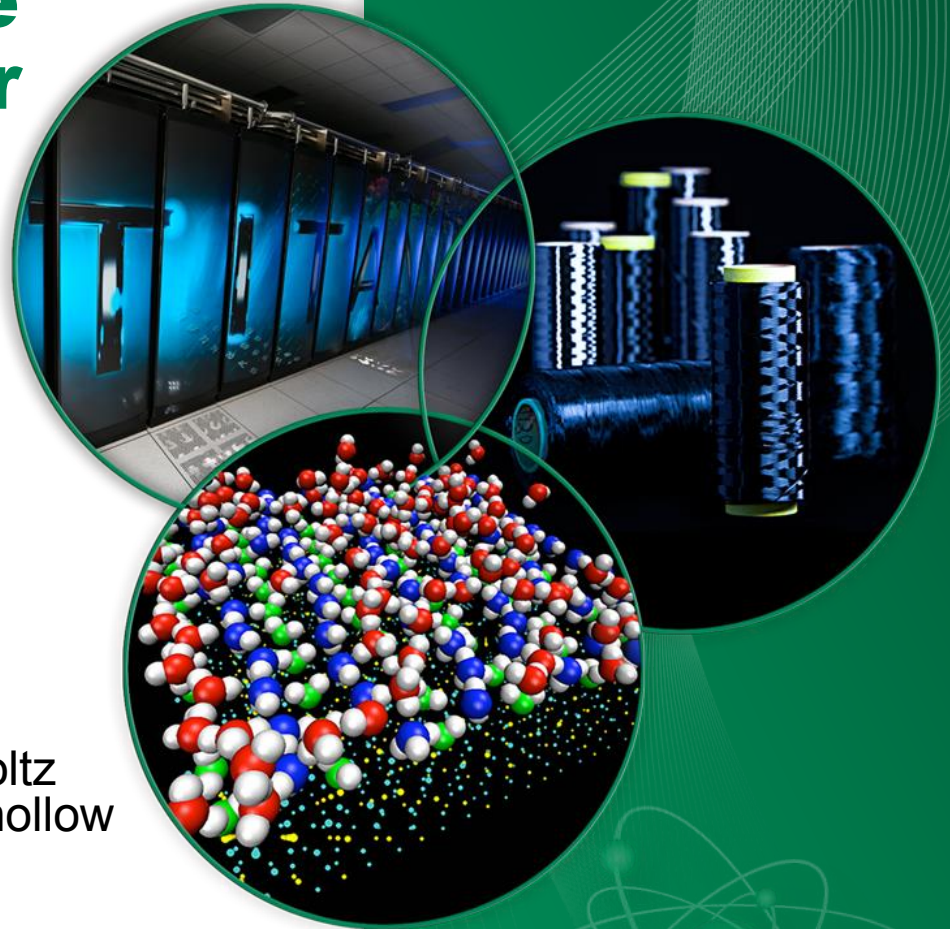


2013 DOE Bioenergy Technologies Office (BETO) Project Peer Review

Resource Analysis Project WBS 1.6.1.3

Date: May 20th, 2013
Technology Area Review:
Analysis and Sustainability

Principal Investigator: Matt Langholtz
Team: Laurence Eaton, Anthony Turhollow
Organization: ORNL



Goal Statement

- Provide timely and credible estimates of feedstock supplies and prices to support
 - the data and analysis of other projects in Analysis and Sustainability, Feedstock Supply and Logistics, Conversion, etc.
 - the development of a bioenergy industry; attainment of EISA, RFS2, and RPS mandates
- MYPP – “Future growth of the U.S. bioenergy industry will depend on the cost, quality, and quantity of biomass available to biorefineries.”

Quad Chart Overview

Timeline

- Project start date: FY07
- Project end date: FY18
- Percent complete: 55%

Barriers

- Ft-A. Feedstock Availability and Cost
- Ft-B. Sustainable Production
- Ft-L. Biomass Material Handling and Transportation
- At-C. Inaccessibility and Unavailability of Data

Budget

- FY11: \$1,390K (100% DOE)
- FY12: \$566K (100% DOE)
- FY13: \$950K (100% DOE)
- FY07 to FY13 avg annual: \$772K avg

Partners

- Agricultural Policy Analysis Center (APAC) University of Tennessee, Oregon State PRISM Climate Group
- INL, PNNL, NREL, ANL
- Other agencies (USDA Forest Service, EPA, USDA-ARS)
- NEWBio Consortium

Project Overview

- History and accomplishments

- Identified adequate supply to displace 30% of petroleum consumption; i.e. physical availability (Billion-Ton Study, 2005).
- Quantified potential economic availability of feedstocks (Billion-Ton Update, 2011).
- Disseminated county-level data (feedstock quantities, by scenario, price, year) through Bioenergy Knowledge Discovery Framework.

