Waste Prevention:

The Environmental and Economic Benefits for Canada

NATIONAL ZERO WASTE COUNCIL

MARCH 2021

zeroWASTE
NATIONAL ZERO WASTE COUNCIL
An Initiative of Metro Vancouver

The National Zero Waste Council, an initiative of Metro Vancouver, is a leadership initiative bringing together governments, businesses and non-government organizations to advance waste prevention in Canada

ACKNOWLEDGEMENTS

This report was completed by
Dillon Consulting and Oakdene Hollins.

The National Zero Waste Council would also like to acknowledge the contributions made by our external reviewers who, in their review of this report, provided their expertise and insight into the Canadian economic sectors analyzed in this report.
Construction: Brenda Martens (Light House);
Manufacturing: Alex Greco (Canadian Manufacturers & Exporters);
Healthcare: Fiona A. Miller (University of Toronto);
Agriculture: Gordon Price (Dalhousie University);
Plastics: Mélanie St-Pierre (Cascades);
Retail: Philippe Cantin (Retail Council of Canada);
Sophie Langlois-Blouin (Recyc-Quebec);
Andrew Marr (Metro Vancouver).

nzwc.ca

Preface

The National Zero Waste Council (NZWC) was created in 2013 by Metro Vancouver as a leadership initiative to advance a waste prevention agenda across Canada. The Council is a collaboration of leaders from governments, business, business associations, non-government organizations, and community groups active in promoting waste prevention at its source and accelerating a transition to a circular economy in Canada.

ABOUT WASTE PREVENTION

Waste prevention consists of actions that prevent or reduce waste from being created in the first place. This does not refer to recycling. While recycling is important, it is an activity that occurs after a product or material is used or consumed. Ambitious recycling and material recovery programs have increased the amount of waste diverted from landfill, but these approaches fall short of achieving zero waste objectives. The linear economy has created a system where decisions made in the early stages of a product's lifecycle (e.g. during the design, manufacturing and packaging stages) are disconnected from the cost and challenges of managing those materials at end-of-life. This disconnect is likely a "fundamental driver for the steady increase in disposable products and packaging, which in turn may be part of the reason that national and global environmental burdens from materials extraction, manufacturing, and distribution have increased steadily."[1]

A focused effort to prevent the creation of waste will mean fewer natural resources are extracted and less energy is used in the production, distribution and consumption of products. It also means that less spending, public or private, will be needed for recycling and disposal programs. Waste prevention provides a magnitude of opportunities for Canada to create green jobs and grow a low-carbon economy while mitigating pollution including greenhouse gas emissions.

Waste prevention involves facilitating both behaviour change and redesigning products and business practices. Businesses and organizations have a key part to play in this from evaluating the amount and type of waste they're producing to rethinking established systems to produce minimal amounts of waste. In addition, changing lifestyles and associated patterns of consumption is another critical path to waste prevention. Actions to change consumer behaviour can be achieved through targeted public awareness campaigns (i.e., WRAP's Love Food Hate Waste) or can be more expansive changes to de-couple well-being and wealth from consumption and economic growth, as envisioned by the concept of sustainable consumption. The latter involves taking actions to adapt economic activity to a level consistent with planetary boundaries while ensuring a more equitable distribution of wealth[2]. Actions to drive changes in behaviour are beyond the scope of this report, this report builds business cases for select waste prevention interventions to provide business and government decision makers with the information that they need to make investment and policy decisions around waste prevention.

WASTE PREVENTION AND THE CIRCULAR ECONOMY

Business as usual will no longer be accepted as companies are realizing the financial and environmental risks associated with the linear economy. Numerous factors are driving the growing interest in a circular economy – the negative social, cultural and environmental impacts of resource extraction, commitments to climate action, and a desire to rebuild local economies.

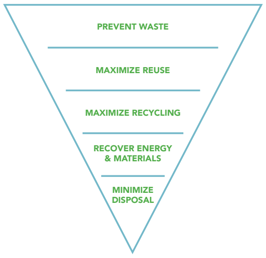
The circular economy is the new standard for sustainable business. In a circular economy, manufacturers deliberately design out waste and pollution at the outset, keeping products and materials in continual cycles of use and reuse, and regenerate

---

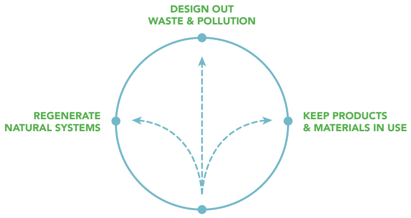
1 US EPA (2011), Materials Management Approaches for State and Local Climate Protection (Background and Motivation Section).

