Advances in Hardwood Plantation Systems Implications for Bio-energy Feedstock

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SWST Austin Texas, June 9, 2013

EU 27 Bio-energy Demand by 2020

- Renewable Energy Directive
  - 20% reduction in GHG from 1990 levels
  - 20% energy efficiency improvements
  - 20% energy from renewable sources
  - 10% increase in biofuels usage

- Source: Biorefining Magazine, February 2011.

Life Cycle Emissions Including Production

Fuel	CO2 emissions kg/GJ	CO2 emissions kg/MWh
Hard coal	134	484
Oil	97	350
Natural gas	75	270
Wood chips @ 25% MC	7	25
Wood pellets @10% MC	9	33

- Source: Biomass Power & Thermal October 2011

UK Renewable Energy 2020 Targets

- 20% of energy needs from renewable sources
- 75% of renewables as wind, solar…
- 25% of renewables as biomass
- 50,000,000 dry tonnes biomass total
- 30,000,000 dry tonnes biomass imported
  - 22 million tonnes wood pellets
  - 24-36 wood pellet facilities (1/3 in US South?)
- 20,000,000 dry tonnes biomass-domestic
  - UK Forestry Commission says 2 million tonnes by 2020 in bio-energy forest plantations

Wood Bio-energy South
Projected Annual Wood Demand 2023
www.forisk.com April, 2013

State	Projects	New Tons*	Current PW Tons*	Harvest Residues**
AL	8	4,947,460	22,319,461	5,100,000
AR	7	1,820,000	8,599,960	
FL	18	10,574,125	8,810,364	4,700,00
GA	36	18,167,578	24,910,968	
LA	4	3,300,000	13,202,538	
MS	8	3,183,239	9,756,782	3,320,000
NC	13	2,796,000	6,516,913	3,617,000
SC	11	2,939,800	11,754,290	3,700,000
TN	6	3,150,000	N/A	
TX	9	2,862,440	8,828,168	
VA	15	2,207,300	N/A	
Total	**156**	**64,407,754**	**125,294,759**	

- *Green tons
- **Green tons estimated as available by state agency or USFS

Post Harvest Residue
Gadsen Co. Florida

Whole Tree Chipped

Conventional Tree Length Harvest

Bio-energy Availability = Zero on Many Logged Sites

Bio-energy Resources (?)

Urban waste

Logging site waste

Florida Harvest and Utilization Study, 2008
Resource Bulletin SRS-162

- Average total harvest 68 tons/acre (15 ton/acre residual)
- 331,000 acres harvested (191,000 acres/year clearcut)

- Softwood 85% utilized 15% residual
  - Residual 3.2 million tons (1.0 million tons stem wood, 2.2 million tons tops and limbs)
- Hardwood 74% utilized 26% residual
  - Residual 1.5 million tons (0.7 million tons stem wood, 0.8 million tons tops and limbs)

So 50 MW, 600,000 green tons/year…60% residual recovery…

Requires residuals from 67,000 of the clearcut acres (1/3 of state!)

Eastern US Hardwood Forest Plantation Opportunities

Cottonwood and Hybrid Poplar

Large *Populus* germplasm collections for deployment in the SE USA

9-year-old Eastern Cottonwood (ECW) on moderately well drained soil in Columbus County, NC

Uses: High quality hardwood pulp & potential for furniture lumber

Productivity: *Populus* is the fastest growing eastern USA hardwood—3-20 Gtons/ac/yr in a pulpwood 10 yr rotation
Site: Eastern USA
Soils: Moderately well drained uplands to alluvial bottomlands—not poorly drained
Site constraints are much greater than for Sweetgum or pine
Silviculture is well defined
Understanding of resource requirements to grow *Populus* on upland moderately well drain soils could be improved
Resource inputs to establish & grow are high
Resource requirements are greater for *Populus* than sweetgum.

