U.S. BILLION-TON UPDATE: BIOMASS SUPPLY FOR A BIOENERGY AND BIOPRODUCTS INDUSTRY

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U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
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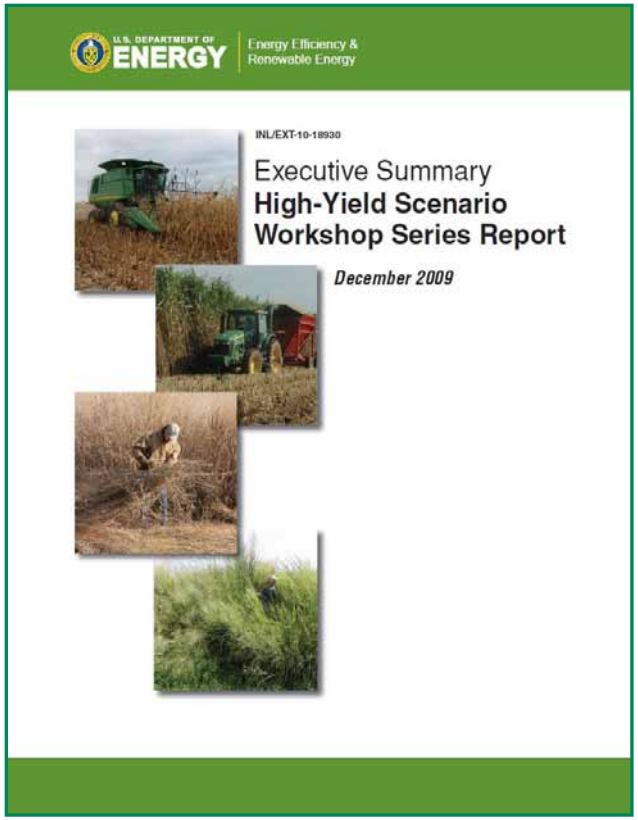
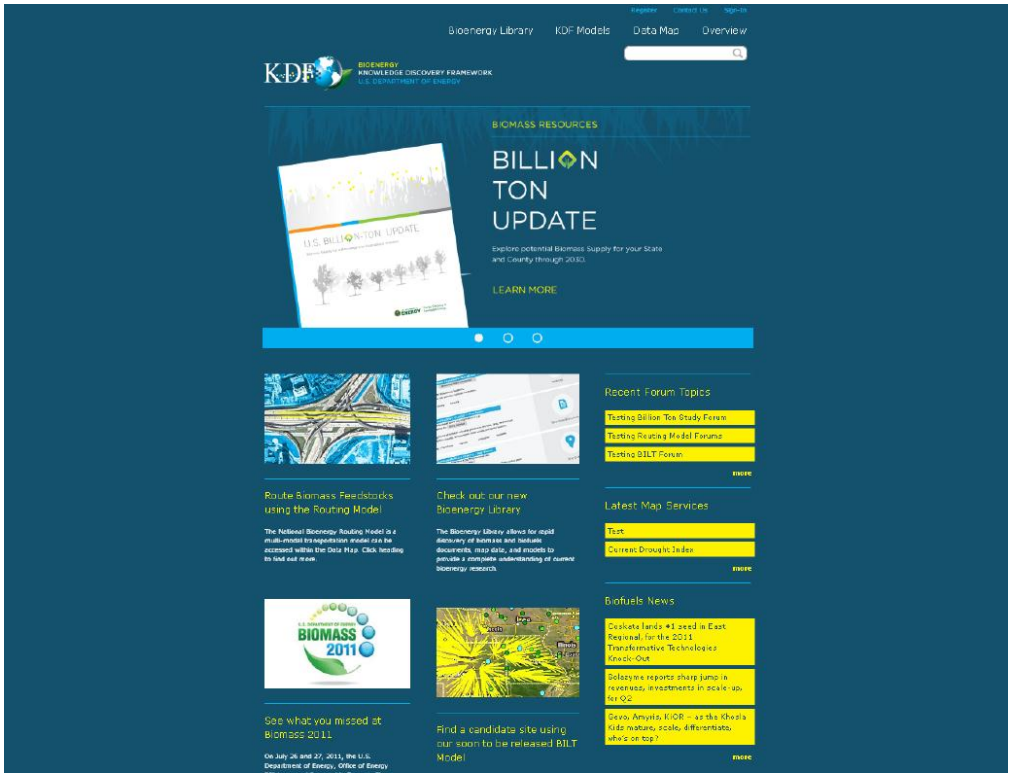


https://inlportal.inl.gov/portal/server.pt/community/bioenergy/421/high_yield_scenario/8985

Additional Notes for Workshops:

- 13 Participants – corn/residues workshop
- 13 Participants – herbaceous crops workshop
- 15 Participants – woody crops workshop

BIOENERGY KNOWLEDGE DISCOVERY FRAMEWORK KDF



http://bioenergykdf.net/

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U.S. BILLION-TON UPDATE

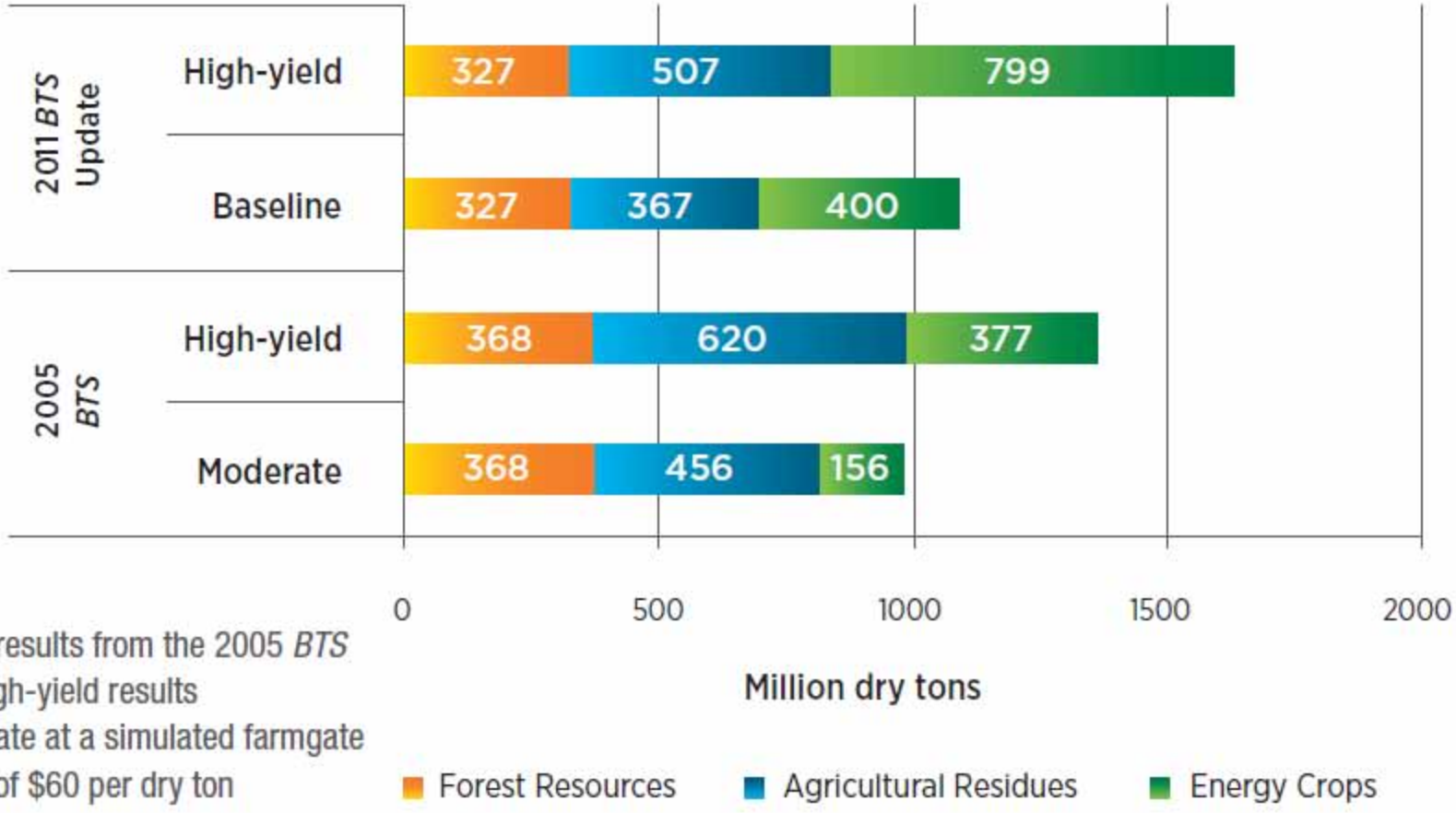
- **Review original study and introduce Billion-Ton Update**
- **Scope of study**
- **Analysis approach**
- **Results**

MAJOR DIFFERENCES BETWEEN THE 2005 BTS STUDY AND THE 2011 UPDATE

- Key commonality – an assessment of biomass potential under a given set of assumptions and available data

