DOE Bioenergy Technologies Office (BETO) 2017 Project Peer Review

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

March 6, 2017
A&S Technology Area Review

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ORNL is managed by UT-Battelle
for the US Department of Energy

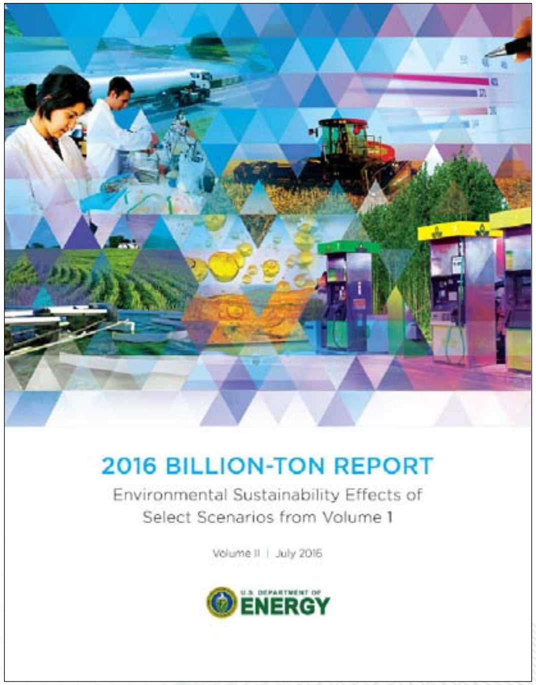
OAK RIDGE National Laboratory

Goal Statement

- Accelerate progress toward a more sustainable bioeconomy by investigating environmental effects associated with land management changes in select biomass production scenarios from the 2016 Billion-Ton (*BT16*) report, volume 1.
- Coordinate and deliver a high-quality, technically rigorous, and integrated set of analyses that are useful to a broad range of stakeholders.
- Provide an online resource to inform future R&D and facilitate efforts to enhance environmental benefits and minimize challenges.

Outcomes

- Stakeholder understanding of
  - Environmental benefits of national and county-level biomass potential in *BT16* volume 1
  - Regions and scenarios where modeled environmental effects raise concerns
- Facilitation of additional analysis
- Strategies to enhance environmental outcomes



Quad Chart Overview

Timeline

- Project start date: FY15
- Project end date: FY17
- Percent complete: 95% (as of end Feb 2017)

Barriers

- **St-B. Consistent and Science-Based Message on Bioenergy Sustainability**
- **St-D. Implementing Indicators and Methodology for Evaluating and Improving Sustainability**
- **St-G. Land-Use and Innovative Landscape Design**
- **Ft-A. Terrestrial Feedstock Availability and Cost**

Budget

	Costs (K)		
	FY 16	FY 17	FY 18 plan
	Contributions from several national lab projects (supported by A&S, FSL, and Algae), as well as USFS		

Partners

- National labs: ANL, NREL, PNNL
- USDA Forest Service
- (next slide)

Contributors to *BT16* Volume 2

Government	Academia	NGO	Industry
• Oak Ridge National Laboratory **(lead)** • Argonne National Lab • DOE/Bioenergy Technologies Office • National Renewable Energy Laboratory • Pacific Northwest National Laboratory • USDA Forest Service	• Oregon State University • University of Georgia • University of North Georgia • University of Tennessee • North Carolina State University	• Allegheny Science & Technology (AST) • National Council Air and Stream Improvement (NCASI)	• Monsanto • Weyerhaeuser Company

Thanks to all of our collaborators!

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Project Overview—Background

2016 Billion-Ton Report: Advancing Domestic Resources for a Thriving Bioeconomy: Volume 1. Economic Availability of Feedstocks

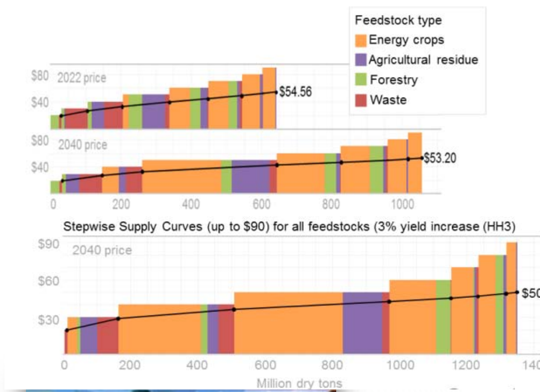
- Data: NASS Census of Agriculture, USDA Baseline Projections, Forest Inventory and Analysis, Sun Grant Initiative, and USFS Forest Products Lab

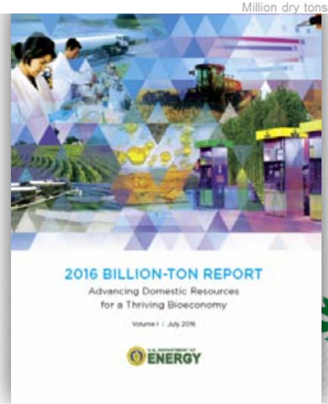
- Models: version of POLYSYS for agriculture and ForSEAM for forest resources, both operating at a county-level

Volume1: Economic Availability of Feedstocks

- Biomass Consumed in the Current Bioeconomy
- At the Roadside: Forest Resources
- At the Farmgate: Agricultural Resources
- Waste Resources
- To The Biorefinery: Delivered Resources
- Microalgae

