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Canadian Wood **Fibre** Centre

An Impact Assessment of Four Research Projects of the Canadian Wood Fibre Centre

Summary Report

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Canadian Wood Fibre Centre
Working together to optimize wood fibre value – creating forest sector solutions with FPInnovations

Canada

Canadian Wood Fibre Centre – An Impact Assessment of Four Research Projects of the Canadian Wood Fibre Centre - Summary Report

Aussi disponible en français sous le titre : Centre canadien sur la fibre de bois – Évaluation des retombées de quatre projets de recherche du Centre canadien sur la fibre de bois – Rapport sommaire

ISBN 978-1-100-54413-7 (Print)
Cat. No. Fo149-8/2012

ISBN 978-1-100-21297-5 (On-line)
Cat. No. Fo149-8/2012E-PDF

100% Recycled paper

PRINTED IN CANADA IMPRIMÉ AU CANADA

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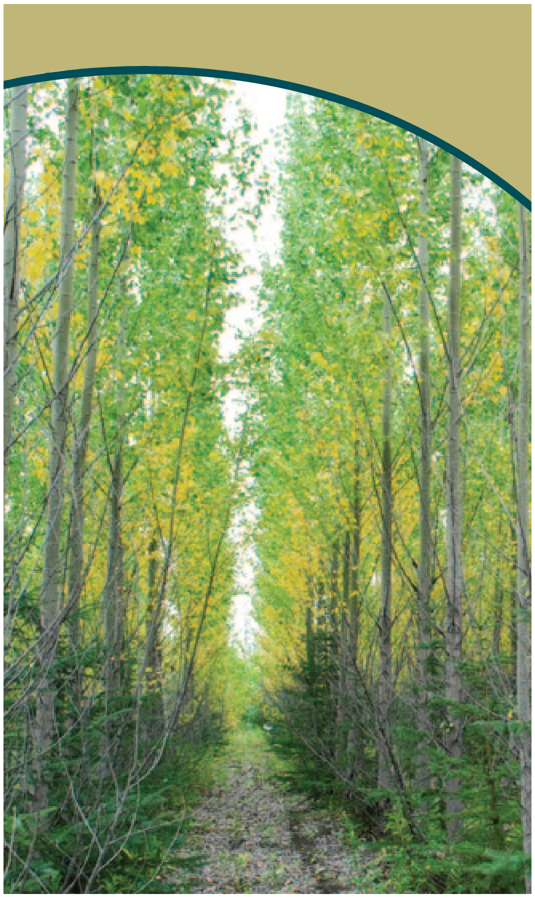


Executive summary

The Canadian Wood Fibre Centre (CWFC) has a mission to create innovative knowledge to expand the economic opportunities for the forest sector to benefit from Canadian wood fibre. Now the CWFC has delivered a potentially high-impact research program for advancing the innovation strategy of the Canadian forest sector. The CWFC collaborated with FPInnovations and other partners in the industry, provinces and universities. The team undertook a study recently to assess the impact of four projects: (i) Enhanced forest inventory systems, (ii) Multi-varietal forestry and somatic embryogenesis, (iii) Hardwood optimization and (iv) Purpose grown fibre.

This assessment estimated the impact of the projects on economic contributions to the Canadian forest sector, contributions to sector transformation, and contributions to science and knowledge exchange. The findings of the assessment will allow the CWFC to take stock of its research, partnerships and contributions to the economic sustainability of Canada's forest sector.

In assessing these projects, the team used the NABC (Need, Approach, Benefits and Competition) approach developed by SRI International. Using the NABC approach, the CWFC has produced four stories to reflect the essential accomplishments of the projects.

In consultation with evaluation professionals at Natural Resources Canada, the team developed a rigorous assessment framework. For an overall investment of $5.7 million by the CWFC, the four projects have leveraged $3.6 million from federal, provincial and industrial partners, achieving $0.63 of external funding in its projects for every $1.00 it invested.

In economic contributions, these projects are projected to produce $29.3 million in net present value with a benefit-cost ratio of 3.1 over the next 10 years. Over the long-term, the economic benefits of the projects are expected to increase steadily.

Industry partners sent the team several testimonials about the contributions that the projects are making in transforming the forest industry from a high-volume to a high-value sector – providing anecdotal evidence that the CWFC projects are contributing significantly to forest sector transformation.

