The Forest BioRefinery
A Partial View

by
B. A. Thorp
bathorp@comcast.net

On Behalf of
Agenda 2020
June 2004
AGENDA 2020

- A Chief Technology Officer’s (CTO) Committee of the American Forest & Paper Association (AF&PA)
- 8 Task Groups:
  - Technologically Advanced Workforce
  - Superior Environmental Performance
  - Sustainable Forest Productivity
  - Fiber Recovery & Utilization
  - New Forest Based Materials
  - Wood/Composite Technologies
  - Improved Energy Performance
  - Breakthrough Technologies
- Currently 60% funded as a Special Project
- The mission is to use leveraged resources to develop and deploy technology to continually improve industry economics
In 2003, there were 147 projects in DOE/Biomass, DOE/ITP, USDA Forest Service/CRESSES and the Forest Products Laboratory with a total 2003 “spend” of about $50 million.

Projects that moved into commercial status include:
- worker training center of excellence,
- soluble PSA,
- Methane DeNOx, and
- IntraMicron

Many more underwent trials or demonstrations.

There are 6 Deployment Platforms illustrated next.
Agenda 2020 Focus for the Future
Meeting the Challenge of Deployment

- **Positively Impacting the Environment**
  - Significant Reduction in Greenhouse Gases
  - Decreased Ecological Footprint

- **Next Generation Fiber Recovery and Utilization**
  - Recycled Fiber Indistinguishable from Virgin Fiber

Advancing the Forest “Bio-refinery”
- Sustainable Forest Productivity
- Extracting Value prior to Pulping
- New Value from Residuals & Spent Liquors

Breakthrough Mfg. Technologies
- Major Manufacturing Cost/Capital Reduction
- Significant Enhancement in Product Properties with Existing Assets
- Substantial Improvement in Energy Efficiency for Existing Processes

Technologically Advanced Workforce
- From Workforce to Knowledge Workers in 7 years

Advancing the Wood Products Revolution
- Improved Building Systems
- Reduced System Costs
The Forest Bio Refinery*

- Consists of three parts:
  1. Sustainable Forest Productivity
  2. Extracting Value Prior to Pulping
  3. New Value Streams from residuals and spent pulping liquors
- This means traditional tree growing and liberation of fibers while inefficiently burning spent liquors becomes the old technology.
- In its place is forest stewardship and the processing of wood in a way to extract fiber, fuel, chemicals, and power streams that are valued by society and the marketplace.
- Today’s focus will be on Parts 2 and 3.
- The intent is to evolve current chemical pulp mills into forest bio refineries, preserving infrastructure, jobs, supply chains & permits.
- The concept is in the next 2 slides

*This is a much more detailed look at the forest products than the “Refinery of the Future” for chemical products published in the Spring Issue of ACS’s Chemistry.
O₂ → Pulp → Paper

Steam, Power & Chemicals

BL Recovery Boiler → Power Boiler

CO₂

Black Liquor & Residuals

Conversion to Energy

90 x 10^6 MT CO₂

Purchased Power – 6 GW $2.0 billion

Current Mill

Manufacturing

Pulp

Paper
The Forest Biorefinery

Net Revenue Assumptions:
- Acetic Acid - $1.73/gallon
- Ethanol - $1.15/gallon
- Pulp - $100/ton net profit
- Purchased Electricity - $43.16/MWH
- Exported Electricity - $40.44/MWH
- Renewable Fisher Tropsch Fuel - $57/bbl

Extract Hemicelluloses
New products chemicals polymers $3.3 billion

BL Gasifier
Wood Residual Gasifier
Combined Cycle System
Process to manufacture Liquid Fuels and Chemicals

Syngas
Power Export $3.8 billion
Or
Liquid Fuels/Chemicals $5.5 billion

Pulp $5.5 billion
Black Liquor & Residuals

Manufacturing

Steam, Power & Chemicals

$66 x 10^6 MT CO_2

Sun
Value Prior to Pulping

Description:
- Adding hot water extraction vessels (low pressure digesters),
- Extracting soluble hemicelluloses,
- Separating the acetic acid, and
- Fermenting the sugar to fuel grade ethanol with known processes.
- Ethanol is at the low end of potential products
- Removing the “sugars” will only improve the throughput potential of existing operations as the “hemis” are removed in pulping. Further work is needed on the energy offsets.
- Development of further value includes a “fermentation system” to produce high value chemicals and produce ethanol with “residuals from the system”.
Value Prior to Pulping (cont)

