Renewable Energy Systems and Sustainability Conference

Fast Growing Trees for Bioenergy

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Florida FGT, LLC

Eucalyptus and Cottonwood

E. grandis Applications & Genetic Resources

Multiple Applications

- Energywood uses in FL have been demonstrated and are planned, e. g., a 60MW biomass plant in Ft. Meade, in addition to three other generating facilities, including *Eucalyptus* as energy feedstock.
- *S*uitable feedstock for cofiring in coal–fired power plants or energy generation at pulp mills in FL.
- Commercial markets for landscape mulch. Demand likely to increase as cypress availability decreases.
- Other current uses include fence posts, lumber, potting soil (peat moss substitute), phytoremediation, and windbreak applications.

E. grandis Cultivars

- Severe freezes of the 1980s led to selection of fast growing, freeze resilient *E. grandis* clones.
- Based on 18 tests on various site/soil types, five *E. nergy* series *E. grandis* cultivars (G1, G2, G3, G4, G5) selected for fast growth, excellent stem form, broad site tolerance, coppicing ability, freeze resilience, and ease of propagation (Rockwood, 2012).
- G1 is no longer commercially viable due to its susceptibility to blue gum chalcid (*Leptocybe invasa*).

Woody Biomass Production Opportunities

Phosphate Mined Clay Settling Areas (CSAs)

- ~64,700 ha of undeveloped CSAs in central FL (Segrest, 2003).
- Potential land base of over 80,000 ha for SRWC production on CSAs and overburden sites in phosphate mined areas in C. FL (Rockwood et al., 2006).

Former Citrus Lands – Citrus Greening (HLB)

Organization

Study Designs

Data Analysis: Yield Predictions

Optimization Model

Yield Curves & MAI Estimates

Financial Results

Discussion & Management Implications

CSA Cultivar Test @ 15 months

Demonstration Trials

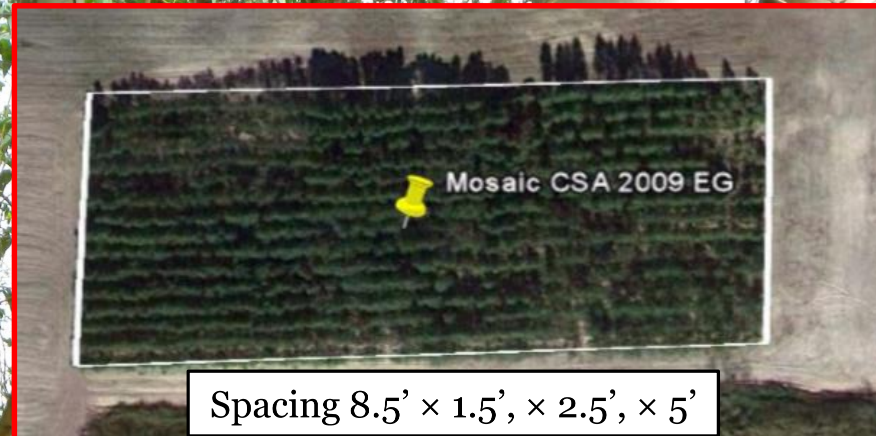
CSA Study Site

Planted September 2009

3 Densities: 1025, 2050, and 3416 TPA

3 Cultivars: G1, G2, and G3

"Operational" silvicultural intensity & no fertilization



Spacing 8.5' × 1.5', × 2.5', × 5'