Output: Feedstock Supply and Price Assessments





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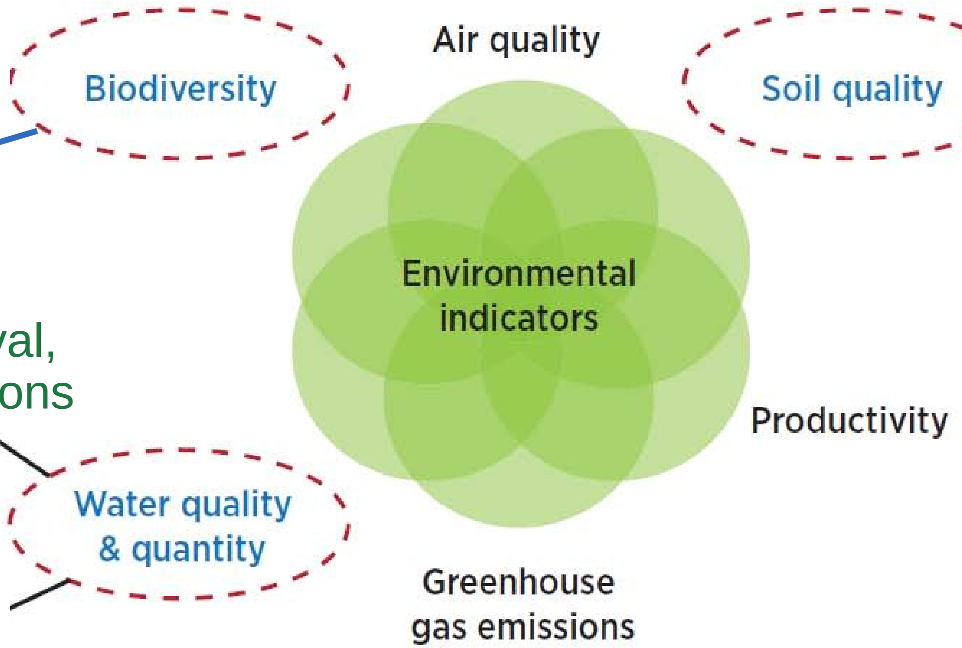
Project Overview—Background and Motivation

- Collaboration between the BETO feedstock and sustainability platforms is needed to move toward estimates of sustainable potential U.S. biomass supply
- Most constraints on supply in the Billion Ton reports are sustainability-related constraints.
- But environmental effects of potential biomass production scenarios have not been quantified.

Categories of indicators for which supply constraints were employed



Excluded areas

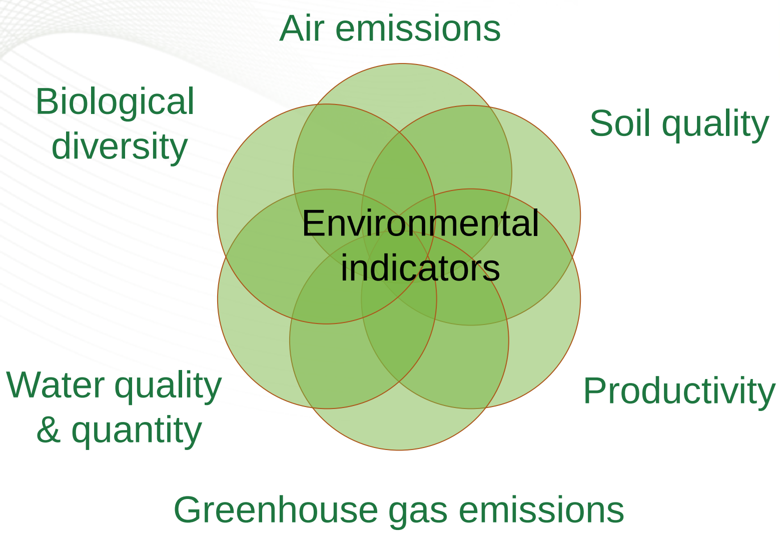
Residue removal, tillage assumptions, excluded areas (soil compaction)

Residue removal, tillage assumptions

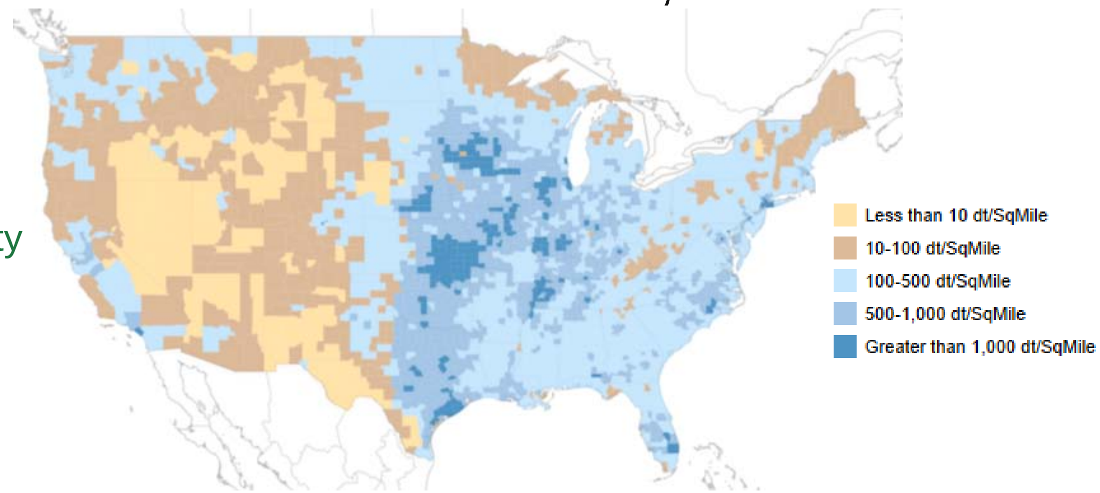
Precipitation-based irrigation constraint

view

Project Overview—Primary Objectives



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

Use national set of county-level output data from *BT16* volume 1 to

- Describe land management effects of agricultural and forestry scenarios that lead to environmental change
- Investigate greenhouse gas emissions, soil organic carbon, water quality and quantity, air emissions, and biodiversity
- Consider near-term (2017) and long-term (2040) effects.
- Consider base yield and high yield scenarios (2040).

