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

Importance of Biomass Production and Supply

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Symbiosis Conference
Cornell University

Bryce Stokes, PhD

Senior Advisor
CNJV
Contractor - DOE

A Second Look – John's Plenary Talk

- DOE (BETO, SC, ARPA-e), other agencies, and partners are working to:
  - Understand and enhance the availability and accessibility of biomass feedstocks
  - Develop technologies and systems to reduce cost of feedstocks and overall final product cost
  - Improve quality of feedstocks at the biorefinery
- Energy crop yield is important for commercialization and important to BETO although production is not program's primary focus.
- Sustainability is very important.
- New, integrated approaches, especially in feedstock supply and logistics with production and conversion, are being developed with partners.

Billion Ton Update

- Originally published in 2005 with about billion dry tons annually. Includes agriculture and forestry
- Update in 2011 has ~half to ~1.5 billion dry tons.
- Includes economics, sustainability, LUC, time, scenarios, etc.
- Focus
  - ✓ County-by-county feedstock availability by cost, type, year, scenario
  - ✓ Models yield and yield increases for ag residues and energy crops
- Additional efforts underway
  - Transportation and storage costs
  - Effects of quality and blended feedstocks
  - Improved economics data
  - Better regional yield data

https://bioenergykdf.net/

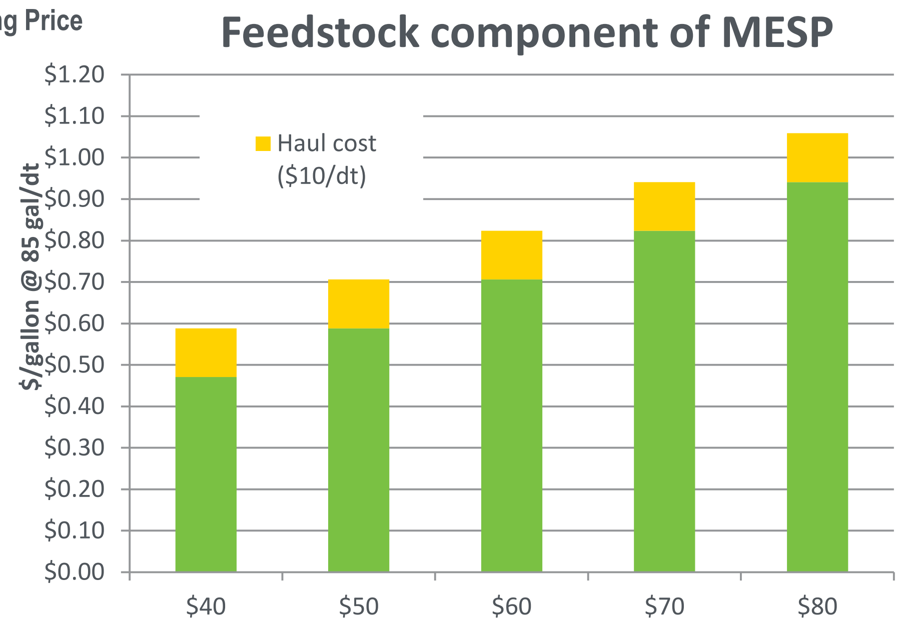
Why a Billion Tons?

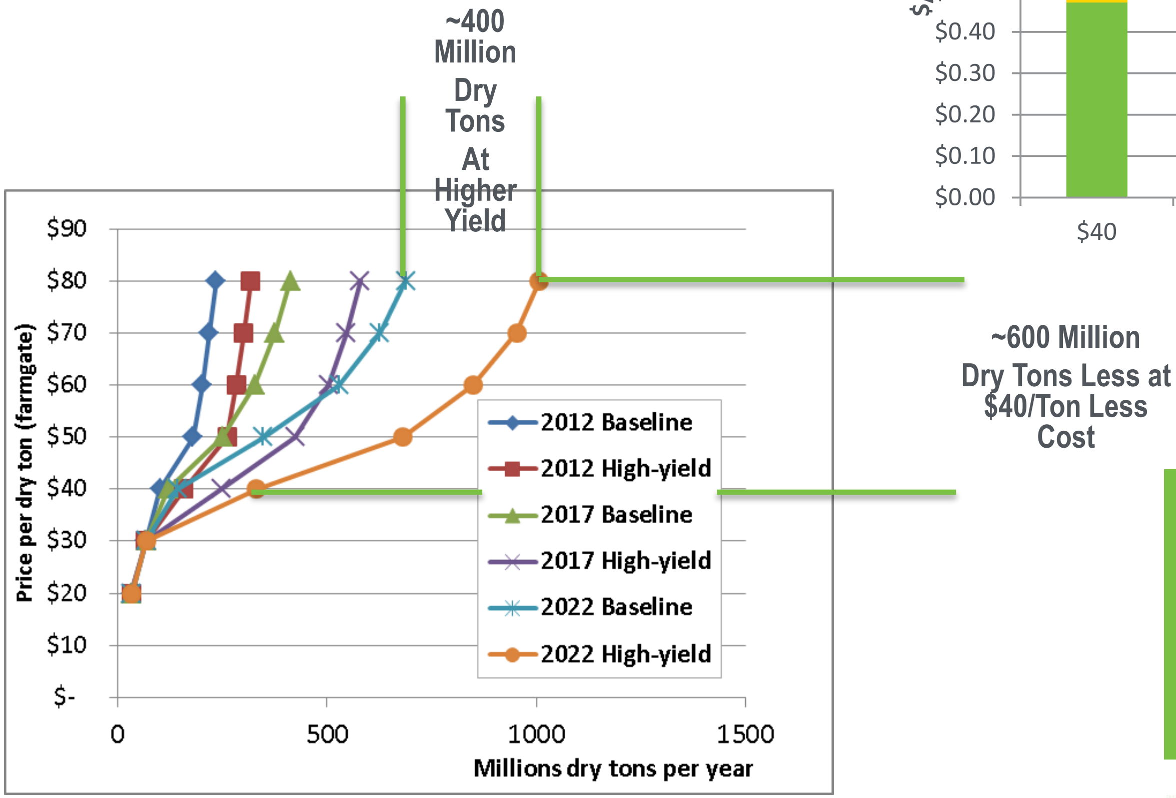
A new bioeconomy from a billion tons will

