Biomass Supply, Context for SAFs

CAAFI, November 17th 2021

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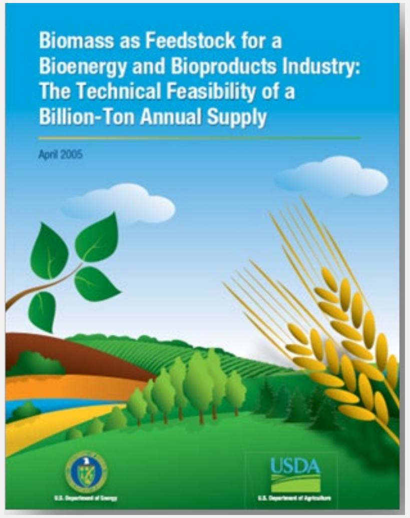
Outline

- Billion-ton Report Overview
- Biomass resources in national context
- Resources close to jet fuel storage locations
- Other SAF work at ORNL

Billion-Ton History

2005



Resource assessment

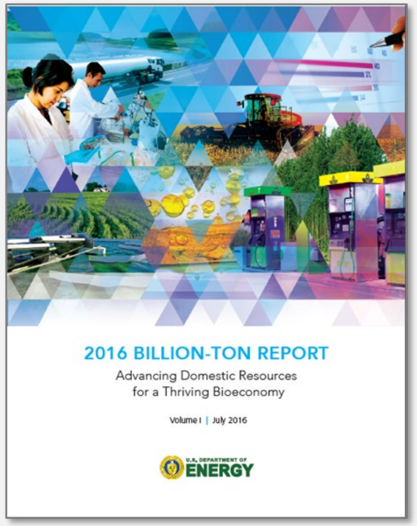
- How much biomass is available in the U.S.?
- Can we produce a sustainable supply of biomass that can displace 30% of the country's current petroleum consumption?

2011

Resource assessment + Economic Analysis

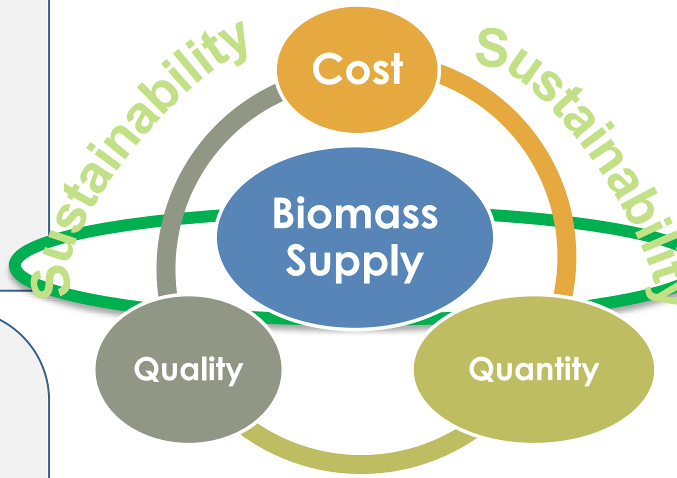
- Timeline to 2030
- County-level biomass feedstock availability estimates
- Broad energy crop definitions and estimates
- Harvesting biomass only (not delivering biomass)

2016



Resource assessment + Economic Analysis

- Extended timeline
- Updated agricultural projections
- Detailed cost analysis
- Algae and energy crops
- Regional analysis
- Environmental sustainability analyses



Contributors

BCS INCORPORATED

USDA

FOREST SERVICE U S DEPARTMENT OF AGRICULTURE

FEDERAL AVIATION ADMINISTRATION

THE UNIVERSITY OF IDAHO 1889

SUNY The State University of New York

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

DEPARTMENT OF ENERGY UNITED STATES OF AMERICA

NIFA

UT

INL Idaho National Laboratory

SOFAC NC State University

SDSU

ESF

Pacific Northwest NATIONAL LABORATORY

OAK RIDGE National Laboratory

AST Allegheny Science & Technology

PRISM GROUP

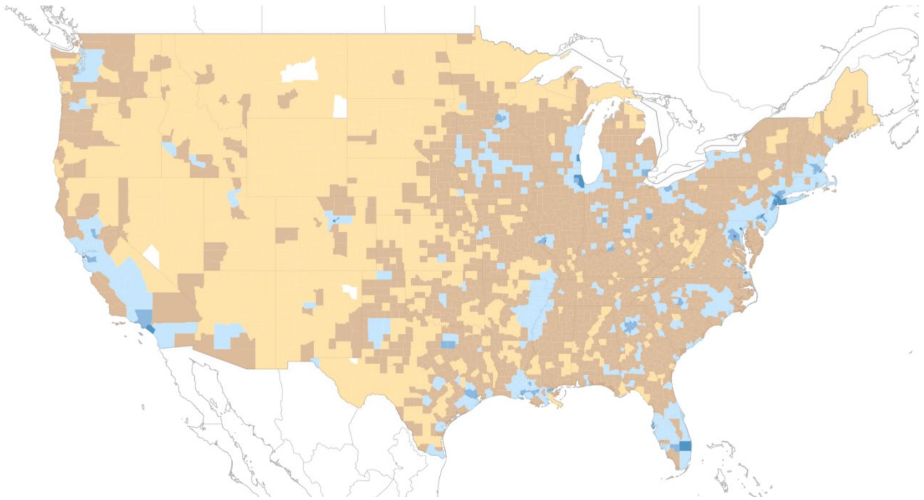
OSU Oregon State UNIVERSITY

NREL NATIONAL RENEWABLE ENERGY LABORATORY

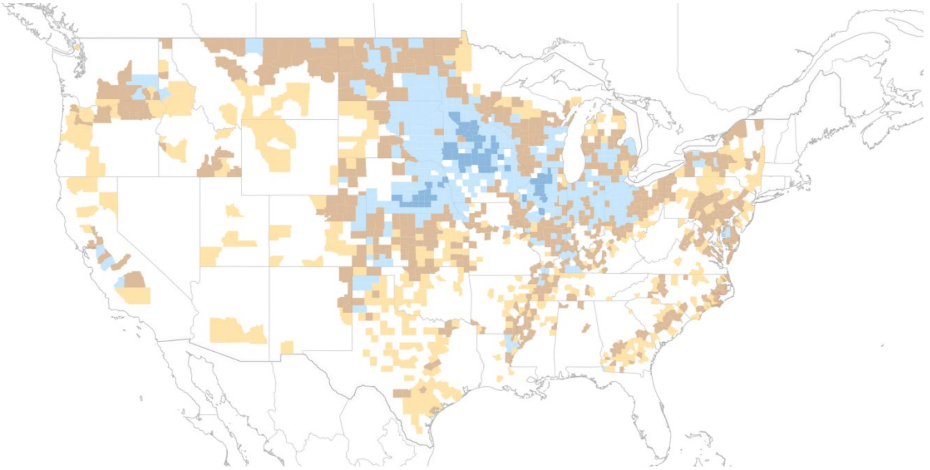
ENERGETICS A Subsidiary of VSE Corporation

Current and potential biomass resources*

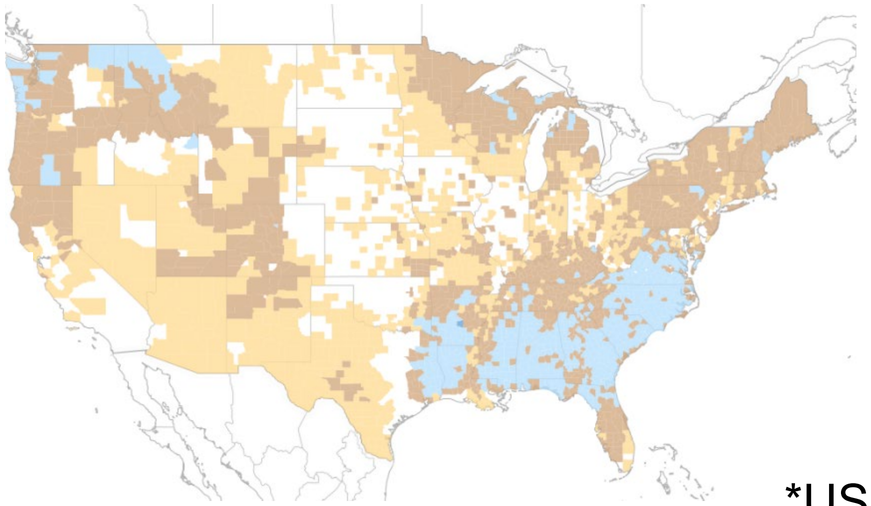
Municipal wastes, ~130 million t yr^{-1}



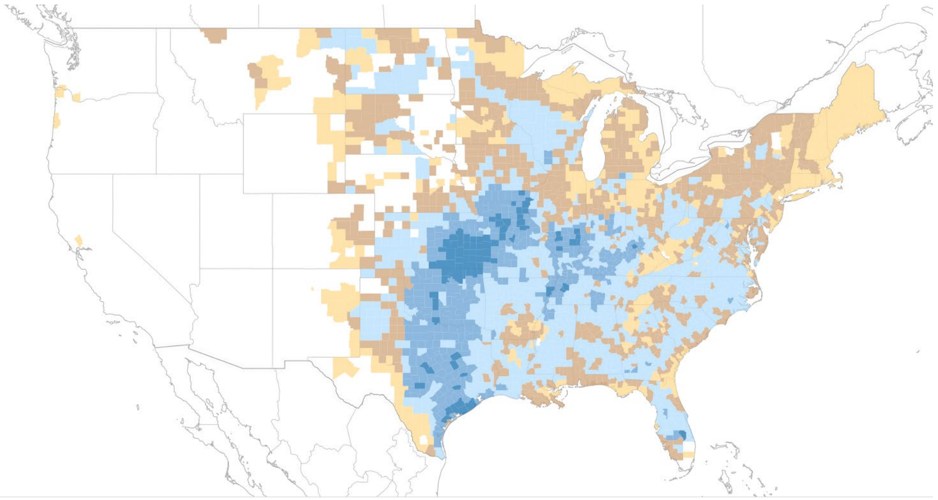
Agriculture wastes, ~110 million t yr^{-1}



Forest management, ~90 million t yr^{-1}



Biomass crops, ~410 million t yr^{-1}



Dry tons/year

- Less than 10 dt/SqMile
- 10-100 dt/SqMile
- 100-500 dt/SqMile
- 500-1000 dt/SqMile
- Greater than 1,000 dt/SqMile

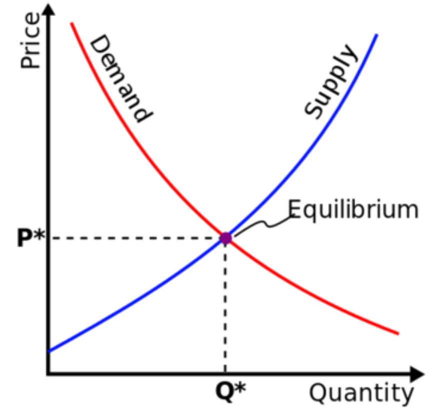
*USDOE 2016, base-case, $60/ton, 2040

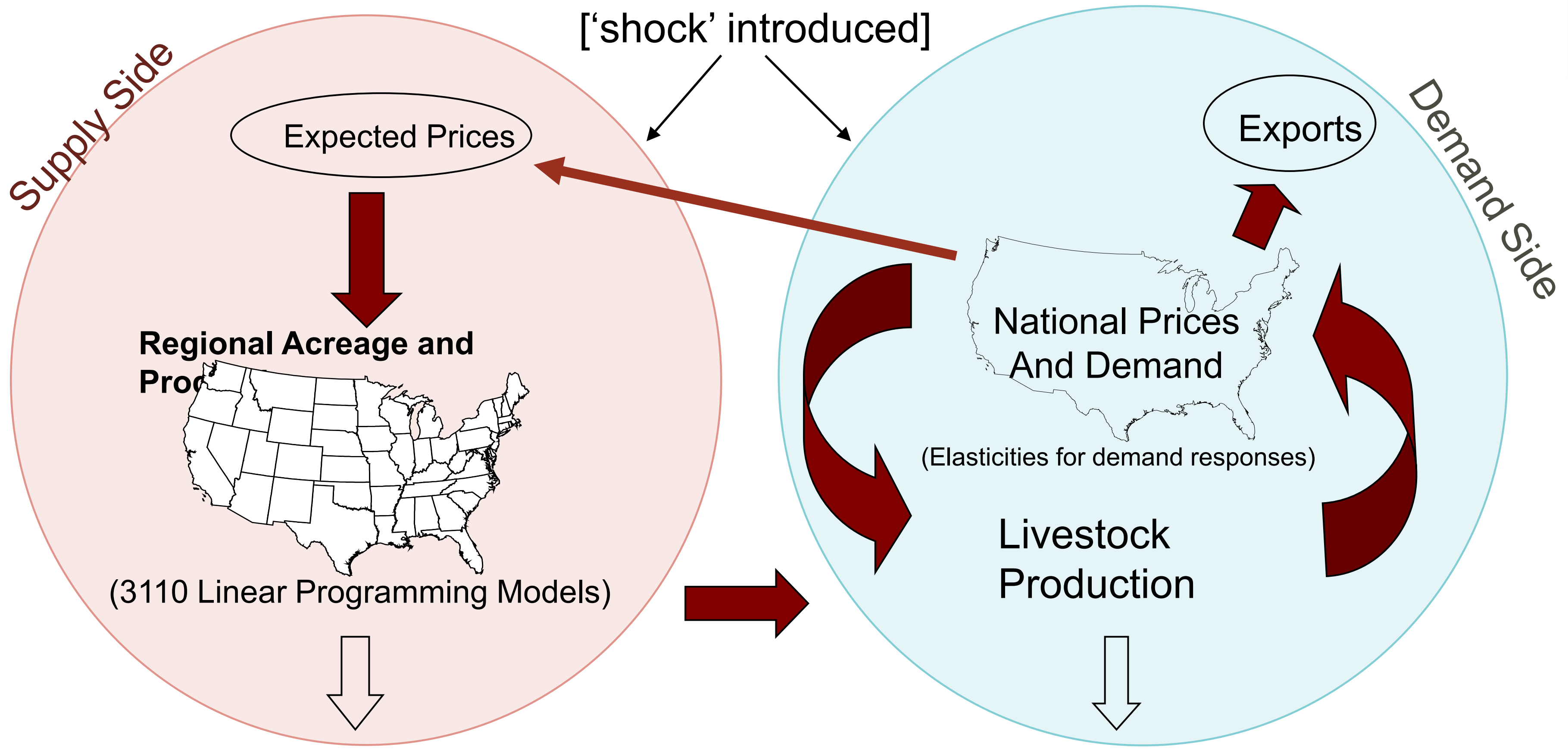
POLYSYS MARTKET FEEDBACKS

Start with USDA Baseline

CORN SUPPLY AND USE, 2019-2046

Item	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Planted	89.9	94.5	89.0	89.0	89.0	89.0	89.0	89.0	88.5	88.5	88.5	88.4	87.3
Harvested	81.8	87.1	81.6	81.6	81.6	81.6	81.6	81.6	81.1	81.1	81.1	81.0	80.0
Yield(Bu/Ac)	168.4	178.5	180.5	182.5	184.5	186.5	188.5	190.5	192.5	194.5	196.5	197.5	198.5
Season Average Price	3.80	3.40	3.40	3.45	3.45	3.50	3.55	3.55	3.60	3.60	3.60	3.48	3.49
Net Retns(Value-Expns)	23186	22299	21244	22669	23024	24091	25042	25572	26639	27245	27810	26117	26273





POLYSYS Regional Output

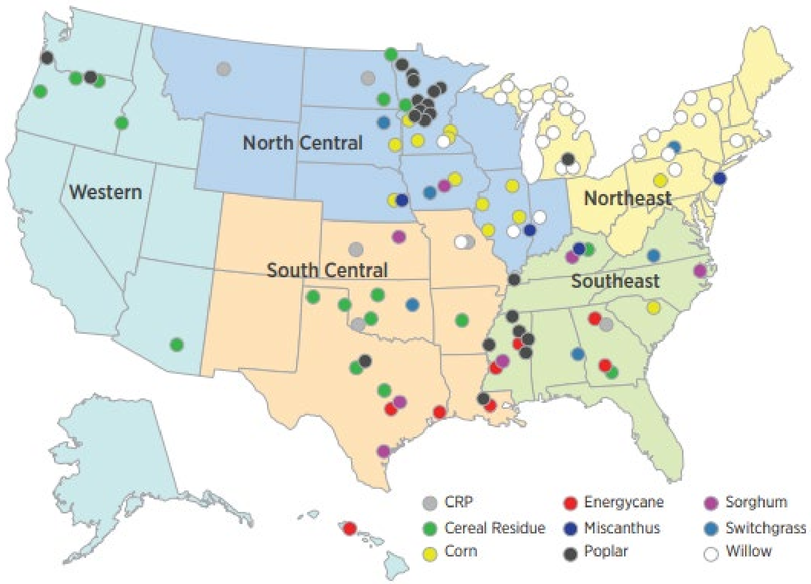
Annual acreage, production, government payments, income

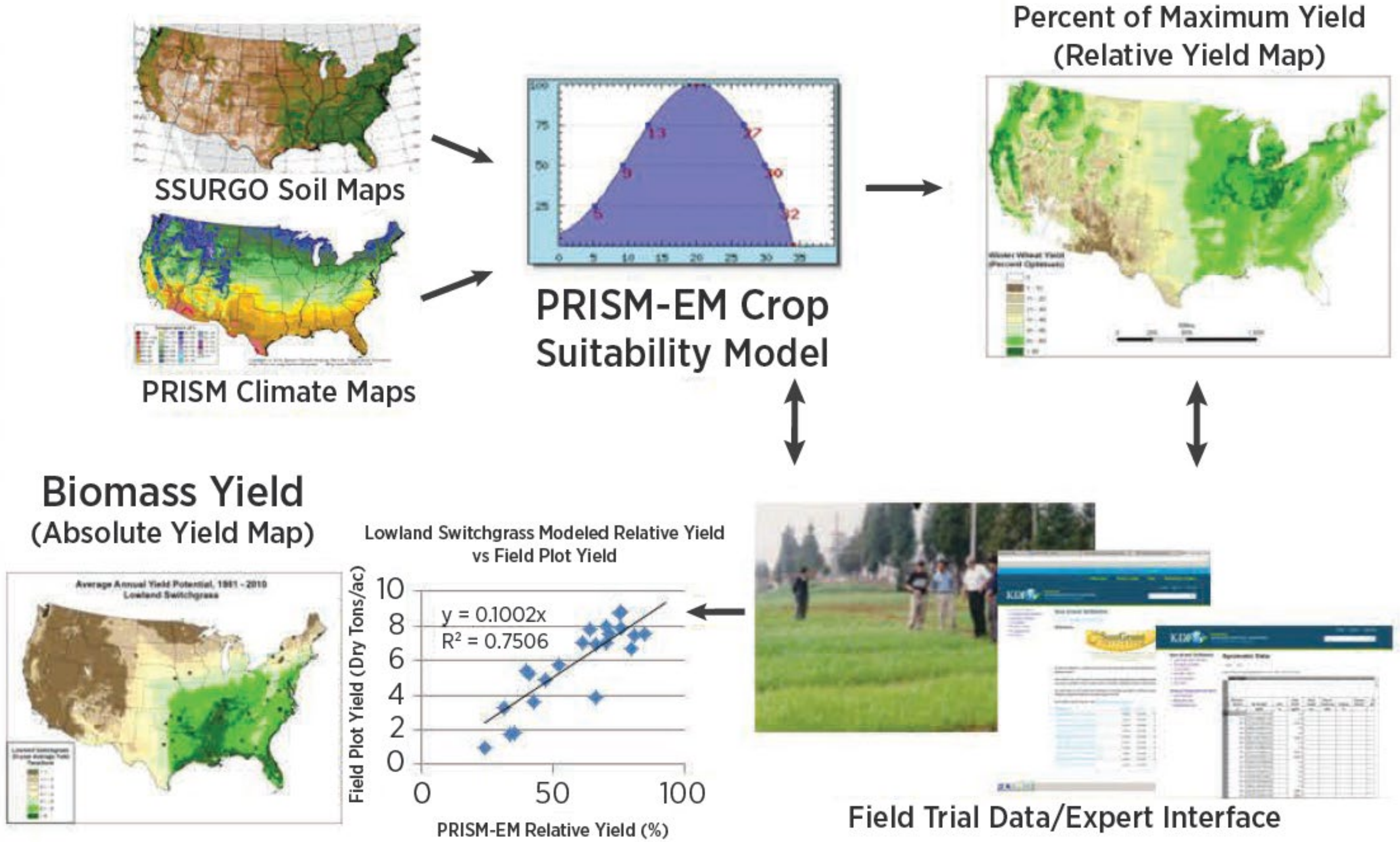
POLYSYS National Output

Annual Prices, production, government payments, exports, income.

