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

Billion-Ton Update and Ongoing Resource Assessment

May 23, 2013

Bryce Stokes
Senior Advisor
CNJV

Matthew Langholtz
Resource Economist
ORNL

Laurence Eaton
Resource Economist
ORNL

- Review 2011 Billion-Ton Update
- Ongoing Resource Analysis Work
- Overview of Database and Website Tools and Analyses

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

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

Preamble

- **Excludes algal feedstocks**
- **Includes "major" feedstocks**
- **Costs are only to roadside/farmgate**
- **No specified end use or conversion process**
- **Raw material in form as described with losses only up to roadside**
- **$60/dry ton was selected as the "illustrative" case, not the expected cost – had wider range depending on feedstock**
- **Projections for "used" and "potential" for 2012 to 2030 from county to national**
- **Uses various databases, datasets, and analytical tools**

Biomass Feedstocks

- **Forest resources**
  - **Logging residues**
  - **Forest thinnings (fuel treatments)**

  Combined into Composite

  - *Conventional wood*

  Added in 2011 Update

  - **Fuelwood**
  - **Primary mill residues**
  - **Secondary mill residues**
  - **Pulping liquors**
  - **Urban wood residues**

- **Agricultural resources**
  - **Crop residues**
  - **Grains to biofuels**
  - **Perennial grasses**
  - **Perennial woody crops**
  - **Animal manures**
  - **Food/feed processing residues**
  - **MSW and landfill gases**

  Added in 2011 Update

  - *Annual energy crop*

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

Approach to Supply Curve Estimation

- **Separate methods for agriculture and forest resources**

- **Contributing authors helped develop technical assumptions and input data and workshops used to develop scenarios**

- **Secondary processing residues and wastes are estimated using technical coefficients**

Forestland resources

- **Resource analysis used to estimate supply curves**
  - **USDA/FS data (FIA, TPO, RPA)**
  - **Uses FRCS model for costs**
- **Logging residue – TPO removals**
- **Forest thinnings – simulated on FIA plots**
- **Forest residue access, recovery, and merchantability coefficients**
- **Requirements for resource sustainability**

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

Agricultural land resources – uses policy model (POLYSYS) to estimate supply curves and land use change for crop residues and energy crops

- **USDA Census and NASS data (yields, acres, crop prices, production, exports, etc.) to 2030**
- **Requirements for resource sustainability**
- **Energy crop are perennial grasses, woody crops, and annuals**
- **Costs**
  - **Grower payments for crop residues & production costs for energy crops**
  - **Collection and harvest costs based on INL and ORNL assumptions/modeling**

Scenarios
- **Baseline is USDA projection and 1% yield increases for energy crops**
- **High yield scenarios are baseline and**
  - **Higher corn yields**
  - **More no-till and residue removal**
  - **Energy crop yields increase at 2%, 3%, and 4% annually**

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

POLYSYS Modeling Framework

- **County model anchored to USDA 10-year baseline & extended to 2030**
  - **Biomass resources are agricultural residues and energy crops**
  - **8 major crops (corn, soybeans, wheat, sorghum, oats, barley, rice, cotton) and hay, livestock, food/feed markets**
  - **Uses USDA projected demands for food, feed, industry, and export**
  - **Land base includes cropland 102 million ha (250 million acres), cropland pasture 9 million ha (22 million acres), hay 25 million ha (61 million acres), permanent pasture 48 million ha (118 million acres)**
    - **Pasture can convert to energy crops if forage made up through intensification**
    - **Restraints limiting land use change**

POLYSYS Modules and Interaction

- Crop Supply (7 /305/ 3110 Regions)
- Expected Returns & Available Acreage
- Livestock (U.S.)
- Acreage Allocation Based on Expected Returns Acreage, Production, Expenditures
- Production Price Available for Domestic Consumption
- Export Use Domestic use
- Food Use Feed Use Bioenery Use Total Use Price
- Value of Exports & Production Gov't Payments Cash Receipts Gross & Net Realized Income Production Expenses
- (U.S.) Crop Demand
- (U.S.) Ag Income

The University of Tennessee
Agricultural Economics

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

Requirements for Resource Sustainability

- **For Agriculture**
  - Includes costs for BMP and sustainable practices
  - Energy crops only on cropland, hay, and pasture
  - Uses residue retention model
  - No residues from conventional tillage
  - All non-irrigated production
  - **Minimal tillage and fertilizer/ herbicide applications**
  - **Land use change limits (e.g., 10% of cropland per year and 25% in total)**
  - Annual energy crops on non-erosive cropland or in rotation
  - **Retained low-levels of biomass for long-term site productivity with nutrient replacement**

- **For Forestry**
  - Includes costs for BMP and sustainable practices
  - No steep or wet sites
  - No road building
  - Uses residue retention coefficients
  - Harvest less than growth
  - **Conventional harvest at historical state levels for conventional markets**
  - Uses integrated logging
  - Thins only overstocked stands
  - Uses uneven-aged prescription

Residue Analysis and Removal Tool
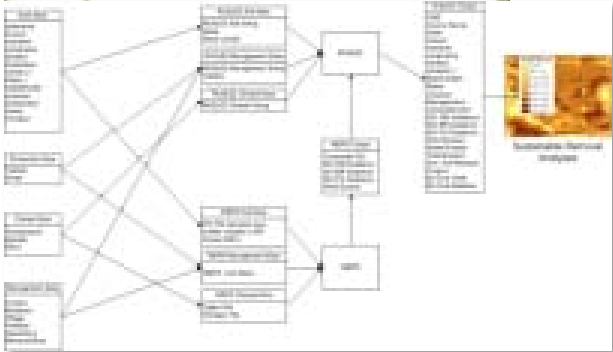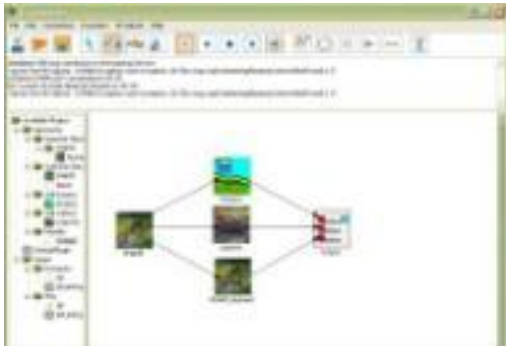
Large Spatial Assessments
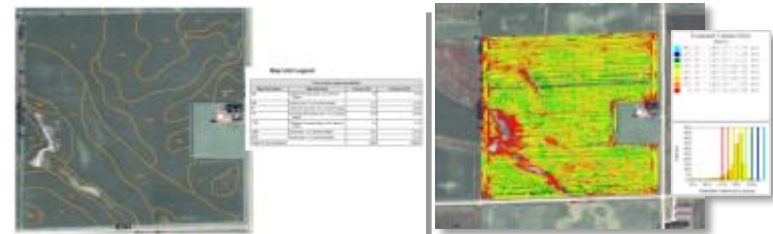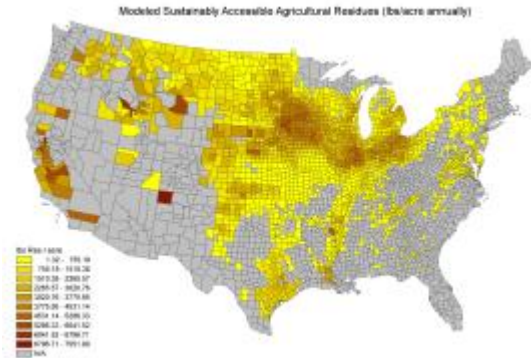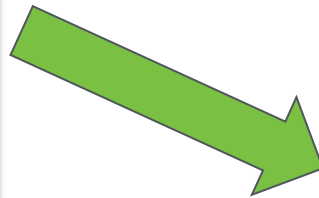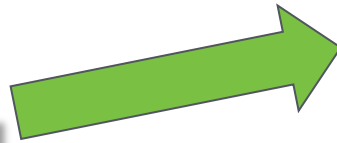
Sustainable Feedstock Production Analysis: Integrated Models Include-
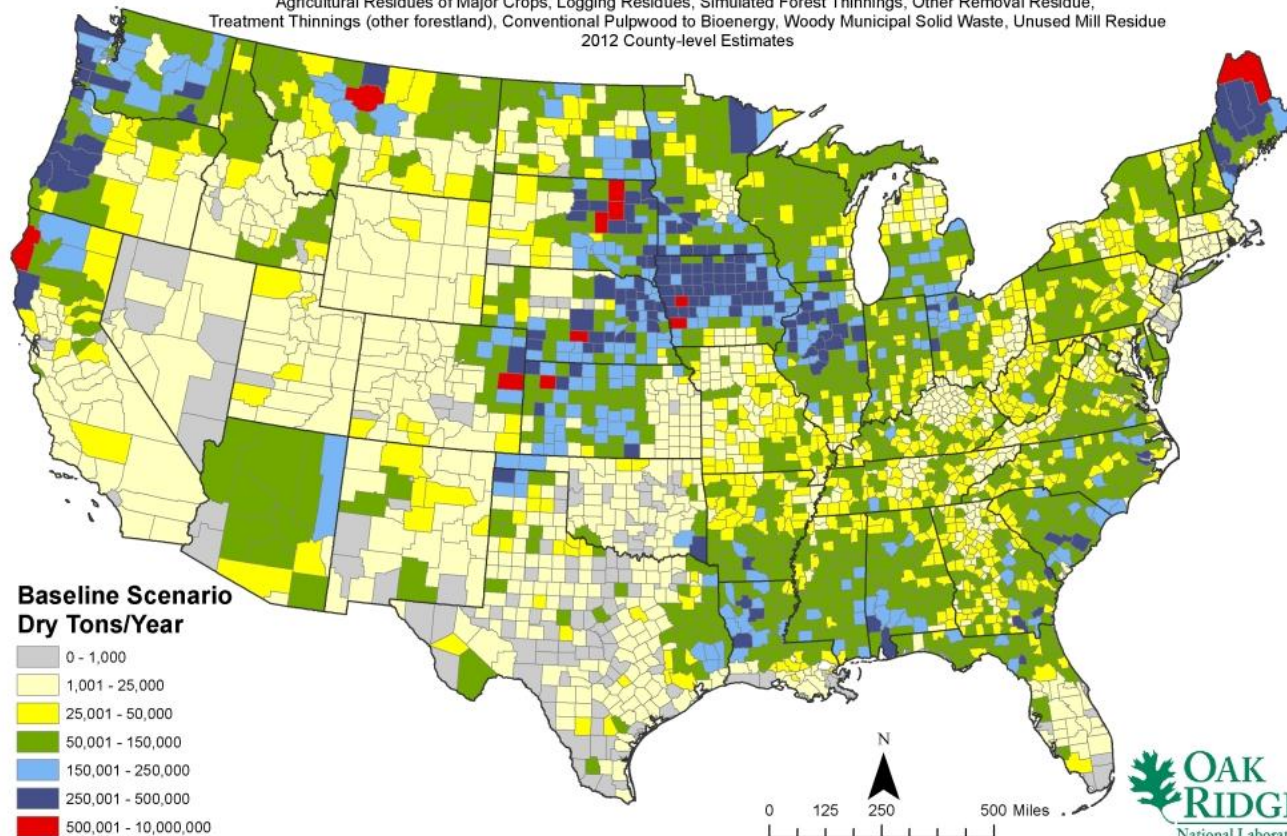- **RUSLE2**
- **WEPS**
- **I-Farm**
- **DayCent**
- **CQESTR**

