U.S. Department of Energy (DOE) Bioenergy Technologies Office (BETO) 2017 Project Peer Review

Project 1.1.1.1
Supply Forecast and Analysis (SFA)

March 6th, 2017

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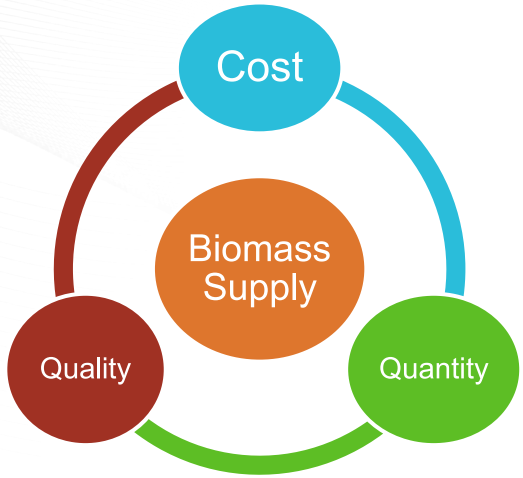
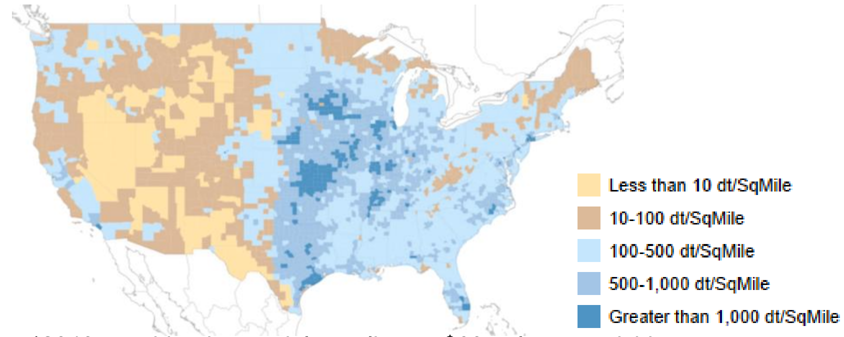
Science Team Leader
Oak Ridge National Laboratory

Goal Statement



All Feedstocks, 2040*



*2040, combined potential supplies, at $60 or less, roadside, base-case scenario, including wastes. Source: https://www.bioenergykdf.net/billionton2016/1/2/tableau

- Why: Program-wide need for information on feedstock supplies (quantity, cost, quality).
- How: Economic, logistic, and environmental models.
- Outcome: Estimates of the potential economic availability of biomass resources (by type, price, year, and production scenario), and a first-time assessment of environmental effects.

Quad Chart Overview

Timeline

- Project start date: FY07
- Current AOP project end date: Ongoing
- Percent complete: N/A

Budget

	Total Costs FY 12 –FY 14	FY 15 Costs	FY 16 Costs	Total Planned Funding (FY 17-Project End Date)
	(million $)			
DOE Funded	$3.1	$1.4	$2.3	$1.9

Barriers

- (A)Ft-A. Feedstock Availability and Cost
- At-C. Data Availability across the Supply Chain
- (A)Ft-B. Sustainable Production
- Ft-H. Biomass Material Handling and Transportation

Partners

- INL, PNNL, NREL, ANL
- Agricultural Policy Analysis Center (APAC) University of Tennessee, Oregon State PRISM Climate Group
- Monsanto, Weyerhaeuser, ArborGen, GreenWood Resources, FDCE
- Other agencies: USDA Forest Service, USDA-ARS
- Sun Grant Regional Feedstock Partnership
- Southern Forest Analysis Consortium

1 - Project Overview

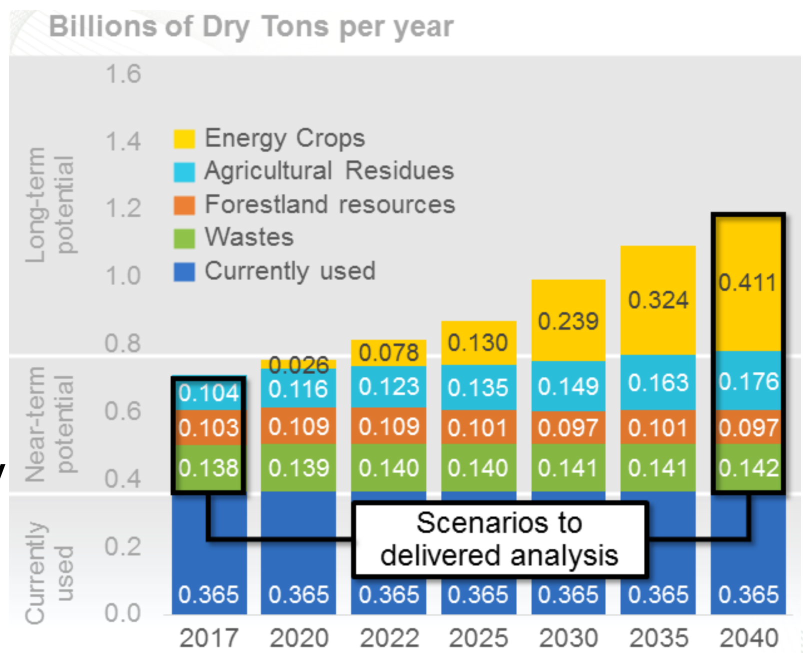
- History and accomplishments
  - Identified adequate supply to displace 30% of petroleum consumption; i.e., physical availability (Billion-Ton Study, 2005).
  - Quantified potential economic availability of feedstocks (Billion-Ton Update, 2011, 2016).
  - Disseminated county-level data (feedstock quantities, by scenario, price, year) through Bioenergy Knowledge Discovery Framework (Billion-Ton Update, 2011, 2016).
- Recent Objectives
  - Full farm-to-reactor analysis. ✔
  - Adding algae, miscanthus, and energy cane to feedstocks. ✔
  - Addressing environmental sustainability, climate variability/change, and uncertainty. ✔
  - Report releases: BT16 Vol. 1 and Vol. 2. ✔

2 – Approach (Management)

- Critical success factors: resource assessments with credible economics and latest available information (e.g., agronomics, logistics, sustainability).
- Challenges: breadth, depth, and interfaces with other projects.
- Teamwork and Collaboration: Weekly calls with team, BETO, and other labs; coordination with USFS, Southern Forest Resource Consortium, Algae Biomass Organization, and others.
- Review process: for modeling assumptions and results.
- Go/No-Go: Q3 2015: Decision to publish BT16.

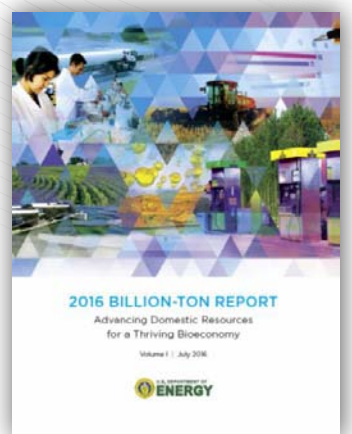
2 – Approach (Technical, Volume 1)

- **Objective:** Quantify the economic availability of biomass feedstocks.
- **Data:** NASS Census of Agriculture, USDA Baseline Projections, Forest Inventory and Analysis, Sun Grant Initiative, and USFS Forest Products Lab.
- **Economic models**: BETO version of POLYSYS for agriculture and ForSEAM for forest resources, both operating at a county-level.
- **Output: Feedstock Supply and Price Assessments**
  - Grower payments (crop residues & energy crops) and stumpage (forest residues)
  - Costs of major feedstocks with delivery and preprocessing to the biorefinery throat



3 – Technical accomplishments (Vol. 1)