2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046

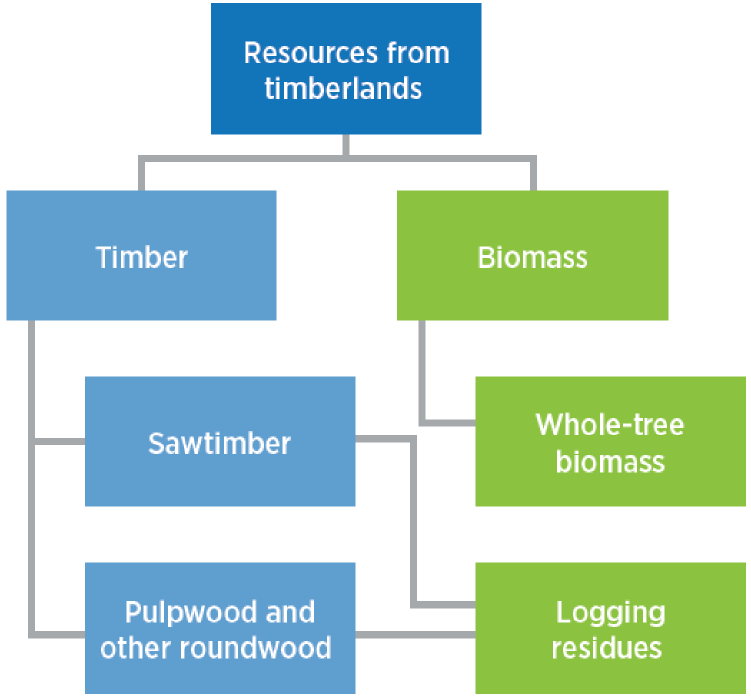
Biomass crop yields modeled with Regional Feedstock Partnership

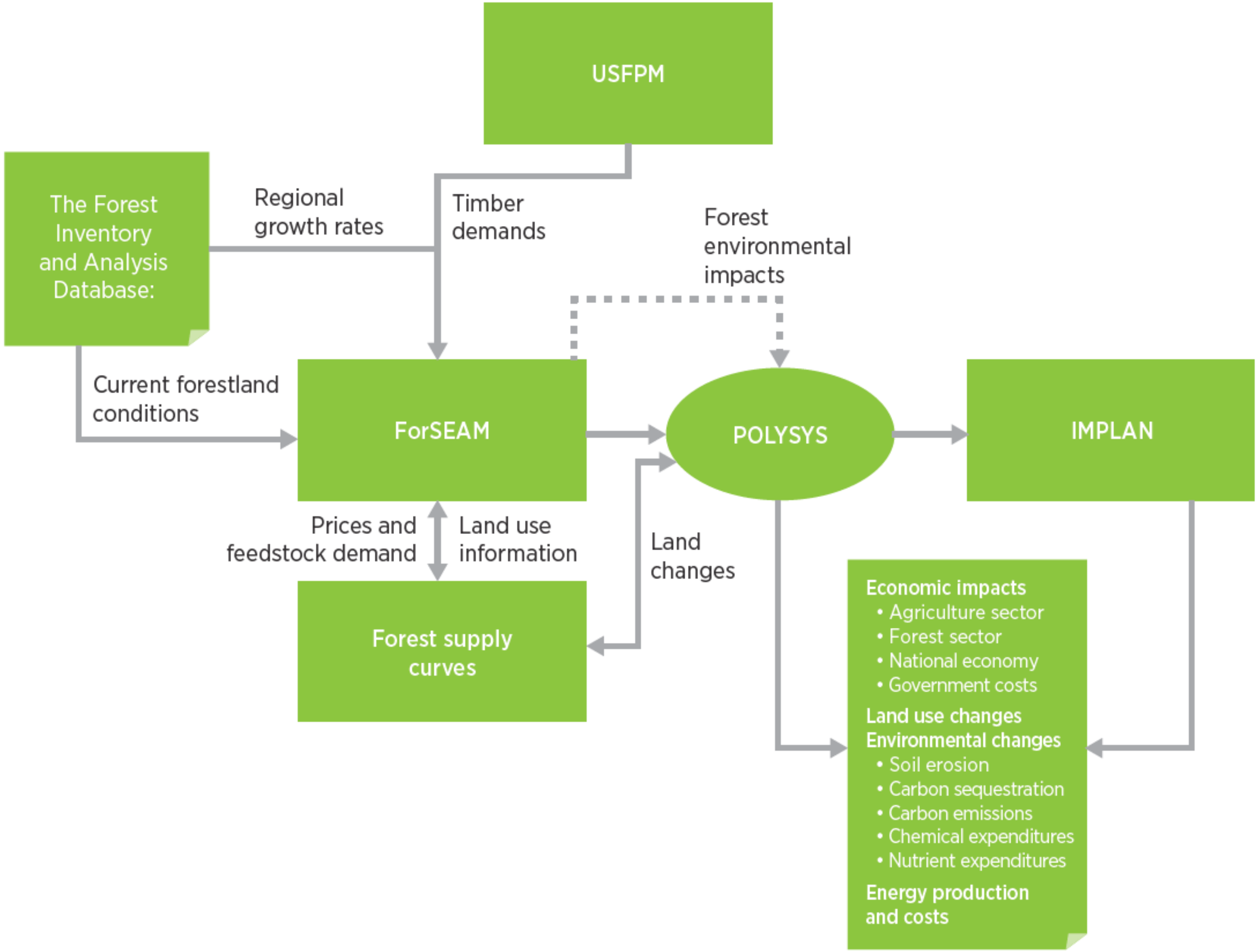




Modeling workshops

Forest Sustainability and Economic Assessment Model (ForSEAM) – University of Tennessee, NCSU, and USFS





OAK RIDGE National Laboratory

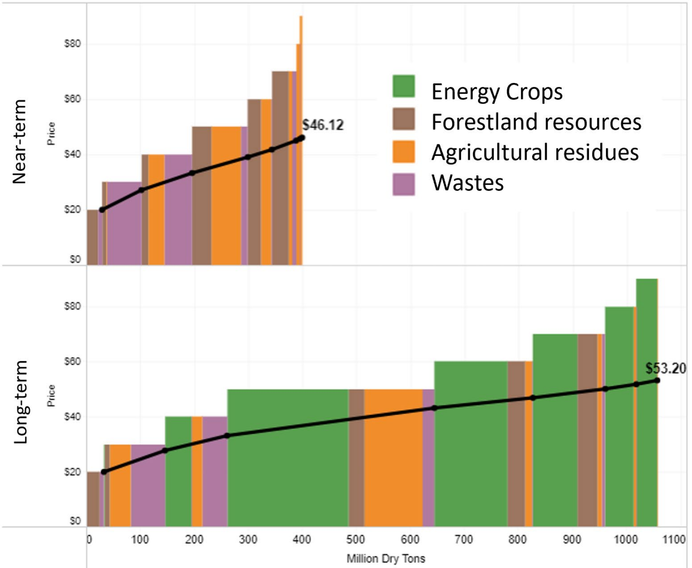
Sustainability Criteria—Agriculture

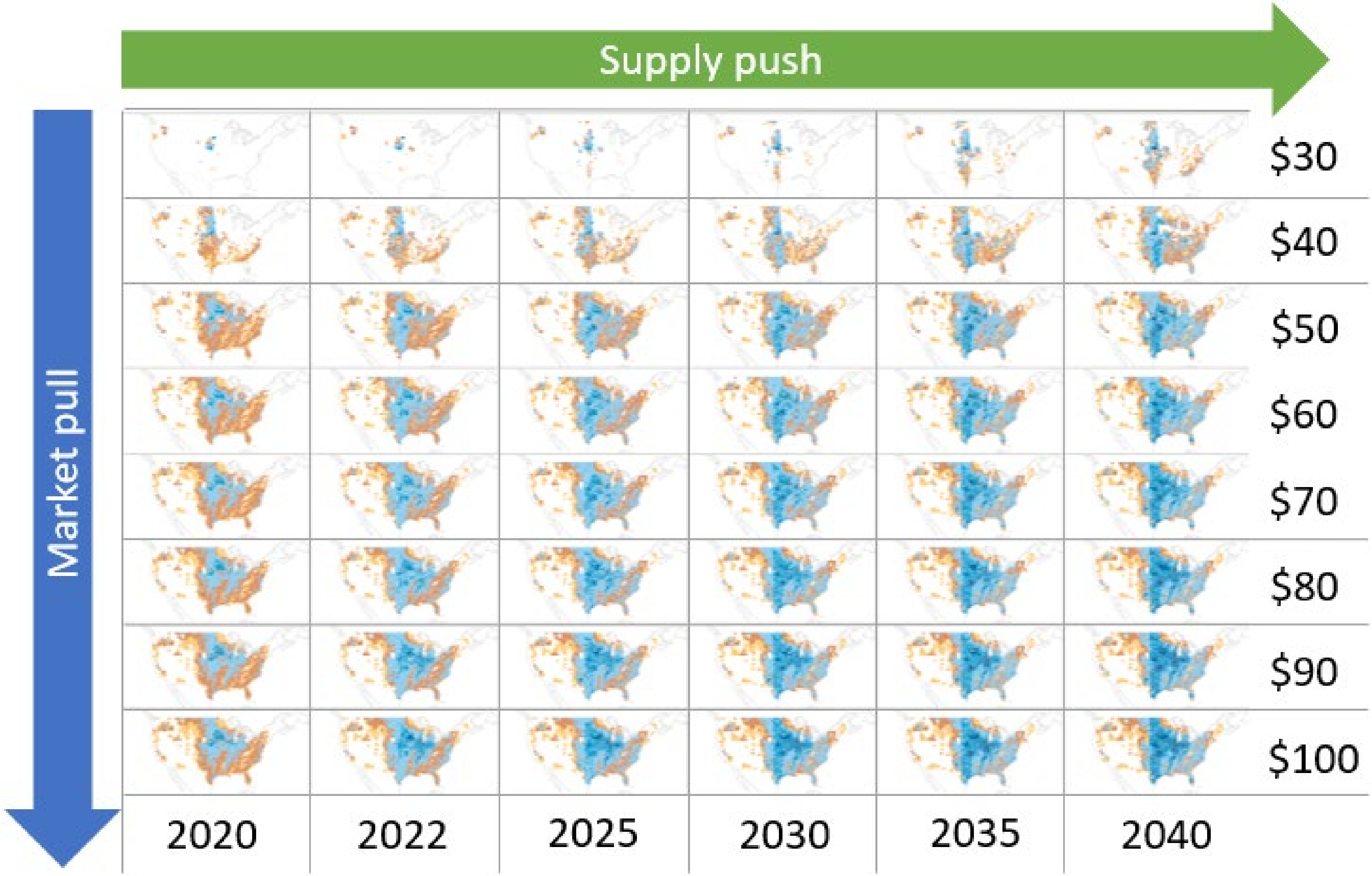
Sustainability Assumption or Constraint	Sustainability Category	Implementation
Trend toward reduced till and no till for corn, wheat	Soil quality, water quality	Management assumptions
High fraction of crop acres no-till		Management assumptions
Residue removal prohibited on conventionally tilled acres		Management assumptions
Crop residue removal based on wind and water erosion estimates and soil carbon loss		Residue removal tool used to estimate retention coefficients
No residue removal for soy		Management assumption
Acceptable residue removal different for reduced and no till		Residue removal tool to estimate retention coefficients
Multi-county NRCS crop management zones (e.g., tillage assumptions)		Spatially explicit rotation and management assumptions
Annual energy crops on land with low erosion potential and assumed part of multicrop rotation		Excluded land area
Irrigated cropland or pasture excluded	Water quantity	Excluded land area
No supplemental irrigation of energy crops		Management assumptions
No use of pastureland in counties west of 100th meridian		Excluded land area
No transition of non-agricultural lands to energy crops	Greenhouse gas emissions	Excluded land area

Sustainability Criteria—Forestry

Sustainability Assumption or Constraint	Sustainability Category	Implementation
Acceptable residue removal for fuel treatment thinning different for different slopes (0%, 60%, or 70%)	Soil quality, water quality	Management assumptions
Acceptable residue removal for logging residues (70%)	Soil quality, water quality	Management assumptions
No biomass removal in wet areas to avoid soil compaction	Soil quality	Excluded land area
No production in administratively reserved forestlands, such as wilderness areas and National Parks	Biodiversity	Excluded land area
No production in roadless areas, as inventoried by USDA Forest Service, which may qualify for wilderness or conservation protection	Biodiversity	Excluded land area

Current and potential biomass resources, **range of prices**





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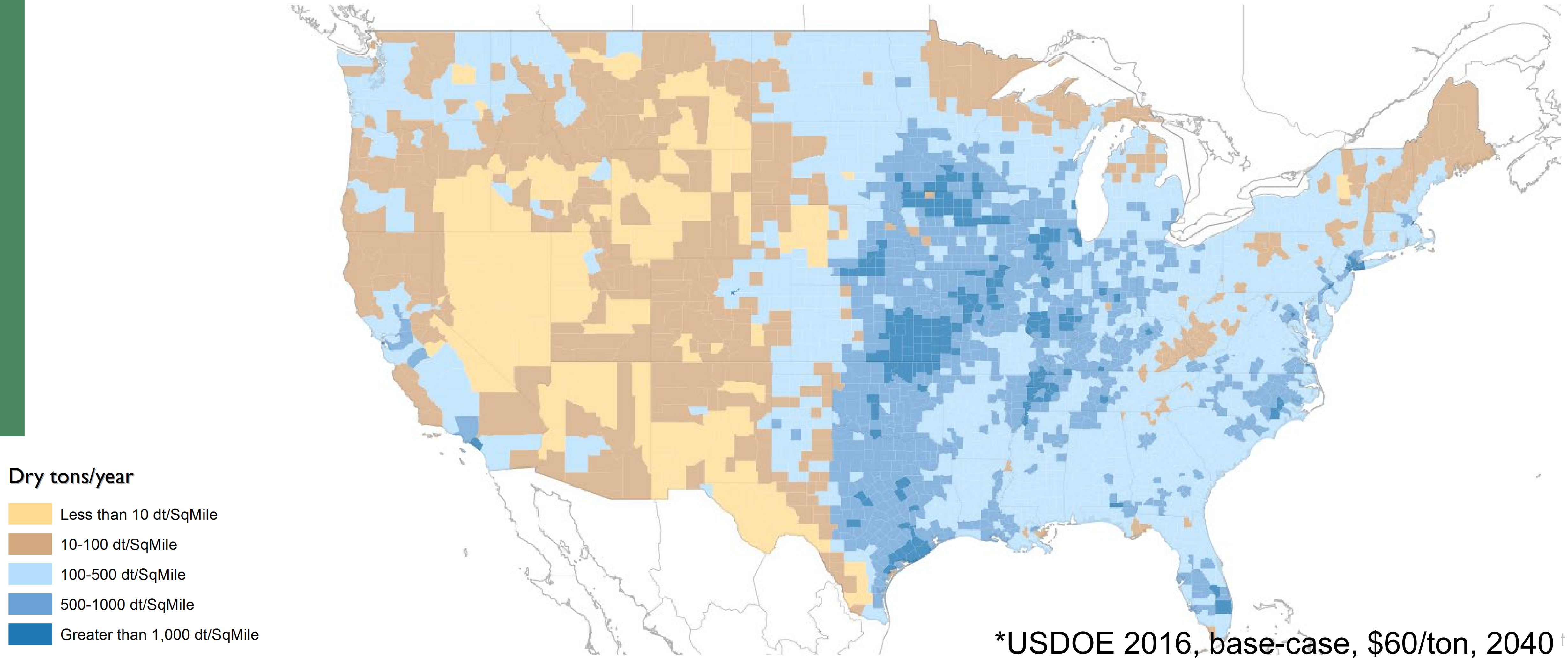
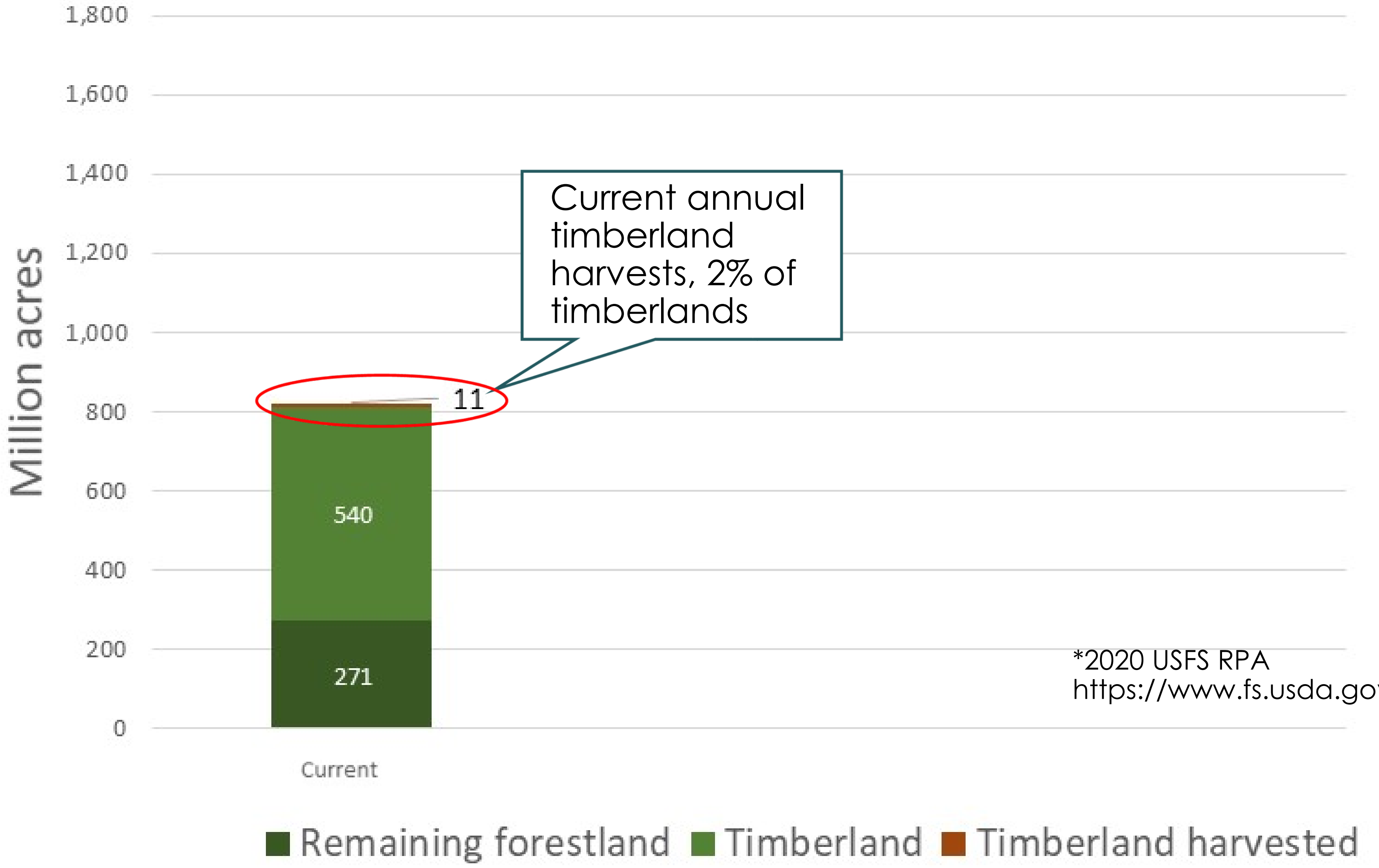
https://bioenergykdf.net/2016-billion-ton-report

