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

A Summary of the Results of the *2016 Billion-Ton Report: Advancing Domestic Resources for a Thriving Bioeconomy, Vol. 1*

July 21, 2016

Oak Ridge National Laboratory

Dr. Mark Elless
U.S. Department of Energy

Dr. Matthew Langholtz
Mr. Laurence Eaton
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Oak Ridge National Laboratory

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Allegheny Science and Technology – Contractor to the U.S. Department of Energy

Agenda

I. Introduction: Bioenergy Technologies Office Mission and Organization
   - Mark Elless, Bioenergy Technologies Office

II. History of *Billion-Ton* Reports
   - Bryce Stokes, Bioenergy Technologies Office

III. *2016 Billion-Ton Report* Results
   - Laurence Eaton, Oak Ridge National Laboratory
   - Matt Langholtz, Oak Ridge National Laboratory

IV. Bioenergy KDF
   - Aaron Myers, Oak Ridge National Laboratory

V. Conclusion

Questions and Comments

Please record any questions and comments you may have during the webinar and send them in using the webinar chat function, or to eere_bioenergy@ee.doe.gov

As a follow-up to the webinar, the presenter(s) will provide responses to selected questions.

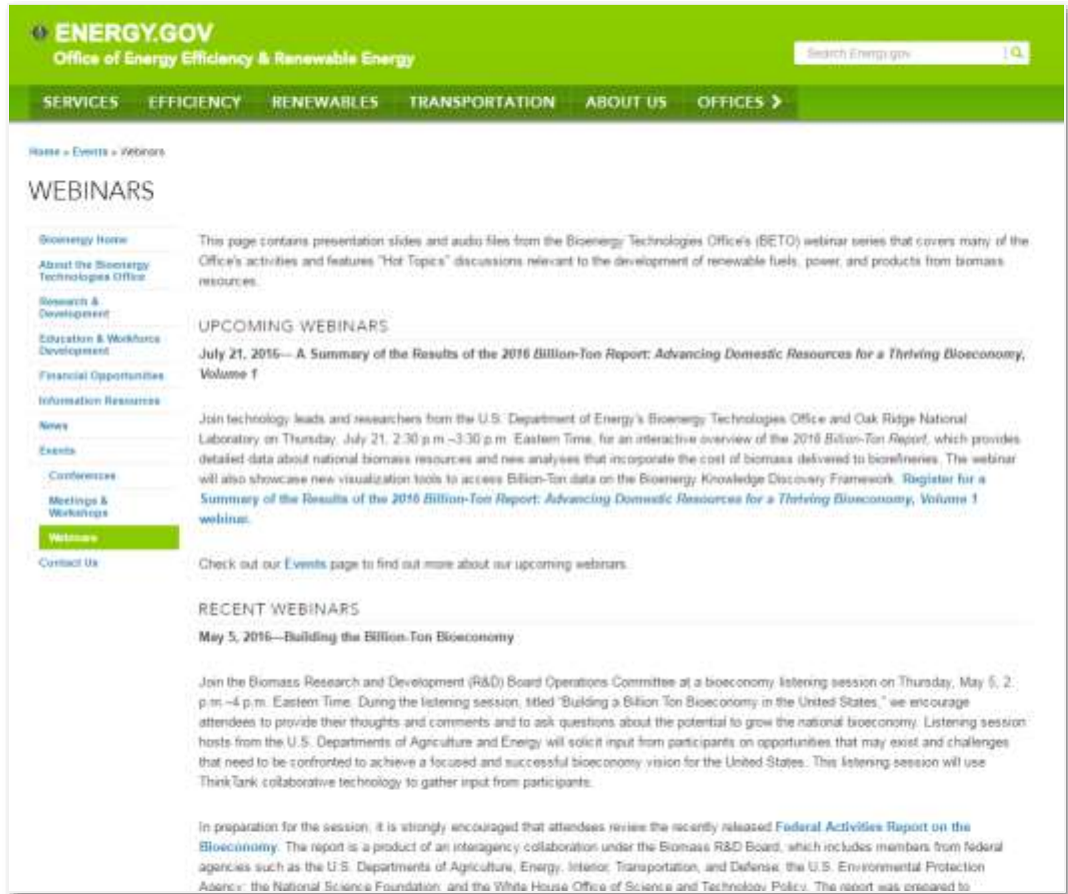
Slides from this presentation will be posted online: http://www.energy.gov/eere/bioenergy/webinars

For general questions regarding the Bioenergy Technologies Office, please email eere_bioenergy@ee.doe.gov

Bioenergy Technologies Office Webinar Series

Started in May 2010 to highlight “hot topics” in biomass and bioenergy industry.

Find past webinars and today’s slides on the Office’s website: http://www.energy.gov/eere/bioenergy/webinars



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Bioenergy Technologies Office

MISSION: Developing and demonstrating transformative and revolutionary bioenergy technologies for a sustainable nation.

Feedstock Supply & Logistics
-Resource assessment; supply analysis
- R&D on Feedstock characterization, handling, and logistics

Advanced Algal Systems
- Competitive projects to increase yields/ productivity/reduce costs
- Targeted R&D along the algal supply chain.

Conversion
- Thermochemical
- Biochemical
- Deconstruction
- Upgrading

Demonstration and Market Transformation
-IBR partnerships
-Infrastructure

Analysis and Sustainability

-Develop and improve critical models and tools : (GREET, BSM, WATER)

Impacts: More than 1 billion tons of biomass could be sustainably produced in the U.S. without impacting markets for food and feed. By 2030, 1 billion tons of biomass could:

- Produce up to 60 billion gallons of biofuels, displacing 30% of U.S. petroleum consumption
- Produce 50 billion pounds of biobased chemicals and bioproducts, replacing a significant portion of the chemical market
- Generate 92 billion kWh of electricity to power 8 million households
- Provide reductions of CO_2 emissions by 500 million tons a year

White House Climate Action Plan
- **Reduce Oil Imports 50% by 2020**
- **Reduce GHG emissions at least 26% by 2025**

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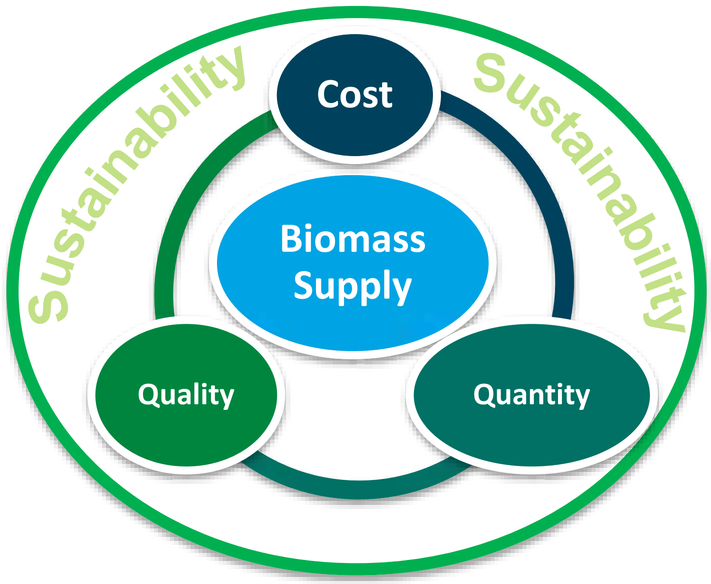
Feedstock Supply and Logistics

Focus

- Fully integrate feedstocks into supply chain (multiple interfaces).
- Reform raw biomass into high-quality feedstocks.
- Use innovative technologies to ensure sustainable supply and reduce costs.
- Reduce risks to enable industry expansion.

Approaches

- Use basic and applied science to understand, model, and manage.
- Provide nationally, but solve locally.
- Meet environmental performance targets and goals while assuring sustainability.
- Work with stakeholders and partners.



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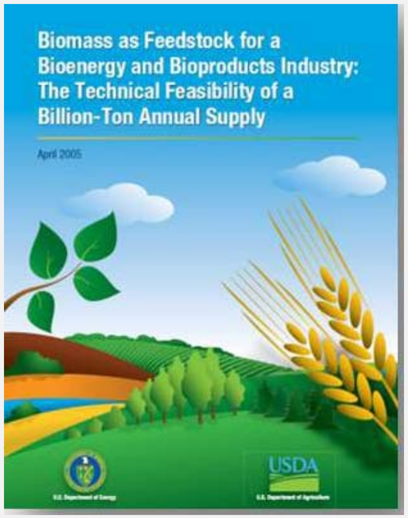
Billion-Ton History

2005



Resource assessment

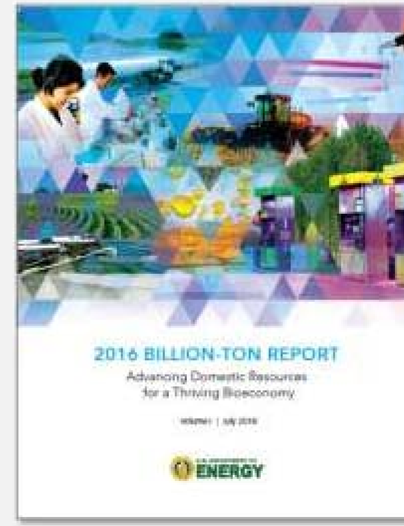
- How much biomass is available in the U.S.?
- Can we produce a sustainable supply of biomass that can displace 30% of the country's current petroleum consumption?

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

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Webinar Agenda

I. Currently Used Biomass
II. Volume 1 Overview
    A. Motivation
    B. Introduction
    C. Contributors
    D. Outline
III. Resource Assessment
    I. Forestry (roadside)
    II. Agricultural Resources (farmgate)
    III. Wastes (roadside)
    IV. Algae
IV. Delivered Costs
V. Quick Update: Volume 2

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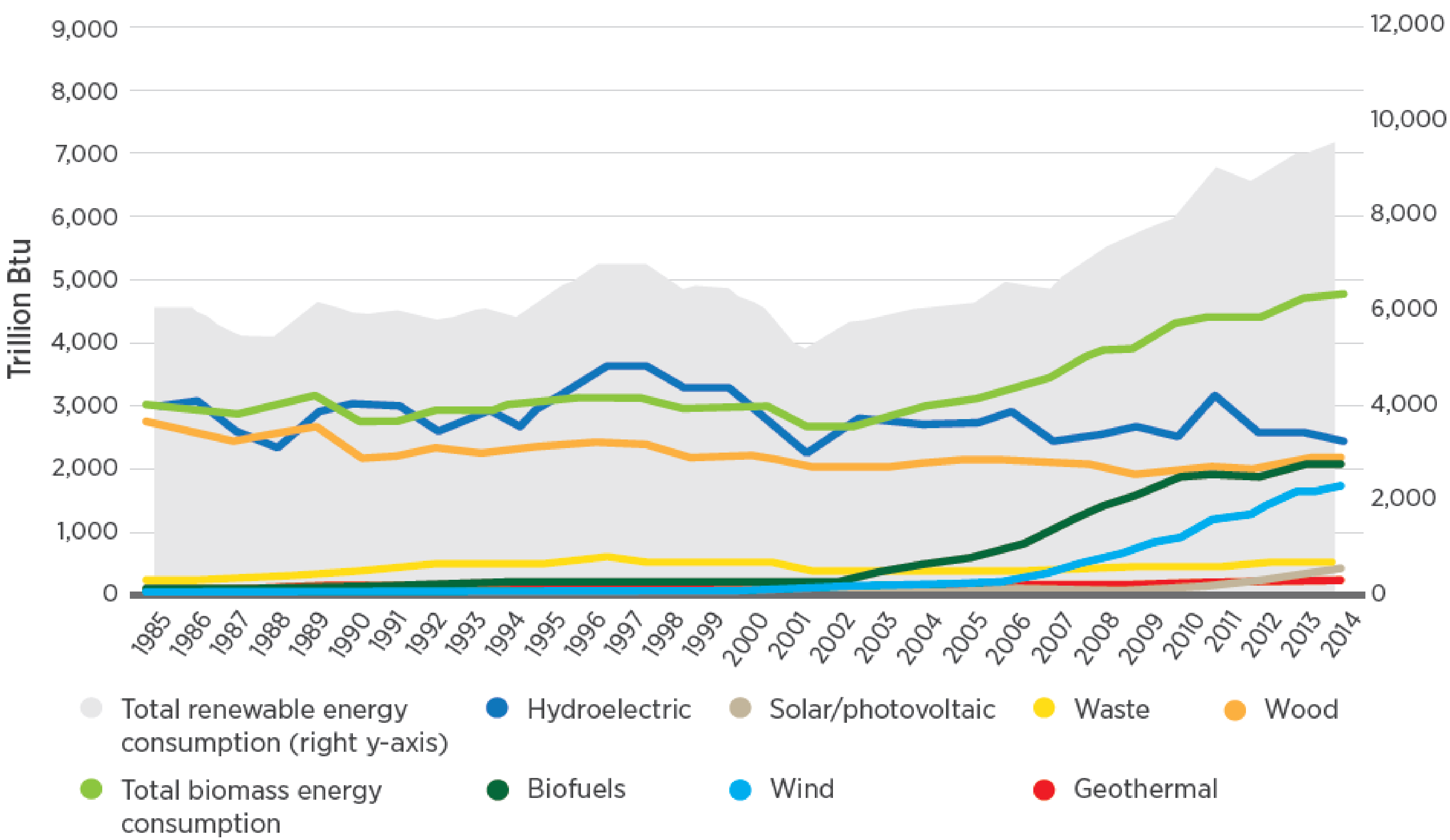
Biomass is Largest Source of Domestic Renewable Energy

Figure 2.2 | Primary renewable energy consumption by source and total consumption (1985–2014)



Source: Data from EIA (2015d).

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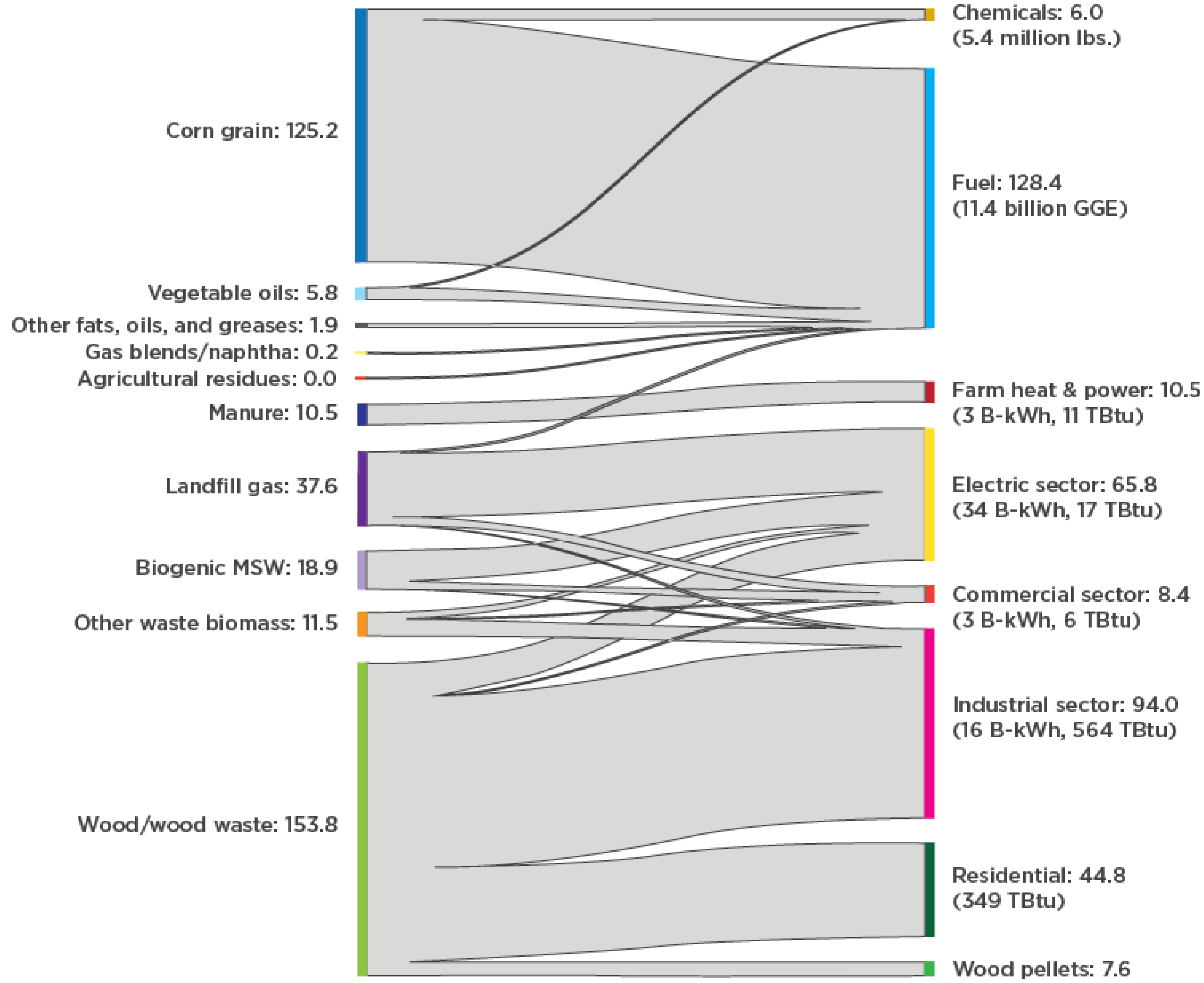
How Biomass is Currently Used

1 million "bioenergy equivalent" dry ton per day (2014)

Figure 2.5 | Sankey diagram of feedstock, sector consumption, and final product distribution, in million dry tons per year[14]



Note: Biomass resources are shown on the left and their allocations are shown on the right. The size of the flow is representative of the amount of biomass allocated to that end use. For this figure, contributions from landfill gas are represented as tons of biomass equivalent by applying a conversion factor of 0.2665 lb/scf.

