Forest Biorefineries: Current Status & Outlook

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Outline

1. What is forest biorefinery?
2. Example
3. Why it is interesting?
4. What is the current state?
5. The long-term outlook
6. Implications to socio-economic research

What is forest biorefinery? Definitions:

1. A biorefinery is a facility that integrates biomass conversion processes and equipment to produce fuels, power, and value-added chemicals from biomass

   (*National Renewable Energy Laboratory, USA / www.nrel.gov/biomass/biorefinery + Wikipedia*)

2. Efficient use of the entire potential of raw materials and by streams of the forest-based sector towards a broad range of high added value products (by co-operation in and between chains)

   (EU Forest-Based Sector Technology Platform / Biorefinery Taskforce, April 17, 2007)

3. Full utilization of the incoming wood biomass for production of fibres, chemicals and energy

   (STFI-Packforsk, Sweden)

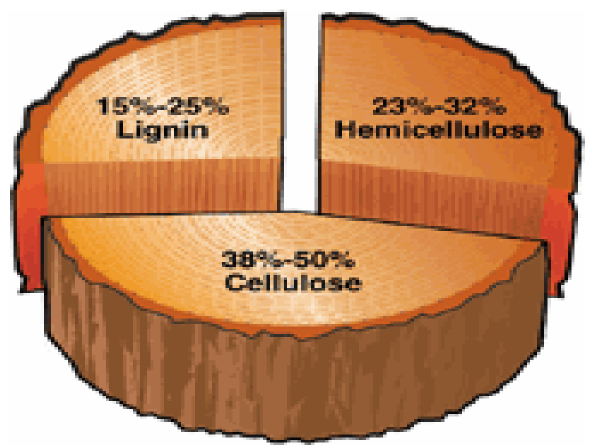
→ Better use and processing of raw-materials and waste streams to produce current and new products

Pulp

Paper

Roundwood, residues, stumps, branches, bark, etc.

black liquor



Biofuels

Chemicals

Heat

Power

chips, bark, sawdust

Lumber

- According to the definition, many forest industry plants are already today ”biorefineries”
- However, the term *forest biorefinery*, which came to more wider use only about 2005-2006, is specially linked to the introduction of following factors:

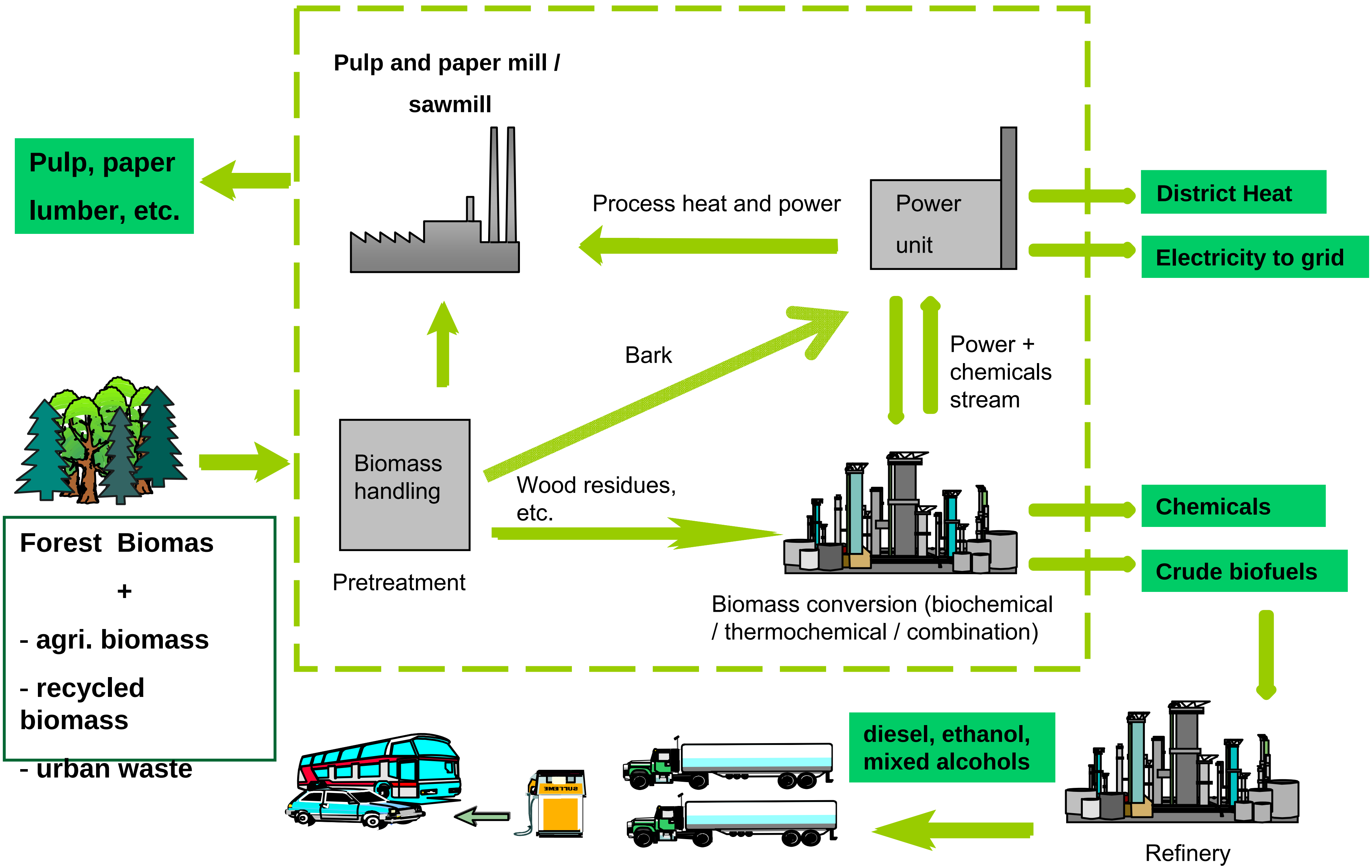
  1. New technology and production processes

  2. New products and business strategies

→ Thus, using the biorefinery concept, instead of pulp and paper mill or sawmill, helps to make the distinction with the current operations and seems to be justified

→ Biorefineries using forest biomass are not restricted to forest industry (power- and chemicals industries)

Integrated Forest Industry Biorefinery



Biorefinery biofuels and chemicals options include:

Biorefinery Product*	Target Market	Comment
FT Naphtha	Motor Gasoline	Upgradeable to gasoline blendstock or can be used as chemical feedstock, e.g., naphtha to olefins. Co-produced with FT distillate.
FT Distillate	Distillate (diesel) Fuel	High cetane, sulfur-free diesel blendstock. Main product of FT synthesis.
Ethanol	Motor Gasoline	Currently ~3.5% of U.S. gasoline market
Higher Alcohols	Ethanol or MTBE, existing alcohol markets	Mixed OHs can be sold as gasoline blendstock or components can be separated & sold into existing alcohol markets
Methanol	Methanol	Methanol as chemical intermediate (e.g., for olefins) is most promising market. Fuel use (MTBE) is in decline.
Dimethyl Ether (DME)	Diesel or LPG	Blendable with LPG to 20-25% with no infrastructure change. Diesel engine use requires fueling infrastructure changes (fleet potential first).
Hydrogen	Hydrogen	Market is growing, mainly for use in refineries (captive market)
Ammonia	Ammonia	Among the largest commodity chemicals (e.g., fertilizer)

* Not an exhaustive list. A wide range of chemicals can be produced from syngas, but their volumes are typically smaller than the fuels and chemicals listed here.