2005 BTS	2011 Update
National estimates – no spatial information	County-level with aggregation to state, regional and national levels
No cost analyses – just quantities	Supply curves by feedstock by county – farmgate/forest landing
Crop residue removal sustainability addressed from national perspective; erosion only	Crop residue removal sustainability modeled at soil – scale; erosion & soil C
No explicit land use change modeling	Land use change modeled for energy crops
Long-term, inexact time horizon (2005; ~2025 & 2040)	2012 – 2030 timeline (annual)
2005 USDA agricultural baseline and 2000 forestry RPA/TPO	2010 USDA agricultural baseline 2010 FIA inventory and 2007 forestry RPA/TPO
Erosion constraints to forest residue collection	Greater erosion plus wetness constraints to forest residue collection

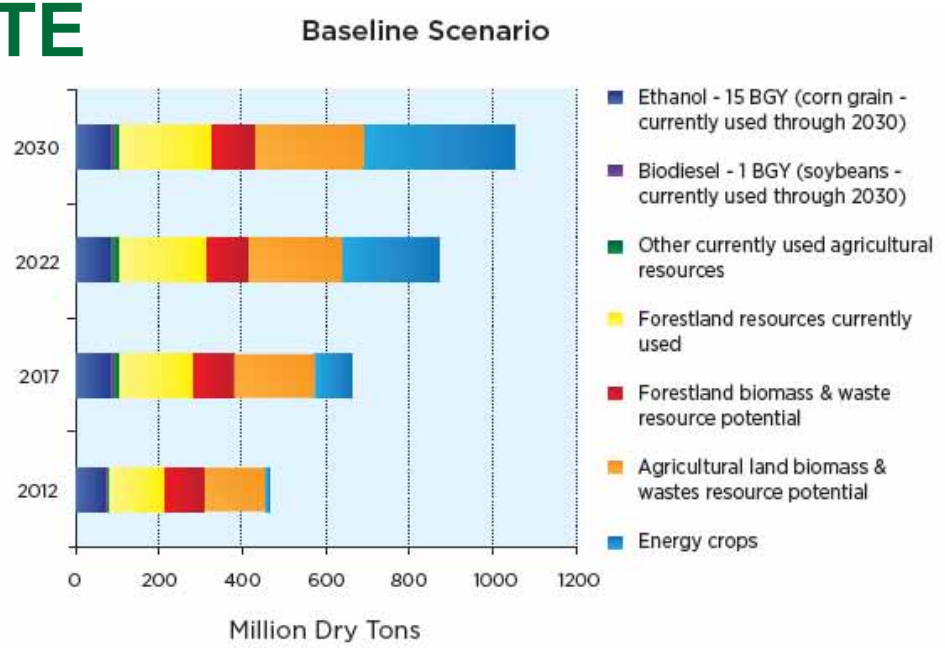
U.S. BILLION-TON UPDATE: COMPARISON WITH THE 2005 BILLION-TON STUDY

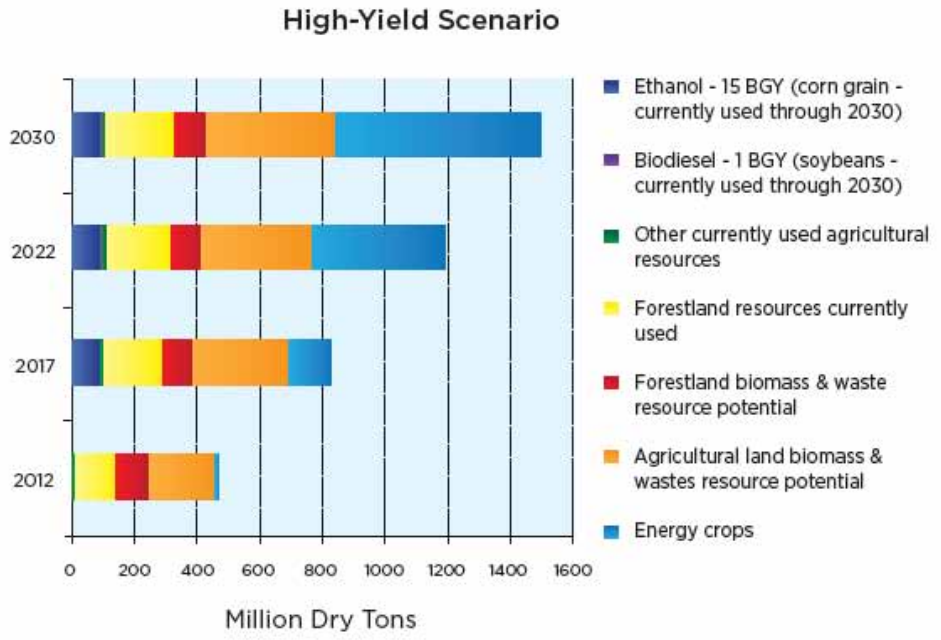


High & moderate results from the 2005 *BTS* and baseline & high-yield results from the *BTS* update at a simulated farmgate or roadside price of $60 per dry ton

U.S. BILLION-TON UPDATE SUMMARY FINDINGS

- Baseline scenario
  - Current combined resources from forests and agricultural lands total about 473 million dry tons at $60 per dry ton or less (about 45% is currently used and the remainder is potential additional biomass)
  - By 2030, estimated resources increase to nearly 1.1 billion dry tons (about 30% would be projected as already-used biomass and 70% as potentially additional)
- High-yield scenario
  - Total resource ranges from nearly 1.4 to over 1.6 billion dry tons annually of which 80% is potentially additional biomass
  - No high-yield scenario was evaluated for forest resources, except for the woody crops





APPROACH TO SUPPLY CURVE ESTIMATION

- Agricultural land resources
  - POLYSYS model (County-level version)
    - Data from NASS, USDA Baseline, Census of Agriculture
    - Key technical assumptions and environmental sustainability
      - Crop residue retention, tillage, rotations
      - Energy crop productivity
    - Costs
      - Grower payments for crop residues & production costs for energy crops
      - Collection and harvest costs based on INL and ORNL assumptions/modeling
- Secondary processing residues and wastes are estimated using technical coefficients
- Contributing authors helped develop technical assumptions and input data and workshops used to develop scenarios

APPROACH TO SUPPLY CURVE ESTIMATION (CONT.)

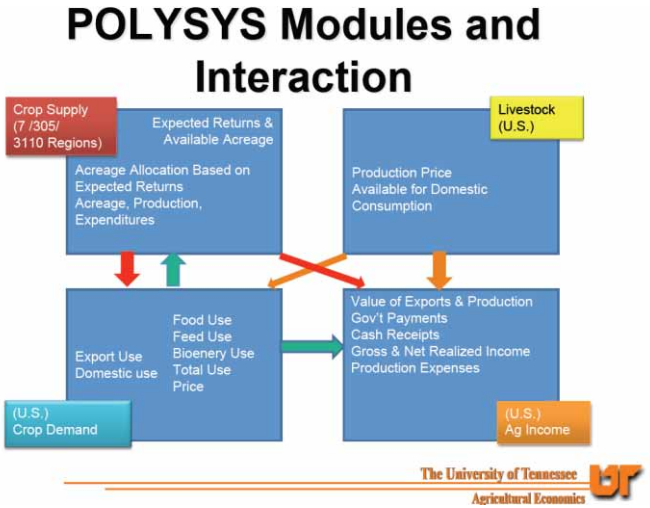
- Forestland resources
  - Costs and quantities for forest residues
    - Data from FIA, TPO, RPA
    - Key technical assumptions and environmental sustainability
      - Forest residue access, recovery, operability, and merchantability
    - Costs
      - Stumpage (primary forest residues and conventionally-sourced wood)
      - Harvest costs estimated from the Fuel Reduction Cost Simulator

SCENARIOS

- Baseline scenario
  - USDA Baseline forecast for crop yields, acres, etc., extended to 2030
  - National corn yield of 160 bu/ac in 2010, increases to 201 bu/ac in 2030
  - Assumes a mix of conventional till, reduced till, and no-till
  - Stover to grain ratio of 1:1
  - No residue collected from conventionally tilled acres
  - Energy crop yields increase at 1% annually attributable to experience in planting energy crops and limited R&D
- High-yield scenario(s)
  - Same as Baseline Scenario except for the following
  - Corn yields increase to a national average of 265 bu/acre in 2030
  - Higher amounts of cropland in no-till to allow greater residue removal
  - Energy crop yields increase at 2%, 3%, and 4% annually (attributable to more aggressive R&D)

POLYSYS MODELING FRAMEWORK

- County model anchored to USDA 10-year baseline & extended to 2030
  - 8 major crops (corn, soybeans, wheat, sorghum, oats, barley, rice, cotton) and hay, livestock, food/feed markets
  - USDA projected demands for food, feed, industry, and export
  - Land base includes cropland (250 million acres), cropland pasture (22 million acres), hay (61 million acres), permanent pasture (118 million acres)
    - Pasture can convert to energy crops if forage made up through intensification
    - Cropland can convert after demands for food, feed, industry, and exports are met
    - Restraints limiting land use change
  - Biomass resources included in POLYSYS are stover, straws, energy crops (perennial grass, coppice and non-coppice woody, annual energy crop)



