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

A Changing Market for Biofuels and Bioproducts

May 27, 2015

Bioenergy Technologies Office (BETO)

Agenda

- Introduction and BETO Overview
  - Kristi Theis, National Renewable Energy Laboratory
  - Jonathan Male, BETO Director
- A Changing Market for Biofuels and Bioproducts
  - Salim Morsy, Bloomberg New Energy Finance
  - Bryce Stokes, CNJV
  - Laurence Eaton, Oak Ridge National Laboratory

Questions and Comments

Please record any questions and comment you may have during the webinar and send them to eere_bioenergy@ee.doe.gov

As a follow-up to the webinar, the presenter(s) will provide responses to selected questions.

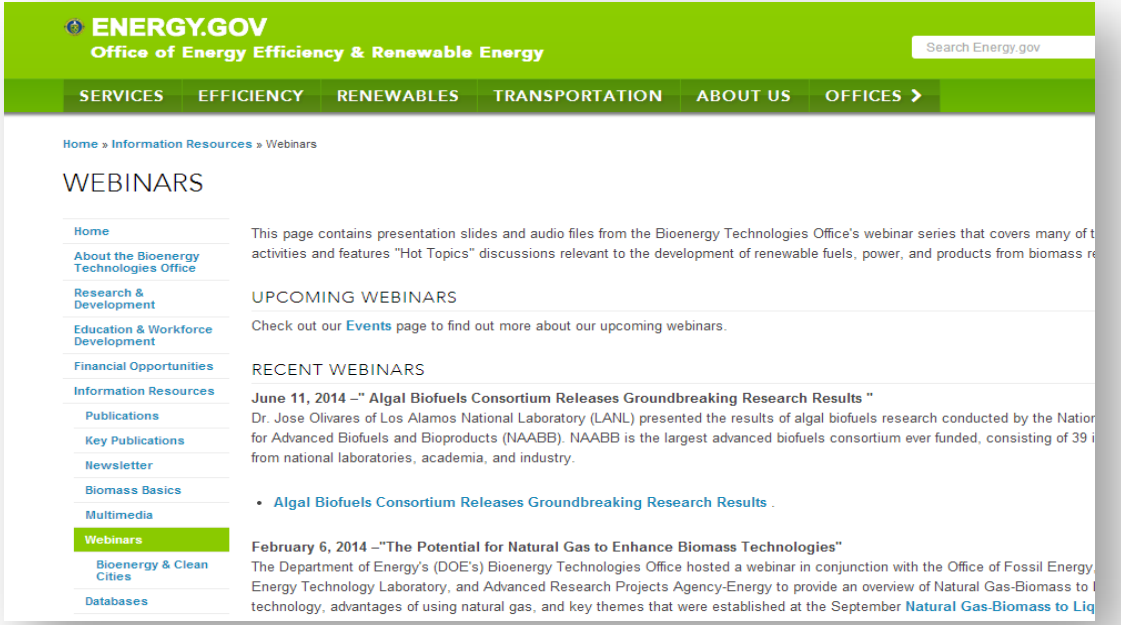
Slides from this presentation will be posted online:
http://www.energy.gov/eere/bioenergy/webinars

For general questions regarding the Bioenergy Technologies Office, please email eere_bioenergy@ee.doe.gov

Bioenergy Technologies Office Webinar Series

Started in May 2010 to highlight “hot topics” in biomass and bioenergy industry.

Find past webinars and today’s slides on the Office’s website: http://www.energy.gov/eere/bioenergy/webinars



Bioenergy Technologies Office

Mission

Accelerate the commercialization of advanced biofuels and bioproducts through targeted research, development, and demonstration supported by public and private partnerships

Strategic Goal

Develop technologies to enable the sustainable, nationwide production of biofuels compatible with today's transportation infrastructure

Performance Goal

By 2017, validate a least one pathway for $3/GGE* hydrocarbon biofuel (with ≥50% reduction in GHG emissions relative to petroleum)

*Mature modeled price at pilot scale.

Through RD&D, BETO reduces risks and costs to commercialization

The Challenge and the Opportunity

THE CHALLENGE

- U.S. gasoline consumption is 8.5 million barrels/day
- 67% of U.S. petroleum consumption is in the transportation sector

THE OPPORTUNITY

- More than 1 billion tons of biomass could be sustainably produced in the U.S.
- 1 billions tons of biomass could displace 30% of U.S. petroleum use by 2030, and reduce 400M tonnes of CO_2e.

Biofuels could displace 30% of liquid transportation fuels

BETO's Core Focus Areas

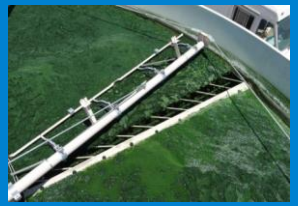
Program Portfolio Management

• Planning • Systems-Level Analysis • Performance Validation and Assessment
• MYPP • Peer Review • Merit Review • Quarterly Portfolio Review
• Competitive • Non-competitive • Lab Capabilities Matrix

Research, Development, Demonstration, & Market Transformation

Feedstock Supply & Logistics R&D

- Terrestrial
- Algae
- Product Preprocessing



Conversion R&D

- Biochemical
- Thermochemical
- Deconstruction
- Biointermediate
- Upgrading

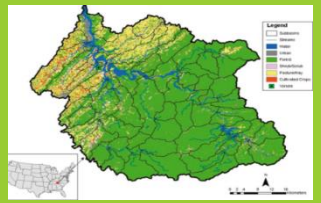
Demonstration & Market Transformation

- Integrated Biorefineries
- Biofuels Distribution Infrastructure

Cross Cutting

Sustainability

- Sustainability Analysis
- Sustainable System Design



Strategic Analysis

- Technology and Assessment
- Market and Impact Analysis
- Model Development & Data compilation

