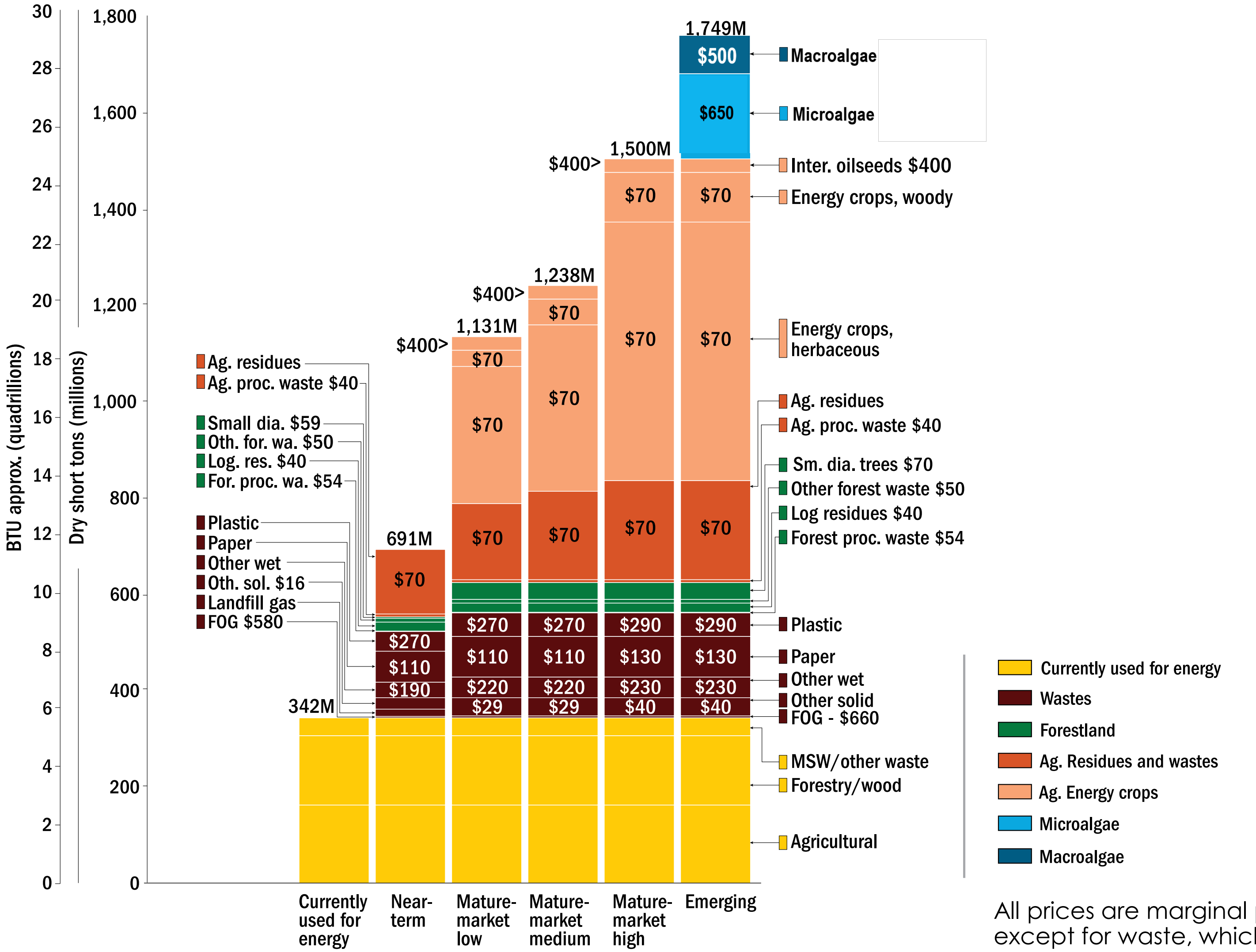
Overview of the 2023 Billion-Ton Report

Fifty-four authors
CAAFI

May 15th, 2024

V4

Results: 0.7-1.7 billion tons production capacity



All prices are marginal prices except for waste, which is weighted average price.

- Bioeconomy currently provides 340 million tons biomass (5 Quads or 5% total)
- Currently available resources can double biomass in **near-term**
- **Mature market** induces another 440-800 million tons biomass depending on yield assumptions
- Emerging resources can supply another 250 million tons
- All estimates include sustainability constraints

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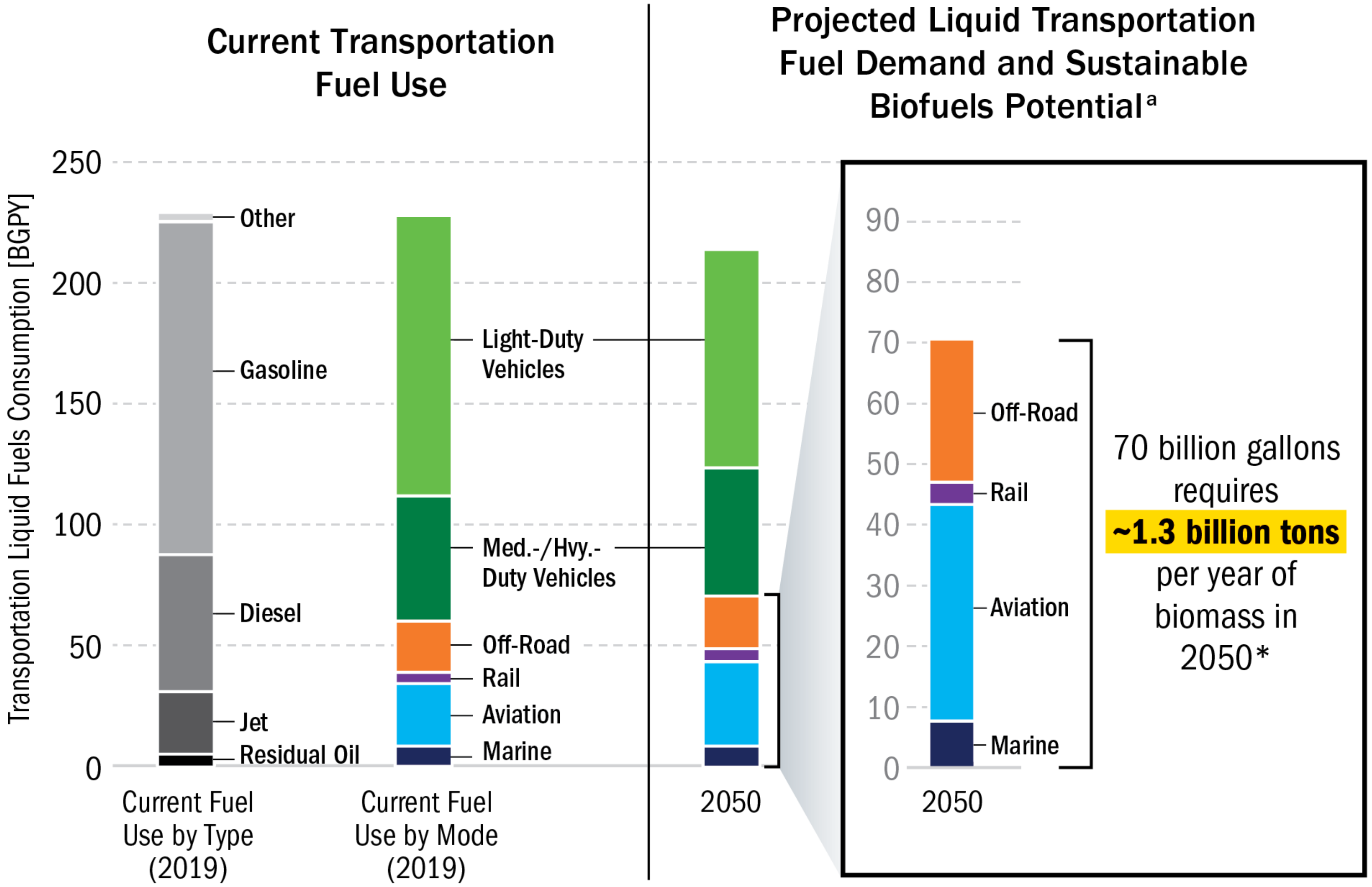
Demands for Decarbonization

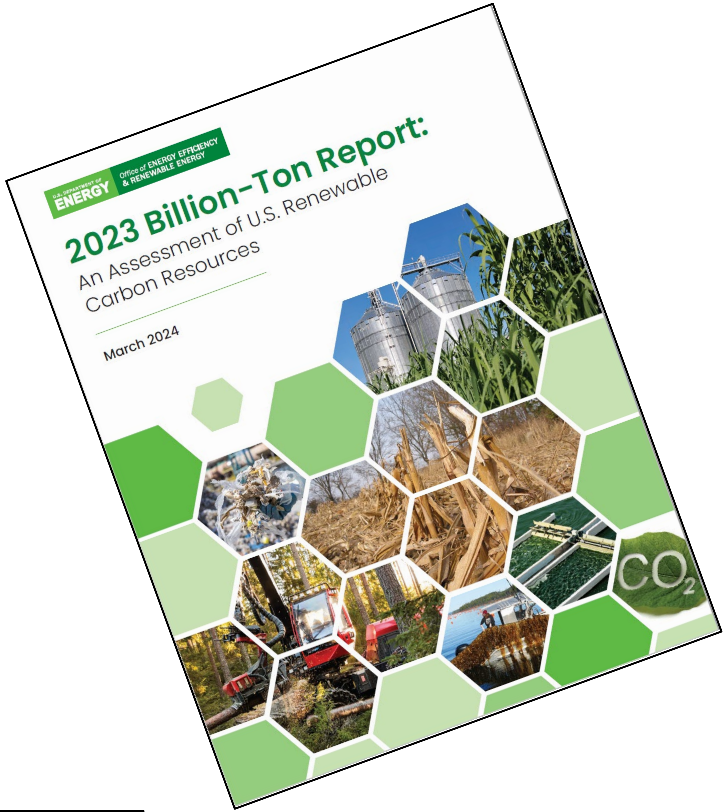


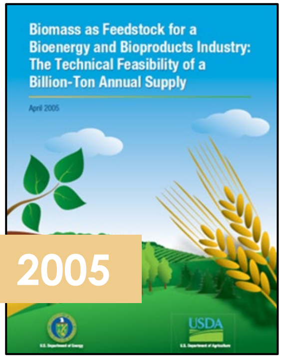
[a] The Base case and Expanded scenario bars above are reported on a GGE basis

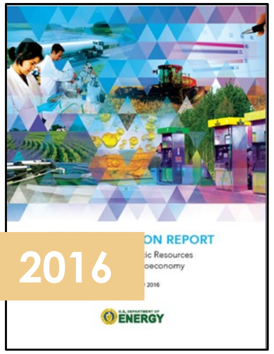
* Assumes a conversion rate of 55 gallons per ton

ENERGY earthshots U.S. DEPARTMENT OF ENERGY | Clean Fuels & Products™

2023 Billion-Ton Report (BT23) is 4th in a series







- To inform research, development, and deployment strategies.
- Update to latest economic conditions
- Better clarity in terms of
  - Production capacity by market maturity
  - Level of resource utilization
- New resources (e.g. oilseeds, macroalgae)

- **Not targets**
- **Not predictions**
- **Policy agnostic**
- **End-use agnostic**

Billion-Ton 2023 Collaborators

Fifty-four contributors

Thirty reviewers

BT23 considers current, available, and future resources

Currently used for energy and coproducts

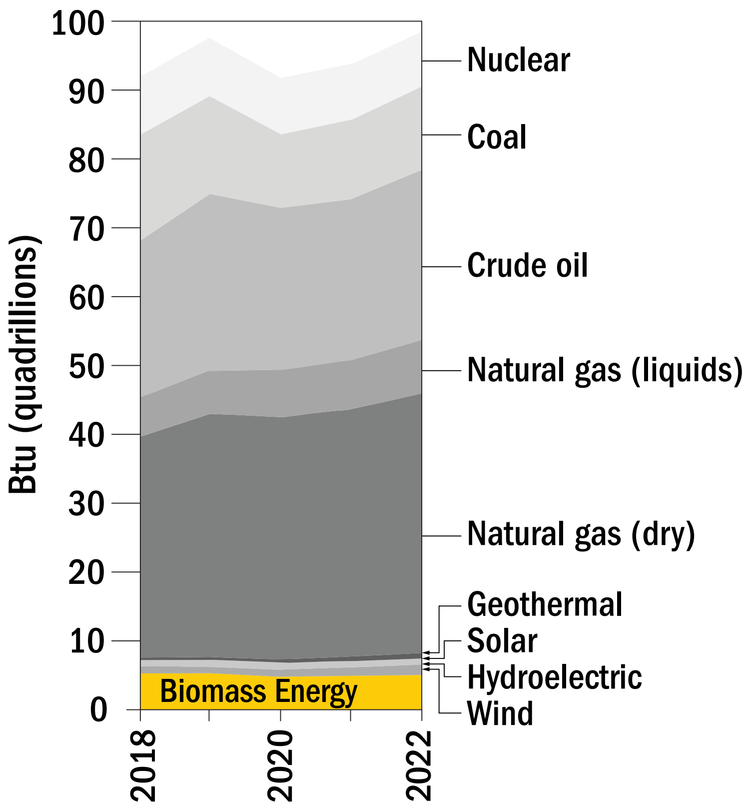
Currently available & Mature-market

Emerging resources

- Currently used resources
- Wastes
- Timberland
- Agricultural resources
- Microalgae
- Macroalgae
- CO2

US currently uses 340 million tons of biomass for fuel & power

U.S. Energy Production

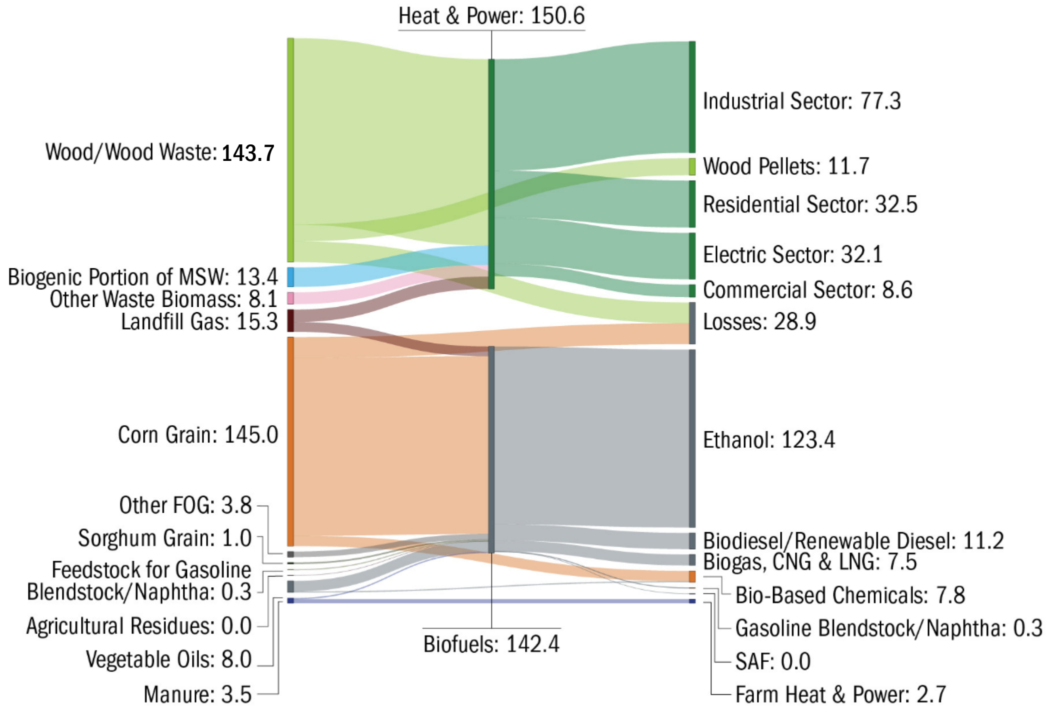


Currently used for energy 342 M

MSW/Other wastes 37 M

Forestry/Wood 144 M

Agricultural 162 M



Million tons per year in 2022

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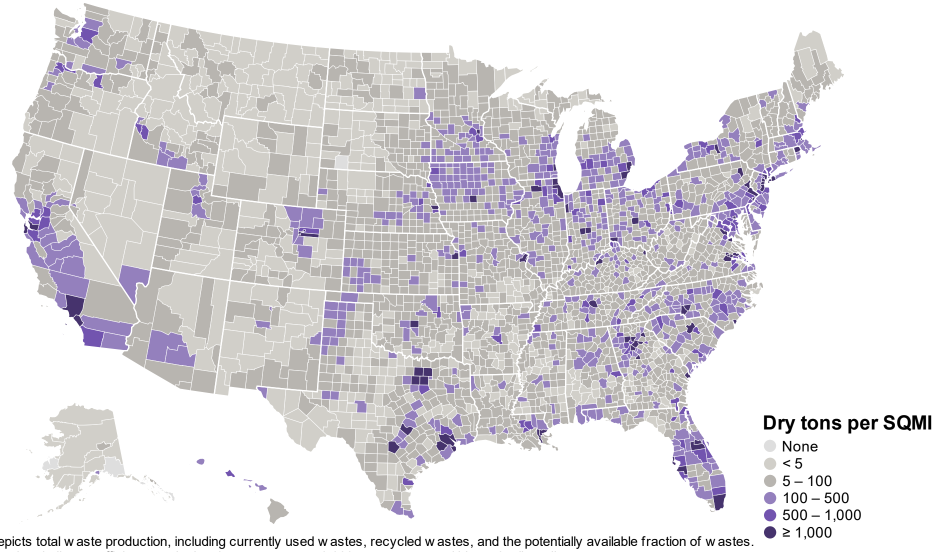
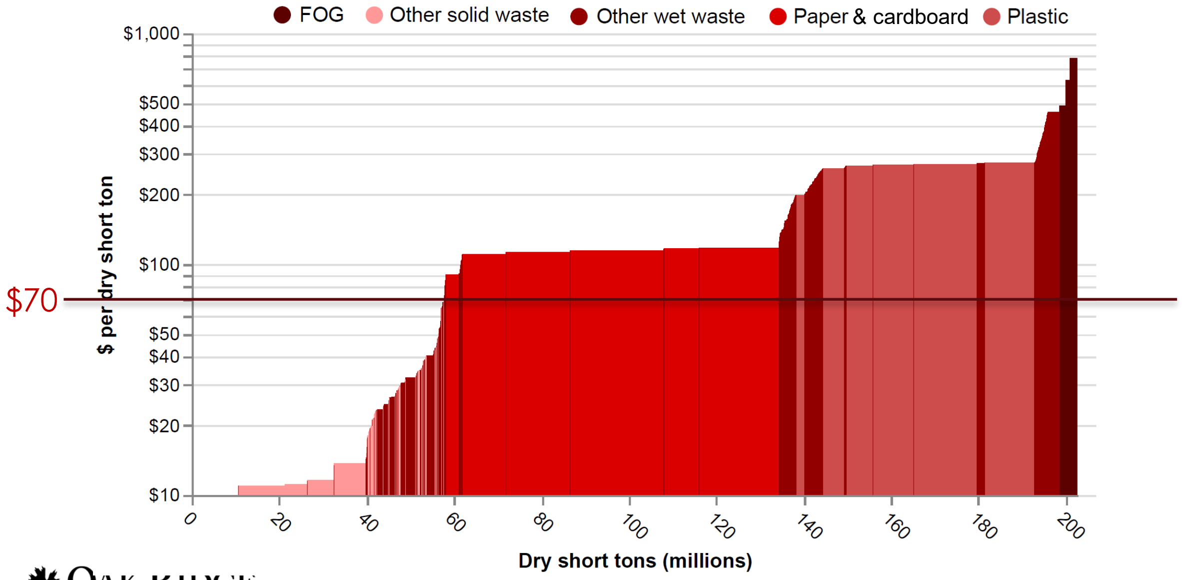
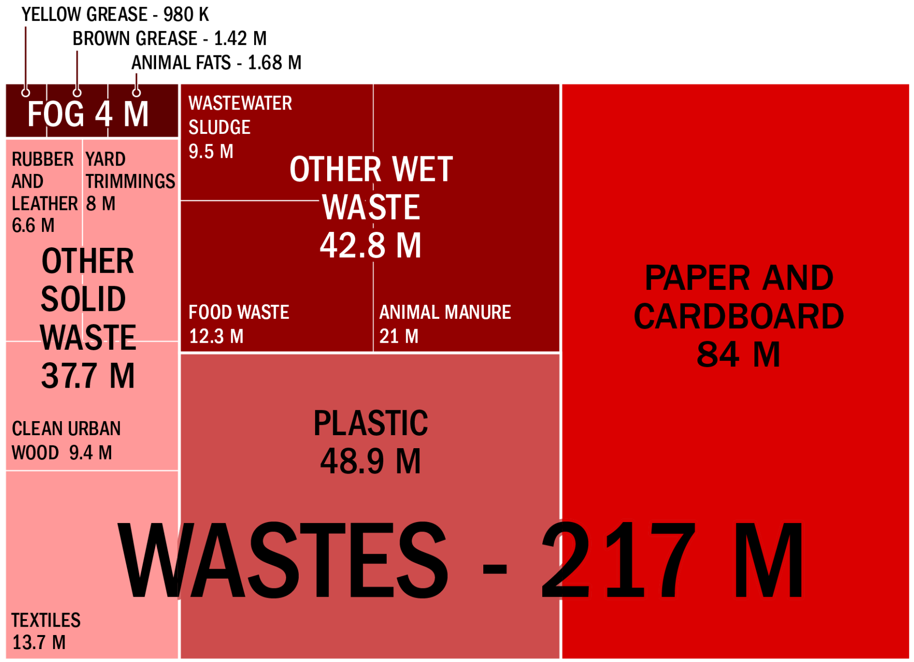
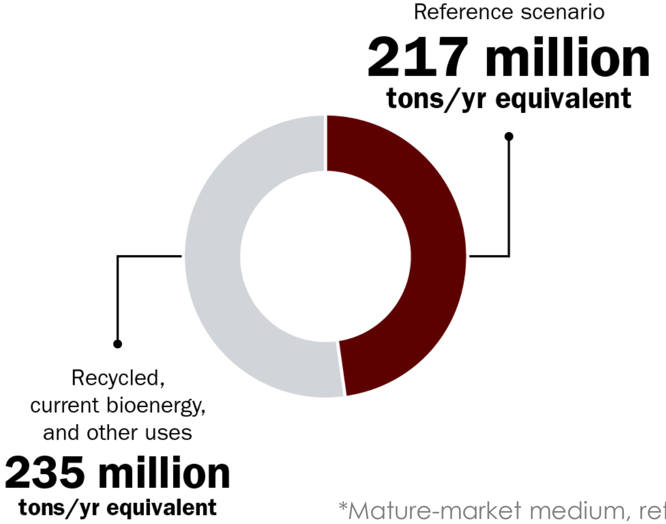
Waste & byproduct resources can provide 180-220 million tons



Map depicts total w aste production, including currently used w astes, recycled w astes, and the potentially available fraction of w astes.
Purple colors indicate sufficient supply density to support >750,000 tons per year w ithin a 50-mile radius.







