# U.S. Billion-ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry

**Marilyn Buford, Presenter**
**USDA Forest Service R&D**

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# Contributors


*Oak Ridge National Laboratory*
Robert D. Perlack*
Laurence M. Eaton
Anthony F. Turhollow
Matt H. Langholtz
Craig C. Brandt
Lynn L. Wright
Robin L. Graham
Mark E. Downing
Jacob M. Kavkewitz
Anna M. Shamey

*Idaho National Laboratory*
David J. Muth
J. Richard Hess
Jared M. Abodeely

*Kansas State University*
Richard G. Nelson

*State University of New York*
Timothy A. Volk
Thomas S. Buchholz
Lawrence P. Abrahamson

*Iowa State University*
Robert P. Anex

*CNJV LLC*
Bryce J. Stokes*

*University of Tennessee*
Chad Hellwinckel
Daniel De La Torre Ugarte
Daniel C. Yoder
James P. Lyon
Timothy G. Rials

*USDA Agricultural Research Service*
Douglas L. Karlen
Jane M. F. Johnson
Robert B. Mitchell
Kenneth P. Vogel
Edward P. Richard
John Tatarko
Larry E. Wagner

*University of Minnesota*
William Berguson
Don E. Riemenschneider

*Texas A&M University*
William L. Rooney

*USDA Forest Service*
Kenneth E. Skog,
Patricia K. Lebow
Dennis P. Dykstra
Marilyn A. Buford
Patrick D. Miles
D. Andrew Scott
James H. Perdue
Robert B. Rummer
Jamie Barbour
John A. Stanturf
David B. McKeever
Ronald S. Zalesny
Edmund A. Gee

*USDA National Institute of Food and Agriculture*
P. Daniel Cassidy

*USDA Natural Resources Conservation Service*
David Lightle

*University of Illinois*
Thomas B. Voigt


*** Co-leads**

# Preamble

- **Excludes algal feedstocks**
- **Includes “major” feedstocks**
- **Costs are only to roadside/farmgate**
- **No specified end use or conversion process**
- **Raw material in form as described with losses only up to roadside**
- **$60/dry ton was selected as the “illustrative” case, not the expected cost**

# Biomass Feedstock Resource Base

Lower 48 States Only

- About one-half of the land in the contiguous U.S.
  - Forestland resources: 504 million acres of timberland, 91 million acres of other forestland
  - Agricultural resources: 340 million acres cropland, 40 million acres idle cropland, 404 million acres pasture (cropland pasture & permanent pasture)

- Forest resources
  - Logging residues
  - Forest thinnings (fuel treatments)

  **Combined into Composite**

  - *Conventional wood*

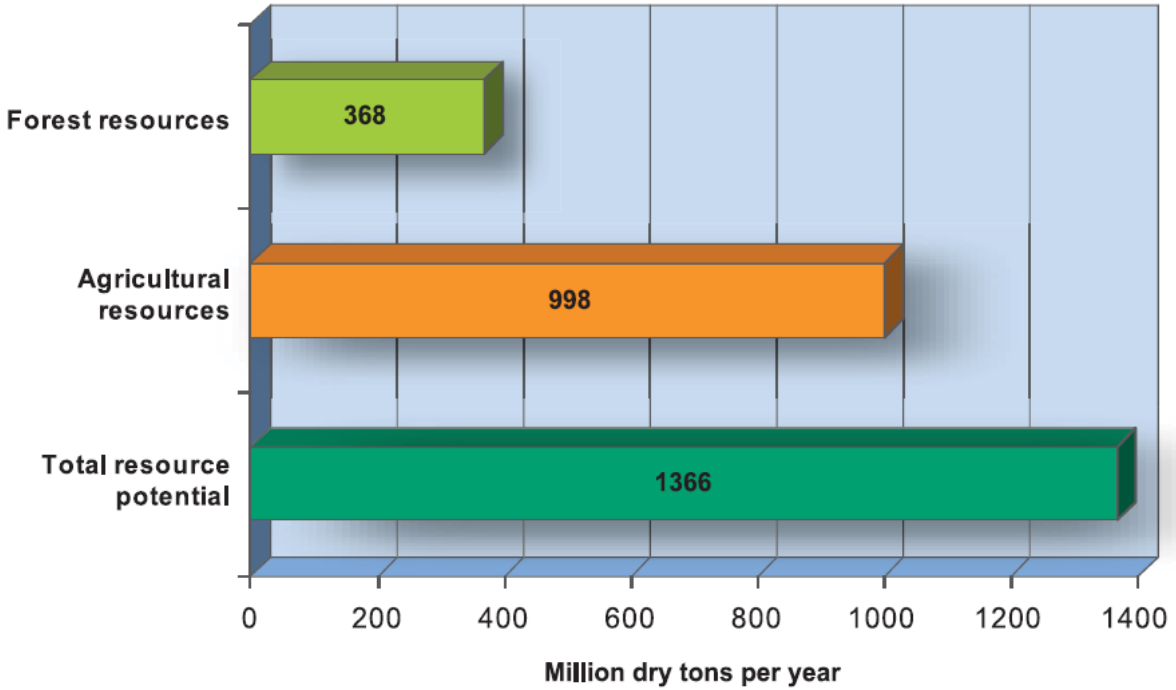
  **Added in 2011 Update**

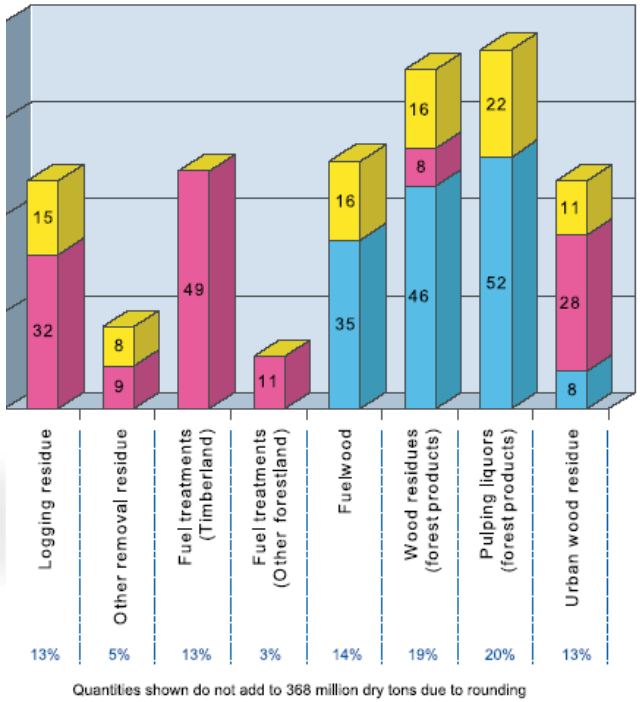
  - Fuelwood
  - Primary mill residues
  - Secondary mill residues
  - Pulping liquors
  - Urban wood residues

- 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*

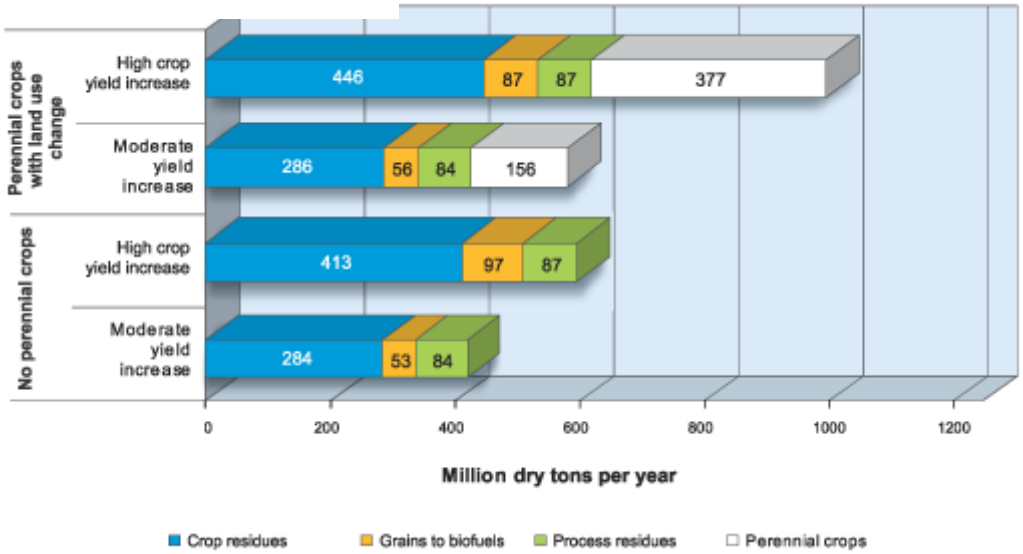
**Added in 2011 Update**

# 2005 BILLION TON ASSESSMENT




Quantities shown do not add to 368 million dry tons due to rounding



# How Much Biomass is Available According to the New 2011 Update?

- **It all depends**
  - Specific feedstock or feedstock category
  - Sorts – currently used or potential
  - Spatial interest
  - Selected price
  - Specific year
  - Scenario
- **How to find**
  - Update report is national summaries at selected prices and years for all feedstocks, sorts, and scenarios
  - KDF for desired spatial analyses, prices, and years for all feedstock categories, sorts, and scenarios

# Approach to Supply Curve Estimation

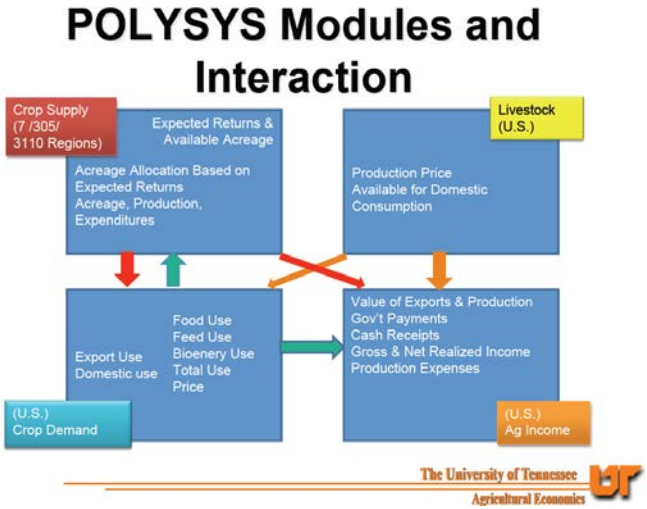
- Separate methods for agriculture and forest resources
- Agricultural land resources
  - Agricultural policy model (POLYSYS) utilized to identify supply curves and land use change for crop residues and energy crops
    - USDA Census and NASS data (yields, acres, crop prices, production, exports, etc.) to 2030
    - Requirements for resource sustainability – crop residue retention coefficients, tillages, rotations
    - Energy crop – perennial grasses, woody crops, annuals
    - 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**
  - **Resource cost analysis used to estimate supply curves (cost-quantities) for forestland resources**
    - **USDA/FS data (FIA, TPO, RPA)**
    - **Forest residue access, recovery, and merchantability**
    - **Requirements for resource sustainability**

