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

2016 Billion-Ton Report Volume 2

BETO Peer Review

March 7, 2017

Kristen Johnson

Technology Manager

Analysis & Sustainability

Bioenergy Technologies Office

Department of Energy

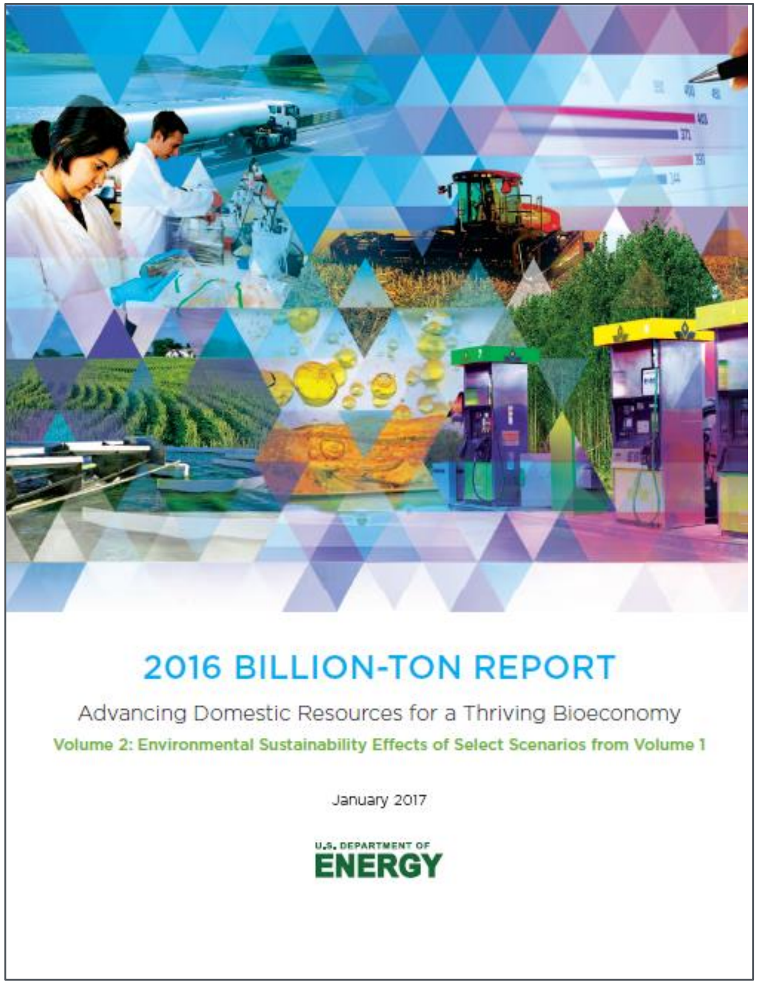
Not for Public Distribution

Importance of *BT16* volume 2

- Previous Billion-Ton studies focus on quantifying potential biomass supplies.

- Volume 2 is a first effort to address a critical knowledge gap about potential environmental implications.

- Volume 2 provides an extensive online resource to enable additional analyses and inform future R&D.

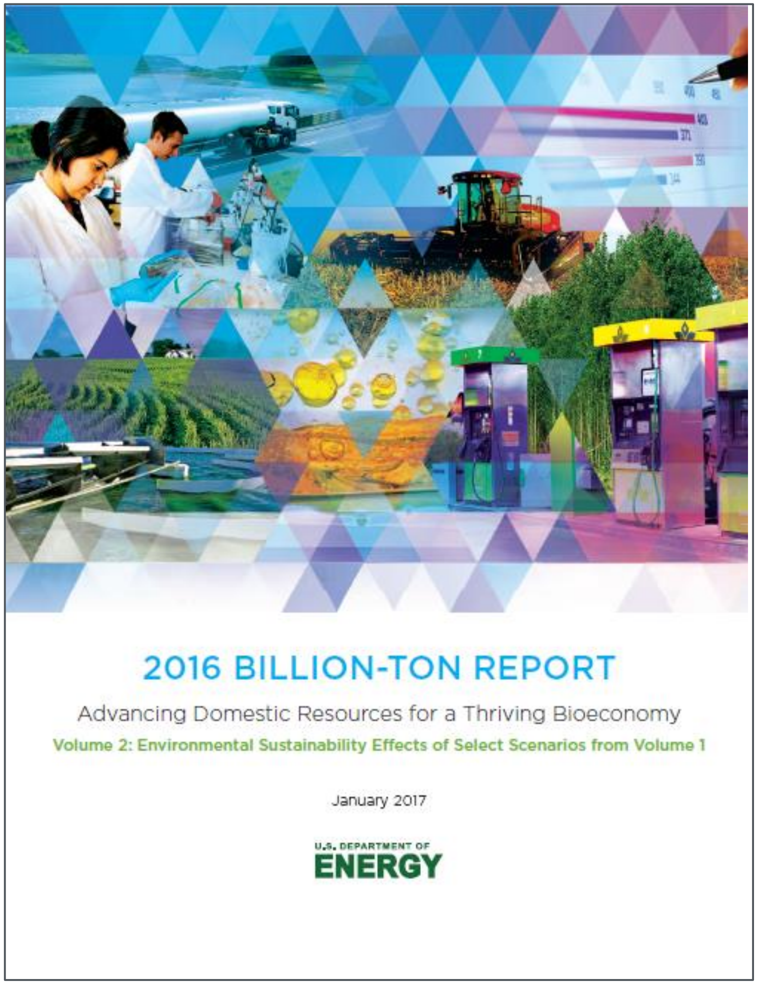


Primary Objectives of *BT16* volume 2

- Assess potential environmental effects of land-management changes in select 2017 and 2040 agricultural and forestry scenarios simulated in *BT16* volume 1 (focusing on residues, energy crops, and forest biomass).