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Motivation

- Enormous U.S. domestic biomass potential
  - 2005 and 2011 reports identified > 1 billion ton annual supply
- Understanding and quantifying biomass supply fosters commercialization to increase
  - Energy security,
  - Energy independence, and
  - Environmental stewardship
- Sustainable production is critical to long-term viability of technology for clean energy

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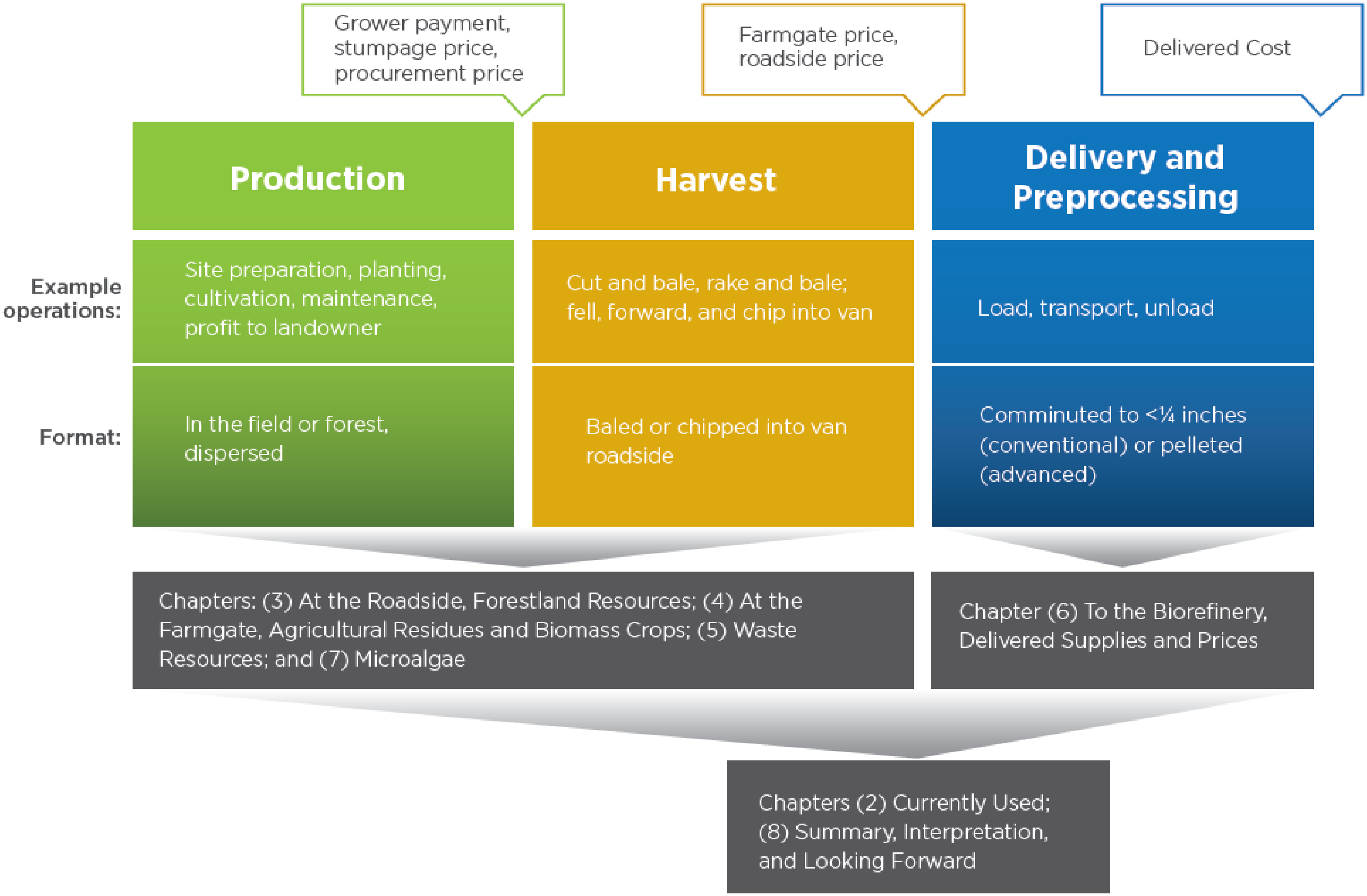
Contributors

Schematic of Biomass Supply Chain



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Major Biomass Sources, 2040

Base case scenario, 2040, $60 per dry ton or less

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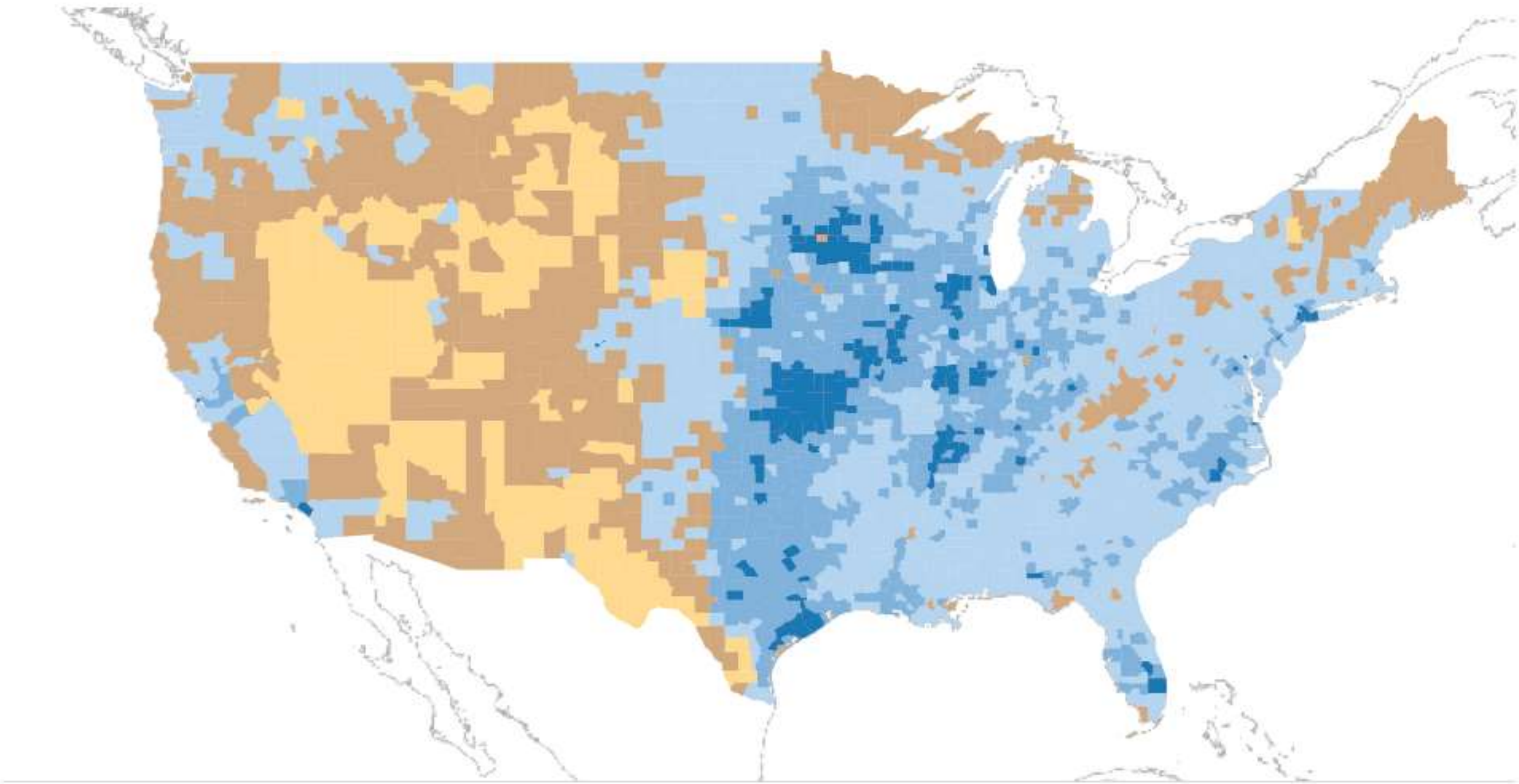
Example Visualization

Figure ES.4 | Combined potential supplies from forestry, wastes, and agricultural resources, base case, 2040[10]



Less than 10 dt/SqMile
10-100 dt/SqMile
100-500 dt/SqMile
500-1,000 dt/SqMile
1,000-5,000 dt/SqMile

[10] Interactive visualization: https://bioenergykdf.net/billionton2016/1/2/tableau

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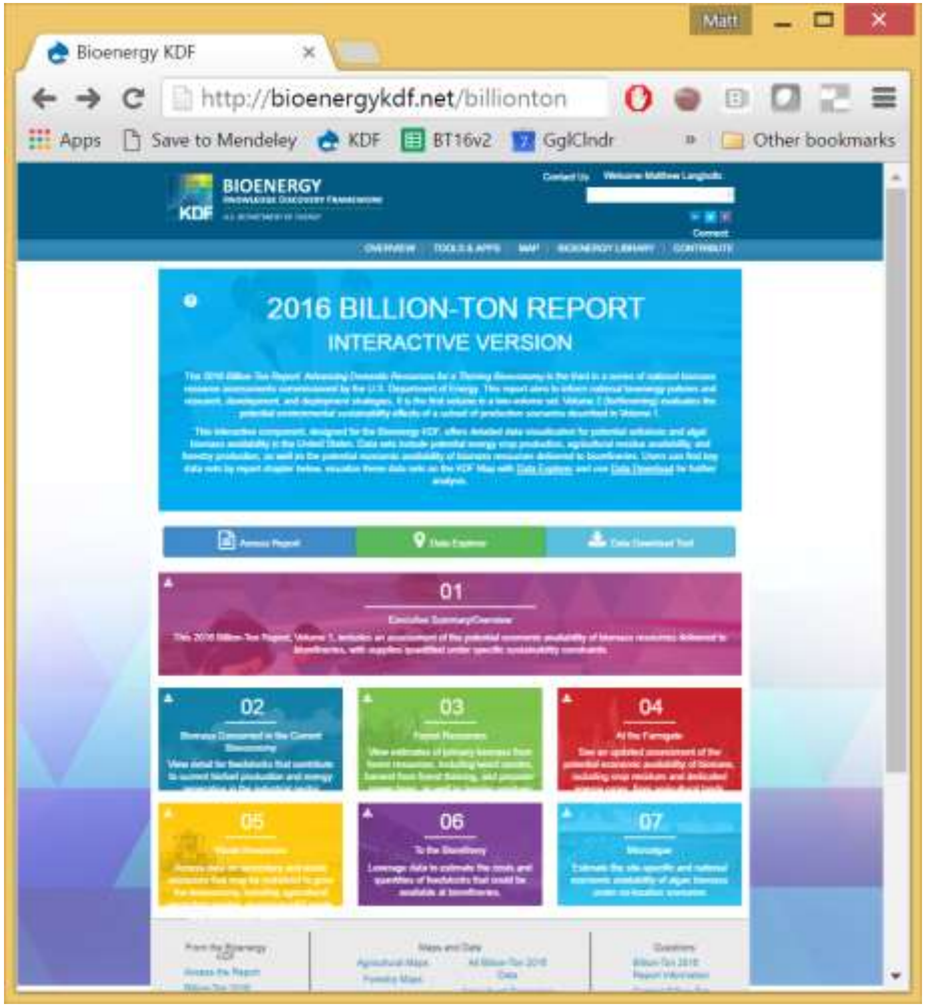
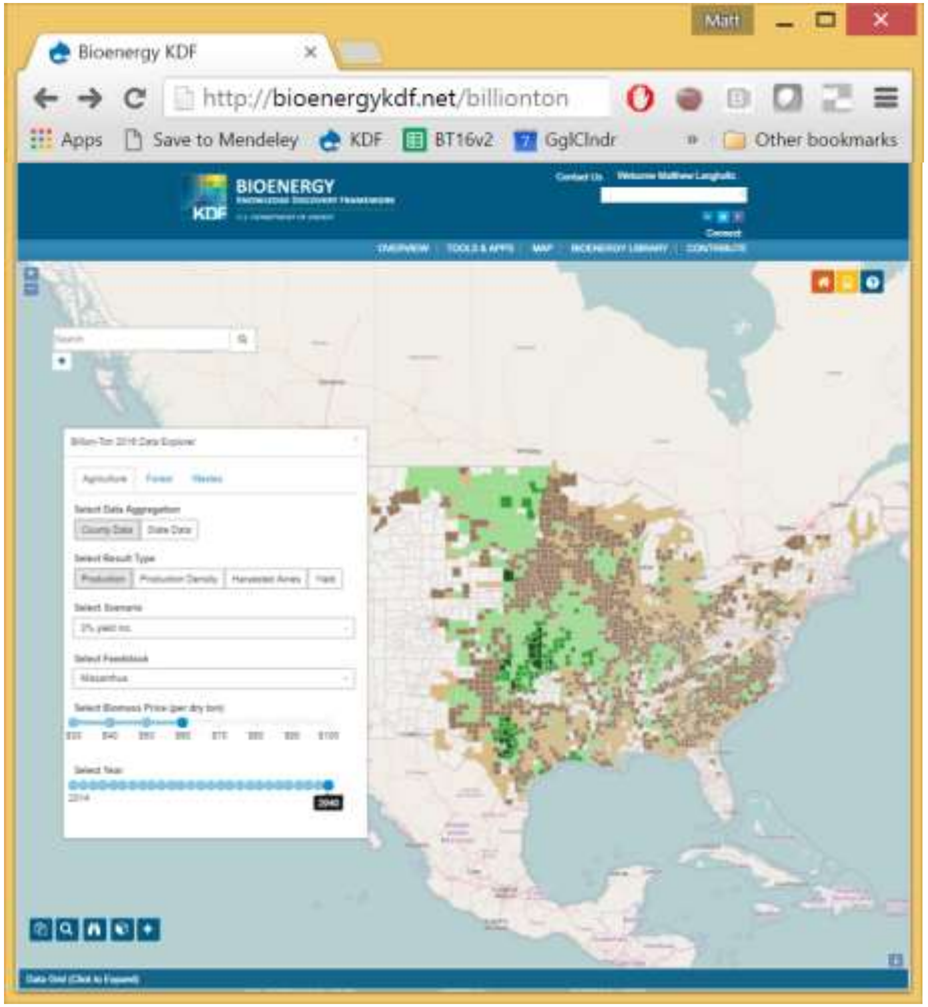
Interactive Resources

