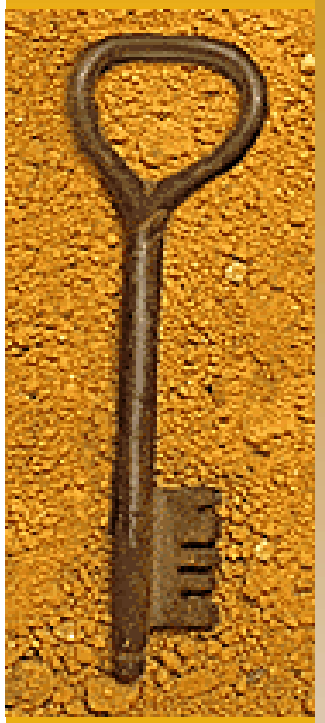


AGENDA
2020

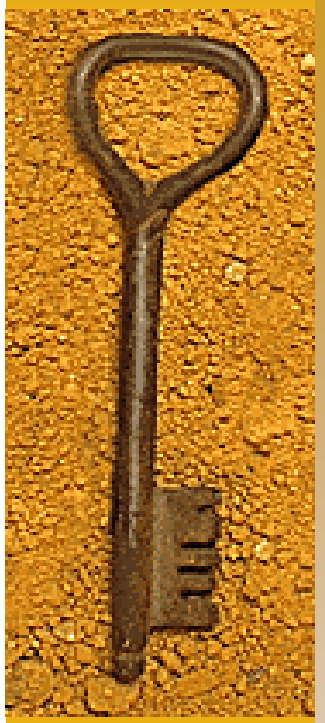
The Forest BioRefinery

A Partial View

by
B. A. Thorp
bathorp@comcast.net

On Behalf of
Agenda 2020

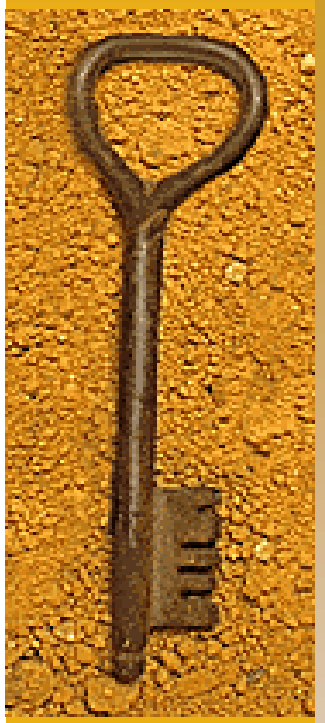
June 2004



AGENDA 2020

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



AGENDA 2020

Agenda 2020 (cont)

- 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

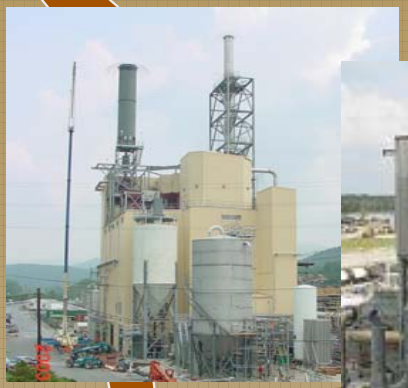
Meeting the Challenge of Deployment

O_2

CO_2

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

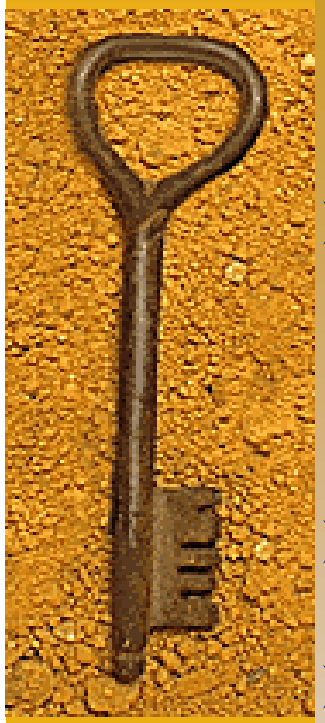
- ***Major Manufacturing Cost/Capital Reduction***
- ***Significant Enhancement in Product Properties with Existing Assets***
- ***Substantial Improvement in Energy Efficiency for Existing Processes***