In contributions to science and knowledge exchange, the four projects have generated 75 publications, with 66 citations on Scopus (a database of peer-reviewed literature). The component leaders of the projects made 217 presentations to professional conferences and industry events.

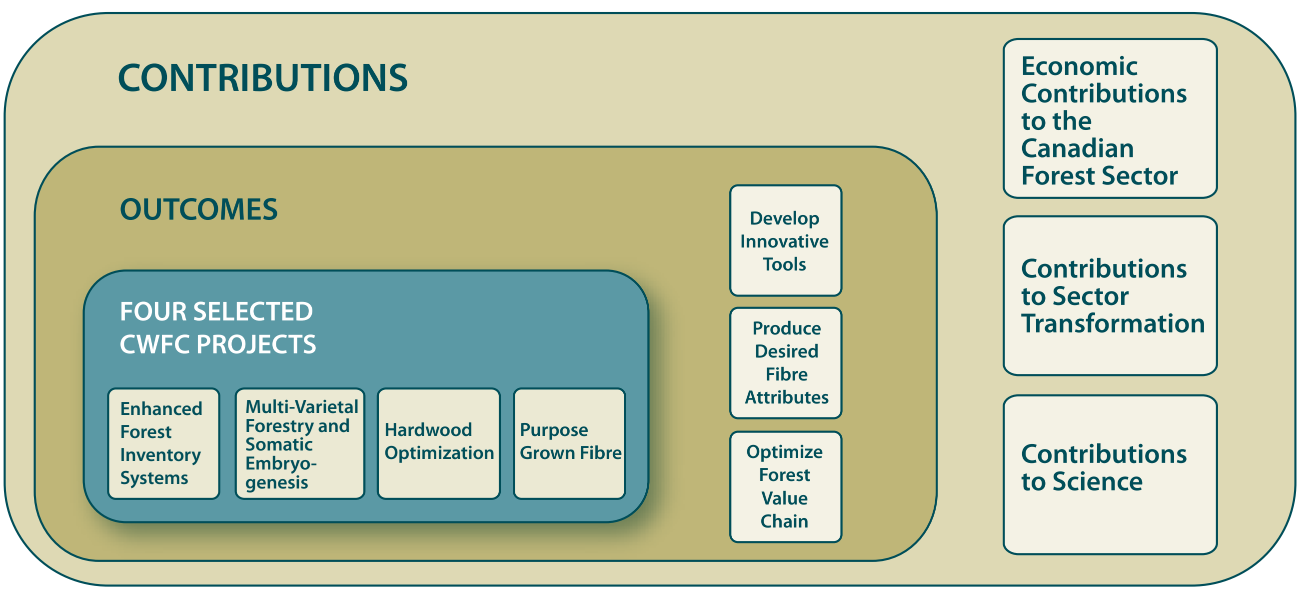
The four CWFC projects have started to generate considerable economic benefits to the forest sector and are playing an important role in delivering value to the sector through close collaborations with FPInnovations, industry, provinces and universities. Through their impacts, the projects are beginning to demonstrate the financial viability of several new technologies, models and processes, which will encourage industry to adopt them. The projects also showcase the CWFC as a leader in creating sector-relevant knowledge products.

1. Introduction

The Canadian Wood Fibre Centre (CWFC) was established in 2006 as a research unit of the Canadian Forest Service, Natural Resources Canada. The CWFC partners with FPInnovations and strengthens the research centre's forest-level research capability. The CWFC's mission is to create innovative knowledge to expand the economic opportunities for the forest sector to benefit from Canadian wood fibre. Now the CWFC has delivered a potentially high-impact research program for advancing the innovation strategy of the Canadian forest sector. The CWFC collaborated with FPInnovations and other partners in the industry, provinces and universities.

The team undertook a study recently to assess the impact of four CWFC projects: (i) Enhanced forest inventory systems, (ii) Multi-varietal forestry and somatic embryogenesis (MVF/SE), (iii) Hardwood optimization and (iv) Purpose grown fibre. This assessment estimated the short-term and potential long-term impacts of the projects. As Figure 1 indicates, the projects help deliver on three key outcomes: develop innovative tools, produce desired fibre attributes and optimize the forest value chain. By contributing to these outcomes, the projects are expected to make a difference, in economic contributions to the Canadian forest sector, contributions to sector transformation and contributions to science. The findings of this assessment will help the CWFC to take stock of its research, partnerships and contributions to the economic sustainability of Canada's forest sector.

