PASI 2008 Pan American Advanced Studies Institute Program on Emerging Trends in Process Systems Engineering

Case Study:

Product and Process Design Methodologies for Engineering the Forest Biorefinery

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Process Integration in the Pulp & Paper Industry

"Economic Stalement" for NA and European Forestry Companies

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Some Forestry Industry Survival Strategies

- Go for Survival in Commodities, or *Make the Most of Our Existing Industry*
- Buy/Build Elsewhere In Emerging Markets, or *Make the Most of Our Pulp and Paper Competency in Emerging Economies*
- Diversify Core Business with Marketing & Technological Partners, or *Make the Most of Our Existing Value Chain by Migration to New Business Paradigms*

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→ **The Forest Biorefinery!**

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The Dilemma

Forest industry strategists are talking about "revenue diversification" and industry transformation via the forest biorefinery….

…do forestry company executives know how to go about designing and implementing biorefinery?

How should we apply process systems engineering techniques to address the biorefinery, recognizing that it is an industry transformation?

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Tembec Temiscaming: Forest Biorefinery?

Temiscaming Complex

Tembec

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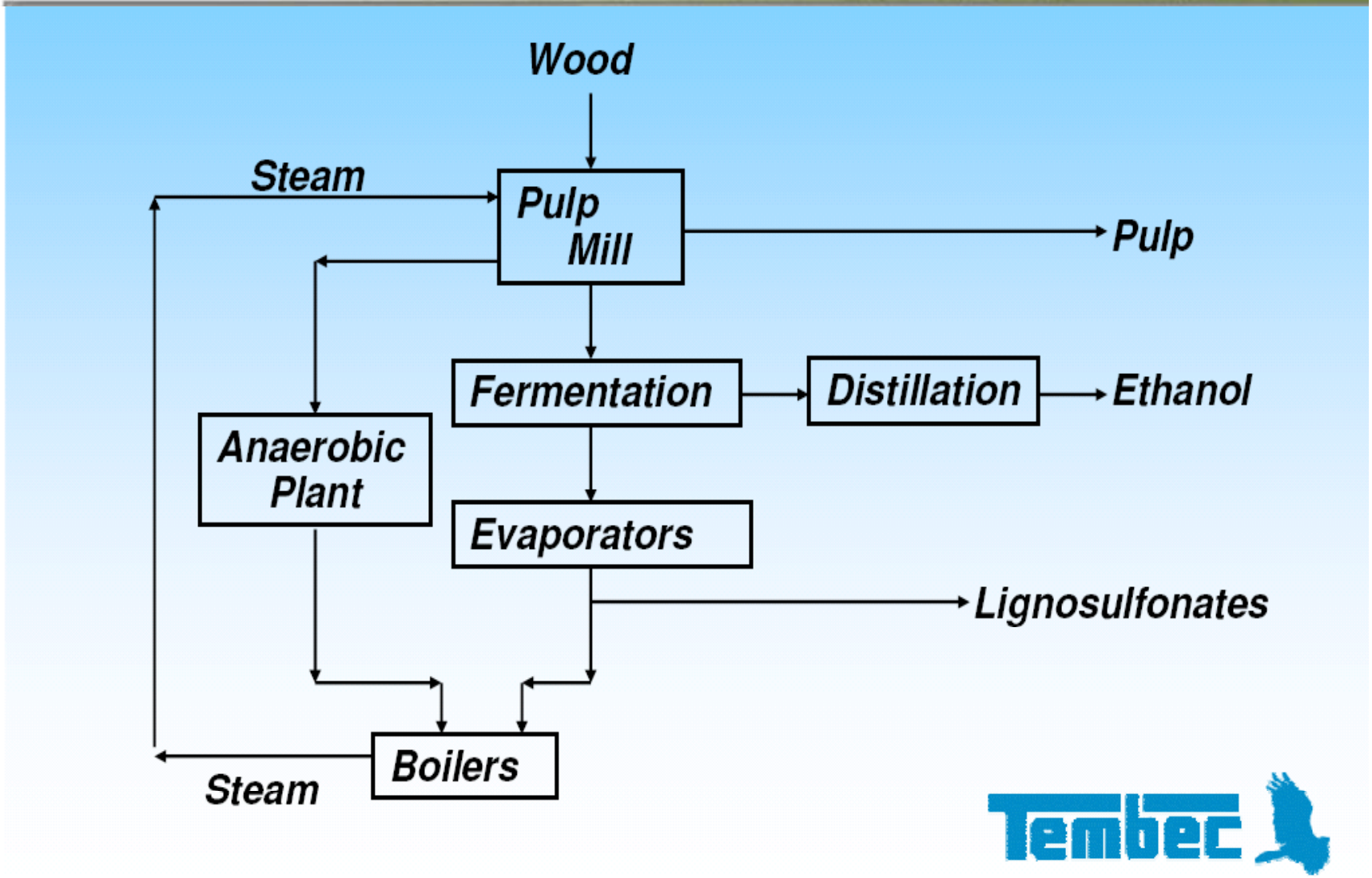
Tembec Temiscaming: Forest Biorefinery?



Tembec

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Tembec Temiscaming: Forest Biorefinery?

Bio-Ethanol

- ***Capacity:***
  - *18 million liters per year*
- ***Second largest industrial alcohol supplier in Canada***
- ***High purity (95%)alcohol produced from a renewable resource***
- ***Vinegar***
- ***Mouth washes***
- ***Pharmaceutical products***
- ***Only "true" green ethanol producer in North America.***

Tembec

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Forest Biorefinery Definition

One forest biorefinery definition:

= full utilization of incoming woody biomass for the production of:

- Wood products
- Pulp and paper products
- Energy
- Chemicals

see background papers by Galbe & Zacchi (2002) and Larson et al (2006)

- Another (more practical) forest biorefinery definition:

  = Maximizing the economic value from trees
  = Improved business model
  = Corporate transformation…

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The Challenge: Mitigating Risks, Improving Existing Core Business

Un clásico. Dos astros.

Pulp & Paper Sector: *Stalemate situation*

Opportunity: *Biorefinery*

Identify & Mitigate risks

- Technical
- Economic
- Commercial

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Objective of this Presentation

To present (certain) critical issues that should be considered by forestry companies seeking to identify promising biorefinery pathways

based on biorefinery design activities, consulting activities, and pulp and paper company strategic planning

leading to a proposed **implementation strategy** and multidisciplinary **design methodology** employing **process systems engineering**, for exploring the implementation of the forest biorefinery.

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Presentation Outline

- Leading companies are implementing the forest biorefinery
- Key biorefinery concepts and definitions
- Biorefinery **implementation strategy** for forestry companies
- Overall **design methodology** for the forest biorefinery
- Some interesting **process systems engineering** approaches that we are exploring

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  - See 3 survey papers by Thorp, March-May 2008
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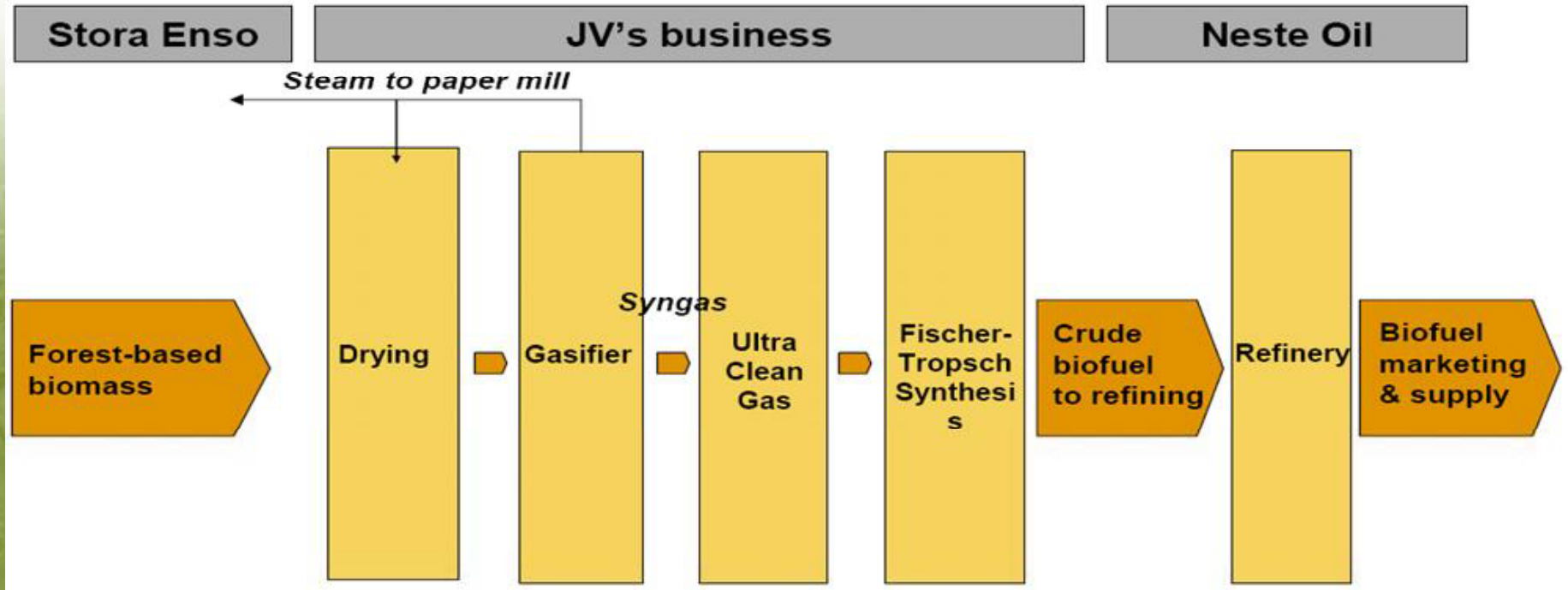
NSE Biofuels Oy Ltd

Demonstration planned for Varkaus Mill (2008)



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Catchlight Energy

Chevron-Weyerhaeuser Biofuels JV (March 2008)

Weyerhaeuser

About Us | Our Businesses | Environment | Media Gateway | Citizenship | Investors | Careers | Suppliers

Weyerhaeuser and Chevron Create Biofuels Alliance

We have signed a letter of intent with Chevron Corporation aimed at developing renewable transportation fuels derived from cellulose.

Chevron

At Weyerhaeuser, we believe in releasing the potential in trees to solve important problems for people and the planet. The need for imaginative, sustainable solutions to the world's challenges has never been greater.

We currently collaborate with several research universities, national laboratories and technology-based companies in research on conversion of forest products into ethanol and other biofuels. Our latest alliance with Chevron Corporation is another step toward finding innovative uses for cellulose fiber to help meet growing energy needs. We feel cellulosic biofuels will fill an important role in diversifying the nation's energy sources.

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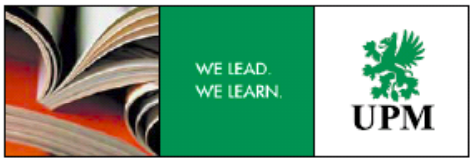
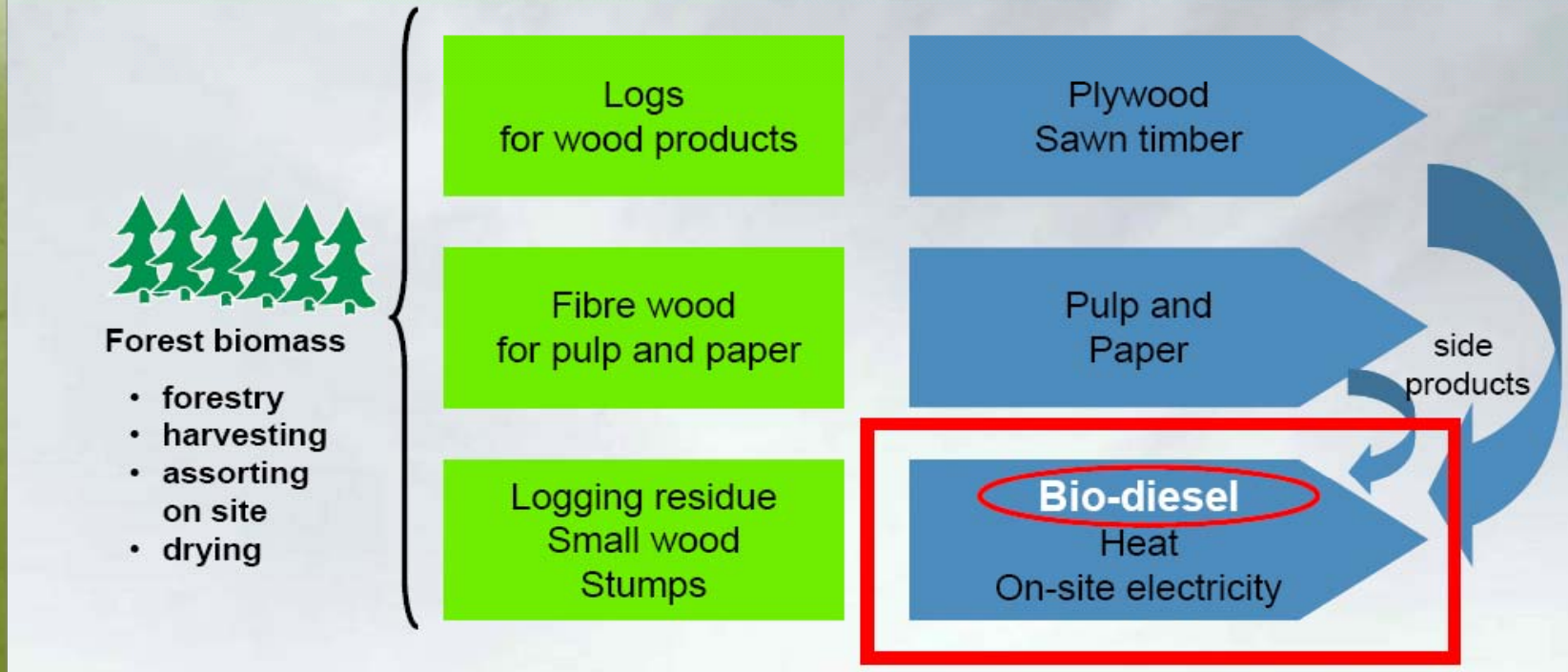
UPM-Kymmene Report to Investors

R&D increased from 50 to 80 MM euros (March 2007)

PORTFOLIO DEVELOPMENT – BIODIESEL

Sustainable optimisation of gain from biomass base adds value





Bio-diesel is a natural extension for a company whose core business is adding value to wood raw material-
primary fibres will remain in pulp and paper production

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  engineering approa
  exploring