Technologically Advanced Workforce

- ***From Workforce to Knowledge Workers in 7 years***

Advancing the Wood Products Revolution

- ***Improved Building Systems***
- ***Reduced System Costs***

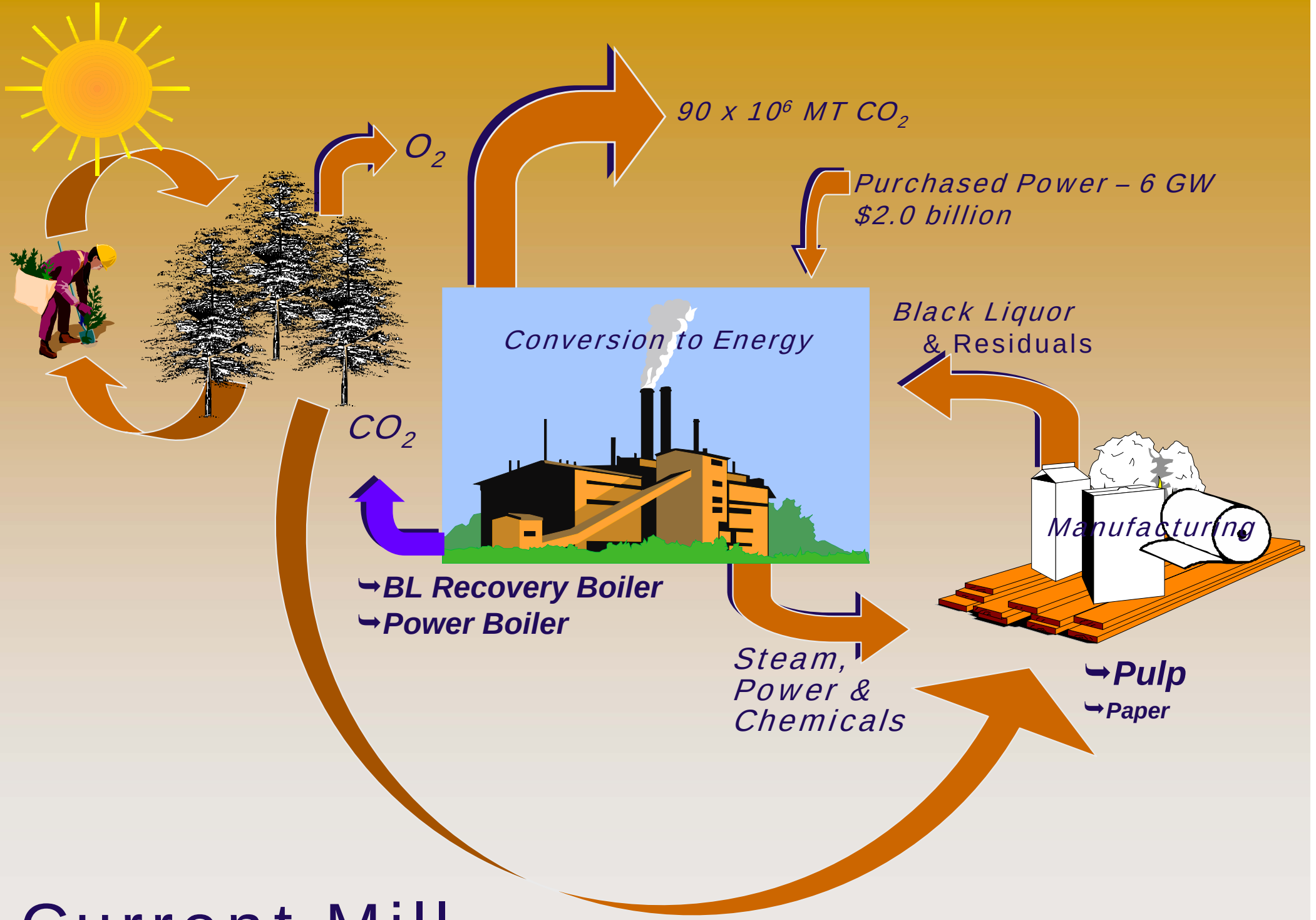


AGENDA 2020

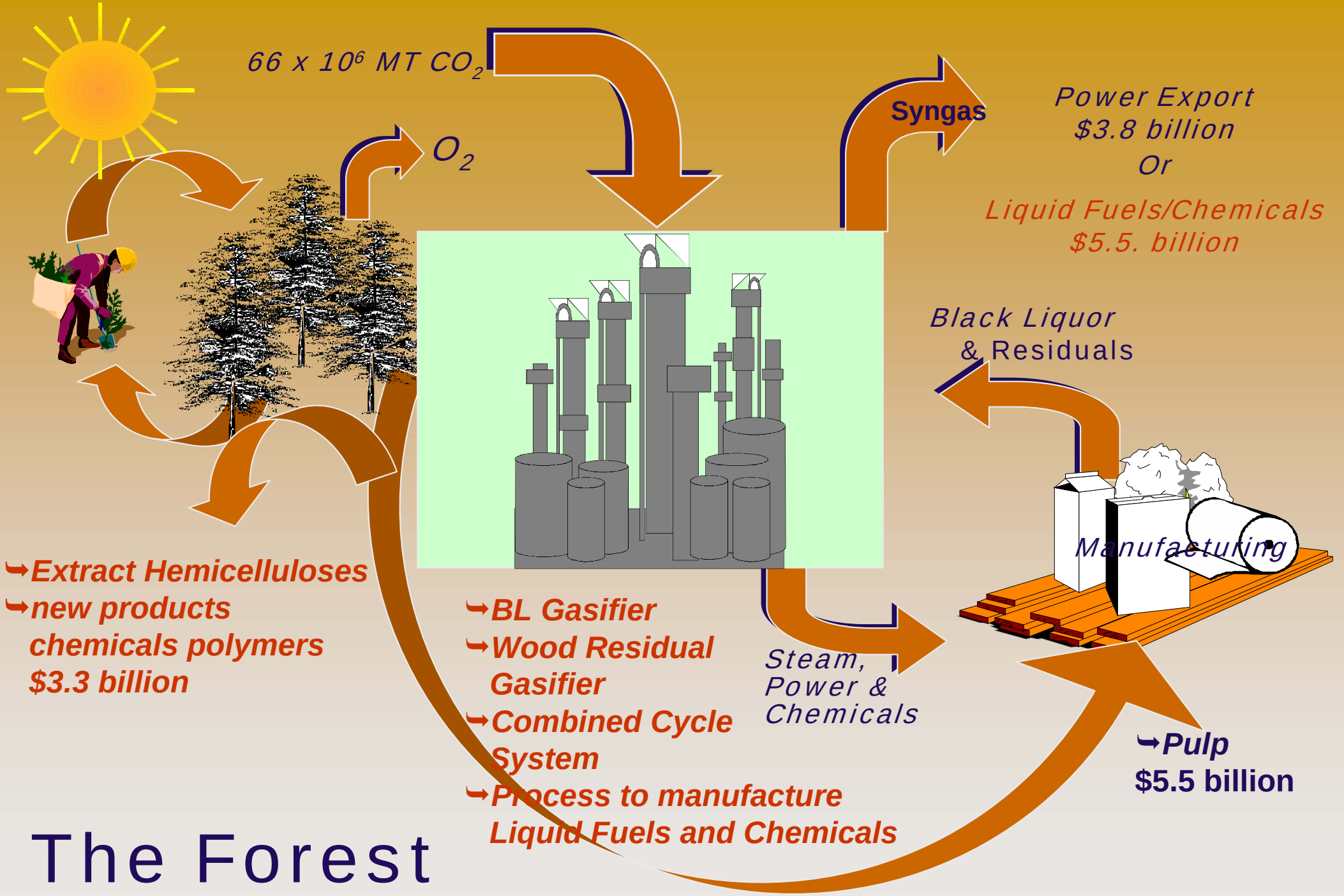
The Forest Bio Refinery*