2 State of Oregon Department of Environmental Quality (2020), Materials Management in Oregon: 2020 Framework for Action. Retrieved December 17, 2020 from https://www.oregon.gov/deq/mm/Documents/mmFramework2020.pdf

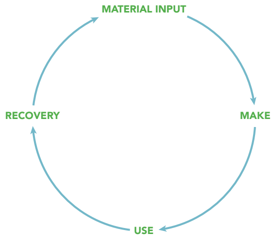
THE CURRENT LINEAR SYSTEM



THE WASTE HIERARCHY



THE 3 PRINCIPLES OF THE CIRCULAR ECONOMY



THE CIRCULAR ECONOMY

natural systems. It offers fresh opportunities for businesses and communities to more effectively compete and function in a resource-constrained and carbon-neutral world.

Waste prevention is the first step to achieving a circular economy. As this strategy is adopted across sectors, there will be less demand for the extraction of virgin resources and businesses can reorganize to use what was once seen as waste as an input.

FINDINGS OF THIS REPORT

While similar work has been developed in other countries, *Waste Prevention:* The Environmental and Economic Benefits for Canada is a first for identifying the economic benefits of focusing on waste prevention interventions in Canada. The report examines the potential economic and environmental benefits of waste prevention interventions in six important Canadian sectors:

- construction
- manufacturing
- healthcare
- agriculture
- plastics
- retail

Each waste prevention intervention is examined for its potential to reduce emissions, create jobs and reduce waste, among other benefits. Interventions examined include utilizing new technology, designing products for resale, reuse and repair, reducing the volume of input materials, capitalizing on goods-as-a-service business models and finding new markets for unused outputs.

It is important to note that the waste prevention interventions examined here are neither exhaustive nor prioritized for action. They are simply examples of waste prevention opportunities that have been identified through our research. Having said that, these case studies identify outstanding financial and economic benefits for businesses and governments who are willing to undertake or legislate waste prevention measures. The authors estimate the impact of the interventions featured in this report are the annual avoidance of 4.9 million tonnes of waste (including 1.1 million tonnes of plastics waste), 5 million tonnes of avoided CO2e emissions and the generation of almost 20,000 jobs and $41 billion in additional revenue.

This research has uncovered significant opportunities for businesses to improve environmental, social and economic outcomes through the implementation of high impact waste prevention however these opportunities are just the tip of the iceberg. We hope this report will trigger creative thinking in businesses committed to using Environmental, Social and Governance (ESG) factors to guide their decision-making as well as governments who can develop policies and invest in projects that address the barriers identified in this report and facilitate changes that will advance waste prevention in Canada.

Contents

Introduction

Canada, like many developed countries, struggles with resource inefficiency and waste generation. According to the World Bank, Canada produces the most waste in the World on a per capita basis. With an annual estimated waste total of over 1.3 billion metric tons, Canadians generate 36.1 metric tons per capita per year[3]. Given our abundant resources and land mass, we have not had the same environmental or spatial constraints as more densely populated countries, such as those in Europe, on our development. In Canada, abundant resources mean virgin raw materials have been relatively cheap and abundant land mass has resulted in low waste disposal cost.

The National Zero Waste Council (NZWC) retained Dillon Consulting and Oakdene Hollins to prepare a research-based value proposition for a waste prevention approach in the Canadian context. Waste prevention is defined here as unused or underutilized materials and products, as well as solid waste, and the embedded material and energy included along the supply chain, primarily as a result of poor or inefficient:

- design decisions;
- procurement and management of feedstock and materials;
- production and distribution processes; and
- end of life or end of use treatment.

Interventions profiled include changes to design and business models, the optimization of business processes, the specification of non-virgin and/or durable materials and products and the recovery and revalorization of end of use/end of life products, among others. One notable exception is the inclusion of minimum recycled content mandates for plastics, which was included, as a result of the current push in Canada to transition towards zero plastic waste.

Given the scope of this project, it is important to note that the metrics calculated for the business cases are high level estimates based on publically available data – extensive modelling was not conducted. Further, the intention of this report is not to suggest that the profiled interventions are the most important or impactful, nor is it meant to be the final word on waste prevention in Canada. This report is meant to be a first step in showcasing the types of intervention that can have a significant impact on waste generation and the circular flow of materials in Canada, estimating the potential benefits of a select group of interventions - much further research in this field is needed to provide a comprehensive approach to tackling waste.

The estimated cumulative impact of these interventions are the annual avoidance of 4.9 million tonnes of waste (including 1.1 million tonnes of plastic waste), 5 million tonnes of avoided CO2e emissions and the generation of almost 20,000 jobs and $41 billion in additional revenue. It should be noted that these values may overestimate the total benefits of undertaking all of these interventions as some interventions have synergies, thereby generating double counting of benefits. In addition, the benefits of some interventions could not be readily quantified due to limited available data. Irrespective of the specific benefits, it is clear that each of the profiled interventions can result in a positive net benefit, with most interventions resulting in positive socio-economic, financial or environmental outcomes.

The concept of a circular economy establishes a vision for what a sustainable economy might look like and how the agenda for waste prevention and resource efficiency can be taken forward. The circular economy sets the ambition for an economy without waste, in which products are designed to be retained in the economy for as long as possible. Practical delivery in this area has real advantages in reducing our dependency on the extraction of virgin raw materials, improving the quality and volumes of secondary materials, bringing with it improvements in resource security, reduced import dependency and possibly cheaper raw materials. Waste prevention is an important but often misunderstood element of the circular economy. This report aims to articulate and present the value of waste prevention as it works into the goal of a circular economy.