*Mature-market medium, reference scenario, all prices

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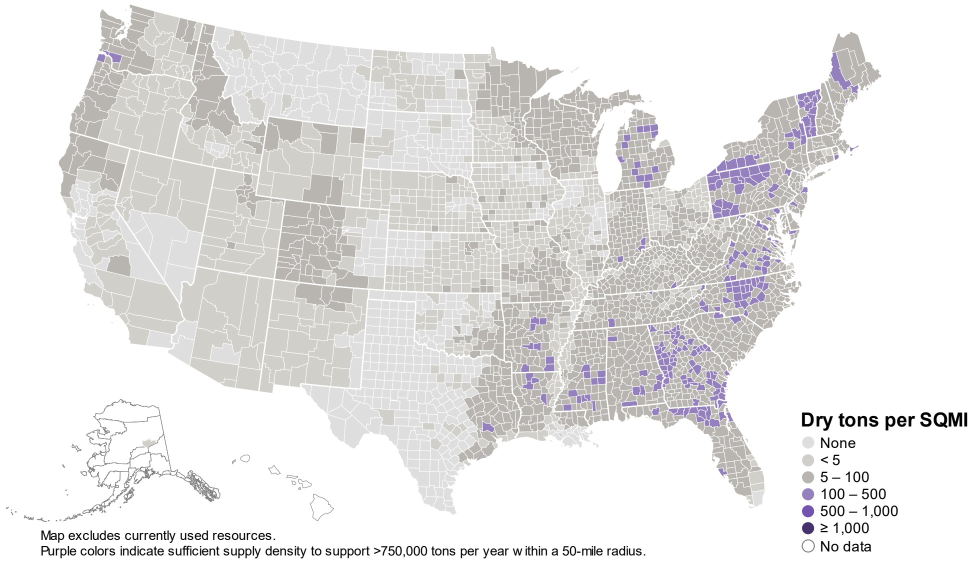
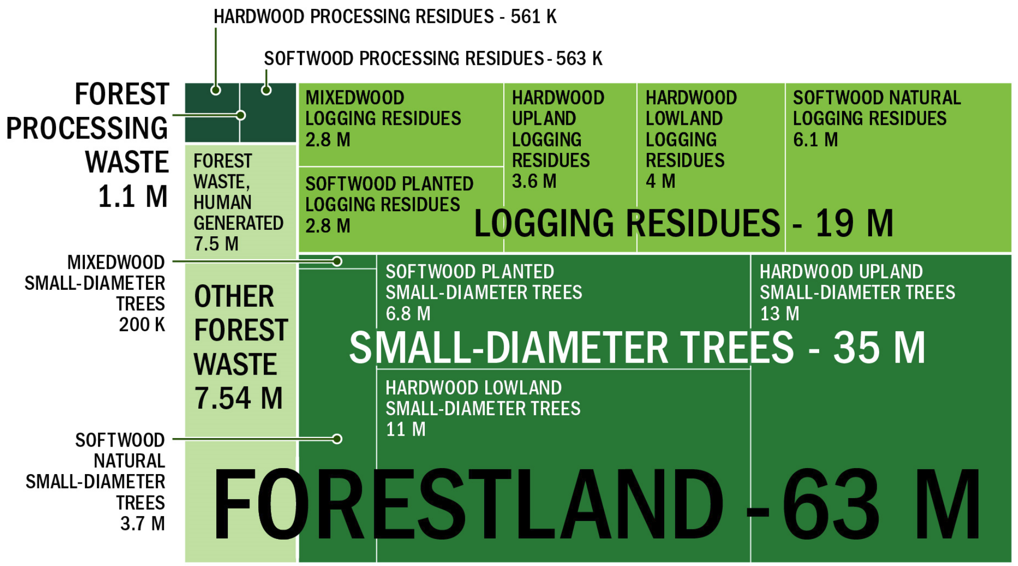
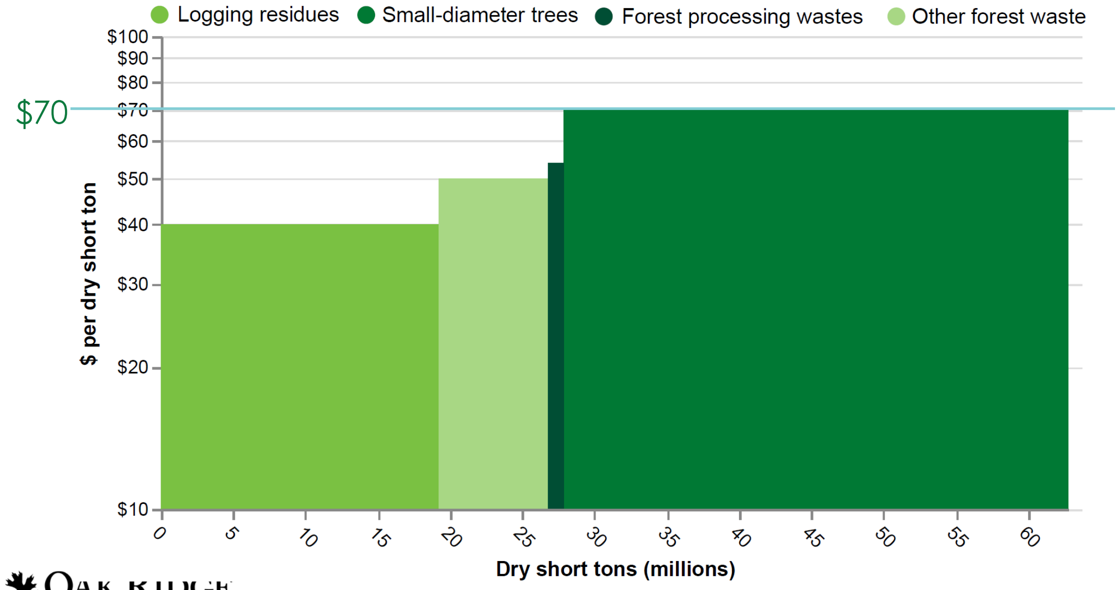
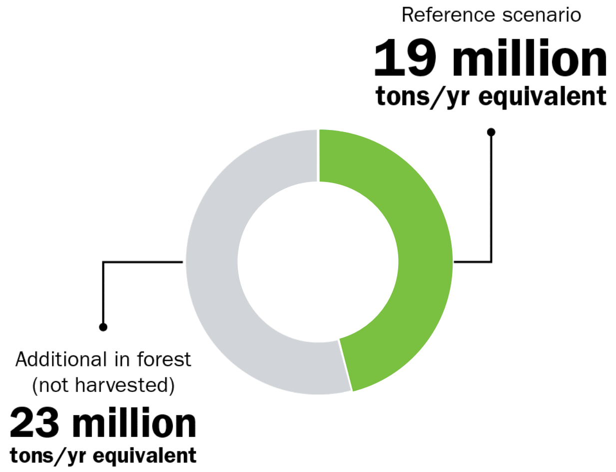
Timberland resources can provide 32-63 million tons



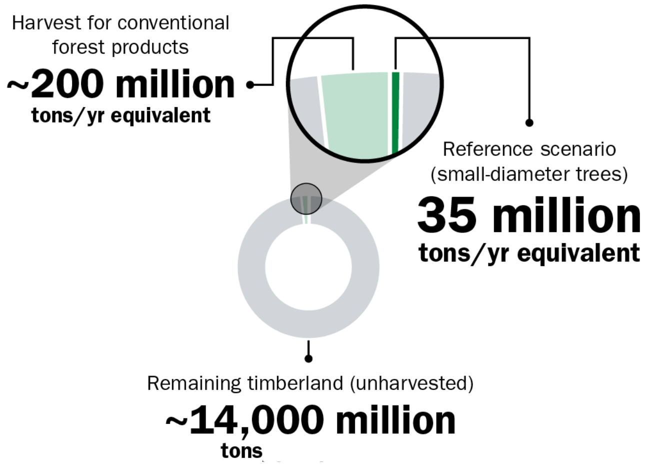




Logging Residues



Tree Biomass



*Mature-market medium, reference scenario, up to $70 per ton

Agricultural resources

Key Input: Regional Feedstock Partnership Yield Data

Resource

Switchgrass

Willow

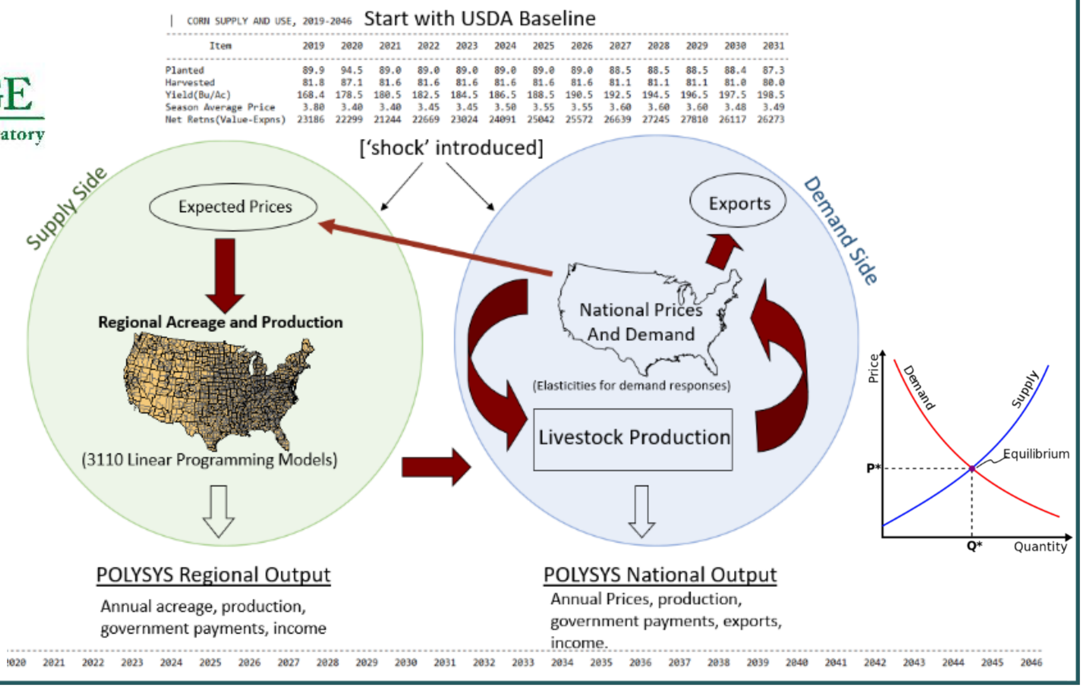
Oil seeds

Analysis

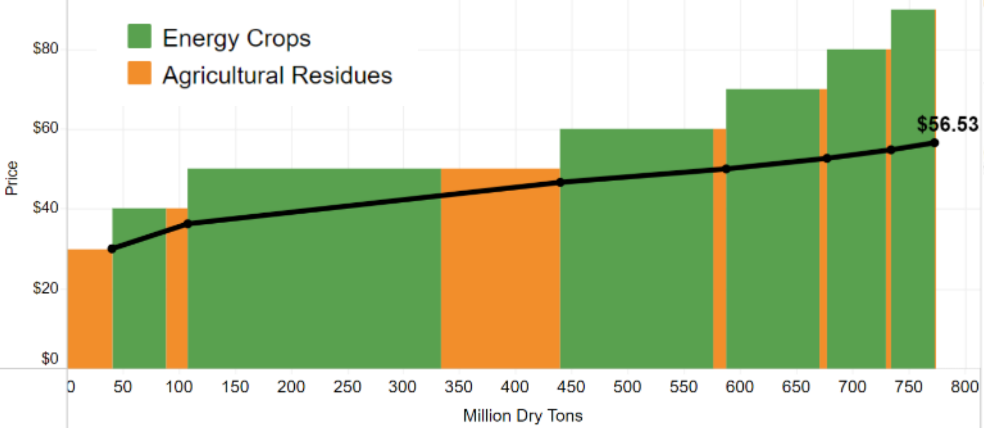
Model: Policy Analysis Systen (POLYSYS)

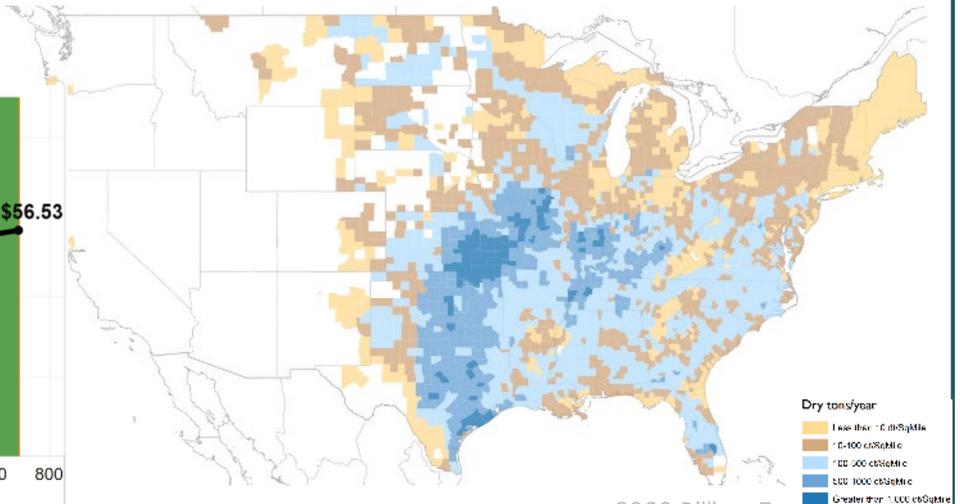
Inputs:

- Conventional (food, feed, fiber, export) demands from 2023 USDA Baseline Projection
- Crop yields (tons/acre/year) from SunGrant Regional Feedstock Partnership
- Crop production budgets from surveys
- 30-meter resolution (2022 Cropland Data Layer)



Outputs: County-level supply curves





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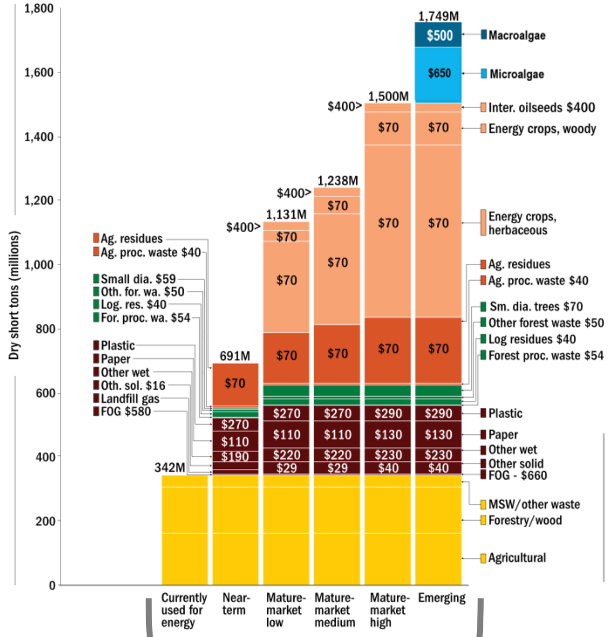
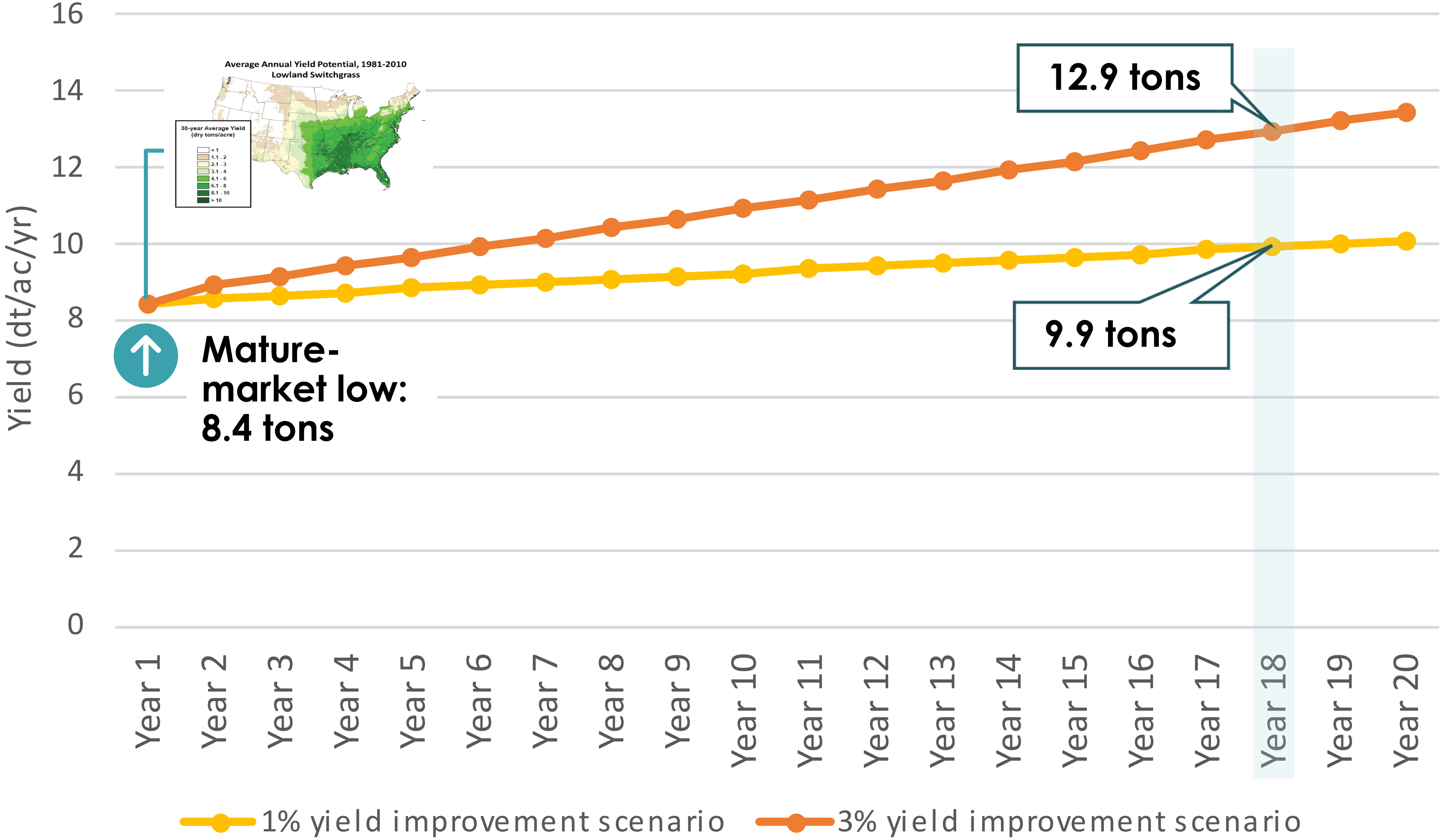
Ag scenario details: (Table 5.1)