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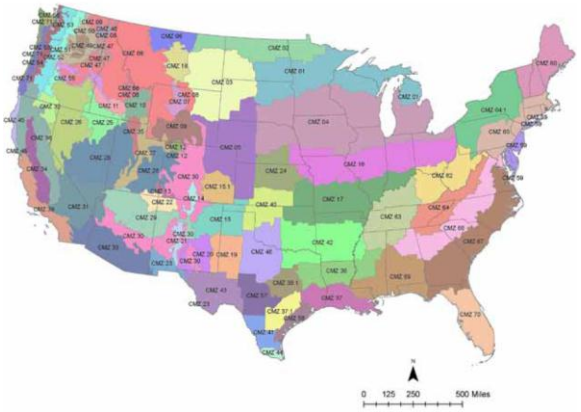
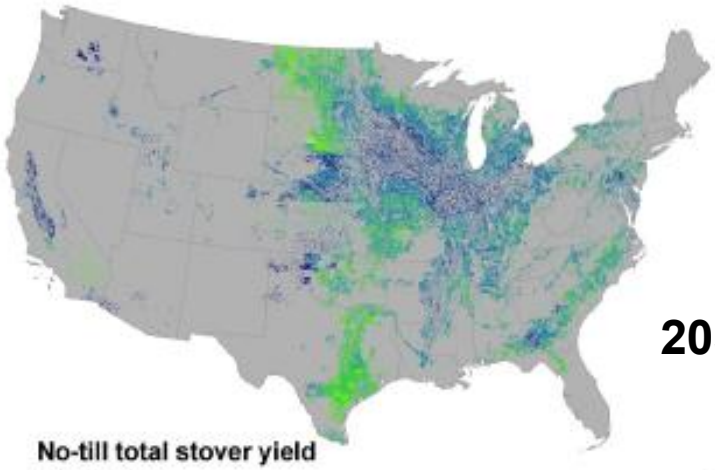
For model background: Daniel G De la Torre Ugarte and Darrell E. Ray. 2000. "Biomass and Bioenergy Applications of the POLYSYS Modeling Framework," *Biomass & Bioenergy* 4(3):1-18.

CROP RESIDUE SUSTAINABILITY

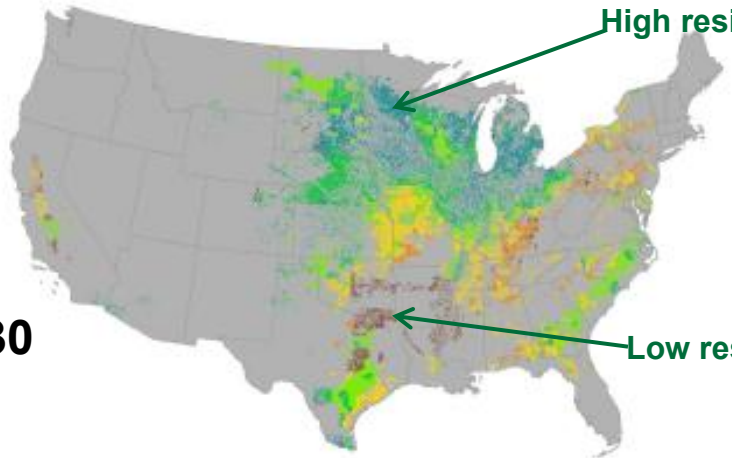
- Retention coefficients estimated for erosion and soil C
  - Separate coefficients for reduced till and no-till
  - No residue removal under conventional till
  - Yield and time dependent in POLYSYS
  - **Dave Muth** (INL), **Richard Nelson** (KSU) and others (ARS, NRCS, UTK)

NRCS CMZs





2030

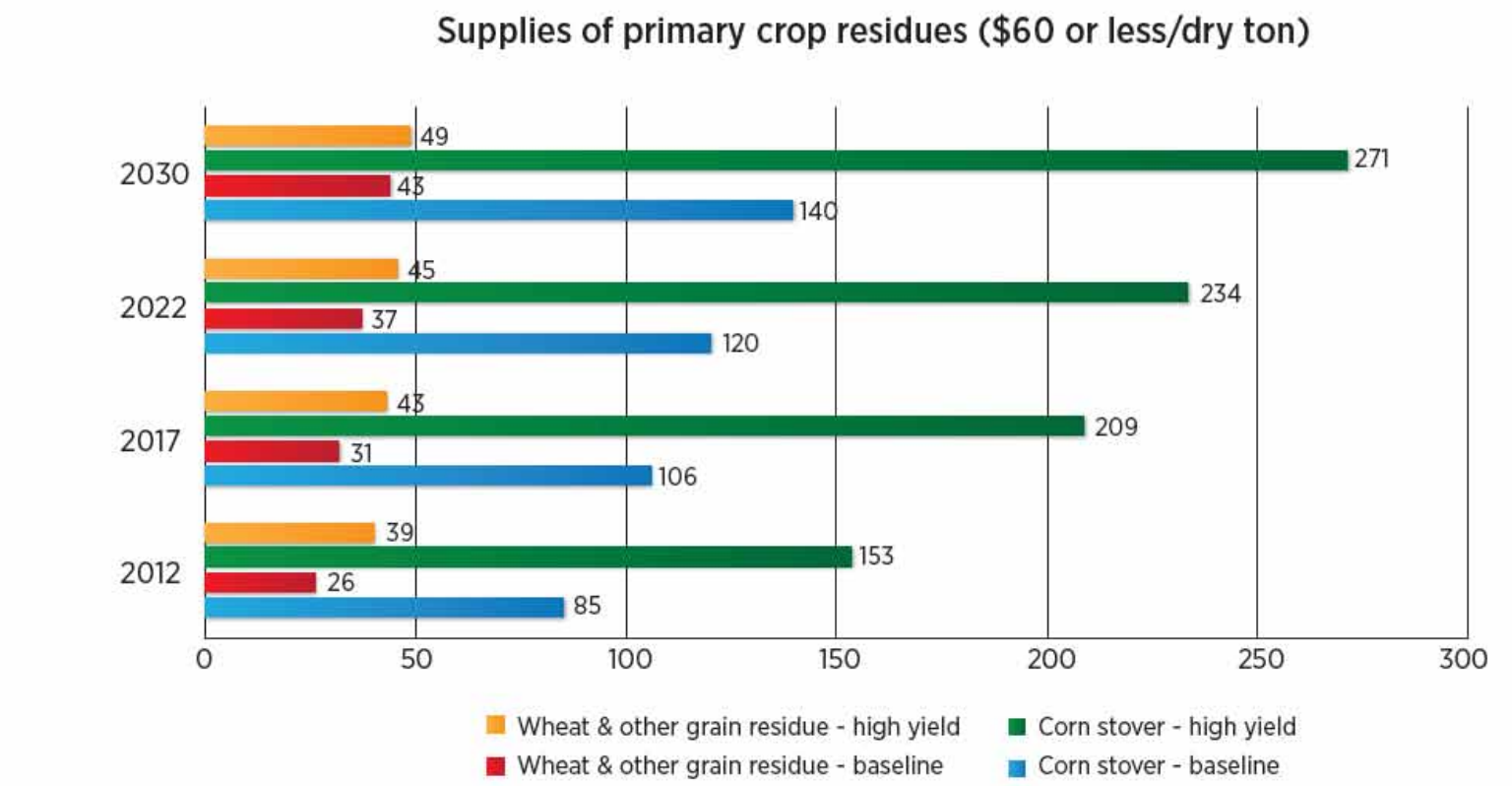


High residue availability

Low residue availability

CROP RESIDUES & AGRICULTURAL WASTES

- Baseline scenario
  - In 2012 about 111 million dry tons, increases to 180 million dry tons by 2030 (mostly corn stover)
- High-yield scenario
  - By 2030, total primary residue is 320 million dry tons, with 85% of this quantity composed of corn stover

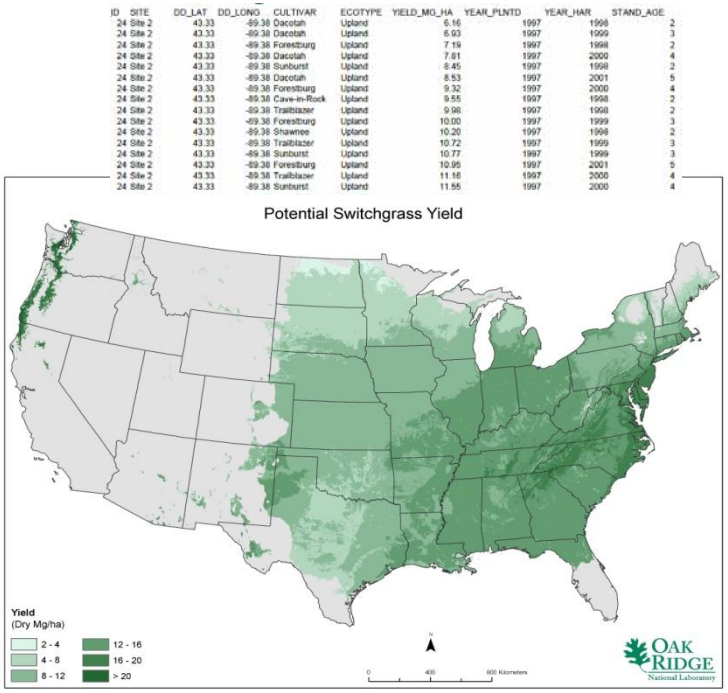


ENERGY CROP SUSTAINABILITY & RESTRICTIONS

- Assumed BMPs for establishment, cultivation, maintenance, and harvesting of energy crops
- Energy crops not allowed on irrigated cropland & pasture
- Conversion of permanent pasture and cropland used as pasture constrained to counties east of the 100th meridian except for Pacific Northwest
- Energy crops returns must be greater than pasture rent plus additional establishment and maintenance costs
- A set of restraints used to limit the amount of cropland, cropland used as pasture, and permanent pasture switching to energy crops in a given year and in total (e.g., 10% of cropland per year and 25% in total)
- Annual energy crops (i.e., energy sorghum) limited to non-erosive cropland and part of multi-crop rotation