- Provide about 68 billion gallons of biofuels or 980 billion kWh per year
- Displace almost 50% of annual gasoline consumption or about 30% of petroleum consumption
- Provide electricity for 87 million households
- Almost twice the current RFS levels of biofuels
- CO_2 reductions of about 600 million tons
- About 2 million jobs and about $100 billion economic output by 2022

Feedstock Availability and Costs (or vice versa)

Higher costs can lead to increased availability, but result in higher prices for products





Increased productivity can lead to more availability at a lower cost under stable market conditions

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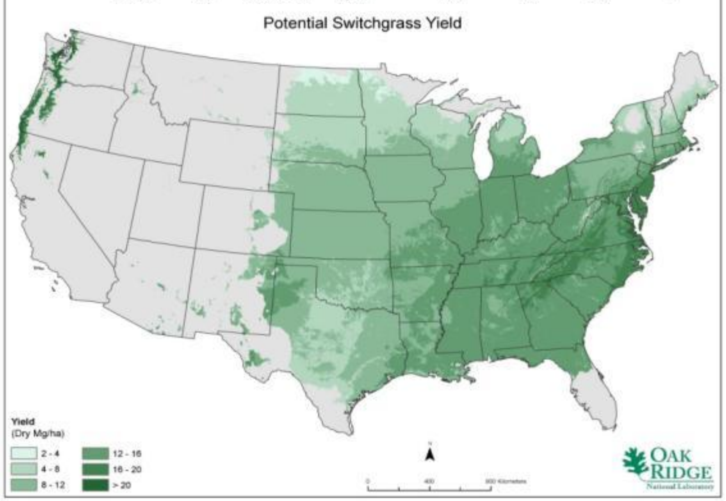
Perennial Grasses – Production Costs and Productivity

ID	SITE	DD_LAT	DD_LONG	CULTIVAR	ECOTYPE	YIELD_MG_HA	YEAR_PLNTD	YEAR_HAR	STAND_AGE
24	Site 2	43.33	-89.38	Dacotah	Upland	6.16	1997	1998	2
24	Site 2	43.33	-89.38	Dacotah	Upland	6.93	1997	1999	3
24	Site 2	43.33	-89.38	Forestburg	Upland	7.19	1997	1998	2
24	Site 2	43.33	-89.38	Dacotah	Upland	7.81	1997	2000	4
24	Site 2	43.33	-89.38	Sunburst	Upland	8.45	1997	1998	2
24	Site 2	43.33	-89.38	Dacotah	Upland	8.53	1997	2001	5
24	Site 2	43.33	-89.38	Forestburg	Upland	9.32	1997	2000	4
24	Site 2	43.33	-89.38	Cave-in-Rock	Upland	9.55	1997	1998	2
24	Site 2	43.33	-89.38	Trailblazer	Upland	9.98	1997	1998	2
24	Site 2	43.33	-89.38	Forestburg	Upland	10.00	1997	1999	3
24	Site 2	43.33	-89.38	Shawnee	Upland	10.20	1997	1998	2
24	Site 2	43.33	-89.38	Trailblazer	Upland	10.72	1997	1999	3
24	Site 2	43.33	-89.38	Sunburst	Upland	10.77	1997	1999	3
24	Site 2	43.33	-89.38	Forestburg	Upland	10.95	1997	2001	5
24	Site 2	43.33	-89.38	Trailblazer	Upland	11.16	1997	2000	4
24	Site 2	43.33	-89.38	Sunburst	Upland	11.55	1997	2000	4

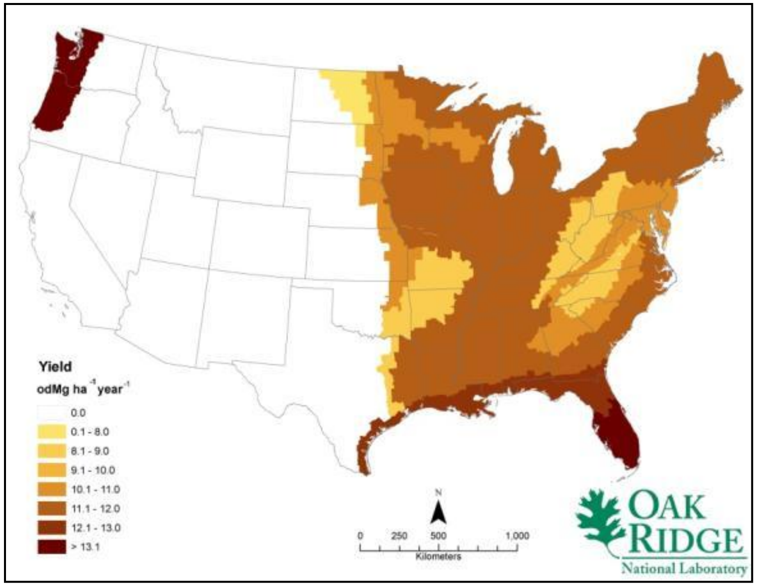
Item	Units	North-east	Appalachia	South-east	Delta	Corn Belt	Lake States	Southern Plains	Northern Plains
Stand life	Years	10	10	10	10	10	10	10	10
Productivity	dry tons/acre	4.0–7.5	5–9.5	3.5–9.5	3–7	4–7	3.5–5	2–6.5	2–6.5
Establishment									
Seed	$/lb.	$10	$22	$22	$22	$10	$10	$22	$10
Planting	lb./acre	5	5	5	5	5	5	5	5
Replants	percent	25	25	25	25	25	25	25	25
No-till drill	-	1-time	1-time	1-time	1-time	1-time	1-time	1-time	1-time
Total kill herbicide	No. applications	1-time	1-time	1-time	1-time	1-time	1-time	1-time	1-time
Pre-emergent herbicide	No. applications	1-time	1-time	1-time	1-time	1-time	1-time	1-time	1-time
Phosphorous	lbs P205/ acre	40	40	40	40	40	40	40	40
Potassium	lbs K20/ac	80	80	80	80	80	80	0	0
Lime	tons/acre	1	2	2	2	1	1	0	0
Total establishment costs	**$/acre**	**$210**	**$340**	**$330**	**$330**	**$200**	**$200**	**$220**	**$150**
Maintenance years									
Reseeding	year applied	2	2	2	2	2	2	2	2
Pre-emergent herbicide	No. applications	0	0	0	0	0	0	0	0
Nitrogen	lbs/acre	60	70	70	50	60	40	40	40
Phosphorous	lbs P205/ acre	0	0	80	0	80	0	0	0
Potassium	lbs K20 /acre	0	0	80	0	80	0	0	0
Harvest costs	**$/dry ton**	**$19.50 – $21.00**	**$18.50 – $19.90**	**$18.00- $20.20**	**$18.60 – $20.60**	**$19.20 – $20.60**	**$20.60 – $21.90**	**$19.20 – $22.10**	**$19.40 – $22.30**