Strategic Communications

- New Communications Vehicles & Outlets
- Awareness and
- Support of Office
- Benefits of Bioenergy/Bioproducts

Bioenergy 2015 Overview

Bioenergy 2015: Opportunities in a Changing Energy Landscape

Tuesday, June 23–Wednesday, June 24, 2015

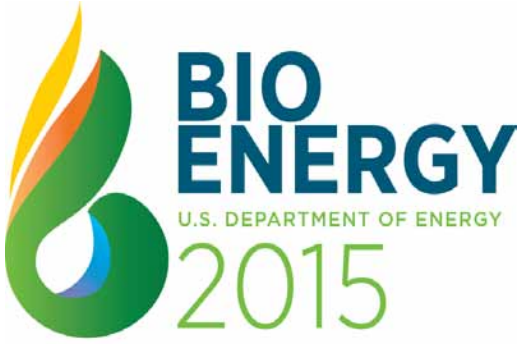
Walter E. Washington Convention Center
801 Mount Vernon Place, NW
Washington, DC 20001

Web site: http://www.energy.gov/eere/bioenergy/bioenergy2015

Program Overview

Bioenergy 2015 will focus on opportunities and challenges in our current highly dynamic energy ecosystem. Each year, approximately 600 participants attend the conference, including key stakeholders from the bioenergy industry, Congress, national laboratories, academia, and the financial community. Attendees will discuss critical bioenergy issues such as the following:

- Impact of changing oil prices
- Vehicle/fuels co-optimization
- Future of the Renewable Fuel Standard
- Environmental benefits of biofuels
- Innovative technologies and emerging pathways
- U.S. manufacturing in a global marketplace.



Confirmed Sessions and Speakers

- **Plenary Sessions Include:**
  - Policy and Market Overview
  - Biofuels in a Global Marketplace
  - Early Market Adopters
  - Fuels of the Future: The Co-Optimization of Fuels and Vehicles
  - Environmental Impacts of Biofuels

Confirmed Sessions and Speakers

- **Confirmed Speakers Include:**
  - David Danielson, Assistant Secretary for EERE, DOE
  - Christopher Grundler, Director of the Office of Transportation and Air Quality, U.S. Environmental Protection Agency
  - Jonathan Male, Director, BETO, DOE
  - Matt Carr, Executive Director, Algae Biomass Organization
  - Ronald R. Chance, Executive Vice President, Engineering, Algenol
  - Daniel Cummings, President, POET-DSM Advanced Biofuels
  - Jim Lane, Editor and Publisher, Biofuels Digest
  - Michael McAdams, President, Advanced Biofuels Association
  - Salim Morsy, Analyst, Bloomberg New Energy Finance
  - Prabhakar Nair, Executive Vice President of Business Development Asia, LanzaTech
  - Patrick Serfass, Executive Director, American Biogas Council
  - Christopher Standlee, Executive Vice President of Institutional Relationships and Governmental Affairs, Abengoa Bioenergy Corporation
  - Chris Tindal, Director for Operational Energy, Office of the Deputy Assistant Secretary of the Navy for Energy

Co-Host and Exhibiting

- *Bioenergy 2015*'s co-host, the Clean Energy Research and Education Foundation (CEREF), is now accepting exhibitors
- Exhibitors will have the opportunity to share their research, technologies, and network.
- More information is on CEREF's site: http://www.ceref.org/bioenergy-2015/exhibitors
- If interested, please contact CEREF at bioenergy@ceref.org or 202-640-6599 extension 317

An exhibit at Biomass 2014

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2011 Billion Ton Update – Outlook on a Changing Market

A Changing Market for Biofuels and Bioproducts

May 27, 2015

Bryce Stokes
Senior Advisor
CNJV, LLC

Laurence Eaton
Research Economist
ORNL M&O Subcontractor to DOE/BETO

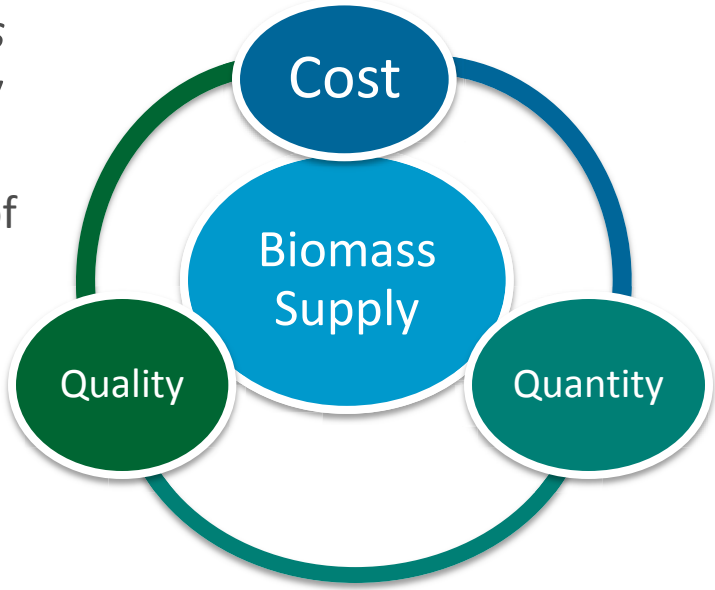
Overview

- Billion-Ton Report and 2011 Update
- Changing resources for 2015-2030
- Market impacts of a changing resource
- Preview of the 2016 Billion-ton Report

Motivation and Goals

*In order to realize a commercial advanced biofuels industry, we need a **significant sustainable supply of biomass***

- DOE is focused on analyzing the resource potential of biomass to understand feedstocks supply for the **bioeconomy** of the future
- Identify the **what, where, when, how** of commercial feedstocks from agriculture and forestry systems for fuels, power, and products
- Provide timely and credible estimates of feedstock supplies and prices to support policy, research, and commercialization
- Supply analysis is housed in the **BETO Feedstock Supply and Logistics R&D Platform**



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.