---

[3] https://eu.usatoday.com/story/money/2019/07/12/canada-united-states-worlds-biggest-producers-of-waste/39534923/

Methodology

SECTOR CHOICES

In identifying which sectors to study, the team used available waste and economic data to identify subsectors that are large producers of waste in Canada, either as a function of their economic size or the typical methodology of production, and that have well understood opportunities for waste prevention. Sectors that contribute large volumes of waste to the Canadian economy, but whose waste prevention opportunities have been extensively studied elsewhere (for example, food processing and consumer food waste), were not included. From this short list, and in consultation with NZWC, six sectors of interest were chosen. These sectors are as follows:

- Construction
- Manufacturing
- Healthcare
- Agriculture
- Plastics
- Retail

WASTE GENERATION BASELINE

For each sector/sub-sector identified, the predominant sources and types of waste were identified and the financial, social, economic and environmental impacts of this waste were estimated using secondary research, including available case studies; academic literature; industry and government studies; and, Statistics Canada Input-Output multipliers. Where international data was used, these impacts were estimated by scaling the data to the relevant Canadian economic sub-sector, if appropriate.

INTERVENTION MAPPING

For each sector/sub-sector, causes and drivers for waste generation in each sector were explored. A long list of potential interventions was generated, as identified through desk-based research and the team's extensive experience identifying global best practice waste prevention interventions. In determining which interventions to study, the interventions were mapped to their 'owners' in the value chain or economic system and barriers and enablers were considered as a way of determining how realistic the adoption of the proposed intervention would be.

In consultation with the National Zero Waste Council, the following list of interventions were considered for this report:

Sector/Subsector	Intervention	Targeted Waste
Construction	Adaptive Reuse	Construction materials
	Offsite Modular Construction	Construction materials
	Design for Disassembly	Construction materials
Manufacturing	Furniture Remanufacturing	Furniture
	Facilitated Repair	Appliances
Healthcare	Reprocessing of Single Use Devices/Purchasing of Durable and Reusable Devices	Single Use Medical Devices
	Servitization of Equipment	Medical and Other Equipment
Agriculture	Tackling "Left In Field"	Food Crops
	Precision Agriculture Technologies	Food Crop Inputs
	Building Integrated Agriculture	Food Crops
Plastics	Optimizing Packaging Design	Single Use Plastics
	Plastic Packaging Reuse	Single Use Plastics
	Minimum Recycled Content Mandates	Virgin feedstock
Retail	Mass Customization	Consumer Products
	Improved Reverse Logistics	Consumer Products

BUSINESS CASE DEVELOPMENT

Using readily available existing literature, case studies and other publically available secondary data sources, the team qualitatively and/or quantitatively considered the high-level socio-economic and environmental benefits and costs of the waste prevention interventions for each of the sectors, using best practices estimation techniques. The business cases are presented herein as stand-alone chapters for easy reference and use.