2016 Billion-Ton Report, Volume 1: The Economic Availability of Feedstocks



	Grower payment, stumpage price, procurement price	Farmgate price, roadside price	Delivered Cost
	Production	**Harvest**	**Delivery and Preprocessing**
Example operations:	Site preparation, planting, cultivation, maintenance, profit to landowner	Cut and bale, rake and bale; fell, forward, and chip into van	Load, transport, unload
Format:	In the field or forest, dispersed	Baled or chipped into van roadside	Comminuted to <¼ inches (conventional) or pelleted (advanced)

Chapters: (3) At the Roadside, Forestland Resources; (4) At the Farmgate, Agricultural Residues and Biomass Crops; (5) Waste Resources; and (7) Microalgae

Chapter (6) To the Biorefinery, Delivered Supplies and Prices

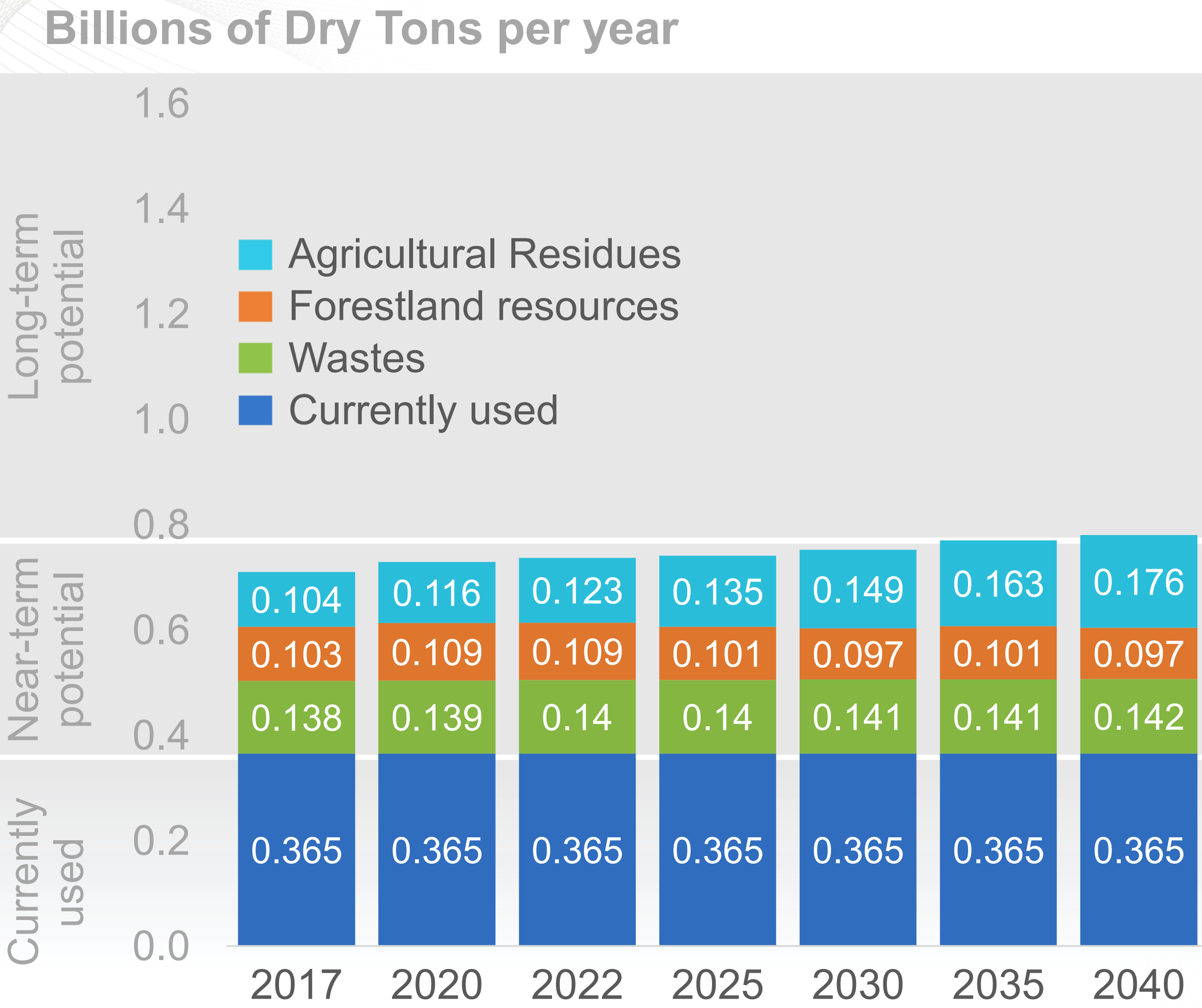
Chapters (2) Currently Used; (8) Summary, Interpretation, and Looking Forward

U.S. Department of Energy. 2016. *2016 Billion-Ton Report: Advancing Domestic Resources for a Thriving Bioeconomy, Volume 1: Economic Availability of Feedstocks*. M. H. Langholtz, B. J. Stokes, and L. M. Eaton (Leads), ORNL/TM-2016/160. Oak Ridge National Laboratory, Oak Ridge, TN. 448p. doi: 10.2172/1271651.

https://www.bioenergykdf.net/billionton2016/overview

3 – Technical accomplishments: Volume 1

Current and Potential, Base-case, $60/dt



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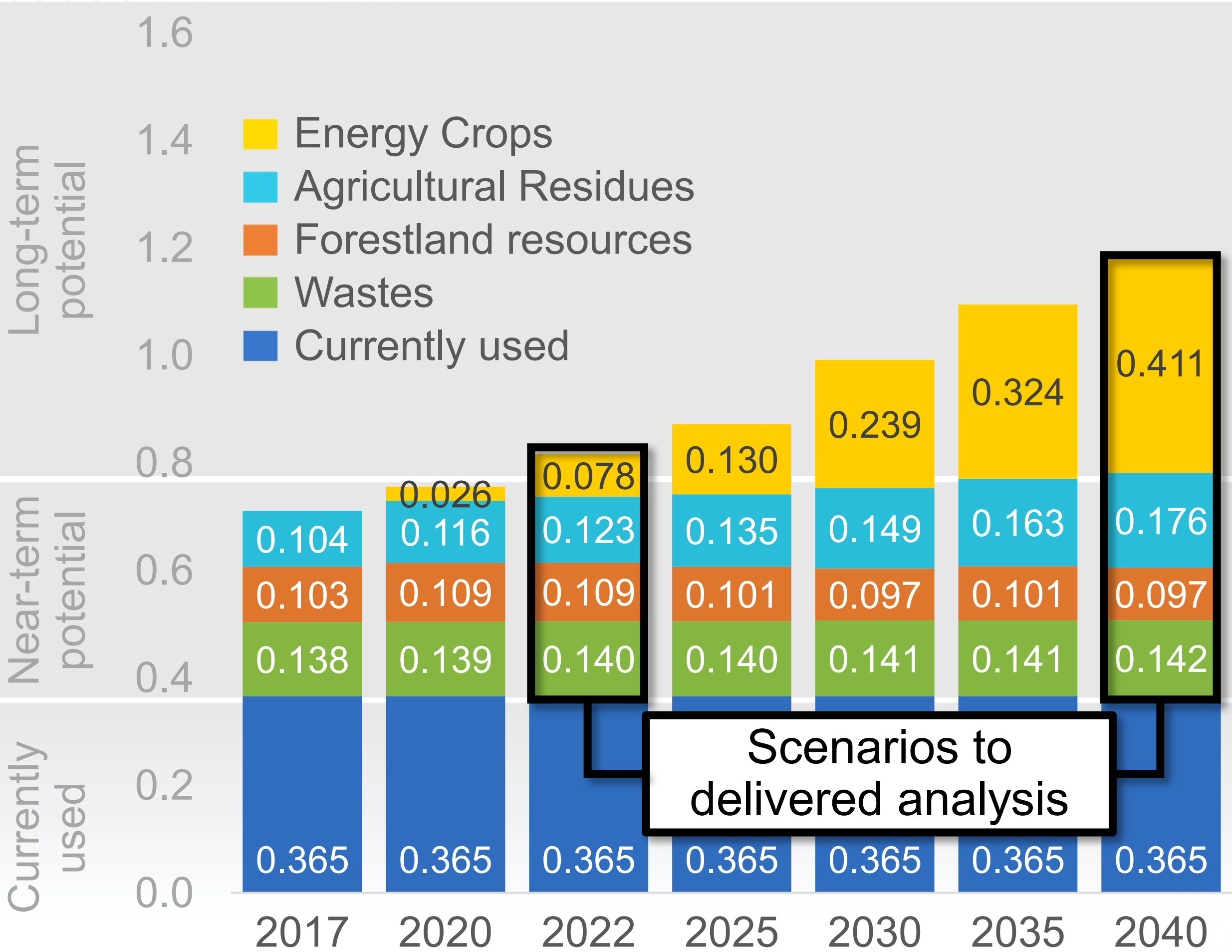
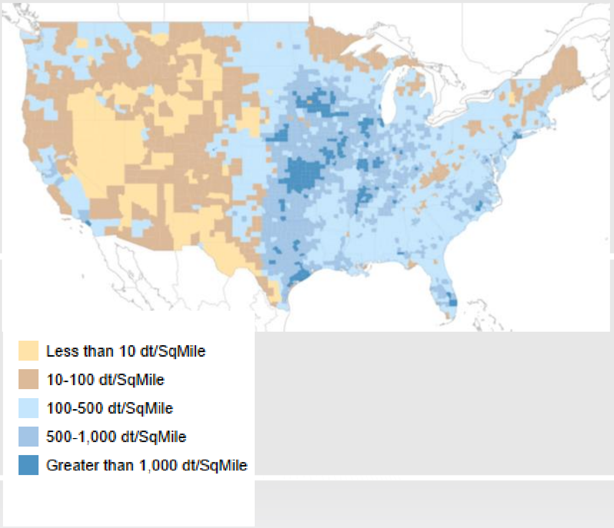
3 – Technical accomplishments: Volume 1