- **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.***



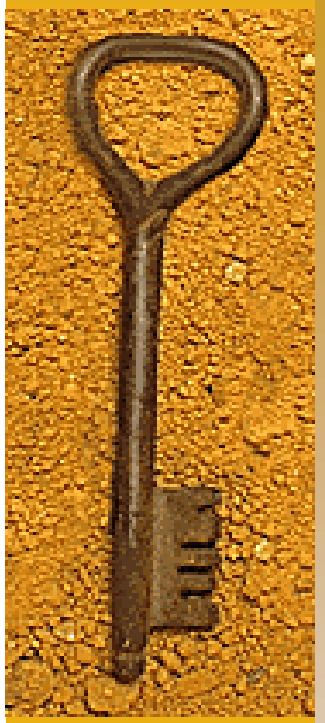
Current Mill



The Forest Biorefinery

Net Revenue Assumptions:

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



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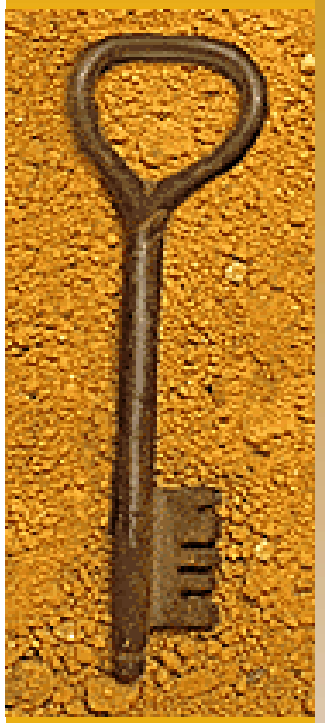
Value Prior to Pulping

