Supply Chain Challenges Associated with Forest Biorefinery Implementation

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Objective of this Presentation

To identify (certain) critical issues related to supply chain management for assessing forest biorefinery options, using the forest company perspective.

The issues that are presented have emerging from our case study based biorefinery design program.

... thank you to Louis Patrick Dansereau, Behrang Mansoornejad, and Jose Melendez!

Presentation Outline

- Forest Biorefinery Introduction
- Supply Chain Management and the Forest Biorefinery
- Key Challenges:
  - Partnership
  - Product Selection and Market
  - Margins-Based SCM Policy
  - Biomass Procurement
  - Manufacturing Flexibility
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Forest Biorefinery Definition

- Forest biorefinery definition emphasizing sustainability:
  - Full utilization of incoming woody biomass:
    - Wood products
    - Pulp and paper products
    - Energy
    - Biofuels, biochemicals, biomaterials...
- Another (perhaps more practical) forest biorefinery definition that drives biorefinery development:
  - Maximize the economic value from trees
  - Improved business model
  - Corporate transformation...

Definition: Building Blocks and Derivatives...

Reducing Volume, Flexible Throughput...
Forest Biorefinery Realities

- Forest biomass is bulky and expensive to transport/harvest
- Biorefinery technologies fed with forest biomass are not well-proven at the commercial scale
- Chips (white wood) make good feedstock for biochemical biorefinery processes, and are more expensive than woody residues
- Low-cost woody residues make good feedstock for thermochemical biorefinery processes, which are capital cost intensive and have good economies of scale

Strategic Approach for Implementing the Biorefinery

**Phase I**
Lower Operating Costs: Replace fuel and capital (natural gas, Bunker C) and/or reduce maintenance costs.

**Phase II**
Increase Revenues: Manufacture of derivatives, market development of new products, higher process complexity and technology risk.

**Phase III**
Improve Margins: Knowledge-based manufacturing and production feasibility.

**Implementation:**
- Concrete and steel: Bunker C, and/or
- Produce "building block" chemicals, lower risk technologies
- Select the most sustainable product platform and partner(s)
- Improve margins: Knowledge-based manufacturing and production feasibility
- Business flow transformation
- Product development
- Partners essential

**Company culture transformation**
- SCM key to success
- Off-shoring, outsourcing, etc...

**Strategic Vision:**
- Phase III must determine Phase I

Biorefinery Goal: New Business Model
- Margins improvement is the objective function
Implementation Strategy for the Biorefinery

**Strategic Design and Planning**
- Objectives for existing core business (eg biomass access)
- Revenue diversification objectives
- Competiveness analysis/strategic planning for product options
- Potential partnership targeting
- Strategies for technology and business risk mitigation, eg. SC policy change, knowledge-based risk
- Preliminary business plan definition

**Technology Disruption**
- Lower Operating Costs: Replace fossil fuels at mill and/or
  Produce "building block" biorefinery chemicals
- Lower risk technologies

**Value Creation**
- Increase Revenues: Manufacture of derivatives
  Market development for new products
- Higher process complexity and technology risk
  Partnership in place

**Value Capture**
- Technology Disruption (facility-level implementation)
- Strategic Design and Planning Objectives for existing core business (eg. biomass access)
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**Overall Biorefinery Design Framework**

- Promising Biorefinery Products
- Technology Strategy

- LCA
- Advanced Thermal Pinch Analysis
- Large Block Analysis of Processes

- Process Simulation
- Set of Preferred Biorefinery Configurations
- MCDM

- Supply Chain Management
- Reconciled Process and Economic Data

- Process Design

**Using MCDM for Forest Biorefinery Design**

- Market-based analysis
- Techno-economic analyses

- Life cycle analysis
- Environmental metrics
- Other: human health, biodiversity, etc.

- Supply chain analysis
- SC: Unique competitive advantage

- MCDM considers all of the above!
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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Unleashing Value in the SC...

...how much value can be unleashed?
Supply Chain Management

Goal of Supply Chain Management:
Deliver the right product, with the right timing, and at the lowest cost - by the coordination of material, cash and information flows from the supplier to the client in order to:

- Maximize overall profitability
- Achieve high customer satisfaction levels
- Create a sustainable competitive advantage

(Shapiro 2007, Chopra & Meindl 2008, Christopher 1999)

Forest Biorefinery Supply Chain Network Design (Feng et al, 2011)

- Optimal investment decisions by selecting products, facilities, technologies, capacities, and their locations
- Objective: maximizing the value of woody biomass

Design and Management of Biomass-Biorefinery SC (Eksioglu et al., 2009)

- Facility location and capacity decision for a grain-ethanol biorefinery in Mississippi
- Objective: Minimize the cost of biofuel delivery
Facility Location and Supply Chain Optimization for a Biorefinery