Provide an extensive online resource to enable additional analyses.

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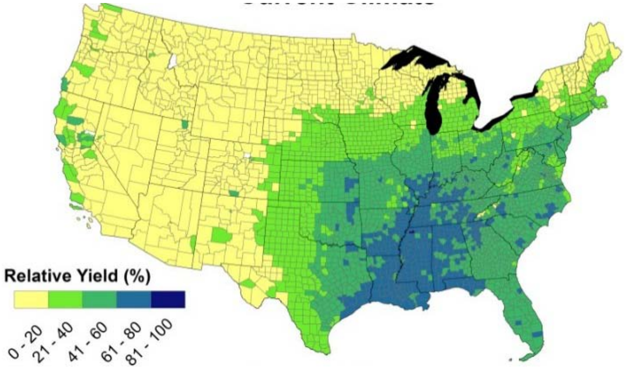
Project Overview—Additional Objectives

Land-use change

- Clarify land-use change (LUC) implications of *BT16* in light of model constraints and assumptions relative to other LUC studies

Sensitivity of energy crops to climate

- Simulate climate sensitivity of agricultural energy crop productivity



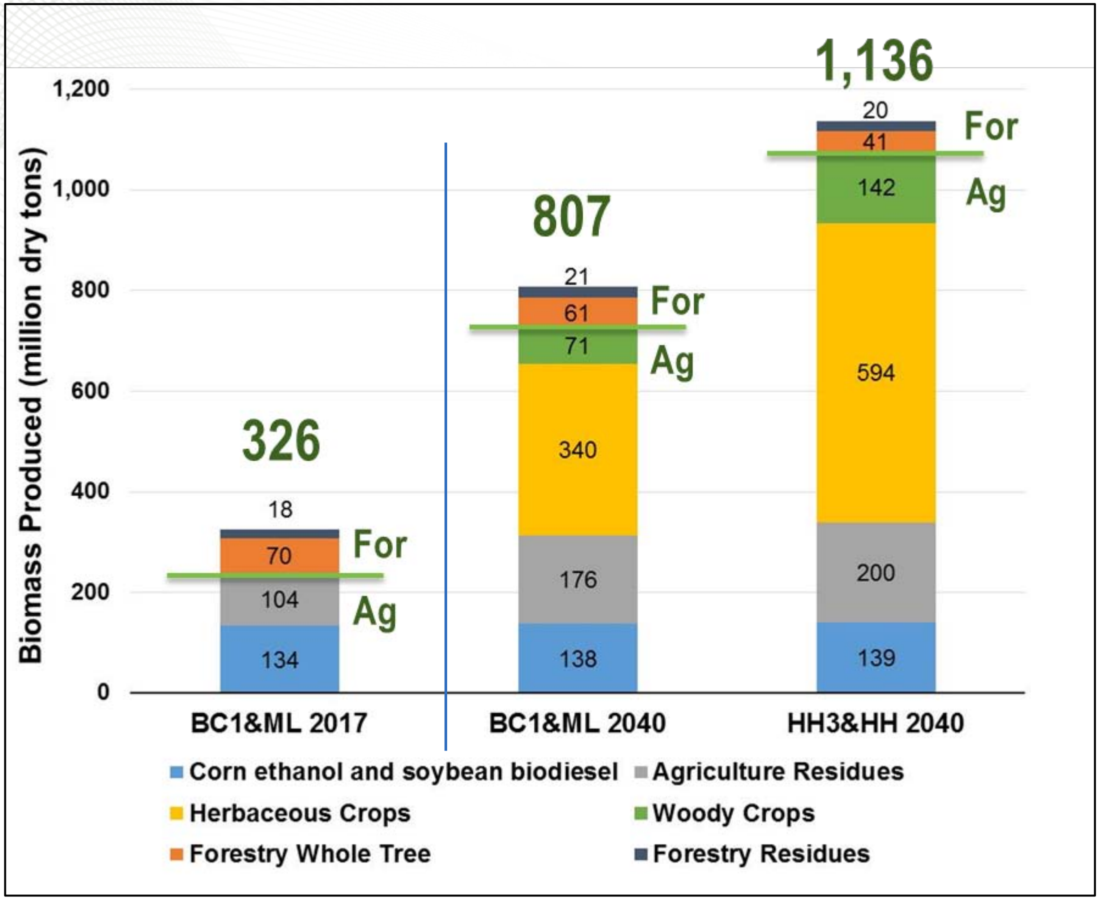
Microalgae

- Assess qualitative environmental effects of potential algae biomass production from *BT16* volume 1

Enhancing environmental outcomes

- Describe strategies for enhancing environmental benefits and minimizing concerns

