

Overview of the 2023 Billion-Ton Report

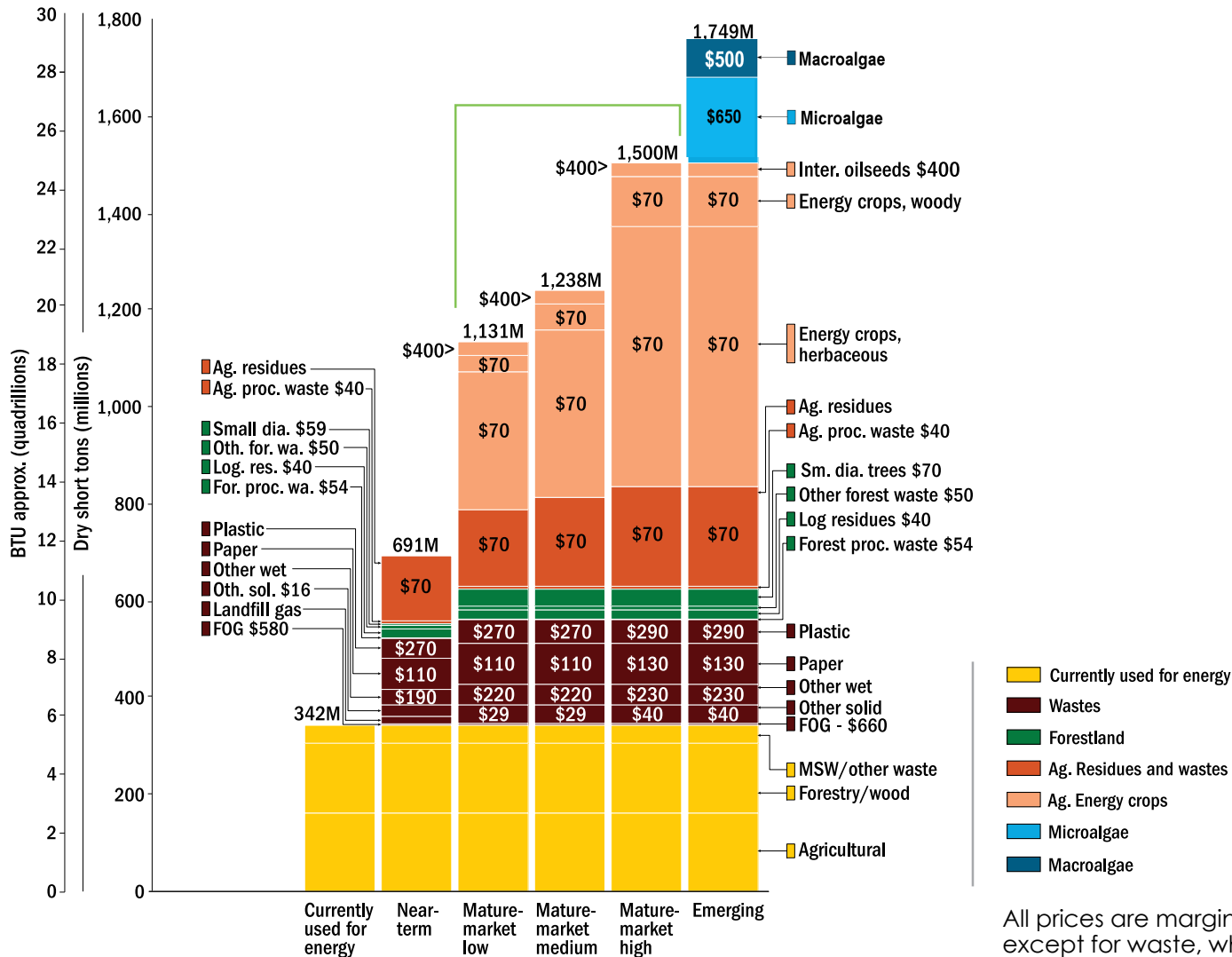
Fifty-four authors, BT23

Clean Fuels and Products Shot Summit

April 9th, 2024

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

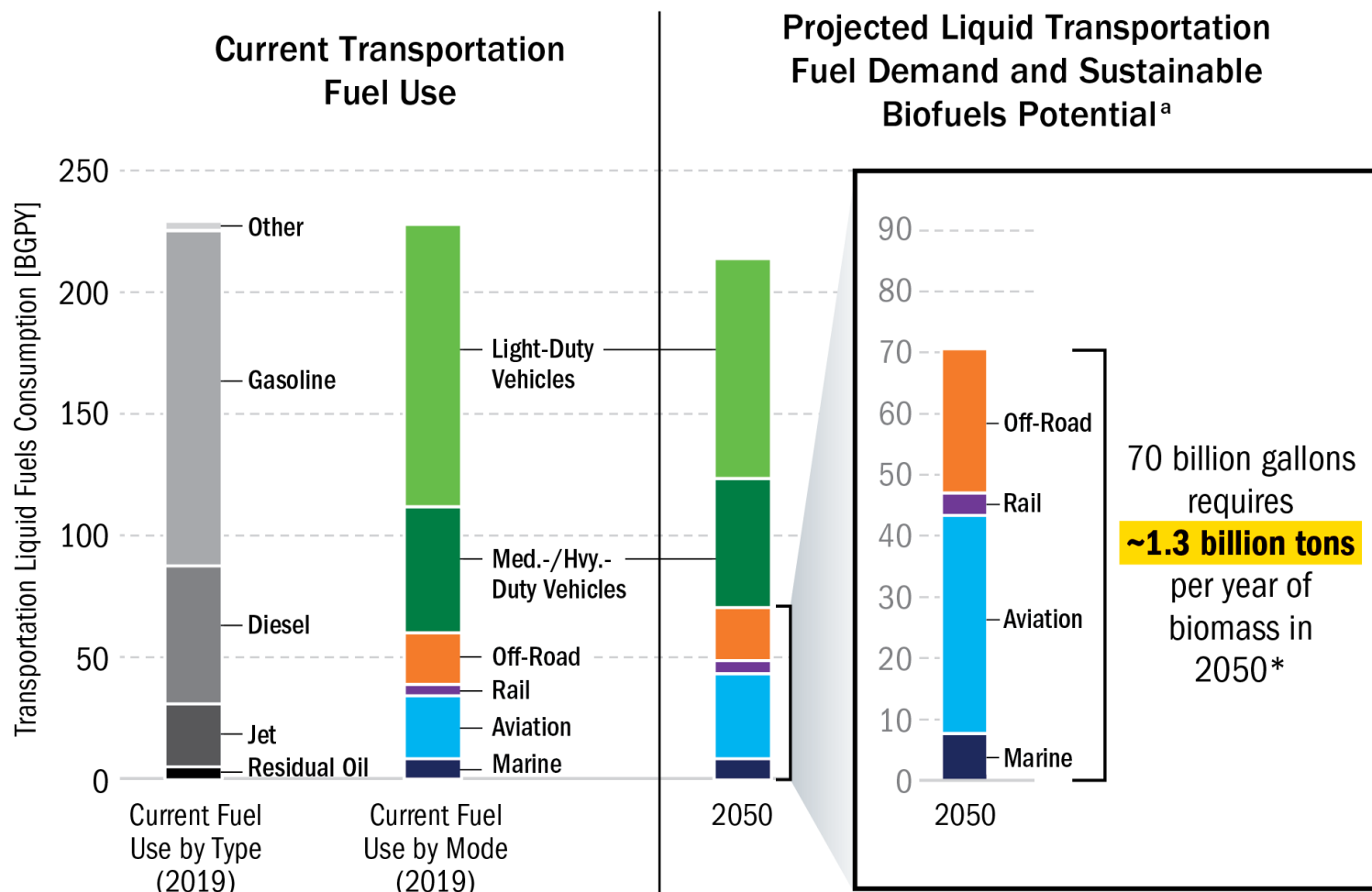
Results: 0.7-1.7 billion tons production capacity



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

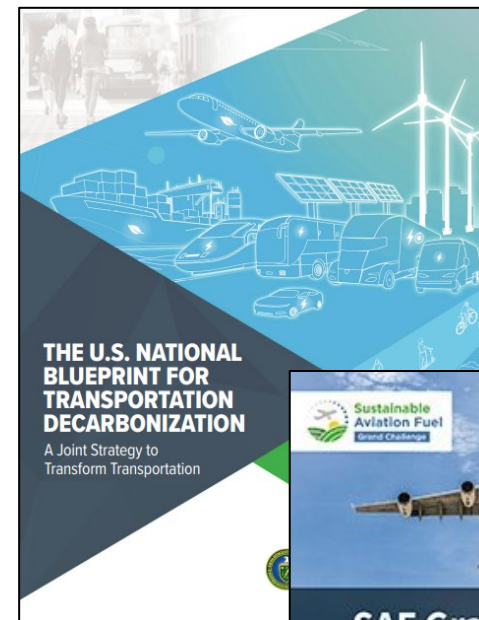
- Bioeconomy currently provides 340 million tons biomass (5 Quads or 5% total)
- Currently available resources can double biomass in **near-term**
- **Mature market** induces another 440-800 million tons biomass depending on yield assumptions
- Emerging resources can supply another 250 million tons
-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

Demands for Decarbonization



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

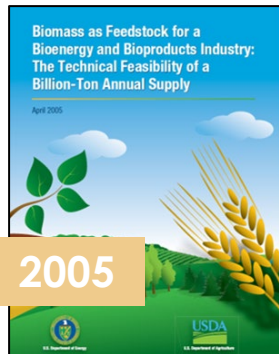
* Assumes a conversion rate of 55 gallons per ton



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)



2005



2011



2016

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

Billion-Ton 2023 Collaborators

Fifty-four contributors



Thirty reviewers

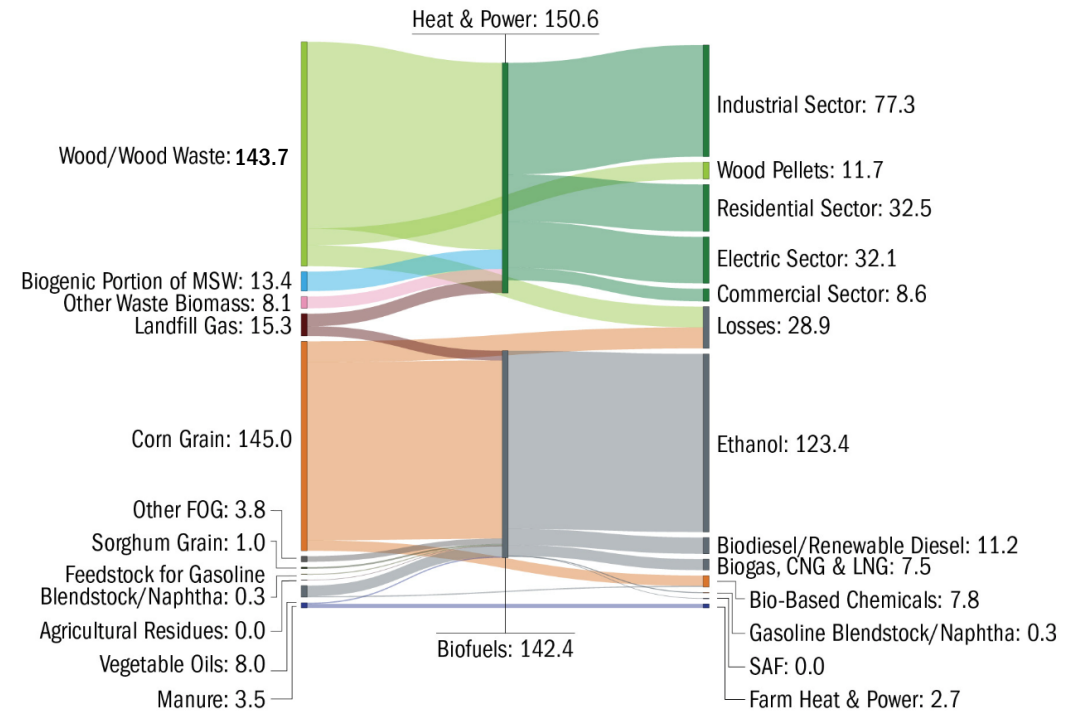
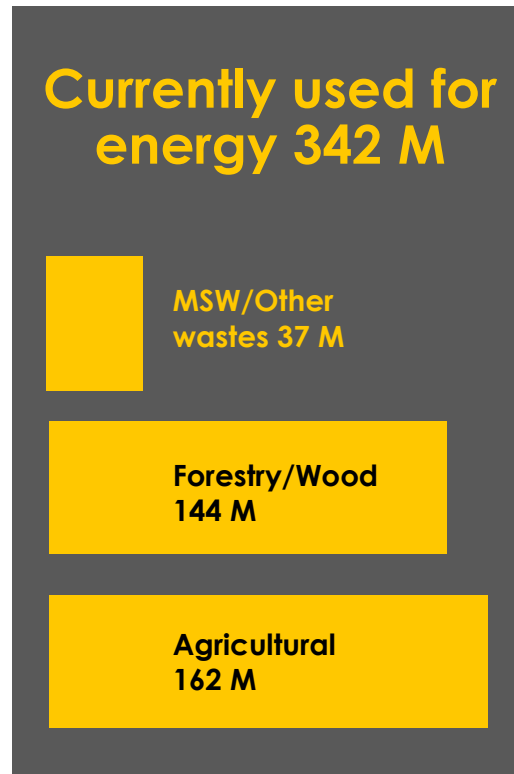
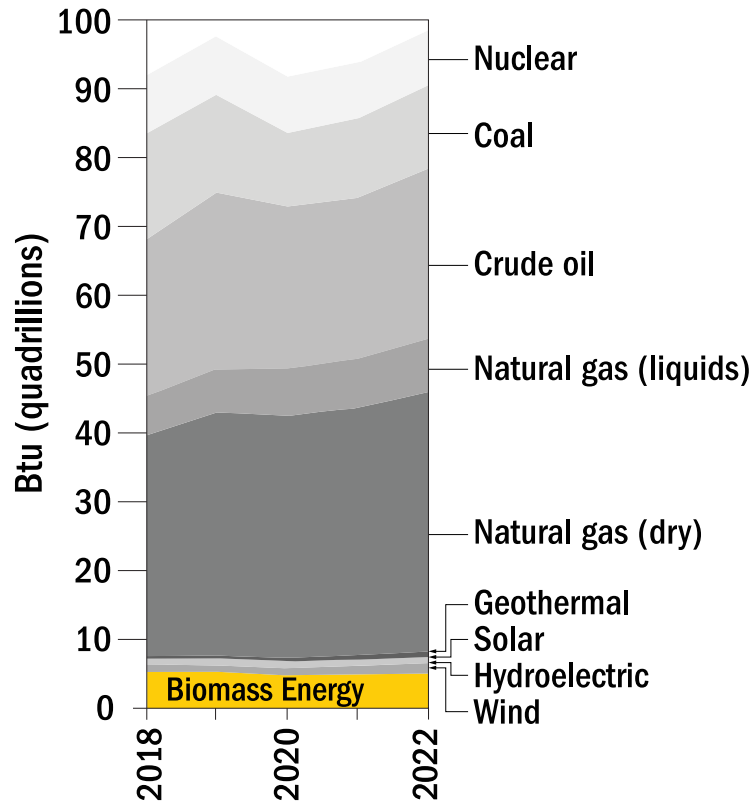


