CIRCULAR ECONOMY GLOBAL SECTOR BEST PRACTICES SERIES

BACKGROUND MATERIALS FOR CIRCULAR ECONOMY SECTORAL ROADMAPS

AUTOMOTIVE MANUFACTURING

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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.
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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 Manufacturing

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AUTOMOTIVE MANUFACTURING

7.1. Introduction to Automotive Manufacturing

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 automotive manufacturing sector. It begins with an outline of the economic and environmental importance of the sector, including data on the 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 snapshots 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 circularity in the automotive manufacturing sector.

7.2. Background

In 2018, the automotive manufacturing sector accounted for 5.7% of global output and around 8% of global exports.[1] While volumes are expected to remain relatively stable after 2025, it is projected that sales of new cars could increase by 17 million units by 2035.[2] In Canada, the sector is the second largest manufacturing industry, adding C$18.28 billion a year to GDP, representing 17% of total merchandise exports, and employing over 126,000 people directly and 500,000 people indirectly.[3] However, Canada's position in the global automotive industry has declined from being the fifth largest vehicle producer in 1999, to the eleventh in 2017.[4]

As the sector grows, so has its demand for raw materials, including rare materials. This has led to an increase in its material costs. In the European car industry alone these costs have increased by several million dollars per year.[5] The automotive manufacturing industry is the world's top consumer of lead. 60% of the global lead supply goes to car manufacturing, amid concerns that lead reserves could run out by 2030.[6] Nickel, a key component of lithium batteries that are used in electric cars, is expected to increase in price as electric vehicle markets grow. Currently, 2 million tonnes of nickel are sold worldwide annually, if electric vehicles reach 10% of the global car fleet the global demand for nickel within batteries alone could reach 400,000 tonnes.[7]

This growing demand for materials is resulting in a change in the material composition of cars. In the future, the automotive industry will likely rely less on steel and more on lighter-weight materials like aluminum and plastics[8]. By 2025 it is expected that 20% of a car's mass will be plastic.[9] In a global survey, automotive industry executives predicted that by 2040, the industry's market share will be 30% battery electric vehicles, 25% hybrid vehicles, 23% fuel cell electric vehicles, and 23% internal combustion engine vehicles.[10] Electric vehicles are expanding rapidly: in 2018, there were over 5.1 million electric cars around the world, an increase of 2 million from the previous year.[11] By 2035, it is expected that battery-powered electric vehicles will account for 40% of industry profits, an increase from just 1% in 2017.[12] Ownership models are also expected to shift. It is anticipated that by 2025, up to 36% of people will use shared mobility services instead of owning a car, which could decrease vehicle sales by 24%.[13]

Internal combustion automobiles require a consistent input of fossil- or bio-fuels. Transportation accounts for 20-50% of a cities' energy consumption (excluding industry). Further 90% of air pollution in cities is caused by vehicular emissions.[14] Compared to a global average internal combustion engine vehicle, an average battery electric or plug-in hybrid electric vehicle emits lower greenhouse gas emissions over its lifecycle.[15] With current and anticipated worldwide government policies, the global electric vehicle fleet could offset around 220 megatonnes of CO_2 equivalent by 2030.[16] Additionally, maintenance costs of electric vehicles can be 50–70% lower than the costs of vehicles with internal combustion engines.[17]

Once a vehicle reaches its end of life, its parts continue to be of value. There are many existing circular economy practices in the automotive sector, and potential for more. In Europe, for instance, the industry that remanufactures car parts is worth an estimated $C12-15 billion.[18] A remanufacturing factory in Choisy-le-Roy, France found that compared to new parts, remanufactured parts use 80% less energy, 88% less water, 92% fewer chemical products and produce 70% less waste.[19] By designing vehicle parts to be remanufactured, the cost of remanufactured vehicles can be reduced by 30-50%.[20] Additionally, remanufacturing of vehicle parts can boost employment by increasing skilled labour requirements by up to 120%.[21] According to Accenture Strategy research, the potential revenue of selected circular economy business models for automotive companies, like shared mobility and lean manufacturing, could more than double by 2030, growing by C$550-830 billion globally.[22] This represents an untapped opportunity for Canada, where about 1.2 million vehicles are taken off the road every year, creating more than 150,000 tonnes of vehicle waste per year in Ontario alone.[23]

7.3. Overview of Circular Economy Practices in the Automotive Manufacturing Sector

Automotive companies have been implementing and researching many circular solutions, driven by sectoral pressures such as increasing demand for raw materials, a commitment to production efficiencies and lean manufacturing to achieve cost-competitiveness, a need to reduce weight to improve fuel economy, and the transition to hybrid-electic and electric-battery vehicle fleets. Figure 7-1 summarizes the specific practices employed in the automotive manufacturing sector, 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 are highlighted below. This is followed by a listing of applied examples of these strategies and practices, with hyperlinks to additional information.