Combined resources, 2040*



*USDOE 2016, base-case, $60/ton, 2040

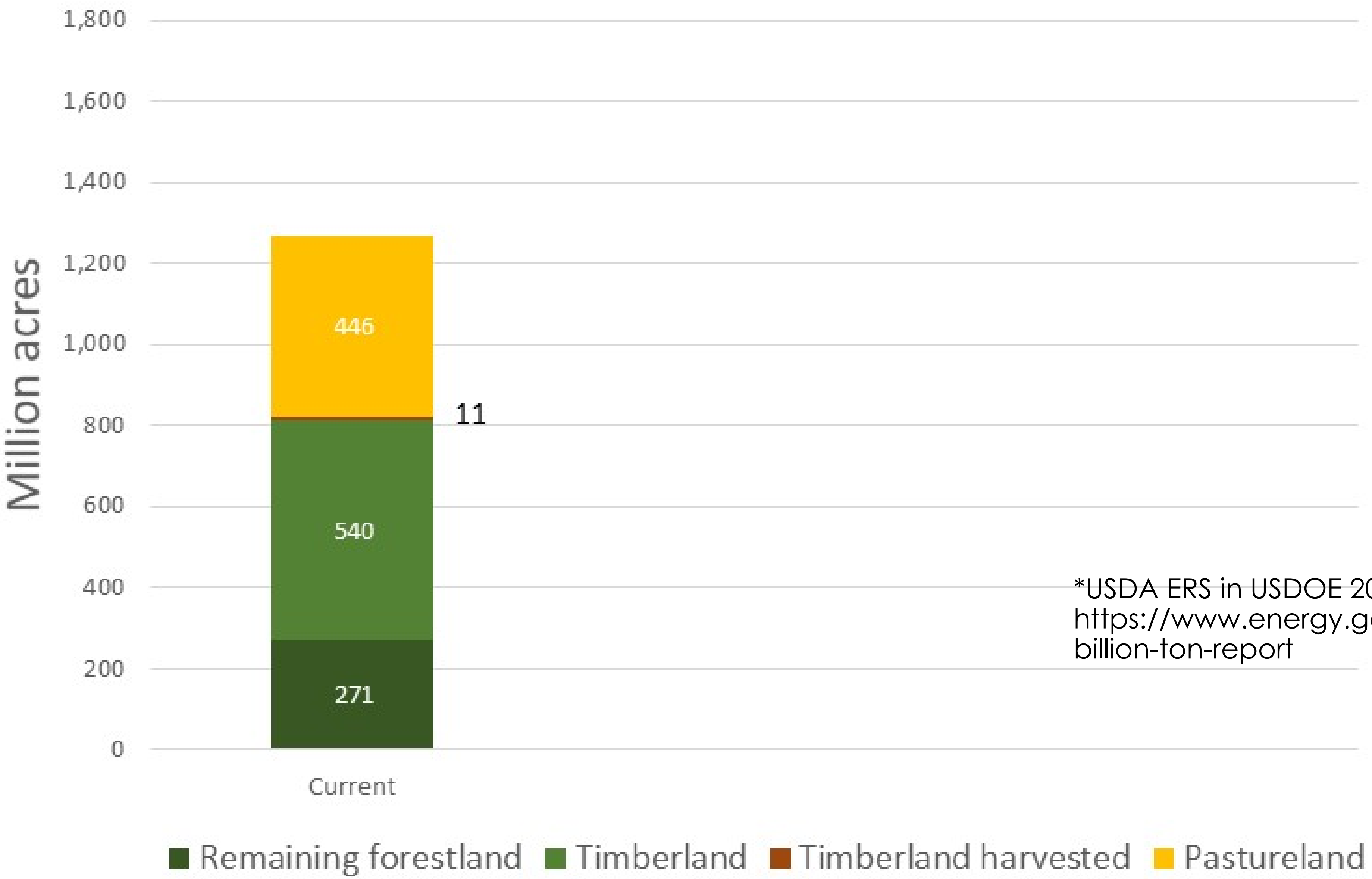
Current forestland and timberland*



*2020 USFS RPA
https://www.fs.usda.gov/treesearch/pubs/57903

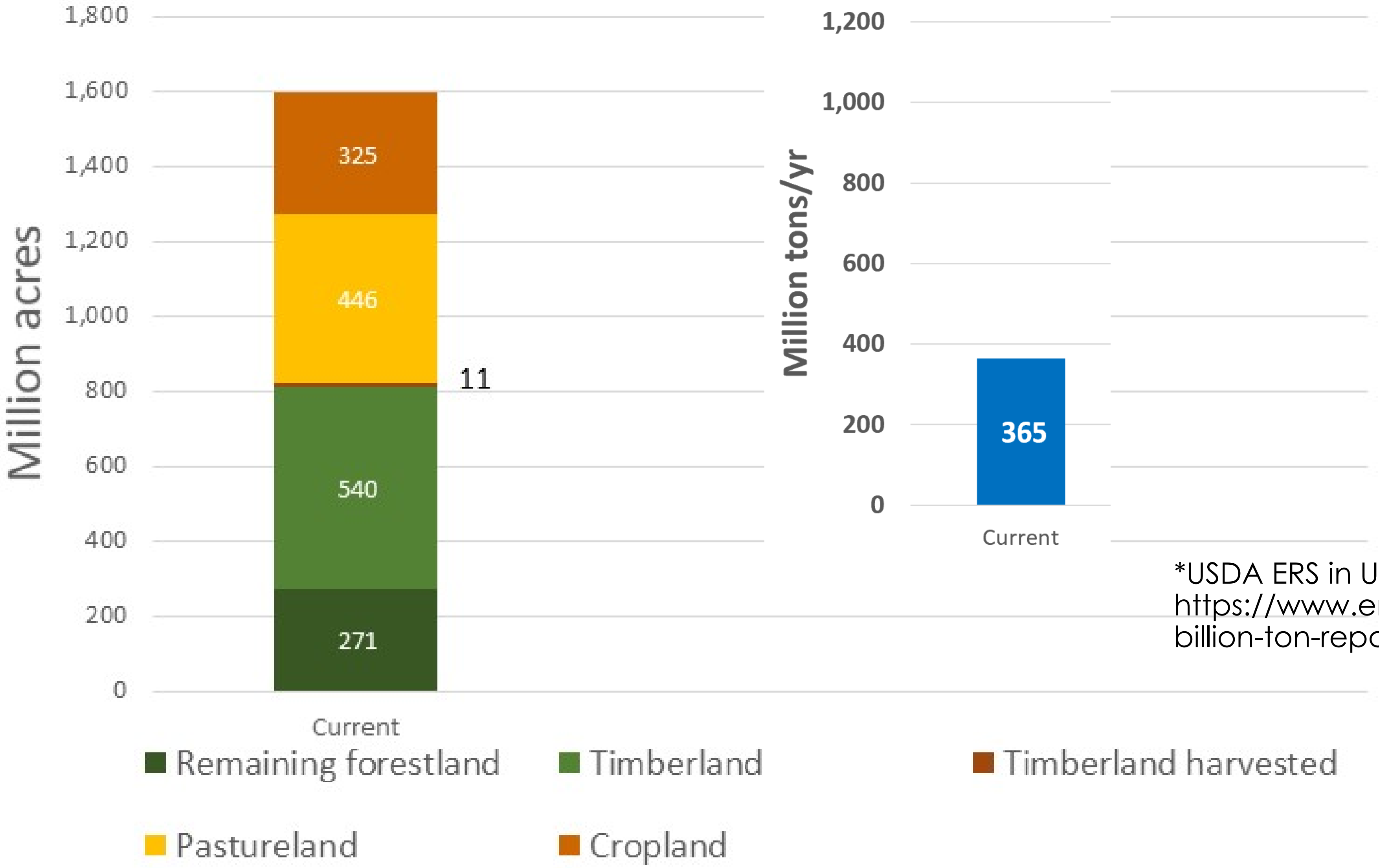
Open slide master to edit

…current pastureland*



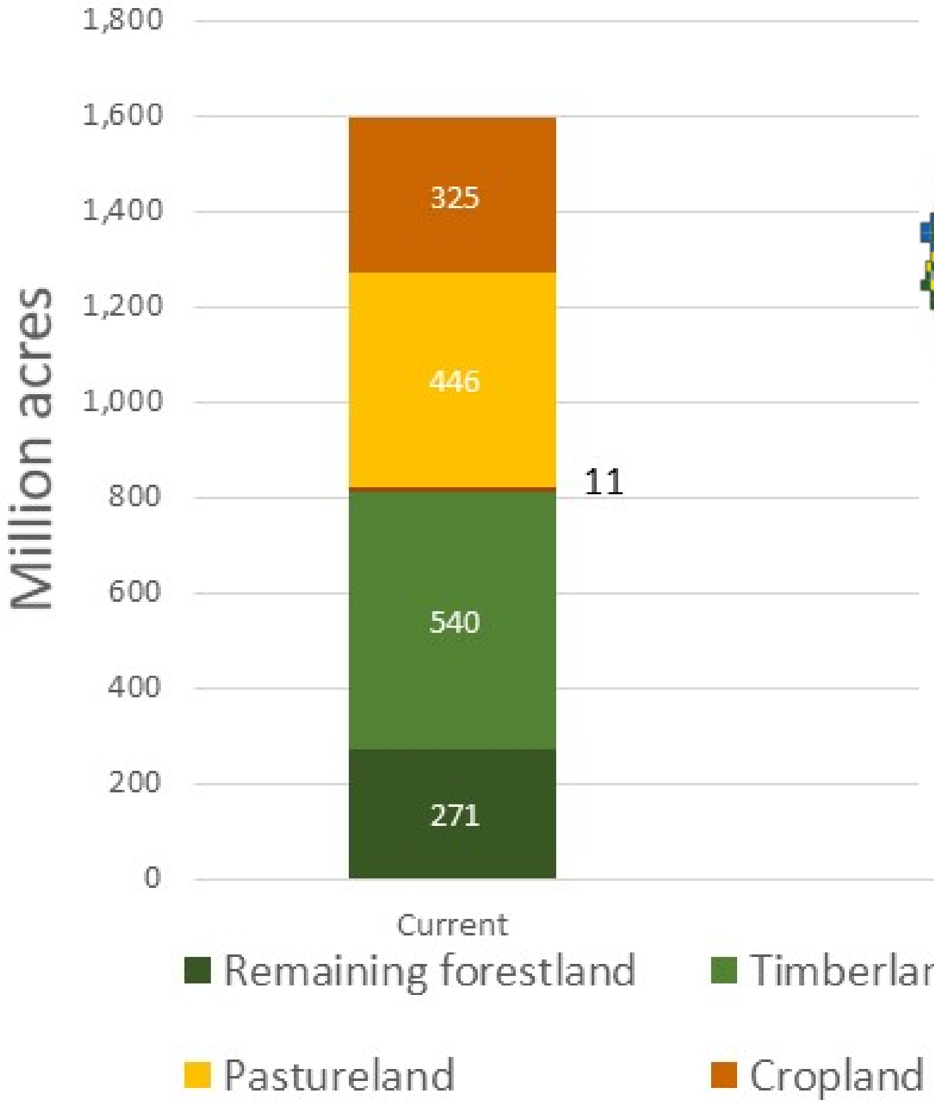
*USDA ERS in USDOE 2016
https://www.energy.gov/eere/bioenergy/2016-billion-ton-report

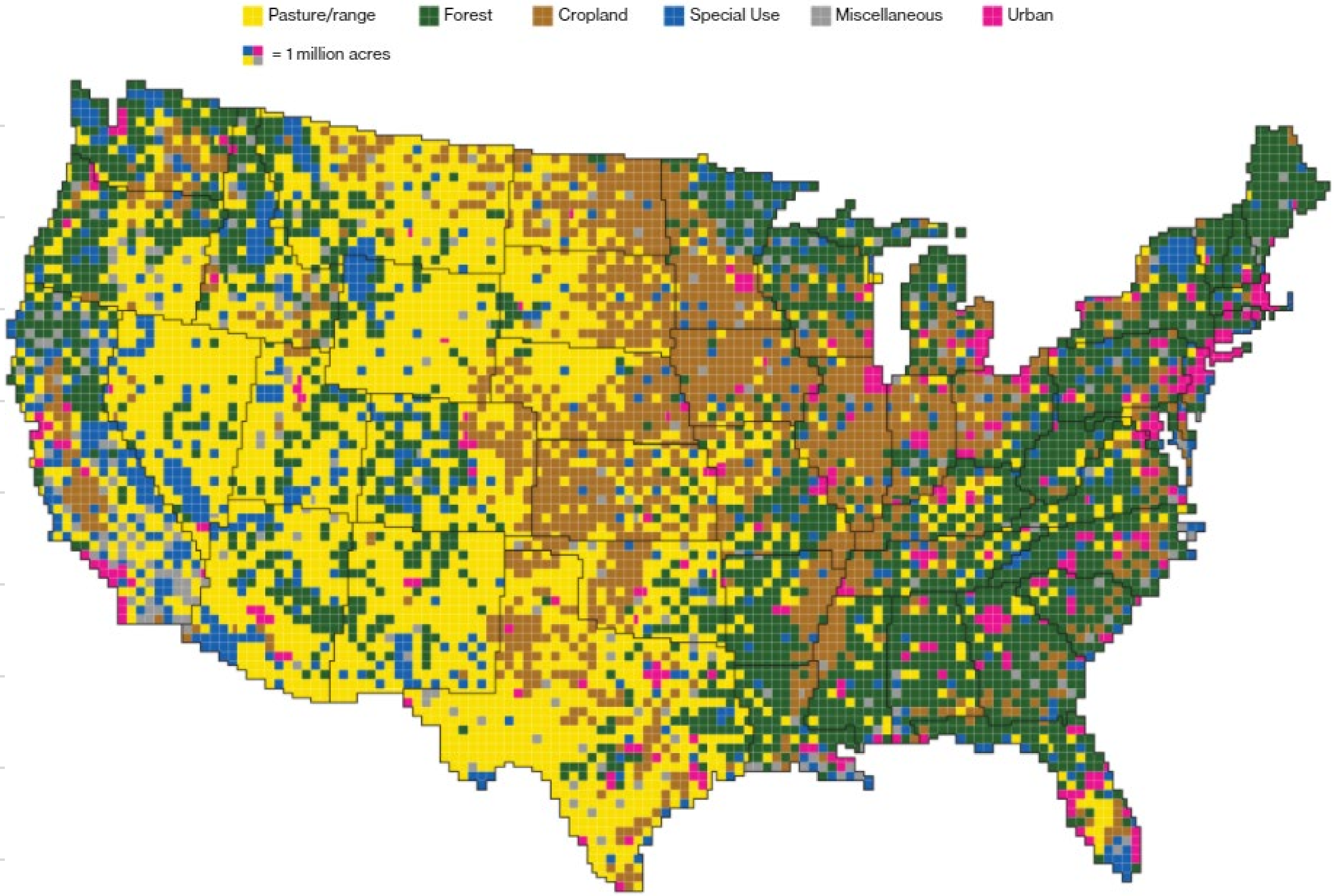
…current cropland*



*USDA ERS in USDOE 2016 https://www.energy.gov/eere/bioenergy/2016-billion-ton-report

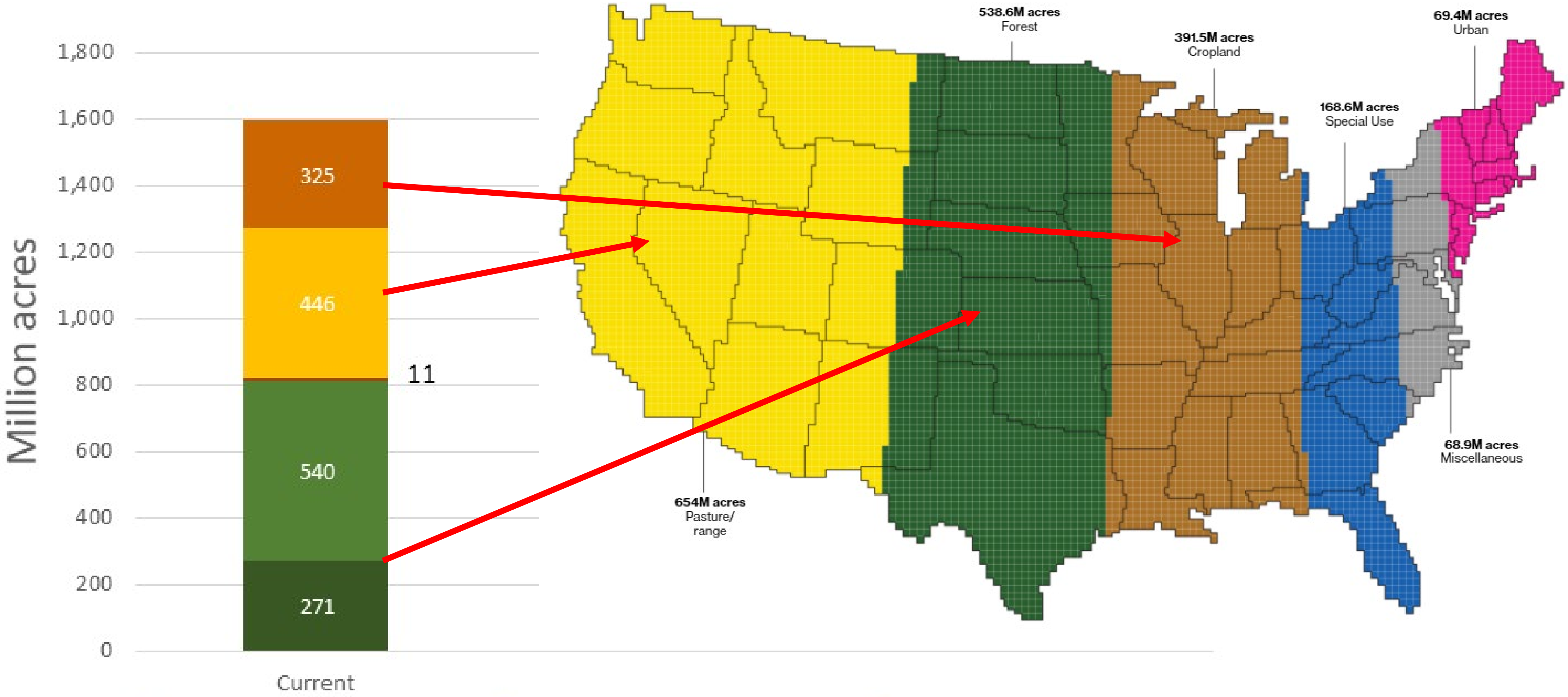
…current land allocation*





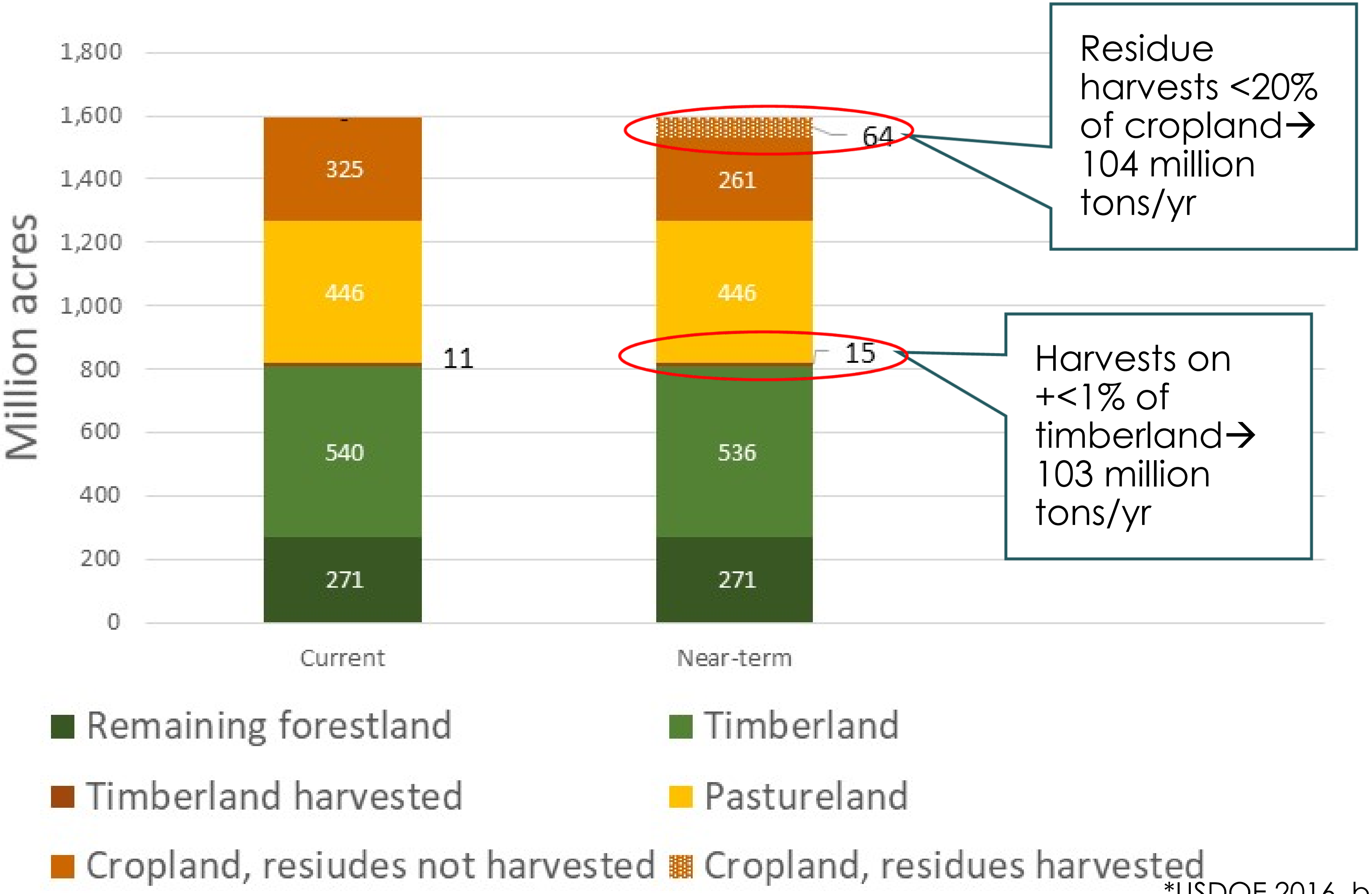
*Bloomberg 2018: https://www.bloomberg.com/graphics/2018-us-land-use/

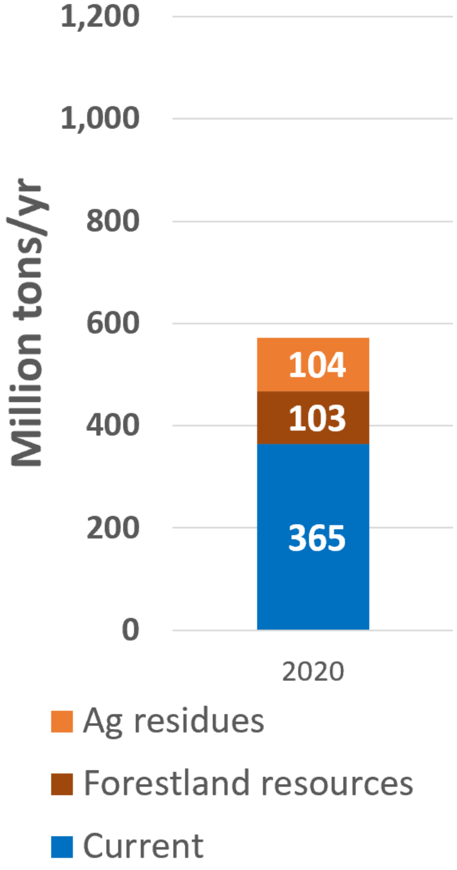
…current land allocation*



*Bloomberg 2018: https://www.bloomberg.com/graphics/2018-us-land-use/

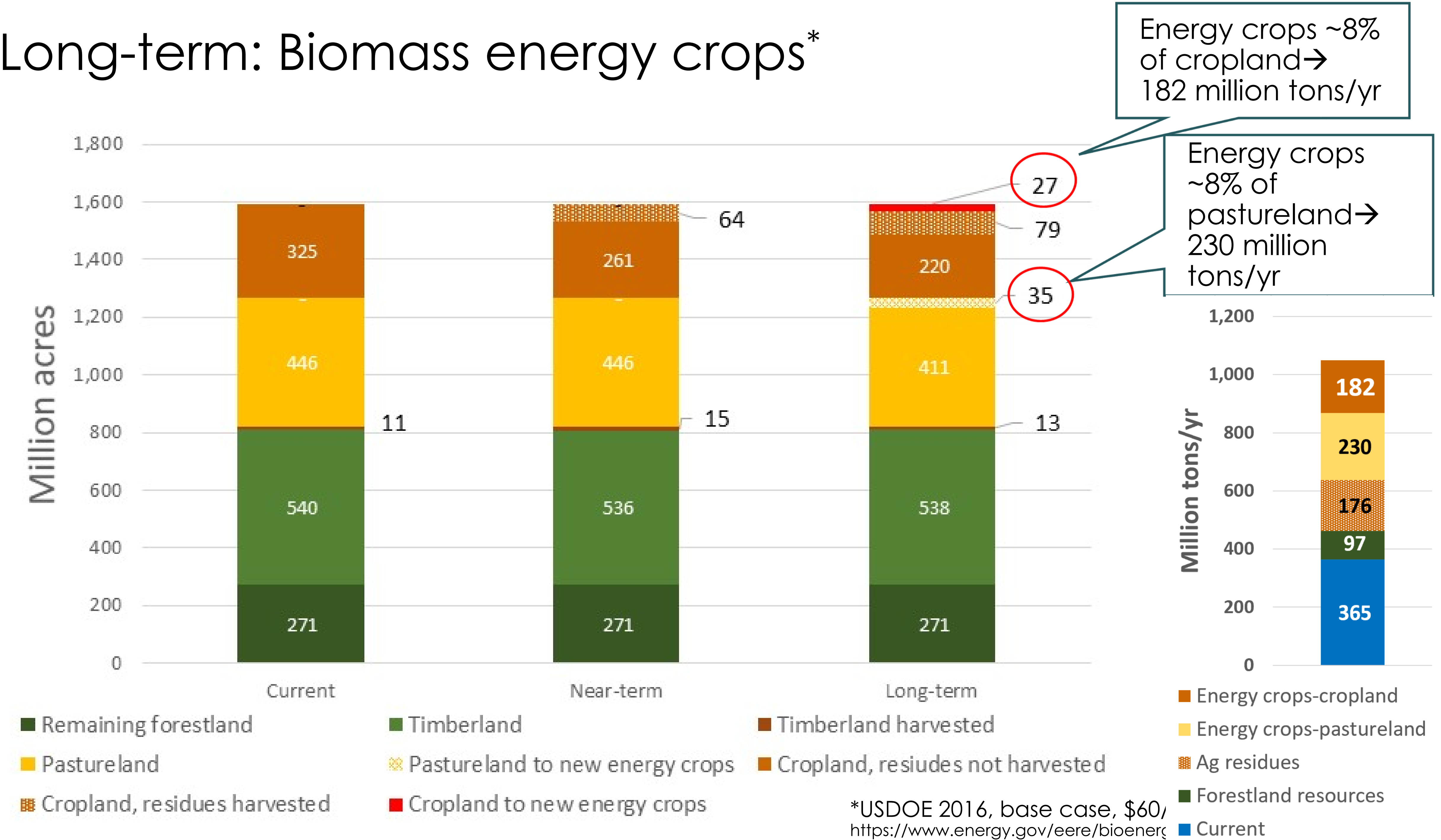
Near-term biomass: residues and timberlands*





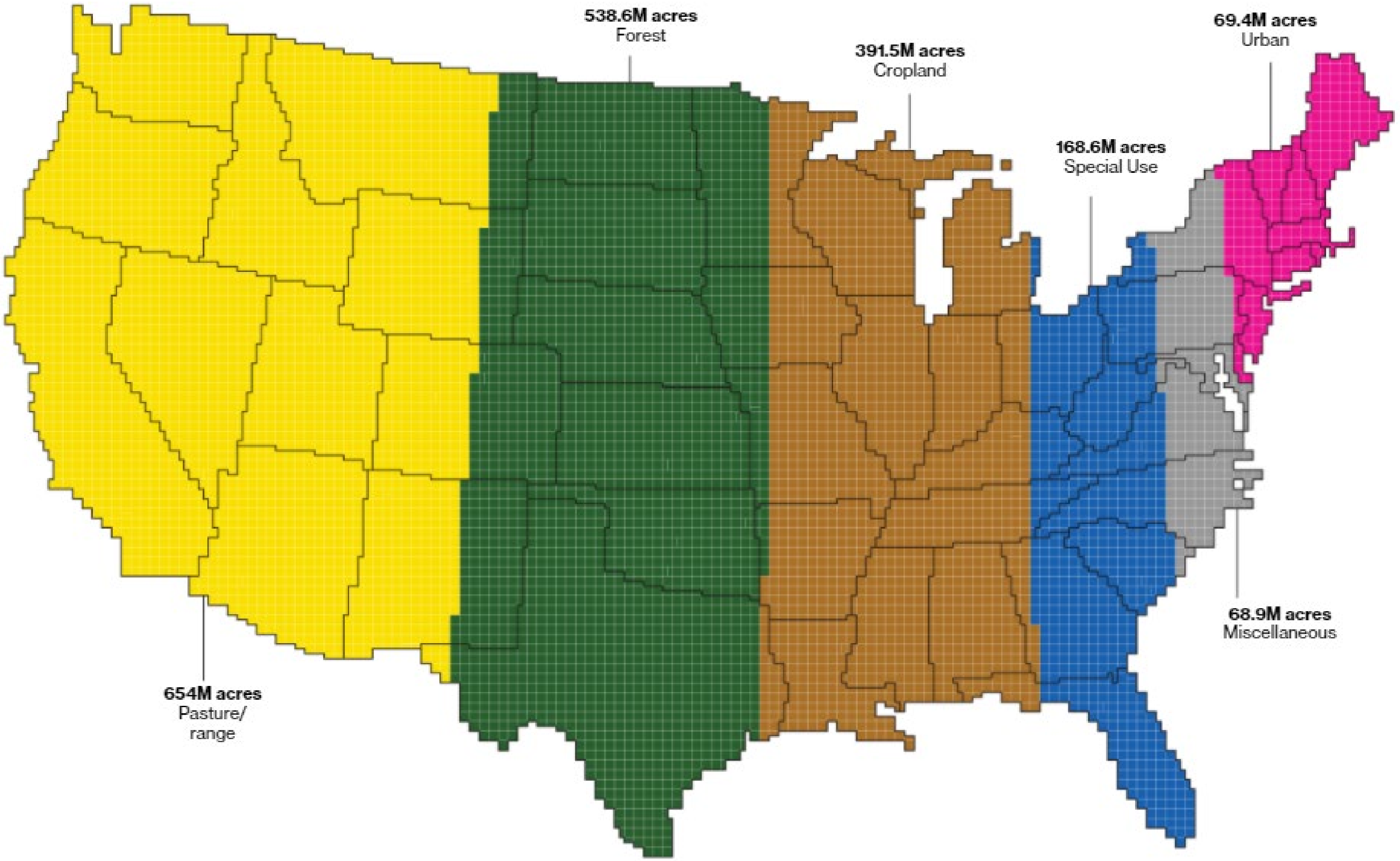
*USDOE 2016, base case, $60/dt
https://www.energy.gov/eere/bioenergy/2016-billion-ton-report