BT23 considers current, available, and future resources



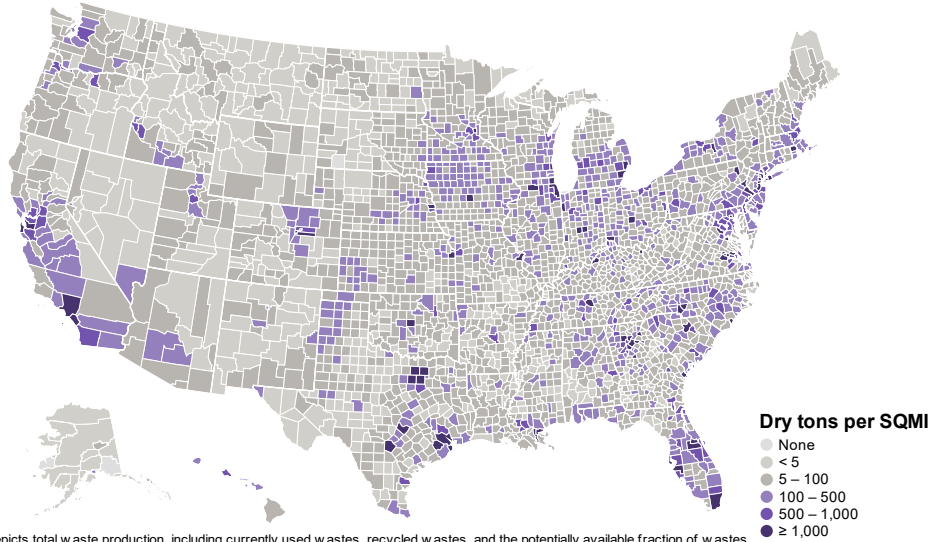
US currently uses 340 million tons of biomass for fuel & power

U.S. Energy Production



Million tons per year in 2022

Waste & byproduct resources can provide 180-220 million tons



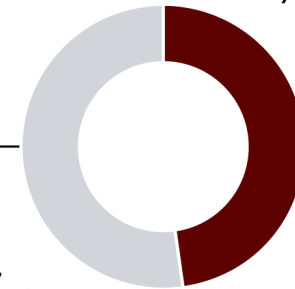
Map depicts total waste production, including currently used wastes, recycled wastes, and the potentially available fraction of wastes. Purple colors indicate sufficient supply density to support >750,000 tons per year within a 50-mile radius.



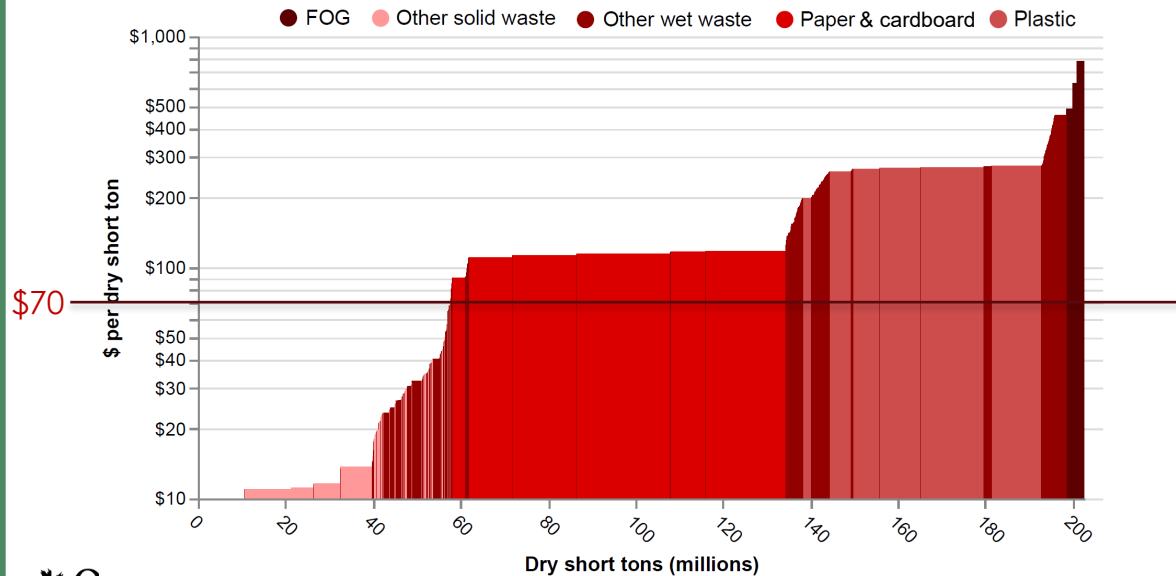
WASTES - 217 M

Reference scenario

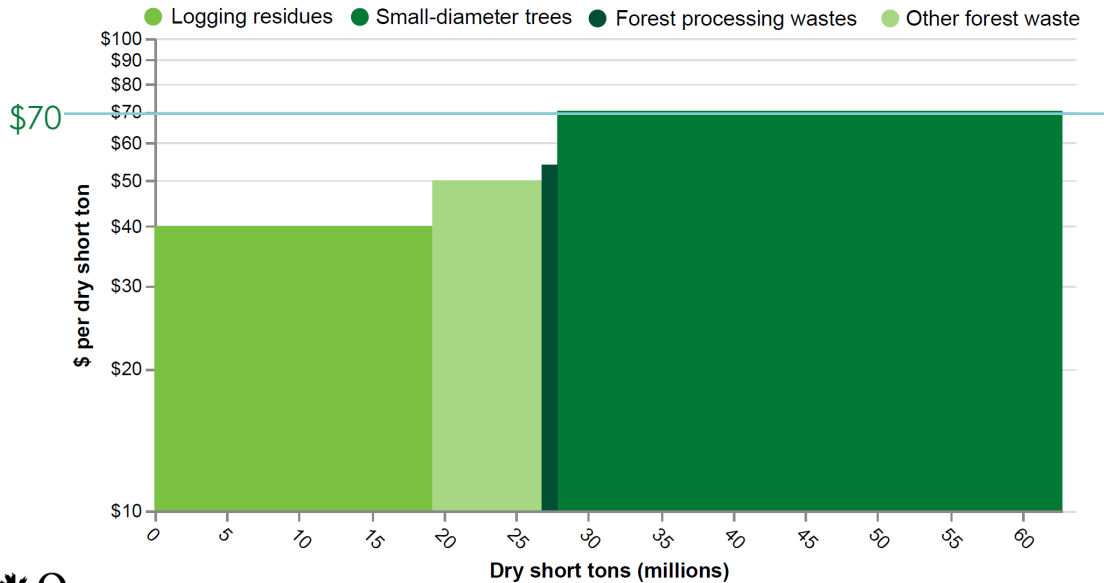
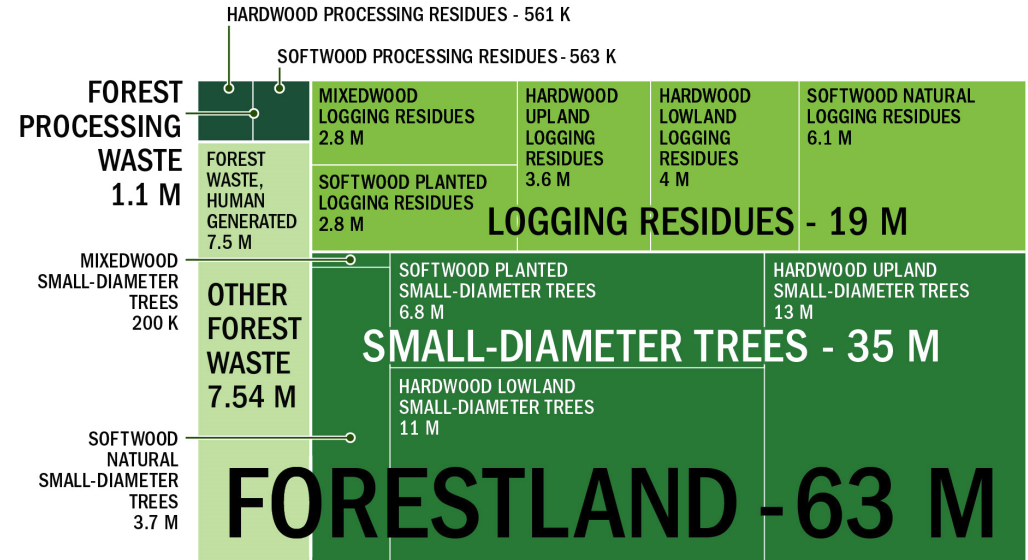
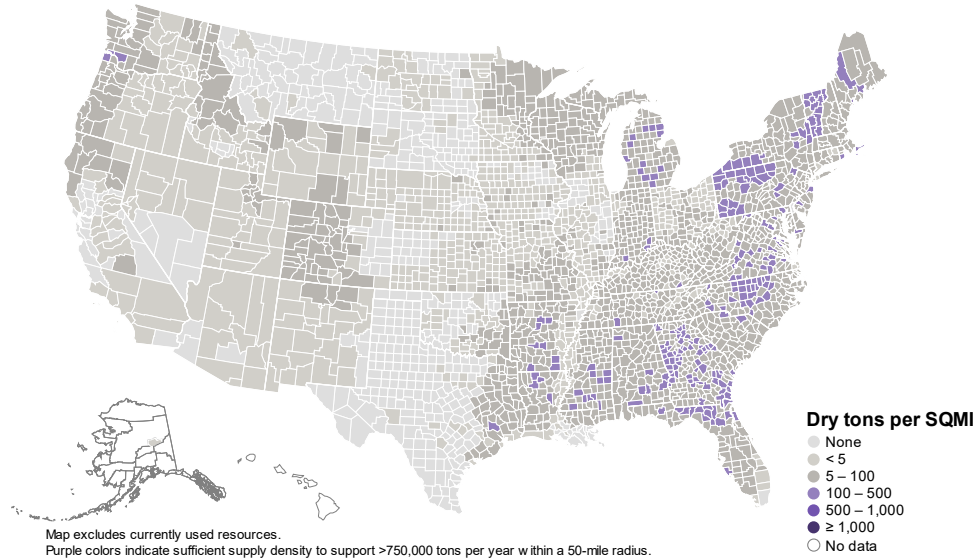
217 million tons/yr equivalent



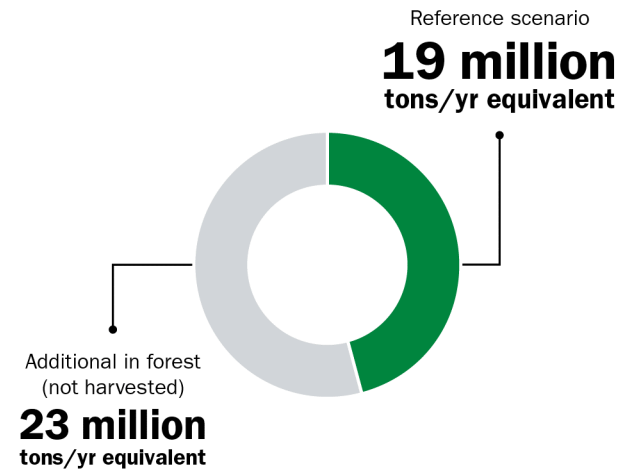
Recycled, current bioenergy, and other uses
235 million tons/yr equivalent



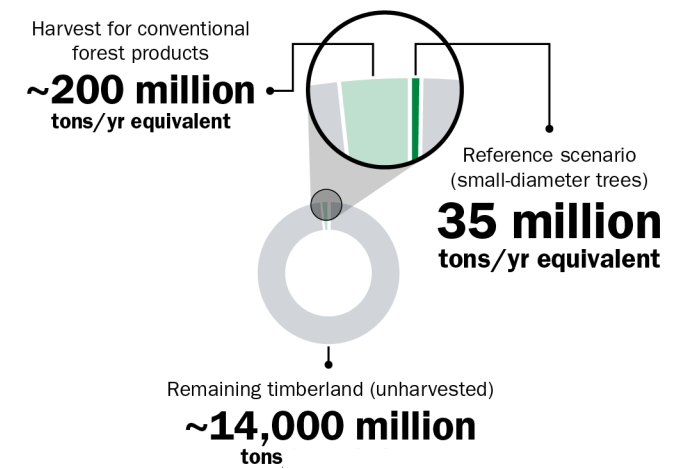
Timberland resources can provide 32-63 million tons