Figure 1. Four selected CWFC projects and their outcomes and contributions



2. Four selected CWFC projects

For this impact assessment, the team chose four Canadian Wood Fibre Centre (CWFC) projects for assessment: (i) Enhanced forest inventory systems, (ii) Multi-varietal forestry and somatic embryogenesis (MVF/SE), (iii) Hardwood optimization and (iv) Purpose grown fibre. These four projects were selected because they are regionally distributed across the country, they have been in operation long enough that the team could analyse their results, and each project addresses a distinct part of the upstream forest value chain. Each project is described in greater detail below.

Enhanced forest inventory systems

Many forest inventories in Canada are more than 20 years old and can not support today's needs for accuracy, spatial detail and timely updates. Enhanced forest inventory systems use aerial and ground-based technologies to provide precise estimates for groupings of trees within forest stands across the entire forest landscape. This information allows industry to better predict fibre supply attributes to optimize harvesting and mill operations. Associated terrain models enable cost savings in road construction and transportation planning. Advanced statistical algorithms enable landowners and land managers to develop accurate models and increase the efficiency and precision of ground-based validation plots. Such stand and site knowledge is related to remotely-sensed information to predict fibre quality across managed forest areas. The Enhanced forest inventory systems' project has distinct components in Newfoundland and Labrador, Quebec, Ontario and Alberta, in each case relying on collaboration with provinces, industry, academia and the geomatics sector.

Multi-varietal forestry and somatic embryogenesis

The goal of the MVF/SE project is to develop and apply advanced technologies to increase plantation growth rates while optimizing wood quality, pest resistance and adaptability to climate change. Specifically, the project aims to grow trees with desirable attributes through biotechnology known as somatic embryogenesis while ensuring their full development through a series of forest management techniques known as multi-varietal forestry. The result of combining these technologies is a significantly reduced growth cycle for trees, enabling forest companies to cut the same amount of wood fibre in a shorter time frame. Today the research for this project is limited to New Brunswick. When successful, however, the technologies will be applied in other Canadian jurisdictions to become a new link in the forest value chain.

Hardwood optimization

The hardwood optimization project aims to develop a high-speed optimization tool to help forest managers take advantage of value-enhancing opportunities while increasing the economic potential and long-term sustainability of eastern hardwood forests. Hardwood optimization tools take currently available information about the forests and advise forest managers on how to harvest the stand to maximize the long-term value of the wood fibre. This research is being conducted in Quebec. When fully implemented, this tool will allow forest managers to maximize their current profit while growing the long-term value of the forests.

Purpose grown fibre

The Purpose grown fibre project aims to offer solutions for using land suitable for forestry by helping develop and supply biomass for energy production while creating economic stability and assisting with carbon sequestration. This project will give resource-dependent communities another option for their land, through the use of short-rotation woody crop (SRWC) systems. By developing software tools and best practices, the project gives landowners the ability to calculate whether SRWC systems would be right for them. The establishment of best practices have ensured that the landowner is able to implement the new approach correctly. This project is in development in Edmonton, Alberta; and Guelph, Ontario. This program benefits private and public landowners, including provincial governments, forest industry and farmers, by giving them more options for managing their land while opening up more uses for Canadian fibre.

3. Assessment approach

To assess the four projects, the team used the NABC (Need, Approach, Benefits and Competition) approach developed by SRI International. The NABC approach captures the most essential information of any given activity or project. It permits a quick identification of the *need* that the project is designed to address, the *approach* taken to address this need, the *benefits* that the project produces, and the *challenges* that the project still faces. Using the NABC approach, the Canadian Wood Fibre Centre (CWFC) produced four stories to reflect the essential accomplishments of the projects, and they are available upon request.

The impact assessment focused on evaluating the extent to which the projects have contributed and are expected to contribute to the forest sector, in measurable terms. The team developed a rigorous assessment framework, based on consultation with evaluation professionals at Natural Resources Canada (NRCan), to carry out the assessment, including quantitative and qualitative analyses.

Quantitative analysis

To quantitatively measure the economic contributions of the projects, the team developed metrics that included the funding leverage ratio, projected benefits and costs, the net present value and the benefit-cost ratio.

First, the team collected information about the amount of funding invested in each of the projects from sources outside the Canadian Forest Service (CFS), NRCan. This "leveraged" funding is a key indicator of external support for the research. Comparing this leveraged funding with the internal project funding provided by the CFS results in a funding leverage ratio, a statistic that demonstrates the relative success of the project in attracting outside funding. In the interests of clarity, only funding support in cash was included in the assessment.