- Identify actions and research that could enhance the benefits while minimizing potential negative impacts with respect to environmental indicators.

BT16 volume 2 Outline



***Released: January 13, 2017**

Volume 2

- Land Allocation and Management
- Greenhouse Gas Emissions (Agriculture and Forestry)
- Water Quality, Water Quantity, Water Consumption Footprint (Agriculture and Forestry)
- Biodiversity (Agriculture and Forestry)
- Air Emissions (Agriculture and Forestry)
- Qualitative Analysis of Environmental Effects of Algae Production
- Climate Sensitivity of Agricultural Feedstock Productivity
- Strategies to Enhance Environmental Outcomes

Contributors to *BT16* volume 2

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

USDOE Bioenergy Technologies Office

Kristen Johnson, Mark Elless, Alison Goss Eng

Biomass and Other Input Data

Craig Brandt, Matthew Langholtz, Laurence Eaton, Maggie Davis, Erin Webb, ORNL

Bryce Stokes, Allegheny Science & Technology

Water Quality and Quantity

Henriette Jager, Latha Baskaran, Jasmine Kreig, Craig Brandt, Mike Hilliard, ORNL

May Wu, Miae Ha, Sashi Yalamenchili, ANL

Ge Sun, Benjamin Rau, Carl Trettin, Liangxia Zhang, Devendra Amatya, USFS

Kai Duan, NC State University

Augustine Muwamba, Ernest Tollner, U Georgia

Sudhanshu Panda, Univ of North Georgia

Greenhouse Gas Emissions and Soil Organic Carbon

Christina Canter, Zhangcai Qin, Hao Cai, Jennifer Dunn, Michael Wang, ANL

D. Andrew Scott, USFS

Air Emissions

Ethan Warner, Yimin Zhang, Annika Eberle, Dylan Hettinger, Daniel Inman, Garvin Heath, NREL

Biodiversity

Henriette Jager, Gangsheng Wang, Nathan Sutton, Jasmine Kreig, Ingrid Busch, Mark Bevelhimer, ORNL
Deahn Donner-Wright, USFS
Darren Miller, Weyerhaeuser Company
Bently Wigley, NCASI

Land-use Change (LUC)

Keith Kline, Maggie Davis, Laurence Eaton, ORNL
Jennifer Dunn, ANL

Climate Change Impacts on Feedstock Productivity

Ben Preston, Matt Langholtz, Laurence Eaton, ORNL
Chris Daly, Mike Halbleib, Oregon State University

Algae

Rebecca Efroymson, Matt Langholtz, Melanie Mayes, Molly Pattullo, ORNL
André Coleman, Mark Wigmosta, PNNL

Discussion and Enhancing Environmental Outcomes

Rebecca Efroymson, Matt Langholtz, Anthony Turhollow, Keith Kline, ORNL
Cristina Negri, ANL
Kristen Johnson, DOE
Ian Bonner, Monsanto