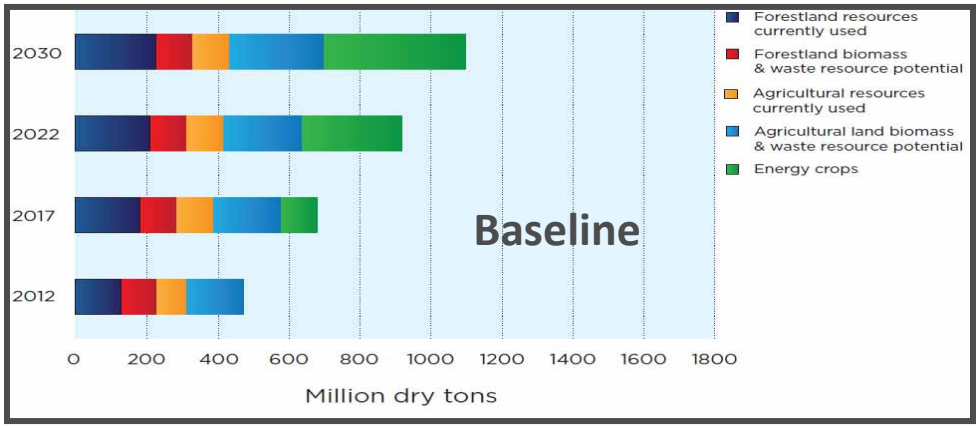
Preamble to Billion-ton Update

- 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

U.S. Billion-Ton Update: Findings

Baseline scenario

- Current combined resources from forests and agricultural lands total about 473 million dry tons at $60 per dry ton or less.
- 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.

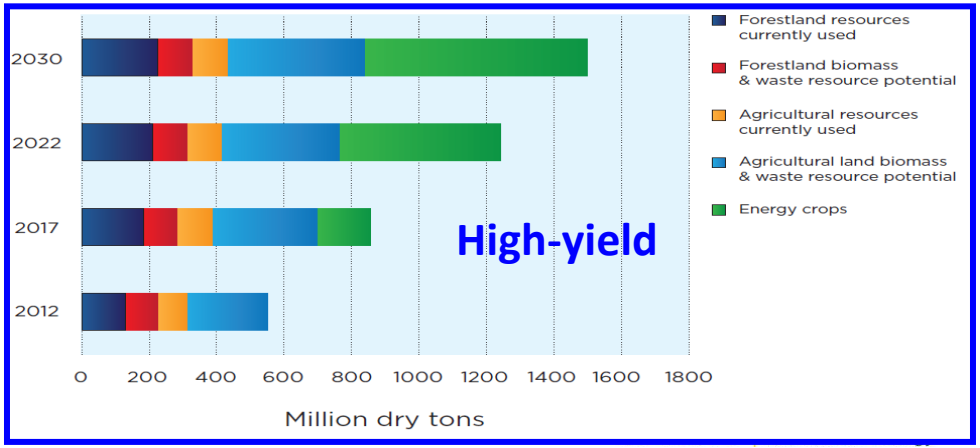


Table ES-1: Current and Potentially Available Feedstocks

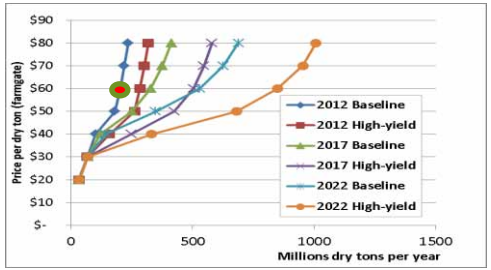
Feedstock	2012	2017	2022	2030
	Million dry tons			
Baseline scenario				
Forest resources currently used	129	182	210	226
Forest biomass & waste resource potential	97	98	100	102
Agricultural resources currently used	85	103	103	103
Agricultural biomass & waste resource potential	162	192	221	265
Energy 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**