Objectives, Strategies and Practices

The automotive sector is a large consumer of resources and many practices in this sector focus on **REDUCED** resource consumption, driven by cost control, fuel efficiency, and climate change pressures. **Ecodesign** reduces consumption inputs at the design stage. One example is the design of battery powered cars and the implementation of electric charging stations.[24] Other applications of ecodesign include using lightweight materials,[25] which also improves vehicle mileage, and the integration of recycled materials[26] into vehicle manufacturing. **Process optimization** techniques include the use of data and analytics to detect and predict manufacturing flaws,[27] and increasing the **resource efficiency**[28] of production in plants. The sector also practices **responsible consumption and procurement** by sourcing vehicle inputs from **sustainable supply chains**.[29]

Other practices in this sector look to **OPTIMIZE** resource use through **intensified use of products**. The **sharing economy** has flourished in the automotive sector, with companies like Uber and Lyft gaining worldwide prominence[30]. Also gaining traction is the short term use of vehicles and tires through **rental, lease or subscription** services. For example, Share Now offers an international fleet of cars that paying members can access via an application platform.[31] Another example is Michelin, who lease tires to companies in the mining, transportation and aviation sector instead of selling them, a service which includes additional maintenance and end of life management.[32]

Figure 7-1. Circular economy objectives, strategies and practices found in the automotive manufacturing sector

Objectives	Strategies	Practices
Reduced resource consumption	**Ecodesign**	Battery electric cars; Electric vehicle charging stations; Hydrogen fuel cell car; Bio-sourced products; Lightweight materials; Reused/recycled or reusable/recyclable material; Modular manufacturing
	Process optimization	Production efficiency (energy, water, materials)
	Responsible consumption and procurement	Sourcing materials from sustainable supply chains
Intensified product use	**Sharing economy**	None found
	Short-term renting	Car and tire rental, lease or subscription
Extending life of products and components	**Maintenance and repair**	Telematics for maintenance prevision; Extended warranty; Repair services
	Donating and reselling	Buy-back or trade-in programs

	Refurbishing	Remanufacturing parts and/or vehicles	
	Performance economy	Product as a service	
Giving resources new life	**Industrial ecology**	None found	
	Recycling and composting	Take-back programs for recycling	Recycling electrical batteries of EV
		Recycling end of life vehicles/ components	
	Energy recovery	Tire-Devrived Fuel	

Extending the life of products and their components is another way to **OPTIMIZE** resource use. Strategies to do this include **designing for durability, repair and refurbishment**. **Modular manufacturing** for example, allows car parts to be easily reconfigured and replaced. **Donating and selling** unwanted vehicles is another strategy. Tesla, for example, runs a **trade-in program** for many types of vehicles, the value of which can be put towards the purchasing of a Tesla vehicle.[33] Car parts removed during servicing can also be **repaired** and sold as **remanufactured** parts or **recycled** for use in new applications.[34] Providing customers with **extended warranties** is another method of extending product life as it holds the manufacturer accountable for the long-term performance of their product. This is seen in practice by Tesla, who offer an eight-year, unlimited battery and drive unit warranty.[35]

Finally, given the high value of the materials used in cars, the automotive sector undertakes **recycling** as a key strategy to **give resources new life**. Approaches to this are varied and include recycling of batteries used in electric vehicles,[36] mining end-of-life cars for their more rare materials[37] and stripping nylon from car seats for use in new vehicles.[38] Companies like BMW for example, offer **take-back programs** which can recycle up to 95% of their vehicles, with 85% of the recovered materials being reused or recycled.[39] Many companies around the world are also using automotive tires as feedstock to create **tire-derived fuels**.

The Ontario BioCar Initiative: Developed bioplastic application in vehicle production

Launched in 2006, the Ontario BioCar Initiative was a four year initiative funded by the Ontario government. It was implemented by a group of Ontario universities including the Universities of Waterloo, Guelph, Toronto and Windsor. It sought to advance the use of plant-based materials in the automotive and agricultural industries, to replace fossil fuel based materials.[40]

Through a collaboration with plastics supplier, A. Schulman, the Universities developed a wheat based bioplastic for use in vehicles. They then approached Ford researchers to include the material in one of their vehicles. Less than eighteen months later, Ford was able to incorporate the bioplastic into their productions plant in Oakville, Ontario. This initiative has resulted in a reduction of 13,600 kilograms of CO_2 emissions per year.[41]

Renault: Recovering end-of-life materials

Renault, a French multinational automobile manufacturer, has been applying circular economy practices since 1995 through the integration of recycled plastics into their vehicles. Renault has established an ecosystem for recovering materials from end-of-life vehicles.[42] This recovery ecosystem includes :

