



Renewable Energy from Sustainable Poplar Tree Farms

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The 23rd Session of the
International Poplar
Commission

Beijing, China
28 October, 2008





Presentation Outline

- GreenWood Resources (GWR) profile
- Drivers for renewable energy development
- Current GWR efforts in developing poplar bioenergy feedstock
- GWR opportunities for CHP in South America
- GWR opportunities for cellulosic ethanol in North America
- Conclusion



GreenWood Resources, Inc.

- Founded in 1998, GWR is a global leader in high-yield, short rotation, sustainable tree farms
- Operations in North America, China, South America-Chile
- Primary Business Groups
 - Tree Improvement and Nurseries
 - 5 nurseries in China
 - Imported and are testing more than 1500 clones in China
 - Resource Management
 - Manage 13,000 hectares in North America
 - Rapid development in bioenergy
 - Capital Management
 - US\$175 GreenWood Tree Farm Fund
 - US\$200 GreenWood China Forestry Company
- Where possible, certifying plantations to the Forest Stewardship Council (FSC) standard.

Poplar Bioenergy in Rural China





Drivers for Renewable Energy Development


- Energy Demand is Exceeding Supply
 - Global energy consumption will increase 50% by 2030
 - Global desire for a more “western” lifestyle
 - Geopolitical tensions increasing over energy
 - Fuels from “hell” decreasing – oil, coal, natural gas
- Global Climate Change
 - Now recognized as a crisis
 - Move to carbon neutral renewable sources of energy
- Biofuels and Clean Energy Technologies are a Growth Area in a Global Economic Slowdown
 - Fuels from “heaven” - Biomass, wind, solar, hydro
 - US Transportation fuels mandate - cellulosic's

Source: Hot, Flat, and Crowded by Thomas Friedman, 2008



Limitations of Corn Based Ethanol

- Important as a first generation biofuel - BUT
- Requires more herbicide and nitrogen fertilizer than other biofuels crops
- Corn ethanol can potentially provide only 5-10% of our transportation fuel needs
- Corn planting is increasing at the expense of other feed crops, resulting in rising commodity prices
- Producing corn ethanol results in a small net energy gain



Bio-Fuels Energy Balance: energy output versus energy input

- Corn Ethanol – 1.3
 - 3000-4000 liters of ethanol per hectare
- Soybean Biodiesel – 2.5
 - 600 liters of biodiesel per hectare
- Sugar Cane Ethanol – 8.0
 - 8000-10000 liters of ethanol per hectare
- Poplar Cellulosic Ethanol – 12.0
 - 12000+ liters of ethanol per hectare

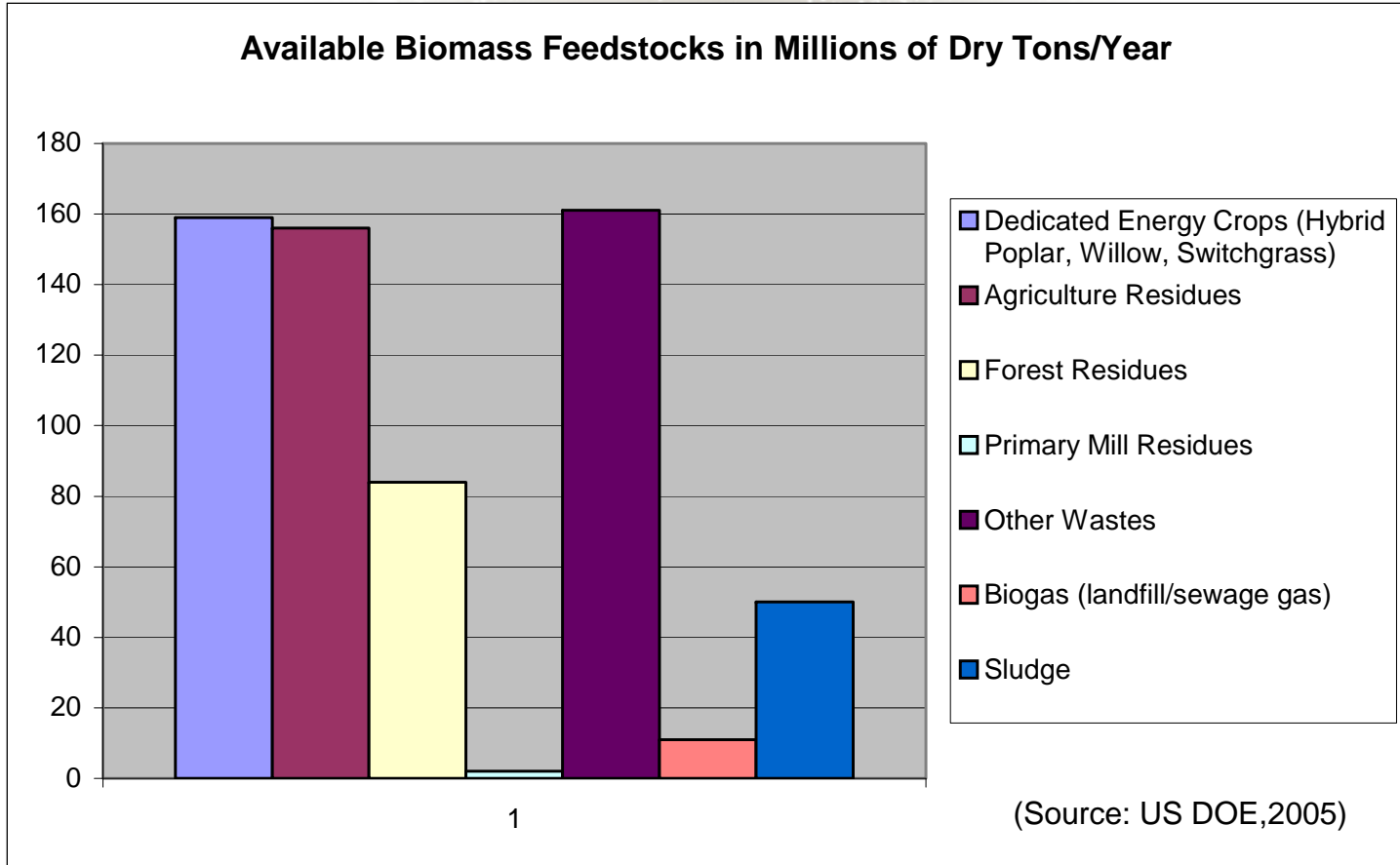
Source: National Geographic Magazine, 2007



