CIRCULAR ECONOMY GLOBAL SECTOR BEST PRACTICES SERIES

BACKGROUND MATERIALS FOR CIRCULAR ECONOMY SECTORAL ROADMAPS

BIOECONOMY
JULY 2021

Smart Prosperity Institute

About Smart Prosperity Institute

Smart Prosperity Institute is a national research network and policy think tank based at the University of Ottawa. We deliver world-class research and work with public and private partners – all to advance practical policies and market solutions for a stronger, cleaner economy.
institute.smartprosperity.ca

Contributors: Catherine Christofferson, Ghita Lkhoyaali, Natalie Sutt-Wiebe
Editors: Stephanie Cairns, Sonia Cyrus Patel

The authors would like to thank two anonymous reviewers for providing valuable feedback on the report.

Any errors or omissions remain the sole responsibility of the authors.

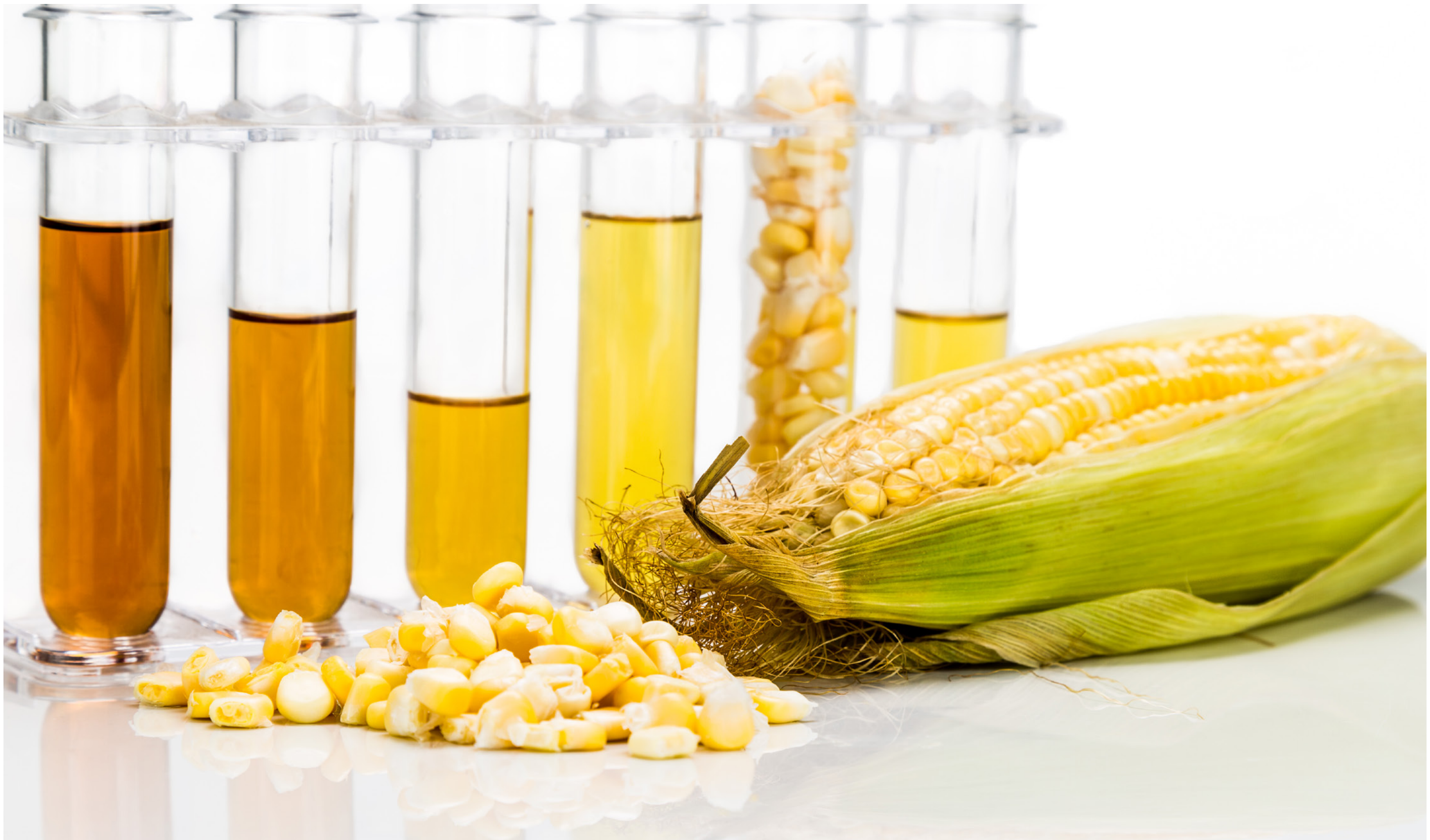
ABOUT THE CIRCULAR ECONOMY GLOBAL SECTOR BEST PRACTICES

This publication series aims to provide a starting point in the journey towards a circular economy. These materials are intended to be used as a background resource and rich reference source for future efforts to engage Canadian firms and innovators in this transition, and to build sector-based roadmaps to a circular economy in Canada.

Twelve core strategies for *rethinking* resource consumption and *optimizing* the use of resources to transition to a circular economy are detailed in the Introduction to the series. Real-world practices supporting these strategies are being catalogued for seven sectors, each profiled in its own document:

1. Minerals and Metals
2. Electronics
3. Agri-food
4. Construction
5. Plastics
6. Bioeconomy
7. Automotive

CONTENTS



BIOECONOMY

6.1. Introduction to Bioeconomy

The *Circular Economy Global Sector Best Practices* series aims to provide a starting point, background resource, and rich reference source for future efforts to engage Canadian firms and innovators in the journey towards a circular economy, and to build sector-based roadmaps to a circular economy in Canada.

This report profiles the bioeconomy. It begins with an outline of the economic and environmental importance of the bioeconomy, including data on economic potential of waste resources where available. It then profiles identified circular practices, organized according to a common framework for circular economy approaches and strategies developed in 2018 by L'Institut EDDEC in collaboration with RECYC-QUÉBEC, and described in the Introduction to this report series. The profile begins with a high-level summary of the circular practices found, followed by a snapshot of these practices in application, and then moves on to list applied, real world examples for each of these strategies and practices. It concludes with a list of additional resources for researchers, practitioners, and policy-makers: selected global public policies and an annotated bibliography of key reports specific to the bioeconomy.

6.2. Background

The bioeconomy encompasses all industries that deal with biological materials at different stages of the value chain: for example, agriculture, forestry, and fishing at the primary stage; food processing, textile manufacturing, and biotechnology in the processing stage; and retail and resource management in the consumption stage. Together they generate around 17% of global GDP annually, a value of about C$16.7 trillion.[1] The bioeconomy produces food, materials, and energy using renewable biological resources – also called biomass. Sources of biomass typically include crops, forests, fish, animals, micro-organisms,[2] and industrial and municipal waste.[3] The world currently harvests around 13 billion tonnes of biomass for food, energy, and materials every year.[4] Around 82% of the biomass extracted globally is used for food production, including for animal feed, followed by bioenergy (11%) and materials (7%).[5] Further, the volume of biomass flowing through the global economy is expected to grow, in large part due to the expected rise of 55% in global food demand by 2050.[6]

The bioeconomy plays an important role in the circular economy. Bio-based materials have the potential to replace fossil fuel-based products and reduce greenhouse gas emissions. For instance, bio-based plastics, which are forecasted to comprise 40% of the global plastics market by 2030,[7] have the potential to be carbon-negative.[8] Some have even been shown to have a negative global warming potential of -2.2 kilogram CO_2 equivalent per kilogram of bio-based polyethylene produced (compared to 1.8 kilogram CO2e per kilogram of fossil-based polyethylene produced).[9] The bioeconomy also finds value in what has traditionally been considered biological waste. For example, recovering renewable bio-gas from urban solid waste—a waste stream expected to reach 2.2 billion tonnes per year globally by 2025[10]—can offset operational costs, generate revenue, and decrease greenhouse gas emissions.[11] One study estimates that processing residual organic waste in Amsterdam has the potential to create over C$223 million in added value and reduce CO_2e emissions by 600,000 tonnes per year.[12]