- Indra, a joint-venture between Renault and Suez, that has created an end-of-life vehicle dismantling network, comprised of 350 dismantlers. Each year, this network dismantles around 300,000 vehicles, from which vehicle parts are sorted for re-use, materials intended for recycling or waste recovery. Parts that are destined for re-use are remanufactured in France and are used to repair in-use vehicles, representing a 80% reduction in energy compared to the production of new parts.[43]

- Gaïa, wholly-owned by Renault, that coordinates the partnerships and the suppliers of materials that take part in the recycling subsidiaries' activities. Through cooperation with its affiliates, Gaïa has created five closed loops around the production of metallic parts, copper, polypropylene (which constitutes bumpers), Platinoïd Group Metals (sourced from used catalytic converters), and metallic wastes from production processes.[44]

Specific Examples: Objective 1, Reduced Resource Consumption

Ecodesign

Battery electric car

- Volvo[45] has committed to producing electrified cars only. They already offer plug-in hybrid options on all their models, and have commited to launching five new fully electric cars, with the ambition that by 2025, half of the cars they sell will be electric.

- BMW Group[46] plans to enlarge its offer of electromobility, including models with electric drivetrains and plug-in hybrid model. By 2025, the company plans to release 25 electrified models, of which twelve will be purely electric.

- Open Motors[47] designs new technology for electric cars. They promote the development of electric vehicles through TABBY EVO[48] a hardware open-source platform for electric vehicles, and developed 'EDIT[49]' a strategic EV, engineered and cost-optimized for MaaS (Mobility as a Service) providers.

- Solvay Specialty Polymers[50] offer solutions for electrification including fluorinated electrolyte additives, salts, binders, and separators, which improve the performance of the new generation of Li-Ion batteries, offer higher stability and allow batteries to work at higher voltages, increasing range and reducing costs.

Hydrogen fuel cell car

- Toyota[51] developed a hydrogen fuel cell technology that was introduced in its model Mirai, mass production hydrogen Fuel Cell Electric Vehicle, powered by hydrogen and only emitting water from the tailpipe.

- RIVERSIMPLE [52] offers hydrogen-fuelled cars. The company has developed a hydrogen fuel cell engine, with regenerative braking and a super-lightweight chassis that customers can rent and pay by the mile rather than own the car. Company leases fuel cells from suppliers based on performance.

Electric vehicle charging stations

- IONITY[53] a consortium of car manufacturers (BMW Group, Daimler AG, Ford Motor Company, and Volkswagen Group with Audi and Porsche) are executing a plan to build a network of fast-charging stations across Europe, along the major highways.

- Tesla[54, 55] has built the Supercharger network consisting of 1,636 Supercharger Stations with 14,497 Superchargers. The network has delivered over 595 Gigawatthours (GWhs) of energy, saving the equivalent of over 75M gallons of gasoline. In parallel, Tesla Energy has installed over 3.5 Gigawatts of solar installations and has cumulatively generated over 13 Terawatthours (TWhs) of emissions-free electricity.

- Engie[56] launched Elec'Car for electrical vehicles recharge, which is offered in the marketing network of Renault since 2006.

Biobased materials

- TU/Ecomotive[57, 58] created Noah, an electric city car with a body and chassis completely made from plants, biological and particularly light materials, which require up to six times less energy to produce than the usual lightweight car materials such as aluminum or carbon. At the end of its useful life, the material can be composted, or the biocomposite can be ground and used as a raw material for other products, such as building blocks. The non-organic parts can be recycled.
- DSM[59] offers bio-based thermoplastics such as EcoPaXX®, a material suitable for "under the hood" automotive applications - made 70% from castor beans with a 100% carbon neutral footprint.
- Ford[60] used soybean-based foam on the seatbacks and cushions of the 2008 Mustang. Over the past decade, they have produced more than 20 million vehicles containing this foam, avoiding over 250 million pounds of CO_2 emissions. In 2018, Ford used around 300 parts made from biobased materials such as soy, wheat, rice, castor, hibiscus, tree cellulose, jute and coconut, and was exploring applications for tomato skin, bamboo, agave fiber, dandelion roots and algae.