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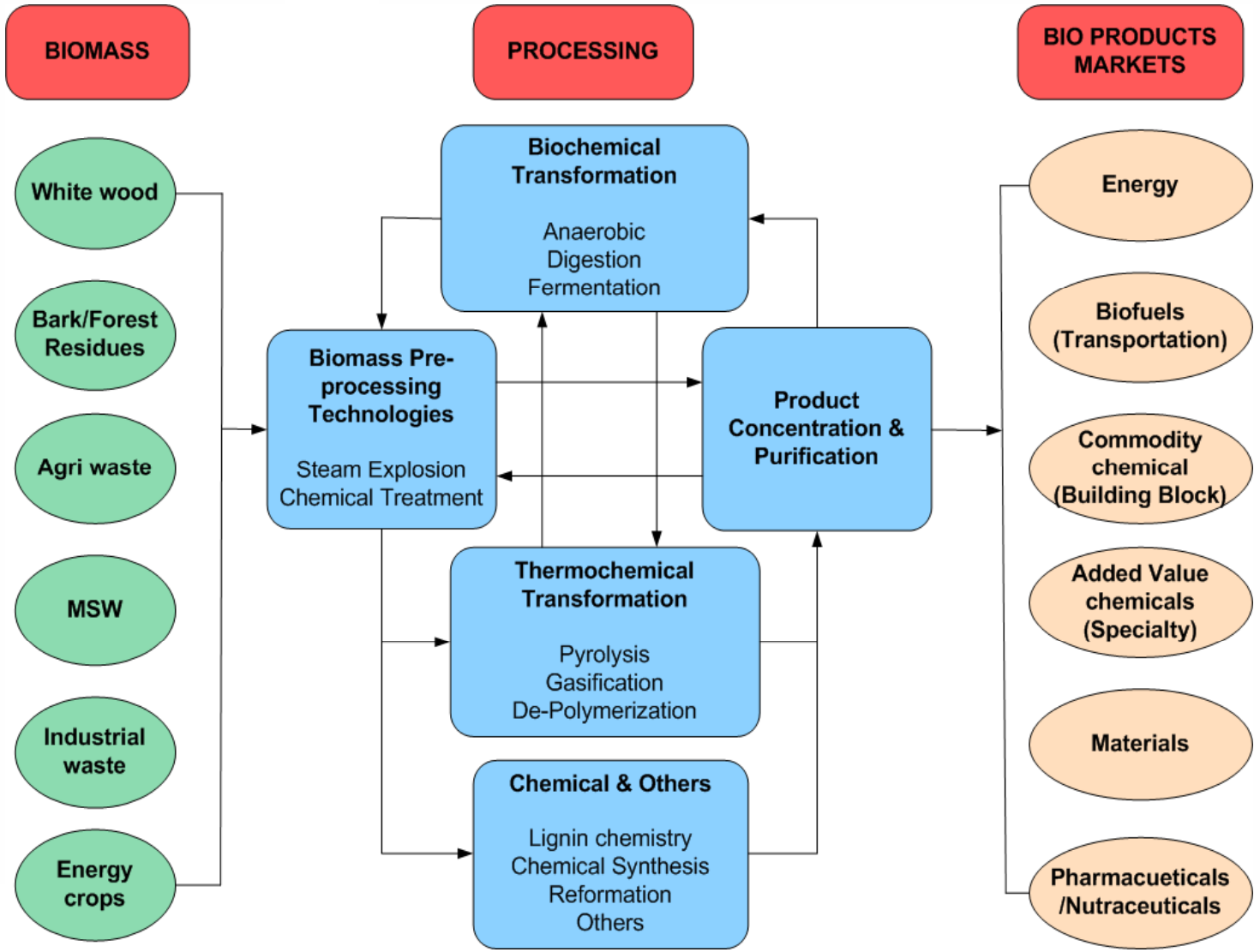
Identifying the Right Biorefinery Configuration is Complex…



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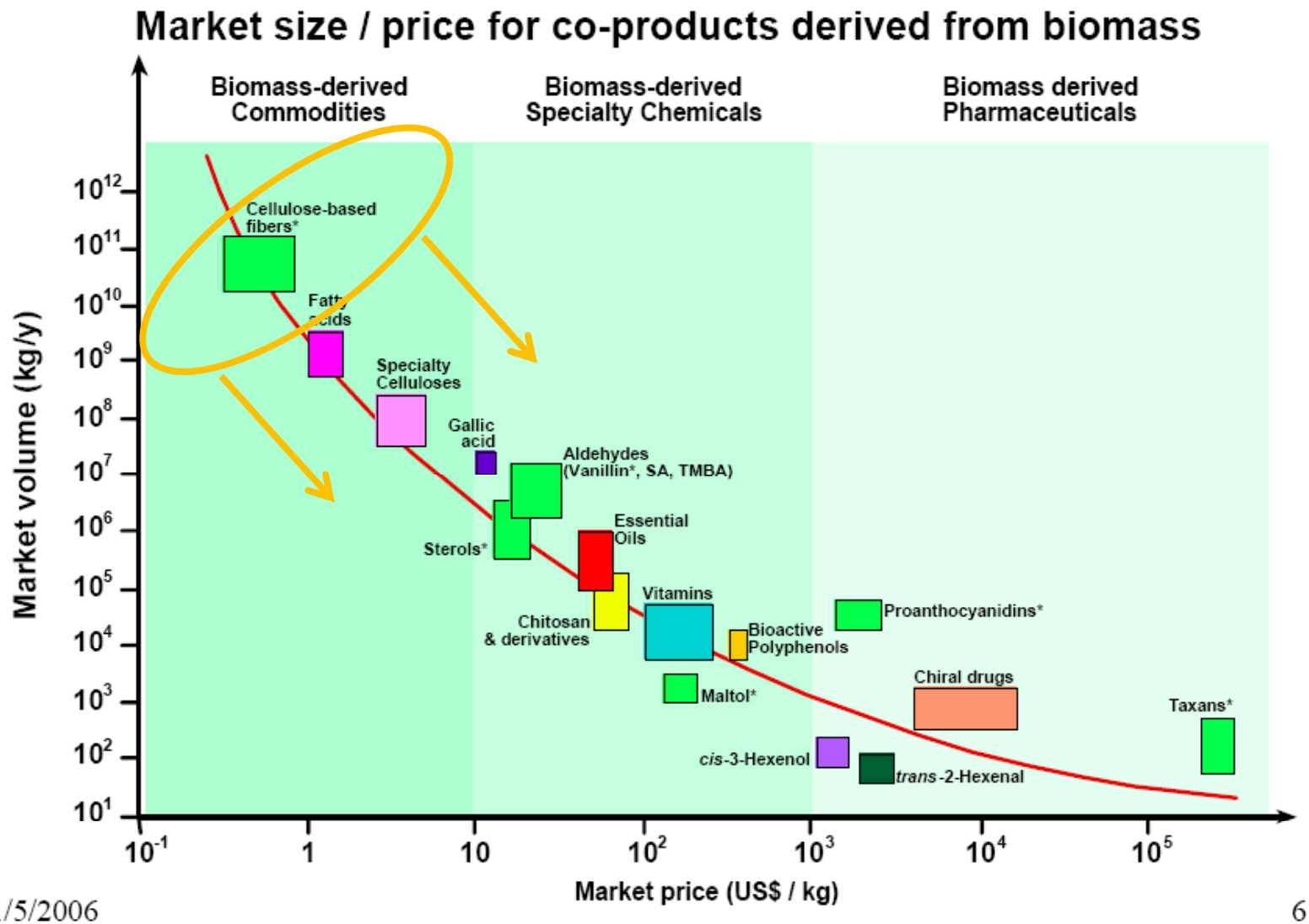
Volume-Margin Trade-Offs for the Forest Biorefinery



Industry Canada Nov 2005

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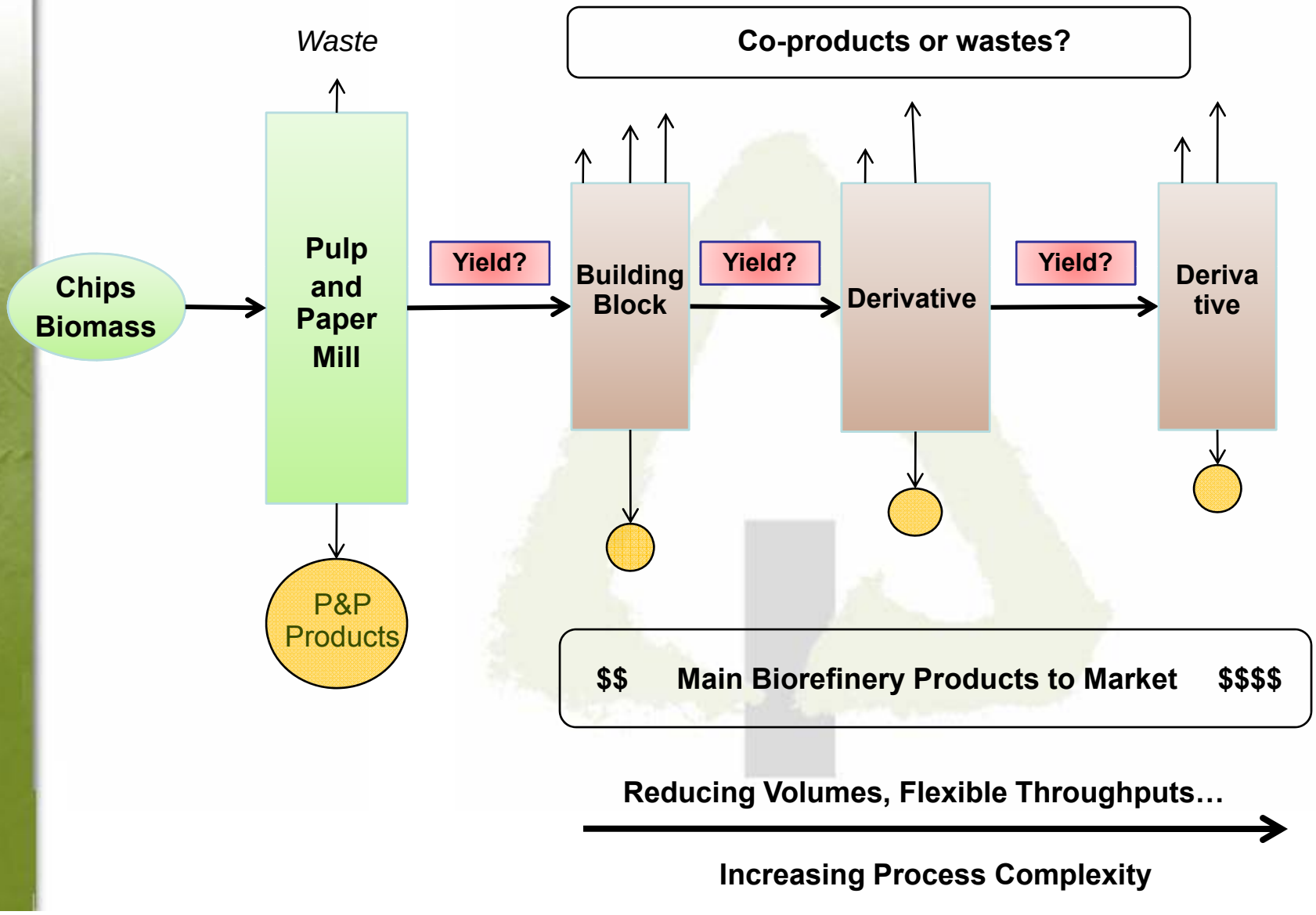
Definition: Building Blocks and Derivatives…



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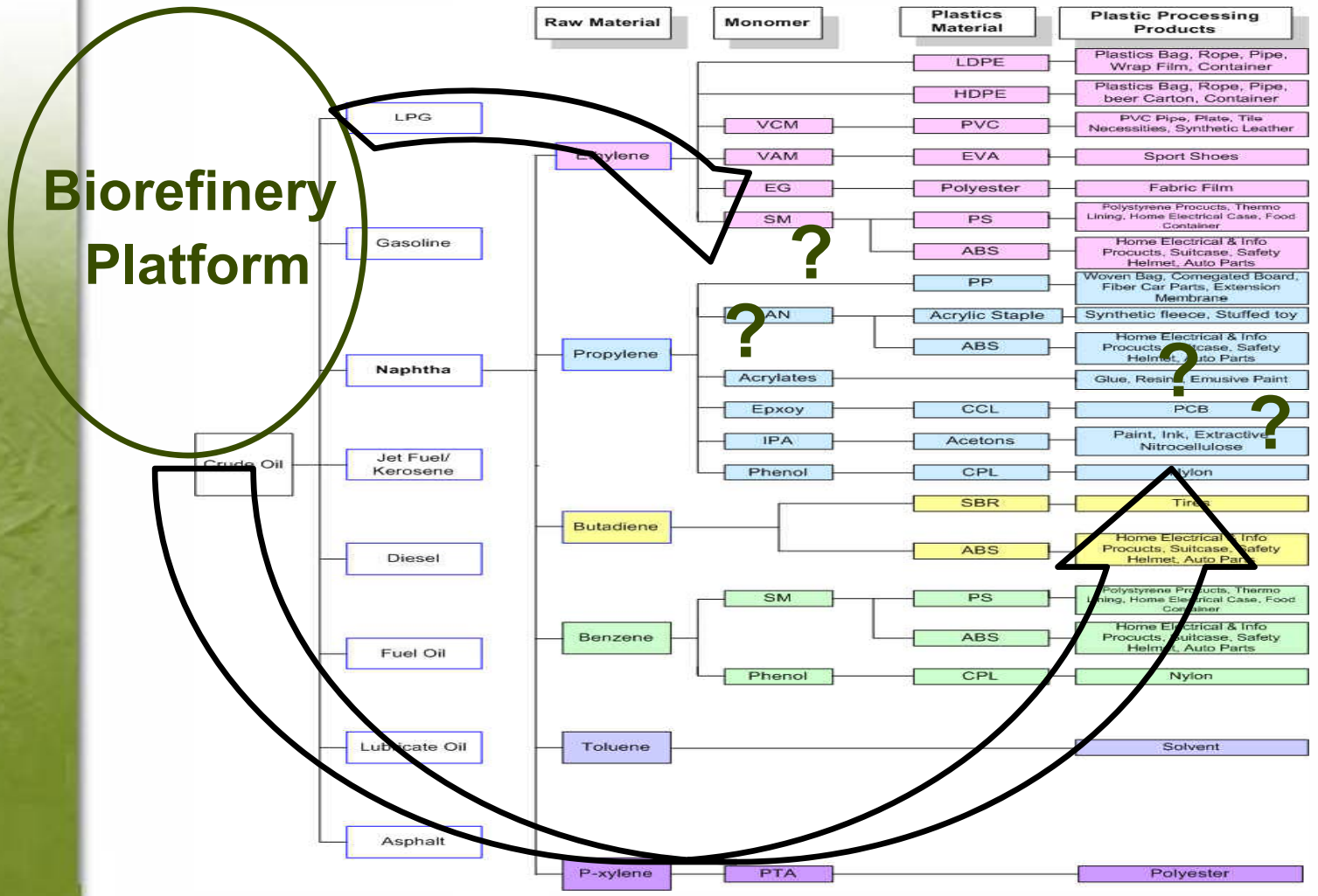
Definition: Petrochemical Value Chains and Product Replacement