Logging Residues

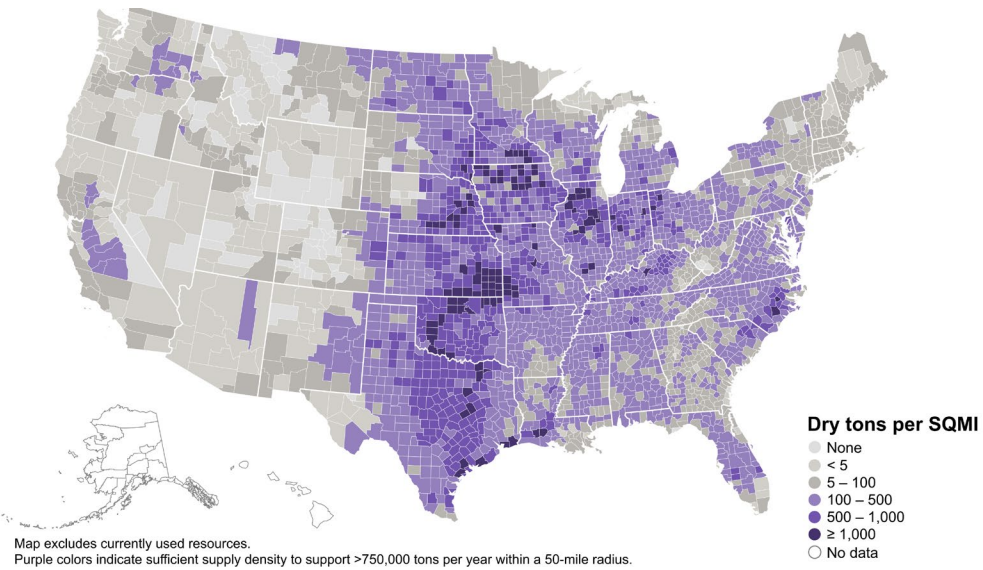


Tree Biomass

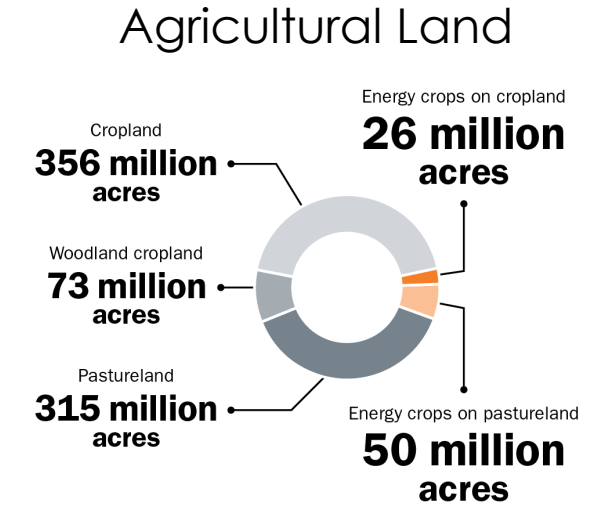
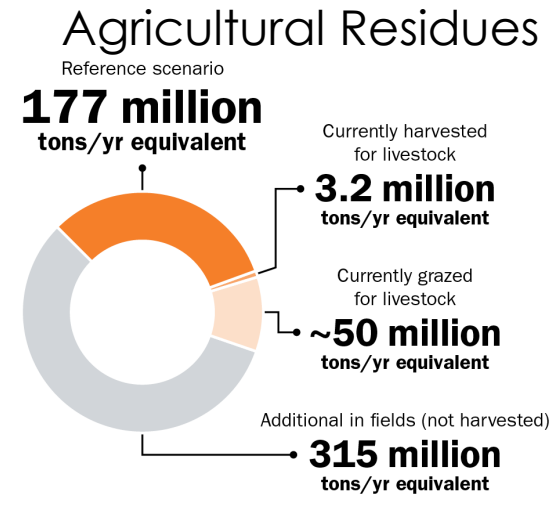
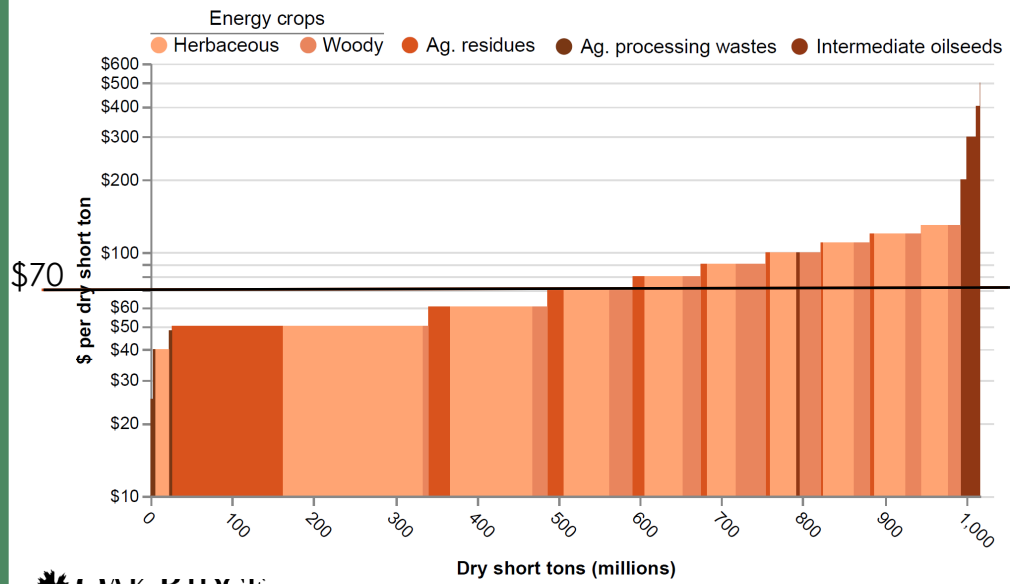
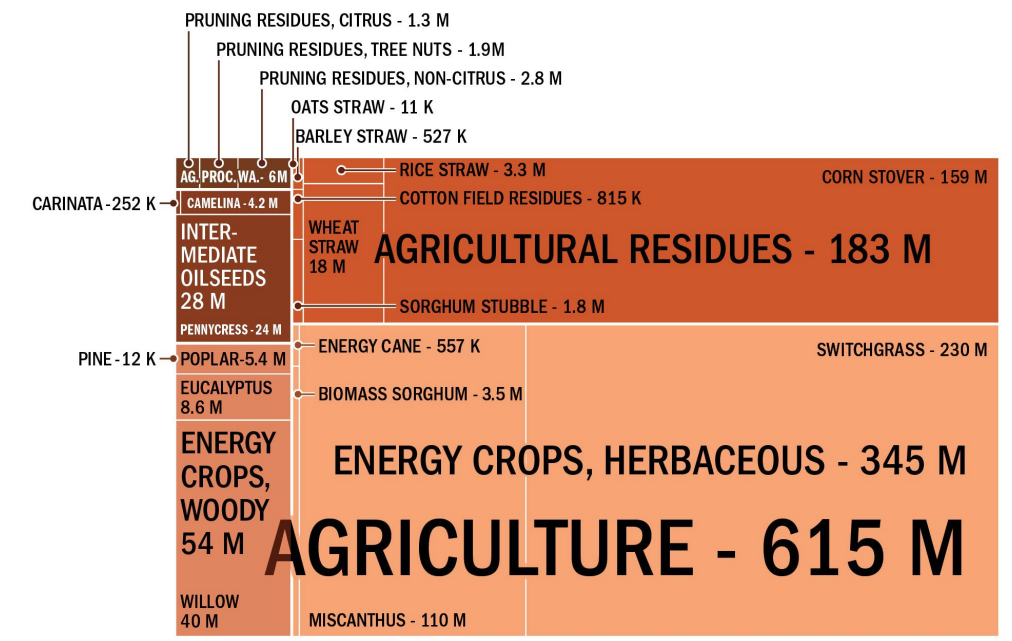


*Mature-market medium, reference scenario, up to \$70 per ton

Agricultural resources can provide 150-800+ million tons

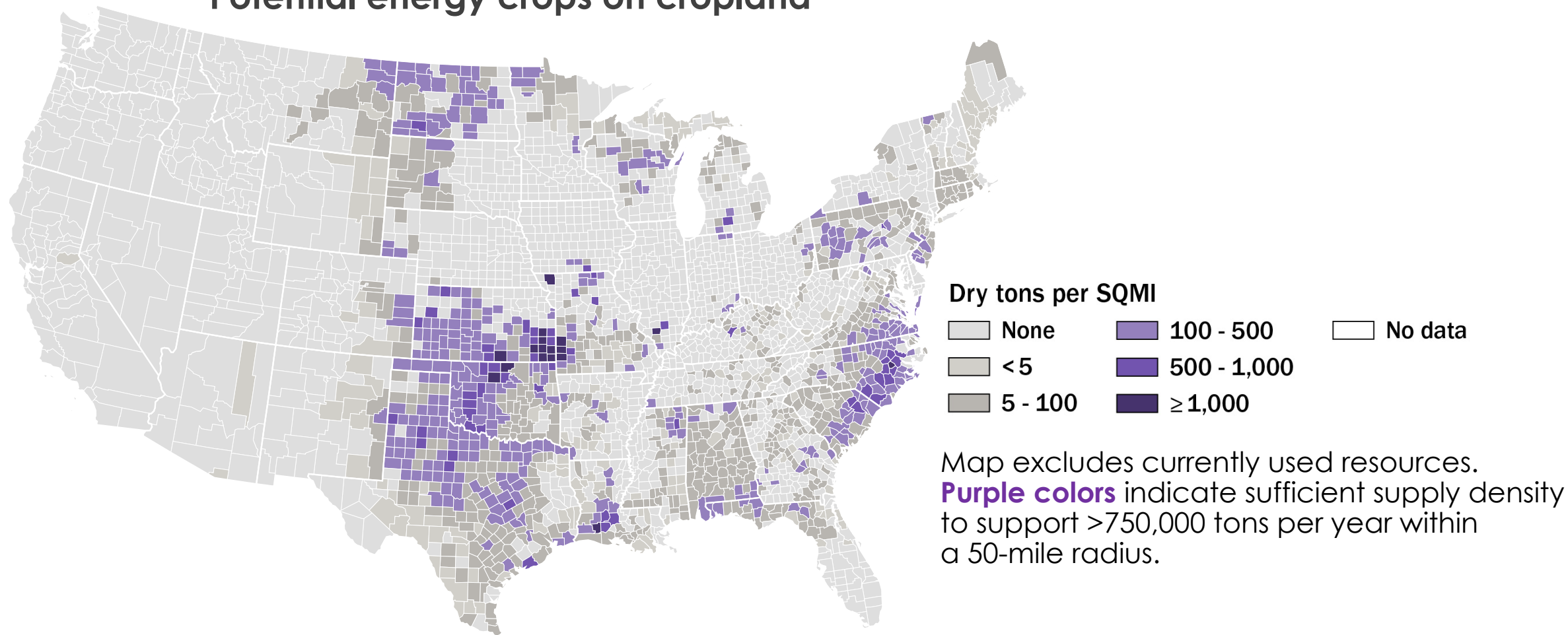


Ag lands can be used to grow 300-600 million tons of cellulosic energy crops. Intermediate oil seeds can provide another 28 million tons.



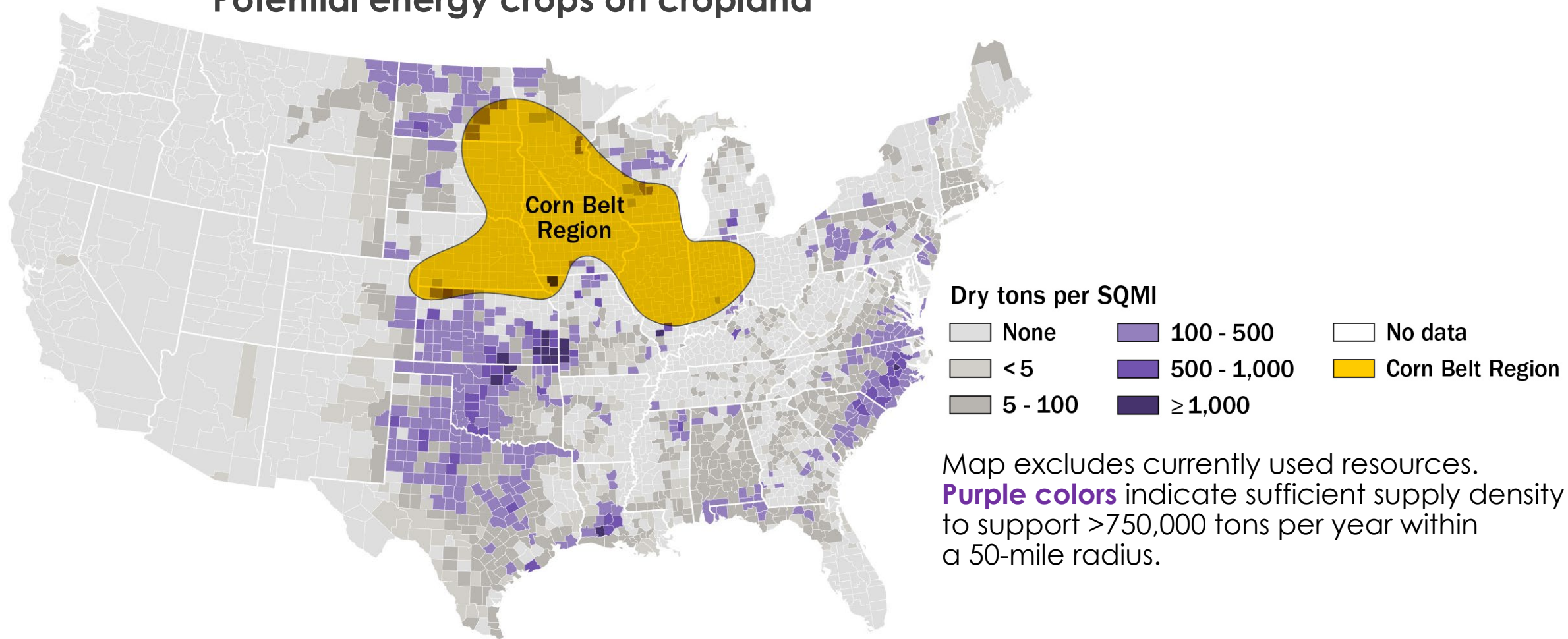
Energy crops results on cropland are outside the corn belt

Potential energy crops on cropland



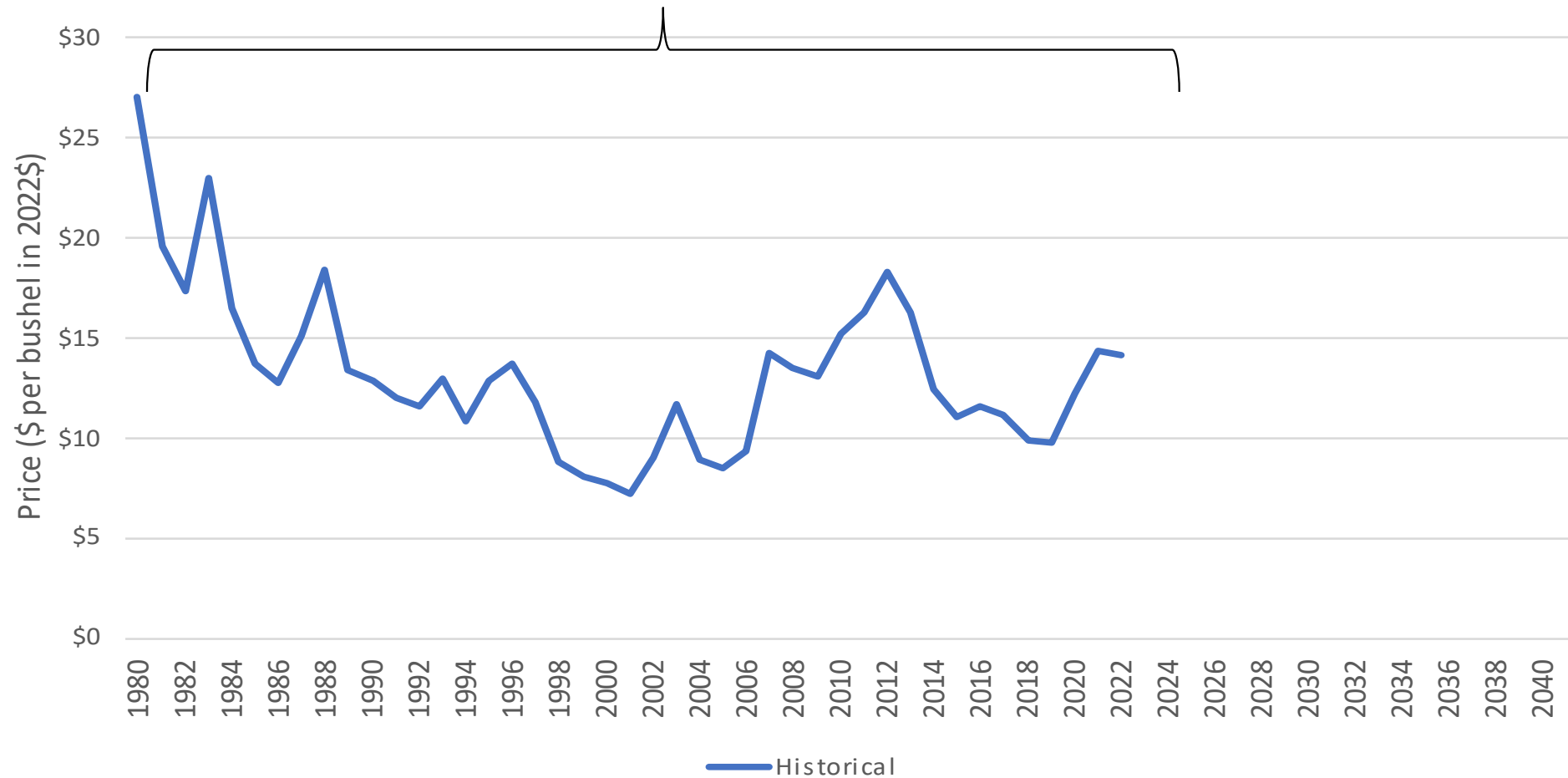
Energy crops results on cropland are outside the corn belt