Current and Potential, Base-case, $60/dt

Billions of Dry Tons per year



2040, $60/dt, Base Case

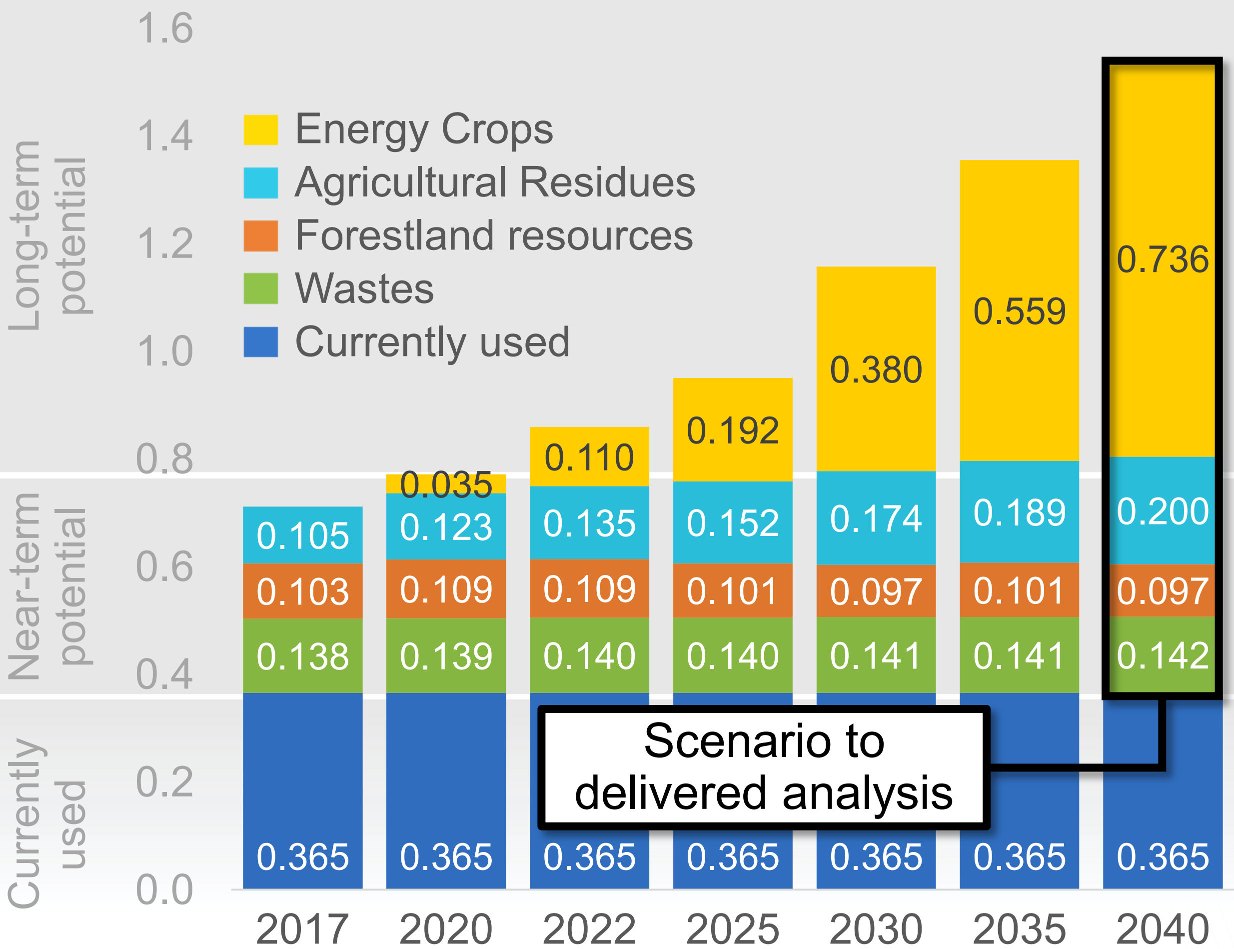


bioenergykdf.net/billionton2016/overview

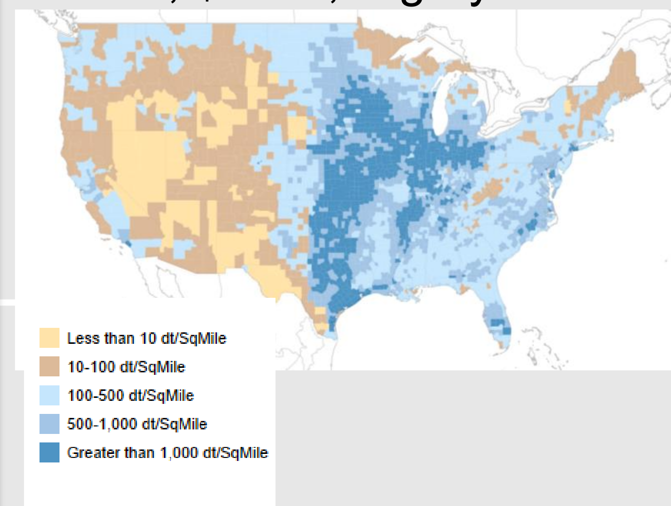
3 – Technical accomplishments: Volume 1

Current and Potential, High-yield, $60/dt

Billions of Dry Tons per year



2040, $60/dt, High-yield



bioenergykdf.net/billionton2016/overview

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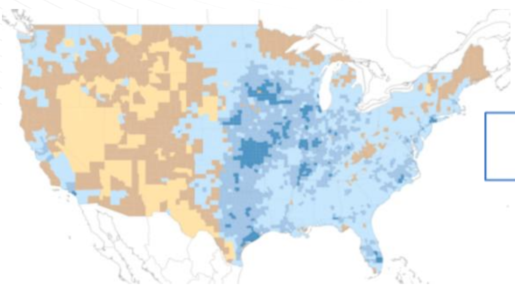
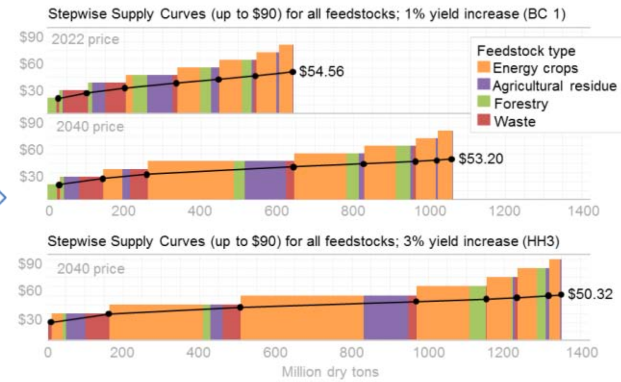
3 – Technical accomplishments: Volume 1

Results, delivered (production and harvest, preprocessing, and transportation to biorefinery throat). Collaboration with 1.2.3.1 Feedstock Supply Modeling.