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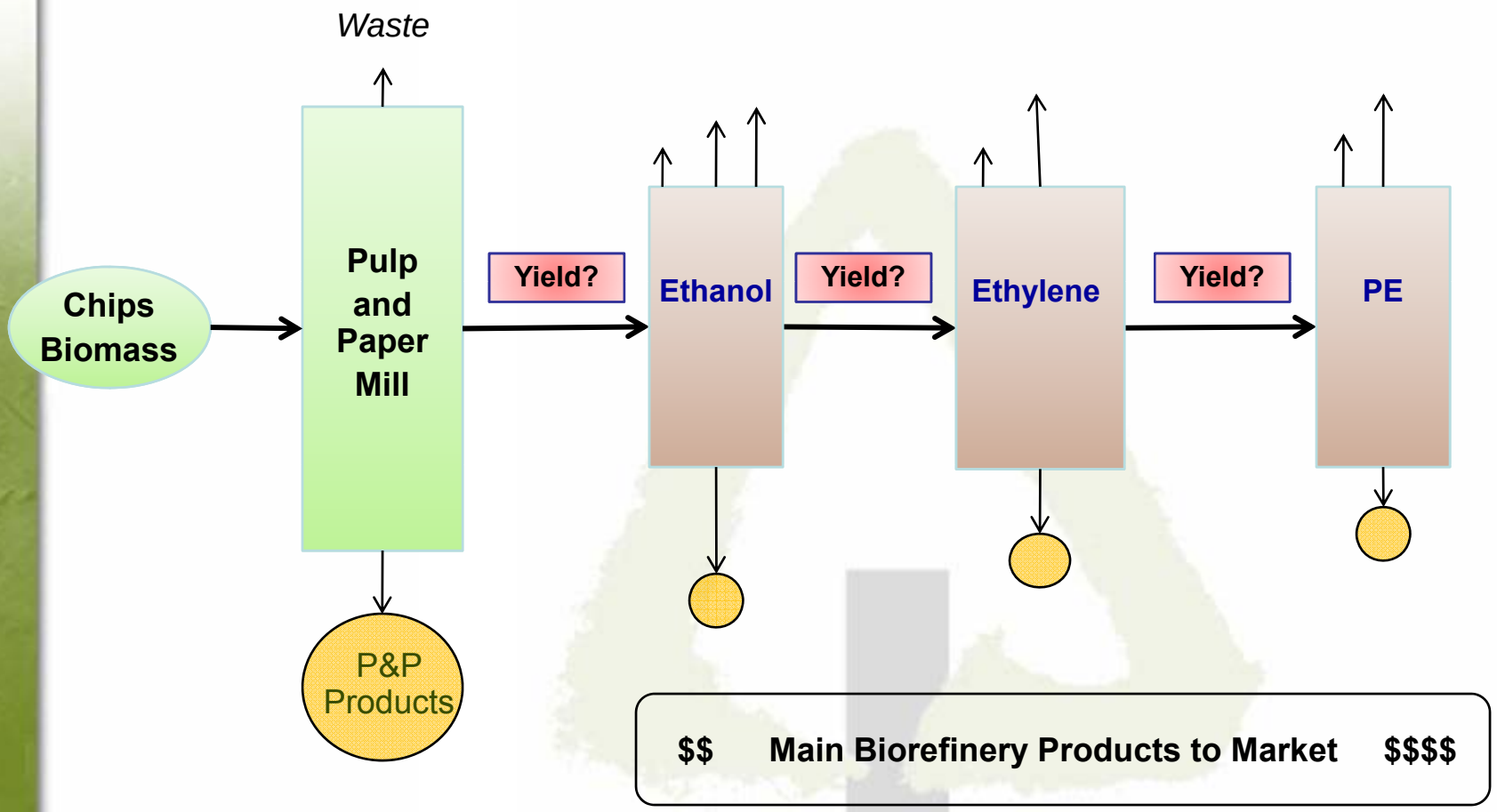
Example: Product Replacement in Mature Supply Chain…



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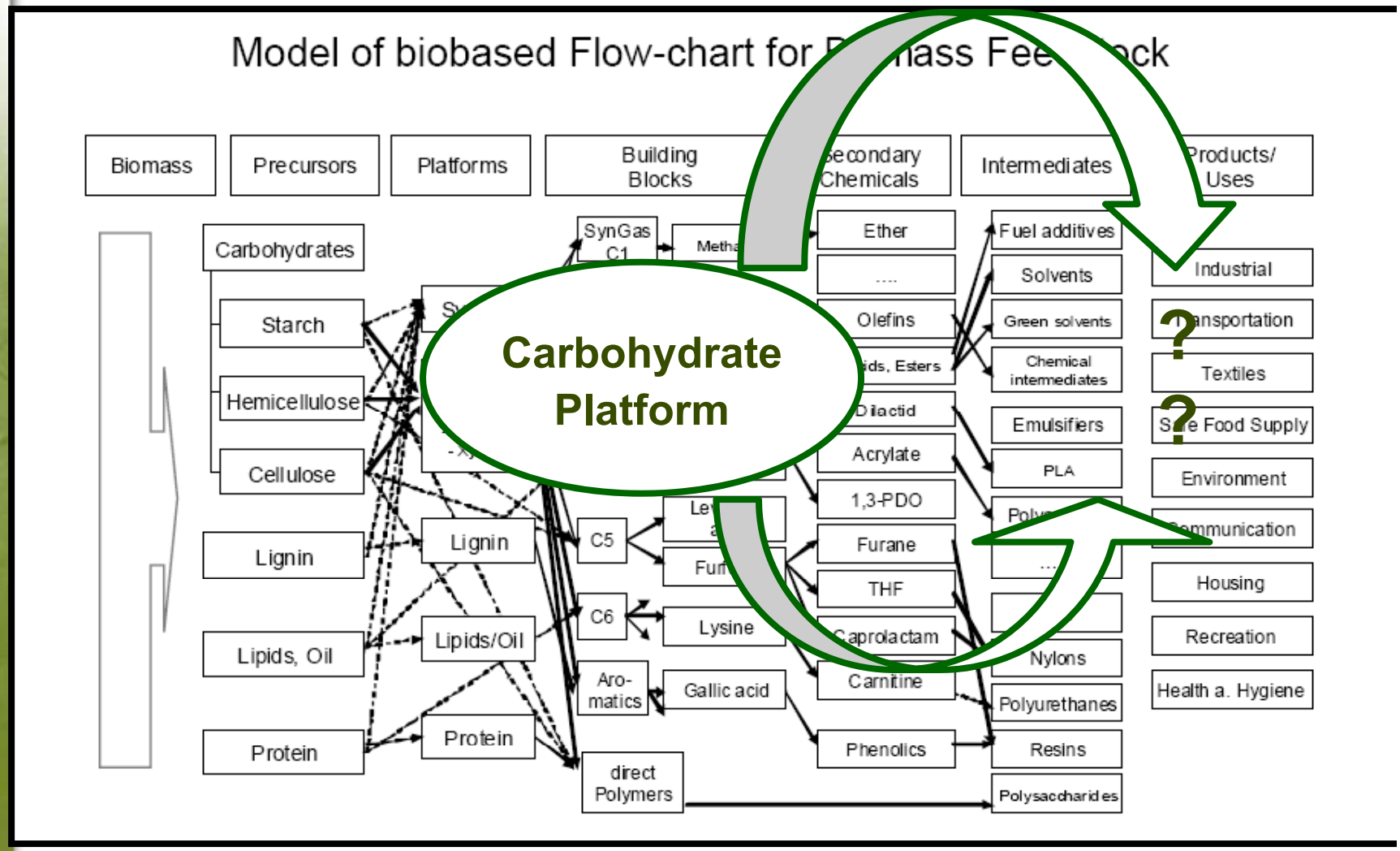
Definition: Emerging Carbohydrate Platforms and Product Substitution



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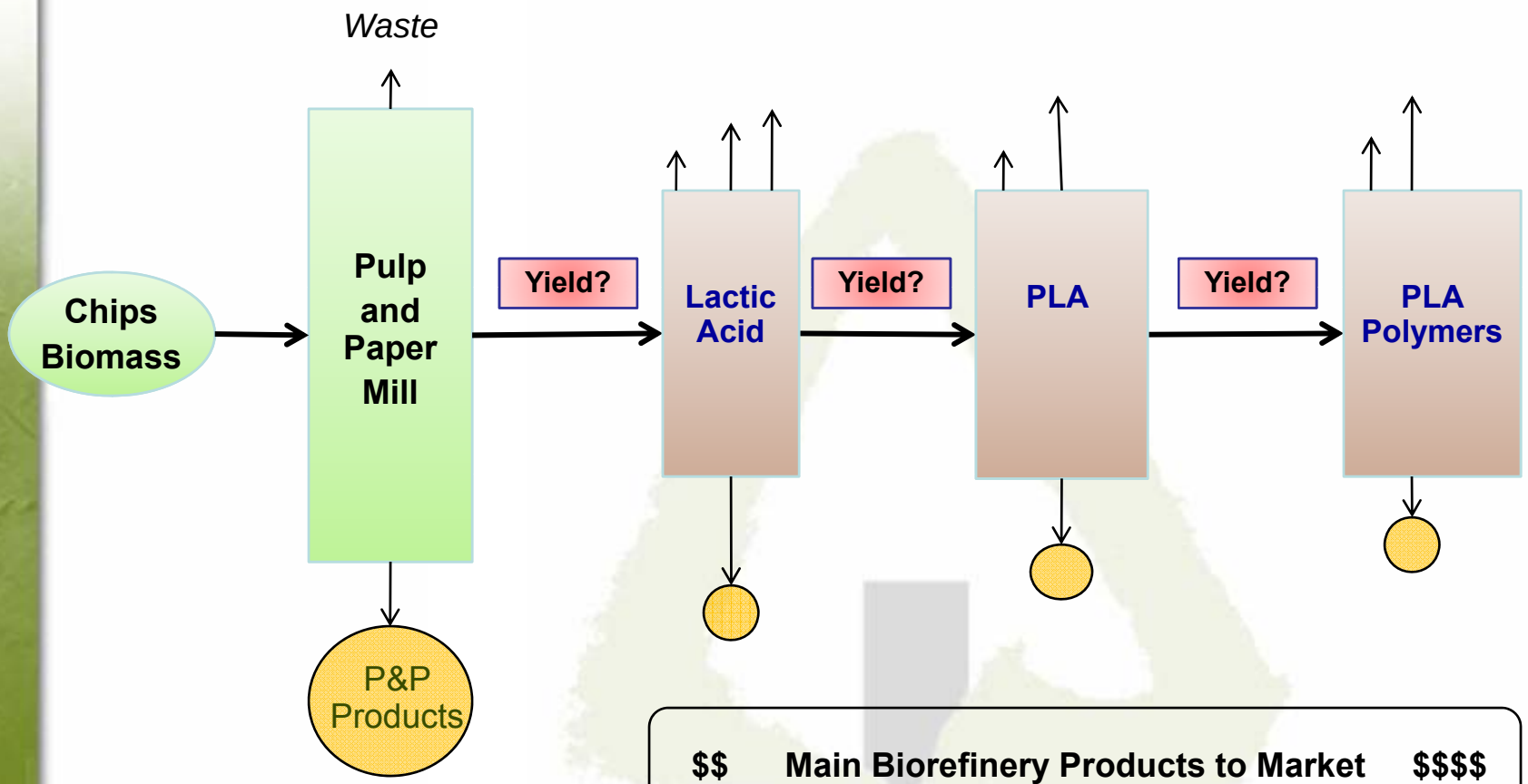
Example: Product Substitution in Emerging Supply Chain…



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Process Integration in the Pulp & Paper Industry

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Process Integration in the Pulp & Paper Industry

Some Key Competitive Factors

- Main competitive advantages for forestry companies:
  - Access to biomass availability and harvesting know-how
  - Existing infrastructure in close proximity to forest biomass
  - Established SC for wood, pulp and paper products
- Main competitive disadvantages for forestry companies:
  - Lack of capital
  - Lack of product development culture
  - Lack of knowledge of product quality requirement, SC practices etc for new bioproducts

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Process Integration in the Pulp & Paper Industry

Some Lessons Learned from Our Case Studies Thus Far...

- Biorefinery **technology** will be critical for competitive position in the short-term, the **unique supply chain** will be critical for competitive position in the longer-term
- In order to be competitive in the longer term: **product design**, before process design
- Meet profitability targets for varying market conditions by designing for **manufacturing flexibility**
- The key to success in the forest biorefinery will be through implementing "**knowledge-based manufacturing**" in conjunction with flexible manufacturing and advanced supply chain management

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Process Integration in the Pulp & Paper Industry

Strategic Approach for Implementing the Biorefinery

Implementation: compete with all capital spending

Phase I
Lower Operating Costs:

- Replace fossil fuels at mill (natural gas, Bunker C), and/or
- Produce "building block" chemicals
- Lower risk technologies

Phase II
Increase Revenues:

- Manufacture of derivatives
- Market development for new products
- Higher process complexity and technology risk
- Partners essential

Phase III
Improve Margins:

- Knowledge-based manufacturing and production flexibility
- Business flow transformation
- Product development culture
- Off-shoring, Outsourcing, etc…

Main challenges

Compete internally for capital

Select the most sustainable product platform and partner(s)

Company culture transformation

SCM key to success

Strategic Vision: Phase III must determine Phase I

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Process Integration in the Pulp & Paper Industry

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- Off-shoring, Outsourcing, etc…

Margins improvement is the goal

Strategic Vision: Phase III must determine Phase I

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Process Integration in the Pulp & Paper Industry

Phase I: Lower Operating Costs

Phase I
Lower
Operating Costs:

- Replace fossil fuels at mill (natural gas, Bunker C), and/or
- Produce "building block" chemical
- Minimum risk technologies

- Generate more free cash flow (EBITDA), in competition with all other capital spending proposals
- The mill operation remains manufacturing-centric, i.e. produces a commodity and seeks to be a low-cost producer
- Seek to reduce biorefinery costs by identifying synergies with the existing mill:
  - Utilization of existing infrastructure to offset equivalent greenfield biorefinery capital cost
  - Exploitation of green credits
- Possible partnership with technology provider

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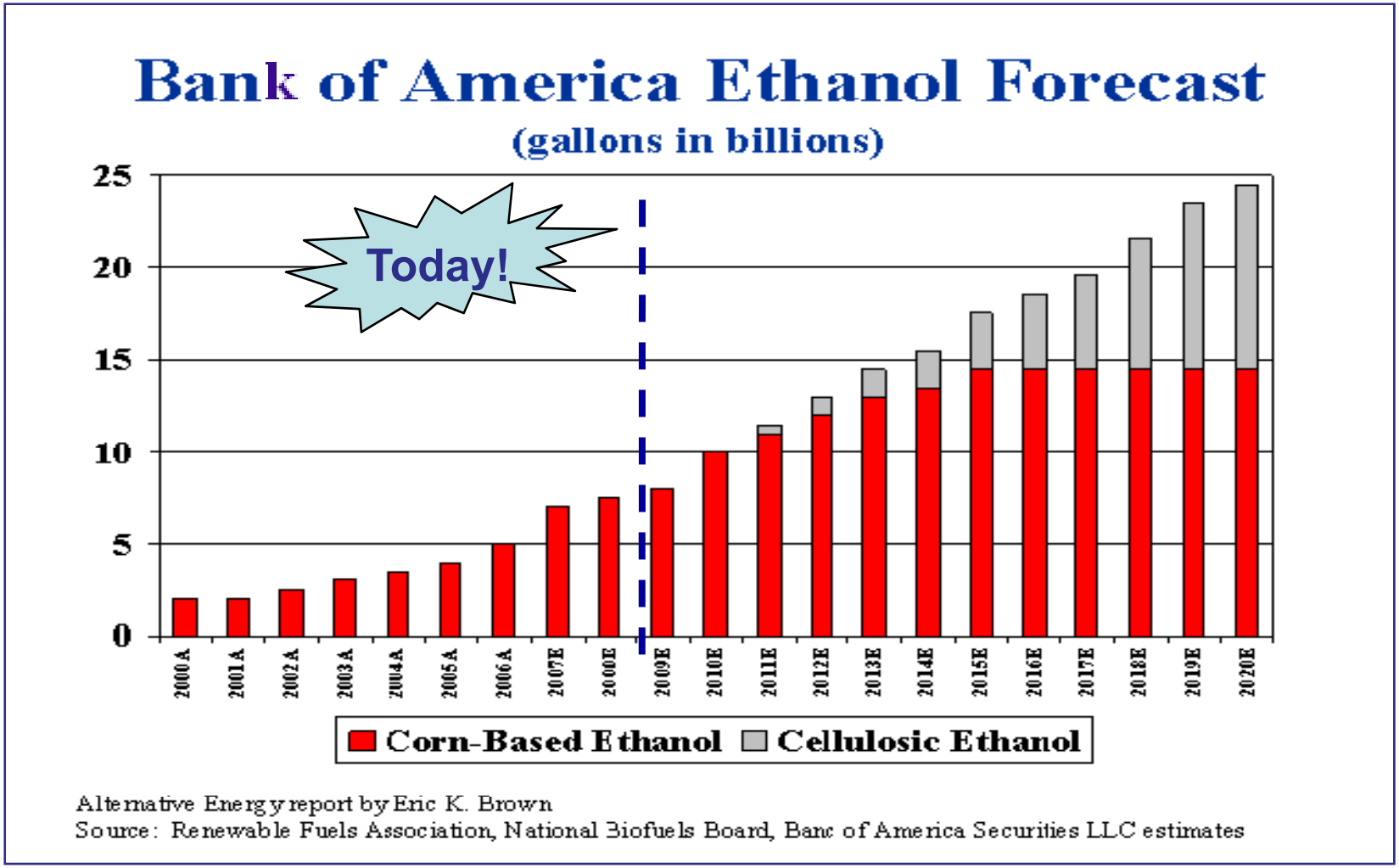
Is Cellulosic Ethanol the Right Product?