Bedded Citrus Site

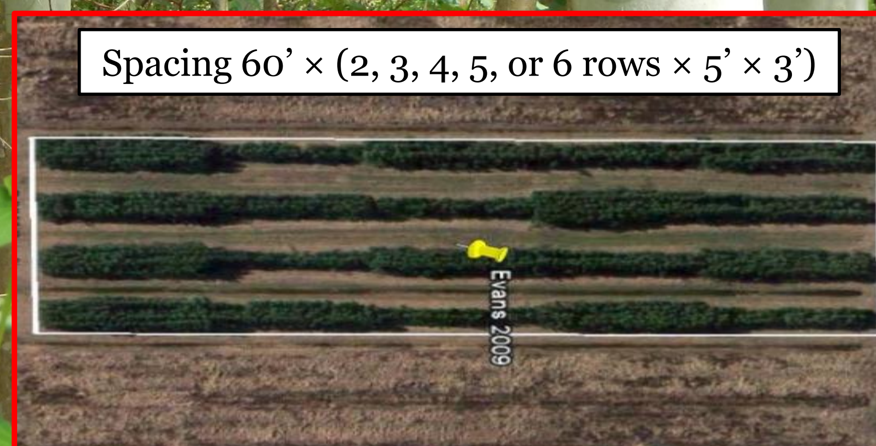
Planted July 2009

5 Densities: 581, 869, 1162, 1452, and 1742 TPA

4 Cultivars: G1, G2, G3, and G5

"Operational" silvicultural intensity, fertilized & unfertilized treatments (establishment only)

Spacing 60' × (2, 3, 4, 5, or 6 rows × 5' × 3')



Summary of Model Scenarios

Activity	Timing	Values
Former Citrus Site		
Land Preparation	One – time start – up cost	$400 and $500/acre
Chemical Site Preparation	Beginning of each cycle	$90 and $120/acre
Planting Costs	Beginning of each cycle	$0.25 and $0.40/tree
Planting Densities	N/A	581, 869, 1162, 1452, & 1742 TPA
Phosphate Mined Clay Settling Area		
Land Preparation	One – time start – up cost	$125 and $250/acre
Bedding	Beginning of each cycle	$50/acre (same)
Planting Cost	Beginning of each cycle	$0.10 and $0.25/tree
Planting Densities	N/A	1025, 2050, & 3416 TPA
Former Citrus Site & Clay Settling Area		
Fertilization	Beginning of each cycle	$55 and $70/acre
Weed Control	Beginning of each stage	$55/acre (same)
Planting Material	Beginning of each cycle	$0.55 and $0.70/propagule
Real Discount Rates	N/A	6%, 8%, and 10%
Stumpage Prices	N/A	$9, $14, and $19/green ton
Coppice Yields	Duration of each stage	Expected and Improved
Number of Stages	N/A	5 Stages Maximum

Cultivar MAI by TPA: CSA Study Site

Cultivar	TPA	MAI (GT/acre/year)	Rotation Age (yrs)
G1	3416	9.2	3.1
	2050	10.4	2.6
	1025	10.1	4.1
G2	3416	16.4	2.8
	2050	27.0	6.4
	1025	25.0	4.2
G3	3416	17.3	3.4
	2050	34.9	4.2
	1025	25.9	4.3

Financial Performance on Phosphate Mined CSAs

Cultivar G3 @ 1025 TPA, expected coppice yields, and high management costs

Stumpage Price ($/GT)	Real Discount Rate	LEV ($/acre)	Harvest Ages
9	6%	301	4.7, 4.7, 4.7, 4.6
	8%	-69	4.6, 4.6, 4.7, 4.7, 4.4
	10%	-292	4.5, 4.6, 4.6, 4.7, 4.7
14	6%	1824	4.6, 4.5, 4.4
	8%	1027	4.5, 4.5, 4.5
	10%	561	4.5, 4.5, 4.5, 4.3
19	6%	3443	4.5, 4.5, 4.3
	8%	2215	4.5, 4.4, 4.3
	10%	1472	4.4, 4.4, 4.3

Cultivar MAI by TPA: Bedded Citrus Site

Most productive cultivar × spacing scenarios

Planting Density (TPA)	Cultivar	MAI_{max} (GT/ac/yr)	Rotation Age (years)
581	G3	24.2	4.3
869	G2	20.1	5.0
1162	G2	31.3	3.5
1452	G5	26.1	5.0
1742	G2	33.6	3.8

Average MAI_{max} and biological rotation age for each planting density.

