in cooperation with Fraunhofer

Forest-Based Composites

Opportunity Roadmap for Ontario

Prepared in collaboration with Fraunhofer Innovation Platform for Composites Research at Western University

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Better Together

Biocomposites pose exciting opportunities for Ontario's forest industry.

As technologies advance and applications expand, demand for wood composite products in Ontario is growing — and this growth is forecasted to continue over the next five years and beyond.

Technological innovations, shortages of and increased costs for traditional materials, and a growing demand for recyclable and biodegradable materials are some of the factors fuelling this demand. Over the next five years, the Ontario biocomposite market is conservatively valued at $127 million — and growing.

Ontario is home to a wealth of industry and raw material that hold great potential for developing and expanding the forest-based biocomposite industry. And Ontario's forestry industry is well positioned to lead in — and benefit from — this development and expansion. The Centre for Research and Innovation in Bio-Ecology (CRIBE) and NextFor are excited to support the province's forestry sector in the biocomposite industry and marketplace, creating a more sustainable and profitable future.

This report provides an introduction to biocomposites, in particular the forest-based materials found in Ontario, including some of their benefits and applications. It provides a snapshot of the current and projected market for biocomposites in Ontario, with the automotive sector as a case study. And it outlines some of the challenges and ways forward for Ontario's biocomposite industry.

What Are Biocomposites?

A composite is any material that is made by combining two or more source, or constituent, materials that have different characteristics. When these source materials are combined to create a composite, they yield a new material with improved performance over the individual constituent materials.

For example, concrete is a composite of loose stones held together with a of cement. Reinforced concrete is a composite of concrete plus steel bars, which add strength to the final material.

All composites contain both matrix and reinforcement constituent materials. The matrix (or binder) surrounds and holds together the reinforcement, which in turn strengthens the matrix. For example, the loose stones in concrete are the reinforcement, while the matrix is cement. Together, the two are stronger and more versatile than each on its own.

A biocomposite is simply a composite material where at least one of the source materials is naturally derived. Forest-based biocomposite materials include:

› **Cellulose fibres** derived from wood or other plants, including flax, hemp, sisal, or jute.

› **Nanocelluloses**: Light solid substances obtained from plant matter including crystalline nano-cellulose (CNCs) and nano-fibrillated celluloses (NFCs). Though nanocelluloses require a high amount of processing, they offer very superior mechanical properties.

› **Wood flour**, a finely powdered wood or sawdust that can have superior properties – for example, a lower specific gravity (less likelihood to swell or shrink) or greater stiffness – than conventional fillers. Wood flour is very abundant and has the added benefit of potentially being sourced from (and thus diverting) waste streams like sawdust.

› **Wood fibres and chips**, which require minimal processing and are abundantly used in fibre-board and lumber production.

› **Lignin**, a complex organic polymer that comprises roughly a quarter of a tree's weight. Once processed and isolated, lignin can be used in biocomposites for fire retardancy and in the manufacture of adhesives.

› **Biochar**, a charcoal produced by the heating of organic material, such as biomass, in the absence of oxygen. Biochar has a variety of composite properties, and can be integrated into new organic systems for farming, building, clothing, and a range of consumer products.

Benefits of Biocomposites

Wood composites have several benefits, including:

› **Performance improvements**: Composite products can be more lightweight, durable, low maintenance, fire retardant, or corrosion resistant than conventional products. Because full biocomposite products decompose at much faster rates than synthetic products, they may not need to be designed for recycling purposes.[1][2]

› **Cost reduction**: Biocomposite products can replace expensive hydrocarbon polymers with less expensive wood derivatives such as residuals and waste-wood products (for example, sawdust).[3][4]

› **Environmental stability**: Using natural fibres in composite products can reduce energy consumption, reliance on hydrocarbons, and landfill waste.[5][6][7][8][9][10] Adding natural fibres to composites could address some of the current technical and economic limitations of recycling composites, which are currently recycled at much lower rates than other prominent materials.

› **Innovation**: Biocomposite products have great design flexibility and are an excellent opportunity for Canadian manufacturers to become industry leaders in the bio-economy.

Biocomposite Applications

Forest-based composites can be used in a wide variety of applications.

› **Conventional applications** include decking, filler material, composite lumber, and particleboard.

› **Emerging applications** include fire-retardant, automotive, and construction products as well as coating materials.

› **Future applications** include the manufacture of carbon fibre from kraft lignin and biochemicals from woody cellulose.[11]

› **Desired applications** of forest-based biocomposites include renewable single-use, returnable, and compostable packaging and products.