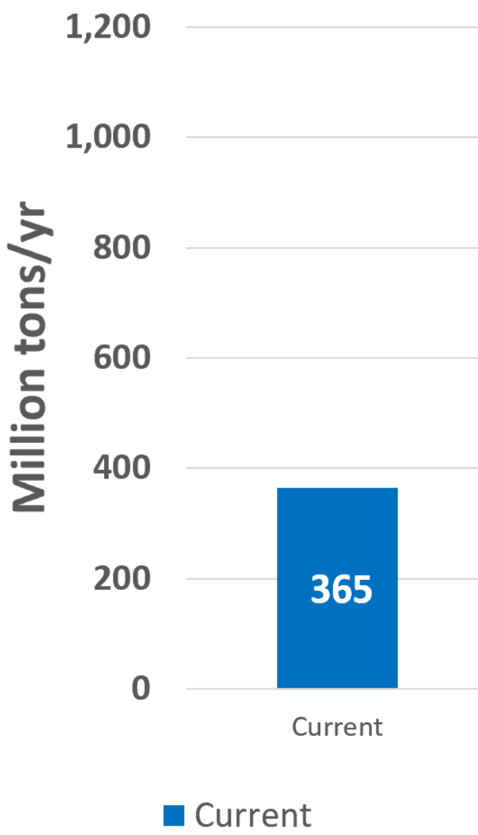
Long-term: Biomass energy crops*



*USDOE 2016, base case, $60/
https://www.energy.gov/eere/bioenerg

Current





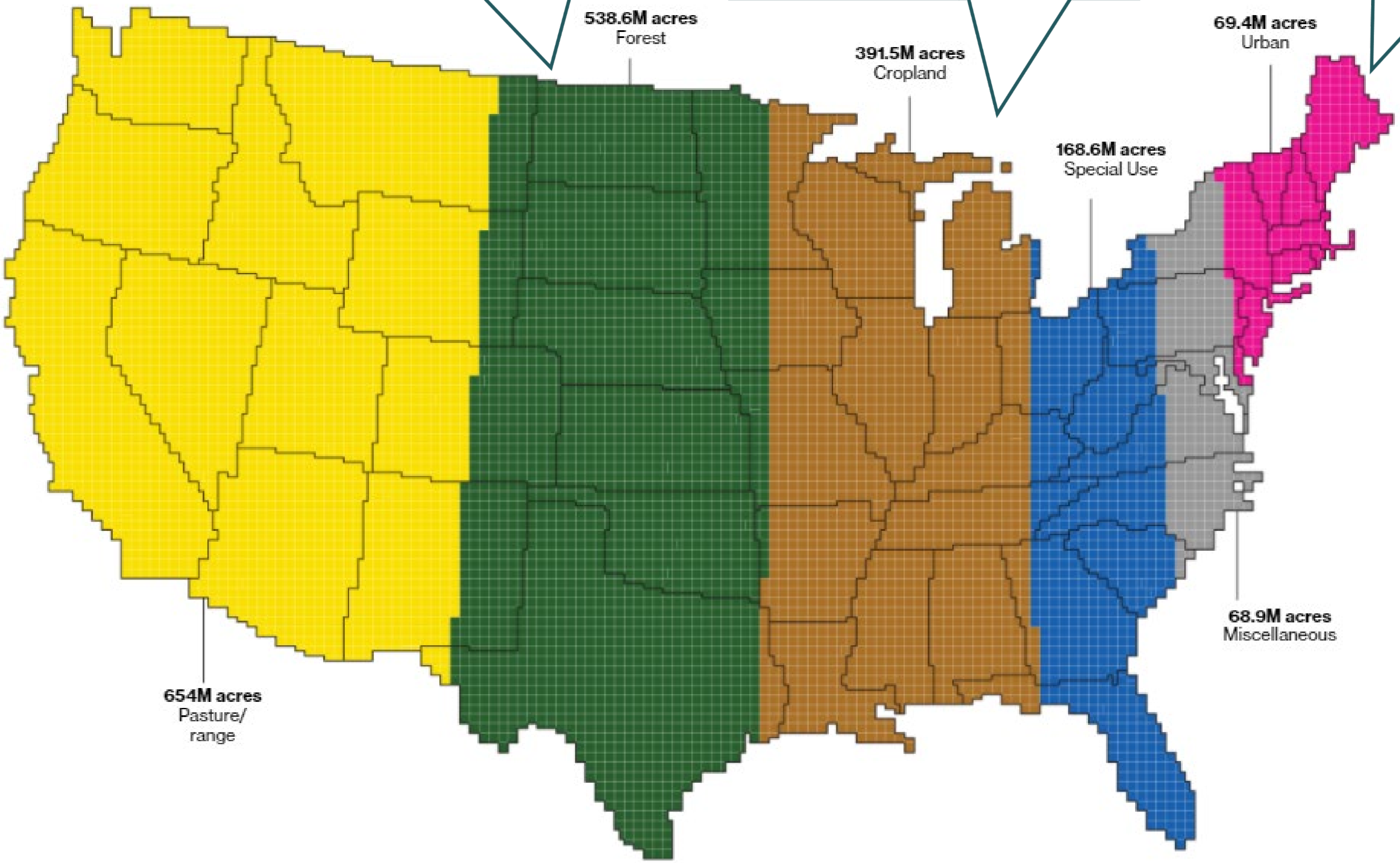
Oak Ridge National Laboratory

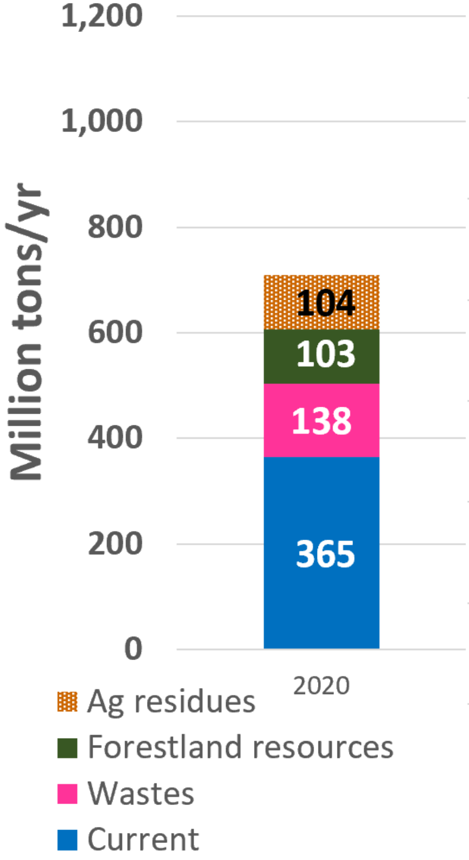
Near-term biomass potential, $60/dt

1% of timberland → ~103 million tons

16% of cropland → ~104 million tons residues

0% of land → ~138 million tons wastes





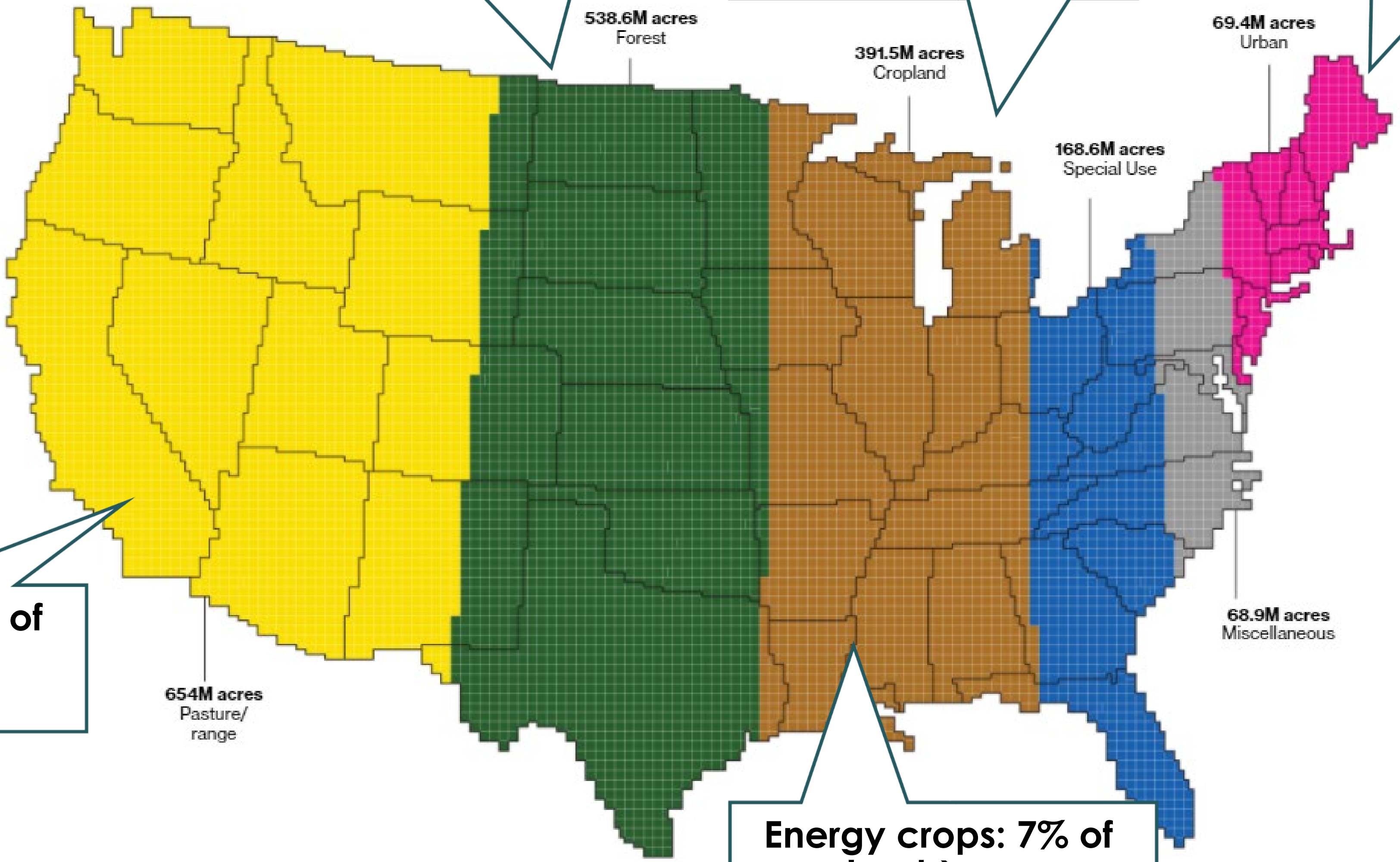
OAK RIDGE National Laboratory

Long-term potential, $60/dt, with energy crops

1% of timberland → ~103 million tons

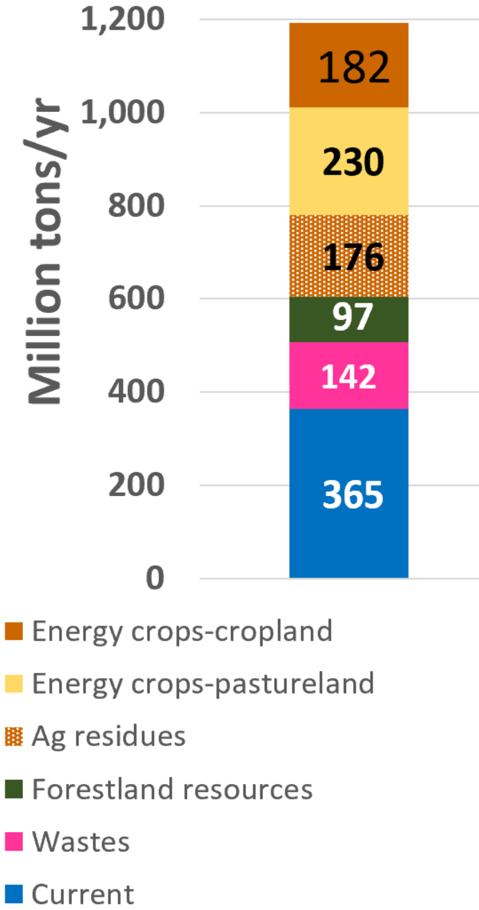
16% of cropland → ~104 million tons residues

0% of land → ~137 million tons wastes



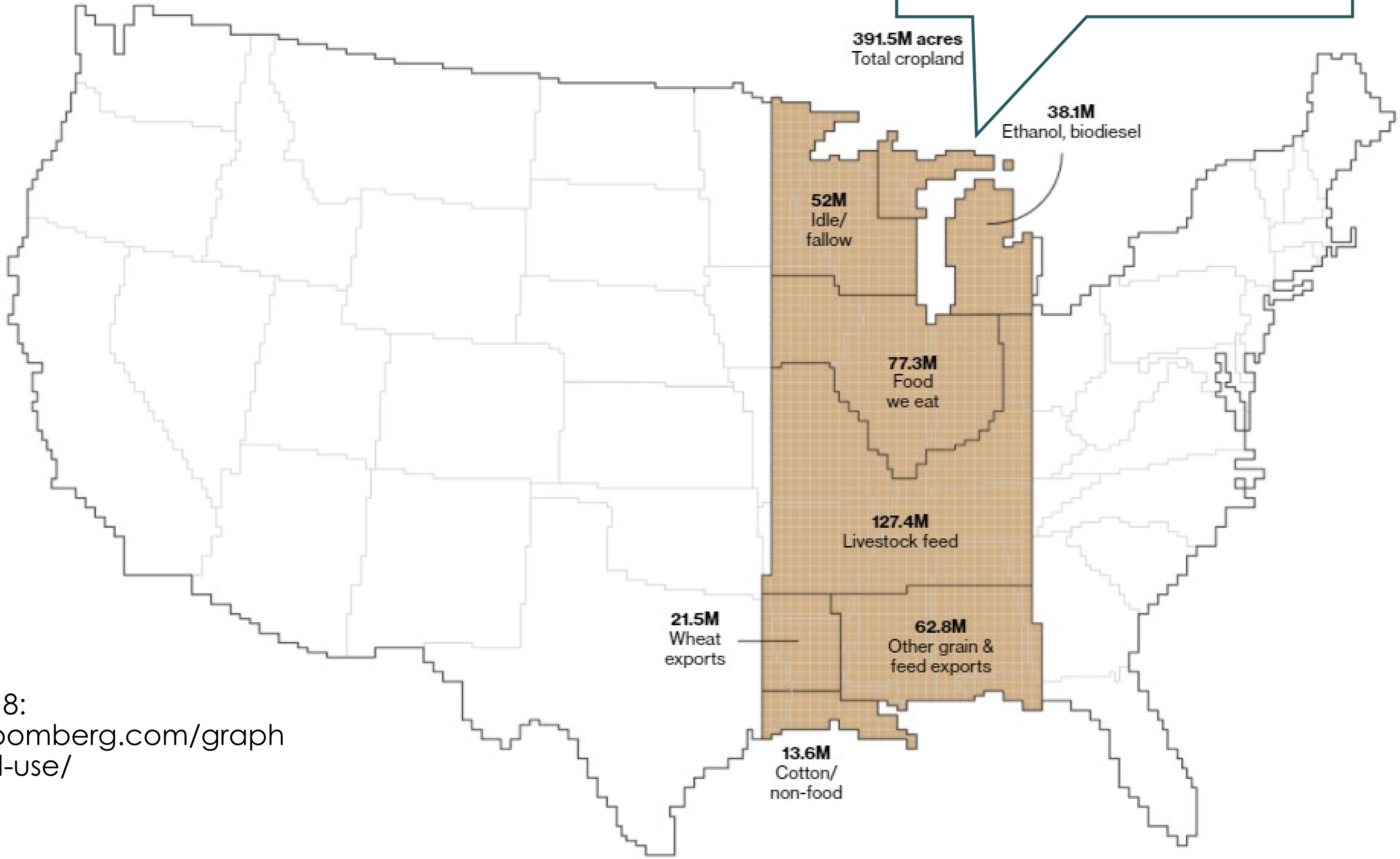
Energy crops: 6% of pasture/range→ 230 million tons

Energy crops: 7% of cropland→ 182 million tons



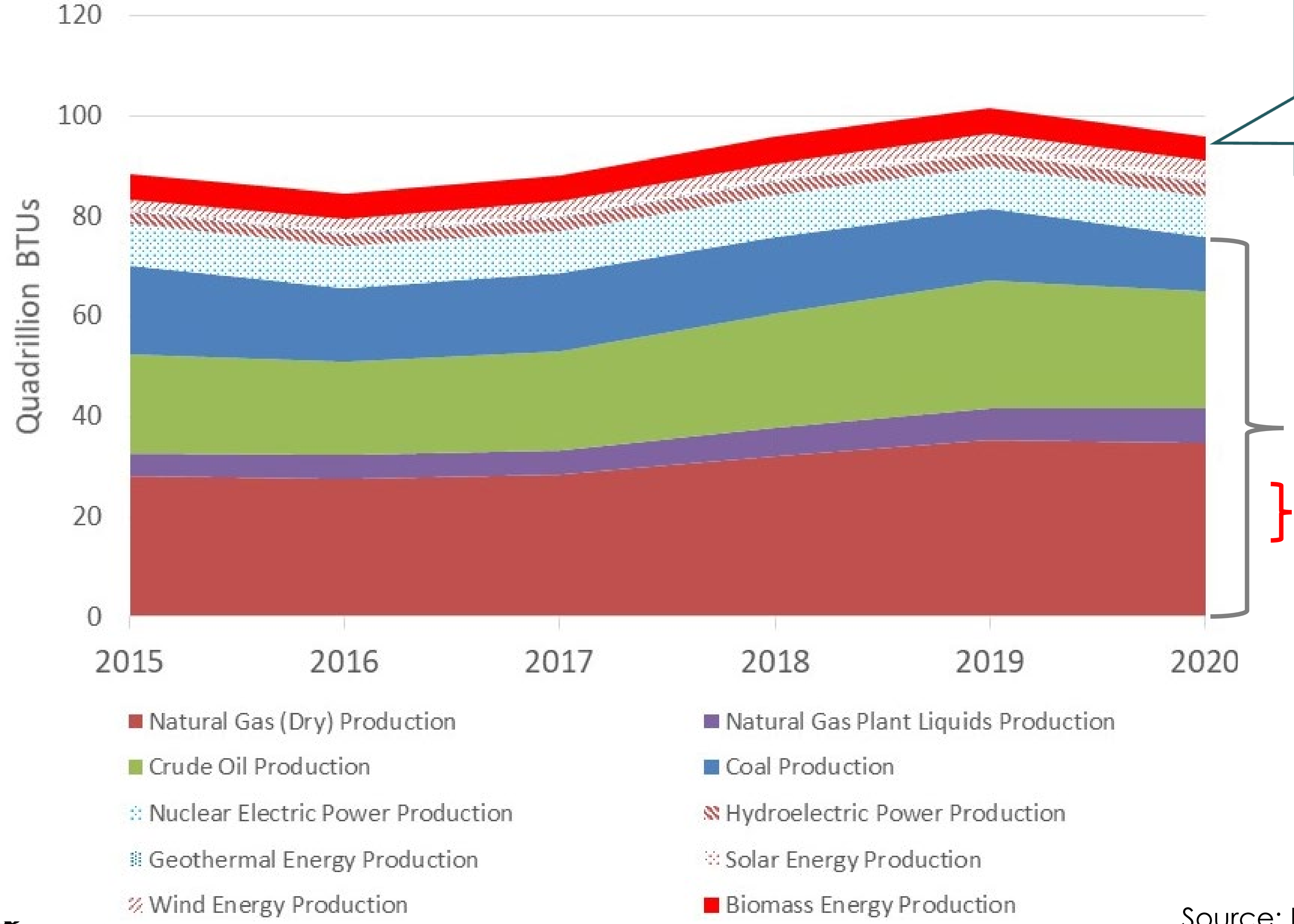
Energy crops on ag land

27 million acres energy crops =7% of cropland; 52% of idle cropland; 70% of current biofuels



*Bloomberg 2018: https://www.bloomberg.com/graphics/2018-us-land-use/

Background – Resource competition



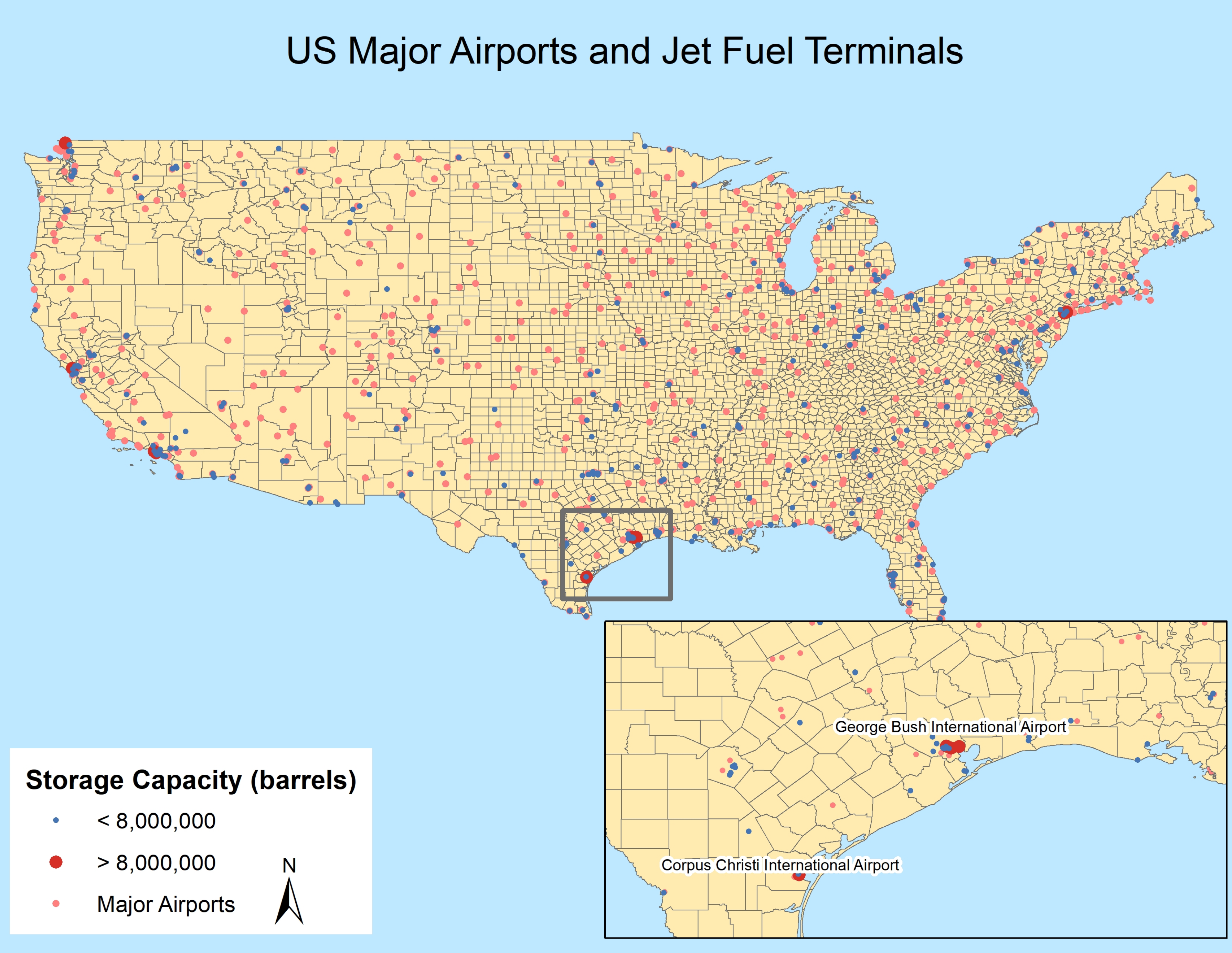
Current bioeconomy: **~4 quads** using 365 million tons