Planting Density (TPA)	MAI_{max} (GT/ac/yr)	Rotation Age (years)
581	12.8	3.8
869	14.0	4.1
1162	22.4	4.1
1452	22.5	4.0
1742	30.9	4.7

Financial Performance on Former Citrus Lands

Most profitable scenarios under high management costs and expected coppice yields

Stumpage Price ($/GT)	Real Discount Rate	Cultivar	Planting Density (TPA)	LEV ($/acre)	Harvest Ages (years)
9	6%	G3	581	-146	4.9, 4.9, 4.8, 4.4
	8%			-422	4.7, 4.8, 4.8, 4.6
	10%			-596	4.6, 4.7, 4.7, 4.7
14	6%	G3	581	1309	4.7, 4.6, 4.3
	8%			627	4.6, 4.5, 4.4
	10%			214	4.5, 4.5, 4.4
19	6%	G2	1162	3043	3.9, 3.8, 3.6
	8%			1800	3.8, 3.8, 3.7
	10%	G3	581	1071	4.4, 4.4, 4.1

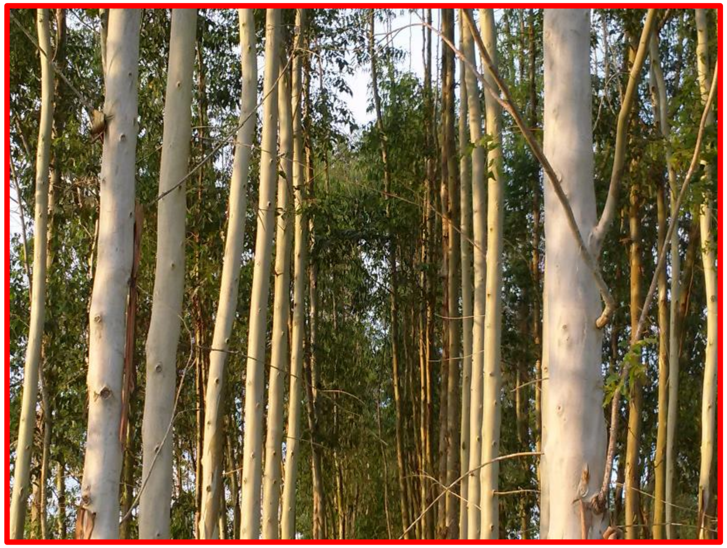
Discussion & Management Implications

Sensitivity Analysis

- Discount rate had little effect on optimum stage lengths. Stage lengths slightly decreased with higher stumpage prices and discount rates.
- Additional growth stages observed at higher discount rates and lower stumpage prices (delay the cost of replanting).
- In general, cycle lengths are shortened at lower discount rates and higher stumpage prices.

Cultivar × Spacing Treatment

- G3 outperformed G2 at the CSA study and is recommended at 1025 trees/acre for mulchwood or energywood production.
- Break–even prices exceed $24/GT at 3416 TPA.
- At the citrus site, G3 at 581 TPA generated higher LEVs under high management costs and low stumpage prices, while G2 at 1162 TPA obtained higher LEVs with low management costs and/or high stumpage prices.
- Planting position on a citrus bed may explain the low productivity of double–row configuration (less plant–available water and low nutrient concentrations).



Slow heating of biomass

Temperature	Solid Phase	Gas Phase
<200ºC	Drying	H_2O
230ºC-250ºC	Retification	Acetic acid, MeOH
250ºC-280ºC	Torrefaction	Extractives
300ºC-500ºC	Devolatilization	Organics, H_2O, gas
>500ºC	Carbonization	Tars, H_2O, gas

Biomass Pyrolysis Processes

	Char	Liquid	Gas
CARBONISATION low temperature long residence time	35%	30%	35%
FAST PYROLYSIS moderate temperature short residence time	12%	75%	13%
GASIFICATION high temperature long residence time	10%	5%	85%

Charcoal Yields

Charcoal yields depend on feeedstock and on process conditions:

- Cellulose, hemicellulose, lignin and ash content
- Pyrolysis temperature
- Process pressure
- Vapor residence time
- Particle size
- Heating rate
- Heat integration (biomass burn off).

