

The Value Prior to Pulping (VPP) Platform for Biomass Utilization

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Today's Presentation

- Industry Context
- Global Issues
- Forest Products Potential
- Integrated Forest Products Biorefinery
 - Concept
 - Forest Products Industry Advantage
 - Mill Integration Model
 - Product/Offtake Options and Markets
 - Initial Economics



Industry Context

- Directly employ 1.3 million people
- Sales of forest and paper ~\$230 billion/yr
- Contribute 7-9% of primary industrial energy
- Biorefinery: more efficient renewable energy



Industry in a Crisis

- Global competition
 - Latest energy efficient technology
 - Wood, energy and labor cost advantages
- Prices have declined
- Mills under intense economic pressure
- Mills have shut down
- Production moved overseas



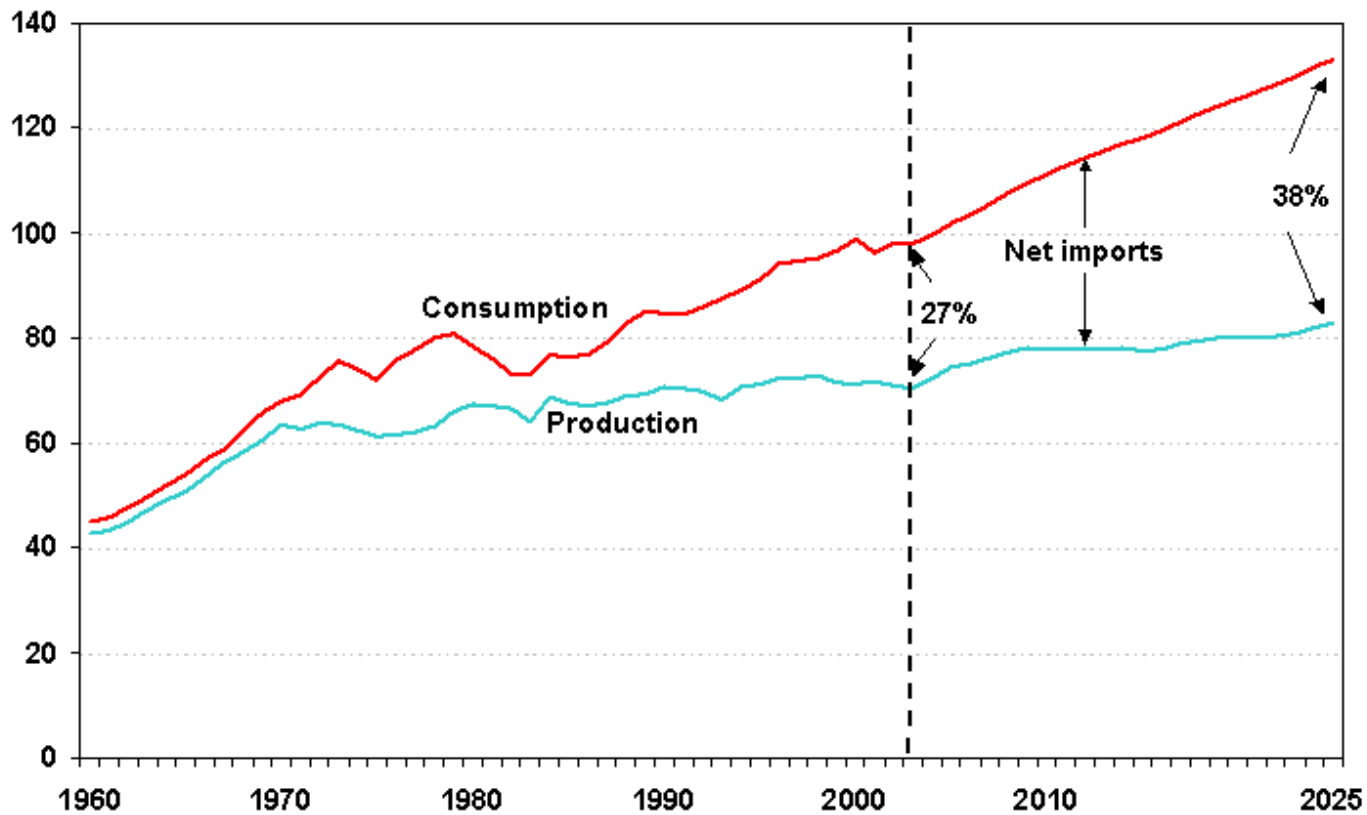
Global Issues

- Energy Supply
- Control fossil-fuel CO₂ emissions
- Climate change



U.S. Energy Production & Consumption

U.S. Energy Production, Consumption, and Net Imports, 1960-2025 (quadrillion Btu)