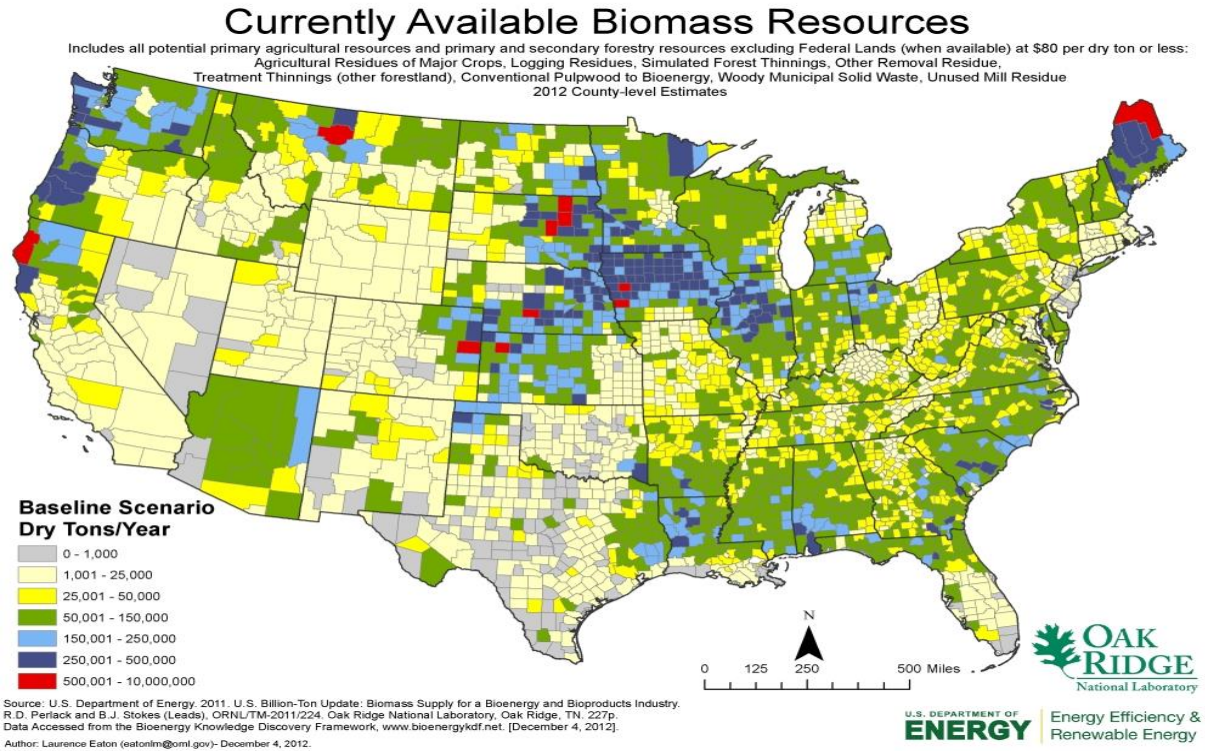
Near-term Potential

www.bioenergykdf.net

- 2012
- Baseline scenario
- $60 dry ton^{-1}

201 x 10^6 dt





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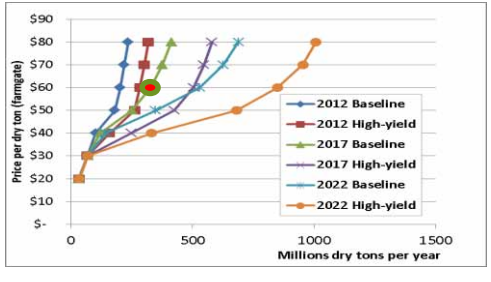
Billion-ton Results

www.bioenergykdf.net

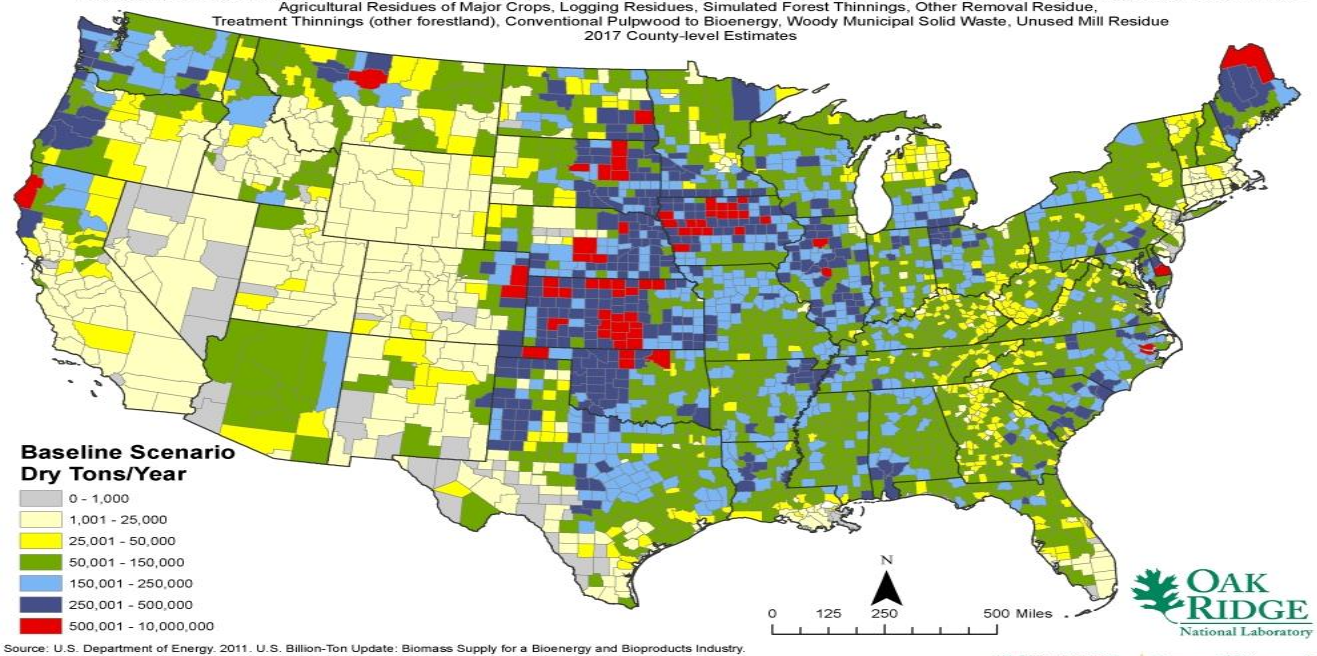
- 2017
- Baseline scenario
- $60 dry ton^{-1}

327 x 10^6 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



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.