- **Reference Mill:**
  - 1580 BD unbleached TPD pulp, which a mill used in the Larson Gasification to Power Study.
  - Mill uses 2089 TPD BD hardwood and 1122 TPD softwood plus 318 TPD bark
  - This mill includes all energy required for the production of~1,722 tpd of “freesheet”.

- **Output:**
  - ~19 million gallons ethanol
  - ~ 6 million gallons acetic acid

- **Capital Cost:** (preliminary estimate)
  - ~$33 million for vessels, distillers, membranes & controls

- **Operating Cost:**
  - ~35 cents/gallon

- **Net Revenue Increase:**
  - ~$33 million
Value Prior to Pulping (cont)

- **Basis Includes:**
  - Studies at Syracuse and Maine show that 53% of the 27% xylose in certain wood can be extracted
  - Yields used in the calculations are very conservative
  - There are 76 ethanol fermentation plants in the U.S.
  - DOE and USDA projects show no way to meet the projected ethanol demand

- **Needs Include:**
  - A detailed fermentation process study and capital cost estimate
  - Research that would lead to the production of higher value added products
New Value from Spent Liquors

- There are two choices:
  - power, or
  - fuel/chemicals

- For each choice, there is:
  - an incremental capital analysis
  - and full capital analysis
**New Value from Spent Pulping Liquors (Power)**

**Description:**
- Add a gasifier and turbine power island.
- Convert to polysulfide pulping because chemicals are available.
- Convert the “off gas” to power the mill and sell excess to grid.
- Reference mill increases biomass consumption by ~50%. (Case from Larson Study.)
- Better economics are possible with acquisition of additional biomass.
- Profit potential is limited by the historically slow moving wholesale electrical prices IN AREAS WHERE COAL DOMINATES, like the southeastern U.S.
New Value from Spent Pulping Liquors (cont)

- Reference Mill: Same
- Output:
  - 833,800 mwh to cover mill purchases ($43.16/mwh assumed)
  - 121,500 mwh for export to grid ($40.44/mwh assumed selling)
  - 226 BD tpd of wood not purchased ($50.26/BD ton assumed)
- Capital Cost: (engineered estimate)
  - Incremental: $70 million
  - Full: $191 million including $122 million diverted from recovery
- Added Operating Cost: (engineered estimate)
  - Incremental: $7 million
  - Full: $7 million
- Net Revenue:
  - Incremental: $38 million
  - Full: $38 million
- This is economically attractive only when the recovery boiler is at the end of its useful life.
New Value from Spent Pulping Liquors (cont)

- **Basis Includes:**
  - Polysulfide pulping is semi-commercial
  - Black liquor and biomass gasification commercial at Weyerhaeuser, New Bern, NC, and in startup at Norampac, Trenton, Canada, and GP, Big Island, VA.
  - Pilot plants have run successfully at 2 mills in U.S., 2 in Sweden, and with a 3rd in startup.
  - Gas turbine technology is commercial in many FPI mills and other industries.

- **Needs Include:**
  - More economical hot gas cleanup and/or a non sulfur added pulping process.
  - A premium for “green power”
New Value from Spent Pulping Liquors Fuel

Description:
- Install a black liquor gasifier.
- Add a Fischer Tropsch unit and convert all the BLG off gases to Renewable Fischer Tropsch Fuel (RFTF) for sales to the petrochemical industry.
- Convert the old chemical recovery unit to a biomass boiler.
- Procure additional biomass to run the mill and install a condensing turbine to convert excess steam into power.
- This is a very rough way to configure a mill.
- Higher values can be obtained by configuring a mill with a proper steam/electrical balance and by adding distillation columns to produce fuels (versus basestock).
New Value from Spent Pulping Liquors (cont)