Potential energy crops on cropland

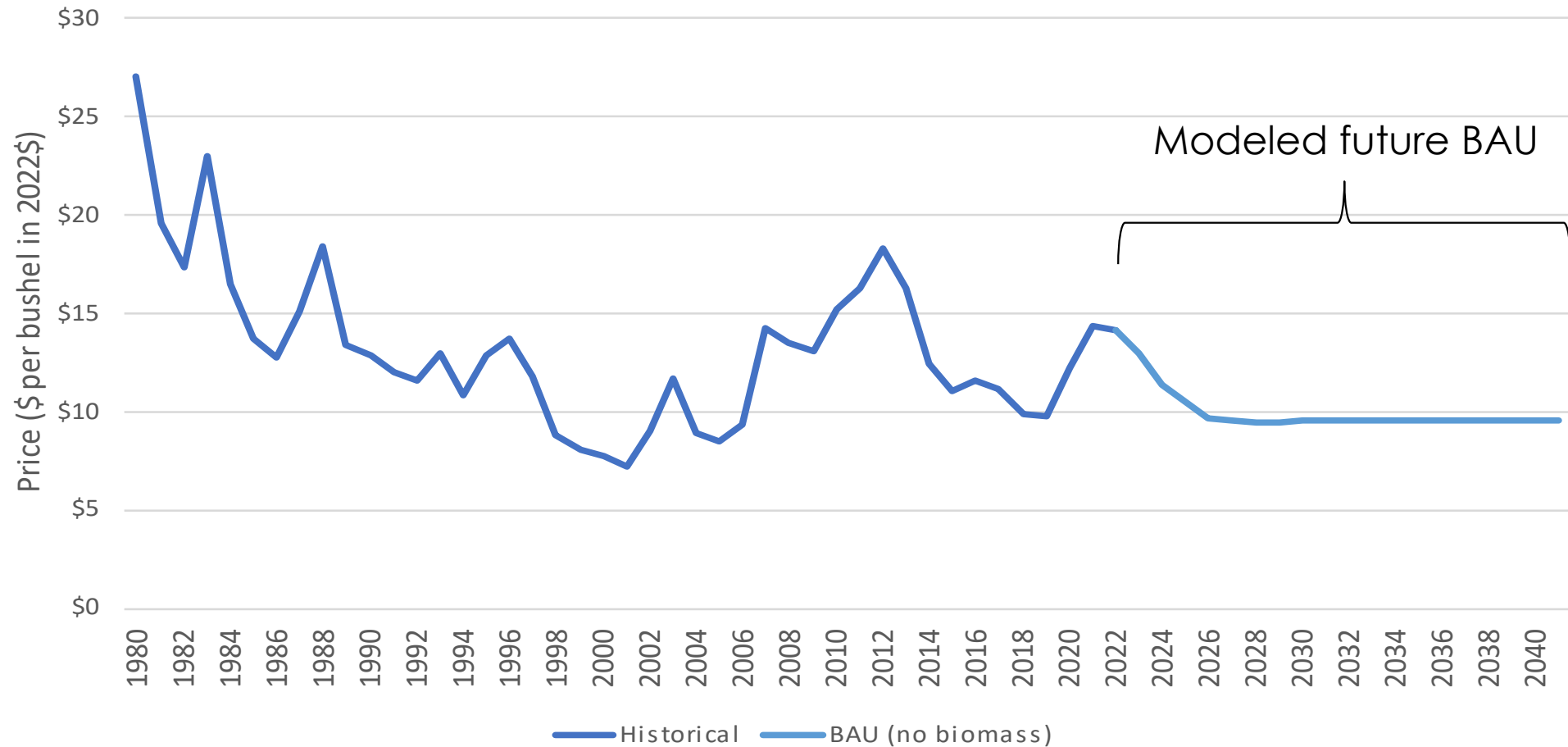


Commodity price impacts: Soy

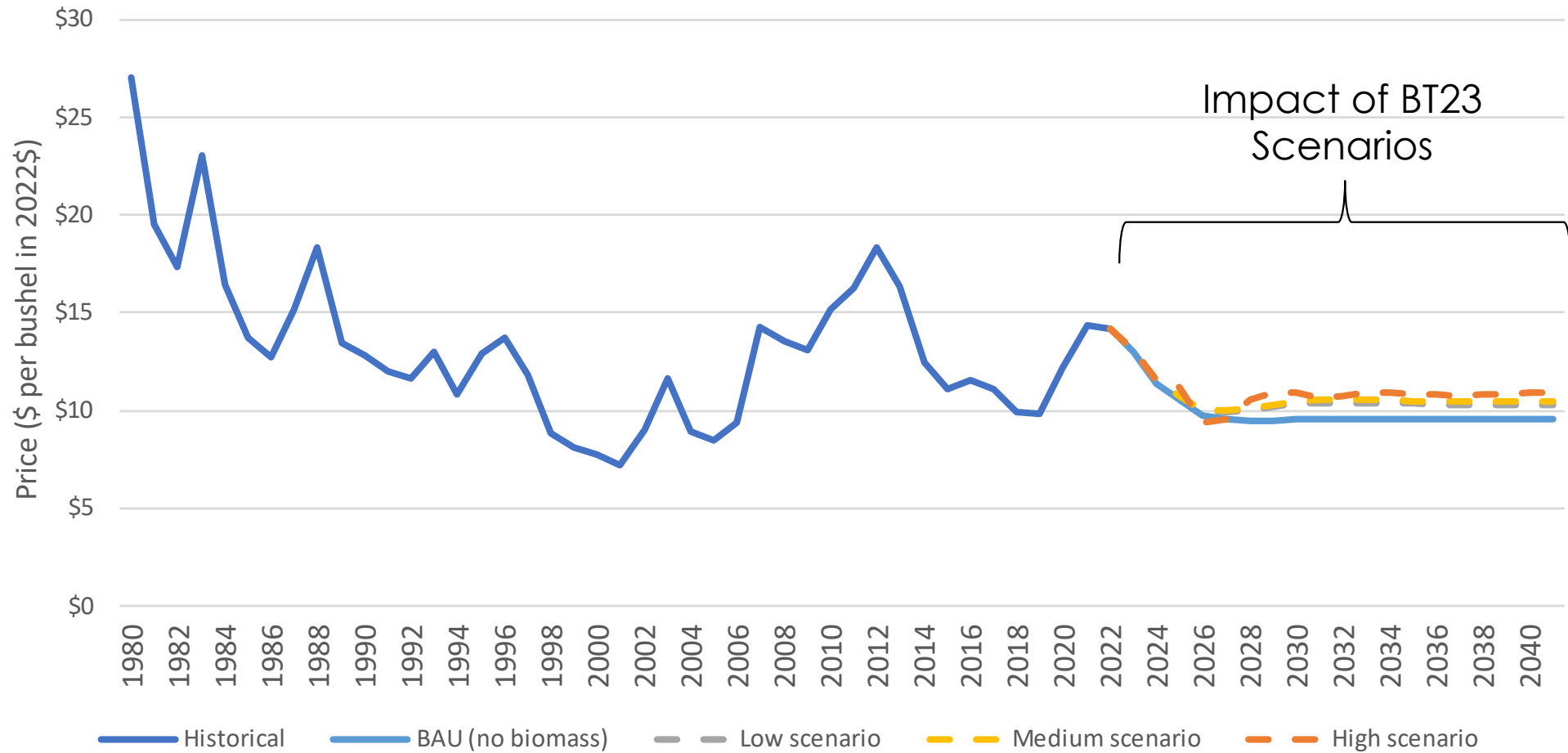
Observed historic prices



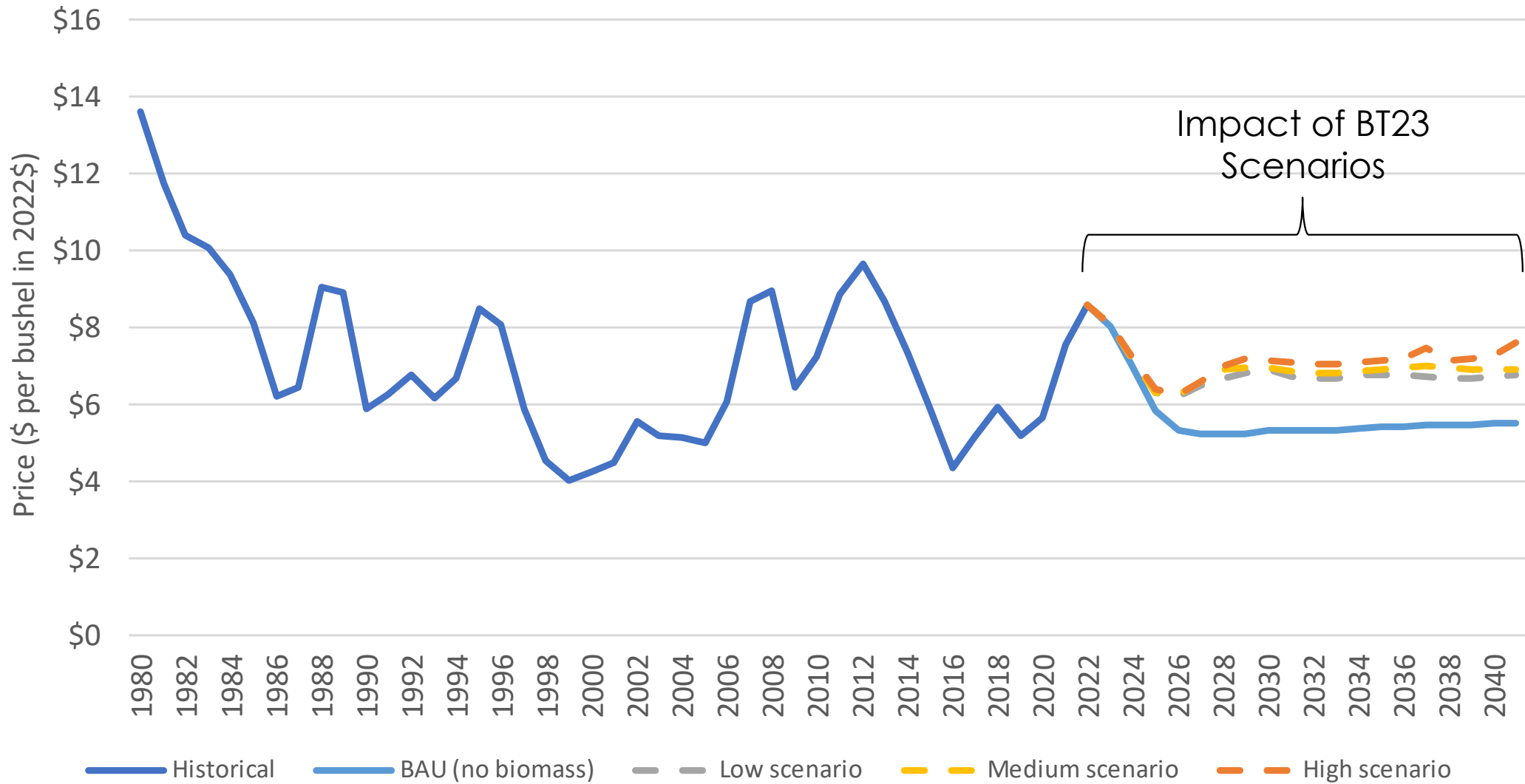
Commodity price impacts: Soy



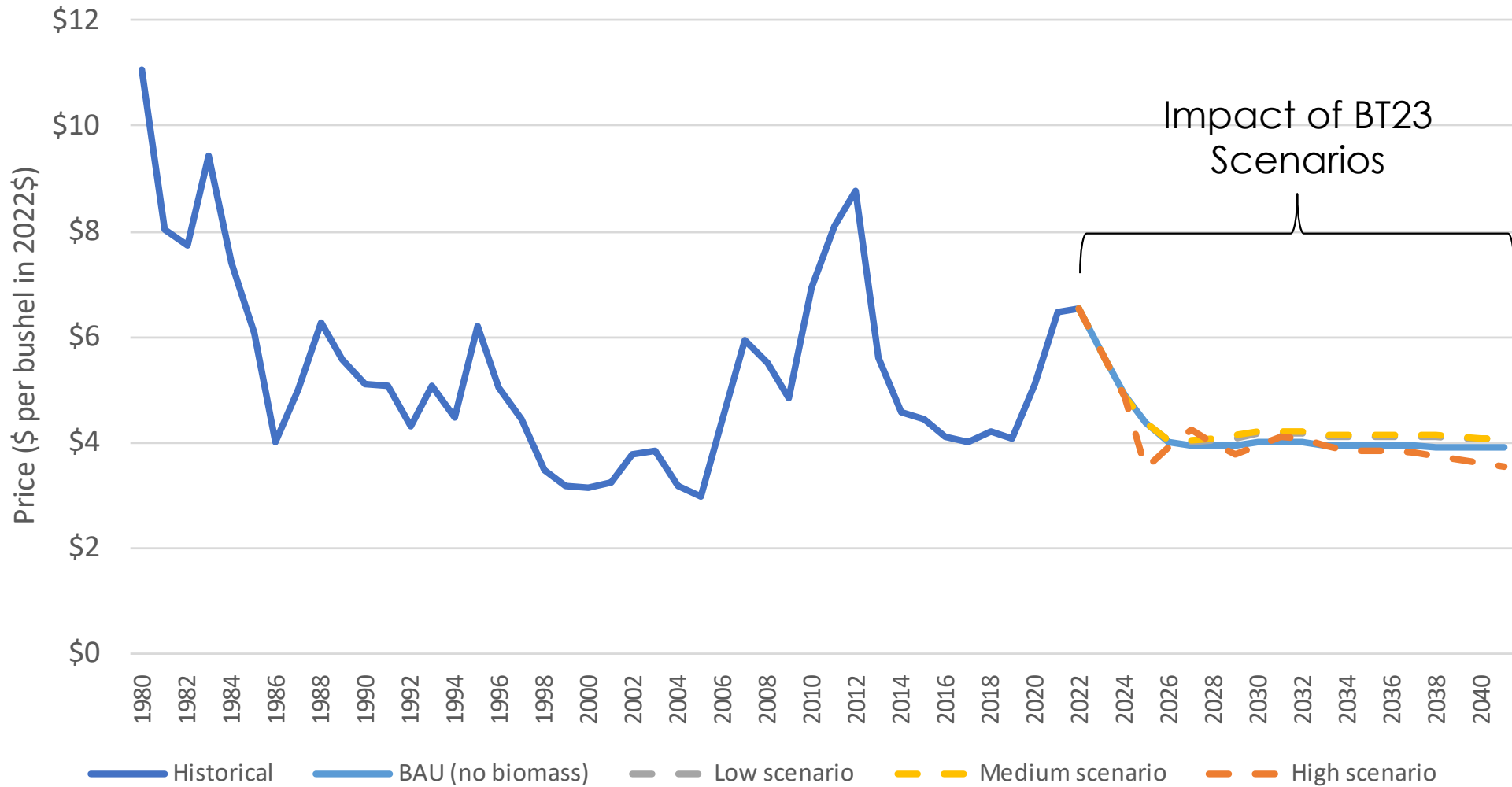
Commodity price impacts: Soy



Commodity price impacts: Wheat

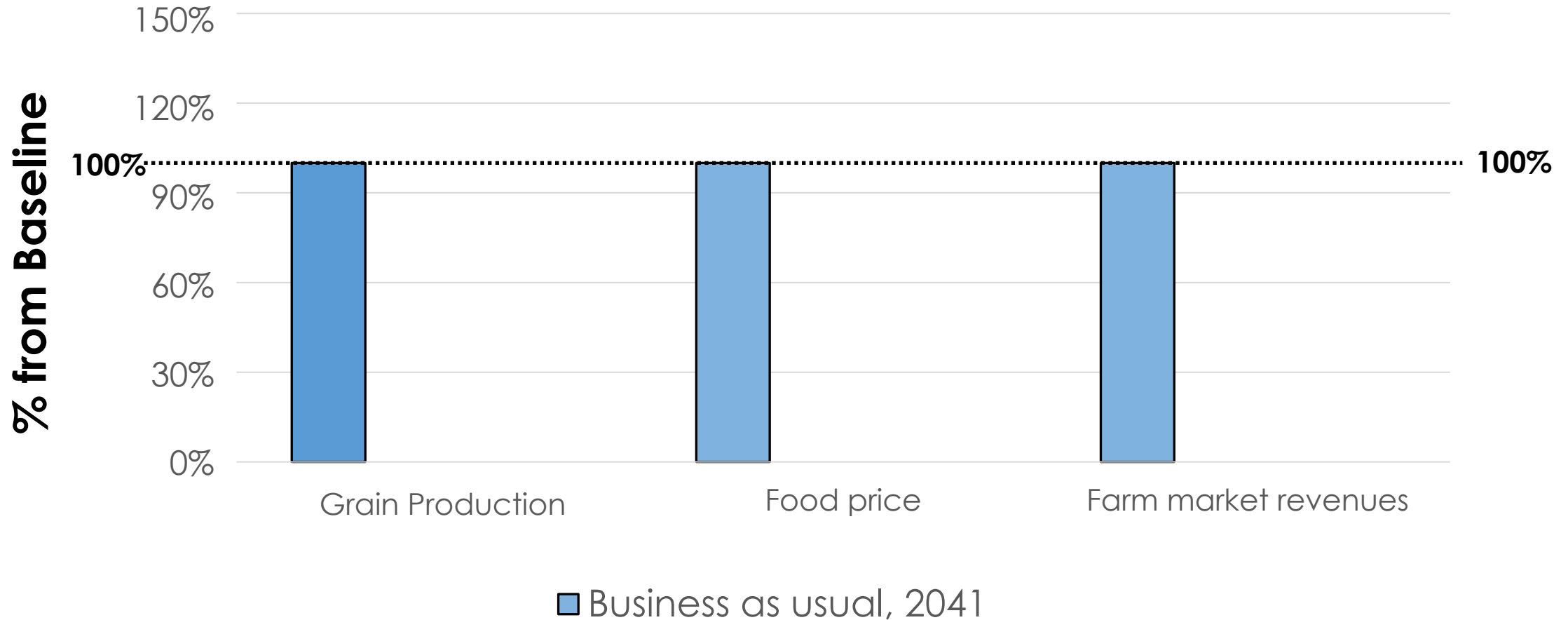


Commodity price impacts: Corn



Energy crops could have nominal impacts on food production

Business as Usual (no energy crops), 2041:



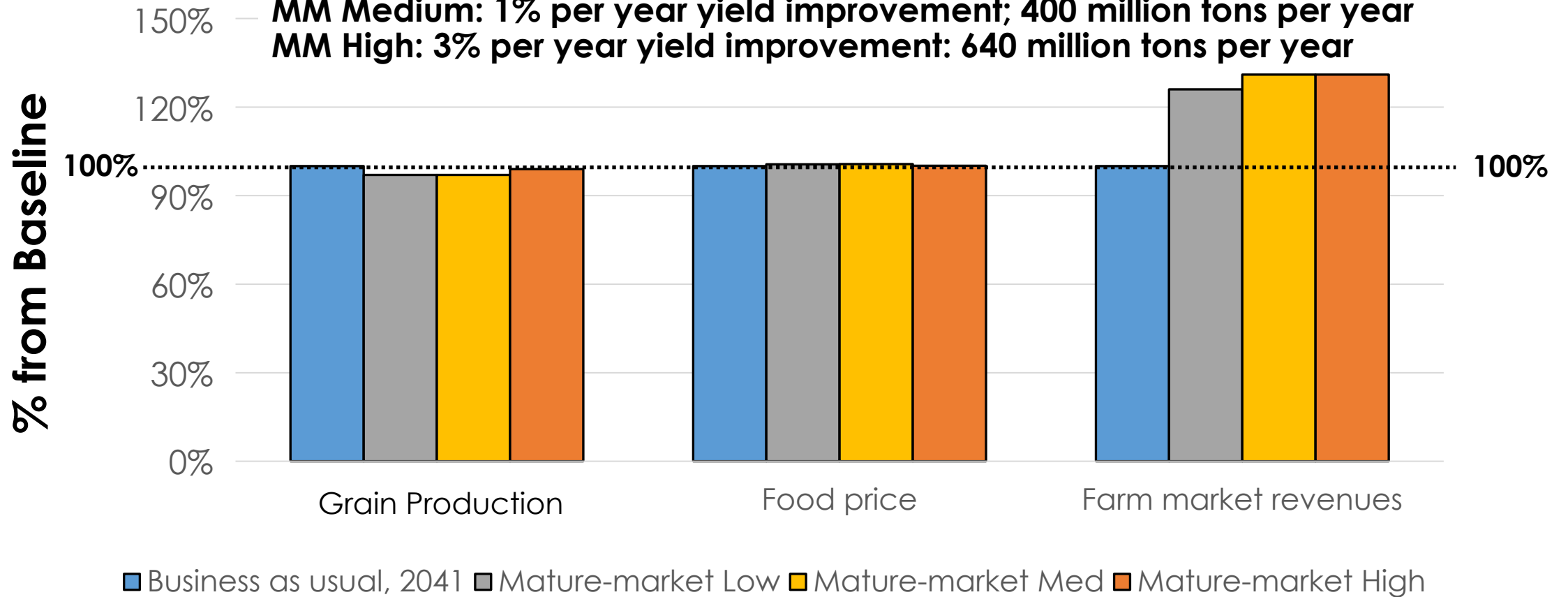
Modeled impacts of energy crop scenarios on US commodity crop production, food prices, and farm revenues. Future yield improvements simulated in the MM High scenario mitigate impacts on conventional production and increase biomass production.

