FOR/Maine

Strategic Investment Attraction Plan for Maine's Forest Industry

Deliverable 1: Report on Lessons Learned from Successful Investment Attraction in Wood Products Industries

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Indufor North America LLC

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1 Introduction

For/Maine's Strategic Investment Attraction Plan aims to produce targeted investment attraction materials and conduct proactive outreach to domestic and international companies who are potential investors in Maine's forest economy. The project builds on the analysis produced for For/Maine's Phase 1 and complements the efforts of multiple investment attraction organizations in the state.

To inform the production of investment attraction materials and outreach to potential investors, the stocktaking report aims to a) assess successful investment attraction efforts in the seven priority products, b) generate insights for Maine's broader forest industry investment attraction process, and c) provide orientation to Phase 2 development of investment attraction materials and approach.

1.1. Scope

For/Maine tasked Indufor with conducting a stocktaking exercise of examples from other states and countries that have successfully attracted new investments in the seven products For/Maine is targeting, namely: dissolving pulp, medium-density fiberboard (MDF), cross-laminated timber (CLT), nanocellulose, cellulosic sugars (for fuels, chemicals and plastics), and pyrolysis oil.

The original emphasis of the stocktaking exercise focused on incentives schemes that encouraged investment in these products. During the project kick-off call, the scope of the stocktaking report was broadened to cover the enabling environment that supported the investments. The broadened scope is particularly relevant when examining the case of Finland, which has implemented a country-wide and industry-wide transformation from pulp and paper production to a forest-based bioeconomy.

1.2. Methods

To complete the stocktaking exercise, Indufor prepared a database of relevant incentives programs and major companies from seven forest product markets. In total, the database covered about 100 investments and incentives programs, which were then screened against the criteria below resulting in about 40 potential cases. We contacted representatives from those cases and completed 14 investment case studies and three jurisdictional cases. We relied on the following criteria to identify and select potential cases, reflecting For/Maine's focus on capital inflows and job creation:

- One of seven forest products or close substitute
- Focus on For/Maine's priorities:
  - Economic development: Minimum of 10M CAPEX
  - Job creation: Minimum of 20 new employees
  - Integrating in to For/Maine's existing industry
- Offers valuable lessons for Maine on enabling conditions for industry transformation in terms of resource availability, technology, infrastructure, workforce, planning, market access, partnerships, and financial incentives

The priority jurisdictions for the analysis emerged to include the United States, Canada, Australia, Finland, and Netherlands because of their experience attracting such investments and similarities in the market or enabling context. For example, we did not include investment cases from China despite their active investments in the priority products because the enabling environment is so different from Maine. We then contacted company representatives, independent experts, and government officials to request information and interviews on the factors driving the investment cases, including incentives programs accessed by the companies.

For each investment case, we drafted a short summary including background on the company, the specific investment, investment drivers, investment impact (jobs, capital expenditure, etc.) and lessons learned. For selected cases, we drafted more detailed summaries on the enabling environment that facilitated investments in the products For/Maine is most interested. Those jurisdictions include Finland, Quebec and Oregon. Where we found compelling investment attraction materials (brochures or flyers, for example), we have included links to them in the deep dives.

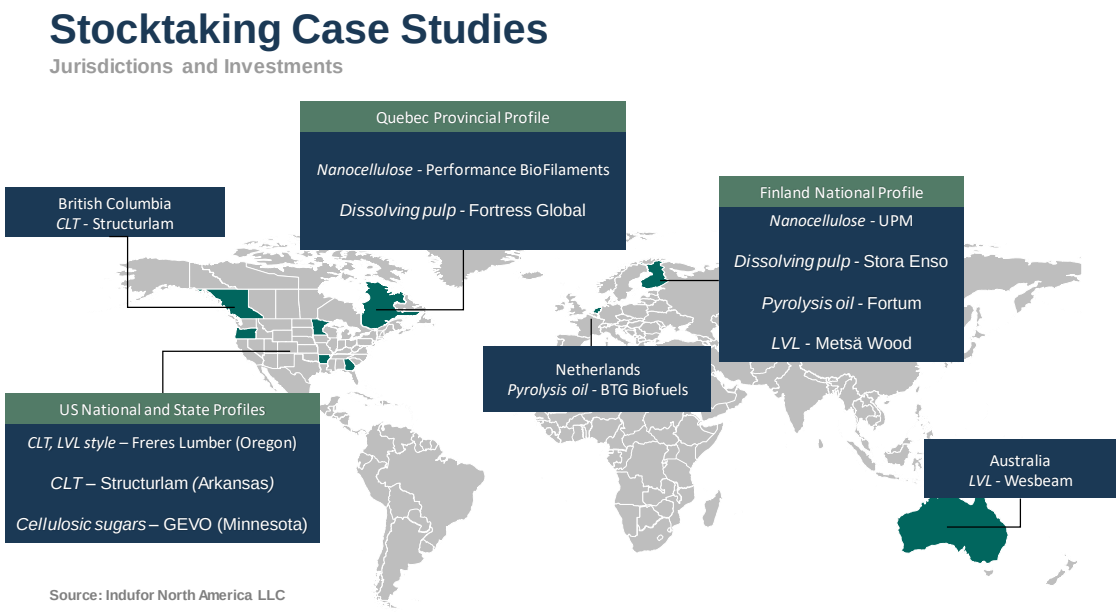
In addition to providing cases for specific jurisdictions and investments, we gathered lessons from recent literature on local economic incentives relevant to Maine's efforts to attract investment to its forest bioeconomy.

1.3. Overview of the Case Studies

Indufor prepared 14 investment case studies and three jurisdictional case studies (Finland, Oregon, and Quebec) as seen in Figure 1.1. The cases cover investments in dissolving pulp, nanocellulose, CLT, LVL, cellulosic sugars and pyrolysis oil. Despite repeated attempts to speak with representatives from MDF manufacturers, including Egger in North Carolina, we were unable to secure interviews. Nonetheless, we believe the characteristics of investments in MDF manufacturing (wood supply requirements, market locations, CAPEX, jobs-creation, etc.) are similar to other products included in the cases. Because of the impressive industry transformation in Finland, we have included an extended deep-dive case study on Finland with four company-specific investment cases to highlight the various forms of industry support and strategic planning over the past decade.

While several national and subnational jurisdictions have incentives programs or technical assistance programs supporting the development of forest product markets, we have not found many that exclusively target one of the seven key forest product markets. Some incentives programs may support forest industry projects broadly, while others focus on a specific subsector or application (e.g., renewable energy) and therefore could be applied toward a subset of the key forest product markets (e.g., cellulosic sugars and pyrolysis oil). Investment attraction tend to draw on one or a combination of the following types of incentives: state or federal government grants, loans, loan guarantees, bonds, technical assistance, tax credits, tax exemptions, government co-financing in infrastructure improvement, discounted land acquisition or land lease payments and technical assistance. The case studies profile a variety of investment attraction cases that reveal a diversity of approaches and the importance of the enabling environment to success.

Figure 1.1: Map of Stocktaking Cases and Jurisdictions



1.4. Limitations

The report has several limitations. First, the cases analyzed in this report are not necessarily representatives of all similar investments in the sector. They were identified to provide relevant lessons for Maine, but they were sourced from dozens of possible cases which could provide additional or different lessons. Second, we focused on cases where we could conduct interviews with key stakeholders in the investment (CEO of the company, representatives from investment promotion offices, etc.), and have therefore omitted cases where we could not learn more about the investment beyond publicly available information. Third, response rates to our interview requests were likely lower given the stresses on companies during the early stages of the COVID-19 outbreak.

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Enabling Environments, Incentives for Local Economic Development and Forest-Based Bioeconomies

Decisions to invest in new facilities to produce existing or emerging wood products are driven by a combination of factors including a company's view on the market, available financing, and execution know-how. Depending on the product, they are also closely linked to the availability of inputs, labor and transportation to end-use markets. Investments in the forestry sector range from CAPEX-intensive projects like new pulp and paper mills to less intensive operations like sawmills or CLT manufacturing. Some emerging products like nanocellulose require potentially even less CAPEX to begin operations. The features of a successful enabling environment for forestry investments varies, therefore, from product to product and can be critical to understand before planning investment attraction outreach efforts.

2.1. Enabling Environment for Investments in the Forestry Sector

A generic company in the forest product processing sector is likely to first evaluate their overall business strategy including their supply chain and wood fiber sourcing, considering their own competitive position relative to others in the industry. Assuming the company decides to move forward with an investment they would next look at screening for candidate locations for their facilities by assessing, for example, general infrastructure density and condition, availability of land and forest resources, market opportunities, government support and regulations, access to financial services and other factors. Upon choosing a jurisdiction to invest in, they are then likely to search for a specific site location by analyzing in more detail the following:

- **Technological infrastructure**: production, logistics, partnerships, labor and management
- **Wood production or procurement costs**: land, yield/productivity, labor, energy, logistics
- **Facilities**: availability or construction costs
- **Processing costs**: land, wood, labor, materials, energy
- **Infrastructure costs and risks**: roads, ports, energy, water, etc.
- **Distribution costs**: transportation, storage, coordination, etc.
- **Social and environmental** risks and mitigation options

A 2014 Indufor study for the World Bank identified a set of enabling factors impacting the attractiveness of forest sector investment throughout the world. Like any sector, investment in the forestry sector is influenced by political, social and economic stability, economic growth, trade rules and taxation. For the

Table 2.1: Enabling Environment Factors for Forestry Investment

External Factors bearing on Forest Sector	Internal Factors of Forest Sector
• Economic and social risks • Infrastructure • Regulatory environment • Governance and law enforcement • Contract enforceability • Corruption • Property rights security • Access to capital and financial services	• Forest resources • Market access • Growing conditions • Input costs • Subsidies and incentives • Forestry regulations (harvest, processing, transport) • Technology availability • Labor availability and skill • Service providers

forestry sector in particular where the raw materials, processing and transportation are keys to success, the following enabling environment factors are critical (see Table 2.1). Subsidies and other financial incentives are just one of many factors that a company will consider before investing.

2.2. Emerging Lessons on Incentives for Local Economic Development

While only a part of the decision-making puzzle, the role of local economic incentives is important to analyze in more detail as For/Maine prepares for more aggressive investment attraction efforts. As one interviewee from an investment promotion office described it to Indufor, "Incentives don't drive the decision but they can break a tie". Emerging research on the role of local economic incentives is useful to review before considering the lessons from the case studies. Relying on research from the W.E. Upjohn Institute for Employment Research, Pew Charitable Trust notes that economic incentives have costs for the jurisdiction and that careful design and deployment of incentives can outweigh the costs. In particular, they note that incentives attracting locally-owned export-oriented companies are most beneficial because they generate new jobs and bring revenues and profits into the local economy. The design of the best performing incentives helps companies access financing early in the investment process. Non-financial incentives that help companies overcome barriers to growth are also highly important. For example, workforce training or export market research can generate significant positive impacts for small-medium sized companies who could not otherwise invest in such initiatives.

Brookings Institute identifies a set of core principles that should guide the design of economic incentives:

1. Grow from within by prioritizing firms in advanced industries that drive local comparative advantage, innovation, productivity, and wage gains.
2. Boost trade by facilitating export growth and trade with other markets in the United States and abroad in ways that deepen regional industry specializations and bring in new income and investment.
3. Invest in people and skills by incorporating workers' skill development as a priority for economic development and employers so that improving human capacities results in meaningful work and wages.
4. Connect places by catalyzing economic place-making, and work at multiple geographic levels to connect local communities to regional jobs, housing, and opportunity.

The Center for American Progress (CAP) presents a more skeptical view on economic incentives, noting that incentives are not as crucial to the decision about where to locate an investment than what companies

lead policy-makers to believe. In fact, they argue, the intersection of the company's geographic/market footprint and the economics of the industry drives site selection more than incentives. They suggest that targeted incentives are better than broad tax cuts, but that often the forgone tax revenues outweigh the job creation realized from the investment. CAP argues that investments in training and infrastructure, which remain in place even after a company leaves a location are better investments of scare public funds.

2.3. Emerging Lessons from Other Bioeconomies

When considering For/Maine's vision for a forest-based bioeconomy, it is also worth examining lessons from economies in Europe that have led industry transformations for insights on enabling environments and incentives applicable in Maine. The term "bioeconomy" lacks a strict definition, but there is new research on the topic published regularly. A forthcoming paper by Hetemäki and Hurmekoski characterizes a forest-based bioeconomy as encompassing "forestry, paper and wood products, as well as emerging new industries, such as textiles, chemicals, new packing and building products, biopharma, and also the services related to these products (R&D, education, sales, marketing, extension, consulting, corporate governance, etc.) and forest services (recreation, hunting, tourism, carbon storage, biodiversity, etc.)." Circular economies, as an extension, seek to maintain the value of natural products and materials as long as possible and avoid waste.

Bioeconomy markets are expected to become increasingly diversified as new technologies emerge and are commercialized. Indeed, the possibilities for the bioeconomy are vast, and as Hetemäki, L. & Hurmekoski state, "There is no single best uniform solution for the forest-based bioeconomy, but rather a large number of different concepts, raw material options, production processes and output mixes, each tailored to be optimal for the local conditions and objectives." Maine is well-placed to define its own forest-based bioeconomy and promote industry collaboration and innovation.

Recent analyses of the factors supporting the transition into forest-based bioeconomies highlight the importance of defining bioeconomy strategies, investing in R&D, smart regulations and risk-taking. Dietz et al. (2018) suggests the following framework for thinking about the policy infrastructure underpinning bioeconomies. Many of the case studies presented in this report feature a mix of the following enabling environment drivers.

Table 2.2: Governance of Bioeconomy growth

Factors	Examples
Promoting Research and Development for Bio-Based Transformation	• Funding research projects • Establishing research facilities • Promotion of research networks and strategic partnerships • Promotion of knowledge and technologies transfer
Improving the Competitiveness of the Bioeconomy Through Incentives	• Quotas for the bioeconomy • Promotion of bio-based public procurement • Promotion of sustainable consumption behavior • Promotion of efficiencies throughout the supply chain • Tax benefits • Special credit programs
Industrial Location Policies for Bio-Based Industries	• Promotion of industry clusters • Promotion of knowledge and technology transfer between research and industry • Promotion of labor education in the field • Creation of appropriate intellectual property rights • Promotion of foreign direct investment (FDI) in the field
Political Support for Bio-Based Social Change	• Promote public dialogues to increase understanding of the functioning of the bioeconomy • Promote public dialogues on the technological risks in the field of bio-economics

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Case Studies Analysis

The case studies of 14 investments and 3 jurisdictions below provide a range of examples of companies and investment promotion tools. Several companies chose to invest in one of the seven priority forest products without accessing incentive programs, instead focusing on site-specific enabling factors and business outlook. Other companies benefited significantly from government incentives, which in some cases were the deciding factor in the decision to locate the investment in a specific jurisdiction. Lastly, some cases featured investments that were part of the wholesale transformation of the forest economy. The cases are informative for For/Maine stakeholders because they provide some guidance on the key factors driving investment in the products that will be part of this project's preparation of investment attraction materials in Phase 2, and they provide higher-level strategic inspiration to decision-makers in Maine about potential avenues to strengthen Maine's investment attractiveness.

The cases fall into three broad categories: construction materials, biomaterials, and fuels/chemicals. The case studies are summarized in Table 3.1 on the following page and color coded to match their category (the color coding follows in the case studies). Below we present key characteristics of the investments and whether they received incentives.

Analyzing the jurisdictions where the investments were made, several observations are worth making, which are summarized in Table 3.3 below. In all jurisdictions, except for Australia, there was some direct financial incentives available to companies. In Arkansas, the governor's strategic reserve fund provided a grant to Structurlam, for example. In Quebec, large co-financing through debt was made available to Fortress Global Enterprises. National and EU grants were pivotal for the establishment of the pyrolysis facilities in the BTG-BTL and Fortum cases. The result of the government incentives varied dramatically, however. The Fortum case demonstrates a successful investment facilitated by government support while the Fortress case demonstrates how a government might take on too much risk in the investment in order to create jobs.

Several cases included novel combination of incentives and services to the investor. In Quebec, for example, the government assumed the environmental liabilities of the facility in order to close the deal with Fortress. In the Netherlands, national power companies entered into long-term offtake agreements with BTG-BTL to support the company reaching financial sustainability. In Finland, there are several examples of industry support, including training, research and development support, and subsidies for facilities. In Oregon, for example, Business Oregon cost-shared an employee from the USFS to support companies secure sustainable wood supply. Freres lumber also received a small grant from the USDA for R&D on mass plywood and tax exemptions from the state.

Lastly, Quebec, Canada, and the Netherlands demonstrate economies that are promoting close cooperation between the government and the forest industry to spur the development of a forest-based bioeconomy. Provincial and national bioeconomy strategies underpin legislation and incentives programs to attract investments in the forest industry, particularly to make use of side-streams and create innovative new products to diversify away from paper production. In the Finland case, the ecosystem of larger pulp and paper companies was enhanced through targeted incentives for the development of new technologies. In addition to funding, dialogue platforms and other research sharing groups were convened by government and universities.