Knowledge Discovery Framework and Visualization

Aaron Myers, Mike Hilliard, ORNL

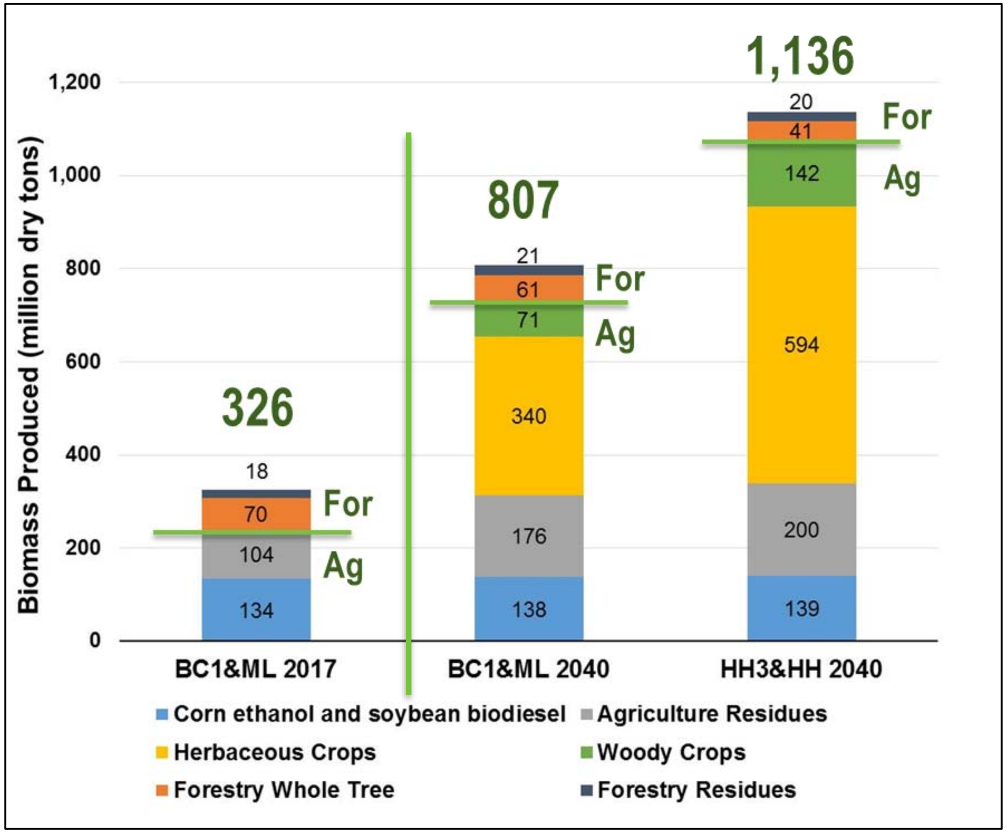
Reviewers of *BT16* Volume 2

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 • North Carolina 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

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

Approach: Supply Scenarios Analyzed in *BT16* volume 2

- Three specific scenarios from *BT16* volume 1 were selected to include a low- and a high-yield scenario and near-term and long-term estimates.
- Volume 2 analyses do not include waste. With waste included, the 2040 scenarios equate to 1.2 and 1.5 billion dry tons, respectively.



	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

Models Used in BT16 volume 2

Indicator Category	Biomass Category	Model
Soil quality	Agricultural	Surrogate CENTURY Soil Organic Carbon model
GHGs	Agricultural & Forestry	Greenhouse gases, Regulated Emissions, and Energy use in Transportation Model (GREET)
Water quality	Agricultural	Soil and Water Assessment Tool (SWAT)
	Forestry	Empirical model
Water quantity	Forestry	Water Supply Stress Index (WaSSI) Ecosystem Services Model
	Agricultural & Forestry	Water Analysis Tool for Energy Resources (WATER)
Air emissions	Agricultural & Forestry	Feedstock Production Emissions to Air Model (FPEAM)
Biodiversity	Agricultural	Species distribution model, Bio-EST
	Forestry	Habitat suitability framework

Inputs and most outputs are at the county level.

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

High-Level Conclusions of BT16 volume 2

- Environmental effects vary by location, biomass type, and previous land management:
  - In some contexts, potential challenges for water quality, water quantity, and air quality.
  - 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.
  - Potential for deep-rooted, high-yielding energy crops to contribute to soil organic carbon gains; some transitions lead to organic carbon losses.
  - Biodiversity effects dependent on species and location, with possible increases in 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 is needed.

Illustrating Key Results from Select Chapters

(Land use, GHG emissions, and water quantity)

Chapter 3 – Land Allocation and Management

Objective

- Clarify land-use change (LUC) implications of the *BT16* scenarios analyzed in volume 2

Major Modeling Assumptions

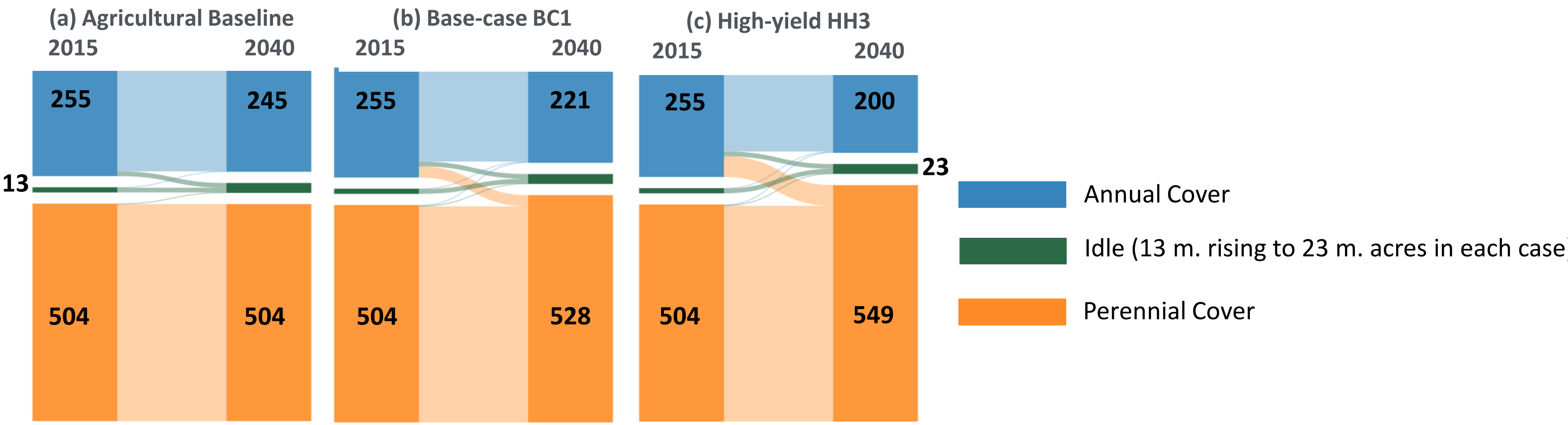
- *BT16* held forest and agriculture lands constant.
- Primary LUC implied in *BT16* involves change in agricult land management.