Energy Use in Key Industrial Sectors

(All Figures in Trillion BTUs)

Sector	Natural Gas	Residual Fuels	Distillate Fuels	LPG/ NGL	Coal and Coke	Derived Net Electricity	Other	Total Use, Net
Chemicals	1984	50	9	51	284	602	749	3729
Mining	1268	5	262	0	77	355	631	2598
Petroleum Ref	948	70	4	33	0	123	2300	3478
Forest Products	659	152	21	9	279	327	1825	3272
Steel	456	29	5	0	48	163	971	1672
Glass	194	3	0	1	0	54	2	254
Aluminum	189	0	1	1	1	246	3	441
Metalcasting	136	0	1	2	0	63	31	233
Agriculture	77	0	339	221	0	221	14	1072
TOTALS	5911	309	642	318	689	2154	6526	16749

Taken from "Profile of Total Energy Use for US Industry", Energetics, Inc. for the US DOE, 12 / 04.

LPG / NGL = Liquefied Petroleum Gas / Natural Gas Liquids

Table does not include energy sources used as raw materials.



Forest Products Potential

- Cellulose – most abundant organic chemical
- 90 billion tons produced per year
- In energy terms: the amount of carbon is equivalent to ~10X the world consumption
- Renewable forest material is carbon neutral



Forest Products Potential

- “The Billion Ton Study” by Departments of Energy and Agriculture
- US potential: 400 million dry tons/year
- Total: 1 billion dry tons from
 - Agricultural biomass
 - Woody biomass
- Equal to 1/3 of all transportation fuels in US



Integrated Forest Products Biorefinery (IFPB)

- Sustainable renewable energy
- Forest products industry evolving into integrated forest refineries
- 1st International Biorefinery Workshop (2005)
- By 2050 all gasoline used in US could be replaced by biomass-derived fuels



Integrated Forest Products Biorefinery (IFPB)

- Unique opportunity to increase revenue
- Contribute to a sustainable stream of
 - High-value (and “green”) chemicals
 - Fuel and/or electric power
- Continue to produce traditional line of products
 - Wood
 - Pulp and paper



Agenda 2020

- Agenda 2020 Technology Alliance provides leadership for industry biorefinery strategy
 - Partnership with industry, government, and academia
 - Innovation in processes, materials, and markets