Management Unit Decision Support

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

Supply Curve Results

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

$$201 \times 10^6 \text{ dt}$$
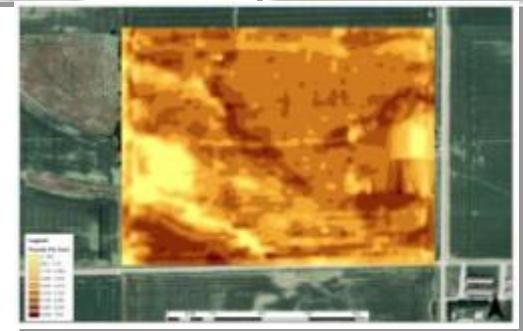
Currently Available Biomass Resources

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].

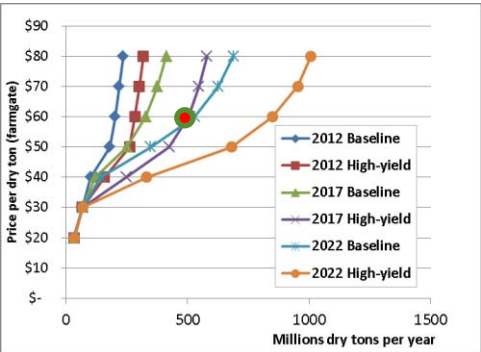Author: Laurence Eaton (eatonlm@oml.gov)- December 4, 2012.

OAK RIDGE National Laboratory

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

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy
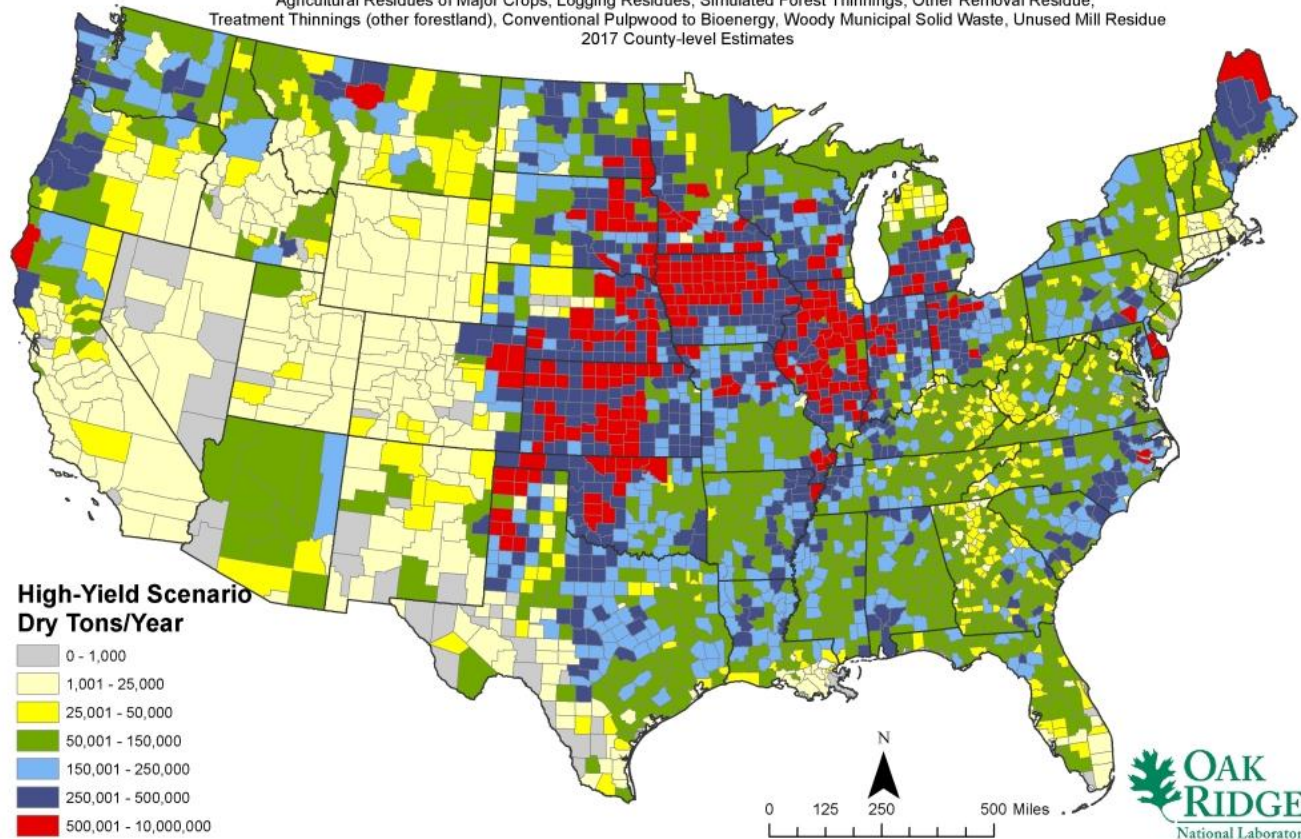
Supply Curve Results
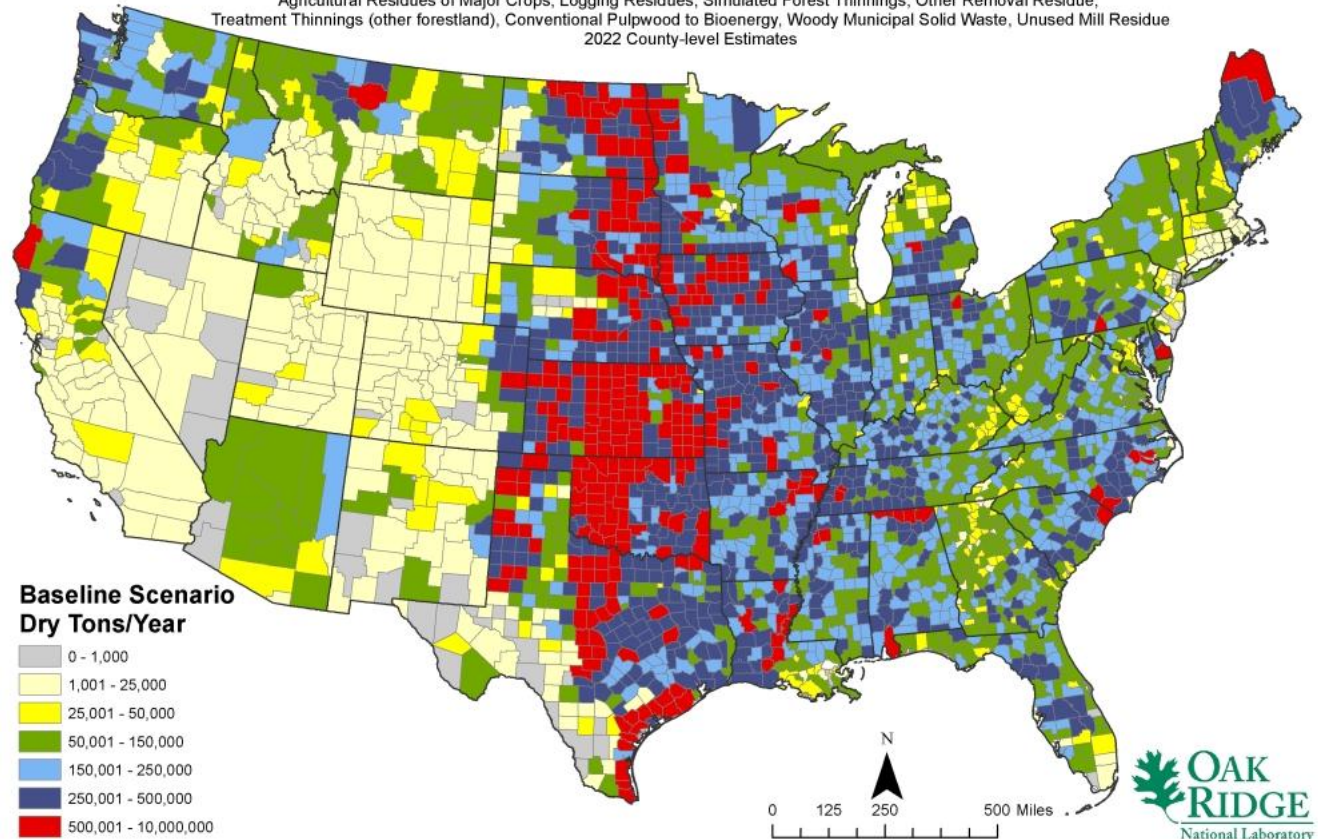
- **2017**
- **Baseline scenario**
- **$60 dry ton^{-1}**

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

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@oml.gov)- December 4, 2012.