- **Herbaceous crop productivity**
  - **Varies geographically**
  - **Baseline yields (dry tons/acre)**
    - **2014 – 3.0 - 9.9**
    - **2030 – 3.6 - 12.0**
  - **Database available**

Woody Crops – Production Costs and Productivity

Item	Units	Poplar	Pine	Eucalyptus	Willow (coppiced)
Rotation	Years	8	8	8	4[a] (5 harvests)
Spacing	sq. ft.	60	60	60	7.5
	trees/acre	726	726	726	5800
Productivity	dry tons/acre-year	3.5–6.0	5.0–5.5	6.0	5.1
Growing range	Region	Northeast, Lake States, Northwest, Midwest, Plains	Southeast	Sub-tropics	Northeast and Lake States
Establishment - year 1					
Cuttings	$/tree	$0.10	$0.06	$0.10	$0.12
Planting	$/tree	$0.09	$0.09	$0.09	$0.02
Replants	percent	5	5	5	0
Moldboard plow	-	1-time	1-time	1-time	1-time
Disk	-	1-time	1-time	1-time	1-time
Cultivate	-	2-times	2-times	2-times	2-times
Total kill herbicide	No. applications	1-time	1-time	1-time	1-time
	lbs a.i./acre	1.5	1.5	1.5	1.5
Pre-emergent herbicide	No. applications	1-time	1-time	1-time	1-time
	lbs a.i./acre	1.5	1.5	1.5	1.5
Phosphorous	lbs/acre	0	40	0	0
Establishment costs	$/acre	$310	$280	$310	$1120
Maintenance years					
Cultivate - year 2	-	2-times	2-times	2-times	1-time
Cultivate - year 3		1-time	1-time	1-time	None
Pre-emergent herbicide - year 2	No. applications	1	1	1	1
	lbs a.i./acre	1.5	1.5	1.5	1.5
Lime - year 3	tons/acre	90	90	90	100
	year applied	-	year3	year3	-
Nitrogen - year 4 and 6	lbs/acre	90	90	90	100
	year applied	4 and 6	2,4, and 6	4 and 6	4
	-	-	-	-	-
Phosphorous - year 3	lbs/acre	20	40	15	-
	year applied	3	3	3	-
Potassium - year 3	lbs/acre	35	40	25	-
	year applied	3	3	3	-
Maintenance costs – year 2	$/acre	$60	$100	$100	$30
Maintenance costs – year 3–8	$/acre	$220	$200	$200	$100[b]
Harvest costs	**$/dry ton**	**$20**	**$20**	**$20**	**$15**



- Woody crop productivity
  - Varies geographically
  - Baseline yields (dry tons/acre)
    - 2014 – 3.5 - 6.0
    - 2030 – 4.2 - 7.2
  - Database available

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Land Use

Includes CRP land, ~ 30 million acres

Table 1

Agricultural and nonagricultural uses of U.S. land, 2007

Land use	Acreage: 48 States	Acreage: United States	Proportion of total: 48 States	Proportion of total: United States
	------*Million acres*------		------*Percent*------	
Agricultural:				
Cropland—				
Cropland used for crops[1]	335	335	17.7	14.8
Idle cropland	37	37	2.0	1.6
Grazing land—				
Cropland used only for pasture	36	36	1.9	1.6
Grassland pasture and range	612	614	32.3	27.1
Forestland grazed	127	127	6.7	5.6
Special uses—				
Farmsteads, farm roads	12	12	0.6	0.5
Total agricultural land[2]	1,159	1,161	61.2	51.3
Nonagricultural:				
Forest-use land not grazed[3]	449	544	23.7	24.0
Special uses—				
Transportation[4]	26	27	1.4	1.2
Recreation and wildlife areas[5]	110	252	5.8	11.1
National defense areas[6]	21	23	1.1	1.0
Urban land	60	61	3.2	2.7
Miscellaneous other land[7]	68	197	3.6	8.7
Total nonagricultural land[2]	734	1,103	38.8	48.7
Total land area[2]	1,894	2,264	100.0	100.0