Genetic Improvement (422 varietals total)

Tests include:

- Wooten Farm, NC – Ag. field
  - Age: 2 yrs
  - Spacing: 10‘ x 4‘ (87 varietals)
- Eastover, SC – Ag. field
  - Age: 4 yrs
  - Spacing: 10‘ x 4‘ (243 varietals)
- Moultry, SC – Former pine site
  - Age: 3 yrs
  - Spacing: 12‘ x 7‘ (161 varietals)
- Floyd, GA – Former pine site
  - Age: 8 yrs
  - Spacing: 12‘ x 8‘ (120 varietals)
- Randolph, AL (2 tests) – Former pine site
  - Age: 3 yrs
  - Spacing: 12‘ x 7‘ (162 varietals) & 12‘ x 4‘ (124 varietals)

- Design:
  - Randomized Complete Block
  - 4 replications at Floyd, 6 replications at all other sites

Selected Hybrid Poplar, Eastover SC
Age 4.5 years

Tree Performance (5 sites; 422 varietals total)

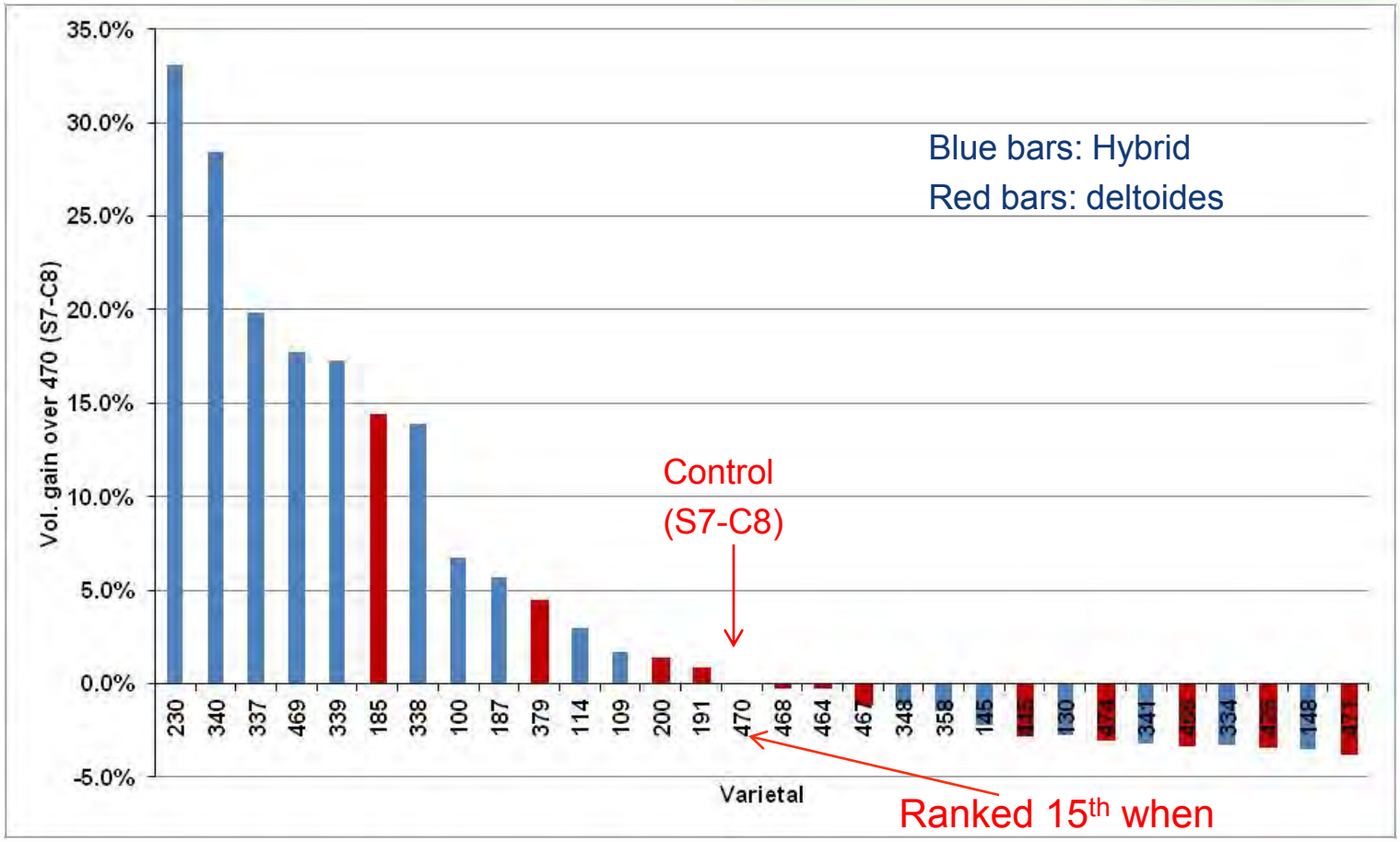
Average tree height & DBH in six tests (range in parentheses)