Table 3.1: Overview of Case Studies

Category	Case	Location	Description	CAPEX	Job Creation	Incentives
CLT	Freres Lumber	Oregon, USA	Mass plywood panel facility	$35 million	24 - 30 jobs	$250k USDA Grant + tax exemptions
	Structurlam Mass Timber	Arkansas, USA	Conway CLT manufactur-ing facility	$90 million	130 long term for operations and logistics	$1.5 million State Grant
LVL	Metsä Group	Lohja and Punka-harju, Finland	Upgrades at the Lohja and Punkaharju LVL factories	€100 million	43 jobs at the Punkaharju mill and 40 FTE in supply chain.	€ 2.5 million Grants in 2019 for entire company (training, research, etc.).
	Wesbeam Pty Ltd	Western Australia	LVL mill	AUD 115 million	60 FTE in the mill and 30+ jobs other associated support	Land and infrastructure for facility 25-year log supply contract
Particle-board	EGGER Group	North Carolina, USA	Raw parti-cleboard and thermally fused laminate	$700 million	770 jobs (400 in phase 1, and further 370 to full production)	In-kind site modifications and $11.3 million
MDF	Calplant 1	California, USA	Rice straw-based MDF plant	$315 million	125 jobs	Private bond raise + $73.7M of tax-exempt green bonds
	SwissKrono	South Carolina, USA	MDF/HDF Expansion	$230 million	105 jobs	$45.3M in NMTC allocation
Nano-cellulose	Performance BioFila-ments	Quebec, Canada	Plant for specialized production of cellulose filaments	CAD 38M	23 jobs	CAD 11.6 million in grants from federal and provincial sources
	UPM	Finland	The Finnish Center for Nano-cellulosic Technolo-gies	Not disclosed	40 jobs	€5 million/year
Dissolving Pulp	Fortress Global Enterprises	Quebec, Canada	Conversion of old kraft pulp mill	CAD 400 million	323 jobs	Tax concessions Environmental liability waived CAD102 Million

Table 3.2: Overview of Case Studies (cont.)

Category	Case	Location	Description	CAPEX	Job Creation	Incentives
Dissolving Pulp	Stora Enso	Finland	Second DP Line	€20 million	No additional jobs	None
Cellulosic Sugars	Gevo	Minnesota, USA	Isobutanol and animal feed	$70 million	30 employees + 20 contractors	None
Pyrolysis Oil	BTG BTL	Overijssel, Nether-lands	Empyro pyrolysis oil plant	€20 million	30 long term for operations and logistics	€20 million in Subsidies from EU and govts.
	Fortum	Joensuu, Finland	Pyrolysis oil plant	€30 million	55 FTE in supply chain, 7 at plant and 15 indirect	€8.1 million from National govt.

Looking at the cases through the lens of the Brookings and Pew research, we can see that most cases address some of the criteria for incentives: supporting export-oriented companies (nano-cellulose, dissolving pulp, cellulosic sugars), in some cases locally-owned (except Fortress, Gevo and Structurlam in Arkansas), In most jurisdictions there were support services provided to help the companies overcome barriers to growth (land, resources, workforce, off-take agreements). In Finland, in particular, there is a strong emphasize on supply chain integration and creation of innovation and learning opportunities across the industry.

Table 3.3: Characteristics of Industry Support in each Jurisdiction Analyzed

	United States	Canada	Finland	Nether-lands	Australia
Direct Financial Incentives Investment made as a result of direct investments, generally to establish a manufacturing facility with multiple options.					
Combination of Incentives Investment benefited from various incentives: • Direct investment • Subsidized site and facilities • Support in training • Tax breaks • Support in research and development • Off-take agreements					
Whole of State and Industry Transformation • Close co-operation between government and the whole of the forest industry developed a bioeconomy strategy • Strategy ensured that legislation, funding for research and development and the industry align to implement bioeconomy					

Weak	Moderate	Strong

3.1. Investment Drivers

Analyzing the key investment drivers in each case also provides useful information to ground the production of investment attraction materials during Phase 2 of this project. As shown in Table 3.4 below, the interviewees from each case were asked to identify the key drivers behind their decision to locate their investment in each location – including resource availability, existing infrastructure, market access, financing and R&D partnerships. Resource availability and R&D Partnerships emerged as the strongest factor in the investment cases, followed by Financing and Infrastructure. Market access was either very strong (for heavy products, lower value products with high transport costs) or not very important (e.g., high value liquid fuels that can be shipped via pipelines). It is worth noting that these factors are important for all the cases and Maine will need to demonstrate compelling investment cases for these product types using the most relevant geographic, resource or cost data available.

Table 3.4: Investment Drivers in Case Studies

Product \ Driver	Resource Availability	Existing infrastructure	Market Access	Financing	R&D Partnerships
Mass Timber	Strong	Strong	Strong	Weak	Strong
LVL	Strong	Moderate	Strong	Moderate	Moderate
MDF & Particleboard	Strong	Strong	Moderate	Strong	Strong
Nano-cellulose	Strong	Strong	Weak	Strong	Strong
Dissolving Pulp	Strong	Strong	Moderate	Strong	Moderate
Cellulosic Sugars	Strong	Strong	Weak	Moderate	Strong
Pyrolysis Oil	Strong	Moderate	Strong	Strong	Strong

Weak **Moderate** **Strong**

3.2. Lessons Learned from Incentives by Product Type

As described above, each product type has specific characteristics that influence how incentives can support investment. Below we present some of the major lessons learned from investment attraction in the products analyzed in the case studies.

Table 3.5: Incentives Lessons from Cases

Category	Inventive Lessons from Cases
Mass Timber	Grants for R&D, testing and certification can help companies overcome barriers to market entry. Provision of land, buildings, infrastructure improvements and access to forest resources are useful incentives.
LVL	Market for LVL is established and pulls investment. Companies might look for land or tax credits to locate in Maine.
MDF and Particle-board	Deals for MDF are highly technical and require exacting site characteristics. Investment in the form of site modifications by both public and private organizations are a consistent theme. MDF deals in the right location can be extremely attractive to private funding raises, with incentives following as public sector aims to capture wins.

Table 3.6: Incentives Lessons from Cases (cont.)

Category	Inventive Lessons from Cases
Nano-cellulose	Grants for R&D, partnerships with research facilities and access to residuals are useful. Support for marketing, strategic ventures and export are also valuable for smaller companies. Industry clusters are important.
Dissolving Pulp	Cases demonstrated conversion of pulp and paper mills to dissolving pulp. Support for identifying facilities, environmental remediation, co-financing and tax incentives were important in Quebec. In Finland, market dynamics incentivized private investment.
Cellulosic Sugars	For companies producing products from cellulosic sugars, incentives to support a company moving from R&D to commercialization can be important. When market pull exists, incentives might not be required. Sustainability of the resource is a key factor.
Pyrolysis Oil	Grants and loans for R&D and facilities construction were important. Given cost of fuel transport, local markets are important; facilitating off-take agreements (e.g., public procurement) and marketing efforts to inform consumers can be valuable.

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Implications for Maine

While the cases included in this report cannot represent all the possible factors influencing investments in the seven priority products for For/Maine, they do provide a window into some of the strategic decision-making behind incentive programs and efforts to generate an enabling environment for forest-based bioeconomies. Several lessons learned emerge from the cases and broader research for Maine.

First, to complete a major industry transformation in Maine, **political and industry leadership is pivotal** to embracing the opportunities and challenges of a forest-based bioeconomy. As seen in Finland, with concerted strategies and a regular implementation drumbeat, major change is possible in a short amount of time.

Second, healthy and strong traditional **timber and pulp production capability** is a prerequisite for the rise of new value-added products. Providing the environment in which this industry can flourish is essential.

Third, **know your investor**. Each industry has its own needs and investment drivers. In cases where resource availability, market access, R&D and workforce are key determinants, Maine is likely to be in a strong position to deliver. In cases where companies require large incentives or complicated deal structures, Maine should take note of the case of Fortress and be sure they understand the investor, their technical capabilities and financial resources. When competing directly against jurisdictions with attractive incentives programs, consider the trade-offs of pursuing investments at all costs.

Fourth, identify ways Maine can **support the forest-based SME ecosystem**. Innovations from the University of Maine can provide jumping-off points for new companies in Maine. Support through small grants, workforce development, facilities, export support or discussion fora can provide value to small and growing companies.

Fifth, **do not crowd out private capital**. For many of the products For/Maine is interested in, there is sufficient market demand to incentives private capital investments. Support services, infrastructure and investments in workforce training are likely more critical than grants or tax incentives.

Table 4.1 below provides a summary of the key lessons emerging from the cases, Maine's Status and Recommendations for strengthening its competitive position.

Table 4.1: Key Lessons and Recommendations for Maine

Lesson	Status	Recommendation
Location and Market Access	Maine is well located to supply the East Coast and Central US.	Ensure clear messaging on benefits of a Maine location (market and logistics facilities).
Resource Availability	Although Maine is well known as being a "Forest State", the fact that significant volumes of wood are available needs to be clearly advertised.	Ensure clear messaging of the availability of fiber in Maine, providing detail on the future availability of logs by grade, species, and location.
Resource Costs	Fiber in Maine remains expensive compared to other States or competing markets.	Identify efficiency gains throughout Maine's supply chain—inclusive of land management, wood brokers, procurement, harvesting, extraction and transport, etc. Communicate advances on other cost elements (power, logistics), as well as current quality of logging and trucking networks.
State-wide "Alignment"	There is some industry integration but weak compared to international competitors. State and industry beginning to work on bioeconomy as a pillar for growth (e.g., Maine Economic Development Strategy 2020-2029)	Develop a fully integrated and aligned strategy to move towards the Bioeconomy. Identify workforce development initiatives and educate public on potential new career paths.
Flexibility in Incentives Provided	It appears Maine is developing along this line, but in the past did not appear to be flexible on this. Groups like Maine and Co. or MITC can provide valuable services to new investors.	Provide flexibility in terms of the range of incentives provided to enable development of business hubs, industry clusters, and services.
Foster Home-Grown Scaling Up	Finland and Canada show examples of fostering local companies and ecosystem. University of Maine and existing ecosystem provide good basis to build on.	Provide continued support for R&D, industry ecosystem and companies that invest profit in state.

Annex 1: Case Studies

Historical Background

The current Finnish bioeconomy transformation is restructuring the forest industry at such a pace that comparable transformations date back more than a hundred years ago. Then, the natural resource economy relied on agriculture and forestry. The first industrial product from forests were wooden ships and the tar to preserve them. Sawmilling slowly evolved and sawn goods were the next major export product. When global paper consumption increased, technologies emerged to manufacture paper from wood instead of rags. These innovations led to a sudden industry transformation around the 1860s, when wood replaced used fabrics as raw material for paper, constructing steam-powered sawmills was permitted, and tar burning and slash-and-burn cultivation started to rapidly decline.

Since then, development of the forest sector has been gradual. A hundred years ago, Finland had just gained independence, agriculture was the main form of livelihood, industrial development was in its infancy and the forest industry relied heavily on manual labor. Today, forest industries form 20% of the total value of Finland's industrial production and total exports. Relative to its size, Finland is more dependent on forests and the forest industry than any other country in the world. Consequently, Finland has unique expertise in forestry and the industrial manufacturing of forest products. Automation, machinery, and ICT developments have increased the efficiency of forestry tremendously. Finland also has a long history of bio-products research and development.

Drivers of Change

The current transformation from traditional natural resource economy to the integrated bioeconomy is driven by global megatrends, including globalization and the economic growth of China, reduction in paper consumption, increase of fast-growing plantation forests, climate change and related international obligations, the transition to clean energy, and shifting from manufacturing to a service-oriented economy.

In the early 2000s, business as usual in the forestry sector continued, and investments were made to increase the capacity of the main products. This created oversupply and increased competition in the markets at a time when product prices had continued to decline for decades and production costs were increasing in Finland. Soon it was clear that business as usual in the declining markets would lead to a profitability crisis. The consensus was that the forestry enterprises had only two options: renew or die. At the same time, political pressure to act on the face of climate change increased. The forestry sector needed to undergo a transformation and approach the environment and energy sectors in search for solutions to the climate change challenge.

The sustainable forest industry forms the core of the transformation, safeguarding biodiversity and supplying sustainable feedstocks and services. It forms a solid platform for the development of new innovative bioproducts. Several overlapping sectors contribute together to create innovations, added value, and well-being from the streams of traditional forest industry, following the key principles of bioeconomy: Inputs are renewable or recyclable, outputs contribute to the carbon neutral society, there is a continuous drive for technological innovations, solutions are provided for domestic and global markets, and there is an embedded mechanism of flexibility and preparedness for changing market conditions.

Creating the Enabling Environment to Facilitate Industry Transformation

Diversification of the forestry sector includes organizational company restructuring, reorientation of public funding, and the creation of new, multidisciplinary R&D programs. Several influential public policy decisions were made following the early decline of the traditional forestry industry that put Finland on the trajectory to transform itself. In 2008, the government initiated the Strategic Programme for the Forest Sector, which aimed to initiate and implement the change process to enhance and renew the forest sector. The Minister of Economic Affairs guided the program and reported on progress to the prime minister's cabinet. The program had 4 pillars: 1) Increase wood construction, 2) Strengthen the basic forest industry, 3) Promote entrepreneurship and innovation in the Finish forest bioeconomy, and 4) Strengthen the

role of wood in the global bioeconomy. Additionally, the European Union's 2012 and 2018 Bioeconomy strategy closely aligned with Finland's bioeconomy efforts.

Emerging in the early 2010s, Finland put in place several national strategies to align public policy behind an enhanced forest sector.

National Forest Strategy 2015-2025

Finland has a long history in creating forest strategies that direct the use of Finnish forests. The new strategy describes priority objectives and more detailed measures that will promote the achievement of the strategic objectives, and highlights priority areas for developing the sector and the most urgent needs for changes on which the public sector must focus in the following years. The vision of the strategy is: "Sustainable forest management is a source of growing welfare". To realize the vision, three strategic objectives were established: i) Finland is a competitive operating environment for forest-based business, ii) forest-based business and activities and their structures are renewed and diversified, iii) forests are in active, economically, ecologically and socially sustainable and diverse use.

Bioeconomy Strategy 2014

The Finnish Bioeconomy Strategy was established to support the industry transformation with a target of EUR100 billion bioeconomy contribution to GDP and 100,000 new jobs. The national strategy is a central tool in involving all stakeholders in the industry transition, emphasizing the importance of policy reforms, and creating new funding programs. The bioeconomy strategy seeks to reduce the dependency on fossil natural resources, to prevent the impoverishment of ecosystems and to promote economic development and create new jobs in compliance with the principles of sustainable development. The strategic goals of the Bioeconomy Strategy are: 1) A competitive operating environment for the bioeconomy, 2) New business from the bioeconomy, 3) A strong bioeconomy competence base, and 4) Accessibility and sustainability of biomasses.

Support Programs focused on R&D and Commercialization

Industry support programs have focused on mitigating risks for research, development and commercialization of new products from wood. Some 15 years ago, Finland's forestry sector was dominated by the three big companies – Mestä Group, Stora Enso and UPM. Few start-ups existed in the sector. The business environment needed to change to be more supportive of small and medium sized companies that play a major role in diversifying the local business environment and creating rural jobs. To begin changing the business environment, Business Finland initiated high potential ecosystems where enterprises, research institutes and start-ups create collaboration platforms.

For example, from 2007-2012, the **Biorefine Program** supported EUR90 million of research into biomass, biorefineries and second-generation biofuels. **Design Driven Value Chains in the World of Cellulose (DWoC)** was a multidisciplinary research collaboration project funded by Tekes from 2013-2018 (the Finnish Funding Agency for Innnovation; now part of Business Finland) focused on finding new and innovative applications for cellulosic materials. More recently, the **Academy of Finland**, a governmental funding body for scientific research, launched a flagship program to develop new materials for packaging, textiles and energy storage. Business Finland also recently launched a EUR300 million **Bio and Circular Economy Program** that provides grants and loans to research and development and company expansion. It also provides services to grantees like networking, market research, and export opportunities.

Other innovations to support the forest bioeconomy growth include open-access pilot facilities typically hosted at universities focused on biofuels and thermochemical conversions, biomass processing, pulp production, chemical process technology and industrial biotechnology and bio-based material. Lastly, CLIC Innovation Ltd. Public-private partnership owned by 30 companies, including major players in the

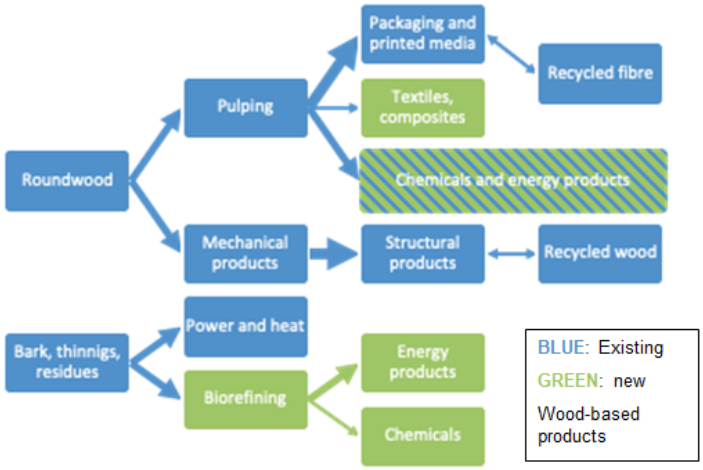
pulp and paper sectors, and government agencies promotes rapid commercialization of new bioeconomy products.

Lastly, The Natural Resource Institute Finland's (LUKE) extensive data collection forms another one of the cornerstones of the bioeconomy transition. Without precise data on the availability of local natural resources now and in the future, investments relying on them will not attract investors. Infrastructure, labor availability and social stability also play a role, but in the end, it is the raw material availability that determines the investment layout.

