Presented to
Agricultural Utilization Research Institute

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Enegis, LLC
BEAM - Goals

• **BEAM** was created to inform opportunities for National Energy Technology Laboratory (NETL)’s Biomass & Advanced Methane Fuels (BAMF) working group for biomass use for power generation
  – Support Federal Energy Management Program’s (FEMP) opportunities for biomass energy usage

• **Maximize Federal utilization of renewable energy**
  – Policy framework (esp. the Energy Policy Act of 2005) in place for attaining energy, environmental and economic goals
  – Energy Saving Performance Contracts (ESPCs) between Energy Service Companies (ESCOs) and the Federal agencies require mutually beneficial terms and conditions
  – BEAM can assist the process by:
    • Quantifying and classifying available biomass resource
    • Scenario building for optimization of transport, storage and usage on local and regional scales
BEAM - Structure

Biomass Energy Analytical Model

Cost/Supply Feedback

Biomass Availability Module
-Models available supply at a given price

Biomass Transport and Storage Module
-Models transport along infrastructure and storage

Biomass Demand Module
-Models usage and demand, and calculates price

Price/Demand Feedback
## Species-Specific Parameters

~60 Species/Commodities Incorporated

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</table>
Crop Residues

USGS Land Cover—Landsat Thematic Mapper
Highly detailed, comprehensive
30 meter resolution

Agricultural Production by County
Crops distributed to
- Pasture Hay
- Cultivated Crops
Species-Specific Parameters

Land Cover
- Open Water
- Perennial Ice/Snow
- Developed, Open Space
- Developed, Low Intensity
- Developed, Medium Intensity
- Developed, High Intensity
- Barren Land
- Deciduous Forest
- Evergreen Forest
- Mixed Forest
- Shrub/Scrub
- Grassland/Herbaceous
- Pasture Hay
- Cultivated Crops
- Woody Wetlands
- Emergent Herbaceous Wetlands

50 Miles
80 Miles
Distributed Woody Residues

Hard and soft wood logging residue by county
Residue distributed to appropriate forest type
National Parks, wilderness, etc considered off limits

Land Cover:
- Restricted to Logging
- Open Water
- Perennial Ice/Snow
- Developed, Open Space
- Developed, Low Intensity
- Developed, Medium Intensity
- Developed, High Intensity
- Barren Land
- Deciduous Forest
- Evergreen Forest
- Mixed Forest
- Shrub/Scrub
- Grassland/Herbaceous
- Pasture Hay
- Cultivated Crops
- Woody Wetlands
- Emergent Herbaceous Wetlands
Industrial Wood Residues

Hard and soft wood industrial residue by county
Residue distributed to appropriate point type

Map showing industrial wood residues distributed by county, with symbols indicating primary and secondary sources.
Manure Residues

Heads of Animals per County
Manure distributed to point sources
Species-Specific Parameters
Biomass Availability Module

- **Purpose:** assess supply, availability, and storage options
- **Quantifies and classifies total biomass able to be collected to a point within a given harvesting radius**
  - Species-specific harvesting and collection parameters
  - Individual species data are carried throughout the model
  - Species are tallied on Btu-equivalent basis
  - Production can be temporally constrained (seasonal or quarterly)

- **Grid BAM**
  - For regional and national level storage site (St) placement
  - Examines a grid of the potential St (50-mile spacing for US – 1204 points)
  - “Collects” biomass within a given economic limit (– 80 miles)

- **Storage/Processing Site BAM (Rosettes)**
  - Quantifies detailed biomass availability for St
  - Models specific biomass processing facilities
  - Used in specific scenarios to model biomass availability to a discrete St
  - Uses actual time/distance transportation radius based on roads
  - Creates Cost/Supply Curves

Grid BAM Scenario Examples—Lower 48 Resource Availability
Lower 48 Biomass Availability Module

