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**TRANSITIONING FROM THE BUCKET TO THE BARREL WEBINAR SERIES**  
NC STATE UNIVERSITY


**Where Will Dedicated Bioenergy Crops Be Grown?**  
Potential Land-use Change Associated with Growing Bioenergy Feedstocks

The webinar starts at 2:00 PM(Eastern Time)

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"The IBSS project is supported by Agriculture and Food Research Initiative Competitive Grant no. 2011-68005-30410 from the USDA National Institute of Food and Agriculture."



"The webinar project is supported by The Renewable Resources Extension Act National Focus Fund Grant no. 2011-46401-31144 from the USDA National Institute of Food and Agriculture."




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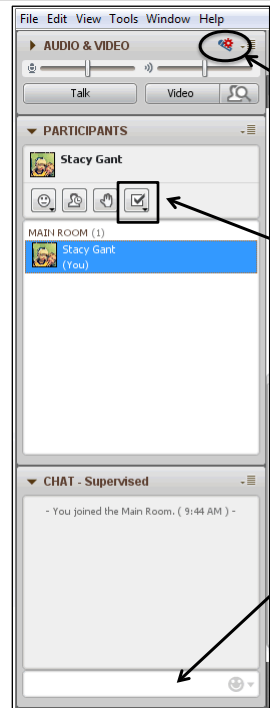
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## Potential Land-use Change Associated with Growing Bioenergy Feedstocks

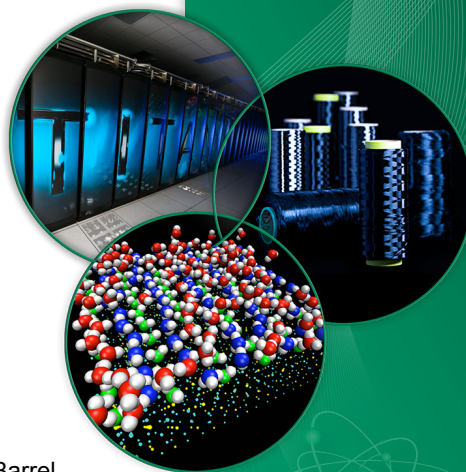
Matthew Langholtz

Laurence Eaton

Anthony Turhollow

Date: August 21<sup>st</sup>, 2013

IBSS Webinar Series:  
Transitioning from the Bucket to the Barrel  
Educational Biofuels Webinar Series



## U.S. Billion Ton Update (2011)

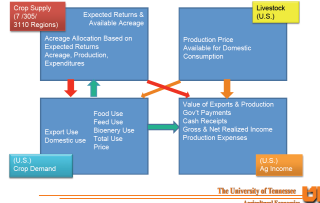
- Forecasts of potential additional biomass
  - Multi-institutional effort
  - 20-year projections of economic availability of biomass (price, location, scenario)
- Forest resources
  - Logging residues
  - Forest thinnings (fuel treatments)
  - Conventional wood
  - Fuelwood
  - Primary mill residues
  - Secondary mill residues
  - Pulping liquors
  - Urban wood residues
- Agricultural resources
  - **Crop residues**
  - Grains to biofuels
  - **Perennial grasses**
  - **Perennial woody crops**
  - Animal manures
  - Food/feed processing residues
  - MSW and landfill gases
  - **Annual energy crop (added for 2011)**



## POLYSYS Modeling Framework

- County model anchored to USDA 10-year projections and extended to 2030
  - 8 major crops (corn, soybeans, wheat, sorghum, oats, barley, rice, cotton) and hay, livestock, food/feed markets
  - Projected demands for food, feed, industry, and exports
  - Biomass resources include stover, straws, energy crops (perennial grass, coppice and non-coppice woody, annual energy crop), allowed only on ag land, no exchange between forest land and ag land.
  - 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
    - Restraints limiting land use change