Lightweight materials

- IAC Group[61] offers low impact materials for the automotive industry that are lighter weight and use renewed material. For example, Coreback™ adds a chemical foaming agent to the resin when molding a vehicle interior component, and creates a product that is a 20-to-30 percent lighter than traditional components. FiberFrame™ is a sunroof frame made of 70 percent renewable, raw-material content, that provides up to 70 percent in weight savings compared to conventional metal-reinforced steel sunroof frames.
- Solvay Specialty Polymers[62, 63] offers polymer solutions designed to replace metal, significantly reducing the weight of a vehicle without compromising safety. The polymers have fire retardant and anti-corrosion properties. Solvay also developed a range of silicas that help tire makers reduce the rolling resistance of their products by up to 25%. Consequently reducing fuel consumption and CO2 emissions by up to 7% while increasing safety performance on wet roads.
- DSM[64, 65] offers thermoplastics that are light, reduce engine friction, and can operate in extreme environments. These include Arnite® XT that helps produce electronic power steering systems that are cost-effective, 50% lighter, and have a 40% smaller carbon footprint compared to aluminum equivalents. DSM also developed materials that can replace metal in the vehicle. such as Akulon® and Stanyl® Diablo thermoplastics that are used to extend the lives of automotive parts like airbag systems and under-the-hood components.

Reused/Recycled or Reusable/ Recyclable material

- Volvo [66] is using recycled material to replace plastic parts and textiles in its cars. Volvo's ambition is that at least 25% of all plastics used in new Volvo cars launched after 2025 will be made from recycled materials. The specially-built version of the XC60 car has had over 60 kilos of its plastic parts replaced with parts made of recycled materials, and seats sewn from two different kinds of textiles, both made from recycled plastic bottles. [67]

Modular manufacturing

- TU/Ecomotive[68] created the car Nova using improved modularity and reconfigurable parts and components that can be exchanged and adjusted with minimal effort.
- Open Motors[69] designs modular electric cars which can be upgraded and used longer.
- CLAUT[70] is an automotive platform that focuses on material innovation and modular manufacturing during the design phase, new business models during the use phase, and remanufacturing and material recycling when cars reach end of use. The platform enables cooperation between suppliers, car manufacturers and leasing companies. It organizes a car-sharing program with 250-500 cars that enables second and third lifetimes for these vehicles and also ensures best end-of-use treatment.

The Ideal

- Continued development and adoption of reusable, recyclable, and compostable material in the car manufacture.
- Accessible electromobility through lower prices and available charging stations.
- Effective processes for recycling rare minerals used in electric batteries. Electromobility requires multiple natural resources that are non-renewable. And while electromobility is progressing at a high speed, the industrial processes to recover and recycle the rare material of electric batteries are lagging behind.

Process optimization

Production efficiency (energy, water, materials)

- Ford[71] reduced their absolute operational water use in 2018 by 7.8 percent, contributing to an overall reduction of 65 percent (10.9 billion gallons) since 2000. Their long-term goal is to reduce the use of freshwater in the manufacturing operations to zero, by using non-water-based technologies and tapping into alternative sources such as other companies' greywater and wastewater. Its target is to reduce water use per vehicle produced by 30 percent from 2015 to 2020.

- Tesla[72] integrates energy and water consumption measures in its renovated and new build plants. In the Fremont Factory, the installation of LED lighting, as well as efficiency improvements to manufacturing systems such as compressed air, castings, injection molding, water test booth and cooling towers, combined with a new energy-efficient paint shop, have resulted in over 10 GWhs of energy savings over the last 5 years. As a result of many improvements, the energy use per vehcle manufactured at the Fremont Factory has decreased by 19% since 2016. Tesla is also installing sustainable energy systems at its Gigafactory 1 facilities, using renewable energy generation and storage where possible. Efficient lighting design uses high-efficiency LED light fixtures combined with an optimized layout that reduces the facility's overall electrical load.Tesla designed and built a chilled water plant equipped with a 10M gallon concrete thermal energy storage reservoir. This design is expected to reduce the factory's electrical consumption for chilled water by as much as 40% and water consumption up to 60%, advancing Gigafactory 1 toward its net-zero emissions goals.

- BMW [73] In 2018 BMW Group covered 79% of the electricity supply for its plants with renewable energy. For example, the Bio2Watt biogas system in South Africa supplies the Rosslyn/ZA plant.

- Volvo[74] (Global) aims to reduce its total operational carbon emissions by 25% per car by 2025 compared to 2018. Around 80% of its global plants are powered by renewable electricity.

The Ideal

- Continued production innovations to advance water and energy efficiency.
- Further efforts to reduce the amount of rare and fossil-based materials used in vehicle production.

Responsible consumption and procurement

Sourcing materials from sustainable supply chains

- Drive Sustainability[75] and the Responsible Minerals Initiative (Global) has developed the Raw Materials Observatory, a standardized toolbox of instruments to assess the sustainability risk of the top raw materials for the automotive sector and identify potentially impactful activities that Drive Sustainability partners (i.e. BMW Group, Daimler, Groupe Renault, Scania, Volkswagen, Volvo, Ford, Honda, Jaguar, LandRover, and Toyota) could pursue collectively to address sustainability risks. The first phase of initiative resulted in the release of a report-assessment for 37 materials.[76]

- Tesla[77] advances sustainability in its supply chain by assessing risks related to conflict mineral such as cobalt from the Democratic Republic of the Congo. Tesla pledges that it uses very little cobalt in its batteries and is working to eliminate it entirely.