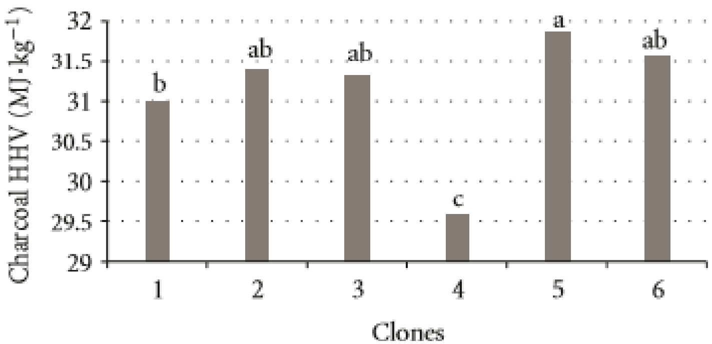


FIGURE 5: Mean values of charcoal higher heating value (HHV) of *Eucalyptus* spp., in $MJ\cdot kg^{-1}$. Standard deviation = 0.80; variation coefficient = 2.6%. Means followed by same letter do not differ at 5% probability by Tukey test.

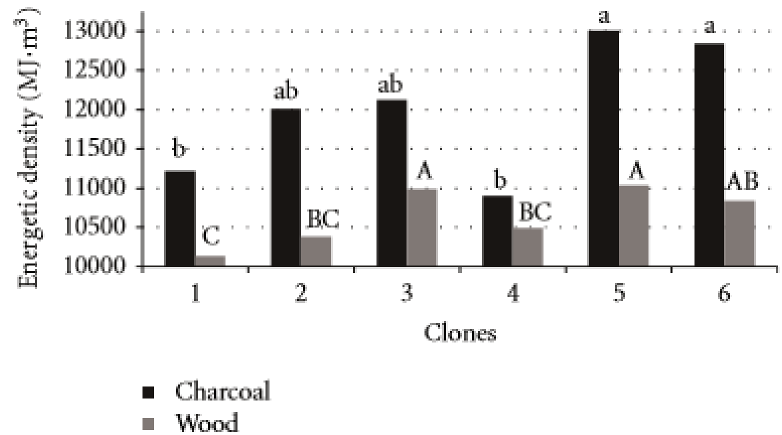


FIGURE 6: Energetic density of charcoal and wood, in $MJ\cdot m^{-3}$. Standard deviation = 865.66 (charcoal), 374.42 (wood); variation coefficient = 7.21% (charcoal), 3.52% (wood). Means followed by same letter do not differ at 5% probability by Tukey test.

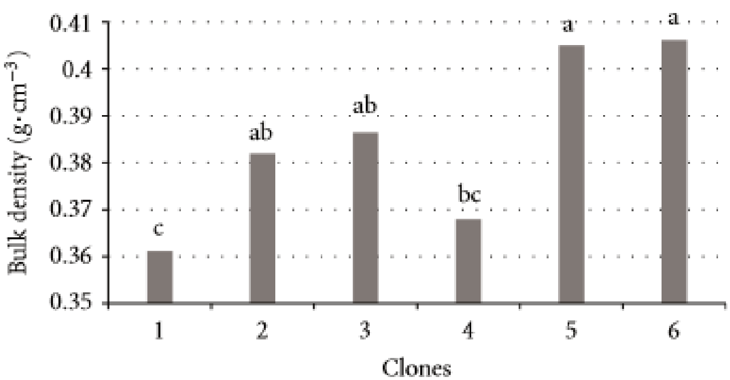


FIGURE 4: Mean values of charcoal bulk density of *Eucalyptus* spp., in $g\cdot cm^{-3}$. Standard deviation = 0.02; variation coefficient = 3.6%. Means followed by same letter do not differ at 5% probability by Tukey test.