### POLYSYS Modules and Interaction

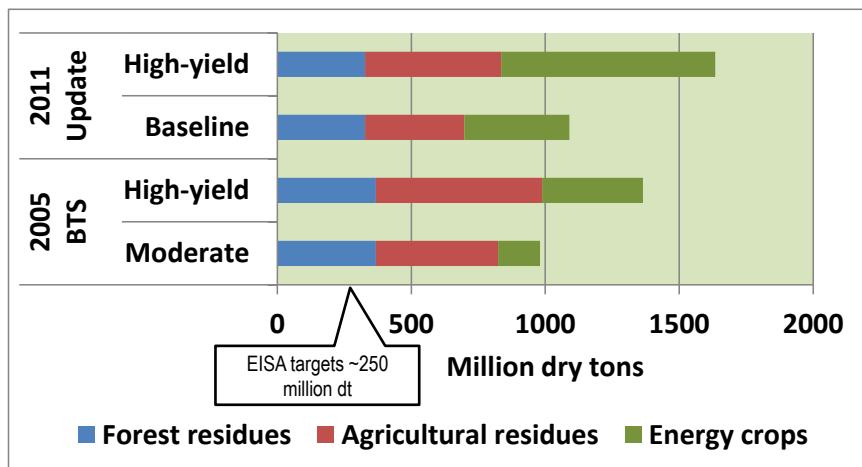


**Chad Hellwinckel** –  
 University of Tennessee -  
 Agricultural Policy Analysis  
 Center (APAC) (  
<http://www.agpolicy.org/>)

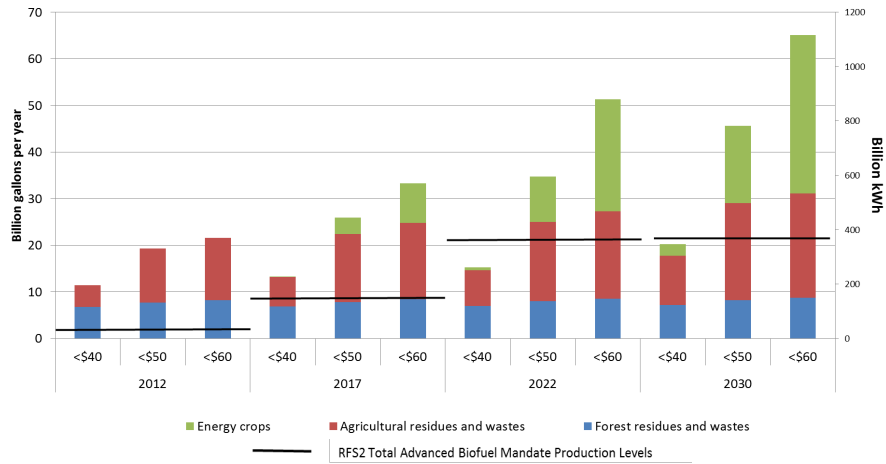
Other model versions:  
 Burt English  
 Daniel G De la Torre Ugarte

## Feedstock supply projections

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



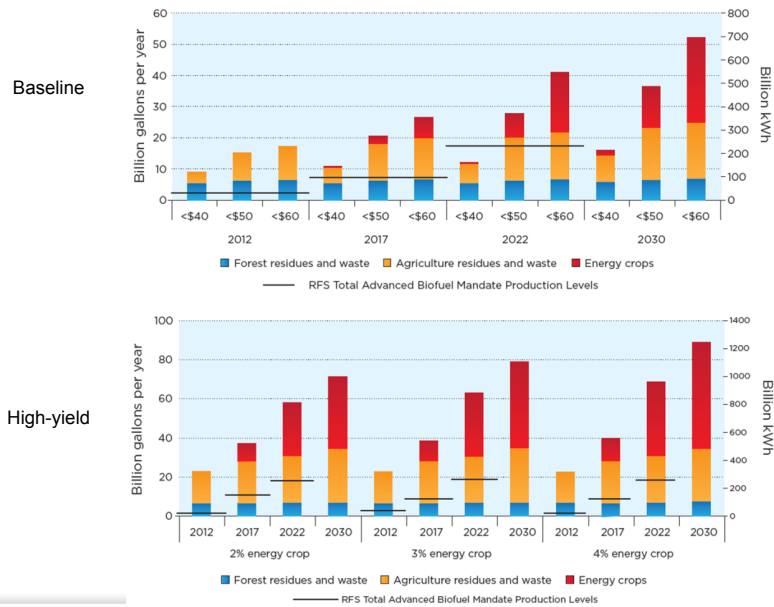
## Baseline Scenario Summary



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## Feedstock supply projections



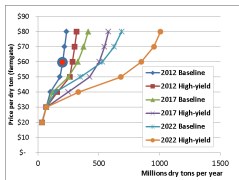
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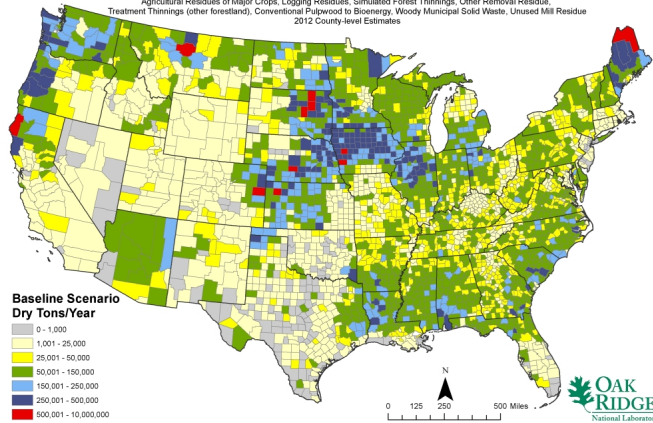
# Supply Curve Results