Fossil: **~77 quads**

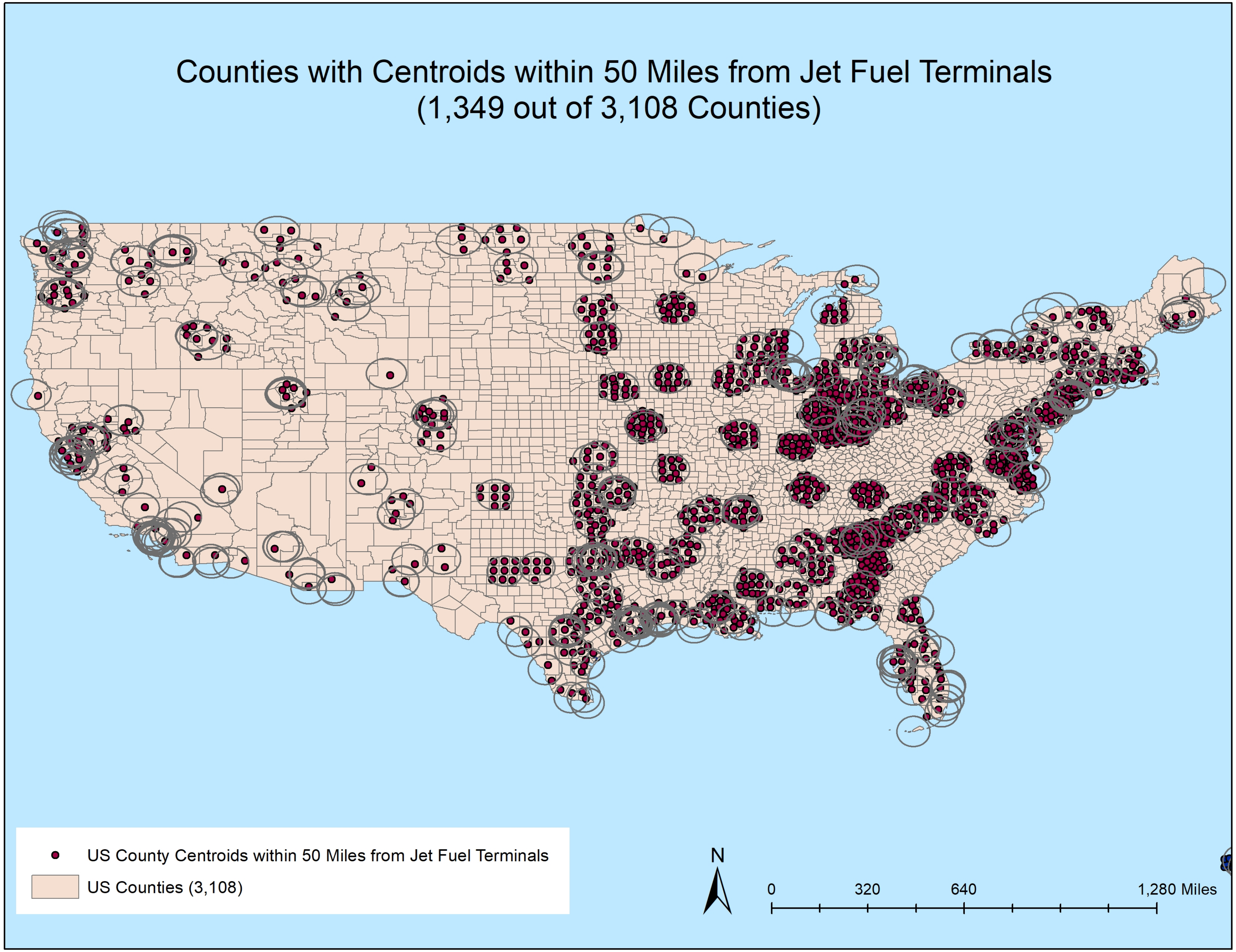
Billion-ton potential could add **~11 quads**. Where to?

Source: EIA Annual Energy Review Table 1.2

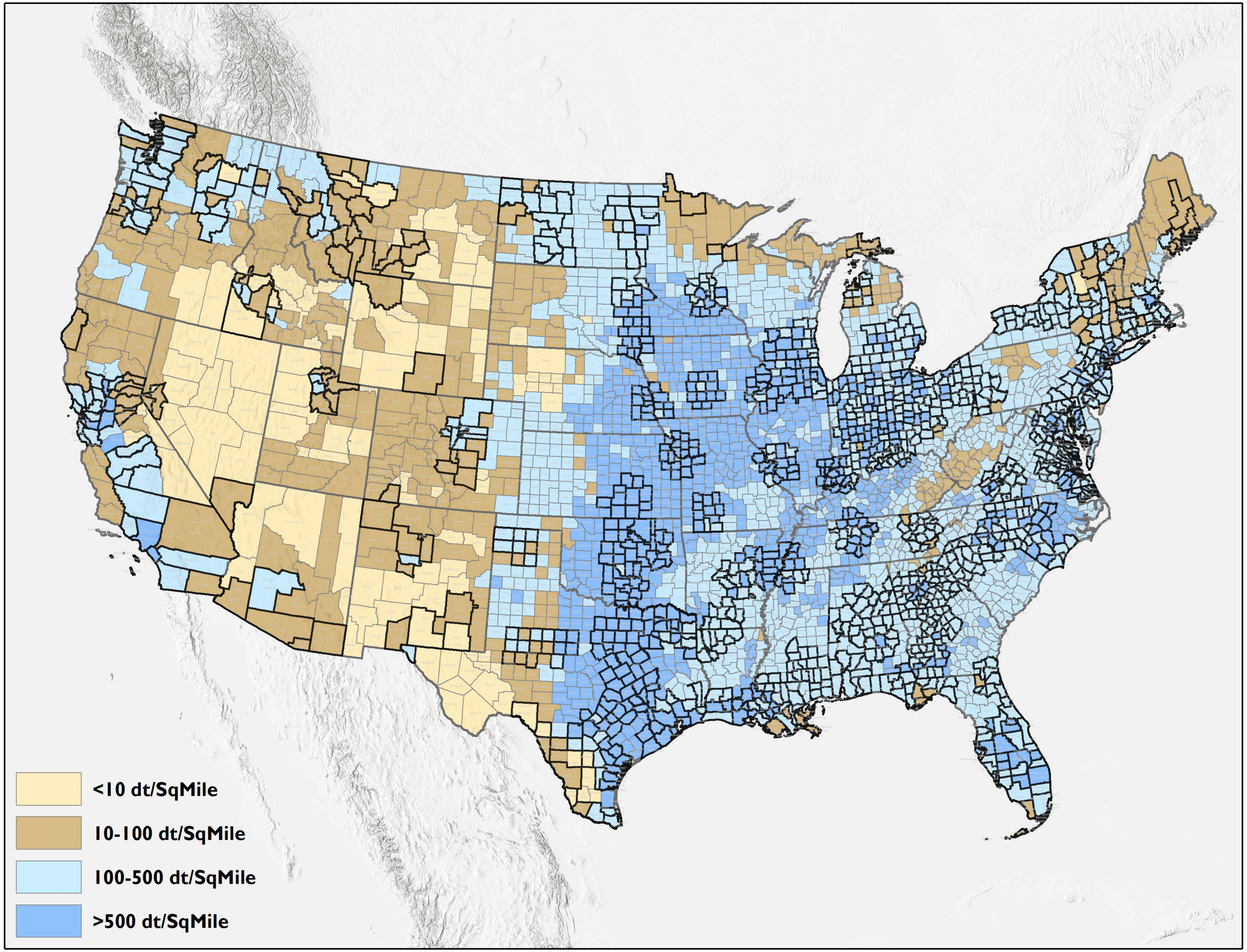
Airports and jet fuel storage locations



1,349 counties within 50 miles of a jet fuel storage location

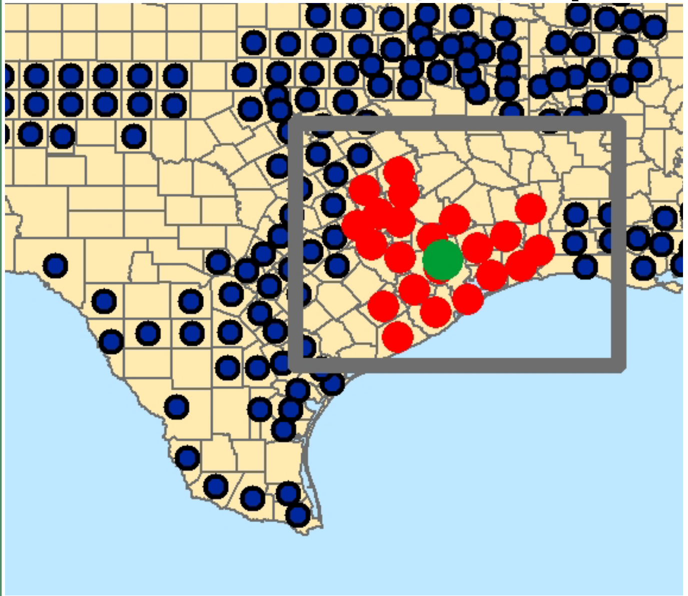


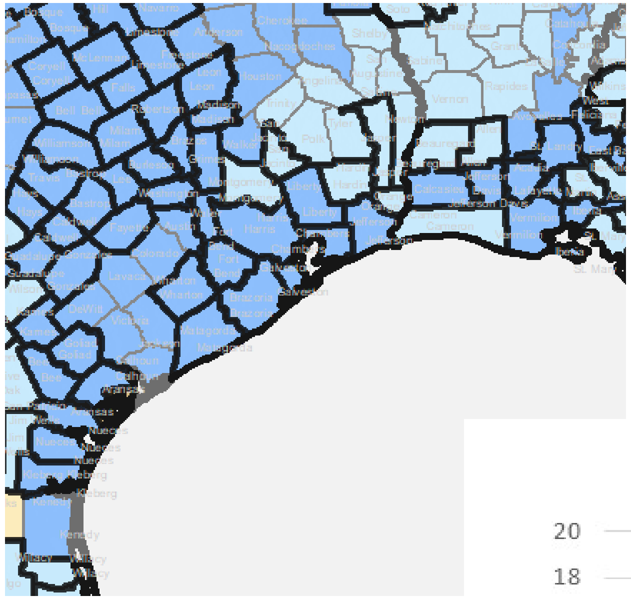
2040, near-term resources + energy crops, and 1,349 selected counties

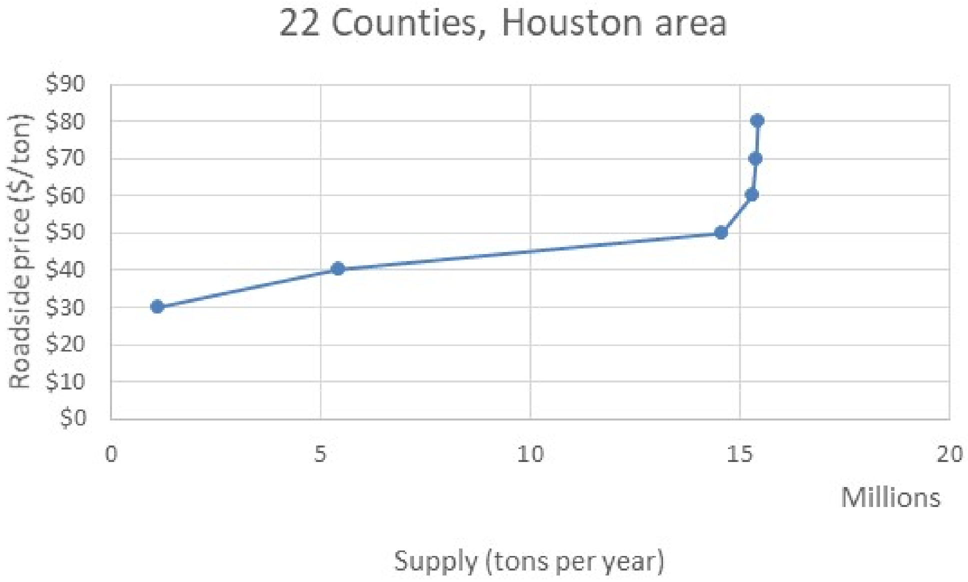


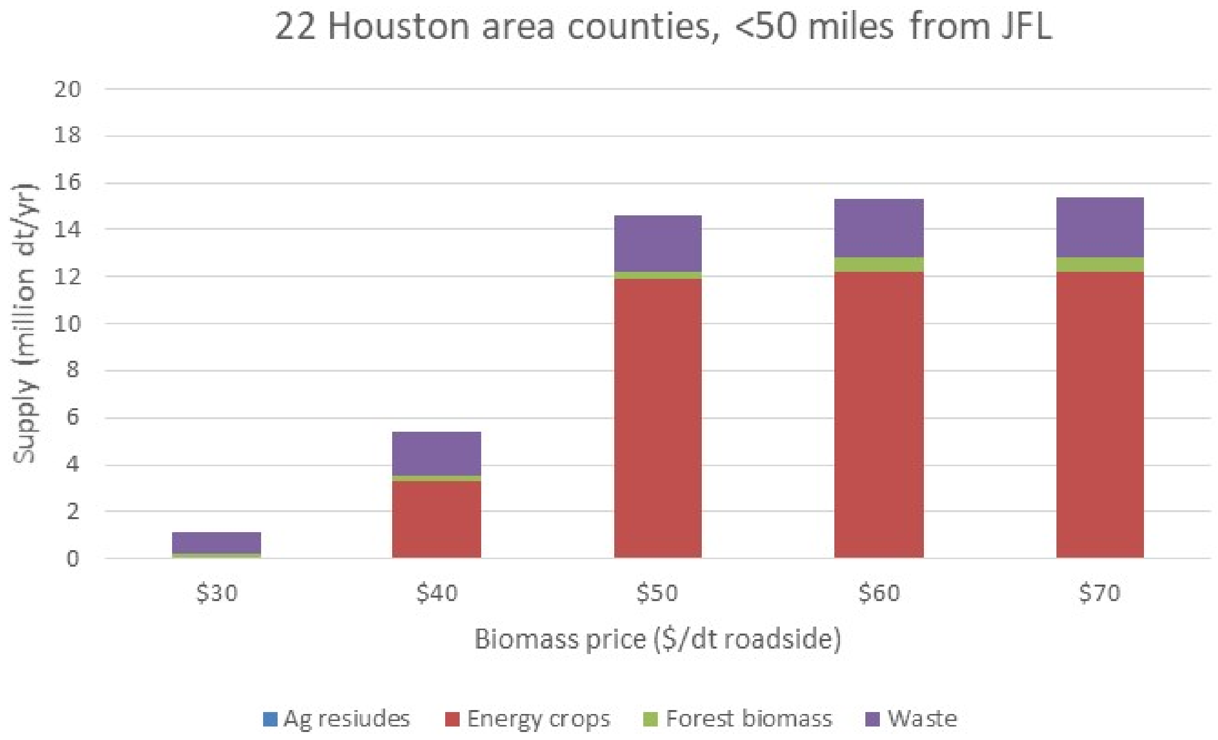
*USDOE 2016, base case, $60/dt
https://www.energy.gov/eere/bioenergy/2016-billion-ton-report