Second, the team asked industry partners for a list of projected benefits and costs attributable to the projects, based on field tests or their own projections. These figures were verified and then used in the assessment.

Third, the benefits and costs submitted by industry partners were combined with a series of conservative assumptions to calculate the economic impact of the projects based on two common economic assessment measures: net present value and benefit-cost ratio. The *net present value* is the difference between the current value of all projected benefits, now and into the future, and the current value of all projected costs, now and into the future. The *benefit-cost ratio* is the ratio between the current value of all projected benefits and the current value of all projected costs.

In private industry, analysts typically use a discount rate of 10–12 percent. Governments, on the other hand, tend to use a lower discount rate for assessing the economic impact of long-term projects. Given the nature of CWFC's research projects, the team used a discount rate of 8 percent to calculate the net present value and benefit-cost ratio.

In most cases, the team limited the estimates to the impacts of the project on costs or values associated with the fibre harvested. It did not consider the economic value of the technology or technological spin-offs.

To estimate the economic impact of a given project, the team needed to consider the impact at harvest, which means that time frames can be quite long. In projects that involve managed plantations, such as the MVF/SE project, the anticipated benefits can not be assessed until the end of the growth cycle, when the affected fibre reaches maturity. Only at the end of this cycle, when the grown trees begin to be harvested, can the economic impact start to be measured. This cycle creates extremely long time frames under the assessment, reaching into the future as far as 2097. Standard economic assessment indicators, such as the net present value and benefit-cost ratio, are not typically used for such long time frames. The discount rate becomes critical because short-term and upfront costs carry more weight than long-term benefits.

Furthermore, these projections must be interpreted with caution. Even with "perfect" information, it is difficult to predict anything with certainty – even within a short time frame of 6 to 24 months. The situations under which a projection can change rapidly include the following: fibre costs drop, labour costs rise, the value of the Canadian dollar fluctuates, and new technologies are introduced that make some of the projects' work obsolete. Thus in making these projections, the goal is to estimate what the impact would be *if all other factors remain relatively constant*, rather than to accurately calculate what the future will hold. This central assumption allowed the team to quantify the conceivable impact of the research while giving the team metrics to use in comparing the four projects. This way, the team can draw reasonable conclusions about the research being conducted in the four projects.

The metrics, despite their limitations, provide a broad sense of the economic feasibility of the four projects over their life cycle. To complement an evaluation over the long term, the team chose to evaluate the short-term economic impacts of the projects from their beginning (2008) to 10 years from now (2022). The team expects that the time frame of 2008–2022 will provide a good idea of how these projects will impact the Canadian economy in the short term and a better idea of their attractiveness to uptake by industry.

Qualitative analysis

To evaluate the contributions of the selected projects to sector transformation and science, additional qualitative indicators were derived. For sector transformation, the team collected testimonials from principal industry partners on the projects' impacts on helping the industry transition to a higher-value future.

For contributions to science, the team examined several indicators, including the number of papers published, the number of times those papers have been cited in Scopus (a database of peer-reviewed literature) and the number of presentations delivered at industry sessions and sector events external to the CWFC and FPInnovations. While these figures do not have the statistical strength of quantitative metrics, such as the net present value and benefit-cost ratio, they nonetheless gave the team a good sense of how these selected projects contribute to the dissemination of sector-relevant knowledge and the advancement of science.

4. Results

The team evaluated each of the four selected projects on its economic contributions to the Canadian forest sector and its contributions to sector transformation and science since 2008.

Economic contributions to the Canadian forest sector

To measure the economic contributions of each of the selected projects, the team assessed the funding leverage ratio, the economic benefits estimated by industry and projections for the net present value and benefit-cost ratio.

Funding leverage ratio

Based on financial records at the Canadian Wood Fibre Centre (CWFC), the team calculated funding leverage ratios for the projects (Table 1).

One project in particular stands out. The Purpose grown fibre project has achieved a high funding leverage ratio of 4.29, i.e. for every dollar that the CWFC invested in the project, external partners invested $4.29. This high ratio illustrates the strategic importance of purpose grown fibre to the industry. While this ratio does not give the greatest rate of return on investment [see "Net present value and benefit-cost ratio," *below*), it is clear that industry, academia and government see a great deal of potential in this project.