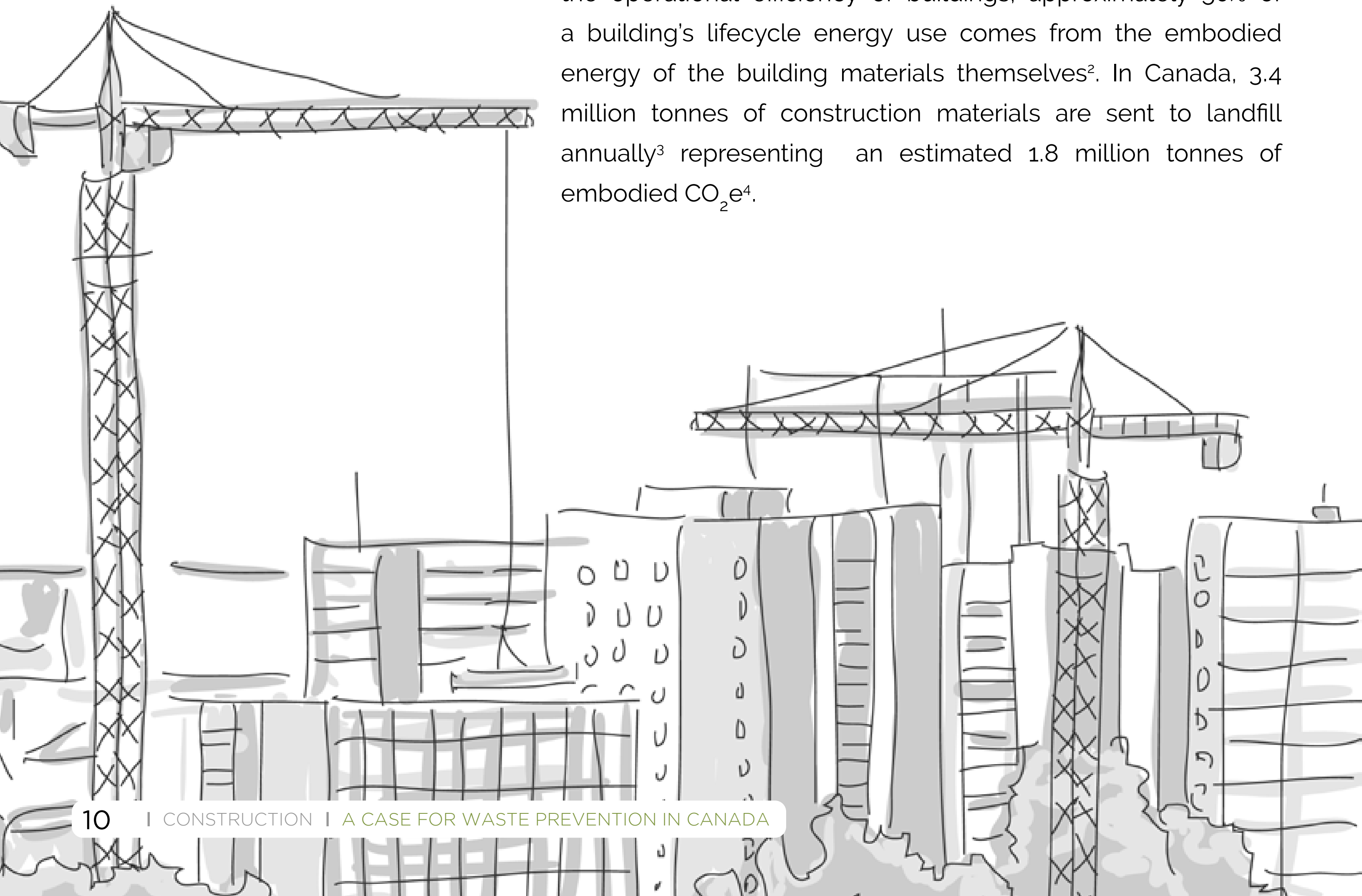
BUSINESS CASES

Construction

SECTOR IN CONTEXT

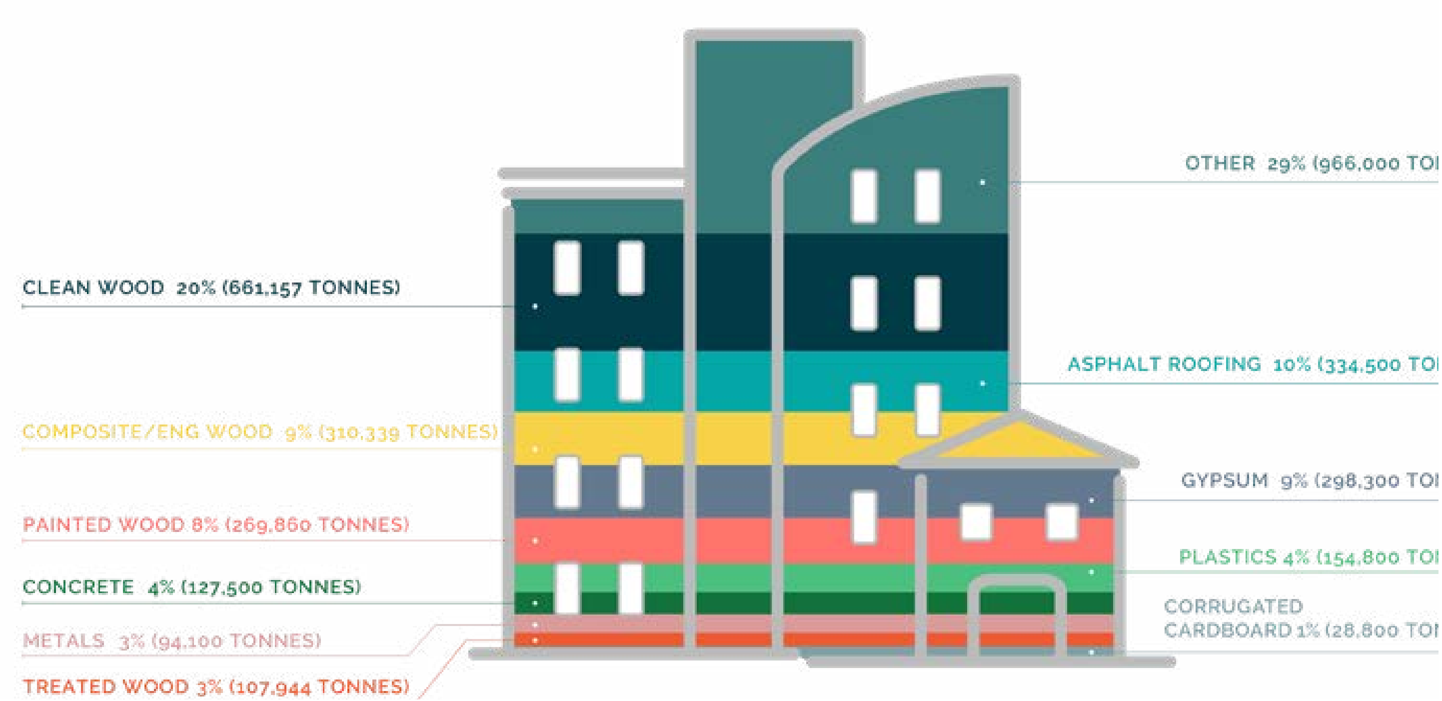
With a sales turnover of $141 billion, the construction sector is the 4th largest in the Canadian economy. It is a big employer in Canada and provides a vital infrastructure role, but has a high waste impact from new build, renovation and demolition activity.