TABLE 3: Mean values of charcoal fixed carbon, volatile matter, and ash contents, in percentage.

Clones	Fixed carbon	Volatile matter	Ash
1	72.93c	26.72a	0.35b
2	74.91ab	24.76bc	0.33b
3	73.86abc	25.79abc	0.35b
4	73.86abc	25.74abc	0.41b
5	73.56bc	26.08ab	0.36b
6	75.13a	24.23c	0.64a
Standard deviation	0.13	0.98	0.92
Variation coefficient (%)	18.5	2.2	0.8

Means in column followed by same letter do not differ at 5% probability by Tukey test.

Charcoal

Global charcoal consumption: ***45 Mton/year***

Africa 23 *Mton/year*

South America *17 Mton/year*

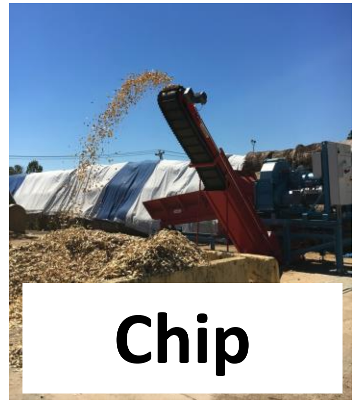
WEC 2007 Survey of Energy Resources FAOSTAT-Forestry

(Ethanol global production: ***60 Mton/year****)*

Cost of charcoal: $100- 400/ton
Applications: fuel, metallurgy, activated carbon

Emerging use as a soil amendment and a carbon sequestrating material.
5.5 Gton carbon released annually by combustion of fossil fuels can be offset by 7.5 Gton of charcoal used as soil amendment