Biomaterials can be used in composites in two primary ways: to create polymers or as reinforcement and filler material. In the next five years, we expect to see growth particularly in non-structural applications of composite processing technologies, in particular in:

› **Injection moulding**: where wood fibres, pulp, or biochar can be used either as a filler or a reinforcement and naturally derived thermoplastic polymers can be used as a matrix.

› **Compression moulding**: where wood fibres, pulp, and biochar can be used as a filler or reinforcement and a certain portion of the polymer can be bio-derived.

Over the next five years, the uses for and applications of forest-based biocomposite products will continue to grow.

Market Review

What is the potential value of the Ontario biocomposite market?

The US composite end-products market was valued at $26.7 billion in 2019, and is forecasted to grow over the next five years to $33.4 billion. Due to Canadian and US trade agreements, this is a significant market that Canada can support.

According to the American Composites Manufacturers Association, Canada's composite industry is an estimated 10% of the US composite end products market, valued at $2.67 billion in 2019. Ontario holds approximately 47.5% of the value of Canada's composite product market, which totaled $1.27 billion in 2019 (**Table 1**). Replacing just 10% of traditional feedstock material with bio-derived constituents, therefore, could be a **$127 million market in Ontario.**

Composite Market Sectors

Composites are used in a variety of different markets, including aerospace, transportation (including buses, commercial vehicles, coaches), sporting and consumer goods, industrial applications (oil/gas, water/wastewater infrastructure), construction (paneling, bathrooms, shower stalls, doors, windows), and marine.

***Table 1**: Composite Market Value by Application*

	Market Size (%)*	Ontario % of that within Canada (approx.)
Aerospace	23%	9%
Transportation	22%	17%
Building & Construction	15%	6%
Wind	12%	2%
Electrical & Electronics	12%	8%
Consumer Goods	9%	5%
Marine	5%	0%
Pipe & Tank	2%	0.5%
	100%	47.5%
Approx. total value in Canada and Ontario	$2.67 billion	$1.27 billion

*Overview of worldwide composite industry, 2010-2015, JEC Composites [12]

The composites market experienced a strong post-pandemic rebound in 2021 for almost all applications except aerospace, which is expected to rebound in 2022 and beyond (**Figure 1**). Transportation and construction lead the way in terms of volume of composite material used and are forecasted to continue to do so until 2025. Therefore, these two industries have strong potential for higher uptake of biocomposite materials in Ontario.

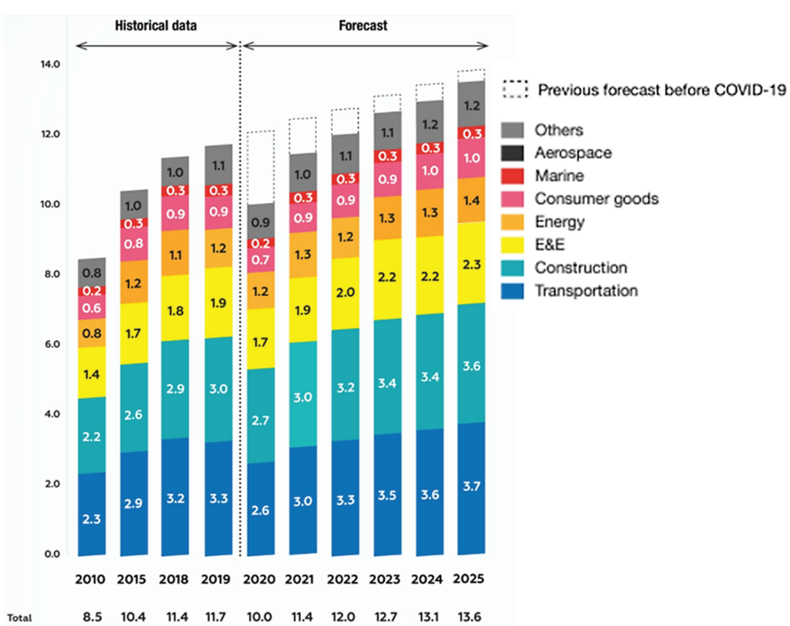

***Figure 1**: Global composites market by application (in Mt)*

Glass-fibre and carbon-fibre composites dominate the composites market, respectively.[13]

The main consumers of glass fibre in the US are the transportation, construction, and pipe and tank segment markets (69% of total usage). Global glass fibre capacity was 12.8 billion pounds in 2019 and is currently estimated at 91% utilization.[13]

In 2019, demand for carbon fibre globally totaled approximately 100,000 metric tons. The market continues to grow at 10–12% per year, fueled by incremental volume gains in carbon fibre use in aerospace and wind turbine blades. Over the next five years, a 15–60% shortage of virgin carbon fibre is forecasted, **creating a significant market opportunity for innovative carbon-fibre manufacturing processes as well as opportunity for recycled carbon fibre products (Figure 2)**.