# 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**
  - **Biomass resources include stover, straws, energy crops (perennial grass, coppice and non-coppice woody, annual energy crop)**
  - **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**
    - **Restraints limiting land use change**




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

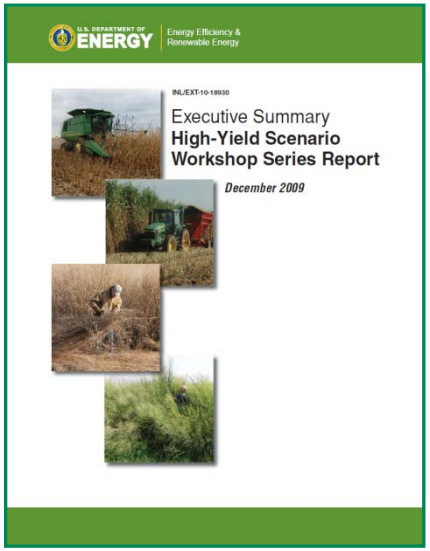
# Billion-Ton Update Scenarios

## Baseline

- USDA Projections extended to 2030
- National corn yield: 160 bu/ac (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

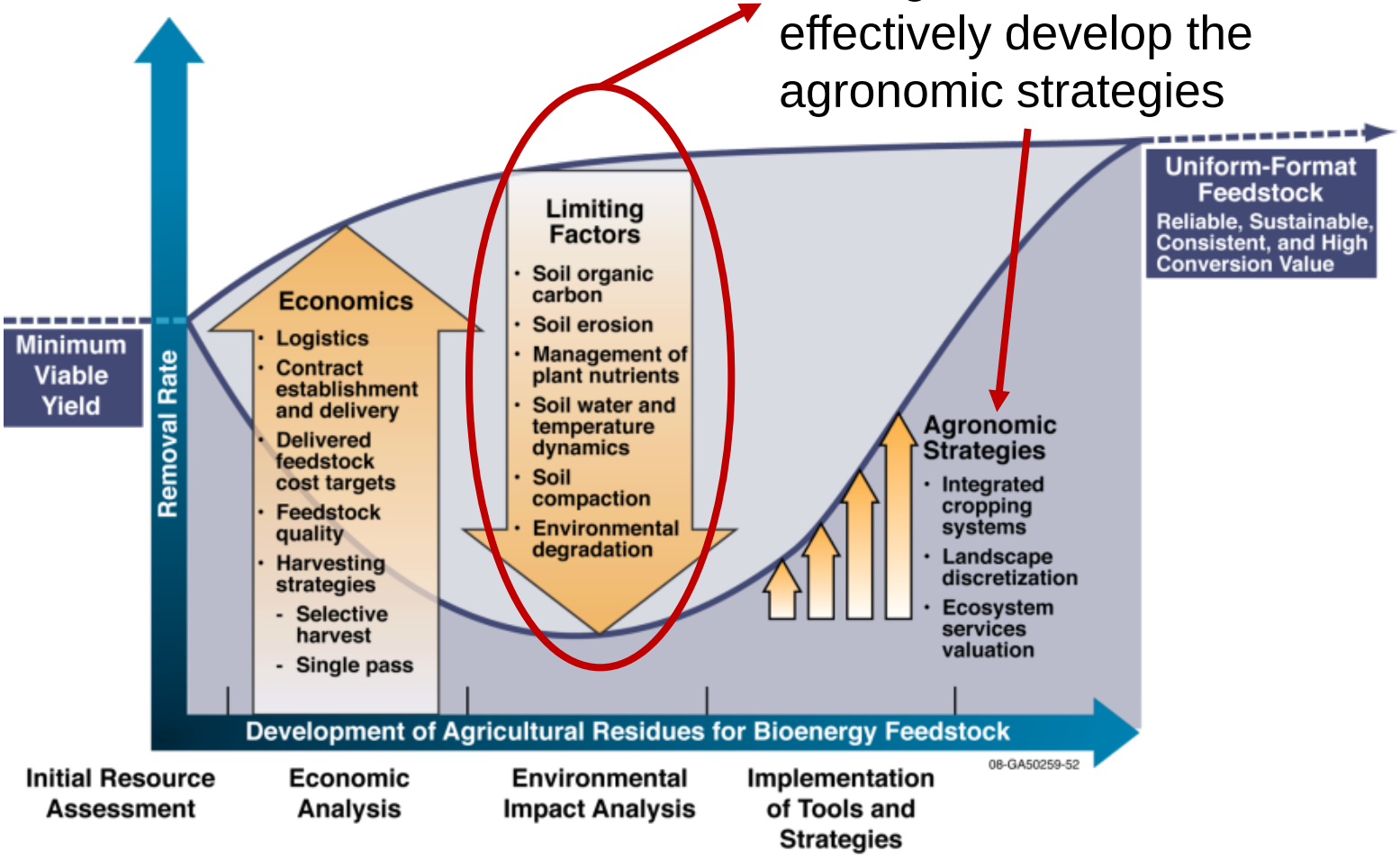
- Same as Baseline Scenario except for the following
  - Corn yields increase to a national average of 265 bu/acre in 2030
  - Higher amounts of cropland in no-till to allow greater residue removal
  - Energy crop yields increase at 2%, 3%, and 4% annually (more R&D)




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

# Residue Removal Tool

Focused on quantifying the limiting factors, so we can effectively develop the agronomic strategies

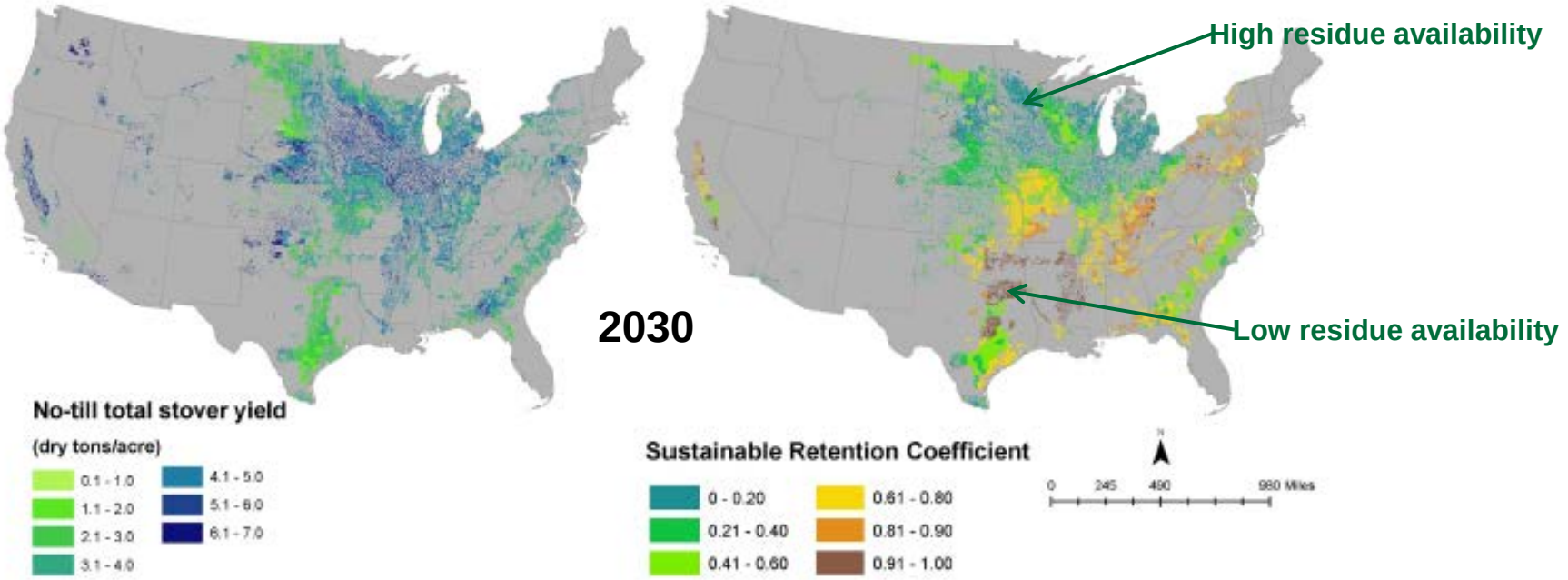


# CROP RESIDUE SUSTAINABILITY

**Retention coefficients estimated for erosion and soil C**

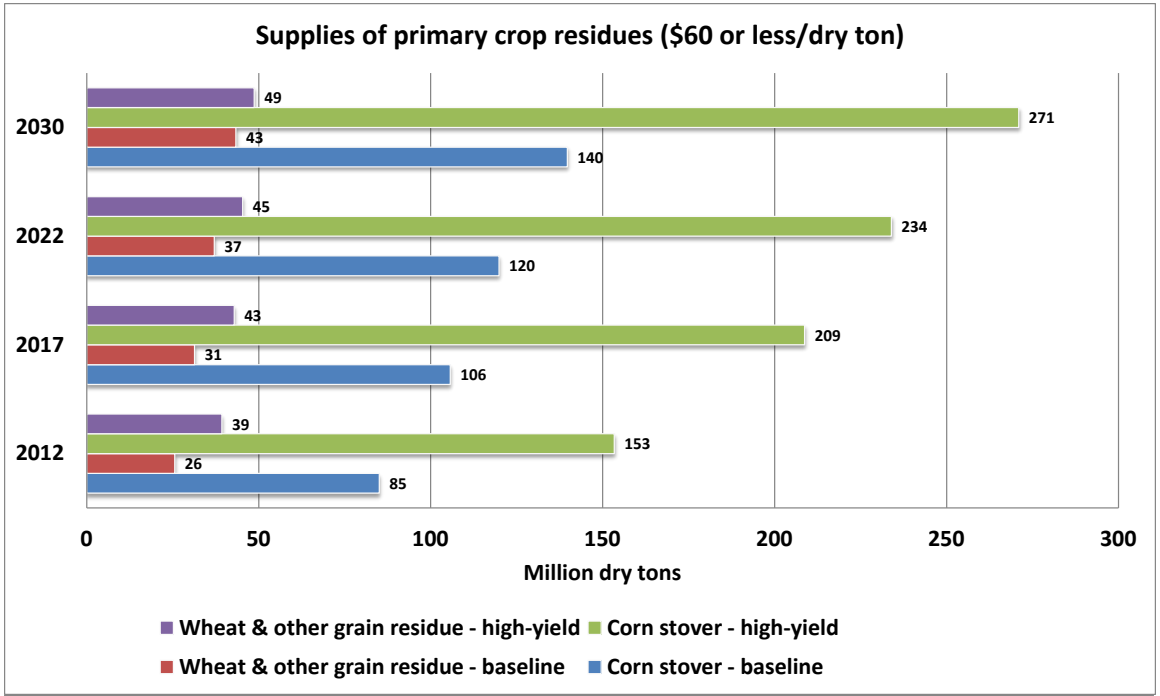
- **Separate coefficients for reduced till and no-till**
- **No residue removal under conventional till**
- **Yield and time dependent in POLYSYS**
- **Dave Muth (INL), Richard Nelson (KSU), Doug Karlen (ARS) and others (ARS, NRCS, UTK)**