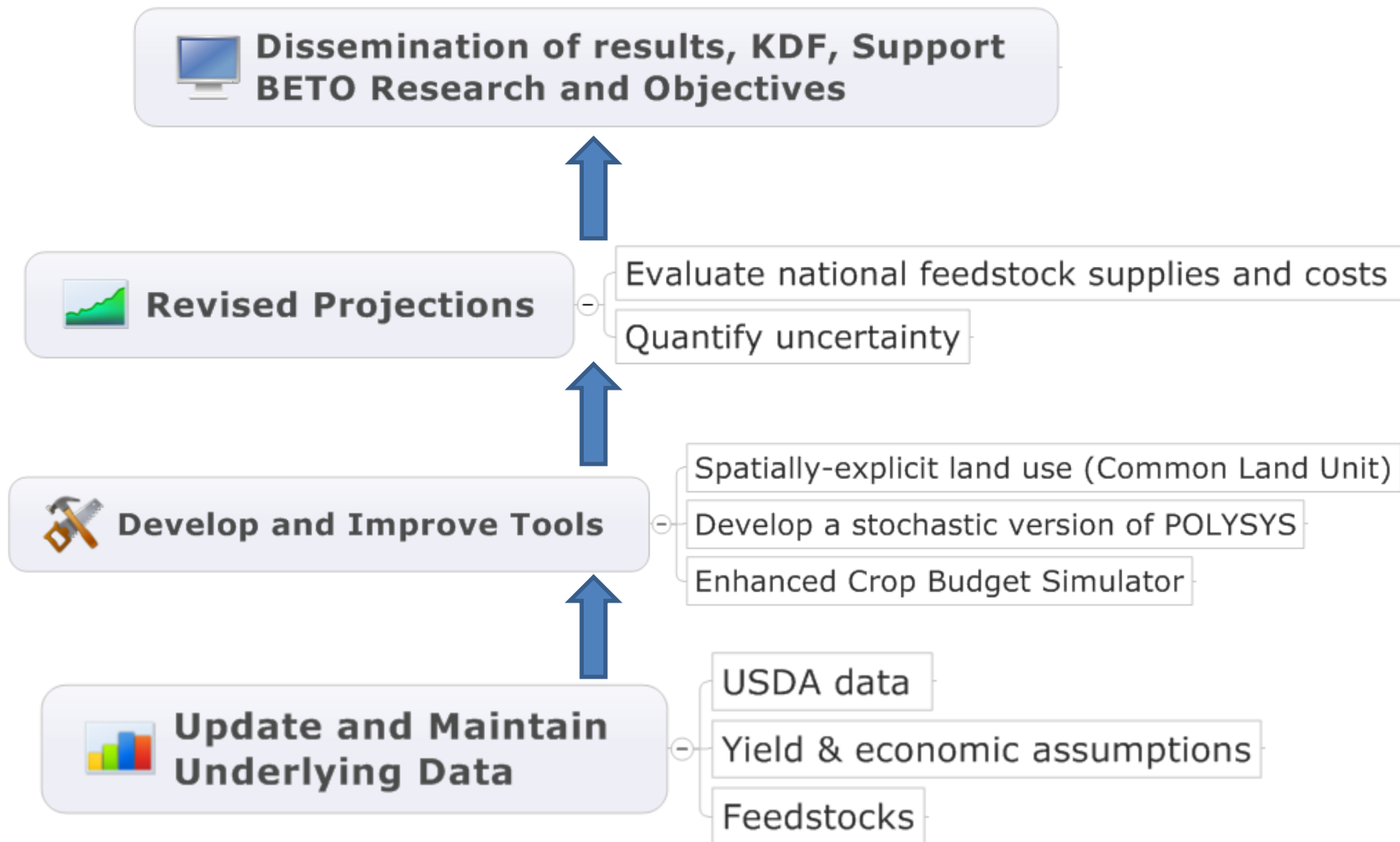
- Ongoing objectives

- Provide current and relevant price projections for existing and new feedstock supplies.
- Support cost targets, MYPP goals, other research.
- Quantify uncertainty (e.g. weather) in feedstock projections.
- Integrate with logistics, sustainability, conversion platforms, etc.
- Contribute to sustainability goals, inform policy, and help realize Integrated Land Management vision.

1 – Approach: Billion-Ton Update

- POLYSYS: BETO version operating at a county-level, for agricultural and forest resources.
- Data from NASS Census of Agriculture, USDA Baseline Projections, Forest Inventory and Analysis, and other data from USFS Forest Products Lab.
- Key technical assumptions from contributing authors and collaborators.
 - Crop residue retention, tillage, rotations
 - Energy crop productivity
 - Forest residue access, recovery, operability, and merchantability
 - Scenarios from high-yield workshops
- Output: Feedstock Supply and Price projections
 - Grower payments (crop residues & energy crops) and stumpage (forest residues)
 - Collection and harvest costs (INL and ORNL models for cropland resources; USFS model for forestland resources)

1 - Approach – Post BT2, Ongoing commercialization



2 - Technical Results

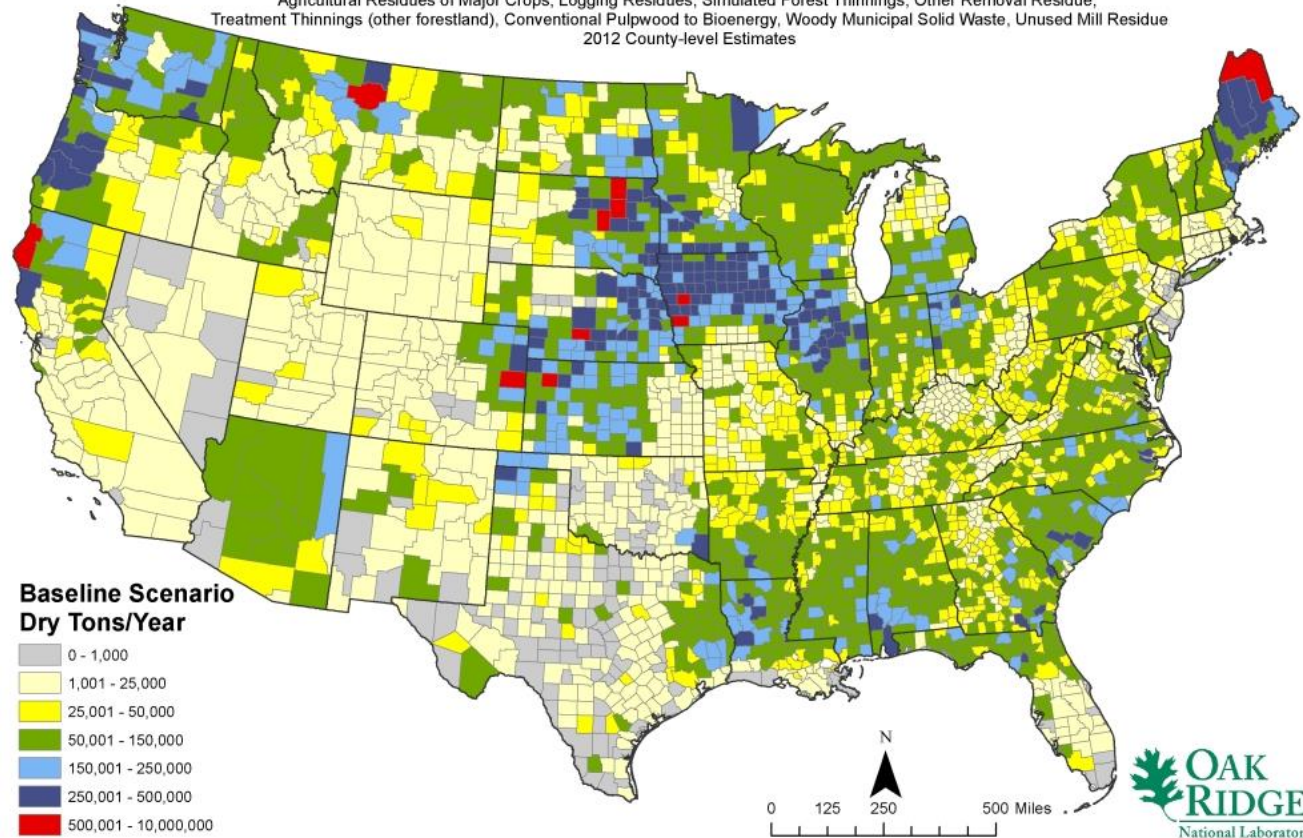
- Billion-Ton Update (DOE, 2011)
 - Multi-institutional effort
 - 20-year projections of economic availability of biomass (price, location, scenario)
- Forest resources
 - Logging residues
 - Forest thinnings (fuel treatments)
 - Conventional wood
 - Fuelwood
 - Primary mill residues
 - Secondary mill 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
 - Annual energy crop (added for 2011)