The built environment is one of the largest consumers of raw materials and energy, and is the largest contributor to waste globally[1]. While significant effort has been made to improve the operational efficiency of buildings, approximately 50% of a building's lifecycle energy use comes from the embodied energy of the building materials themselves[2]. In Canada, 3.4 million tonnes of construction materials are sent to landfill annually[3] representing an estimated 1.8 million tonnes of embodied CO_2e[4].



VOLUME OF CONSTRUCTION WASTE SENT TO LANDFILL IN CANADA PER ANNUM (TONNES)[3]

TOTAL: 3.4 MILLION TONNES



SOURCES OF WASTE

The table below highlights the causes and types of waste generated during the various phases of construction. Interventions for three waste generating "hotspots" namely demolition, onsite construction, and "non-standardized" withe material inefficient construction are highlighted.

SOURCES OF WASTE

Some Causes of Construction Waste		
		Causes of Construction Waste
Point Along the Supply Chain Where Waste is Generated	Design & Specification	• Errors in contract documents • Contract document incomplete at commencement of construction • Design changes • Design and construction detail errors • Unclear and unsuitable specification • Poor coordination and communication (late information, last minute client requirements, slow drafting revision and distribution) • Bespoke designs that don't allow for some level of standardization
	Procurement/Material Feedstock	• Ordering errors • Excess material ordering • Supplier errors • Inappropriate site storage/improper storage methods leading to damage or deterioration • Materials stored far away from the point of use • Packaging waste • Damage of materials during transport and unloading • Only using virgin materials
	Production	• Lack of on-site waste management plans • Lack of on-site material control • Lack of supervision • Accidents due to negligence • Unused materials and products • Equipment malfunction • Poor craftsmanship • Use of wrong materials resulting in their disposal • Time pressure
	Distribution and Retail	• Sale of only pre-cut and pre-formed quantities and sizes of materials
	Demand and Use Management	• Buildings not designed to be retrofitted or upgraded
	Recovery & Extension	• Demolition and disposal of materials during renovations • Demolition and disposal of end of use/life buildings

PROFILED INTERVENTIONS

Adaptive Reuse - Rather than demolishing functionally obsolete buildings, adaptive reuse encourages the retention and repurposing of building components -such as the structural elements - for the new structure.

Offsite Modular Construction - Offsite Modular Construction (OMC) is a subset of lean manufacturing that allows both mass customization and process standardization, thus reducing material waste and build time compared to traditional onsite construction techniques.

Design for Disassembly - Designing for disassembly is an eco-design strategy that extends the useful lifecycle of buildings and their components by enabling the building to be more easily upgraded, maintained and modified. End of life disassembly enables the collection and reuse of building materials and components.

Intervention 1: Adaptive re-use

Adaptive reuse is an end-of-life alternative for functionally obsolete buildings that encourages the repurposing of the buildings basic structure and reusing or recycling the building materials removed from site.

WHY ADAPTIVE RE-USE?

Available studies suggest that the adaptive reuse of buildings delivers environmental benefits over demolition and new construction.

The Preservation Green Lab[5] considered the reuse of a range of building types across North America and found that:

- For all building types, except warehouse-to-multi-family conversions, key life-cycle indicators were 5% to 46% lower than demolition and new construction for energy efficient buildings.
- All building conversions showed climate change benefits of between 5% and 25% over a 75 year life-span.

A 2009 study in Canada by the Athena Institute[6] had similar findings: avoided impacts associated with the reuse of four existing buildings ranged from a savings of 185 to 1,562 tonnes of CO2e and between 2.6 million to 43 million MJ of primary energy, each.

The cost and socio-economic benefits of adaptive reuse are less straightforward and is likely highly variable depending on building size, type, age and location.

THE CASE FOR ADAPTIVE REUSE

INTERVENTION 1: ADAPTIVE RE-USE

THE CASE FOR ADAPTIVE REUSE

Reusing existing buildings is important for preserving historical architecture and civic memory and has significant environmental benefits including reducing raw material use, waste volumes and emissions generated. While adaptive reuse generates more direct jobs than demolition and new construction, it generates fewer jobs overall due to job losses in the value chain, including in raw material extraction and manufacturing. The capital cost of adaptive reuse can be lower than demolition and new construction depending on the type of building, condition, age and location.