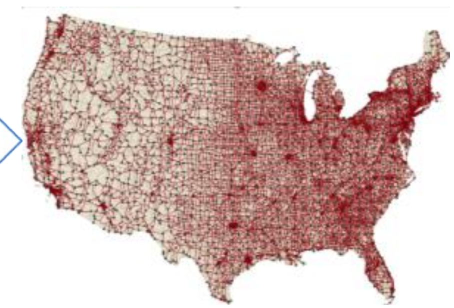
County-level roadside supplies



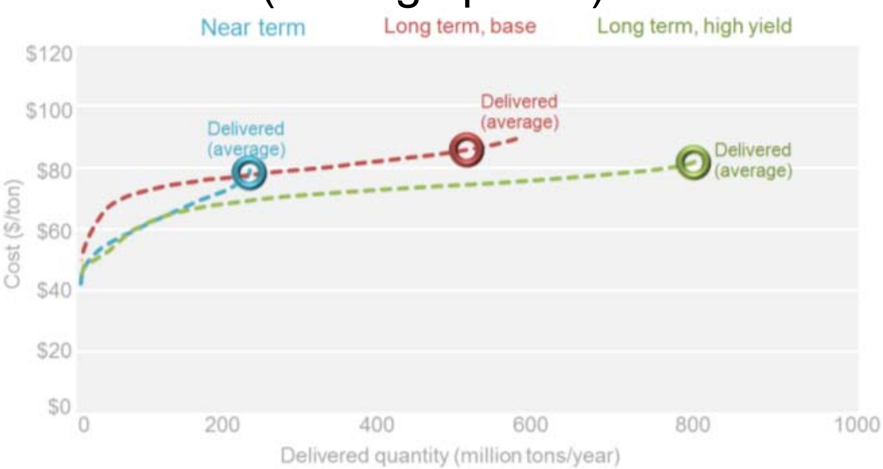
Feedstock-specific prices



Transportation network to potential biorefinery locations



Supply curves of delivered supplies (average prices)

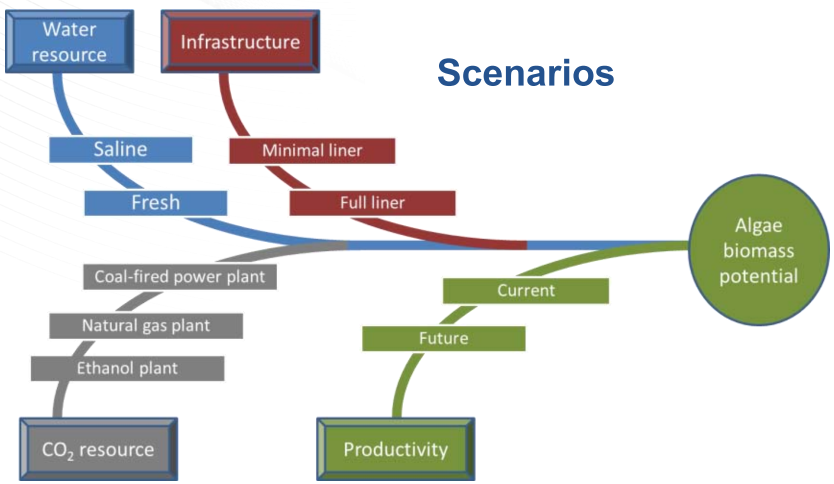


Summary of delivered results

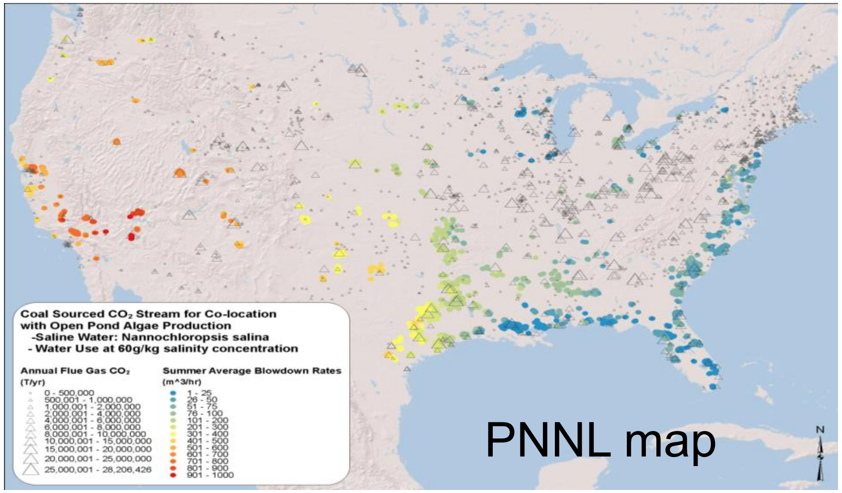
Price per dry ton	Near term	Long term base case	Long term high yield
Roadside ≤$60	310	679	985
Delivered ≤$84	217	467	825
Delivered ≤$100	217	564	825
Unused	93	114	160

3 – Technical accomplishments: Volume 1

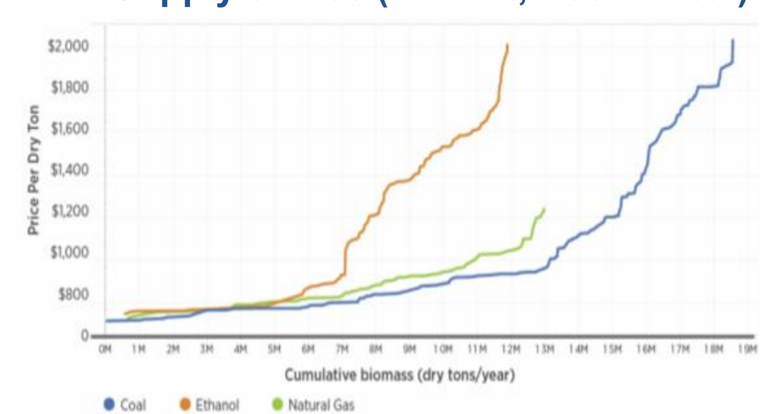
Potential economic availability of algal biomass, collaboration with 1.3.1.500 (ORNL) 1.3.1.102 (PNNL), and 1.3.1.200 (NREL).