USDA ERS 2011. http://www.ers.usda.gov/Publications/EIB89/EIB89.pdf

Major Classes

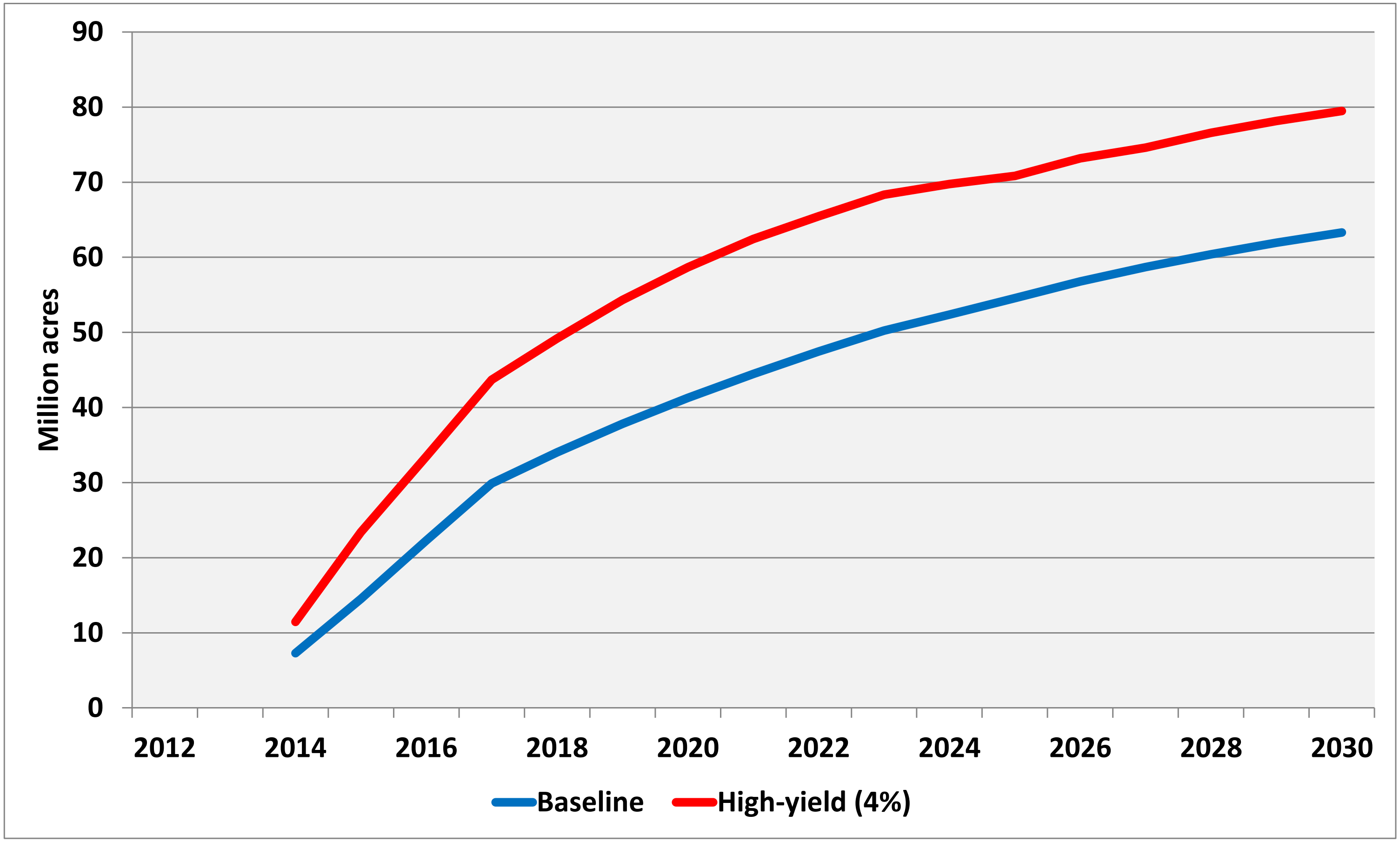
- **Cropland**
- **Grassland Pasture and Range**
- **Forest-Use Land**
- **Urban and Rural**

<80

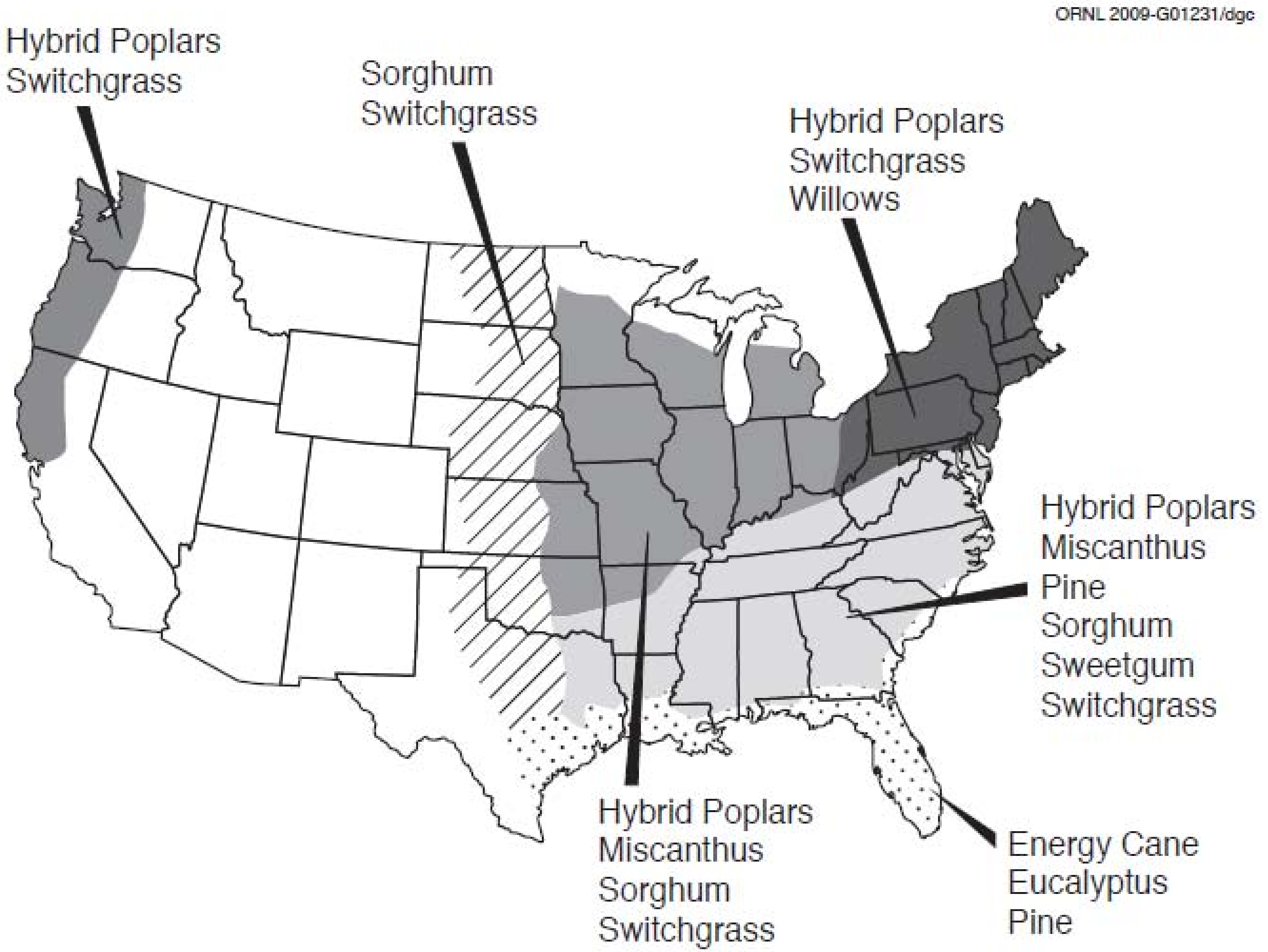
Total Forest Land

Land Use Change for Energy Crops

Total land use change ($60/dry ton) is 63 million acres under the baseline scenario and 79 million acres under the high-yield scenario (4% annual growth in energy crop yield) by 2030