- 2012
- Baseline scenario
- \$60 dry ton<sup>-1</sup>

201 x 10<sup>6</sup> dt



**Currently Available Biomass Resources**  
Includes all potential primary agricultural resources and primary and secondary forestry resources excluding Federal Lands (when available) at \$80 per dry ton or less: Agricultural Residues of Major Crops, Logging Residues, Simulated Forest Thinnings, Other Removal Residue, Treatment Thinnings (other forestland), Conventional Pulppwood to Bioenergy, Woody Municipal Solid Waste, Unused Mill Residue  
2012 County-level Estimates



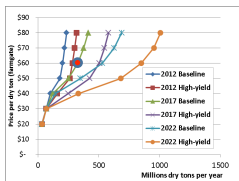
Source: U.S. Department of Energy 2011 U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry. R.D. Perack and B.J. Stokes (Leads), ORNL/TM-2011/024. Oak Ridge National Laboratory, Oak Ridge, TN. 2012. Data Accessed from the Bioenergy Knowledge Discovery Framework, www.bioenergykdf.net. [December 4, 2012]. Author: Laurence Eaton (eatonl@ornl.gov) December 4, 2012.



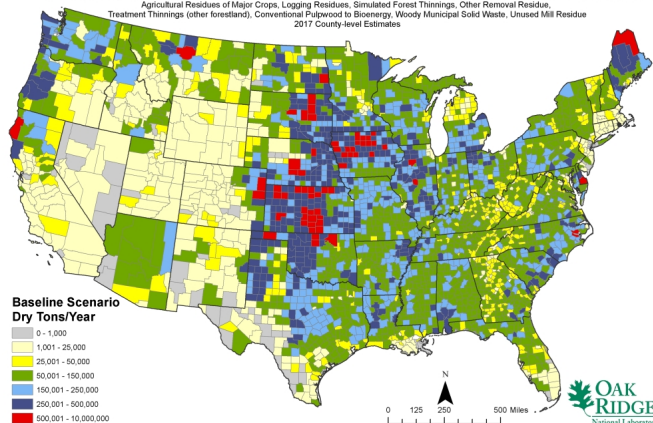
# Supply Curve Results

- 2017
- Baseline scenario
- \$60 dry ton<sup>-1</sup>

327 x 10<sup>6</sup> dt



**Potentially Available Biomass Resources**  
Includes all potential primary agricultural resources and primary and secondary forestry resources excluding Federal Lands (when available) at \$80 per dry ton or less: Agricultural Residues of Major Crops, Logging Residues, Simulated Forest Thinnings, Other Removal Residue, Treatment Thinnings (other forestland), Conventional Pulppwood to Bioenergy, Woody Municipal Solid Waste, Unused Mill Residue  
2017 County-level Estimates



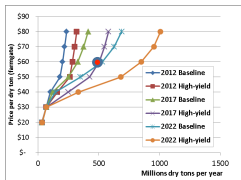
Source: U.S. Department of Energy 2011 U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry. R.D. Perack and B.J. Stokes (Leads), ORNL/TM-2011/024. Oak Ridge National Laboratory, Oak Ridge, TN. 2012. Data Accessed from the Bioenergy Knowledge Discovery Framework, www.bioenergykdf.net. [December 4, 2012]. Author: Laurence Eaton (eatonl@ornl.gov) December 4, 2012.