Slide source: Ryan Katofsky "The Thermochemical Biorefinery", Flordia Farm to Fuel Summit, July 2007, Navigant Consulting Inc.

Example: Processing lignin to electricity and heat in Sweden

LingoBoost, a subsidary company of STFI-Packfrosk

(jointly financed by STFI-Packforsk, Södra, Stora Enso, Fortum, Värme and the Swedish Energy Agency)

High quality lignin extracted from black liquor (kraft pulp mill)

→ Electricity + heat

→

Pellets directly from the pieces of a kraft lignin cake

→ Could also produce chemicals

Lingoboost demonstartion plant in operation since late 2006

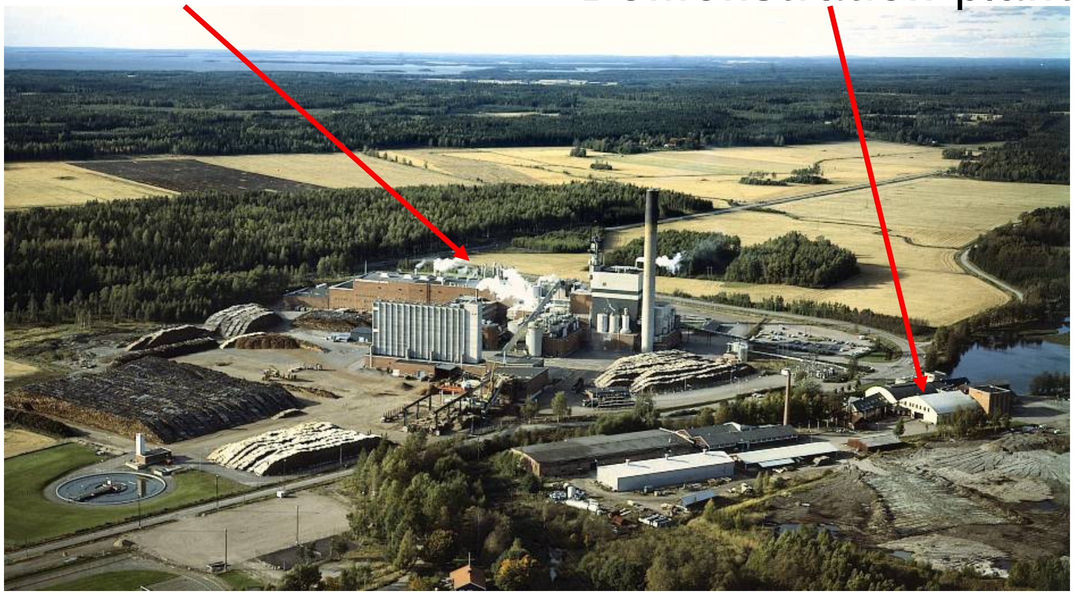
Wermland Paper,

Bäckhammar mill

LignoBoost

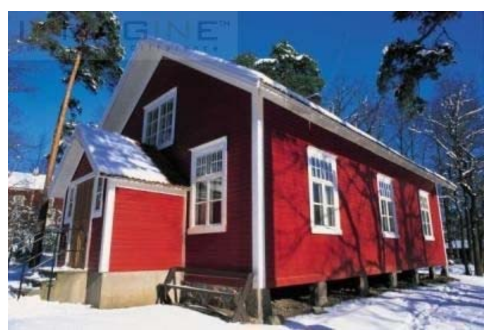
Demonstration plant

- market value appx. 150 €/ton



4000 t/a lignin by rail to Stockholm

Fortum power company



”Green” electricity and heating to 1 300 family houses in Stockholm

World Lignin Potential

Lignin in Different Black Liquors

kg/t pulp	Spruce	Birch	Eucalypt
Lignin	510	340	340

- World production of kraft pulp approx 100 million tonnes
- Assume 25 % lignin will be removed per ton of pulp; and an avergae of 400 kg lignin per ton of pulp → world total lignin potential would be 10 million tons
- Assume a lignin price of 150 €/t → world total would be 1.5 € billion
- *”A full-scale plant is expected to recover more than ten times the amount of lignin produced by the demonstration plant. A market study shows that there is a potential for full-scale operations in more than 100 pulp mills all over the world”* (LignoBoost, press release, 12 February 2007)

What makes forest biorefinery interesting?

- It has the potential to marry the interests of the *society*, *environment* and the *industry (forest sector)*

Society + environment:

- Jobs, taxes, rural communities, etc.
- Energy security
- Help to mitigate climate change

Industry + forest sector:

- New products and profitability boost for the industry
- Help to re-structure and re-innovate the struggling forest sector in countries such as Canada, Finland, Sweden, USA
- Image-factor. Something different from the ”sun-set industry” and ”smokestack” label often linked to the forest sector

  → *bioeconomy*, *innovative technology*, *carbon neutral*, etc.

What is the current state?

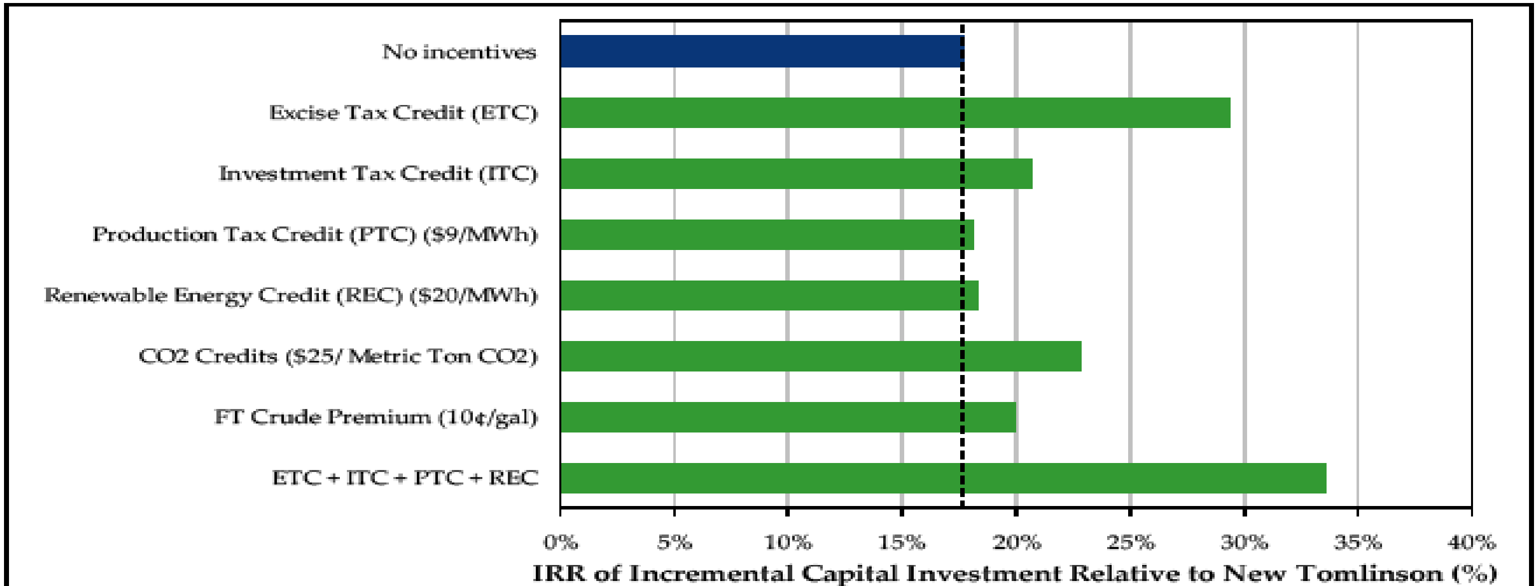
- Many serious forest biorefinery projects are in progress, e.g.:

  1. LignoBoost (Sweden); 2. Stora-Enso & Neste Oil (Finland); 3. UPM & Cargil (USA); 4. Weyerhauser & Chevron (USA); 5. Flambeau River Papers (USA); 6. Potlatch Corporation (USA)

- Intensive R&D, specially in North America and Scandinavia
- R&D so far very much technologically and company driven. Very little or no socio-economic research
- *Biochemical platform*: R&D breakthroughs needed to improve conversion and reduce costs
- *Thermochemical platform*: conversion technologies available today e.g. for FTL & DME – no major R&D breakthroughs needed
- Development is very much pulp and paper industry centered. Almost no discussion or R&D in *sawmill* sector. Serious shortcoming!

Biorefinery may provide good return on capital already today

Internal Rate of Return Analysis: FTc



- $330 million incremental capital investment
- $50/bbl Crude Oil Scenario (AEO '06 Reference Projection)
- Electricity sale price: 5.3 c/kWh (without incentives)
- Incentives examined:
  - Excise Tax Credit (ETC): Equivalent to existing $0.51/gal for ethanol on energy basis.
  - Investment Tax Credit (ITC): 20% gasification tax credit (under EPAct 2005).
  - Production Tax Credit (PTC): $9/MWh for 10 years (on incremental electricity relative to Tomlinson).
  - Renewable Energy Credit (REC): $20/MWh (e.g., under RPS or green credits). Applies only to incremental electricity.
  - CO_2 Credits: $25/tCO2 applied to net reductions (including grid offsets and petroleum displaced)
  - FT Crude Premium: $4.2/bbl for superior performance

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Source: Larson, E.D., Consonni, S., Katofsky, R.E., Iisa, K. & Frederick, J. (2006). A Cost-Benefit Assessment of Gasification-Based Biorefining in the Kraft Pulp and Paper Industry, Vol. 1., 21 December 2006, Princeton University.

Some cautionary observations

- Forest biorefinery interest and enthusiasm is of a very recent origin.
- Expectations are great and sometimes probably not very realistic.Typical feature, which may even be necessary to get the new ideas and projects moving on the agenda
- However, critical assessment of biorefinery are required at least for the following reasons:

1. Investments in biorefinery (e.g. pilot plants) that do not meet the expectations, may frighten away investors, and hence hinder the general development
2. Potential negative side impacts of biorefeineries (e.g. biodiveristy, crowding-out other activities) should be addressed, and taken care at the early stage – before they come serious problems
3. If the potentially problematic societial (genetechnology) and environmental impacts (forest biodiversity) are clealry addressed and pointed out, the credibility of biorefienries will be enhanced

The Outlook

The outlook for forest biorefineries depedns largely on the following factors:

1. Policy (bioenergy-, climate change- & rural policies)
2. Fossil fuel prices (oil)
3. Technology development (less costly biorefinery production processes)
4. Social-environmental (general attitudes to green energy and how the potential negative side impacts of biorefineries are overcome)

Policy (regulations) drives development

- No new markets need be created for biorefinery products. They have been created by political decisions even before production has been started up:

1. **Energy security**. Oil and gas production will be increasingly concentrated in a small number of countries, and government controlled companies (e.g. OPEC, Russia)
2. **Climate change mitigation policies**. Policies getting stricter → costs of fossil energy consumption increases
3. **Rural area policies** (EU, USA). Strong lobby groups for agricultural sector
4. **R&D policies** (EU Technology Platform; Agenda 2020)

- However, there may be conflicts between polices 1.-3.