http://bioenergykdf.net/billionton





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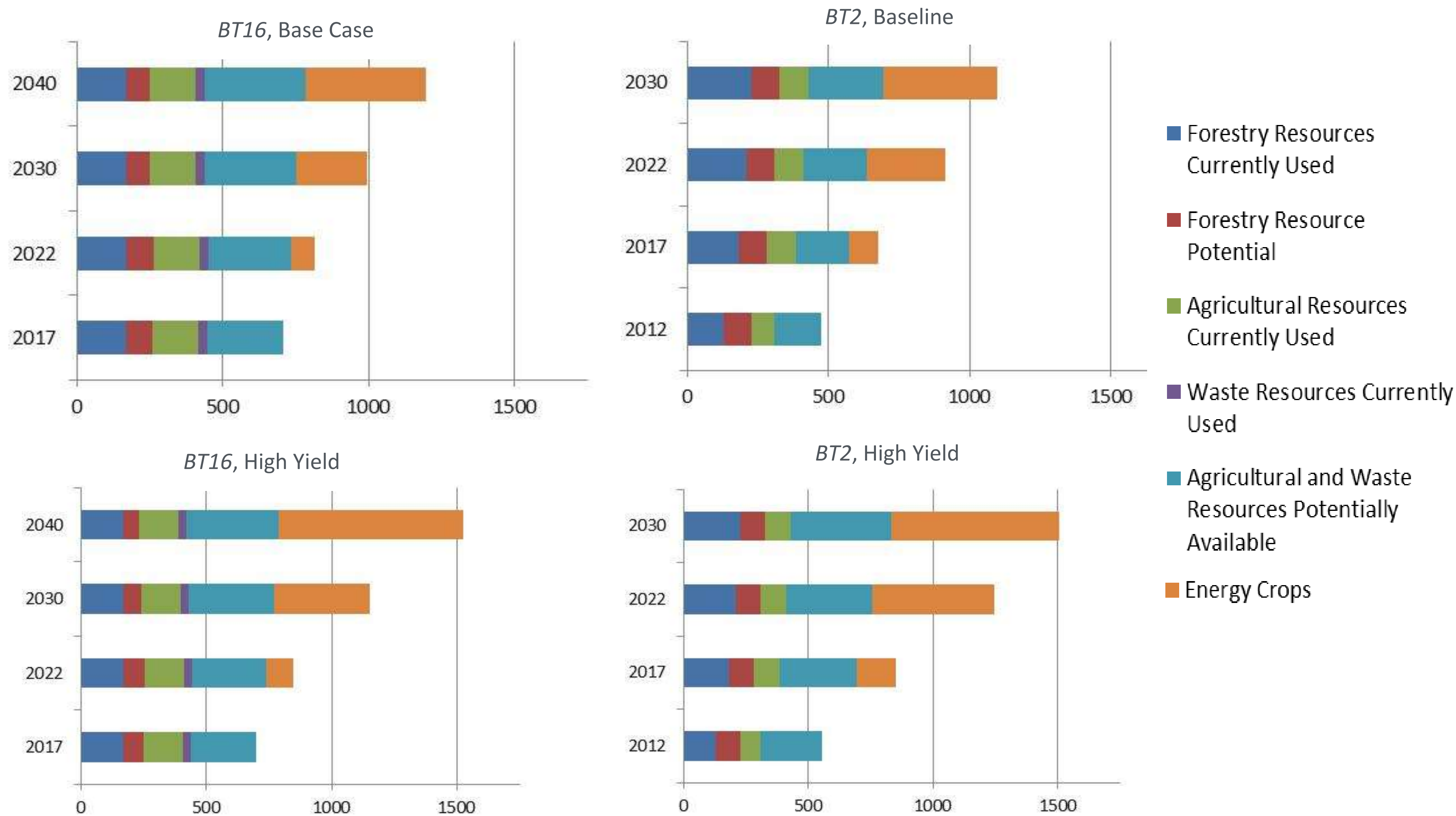
Similar Potential as 2011 *BT2*



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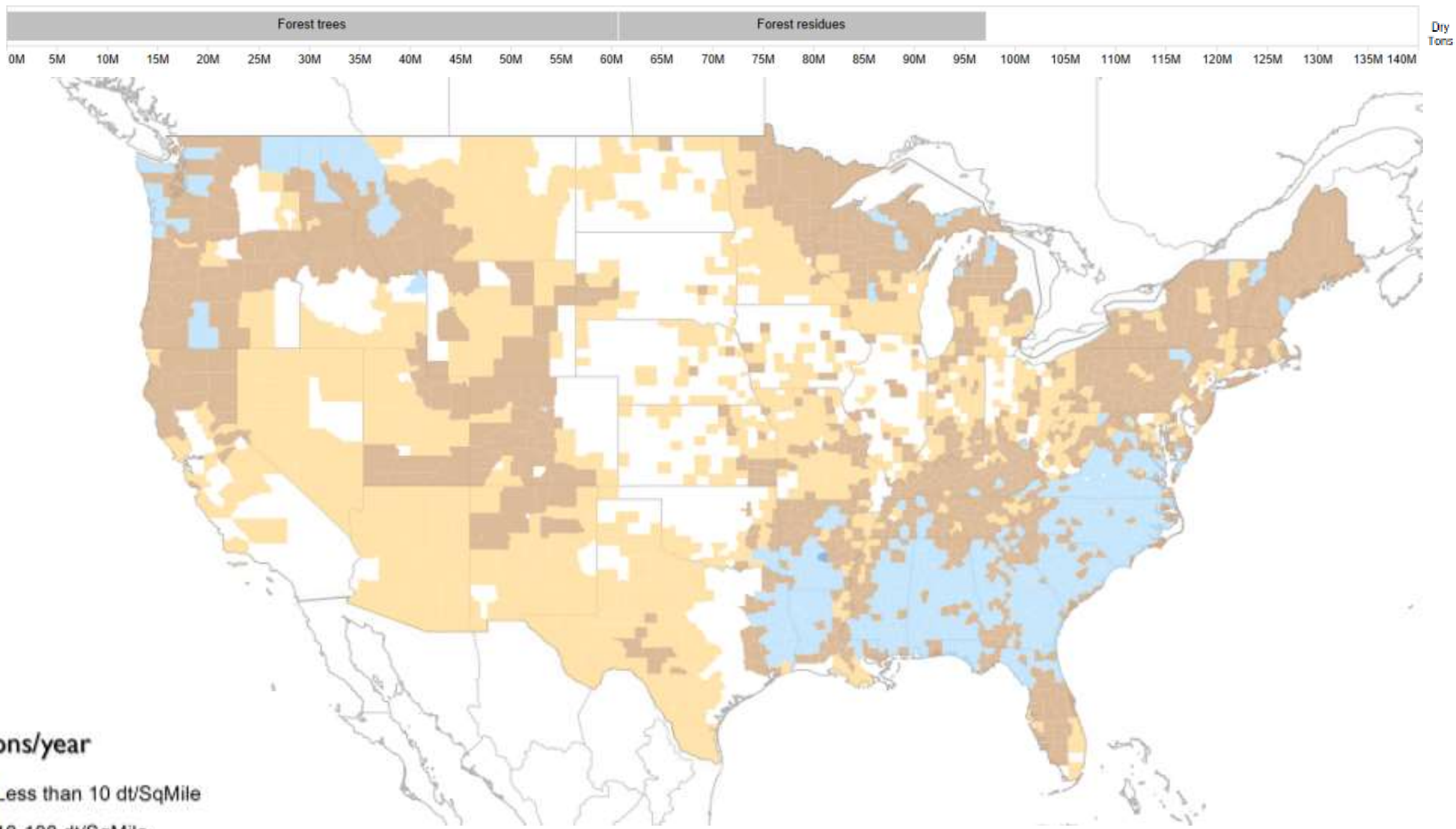
Sustainability Criteria—Forestry

Sustainability Assumption or Constraint	Sustainability Category	Implementation
Only includes timberlands, removal of fragile, reserved, protected, and environmentally sensitive forestland from database	Soil quality, water quality	Excluded land area
Only stands with ½ mile of road was harvested – no road building		Excluded land area and management assumption
Use of production and harvest systems specified for particular species, timber size, and land condition		Management assumptions
Management of residue removal levels to protect soil and water, and ensure long-term productivity		Land characteristic assumption
Leaving at least 30% of logging residues onsite to protect soil, provide habitat, and maintain soil carbon		Management assumption
Inclusion of funding for use of best management practices (BMPs) in cost estimates		Management assumption
Management of harvest levels to ensure growth always exceeds harvest at the state level		Spatially explicit management assumptions
No removal of timber or biomass on slopes greater than 40%, except in Pacific Northwest		Excluded land area

Base-case scenario, $60 roadside, forestry resources, year 2040



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

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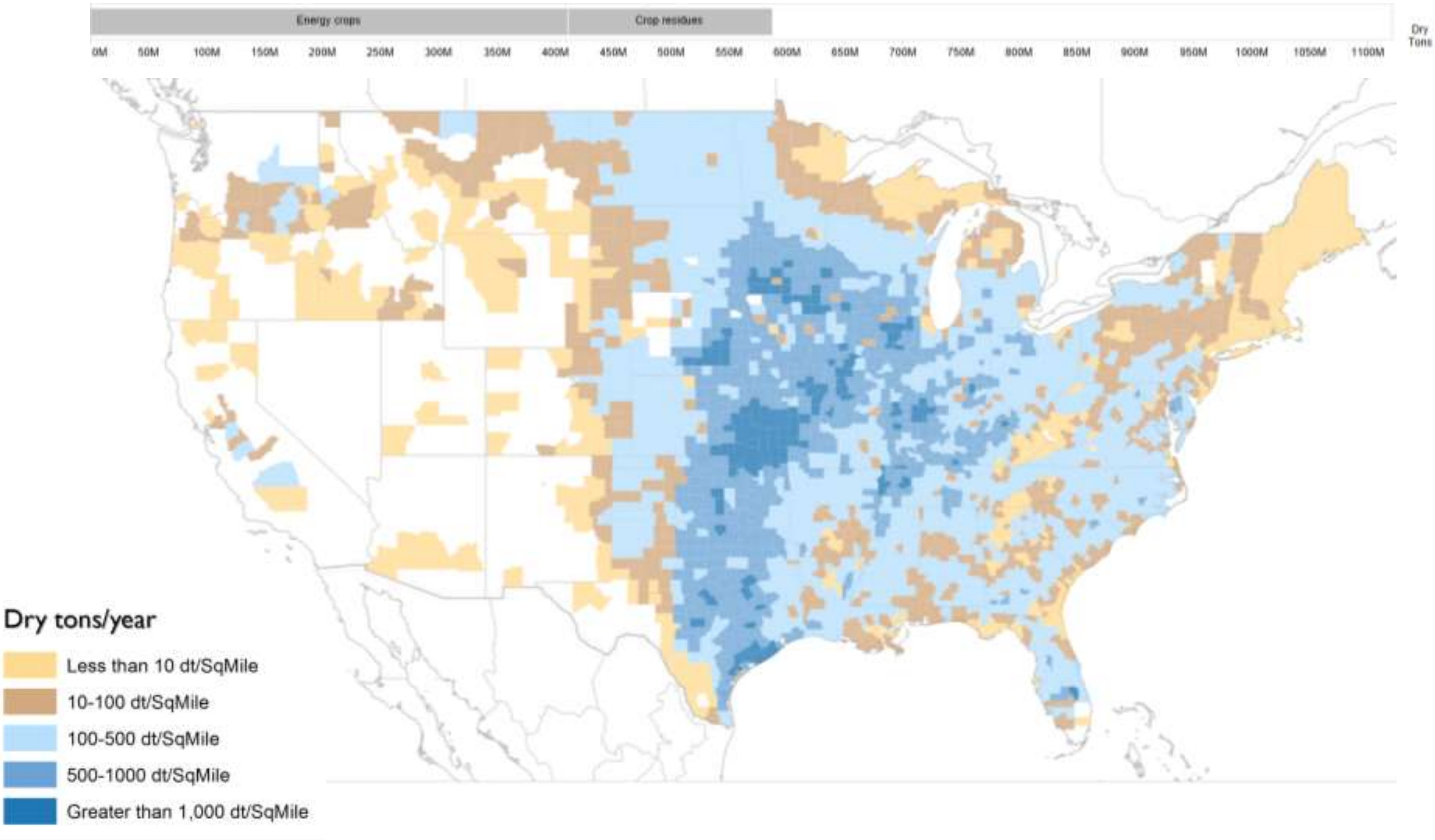
Sustainability Criteria—Agriculture