Source: NREL - 2006

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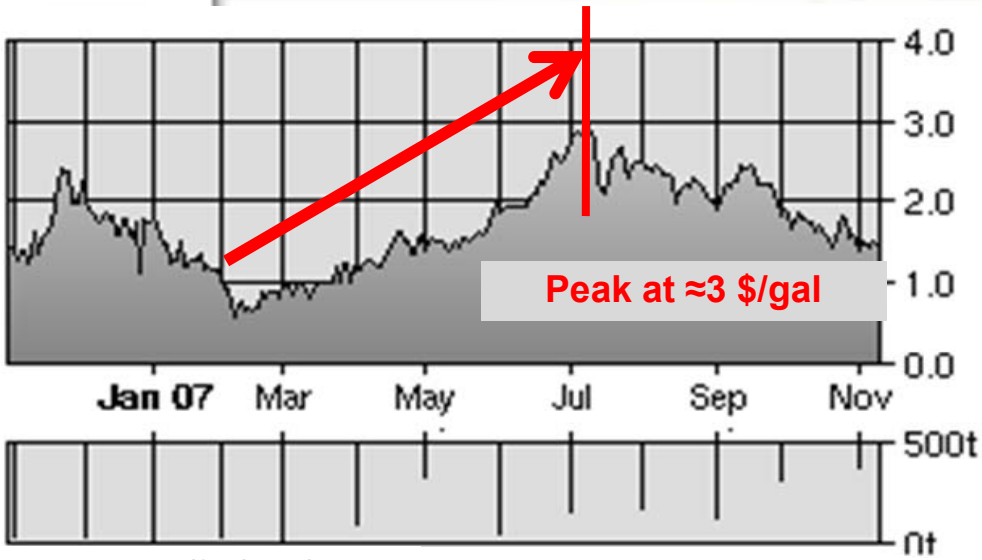
Process Integration in the Pulp & Paper Industry

Ethanol Price Volatility: An Important Risk



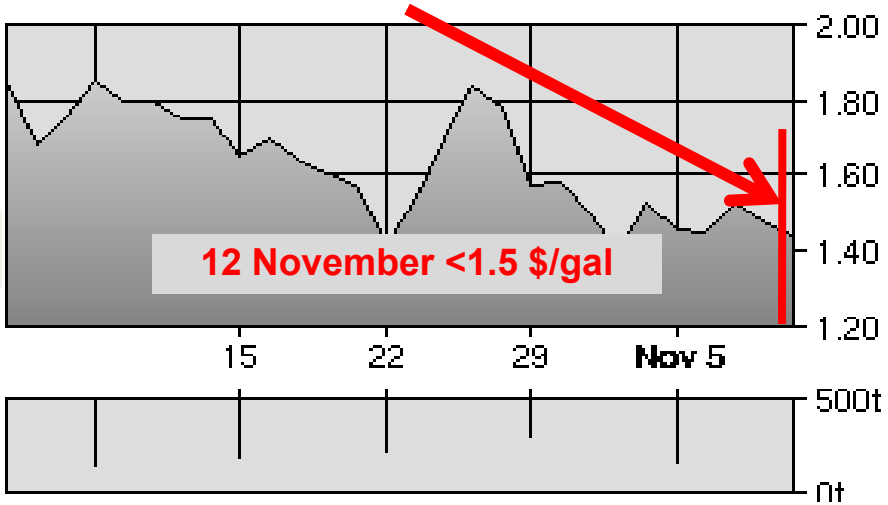
Source: Gulf Ethanol Corp

Price volatility due to:

- Impact of crude oil and natural gas prices
- Changing balance between supply and demand
- Diverse feedstock types and their relative competitiveness
- Energy legislation – tax credits and incentives

In 4 months: Ethanol prices dropped by half…

How can companies stabilize margins in the context of volatility and uncertainty?



Source: Gulf Ethanol Corp

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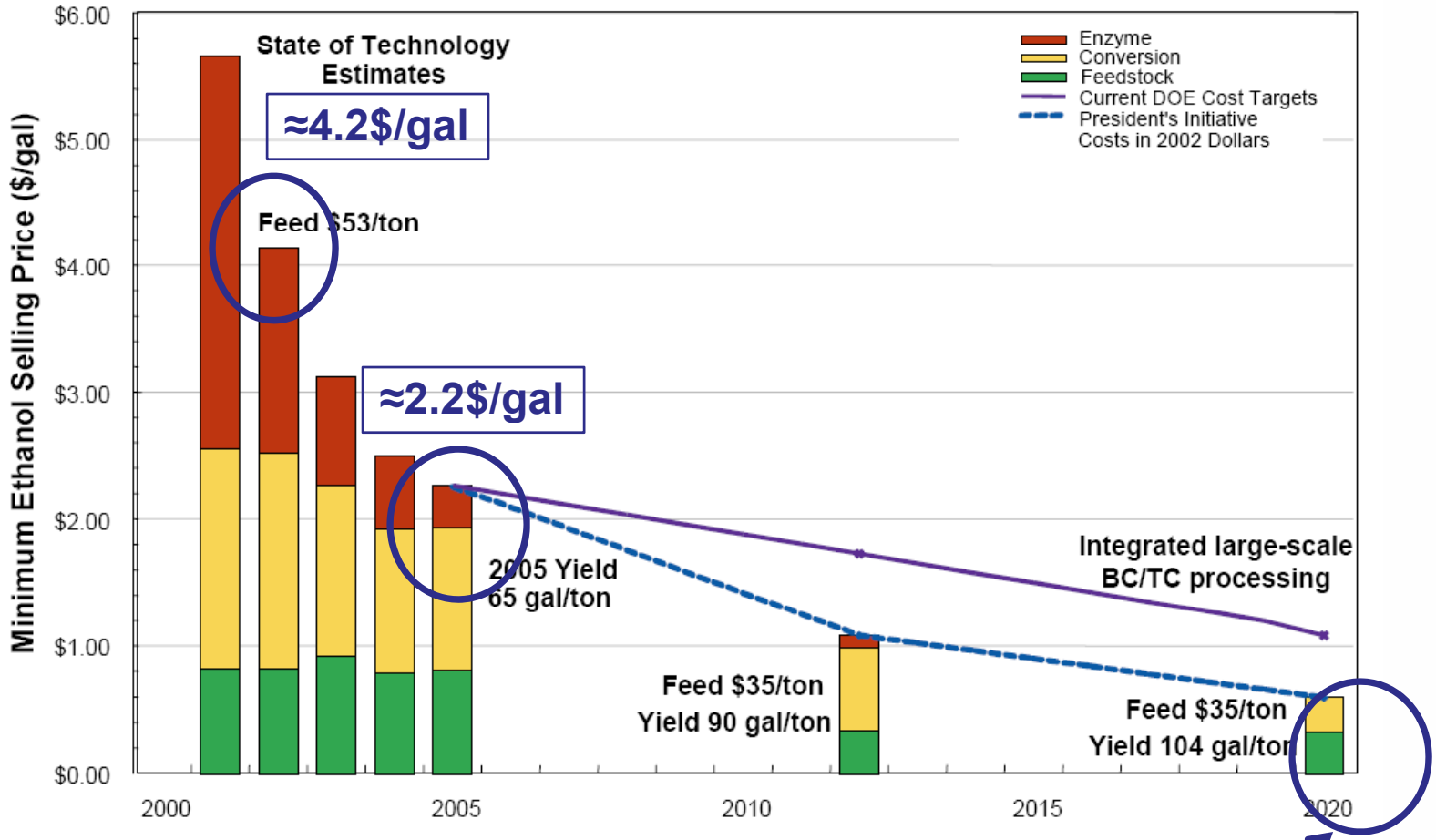
Biochemical Ethanol Technology

Building on Past Successes



Source: NREL - 2006

≈0.6$/gal

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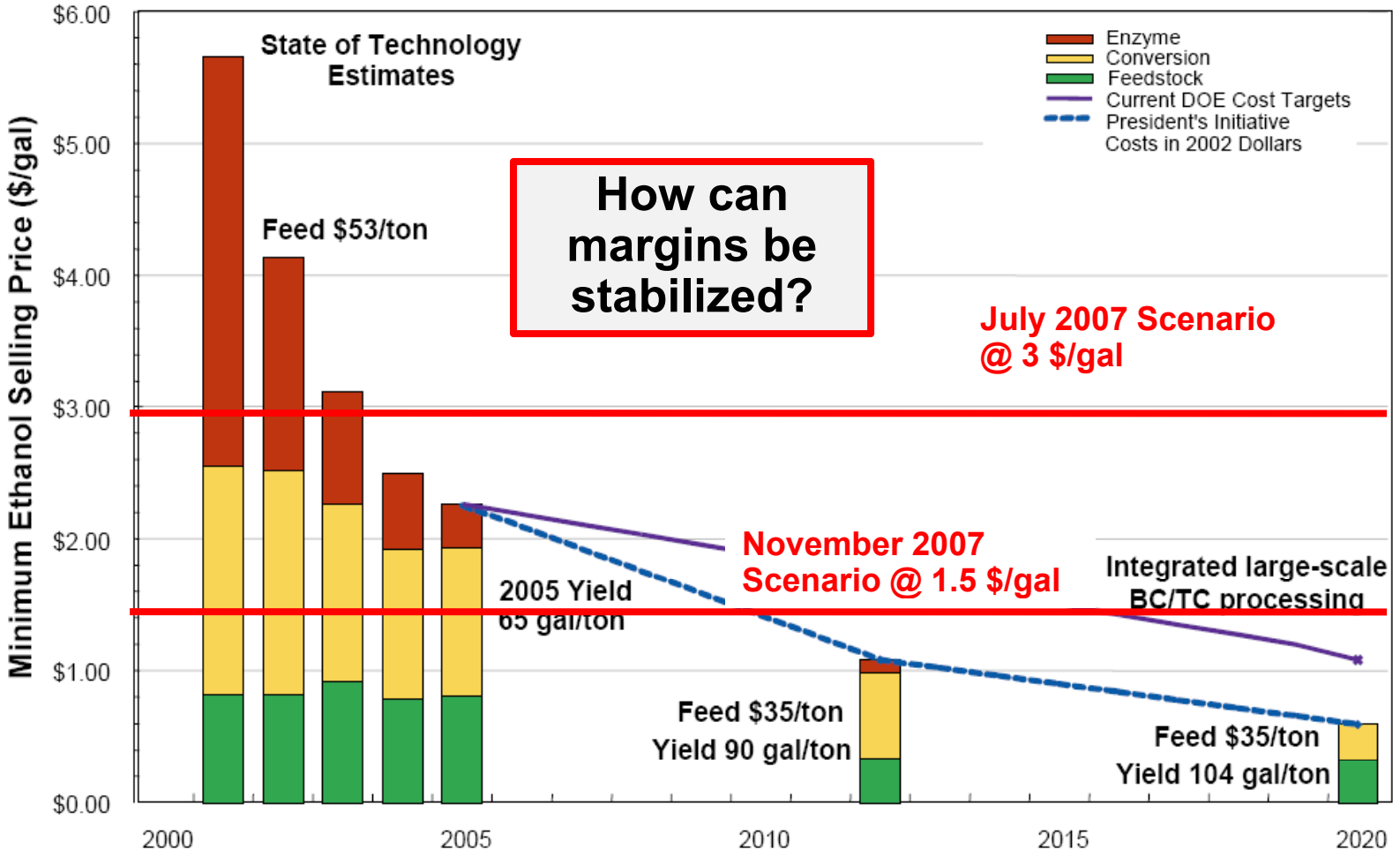
Should Biochemical Ethanol be Implemented Today?

Building on Past Successes



Source: NREL - 2006

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Is Cellulosic Ethanol the Right Product?