The Enhanced forest inventory systems project had a funding leverage ratio of 0.17.

The Multi-varietal forestry and somatic embryogenesis (MVF/SE) and Hardwood optimization projects, on the other hand, had no sources of external funding. However, industry and provincial partners in these projects provided considerable in-kind contributions.

Table 1. Funding leverage ratio

Project	CWFC (millions of dollars)	External (millions of dollars, cash only)	Funding leverage ratio
Enhanced forest inventory systems (four components)	3.66	0.60	0.17
Multi-varietal forestry and somatic embryogenesis	0.73	0.00	0.00
Hardwood optimization	0.59	0.00	0.00
Purpose grown fibre	0.70	3.00	4.29
Overall	**5.68**	**3.60**	**0.63**

For an overall investment of $5.68 million from 2008/2009 to 2010/2011, the four projects had an average funding leverage ratio of 0.63. This means the CWFC attracted $0.63 of external funding for every $1.00 it invested. Because this ratio does not include in-kind contributions to these projects, leverage is underestimated.

Economic benefits

For three of the four selected CWFC projects, industry provided projections of the expected economic gains (benefit type) and cost savings (value) attributable to them. These projections are summarized in Table 2. While these numbers are not directly comparable across the projects, they provide a sense of the economic impact of each project.

Table 2. Economic benefits of selected CWFC projects

Project		Benefit type	Value	Location
Enhanced forest inventory systems	Newfoundland and Labrador	Cost reductions from species substitution from spruce to fir	$230,000 per year for every 1 percent substituted	Corner Brook Pulp and Paper mill
	Ontario	Cost reductions in road construction and wood delivery	$2.4 million per year	Romeo Malette Forest
	Quebec	Reduction in expenditures on ground plots	$3 million per year for 10 years	Quebec
	Alberta	Expected cost reductions in ground plots, and expected value gain through predictable wood delivery	To be determined	Hinton Forest Management Area
Multi-varietal forestry and somatic embryogenesis		Reduction in rotation length from 45 to 35 years	$40 million per year over the next cutting cycle	New Brunswick
Hardwood optimization		Volume gain from improved harvesting modelling	Immediate volume gain of 7 percent	Hautes-Laurentides, Quebec
Purpose grown fibre		Expected reductions in plantation establishment and recovery costs through refining practices and regimes	20–25 percent expected cost reductions in the future	National Network of SRWC* sites

* Short-rotation woody crops

The Enhanced forest inventory systems project focuses on cost reductions. In Newfoundland and Labrador, cost reductions are expected as a result of improvements in inventory information that reduces logging and transportation costs without affecting the quality of pulp. Forest managers can now replace low-density spruce further from the mill with high-density balsam fir harvested closer to the mill. For each 1 percent of spruce that the company can replace with balsam fir, the pulp mill would save $230,000. In Quebec, thanks to the K Nearest Neighbour (KNN) method developed by the CWFC, the Province is expected to save $3 million per year over the next 10 years by reducing the number of ground plots surveyed. The KNN statistical analysis allows the Province to achieve the same level of accuracy with a smaller number of ground plots. In Ontario, employing CWFC's enhanced forest inventory systems, forest companies expect to save $3–$5 per cubic metre by building fewer forest roads to extract their allowable annual cut. For the Romeo Malette Forest, in Timmins and licensed to Tembec Inc., this represents approximately $2.4 million in annual cost savings.

The Multi-varietal forestry and somatic embryogenesis (MVF/SE) project holds great promise. Researchers of the project confirm that SE seedlings in MVF plantations will see an impressive 25 percent volume gain or a shortened rotation cycle from 45 to 35 years.

The Hardwood optimization project has generated a volume gain of 7 percent in the Hautes-Laurentides region in Quebec. Because it developed optimized models for long-term harvesting and regeneration, the project is also projected to increase the residual value of the timber in the affected forest by 7 percent over the next 30 years. This project has demonstrated that it can improve the profitability of the forest industry of today without sacrificing from the forest industry of tomorrow.

The Purpose grown fibre project has built a best practices guide and established technically feasible processes. Over the next few years, the project will focus on profitability, and it expects cost reductions from present of 20–25 percent.

Net present value and benefit-cost ratio

To make reasonable projections about the economic impact of each project in this assessment, the team made some assumptions. The major assumptions for each of the four projects are documented and are available upon request.