Why Cellulosic Feedstock?

- Grown with less water and fertilizer
- Produce up to 3 times the biomass per acre
- Less intensive than annual crops
- Can not get to biofuels goals with corn and grain feedstock alone
- Superior energy budget

Dedicated Crops Drive Growth



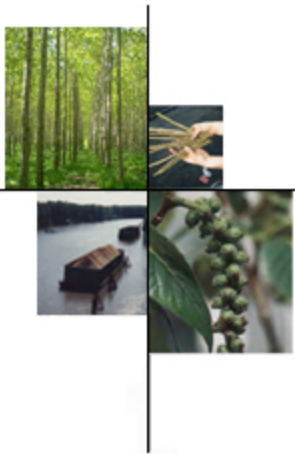


GreenWood's Strategy: Two Pathways

- Strategic Objective: Promote poplar from dedicated energy tree farms as the feedstock of choice for CHP and cellulosic ethanol
 1. Production Systems
 - Adapting Silvicultural techniques to multiple coppice cycle rotations – density, cultural treatments, cycle length
 - Equipment automation – planting, cultivation, and harvesting
 2. Feedstock Quality
 - Utilizing poplar genomics to drive breeding
 - Screening for high wood density, favorable wood chemistry for ethanol conversion

Production Systems

- Biomass Yield:
 - GWR has the largest poplar breeding program in North America and access to material from all over the world
- Silvicultural activities to maximize productivity:
 - Sustainable coppice rotation (2-5 years), fertilizer, weed control, pest control, irrigation
 - Developing systems for US and SA locations
- Harvesting and processing energy crops:
 - Cooperating in the development of combine-like harvesters



Improving Production Economics: Farming Strategy



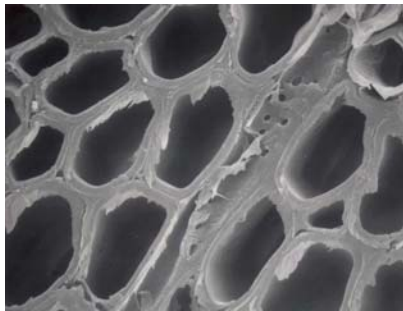
Silviculture - High-density plantings of 5-6,000 stems per hectare managed on 2 to 5-year coppice rotations



Harvesting and Processing - Combine-like harvesters operating to fell, shred, and load feedstock

Feedstock Quality

- Wood Chemistry and Conversion:
 - Gene association studies to identify genes controlling cellulose and lignin biosynthesis and use this to guide hybridization
 - Use the information to breed a new generation of energy cultivars for high yield and ease of conversion
- Adaptability to Sites of Marginal Agronomic Quality
 - Pest and disease tolerance
 - Drought and salt tolerance



