U.S. Biomass Supply for Power & Environmental Implications (Draft Results)

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Key Questions

• How much biomass is available to the electric sector?

• Are there (supply-side) environmental implications?
  – For land-use?
  – For greenhouse gases?
  – For water?

• [Are there biofuel production implications?]
Public Context

• Evaluation of fuel feedstock and generation options

• Complex bioenergy policy environment
  – “Renewable” electricity
  – CAA Tailoring Rule and bioelectricity emissions
  – Climate change legislative proposals
  – Renewable fuels standard

• Sensitive public issues
  – Climate change concern
  – Energy security
  – Life-cycle GHG emissions
  – Forest land loss
  – Farm and forest sector income
  – Food security
  – Soils and water
How much biomass is available to the electric sector?
Approach

- Dynamic modeling of U.S. agriculture & forestry production & markets, including land-use allocation decisions
  - Simultaneous modeling of agriculture and forestry bioenergy feedstocks and end-uses – captures competition, complementarities, & co-products
- Sub-national resolution and international trade
- GHG accounting and abatement
- Policy baseline: EISA renewable fuels mandate imposed, Conservation Reserve Program (>30 mill acres)

⇒ Estimating biomass supply for electricity (delivered to power plant gates) accounting for food, feed, and biofuel demands & production
Biomass Feedstocks, Costs, GHG Value in the Modeling

~ 45 feedstocks

<table>
<thead>
<tr>
<th></th>
<th>Ethanol</th>
<th>Cellulosic ethanol</th>
<th>Biodiesel</th>
<th>Bioelectricity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starch- &amp; Sugar-Based Crops</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crop Residues</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Energy Crops</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Pulpwood</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
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<tr>
<td>Logging Residues</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
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<tr>
<td>Processing Residues</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Oils &amp; Fats</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

- Relative value of a feedstock a function of...
  - Direct costs (harvesting, transportation, storage, processing)
  - Opportunity costs (commodity & GHG)
  - HHV
  - Moisture content
  - Energy prices
  - Co-products (e.g., oil, feed substitutes)
  - Direct GHG benefit if valued (e.g., ethanol vs. gasoline)
  - Net GHG effect if valued
U.S. Biomass Supply for Electricity

- 1 quad Btu ≈ 100 TWh
- US Electric Sector (all fuels) ≈ 40 quad Btu

Current U.S. wood-based electricity

$ per MMBtu

Quadrillion Btu (annual average 2010-2030)
U.S. Biomass Supply for Electricity

- $2 per MMBtu
- $4 per MMBtu
- $6 per MMBtu
- $8 per MMBtu
- $10 per MMBtu
- $12 per MMBtu
- $14 per MMBtu

- 100% forestry residues

Quadrillion Btu (annual average 2010-2030)
U.S. Biomass Supply for Electricity

- 55% forestry residues
- 36% energy crops
- 2% ag residues
- 7% logs

Quadrillion Btu (annual average 2010-2030)
U.S. Biomass Supply for Electricity

$ per MMBtu

$0 $2 $4 $6 $8 $10 $12 $14

Quadrillion Btu (annual average 2010-2030)

- 13% forestry residues
- 82% energy crops
- 2% ag residues
- 3% logs
U.S. Biomass Supply for Electricity

- 8% forestry residues
- 56% energy crops
- 31% ag residues
- 5% logs
Largest Supplies in Midwest, South, Plains

Quadrillion Btu (annual average 2010-30)

$ per MMBtu
Our U.S. Estimate Over 50% Less than EIA’s

- Quadrillion Btu (annual average 2010-2030)
- $ per MMBtu

EIA AEO 2010
Part of the Difference – Storage & Transportation to Existing Generation

Off-site storage and transportation to existing generation increase delivered cost

Quadrillion Btu (annual average 2010-2030)
Another issue – GHG Incentives Can Increase Delivered Cost (e.g., $30/tCO$_2$e + 5% per year)

With GHG price...
- Increased delivered cost, but also
- Increased incentive for using biomass
- Ag/forest offsets