Supply Curve Results

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

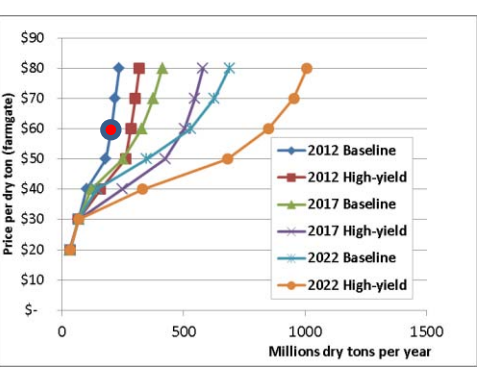


Source: U.S. Department of Energy. 2011. U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry. R.D. Perlack and B.J. Stokes (Leads), ORNL/TM-2011/224. Oak Ridge National Laboratory, Oak Ridge, TN. 227p. Data Accessed from the Bioenergy Knowledge Discovery Framework, www.bioenergykdf.net.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

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

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

201 x 10⁶ dt



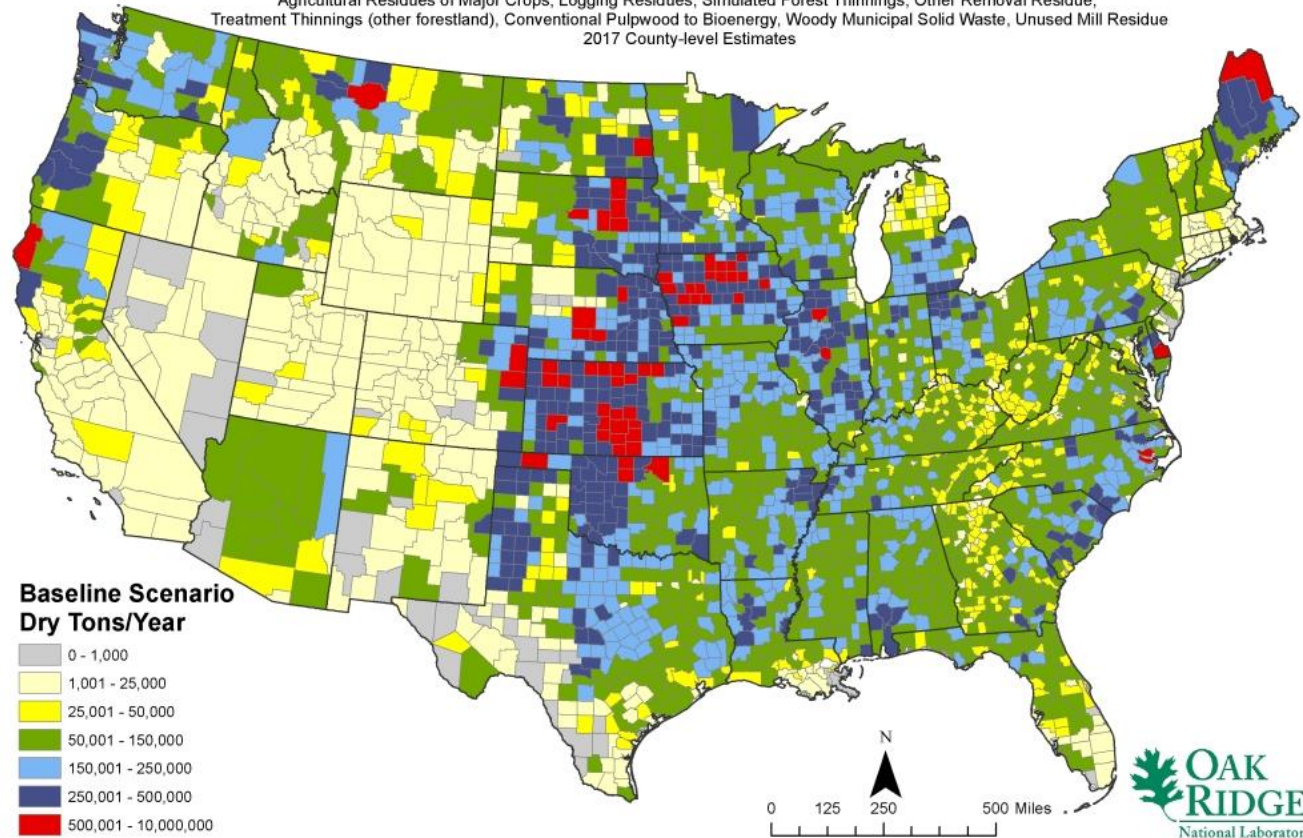
Supply Curve Results

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

327 x 10⁶ dt

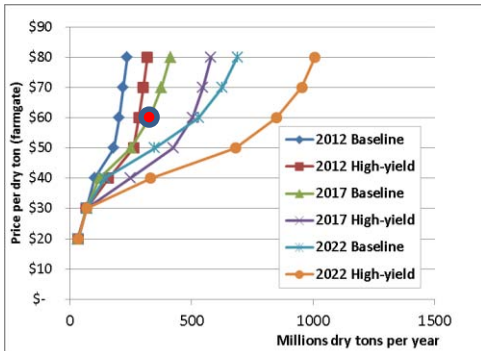
Potentially Available Biomass Resources

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



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