Components of the Agenda 2020 IFPB Technology Strategy

Value Prior to Pulping –

Fermentation/Biochemical Pathway

New Value Streams from residuals and spent pulping liquors –

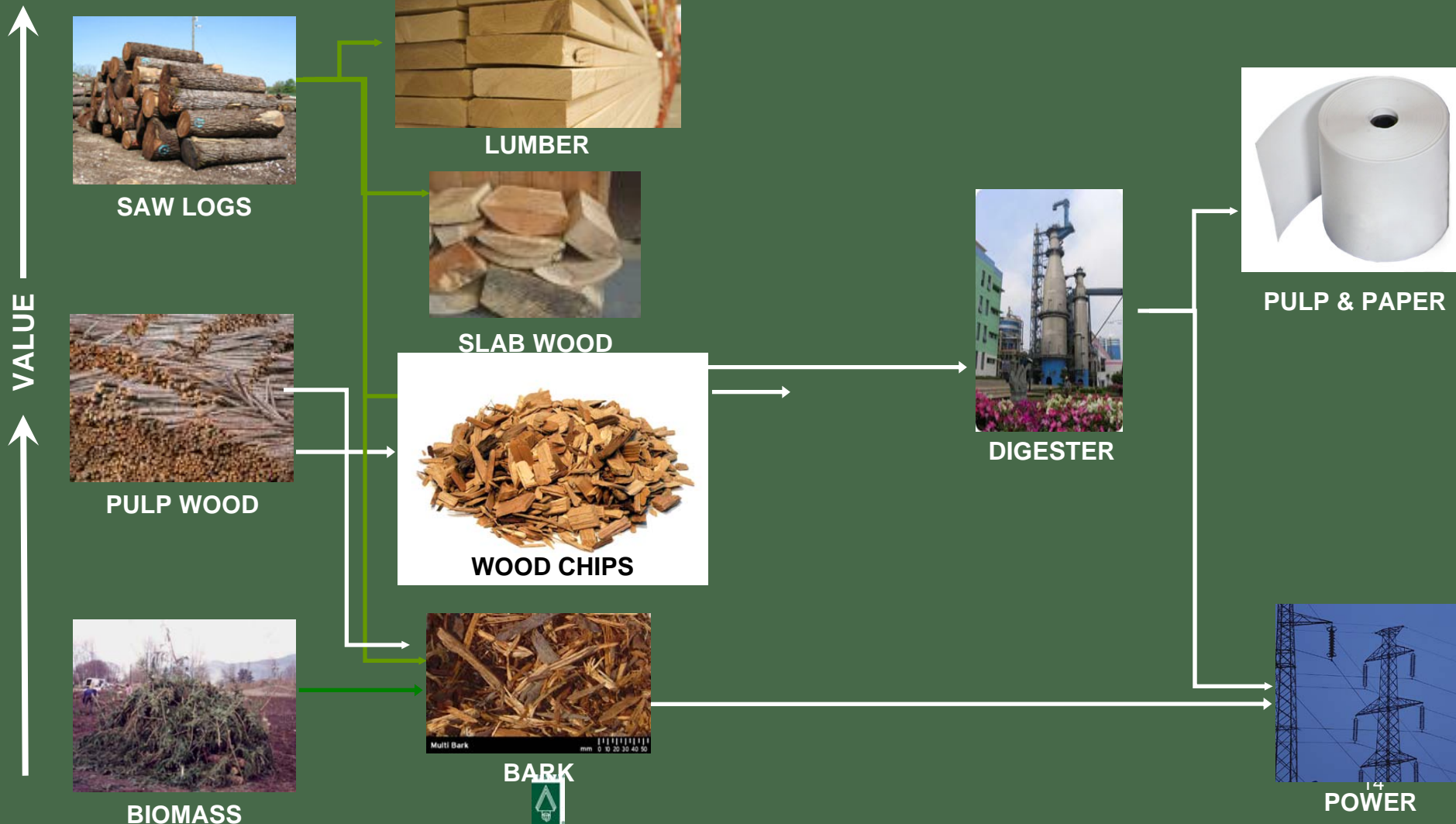
Thermochemical Pathway

Sustainable Forest Productivity

Feedstock Pathway



Forest Value Map



Forest Value Map



Forest Products Industry Advantages

- Forest-based materials as feedstock
- Industry has infrastructure and expertise
- IFPB technologies have potential for significant national benefits
- Carbon benefits
- Initial economics are compelling



Bioconversion Pathway (Fermentation)

- Hemicellulose makes up about 20 to 30% of the wood
- Hemicellulose extracted without damaging the fiber
- Hemicellulose fermented and distilled into ethanol



Thermochemical Pathway (Gasification)

- Achieve high conversion efficiencies
- Biomass stream converted to a higher value products
- Convert all of the plant and not limited to the sugars.
- Conversion efficiencies in excess of 75%
- ~60% of energy converted into synthetic gas
 - Fuel in boilers, gas turbines, lime kilns, direct fired dryers, etc.
 - Converted to a bio-crude or (Fischer Tropsch) fuels/chemicals
- Additional 20% to 25% of the energy recovered and converted to steam



Value Prior to Pulping

Separate and extract selected components of wood prior to pulping, and process these streams to produce commercially attractive chemical and liquid fuel products

- Hot water extraction vessels
- Hemicelluloses extracted
- Acetic acid separated, and sugars fermented to ethanol
- Ethanol - low end of products
- Improves throughput potential
- Fermentation - produce high-value chemicals and ethanol
- Key Technologies
 - Hemicellulose extraction
 - Hydrolysis and Saccharification
 - Fermentation (enzymes)



