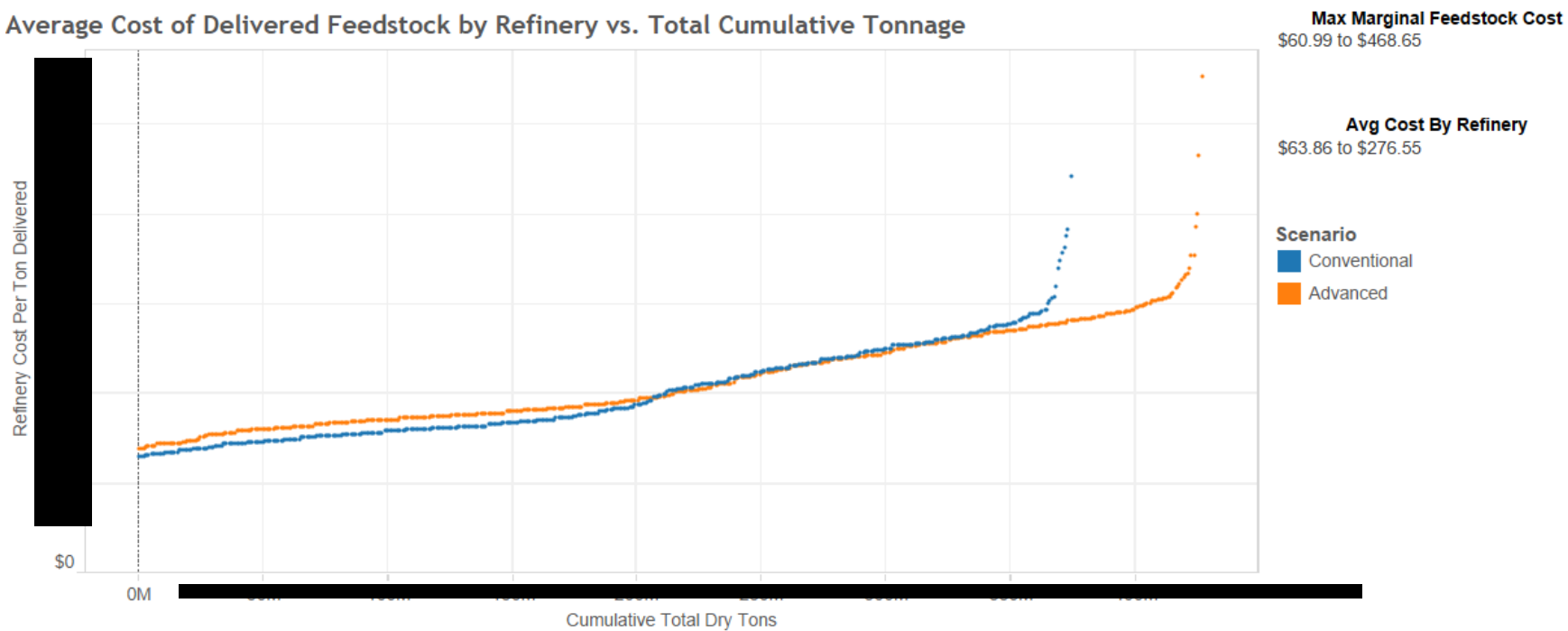


BT16 Delivered Supplies: (preliminary, do not cite, values redacted)