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

MM Low: No future yield improvement; 325 million tons per year

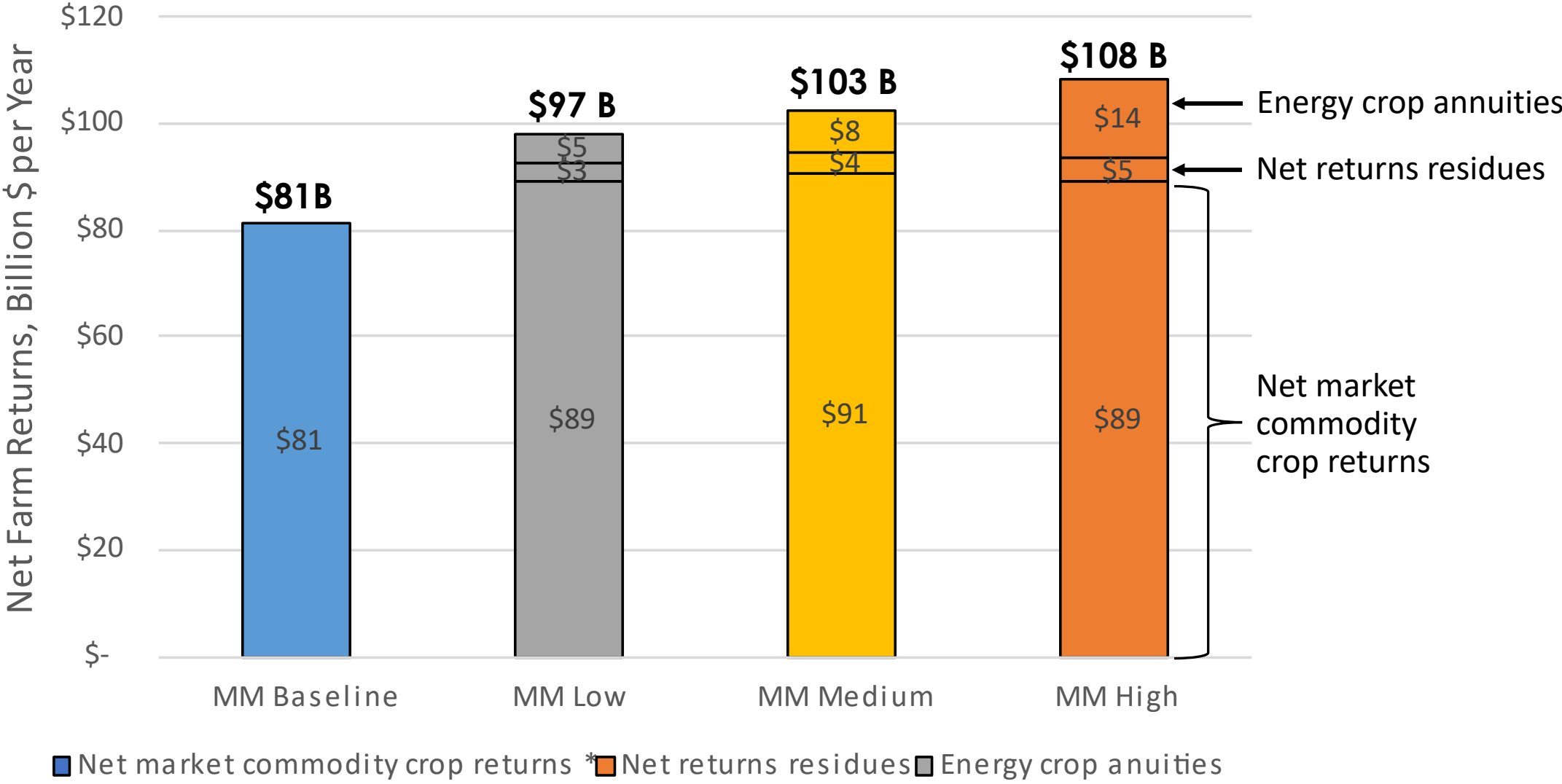
MM Medium: 1% per year yield improvement; 400 million tons per year

MM High: 3% per year yield improvement: 640 million tons per year



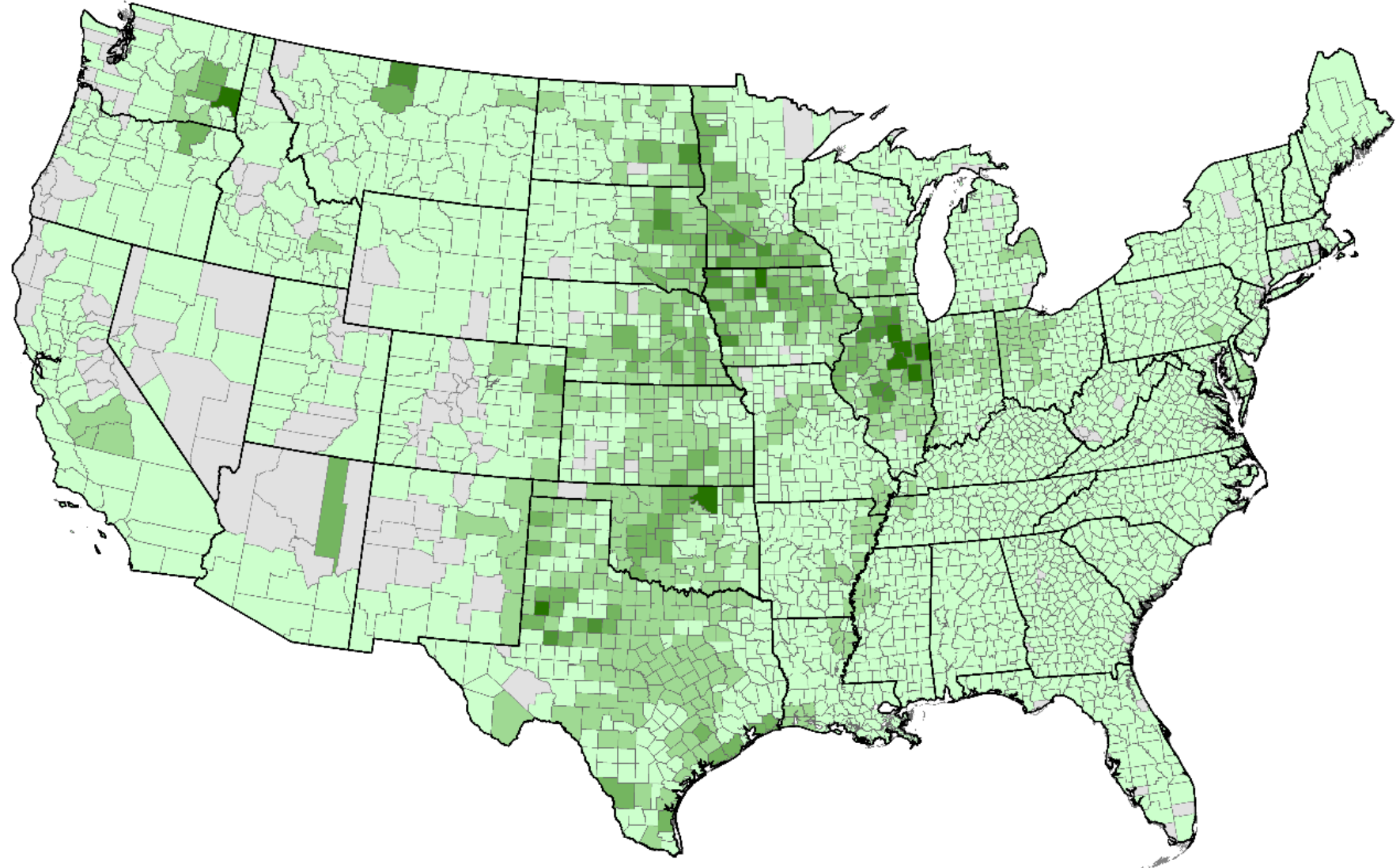
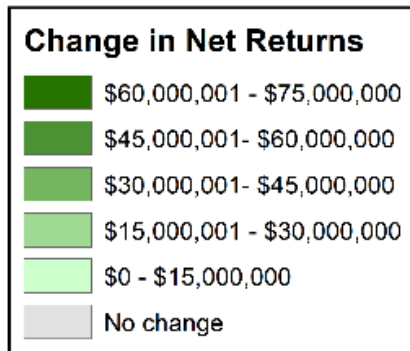
Modeled impacts of energy crop scenarios on US commodity crop production, food prices, and farm revenues. Future yield improvements simulated in the MM High scenario mitigate impacts on conventional production and increase biomass production.