Incentives for forest/ag GHG abatement increase delivered price even further
Are there (supply-side) environmental implications?
Nationally, Forest & Cropland Expand with Pasture Conversion as Bioelectricity Increases

e.g., 2030 acreage

$ per MMBtu

Million acres

Cropland
Pasture
Forest

CRP Developed

Rangeland unchanged (not shown)
Nationally, Forest & Cropland Expand with Pasture Conversion as Bioelectricity Increases

![Graph showing the expansion of Forest, Cropland, and Pasture acreage with increasing bioelectricity.](image)

- **Cropland**
- **Pasture**
- **Forest**

The graph illustrates the distribution of land use categories (Cropland, Pasture, Forest) across different price ranges ($ per MMBtu) and million acres. The $14 per MMBtu price level is depicted with the CRP Developed area.

Rangeland is unchanged (not shown).
Direct GHG Offset of Fossil Fuels – GHG Beneficial but Not Neutral

Percent of fossil emissions offset per unit energy (e.g., Southeast)

<table>
<thead>
<tr>
<th></th>
<th>Ethanol</th>
<th>Cellulosic ethanol</th>
<th>100% bioelectricity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>32-35%</td>
<td>69%</td>
<td>97%</td>
</tr>
<tr>
<td>Corn residue</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Softwood pulp</td>
<td>77%</td>
<td></td>
<td>98%</td>
</tr>
<tr>
<td>Softwood harvest residue</td>
<td>77%</td>
<td></td>
<td>98%</td>
</tr>
<tr>
<td>Softwood mill residue</td>
<td>82%</td>
<td></td>
<td>99%</td>
</tr>
<tr>
<td>Switchgrass</td>
<td></td>
<td>74%</td>
<td>92%</td>
</tr>
</tbody>
</table>

**Included**: production, hauling, processing fertilizer manufacture, feedstock conversion, and byproduct credit GHG emissions and carbon sequestration

**Not included**: land conversion and land management change GHGs (next slide)
Indirect US Landscape GHG Changes – Driven by Forest Adjustments

Change in cumulative emissions w/ $9 vs. $1/MMBtu demand

- Forests: Net uptake with growth
- Other landscape emissions

Increased carbon emissions from forests with management changes; also new plantings

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Net GHG Implications (US Direct + Indirect)

Change in cumulative emissions w/ $9 vs. $1/MMBtu demand

GtCO₂eq (cumulative change)

-20 2015 2020 2025 2030 2035 2040 2045 2050

Forests

Other landscape emissions

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Net GHG Implications (US Direct + Indirect)

Change in cumulative emissions w/ $9 vs. $1/MMBtu demand

- Forests
- Other landscape emissions
- Bioelectricity displacement of coal electricity
- Net GHG Beneficial
National Water and Nitrogen Implications with Increased Biomass Demand

Changes by 2030 with $9 vs $1/MMBtu demand

- Cropland: 12%
- Non-energy cropland: 2%
- Irrigation: 4%
- Nitrogen: 8%

Increased intensity of inputs on crops
Are there biofuel production implications?
Ethanol Implications

Change in ethanol feedstocks for meeting EISA mandate with $9 vs. $1/MMBtu bioelectricity demand

Billion gallons (average annual 2010-2030)

Conventional ethanol changes

- Corn
- Other grains

Cellulosic ethanol changes

- Corn residues
- Energy crops
- Forestry feedstocks
- Ag processing residues
Summary and Concluding Remarks

- Detailed economic modeling of U.S. agriculture & forestry markets, including multiple bioenergy feedstocks and land-use

**Insights**

- Cost of biomass feedstocks for generation far from straightforward and more expensive than previously estimated
- Variation in feedstocks & regional supply will be important
- Bioelectricity can…
  - Yield net gains in forest acreage
  - Out-compete biofuels on a GHG basis (per unit energy)
  - Be net GHG beneficial in the U.S.
- Biofuels market likely affected
- Biomass end-use allocation and electricity penetration will depend on performance, cost, technology options, and policy
Thank you!

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