Supply Curve Results

- **2017**
- **High-yield scenario**
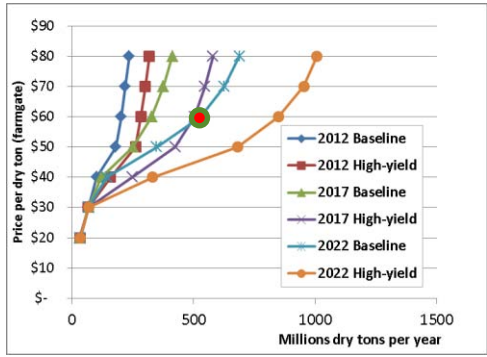- **$60 dry ton^{-1}**

$$503 \times 10^6 \text{ dt}$$

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

High-Yield Scenario Dry Tons/Year

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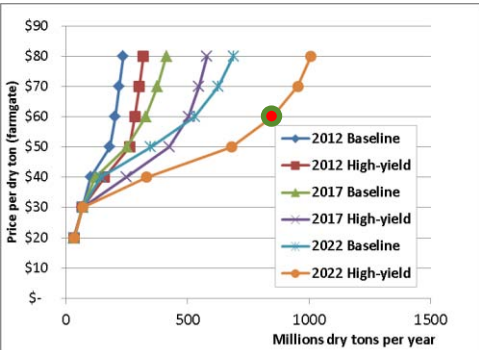- 250,001 - 500,000
- 500,001 - 10,000,000

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].

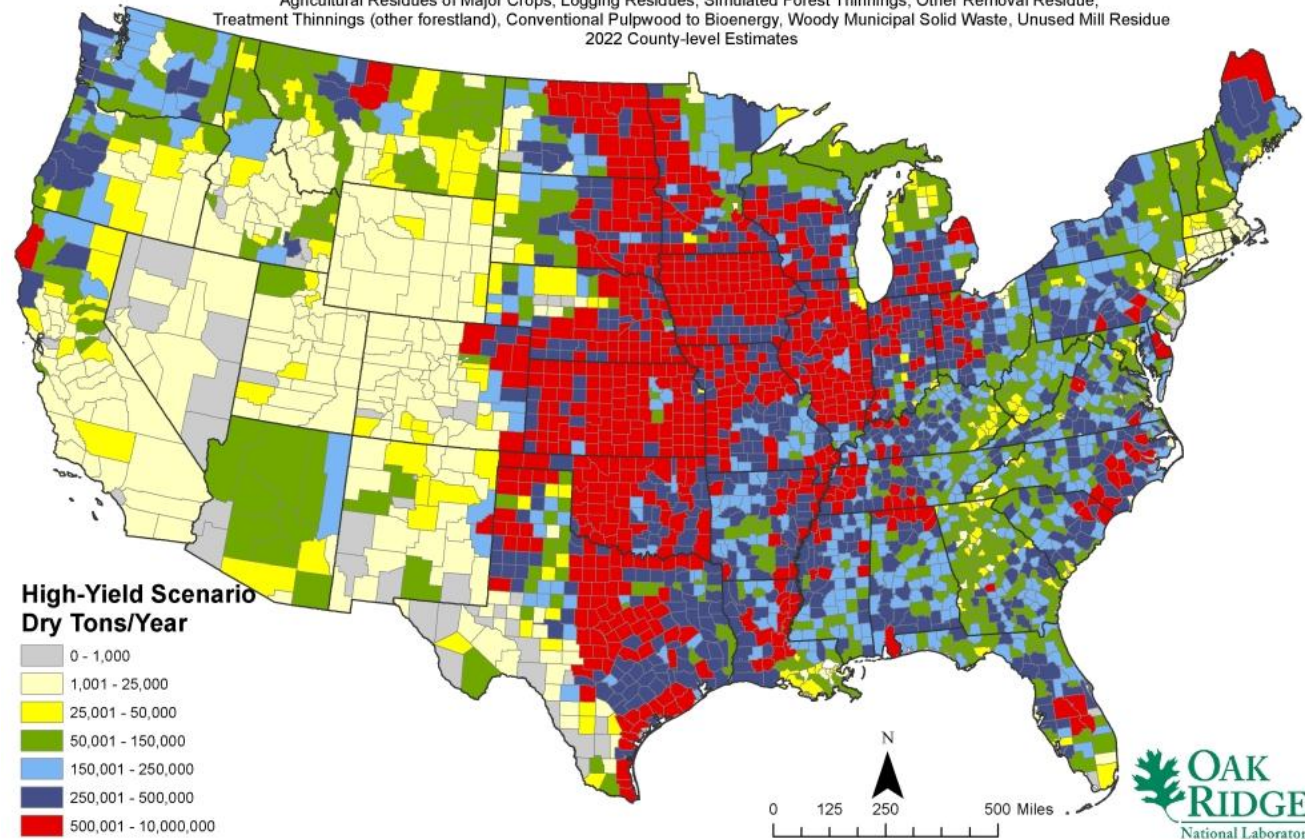Author: Laurence Eaton (eatonlm@oml.gov)- December 4, 2012.

Supply Curve Results

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

$$529 \times 10^6 \text{ dt}$$

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 2022 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.

OAK RIDGE National Laboratory

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

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

# Supply Curve Results

- **2022**
- **High-yield scenario**
- **$60 dry ton^{-1}**

$$848 \times 10^6 \text{ dt}$$

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
2022 County-level Estimates

High-Yield 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@oml.gov)- December 4, 2012.

Supply Results, Policy Implications

Baseline scenario:
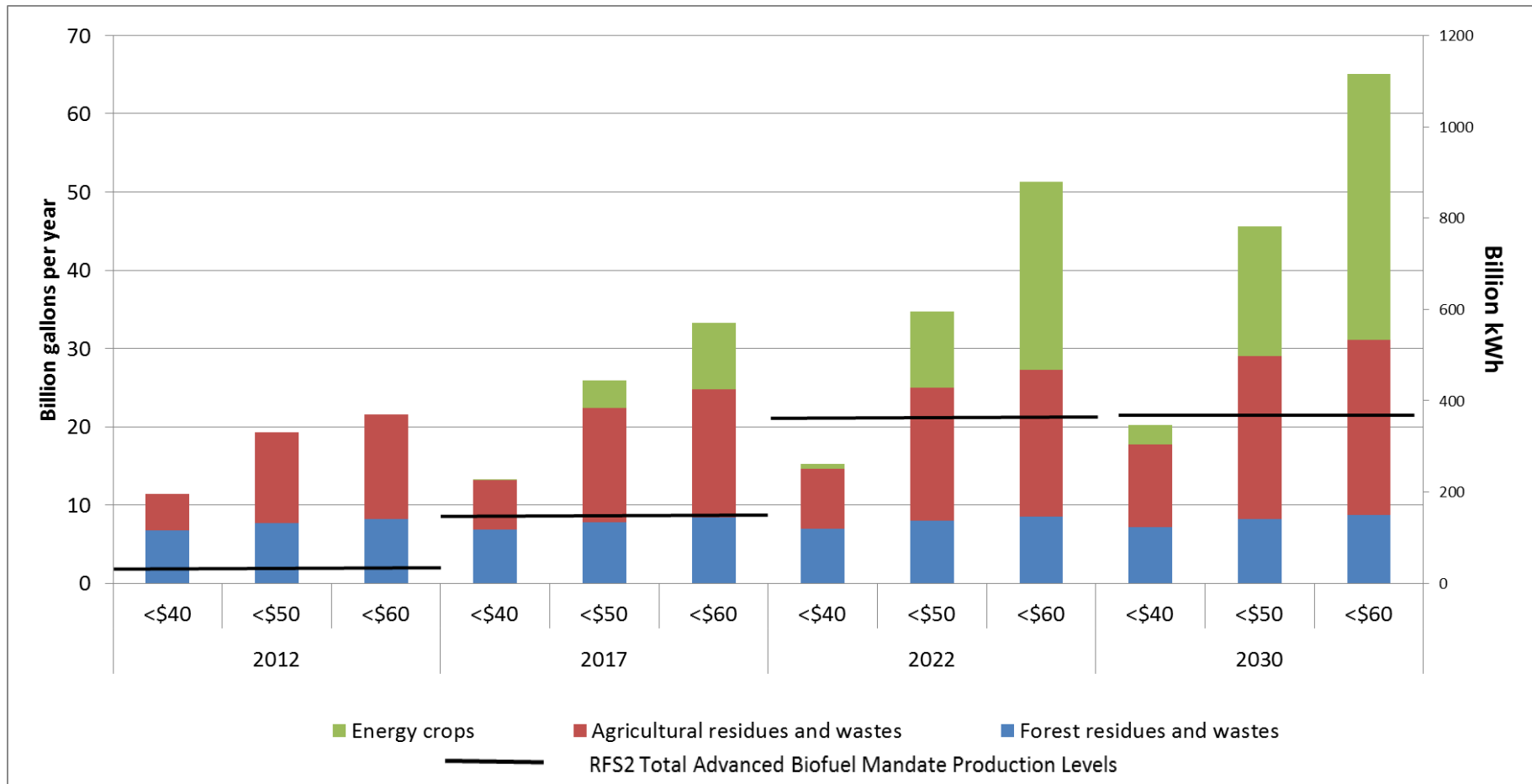
Land Use Change for Energy Crops