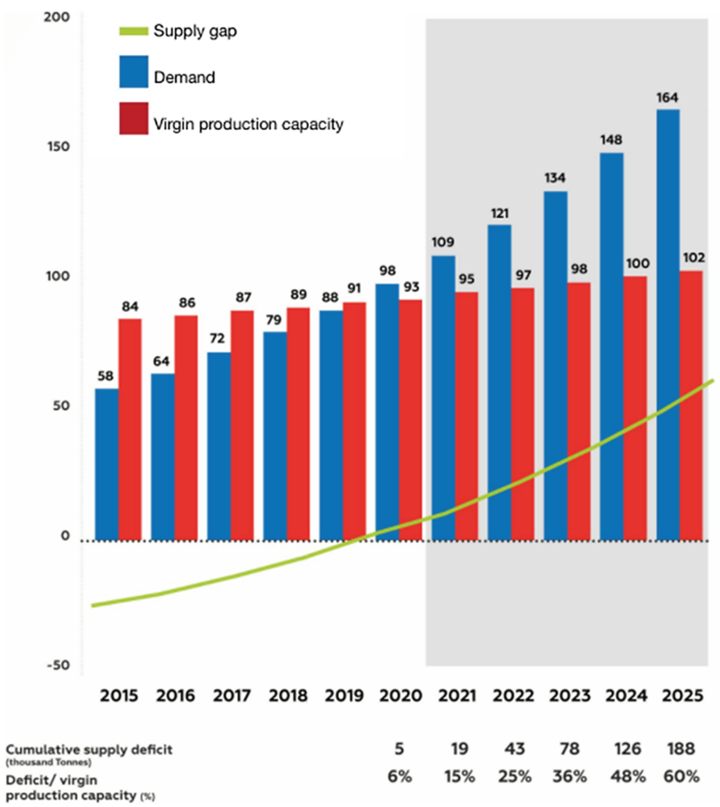

Figure 2: *Global carbon fibre capacity (thousand Tonnes)*[13]

Snapshot: Biocomposites in the Automotive Industry

As noted above, the automotive and transportation industries are major users and producers of biocomposites.

For example, General Motors has announced that, by 2030, it aims to make its vehicles with at least 50% sustainable content.[14] These materials may range from bio-based renewables to highly recyclable resources. As GM seeks innovations and improvements to decrease the environmental impacts of their vehicles, the use of lightweight, bio-based, and recycled materials will help eliminate the use of virgin plastics as well as to incorporate circular design practices.[14]

Ford Motor Company also aspires to achieve carbon neutrality, and to use only recycled and renewable plastics in their vehicles globally by 2050. Since 2000, Ford has used plant-based materials in their production vehicles and has set an interim goal of 20% sustainable materials by 2025. Ford has found that natural fibre-reinforced materials improve fuel economy because they weigh less. In 2018, Ford introduced an award-winning wood-based composite into the consoles of the Lincoln Continental and is currently testing whether it can be used in other new applications.[15]

Both GM and Ford are strongly focused on reducing the impact of packaging. Ford's packaging guidelines for North America and Asia Pacific require their suppliers' packaging to have a least a neutral (if not positive) environmental footprint, achieved using 100% renewable or recyclable materials.[15]

Biomaterials are being tested and used in numerous other automotive components:

› **Flax, sisal, and hemp** are used in door interiors, seatback linings, package shelves, and floor panels.

› **Coconut fibre and bio-based foams** have been used to make seat bottoms, back cushions, and head restraints.

› **Cotton and other natural fibres** have been shown to offer superior soundproofing properties and are used in interior components.

› **Abaca fibre** has been used to make underbody panels.

Car manufacturers have also attempted to use natural fibre composites in structural applications. Though exterior, under-the-hood, and structural applications are more limited and often still in various stages of research, they represent some of the high-value applications of biomaterials and could potentially become an important part of the market. Biocomposites have also been used in a few exterior or under-the-hood applications:

› **Toyota** has used natural fibres in its exterior tire covers and under-the-hood radiator end tanks.

› **Rieter Automotive** has manufactured underbody panels for Mercedes using abaca fibres to replace glass reinforcement.