The Ideal

- Further responsible mineral sourcing, partcularly with regards to conflict minerals.
- Further innovation efforts for replacing rare, and fossil-based materials with alternative eco-friendly materials.

Specific Examples: Objective 2, Intensified Product Use

Sharing economy is not significantly addressed by the sector

Short term use

Car and tire rental, lease or subscription

- Share Now[78] is a car-sharing service provided by Daimler AG and BMW. The members of Share Now have access to the car fleet without owning the cars.
- General Motors[79] offers Maven; a car-sharing service that makes it possible to use a car for a limited time.
- Volvo[80] provides M- Volvo car mobility, for users to rent cars for a limited time.
- Care by Volvo[81, 82] is a car subscription service in the form of a leasing program where Volvo takes care of insurance, repairs, and maintenance.
- Michelin[83] offers trucking, airline and mining companies to use the tires rather than owning them, i.e., Michelin supplies the tires, oversees their management and invoices the customer based on the distance covered, landings made or weight carried. Michelin handles the tires' end-of-life recycling.

The Ideal

- New buisness models that encourage renting, leasing or subsciptions of vehicles or their parts become mainstream.
- Automotive manufacturers working with the companies operating mobility-as-a-service business models to adapt their vehicles to the new mobility needs.

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

Maintenance and repair

Telematics for maintenance prediction

- Business Lease Group[84] provides telematics solutions to help fleet owners manage the costs, lifetime and utilization rate of their fleet. Their solution, called Connected Car, is an in-car technology that provides advanced data safety, maintenance and mileage, as well as predicting motor defects before they occur.

Extended warranty

- Tesla[85] offers an eight-year, unlimited battery and drive unit warranty as part of its Life Extension circular model.

Repair services

- Belron Group[86] repairs and replaces vehicles' windows.

The Ideal

- Availability of new and used quality parts for vehicle maintenance and repair continues to grow.

Donating and reselling

Cars buy-back or trade-in programs

- Tesla[87] has a program to trade-in cars, trucks, vans, and SUVs towards the purchase of a new or used Tesla.

The Ideal

- Reselling is a popular practice for car owners within the useful life of vehicles.
- More manufacturers establish trade-in and buy-back programs for vehicles in good condition and those that can be refurbished.

Refurbishing

Remanufacturing parts and/or vehicles

- Autocraft Drivetrain Solutions Limited [88, 89] operates engine remanufacturing and assembling, supplying original equipment (OE) manufacturers such as Jaguar, Land Rover, Ford, Volvo, Aston Martin and JCB.

- Refuse Vehicle Solutions Ltd (RVS) [90] provides a cost-effective alternative for the public and private sector to purchase new, high quality used, or remanufactured household waste management vehicles. They carry out major modifications, provide specialist preventative repairs and maintenance services, and stock a comprehensive range of used spare parts for waste recycling and waste collection vehicles.[91]

- ACtronics[92] offers test equipment and remanufacturing for the electronic components of vehicles to reduce replacement of parts when this is not necessary. Both the software and hardware parts, as well as the mechanical design, are tested. ACtronics works with garages and dealerships across Europe to provide high-quality, remanufactured components and spare parts for maintenance and repair.

- Perfect Green /No risk parts[93] offers to refurbish used parts of vehicles for reuse.

- Guangzhou Huadu Worldwide Transmission[94] is a Southern Chinese remanufacturing company that services gearboxes and other automotive transmission systems. Guangzhou Huadu owns repair and service centers that produce 35,000 remanufactured units each year. The main driver for success has been the development of an ecosystem that allows for the smooth collection and distribution of parts. Key partners include 21 auto companies and the large 4S automotive spare part franchise.[95]

- Ford's Go Green Dealer Sustainability Program[96] collects parts such as the headlights, bumpers and windshield wiper motors removed during servicing for potential reprocessing from U.S. dealership service centers. The parts are either cleaned, machined and tested before being sold as remanufactured parts, or dismantled and recycled for use in new applications.

The Ideal

- Manufacturers and affiliates offer manufacturer warrantees for refurbished vehicles and parts like they do for new vehicles and parts.

Performance economy

Product as a service

- Uber[97] is a platform that connects car owners with car users to provide on-demand mobility services.

- Eva[98] is a cooperative ride-sharing application based on blockchain.

The Ideal

- Product as a service business models reduce the overall demand for vehicles ownership and the number of vehicles on the road.