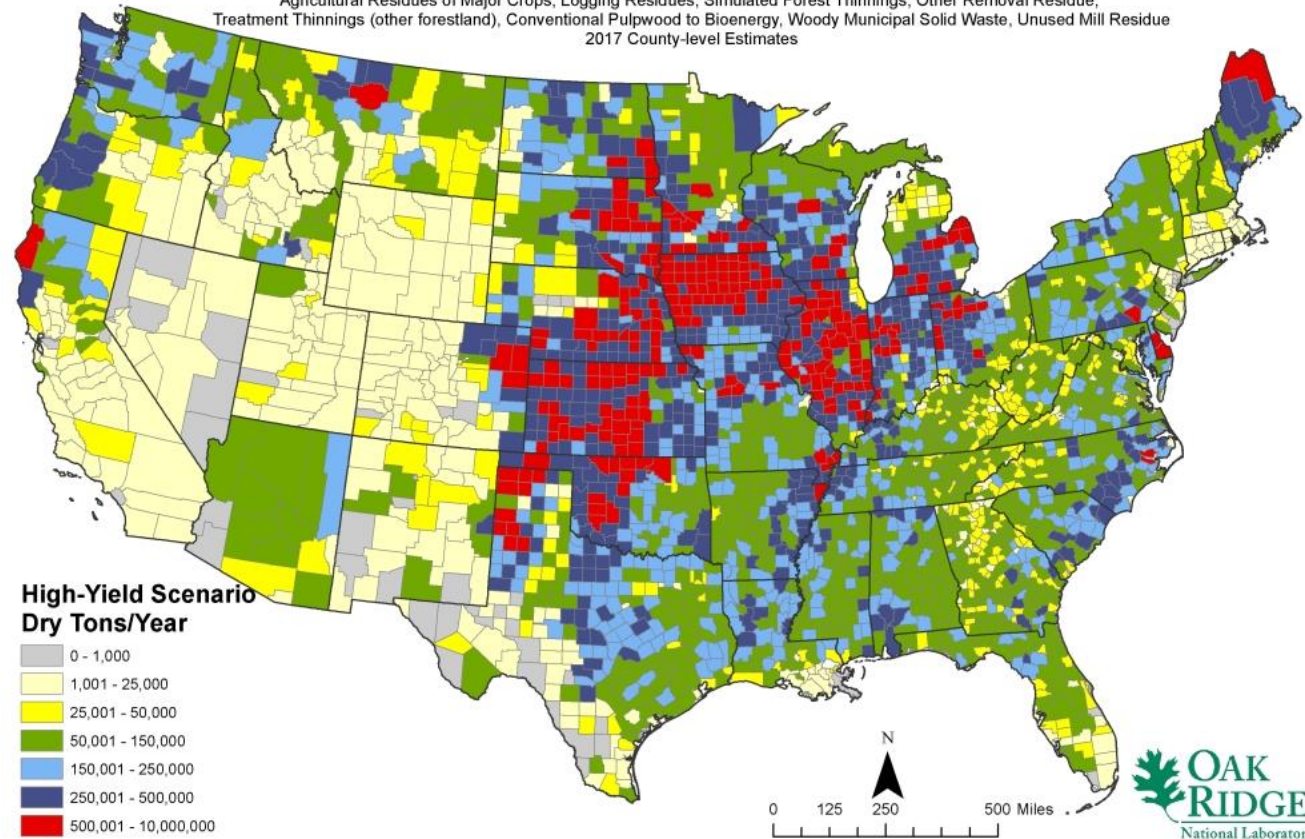
Source: U.S. Department of Energy. 2011. U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry. R.D. Perlack and B.J. Stokes (Leads), ORNL/TM-2011/224. Oak Ridge National Laboratory, Oak Ridge, TN. 227p. Data Accessed from the Bioenergy Knowledge Discovery Framework, www.bioenergykdf.net.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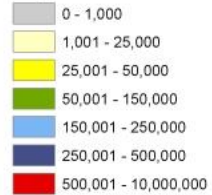
Supply Curve Results

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

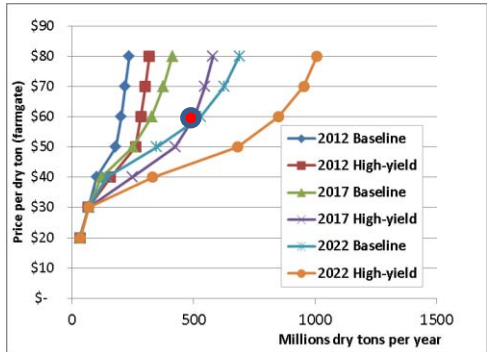


Source: U.S. Department of Energy, 2011. U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry. R.D. Perlack and B.J. Stokes (Leads), ORNL/TM-2011/224. Oak Ridge National Laboratory, Oak Ridge, TN. 227p. Data Accessed from the Bioenergy Knowledge Discovery Framework, www.bioenergykdf.net.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