Energy Crops Across the U.S.

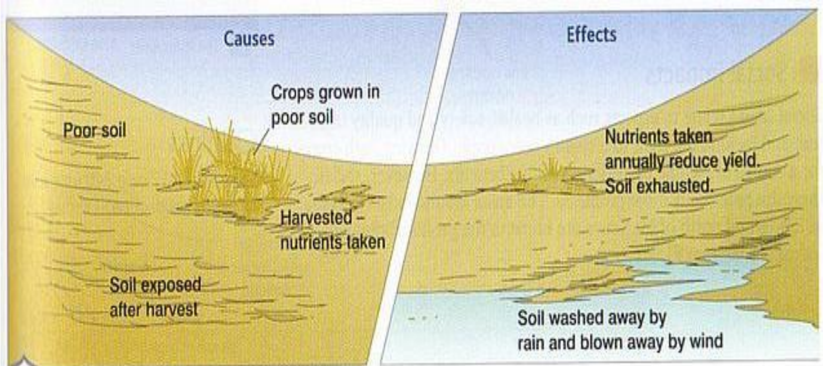


Marginal Lands – Opportunities for Symbionts

Definition: Land having limitations which in aggregate are severe for sustained application of a given use (FAO, 1997). Increased inputs to maintain productivity or benefits will be only marginally justified. With inappropriate management, risks of irreversible degradation.

Biophysical Constraints: Soil constraints (low fertility, poor drainage, shallowness, salinity), steepness of terrain, unfavorable climatic conditions (FAO, 1997).

Opportunities: Endosymbionts capable of conferring tolerance towards drought, salinity, and high temperatures to host plant, thereby increasing biomass yields, particularly in marginal lands.



C The effects of growing crops on marginal land

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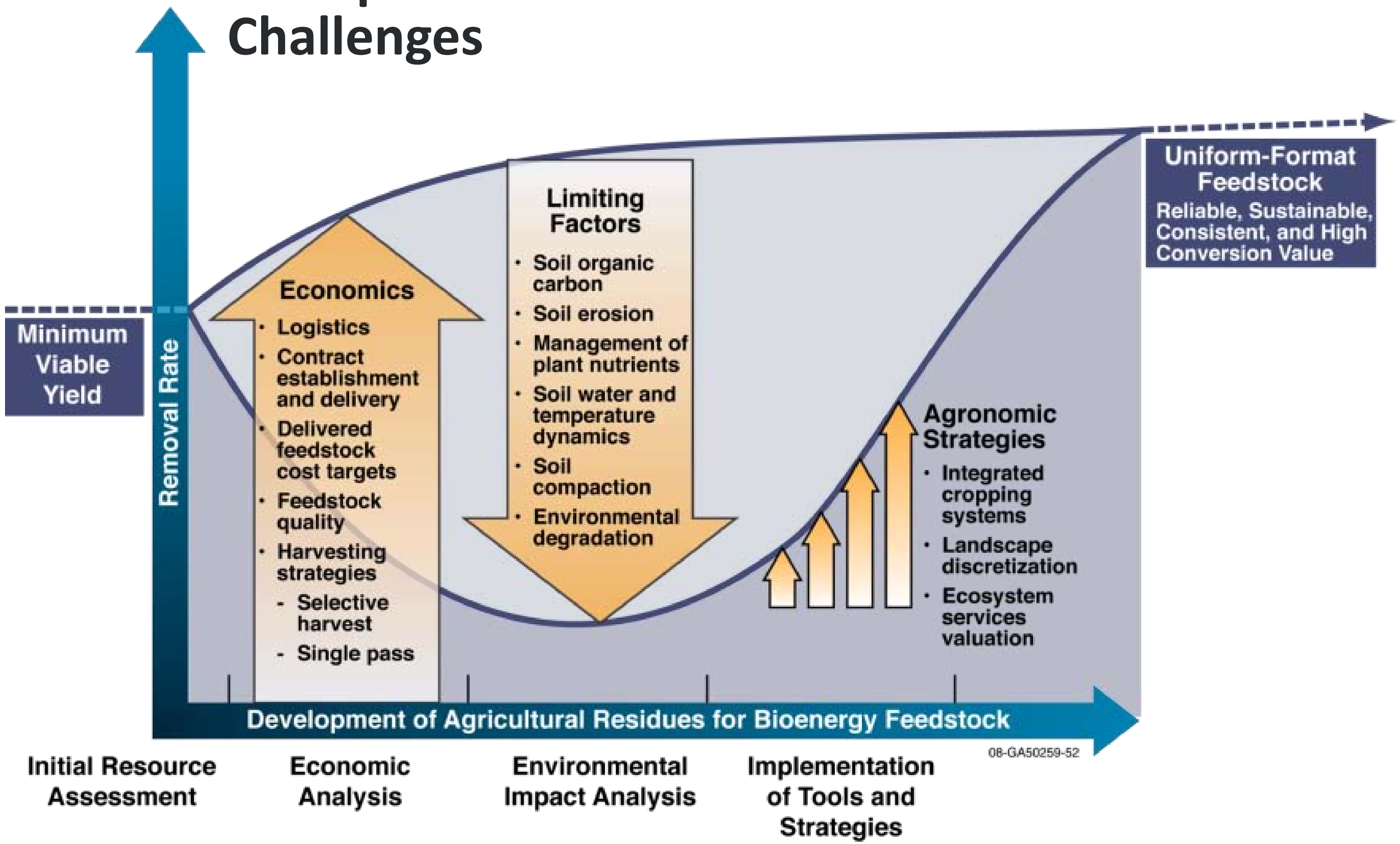
Understanding and Overcoming Limiting Factors