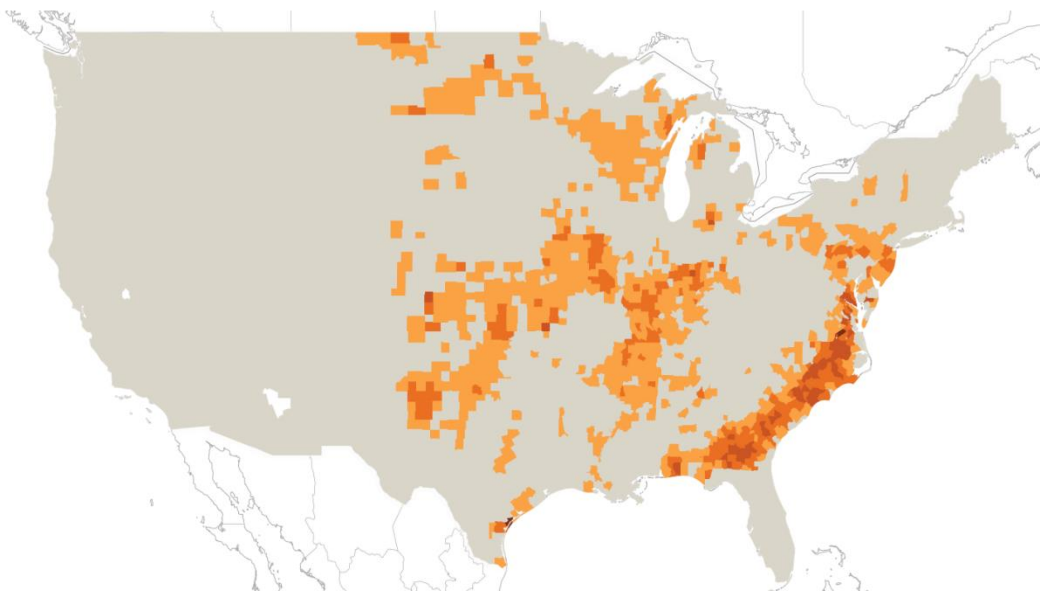
Main Findings

- 24 million (in BC1 2040) or 45 million acres (in HH3 2040) of cropland transitions from annual to perennial cover, about 8% or 15%, respectively—compared to USDA 2015 baseline.
- 37 million (in BC1 2040) or 39 million acres (in HH3 2040), or about 8% of total pasture area in USDA 2015 baseline would undergo changes in management for energy crops.

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

Chapter 3 – Land Allocation and Management





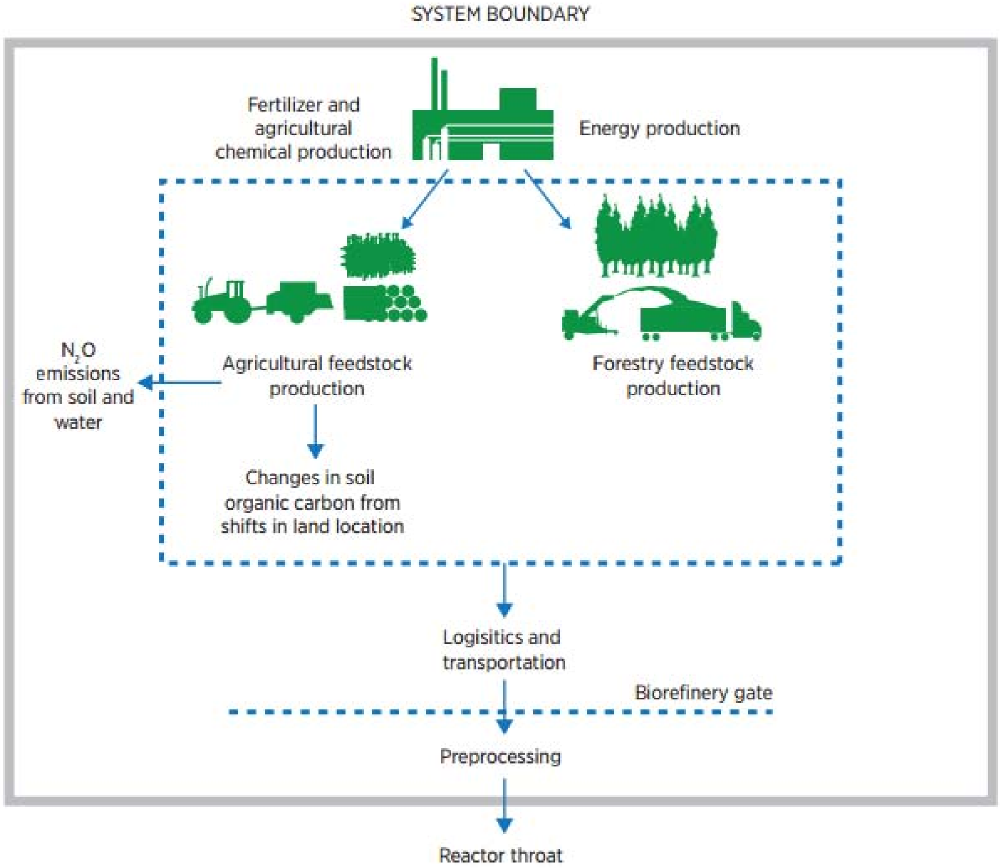
Geospatial distribution of changes in perennial cover under the base-case (BC1) 2040 scenario