Using the projected benefits from industry (listed in Table 2, above) and applying a series of conservative assumptions, the team estimated the net present value and benefit-cost ratio for the four projects. The assessment results are presented in Table 3.

Table 3. Net present value and benefit-cost ratio at a discount rate of 8 percent

Project	Time frame	Net present value (millions of dollars)	Benefit-cost ratio
Enhanced forest inventory systems (four components)	2008–2097	34.3	11.7
Multi-varietal forestry and somatic embryogenesis	2008–2082	16.9	3.8
Hardwood optimization	2008–2037	28.7	11.2
Purpose grown fibre	2008–2035	-3.3	0.4
Overall		***76.6***	***5.4***

Limiting the time frame to the next 10 years, until 2022, the team calculated the short-term economic impacts of the selected projects, as shown in Table 4.

Table 4. Net present value and benefit-cost ratio, 2008–2022

Project	Time frame	Net present value (millions of dollars)	Benefit-cost ratio
Enhanced forest inventory systems	2008–2022	20.1	7.3
Multi-varietal forestry and somatic embryogenesis	2008–2022	-4.6	0.0
Hardwood optimization	2008–2022	17.9	10.1
Purpose grown fibre	2008–2022	-4.2	0.0
Overall	***2008–2022***	***29.3***	***3.1***

The results suggest that the Enhanced forest inventory systems project will yield the highest returns of the four projects: its net present value is $34.3 million and the benefit-cost ratio is 11.7. This project has the highest returns because the cost reductions happen in the near future for industry. The Quebec component has a particularly quick turnaround because it involves improved statistical analysis of current inventory, rather than the building of a new inventory. As a result, the inventory project has a high positive net present value, even over the next decade.

The results for the MVF/SE project will take a long time because somatic embryogenesis is conducted at the seedling stage, to improve the genetic quality of the seedlings produced. Thus the forest industry must wait until these seedlings are planted and grown to maturity before it can reap the benefits from harvest. In the short term, this leads to a net present value of -$4.6 million and a benefit-cost ratio of 0.0 by 2022. Despite the long delay in reaping financial benefits, the project has a projected net present value of $16.9 million and a benefit-cost ratio of 3.8 by 2082.

The results for the Hardwood optimization project are also encouraging, with a net present value of $28.7 million and a benefit-cost ratio of 11.2. This project, which involves developing an optimization software program, generates benefits and cost reductions immediately because it can be applied to current forest inventory. The immediacy of benefits results in $17.9 million in net present value and a benefit-cost ratio of 10.1 by 2022.

The purpose grown fibre project is the only project with negative estimated results. It has a net present value of -$3.3 million and a benefit-cost ratio of 0.4. However, the financial profitability of the project would likely become more attractive if you considered benefits arising from the sale of project-related technologies, such as biobalers, and from the transfer of best practices and improved plantation processes. The significantly high funding leverage ratio (4.29, as shown in Table 1 on page 6) suggests there is a great deal of interest in the project's potential to add value to the Canadian forest sector.

The results suggest a possible challenge in getting forest companies to adopt the research conducted and integrate it into their operations. Several of the projects have a high upfront cost with the benefits expected far into the future. A clear example of this challenge is MVF/SE, which demands significant upfront investment by a company – without a return until the trees mature in 35 years. In the current economic environment, many companies are fighting for survival. It will be difficult to get them to make the required investment now, when they may not be around to reap the benefits for decades. Of the four projects assessed, Hardwood optimization may be the most attractive for private industry because the return on investment accumulates almost immediately. With Enhanced forest inventory systems, firms need wait only a few years for the forest inventory to be renewed before they start reaping significant benefits. MVF/SE and purpose grown fibre are less attractive to industry because companies must wait for their fibre investments to mature. Uptake from these projects will likely be restricted to firms that have the long-term financial stability to withstand the long wait to realize a return on investment. Likewise, Enhanced forest inventory systems and Hardwood optimization will likely be more applicable to the forest sector as a whole due to their quick returns on investments.

Contributions to sector transformation

During the process of collecting data for the assessment, the team received several testimonials about the contributions that the selected projects were making in transforming the forest industry from a high-volume to a high-value sector. Some of the testimonials are listed below. (Note: All testimonials cite facts and figures that were accurate on May 18, 2012.)