Total land use change ($60/dry ton) is 63 million acres under the baseline scenario and 79 million acres under the high-yield scenario (4% annual growth in energy crop yield) by 2030

U.S. DEPARTMENT OF **ENERGY** | Energy Efficiency & Renewable Energy
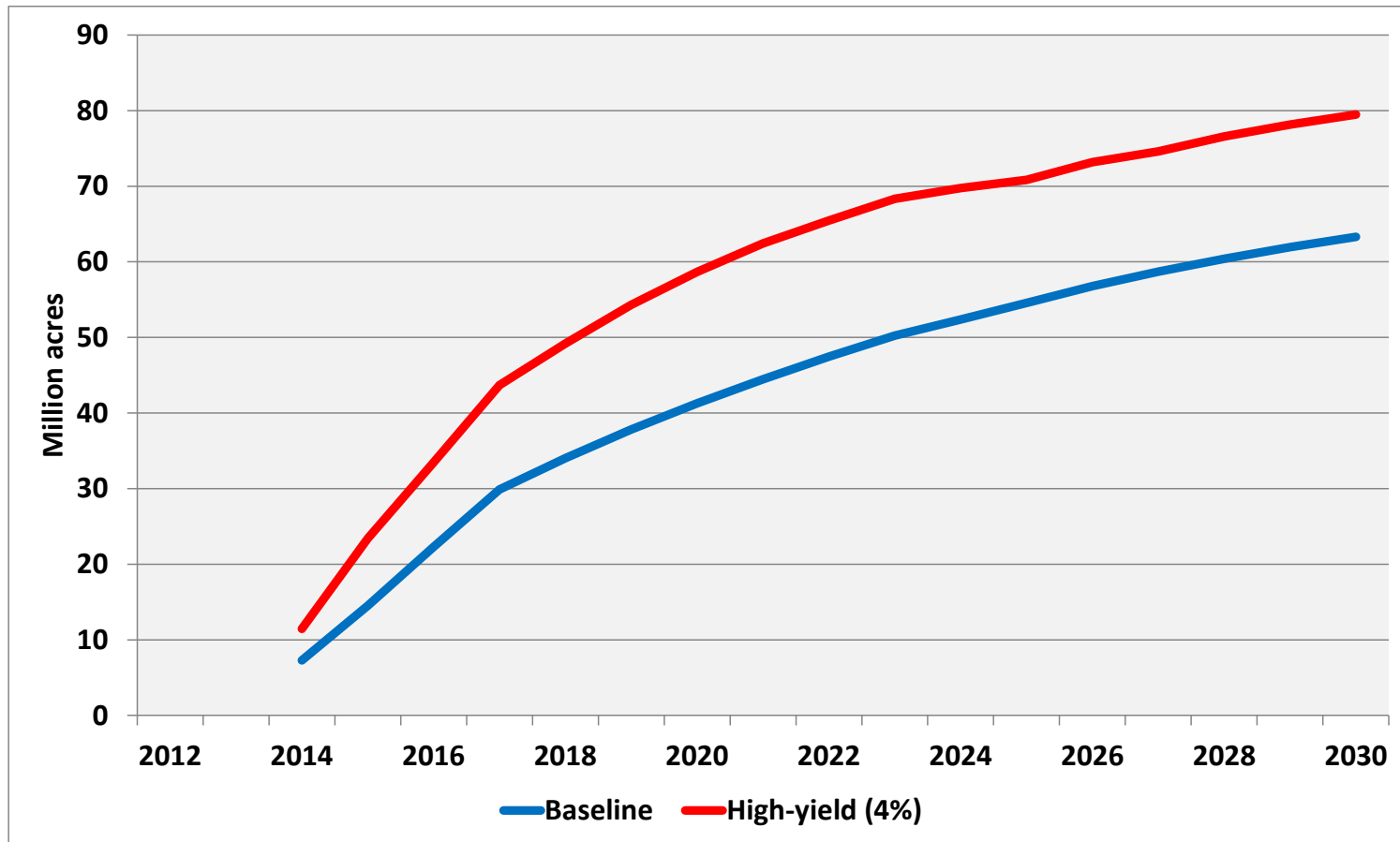
Billion-Ton Update Summary

- **Baseline scenario**
  - **Current combined resources from forests and agricultural lands total about 473 million dry tons at $60 per dry ton or less (about 45% is currently used and the remainder is potential additional biomass)**
  - **By 2030, estimated resources increase to nearly 1.1 billion dry tons (about 30% would be projected as already-used biomass and 70% as potentially additional)**
- **High-yield scenario**
  - **Total resource ranges from nearly 1.4 to over 1.6 billion dry tons annually of which 80% is potentially additional biomass**
  - **No high-yield scenario was evaluated for forest resources, except for the woody crops**
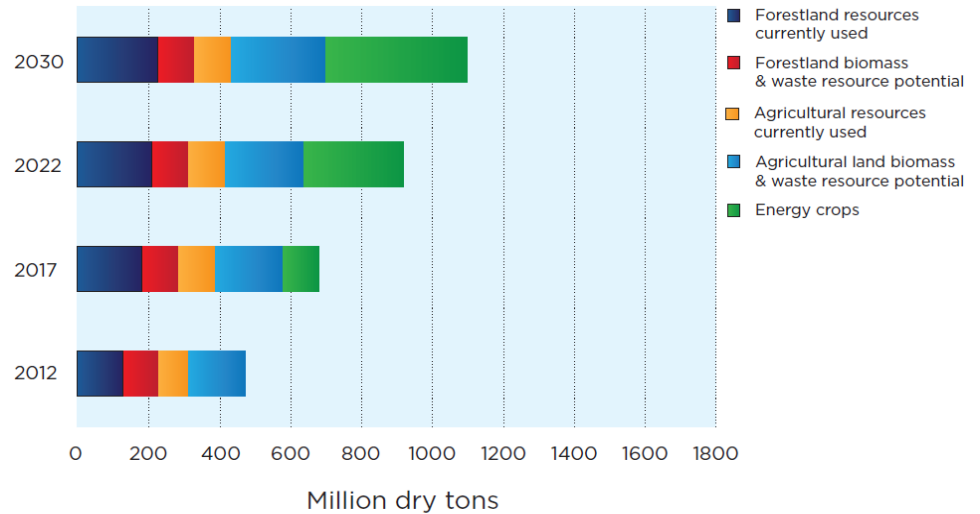
U.S. DEPARTMENT OF **ENERGY** | Energy Efficiency & Renewable Energy
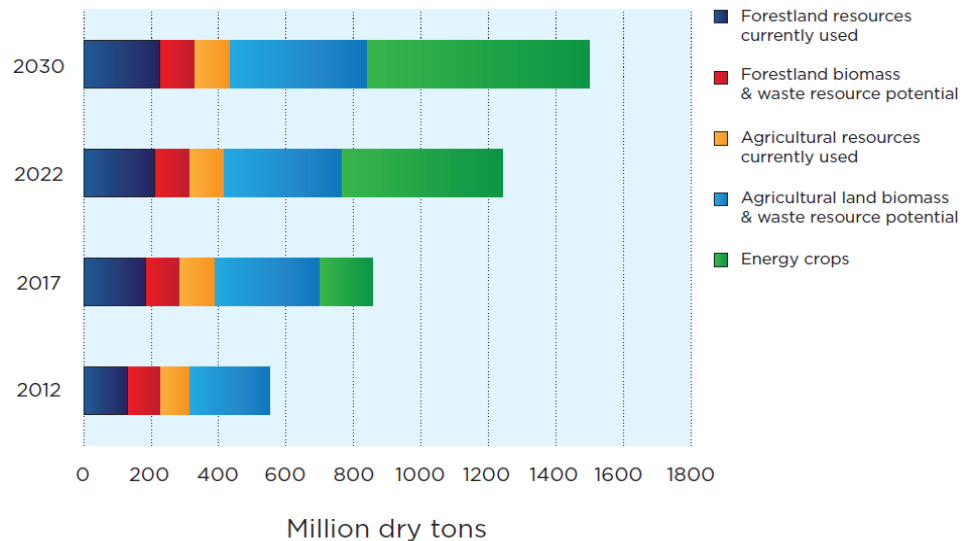
Commercialization: Feedstock price ~1/4 of MESP