Example: EU

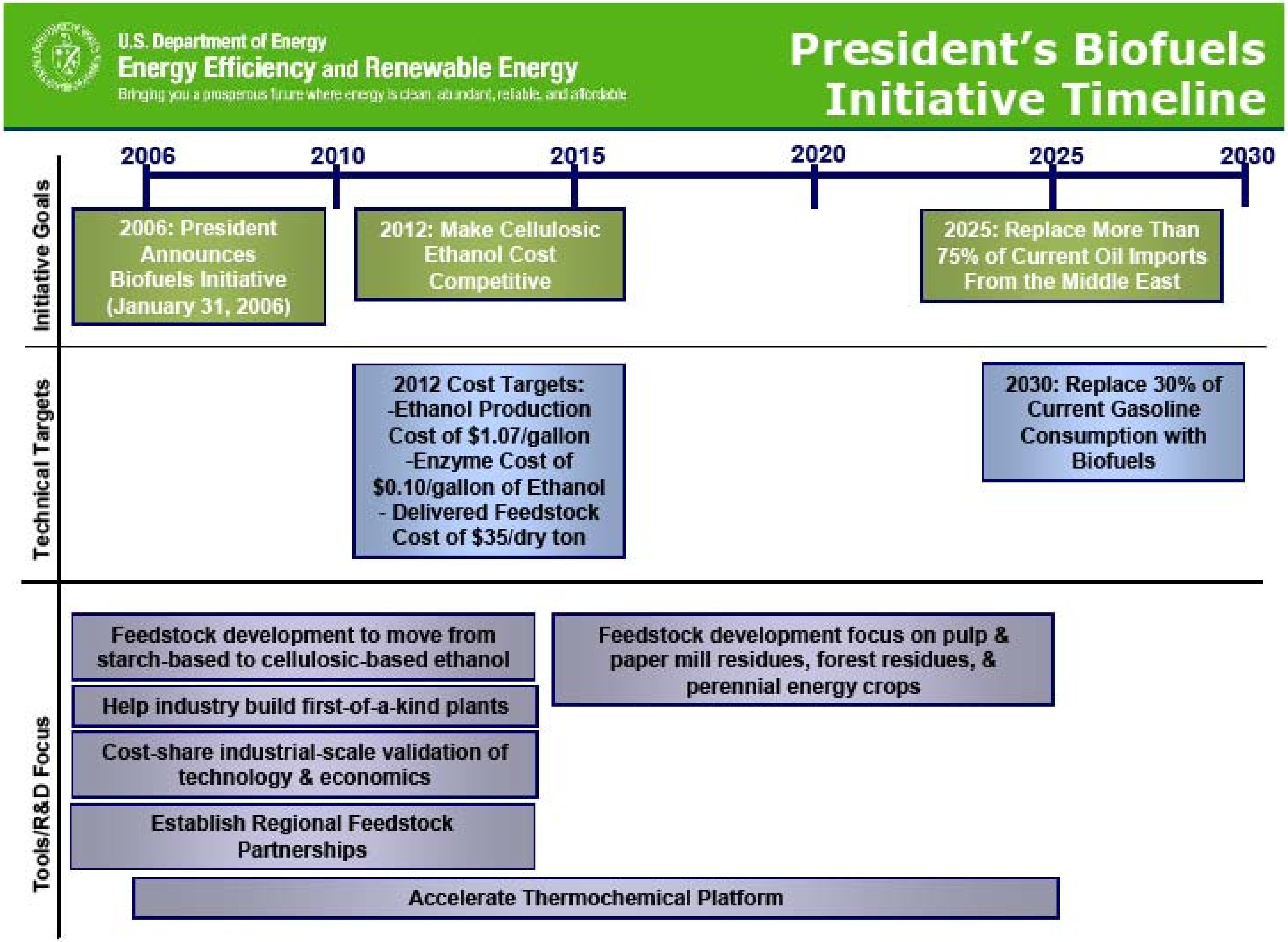
Agreed actions

- **Energy Policy:**
  - Energy efficiency: 20% improvement by 2020
  - Renewable energy: 20% mandatory objective by 2020
    - differentiation of targets between countries
    - flexibility in target setting within a country between sectors
  - Biofuels target of 10% by 2020
  - **Strategic Energy Technology Plan**
  - Internal market-options unbundling & regulatory powers:
    - Important for functioning EU ETS
    - Overcome hurdles for renewables
  - Sustainable power generation from fossil fuels: 12 large scale CCS demonstration plants by 2015; aiming at near-zero emissions by 2020
  - Nuclear: member states' choice
- **Climate Strategy:**
  - EU ETS (Review, aviation)
  - Other policies (e.g. fuel quality)
  - Global carbon market (incl. CDM)