Structure of Finland's Forest Business Ecosystem

Traditional timber and pulp production is a prerequisite for the rise of new value-added products. New bioproducts and innovations are in most cases extensions to existing product portfolios in Finland. For example, the manufacturing of pulp generates valuable side-streams that can be utilized for new value-added products. Figure 1 below presents the linkages between the various parts of the value chain in Finland's forest bioeconomy.

Figure 1: Finland's Wood-based Value Chain



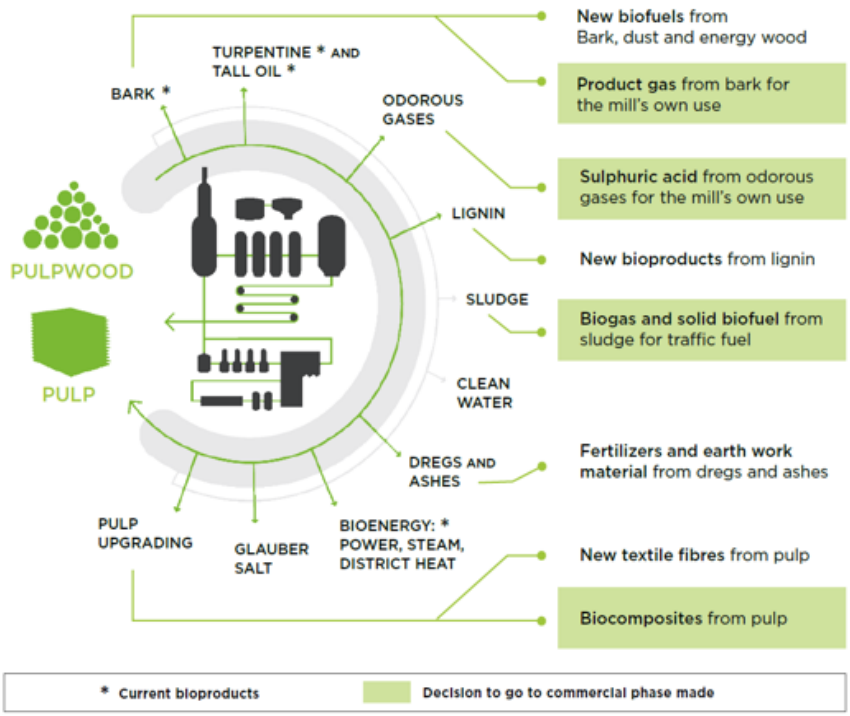
Adapted from Ministry of Economic Affairs and Employment (2017)

Even in Finland, biomass from forest is not a limitless resource. It must be utilized in a sustainable way. Developed technologies must be resource-efficient and produce various products with different values and minimize waste. Metsä Group's modern Äänekoski mill is an example of resource efficiency. Together with Itochu, Metsä Group began to plan and implement the world's biggest bioproduct mill in Äänekoski. In addition to high-quality pulp, the mill produces a broad range of bioproducts, such as tall oil, turpentine, biocomposites as well as product gas, biogas and sulphuric gas. Potential new products created from production side streams include textile fibres and lignin products. The bioproduct mill uses 100 per cent of the raw materials and side streams to produce bioproducts and bioenergy. The electricity self-sufficiency rate of the mill is 240%. See in Figure 2.

Impacts of the Finnish bioeconomy

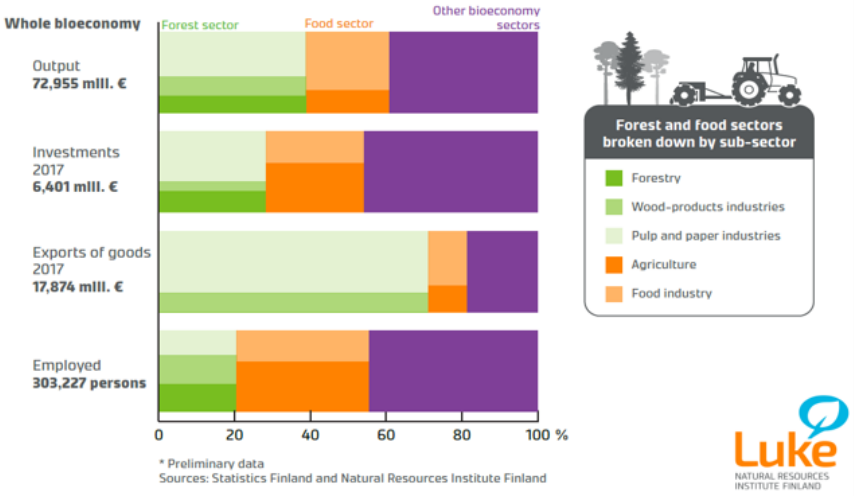
The most recent data shows that the output of bioeconomy in Finland is almost EUR73 billion, investments to the bioeconomy reach almost 6.5 billion, and exports of the bioeconomy reach almost EUR18 billion and more than 300 000 people are employed in the bioeconomy sector (Figure 3). Forestry is a key contributor to economic output and exports but lags in terms of employment compared to other sectors.

Figure 2: Äänekoski Mill Production Streams



Metsä Group

Figure 3: The Forest Sector in the Finnish Bioeconomy, 2018



Lessons Learned from Finland's Transformation

Finland has become one of the richest countries in the world, in part, because of its ability to sustainably utilize the abundant natural resources. Some 80% of its land is covered with forest, which is managed sustainably and grows more timber than what is annually harvested. Side streams of the forest industry are utilized efficiently. Finland has strong know-how in technology, construction, energy, chemistry, food, and health sciences. Innovation, cooperation, and combined technologies in these fields have made Finland a true leader in bioeconomy. Political will and common effort from all stakeholders have been required to bring Finland through such a profound industry transformation. The Bioeconomy Strategy was created to guide the process and gather information on the impact of bioeconomy. The National Forest Strategy 2015-2025 directs the use of forests.

Finland has invested in long-term bioproducts research and development for decades. Steady and secure funding in research has made it a safe sector to make a career in. In long-term research it is more feasible to have secured long-term funding, even if the invested amounts are low. VTT enjoys steady funding in many of its programs, although the closer the product is to commercialization, the bigger grows the share of private funding. A classic example is the fast pyrolysis bio-oil research that started as early as 1980s in VTT. The first technology development consortium was established in 2007 with relevant enterprises. In 2013 the product was fully commercialized. In these three decades, most of the research was done at VTT, then public and private funding from the BioRefine program stepped in to carry the product over the valley of death, and finally the enterprises commercialized the product. A completely different approach to research funding is showcased in the nanocellulose example, which began as a research center of research institutes and enterprises already with a significant amount of private and public funding. In the 5 years of the center's operation many products were commercialized, but at the end of the funding period many products fell in the valley of death. Some enterprises, like UPM, have been able continue their own nanocellulose R&D in various other collaborations.

Dialogue between research and enterprises is very valuable. The public funding structure of Finland supported research consortiums that covered the whole product supply chain from raw material to end users and beyond. Research institutes are normally concentrated on developing the product and its characteristics, while the enterprises' expertise is required to solve the adaptions in the supply chain. Concentrating research on only a narrow area of the supply chain would miss the weak links elsewhere. Researching the whole supply chain from the beginning to the end speeds up commercialization and lowers the overall project cost. Nowadays the funding structure of Business Finland is focused more to utilization of current research results and finalizing product commercialization.

Political decisions have a great impact on bioeconomy development. Existing legislation can either promote or slow down product commercialization. For example, the production of bio-oil from logging residues might suffer if a political decision was made that burning logging residues for energy is not carbon neutral. On the other hand, bio-oil could be promoted by mandating a transition from fossil fuels to biomaterials in local businesses.

Development of new technologies and novel products is one opportunity in strengthening the competitiveness of the forest industry in a changing operating environment. However, bringing a novel product and creating a market for it from nothing takes much effort in marketing and convincing clients of the security of supply. For example, Metsä Wood was the sole manufacturer of LVL in Europe for decades. When competing LVL manufacturers started to show up in 2014, Metsä Wood welcomed the competition as multiple manufacturers allow for competitive biddings and improve the credibility of the product in the eyes of construction investors. New operators entering Europe's LVL markets also accelerate the wood construction trend. In Stora Enso's dissolving pulp case, neither the product nor the technology were new to the textile markets, but required a completely new marketing strategy for the company. Stora Enso is engaged in developing a more sustainable way to produce fabric from wood, and with the already existing dissolving pulp mill, Stora Enso will be controlling most of the value chain of the new fabric when it commercializes. However, the marketing challenge remains, especially if Stora Enso remains the only manufacturer of their new product.

Fortum Oyj

Espoo, Finland

- Pyrolysis Oil
- CAPEX: 30 million EUR
- Jobs created: 55 FTE in the supply chain, 7 at the plant and 15 indirect jobs

Case summary

Fortum Oyj is a Finnish state-owned energy company focusing on the Nordic and Baltic countries, Germany, Poland, Russia and India. Fortum's business activities cover the production and sales of electricity and heat, waste-to-energy and circular economy solutions as well as energy-sector expert services and various consumer solutions. The global mega-trends affecting forestry industry have also affected the energy sector and brought the industries closer together. To move the energy sector from fossil fuels to low-emissions energy system and optimal energy and resource efficiency, Fortum has invested in hydro, nuclear, wind and solar power production, CHP, as well as circular economy and resource efficiency. As a part of the circular economy strategy, Fortum has developed an integrated pyrolysis technology that is presently used to produce renewable heating oil, replacing fossil fuels.

First R&D studies on fast pyrolysis in Finland started in the 1980s by VTT, the Technical Research Centre of Finland. The project was encouraged by the energy crisis of the 1970s, after which the national energy policy guidelines were formed with the aim of finding domestic energy sources as an alternative to foreign fossil fuels. The naturally abundant raw materials in Finland are forest and sawmilling residues as well as agricultural waste, which VTT started testing in various thermochemical processes to produce bio-oil. One of these projects concentrated on fast pyrolysis. The research was done in collaboration with the International Energy Agency (IEA) to be able to use the best material from the global network of scientists. In the beginning, funding for the pyrolysis R&D came mainly from VTT itself and other national public funds, but as the technology progressed from laboratory scale to Process Development Units (PDU), it was necessary to bring in relevant industrial stakeholders for further scaling up of the process.

At the time Business Finland, the public funding agency for research funding in Finland, had a funding program called BioRefine, the aim of which was to increase the value added from wood- and other biomass, and to promote cooperation for innovation related to biorefineries. In addition to a funding vehicle, the BioRefine program was formed as a kind of discussion forum to bring together a network of national research institutes, universities, and enterprises. Research institutes were not able to apply for public funding independently but had to form cooperation projects with private funding from enterprises that covered the whole product supply chain. It was vital to research not only the product, but all the moving parts in the supply chain, as one weak link could break the chain. Together with the special pilot and demo funding of the Ministry of Employment and the Economy, the BioRefine program proved extremely attractive for stakeholders. The volume of the projects under the BioRefine program reached approximately EUR 200 million.

For VTT to gain public funding from Business Finland (at the time called Tekes), the project needed to attract investors from relevant stakeholders covering the whole product supply chain. The first technology development consortium with Valmet, UPM and VTT kicked off in 2007, with funding from the BioRefine program. Valmet (at the time Metso) as machinery manufacturer has technology expertise and was able to provide cold model tests of industrial scale for the bio-oil production at the Valmet R&D center in the city of Tampere. UPM on the other hand is the expert on wood resources supply and management. In 2009 Fortum joined the team, offering the opportunity for integrating the pyrolysis plant into one of Fortum's CHP plants. It was calculated that significant cost and efficiency advantages could be achieved by integrating the pyrolysis process with an industrial CHP plant compared with a stand-alone pyrolysis plant. Fortum also saw the opportunity to grow its business, diversify its product portfolio, and slowly replace its use of

heavy oil. Joensuu was selected due to the plant already having a bubbling fluidized bed boiler that could be easily be integrated with the pyrolysis reactor. Joensuu is also surrounded with an abundance of the raw material: sawmilling and logging residues. Most of the feedstock is logging residues collected in a 50 km radius from the plant, and there exists sawmills with a 500 000 m^3 joint production capacity in the same radius.

In 2012 construction began on the world's first industrial scale integrated bio-oil plant in Joensuu, Finland, and in 2013 the new pyrolysis reactor was inaugurated. Valmet delivered the plant to Fortum as a turn-key delivery, including civil and construction works, fuel handling and pretreatment, bio-oil production and storage equipment, a Metso DNA automation system, and EI. The Ministry of Employment and the Economy granted Fortum's bio-oil project EUR 8.1 million as a new technology investment. The total value of the investment was about EUR 30 million, Fortum covering the remainder of the investment. The CHP plant annually uses 250 000 solid m^3 of wood (100 000 dry tons) and produces 50 000 tons of bio-oil from wood-based fuels, in addition to electricity and district heat. The plant is fully integrated: the pyrolysis reactor is connected as a fixed part to the CHP plant's boiler. The overall energy efficiency of the plant is 90%. The bio-oil production corresponds to 200–250 GWh in fuel energy, reducing CO2 emissions of heating by 59 000 tons and SOx emissions by 320 tons per year compared to heavy fuel oil. Compared to fossil fuels, energy produced with bio-oil reduces greenhouse gas emissions by 70%. In 2016 the plant employed 8 full-time supply chains (harvester-forwarder-timber truck) to feed the plant. The employment effect is 55 full-time equivalent (FTE) in the supply chain, 7 at the plant and approximately 15 indirect jobs. All in all, EUR 8.5 million circulates in the local economy instead of paying it out in oil bills. As an anecdote, in December 2019, Fortum announced its divestment of the Joensuu plant to a local energy company Savon Voima.

Fortum, Valmet and UPM have continued to develop the pyrolysis technology to produce advanced high value lignocellulosic fuels, such as transportation fuels or higher value bio liquids. Pyrolysis technology is seen as the most competitive route to produce advanced lignocellulosic biofuels and efficiently reduce greenhouse gas emissions in the transportation and heating sectors. In 2018 Fortum and Valmet were continuing with this project in collaboration with the Swedish refinery company Preem.

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Challenges

- Intellectual property rights must be agreed on clearly between the research institution and the enterprises to avoid future disputes.
- Building the first commercial level plant with completely new technology never goes according to original plan and budget. In this case, the heterogeneity of the raw material caused some hiccups in consistent product quality.
- The availability of the raw material – logging and saw-milling residues – is affected by seasons, weather, forest road conditions, the coverage of the forest road network, and other variables affecting loggings in general.
- Long distance (70 – 100 km) transportation of logging residues is unprofitable.
- High transportation costs of the end product are also a challenge.
- Since the oil crisis in the 1970s, oil has become more affordable in Finland, which has discouraged many to jump from heavy oil to the more expensive bio-oil. The whole value-chain from the fuel procurement to the end-use should be capable of operating in the margin between the price of the fossil fuel to be replaced and the price of the feed stock.
- The additional investments to adapt the fuel storage, pumps, valves, and burners to bio-oil discourages many customers to make the transition from oil to bio-oil.
- The security of supply is also a challenge when there is only one manufacturer.
- In a 2017 questionnaire, many local entrepreneurs were not aware of the possibility to start using bio-oil. The entrepreneurs also mentioned substituting oil with wood rather than bio-oil.
- As a result of the challenges in marketing and high investment costs for customers, the Fortum pyrolysis plant has not run on full capacity most years after its inauguration.
- The greatest challenge is still the competition with fossil fuels.

Enabling conditions

- In the 1970s, the government of Finland decided on national energy guidelines, aiming to reduce the nation's dependency on foreign oil and increase its energy self-sufficiency. There was political encouragement for VTT to start researching pyrolysis and other thermochemical processes to produce bio-oil. The level of funding for energy innovations has been consistently high.
- Since the 1980s the research was carried out in collaboration with IEA and its global network of energy scientists. However, VTT registers its own patents, as patent-secured technology attracts investors.
- VTT was able to develop the pyrolysis technology from laboratory level to Process Development Unit level. At this level, the technology became attractive to industrial enterprises, as scaling up at least from laboratory to PDU was proven. Valmet and Fortum are highly experienced in machinery and energy technology and had high motivation to bring their technologies forward by joining the pyrolysis project.

Enabling conditions (cont.)

- Business Finland's BioRefine program was a perfect fit for the project. Funding from the program was guaranteed, it was just a question of how much the program could cover.
- Effective integration of the pyrolysis plant meant low investments costs for Fortum.
- High quality feed stock and existing procurement systems already existed around the Joensuu plant. Local raw materials also increased the economic sustainability of Fortum.
- Bio-oil can replace heavy oil with minor adaptations of fuel storage, pumps, valves, and burners to resist low pH. In essence, bio-oil was able to enter the well-established markets of heavy oil with minor investments from the clients.
- Fortum, Valmet and UPM were interested in further developing the product into high value lignocellulosic fuels after this initial project was done.

Takeaways

- The BioRefine program was more than just a funding vehicle. The program created a forum for research institutions, universities, and enterprises to promote cooperation for innovation related to biorefineries. In order to receive public funding, research institutions had to also get private funding from Finnish enterprises from the whole product supply chain. Researching the whole supply chain from the beginning speeds up commercialization and lowers the overall project cost. Such a structure is not unique to the BioRefine program but is the basis of most public funding for research institutions. The structure has helped numerous innovations to commercialize. Today it is possible to invite foreign companies to complement the supply chain, but originally the rules forbid foreign investors.
- R&D from scratch demands time and patience. Many countries boost investment to a certain research project for a while, but later the funding diminishes. Fluctuation in funding programs creates gaps in knowledge transport from one generation of scientists to the next. In long-term research it is more feasible to have secured long-term funding, even if the amounts are low.
- Companies must be open to fund research projects from the beginning and understand that results are not achieved immediately.
- The pyrolysis plant must be carefully located within reach of abundant supply of raw material and have a well-planned storage solution to diminish the effects of the seasonal availability of the raw material.