Description:

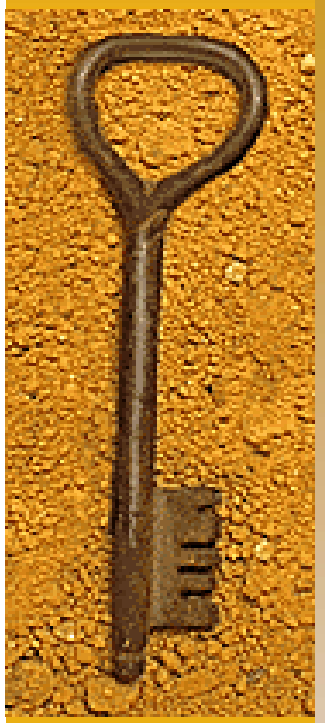
- **Adding hot water extraction vessels (low pressure digesters),**
- **Extracting soluble hemicelluloses,**
- **Separating the acetic acid, and**
- **Fermenting the sugar to fuel grade ethanol with known processes.**
- **Ethanol is at the low end of potential products**
- **Removing the “sugars” will 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”.**



AGENDA 2020

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**



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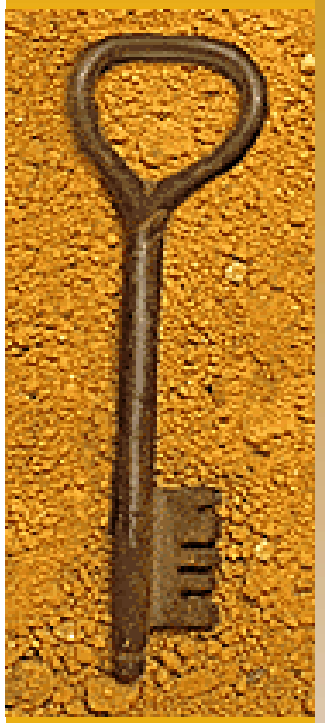
Value Prior to Pulping (cont)

- **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**



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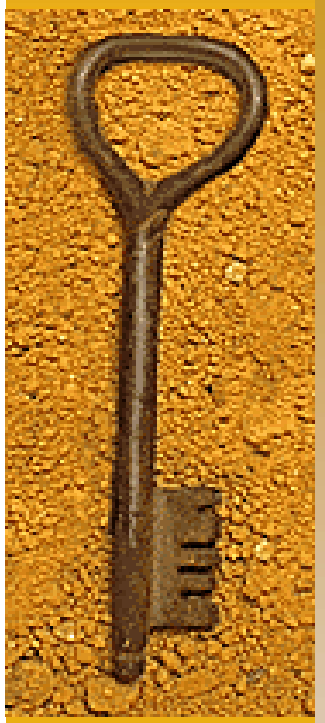
New Value from Spent Liquors

- There are two choices:
  - power, or
  - fuel/chemicals
- For each choice, there is:
  - an incremental capital analysis
  - and full capital analysis



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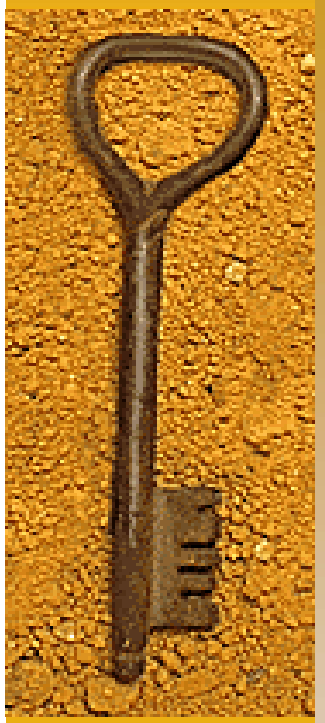
New Value from Spent Pulping Liquors (Power)

Description:

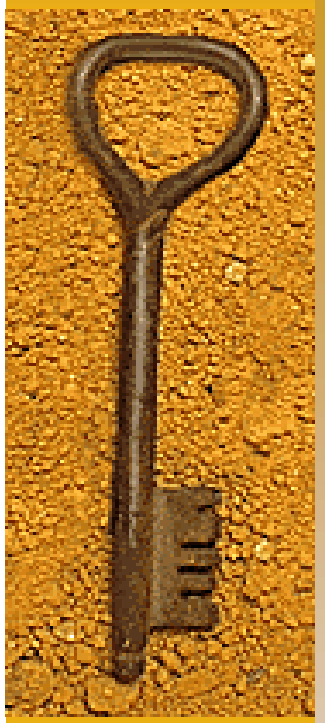
- **Add a gasifier and turbine power island.**
- **Convert to polysulfide pulping because chemicals are available.**
- **Convert the “off gas” to power the mill and sell excess to grid.**
- **Reference mill increases biomass consumption by ~50%. (Case from Larson Study.)**
- **Better economics are possible 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.**