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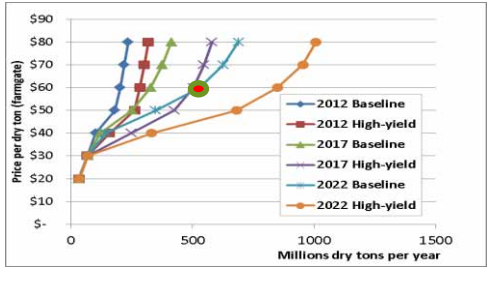
Billion-ton Results

www.bioenergykdf.net

- 2022
- Baseline scenario
- $60 dry ton^{-1}

529 x 10^6 dt



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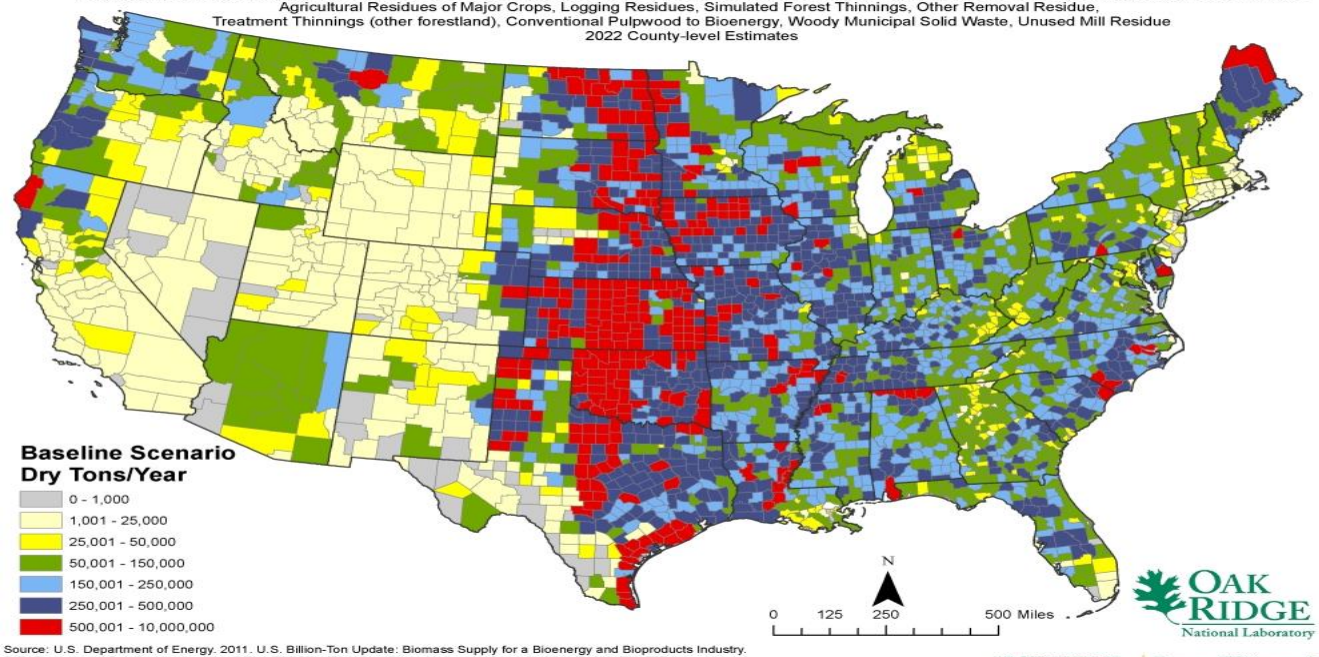
2022 County-level Estimates



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How much is a billion tons?

One billion tons of biomass would fill the **Dallas Cowboys AT&T Stadium 1600 times.**

(assumed average biomass density 12 lb / ft^3)

Dallas Cowboys AT&T Stadium – Arlington, Texas

A BILLION DRY TONS OF BIOMASS

HAS THE POTENTIAL TO PRODUCE

1.5 MILLION JOBS and keep about **$200 BILLION** dollars in the U.S. every year.

92 BILLION kWh of electricity to power **8 MILLION** households.

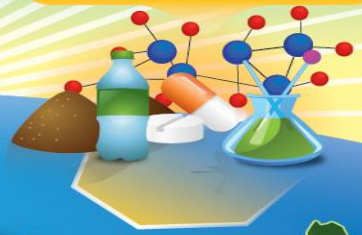
AND

60 BILLION gallons of biofuels displacing almost **30%** of all transportation fuels.

AND

50 BILLION POUNDS of biobased chemicals and bio-products, replacing a significant portion of the chemical market.

reductions of CO_2 emissions by **500 MILLION TONS** a year.



STEPS TO BUILDING THE BIOECONOMY

1. Accelerate research & technology development
2. Develop production, conversion and distribution infrastructure
3. Deploy technology
4. Create markets and delivery methods

Projection based on the 2011 Billion Ton Study Report

Dave Danielson, Advanced Bioeconomy Leadership Forum, March 11, 2015. Washington, DC.

Global Biomass Potential

Region	Energy Crops (Million Acres)	Supply Potential (Billion Dry Tons)
Europe	62-222	0.4-1.5
USA 2005 BTS	74	1.1
USA 2011 BTS	63	1.4
Latin America	299	1.5
China & India	212	1.7
Australia	-	<4M

From Bauen et al., 2009. Timeframes are 2017-2030 and Table 6.4, Billion-ton Update.