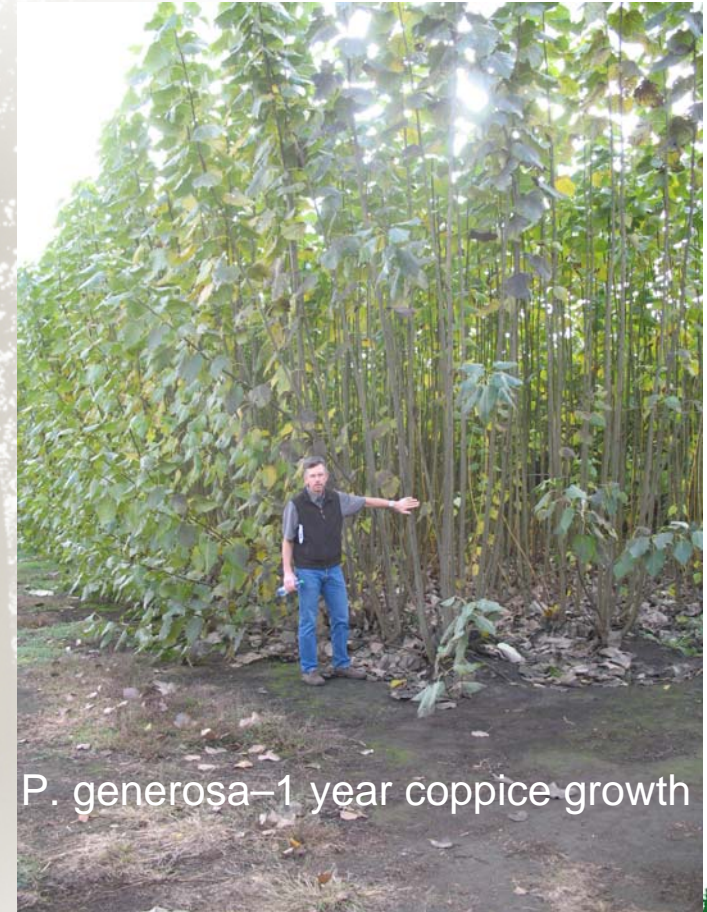
Advantages of Poplar Biomass for Energy & Liquid Fuels



1. Rich knowledge base in breeding and Silviculture
2. Known yield, logistics and economics
3. Stored on the stump
4. Superior energy budgets and environmental benefits
5. Wider site adaptability-marginal farmland
6. Perennial crop
7. Integrates well with cellulosic conversion processes

GWR South America: Los Angeles, Chile

- Main activity is in biomass for Combined Heat and Power (CHP)
- Result of constrained natural gas supply
- Concept is to develop small 10-20 MW power plants fueled by poplar biomass
- Organizing an investment fund for SA



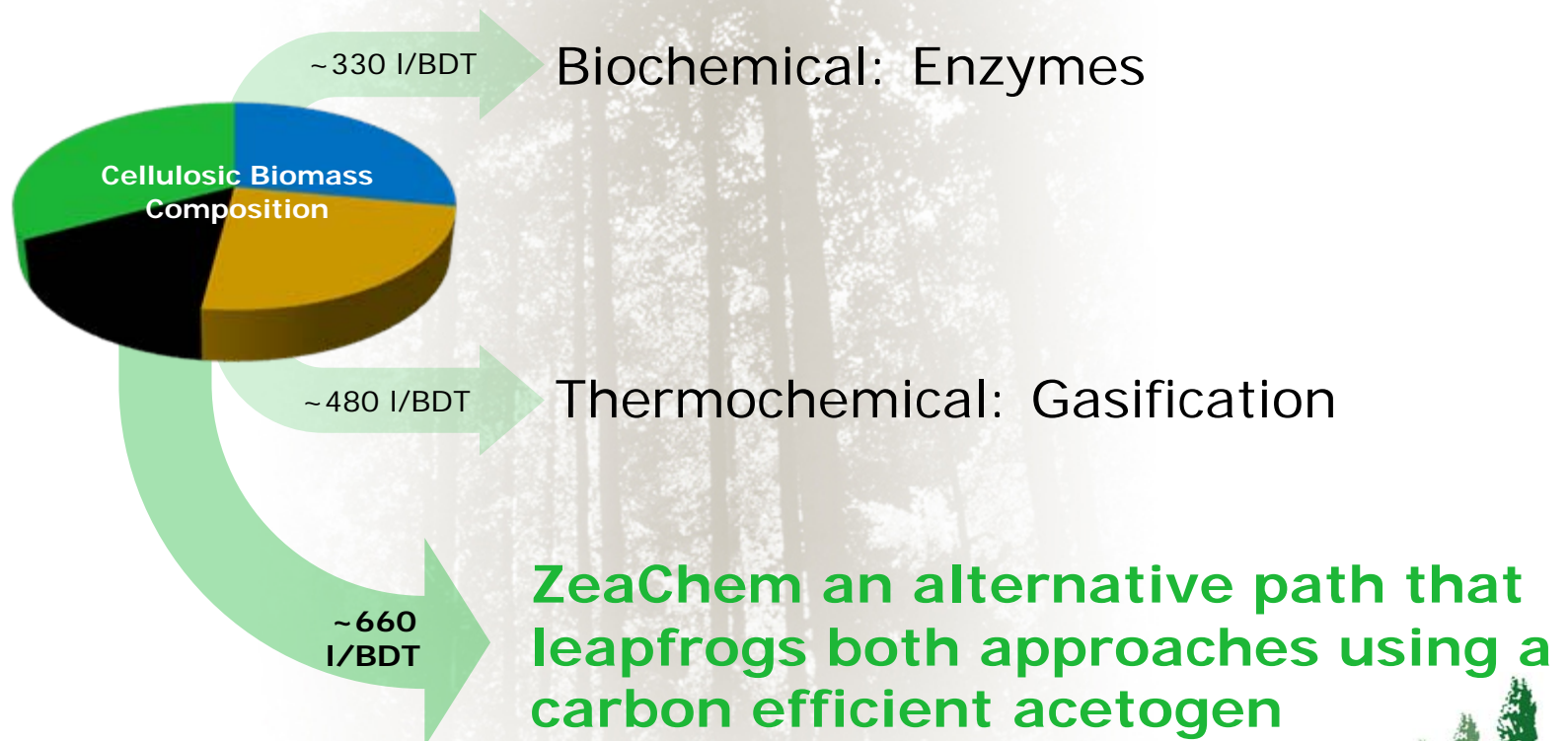
GWR South America: Bioenergy Trials in Chile