AGENDA 2020

New Value from Spent Pulping Liquors (cont)

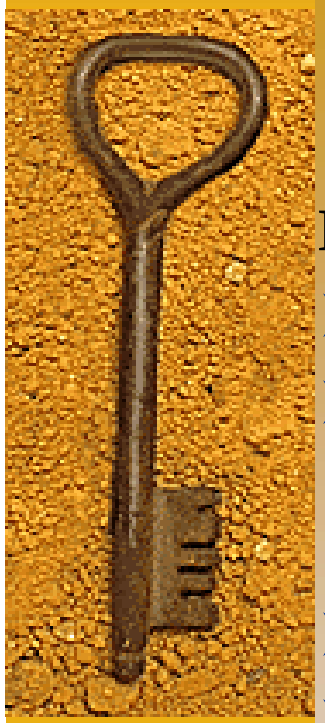
- **Reference Mill:**
  - **Same**
- **Output:**
  - **833,800 mwh to cover mill purchases ($43.16/mwh assumed)**
  - **121,500 mwh for export to grid ($40.44/mwh assumed selling)**
  - **226 BD tpd of wood not purchased ($50.26/BD ton assumed)**
- **Capital Cost: (engineered estimate)**
  - **Incremental: $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.**



AGENDA 2020

New Value from Spent Pulping Liquors (cont)

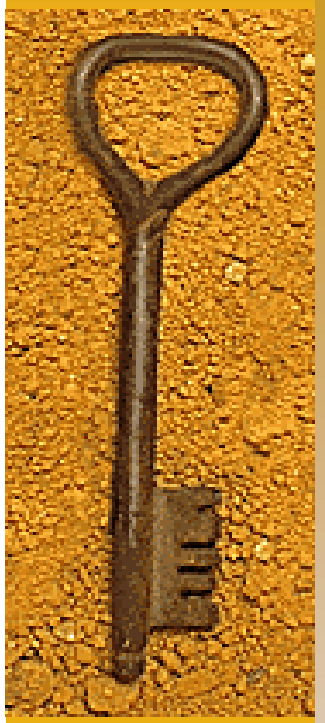
- **Basis Includes:**
  - **Polysufide pulping is semi-commercial**
  - **Black liquor and biomass gasification commercial at Weyerhaeuser, New Bern, NC, and in startup at Norampac, Trenton, Canada, and GP, Big Island, VA.**
  - **Pilot plants have run successfully at 2 mills in U.S., 2 in Sweden, and 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).**



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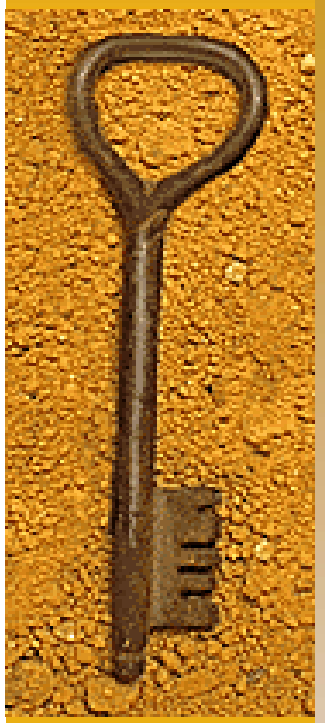
New Value from Spent Pulping Liquors (cont)

- **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.**

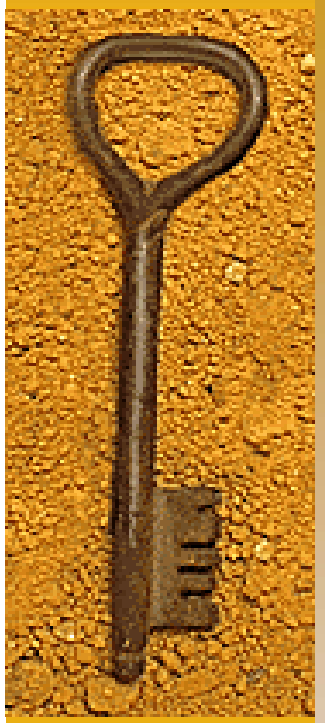


AGENDA 2020

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**



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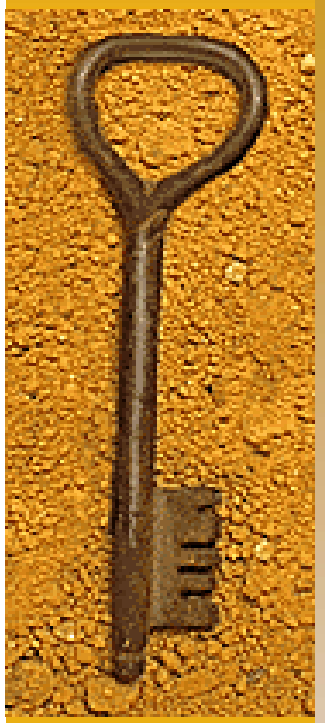
Major Hurdles