- > 35% change
- > 25% change
- > 15% change
- > 5% change
- Less than 5% change or less than 1000 acres perennial

Chapter 4 – GHGs and Soil Organic Carbon

Objectives

- Estimate fossil energy consumption and GHG emissions associated with producing biomass.
- Consider the contribution of changes in soil carbon to net GHG emissions.
- Include illustrative estimates of GHG reductions when biomass is converted to biofuel, bioproducts, and biopower (from Rogers et al. (2016)).



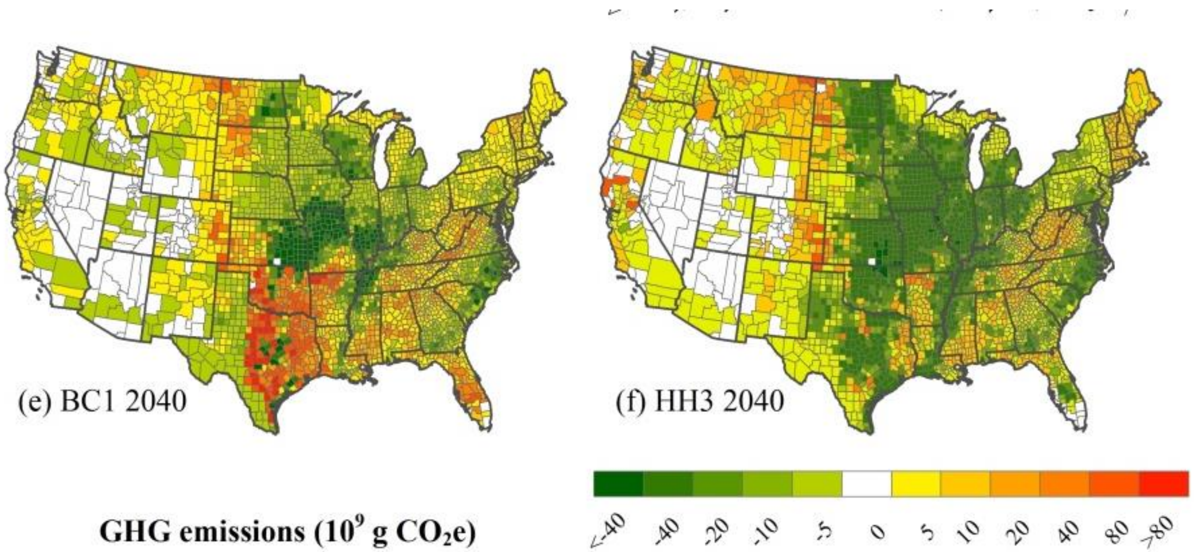
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Chapter 4 – GHGs and Soil Organic Carbon

Key Results

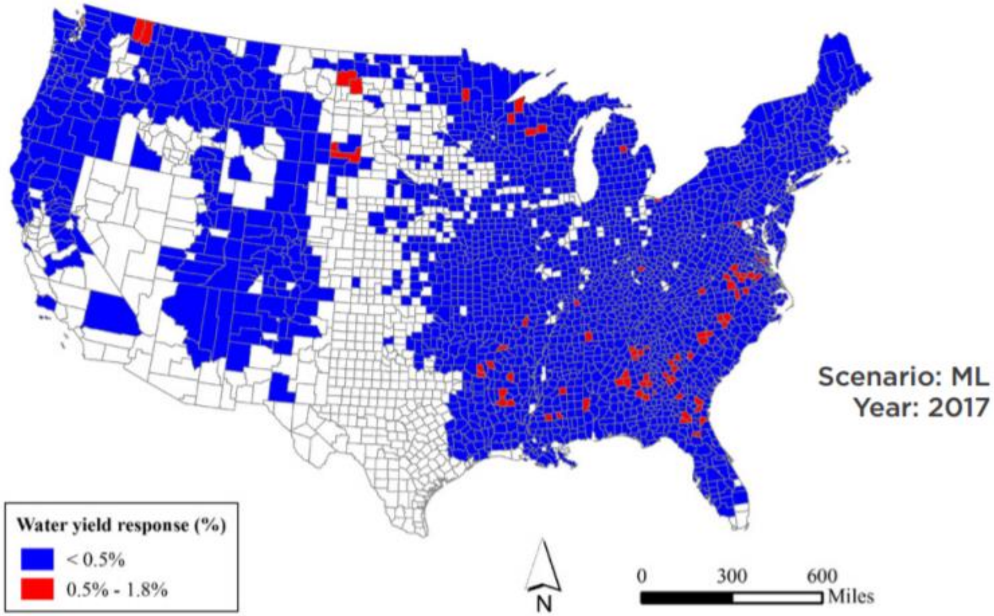
- Key drivers were preprocessing in advanced logistics operations in 2040 and soil organic carbon changes.
- Deep-rooted, high-yielding feedstocks have significant potential to contribute to soil organic carbon gains; however, some transitions may lead to organic carbon losses.