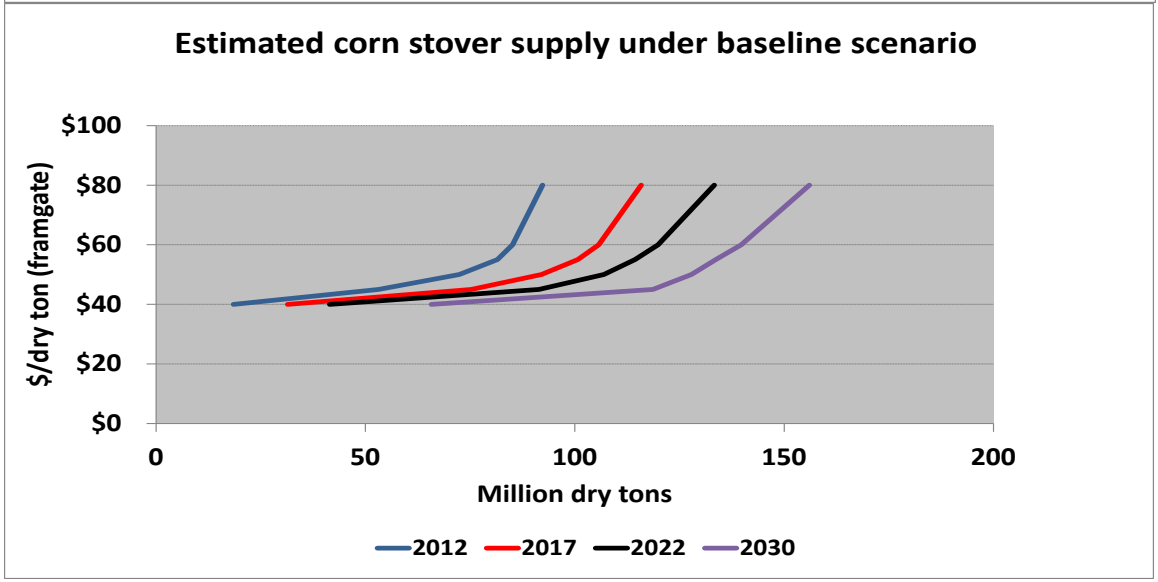
**NRCS CMZs**



# Crop Residue Estimated Supply

- **Baseline scenario**
  - **About 111 million dry tons (mostly 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 ~ 85% corn stover**



# Energy Crop Assumptions

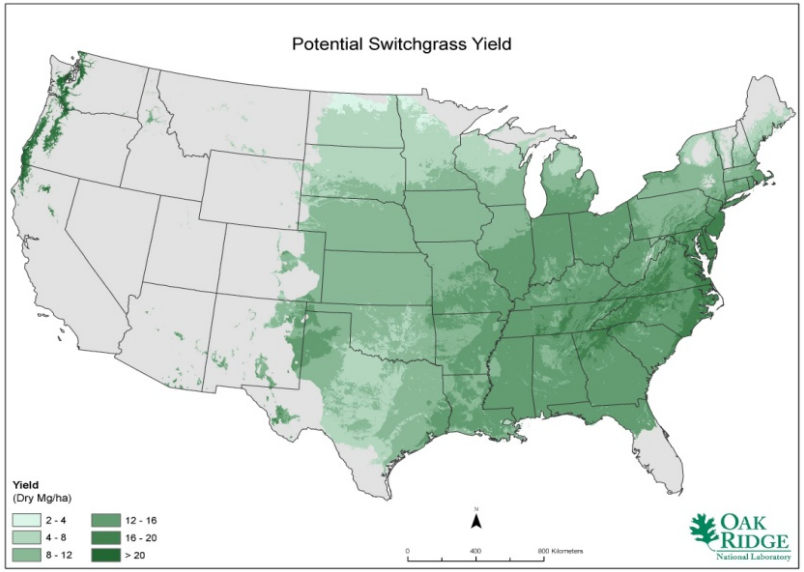
- **Crops include**
  - **Perennial grasses (switchgrass, and other grasses)**
  - **Woody Crops (eucalyptus, southern pine, poplar, willow)**
  - **Annual Energy Crop (sorghum)**
- **Allowed on cropland, cropland pasture, and permanent pasture**
- **All non-irrigated production**
- **Cultural practices based on minimal tillage and recommended fertilizer and herbicide applications**
- **Intensification of pasture land required to meet lost forage**
- **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**

# Energy Crop Sustainability & Restrictions

- **Assumed BMPs for establishment, cultivation, maintenance, and harvesting of energy crops**
- **Energy crops not allowed on irrigated cropland & pasture**
- **Generally assumed landscape diversity of energy crops with other agricultural and forestry activities**
- **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**
- **Retained low-levels of biomass for long-term site productivity with nutrient replacement**

# Perennial Grasses – Production Costs and Productivity

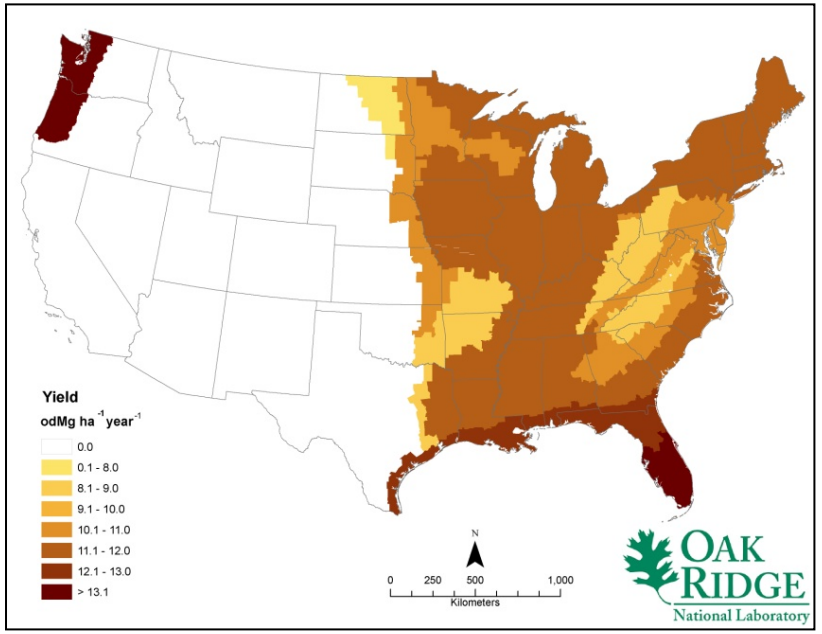
| Item | Units | Northeast | Appalachia | Southeast | Delta | Corn Belt | Lake States | Southern and Northern Plains |
|---|---|---|---|---|---|---|---|---|
| **Perennial grasses** | | | | | | | | |
| Stand life | Years | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| Productivity | dry tons/ acre | 4.0–7.5 | 5–9.5 | 3.5–9.5 | 3–7 | 4–7 | 3.5–5 | 2–6.5 |
| **Establishment** | | | | | | | | |
| Seed | $/lb | $10 | $22 | $22 | $22 | $10 | $10 | $22 |
| Planting | lb/acre | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Replants | percent | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| No-till drill | - | 1-time | 1-time | 1-time | 1-time | 1-time | 1-time | 1-time |
| Total kill herbicide | No. applications | 1-time | 1-time | 1-time | 1-time | 1-time | 1-time | 1-time |
| Pre-emergent herbicide | No. applications | 1-time | 1-time | 1-time | 1-time | 1-time | 1-time | 1-time |
| Phosphorous | lbs P2O5/ acre | 40 | 40 | 40 | 40 | 40 | 40 | 40 |
| Potassium | lbs K2O/ac | 80 | 80 | 80 | 80 | 80 | 80 | 0 |
| Lime | tons/acre | 1 | 2 | 2 | 2 | 1 | 1 | 0 |
| **Total establishment costs** | **$/acre** | **$210** | **$340** | **$330** | **$330** | **$200** | **$200** | **$220** |
| **Maintenance years** | | | | | | | | |
| Reseeding | year applied | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Pre-emergent herbicide | No. applications | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nitrogen | lbs/acre | 60 | 70 | 70 | 50 | 60 | 40 | 40 |
| Phosphorous | lbs P2O5/ acre | 0 | 0 | 80 | 0 | 80 | 0 | 0 |
| Potassium | lbs K2O / acre | 0 | 0 | 80 | 0 | 80 | 0 | 0 |
| **Harvest costs** | **$/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** |
| **Annual Energy Crops** | | | | | | | | |
| Productivity | dry tons/ acre | 6–8.2 | 6–8.7 | 6–9 | 6–9 | 6.7–9 | n/a | 6.5–9 |
| Production costs | $/acre | $310 | $330 | $300 | $310 | $420 | n/a | $230 |
| Harvest costs | $/dry ton | $12.50 | $12.10 | $11.80 | $11.80 | $12.20 | n/a | $12.10 |