- 2017
- High-yield scenario
- \$60 dry ton⁻¹

503 x 10⁶ dt



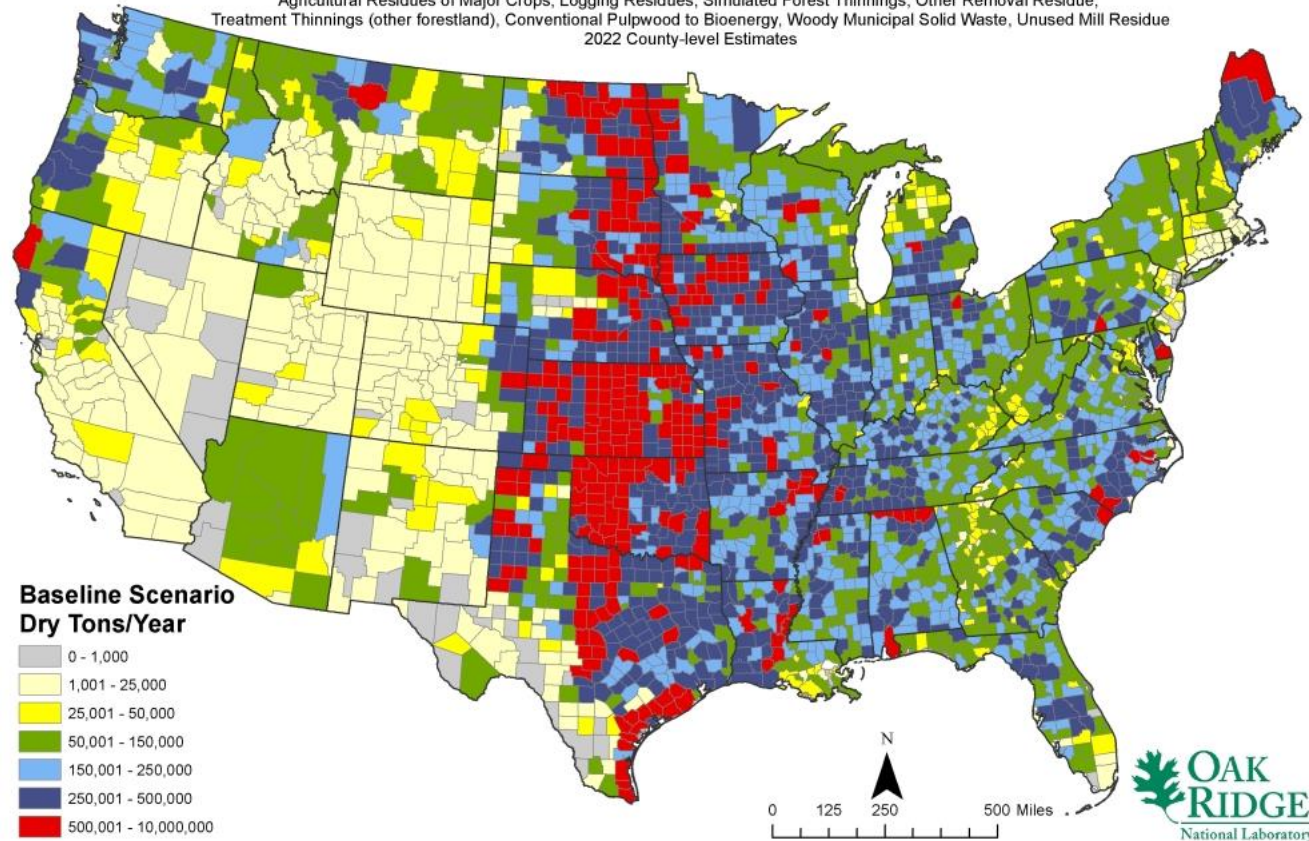
Supply Curve Results

- 2022
- Baseline scenario
- \$60 dry ton⁻¹

529 x 10⁶ dt

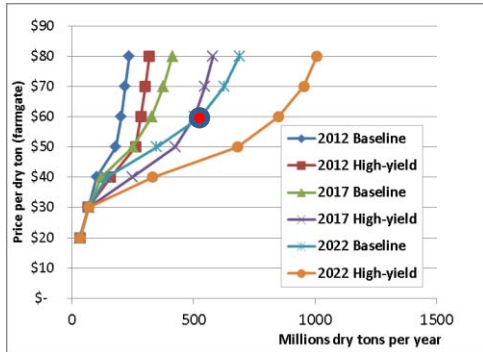
Potentially Available Biomass Resources

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
 2022 County-level Estimates



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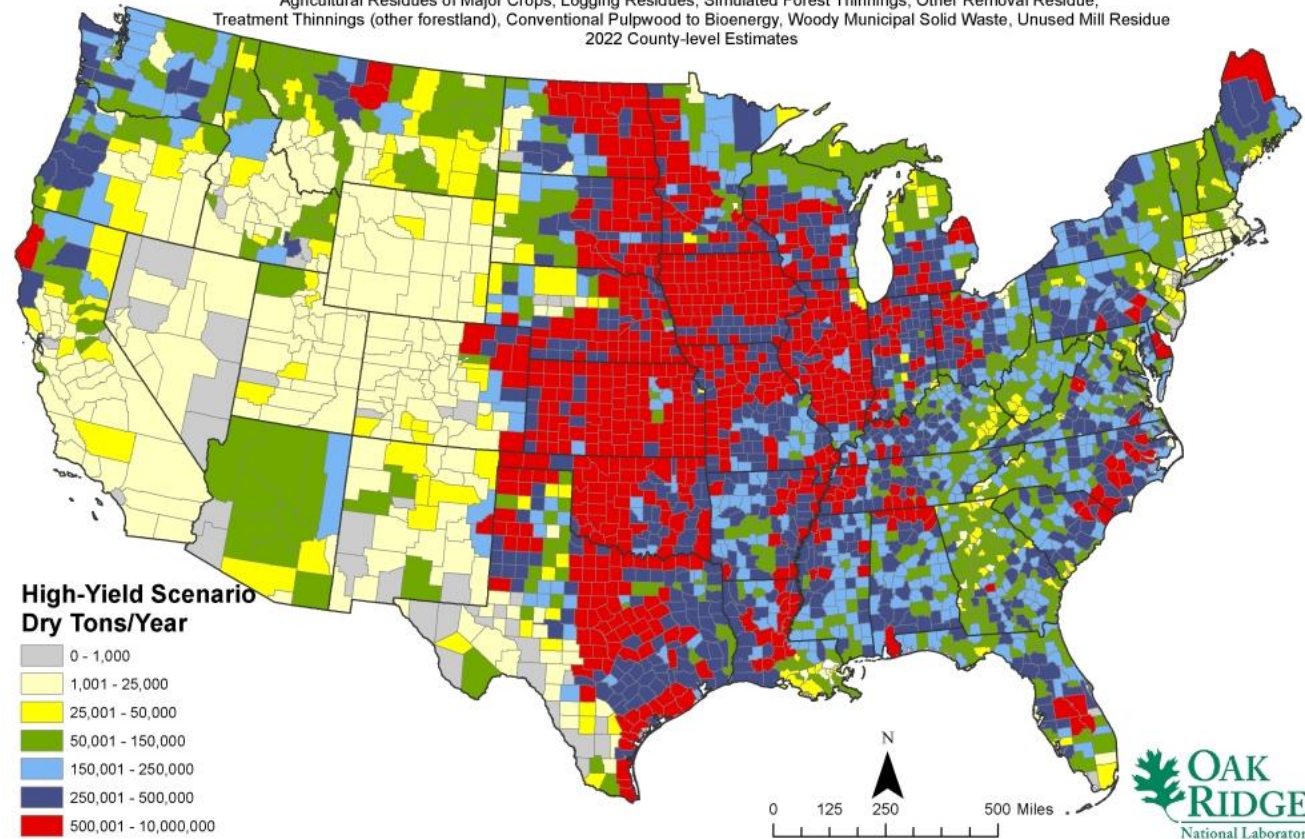
Source: U.S. Department of Energy, 2011. U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry. R.D. Perlack and B.J. Stokes (Leads), ORNL/TM-2011/224. Oak Ridge National Laboratory, Oak Ridge, TN. 227p. Data Accessed from the Bioenergy Knowledge Discovery Framework, www.bioenergykdf.net.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