Farmgate price **$50-$60/dt** plus haul cost (@85 gal/dt) **~=$0.70-$0.80/gal,** or ~¼ of $3.00/g MESP
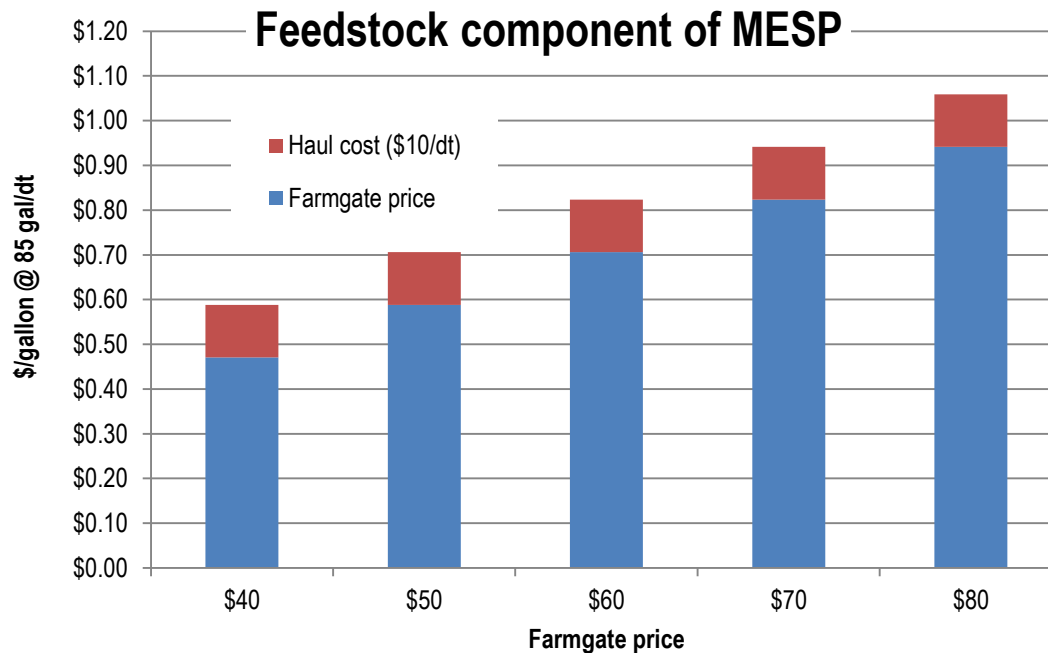
Resource Analysis: Economic Change

USDA Baseline Changes

Soybean price ($/bu)
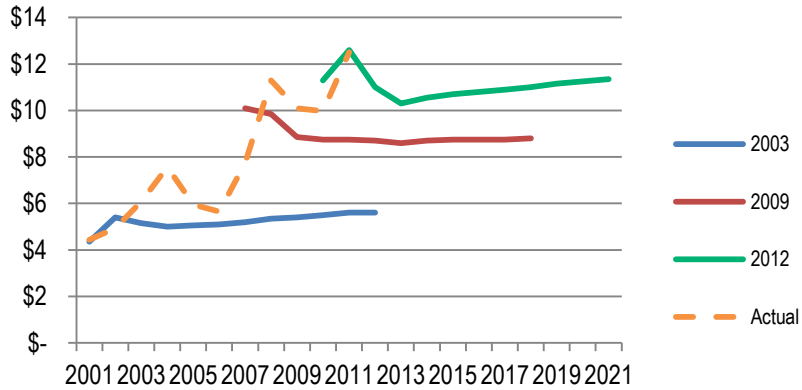
Soybean Returns (Net over Variable Costs ($/ac))
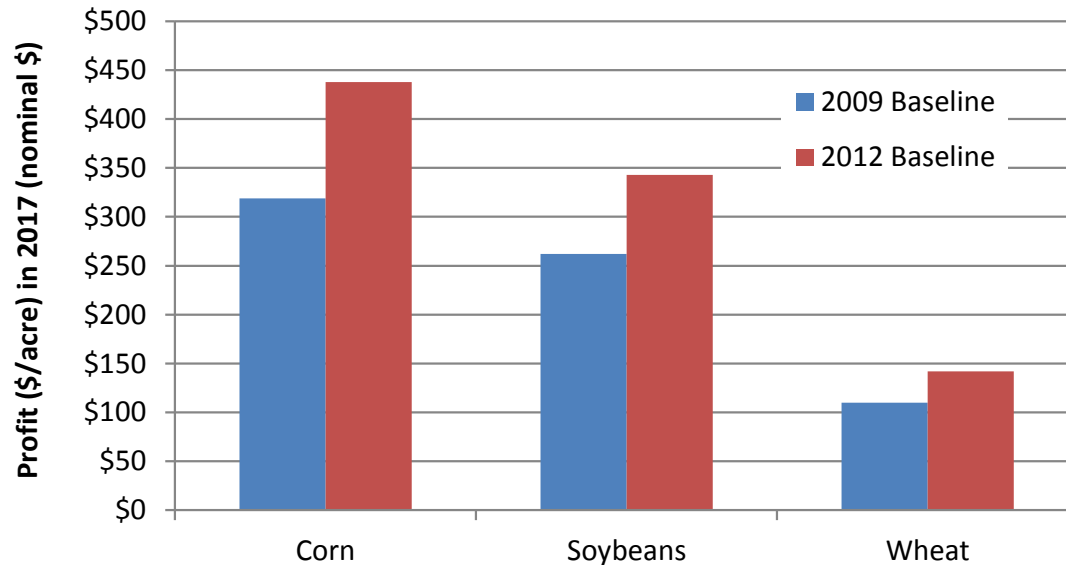

Crude oil price ($/barrel)
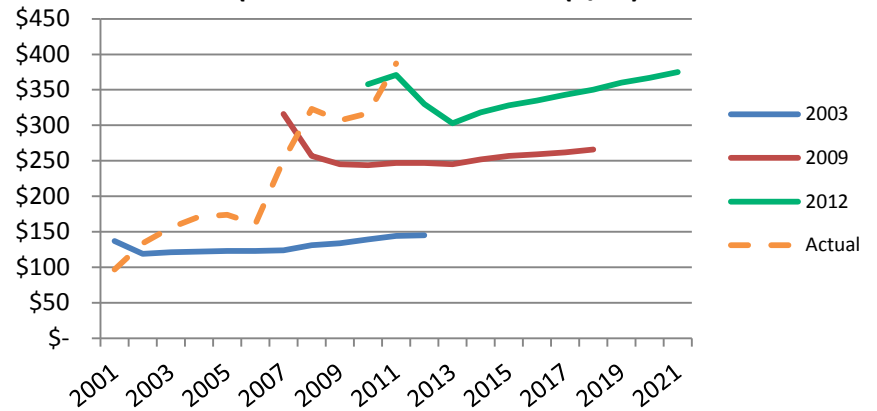
source:
http://www.ers.usda.gov/datafiles/Commodity_Costs_and_Returns/Data/Recent_Costs_and_Returns_Soybeans/russ oyb.xls
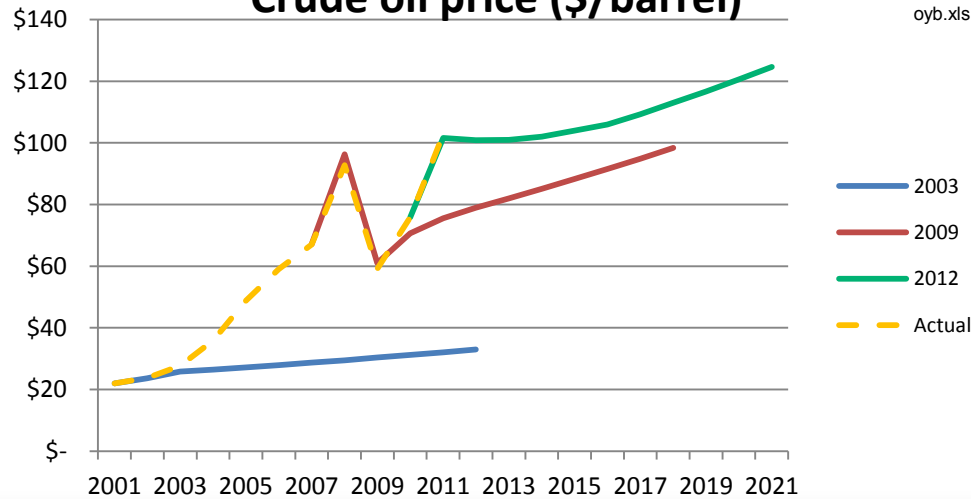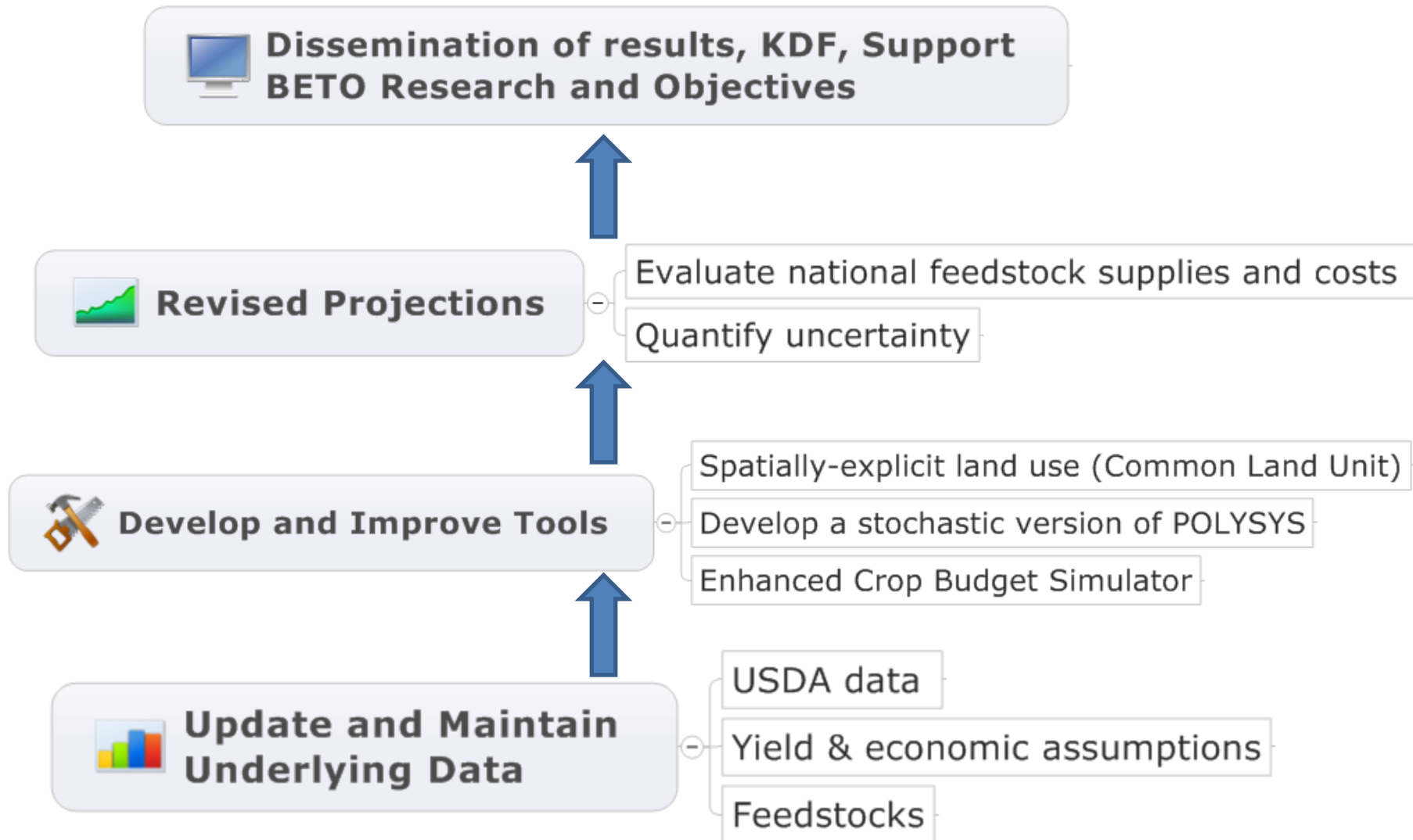
Resource Analysis: <u>Economic Change</u>