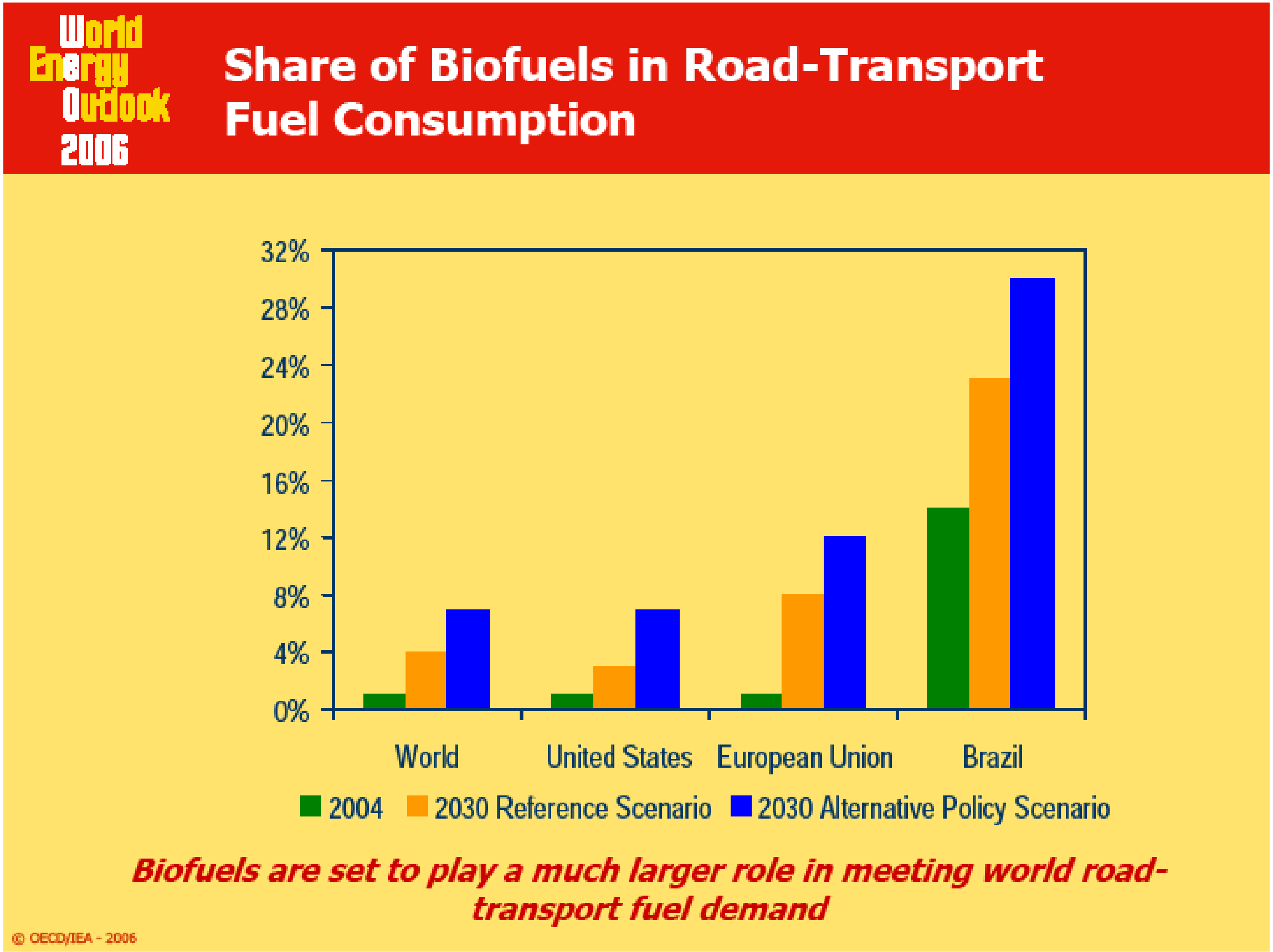
At least -20 % CO_2

Up to - 5% of GHG emissions

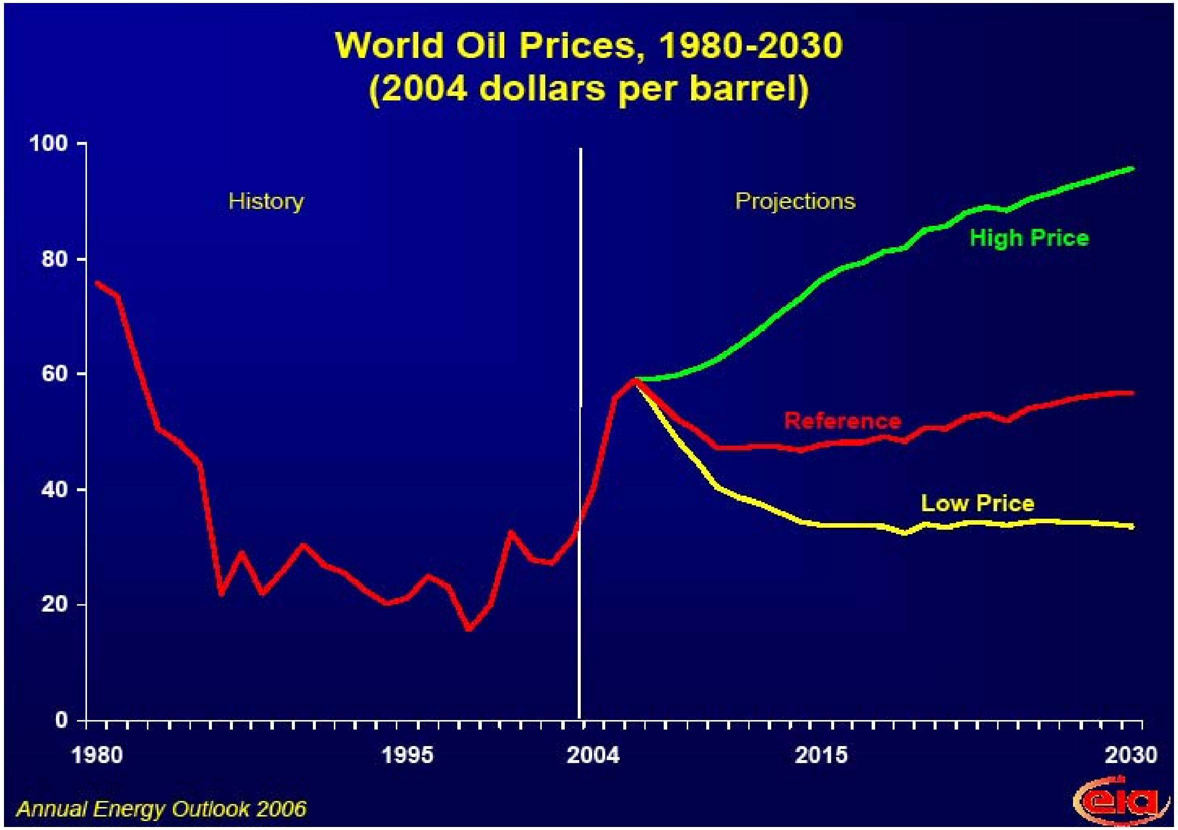
Example: USA


U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable
President's Biofuels Initiative Timeline
2006
2010
2015
2020
2025
2030
Initiative Goals
2006: President Announces Biofuels Initiative (January 31, 2006)
2012: Make Cellulosic Ethanol Cost Competitive
2025: Replace More Than 75% of Current Oil Imports From the Middle East
Technical Targets
2012 Cost Targets: -Ethanol Production Cost of $1.07/gallon -Enzyme Cost of $0.10/gallon of Ethanol - Delivered Feedstock Cost of $35/dry ton
2030: Replace 30% of Current Gasoline Consumption with Biofuels
Tools/R&D Focus
Feedstock development to move from starch-based to cellulosic-based ethanol
Help industry build first-of-a-kind plants
Cost-share industrial-scale validation of technology & economics
Establish Regional Feedstock Partnerships
Feedstock development focus on pulp & paper mill residues, forest residues, & perennial energy crops
Accelerate Thermochemical Platform

IEA Biofuels Markets Scenarios



Critical Driver: Oil price



→ Example: The *high price* scenario would make forest biorefinery prospects very good, but *low price* scenario bleak

→ *”One of the most challenging aspects of the biorefinery economic analysis is deciding what future energy prices to use”* (Eric Larson et al. 2006)

The long-term outlook (enlightened guestimation)

- There will be a number of different forest biorefinery concepts, which vary according to local conditions and markets
- 2007-2010: forest biorefineries (based on ”2nd generation technology”) are at demonstration/pilot stage
- 2010-2013: first commercial scale forest biorefineries are built
- 2013-2020: forest biorefineries investment boom
- 2020 - :major impact on the forest sector and local bioenergy markets, but realtively small impact on global energy markets
- To what extent forest biorefineries will be located in South-America, Asia, Russia *vs.* Scandinavia and North America?
- When will the biorefineries boom take place in the sawmill and plywood industries?

Biorefinery Uncertainties & Risks

1. Energy prices (nobody knows)
2. Policy (regulations may change, a complex set of policies)
3. Advancment in biofuels production & technologies (when do new technologies become applicable on commercial scale?)
4. Rawmaterial availability & prices (forest biomass demand-supply changes)
5. Where to invest (Scandinavia and North America vs. South America and Russia)?