Value Prior to Pulping

- Reference Mill
 - Single large Kraft pulp mill
 - Using the base case from Larson et al, 2002
- Output
 - 9.5 - 14.3 million gallons of ethanol
 - 3.0- 4.5 million gallons of acetic acid
- Capital Cost (preliminary estimate)
 - ~ \$50 million for vessels, distillers, membranes & controls
- Operating Cost
 - ~ 8.7 million or ~ 35 cents/gallon
- Net Revenue Increase
 - ~ \$8.8-13.2 million per year



Value to the US Pulp & Paper Industry

- Potential economic benefit to the US Pulp & Paper Industry, given wide scale implementation of the technology:
 - 740 - \$1,100 million/year of new revenue
 - 1.6 – 2.4 billion gallons of ethanol
 - 260 – 400 million gallons of acetic acid
- Replacing 1.6 to 2.4 billion gallons of gasoline with ethanol eliminates
 - 15 to 21 million tons of CO₂,
 - 13 to 20 thousand tons of nitrous oxide
 - 8.5 to 13 thousand tons of VOCs.



Value Prior to Thermo Mechanical Pulping

- Reference Mill
 - 350 BD bleached TPD Spruce TMP pulp mill
- Ethanol Output
 - ~ 1.5 million gallons ethanol
- Energy Savings
 - 20% reduction in refiner energy
 - 62 megawatt-hours saved annually
 - \$3,400,000/year energy savings (\$55/Mwh)
- Softwood Kraft Savings due to stronger TMP
 - 5-6 parts of SWK reduced
 - \$5,500,000 saved fiber costs
- Operating Costs = \$1- 2 million/year
 - Extra wood costs and pretreatment costs
 - Enzymes, fermentation, and distillation costs
- Potential = \$10,000,000/year in net revenue and cost reductions
- Given wide scale implementation in the US
 - 40 million gallons/year ethanol
 - \$250,000,000 in new revenue and variable cost reductions



Value to Our Industry

- Potential of changing the nature of the pulping process - pulping without sulfur
 - A sulfur-free pulping process - simplify the downstream processes
 - Improve the economic and environmental outlook
- Maintain the competitive position of paper industry
- New facilities built — significantly expanding production potential
- Pulp mills - attractive sites/partners for ethanol producers
 - The incremental capital much less than for a “green field” plant
 - The integration of ethanol production facility - significant savings in operating costs