- Implementing the forest biorefinery is about mitigating risk…
- …and clearly ethanol represents a great opportunity, but also presents risks
- These can be mitigated as part of a forest biorefinery product design strategy, e.g.:
  - What derivatives can be made from ethanol?
  - What opportunities are there with by-product lignin?
  - What manufacturing flexibility between products is required, including perhaps producing ethanol from cellulose?
- Before implementing ethanol production facilities, know what product portfolio your company will ultimately produce…

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Process-Centric and Product-Centric Design

- "*Towards a Product-Centered Chemical Industry - Rethinking the Role of R&D and its Interaction with Marketing and Business Strategy*" FOCAPD (2004), and AIChE webcast (2004 – see link in background materials)

George Stephanopoulos, MIT

- Chemical Engineering is moving from being process-centric to product-centric
- Product centered: market trends → product specifications → components and subsystems → chemicals and materials → manufacturing systems design

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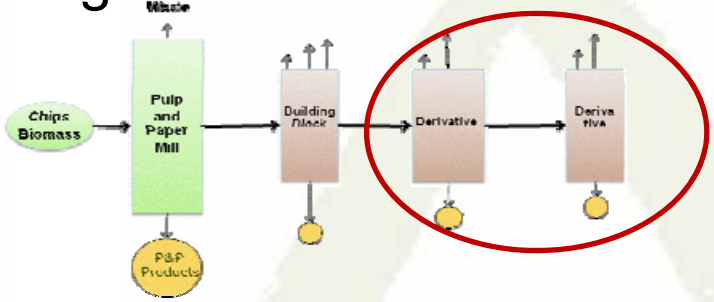
Start With Phase II: Define your Product Portfolio

Phase II
Increase Revenues:
- Manufacture of derivatives
- Market development for New products
- Higher complexity and risk technologies
- Partners with SC

- Product Design first, Process Design second
  - Increase revenues by producing new "green" organic chemicals



Derivatives

- Determine promising product portfolios for your company using a market perspective
  - Which are technically feasible?
  - Secure the best partners for securing the value chain…
  - Examine the implied company transformation

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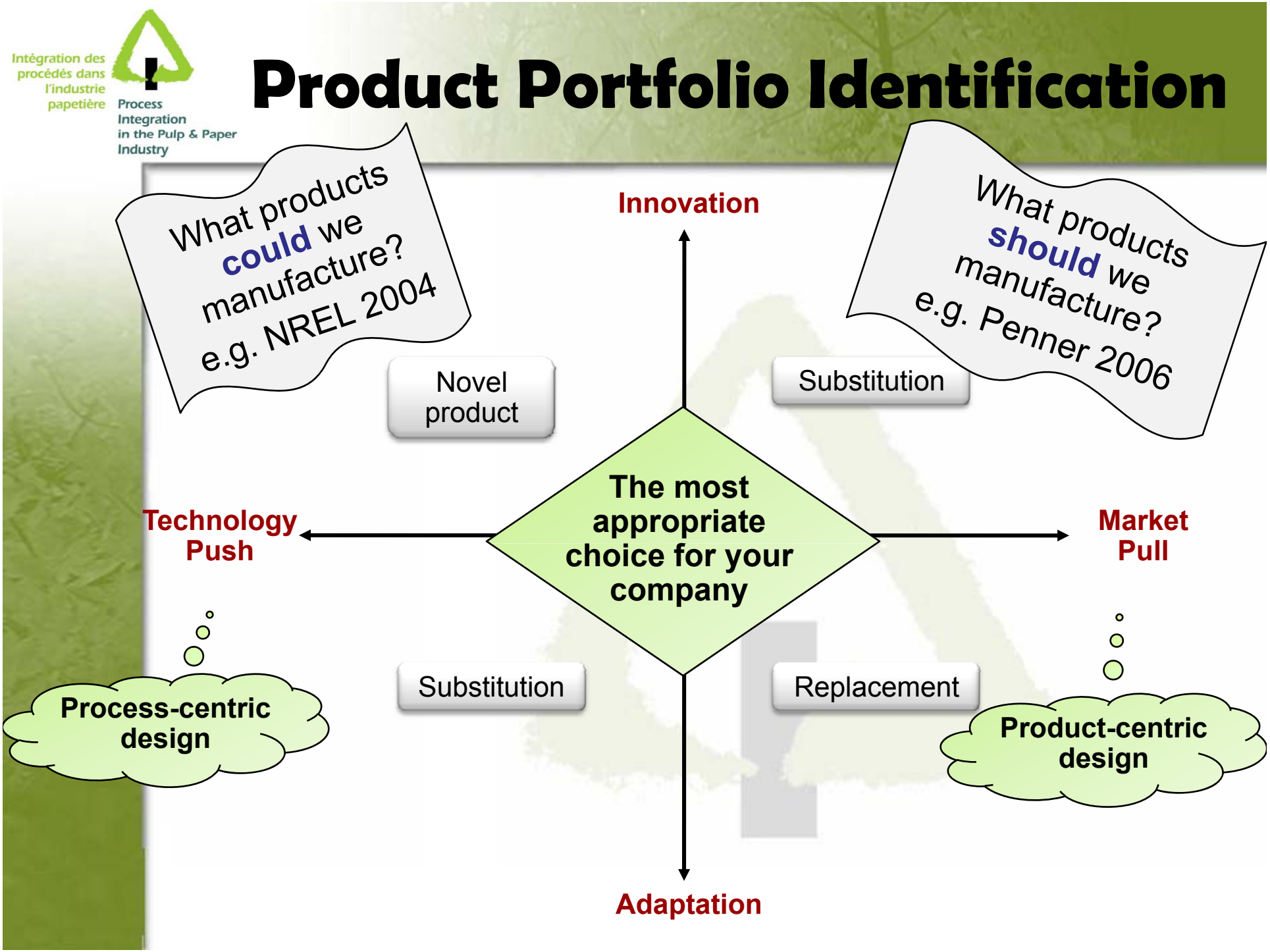
Product Portfolio Identification



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Phase III = Enterprise Transformation

Phase III
Improve Margins:

- Knowledge-based manufacturing and production flexibility
- Business flow transformation
- Product development culture
- Off-shoring, Outsourcing, etc…

- **Supply Chain Restructuring**, e.g., simplifying supply chains, negotiating just-in-time relationships, developing collaborative information systems
- **Outsourcing & Offshoring**, e.g., contracting out manufacturing, information technology support; employing low-wage, high-skill labor from other countries
- **Process Standardization**, e.g., enterprise-wide standardization of processes for product and process development, R&D, finance, personnel, etc.
- **Process Reengineering**, e.g., identification, design, and deployment of value-driven processes; identification and elimination of no value creating activities
- **Web-Enabled Processes**, e.g., online, self-support systems for customer relationship management, inventory management, etc.
- **Market-driven culture** to be established through a phased transformation

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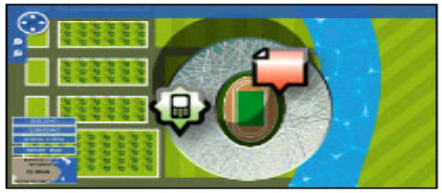
Presentation Outline

Argentina knock out rivals Brazil

Argentina beat Brazil 3-0 to set up an Olympic final against Nigeria in the men's football competition.

Aguero celebrates scoring against Brazil in Beijing



BBC Sport's Olympic

Find out about the Beijir football venue

Football medals ta

- Overall **design methodology** for the forest biorefinery
- Some interesting **process systems engineering** approaches that we are exploring

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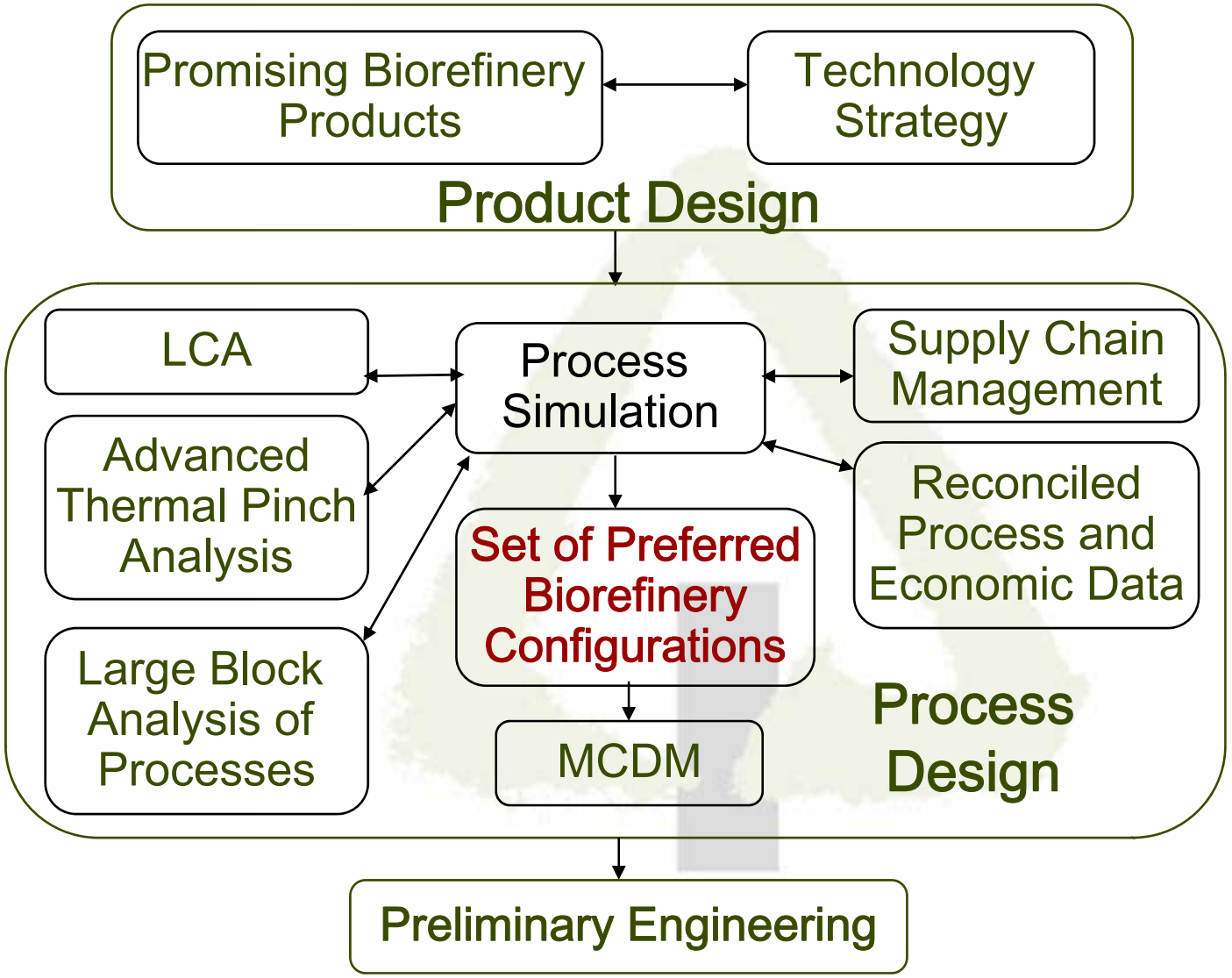
Overall Biorefinery Design Framework



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Process Integration in the Pulp & Paper Industry

Coupling the Problem Context with the Design Approach

- The forestry executives we work with understand the story to this point in the presentation, but don't understand PSE tool strengths and limitations.
- How can we apply PSE tools to create competitive advantage during the implementation of the sustainable biorefinery…?
- This is a great case study in product and process design – there is a race for forestry companies to identify novel and sustainable strategies, and secure quality partners as well as market strategies
- What strategies best meet industry's profitability requirements, and at the same time are sustainable?

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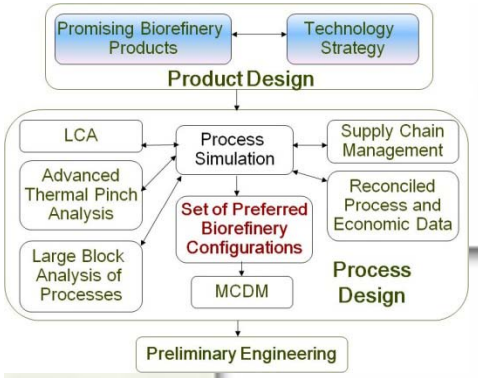
Product Design: Which Biorefinery Sequence?



Product family analysis:

- Creating added value along the value chain
- What are the competitive factors associated with the aggregated product family?

Risks?

Product Portfolio:

- What potential new supply chain opportunities are there?
- Will a unique SC result, that can't be achieved by others?

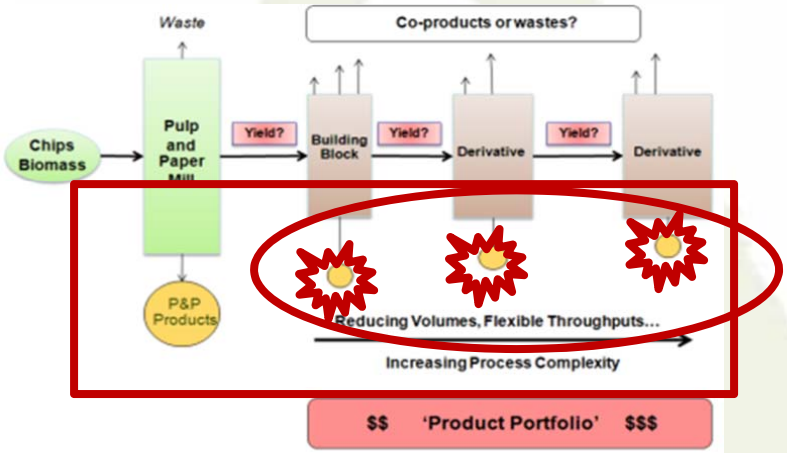
Risks?

Partnership Selection:

- Who are the promising partners for the candidate product families?
- Do their corporate visions align with yours, i.e. implementing the biorefinery in partnership?

Individual Product Analysis

- Which replacement/substitution products should be considered?
  - Promising technologies
  - Product growth
  - Potential for competitive advantage with green product
- Competitive manufacturing costs/existing value chain



Risks?

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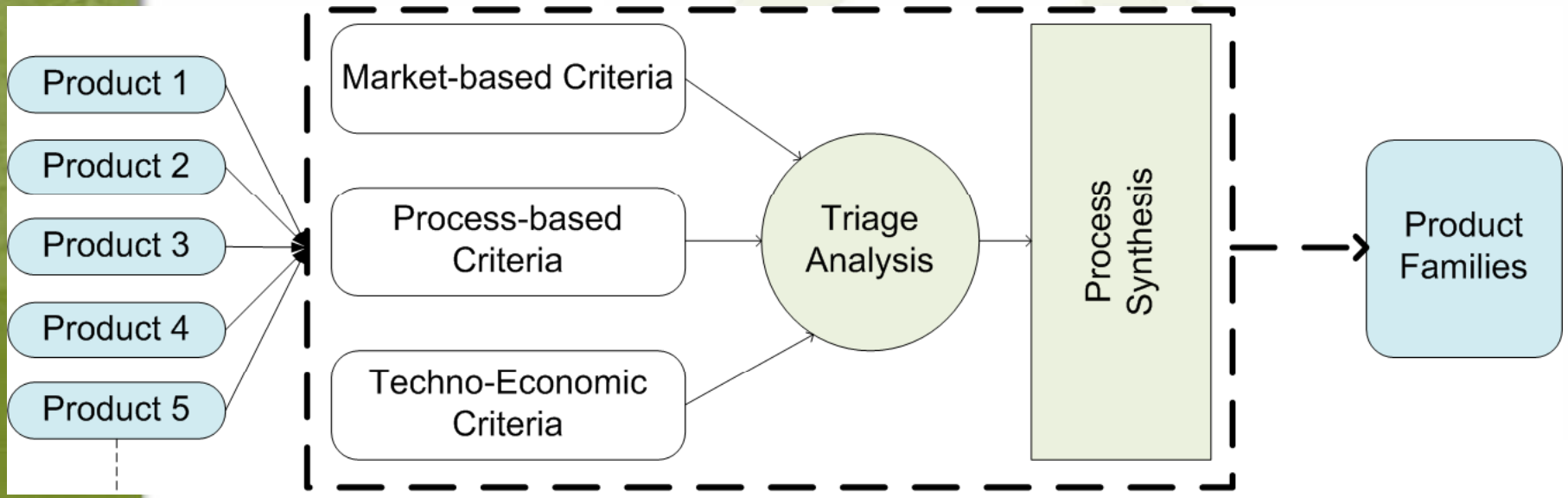
Process Integration in the Pulp & Paper Industry

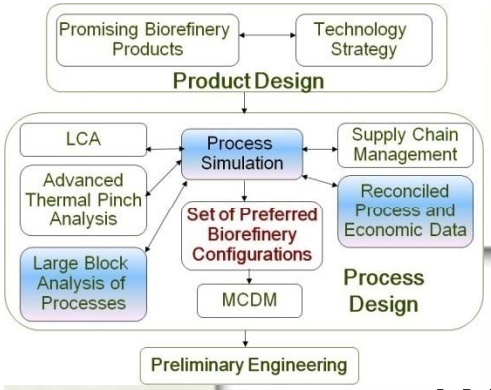
Overall Product/Process Opportunities Methodology

Partnership Screening
Opportunistic Identification

Market-based Assessment and Product Triage
Refined List of Opportunities

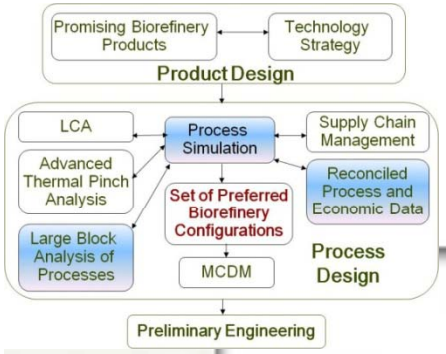
Potential Product Families
Preliminary Process Definitions





Techno-Economic Analysis: Some Key Questions

- What are the available feedstocks, and emerging processes available to manufacture the set of targeted products? Other "**show-stoppers**"?
- Is there a competitive opportunity through partnership with **innovation** companies?
- How will biorefinery implementation enhance the competitive position of the **core business** of pulp and paper products?
- How can the capital cost of the biorefinery be reduced through existing **mill infrastructure**?