Test	Age (yrs)	Height (ft)	DBH (in)
Wooten Farm, NC	2	14.2 (6.0-18.8)	1.4 (0.8-2.1)
Eastover, SC	4	30.0 (12.4-37.7)	3.1 (0.9-5.2)
Moultry, SC	3	11.9 (5.7-20.5)	1.2 (0.2-2.9)
Floyd, GA	8	55.9 (41.2-69.9	6.2 (3.5-8.3)
Randolph-1, AL	3	18.0 (13.0-22.9)	1.9 (1.1-2.5)
Randolph-2, AL	3	17.2 (10.5-25.5)	1.6 (0.7-2.7)

4-year-old tree in Moultry, SC test

BLUP Analysis – Standardized Volume

(Top 30 varietals)



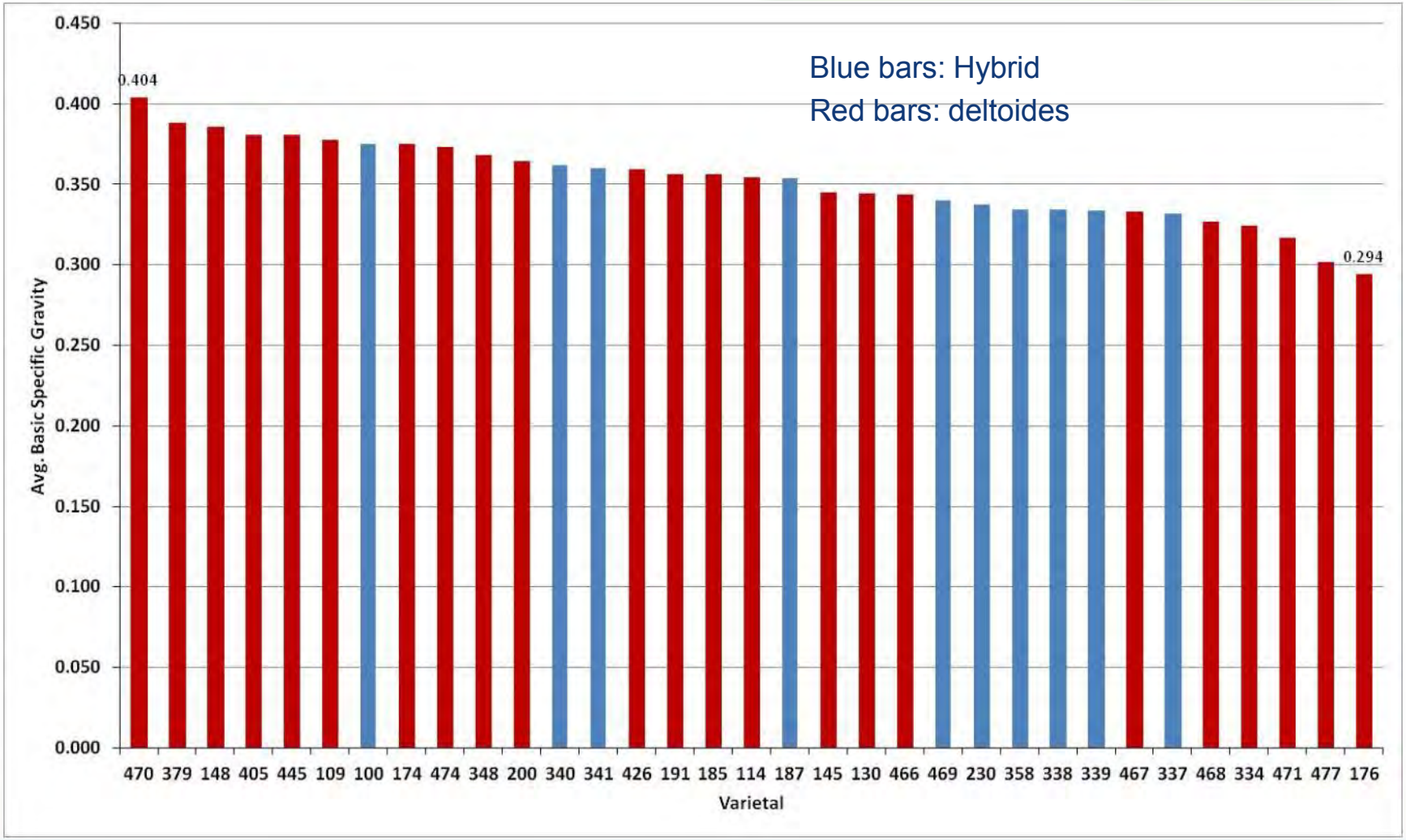
Vol. outside bark (ft^3) = 0.06 + 0.00221 D^2H