2040 supply (base-case), 22 counties, within 50 miles

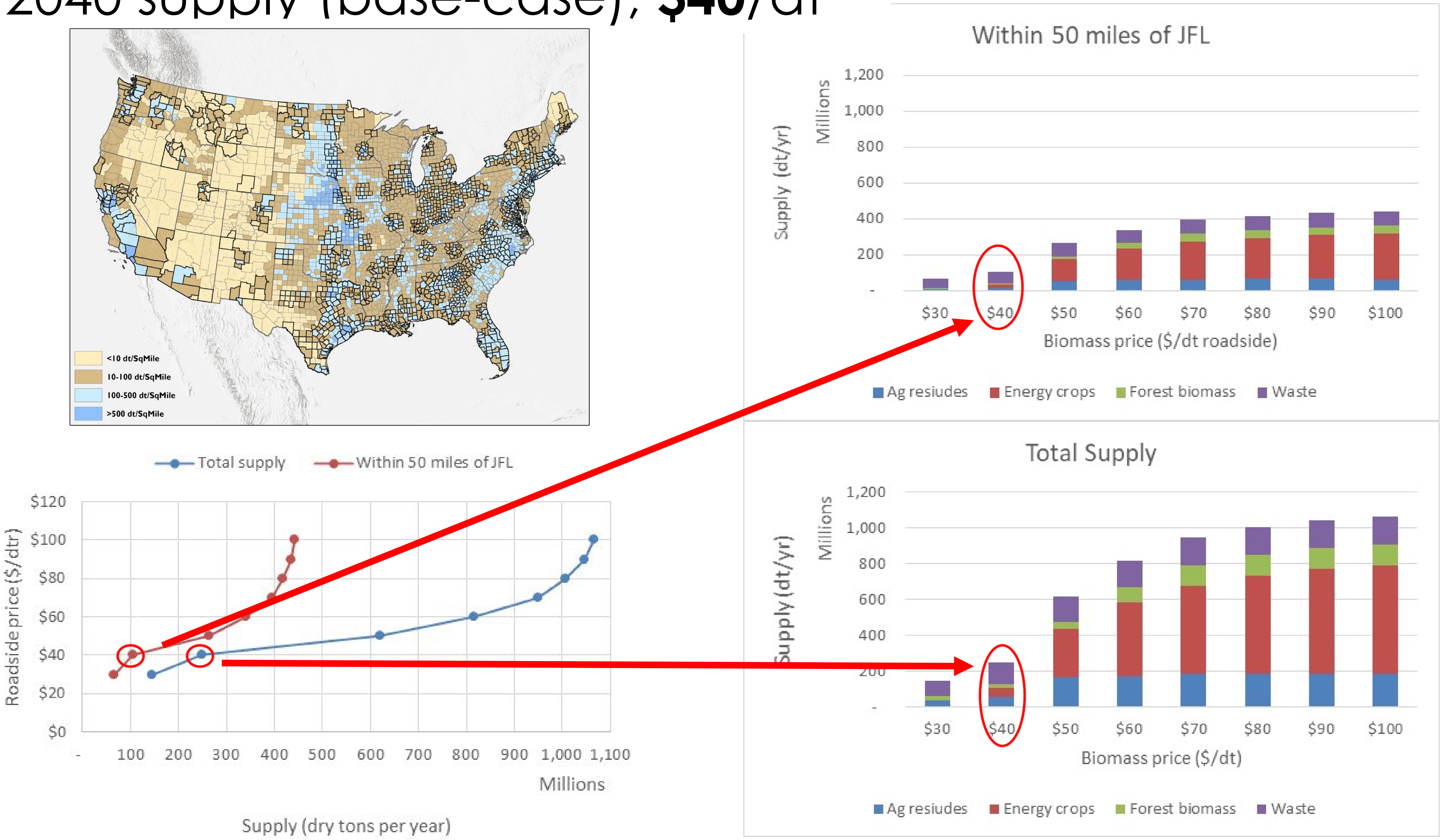




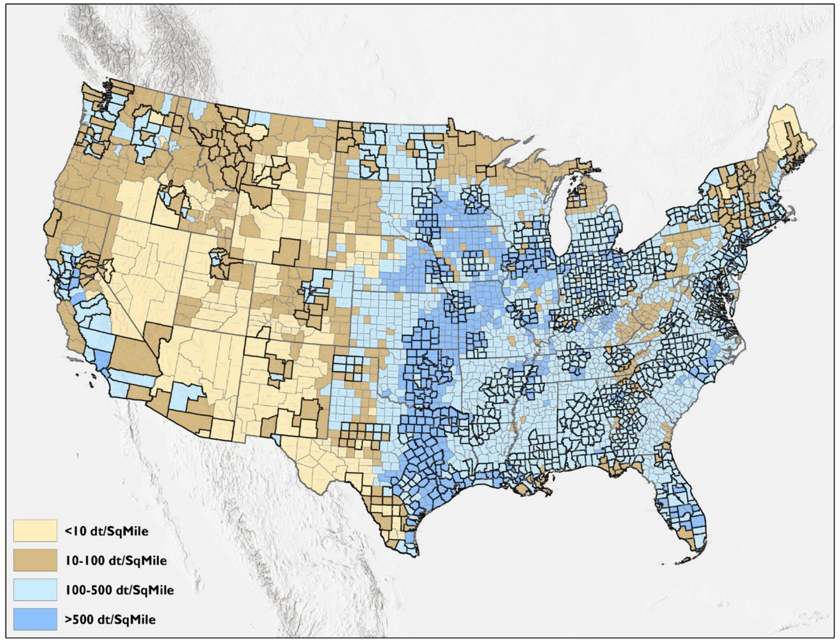


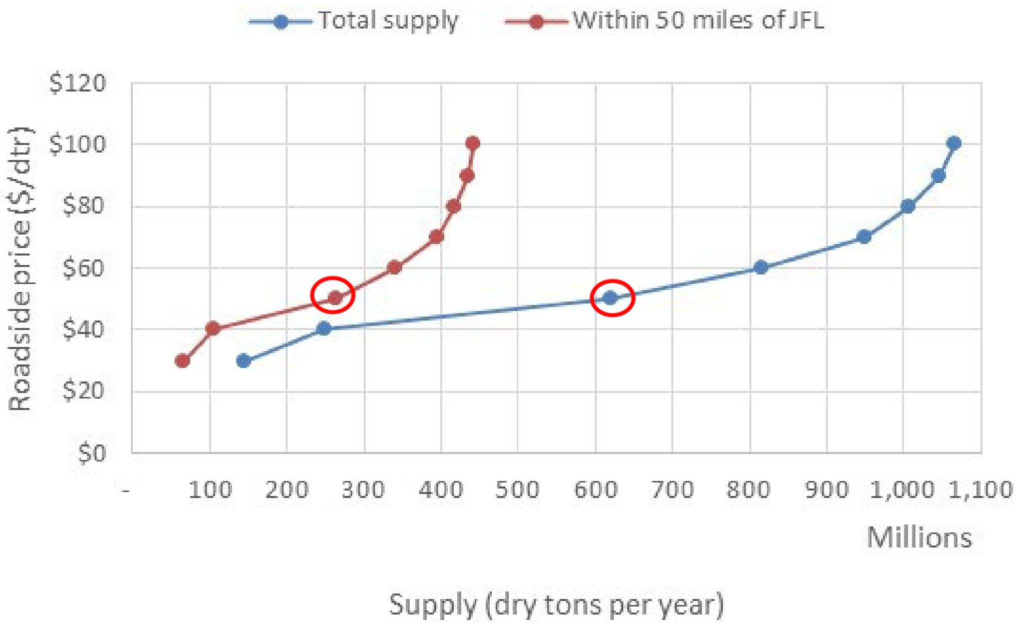


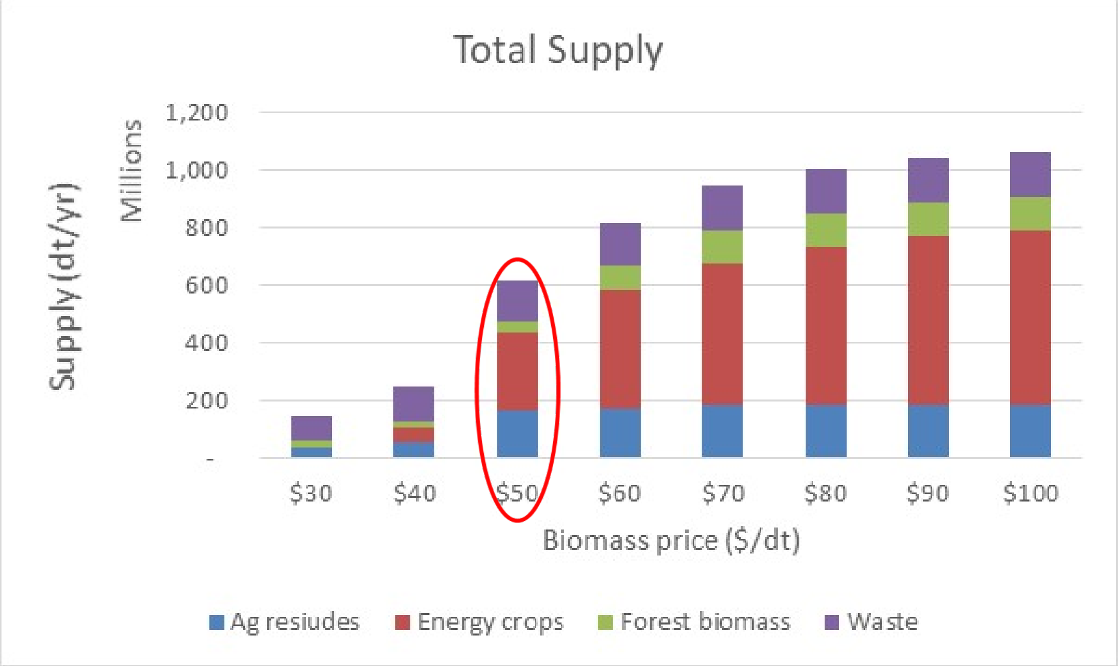
2040 supply (base-case), **$40**/dt



2040 supply (base-case), **$50**/dt







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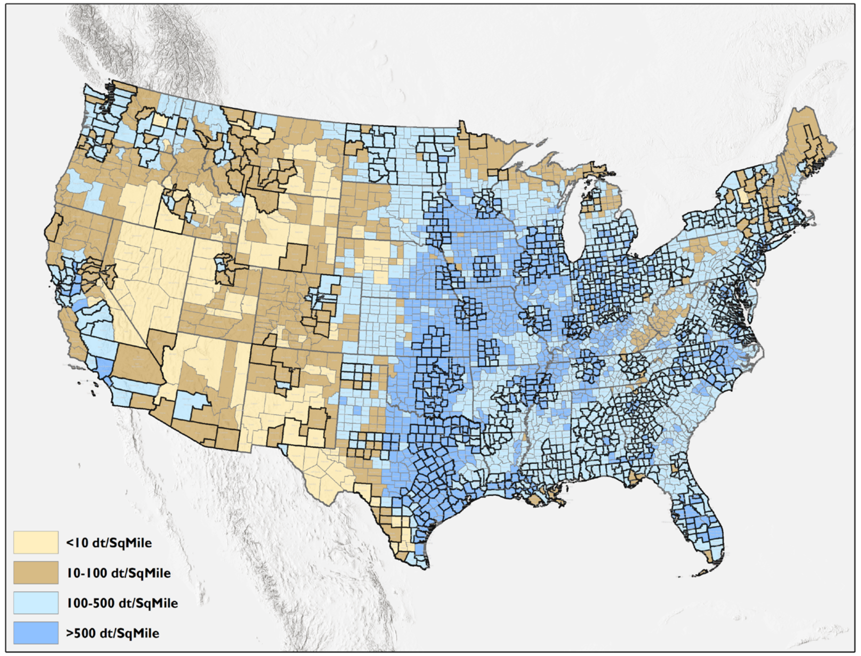
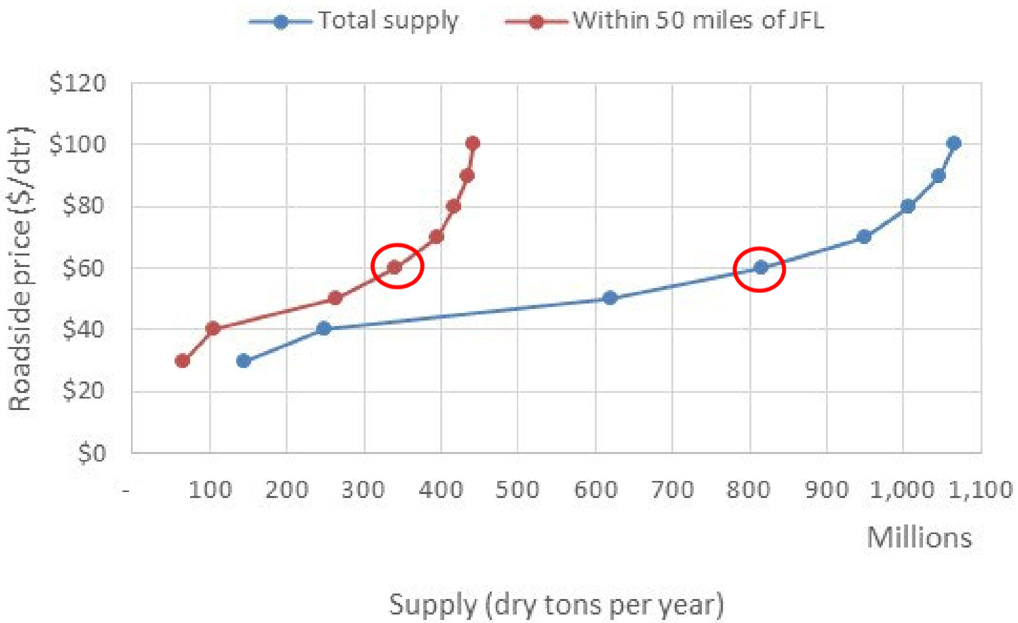
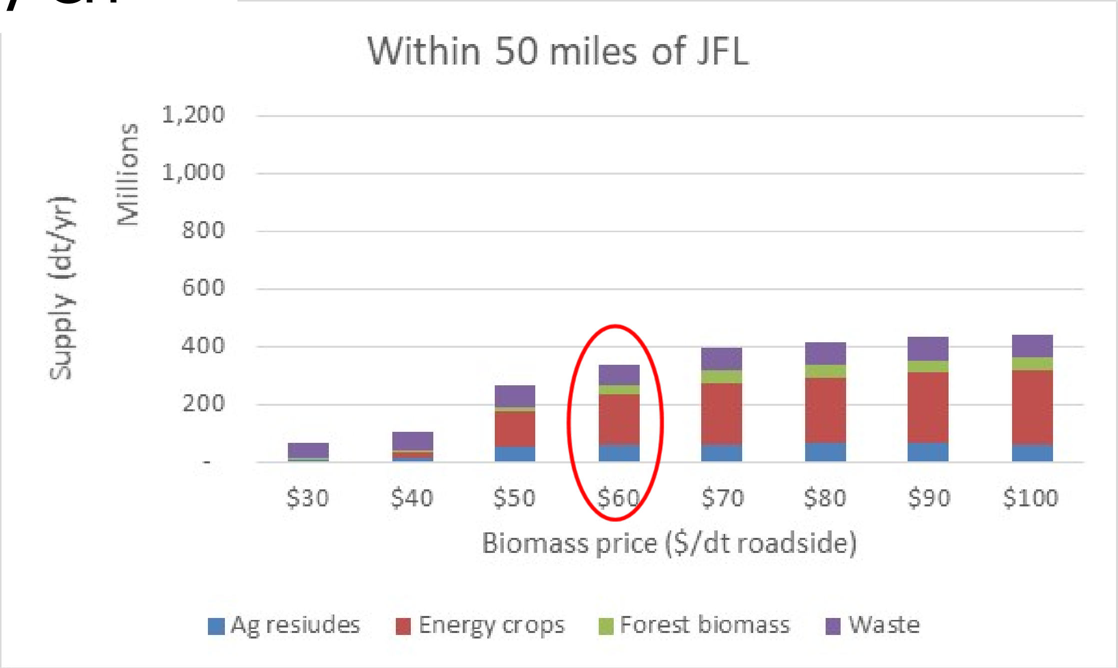
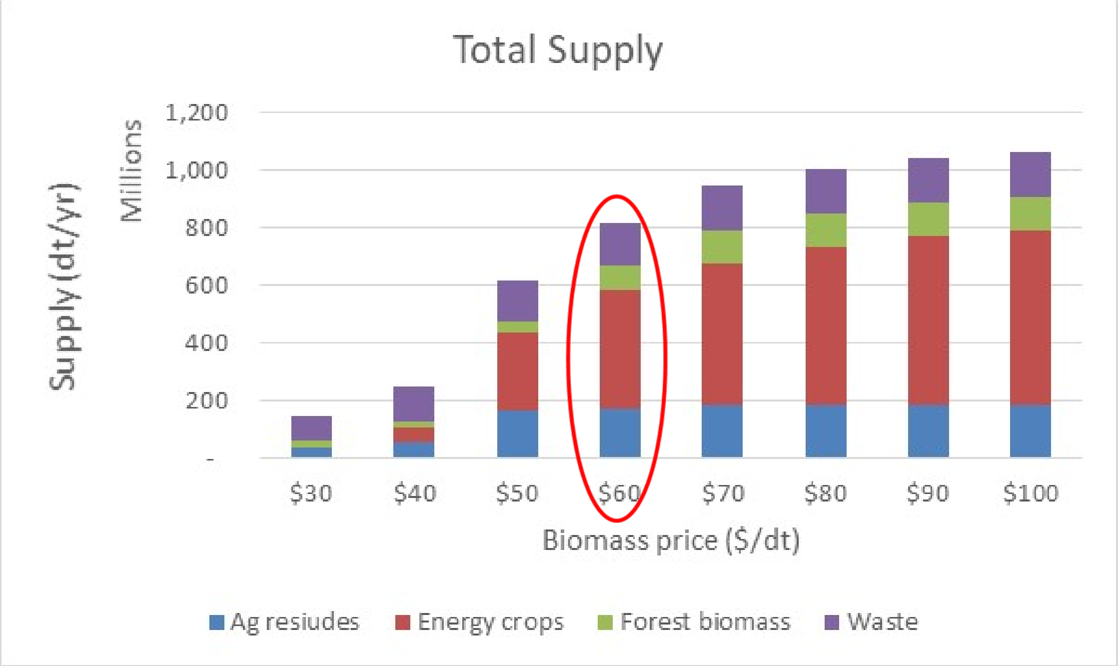
2040 supply (base-case), **$60**/dt









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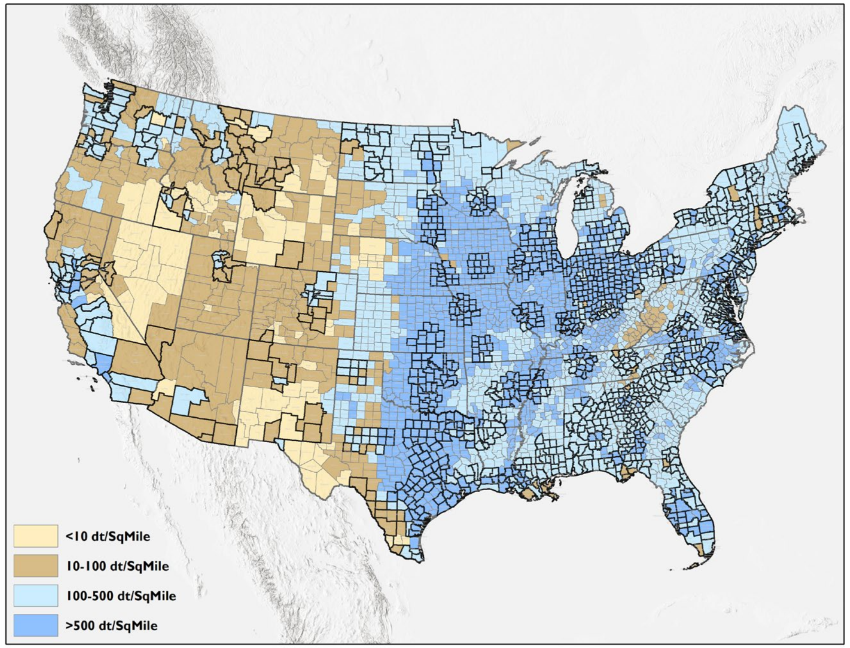
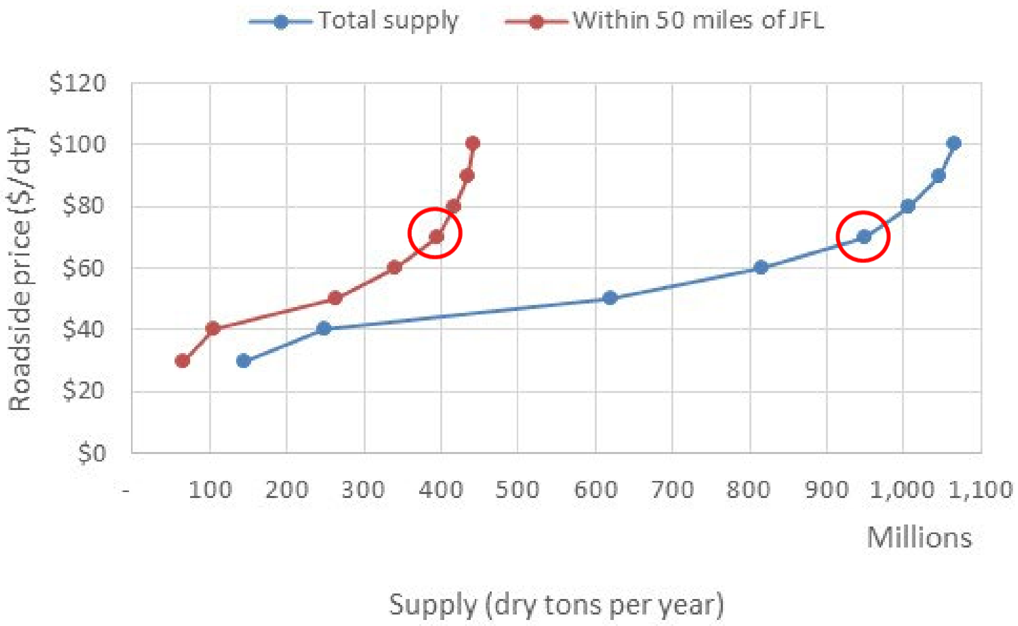
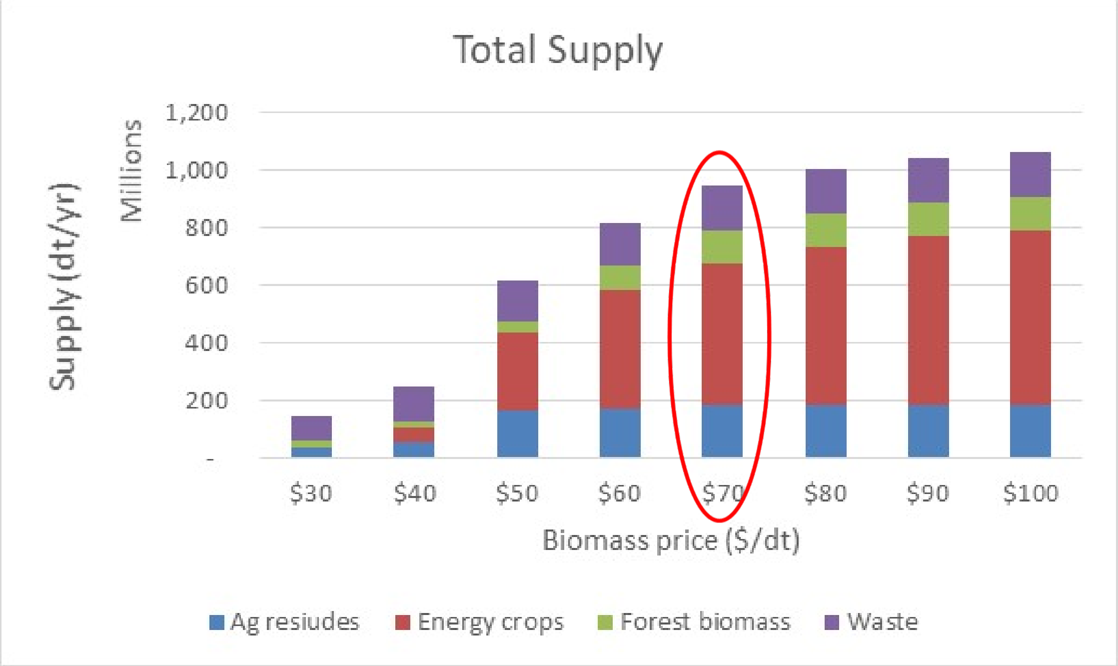
2040 supply (base-case), **$70**/dt







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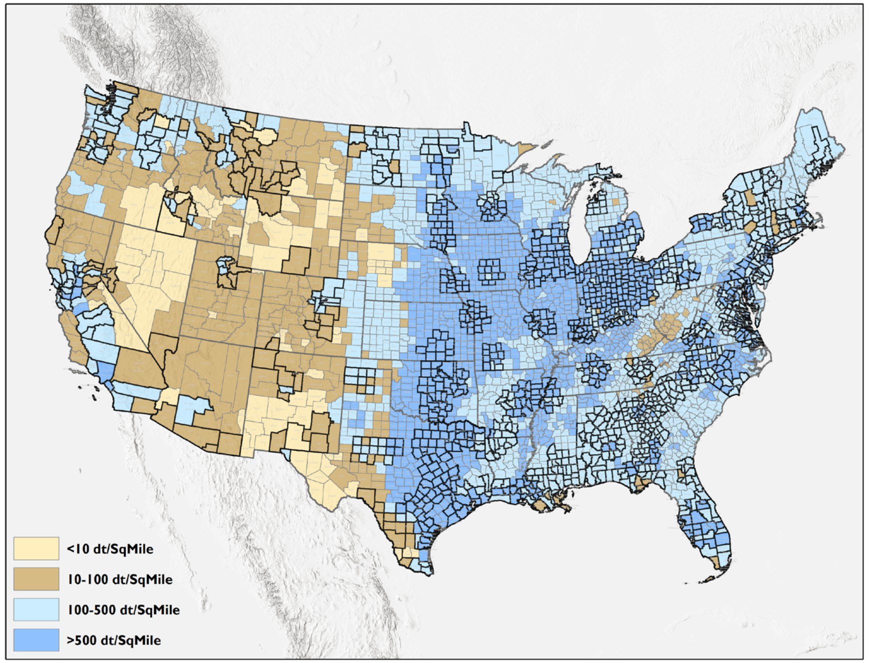
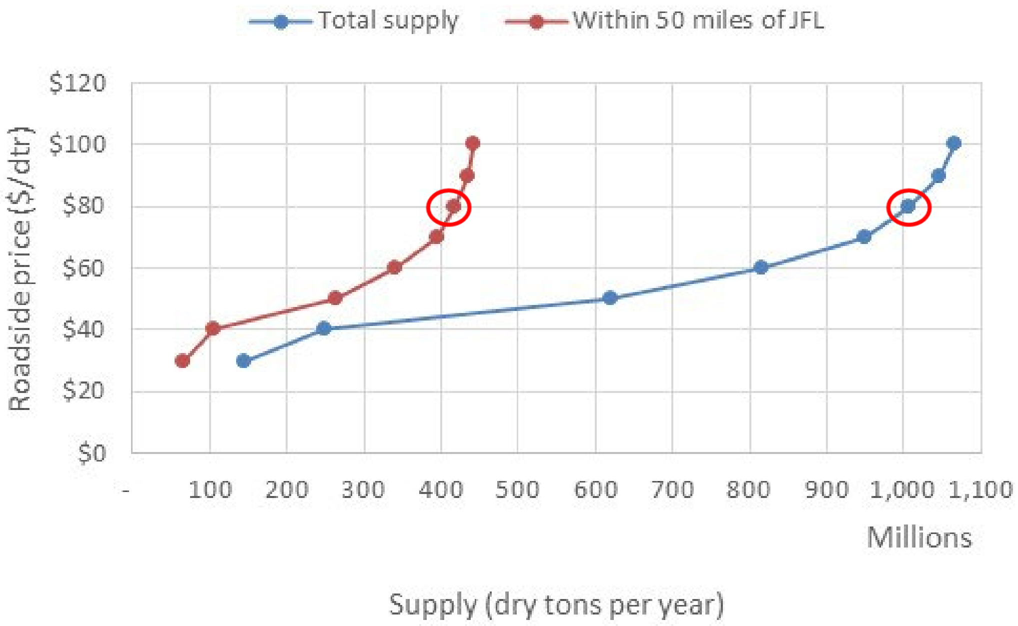
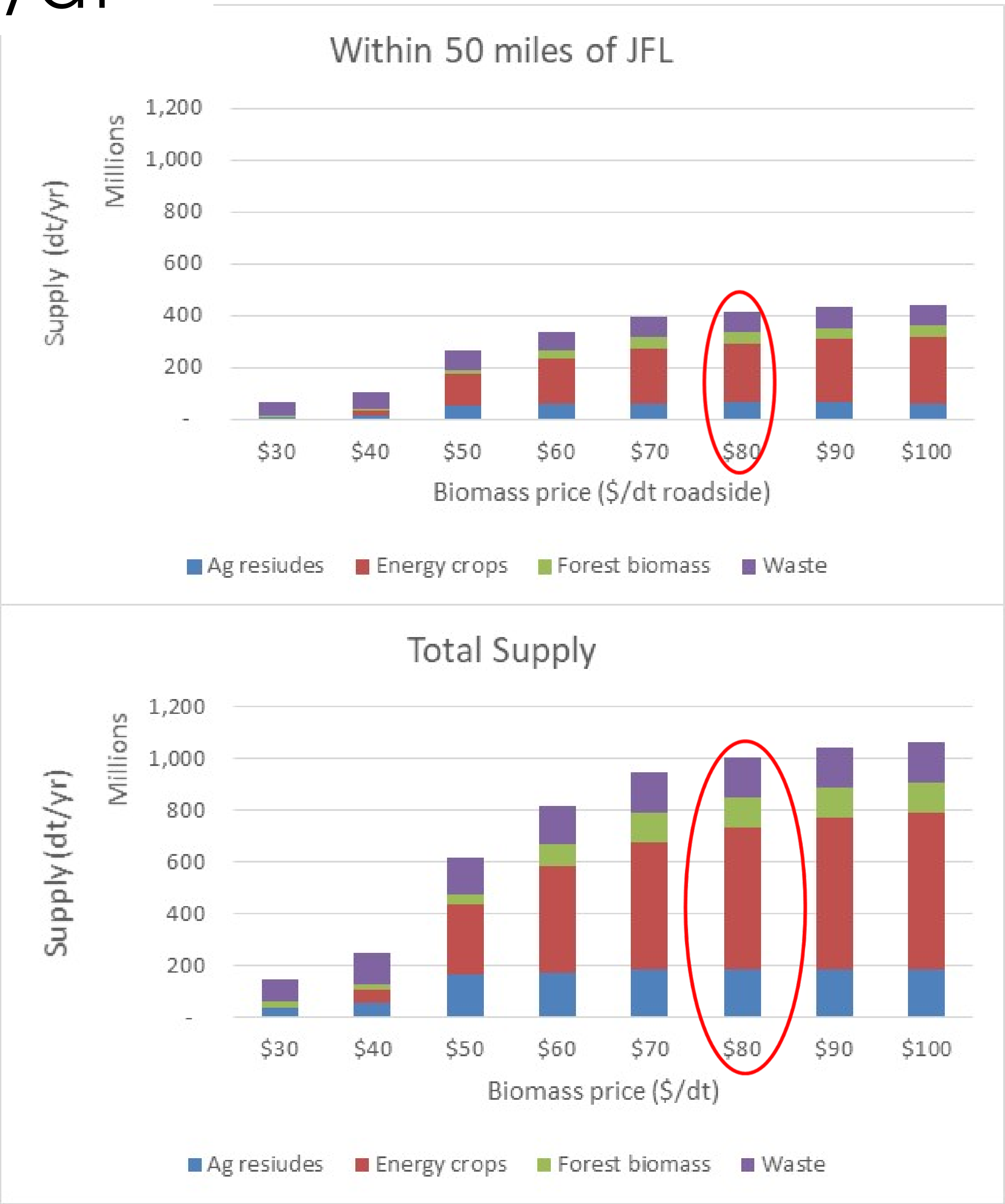
2040 supply (base-case), **$80**/dt