Data Processing and Data Reconciliation

Data Processing

Objectives

- Cleansed data
- Near steady-state detection
- Process trends

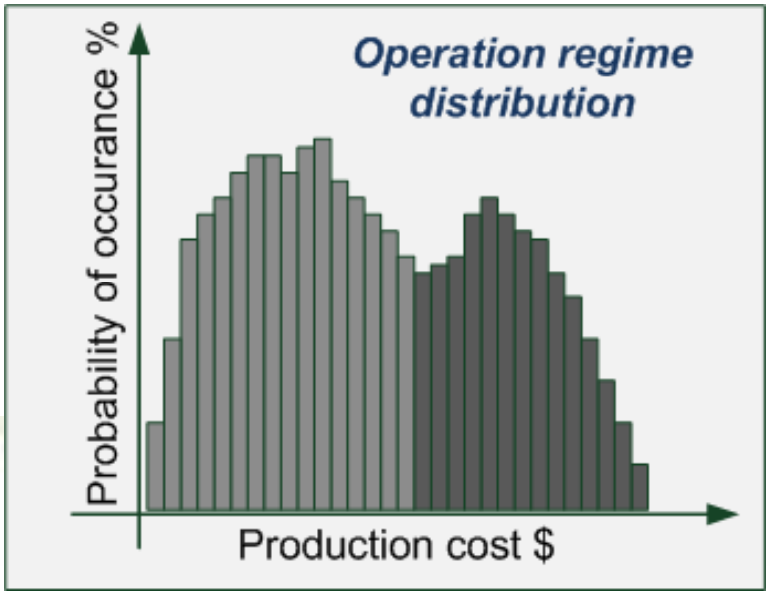
Process Data Reconciliation

Objectives

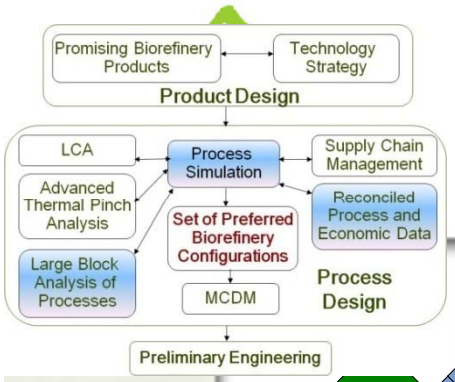
- Further improved data quality by making it consistent with an underlying process model

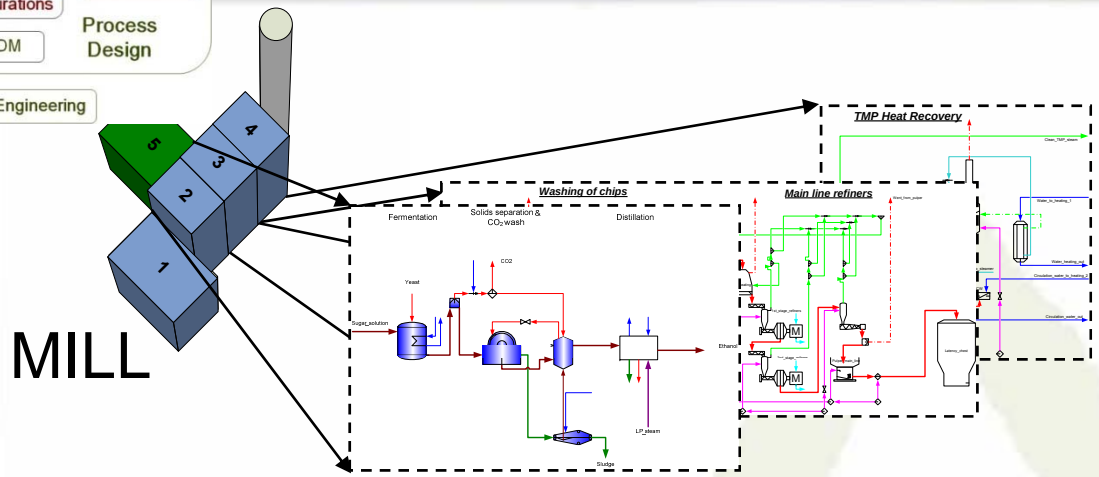
Process-Driven Cost Modeling

- Bottom-up approach to linking costs with process data
- ABC-like methodology for tracking resources consumption in mill



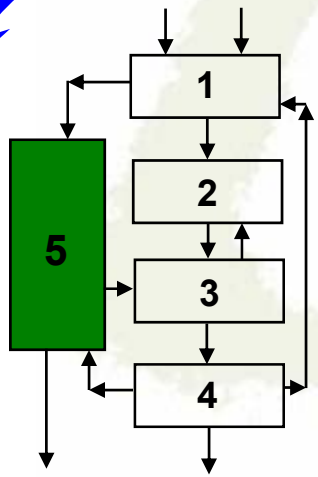
Activity-Based Cost (ABC) Accounting





Forest biorefinery

INPUTS	VALUE
Raw material	
…	
Chem cons.	
…	

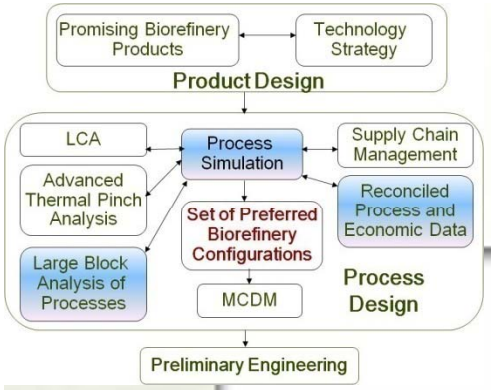


Process Analysis

Mill wide data reconciliation

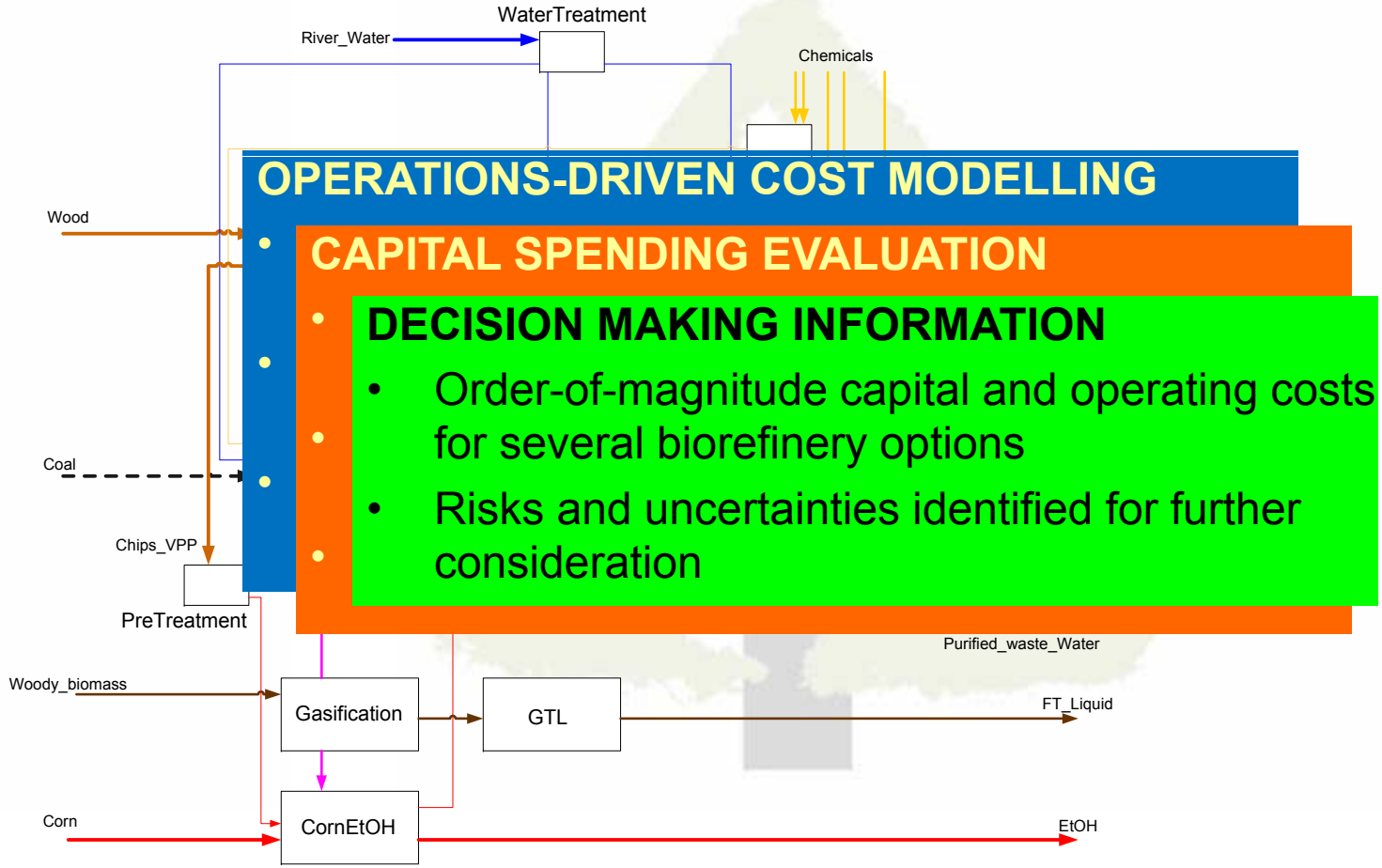
Process-Driven Cost Modelling

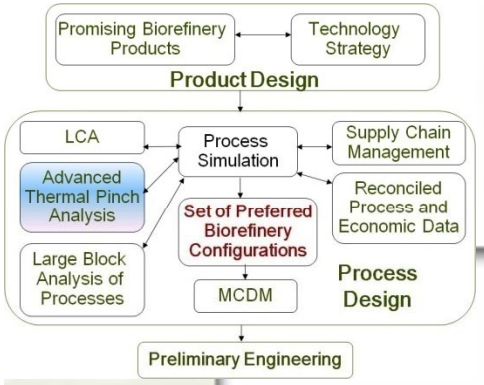
Technology Strategy



Value from this Preliminary Analysis?

Large block analysis of biorefinery technologies

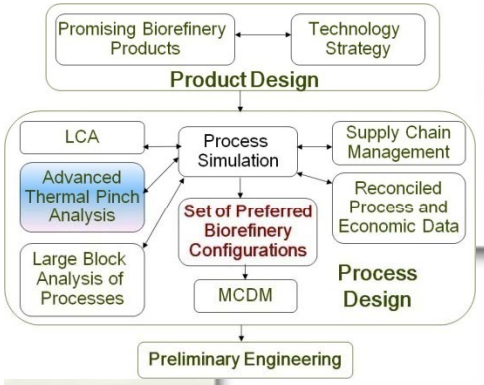




Energy Planning: Some Key Questions

- What is the most practical **thermal pinch analysis** methodology for exploring the biorefinery?
  - Retrofit context
  - Simultaneous water use and energy use reduction
- Do we need to be as **energy efficient** as possible, in order to have the best energy profile for the

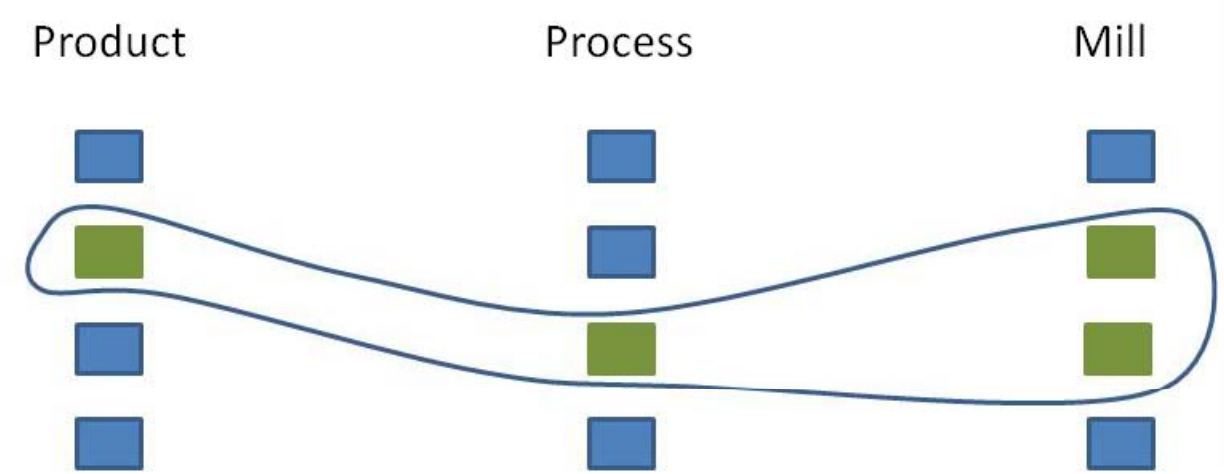
Matches	For Argentina	Draw	For Brazil	Goals
93	34	24	35	149/145[1]



