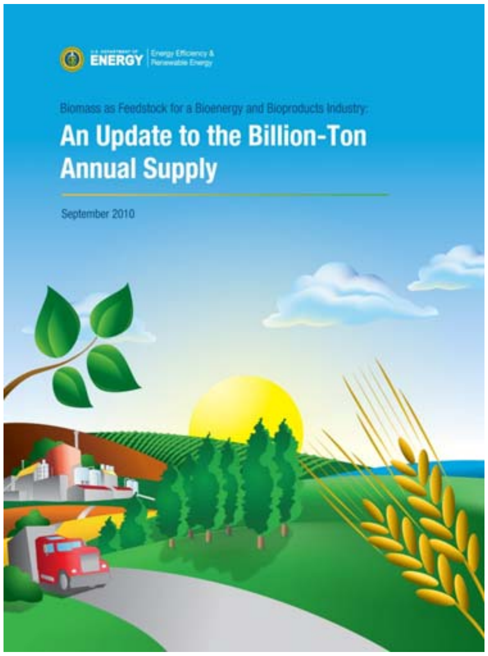

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Abbreviated Presentation Handout

Cellulosic Supply Chains for Bioenergy
Penn State University

November 11, 2010

OVERVIEW

- 2005 Billion Ton Report recap
- Goals of the 2010 Update
- Key assumptions of methods of analysis
  - Agricultural Resources
  - Forest Resources
- Results

2005 Billion Ton Report

- Does the U.S. land base have the potential to produced a sustainable supply of biomass to displace 30% of current (2005) petroleum consumption?
- Identified >1.3 billion tons of feedstocks annually to support a bioenergy and bioproducts industry

Policy Environments of 2005 vs. 2010

- EISA (2007) mandates 36 billion gallons of ethanol by 2022
  - Maximum of 15 billion gallons of corn ethanol
  - Remaining 21 billion gallons to come from cellulosic and advanced sources

Goals of the Update

- To address potential biomass resource availability at target prices and high spatial resolution
- To improve upon the data, the methodology, and projections of 2005 Billion Ton Study
- To make the data and analysis transparent and available to others
- To address concerns and issues from the 2005 study

Key Differences Between the 2005 Billion Ton Study and the 2010 Billion Ton Update

2005 Billion Ton Report	2010 Billion Ton Update
National estimates	County-level with aggregation to state, regional and national levels
No price or cost analyses	Supply curves by feedstock by county at farmgate/forest landing
Crop residue removal sustainability addressed from national perspective; erosion only	Crop residue removal sustainability modeled at soils level; erosion & soil carbon
No explicit land use change modeling	Land use change modeled for energy crops
Long-term, inexact time horizon (2005, 2025 – 2050)	2010 – 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 for forest residues	Greater erosion plus wetness constraints for forest residues

Contributors to the Billion-Ton Update

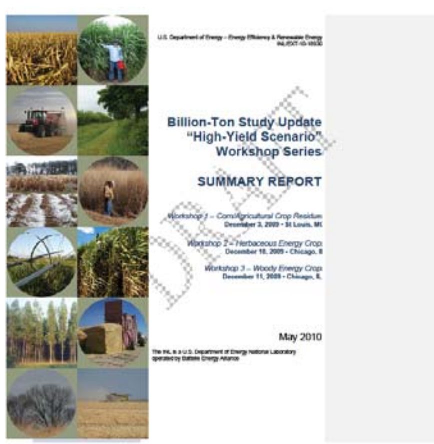
- Oak Ridge National Laboratory - 10
- Idaho National Laboratory - 3
- Agricultural Policy Analysis Center (University of Tennessee) - 5
- Navarro Research & Engineering (DOE Golden Field Office) - 1
- USDA/Forest Service - 13
- USDA/ARS - 7
- USDA/NRCS – 1
- USDA/NIFA - 1
- Iowa State University – 1
- Kansas State University - 1
- State University of New York – 3
- Texas A&M – 1
- University of Illinois - 1
- University of Minnesota - 2

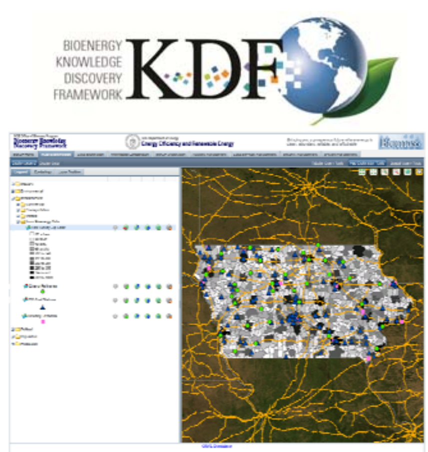
Summary:
• 50 contributors
• 2 Labs (ORNL & INL)
• 4 USDA agencies
• 7 Universities

