Final Report – Exploring Circular Economy for Rubber in Canada

Prepared for Environment and Climate Change Canada

Prepared by Dillon Consulting Limited and Oakdene Hollins

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Value-driven consulting

Science-led research

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Glossary

$CAD	Canadian currency
€	Euro currency
$US	U.S. currency
ABS	acrylonitrile butadiene styrene
ADF	advanced disposal fee
ADP	acid deposition potential
ARMA	Alberta Recycling Management Authority
ASNZ	Auto Stewardship New Zealand
ASR	automotive shredder residue
ASTM	ASTM International, formerly known as American Society for Testing and Materials, an international standards organization
B[a]P	benzo[a]pyrene
BART	Bay Area Rapid Transit
BAU	business as usual
BIIR	brominated butyl rubber
BISYKA	biomimetic synthetic rubber
BR	butadiene rubber
CAGR	compound annual growth rate
CATRA	Canadian Association of Tire and Rubber Agencies
CE	Circular Economy
CIIR	chlorinated butyl rubber
CRM	critical raw material
CSR	corporate social responsibility; commitment to practice environmental and social sustainability
CUSMA	Canada-United States-Mexico agreement
Dillon	Dillon Consulting Limited
ECCC	Environment and Climate Change Canada
EfW	energy from waste
ELV	EoL vehicle
ELT	EoL tire
EoL	end-of-life
EPA	U.S. Environmental Protection Agency
EPDM	ethylene propylene diene monomer
EPR	extended producer responsibility
EPU	equivalent passenger unit
eq	Equivalent
EU	European Union
EVA	ethylene-vinyl acetate
GDP	gross domestic product
GHG	greenhouse gas
GM	General Motors
GPSNR	Global Platform for Sustainable Natural Rubber
GWP	global warming potential (quantified as tonnes CO_2 equivalent)
HDPE	high density polyethylene
IIR	butyl rubber
IPR	individual producer responsibility
LCA	life cycle analysis
LGNR	liquid guayule natural rubber
MFA	material flow analysis
MSW	municipal solid waste
N/A	Not applicable
NAFTA	North American Free Trade Agreement
NAICS	North American Industry Classification System
NBR	nitrile butadiene rubber
n.d.	no date available, for reference data source
OEM	original equipment manufacturer
OTR	off the road
PAH	polycyclic aromatic hydrocarbons
PM	particulate matter
POM	placed on market

PROs	producer responsibility organizations
PSO	Product Stewardship Organization
PVC	polyvinyl chloride
rCB	recovered carbon black
RCO	Recycling Council Ontario
RMA	rubber modified asphalt
R&D	research and development
SBR	styrene-butadiene rubbers
SEBS	styrene-ethene-butene-styrene
TDA	tire derived aggregate
TDF	tire derived fuel
TRACC	Tire Recycling Atlantic Canada Corporation
TRL	technology readiness level
TWP	tire wear particulate
UK	The United Kingdom of Great Britain and Ireland
U.S.	The United States
USA	The United States of America
USTMA	U.S. Tire Manufacturers Association
VAT	value added tax (U.K.)
VRPs	value retention processes
WBCSD	World Business Council for Sustainable Development
WEEE	waste electrical and electronic equipment
WRAP	Waste and Resources Action Programme (UK)
WTE	waste-to-energy
ZnO	zinc oxide

Units

Conventional International System of units (SI) and prefixes used throughout.

kt, Mt	Thousands, millions of metric tonnes mass (1 tonne = 2205 lb)
g, kg	Grams, kilograms mass (1 kg = 2.205 lb)
lb	Pounds (imperial) mass
kg CO_{2e}	kg of global warming potential gases expressed as equivalent kg of CO_2
MJ/m^3	Megajoules per cubic meter
MJ/kg	Megajoules per kilogram
$CAD million	Millions of Canadian dollars
µm	Micrometer ($1*10^{-6}$ m)

Definitions – related to EoL treatment

Core A product assembled from durable components suitable for recovery and remanufacture. Paraphrased from (Patterson, Ijomah, & Windmill, 2017)

Prevention Measures taken before a substance, material or product has become waste, that reduce the quantity of waste, including through the re-use of products or the extension of the life span of products. (The European Parliament and the Council of the European Union, 2008)

Recovery Any operation where the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy. (The European Parliament and the Council of the European Union, 2008)

Recycling Any recovery operation by which waste materials are reprocessed into products, materials, or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations. (The European Parliament and the Council of the European Union, 2008)

Reuse Any operation by which products or components that are not waste are used again for the same purpose for which they were conceived. (The European Parliament and the Council of the European Union, 2008)

Waste Any substance or object which the holder discards or intends or is required to discard. (The European Parliament and the Council of the European Union, 2008)

Contents amendment record

This report has been amended and issued as follows:

Version	Date	Description	Authors	Editor
1	March 30, 2021	First draft for client review	L. Andrews, L. Oldfield	
2	April 7, 2021	Final for client sign-off	L. Andrews, J. Bertrand, L. Oldfield	C. Weins

1 Introduction and Background

This document is a report on the work carried out under Environment and Climate Change Canada's (ECCC) bid solicitation 500 004 7787, Exploring Circular Economy for Rubber in Canada, completed in April 2021.

The study has been carried out, on behalf of ECCC, to develop a profile of the Canadian rubber industry and market, and to explore the flow of materials and products through the value chain, from feedstock to end of life (EoL) treatment.

Findings of this study will help inform the development of a national strategy through identification of opportunities and barriers to transitioning to a circular economy (CE) for rubber in Canada. This strategy might involve a mix of measures, such as regulatory or market interventions, from the technology employed through sustainable product supply chains to the circular 'loops' which can regenerate products, to reduction of barriers and identification of opportunities for further research that have a high potential for enhancing the circular economy of rubber.

This initiative is part of ECCC's ongoing work to support a circular economy approach for the management of products and waste, and to implement the comprehensive federal agenda on waste reduction.

1.1 Project Tasks

Dillon Consulting Limited (Dillon) and Oakdene Hollins Ltd. were retained by ECCC to research and develop a profile of the Canadian rubber industry and market. The scope of this investigation covered the flux of materials and products through the value chain from feedstock to end of life (EoL) treatment to determine opportunities and barriers to transitioning to a circular economy for rubber in Canada. The team acquired an understanding of the current size and shape of the Canadian rubber industry, through four project tasks:

Task 1 – Characterization of the production, flows and fate of materials and products container rubber.

Task 2 – Economic profiling and competitive analysis of the Canadian Rubber Industry.

Task 3 – Identification and analysis of emerging solutions and technologies to reduce rubber waste.

Task 4 – Synthesis of findings from Tasks 1 through 3 related to the opportunities and challenges and potential socio-economic and environmental benefits of transitioning to a circular economic in Canada, including identifying information gaps and recommendations for further research.

Figure 1 overviews the relationship of tasks conducted (coloured) to their expected outputs (greyed) in this project.

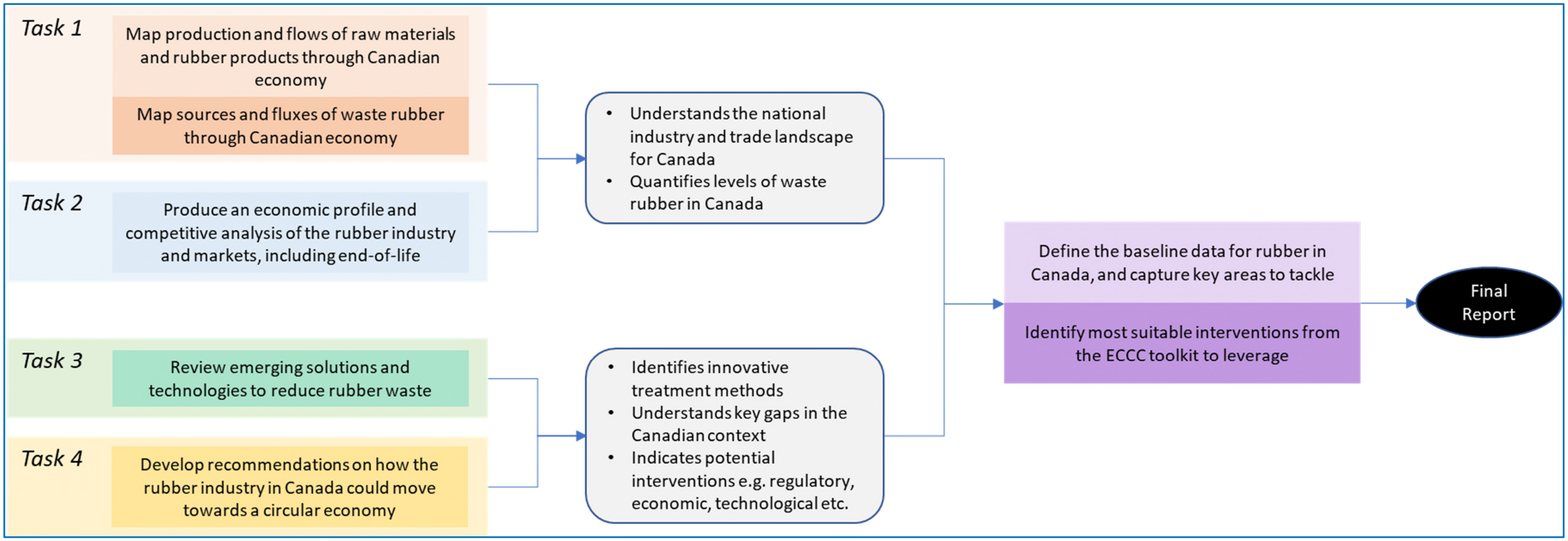

Figure 1: Estimates of Imports/Exports of Resins, Rubbers and Additives for 2019

1.2 Project Scope

The scope of work included the following:

- Undertaking desk-based, primary and secondary data collection to develop a national profile of rubber resin production, import, export, and waste management for rubber products in Canada.
- Preparing an economic profile for primary and secondary rubber, and competitive analysis of the rubber industry and markets including end-of-life (EoL) industry in Canada.
- Identifying factors that influence the pricing, demand and supply of primary and secondary rubber and assessing competition within the domestic market and from international sources.
- Identifying existing barriers, including financial, regulatory, technological, labour, availability of materials, foreign competition, trade barriers, etc., that are inhibiting the growth of rubber industry activities in Canada.
- Identifying measures that have influenced market functions in support of a circular economy and reducing rubber waste.
- Identifying and analyzing the overall benefit and success of current and emerging technological innovations to reduce rubber waste and increase the circularity of rubber.
- Rating of technologies/processes using a balanced scorecard approach to reveal the best opportunities for technological solutions towards more circularity in rubber.
- Identifying opportunities for the Government of Canada to positively influence market forces to encourage increased rubber industry activity using a range of approaches including policies, purchasing behaviors, research, taxation.
- Synthesizing the findings of challenges and opportunities and discussing the potential socio-economic and environmental benefits of transitioning to an enhanced circular rubber economy in Canada.

1.3 About this report

This report summarizes the salient findings and supporting information from all component tasks of the research. A high-level summary of the findings and conclusions is provided in a separate Executive Summary and is not repeated here. However, this report does bring to the attention of the reader the following:

- **Future research topics** – gaps in knowledge, practice or understanding that deserve further investigation to reduce significant uncertainties in possible future actions.
- **Context information fragments** – noteworthy points which have lower stand-alone significance, but which contribute with other fragments to forming the bigger picture.
- **Transferable learning points** – typically policy and practice domestically or from abroad which demonstrates successful, practical approaches to CE in rubber or related materials.

Within the text, these highlights are displayed using the following colouring and icons.

	Future Research topic		**Context information fragment**		**Transferable learning point**

2 Method and Approach

The following outlines the team's approach to data collection, jurisdictions reviewed, COVID-19 impacts, currency and research engagement for this project.

2.1 Data Collection

Significant efforts were put towards the collection and assimilation of existing data and information from existing studies and research, largely from other jurisdictions. Data gaps were filled through interviews with Canadian industry members and through the development of proxies based on proven best practices from other jurisdictions, academic literature and other relevant technical methods. For example, while data can be limited in Canada, a proxy for production and waste volumes of rubber based on product lifecycles and historical production and trade data to estimate when rubber products will reach end of life (EoL) was used. In cases where proxies are used, methods and sources have been provided.

Overall, industry engagement was moderate so some caution must be applied to generalization of the findings. However, the responses received were very much in line with what has been discovered in other developed economies. Further, the interviews provided an opportunity for industry players to review, refute and improve the findings. No major objections to the findings were received during this process and the report has been moderated where appropriate.

A limitation of much of the research and data in Canada is the lack of information regarding circular economy activities for much of the rubber industry. Of the three main rubber sub-industries, the tire manufacturing industry publishes by far the most detail on the trajectory of their products, from upstream processing and manufacturing activities, through the industry itself, and on to end users (in the linear economy) and beyond (in the circular economy).

2.2 Jurisdictional Review

This study has focussed on the rubber industry in Canada but includes a review of international practice. This allows some benchmarking of Canadian activity and practice against competitors, understanding potential barriers and supporting measures as well as assisting in modelling impacts, costs and benefits. The review has examined the state of play in the North America, EU, United Kingdom (UK), Asia, and South America.

2.3 COVID-19 Impact to Business Data

Relatively early in the project, the hazards of COVID-19, became very apparent to all countries. In March 2020, North American economies enacted 'lockdown' measures impacting the movement of and contact between citizens. The tire manufacturing industry in Canada exhibited contraction mainly due to the pandemic in 2020. Declines in vehicle sales in North America and significant reduction of travel in 2020 arising from pandemic lockdown measures are the primary reasons for this decline. The longer-term effect on the industry due to the global pandemic will remain unknown for the foreseeable future. We acknowledge that in such a fluid situation, great uncertainty in forecasting will remain. Data collected in 2020 was not available at the time of this report with updated data due to COVID-19 economic impacts.

2.4 Financial Currency

Unless otherwise stated, where financial statistics (revenues, etc.) are converted in a foreign currency at a particular date, they have been transcribed to Canadian dollars ($CAD) using the exchange rate prevailing at the time, using rates quoted by the Bank of Canada.

2.5 Research Engagement

The industry players that were contacted and contributed directly or indirectly in the research have contributed data that has been consolidated. Note that the content of this study is the work of the authors and is informed by the contributions but may not reflect the views of the participants in full. The one-to-one interviews have been rich, accounting for the high-level sector views. The team scanned government websites for any potentially relevant legislation or extended producer responsibility (EPR) policies The extent to which circular economy activities are present in the provinces and territories is not known and not routinely monitored to date.

3 Characterization of Production, Flows and Fate of Rubber Materials and Products

This report section, addressing Task 1 of the project, focuses on the rubber demand in Canada in tire and non-tire automotive rubber production. This accounts for approximately 85% of total rubber demand in Canada (Personal Communication, Tire and Rubber Association of Canada (TRAC), 2020). Limited information on the mass and value of other rubber products produced, imported and exported in Canada was found.

3.1 Rubber Production Profile

Arlanxeo is the only known producer of synthetic rubber in Canada. Their site is located in Sarnia, Ontario (ChemInfo, 2013). No production of natural rubber occurs in Canada. Any natural rubber is imported into Canada.

3.1.1 *Production and Trade of Primary Rubber Resins*

The primary types of rubber used in tires and non-tire automotive rubber products are summarized in **Table 1.** Domestic production of rubber products in 2019 in Canada totalled approximately $CAD 6.69 billion.

Table 1: Rubber Types Used in Tire and Non-Tire Automotive Rubber Products in Canada

Rubber Type	Application
Butadiene Rubber (BR)	Tires
Styrene Butadiene Rubber (SBR)	Tires, hoses, vibration dampeners, belts, other automotive rubber
Butyl Rubber (IIR)	Tires
Ethylene Propylene Diene Monomer (EPDM)	Weather stripping, hoses, vibration dampeners, belts, other automotive rubber
Polychloropene (Neoprene)	Hoses, vibration dampeners, belts, other automotive rubber
Natural Rubber	Tires, hoses, vibration dampeners, belts, other automotive rubber

Research indicates that all natural rubber used in Canada is imported and that there is only one producer of synthetic rubber in Canada –Arlanxeo, formerly owned by Lanxess. In 2018, Lanxess completed the sale of Arlanxeo to Saudi Aramco, defining the two separate businesses and transferring ownership of the Sarnia plant to Arlanxeo[1]. At their Sarnia plant, Arlanxeo produce un-halogenated butyl rubbers (IIR), chlorinated butyl rubber (CIIR) and brominated butyl rubber (BIIR) (Cheminfo, 2013).

Using available production and economic data from Statistics Canada, market prices for commodities and available market reports, Dillon and OH have estimated the value and mass of additives, resins and rubber products related to tire and non-tire automotive rubber products that were produced, imported and exported in Canada in 2019, as well as the end-of-life (EoL) generation of these products. These estimates were then sense-checked using available industry data and calculations of domestic demand for resins and additives based on available rubber and resin formulas. Given the level of disaggregation of available data, the production numbers presented in this report should be considered high level estimates.

[1] https://lanxess.com/en/Investors/Publications/IR-Releases/2018/12/LANXESS-completes-sale-of-ARLANXEO-to-Saudi-Aramco

Imports/Exports of Latex, Additives and Rubber

Natural rubber, primarily derived from the *Hevea brasiliensis* rubber tree, is imported to Canada primarily from southeast Asia. However, there are current studies underway by the US government and companies such as Bridgestone Tires to determine the natural rubber from the Guayule shrub, found in the southern United States and Mexico, may be a viable alternative (Bridgestone Tires, 2015).

It is our understanding that all other synthetic resin and rubbers (other than those outlined elsewhere in this report) are currently imported. **Table 2** summarizes estimates of the current value and volume of imported and exported resins, rubbers and additives.

Table 2: Estimates of Imports/Exports of Resins, Rubbers and Additives for 2019

Rubber Latex, Inputs, and Compounded Rubber	Imports		Exports	
	Value ($CAD million)	Mass (kt)	Value ($CAD million)	Mass (kt)
Resin				
Natural/Compounded Rubber	460	118.8	0.4	0.114
Latex	85	22.0	0.2	0.052
Compounded Rubber & Tire Rubber Product				
Compounded SBR/BR/IIR[1]	506	131.5	371.7	96.2
Compounded NBR/EPDM rubber	121	31.2	7.0	1.8
All Other Rubber Inputs	205.7	53.2	354.3	91.6
Unvulcanized Tire Rubber	251	65.3	424.2	110.1
Additives				
Emulsifier / Accelerator[2]	61.3	14.7	2.8	0.5
Antioxidants[2]/ Softeners/Extenders[2]	117.7	23.9	85.6	21.8
All Other Chemicals[2]	6,907	3,360	3,295	1,603

Notes:
1. Chemistry Industry Association of Canada, 2019
2. We could not achieve sufficient disaggregation of data, therefore these values also include chemical products used by other industries

3.1.2 *Domestic Demand of Latex, Additives and Rubber*

The value and volume of domestic demand for resins, additives and rubber (**Table 3**) in Canada has been estimated based on economic data (where disaggregated data exists) or from bottom up estimates to meet the domestic production of tires and non-tire automotive rubber.

Table 3: Estimates of Domestic Demand of Resins, Rubbers and Additives for 2019

Rubber Latex, Inputs, and Compounded Rubber	Estimate of Domestic Demand	
	$CAD million	Tonnes
Resin		
Natural/Compounded Rubber	458.75	118.9
Butadiene/Styrene Latex	85.0	250
Compounded Rubber		
Compounded SBR/BR/IIR	555.1	171
Compounded NBR/EPDM rubber	113.9	29.6
All Other Rubber Inputs	152.4	39.49
Tire Rubber Product		
Unvulcanized Tire Rubber	187.8	48.34
Additives		
Emulsifier / Accelerator[1]	86.7	20.7
Antioxidants[1]/ Softeners/Extenders[1]	146.7	28.9
All Others	No data	604.1

Note:

1. These values also include chemical products used by other industries because disaggregation of data was not possible.

3.1.3 *Production and Use of Tire and Non-Tire Automotive Rubber Products in Canada*

Rubber Products Produced and used in the Automotive Sector

To quantify the rubber products produced and used by major sectors per annum in Canada, an estimate of tire and non-tire automotive rubber stocks and flows were produced. Stocks represent the rubber products in Canada in the 'in use' phase of their lifecycle. Flows represent the domestic demand for new rubber products and the generation of EoL rubber products in Canada per annum. An estimate of the number of tires produced, imported and exported in 2019 and their value is summarized in **Table 4**.

Table 4: Estimate of Tire Production, Imports and Exports in Canada in 2019

Tires	Domestic Production (tires)		Imports[1]		Exports	
	Tires (millions)	Value ($CAD million)	Tires (millions)	Value ($CAD million)	Tires (millions)	Value ($CAD million)
Passenger	17.6	1,422	31.7	2,561	12.4	1,000
Commercial	2.6	1,148	7.6	1,255	6.4	1,058
OTR[2] / Other	1.11	393	5.3	1,307	0.48	101.8
Retread -Passenger/ Commercial	1.607	113.2	0.035	1.1	0.011	0.6
Retread -OTR / Other	0.035	57.9	0.041	8.4	0.0044	8.0

Notes:

1. Includes tires imported on finished vehicles
2. Off-the-Road (OTR) vehicles (excavators, mining trucks, tractors, etc.)

An estimate of domestic demand and EoL generation of tires in Canada in 2019 is summarized in **Table 5**.

Table 5: Estimate of Tire Demand and Generation of EoL Tires in Canada in 2019

Tires	Domestic Demand (tires, millions)	EoL Tires Generated (tires, millions)
Passenger	36.9	33.7[1]
Commercial	3.8	3.3[2]
OTR / Other	6.9	9.6[3]
Retread -Passenger/Commercial	1.63	NA
Retread – OTR / Other	0.06	NA

Notes:

1. Assumes a lifecycle of 5 years
2. Assumes a lifecycle of 2 years
3. Assumes a lifecycle of 3 years

An estimate of the mass and value of non-tire automotive rubber products produced, imported and exported in Canada in 2019 is summarized in **Table 6**.

Table 6: Estimate of Non-Tire Automotive Rubber Production, Import and Export in Canada in 2019

Other Automotive Products	Domestic Production		Imports		Exports	
	Mass (kt)	Value ($CAD Million)	Mass (kt)	Value ($CAD Million)	Mass (kt)	Value ($CAD million)
Weather-stripping	18	154.4	42.9	343.2	14.9	125.0
Belts/Hoses	13.9	155.3	58.5	658.2	4.48	50.4
Vibration Isolators	13.8	115.6	32.1	269.4	11.2	94.0
Other	20.9	175.1	32.3	271.1	16.4	137.6
Total	**66.6**	**600.4**	**165.8**	**1,541.9**	**47.0**	**407.0**

An estimate of domestic demand and EoL generation of non-tire automotive rubber products in Canada in 2019 is summarized in **Table 7**.

Table 7: Estimate of Non-Tire Automotive Rubber Demand & EoL Generation in Canada in 2019

Other Automotive Products	Domestic Demand (kt)	EoL Generated (kt)[1]
Weather stripping	46.4	44.8
Belts / Hoses	67.9	62.5
Vibration Isolators	34.7	33.5
Other	36.8	31.3
Total	185.8	172

Note:

1. Assumes a lifecycle of 7 years

An estimate of the 'in use' tire and non-tire automotive rubber products in Canada in 2019 is summarized in **Table 8**.

Table 8: Estimates of 'In Use' Tires and Non-Tire Rubber Automotive Products in Canada in 2019

Tires units	Tires Mass (kt)	Weather stripping Mass (kt)	Vibration Isolators Mass (kt)	Hoses/Belts Mass (kt)
213,466,010	5,826	624	468	1,092

3.1.4 *Overview of Rubber Additives Used in the Automotive Sector*

An overview of the identified additives used in rubber manufacturing and their impact on the end-of life fate of rubber is summarized in **Table 9**. The major barrier, globally, to greater circularity of rubber, is the vulcanization process: The creation of sulfur bonds in natural and synthetic rubber gives the end product its desired strength, but makes the material extremely difficult to recycle fully. Great strides have been made globally to collect and 'find a use for' used rubber products (mainly tires), thereby avoiding stockpiling. However, the fact remains that too high a proportion of the EoL rubber from high volume products, such as footwear and tires, are either incinerated as fuel or 'downcycled', after which the rubber cannot be recovered or recycled a second time.

True circularity for rubber will only occur when an effective and economic process for the conversion of used rubber crumb into a material suitable as feedstock for the manufacture of new, high tech products, is available.

Over twenty years the authors have witnessed many varied attempts to achieve true devulcanization of rubber crumb, by chemical, thermal and biological treatment, or to develop a surface treatment process that would enable the used rubber to bond effectively with virgin materials, thereby achieving higher recycled content new products. None of these have yet proven commercially viable. Many such processes remain at the laboratory/pilot phases.

Table 9: Primary Additives Used for Tires and Non-Tire Automotive Products and Their Impact on EoL Use

Name	Uses	Impact on EoL Fate
Carbon Black	Filler to strengthen and increase rubber volume	Due to the embodied value of carbon black, and open secondary markets, its use drives EoL tire rubber to pyrolysis, the most common carbon black recovery route. This drive is bolstered by the opportunity to recover steel in tandem[2].
Sulphur	Vulcanizing Agent	Sulphur itself is of little concern as a material, but the process of vulcanization is the largest impactor on EoL fate across all rubber streams. There has been little in the way of success of devulcanizing rubber due to the strength of the bonds formed, meaning direct recycling is challenging and the rubber tends to be downcycled.
Zinc Oxide (ZnO)	Activator	Zinc oxide presents acute and chronic toxicity in aquatic environments. Zinc is the key issue in this compound, as along with the above concerns it can accumulate in biological systems and is of particular concern in the case of rubber mulch from tires/other rubber which may leach[3]. As such, mulch is not a recommended treatment/second life route for rubber waste.
Stearic Oxide	Softener	Though stearic acid, the raw material going into tires, is of concern, the compound stearic oxide is not of great concern and does not appear to impact chosen tire EoL route.
Accelerators	Increases the speed of vulcanization	As with sulfur above, vulcanization accelerators (e.g., sulfonamide, thiozoles[4]) are not of great concern, though the process they take part in is the greatest barrier to rubber recycling.

[2] https://www.grandviewresearch.com/industry-analysis/recovered-carbon-black-market
[3] Masakazu Kanematsu, Ai Hayashi, Michael S. Denison, Thomas M. Young, Characterization and potential environmental risks of leachate from shredded rubber mulches, Chemosphere, Volume 76, Issue 7, 2009, p952-958. https://www.sciencedirect.com/science/article/pii/S0045653509004809
[4] Vulcanization Accelerators - The Next Level Solution for Tire Manufacturing

Name	Uses	Impact on EoL Fate
Loading or filling pigment	Fillers are fine particulate materials added to a substance to modify or enhance its physical properties or to extend more costly or scarce materials. Includes Carbon Black, silicate, clay	It should be noted that, over recent years, carbon black has been substituted in higher quantities by silica as a filler. This has little effect, unless devulcanization is the desired recycling route. If this is the case, silica is noted as making the tire rubber harder to devulcanize (in that a lower tensile strength can be recovered via the process, 70% vs 95%)[5].
Reclaim rubber	Can be waste from processes or EoL rubber products	Reclaim rubber is typically vulcanized rubber that is ground and mixed with crude rubber for compounding (i.e. scrap prepared for recycling/reuse[6]). In this sense, it does not impact on the EoL treatment, though it must be considered that most materials will have a limited cycle life.
Softener, Extender, Plasticizers	Softeners (mineral oils and liquid softeners).	Extender oil contains polycyclic aromatic hydrocarbons (PAHs) - including Benzo[a]pyrene (B[a]P)[7]. These are classed as probable carcinogens, and though they do not pose a physical barrier to recycling, they 'may constitute a danger in Canada to human life or health'[8]. Hence, recycled tire use in public spaces (e.g., playground flooring, floor tiles), should be reconsidered. Plasticizers, namely phthalates, have been of high concern in the plastics (PVC) recycling industry over recent years. Due to their accumulation in the recyclate material, and associated health concerns, PVC recycling plant Vinyloop was closed in 2018[9]. Insufficient removal or treatment may lead to similar issues in the tire market depending on envisaged second life route.
Antioxidants and Stabilizers	Slow down the degradation potential of the rubber due to ozone	These compounds, also called antiozonants, act as a barrier layer on tire surfaces. The most common, p-phenylenediamine, has numerous health concerns via oral and dermal routes including acute toxic, irritant and environmentally hazardous[10]. As with PAHs above, these are not expected to present a physical barrier to recycling, but certain public product EoL routes are not recommended[11] [12].
Anti-degradants	Slow down the degradation potential of the rubber when it is exposed to heat	Many antiozonants are also anti-degradants vs. heat. Again, the most common is p-phenylenediamine[13]. This presents the same issues as discussed in Antioxidants and Stabilizers.
Liquid Nitrogen	Used to Produce Rubber Crumb from EoL Tire	Assuming correct safety practices are followed and PPE is used, liquid nitrogen is a relatively low risk material. As it is only used to produce rubber crumb at EoL and then dissipates, there are no health concerns with reference to interaction with the public in second life rubber products. It can be argued that this is an EoL enabler, rather than barrier.

[5] Van Hoek, J., Heideman, G., Noordermeer, J., Dierkes, W., Blume, A., 2019. Implications of the Use of Silica as Active Filler in Passenger Car Tire Compounds on Their Recycling Options. Materials. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6427782/
[6] http://www.sriimpex.com/reclaim-rubber-synthetic-rubbers/
[7] Maria Llompart, Lucia Sanchez-Prado, J. Pablo Lamas, Carmen Garcia-Jares, Enrique Roca, Thierry Dagnac, Hazardous organic chemicals in rubber recycled tire playgrounds and pavers, Chemosphere, Volume 90, Issue 2, 2013, p423-431. https://www.sciencedirect.com/science/article/pii/S0045653512009848
[8] ARCHIVED - Polycyclic Aromatic Hydrocarbons - PSL1 - Canada.ca
[9] https://www.plasteurope.com/news/VINYLOOP_t240095/
[10] EPA, p-phenylenediamine. https://bit.ly/3ltTK2e
[11] Nicholas P. Cheremisinoff, Condensed Encyclopedia of Polymer Engineering Terms, Butterworth-Heinemann, 2001, p39-81, https://www.sciencedirect.com/science/article/pii/B9780080502823500081
[12] https://pubchem.ncbi.nlm.nih.gov/compound/p-Phenylenediamine
[13] Nocil Limited, Antioxidants & Antidegradants. https://bit.ly/3pr9uFE

Name	Uses	Impact on EoL Fate
Polyurethane	Used in moulded rubber products	Polyurethane is a widely used polymer to produce foams. Currently, the EoL prospects for this material are typically limited to landfill, incineration or downcycling into (e.g., carpet underlay).

There are a number of additives, particularly antioxidants and anti-degradants, which raise health concerns noted by regulators worldwide. A review of safety data might usefully lead to lists of permissible or banned uses for rubbers containing these, particularly where more susceptible persons might be affected.

3.1.5 *Future Domestic Demand of Rubber Products in the Automotive Sector*

Estimates of future domestic demand for tires and non-tire automotive products under a business as usual (BAU) scenario from 2020 - 2030 is summarized in **Table 10** and **Table 11**.

Table 10: Estimate of Future Demand (kt) for Tires in Canada from 2020-2030[1]

Product	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Passenger Tires	406	426	426	447	447	469	469	492	492	516	516
Commercial Tires	196	206	216	226	238	249	261	274	288	302	316
OTR Tires	259	272	285	299	314	329	345	362	380	399	418
Other tires	62	65	68	71	74	78	82	86	90	95	99
Retread - Passenger /Commercial Tires*	84	88	92	97	102	106	112	117	124	130	136
Retread OTR* /Other*	5	6	7	7	7	8	8	8	9	9	9

Note:

1. Based on a compound annual growth rate (CAGR) of 4.9% (Global NewsWire, March 2020.)

   *Assumes same CAGR as new tires

Table 11: Estimate of Future Demand (kt) for Non-Tire Automotive Rubber Products in Canada from 2020-2030[1]

Product	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Weather-stripping	48	50	53	55	58	60	63	66	69	72	76
Belts	29	30	31	32	33	35	36	37	39	40	42
Hoses	42	44	46	48	50	52	55	57	60	63	66
Vibration Isolators	36	38	39	41	43	45	47	49	52	54	57
Miscellaneous	40	42	44	46	48	51	53	56	59	62	65

Note:

1. Based on a CAGR of 7.2% for passenger vehicles (Business Newswire, July 2020), 2% for commercial vehicles (Deloitte, 2014) and 4.3% for OTR (Grandview Research, April, 2020)

3.1.6 *Other Rubber Products Manufactured*

Given that the scope of the project was limited to tire and non-tire automotive rubber products in Canada, limited research was conducted on the production, import and export of other rubber products. **Table 12** summarizes the information identified.

Table 12: Other Rubber Products Produced, Imported and Exported in Canada in 2019

Other Rubber Products	Domestic Production		Imports		Exports		Domestic Demand
	Mass (kt)	Value ($CAD million)	Mass (kt)	Value ($CAD million)	Mass (kt)	Value ($CAD million)	Mass (kt)
Conveyor Belts	12.7	142.7	16.7	187.9	8.4	94.6	21
Flooring and Roofing	8.8	73.5	14.2	119.1	7.8	65.1	15.2
Other Construction Products	36.0	56.8	12.1	101.6	6.7	56.6	41.4
Other tubes, pipes and hoses[1]	18.4	206.5	34.1	383.4	9.6	108.2	42.9
All Other Rubber Product	36.0	301.7	111.7	937.2	29.5	247.4	118.2
Total	**111.9**	**781.2**	**188.8**	**1,729.2**	**62.0**	**571.9**	**238.7**

Note:

1. These numbers include plastic hose rubbers because it was not possible to sufficiently disaggregate the data.

It is our understanding that none of these products are currently collected for recycling. While it is therefore assumed that all of this rubber will be disposed of at landfill at the EoL, given the variable lifecycle duration for these products, we are unable to estimate an annual rate of EoL generation. However, if we assumed the experience is similar to plastics, a reasonable maximum case would be that disposals quantities are the same as purchases quantities, and on a minimum case, all application is in construction where capacity building is about 75% of input (25% disposal).

An estimate of future demand for these product in Canada is summarized in **Table 13**.

Table 13: Estimate of Future Demand for Other Rubber Products in Canada

Product[1]	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Conveyor Belts	22.1	23.2	24.3	25.5	26.8	28.1	29.5	31.0	33.0	34.2	35.9
Flooring and Roofing	16	16.8	18.0	18.5	19.4	20.4	21.4	22.5	23.6	24.8	26.0
Other Construction Products	43.5	45.6	47.9	20.3	52.8	55.5	58.3	61.2	64.2	67.4	70.8
Other tubes, pipes and hoses[2]	45.0	47.3	49.7	52.1	54.8	57.5	60.4	63.4	66.6	69.9	73.4
All other rubber product	124.1	130.3	136.8	143.7	150.9	158.4	166.3	174.6	183.4	192.5	202.2
Total	**250.6**	**263.2**	**276.3**	**290.1**	**304.6**	**319.9**	**335.9**	**352.7**	**370.3**	**388.9**	**408.3**

Notes:

1. Based on a CAGR of 5% for Industrial Rubber Products Industry (Intrado GlobeNewsWire, 2020).
2. We were unable to achieve sufficient disaggregation of data, therefore this data also includes plastic hoses.

3.2 Rubber Waste Generation and Management

Currently in Canada, only rubber tires are collected for reuse, recycling and/or for fuel, estimated to be 508 kt in 2019. It is our understanding that the remaining rubber products used in Canada are disposed of in landfills. For tire and non-tire automotive rubber alone, we estimate a total of 210 kt of rubber was landfilled in 2019. A further 149 kt of EoL rubber was unaccounted for.

3.2.1 *Estimates of EoL Tire and Non-Tire Automotive Rubber Generated*

Estimates of tire non-tire automotive EoL rubber products generated in 2019 is summarized in **Table 14.**

Table 14: Estimate of Tire and Non-Tire Automotive EoL Rubber Products Generated in Canada In 2019

Rubber Waste Generated	Mass (kt)
Retread Waste	15
Tire Process Waste	0.03
EoL Tires Generated	720
EoL Non-Tire Automotive Rubber	172
Waste to Environment (tire wear from EoL tires during their 'in use' phase only)	101
Recycling Waste	38
Total EoL Rubber Generated	**1,046**

3.2.2 *EoL Rubber Treatment in Canada*

Available lifecycle assessments for EoL tire treatment, compare EoL uses to determine preferred pathways. One criticism of the available literature is that the studies only evaluate one lifecycle and therefore don't evaluate the compounding benefits of keeping materials in the economy for as long as possible. Consequently, terminal EoL uses such as tire derived fuel appeared to have superior environmental benefits compared to other EoL uses. However, common sense dictates that recycling EoL products for a second or third life before using it as tire derived fuel would compound those benefits.

ECCC should consider assembling lifecycle data which uses a real-world view of the correct functional unit in its assessment of relative benefits. This would certainly be required in follow on work because of the implications on choice of techniques, systems and capacities and their consequential costs and benefits.

Ultimately, using the circular economy framework as a guide, rubber tires should be maintained in the economy for as long as possible through reuse (via retreading), followed by recycling or substitution for other products where lifecycle analysis indicates superior benefits (and in applications where the rubber can be reclaimed multiple times), followed by use as fuel in lieu of coal. Tire retreading has been on the decline over the past 5 years, as cheaper, new imported tires have come on the market. Industry stakeholders have indicated that many of these tires cannot be retread, further exasperating the issue. Opportunities to incentivize tire retreading, such as minimum standards for new tires, taxes levied on environmentally inferior tires and tax breaks on retreaded tires, should be considered.

Recycling

It is our understanding that the only rubber products currently captured in Canada for reuse/recycling at the EoL are tires. To clarify, the definition of tire recycling is "a process in which scrap tires are collected, stored, separated or reprocessed for reuse as a different product or shredded into a form suitable for use in rubberized asphalt or as raw material for the manufacture of other products"[14]. It should be noted that we consider rubberized asphalt to be indirect recycling as opposed to activities such as use as recycled content in manufacturing/retread (i.e. direct recycling).

The primary method of capture is through the provincial stewardship programs, primarily for passenger and commercial tires although a couple of programs do collect some OTR tires (**Table 15**). In addition, tire retreaders capture commercial and OTR tires from the market or from their clients during tire replacement. It does not appear that any other automotive rubber is currently captured for reuse or recycling (Personal Communication, Susan Sawyer-Beaulieu, October 15, 2020).

[14] https://www.lawinsider.com/dictionary/tire-recycling

Table 15: Provincial Tire Collection Programs (info obtained from CATRA, N.D.)

Province/ Territory	Mass Collected (Tonnes)	Recycled (Tonnes)	Tire Derived Fuel (Tonnes)	Types of Tires Collected
NS	11,982	14,272	0	Passenger, Commercial
NB	10,845	10,845	0	Passenger, Commercial
QC	91,851	83,601	8,249	Passenger, Commercial, Agricultural, Small OTRs
PE	2,625	332	2,022	Passenger, Commercial, OTRs
NL	5,929	990	4,939 (in QC)	Passenger
ON	156,518	210,704	0	Passenger, Commercial, OTRs
MB	18,177	15,972	33	Passenger, Commercial, OTRs
SK	21,675	17057	00	Passenger, Commercial, Agriculture and OTRs (except Giant)
AB	67,875	67,611	0	Passenger, Commercial, Forklift and Logger/Skidder, OTRs (not Giant and not Agricultural)
BC	51,419	39,437	10,793	Passenger, Commercial, Agricultural Tires, Forklift and Logger/Skidder Tires
YK	613	613	0	Passenger, Commercial, Forklift and Logger/Skidder Tires, OTRs ((not Giant and not Agricultural)
NWT	0	0	0	No known collection program
NU	0	0	0	No known collection program
Total	**439,508**	**450,080**	**43,060**	

Based on research conducted on the treatment of rubber products at the EoL for the other major rubber using sectors (construction, industrial, mining, etc.), no other rubber products, other than tires, are currently captured for recycling and are likely disposed of in a landfill.

Canadian Association of Tire and Rubber Agencies (CATRA) (2019) reported the following Tire Derived Product uses in Canada for 2018 (**Table 16**).

Table 16: Tire Derived Product Uses by CATRA Members in 2018

Product	Volume Produced (Tonnes)
Rubber Crumb	152,649
Molded Rubber	145,837
Tire Derived Aggregate	58,038
Steel	64,046
Blasting Mats	9,859
Tire Derived Fuel	26,036
Waste	38,391
Other Tire Product	3,932
Total	**526,474**

A web search of rubber recyclers in Canada identified at least 20 companies that recycle tires or use them for fuel in Canada (**Table 17**). As previously mentioned, the current feedstock for rubber recyclers in Canada appears to be scrap tires only. However, one recycler that we spoke with indicated that they are looking at the possibility of recycling other rubber types (such as EPDM, a type of synthetic rubber that is used in many applications such as roofing) once their newest plant is operational.

Table 17: Rubber Recyclers in Canada

Company	Location	Tire Related Service
Bano Recycling	Hamilton, ON	Tire shredding, Tire Derived Fuel (TDF) production
ARJES	Ste-Adéle, QC	Commercial shredding
EcoFlex / Champagne Edition Inc.	Sturgeon County, AB	Recycles tires into numerous reusable products
National Tire Recycling Group (NTRG)	Edmonton, AB	Mobile tire shredding, rubber mulch and rubber crumb
AAF Traders	Brampton, ON	Rubber scrap buyer / recycler
Tyromer Inc.	Waterloo, ON	Commercialize a rubber devulcanization technology TDP
Fulcrum Environmental Solutions Inc	Edmonton, AB	Tire recycling Thermal-Static Internal Pyrophinic System (TiPs)
RTI Cryogenics Inc.	Cambridge, ON	Primary Tire Recycling: Thermoplastic elastomer (TPE) pellets from crumb rubber and recycled post-industrial and post-consumer plastic
EKO Environmental - Eko Corp	Owen Sound, ON	WirePak crushing units have been specifically designed to crush loose "hairy" tire wire that is produced during the recycling process of automotive and Truck tires
Durable Shredder Knives / Zenith Cutter	Canada	Supplier of durable shredder knives for tire recycling
Tire and Rubber Association of Canada	Mississauga, ON	The Rubber Association of Canada is the national trade association for Canadian rubber manufacturers and distributors of rubber goods.
Eco Management Solutions Inc.	Waterloo, ON	Tire recycling
Highway Rubber & Safety Inc.	Boisbriand, QC	Specializes in designing and manufacturing products made of steel and / or recycled rubber.
Environmental Waste International Inc.	Whitby, ON	Reverse polymerization of tires to recycled carbon black, oil, and steel
Shred-Tech - Model ST-75 - Two Shaft Shredder	Cambridge, ON	Tire shredders
Thermogenics Inc.	Aurora, ON	Rubber manufacturing boilers
Bridgestone Americas Tire Operations, LLC	British Columbia	Tires4ward - 100% rate of valuable reuse for all tires received at Bridgestone Retail Operations
Animat Inc.	Sherbrooke, QC	Specializes in the design and manufacture of recycled rubber flooring
Liberty Tire Recycling Canada Ltd	Brunner, ON	
Tire Recycling Atlantic Canada Corporation (TRACC)	Minto, NB	Tire recycling to TDF shred, crumb rubber, mulch, etc.
Highway Rubber & Safety Inc.	Boisbriand, QC	Designing and manufacturing products made of steel and / or recycled rubber
Sigma Recycling Inc.	Brampton, ON	Tire recycling
Alberta Recycling Management Authority	Edmonton, AB	Not-for-profit association responsible for managing Alberta's tire and electronics recycling programs
RCI Environment Inc.	Anjou, QC	Recovery, collection, and recyclable material sorting for processing
Emterra Tire Recycling	Ontario	Hauls and processes used tires to 99.7% clean crumb rubber

Most recyclers identified in this study, shred or crumb the tires for use in other products such as athletic fields, playgrounds, mats, speed bumps, etc. A few recyclers break the tire down to carbon black, oils and steel. One recycler devulcanizes the tires to produce recycled rubber that is currently being reused in tire retreading in Canada. Based on conversations with industry, it is our understanding that recyclers in

Canada have excess capacity and suggested that the inclusion of OTR tires in provincial collection schemes could be a way to increase tire recycling in Canada utilizing existing capacity.

There is a further comment on OTR later in this section. It is uncertain whether lower recovery of tires in this sector is related to disposal/collection practices or to downstream treatment capacity / availability.

Tire Retreading

The types of tires retreaded in Canada are primarily commercial truck tires with some OTR retreading and minimal passenger tire retreading. Based on conversations with industry, there is no technical reason why passenger tires cannot be retreaded - it is simply not economical due to the cost of new tires and, again, there may continue to be the perception of low quality. An estimate of the tires retreaded in Canada per annum is summarized in **Table 18**.

Table 18: Estimate of Tires Retreaded in Canada in 2019

Tires	Domestic Production (Tires)	Domestic Production (Tonnes)	Percentage of EoL tires Retreaded in 2019
Retread Passenger	7,333	77	0.02%
Retread Commercial	1,600,000	80,000	49%
Retread OTR	25,000	5,625	3%
Retread Other	5,367	59	0.06%

Waste generated as a result of retreading activities is estimated to be 15 kt and it is our understanding that this waste is recycled. At least one retreader is using up to 20% reclaimed rubber in their retreading process. It is our understanding that scrap tires that cannot be retreaded, as well as waste generated during the retreading process that cannot be reused, is sent to rubber recyclers through the provincial tire waste management programs.

Lost to the Environment

Using data obtained from Pehlken and Essadiqi (2005), we estimate that between 10% and 15% of tires are lost to the environment through tire wear during the course of their lifecycle. The 15% loss estimate is supported in the Australian study (Envisage Works for the Department of the Environment and Energy, 2019). It is identical to the estimate made in a Swedish study (RISE Sustainable Business, 2018). For EoL tires generated in 2019, this represents approximately 101 kt that was lost to the environment due to tire wear during their 'in use' period.

The annual rate of tire wear for all 'in use' tires in 2019 in Canada is estimated to be 299 kt.

Landfilled

It is our understanding that, of automotive rubbers used in Canada, only tire rubber gets collected and recycled. It is also our understanding that the residual waste from the recycling process is landfilled. This represents an estimated 210 kt of rubber disposed to landfill in 2019 from the automotive sector.

Unaccounted For EoL Tire

It is estimated by industry that approximately 149 kt of EoL rubber tires are currently unaccounted for. Industry representatives believe that most of these tires are likely OTR tires that are not collected by the provincial stewardship boards. He indicated that these large tires have economic value and that it is likely that they are collected by private recyclers rather than being disposed of in landfills. However, a recent report on OTR tire collection in New Brunswick (Leger, 2020) suggested that while these tires didn't end up in provincial landfills, it was suspected that at least some of these tires are buried or thrown into private dumps, pits or forest.

Although there is an industry EPR scheme in place, but it is not as effective as top performing schemes elsewhere, further investigation into industry practices and barriers to compliance may be necessary in order to formulate an effective response which assists industry bodies to carry out their obligations. This may result in a harmonized EPR approach across Canada. See also **Section 3.3.2.**

OTR is not 'typically' included in the product stewardship schemes, so introducing a harmonized EPR across the whole of Canada would be beneficial and advance the existing schemes. Adding OTR is a case in point.

3.2.3 *A Profile of Value Recovery Facilities in Canada*

Tire Retreading

The retreading market in North America is dominated by Bridgestone (Bandag), Goodyear and Michelin however there are also a number of independent retreaders. Daystar et al. (2018) estimates that there are approximately 73 tire retread plants in Canada (**Table 19**). One Canadian retreader indicated that the number of retreaders in Canada has decreased in the last 5 years due to increasing competition with cheap, new tire imports as well as a lingering public perception that retreading is unsafe or produces low quality tires. This reputation is due to the historical presence of low quality retreaders; however, there has since been a consolidation of the market and mostly only high quality retreaders are expected to remain. See **Table 20** for retreaders identified during this study.

Table 19: Number and Location of Retreading Plants in Canada (Daystar et al., 2018)

Province	Estimated Number of Plants
Quebec	25
Ontario	16
Alberta	8
British Columbia	8
New Brunswick	5
Nova Scotia	5
Newfoundland	3
Saskatchewan	3

Table 20: Tire Retreaders Identified through this Study

Company	Retreading Location	Technology Employed	Capacity and Tire Type
Denray	All provinces except Atlantic Canada – primarily clustered in the Prairies.	Michelin Retread Technologies	Their Brandon, MB plant has a target capacity of 30,000 retreads per year[1]
KalTire	Multiple	Unknown	Largest Canadian Retreader, largest OTR retreader
LanOTR	Lanoraie, QC	Bandag (Bridgestone) retreading plant	Unknown
GCR Tire and Service	2 retread plants and provides services at three mining sites in QC (not sure what services)	Unknown	Unknown
Pneus Metro Inc	Farnham, QC	Bandag (Bridgestone) Retreading plant	Industrial and commercial tires. One of Canada's largest tire retreaders.
Belisle Retreading	Quebec City, Saint-Jerome in the Laurentians, QC	Michelin Retread Technologies	Unknown
Goodyear Canada	Ville Saint Laurent, QC	Goodyear plant	69,000 tires per year[2]

Company	Retreading Location	Technology Employed	Capacity and Tire Type
RTS Ringtread System	Montreal, QC	Marangoni Technology	Light and Medium Commercial Trucks
Groupe Robert Bernard	Granby, QC	Michelin Retread Technologies	Unknown
Goodyear/Tiremaster Limited	North Bay, ON	Goodyear Plant	Unknown
Treads West	AB	Michelin Retread Technologies - 2 plants	Unknown
Canadian Treads/ Tiremaster	ON	Michelin Retread Technologies	Unknown
Pneus Nortop	Montreal QC	Unknown	Unknown
Polar Retreading	Oshawa ON	Margaroni technology	Giant Tires
Super Steve's Tire and Mechanical	Aldergrove BC	Unknown	Unknown
Tire Terminal	Mississauga ON	Unknown	Light and Medium Commercial Trucks
West End Tire	Winnipeg, MB	Unknown	Light and Medium Commercial Trucks
Fleet Retreading Services/Miller Tire Tirecraft	NS	Michelin Retread Technologies	Unknown
A-1 Tires Limited	Truro ON	Unknown	Unknown
Fountain Tire	ON, AB, SK, MB, YK, BC	Goodyear Authorized Retreader	Commercial, OTR, Farm Tires
Eastern Tire Service	New Glasgow, NS	Bead to bead remoulds	Passenger, Light and Medium Commercial Truck Tires
Systems de Rechapage	Villa LaSalle QC	Marangoni technology	Unknown
Techno Pneus	Rimouski, QC	Unknown	Passenger, Light and Medium Commercial Truck Tires
Ironhead Rubber Technologies	Mississauga, ON	Unknown	Light and Medium Commercial Truck Tires
Benson Tire	Cornwall, ON	Goodyear Authorized Retreader	Light and Medium Commercial Truck Tires

Notes:

1. Tire Business. 2019.
2. Rubber News. 2005.

This topic can usefully be informed by another just-completed project into remanufacturing and other value retention processes (VRPs), conducted for ECCC by Dillon and OH. Although statistics fluctuate according to source, that research confirms that polymer savings from retreading are in the region of 17-20 kt/yr and with similar levels of CO_2e avoidance. This impact is dominated by OTR tires despite much lower volumes handled. However, like other product-service strategies, retreading is also a net employment creator. Policies on material recovery will, therefore, also positively impact on job creation if correctly formulated.

Rubber Recyclers

As previously mentioned, the feedstock for rubber recyclers in Canada appears to be scrap tires only. One recycler (Tyromer) indicated that they are looking at the possibility of recycling other rubber types (such as EPDM) once their newest plant is operational. Most recyclers identified in this study, shred or crumb the tires for use in other products such as athletic fields, playgrounds, mats, speed bumps, etc. A few recyclers break the tire down to carbon black, oils and steel. One recycler (Tyromer) devulcanizes the tires to produce recycled rubber that is reused in the retreading process. A list of tire recyclers identified in this study, and their current capacity, is outlined in **Table 21**. Unless otherwise indicated, the information obtained came directly from the company's websites.

Table 21: Identified Rubber Recyclers and their Current Capacity

Company	Products Produced	Location	Capacity (Tonnes)	Type of Tires Processed/Other
Alberta Environmental Rubber Products	Rubber crumb used in athletic fields, absorbing material for O&G, playgrounds, acoustical underlay, rubberized roofing, landscaping, portable speed bumps, anti-fatigue mats	Edmonton AB	13,600	
Environ-mental Waste International	Reverse Polymerization to create Carbon black, oil and metal	Ajax ON	28,860	Pilot plant in Sault Ste. Marie ran for 5 years. Recovered 6,350 tonnes of carbon black per year at a single TR60000 facility
Royal Mat	Vulcanized mats, interlocking squares, crumb rubber, door mats and mud flaps from recycled tires	Beauceville QC	121,500	Recycles 4.5 million scrap car and truck tires per year
Eco-Flex	Eco-wall (sound wall), floor mats, rubber walkways, patio blocks, speed bumps	Edmonton AB	162,000	Recycles passenger car tires 6 million tires per year
Shercom Industries	Rubber paving, landscape mulch, variety of molded products	Saskatchewan	23,400	50,000 passenger tire equivalents per week
Ryse Solutions Inc	Unknown	Burlington ON	Unknown	
Reliable Tire Recycling	Landscape mulch and borders, truck bed mats, floor mats, speed bump, sidewalk blocks, playground tile (sold through Wow Rubber), rubber paving (sold through Prairie Rubber Paving), blast mats and crumb rubber. Use EPDM for rubber paving	Winnipeg MB	15,173	Accounts for 95% of collection, processing and manufacturing activity in MB
Euroshield	Shingles	Calgary AB	Unknown	Contains approximately 95% recycled materials. From 250 to 1,000 rubber tires are used in the production of a EUROSHIELD® roof for an average-sized home
Evolve Recycling Inc	Crumb rubber, mulch and playground surfaces	Across ON	Unknown	Committed to zero residual waste through the recycling process
Liberty Tire Recycling	Shred for Tire Derived Aggregate, Crumb, tire derived fuel, Mulch (in the future)	Sturgeon County, AB	22,146	Accounts for ⅓ of all scrap tires within AB - primarily passenger tires but will pick up commercial and OTR tires
TRACC Tire Recycling	Delineator bases, playground surfacing, mulch, rubber matting, crumb, shred,	Minto, NB	10,800	1.2 million passenger tire equivalents per annum. Purchased equipment to recycle OTR tires in 2019 but not yet functional. Indicated that they would be willing to make additional investment if an OTR recycling program was started and they were named as the designated recycler[1]

Company	Products Produced	Location	Capacity (Tonnes)	Type of Tires Processed/Other
Green Carbon/ Titan Tire Reclamation Corp	Separates oil, carbon black, steel, gas	Fort McMurray, AB	Unknown Industrial Mining Tires.	First of its kind technology. Process includes evaluate and repair, cut to smaller size followed by thermal vacuum recovery process
National Tire Recycling Group	Water tanks for livestock, animal arena surface, mulch, playground surfacing	Edmonton, AB	Unknown	
Crumb Rubber Manufacturer	crumb rubber for rubberized asphalt, sports fields and track infill and rubber-molded products	Brantford ON	NA	
ArticCan Energy and Enviro Systems	Carbon black, oil, steel and gas	Regina, Saskatchewan	30,000	
Tyromer	Recycled rubber.	Kitchener, ON (AirBoss); Windsor, ON	7,900	Input is rubber crumb from tires but in their new Windsor plant there is potential to look at other rubbers such as EPDM. Zero waste devulcanization process using CO_2
Provincial Bandag[1]		Saint-Basile, NB	Unsure if this is currently operational	Pyrolysis
Lafarge	TDF	Enfield, NS	7,300[2]	Cement kiln
Lafarge	TDF	Richmond, BC	Unknown	Cement kiln
Lafarge/St. Lawrence Cement (2 separate facilities)	TDF	Montreal, QC	27,500[3]	Cement kiln

Notes:
1. Leger, M. 2020
2. Baker McKenzie, 2020
3. Stone, M. 2001

The recyclers listed above have an estimated minimum capacity of 470 kt per annum. In speaking with CATRA, they indicated that their members have additional capacity; however, there is not enough feedstock for processors to increase their output. They suggested that all provincial governments should mandate collection schemes for OTR tires, to increase the feedstock to their members.

3.2.4 *Commodity Value and Energy Value of Rubber Waste Generated in Canada*

The heating value associated with tire derived fuel (TDF) and coal is illustrated in **Table 22**. Based on this, the energy value of all tire and non-tire automotive EoL rubber generated in 2019 (estimated to be 855 kt, excluding retreaded tires and tire wear loss) in Canada is 2,370,000 GJ. To get the same energy from coal would require an estimated 979 kt of coal. At a commodity value of $51.30 USD (Business Insider, Nov 9 2020) ($67.43 CDN) for coal, this represents a value of $66 million CDN.

Table 22: Typical Material Analysis of Fuels (Source: Rafique, 2012)

Analytical Element	Coal	TDF
Volatile (%)	36.8	72
Ash (%)	14	7
Carbon (%)	80.6	84
Hydrogen (%)	4.64	5
Sulphur (%)	0.7	2
Nitrogen (%)	0.3	1.8
Lower Heating Value (KJ/Kg)	27,430	31,400

This energy density of rubber (notably tires), in comparison to coal, is supported by **Table 23** which shows a comparison of the energy content of various fuels. Whole tires have an energy content higher than that of coal and wood biomass. For example, 1 kg of whole tires has the same energy content as 1.25kg of coal.

Table 23: Energy Content of Fuel (Source: Pehlken and Essadiqi, 2005)

Fuel	Energy Content of Fuel
Heating oil	42 MJ/kg
Natural gas	38 MJ/m^3
Coal	25 MJ/kg
Wood biomass	20 MJ/kg
Tires (whole)	30 MJ/kg
Tires (steel removed)	36 MJ/kg
Mixed plastic waste	43 MJ/kg

3.2.5 *Future rubber waste generation in Canada under business-as-usual scenario*

Using a defined lifecycle and estimates of domestic demand for each product, we estimated the mass of EoL tire and non-tire automotive rubber products in Canada from 2020-2030 is outlined in **Table 24**.

Table 24: Estimate of Future EoL Tire and Non-Tire Automotive Rubber Generation in Canada (kt)

Product	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Passenger Tires	209	288	312	320	332	348	365	383	402	421	442
Commercial Tires	203	168	177	185	194	204	214	224	235	147	259
OTR Tires	154	220	222	233	245	257	269	283	297	311	326
Other tires	83	56	50	53	55	58	61	64	67	70	74
Non-Tire Automotive Rubber	151	157	167	169	192	192	187	195	204	213	222
Total	**800**	**889**	**928**	**960**	**1,018**	**1,059**	**1,096**	**1,149**	**1,205**	**1,162**	**1,323**

It is assumed that all non-tire automotive rubber will be disposed of in a landfill. Using the same material treatment ratios as today, we would expect that, in 2030, 98 kt of EoL tires would be used for retreading, 642 kt will be recycled (includes waste-to-energy (WTE)), 127 kt will be lost as tire wear, 266 kt will be landfilled as waste and 189 kt will be unaccounted for.

3.3 Material Flow Analysis (MFA)

A material flow analysis of tire and non-tire automotive rubber production, use and EoL generation was carried out for this study. The MFA methodology utilized economic analysis of Statistics Canada data, estimates of available market prices for commodities and market and industry reports to estimate the production, imports and exports, of resins, additives and rubber products. These are high level estimates, especially for products where there is a low level of disaggregation. However, all were sense-checked and supplemented based on primary data obtained from industry as well as bottom-up calculations of domestic demand for resins, rubber and additives based on resin and tire and non-tire automotive rubber formulas.

An estimate of inputs for the 2019 domestic production of tire and non-tire automotive rubber products is summarized in **Annex A, Table 83**. The corresponding total estimated inputs for this production are summed in **Annex A, Table 84.**

Using an average lifecycle duration for each product, the year of production for each EoL product in 2019 was determined. Estimates of the mass of EoL rubber products, process waste generated and their EoL treatment in 2019 was based on the domestic demand for that product in that year; findings are summarized in **Table 25** and **Table 26**.

Table 25: Estimate of EoL Tire and Non-Tire Automotive Rubber Generated in Canada in 2019

Rubber Waste Generated	Mass (kt)
Retread Waste	15
Tire Process Waste	0.03
EoL Tires Generated	720
EoL Non-Tire Automotive Rubber	172
Waste to Environment (tire wear from EoL tires during their 'in use' phase only)	101
Recycling Waste	38
Total EoL Rubber Generated	**1,046**

Table 26: Estimate of Treatment of EoL Tire and Non-Tire Automotive Rubber Generated in Canada in 2019

EoL Treatment	Mass (kt)
Tires Recycled/WTE	508
Tires Retreaded	77
Rubber to Landfill	210
Rubber to Environment (through tire wear during the tire lifecycle)	101
Rubber Unaccounted For	149
Total EoL Treatment	**1,046**

3.3.1 *Material Flow Model/Diagrams*

The following two figures are Sankey diagrams illustrating the material flow quantities in Canada in 2019 for tires and non-tire automotive rubber products.

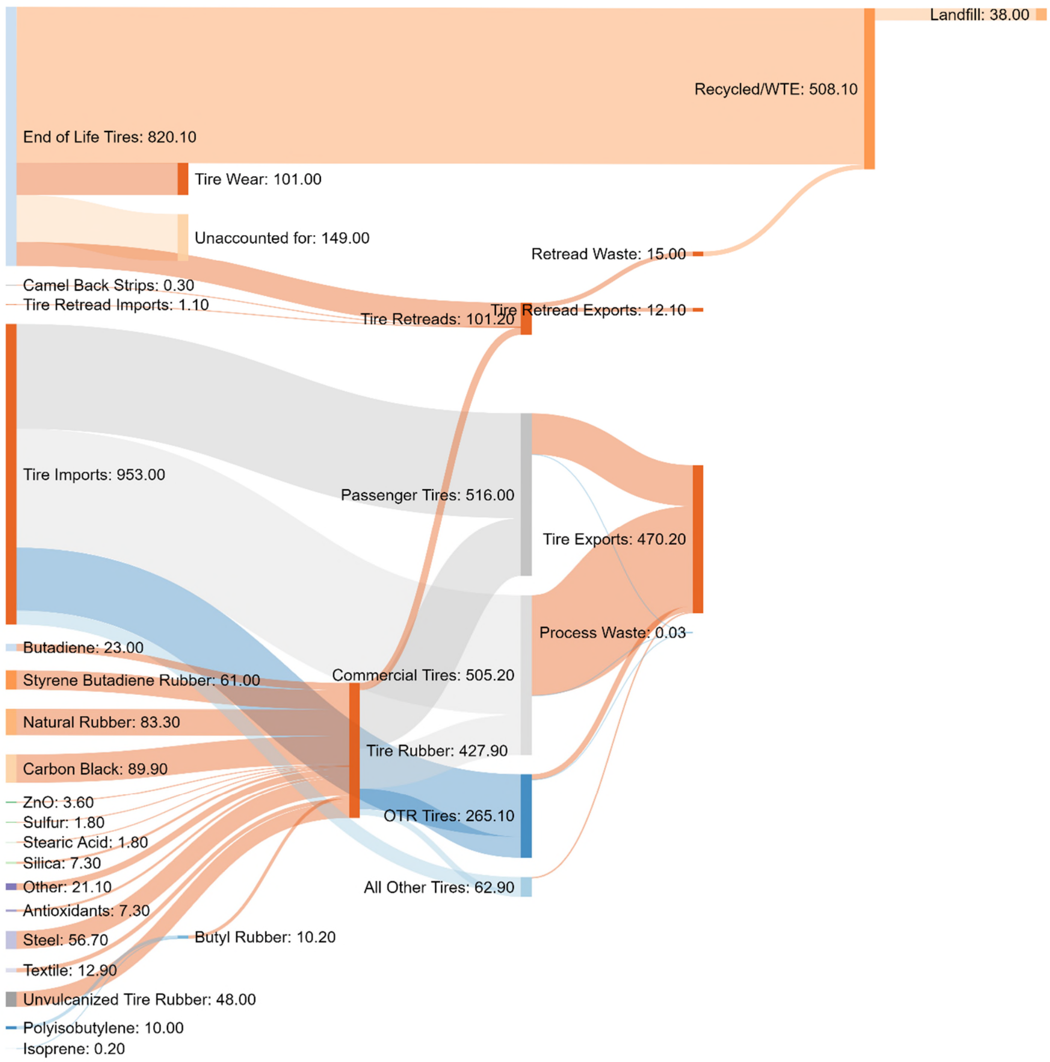

Figure 2: Sankey Diagram for Tire Material Flows in Canada in 2019

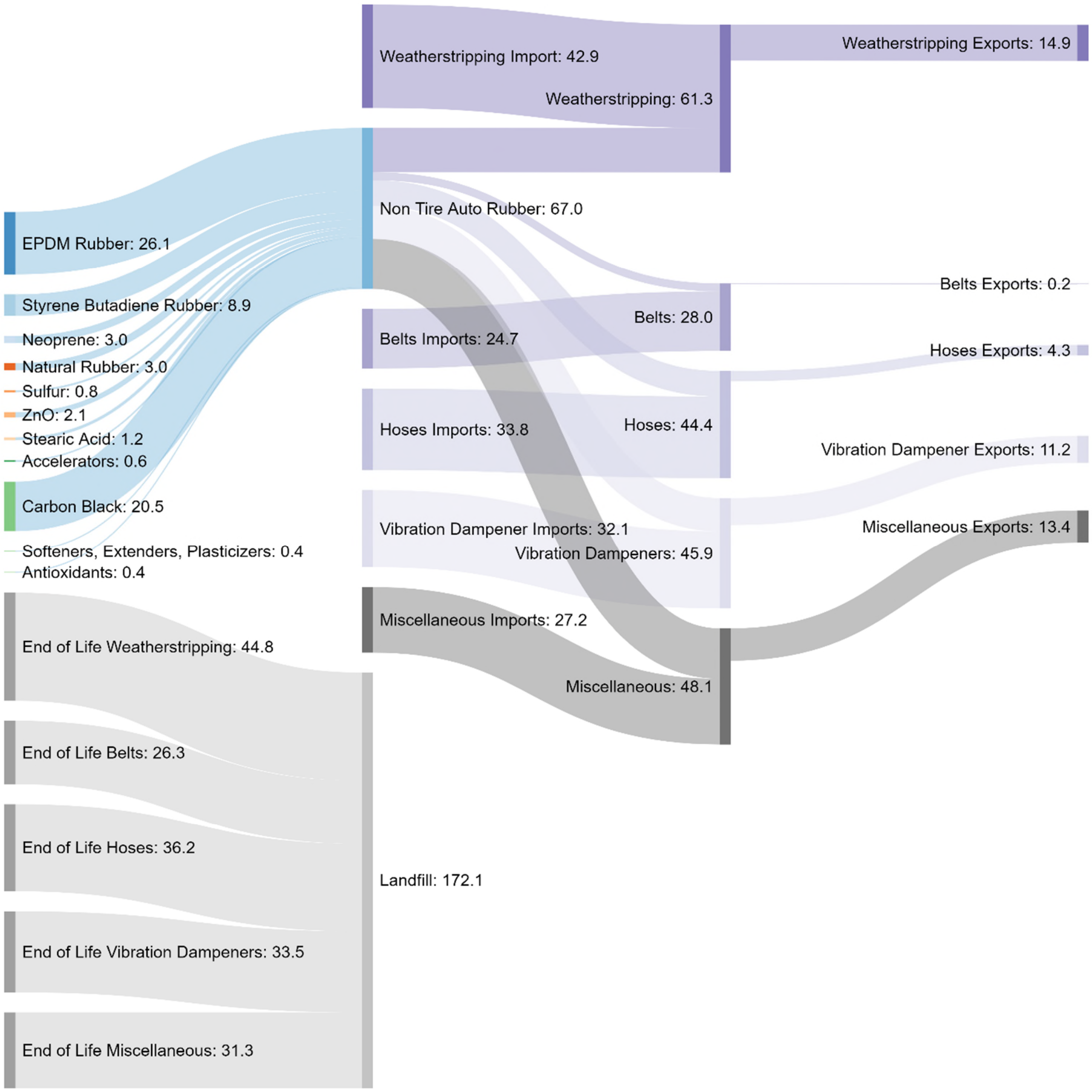

Figure 3: Sankey Diagram for Non-Tire Automotive Rubber Products in Canada in 2019

3.3.2 *Key Market Drivers Influencing the Supply and Demand for Rubber throughout the Value Chain*

Factors Driving Production, Use, Recycling and Disposal

For key sections of the value chain, and in the case of EoL – sub-sections of it, key factors of interest are drawn out below in **Table 27.**

Table 27: Driving Factors and Barriers in the Rubber Value Chain

Production	Use	Recycling	Disposal
Demand for rubber is high due to well established use phase	Low cost and suitability in specific applications (e.g., tires, tubing) leads to high levels of demand for rubber products the world over	Vulcanization restricts 2nd life options significantly	Few EoL routes and low demand drive value of material down
			High energy content driving RDF/EfW
Raw material production is an increasing risk factor especially regarding natural rubber	Varying levels of natural and synthetic rubber use within product compositions drives high demand for both materials	Downcycling (especially with respect to tyres) is common (i.e. playground flooring, landfill walls, etc.)	Bulk and weight
			Harmful additives

Perhaps one of the most influential and widely glazed-over factors in the use phase of the value chain is the variation between natural vs. synthetic rubber used in tire compositions. Natural rubber, as noted in **Section 3.1**, is typically sourced from *Hevea brasiliensis* rubber trees. In 2017, the European Union listed natural rubber as a critical raw material – the only biotic material to be included in the globally impactful list – and it remains there to date[15]. Synthetic rubber is produced from crude oil and can be made from numerous chemical compounds, which, as a product of fossil fuels, has raised environmental concerns. Clearly, then, both natural and synthetic materials have sustainability concerns, effectively borne from the impact of extractive processes, material scarcity and risk.

The exact percentage of natural and synthetic rubber used in tires is idiosyncratic to each manufacturer and highly confidential in some cases; a ballpark figure in the USA has been estimated at 14% natural and 27% synthetic for passenger tires, and the reverse for truck tires – 27% natural and 14% synthetic. The same source estimates that in the European Union (EU) the figures are 22% natural and 23% synthetic for passenger tires and 30% natural and 15% synthetic for truck tires. (Progress in used tyres management in the European Union: A review, 2012). Although specific compositions vary, both regions show agreement in that passenger tires use a higher percentage by weight of synthetic rubbers and OTR the reverse.

The majority of tire innovations come from tire manufacturers whose main market is in passenger tires. Given the higher percentage of synthetic rubber used in comparison to natural rubber, it is no surprise that there have been movements in industry to transition to using only natural rubber in tires. However, these more sustainability calls are being led by General Motors (GM), an automotive manufacturer, as opposed to the tire industry[16]. There are technical impacts to producing tires from one type of rubber, perhaps why four major tire manufacturers - Bridgestone, Michelin, Goodyear & Continental – have instead pushed forwards the notion of a sustainable supply chain for natural rubber in tandem with GM, rather than 100% natural rubber tires[17].

[15] https://www.etrma.org/news/eu-lists-natural-rubber-as-a-critical-raw-material-reconfirming-its-economic-importance-and-the-need-for-supply-diversification/
[16] https://www.greenmatters.com/news/2017/05/18/19oD5g/gm-tires-natural-rubber
[17] https://www.rubbernews.com/article/20180216/NEWS/180219950/gm-shows-progress-in-efforts-to-promote-sustainable-rubber

Some of the actions on this topic by these and other manufacturers include:

- Bridgestone and Pirelli investing in research and development (R&D) in relation to the guayule plant which produces a similar rubber compound to *Hevea brasiliensis* rubber trees, in a different climate with lower water consumption.
- Michelin evaluating the Corporate Social Responsibility (CSR) practices within their rubber supply chain, drawing on EcoVadis credentials of direct suppliers and utilizing Rubberway (developed in partnership with Continental and Smag) to check the practices of their upstream supply chain[18].
- A partnership with the WWF on a Zero Deforestation Policy, a commitment to responsible rubber sourcing[19]. (Initially led by Michelin in 2016 followed by Bridgestone, Goodyear, Continental, Pirelli, Hankook, Sumitomo, Yokohama and Toyo Tires.)

Problematic Waste Streams/CE Barriers

Tire Wear Particulates in the Natural Environment

Tire and road wear particles (TRWP or TWP) have been of concern since the 1990s, and under close review since the 2000s. They are produced in the abrasion of tires due to contact friction with road surfaces and are comprised of tire tread rubber (roughly contributing 60% by weight) and road surface material. Though a low percentage of air particulate pollution (in the categories of PM^{10} and $PM^{2.5}$), larger particulates are significant pollutants in rainfall run off from roads – leading to increased microplastics in our environment.

As means to addressing issues arising from TRWP, the Tire Industry Project was set up in 2005, led by the World Business Council for Sustainable Development (WBCSD), to support research into the topic. Project members include Bridgestone, Continental, Coopertires, GoodYear, Hankook, Kumho Tire, Michelin, Pirelli, Sumitomo Rubber Industries, Toyo Tires and Yokohama (USTMA, 2020).

Though the total mass of these particulates is unknown, the fact that they are all leaked to the environment at present, along with their high surface area and distribution potential, make them a critical hotspot with regards to pollution. It may be noteworthy that, in the U.K., around 63,000 tonnes of TWP are deposited on roads each year – the same source estimates that 28% of all ocean plastic is via contribution from tires. Given population densities, we expected that the quantity of TWP in Canada will be lower than 63,000 tonnes, but the contribution of tires to ocean plastic will be similar[20].

Automotive Non-Tire Rubber has a 0% Collection Rate, Driving High Volumes to Landfill

Through conversation with a representative from the University of Windsor studying non-tire automotive rubber, it has been raised that the collection rate is 0%. In essence, all the non-tire rubber is landfilled with other low value automotive materials at EoL as a component of automotive shredder residues (ASR). We estimate that this accounts for around 168 kt of rubber to landfill in Canada in 2019.

Sources and Supply Chain for Natural and Synthetic Rubber at Risk/Of Concern

In tires, natural and synthetic rubbers are required in varying ratios depending on the tire application. Natural rubber provides reduced internal heat generation and high mechanical resistance (i.e. resistance to abrasion). On the other hand, synthetic rubber provides the feature of hysteresis (an object returning to its original shape after stress is removed) alongside improved longevity and rolling resistance[21]. Although tire manufacturing data is protected within the industry, it is reasonable to assume that the

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[18] https://www.environmentalleader.com/2018/12/tire-industry-sustainable-rubber/
[19] https://www.worldwildlife.org/projects/transforming-the-global-rubber-market
[20] https://www.iom3.org/events-awards/ems-event-calendar/invisible-ocean-pollutants-from-our-roads.html
[21] https://thetiredigEstimate ofmichelin.com/an-unknown-object-the-tire-materials

rough mix of these materials remains relatively consistent within each category (e.g., passenger/light vehicle, commercial vehicle and OTR).

In terms of changing the natural-to-synthetic rubber composition in tires, market and risk factors appear to be more of a driver than manufacturers chasing technical improvements. Historically, Brazil was the highest natural rubber producer, but has given way to the Asian producers – Thailand, Indonesia and Malaysia – who now dominate the market[22]. Part of the reason for this decline, apart from general market competition and growth, is that the fungus *Microcyclusulei* has decimated Brazilian plantations[23]. If this were to spread globally, natural rubber production would be at risk.

Two approaches to this are improving the properties of synthetic rubber and looking for alternative sources of natural rubber. Researchers at several of the German Fraunhofer Institutes have been addressing the former: Their biomimetic synthetic rubber (BISYKA), developed in 2019, is stated as reducing tire mass loss by 30% and tread loss by 50% compared to natural rubber. As replacements for usual natural rubber sources, dandelion and guayule rubbers are both being investigated further. In the same vein as rubber from rubber trees, 95% of dandelion rubber consists of polyisoprene. With a three-month production cycle, in contrast to the 7-year cycle of rubber trees, dandelions offer more supply chain versatility. In the U.S. and Mexico, liquid guayule natural rubber (LGNR) appears to be a promising alternative also, showing improvements to energy consumption in the mixing stage of production (Ren et al, 2020) alongside improved material security in the U.S. and Canada compared to Asian alternatives.

Logistics Issues Relating to Tire Bulk and Weight

OTR tires represent about 15% of Canada's tire volume by weight (Unknown Author, 2018) however OTR tires are only collected by some of the provincial stewardship programs. A recent report completed on behalf of Recycle NB on the feasibility of an OTR Tire Recycling Program in the province (Leger, 2020) indicates that some informal take back and reuse/recycling/retreading occurs for OTR tires in New Brunswick. However, the disposal comes at a significant cost to the dealer which is a barrier. The number of tires collected is less than the number sold and it is suspected that these are buried or thrown into private dumps, pits or forests. Dealers were very supportive of a provincially run OTR recycling program. One of the main barriers identified was that the current collection and transportation system was not equipped to deal with tires of this size.

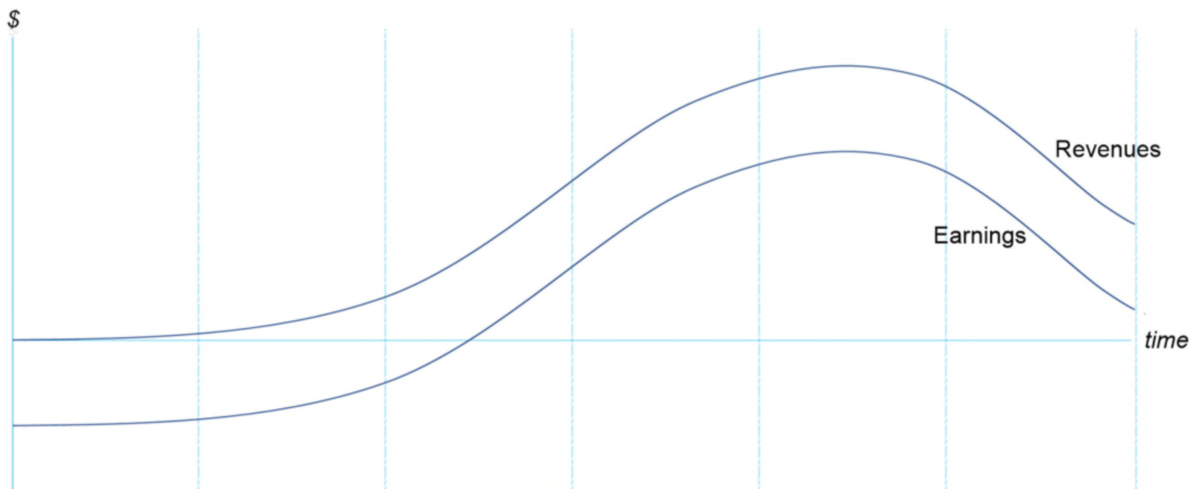
[22] https://www.coruba.co.uk/blog/the-biggest-rubber-producing-countries/
[23] https://phys.org/news/2019-04-synthetic-rubber-outperforms-natural.html

4 Economic Profile and Competitive Analysis

This report section addresses Task 2 of the project, provides an economic overview of the Canadian rubber industry. For each sector of the Canadian rubber market, a high-level analysis has been undertaken. In addition, Canada's position within the global rubber market context is assessed and the current status of Canada's EoL rubber stewardship program and its contribution to the circular economy (CE) is highlighted.

4.1 Approach and Influential Factors

The Life Cycle Approach to industry analysis takes into consideration that firms, and hence the industries that are comprised of such firms, progress through predictable lifecycles. Analogous to humans, industries are born, reach maturity and suffer decline. Each stage is characterized by unique strategic behaviours and operational focus that are key to the viability (i.e. the ability to generate revenue and profits) of the industry at that point in time and which sets the stage for its future evolution. In general, the industry life cycle consists of six stages as illustrated below in **Figure 4.**



Stage One	Stage Two	Stage Three	Stage Four	Stage Five	Stage Six
Start Up	Young Growth	High Growth	Mature Growth	Mature Stable	Decline
Idea generator; identification of unmet demand	Develop business models that convert ideas into potential revenues and earnings	Building businesses; convert potential into actual revenues and earnings	Businesses grow and turn the corner to profitability	Stable revenues that businesses try to defend from new competitors and find new markets	Scale down business

Source: Damodaran, A. (2014).

Figure 4: Life Cycle Stages of Industry

As an industry moves through these stages, new challenges arise that must be responded to in order to maintain market share. For example, in Mature and Stable industries, it is common to see many participants enter the market (both domestic and international). This constrains the ability of firms to enhance revenues through increases in sales and/or prices. The dominant strategies exercised by incumbents in these markets therefore tend to be defensive in nature, and strategic initiatives are often implemented to control costs and protect profitability.

Canada's rubber market is best described as a Mature Stable Industry, with some evidence of decline. Key features of this industry suggest it has reacted to increased competitive pressures – particularly from imports – in exactly the way described above.

The available data suggests that, relative to domestically produced rubber products, imports benefit from significant cost advantages, particularly in labour expense. Moreover, for products manufactured in the Unites States, Canada's largest trading partner, the open market originally created by the North American Free Trade Agreement (NAFTA) allows U.S. producers to leverage larger operations to generate cost advantages through economies of scale. We note that the NAFTA has been recently replaced by CUSMA Canada US Mexico Free Trade Agreement. To the extent that other countries have less stringent environmental regulations than Canada, the cost competitiveness of imports would likely be further enhanced. Caution is warranted when considering the impact of environmental regulation on an industry's competitiveness, however, as it is common for estimated impacts to be as high as ten times greater than realized costs[24].

Influential Factors – Multiplier Effects

In analyzing the economic impact of a specific industry within Canada's rubber market, rather than narrowly focusing on industry specific attributes such as revenues and jobs, it is often useful to understand what impact an industry has on the broader Canadian economy (Gross Domestic Product, GDP). This is especially true when viewed from a public policy perspective.

Economic theory suggests the total impact of an industry on the overall economy is significantly higher than is implied by the direct level of goods, revenues, jobs and wages it generates. This is because, for every dollar an industry spends on each of these activities, other related economic variables change in response. Such responses are captured using statistical tools, and their cumulative impacts on the economy are captured by the following multipliers:

- **Direct Multipliers** measure the initial requirements for an extra dollar's worth of output for a given industry. The direct impact on the output of an industry is a one dollar change in output to meet the change of one dollar in final demand.
- **Indirect Multipliers** measure the changes due to inter-industry purchases as they respond to the new demands of the directly affected industries.
- **Induced Multipliers** measure the changes in the production of goods and services in response to consumer expenditures induced by household incomes (i.e. wages) generated by the production of the direct and indirect requirements.
- **Simple Multipliers** measure the total value of production required from all industries across all stages of production to produce one unit of output for final use (i.e. Direct Multiplier Impacts + Indirect Multiplier Impacts).
- **Total Multipliers** measure the sum of the direct, indirect and induced multipliers.

For the purposes of this report, Total Multipliers will be used to estimate an industry's overall impact on Canadian GDP[25].

4.2 Market Profile

Commonly used for over a thousand years, rubber appears in two distinct forms: natural and synthetic. Both forms have high tear resistance, heat resistance, chemical resistance, fluid resistance, and electrical resistance, making them useful in a broad array of applications. However, both rubber types also have competitive advantages in certain applications relative to each other. Overall, natural rubber's beneficial properties outweigh the performance of synthetic rubber, while synthetic rubber has the advantage that it is easier to produce than natural rubber[26]. In instances where performance is similar for like applications, purchasing decisions typically come down to price.

[24] Monahan, K., McFatridge, K. and Whittaker-Cumming, A., Smart Prosperity Institute. (2018).
[25] Note: *Total Multipliers assume that household wages are redirected through the economy through household expenditures whereas Simple multipliers assume no feedback between wages and production.*
[26] Malaysian Rubber Board. (2020).

4.2.1 *Primary Rubber Market – International*

Natural Rubber

The extraction of natural rubber occurs exclusively in foreign markets as Canada has no reserves of naturally occurring rubber plants. Natural rubber was identified as the most critical biotic raw material on the EUs critical raw material list, which was published in May 2014. This status was a result of natural rubber's economic importance, moderately concentrated production (over 10 countries producing natural rubber globally), lack of closed-loop recyclability and currently no substitutes that provide the same overall desirable performance characteristics[27].

Two approaches to mitigate this risk are improving the properties of synthetic rubber and identifying alternative sources of natural rubber. Researchers at several of the Fraunhofer Society Institutes have been addressing the former - their biomimetic synthetic rubber (BISYKA), developed in 2019, is stated as reducing tire mass loss by 30% and tread loss by 50% as opposed to natural rubber.

As illustrated in **Table 28**, the world's leading producer of natural rubber is Thailand which accounts for roughly 38% of production or approximately 4,842 tonnes per year. The next largest producer is Indonesia with roughly 26% of world output. The remaining half of the market is primarily served by a handful of other Indio-Asian countries.

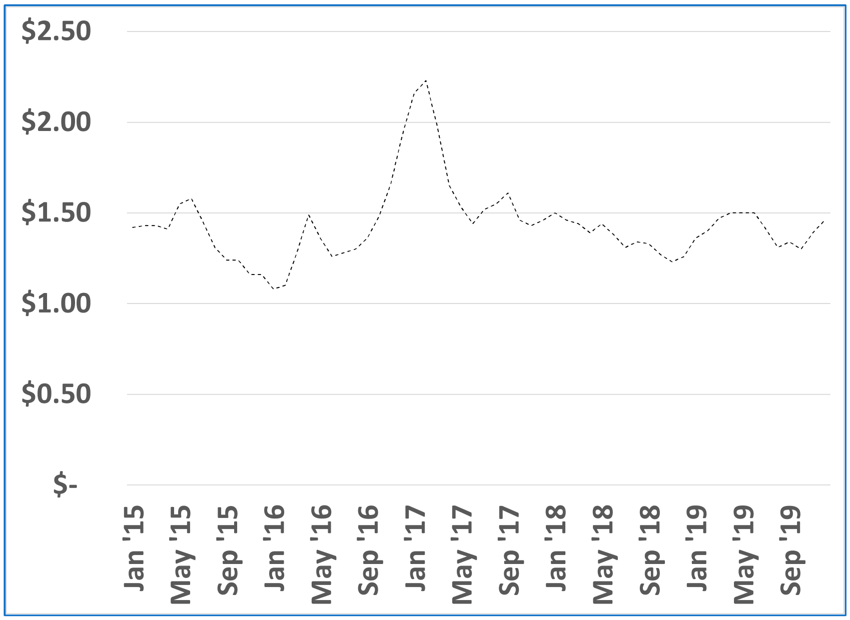
Table 28: Worldwide Rubber Production

Country	Natural Rubber Production (kt)	Share of Industry
Thailand	4,852	37.65%
Indonesia	3,301	25.61%
Vietnam	1,185	9.20%
China	813	6.31%
India	702	5.45%
Malaysia	640	4.97%
Others	1,394	10.82%

Source: Statista, 2019.

One challenge for downstream rubber users in Canada frequently cited in the literature is volatility in the international price of raw materials, particularly natural rubber[28]. This can be seen in **Figure 5** below, where over the past ten years the price has remained stable overall, but monthly fluctuation can vary as much as 16%.

[27] Blagoeva, D. (European Commission, DG Joint Research Centre, Petten, Netherlands), et al. (2017).
[28] Gonzales, McGrath, 2019 and 2020 Mieles, 2020.



Source: Statista, 2020
Prices in $US / kilogram

Figure 5: Price of Natural Rubber

At $US 3.4 billion per year, China is the world's leading importer of natural rubber as shown in **Figure 6**. Canada is the world's twelfth largest consumer of natural rubber, with annual imports valued at approximately $US 243 million in 2019.

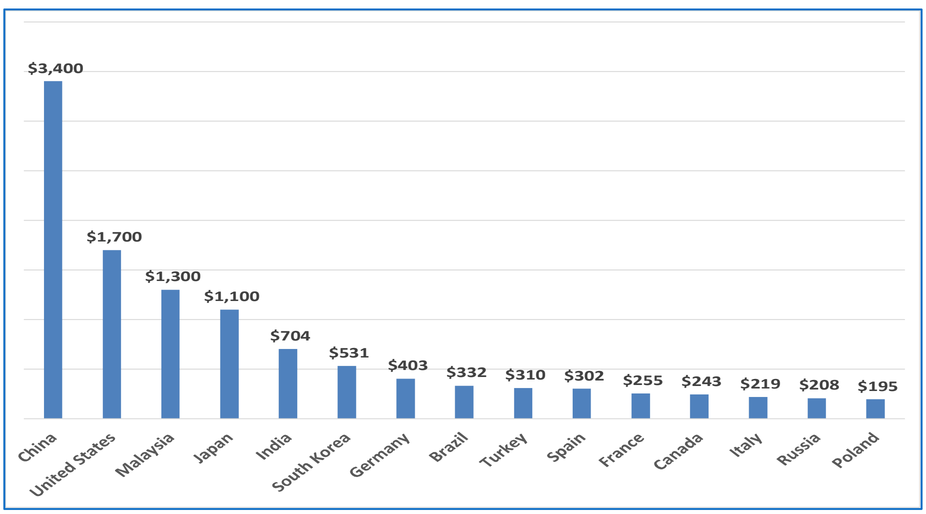


Figure 6: Imports of Natural Rubber

Source: Statista, 2020 (USD millions)

Despite the slow or declining growth rates forecast for much of Canada's rubber industry, the value of natural rubber imports into Canada has increased significantly over the past five years, from $CAD 214 million in 2015 to $CAD 306 million in 2019, or an annual average growth rate of about 11%. This is driven by a sharp year over year increase in the price of natural rubber in 2016-17 and again in 2018-19 (**Table 29**) which more than offset the slight decrease in quantities imported.

Table 29: Canadian Imports of Natural Rubber

Year	Value of Natural Imports ($CAD million)
2015	214
2016	245
2017	265
2018	257
2019	306

Source: TrendEconomy.Com

Based on the total multiplier for the rubber industry in Canada, the average value of natural rubber imports into Canada of $CAD 257 million spurred an additional $CAD 60 million in economic activity for the economy overall[29]. 62% of Canadian natural rubber is sourced from Indonesia, with other primary sources including Liberia and Thailand[30]. At approximately $CAD 3.8 million, exports of natural rubber products from Canada are trivial, with 98% of exports landing in the United States.

Synthetic Rubber

Although natural rubber exhibits many excellent mechanical properties, some applications may be better suited for synthetic rubber, especially those where thermal stability and compatibility with petroleum products and certain other chemicals is important[31].

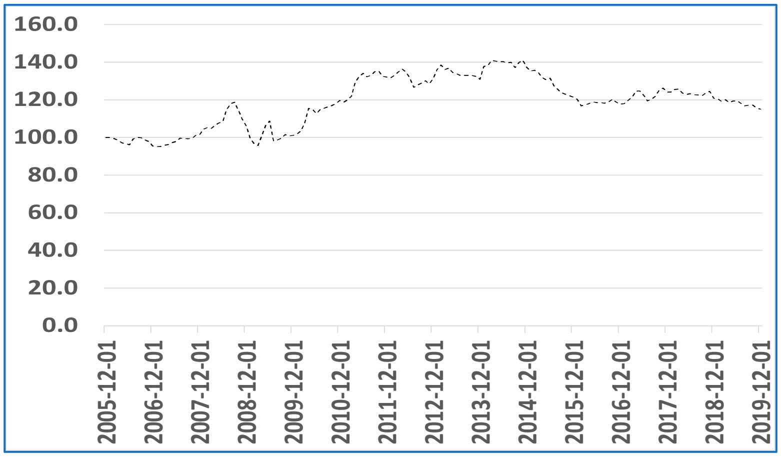
Synthetic rubber, like other polymers, is made from various petroleum-based monomers with the most being styrene-butadiene rubbers (SBR) that is derived from the copolymerization of styrene and 1,3-butadiene. Other synthetic rubbers include those based on polyisoprene (prepared by polymerization of synthetic isoprene).

In terms of replacing typical natural rubber sources, dandelion and guayule rubbers are both being looked into further. In the same vein as rubber from rubber trees, 95% of dandelion rubber consists of polyisoprene. In the U.S. and Mexico, liquid guayule natural rubber (LGNR) appears to be a promising alternative also, showing improvements to energy consumption in the mixing stage of production alongside improved material security in the U.S. and Canada as opposed to Asian alternatives.

Global production of synthetic rubber steadily increased during the past 20 years, with output improving from 10.9 million tonnes in 2000 to 15.1 million tonnes in 2019[32].

In general, the price of synthetic rubber tracks the price of natural rubber. As both are substitutes linked to commodity prices. The price of natural rubber is influenced by the world price of oil. The cost structure of this industry is subject to volatility and price shocks. Like natural rubber, the price of synthetic rubber exhibits a high level of variance, which can be seen in the synthetic price index in **Figure 7**. Average prices in this market changed at a rate of about 1.5% per month, with the single biggest variance being a 10% increase in the month over month level of the index.

[29] Statistics Canada, (2017).
[30] WorldBank, (2020).
[31] Canada Rubber Group, (2020).
[32] Malaysian Rubber Board, (2020).



Source: US Department of Labour Statistics, Base Year = 2005. Y-axis is price index.

Figure 7: Synthetic Rubber Price Index

Canadian trade in synthetic rubber is overwhelmingly tilted toward imports (**Table 30**), with exports being an insignificant generator of wealth for the Canadian economy. 98% of Canadian imports of synthetic rubber are from the United States. Similar to natural rubber, Canada is not a significant player in synthetic rubber export markets, with the limited amount that is shipped internally destined for the United States[33]. The total multiplier impact of this industry on Canada's economy is estimated to be approximately $CAD 35 million contribution to the GDP.

Table 30: Synthetic Rubber Imports

Year	Value of Synthetic Imports ($CAD million)
2015	65.3
2016	64.6
2017	91.2
2018	97.9
2019	76.0

Source: WorldBank, 2020.

Vulcanization

Once virgin rubber has been processed (natural) or produced (synthetic), the next step in its material flow involves further processing of the virgin rubber for incorporation into manufacturing processes that, eventually, culminate in the production of finished rubber products.

The first step involves blending one or more types of virgin rubber with additives such as carbon black, oil, anti-oxidant, catalyst, plasticizer, pigment, accelerator and filler. This 'compounded' rubber is processed to the desired shape through extrusion, compression moulding, injection molding, lathe cutting, or calendaring.

In rubber extrusion, a high-pressure extrusion machine is used to force rubber through a shaped die. Compression moulding, on the other hand, occurs when uncured rubber is directed into a mold cavity and, through compression, transformed into a useable product. Injection molding involves heating rubber

[33] World Bank, (2020).

to a liquid state, transferring it to a 'pot', then forcing the rubber through an aperture into a cavity that has the desired mold shape. In lathe cutting, rubber is shaped by pushing a rotating cylindrical workpiece against a cutting tool called a bit. Finally, calendaring coats a substrate like glass fibre or textile with rubber.

At this stage, rubber can still be permanently deformed as it has not yet been vulcanized. Vulcanization transforms the rubber – through the formation of new chemical bonds that crosslink polymer chains - into an elastomer. Elastomers are capable of recovering their original shape after a deforming stress is relieved and are what give rubber its familiar elastic properties.

In some cases, the moulding and vulcanizing operations are combined in a single step. It is also common for moulding processes to occur further downstream during the manufacture of finished rubber products. Generally speaking, at this point in its material flow rubber progresses through many transformative steps ('Tiers') as raw material suppliers tailor the product to meet the demand of downstream manufacturers.

4.2.2 *Primary Rubber Market - Domestic*

Key suppliers in Canada of vulcanization product consist of two tiers as shown in **Figure 8** and include:

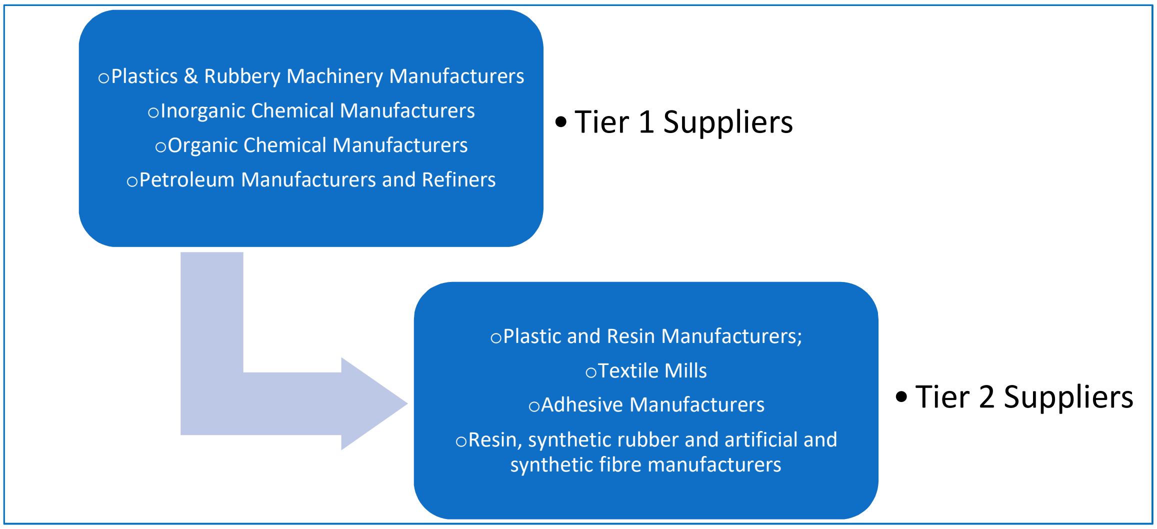


Figure 8: Key Upstream Suppliers in Canada

Products from these upstream market participants are then used as inputs into the three primary downstream industries.

Next, vulcanized rubber (moulded or unmoulded) flows into Canada's rubber equipment manufacturing industry, where it is transformed into products that enter distribution channels for end- consumer use or are used as inputs into Original Equipment Manufacturers (OEMs)[34]. Key participants in this stage of rubber's material flow include:

- Rubber Product Manufacturing in Canada (NAICS 32629)
- Hose & Belt Manufacturing in Canada (NAICS 32622)
- Tire Manufacturing in Canada (NAICS 32621)

Like the configuration of downstream customers of vulcanized rubber suppliers, downstream users of rubber products in Canada are similarly tiered, and illustrated in **Figure 9**.

[34] For example, finished rubber products include vehicle tires that are attached to cars during the car manufacturing process.

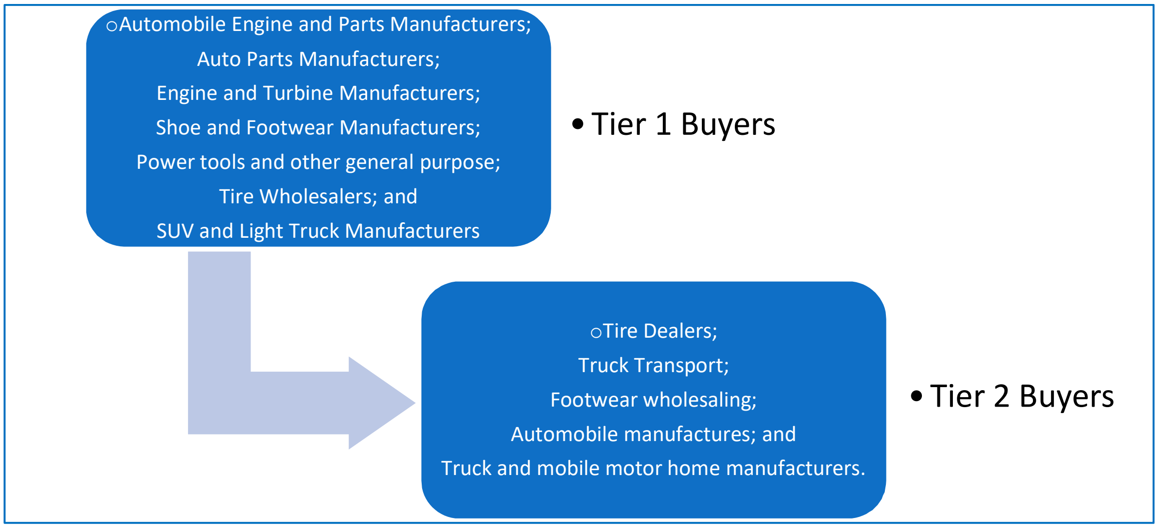


Figure 9: Key Downstream Buyers

Rubber Product Manufacturing in Canada (NAICS 32629)

Overview

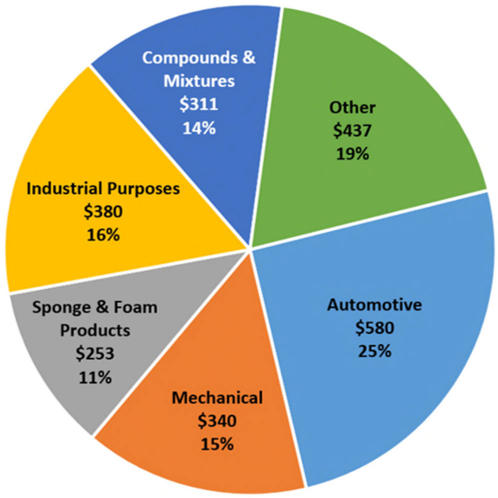
This industry produces products ranging from doormats to rubber bands. Downstream consumers include the manufacturing, construction and health care industries. This diverse portfolio of products supports the approximately $2.3 billion in revenues generated annually by the industry[35].

Key activities include:

- Rubber goods manufacturing
- Roofing manufacturing
- Rubber tubing
- Rubber sheeting, flooring and stair tread manufacturing

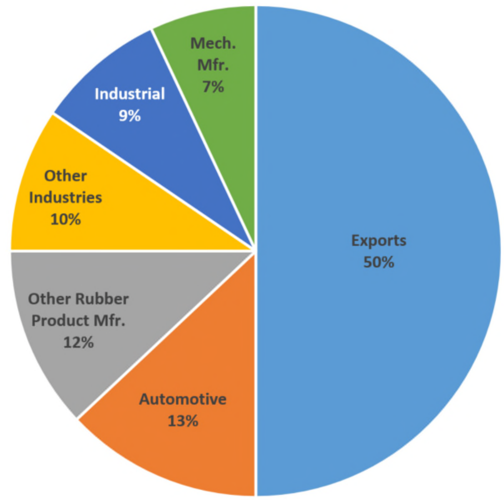
Using the same type of moulding processes often performed by upstream suppliers, this industry further transforms rubber products into useable products. 25.2% of industry output, for example, consists of products like mud flaps, brake pedal pads, and hood shields that flow to the automotive industry as inputs into car and automobile manufacturing (see **Figure 10**). The remaining 74.8% of output is a diversified mix including products with applications in industry; products related to the transportation sector such as rail and off-road transportation; sponge and foam products for use in non-residential construction; compounds and rubber used in aeronautical, automotive and protective applications; as well as miscellaneous products such as balloons, film, ink, and pencil erasers.

[35] McGrath, S., Ibis World: Industry Research Reports, Canada. (2019).



Source: McGrath, 2019. ($CAD million), rounded.

Figure 10: Rubber Good Manufacturing Industry - Product Mix



Source: McGrath, 2019, rounded.
Notes: Mechanical (Mech.), manufacturers (mfr.)

Figure 11: Rubber Goods Manufacturing - Market Segments

A number of different markets exist that shape the demand for the industry's product offerings. Exports are the largest market, accounting for fully 50% of industry revenues (**Figure 11**). The dominant importer of industry products is the United States, a natural destination given its close proximity (low transportation costs) to Canada and the existence of the North American Free Trade Agreement (low transaction costs). Domestic market share is relatively evenly split in downstream applications such as industry machinery products; automotive manufacturing; medical supply wholesalers and rubber components for use in industry; and heavy-duty equipment manufacturing.

Industry Performance

As illustrated in **Table 31** and **Table 32** below, industry revenues remained relatively stable over the five-year period ending in 2019, growing at a sluggish annual rate of 0.10% per year. Despite the fact that, over the same period, the Canadian economy was growing at a much higher level, averaging 1.70% per year with domestic demand for industry output matching that pace. With imports growing at an average rate of 3.10% per year, collectively these trends indicate that domestic demand is being increasingly met by foreign competition. A significant decline in both the number of operating establishments and in employment levels (average of -1.25% per year and -0.52% per year, respectively) was also observed.

Table 31: Historical Performance

Year	Revenue[1]	IVA[1,4]	Establishments[2]	Enterprises[2]	Employment[3]	Exports[1]	Imports[1]	Wages[1]	Domestic Demand [1]
2015	2,333	665	216	182	7,942	1,143	1,574	442	2,763
2016	2,260	574	224	189	8,217	1,118	1,567	442	2,709
2017	2,275	574	228	193	7,798	1,087	1,607	424	2,795
2018	2,343	620	218	184	7,882	1,150	1,579	430	2,772
2019	2,311	599	215	182	7,800	1,159	1,704	425	2,857

Source(s): McGrath, 2019.
Notes:
1. In $CAD million
2. An Enterprise is separately managed and keeps consolidated management accounts. An Establishment is the smallest type of accounting unit operating in a single physical location consolidated up into the Establishment.
3. Total jobs

4. IVA (Industry Value Added) is the market goods and services net of cost of goods sold. It is a proxy for the industry's contribution to GDP

Table 32: Year over Year Change (%)

Year	Revenue	IVA	Establishments	Enterprises	Employment	Exports	Imports	Wages	Domestic Demand
2015	1.35%	0.89%	-6%	-6%	-1%	6.21%	7.24%	5.13%	4.37%
2016	-3.13%	-13.68%	3.70%	3.85%	3.46%	-2.19%	-0.44%	0.00%	-1.95%
2017	0.66%	0.00%	1.79%	2.12%	-5.10%	-2.77%	2.55%	-4.07%	3.17%
2018	2.99%	8.01%	-4.39%	-4.66%	1.08%	5.80%	-1.74%	1.42%	-0.82%
2019	-1.37%	-3.39%	-1.38%	-1.09%	-1.04%	0.78%	7.92%	-1.16%	3.07%

Source(s): McGrath, 2019

These recent performance metrics, taken as a whole, are indicative of an industry operating in the mature stage of its life cycle, with limited opportunity for significant growth. As the decline in the number of industry and firm establishments shows, to preserve profitability incumbents are reacting to increased low-cost foreign competition by attempting to optimize cost structures through consolidation and mergers (enhanced economies of scale) or through the implementation of new technologies (to save on the wage bill).

	Stage One	**Stage Two**	**Stage Three**	**Stage Four**	**Stage Five**	**Stage Six**
Sector Stage	Start Up	Young Growth	High Growth	Mature Growth	Mature Stable	Decline

Figure 12: Domestic Rubber Sector - Lifecycle Stage

Estimated Impacts

Table 33: Rubber Product Manufacturing - Economic Impact

Multiplier Type	Output[1]	GDP at Market Prices[1]	Labour Income[1]	Taxes on production[1]	Jobs
Direct	2,304	1,247	106	74	11,524
Indirect	1,293	680	60	25	6,464
Induced	862	569	36	39	4,756
Simple	3,597	1,926	166	99	17,990
Total	**4,461**	**2,496**	**202**	**138**	**22,744**

Source(s): McGrath 2019; Statistics Canada, 2020.
Note:
1. In $CAD million

Adding up the direct, indirect, and induced multipliers provides an estimation of the total impact this industry has on the Canadian economy (**Table 33**). At an estimated impact of approximately $CAD 4.5 billion, this industry accounts for 2.59% of Canada's total manufacturing sector or 0.26% of Canadian GDP. The industry on average contributed 22,744 jobs to the Canadian economy.

The industry's largest market, automobile manufacturing, is expected to continue to be the dominating downstream consumer of goods for the foreseeable future. The industry is expected to come under increasing competitive pressures from imports, even if the dollar depreciates, as firms located in the United States continue to leverage economies of scale and firms located abroad continue to leverage low wage bills to enter the market on a cost competitive basis.

Drivers of Demand

There are a handful of external factors that drive demand in the Canadian Rubber Product Manufacturing industry. A list of these, as well as an assessment of their directional impact, are summarized below in **Table 34**.

Table 34: Rubber Product Drivers of Demand

Driver	Impact	Trend	Outlook
Canadian Effective Exchange Rate (CEER) Index	When the value of the Canadian dollar falls, Canadian exports become cheaper in foreign markets and imports become relatively more expensive in Canada. Demand for rubber goods is therefore inversely related to the **CEER**.	+	Marginally Positive
Demand from Car and Automobile Manufacturing	This sector manufactures numerous intermediate products that are used in car and automobile manufacturing, including mud flaps brake pedal pads and hood shields. As consumer demand for automobiles rise, demand for rubber products also increases.	-	
Industrial Capacity Utilization	This industry supplies OEMs with a variety of rubber compounds and products. Industrial capacity utilization is sensitive to consumer demand. As demand for durable goods increases, operations must be expanded to meet this demand, increasing the demand for products produced by this sector.	+	
Value of Non-residential construction	Construction market uses manufactured rubber products for insulation and sealing, subflooring and roofing applications. As the level of construction activity increases, demand for rubber products increases as well.	-	
World Price of Rubber	World price of rubber tracks the price of natural rubber that is normally sourced from Asia. Canadian products are composed of a combination of natural, synthetic and recycled rubber. As price decreases in rubber tend to be passed on to end users, revenue in the industry correlates with rubber prices.	**+**	

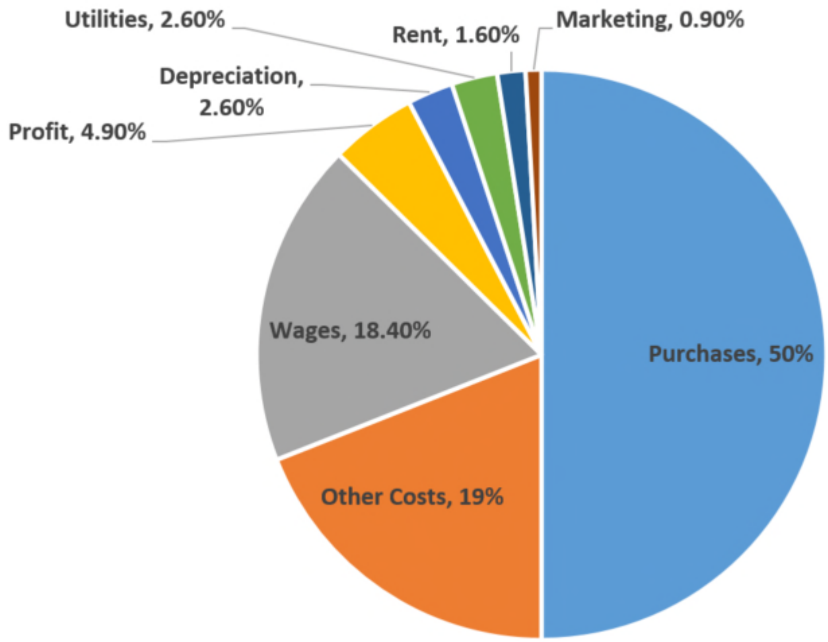
Source: McGrath, 2019.

Consistent with its stage of maturity, the near-term outlook for this industry is marginally positive. On the positive side, growth is expected to be buoyed by a decline in the Canadian Effective Exchange Rate (CEER), as the dollar is forecasted to depreciate through 2022. Furthermore, it is anticipated that macro-economic activity will pick up as the economy recovers from the pandemic, leading to increased demand from the automobile and industrial application sectors as well as from non-residential construction. Longer term, as the Canadian dollar appreciates and the sector comes under increasing pressure from low-cost foreign suppliers, growth prospects will deteriorate.

Supply Considerations

The Rubber Market Product Manufacturing Industry in Canada is characterized by a low level of market concentration, with the three largest industry operators accounting for less than 15.0% of industry output. The industry is comprised of a relatively large number of small to medium sized operators offering a wide array of products into a broad spectrum of markets. As such, individual operators have relatively little ability to exert market power to influence the market.

This fragmented market structure, along with the volatile nature of input prices and prevalence of substitute products, underscores the importance of cost optimization. Asian competitors, for example, are able to leverage lower wage bills and transportation costs (due to their closer proximity to raw material sources) to their advantage. In particular, higher profit margins allow them to better manage volatility in input costs in a competitive environment where increases in the cost of inputs are not able to be passed on to consumers.



Source: McGrath, 2019.

Figure 13: Rubber Product Manufacturing Industry - Cost Structure

As illustrated in **Figure 13**, after material purchases, other costs and wages constitute the next two largest drivers of operating costs. Most of the remaining costs of production, including freight bills, insurance premiums, and third-party billing, lie outside of the firm's control. Consequently, firms in this industry tend to focus on internal cost control through investment in labour saving technology or through consolidation activity to enhance productivity through the exploitation of economies of scale.

Some firms in the industry, however, do compete based on product differentiation. They do this through the production of output tailored to meet specific customer needs or through the manufacture of higher quality products. This competitive advantage is not widespread as it requires the ability to access incremental capital for investment in research and development and in the reconfiguration of existing production lines.

Hose & Belt Manufacturing in Canada (NAICS 32622)

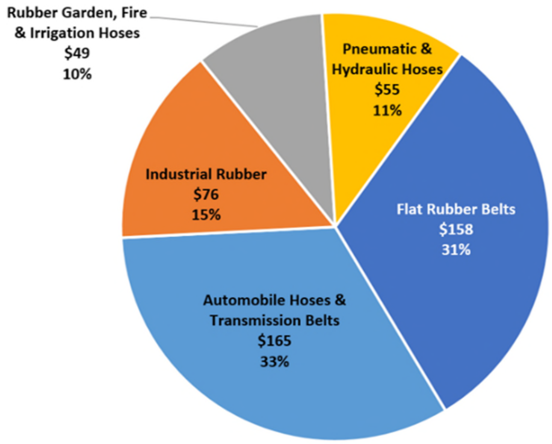
Overview

The Hose and Belt Manufacturing industry in Canada contributes an average of $CAD 541 million to the Canadian economy. Output consists of a range of rubber and plastic hoses and belts (**Figure 14**). These products then flow downstream to industrial manufactures, oil and gas industries as well as the automotive sector which uses them as inputs into their processes and end products.

Key activities for the sector include:

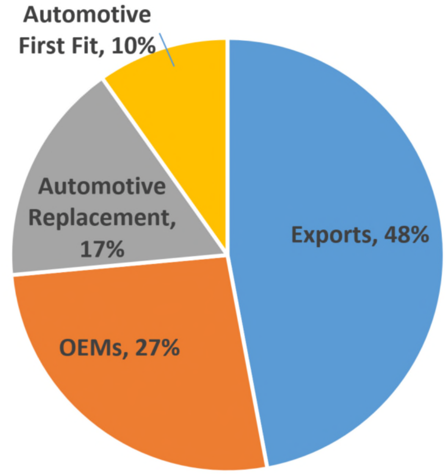
- Garden hoses manufacturing,
- Manufacturing of automobile belts, hoses, transmission belts, fan and timing belts,
- Manufacture of vacuum cleaner belts, and
- Pneumatic hoses manufacturing.

The sector is an important supplier to both OEMs and aftermarket wholesalers (direct sales to consumers seeking to repair already purchased goods). Revenues are highly levered to growth in the automobile sector - high pressure rubber and plastic hoses found in air conditioning and brake line systems are the largest product line accounting for nearly 33% of industry revenue. The next largest source of revenue, at 31%, are flat rubber and plastic belts. Downstream industrial and manufacturing sectors use these products for parts in equipment they use or as inputs into goods they produce. At 15% of sales, industrial rubber and plastic hoses are primarily used by the manufacturing, oil and gas industries. Finally, garden and water hoses generate about 10% of industry sales – products which are necessary to maintain lawns and gardens and therefore generate a relatively stable source of revenue for the industry.



Source: Gonzales, 2020. ($CAD million)

Figure 14: Hose and Belt Manufacturing Industry - Revenue



Source: Gonzales, 2020.

Figure 15: Hose and Belt Manufacturing - Markets Segments

Major markets served by the Hose and Belt Manufacturing industry in Canada consist of exports, OEMs, and automotive (first fit and replacement). As shown in **Figure 15**, at 48% of industry revenues, exports are the dominant market segment served by the industry. Due to its proximity to Canada and the Free Trade Agreement, the United States accounts for the vast majority of (90%) of these sales revenues. Domestically, OEMs, the industry's next largest market, consists of diversified set of downstream consumers such as manufacturers of equipment used in agriculture, construction, as well as the oil and gas and mining industries.

Despite the diversity of customers found in this market segment, revenues generated by this segment tend to be volatile as demand is closely linked to cyclical activity in world commodity markets. Finally, sales to the automotive industry in Canada generates 27% of industry revenues. Of this, First-fit products (belts and hoses used directly in the production of new vehicles) accounts for 10% of demand; while the automotive replacement market (firms that repair automobiles and distributors of automotive parts) consumes 17% of industry output.

Profile

As previously noted, the Hose and Belt manufacturing industry in Canada produces a diverse range of products and serves a wide range of customers. However, demand from many downstream buyers is linked to commodity prices and other macroeconomic forces such as the demand for automobiles. Consequently, the industry is subject to volatile revenue streams. Over the five-year period ending in 2019, average sales grew at a modest pace of 0.64%, with year over year growth ranging from a low of -4.24% to a high of +4.43% (**Table 35** and **Table 36**).

Similarly to the growth of the Rubber Product Manufacturing Industry, average domestic demand grew at a fairly robust rate of 3.95% per cent per year. However, international competition continues to be strong, with an average annual growth rate of 3.3% in imports accounting for much of the increase in domestic demand. Of that, sales by US firms accounted for over half of all Canadian imports as they continue to leverage their primary source of competitiveness, taking advantage of their larger size to generate economies of scale to produce lower cost goods. Cost pressures on Canadian firms are further exacerbated by the fact that these firms are clustered in Ontario where average wages have historically been higher than in most other parts of the country.

Table 35: Historical Performance

Year	Revenue[1]	IVA[1,4]	Establishments[2]	Enterprises[2]	Employment[3]	Exports[1]	Imports[1]	Wages[1]	Domestic Demand [1]
2015	535	170	76	61	1,994	222	980	92	1,293
2016	521	160	79	63	2,006	209	982	102	1,294
2017	542	174	73	58	2,118	219	1,078	101	1,402
2018	566	184	74	59	2,240	248	1,124	107	1,443
2019	542	177	72	57	2,084	260	1,087	106	1,370

Source(s): Gonzales, 2020.

Notes:

1. In $CAD million
2. An Enterprise is separately managed and keeps consolidated management accounts. An Establishment is the smallest type of accounting unit operating in a single physical location consolidated up into the Establishment.
3. Total jobs
4. IVA (Industry Value Added) is the market goods and services net of cost of goods sold. It is a proxy for the industry's contribution to GDP.

Table 36: Year over Year Change (%)

Year	Revenue	IVA	Establishments	Enterprises	Employment	Exports	Imports	Wages	Domestic Demand
2015	1.61%	5.73%	-1%	0%	12%	-1.95%	5.72%	16.50%	5.38%
2016	-2.62%	-5.88%	3.95%	3.28%	0.60%	-5.86%	0.20%	10.87%	0.08%
2017	4.03%	8.75%	-7.59%	-7.94%	5.58%	4.78%	9.78%	-0.98%	8.35%
2018	4.43%	5.75%	1.37%	1.72%	5.76%	13.24%	4.27%	5.94%	2.92%
2019	-4.24%	-3.80%	-2.70%	-3.39%	-6.96%	4.84%	-3.29%	-0.93%	-5.06%

Source(s): Gonzales, 2020.

The recent history of this industry suggests that it is transitioning from the Mature Stable phase (**Figure 16**) of its lifecycle to the Decline Stage. While overall employment levels grew at an average of 3.40% per year, this trend masks the more recent dramatic drop in employment of 6.96% following rounds of industry consolidation in reaction to continued competitive pressures. Industry decline is also noticeable in the drop in the number of establishments and firms currently operating.

	Stage One	Stage Two	Stage Three	Stage Four	Stage Five	Stage Six
Sector Stage	Start Up	Young Growth	High Growth	Mature Growth	Mature Stable	Decline

Figure 16: Hose and Belt Sector - Lifecycle Stage

Estimated Impacts

Table 37: Hose & Belt Manufacturing in Canada - Economic Impact

Multiplier Type	Output[1]	GDP at Market Prices[1]	Labour Income[1]	Taxes on production[1]	Jobs
Direct	541	293	25	17	2,707
Indirect	304	160	14	6	1,518
Induced	202	134	9	9	1,117
Simple	845	452	39	23	4,225
Total	**1,048**	**586**	**47**	**32**	**5,342**

Source(s): Gonzales; Statistics Canada, 2020.
Note:
1. In $CAD million

In total, multiplier estimates indicate that the industry contributes total economic benefits of $CAD 1.1B to the Canadian economy on an annual basis. This represents about 0.63% of Canada's total manufacturing sector or 0.06% of Canadian GDP. The sector also generates approximately 5,342 jobs each year (**Table 37**).

Domestic downstream activity such as manufacturing and industrial output are important drivers of industry demand. High levels of international trade also characterize the industry, meaning industry capacity utilization in the United States is similarly important to industry growth. Overall, it is expected the trend toward decline in this industry will continue unabated. The downturn in international economies due to the pandemic, coupled with the expected appreciation in the Canadian dollar and subsequent increased import penetration are likely to negatively hamper growth prospects for the foreseeable future.

Drivers of Demand

Table 38 summarizes key drivers of revenue growth for the Hose and Belt Manufacturing industry.

Table 38: Hose and Belt Manufacturing Industry - Drivers of Demand in Canada

Driver	Impact	Trend	Outlook
Canadian Effective Exchange Rate Index	Demand is inversely related to the value of the Canadian dollar relative to its trading partners. An increasing CEER index makes imported goods less expensive and more competitive against local goods.	(+)	Marginal Decline
Demand from Car and Automobile Manufacturing	Rubber and plastic hoses and belts are key components of automobiles. As a result, demand for this industry is directly related to levels of activity in the automobile sector.	(-)	
Industrial Capacity Utilization	Industrial and manufacturing activity drives demand for this industry's products. Demand therefore is positively correlated with activity in these upstream consumers.	(-)	
World Price of Rubber	World price of rubber tracks the price of natural rubber that is normally sourced from Asia. Canadian products are composed of a combination of natural, synthetic and recycled rubber. As price decreases in rubber tend to be passed on to end users, revenue in the industry correlates with rubber prices.	(+)	
Per Capita Disposable Income	Hoses and belts are inputs into many big-ticket products such as automobiles. Higher levels of income increase demand for these consumer durables	**(-)**	

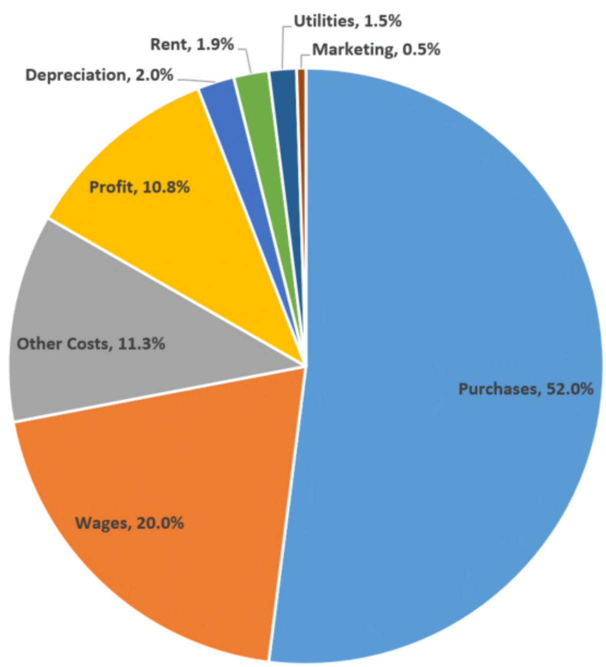
Source: Gonzales, 2020.

Consistent with this stage in its industry lifecycle, the outlook is for continued revenue deterioration. Although industrial capacity utilization is expected to pick up marginally, the industry has shown limited ability to remain cost competitive at home and in international markets. Imports are expected to continue to capture domestic market share, spurring further rounds of industry consolidation.

Supply Considerations

The hose and belt manufacturing industry in Canada is characterized by low levels of market concentration, with the top four firms accounting for less than 40% of industry revenues. Almost entirely composed of small to medium sized manufacturers, competition is primarily based on product quality, price, and the ability to establish relationships and secure long-term contracts with both upstream suppliers and downstream buyers (**Figure 17**).

In some instances, product differentiation can be a source of competitive advantage as those firms with specialized knowledge can tailor products to meet the specific requirements of customers. Product quality can also be important, with attributes such as weight, performance, strength and even the ability to be recycled all being valued by downstream users.



Source: Gonzales, 2020.

Figure 17: Hose and Belt Manufacturing Industry - Cost Structure

With no significant regulatory barriers, initial capital investment requirements are the primary barrier to entry. Companies seeking to compete in this sector must have the financial resources required to invest in facility space and to purchase the equipment needed to manufacture rubber products. High levels of working capital are also essential in order to retool short production lines in response to changing consumer demand. This helps firms to weather periods of revenue instability. High fixed costs are pushing the industry to greater consolidation in order to drive down unit costs and keep pace with its US competitors.

Material purchases drive the majority of industry costs, with firms needing to acquire raw materials such as chemicals, petroleum-based polymers, plastic resins and finished rubber to support their production processes. Most operators procure goods from independent suppliers, although a few are vertically integrated and produce their own fibres and chemicals. Wages are an ongoing source of cost pressure, especially in the competitive Ontario workplace. Operators are continuing to explore new ways to control labour costs and enhance profitability.

The most important factors for success in this industry include:

- Stability of Supply – Long term contracts can isolate firms from cost volatility;
- Quality Control – Defend market share against competitively priced substitute products;
- Long Term Contracts – Secure revenues facilitate long term capital planning; and
- Economies of Scale – Reduce per unit costs to enhance profitability.

Of note, technological innovation in the form of the emergence of big data and the internet of things are expected to be a disruptive force. Applying these technologies will allow industry operators to streamline supply chains, lower costs and improve productivity, as well as more effectively and efficiently meet consumer demand (Gonzales, 2020).

Tire Manufacturing in Canada (NAICS 32621)

Overview

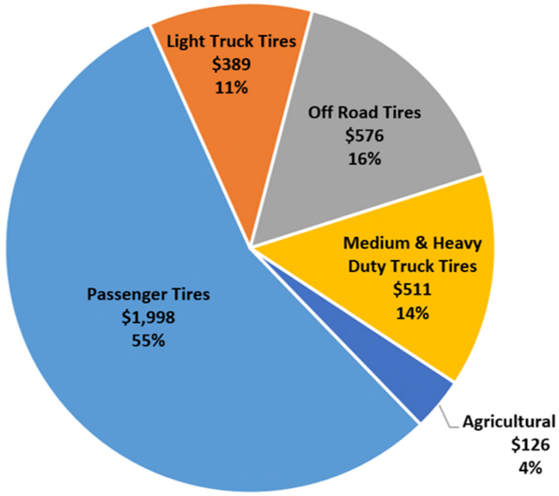
Tire Manufacturing in Canada is a $CAD 3.5 billion per year industry that is primarily engaged in the manufacturing and retreading of tires, as well as producing inner tubes from natural and synthetic rubber. Output from the industry is typically sold downstream to automobile manufacturers and tire wholesalers (**Figure 18**).

Key activities in the sector include:

- Inner tube manufacturing;
- Motor vehicle tire manufacturing;
- Tire repair material manufacturing; and
- Pneumatic and semi-pneumatic and solid tire manufacturing.

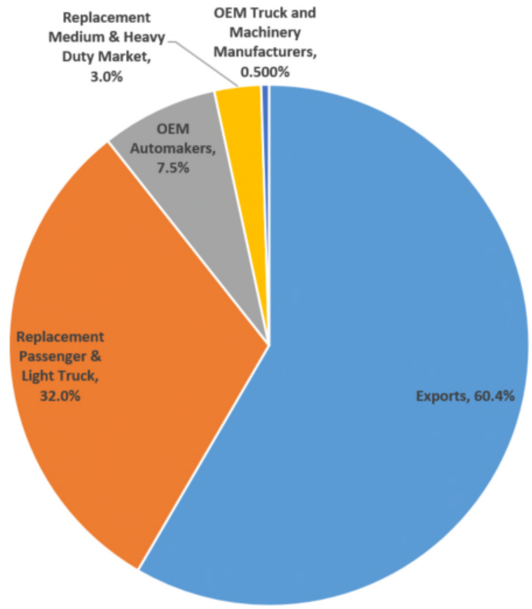
Passenger vehicle tires is the largest product segment generating 55.5% of revenues. This segment has been buoyed recently by strong new vehicle sales, an increase in income levels that have prompted consumers to purchase more expensive tires, and a decrease in fuel prices leading to increased travel and additional wear and tear on previously sold tires. Medium-and heavy-duty truck tires account for the next largest market share at 14.2%. These vehicles typically move freight or heavy materials so that demand for tires in this segment are closely linked to the level of trade activity.

After a brief shift away from SUVs, minivans and pickup trucks, consumer sentiment has responded favourably to falling fuel prices by shifting purchase back toward these vehicles. Currently medium-and-heavy duty truck tire sales account for approximately 10.8% of industry revenue. Off the road tires covers all forms of vehicle tires that are not for on road use. This segment includes ATVs, recreational vehicles, and agricultural machinery (tractors and combines). Taken collectively, this product offering represents about 16.0% of total industry sales.



Source: Mieles, 2020. ($CAD million)

Figure 18: Tire Manufacturing Industry - Revenue



Source: Mieles, 2020.

Figure 19: Tire Manufacturing - Markets Segments

Major downstream markets for the tire manufacturing industry include exports of OEMs, and replacement tire markets. Exports, accounting for 60.4% of the market, are almost wholly driven by the pace of industry activity in the United States which is the dominant destination for industry sales (accounting for almost 96% of export sales). Automotive OEMs purchase tires directly from tire manufactures and affix them to cars during the assembly process. This segment accounts for approximately 7.6% of industry revenue with Canadian automakers representing the largest portion of OEMs demand. At 32% of the market, replacement tires are also a significant source of industry revenue (**Figure 19**). Replacement tires are sold to independent dealers, to retail outlets that are vertically integrated into tire manufacturing companies, or to miscellaneous outlets. Independent dealers account for the majority of demand with manufacturer's storefronts or franchises making up the smallest component of this market.

The replacement tire market is the largest domestic market for this industry. International trade also continues to be integral to industry performance, with the United States being the pivotal trading partner. Growing emphasis on environmental concerns and fuel efficiency is a growing contributor to market dynamics, generating increased demand for better tires. Volatile input prices coupled with pressure from imports and an increased focus by consumers toward cost-efficient products has led to industry rationalization and the trend of shifting production toward countries with lower wage bills.

This is a mature industry with limited upside growth potential with sales closely tracking growth in Canada's GDP. On average, annual revenues grew at 1.72% for the five-year period ending in 2019. Exports to the United States generally dictate the pace of the entire industry and, as downstream US consumers have shifted toward sourcing tires from more cost-effective supply sources, Canadian firms have come under increasing competitive pressure. Over the last five years, exports grew only 0.5% per year on average. Imports, on the other hand, experienced significantly higher gains, growing at an average annual rate of approximately 3.31%. These factors have forced Canadian firms to consolidate, invest in fixed capital to capture economies of scale, and automate production in an effort to remain competitive in the domestic market. As a result, the number of operational enterprises has fallen at the significant pace of 5.18% per year (**Table 39** and **Table 40**).

Table 39: Historical Performance

Year	Revenue[1]	IVA[1,4]	Establishments[2]	Enterprises[2]	Employment[3]	Exports[1]	Imports[1]	Wages[1]	Domestic Demand [1]
2015	3,357	514	71	51	6,335	2,217	4,414	384	5,554
2016	3,351	487	69	48	6,604	2,256	4,175	350	5,270
2017	3,679	623	64	45	7,312	2,138	4,259	410	5,800
2018	3,648	615	61	43	7,246	2,163	4,342	406	5,827
2019	3,621	615	59	42	7,184	2,186	4,706	403	6,140

Source(s): Mieles, 2020.

Notes:

1. In $CAD million
2. An Enterprise is separately managed and keeps consolidated management accounts. An Establishment is the smallest type of accounting unit operating in a single physical location consolidated up into the Establishment.
3. Total jobs
4. IVA (Industry Value Added) is the market goods and services net of cost of goods sold. It is a proxy for the industry's contribution to GDP.

Table 40: Year over Year Change (%)

Year	Revenue	IVA	Establishments	Enterprises	Employment	Exports	Imports	Wages	Domestic Demand
2015	0.58%	10.10%	-5%	-7%	-1%	3.75%	9.61%	2.94%	6.24%
2016	-0.18%	-5.25%	-2.82%	-5.88%	4.25%	1.76%	-5.41%	-8.85%	-5.11%
2017	9.79%	27.93%	-7.25%	-6.25%	10.72%	-5.23%	2.01%	17.14%	10.06%
2018	-0.84%	-1.28%	-4.69%	-4.44%	-0.90%	1.17%	1.95%	-0.98%	0.47%
2019	-0.74%	0.00%	-3.28%	-2.33%	-0.86%	1.06%	8.38%	-0.74%	5.37%

Source(s): Mieles, 2020.

Recent performance of the industry suggests the sector has reached the Mature Stable phase (**Figure 20**) in its lifecycle.

	Stage One	Stage Two	Stage Three	Stage Four	Stage Five	Stage Six
Sector Stage	Start Up	Young Growth	High Growth	Mature Growth	Mature Stable	Decline

Figure 20: Tire Sector - Lifecycle Stage

Estimated Impacts

The sector as a whole contributes about $CAD 6.8 billion in total economic benefit to the Canadian economy every year, accounting for approximately 3.91% of Canada's total manufacturing sector or 0.40% of Canadian GDP. At 34,853 jobs, it is also a significant source of employment in Canada (**Table 41**).

Table 41: Tire Manufacturing - Economic Impact

Multiplier Type	Output[1]	GDP at Market Prices[1]	Labour Income[1]	Taxes on production[1]	Jobs
Direct	3,531	1,910	95	113	17,660
Indirect	1,981	1,042	54	39	9,905
Induced	1,321	872	33	60	7,288
Simple	5,512	2,952	150	152	27,568
Total	**6,836**	**3,824**	**182**	**212**	**34,853**

Source(s): Mieles; Statistics Canada, 2020.

Note:

1. In $CAD million

Industry performance is driven by a wide array of domestic and international macro-economic factors, including disposable income, the value of the Canadian dollar and fuel economy regulation. Volatile input prices, coupled with increased competition from imports, have offset some of the gains conferred on industry profitability (e.g., trends toward purchase of higher quality tires and the increased amount of driving being spurred by lower gas prices).

Drivers of Demand

The key external drivers of demand for this industry are summarized in **Table 42**.

Table 42: Tire Industry - Drivers of Demand

Driver	Analysis	Trend	Outlook
Canadian Effective Exchange Rate Index	Exported tires make up the majority of all tires manufactured in Canada. As a result, industry activity ebbs and flows with the value of the Canadian dollar relative to the US currency.	(+)	Marginally Positive
Per Capital Disposable Income	Consumer income has a direct impact on purchasing decisions. The lower per capital income, the more likely the decision to repair or purchase tires will be deferred and the less likely the demand for new automobiles.	(+)	
Total Vehicle kilometers	Total kilometers driven is a strong proxy for wear and tear on tires. The higher the number of kilometres driven, the more likely the tires will need to be replaced.	(+)	
Demand from motor vehicle manufacturing	Motor vehicle manufacturers purchase tires as part of the auto production process. Size of the industry's shipments to downstream customers is closely tied to the demand for tires from automakers.	(+)	

Source: Mieles, 2020.

The recent strong growth in North American car sales is expected to taper off in upcoming years. Cost conscious consumers are anticipated to increase their demand for fuel efficient tires which are more profitable than regular tires. Input prices are expected to continue to be volatile, making it challenging for industry to pass on cost increases to downstream tire distributors. Falling rubber prices did improve profitability but commodity prices are likely to rebound. Overall, this industry is expected to increase at an annualized rate of 1.6%.

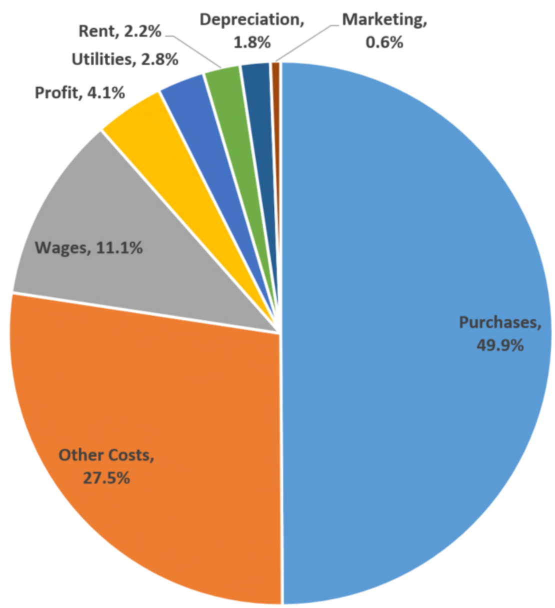
Supply Considerations

The Canadian Tire Manufacturing industry has a high level of market concentration with three major market participants accounting for roughly 75% of total revenue. The largest manufacturers in this industry are the following multinational companies, all with strong global positions:

- Michelin North America (Canada)
- Goodyear Canada
- Bridgestone Canada

While these factors have forced smaller competitors to exit the market – and make it challenging for potential competitors to enter – fierce competition exists between the major domestic players as well as between domestic players and international firms. Opportunities for product differentiation are limited but do exist. For example, the movement toward higher margin products such as high-performance and ultra-high-performance tires affords manufacturers some latitude in this regard. But overall, advertising and brand messaging is key to protecting market share. Imported products sourced from low-cost countries are a growing presence in the domestic market. In response, domestic companies have responded by increasing efforts to lobby government for additional import duties to increase the domestic price of imported tires.

Although the industry has no significant regulatory barriers to entry, high levels of investment capital can make market entry challenging. High initial investments are required to purchase equipment and related resources (**Figure 21**). As incumbents have control over a limited number of distribution channels for their products, the costs of winning distribution rights also pose challenges for competition in the industry. Finally, new entrants must also incur the costs of sourcing the skilled labour required to produce tires that comply with demanding quality and safety regulations.



Source: Mieles, 2020.

Figure 21: Tire Industry - Cost Structure

Material purchases drive most of industry costs, with firms needing to acquire raw materials such as resin, synthetic and artificial rubber, as well as synthetic fibres as inputs into their production process. The high amount of rubber used in the industry makes it very sensitive to the level of raw material prices, including oil. Most operators purchase goods from independent suppliers although a few source textiles and chemicals from internal sources. In response to increasing cost pressures, companies are allocating employees internally to more automated manufacturing processes and hiring more skilled research and development workers in an attempt to innovate and explore new ways to control costs and enhance profitability.

The most important factors for success in this industry include:

- Controlling Raw Material Cost – Managing volatile input costs will lower production costs.
- Strong Industrial Relations – Strong labour contracts will reduce the risk of work stoppage.
- Aggressive Marketing – Purchase market share given the low level of product differentiation.
- Use of specialized equipment – Operate plant at higher capacity to reduce unit production rates.

4.2.3 *Secondary Rubber Market – Domestic*

This sub-section focuses on EoL activity for tires. Lessons learned in this sector may prove useful when thinking of the application of circular economy principles in other sectors.

Background

Thirty years ago, all scrap tires in Canada were landfilled, stockpiled or scattered across the countryside. Despite the efforts of some early proponents of the circular economy who recognized the latent value in these assets, the prevailing view was one of used tires being a waste product to be disposed of at the lowest cost possible. Tire dumping or stockpiling met this objective because it doesn't require upfront capital investment and, since recycling facilities were typically located far away, transportation costs were minimized.

In 1990, the risks associated with this strategy were brought to the forefront when a stockpile of used tires in Hagersville, Haldimand County, Ontario burned out of control for months, consuming more than 14 million tires and polluting the air with thick, toxic smoke. Also, at that time there was growing recognition that these stockpiles generate significant health hazards, as tires are excellent breeding grounds for mosquitoes carrying the West Nile virus. Provinces responded by instituting tire programs that ban tire landfilling; that led to the cleaning up of landfills; and that created incentives for entrepreneurs to extract the circular economy value stored up in used tires.

Over time, these programs have proven to be successful, incentivizing the development of a diverse product base and in the innovation in manufacturing techniques required to produce them. The tire industry itself has adapted its own version of the ReSOLVE model, typically referred to as the 4Rs:

- Reduce;
- Reuse;
- Recycle; and
- Recover.

Reduce is best overall for the environment as it eliminates solid waste and saves natural resources. Tire manufactures are prolonging the life expectancy of automobile and truck tires through new and improving technologies. As consumers become better informed of the benefits of the circular economy, they contribute to reducing the use of natural resources through simple behavioural changes such as maintaining proper tire pressure, regular rotation of tires, and keeping wheels properly aligned – activities which, in and of themselves, can increase the life expectancy of tires up to 30%.

Currently, the single biggest market is for raw materials that can be recovered from scrap tires. In the past reuse of tires was more limited due to safety issues, but this has changed to the point where the primary challenges are economic ones. A relatively strong market for retreading tires does exist in some sectors of the transportation industry. For example, both commercial truck and aircraft tire casings are designed with retreading in mind. Tire casings used in these applications are retreaded several times before being discarded.

While exact tire compositions are unknown (companies keep their specific compositions secret), as illustrated in **Table 43**, tires are composed of a handful of material that could have value if liberated.

Table 43: Tire Material Composition and Weight

Key Element	Passenger Vehicle	Truck Tire
Natural Rubber	14%	27%
Synthetic Rubber	27%	14%
Carbon Black	28%	28%
Steel	14-15%	14-15%
Fibre, fillers, accelerators, antiozonants, etc.	16-17%	16-17%
Average Weight New	10.5kg.	50kg.
Average Weight: Scrap	9kg	45kg

Source: Tire and Rubber Association of Canada, 2019

Differences in tire composition across the passenger and truck tire vehicle classes are thought to be driven by performance and safety considerations. Passenger tires tend to contain more synthetic rubber than natural rubber as consumers in this segment demand higher quality standards such as low resistance, improved skid resistance, and good wear and tear. On the other hand, the focus for truck and off the road tires is on durability to cope with longer distances and heavier loads rather, than on the safety, smoothness, and speed of the ride.

Most Common Recovery Technologies

Ambient Grinding

This process is referred to as ambient because all grinding takes place at or near ambient temperatures. The tires are first shredded then enter into a granulator where chips are reduced to a size of less than 10mm in diameter. This liberates most of the steel and fibre from the granules. After exiting the granulator, steel is removed magnetically and fibre is removed through a combination of shaking screens and wind sifters. This is the preferred technology for the production of relatively coarse crumb rubber.

Cryogenic Grinding

In this process, whole tires or tire chips are cooled using liquid nitrogen to a temperature below -80C. At this temperature, a phase transition in the rubber occurs where it becomes almost as brittle as glass and size reduction is achieved through crushing and breaking. The first step is the same as ambient grinding, where tires are shred. The chips from shredded tires are then continuously cooled in an operating freezing tunnel after which they are dropped into a quickly rotating hammer mill where they are shattered into a wide range of sizes. Upon leaving the hammer mill, the chips are dried. This process is the preferred method used when finer rubber particles are required.

Devulcanization and Surface Treatment

From a chemical perspective, this process involves returning rubber from its thermoset, elastic stage back to a plastic, mouldable state. The process requires that the rubber has underdone previous ambient or cryogenic processing, which enables a much larger percentage of the recycled material to be recovered without comprising quality, appearance or performance. Important devulcanization methods include:

- Thermal reclamation;
- Mechanical devulcanization;
- Devulcanization with ultra-sound; and
- Bacterial devulcanization.

Markets for Recycled Tires

Canada has emerged as one of the leaders in the field of scrap tire management programs. Each province, and one territory in Canada, have established a program to recycle used tires (**Table 44**). In response, markets have produced diverse products and a tire processing industry capable of making these products. Scrap tires have progressed from likely one of the most glaring examples of the shortfalls of the linear economy, to a prime example of how a circular economy approach transformed tire disposal liability into a valuable resource with broad market penetration.

Rubber Reuse – Retreaded Tires

Retreaded tires account for nearly half of all commercial truck and bus tires in the U.S. and Canada, with approximately 44 percent of all commercial tires on the road in the U.S. and Canada being “retread” tires, including specialized mining sector vehicles. Up to 90% of large fleets in the U.S. and Canada use retreads in both on and off-road vehicle applications.

Historically, one of the challenges faced by the industry has been the safety narrative – the commonly held belief was that retreaded tires did not offer the same reliability compared to new tires of the same tread type and application. However, on balance, research into the issue by industry experts has concluded that a well-maintained retreaded tire offers equivalent reliability to a well-maintained new tire[36].

Retreaded tires offer many economic and environmental benefits relative to new tires, including:

- **Extended road life** – retreading a tire two times can keep a tire on the road up to 500 times longer than ultra-low-cost tires.
- **Cost Savings** – each time a well-maintained tire is retreaded, up to 50 percent of costs can be saved compared to buying a high-quality new tire, with larger mining vehicle tires being retreaded two or three times.
- **Environmental Benefits** – compared to ultra-low-cost competitors, use of retreaded tires in Europe lowered greenhouse gas emissions by 24%; reduced pressures on natural resources by 70%; reduced water consumption by 19%; reduced air pollution by 21%; and reduced land use by 29% [37].

Despite the obvious advantages from a circular economy perspective, retreading is under enormous competitive pressures from ultra-low-cost tires manufactured in countries that enjoy significant cost advantages, particular as it pertains to labour. Since 1998, retreaded tire's share of the replacement tire market has dropped from 54% to 44%; premium new tire share has dropped from 42% to 38%; with ultra-low-cost tires picking up a full 17% of market share over the same time period. As a result, the number of retread plants operating in North America has drastically dropped from 1,123 firms in 2000 to 668 in 2016 [38].

The increased substitution of ultra-low-cost tires for retreaded tires over the past decade - despite the clear environmental advantages of the latter – is an obvious advantage of a market failure being perpetuated by linear economic thinking. From a circular economy point of view, what is required is government intervention to ensure all lifecycle costs and benefits of rubber use are incorporated into the replacement tire purchasing decision.

Two possible policy prescriptions that would help promote circular economy principles and enhance the viability of the North American retread tire market are[39]:

- Establish new incentives for the production or purchase of retread tires.
  - These could target the end-users or the retread producers themselves and could take the form of year-end tax credits, lower sales tax on retread tire, or implementing the 'deposit/reimbursement' model.
- Introduce more stringent policy and third- party verification of tires.
  - While this is unlikely to single-handedly stop the growth of ultra-low-cost imports, more stringent environmental policies and verification will raise the standard for tires imported into the U.S. and Canada.

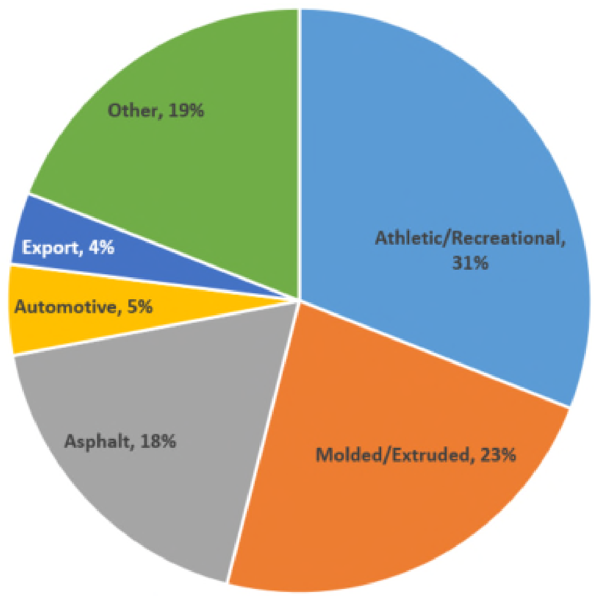
Rubber Reuse - Crumb Rubber

Within the scrap tire recovery hierarchy in Canada, due to its performance characteristics, crumb rubber has the highest-value applications. These applications can be grouped into major market segments:

[36] U.S. Department of Transportation – National Highway Traffic Safety Administration (2008), and Laubie, D. and the Maintenance Council (TMC), (1999).
[37] McKinsey & Company Ltd., McKinsey Center for Business and Environment. (2016).
[38] Daystar, J. (Duke University), Jay Golden (East Carolina University), Rob Handfield (North Carolina State University), John Woodrooffe (University of Michigan Emeritus). (2018).
[39] Ibid.

- **Athletic / Recreational surfaces** - Use in artificial turf, natural (grass) turf, and playground cushioning.
- **Molded and Extruded Products** - Diverse products including mats and bumpers.
- **Rubber Modified Asphalt (RMA)** - crumb rubber is added to asphalt binder to improve highway performance characteristics.
- **Tires/Automotive** - ground rubber is used in manufacturing some new tires, retreading old tires, and in molded automobile parts.
- **Export** - Ground rubber is directly sold to markets in Europe and the Far East.
- **Other** - Animal mats, colored mulch, horse arena safety cushioning.

Although data from Canada is not available, it is available from the United States (**Figure 22**) and it is believed that Canadian markets would be similar. At over 54% of market share, the Athletic / Recreational and Molded / Extruded components account for the majority of sales in the crumb rubber market. Exports play a minor role in the market at 4% of market share. Other markets which include products such as safety cushioning in horse arenas also represent a significant share of industry sales.



Source: Mieles, 2020.

Figure 22: United States Crumb Rubber Market Composition

Rubber Reuse - Tire Derived Aggregate (TDA)

A broad range of civil engineering applications in the United States and Canada consumer substantial quantities of derived aggregate. For example, Tire Derived Aggregate (TDA) can be substituted for conventional drainage aggregate across a range of applications when the latter is more expensive or is unavailable. TDA is also useful in some lightweight fill applications where its low density offers economic advantages. In general, the economics of using TDA will depend on its cost relative to competing alternative construction materials.

Although TDA is not a generally cost-effective substitute for conventional earth fill, its performance characteristics lends it well to applications such as:

- drainage layers within landfills,
- permeable aggregate for landfill gas collection layers,
- free draining aggregate for edge grade on roadways,

- septic system drain fields,
- lightweight fill over unstable underlying soils (particularly in coastal areas), and
- stabilization of landfill areas.

Tire Derived Fuel (TDF)

Scrap tires have been used to supplement energy resources in places such as Japan, Europe and the United States since the 1970s. It was the cornerstone of initial waste management programs and remains important, even as higher-value uses are developed. TDF played an especially important transitional role in Canada's stockpile abatement program where it consumed large quantities of scrap tires as other markets were being developed.

Tires are constructed out of hydro-carbon based material that is derived from oil and gas. With a heat content of 7,800 to 8,600 kcal/kg, tires compare favourably with coal as a fuel source (heat content of 5,550 to 7,200 kcal/kg). This higher heat content means that TDF generates less carbon per kilojoule than coal, and therefore lower greenhouse gas emissions relative to the burning of coal.

Whole or shredded tires can be used as potential energy sources, depending on the capabilities of the facilities under consideration. Regardless of particle size, systems must be able to receive and combust it to be a candidate for TDF use. Examples of facilities that have a demonstrated ability to use TDF include:

- **Cement Manufacturing Kilns** – tires have been successfully used in all major cement manufacturing processes.
- **Power Generation Plants** – In boilers conducive to complete combustion of TDF particles, TDF has displaced coal usage.
- **Paper Mills** – The high energy content of TDF has been used in some paper mills as an octane booster to enhance boiler performance and complete combustion.

Recovered Steel

The composition and properties of the steel in a tire bead has led to significant issues in the marketing of steel recovered from scrap tires. For example, the alloy content of tire steel, which is meant to protect it from corrosion, is an issue. Although research and development is ongoing in this area, the general consensus is that steel recovered from scrap tires is an inconsistent, low-quality material that only gains market traction during periods of high demand.

Recovered Fibre

Very little market demand has materialized for fibre generated as a result of the crumb rubber production process. Reasons for this vary from substantial contamination of fibre by rubber particles; lack of a proven cleaning technology; and the size and shapes of fibre particles. Few fibre users have experience with tire derived fibres.

Recovered - Other

Other materials can be derived from the thermal decomposition of scrap tires such as:

- Oil;
- Gas; and
- Carbon Black.

Issues with consistency and quality have been a problem in developing markets for these products. Currently, there are no active and liquid markets for these products operating in Canada.

Tire Stewardship Programs - Current Status

Canada has done much to enhance scrap tire stewardship through the development of programs that price the negative externalities associated with waste tire stockpiles. This has incentivized consumer and industry participation in markets to extract value from these products.

Tire stewardship is multi-faceted, differing from province to province. Retailers collect levies from consumers and remit the funds to a provincial scrap tire agency. From there, the agencies provide incentives to processers to produce value-added materials such as rubber shred and crumb. Governance is maintained through the requirement that producers show proof of sale to a third party prior to receiving the incentive. These programs have been highly effective. As of 2019, all of Canada's provinces and one territory (Yukon) have highly effective scrap tire recycling programs which have led to an effective diversion rate near 100%; the Northwest Territories and Nunavut are the only Canadian jurisdictions without tire stewardship programs[40].

Summary of the key attributes of Canada's tire stewardship programs is provided in **Table 44**. A wide range of levies are applied depending on tire type and location. These range from a low of zero for some agricultural tires in the Yukon to a high of $1,015 for giant off the road tires in Ontario. A continuing source of concern is the stewardship of giant off-road tires. Currently, only Ontario has a program in place to incentivize value-added EoL stewardship of these assets.

Table 44: Tire Stewardship Programs in Canada

Tire Category	Tire Sub-Category	YT	BC	AB	SK	MB	ON eTracks	ON Other	QC	NB	PE	NS	NL
Passenger/ Light Truck	Passenger, Small RV, Light Truck	$7	$5	$4 or $9	$5	$3.75	$4	Varies depending on individual producer responsibility organization.	$3	$4.50	$4 or $11.25	$4.50	$3 or $9
	Motorcycle, Golf Cart, ATV	$5	$5	$4	$5	$3.75	$4		$3	$3	$4	$4.50	$9
	Small Utility, RV Trailer	$5	$5	$4	$5	$3.75	$4		$3	$4.50	$4	$4.50	$3
	Lawn & Garden Tractor	$5	$5	$4	$5	$3.75	$4.55		$3	$3	$4	-	-
Truck / Bus	Medium Truck, Bus, Highway Trailer	$9	$9	$9	$14	$9	$14		$3	$13.50	$11.25	$13.50	$9
Agricultural	Small	-	$5	-	$5	$3.75	$9,10		$3	-	$11.25	-	-
	Medium	-	$15	-	$25	$9	$22.76		$3	-	$11.25	-	-
	Large	-	$35	-	$25	$30	$36.41		$3	-	$11.25	-	-
Industrial	Forklift, Bobcat / Skid Steer	$7	$5 or $15	$4 or $40	$5 or $14	$3.75 or $9	$9.10 to $45.51		$3	-	$4	-	-
	Logger / Skidder	$7	$35	$100	$57	$135	$36.41		$3	-	$11.25	-	-
	Skid Steer, Loader	$7	$35	$40	$14	$9	$22.76		$3	-	$11.25	-	-
	Aviation	-	-	-	-	-	-		-	-	-	-	-
Off the Road	Small	$40	-	$40	$57	$60	$22.76		$3	-	$11.25	-	-
	Medium	$100	-	$100	$140	$135	$141.10 to $273.09		-	-	$11.25	-	-
	Large	$200	-	$200	$140	$135	$423.29		-	-	$11.25		
	Giant	-	-	-	-	$135	$1,014.98		-	-	$11.25	-	-

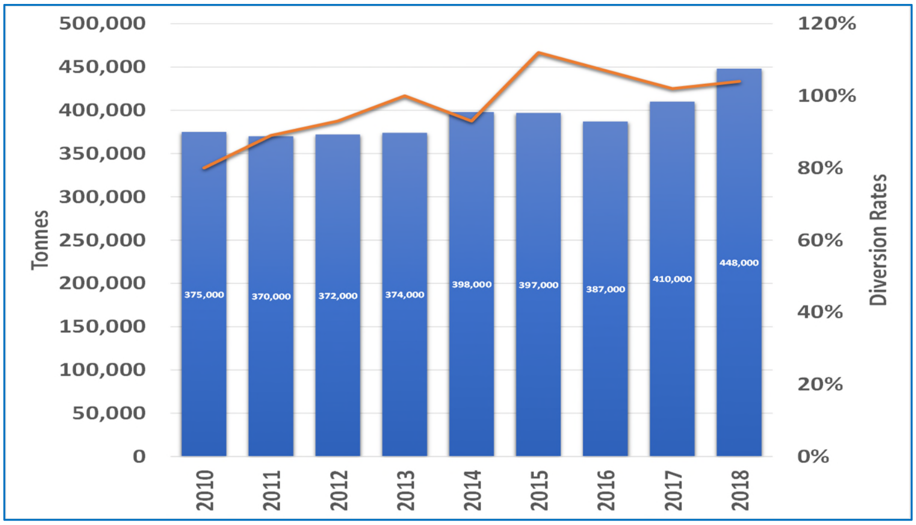
Source: CATRA, 2019.

[40] Alternatives Journal-Canada's Environmental Voice, (2019).

The success of Canada's tire stewardship programs in contributing to the circular economy can be assessed by understanding the volume of tires that are recovered to be used in the production of higher valued products.

In addition to cleaning up of tire scrap piles from landfills with a near 100% diversion rate, the data supports the notion that collection of scrap tires in Canada continues to grow and that these tire volumes are being reinjected back into the economy into value-added activities.

Collection of tires for recovery have increased from approximately 375,000 in 2010 to approximately 448,000 in 2018. Overall, the cumulative average growth rate is 2.25% (correlating with population growth and increases in winter tire purchases) but has accelerated sharply in recent years (due to clean-ups of EoL tires that were previously unavailable for collection). **Figure 23** shows trends in total volume of tire diversion and tire diversion rates[41] in Canada while **Table 45** illustrates geographic split of tire diversion volumes based on geography.



Source: CATRA, 2019.

Figure 23: Tire Diversion – Total Volume and Rates

Table 45: Tire Diversions across Canada

Location	Diverted Tires (Tonnes)
Yukon	613
British Columbia	50.230
Alberta	67,611
Saskatchewan	17,057
Manitoba	16,005
Ontario	210,704
Quebec	91,850
New Brunswick	10,845
Prince Edward Island	2,354
Nova Scotia	14,272
Newfoundland	5,929
Canada	**487,470**

Source: CATRA, 2019.

[41] Note: The Diversion Rate = (Tires Recycled + Tires Sent to Energy Recovery) / Total Tires Collected

4.2.4 ***Secondary Rubber Market – International***

Duty of Care

In 2019, Michelin released their Duty of Care Plan[42] whose environmental focus is mirrored by Bridgestone and Continental in their corporate social responsibility (CSR) progress (enforced in China, India and Indonesia) which includes, but is not limited to:

- zero waste to landfill in select factories;
- projects such as Tires4ward which ensures recovery and "valuable new use" of a waste tire for each new tire bought[43];
- 100% closed resource and product cycles by 2050, and
- alignment of internal environmental policy with Sustainable Development Goals (SDGs)[44].

These plans and publications show a significant drive from key manufacturers in the tire industry to improve best practices in the duty of care for products.

Landfill Bans

In Europe, landfill disposal for whole tires was banned in 2003, and in 2006 the ban was expanded to include partial and shredded tires. In 2019, the US Tire Manufacturers Association (USTMA) reported that, in the US, 39 US states had banned whole tires from landfill and 13 had banned shredded tires from landfill[45]; preventing materials from being accepted at a municipal solid waste (MSW) landfill while a mandatory recycling law levy fines against those placing specified items into domestic waste streams as opposed to domestic recycling streams[46].

In Australia, as part of the Queensland Waste Avoidance and Resource Productivity Strategy (2014 to 2024), the landfill ban of tires in Australia was selected to cover all regions, with three benefit areas: reduced cost of landfilling, greenhouse gas (GHG) emissions from landfilling, and increased value of recovered material.

Extended Producer Responsibility (EPR)

In New Zealand, Tyrewise, an industry-led product stewardship scheme, has been in place since 2012, managed by a Product Stewardship Organization (PSO) called Auto Stewardship New Zealand (ASNZ). This scheme places an advanced disposal fee (ADF) on tires, $5.50 ($CAD 5.04) per equivalent passenger unit (EPU), a standardized measure for the quantity of EoL tires. One EPU contains the same material as a 'typical' passenger tire. New EPU weight is estimated to be 9.5 kg, while used EPU weight is estimated to be 8 kg[47]. Reviewing prices of typical passenger tires (14 to 19 inches in size) on a New Zealand website, we take $200.00 NZD ($183.32 CAD) to be a high-level average tire price, suggesting the ADF is typically around 3% of new tire value.

In the Republic of Ireland, EPR for tires has been in place since 2007. Due to poor systems and low enforcement, the €2.80 (€3.44 including VAT or $CAD 4.35-5.34) passenger car tire fee was not being utilized for improving recovery and recycling in Ireland. Since 2017, the EPR scheme has been led by Repak ELT to improve the system and is based on the *Waste Management (Tyres and Waste Tyres) Regulations 2017*.

[42] https://www.michelin.com/en/documents/duty-of-care-plan/
[43] https://www.bridgestoneamericas.com/en/corporate-social-responsibility/environment-and-sustainability
[44] https://www.continental.com/en/sustainability
[45] https://www.ustires.org/sites/default/files/2019%20USTMA%20Scrap%20Tire%20Management%20Summary%20Report.pdf
[46] https://earth911.com/business-policy/landfill-bans/
[47] https://www.environment.gov.au/protection/waste/tyres

It is Repak ELT that is responsible for ensuring the compliance of producers and monitoring of the scheme[48] in cooperation with the Waste Enforcement Regional Local Authorities and the Irish Environmental Protection Agency.

Tax Scheme for EoL Tire Management

Following the 2015 release of the EU's Circular Economy Package, and subsequent release of the EU's Circular Economy Action Plan, policy drivers towards more sustainable through-life-management of products and materials have been substantial. In Croatia, tire producers (manufacturers/ importers) are required to pay a set fee to the Environmental Protection and Energy Efficiency Fund (public body). This fee is only required if the tires are intended to enter the Croatian market, not for exports. At EoL, registered collectors take charge of the tires who then pass the entire fee on to registered processors of waste tires. These processors report to the Environmental Protection and Energy Efficiency Fund on a monthly basis to monitor waste recycled and remaining for disposal. This system has been in place since 2007, six years before Croatia joined the European Union. From 2007 to 2016, average annual placed-on-market (POM) figures have outweighed collection figures 2,154,232 tonnes to 1,926,707 tonnes.

In Denmark, since 1995, economic incentives for the recycling of ELT have been in place. Tire producers (manufacturers and importers) pay a levy to the Customs and Tax Administration (Skat), which is then passed on to the Danish Environmental Protection Agency. Unlike the ADF in New Zealand, the Danish levy varies depending on tire type and size, from $10 to $225 DKK ($CAD 2.09-46.91). Collection locations include car dealers, tire shops, garages, etc. and consumers are not charged. A hierarchy is followed for EoL treatment, initially looking for tires to be retreaded, then granulated or pyrolyzed. Tire collectors are paid subsidies through the U.S. Environmental Protection Agency (EPA) via the Danish Tyre Trade Environmental Foundation for ELTs delivered to approved recyclers[49].

In Denmark, between 1996 and 2019 the percentage of collected tires recycled has increased from 57% to 96%, or 7,193 to 47,816 tonnes. In tandem, collection and recycling have been increasing steadily, with tire sales remaining relatively consistent.

Summary

Landfill bans are a successful regulatory approach used globally. Canada currently does not have a national ban on tires from landfills and this could be employed to help keep tires from going to landfills and ensure they are fed back into the recycling system. Although Canada has more than ten differing provincial and territorial EPR provincial tire stewardship programs, a national modulated EPR scheme would drive product design improvement and EoL improved prospects.

4.3 Assessment of Global Competition

4.3.1 Canadian Rubber Market in World Context

As a small, open, commodity-driven economy, Canada faces many challenges to its manufacturing sector. Its rubber market manufacturing industry is no exception. For the three rubber market industries examined in this report, on average import penetration into the domestic market is approximately 72%, while exports constituted an estimated 53% of total sales[50].

The cost of labour and raw materials is the primary source of profitability pressure in the industry and also a source of competitive advantage, with the value of the Canadian dollar relative to its trading partner's currencies also having a significant impact.

[48] https://repakelt.ie/regulation/
[49] https://www.daekbranchens-miljoefond.dk/english
[50] Gonzales, McGrath, 2019 and 2020 Mieles, 2020

With respect to its primary trading partner, the United States, Canada's main advantage stems from the lower value of the Canadian dollar relative to the American dollar. This advantage is hampered by the lower cost structures in the USA, where the firms are generally larger and can leverage economies of scale to drive down per unit production costs. One of the main threats to the Canadian economy, as a developed mature country, is the relatively high cost of labour when compared to companies located in other areas of the world that are less developed.

In this type of operating environment, enhanced productivity is a necessary precursor to continued industry success. In this light, it is clear that Canadian companies as a whole are falling behind some of our many industrialized counterparts. According to the 2019 Global Competitiveness Index, Canada ranked 14th with a score of 79.6, below international competitors such as the USA, Japan, South Korea and Taiwan.

Countries productivity critically depends on which stage of development they are in measured by the Global Competitive Index, 2019:

- In the factor-driven stage, countries compete based on their factor endowments, primarily unskilled labor and natural resources. Companies compete on the basis of prices and sell basic products or commodities, with their low productivity reflected in low wages.
- In the efficiency driven stage, rising wages mean countries must develop more efficient production processes and increase product quality.
- In the innovation-driven stage, higher wages are only sustainable if businesses are able to compete by providing new or innovative products.

At the current time, the Canadian rubber industry is in the efficiency-driven stage; it is struggling to compete with competitors that are in the factor-driven stage that have lower costs of production. The pillars of competitiveness at this stage include higher education and training, the ability to leverage existing technologies, and market size. Industry has taken steps toward addressing some of the internal cost pressures which it has a level of control over such as labour and per unit production costs. This has been achieved through increasing research and development programs, the implementation of labour-saving technologies, and securing long term supply contracts wherever possible.

As many of the drivers of growth are not controlled by the industry (such as world commodity prices and the Canadian exchange rate) these changes are necessary and should continue but, in of themselves, are not sufficient to secure the long-term future of the industry in Canada.

In the long run, a country's economic fortunes are a function of proactive choice, both at the micro (firm level) and the macro (economy and/or government level). Decisions made at these levels interact in various complex ways over time to impact productivity. Investing in infrastructure, health and education, macro-economic stability, business dynamism, and efficient labour markets are all critical to how productive a firm, industry, or country are.

From this approach it appears that what is needed for the Canadian rubber industry to remain relevant in the global context is the implementation of systems thinking. Government and industry leaders must act cohesively to identify and assess the factors that underpin economic growth. For the rubber industry as a whole, these leaders should focus on the path to the innovation stage of industry development, where investments in the above-noted pillars of competitiveness lead to the development of innovative products at competitive prices.

An example of systems thinking in Canada is in the secondary rubber market (tire recycling) where Canada has emerged as a world leader. Success in this sector is built upon environmental concern and knowledge amongst Canadian citizens. Due to the relatively high impact of climate change on Canada's environment, particularly in the North, the vast majority of Canadians consider climate change an extremely serious issue. These micro-motives in the tire industry have led to innovative macro-responses by various levels of government. This includes the implementation of tire stewardship programs that generate the incentives required for the appropriate private sector response.

There may also be an opportunity for Canada and its rubber industry to leverage this success and export this knowledge abroad. Canada could become a world leader in the design of the innovative institutional structures that unlock the value of the circular economy.

4.4 Identification & Analysis of Market Barriers

As previously noted, the Canadian rubber industry primarily consists of three distinct industries:

- Rubber Product Manufacturing in Canada (NAICS 32629);
- Hose & Belt Manufacturing in Canada (NAICS 32622); and
- Tire Manufacturing in Canada (NAICS 32621).

This industry is best described as being mature, with growth prospects expected to match or under-perform the Canadian economy as a whole. Existence of competition (both domestic and foreign); the high level of market concentration in some segments, and the general inability to differentiate products means that firms in this industry compete primarily on price. The strategic focus is therefore generally on cost control, especially as pertains to labour and raw materials.

Investments in equipment and technology to improve economies of scale and drive down the wage bill are common and can be a significant barrier to entry for new firms. Price volatility in raw materials can also hinder entry as new entrants must have sufficient resources to manage swings in profitability.

4.4.1 *Technology Related Barriers*

Technology in the industry is considered a 'medium' barrier to entry. For example, machinery is relatively easy to acquire if not operate and there are few intellectual property blocks. (**Table 46**).

Technological innovation in this sector is primarily aimed at controlling costs in an effort to insulate profits from the risk of volatile input prices and competition from firms that operate in low labour cost environments. The emergence of big data and the internet of things is one such innovation that firms are currently implementing in order to streamline the supply chain, respond to customers more efficiently, and lower working capital requirements.

Other trends in the industry include investment into research and development into computer automation and computer controls in an effort to substitute technology for labour. Other innovations involve investment in equipment and technology required to retrofit short production lines in order to efficiently respond to changing customer needs.

Table 46: Technology Related Barriers to Entry

Sector	Strength of Barrier	Overall Assessment
Rubber Product Manufacturing	Medium	Medium
Tire Manufacturing	Medium	
Hose & Belt Manufacturing	Medium	

Source (s): Gonzales, McGrath, 2019 and 2020 Mieles, 2020.

4.4.2 *Competition Related Barriers*

Competition in this industry varies from sector to sector, but overall is considered to be a 'medium' barrier to entry, meaning competition related factors do not significantly add to the threat of disruptive potential but do not detract from them either (**Table 47**).

For the Hose and Belt Manufacturing sector, there is no single dominant player, underscoring the importance of product quality and pricing. Product differentiation is sometimes significant as products are often tailored to meet the specific requirements of customers.

The Rubber Product Manufacturing sector shares many of these same competitive attributes with the added threat of substitute products. For example, manufacturers in other industries produce similar products comprised of substitute materials such as plastic and polyurethane.

Tire Manufacturing also has limited product differentiation potential, faces a high level of competition from imports, and is highly concentrated. Entrants to this market must consider the prospects of competing against large, well-resourced multinational companies.

Table 47: Competition Related Barriers to Entry

Sector	Strength of Barrier	Overall Assessment
Rubber Product Manufacturing	Medium	Medium
Tire Manufacturing	Medium	
Hose & Belt Manufacturing	Medium	

Sources: Gonzales, McGrath, 2019 and 2020 Mieles, 2020.

4.4.3 *Regulatory & Policy Related Barriers*

Overall regulatory and policy considerations are not significant barriers to entry in the industry, (i.e. 'light' barriers) (**Table 48**). As with other manufacturing industries, firms must comply with environmental regulations including meeting emissions and air pollution standards. Compliance with these regulations may be a cost consideration for market entrants. In addition, operators in Tire Manufacturing also must take into account costs related to meeting tire safety and fuel efficiency standards, (i.e. with regard to regulatory and policy barriers they have 'medium' strength barriers).

Table 48: Regulatory Related Barriers to Entry

Sector	Strength of Barrier	Overall Assessment
Rubber Product Manufacturing	Light	Light
Tire Manufacturing	Medium	
Hose & Belt Manufacturing	Light	

Sources: Gonzales, McGrath, 2019 and 2020 Mieles, 2020.

4.4.4 *Market Concentration Related Barriers*

Generally, the industry consists of a large number of small to medium firms, limiting the ability of incumbents to use market power to control prices to undercut the ability of new firms to enter the market; therefore, strength of the market concentration related barriers is 'low' (**Table 49**).

The exception is the tire manufacturing sector, where a very high level of industry concentration exists, and hence 'high' market concentration related barriers. This sector is dominated by a few multi-national firms that are well capitalized, have control of downstream distribution channels, and own large manufacturing facilities to leverage economies of scale. A very challenging environment for new firms seeking to enter the market in profitable fashion.

Table 49: Market Concentration Related Barriers to Entry

Sector	Strength of Barrier	Overall Assessment
Rubber Product Manufacturing	Low	Low +
Tire Manufacturing	High	
Hose & Belt Manufacturing	Low	

Sources: Gonzales, McGrath, 2019 and 2020 Mieles, 2020.

4.4.5 *Industry Assistance Related Barriers*

Industry assistance related barriers in both the rubber product manufacturing and the hose and belt manufacturing sectors is 'low' and generally does not significantly impair ease of entry into the market (**Table 50**). This is due to the existence of the North American Free Trade Agreement, which essentially eliminated tariffs in these sectors. The fragmented nature of the market structure in these industries is also a factor as it tends to limit the ability of incumbents to organize and exert significant lobbying power.

Assistance to tire manufacturing is higher than in the other sectors due to the receipt of financial help in the form of subsidies for investment in Canadian production facilities. Incumbents in the sector also benefit through support received from industry associations such as the Tire and Rubber Association of Canada and the Suppliers Council to the Canadian Tire Industry. As a result, Tire Manufacturing has 'medium' industry assistance related barriers.

Table 50: Industry Assistance Related Barriers to Entry

Sector	Strength of Barrier	Overall Assessment
Rubber Product Manufacturing	Low	
Tire Manufacturing	Medium	Low
Hose & Belt Manufacturing	Low	

Sources: Gonzales, McGrath, 2019 and 2020 Mieles, 2020.

4.4.6 *Capital Intensity Related Barriers*

The rubber and tire manufacturing industries are well established. Start-ups seeking to enter the market must overcome the large investments required in land, manufacturing equipment and technology, therefore the capital intensity related barriers are deemed 'medium'. Moreover, high working capital requirements are necessary to withstand pressures on profitability when commodity prices rise. Also, some segments of this industry require the financial capacity to retool production processes on the fly to tailor products to changing and specific customer needs. Beyond 2020, it is expected that the capital intensity will be more of a barrier to entry as the industry invests in innovation products to maintain or grow both domestic and international markets.

Table 51: Capital Related Barriers to Entry

Sector	Strength of Barrier	Overall Assessment
Rubber Product Manufacturing	Medium	
Tire Manufacturing	Medium	Medium +
Hose & Belt Manufacturing	Low	

Sources: Gonzales, McGrath, 2019 and 2020 Mieles, 2020.

Conversely, hose and belt manufacturing are 'low' with respect to capital intensity related barriers as they consist of a large number of small to medium sized companies that require lower levels of investments than tire or rubber product manufacturers.

4.5 The Circular Economy

From extraction, to processing and manufacturing, to end-use, the conventional view of the utility of commodities is a linear one (**Figure 24**) with the final destination of rubber being waste disposal. In this view, rubber material ends its life cycle as a waste product with no value that must be disposed of at minimum cost. The logical outcome of this type of linear flow is ultimately unsustainable - harmful effects on the environment and the economy accumulate in response to increasing levels of rubber ending up as waste disposal.

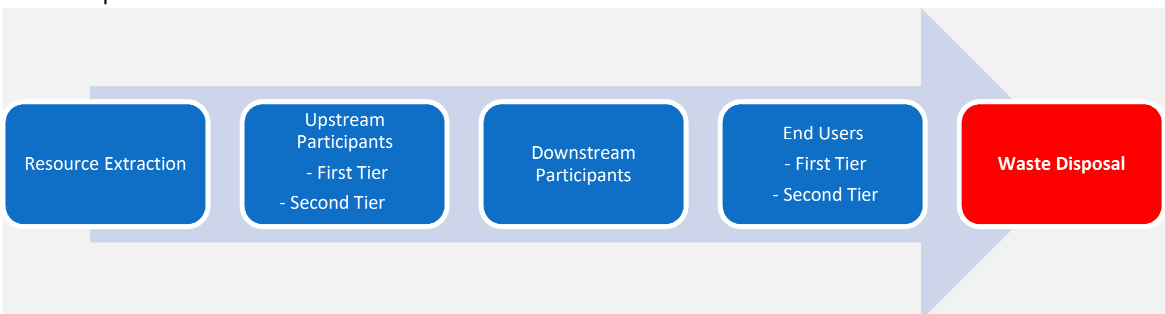


Figure 24: The Linear Rubber Economy

How can Canada avoid this linear trap and its harmful impacts on the environment, while at the same time increasing prosperity and reducing dependence on primary materials and energy? The circular economy can be part of the answer. Instead of the take-make-dispose model of the linear economy, an economy built on circular principles is restorative by design. The goal is to use and reuse natural capital as efficiently as possible, enhancing the value of finished products throughout their lifecycle.

In general, the circular economy is governed by three overarching principles:

- **Preserve and enhance** natural capital by controlling finite stocks and balancing the flow of renewable resources.
- **Optimize** resource yields by circulating products, components, and materials in use at the highest possible levels at all times.
- **Raise effectiveness** of the system by eliminating negative externalities.

Implementing these principles requires coordinated, and somewhat complex efforts at the local, national, regional and global levels. Specifically, transitioning the linear economy to a circular one requires countries to change behaviours so that actions are taken in alignment with the ReSOLVE model[51]:

- **Regenerate** - Shift to renewable energy /materials to reclaim and regenerate ecosystems.
- **Share** - Maximize lifespan of products through peer-to-peer sharing and prolong life spans through ongoing maintenance and design for durability.
- **Optimize** - Improve the performance and efficiency of products.
- **Loop** - Keep components and materials in closed loops and prioritize the inner ones. For finite materials, this means remanufacturing products or components and recycling materials. For renewable materials, it involves anaerobic digestion and the extraction of biochemicals from organic waste.
- **Virtualize** - Deliver utility virtually.
- **Exchange** - Replace old materials with advanced renewable ones; apply new technologies, such as 3-D printing and electric engines.

[51] McKinsey & Company Ltd., McKinsey Center for Business and Environment. (2016).

Each of these actions enhances the lifecycle value of economic output through an increase in the use of physical assets and shifting resource use away from finite resources toward renewables. Taken collectively, behaviour undertaken according to the ReSOLVE model have the potential to generate positive feedback loops where each action reinforces and accelerates the performance of the others. Such a virtuous cycle could have significant impacts on a country's cost competitiveness and overall economic performance.

As noted in **Table 52**, for most manufacturing industries, adapting at least one of the ReSOLVE actions would likely provide highly profitable opportunities for the sector. For the rubber industry in Canada, adapting the circular economy actions of sharing, looping, and optimizing are the areas highlighted as having the highest potential.

Table 52: ReSOLVE Framework by Manufacturing Sector

Sector	Regen.	Share	Optimize	Loop	Virt.	Exc.
Wood & Paper Products Manufacturing	High	High	Medium	Low	High	Low
Manufacturing of textile and apparel	High	High	Medium	Low	Medium	Medium
Manufacture of transport products	Low	High	Medium	High	High	Medium
Manufacture of furniture	High	High	Medium	High	High	Medium
Manufacture of electric and electronics	Low	Medium	Medium	High	Medium	Medium
Manufacture of machinery and equipment	Low	Medium	Medium	High	Medium	Medium
Manufacture of rubber and plastics	Medium	Medium	Medium	High	Low	Medium
Manufacture of food, beverage and tobacco products	High	Low	Medium	High	Low	High
Manufacture of coke, refined petroleum, and chemical products	Low	Low	Medium	Medium	Low	High
Manufacture of pharmaceuticals, medical and botanicals	Medium	Low	Medium	Medium	Low	Medium

Source: McKinsey, 2016.

4.5.1 *Data Limitations*

A limitation of much of the research and data in Canada is the lack of information regarding circular economy activities for much of the rubber industry. Of the three main sub-industries, the tire manufacturing industry publishes by far the most detail on the trajectory of their products, from upstream processing and manufacturing activities, through the industry itself, and on to end users (in the linear economy) and beyond (in the circular economy).

The pandemic has affected the rubber market in the same manner as numerous industries around the world. Rubber industry impacts as a result of the global COVID-19 pandemic have included:

- Michelin, Bridgestone, and Goodyear closed some Canadian plants temporarily in early 2020 to mitigate the spread of the pandemic contagions. Other countries also declared complete shutdowns including: China, India, Germany, Italy, Brazil and the U.S.
- Demand fell drastically for industry products in the U.S., as both export and import volumes declined between the U.S. and Canada in 2020.
- Passenger car replacement tire sales declined in 2020 as travel for work and leisure purposes decreased significantly as a result of the lockdown measures of the pandemic.

4.5.2 *Trend and Outlook*

The Tire Manufacturing industry in Canada exhibited contraction mainly as a result of the pandemic in 2020. Declines in vehicle sales in North America and significant reduction of travel in 2020 as a result of pandemic lockdown measures are the primary reasons for this decline. The depreciation of the Canadian dollar typically encourages export growth. However, import competition from other countries in the United States, Canada's largest export market, offset any benefits from a weaker currency. As a result, revenue declined by 18.2% in 2020, leading revenue to decrease to reach $CAD 2.7 billion over the past five years to year end 2020. Future North American car sales are projected to grow, but the Canadian dollar is anticipated to appreciate over the next five years which should place downward pressure on exports. Tires that improve gas mileage for consumers will continue to experience increased consumer interest as consumers seek to reduce fuel expenses.

The rising usage of rubber in textiles and industrial goods is expected to act as a driving factor for the growth of the market after the pandemic measures are lifted, and the development of novel products is expected to create immense growth opportunities for the future non-tire rubber market. The demand for synthetic rubber for tires is expected increase due to its properties such as better abrasion resistance, high heat resistance, elasticity, toughness and cost effectiveness compared to natural rubber.

The longer term effect on the industry due to the global pandemic will remain unknown for the foreseeable future.

5 Identification and Analysis of Emerging Solutions and Technologies to Reduce Rubber Waste

This report section, addressing Task 3 of the project, provides a list of measures and opportunities for intervention that have been identified in other jurisdictions to offer the greatest opportunities for increased rubber circularity. This is applicable to the key rubber industry players and processes in the rubber supply chain. The potential areas of opportunities are presented under the following categories:

- Regulatory;
- Economic;
- Technological;
- Information and data;
- Social; and
- Voluntary initiatives.

The overriding barrier to increased tire recycling is a technical one, that of the absence, globally, of a true devulcanization process, or equivalent technology, that would enable rubber particles from used rubber products to be converted into feedstocks for new rubber products at a high level of recycled content. In overcoming this barrier, focus must be on transportation products (predominantly tires but also hoses, belts, gaskets, and weather stripping), and on a wide range of industrial rubber products and footwear.

While our experience suggests that this area of research will yield the greatest opportunity for increased circularity of rubber and rubber products in Canada, we are also aware that rubber waste and losses also occur in the upstream areas of the supply chain, from production of natural and synthetic rubber to new product manufacture. Opportunities therefore exist for intervention in these areas as well. This review of demonstrated measures, technologies and processes includes the rubber life cycle, from resin production through to end-product applications.

The review is presented as two key sections:

Section 5.1: Demonstrated Public and Private Sector Measures, and
Section 5.2: Emerging Technologies, Processes, and Other Innovations Measures.

Both reviews present measures that have potential opportunities for implementation to reduce rubber waste and shift Canada towards a circular economy for rubber.

5.1 Demonstrated Public and Private Sector Measures

Section 5.1 identifies and analyses current and emerging market and other solutions and measures to reduce rubber waste and increase the circularity of rubber in demonstrated global jurisdictions. Using the rubber market knowledge gained in this project's **Tasks 1 and 2**, the types of measures by category identified include:

Section 5.1.1 Regulatory Interventions
These type of interventions include: "duty of care" applications to improve land, air and water management controls, EoL vehicle and waste tire policy, performance standards for tire wear, landfill bans, stricter regulation on the use of rubber crumb, and an assessment of regulatory measures for Canada.

Section 5.1.2 Economic Schemes for EoL Tire Management
Economic schemes include producer responsibility measures to drive investment in new processing technologies and new end uses through extended producer responsibility (EPR) schemes, tax schemes for EoL tire management, and voluntary economic schemes.

Section 5.1.3 Technological Interventions
These interventions consist of provision of technical product standards for secondary rubber products/ recyclates, and industry driven technological interventions.

Section 5.1.4 Informational and Data Interventions
Data and informational collection interventions inform priority areas for intervention and deliver the metrics for increased circularity and noted gaps in available data.

Section 5.1.5 Education and Public Awareness Campaigns
These include programs regarding tire care, use of retreaded tires, recycling of secondary materials, illegal dumping, ocean plastics, and TWP chemical leaching.

Section 5.1.6 Voluntary Initiatives
Voluntary initiatives encompass support for existing and new stewardship programmes for tires, benchmarking best practice, and support for brand-led initiatives for increased recycling.

5.1.1 *Regulatory Interventions*

Duty of Care Application and Standards

Duty of care is a legal requirement for businesses to adhere to, but setting standards for duty of care and driving the application of duty of care is a regulatory intervention. The duty of care should stretch across the supply chain for a product, with each actor shouldering their own share of responsibility. In terms of tires, the duty of care needs to be considered especially thoroughly in the context of waste through the chain and at EoL which are considered to be key environmental hotspots. When initially considering the duty of care, improving waste management controls on the handling and storage of tires stands out as a basic step. By implementing policies discussed in later sections of this **Task 3** report, governments can have significant impact on ensuring responsible management, but proper duty of care also requires significant input from:

- consumers (proper disposal);
- tire retailers (proper collection);
- tire collectors (proper logistics and management by recycler), and
- tire recyclers (proper recycling and waste treatment).

What can sometimes be overlooked is the responsibility of tire manufacturers, as their duty of care is often viewed as ending when their product is purchased by a consumer. More frequently, manufacturers of goods are taking on mild (and sometimes significant) levels of product stewardship. In this sense, mild refers to a more holistic consideration of products throughout their life and how the manufacturer can improve the supply chain and future impacts of their products.

In 2019, Michelin released their Duty of Care Plan[52] which covers “Ethics and compliance,” “Human rights,” “Employee health and safety” and “Environment and climate change.” The area of “Environment and climate change” is critical here as it covers eco-design of products and services (improving product production and EoL impacts) alongside sustainable operations. This environmental focus is mirrored by Bridgestone and Continental in their corporate social responsibility (CSR) progress (enforced in China,

[52] https://www.michelin.com/en/documents/duty-of-care-plan/

India and Indonesia), referenced here to show the environmental drive of the industry players at work in Canada, which includes, but is not limited to:

- Zero waste to landfill in select factories, as part of their CSR policy, noting that this would be individual private sector internal CSR policy, and that not all businesses will have the same level of corporate sustainability as per their own choice.
- Projects such as Tires4ward which ensures recovery and "valuable new use" of a waste tire for each new tire bought[53].
- 100% closed resource and product cycles by 2050.
- Alignment of internal environmental policy with Sustainable Development Goals (SDGs)[54].

These plans and publications show a significant drive from key manufacturers in the tire industry to improve best practices in the duty of care for products. The focus that producers have put on these initiatives should facilitate engagement to improve the environmental management of tires alongside policy makers at local, regional, and federal levels.

EoL Vehicle (ELV) and Waste Tire Policy

EoL vehicles (ELV) and waste tire policy links closely with plastics in the automotive space. Research into the recovery of ELV plastics is ongoing. At the dismantling stage, the simple-to-remove items, such as bumper and gas tanks are retained and the remainder shredded. This automotive shredder residue (ASR) has limited EoL prospects.

There may be potential here to "piggyback" rubber recovery alongside ELV plastics recovery with the removal of belts, hoses and, potentially, weather stripping.

As with non-dismantled plastics in ASR, any shredded rubber (typically the vast majority of non-tire rubber) is currently going to low value EoL routes, (e.g., landfill). This is due to the low embedded value of the material, relative cheapness of landfilling rubber due to weight-based landfill costs, and lack of value-added recycling streams.

There may be potential for improvements to infrastructure and processing technologies here, and though this may fall under the "Economic Intervention" driver due to the investment required for infrastructure upgrades, the supportive environment for these changes will likely need to be driven by end use applicability and policy (e.g., impact based landfill costs/ban of rubber to landfill), and investment may be required from governments, leaving it in the "Regulatory" driver intervention bracket.

The most progressive regulatory measures for tires employed in Canada are those of Ontario (ON). Following the release of Ontario's "Resource Recovery and Circular Economy Act" in 2016, the active tire recycling program was replaced as of 2019 with a new framework, effectively a modified extended producer responsibility (EPR) scheme called the Individual Producer Responsibility Framework (IPR)[55].

The IPR involves a multitude of Producer Responsibility Organizations (PROs) which ensure compliance with EoL tire (ELT) obligations and report to Ontario's Resource Productivity Recovery Authority (RPRA)[56]. These Ontario tire PROs include:

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53 https://www.bridgestoneamericas.com/en/corporate-social-responsibility/environment-and-sustainability
54 https://www.continental.com/en/sustainability
55 https://rpra.ca/programs/tires/
56 https://www.catraonline.ca/

- Critical Raw Material (CRM);
- eTracks Tire Management Systems;
- Mobius PRO Services;
- Reclay PRO;
- Ryse Solutions Inc.; and
- YESS[57].

The key economic mechanisms that can be employed, regulatory or market driven (including EPR and EPR style schemes), are discussed in more detail in **Section 5.1.2**.

Implementation of Performance Standards for Tire Wear

Implementation of performance standards for tire wear is a regulatory approach that governments can adopt to prevent low-performing tires from accessing the market. This regulatory approach lowers the emissions of microplastics into the environment by reducing the number of low-performing tires sold into the market. Tires not meeting performance standards may be taxed at a higher rate in comparison to tires that meet performance standards. Alternatively, tires not meeting regulatory performance standards may not be permitted to enter the market due to the negative environmental impact of releasing microplastics, tire particulates and chemicals into the environment at a faster rate.

A recent assessment by ICF Incorporated (originally known as Inner City Fund) and Eunomia (2018) consulting firms, of policy options for the EU to reduce microplastics from tire wear, identified the use of **Abrasion Product Standards** to prevent low-performing tires from accessing the EU market. The proposed implementation of the standard involved:

- Developing a standard to test and measure the rate of tire wear under standard conditions.
- Rating and labelling the tires, based on the results of the standard tests, to inform consumers about tire wear performance.
- Setting a threshold tire wear performance requirement and barring tires that do not meet that threshold from the EU market.

Amongst other useful advice, the Eunomia report indicates that the current lack of abrasion performance data provided to end-users results in a market failure; this negatively impacts consumers who could benefit from cost savings if they understood which tires shed less and, as a result, last longer.

Tire manufacturers would also benefit, as they would see quicker return on investment from research and development spending into developing tires with longer lifespans. Societal benefits could also be achieved by decreasing the negative impacts caused by tire wear on air quality and the environment. According to the 2018 report, the estimated costs of implementation were:

- €500,000 to €1.5 million ($777,190 to $2.3 million CAD) to develop a standardized abrasion test procedure. They suggest that amending the wet grip, rolling resistance and external noise tests could be done in tandem.
- €5,000 and €40,000 ($7,772 to $62,161 CAD), depending on the distance travelled, per tire model to test for abrasion.
- The anticipated cost for displaying the labelling scheme was marginal and no cost was provided for the regulation changes.

The projected efficiency of the proposed interventions to reduce tire wear, and the estimated annual cost per tonne prevented microplastic emissions at source and to surface water are shown in **Table 53**.

[57] https://rpra.ca/programs/tires/producer-responsibility-organizations/

Table 53: Projected Efficiency and Cost of Proposed Interventions on Tire Microplastics Reductions

Intervention Measure		Cumulative Emissions 2017 to 2035 (Tonnes)		Cumulative Reduction of Emissions from Baseline 2017 to 2035 (Tonnes)		Estimated Annual Cost per Tonne Prevented Emissions at Source
		Source Emissions	Surface Water Emissions	Source Emissions Reduction	Surface Water Reduction	
Baseline		11,200,000	2,100,000	-	-	-
Measure 2 – Tire Label	Low	10,900,000	2,040,000	300,000	60,000 (3%)	€11,000 ($17,096 CAD)
	High	10,400,000	1,900,000	800,000	200,000 (8%)	€4,000 ($6,216 CAD)
Measure 3 – Type Approval		10,100,000	1,900,000	1,100,000	200,000 (10%)	€3,000 ($4,662 CAD)
Combined (Measure 2 and 3)		8,700,000	1.600,000	2,500,000	500,000 (22%)	€1,300 ($2,020 CAD)

Notes:
Source: ICF and Eunomia, 2018
Emissions figures round to nearest 100,000 or 10,000 for those less than 100,000.

Landfill Bans

Landfill bans are a regulatory approach implemented by a regulatory body. Canada currently does not have a national tire ban from landfills. In Canada, landfill bans typically fall under provincial (environmental approvals branch) or municipal jurisdiction (waste management policy).

In Europe, landfill disposal for whole tires was banned in 2003, and in 2006 the ban was expanded to include partial and shredded tires.

In 2019, the US Tire Manufacturers Association (USTMA) reported that, in the US, 39 US states had banned whole tires from landfill and 13 had banned shredded tires from landfill[58]. Though this indicates progress, the lack of an overarching US federal government regulation to prevent the landfilling of both streams of tires means that the remaining 11 states still allow landfilling of whole tires and 37 allow landfilling of shredded tires. It is also noted that, in the US, a ban prevents materials from being accepted at a municipal solid waste (MSW) landfill while a mandatory recycling law levies fines against those placing specified items into domestic waste streams as opposed to domestic recycling streams[59]. While this is not a suggestion for tires to be driven into domestic recycling streams, it is possible that wider sanctions could be employed to help capture tires going to waste and ensure they feed into recycling routes.

In Australia, as part of the Queensland Waste Avoidance and Resource Productivity Strategy (2014 to 2024), research has been carried out on the associated costs and impacts of landfill bans, including for tires[60]. Bans were considered for application across South-East, North-East and Inland regions or a subset of them. For tires, the landfill ban in Australia was selected to cover all regions, despite the fact that the number of tire recyclers in each region at that time were:

- Four (4) (South East);
- One (1) (North East); and
- Zero (0) (Inland).

[58] https://www.ustires.org/sites/default/files/2019%20USTMA%20Scrap%20Tire%20Management%20Summary%20Report.pdf
[59] https://earth911.com/business-policy/landfill-bans/
[60] https://www.qld.gov.au/__data/assets/pdf_file/0021/94062/qld-waste-avoid-resource-prod-strat-2014-24.pdf

Table 54 summarizes the Present Value (PV) estimates of the net economic impact of implementing a landfill disposal ban for tires in Australia, shown by region. Key areas of note here are the three (3) benefit areas which provide positive financial gain:

- Reduced cost of landfilling;
- Reduced GHG emissions from landfilling; and
- Increased value of recovered material.

The four (4) cost areas which require investment, likely shared between government and waste management companies are:

- Increased cost of resource recovery;
- Illegal dumping;
- Compliance;
- Monitoring; and
- Enforcement costs.

From **Task 2**, the Canadian experience in tire diversion from landfill has had success. The success of Canada's tire stewardship programs in contributing to the circular economy can be assessed by understanding the volume of tires that are diverted from landfill to be used in the production of higher valued products. In addition to cleaning up of tire scrap piles from landfills (with a near 100% diversion rate) the data supports the notion that collection of scrap tires in Canada continues to grow, and that these tire volumes are being reinjected back into the economy into value added activities.

Collection of tires for recovery has increased from approximately 375,000 in 2010 to approximately 448,000 in 2018. Overall, the cumulative average growth rate is 2.25% (correlating with population growth and increases in winter tire purchases) but has accelerated sharply in recent years (due to clean-ups of EoL tires that were previously unavailable for collection). The bulk of the geographic split of tire diversion volumes based on geography is in Ontario, Quebec, Alberta and British Columbia. On a per capita basis, the kg/capita of tires recovered as an inter-provincial Canadian average is 11.3 kg/cap.

Table 54: NPV of a Landfill Disposal Ban on Tires by Region in Queensland

Tires Landfill Ban (Australia)	PV for South-East Region (4 tire recyclers)	PV for North-East Region (1 tire recycler)	PV for Inland Region (0 tire recyclers)	PV Total for Regions (5 tire recyclers)
Impact	**$CAD**	**$CAD**	**$CAD**	**$CAD**
Reduced cost of landfilling	90,366	39,818	3,982	134,167
Reduced cost of GHG emissions from landfilling	33,028	15,826	1,583	50,437
Increased value of recovered material	130,704	62,629	6,263	199,597
Total benefits	**254,098**	**118,273**	**11,829**	**384,200**
Increased resource recovery costs	182,986	87,681	8,768	279,435
Increased cost of illegal dumping	11,273	5,402	540	17,215
Increased compliance costs	2,819	1,351	135	4,304
Ongoing monitoring and enforcement costs	2,763	1,324	133	4,221
Total costs	**199,841**	**95,757**	**9,576**	**305,174**
Net impact of a landfill disposal ban	**54,258**	**22,516**	**2,253**	**79,026**

Continuing with the Australian demonstrated data, due to the low tonnages of tires being sent to landfill in Queensland at the time of the study (shown below in **Table 55**), and the strong and accessible nearby

Asian markets for rubber waste and crumb, a significant cost benefit can be clearly seen in modelling of putting the ban in place. With the ban in place, it is estimated that both the cost of recovery and reprocessing, and market price will not deviate from the base case – $140/tonne ($137 CAD) and $100/tonne ($98 CAD), respectively.

Table 55: Collection and Diversion Data for Tires in Queensland from 2012/2013

Region	Tonnes recovered	Tonnes Landfilled	Interstate/overseas market
South-East	22,838	192	Yes - significant interstate and overseas markets
North-East	10,226	92	Yes - significant interstate and overseas markets
Inland	1,023	9.2	Yes - significant interstate and overseas markets

Reproduced from Queensland Waste Avoidance and Resource Productivity Strategy

Though the cost analysis given here is specific to Queensland, many other countries (as discussed above) have implemented these bans and seen positive impacts. Specifically, reduction in waste sent to landfill and improvements to recycling rates following these bans are common. Results from several European countries, in which these bans are now mature, are detailed in **Table 56**.

Table 56: Results stemming from Landfill Bans in Several European countries

Jurisdiction	Reduction in landfill disposal	Increase in material recovery
Austria	Reduction in proportion of waste being disposed of via landfill from 29% in 1999 to 4% in 2006	3% increase in waste material recovery
Belgium	Reduction in proportion of waste being disposed of via landfill from 25% in 1997 to 3% in 2007	60% increase in waste material recovery
Estonia	Reduction in tonnage MSW being disposed of via landfill - 267,000 tonnes in 2010 compared to 403,000 tonnes in 2001	Increase to recycling rate from 5% of MSW generated in 2001 to 20% in 2010
Finland	Landfill ban has been found to be ineffective and unenforceable - government is currently in the process of redesigning a stricter ban to be implemented in the foreseeable future. 3% increase in waste material recovery	
Germany	Reduction in proportion of waste being disposed of via landfill from 27% in 2000 to 1% in 2006	25% increase in waste material recovery
Netherlands	Reduction in proportion of waste being disposed of via landfill from 35% in 1995 to 10% in 2006	27% increase in waste material recovery
Sweden	Reduction in proportion of waste being disposed of via landfill from 23% in 2001 to 4% in 2007	32% increase in waste material recovery

Reproduced from Queensland Waste Avoidance and Resource Productivity Strategy

In addition to the positive impacts detailed in **Table 57**, it should be noted that there remains the potential for unintended consequences to have a negative impact following a ban. Such negative consequences may include:

- An increase in illegally dumped waste.
- Increases in the cost of waste management for businesses due to a lack of capacity in the recovery and processing market; or
- Reduced value of recovered material on markets due flooding of material onto the market.
- A lack of end uses for the material.

Given the technical uses and abundance of opportunities to utilize waste rubber in Canada (discussed in **Section 5.2**), we do not see the latter as a great concern, but do see ensuring the highest environmental value routes are fed first and that essential logistics to enable recyclers access to the material are properly developed as notable risk factors.

Rubber Crumb in Surface Applications

Utilization of rubber crumb in road and paving surfaces is a route that is being more commonly driven for EoL tires and plastic alike (M. Sasidharan et al, 2019). In this case, we look to rubber crumb in the production of tire derived aggregate (TDA), noted as providing technical improvements over typical aggregate. TDA may be useful as a backup route for rubber crumb that is unusable in other applications. These may include, for example: tire retreading, recycled content tires and other recycled tire products assuming they do not have the capacity to absorb the quantity on the market.

A 2013 paper studying the incorporation of waste plastics (including crumb rubber) in pavement and their performance provides insight here. The study concluded that various polymers positively impact upon the asphalt in different ways, but recommended that polymers such as styrene-butadiene-styrene (SBS), ethylene-vinyl acetate (EVA) or high density poly ethylene (HDPE) be further researched as they provide the greatest technical benefit but have existing issues (namely storage stability); and that crumb rubber or acrylonitrile butadiene styrene (ABS) plastic may be used currently, despite showing fewer technical improvements versus the aforementioned materials (L. Costa et al, 2013).

For many plastics, there are typically more high value recycling routes available. It would be prudent to ensure that these are fully exhausted before high value plastic is used in asphalt to replace a portion, up to 25%, of the bitumen in asphalt surfaces. The same can be said for high value uses of rubber crumb. The amount of material that, in general, goes to lower value/environmental benefit recycling must be carefully reviewed, in all cases.

Though TDA is not directly driven by the regulatory measures mentioned in this report, a landfill ban, and minimum recycled content in tires and eco-modulated EPR, would all be likely to drive TDA abundance differently. In terms of TDA:

- A landfill ban would likely be the most supportive.
- Minimum recycled content the least supportive.
- EPR support dependent on how the eco-modulation is derived.

As an option in the waste hierarchy, TDA is not likely to be pushed outright by a regulatory policy measure but could instead be impacted peripherally; this with a landfill ban likely being the most supported, minimum recycled content the least supported, and EPR dependent on how the eco-modulation is derived. As an option in the hierarchy, and not the most environmentally beneficial, this is not likely to be pushed outright by a policy measure but will instead be impacted peripherally.

Eco-Modulated Extended Producer Responsibility (EPR)

Eco-Modulated EPR refers to modulated fees used to encourage producers to make more sustainable design, production and purchasing decisions in line with the waste hierarchy and federal/provincial environmental priorities. For example, in an EPR system funded by its product producers, the producers may pay a lower EPR obligation fee for their products which are easy to reuse, repair or recycle and an EPR funding penalty for those that are not. Eco-modulated EPR could include such regulating factors as:

- durability in terms of minimum life expectancy measured in kilometers (to penalize the cheaper lower quality imports);
- reparability/re-manufacturability (can the product be retreaded?); or
- recyclability where hazardous or potentially harmful substances are excluded from the product.

Assessment of Regulatory Measures for Consideration in Canada

The following **Table 57, Table 58, Table 59, and Table 60** present an assessment of the top four (4) ranked regulatory measures, from the longer list described above, and have potential for further consideration in Canada:

1. National banning of Whole or Shredded Tires Being Sent to Landfills (Table 57).

2. Setting a Minimum Recycled Content in Tires (Table 58).
3. Implementing an EPR Scheme with an Eco-Modulation Component (Table 59).
4. Implementing a Product Stewardship Benefits Scheme (Table 60).

Of note, EPR is listed here as an economic type of intervention. Globally, EPRs are typically enforced by governments. The governance structure is headed by the governmental body, and actors in the scheme are ultimately held responsible by the government. Any changes to the scheme (e.g., applying eco-modulation fees to an EPR scheme) would be overarchingly controlled by the government. Thus, eco-modulated EPR is included here as a regulatory measure for completeness.

Approximately 98% of Canadian imports of synthetic rubber are from the United States. Similar to natural rubber, Canada is not a significant player in synthetic rubber export markets, with the limited amount that is shipped internally destined for the United States, [61] a natural destination given its close proximity (low transportation costs) to Canada and the existence of the North American Free Trade Agreement (low transaction costs). Note that United States–Mexico–Canada Agreement (USMCA) came into play July 1, 2020. The Canadian rubber industry is expected to come under increasing competitive pressures from imports, even if the dollar depreciates, as firms located in the United States continue to leverage economies of scale and firms located internationally continue to leverage low wage bills to enter the market on a cost competitive basis. Asian competitors, for example, are able to leverage lower wage bills and transportation costs to their advantage due to their closer proximity to raw material sources.

Table 57: Assessment of Landfill Bans

Key aspect	Discussion
Objective of the measure	National ban on tires being sent to landfill.
Targeted rubber product and/or material	Whole and partial/shredded tires.
Life cycle stage targeted by the measure	EoL.
Maturity of the measure	Tried and tested in the EU-28 member countries; a successful regulatory measure.
Effectiveness	Landfill bans are a highly effective regulatory measure and is successful in increasing the recycling quantities and driving improved treatment routes for tires.
Gaps and weaknesses of the measure	Landfill bans are often criticized for simply diverting waste to the next worst option, typically energy recovery. Does not include rubber from other sources (e.g., automotive rubber such as tubing, construction rubber belts).
Feasibility in Canada	A national ban is highly feasible in Canada since alternatives of EoL tires to landfill (e.g., rubber crumb production, TDA, energy recovery) are widely available/established alternatives and have capacity for expansion. The **Task 4** report expands on rubber recycling in Canada.
Barriers	As this looks to tackle material being lost to the "bottom-rung" of the waste hierarchy, no major barriers are foreseen.
Lessons learned	Widening the scope of the measure to all sources of rubber and, in accordance with more modern zero waste to landfill policies, include a ban on incineration with no energy recovery.

[61] World Bank (2020).

Table 58: Assessment of Minimum Recycled Content in Tires

Key aspect	Discussion
Objective of the measure	Set a minimum recycled content in tires.
Targeted rubber product and/or material	Tires.
Life cycle stage targeted by the measure	Design, manufacturing, and EoL.
Maturity of the measure	This measure is currently being developed for plastic products in Europe via the "plastic tax," (i.e.) any products with a recycled content below 30% will be subjected to the tax. However, in terms of rubber, minimum recycled content has not been implemented in any country to our knowledge due to the difficulties of adding recycled rubber into virgin feedstock, (i.e.) vulcanized rubber can be difficult to combine effectively, alter material properties and be detrimental to the mechanical properties of the final product. Recycled content is feasible but the percentage would depend on technology, with most of the large tire manufacturers actively developing their own technologies.
Effectiveness	Would establish a market pull/demand mechanism and would ensure the recovered rubber from waste tires is, at least in part, directly displacing virgin natural or synthetic rubber.
Gaps and weaknesses of the measure	Unknown how accessible technology is to ensure recycled content in all tires, (e.g., the small producers may have greater difficulty accessing the secondary materials markets). However, this can be overcome by setting a *de minimis*, (e.g., producers placing less than a specified number of tires onto the market will be exempt from this measure).
Feasibility in Canada	Given the low production rate of tires within Canada, this would effectively set a standard for tire imports – which may act as a filter for low-end low quality tires.
Barriers	The ability of the market to hit a minimum recycled content target must be considered. It may increase the price paid by consumers for tires significantly and/or it may limit the availability of tires in Canada, at least for a time.
Lessons learned	N/A

Eco-modulated EPR could include such modulating factors as durability in terms of minimum life expectancy measured in kilometres (to penalize the cheap imports), reparability/re-manufacturability (can the product be retreaded?) or recyclability where hazardous or potentially harmful substances are excluded from the product. An assessment of Eco-modulated EPR is in **Table 59**.

Table 59: Assessment of Eco-Modulated EPR

Key aspect	Discussion
Objective of the measure	Eco-modulated EPR. (Concept: design of product that is more ecologically friendly and sustainable, then the producers fees and recycling recovery costs will be less for that producer, whereas, an non eco -friendly product design is charged a higher EPR producer fee due to the higher cost burden to the recovery program (i.e. higher environmental burden).
Targeted rubber product and/or material	Tires.
Life cycle stage targeted by the measure	Design, manufacturing, in-use and EoL.
Maturity of the measure	Eco-modulated EPR is tried and tested for other product categories (e.g., portable batteries and furniture [in France], but not for tires).
Effectiveness	EPR (but not eco-modulated EPR) has been successful for tires (e.g., New Zealand TyreWise scheme, discussed further in **Section 5.1.2**) in transferring the full net costs of EoL waste management from local authorities to producers. It is also successful in generating the funds required to invest in improved recycling infrastructure and/or R&D. However, such EPR initiatives do not target other stages in the life cycle of the tires, such as the design phase, and **eco-modulated EPR** has been successful for other product categories (e.g., portable batteries).
Gaps and weaknesses of the measure	The administrative burden of appraising each product against the "eco-modulation" criteria can be significant from both a producer and data validation perspective.

Feasibility in Canada	The Product Stewardship Schemes (PSS) currently in place in Canada act in a very similar way to a conventional EPR. The provincial tire EPR programs currently do not have regulatory requirements other than for the recycling of the tires and funding by its producers. There is no requirement to support a mandate for a more environmental sustainable design of the tires. Hence, the key challenge for Canada would be the new introduction or addition of an "eco modulation" aspect to the EPR measure to established tires programs. The addition of eco-modulation to the EPR tire programs adds a level of complication to the operation of the EPR program and framework, (i.e. distribution of program funds to various tire treatment process) (i.e. who should review funds based on their selected processes and tire eco designs, compliance of producers, criteria for tire recovery process) (e.g., treatment route hierarchy to retain higher value and support sustainable design), validation of the tire processes and treatment options and overall administrative burden.
Barriers	The ability of all producers to hit the objectives must be considered from an "administrative burden" perspective. The development of the eco modulation criteria is therefore a critical element of this measure.
Lessons learned	Considering EPR in general in Canada, provincially regulated at present, we see that there is no standard hierarchy or definition for recycling (leading to a variation in treatments accepted as recycling). If an eco-modulated EPR were to be considered, standardization of definitions and potentially a federally led scheme would be required to ensure a level playing field and that equal practice was maintained.

A further consideration is a product stewardship benefits scheme similar to that in operation for used-oil in Australia[62]. Here, a standard levy is paid into the scheme, but the benefits received are dependent on the end fate, (e.g., re-refining receiving a higher fee than burning). The Product Stewardship Institute states that similar schemes for tires exist in some jurisdictions (presumably in the US, but none are specifically stated) and that the benefits received "can be a sliding scale based on the end use … the higher value the product, the more incentive a processor receives"[63].

Table 60: Implementing a Product Stewardship Benefits Scheme

Key aspect	Discussion
Objective of the measure	Product stewardship benefits scheme.
Targeted rubber product and/or material	Tires and general rubber.
Life cycle stage targeted by the measure	EoL.
Maturity of the measure	In place in Australia to drive best practice for used oil treatment; well-grounded for said product category. In place in other jurisdictions as per PSI.
Effectiveness	Can drive EoL prospects up the waste hierarchy. However, this is dependent on cost, Technology Readiness Level (TRL) and accessibility, some measures may not be suitably encouraged if the remuneration is too low. For example, in the case of used oil in Australia, very few, if any, companies have invested in re-refining infrastructure to maximize the revenue they receive from the scheme.
Gaps and weaknesses of the measure	Although the scheme provides an economic incentive to invest in higher end waste management facilities, in many instances such facilities are far more expensive than the lower end facilities. For example, in the case of Energy from Waste, the facilities are often already well established and hence the revenue received from such schemes is additional revenue.
Feasibility in Canada	Given the current EoL tire management structure in Canada, there is scope to raise typical tire treatment up the rubber value chain hierarchy.
Barriers	Promoted EoL methods must have the operational and infrastructure capacity to enable wider use in the jurisdiction.
Lessons learned	N/A

[62] https://www.environment.gov.au/protection/used-oil-recycling/product-stewardship-oil-program
[63] Product Stewardship Institute. (2015).

Of note, that Transport Canada has recently (December 4, 2020) presented a Schedule of Proposed Regulations plan. The ‘forward regulatory plan’ includes a three-year look ahead of regulatory changes or actions that are under consideration by Transport Canada’s Road Safety Programs group, as well as regulations proposed in the Canada Gazette Part I and finalized in the Canada Gazette Part II in the last year. Amendments to the Motor Vehicle Safety Regulations (MVSR) and Motor Vehicle Tire Safety Regulations (MVTSR) are developed under the authority of the Motor Vehicle Safety Act (MVSA). The plan is intended to provide consumers, business, stakeholders, and trading partners advanced notice of an opportunity to provide input on potential regulations or actions that the department is considering. This may be an added opportunity to introduce and consult on circular economy interventions discussed above in this section related to tire regulations with the objective of reduce tire solid waste in Canada. We also note that most of the regulations at Transport Canada are performance regulations (i.e. do not specify the content of the tire, but a performance it must reach).

5.1.2 *Economic Schemes for EoL Tire Management*

It is commonly accepted that there are three (3) key types of systems or economic schemes to support sustainable EoL tire management. These are:

- Extended Producer Responsibility (EPR) System;
- Tax System; and
- Voluntary (Free Market System).

These three (3) economic schemes have significant differences. **Table 61** presents a summary description of their key aspects and idiosyncrasies in the categories of:

- key aspects,
- responsibility,
- governance, and
- funding.

Table 61: Economic Schemes for EoL Tire Management

System	Key Aspects	Responsibility	Governance	Funding
EPR	The Producer Responsibility Organization (PRO) set up to manage the system drives cost optimization and efficiency of the EoL management Reporting obligations improve data collection, traceability and fee transparency PRO can drive preferred options for EoL treatment – cost or environmental effectiveness Some countries may experience reduced competition due to PRO	Producer (manufacturer or importer) of tires held responsible by government to organize management Collection targets set by the POM tire quantities, (i.e.) quantity sold onto the market.	Producers can set individual management systems or collaborate to set up a PRO (the latter is typical, or utilization of an existing PRO (e.g., trade association) In either case, the organization is in charge of funding the management of collection and recovery operations	Fees collected from producers, and typically passed on to consumers in product price As different aspects of the scheme change over time, the cost should decrease.
Tax	Government sets standards for all tires on the market, ensuring a level playing field Tax may drive more environmentally friendly recovery routes (e.g., recycling over energy recovery) and support obsolescence of poor treatment (e.g., landfill)	Government responsible for system Collection targets set by government, no mandatory criteria to how they are set	Government responsible for organization and enforcement of system and remuneration of operators in the recovery chain	Funded via tax levied on tire producers and importers – paid to the government and passed on to consumers Fee should cover the full net costs of recovery – including collection, logistics and treatment
Voluntary (Free Market)	Minimal government and producer involvement Market forces the leading driver (i.e. highest cost/recovery efficiency routes take precedence) Voluntary involvement of companies Typically, more challenging for more environmentally friendly treatment routes to develop due to lack of drivers	No party directly assigned as responsible Legislator sets targets to be met	Not assigned, ELT issues tackled by waste regulations or governance system Common practice to have an industry association in charge of promotion	No regulated fee collected to fund ELT management and treatment

The following three sections describes the three economic systems as implemented in various international jurisdictions.

Extended Producer Responsibility (EPR)

In New Zealand, Tyrewise, an industry-led product stewardship scheme, has been in place since 2012. This product stewardship scheme places an advanced disposal fee (ADF) on tires, $5.50 ($5.04 CAD) per equivalent passenger unit (EPU), and a standardized measure for the quantity of EoL tires. One EPU contains the same material as a 'typical' passenger tire. New EPU weight is estimated to be 9.5 kg, while used EPU weight is estimated to be 8 kg[64]. Reviewing prices of typical passenger tires (14 to 19 inches in size) on a New Zealand website, we take $200.00 NZD ($183.32 CAD) to be a high-level average tire price, suggesting the ADF is typically around 3% of new tire value.

Following legal advice in 2013 for the most suitable structure for the scheme, a Product Stewardship Organization (PSO) called Auto Stewardship New Zealand (ASNZ) was set up to manage the programme and funds. The governance structure of ASNZ is comprised of a board (governing on behalf of the supply chain), advisory group (industry representatives to support/inform) and programme manager (delivering operation aspects of the programme). The in-scope tires covered by the scheme are aircraft, bus, caravan, crane, excavators and graders, farm machinery, forklifts, light commercial vehicles, mining and earth moving vehicles, motorcycles, passenger cars, trucks and trailers. The decision to include OTR tires was a conscious one as, despite geographic barriers to collection, they contain high quantities of rubber and steel available for recovery (Tyrewise, 2020). This is in line with our earlier recommendation that ECCC consider recovery of OTR tires.

In the Republic of Ireland, there is a case to learn from. EPR for tires has been in place there since 2007, but due to poor systems and low enforcement, the (at present) €1.50 (€1.85 including VAT) ($2.33 -$2.87 CAD) per motorcycle tire and €2.80 (€3.44 including VAT)) ($4.35 - $5.34 CAD) passenger car tire fees were not being utilized for improving recovery and recycling in Ireland. Since 2017, the EPR scheme has been led by Repak ELT and is based on the *Waste Management (Tyres and Waste Tyres) Regulations 2017*.

It is Repak ELT that is responsible for ensuring the compliance of producers and monitoring of the scheme[65] in cooperation with:

- waste Enforcement Regional Local Authorities (WERLA) (set up to support local authorities enforce waste regulations),
- local authorities (responsible for retail enforcement), and
- the Environmental Protection Agency (EPA) (responsible for regulation enforcement).

This scheme is clearly focussed on consumer tires and not OTR tires, therefore the Tyrewise example may be more effective for Canada.

It is important to note that the scope of EPR is much broader than that of tax/voluntary free market systems. While the tax/voluntary free market systems do not directly drive through life improvements, EPR can be leveraged to do so. Derived from a study commissioned by Environment Canada (now ECCC) and the Recycling Council of Ontario (RCO), an evaluation tool for EPR schemes has been produced. Based on the original "Guidance Manual for Governments" produced in 1982 (T. Lindhqvist & C. van Rossem, 2005), the crux of the report was the two (2) environmentally related EPR goals shown in **Figure 25**. Application of a modulated EPR scheme that promotes and incentivizes design improvements of products alongside improved EoL prospects should be considered. Currently, Canada has more than ten

[64] https://www.environment.gov.au/protection/waste/tyres
[65] https://repakelt.ie/regulation/

differing provincial and territorial EPR provincial tire stewardship programs. A national modulated EPR scheme drives product design improvement and EoL improved prospects.

Canada's tire stewardship programs has successfully diverted tires from landfills with a near 100% diversion rate, being reinjected back into the Canadian circular economy as value-added products.

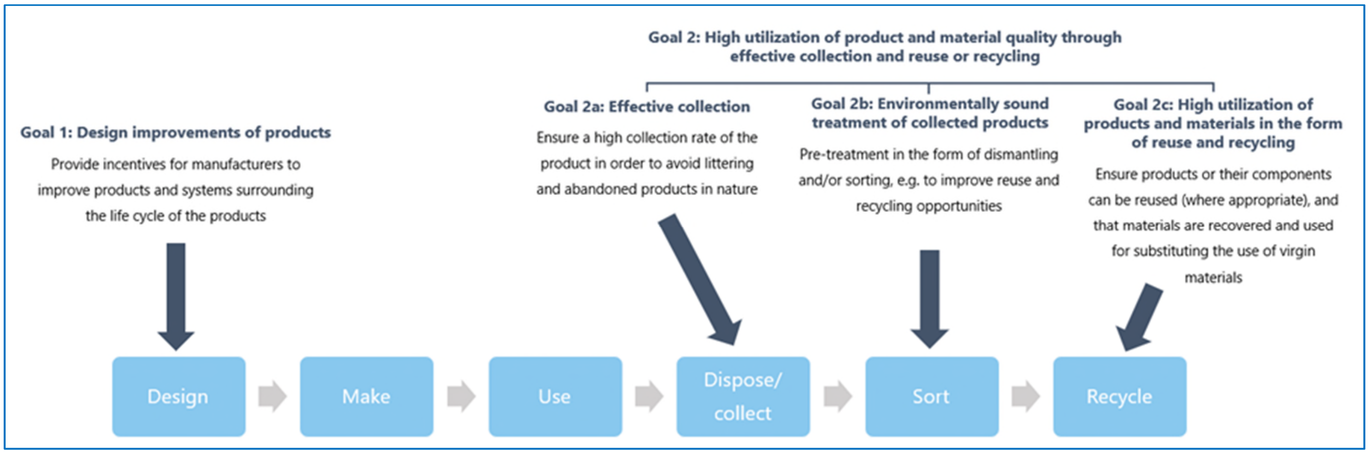
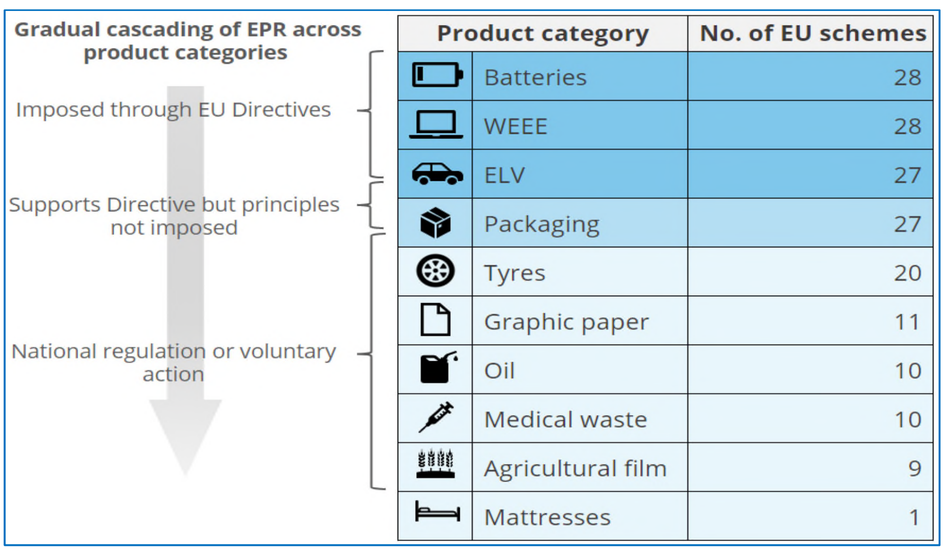


Figure 25: The Two Fundamental Goals of an EPR System

Further to considerations of EPR form (standard or eco-modulated), management by provincial or federal government must be addressed. In the EU, we see that EU directive led EPR tends to have a deeper market penetration than national or voluntary equivalents. This is clearly shown in Error! Reference source not found.. In Canada, this clearly translates to a federal, provincial and voluntary structure, with federal being the most likely to drive meaningful impact due to collective engagement. A consistent, national, harmonized, eco-modulated EPR system nation-wide would mitigate the current provincial disjointed EPR tire system across Canada.



Product category	No. of EU schemes
Batteries	28
WEEE	28
ELV	27
Packaging	27
Tyres	20
Graphic paper	11
Oil	10
Medical waste	10
Agricultural film	9
Mattresses	1

Figure 26: Market Penetration of Directive-Led, National and Voluntary EPR Schemes for Different Product Categories in the EU

Tax Scheme for EoL Tire Management

The following examples of tax based economic schemes provided are based within Europe. It should be noted that, following the 2015 release of the EU's Circular Economy Package, and subsequent release of the EU's Circular Economy Action Plan, policy drivers towards more sustainable through life management of products and materials are substantial.

In Croatia, tire collection and recycling are in accordance with the "Law on Sustainable Waste Management" and "Decree of Waste Tyres Management." As such, tire producers (manufacturers/ importers) are required to pay a set fee to the Environmental Protection and Energy Efficiency Fund (public body). This fee is only required if the tires are intended to enter the Croatian market, not for exports. At EoL, registered collectors, of which there are currently 15, take charge of the tires. They then pass the entire fee on to registered processors of waste tires. These processors report to the Environmental Protection and Energy Efficiency Fund on a monthly basis to monitor waste recycled and remaining for disposal. This system has been in place since 2007, six years before Croatia joined the European Union.

From 2007 to 2016, average annual POM figures have outweighed collection figures 2,154,232 tonnes to 1,926,707 tonnes. **Figure 27** below presents the assessment of EoL routes from 1996 to 2015, showing relatively low retreading activity, with the majority of EoL tires going for material and energy recovery (I.Š. Nukić & I. Miličević, 2019).

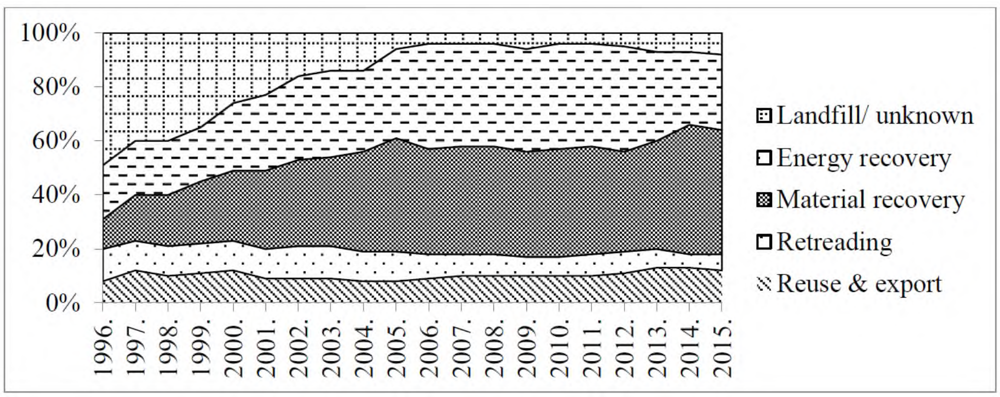


Figure 27: EoL Tire Treatment Routes Derived for Croatia from 1996 to 2015

In Denmark, since 1995, economic incentives for the recycling of ELT have been in place. Tire producers (manufacturers and importers) pay a levy to the Customs and Tax Administration – Skat, which is then passed on to the EPA. An interesting element of this scheme is that, unlike the ADF in New Zealand, the levy varies, depending on tire type and size, from 10 to 225 DKK ($2.09 to $46.91 CAD). Collection points include car dealers, tire shops, garages, etc. and consumers are not charged. A hierarchy is followed for EoL treatment, initially looking for tires to be retreaded, then granulated or pyrolyzed. Tire collectors are paid subsidies through the EPA via the Danish Tyre Trade Environmental Foundation for ELTs delivered to approved recyclers[66]. This subsidy is as follows:

Table 62: Current and Future Subsidies Paid to Tire Collectors for Delivery to Approved Recyclers

Timescale in Operation	Subsidy per kg including VAT for tires < 24-inch diameter (max)	Subsidy per kg including VAT for tires ≥ 24-inch diameter (max)
Until December 31, 2020	1.55 DKK ($0.32 CAD)	2.10 DKK ($0.44 CAD)
From January 1, 2021	1.43 DKK ($0.30 CAD)	1.98 DKK ($0.41 CAD)

[66] https://www.daekbranchens-miljoefond.dk/english

The impact of the scheme is clear to see. Between 1996 and 2019 the percentage of collected tires recycled has increased from 57% to 96%, or 7,193t to 47,816t. In tandem, collection and recycling have been increasing steadily, with tire sales remaining relatively consistent, as shown in **Figure 28** (Daekbranchens Miljoefond, 2020).

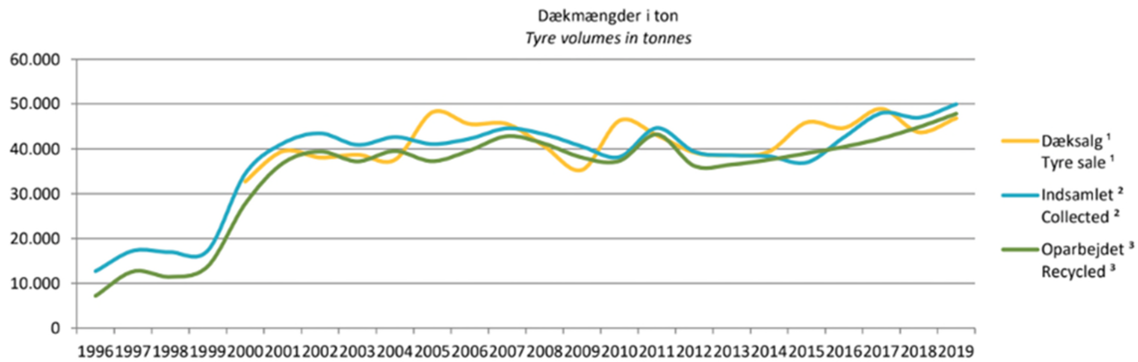


Figure 28: Comparison of Tire Sales, Collection and Recycling Tonnes from 1996 to 2019

Voluntary Economic Schemes

The least formal system for managing EoL Tires (ELT) is when no fee is collected, nor is a party responsible for the impact and outcomes, rather all cooperation is voluntary and targets are set by legislation. This is industry-led and favoured by the UK, Germany, Austria and Switzerland. There are different levels of government interventions in such voluntary economic schemes. Out of the four (4) countries listed above, the UK is the only one to have a "managed free market" system, meaning that ELT collectors and treatment operators are obliged to report their activities to national authorities (I.Š. Nukić & I. Miličević, 2019), maintaining a level of accountability and transparency.

5.1.3 *Technological Interventions*

Activity in technological areas is centred mainly on direct recycling, a natural progression from natural rubber versus synthetic rubber substitutions initially targeted by industry. It is industry that is driving these direct recycling technological innovations, and therefore the technology in-turn is driving recycled content increases in tires. This recycled content is typically targeted to be tread rubber, but carbon black and also pyrolyzed oil are also being investigated.

Before moving on to direct recycling, it is worth noting that in **Task 1** we discussed movements on the topic of synthetic to natural rubber, the combination still used by the tire industry. In a similar vein to this, targeting instead low impact synthetic material, Sumitomo unveiled "ENASAVE 100," the fossil resource-free tire, in 2013 and were presented with the "Environmental Achievement of the Year" at the 2014 Tire Technology Expo[67]. Despite this, there has been little movement on this topic since.

Activity around recycled content technology has been more apparent. Continental set up an award-winning plant in Hanover, Germany called ContiLifeCycle. With this retreading and rubber recycling plant Continental have noted that, using their technology with the recovered rubber, in 2019 it was using 3% recycled material in tire production and is confident of increasing that to 10% recycled rubber by 2025[68].

Michelin purchased Lehigh technologies in 2018. Lehigh own a micronized rubber powder process and Michelin claim they have increased the percentage of renewable or recycled material in their tires to 30%. Other tire manufacturers note the improvements to their recycled content using the material.

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[67] https://www.tyrepress.com/2013/11/market-debut-for-fossil-free-enasave/
[68] https://www.truckinginfo.com/327219/sustainable-tires-reduce-reuse-and-recycle

Bridgestone states that it contributes 5% of the tread compound in the Ecopia Tire, and Yokohama tote a doubling of the percentage use of recycled rubber between 2008 and 2016[69].

Bridgestone, like Continental, are moving forward with retreading, but their recycled content work focuses on carbon black as opposed to rubber. A partnership with Delta-Energy Group has led Bridgestone Americas to use recovered carbon black (rCB) in agriculture and passenger vehicle tires.

This partially replaces virgin carbon black, though it is not stated in what quantity. The D-E Black (Delta Energy's proprietary carbon black product) claims to reduce on the CO_2 emissions of virgin carbon black production by 81%[70].

Tyromer, which has developed a tire devulcanization technology process to recycle EoL tires at their rubber recycling plant in Ontario (they are in the process of building a second), supplies recycled rubber to KalTire for their retreading process. Tyromer indicated that up to 20% of the retreading feedstock can be recycled content, depending on the quality of the tire that is recycled. Tyromer's technology process uses a "supercritical, carbon-dioxide assisted, thermal mechanical extrusion process" to convert scrap tires into Tire Derived Polymer (TDP) with a conversion efficiency of 99% and no waste by-products[71].

The quality of tires to be recycled directly impacts the quality of recycled material, which suggests that it may not be a solution for all EoL tires without a product standard for new tires that considers the quality needed for EoL reuse. Based on conversations with a Tyromer representative, they are speaking with a number of top tire brands in Canada about their technologies, however they are facing several barriers including the negative stigma of recycled material being inferior to virgin, the presumed risk of dealing with a small company and their small scale, licensed business model when most companies are looking for a large-scale solution. A search for technical product standards for secondary rubber products and recyclates identified in **Table 63**. Better standards enable better quality recyclable materials and drive up the value of those materials.

Table 63: Technical Product Standards for Secondary Rubber Products and Recyclates

Issuing Body	Standard Name	Scope	Limits
ASTM	ASTM D5603-19a Standard classification for rubber compounding materials- recycled vulcanizate rubber.	Standard classification for recycled vulcanizate particulate rubber that is used as feedstock for thermal decomposition, devulcanization, recovered carbon black, tire-derived aggregate, synthetic turf infill, asphalt-rubber, molded rubber products, tire-derived fuel, and other tire and non-tire derived products and end uses.	These standards do not address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.
ASTM	ASTM D8268-19 Standard Practice for Rubber Compounding Materials- Evaluation of Recycled Vulcanizate Particulate Rubber.	Covers the evaluation methods for the compounding material commercially known as recycled vulcanizate particulate rubber. The methods are of general usage in quality control or are needed for the classification of the recycled vulcanizate particulate rubber according to Classification D5603.	

[69] https://lehightechnologies.com/our_markets/tires/
[70] https://www.bridgestone.com/responsibilities/environment/resources/action02/
[71] https://tyromer.com/technology/

Issuing Body	Standard Name	Scope	Limits
ASTM	ASTM D5644-18 Standard Test Method for Rubber Compounding Materials – Determination of Particle Size Distribution of Recycled Vulcanizate Particulate Rubber	Describes the procedures for determining average particle size distribution of recycled vulcanizate particulate rubber by the Ro-tap sieve test method for 90 µm (170 mesh) or larger particles.	

ASTM has also established a committee (D36) which will develop standards for recycled Carbon Black[72].

5.1.4 *Informational and Data Interventions*

In the analysis of data phase of this study, it was found that the data for passenger and commercial tires was relatively robust, being captured through the PSS in operation across Canada. However, a major data gap was associated with OTR tires, in terms of the overall tonnage and number of waste tires being generated and the end fates for OTR tires. Anecdotal evidence suggests that from a circularity perspective, many of these tires represent leakages from the system, (e.g., are landfilled or incinerated).

The product stewardship benefits scheme discussed above in **Section 5.1.2** would be particularly useful at monitoring the transfer of program funds to EOL processors and disposal providers, which allows for tracking the potential shift towards the more sustainable solutions further up the waste hierarchy. For example, a shift towards higher recycled content requirements for tire manufacturing could be a particular area of area of interest.

5.1.5 *Education and Public Awareness Campaigns*

There is potential for public awareness campaigns and public education programs to improve areas in the rubber life cycle, and specifically with regard to tires. A recent study carried out by eTracks Tire Management Systems in Ontario revealed that only 37% of the survey group knew tires were recycled in ON, and 50% were unclear of EoL routes[73].

USTMA has an initiative on placing stations on “Know Your Roll,” to educate motorists about tire care, safety and maintenance, including the potential dangers of unsafe used tires, and final disposal according with the law and regulations. These stations located on the roadsides could provide information on tire pressure, alignment, and tire wear, and tire recycling[74].

Specific topics for public education learning to decreased carbon generation and increased circularity of tires include:

- **Tire care**: Life cycle assessments (LCAs) show that the “in use” stage in a tire’s life cycle accounts for over 80% of the Global Warming Potential (GWP) of a tire across its whole life cycle (K. Piotrowska et al, 2019) and that correct tire pressures, wheel balancing, and other tire related vehicle maintenance can have a significant impact on fuel consumption, and hence, the carbon impacts.
- **Use of retreads**: this extends a products’ lifetime, which impacts on both the primary raw materials demands and the total waste being generated.
- **Recycling**: secondary materials (recyclate) results in the substitution of primary materials, including natural or synthetic rubber in the case of closed loop recycling back into tires.

[72] https://weibold.com/development-of-standards-for-recycled-carbon-black-in-u-s
[73] https://www.catraonline.ca/news/65%7D/survey-aims-to-dispel-myths-and-misinformation-about-ontario-s-tire-recycling-program
[74] https://www.ustires.org/ustma-knowyourroll-national-tire-safety-week

- **Illegal dumping**: Although the PSSs in place in Canada typically results in the free disposal of EoL tires, in some cases a disposal fee is in place. For example, in the City of Whitehorse, Yukon it is specified that "*tires with an inner diameter smaller than 62 cm, removed from rims, may be deposited without charge. Larger tires are subject to a fee.*" This disposal fee can drive the illegal dumping of these larger tires[75].
- **Ocean plastics**: A 2020 Norwegian study reports that, globally, more than 200,000 tonnes of tiny plastic particles from worn tires and brake pads are blown from roads into the oceans every year (N. Evangeliou et al, 2020).
- **Tire wear particulate (TWP) chemical leaching**: A 2021 US study looks beyond the microplastics element of TWP and to impacts on aquatic life which are dying following contact with storm water. Following rigorous research into plasticizers, antioxidants, emulsifiers and transformation products it was found that the antiozonant "6PPD" [N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylenediamine], which is used globally and constitutes 0.4 to 2% of passenger and commercial vehicle formulations by mass, matched the suspected chemical toxicant following its reaction with ozone. The "6PPD-quinone" formed in this reaction was confirmed to be the candidate toxicant. An area of concern noted in this paper is that these transformation products, following reactions of additives in industrial manufacturing and in environmental systems, are widely undocumented and lack commercial standards (Z. Tian et al, 2021).

5.1.6 *Voluntary Initiatives*

As discussed previously in **Section 5.1.3**, many of the OEMs are looking to develop recycling technologies that allow them to increase the recycled content of their tires. The information previously noted on this technology clearly shows brand-led initiatives for increased recycling are ongoing. In addition to this, and in keeping with our highlighted points of interest for this project, benchmarking activities would be supportive from the public and private sector. Public sector benchmarking of best practice with initiatives such as the UK's "Responsible Recyclers Scheme" for tires would support the assessment of the necessity for EPR, tax or free market systems. Additionally, from the public or private sector, benchmarking best in class "retread" tires with respect to roll resistance, material value retention, etc., would showcase the circularity value of moving more of the retread market to this current best in class status.

Existing stewardship programs for tires appear to be well supported by provincial and territorial governments, the OEMs, recyclers and the public. A recent Canadian survey was conducted by the Tire and Rubber Association of Canada (TRAC) on Canadian consumers' knowledge levels and motivations on topics such as proper tire inflation, tire maintenance and their opinion on tire recycling in each province. Recycle NB's Tire Stewardship was identified as one of the best tire recycling programs in Canada. No other results from that survey could be identified. In speaking with representatives with Canadian Association of Tire Recycling Agencies (CATRA), it was indicated that the government could further support tire recycling through preferential public procurement of recycled rubber products (including, presumably, retreaded tires), helping in the development of new markets for recycled products and increasing the feedstock of EoL tires through the inclusion of OTR and other tires currently not included in most provincial stewardship programs.

Support for new product stewardship programs was not apparent, other than for OTR tires. Other work done by Dillon-Oakdene Hollins for ECCC on the potential recovery of plastics from EoL vehicles (ELVs) revealed that a majority of ELVs bypassed dismantlers and went straight to shredders, after which the recovery of plastics and rubber required advanced technologies. While some automotive rubber products would be relatively simple to do at the dismantling stage (hoses and belts), other embedded rubbers would not be easily recovered. However, without a regulatory incentive to recover plastic and rubber products from ELVs, it is unlikely that this would occur on a voluntary basis.

[75] https://whitehorse.ca/departments/water-and-waste-services/waste-management-facility

5.2 Emerging Technologies, Processes and Innovations for Rubber

This section presents an overview and assessment of emerging technologies, processes and other innovations with the potential to reduce rubber waste and support a shift in the Canadian rubber industry sector towards a circular economy for rubber. These technologies and processes cover the full range of the rubber life cycle, from resin production all the way to rubber disposal.

Section 5.2.1 Emerging Innovations identifies current and emerging technical innovations with the potential to reduce rubber waste and increase the circularity of rubber. **Section 5.2.2 Technologies, Benefits and Barriers** then presents an assessment of the overall benefits and likelihood of success of each technology or process and the relevance, barriers and risks of adoption, of the technologies in Canada.

5.2.1 *Emerging Innovations*

Considering tires and rubber products holistically, reducing rubber waste over its life cycle must include each step in the life of a tire (and its respective waste stream) as follows:

- Rubber/resin production (wastes: monomer/production/processing);
- Tire production (post-manufacturing waste);
- The tire during its life cycle (TWP); and
- EoL (EoL of tires themselves).

Rubber Production.

In terms of best practice for synthetic rubber production, Lanxess plant in Singapore is hailed as the most modern of its kind in Asia producing 100,000 tonnes per annum of butyl/halobutyl rubber. Around €40 million ($39.9 million CAD) of the total €400 million ($399.4 million CAD) investment went into environmentally superior technologies in 2013 when the plant was commissioned. These include the reduced use of steam in manufacturing leading to energy savings and chemicals from the production process being treated in thermal off gas unit, so as not to impact on the environment[76]. It is noted that Lanxess operate a butyl rubber plant in Canada[77]. Given their clear inclination to drive environmental best practice, it may be prudent for the Canadian government to engage with them to discuss improved environmental performance and any collaborative efforts.

Though not a direct waste reduction measure, reducing the impact of extraction processes does reduce waste further up the value chain. In 2018, Yokohama developed the first technology for producing isoprene (a monomer of polyisoprene synthetic rubber) from biomass. Currently isoprene is produced as a by-product of naphtha, derived from crude oil. Researched collaboratively between Yokohama Rubber, RIKEN and Zeon since 2013, in 2015 the breakthrough was achieved using "computer-based in-silico metabolic design" technology. Now, cells have been produced which produce isoprene from sugar using an artificial pathway (cutting the typical mevalonic acid to isoprene process from five stages to two and highly active enzymes (more so than any natural enzymes)[78]. At the time of writing, it is unknown how scalable this process is at present.

In order to drive the most sustainable practice around natural rubber production, in 2017 Michelin and Smag released the Rubberway app, a mapping tool of sustainability practices across the natural rubber industry. In 2019, Continental collaborated with them to develop it further. The app has been used in countries such as Thailand, Indonesia, Ivory Coast, Nigeria, Ghana and Brazil, and was designed to comply with the Global Platform for Sustainable Natural Rubber (GPSNR)[79]. We have previously, in **Task 1**,

[76] https://www.tyrepress.com/2013/06/most-modern-butyl-rubber-plant-opens/
[77] https://www.tyrepress.com/2012/05/pilot-plants-at-lanxess-butyl-rubber-site-to-test-new-technology/
[78] https://www.y-yokohama.com/release/?id=3063&lang=en
[79] https://www.michelin.com/en/press-releases/michelin-continental-and-smag-create-a-joint-venture-to-develop-rubberway-the-smartphone-application-designed-to-map-sustainability-practices-across-the-natural-rubber-industry/

touched on the use of the guayule plant and dandelions as sources of natural rubber that may ease pressure on the typical rubber supply chain and support the sustainability goals outlined by GPSNR. Aside from supporting the ongoing research in this area and considering what can be produced within Canada, as natural rubber production does not currently take place in Canada, impacting on the reduction of natural rubber waste is challenging as there is no direct involvement (e.g., the harvesting of rubber trees).

The application of lean manufacturing analysis and techniques can reduce wastes. In crumb rubber production, studies on the topic have shown that overproduction of crumb rubber is the major waste category, followed by inventory and defects. The crumb rubber production flow process is split into two stages: wet followed by the dry processing. In the wet process, the raw material must be milled, then added to a mixing tank, mangle and undergo hanging, driving excess inventory. The second stage, or the wet stage involves a cutter mill, oven, weighing and packaging. From a lean manufacturing perspective study, in crumb production process flow, the main processes that contribute to waste production are transportation (between machinery), over production and over processing. Varying market demand is a factor which further extenuates these issues. (E. Amrina et al, 2019). Though no suggestions for improving the production techniques were provided in this study, more detailed industry research and development into this topic may prove fruitful.

Tire Production

Cooper Tire, as lead of the Biomass Research and Development Initiative in the US, completed research from 2012-2017 on developing enhanced manufacturing processes for the production of rubber from the guayule plant as an alternative rubber source for the tire industry. The research was funded through a $6.9 million USD grant from the US Department of Agriculture. In addition to advances achieved in defining the guayule genome, using improved strains of guayule and improving rubber extraction technology, the consortium also developed several concept passenger tires in which all natural and synthetic rubber was replaced with guayule rubber.

In-Life Tires

Testing of the guayule tires by Cooper Tire and Rubber Company determined that the tires overall performance was at least equal to traditional tires, including for functions such as wear and cold weather performance, and performed better in rolling resistance, wet handling and wet braking. A life cycle analysis (LCA) completed by Clemson University estimated that the guayule tire had between 6 and 50% lower emissions and impacts in 10 categories compared with the traditional tire[80]. Communications with Greg Bowman, Senior Sustainability Specialist with Cooper Tire, for a previous project indicated that they have not tested whether guayule tires shed fewer microplastics and indicated that he was not aware of any research that directly addresses that question (Personal Comm, Greg Bowman, Aug. 24, 2020).

The Tyre Collective recently won the UK National James Dyson Award for a device they designed that uses electrostatic and airflow to collect microplastics as they are shed from car tires. The device is installed at the back of the tire and can be powered directly by the car's alternator. Their prototype collected up to 60% of all airborne particulates during testing[81]. They hope to enable a closed-loop model for rubber. Tire particles under 50 microns that are collected in their device can be reused in new tires[82].

Tire wear microplastics are found in storm water. It is relevant here to recognize any associated technology correlated to storm water management. Tonnes of tire wear are carried to final disposal in

[80] http://coopertire.com/news/guayule-research
[81] https://www.jamesdysonaward.org/2020/project/the-tyre-collective/
[82] https://www.thetyrecollective.com/

the storm water management system. The following study below, shows an estimated 35,855 tonnes of tire wear per year is generated on Canadian roadways[83].

Table 64: Tire Wear per Capita per Year

Country	Tire wear Emission per Capita/year (kg)	Country	Tire wear Emission per Capita/year (kg)
The Netherlands	0.52	Japan	1.90
Norway	1.50	China	0.55
Sweden	1.30	India	0.23
Denmark	1.20	Australia	0.87
Germany	1.10	USA	4.70
United Kingdom	0.98	Brazil	1.40
Italy	0.81		
Aggregate all countries		**0.95 kg/person/year**	
Canada 2020 total estimation tire wear/year	**35,855 t/year**		

EoL Tires (ELT)

From a circular economy hierarchy perspective, the first treatment routes that should be considered here are re-use and remanufacturing ((i.e.) retreading). It should be noted that, due to the typical use phase of a tire (i.e.), until the tread is fully worn, direct reuse – defined by the European Commission as "any operation by which products or components that are not waste are used again for the same purpose for which they were conceived" – is uncommon within the product category. Though whole tires have historically been used to line landfills and in port/coastal/river engineering, this is considered low value and an outdated practice and will not be discussed further here.

If direct re-use and retreading are not feasible, recycling must be considered. In **Task 1** we discussed the importance of the opportunity for retreading in Canada; this has clear benefits over the almost automatic tendency of many to resort to buying new tires. As previously indicated, a study of the socio-economic impact of truck tire retreading in Europe by EY[84] quotes retreading as saving 70% natural resource extraction (namely oil and ore for steel production), 29% land use (for the growing of the Hevea (rubber) tree), 24% CO_2 emissions, 21% air pollution (specifically particulate matter(PM)) and 19% water consumption. A global retreading company named Marangoni, based in Italy and operating across the USA, Brazil, China and several other countries, quotes similar figures for the retreading of truck and bus tires. 69% reduced oil consumption is key and quantified as 26 litres required for retreading as opposed to the 83 litres required for new production of one new tire. Estimated CO_2 saving for a set of four tires is 2.5 tonnes, or 625 kg per tire.

High level values for the global impact of retreading, noted as being provided by tire retreaders associations, pose that retreading saves 4.55 million tonnes of tires going to the environment, 3.9 billion litres of oil and other derivatives being used and 8.45 billion euros in the transportation industry[85]. As is discussed, both of these sources focus primarily on truck tires. These share significant attributes (e.g., steel content) with OTR tires, a key problem area for Canada derived in **Task 1**. Application of retreading technology may then drive a higher capture and treatment rate of OTR tires in Canada. On this topic, it is worth noting that there are a few retread companies that co-locate with mines specifically, in order to

[83] https://www.semanticscholar.org/paper/Wear-and-Tear-of-Tyres%3A-A-Stealthy-Source-of-in-the-Kole-L%C3%B6hr/5d03295f0cb0033fc8c93b70d08b8603dbd625b1
[84] https://www.etrma.org/wp-content/uploads/2019/09/201611-ey_retreading_lr.pdf%20%20
[85] https://www.marangoni.com/en/sustainability/

access the OTR tire stream. There are three in Quebec (GCR Tire and Service), KalTire has an exclusive mining branch (though the business model is not clear whether it is (i.e.) distributed versus centralized)[86], and Goodyear has an OTR retread facility in North Bay, Ontario.

Though retread shows this potential for commercial and OTR tires, passenger tires do not contain steel in the same quantity as the other categories. As this is one element of commercial/OTR tires that gives them significant embedded value and carbon, the lack of these economic and environmental drivers for passenger tires leads them to be more typically recycled. The top-level goal at the recycling stage, from a circular economy and industry perspective, is to recycle as much of the tire (tread or otherwise) as possible back into tires without downcycling or breaking it back down to component material level. Numerous methods have been investigated to achieve and increase the recycled content using this route. Typically following grinding of the tire rubber into rubber crumb, three (3) processes have been investigated in depth:

- Devulcanization;
- Resin polymer treatment; and
- Nano-polymer treatment.

Beyond this, due to difficulties with recycling of tire material back into tires, we look at indirect recycling methods which have typically been used to date. Next on the hierarchy would be to break the product down in order to utilize the monomers and additives. Carbon Black and other additives are discussed elsewhere in this report, including in **Section 5.1.3**. This leads us on to pyrolysis, a common method to retain value from tires where direct recycling is not an option. Other indirect recycling methods can be the use of tires in road paving (i.e. TDA) or flooring (e.g., outdoor children's playgrounds, indoor rubber mats or tiles). Shredding of tires and conversion into flooring mulch has also been explored, however health concerns have been raised around this use.

Moving further away from utilization of the material and its properties as a product, utilization of embedded calorific value is considered next. This takes us on to TDF in cement kilns, in paper mills as an octane booster to enhance boiler performance, and energy from waste plants; what we understand to be relatively common in Canada. It has been used to supplement energy resources in Japan, Europe, and in the U.S. since the 1970s. Finally, there is the treatment of the material as a waste, with landfill and incineration at the bottom of the hierarchy, retaining no embedded economic or environmental value. The majority of these indirect recycling routes are longstanding, have low value retention options and are potentially outdated. Only the innovations with respect to pyrolysis and TDA will be discussed as advances in these areas have been made.

5.2.2 *Technologies, Benefits and Barriers*

This section reviews the listing obtained above, in **Section 5.2.1** to assess the overall benefits and likelihood of success of each technology or process and the relevance, barriers and risks of adoption, of the technologies in Canada.

Of note, TDF is used in cement kilns for cement production and in paper mills as mentioned above, while in practice in Canada, is not an emerging technology. When compared to the following technologies presented that retain tire/product value, TDF a low value retention option for tires in a Circular Economy and is at the bottom of the waste hierarchy as priority approach.

Retreading

As discussed in the previous section, retreading of truck and bus tires (and OTR in general) shows significant promise and is conducive with the current retreading appetite in Canada discussed in **Task 1**. Retreaded tires account for nearly half of all commercial truck and bus tires in the U.S. and Canada, with

[86] https://www.kaltiremining.com/en/region/canada/

approximately 44 percent of all commercial tires on the road in the U.S. and Canada being "retread" tires. Up to 90% of large fleets in the U.S. and Canada use retreads in both on and off-road vehicle applications. Despite the obvious advantages from a circular economy perspective, retreading is under enormous competitive pressures from ultra-low-cost tires manufactured in countries that enjoy significant cost advantages, in particular as it pertains to labour. Government intervention in the form of new incentives for production or purchase of retread tires, and stringent third-party verification of tires, will be needed to ensure all lifecycle costs and benefits of rubber use are incorporated into the replacement tire purchasing decision.

Table 65: Retreading Assessment

Retreading	Discussion
Benefits	Resource, land, CO_2, air pollution and water consumption savings vs. virgin tire production. Economic savings and high potential for job creation. Each time a well-maintained tire is retreaded, up to 50 percent of costs can be saved compared to buying a high-quality new tire with mining vehicle tires can be retreaded up to three times.
Likelihood of success of technology/process	High – proven.
Relevance in Canada	High relevance as there are both retreaders with capacity and tires available to be retreaded. For commercial vehicles ≈ 380,000 tires/year For passengers tires ≈ 190,000 tires/year
Barriers to adoption of the technology in Canada	Potential scale up capacity in Canada of current retreading operations, potential increase in costs associated with retreading larger tires, diversion of ELTs to retreaders and competition with other recovery processes (e.g., EfW and TDF). Cheaper and less eco-friendly tires are a barrier.
Risks of adoption of the technology in Canada	To enable effective retreading, the cost of retreading would need to maintain a low enough level to effectively support a competitive business case. For passenger and light commercial vehicles, there may be behavioral change/education necessary to build public trust in retreads.
High level environmental impacts to air/land/water	Rubber particulates from tire buffing. Best practice captures them ((i.e.) using high-power fans) and they are stored for recycling. If poor practice is used, these could be land/water pollutants.

Rubber Crumb – Ambient and Cryogenic Grinding

As a prelude to the rubber crumb section, it should be noted that ambient ground rubber crumb typically falls into three size classes:

- Shredded/chipped rubber (13 – 73 mm),
- Crumb rubber (0.425 – 4.75 mm), and
- Ground rubber (0.075 – 0.425 mm).

The ranges given are often disputed, though the categories are not. Modern techniques can enable grinding to finer sizes, such as that of Lehigh Technologies which produces 'micronized rubber'[87]. This range falls just below the size range of ground rubber above, to 0.050 mm. Different applications require different sizes of rubber, with products such as flooring being open to shredded/chipped rubber and techniques such as nano-polymer treatment requiring finer ground rubber. Further research on any

[87] https://lehightechnologies.com/products_services/overview

environmental concerns regarding PM10 (0.01 mm), and PM2.5 (0.0025 mm) releases to air would need to be studied.

Crumb rubber has the highest-value applications. These applications can be grouped into major market segments:

- **Athletic / Recreational surfaces** – Use in artificial turf, natural (grass) turf, and playground cushioning.
- **Molded and Extruded Products** – Diverse products including mats and bumpers.
- **Rubber Modified Asphalt (RMA)** – crumb rubber is added to asphalt binder to improve highway performance characteristics.
- **Tires/Automotive** – ground rubber is used in manufacturing some new tires, retreading old tires, and in molded automobile parts.
- **Export** – Ground rubber is directly sold to markets in Europe and the Far East.
- **Other** – Animal mats, colored mulch, horse arena safety cushioning.

Although data from Canada is not available, it is available from the United States and it is believed that Canadian markets would be similar. At over 54% of market share, the Athletic / Recreational and Molded / Extruded components account for the majority of sales in the crumb rubber market. Exports play a minor role in the market at 4% of market share. Other markets which include products such as safety cushioning in horse arenas also represent a significant share of industry sales.

Cryogenic treatment is the freezing, typically to extreme temperatures using liquid nitrogen to a temperature below -80C. At this temperature, a phase transition in the rubber occurs where it becomes almost as brittle as glass and size reduction is achieved through crushing and breaking of rubber to enable the material to be ground into rubber crumb more cleanly than typical ambient grinding (K. Mushunje et al, 2018). This is not a recycling technology as much as it is an intermediary step - an enabler of recycling. The rubber crumb produced will typically be used to produce value added products (e.g., flooring, conveyor belts, insulation, mats). While the typical shredding method produces larger, more non-uniform rubber crumb – falling into the shredded/chipped rubber category – cryogenic freezing in combination with modern shredding techniques can achieve ground rubber size particles.

Civil Engineering uses has a large potential, such as:

- Lightweight aggregate (often highway use),
- Retaining wall backfill,
- Landslide stabilization (slide repair),
- Slope stability,
- Road construction materials (embankments, berms, road base, landfill access roads),
- Septic system drainage material,
- Porous media for leachate and gas collection and redistribution systems,
- Drainage aggregate, and
- Storm water infiltration gallery/bio retention.

Canada needs to develop and create markets conditions to incentivize civil engineering uses.

Table 66: Rubber Crumb-Cryogenics Assessment

Rubber Crumb – Cryogenics	Discussion
Benefits	Well established process, and a simple procedure with few technical elements.
Likelihood of success of technology/process	High – proven

Rubber Crumb – Cryogenics	Discussion
Relevance in Canada	As a means of producing rubber crumb, it is a common process with high applicability in Canada. It enables the production of a myriad of products which rely on rubber crumb.
Barriers to adoption of the technology in Canada	Chemical restrictions around the use and transport of cryogenic substances.
Risks of adoption of the technology in Canada	As a longstanding method for rubber crumb production, it is likely to become outdated. Rubber crumb produced by this process may need further refining for certain applications. Markets for the recyclate material must be stable.
High level environmental impacts to air/land/water	There are no air/water pollution concerns for liquid nitrogen as it can boil off and remain inert in the atmosphere.

Rubber Crumb – Water Treatment

In 2020, at the Tire Technology International Expo, the award for "Environmental Achievement of the Year" was presented to RubberJet Valley for their granulation technique using water jets. Following pre-separation of the tread and sidewall rubber, the two are granulated using high pressure water jets and sold as two separate recyclates to the tire and rubber industries[88]. Again, this is an intermediary step - an enabler of recycling, with the same/similar routes for the above treatment. Particle sizes range from 0.2 – 3.3 mm, classifying the output as crumb rubber.

Table 67: Rubber Crumb-Water Treatment Assessment

Rubber Crumb – Water Treatment	Discussion
Benefits	Low energy use, the process runs at cold temperatures and no chemical substances are used.
Likelihood of success of technology/process	High – proven
Relevance in Canada	Enables the production of a myriad of products which rely on rubber crumb.
Barriers to adoption of the technology in Canada	As it is currently at a relatively small scale, output production rate and TRL must be considered.
Risks of adoption of the technology in Canada	Given the inert nature of the process, chemical regulations will be of minimal concern. However, on being high water demand, the likelihood of potential releases are always there. The process of separation of the tire sections may be manual.
High level environmental impacts to air/land/water	All water used in the process is reused within a closed loop system and no PM is produced that could be of concern for land/water.

Devulcanization

The most commonly sought-after process for dealing with ELT, as the vulcanized nature of the rubber is a major barrier to EoL prospects as it prevents re-bonding in new materials. There have been numerous processes aimed at devulcanization of rubber, such as Tyromer's approach in Canada using a supercritical CO_2 catalyst and a twin-screw extruder, producing rubber at a rate of 1,500 lbs/hour (Tyromer presentation, 2019). From a chemical perspective, this process involves returning rubber from its thermoset, elastic stage back to a plastic, mouldable state. The process requires that the rubber has underdone previous ambient or cryogenic processing, which enables a much larger percentage of the

[88] https://rubberjetgroup.com/en/technology/

recycled material to be recovered without comprising quality, appearance or performance. Important devulcanization methods include:

- Thermal reclamation;
- Mechanical devulcanization;
- Devulcanization with ultra-sound; and
- Bacterial devulcanization.

Research has been carried out into ultrasonic and bacterial methods, but these have not proven commercially viable. Key barriers to devulcanization have historically been cost (that of processing, compounded by a lower value for the end product than virgin rubber, leads to an ineffective business case), lack of scalability of predominantly lab-based technologies, the mixture of rubber types present in a tire (requiring optimization of devulcanization technologies to treat the maximum proportion of the rubber sample and sometimes hampering their effectiveness) and acceptance in high value markets (if the rubber is not of similar technical specifications to virgin rubber then they cannot be mixed, limiting application).

Today, multiple devulcanization methods have been tried and tested, with drivers external to the market (e.g., the sustainability agenda, policy changes) raising demand for the product[89]. Through our research and stakeholder input, it seems clear that demonstration of an effective business case, attainment of a high technology readiness level and gaining market penetration are key barriers to uptake of devulcanization processes at present. Tyromer has two (one operational, one in construction) devulcanization plants (Combined 7,800 tonnes/year).

Their product is combined with 20% of crumb rubber and used in the KalTire retreading process. It is notable that key issues they face include managing quality of feedstock (i.e. low quality feedstock produces low quality product) and mandated tire specifications could help with this. In interview, they indicated that scaling is an issue and discussed a distributed business model, although further clarified that there was low appetite in the market for this. Tyromer will be looking at the possibility of recycling EPDM in the new plant once it is up and running (Stakeholder interview, conducted October 2020).

One method that stands out in this area is that employed by Green Rubber. It is a process which utilizes a proprietary chemical compound called "DeLink" in combination with rubber crumb to uncouple the sulphur bonds (created during the vulcanization process) and enable both natural and synthetic rubber to be recycled into tires, shoes, mats and other products[90]. It is estimated that a 30% recycled content can be achieved in tires through this process. Currently at a TRL of nine (9), the material has been proved commercially successful, with a new plant in the process of being commissioned.

Though not active in Canada, they have indicated that this would be possible (Personal Comm, Steve Nieto, Dec 3, 2020). One concern that has been raised, in an interview with an innovative rubber recycler, is that typical devulcanization methods only achieve the devulcanization state for a short period of time (anecdotally several weeks) before the sulphur bonds reform. It is unclear if Tyromer have addressed this challenge or not, Green Rubber state that the bonds are broken and only reform when subjected to heat.

Table 68: Devulcanization Assessment

Devulcanization	Discussion
Benefits	Enables the widest and most value-added recycling of rubber, addressing the largest barrier to recycling tires and other vulcanized rubber products.

[89] CalRecovery Inc. (2004).
[90] https://www.greenrubbergroup.com/

Devulcanization	Discussion
Likelihood of success of technology/process	To date, devulcanization processes have not been widely successful. The Green Rubber process seems to have a relatively high TRL, but step would need to be taken to test its viability at scale in Canada.
Relevance in Canada	Globally sought after by public and private sector, this process is equally as important in Canada and could be transformative to EoL prospects for rubber.
Barriers to adoption of the technology in Canada	Given the proprietary nature of the Green Rubber process and unknown scalability, there are potentially economic and technological barriers.
Risks of adoption of the technology in Canada	The only major risk here is if the process invested in were to be made obsolete by a new process, however given the slow progress on this front the perceived risk is low.
High level environmental impacts to air/land/water	Thermomechanical methods typically use higher temperatures and more energy than chemo-mechanical methods. However, the latter use chemicals which may be harmful via inhalation and to aquatic life. It is worth noting that said chemicals are also used in the vulcanization of tires.

The following two methods for treating tire rubber have been discussed with an innovative tire recycler who developed a technology in the UK with Biffa award funding in the late 2000s. It is noted that the funding looked at six methods: four devulcanization, one resin polymer and one nano-polymer treatment. The contact we interviewed developed the nano-polymer treatment and has taken it forwards.

Resin Polymer

What may be considered a low value approach, and did not show great promise in the aforementioned testing, rubber crumb is mixed with polymer resins (e.g., epoxy, polyester, and melamine to improve their technical properties). Studies have been carried out recently on this topic (A. Hejna et al, 2020), with addition of rubber crumb increasing toughness or flexure of the resins, but often negatively impacting the mechanical properties.

As this treatment route is still being reviewed in a strictly academic manner, and has no foreseeable use in a commercial setting, we will not assess it further here.

Nano-Polymer Treatment

This treatment method requires a nano-polymer to be combined with rubber crumb, and in a process called surface polymerization, has been found to greatly increase rubber crumb content in retreads. The results of testing in 2007 with the UK Waste and Resources Action Plan (WRAP) state that rubber crumb could be incorporated into tire treads at levels of up to 40% (anecdotally 50%) with no loss of durability and in some cases improved durability (anecdotally a rolling resistance improvement of 12% over a leading manufacturer tire in the Biffaward work and 15% improvement over the same manufacturer tire in the WRAP work). It is also stated that the curing was 20% quicker (anecdotally the vulcanization time is now 15% faster and mixing time is 15 to 20% faster). These tests were carried out on truck and earthmover (OTR) tires[91]. Envirogen Technologies are leading the development of this process. Our source on this topic has stated that this process can now achieve 75% recycled content in tread, 80% recycled content in sidewall and 95% recycled content in shoe soles (Stakeholder interview, conducted September 2020), though we recommend there be tests carried out to verify these statements.

[91] https://www.recyclingtoday.com/article/wrap-study-finds-strong-opportunities-for-recycled-rubber-in-truck-retreads/

Table 69: Nano-Polymer Treatment Assessment

Nano-Polymer Treatment	Discussion
Benefits	Potentially between 40 to 75% recycled content in tire treads, conducive with retreading operations, applicable to OTR tires.
Likelihood of success of technology/process	Testing to date (not predominantly in Canada, but to our knowledge it has been tested in Canada using material on the market) has been indicative of a successful technology/process.
Relevance in Canada	To drive direct recycling, retreads and reduce rubber waste this is extremely relevant in Canada.
Barriers to adoption of the technology in Canada	Scale up of process, markets for product and potential consistency of rubber crumb content.
Risks of adoption of the technology in Canada	Post-testing few risks of adoption are seen, unless industry does not use the product.
High level environmental impacts to air/land/water	It is unclear what the potential impacts of the nano-polymer are on the environment, though with proper treatment they are expected to be negligible.

Rubber Conveyor Belts/Hoses/Insulation

EcoTech, a company based in Petra Tikva near Tel Aviv has developed a proprietary process for processing rubber into "Active Rubber" which can be used across various segments including conveyor belts (used by Dunlop), automotive (used by Ford in natural rubber recipes up to 25%), agricultural mats, insulation materials, fenders/bumpers and the tire industry[92]. EcoTech have a patented process which uses semi-cryogenic freezing of rubber pieces (180mm) down to -70°C without liquid nitrogen, milling to produce ground rubber, filtering to remove remaining textiles, mixing with a chemical formulation to 'activate' the rubber and then pressing into sheets before cooling. The chemical formulation is proprietary, but it is not thought to be a devulcanization process. The final product is labelled as synthetic rubber – with the focus of the process being green production of synthetic rubber.

Table 70: Rubber Conveyors/Mats/Insulation Assessment

Rubber Conveyors/ Insulation	Discussion
Benefits	Utilizes rubber crumb in value-added products, some of which can be used in high impact industries.
Likelihood of success of technology/process	High – proven.
Relevance in Canada	Use in the construction/mining industry conveyor belts would help drive sustainability in the sector which is key for Canada. Other products may be niche, but demand for environmentally conscious goods is rising. Currently there are three active patents for Active Rubber formulation in the U.S. There are no identified patents for Canada at this time.
Barriers to adoption of the technology in Canada	Industry and consumer engagement with the products may be low.
Risks of adoption of the technology in Canada	Market openness and consumer demand.
High level environmental impacts to air/land/water	Cryogenic and semi-cryogenic treatment raises no concerns though proper air treatment from milling is required to remove particulates. The 'chemical formulation' is unclear and may cause environmental damage if improperly managed.

[92] https://ecotrc.com/

Rubber Mats / Flooring

SpaceBlue, a UK based spin out from the University of Manchester, uses recycled tire rubber and natural rubber combined with graphene to produce modular floor mats[93]. The inclusion of graphene has been noted as increasing the compression strength up to 2 times, increasing durability of the product. This has the benefit of tackling the issue faced by previous recycled rubber mats crumbling at the edges and leading to further rubber particulate. The mat itself is composed of 80% recycled rubber and 20% graphene-enhanced natural rubber.

Table 71: Rubber Flooring Assessment

Rubber Flooring	Discussion
Benefits	Utilizes rubber crumb in a value-added product
Likelihood of success of technology/process	Medium – currently small scale
Relevance in Canada	Use may be niche but demand for environmentally conscious goods is rising.
Barriers to adoption of the technology in Canada	Supply of rubber waste may move to cheaper or higher added value processes.
Risks of adoption of the technology in Canada	Market openness and consumer demand.
High level environmental impacts to air/land/water	Typical rubber mats may crumble and produce particulate potentially of concern to land and water – though this product does not. Rubber crumb used in production must be correctly handled and disposed of.

Shoe Soles

Both Green Rubber's devulcanization and Envirogen Technologies' nano-polymer treatment produce recycled content rubber that can be used in shoes soles. As a globally essential market, this may prove a strong route for recycled material. Companies such as Timberland (who currently partner with Green Rubber) show that this route has a substantiated business case[94]. One Canadian manufacturer called Kamik has high sustainability standards and produces boots from recycled rubber in its North American plants. Global footwear brands such as Nike do not manufacture footwear in Canada (they have 3 plants in Canada but none making footwear), Adidas also have plants in Canada, 29 to be exact, but it is not clear what is produced in them.

Table 72: Shoe Soles Assessment

Shoe Soles	Discussion
Benefits	Utilizes rubber crumb in a value-added product with a well-established, large market.
Likelihood of success of technology/process	High – proven.
Relevance in Canada	As globally, Canada has a high demand for footwear and could utilize this route.
Barriers to adoption of the technology in Canada	Adoption by footwear manufacturers is the key barrier here.
Risks of adoption of the technology in Canada	Quantity of material usable in Canada (i.e. in shoe manufacturing operations) must be considered, else much of the material may need to be exported.
High level environmental impacts to air/land/water	Rubber crumb used in production must be correctly handled and disposed of.

[93] https://spaceblue.co.uk/
[94] https://www.businesswire.com/news/home/20090331006457/en/Timberland-Teams-with-Green-Rubber%E2%84%A2-to-Reduce-Global-Tire-Waste

Pyrolysis

This process involves high temperature heating of used rubber/tires to convert the rubber back into oils and additives. Both Pyrolyx (Pyrolyx presentation, 2019) and Delta Energy (Delta Energy presentation, 2019) utilize this process to, mainly, produce recovered carbon black (rCB). Whereas Pyrolyx use a typical high temperature process, Delta Energy utilize a catalyst to keep the temperature lower in a process called “depolymerization.” Both outputs will produce rCB, Oil, Steel and gas.

Table 73: Pyrolysis Assessment

Pyrolysis	Discussion
Benefits	Retention of raw materials and production of recyclates.
Likelihood of success of technology/process	High – proven.
Relevance in Canada	Much lower retained value as opposed to retreading and rubber recycling but presents more benefits than EfW.
Barriers to adoption of the technology in Canada	Already adopted.
Risks of adoption of the technology in Canada	Already adopted in Canada, but likely to face further competition for resources from higher value-added processes (e.g., tire retreaders feeding the automotive sector, crumb rubber producers feeding devulcanizers, conveyor/insulation/ mat producers). Requires high temperatures (i.e. high energy use).
High level environmental impacts to air/land/water	High temperatures are used in pyrolysis, potentially leading to harmful emissions if air treatment is not suitable. Ash residue composed of metal oxides, sulfides, and silica must be properly treated.

Tire Derived Aggregate (TDA)

Tire Derived Aggregate (TDA) or RMA is a road paving material which includes rubber crumb as an indirect recycling route and for technical improvements. Asphalt Plus LLC promote this material and note that the technology has struggled to penetrate further into the market over the past 20 years due to saturation and technical issues, which have now been mostly addressed (e.g., the wet process which was commonly used, was more expensive, less popular with contractors due to difficulty to work with and gave comparable performance at a higher price point). The more modern dry process (as opposed to the wet process) for production appears to make TDA more viable (Asphalt Plus LLC presentation, 2019). Through previous discussions with an industry stakeholder, it has been noted that, due to a state subsidy and supportive legislation, a great deal of rubber is used in asphalt in California (Stakeholder interview, conducted 2020). The Ray discusses two (2) examples of where TDA has been used in the US, in 2017 and 2019 (The Ray presentation, 2019).

Table 74: Tire Derived Aggregate (TDA) Assessment

Tire Derived Aggregate (TDA)	Discussion
Benefits	Improvements to road surface, wear and mechanical properties.
Likelihood of success of technology/process	Medium – contested process and market.
Relevance in Canada	Where plastics are being used in aggregate, they can be substituted by tires – however neither are high value EoL routes.
Barriers to adoption of the technology in Canada	Market demand and saturation.
Risks of adoption of the technology in Canada	Low value-added method, likely to see low rubber volumes directed to it.

High level environmental impacts to air/land/water	As rubber particulates are bound in the aggregate mix, there are no land or water concerns. In production, material is heated, potentially producing air pollution if air treatment is not suitable.

6 Assessment of Circular Economy Opportunities for Rubber in Canada

6.1.1 *Overview of the Hierarchy of Circular Economy Interventions in Canada*

Circular Economy R-Hierarchy for Tires

Rubbers are thermosetting materials, which makes material recovery challenging because of the vulcanization process during manufacturing (see Adhikari et al., 2000; Medina et al., 2018). Pneumatic tires are a combination of synthetic and natural rubber, carbon black, elastomer compounds, steel chords, textiles fibres; in addition to several other inorganic and organic compounds (Torretta et al., 2015). Due to these challenges for tire rubber recovery, a circular economy approach would aim to reduce waste and retain material value where possible in the supply chain and tire lifecycle. The hierarchy of waste reduction options for tires applies the traditional three Rs waste hierarchy (reduce, reuse, recycle) but goes beyond these three Rs.

There are eight levels in a circular economy R-Hierarchy for tires (see **Table 75**).

Table 75: Tire R-Hierarchy Waste Reductions Options

R	Tire R-Hierarchy for Waste Reduction Options
R0	**Refuse** via reducing vehicle ownership and using alternative modes of transport;
R1	**Reduce** via life extension
R2	**Resell/Reuse** discarded tires which are safe and functional
R5	**Remanufacture** by retreading functionally sound discarded tires
R6	**Repurpose** without or using less physical or chemical treatment
R7	**Recycling** via processes including devulcanization and grinding into crumb, ideally back into tires (wider recycling includes shredding for use in e.g., road paving, leachate drainage blankets for landfills and other civil engineering applications; ground for use in rubber athletic fields and playgrounds, asphalt, moulded products, shingles)
R8	**Recovery** of components and oil as fuel or whole product as energy via pyrolysis or incineration TDF.

In terms of the Circular Economy opportunities for rubber in Canada, first on the R-hierarchy is product reuse (R2), which involves the direct sale of a tire whose tread is still deep enough for safe use. Second, retreading (R5), which involves replacing the outer tread of a tire, when its general condition is insufficient. Repurposing (R6) is the reuse of a tire for alternative uses, for which it was not originally designed, such as protection of racing tracks, materials for artwork, swings, etc.

Grinding (R7), involves the crushing and granulation of tires to extract rubber and other components, such as steel and textile fibres. Grinding produces rubber that is of relatively low quality, meaning only a small percentage (1–5%) can be used in new tires. Devulcanization (R7) is a technological process where the rubber is chemically recycled to obtain higher quality rubber that can be used in higher percentage in new tyres (up to 30%) (Myhre et al., 2012). However, this technology is not yet commercially viable and has not been deployed on a large scale (Saiwari et al., 2019).

Finally, pyrolysis (R8) uses high temperatures (without oxygen) and chemical additives, for the recovery of energy, carbon black, activated carbon, oil and steel from EoL tires; if well managed, the process can have relatively low emissions (Myhre et al., 2012; Myhre and MacKillop, 2002; Sienkiewicz et al., 2012). Incineration (R8) involves the burning of tires with oxygen for the recovery of energy (often for cement kilns and other industrial furnaces); this process is less complex than pyrolysis but creates a significant amount of greenhouse gases and other air pollutants (Myhre and MacKillop, 2002).

While the notion of the 'R-hierarchy' above might prescribe a preferable set of recovery operations, these only relate to the product or material attributes and do not account for contextual and broader systems factors, e.g., energy recovery. This might mean a lower R-strategy, could be preferable under some contexts and conditions.

Currently in Canada, most end of life tires are collected for recycling. Corresponding with the R- hierarchy above, the variety of end-of-life recovery and treatment options, most commonly applied to Canadian tires include the following:

- (R7) shredding them for use as tire derived aggregate (TDA),
- (R7) crumbing them for use in:
    - Rubber athletic fields and playgrounds,
    - Asphalt,
    - Moulded products, and
    - Shingles,
- (R5) tire retreads, and
- (R8) use as tire derived fuel (TDF).

With most activity in the lower R7 and R8 activity and fewer in the R5 activity, there is opportunity in the Canadian tire reuse and recovery system to apply higher value circular economy approaches, operations and value retention processes (VRPs).

6.2 Socio-economic and Environmental Benefits and Costs of Rubber EoL Treatment

It is important to understand the environmental, economic/financial and social costs and benefits associated with each end-of-life treatment in order to better inform policy, regulations, industry standards and guidelines, stewardship responsibilities, corporate sustainability strategies and a global shift towards a circular economy. The following is a commentary on the triple bottom line - Socio, Economic and Environmental - costs and benefits of rubber end of life treatment.

6.2.1 *Financial Impacts*

Financial benefits relate to opportunities for firms to generate revenues or reduce costs based on the end of life treatment of rubber products. Financial costs and benefits can be expected to vary with the specific end of life process, but thematically, recirculating rubber throughout the economy can be expected to have financial benefits for firms. However, it should be noted that limited information and peer-reviewed studies are available on the financial costs and benefits associated with end-of-life rubber treatment.

An example of an economically viable use of end of life rubber is tire-derived aggregate (TDA). For example, in California, tire-derived aggregate is more cost effective than other substitute aggregate materials. Considering a sample of six California projects, tire-derived aggregate substitute materials were between 139% and 492% more costly than TDA itself. Given that tire-derived aggregate is more cost effective than its counterpart options, its use in these applications leads to better financial outcomes for firms (CalRecycle, 2016).

One California project example was the use of TDA for vibration damping for the Bay Area Rapid Transit (BART) construction project. TDA has proven to be an effective vibration mitigation alternative material. The tracks requiring TDA vibration mitigation were in close proximity to housing developments. In this case, the estimated cost of the transit track using TDA was determined to be about $121 US per foot. This cost was much lower than the cost for sections of track using an alternative method of vibration mitigation, which ranges from $600 to $1,000 US per foot.

Another example was the use of TDA in septic fields. Rock aggregate (natural or crushed gravel) is the traditional medium used for septic system leach fields. However, the practice of gravel mining is increasingly limited due to environmental degradation associated with the practice. Environmental controls on rock quarries have increased the operational costs of these facilities, and in some cases, they have ceased operation. The net result is that rock aggregate has become expensive and difficult to obtain in many locations.

TDA has numerous benefits that make it an excellent alternative to rock aggregate for drainage applications. It has higher permeability than traditional drain rock aggregate and a substantially lower unit weight; it has a higher surface area per unit volume, which increases the area for biofilm development and subsequent biological treatment of the drainage water.

The driving force for the use of TDA has been largely economic. Depending on the production and transportation expenses, construction cost savings for drain fields can range from 10 percent to 90 percent when TDA is used in place of rock aggregate. Because the density of TDA is about one-third that of gravel, only one-third of the tonnage of TDA is required for the same size drain field, i.e., approximately 15 tons (13.6 tonnes) of TDA is required compared to 50 tons (45 tonnes) of conventional rock aggregate for a single-family dwelling. This is a ratio of 1:3.3 in construction material savings.

Tires provide an effective source of fuel with similar energy potential to coal. Financial analysis of the capital expenditure required to process tires for fuel purposes notes high nominal returns on investment with short payback periods through avoided costs associated with coal energy usage. Specific returns will vary for firms based on the discount rate, capital costs and other economic factors influencing returns (Duggirala, 2009).

Similar to the examples above, the use of end-of-life rubber products can be reasonably expected to displace a virgin material in manufacturing production processes. Based on this assumption, recirculating recycled rubber has financial benefits associated with the lower costs of waste rubber material relative to virgin rubber materials, if recycled rubber is to be used in manufacturing and production processes.

The above section discusses the financial costs from a free market perspective. It is also important to consider fiscal policies that can increase the financial viability to stakeholders, such as, Product Stewardship Schemes or Extended Producer Responsibility, which provide the support and, at best, full net costs of end of life treatment.

Value Added Products

TDA discussed above, is a lower quality product produced from EoL tires. Products manufactured from crumb rubber of various sizes and specs are of higher quality and are higher value products. For a circular economy, the goal is to aim for the higher value products where possible, in order to keep the material in the economy for as long as possible and align with the waste hierarchy. A circular economy is not achieved by striving for lower value options as a priority, e.g., TDF.

Value-added products, i.e. ground rubber products, have an economically viable benefit for end of life rubber tires in Canada. Even at the end of life stage, the rubber still has value as a secondary raw material. End of life tires that can no longer be retreaded can be converted into ground or crumb rubber. Crumb rubber can then be used for rubber-modified asphalt, running tracks, sports fields, ground cover under playgrounds, molded rubber products and mulch in landscape applications. The benefits of tire rubber as a material are that it is lightweight, permeable, good insulators, shock and noise absorbent and long lasting.

Crumb rubber, ground to between 4 and 100 mesh in size, can be used as a raw material in the manufacture of a variety of rubber products, from mats, hoses, and truck bed liners to flowerpots and more. Market acceptance of these products has been slow, although some products are starting to find greater recognition in North America.

The use of crumb rubber as a product or as a feedstock raw material in new product manufacturing is considered to be one of the highest value end uses for end of life tires. Over the years, crumb rubber production has become more efficient and cost-effective, as technologies have evolved to manufacture a greater amount of tire material into crumb rubber products. These markets, however, have been slow to develop, and crumb rubber product is costly to manufacture.

EoL tire processors manufacture a crumb rubber product. As stated above, crumb rubber markets have been slow to develop, as it is costly to manufacture. Some of these processors are targeting specific markets, such as high value molded products, e.g., carpet underlay, dock bumpers, patio decks, railroad crossing blocks and movable speed bumps. Others are manufacturing their own end products. EoL tire processors are diversifying their markets to avoid economic collapse if any one market drops significantly.

Within the U.S. and Canada, markets have not matured to the point of being able to absorb all the tires produced. Canada exports considerable amounts of crumb rubber to the U.S (PSI, 2015). Task 3 did not locate Canadian data but US data was assumed to be similar to Canada. The market share for export of crumb rubber is estimated to be 4%. This is estimated to be 6,106 tonnes based on Table 14. To date, it is estimated that approximately 25 percent of the U.S.'s end of life tires go to crumb rubber applications. Tire processors are diversifying their markets to avoid economic collapse if any one market drops significantly. The hope is that diverse and sustainable markets will strengthen the tire recycling infrastructure over time and enable more end of life tires to be turned into crumb rubber products.

6.2.2 *Social Impacts*

Social benefits and costs are likely to be derived from the financial and environmental consequences of end of life treatment. This may include job opportunities and the social benefits of reduced externalities in our economic system such as environmental degradation. For example, Michelin (2017) reports that in the EU the retread industry results in:

- At equivalent use, a retreaded tire supports 4.3 times as many jobs as a non-re-treadable imported tire.
- Retreading supports the employment of 32,000 jobs in EU27.

Social benefits and costs are likely to be negligible for tire-derived aggregate. Since the material is a substitute for another aggregate, it is expected there would be minimal changes in labour outcomes for TDA. In this case, no jobs would be lost locally and no additional jobs would need to be created by the business. Social costs and benefits will be indirect, uncertain and variable, if apparent. They will be the function of social benefits derived from improved financial or environmental performance, recognizing the interlinkages of these three environments.

Jobs would be created in the economy for remanufacturing of tires where an increase in retread activities would require an increase in the skilled labour force. Manufacturing of high value products, such as molded products from crumb rubber, would be created through the expansion of these markets by market development or incentives, such as eco modulated EPR schemes or through circular economy procurement policy which prefers recycled content in the purchase of products or services.

6.2.3 *Environmental Impacts*

Haines et al. (2010) completed a LifeCycle Analysis (LCA) for end of life tire uses for the Alberta Recycling Management Authority (ARMA) in 2010. The study compared the impacts (including GHG's generated, power and fossil fuel input, acid deposition potential (ADP), dioxins and furans emissions, PM generated, heavy metal emissions and polycyclic aromatic hydrocarbons (PAHs)) of end of life tire uses compared to their traditional alternative and to each other. The list of options studied, and their alternatives, are summarized in **Table 76**.

Table 76: EoL Tire Options Studied by Haines et al. (2010).

EoL Tire Recycling Option Studied	Traditional Product
Tire Derived Aggregate	Gravel for Landfill Leachate Collection System
Rubber Rig Mat	Timber Rig Mat
Rubber Curbs	Concrete Curbs
Rubber Shingles	Asphalt Shingles
Tire Crumb	PP Crumb
TDF	Coal (at power plant and at cement kiln)
Tire Derived Energy	AB Grid Power

The core lifecycle stages considered for this study included the specific recycling processes and the displaced process as well as the emissions associated with the collection, processing, manufacturing, transportation and end usage of each option. Downstream impacts such as off-gassing and leaching of installed products was not included.

- Results indicated that the benefits of recycling depends greatly on whether the displaced material type is wood, concrete or "asphaltene".
- Displacing concrete curbs and asphalt shingles had the highest GHG net benefit.
- Rubber curbs over concrete also delivered reductions in PM and carbon monoxide but resulted in a marginal net increase of VOC emissions and acid deposition precursors.
- Rubber shingles over asphalt shingles showed a significant net decrease in VOC emissions and a marginal net decrease in PM and heavy metal generated but a slight increase in carbon monoxide emissions.
- Rubber versus timber rig mats also showed a substantial improvement in carbon monoxide emissions with a slight increase in VOC emissions.
- The TDA versus gravel for landfill leachate collection systems showed no substantial improvement over gravel.
- The best tire derived fuel option was the tire derived energy versus AB grid power (primarily derived from coal).
- All TDF/TDE options resulted in net negative benefits compared to non-burning reuse options.
- With regards to cost benefit analysis for carbon pricing and CO_2/CO impacts, from an environmental standpoint, the key focus here are the VOC emission, PM and heavy metal reductions. Arguably, reducing the pollution and risk to human/animal health from these is more significant than any financial incentive. Carbon monoxide, according to IPCC calculations, has low direct GWP but indirect radiative effects similar to CH_4. Its estimated global warming potential (GWP100) is between 1 and 3. As such, taking the conservative end of the scale, it would not differ to CO_2 from a carbon pricing standpoint. Under current Canadian policy this would equate to a cost of $CAD 40 (rising to $CAD 170 by 2030).

Table 77 provides a summary of the global warming potential savings identified in the study.

Table 77: EoL Tire Options Studied by Haines et al. (2010).

EoL Tire Recycling Option Studied	Environmental impact (% reduction in kg CO_2e/t through use of recycled tires)
Tire-Derived Aggregate	-36%
Rubber Rig Mat	-1%
Rubber Curbs	-67%
Rubber Shingles	-67%
Tire Crumb	-34%
TDF	-1%
Tire-Derived Energy	-8%

Fiksel et al. (2011), conducted a comparative LCA of using scrap tires as alternatives for a variety of products (See **Table 78**) including artificial turf, asphalt, tire retreading with crumb rubber rather than virgin, molded products, backfill, leachate collection system, incineration with MSW and as an addition to coal in industrial boilers and cement plants. It should be noted that this study was commissioned by Holcim Cement.

Table 78: EoL Tire Options Studied by Fiksel et al. (2011)

Traditional Use	Alternative	Assumptions
Cement Production with Coal	TDF	No info on rate of substitution
Incineration and Industrial Boilers	TDF	Substitute 8% of feedstock with TDF
Backfill	Shredded Tires	No info on rate of substitution
Asphalt	Asphalt with Crumb Rubber	No info on rate of substitution
Molded Products	Molded Products with Crumb Rubber	100% substitution
Artificial Turf (EPDM)	Artificial Turf with Crumb Rubber	100% substitution
Tire Retreading with Virgin Rubber	Tire Retreading with Crumb Rubber	Assumed 10% substitution

Their analysis suggests that the largest emissions reductions came from the substitution of scrap tires in artificial turf (~2,000 kg CO_2 eq per metric tonne) and substitution for coal in cement plants, incinerators, and boilers (~250-500 kg CO_2 eq per metric tonne).

- Using crumb rubber in tire retreading and using shredded tire as backfill or as leachate collection systems, produced a modest reduction in CO_2 emissions (~<100 kg CO_2 eq per metric tonne).
- Using crumb rubber as a substitute in asphalt was the only option that caused an increase in CO_2 eq emissions.
- Using TDF in cement plants and rubber crumb in artificial turf was also found to reduce dioxins, heavy metal emissions and acidification potential.
- Using TDF in an industrial boiler increased heavy metal emissions.
- Acidification potential was reduced for TDF uses, especially in boilers and cement plants as well as artificial turf, which also reduced ecotoxicity. These uses also saw a decrease in eutrophication.
- TDF in a cement plant and rubber crumb in artificial turf also reduced cancer and non-cancer human health impacts - the opposite was identified for incineration and use in a boiler.
- Use of rubber crumb in asphalt saw increases in negative impacts in almost all categories. We note that this study's results contradict a study presented in **Task 3** regarding rubber crumb and its

positive environmental impacts. The difference in LCA scopes can impact results in differing studies.

- Use of rubber crumb for retreading tires showed minimal positive or negative impacts across most categories compared to using virgin rubber.
- The use of crumb rubber in molded products showed modest improvements across nearly all categories of impact.

It should be noted that while this study found that TDF showed significant environmental improvements in some categories, the use of rubber for fuel effectively removes that product from uses over multiple lifecycles.

Pyrolysis is the thermal degradation of tires in the absence of oxygen to produce steel, diesel-like oil and carbon black (Rafique, 2012). Rafique suggests that pyrolysis of tyres is a better option for recycling than retreading, shredding, TDF and other processes, but the products obtained are not of virgin quality and thus of lower economic value.

Boustani et al (2010) suggest that retreading end of life tires is superior to manufacturing new tires because up to 80% of embedded energy and the original tire material is retained in the casing of the tire. Tire retreading can reduce the production energy demands for tires by as much as 66% where the rolling resistance of retreaded tires is the same as new (Boustani et al. 2010). Good quality tires can be retreaded up to three times (Personal communication, Cam Johnston, 2020) thereby compounding these impacts.

The CANMET (2005) study reports that the manufacturing of a retread tire results in a savings of 27 kgCO_2 per retread tire. However, it has been reported that retread tires do not perform to the same quality as new tires with the rolling resistance of retread tires being at least 3% higher than that of a new tire. This can be significant since Goodyear reports that the ‘in use’ phase accounts for 86% of the entire environmental impact of a tire, with end of life only accounting for 1% (Goodyear sustainability report 2018). Conversely, it is noted that as far back as 2013, a Continental plant in Hanover-Stöcken – the ContiLifeCycle plant – has reported producing retreaded tires that equal the performance characteristics and rolling resistance of new tires[95].

A study in Sweden (RISE – Sustainable Business, 2018) reports that the global warming potential of a new tyre is 20kg per tyre and 11kg for a retread tire (excluding the impact in rolling resistance). The difference between the Canadian estimate (27kg) and the Swedish estimate (9kg difference) is primarily due to the type of tires being evaluated, where it is very large OTR tires in the Canadian case versus smaller heavy duty truck tires in the Swedish case.

A French study (Clauzade et al, 2010) quantified the absolute environmental impacts, (**Table 79**). This showed that the use of tire derived rubber (TDR) in synthetic turf results in the highest environmental benefit for end of life tires, when they can no longer be retreaded. However, it is stressed that this market is quite modest with respect to the levels of TDR being generated. Additionally, the study shows that the use of TDR in energy recovery results in a significant benefit. This differs significantly from the results of the study in Alberta where only modest benefits were reported. Unfortunately, insufficient background information is provided in the two studies to determine why the results are so different.

[95] https://www.continental-tyres.co.uk/truck/company/sustainability/award-winning-innovations/european-sustainability-award-for-plant

Table 79: Absolute Environmental Impacts of EoL Treatment Routes

Type of recovery	Application	Substitution per 1 tonne of tire derived rubber	Environmental impact (kg CO_2e/t of tires recycled)
Public works recovery	Retention basins	1.95t concrete or 0.3t polyethylene	-448
	Infiltration basin	6t gravel	-11
Material recycling	Steel works	0.59t anthracite and 0.16t scrap	-672
	Foundries	10t foundry coke	-1,193
	Moulded objects	1t polyurethane	-2,703
	Synthetic turf	0.5t EPDM and 2t chalk	-3,217
	Equestrian floors	44t sand	-342
Energy recovery	Cement works	0.7t petroleum coke and 0.29t coal	-1,466
	Urban heating	1.15t coal	-1,275

Conversely, two additional studies in the USA provide estimates that fall between these two extremes. Federaldi et al (2012) reports that the global warming potential (GWP) of 1 tonne of mixed US scrap tires is:

- –501 kg CO_2e for energy recovery, and
- –1,487 kg CO_2e for material recycling.

Clean Tech Environ policy (2011) reports that the savings in using TDF, substituted for coal in cement kilns is 543 kg CO_2e per tonne. A more recent study (Force Technology, 2020) reports more modest environmental benefits for both artificial turf and energy recovery, **Table 80**.

Table 80: Environmental Impact of Tire Incineration vs. Material Recycling

Application	Substitution	Environmental impact (kg CO_2e/t of tires recycled)
Co-incineration: Cement kiln	Not disclosed	-197
Material recycling: 3rd generation artificial turf	Styrene Ethylene Butylene Styrene (SEBS) infill	-838
	Ethylene Propylene Diene Monomer (EPDM)	-972

Source: Rafique, 2012

This energy density of rubber (notably tires), in comparison to coal, is supported by **Table 81**, which shows a comparison of the energy content of various fuels. Whole tires have an energy content higher than that of coal and wood biomass. For example, 1 kg of whole tires has the same energy content as 1.25 kg of coal.

Table 81: Energy Content of Fuel

Fuel	Energy content of fuel
Heating oil	42 MJ/kg
Natural gas	38 MJ/m^3
Coal	25 MJ/kg
Wood biomass	20 MJ/kg
Tires (whole)	30 MJ/kg
Tires (steel removed)	36 MJ/kg
Mixed plastic waste	43 MJ/kg

Source: Pehlken and Essadiqi, 2005

6.3 Barriers to a Circular Economy for Rubber

6.3.1 *Scaling Devulcanization Processes*

Devulcanization is a method of potentially 'upgrading' end-of-life tire rubber. Devulcanized rubber is a higher valued form of end-of-life rubber, since devulcanized material can be partly revulcanized and partially replace virgin rubber in specific compounds and applications, including tires. Currently, only a small number of devulcanization systems are operating on industrial scale. These are primarily small-capacity systems, which are devulcanizing rubber production rejects (NR, SBR, NBR, EPDM, Butyl, etc.) or rubber recovered from waste tires.

There are different types of devulcanization technologies on the market; among them are chemical, purely mechanical, mechanical with supercritical CO_2, chemical/ mechanical, microwave, ultrasonic and organic. At the given moment, virgin rubber prices are too low to recommend any of the devulcanization technologies and the industry experts are indecisive for its outlook. Ideally, devulcanization would yield a product that could serve as a substitute for virgin rubber, both in terms of properties and in terms of cost of manufacture. Properly devulcanized, much of the excellent properties of rubber are retained.

Devulcanized rubber can be used in meaningful amounts in a wide variety of high-end and critical applications, including new and retreaded tires. Achieving devulcanization through these various methods in research labs at low throughput has been possible, but the true test of viability is scaling to commercial output levels that match the needs of large manufacturers. In a tire tread compound, some companies claim that their devulcanized rubber can usually be added at 10-20% with excellent results, compared to 4-8% with reclaimed rubber or modified crumb rubber such as MRP[96].

Over twenty years, the authors have witnessed many varied attempts to achieve true devulcanization of rubber crumb, by chemical, thermal and biological treatment, or to develop a surface treatment process that would enable the used rubber to bond effectively with virgin materials, thereby achieving higher recycled content new products. None of these have yet proven extensively commercially viable.

However, it is noted that Green Rubber (current at a technology readiness level of 8) and Tyromer devulcanization and recycled content rubber production processes, alongside Nano polymer treatment (which is posited to enable high quality, high recycled content rubber), are promising processes that are beginning to enable greater circularity of rubber. Large investments have been made by the tire industry to support processes which improve end of life prospects for tires e.g., rubber crumb production. Many other processes to improve end of life for vulcanized rubber remain at the laboratory/pilot phases.

One query is what is needed to make investment appealing. That perspective is best suited for the tire manufacturers to answer. Michelin purchased Lehigh technologies in 2017, and now own their patented cryogenic shredding process to produce micronized rubber for use in multiple industries. Given that the material can be used in tires, it fits their sustainability strategy – making tires with 80% sustainable materials by 2048 and recycling 100% of tires by 2048. Aside from alignment with their objectives, high TRL, and we assume a well presented business case, it is not clear what the drivers are for specific decision makers. However, with supporting evidence, the scale up or business case development of the R&D technologies would drive investment.

In order to scale up rubber devulcanization operations in Canada, especially for end of life tires, investment in devulcanization infrastructure development would be needed in Canada. An assessment of the required investment is beyond the scope of this study, but is recommended as a next step. While end of life tires are generated in every province and territory annually, the lack of facilities to devulcanize end of life tires and rubber products is a current barrier to a circular rubber economy in Canada until industry incentives and investments are supported. In addition to the infrastructure gap and needs, policy for

[96] http://tyromer.com/wp-content/uploads/Rubberworld-Tyromer-Article.pdf

minimum post-consumer recycled content requirements, by industry and or government, would also drive end of life tires up the value chain towards retreading and devulcanization, rather than used as lower value chain purposes such as fuel or crumb TDA, as they currently are in Canada.

In addition to the infrastructure need, is the market cost of virgin rubber to recycled rubber. The oil and petroleum industry provides synthetic virgin rubber to manufacturers to produce new rubber products. The oil and petroleum industry is greatly subsidized by governments globally. These subsidies greatly benefit the virgin rubber markets. It is reported that last year, Canada spent $2 billion on fossil fuel subsidies, while agencies like Export Development Canada provide roughly $13 billion more for domestic and international fossil fuel production and exploration[97]. A recycled rubber market would need to compete in the same market as subsidized virgin rubber. Hence, a portion of subsidies for virgin rubber would need to shift and transition to recycled rubber to balance the demand and focus. In addition a skilled labour force required to support a circular rubber economy, would partially need to transition from the current oil and petroleum industry in Canada to a circular recycled rubber economy that develops the necessary infrastructure for the scale up of devulcanization and retreading where tires are sold. The reduced GHG impacts of recycled rubber compared to virgin rubber products is also a benefit, as discussed in Task 3. The United Nations Framework Convention on Climate Change (UNFCC) count emissions in the country where the GHG burned. Therefore while Canada may also import tires produced overseas, we are responsible for their management at their end of life and the associated GHG impacts.

6.3.2 *Impact of Rubber Additives on EoL Fate*

An overview of the identified additives used in rubber manufacturing and their impact on the EoL fate of rubber was summarized earlier in **Table 9**. The major barrier, globally, to greater circularity of rubber, is the vulcanization process: The creation of sulfur bonds in natural and synthetic rubber gives the end product its desired strength, but makes the material extremely difficult to recycle fully. Great strides have been made globally to collect and 'find a use for' used rubber products (mainly tires), thereby avoiding stockpiling. However, the fact remains that too high a proportion of the EoL rubber from high volume products, such as footwear and tires, are either incinerated as fuel or 'downcycled', after which the rubber cannot be recovered or recycled a second time.

True circularity for rubber will only occur when an effective and economic process for the conversion of used rubber crumb into a material suitable as feedstock for the manufacture of new, high tech products, is available (and in the case of tires, true circularity will be the direct recycling of end of life tires into new tires).

Current processes commonly being used and invested in by the tire industry, such as micronized rubber, retreading, etc., have a cap on recycled content possible. Devulcanization, theoretically and with further development, has the potential to go beyond current caps and increase recycled content of tires (and other products). In the earlier tasks, we have touched on the sustainable material and tire recycling targets of one tire manufacturer. In the future, they (and other tire manufacturing market players) will need technologies to provide higher recycled content tires. Their targets are likely to drive devulcanization.

From a policy perspective, setting increasing recycled content targets for tires and rubber products would likely drive devulcanization. This was discussed above as one of the options to consider.

6.3.3 *Future Rubber Waste Generation in Canada under Business-as-Usual Scenario*

Using a defined lifecycle and estimates of domestic demand for each product, we estimated the mass of end of life tire and non-tire automotive rubber products in Canada from 2020-2030 as outlined in **Table**

[97] Carter, A.V and Dordi, T. Meeting Canada's climate commitments requires ending supports for oil and gas production Cascade Institute, April 14, 2021.

82. Note that data available for these estimates was collected pre pandemic activities, which began in March 2020. Market insights are evolving in response to covid-19 and are being updated by industry experts at this time of this report. The Tire Manufacturing industry in Canada exhibited contraction mainly as a result of the pandemic in 2020. Declines in vehicle sales in North America and significant reduction of travel in 2020 as a result of pandemic lockdown measures are the primary reasons for this decline.

Table 82: Estimate of Future EoL Tire and Non-Tire Automotive Rubber Products Generation in Canada (kt)

Product	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Passenger Tires	209	288	312	320	332	348	365	383	402	421	442
Commercial Tires	203	168	177	185	194	204	214	224	235	147	259
OTR Tires	154	220	222	233	245	257	269	283	297	311	326
Other tires	83	56	50	53	55	58	61	64	67	70	74
Non-Tire Automotive Rubber	151	157	167	169	192	192	187	195	204	213	222
Total	**800**	**889**	**928**	**960**	**1,018**	**1,059**	**1,096**	**1,149**	**1,205**	**1,162**	**1,323**

It is assumed that all non-tire automotive rubber will be disposed of in a landfill. Using the same material treatment ratios as today, we would expect that, in 2030:

- 98 kt of EoL tires would be used for retreading;
- 642 kt will be recycled (includes WTE);
- 127 kt will be lost as tire wear to the environment;
- 266 kt will be landfilled as waste; and
- 189 kt will be unaccounted for.

7 Recommended Industry and Government Actions Towards a Circular Rubber Economy

7.1 Recommended Policy Changes

The potential benefits of circular economy are based on implementing industry and government actions that could enable the transition of rubber accordingly. The actions that could enable a transition to a circular economy for rubber in Canada are summarized below.

An assessment of the governance of the tire sector has been completed. It commented on the existing system, including its circularity and value retention outcomes. The tire EPR system currently functions with limited circularity and sustainability outcomes, despite high material recovery levels. To address these issues, we recommend the following overall objectives:

- The continuous improvement of recovery and sustainability targets beyond a single product life cycle, i.e. multiple use and reuse of the rubber.
- A more transparent and inclusive EPR governance system with an objective of driving end of life treatments up the recovery hierarchy, including OTR tires and across all jurisdictions such as the First Nations and Territories. This can also include the funding of R&D trials through the EPR system. For example, the paint stewardship scheme in operation in Australia funds education, marketing and communication, R&D investment, transport and processing of waste paint from trade and domestic sources across the country (Global Product Stewardship Council). Additionally, the Product Stewardship for Oil Program (PSO) in Australia includes a variable benefits rate, e.g., re-refiners receive 50 cents per litre of oil re-refined, whereas, organizations burning the oil only receive 3 cents per litre.
- Regulatory jurisdictions need to be considered when incorporating the First Nations and Territoritorial jurisdictions. The EPR agencies in each province typically ensure the collection sites and the end processors for the designated collected materials are registered and abide by the relevant bylaws and legislation. However, First Nations do not fall under provincial jurisdiction. The Federal Government of Canada administers Indian status, local First Nations governments, and management of reserve land through the Indian Act. Solid Waste Management regulations for First Nation Communities are governed by the Federal Government of Canada under this Act and under Indian Reserve Waste Disposal Regulations C.R.C., c. 960. Indigenous Service Canada's (ISC) responsibilities include ensuring the requirements of the Indian Reserve Waste Disposal Regulations are enforced, approve permits, allocate funding, construction and operation of waste sites, and provide technical advice and assistance. As a best practice, ISC takes the position that projects or activities on federally administered lands should, at a minimum, meet the standards of the surrounding provincial/territorial jurisdiction to the extent possible. The role of the provincial government in this respect is to address any off-site impacts, and work through federal departments such as ISC or directly with the First Nation to correct any situations. In this case, EPR provincial programs do not have First Nations jurisdiction and a First nation would have to make special agreements and arrangements to be part of a provincial EPR program, which tends to require more that the limited resources, transportation costs and staff needs to be practical, depending on the size of the First Nation. EPR programs across Canada need to be practical for First Nations, remote and northern communities across Canada; some of the most venerable communities and environments at risk with respect to waste management.

- On a higher perspective, a greater focus on sufficiency[98] strategies, e.g., industry and regulatory tire design and standards for durability and retread (reuse, remanufacturing) and a broader transformation of Canadian transportation models and GHG reduction.

7.1.1 *Policy Mix Considerations*

In order to support a circular intervention, a jurisdiction will likely design and use a mix of different policies, depending on context and which policies are already in place. In Canada, there is only one policy for tire recycling, which is EPR tire policy in the ten provinces and the Yukon. There is no eco-modulated EPR, no national landfill bans, no recycled content minimum, no re-treadability standard, no import standard for re-treadability, no procurement policies to support recycled rubber, no market development incentives, and no tax break incentives to support rubber recycling. The prioritization of policies can, and will, differ across the jurisdiction's support for circular interventions. Policy instruments will vary between jurisdictions based on how far along they are in their circular transition and subject to the constraints of legislative mandates. In summary, Canada lags behind Europe and Australia in its policy mix to support a circular economy for rubber.

In advancing the CE cause, Italy provides a useful case study in its efforts to introduce a technological standard for communicating the recycled content of products. To increase the visibility of such an initiative, Italian authorities partnered with an NGO formed by the National Association of Recyclers to develop a voluntary certification (label) based on the technological standard. To increase its adoption, the government introduced a regulation to integrate the certification as a requirement in its Green Public Procurement (GPP) process and provided certified companies with the possibility of applying for subsidies and tax breaks.

A Canadian transition to a circular economy for rubber is beneficial – socially, economically and environmentally as discussed in **Section 6.2** above. The following suggestions are areas for consideration and further exploration to help enable a circular economy for rubber within Canada:

- Identification of the challenges to a federally led robust EPR system standardized across Canada. Identify what a federally enforced tire EPR program, controlled by each province, may look like and a standardization/ rationalization of its approach on a national level. In a national standardized EPR system for EoL tires, there would be a standard set of designated tire types. Currently OTR tires are not accepted in all provincial programs. This is partially due to the added cost and low volume of OTR tires compared to passenger or light truck tires. A portion of OTR tires tend to be for heavy duty equipment and mining machinery, therefore far from recovery centres at their EoL. Their large sizes and weight also results in higher costs for handling and transportation. A national standard for EPR tire programs should include OTRs as well.
- Government and industry cooperative engagement and investment into new technologies.
- Support for Tire-to-Tire recycling, rather than 'salve on wound' processes, which do not represent truly circular solutions. Key processes to support Tire-to-Tire recycling include devulcanization and high recycled content rubber with tire-suitable technical properties, our research suggests that the following are worth exploring further:
  - Tyromer devulcanization (devulcanization process, recycled rubber has the potential to be used in tire production, present in Canada already).
  - Green Rubber (devulcanization and recycled content rubber production, high TRL, low temperature, recycled rubber has the potential to be used in tire production, potential to be brought to Canada).
  - Nano polymer treatment (promising claims, appears to be a well proven concept, recycled rubber has been used in tire production and initial testing carried out, ready to be tested in Canadian market).

[98] For the affluent consumer, sufficiency means necessarily "downsizing" one's consumption and living standards. (Brown and Cameron, 2000)

- Consider initiatives that best support the retreading industry, notably in OTR tires, which are a large and hidden stream.
- Phase in a minimum recycled content in tires to support the demand of devulcanized rubber.
- Phase in a requirement that all tires sold and manufactured in Canada are re-treadable.
- Regulations for "Zero automotive waste to landfill". This is potentially an evolution to the end-of-life vehicle regulations and would drive recovery and improved end of life treatment of other automotive rubber such as hoses, belts and tubes. Technology development for processing and recycling, end market development and collection logistics will need to be addressed as part of a strategy and regulatory goal towards "zero to landfill". The automotive sector, as producers of these rubber products, will need to develop such as strategy and achieve support and buy in across its sector and align with associated proposed regulations.
- Regulations and policies that include barriers to transboundary or cross jurisdiction flow need to be addressed in a new EPR framework. While provincial EPR programs are designed and unique for each province, this can be a barrier to flow of designated materials across jurisdictions, e.g. tires to higher value end of life processing options. A national standardized EPR program should support the recovery of all tires across all Canadian jurisdictions for higher value recovery processes such as devulcanization or retreading. For illustration, tires in Eastern Ontario currently may be sent to lower value processes (TDA crumb or as cement kiln fuel) in Ontario because their EPR boundaries restrict them from going over the provincial border to Quebec where a retreading plant may exist. This current barrier does not support the activities central to a circular economy.

7.1.2 *Regulatory and Policy Levers*

Regulatory trends, strategies and approaches that Canada could emulate, or leverage, to transition to a circular rubber economy goal may include:

- National EPR (Extended Producer Responsibility) framework, with industry recovery targets and appropriate monitoring and verification of compliance;
- Minimum recycled content regulations to enhance the secondary rubber market;
- Mandating that all tires entering or sold in Canada be retreadable;
- Mandating product design standards (design for durability, retread-ability, minimum industry quality standard);
- Implementing a user levy on non-recyclable rubber products;
- Supporting the further development of value retention processes (VRPs) capacity and infrastructure in Canada and the further development of a VRP secondary market (retreading, devulcanization); and
- Banning tires from landfill.

7.2 Gap Analysis

The following section identifies gaps in the current system of the Canadian rubber industry with respect to moving forward towards a circular rubber economy. These gaps include information and data gaps, and the need for further or additional research to inform policy development and industry incentives to support a Circular Economy for rubber in Canada.

7.2.1 *EPR Frameworks and Circularity Measurement*

In **Task 3** of this study, we examined EPR and tire recycling, various treatment options and progress across jurisdictions, including the steady departure from tire landfilling. EPR program schemes can vary in level of performance and robustness since there is no one standard EPR system or best practice. Each jurisdiction designs their own EPR program as well as the policies supporting it and their regulatory targets for performance and recovery. EPR systems vary across jurisdictions, including Canadian provinces. Since waste management is a provincial jurisdiction in Canada, each province has developed their own unique EPR program for tires. EPR program frameworks can vary in policy approaches (eco modulated EPR), successes (recovery or diversion targets for the materials designated) and have limitations (end markets for recycled end of life material). An EPR system does not necessarily guarantee that waste tires are disposed of in the most environmentally beneficial manner, or in accordance with the waste hierarchy. They outcome may be only that they are diverted from landfill. As discussed earlier in this report, EoL tires are used for a variety of end markets: fuel, construction fill, TDA, crumb rubber, and some retreading. Further examination of the trade-offs of increased material circularity of tires, contracted against other sustainability indicators (e.g., human and ecosystem health) is to be considered. Increased material circularity is beneficial from a resource perspective, but not necessarily from other environmental perspectives such as release to the environment.

The circular economy emphasizes closing material loops to retain material value and reduce GHG emissions resulting from raw material production, extraction and transport/shipping. The current practice of tire recycling in Canada, through a system of EPR, appears to be a success (without deeper analysis), with claims of near 100% recovery from landfill. Yet, there is limited understanding regarding the system’s circularity, considering alternative value retention options and resource recovery outcomes. Most Canadian EoL tires are used as a fuel or TDA. Further analyses into individual provincial EPR programs for tires could provide insight into how they could be improved from a systemic circular economy perspective. One consideration for review is the lack of an eco-modulated EPR framework in Canada. Currently there is no incentive to use EoL tires for higher value retaining processes (VRPs) such as tire retreading i.e. remanufacturing (there is some; mostly heavy duty tires) and devulcanization (very little). The benefit of an eco-modulated EPR framework across Canada, is to transition to VRPs (reduce GHG) and direct less tires to the low value fuel and TDA end-of-life disposal currently applied. Eco-modulated frameworks would have to be established as the national path forward, then implemented across each provincial EPR regulation, and in-turn industry implemented and operated.

In addition to eco-modulation EPR frameworks, standards with respect to high recovery targets for all rubber tires (high recovery diversion rates arealready achieved since some programs are only required to collect passenger tires), a standardized list of designated tires (many programs do not collect OTR or other tires such as recreation tires or bicycles), as well as post consumer recycled material targets, and regulations to support retreading and devulcanization are needed to drive demand to VRPs. Currently there are as many variations on the provincial EPR programs policies as there are provinces. A national standard would be of benefit to support a circular rubber economy.

Building on these examples, a critical examination of the tire stewardship management organizations and the performance of the existing tire **Table 79**, to reflect on its strengths and suitability to deal with the broader needs within the circularity of tires debate needs to be considered.

The question of how effectively do current EPR systems function in relation to the current ambitions of circular economy should be further examined. How circular is the rubber industry in Canada now and how circular does the rubber industry need to become to achieve GHG targets and solid waste diversion targets?

7.2.2 *LCA Assessments*

Available lifecycle assessments for end of life tire treatment compare end of life uses to determine preferred pathways. One criticism of the available literature is that the studies only evaluate one lifecycle and therefore don’t evaluate the compounding benefits of keeping materials in the economy for as long as possible (i.e. several lifecycles). Consequently, terminal end of life uses, such as tire derived fuel appeared to have superior environmental benefits compared to other end of life uses. Common sense dictates that recycling end of life products for a second or third life, before using it as tire derived fuel, would compound those benefits. By supporting the research and development of a circular approach to lifecycle analysis in which more than one lifecycle, (e.g., a linear product lifecycle of product production, product use, collection of end of life product, end of life fate as TDF) which removed the rubber product from reuse and circulation in the economy.

7.2.3 *Circular Hierarchy Incentives*

Ultimately, using the circular economy framework as a guide, rubber tires should be maintained in the Canadian economy for as long as possible. The following hierarchy ranking for rubber should be referenced when considering incentive models and policy frameworks:

1. Remanufacture (via tire retreading).
2. Closed loop recycling (i.e. Tire to tire recycling).
3. Followed by open loop recycling or substitution for other products where lifecycle analysis indicates superior benefits (and in applications where the rubber can be reclaimed multiple times and not just once such as TDF).
4. Use as fuel (TDF) in lieu of coal.

A driver to effect a move to 'upper hierarchy' options may be a financial one. Using the Australian example presented in **Task 3**, by applying the oil treatment model, a similar financial incentive program approach may drive rubber material recovery.

Identification of effective financial incentives to drive end of life tire material up the hierarchy should be examined and understood for the Canadian tire and rubber industry sector through consultation and economic analysis.

7.2.4 *Tire Retreading Support*

Tire retreading has been on the decline over the past five years as cheaper imported, new tires have come on the market. Industry stakeholders have indicated that many of these tires cannot be retreaded, further exasperating the issue.

The EU and the Indian government[99] provide an example of international action on cheaper Chinese tire imports. These centre on applying anti-dumping duties[100] in order to support their own national industry, retain jobs and rely less on Chinese imports[101]. Potentially this may be a narrative that could be applied in Canada to support tire retreading in Canada by implementing import duties on cheaper and lower quality and Asian imported tires that cannot be retreaded for reuse and impede a transition to a circular rubber economy in Canada.

Opportunities to support and incentivize tire retreading industry in Canada should be considered, with priorities such as:

- implementing minimum quality standards for new tires manufactured and sold in Canada, and also specifically for imported tires, to ensure that they all meet the quality standards required to make them eligible for retreading;
- the application of taxes levied on environmentally inferior tires, such as those with additives that pose environmental concern and which wear faster and release rubber into the environment and;
- providing tax breaks on retreaded tires as a financial incentive, especially in the passenger and light truck tire sector.

[99] https://indianexpress.com/article/business/tyre-imports-restrictions-china-atma-6463342/
[100] https://www.thetruckexpert.co.uk/eu-takes-action-against-dumped-chinese-truck-tyres/
[101] https://www.tyrepress.com/2018/10/eu-makes-final-truck-tyre-anti-dumping-duties-decision-retains-fixed-rates-for-manufacturers/

7.2.5 *Market Incentives for Higher Uses of EoL Tires*

Support for market development is a key component in creating opportunities for higher end uses of EoL tires that follows the hierarchy of options discussed above. Market challenges include:

- The convenience and low cost of tire-derived fuel and landfilling;
- The need for greater government agency acceptance of new end uses; and
- Public concern over EoL tire use in particular products.

Government policies, including government procurement and restricting the use of EoL tire fees to tire-related purposes, can help support higher end EoL tire markets. Another option is to provide incentives to collect, haul, and process tires as has been done in some provincial EPR jurisdictions. These incentives can be a sliding scale based on the end use (e.g., the higher value the product, the more incentive a tire recycling processor receives). This lends to the eco-modulation EPR type system. This can help drive production of higher value products.

8 Gaps and Further Research

This report has identified a number of topic areas where basic understanding of the Canadian market, material fluxes, practices or state of technology and materials science might adversely affect policy formulation. They have been highlighted in the report by the 🔍 icon but are gathered here in summary for convenience. (Note they are hyperlinked to the original text in the report.)

8.1 Additives, Antioxidants and Anti-degradants

There are a number of additives, particularly antioxidants and anti-degradants, which raise health concerns noted by regulators worldwide. A review of safety data might usefully lead to lists of permissible or banned uses for rubbers containing these, particularly where more susceptible persons might be affected.

8.2 EoL Rubber Treatment in Canada – LCA data

ECCC should consider assembling lifecycle data which uses a real-world view of the correct functional unit in its assessment of relative benefits. This would certainly be required in follow on work because of the implications on choice of techniques, systems and capacities and their consequential costs and benefits.

8.3 Approach to EPR Schemes

Although there is an industry EPR scheme in place, it is not as effective as top performing schemes elsewhere. Further investigation into industry practices and barriers to compliance may be necessary in order to formulate an effective response which assists industry bodies to carry out their obligations. This may result in a harmonized national EPR approach across Canada. See also **Section 3.3.2.**

8.4 EPR Frameworks and Circularity Measurement

Building on examples of provincial stewardship schemes, a critical examination of the tire stewardship management organizations in each province and territory and the performance of the existing tire recovery routes, **Table 79**, to reflect on its strengths and suitability to deal with the broader needs within the circularity of tires debate needs to be considered.

8.5 Circular Hierarchy Incentives

Identification of effective financial incentives to drive end of life tire material up the hierarchy should be examined and understood for the Canadian tire and rubber industry sector through consultation and economic analysis.

9 Next Steps

As a result of this study, the ECCC is better informed regarding the state of the Canadian rubber sector and the opportunities that can be harnessed to shift it to a more circular rubber economy. While this study has a Canadian context, we recognize that the rubber industry is a global multi-national one, and that a circular economy is best achieved in collaboration with other jurisdictions also looking to shift to a more circular economy. A circular rubber economy is a slow stepwise process of transformation: There are no single action items that can bridge the circularity gap.

Synthetic rubber is a plastic material, most of which is derived from extracted fossil oil. This means that, as in the case of single-use plastics especially, the material is of rising global interest. However, it is a more complex chemical assembly: Considering the many materials and chemicals used in the manufacture of rubber and its products, the ECCC may want to first establish an environmental ecological risk assessment, by literature research, on the impacts of the various end of life options identified in this study and their risk profiles. A circular economy aims to retain value for resources and products and to extend their useful life. It must however, be underwritten by a sound evidence base on the alternative tactics and guiding principles before proceeding with policy development, new industry standards, circular strategies and R&D plans.

The following are recommended next steps for Canadian rubber studies:

- A material mapping flow of rubber and rubber products, across the rubber supply chain including the origins of the rubber supply and any imported materials;
- A geographical mapping and capacity assessment of tire retreading and devulcanization operations and facilities across Canada;
- A capacity analysis to explore how the processing capacity of the current facilities could be expanded;
- A quantification of imports versus exports of rubber supply chain by product type and including end of life rubber and waste;
- Development of an industry minimum standard for imported tires into Canada, and extending into North America through an industry initiative. The standard would require a minimum quality standard to be met for tires so that all tires sold into Canada meet the quality eligible for retreading remanufacturing in Canada;
- An estimate of the future costs and investments required for processing capacity development across Canada to fulfill the current infrastructure gaps for a circular rubber economy; and
- An assessment and roadmap of system requirements of a Canadian circular rubber economy in order to achieve zero rubber waste in Canada.

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Annex A *Estimate of Resin and Additive Demand for Rubber Products, 2019*

Table 83: Estimate of Resin and Additive Demand for Domestic Production of Tires and Non-Tire Automotive Rubber Products 2019

Product	Domestic Production (kt)	Inputs	Mass (kt)
IIR	96	Polyisobutylene	94.1
		Isoprene	1.9
New Passenger Tires	184	BR	13
		SBR	30
		IIR	5.9
		NR	26
		Carbon Black	42
		ZnO	1.6
		Sulfur	0.8
		Stearic Acid	0.8
		Silica	3.2
		Other	13
		Antioxidants	3.2
		Steel	16
		Textile	6.4
		Unvulcanized Rubber	23
New Commercial Truck Tires	127.5	BR	3.1
		SBR	7.3
		IIR	1.4
		NR	37
		Carbon Black	26
		ZnO	1.7
		Sulfur	0.5
		Stearic Acid	0.5
		Silica	2.2
		Other	4.3
		Antioxidants	2.2
		Steel	26
		Textile	0
		Unvulcanized Rubber	16

Product	Domestic Production (kt)	Inputs	Mass (kt)
New OTR Tires	66	BR	4.3
		SBR	9.8
		IIR	1.9
		NR	11
		Carbon Black	13
		ZnO	0.6
		Sulfur	0.3
		Stearic Acid	0.3
		Silica	1.1
		Other	1.7
		Antioxidants	1.1
		Steel	7.8
		Textile	5.7
		Unvulcanized Rubber	8.1
New All Other Tires		BR	1.4
		SBR	3.3
		IIR	0.6
		NR	2.7
		Carbon Black	4.4
		ZnO	0.2
		Sulfur	0.09
		Stearic Acid	0.09
		Silica	0.3
		Other	1.4
		Antioxidants	0.3
		Steel	1.7
		Textile	0.7
		Unvulcanized Rubber	1.5

Product	Domestic Production (kt)	Inputs	Mass (kt)
Retread Passenger Tires	0.08 (incl. Retained material)	BR	0.002
		SBR	0.004
		IIR	0.001
		NR	0.003
		Carbon Black	0.005
		ZnO	<0.001
		Sulfur	<0.001
		Stearic Acid	<0.001
		Silica	<0.001
		Other	0.002
		Antioxidants	<0.001
		Steel	0.002
		Textile	<0.001
Retread Commercial Truck Tires	80 (incl. retained material)	BR	0.6
		SBR	1.4
		IIR	0.3
		NR	7.2
		Carbon Black	5.1
		ZnO	0.2
		Sulfur	0.1
		Stearic Acid	0.1
		Silica	0.4
		Other	0.8
		Antioxidants	0.4
		Steel	4.5
		Camel Back Treads	0.34
Retread OTR Tires	5.6 (incl. Retained material)	BR	0.1
		SBR	0.3
		IIR	0.05
		NR	0.3
		Carbon Black	0.3
		ZnO	0.02
		Sulfur	0.01
		Stearic Acid	0.01
		Silica	0.03
		Other	0.05
		Antioxidants	0.03
		Steel	0.2
		Textile	0.2
Retread Other Tires	0.06 (incl. Retained materials)	BR	0.001
		SBR	0.003

Product	Domestic Production (kt)	Inputs	Mass (kt)
		IIR	0.001
		NR	0.002
		Carbon Black	0.004
		ZnO	<0.001
		Sulfur	<0.001
		Stearic Acid	<0.001
		Silica	<0.001
		Other	0.001
		Antioxidants	<0.001
		Steel	0.001
		Textile	<0.001
Weather stripping	18	EPDM	11
		Sulfur	0.2
		ZnO	0.6
		Stearic Acid	0.3
		Accelerators	0.2
		Pigment (assume Carbon black)	5.6
		Softeners/Extenders	0.1
		Antioxidants	0.1
Belts	3.3	EPDM	1
		SBR	0.6
		Neoprene	0.2
		NR	0.2
		Sulfur	0.04
		ZnO	0.1
		Stearic Acid	0.06
		Accelerators	0.03
		Pigment (assume Carbon black)	1
		Softeners/Extenders	0.02
		Antioxidants	0.02

Product	Domestic Production (kt)	Inputs	Mass (kt)
Hoses	11	EPDM	3.2
		SBR	1.9
		Neoprene	0.6
		NR	0.6
		Sulfur	0.1
		ZnO	0.3
		Stearic Acid	0.2
		Accelerators	0.1
		Pigment (assume Carbon black)	3.2
		Softeners/Extenders	0.06
		Antioxidants	0.06
Vibration Dampeners	14	EPDM	4.2
		SBR	2.5
		Neoprene	0.8
		NR	0.8
		Sulfur	0.2
		ZnO	0.4
		Stearic Acid	0.3
		Accelerators	0.1
		Pigment (assume Carbon black)	4.2
		Softeners/Extenders	0.07
		Antioxidants	0.07
Miscellaneous Non Tire Automotive Rubber	17	EPDM	6.4
		SBR	3.8
		Neoprene	1.3
		NR	1.3
		Sulfur	0.3
		ZnO	0.6
		Stearic Acid	0.4
		Accelerators	0.2
		Pigment (assume Carbon black)	6.4
		Softeners/Extenders	0.1
		Antioxidants	0.1
Rubber Crumb	153	Liquid Nitrogen	265
Molded Rubber	146	Polyurethane	11.7

Table 84: Sum of Estimated Inputs for the Domestic Production of Tire and Non-Tire Automotive Rubber Products in 2019

Input	Mass (kt)
Butadiene	23
SBR	61
IIR	10
EPDM	26
Neoprene	3
Natural rubber	86
Carbon Black	110
ZnO	6
Sulfur	3
Stearic Acid	3
Silica	7
Other tire ingredients	21
Antioxidants	8
Steel	57
Textile	13
Softeners/Extenders	0.4
Camel Back Strips for Retread	0.3
Unvulcanized Tire Rubber	48
Polyurethane	12
Liquid Nitrogen	265
Polyisobutylene	10
Isoprene	0.2

Authors

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Lori has 20 years of technical experience as an Engineer specializing in waste management. She joined Dillon Consulting Ltd. in Toronto as a Waste Management Engineer in 2017. She is experienced in assessing the flow of materials and and their end of life recovery options. Her main focus is on waste diversion and resource recovery strategies and master plans for both the municipal and private sectors in Canada.

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Dawne has over 16 years of experience in environmental engineering. She is an emerging expert in the circular economy. Dawne was recently invited by the federal government to speak at the National Circular Economy Experts Roundtable to inform federal policy decisions on the circular economy in Canada.

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Following a degree in physics, Jake joined Oakdene Hollins in 2018. He has been heavily involved in projects relating to batteries, electronics and problematic waste streams. His key skills include technical assessment of materials and products in relation to their sustainability credentials, processing and communication of complex topics and data analysis.

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Peter has over 22 years experience consulting with Oakdene Hollins, with a background in manufacturing systems engineering and more specifically lean manufacturing / lean thinking. Peter has led on a number of large policy studies at UK and European level, including three linked studies for Defra to quantify the potential savings that the UK economy can achieve through resource efficiency and a study for the European Parliament (STOA) on how the European waste management sector can support the delivery of the Circular Economy Plan.

Steve Slater, Principal Consultant, Oakdene Hollins

Steve has been with Oakdene Hollins since 2001, with over 20 years' environmental consultancy experience built on a background of manufacturing management. This included 17 years at director level in an international corporation. As a result he has a practical and realistic understanding of the needs of industry, commerce and public sector, based on the key principles of customer service, quality and operating efficiency, the latter including the reduction of waste in all its forms.