› **General Motors** has used wood fibre in the Cadillac DTS's seatbacks and in the cargo area floor of the Chevrolet Trailblazer and GMC Envoy.

› **Honda** uses wood fibre in various floor area parts.[16]

Table 2 lists list some vehicles that contain bio-based automotive components.[16]

***Table 2**: Composite Market Value by Application*

Model(s)	Feedstock	Material	Application
Cadillac DeVille	Wood	Polypropylene	Seatbacks
Chevrolet Impala	Flax	Polypropylene	Trim, rear shelf
Ford Flex	Wheat straw	Polypropylene	Interior storage bins
Ford Focus BEV	Coconut	Polypropylene	Loadfloor
Ford vehicles (Multiple)	Soy	Polyurethane	Foam seating, headrests, headliner
GMC Terrain	Cotton, kenaf	Polyester	Acoustic insulator, ceiling liner
Honda Pilot	Wood	N/A	Floor area parts
Lexus CT200h	Bamboo, corn	Polyethylene terephthalate, Sorona	Luggage-compartment, speakers, floor mats
Mazda 5 Hydrogen RE Hybrid	Corn	Polylactic acid	Console, seat fabric
Mercedes-Benz A-Class	Abaca/banana, flax, other natural fibers	Composite material	Underbody panels, seatbacks, spare tire cover
Mercedes-Benz C- and -A-Class	Flax	Polyethylene	Engine and transmission cover, underbody panels
Toyota Prius	Corn	Sorona EP	Instrument-panel, airconditioning vent
Toyota Raum	Kenaf, starch	Composite material	Floor mats, spare tire cover

Composite Recycling

Globally, composite materials are recycled at a much lower rate than other prominent materials. Adding natural fibres to composites could address some of the technical and economic limitations of recycling — thus potentially driving demand for biocomposites. This growth may also be driven by a shortage of virgin materials, price competitiveness, and environmental sustainability goals (**Figure 3**).

Naturally derived thermoplastic resins and carbon fibres are well suited for recycling, while thermoset resins and glass fibres can be recycled with some limits (**Figure 4**). For example, adding lignin to phenolic and epoxy resins can improve their life cycle, as well as qualities like fire retardancy.

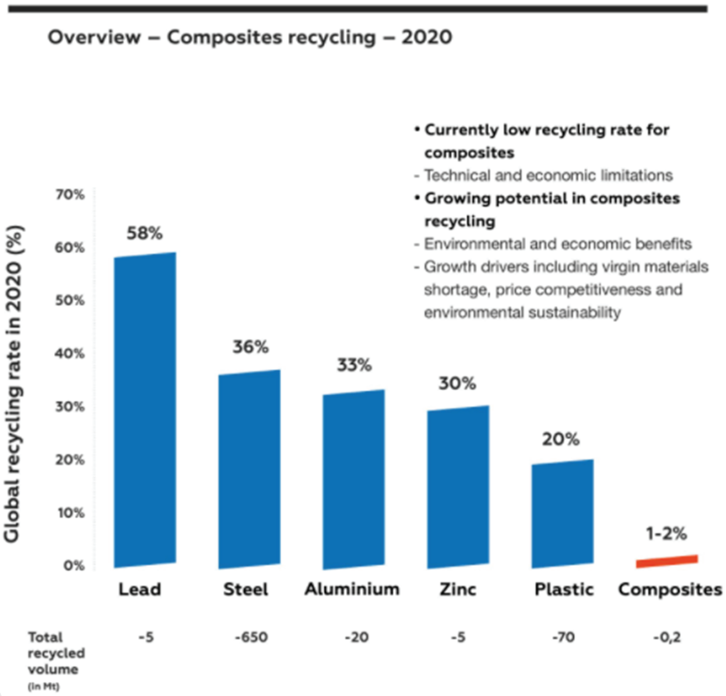

Figure 3: *Composite recycling 2020* [13]