As the country with the most biomass per capita in the world,[13] Canada is well-positioned to take advantage of opportunities created by the bioeconomy, across economic sectors. In 2015 forestry was the largest source of biomass in Canada, producing 12.3 million metric tonnes of biomass, of which 8.5 million metric tonnes came from processing residue from pulp-and-paper mills.[14] With 9% of global forests, Canada's forestry bioeconomy has high-growth potential, in both urban and rural areas.[15] The agricultural sector was the second largest source of biomass, producing 8.8 million metric tonnes produced, primarily from grains and oilseeds.[16] Recognizing this economic opportunity, the Canadian federal government announced a C$22.1 million joint-investment, in collaboration with industry, in bioproducts in the agricultural sector.[17] Canada also represents 6.5% of global bioenergy potential.[18] Replacing just 5% of its gas supply with renewable gases could reduce GHG emissions by 10-14 megatonnes per year.[19]

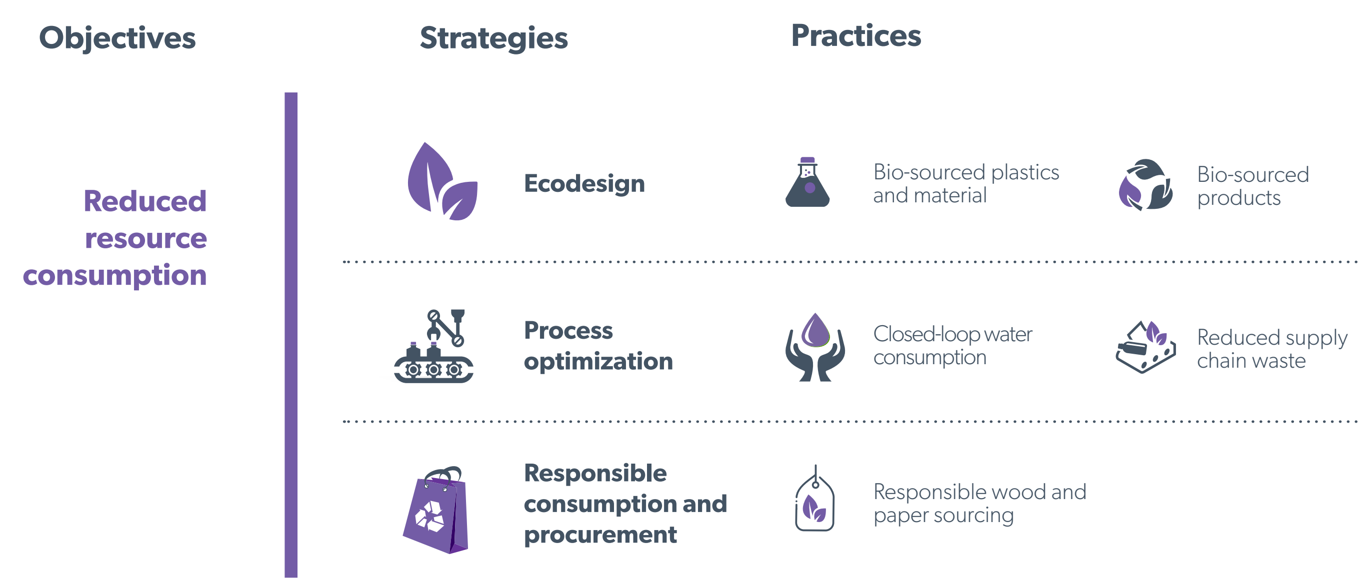
The bioeconomy has the potential to deliver significant environmental and economic benefits. According to a survey by Statistics Canada, in 2015 the Canadian bioeconomy purchased C$2.3 billion worth of biomass inputs, predominantly forestry and agricultural biomass.[20] The same year, bioproducts including biofuels, bioenergy, biochemicals, and biomaterials, accounted for an estimated C$4.3 billion worth of sales.[21] Bioproduct co-products, like distillers' dry grains, carbon dioxide, and glycerine, produced additional sales of C$441.5 million.[22]

Canada's traditional bioeconomy, forestry and agriculture, have more than 900 processing companies, employ 2 million people, and generate C$300 billion in sales per year.[23] The estimated 190 firms operating in the Canadian bioproducts sector further employ over 5600 people.[24]

6.3. Overview of Circular Economy Practices in the Bioeconomy

Bioeconomy companies have been investing in research and implementation of various practices that can support a circular economy. Figure 6-1 summarizes the specific practices employed in the bioeconomy, organized according to the four objectives for a circular economy and twelve core supporting strategies described in the Introduction to this publication series. Some of these practices are highlighted below. This is followed by a listing of applied examples of these strategies and practices, with hyperlinks to additional information. Canadian examples are denoted by a red superscript (CDN).

Figure 6-1. Circular economy objectives, strategies, and practices found in the bioeconomy



Category	Practice	Examples	
Intensified product use	Sharing economy	None found	
	Short-term renting	None found	
Extending life of products and components	Maintenance and repair	None found	
	Donating and reselling	Re-appropriation of food by-products, surplus, and waste	
	Refurbishing	Wood-based furniture refurbishment	
	Performance economy	None found	
Giving resources new life	Industrial ecology	Valorization of organic by-products and waste	
	Recycling and composting	Paper recycling	Wood recycling
	Energy recovery	Bioenergy production	

Objectives, Strategies and Practices

In the bioeconomy, many circular practices focus on **REDUCED** resource consumption. **Ecodesign** applications in the bioeconomy include **bio-sourcing plastics and materials** which substitute petroleum-based products with plant-derived materials. These often perform better than the fossil fuel-based products they replace and can be recycled or composted if appropriate sorting and processing facilities are available. **Bio-based products** are also increasingly being used in product packaging, thereby mitigating the use-cost of single-use packaging. Other applications include bio-based products like coffee pods, paint resins, and feed additive for ruminants, as well as bio-based chemicals. **Process optimization** approaches include developing techniques to improve manufacturing processes of bio-based materials and products. Under **responsible consumption and procurement**, wood traceability programs ensure that timber is being used at the highest environmental and social standard.

Due to the perishable nature of many of the products in the bioeconomy, there are limited ways to **OPTIMIZE** resource use. This is, however, possible for a few products. **Refurbishment** is one strategy to **extend the life of products and their components**. For example, Ikea's takeback program allows customers to return used furniture, which it then refurbishes and resells.

Finally, there are a number of strategies that that can **give new life to resources** in the bioeconomy. **Industrial ecology f**or instance has a diversity of applications, including the valorization of organic by-products and waste. Organizations like the French company Veolia collect biowaste from food and beverage companies, which can then be transformed into renewable gas, organic fertilizer, or animal feed. **Recycling and composting r**epresent another avenue to give resources new life, as with the Sustana Group in the US, which collects 2.2 million pounds daily of FSC Certified recycled fibre. There is also much being done in the realm of **energy recovery** in the bioeconomy. Research is underway to better understand how plant-based sources, such as grass clippings, can be used to supplement or supplant fossil fuel-based energy in uses such as an engine fuel source or fuel additive.

The Bazancourt-Pomacle Biorefinery

Located a few kilometers outside of the city of Reims in France, the Bazancourt-Pomacle biorefinery is a joint venture between the two municipalities of Bazancourt and Pomace. The biorefinery is one of the largest in the world, employing 1,200 people directly in the Reims region, and another 1,000 indirectly.

The biorefinery creates environmentally-friendly economic development from the agricultural resources of the territory. Every year it transforms 4 million tonnes of biomass into sugar, glucose, starch, food, pharmaceutical alcohol, and cosmetic active ingredients, generating 800 million euros of value. [25, 26, 27, 28]

LOOP: Creating new products from food waste

Loop is a food and beverage company founded on circular economy strategies. It aims to reduce food waste by transforming rejected food into juice, alcoholic beverages, and soaps. The company collects food sector materials that would otherwise be discarded, directly from food retailers and wholesalers. To generate further value, the by-product pulp is then given to a start-up company that turns it into high-fiber dog treats.