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

Base-case scenario, $60 farmgate, agricultural resources, year 2040



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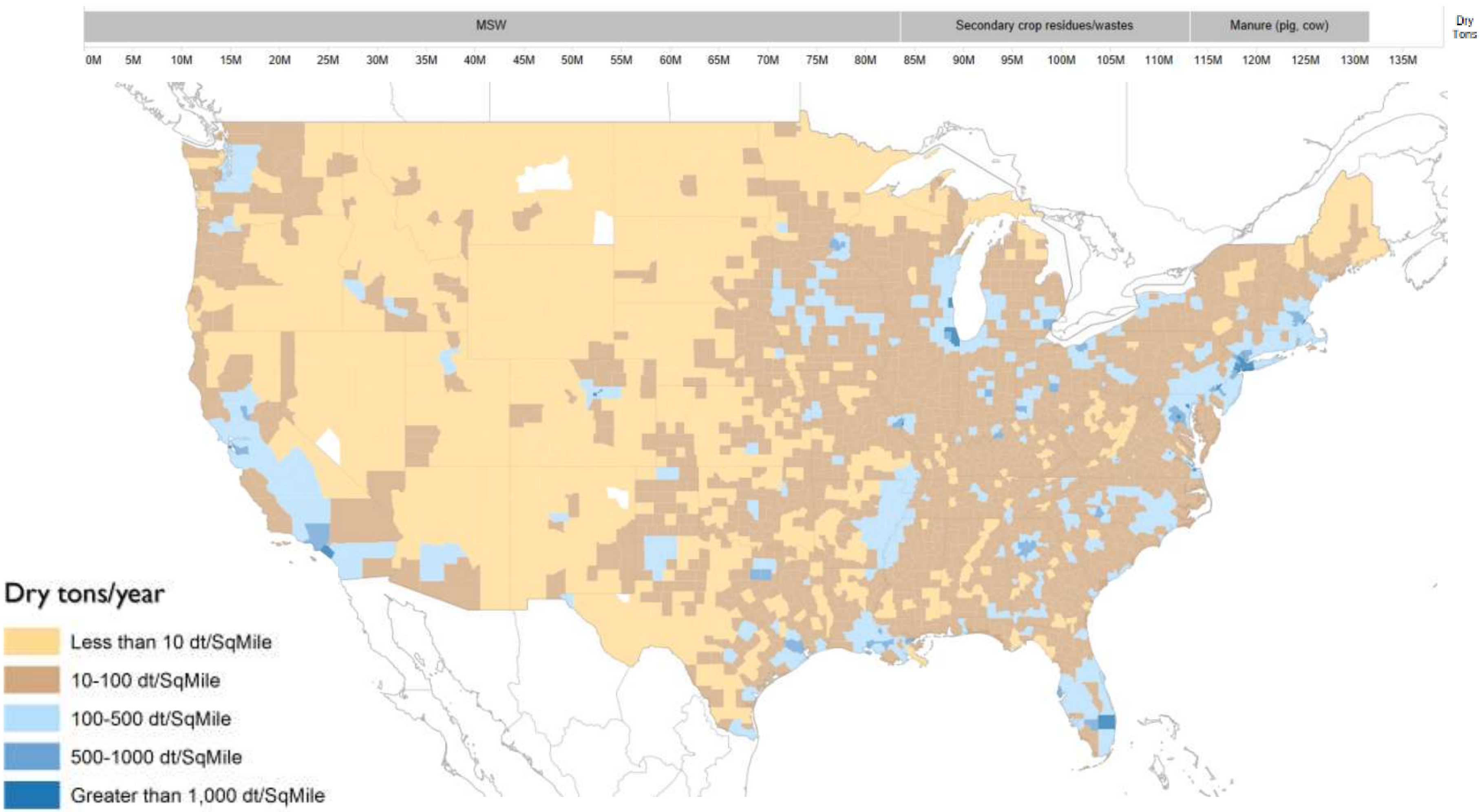
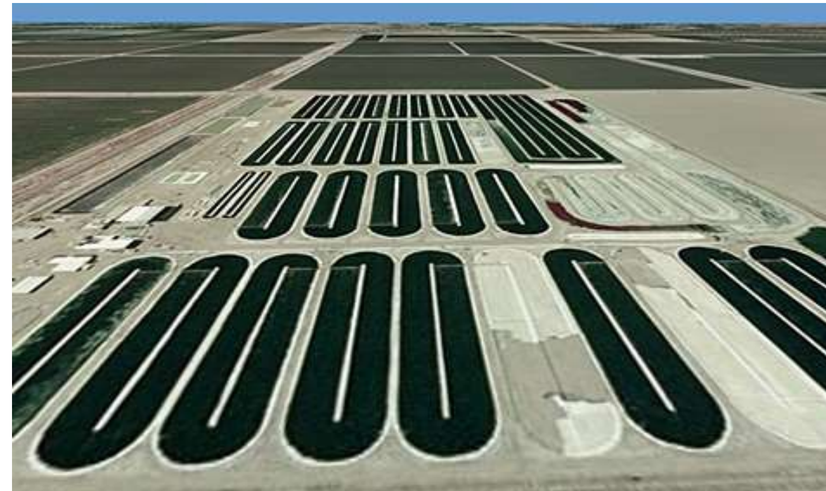
Base-case scenario, $60 offered price, waste resources, year 2040

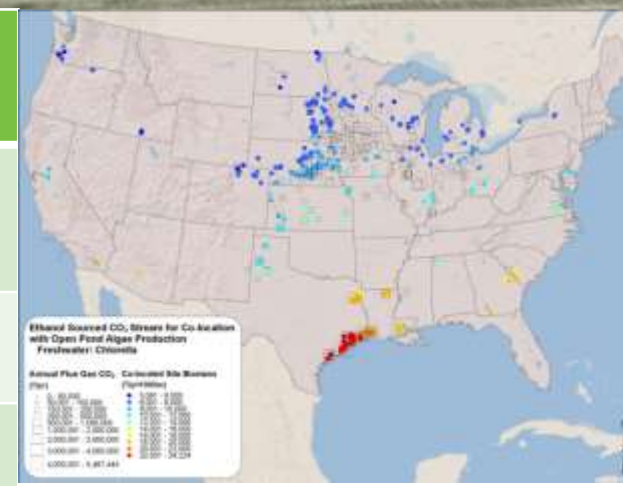


Microalgae Resources Analysis

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



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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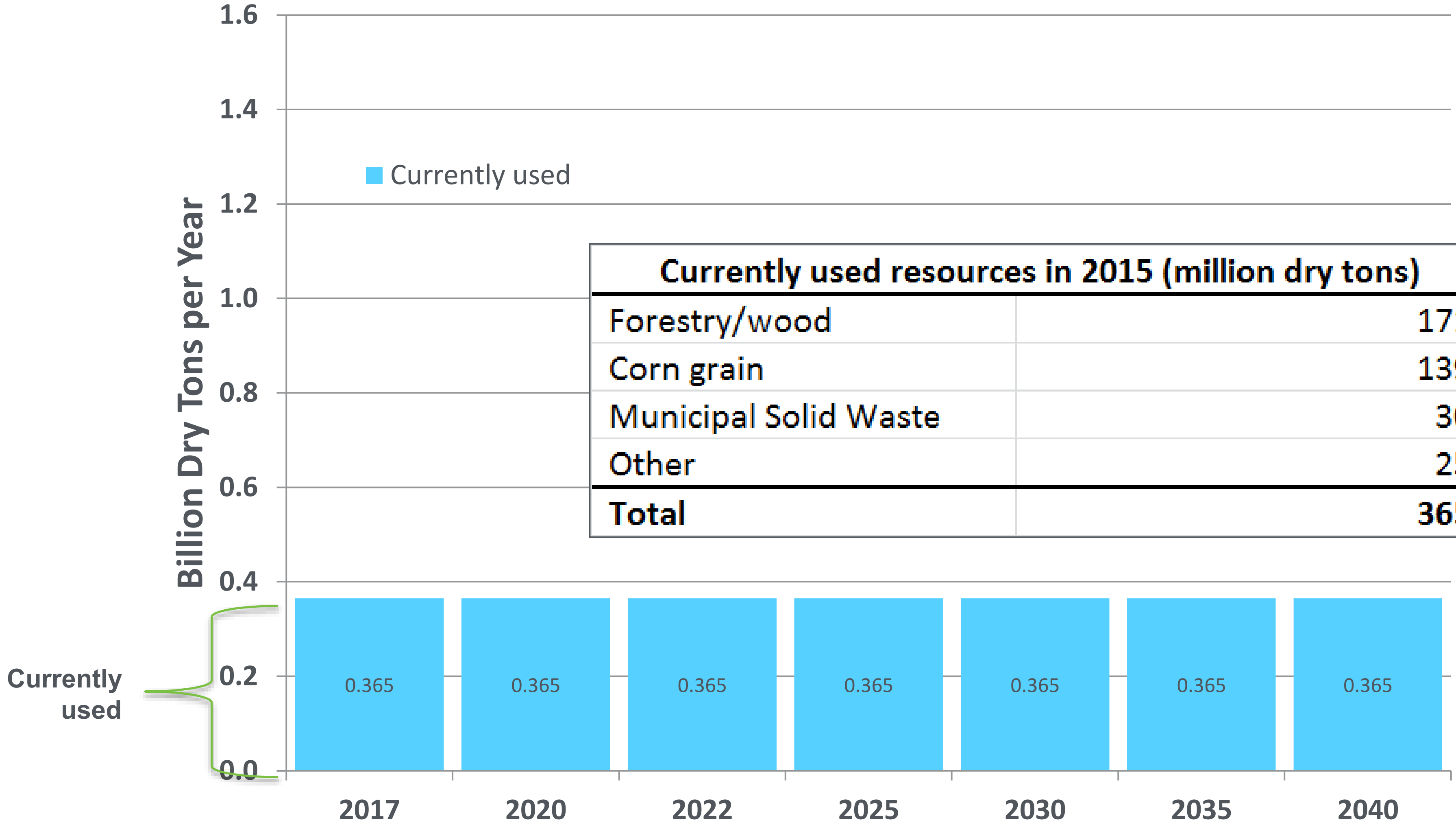
Current and Potential, Base Case



Currently used resources in 2015 (million dry tons)	
Forestry/wood	171
Corn grain	139
Municipal Solid Waste	30
Other	25
Total	**365**

Currently used at market prices, potential supplies up to $60/dt (2014$)

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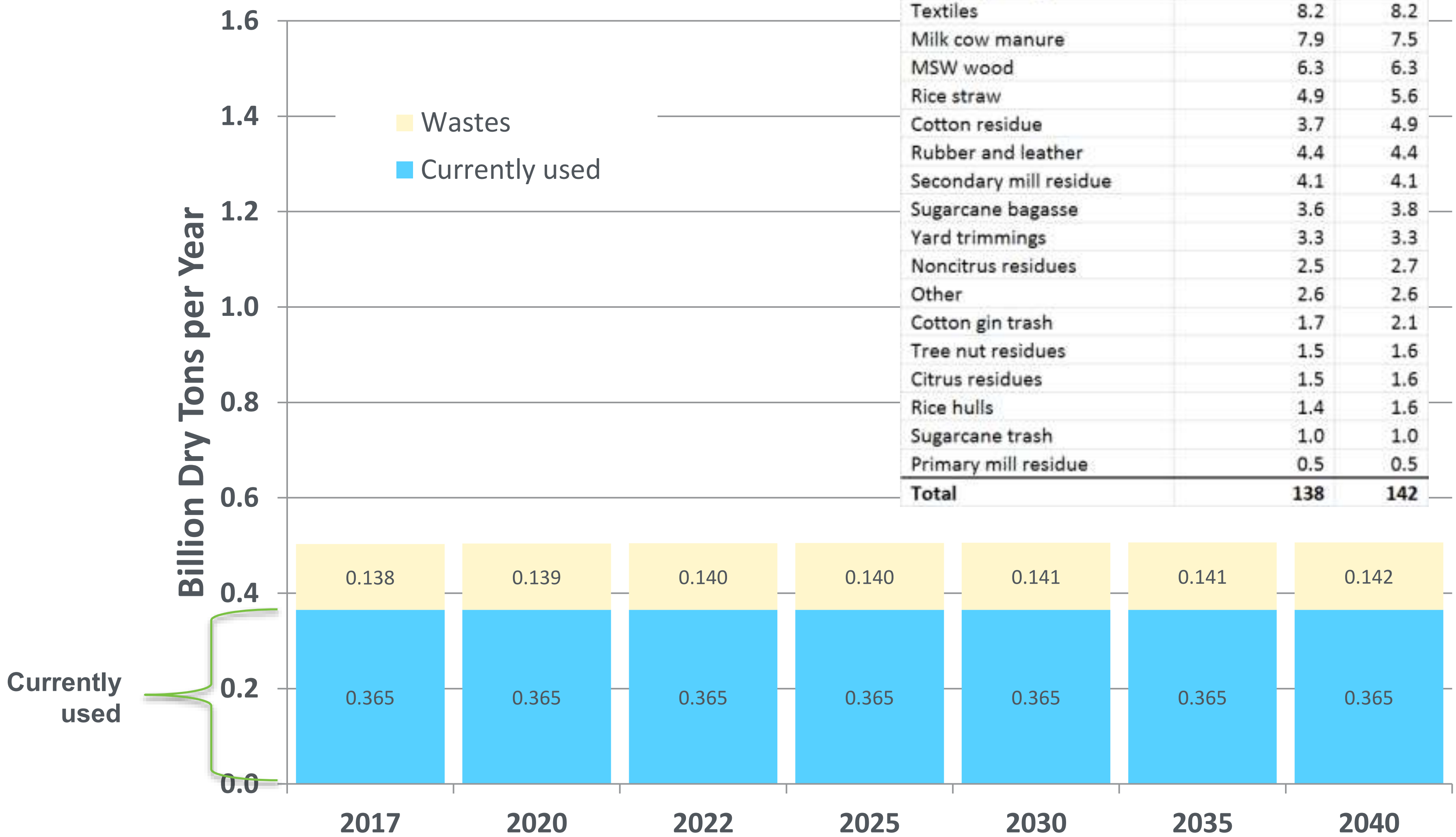
Current and Potential, Base Case at $60/dt



Currently used at market prices, potential supplies up to $60/dt (2014$)

Waste Resources	2017	2040
	(million dry tons)	
C&D waste	22.8	22.8
Plastics	19.9	19.9
Paper and paperboard	16.1	16.1
Hog manure	10.2	10.9
Fats, oils, and greases	10.0	10.0
Textiles	8.2	8.2
Milk cow manure	7.9	7.5
MSW wood	6.3	6.3
Rice straw	4.9	5.6
Cotton residue	3.7	4.9
Rubber and leather	4.4	4.4
Secondary mill residue	4.1	4.1
Sugarcane bagasse	3.6	3.8
Yard trimmings	3.3	3.3
Noncitrus residues	2.5	2.7
Other	2.6	2.6
Cotton gin trash	1.7	2.1
Tree nut residues	1.5	1.6
Citrus residues	1.5	1.6
Rice hulls	1.4	1.6
Sugarcane trash	1.0	1.0
Primary mill residue	0.5	0.5
Total	**138**	**142**

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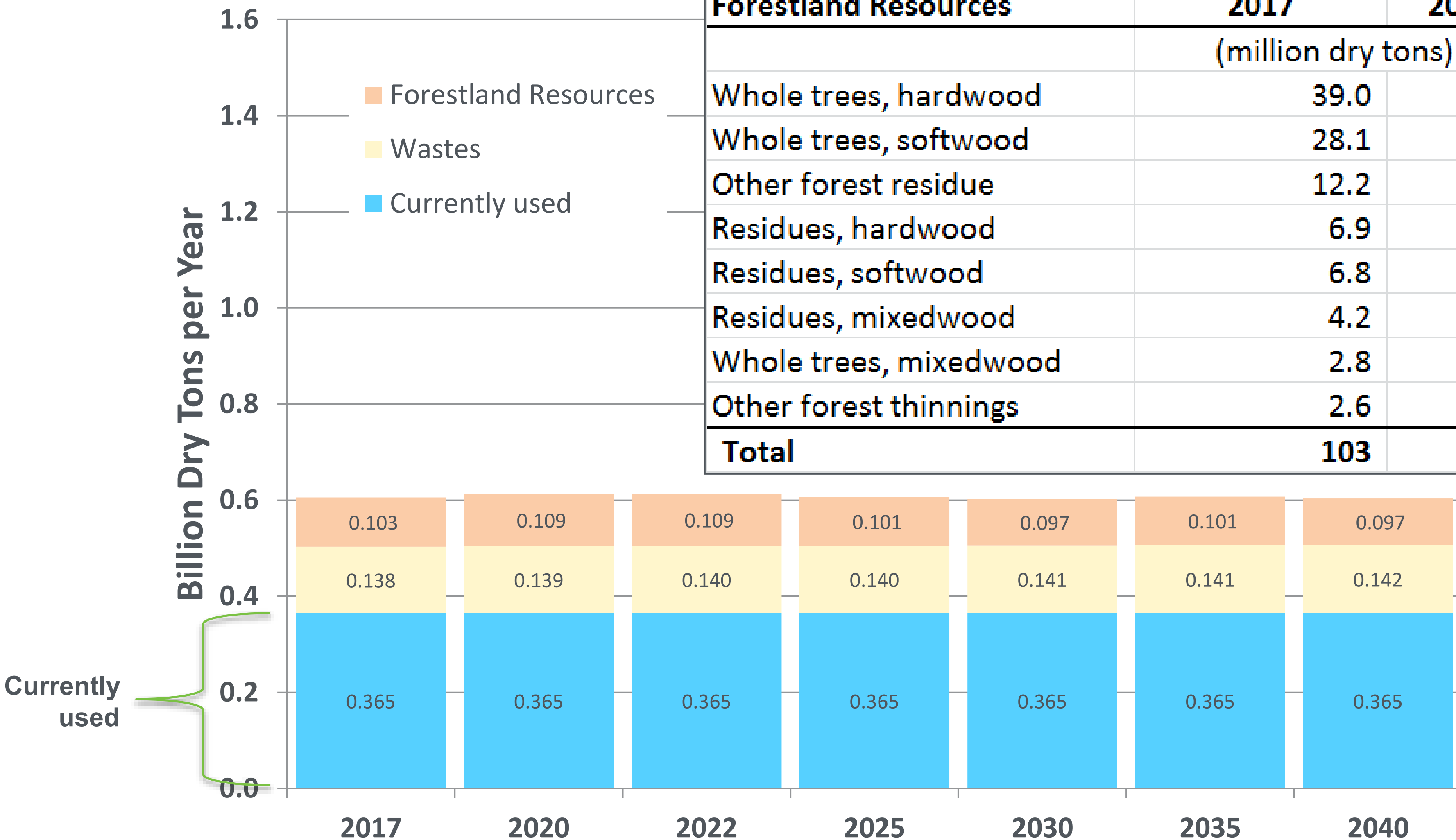
Current and Potential, Base Case at $60/dt