Supply Curve Results

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

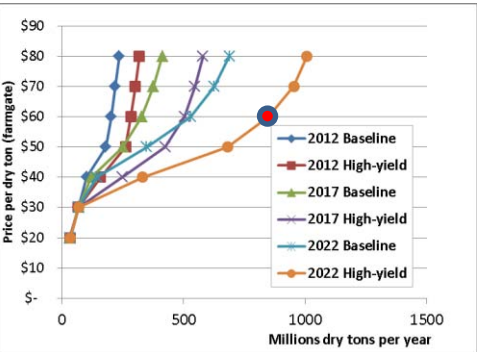


U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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].
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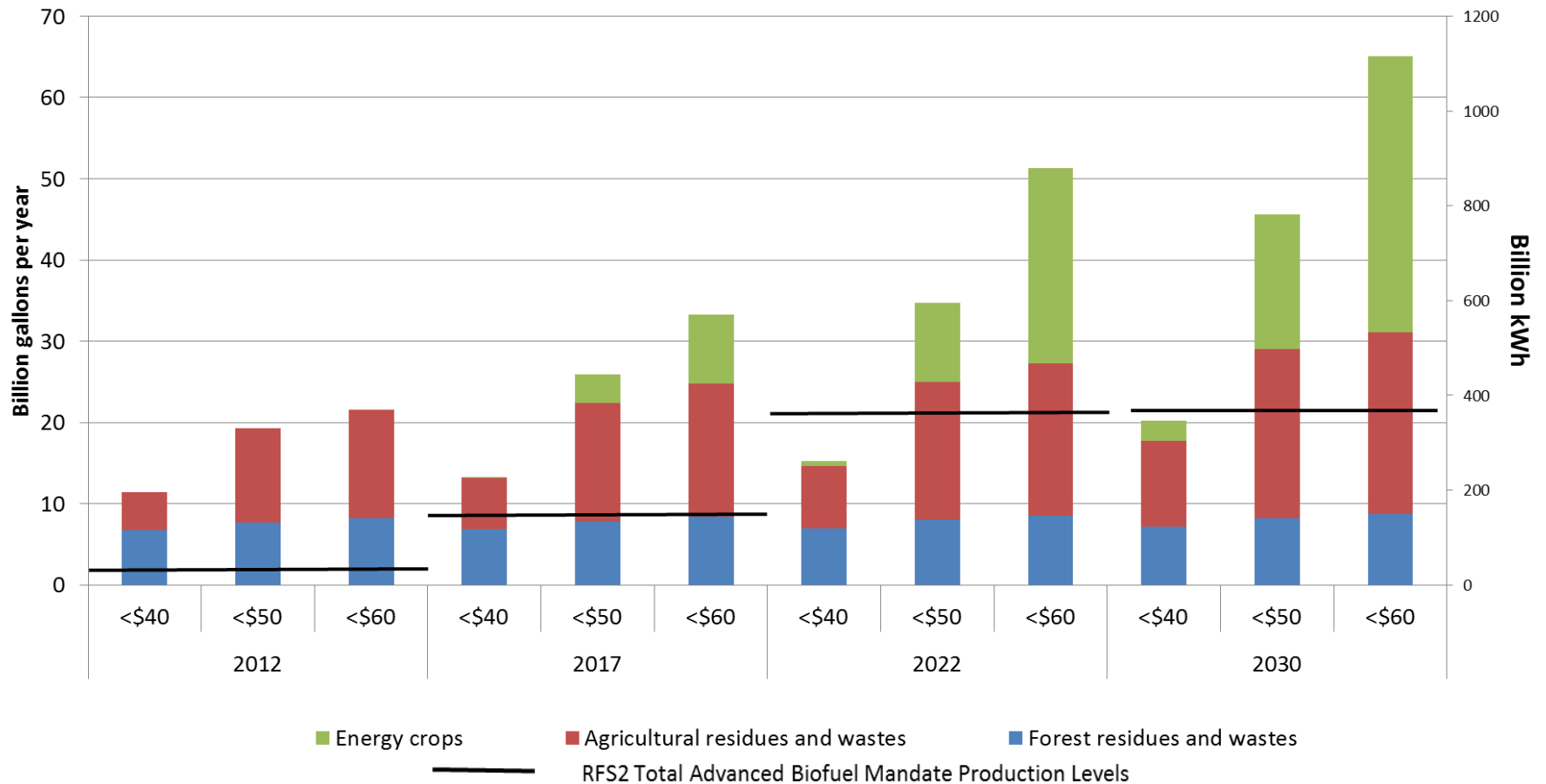
- 2022
- High-yield scenario
- \$60 dry ton⁻¹

848 x 10⁶ dt



2 - Technical Results (cont'd)

Baseline scenario:



2 - Technical Results (cont'd)

- Dissemination: Billion-Ton Update rollout, integration with KDF: 13,500 view of overview page, 2,750 dynamic maps, 2,260 canned/scenario maps, 1,000 full downloads, 2,400 custom downloads
- Enabled research:
 - Feedstock price targets for MYPP: “Price projections of feedstocks for biofuels and biopower in the U.S.”, Energy Policy, 2012.
 - Economies of scale in biochem and thermochem biorefineries (Argo et al. 2013, and in review).
 - Interface between terrestrial and algal feedstocks: “Potential Land Competition Between Open-Pond Microalgae Production and Terrestrial Dedicated Feedstock Supply Systems in the U.S.”, Biomass and Bioenergy, in review.
 - Climate risk management for the industry: “Managing Climate Risk to the U.S. Cellulosic Biofuels Supply Chain”, Climate Risk Management Journal, in review.
- Yield assumptions validated by Sun Grant Regional Feedstock Partnership

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

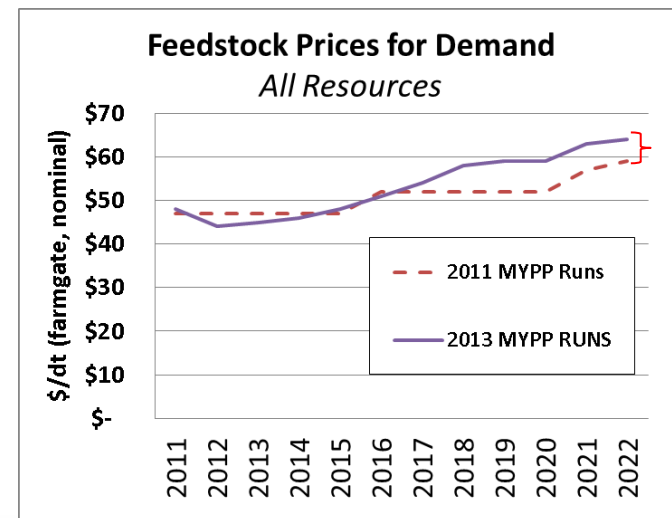
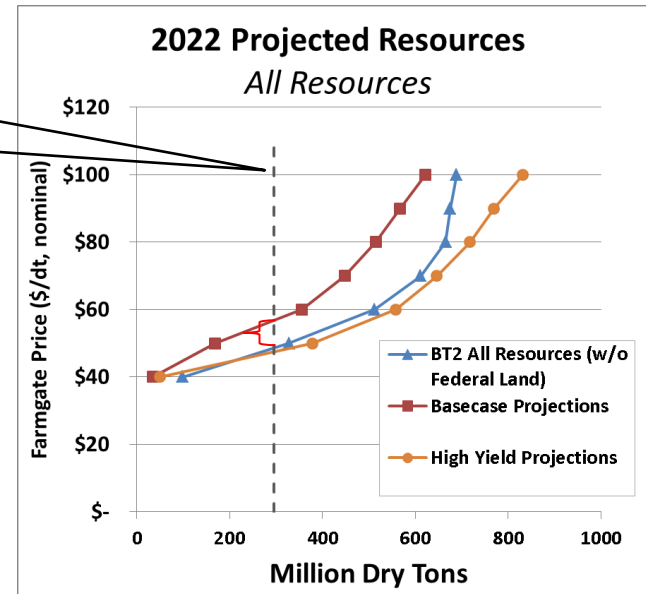
325 million tons/yr=
EISA+BioPower