Approach—Scenarios from *BT16* Volume 1

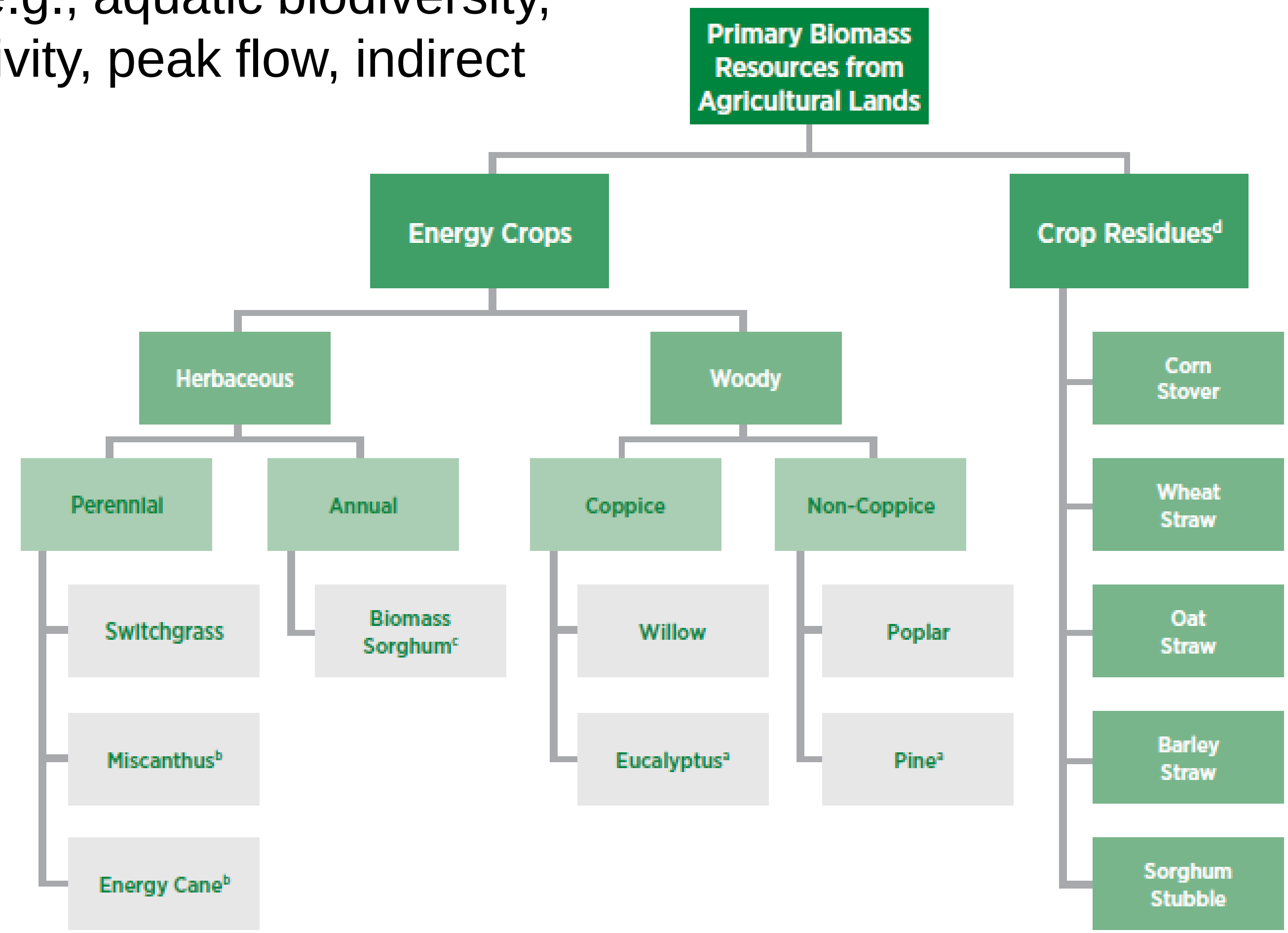


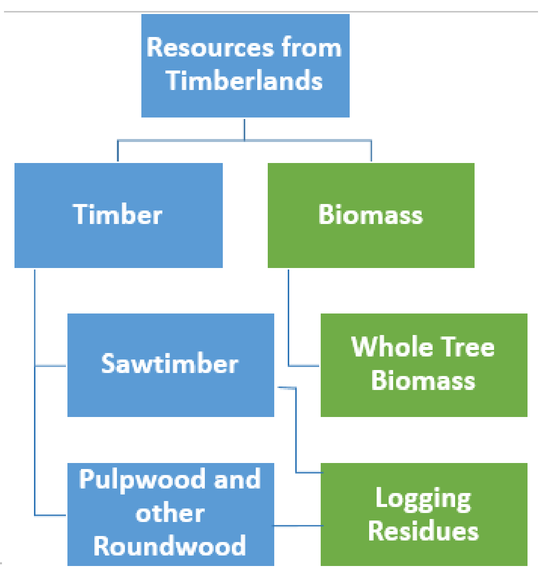
- Three specific scenarios selected to include
  - low- and a high-yield scenario
  - near-term and long-term estimates
- No business-as-usual comparison (modeling agricultural and forestry sectors outside scope)
- Additional reference cases in individual studies

	Agriculture (Ag)	Forestry (For)	Annual Yield Increase
2017	base case, BC1	baseline, ML	1%
2040	base case, BC1	baseline, ML	1%
2040	high yield, HH3	High housing, high wood energy, HH	3% (ag) or specified wood energy demand

Approach—Scope

- County-level inputs
- County-level outputs for most analyses
- Conterminous US extent for most outputs
- Many types of environmental effects, with some exceptions (e.g., aquatic biodiversity, ecosystem productivity, peak flow, indirect land-use change)





Approach—Environmental Indicators

	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

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

	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 emissions (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

Light orange—indicators in *BT16* volume 2

White—other BETO- and ORNL-recommended indicators

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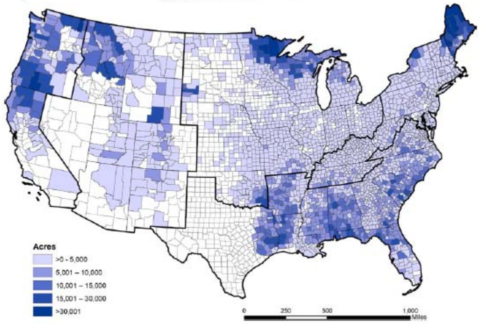
Approach—Models

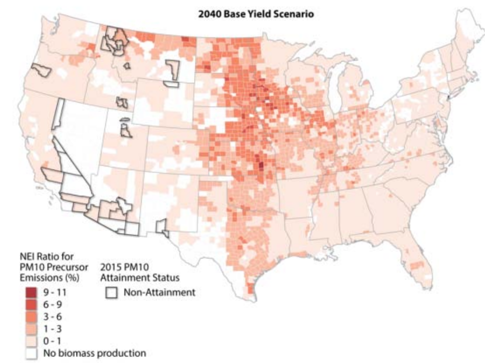
Land cover + management practices for scenarios



+ Equipment budgets for scenarios

+ Model-specific inputs (climate, land-use history, downscaled landscapes, habitat suitability, etc.)