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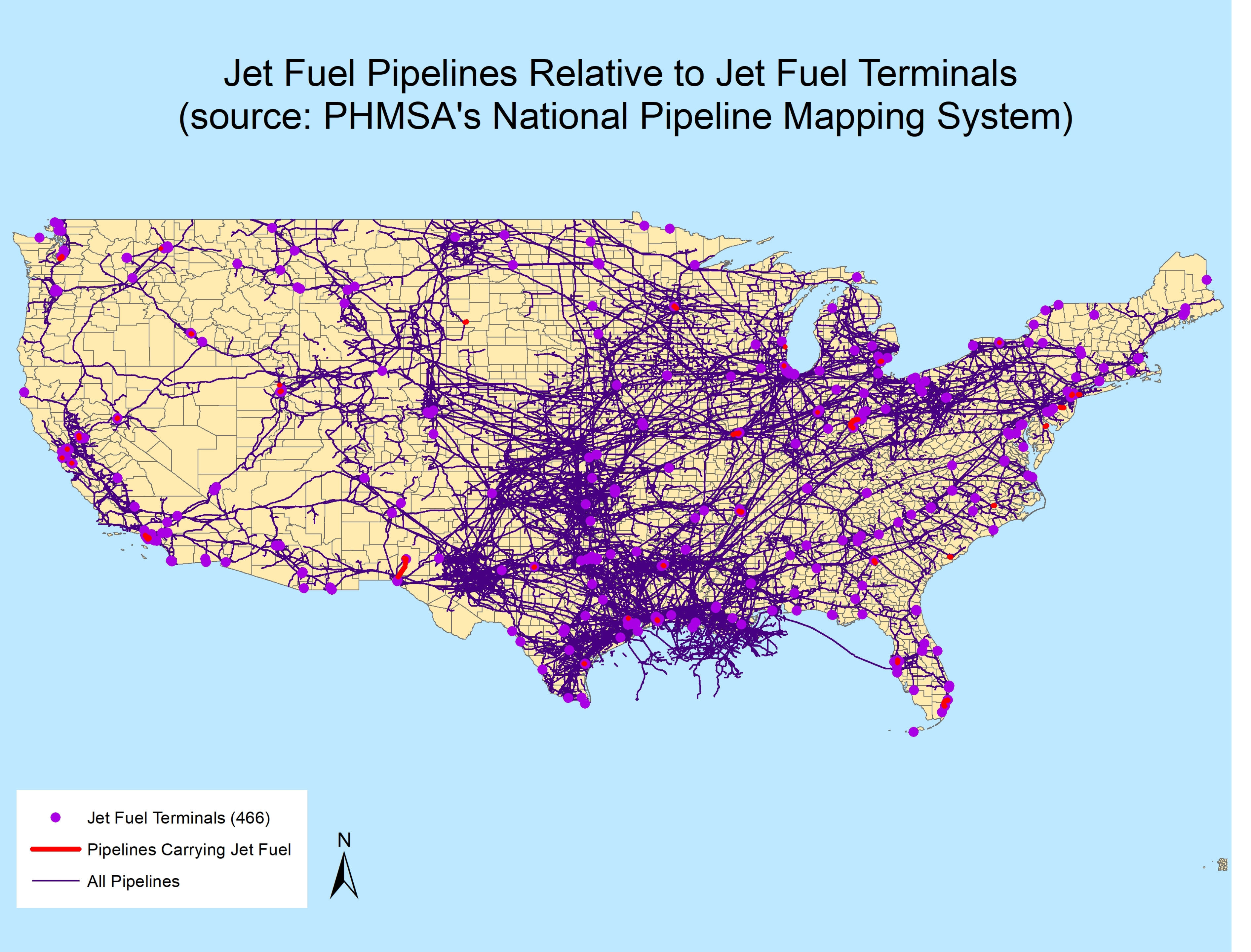


SAF logistical options (from Moriarty and Kvien 2021)

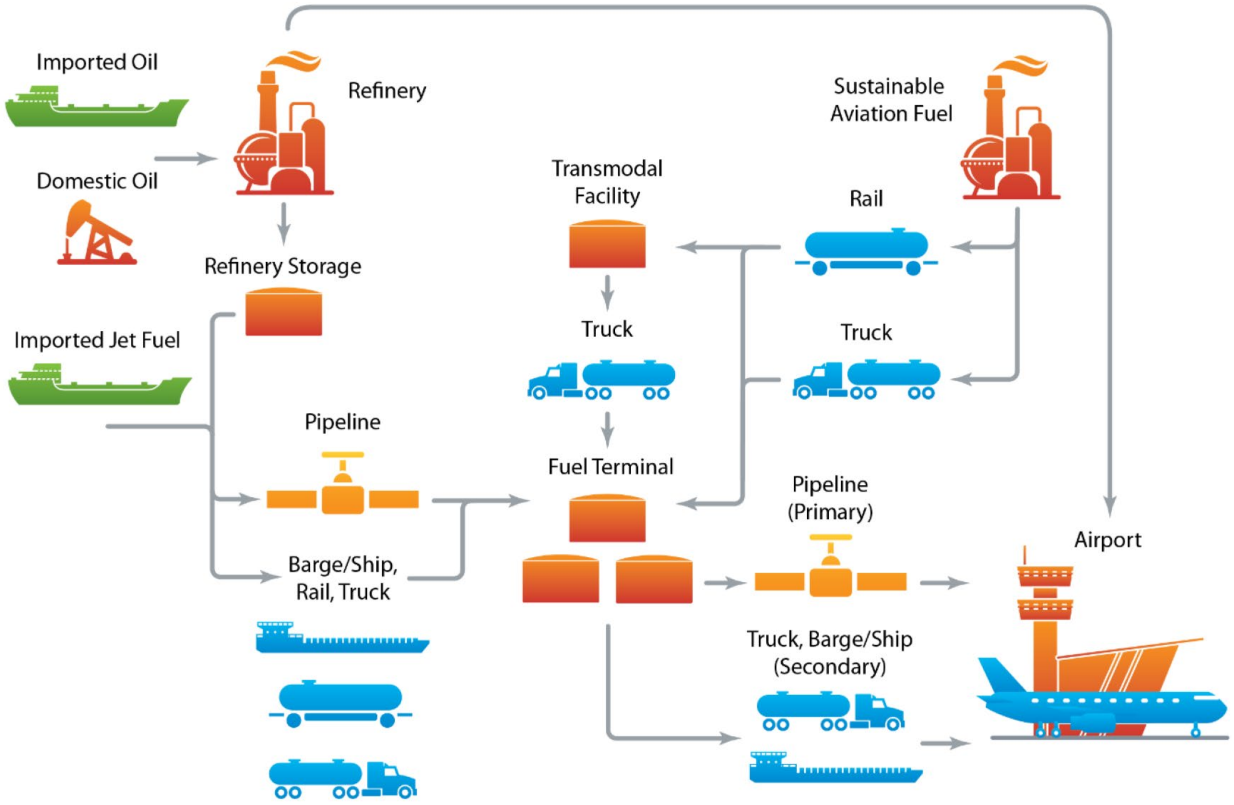


Figure 6. Fuel supply chain

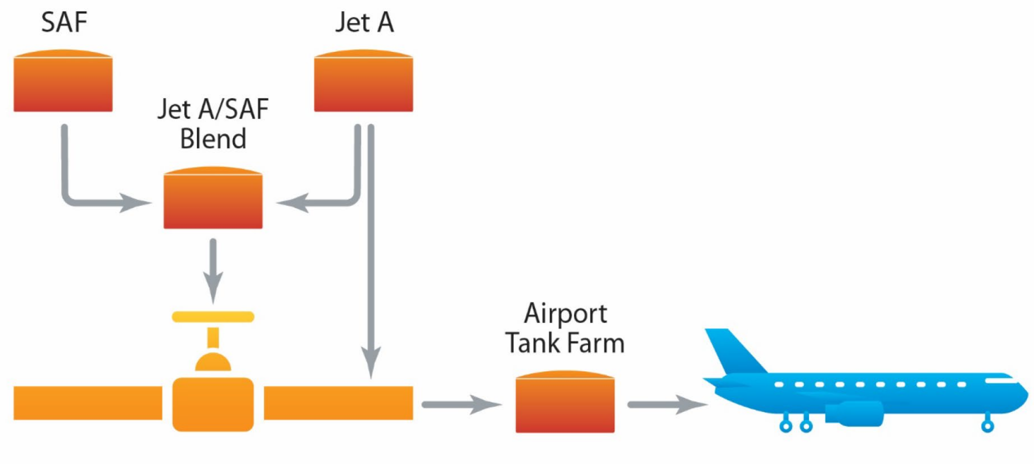


Figure 7. Option 1 Jet A and SAF blending at a terminal

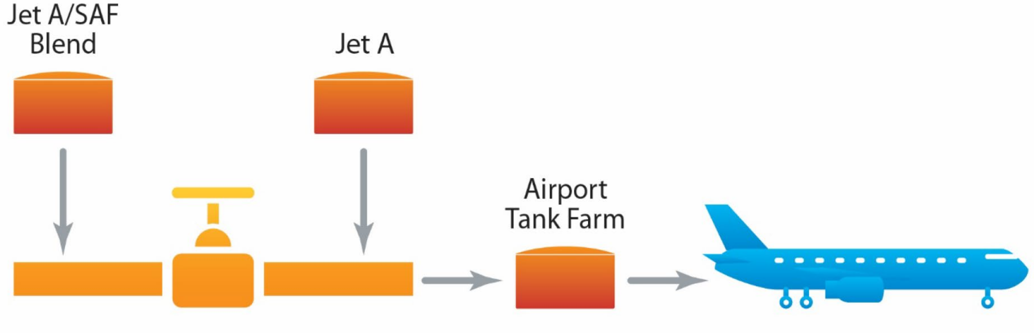
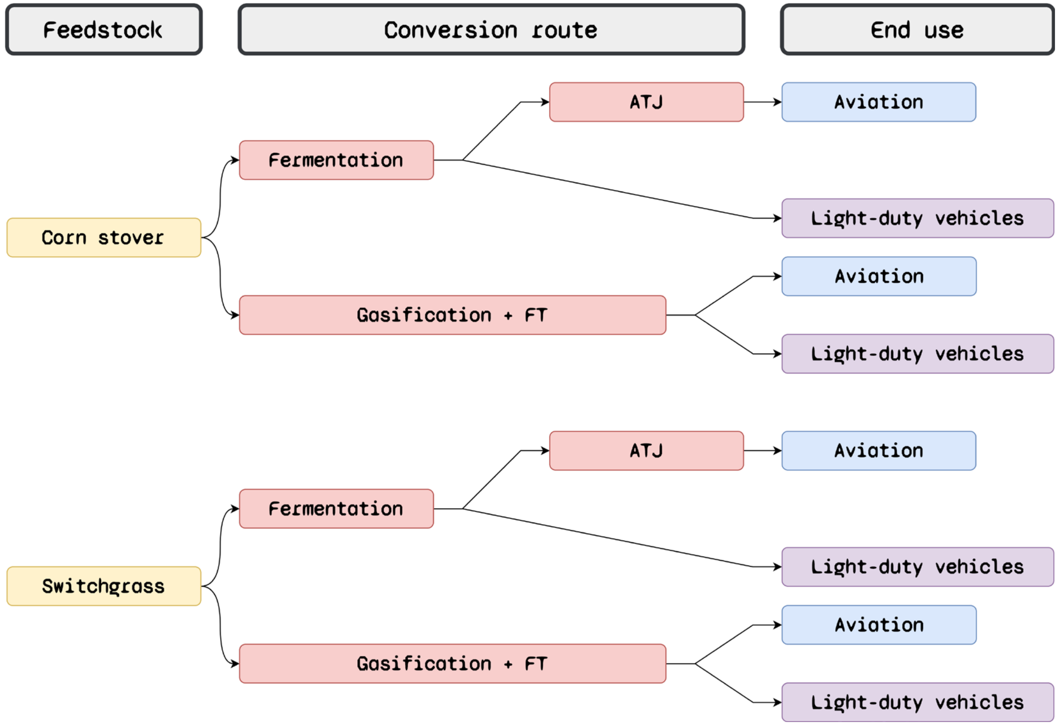


Figure 8. Option 2 Jet A and SAF blending at a terminal

Source:
U.S. Airport Infrastructure and Sustainable Aviation Fuel
Kristi Moriarty and Allison Kvien
National Renewable Energy Laboratory

Other BETO SAF at ORNL

- Alcohol-To-Jet (ATJ) through ChemCatBio
- Economic conditions/policies for aviation and marine
- Oilseed crops for SAF
  - Cover crops: no land pressure, but low yield
  - Summer oilseed crops: land pressure but high yield
- Carbon avoidance cost curves
  - Soil organic carbon and above-ground carbon incentives
  - Rail, barge, and multi-modal logistics



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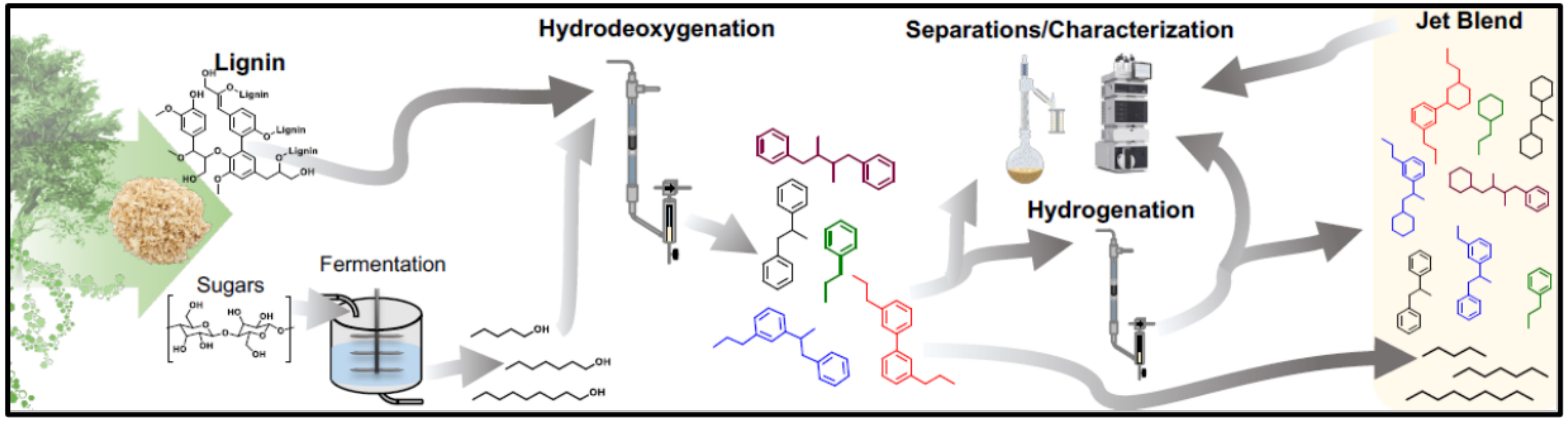
Center for Bioenergy Innovation's Vision

THE CENTER FOR BIOENERGY INNOVATION

To accelerate domestication of bioenergy-relevant non-model plants and microbes to enable high-impact innovation across the bioenergy supply chain

CBI has three new hydrocarbon projects that utilize lignin and the carbohydrates found in biomass, to produce SAF

1. Catalytic Upgrading of Alcohols: Mechanisms to improve hydrocarbon distribution from ethanol
2. Catalytic upgrading of n-butanol to synthetic jet
3. Depolymerized lignin to jet fuel via catalytic upgrading



CBI: Multi-institutional, inter-disciplinary center

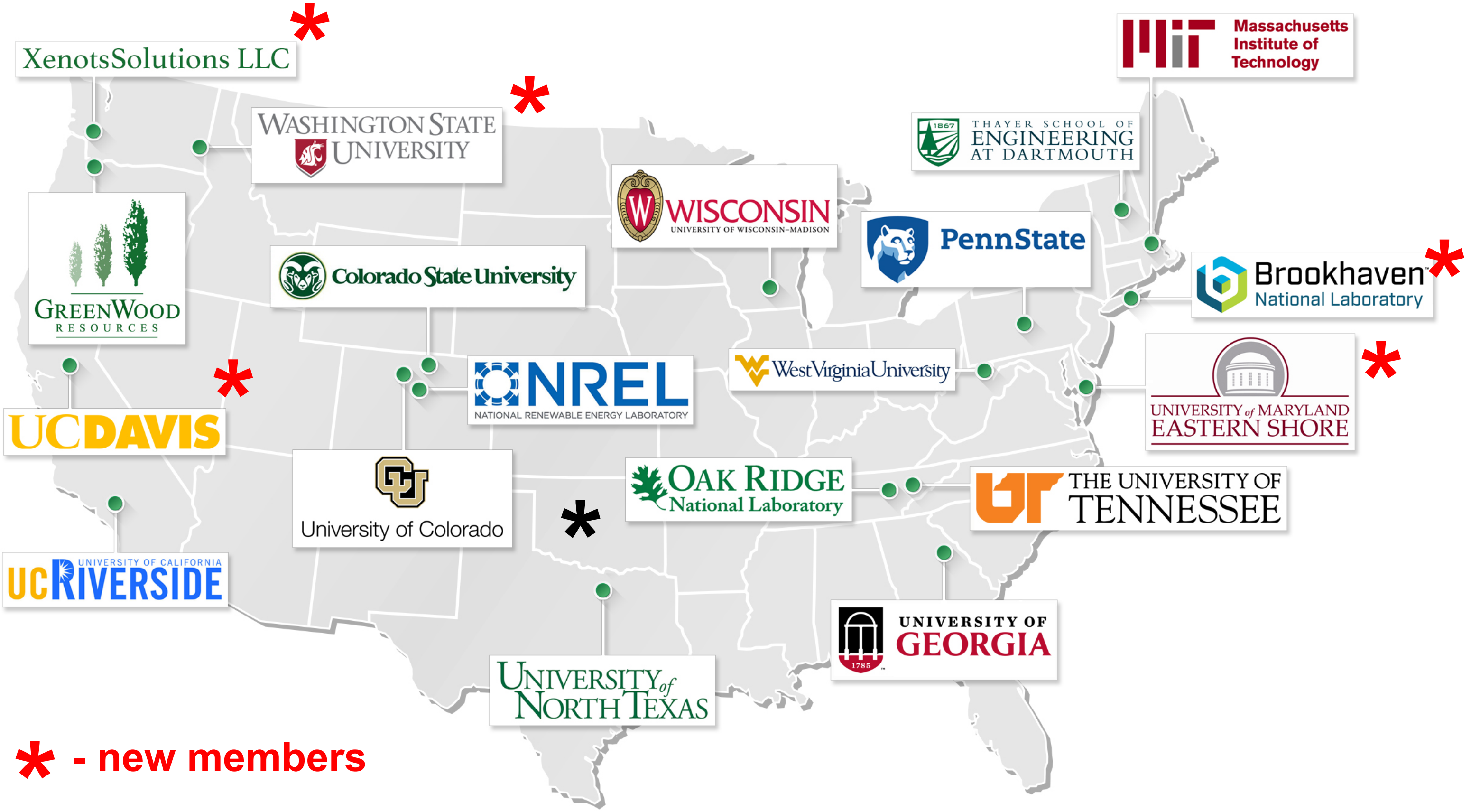
THE CENTER FOR BIOENERGY INNOVATION

CBI research partners:

- 3 national laboratories
- 14 academic institutions
  - -- including 1 HBCU
- 1 private company

CBI has world-leading expertise in:

- Genome-scale synthetic biology
- Metabolic modeling
- Advanced heterogeneous catalyst design
- Anaerobic communities
- Lignin valorization
- Technoeconomic analyses
- Plant genomics
- Cell wall biosynthesis
- Biomass deconstruction/conversion