Spatial co-location



Supply curves (current, fresh water)

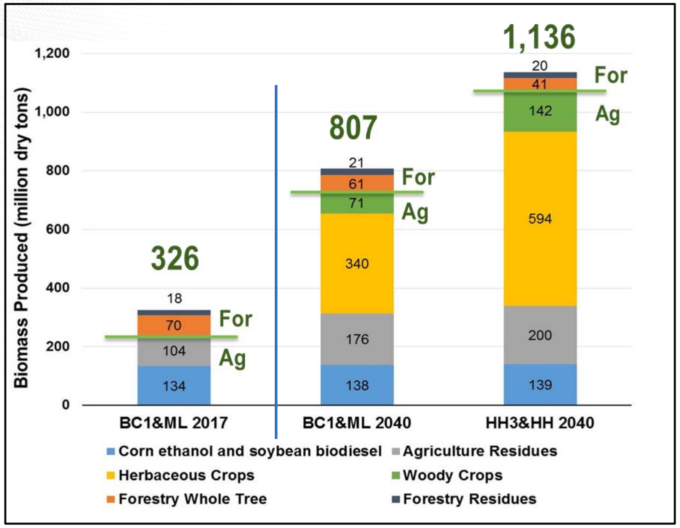


Millions of tons of biomass and price ranges

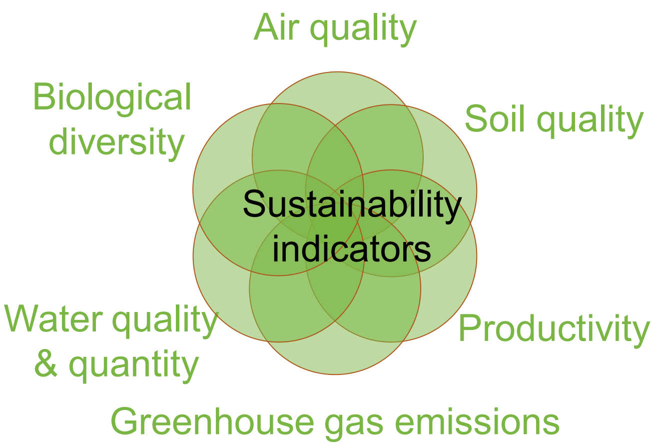
Productivity & media	Ethanol plant	Coal power plant	Natural gas power plant	Range of min prices per dry ton
Current, freshwater	12	19	15	\$719-\$2030
Current, saline	10	54	21	\$755-\$2889
Future, freshwater	13	10	N/A	\$490-\$1327
Future, saline	11	12	N/A	\$540-\$2074

2 – Approach (Technical, Volume 2)

Three scenarios evaluated



13 Indicators applied



- Applied to 2017, 2040 base-case, and 2040 high-yield scenarios
- Address thirteen indicators in 6 indicator categories
- Models specific to indicators (SWAT, Century, GREET, F-PEAM, species distribution model) with several national labs and USFS
- Output: environmental effects of three scenarios from vol 1.

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2 – Approach (Technical, Volume 2)

Methodology for environmental sustainability

	Indicator
Soil quality (ANL)	1. Total organic carbon (TOC)
	2. Total nitrogen (N)
	3. Extractable phosphorus (P)
	4. Bulk density
Water quality and quantity (ANL, ORNL, USFS)	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 (ANL)	12. CO_2 equivalent emissions (CO_2 and N_2O)
Biodiversity (ORNL, USFS)	13. Presence of taxa of special concern
	14. Habitat area of taxa of special concern
Air quality (NREL)	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})
	Additions: VOCs, SO_x, NO_x, NH_3
Productivity	19. Aboveground net primary productivity or Yield

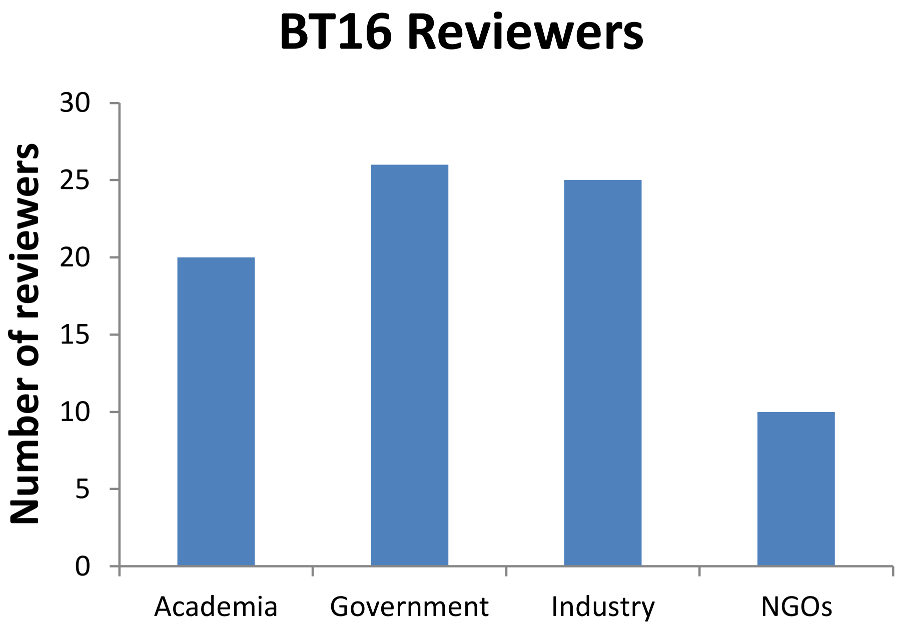
McBride et al. (2011) *Ecological Indicators* 11:1277-1289

Yellow—indicators in Billion Ton 2016

White—other BETO- and ORNL-recommended indicators

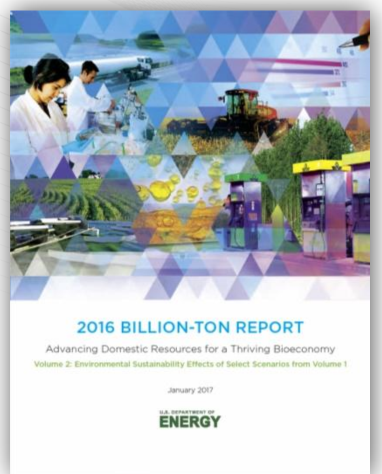
2 – Approach (Review process)

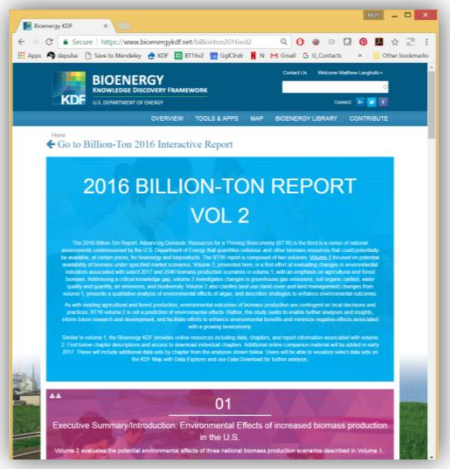
- Workshop titled "Presentation and Expert Review of the 2016 Billion-Ton Report" was held December 9–10, 2015, in Washington, D.C.
  - 25 Institutions and 28 individuals
- Workshop titled "Presentation and Expert Review of the 2016 Billion-Ton Report Volume 2" was held May 11, 2016, in Washington, D.C.
  - 34 Institutions and 46 individuals; representatives from agencies and industries
- Written review of volume 2, July-Sept. 2016.
- Review by the Algae Biomass Organization
  - 6 reviewers



3 – Technical accomplishments

2016 Billion-Ton Report, Volume 2: Environmental Sustainability Effects of Select Scenarios from Volume 1





U.S. Department of Energy. 2017. 2016 *Billion-Ton Report: Advancing Domestic Resources for a Thriving Bioeconomy, Volume 2: Environmental Sustainability Effects of Select Scenarios from Volume 1*. R. A. Efroymson, M. H. Langholtz, K.E. Johnson, and B. J. Stokes (Eds.), ORNL/TM-2016/727. Oak Ridge National Laboratory, Oak Ridge, TN. 642p. doi 10.2172/1338837

https://www.bioenergykdf.net/billionton2016vol2

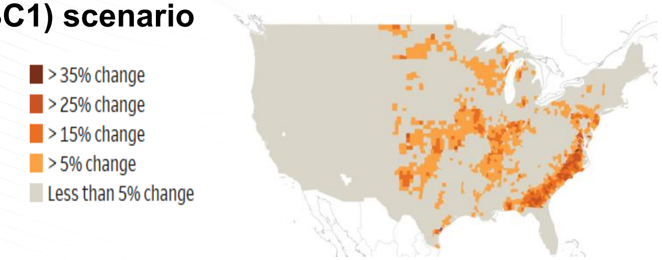
<u>MYPP Sustainability Strategic Goal</u>: To understand and promote the positive environmental, economic, and social effects and reduce the potential negative impacts of bioenergy production activities.