PERENNIAL GRASSES- PRODUCTION COSTS AND PRODUCTIVITY

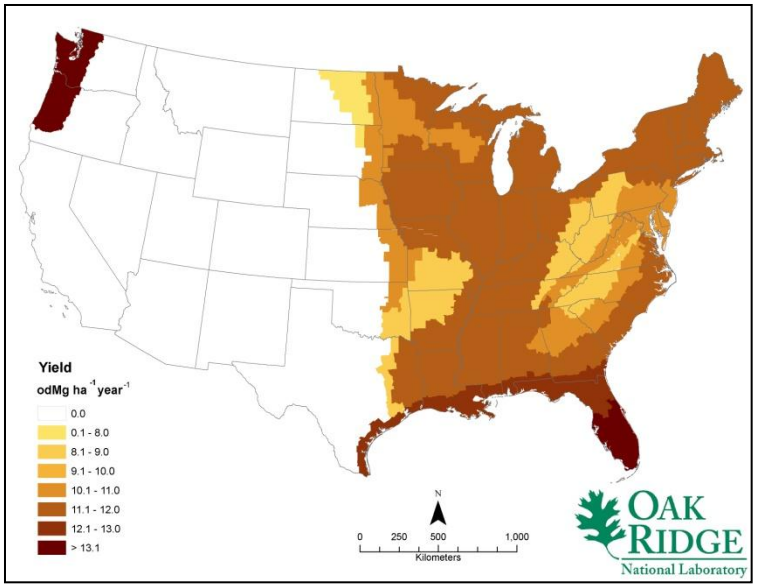
Item	Units	North-east	Appalachia	South-east	Delta	Corn Belt	Lake States	Southern Plains	Northern Plains
Stand life	Years	10	10	10	10	10	10	10	10
Productivity	dry tons/acre	4.0–7.5	5–9.5	3.5–9.5	3–7	4–7	3.5–5	2–6.5	2–6.5
Establishment									
Seed	$/lb.	$10	$22	$22	$22	$10	$10	$22	$10
Planting	lb./acre	5	5	5	5	5	5	5	5
Replants	percent	25	25	25	25	25	25	25	25
No-till drill	-	1-time	1-time	1-time	1-time	1-time	1-time	1-time	1-time
Total kill herbicide	No. applications	1-time	1-time	1-time	1-time	1-time	1-time	1-time	1-time
Pre-emergent herbicide	No. applications	1-time	1-time	1-time	1-time	1-time	1-time	1-time	1-time
Phosphorous	lbs P2O5/ acre	40	40	40	40	40	40	40	40
Potassium	lbs K2O/ac	80	80	80	80	80	80	0	0
Lime	tons/acre	1	2	2	2	1	1	0	0
Total establishment costs	**$/acre**	**$210**	**$340**	**$330**	**$330**	**$200**	**$200**	**$220**	**$150**
Maintenance years									
Reseeding	year applied	2	2	2	2	2	2	2	2
Pre-emergent herbicide	No. applications	0	0	0	0	0	0	0	0
Nitrogen	lbs/acre	60	70	70	50	60	40	40	40
Phosphorous	lbs P2O5/ acre	0	0	80	0	80	0	0	0
Potassium	lbs K2O /acre	0	0	80	0	80	0	0	0
Harvest costs	**$/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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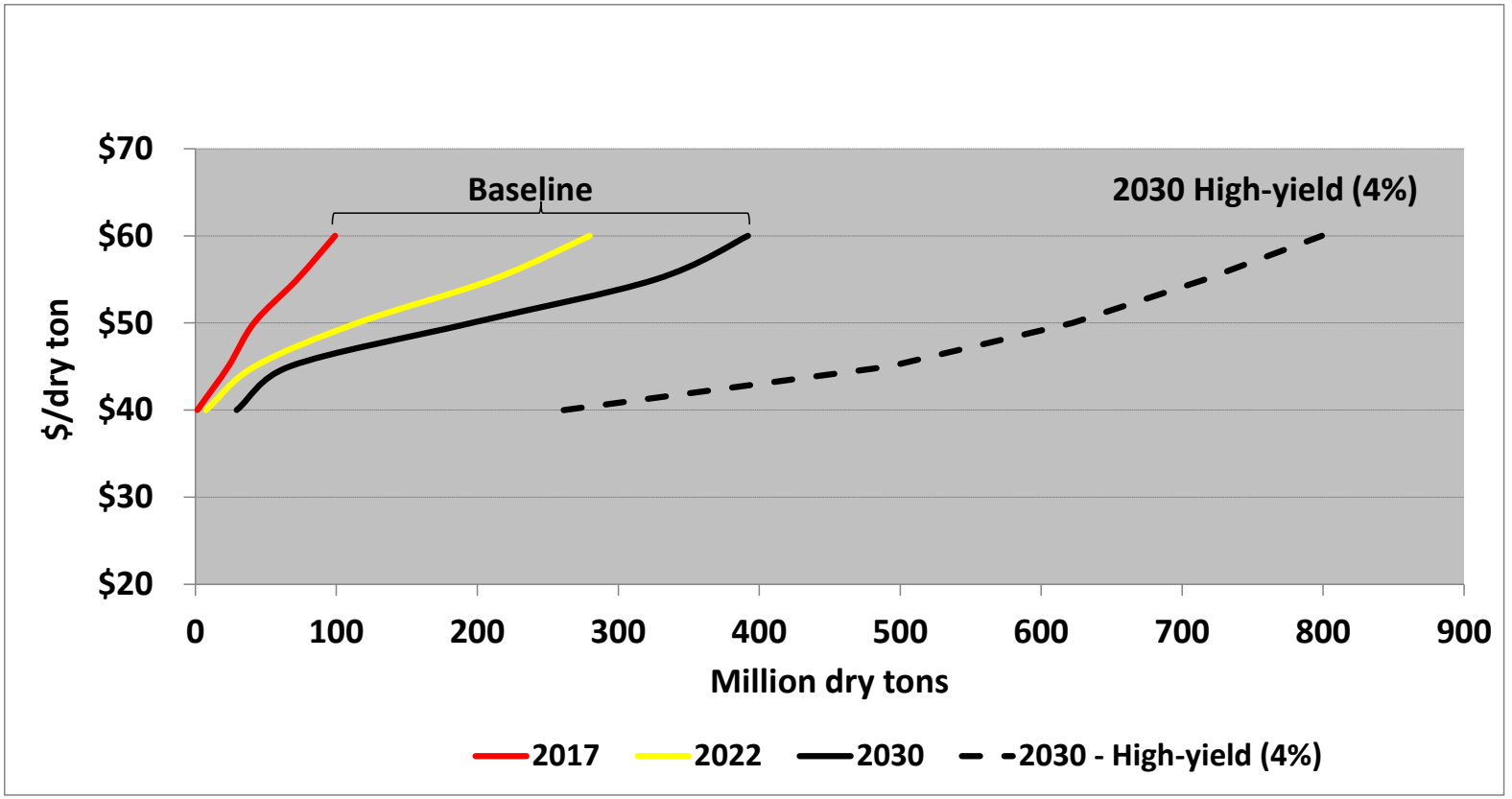
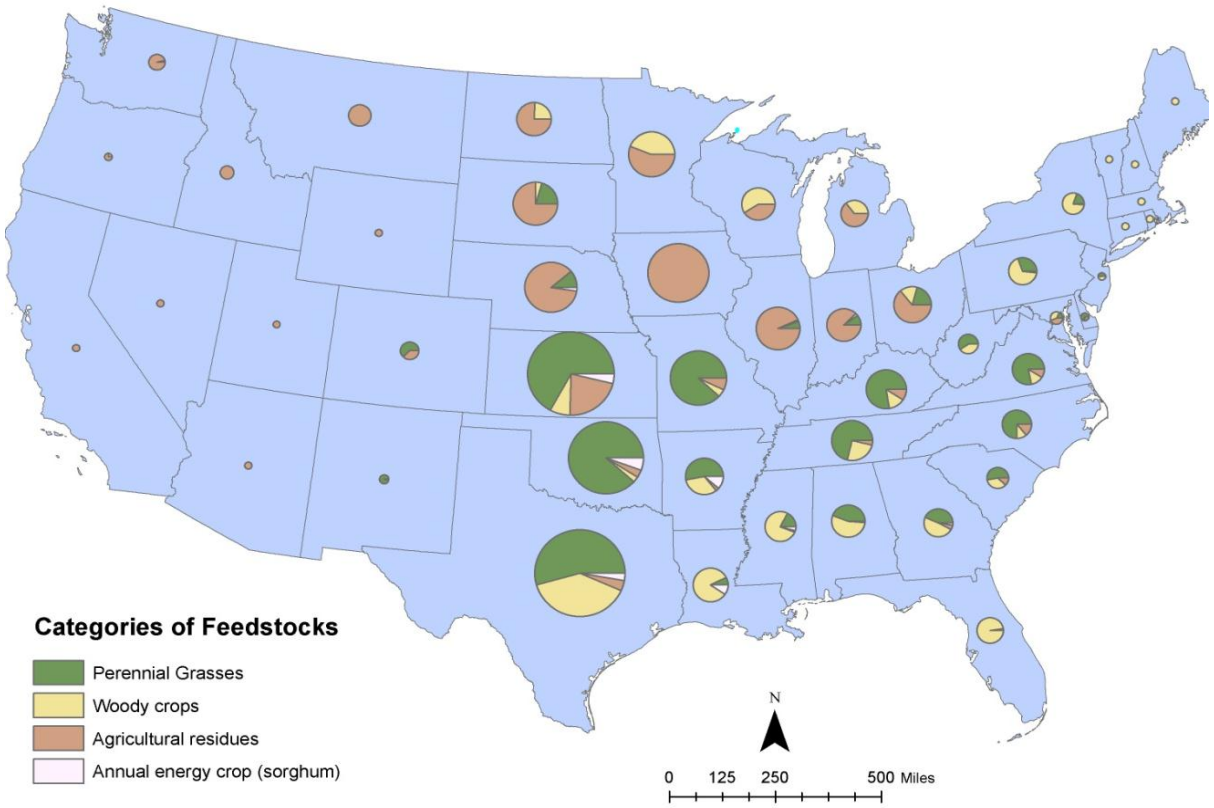
ENERGY CROP SIMULATED SUPPLY CURVES – BASELINE SCENARIO