**USDA Baseline
Profit Projections at 2017**

- Profits for corn, soybeans, and wheat increased 37%, 31%, and 29%, respectively from 2009 USDA Baseline used in BT2 to 2012 USDA Baseline released in February 2012. <u>This does not include price increases associated with the 2012 drought.</u>
- Under 2012 Baseline, prices for energy crops must be higher to incentivize farmers to switch from conventional crops to energy crops.

1 - Approach – Post BT2, Ongoing commercialization

Dissemination of results, KDF, Support BETO Research and Objectives

Revised Projections
- Evaluate national feedstock supplies and costs
- Quantify uncertainty

Develop and Improve Tools
- Spatially-explicit land use (Common Land Unit)
- Develop a stochastic version of POLYSYS
- Enhanced Crop Budget Simulator

Update and Maintain Underlying Data
- USDA data
- Yield & economic assumptions
- Feedstocks

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE U.S. DEPARTMENT OF ENERGY

2 - Technical Results (cont'd), BT2 and 2012

325 million tons/yr= EISA+BioPower

Price run:

- BT2 = ~$50/dt

- 2013 revision= ~$58/dt

17% biomass price increase

Demand run, 325 mm t/yr:

- MYPP = $59/dt

- 2012 revision = $64/dt

8.5% biomass price increase

- Corn Price increase 24%

2022 Projected Resources
All Resources

- BT2 All Resources (w/o Federal Land)
- Basecase Projections
- High Yield Projections

X-axis: Million Dry Tons
Y-axis: Farmgate Price ($/dt, nominal)

Feedstock Prices for Demand
All Resources

- 2011 MYPP Runs
- 2013 MYPP RUNS

Y-axis: $/dt (farmgate, nominal)

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE U.S. DEPARTMENT OF ENERGY
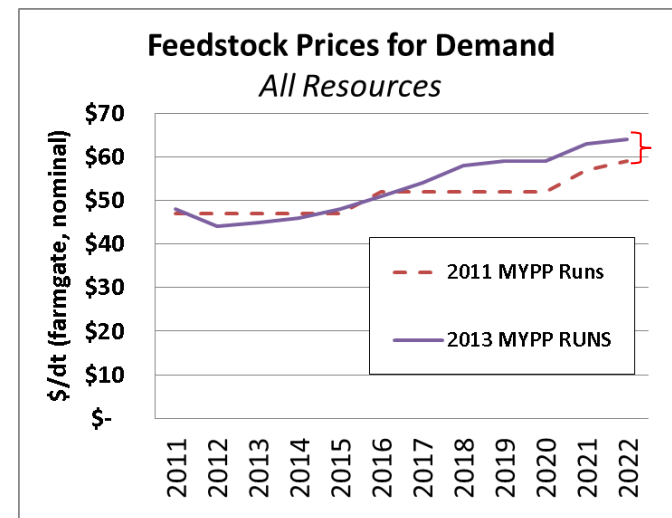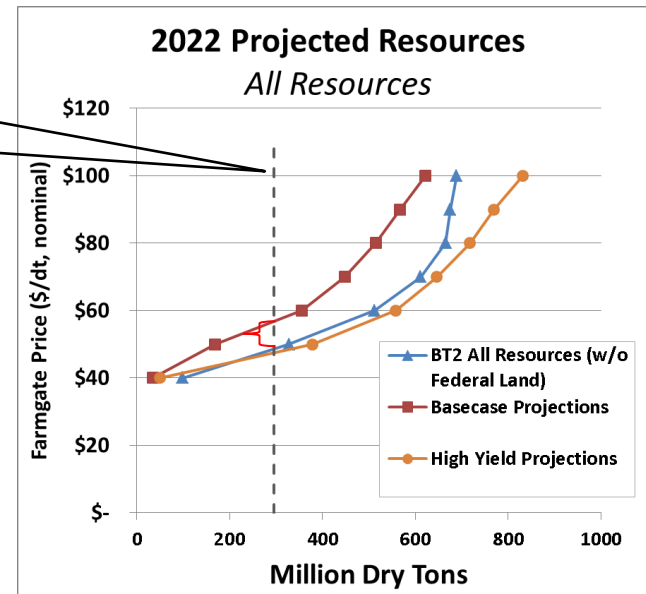
Quantifying Uncertainty, Preliminary
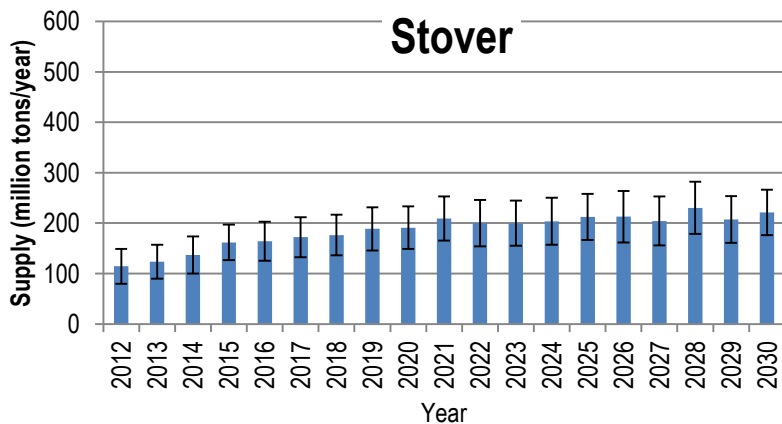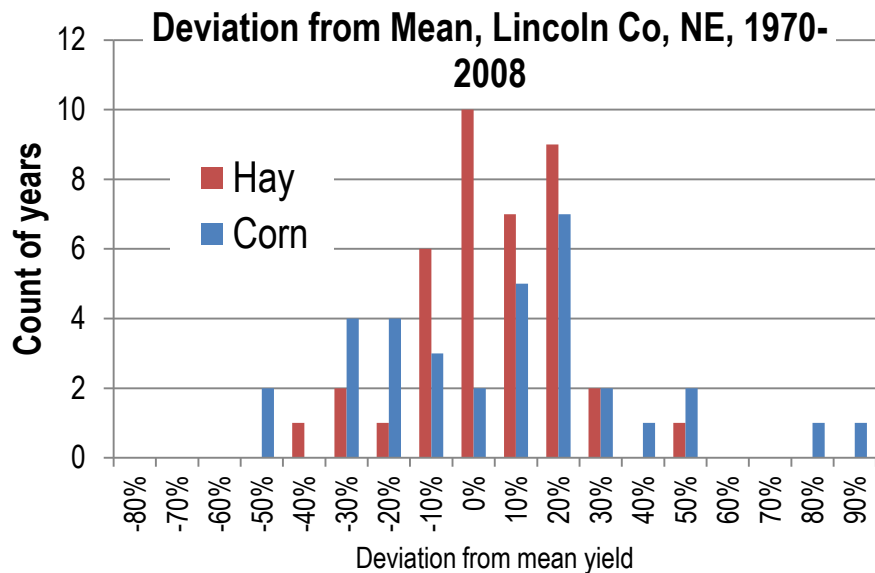
*$80/dt, nominal. Base case. Do not cite.