Market Scenarios

Scenario	Assumptions
Near term	Near term (simulated as 7 years after 2023) Only crop residues (corn, wheat, sorghum, barley, and oat) No harvest technology improvements
Low	Mature market (simulated as 18 years after 2023) No energy crop yield improvements Conventional crop yield improvements assume USDA baseline No harvest technology improvements
Medium	Mature market (simulated as 18 years after 2023) 1% per year energy crop yield improvements Conventional crop yield improvements assume USDA baseline Harvest technology improves from 50% to 90% efficiency
High	Mature market (simulated as 18 years after 2023) 3% per year energy crop yield improvements Conventional crop yields improve 1.5 times the USDA trend Harvest technology improves from 50% to 90% efficiency

Impact of R&D on yields



*Example of switchgrass yield from Crittenden County, KY; 2009 High-Yield Scenario Workshop Series Report

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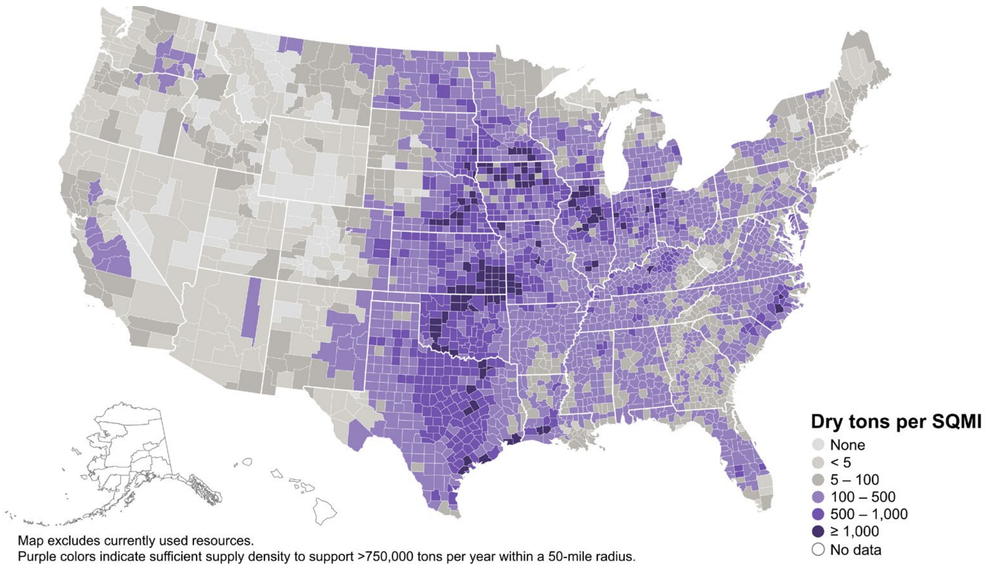
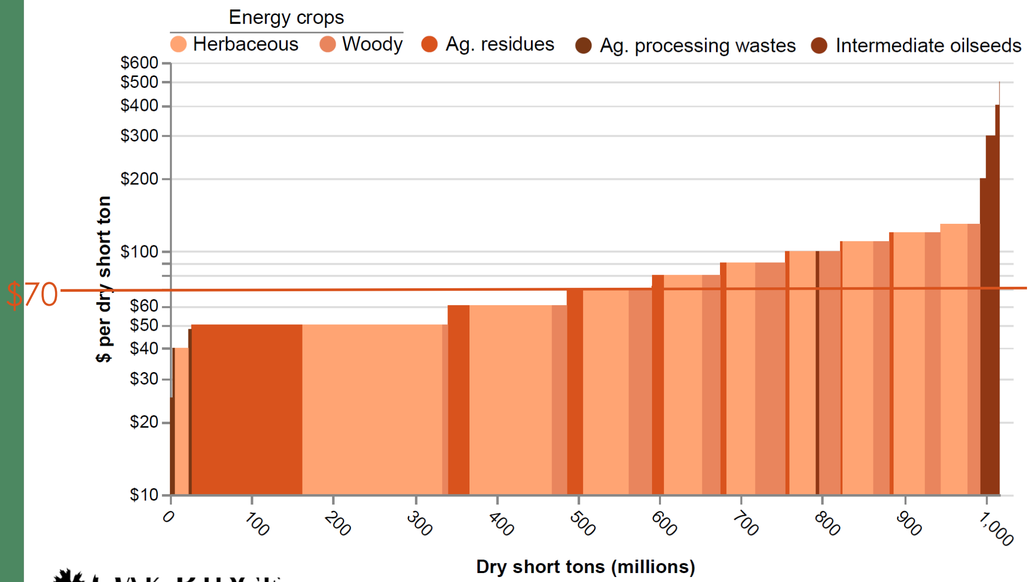
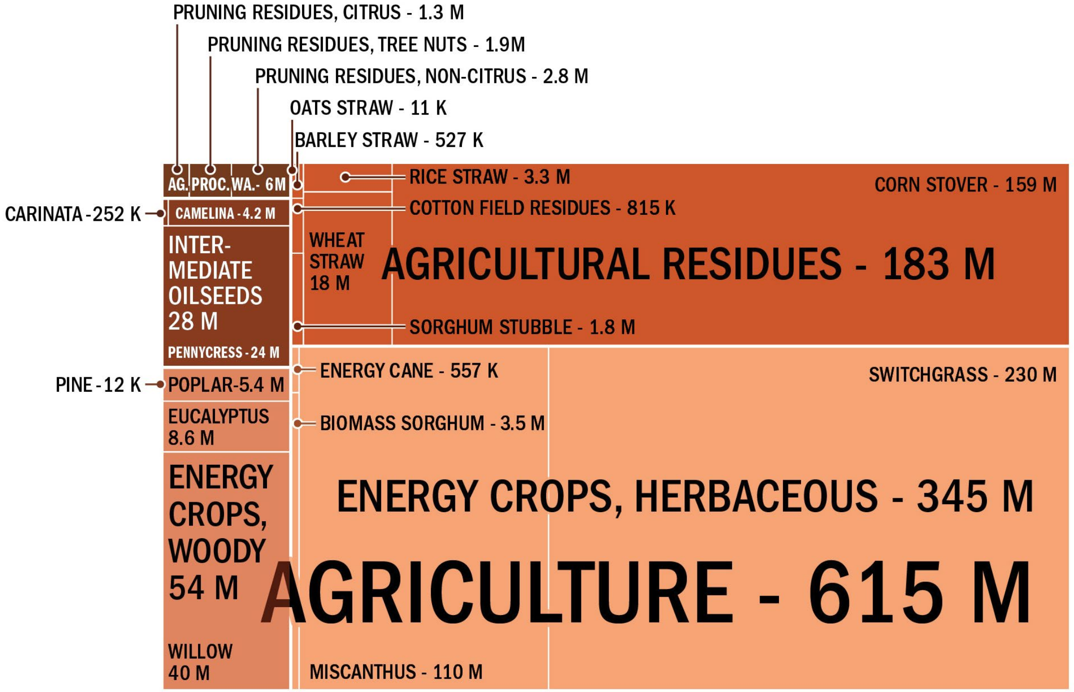
Agricultural resources can provide 150-800+ million tons

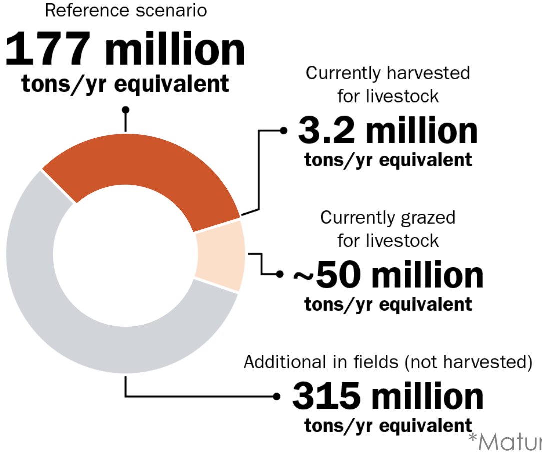




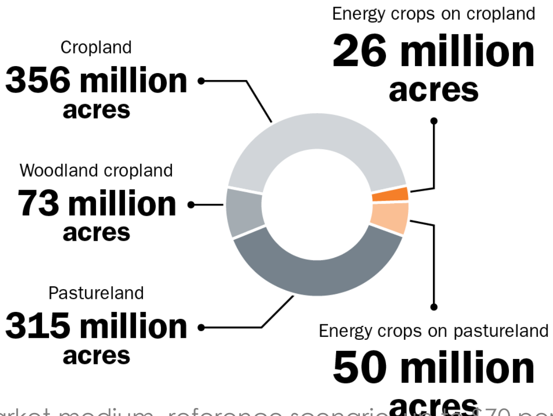
Ag lands can be used to grow 300-600 million tons of cellulosic energy crops. Intermediate oil seeds can provide another 28 million tons.



Corn Stover & Wheat Straw



Agricultural Land



*Mature-market medium, reference scenario, up to $70 per ton

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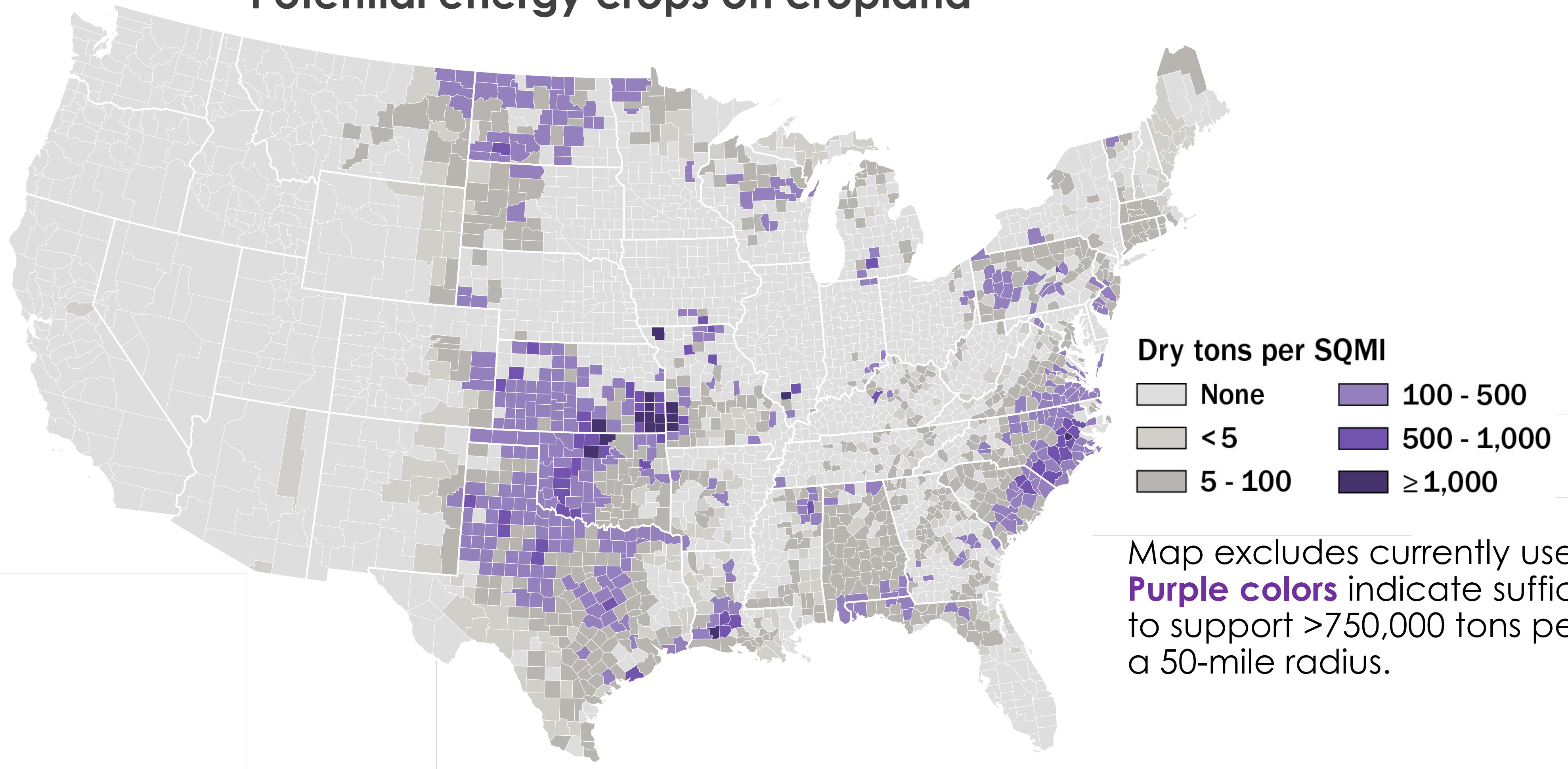
Energy crops results on cropland are outside the corn belt

Potential energy crops on cropland



Map excludes currently used resources. **Purple colors** indicate sufficient supply density to support >750,000 tons per year within a 50-mile radius.

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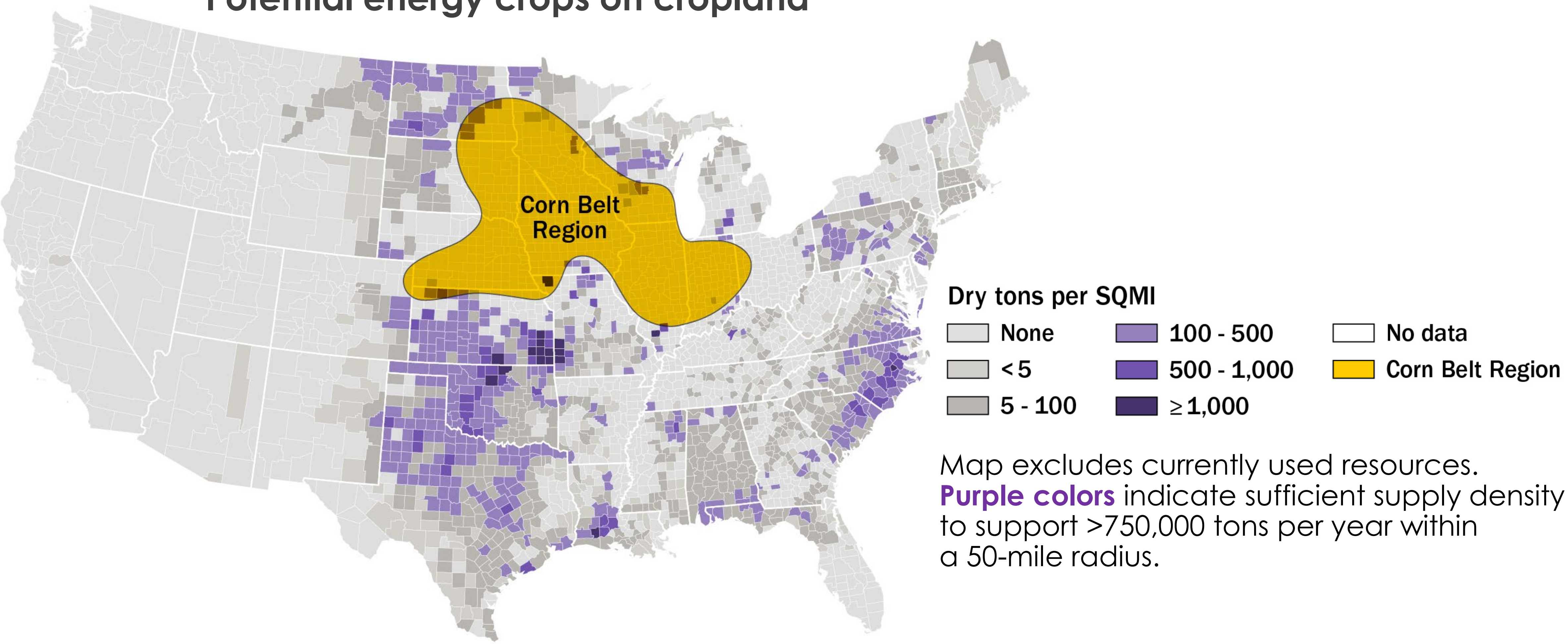