<u>MYPP 2016 milestone</u>: By 2016, evaluate environmental sustainability indicators for updated assessment of potentially available feedstock supplies and identify conditions or conservation practices under which feedstock production scenarios are likely to maintain or improve soil quality, biodiversity, and water quality in major feedstock production regions while meeting projected demands for food, feed, and fiber production.

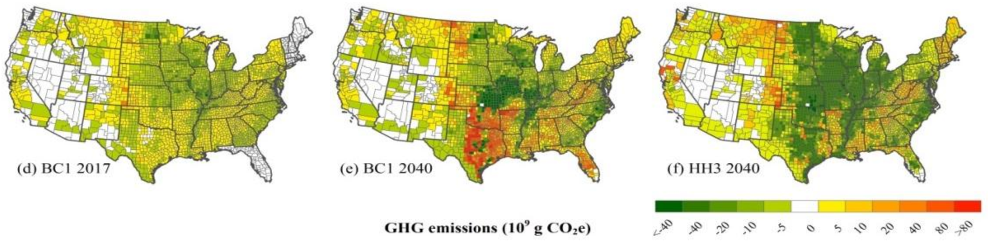
3 – Technical accomplishments: Volume 2

BT16 volume 2, *Environmental Sustainability Effects of Select Scenarios from Volume 1*

Changes in perennial cover under the base-case (BC1) scenario

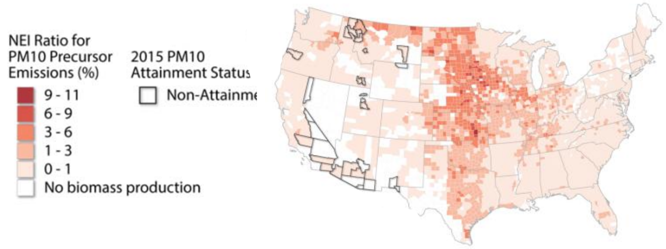


Potential increase in perennial cover of 24-45 million acres from 2015 (ORNL, project 4.2.1.41).



Potential GHG and SOC changes: dependent on yield, local soil characteristics, and weather (ANL, project 4.1.1.10).

County-level NEI changes, Base-Yield 2040



Most counties might not see significant challenges in meeting air-quality standards, but 25% are estimated to emit ~1-10% of the NEI (NREL, project 4.2.1.30).

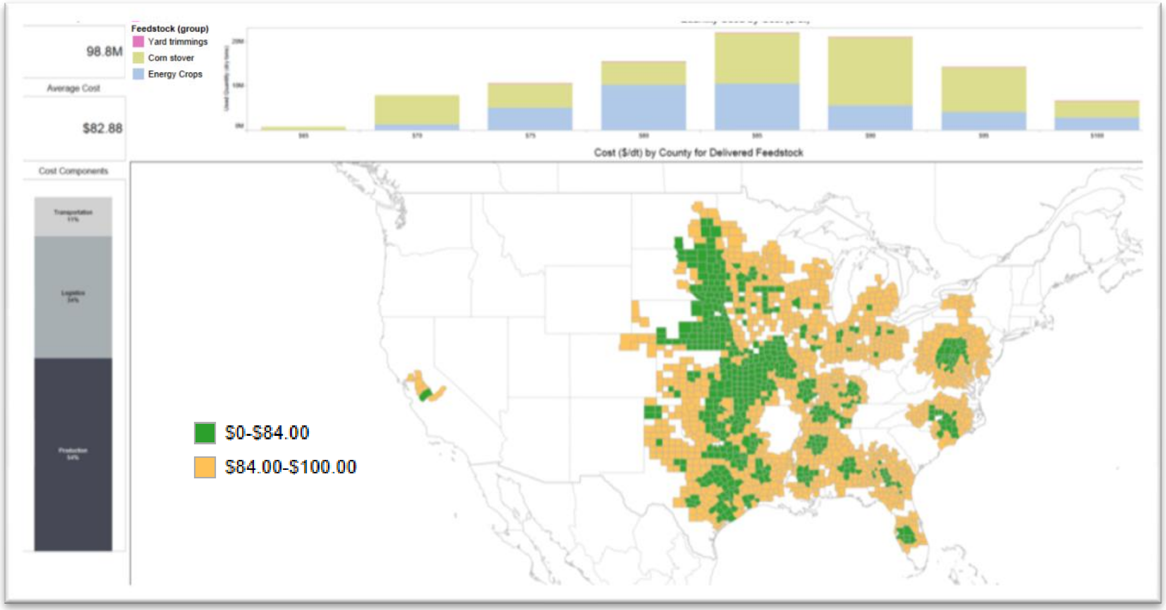
3 – Technical accomplishments: Data availability

Thousands of hits, visualizations, and downloads on www.bioenergykdf.net/billionton2016/overview

4 – Relevance

- Feedstocks represent about one-third of the cost of production of biofuels (Aden et al, 2009; Davis et al, 2011).
- Results inform biofuels commercialization strategies with feedstock quantities, prices, types, and spatial distribution.
- Analysis extends beyond the farmgate to delivered scenarios to better reflect potential industry.
- Work referenced by EIA, IRENA, DOE, and others