1) Surrogate CENTURY Soil Organic Carbon model
2) Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model
3) Soil and Water Assessment Tool
4) Empirical water quality model for forest harvests
5) Water Supply Stress Index Model
6) WATER
7) Feedstock Production Emissions to Air Model
8) Bioenergy-biodiversity Estimation Modeling Framework
9) Habitat suitability framework



Environmental Effects

&

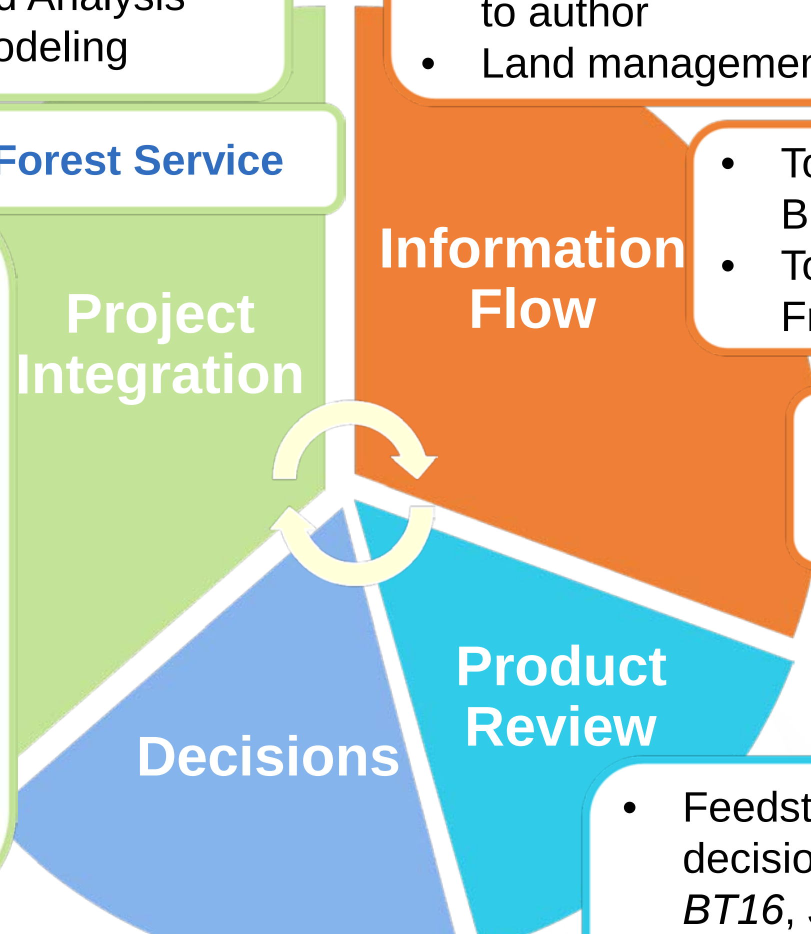
Comparisons among scenarios

Approach—Management

Billion-Ton volume 1 team
- Supply Forecasts and Analysis
- Feedstock Supply Modeling

USDA Forest Service

National lab projects
- GREET Development
- Biofuel Air Emissions Analysis
- Impact of Projected Biofuel Production on Water Use and Water Quality
- Forecasting Water Quality and Biodiversity
- Collaborations to Assess Land Effects of Bioenergy
- Bioenergy Knowledge Discovery Framework



- *BT16* volume 1 data to volume 2 authors
- New aggregations of data from author to author
- Land management analyses to authors

- To and from BETO and BCS
- To Knowledge Discovery Framework

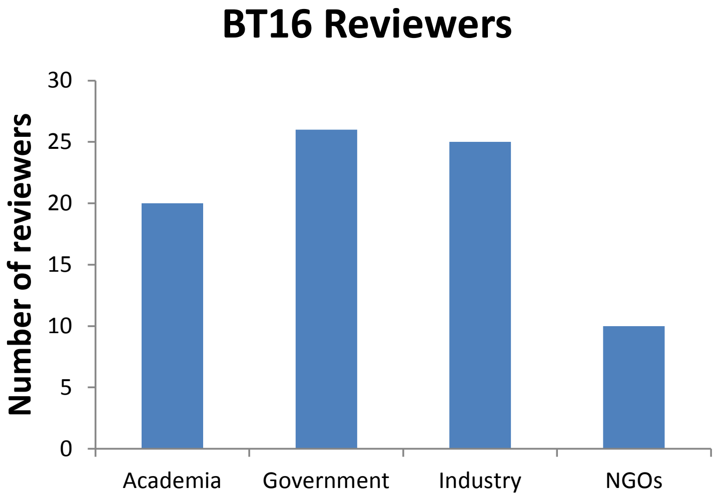
- Report, factsheets, and data from KDF to stakeholders

- Feedstock program go no-go decision to proceed with *BT16*, June 2015
- Peer-review workshops and report reviews
- DOE review