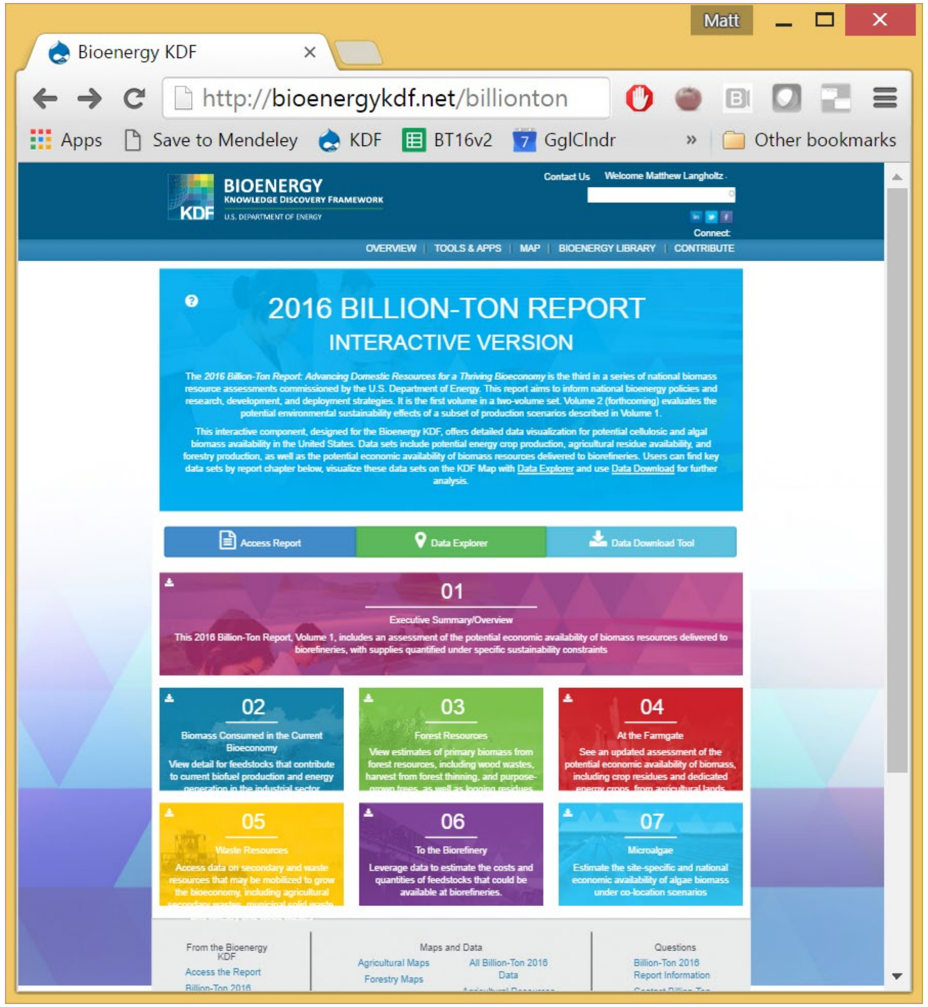
*** - new members**

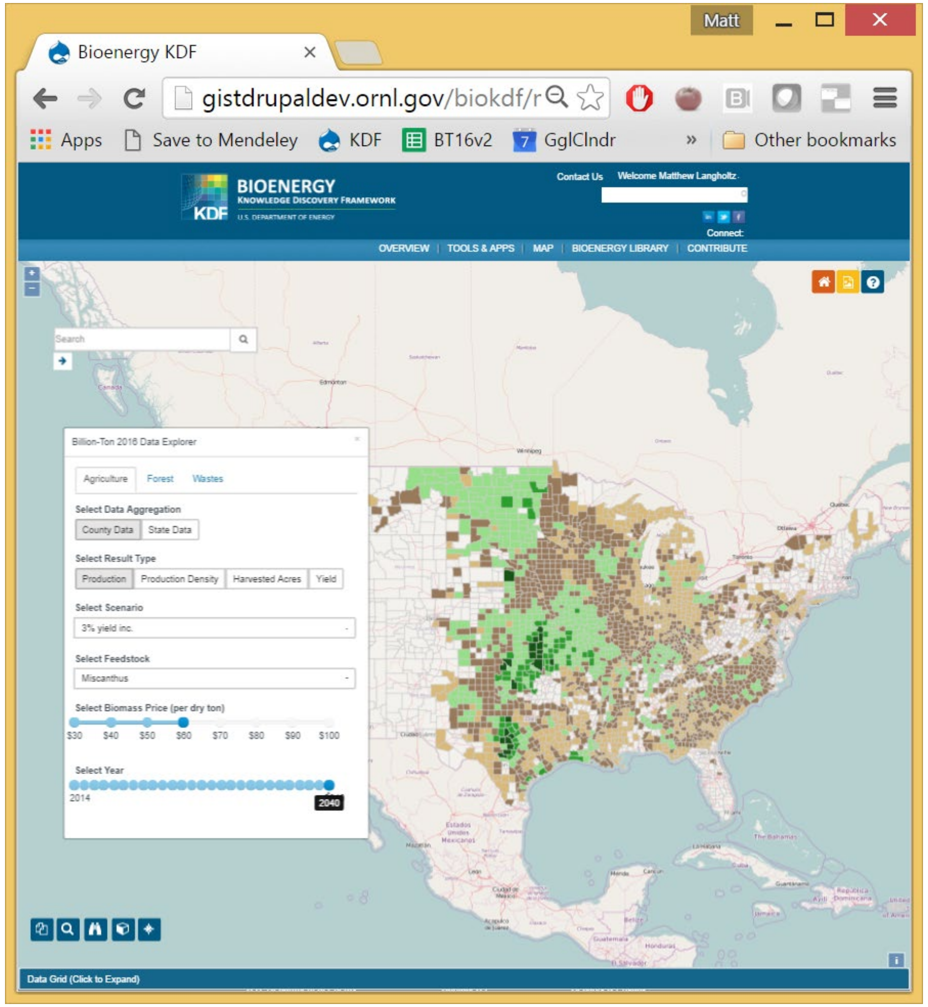
*** - Noble Research Institution closed their plant sciences division**

Thank you!

Matt Langholtz
langholtzmh@ornl.gov

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





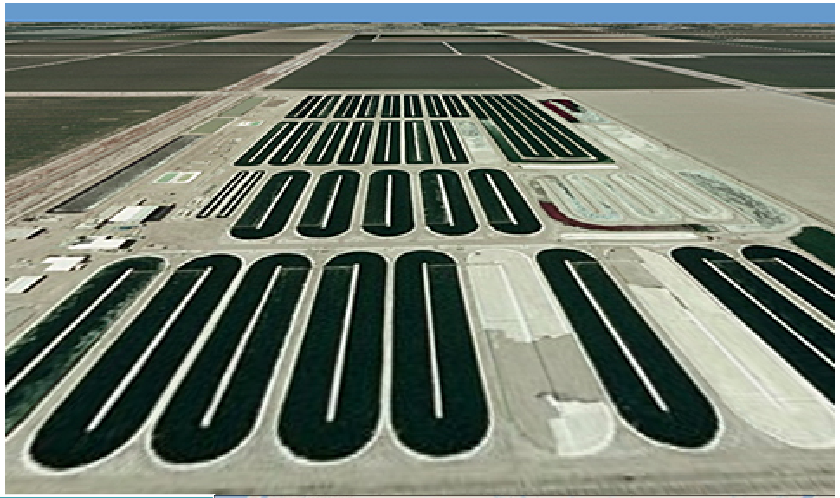
References

- https://bioenergykdf.net/2016-billion-ton-report
- https://www.energy.gov/sites/prod/files/2016/07/f33/regional_feedstock_partnership_summary_report.pdf
- U.S. Airport Infrastructure and Sustainable Aviation Fuel, Kristi Moriarty, Allison Kvien. https://afdc.energy.gov/files/u/publication/U.S.-airport-infrastructure-and-sustainable-aviation-fuel.pdf
- https://github.com/VolpeUSDOT/FTOT-public

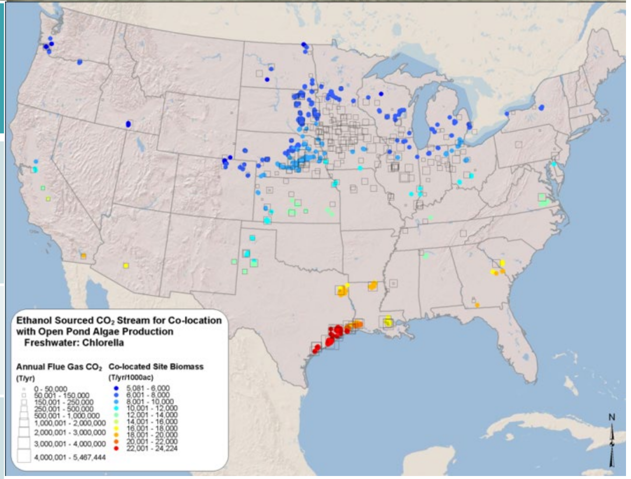
Back slides

Microalgae Resources Analysis

- Co-location near CO2 facilities
- Freshwater and saline culture
- Open ponds/raceways
- Lined and unlined ponds



Scenario	Ethanol plant	Coal EGU	Natural gas EGU	Million tons	Prices per dry ton
Present productivities, freshwater	12	19	15	<46	\$719–\$2,030
Present productivities, saline	10	54	21	<86	\$755–\$2,889
Future productivities, freshwater	13	10	0	<23	\$490–\$1,327
Future productivities, saline	11	12	0	<24	\$540–\$2,074



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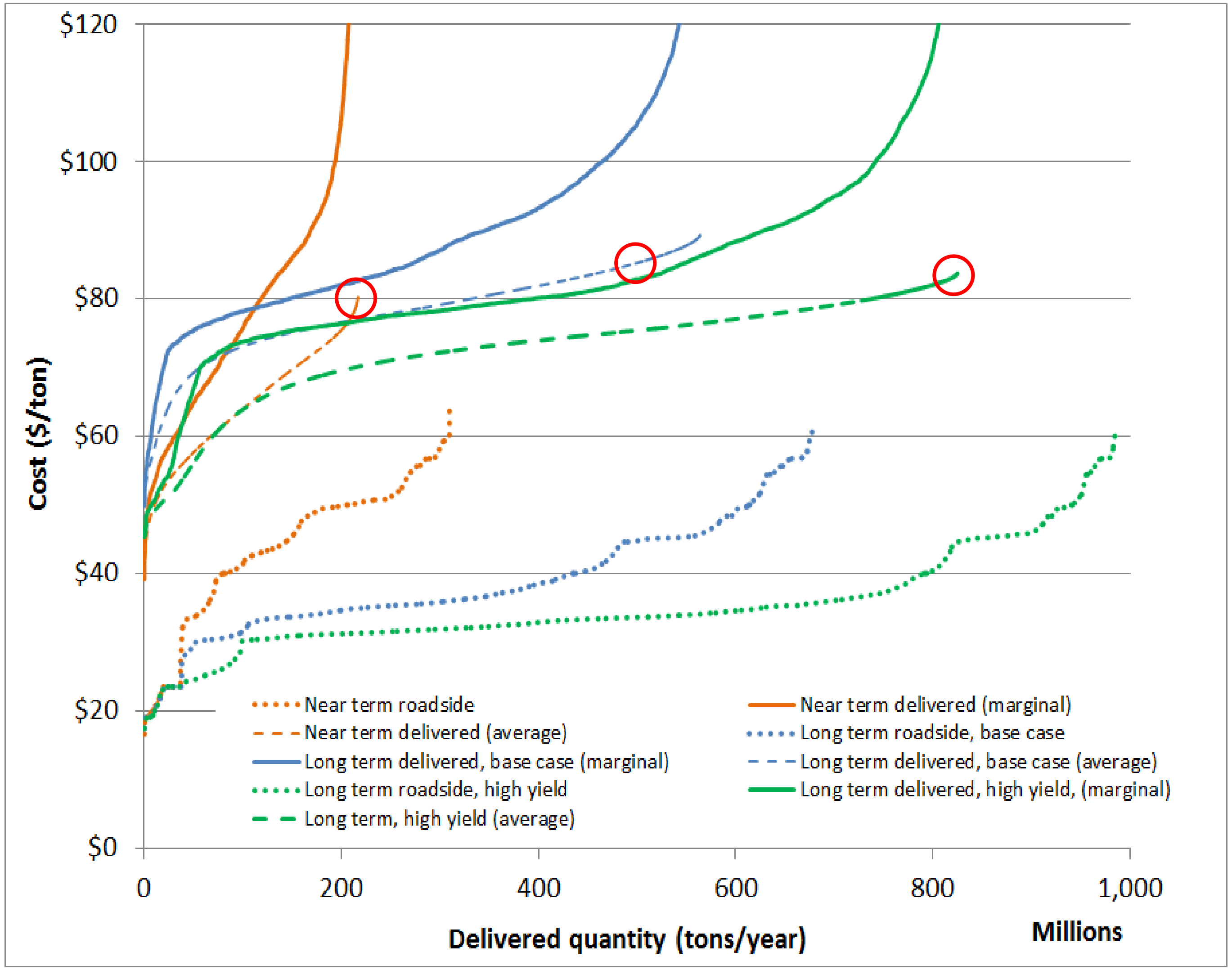
Delivered Scenario Analysis



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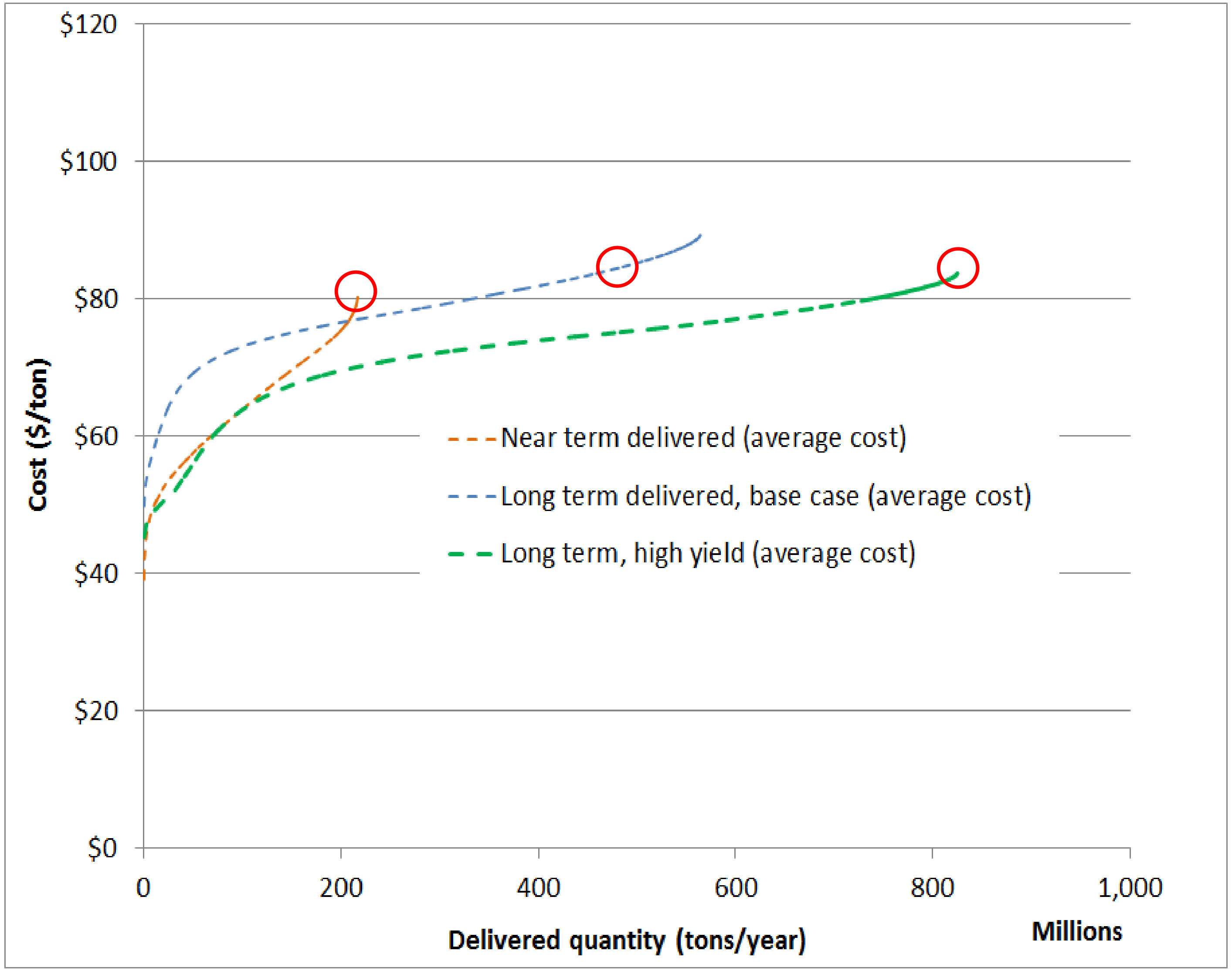
Delivered Scenario Analysis



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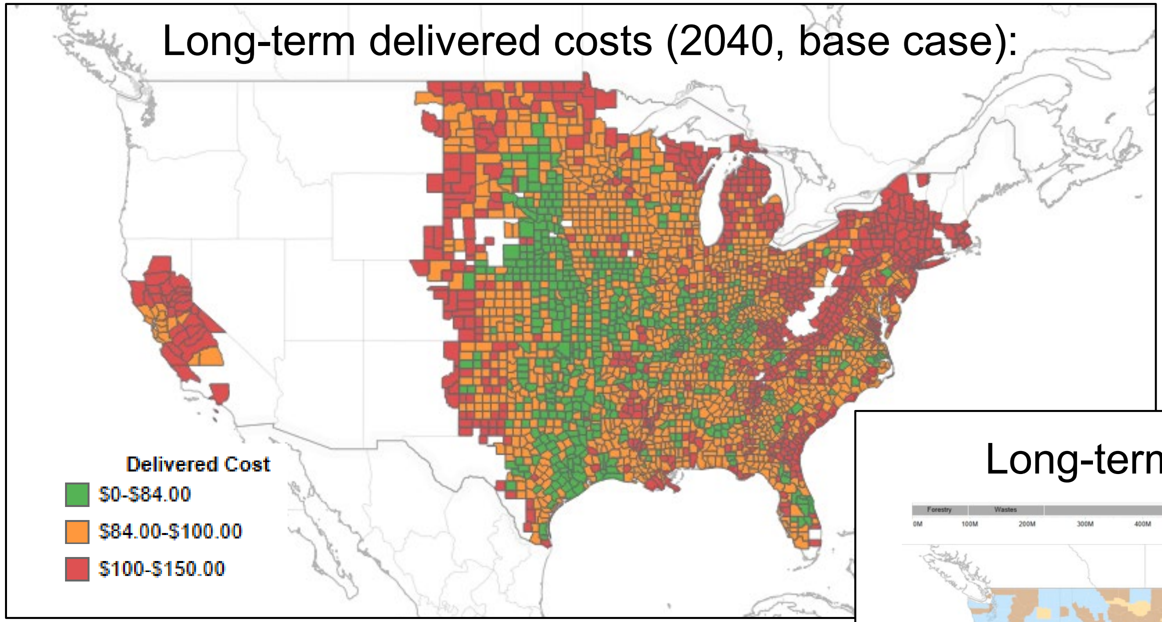
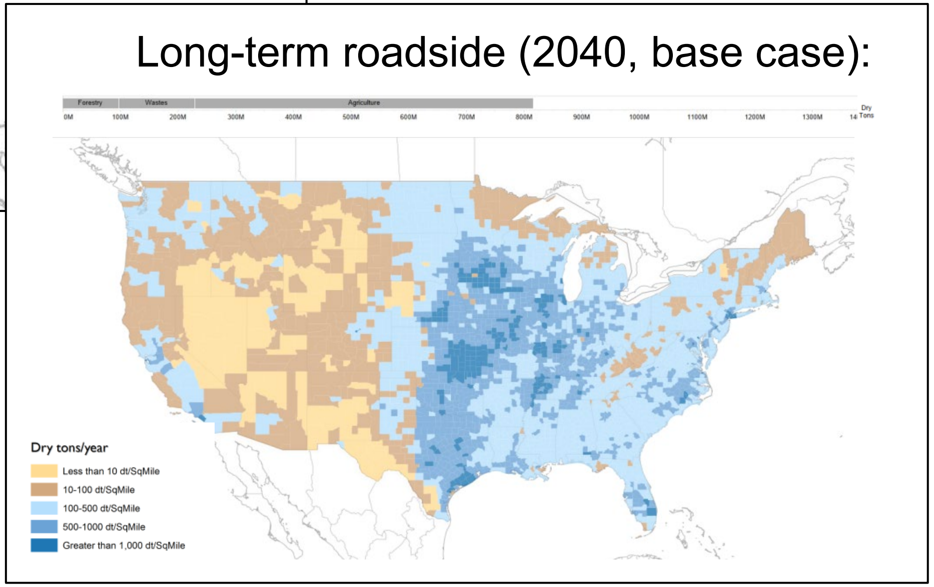
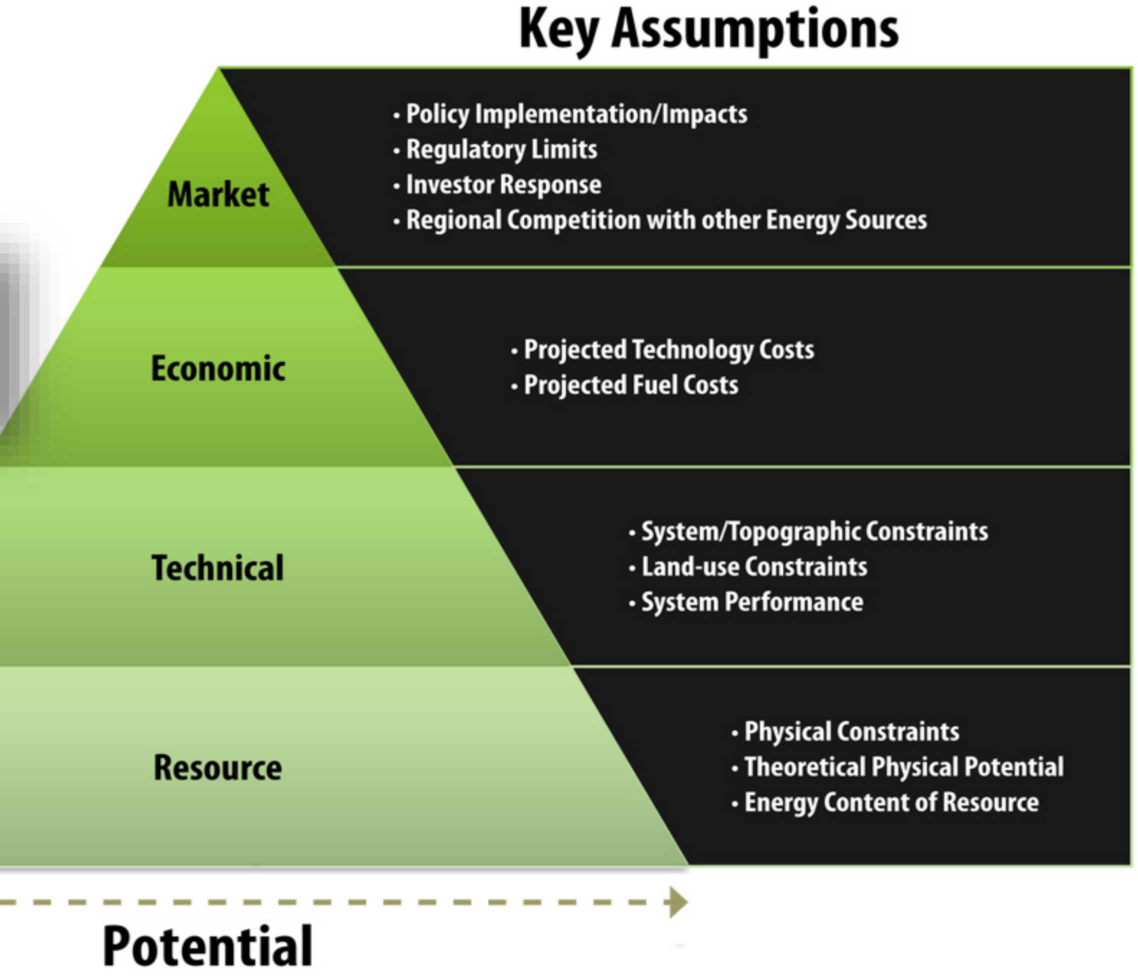
Delivered Cost by County, Base Case, 2040





https://bioenergykdf.net/billionton2016/6/2/tableau

Advancing Resources



Adapted from DOE-EERE (2006) and NREL (2011). See also Batidzirai, Smeets, and Faaij (2012)

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