- Reference Mill:
  - Same
- Output:
  - 1,090,000 barrels “RFTF”
- Capital Cost: (part engineered estimate, part preliminary)
  - Incremental: $83 million
  - Full: $205 million
- Added Operating Cost:
  - Incremental: $19 million
  - Full: $19 million
- Net Revenue:
  - Incremental: $55 million
  - Full: $55 million
- This is economically attractive only when the recovery boiler is at the end of its useful life.
New Value from Spent Pulping Liquors (cont)

- **Basis Includes:**
  - Polysulfide pulping is semi-commercial
  - Gasification – same as previous case
  - Fischer Tropsch units are commercial in other industries and have been trialed on black liquor

- **Needs include:**
  - A detailed liquid fuels process study, market study, and capital cost estimate.
  - More economical hot gas cleanup and/or a non sulfur added pulping process
  - Integration into commercial plant operations
Major Hurdles

- Lack of industry capital
- Historical lack of technical entrepreneurship/leadership
- Detailed process studies and cost estimates for first & third cases
- Assembling a technical needs pathways and a strategy for DOE funding to include:
  - Refractory
  - Materials selection
  - Bed fluidization and uniformity (LTG)
  - Hot gas cleanup (for cases 2 and 3)
  - Integration into existing mill systems
- Assembling a compelling case
- Recruiting a consortium
- Identifying a mill or mills that meet “host” criteria
Preliminary Steps and Agenda 2020 Timing

- Preliminary case w/technical need pathways for DOE: Jun 2004
- Compelling case for DOE and Industry: Jul 2004
- Prospectus for Bio-Refinery consortium: Aug 2004
- Potential members identified: Aug 2004
- Consortium Manager to recruit members: Oct 2004
- Ethanol fermentation study completed: Dec 2004
- Liquid fuels study completed: Jun 2005
- Technical needs RFP’d, contracted and solutions flow: Oct 2004 to Dec 2008
- Implementation Plan in place: Dec 2005
- Fermentation deployed at a site: Dec 2006
- Spent liquor deployed at same or suitable site: Dec 2008
Summary

The next 2 schematics depict the change from tree planting and energy intensive fiber liberation to:

- forest stewardship,
- closeness to traditional customers,
- more environmentally friendly manufacturing facilities
- Facilities that are valued by society.
FROM

Intellectual Capital

Organizational Capital

Human Capital

Intel. Assets

I.P. $

Land & Forests (Trees)
[Structural Assets]

Complimentary Business Assets

Mfg.
- Pulp/Paper
- Wood
- EWP

Distribution

Customer Relationships (Mrktg.)

Sales Force

$8 billion
Net Cash Flow

Pulp
Wood
EWP
Faux
Integrated
From: Ownership of Resources

Growing Trees

Industrial Interests

Environmental Interests

Aesthetic Interests

From Growing Trees:
- Logs
- Chips
- Fiber

Fiber leads to:
- Solid wood
- EWP
- Pulp
- Packaging
- Paper

Manufacturers & Distributors
To: Stewardship

Environmental Values (Interests)

Production (Industrial Interests)

Sustaining Forest Land

Society's Sustainable Resource

Aesthetic Values (Interests)

Logs
Chips/Strands
Fiber
Bio-“Chem” (as in petro-chem)
Energy

Sustainable Resource Processes Materials Penultimate Products End-Products Mfgs./Mrkts. Consumers & End-Users

Benefits: Jobs that consumers need doing
Conclusion

- There is a unique opportunity in the U.S.
- We reside in the world’s largest and most demanding marketplace.
- All our products are made from renewable resources.
- We can customize or develop improved products for the demanding marketplace and renewable fuels for the benefit of the nation and society.
- Our aging mills turn out to be another asset. The return on assets favor installing much of the technology as recovery boilers reach the end of their useful life. Our aging fleet of boilers can give us a 30-year competitive advantage over newer tropical pulp mills.
- Further, we can see ways to extend this if we develop skills in profitability deploying new technology.
- Our fate is in our hands.