To date LOOP has rescued 5,388 tons of fruits and vegetables, avoided 4,351 tons of GHG emissions and saved 415,138,995 of water. [31]

Sustana Group: Integrating circular principles in pulp and paper manufacturing

Located in Wisconsin and Québec, the Sustana Group is a North American pulp and paper company manufacturing sustainable fibers as well as recycled paper. The group applies circular economy principles in the manufacturing processes through the following processes: [29, 30]

- Responsible sourcing: In 1989, Sustana's Breakey Fibers mill began recycling wastepaper and producing recycled pulp for paper production. To this date, Sustana Group focuses on using recycled paper as much as possible in its operations, as well as using and manufacturing post-consumer recycled fibers. Sustana's facilities process 2.2 million pounds of wastepaper every day.
- Energy efficiency: The main energy source in Sustana's paper mill in Canada is biogas. It is transported in a dedicated 8-mile pipeline from a nearby landfill to fulfill 93% of the mill's needs, reducing annual carbon dioxide emissions by 70,000 tons – equivalent to 23,400 compact cars.
- Water conservation and wastewater treatment technology: In the Fox River Fiber facility in Wisconsin, cold water is diverted from pipes near the end of the production line back to the beginning of the process and to the plant's cold-water supply, reducing the use of both water and gas.
- Product innovation: The group conducts a Life Cycle Assessment (LCA) to evaluate the life cycle potential environmental impacts of EnviroLife™ food-grade fiber and Rolland Enviro™ paper, from raw material extraction and processing to manufacturing, distribution, and end-of-life. The LCA relates information about the product's contribution to climate change, its water consumption, and its contribution to freshwater eutrophication.
- By-products recycling: Sustana Group diverts process by-products from landfill. At Fox River Fiber, 77% of process by-products are used for animal bedding. And at Breakey Fibers, 100% of process by-products are used for land farming.
-

Specific Examples: Objective 1, Reduced Resource Consumption

Ecodesign

Bio-sourced plastics and material

- BASF[32,33] produces a certified compostable polymer, ecovio®, containing bio-based content, for use in a variety of applications from organic waste bags to agricultural films. BASF's ecoflex® polymer is biodegradable and certified compostable.

- Avantium[34] is commercializing plant-based polymers like PEF (polyethylene furanoate) packaging that can replace PET, glass, or aluminum. The product is a 100% recyclable plastic with better performance than petroleum-based plastics.

- Mitsubishi Chemical[35,36] produces BioPBS™ plastic, derived from renewable resources like sugarcane, cassava, and corn. BioPBS™ can be composted in 30°C soil in open-air landfills. Mitsubishi Chemical's bio-based plastic DURABIO™ is derived primarily from plant-based isosorbide.

- Bosk Bioproducts Inc[37][CDN] is developing the REGEN™ resins, a bioplastic made from paper mill sludge and wood fiber residue, non-food carbon sources, and non-toxic ingredients. REGEN is compostable and is compatible with plastic manufacturers' existing equipment. It is suitable for multiple applications like injection molding, thermoforming, 3D printing, or extrusion blow molding.[38]

- Stora Enso[39] developed DuraSense™, a wood-fiber biocomposite offering the mouldability of plastics and the strength and sustainability of wood, and an up to 80% reduced CO_2 footprint. The material is suitable for a wide range of injection molded products such as furniture, storage & logistics items, packaging, consumer goods, industrial components, automotive details, and food contact plastics. DuraSense is used in the existing molds with little or no change to production techniques.

- Innventia[40] is working on project LightFibre, a carbon fiber based on raw materials harvested from the Swedish forests, as an alternative to the current carbon fiber that is primarily fossil-based and too expensive to be a viable alternative to steel.

- Corbion and Total[41,42] partnered to produce Poly Lactic Acid (PLA) polymers, obtained through the conversion of lactic acid into lactide monomers. Biodegradable and industrially compostable, PLA is currently used in a broad range of markets, including food packaging, single-use tableware, textiles, oil and gas, electronics, automotive, and 3D printing.

- Sulpac[43,44] produces a material made of wood and plant-based binders. Sulapac® material is non-toxic, sustainably sourced, microplastic-free, recyclable via industrial composting, and the wood used is industry by-product. Sulapac® can be used with existing plastic product manufacturing machinery for applications such as cosmetics packaging, personal care items, and clothing hangers, as well as mass-producible straws.

- Stora Enso[45] promotes the use of wood as a renewable resource in construction. Wood is a strong, high-quality, and light-weight material. The use of wood in construction achieves improved thermal insulation and acoustic performance. Stora Enso produces massive wood products such as cross-laminated timber (CLT), laminated veneer lumber (LVL), and glulam.

- Swerea[46] helps companies to develop functional fibers made of materials other than conventional thermoplastics. They work with fibers derived from bio-based raw materials, such as cellulose and lignin from forestry products, in developing new types of fibers, both for technical applications and textiles.

Bio-sourced products

- Sustana Group[47] developed EnviroLife™ a food packaging product from 100% post-consumer recycled fiber. EnviroLife is FDA-compliant for direct food contact under all conditions of use. EnviroLife eliminates the need for coating with polyethylene films, waxes, or foils. The impact of EnviroLife on climate change is 26% lower than the average virgin fiber.

- Stora Enso[48] offers PE Green barrier coating for food packaging to replace the traditional polyethylene and still provide humidity protection. PE Green is made of renewable, and recyclable, plant-based raw material. It performs the same way as polyethylene and can be used in products such as drinking cups and packages for frozen food, ice cream, and yogurt.

- Stora Enso[49] developed PureFiber based eco-products that are plastic-free, made of renewable materials, recyclable, and biodegradable. PureFiber can be used for single-use food packaging items such as plastic-free cups, bowls, and coffee cup lids, as well as for non-food items to replace plastic consumables in agriculture, electronics, and cosmetics packaging.[50]

- Good Natured[51] CDN manufactures renewably-sourced, plant-based food packaging, bioplastic roll stock sheets, and organizational products for home and business following the ASTM D6400 composting standard that requires breakdown within 180 days in a commercial compost facility.

- Green Circle Dine Ware Ltd[52] CDN manufactures drinking straws for the restaurant industry made with Canadian pulp and paper, as well as biodegradable single-use dining ware.

- GCUP — Technology Corp[53]CDN is developing a completely plant-based and compostable single-use coffee pod from bioplastic and wood fiber.

- DSM[54] developed Bovaer®, a feed additive for cows and other ruminants such as sheep, goats, and deer. A quarter teaspoon of Bovaer per cow per day suppresses the enzyme that triggers methane production in a cow's rumen and consistently reduces enteric methane emission by approximately 30%.

- DSM[55] produces Decovery® plant-based paint resin containing up to 50% bio-based content, mainly from agricultural material that doesn't interfere with the food chain, such us tree bark, seeds and other organic materials. Decovery has a carbon footprint up to one-third lower than traditional solvent-borne paint resins.

- West Fraser's [56] CDN Hinton pulp mill operates Canada's first commercial-scale lignin recovery plant, which produces 30 tonnes of lignin per day. This biochemical can be used to displace petrochemical equivalents with biomass-based alternatives. As a natural, renewable green alternative, it is a bio-based alterative for fossil fuel-based chemicals that are used in adhesives, resins, and composite materials.

- Terra Humana[57] developed the 3R zero-emission and high-temperature pyrolysis technology to recover Bio-Phosphate made from food-grade animal bones. Such Bio-Phosphate contains around 30% of phosphorus pentoxide and works well as a controlled-release fertilizer. This technology also fills a need for large-scale bio-fertilizer production in the EU and contributes to securing demand for bio-based nutrients and their flow between European regions.