IEA Technology Roadmap *Biofuels for Transport* (2011)

- Biomass can provide 27% of world's transportation fuel by 2050
- Around 3 billion tonnes of biomass per year will be needed required
- Requires approximately 1 billion tonnes of biomass residues and wastes
- Production needs to be supplemented by production from around 100 million hectares of land - around 2% of total agricultural land - three-fold increase
- Need for the biofuels yield to increase 10x

High-Level Goals of 2016 Billion-Ton Report (BT16)

- Assess current demand of commercial biomass-to-energy feedstocks
- State-of-science biomass potential supply to 2040
  - Agricultural, forestry, algal, and waste resources
  - From farm to roadside to regional delivery points
- Environmental sustainability analysis of potential supply

Genera Energy/UT-Knoxville Bioenergy Field Day, 2013. Credit: Laurence Eaton

Photo Credit: Sapphire Energy
(http://zebrapartners.net/sapphiremedia/Green-Crude-Farm-2013.html)

Major Differences: Three National Assessments

Purpose of the 2016 *Billion-Ton Update*

- Evaluate biomass resource potential
- Improve and expand upon the previous studies
  - Greater detail of dedicated energy crop systems; revised BMP
  - Include algae resources
  - Analysis of regional transportation costs
  - Volume 2 will feature risk assessment and environmental sustainability analysis covering air quality impacts, greenhouse gases, and water quality

2005 BTS	2011 Update	2016 Update
National estimates – no spatial information	**County-level** with aggregation to state, regional and national levels	**County-level** with regional analysis of potential delivered supply
No cost analyses – just quantities	**Supply curves by feedstock and county – farmgate/forest landing**	**More detailed costing analysis to provide cost of production along supply chain to new facilities**
No explicit land use change modeling	**Land use change modeled for energy crops**	**LUC modeled and accessed for soil carbon impacts**
Long-term, inexact time horizon (2005; ~2025 & 2040-50)	**2012 – 2030** timeline (annual)	**2016 – 2040** timeline (annual)
2005 USDA agricultural projections; **2000** forestry RPA/TPO	**2010** USDA agricultural projections; **2010 FIA inventory; 2007** forestry RPA/TPO	**2015** USDA agricultural projections; **2012 USDA Census**
Crop residue removal sustainability addressed from national perspective; **erosion only**	Crop residue removal sustainability modeled at soil level (**wind & water erosion, soil C**)	Crop residue considered in scenario of **integrated landscape management**
Erosion constraints to forest residue collection	**Greater erosion plus wetness constraints** to forest residue collection	Volume 2 will feature **robust analysis of environmental sustainability**

Two-Volume Approach

- Volume 1: Resource analysis
  - Supply curves at field/forest level and delivered to collection point
  - June 2016 publish target
- Volume 2: Environmental sustainability analysis
  - Air quality, water, GHG, biodiversity analysis
  - Climate change impacts
  - September 2016

Five USDA-ARS energycane varieties planted at a Mississippi State University field site sponsored by DOE in the Regional Feedstock Partnership. (Award # GO85041). Photo Credit: Steve Thomas

Collaborators

Hybrid Poplar Stand in Oregon
Photo Credit: Laurence Eaton and Mike Halbelib

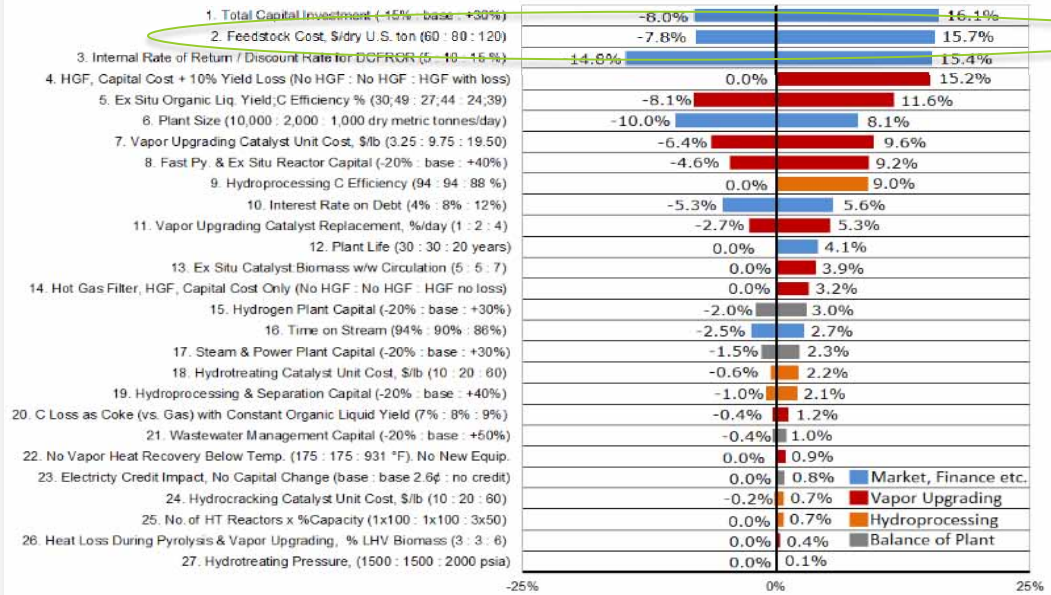
- Lead organization: ORNL
- Sustainability analysis led by national labs: ANL, INL, NREL, ORNL

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)

