Potential for Fast-Growth Poplar Plantations for Cellulosic Ethanol Production – A Life Cycle Approach

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Outline

- Policy and context
- What are the questions?
- Modeling energy production systems
- Biomass production
- Biofuels conversion
- Challenges
- Preliminary results

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Background

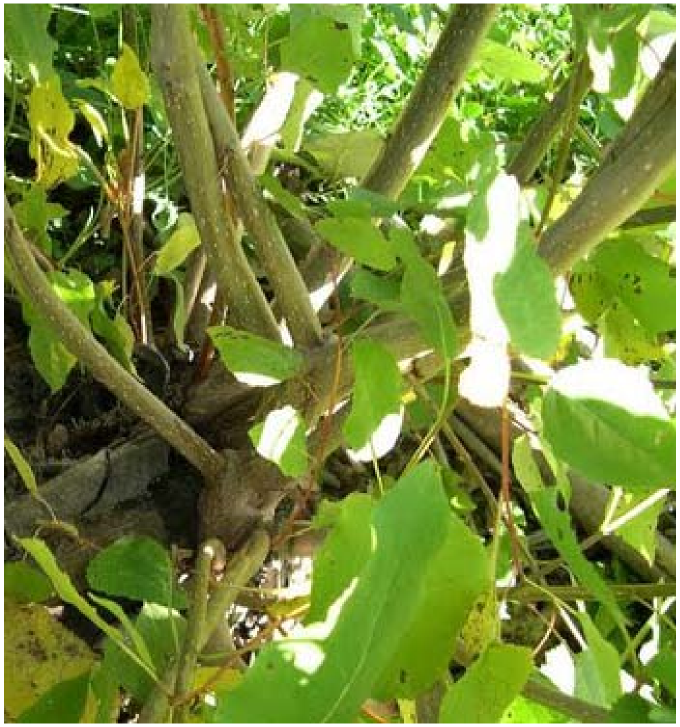
- Climate change mitigation → GHG emissions reductions → Displace fossil transportation fuels → Liquid fuels from wood
- Transportation fuels are the "ends, needs", and the landbase and energy are the "scarce resources"
- BC policies & law: carbon tax; 33% reduction in GHG emissions by 2020; 5% biofuels by 2010[1]
- BC demand: 850 mil. litres/yr biofuels in by 2025[2]
- BC resource: 17 mil. dry t/yr (4 mil. energy crops)[3,4]
- Large scale production capacity:
  - 20 – 100 mil gal EtOH/yr[5] (117 – 234 optimal[6])

Background (cont'd.)

- Corn ethanol and soybean biodiesel – transition to advanced biofuels
- Cellulosic biomass advantages:
  - avoids the food & feed vs. fuels debate
  - reclaimed from waste streams, residuals from current forestry operations
  - grown on idle or abandoned land
  - requires less fossil fuel, fertilizer, pesticides
  - can be used for heat & power at biorefinery, displacing even more fossil fuel power
- Still, it needs land, which is scarce…

State of Knowledge

- Main focus is on grain ethanol; mainly material and energy balances
- Important aspects seldom considered:
  - biomass carbon sequestration
  - land use change – emissions and carbon calculations (Calif. & EPA)
  - boundaries set for compliance/ regulatory purposes
  - water impacts
  - environmental dynamics
  - time and space



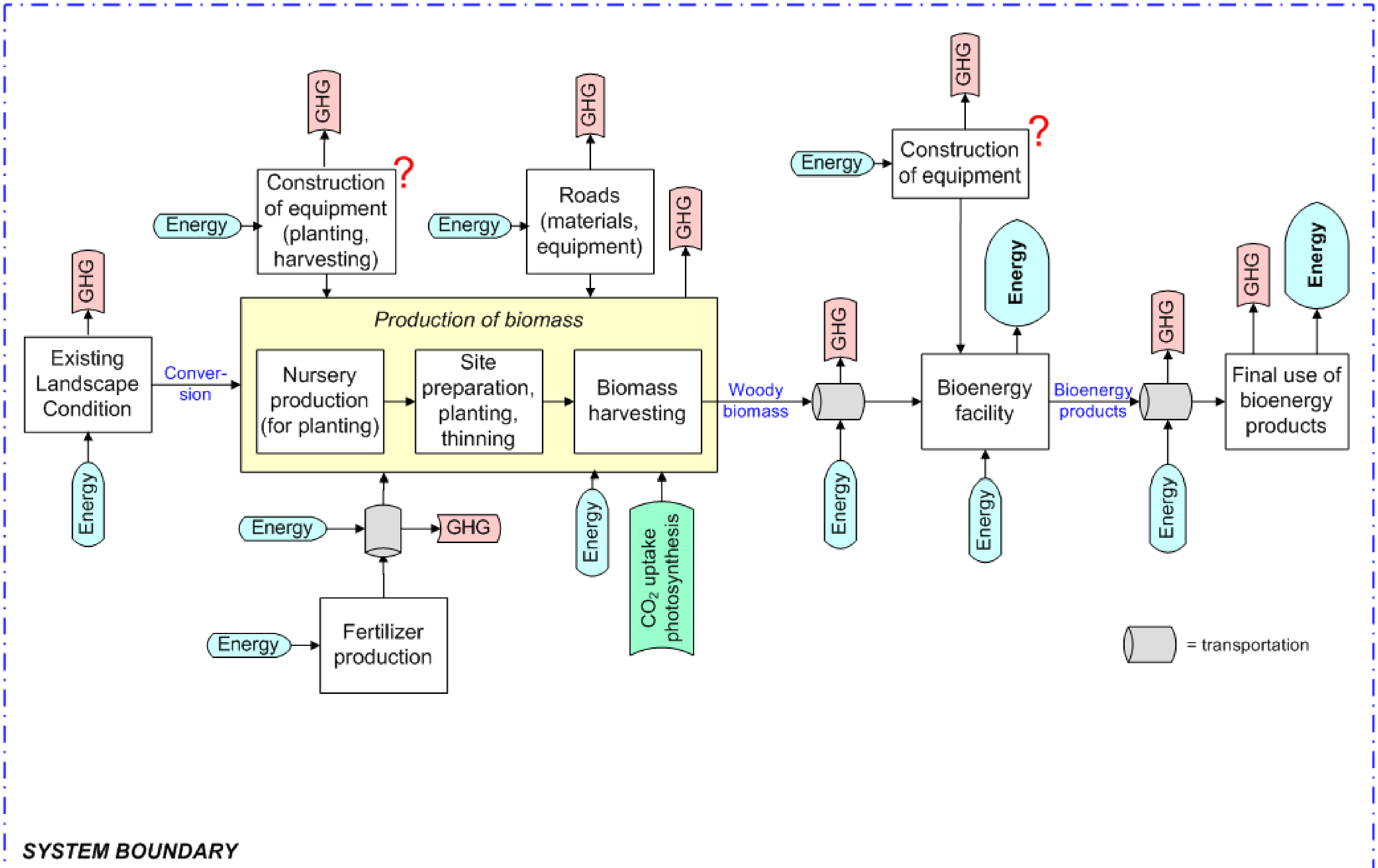
What are the questions?