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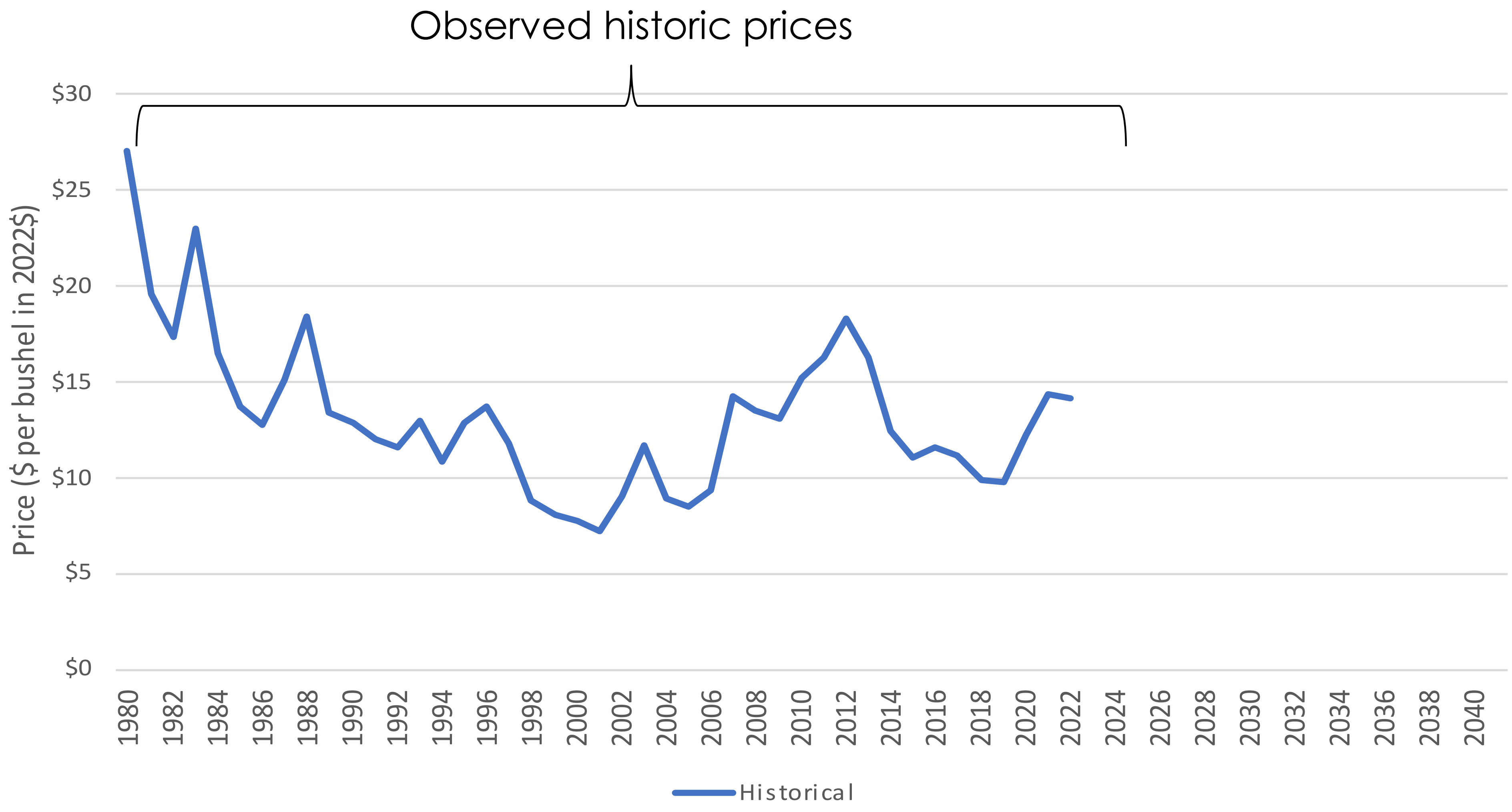
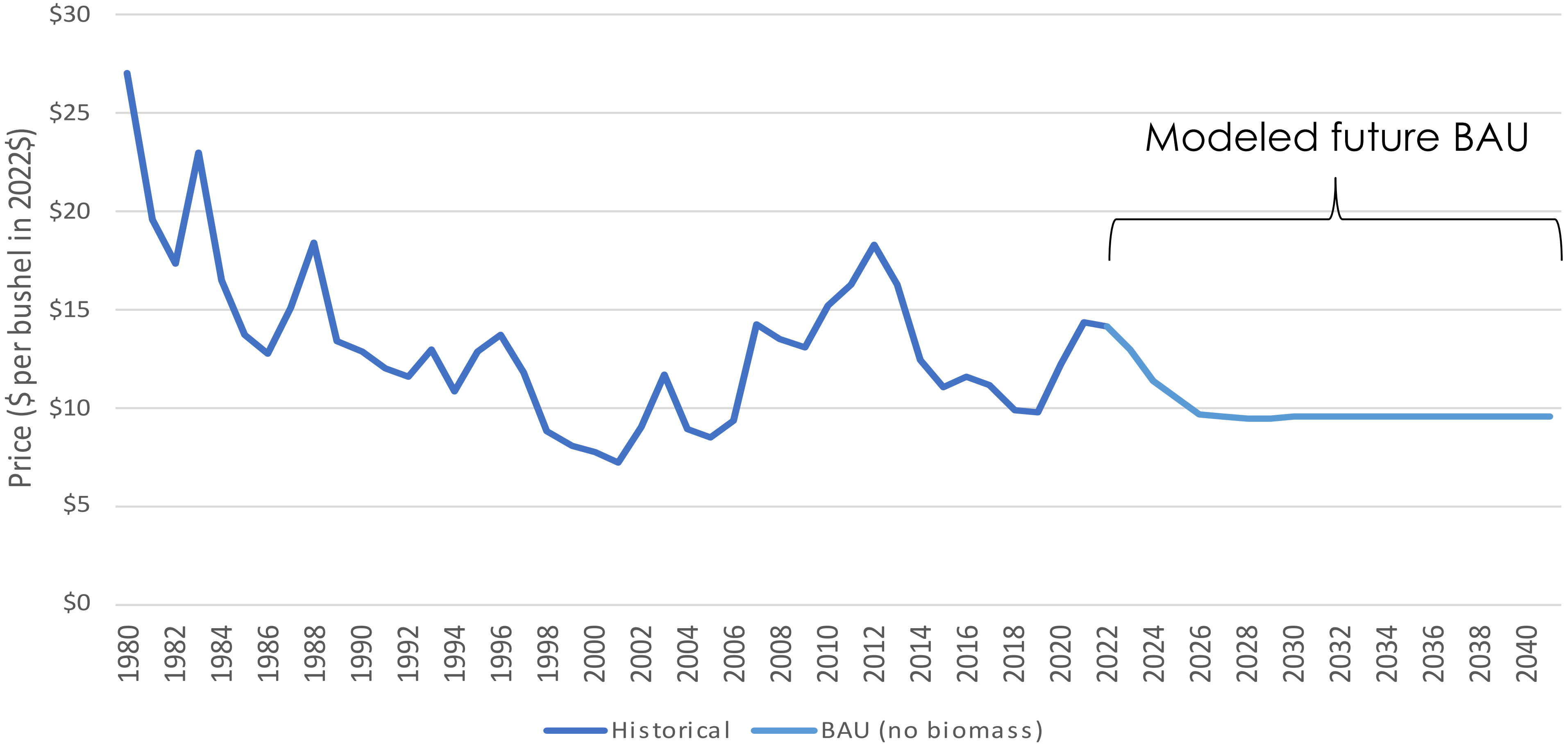
Commodity price impacts: Soy



Commodity price impacts: Soy



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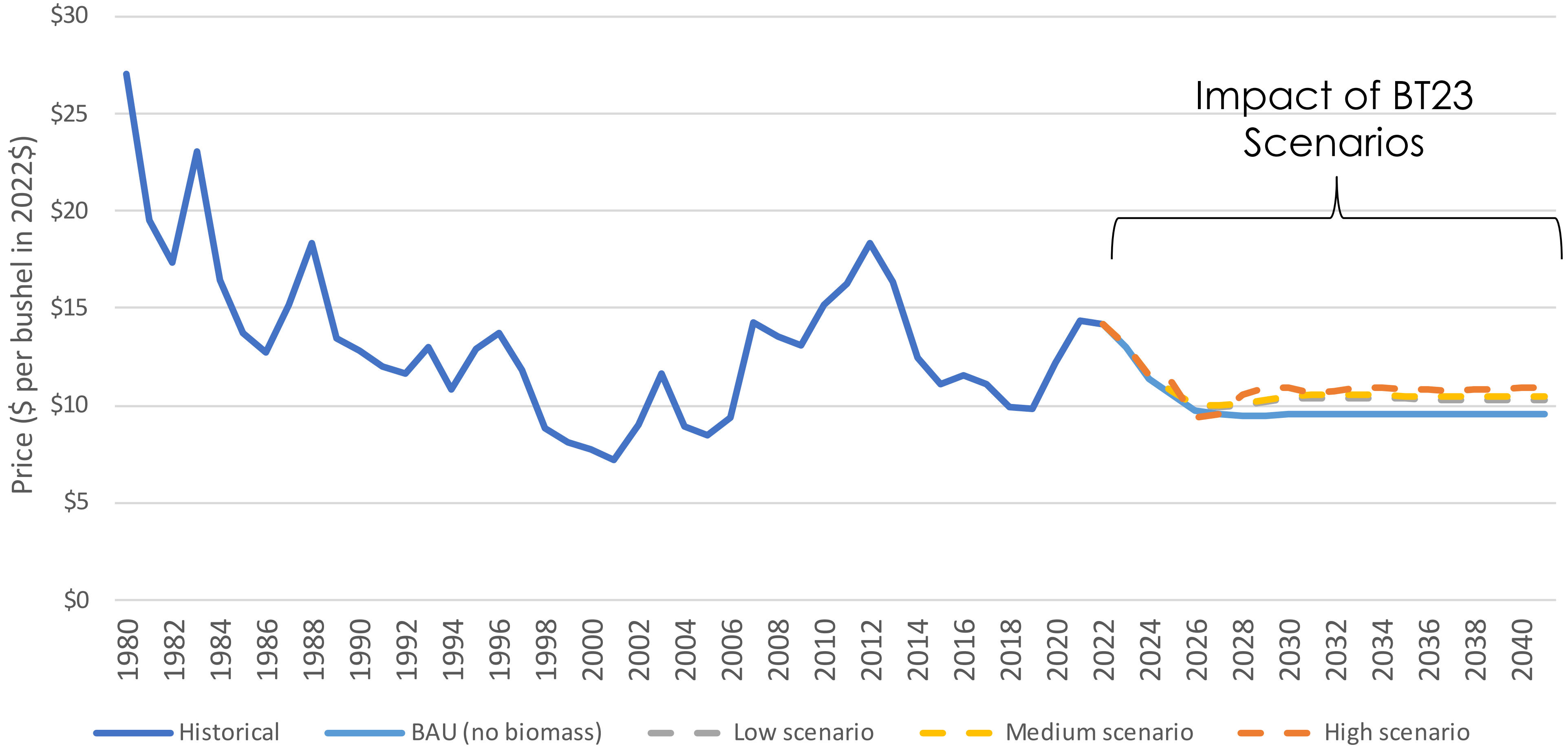
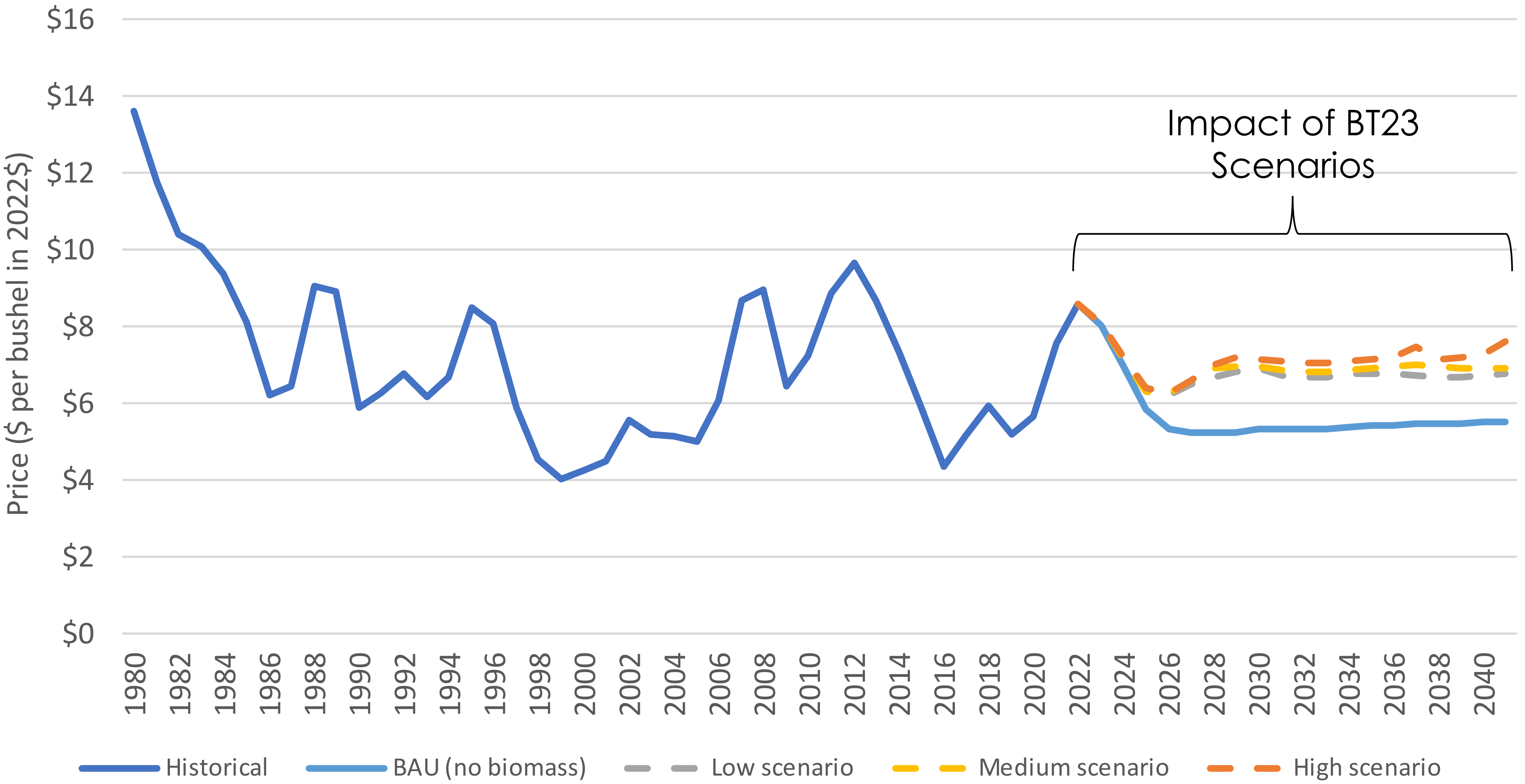
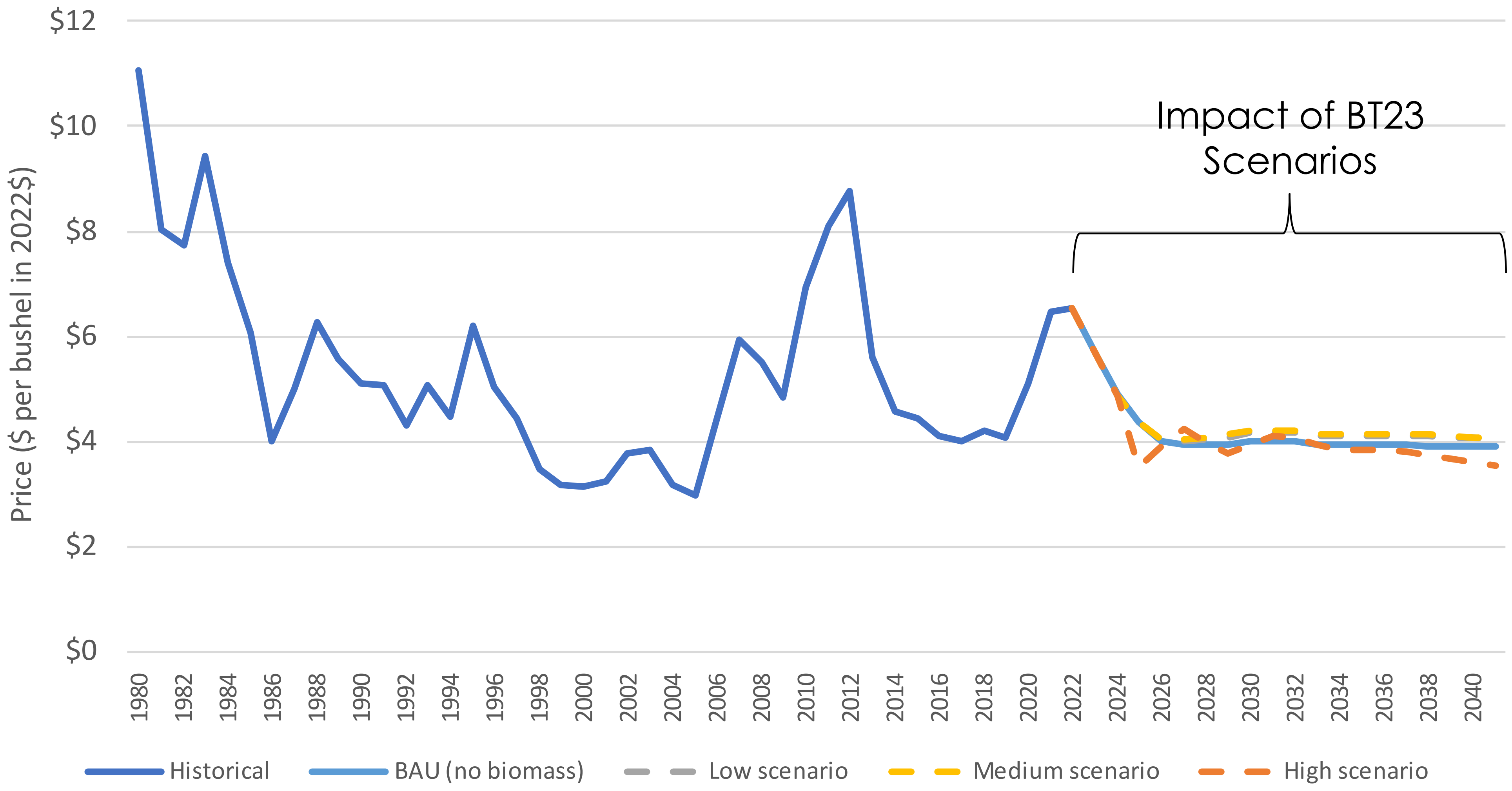
Commodity price impacts: Soy



Commodity price impacts: Wheat



Commodity price impacts: Corn



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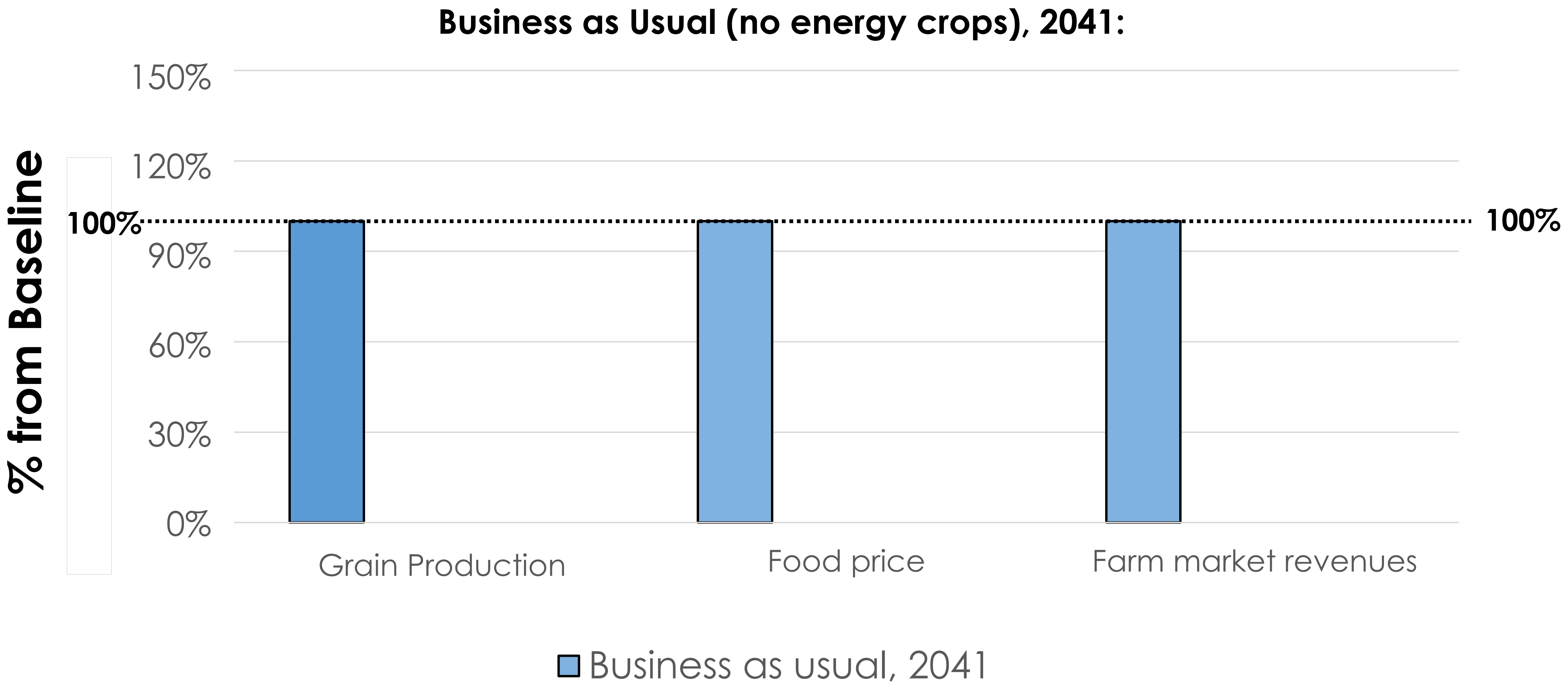
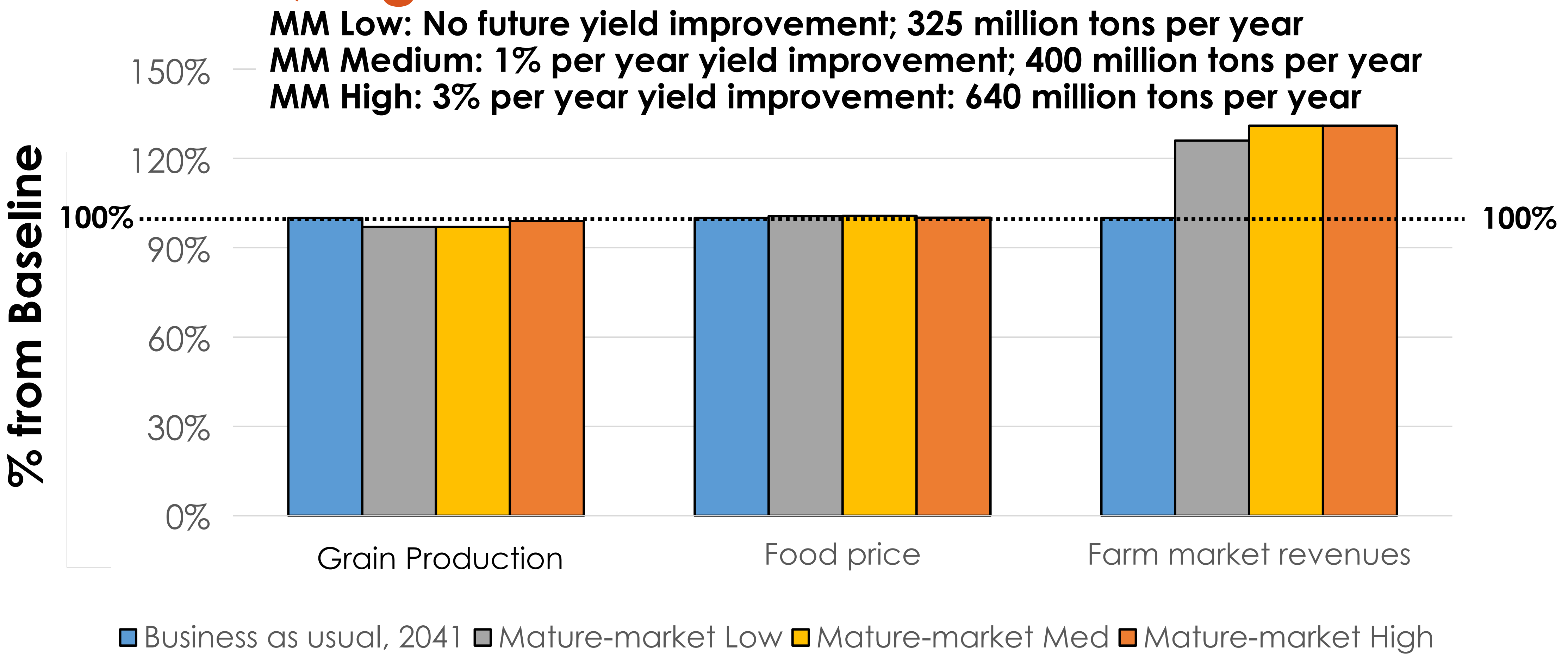
Energy crops could have nominal impacts on food production