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Stora Enso

Helsinki, Finland

- Repurposing to Dissolving Pulp Mill
- CAPEX: 52 million EUR
- Jobs created: N/A

Case summary

Stora Enso was among the companies that shut down and sold pulp and paper mills in the 2000s, namely the Kemijärvi and Norrsundet pulp mills, Summa paper mill and Anjalankoski paper machine in 2007, and the Kotka paper mill in 2008. In 2009 some of Stora Enso's mills were idling, among them the Enocell pulp mill in Uimaharju. By 2011 the pulp and paper giant had laid off over one-third of its 30,000 employees. It was clear that quick decisions to solve the crisis needed to be made and the company's strategy rewritten.

Stora Enso's new strategy focused on the transformation into a renewable materials growth company. The most important building blocks in the strategy include sustainable building solutions, fibre-based packaging, and innovation in biomass and chemicals. To realize the latter goal, Stora Enso decided to start specializing its pulp mills around Finland and Sweden: now the Sunila pulp mill in Kotka specializes in Lignin products, the Skutskär mill in Sweden specializes in fluff and the Enocell mill specializes in dissolving pulp. The latter investment also supports the future plans for Enocell Mill to become an integrated biorefinery plant for new bio-based chemicals. Dissolving pulp was chosen for the Enocell mill due to its positive market outlook.

In 2012 Stora Enso converted one of the two softwood kraft pulp lines in its Enocell pulp mill to produce dissolving pulp from birch. The small investment resulted in commercial production of 150 000 tons of dissolving pulp with capability to swing back to regular production of bleached softwood kraft pulp if required. In October 2017 Stora Enso announced a EUR 52 million investment to convert the second line at its Enocell mill to produce softwood dissolving pulp. After the second investment, softwood kraft pulp production ceased at the mill altogether, although the lines are able to swing back to producing it. In December 2019, the second investment was finished, and the mill's production capacity increased to a total of 430,000 tons of dissolving pulp, of which 185,000 tons is hardwood and 245,000 tons softwood pulp. Stora Enso is one of the first companies able to provide both types of dissolving pulp, which opens possibilities to broaden the customer portfolio into specialties and new applications.

Some of the dissolving pulp produced at the Enocell mill is further processed in Finland into different products, for example acoustic surfaces in buildings. Such surfaces are already in use in noteworthy buildings such as the Parliament house and the new Oodi library in Helsinki. This innovation has been developed by the company Lumir, in close cooperation with Stora Enso. Dissolving pulp and its different kind of cellulose derivatives can be applied for many other end-uses as well, such as clothes, tires, paints, cosmetics, food, medicine, and cellophane.

Most of the dissolving pulp Stora Enso produces is shipped to China where the main market is the textile industry. There, dissolving pulp is further processed into viscose and used in e.g., clothing, decorative fabrics, knitwear and non-wovens. The dissolving pulp product segment is growing above the industrial average. The growth is driven by increased demand for non-woven applications, and viscose-type fabrics in the textile industry. Viscose is viewed as a wood-based substitute for oil-based polyester fabrics as well as for cotton, which has many land-use related challenges. However, the processing of dissolving pulp into viscose uses toxic chemicals such as carbon disulphite. Due to the environmental and social risks, viscose production has moved from Europe to China, where the regulatory environment is not as strict. Stora Enso is actively researching new innovations to replace the viscose manufacturing process with a safer and more environmentally friendly method.

Since 2013 the company has been in partnership with Aalto University and University of Helsinki to develop the Ioncell technology that turns used textiles, pulp or old newspapers into new textile fibers sustainably and without harmful chemicals. Additionally, in 2018, Stora Enso joined the already existing partnership with HM, Inter IKEA and innovator Lars Stigsson to industrialize their joint venture TreeToTextile AB, whose aim is to develop new textile fibers in a sustainable way at attractive cost levels.

Challenges

- Switching from pulp to dissolving pulp meant switching form serving the paper industry to serving the textile industry, which are completely different worlds in terms of marketing and desired product characteristics. The textile industry is already heavily competitive and entering it as a novice manufacturer was a great challenge.
- Dissolving pulp from birch has been manufactured at the Enocell mill since 2012, so the product development and marketing process is quite finalized. However, in 2019 the mill started also producing softwood dissolving pulp, which has different characteristics. There is much learning to be done for the product to pass the clients' standards.
- The manufacturing of dissolving pulp is not difficult and requires only small initial investments. When the price difference between pulp and dissolving pulp grows large enough, new manufacturers can easily enter the market and old manufacturers with swing capability can switch from pulp to dissolving pulp and cause fluctuation in the product prices. For example, the European dissolving pulp production capacity doubled between 2010 and 2014 due to price increase of dissolving pulp and demand decrease of paper around this time, which later led to rapid price decrease of dissolving pulp and financial troubles for many who just entered the market.

Takeaways

- Stora Enso quickly made the decision to start specializing its pulp mills around Finland and Sweden, when the traditional pulp and paper industry faced troubles.
- Finland lost most of its textile industry in the 1970s to lower-cost countries. Establishing wood-based fabric manufacturing in the forest-dense country would bring at least some of the textile industry jobs back.
- Although dissolving pulp has current applications in the textile industry, Stora Enso is also engaging in long term development of new innovations to manufacture environmentally friendly, wood-based textiles.
- The competition in the textile industry is fierce and will get more competitive once breakthroughs in R&D occur and new bio-based or recycled fibres enter the market.

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UPM

Helsinki, Finland

- Finnish Center for Nanocellulosic Technologies
- CAPEX: N/A
- Jobs created: 40

Case summary

UPM went through major restructuring of its businesses in the 2000s. Between 2006 and 2008 UPM closed three pulp and paper mills in Finland and laid off more than 4,000 people. Throughout the next 10 years, several plywood and sawmills were closed, as well as P&P mills in USA, New Brunswick, France and Germany. In parallel with the restructuring of its business areas, UPM engaged in product innovation. As a result, the UPM Biocomposites business was established in 2007 and in 2015, the production of wood-based biofuels started at the biorefinery in Lappeenranta, Finland. Today, UPM has three key focus areas: high value fibre, molecular bioproducts, and specialty packaging materials. UPM develops its molecular bioproducts in two distinct business branches: biochemicals and biomedicals. One success story from the biomedicals department is nanocellulose, which UPM began to develop in a research consortium in 2008. So far, UPM has launched three nanocellulose products in the biomedical field: GrowDex® hydrogel range for cultivating 3D cell cultures, GrowInk™ bioink range for 3D bioprinting suitable for use with any printer, and FibDex®, an advanced one-time application wound dressing.

There had been some research and general interest on nanocellulose in the early 2000s in universities and research centers in Europe, Canada, and Japan. In Finland, the large scale public nanocellulose research and development work was initiated by the Aalto University (at the time TKK), UPM and VTT, the Technical Research Centre of Finland. In early 2008 UPM, VTT and Aalto University created The Finnish Center for Nanocellulosic Technologies as an equal consortium. The three partners brought together multidisciplinary experience in basic and applied research as well as productization and business expertise in the process industries. The aim of the center was to create new commercial opportunities for nanocellulose as a raw material and as a product itself. At first, UPM focused on the research on applications in paper and packaging. Because the potential of nanocellulose was vast and had applications outside forest industries, VTT and Aalto created a separate cooperation project inside the center, where they gathered approximately 10 other companies for collaboration. This part of the technology center concentrated researching a variety of nanocellulose applications in e.g., composites, paints, filters, insulation materials and food.

The Center of Nanocellulosic Technologies employed 40 researchers for 5 years. The Center did not have a physical location, but rather it was a virtual cooperation program and a project portfolio. VTT and Aalto University both have research laboratories in Otaniemi, City of Espoo, although in separate buildings. The annual project budget was EUR 5 million for each of the 5 years from Tekes (now Business Finland), the national funding agency for research and innovation in Finland. The research and development funding was allocated according to the rules of Tekes to each project of the center's project portfolio. The amount of funding received varied between 50% and 70 % of the total budget for the projects. The partners and participating companies were responsible of the rest of the funding. As a completely new but highly potential and versatile product, nanocellulose was an attractive funding target. The Center also applied for funding from the EU and other public sources for additional projects. As individual products approached the phase of commercialization, public funding diminished, and the enterprises' funding responsibility increased.

The Finnish Center was disbanded after 5 years when national funding from Tekes was discontinued. After that, many businesses and new research consortiums around nanocellulose emerged, but there were also many product development projects that couldn't cross the, so called, "valley of death".

Some examples of the research programs arisen from the platform created in connection of the center are the Design Driven Value Chains in the World of Cellulose (DWoC) research program funded by TEKES and VTT; Aalto and a few other universities between 2013 and 2018, and FinnCERES, a scientific research program by VTT and Aalto University for development of applications of lignocellulosic materials funded by Academy of Finland starting from 2018 and planned to continue until 2026. VTT and Aalto University have also continued research on their own as well as in cooperation together and with various businesses. Since 2008, VTT has invested EUR 60 million in nanocellulose research with 50 different partners and customers.

Enabling Environment

- In the face of the industry transformation, the forest industries were interested in innovating completely new products. The public funding agency was also looking to help the industry overcome the transformation by funding novel innovations.
- The key people from UPM, VTT and Aalto had the will and resources to push for an establishment of a common nanocellulose research center.
- At the time, the funding structure of Tekes (Business Finland) supported consortiums of research institutions and enterprises. Nowadays the funding is focused more to utilization of research results and product commercialization.
- After the Center, UPM was able to continue product development in various other consortiums together with both domestic and international partners. UPM has had the means to carry product development for over 10 years.

Takeaways

- Development of new technologies and novel products is one opportunity in strengthening the competitiveness of the forest industry in a changing operating environment.
- There must be a strong will and dedication in pushing for novel product development in all phases of the commercialization and in all links of the supply chain.
- The funding structure of Tekes (now Business Finland) supported the consortium when it was founded, but the continuation of the funding was limited to 5 years and after 5 years project period the Center was discontinued.
- Nanocellulose R&D begun by finding applications in the pulp and paper industry, but soon diversified to many other applications. Flexibility and diversity in the research allowed for commercialization of multiple products.

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Design Driven Value Chains in the World of Cellulose
FinnCERES

Metsä Group

Helsinki, Finland

- Laminated Veneer Lumber (LVL) mill
- CAPEX: 100 million EUR
- Jobs created: 43 jobs at the Punkaharju mill and 40 FTE in the supply chain. Neutral effect at the Lohja mill.

Case summary

In the early 2000s, Metsä Group was an international actor with more than 25 000 employees in dozens of countries. The forest industry transformation made Metsä go through a systematic structural change, which the company implemented between 2005 and 2012. Metsä Group divested its whole Graphic Paper sector, a pulp mill in Uruguay, and sold parts of its Metsä Fibre sawn wood and pulp operations to Itochu Corporation. Now Metsä Group employs 9 300 people. In addition to traditional pulp products and the novel bioproducts from the Äänekoski mill, Metsä Group engages in promoting the use of wood in construction, industrial and distribution applications. Metsä Group aims to be a world leader in production of premium quality engineered wood products. Metsä Wood's primary products are Kerto® LVL (laminated veneer lumber) and birch and spruce plywood.

The use of laminated veneer lumber (LVL) in Finland has steadily been growing since 1975, when Metsä Wood constructed the first LVL factory in Europe. The initial driver for the development of LVL has been efficiency in using all the raw material – even small-diameter logs can be used to produce long LVL beams – as well as the uniform quality of LVL. Both qualities improve the overall material and time efficiency especially in industrial applications and offsite production of construction elements. Recently, environmental pressures have increased the popularity of wood-based construction materials and conquered market share from concrete and steel construction.

Parallel oriented plywood products have been used in the furniture industry since the beginning of the 20th century. The original LVL was developed in the USA at the R&D center of USDA Forest Products Laboratory, and researcher Peter Koch advanced the product in the 1960s–1970s to its current form. Around this time, industry breakthroughs were achieved in the development of a significantly lower-cost thermosetting phenol adhesive and a continuous hot-pressing implementation. The first commercial solution utilizing these advancements for manufacturing LVL was created in 1972 by the company Trus-Joist, for the substitution of finger-jointed sawn timber in the flanges of I-joists. The product took only 5 years to break through in the I-joist market.

In Finland, an invention to produce blockboard as a continuous billet was patented by Nils Alenius in 1964. Alenius had discussions with Peter Koch due to the similarities of their products and together they presented the idea of LVL to Metsä Wood. Emeritus Professor Matti Kairi was also a central agent in pushing for LVL production in Finland. At the time, Metsä Wood was actively searching for alternatives for the oversupplied spruce sawn goods. The technology push and market pull culminated in 1975, when Metsä Wood started the Kerto®-LVL pilot production line in Punkaharju, Eastern Finland. Metsä Wood expanded the LVL production in 1980s by constructing a new factory in Lohja, Southern Finland.

Metsä Wood operated as the only LVL manufacturer in Europe (excluding Russia) from the 1970s until 2014, after which the German Pollmeier and STEICO, and the Finnish Stora Enso started constructing their own LVL production lines. Pollmeier announced an investment of EUR 105 million to build a 180 000 m^3 beech LVL line in Germany in 2014. The company is still the only hardwood LVL manufacturer in Europe. In 2019 the company diversified the line to also manufacture spruce LVL. Around the same time as Pollmeier made its first investment, STEICO invested EUR 23 million in a 80 000 m^3 LVL line in Poland. Two years later STEICO invested another EUR 17.5 million in a second LVL line at the Poland

factory, doubling the production capacity to 160 000 m^3. STEICO uses spruce and pine veneers as raw material. Stora Enso jumped into the LVL race in 2015 by announcing an investment of EUR 43 million in a modern 100 000 m^3 spruce LVL line in Finland.

Metsä Wood has welcomed the competition, because multiple manufacturers allow for competitive biddings and improve the credibility of the product in the eyes of construction investors. The competition in LVL products also promotes wood construction as a whole and meets growing demand. In Metsä Wood's view, LVL's potential market covers not only timber construction but it will also gain market share from concrete and brick building, which makes the potential market much wider than what is currently produced. Now, the total capacity of LVL production in Europe is 640 000 m^3, while North America produces more than 2 million m^3 of LVL annually. The outlook of timber construction is very positive, as the government and municipalities have announced plans to increase the use of wood in public construction projects due to environmental reasons.

The breakthrough of LVL occurred around the middle of the 1990s both in North America and in Europe. Other regions of the world do not yet have a strong tradition in production and use of LVL. Notably, its use in the two main markets differ considerably. North America has more than 10 companies producing LVL, and most of them purchase their raw material as dried and graded veneers from veneer mills. The veneer line width is usually 1.2 meters, which limits the end use applications of LVL produced this way. North American LVL mills only need to invest in veneer handling, hot pressing, and further handling of the LVL billets, which makes the start-up investment low. The most common North American LVL products are beams, headers, and I-joist flanges. The end use applications in Europe are considerably more versatile than in North America. There are 4 manufacturers in the EU and 2 in Russia, most of which operate the whole product supply chain from logs to product. The maximum width of LVL is 2.5 m and maximum length 25 m. Europeans produce for example beams, joists, trusses, frames, studs, formwork, and panels, but the production is shifting more and more to construction elements and modules prefabricated offsite and delivered to building sites.

In the beginning of June 2016, Metsä Wood announced a significant investment program of EUR 100 million for its Kerto®-LVL and plywood businesses in Finland and Estonia. The investment was driven by renewal needs of the mills as well as market demand increase in specialty products. Metsä Wood's view is that urbanization will increase the need for prefabricated construction products. The investments were carried out fully by Metsä Wood, without public funding or external incentives.

As a part of the investment program, in 2019 a new LVL line was inaugurated at the Punkaharju factory, increasing the mill's production from 125 000 m^3 to 190 000 m^3. The line is the mill's third LVL line. The EUR 52 million investment included other improvements at the mill, and 13 000 m^2 of new covered operational area at the mill site. Main equipment suppliers were Raute and Pinomatic, and the main construction contractor was Rakennusliike U. Lipsanen. 43 new jobs were created at the factory, 35 of which were apprenticeships, and 40 FTE were created in the supply chain, as log demand increased by 160 000 m^3. The Punkaharju mill now employs approximately 500 people. Punkaharju resides in the municipality of Savonlinna, and the city of Savonlinna has strongly contributed to Metsä Wood's expansion project by participating in the real estate and infrastructure issues. Savonlinna committed to constructing office spaces, parking lots, and the infrastructure to support the waste-water treatment logistics. The investments would be paid back by rental income from Metsä Wood. There is also a plan to build a power plant at the mill, in which Savonlinna would be part owner. Savonlinna benefits from the arrangements not only by improving the city's employment but also by strengthening the city's position as the center of engineered wood manufacturing in Finland. Savonlinna has previously supported forest industries in its area by constructing a deep-water port and investing in the many mill projects in the area.