Krinard, RM. 1988. Volume equations for plantation cottonwood trees (*Populus deltoides*). Research Note SO-347, USDA Forest Service

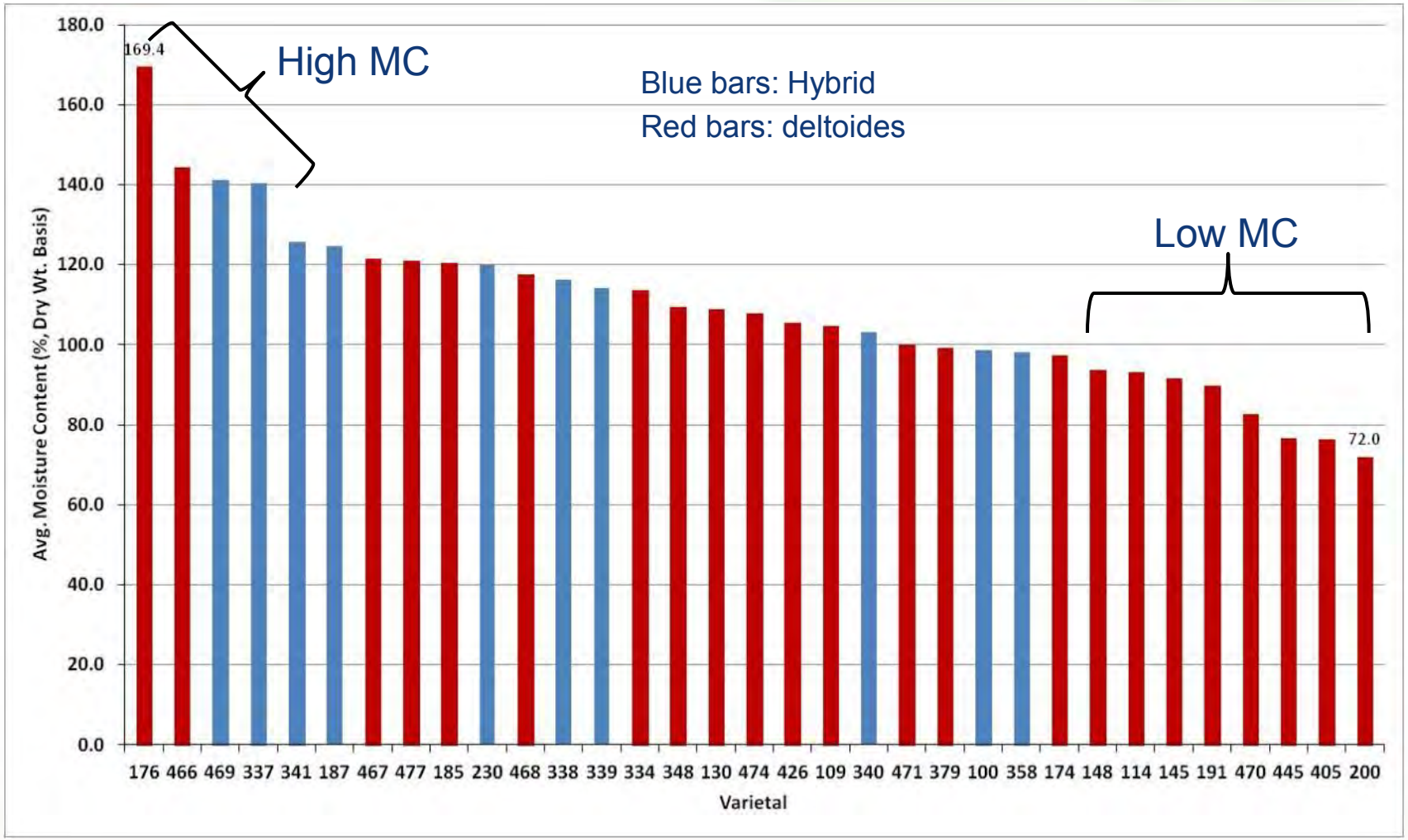
Wood Property: MC & Basic Specific Gravity (after 2012 growing season)