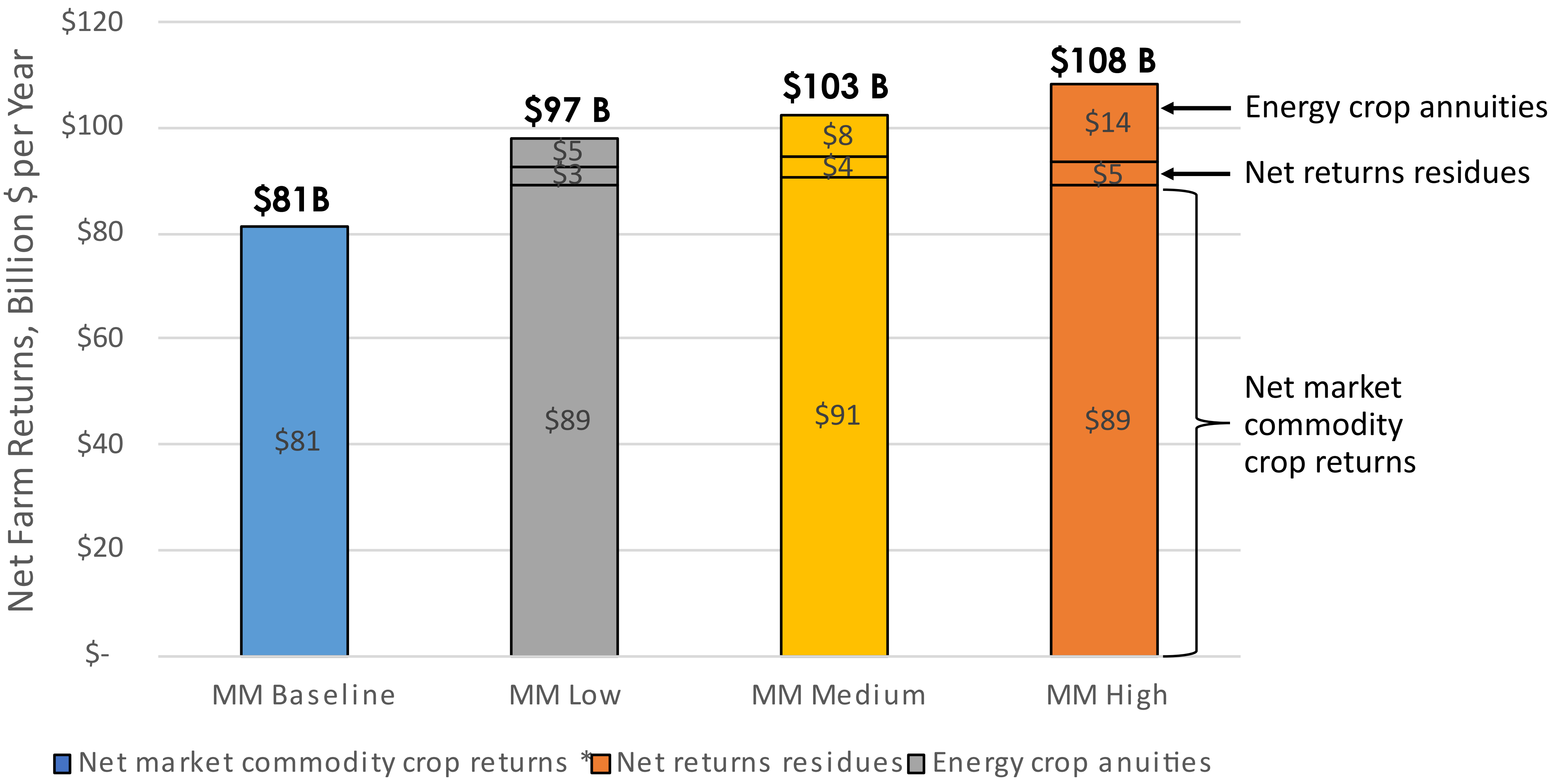
Modeled impacts of energy crop scenarios on US commodity crop production, food prices, and farm revenues. Future yield improvements simulated in the MM High scenario mitigate impacts on conventional production and increase biomass production.

Energy crops could have nominal impacts on food production, big increases in farm revenues



Modeled impacts of energy crop scenarios on US commodity crop production, food prices, and farm revenues. Future yield improvements simulated in the MM High scenario mitigate impacts on conventional production and increase biomass production.

Farm net returns increase $17-$27 Billion per year



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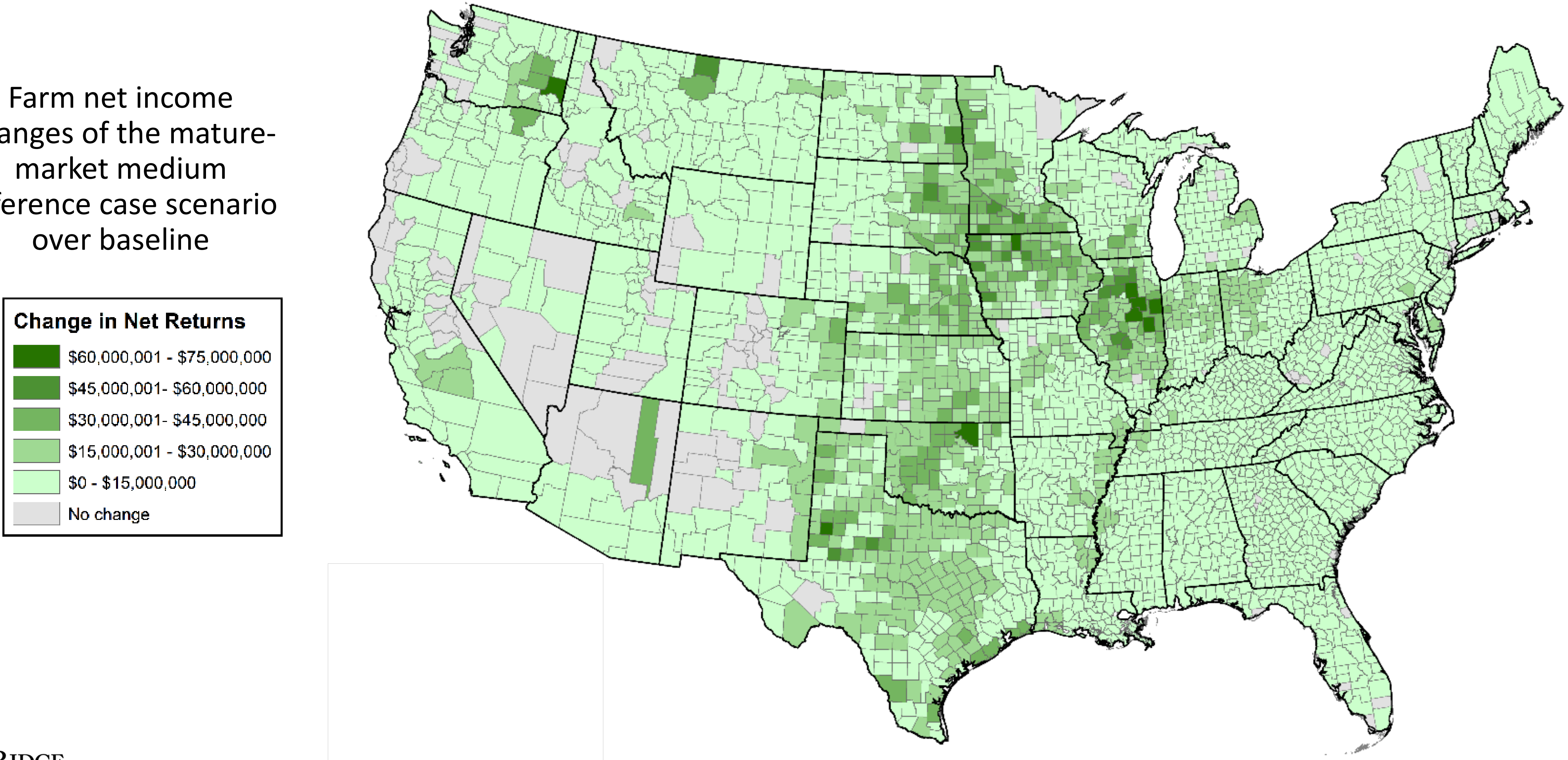
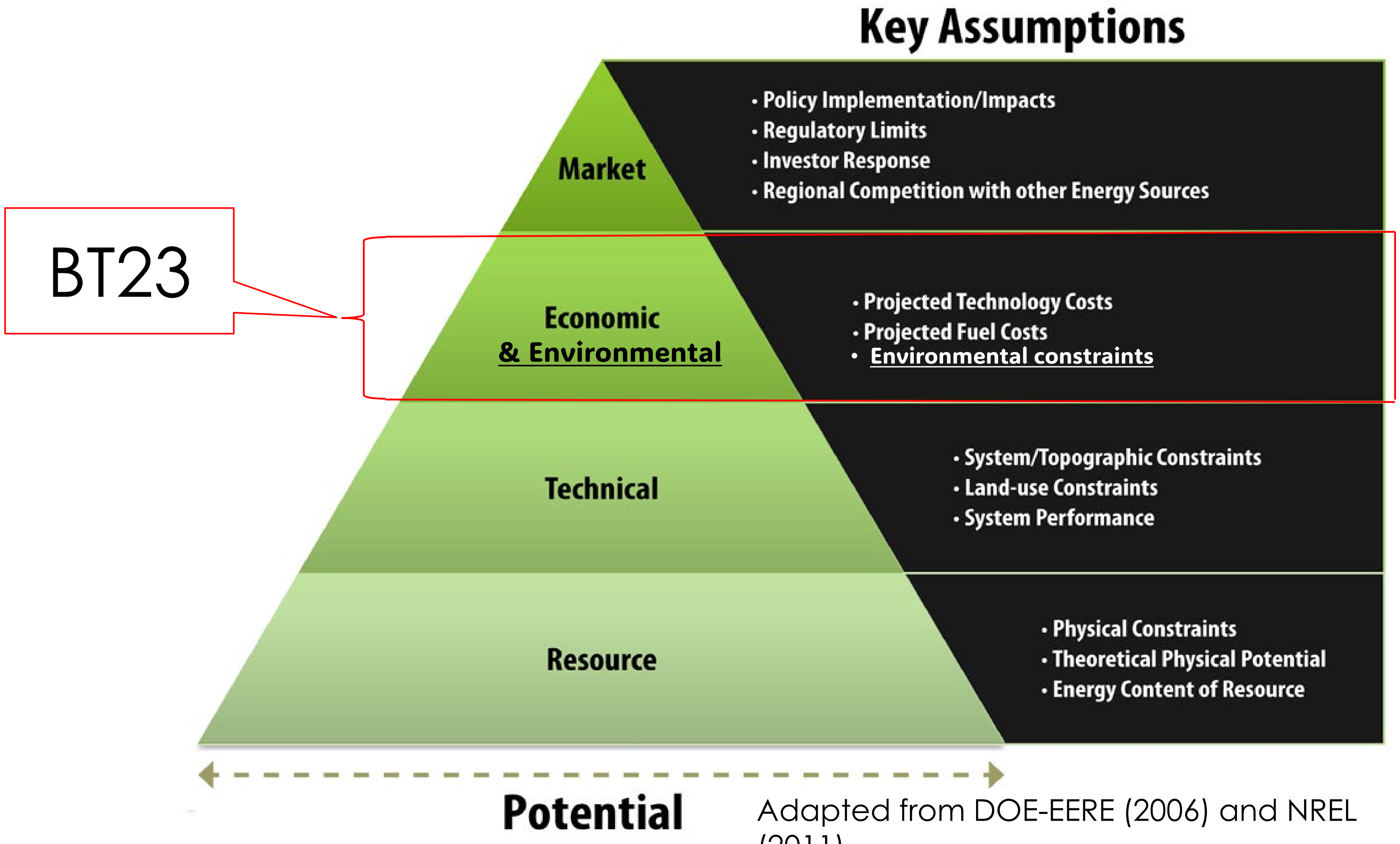
Farm net returns increase $17-$27 Billion per year

Farm net income changes of the mature-market medium reference case scenario over baseline

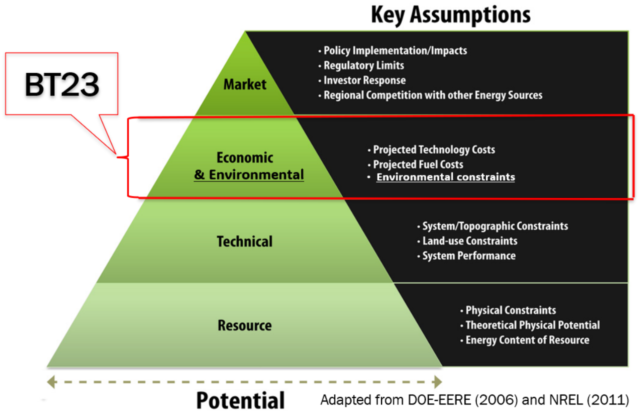


How optimistic is this?

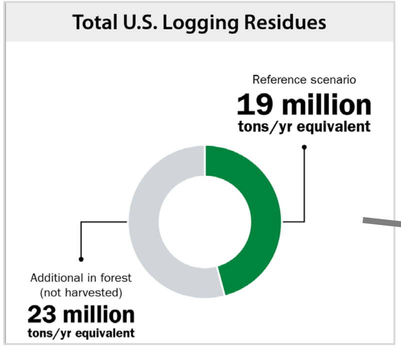


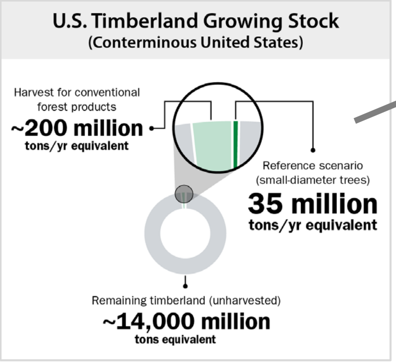
Adapted from DOE-EERE (2006) and NREL (2011)

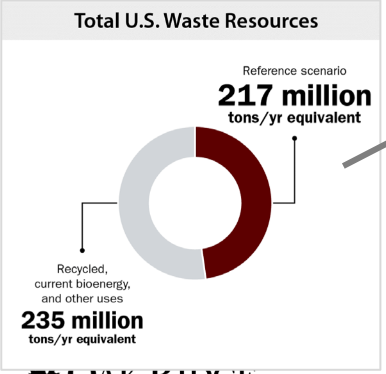
How optimistic is this?

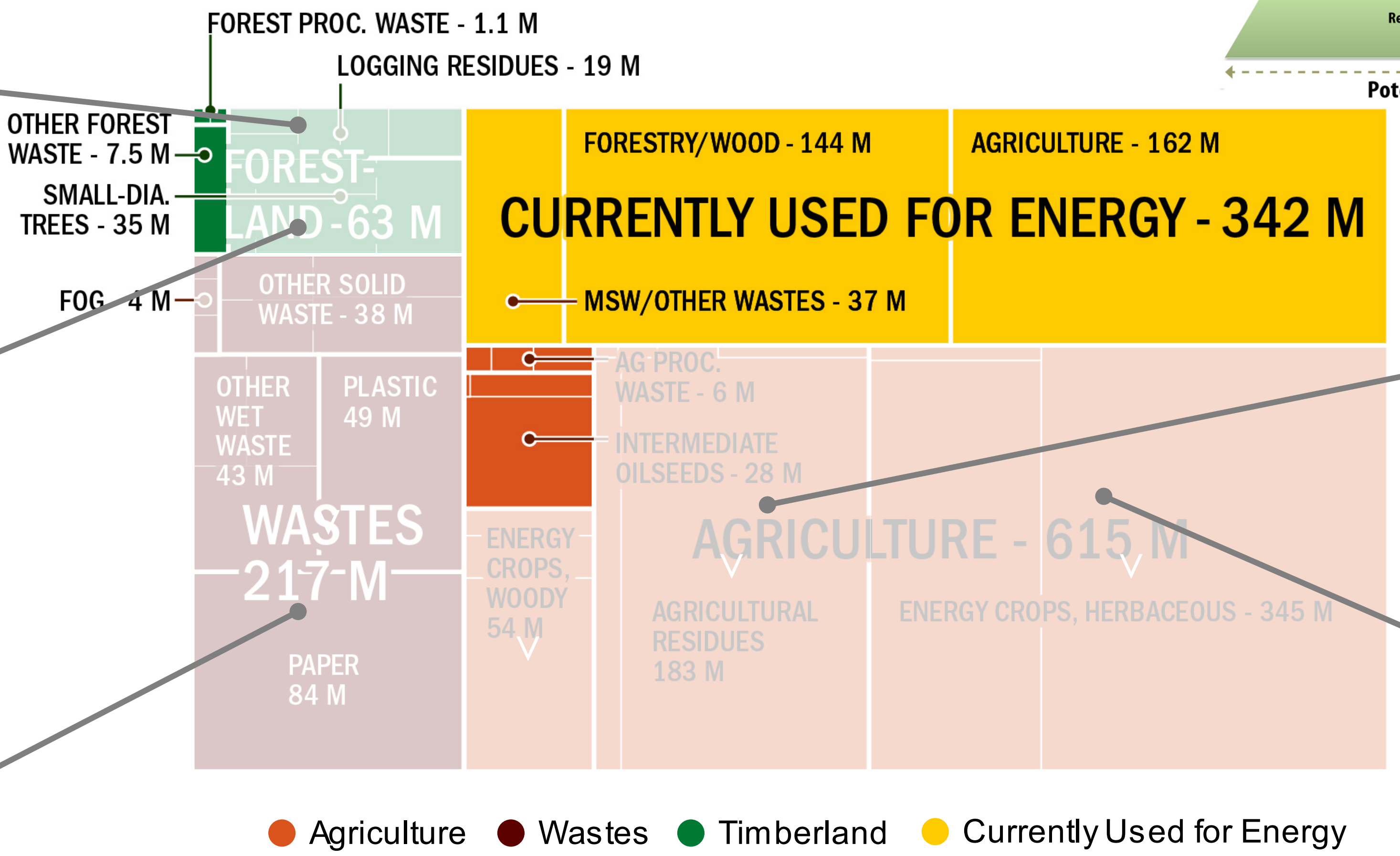


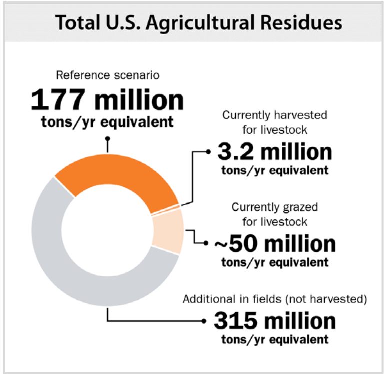
Mature-market medium

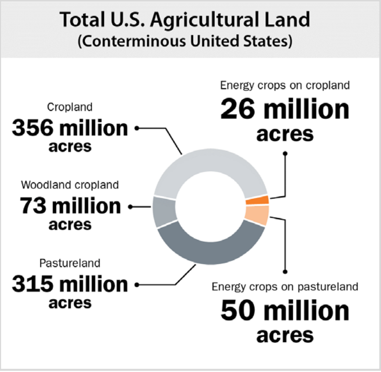












1.2 billion tons per year

- Energy crops are the biggest source, and the biggest dial.
- Yield uncertainty.