- 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



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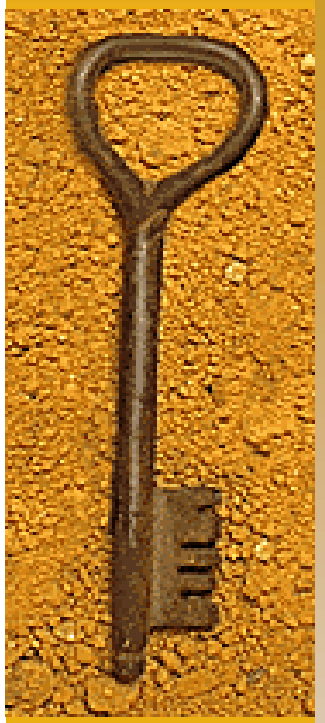
Preliminary Steps and Agenda 2020 Timing

➢ 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



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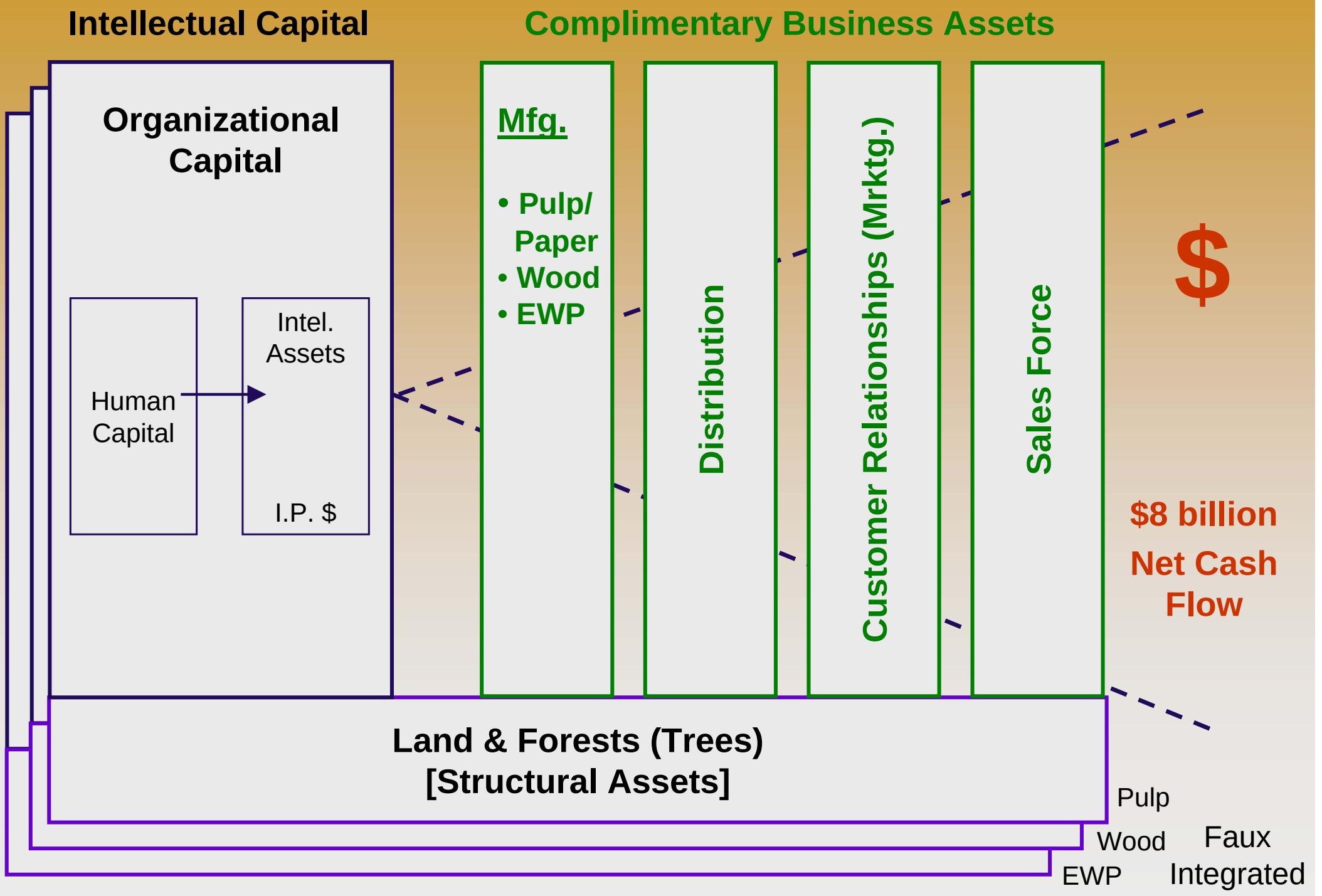
Summary