At the Lohja mill, two of the three Kerto®-LVL production lines were replaced by a new, more efficient line. The mill's output was increased by 20 000 m^3, bringing the total capacity to 120 000 m^3. Raute announced the supply of the new LVL line, as well as other equipment for birch veneer production in the nearby Äänekoski mill, to be worth EUR 25 million. The new LVL line was inaugurated in August 2017. The employment effect of the investment was quite neutral at the mill, and the presence of the nearby new

Äänekoski bioproduct mill complicates estimations of employment impact the supply chain. Approximately 150 people work at the Lohja mill. The new LVL line capable of producing maximum widths of 1.8 m and any lengths between 2 m and 25 m. As a side note, in 2013 a bio heating plant was built next to the mill. The heat energy produced at the plant fully covers the needs of the mill, as well as the heating of the City of Lohja.

Challenges

- Bringing a new product to the construction market is always challenging, even if the product's structural characteristics are proven. Metsä Wood has put much effort into educating architects and construction designers to start using LVL.
- As the only producer of LVL in Europe, Metsä Wood needed to convince customers of MW's supply capacity.
- Architects and construction designers are agile in adopting new proven products, but investors are harder to convince. Construction is still mostly based on concrete and steel and changes in the sector are slow.

Enabling Environment

- In the 1970s, the technology push as well as the oversupply of spruce sawn goods culminated in the inauguration of a novel LVL production line in Finland.
- Environmental pressures are further increasing the demand for wooden construction materials.
- Municipalities often want to support industries in their area, and usually provide help with real estate, infrastructure, and environmental issues. The city of Savonlinna contributed to Metsä Wood's expansion project by assisting to solve real estate and infrastructure issues.
- Apprenticeships are quite common in the Finnish forest industry and provide local workforce for the remote mills. Apprenticeships are aimed at young people who have finished primary school but do not want to continue to high school or vocational school, which are the secondary levels of education and optional for students in Finland. Apprenticeships are done in collaboration with local learning institutes and usually lead to an official diploma comparable to vocational school graduation diploma.

Takeaways

- Since the 1970s, Metsä Wood has vigorously marketed the new product to architects and construction designers to create a strong user base and tradition of LVL use in Finland.
- When competing LVL manufacturers started to show up in 2014, Metsä Wood welcomed the competition as multiple manufacturers allow for competitive biddings and improve the credibility of the product in the eyes of construction investors. New operators entering Europe's LVL markets also accelerate the wood construction trend.

Takeaways (cont.)

- The LVL product portfolio is more versatile in Europe than in North America. While NA concentrates on manufacturing headers, beams and I-joists, Europe produces LVL in many dimensions and for a wide array of end uses, although now the European production is shifting to construction elements and modules prefabricated offsite and delivered to building sites. There is an opportunity for North America to diversify their LVL product portfolio based on product-specific successes in Europe.

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Quebec Deep-Dive

Investment Attraction in Quebec

Over the past decade, Quebec's forest industry has grappled with a paradigm shift toward sustainable, multiple use, and transformed through innovation of higher-value wood products.

In 2013, Quebec introduced a new forest regime that limited volumes and timelines for wood harvest, and centralized government responsibility over forest management—creating a more complex operating environment for private forest industry. Allowable cuts fell by 22% in Quebec between 2000 and 2018. Softwood tree size and hardwood tree quality steadily declined, and harvest costs increased. Fluctuations in the use of forest products in Quebec also reflected the increasing difficulty of selling low-quality hardwood and softwood lumber byproducts. Quebec's Softwood Lumber Agreement with the United States ended in 2015.

To enhance the competitiveness of Quebec's industry, the Ministry of Forests, Fauna, and Parks (MFFP) adopted new strategies to provide comprehensive policy direction and financing for forest value chains, spanning primary and secondary production:

- **Wood Production Strategy (2018)**: set provincial targets, including increasing the value of harvested timber supply by at least 30% within 20 years. The strategy promotes measures to enhance the value of harvested timber supply rather than on volume alone—and strengthens the economic part of the province's existing Sustainable Forest Management Strategy. While the strategy provides benefits for forest industry, First Nations have opposed the strategy's introduction of intensified wood production areas.
- **Strategy for Development of Quebec's Forest Products Industry (2019)**: advanced measures along five axes including:
  - Innovation:
    - *Wood Innovation Program*: has provided CAD 72 million to 117 projects since 2016, catalyzing CAD 573 million in investments for a leverage of 1;7, creating 4,798 current jobs. The program renewed funding of CAD 120 million through 2023 to support projects that provide some innovation or advance processing of inferior quality wood. Funding recipients include Cellufuel (synthetic biodiesel production from forest residues).
    - *Smart Manufacturing 2.0 (SM2) Initiative*: advances the competitiveness of the sawmill industry through technological development (CAD 13 million, 2017– 2021). Funding recipients include FPI and Autolog which developed an automated system for identifying softwood species using near-infrared measurement, enabling precise separation of different types of softwood.
    - *Technological Showcase Program for Buildings and Innovative Wood Solutions*: has awarded CAD 8 million to 16 projects, supporting demonstrations in the construction sector including mass timber projects Origine and Arbora using CLT and glulam.
    - *Center of Expertise on Commercial Wood Construction)*: offers technical support and training to building professionals on wood design, granted CAD 2 million for 2017-2021. In 2018-2019, responded to over 400 requests for technical support, contributing to the completion of 64 commercial, institutional, and residential wooden buildings. Major projects include the Levis Multi-functional Aquatic Complex and the Quebec Wildlife Protection Training and Development Center.
  - Modernization and improvement of equipment and processes:
    - Plan by Quebec's government to broaden the scope of the Mines Hydrocarbons Capital Fund to include all natural resources (including forestry) beyond mining and hydrocarbons, renaming it the *Natural Resources and Energy Capital Fund*.

- ◊ *Electricity Discount Program*: as of 2019, 20 companies in the forest industry billed for industrial power had obtained certification under the program, qualifying for discounts on electricity of CAD 799 million.

– Policy and regulation:
  - ◊ *Committee of climate change mitigation experts*: has assessed the contribution of Quebec's forest sector to reducing GHG emissions, and identified priority actions, providing the basis for CAD 5 million to optimize the forest sector's ability to combat climate change, using a GHG reduction tool developed by REIT and the University of Quebec
  - ◊ *Carbon calculator*: Digital calculator online (gestimat.ca) free for anyone to use to assess the carbon footprint of a building, enabling comparison of carbon footprints of different structural materials under different scenarios

– Business environment:
  - ◊ The Ministry of Labor, Employment, and Social Solidarity committed CAD 30 million (2018 - 2023) to support *workforce training, skills development, and human resources management* for companies in the forestry sector
  - ◊ *Forest Development Assistance Program*: with an annual budget of CAD 28.5 million, provides financial assistance and support to forest producers for carrying out sustainable forest management and harvest in private forests, to enhance supply to forest industry. The program achieved 92% of commercial provincial targets for 2018-2019, with the support of CAD 10 million for the work during that period

– Markets:
  - ◊ *Forest Residual Biomass program*: finances projects converting forest residues to energy, encouraging infrastructure development and distribution networks (CAD 90 million, 2017 – 2021).

Forest industry, rural communities, and research organizations working in the forest sector in Quebec have also tapped into federal funding via the Canadian Forest Service through a variety of programs:

Investments in Forest Industry Transformation (IFIT) Program [used by Performance Biofilaments]: launched in 2010, offers non-repayable contributions to Canadian forest industry of up to 50% of costs for demonstration of innovative, first-in-kind technologies (CAD 190 million, 2010–2018). While public funds are often available to support R&D from concept to prototype development, IFIT focuses on helping finance demonstration and/or first-commercial facilities to help the technology reach market. Projects include bioenergy, biomaterials, biochemicals, and next-generation building products. Over the years, the program has adjusted its procedures in response to participating companies. For example, projects awarded IFIT funding are sometimes strategic and not yet shovel-ready at the time of grant allocation. The program has adjusted to become more adaptable to company needs.

Pulp and Paper Green Transformation Program [used by Fortress]: aims to enhance the environmental performance of Canada's pulp and paper companies, assisting them in making capital investments that improve facility environmental performance. Key challenges with the program included the short timeframe for project application and implementation, and the length of the project review process, including environmental assessments.

Green Construction through Wood (GCWood) Program: launched in 2018, provides non-repayable contributions of up to 100% of a project's eligible incremental costs for demonstration of innovative wood products and systems that advance a) adoption and commercialization of wood-based products in construction of innovative tall wood buildings, timber bridges, and low-rise wood buildings; b) replication of demonstrated innovative wood-based buildings and timber bridges; and c) research that addresses the gap in technical information needed to revise the 2020 and 2025 National Building Code of Canada to allow tall wood buildings beyond the current six-storey limit. Example investments include The Arbour, Ontario's first mass timber, low-carbon institutional building.

Indigenous Forestry Initiative: provides funding to support Indigenous-led economic development in Canada's forest sector (CAD 10 million 2017–2020). Projects span environmental stewardship; use and management of forest resources, and participation in the forest bioeconomy (e.g., biomass for heat/energy, pellet manufacturing, etc.). Eligible activities for funding include preparation of plans/assessments that cultivate economic opportunities in forestry; training and skills development; business planning; and development of forestry-related tools, technology, products, and services.

Expanding Market Opportunities Program: funds forest product associations, provinces, and wood product research organizations to enhance Canada's presence in national and international wood markets; enhance knowledge of Canadian wood products among wood suppliers and customers; and promote use of Canadian wood in nontraditional construction such as mid-rise and non-residential buildings. To help Canadian wood producers diversify and expand export opportunities for their products in overseas markets, EMO supports market development offices in Shanghai, Beijing, Tokyo, Seoul, London, Toulouse and Mumbai. The program combines activities from older programs dating back to 2002.

Forest Innovation Program: supports research, development, and technology transfer activities across Canada's forest sector, with roots dating back to 2007.

Clean Energy for Rural and Remote Communities: supports projects to reduce the reliance of rural and remote communities on diesel fuel for heat and power, including bioheat and bioenergy through use of woody biomass.

Table 1: Marketing Materials

Program/entity	Examples
Strategy for Development of Quebec's Forest Products Industry	• Strategy summary transfer
Investments in Forest Industry Transformation (IFIT) Program	• IFIT online information: nested within funding opportunities section of Government of Canada website • One-pagers on IFIT-funded projects (example attached) • Replicability fact sheets (example attached): easily sharable fact sheets that summarize findings for the IFIT program's investments in first-in-kind technologies in green energy, biomaterials, and solid wood products—including technology maturity, ease of implementation, market opportunities, and social benefits • Graphic on IFIT program success
Other Canadian Marketing Materials	• Naturally:wood: comprehensive information resource promoting British Columbia as a global supplier of quality, environmentally-responsible forest products from sustainably-managed forests

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Performance BioFilaments

Quebec, Canada

- Construction of commercial plant for specialized production of cellulose filaments and upgrade of existing paper mill
- CAPEX: 38 million CAD
- Jobs created: 23

Case summary

In 2014, Mercer International and Resolute Forest Products were both evaluating new technologies to diversify their product mix. Together they decided to establish Performance BioFilaments as a joint venture, with the sole mandate of developing innovative applications for nanofibrillated cellulose. To support this new joint venture, Resolute Forest Products announced in early 2020 that it would make a CAD 27M investment constructing a new commercial plant for production of nanofibrillated cellulose filaments at its Kénogami paper mill in Quebec, with the production capacity of 21 metric tons per day.

The filaments are a new sustainable biomaterial derived from wood fibre that is mechanically processed using renewable sources, without chemicals or enzymes, resulting in a low carbon footprint. The filaments can be integrated into commercial and consumer products from many industries, including transportation, construction and energy. The company is also investing CAD 11M into upgrading the Kénogami paper mill itself by modernizing equipment to produce high-grade SCA+ supercalended paper—allowing the existing mill to access more favourable markets. The mill has a production capacity of 133,000 metric tons of specialty papers per year.

The startup phase, slated for 2021, is anticipated to bring in eight jobs. A total of 23 jobs is planned once the plant reaches full production capacity of 21 metric tons a day. These jobs are in addition to the 200 existing positions at the paper mill. While the coronavirus outbreak has hit Quebec hard, Performance BioFilaments is still aiming to complete construction by mid-2021, building in a 4-6 month buffer.

The plant's location in the middle of northern Quebec is somewhat weak on market access, but has good existing infrastructure, and access to energy. The bulk of material needs to be transported to a secondary facility for packaging and logistics. The secondary facility is proving complex to site and plan because the key applications for the filaments are diverse, hence different customers have different needs. The company is considering existing facilities in, Canada and the United States that can provide some cost-efficiencies in retooling existing operations. Resolute, which owns the Kénogami mill, has a strong record of sustainable forest management and product manufacturing in the region. All of Resolute's facilities comply with at least one globally recognized chain-of-custody standards: the Sustainable Forestry Initiative (SFI), Program for the Endorsement of Forest Certification (PEFC), and Forest Stewardship Council (FSC). All of its facilities in the region are ISO 14001 certified.

Incentives

Funding from Quebec's Ministry of Forests, Wildlife and Parks (CAD 2.5M), Investissement Quebec (CAD 4.2M), and Natural Resources Canada (CAD 4.9 million) covers 25% of the total project cost. The Ministry of Forests, Wildlife, and Parks is providing funding through the Investments in Forest Industry Transformation (IFIT) Program. IFIT, operated like a strategic investment fund, provides non-repayable funding of up to 50% of project costs for Canadian forest industry to implement innovative, first-in-kind technologies in their facilities—with the goal of providing funding for projects at the pilot to commercialization phase in order to help technologies get to market.

Enabling Environment

- Joint venture drawing on expertise and proven record of two competitors, Resolute Forest Products and Mercer International.
- Extraction technology already developed by FPInnovations, one of Canada's largest scientific forest product research and development centers, of which Resolute is a member. The core technology was deemed furthest ahead with respect to commercialization, and lowest risk among technologies evaluated.
- Lower cost of upgrading existing Kénogami paper mill owned by Resolute, including the building, infrastructure, and electricity. The paper mill already has a trained workforce, reducing costs associated with workforce development. The mill is part of Resolute's industry cluster of some 18 establishments and distributed forestry operations in the Saguenay–Lac–Saint-Jean region, including: Four pulp and paper factories, Five sawmills, Installation of processed wood products, Planing plant, Seven hydroelectric power stations, and Logging operations in seven forests.
- Performance BioFilaments also considered other facilities in BC and the US Midwest. Investing in a greenfield facility would have taken double the time and require more than a CAD 100M capital investment. Choosing to repurpose existing assets cut costs by 75

Takeaways

- Centers of excellence and partnerships with universities and national research labs are key to incubating new technologies.
- Incentives programs should provide more flexibility in tailoring to the needs of potential funding recipients. Projects may be strategic in nature and not yet shovel-ready at the time of grant allocation. Performance BioFilaments leadership provided feedback to IFIT in previous years, helping inform improvements to the program to become more adaptable to company needs.
- It is important to manage demand for both the paper and nanocellulose production to ensure some balance. Within the joint venture, there is an arrangement so that even if Resolute has internal use for nanocellulose in its existing products, Performance BioFilaments has the option to first allocate it for its own use, particularly if there is a limit on availability.
- The most important elements for marketing nanocellulose for Performance BioFilaments have been price, performance, safety, and sustainability—in that order. Sustainability has helped open the door and start the dialog with some customers, but the other elements are more fundamental.

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Fortress Global Enterprises

Quebec, Canada

- Conversion of old kraft pulp mill + construction of cogeneration plant (now closed)
- CAPEX: 400 million CAD
- Jobs created: 323 at peak

Case summary

Fortress Paper was incorporated in 2006 in Vancouver, Canada, and eventually renamed Fortress Global Enterprises to reflect its interest in producing a diverse set of innovative, high-value biomass-based materials. Founding CEO Chad Wasilenkoff brought a long record of creatively upgrading unused and underused assets in various industries ranging from forestry to uranium. Fortress initially purchased the Dresden wallpaper mill in Germany and Landqart security paper product mill in Switzerland from Mercer International, repurposing them for higher-end specialty papers. Fortress transformed the former mill to produce non-woven wallpaper, growing it to occupy 60% of the market share by 2012, and transformed the security paper product mill to produce high-end specialized banknote paper.

As the market for dissolving pulp opened, Fortress began to evaluate the potential of repurposing existing mills for dissolving pulp production. The company noted batch mills as ripe for conversion to dissolving pulp production. Batch mills tended to be older and more expensive to operate compared to mills with continuous digesters, however, were better suited for dissolving pulp production. Unless repurposed, such mills lacked a compelling risk-to-reward profile to attract investment based on their existing products. Batch mills used for pulp and paper production would still need new stainless-steel digesters, given the different chemical environment needed to produce dissolving pulp. Fortress evaluated many mills for repurposing around the world, including the Evanston mill and Brookfield mill in Maine. The company chose not to proceed in Maine in part because of issues with the assets, e.g., the lack of a dryer, which would have been essential for readying dissolving pulp for export to China to convert to rayon.

In 2010, Fortress settled on acquiring a bankrupt kraft pulp batch mill in Thurso, Quebec from Fraser Papers for CAD 1.2 million, seeking to convert the mill from producing commodity paper pulp to dissolving pulp. At the time, forestry was undergoing a prolonged downturn in the area, with little investor confidence. However, the market fundamentals for dissolving pulp production at the mill appeared strong. Shortages on cotton supply were driving up the price of cotton—and in turn the price of dissolving pulp given rayon as a substitute in the textiles market, from CAD 800 per tonne to CAD 2,750 per tonne.