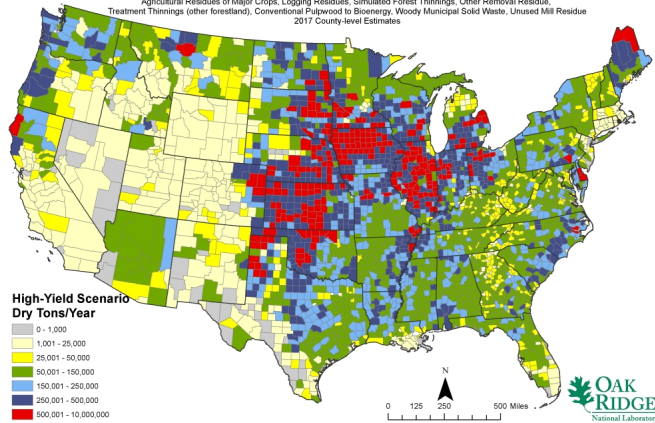
# Supply Curve Results

- 2017
- High-yield scenario
- \$60 dry ton<sup>-1</sup>

503 x 10<sup>6</sup> dt



**Potentially Available Biomass Resources**  
 Includes all potential primary agricultural resources and primary and secondary forestry resources excluding Federal Lands (when available) at \$80 per dry ton or less:  
 Agricultural Residues of Major Crops, Logging Residues, Simulated Forest Thinnings, Other Removal Residue,  
 Treatment Thinnings (other forestland), Conventional Pulpmill to Biorefinery, Woody Municipal Solid Waste, Unused Mill Residue  
 2017 County-level Estimates



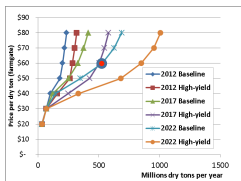
Source: U.S. Department of Energy 2011 U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry.  
 R.D. Perack and B.J. Stokes (Leads), ORNL/TM-2011/224. Oak Ridge National Laboratory, Oak Ridge, TN, 237p.  
 Data Accessed from the Bioenergy Knowledge Discovery Framework, www.bioenergyfd.net. (December 4, 2012)  
 Author: Laurence Eaton (eatonl@ornl.gov) December 4, 2012.



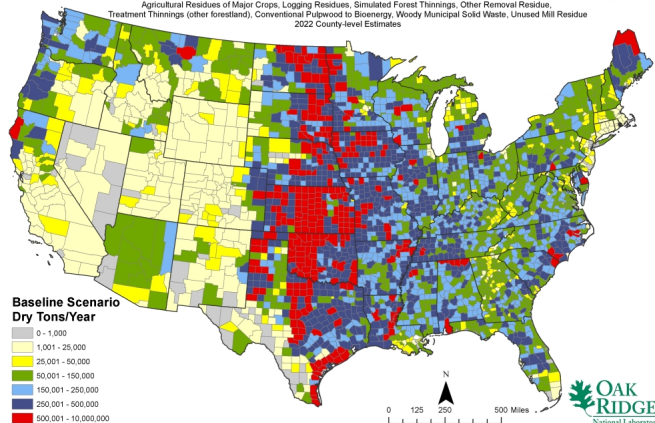
# Supply Curve Results

- 2022
- Baseline scenario
- \$60 dry ton<sup>-1</sup>

529 x 10<sup>6</sup> dt



**Potentially Available Biomass Resources**  
 Includes all potential primary agricultural resources and primary and secondary forestry resources excluding Federal Lands (when available) at \$80 per dry ton or less:  
 Agricultural Residues of Major Crops, Logging Residues, Simulated Forest Thinnings, Other Removal Residue,  
 Treatment Thinnings (other forestland), Conventional Pulpmill to Biorefinery, Woody Municipal Solid Waste, Unused Mill Residue  
 2022 County-level Estimates



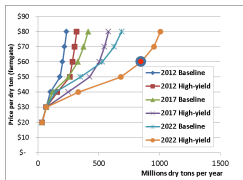
Source: U.S. Department of Energy 2011 U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry.  
 R.D. Perack and B.J. Stokes (Leads), ORNL/TM-2011/224. Oak Ridge National Laboratory, Oak Ridge, TN, 237p.  
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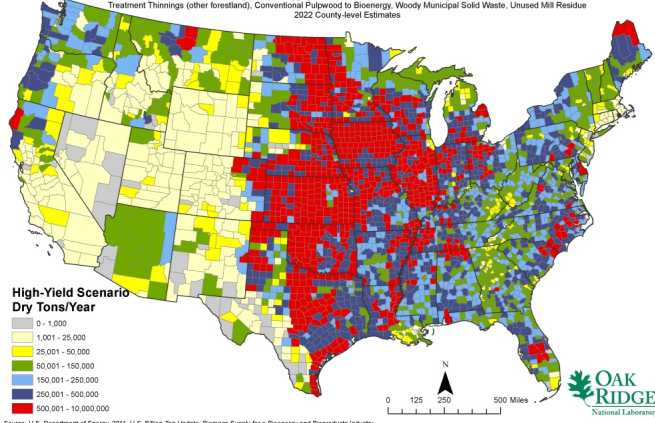
# Supply Curve Results