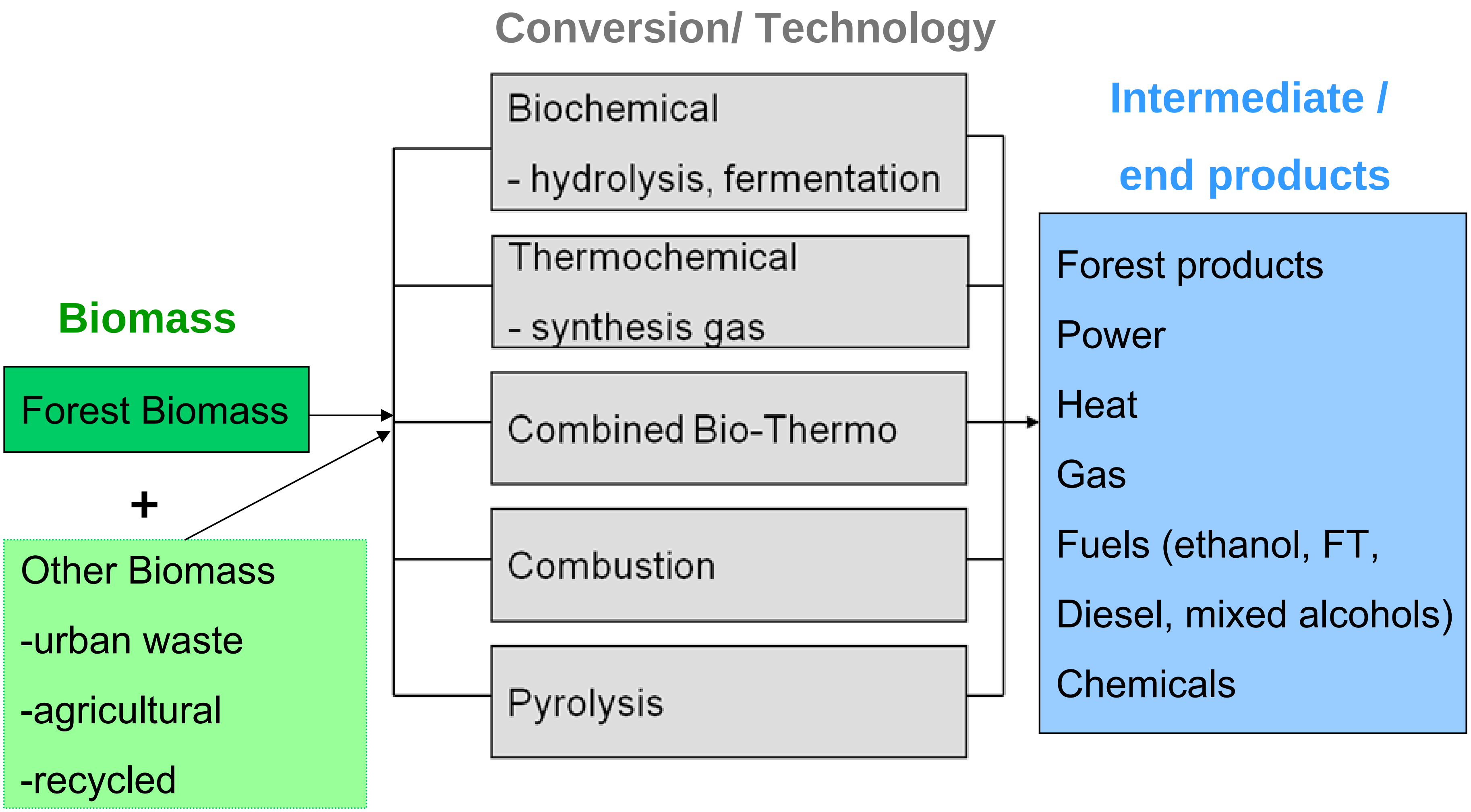
Implications to socio-economic research

1. Understanding the new concepts and their implications (energy and chemicals markets, forest sector multiple output technology, etc.)
2. Need to link the biofuels (energy) and chemcials markets to forest sector. Basically need to model demand and supply of forest biomass in a new setting
3. Model feed-back effects and links between forest products and biofuels/chemicals markets
4. Need to provide different scenarios (unceratinty & risks). For example: Oil price $40 vs. $100; tax exemption for forest biomass based diesel 0% vs. 100%, etc.
5. Undoubtedly – many other open issues. Room for pioneering research!

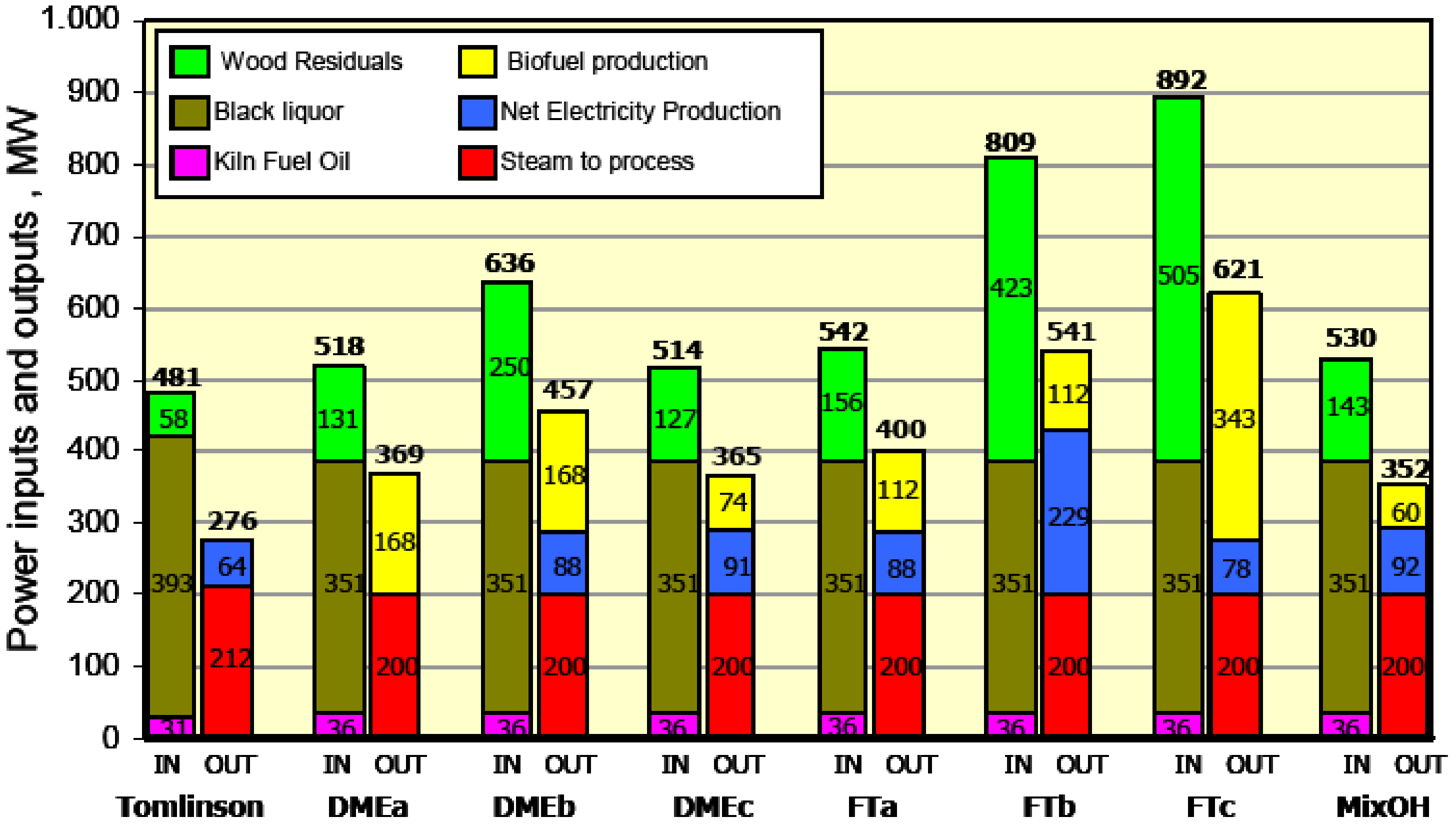
Thank you!

Supplamentary slides

Forest Biorefinery Conversion Routes



Overall Energy In and Out



Slide source: Eric Larson (Princeton University) "Pulp Mill Integrated Gasification". Presentation at the TAPPI Renewable Energy Conference, Atlanta 10-11 May 2007 , p.8.

US Forest Industry & Ethanol -example*

- US forest products industry harvested 278 million bone-dry tons of wood in 2003
- This contained appx. 90 million tons of hemicellulose

→ assume forest industry can extract half of this hemi = 45 m.t.

→ this can be fermented to about 20 m.t. or 22.7 billion liters (6 bil. gallons) of ethanol

→ this is equivalent to 1/7 of the US national 35 billion gallon /year target

- ”This does not require harvesting one additional log” ???