	Adaptive Reuse	Demolition and New Construction
Capital Cost per sq. m.[7,8]	\$800-\$2565	\$1056 -\$2165
Waste generated per sq. m.	125 kg (assumes 85% material reuse and recycling[10])	Up to 800 kg[9]
CO_2 eq. generated[11] (kg/m^2)	268	415
Jobs generated per 1000 sq. m. (direct, indirect and induced)[8]	8-13	12-14

An estimated 45,000 tonnes* of CO2 avoided[12]

per annum if 20% of the buildings slated for demolition in Canada underwent adaptive reuse instead (assumes 25% material reuse)

4,900 tonnes of plastic waste avoided in construction plastic waste[13]

per annum if 20% of the buildings slated for demolition in Canada underwent adaptive reuse instead (assumes 25%material reuse)

106,000 tonnes of waste avoided[13]

per annum if 20% of the buildings slated for demolition in Canada underwent adaptive reuse instead (assumes 25%material reuse)

**Assumes pro rata savings across the known waste profile*

CHALLENGES AND ENABLERS

INTERVENTION 1: ADAPTIVE RE-USE

CHALLENGES

- Adaptive reuse may not be economical (compared to demolition and new construction) for all building types and locations.
- Limited experience in adaptive reuse compared to demolition and new build can lead to cost and schedule uncertainty.
- Limited market for used construction material in Canada.
- Lack of government support (policies, subsidies, funding, incentives);
- Policy barriers (for example, zoning and parking requirements).
- Significant up-front planning to optimize material recovery and reuse, operational performance upgrades and cost.
- Lack of structural re-certification for salvaged components.
- Lack of a consistent supply of salvaged materials.

ENABLERS

- Increasing landfill tipping fees
- Enacting landfill bans or diversion targets for construction materials that can be reused or recycled
- Requiring eco-design approaches, such as design for disassembly, and the consideration of adaptive reuse as part of the building permit process
- Incentivizing adaptive reuse and building material reuse through public procurement
- Providing tax incentives, subsidies or grants for adaptive reuse projects
- Developing/supporting programs that develop the necessary skills for the building construction and design industry
- Municipal zoning by-law updates to accommodate adaptive reuse
- Development of a market for used building materials and a platform that provides data on available materials
- Improved decision making tools for owners and contractors to determine the economic and technical viability of adaptive reuse for individual projects
- Requiring builders to develop material passports for new buildings to enable pre-demolition material reuse planning

EMERGING SOLUTION

The Danish Gen Byg Data is an online platform that provides data on available materials and enables pre-demolition asset-tracking of a building with the help of a geographic information system developed by Skive Municipality.

Intervention 2: Offsite Modular Construction

Off-site modular construction, a subset of lean manufacturing, involves the construction of building components in a factory setting before assembling them on the building site.

WHY OFFSITE MODULAR CONSTRUCTION?

Construction is a creative process that can offer bespoke solutions to meet client needs. However, this does not mean that there is no place for standardization through harmonized design and construction practices, performance criteria and especially at component and subsystem production levels.

Offsite modular construction (OMC) is in essence a subset of Lean Manufacturing, turning construction from a craft into an end-to-end manufacturing process permitting mass customization. Through the standardization of components and processes, OMC can deliver significant environmental, quality and cost benefits over traditional construction techniques.

A case study of a UK OMC company found that up to 90% of waste could be avoided through stringent offsite construction practices. 50% of the waste was avoided through design optimization and standardization.[14]

The same study also reported that this type of construction process required 67% less energy than traditional construction methods.[14]

THE CASE FOR OFFSITE MODULAR CONSTRUCTION

INTERVENTION 2: OFFSITE MODULAR CONSTRUCTION

THE BOTTOM LINE

In addition to waste avoidance, OMC can increase the speed of construction by as much as 50%[15], reduce costs by 20% [15] and reduce defects by 50%[16].

An estimated 18,400 tonnes of plastic waste

could be avoided per annum if all new construction in Canada was constructed using OMC[13]

Up to 400,000 tonnes of waste avoided

per annum assuming all new construction in Canada was constructed using OMC[13]

An estimated 173,000 tonnes* of embodied CO2e

could be avoided per annum if all new construction in Canada was constructed using OMC[12]

**Assumes pro rata savings across the known waste profile*

THE CASE FOR OFFSITE MODULAR CONSTRUCTION

INTERVENTION 2: OFFSITE MODULAR CONSTRUCTION

Projections suggest that there is a large market opportunity for offsite modular construction in Canada. With a potential annual savings of $3.3 billion in construction costs (see chart below), 85% to 90% of labour is expected to be converted to the manufacturing process, where it is more productive than traditional construction. While this suggests net job losses of 25%, this may ease some of the market shortages for-high skilled labour in this industry.

ESTIMATE OF MARKET POTENTIAL AND POTENTIAL SAVINGS FROM MODULAR CONSTRUCTION IN CANADA (ADAPTED FROM 16).