(Bowling et al. 2011)

- Facility location of a biodiesel plant with pre-processing hubs
- Nonlinear economy-of-scale behaviour of capital investment
- Objective: Maximize profit

Critical Analysis of the Literature

- Biomass logistics modeling
  - Eksioglu et al. (2009)
  - Rentizelas et al. (2009)

- Strategic facility location optimization problems
  - Agriculture
    - Eksioglu et al. (2009)
    - Biofuel facility location and capacity decision
    - Parker et al. (2010)
    - Bowling et al. (2011)
      - Facility location of a biodiesel mill with pre-processing hubs options
      - Non linear economy-of-scale behavior of capital investment

- Strategic facility location optimization problems (con't)
  - Forestry
    - Feng et al. (2011)
    - Product/process/biomass selection, facility location

- Selection of the product/process portfolio
  - Optimization-based approach: Sammons et al. (2009)
Critical Analysis of the Literature

- Margins-based planning and the biorefinery:
  - Management of product portfolio, market volatility
  - Manufacturing flexibility design for margins-based planning
  - Coproduction potential of the biorefinery
- Representation of the investing companies:
  - Retrofit
  - Partnerships
- Combined forest and agriculture biomass:
  - Biomass procurement strategies:
    - specialty products vs commodities

Critical Research Questions

- Can the fixed and variable costs for different biorefinery strategies be well-estimated, including change-over costs etc?
- How should the business model be segmented for distinct biorefinery products?
- What should be targeted as SC objectives for a particular biorefinery strategy, at each of the strategic and tactical/operational levels?
- How can the potential value and competitive advantage be estimated quickly for several different biorefinery strategies?

Critical Research Questions

- For a unique biorefinery portfolio including commodity and/or added-value products:
  - What are the decoupling points (MTS/MTO)?
  - What manufacturing flexibility should be targeted?
- What is the best biomass procurement strategy for different biorefinery portfolios?
- How can the biorefinery strategy be implemented incrementally, with market and financial success each step?
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**Partnerships**

- Value chain partnership
  - Companies with complementary skills, which link their capabilities to create value
- Critical elements in partnership creation
  - Strategic compatibility of business models and visions
  - Ability to provide long-term capital investment required
  - Revenue diversification targets
- Potential Advantages
  - Accessing complementary assets and know-how
  - Reducing time to market
  - Sharing investment costs
**Potential Partnerships**

- Biomass suppliers: forest biomass, agricultural feedstocks, urban forest
- Other wood and/or pulp and paper products companies
- Venture capitalists
- Chemical, petrochemical and energy companies
- Technology providers
- Plants
- Products
- Customers
- Suppliers
- Service
- Transport

**Partnership; Challenges and Key Issues**

- First-to-market advantage for an added-value product: essential to find a good partner with a flexible vision of the end result
  - Small number of good partnership opportunities relative to a larger number of biorefinery product-process opportunities
- Partners must put in money, over the long-term
- Partners must address the weaknesses of forestry companies
- The structure of the partnership must be able to create competitive advantage:
  - Technology partnership: short-term competitive advantage
  - Manufacturing partnership: long-term competitive advantage

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Biorefinery Product Strategy

True commodities
- Biomass and replacement commodity chemicals (EDC, FT tanks, bio-ethylene)
- Large volume, sold to accepted composition limits
- Price is the main buying criterion
- Production rather continuous and campaign, mostly MTE
- Demand recurrent and forecastable

Pseudo commodities
- Large tonnage bioplastics and biomaterials (rayon, PLA)
- Large quantities, sold according to performance
- Bought by a few large customers
- Customization often at the end, MTO/MTS

Fine chemicals
- Substitution chemicals, intermediates (vanillin, succinic acid)
- Lower volumes
- Small number of specialized customers
- Continuous and also batch (campaign), mainly MTS

Specialty chemicals
- Low volume bioplastics and biomaterials (NCC, carbon fiber)
- Small quantities and designed according to customer specific characteristics
- Several small volume customers
- Multipurpose batch, small lot size and volume, MTS
- Demand dependent on customer service

Degree of differentiation
- Undifferentiated
- Differentiated

Basic Product Design

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

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

Product Portfolio:
- What potential new supply chain opportunities are there?
- Will a unique ISC result, that can’t be achieved by others?

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?