OAK RIDGE NATIONAL LABORATORY
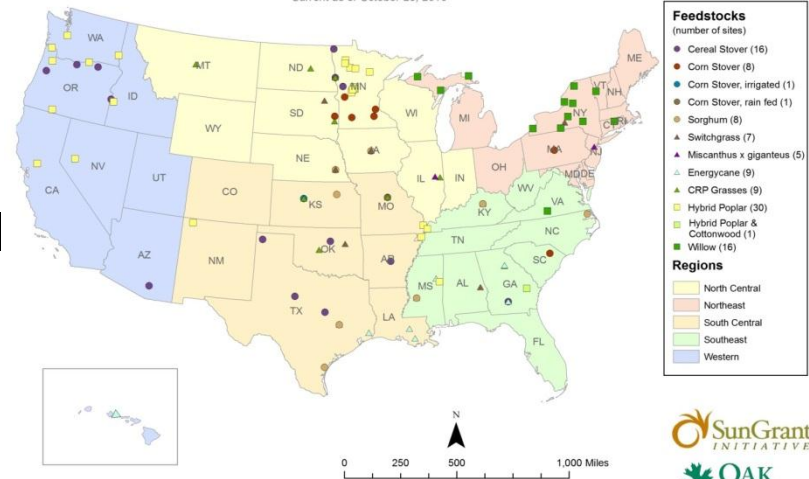MANAGED BY UT-BATTELLE FOR THE U.S. DEPARTMENT OF ENERGY
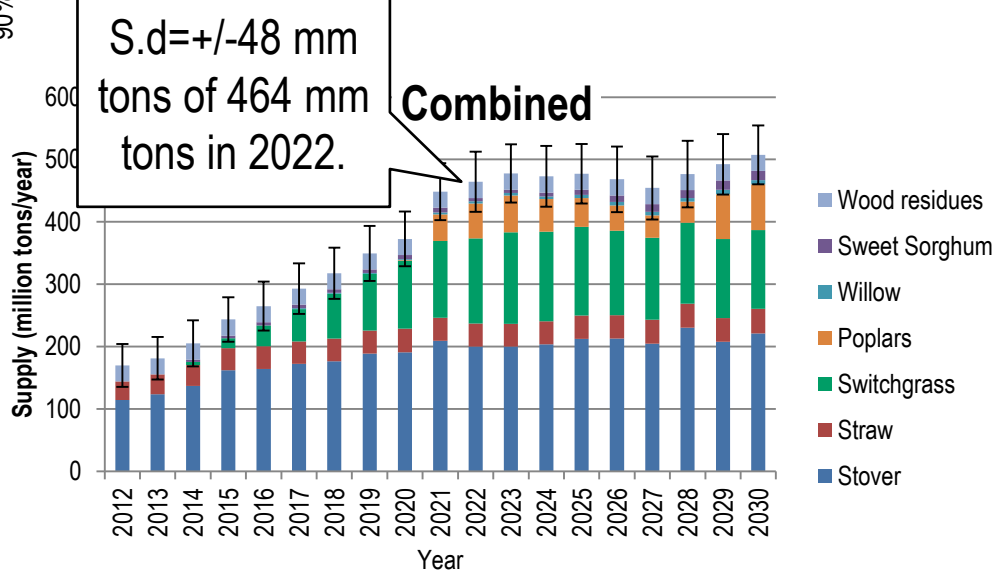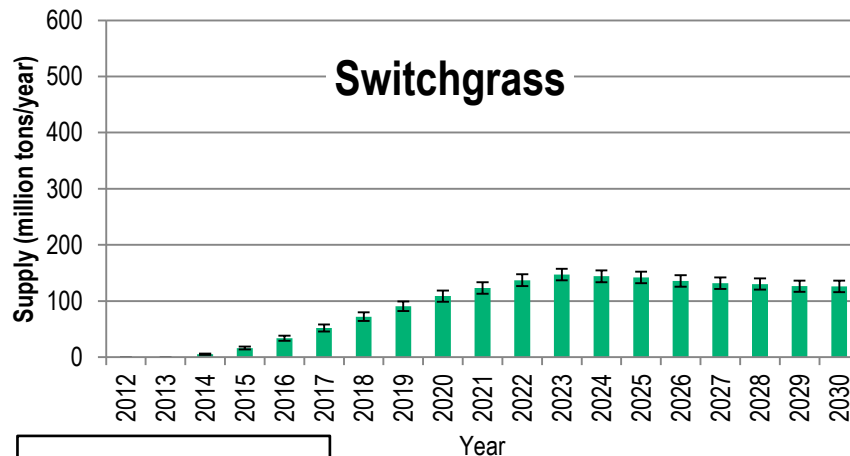
Future Work

- Current and relevant feedstock price and supply projections.

- Incorporation of additional feedstocks (e.g., algae, MSW).

- Move toward Integrated Land Management.

- Spatially-explicit realizations
  - Stranded resources
  - Farmgate to Rx throat
  - Integrated modeling of externalities
  - Testing of policy scenarios

Current and Future Estimates (± Uncertainty) of Sustainable Supply
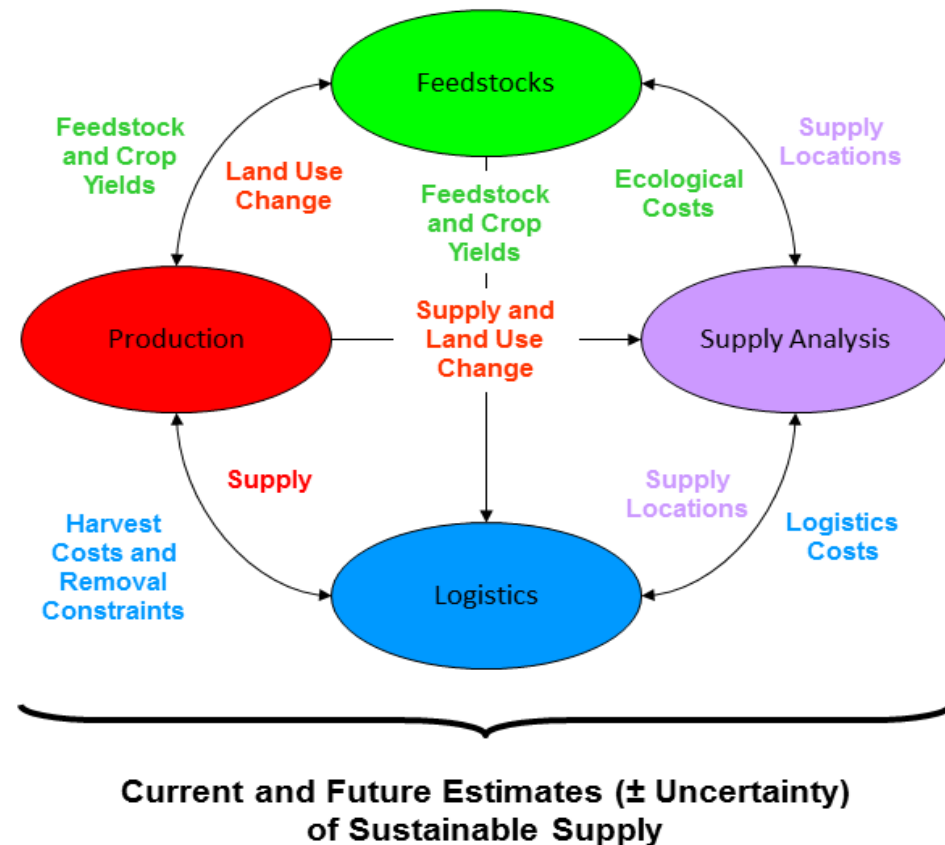
Feedstock Yield and Management Development

- **New commercial varieties tested, "Best Local Varieties" identified via in SGI Regional Feedstock Partnership (40+ Institutions)**

- **Synthesis of field trials to create site potential yield based upon best reasonable management practices**

- **Expert meetings for each crop team (energy cane, switchgrass, *Miscanthus x Giganteus*, willow, poplar, CRP grasses, biomass sorghum)**
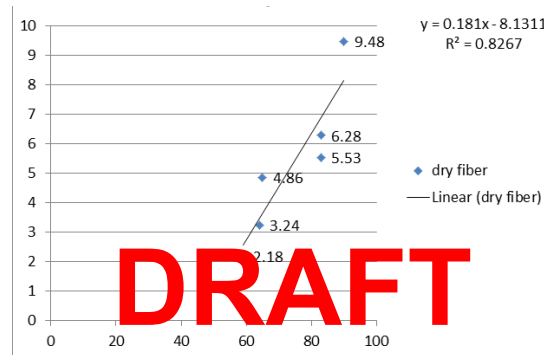

Sun Grant Initiative Regional Feedstock Partnership
Field Site Locations
Current as of October 25, 2010

Feedstocks (number of sites)
- Cereal Stover (16)
- Corn Stover (8)
- Corn Stover, irrigated (1)
- Corn Stover, rain fed (1)
- Sorghum (8)
- Switchgrass (7)
- Miscanthus x giganteus (5)
- Energycane (9)
- CRP Grasses (9)
- Hybrid Poplar (30)
- Hybrid Poplar & Cottonwood (1)
- Willow (16)

Regions
- North Central
- Northeast
- South Central
- Southeast
- Western

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.