- Supplies increase over time due to yield growth and woody crop production
- Energy crops displace mostly commodity crops at low supply curve prices and move onto pasture at higher prices



POTENTIAL SUPPLY OF PRIMARY AGRICULTURAL RESOURCES BY STATE

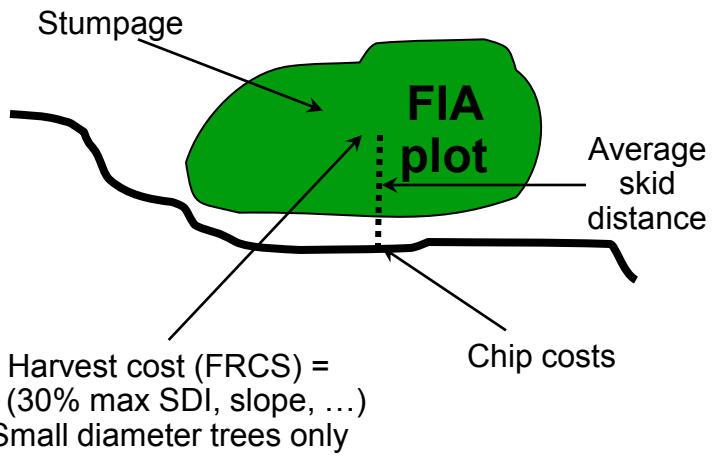
- Potential supplies are generally widely distributed
  - Considerable perennial grass potential in Southern Plains
  - Residue in Midwest and Northern Plains
  - Woody crops in the North and South



Baseline scenario - $60/dry ton; year 2030

FOREST RESIDUES MODELING AND SUSTAINIBILITY

- Land base – 504 million acres of timberland & 91 million acres of “other forestland”
- Evaluated biomass removal sustainability (erosion, soil nutrients, biodiversity, soil-organic carbon, and long-term soil productivity)
- Accounted for changes in FIA database since 2009
- Re-estimated supply curves for integrated operations for logging residues and fuel treatment thinnings on timberland
- Estimated supply curves for conventionally sourced wood (i.e., pulpwood) from additional harvests and shift from current uses to bioenergy

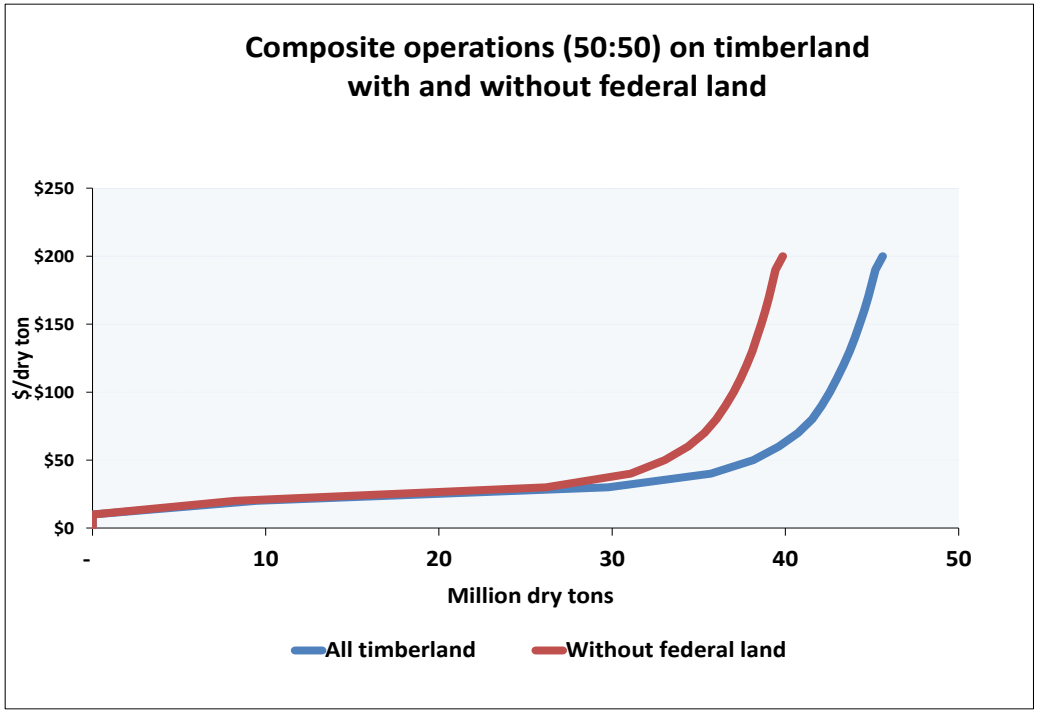


- FIA data (~37,000 permanent field plots)
  - Exclude roadless areas and reserved, steep, and wet lands
  - All fire regime condition classes
  - Treated if greater then 30% of maximum stand density for forest type/ecoregion
  - Thin over 30-year period

FOREST RESIDUE RESULTS

- Sustainability based on biomass retention levels by slope class
  - Logging residues - 30% left on-site
  - Fuel treatment thinnings - Slope <40% = 30% of residue left on-site; Slope >40% to <80% = 40% of residue left on site; Slope >80% = no residue is removed (no limbs or tops yarded)
  - Removed steep, wet and roadless sites from consideration

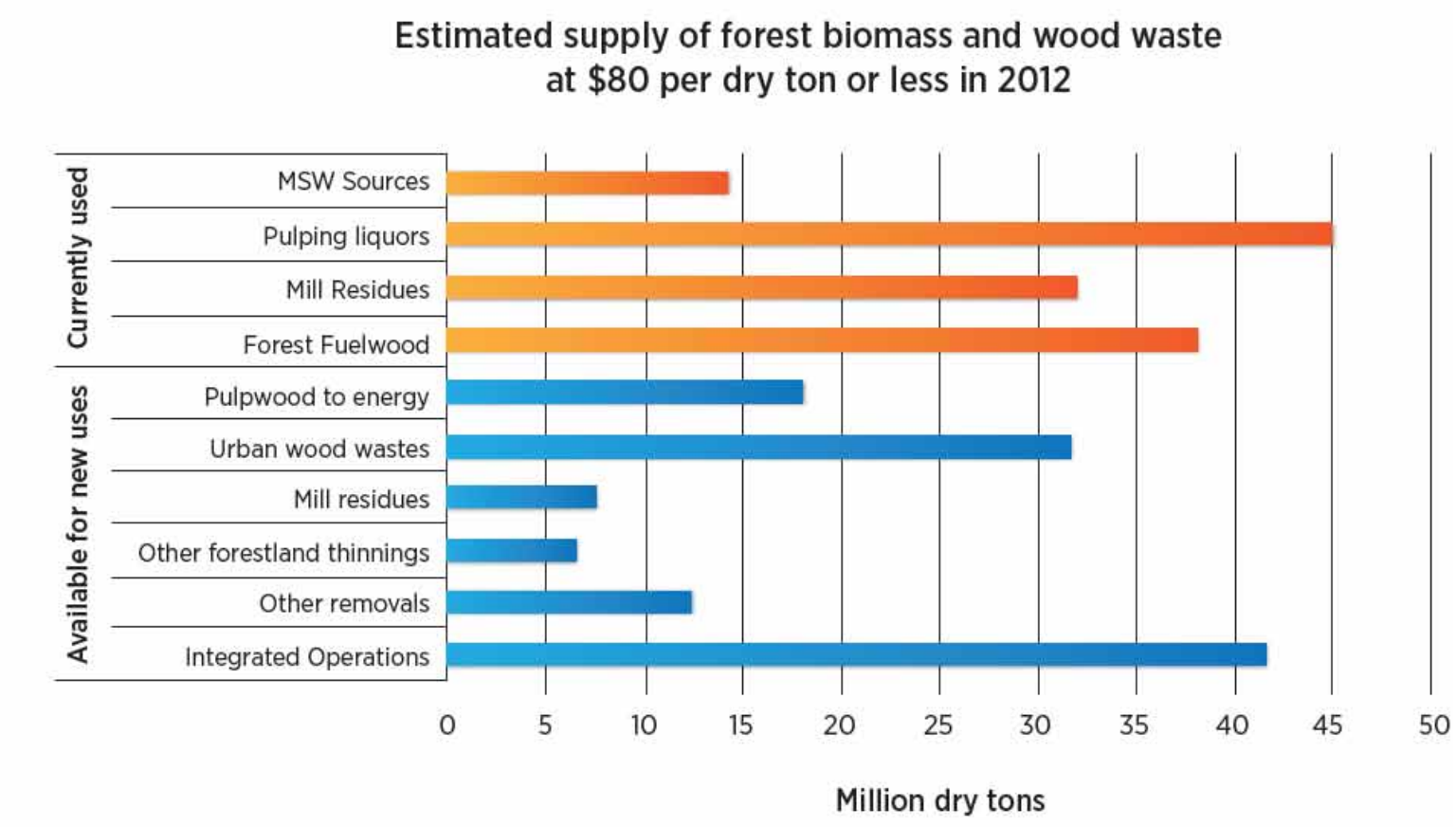
- Roadside supply curves
  - Includes stumpage & chipping costs
  - Fuel Reduction Cost Simulator model for harvesting
  - Projections based on latest RPA/TPO
  - With & without federal land