County-level SOC changes highly dependent on yield, local soil characteristics, and weather



Chapter 7 – Water Quantity (Forestry)

Objective
Investigate how forest-harvesting scenarios affect mean seasonal and annual water yield at the county level.



WaSSI modeled response of mean annual water yield to ML 2017 harvesting scenario (relative response by percentage). Of the scenarios, ML 2017 represents the greatest hydrological disturbance related to forest biomass.

Results

- Small magnitude of hydrological response to biomass removal may not have much significance, positive or negative, in terms of county-level water supply.
- However, concentrated biomass-removal activities may cause substantial local impacts on watershed hydrology, such as increasing stormflow volume and potentially causing water-quality concerns.

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

Chapter 14 – Enhancing Environmental Outcomes

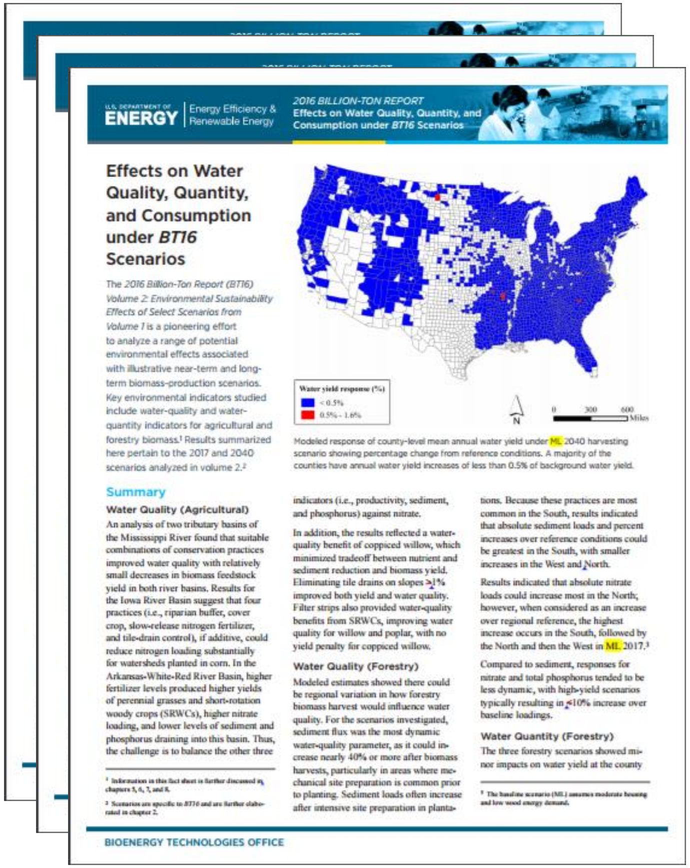
- A broad perspective on synthesis and interpretation of results
- Strategies to enhance environmental outcomes
  - Best management practices
  - Landscape design
  - Precision agriculture with subfield management and GPS technology
  - Multipurpose biomass production and harvesting
- Summary of gaps/needs
  - Field data
  - Reducing model uncertainties
  - Developing mitigation approaches

Coming Soon

- Fact-sheets
  - Overview of *2016 Billion-Ton Report, Volume 2*
  - Land-Use Change Implications
  - Effects on Air Emissions
  - Effects on Water Quality, Quantity, and Consumption
  - Effects on Biodiversity
  - Effects of Algae Production

- Virtual Symposium
  - Presentations on each chapter
  - Q&A
  - Hosted on the Bioenergy KDF: https://bioenergykdf.net
  - **Register for a KDF account to receive news blast with details.**

- Data Sets
  - Available on Bioenergy KDF
  - https://bioenergykdf.net/billionton2016vol2



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

2016 BILLION-TON REPORT
Effects on Water Quality, Quantity, and Consumption under *BT16* Scenarios

Effects on Water Quality, Quantity, and Consumption under *BT16* Scenarios

The *2016 Billion-Ton Report (BT16) Volume 2: Environmental Sustainability Effects of Select Scenarios from Volume 1* is a pioneering effort to analyze a range of potential environmental effects associated with illustrative near-term and long-term biomass-production scenarios. Key environmental indicators studied include water-quality and water-quantity indicators for agricultural and forestry biomass.[1] Results summarized here pertain to the 2017 and 2040 scenarios analyzed in volume 2.[2]

Modeled response of county-level mean annual water yield under ML 2040 harvesting scenario showing percentage change from reference conditions. A majority of the counties have annual water yield increases of less than 0.5% of background water yield.