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

# Woody Crops – Production Costs and Productivity

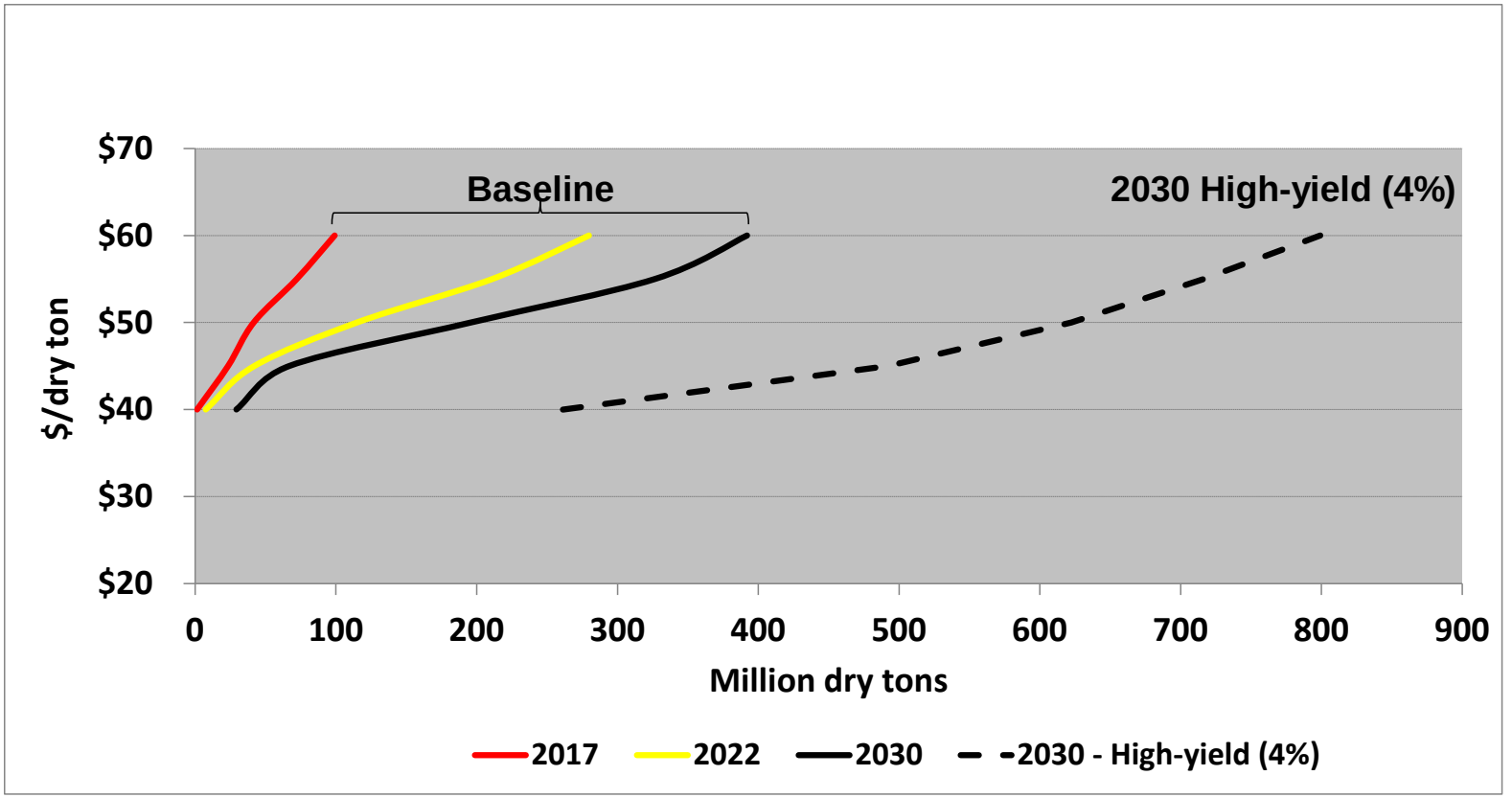
| Item | Units | Poplar | Pine | Eucalyptus | Willow (coppiced) |
|---|---|---|---|---|---|
| Rotation | Years | 8 | 8 | 8 | 4[a] (5 harvests) |
| Spacing | sq. ft. | 60 | 60 | 60 | 7.5 |
| | trees/acre | 726 | 726 | 726 | 5800 |
| Productivity | dry tons/acre-year | 3.5–6.0 | 5.0–5.5 | 6.0 | 5.1 |
| 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 | - | year 3 | year 3 | - |
| 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**
  - **Baseline yields (dry tons/acre)**
    - **2014 – 3.5 - 6.0**
    - **2030 – 4.2 - 7.2**

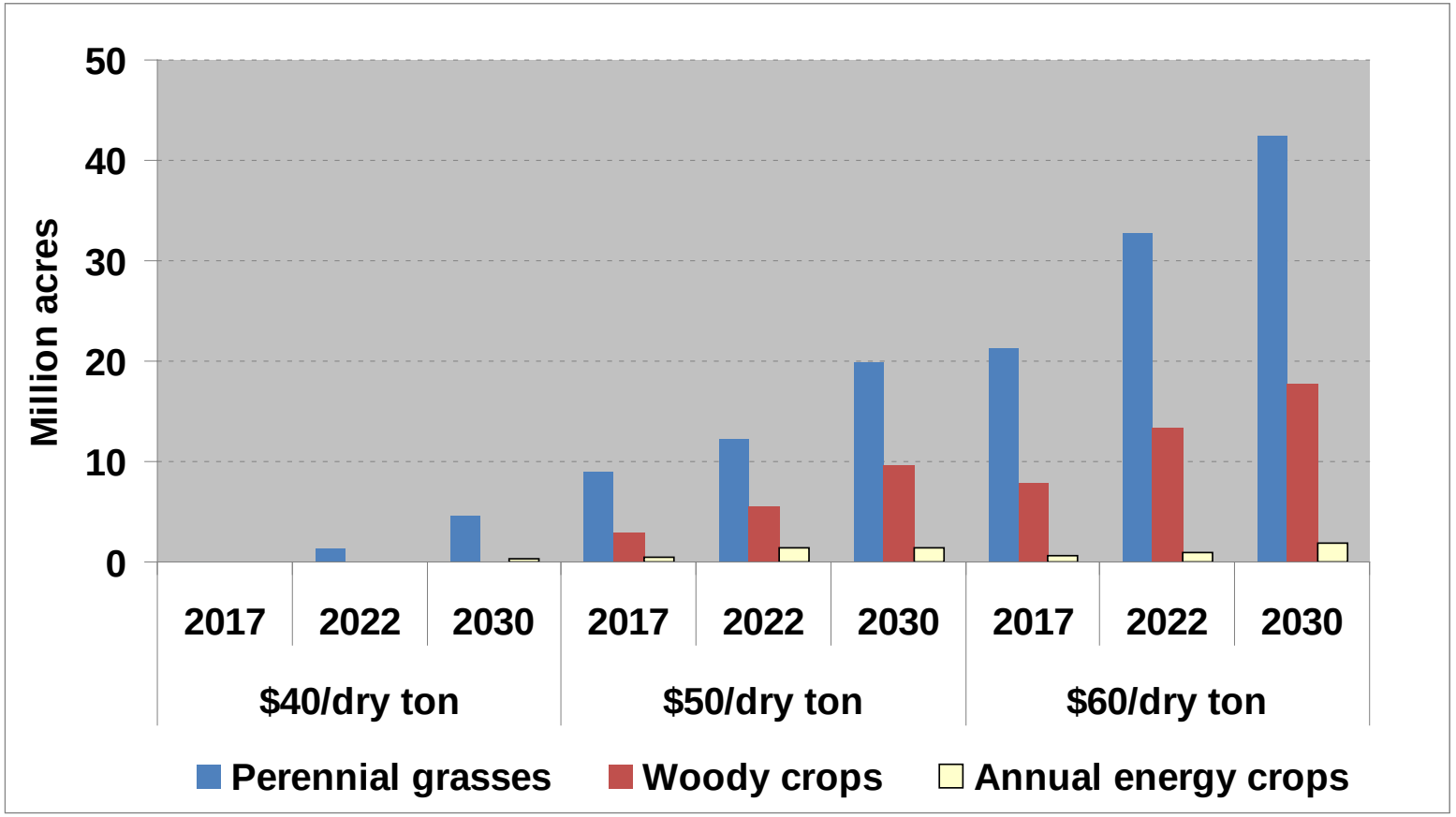
# Energy Crop Simulated Supply Curves – Baseline Scenario

- **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**



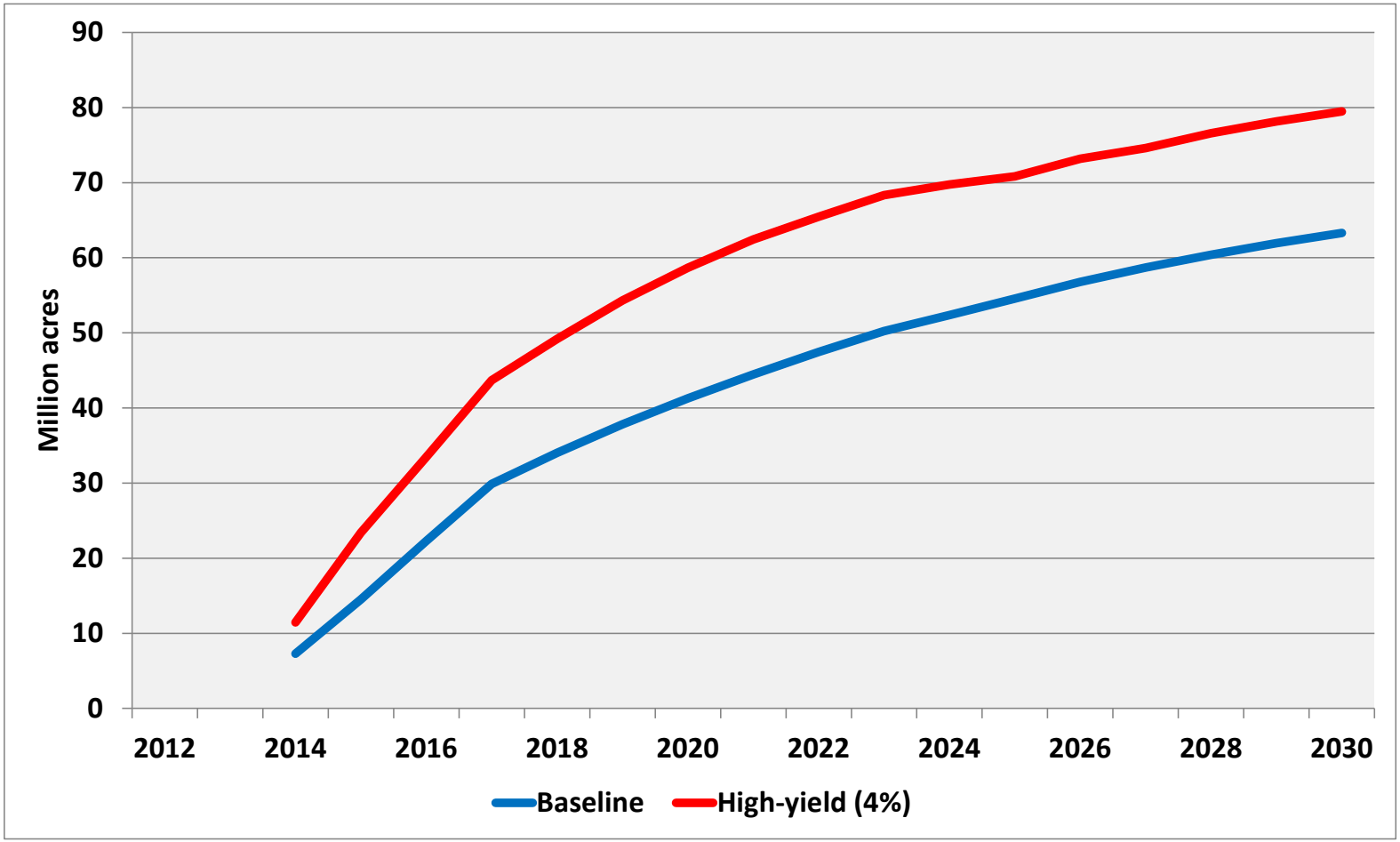
# Energy Crop Simulated Land Use Change

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



# 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**



# Forest Resources

- **Forestland resources in U.S.**
  - **504 million acres of timberland**
  - **91 million acres of other forestland**
- **Forest resource feedstocks**
  - **Composite (combination of logging residues and forest thinnings)**
    - **Logging residues**
    - **Forest thinnings (health treatments on timberlands)**
  - **Thinnings on other forestlands**
  - **Other removal residues**
  - ***Conventional wood***
  - **Fuelwood**
  - **Primary mill residues**
  - **Secondary mill residues**
  - **Pulping liquors**
  - **Urban wood residues**