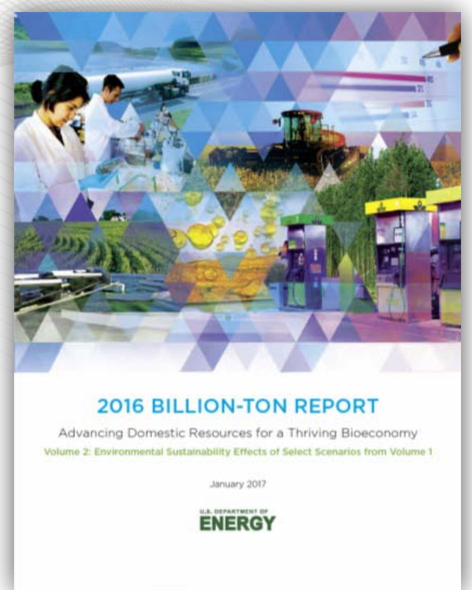
- Expansion of planned *BT16* environmental effects chapter to a volume with 14 chapters
- Scenario selection
- Selection of scope and contributors
- Future research priorities

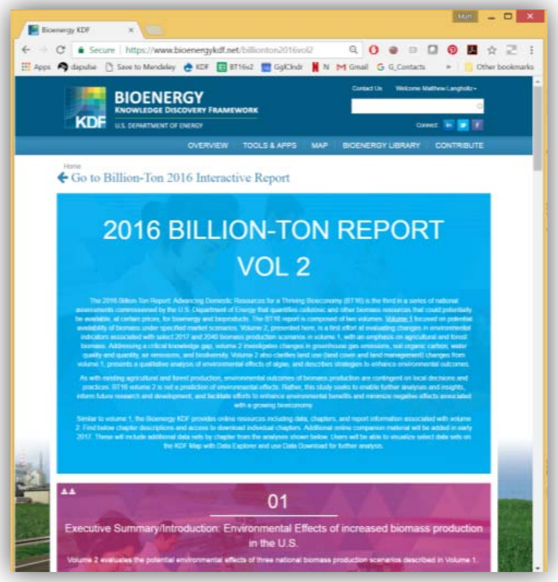
Approach—Review Process

- 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
  - Informal review of plans for *BT16* volume 2
- Workshop titled “Presentation and Expert Review of the 2016 Billion-Ton Report Volume 2” was held May 11, 2016, in Washington, D.C.
  - Focus on objectives and methods
  - 34 Institutions and 46 individuals
  - Representatives from government agencies (multiple divisions of EPA and USDA), academia, industry, NGOs
  - Breakout sessions for all chapters
- Written review of volume 2, July-Sept. 2016.
  - Review of entire chapters, including results and discussion
- DOE reviews, including Secretary Moniz



Results—*BT16* Volume 2 Report





This presentation emphasizes overarching results.
Individual investigators will describe results for the individual analyses.

https://www.bioenergykdf.net/billionton2016vol2

- 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

Results—*BT16* Volume 2 Chapters

Chapter 1	**Introduction**
Chapter 2	BT16 Feedstock Assessment Methods and Focal Scenarios
Chapter 3	Land Allocation and Management: Understanding Potential "Land-Use Change" (LUC) under BT16 Scenarios
Chapter 4	Fossil Energy Consumption and Greenhouse Gas Emissions, Including Soil Carbon Effects, of Producing Agriculture and Forestry Feedstocks
Chapter 5	Water Quality Response to Managing Agricultural Lands for Biomass Production in Two Tributary Basins Draining to the Mississippi River
Chapter 6	Water Quality Response to Forest Biomass Utilization
Chapter 7	Impacts of Forest Biomass Removal on Water Yield Across the United States
Chapter 8	Water Consumption Footprint of Producing Agriculture and Forestry Feedstocks
Chapter 9	Implication of Air Pollutant Emissions from Producing Agricultural and Forestry Feedstocks
Chapter 10	Simulated Response of Avian Biodiversity to Biomass Production
Chapter 11	Forest Biodiversity and Woody Biomass Harvesting
Chapter 12	Qualitative Analysis of Environmental Effects of Algae Production
Chapter 13	Climate Sensitivity of Agricultural Feedstock Productivity
Chapter 14	Summary, Interpretation, and Strategies to Enhance Environmental Outcomes

Results—High-level

- The principal land management change is a transition of some agricultural acreage from annual cover to perennial cover (2015 ag baseline to BC12040 scenario).
- Environmental effects vary by location, biomass type, and previous land management, with several general findings:
  - In some contexts, potential challenges or tradeoffs for water quality management, water quantity, and air emissions, all of which would benefit from further research and technological improvements.
  - For most counties, potential for a substantial increase in biomass production with negligible or manageable effects on water quality, water quantity, and air pollutant emissions.
  - Biodiversity effects dependent on species and location, with possible benefits to richness and range for some species and potential adverse impacts to others that may require additional safeguards.
  - Favorable performance of cellulosic biomass relative to conventional feedstocks in terms of soil organic carbon, GHG emissions, air emissions, and water quantity.
- Future research, science-based monitoring, and adaptive management are needed to enhance benefits while mitigating potential negative effects.

Numerous strategies are available to enhance environmental outcomes (chapter 14)