- Corbion[58] produces biochemicals derived from lactic acid for several applications such us: PURASOLV® that enhance solvency in agrochemical formulation; PURALACT® lactide that boosts resin and coating performance in areas like hardness, adhesion and gloss; and PURASAL® S/HQ 60, a skin moisturizing agent, as well as other applications in home care, pharma production, and animal health.

- Solvay[59,60] developed AgRho® S-Boost, a root booster based on a biodegradable formulation that ensures rapid growth and healthy plants, and AgRho® N-Protect, eco-friendly nitrogen stabilizers that increase crop yield while reducing greenhouse gas emissions and improving water quality.

The Ideal

- The development of more bio-based materials and products which can replace fossil-fuel counterparts wherever possible

Process optimization

Closed-loop water consumption

- Sustana Group[61] CDN diverts cold water from pipes near the end of the production line of its Fox River fiber plant (which prodocues a closed-loop fiber) back to the beginning of the process and to the plant's coldwater supply, saving water and gas. Every drop of water at its de-inking facility is recirculated 17 times, and more than 30 times at its paper mill.

Reduced supply chain waste

- Atelier Extramuros[62] a social enterprise specializing in upcycling in the furniture sector, using reclaimed material from discarded professional furniture. It customizes the furniture produced depending on the need and means of their clients, thereby avoiding unsold inventory losses.

The Ideal

- Bioeconomy industries develop optimized processes for production that minimize environmental impacts like water consumption and waste generation

Responsible consumption and procurement

Responsible wood and paper sourcing

- DS Smith Packaging[63] uses 100% recycled papers and maintains 100% of sites holding a chain of custody certification.
- Resolute Forest Products[64] CDN ensures 100% of the timberlands managed by the company and its fiber-tracking systems are third-party certified to at least one internationally recognized forest management standard: Sustainable Forestry Initiative® (SFI®) or Forest Stewardship Council® (FSC®). These standards aim to protect biodiversity, water quality, wildlife habitat, species at risk, and forests with conservation value.
- Stora Enso's[65] wood supply chains are covered by wood traceability systems that are certified according to PEFC™ or FSC® chain of custody system or both. These ensure that the timber comes from a forest managed to the highest environmental and social standards.

The Ideal

- All feedstock used in the bioeconomy industry are sourced responsibly

Specific Examples: Objective 2, Intensified Product Use

Sharing economy is not significantly addressed

Short-term renting is not significantly addressed

Specific Examples: Objective 3, Extending Life of Products and Components

Maintenance and repair is not significantly addressed

Donating and reselling

Re-appropriation of food by-products, surplus, and waste

- Wilder Harrier [66] CDN is a start-up that uses the residual pulp food produced by the beverage company LOOP for the manufacture of vegan dog treats[67].
- Oreka Solutions[68] CDN collects pre-consumer food waste and by-product streams from food retailers and processors in the Wellington-Waterloo region, and feeds black soldier flies with these nutrients. The larvae are converted into three products: a solid fertilizer for soil-based farming that enhances the soil's microbiome; a liquid biofertilizer that can be used in aquaponic growing solutions; and a feedstock for fish, pigs, and chickens.
- Rothsay[69] CDN turns old cooking oil, grease trap maintenance, and meat by-products from restaurants, retailers, processing facilities, and livestock raising into animal feed and biofuel.
- Loop[70] is a Finnish restaurant that collects 600kg of surplus food each day from six suppliers and supermarkets. It uses this collected food to create high quality canteen food, gourmet meals, and artisanal ice cream. Any remaining edible food is directed to charities or composted.

- Boomerang[71] CDN is a Canadian company that produces flour from spent grain. In addition to reducing food waste, this product reduces the transportation, agricultural land, and water required for flour production, thus reducing carbon and water footprints.

The Ideal

- Surplus edible food and agri-food by-products are recovered for human consumption
- Food waste is reprocessed into new products, such as food products and animal feed

Refurbishing

Wood-based furniture refurbishment

- IKEA[72] offers to take back their furniture when it is no longer wanted, refurbishes it, and sells it at a reduced rate to new customers. Customers can exchange their unwanted furniture for a voucher to spend in store.

The Ideal

- Alll wood-based furniture is refurbished to extend it's lifespan

Performance economy is not significantly addressed

Specific Examples: Objective 4, Giving Resources New Life

Industrial ecology

Valorization of organic by-products and waste

- Favini[73 74] recovers bran residues from the milling of Barilla wheat, a by-product that no longer usable for human consumption. The company processes this along with cellulose to produce CartaCrusca paper. Favini also produces Crush paper, which includes by-products from citrus fruits, grapes, cherries, lavender, corn, olives, coffee, kiwis, hazelnuts, and almonds. This lowers CO_2 emissions by 20% compared to the production of standard Favini paper at the same plant[75].

- Sustana Group[76] provides 77% of process by-products of its Fox River Fiber plant for use as animal bedding, and 100% of process by-products of its Breakey Fibers.

The Ideal

- The identification and development of new ways for industries in the bioeconomy to repur-pose each other's waste

Recycling and composting

Paper recycling

- Sustana Group's[77] main source of raw material is the "urban forest"—recycled fibers recovered from FSC Certified suppliers. It processes 2.2 million pounds of wastepaper every day through its Sustana Fiber facilities, and recycles enough paper every year to save over 4 million trees and save over 1 million cubic yards of landfill space.

- DS Smith Packaging[78] achieves 97 per cent recycled or chain of custody certified papers used in their operations. They seek to manufacture 100% reusable or recyclable packaging by 2025.

Wood recycling

- Valdelia[79] is a French company which collects and recycles used furniture from the industrial, commercial and institutional sector. Financed by an eco-fee included in the sale price of all new professional furniture, Valdelia operates on behalf of 1200 members including manufacturers, distributors, and importers of new professional furniture. Furniture in good shape is donated to social purpose non-profits, and the rest is dismantled for material recycling or energy recovery.

The Ideal

- Continued development of recyclable and compostable bio-based material
- Continued use of recycled paper and fibers

Energy recovery

Bioenergy production

- Cascades[80 81 CDN] generated 27% fewer emissions at the Cascades Containerboard Packaging plant in Cabano, in Québec, following the installation of residual bark-fuelled biomass steam boiler which allowed it to significantly decrease its heavy-fuel oil consumption.
- West Fraser's [82 CDN] Slave Lake Pulp has built a unique energy plant that uses the mill's effluent (wastewater) to produce energy using biological organisms. The installation relies on the collection of gases produced by the breakdown of organic matter in the pulp mill's effluent. Microorganisms digest waste products in the effluent and their digestion generates methane-rich biogas. It is is expected to reduce greenhouse gas emissions by 22,000 tonnes annually.
- Cascades'[83 CDN] subsidiary Greenpac Mill, LLC burns Cascade pulping residues from the Niagara Falls and Greenpac containerboard plants to generate the steam used for drying products, in partnership with Covanta[84], a company specializing in waste-to-energy solutions located close to Cascades' sites.
- Farmers in France and Québec [85 86 CDN] installed anaerobic digesters on their farms for the valorization of the farm waste. The anaerobic digesters allow the farmers to produce energy (i.e. biogas, electricity, heat) as well as fertilizer. In France, the practice is subsidized by the government, and makes it possible to increase the farmers' revenue and cut energy expenses (see also MAPAQ report[87]).
- Research Institute of Sweden (RISE)[88] has developed methods and technical solutions for the manufacture of fuels from renewables. One example is aviation fuel from lignin, a waste product of chemical pulping and paper manufacture.
- StoraEnso[89] extracts the crude tall oil from softwood, refining it into biofuels which can replace fossil-based fuels and vegetable-based oils. It can also add value in products such as detergents and soaps, adhesives, lubricants, paints, and coatings.
- DSM's Bio-based Products & Services business[90 91] developed eBOOST™, a yeast that improves ethanol yield by increasing the energy generated from corn. Compared with existing yeast products, eBOOST increases ethanol yields by up to 6% while reducing glycerol production by as much as 75%. For producers, this is a game-changer: a 5% average increase in output allows a typical ethanol plant to produce three million additional gallons of ethanol a year from the same volume of corn. This is the equivalent of opening seven new production plants.
- INEOS Biorefinery[92] in the Indian River Bioenergy Center was designed to produce cellulosic ethanol and generate renewable electricity. The Biorefinery converts biological matter, like wood scraps and grass clippings, into transportation fuels, heat, and power [93].