Delivered Supply Cost Components*

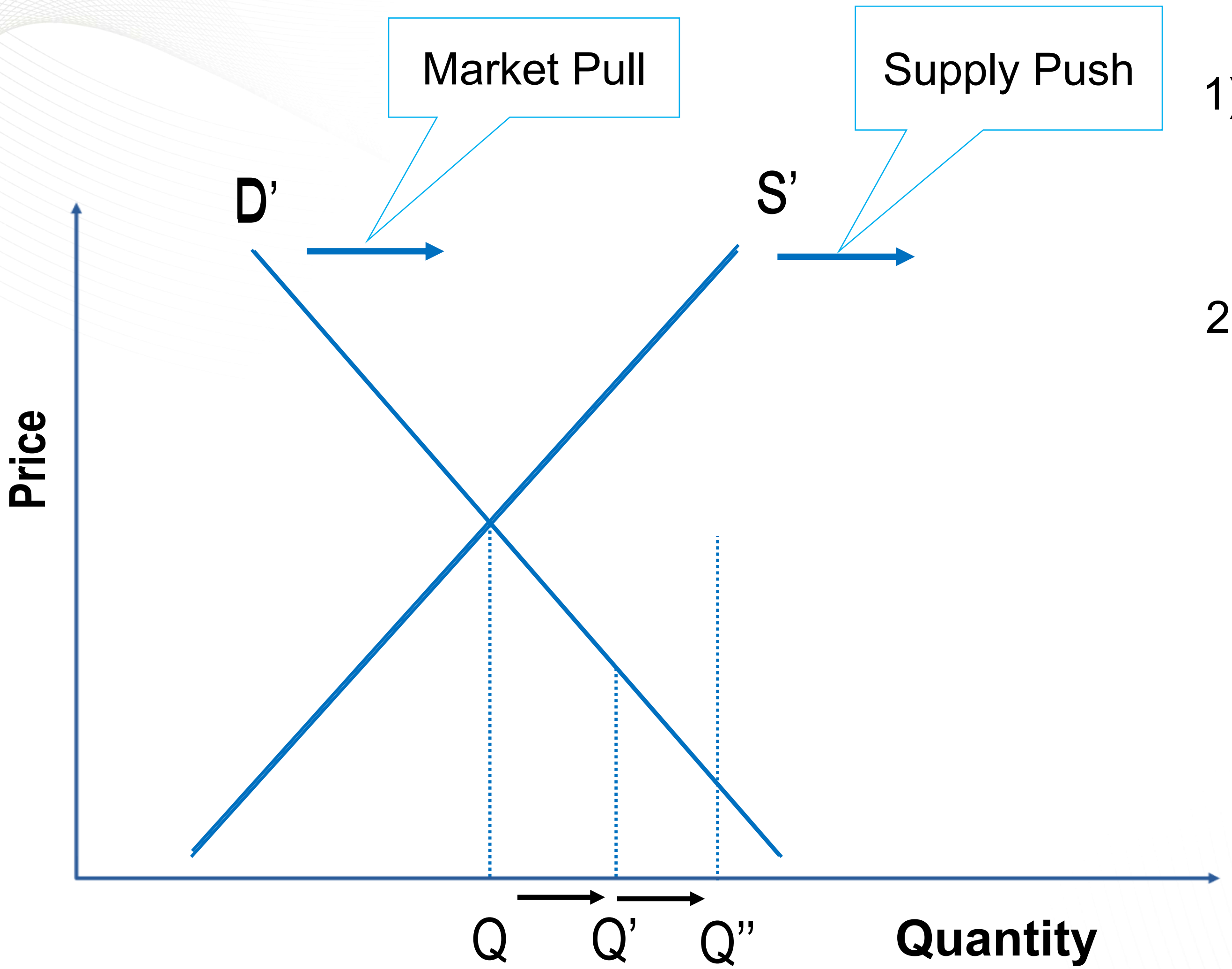


*Source: https://www.bioenergykdf.net/billionton2016/6/2/tableau

Aden, A., T. Foust, 2009. Technoeconomic analysis of the dilute sulfuric acid and enzymatic hydrolysis process for the conversion of corn stover to ethanol. Cellulose, 16:535-545.

Davis, R., Tao, L., E. Tan, M. Biddy, G. Beckman, C. Scarlata, J. Jacobson, K. Cafferty, J. Ross, J. Lukas, D. Knorr, P. Schoen. 2013. Process Design and Economics for the Conversion of Lignocellulosic Biomass to Hydrocarbons: Dilute-Acid and Enzymatic Deconstruction of Biomass to Sugars and Biological Conversion of Sugars to Hydrocarbons. NREL/TP-5100-60223.

5 – Future Work

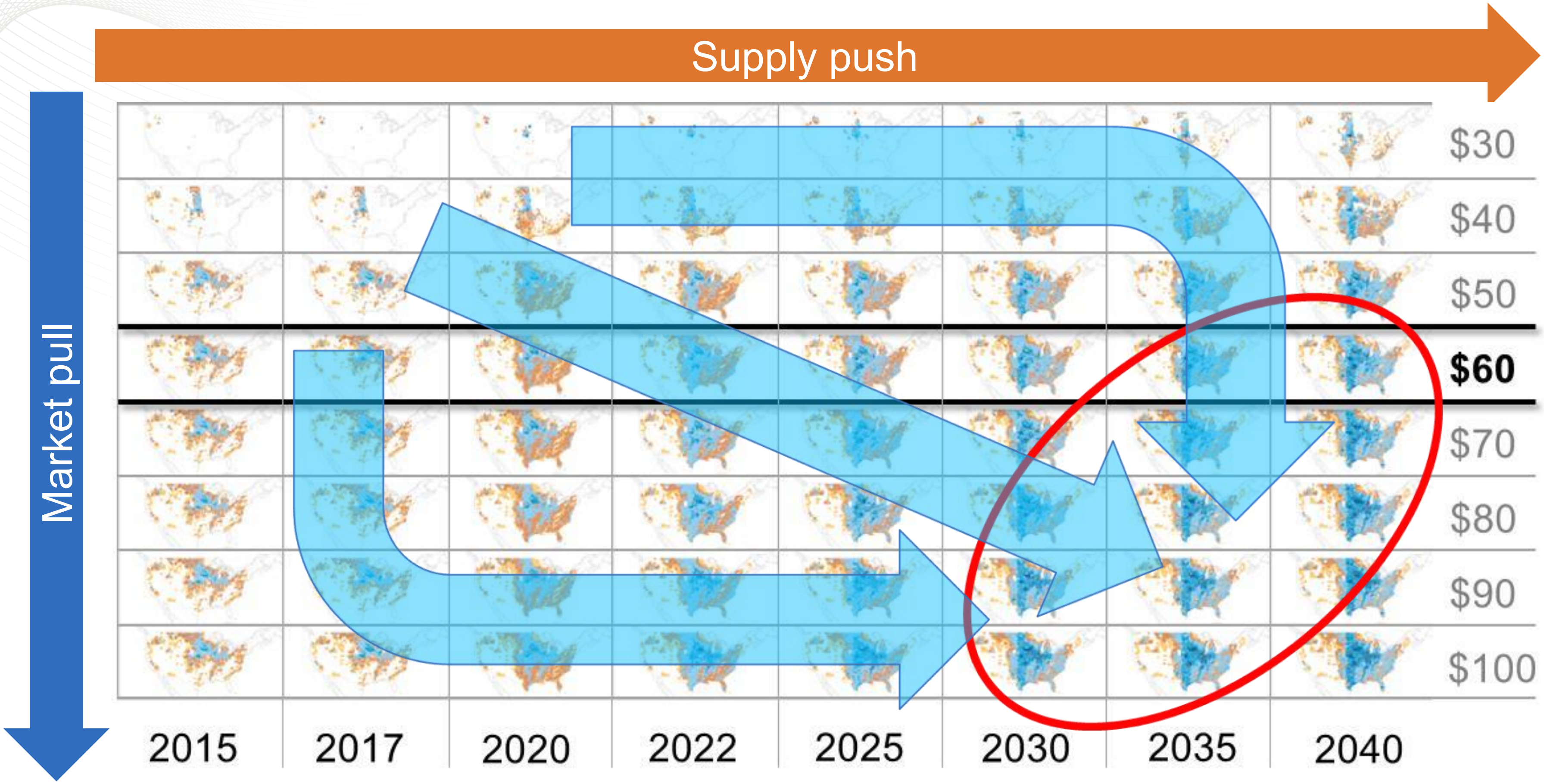


Future research:

1) Supply push
   a) Crop improvement
   b) Advanced logistics
   c) Precision agriculture

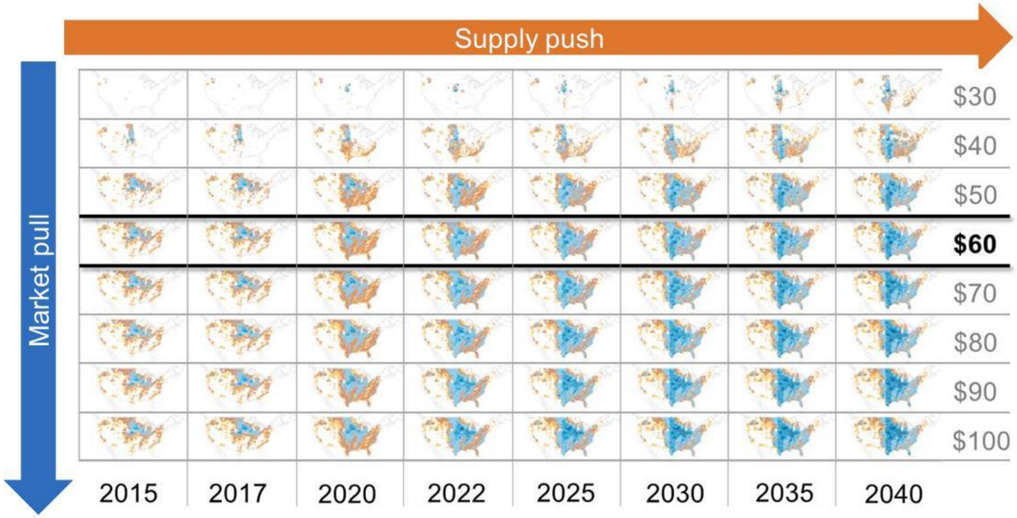
2) Market pull
   a) Conversion processes
   b) Commoditization
   c) Co-optimization
   d) Co-products
   e) Aviation biofuels
   f) International markets
   g) Policy impacts