** Example presented in: Thorp & Frederick ”Project Comparison Reveals Leadership Gap”. Presentation at the TAPPI Renewable Energy Conference, Atlanta 10-11 May 2007 , p.8.*

U.S. Pulp/Paper Industry Technical Potential for Biofuel Production in 2034

(billion gallons per year ethanol equivalent)

- FT configurations: 5 to 14 billion gal/yr
- DME configurations: 3 to 7 billion gal/yr
- For comparison:
  - 2005 corn ethanol production: 4 billion gallons
  - Latest administration goal: 35 billion gallons in 2017

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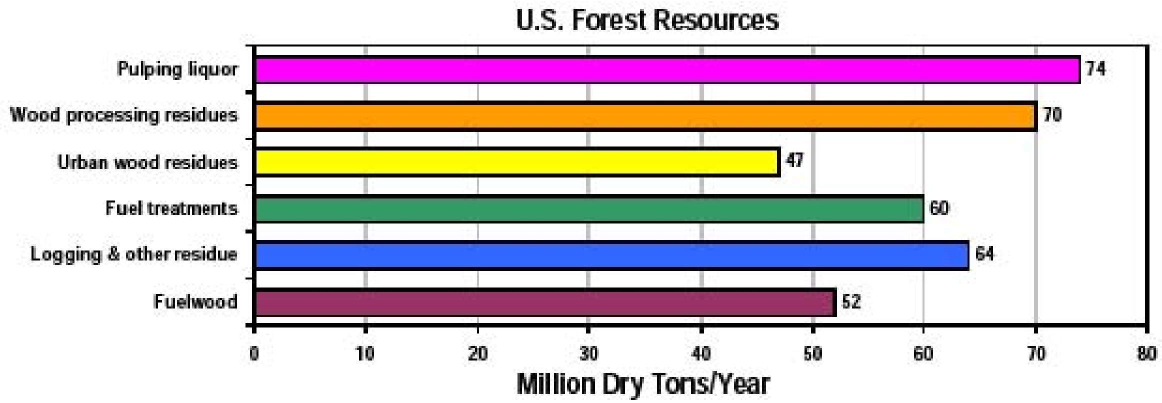
Slide source: Eric Larson (Princeton University) ”Pulp Mill Integrated Gasification”. Presentation at the TAPPI Renewable Energy Conference, Atlanta 10-11 May 2007 , p.8.

The world of secondary forest resources, when thought of as bioproducts feedstocks, is huge



If converted to ethanol at 100 gals/ton, these feedstocks represent over 35 billion gallons/yr

AND — it's sustainable and renewable

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**Denny Hunter (vp technology, Weyerhauser)"Biorefining Choices". Presentation at the TAPPI Renewable Energy Conference, Atlanta 10-11 May 2007 , p.8.*

U. S. Poplar Plantation Industry: Pulp and Paper Production

Region	Biomass Growth Rate (MT ha^{-1} yr^{-1})	Rotation (yrs)	Area [1] (ha)
Pacific Northwest	13.5	6 to 8	14,000
North Central	9.4	12	10,000
Mississippi River Valley	10.1	8 to 10	11,000

1/ FAO. 2004. Synthesis of Country Progress Reports, 22nd Session, International Poplar Commission, Santiago, Chile, November 28 – December 9, 2004. Working Paper IPC/3, Forest Resources Division, FAO (Rome).

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**Brian Stanton (managing director, tree improvement group, Green Wood Resources) "Hybrid Poplar Feedstock Production". Presentation at the TAPPI Renewable Energy Conference, Atlanta 10-11 May 2007 , p.8.*

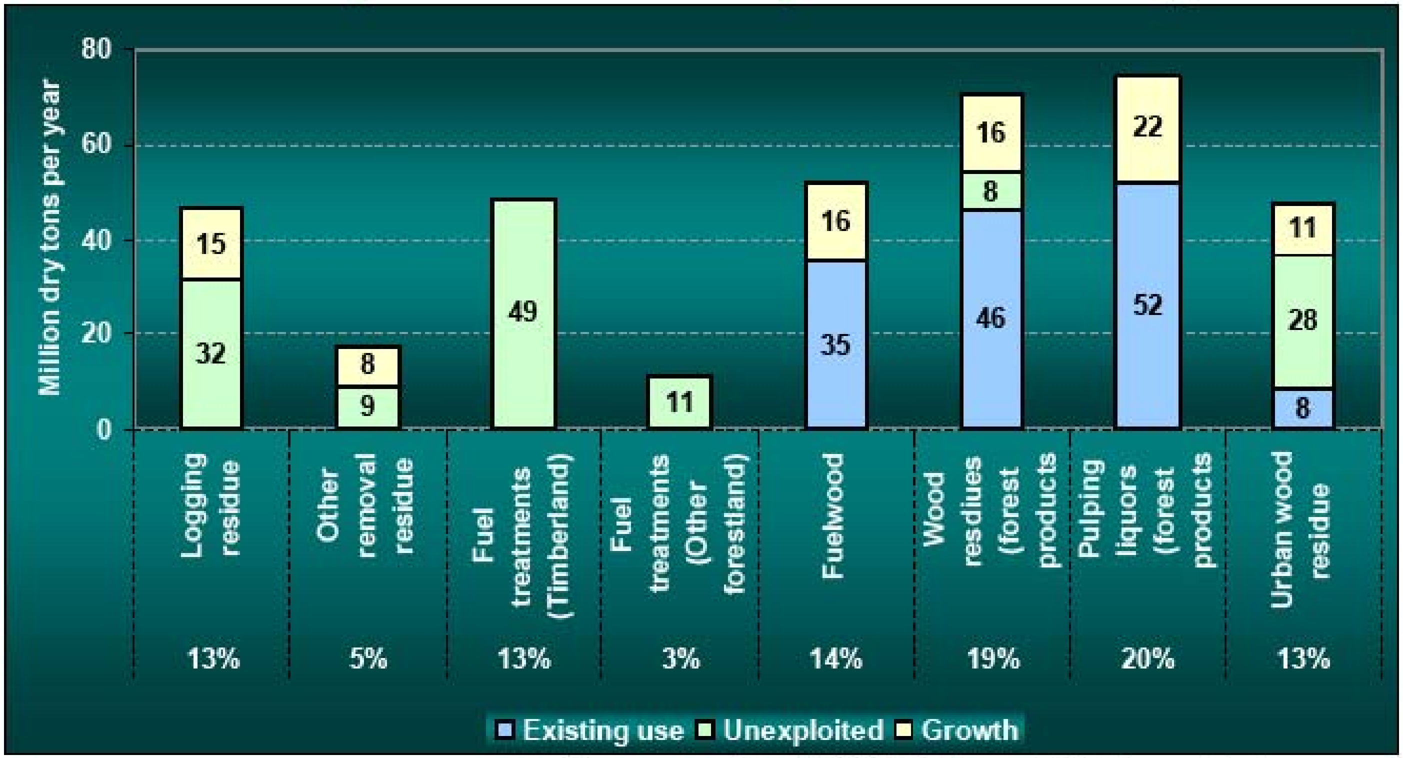
U.S. Department of Energy
Energy Efficiency and Renewable Energy

USDA U.S. Department of Agriculture

biomass program

Forest Resource Analysis

The sustainable forest resource potential is nearly 370 million dry tons annually