Specific Examples: Objective 4, Giving Resources New Life

Industrial ecology is not significantly addressed by the sector

The Ideal

- Industrial sysmbiosis networks develop in the automative industry.

Recycling and composting

Cars take-back program for recycling

- INDRA[99] a joint venture between Renault and Suez, has created an end-of-life vehicle treatment program comprised of 350 end of life (EVL) dismantlers. Every year the venture recovers around 300,000 end of life vehicles.[100]

- BMW [101] has installed recovery systems for end-of-life vehicles in 30 countries and offers environmentally friendly vehicle recycling at more than 2,500 recovery centers. This results in 95% total recycling, with 85% reuse and material recycling.

- Ford[102] offers access to a free take-back network to Ford owners, with sites ensuring the vehicles are treated responsibly at the end of their useful life.

Recycling electrical batteries of EV

- ReCharge[103] a joint project of Suez and Engie, studies the possibility for used batteries of electric vehicles to be used in other applications.

- Tesla[104] is developing a battery recycling system at Gigafactory 1 that will process both battery manufacturing scrap and end-of-life batteries. The goal is to recover critical minerals such as lithium and cobalt, along with all the other metals used in the battery cell, such as copper, aluminum and steel, in forms optimized for new battery material production.

- BMW [105] uses batteries that are no longer suitable for vehicles in stationary storage systems. They are gradually installing battery storage systems at their sites. In the Leipzig/DE plant, BMW uses high-voltage batteries from the BMWi3. The storage farm is connected to the public electricity grid and can take the load off the grid in times of renewable energy peak generation and feed the electricity back into the grid when supply is low. Ultimately, BMW aims to achieve the highest possible rate of recycling of the valuable resources contained in the batteries. In collaboration with a university partner, the BMW Group has developed a procedure which can achieve a recycling rate of more than 90%; in contrast, conventional recycling methods achieve just above 50%.

Recycling end of life vehicles/components

- WIPAG[106, 107] recycles post-industrial and post-consumer plastic waste from several industries with a main focus on automotive parts. Recycled parts comprise bumpers, dashboards, wheel-arch-liners, rocker-panel, front-ends, etc. End products are used for the production of new automotive parts. The product Wipalen can be included in new production up to 35%, and Wipelast can be included in new production from 40 to 100% of the total amount.

- ZICLA[108] recycles plastic parts from scrapped end-of-life vehicles into high-added-value granules.

- Refil[109] produces fully recycled ABS filament made from car dashboards, door panels, and other plastic car parts. The ABS filaments are mainly used for 3D printing.

- Black Bear[110] uses end-of-life tires as a feedstock to produce consistently high-quality Carbon Blacks. This has several applications in the production of tires, technical rubbers, inks, and coatings. One Black Bear plant prevents more CO_2 emissions than one million trees can sequester.[111]

- Umicore [112, 113] recycles, refines, transforms and sells precious metals, cobalts, and materials recovered from industries, including the automotive sector. Eco-efficient recycling and refining services recover and sell precious metals (silver, gold, platinum, palladium, rhodium, iridium, ruthenium), minor metals (indium, selenium, tellurium, antimony, tin, bismuth) and base metals (lead, copper, nickel).

- Geo-Tech's[114, 115] nontoxic toll processing reclaims thermoplastics from post-consumer plastic scrap like car bumpers, and manufactures engineering-grade thermoplastic compounds that can be used in high-end applications. Geo-Tech's process returns the value of these materials to the manufacturing customers for re-use in high-end exterior automotive applications with significant potential for cost reduction.

- Ecore Group[116, 117] recycles end-of-life vehicles and waste from electrical and electronic equipment. They recycle ferrous metals (steel), non-ferrous metals (aluminum, copper ...), lead-acid batteries, paper-cartons and plastics. Thanks to their treatment centers, Ecore Group achieves a material recovery rate of more than 80% for all materials and up to 98% for battery components.

- Ford[118] uses nylon from recycled, post-consumer carpet, as molded engine components. In 2018, they launched an extension dash panel on the 2019 Ford Edge made from recycled tires.

- ARN[119] aims to recover and recycle parts and materials of end-of-use vehicles. In 2011, ARN opened the PST plant, where shredder waste from cars is processed into reusable materials.

The Ideal

- Increased "extended producer responsibility" related to vehicle's recycling after the end of its useful life.
- Promoting the environmental and economic opportunities related to establishing a take-back scheme for materials and parts recovery.

Energy recovery

Tire-Derived Fuel

- Glocal Clean Energy[120] is a waste to energy company that uses end-of-life tires to create a tire derived carbon balck to repace crude oil derived carbon black for pigmentation and lower grade rubber products.