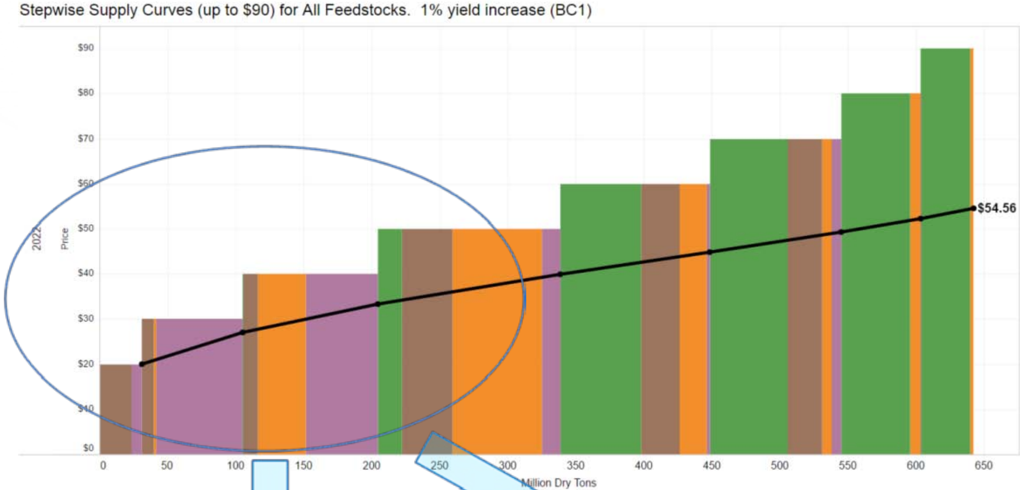
- Ch 14 provides a broad perspective on synthesis and interpretation of results.
- Ch 14 provides strategies to enhance environmental outcomes.
  - Supply constraints (e.g., restricting areas on which bioenergy crops may be grown or residues may be collected).
  - Best management practices.
  - Landscape design.
  - Precision agriculture with subfield management and GPS technology.
  - Multipurpose biomass production and harvesting (mineland reclamation, phytoremediation, biomass removal at wildland-urban interface, waste treatment and algae production).
  - Monetary strategies (ecosystem valuation).
  - Understanding and informing farmer or forester choices.

- Ch 14 provides a summary of needs—for field data, reducing model uncertainties, and developing mitigation approaches.

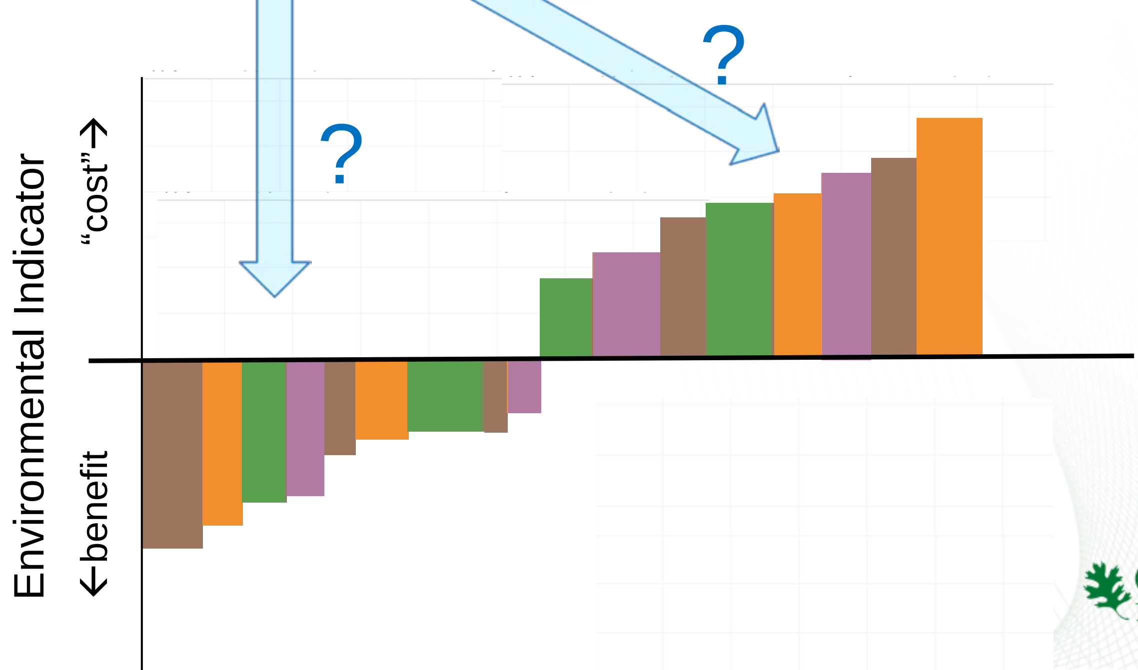
Future Work—Determine environmental effects of the least-cost biomass

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

Feedstock type
- Energy Crops
- Forestry
- Agricultural Residues
- Waste



Environmental effects of biomass (illustration)



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Future Work—Conduct additional integrated analyses

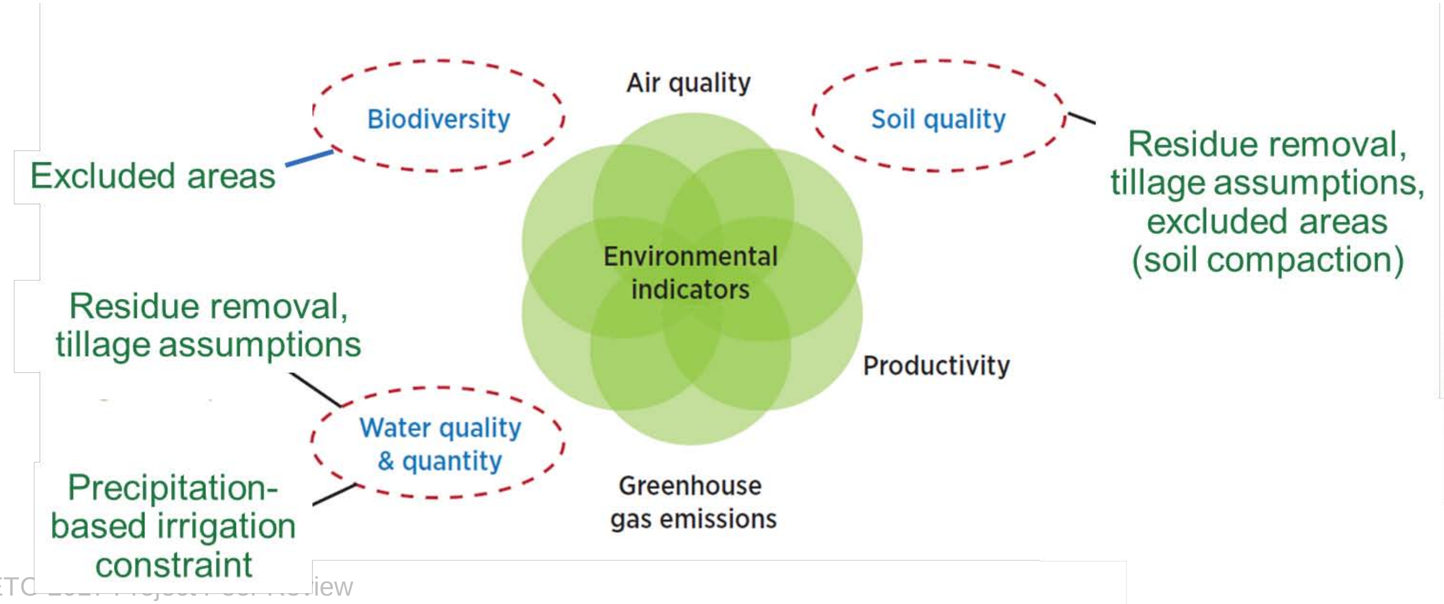
Conduct targeted analyses and enable others to conduct analyses using the large database from this project.