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



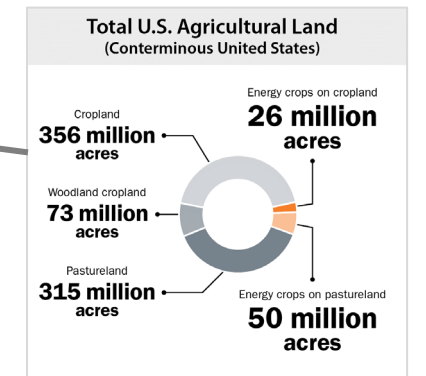
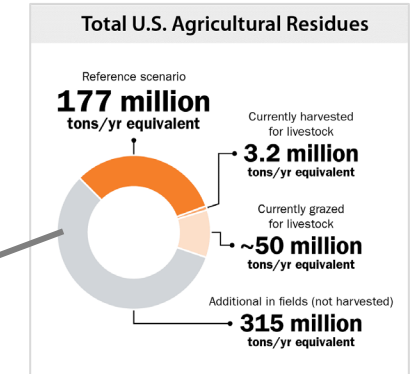
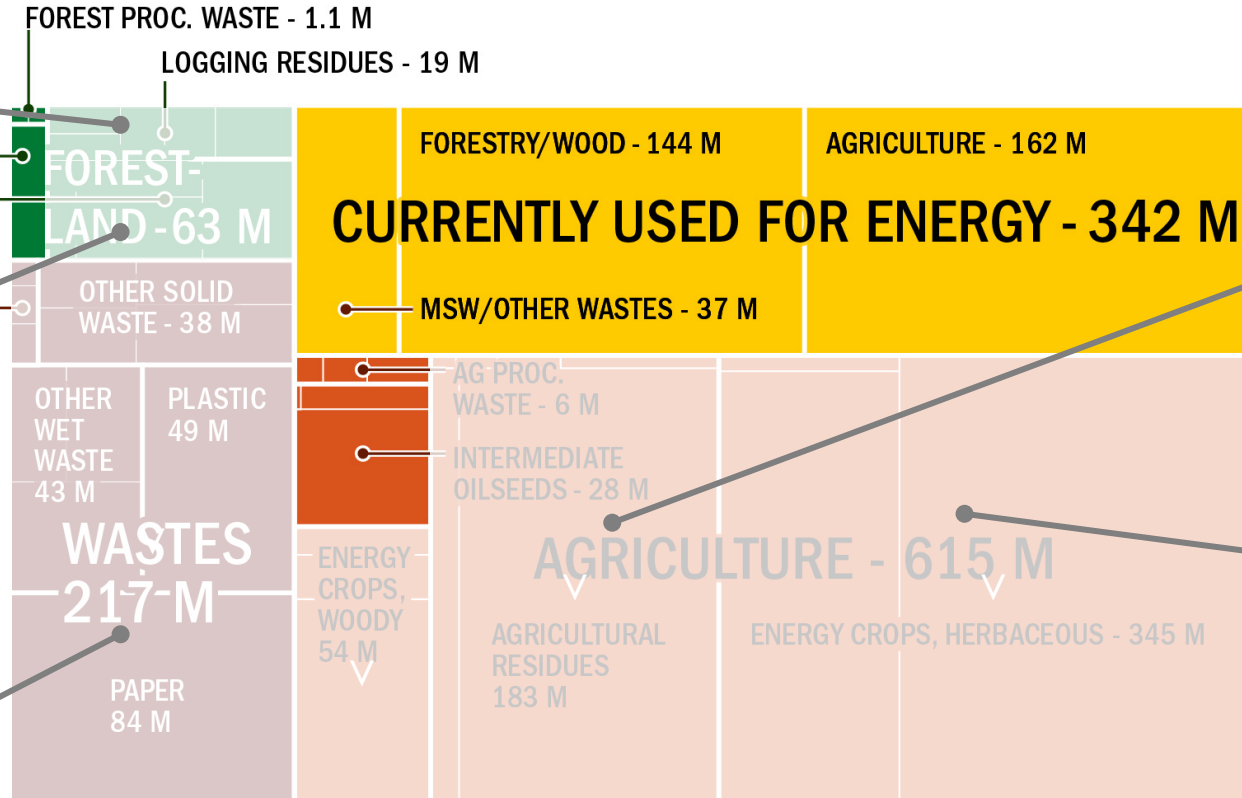
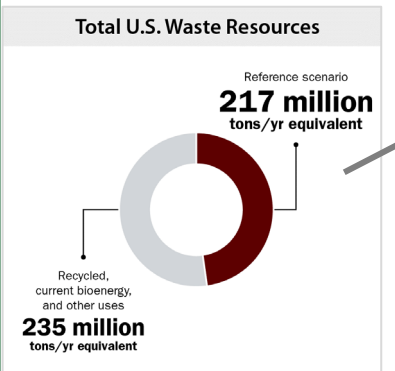
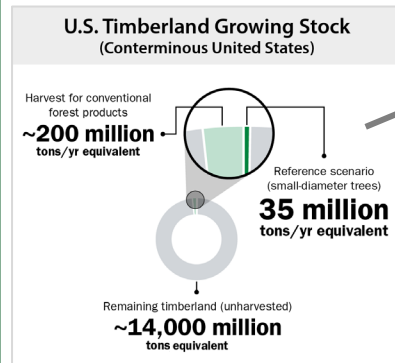
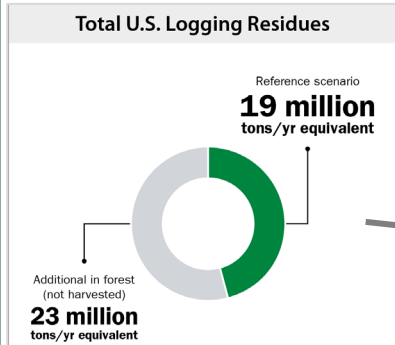
Farm net returns increase \$17-\$27 Billion per year

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



How optimistic is this?

Mature-market medium

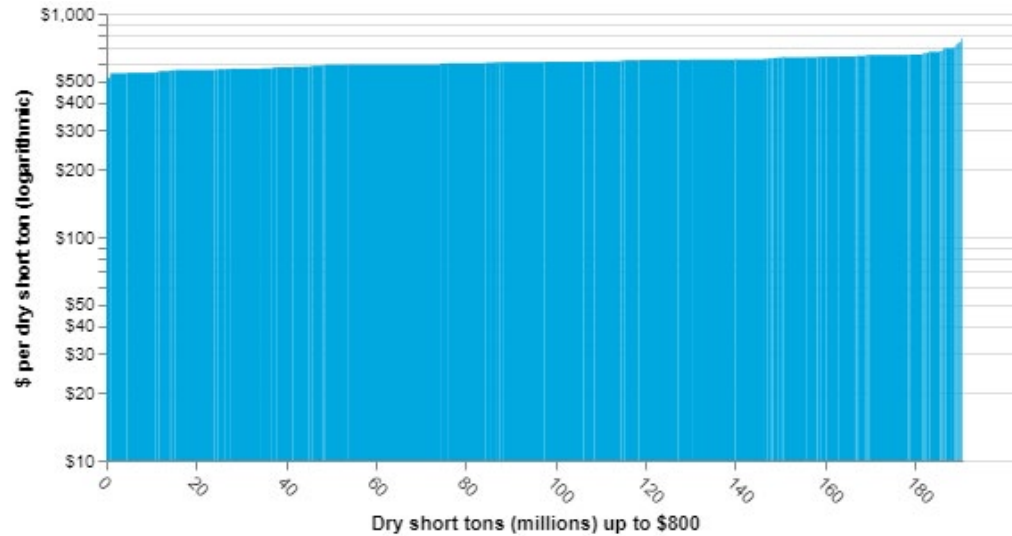
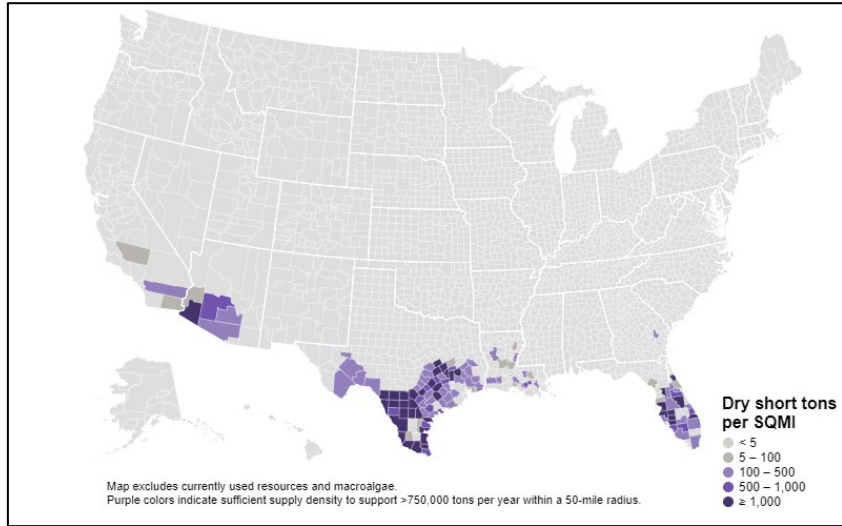


● Agriculture ● Wastes ● Timberland ● Currently Used for Energy

1.2 billion tons per year

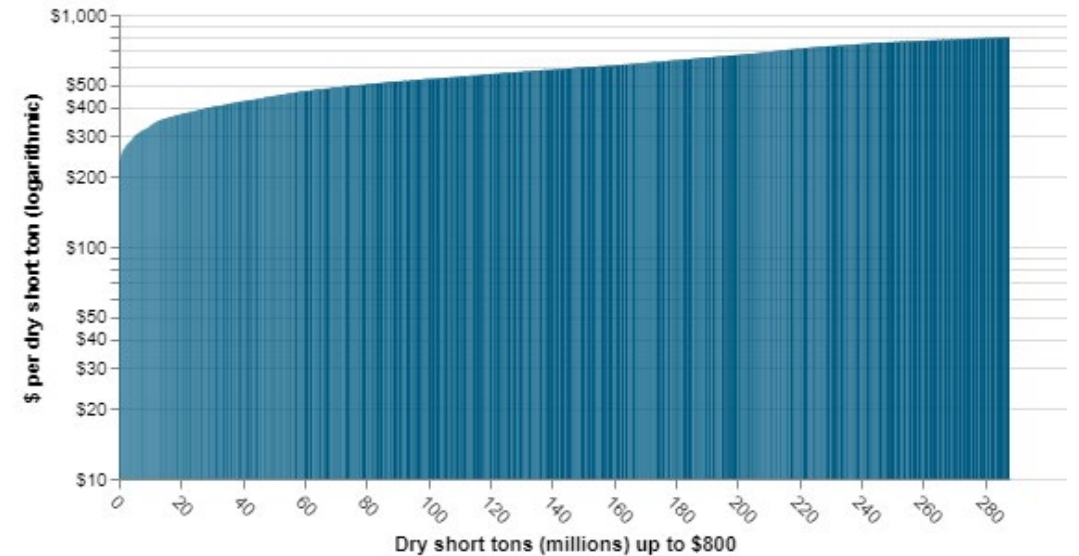
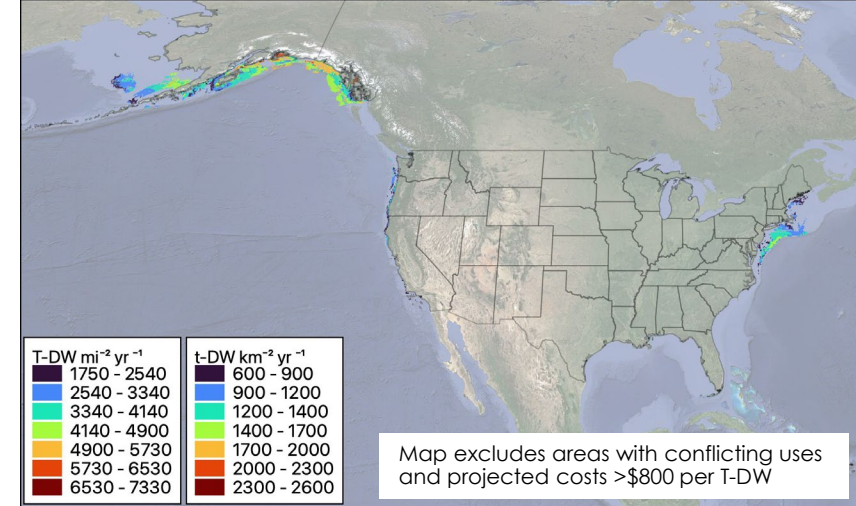
Emerging resources can provide 250+ million tons in future