Price run:

- BT2 = ~\$50/dt
- 2013 revision = ~\$58/dt
- 17% biomass price increase

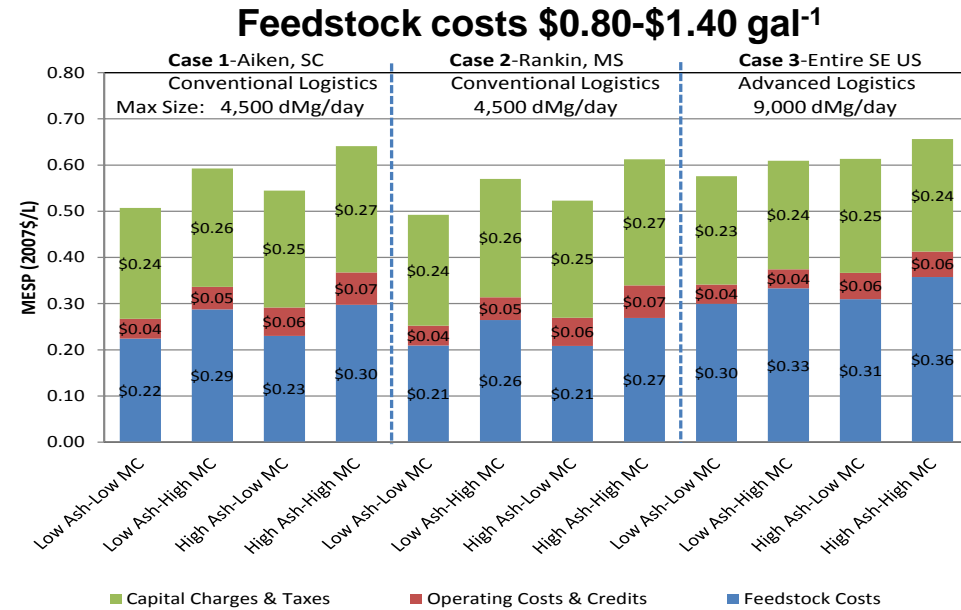
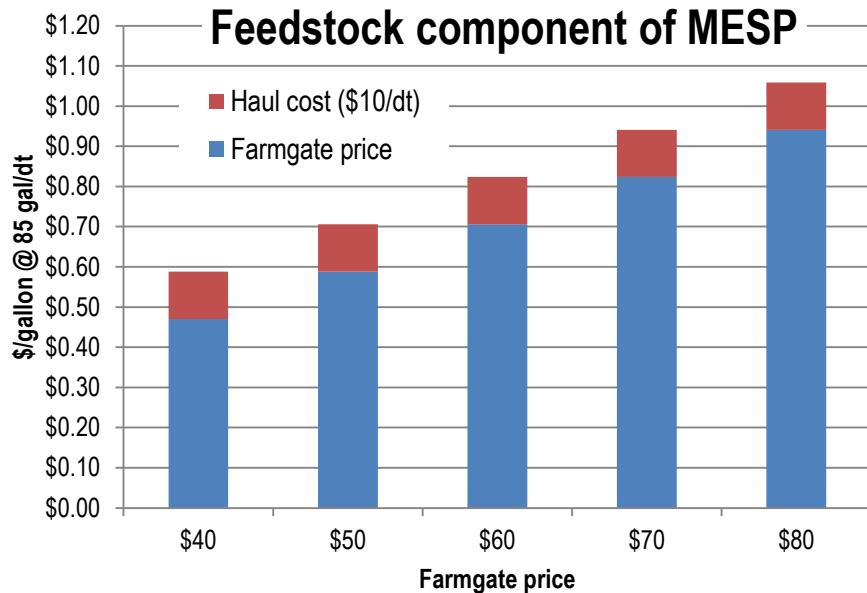
Demand run, 325 mm t/yr:

- MYPP = \$59/dt
- 2012 revision = \$64/dt
- 8.5% biomass price increase
- Corn Price increase 24%



3 - Relevance: Feedstock price ~1/4 of Minimum Ethanol Selling Price

Farmgate price \$50-\$60/dt plus haul cost (@85 gal/dt) ~=\$0.70-\$0.80/gal, or ~1/4 of \$3.00/g MESP



Variables:

Muth et al., in preparation

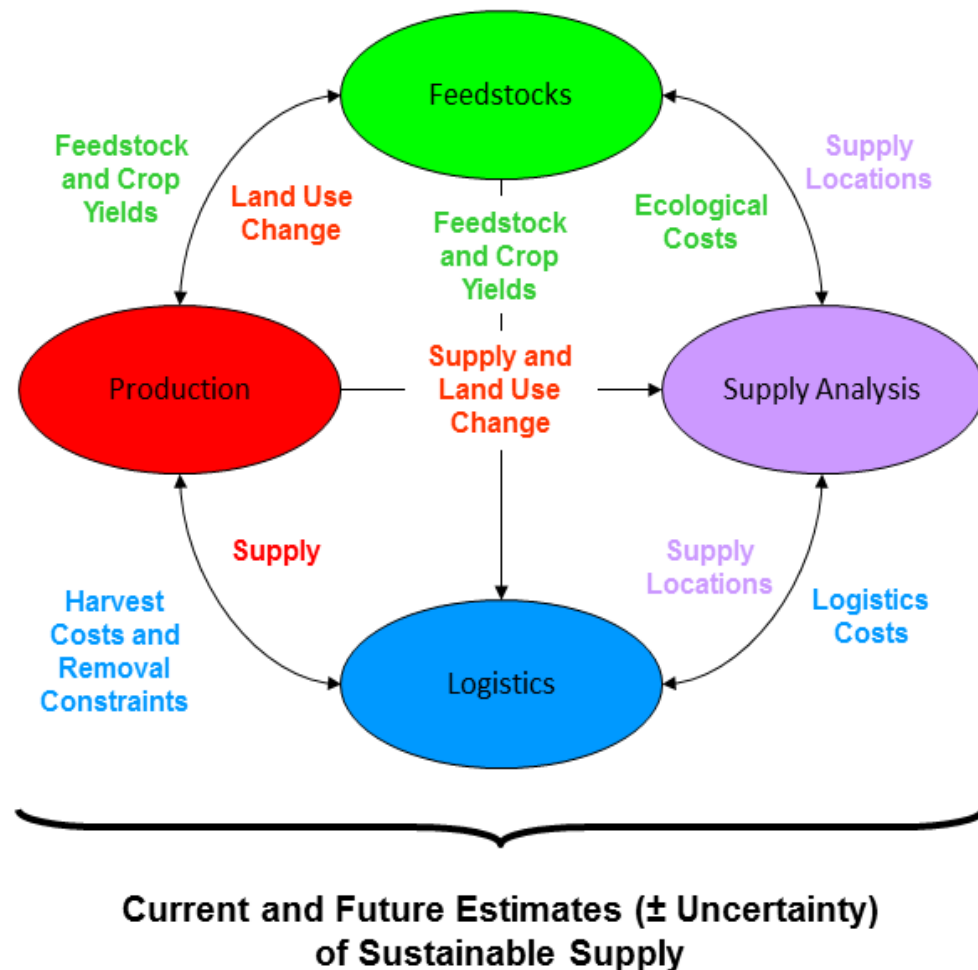
- Economic climate
- Climatic events
- Production budgets
- Yields (tons/acre)
- Sustainability constraints