- Conditions for economic feasibility of large-scale bioenergy production systems
- Suitability of poplar ethanol to substitute fossil fuels?
  (energy & carbon balance, costs)
- Landbase impacts of bioenergy:
  - GHG balances and mitigation costs
  - Scale of biomass production areas
  - Water use, energy use

Modeling energy production systems

- Our approach:
  - Project-level analysis: single biorefinery; associated plantations
  - Life cycle optimization model based on linear programming
    - with an embedded harvest scheduling model, Type II
  - Multi-objective: mill gate production costs, carbon benefits, energy use, CO_2-equivalent emissions
  - Entire life cycle: from initial landscape state to final end-use of biofuel

The Bioenergy Production System



Feedstock production & logistics

Biofuels production

Biofuels end use

Biomass production

- Short rotation forestry vs. short rotation coppice
  - soil carbon, soil nutrients, production costs, feedstock "quality" for various bioenergy products (CH&P vs. ethanol), GHG balances
  - Sustained yield (MAI) of improved hybrids culminating well after 7-8 years
  - Rotation age affects planting densities, management activities, harvesting methods
- Agricultural vs. forest lands – the BC context
  - 12-year max for ag. lands, tax breaks, activities protected through Farm Practices Prot. Act (clearing, irrigating, fertilizers, pesticides
  - Forest and Range Practices Act, SFM Criteria & Indicators
- Land suitability, environmental variables
- Growth & yield curves, by genotypes, sites, production method
- Carbon in above- and below-ground biomass pools
- Costs, emissions and energy use for all production activities

Preliminary results

Capacity		low		med		high	
Ethanol production	[mil. gal/yr]	20		100		250	
Conversion yield	[gal/BDT]	87	78	87	78	87	78
Feedstock diet	[BDT/day]	630	705	3,152	3,526	7,273	8,816
Biomass yield	[BDT/acre/yr]	9	4	9	4	9	4
Plantation area needed (100% dedicated)	[acres]	25,700	64,250	128,000	321,000	318,700	803,000

NAS (2009): capacity = 20-100 mil. gal/yr; yield = 67–78–87 gal/BDT
Huang (2009): optimal 117-234 mil. gal/yr; 88.2 gal/BDT
Estimated BC ethanol sales by 2025: upwards of 735 million litres/year (Globe 2007, StatsCan 2009)

Biofuels conversion

- Conversion technology
  - biochemical conversion, separate enzymatic hydrolysis and fermentation, dilute-acid pretreatment
- Biorefinery (none at commercial stage)
  - techno-economic analysis
    - ethanol yields
    - residual chemical yields
    - processing costs
    - energy consumption
    - carbon (equiv.) emissions
  - sensitivity analysis for ranges of inputs
- End-use: transport, energy, emissions, costs

US DoC 2007: to reduce ethanol production cost to 28 ¢/l* (from 70 ¢), need to improve:

o feedstock -- 30 $/ton (from $60)
o ethanol yield -- 340 l/dry ton(227)
o enzymes -- 1.3 ¢/l (from 10.6 ¢)

**DOE target*

Challenges

- Economies of scale for plantation land – additional feedstocks needed
- Potential for carbon offsets – accounting for carbon in all "pools" (live biomass, DOM, soil)
- Tracking GHGs through the life cycle
- Carbon and bioenergy standards – not mature, nor agreed upon
- Operations start-up: match feedstock growth w/ biorefinery construction
- Public attitudes on managed forest lands (SFM) and on large-scale plantations
- Possible integration with other streams (solid wood prod.) – however, residues for bioenergy are the least value in the chain

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Acknowledgements

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