Enhanced forest inventory systems

"A good understanding of the fibre characteristics of our forest resource is key to allocating timber to its best end use. It will also be instrumental in future harvest planning and how wood is sorted at the stump for different products . . ."

– Tim Moulton
Corner Brook Pulp and Paper Limited

"We have taken an estimate of the value of enhanced inventory to Tembec using the Romeo Malette as an example. The value to us is primarily in improved road-building decisions, improved sawmill performance by avoiding poor wood and improved logging costs for the same reason. Based on this estimate:

- *we believe we save $400,000 annually on road-building costs by lowering costs approximately 5 percent*
- *through improved logging and sawmilling, we estimate another approximately 2 percent improvement, or approximately $2 million per year*

Therefore, rough estimates would indicate a value of $2.4 million to us."

– Al Thorne
Tembec Inc.

"With LiDAR-derived [LiDAR = light detection and ranging] outputs, we are able to accurately describe the wood size characteristics to the mill managers. Having diameter size class as well as diameter distributions by block are definitely allowing this to happen.

Our initial comparison of LiDAR-derived block level volume estimates is astounding. It appears that the LiDAR-estimated volumes per block are within 10 percent of what we realized from scaling. In the past, these data were not available, and it was pretty much a guessing game or the foresters would spend a lot of time doing field 'cruising' work."

– Chad St-Amand
Tembec Inc.

"When I'm asked questions about the status of our current growing stock, I reference our LiDAR-based volume projections because they are simply more accurate and precise than volumes projected from standard methods like traditional volume tables. An important new development is the ability to view the variability of volume within each stand. If utilized correctly, this information has the potential to streamline the planning process and significantly reduce costs. We are still in the initial development stages, but we are starting to use these data to enhance our forest inventory. We are convinced LiDAR-based layers will help us to ensure sustainability, generate substantial cost savings and improve our ability to capture higher value from our timber into the future."

– Glenn Buckmaster
Hinton Wood Products

Multi-varietal forestry and somatic embryogenesis

"J.D. Irving, Limited has strongly supported the CWFC [Canadian Wood Fibre Centre] Multi-varietal forestry / somatic embryogenesis project conducted by Dr. Yill-Sung Park et al. We have worked collaboratively with Dr. Park for many years and see strong benefits of multi-varietal forestry on part of our forest landscape.

Increased growth rates, tree quality and insect resistance based on the broad genetic variation in our tree populations can be efficiently propagated through somatic embryogenesis. This will have a positive impact on sustainable harvest levels while at the same time allowing for management for the broad range of ecological and societal values at the forest landscape level."

– Greg Adams
J.D. Irving, Limited

Hardwood optimization

"The timber cutting rules based on Biolley II, a new method of optimizing tree selection, that were adopted in the Upper Laurentians region have helped to increase the amount of harvested timber by 7% (0.75 m^3/hectare), while increasing the residual value of standing trees after 30 years by a similar amount, i.e., 7% or $353/hectare. These results have a significant impact on the profitability of hardwood sawmills.

This project was carried out in close collaboration with members of Signature Bois Laurentides through a partnership with the Canadian Wood Fibre Centre. It is a concrete example of an effective joint project producing tangible results for the industry."

– Denise Julien, Director General
Signature Bois Laurentides

Purpose grown fibre

"Research conducted by the Canadian Wood Fibre Centre (CWFC) has provided Alberta-Pacific Forest Industries Inc. (Al-Pac) with the opportunity to see first-hand some of the current options, and future possibilities, for short-rotation woody crops (SRWCs) in our region.

Al-Pac's operational Poplar Farm Program has benefited from the CWFC's interest in SRWC and its demonstration of alternative best practices for plantation design, site preparation and maintenance. The Biobaler project has provided valuable data that Al-Pac will use when developing a long-term biomass supply plan, to meet increasing feedstock requirements resulting from increased power production, and other projects currently under consideration. Overall, the CWFC's research to develop and demonstrate new technologies and possibilities for SRWC has resulted in tangible benefits to our company."

– Randy McNamara
Alberta Pacific Forest Industries Inc.

These testimonials demonstrate that the selected CWFC projects are making a significant contribution to forest sector transformation.

Contributions to science and knowledge exchange

One important benefit of the CWFC's research is the opportunity to not only transform the Canadian forest industry but also contribute scientifically to the body of knowledge in relevant forest science disciplines.