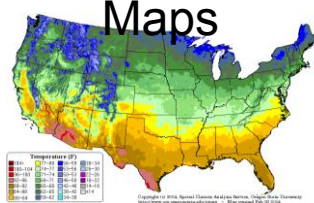### Energycane Yield (dry fiber) x predicted suitability

$y = 0.181x - 8.1311$
$R^2 = 0.8267$

- 9.48
- 6.28
- 5.53
- 4.86
- 3.24
- 2.18

♦ dry fiber
— Linear (dry fiber)

DRAFT
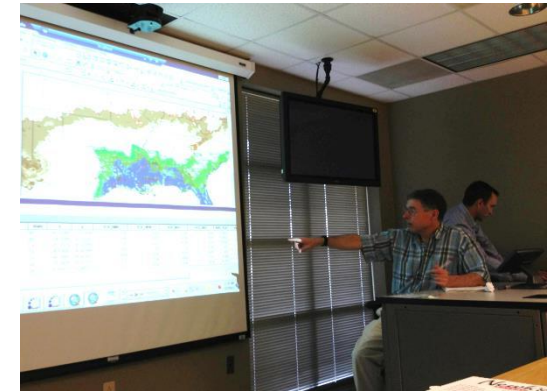
May 7-8, 2013 Energy cane expert meeting, Raymond, Mississippi

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE U.S. DEPARTMENT OF ENERGY

Yield Projections of New Commercial Feedstocks
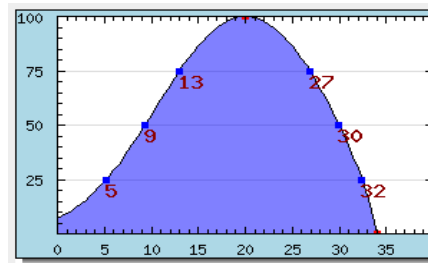
- **Synthesized yield trials to create spatial gradient of potential crop suitability**

- **30-year climate history, soils, 4km resolution at annual time intervals**

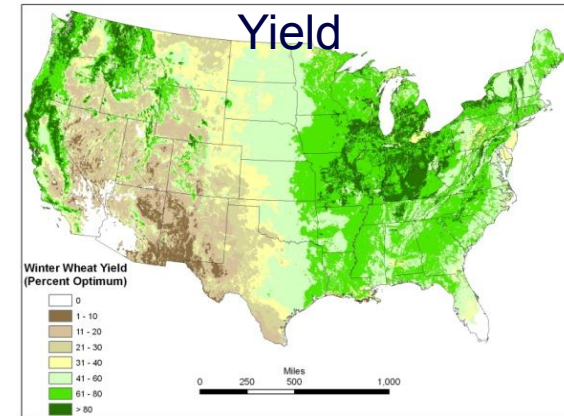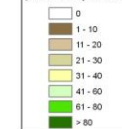- **Yield projections guide cropping decisions and identify new information gaps**

SSURGO Soil Maps
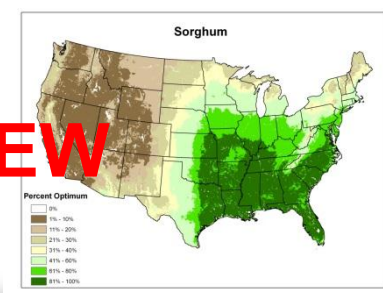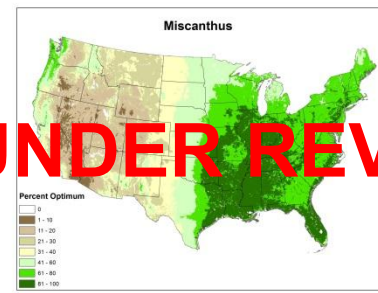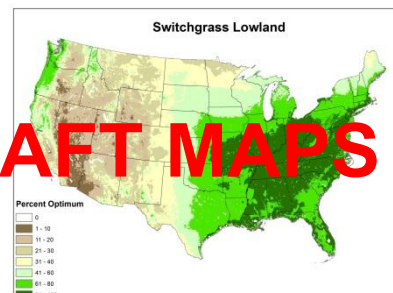
PRISM Climate Maps

Crop Growth/ Environmental Model

Percent of Maximum Yield

Energy cane

Switchgrass Lowland

Miscanthus

Sorghum

DRAFT MAPS UNDER REVIEW

OAK RIDGE NATIONAL LABORATORY
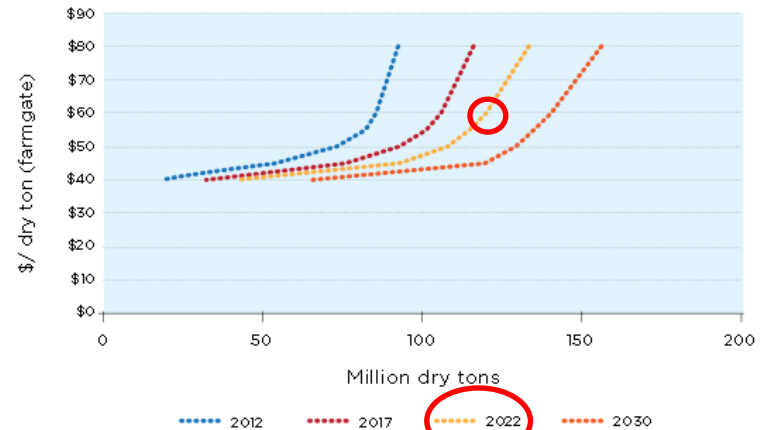MANAGED BY UT-BATTELLE FOR THE U.S. DEPARTMENT OF ENERGY
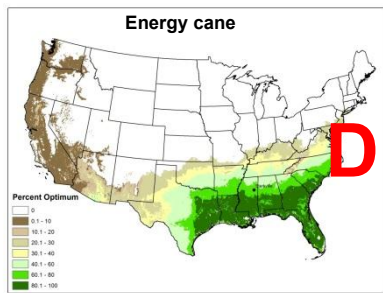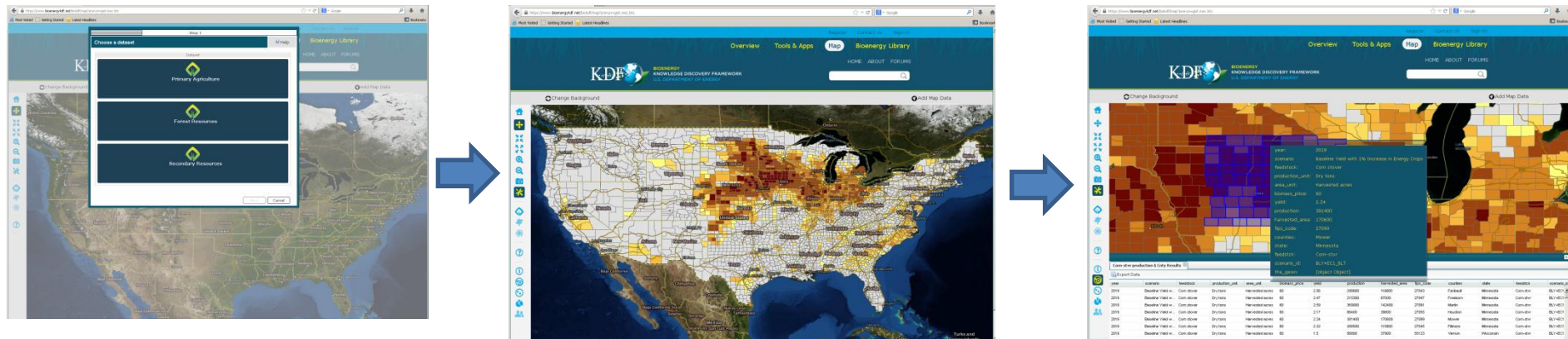
Bioenergy KDF Resources

- Billion Ton Data Explorer

  - Visualize custom supplies from the BT2 findings

  - Available for all potential resources identified as new biomass sources

Corn Stover Supply

Figure 4.11 Supply curves of potential corn stover production for various years under baseline assumptions

2012   2017   2022   2030

69

Online Tool Workflow

https://bioenergykdf.net/

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE U.S. DEPARTMENT OF ENERGY
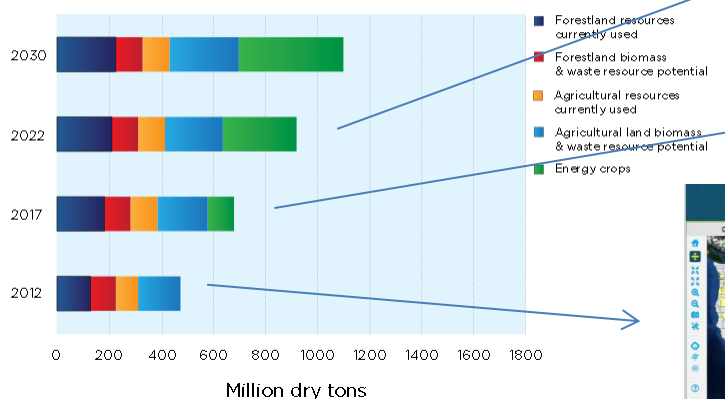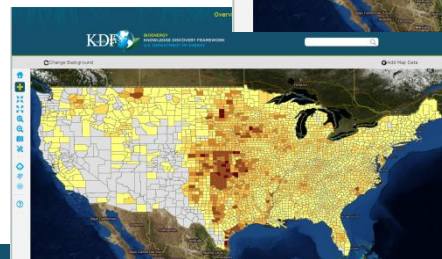
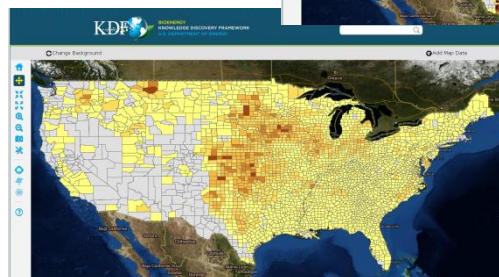# Bioenergy KDF Resources

- ## Composite Aggregation tools

Figure 6.5 Summary of currently used and potential resources at $60 per dry ton or less identified under baseline assumptions

2022 Baseline Resources

2017 Baseline Resources

2012 Baseline Resources

- # Data Download tool

  – Export custom aggregations of feedstock resource types at all price points for various years

- # Developer API

https://bioenergykdf.net/

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE U.S. DEPARTMENT OF ENERGY