Microalgae



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

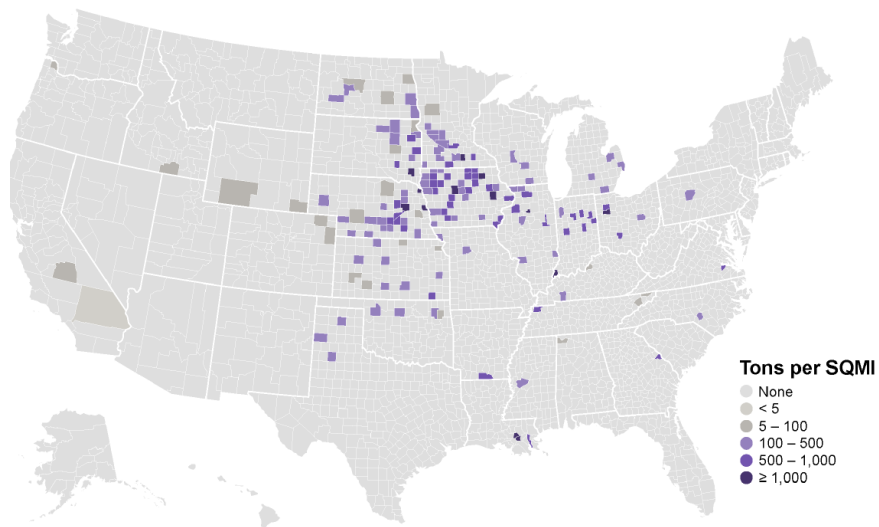
Macroalgae



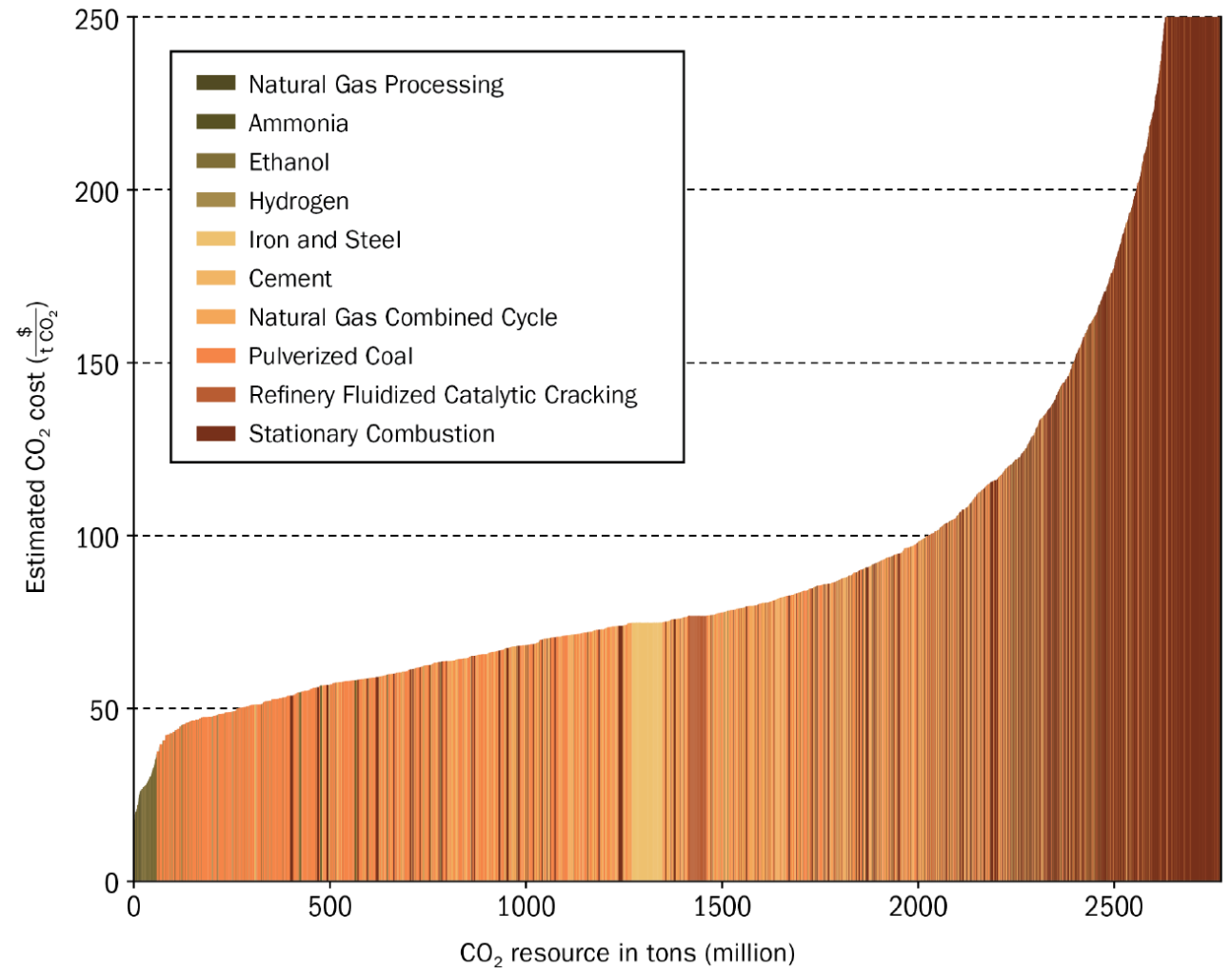
Carbon Dioxide: Stationary Sources

Total U.S. CO₂ from stationary sources: 2.7 billion tons per year

**High-purity CO₂ sources:
47.2 million tons per year,
<\$30/ton**

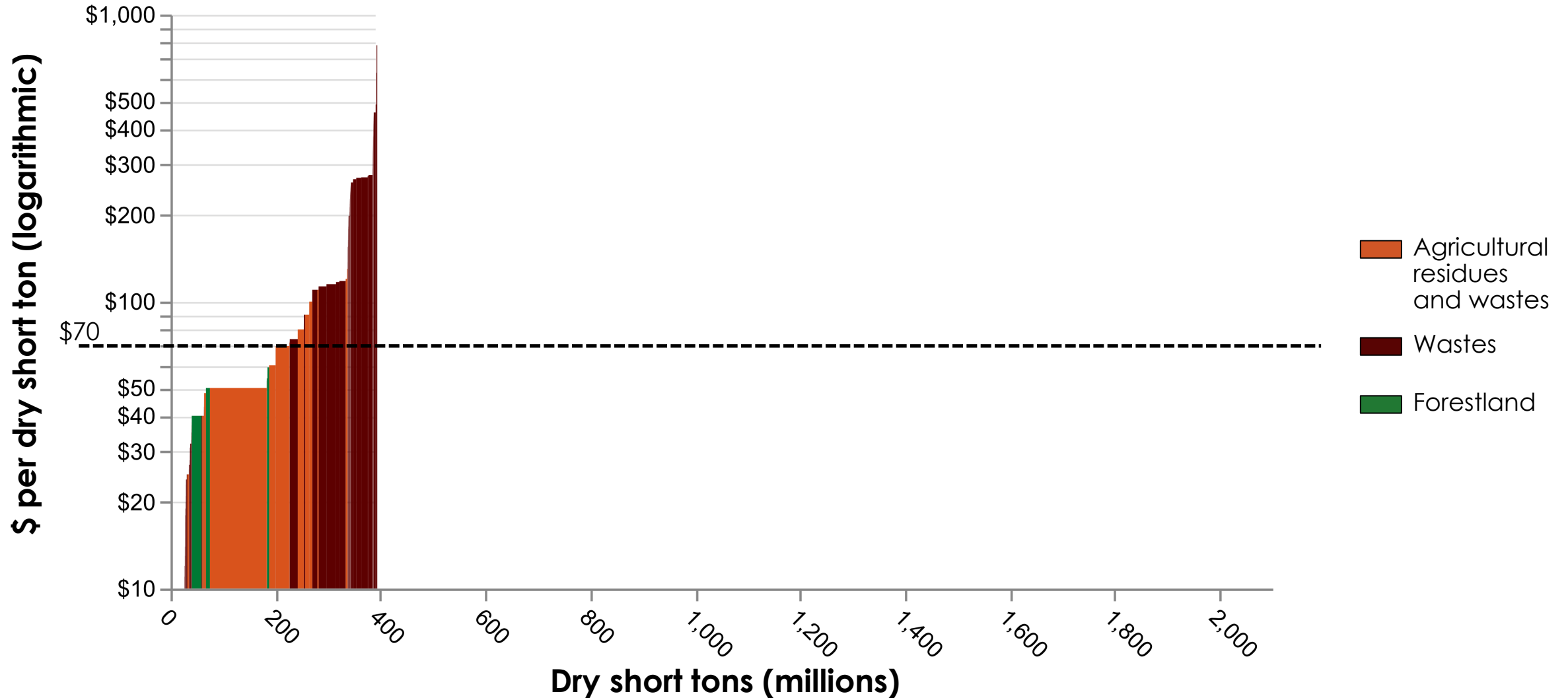


High-purity CO₂ from ethanol and ammonia production.

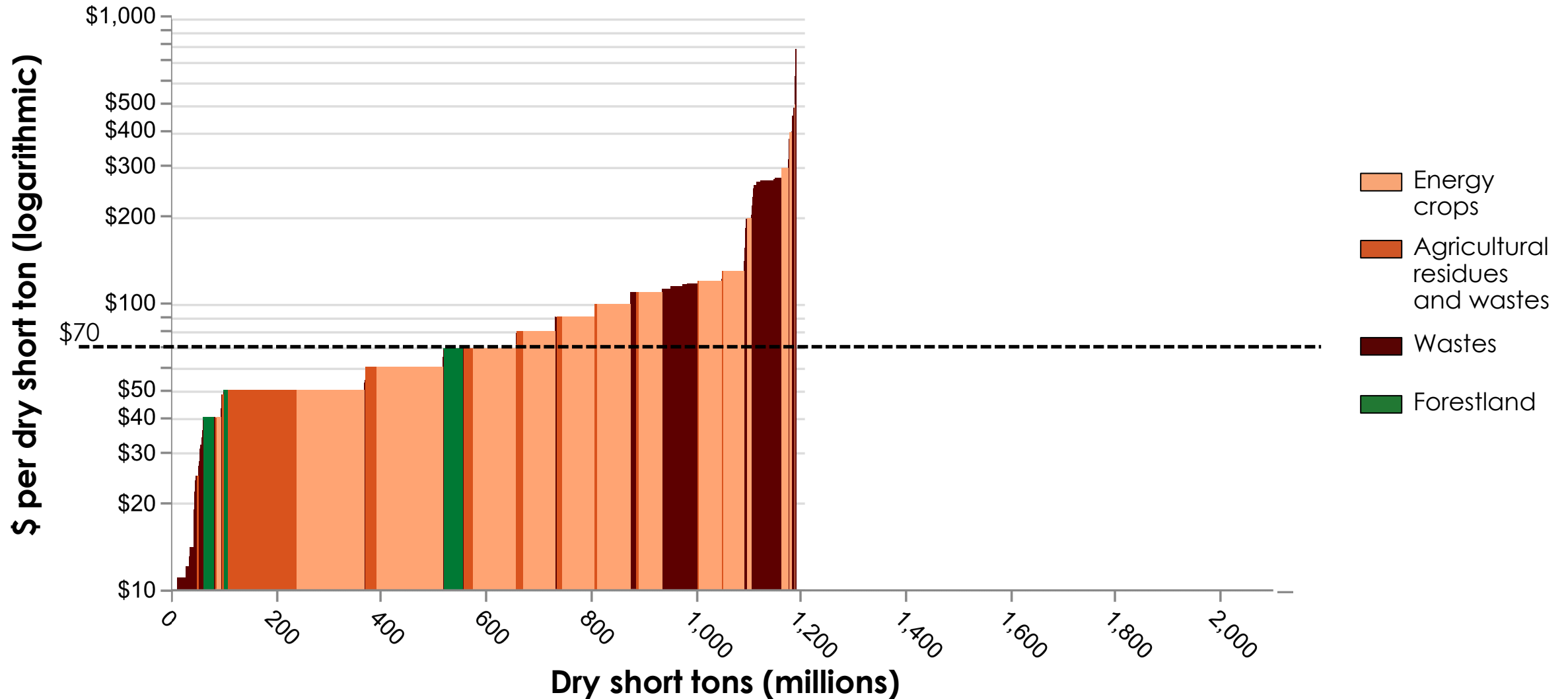


Subset of total CO₂ resource by facility category for stationary source and estimated cost of CO₂ capture and purification. Figure using data from NETL and the Office of Fossil Energy and Carbon Management (NETL 2023; Fahs et al. 2023; Schmitt et al. 2023). See BT23 appendix for further information.

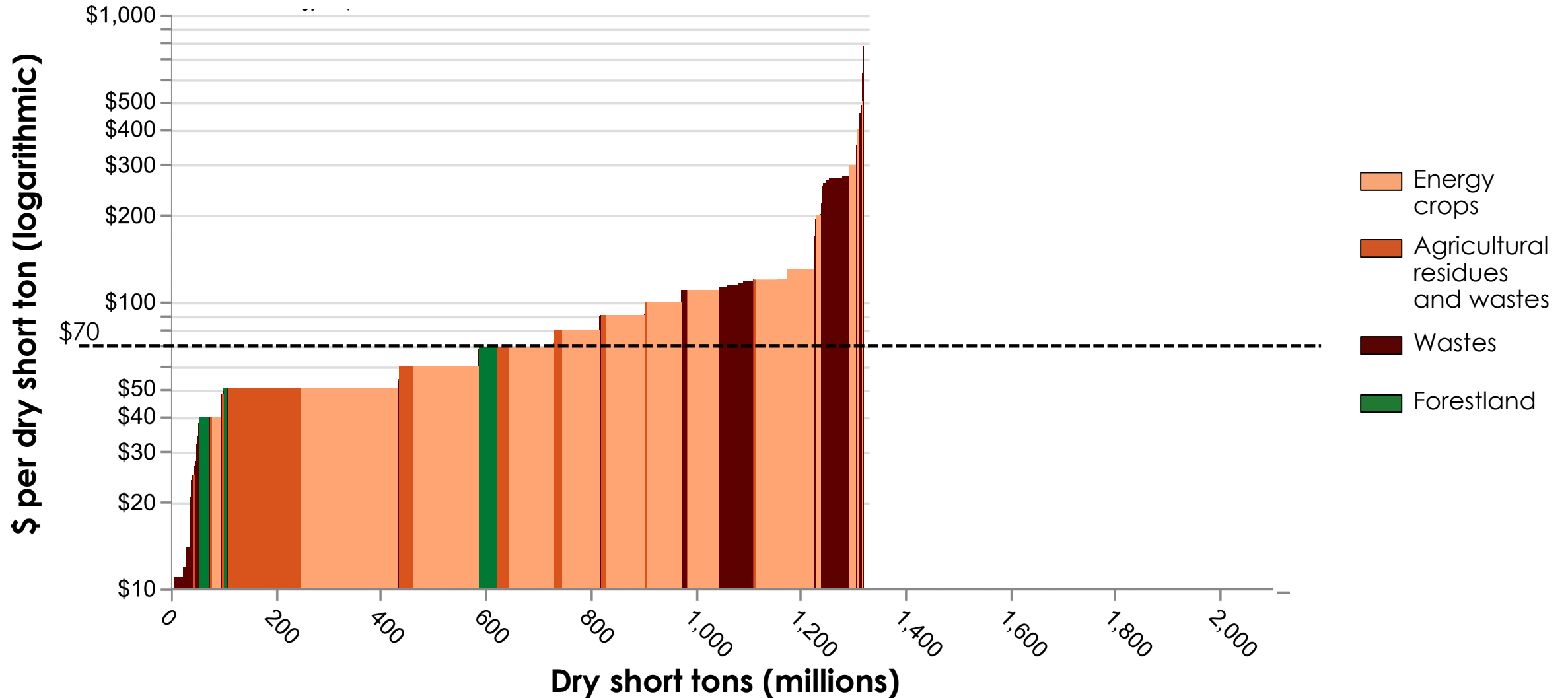
Potential biomass depends on price (Near Term)



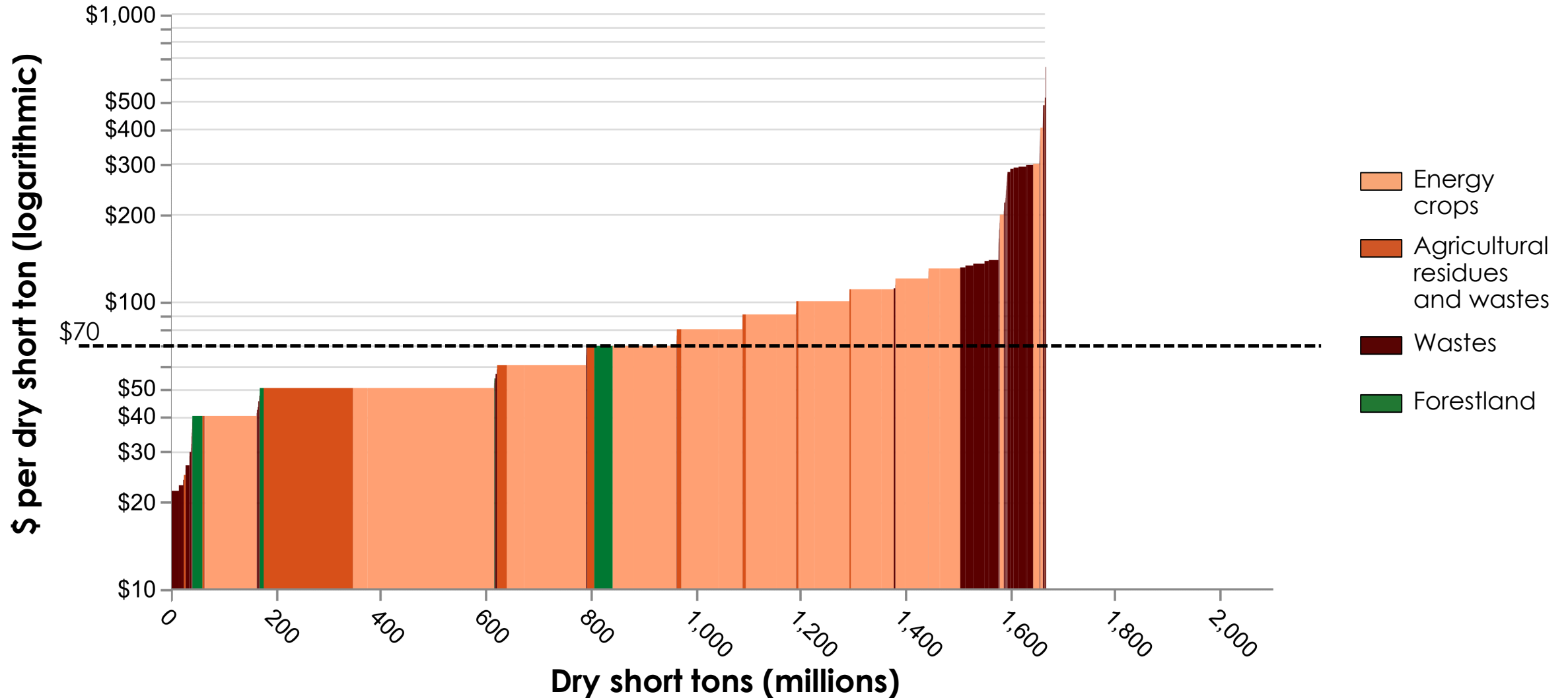
Potential biomass depends on price (Mature-Market Low)