**Significant contributions from USDA Forest Service:
Ken Skog, Dennis Dykstra, Patty Lebow, and Pat Miles**

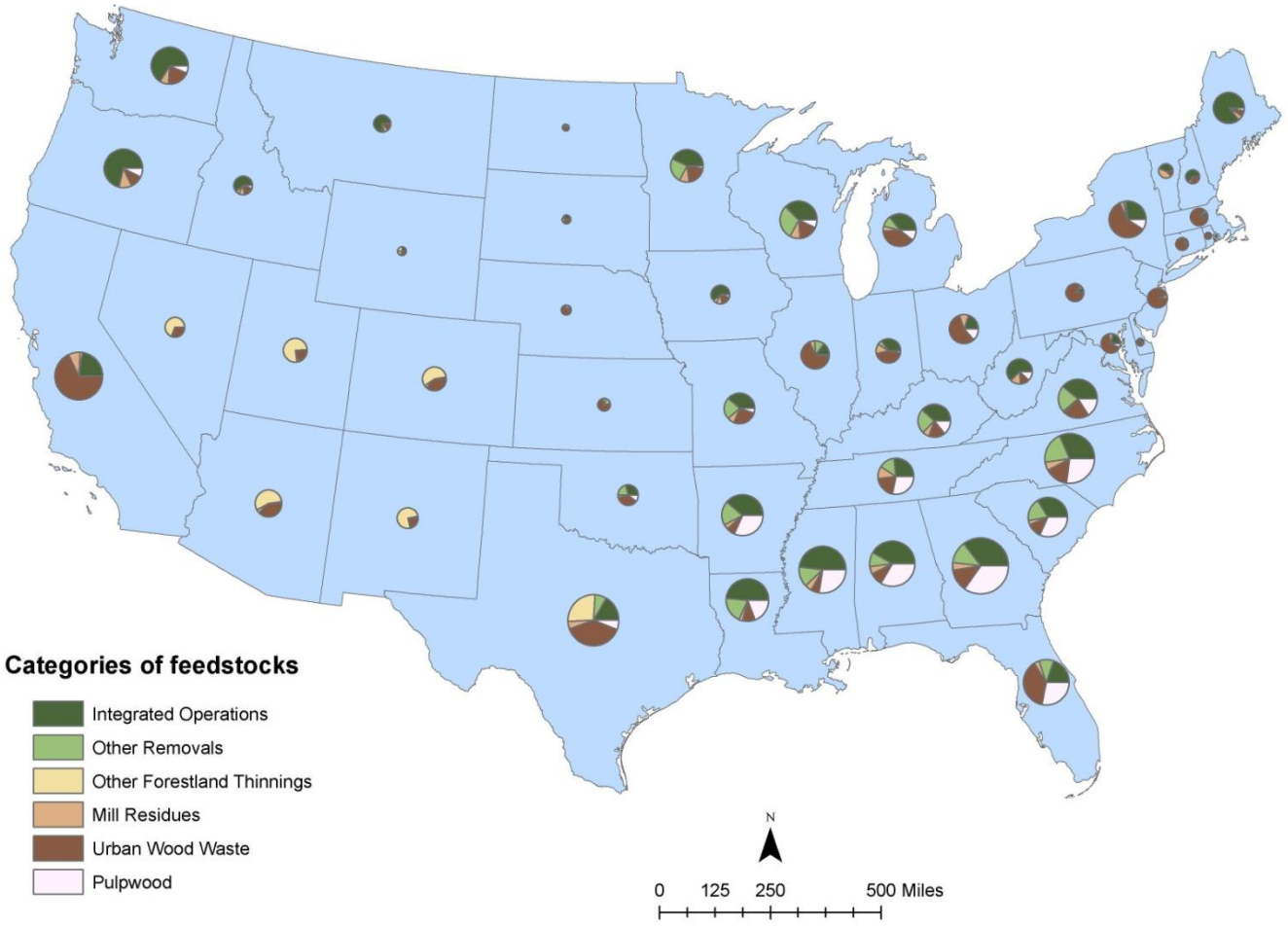
FOREST BIOMASS AND WOOD WASTES

- Over a price range of $20 to $80 per dry ton at roadside, quantities of forest residue biomass potential vary from about 33 to 119 million dry tons currently, to about 35 to 129 million dry tons in 2030