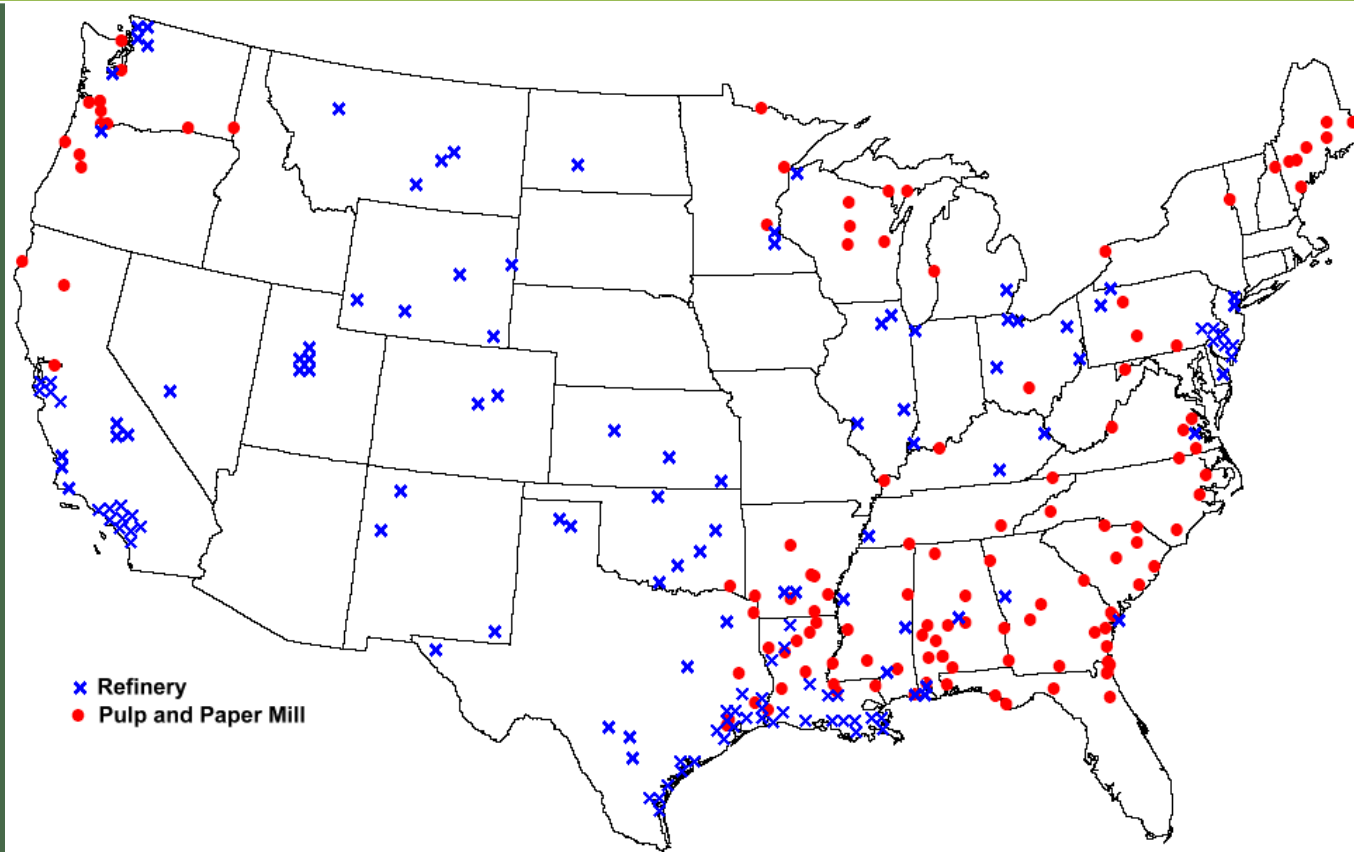
Potential Markets for Fuels and Chemicals

	U.S. Market Size, 2005		Average refinery gate price (excl. taxes), 2005	Approximate market U.S. wholesale, 2005
	Physical Units	Quads per yr		
FUELS				
Motor gasoline	9.13 million bbl/day	17.2	\$1.67/gal \$13.6/million BTU	233 B\$/yr
Motor diesel	4.11 million bbl/day	8.74	\$1.75/gal \$12.6/million BTU	110 B\$/yr
LPG	2.02 million bbl/day	3.05	\$0.92/gal \$9.36/million BTU	29 B\$/yr
Ethanol	0.26 million bbl/day	0.34	\$1.89/gal \$22.4/million BTU	8 B\$/yr
Natural Gas	21.98 trillion SCF	22.6	\$7.51/scf (well head) \$7.31/million BTU	165 B\$/yr
CHEMICALS				
Methanol	0.185 million bbl/d (2001)			3-4 B\$/yr
Hydrogen	10 million t (15% of which is merchant)			15-75 M\$/yr (merchant)
Ammonia	21 million tons (2001)			2-7 B\$/yr
Mixed Alcohols	3.7 billion pounds			3-4 B\$/yr

Source: Princeton/Navigant

Pulp & Paper Mills and Petroleum Refineries

Location of U.S. Refineries and Pulp and Paper Mills



Sources: Paper mills: Lockwood-Post, 2001; Refineries: National Petrochemical and Refiners Association, *NPRA United States Refining and Storage Capacity Report*, July 2004 (NPRA data based on DOE EIA's 2003 Petroleum Supply Annual and covers 149 refineries)