Synthetic Green Diesel from Woody Biomass

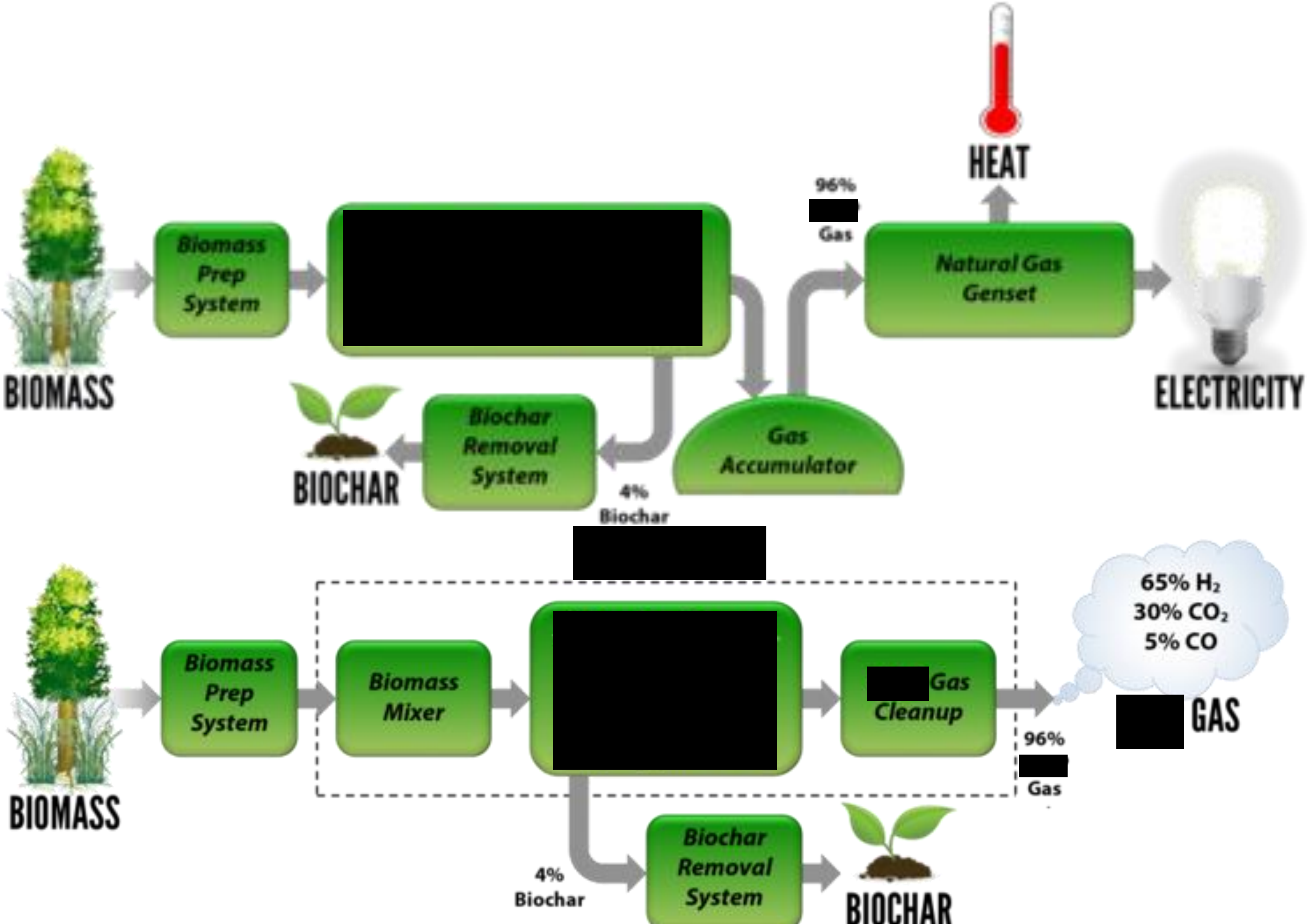


Convert: Modular repeating Pyrolysis/Gasification tubes

Distill: Low temp/low pressure

Direct conversion to ASTM D975 low sulfur diesel with NO Catalyst!

- **At Scale since 2013**
- **Emissions a small fraction of Minor Source limits**
- **Modular design**
- **Operational commercial fuel module (8 tubes per fuel module)**
- **Operational at scale, over 90% uptime since 2014**
- **Performance Guarantee 90 gallons per bone dry ton**
- **Performance insurance available through ENERGI**
- **EPC Wrap available from a Global EPC Firm**
- **Virtually all hardwood and softwood species acceptable**
- **10,000 acres should produce 5+ million gallons of diesel perpetually**
- **Direct sales and/or partnering opportunities, financing available**


BIOMASS
Biomass Prep System
[redacted]
96% [redacted] Gas
HEAT
Natural Gas Genset
ELECTRICITY
Gas Accumulator
Biochar Removal System
BIOCHAR
4% Biochar
[redacted]
BIOMASS
Biomass Prep System
Biomass Mixer
[redacted]
[redacted] Gas Cleanup
65% H_2
30% CO_2
5% CO
[redacted] GAS
96% [redacted] Gas
4% Biochar
Biochar Removal System
BIOCHAR

Florida FGT in association with
Sustainable Earth Partners
offers the technology on a global basis.

We are seeking opportunities!

- **All inquiries confidential,**
- **All parties must be registered**
- **FFGT and SEP protected by existing Sales and Representation Agreement**
- **NDA must be in place prior to receiving more information**