Biorefinery Strategy

Integrated to Core Business
Parallel ("exit") Biorefinery Process Strategy

Continuous and Batch Processes

Product Strategy is Critical

- Product strategy and market characteristics will guide the design of your supply chain:
  - Process design
  - Manufacturing flexibility
  - Biomass procurement and product distribution strategies
- Different strategies are needed, eg:
  - Commodities e.g. biofuels
  - Mixture of commodities and fine chemicals/specialties; e.g. BuOH + succinic acid
  - Fine chemicals/specialties, e.g. dicarboxylic acids
    - Flexible in terms of product and throughput
Forest Biorefinery Introduction

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Manufacturing-Centric Production

Biggest challenge for the forestry industry for implementing the biorefinery will be to move away from the commodity business mentality (Thorpe 2006)

Currently, P&P companies are “manufacturing-centric”
- View process efficiencies as the key for low-cost manufacturing and profitability
- “KPI Culture”: machine uptime, grade run times...

This is commodity thinking, and not the best strategy:
- Does not optimize grade changes for maximum profit
- Does not account for changing market conditions
- Other SC costs ignored

Margins-Centric Approach

In implementing the biorefinery, forest companies should use a margins-centric supply chain policy:
- Design and exploit manufacturing flexibility
- Maximize margins over the entire SC (even with increased grade change and higher manufacturing costs)
- Allocate capacity to the most profitable/desirable sales
- Transform to new SCM concepts, and SC restructuring

Marginal costing and integrated planning are critical:
- Break-down costs to evaluate trade-offs between different operating regimes and/or capacity levels
- Segmentation of sales/procurement to identify marginal behavior
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**Biomass Implications: Strategies**

- Feedstock source(s) are less important in the design phase as long as they meet the biorefinery strategy requirements, including for example:
  - Biorefinery process requirements
  - Local/regional availability
  - Secure long-term supply
  - etc

**Biomass Prices will Increase!**

- Due to increasing competition for currently used biomass sources (pulpwood, sawmill residues, etc.) from current and new players - Bradley, 2009
- Wood, pulp and paper product business models are necessarily linked, and this will be equally true in the context of the biorefinery - Stuart, 2009
Biomass Procurement

- Full accounting of available biomass, economic models
- Changes in harvesting technology
- Scenarios for how much biomass prices will increase
- Impact on different product-process biorefinery strategies is geographic

Model biomass procurement using two distinct objective functions:

- One that maximizes biomass volume for less than a target price for producing commodity bioproducts
- One that minimizes price for a target volume for producing added-value bioproducts

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Types of Flexibility

- Flexibility can be employed to mitigate risks associated with different types of uncertainty
- Specific types of flexibility have been defined

<table>
<thead>
<tr>
<th>Flexibility</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Recipe</td>
<td>The set of adaptable recipes that can control the process output</td>
</tr>
<tr>
<td>Product</td>
<td>The ability to changeover to produce a new (set of) product(s)</td>
</tr>
<tr>
<td>Volume</td>
<td>The ability to operate a system profitably at different production volumes</td>
</tr>
<tr>
<td>Process</td>
<td>Capability of process to have feasible operation under changing conditions</td>
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Manufacturing Flexibility: Economic-Market Perspective

- Manufacturing flexibility implies a justifiable increase in capital and operating costs resulting in the ability of the process to manufacture with flexibility, such that expected volatility in market conditions can be mitigated.

- Manufacturing flexibility for the biorefinery refers to the ability to produce several bioproducts (product flexibility) with different production rates (volume flexibility) in different time periods, based on product price and demand.

Hierarchical Biorefinery SC Design Methodology

1. Estimate manufacturing flexibility
   - Design the possible operating windows of processes
   - Verify the operating windows, feedback, and product
   - Characterize the manufacturing system
   - Define design alternatives
   - Calculate capital and operating costs for each alternative

2. Identify SC network options
   - Identify the specifications of the new SC network alternatives
   - Combine process alternatives and SC network alternatives
   - Calculate the SC profit for each scenario/alternative

3. Estimate the performance of the biorefinery SC
   - Assess the performance of the biorefinery SC
   - Generate scenarios based on price/supply/demand
   - Calculate the SC profit for each scenario/alternative
   - Combine process alternatives and SC network alternatives
   - Compare alternatives based on the new SC profit/loss

Tactical Planning Model for Margins-Based Operations

- Integrated model of the company (procurement to sales, decision levels and geography)
- Good representation of a company’s profit-loss structure
- Sales and procurement:
  - Customer/supplier segmentation and distinction between contracts and spots
  - Non-linear behavior of contracting practices (discounts on tonnage)
- Production:
  - Energy balances (steam and electricity)
  - Manufacturing flexibility
  - ABC inspired costing
SC analysis is critical for evaluating biorefinery strategies, and should be related to the following key issues:

- Collaboration with potential partners
- Product portfolio options
- Process options and manufacturing flexibility
- Biomass procurement strategies and logistics
- Different market demand scenarios
- Strategic decisions based on their impact on tactical/operational activities
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Thank You!

Merci!