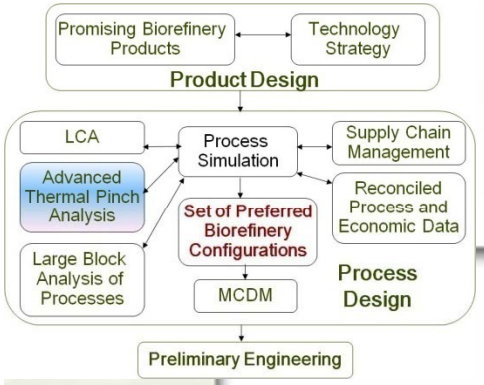
Energy Planning for the Biorefinery

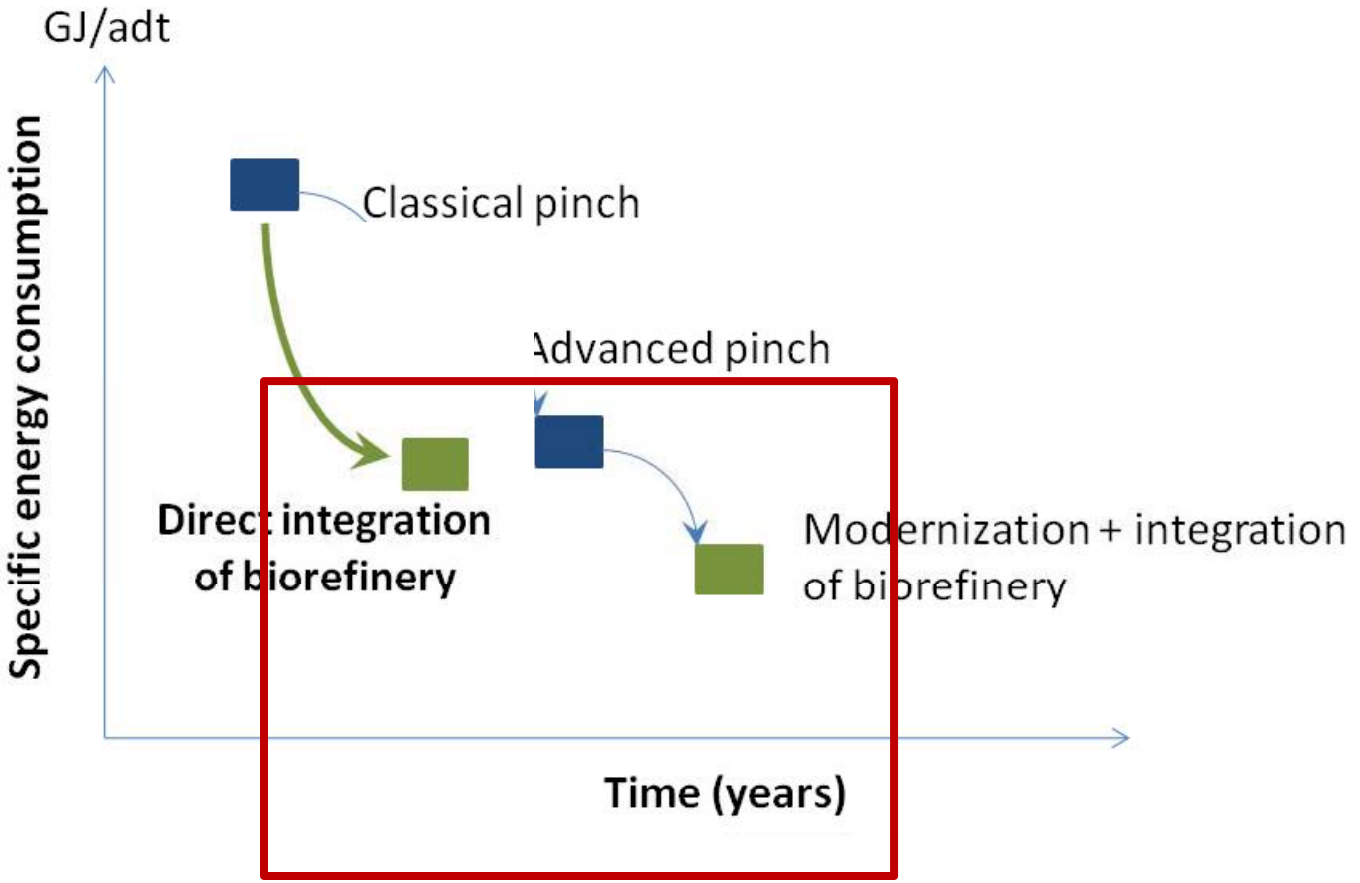
Market → product → process →

Mass and energy balances for the targeted biorefinery processes

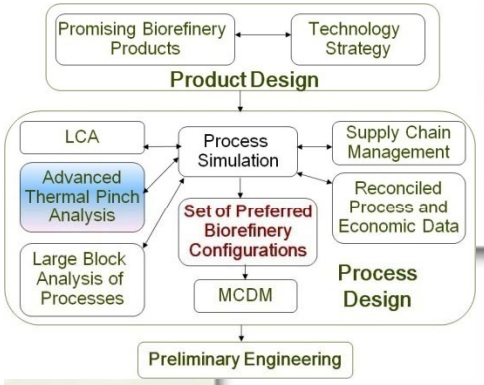


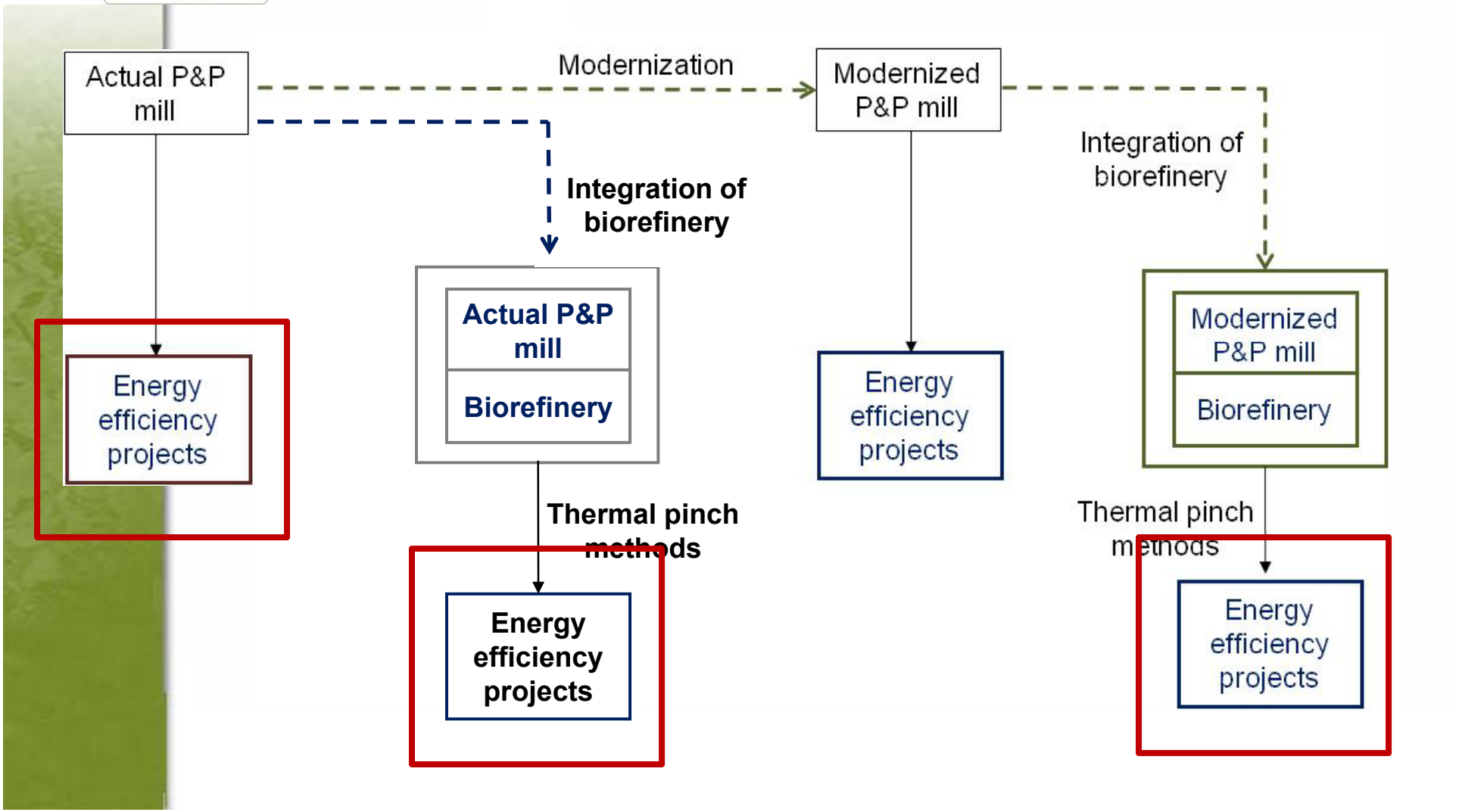
Energy Planning for the Biorefinery





Energy Planning for the Biorefinery

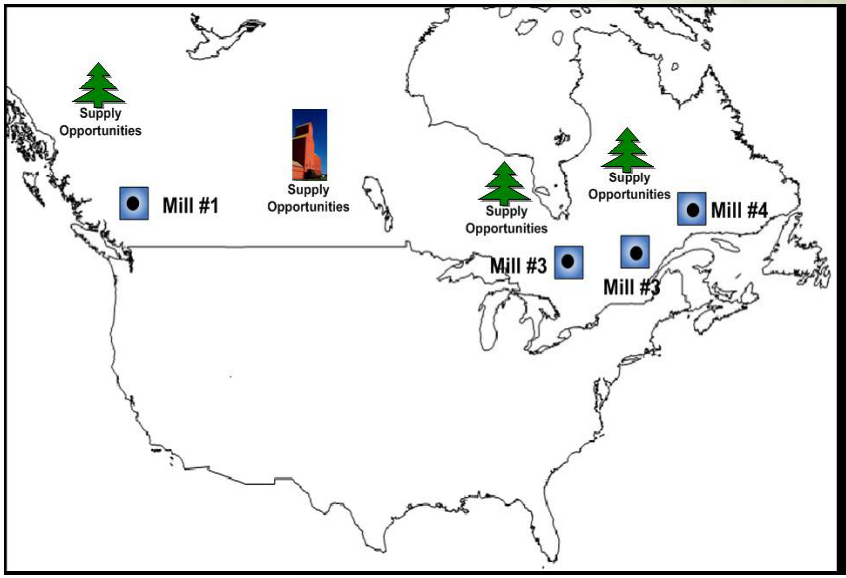




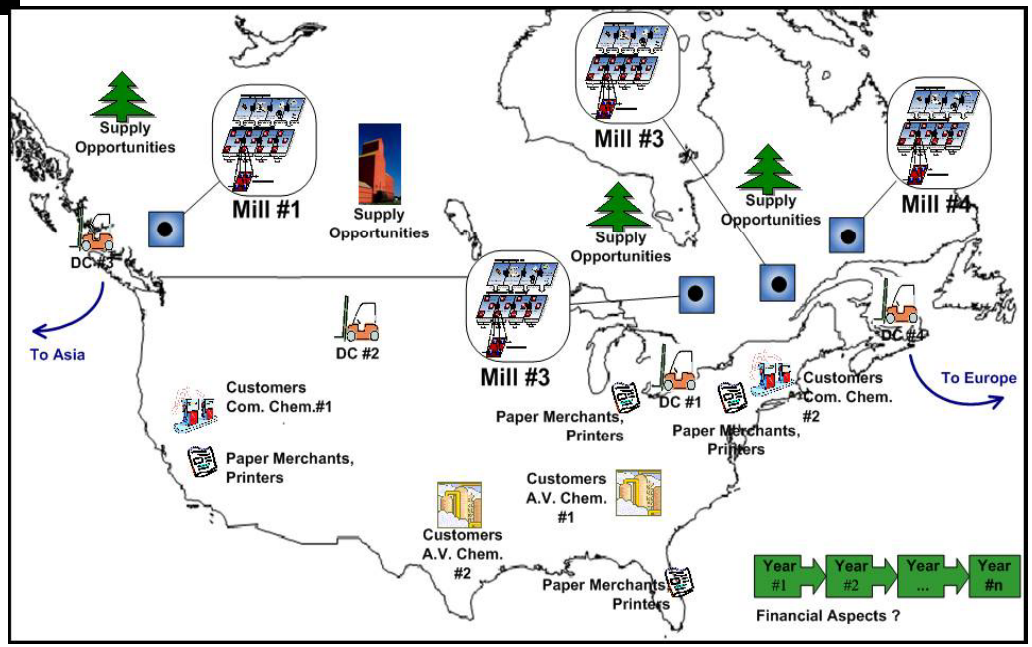
Intégration des procédés dans l'industrie papetière

Process Integration in the Pulp & Paper Industry

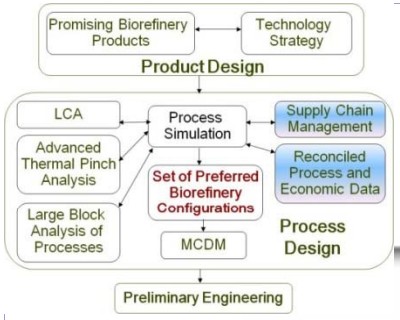
The Biorefinery Supply Chain will be Significantly More Complex



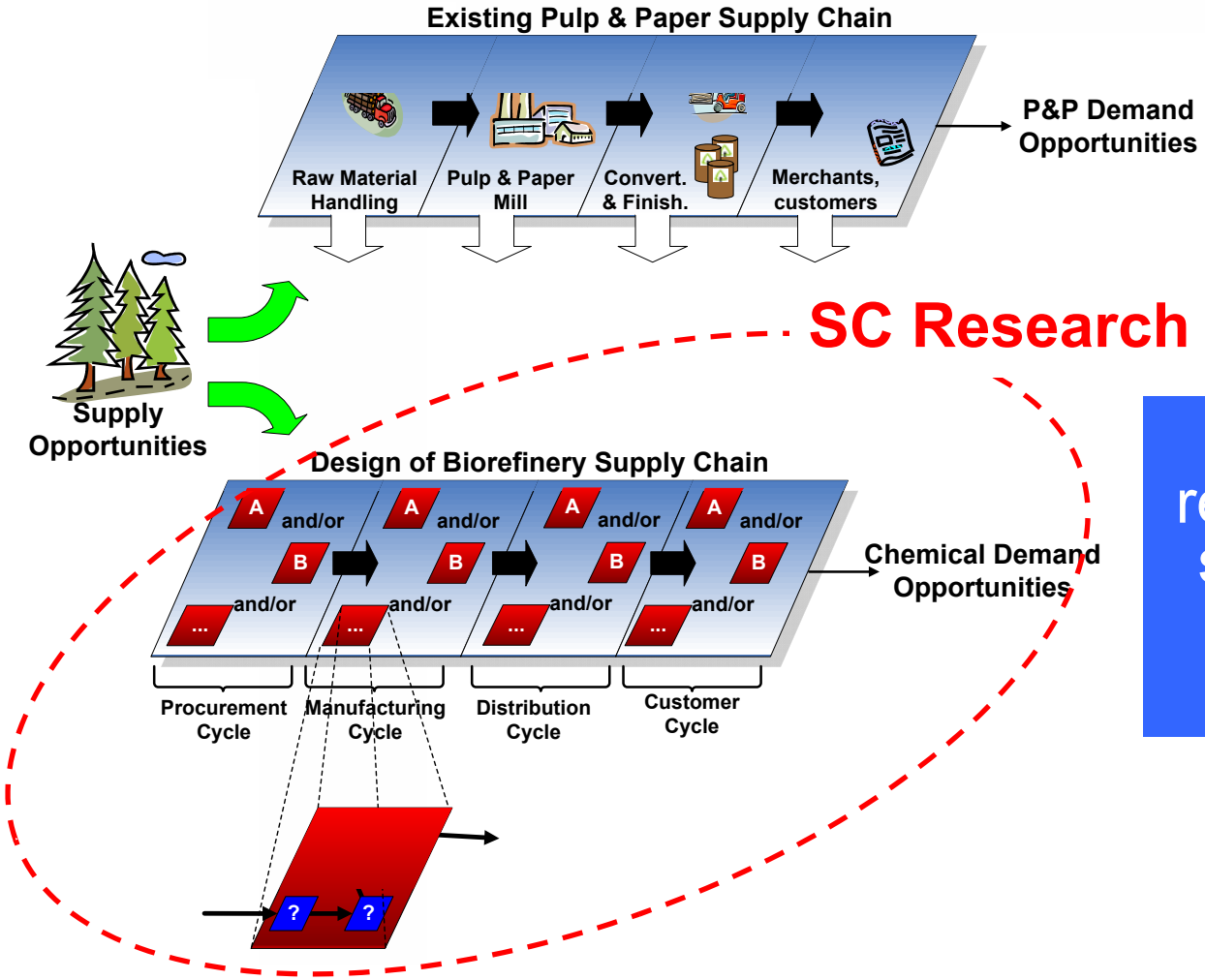
Existing SC



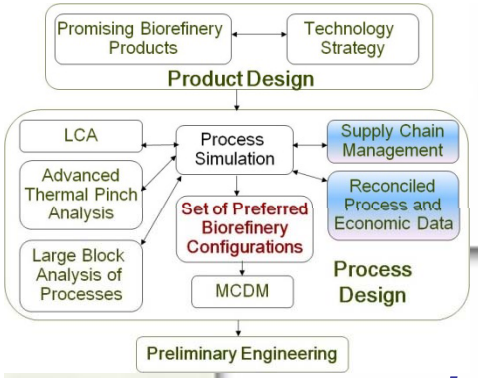
Biorefinery SC



The Unique Biorefinery Supply Chain



For competitive reasons, the FBR SC should be unique to the company implementing it.