As part of the assessment, the team asked project leaders to provide a list of publications resulting from the research. The team also asked them for the number of presentations on the projects given to professionals and industry partners external to the CWFC and FPInnovations over three years, 2008–2011. With this information and the academic research tool Scopus, the team evaluated the publications to find out how many times other academic papers cited them. The results of this evaluation are presented in Table 5.

Enhanced forest inventory systems and Purpose grown fibre have produced the most publications with 27 and 26, respectively. However, the MVF/SE project has attracted more attention in the academic community, as suggested by the 29 citations it has spawned from only 17 publications. Hardwood optimization had zero citations from five publications, but it is still early in the project's development.

Table 5. Contributions of the CWFC's selected projects to science

Project	Publications (articles, reports, etc.)	Citations (Scopus)	Presentations (conferences and industry events)
Enhanced forest inventory systems	27	10	114
Multi-varietal forestry and somatic embryogenesis	17	29	16
Hardwood optimization	5	0	8
Purpose grown fibre	26	27	79
Total	***75***	***66***	***217***

Enhanced forest inventory systems and Purpose grown fibre, however, lead the way with 114 and 79 external presentations respectively. MVF/SE and Hardwood optimization follow with 16 and 8 respectively. The apparent inverse relationship between citations and presentations may suggest the state of development and nature of the projects. The work in Enhanced forest inventory and Purpose grown fibre is ready to be implemented and thus is looking for industry uptake and adoption – hence the lower rate of citations and the higher rate of presentations. MVF/SE, on the other hand, is focused on developing new science, rather than uptake by industry. This may suggest why MVF/SE has a higher number of citations and a relatively small number of presentations. If this relationship holds, you will see more presentations on MVF/SE and Hardwood optimization as their research matures.

5. Conclusion

This impact assessment has shown that the four selected projects have delivered or are expected to deliver significant impact to the forest sector. Overall, the four projects have leveraged $3.6 million from federal, provincial and industry partners. The projects have started to generate considerable economic benefits to the forest sector and are playing a pivotal role in delivering value to the sector through close collaborations with FPInnovations, industry, provinces and universities.

Over the next 10 years, these projects are projected to generate $29.3 million in net present value with a benefit-cost ratio of 3.1. Over the long term, benefits are expected to grow, with the net present value rising to an estimated $76.6 million and the benefit-cost ratio expanding to 5.4 by 2097.

Industry testimonials revealed that these projects have contributed significantly to sector transformation. Furthermore, with 75 publications, 66 citations and 217 presentations, these projects have made a significant contribution to science and knowledge exchange.

Through their success, the projects are demonstrating the financial viability of several new technologies, models and processes that will encourage their adoption by industry. The projects also showcase the Canadian Wood Fibre Centre as a leader in creating sector-relevant knowledge products.

Acknowledgments

This impact assessment would not have been possible without the assistance provided by many people over the past several months. First, from the Canadian Wood Fibre Centre, we wish to acknowledge George Bruemmer, Denis Ouellet and Raoul Wiart for their guidance and support. We thank the component leaders of the selected projects for their collaboration, specifically Joan Luther, Doug Pitt, Chhun-Huor Ung, Jim Stewart and Roger Whitehead of the Enhanced forest inventory systems project; Yill-Sung Park of the Multi-varietal forestry and somatic embryogenesis project; Jean-Martin Lussier of the Hardwood optimization project; and Derek Sidders and Tim Keddy of the Purpose grown fibre project. We would also like to thank Karen Bryson for her able assistance in finding and verifying the relevant funding information over the last several years. We acknowledge Ann Marie Hussar-Lucas for her many valuable comments and suggestions throughout the assessment process.

We thank Darcie Booth, Glenn Hargrove, Mark Boyland and Zhichao Derek Wang from the Policy, Economics and Industry Branch, Canadian Forest Service, for their guidance and advice on assessing the economic impact of programs. We express our appreciation to Gerry Godsoe, Cairine Chisamore, Marc Bennett and Nicholas Kowbel of Natural Resources Canada's Evaluation Group for their expertise and assistance in helping us develop a rigorous assessment framework.

We thank Jean-Pierre Martel and Chris Gaston of FPInnovations for their collaboration in this assessment.

Last but not least, we express deep appreciation to the following industry partners who provided testimonials on the impact of the CWFC's research: Al Thorne, Chad St-Amand, Denise Julien, Glenn Buckmaster, Greg Adams, Randy McNamara and Tim Moulton.

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