- Abengoa (Spain and Global) [94] creates facilities for the energy recovery from all types of waste and biomass, producing renewable and sustainable energy in the form of heat, cold, electricity, or fuel. Technologies include bioethanol production from wheat and corn; electricity and steam generation from bagasse straw; renewable fuels (biodiesel) production from the transformation of vegetable oils; electricity generation from cereal straw; and electricity generation from poultry manure.

- Abengoa Bioenergy Biomass of Kansas[95] is a commercial-scale integrated biorefinery for the production of ethanol from lignocellulosic biomass with a capacity to produce approximately 25 million gallons of cellulosic ethanol per year. It will reduce about 139,000t of carbon dioxide emissions a year, equivalent to removing 35,000 cars from the road. The plant co-generates 21MW of electricity for captive consumption, while the excess power is supplied to the local community. Lignin and animal feed are produced as by-products.

- Project LIBERTY[96] POET-DSM's biorefinery in Emmetsburg, Iowa, produces cellulosic ethanol from corn stover. The facility uses a biological process to convert post-harvest cobs, leaves, husks, and upper stalks into a biofuel. It has the capacity to produce up to 25 million gallons of cellulosic ethanol annually. It is one of the first generation of large-scale U.S. biorefineries to produce biofuel from agricultural waste. It is a joint venture of POET, a bio-ethanol producer, and DSM, a global science-based company that is active in health, nutrition and materials, as well as driving environmental progress[97].

- Biorefinery La Mède[98] is a biorefinery operated by the oil company Total designed to produce biofuels from various types of oils. This includes vegetable oils certified sustainable according to E.U. criteria as well as used oils, residual oils and animal fats. La Mède's feedstock will be made up of 60% to 70% crude vegetable oils (rapeseed, sunflower, soybean, oil palm, corn, or new plants such as carinata) and 30% to 40% treated waste (animal fats, cooking oil, residues, etc.).

The Ideal

- Continued increase in the production of bioenergy that can replace fossil fuel-based energy sources

6.4. Additional Resources

The following are additional resources that researchers, practitioners, and policymakers can draw on to further advance awareness and understanding of opportunities for circularity for Canada's bioeconomy.

Selected Global Public Policies Supporting Bioeconomy Circularity

- *Europe's new bioeconomy strategy:* released by the EU in 2012, this strategy aims to "improve and scale up the sustainable use of renewable resources to address global and local challenges such as climate change and sustainable development". The new strategy consists of establishing "a €100 million Circular Bioeconomy Thematic Investment Platform to bring bio-based innovations closer to the market" and "a pledge to build 300 new sustainable biorefineries across Europe by 2030—it also complements an EU directive to ensure that 20% of the EU's total energy needs are met with renewables by 2020". [99,100]
- *Grenelle II Law:* France requires all large producers of bio-waste (in particular large retailers) to sort, collect, and recover their biowaste, as of January 2012. [101,102]
- *Quebec's residual materials management policy:* includes an Organic Materials Treatment Program for biomethane and composting (PTMOBC)[103]. It aims to reduce the amount of waste per capita and banning the landfilling of organic matter starting in 2022.[104]

Selected Documents on Circular Economy and Bioeconomy

Understanding the role of the bioeconomy in the circular economy

Carus, M. (2017). *Bio-based economy and climate change – Important links, pitfalls and opportunities. nova-Institut. Retrieved from* http://bio-based.eu/download/?did=83344&file=0

Written for the United Nations Food and Agriculture Organization (FAO), this report provides a helpful overview of climate change implications for the bioeconomy, along the value chain. It identifies strategies adopted to help the bioeconomy reach its potential for reducing greenhouse gas emissions.

Ellen MacArthur Foundation. (2018). *Renewable Materials for a Low-Carbon and Circular Future*. Retrieved from https://www.ellenmacarthurfoundation.org/assets/galleries/ce100/CE100-Renewables_Co.Project_Report.pdf

A bioeconomy, based on renewable materials, has the potential to drive innovation and create new economic opportunities, but these benefits require an understanding of renewables' role in the circular economy. This paper establishes key concepts relating to the bioeconomy and highlights opportunities and challenges in the use of renewable materials.

Ellen MacArthur Foundation (2017). *Urban Biocycles*. Retrieved from https://www.ellenmacarthurfoundation.org/publications/urban-biocyles

This paper highlights the potential to apply circular economy principles to capture value in the high levels of organic waste in urban environments. Through global bioeconomy statistics and international examples, the paper demonstrates that urban organic waste, rather than being a costly economic and environmental problem, can be a source of revenue while helping to restore natural capital.

Understanding the bioeconomy in Canada

Bioindustrial Innovation Canada (BIC). (2017). *Innovation in Agriculture: Canadian Industrial Bioproducts Industry Priorities & Recommendations*. Retrieved from https://www.bincanada.ca/single-post/2018/02/14/Report-Innovation-in-Agriculture-Canadian-Industrial-Bioproducts-Industry-Priorities-Recommendations

This report identifies six priority areas for industry, academia, and policymakers to advance Canada's bioeconomy in the agricultural sector, recognizing Canada's potential to be an agricultural bioeconomy leader. Recommending an action plan for each of the priority areas, the report presents a framework for the sector to create jobs, leverage innovation, reduce greenhouse gas emissions, and create new market opportunities.

Bioindustrial Innovation Canada (BIC). (2019). *Canada's Bioeconomy Strategy: Leveraging our Strengths for a Sustainable Future*. Retrieved from https://www.bincanada.ca/biodesign

Supported by cross-Canada consultations with companies and industry associations, this strategy highlights the need for a national bioeconomy strategy and recommends actions based on bioeconomy priority areas identified by the Advisory Council on Economic Growth, the Economic Sector Strategy Tables, and the Canadian Council of Forest Ministers. This strategy was developed by Bioindustrial Innovation Canada, BIOTECanada, the Forest Products Association of Canada, and FPInnovations.

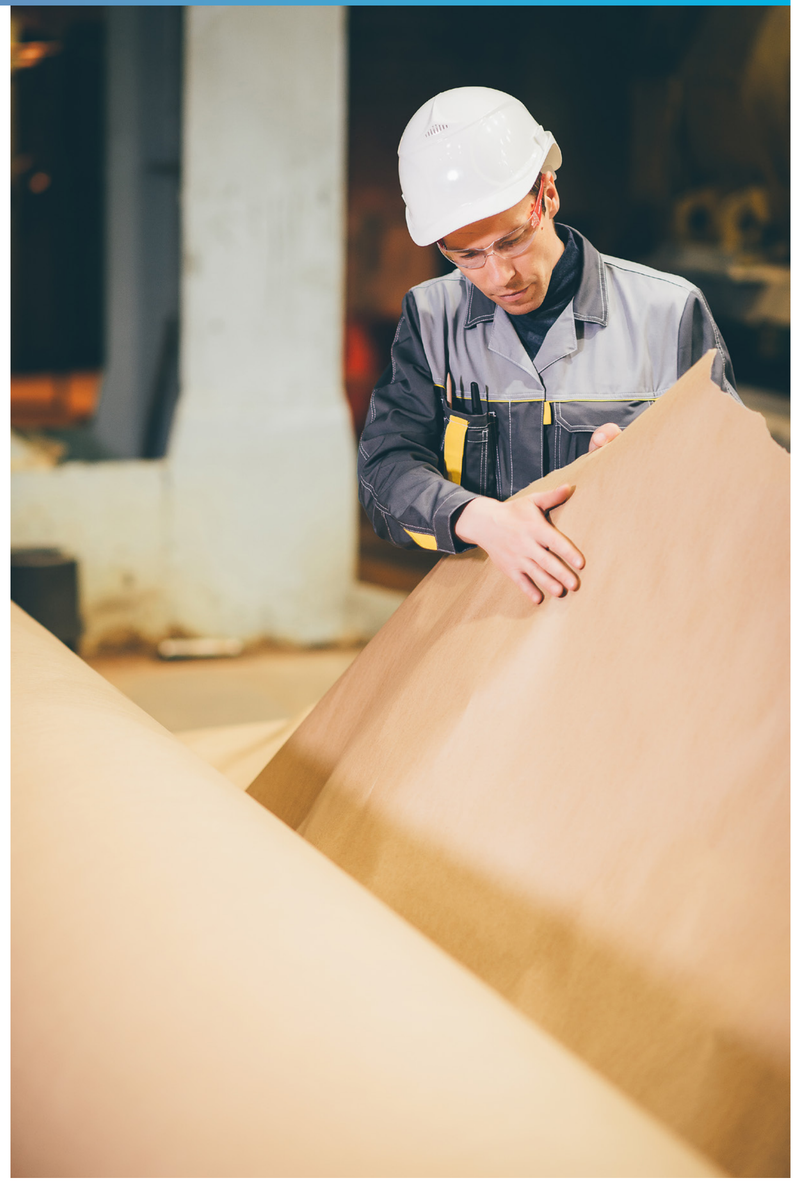
Natural Resources Canada. (2017). *A Forest Bioeconomy Framework for Canada*. Canadian Council of Forest Ministers. Retrieved from https://cfs.nrcan.gc.ca/publications?id=39162