Forestland Resources	2017	2040
	(million dry tons)	
Whole trees, hardwood	39.0	24.9
Whole trees, softwood	28.1	33.4
Other forest residue	12.2	13.0
Residues, hardwood	6.9	8.0
Residues, softwood	6.8	10.0
Residues, mixedwood	4.2	2.7
Whole trees, mixedwood	2.8	2.4
Other forest thinnings	2.6	2.6
Total	**103**	**97**



Currently used at market prices, potential supplies up to $60/dt (2014$)

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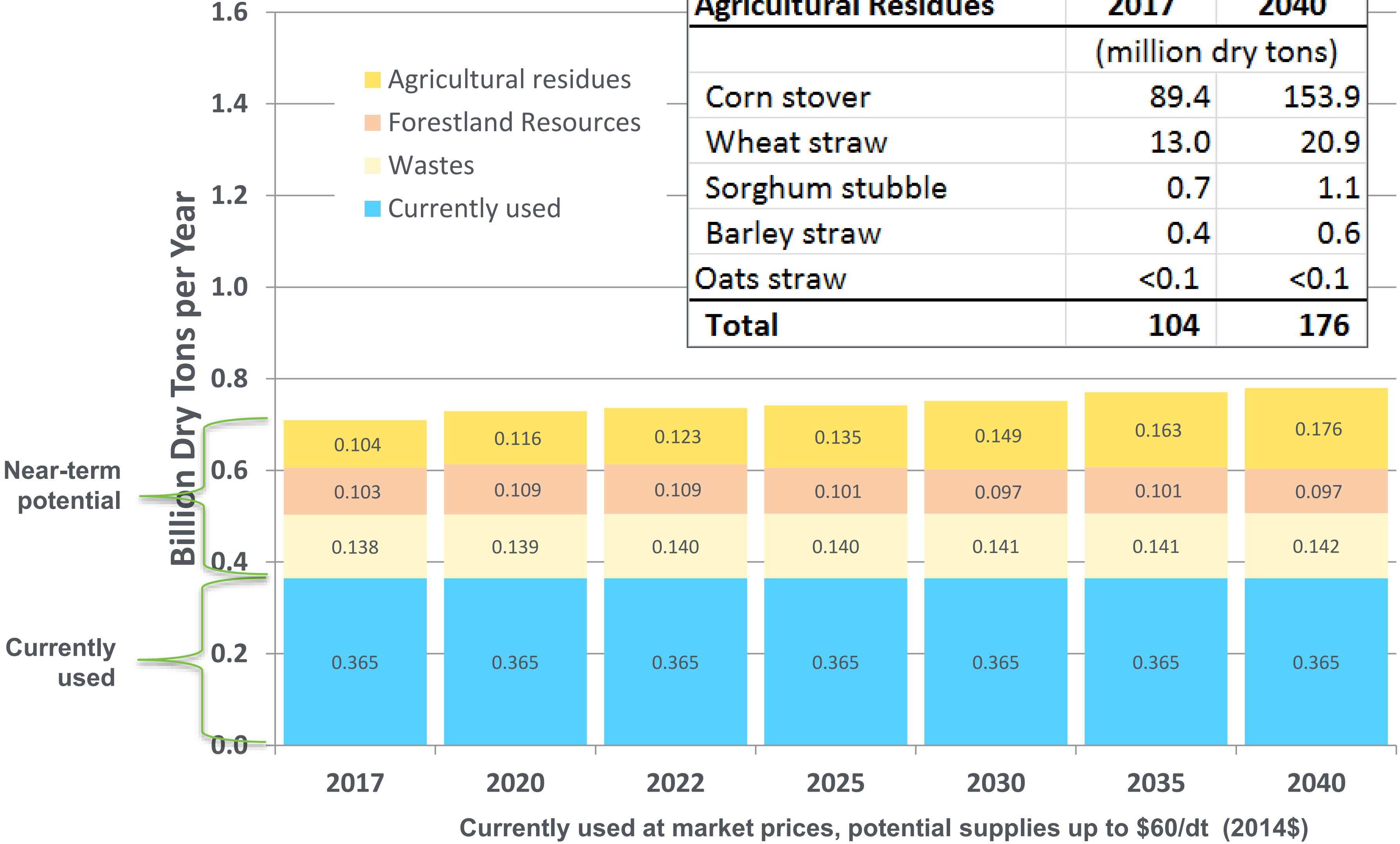
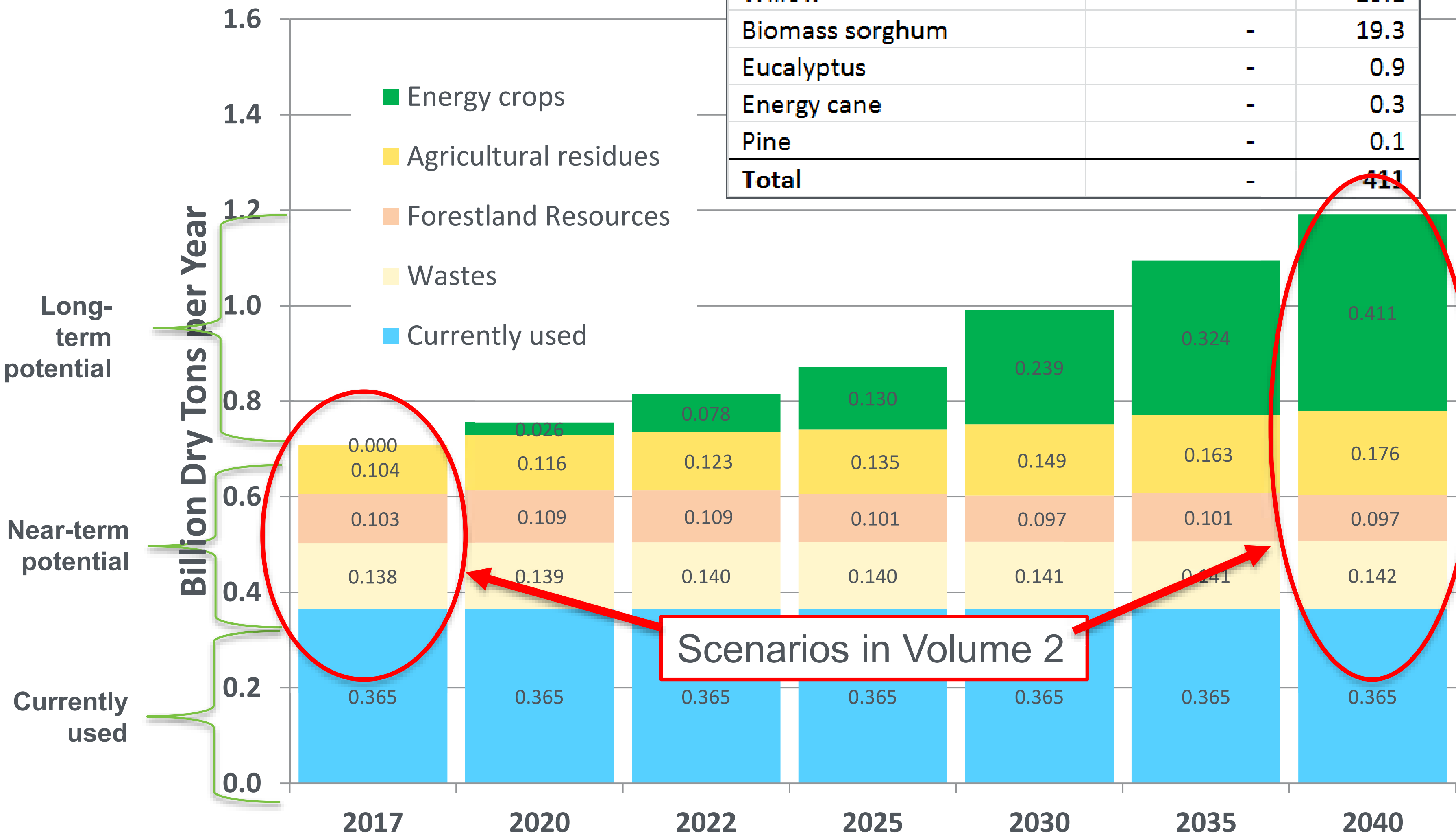
Current and Potential, Base Case at $60/dt



Agricultural Residues	2017	2040
	(million dry tons)	
Corn stover	89.4	153.9
Wheat straw	13.0	20.9
Sorghum stubble	0.7	1.1
Barley straw	0.4	0.6
Oats straw	<0.1	<0.1
Total	**104**	**176**

Current and Potential, Base Case at $60/dt

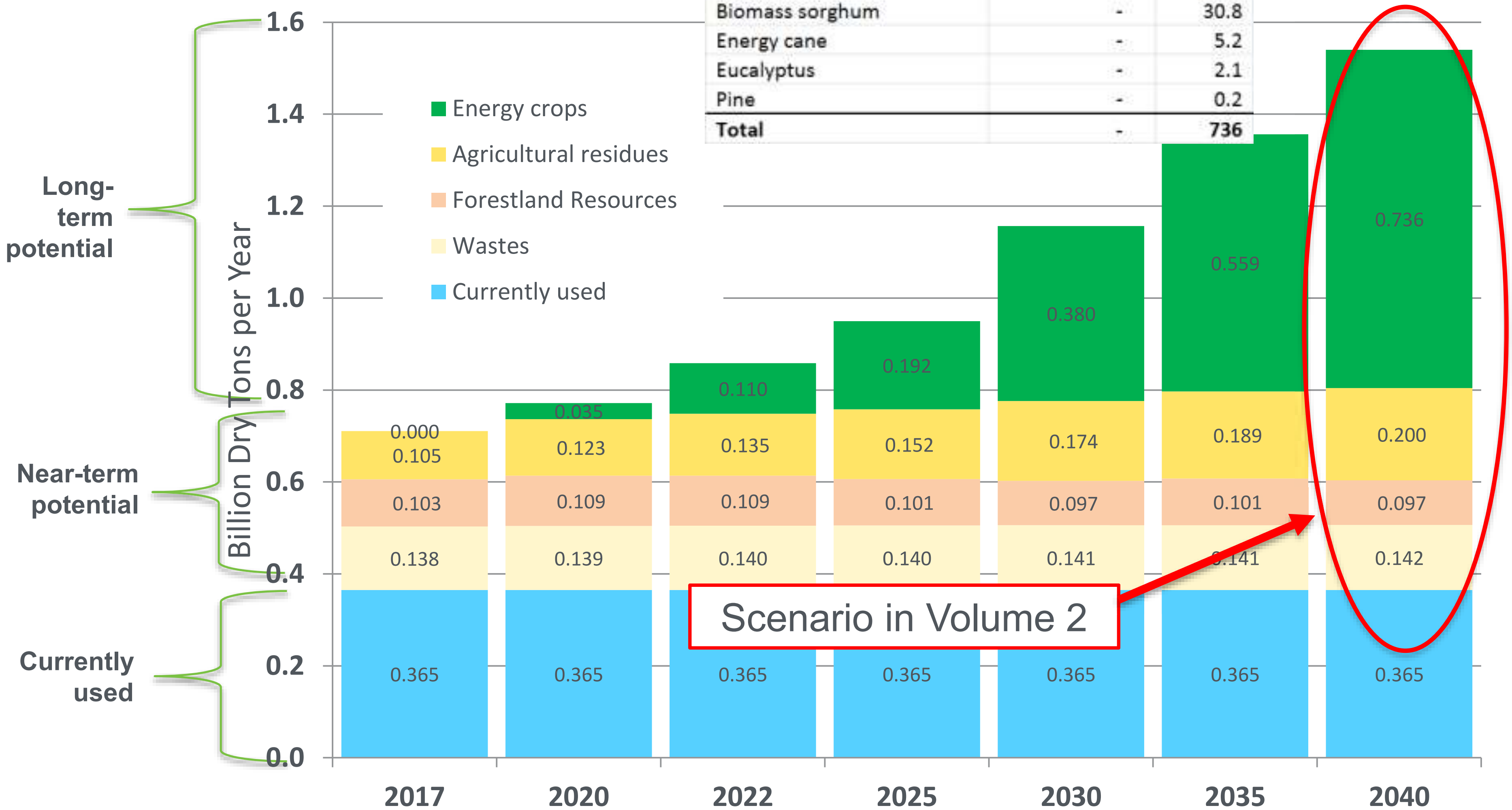
Energy crops	2017	2040
	(million dry tons)	
Switchgrass	-	160.5
Miscanthus	-	160.0
Poplar	-	44.9
Willow	-	25.1
Biomass sorghum	-	19.3
Eucalyptus	-	0.9
Energy cane	-	0.3
Pine	-	0.1
Total	-	**411**



Currently used at market prices, potential supplies up to $60/dt (2014$)

Current and Potential, High Yield Ag. at $60/dt

Energy crops, High yield	2017	2040
	(million dry tons)	
Miscanthus	-	369.6
Switchgrass	-	188.7
Poplar	-	74.5
Willow	-	65.1
Biomass sorghum	-	30.8
Energy cane	-	5.2
Eucalyptus	-	2.1
Pine	-	0.2
Total	-	**736**



Currently used at market prices, potential supplies up to $60/dt (2014$)

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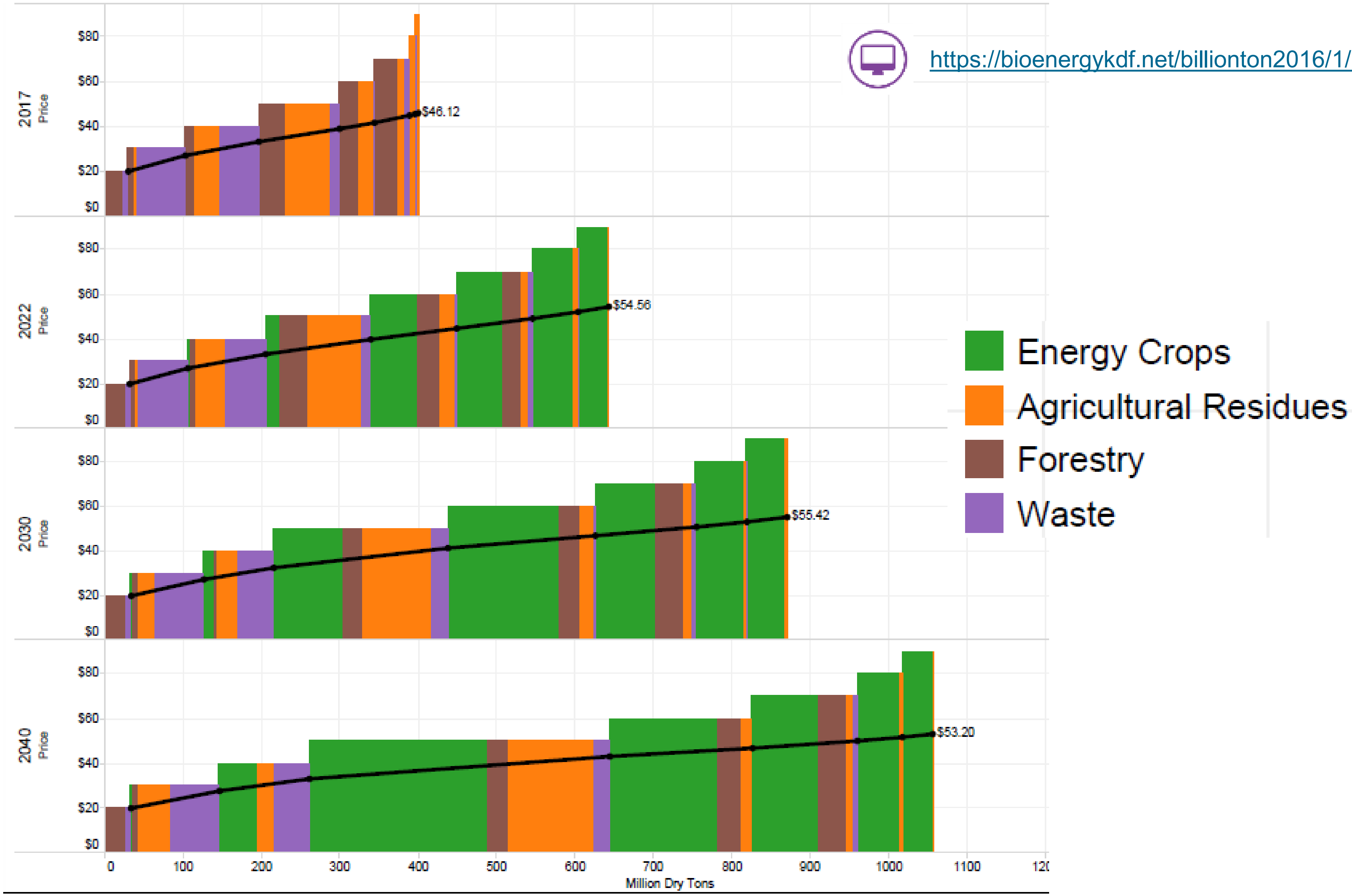
Supplies Vary with Price and Time