🟩 *Low* ▨ *Medium* ■ *High*

						Rationale		
			Construction Expenditure **$bn**	Market Potential $bn	Savings ($) $bn	Repeatability	Unit Size	Value density
Building type	**Residential**	**Single family**	61	4	0.7	🟩	▨	▨
		Multi-family	62	9	1.4	▨	■	▨
	Commercial	**Office buildings**	11	1	0.3	■	▨	▨
		Hotels and Restaurants	3	0.8	0.1	■	■	■
		Retail	7	1	0.1	▨	🟩	▨
		Warehousing	4	1	0.1	■	▨	▨
	Public	**Schools**	6	1	0.2	■	■	▨
		Hospitals	3	0.4	0.09	▨	■	■
	Other		21	1	0.2	▨	🟩	▨
Building total			182	22	3.3			

Note:

-Repeatability assumes no unique layout requirements from regulation or design requirements

-Unit size is important as a smaller unit size is easier to transport

-Value density assumes high complexity of units

CHALLENGES AND ENABLERS

INTERVENTION 2: OFFSITE MODULAR CONSTRUCTION

CHALLENGES

Barriers to Offsite Modular Construction include:

- The development of offsite construction facilities requires capital investment and is a significant departure from the traditional way of doing things.
- Architects and designers believe that standardization leads to ‘boring’ design and cramps creativity[17].
- Clients equate offsite modular construction with cheap, low quality modular and mobile homes[15].
- Builders and contractors not adopting a Lean Manufacturing mindset, in particular, to treat platform design and off-site manufacturing as core critical competencies[17].
- Local building and construction codes may inadvertently hamper offsite construction[15].

ENABLERS

Possible enablers include:

- Educating clients (including developers, home owners, building owners) about the cost, schedule and quality benefits of offsite modular construction.
- Updating building and construction codes to enable offsite construction.
- Using public procurement to motivate industry change.
- As in many sectors, exploiting new ICT and database possibilities such as BIM to ease and reduce errors in information transfer through build life.

Intervention 3: Design for disassembly (DfD)

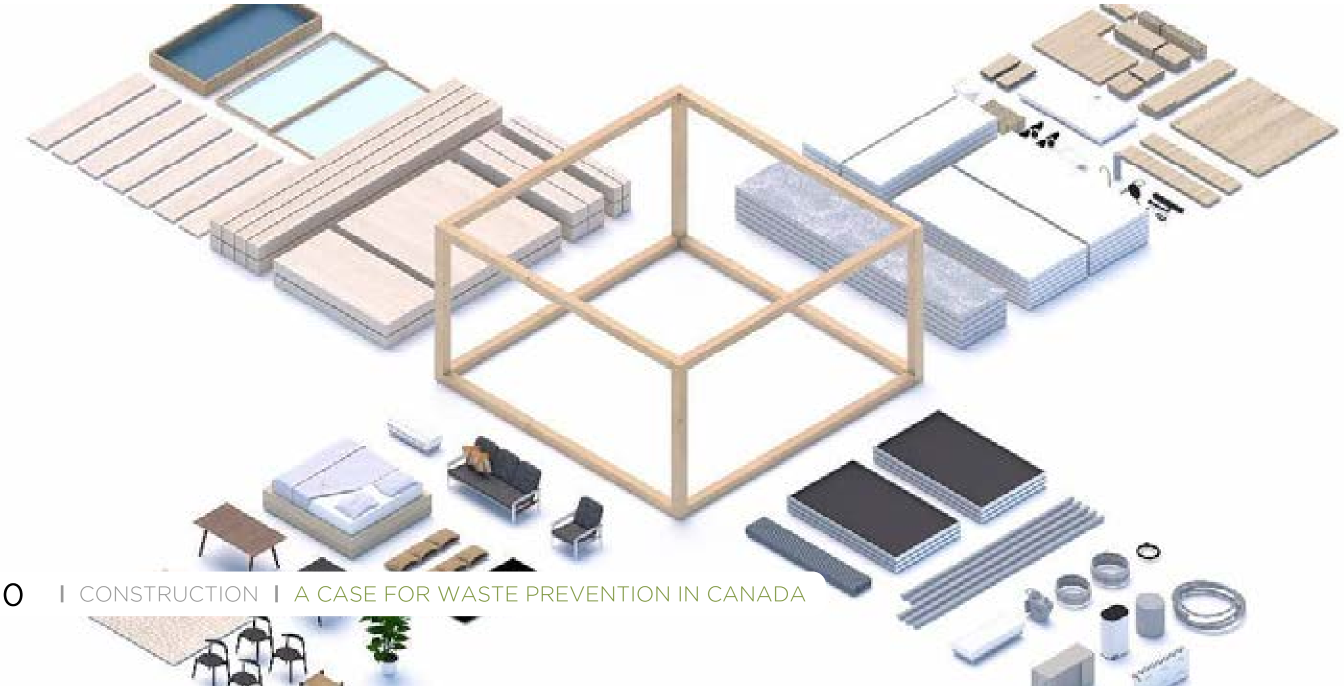
Designing for disassembly is an eco-design strategy that enables the disassembly and reconstruction of buildings or the reuse of its components and materials.