1204 Grid Points
50 Mile Spacing
Agriculture Residues Results—All Species

Tonnes per Year within 80 miles

Map showing the distribution of agriculture residues across the United States, with different colors indicating the number of millions of tonnes per year within 80 miles. The legend shows the tonnage ranges from 0 - 0.55 to 13.9 - 15.6.
Woody Residues Results—All Species

Tonnes per Year within 80 miles
Agriculture and Woody Results—All Species

Tonnes per Year within 80 miles
Grid BAM Scenario Examples—
Northern Missouri (NOMO) Switchgrass
Northern Missouri Switchgrass Exercise

CBTL Case Study Topics

- Scope: Single 30,000 bpd Plant, 30% switchgrass, 70% Illinois #6 Coal
  - Effects to other markets (biomass offsets; e.g. animal feed)?
  - DECISION: Switchgrass Land: Mix of Land Types based on Available Land Types within 50-miles
  - Indirect Land use change will be scaled by on RFS2 methodology.
- Plant Location
  - Northern Missouri
  - Within 50-miles of Switchgrass
  - Rail transport of Coal from Galatia Mine
  - EOR Field, Spur pipeline to major pipeline
  - EOR Field: Preference Danbury Line to Louisiana
- Switchgrass Feed Rate: 4,240 short tons per day (as received)
Northern Missouri Switchgrass Exercise (cont)
### Northern Missouri Switchgrass Exercise (cont)

**Required Land Conversion:**
- 10% Hay/Pasture
- 5% Cultivated Cropland

#### Commodity Table

<table>
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<tr>
<th>Commodity</th>
<th>Annual Tons</th>
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<th>After Switchgrass Conversion</th>
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<td>Resultant Yield</td>
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<td>542,219</td>
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#### Map

- Switchgrass within 50 Miles
  - CEBL - Product Pipelines
  - CEBL - Major Railroads
  - Tons of Switchgrass Per Year
    - < 500,000
    - 500,001 - 750,000
    - 750,001 - 1,000,000
    - 1,000,001 - 1,250,000
    - 1,250,001 - 1,500,000
    - 1,500,001 - 1,750,000
    - 1,750,001 - 2,000,000
    - 2,000,001 - 2,500,000
    - 2,500,001 - 3,000,000
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- Source: NEDC Map
Storage/Processing BAM Scenario Examples—FEMP Sites Scenario Analysis
FEMP Sites Scenario Analysis

• **Approximately 50 sites**
  – In the western US
  – Ranging from combined heat and power plants to administration building heating
  – Demand is highly project-specific

• **Evaluate clusters of demand**
  – A central storage site feeds into surrounding FEMP demand sites
FEMP Sites Scenario

Storage Site

FEMP Demand Point
- No Capacity Data
- Capacity Data

Biomass Collection Extent

Maps showing the distribution of FEMP sites across the United States, with symbols indicating storage sites and demand points with different capacity data.
Storage Site 9, California

Capacity values in MW

Map showing storage site capacity values in MW.
Storage Site 9, California
Storage Site 9, California
Biomass Process Flow

Biomass Cultivation, Harvest & In Situ Densification

Transportation (Trucking)

Processing & Storage

Transportation (Truck, Rail, or Barge)

Demand Plant

To Farm/Forest Gate:
1. Cultivation
2. Harvest
3. In Situ Densification

To Pre-Densification:
1. Trucking
2. Loading and Unloading

To Post-Densification:
1. Densification
   A. Pelletization
   B. Briquetization
   C. Torrefaction
   D. Chipping
2. Storage

To Plant Gate:
1. Delivery Cost
   A. Truck
   B. Rail
   C. Barge

Storage Profit
Credits/Allowances/Incentives

Track Cost, Carbon Footprint and Energy Balance at each stage

Producer Payment

Processing In Situ (Farm Gate)

• Agriculture residues – function of type
  – Bale/bundle grassy residue
  – Bale/bundle other types of residue

• Woody residues:
  – Option 1: chip and/or grind
    • Increases density
    • Facilitates transportation
    • Speeds decomposition
  – Option 2: bale/bundle
    • Increases density
    • Retards decomposition
  – Option 3: haul as is
Pre/Post Densification Transportation Options

- All pre-densification transport is performed by truck
- Choice of In Situ Densification
- Trucking capacity is volume-limited
  - Increases the tonnes per truck load
  - Affects the outcome for cost, carbon footprint and energy efficiency for transport
- Preprocess: chip/grind and drying—biomass needs to be < ¼ inch for different processes:
  - Option 1: pelletize
    - Compress biomass into small pellets
  - Option 2: briquette
    - Compress biomass into large pellets
  - Option 3: torrefaction
    - Pyrolysis of biomass to create char
    - Add binding agent (starch) to char and create a pellet or briquette
## Biomass Energy Balance and Carbon Footprint

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# Biomass Costs

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<tr>
<td>Pelletization with Chipper</td>
<td>12.31</td>
<td>36.16</td>
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<td>Briquetization with Chipper</td>
<td>16.40</td>
<td>32.71</td>
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<td>Torrefacation with Chipper</td>
<td>13.86</td>
<td>39.61</td>
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<td>Pelletization</td>
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<td>15.80</td>
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<td>Torrefacation</td>
<td>13.27</td>
<td>36.16</td>
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<tr>
<td>Storage</td>
<td>6.91</td>
<td>2.20</td>
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</table>
Storage Site 9, California—Pre-Densification

Biomass cost

$ per Tonne

- < $2.95
- $2.95 - $3.69
- $3.69 - $4.22
- $4.22 - $4.65
- $4.65 - $5.18
- $5.18 - $5.71
- $5.71 - $6.24
- $6.24 - $7.19
Storage Site 9, California—Pre-Densification

Biomass energy balance

Storage Site 9 (St09)
FEMP Demand Site

MMBtu per Tonne

- < 0.025
- 0.025 - 0.037
- 0.037 - 0.049
- 0.049 - 0.061
- 0.061 - 0.072
- 0.072 - 0.084
- 0.084 - 0.096
- 0.096 - 0.11
Storage Site 9, California—Post-Densification

Biomass cost

$ per Tonne

- < $56.48
- $56.48 - $57.22
- $57.22 - $57.75
- $57.75 - $58.18
- $58.18 - $58.71
- $58.71 - $59.24
- $59.24 - $59.77
- $59.77 - $60.72
Storage Site 9, California—Post-Densification

Biomass carbon footprint

Storage Site 9 (ST09)
FEMP Demand Site

kg CO2 per Tonne

- < 360.3
- 360.3 - 361.2
- 361.2 - 362.1
- 362.1 - 363.0
- 363.0 - 363.9
- 363.9 - 364.9
- 364.9 - 365.8
- 365.8 - 366.7

Enegis LLC
Storage Site 9, California—Post-Densification

Biomass energy balance

Storage Site 9 (S109)
FEMP Demand Site

MMBtu per Tonne

- < 3.82
- 3.82 - 3.83
- 3.84 - 3.85
- 3.85 - 3.86
- 3.86 - 3.87
- 3.87 - 3.88
- 3.88 - 3.89
- 3.89 - 3.90

Enegis LLC
Cost-Supply Curve

SP009 Cost/Supply

Thousands of Tonnes of Pellets

Post-Densified Cost ($/tonne)
About Enegis

- Small business, located in Fairfax, VA
- Specialize in highly-tailored, data-driven, quantitative GIS models and analyses
  - Energy and economic decision analyses
  - Project Due Diligence
  - Resource assessments
  - Decision support models
  - Policy analysis
  - Scenario modeling
  - Strategy planning
  - Royalty evaluations
  - Technology assessments
- 98% D&B Performance Rating

- Areas of Expertise
  - Energy resources and power generation
    - Natural gas, oil, biomass, coal, geothermal, solar, wind, geologic CO2
  - Carbon capture and sequestration
  - Environment and energy rationalization
  - Policy analysis

- Based on our analyses
  - Testified before Congress
  - Presented to the White House and Department Secretaries
  - Presented to high-level executives
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