- Identify common drivers of multiple environmental effects.
- Determine tradeoffs among environmental indicators in particular locations.
- Understand land transitions that are beneficial for most indicators (annual to perennial?).
- Conduct sensitivity analyses for biomass-related inputs (e.g., management practices, feedstocks).
- Develop best practices that can reduce multiple negative environmental effects.
- Measure and model social and economic indicators.

Future Work—Identify additional supply constraints that could improve environmental indicators in future national resource analyses

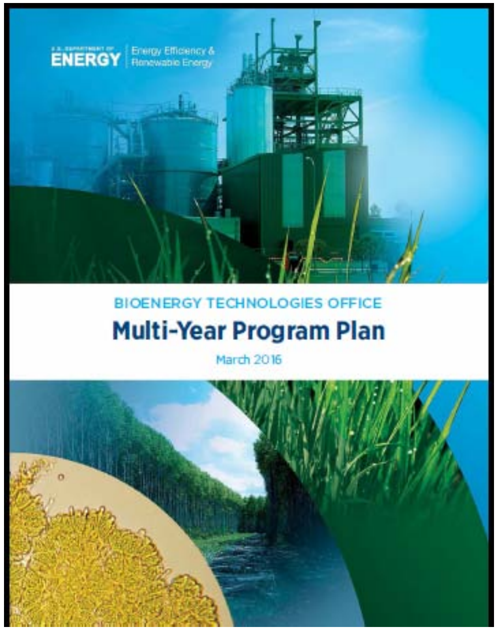
Examples of excluded areas and best practices

- Exclude water-stressed areas.
- Exclude areas of air quality concern, e.g., nonattainment counties (except where biomass would replace land corn grain or other higher emitting activities).
- Assume the use of more efficient equipment or equipment requiring fewer passes.
- Implement wildlife-friendly practices, such as timing of harvest and raising height of mowing equipment.
- Assume the use of cover crops and riparian buffers.



Relevance of Project Goals to BETO Goals

- BT16 volume 2 is a first effort to reduce a critical knowledge gap—i.e., understanding the environmental effects of national biomass potential.



Relevant to DOE/BETO Sustainability Area goals

- To understand and promote positive economic, social, and environmental effects and reduce potential negative impacts of bioenergy production

Multi-year Program Plan 2016 Milestone

- 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.

Additional Slides

Contributors

Project Leads and Editors: Rebecca Efroymson, Matthew Langholtz, Kristen Johnson, Bryce Stokes

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BT16 Feedstock Assessment Methods and Focal Scenarios
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Bryce Stokes, Allegheny Science & Technology
Chad Hellwinckel, University of Tennessee

Land-use Change (LUC)
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Jennifer Dunn, ANL

Greenhouse Gas Emissions and Soil Organic Carbon
Christina Canter, Zhangcai Qin, Hao Cai, Jennifer Dunn, Michael Wang, ANL
D. Andrew Scott, USFS

Water Quality-Agriculture
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Water Quality-Forestry
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Sudhanshu Panda, Univ of North Georgia

Water Quantity-Forestry
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Water Footprint
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Air Quality
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Molly Pattullo, University of Tennessee

Climate Change Sensitivity
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Synthesis, Interpretation, and Strategies to Enhance Environmental Outcomes
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Kristen Johnson, DOE
Cristina Negri, ANL
Kristen Johnson, DOE
Ian Bonner, Monsanto

Knowledge Discovery Framework and Visualization
Aaron Myers, Mike Hilliard, ORNL

- No comments on this task were received from DOE/BETO Feedstock platform at 2015 peer review

Reviewers of BT16 Volume 2

Government	Academia	Non-Government Organizations	Industry
• EPA/OTAQ • EPA/ORD • EPA/Water • EPA/Climate Change Division • USDA/ARS • USDA/NIFA • USDA Office of Energy Policy and New Uses • USDA Forest Service Forest Products Laboratory • Argonne National Lab • Texas Parks & Wildlife Dept	• Drexel Univ • Iowa State Univ • Michigan Tech • Ohio Univ • NC State • Penn State • SUNY College of Environmental Science and Forestry • Texas Tech Univ • UC Berkeley • UC Davis • U Idaho • U Washington	• American Tree Farm System • Environmental Defense Fund • EPRI • Field to Market • NCASI • The Nature Conservancy	• Global Algae Innovations • Joule Unlimited • Resource Management Services • Algae Biomass Organization