This report presents a framework for a transition to a low-carbon economy in the forest sector, envisioning Canada as a forest bioeconomy world leader. Seeking to increase the use of forest biomass throughout the economy, the framework has four pillars, and examples of policies for each, to increase community partnerships, facilitating innovation, and generating and meeting market demand.

6.5. Conclusion to Bioeconomy

This global scan of best circular economy practices in the bioeconomy reveals that selected firms and operations are already implementing a wide range of practices that support circular economy objectives and strategies, whether or not these practices are explicitly identified as circular. Bioeconomy practices that can contribute to the development of a circular economy include the creation of biofuels, bioenergy, and innovative bio-based products such as textiles, composites, pharmaceuticals, and chemicals. These offer substitutes for hydrocarbon-based products, reduced greenhouse gas emissions, and creation of value from what is today considered waste. As the country with the most biomass per capita in the world, Canada is well-positioned to take advantage of opportunities created by the bioeconomy, making this one of Canada's strongest opportunities for a circular economy.

In cataloging these examples, our intent is to demonstrate real-world strategies and practices that offer a starting point in the journey towards a circular economy. This information is offered as a background resource and reference source for future efforts to engage Canadian firms and innovators in the journey towards a circular economy, and –ideally– to begin building a Canadian bioeconomy roadmap to a circular economy.



REFERENCES

1 Ellen MacArthur Foundation (2017). *Urban Biocycles*. Retrieved from https://web.archive.org/web/20200808020340/https://www.ellenmacarthurfoundation.org/assets/downloads/publications/Urban-Biocycles_EllenMacArthurFoundation_21-06-2017.pdf

2 Ellen MacArthur Foundation. (2018). *Renewable Materials for a Low-Carbon and Circular Future*. Retrieved from https://web.archive.org/web/20200826202932/https://www.ellenmacarthurfoundation.org/assets/galleries/ce100/CE100-Renewables_Co.Project_Report.pdf

3 Ibid.

4 Ellen MacArthur Foundation (2017). Op.cit.

5 Ibid.

6 Ibid.

7 Ellen MacArthur Foundation. (2018). Op.cit.

8 Ellen MacArthur Foundation. (2016). *The New Plastics Economy: Rethinking the Future of Plastics*. Retrieved from https://web.archive.org/web/20200715165340/https://www.ellenmacarthurfoundation.org/assets/downloads/EllenMacArthurFoundation_TheNewPlasticsEconomy_Pages.pdf

9 Ibid.

10 Ellen MacArthur Foundation. (2017). Op.cit.

11 Ibid.

12 Ibid

13 Natural Resources Canada. (2017). *A Forest Bioeconomy Framework for Canada*. Canadian Council of Forest Ministers. Retrieved from https://web.archive.org/web/20190410222342/http://cfs.nrcan.gc.ca/publications?id=39162

14 Rancourt, Y., Neumeyer, C., & Zou, N. (2017). *Results of the Bioproducts Production and Development Survey 2015*. Statistics Canada. Retrieved from https://web.archive.org/web/20190629141101/https://www150.statcan.gc.ca/n1/pub/18-001-x/18-001-x2017001-eng.htm

15 Natural Resources Canada. (2017). Op.cit.

16 Rancourt, Y., Neumeyer, C., & Zou, N. (2017). Op.cit.

17 Agriculture and Agri-Food Canada. (2019). *Investing in Canada's bioeconomy to help provide opportunities for farmers and grow the clean economy*. Retrieved from https://web.archive.org/web/20190814143815/https://www.canada.ca/en/agriculture-agri-food/news/2019/04/investing-in-canadas-bioeconomy-to-help-provide-opportunities-for-farmers-and-grow-the-clean-economy.html

18 Natural Resources Canada. (2017). Op.cit.

19 Grosshans, R. (2018). *Canada Should Copy Europe When It Comes to the Bioeconomy*. International Institute for Sustainable Development. Retrieved from https://web.archive.org/web/20200826214028/https://www.iisd.org/articles/canada-europe-bioeconomy

20 Rancourt, Y., Neumeyer, C., & Zou, N. (2017). Op.cit.

21 Ibid.

22 Ibid.

23 Bioindustrial Innovation Canada (BIC). (2019). *Canada's Bioeconomy Strategy: Leveraging our Strengths for a Sustainable Future*. Retrieved from https://web.archive.org/web/20200826214316/https://www.bincanada.ca/biodesign

24 Rancourt, Y., Neumeyer, C., & Zou, N. (2017). Op.cit.

25 L'Actualité Chimique. (2013). *La bioraffinerie de Bazancourt-Pomacle : une plate-forme d'innovation ouverte au cœur d'un complexe agro-industriel*. Retrieved from: https://web.archive.org/web/20200106182349/https:/www.lactualitechimique.org/La-bioraffinerie-de-Bazancourt-Pomacle-une-plate-forme-d-innovation-ouverte-au-coeur-d-un-complexe.

26 Ministère de L'Agriculture et de L'Alimentation. (2016). *Transformer : la bioraffinerie de Bazancourt-Pomacle*. Retrieved from: https://web.archive.org/web/20191222035728/https:/agriculture.gouv.fr/transformer-la-bioraffinerie-de-bazancourt-pomacle

27 InfoChemie. (2018). *Bazancourt-Pomacle : Un des exemples les plus aboutis de bioraffinerie en Europe*. Retrieved from: https://web.archive.org/web/20191222040217/https:/www.info-chimie.fr/un-des-exemples-les-plus-aboutis-de-bioraffinerie-en-europe,90932

28 Chauvet, J-M. (n.d.) *La bioraffinerie de Bazancourt-Pomacle: un modèle d'intégration au cœur du pôle IAR*. Retrieved from: https://web.archive.org/web/20191222040633/https:/www.rfeit.fr/Actes/rfeit_2014_07_visite_pomacle.pdf

29 Sustana. (2018) *Creating a Sustainable, Closed-Loop Fiber Future: Sustana Group's Sustainability Plan*. Retrieved from: http://web.archive.org/web/20191121152907/https:/www.rollandinc.com/sites/default/files/d3415_plandurabilite_en_web_v1.pdf

30 Rolland. (n.d.) *Biogas Energy: A green and local source*. Retrieved from: https://web.archive.org/web/20190611063302/https:/www.rollandinc.com/en/environmental-stewardship/biogas-energy