Once Fortress secured an agreement with the Quebec government, the company bought the mill for CAD 1.2 million, and hired a management team including an executive experienced in doing pulp mill conversions. The mill became known as the Fortress Specialty Cellulose (FSC) mill. The mill conversion took two years and went CAD 140 million over budget, forcing the company to raise another CAD 70 million from the investment community. All told, it took CAD 400 million to rebuild the mill and ramp it up into production over three years. Leadership attributed the overruns in cost primarily to a) the high cost of constructing a new cogeneration plant (as opposed to acquiring an existing plant, which was the original plan but fell through when the seller of the plant decided not to sell) and b) building a fifth digester (actual costs greatly exceeded estimates by engineering firms).

Incentives

Fortress approached the Quebec government to negotiate a deal, reaching out to Investissement Québec and speaking with officials without linking to a particular incentives program. Fortress stated the company was interested in investing in the Thurso mill and could improve the overall economic situation of the region, providing figures on job multipliers. The company conveyed that they had already attempted to raise capital on a commercial basis from banks and other traditional lending institutions, who had declined them. They were willing to bring in equity but needed debt. Although the Fortress management team had a strong track record, and markets for dissolving pulp were open, it was not possible to raise the capital for the plant on a purely commercial basis. Commercial investors saw the forestry sector as unattractive and presenting major operational risk. This was particularly the case for a large industrial site that had never made a new product such as dissolving pulp, likely to face ramp-up issues compared to a greenfield investment that assembled the plant from scratch. There was some uncertainty in calculating whether a plant that used to make a certain amount of paper pulp could be retooled to make a corresponding amount of dissolving pulp. If projections about the volume of dissolving pulp production were off by even a couple of percentage points, it could make a major difference.

In response to Fortress's pitch to help recover the local economy, the government agreed to cover the cost of an environmental clean-up of the existing site and provide a low-interest CAD 102 million loan out of a projected total cost of CAD 175 million, with a four-year holiday. Legacy environmental issues are often the utmost concern to investors considering brownfield sites; in this case the government was willing to cover the liabilities. Government support also enabled Fortress to help raise equity from other investors and to raise commercial debt to support the retrofitting of the plant.

Conversion of the FSC mill involved construction of a 24 MWH cogeneration plant and an agreement for green energy sales to Hydro Quebec—another crucial enabling condition. The Pulp and Paper Green Transformation Program run by the federal government granted the mill CAD 9.9 million to generate more renewable thermal energy and cut its greenhouse gas emissions.

While Fortress was expanding dissolving pulp production at the first mill, it also invested up to CAD 40 million to convert a second mill acquired in Lebel-sur-Quévillon, northern Quebec to dissolving pulp production—anticipated to be one of the lowest-cost softwood dissolving pulp mills in the world. This second mill was located near a mercury chloride plant that had been accidentally leaking chemicals into the ground, causing birth defects downstream. Although the plant was a multi-million-dollar asset, no one had been willing to buy it given the environmental legacy issues. Fortress purchased all of the assets aboveground for a negligible sum, while belowground rights stayed with the government. The government agreed that so long as Fortress did not touch the area underground, the company was not responsible for the associated environmental legacies on the site.

This new mill was put on hold once China announced plans to implement an import duty on new products coming into the market. Uncertainty around the importation duty (eventually set at 23.7%) dampened buyers' interest in purchasing dissolving pulp from Canada, the United States, and Brazil, hurting Fortress's ability to sell its dissolving pulp. In addition, competitors were quicker to convert and restart idle dissolving pulp mills, leading to an oversupply of dissolving pulp by the time the Thurso mill was producing at capacity.

The cogeneration plant turned out to be the primary driver of profitability, bringing in CAD 20-25 million in earnings before interest, taxes, depreciation, and amortization (EBIDTA) annually while the dissolving pulp production lost CAD 10-15 million a year, netting CAD 10 million a year.

In 2015, Fortress announced Yvon Pelletier as the new CEO for the mill, with Wasilenkoff reducing his role dealing with operational issues while still serving as the largest shareholder. Seeking to diversify

the mill's revenue streams further, Fortress purchased another company, S2G Biochemicals, in order to use proprietary technologies developed by S2G and Mondelez to produce xylitol from hemicellulose, a residue of dissolving pulp. Fortress planned to construct a demonstration plant to produce xylitol at the Thurso mill—to follow with construction of a $150 million full-scale plant following successful completion of the demonstration plant. The full-scale plant was anticipated to generate up to CAD 40 million of EBITDA annually, providing C5 sugars as feedstock for up to 20,000 tonnes per year of xylitol production. Because of the continued decline in dissolving pulp prices, the xylitol component was never fully realized.

In October 2019, the Fortress Pulp Mill laid off 273 of its 323 workers while implementing a production freeze and searching for additional financing. At the same time, the Quebec government agreed to give Fortress until 2022 to start repaying the loan, and also lent up to CAD 8 million to try to restart the temporarily shuttered plant. The company intended to restart operations once dissolving pulp prices recovered and if it could reduce production costs. By the end of the year, the company announced permanent closure of the mill after failing to find a buyer. Fortress laid off the remaining staff at its mill and all management except the CEO and CFO resigned. The mill closure has affected approximately 1,000 workers working in various fields, including 76 forestry producers in the Outaouais and Laurentides. In December 2019, the company's senior secured lenders (Investissement Québec and Fiera Capital) have filed an application with the Superior Court of Québec to commence restructuring proceedings, which are ongoing. As of July 2020, under the restructuring proceedings, three potential acquirers have expressed interest, but the creditors and restructuring monitor, Deloitte, do not expect any transaction within the near term. They write in their monitoring report that the COVID-19 pandemic and the resulting economic downturn has resulted in investors delaying new investments.

Takeaways

- Government support was the largest enabling factor attracting Fortress's investment in Thurso, Quebec, consisting of low-interest financing, sponsoring of an environmental clean-up, and an offtake agreement with a public utility for the cogeneration plant. Governments that cannot provide generous financial incentives packages could provide loan guarantees to back a commercial loan. This presents less legwork and lower cost of capital for government, while enabling smoother project financing.
- Creative investors who have higher risk appetite remain interested in reentering the forestry market for the right opportunity. However, it remains hard to attract capital into the forestry sector from the majority of investors given their low appetite for risk, environmental legacy issues, and the high capital expenditures needed to retool many assets.
- The difficulties encountered by the mill also led to greater intervention and cost burden for Quebec's government, which provided new loans and tax holidays offered over the years to give the company more room to find new investors and restart operations—in the interest of saving forest industry and jobs in the area.

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Investment attraction in Oregon

Oregon has been a leading state for production of softwood lumber and veneer/plywood for decades. State and local authorities have fully signed on to use of mass timber across a variety of building types. In 2018, the state proactively adopted tall wood provisions, enabling use of mass timber in buildings of up to 18 stories. Most other states will not include these provisions until at least 2021. Two businesses in Oregon help coordinate the output of mass timber producers with the needs of building contractors—DR Johnson and Freres Lumber. The state has a large roster of architects, engineers, building contractors, and developers with expertise and experience in mass timber construction. State and local officials across political lines have invested millions in hosting symposiums, funding design competitions, and mass timber think tanks to enhance awareness and rally talent and investment around mass timber.

CLT is Oregon's signature innovation, establishing the state as home to the country's first manufacturers of cross-laminated timber and mass plywood panels, Washington and California have surpassed Oregon in terms of overall private manufacturing investment in mass timber production. As of late 2019, Oregon accounted for 46 mass timber buildings either in design, in construction, or built, trailing only California (99) and Washington (69). Nationally, mass timber has dominated among grant awards under the Wood Innovation Grant Program, run by the US Forest Service.

To enhance the state's competitiveness, Business Oregon submitted a request for $250,000 from the Strategic Reserve Fund in 2019 to support development of a mass timber industry roadmap for Oregon. The roadmap will include analysis and recommendations on state or regional policies influencing forest restoration and management; public construction, housing, seismic, building retrofits, and incentives to catalyze investment and job growth in the mass timber industry over the next five years. The study would include an opportunity assessment for the mass timber industry to expand, e.g., exploring potential mergers and acquisitions between Oregon companies with domestic/foreign companies; new niche or specialty markets; public/private partnerships that leverage federal, foundation, or other financial resources to grow the industry (i.e. the Timber Innovation Act, annual appropriations for the US Forest Service, US Department of Commerce, and US Department of Defense); sustainability; product alignment, and new marketing materials. The study will also identify various-sized business investment and operational models that are a fit for Oregon, and can be used to attract investment.

Beyond betting on mass timber, Oregon has been working to revitalize rural economic development through other forest industry investments. The state does not have any special formalized incentives directed to the forest industry, the most valuable of which is property tax abatement. Business Oregon provides the following sector-agnostic incentives, some applied to forest industry:

- Standard Enterprise Zone Program
- Construction-in-Process
- Strategic Investment Program
- Immediate Opportunity Fund
- Special Public Works Fund
- Governor's Strategic Reserve Fund
- Oregon Business Expansion Program

Business Oregon pays halftime for a US Forest Service specialist. He provides guidance for companies wanting to understand investment opportunities in Oregon, and helped the state attract investment for the Restoration Fuels torrefaction plant in John Day, Oregon—the first commercial-scale torrefaction plant in the country, with construction slated for completion by spring 2020. Development of the project

has spanned nearly a decade, drawing on contributions from the US Endowment for Forestry and Communities, private companies, research organizations, utilities, landowners, and project developers. The endowment made small investments over the past decade in a range of areas and technologies to see what was viable—starting to focus on torrefaction only four or five years ago given that the technology was ready for commercialization compared to liquid biofuels, which presented a larger technical and financial challenge for an endowment to handle.

Table 2: Marketing Materials

Program/event	Materials
Business Oregon	• Incentives Overview (attached) • Forestry and Wood Products Industry • How We Can Help
International Mass Timber Conference	• Website • Promotional video
Oregon Forest Resources Institute	• Forest Proud Oregon video • Wood Products in Our Daily Lives (overview of Oregon forest product mix)

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Freres Lumber

Oregon, United States

- Mass Plywood and Structural Composite Lumber Facility
- CAPEX: 35 million USD
- Jobs created: 24-30

Case summary

Founded in 1922 as a lumber mill, Freres Lumber evolved to become a leading producer of high-quality sheathing and touch sanded plywood panels. By 2015, the company faced substantial competition from both imports and substitutes for commodity plywood panels. It was becoming a struggle for the company's plywood mill—which dealt primarily in half-inch rated sheathing (CDX) products—to compete against oriented strand board (OSB) and imports. The company began looking for opportunities to create a higher-value product resilient to the commodity markets.

In the same year, Oregon State University (OSU) was organizing a trip to the LIGNA Conference in Hanover, Germany. Freres Lumber joined them for that trip and visited a couple of CLT facilities and met the developer of CLT – Austria-based Dr. Gerhard Schickhofer in Austria. Freres leadership discussed with Schickhofer the opportunity of creating a new type of mass timber panel using a veneer-based product—mass plywood panels (MPP) as a substitute for cross-laminated timber (CLT). Late 2015 and early 2016, Freres Lumber began R&D and testing of the new product to establish proof of concept, together with OSU. Encouraged by positive initial results, the company decided to invest in a new facility to produce MPPs. Freres Lumber continued to test and refine MPP production with technical input from the Tallwood Design Institute, a collaboration between OSU's College of Forestry and Engineering and the University of Oregon's College of Architecture.

The company sited the new MPP facility in the middle between its veneer facility in Lyons and plywood plant in Mill City, six miles away to enable all of the plants to work together. It took three years to bring the MPP facility online. Investment in the product and facility altogether took more than USD 35 million. Freres Lumber self-financed the majority of this, with a USD 250,000 award from the US Department of Agriculture for investment in R&D specifically related to the purchase and installation of a Weinnman CNC machine. The company also obtained an enterprise zone designation, which provided a short-term tax exemption. The new facility provided the basis for creation of new jobs, with the MPP facility requiring about 24-30 people to cover the facility.

Freres Lumber creates MPPs using their own structural composite lumber (SCL) panels, thin layers of wood veneer called lamellas. The veneers are sent to the plywood facility to lay the veneer into a base panel. The company glues and presses together density-graded Douglas fir veneers to create large-format wood platforms, beams, and columns in thicknesses of one-inch increments up to two feet. The individual layers of veneer are very thin, allowing for flexibility in orientation. MPP can span longer distances than CLT, and provides greater strength and density. Veneer as a raw material for a mass timber panel can potentially achieve the same structural qualities of a CLT panel while using 20% less wood, and allows for more structural variations. The initial panels are then sent back to the MPP facility, scarfed into a larger lamella in order to lay it into large MPP panels. Large format panels can be manufactured at the production facility including window, door, and other cut-outs, which therefore reduce waste and labor constructing at the job site. The panels are relatively light, which helps limit transportation costs, lowering the carbon footprint compared to other building materials.

Freres Lumber first certified the MPP product under the SCL standard, ASDM D5456. Although MPP is unique from cross-laminated timber, the company was able to also certify them as a CLT panel under the CLT standard PRG 32, making Freres Lumber just one of three companies in the United States that have

received that certification. MPPs are expected to continue falling under the CLT standard; while PRG 320 requires alternating orthogonal layers, which are not present in MPP, certification body APA did not feel that it was a strong consideration to be certified under the standard. Because there are many more variations of manufacturing possible through MPP, it required significantly more testing to get certified compared to what would be needed for a standard CLT panel manufacturer. The company is continuing to work with APA on securing additional certification—including on an industrial matting certification—and anticipates testing to continue for the next five or more years.

Freres Lumber secured patents for MPP production not only in the US, but also four other countries covering the company's product and manufacturing process. To raise awareness of its new product, Freres Lumber gave two to three tours a week of its facilities (prior to the COVID-19 outbreak). The tours allowed people to see the process and understand the idiosyncrasies of the production process, and better grasp how MPPs compare with CLT on various measures. The company has also been aggressive in raising awareness through social media, using LinkedIn, Facebook, and a blog where the company provides information on more the technical aspects.

While the concrete and steel industry opposes the rise in mass timber products, Freres Lumber leadership is confident in the efficiency and sustainability of mass timber production. As more people use mass timber and MPP in particular, Freres Lumber anticipates that it will become obvious that it is cost-competitive with CLT, concrete, and steel alternatives.

The company is finding demand for its MPPs not only in North America, but in other regions. Freres Lumber has the ability to load containers with access to intermodal shipping, which opens up a lot of opportunity. Through its cluster of facilities, the company has also been able to continuously push its process to be more versatile, taking advantage of its backend products to produce a versatility of products. The SCL itself can be used as an LVL product. More recently, Freres Lumber completed another $5 million project at the facility for a beam and column line, which can make glulam-equivalent beams of up to 24 inches deep and 4 feet wide. The vision is that when the MPP facility is ramped up to full production, it could pull 40-50% of the company's plywood production away from commodity products to higher-value MPP production instead.

As of mid-2020, two out of Freres Lumber's six facilities are running during the outbreak. Freres Lumber leadership says that while it is difficult to think about additional capital investments under the outbreak, they would be interested in investing in a new facility and/or licensing their technology to other companies in the future—including in other states.

Enabling Environment and Incentives

- Freres Lumber self-financed the majority of this, with a USD 250,000 award from the US Department of Agriculture for investment in R&D specifically related to the purchase and installation of a Weinnman CNC machine. The company also obtained an enterprise zone designation, which provided a short-term tax exemption. The new facility provided the basis for creation of new jobs, with the MPP facility requiring about 24-30 people to cover the facility.
- Freres Lumber has developed its own cluster of plants over the past century that can work together, including a large log veneer plant, small log veneer plant, dryer, plywood plant, cogeneration facility and MPP facility. The MPP facility was sited in the middle between the veneer facility in Lyons and plywood plant in Mill City, so the plants work together to produce the final product.
- Freres Lumber is sitting in a very strong wood basket with a superior softwood species of Douglas fir that has great strength characteristics, which provides a reliable supply of high-quality fiber.

Enabling Environment and Incentives (cont.)

- Freres Lumber was able to tap into some federal government funding and a tax exemption by virtue of qualifying for Business Oregon's Standard Enterprise Zone Program, but put up most of the capital for MPP R&D and production on its own.
- OSU has been a valuable partner on the testing side from the beginning. Freres Lumber has hired at least one person from their program and is likely to continue working with them on analysis for future certification possibilities.

Challenges

- Freres Lumber has found some state policies in the Pacific Northwest to be less business-friendly and that political will to support sustainable forest harvest at scale is limited, which lends to supply issues.
- Extensive testing was needed to obtain certification for MPP as a new product – both initially for structural composite lumber via the SCL standard, ASDM D5456, as well as the MPP panels through the CLT standard. Because there are many more variations of manufacturing possible through MPPs, it required significantly more testing to get certified compared to what would be needed for a standard CLT panel manufacturer.
- While MPPs are stronger compared to CLT, they are not a full substitute. MPPs are meant to be a structural product, and less focused on architectural appearance. Therefore, in some areas people still prefer CLT for its visual appearance.
- Not many contractors have used mass timber products, and therefore tend to add additional cost to their estimated budget to hedge against risks—which puts Freres Lumber out of the range on some products. This is anticipated to change as more contractors develop experience using the product; Freres Lumber leadership says it will become obvious that MPP and other mass timber products can perform better on cost as well compared to concrete and steel.

Takeaways

- Producers of existing commodity plywood panels and other commodity products are seeking to overcome the competition by shifting to production of higher-value products that use the same building blocks. In Freres Lumber's case, the company's cluster of facilities is evolved to create MPP using veneer-based SCL, offer SCL itself as an LVL-type product, and also produce glulam-equivalent beams and columns. The vision is that MPP production, once scaled up, can act as an engine to pull product from all of the facilities through the MPP facility into higher-value product.
- Development of a new or diverse product mix requires a significant amount of testing for certification—the more the variations of the product(s), the more testing necessary. Partnership with a university helps with this. Developing a new product also requires substantial education of the industry and potential customers through tours and media coverage.