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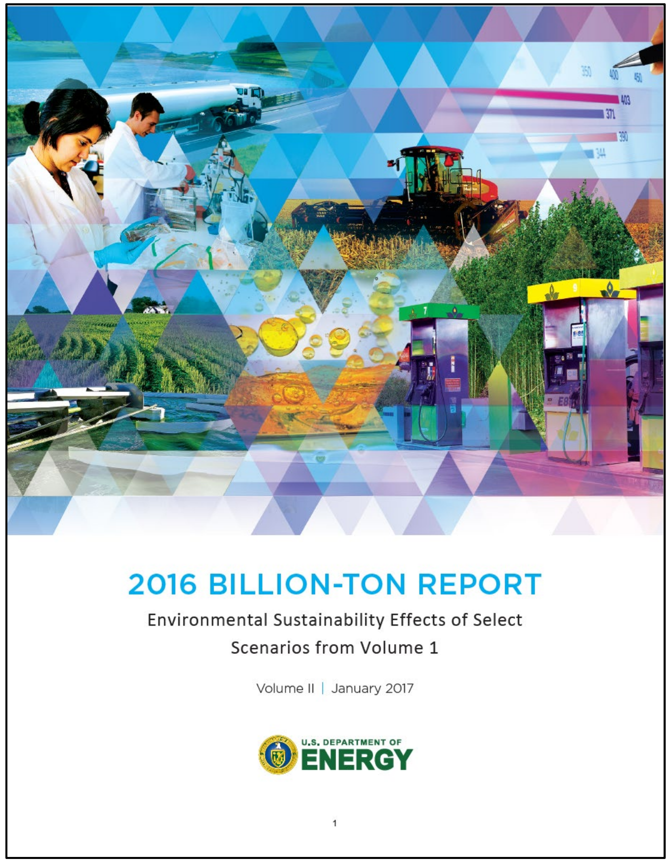
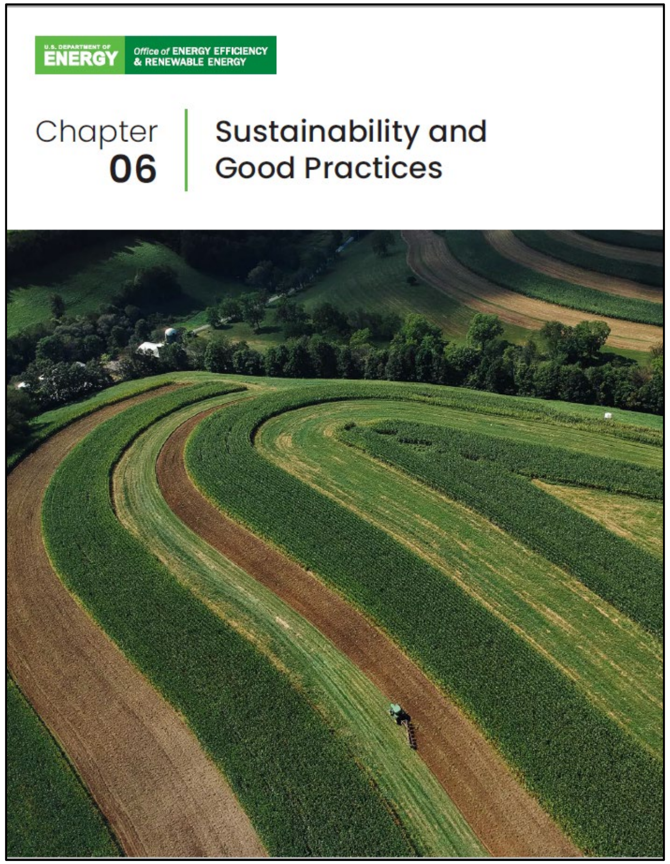
Sustainability

BT16 Volume 2: Environmental Sustainability Effects of Select Scenarios from Volume 1



https://bioenergykdf.net/2016-billion-ton-report-vol-2

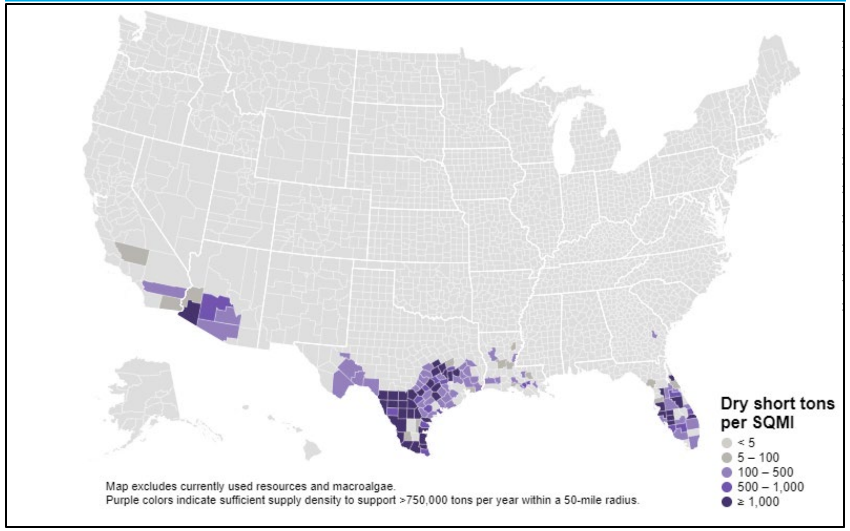
BT23 Chapter 6: Sustainability and Good Practices

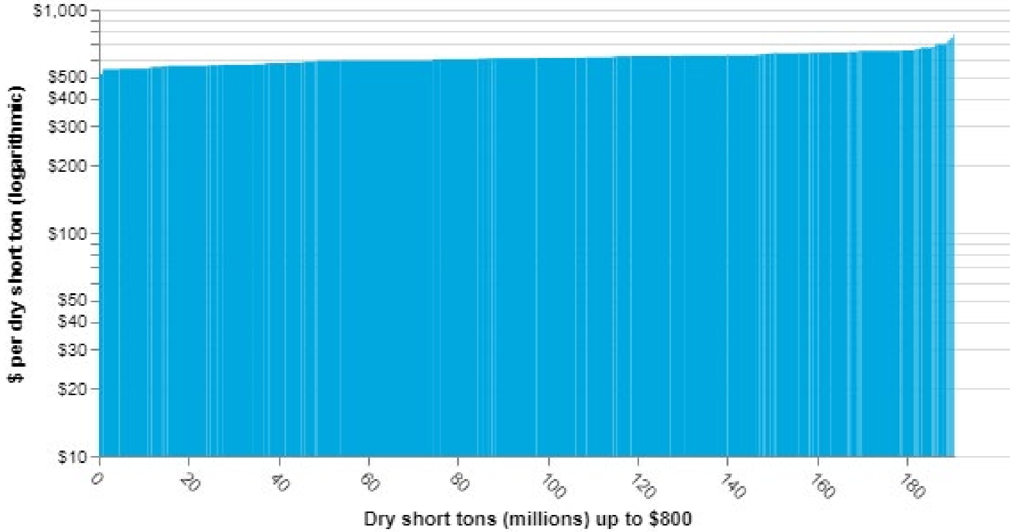


https://bioenergykdf.net/document/2023-billion-ton-report

Emerging resources can provide 250+ million tons in future

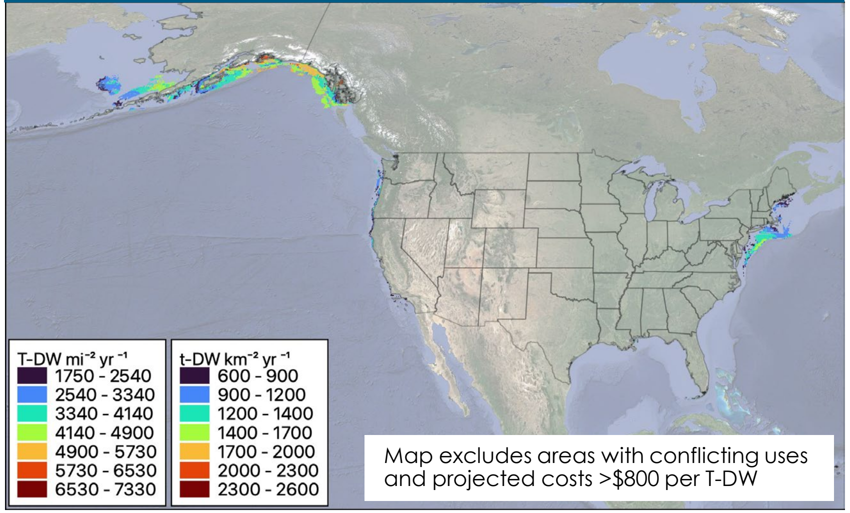
Microalgae

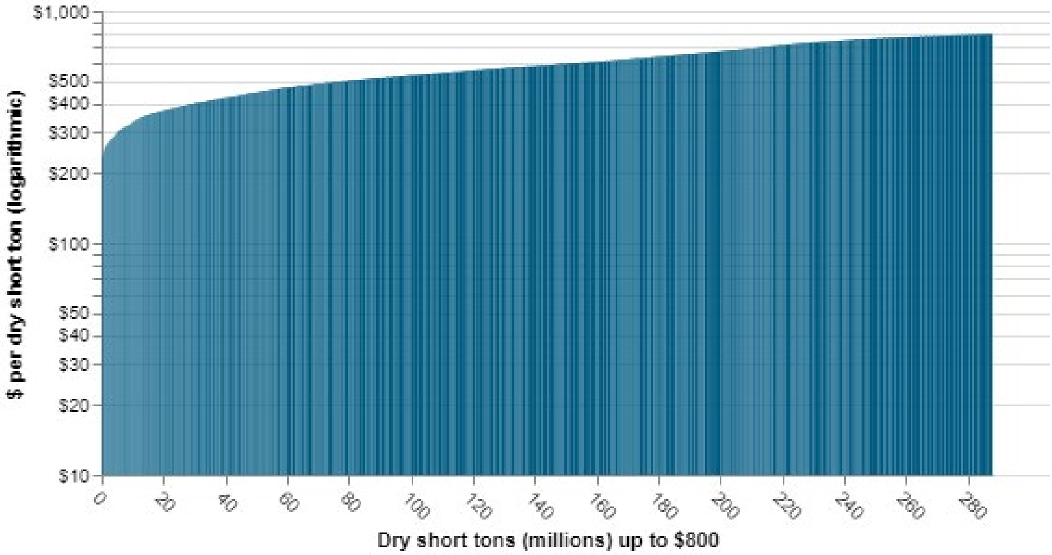




Microalgae supply curve based on weighted average cost of individual sites by county.

Macroalgae

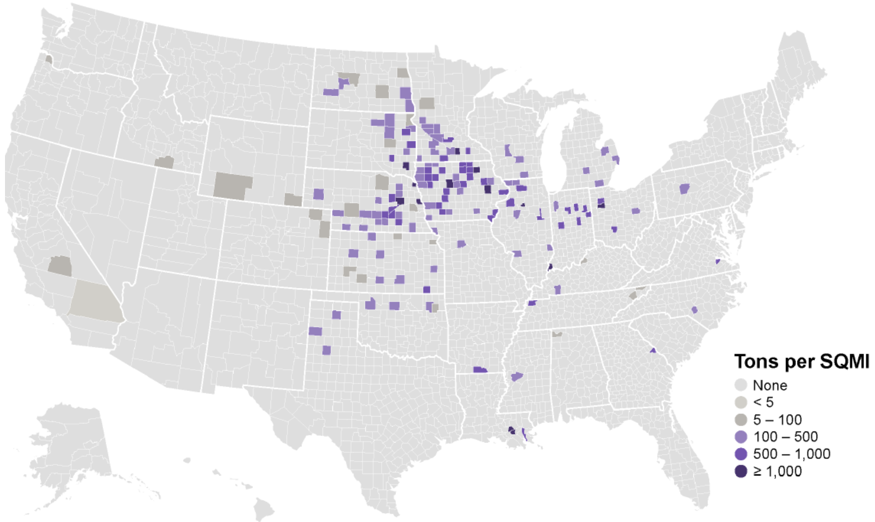




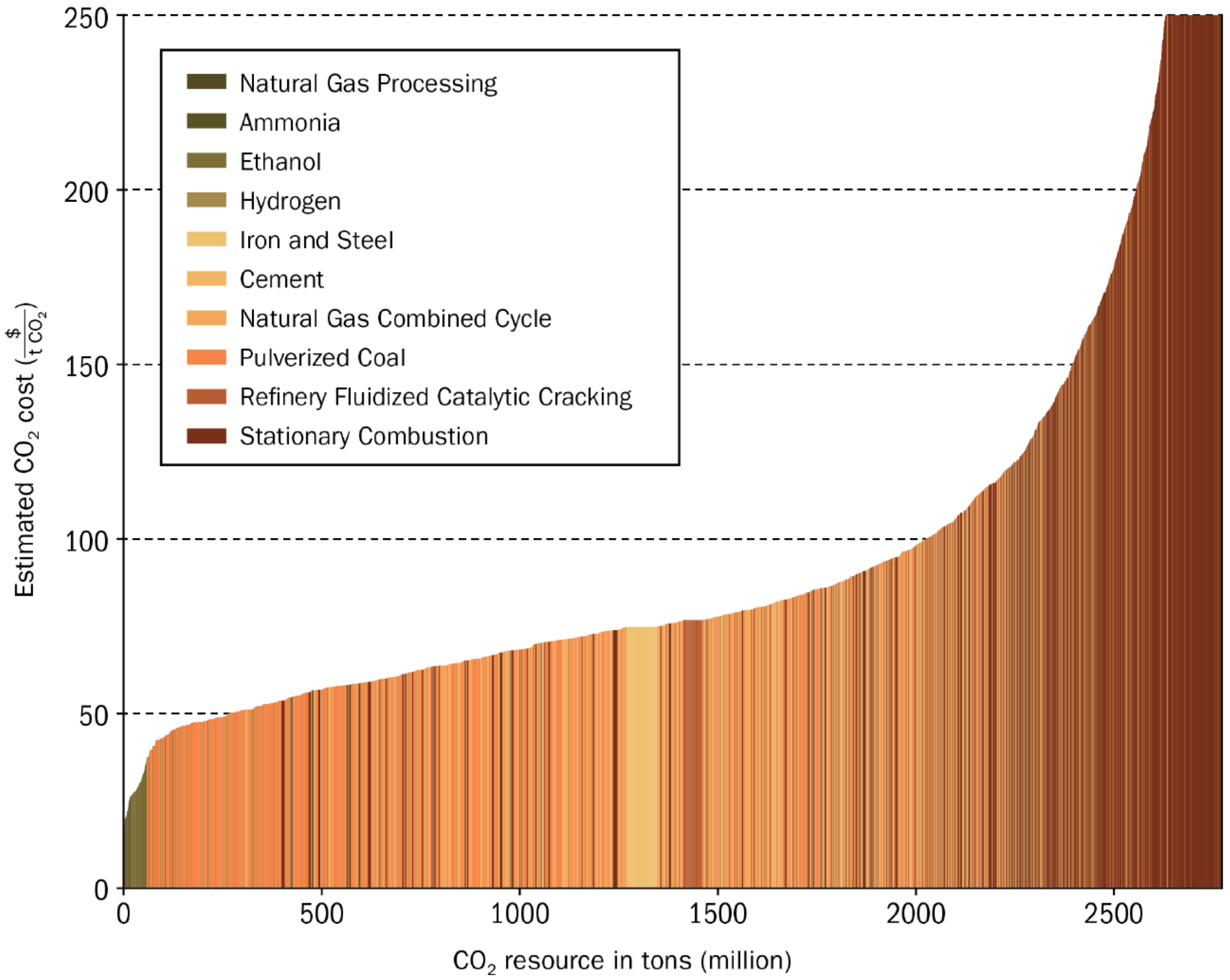
Carbon Dioxide: Stationary Sources

Total U.S. CO_2 from stationary sources: 2.7 billion tons per year

High-purity CO_2 sources: 47.2 million tons per year, <$30/ton

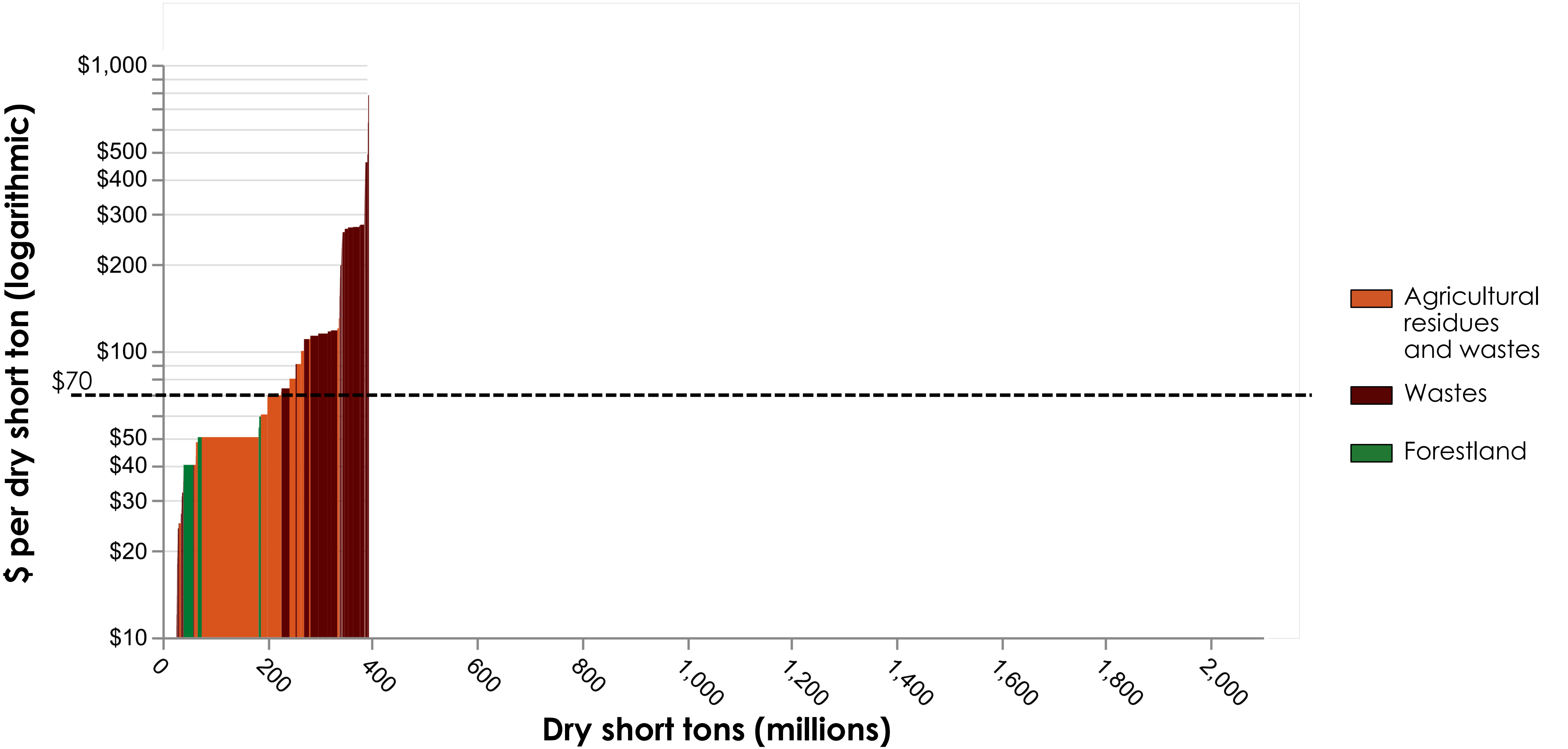


High-purity CO_2 from ethanol and ammonia production.