- 3 sites
  - Randolph, AL (Age: 4 yrs)
  - Moultry, SC (Age: 4 yrs)
  - Eastover, SC (Age: 5 yrs)
- Core samples
  - Top 30 varietals from BLUP analysis based on volume gain
  - 3 trees/variety/site
  - 5.1 mm diam. cores extracted in Oct & Nov. 2012
  - Core green weight taken in the field as soon as collected
  - Core volume estimated using water immersion method
  - Cores dried at 101°C until constant weight

Average Basic Specific Gravity



Average Moisture Content (%, Dry wt Basis)



Sweetgum

Large SG germplasm pool In the USA

Uses: Hardwood pulp, lumber and biomass for energy
Species: *Liquidambar styraciflua*
Site: SE USA –Similar to loblolly
Soils: Poorly to well drained soils
SG is the native hardwood with the broadest deployment potential in the SE USA.
Productivity range: 6-10 Gtons/ac/yr
-**Silvicultural** regimes for establishing and growing SG are well understood and practical
Improvements: Hybrids with Asian SG

14-year-old Sweetgum plantation Berkeley County, SC—9Gtons/ac/yr

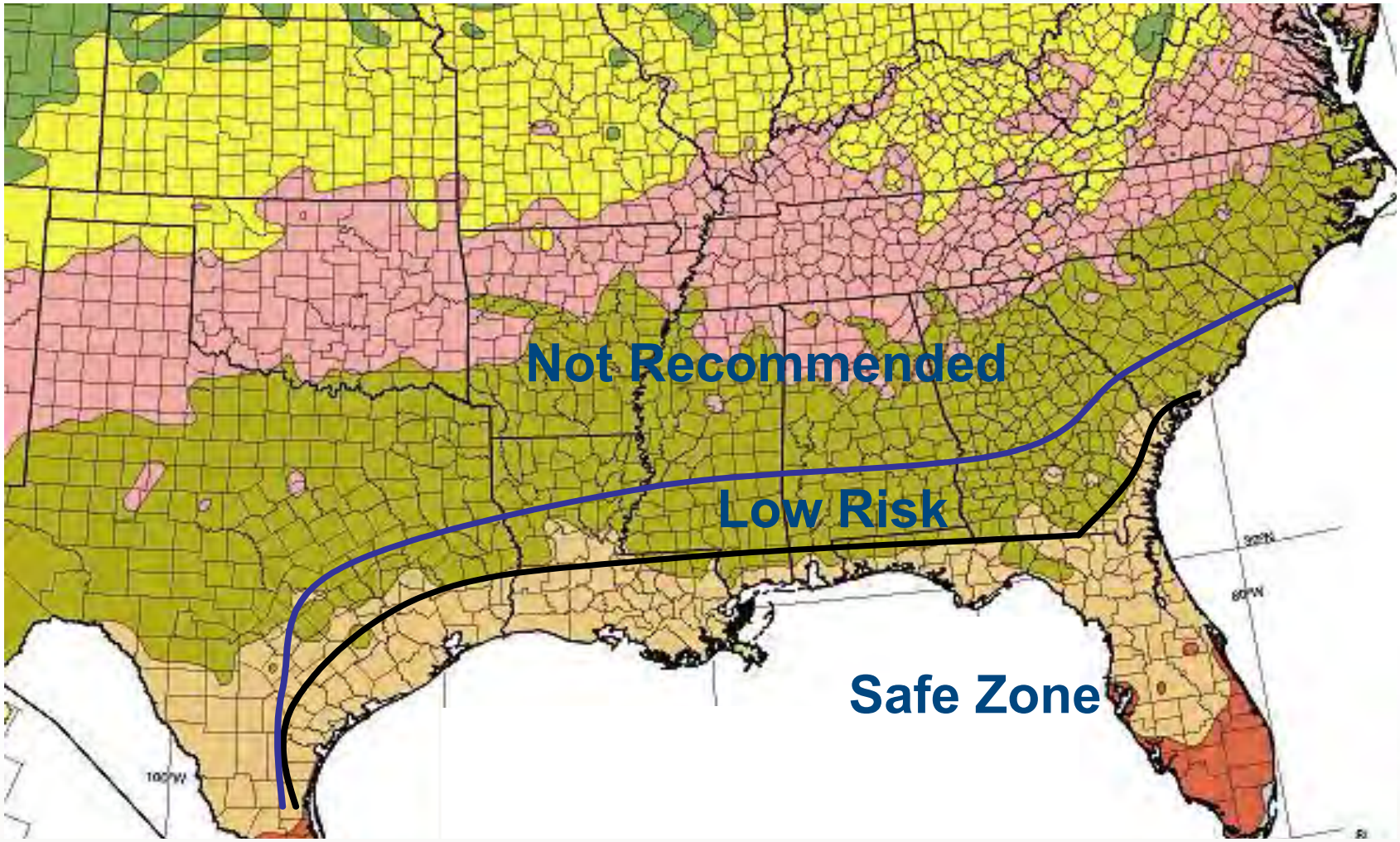
L. styracaflua X L. formosana

Hybrid Sweetgum Clone– Age Two Years

Conventional Eucalyptus

- **Uses**: Mulch, Hardwood Pulp & Biomass for energy
- **Species**: *Eucalyptus benthamii*
- **Sites**: Lower latitudes in the SE USA
- **Soils**: Somewhat poorly with good internal drainage to well drained soils
- **Silviculture**: Good understanding but will improve
  - Establishment cost > than pine
  - Coppice for additional rotations
- **Risk**: Freeze damage- Unknown pest
- **Productivity range**: 9-16 Gtons/ac/yr pulp wood rotation 7-8 yrs. Specific gravity 0.46 to 0.52
- **Improvement activities**: Seed source testing, NCSU FPC screening

Eucalyptus benthamii Planting Zones



Native Eucalypts to Plantations

Species Introductions

E. benthamii South Carolina USA
Age 6 years

Eben – age 12 years

Eben, Age 20 months, near Georgiana AL

Eucalyptus benthamii (Eben)

- Most cold tolerant eucalyptus we have tested
- Current planting stock are seed collections from multiple sources which produce good but variable performance
- Large effort in US seed production