Takeaways (cont.)

- When it comes to considering site feasibility for a new facility, Freres Lumber would be looking for a good wood basket, access to ports and infrastructure, business-friendly environment, and certification support. Maine is pro-business, while forest industry in Oregon does not get a lot of support—many policies being anti-business.
- A good wood basket where the local softwood species offers reliable strength characteristics is key to ensuring a high-volume source of quality fiber for production. While CLT panels were originally sold as an opportunity to take low-value lumber and generate a structurally sound premade panel, CLT manufacturers have found that it's a garbage in, garbage out process; feeding cheap lumber into a panel will produce cheap panels. Great access to fiber in the South has attracted forest industry players, one reason why the Pacific Northwest has seen reduced investment overall.

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EGGER Group

Lexington, North Carolina

- Raw particleboard and thermally fused laminate (TFL)
- CAPEX: 700 million USD ($300M in phase 1, and further $400M to full production)
- Jobs created: 770 (400 in phase 1, and further 370 to full production)

Case summary

EGGER Group (EGGER) is global family owned company based in Austria, first started by Fritz Egger Sr. in 1961. Since the first chipboard plant in Tyrol, Austria, EGGER's success story has been driven by a truly diverse value-add production capacity with a range from furniture and interior design to wood construction and flooring. EGGER currently has 19 production plants across Europe and Latin America, with one in construction in North America. The company employs approximately 9,600 employees (9,481 in FY19), who processes 8.8 million m^3 of timber annually, driving sales of EUR 2.84B in FY19.

To maintain the company's stability and chart long-term growth, EGGER continuously finances investments from internal resources (using external financing in a targeted and limited manner when required). As evidence of this, the company made growth and maintenance investments of EUR 489.1 million in FY19. Of this pool, one of the largest investments in recent years was EGGER's first production facility in the United States based in Lexington, North Carolina.

First announced publicly in July 2017, the year-long process was led by EGGER's Karl Grasser. After initial scoping, EGGER's initial list of 50 sites was whittled down to North/South Carolina and Georgia due to their relative resource base and proximity to large population centers. On the North Carolina side, the deal began to materialize when EGGER contacted the Economic Development Partnership of North Carolina (EDPNC) with a list of specific site requirements that included:

- A Sustainable supply of the raw materials of particle board (wood chips, sawdust, and slab pieces);
- An industrial site with 200 flat acres and no wetlands;
- High pressure natural gas, on site rail, and a redundant electric power source; and
- A strong potential for workforce development.

As raw materials would likely be one of the principal drivers of EGGER's decision, EDPNC arranged a series of meetings with local industry experts as well as faculty at North Carolina State University to illustrate the resource potential of the area. Similar public-private efforts followed for the other components on EGGER's site request list, including North Carolina Railroad Company and Duke Energy. Other partners included North Carolina Department of Commerce, Environment, and Transportation, Davidson County Board of Commissioners, the City of Lexington, Davidson Water Inc., Norfolk Southern Railroad, North Carolina Community College System, and the Golden LEAF Foundation. The host of organizations involved illustrates the relative complexity, and requirements for such a deal, with each playing a key role in solving potential hurdles from the community to corporate context.

The group eventually landed on the I-85 Corporate Center Industrial site just Southwest of Lexington, North Carolina, which addresses (or was modified to address) all initial criteria of EGGER. The modifications and in-kind contributions by local organizations are likely the elements that sealed the deal for EGGER. Examples include North Carolina Railroad Company, which provided $3.5M to connect the site to Norfolk Southern's mainline via a rail spur; and Duke Energy which rerouted a major transmission line to the site. Other incentives either in the form of grants or no/low-interest loans include $5.3M in performance-based incentives from the state Job Development Investment Grant, $2.5M from the One North Carolina

Fund, and $2.5M in matching local incentives, and $1M for sewer infrastructure from the Golden Leaf Foundation.

While many of these incentives were key in facilitating the deal, they also played a more understated role in improving goodwill and the ease of mutually-beneficial collaboration. This goodwill will be critical in building the community-oriented workforce that EGGER searches for in its investments, as the resulting investment deal is comprised of three parts, spanning a total of 15-years. The first phase (400 jobs) of the EGGER plant began in 2018, with construction for a thermally fused laminate and particleboard production facilities, stock distribution center, design center, and training facility. Initial production is still on track, despite COVID-19, and is expected to begin at the end of 2020. The second (120 jobs) and third phase (250 jobs) will follow with finishing lines for added value production, and a second composite wood panel line. Total investment is expected at $700M and will bring 770 jobs, with a company-estimated multiplier of 1.5 jobs per job created through the facility.

Takeaways

- Investment in the form of site modifications by both public and private organizations are a consistent theme in particleboard/MDF plants. While the perfect site might not exist in a state, agencies that are able to quickly mobilize and modify existing sites can still secure bids.

Background on Distinctions Between MDF and Particleboard Products and Markets

- Particleboard and MDF are both used extensively in furniture production; however, particleboard is more commonly found in furniture carcasses (e.g., kitchen cupboards, sides/shelves/back, box/flat pack furniture, and lower end melamine kitchen tops), while MDF is commonly found in laminate flooring (using a high density MDF) or situations that require additional craftsmanship or rounded edges (e.g., doors, higher end furniture).
- The panel product market, which drives most particleboard demand, is an established and aging industry in the United States. New large-scale mills, that have connections to a network or series of large furniture manufactures, would have considerable competitive advantage.
- On average, particleboard is cheaper to produce as it comparatively requires less energy, can use a lower quality fiber, and less resin.
- MDF's relative cost competitiveness is closely linked to cost of electricity as the process is considerably more energy intensive. These cost dynamics can play a large role in regional site selection. For example, markets in the South (particularly South Atlantic, East/West South Central) beat out the North and Pacific regions by a factor of two on the industrial price of electricity.

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CalPlant

California, United States

- Rice straw-based MDF plant
- CAPEX: $315 million
- Jobs created: 125

Case summary

CalPlant 1 in California (rice straw-based MDF plant) will finish construction in late 2020. While there have been delays due to COVID-19, the $315M CalPlant 1 will be the world's first commercial-scale producer of rice-straw based MDF. Annual production capacity is estimated to supply 30 percent of California's MDF demand, or 140 million square feet (3/4-inch basis). CalPlant 1 was particularly attractive to Glen County, where it is based, as the investment is estimated to produce 300 construction jobs, 800 ancillary jobs, 500 seasonal positions during the annual straw-collection process, and employ 125 full-time employees. The plant will also benefit the local economy by sourcing within a 25-mile radius. Financing initially stalled out in the aughts, with the global financial crisis, but was restarted in 2017 when Stifel Nicolaus and Citigroup underwrote the bonds—bringing the deal to market in May with a secured $834M in bids (well over the initial target of $225M). An additional $73.7M was issued in tax-exempt green bonds approved by California Pollution Control Financing Authority (CPCFA) in 2019, as the plant is expected to avoid emissions of 57,000 tons of methane and save 17.8 billion gallons of water annually.

Takeaways

- MDF deals in the right location can be extremely attractive to private funding raises, with incentives following as public sector aims to capture wins.
- CalPlant 1 and the journey of CEO Jerry Uhland illustrate the long timetables that are often involved between innovation and production reality. CalPlant was initially awarded a U.S. process patent in 2003, but fluctuating economic conditions and lack of investment interest delayed inital investment and construction until mid-2017.

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SwissKrono

South Carolina, United States

- MDF/HDF Expansion
- CAPEX: $230 million
- Jobs created: 105

Case summary

SwissKrono in South Carolina (MDF/HDF) finished construction in 2019. The $230M high-density fiberboard (HDF) mill and laminate flooring production expansion to its existing Barnwell manufacturing facility will allow the facility to produce 300,000 m^3 of HDF and an additional 8 million m^2 of laminate flooring. The extension will add 105 new full-time employees, an estimated 375 indirect/induced jobs, 500 construction jobs, and contribute significantly to the local timber economy—as sourcing is defined to a 75-mile radius. SwissKrono's investment was matched with help from four community development entities (CDEs) through the New Markets Tax Credit (NMTC) program. Because Barnwell has not witnessed the same economic gains as other regions in South Carolina, the investment was able to benefit from several overlapping incentives. Barnwell's relative poverty and unemployment rate, respectively at 17.4 and 14.4 percent (during time of investment in 2019), as well its status as a FEMA disaster area, State Enterprise Zone, and South Carolina Low-Country Promise Zone resulted in a total NMTC allocation of $45.3M. The NMTC allocation included $17M from National New Markets Fund, $11.3M from the Innovate Fund, $10M from Dakotas America, and $7M from SunTrust; SunTrust also provided $14.5M in equity investment.

Takeaways

- The size and scale of overlapping incentives that accompanied SwissKrono's investment in Barnwell are not fully characteristic of the capacity of many regions in the United States. It is clear, however, that the primary draw of NMTC allocations was consistent throughout the CDEs—SwissKrono's ability to bring a large number of construction, induced, and permanent jobs to the region.

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Gevo

Minnesota, United States

- Retrofit of ethanol plant product isobutanol
- CAPEX: $70 million
- Jobs created: 30

Case summary

Gevo is a publicly listed company that specializes in producing renewable chemicals and advanced biofuels. It was founded in 2005 as a collaboration between professors and collaborators at the California Institute of Technology and the University of California, Los Angeles, with venture capital from green energy fund Khosla Ventures. The company obtained exclusive license to bio-based isobutanol technology that the founders had incubated at Caltech and UCLA.

The company moved its headquarters to Colorado in 2008, attracted by the state's hub of biofuel companies and talent, lab space, and presence of the National Renewable Energy Laboratory. GEVO and ICM, Inc. entered a strategic alliance to commercially develop Gevo's Integrated Fermentation Technology (GIFT), which enables production of isobutanol and hydrocarbons from retrofitted ethanol plants.

In 2009, Gevo signed a licensing agreement to use Cargill's micro-organisms in its GIFT process, enhancing its ability to produce isobutanols from cellulosic sugars derived from plant materials ranging from corn stover and switchgrass to forest residues. The same year, the company set up a facility in St. Joseph, Missouri as part of ICM's biofuels research center to demonstrate its model for repurposing ethanol plants for scalable isobutanol production. The plant had a capacity of 1 million gallons per year (MMgy), requiring a low upfront capital investment of about 30 cents per gallon of installed ethanol capacity. The plant took fewer than three months to retrofit, and would prove useful over the years in piloting new processes.

In 2010, Gevo became the first company to receive certification from the Environmental Protection Agency (EPA) for isobutanol as a fuel blendstock after meeting Clean Air Act standards. In the same year, the company purchased a corn-based ethanol plant from Agri-Energy for $20.7 million in Rock County near Luverne, Minnesota, with the capacity of 22 MMgy—slated to become the company's first commercial production facility. The plant enjoyed close proximity to large volumes of sustainably grown and affordable corn stover. Additionally, the plant's access to renewable energy sources via proximity to wind towers and access to biogas for methane were key factors in providing a sustainable basis for electricity and heat generation. Once retrofit, the facility would be able to produce both ethanol and isobutanol. The isobutanol could be used for jetfuel and gasoline, as well as an ingredient in solvents and other chemicals.

In 2011, the company converted the Luverne plant. At the beginning, the Luverne plant produced mostly ethanol while fermenting isobutanol in batches, taking time to refine the isobutanol fermentation process.

The company received patents on technologies enabling low-cost, high-yield production of biobased isobutanol. Friction emerged when it became clear that Gevo's competitor Butamax Advanced Biofuels (joint venture between BP and DuPont) had its own patented biocatalyst and process technology for producing isobutanol. For the next four years, Gevo and Butamax were embroiled in lawsuits, suing each other over patent infringement and associated damages. Litigation cost Gevo for 30-40% of the company's monthly cash burn, and more during trials. The two companies eventually agreed to settle and cross-license their isobutanol technologies, whereby Gevo could produce isobutanol for jets, and Butamax for vehicles.

In 2016, Gevo was finally able to ramp up the Luverne plant to achieve continuous, commercial production of 750,000 gallons to 1 million gallons a year, a seven- to tenfold increase from before. At full capacity, the plant produced isobutanol, ethanol, high-value animal feed, isooctane, and corn oil, providing a diverse

set of revenue streams. Beyond operating its own plants, Gevo also came to operate other plants under contract, providing additional revenues.

In the same year, the company produced the world's first cellulosic renewable jet fuel specified for commercial flights, using sugars derived from woody biomass in the Pacific Northwest sourced through the Northwest Advanced Renewables Alliance (NARA). Gevo produced the isobutanol at its demonstration facility in Missouri, then transported the isobutanol to its biorefinery facility in Silsbee, Texas (operated jointly with South Hampton Resources, Inc.) to convert into jet fuel. The specification for the alcohol-to-jet fuel has been broadened to use renewable isobutanol regardless of the carbohydrate feedstock (i.e. cellulosics, corn, sugarcane, molasses). Currently, however, woody biomass is to costly to produce when compared to other feedstocks like corn. In 2018, Gevo signed a joint agreement with technology licensor Renmatix to evaluate the commercial feasibility of creating renewable jet fuel using Renmatix's Plantrose process and Gevo's GIFT technology.

In line with its focus on sustainability, in 2019 Gevo obtained certification under the International Sustainability and Carbon Certification (ISCC) PLUS scheme, a scheme for bio-based applications such as chemicals, food, and feed products in the bioenergy sector. The certification demonstrates the sustainable production and traceability of Gevo's liquid biofuels. In early 2020, Gevo also obtained Roundtable on Sustainable Biomaterials (RSB) certification for its sourcing of corn and production of isobutanol in Luverne.

Over the years, the Luverne plant became the top source of industry revenue for Luverne. However, gasoline demand has dropped during the COVID-19 outbreak, placing great pressure on the biofuel industry. Nearly 30% of the 204 biofuel plants in the United States have been idled since March 2020, while others have reduced production. Gevo has suspended production operations and let go of 30 employees.

Despite the downturn, company leadership remains confident about prospects for recovery and expects to expand the facility to produce greater quantities of low-carbon isobutanol, aviation fuel, and isooctane—in part to serve offtake agreements already signed with Delta Airlines and HCS Group in 2019. Altogether, Gevo has roughly $500 million worth of take-or-pay contracts in place for a combination of renewable jet fuel and renewable isooctane for gasoline, totaling 60 to 70 million gallons of hydrocarbon fuels. Most demand for production is for gas rather than jetfuel, particularly now that airlines are under duress. Gevo's isooctane for gas provides a low-carbon alternative that complements existing transportation infrastructure, providing a practical alternative to electric vehicles as a means to achieving net-zero vehicle emissions.

Gevo has hired Citigroup Global Markets to help it secure additional project funding for expansion—both at Luverne and in establishing two additional sites. The company is searching for other sites based on the same type of enabling conditions as for the Luverne plant: a combination of feedstock sustainability and availability, access to renewable energy, cost to serve the marketplace for that site, and financial incentives and capital. Gevo also plans to undertake additional decarbonization projects at the Luverne facility. This includes a 5 MW wind energy generating facility to help decarbonize production, add jobs, and expand access to low-carbon markets such as California.

Challenges

- It took about five years before the company was able to continuously produce isobutanol and survive the "valley of death," where the company had to navigate an expensive patent litigation process and spent significant time to refine the isobutanol fermentation process. It took years before the company was able to turn a profit. Ethanol production remained a key contributor to revenue.

Challenges (cont.)

- While Gevo's leadership is very interested in using woody biomass as feedstocks, to date the company primarily uses corn as feedstock. Lignin still needs substantial derisking. Cellulosic sugars are still more expensive than corn sugars. Although there is great market potential for lignin, adding a cellulosic technology would involve extensive engineering and development to get right, and can double the capital investment required—requiring more fundraising. Any capital that the company would need in to put already for a typical $250 million isobutanol/jetfuel production plant would need to be matched by another $250 million on the cellulosic side to support a $500 million project investment. If the economics justified the investment, Gevo would have gone ahead.

Enabling Environment and Incentives

- Gevo leadership cites the top criteria for site selection as sustainability; cost; and availability of raw materials and renewable energy, and available incentives/capital. While lower on the list, access to pipeline and rail is also essential to enable transport of jetfuels and gasoline. Gevo would never site a plant in a landlocked place without access to rail or pipelines.
- Gevo anchored its commercialization model around retrofitting ethanol plants given the low cost and versatility in leveraging existing infrastructure to produce ethanol, isobutanol, isooctane, corn oil, and animal feed as complementary revenue streams. Prior to investing in the Luverne facility, Gevo had partially derisked its isobutanol production technology by testing it at its demonstration plant in Missouri.
- Gevo chose to invest in Minnesota because of the fundamentals around the plant, not because of any state-specific investment attraction. The company chose the plant at the Luverne site in part because the plant was small enough while still on the flat part of the curve in terms of economies of scale. 20 million gallons, while large for other industries, is considered small for the ethanol industry. Gevo leadership had worked in the region before and knew about the availability of cheap corn and livestock manure for biogas.
- Company leadership saw equity was the most essential part of financing. Loans are easy to obtain once the equity is there. Gevo leadership perceived federal and Minnesota financing as onerous and not worth applying for, particularly given that the company had already derisked its technology and could more easily raise private capital.
- Gevo has enjoyed success in private sector fundraising from high-profile investors in part due its visible record of innovation and sustainability at Caltech/UCLA and its partnerships with major industry players. The company has been able to further differentiate itself from other biofuel companies through its interdisciplinary expertise across biotech, engineering, and chemistry.
- Securing large-volume offtake agreements has been key to ensuring a long pipeline of demand for Gevo's expansion, particularly when weathering the outbreak and economic downturn. For example, in 2019, Delta Airlines agreed to purchase 10 million gallons of advanced renewable biofuels per year once the Luverne plant has completed expansion. HCS Group has agreed to purchase renewable isooctane worth up to $180 million over 10 years contingent on the expansion.