- 2022
- High-yield scenario
- \$60 dry ton<sup>-1</sup>

848 x 10<sup>6</sup> dt



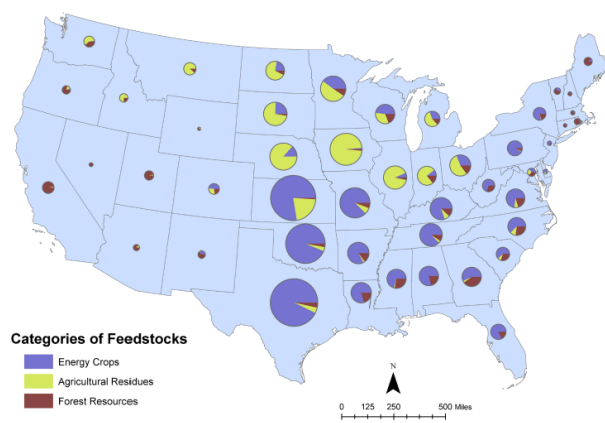
**Potentially Available Biomass Resources**  
Includes all potential primary agricultural resources and primary and secondary forestry resources (excluding Federal Lands (when available)) at \$80 per dry ton or less: Agricultural Residues of Major Crops, Logging Residues, Simulated Forest Thinnings, Other Removal Residue, Treatment Thinnings (other forestland), Conventional Pulpwood to Bioenergy, Woody Municipal Solid Waste, Unused Mill Residue  
2022 County-level Estimates



Source: U.S. Department of Energy, 2011, U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry, R.D. Parlack and B.J. Stokes (Leach), ORNL/TM-2011/024, Oak Ridge National Laboratory, Oak Ridge, TN, 2011. Data Accessed from the Bioenergy Knowledge Discovery Framework, www.bioenergyfd.net. (December 4, 2012). Author: Laurence Eaton (leaton@ornl.gov) December 4, 2012.



# State-level Shares of All Potentially Available Resources at \$60 Per Dry Ton or Less in 2030, Under Baseline Assumptions

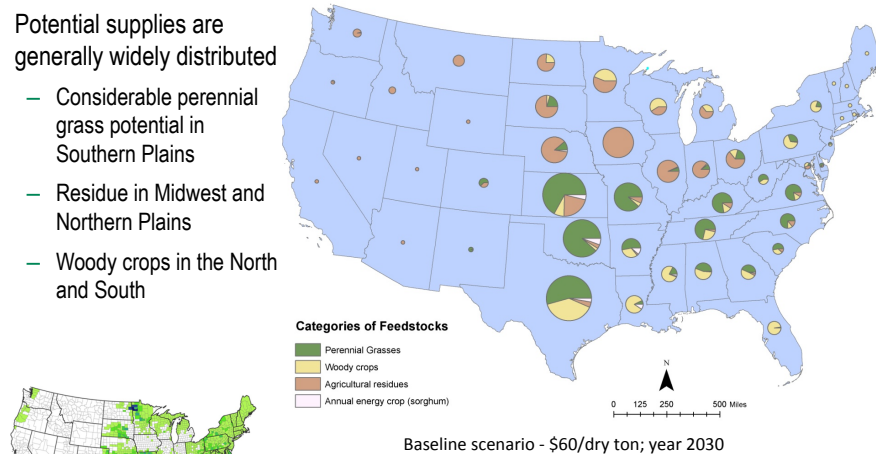


Baseline scenario - \$60/dry ton; year 2030

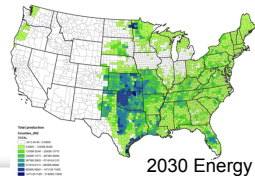


## Potential to Supply Crop Residues and Energy Crops by State

- 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



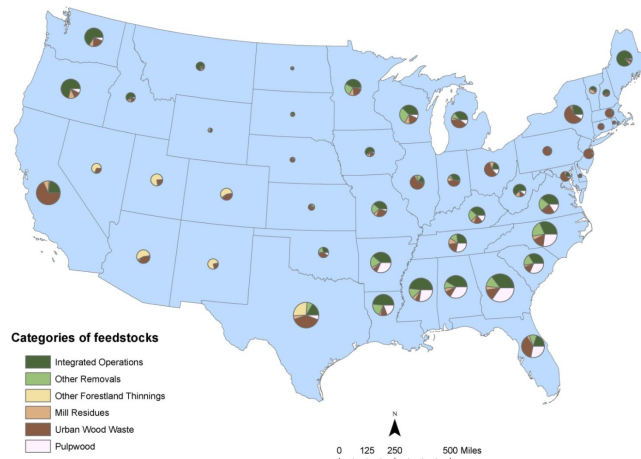
2030 Energy crop county estimates

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## Potential to Supply Forest Residues by State