3-yr-old Eben planted near Jackson, AL

Eben seed production

Bellamy clonal orchard

Age one year – will be Seedling Seed Orchard

Pawns to Clones

Selected Ecam, Age Two Years

E. camalduensis, Age three years

E. urograndis south Florida

Coppice 3 months

EH1 at age 12 months

E. urograndis South Florida

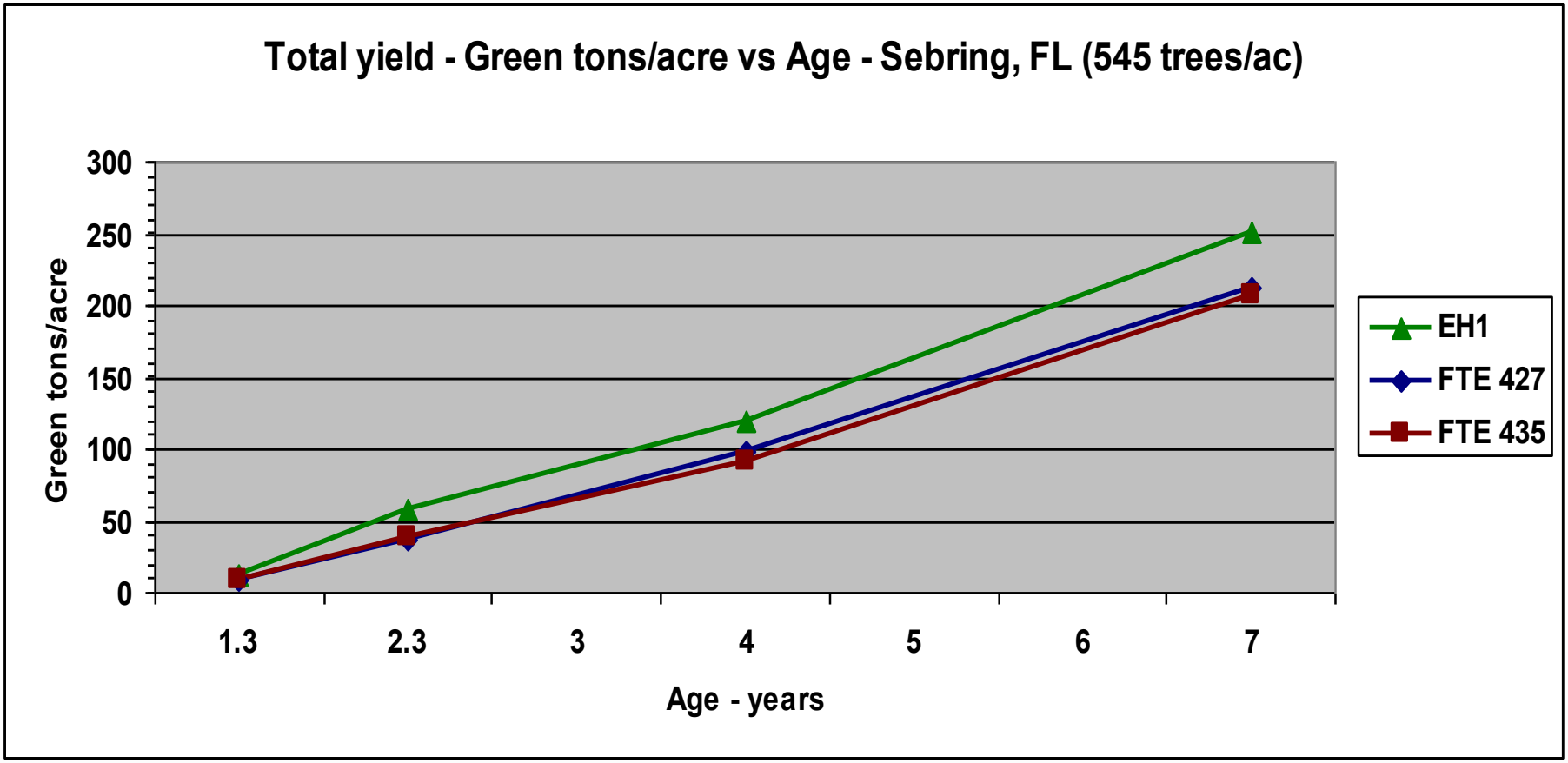
Age 12 months

Age 4 months

EH1 Sebring Florida. Age Four Years.

14 dry short tons/acre/year

Total Yield Sebring FL



Bio-energy Analysis

Field Crew – Brute Force

Lab Crew – Intelligent Force

Eucalypt potential for cellulosic ethanol

Gonzalez R, Treasure T, Jameel H, Saloni D, Phillips R, Abt R, and Wright J. Converting Eucalyptus Biomass Into Ethanol: Financial And Sensitivity Analysis In A Co-Current Dilute Acid Process. Part II. Biomass and Bioenergy 2010.

Eucalypts for solid bio-energy production

Bio-energy such as wood pellets and briquettes can be effectively manufactured from Eucalyptus

PIRRAGLIA, ADRIAN; GONZALEZ, RONALDS; DENIG, JOSEPH; SALONI, DANIEL and WRIGHT, JEFF (2012).Assessment of the most adequate pre-treatments and woody biomass sources intended for direct co-firing in the US. BioResources 7(4)4817-4842.