31 LOOP. (2019). *Our rescue mission*. Retrieved from: https://web.archive.org/web/20191207020656/https://loopmission.com/

32 BASF. (n.d.). *ecovio® – certified compostable polymer with biobased content*. Retrieved from http://web.archive.org/web/20191104013457/https://products.basf.com/en/ecovio.html

33 BASF. (n.d.). *ecoflex® – the original among the certified compostable plastics – developed by BASF*. Retrieved from http://web.archive.org/web/20191104013554/https://products.basf.com/en/ecoflex.html

34 Avantium. (n.d.) *Renewable Polymers*. Retrieved from http://web.archive.org/web/20191027174905/https://www.avantium.com/renewable-polymers/

35 Mistubishi Chemical. (n.d.). *BioPBS™*. Retrieved from http://web.archive.org/web/20191031153647/https://www.m-chemical.co.jp/en/products/departments/mcc/sustainable/product/__icsFiles/afieldfile/2016/05/20/BioPBS_brochure.pdf

36 Mitsubishi Chemical. (n.d.). *New Bio-based Engineering Plastic DURABIO™*. Retrieved from http://web.archive.org/web/20191107211600/https://www.m-chemical.co.jp/en/products/departments/mcc/sustainable/product/1201026_7964.html

37 Bosk bioproducts. (2019). *Products: Compostable bioplastics*. Retrieved from https://web.archive.org/web/20191202214208/https://www.bosk-bioproducts.com/compostable-bioplastics.html

38 Levasseur, J.-F (Guest). (2019). *Are bioplastics better than regular plastics*? [Audio podcast]. Natural Resources Canada. Retrieved from http://web.archive.org/web/20191108002709/https://www.nrcan.gc.ca/simply-science/21420

39 Stora Enso. (2019). *Biocomposites*. Retrieved from https://web.archive.org/web/20191202215304/https://www.storaenso.com/en/products/biocomposites

40 Research Institute of Sweden. (2019). *Lignin and cellulose create a strong bio-based carbon fibre*. Retrieved from https://web.archive.org/web/20191202215837/https://www.ri.se/en/our-stories/lignin-and-cellulose-create-strong-bio-based-carbon-fibre

41 Total Corbion. (2019). *PLA (Poly Lactic Acid)*. Retrieved from https://web.archive.org/web/20191202224611/https://www.total-corbion.com/

42 Corbion. (2019). *Bioplastics: Total Corbion PLA*. Retrieved from https://web.archive.org/web/20191202225311/https://www.corbion.com/bioplastics/total-corbion-pla

43 Sulapac. (2019). *Portfolio*. Retrieved from https://web.archive.org/web/20191202213209/https://www.sulapac.com/portfolio/
44 Sulapac. (2019). *Portfolia. Compatabilioty*. Retrieved from https://web.archive.org/web/20191202213738/https://www.sulapac.com/compostability/
45 Stora Enso. (2019). *Massive wood construction: Reaching new heights in sustainable construction*. Retrieved from https://web.archive.org/web/20191205164906/https://www.storaenso.com/en/products/wood-products/massive-wood-construction
46 Swerea. (2019). *Wood-based textiles will become more common*. Retrieved from https://web.archive.org/web/20191205180602/https://www.ri.se/en/what-we-do/our-areas/textile?refdom=www.swerea.se
47 Sustana Group. (2018). *Creating a Sustainable, Closed-Loop Fiber Future: Sustana Group's Sustainability Plan*. Op.cit.
48 Stora Enso. (2019). *Barrier coatings*. Retrieved from https://web.archive.org/web/20191201200614/https://www.storaenso.com/en/products/paper-board-materials/barrier-coatings
49 Stora Enso. (2019). *Formed fiber; Next generation eco-products designed for purpose*. Retrieved from https://www.storaenso.com/en/products/formed-fiber
50 Stora Enso. (2019). *MFC for other end-use applications*. Retrieved from https://web.archive.org/web/20191202211539/https://www.storaenso.com/en/products/bio-based-materials/mfc-for-other-end-use-applications
51 Good Natured. (n.d.). *Compostable Packaging*. Retrieved from http://web.archive.org/web/20191107211350/https://goodnatured.ca/sustainability/compostable-packaging/
52 Green Circle. (2019). *Home page*. Retrieved from https://web.archive.org/web/20191202212121/https://www.greencircleshop.ca/
53 G-Pak. (2019). *Home*. Retrieved from https://web.archive.org/web/20191202214628/https://g-pak.com/
54 DSM. (2019). *More sustainable farming through lower methane emissions*. Retrieved from https://web.archive.org/web/20191117160123/https://www.dsm.com/corporate/solutions/climate-energy/minimizing-methane-from-cattle.html
55 DSM. (2019). *Paint from plants with Decovery® The ultimate in 'green' paint*. Retrieved from https://web.archive.org/web/20191202221628/https://www.dsm.com/corporate/solutions/resources-circularity/recovering-organic-waste-with-decovery.html
56 Forest Products Association of Canada (n.d). *Decarbonization Through Innovation and Displacement: One of the ways Canada's Forest Sector is Helping Power the Drive to Net-Zero 2050*.
57 Terra Humana. (2019). *Animal Bone Char Bio-Phosphate Product Specification.* Retrieved from https://web.archive.org/web/20191202220816/https://www.3ragrocarbon.com/Bio-Phosphate
58 Corbion. (2019). *Biochemicals : How could lactic acid improve your application?*. Retrieved from https://web.archive.org/web/20191202225507/https://www.corbion.com/biochemicals
59 Solvay. (2019). *Agriculture : Solutions to help the farming industry meet the needs of our planet's growing demand for food*. Retrieved from https://web.archive.org/web/20191205193908/https://www.solvay.com/en/solutions-market/agriculture
60 Solvay. (2019). *Plant nutrition*. Retrieved from https://web.archive.org/web/20191205194945/https://www.solvay.com/en/solutions-market/agriculture/plant-nutrition
61 Sustana Group. (2018). *Creating a Sustainable, Closed-Loop Fiber Future: Sustana Group's Sustainability Plan*. Op.cit.
62 Atelier Extramuros. (2019). *Lignes*. Retrieved from https://web.archive.org/web/20191205212837/https://www.atelier-extramuros.com/copie-de-realisations-1
63 DsSmith. (2019). *Sustainability report 2019*. Retrieved from https://web.archive.org/web/20191202204331/https://www.dssmith.com/contentassets/c187988864b9404bb959135d7b92b92c/ds-smith-sustainability-report-2019.pdf
64 Resolute forest products. (2019). *Forest Certification: Forest Management Standards and Third-Party Certification*. Retrieved from https://web.archive.org/web/20191205215824/https://www.resolutefp.com/Sustainability/Forestry_and_Fiber_Sourcing/Forest_Certification/
65 Stora Enso. (2019). *Massive wood construction*. Op.cit.
66 Poiré, Anne Sophie. (June 11, 2018). *Loop, le jus de l'économie circulaire*. Retrieved from https://web.archive.org/web/20191207021240/https://www.info-presse.com/article/2018/6/11/loop
67 Wilder Harrier. (2019). *The Wilder Difference*. Retrieved from https://web.archive.org/web/20191222042049/https://www.wilderharrier.com/
68 Oreka Solutions. (2019). *Harnessing the Power of Insects*. Retrieved from https://web.archive.org/web/20191207021727/https://www.oreka-solutions.com/
69 Rothsay. (2019). *Biodiesel production*. Retrieved from https://web.archive.org/web/20190120073522/https://www.rothsay.ca/sustainability/biodiesel-production/
70 Ellen MacArthur Foundation. (2018). *The Role of Restaurants in a Circular Urban Food System*. Retrieved from https://web.archive.org/web/20190729201032/https://www.ellenmacarthurfoundation.org/our-work/activities/food/stories/the-role-of-restaurants-in-a-circular-urban-food-system
71 Boomerang-Coop (n.d). *Our Flours*. Retrieved from https://web.archive.org/save/https://boomerang-coop.com/en/our-flours/
72 IKEA. (2018). *IKEA Sustainability Report FY18*. Retrieved from https://web.archive.org/web/20191221193339/https://preview.thenewsmarket.com/Previews/IKEA/DocumentAssets/535135.pdf
73 Favini. (2019). *CRUSH The eco-friendly paper with agro-industrial waste*. Retrieved from https://web.archive.org/web/20191207030329/https://www.favini.com/gs/en/fine-papers/crush/cartacrusca-case-history/
74 Ibid.
75 European Circular Economy Stakeholder Platform. (2019). *Favini pairs with Barilla to create CartaCrusca, using up bran residues from the mills*. Retrieved from https://web.archive.org/web/20191207202601/https://circulareconomy.europa.eu/platform/en/good-practices/favini-pairs-barilla-create-cartacrusca-using-bran-residues-mills
76 Sustana Group. (2018). *Creating a Sustainable, Closed-Loop Fiber Future: Sustana Group's Sustainability Plan*. Op.cit.
77 Ibid.
78 DS Smith. (2019). *Sustainability report 2019*. Retrieved from https://web.archive.org/web/20191202204331/https://www.dssmith.com/contentassets/c187988864b9404bb959135d7b92b92c/ds-smith-sustainability-report-2019.pdf
79 Valdelia. (2019). *Recycler ses meubles professionnels usagés*. Retrieved from https://web.archive.org/web/20191207025854/http://www.valdelia.org/recycler-ses-meubles-professionnels-usages/
80 Cascade. (2019). Gaz à effet de serre. Retrieved from https://web.archive.org/web/20191205200403/https://cascades.metrio.net/indicators/ppd/planet/ghg_ratio
81 Cascade. (February 10, 2017). *Energy efficiency - the Quebec government and Cascades invest $11.3 million in two energy efficiency projects*. Retrieved from https://web.archive.org/web/20191205201641/https://www.cascades.com/en/media-centre/press-releases-and-news/press-release/2017/6010/energy-efficiency-the-quebec-government-and-cascades-invest-113-million-in-two-energy-efficiency-projects#sharethisContent
82 West Fraser (n.d). *Energy Initiatives*. Retrieved from https://web.archive.org/web/20181224220656/https://www.westfraser.com/products/energy-initiatives-0
83 Cascade. (2019). *Matières résiduelles*. Retrieved from https://web.archive.org/web/20191205202526/https://cascades.metrio.net/indicators/ppd/planet/matieres_residuelles_ratio
84 Covanta. (2019). *Energy from waste*. Retrieved from https://web.archive.org/web/20190406060820/https://www.covanta.com/Sustainability/Energy-from-Waste