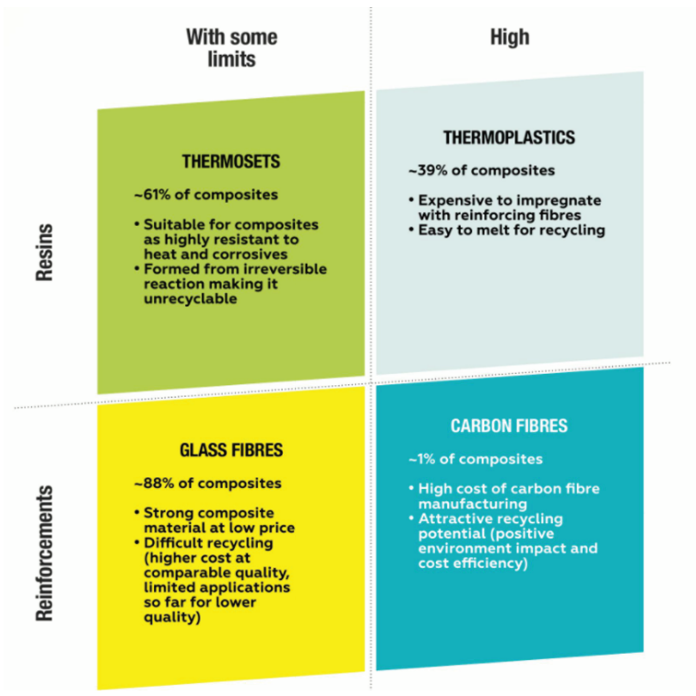

Figure 4: *Composite recycling potential* [13]

Biocomposites: Challenges & Ways Forward

Challenges

Multiple challenges prevent wood fibre from being more used in the manufacturing of composites. These challenges include:

› **Global market variation**: Global markets have matured differently due to variation in access to natural resources, different geopolitical drivers, and different consumer bases. These factors make it difficult to replicate successful bio-economy models from one region to another.

› **Limited value chains**: Factors such as the 2008 North American financial crisis and oil fracking have stalled sustainable and ecological efforts, including further development of resource supply chains and value chains for biocomposites.[18] Currently, bio-based materials have difficulty competing against more developed supply chains with access to stable markets.[19] Finally, a lack of market awareness can make it difficult for potential material manufacturers to reach end users.

› **Manufacturing limitations**: The hydrophilic (water-attracting) nature of wood fillers poses challenges regarding the water-absorption capacity of certain composites. The use of less processed materials like wood flour and fibres in composites is limited, as these materials experience thermal degradation at higher temperatures.[20] The extensive processing required for high-performance resources like lignin, cellulose, and bioplastics is another notable limitation. Finally, certain wood-plastic composites – like synthetic polymers reinforced with natural fibres – have limited end-of-life renewability.[21]

› **Cost**: Material manufacturers are reluctant to invest in composite materials supply chains without a profitable end-user industry. Conversely, the end-user industry doesn't want to invest in the initial high costs related to the adoption of new materials and technology.

Ways Forward

Three important strategies or considerations to overcoming the above obstacles include:

› **Part design**: Existing manufacturing processes are often used even after new materials are adopted, in order to save costs. Unfortunately, existing processes may not be the best choice for new materials, including biocomposites, and can lead to subpar performance for the intended part material. Design, therefore, should be optimized with every change in material. This is an important and often overlooked aspect of manufacturing.

› **Compatibility of composites**: To facilitate easy adoption of alternative, bio-based materials, the composite feedback materials must be similar in form and properties to conventional raw materials. To produce quality end products, bio-based material manufacturers must understand and take into account raw material and downstream processing requirements. Feedback from end users can help be helpful here.

› **Cost**: With higher demand, production costs could decrease (economies of scale). With higher demand, multiple suppliers can emerge resulting in price competition. Feedstock and material can be grown locally in Ontario, resulting in reduced transportation costs.

The Opportunities

Products

resins, carbon-fibre

Industries

automotive, construction

Challenges to Overcome

Integrating forest-based Biocomposites into the existing manufacturing processes, ensuring the forest-based Biocomposites are cost and performance competitive

Conclusions

The composites market share is expected to grow in the next five years, especially within the transportation and construction markets. Ontario is well positioned to become a leader and driver in this emerging industry.

Automotive manufactures have expressed their dedication to using sustainable materials in their vehicles. However, for these materials to be readily implemented, they need to meet technological and economic specifications. While plant-based fibers have replaced their synthetic counterparts in many automotive applications, wood fibre still appears to be underutilized, due to current structural limitations imposed by its fibre orientation. More research and development into the potentials of forest-based biomaterials – including lignin and biochar – in the automotive industry will be an important driver for the biocomposite industry.

As multiple suppliers emerge, larger application volumes would allow for price competition. Higher demand for biomaterials would allow producers to further reach economies of scale, thus lowering production costs.

In addition to economic considerations, biomaterials face specific limitations in technical properties such as rigidity, heat and chemical resistance, and water absorption. Additional research and development work is needed to address these challenges.

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