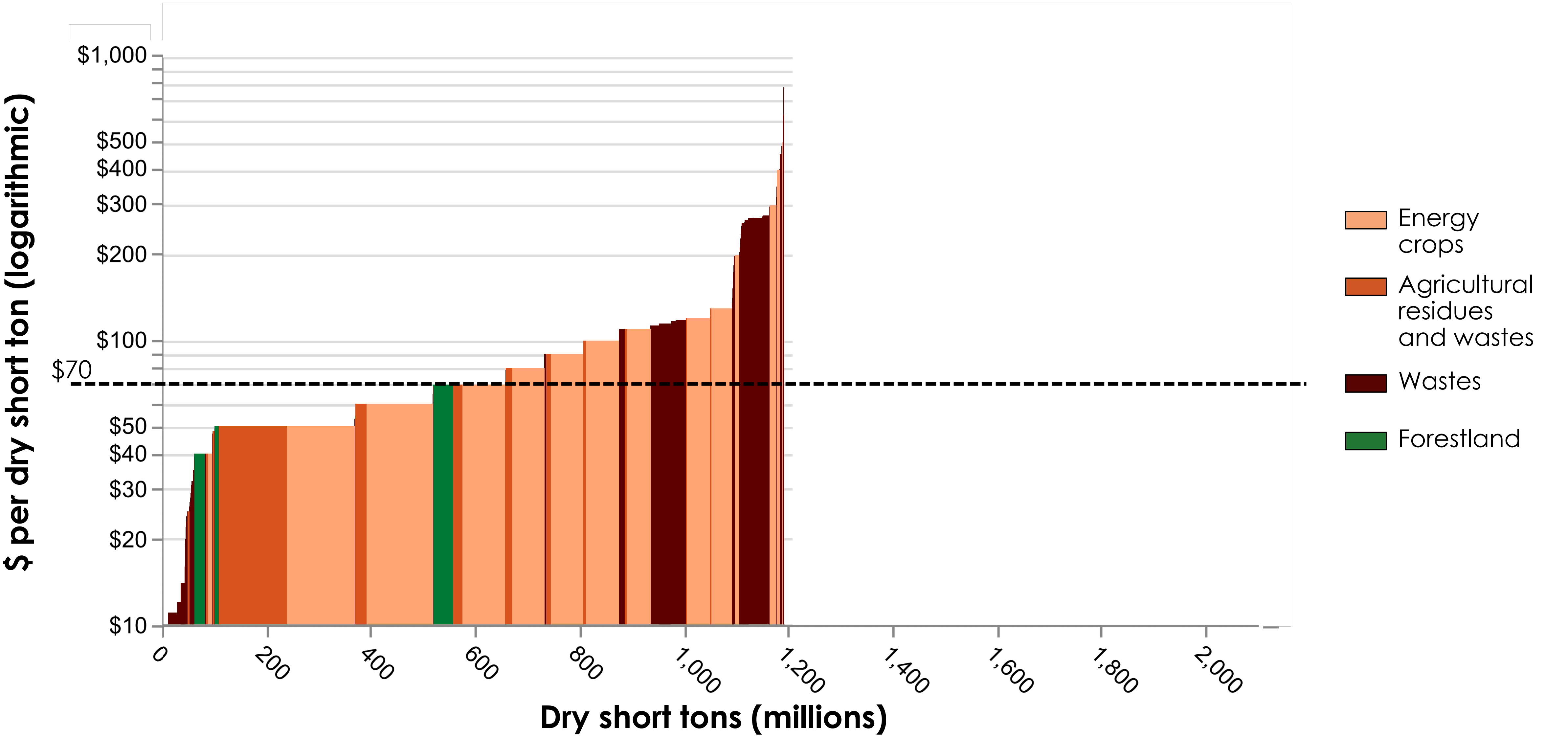


Subset of total CO_2 resource by facility category for stationary source and estimated cost of CO_2 capture and purification. Figure using data from NETL and the Office of Fossil Energy and Carbon Management (NETL 2023; Fahs et al. 2023; Schmitt et al. 2023). See BT23 appendix for further information.

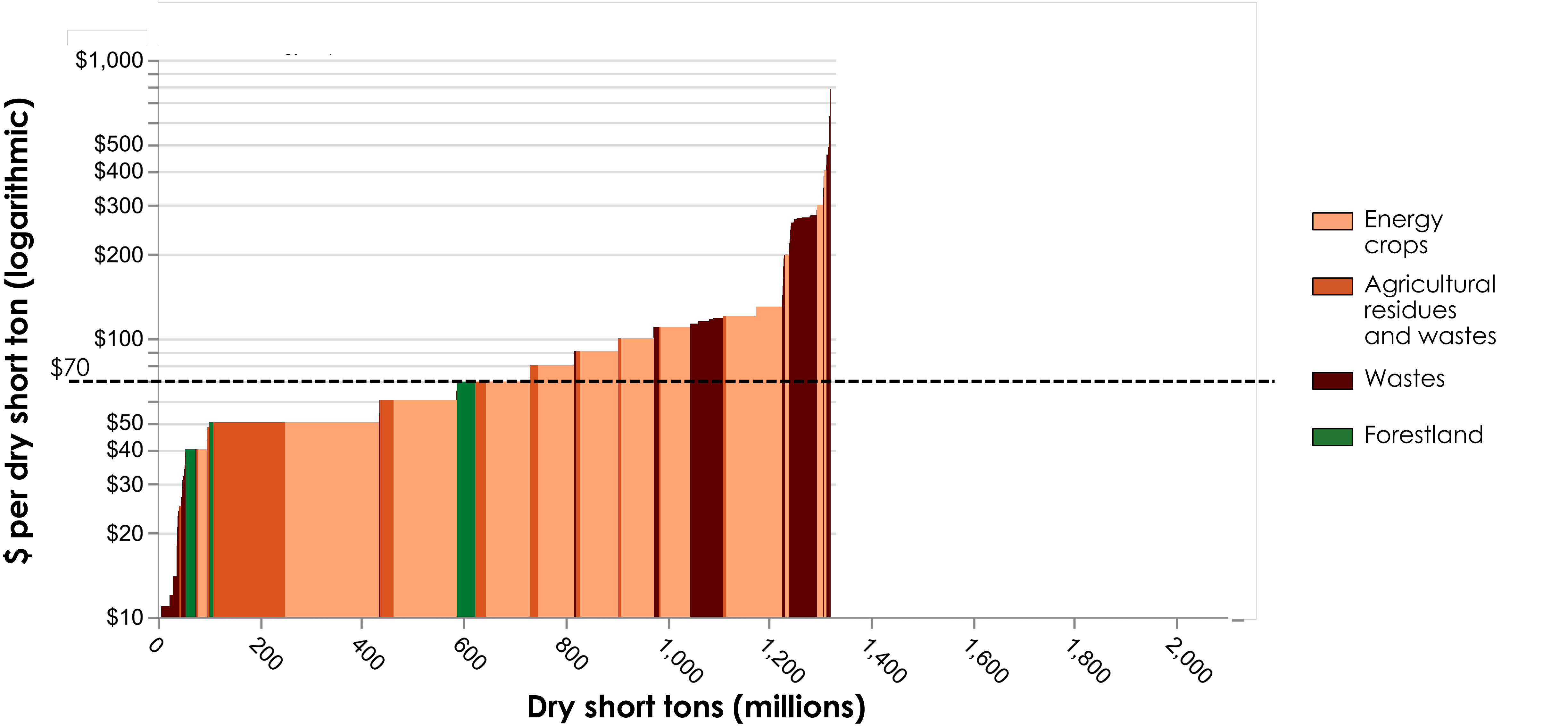
Potential biomass depends on price (Near Term)



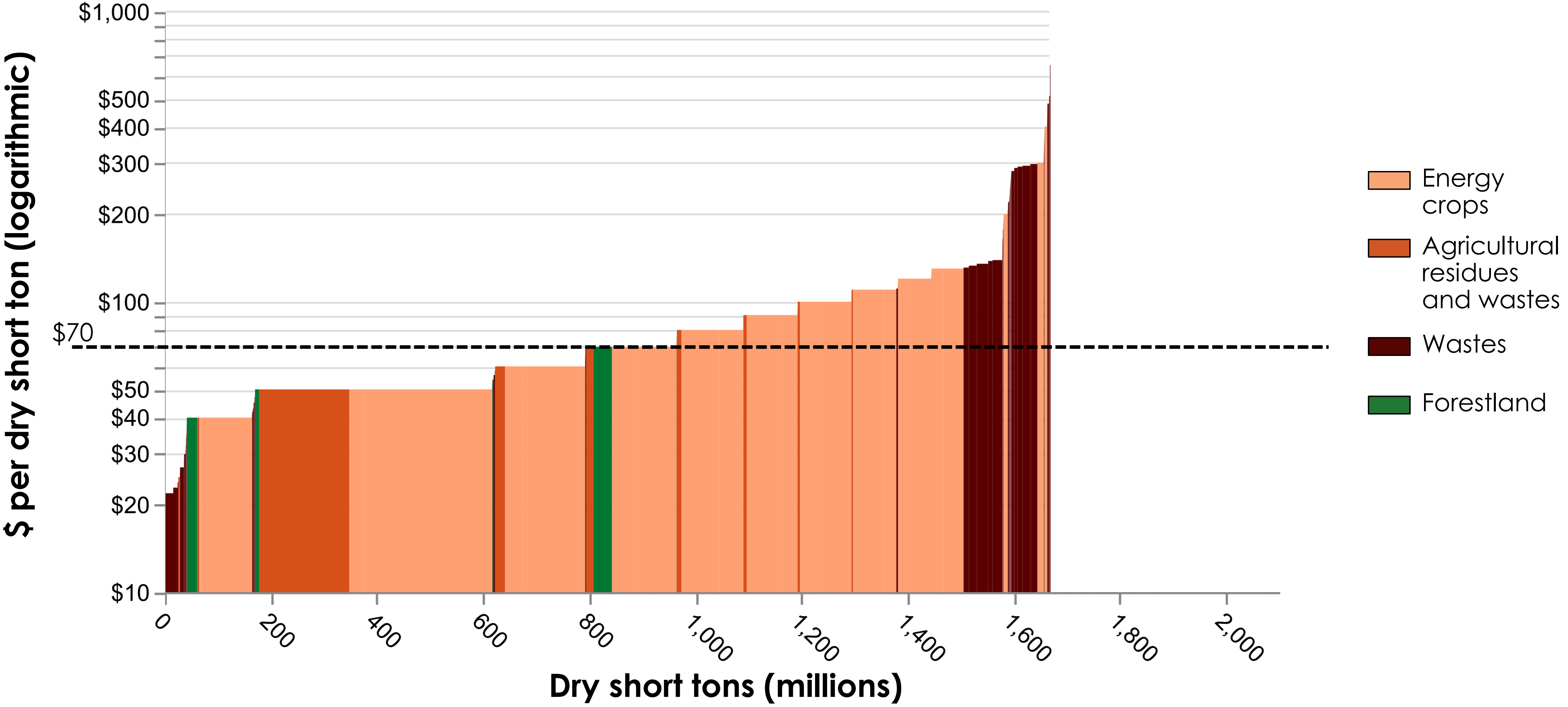
Potential biomass depends on price (Mature-Market Low)



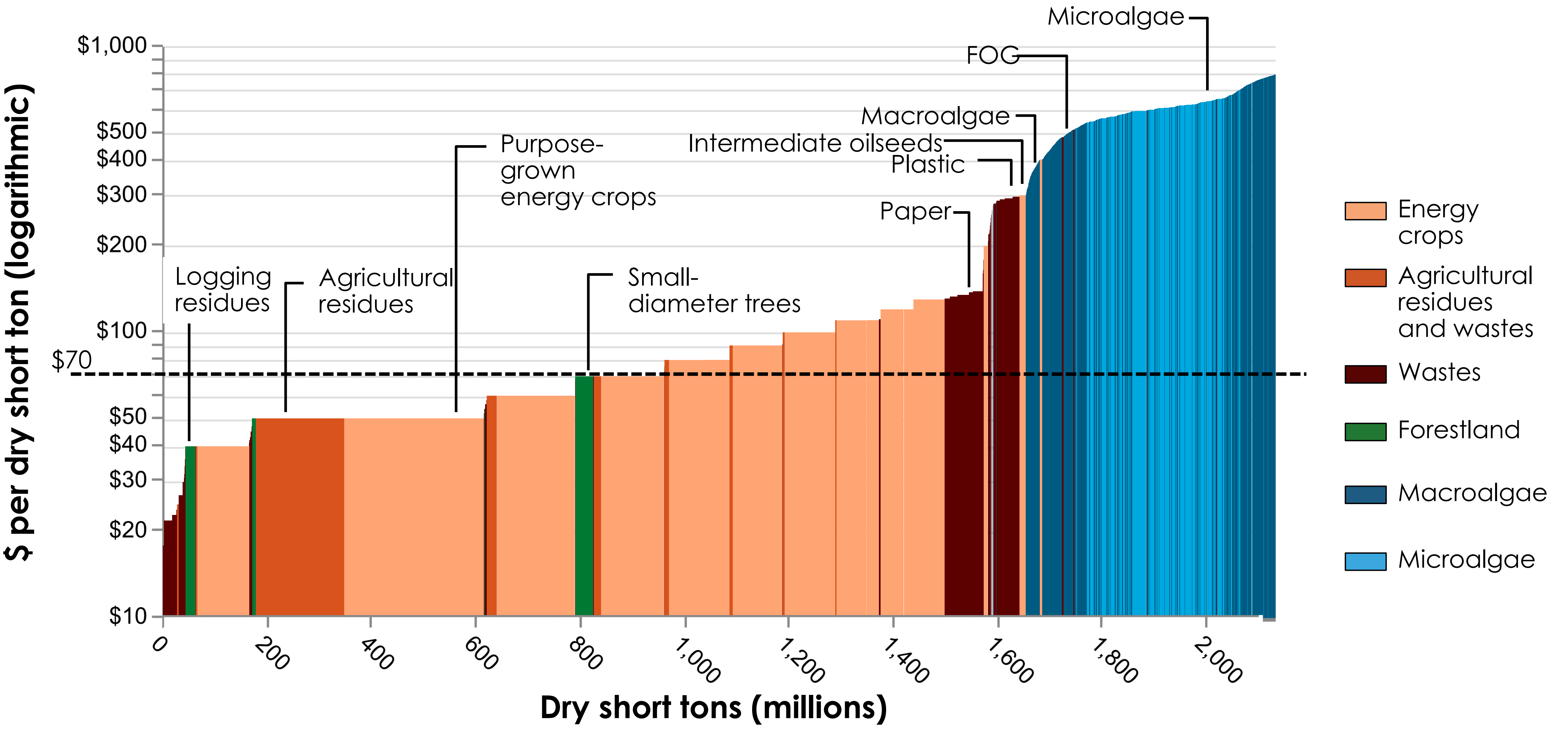
Potential biomass depends on price (Mature-Market Medium)



Potential biomass depends on price (Mature-Market High)



Potential biomass depends on price (Emerging scenario)



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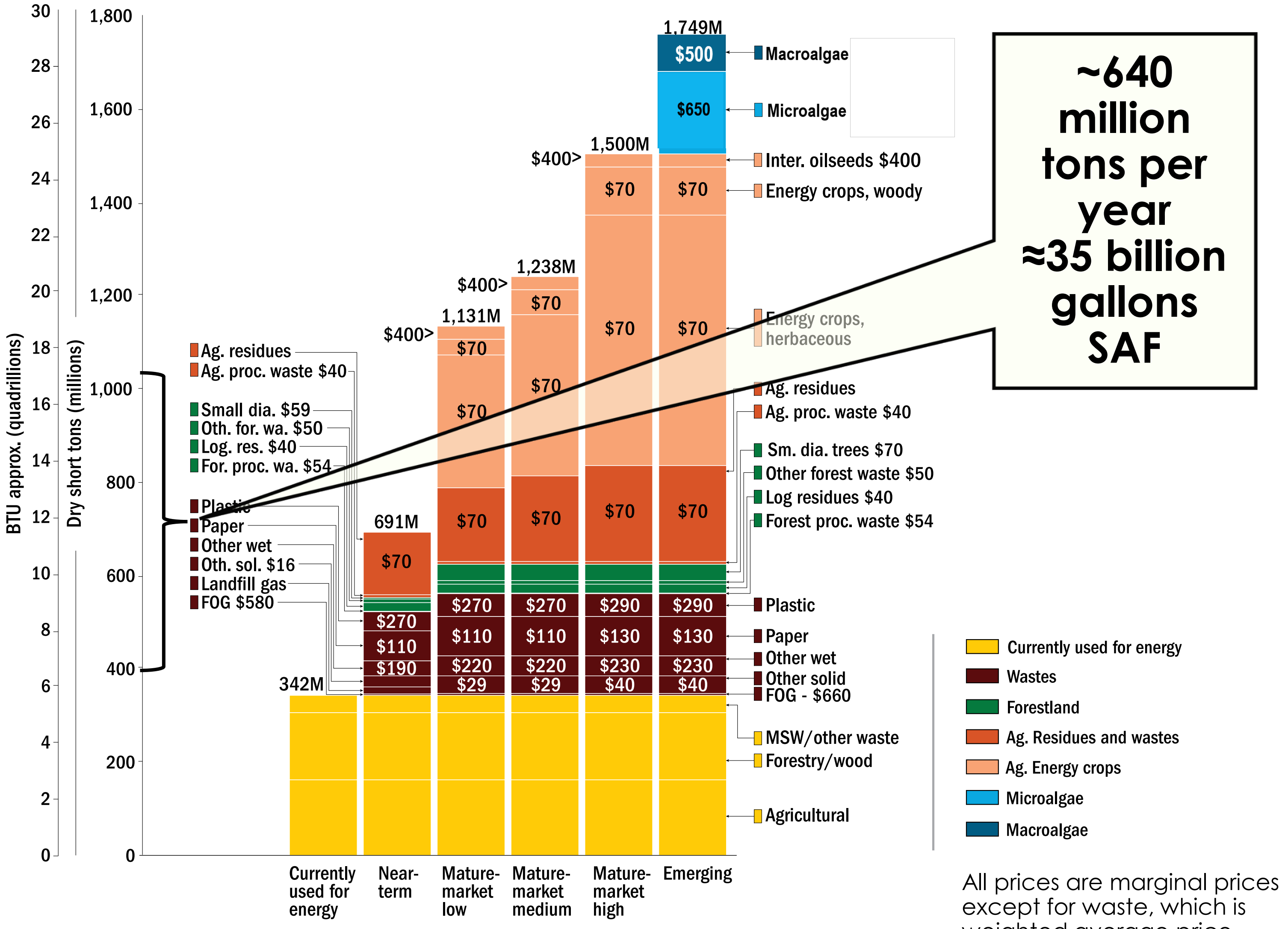
Results: 0.7-1.7 billion tons production capacity