85 Radio-Canada. (June 12, 2019). *Bas-Saint-Laurent : une ferme de Rimouski se lance dans la production de biogaz*. Retrieved from https://web.archive.org/web/20191222044449/https://ici.radio-canada.ca/nouvelle/566142/biogaz-ferme-rimouski

86 Lallouët-Geffroy, J. (January 23, 2019*). La méthanisation, l'usine à gaz qui séduit les gros agriculteurs*. In Reporterre.net. Retrieved from https://web.archive.org/web/20191222043512/https://reporterre.net/la-methanisation-l-usine-a-gaz-qui-seduit-les-gros-agriculteurs

87 Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec. (July 2011). *Évaluation du potentiel de production de biogaz par la méthanisation de la biomasse agricole dans la région de Saint-Jean-Valleyfield*. Retrieved from https://web.archive.org/web/20191222044911/https://www.mapaq.gouv.qc.ca/SiteCollectionDocuments/Agroenvironnement/1457_Rapport.pdf

88 Research Institute of Sweden. Op.cit.

89 Stora Enso. (2019). *Tall oil*. Retrieved from https://web.archive.org/web/20191207220151/https://www.storaenso.com/en/products/bio-based-chemicals/tall-oil

90 DSM. (2019). *Clean, renewable transportation fuel is no longer a dream*. Retrieved from https://web.archive.org/web/20191207220716/https://www.biofuelthefuture.com/

91 DSM. (2019). *A breakthrough for biofuel: Boosting the energy generated from corn*. Retrieved from https://web.archive.org/web/20191207221517/https://www.dsm.com/corporate/solutions/climate-energy/advanced-biofuels.html

92 US Office of Energy Efficiency & Renewable Energy. (2019). *INEOS-New Planet: Indian River Bioenergy Center*. Retrieved from https://web.archive.org/web/20191222181726/https://www.energy.gov/eere/bioenergy/ineos-new-planet-indian-river-bioenergy-center

93 US Department of Energy. (February 9, 2011). *Turning Waste Into Fuel: How the INEOS Biorefinery Is Changing the Clean Energy Game*. Retrieved from https://web.archive.org/web/20191222182818/https://www.energy.gov/articles/turning-waste-fuel-how-ineos-biorefinery-changing-clean-energy-game

94 Abengoa. (2019). *Energy Recovery from Waste and Biomass*. Retrieved from https://web.archive.org/web/20191222183416/http://www.abengoa.com/web/en/negocio/energia/residuos/

95 Chemicals Technology. (2019). *Abengoa Cellulosic Ethanol Biorefinery, Kansas*. Retrieved from https://web.archive.org/web/20191222184333/https://www.chemicals-technology.com/projects/abengoa-cellulosic-ethanol-biorefinery/

96 POET-DSM. (2019). *About POET-DSM; A transformative idea with global potential*. Retrieved from https://web.archive.org/web/20191222185810/http://poet-dsm.com/about

97 POET-DSM. (2019). *Project liberty*. Retrieved fro https://web.archive.org/web/20191222190100/https://www.energy.gov/eere/bioenergy/poet-dsm-project-liberty

98 Total. (2019). *La Mède: A Facility Focused On The Energies Of Tomorrow*. Retrieved from https://web.archive.org/web/20191222190636/https://www.total.com/en/energy-expertise/projects/bioenergies/la-mede-a-forward-looking-facility

99 European Commission. (October 10, 2018). *A new bioeconomy strategy for a sustainable Europe*. Retrieved from https://web.archive.org/web/20200107211456/https://ec.europa.eu/commission/presscorner/detail/en/IP_18_6067

100 Grosshans, R. Op.cit.

101 Legifrance. (2010). *LOI n° 2010-788 du 12 juillet 2010 portant engagement national pour l'environnement (1).* Retrieved from: https://web.archive.org/web/20200107212915/https:/www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000022470434&categorieLien=id

102 Veolia. (2019). *Biowaste management, a major environmental challenge* .Retrieved from: https://web.archive.org/web/20200102174759/https://www.veolia.com/en/solution/biowaste-management-green-energy-environmental-challenge

103 Environnement et Lutte contre les changements climatiques. (n.d.) *Programme de traitement des matières organiques par biométhanisation et compostage (PT-MOBC).* Retrieved from: https://web.archive.org/web/20200107214236/http:/www.environnement.gouv.qc.ca/programmes/biomethanisation/index.htm

104 Environnement et Lutte contre les changements climatiques. (n.d.) *Politique québécoise de gestion des matières résiduelles*. Retrieved from: https://web.archive.org/web/20200107214119/http:/www.environnement.gouv.qc.ca/matieres/pgmr/

Smart Prosperity Institute

institute.smartprosperity.ca

ACKNOWLEDGEMENTS

This project has been supported in part through the Smart Prosperity Institute Research Network and its Greening Growth Partnership, which is supported by a Social Sciences and Humanities Research Council of Canada Partnership Grant (no. 895-2017-1018), as well as by Environment and Climate Change Canada's Economics and Environmental Policy Research Network (EEPRN).

This research project was supported by Smart Prosperity Institute's Economics and Environmental Policy Research Network (EEPRN) and the Greening Growth Partnership

Ce projet a été réalisé avec l'appui financier de :
This project was undertaken with the financial support of:

Environnement et Changement climatique Canada
Environment and Climate Change Canada

SSHRC CRSH

uOttawa
Institut de l'environnement
Institute of the Environment