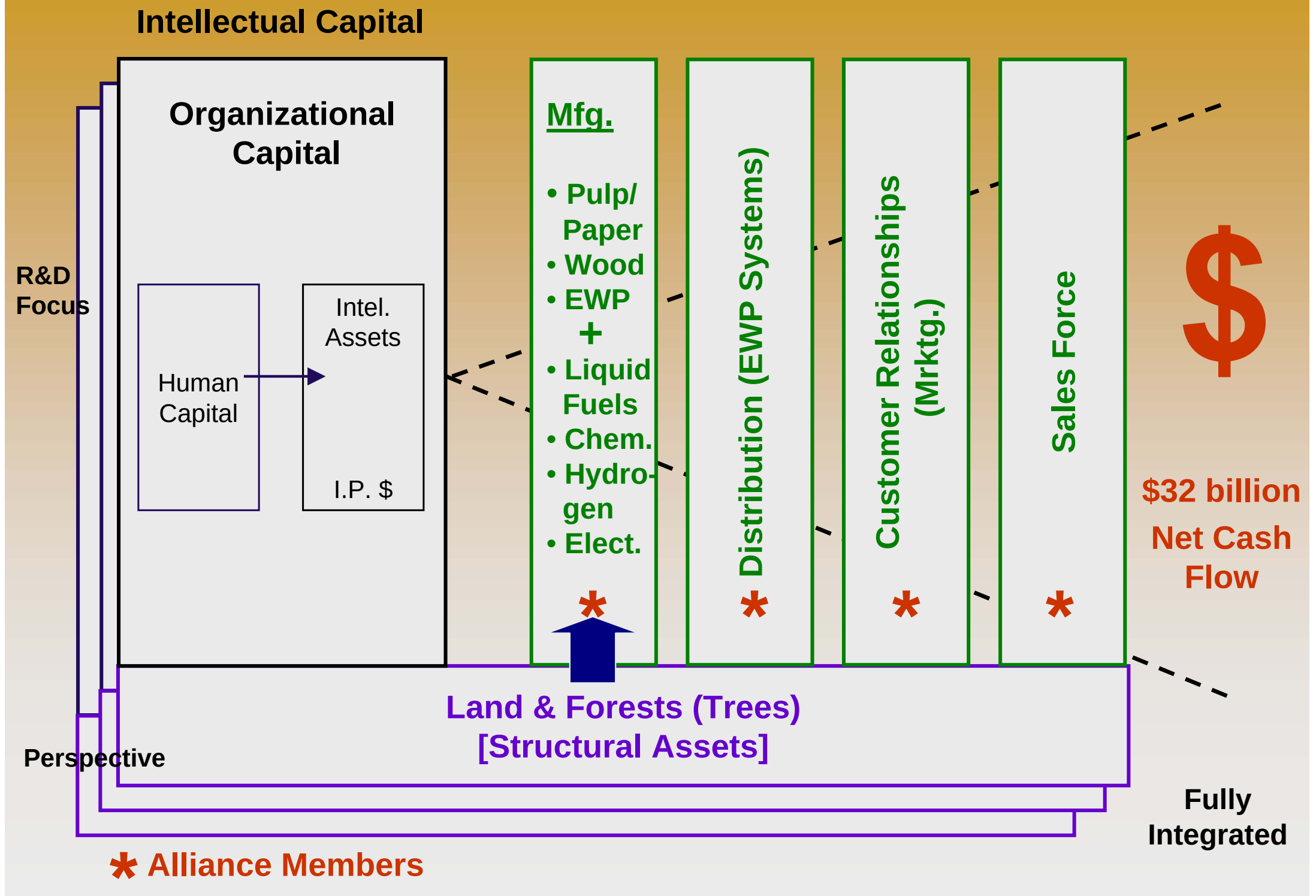
The next 2 schematics depict the change from tree planting and energy intensive fiber liberation to:

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

FROM


Intellectual Capital
Complimentary Business Assets
Organizational Capital
Human Capital
Intel. Assets
I.P. $
Mfg.
• Pulp/ Paper
• Wood
• EWP
Distribution
Customer Relationships (Mrktg.)
Sales Force
$
$8 billion
Net Cash Flow
Land & Forests (Trees)
[Structural Assets]
Pulp
Wood
EWP
Faux
Integrated

TO

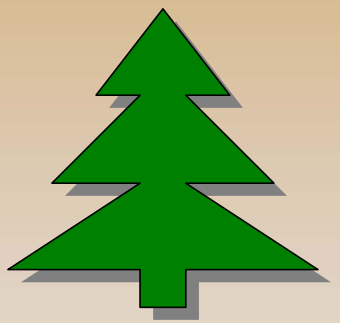

Intellectual Capital
Organizational Capital
Human Capital
Intel. Assets
I.P. $
R&D Focus
Mfg.
• Pulp/ Paper
• Wood
• EWP
+
• Liquid Fuels
• Chem.
• Hydro-gen
• Elect.
*
Distribution (EWP Systems)
*
Customer Relationships (Mrktg.)
*
Sales Force
*
$
$32 billion Net Cash Flow
Land & Forests (Trees)
[Structural Assets]
Perspective
Fully Integrated
* Alliance Members

From: Ownership of Resources

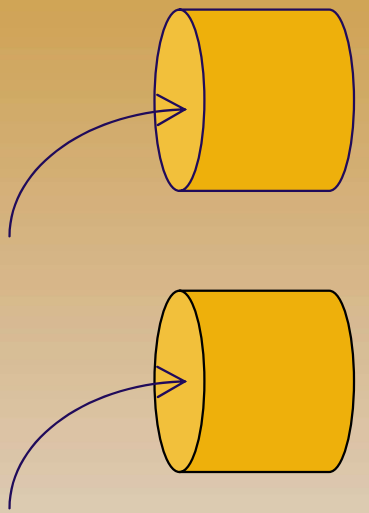
Aesthetic Interests

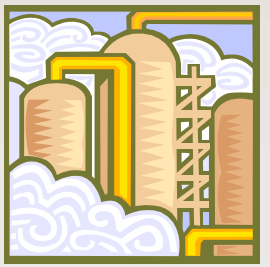
Environmental Interests

Industrial Interests



Growing Trees





Logs

Chips

Solid wood

EWP

Fiber

Pulp

Packaging

Paper

Manufacturers & Distributors

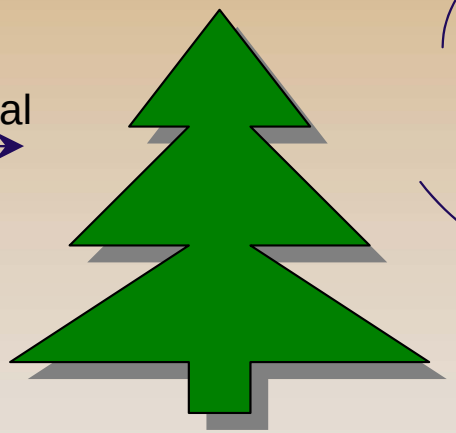
To: Stewardship

Aesthetic Values (Interests)

Environmental Values (Interests)

Production Resource (Industrial Interests)

Society's Sustainable Resource



Logs

Chips/ Strands

Fiber

Bio- "Chem" (as in petro-chem)

Energy

Paper

Pkging

Pulp

Solid

Liquid

Lumber

EWP

Commun- ication

Shipping Protecting

Absorbent

Benefits: Jobs that consumers need doing

Sustaining Forest Land

Form | Conv.

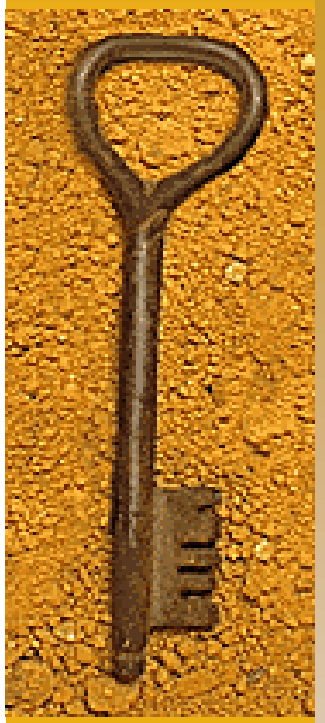
Processes

Materials

Penultimate Products

End-Products Mfgs./Mrkts.

Consumers & End-Users



AGENDA 2020

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.