Summary

Water Quality (Agricultural)

An analysis of two tributary basins of the Mississippi River found that suitable combinations of conservation practices improved water quality with relatively small decreases in biomass feedstock yield in both river basins. Results for the Iowa River Basin suggest that four practices (i.e., riparian buffer, cover crop, slow-release nitrogen fertilizer, and tile-drain control), if additive, could reduce nitrogen loading substantially for watersheds planted in corn. In the Arkansas-White-Red River Basin, higher fertilizer levels produced higher yields of perennial grasses and short-rotation woody crops (SRWCs), higher nitrate loading, and lower levels of sediment and phosphorus draining into this basin. Thus, the challenge is to balance the other three indicators (i.e., productivity, sediment, and phosphorus) against nitrate.

In addition, the results reflected a water-quality benefit of coppiced willow, which minimized tradeoff between nutrient and sediment reduction and biomass yield. Eliminating tile drains on slopes ≥1% improved both yield and water quality. Filter strips also provided water-quality benefits from SRWCs, improving water quality for willow and poplar, with no yield penalty for coppiced willow.

Water Quality (Forestry)

Modeled estimates showed there could be regional variation in how forestry biomass harvest would influence water quality. For the scenarios investigated, sediment flux was the most dynamic water-quality parameter, as it could increase nearly 40% or more after biomass harvests, particularly in areas where mechanical site preparation is common prior to planting. Sediment loads often increase after intensive site preparation in plantations. Because these practices are most common in the South, results indicated that absolute sediment loads and percent increases over reference conditions could be greatest in the South, with smaller increases in the West and North.

Results indicated that absolute nitrate loads could increase most in the North; however, when considered as an increase over regional reference, the highest increase occurs in the South, followed by the North and then the West in ML 2017.[3]

Compared to sediment, responses for nitrate and total phosphorus tended to be less dynamic, with high-yield scenarios typically resulting in ≤10% increase over baseline loadings.

Water Quantity (Forestry)

The three forestry scenarios showed minor impacts on water yield at the county

[1] Information in this fact sheet is further discussed in chapters 5, 6, 7, and 8.

[2] Scenarios are specific to *BT16* and are further elaborated in chapter 2.

[3] The baseline scenario (ML) assumes moderate housing and low wood energy demand.

BIOENERGY TECHNOLOGIES OFFICE

Thank You

For more information on BT16 Volume 2, visit:

https://bioenergykdf.net

Appendix

Addressing Challenges (Examples)

	Example Mitigation Strategies and Future Research
Water quality	• Further development and testing of conservation practices (e.g., riparian buffer, cover crops) could achieve a win-win situation in which biomass production helps to reduce downstream nutrient loadings. • Continued adherence to and increased adoption of forest best management practices should minimize biomass-harvest impacts; however, additional field-scale empirical studies are needed to measure effects of biomass removal.
Water availability	• Future watershed-scale studies should focus on the regions identified as most likely to experience hydrological impacts. • Additional research is needed to place the water consumption findings in the context of regional water availability.
Air emissions	• Development of higher yielding seed varieties, energy crops with high nutrient use efficiency, more efficient farm engines, and wider adoption of less intensive tillage practices would reduce key drivers of emissions.
Biodiversity	• Guidelines for managing bioenergy crops may be needed to maintain biodiversity of grassland birds and other species. • Empirical studies are needed to understand the response of wildlife species to miscanthus and other energy crops as well as the effects of forest residue removal.

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

Table ES.1. Scenarios Considered in *BT16* Volume 2 Analyses

Combined agricultural and forestry scenarios		Agricultural scenarios			Forestry scenarios			
Combined identifier	Year	Identifier	Energy crop annual yield increase[1]	Corn annual yield increase	Identifier	Description	Housing starts	Wood energy demand
BC1&ML 2017	*2017*	BC1 (base case yield)	1%	0.8%	ML (baseline)	Moderate housing–low wood energy	Returns to long-term average by 2025	Increases by 26% by 2040
BC1&ML 2040	*2040*	BC1 (base case yield)	1%	0.8%	ML (baseline)	Moderate housing–low wood energy	Returns to long-term average by 2025	Increases by 26% by 2040
HH3&HH 2040	*2040*	HH3 (high yield)	3%	1.9%	HH (high demand)	High housing–high wood energy	Adds 10% to baseline in 2025 and beyond	Increases by 150% by 2040

[1]Yield improvements are only applied at establishment and are not applied after year one for perennial crops until replanting