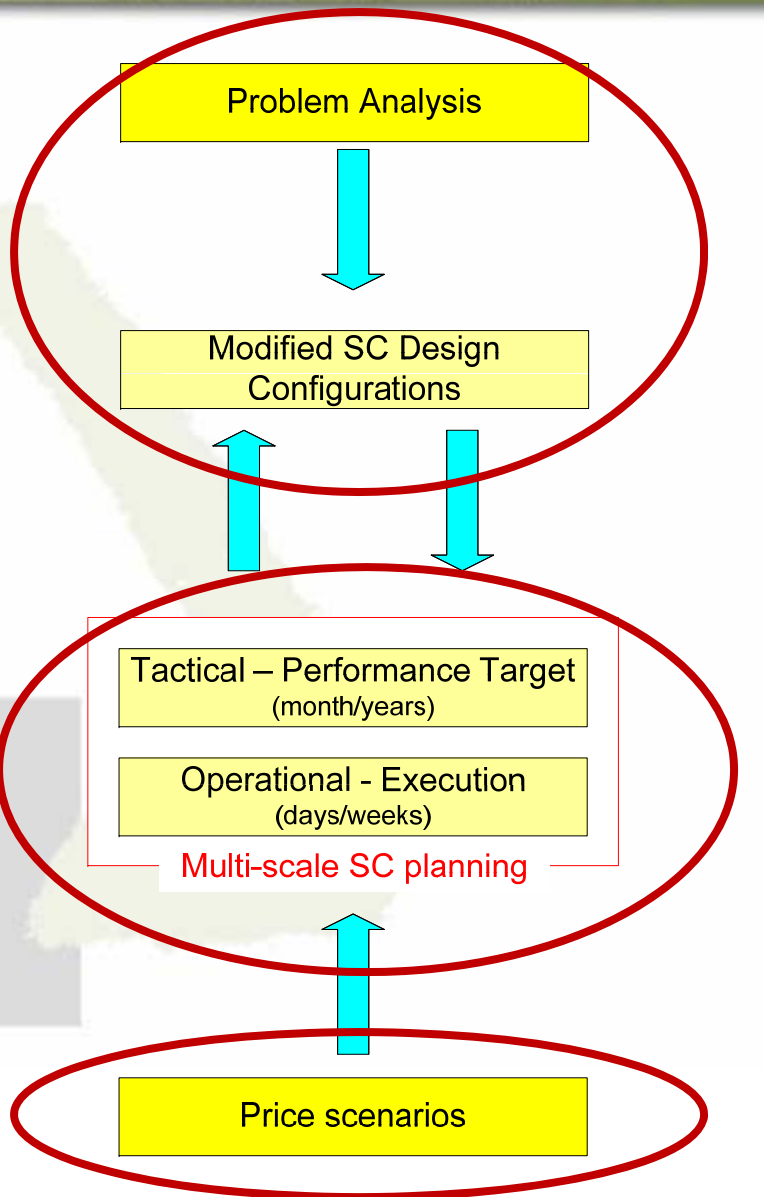
Biorefinery Supply Chain: Key Issues

- ***Product Strategy***
  - Product versus product family versus product portfolio…
  - What are the SC synergies for different product scenarios?
- ***Supply Chain Design***
  - What are the opportunities for improved SC design for different biorefinery product opportunities?
  - What are the impact of strategic SC design on tactical/operational planning
- ***Supply Chain Planning***
  - How can we best manage the complexity of this new SC?
  - How can manufacturing flexibility be best exploited at the SC level so as to mitigate against price volatility?

Intégration des procédés dans l'industrie papetière
Process Integration in the Pulp & Paper Industry

Exploring the Biorefinery SC Design and Management

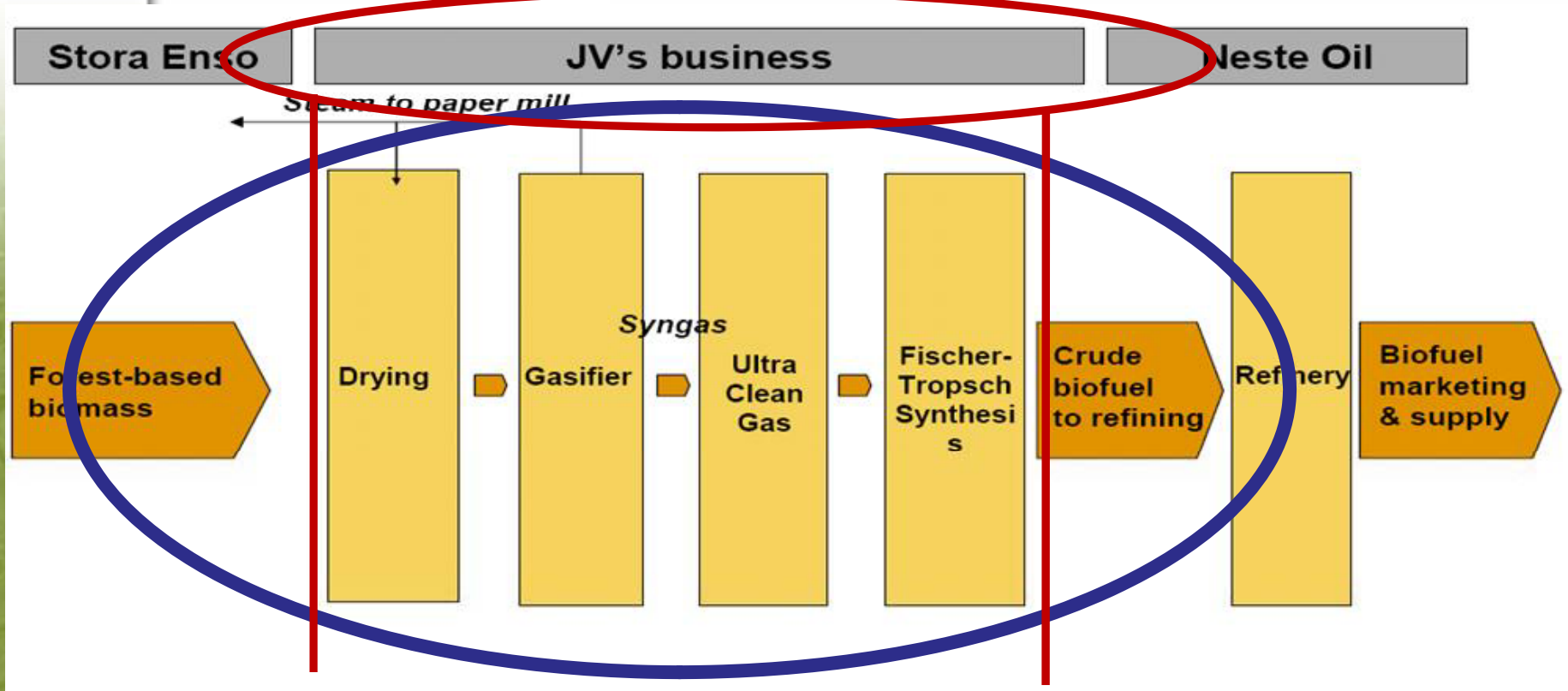
- For a given product portfolio:
- Fixed number of SC design configurations based on system analysis
- Explore the margins-based SC management strategy: this implies a significant transformation…
- Explore the impact of key factors on profit – especially price scenarios based on possible market conditions
- Designing for manufacturing flexibility…



Intégration des procédés dans l'industrie papetière

Process Integration in the Pulp & Paper Industry

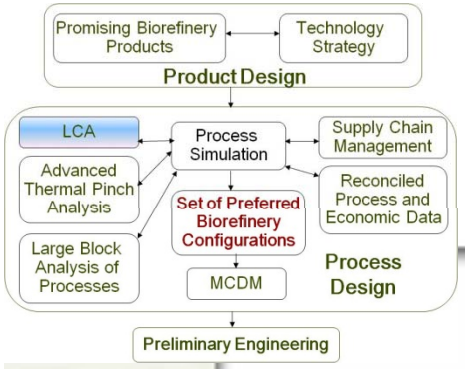
Managing the Biorefinery SC: Manufacturing Flexibility



Expand the JV in order to have better flexibility?

STORAENSO

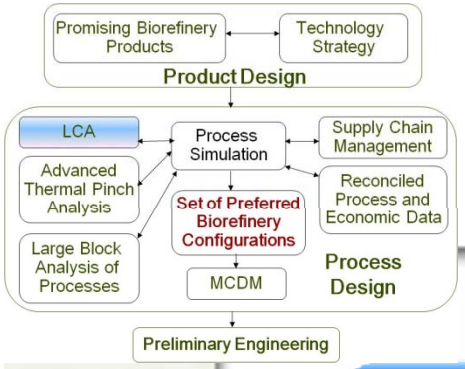
NESTE OIL



Biorefinery Environmental Impact: Key Questions

- What is the environmental performance of the **cradle-to-grave product chain** for the new biorefinery products?
- How does this environmental performance compare with the **traditional product chain**?
- What methodology should we use to make this comparison at the **product portfolio** level?
- How should **trade-offs** be considered between different environmental criteria?

Biorefinery Environmental Impact: Life Cycle Thinking



- Boundaries
- **Allocation**
- Indicators
- **Normalization**
- **Weighting**

LIFE CYCLE ASSESSMENT

- Goal and scope definition
- Life cycle inventory
- Life cycle impact assessment
- Interpretation

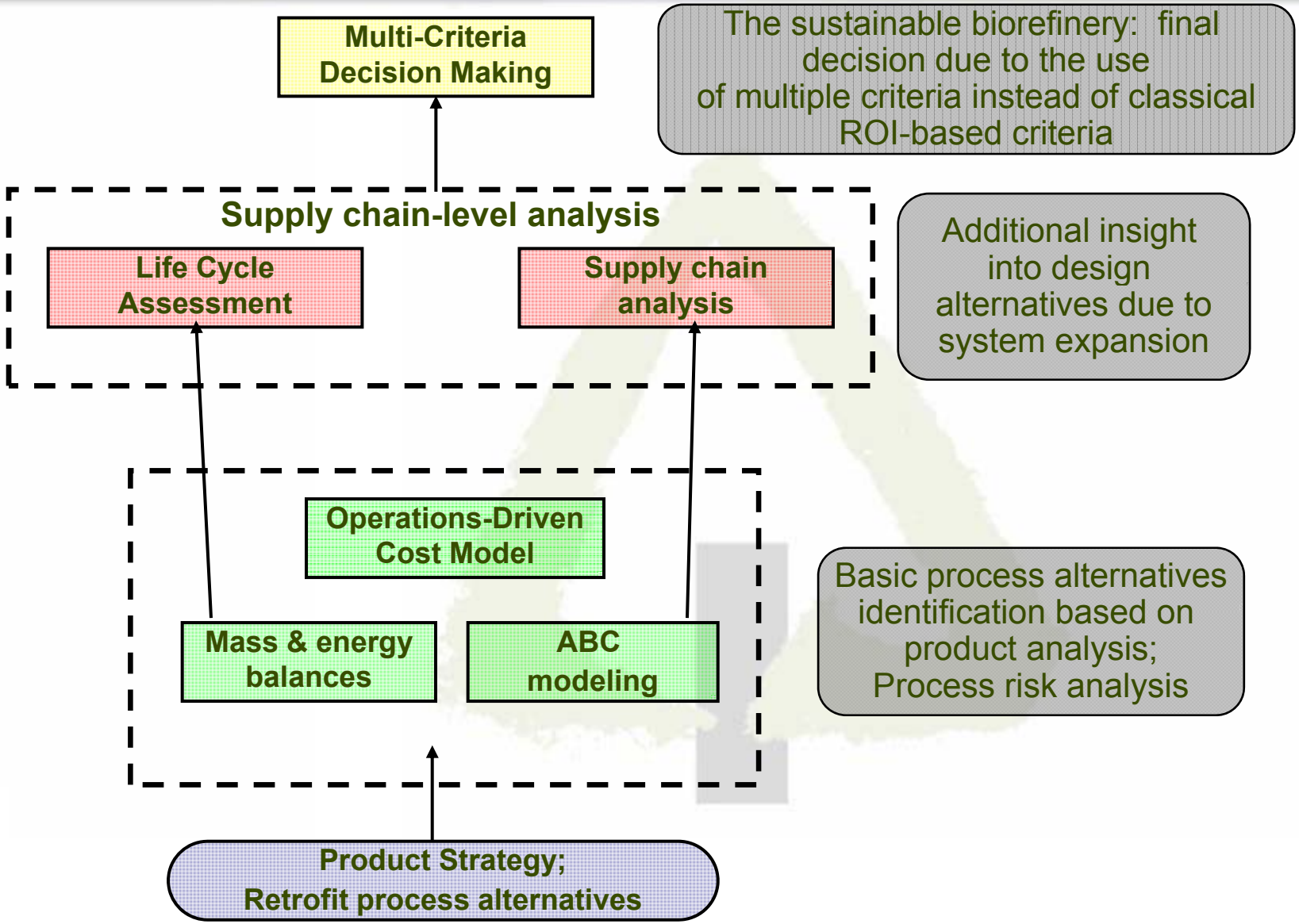
IMPLICATIONS OF METHODOLOGICAL CHOICES FOR PROCESS DECISION-MAKING

- ✓ Operational level: Continuous environmental improvement and environmental management systems
- ✓ Tactical level: Retrofit process design
- ✓ Strategic level: Forest biorefinery (FBR)

OTHER TOOLS

Intégration des procédés dans l'industrie papetière
Process Integration in the Pulp & Paper Industry

Biorefinery Decision-Making: MCDM for Evaluating Sustainability…



Intégration des procédés dans l'industrie papetière
Process Integration in the Pulp & Paper Industry

Conclusions

- **Risk mitigation** associated with the implementation of the biorefinery can be achieved through careful strategic planning, and by employing systematic product and process design methodologies:
  - Starting with **market-based product portfolio desi**gn
  - **Partner selection and partnership model** are critical in determining the company's unique biorefinery supply chain
  - **Enterprise transformation** is implicated - SC design and management must be examined, incorporating issues of manufacturing flexibility…
- The **industrial context** is critical to the PSE approach we use – the industrial context is complex, subtle, and changes with time…
- **Exciting point:** this business-driven biorefinery strategy is generally consistent with Dr. Siirola's analysis using the perspective of sustainability…

PASI 2008 Pan American Advanced Studies Institute Program on Emerging Trends in Process Systems Engineering

Case Study:

Product and Process System Design Methodologies for Engineering the Forest Biorefinery

Thank you!

Cristina Kirchner, President of Argentina, with Luiz Inacio Lula da Silva, President of Brazil.

ÉCOLE POLYTECHNIQUE MONTRÉAL