- Trials established from North to South
- Irrigated and non irrigated, upland and valley bottom sites
- Productivity as high as 30-40 bdt per hectare per year
- Aligning with a technology partner



Poplar Cellulosic Ethanol: ZeaChem (www.zeachem.com)

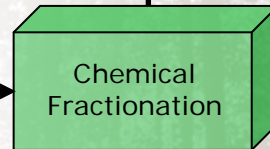
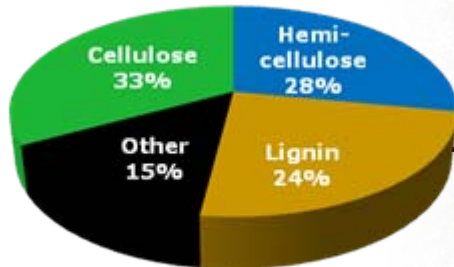
- Market currently views only viable options as either enzyme or gasification based



ZeaChem Process

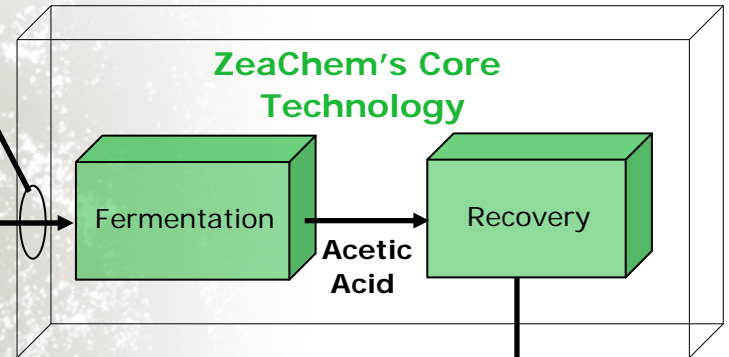
- Use an acetogen rather than yeast for fermentation for C5 & C6 sugars
- Fermentation is nearly 100% carbon efficient & No CO₂
- Produce an acetate intermediate rather than ethanol
- Hydrogen used to hydrogenate the acetate to produce ethanol or other chemicals

Cellulosic Biomass Composition

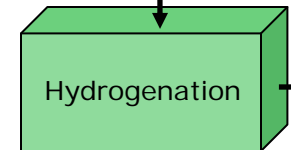


C5 & C6 Sugars

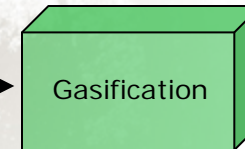
Carbohydrates



Ethyl Acetate



Residue



Hydrogen

Ethanol

NEV = 12

Yield = 660 l/BDT (Highest Theoretical Efficiency)

GWR Next Steps with Poplar Cellulosic Ethanol

- 2009 - ZeaChem to construct a pilot plant in OR to use 20,000 bdt of poplar residuals and produce 8 million liters per year
- 2011 – ZeaChem to construct first production scale facility that's 10 times the annual capacity
- Beyond – Pacific Ethanol, ZeaChem nth facility, China ??????

Conclusion

- GWR is well positioned to commercialize poplar tree farms for renewable energy
 - Global leader in developing elite *Populus* germplasm
 - Optimizing production systems for biomass energy feedstock
 - Access and organize capital
 - Key relationships with technology partners