Reviewers
• 3 USDA
• 4 University
• 1 National Council
• 1 National Institute
• 2 International

Energy Crop Chapter Authors:
•Grasses – Mitchell and Vogel, ARS
•Miscanthus – Voigt, U. IL
•Sugarcane – Richard, ARS
•Sorghum – Rooney, TX A&M
•Poplar – Riemenschneider, U. MN
•Willow – Volk and Abrahamson, SUNY
•Eucalyptus – Langholtz, ORNL
•Southern Pine – Wright, ORNL

Associated Efforts

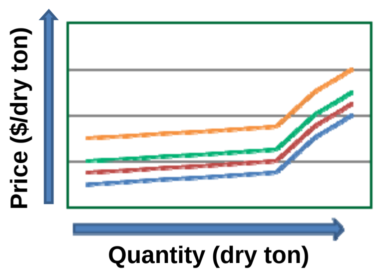




http://bioenergykdf.net

How Much Biomass is Available?

feedstock; price, year, yield assumptions (scenarios); current use status; geography



Feedstocks
- Forest
- Agriculture

Selected Prices
- $10-$100 (Forest)
- $20-$80 (Agriculture)

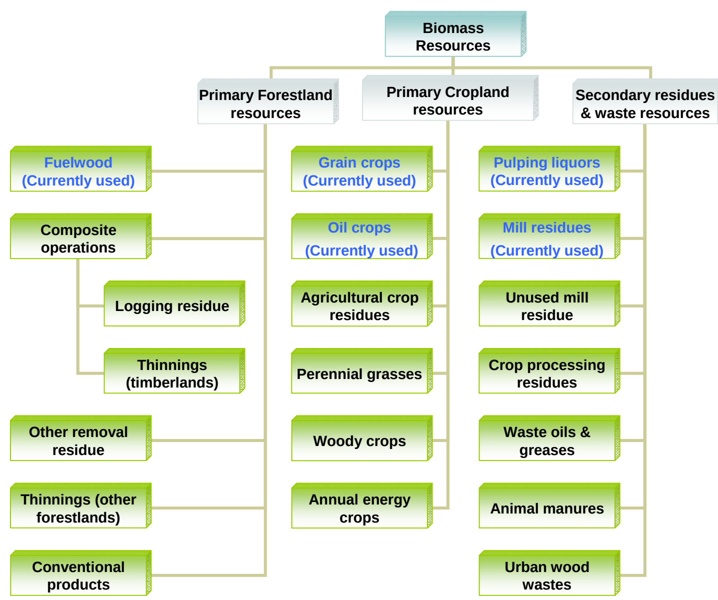
Year
- 2010 (base)
- 2017
- 2022
- 2030

Scenarios
- Baseline
- High-yield
  - 2%, 3%, 4% annual growth

Use Status
- Currently used
- Potential

Scale
- National
- Regional
- State
- Multi-county
- County

The Taxonomy of Biomass Feedstocks



General Approach

- Supply curves are estimated at the roadside (farmgate, landing) as *bales or chips*
  - Resource acquisition costs
    - Grower payments for crop residues
    - Production costs for dedicated energy crops
    - Stumpage costs for forest residues and conventional wood
  - Collection and harvest costs
    - INL, ORNL, EcoWillow models for cropland resources
    - FRCS model revised to handle small trees, tops & limbs in all regions
- Key technical and factor input cost data, enhancement of models (e.g, POLYSYS), and analyses developed through coordination among partners

General Approach

County-level feedstock supply curves for major primary agriculture and forest resources

1. **For primary agriculture resources** - Crop residues and energy crops (supply curves)
   - POLYSYS- Policy Analysis System Model
   - Based on NASS, USDA Census data, USDA Agricultural Baseline projections
   - Predicts optimal farm land use with the additional option of collecting annual residues or choosing purpose grown energy crops
2. **For primary forest resources** - Resource cost analysis used to estimate supply curves
   - Based on USDA/FS data (FIA, TPO, RPA, …); meet RPA projections for pulp, timber, veneer
   - Resource constraints include forest residue access, recovery, and merchantability
   - Requirements for resource environmental sustainability

Agricultural Resources

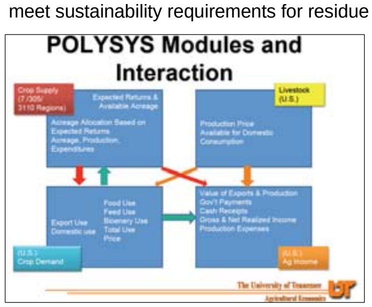
Calibrated OBP version of POLYSYS – dynamic, county-level model of the U.S. agricultural sector