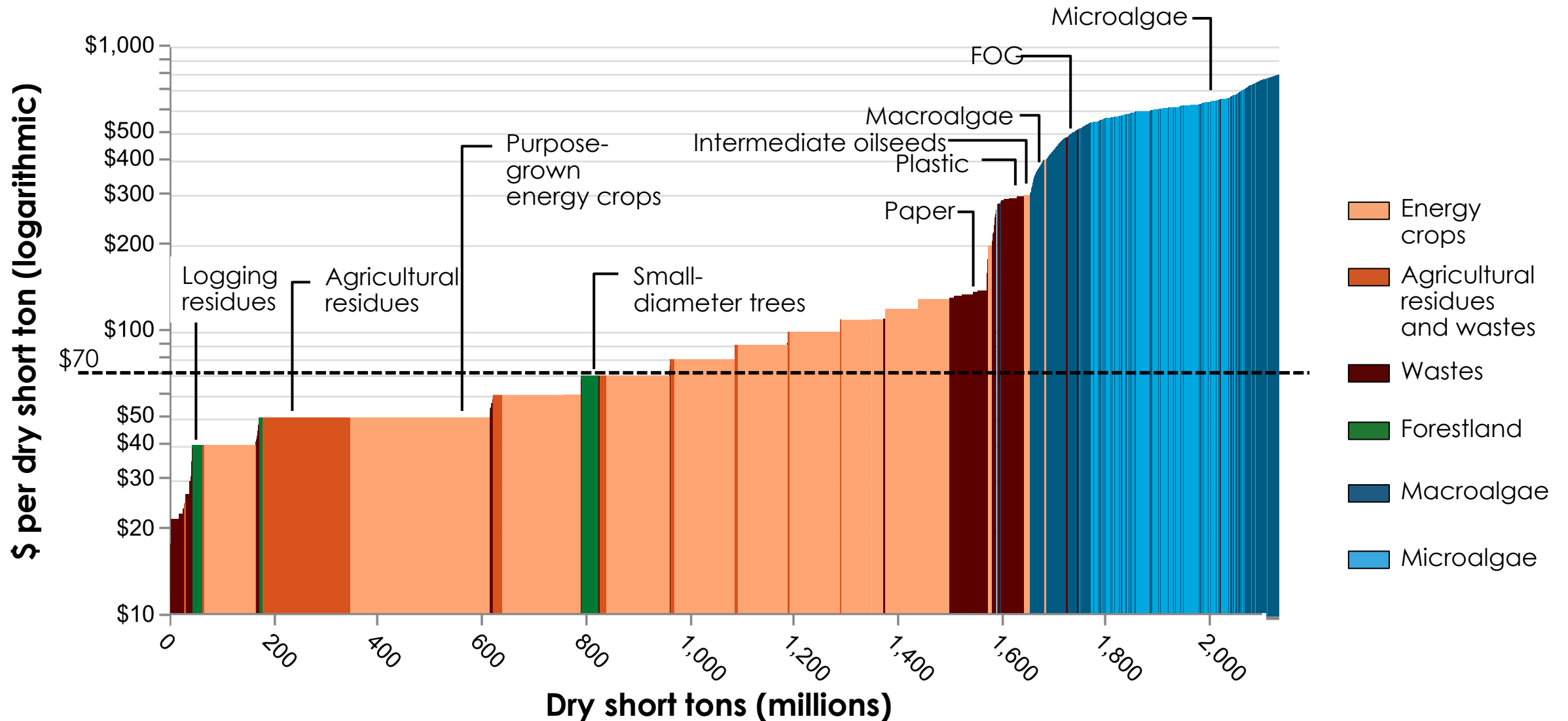
Potential biomass depends on price (Mature-Market Medium)



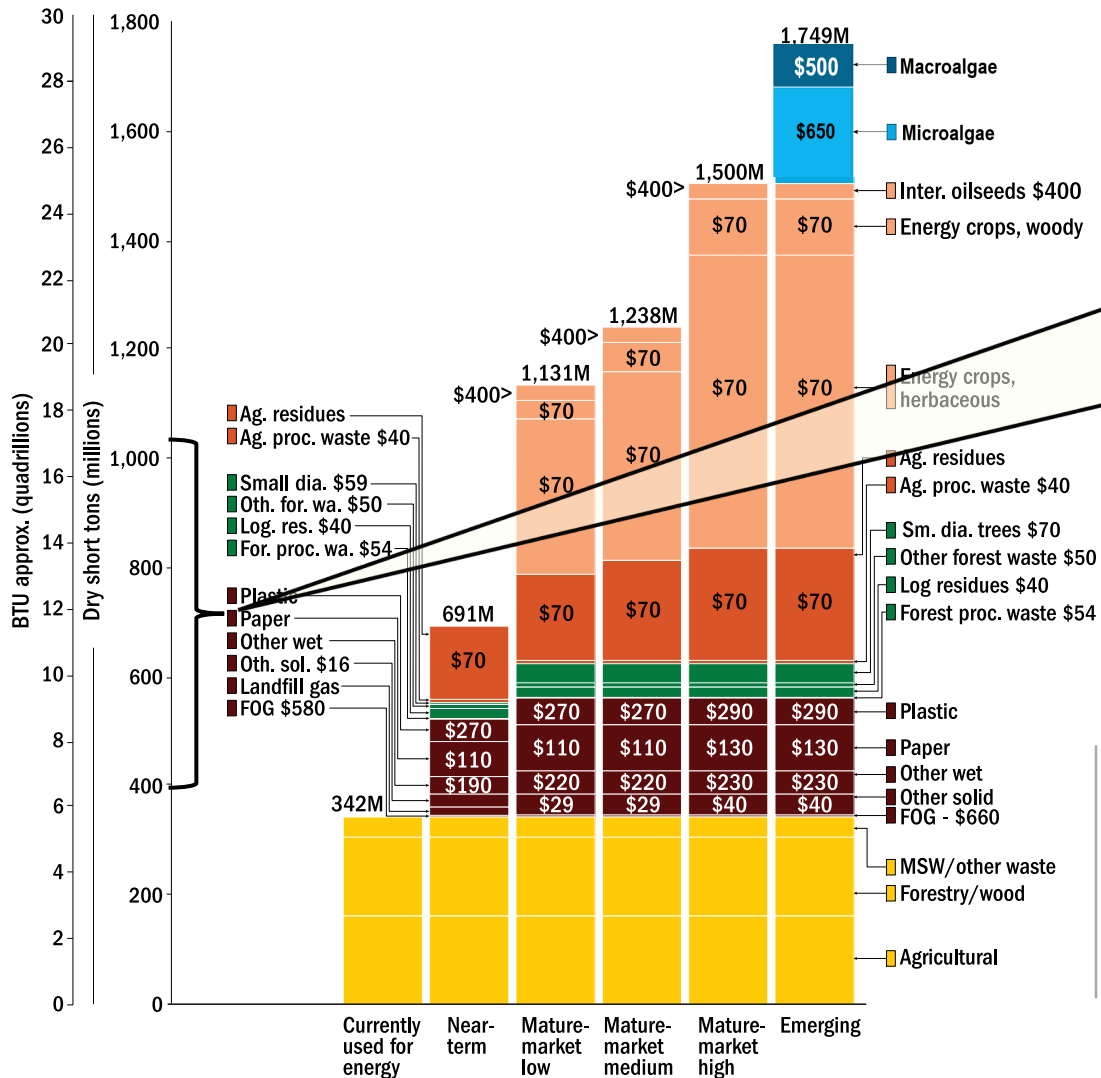
Potential biomass depends on price (Mature-Market High)



Potential biomass depends on price (Emerging scenario)



Results: 0.7-1.7 billion tons production capacity

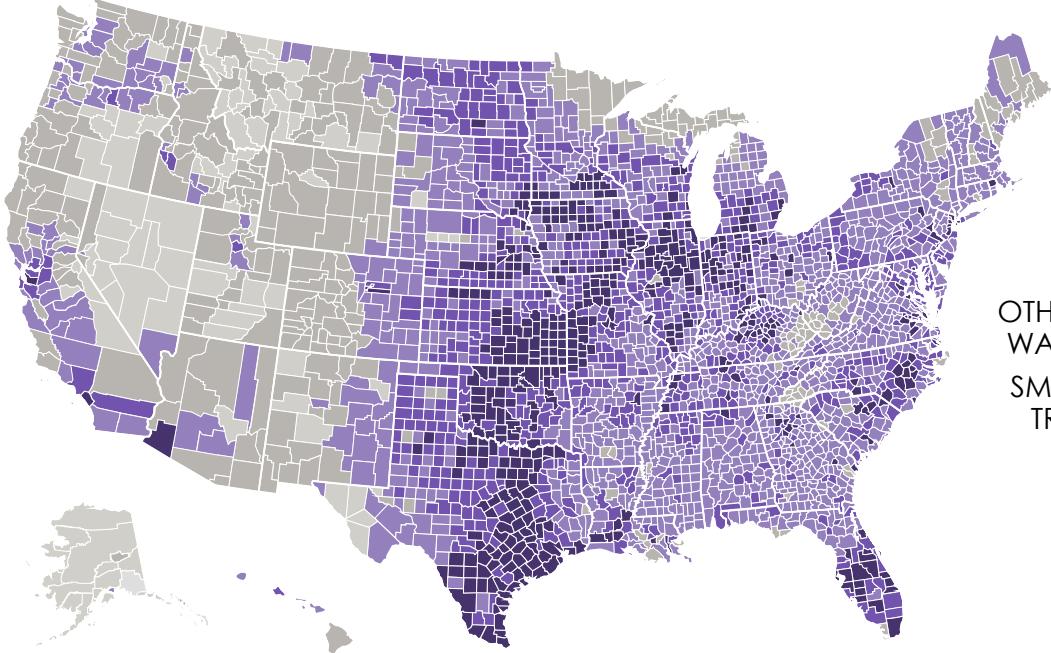


~640 million tons per year
 ≈35 billion gallons SAF

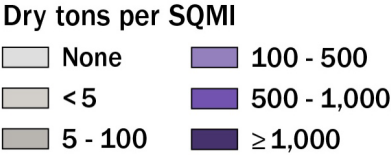
- Bioeconomy currently provides 340 million tons biomass (5 Quads or 5% total)
- Currently available resources can double biomass in **near-term**
- **Mature market** induces another 440-800 million tons biomass depending on yield assumptions
- Emerging resources can supply another 250 million tons
-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

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

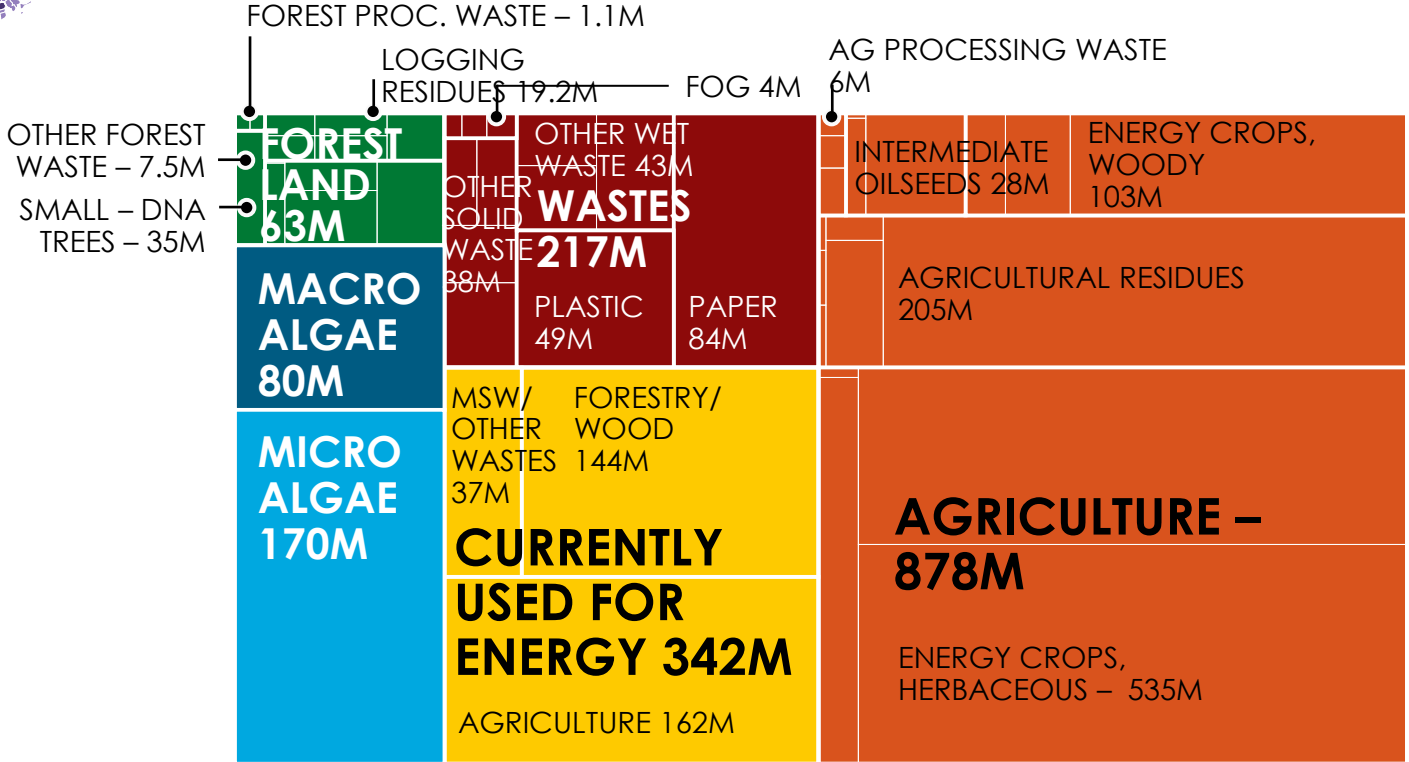
BT23: 1.7 billion tons under Emerging market scenario



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



57 resources, 4 analysis classes



1,749 M