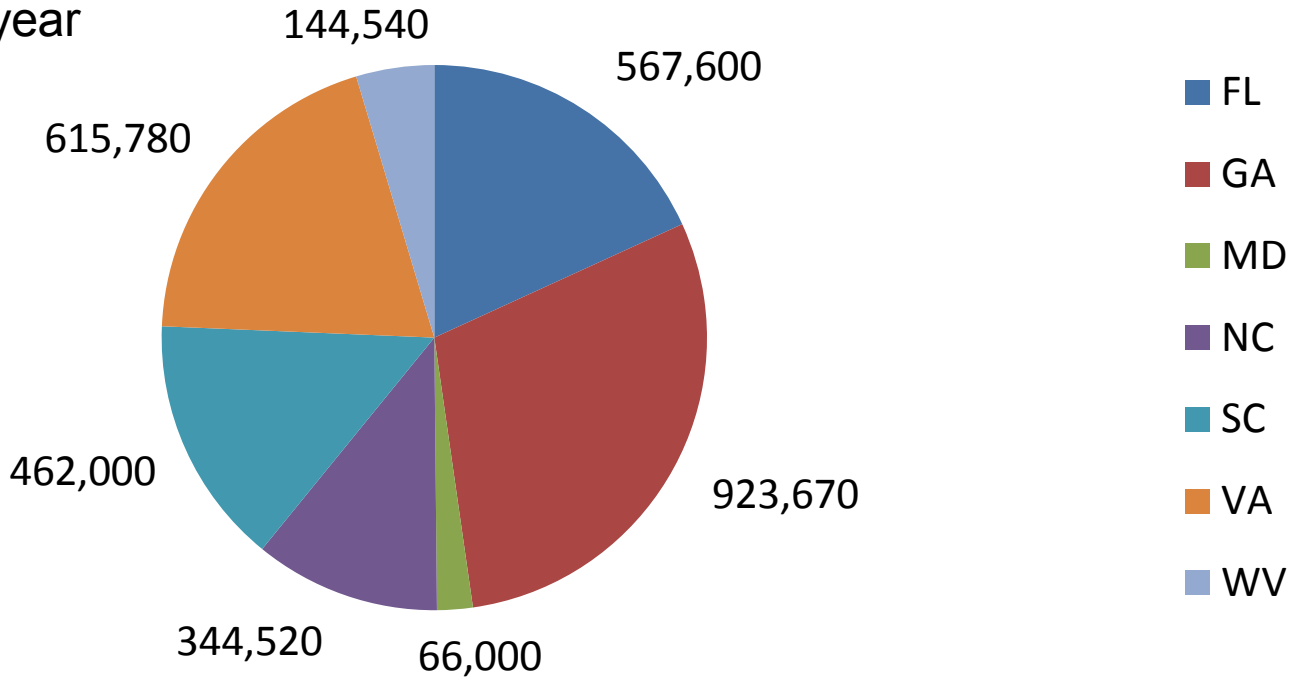
PIRRAGLIA, ADRIAN; GONZALEZ, RONALDS; SALONI, DANIEL; WRIGHT, JEFF and DENIG, JOSEPH. (2011). Fuel properties and suitability of *Eucalyptus benthamii* and *Eucalyptus macarthurii* for torrefied wood and pellets. BioResources 7(1):217-235.

PIRRAGLIA, ADRIAN; GONZALEZ, RONALDS; SALONI, DANIEL and WRIGHT, JEFF. (2010). Wood pellets: An expanding market opportunity. Biomass Magazine 6:68-75.

Wood Pellets: NCSU Dr. Daniel Saloni July 2012

Current Production by State (Tons/year)

Total
3,124,110 tons/year



Georgia is the largest producer with second fewest pellet plants

Global Pellet Production and Demand
(millions metric tonnes)

	Demand		Production	
	2010	2020	2010	2020
• EU	10.8	23.8	7.7	13.0
• China	0.6	10.0	0.6	10.0
• Japan/Korea	0.2	5.5	0.1	1.1
• North America	3.4	5.6	4.9	11.0
• Total	15.0	44.9	13.3	35.1

- (Pellet Mill Magazine, Fall 2011)

Drax Wood Pellet Investments

- Amite BioEnergy in Mississippi
- Morehouse BioEnergy in Louisiana

- Port facility Baton Rouge

- Total pellet production 900,000 tons/year
- Wood demand 1,800,000 green tons/year

Woody Biomass Harvest and Transport

Led Zeppelin
1971

Stem Size Matters

Eucalypt Bio-energy Harvest

Plantation age 18 months

Harvesting Systems – Whole Tree Biomass

Bales at roadside $9.25/green ton

Whole tree chips at roadside $10.42/green ton

D. Mitchell, USFS, October 2012

Range of Returns for Eucalypt Plantations (1)

Rotation	Origin	Cost/acre ($)	Harvest Age (green tons/acre)	Stumpage Prices @ return rate 6%	10%
1st	Seedlings	525	89	9.02	11.44
2nd	Coppice	215	102	3.42	4.24
3rd	Coppice	215	88	3.86	4.80

- (1) Dougherty, Derek and Wright, Jeff (2012). Silviculture and economic evaluation of eucalypt plantations in the southern US. BioResources 7(2):1994-2001.

US South Delivered Wood Fuel Prices

- Wood fuel defined as by product of pulpwood chipping
- Price in Q4 2012 was $19.36/delivered green ton (1)
- Plantation growing cost (stumpage) $4-10/green ton
- Cut, chip, haul cost $14-18/green ton
- Total $18-28/delivered green ton

- (1) Source: Forest2Market December 2012

- —It's all very well having these slightly detached, bourgeois views, but we have to deal with the practicalities. It is my principal responsibility to keep the lights on and if the lights go off, it's no good me saying 'I was for the right reasons'. Biofuels are part of an energy mix that is going to keep the lights on."

- John Hayes, UK Energy Minister
- 8 March 2013