- Liberty Tire Recycling[121] reclaims more than 3 billions pounds of rubber for innovative products. The recycled rubber produced by Liberty is used as industrial feedstock for tire-derived fuel for industrial kilns, mills and power plants among other applications.

The Ideal

- All automative waste materials with no higher and better use are used to generate energy rather than sent to landfill.

7.4. Additional Resources

The following are additional resources that researchers, practitioners, and policy-makers can draw on to further advance awareness and understanding of opportunities for circularity for Canada's automotive manufacturing sector.

Selected Global Public Policies Supporting Automotive Manufacturing Circularity

- *EU's Directive on End-of-life Vehicles (ELV) :* aims to make the dismantling and recycling of ELVs more environmentally friendly. It sets clear quantified targets for reuse, recycling and recovery of the ELVs and their components. It also pushes producers to manufacture new vehicles without hazardous substances thus promoting the reuse, recyclability and recovery of waste vehicles.[122, 123]

- *Québec's Politique de mobilité durable 2030 :* promotes car-sharing, electromobility and low emission mobility. [124]

- *Québec Plan d'action en électrification des transports 2015-2020:* set targets of 100,000 electric and hybrid vehicles on Quebec roads by 2020 and 300,000 by 2026, supported by $420 million in funding, mostly from the Fond Vert. Among the measures, programs of note are: Roulez Électrique, which offers an $ 8,000 rebate on the purchase of an electric vehicle; Branché au Travail of the Ministry of Energy and Natural Resources (MERN), providing financial assistance to businesses and municipalities for the installation of charging stations in the workplace; and Circuit Électrique, the provincial network of public electric charging stations. [125]

- *Ontario's BioCar Initiative :* was a partnership between the automotive industry and the public sector aimed at accelerating the use of biomass in automotive materials. [126]

- *Germany's National Platform for Electric Mobility :* was set up in 2010 with representatives from the German government, industry, unions and civil society, to promote electromobility in Germany.[127, 128]

Selected Documents on Circular Economy and the Automotive Manufacturing Sector

Understanding the circular economy in the global automotive sector

Drabik, E., & Rizos, V. (2018). *Prospects for electric vehicle batteries in a circular economy*. Centre for European Policy Studies (CEPS). Retrieved from https://www.ceps.eu/ceps-publications/prospects-end-life-electric-vehicle-batteries-circular-economy/

This report examines the end-of-life impacts for lithium-ion batteries in Europe and considers how valuable materials contained in batteries can be recycled and recovered. Due to increasing demand for electric vehicles, demand for lithium-ion batteries is increasing. It recommends that Europe increase the recycling and collection of electric vehicle batteries to reduce dependence on critical materials, and concludes that initative would increase jobs, reduce greenhouse gas emissions, and lead to more material value retained within the European economy.

Kemps, D., Vos, R., Kubbinga, B., Ramkumar, S., Bardout, M., Rienstra, F., & Marc de Wit, M. (2016). *On the Road to the Circular Car: How car component suppliers can become future-proof by applying circular economy principles*. ABN AMRO & Circle Economy. Retrieved from https://publish.circle-economy.com/thecircularcar

This report highlights how growth in connectivity and shared services are having a significant impact on the automotive industry. It finds that innovative circular economy practices can help the industry respond to the major trends that it faces. Written with the Dutch automotive sector in mind, the report suggests circular strategies that could be applied globally, including the use of recyclable, low-impact materials, design for disassembly, and introducing take-back programs.

Ellen MacArthur Foundation. (2012). *The Circular Economy Applied to the Automotive Industry*. Retrieved from https://www.ellenmacarthurfoundation.org/news/the-circular-economy-applied-to-the-automotive-industry-2

Highlighting the importance of materials to the automotive industry, this report identifies that price increases and geopolitical risks could potentially impact the sector. As a result, recycling and the use of recycled materials is one strategy that could mitigate these impacts. This article profiles a case study of a car part remanufacturing site in Choisy-le-Roi, France, which produces no raw material waste and uses 88 percent less energy compared to the manufacturing of new car parts.

Ellen MacArthur Foundation & Arup. (2019). *Urban Mobility System*. Retrieved from https://www.ellenmacarthurfoundation.org/assets/downloads/Mobility_All_Mar19.pdf

This report outlines promising circular economy strategies for the automotive sector. For example, vehicles can be designed for adaptable and shared use and be reconfigured through modularity. Existing internal combustion engine vehicles could switch to biofuels made from by-products. Highlighting the connectivity of urban mobility systems, the report also outlines circular mobility strategies beyond the automotive manufacturing sector, from compact development to urban freight strategies.