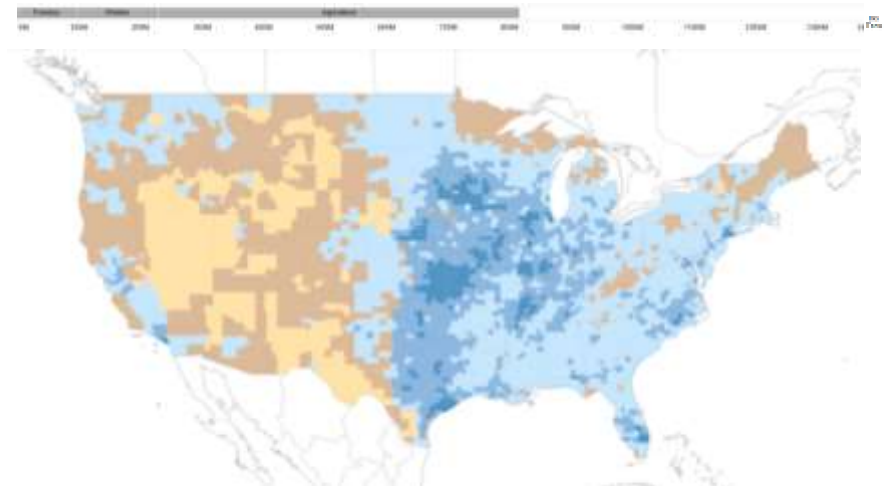
https://bioenergykdf.net/billionton2016/1/9/tableau

BT16 Fig. ES.6

Supplies Vary Spatially and Temporally

Near-term potential (2017):

Long-term potential (2040, base case):



Dry tons/year

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

https://bioenergykdf.net/billionton2016/1/2/tableau

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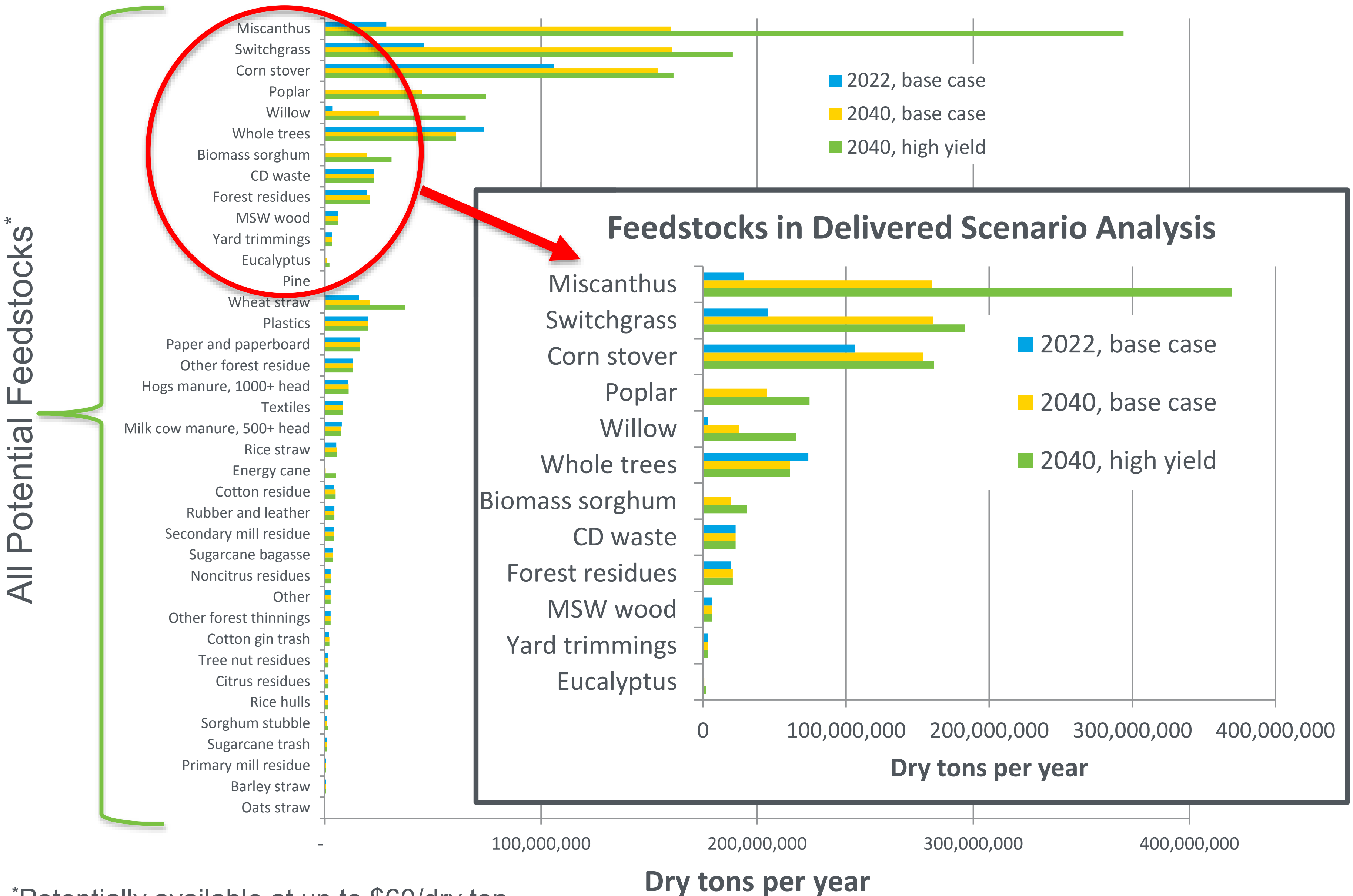
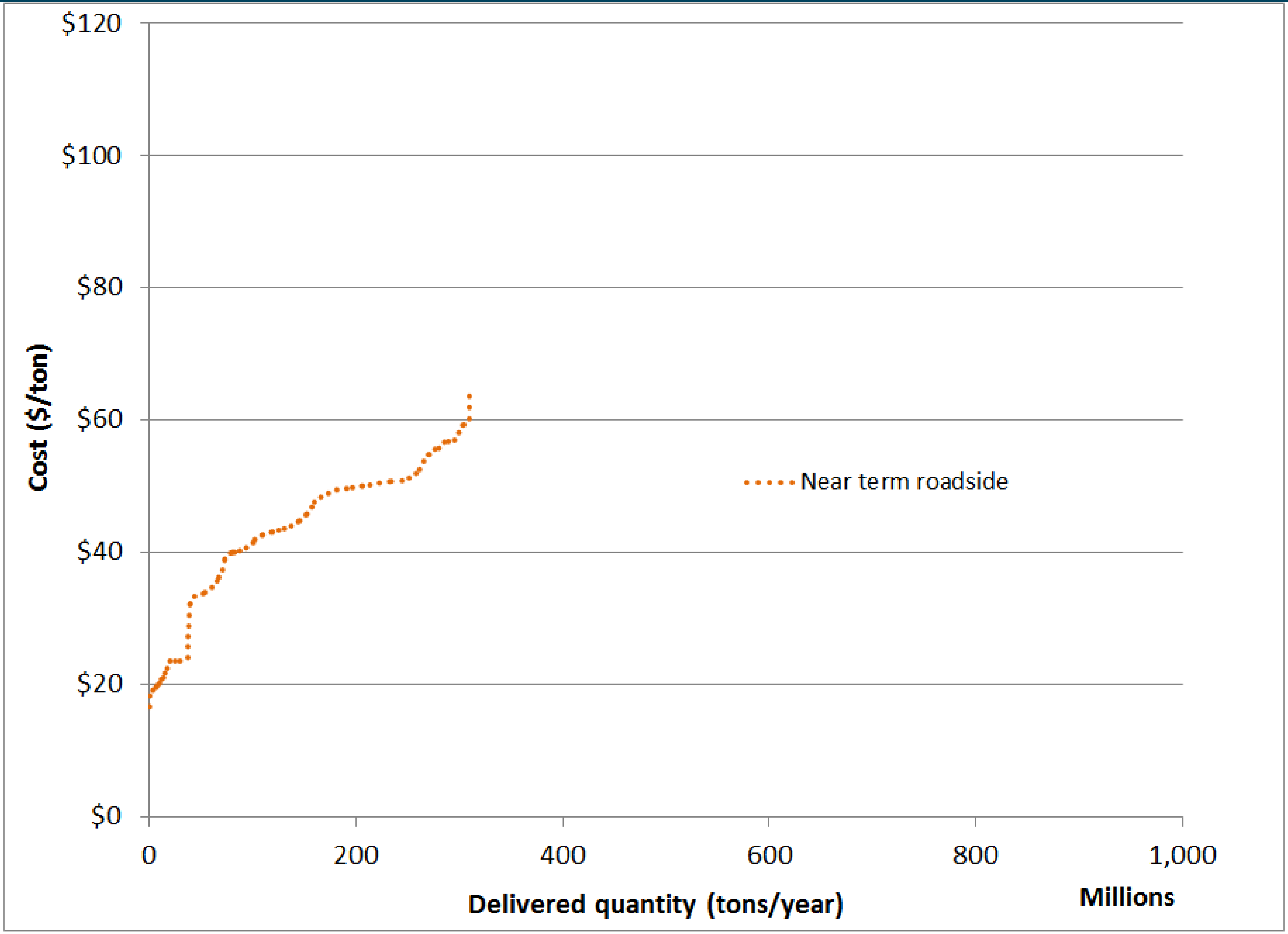
Feedstocks to the Delivered Analysis



*Potentially available at up to $60/dry ton

Delivered Scenario Analysis



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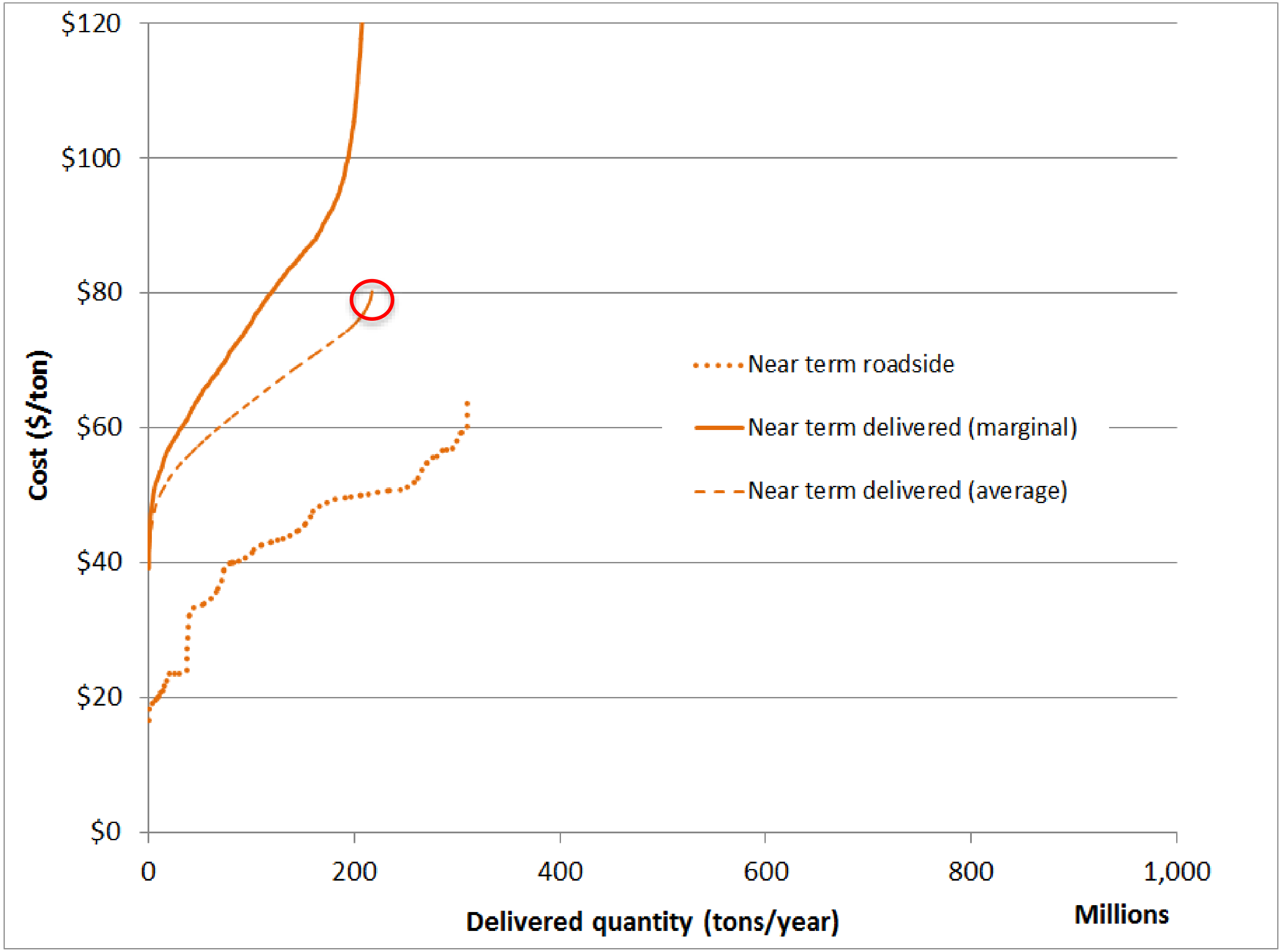