Forest residue resources are where expected



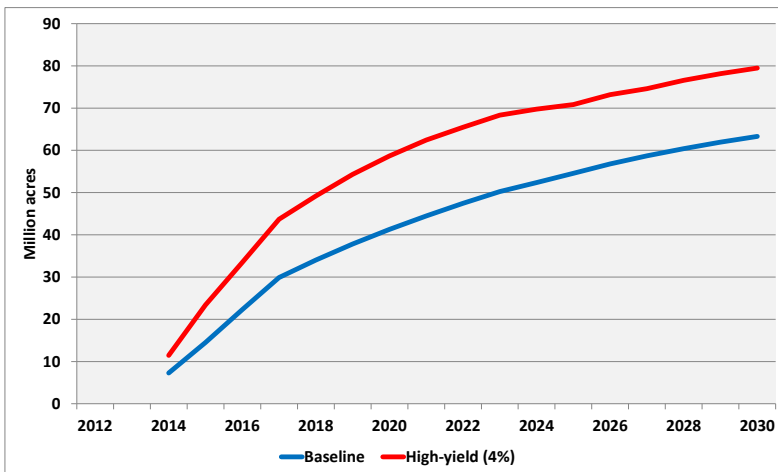
Baseline scenario - \$60/dry ton; year 2030

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## Land-use Change

- 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

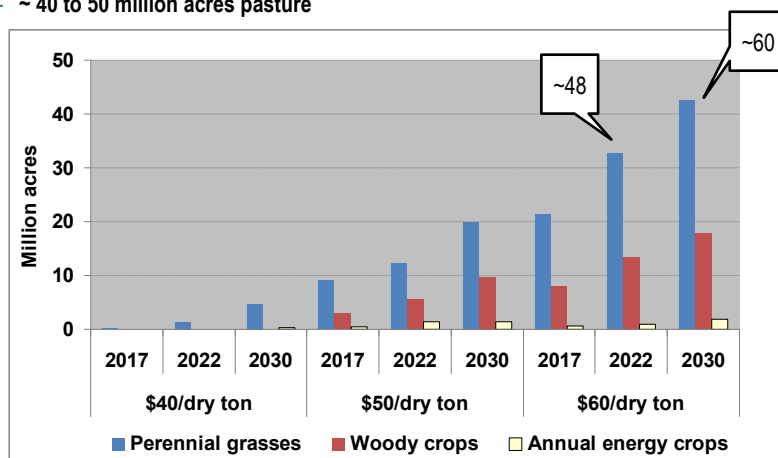


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## Land Use Change by Energy Crops

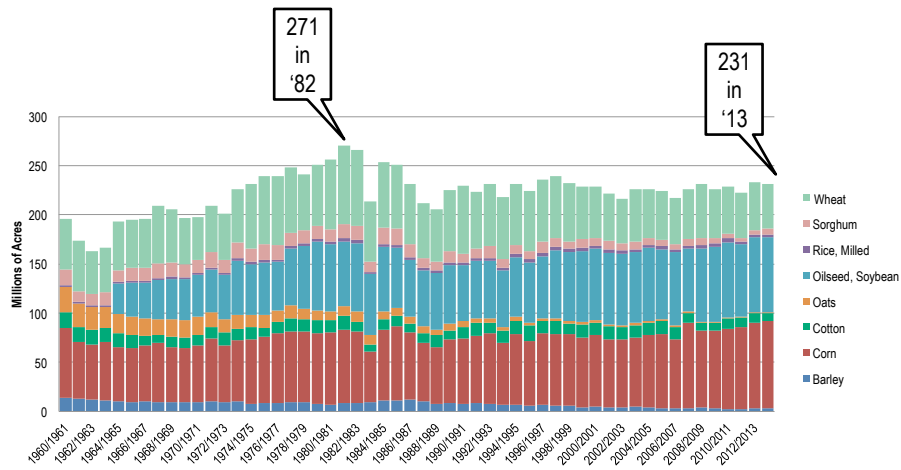
- At highest simulated price
  - ~ 22 to 30 million acres cropland
  - ~ 40 to 50 million acres pasture



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## Historical Acreage Harvested of 8 Major US Crops, 1961-2012