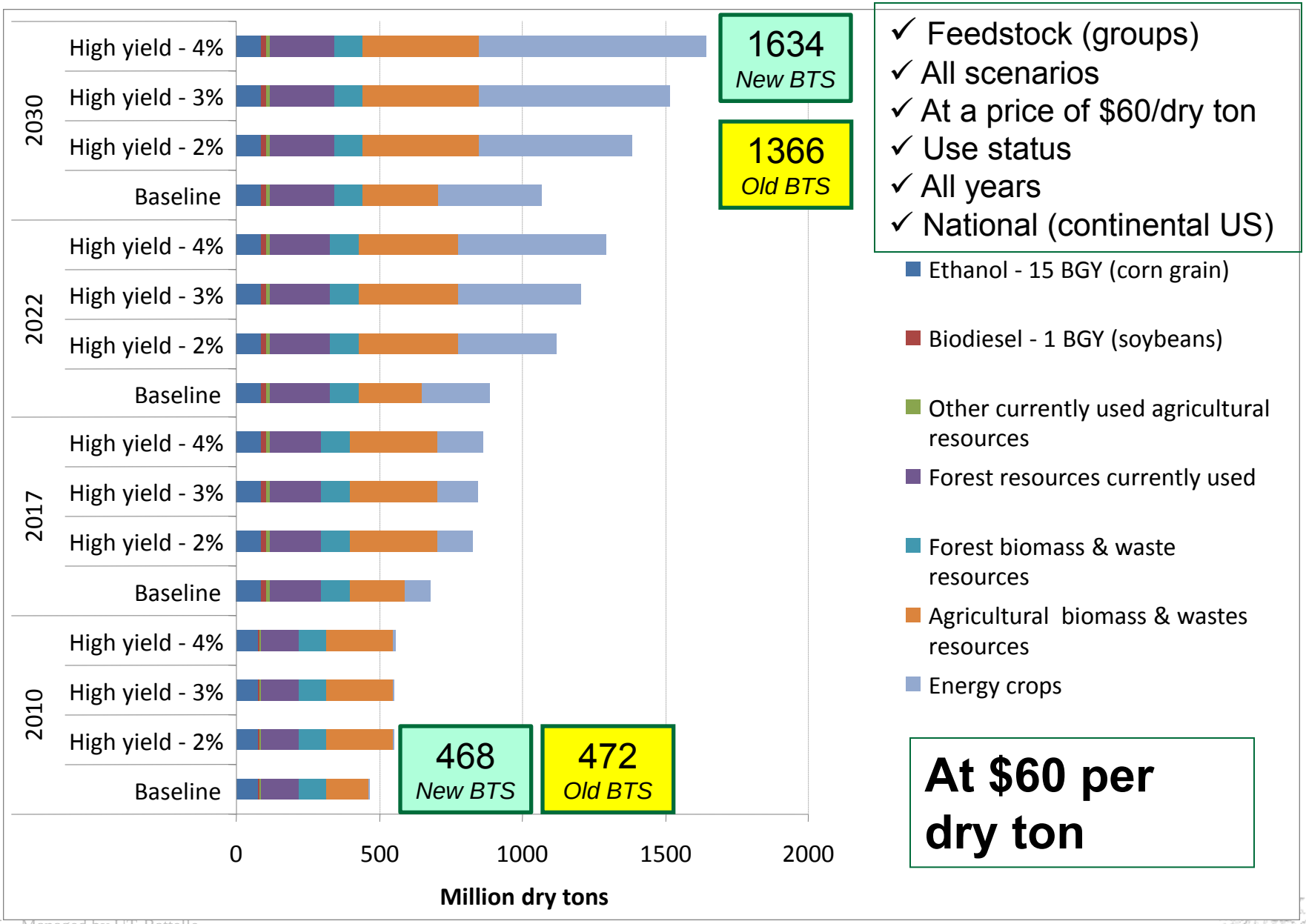


POTENTIAL SUPPLY OF FOREST RESIDUES BY STATE

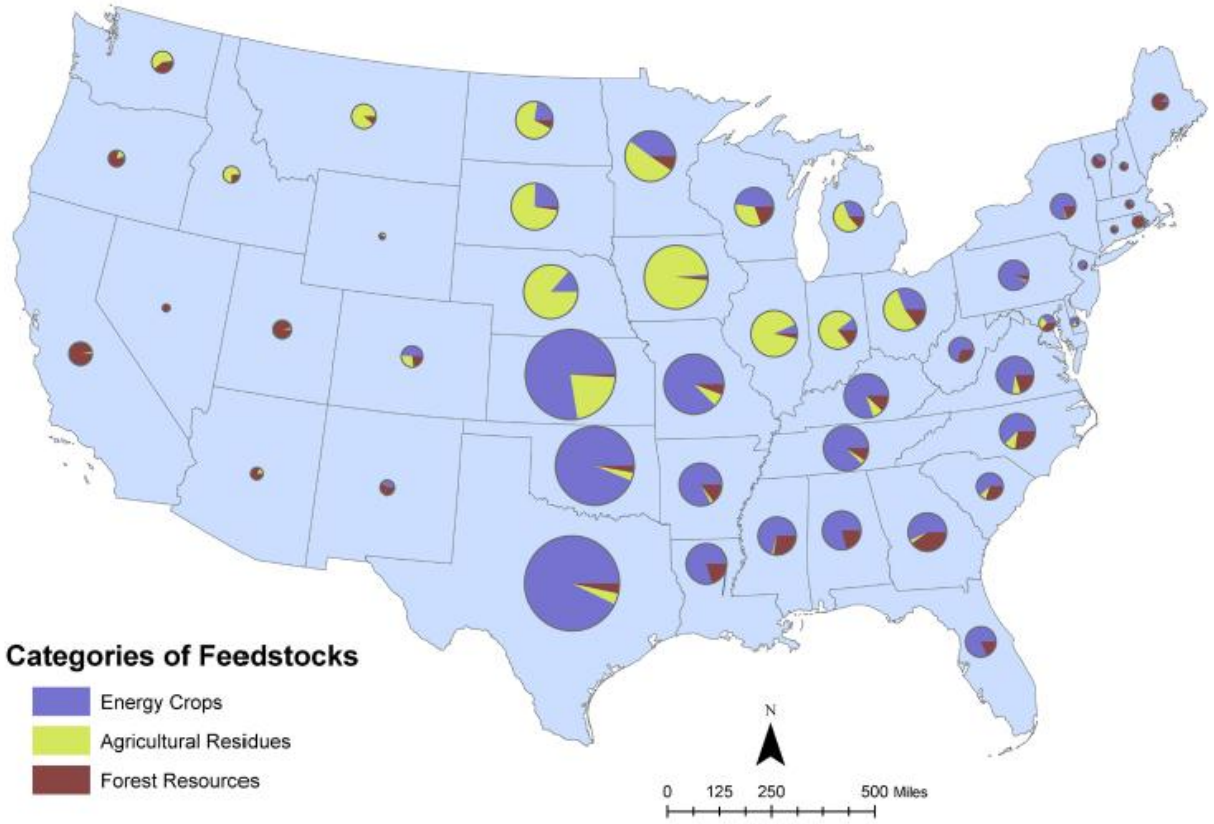
- Forest residues are widespread in the Southeast, North, and Northwest



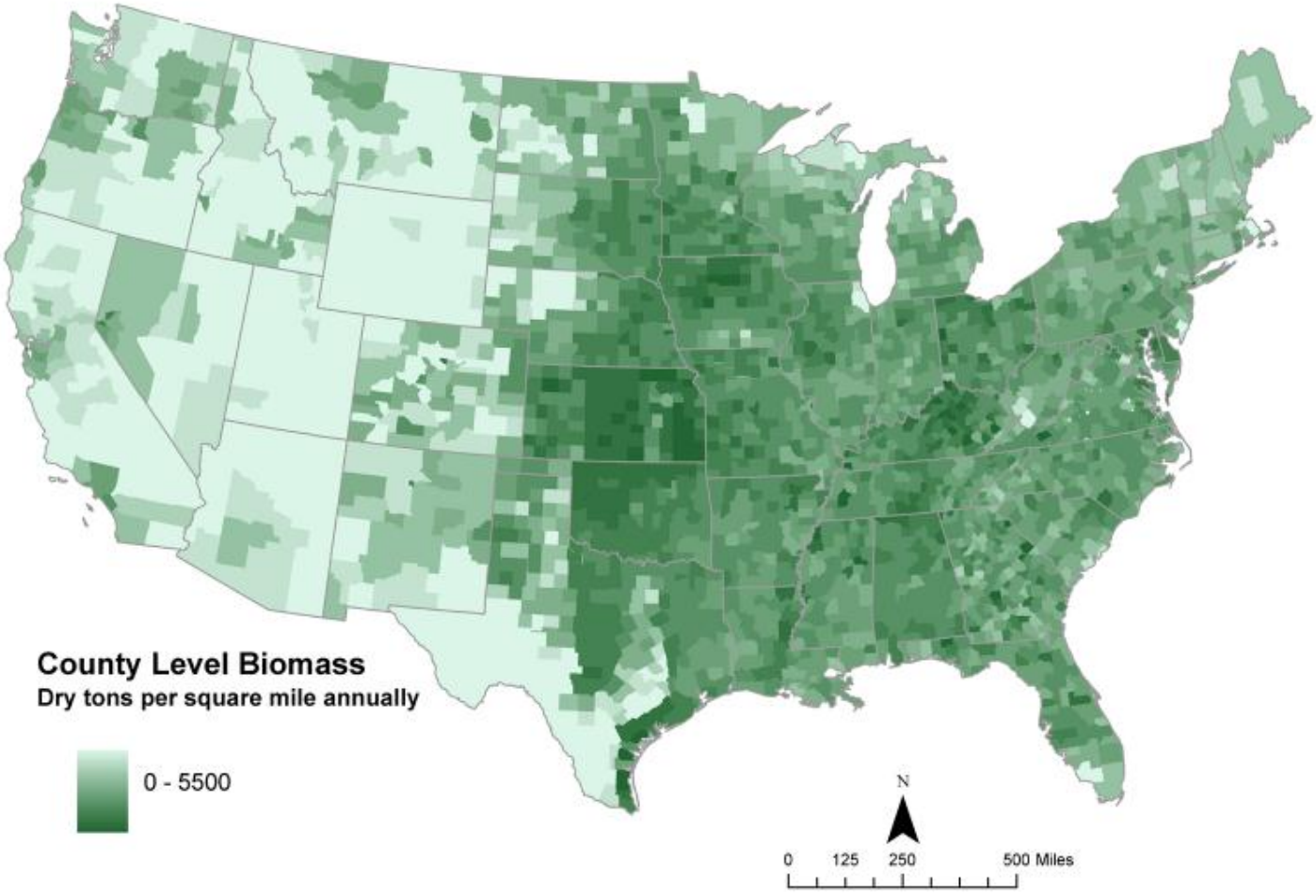
Summary of Available Biomass Per Year



STATE-LEVEL SHARES OF ALL POTENTIALLY AVAILABLE RESOURCES AT $60 PER DRY TON OR LESS IN 2030, UNDER BASELINE ASSUMPTIONS



POTENTIAL COUNTY-LEVEL RESOURCES AT $60 PER DRY TON OR LESS IN 2030, UNDER BASELINE ASSUMPTIONS



SUMMARY FINDINGS

- Forest residue biomass potential is somewhat less – removal of unused resources, decline in pulpwood and sawlog markets
- Crop residue potential is less – consideration of soil carbon, no residue from conventionally tilled acres
- Energy crop potential is greater – permanent pastureland, POLYSYS modeling
- Modeling framework is developed and can be adapted to wide range of analyses in addition to estimation of supply curves, land use change, etc.
- Modeling results are available through the Bioenergy KDF

http://www.bioenergykdf.net

Thank you for your attention

- Questions?