4 - Critical Success Factors

- Accurate projections.
- Sustainability criteria are incorporated.
- Positioned to revise and add more criteria as they become available.
- Knowledge of the economic availability of biomass feedstocks contribute to the commercialization of biofuels, biopower, and bioproducts.

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



Summary

- 1) Approach: Robust modeling framework to evaluate the economic availability of biomass feedstocks.
- 2) Technical accomplishments: County-level estimates of feedstock supplies by type, price, year, and scenario.
- 3) Relevance: Expected prices of about \$60 dry ton⁻¹ represent about ¼ of \$3/gal MESP.
- 4) Critical Success factors and challenges: Enabling R&D, integrating with other research areas.
- 5) Future Work: climate change and variability impacts, incorporating algae & MSW, spatially explicit realizations, evaluating policy options to integrated land management.
- 6) Technology transfer: continued dissemination through KDF.

Additional Slides

Responses to Previous Reviewers' Comments

- The plan to explicitly link [the Billion-Ton Update] to the KDF will give some (?) capability for interim revision at a shorter time step and this may be a critical improvement over the last report which has stood unchanged in spite of the rapid evolution of the science and data underpinning arguments.
 - Revision releases are planned for approximately every two years, starting in 2014, with dissemination through the KDF.

Responses to Previous Reviewers' Comments

- Could be improved by accounting for climate change.
 - A stochastic version of POLYSYS has been employed, to quantify uncertainty associated with climate variability and extreme events.
 - A future POLYSYS version is planned to model climate change trends superimposed over climate variability.

Responses to Previous Reviewers' Comments

- ...does not begin to address the potential biomass supply when integrated with changes and innovation in agriculture, for example the use of more double crops. I think this needs to be the focus in any third or subsequent study.
 - There are many areas where the study can be further improved and refined. The potential of double cropping is one such study.

Publications, Presentations, and Commercialization

Reports

- 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.
- Downing, Mark, et al. U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry. ORNL/TM-2011/224. Oak Ridge, TN: Oak Ridge National Laboratory. 2011.
- Wright, L.L., Perlack, R.D., Turhollow A.F., Eaton, L.M. 2011. Switchgrass production in the USA. IEA Bioenergy. In Promising Resources for Producing Bioenergy Feedstocks. Task 43: Biomass Feedstocks for Energy Markets.

Journal Articles

- Langholtz, M., R. C. Graham, et al. (2012). "Price Projections of Feedstocks for Biofuels and Biopower in the U.S." Energy Policy 41: 9.
- Argo, A, Tan, E., Inman, D., Langholtz, M., Eaton, L., Jacobson, J., Wright, C., Muth, D., Wu, M., Chiu, Y., Graham, R., (2013). "Investigation of biochemical biorefinery sizing and environmental sustainability impacts for conventional bale system and advanced uniform biomass logistics designs". Biofuels, Bioproducts, and Biorefining. DOI: 10.1002/bbb.1391.
- Dale, V., Langholtz, M., Beau, W., Eaton, L. (2013) "Environmental and socioeconomic indicators for bioenergy sustainability as applied to eucalyptus" International Journal of Forestry Research. <http://dx.doi.org/10.1155/2013/215276>
- Langholtz, M., Coleman, A., Eaton, L., Wigmosta, M. "Potential Land Competition Between Open-Pond Microalgae Production and Terrestrial Dedicated Feedstock Supply Systems in the U.S.", Biomass and Bioenergy, in review.

Book Chapters

- Wright, L., Eaton, L., Perlack R., Stokes, B. 2012. Woody Biomass. In: Sayigh A, (ed) *Comprehensive Renewable Energy*, Vol 5, pp. 263-291. Oxford: Elsevier.

Publications, Presentations, and Commercialization

Presentations

- Langholtz, M., Fourth Annual EBI Biofuels Law and Regulation Conference, A review of the Billion-Ton Update report, Urbana, IL, April 25th, 2012.
- Langholtz, M., EPSCoR 2012: Billion-Ton Update. A review of the Billion-Ton Update report, Stillwater, OK, April 10th, 2012.
- Langholtz, M., IPST and Kimberly-Clark, Aug 28th, A review of the Billion-Ton Update report, Atlanta, GA, Aug 28th, 2012.
- Langholtz, M., Billion-ton Update: An Overview, Florida Energy Summit. Orlando, FL., November 10th, 2011.
- Eaton, L. Billion Ton Update: An overview. Biomass Research and Development Initiative. Technical Advisory Committee. October 2011.
- Eaton, L. The Billion-ton Update Report: Approach and Assumptions. Biomass 2011. July 27, 2011. Washington, DC.
- Eaton, L. U.S. Billion-ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry. Advance Engine Cross-cut Team Meeting. September 8, 2011.
- Eaton, L. DOE's U.S. Billion-ton Update Report. An Overview of Assumptions and Analysis. US/EU Workshop on the Sustainability of Biomass Production for Bioenergy. October 26, 2011. Champaign, IL.
- Eaton, L. Billion Ton Update. Society for Industrial Microbiology. Symposium for Biofuels and Biotechnology. New Orleans, April 2012.

Acronyms, abbreviations, and initialisms

- BT2: Billion-Ton Update
- EISA: Energy Independence and Security Act
- KDF: Knowledge Discovery Framework (www.bioenergykdf.net)
- MESP: Minimum ethanol selling price
- MSW: Municipal solid waste
- NASS: National Agricultural Statistics Service
- RFS2: Renewable Fuel Standard 2

2 - Technical Results (cont'd)

High-yield scenario, \$60 dry ton⁻¹:

