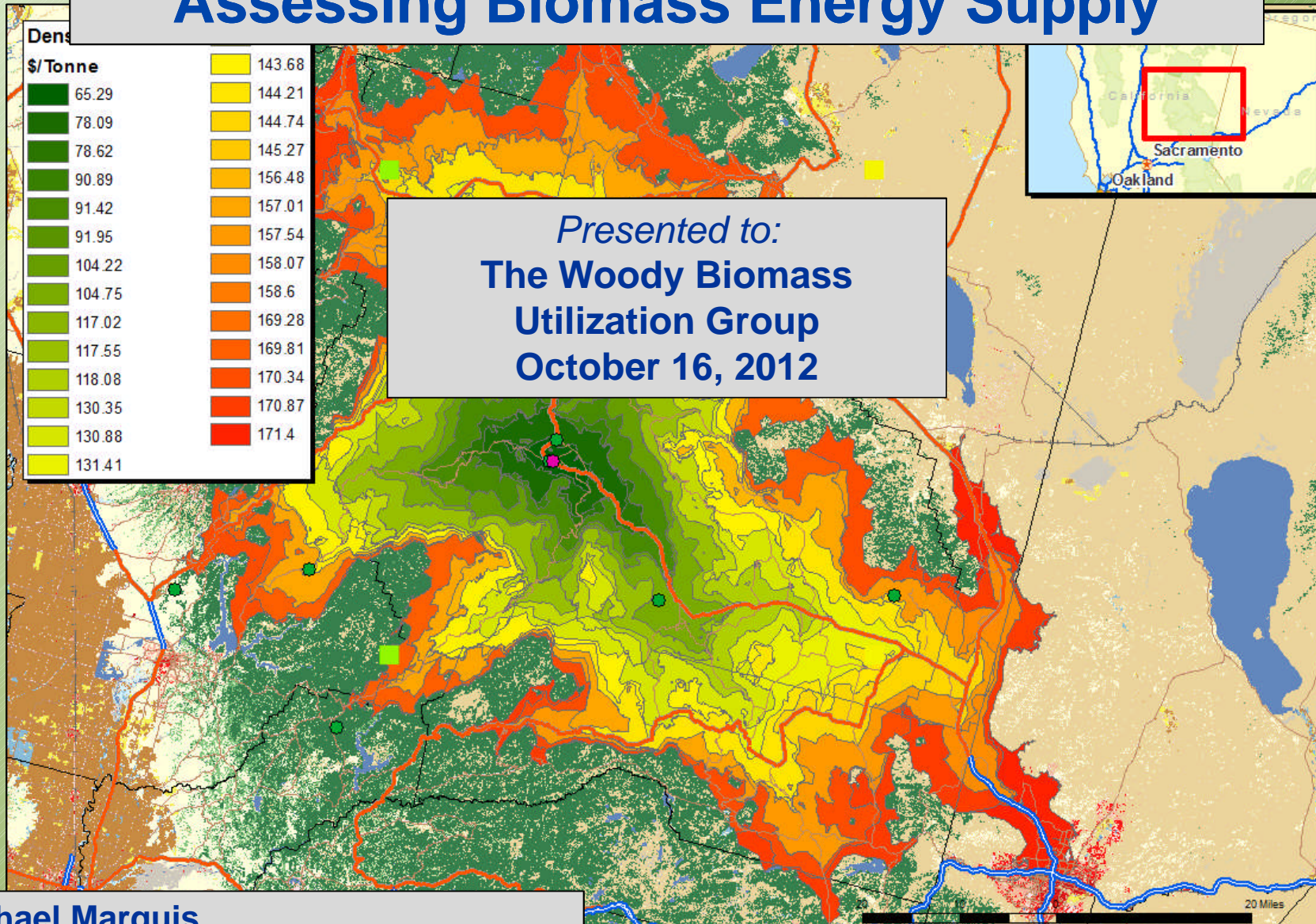


Assessing Biomass Energy Supply



Michael Marquis
Enegis, LLC

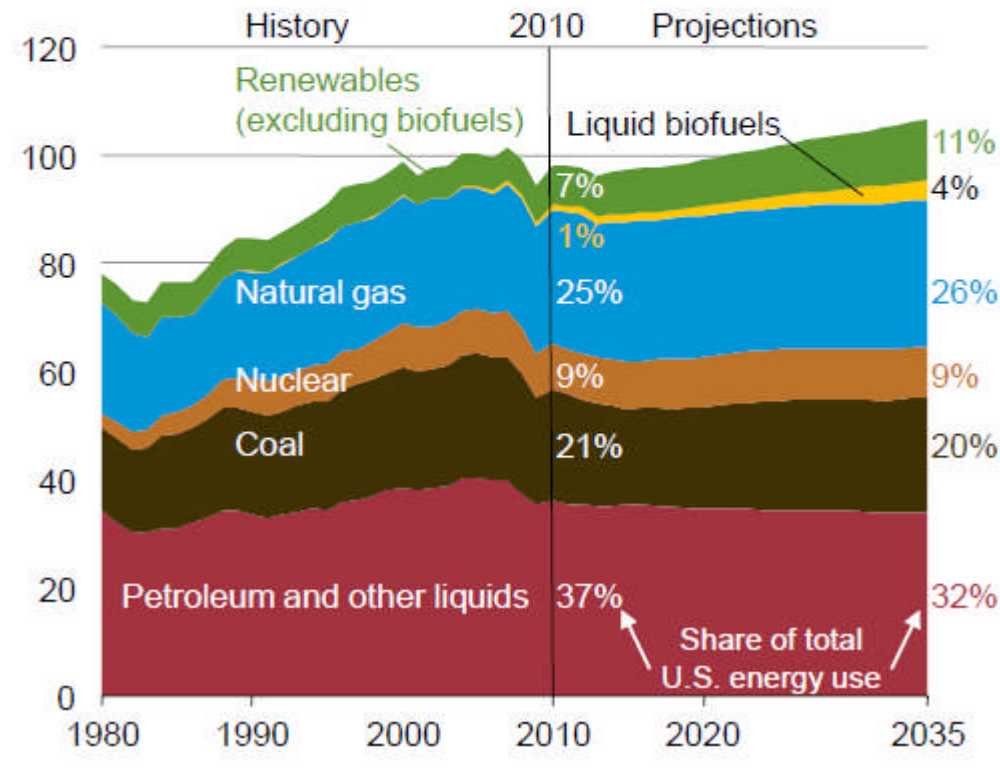
Biomass Energy Analytical Model



Biomass Usage Set to Rise Sharply

Renewable energy sources lead rise in primary energy consumption

Figure 73. Primary energy use by fuel, 1980-2035 (quadrillion Btu)



Biomass Energy Analytical Model[®]

- **Features**

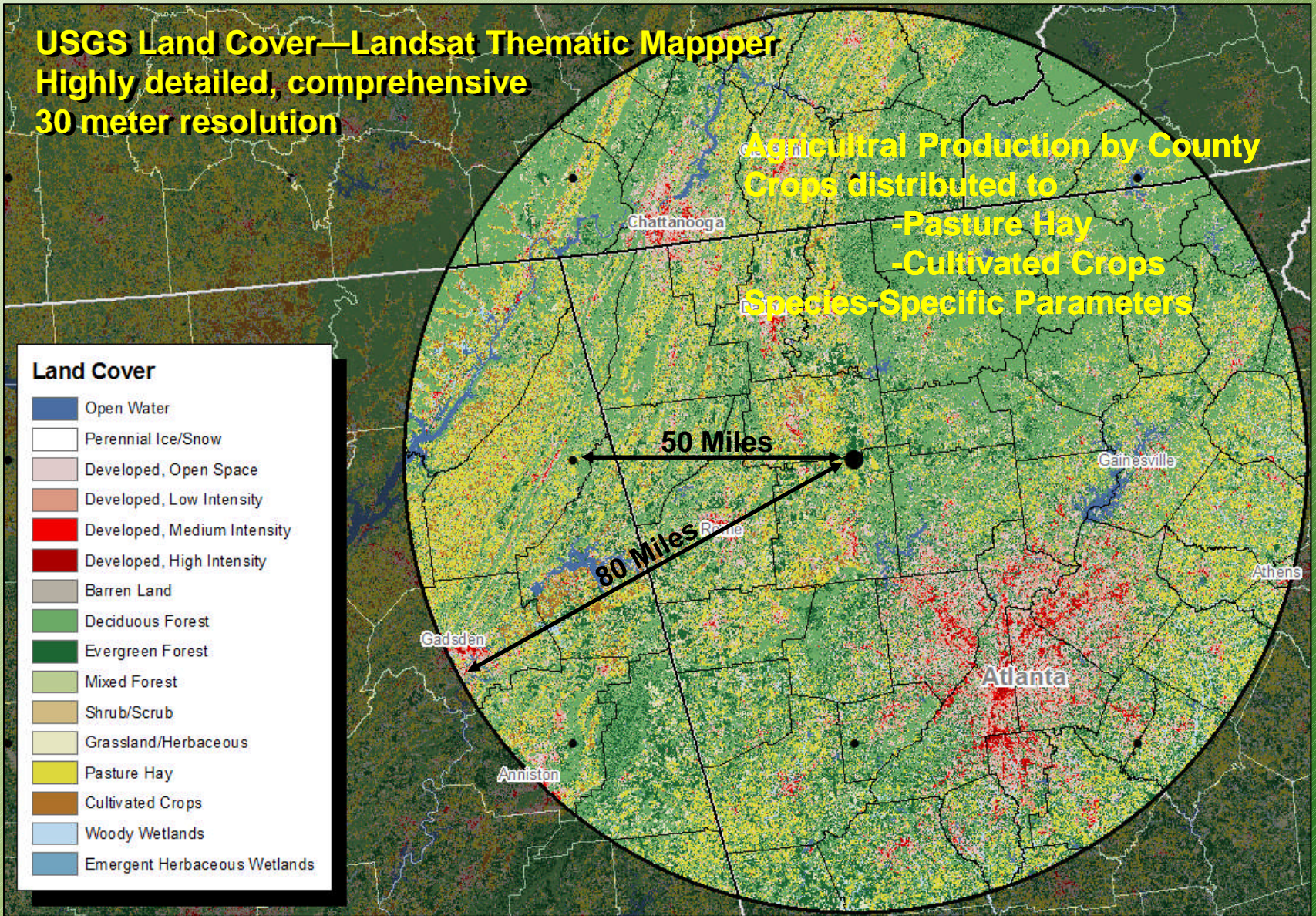
- Assess biomass availability, transport options, and delivery cost
- Models the biomass resource from field/forest, through processing, to demand
 - Geographic resources quantification
 - Storage and densification options
 - Transportation costs
- Can be used for both site-specific, regional, or national-scale biomass assessments
 - 30 m resolution for the lower 48 states
 - ~60 species and commodities can be analyzed
 - Focuses on residual biomass, although dedicated energy crops can be readily analyzed
- Costs, net energy and net carbon carried forward at all modeling steps

Assessing Biomass Availability

- Estimates total biomass able to be collected to a point within a given harvesting radius
 - Resource quantities based on published assessments
 - National Agricultural Statistics Service
 - US Forest Service
 - Western Governor's Association
 - Uses species/commodity-specific geographic and harvesting parameters
 - Production can be temporally constrained
 - Seasonal or quarterly
 - Species can be tallied on a tonnage- or Btu-equivalent basis
 - Individual species data are carried throughout the model
- Allows for optimization for site selection

Crop Residues

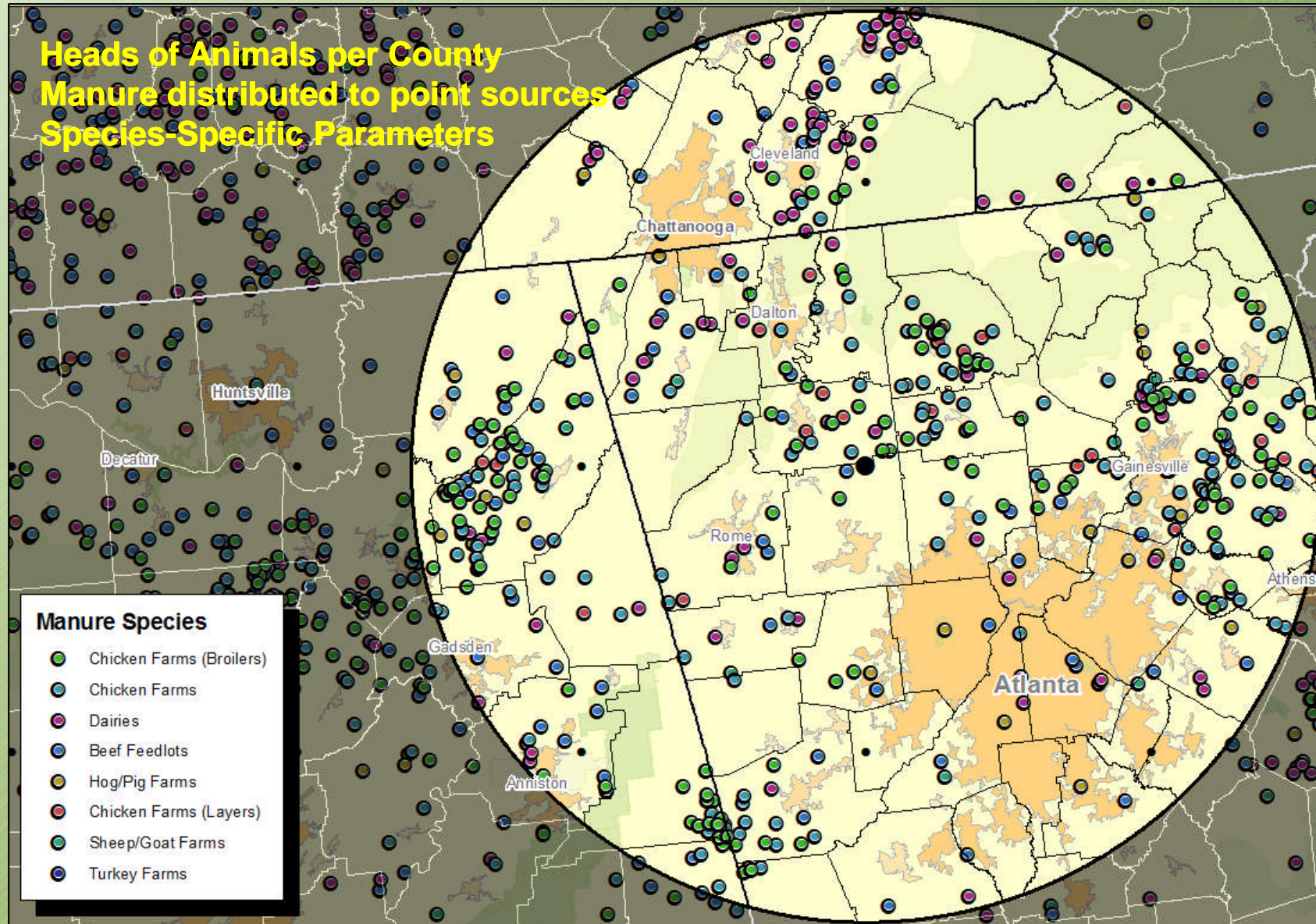
USGS Land Cover—Landsat Thematic Mapper
Highly detailed, comprehensive
30 meter resolution



Land Cover	
Blue	Open Water
White	Perennial Ice/Snow
Light Brown	Developed, Open Space
Light Red	Developed, Low Intensity
Red	Developed, Medium Intensity
Dark Red	Developed, High Intensity
Grey	Barren Land
Light Green	Deciduous Forest
Dark Green	Evergreen Forest
Medium Green	Mixed Forest
Light Tan	Shrub/Scrub
Light Yellow	Grassland/Herbaceous
Yellow	Pasture Hay
Brown	Cultivated Crops
Light Blue	Woody Wetlands
Dark Blue	Emergent Herbaceous Wetlands

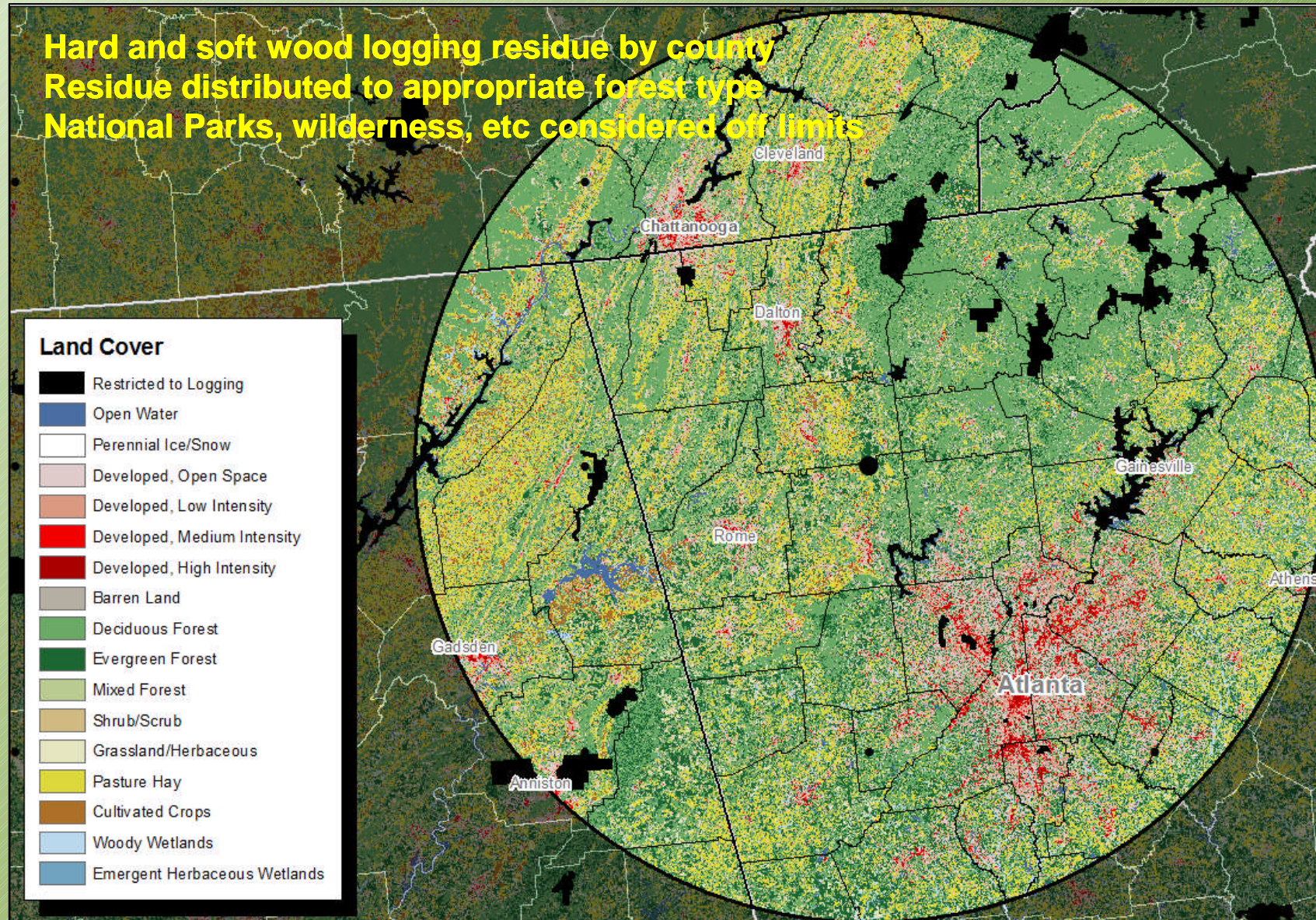
Manure Residues

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



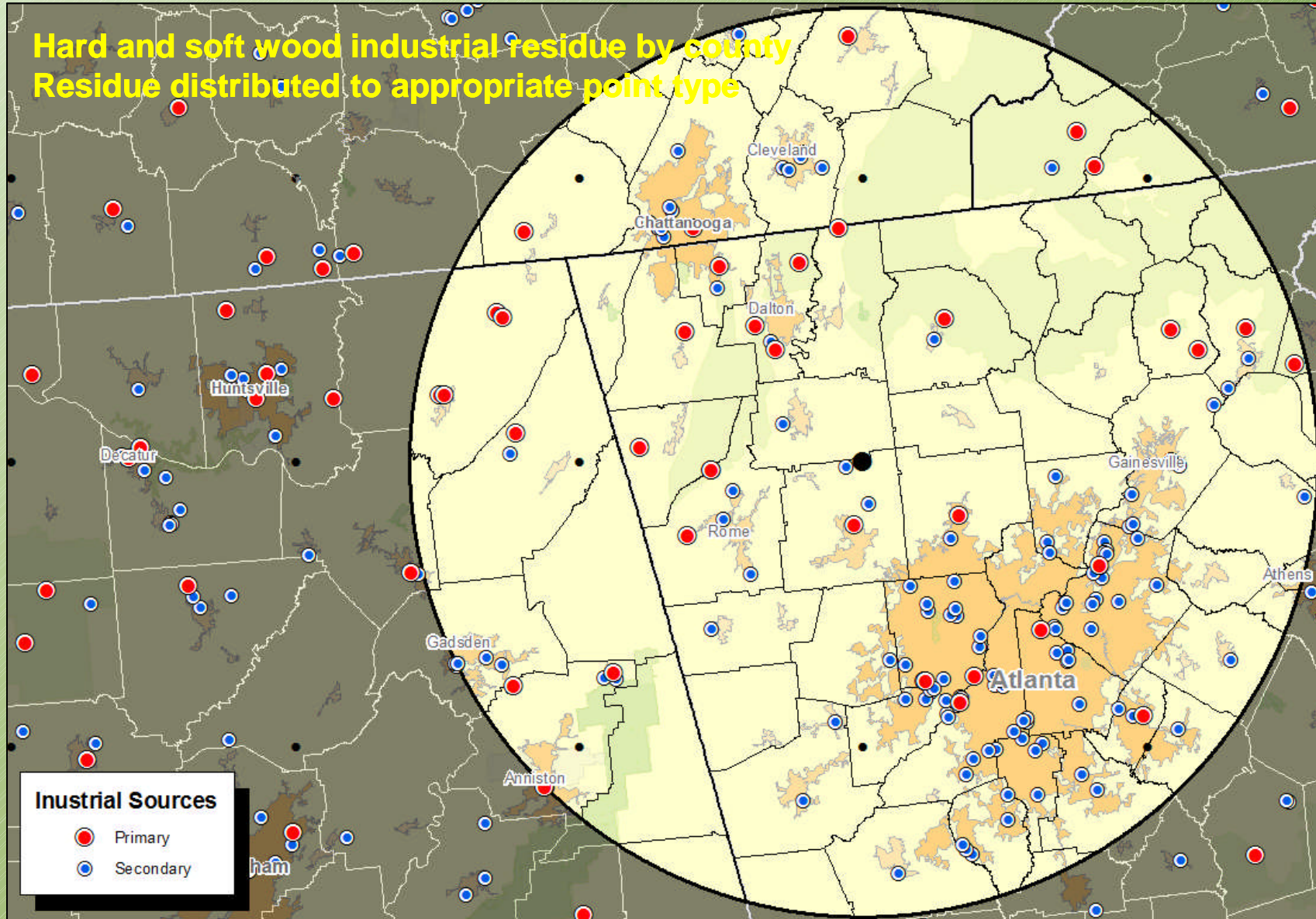
Distributed Woody Residues

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



Industrial Wood Residues

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



Species-Specific Parameters

~60 Species/Commodities Incorporated

Seasonality Parameters

Species	Data Source	Species	Data Source	Species:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
					%	%	%	%	%	%	%	%	%	%	%	%	%
Agriculture Residues:		Agriculture Residues Cont:		Hay All (Dry)	-	-	-	-	10	20	30	20	10	10	-	-	100
Hay All (Dry)	USDA NASS	Sweet Corn For Processing	USDA NASS	Hay Alfalfa (Dry)	-	-	-	-	10	20	30	20	10	5	5	-	100
Hay Alfalfa (Dry)	USDA NASS	Wheat Winter All	USDA NASS	Rice All	-	-	-	-	-	10	20	40	30	-	-	-	100
Rice All	USDA NASS			Sorghum For Grain	-	-	-	-	-	-	-	10	15	45	30	-	100
Sorghum For Grain	USDA NASS			Barley All	-	-	-	-	-	-	25	50	25	-	-	-	100
Barley All	USDA NASS			Canola	-	-	-	-	20	30	30	20	-	-	-	-	100
Canola	USDA NASS	Woody Residues:		Corn For Grain	-	-	-	-	-	-	-	-	25	50	25	-	100
Corn For Grain	USDA NASS	Logging Residue - HardWood	USDA FS	Cotton Amer. Pima	-	-	-	-	-	-	-	-	20	50	15	15	100
Cotton Amer. Pima	USDA NASS	Logging Residue - SoftWood	USDA FS	Cotton Upland	-	-	-	-	-	-	-	-	20	50	15	15	100
Cotton Upland	USDA NASS	Forest Management Residue - HardWood	BAMF Hazardous Fuels	Beans Dry Edible	-	-	-	-	-	-	-	25	50	25	-	-	100
Beans Dry Edible	USDA NASS	Forest Management Residue - SoftWood	BAMF Hazardous Fuels	Wheat Durum	-	-	-	-	-	-	25	50	25	-	-	-	100
Wheat Durum	USDA NASS	Coarse Wood Residue - Hardwood	BAMF Industrial Wood Waste	Flaxseed	-	-	-	-	-	50	50	-	-	-	-	-	100
Flaxseed	USDA NASS	Coarse Wood Residue - Softwood	BAMF Industrial Wood Waste	Peanuts for Nuts	-	-	-	-	-	-	-	-	25	50	25	-	100
Peanuts for Nuts	USDA NASS	Fine Wood Residue - Hardwood	BAMF Industrial Wood Waste	Potatoes All	-	-	-	-	-	-	-	-	25	50	25	-	100
Potatoes All	USDA NASS	Fine Wood Residue - Softwood	BAMF Industrial Wood Waste														100
Hay Other (Dry)	USDA NASS	Urban Wood Waste - Tree clippings	Based on US Census Bureau														100
Oats - (Fall)	USDA NASS																100
Rye	USDA NASS																100
Safflower	USDA NASS																100
Soybeans	USDA NASS																100
Sugarcane For Sugar	USDA NASS																100
Sunflower All	USDA NASS																100
Sweet Potatoes	USDA NASS																100
Sugarbeets	USDA NASS																100
Wheat Other Spring	USDA NASS																100
Tobacco Air-Cured Light Burley	USDA NASS																100
Tobacco Flue-Cured Class 1	USDA NASS																100
Green Peas For Processing	USDA NASS																100
Snap Beans For Processing	USDA NASS																100

Biomass Residue Conversions

Process	UID	Species	Commodity to Biomass Conversion												
			Category	Product	Unit	Conversion	Residue	Animal	Other	Collection					
						to Biomass	Cover	Feed	Use						
			factor	%	%	%	%								
Y	AH08	Hay All (Dry)	Crop Residue	Grass/plant	tonnes	1.00	0.30	0.25	0.15	0.30					
Y	AL08	Hay Alfalfa (Dry)	Crop Residue	Grass/plant	tonnes	1.00	0.30	0.25	0.15	0.30					
Y	AR08	Rice All	Crop Residue	Husk/Shell/Pit	tonnes	1.40	0.30	0.25	0.15	0.30					
Y	AS08	Sorghum For Grain	Crop Residue	Straw (stalk/cob/ear)	tonnes	1.40	0.30	0.25	0.15	0.30					
Y	AW08	Wheat All	Crop Residue	Straw	tonnes	1.30	0.30	0.25	0.15	0.30					
Y	BR08	Barley All	Crop Residue	Straw (stalk/cob/ear)	tonnes	1.20	0.30	0.25	0.15	0.30					
Y	CN08	Canola	Crop Residue	Stalks	tonnes	2.20	0.30	0.25	0.15	0.30					
Y	CR08	Corn For Grain	Crop Residue	Corn stover	tonnes	1.00	0.30	0.25	0.15	0.30					
Y	CTP08	Cotton Amer. Pima	Crop Residue	Cotton Stalks	tonnes	4.50	0.30	0.25	0.15	0.30					
			Crop Residue	Cotton Stalks	tonnes	4.50	0.30	0.25	0.15	0.30					
			Crop Residue	Straw (stalk/cob/ear)	tonnes	1.20	0.30	0.25	0.15	0.30					
			Crop Residue	Straw (stalk/cob/ear)	tonnes	1.30	0.30	0.25	0.15	0.30					
			Crop Residue	Straw (stalk/cob/ear)	tonnes	1.20	0.30	0.25	0.15	0.30					
			Crop Residue	Husk/Shell/Pit	tonnes	1.00	0.30	0.25	0.15	0.30					
			Crop Residue	Stalks/Leaves	tonnes	0.40	0.30	0.25	0.15	0.30					
			Crop Residue	Grass/plant	tonnes	1.00	0.30	0.25	0.15	0.30					
			Crop Residue	Straw	tonnes	1.30	0.30	0.25	0.15	0.30					
			Crop Residue	Straw	tonnes	1.60	0.30	0.25	0.15	0.30					
			Crop Residue	Straw (stalk/cob/ear)	tonnes	1.20	0.30	0.25	0.15	0.30					
			Crop Residue	stalks/leaves	tonnes	2.10	0.30	0.25	0.15	0.30					
			Crop Residue	Bagasse	tonnes	1.60	0.30	0.25	0.15	0.30					
			Crop Residue	Straw (stalk/cob/ear)	tonnes	2.10	0.30	0.25	0.15	0.30					
			Crop Residue	Stalks/Leaves	tonnes	1.00	0.30	0.25	0.15	0.30					
			Crop Residue	Grass/plant	tonnes	0.20	0.30	0.25	0.15	0.30					
			Crop Residue	Straw	tonnes	1.30	0.30	0.25	0.15	0.30					
			Crop Residue	stalks / stems	tonnes	0.75	0.50	-	-	0.50					
			Crop Residue	stalks / stems	tonnes	0.33	0.50	-	-	0.50					
			Crop Residue	stems / leaves	tonnes	1.50	-	-	-	1.00					
			Crop Residue	stems / leaves	tonnes	2.10	-	-	-	1.00					
Y	VSC08	Sweet Corn For Processing	Crop Residue	Corn stover	tonnes	1.00	0.30	0.25	0.15	0.30					
Y	WW08	Wheat Winter All	Crop Residue	Straw	tonnes	1.30	0.30	0.25	0.15	0.30					

Detailed Physical Parameters

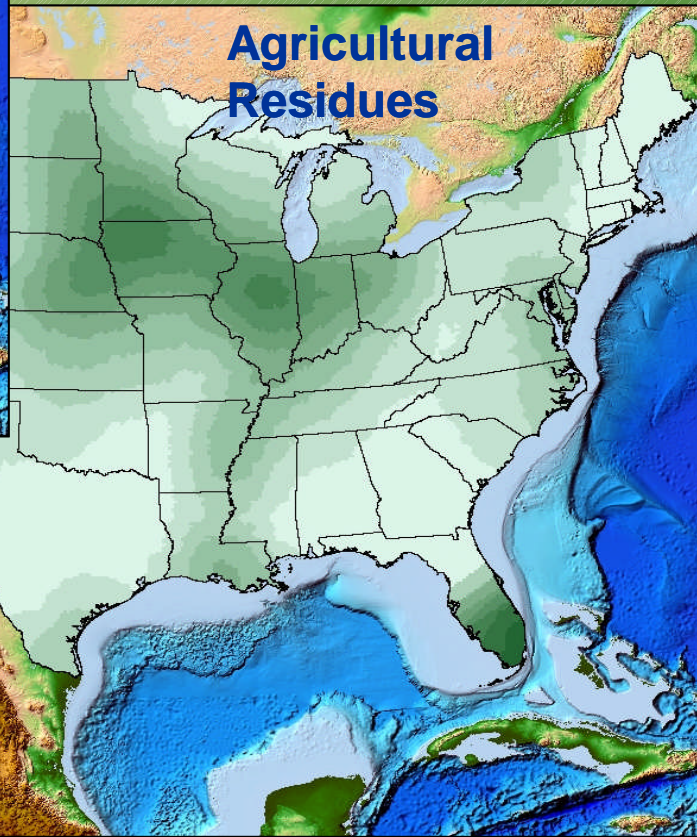
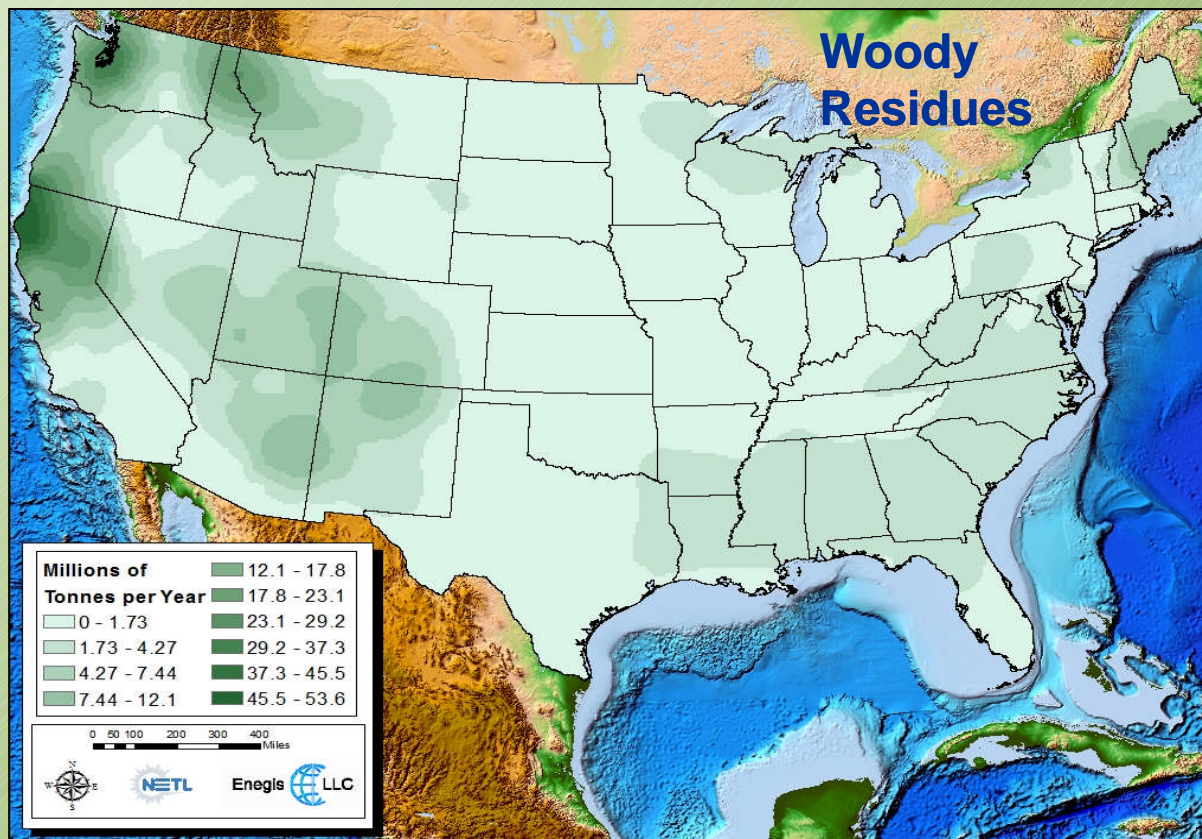
Species:	Physical Parameters											
	BtuHHV /Tonne	BtuLHV /Tonne	Ash Avg %	Ash Min %	Ash Max %	Moisture %	Potassium (K) g/kg (DAF)	Sodium (Na) g/kg (DAF)	Chlorine (Cl) weight % (DAF)	Carbon (C) weight %	Mercury (Hg) weight % (DAF)	Sulfur (S) weight % (DAF)
Logging Residue - HardWood	18.8	17.4	0.9	0.2	2.6	11.3	1.20	0.01	0.0	49.7	0.0	0.1
Logging Residue - SoftWood	19.9	18.5	1.6	0.4	4.1	4.7	1.68	0.25	0.0	51.9	0.0	0.0
Forest Mgmt. Residue - HardWood	18.8	17.4	0.9	0.2	2.6	11.3	1.20	0.01	0.0	49.7	0.0	0.1
Forest Mgmt. Residue - SoftWood	19.9	18.5	1.6	0.4	4.1	4.7	1.68	0.25	0.0	51.9	0.0	0.0
Coarse Wood Residue - Hardwood	18.5	17.2	0.9	0.4	2.1	15.2	0.98	0.04	0.0	50.0	0.0	0.1
Coarse Wood Residue - Softwood	19.3	18.0	0.3	0.3	0.3	9.3	0.38	0.04	0.0	49.8	0.0	0.0
Fine Wood Residue - Hardwood	17.2	16.0	1.5			8.0	-	-		50.8	0.0	0.0
Fine Wood Residue - Softwood	18.4	17.2	1.1			34.9	0.49	0.03	0.0	49.3	0.0	0.0
Urban Wood Waste - Tree clippings	19.5	18.4	15.6	1.4	39.4	35.4	4.15	2.05	0.1	51.1	0.0	0.1



Densification and Processing Options

Activity		CAPEX	OPEX	Energy Balance	Carbon Footprint				
		\$/tonne		Mbtu / tonne	kg CO ₂ / tonne	CAPEX	OPEX	Energy Balance	Carbon Footprint
Field/Forest Options	Wood as is	-	-	-	-				
	Wood Bundler	0.89	13.78	38.60	2.99				
	Small Wood Chipper	0.51	10.38	79.50	6.15				
	Large Wood Chipper	0.08	6.40	13.00	1.04				
	Gen Ag Bundler	1.64	8.60	52.90	4.09				
	Grassy Ag bundler	3.03	5.89	73.40	5.68				
	Producer Payment	-	-	-	-				
						\$/tonne		Mbtu / tonne	kg CO ₂ / tonne
Densification Options	Pelletization with Chi	12.31	36.16	3,800.00	358.00				
	Briquetization with C	16.40	32.71	3,780.00	357.00				
	Torrefaction with Chi	13.86	39.61	1,220.00	133.00				
	Pelletization	11.71	32.71	3,780.00	357.00				
	Briquetization	15.80	29.00	52.90	4.09				
	Torrefaction	13.27	36.06	1,200.00	132.00				
	Large Wood Chipper	0.08	6.40	13.00	1.04				
	Storage	6.91	2.20	31.00	2.00				

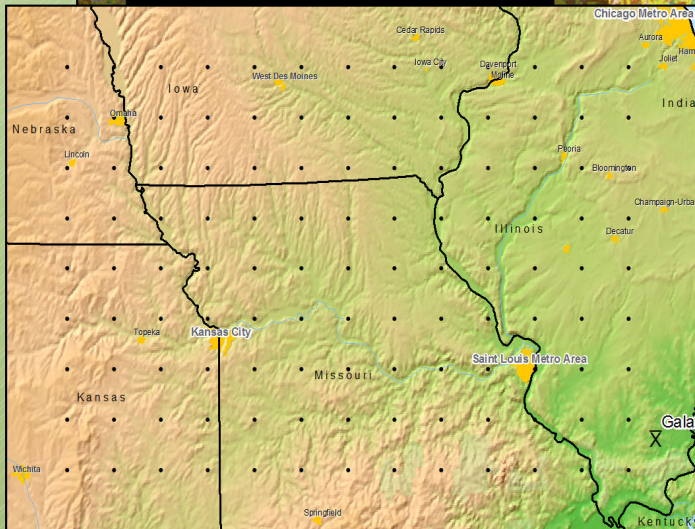
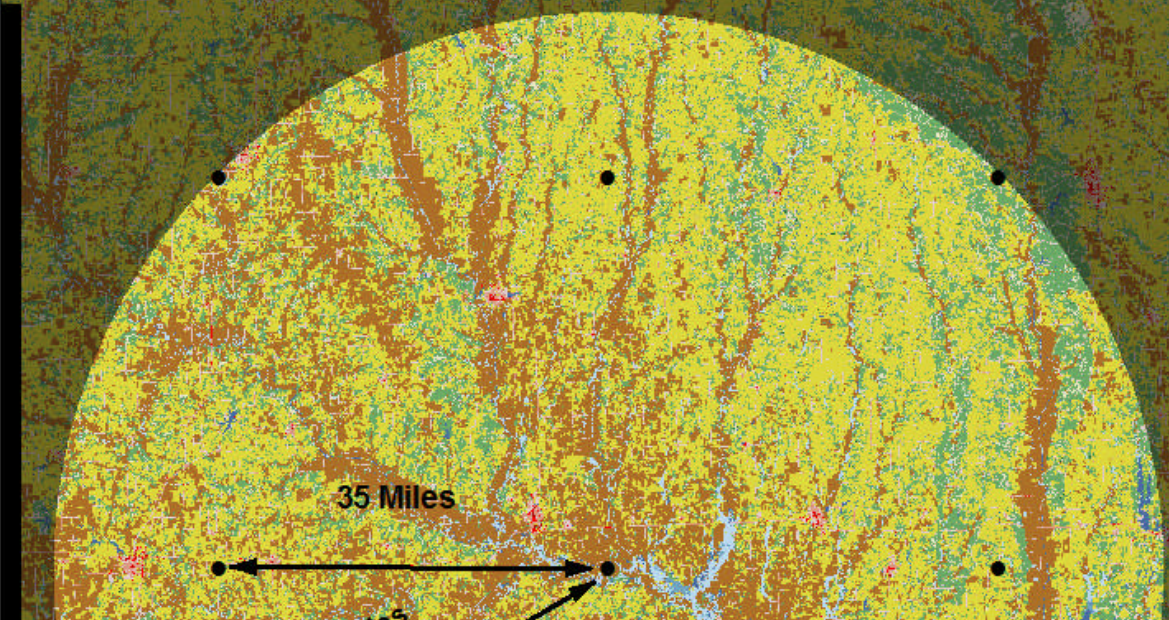
BEAM[®] Lower 48 States, Site Availability Assessment (Grid Mode)



BEAM[©] : Northern Missouri Switchgrass

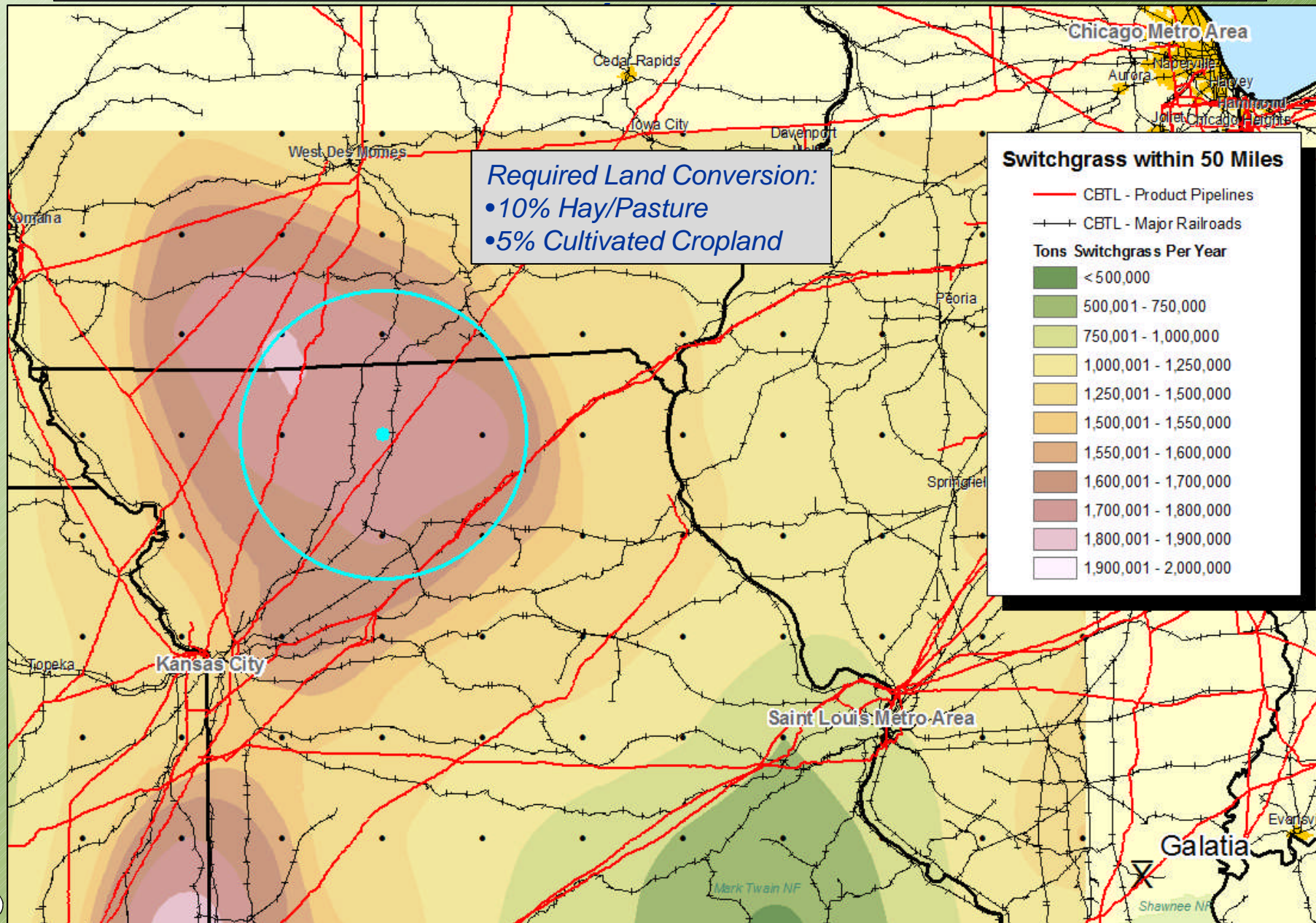
Land Cover

	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

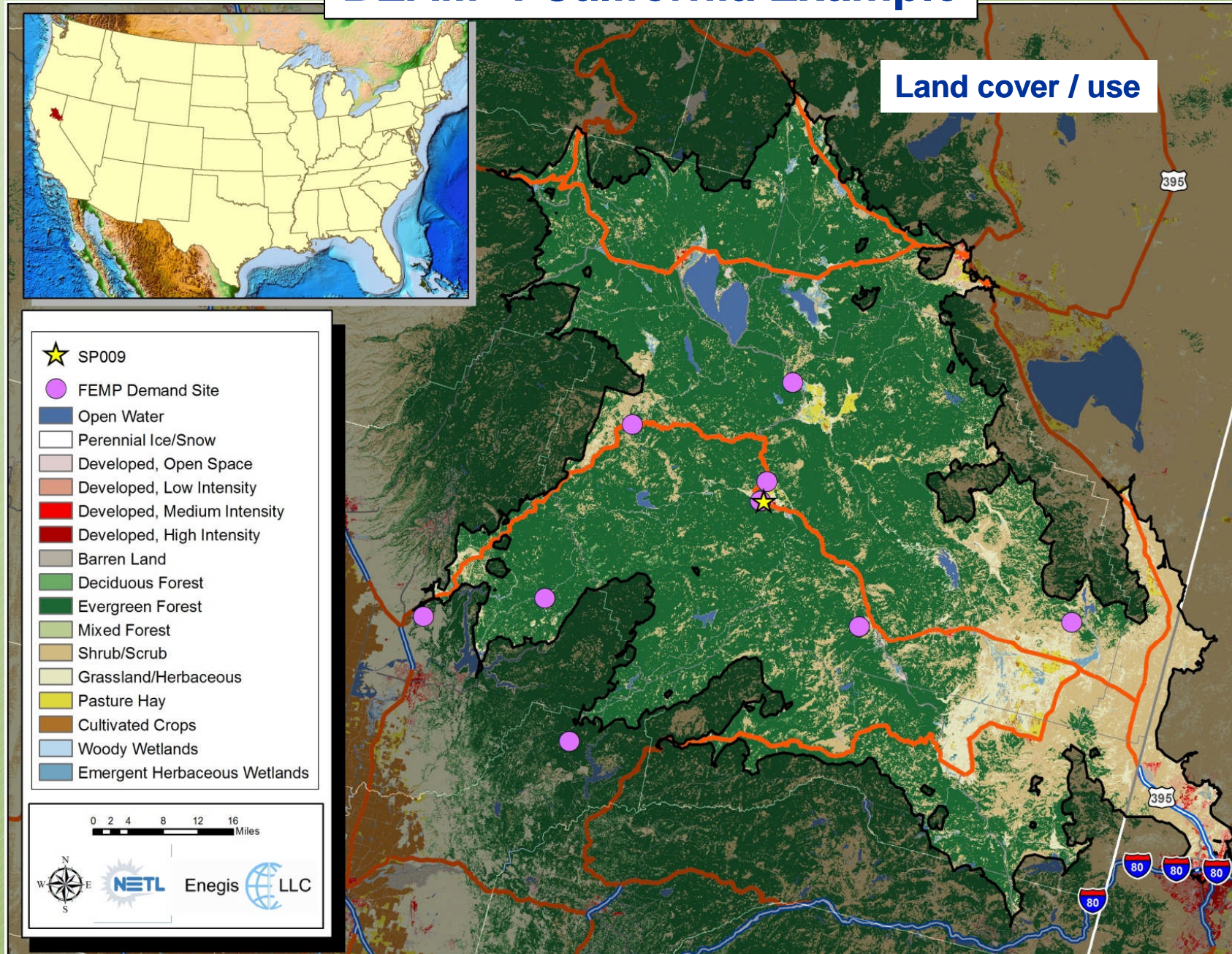


- **Scope: Single 30,000 bpd plant, 30% switchgrass, 70% Illinois #6 coal**
- **Decision: switchgrass land--mix of available land types (cultivated/hay-pasture) within 50-miles**
- **Plant location criteria**
 - Northern Missouri
 - Rail transport of coal
 - Spur pipeline to major pipeline
 - Switchgrass feed rate: 4,240 short tons per day

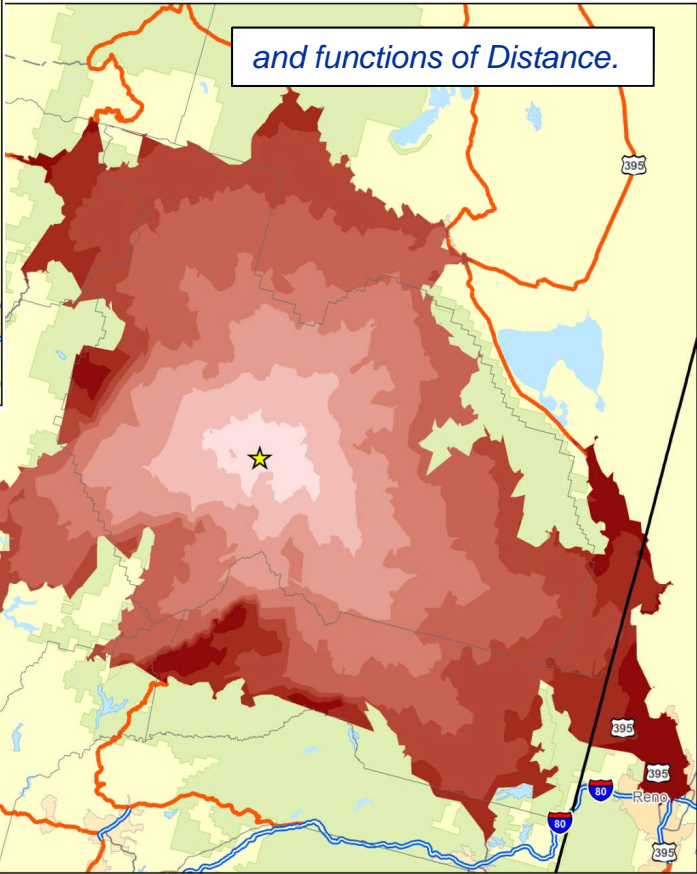
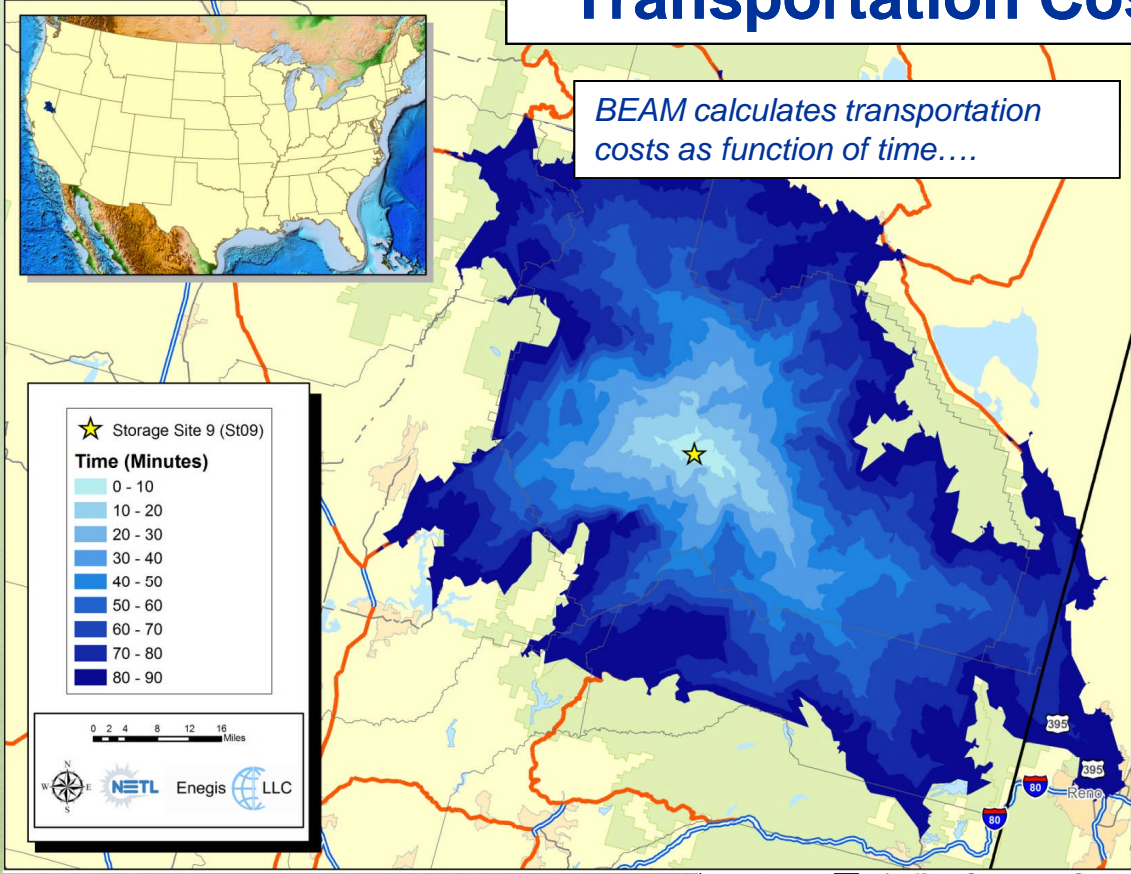
BEAM[®] Northern Missouri Switchgrass Exercise



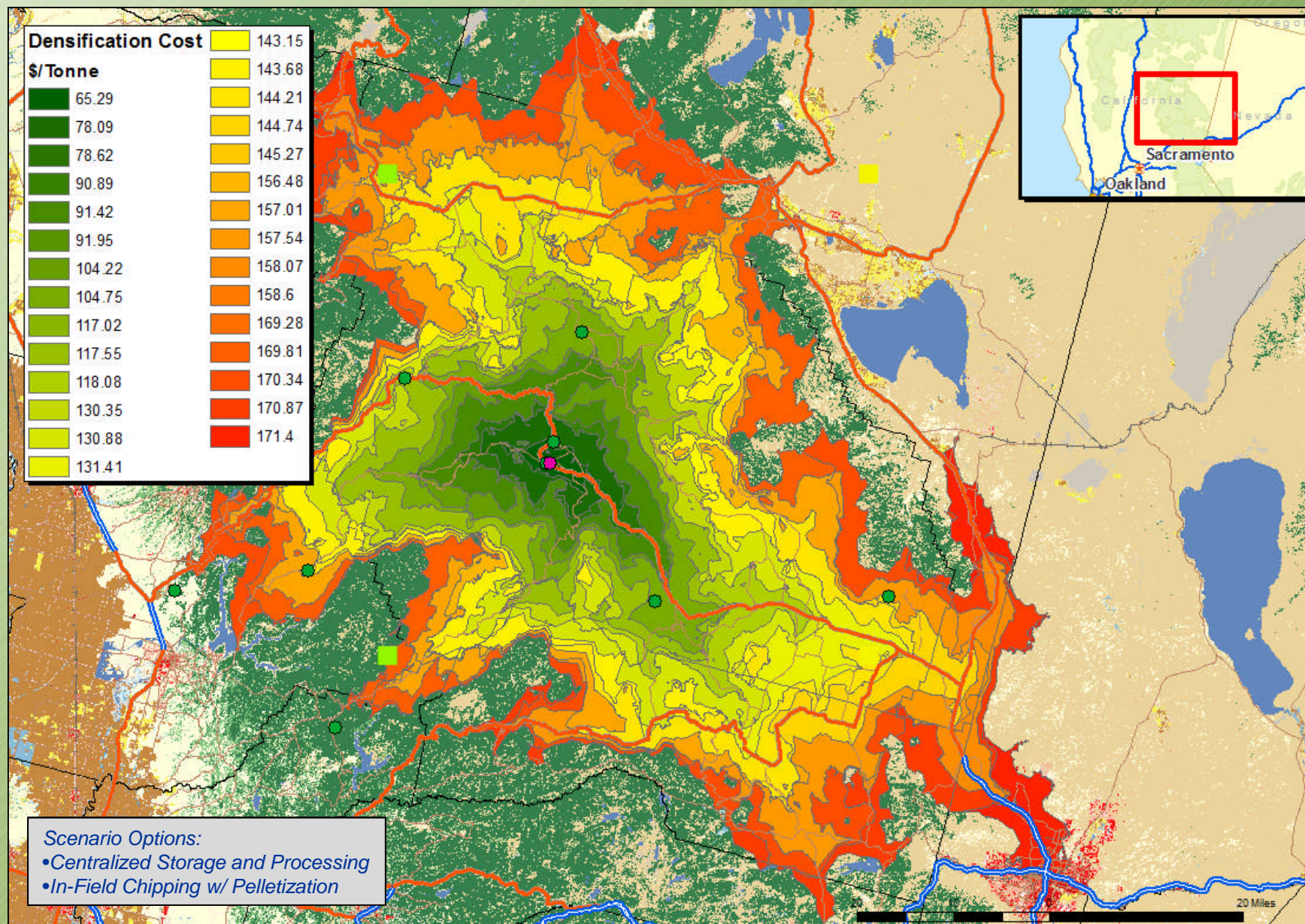
BEAM[©]: California Example



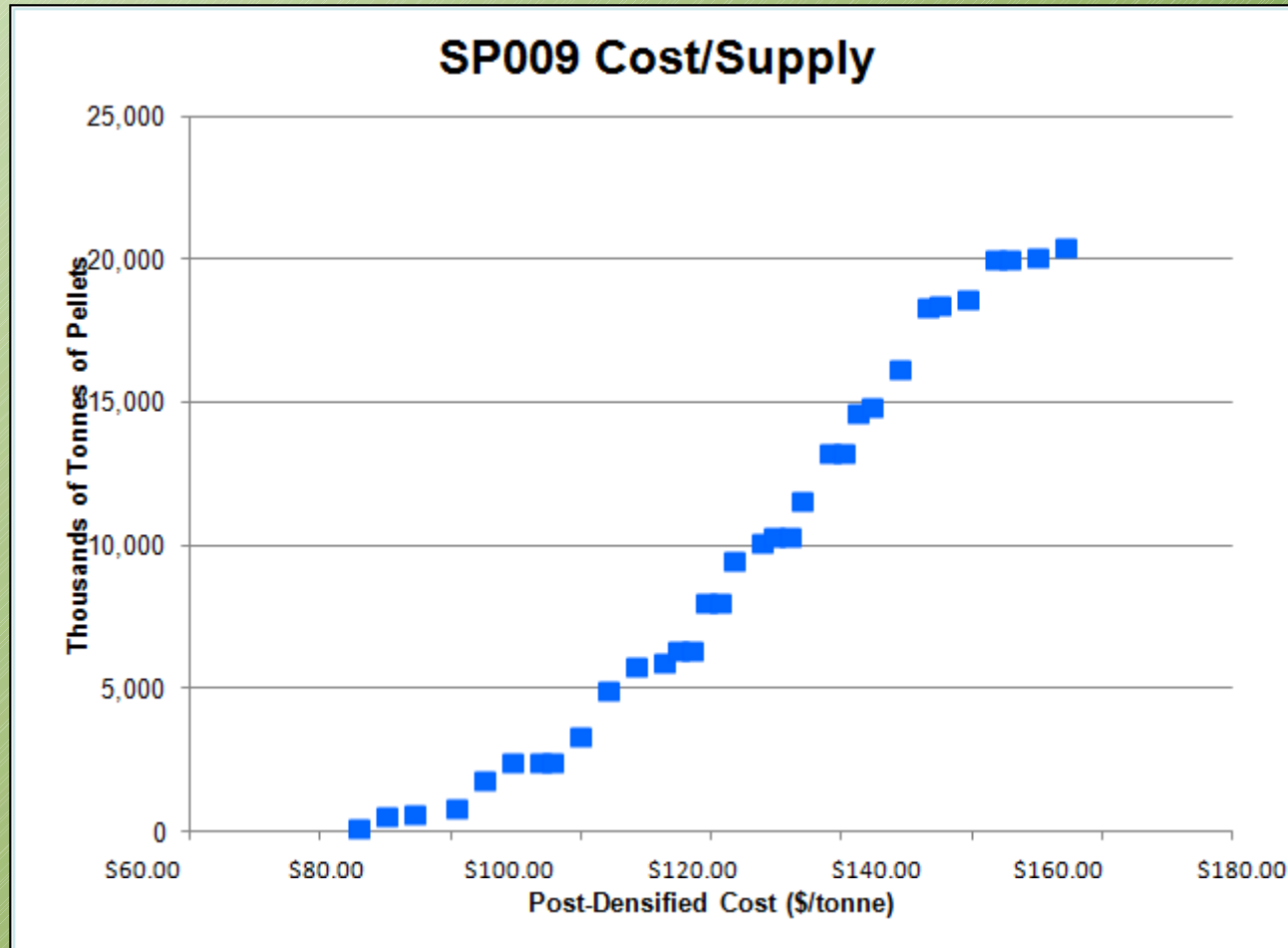
Transportation Costs



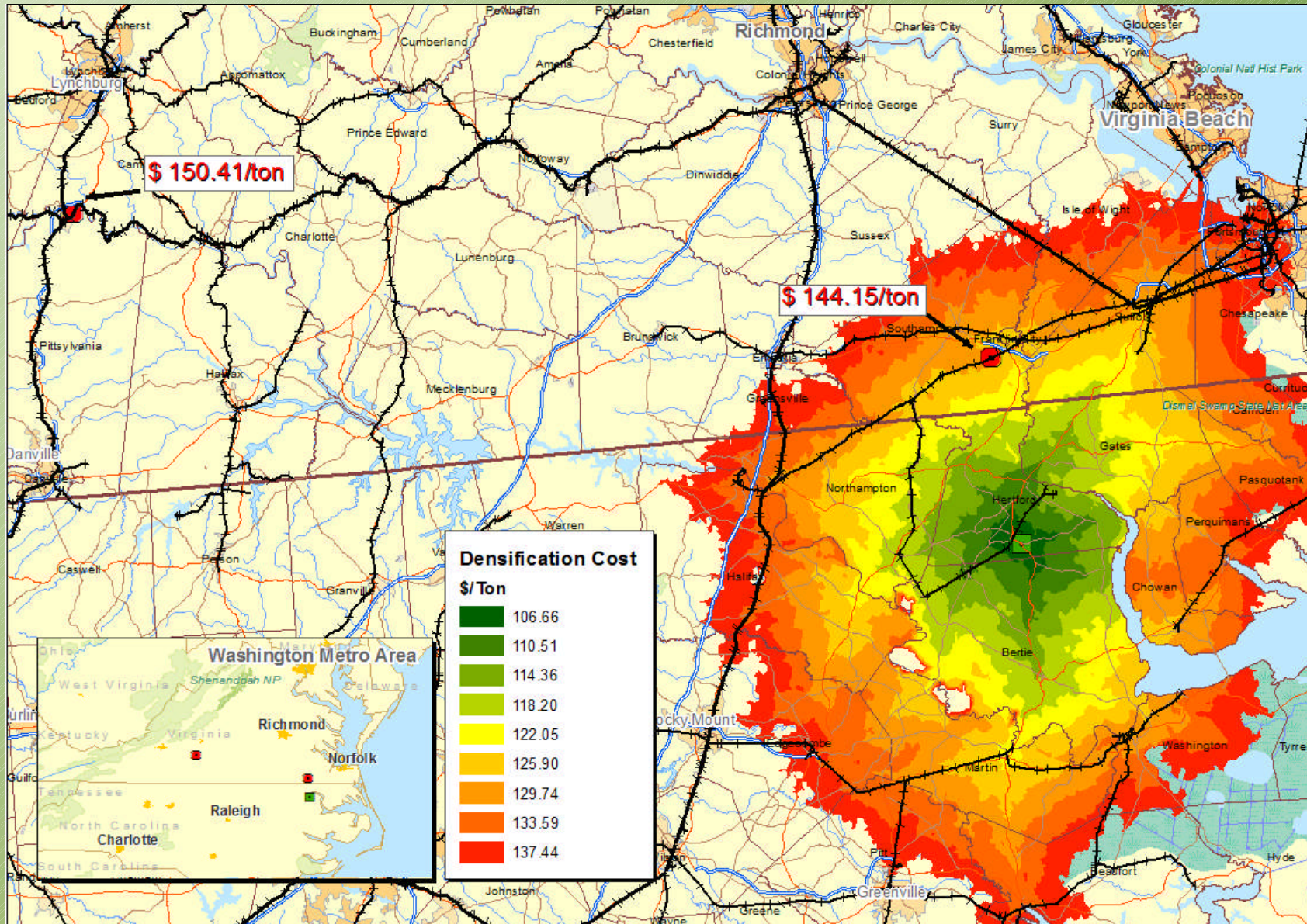
BEAM[®]—Results: Pellets, Processed and Stored



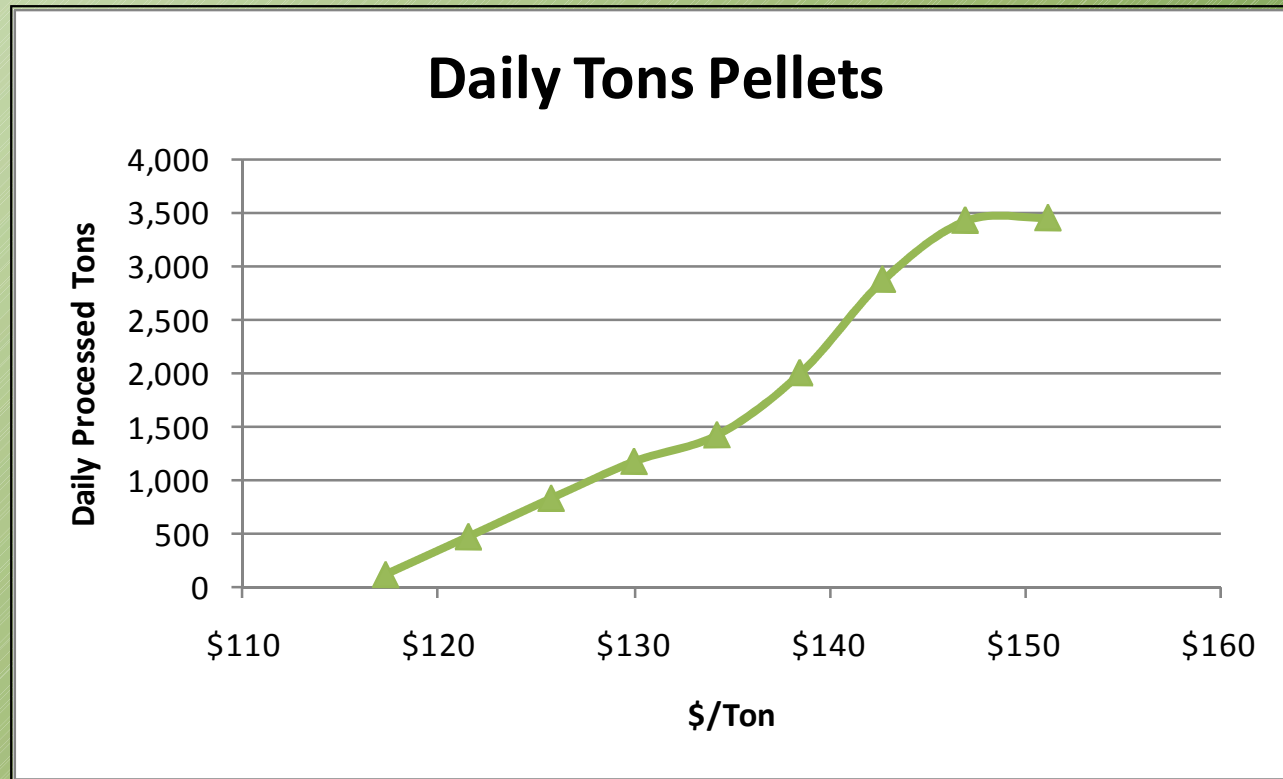
Cost-Supply Curve



CFPP Biomass Conversion



Biomass Conversion



- **Need to calibrate costs to local market**

About Enegis

- **Small business, located in Fairfax, VA**
- **Specialize in highly-tailored, data-driven, quantitative GIS models and analyses**
 - Decision support models
 - Energy and economic decision analyses
 - Policy analysis
 - Scenario modeling
 - Strategy planning
 - Royalty evaluations
 - Technology assessments
- **Analytical Capabilities:**
 - BEAM[®] analyses for biomass
 - CO₂ and EOR
- **98% D&B Performance Rating**

About Enegis

- **Areas of Expertise**

- Energy resources and power generation
 - Biomass, coal, geothermal, natural gas, solar, wind
- 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

- **Clientele**

- Public utilities
- Trade associations
- Multilateral banks
- Investment banks
- Major and minor energy companies
- Federal Sector
 - Department of Energy
 - Department of the Interior
 - Department of Agriculture
- International scope
 - Canada, Latin America, Asia, Europe, Australia and Africa



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