Takeaways

- Given that sustainability is part of its core thesis, sustainability of feedstocks factors is the first consideration (whereas it may be only the tipping factor for other companies).
- The ethanol market is saturated so there is not much room for new entrants. Gevo and Butamax have already staked intellectual rights to bio-based isobutanol production for key markets and are well positioned to remain the dominant players. Should Maine's forest industry be interested in entering this space, it could explore collaboration with these players, e.g., through licensing agreements or helping jointly incubate developments using woody biomass. Gevo works as both a developer and licensor, and works across states. Gevo's leadership is committed to eventually using more woody biomass but still sees it as very expensive.
- Gevo's decision to invest in Minnesota was based primarily on existing infrastructure and resource availability, and not based on Minnesota-specific investment attraction. Company leadership points to Iowa and Nebraska as states that have had relatively stronger tax incentives in place to attract investment in biofuels. The perception is that federal loan programs and Minnesota incentives programs can be onerous to navigate, and that it is perhaps more necessary for companies that have yet to derisk their technologies to go to government for funding. For others, the company stresses the advantages of fundraising through the private sector.
- While the Luverne plant has temporarily suspended operations, the company's leadership maintains confidence in its offtake agreements and projects that the market for bio-based isobutanol will recover within a couple of years. Many oil fields have been decommissioned given the collapse in oil prices, and would take years to start up again—potentially creating more opportunities for renewable energy.

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Structurlam

British Columbia, Canada

- Laminated beams and cross-laminated timber (CLT)
- CAPEX: $90 million
- Jobs created: 130

Case summary

Structurlam's origins date back to 1962 when local Okanagan construction company Greyback developed a plant and company to manufacture glulam beams. Since the early days, the company has focused on providing building solutions for clients. Structurlam has over many years engineered and supplied the glue laminated structures for iconic building projects around the world. From the early stages Structurlam has not been a commodity producer - they are custom manufacturers. Structurlam's buildings are completely designed in house down to the individual screw connections before the beams and panels are made.

In 2007, the company expanded further tripling its glulam capacity. In 2011, with 2.5 million CAD economomic development grants from the provincial government of British Colombia and the same amount from the federal government, Structurlam opened North America's first CLT plant and began manufacturing its trademark Crosslam CLT. The company made a bet that CLT would be a winner, and at those early days, it was a significant risk. Without the provincial government support, it would have been unlikely Structurlam would have invested in CLT at that time. At that time, only a small number of people expected that CLT would be on the trajectory it is on today. Structurlam's current owners, the Kingfish Group, purchased the company in December 2018. In 2019 Structurlam expanded once again, opening a third manufacturing facility close to Okanagan Falls location. This facility has the latest in CNC machining, to allow for highly detailed milling of the CLT and laminated beam components. Today Structurlam has its head office in Penticton, British Columbia and has mass timber production facilities in Penticton, Okanagan Falls, and Olivier, BC.

Currently between 85 and 90 per cent of Structurlam's business is non-residential, including heavy industry and commercial. Notable projects in Canada include the waterfront Vancouver Convention Centre, the Wood Innovation and Design Centre in Prince George, B.C., the Shane Holmes YMCA at Rocky Ridge in Calgary, the Art Gallery of Ontario and Microsoft's new headquarters in Mountain View, Calif. Structurlam today employs around 225 people at four manufacturing facilities and the head office. Depending on what products are going through, the facilities will run 24/7, 365 days a year. The key success factor for Structurlam, according to its CEO Wentzel, is keeping on track, or "sticking to our knitting.

With the increasing market demand for CLT in the USA, Structurlam decided to investing in a manufacturing facility in the USA. The location of the new expansion is Conway, Arkansas. This location has been partly selected due to a new investor in the business, Walmart, who is in the process of developing its own home office campus in Bentonville, Arkansas , using some 1.1 million ft3 of mass timber in its construction . The new plant will supply the CLT panels for the project. Conway's location is also strategic, as it is surrounded by 19 million acres of Southern Pine plantation forest, and has well established transport routes to the Southern, Central and Easters United States. This will allow for the effective distribution of CLT to those parts, while Canada, the Pacific North West and California will be supplied from the Canadian plant. As part of attracting Structurlam to Arkansas, the Arkansas Economic Development commission provides through the incentives funds US$1.5 million towards the project, as well as tax refunds and rebates. In addition, Structurlam was selected to construct the new fire department facility in Camden, Arkansas.

The new plant will be built in a former steel plant, which will be retrofitted and equipped, at a cost of USD90 million. The plant will source softwood lumber locally, utilizing southern pines. In total, the plant is expected to employ some 130 people directly once it is up and running by mid-2021

Enabling Environment and Incentives

- Government support in the initial CLT investment was critical. Without this backing, the investment would most likely not have been made.
- Support from local research and universities in with technical research and development of technical materials – i.e. the CLT handbook, first produced by FP Innovations in 2011.
- Global interest and growing demand in mass timber construction.
- Conway, Arkansas is a strategic location, both in terms of raw material supply as well as ability to target key markets.
- Investment by Walmart into Structurlam, in part to secure the supply of mass timber products for its new Home Office Campus, focused the location search on nearby Conway.
- State support for the new investment helped with finalizing the decision by Structurlam to invest in Arkansas.

Takeaways

- The initial move into CLT manufacturing was a logical extension of the historical business operations and supported by local and regional grants.
- Structurlam selected Arkansas for the location of a new plant due to the direct investment by Wallmart into Structurlam, and the desire of Wallmart to develop a new central business campus in Arkansas out of mass timber.
- The new location also provides Structurlam with a strategically located mill to supply into the US market
- State support further assisted in finalizing the decision to invest in Arkansas.

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BTG Biomass to Liquid (BTL)

Overijssel, Netherlands

- Empyro pyrolysis oil plant
- CAPEX: 20 million EUR
- Jobs created: 30

Case summary

Biomass Technology Group (BTG) formed in 1987 in the Netherlands as a spinoff of University of Twente engineers, specializing in converting biomass into useful fuels and energy. In 1993, BTG purchased rights from the university to further develop and scale up a technology to produce pyrolysis oil from plant-based residues such as wood residues and roadside grass. In 2005, BTG installed a small 2 t/h pyrolysis oil production plant in Malaysia, using empty fruit bunches of oil palm as feedstock. This initial plant provided BTG experience in optimizing equipment processing conditions.

In 2008, BTG established BTG Biomass to Liquid (BTL) as a sister company dedicated to demonstrating the technical and commercial feasibility of producing oil from sawdust. BTG-BTL began designing and planning construction of a 25-MWth plant to be based in Hengelo, Overijssel Province near the company's head office. The company opted for a medium-scale plant of 25 MWth within 50 to 70 km of sources of wood residues to avoid transporting biomass across large distances. BTG-BTL's standard plant design entailed recovering excess heat as steam, for use in industrial or local heating and electricity production.

Design and construction of the Empyro plant required an investment of €20 million. The company first secured financial commitments covering 40% of this total using European, national and local subsidies. Government subsidies consisted of research funding from the EU's 7th Framework Program and the Dutch government's Top Consortiums for Knowledge and Innovation Bio-based Economy (TKI-BBE) program, and a subsidy from the provincial government. In turn, the company raised another third through equity capital from the Province of Overijssel (Energy Fund) and a local private investor. BTG-BTL borrowed the final third from a bank. BTG-BTL established Empyro BV in 2009, sharing ownership with renewable energy investor Tree Power, Energy Fund Overijssel, and a private investor.

Environmental, building, water, Nature 2000, and other permits were obtained in 2012. In 2014, to ensure a reliable supply of feedstocks, BTG-BTL signed agreements to source wood residues for four to five years from forest industry in the vicinity that made furniture and wood pellets. Empyro secured two 12-year offtake agreements for steam and oil with nearby AkzoNobel and Friesland Campina facilities, respectively. By siting close to the AkzoNobel utility, the Empyro plant would be able to reduce capital expenditures by 10-30% by sharing residual heat, electricity, and boiler feed water with the utility. The long-term offtake agreements were made possible thanks to support from a renewable energy subsidy scheme run by the federal government (SDE+). Friesland Campina would receive a subsidy for steam production with pyrolysis oil, while Empyro would receive a subsidy for supplying steam to Akzo Nobel and electricity produced using a steam turbine.

BTG-BTL reached financial close in December 2013 and began plant construction in 2014. Empyro launched bio-oil production in 2015, becoming the first plant in the world to continuously produce pyrolysis oil on a commercial scale to be used for industry applications. At capacity, the plant produced 20 million liters of oil per year, replacing 12 million cubic meters of natural gas, the equivalent annual consumption of 8,000 Dutch households—saving up to 20,000 tonnes of CO2 emissions per year. The technology improved energy efficiency by 85-90% based on biomass in and oil, heat, and electricity. Plant construction generated 70 to 80 short-term jobs. Operating the plant took 10 people, while transportation of oil and biomass required another 20, generating about 30 long-term jobs. In 2018, municipal renewable energy utility and waste processor Twence Holding approached BTG BTL to buy the Empyro plant. BTG-BTL

agreed to sell, and to collaborate with Twence to further develop the plant and explore new sustainable avenues including processing of roadside grass into pyrolysis oil. The transaction was finalized in 2019. Following the initial project with Twence, BTG-BTL sold nearly identical copies of the Empyro plant to companies in Sweden and Finland in 2019, to produce pyrolysis oil through sawmill waste such as sawdust. BTG-BTL has been working to find other adopters to replicate the same size plant and contribute to the global energy transition—in the business of selling rather than operating plants.

Enabling Environment and Incentives

- BTG owned the patent for the fast pyrolysis process and had experience testing and optimizing the technology with the pilot plant in Malaysia, informing the design and operation of the Empyro plant.
- BTG-BTL located the Empyro plant within 10 km of the head office to ensure accessibility for company staff, and near the AkzoNobel utility site to support the offtake agreement for steam as residual heat. The site was also within 35 km of Friesland Campina's sustainable energy facility in Burculo, supporting the second offtake agreement for oil.
- The 12-year offtake agreements for steam and oil were key enablers, even more so than subsidies in helping bridge the "valley of death" to full commercialization and providing stable pricing. Energy contracts are conventionally short-term, e.g., ranging from a couple of months to half a year. The Dutch SDE+ program helped incentivize offtake agreements for renewable energy.
- The broader mix of government subsidies through formal subsidy programs and ad hoc investment helped secure upfront financing to enable BTL to raise equity and loan capital from other sources.
- Long-term agreements for forest industry in the vicinity provided a reliable source of feedstocks for pyrolysis oil production. The maximum distance for cost-efficient and sustainable transport was set as 100 km from the plant. Typically 60-70 percent of the feedstock is contracted long-term while the rest is short-term, with some feedstock sourced on the spot market.
- BTG-BTL leadership did not see the need to site within a larger industrial cluster, which could come with other competition.

Takeaways

- BTG-BTL leadership sees two to four years for fundraising as typical, even for investments in mature technologies. In this case, it took the company roughly two years to reach financial close.
- A roughly even split between subsidies, equity, and loans (a third each) provides a healthy way to structure financing for investment in a new plant, sharing risk across parties. It helps to obtain subsidies prior to going to equity investors so that the company is not required to dilute their shares too much in order to raise capital. It is recommended to go to the bank last once other financing is already secured, as commercial banks may have less appetite for risk and tend to remember any insecurities they have about a particular investment.
- Utilities can serve as offtakers as well as prospective buyers/operators of a pyrolysis oil production plant. Long-term offtake agreements for heat and oil are crucial to provide a steady and balanced source of revenue. Risks for offtakers are limited, given that they do not have to pay anything upfront—only once the company actually delivers on production.

Takeaways (cont.)

- While energy contracts tend to be short, government renewable energy programs—in this case the Dutch SDE+ program—can help provide the basis for longer-term offtake agreements. Ensyn avails of a similar government subsidy to help supply heat for a hospital in Canada. In the United States, contracts are short term such that prices fluctuate over the course of weeks. While larger companies could afford to use balance-sheet financing to bridge the valley of death, small entrepreneurs would find it especially hard to navigate such pricing risk and lack of clarity on a long-term revenue source. The government in Maine could similarly help support long-term offtake agreements via renewable energy incentives.
- While there is a tendency for companies in the energy industry to go for large-scale operations—e.g., in the petrochemical industry—medium-scale plants are recommended for pyrolysis oil production given the inefficiencies of transporting biomass over long distances. Another advantage is that pyrolysis plants can be located close to attractively priced biomass.
- It is important to ensure sustainable sourcing of biomass and educate key stakeholders and the public on the sourcing to ensure social license. It is somewhat easier for people to understand the sustainability of biomass energy production if the biomass is coming from sawmill residues as opposed to being harvested from the forest.
- The BTG-BTL technology has been tested on over 45 different types of feedstock. Woody biomass provides the highest yields typically, but the technology can also process rice husk, bagasse, sludge, tobacco, energy crops, palm oil residues, straw, olive stone residues, and chicken manure.
- Pyrolysis oil production in Europe is resilient to the fall in oil prices as a result of the COVID-19 outbreak given Europe's formalized support for second-generation biofuels. On the other hand, oil companies are being more careful now given their lower profitability. The policy environment is shakier in the United States and depends on states' support of renewable energy.
- BTG-BTL leadership would be interested in presenting the pyrolysis oil production for use in Maine, adapting the same model from the 25-MWth Empyro reference plant. The company is able to deliver new plants within 12 months.

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Wesbeam

Queensland, Australia

- Laminated Veneer Lumber (LVL) mill
- CAPEX: 115 million AUD
- Jobs created: 60+

Case summary

Case summary Wesbeam Pty Ltd (Wesbeam) is a Western Australian based LVL producer. Wesbeam has its origins nearly 100 years ago, when Thomas Cullity, an Irish immigrant started Cullity Timbers in 1928. The company and family has had a continued involvement in the forest industry in Western Australia, and opened its first plywood plant in 1942. The company evolved into Wesfi, which at its height operated particleboard and MDF manufacturing facilities as well as veneer and laminated production and owned a plywood mill in Fiji.

Wesfi was purchased in 2002 by Laminex. This takeover left both the Cullity family and a close management team with the opportunity to develop a new project. Western Australia has a sizable Pinaster Pine resource, which did not have a major local industrial processer nearby. The resource produces a relatively high density material, and a high strength veneer product, ideally suited for structural uses, such as LVL. In addition, the Australian market for LVL was well established with one other local producer, and significant imports from both the USA and New Zealand.

The team identified the opportunity, and Wesbeam was formed in 2001, with the strategy of developing an LVL mill. No direct financial support was provided by the State or local government. The industrial area, developed by the state-owned land management company (LandCorp), in which the mill is located, was under development at the time. Wesbeam was provided with a 10Ha site, with an additional option to extend by a further 5 Ha if required. An interest free facility was put in place for this, allowing Wesbeam to pay for the site over a 10 year period. Other infrastructure costs where paid for by LandCorp.

Wesbeam negotiated an exclusive supply contract for the wood resource, providing a guaranteed supply for a period of 25 years. This provided Wesbeam with the security required to confidently go ahead with the build of the mill.

By 2003, the AUD115 million mill was under construction, and the first LVL billet was produced in 2004. Key to the development of Wesbeam was the combination of the continued interest of the Cullity family in the industry, the availability of a tight and capable management team, the supply security provided by the state owned Forest Products Commission and a sizable and expanding LVL market in Australia.

Since producing its first LVL billet in 2003, Wesbeam has continued to evolve and innovate. This has included, but is not limited to the development if I Beam construction, adaptation of technological advances in peeling technology, continual expansion in production throughput, introduction of mixed species layups, mass timber building components, whole of house design and specification software and unique developments in supply chain management.

Today, Wesbeam has a production capacity of well over 80 000 m^3/a and provides a full range of LVL, I Beam and mass timber components, through a nationwide distribution network, with warehouses in all the key states. The CEO, James Malone and his tight management team continue to challenge the status quo of engineered wood products and mass timber products in Australia on a daily basis.

Enabling Environment

- Wesbeam was able to secure long term access to a desirable resource, and develop a modern and competitive mill supplying into a growing market. Local resource is limited, presenting challenges to expand operations.
- Cornerstone investment by the Cullity family as backing by the management team.
- Local knowledge and in-depth industry knowledge was key to setting up and securing finance in the early days.
- Secure funding to allow for the build of (at the time) a world class LVL mill. Continued innovation comes at a cost, and Wesbeam remains a relatively small manufacturer.
- Continued drive to innovate all aspects of the business ensuring product and market leadership.

Takeaways

- The establishment of Wesbeam was a locally driven business. It is unlikely an outside investor would have seen all the aspects which created this opportunity.
- Location is key to the success of the business – providing access to a unique, but very suitable resource.
- A single mill operation provides unique challenges – however Wesbeam believes that the benefits of small, nimble, and innovative outweigh the negatives

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