- Contact information:

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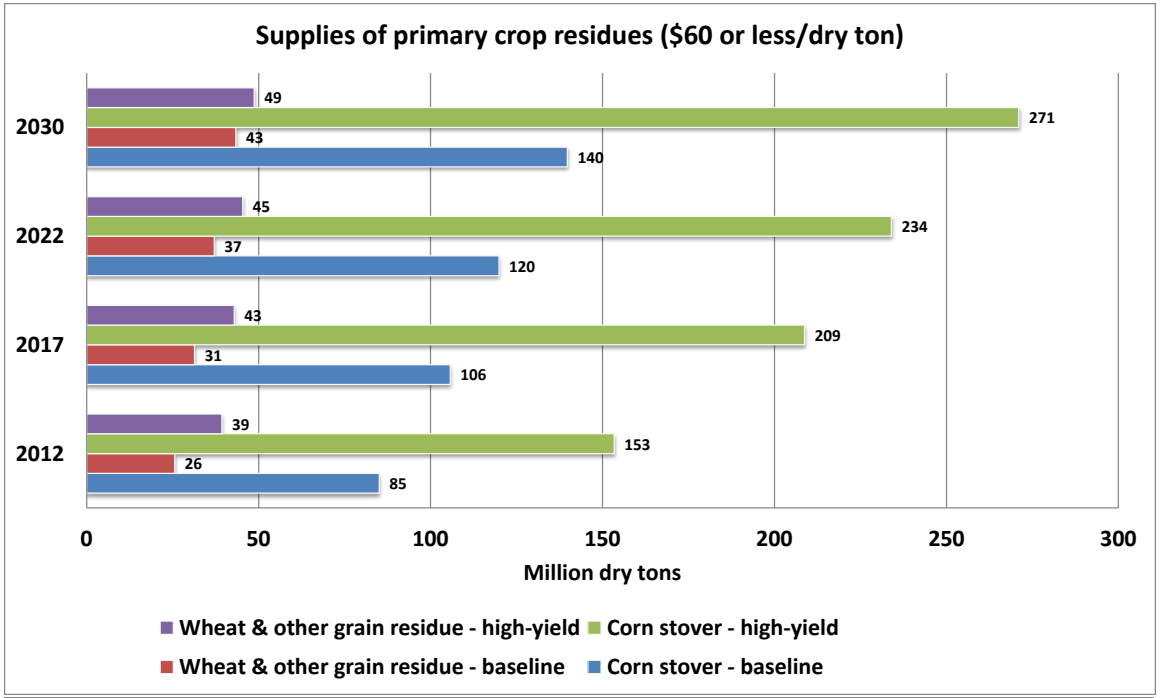
ADDITIONAL SLIDES

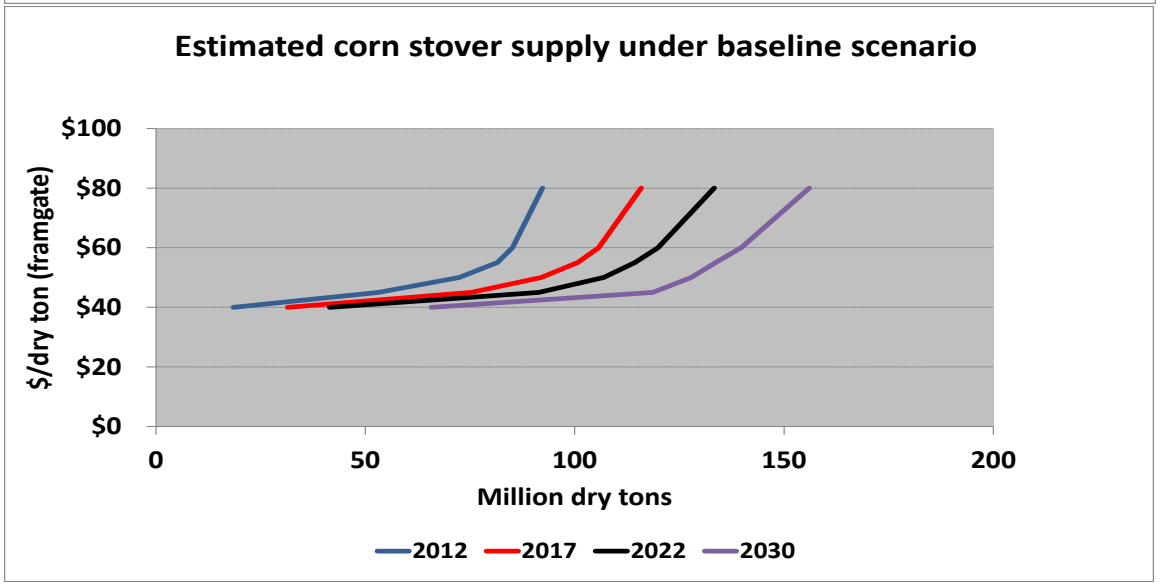
ENHANCEMENTS & UPDATES TO POLYSYS

- Crop residue retention coefficients
- Four energy crops
- Energy crop yields
- Grower payments and production costs
- Harvest and collection costs
- Model programming and output files
- Executable versions at ORNL

CROP RESIDUE ESTIMATED SUPPLY

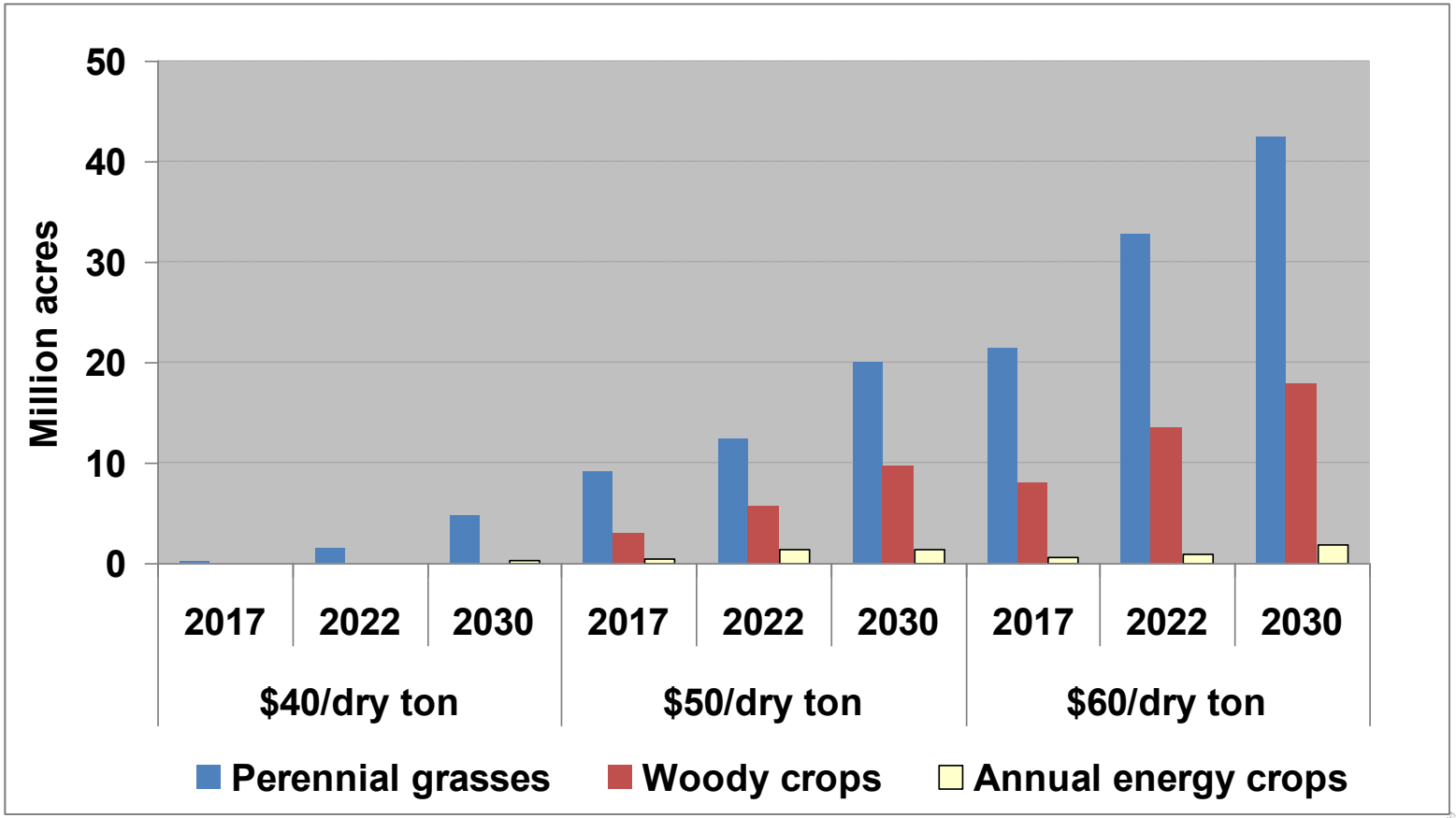
- Baseline scenario
  - About 111 million dry tons (mostly corn stover)
  - By 2030, supplies exceed 180 million dry tons (higher crop yields and higher use of reduced- and no-till
- High-yield scenario
  - Amount of corn stover increases significantly
  - By 2030, total primary residue is 320 million dry tons with 85% of this quantity corn stover





ENERGY CROP SIMULATED LAND USE CHANGE

- Land use change at highest simulated prices by 2030
  - 22 to 30 million acres cropland
  - 40 to 50 million acres pasture



FOREST AND AGRICULTURAL RESIDUES AND WASTES AND ENERGY CROPS AT SELECTED PRICES AND YEARS UNDER BASELINE ASSUMPTIONS