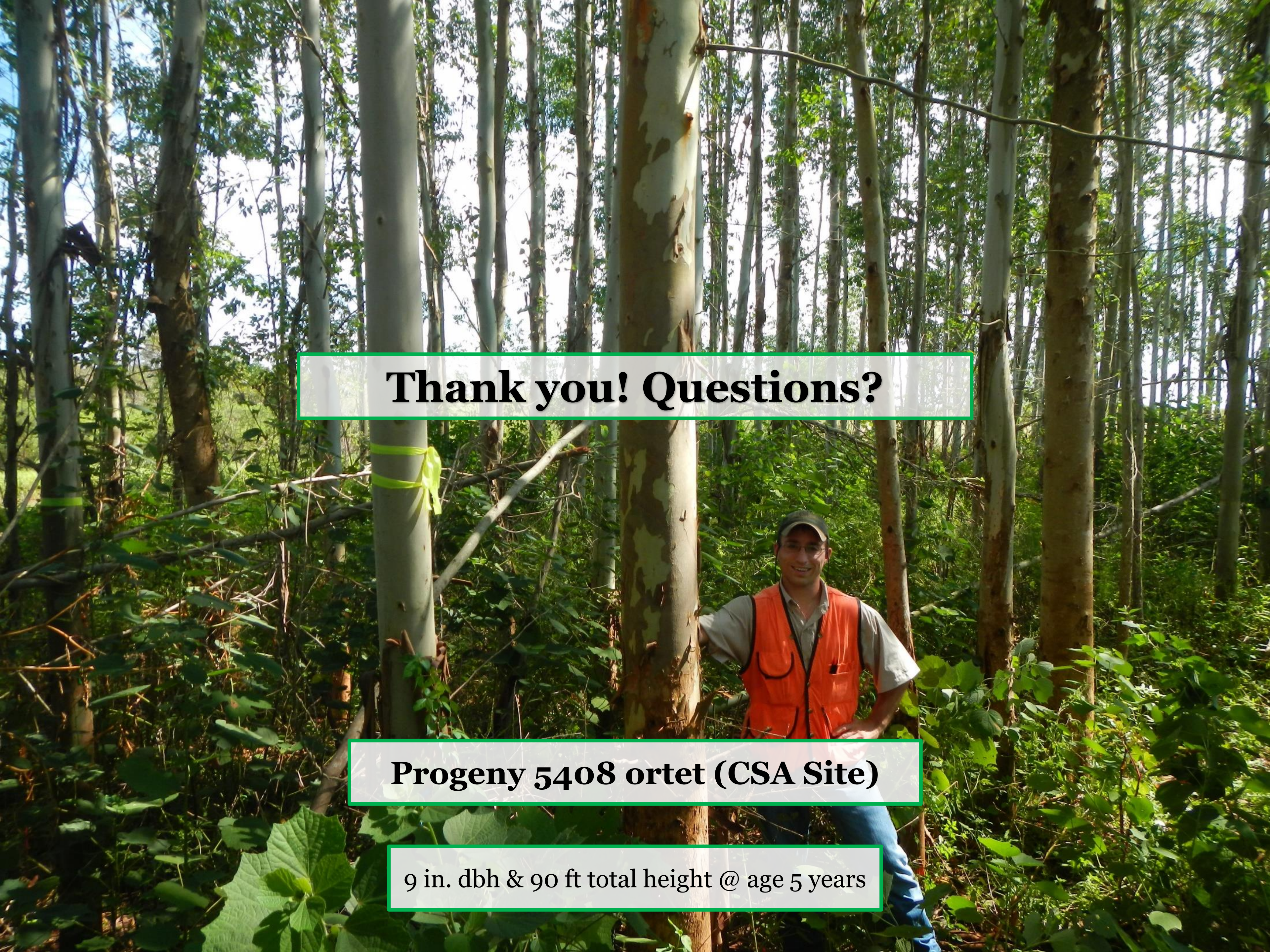
Please Contact Dr. Donald Rockwood at 352 256-3474

Fast growing trees such as eucalypts have a number of potential bioenergy applications.

Their productivity can be maximized as short rotation woody crops.

Many conversion technologies are well understood, and several are being developed.

Biomass characteristics, difficulty in securing adequate and cost effective supplies early in project development, and planning can be constraints.


Thank you! Questions?
Progeny 5408 ortet (CSA Site)
9 in. dbh & 90 ft total height @ age 5 years

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