Example: Sustainable Residue Removal Challenges



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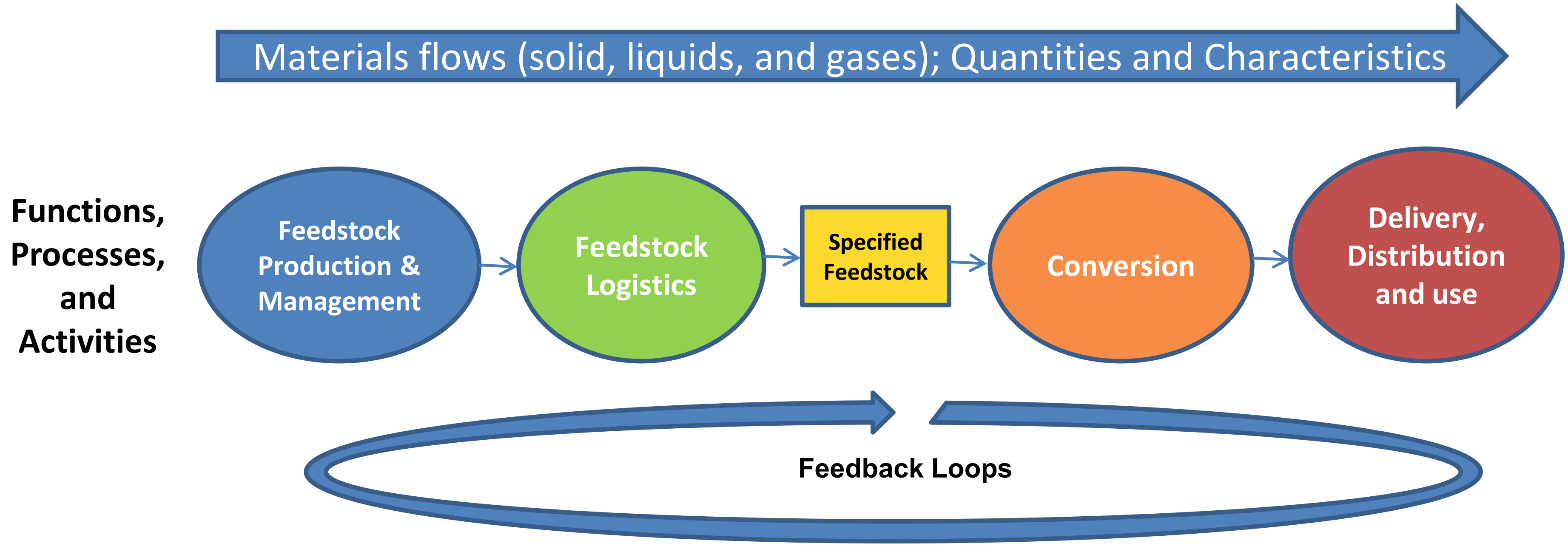
Using an Integrated Approach

Final Product Cost Can be Managed by Managing Components in Biomass Supply Chain Holistically



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Extra Slides

The End

Thank You!

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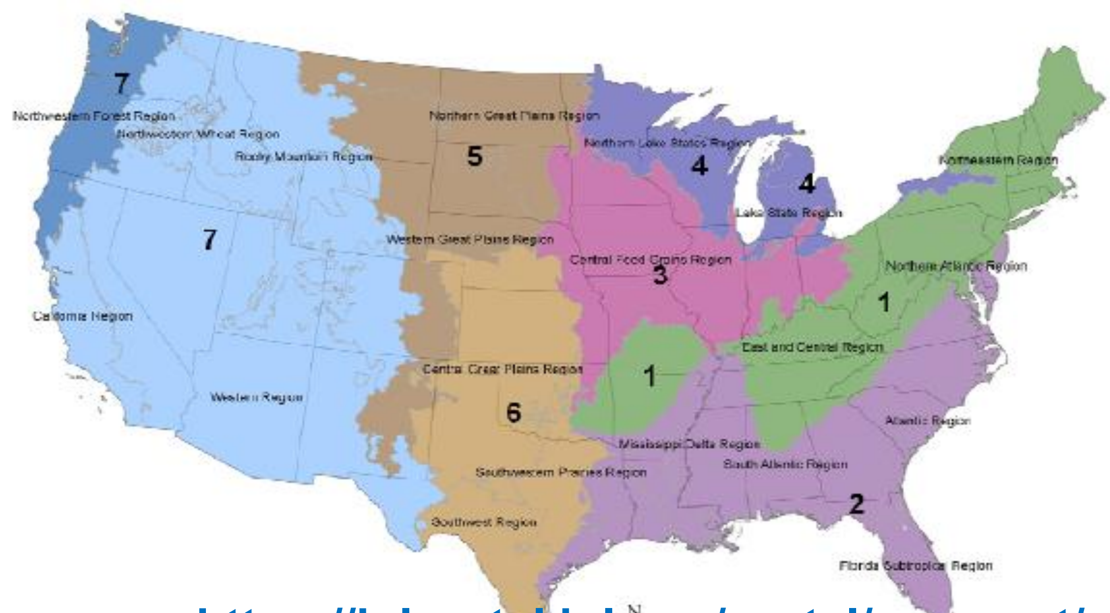
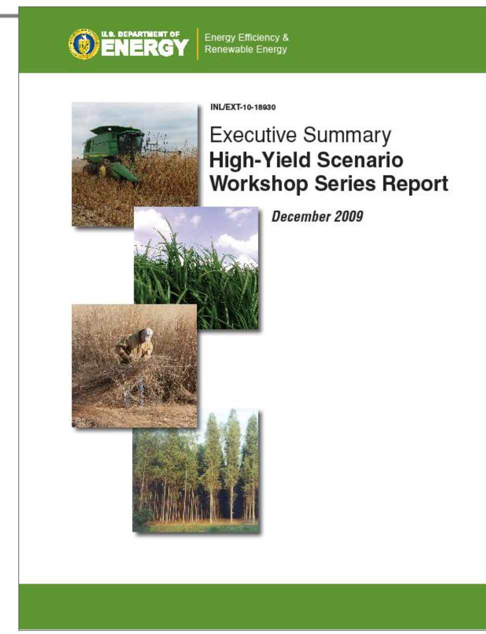
Herbaceous Energy Crops Yields

Table 2-1. Currently achievable HEC yields agreed upon by participants (dry tons per acre) for each land resource zone shown in Figure 2-1.