Cost variability = RISK

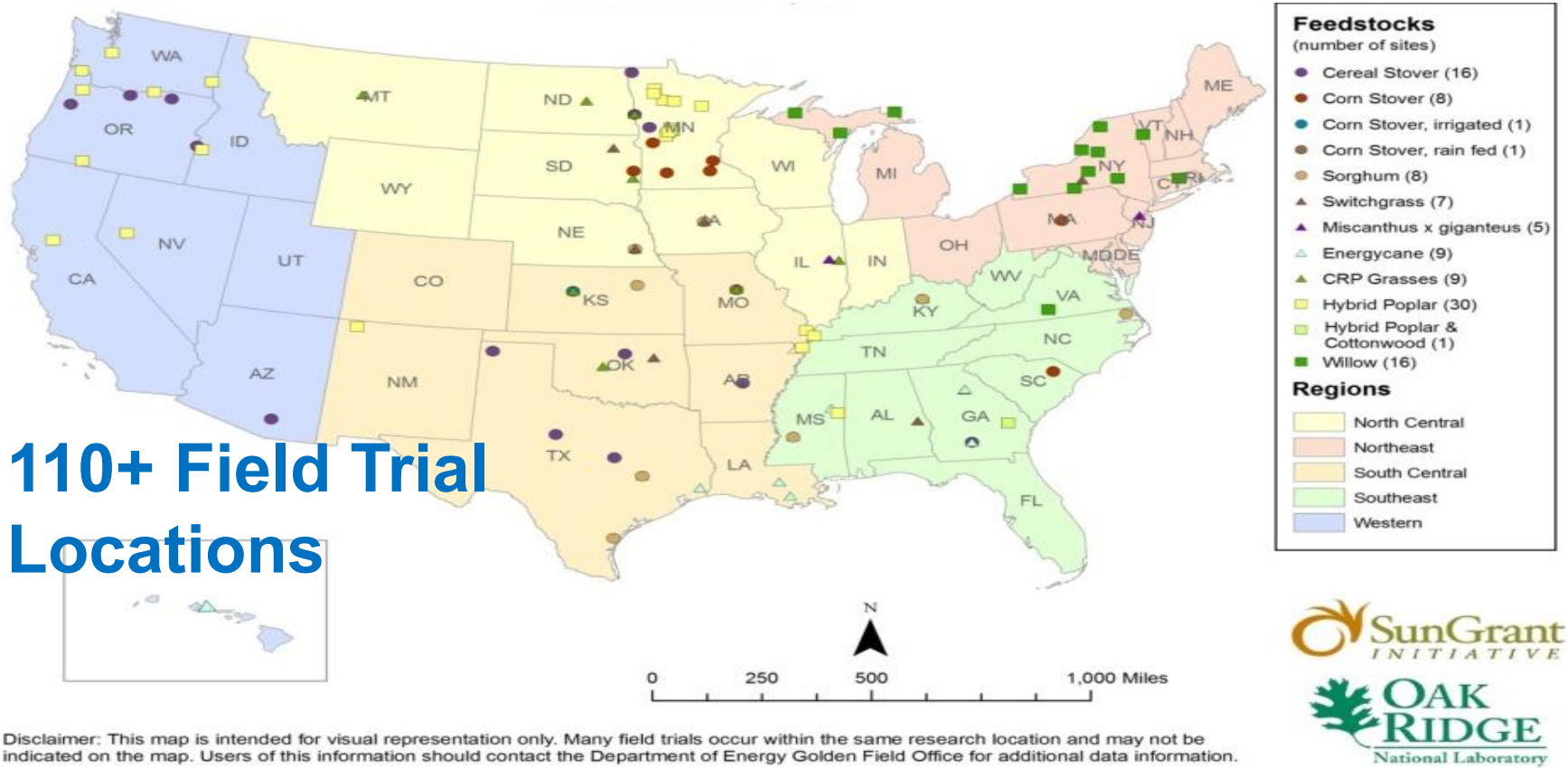
Relevance – Scenarios and Sensitivity



Example of sensitivity studies for *ex situ* case

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

SGI Regional Feedstock Partnership Field Trial Network



110+ Field Trial Locations

Disclaimer: This map is intended for visual representation only. Many field trials occur within the same research location and may not be indicated on the map. Users of this information should contact the Department of Energy Golden Field Office for additional data information.

SunGrant INITIATIVE

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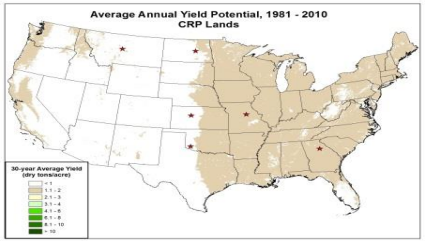
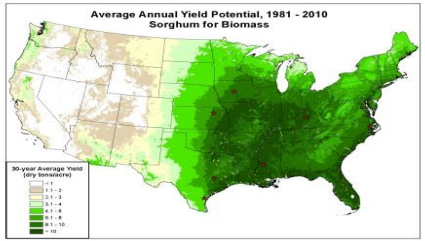
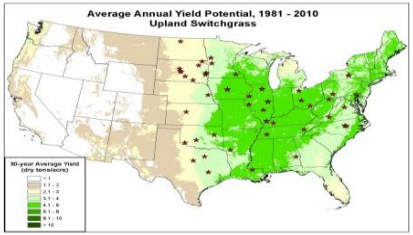
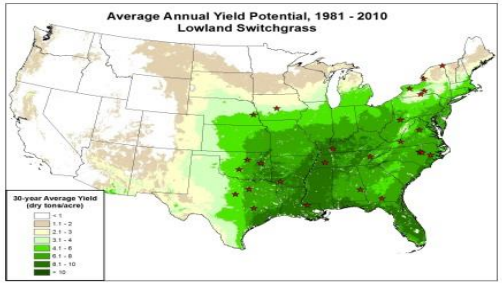
Enhanced Energy Crop Potential Yield