Lacy, P., Gissler, A., & Pearson, M. (2016). Automotive's latest model: *Redefining competitiveness through the circular economy.* Accenture. Retrieved from https://eu-smartcities.eu/sites/default/files/2017-12/Accenture-POV-CE-Automotive.pdf

This report recommends that the automotive sector adopt circular economy principles to maintain its competitiveness. Sharing services, circular supply chains, products as a service, product life extension, and recovery and recycling could lead to billions of dollars in revenue for the sector by 2030, while reducing the base cost of cars. These benefits could be achieved through developing circular economy strategies, establishing partnerships, enacting organizational changes, and managing a product's lifecycle.

Circular economy principles in the Canadian automotive sector

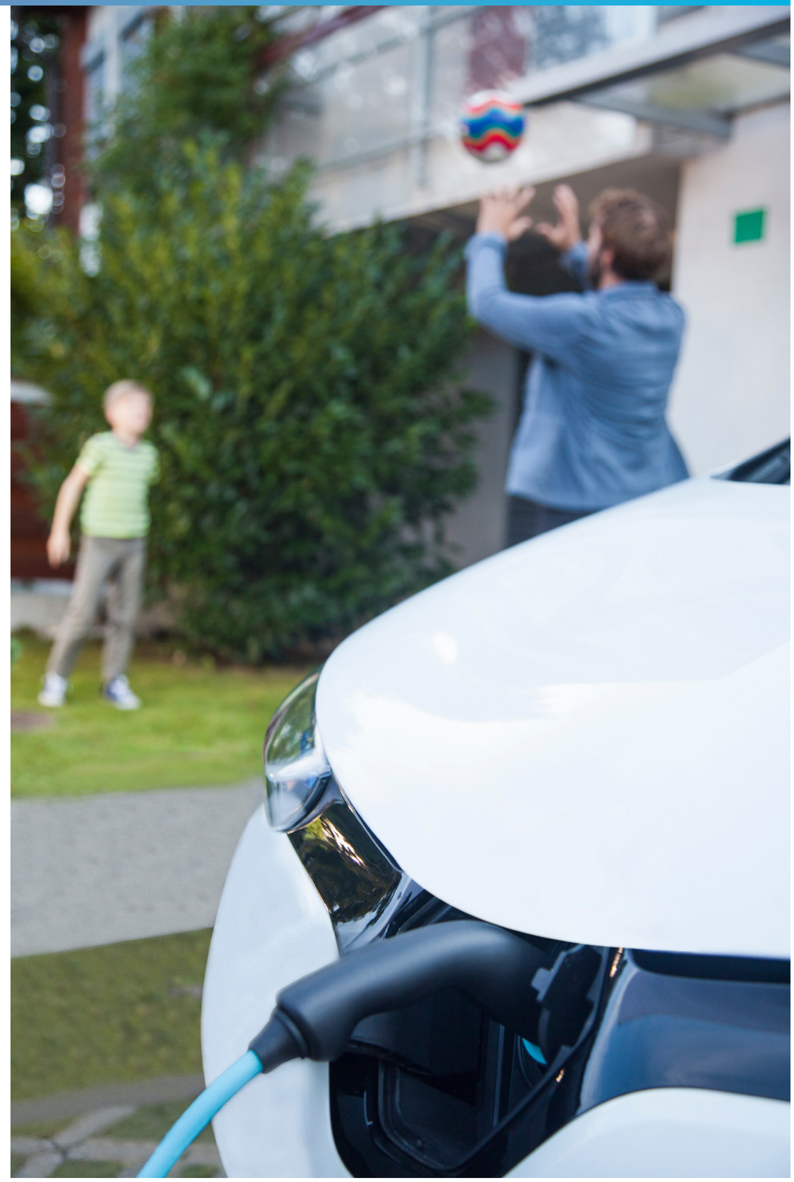
KPMG. (2019). *The state of Canada's auto sector: Recalculating the route ahead*. Retrieved from https://assets.kpmg/content/dam/kpmg/ca/pdf/2019/02/the-state-of-canada-s-auto-sector.pdf

With a globally competitive supply chain, Canada can remain a global automotive competitor in a changing sector. This report identifies technological changes, shifting consumer preferences, and changing trade and economic trends as major impacts in the sector. According to the report, the government can play a role in securing trade and managing changes in mobility. It states that suppliers that can provide cost-effective lightweight materials will become the suppliers of choice.

7.5. Conclusion to Automotive Manufacturing

This global scan of best circular economy practices in the automotive manufacturing sector reveals that many firms and operations are already implementing a wide range of practices that support circular economy objectives and strategies, whether or not these practices have been explicitly identified as circular. However, more wide-spread adoption of such strategies and practices will be key to reducing the sector's resource consumption and greenhouse emissions, and to recovering valuable precious metals and materials at the end-of-life of vehicles.

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 roadmap for the Canadian automotive manufacturing sector's journey to a circular economy.



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