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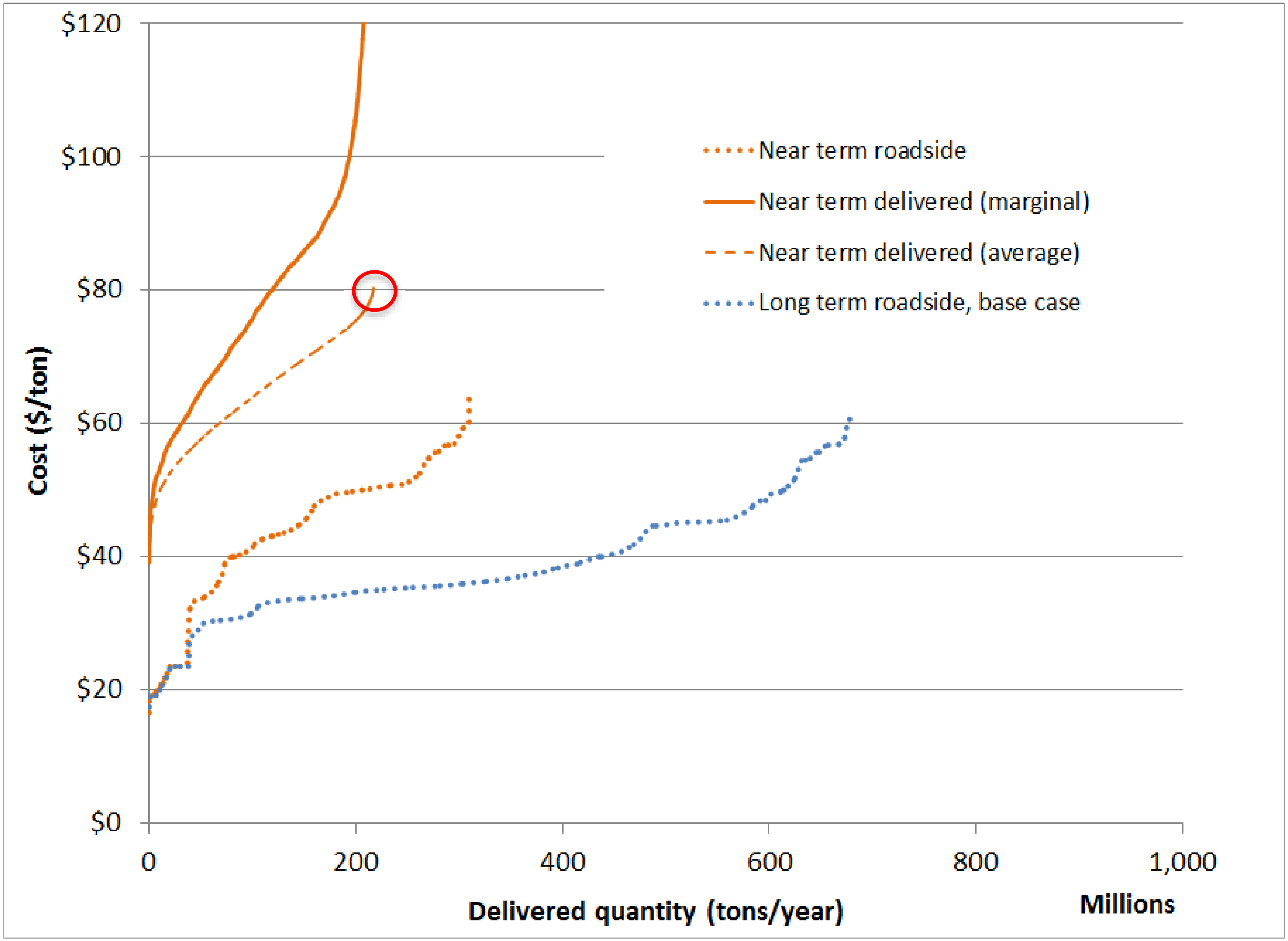

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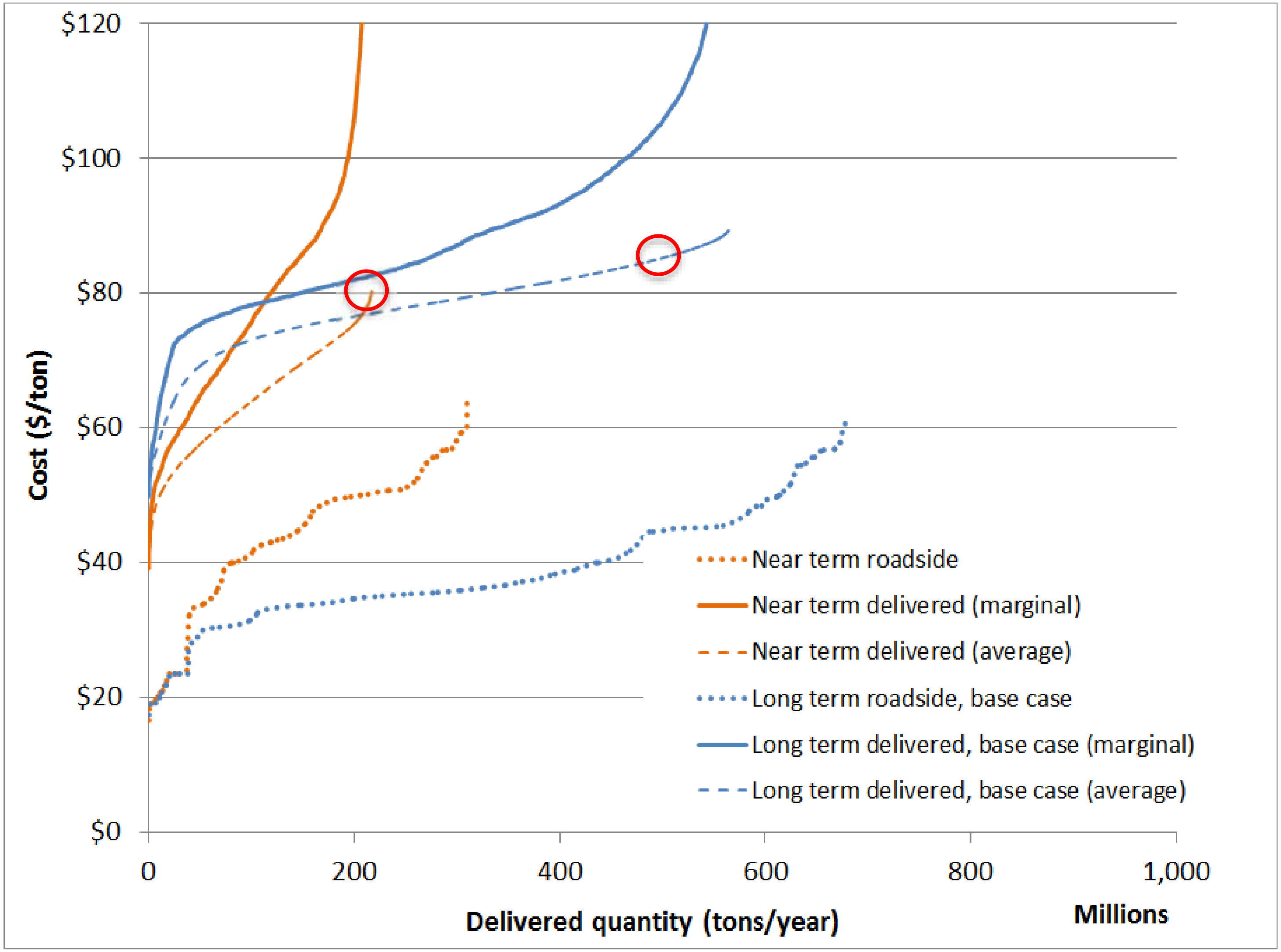

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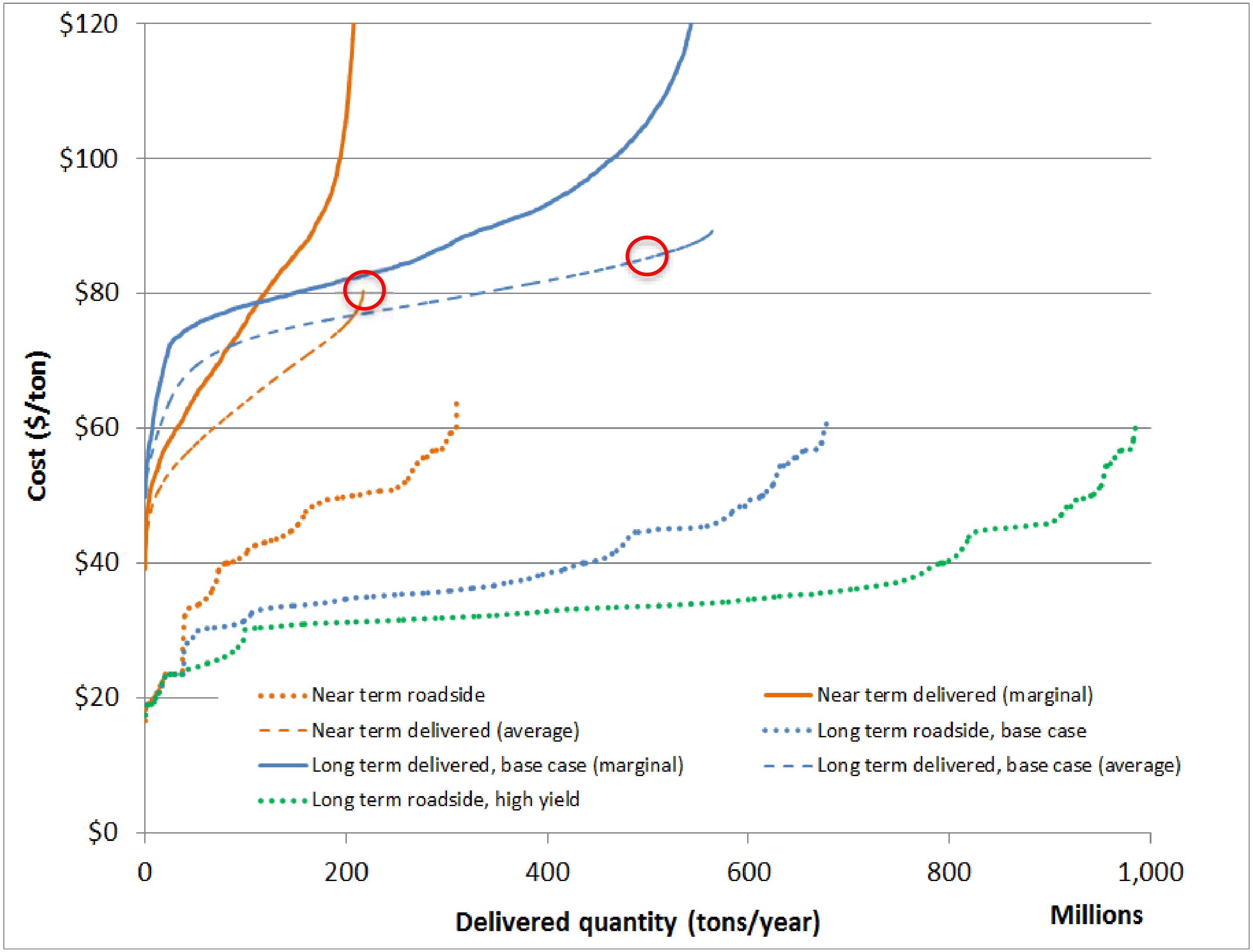

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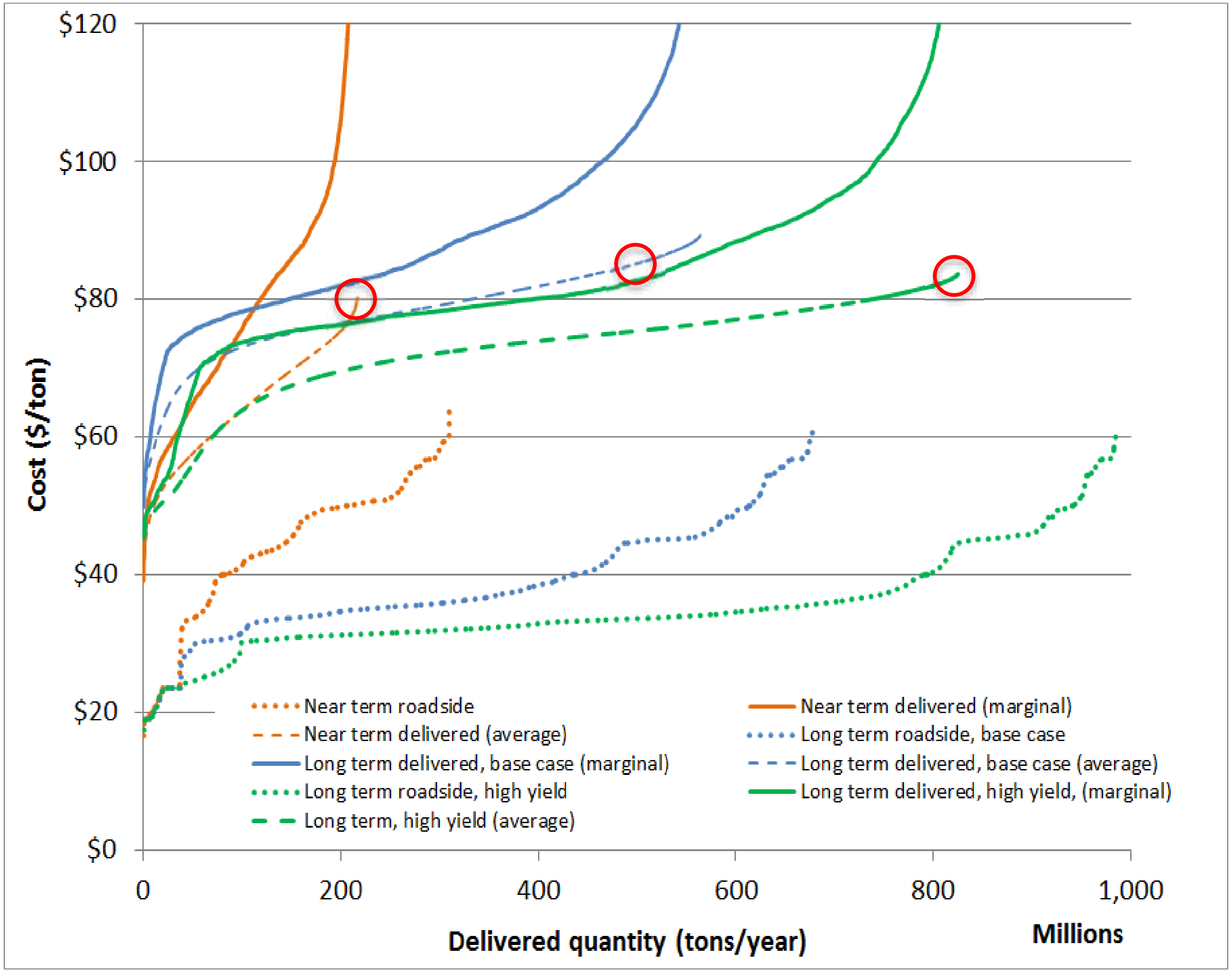
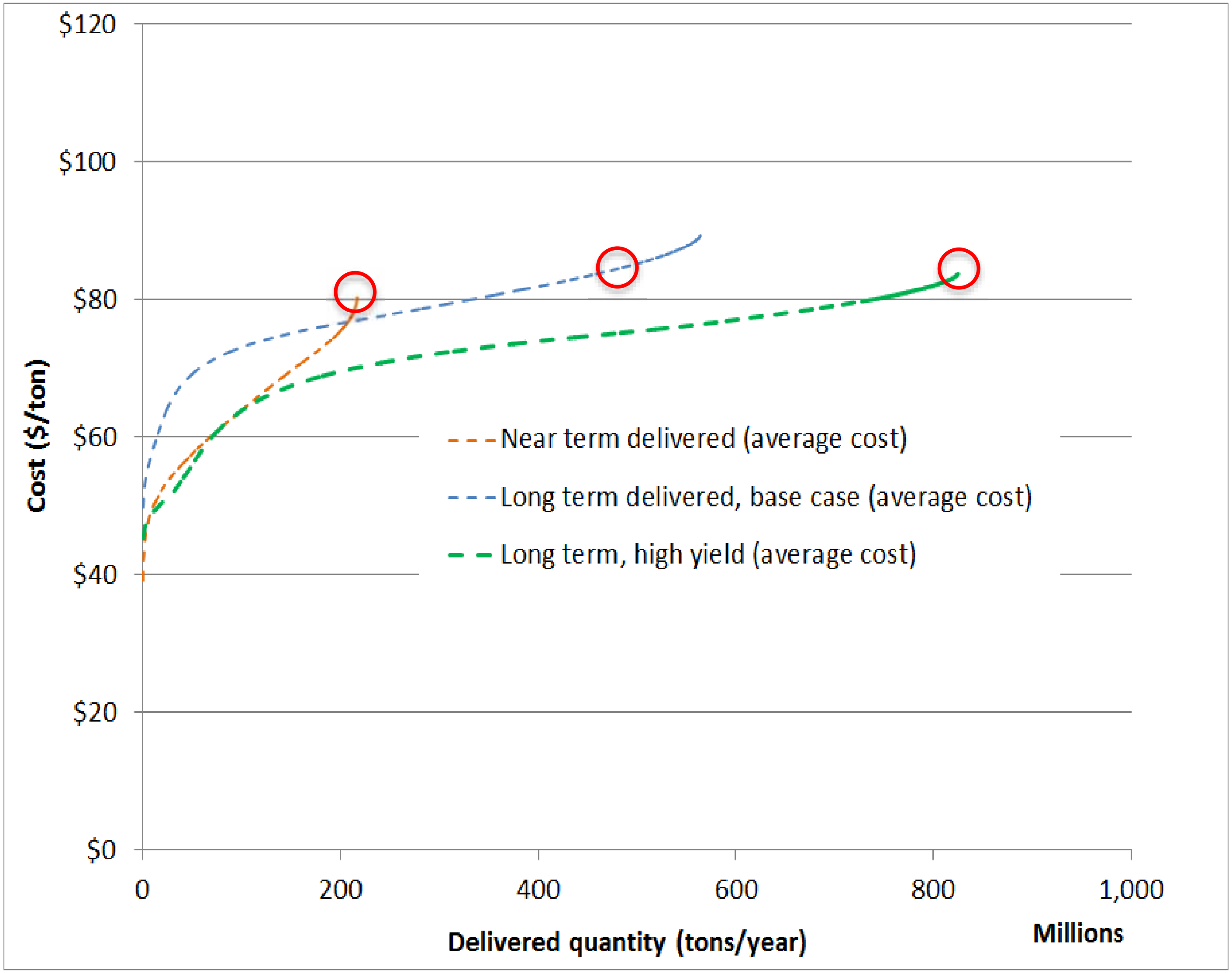
Delivered Scenario Analysis