**Forestland – minimal of 1 acre and 10% live tree cover**

**Timberland – capable of growing 20 $ft^3$/acre/year**
**Other Forestland – other than timberland or reserved land**

**Reserved forestland – administratively removed from production**

Currently used
- Fuelwood
- Mill residue
- Pulping Liquor
- MSW

Potential
- Composite
- Other removal residue
- Thinnings on other forestlands
- Mill residues
- Urban
- Conventional wood to energy

# Assumed Integrated Logging to Estimate Logging Residues, Thinnings, and Composite Feedstocks Categories

**Logging Residues (Current)**

**Logging Residues (Assumed)**

**Thinnings**

**Integrated Logging = Merchantable Materials + Biomass**

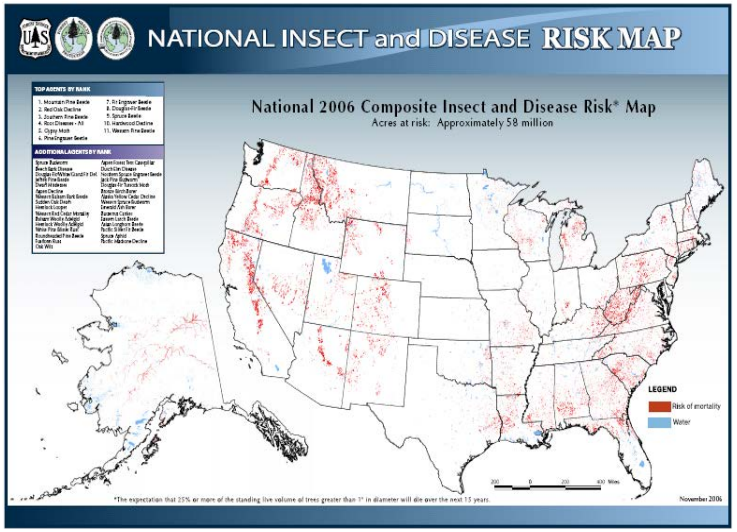
**Composite Feedstock Category = Selected Portion of Logging Residues + Selected Portion of Thinnings**

# Forest Resources Data Sources

- U.S. Forest Service Forest Inventory and Analysis (FIA)
  - Downloaded data from FIA DataMart4 (February/March 2010) - http://199.128.173.17/fiadb4-downloads/datamart.html
  - Used specific data for biomass
    - Small trees (1-5 inch dbh in East and 1-7 inch dbh in West)
    - Non-merchantable tree components of trees great than 5/7 inch dbh
      - Limbs and tops
      - Non-merchantable bole
      - Dead trees
- Includes new method for calculating the non-merchantable volumes of the merchantable trees
  - Component ratio method (CRM)
  - Consistently lower volumes vs. old method
    - 6-8% generally
    - Up to 30% for specific species and stand type
- 2009 RPA (Resource Planning Act) Assessment (Smith et al.)
  - Growth projections
- 2005 RPA Timber Assessment
  - Harvest projections
- RPA Timber Products Output (TPO) database
  - Logging and other removal residue
  - Downloaded (March 2010)
  - http://srsfia2.fs.fed.us/php/tpo_2009/tpo_rpa_int1.php

# Assumptions

- No road building (0.5 mile)
- Cut, skid, process at deck, and chip biomass (whole tree to deck)
- Integrated logging
- Biomass
  - Small stems
  - 1-5 inch dbh in East
  - 1-7 inch dbh in West
  - Limbs and top, and cull components of merchantable trees
  - Dead trees
- Federal land separated
- No stumpage on federal land
- Logging residues and thinnings – chipping cost only
- Conventional - all costs and wood go to biomass
- Thinnings on 30% greater than max SDI




- Recovery
  - 70% for logging residues, thinnings and conventional
  - 50% for other removals
- Merchantability – FIA biomass equations

# Forest Sustainability Approach

- **Evaluated biomass removal sustainability (erosion, soil nutrients, biodiversity, soil-organic carbon, and long-term soil productivity) – used to develop assumptions**
- **Sustainability based on biomass retention levels by slope class**
  - **Logging residues - 30% left on-site**
  - **Thinnings**
    - **Slope <40% = 30% left on-site**
    - **Slope >40% to <80% = 40% left on site**
    - **Slope >80% = no removal**
- **Removed reserved and roadless designated stands**
- **Removed steep and wet areas, and sites requiring cable systems**
- **Only thinned over-stocked stands and used uneven-aged prescription**
- **Used costs incorporated for BMP implementation as surrogate for other non-biomass retention related criteria, e.g. biodiversity, habitat, stream crossings, etc.**
- **No removals greater than growth by state**
- **Merchantable capacity limits by state**
- **30 year for thinning return**

# Forest Feedstock Supply Curve Estimation

- Key forest feedstocks
  - Forest Residues from integrated logging (sawlogs/pulpwood + biomass)
    - Composite estimate sources – logging residue data, forest thinning simulations
  - Conventionally sourced wood (i.e., pulpwood) from 1) additional harvests and 2) shift from current pulpwood uses to bioenergy
- Estimation elements
  - Supply amount by price (= stumpage cost + harvest cost)
  - Limits on amounts of supply
- Only Baseline Scenario for Forest Resources

# Forest Residue Supply Curve Estimation

- **Composite estimate sources – logging residue data, forest thinning simulations**
- **Amounts**
  - **Logging residue – Forest Service Timber Product Output database, removals limited to 70%**
    - **Increased over time with projected increased harvest**
  - **Forest thinnings – simulated on Forest Service FIA plots, removals over 30 years**
    - **Limited so projected sawlog/ pulpwood harvest not exceeded**
- **Costs**
  - **Stumpage (forest residues and conventionally-sourced wood)**
  - **Harvest costs estimated using the Fuel Reduction Cost Simulator**

# Forest Residue Stumpage Prices

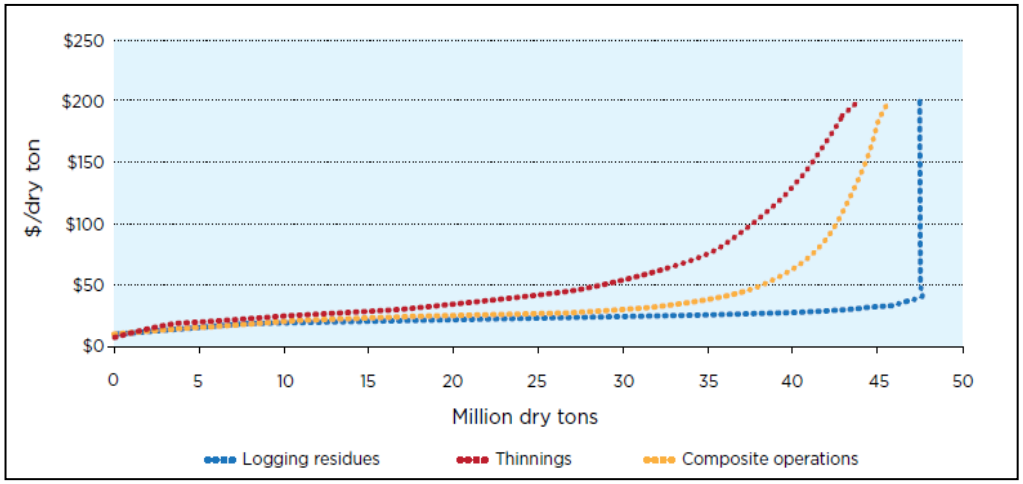
- **With low supply - stumpage price of $4/dry ton for tops/branches, increases to 90% of pulpwood stumpage price with high supply**

- **Use Regional Pulpwood stumpage prices**
  - **Hardwoods: North $15.40/dry ton; South - $13.30/dry ton**
  - **Softwoods: North - $20.70/dry ton; South - $15.70/dry ton**
  - **West - $27.60/dry ton**

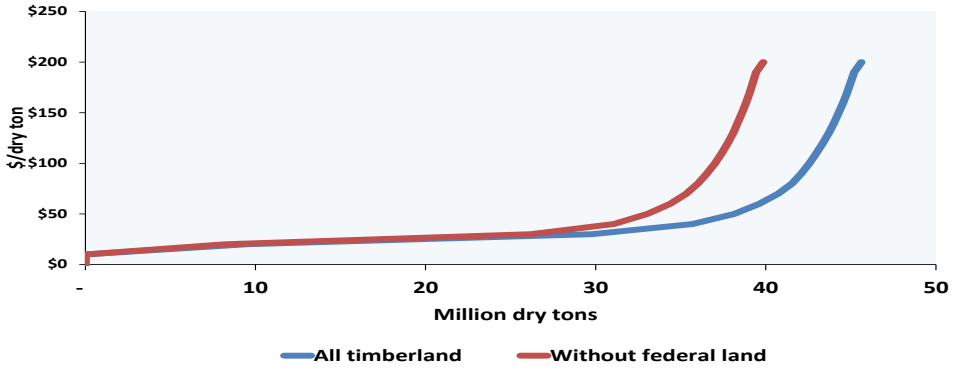
# Forest Residues - Composite Results

- Estimates
  - $20-$200/dry ton
  - Current - 2012
  - Potential – 2017-2030
  - Federal and non-federal (ESIA exclusion)
- Roadside supply curves
  - Includes stumpage & chipping costs
  - Fuel Reduction Cost Simulator model for harvesting
  - Projections based on latest RPA/TPO
  - With & without federal land
  - Based on integrated logging