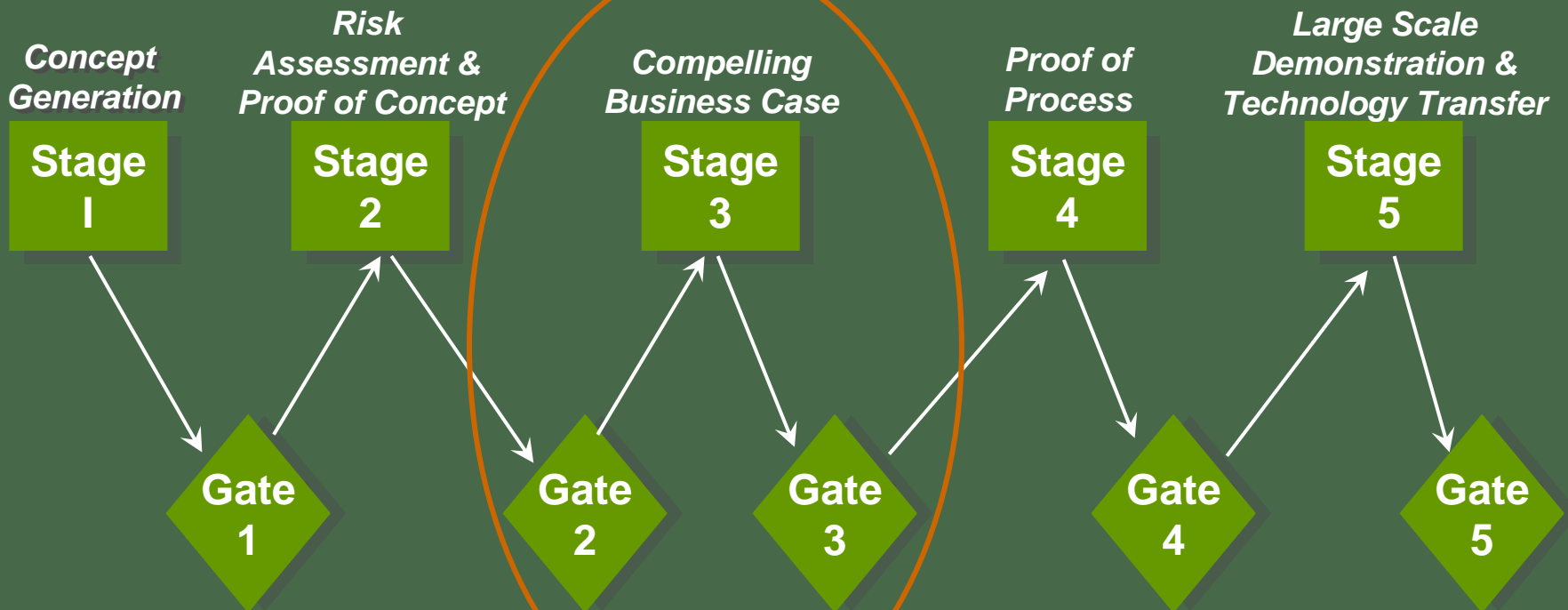


Industry Goals of Project

- Objective of VPP - Demonstrate commercial feasibility
- Goal - develop scientific and economic information to make informed decisions:
 - Credible and convincing business case?
 - Sufficient positive societal impact?
 - Move to commercialize and deploy technology?



VPP Status – Where are we?



VPP Status – 2008

- Project Kickoff meeting held in 2007
- DOE grant for \$1,523,000 project finalized
- Total current committed resources - \$2,656,000
- Additional resources being pursued - \$580,000
- Additional VPP membership being pursued



VPP Status – Project Teams

- Pre-Extraction & Pulping
- Extract Processing
- Fermentation & Ethanol Production
- Modeling & Business Case Development



Proof of Concept Deliverables

- Pre-extraction of hemicellulose sugars
- maintaining value and quality of pulp
- High yield production of ethanol from pentose and hexose sugars
- Recover acetic acid
- Integration of production processes into pulp mills



Compelling Business Case Deliverables

- Process modeling, capital costs, equipment, energy & environmental analysis and economics
- Business Cases developed for both kraft and TMP
- Economic implications of non-sulfur pulping options



Participating Pulp & Paper Companies

Pulp & Paper Companies

- New Page
 - International Paper Company
 - MeadWestvaco
 - Potlatch
 - Longview Fibre
 - SAPPPI
 - Weyerhaeuser
-
- DOE contract Managed by Clean Tech Partners



Questions?

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