5 – Future Work



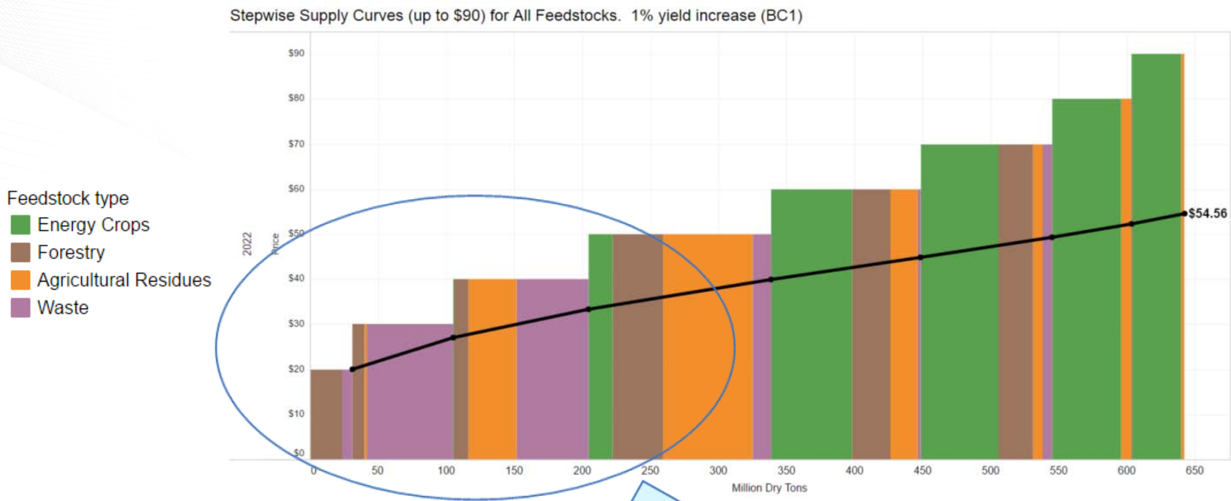
5 – Future Work

- Supply push
  - Quantify annual supply variability
  - Alternative supply scenarios
  - Oilseed crops
- Market pull
  - Spatially explicit demand runs
  - Market evolution
  - Custom assessments for design cases
  - Evaluate trade

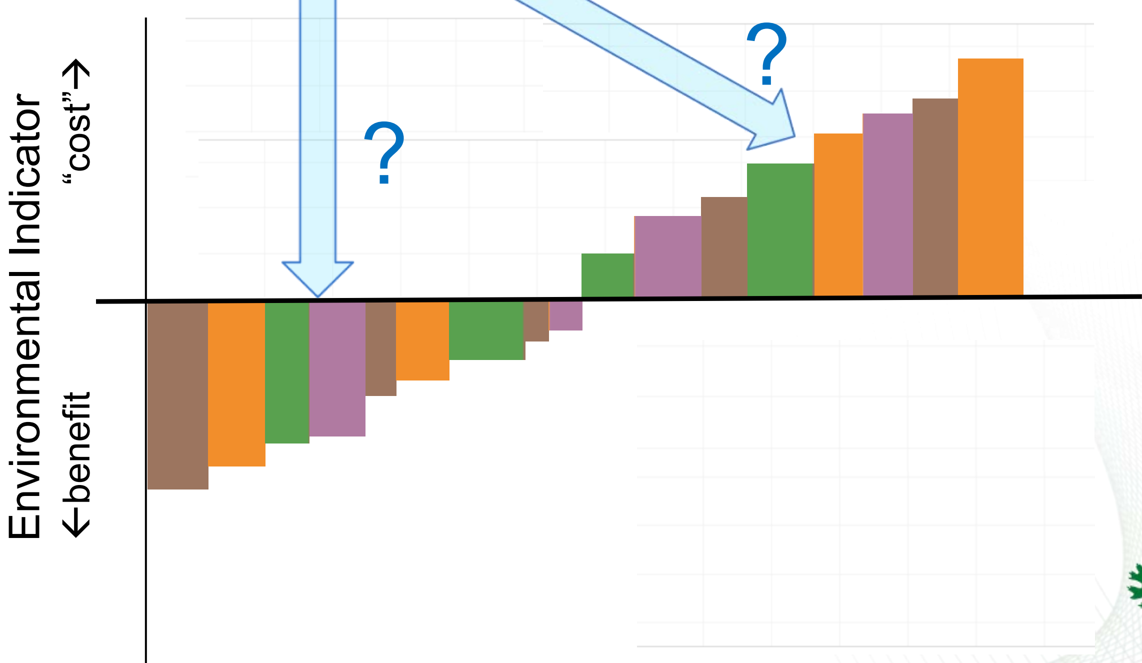


5 – Future Work

Economic availability of feedstocks (source https://www.bioenergykdf.net/billionton2016/1/9/tableau):



Environmental **availability of feedstocks (illustration):**



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Summary

1. Overview: Critical need for up-to-date information on feedstock supplies, prices, and environmental effects.
2. Approach: Improve established modeling approach, collaborate with other projects.
3. Technical Accomplishments/Progress/Results: *2016 Billion-Ton Report, Advancing Domestic Resources for a Thriving Bioeconomy*, volumes 1 and 2, and online companion material.
4. Relevance: Feedstock is about 1/3 of biofuels price. Supply information is needed.
5. Future work: Inform commercialization strategies.

Additional Slides

Responses to Previous Reviewers' Comments

- "The double cropping idea needs to be explored further as it may allow us to produce much more biomass more sustainably without additional acres." *We will evaluate inclusion of double cropping in future analyses.*
- "This is a critically important project that is well carried out. The way this information is characterized is very important to the project's credibility because real experiences in these early developmental days of the industry will not be consistent with this work." *It is important to characterize these supplies as potential, contingent upon demand, particularly for the energy crops.*
- "Good project and important level of analysis to get closer to potential delivered costs and supply curves." … "Excellent project. Well done, with high impact."

Publications, Patents, Presentations, Awards, and Commercialization

- U.S. Department of Energy. 2016. 2016 Billion-Ton Report: Advancing Domestic Resources for a Thriving Bioeconomy, Volume 1: Economic Availability of Feedstocks. M. H. Langholtz, B. J. Stokes, and L. M. Eaton (Leads), ORNL/TM-2016/160. Oak Ridge National Laboratory, Oak Ridge, TN. 448p. doi: 10.2172/1271651. http://energy.gov/eere/bioenergy/2016-billion-ton-report.

- U.S. Department of Energy. 2017. 2016 *Billion-Ton Report: Advancing Domestic Resources for a Thriving Bioeconomy, Volume 2: Environmental Sustainability Effects of Select Scenarios from Volume 1*. R. A. Efroymson, M. H. Langholtz, K.E. Johnson, and B. J. Stokes (Eds.), ORNL/TM-2016/727. Oak Ridge National Laboratory, Oak Ridge, TN. 642p. doi 10.2172/1338837

- Eaton, L., Langholtz, M.. "Life, Liberty, and the Pursuit of Biomass: The 2016 Billion-Ton Report Release Plenary". Bioenergy 2016: Mobilizing the bioeconomy through innovation. Washington, D.C., July 12th, 2016.

- Langholtz, M., Eaton, L., *Feedstocks for the Bioeconomy.* Advanced Biofuels Leadership Conference. Miami, Florida, June 6th 2016

- Davis, M. Eaton, L., Langholtz, M., Turhollow, A., Hellwinckel, C., Brandt., C., Hilliard, M. "At the Farmgate: Agricultural Residues and Biomass Energy Crops". ASABE 2016 Annual International Meeting. Orlando, FL. July 17th, 2016.

- Hellwinckel, C., Clark, C., Langholtz, M. and Eaton, L. (2016), Simulated impact of the renewable fuels standard on US Conservation Reserve Program enrollment and conversion. GCB Bioenergy, 8: 245–256. doi:10.1111/gcbb.12281

- Langholtz, M.. "The 2016 Billion-Ton Report, Towards a Thriving Bioeconomy". CRC LCA 2015 Workshop, Argonne, Illinois, USA, October 27th, 2015.