## Example Supply Curves

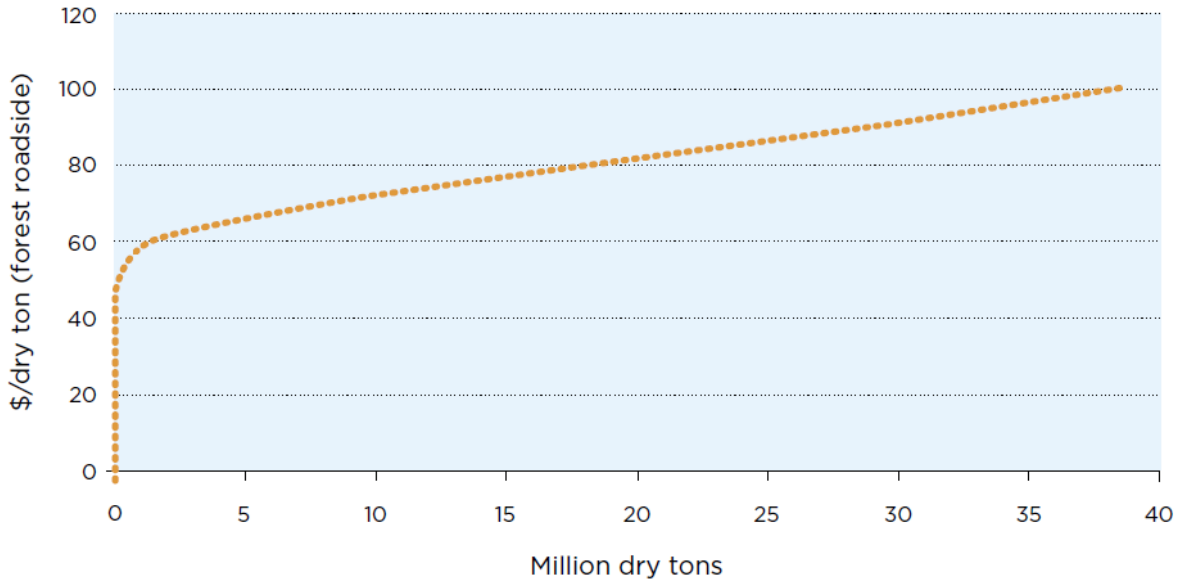



**Composite operations (50:50) on timberland with and without federal land**



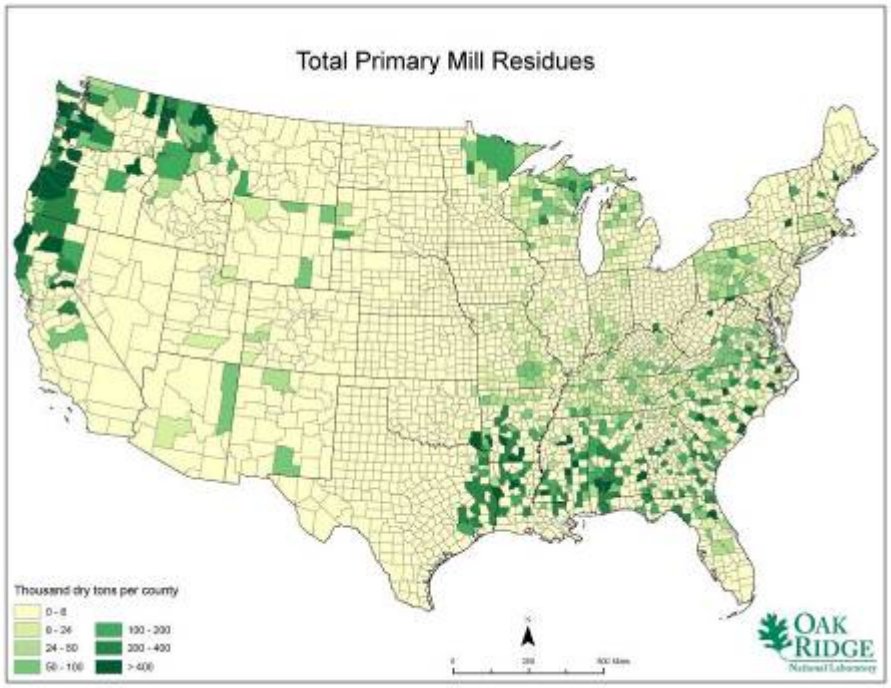
# Forest Biomass – Conventionally Sourced Wood (Pulpwood)

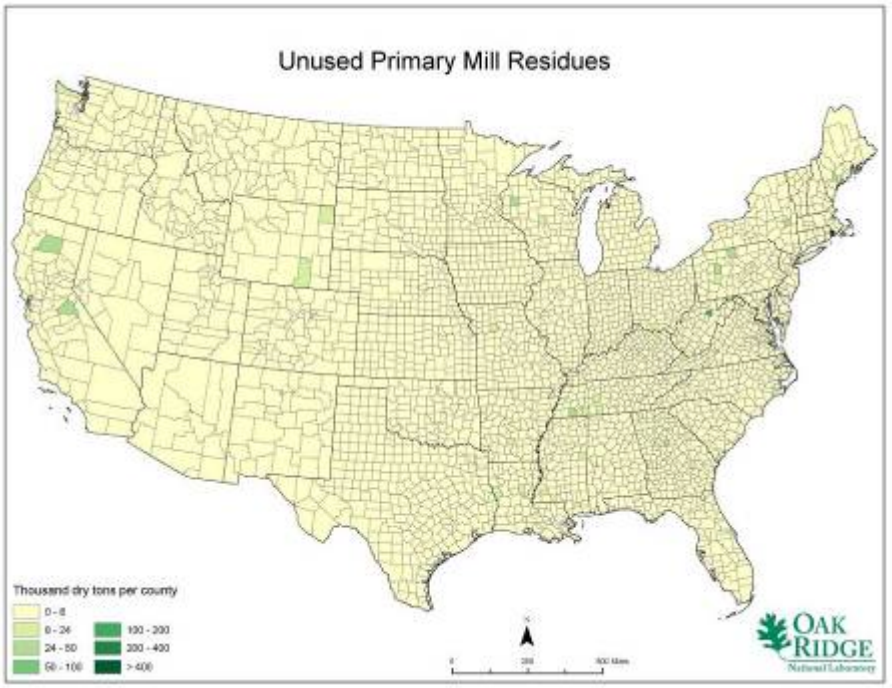
- **Sources:**
  - **Additional harvest of sites for pulpwood – for biomass only – no sawlogs**
  - **Shift of pulpwood use from current users to bioenergy use (away from pulp / panel production)**
- **Prices – based on recent pulpwood price and elasticities of supply & demand**
- **Limitations:**
  - **Additional harvest for biomass cannot exceed current timber growth by state**
  - **Shift from current use cannot exceed 20% of current use in a state**
- **Caveats**
  - **Rough estimates**
  - **Short range**
  - **Estimates will change with pulpwood market conditions and forest growth**



# PRIMARY MILL RESIDUES

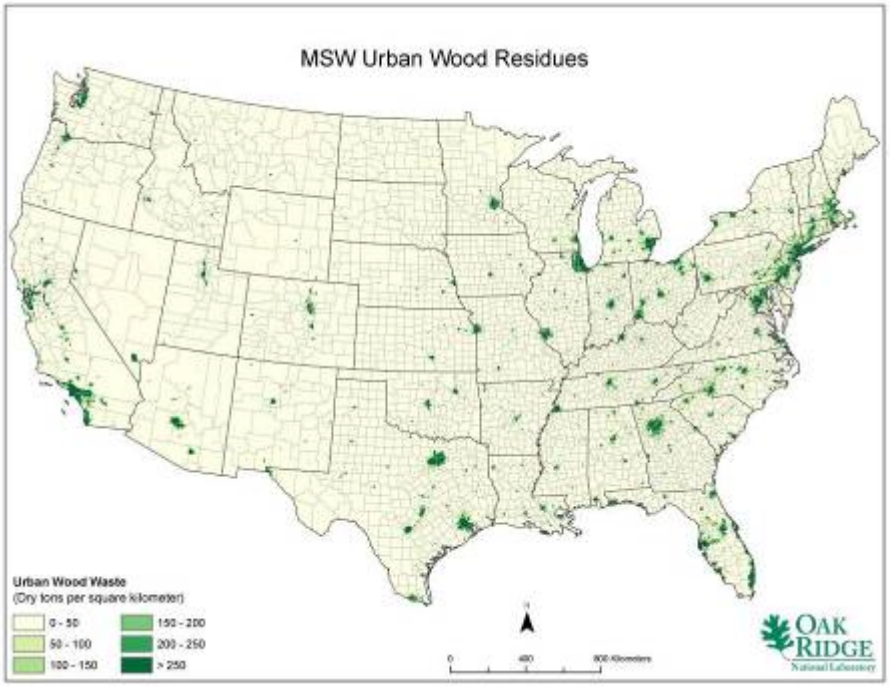
- Very little primary mill residue goes unused
- Potential to divert some lower value uses (e.g., mulch) to bioenergy



# URBAN WOOD WASTES

- **Urban wood residues are the woody component in MSW and C&D landfills**
- **Projections based on population growth subject to improvements in reduction, reuse, and recycling**




# Currently Used Forest Biomass Feedstocks

**Table 2.1** Projected Consumption of Currently Used Biomass Feedstocks (Million Dry Tons per Year)

| Source | Current | 2017 | 2022 | 2030 |
|---|---|---|---|---|
| **Forest** | | | | |
| Fuelwood | 38 | 72 | 96 | 106 |
| Mill residue | 32 | 38 | 39 | 42 |
| Pulping liquors | 45 | 52 | 54 | 58 |
| MSW sources | 14 | 20 | 20 | 20 |
| **Total forest** | **129** | **182** | **209** | **226** |

# Potential Forest Biomass and Wood Wastes for 2012

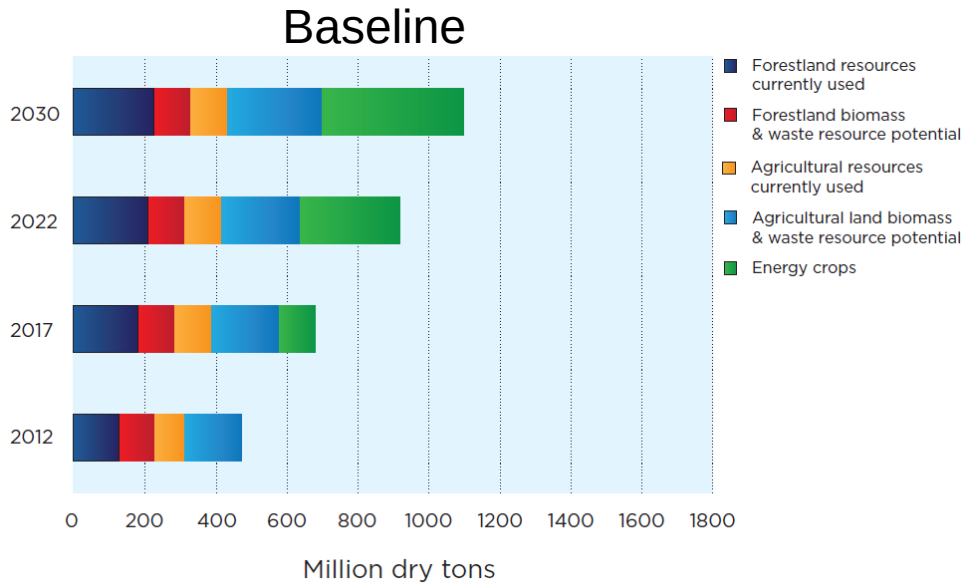
**Table 3.3** Summary of Potential Forest Biomass and Wood Wastes (2012)