- **POLYSYS is anchored to the USDA Baseline Forecasts**
- **451 million acre land base- Cropland (250 million acres); Cropland used as pasture (22 million acres); Hayland (61 million acres); Permanent pasture (118 million acres)**
- **Includes detailed cropping budgets (traditional and dedicated energy crops)**
  - **Estimated discounted average cost of production**
- **Established yield potentials from published literature**
- **Identified land suitability (constraints) for sustainable production**
- **Energy Crops compete with traditional crops for acreage**
- **Forest resources exogenous to the model**

Agricultural Resources

Calibrated OBP version of POLYSYS – dynamic, county-level model of the U.S. agricultural sector

- To create biomass supply curves POLYSYS is run at a set of feedstock prices ($40 to $60/dry ton at $5 increments)
- POLYSYS calculates the land use (acreage of land type) in each county that will simultaneously
  - maximize farmer profit
  - meet USDA baseline production of 8 major crops and livestock demands
  - meet sustainability requirements for residue removal



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

University of Tennessee - Agricultural Policy Analysis Center (APAC) (http://www.agpolicy.org/)

Crop Residues

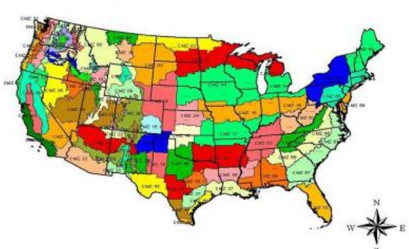
- **Threshold grower payments – based on nutrient replacement cost (fertilizer) plus organic matter (~$15/dry ton) plus $10/dry ton (regional variability due to regional variation in fertilizer prices)**
  - **Apply to stover and straws**
- **Crop residue collection costs**
  - **Sensitive to amount removed/acre ; decreases exponentially as removal amount increases**

Crop Residues

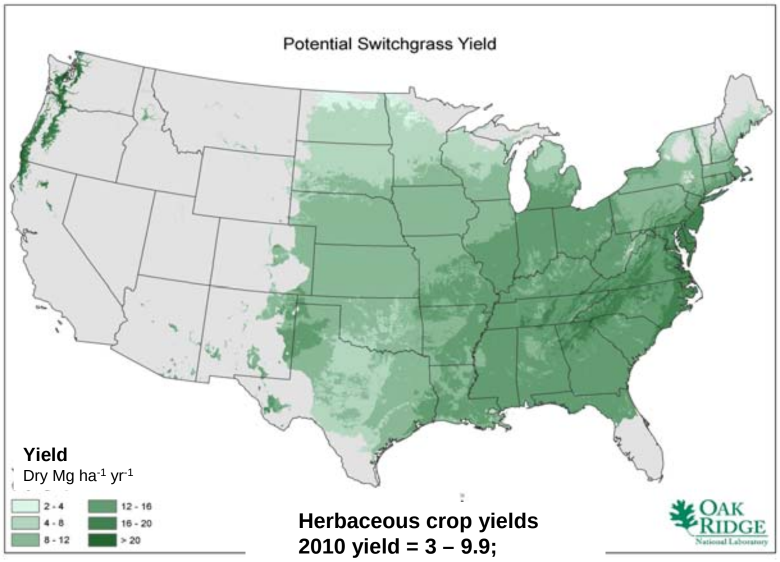
Residue Sustainability

- **Residue retention coefficients estimated using RUSLE2, WEPS, and SCI for erosion and soil carbon**
  - **Separate coefficients for acres under reduced till and no-till cultivation**

Crop Management Zones



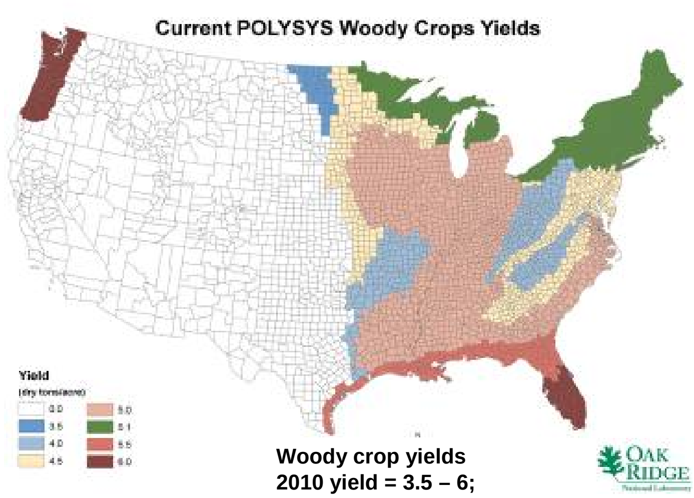
Dedicated Energy Crops: Yields



Herbaceous crop yields
2010 yield = 3 – 9.9;
2030 yield = 3.6 – 12.0
(baseline scenario)