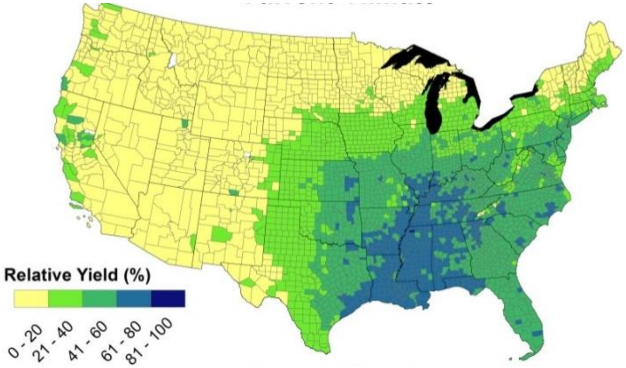
Additional Components of volume 2

Land-use change

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

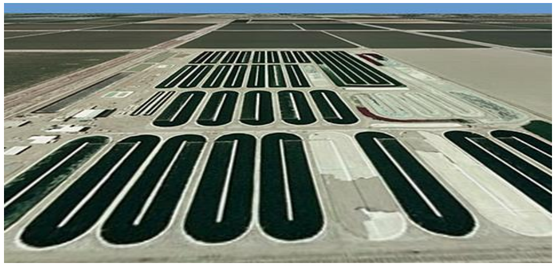
Sensitivity of energy crops to climate

- Simulates climate sensitivity of agricultural energy crop productivity



Microalgae

- Assesses qualitative environmental effects of potential algae biomass production from volume 1

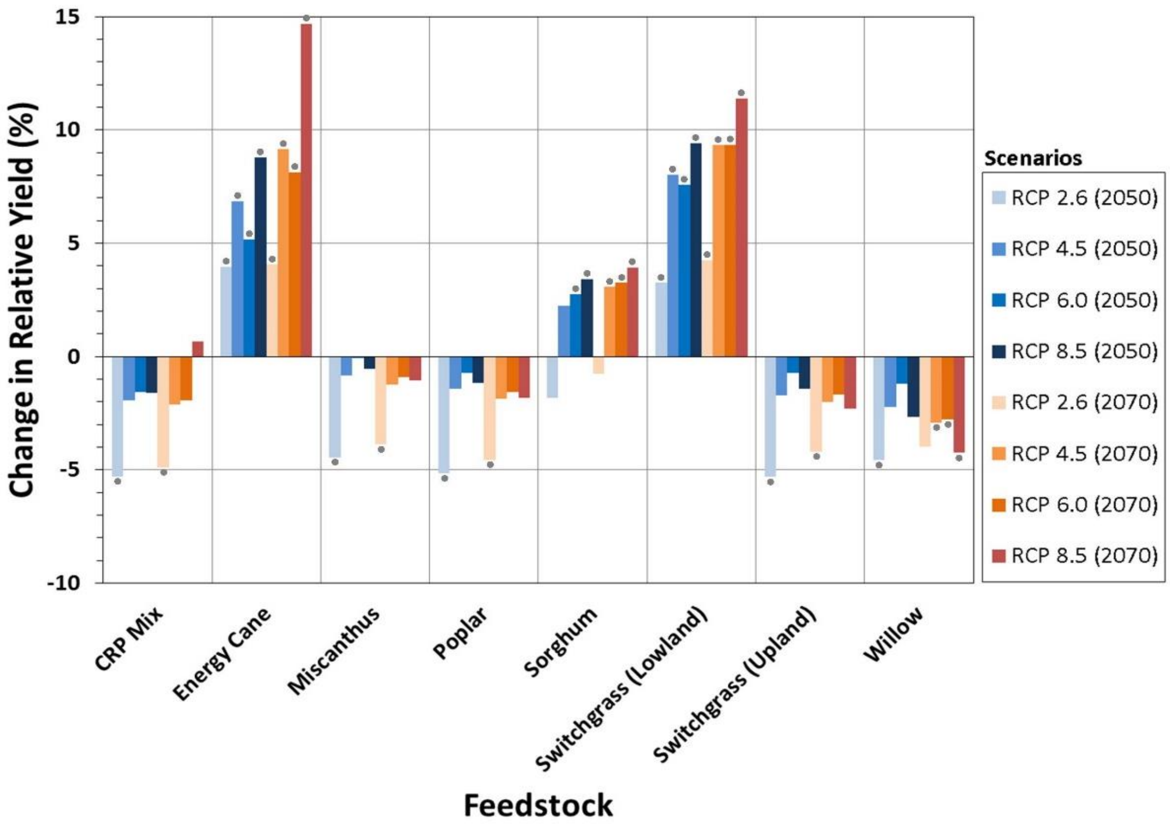


Enhancing environmental outcomes

- Describes strategies for enhancing environmental benefits and minimizing concerns

Chapter 13 – Climate Sensitivity - Additional Findings

- Climate change could alter yields.
- Both significant increases and decreases in feedstock yields are projected to occur in future decades, given the current genetic composition of feedstocks and levels of technology associated with feedstock production and the biomass supply chain.
- Variability is a function not only of geographic variability in current climate and future climate change, but also variability in the inherent sensitivity of different feedstocks and cultivars.



- The development of a more process-based understanding of bioenergy feedstock responses to changing climatic conditions would assist in reducing uncertainties associated with purely empirical methods.