	Switchgrass	Miscanthus	Sorghum	Mixed Grasses	Energycane[1]	Sorghum
Region 1	5–10	2–16	6–12	0.5–5	0–12	6–12
Region 2	5–12	4–16	8–14	5–12	10–14	8–14
Region 3	3–8	4–16	9–13	3–8	0	9–13
Region 4	2–6	2–12	0–8	2–6	0	0–8
Region 5	2–6	1–5	0–6	2–6	0	0–6
Region 6	3–13	2–15	8–9	3–13	7–8	8–9
Region 7		10–16			(coast 10–16)	





https://inlportal.inl.gov/portal/server.pt/community/bioenergy/421/high_yield_scenario/8985

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Energy Crop Yield Growth

	2012	2017	2022	2030	2017	2022	2030
Crop	Yield	Baseline 1% annual growth			High-yield 2%–4% annual growth		
		Dry tons/acre/year			Dry tons/acre/year		
Low end of yield range	2	2.1	2.2	2.4	2.2 – 2.4	2.4 – 3.0	2.9 – 4.1
	3	3.2	3.3	3.6	3.3 – 3.6	3.7 – 4.4	4.3 – 6.1
	4	4.2	4.4	4.8	4.4 – 4.9	4.9 – 5.9	5.7 – 8.1
	5	5.3	5.5	6.0	5.5 – 6.1	6.1 – 7.4	7.1 – 10.1
	6	6.3	6.6	7.2	6.6 – 7.3	7.3 – 8.9	8.6 – 12.2
Middle of yield range	7	7.4	7.7	8.4	7.7 – 8.5	8.5 – 10.4	10.0 – 14.2
	8	8.4	8.8	9.6	8.8 – 9.7	9.8 – 11.8	11.4 – 16.2
High end of yield range	9	9.5	9.9	10.8	9.9 – 10.9	11.0 – 13.3	12.9 – 18.2
	10	10.5	11.0	12.0	11.0 – 12.2	12.2 – 14.8	14.3 – 20.3
	11	11.6	12.2	13.2	12.1 – 13.4	13.4 – 16.3	15.7 – 22.3
	12	12.6	13.3	14.4	13.2 – 14.6	14.6 – 17.8	17.1– 24.3

Notes: The yields shown for 2017–2030 for the baseline and high-yield scenarios reflect the standing yield of the energy crop before losses. It is the yield for the energy crop planted in that particular year. For example, if the 2009–2012 yield for a particular crop is 5 dry tons per acre, the yield for that crop would be 5.5 dry tons per acre if planted in 2022 under the baseline and 6.1 to 7.4 dry tons per acre under the high-yield scenario.

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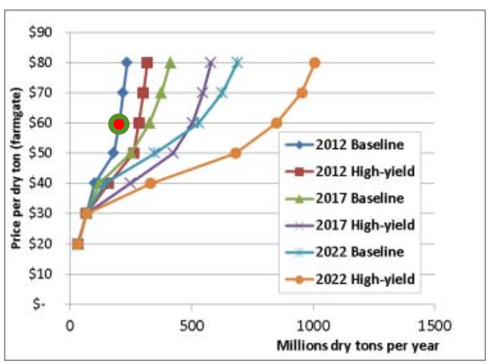
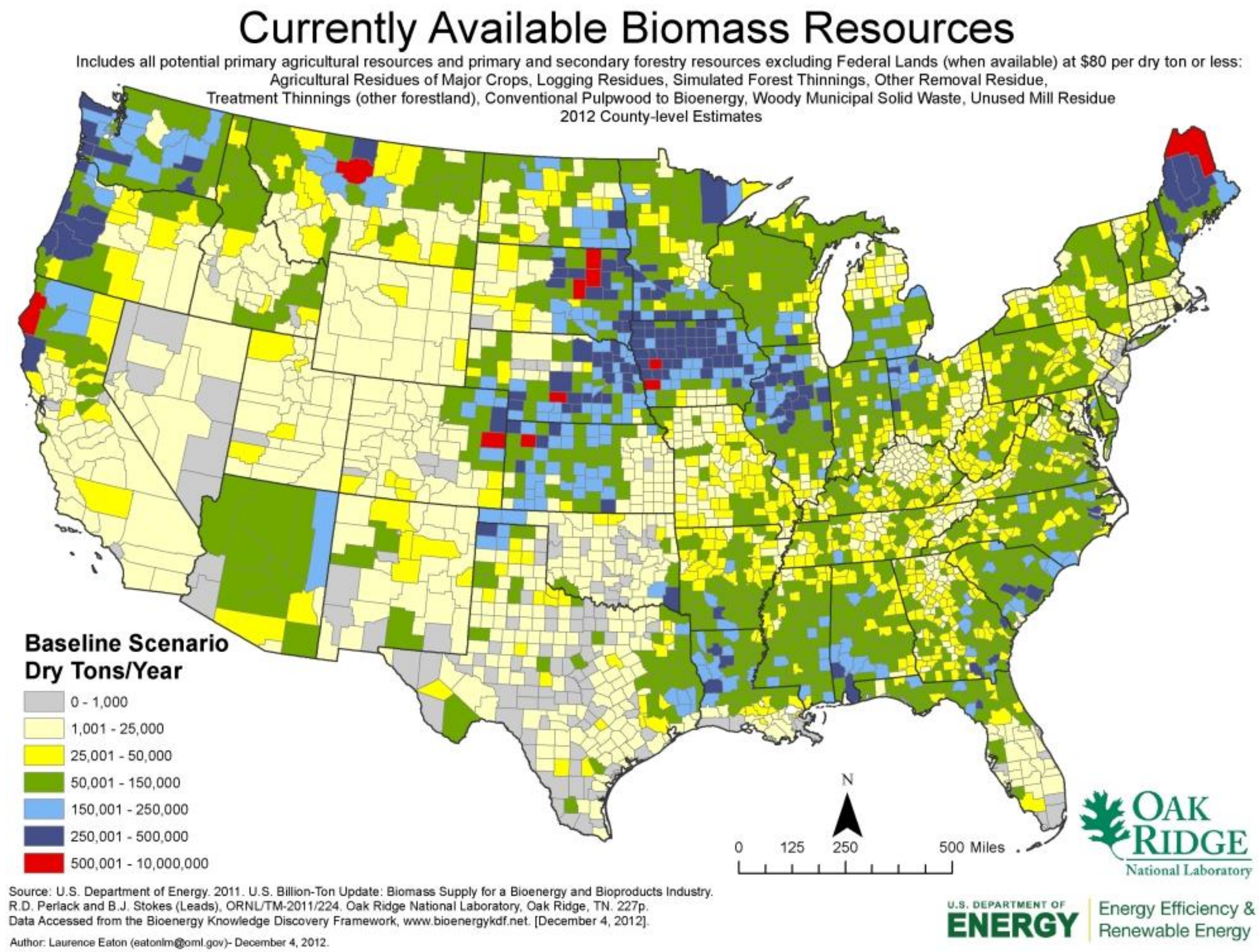
Supply Curve Results