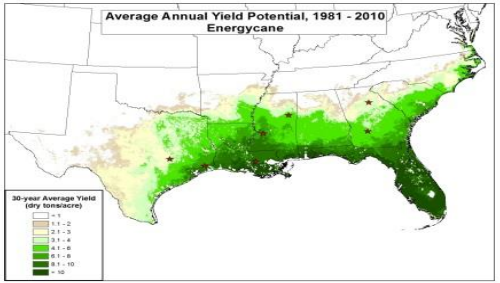
Herbaceous Energy Crops



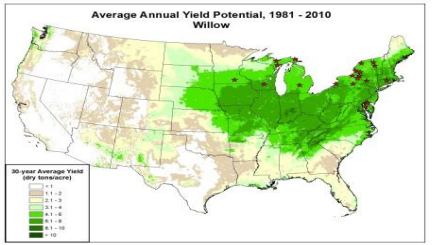


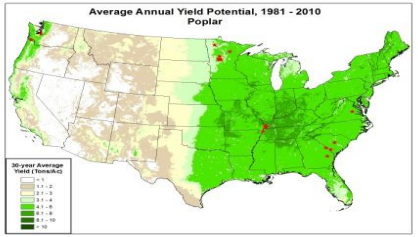


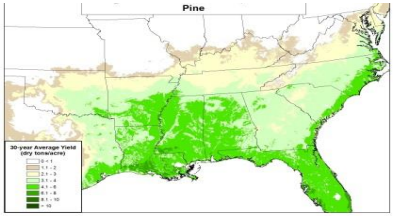




Woody Crops







Manuscript in preparation by SGI Field Trial and Resource Assessment Teams

Credit: Oregon State University PRISM Climate Group

Factors to improve economics of perennial crop systems

- Improved yield
  - **Increased establishment success**
  - **Better varieties for site conditions**
  - Reduced yield variability between dry/wet years
- Reduced need for herbicides and nutrients
- **Reduced harvest costs (DOE High-tonnage Logistics Project and Project 1.2.3.1 Supply Chain Analysis)**

Switchgrass production example

- Reference Case
  - 10-year rotation length
  - Yield at 33% of maturity in year 1, 66% in year 2, and 100% in years 3-10
  - Discount rate 6.5%
  - Switchgrass follows soybeans and is established using no-till methods
  - Costs include establishment, maintenance, and harvest
- Improved Cases

  1) Yield at 50% of maturity in year 1, 75% in year 2, and 100% in years 3-10

  2) Reduced harvest and on-farm transport cost of $4/dt

Example Scenario of Cost Impacts of Switchgrass Improvements

Scenario	Average Cost of Production	Cost Reduction
Reference*	$ 55.06	
1) Increased Maturity	$ 53.06	-3.6%
2) Reduced Harvest Cost**	$ 52.75	-4.2%
1+2) Increased Maturity and Improved Harvest	$ 50.66	-8.0%

* Production budgets include land rental rate of $77/acre for improved pasture in Iowa; Mature yield of 6 dry tons/acre; Cost assumptions from Iowa State “Estimated Cost of Establishment and Production of ‘Liberty’ Switchgrass,” May 2015 (File A1-29)

** Demonstrated $4/dry ton by TennEra High-tonnage Logistics Project validated by ORNL 1.2.3.1 Supply Chain Analysis Project

Example Scenario of Cost Impacts of Switchgrass Improvements

Scenario	Average Cost of Production	Cost Reduction
Reference*	$ 55.06	
1) Increased Maturity	$ 53.06	-3.6%
2) Reduced Harvest Cost**	$ 52.75	-4.2%
1+2) Increased Maturity and Improved Harvest	$ 50.66	-8.0%
Increased Maturity, Decreased Harvest, Increased Yield (7 dry tons/acre)	$ 42.81	-22.2%

* Production budgets include land rental rate of $77/acre for improved pasture in Iowa; Mature yield of 6 dry tons/acre; Cost assumptions from Iowa State "Estimated Cost of Establishment and Production of 'Liberty' Switchgrass," May 2015 (File A1-29)

** Demonstrated $4/dry ton by TennEra High-tonnage Logistics Project validated by ORNL 1.2.3.1 Supply Chain Analysis Project

Future Events and More Information

- Visit the Feedstock Supply and Logistics Breakout Session at Bioenergy 2015
- Important report release dates:
  - 2016 Billion-Ton Report
    - Volume 1 target date: June 2016
    - Volume 2 target date: September 2016
  - Sun Grant Regional Feedstock Partnership Synthesis Report: June 2016
    - Target date June 2016

2011 Billion-Ton Update Report Landing Page
http://bioenergykdf.net/content/billiontonupdate

Closing

The creation of a robust, next -generation domestic bioenergy industry is one of the important pathways for providing Americans with sustainable, renewable energy alternatives. Through research and development to produce renewable fuels sustainably and affordably, we can provide home-grown alternatives for the transportation, energy, and bioproducts sectors.

Questions?

Email eere_biomass@ee.doe.gov

Please include “Biofuel Markets” in Subject Line

Thank you!

References

- U.S. Department of Energy and U.S. Department of Agriculture. 2005. **Biomass as a feedstock for a bioenergy and bioproducts industry: The technical feasibility of a billion-ton annual supply.** DOE/GO-102005-2135 ORNL/TM-2005/66.
- 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.
- U.S. Department of Energy. 2015. **Multi-year Program Plan.**

Models

- CENTURY: Soil carbon, nitrogen, phosphorus, and sulfur model.
- F-PEAM: Feedstock Production Emissions to Air Model
- ForSEAM: Forest Sustainable and Economic Analysis Model
- GREET: The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model
- POLYSYS: Policy Analysis System
- SRTS: Subregional Timber Supply Model
- SWAT: Soil and Water Assessment Tool
- WATER: Water Assessment for Transportation Energy Resources