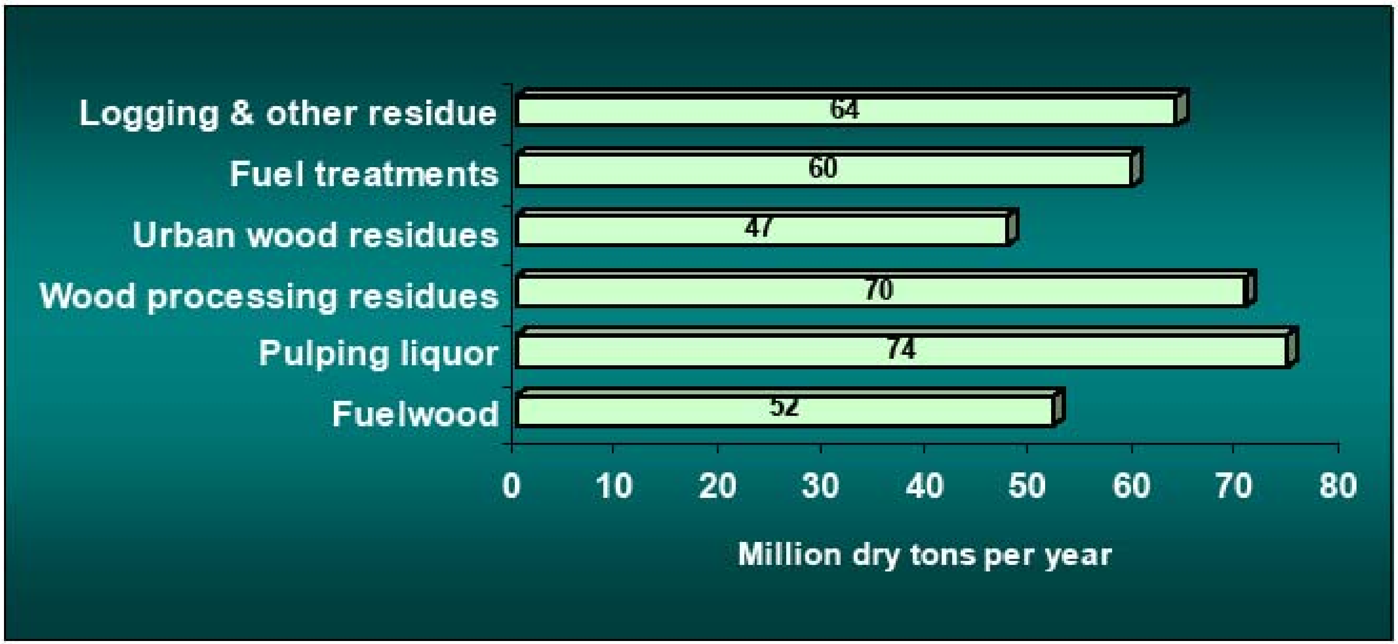
For conversion, (2000 lbs) tons x 0.907 = metric tonnes

**Bryce Stokes (national program leader, U.S. Forest Service R&D) "The Billion-Ton Report". Presentation at the TAPPI Renewable Energy Conference, Atlanta 10-11 May 2007 , p.8.*

U.S. Department of Energy
Energy Efficiency and Renewable Energy
U.S. Department of Agriculture
biomass program

Forest Resource Summary

The sustainable forest resource potential
~ 370 million dry tons per year



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Next Generation Feedstocks

Feedstocks for Biorefining

Starch, Sugar & Oil

Corn	Wheat
Soybean	Barley
Palm	Triticale
Sugar cane	Canola

Cellulose / Hemicellulose

Hybrid Poplar	Grasses
Forest residue	Hemp
Sawdust	Cereal straw
Yard waste	

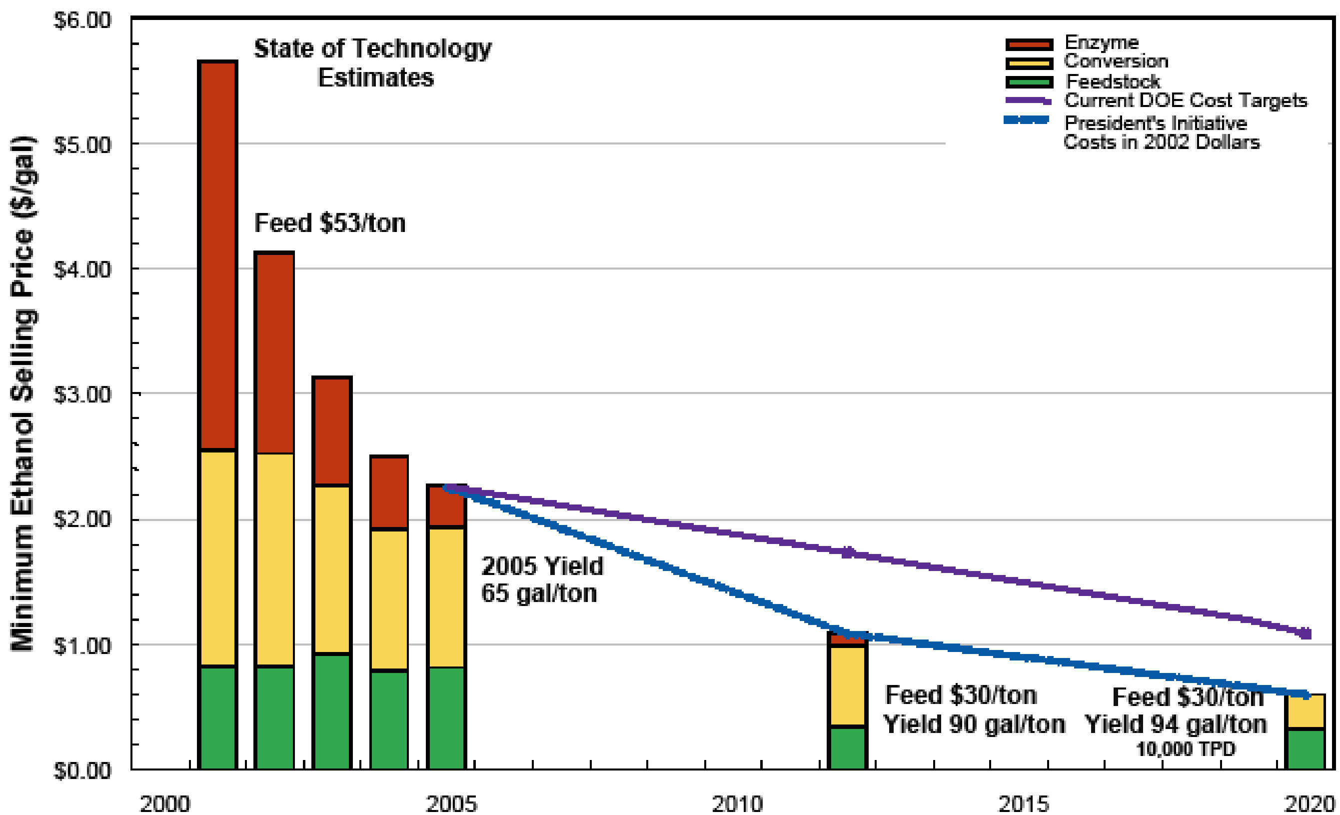
Livestock and Food Processing Wastes

Manure	Animal fats & used frying oils
Cheese whey	Food processing wastes
Corn syrup	Fruit processing wastes
Milling byproducts	Biorefinery wastes

April 10, 2007 17

Slide source: Stewart Campbell (vice pr., commercial development, Canadian Bioenergy Corporation) ”Biorefining: New Demand / New Landscape, Presentation at the TAPPI Renewable Energy Conference, Atlanta 10-11 May 2007

Reducing the Cost of Cellulosic Ethanol



Michael Pacheco (director of national bioenergy center, NREL, USA) "Overview of Liquid Biofuels Technologies". Presentation at the TAPPI Renewable Energy Conference, Atlanta 10-11 May 2007 , p.8.