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

201 x 10^6 dt





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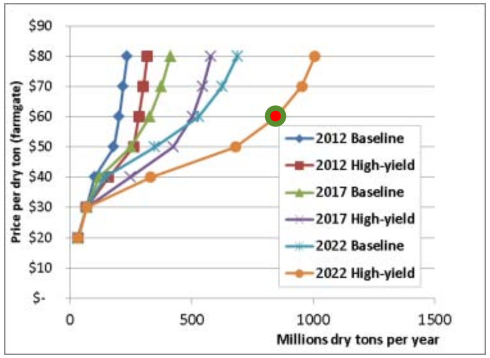
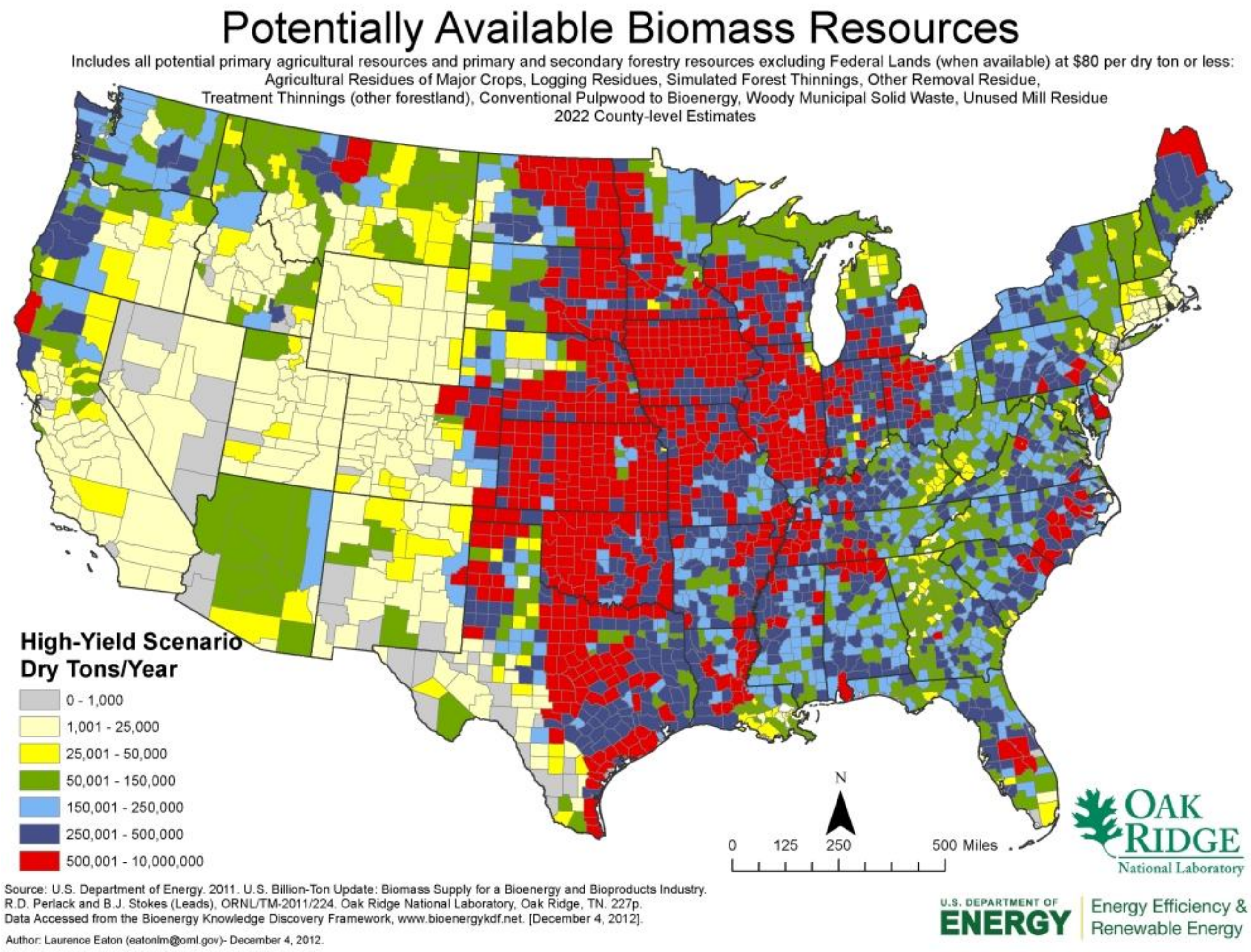
Supply Curve Results

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

848 x 10^6 dt





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