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

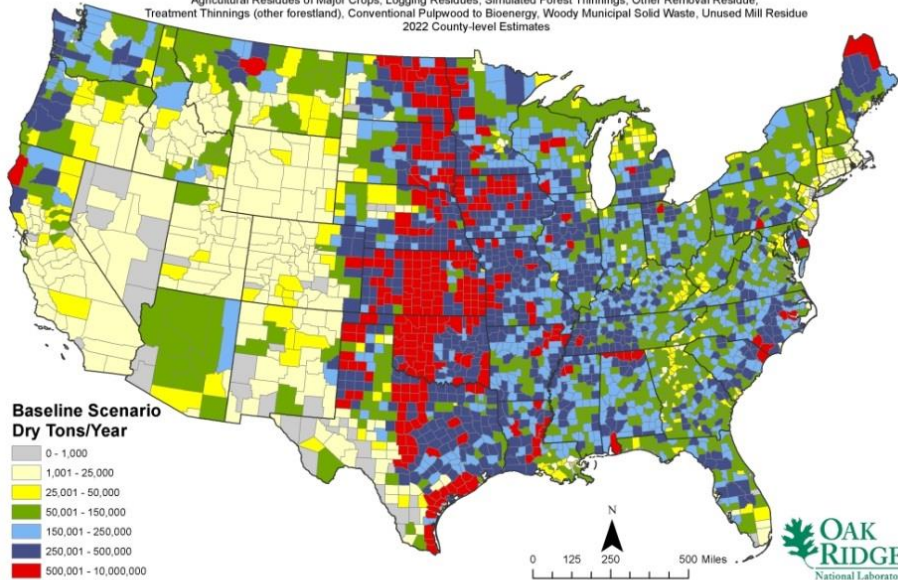
Average Cost of Delivered Feedstock by Refinery vs. Total Cumulative Tonnage



Approach: Sustainability in Billion Ton 2016

Potentially Available Biomass Resources

Includes all potential primary agricultural resources and primary and secondary forestry resources excluding Federal Lands (when available) at \$80 per dry ton or less:
Agricultural Residues of Major Crops, Logging Residues, Simulated Forest Thinnings, Other Removal Residue,
Treatment Thinnings (other forestland), Conventional Pulpwood to Bioenergy, Woody Municipal Solid Waste, Unused Mill Residue
2022 County-level Estimates



Source: U.S. Department of Energy 2011, U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry. R.D. Perlack and B.J. Stokes (Leads), ORNL/TM-2011/224. Oak Ridge National Laboratory, Oak Ridge, TN. 227p. Data Accessed from the Bioenergy Knowledge Discovery Framework, www.bioenergykdf.net. [December 4, 2012].
Author: Laurence Eaton (eatontm@ornl.gov)- December 4, 2012.

U.S. DEPARTMENT OF ENERGY Energy Efficiency & Renewable Energy

Air quality

Biological diversity

Soil quality

Task 1a.
Sustainability indicators

Water quality & quantity

Productivity

Greenhouse gas emissions

- Address multiple indicators in 6 indicator categories
- Use multiple models (SWAT, Century, GREET, F-PEAM, species distribution model)
- Involve multiple national labs and agencies
- Focus on 2040, with potential outputs for 2030 and 2020
- Outputs: projected environmental effects, tradeoffs among effects

Approach: Sustainability in Billion Ton 2016

Environmental sustainability indicators

	Indicator
Soil quality	1. Total organic carbon (TOC)
	2. Total nitrogen (N)
	3. Extractable phosphorus (P)
	4. Bulk density
Water quality and quantity	5. Nitrate loadings to streams (and export)
	6. Total phosphorus (P) loadings to streams
	7. Suspended sediment loadings to streams
	8. Herbicide concentration in streams (and export)
	9. Storm flow
	10. Minimum base flow
	11. Consumptive water use (incorporates base flow)
	Addition: Water yield