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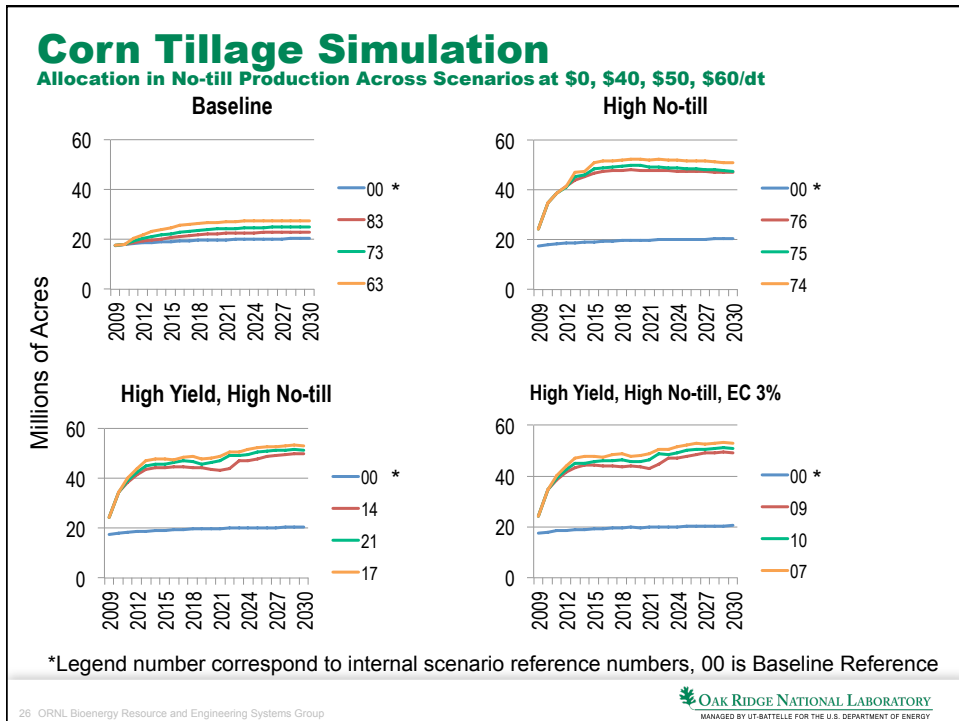
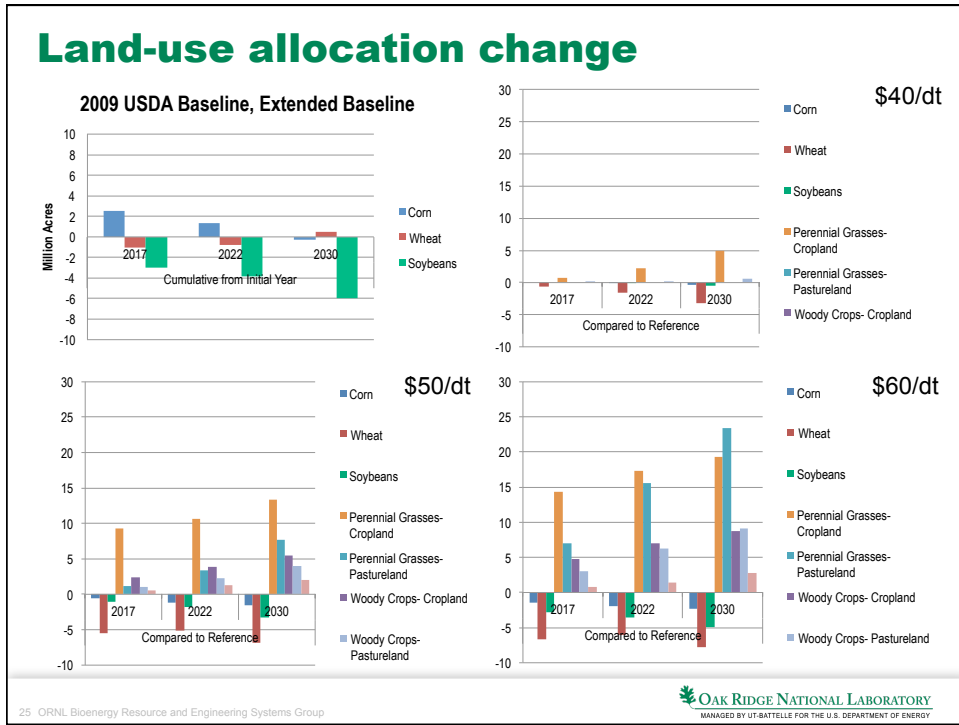
## Perspective:

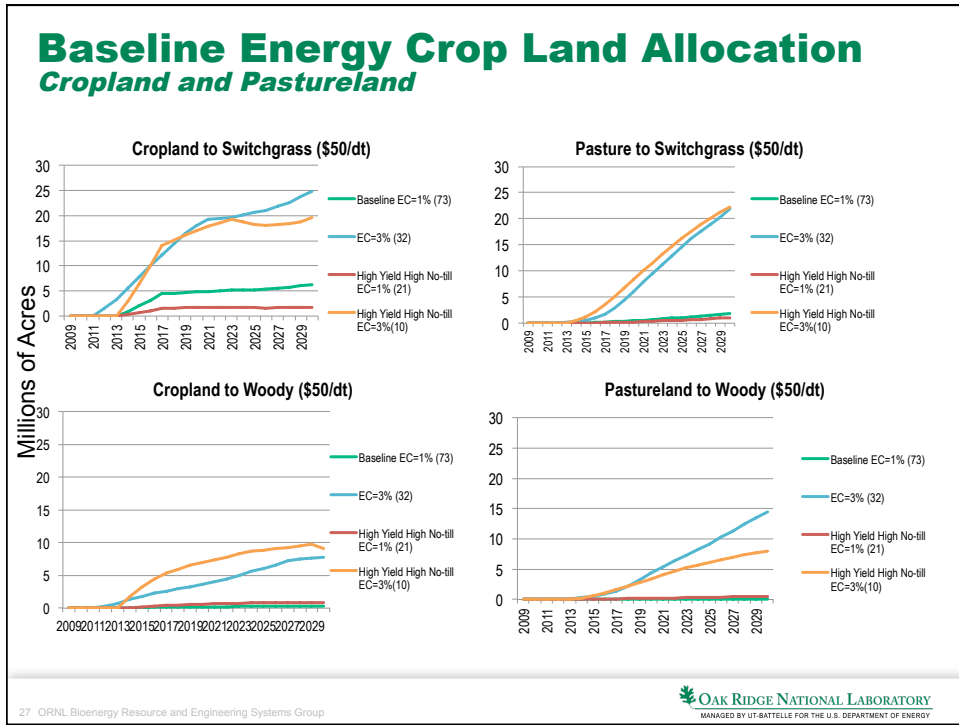
Under the baseline scenario at \$60, in 2030:

- Over 1 billion dry tons produced, i.e. about 85 bg/yr or 30% of current petroleum consumption (i.e. 4x EISA target of 21 bg/yr by 2022).
- Includes dedicated crops on up to 30 million acres of cropland and up to 50 million acres pastureland (not both).
- Current cropland is 231 million acres, off from a high of 271 million in 1982 (simulation is 13% of current, 11% of high).
- Current pastureland is 460 million acres (simulation is 11%).

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## Bioenergy KDF Resources

- Billion Ton Data Explorer
  - Visualize custom supplies from the BT2 findings
  - Available for all potential resources identified as new biomass sources

### Corn Stover Supply

**Figure 4.11** Supply curves of potential corn stover production for various years under baseline assumptions

The graph shows that as the quantity of corn stover increases, the cost per dry ton also increases. The 2022 scenario (circled in red) shows a cost of approximately \$45 per dry ton for 100 million dry tons.

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### Online Tool Workflow

The workflow starts with a search interface, moves to a map view showing biomass potential across the United States, and finally to a detailed data table with columns for location, biomass potential, and other metrics.

<https://bioenergykdf.net/>

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## Conclusions



Future not certain, but,

- Wide range of feedstocks types potentially available, wide geographic distribution
- Farmgate prices of \$50/dt produces more than enough supply to meet EISA targets by 2022, over 1 billion tons (~30% of current US petroleum consumption) by 2030
- Production of >1 billion tons, or 30% of fuels, might use ~10% of cropland and 10% pastureland.
- Questions?: Matt Langholtz: [langholtzmh@ornl.gov](mailto:langholtzmh@ornl.gov), 865-574-6520; Laurence Eaton, [eatonlm@ornl.gov](mailto:eatonlm@ornl.gov), 865-241-5877

<https://bioenergykdf.net/>

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## Additional Slides

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## Price Elasticity of Supply

- $E_s = \Delta(\text{Acreage}) / \Delta(\text{Feedstock Price})$
- Responsiveness of land change to biomass prices
- Compare Cropland and Pastureland
- Mid-point formula used for biomass prices \$40-\$80/dt at \$5 increments (\$42.50, \$47.50, etc)

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