Delivered Scenario Analysis



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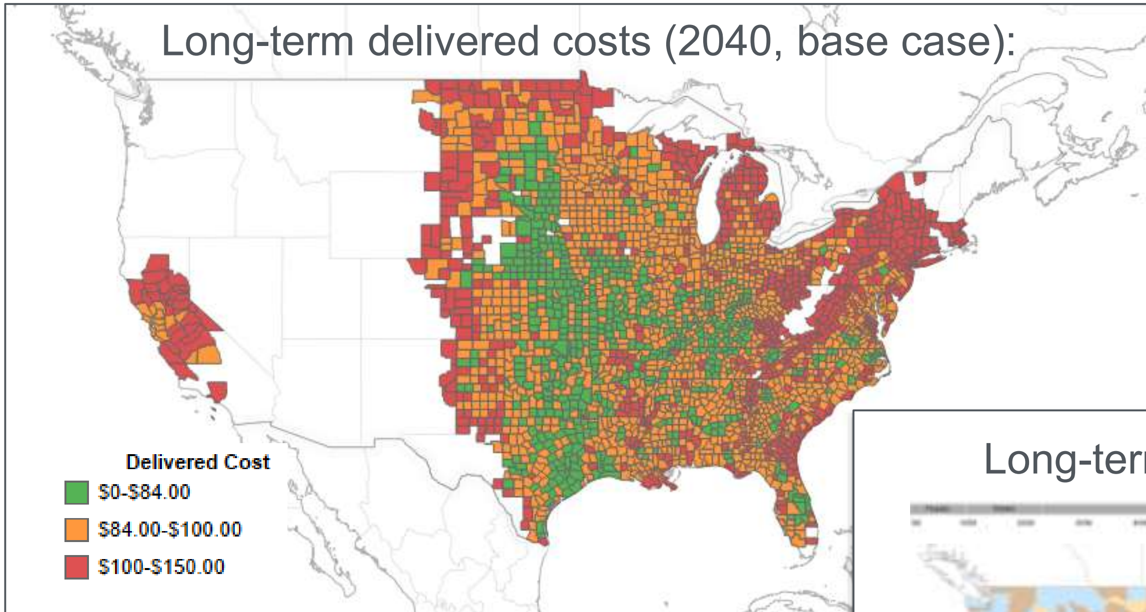
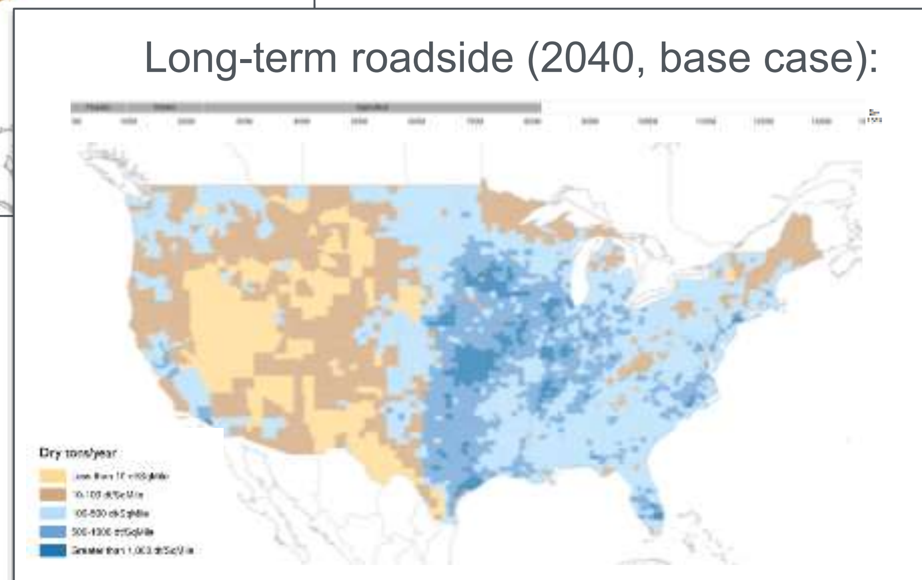
Delivered Cost by County, Base Case, 2040





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

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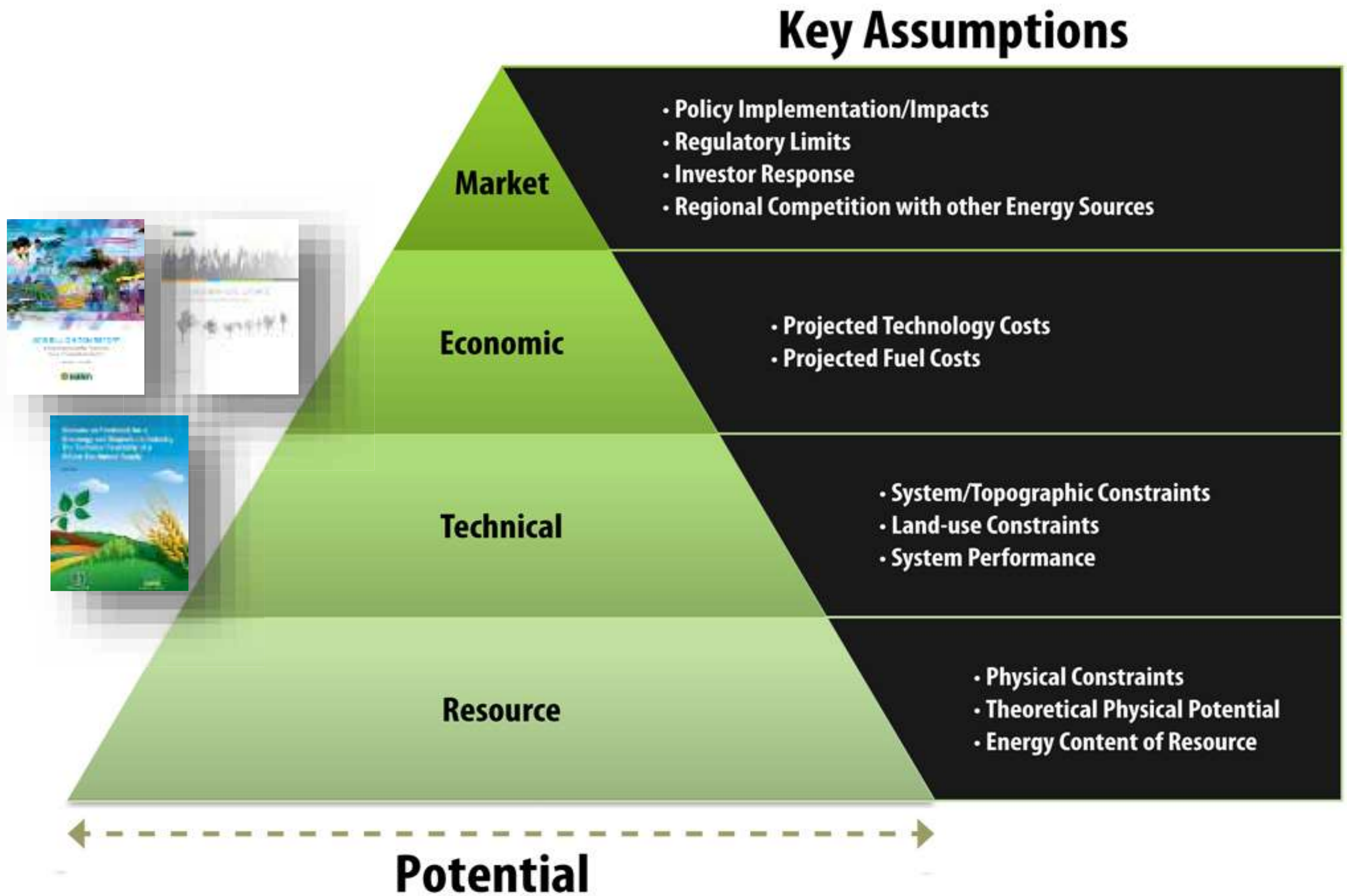
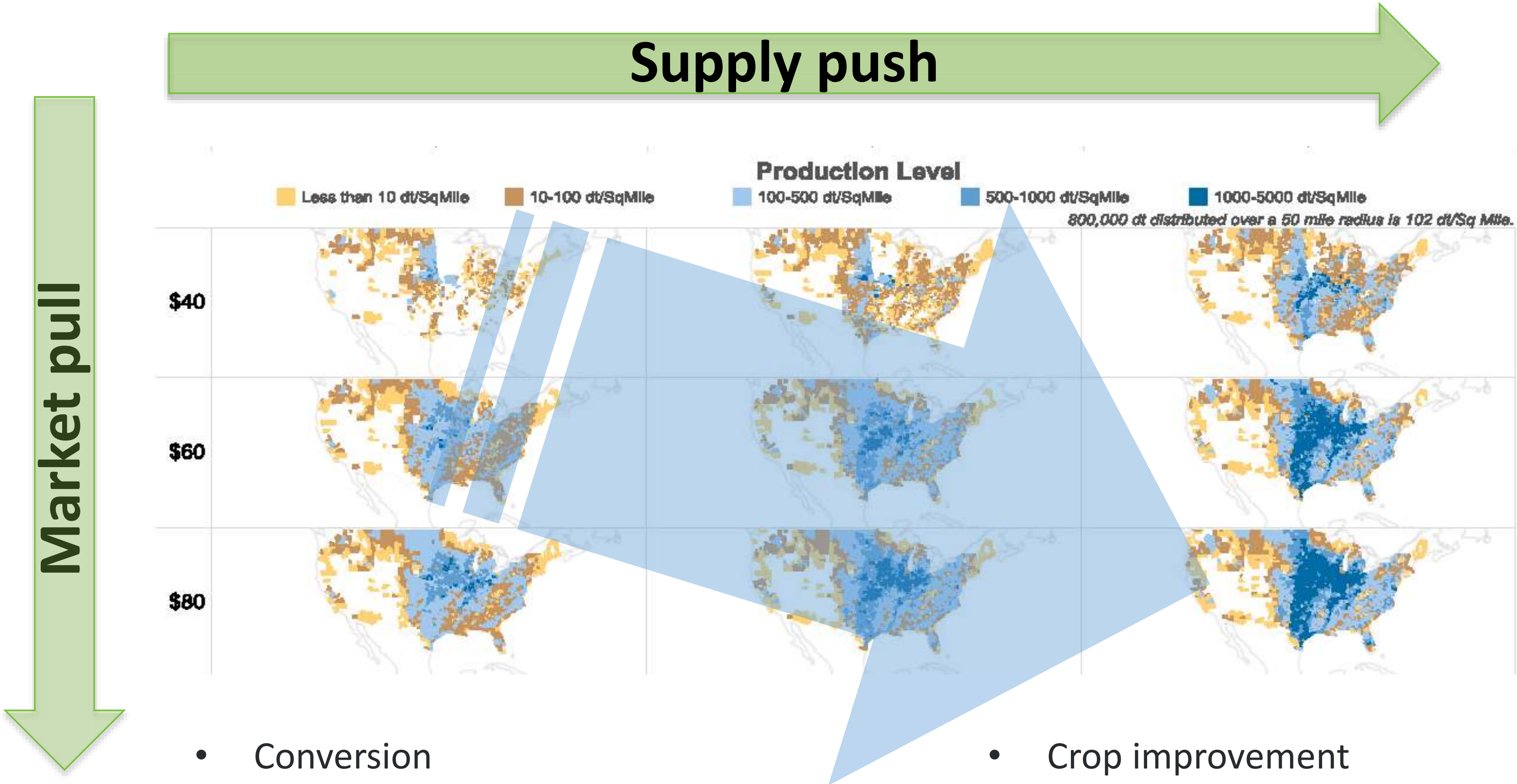
Advancing Resources



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

Advancing Resources



- Conversion
- Bioproducts
- International markets

- Crop improvement
- Advanced logistics
- Precision agriculture

BT16 Volume 2

	Indicator
Soil quality	1. Total organic carbon (TOC)
	2. Total nitrogen (N)
	3. Extractable phosphorus (P)
	4. Bulk density
Water quality and quantity	5. Nitrate concentration in streams (and export)
	6. Total phosphorus (P) concentration in streams (and export)
	7. Suspended sediment concentration in streams (and export)
	8. Herbicide concentration in streams (and export)
	9. Storm flow
	10. Minimum base flow
	11. Consumptive water use
	Additional: Water yield

	Indicator
Greenhouse gases	12. CO_2 equivalent emissions (CO_2 and N_2O)
Biodiversity	13. Presence of taxa of special concern
	14. Habitat area of taxa of special concern
Air quality	15. Tropospheric ozone
	16. Carbon monoxide
	17. Total particulate matter less than 2.5µm diameter ($PM_{2.5}$)
	18. Total particulate matter less than 10µm diameter (PM_{10})
	Additional: VOCs, SO_x, NO_x
Productivity	19. Aboveground net primary productivity or Yield

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

[yellow box] Addressed in BT16 volume 2

Summary

- Resource assessments indicate vast national sustainable potential, over 1 billion tons/yr.

- Future biomass utilization is a function of supply and demand interactions.

- Resource assessments can help evaluate impacts of supply push and market pull and inform strategies to increase biomass utilization.

- Future research should advance from “how much is there” to “how can it happen”.

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Thank you!

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Conclusions

Questions?

Email eere_bioenergy@ee.doe.gov

Please include "Billion-Ton Report Webinar" in the Subject Line

Thank you!