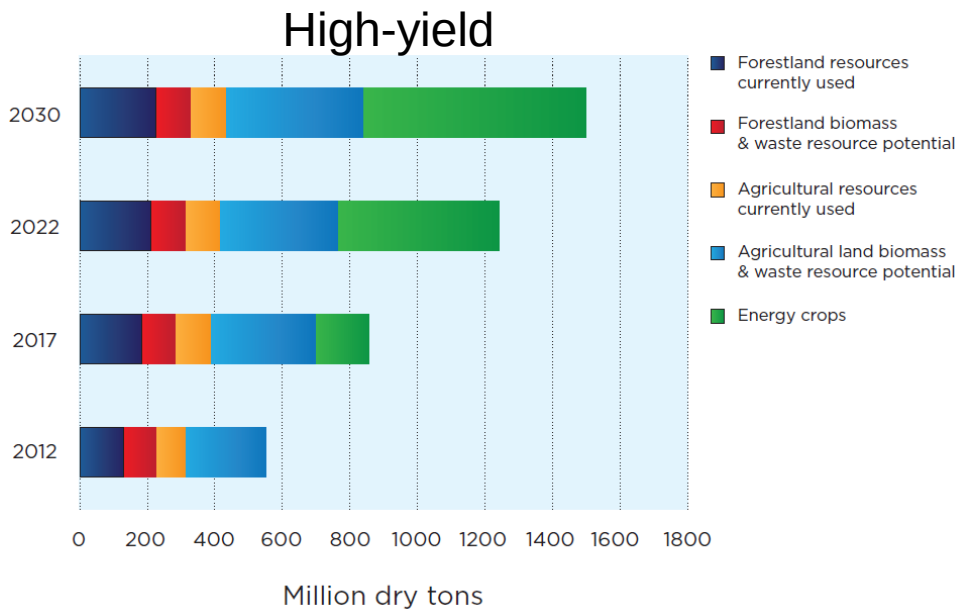
| Feedstock ($ per dry ton) | <$20 | <$30 | <$40 | <$60 | <$80 | <$100 |
|---|---|---|---|---|---|---|
| | Million dry tons | | | | | |
| Other Removal Residue | 4.4 | 12 | 12 | 12 | 12 | 12 |
| Composite Operations | 9.5 | 30 | 36 | 40 | 42 | 43 |
| Without Federal Land | 8.3 | 26 | 31 | 35 | 36 | 37 |
| Treatment Thinnings, Other Forestland | 0 | 0 | 0 | 3.2 | 6.4 | 6.4 |
| Without Federal Land | 0 | 0 | 0 | 1.8 | 3.6 | 3.6 |
| Mill residue, unused primary | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 |
| Mill residue, unused secondary | 6..1 | 6.1 | 6.1 | 6.1 | 6.1 | 6.1 |
| Urban Wood Waste – C & D | 4.4 | 11 | 14 | 22 | 22 | 22 |
| Urban Wood Waste – MSW | 7.7 | 8.7 | 9.2 | 10 | 10 | 10 |
| Conventional Pulpwood to Energy* | 0 | 0 | 0 | 1.5 | 19 | 40 |
| **Total – All Land** | **33** | **70** | **79** | **97** | **119** | **142** |
| *Total – Without Federal Land* | *32* | *66* | *75* | *90* | *111* | *133* |

***Notes:*** *Does not include currently used biomass from Chapter 2. Totals may not add up correctly due to rounding*

# U.S. Billion-Ton Update: 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



# Summary of Currently Used and Potential Forest and Agriculture Biomass at $60/Dry Ton or Less, under Baseline and High-Yield Scenario Assumptions

| 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** |

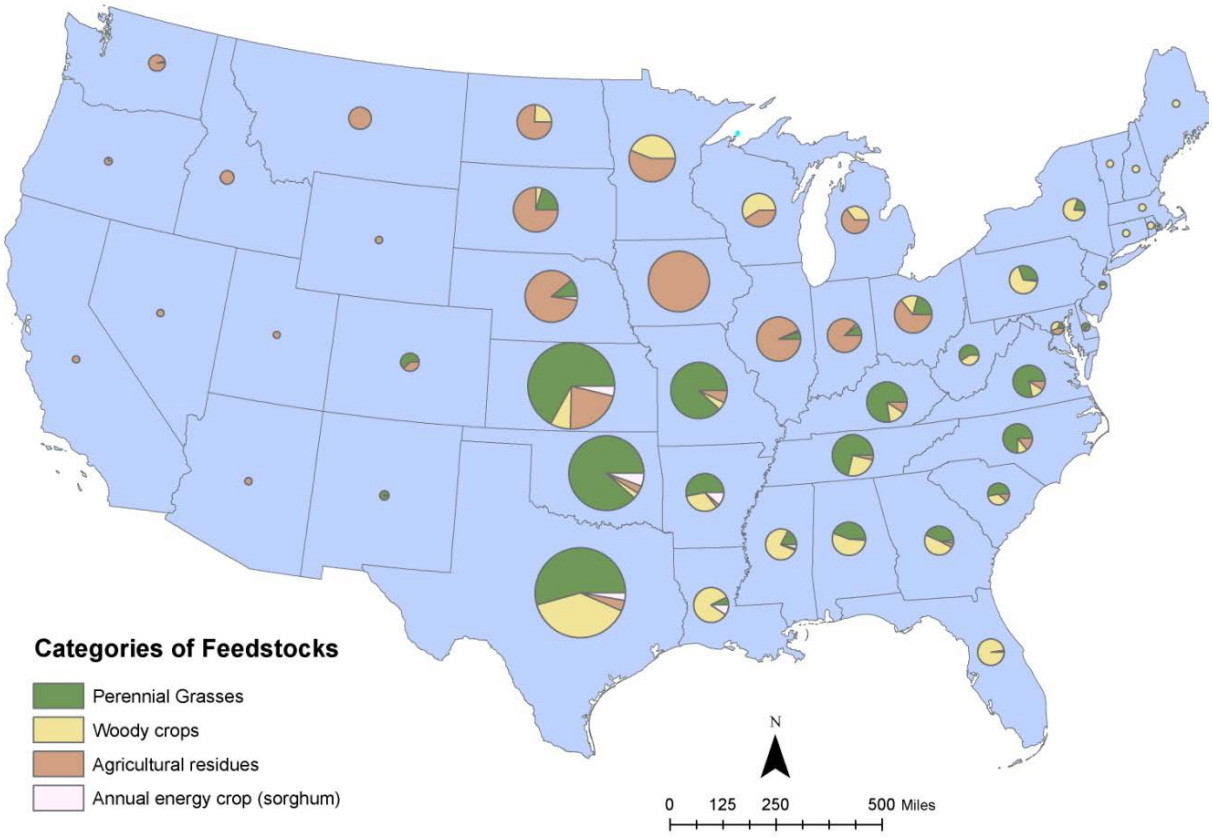
***Note:*** *Under the high-yield scenario, energy crops are shown for 2% to 4% annual increase in yield. Numbers may not add up due to rounding.*

[a] Energy crops are planted starting in 2014.

[b] Agricultural residues are generated under a high-yield traditional crop scenario with high no-till adoption (see Table 4.6). Energy crop yield growth follows a baseline growth pattern of 1% annually.

# Potential to Supply Crop Residues and Energy Crops by State

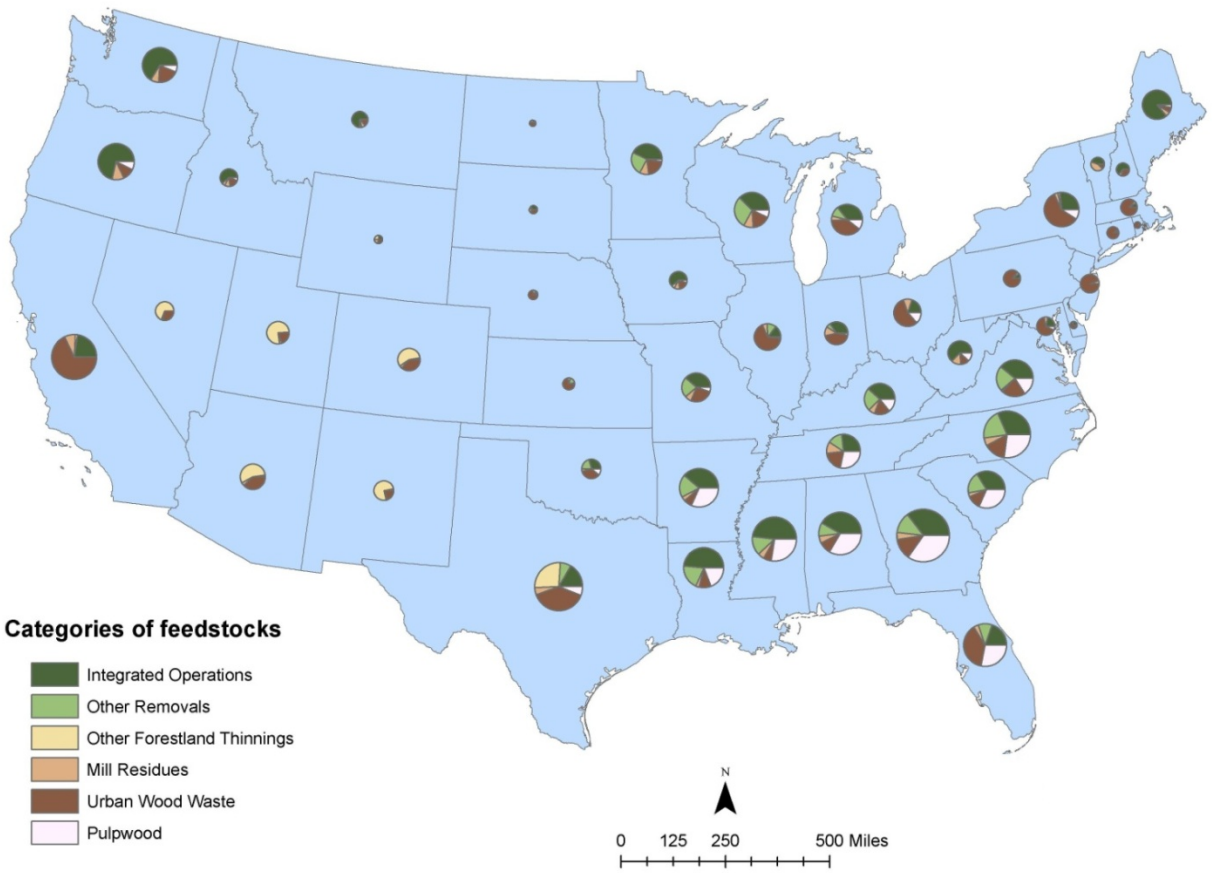
- Potential supplies are generally widely distributed
  - Considerable perennial grass potential in Southern Plains
  - Residue in Midwest and Northern Plains
  - Woody crops in the North and South



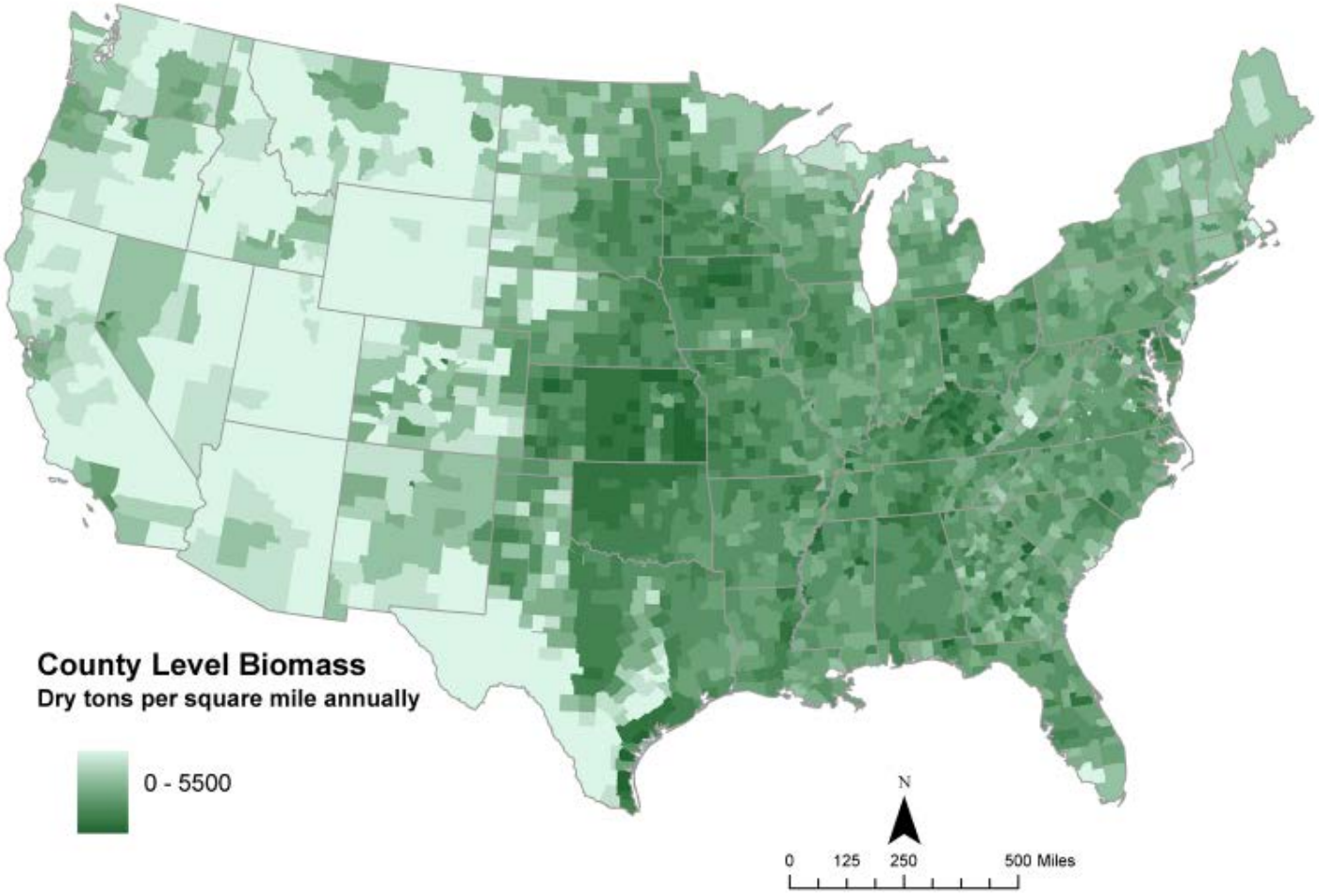

Baseline scenario - $60/dry ton; year 2030

# Potential to Supply Forest Residues by State

- Forest residues are where expected
  - Composite residues found in the South, North, and Northwest
  - Other removals in Eastern U.S.
  - Urban in large metropolitan areas

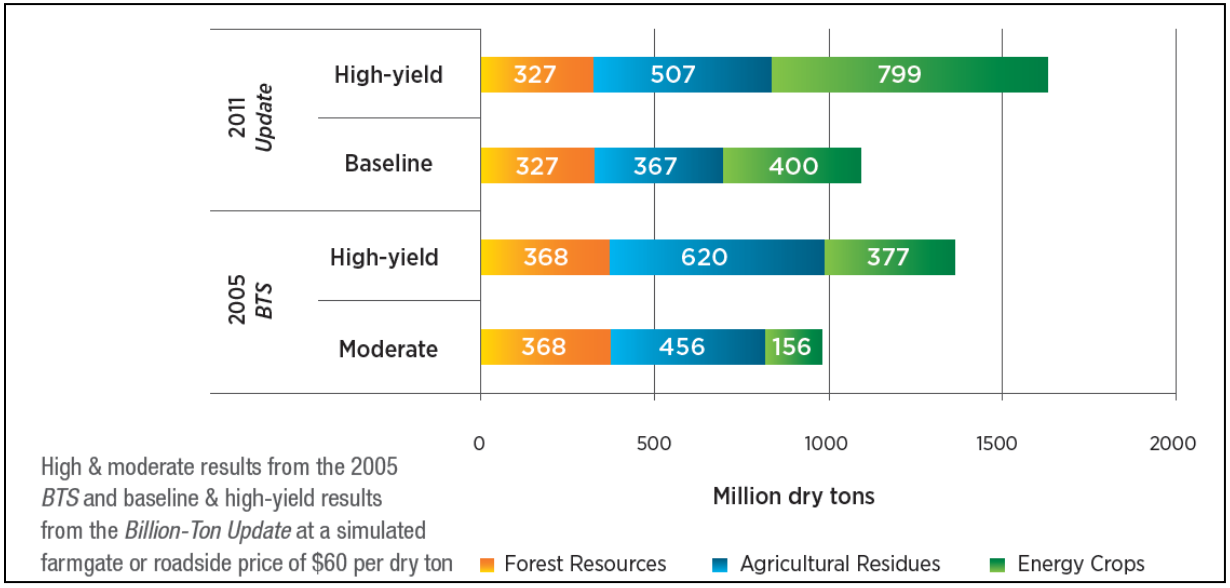


# Potential County-level Resources at $60 Per Dry Ton or Less in 2030, Under Baseline Assumptions



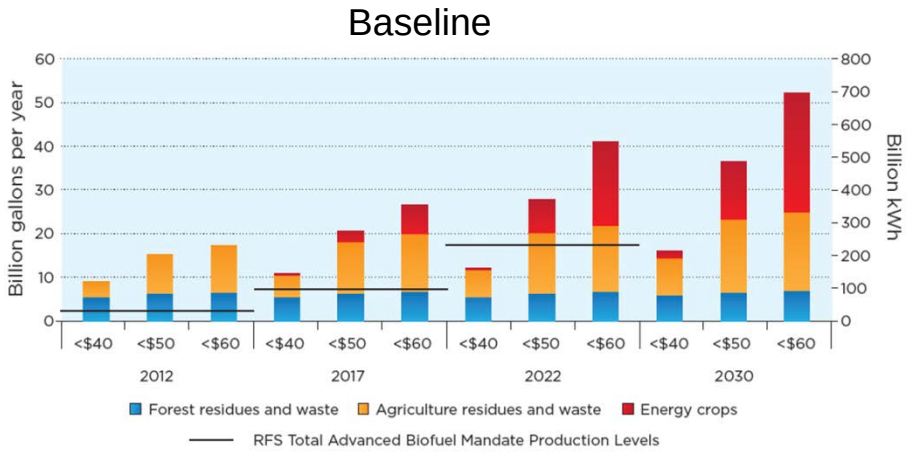
# Comparison with the 2005 BTS

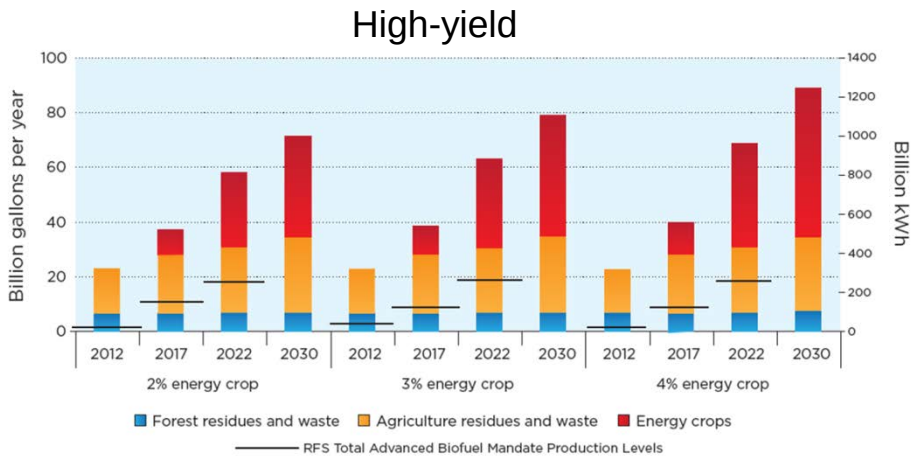
- Forest residue biomass potential is less – removal of unused resources, decline in pulpwood and sawlog markets
- Crop residue potential is less – consideration of soil carbon, no residue from conventionally tilled acres
- Energy crop potential is greater – addition of pastureland, land use change modeling



# Summary

- Biomass feedstock resources in 2030 range from 1.1 to 1.6 billion dry tons at $60/dry ton or less with 70 to 80% of the total available for new uses
- Biomass resources are widely distributed across the United States with the exception of some arid parts of the west
- Enough resource potential to meet the 2022 RFS2 advanced biofuel goals as well as significant additional biomass for electricity, chemicals, transportation fuels, and other uses
- Purpose-grown energy crops are the single largest source of new feedstock potential, a natural extension of current farm systems, offering landowners opportunities for additional profits while enhancing sustainability.
- Bioenergy KDF provides specific results of the update – feedstock categories, years, prices and quantities, and spatial interest (www.bioenergykdf.net/)




**http://www1.eere.energy.gov/biomass/pdfs/billion_ton_update.pdf**