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- Currently available resources can double biomass in **near-term**
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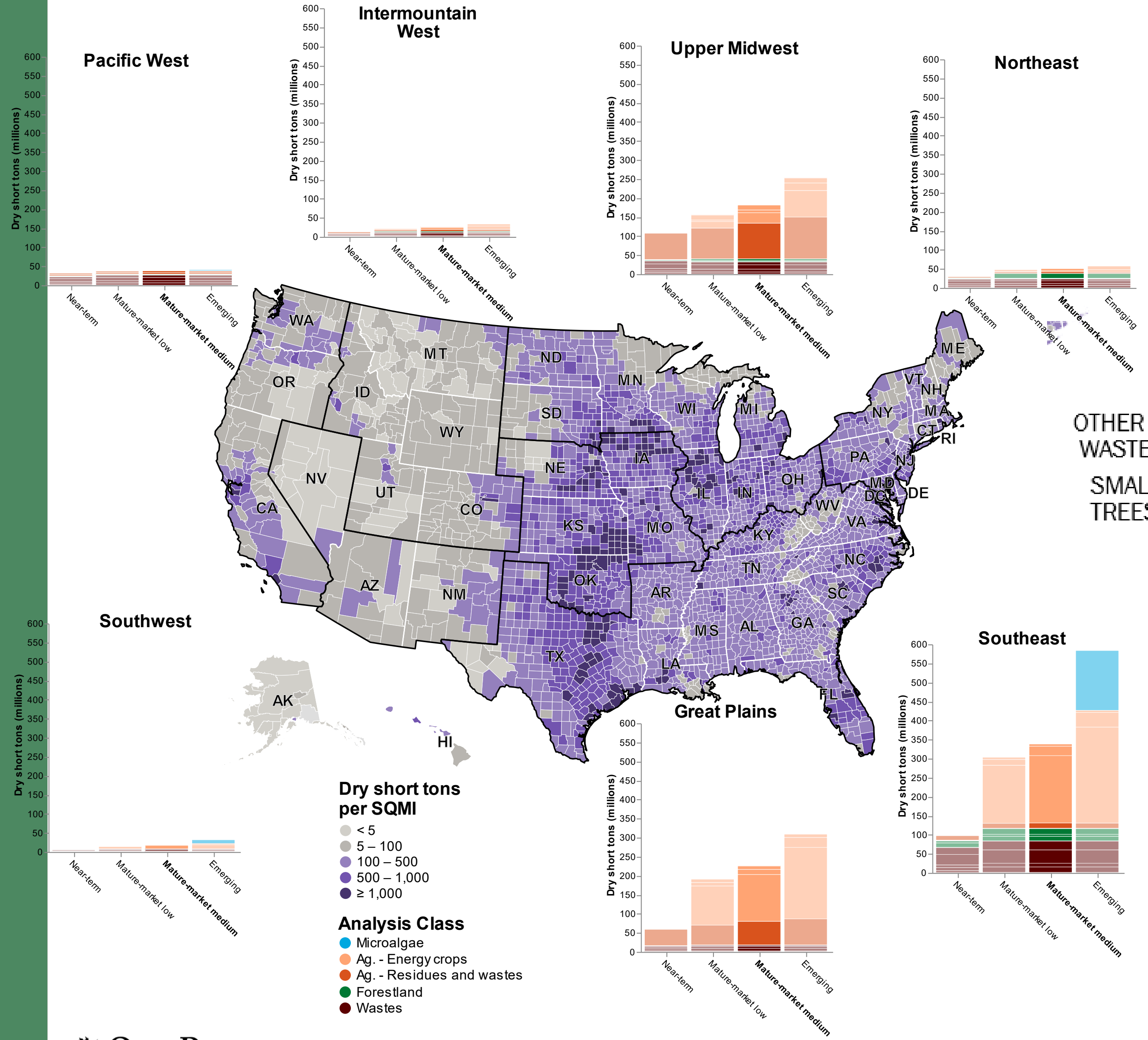
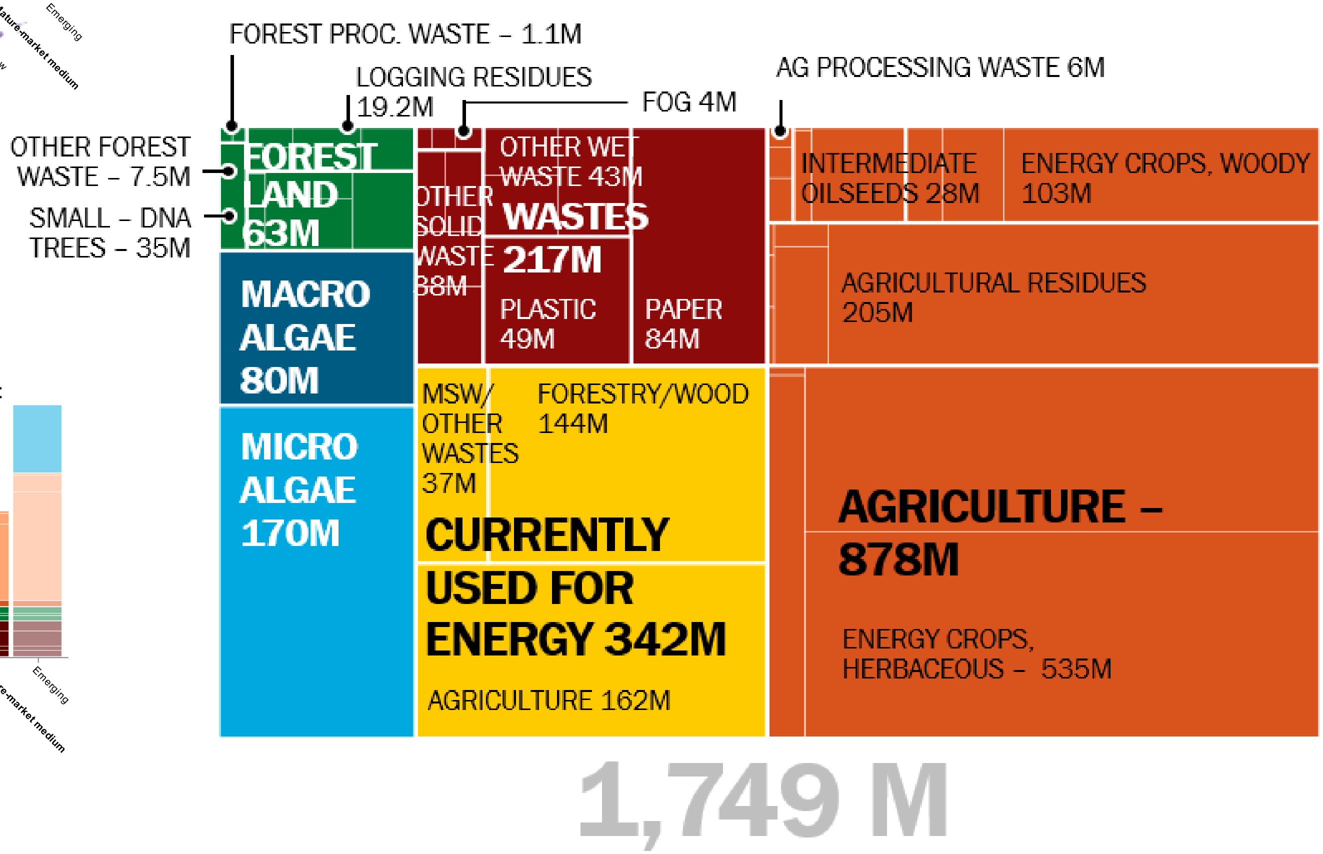
BT23: 1.7 billion tons under Emerging market scenario



57 resources, 4 analysis classes



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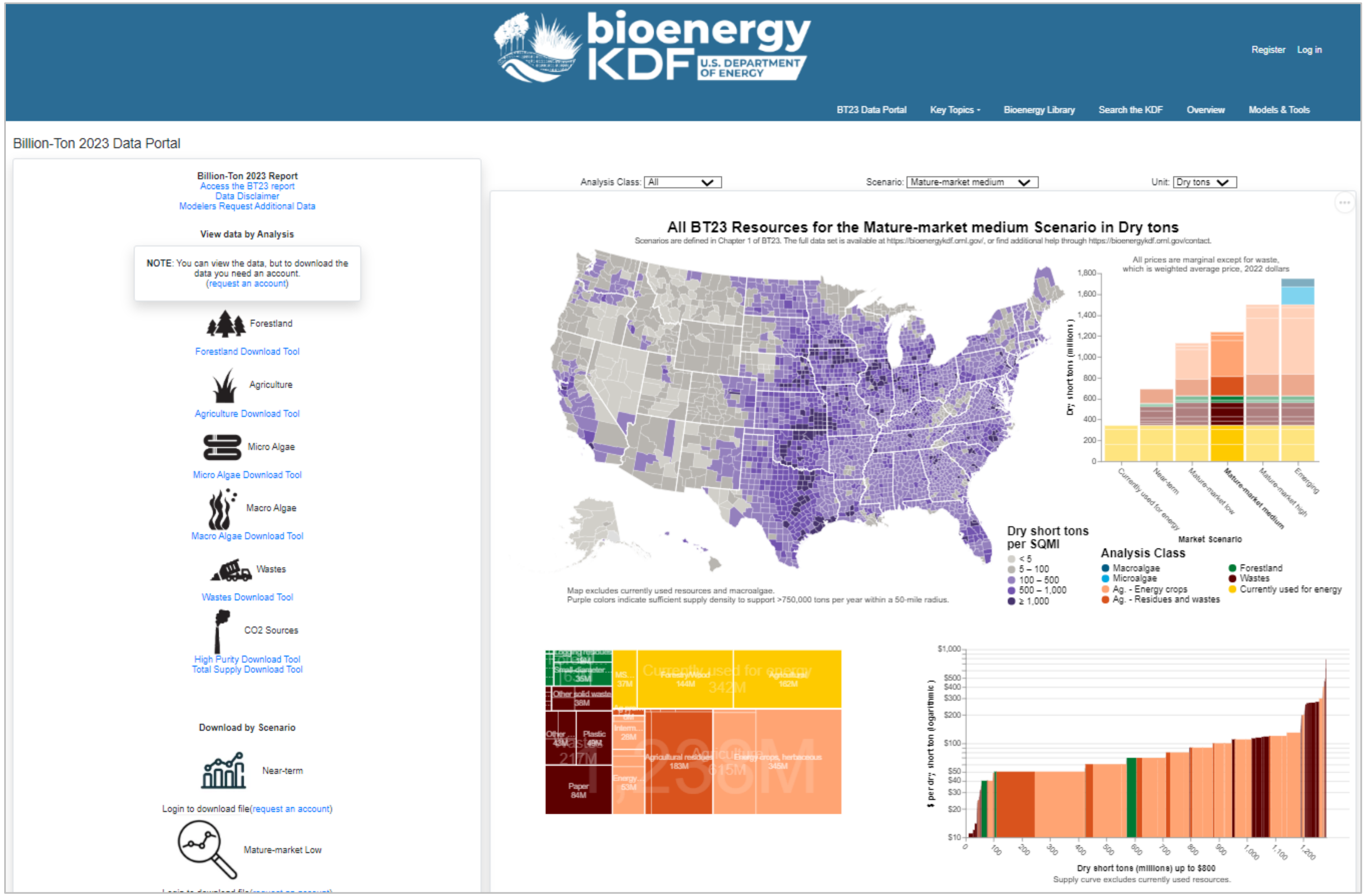
2023 Billion-Ton Report

BT23 Data Portal

bioenergy KDF

https://bioenergykdf.net/

langholtzmh@ornl.gov



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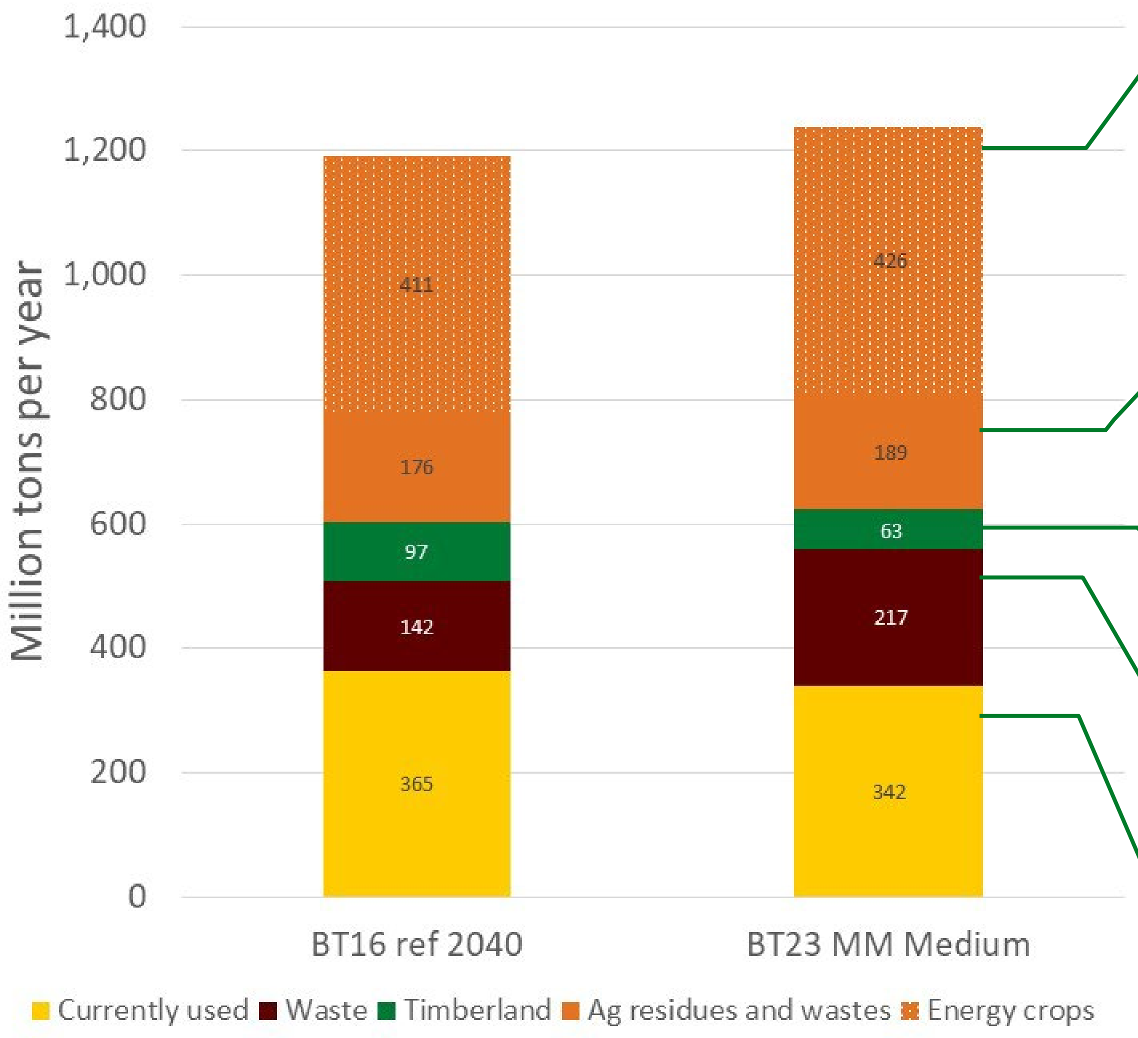
Base-case comparison with BT16



Energy crops @ $70/ton. Cellulosics reduced to ~400 million tons by 2023 USDA Baseline Projection, but ~28 million tons intermediate oilseeds added at $400/ton

Ag residues @ $70/ton. Includes 13 million tons of ag processing wastes

Forestry is now constrained to <$70/ton price vs cost

Wastes now included at all prices, e.g. plastics, paper, and FOGs

Net decrease of 23 million tons, primarily due to sawmill closures

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Assumptions matter

Yield assumptions:

Modeling and Analysis

Biofpr Biofuels Bioproducts & Biorefining

The impact of alternative land and yield assumptions in herbaceous biomass supply modeling: one-size-fits-all resource assessment?

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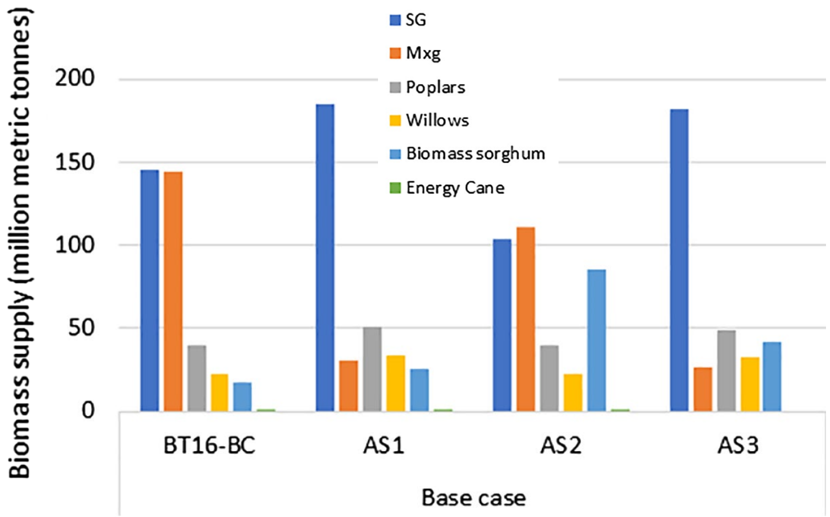
View online at Wiley Online Library (wileyonlinelibrary.com);
DOI: 10.1002/bbb.1946; *Biofuels, Bioprod. Bioref.* (2018)

Abstract. The Billion-ton Reports series has addressed the technical economic potential of supplying additional biomass from farmland and forests.[1–3] Underlying each of the reports and supporting scenarios is a series of assumptions that drive the modeled output. The assumptions have developed over time with the support of technical experts from industry, academia, and government.[4] Energy crops have not yet reached commodity scale, and only exist in commercial production in a limited number



Market assumptions:

Original Article

Biofpr Biofuels Bioproducts & Biorefining

Supply analysis of preferential market incentive for energy crops

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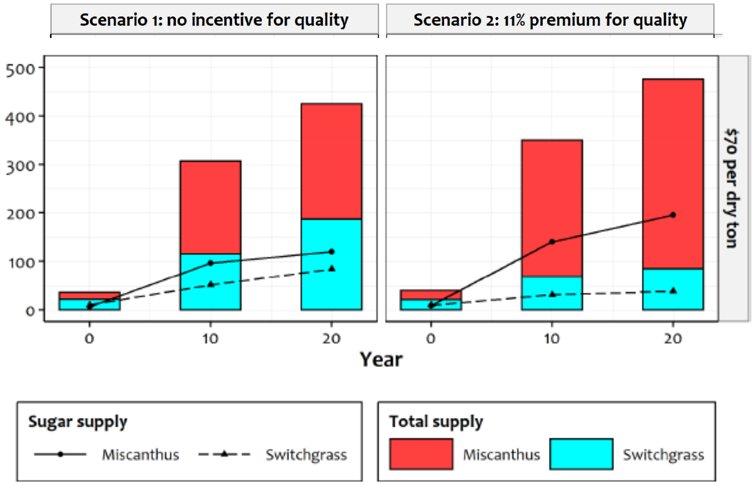
View online at Wiley Online Library (wileyonlinelibrary.com);
DOI: 10.1002/bbb.2184; *Biofuels, Bioprod. Bioref.* (2021)

Abstract: This analysis explores the valuation of feedstock quality attributes of switchgrass and miscanthus – two energy crops poised for future expansion – and compares the relative economic availability of these two crops under two scenarios: (i) uniform price assumptions (i.e., no incentive for quality), and (ii) a scenario of a price premium based on convertibility (i.e., an incentive for quality). Given data on cellulose content, hemicellulose content, and their relative convertibility, miscanthus is expected to be 11% more efficient at conversion to biofuels than switchgrass under the biochemical conversion route. Based on this scenario of improved conversion efficiency and associated profit, we simulate an 11% price premium for miscanthus over other feedstocks in a base-case scenario. By adding this price premium, supplies of miscanthus increase over the base case by about 4 million (44%), 94 million (64%) and 166 million (94%) tons in year 0, 10, and 20 after simulated contracts for production are



Climate change: