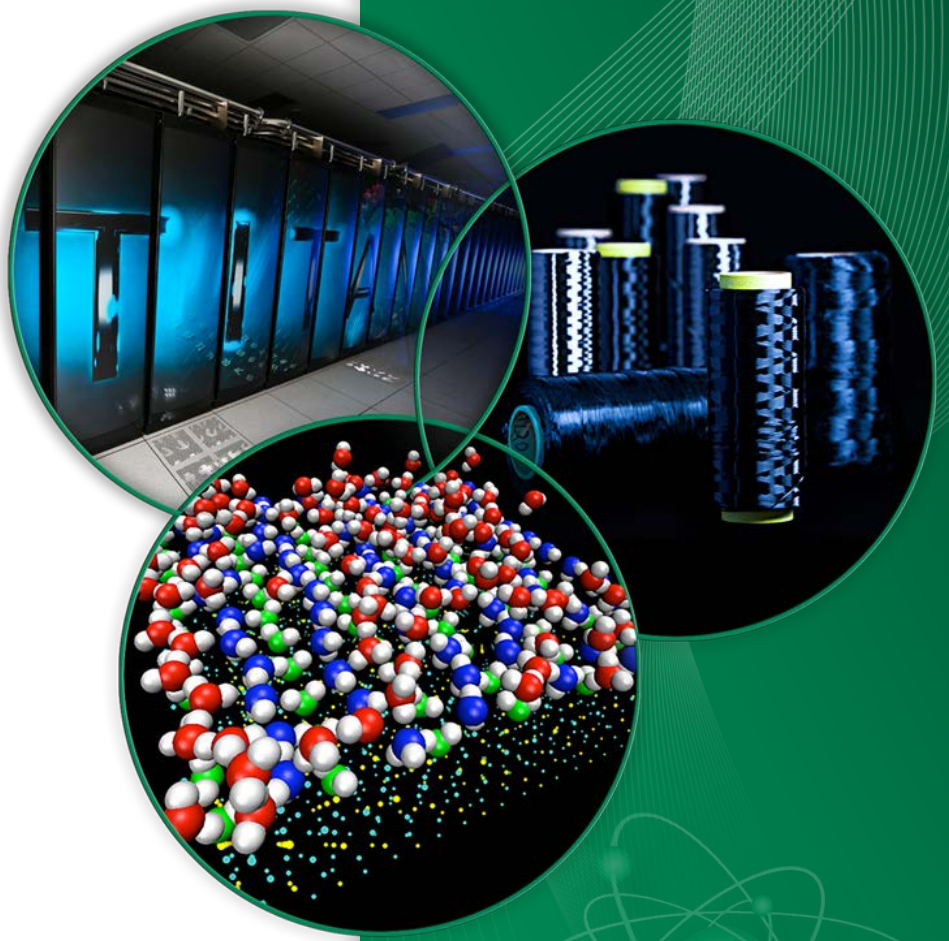
U.S. Biomass Resource Potential



CRC LCA 2015

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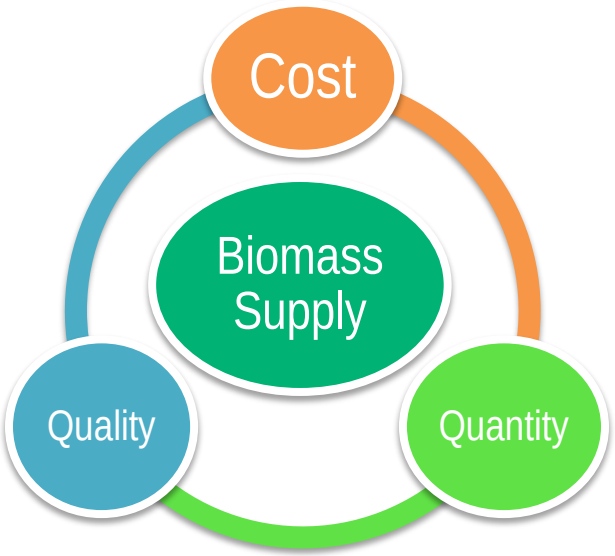
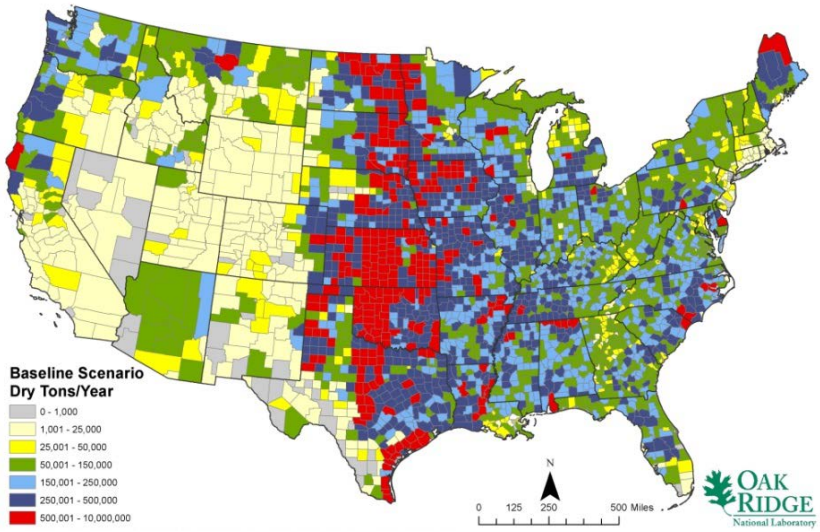
Outline

- Biomass resource analysis objectives.
- National resource assessments to date.
- 2011 Billion-ton Update summary.
- Yield assumptions.
- 2016 Billion-ton Report preview.
- www.bioenergykdf.net

Resource Analysis Objectives

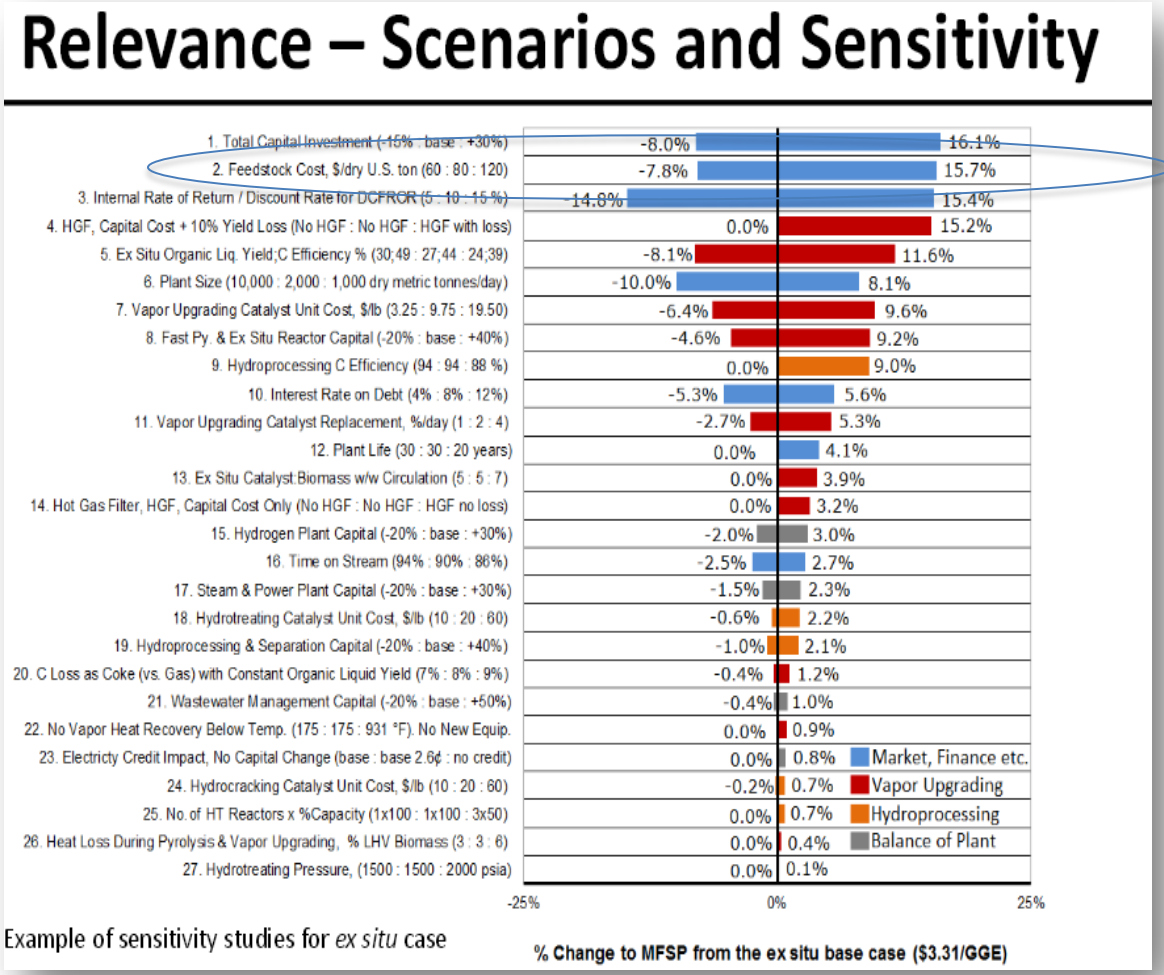
- In order to realize an advanced biofuels industry, we need a **significant sustainable supply of biomass**
- Goal: Provide timely and credible estimates of feedstock supplies and prices to support
  - the development of a bioeconomy; feedstock demand analysis of EISA, RFS2, and RPS mandates
  - the data and analysis of other projects in sustainability, logistics, conversion, etc.





Economics of Biomass and Conversion

- Feedstock cost is 2nd largest source of cost variability in 2014 Thermochemical Minimum Fuel Selling Price (-7.8% to +15.7%)
- In Biochemical and Thermochemical process design cases (Technoeconomic Analysis), feedstocks costs consistently account for about 1/3 of Minimum Fuel Selling Price (MFSP)



Example of sensitivity studies for *ex situ* case

Cost variability = RISK

http://www.energy.gov/sites/prod/files/2015/04/f21/thermochemical_conversion_dutta_210302.pdf

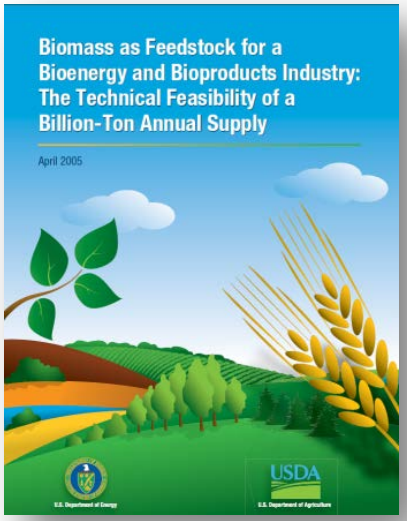
Previous Analyses

Billion-Ton Study (BTS), 2005

- **Technical assessment** of agricultural and forestry systems to supply low-valued biomass for new markets
- Identified adequate supply to displace **30%** of petroleum consumption; i.e. physical availability

Billion-Ton Update (BT2), 2011

- Quantified potential **economic availability** of feedstocks for 20-year projection
- Publicly released **county-level supply curves** for 23 candidate feedstocks through Bioenergy Knowledge Discovery Framework.



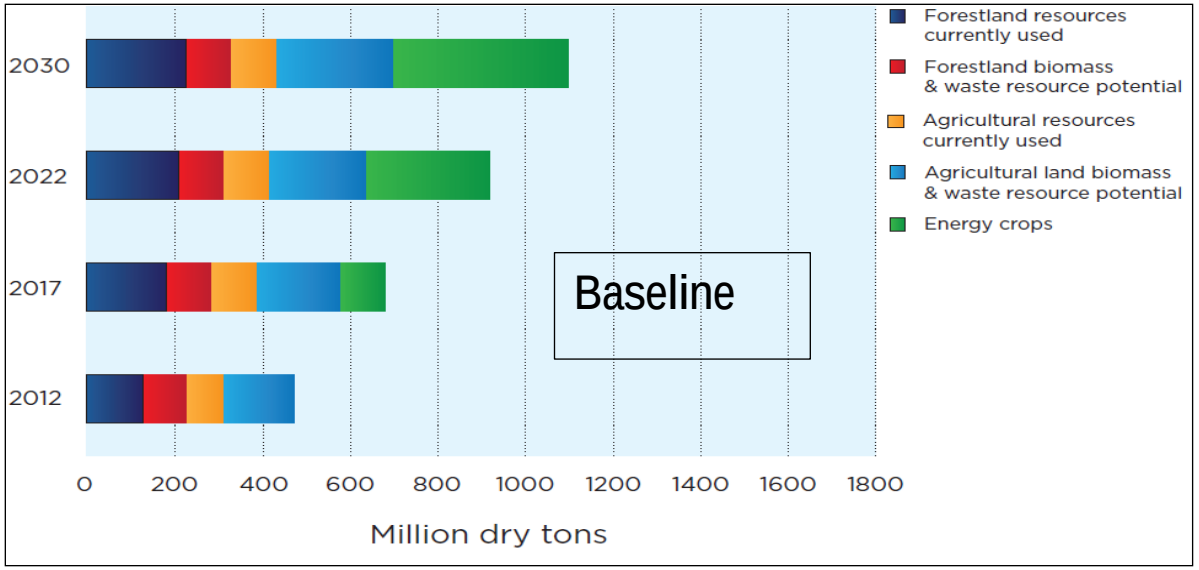
Preamble to the 2011 Billion-ton Update

- Resource assessment – not demand estimates
- Excluded algal feedstocks
- Included “major” feedstocks
- Costs were only to roadside/farmgate
- No specified product end use or conversion process
- Raw material in form as described with **losses only up to roadside**
- Does not represent full cost or actual, usable tonnage at facility

2011 U.S. Billion-Ton Update: <$60/dt

Baseline scenario

- **2012 combined resources from forests and agricultural lands total about 473 million.**
- **By 2030, estimated resources increase to nearly 1.1 billion dry tons.**



High-yield scenario

- **By 2030, total resource ranges from 1.4-1.6 billion dry tons annually.**
- **No high-yield scenario was evaluated for forest resources.**

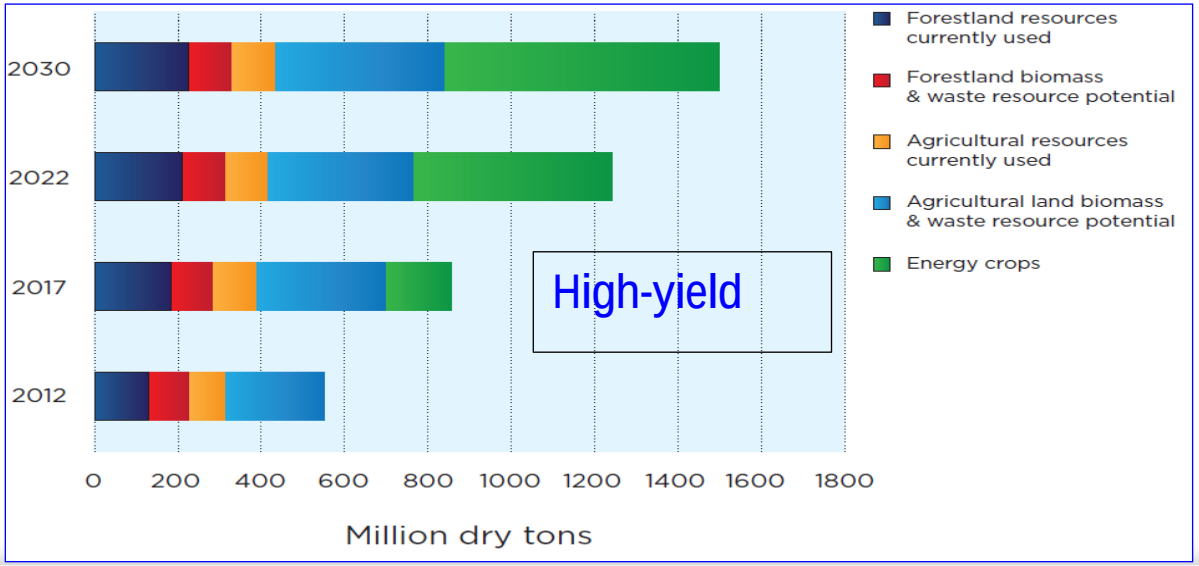


Table ES-1: Current and Potentially Available Feedstocks, $60/dt

Feedstock	2012	2017	2022	2030
		Million dry tons		
Baseline scenario				
Forest resources currently used	129	182	210	226
Forest biomass & waste resource potential	97	98	100	102
Agricultural resources currently used	85	103	103	103
Agricultural biomass & waste resource potential	162	192	221	265
Energy crops[a]	0	101	282	400
Total currently used	**214**	**284**	**312**	**328**
Total potential resources	**258**	**392**	**602**	**767**
Total – baseline	**473**	**676**	**914**	**1094**
High-yield scenario (2%–4%)				
Forest resources currently used	129	182	210	226
Forest biomass & waste resource potential	97	98	100	102
Agricultural resources currently used	85	103	103	103
Agricultural biomass & waste resource potential[b]	244	310	346	404
Energy crops	0	139–180	410–564	540–799
Total currently used	**214**	**284**	**312**	**328**
Total potential	**340**	**547–588**	**855–1009**	**1046–1305**
Total high-yield (2-4%)	**555**	**831–872**	**1168–1322**	**1374–1633**

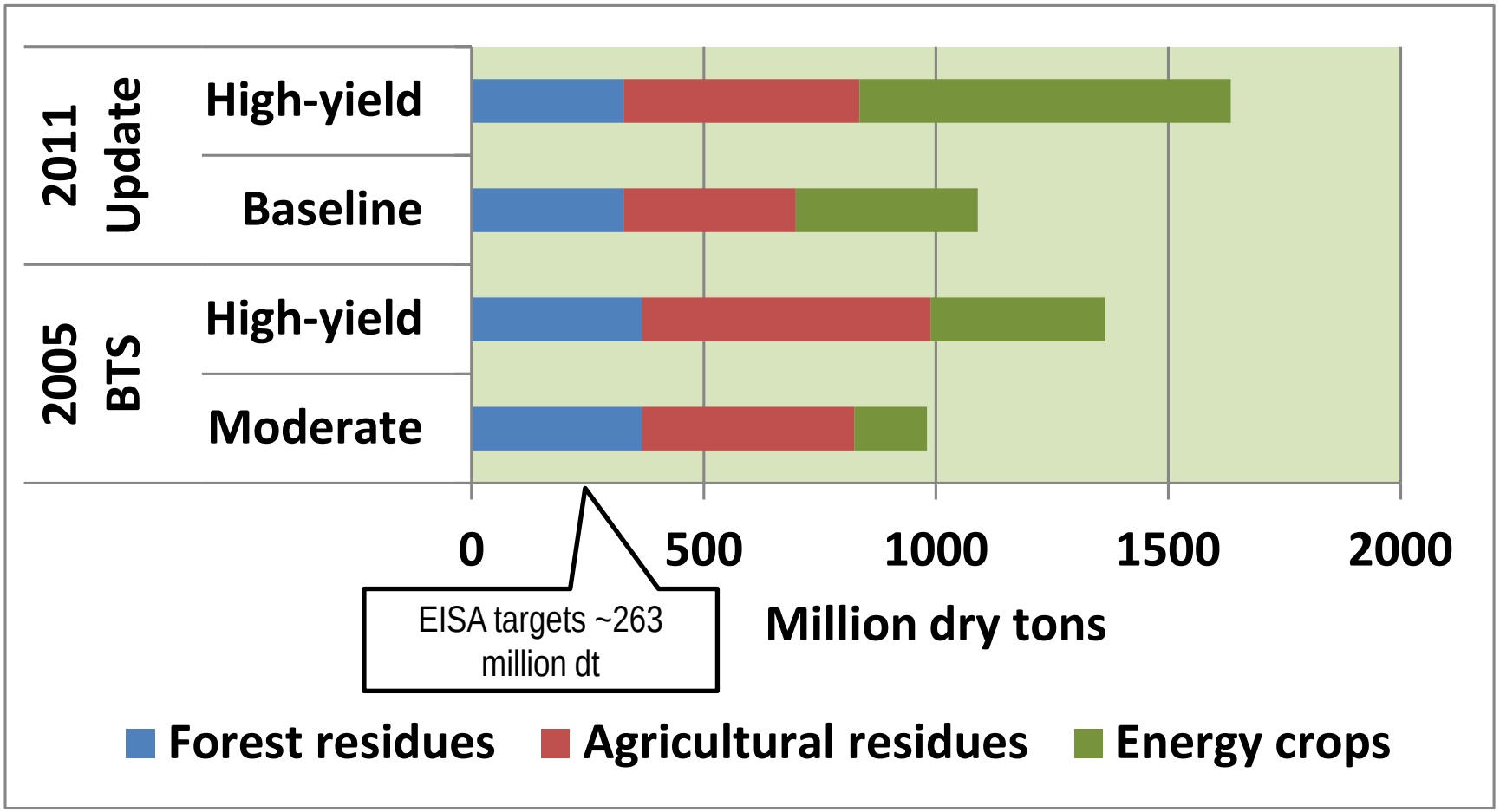
Perspective:

Under the baseline scenario at $60, in 2030:

- Over 750 million dry tons additional=~60 bg/yr
- Includes 400 million dt/yr of dedicated crops on 22 million acres of cropland and 40 million acres pastureland.
- 2013 cropland was 231 million acres, down from 271 million in 1982.
- 2013 pastureland was 460 million acres.
- From a supply perspective, EISA could be realized on residues alone. A greater bioeconomy vision would require energy crops.

Comparison of 2005 BTS with 2011 BT2

Comparison of 2030 at $60/dry ton with the 2005 BTS

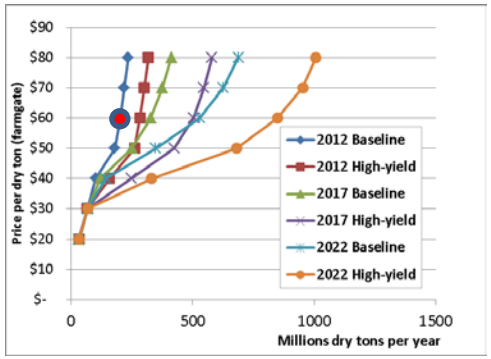


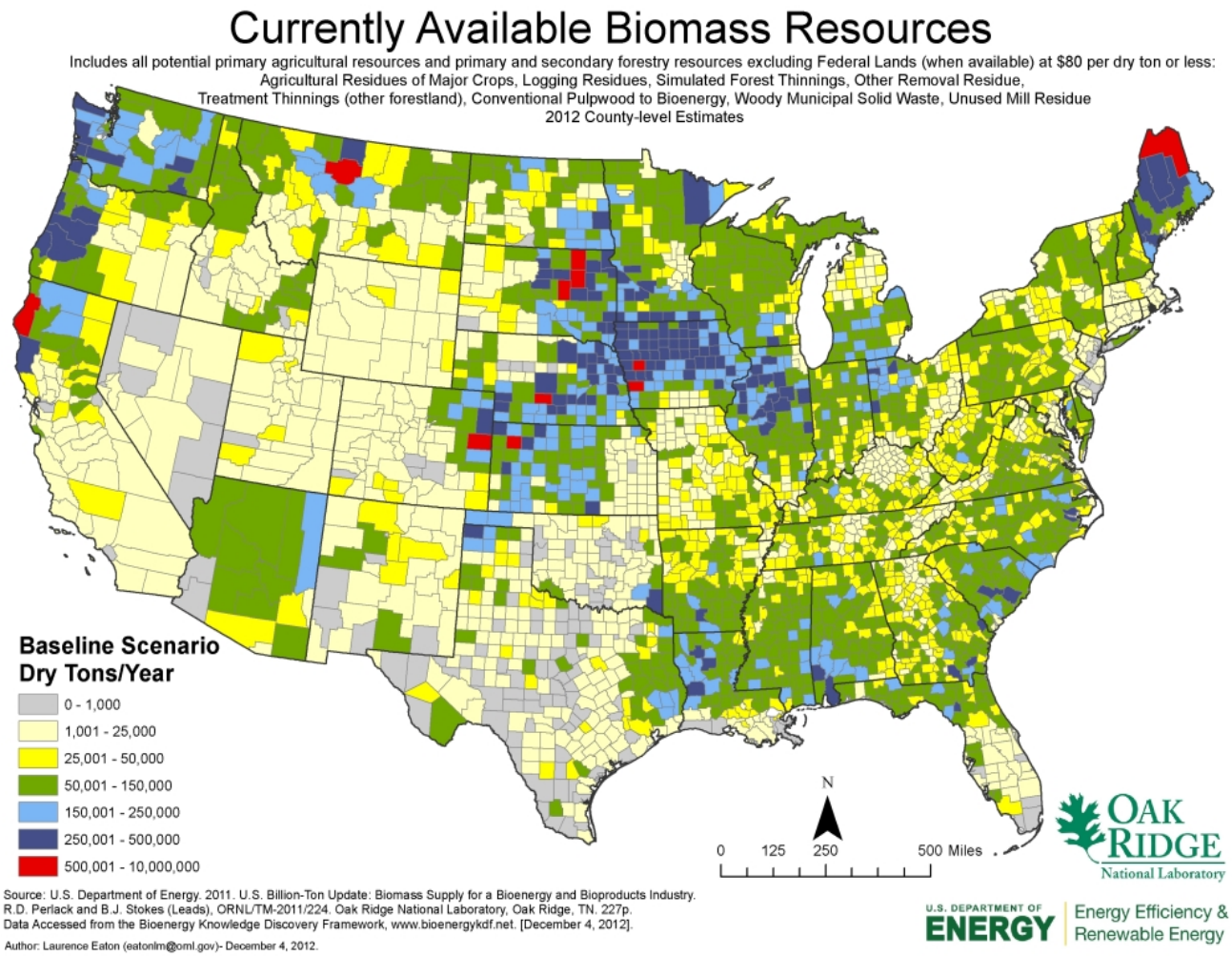
Near-term Potential

www.bioenergykdf.net

- **2012**
- **Baseline scenario**
- **$60 dry ton^{-1}**

201 x 10^6 dt



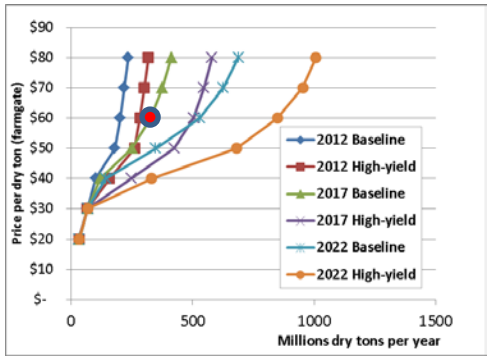


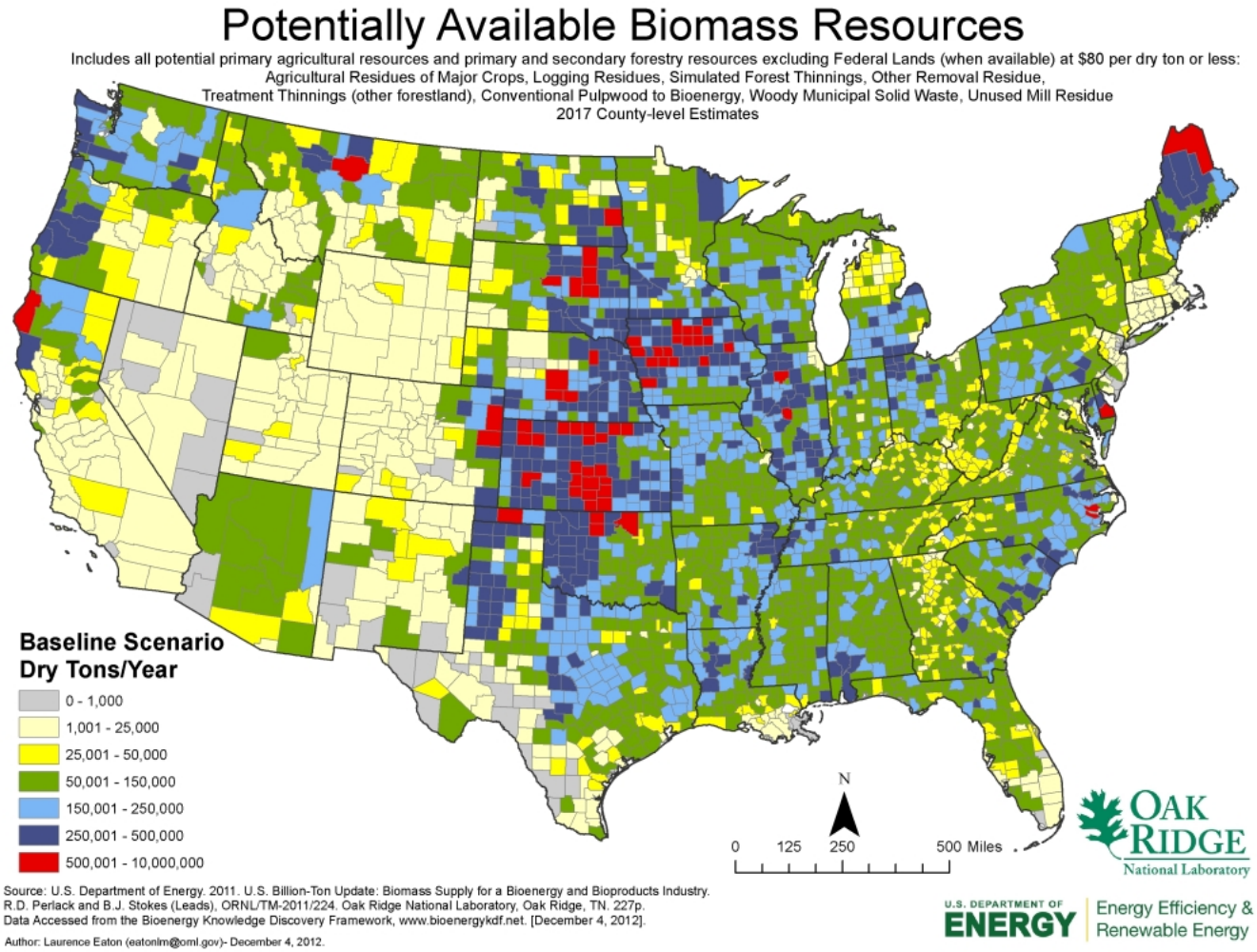
Billion-ton Results

www.bioenergykdf.net

- **2017**
- **Baseline scenario**
- **$60 dry ton^{-1}**

327 x 10^6 dt



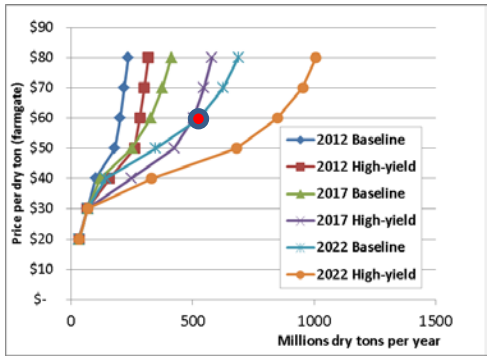


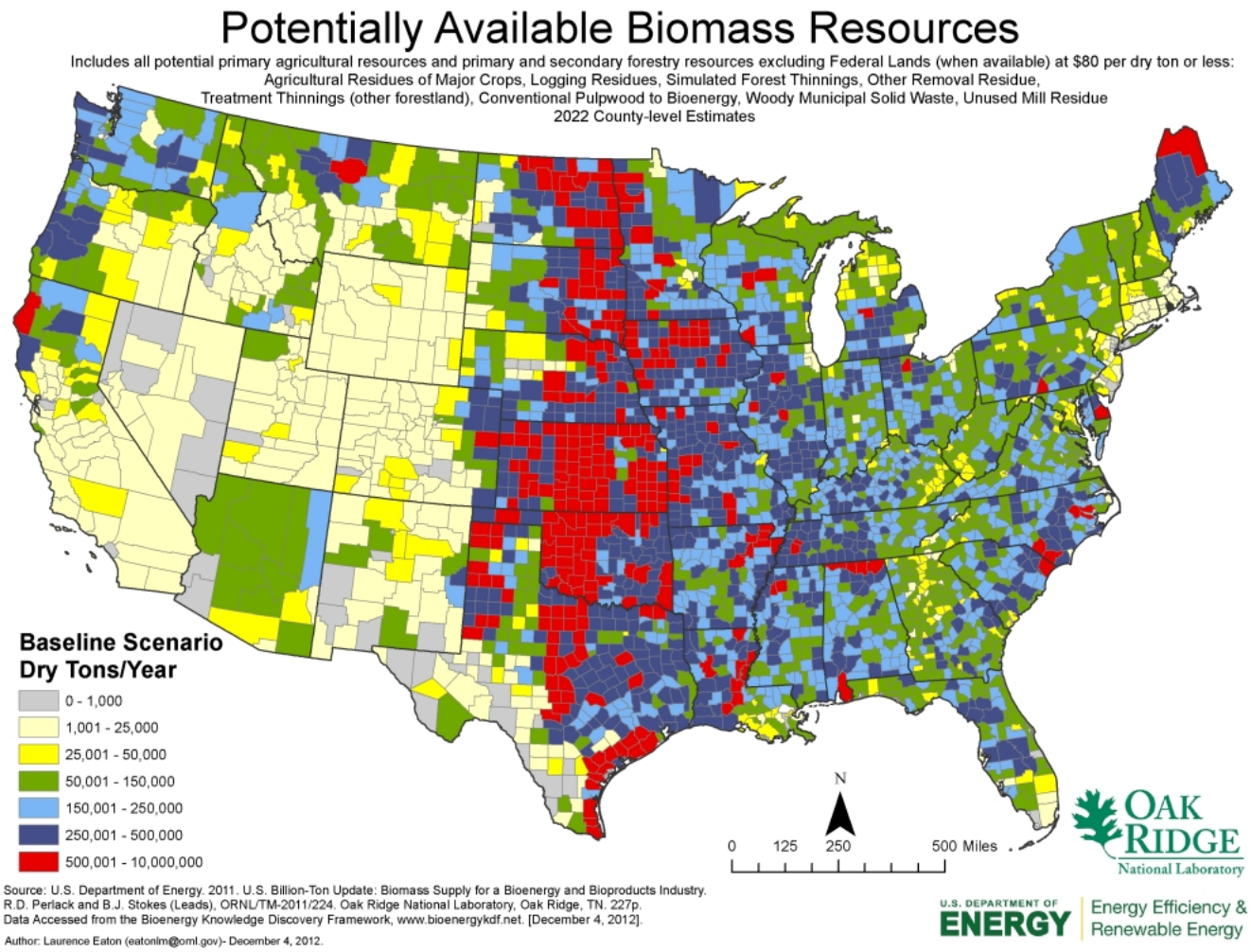
Billion-ton Results

www.bioenergykdf.net

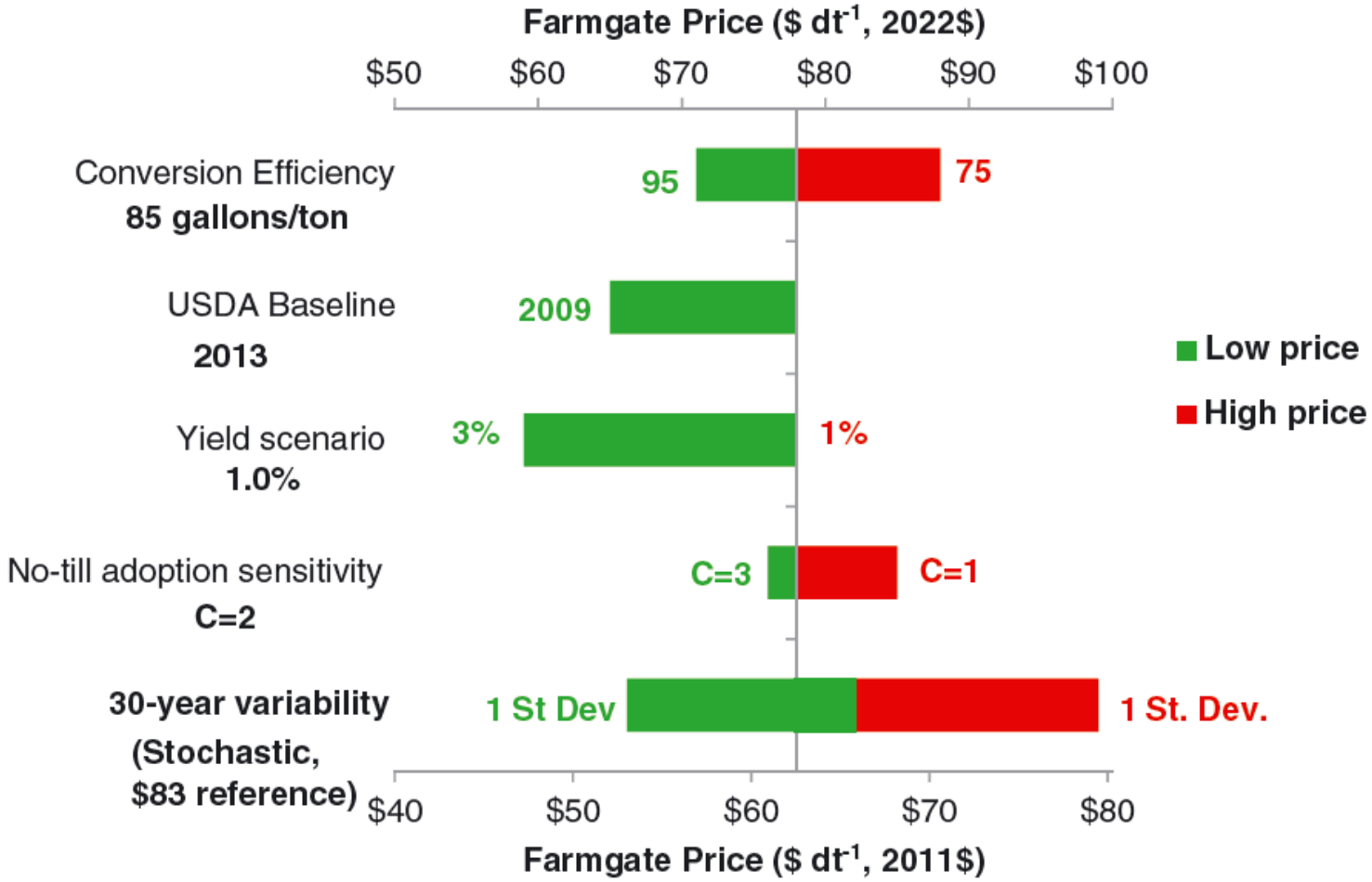
- **2022**
- **Baseline scenario**
- **$60 dry ton^{-1}**

529 x 10^6 dt





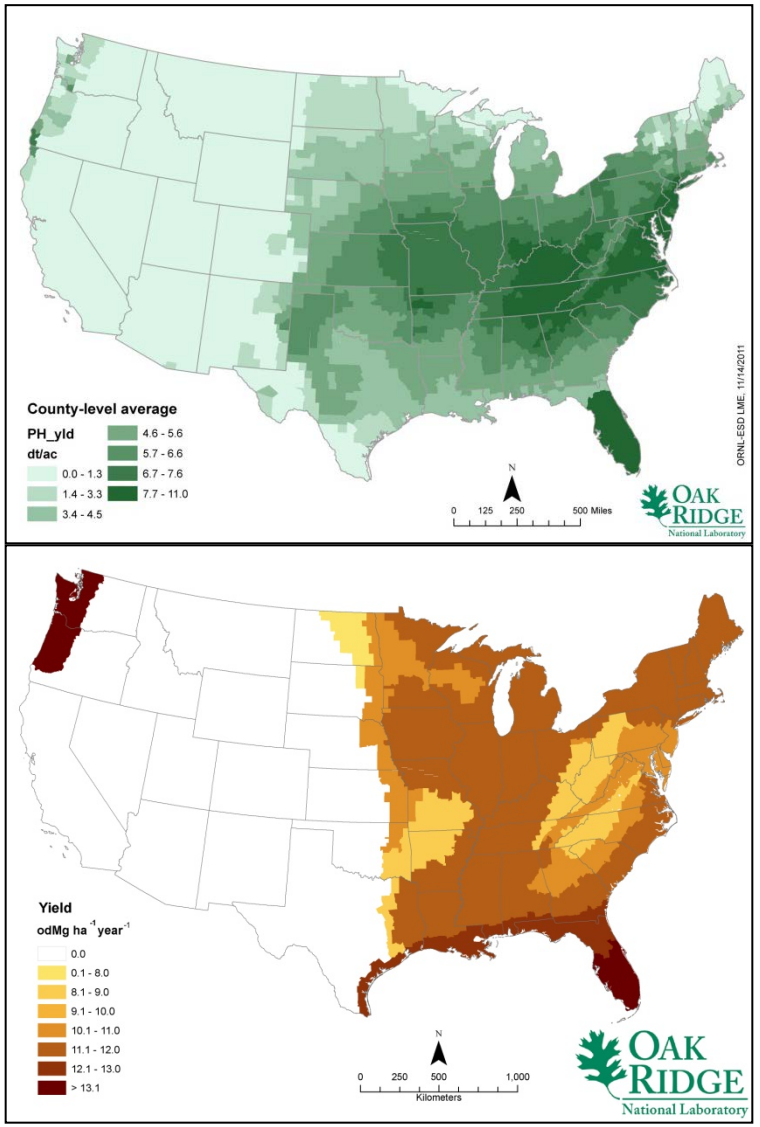
Sensitivity analysis to key variables, 250 million dry tons in 2022



Source: Langholtz MH, Eaton LM, Turhollow A, Hilliard MR. 2013 Feedstock Supply and Price Projections and Sensitivity Analysis. Biofuels Bioprod Biorefining-Biofpr [Internet]. 2014;8(4). Available from: http://onlinelibrary.wiley.com/doi/10.1002/bbb.1489/abstract

Energy Crop Productivity, 2011 BT2

- Herbaceous crop productivity
  - Baseline yields (dry tons/acre)
    - 2014 – 3.0 - 9.5
    - 2030 – 3.6 - 12.0
- Woody crop productivity
  - Baseline yields (dry tons/acre)
    - 2014 – 3.5 - 6.0
    - 2030 – 4.2 - 7.2

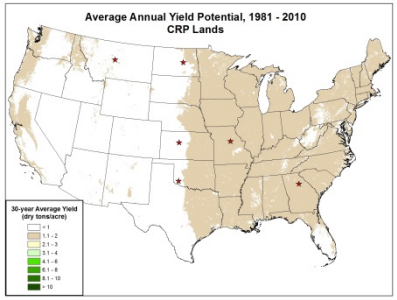


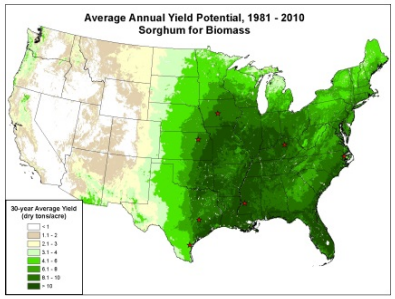
BT16, revised yields, national averages, high-yield scenarios (dt/ac/yr)

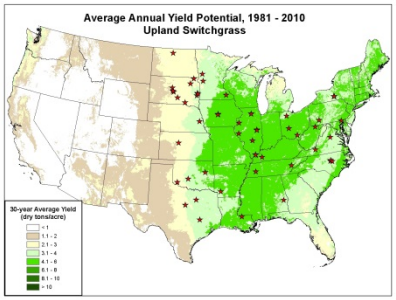
	2019			2040		
Scenario:	2%	3%	4%	2%	3%	4%
Switchgrass	2.9	3.0	3.1	7.0	8.0	9.2
Poplar	5.9	5.9	5.9	6.0	7.5	8.7
MxG	4.1	4.2	4.3	6.7	7.2	7.9
Energy Cane	9.2	9.3	9.5	13.9	16.7	19.9
Sorghum	11.7	11.0	11.4	14.1	14.1	15.7
Willow	7.5	7.8	8.2	10.5	11.9	13.4

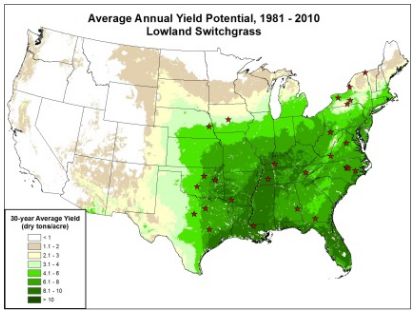
Enhanced Energy Crop Potential Yield, BT16

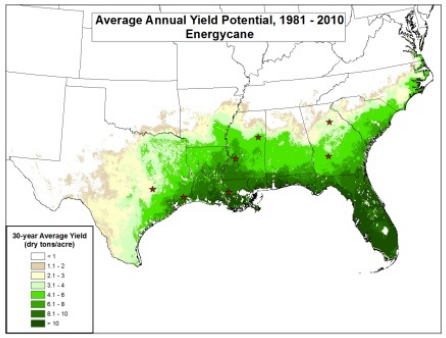
Herbaceous Energy Crops



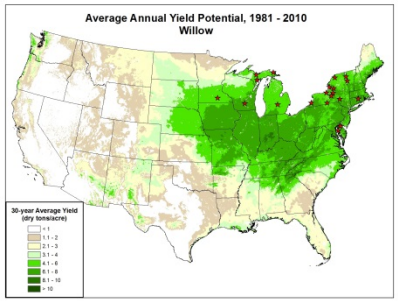


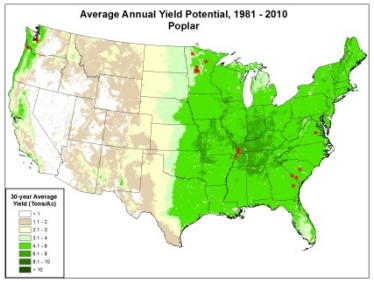


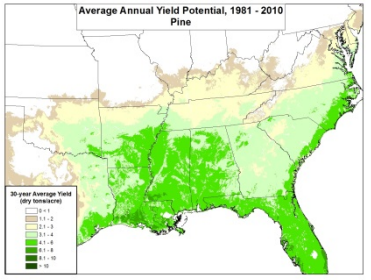




Woody Crops







Manuscript in preparation by SGI Field Trial and Resource Assessment Teams

Credit: Oregon State University PRISM Climate Group

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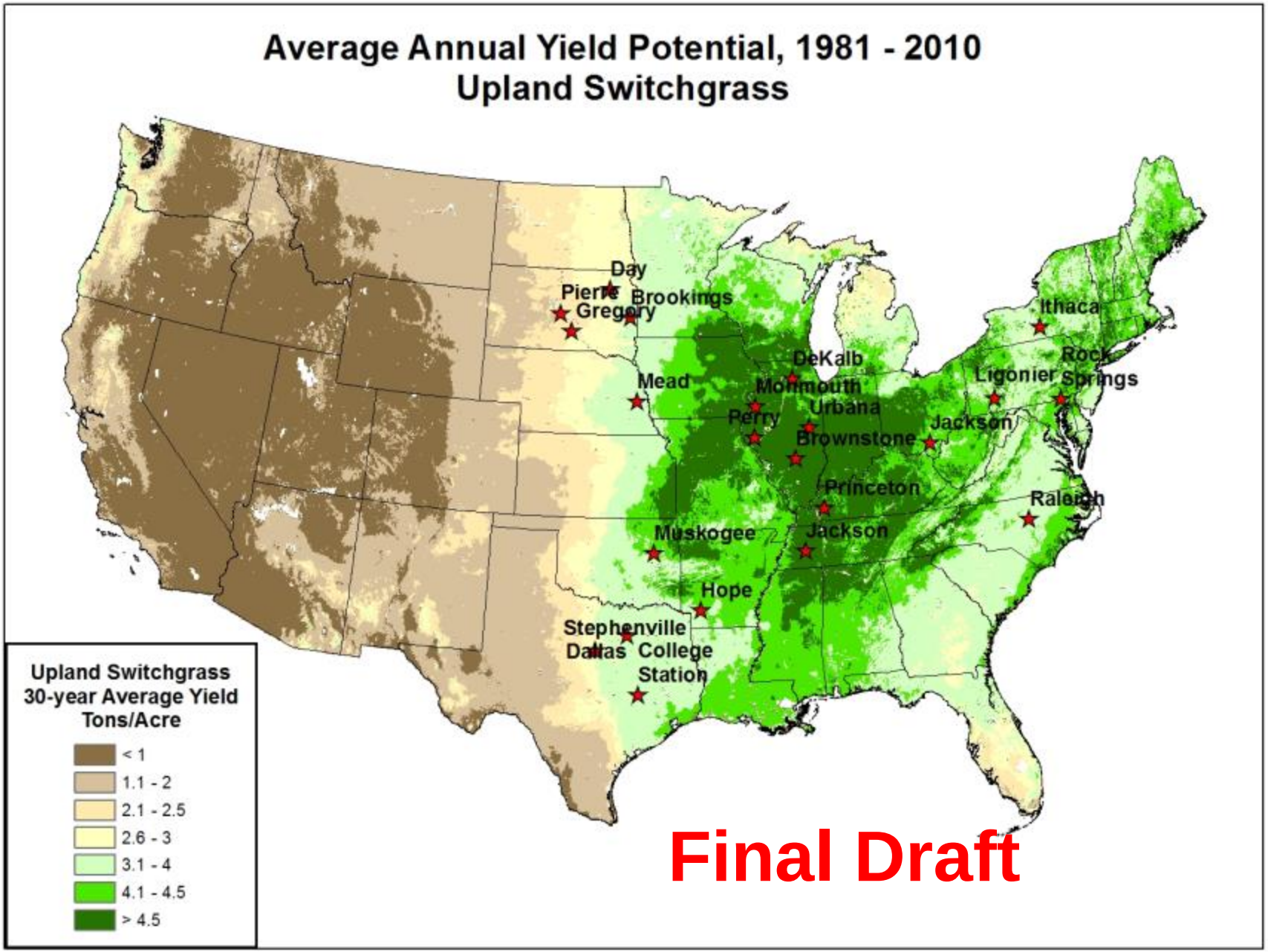
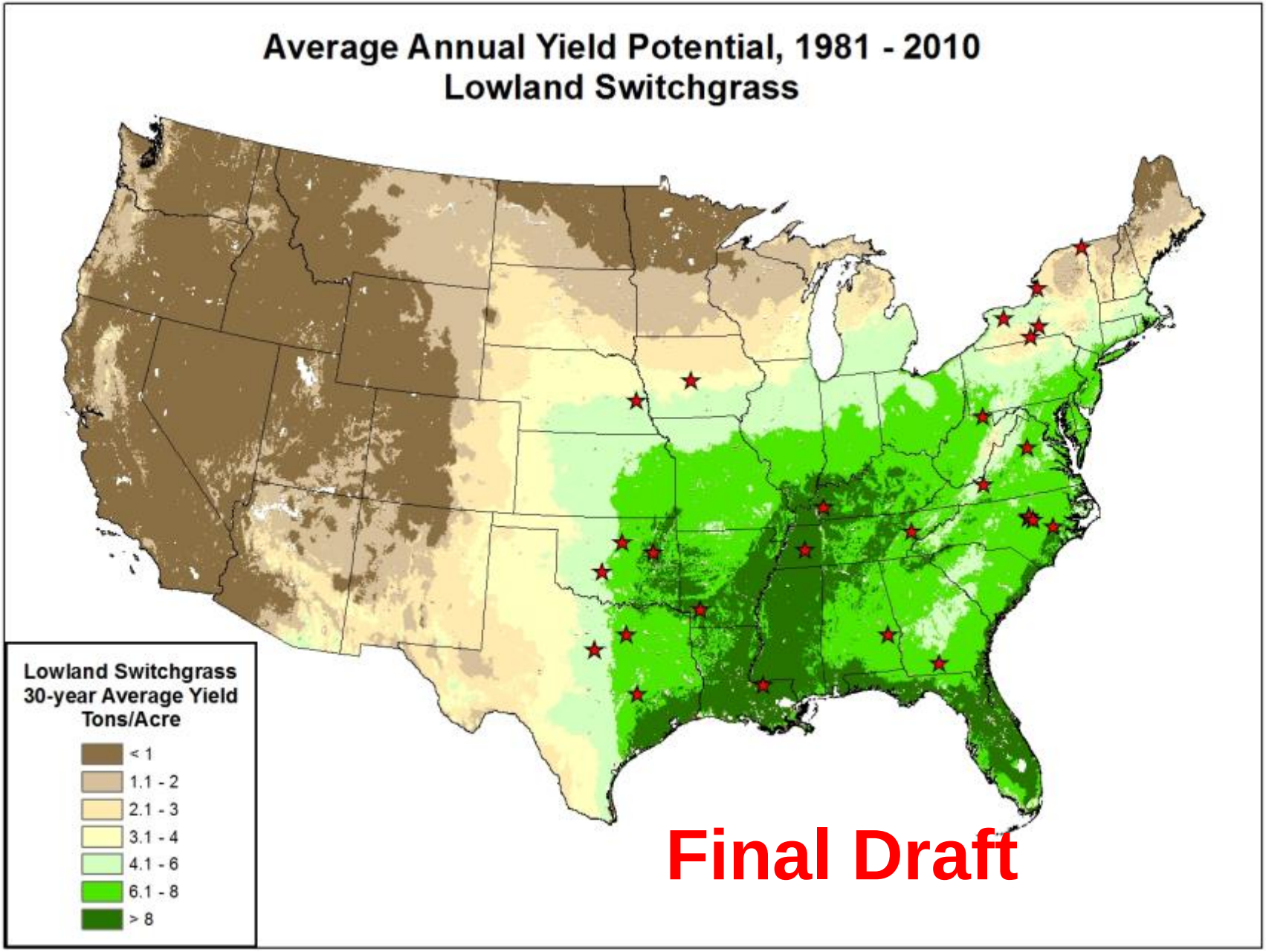
>40 participants from >110 trials

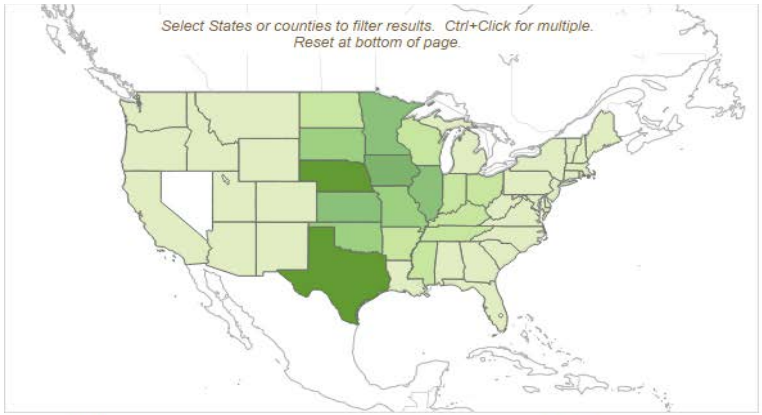

Average Annual Yield Potential, 1981 - 2010
Upland Switchgrass
Day
Pierre
Brookings
Gregory
Ithaca
DeKalb
Rock
Springs
Ligonier
Mead
Monmouth
Urbana
Perry
Jackson
Brownstone
Princeton
Raleigh
Muskogee
Jackson
Hope
Stephenville
Dallas
College
Station
Upland Switchgrass
30-year Average Yield
Tons/Acre
< 1
1.1 - 2
2.1 - 2.5
2.6 - 3
3.1 - 4
4.1 - 4.5
> 4.5
Final Draft

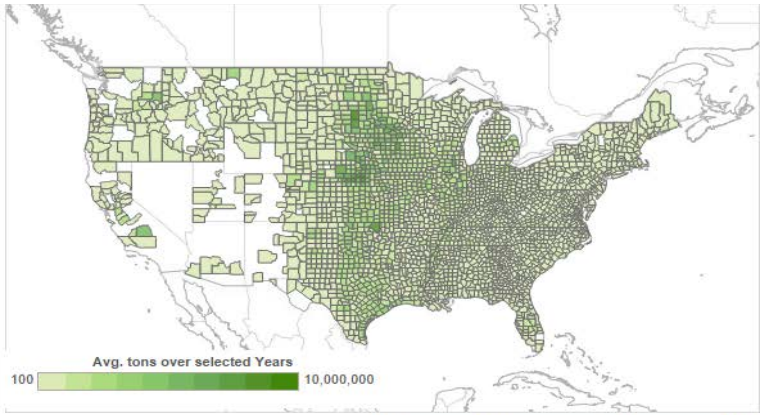

Average Annual Yield Potential, 1981 - 2010
Lowland Switchgrass
Lowland Switchgrass
30-year Average Yield
Tons/Acre
< 1
1.1 - 2
2.1 - 3
3.1 - 4
4.1 - 6
6.1 - 8
> 8
Final Draft

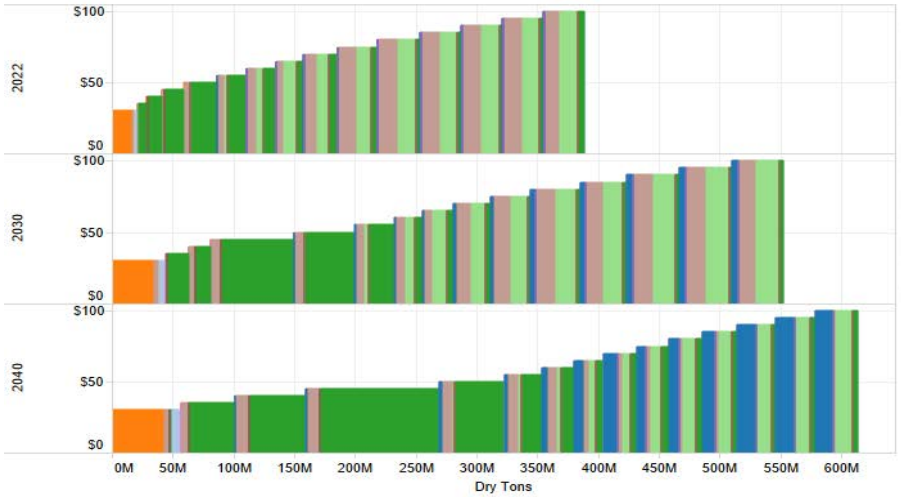
2016 Billion-Ton Report-Additions

- **Characterization of delivered supplies**: feedstock mixes, prices, comparison of logistics scenarios.
- **Additional sensitivity analyses** and specified-demand scenarios.
- **Interactive visualization** of biomass supplies, costs, types, and spatial distribution.
- **Additional crops:** Miscanthus, energy cane, poplars, and eucalyptus.
- Biomass **crop yields** derived from empirical model of 30-year climate average.
- Development and application of **POLYSYS forest module** for primary forest resources.
- Supplies and prices of **algae** from co-located production systems.
- **Two-volumes**: Volume 1, economic availability of feedstocks; Volume 2, environmental effects of select scenarios.

BT16 Farmgate: Pending interactive visualization (preliminary results, do not cite)

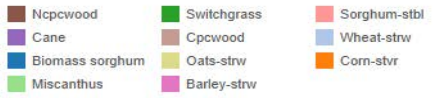




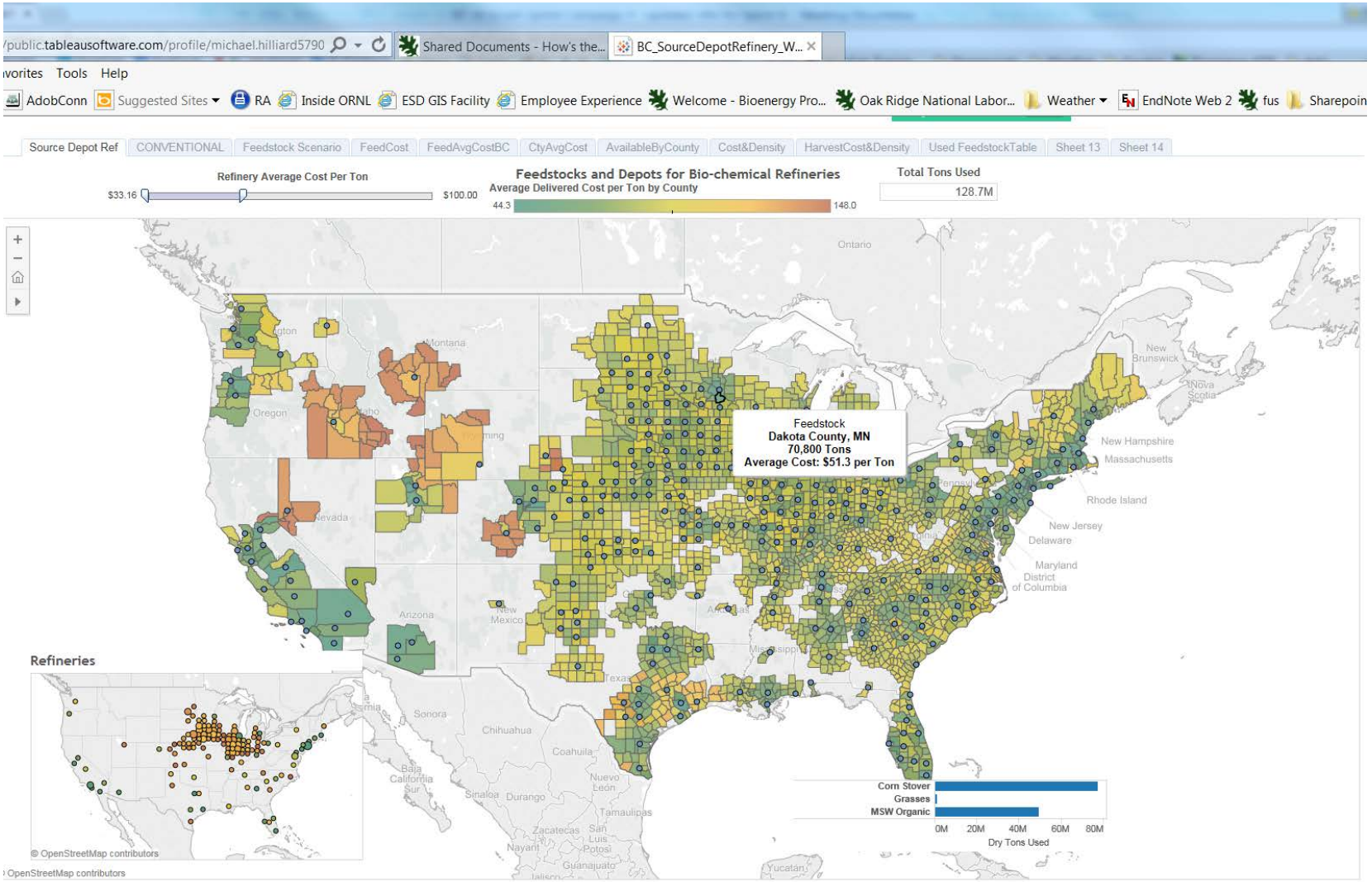


	2017	2022	2030	2040
Switchgrass		116,547,162	184,747,571	288,717,747
Cpcwood		131,791,440	146,786,868	74,552,886
Miscanthus		109,008,323	138,317,711	84,194,745
Corn-stvr	8,387,605	24,209,584	43,559,666	52,986,447
Biomass sorghum		3,133,188	31,313,181	101,960,934
Wheat-strw	2,322,085	3,302,095	6,789,460	9,175,833
Ncpcwood			399,665	521,039
Cane		451,461	277,434	549,274
Barley-strw	10,021	112,642	159,624	636,643
Sorghum-stbl	14,703	37,490	56,316	320,504
Oats-strw	6,236	7,415	13,697	17,391
Grand Total	10,740,650	388,600,801	552,421,193	613,633,442

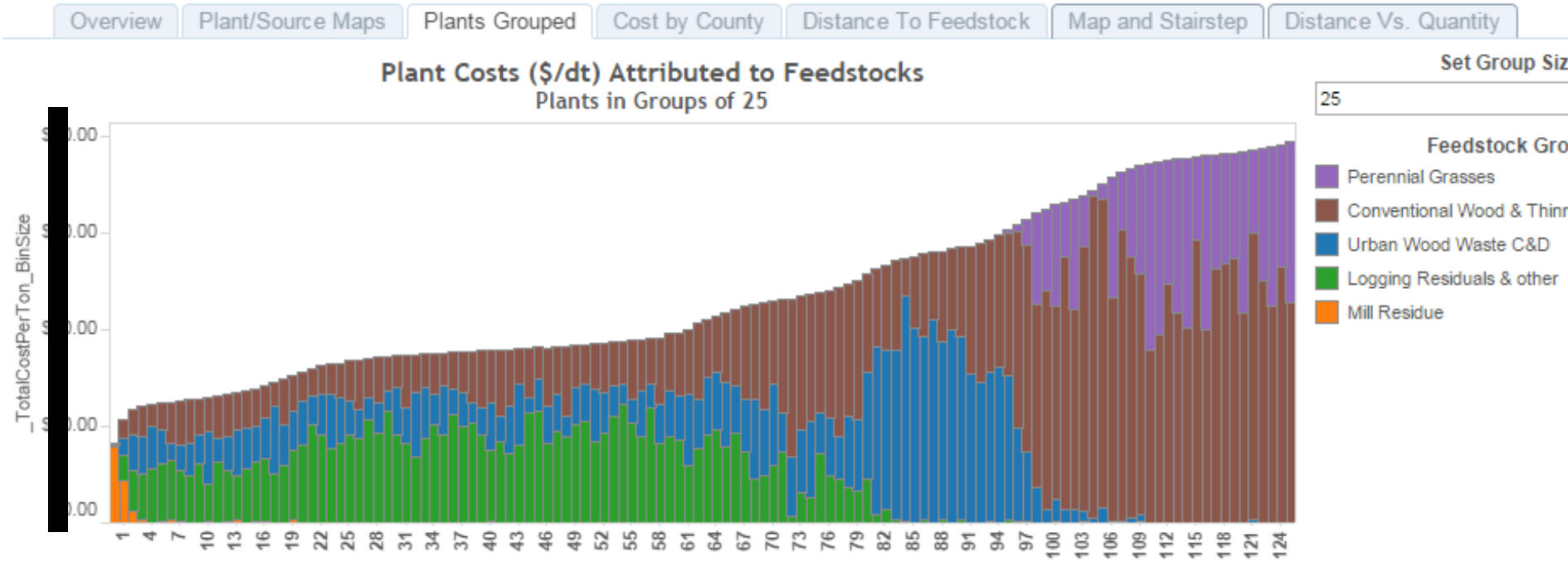
Click on a column, row or entry to filter results. Ctrl+Click to select multiple years or feedstocks.



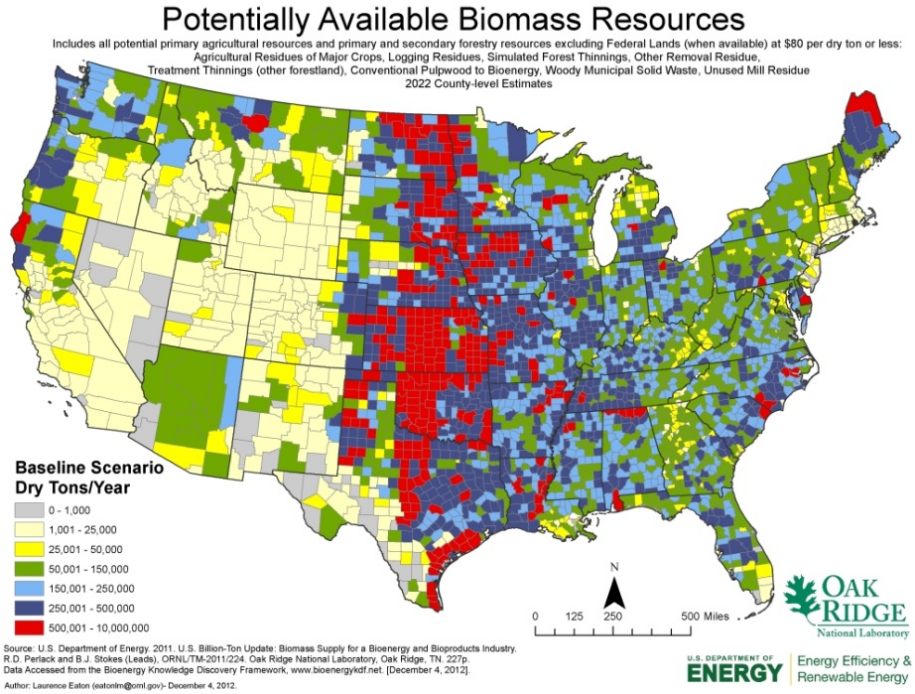
BT16 Delivered Supplies: (preliminary, do not cite)

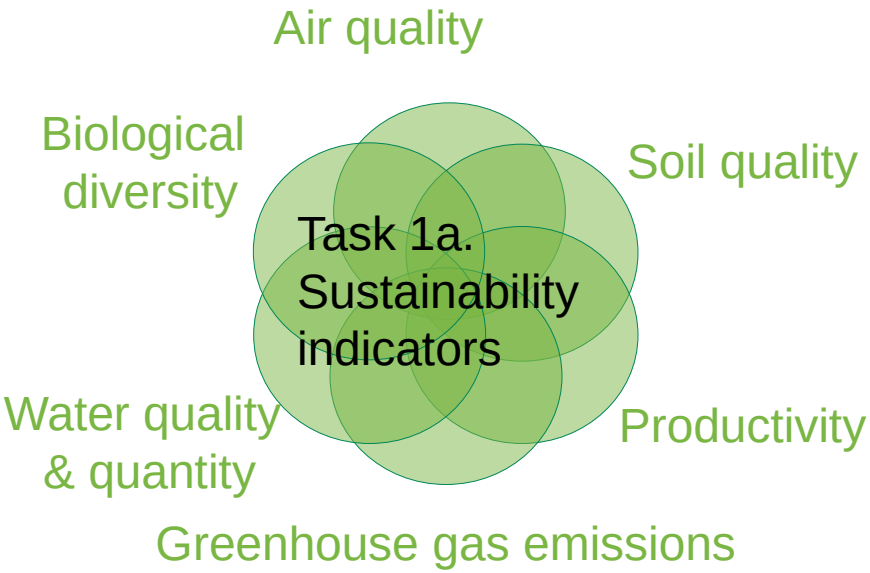


BT16 Delivered Supplies: (preliminary, do not cite, values redacted)



Approach: Sustainability in Billion Ton 2016





- Address multiple indicators in 6 indicator categories
- Use multiple models (SWAT, Century, GREET, F-PEAM, species distribution model)
- Involve multiple national labs and agencies
- Focus on 2040, with potential outputs for 2030 and 2020
- Outputs: projected environmental effects, tradeoffs among effects

Approach: Sustainability in Billion Ton 2016

Environmental sustainability indicators

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

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

	Indicator
Greenhouse gases (ANL)	12. CO_2 equivalent emissions (CO_2 and N_2O)
Biodiversity (ORNL)	13. Presence of taxa of special concern
	14. Habitat area of taxa of special concern
Air quality (NREL)	15. Tropospheric ozone
	16. Carbon monoxide
	17. Total particulate matter less than 2.5 μm diameter ($PM_{2.5}$)
	18. Total particulate matter less than 10 μm diameter (PM_{10})
	Possible additions: VOCs, SO_x, NO_x, NH_3
Productivity (ORNL)	19. Aboveground net primary productivity or Yield

Summary

- Biomass resource analysis aims to support national bioenergy and biofuels strategies and a bioeconomy vision.
- Aiming to release BT16 Volume 1 in July of at Bioenergy 2016, Volume 2 in September 2016.
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- Thank you!