Dedicated Energy Crops: Yields

- **Woody crops (poplar, pine, eucalyptus, willow)**



Woody crop yields
2010 yield = 3.5 – 6;
2030 yield = 4.2 – 7.2
(baseline scenario)

Dedicated Energy Crops: Costs

- Production costs
  - Planting (site prep, materials, etc)
  - Maintenance (weed control, fertilization, etc)
- Harvesting
  - Herbaceous crops (mow, rake, bale, move/stack roadside)
  - Non-coppice woody crops (fell, bunch, chip)
  - Coppice woody crop (continuous cut and chip)

Dedicated Energy Crops: Sustainability

- Energy crops allowed on non irrigated land
- Minimal tillage, fertilizer and herbicide applications
- Used BMPs for establishment, cultivation, and harvesting
- Some intensification of pasture land required (Management Intensive Grazing) to meet lost forage when energy crops displaced pasture

Forestland resources

504 million acres of timberland, 91 million acres of “other forestland”

Types	Source
Timberland- Logging residues	FIA plots (federal & nonfederal lands)
Timberland- Fuel treatments	FIA plots (federal & nonfederal lands)
Timberland - Conventional wood (pulp)	FIA plots (federal & nonfederal lands)
Timberland - Land clearing & silvicultural treatments	FIA plots (federal & nonfederal lands)
Thinnings from “other forestland” (<20ft3/yr) e.g pinyon juniper	FIA plots (federal & nonfederal lands)
Fuelwood*	EIA
Primary Mill residues*	TPO
Secondary mill residues*	EIA, Surveys
Pulping liquors*	EIA
Urban wood residues	EPA and ISFS Forest Products Lab

* *Fraction in current use are considered not available*

Forestland resources

FIA-based forest resources

- Evaluated the “state-of-the-science” for biomass removal
  - erosion, soil nutrients, biodiversity, soil-organic carbon, and long-term soil productivity
- Developed woody retention levels by slope classes within context of a science review
- Projections based on 2007 RPA/TPO (accessed February 2010)

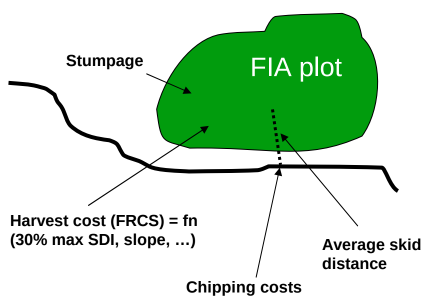
Forestland resources

Sustainability assumptions for forest residue retention

- Logging residues
  - 30% left on-site
- Fuel treatment thinnings
  - Slope <40% = 30% of residue is left on-site
  - Slope >40% to <80% = 40% of the residue left on site
  - Slope >80% = no residue is removed (no limbs or tops yarded)
- Removed steep, wet and roadless sites

Forestland resources

FIA-based forest resources



~37,000 permanent field plots

- All fire regime condition classes
- Forests could have fuel treatment if stand density greater than 30% of maximum stand density for forest type/ecoregion
- Thin over 30-year period

Scenarios (1 of 3)

- Baseline scenario assumptions
  - Published USDA Baseline forecast for crop yields, acres, etc.
  - Baseline forecast extended to 2030 based on trends in last 3-years of published forecast
  - Stover to grain ratio of 1:1 assumed
  - National corn yield average of 160 bu/ac in 2010 and assumed to increase to 201 bu/ac in 2030

Scenarios (2 of 3)

- Baseline scenario assumptions (continued)
  - Assumes a mix of conventional till (CT), reduced till (RT), and no-till (NT)
    - For corn
      - 2010 – 38% conventional till, 43% reduced till, 20% no-till
      - 2030 – 34% conventional till, 43% reduced till, 23% no-till
    - No residue collected on conventionally tilled acres
  - Energy crop yields increase of 1% annually (determined by year of planting)
    - Yield growth attributed to learning by doing in energy crops and limited R&D

Scenarios (3 of 3)

- **High-yield scenario(s) assumptions**
  - **Corn yields increase to 265 bu/acre in 2030 (national average)**
  - **Higher amounts of cropland in no-till cultivation allow greater residue removal**
  - **Energy crop yields increase at 2%, 3%, and 4% annually**
    - **Higher yields attributed to more aggressive R&D**

Final Comments

- Energy crops displace mostly commodity crops at low prices
- Significant quantities of pasture (cropland pasture and permanent pasture) are displaced at higher prices
- Lost forage needs to be replaced
  - Growing of additional hay (alfalfa)
  - Intensification of pasture (e.g., management intensive grazing, rotational grazing, etc.)
  - Both

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