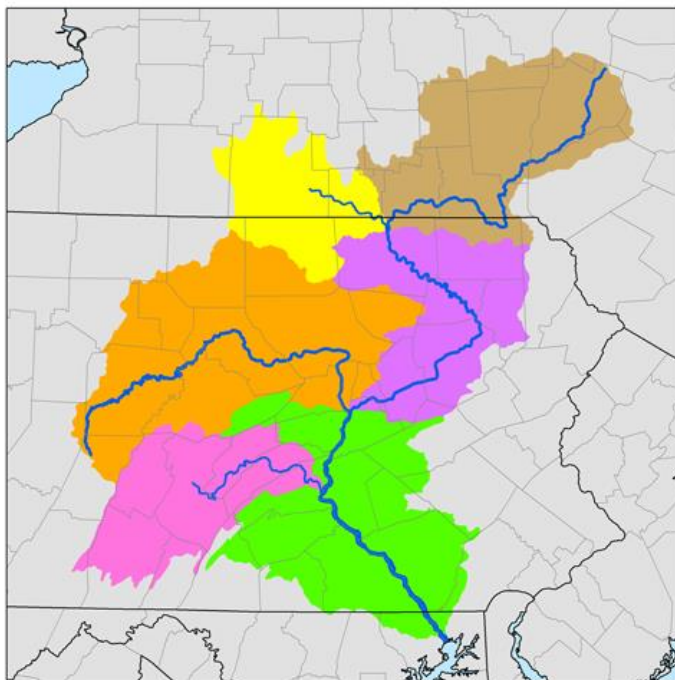
	Indicator
Greenhouse gases	12. CO ₂ equivalent emissions (CO ₂ and N ₂ O)
Biodiversity	13. Presence of taxa of special concern
	14. Habitat area of taxa of special concern
Air quality	15. Tropospheric ozone
	16. Carbon monoxide
	17. Total particulate matter less than 2.5 μm diameter (PM _{2.5})
	18. Total particulate matter less than 10 μm diameter (PM ₁₀)
	Possible additions: VOCs, SO _x , NO _x , NH ₃
	19. Aboveground net primary productivity or Yield
Productivity	

McBride et al. (2011) *Ecological Indicators* 11:1277-1289

Approach: Sustainability in Billion Ton 2016

Mitigate adverse effects on projected environmental effects

Example 1: mitigate projected effects by reallocating biomass at the sub-county level (e.g., soil quality)



County boundaries do not correspond with watershed or soil classification boundaries

Example 2: mitigate projected effects through conservation practices (e.g., water quality)

Conservation practice	Upper Mississippi River Basin	Arkansas White Red River Basin
No till, conservation till	corn	Sorghum, winter wheat
Ag residue removal	corn	Winter wheat, sorghum
Reduced fertilizer	switchgrass	Perennial grasses
Riparian buffer	switchgrass, poplar	
Winter or summer cover crop (non-feedstock)	rye	Clover or sorghum with winter wheat

Summary

- **Biomass resource analysis aims to support national bioenergy and biofuels strategies and a bioeconomy vision.**
- **Aiming to release BT16 Volume 1 in July of at Bioenergy 2016, Volume 2 soon after.**
- **www.bioenergykdf.net**
- **langholtzmf@ornl.gov,
efroymsonra@ornl.gov**
- **Thank you!**



Questions and Discussion

Moderated by Helene Cser





Thank You For Your Participation!

A recording of this webinar will be available at:

[http://www.forestrywebinars.net/previous-
webinars](http://www.forestrywebinars.net/previous-webinars)

Upcoming Webinars

October 21, 2015



Developing the U.S. bioeconomy within a global context* (1:00 – 2:20 PM/EST)

Developing New Feedstock for the Bioeconomy, Tim Rials, Director, The Center for Renewable Carbon, University of Tennessee,

Thermochemical conversion of biomass to fuels and other products, Steve Chmely, Assistant Professor, University of Tennessee

Indirect Effects of Bioenergy: International Standards and Science, Maggie Davis, R&D Associate Staff, Oak Ridge National Laboratory

Using science to promote sustainable biofuels production in the southeastern United States* (2:30 – 3:50 PM/EST)

Environmental and socioeconomic sustainability analysis of switchgrass-to-ethanol production in Eastern Tennessee, Esther Parish, Scientist, Landscape Ecology and Regional Analysis, Oak Ridge National Laboratory

Examining the effects of woody biomass production for bioenergy on water quality and hydrology in the southeastern United States, Natalie Griffiths, Researcher in the Ecosystem Observations and Experiments, Oak Ridge National Laboratory

Future bioenergy production in two southern tributary basins of the Mississippi River Basin is projected to improve water quality, Henriette Jager, Senior Scientist, Oak Ridge National Laboratory

*Live presentations will be held at University of Tennessee and broadcasted to online participants via the Southern Regional Extension Forestry [Bioenergy webinar portal](#). Continuing education credits are available.

<http://www.se-ibss.org/webinars-1/upcoming-webinars/>