WHY DFD ?

All infrastructure must eventually be decommissioned. Designing and constructing a building for disassembly can enable its deconstruction, for the recovery and reuse of its materials and components, at the end of life. DfD can also extend the useful life of infrastructure and improve its ability to be upgraded, adapted and repaired.

To fully realize opportunities for circular or closed loop buildings, engineers, architects and contractors will need to design infrastructure in a way that allows all materials and components to be easily accessed, maintained, replaced and upgraded without damaging or destroying other components.

Designing for disassembly is an enabling intervention for the other interventions profiled in this series. For example, the adaptive reuse of infrastructure can be significantly enabled by techniques such as design for disassembly which minimize collateral damage during retrofitting, repair or relocation. Further, standardized, off-site-manufacturing requires that components and systems be capable of assembly, so it is no great leap to make them capable of disassembly.



THE CASE FOR DFD

INTERVENTION 3: DESIGN FOR DISASSEMBLY (DFD)

THE BOTTOM LINE

Designing and constructing buildings for disassembly is not standard practice, therefore additional labour costs are anticipated until skills and methods can become standardized across the supply chain. Further, the environmental and financial benefits of DfD may not be evident during the design and construction phase. For example, a case study of the design and construction for disassembly of a 14 story precast concrete apartment building increased the initial cost (43%), energy use (23%) and carbon emissions (16%) compared to traditional construction, however the disassembly and reuse of the structural elements for a second life cycle decreased the overall (first + second life) costs, energy use and CO2e emissions by 11%, 35% and 38%, respectively[18]. A University of Florida assessment[17] of dedicated DfD projects found recovery and reuse rates ranged from 50% to 90% but was typically around 85% for non-residential types.

An estimated

1.3 million tonnes* of embodied CO2e could be avoided[12]

per annum if all buildings renovated or demolished in Canada were disassembled and reused (assumes 85%[19] material reuse)

An estimated

116,000 tonnes of plastic waste[13] could be avoided per annum

per annum if all buildings demolished or renovated in Canada were disassembled and reused (assumes 85%[19] reuse)

An estimated

2.5 million tonnes of waste[13] could be avoided per annum

per annum if all buildings demolished or renovated in Canada were disassembled and reused (assumes 85%[19] reuse)

Assumes pro rata savings across the known waste profile

CHALLENGES AND ENABLERS

INTERVENTION 3: DESIGN FOR DISASSEMBLY (DFD)

CHALLENGES

- Cost to design and construct for disassembly is typically more expensive than traditional construction due to lack of experience in, and the structure of, the supply chain
- Lack of experience with DfD in the supply chain may lead to cost and schedule risk
- Clients may think that the potential benefit of DfD is too far in the future and ownership of the building may change before end of life
- Lack of recertification process for used materials/components
- Lack of demand for used building materials/ components
- No building codes or regulations requiring consideration of the end of life value retention of a building
- The common use of adhesives and sealants for the purpose of achieving building envelope air-tightness.

ENABLERS

- Standardizing design, materials and components can reduce the cost of designing and constructing for disassembly
- Investment in the development of DfD skills for engineers and contractors
- Changes to design codes or building bylaws to consider end of life material management
- Developing recertification standards for used building materials, especially structural components
- Developing material market places for used building materials
- Approving fittings, fasteners, adhesives, sealants etc that allow for disassembly.
- Educating building owners, government and the supply chain on the benefits of DfD

OTHER OPPORTUNITIES FOR WASTE PREVENTION IN CONSTRUCTION

- Reduce over ordering of construction materials
- Ensure appropriate storage and handling of construction materials on site and in transit
- Minimize rework due to errors, poor workmanship or incomplete/erroneous designs
- Develop and implement on-site waste management and mitigation plans
- Hire a site material and waste manager
- Develop and implement deconstruction (not demolition) plans
- Implement 3-D printing of components rather than relying on standard material and component shapes sizes
- Reuse surplus and salvaged materials

REFERENCES

1. *ARUP. 2016. The Circular Economy in The Built Environment.*
2. *Crowther, P. (2015) Re-evaluating construction materials and components through design for disassembly.*
3. *VanderPol, P. and Perry, G. (2014). Characterization and Management of Construction, Renovation and Demolition Waste in Canada*
4. *VTT Carbon impacts for construction products, ISBN 978-951-38-8042-2"*
5. *Preservation Green Lab (2011) The Greenest Building: Quantifying the Environmental Value of Building Reuse*
6. *Athena Sustainable Materials Institute (2009) A Life Cycle Assessment Study of Embodied Effects for Existing Historic Buildings*
7. *Shipley, R. (2006). Does Adaptive Reuse Pay? A study of the Business of Building renovation in Ontario, Canada.*
8. *Stas, N. (2007). The Economics of Adaptive Reuse of Old Buildings A Financial Feasibility Study & Analysis.*
9. *USEPA. (Nd). Estimating 2003 Building -Related Construction and Demolition Materials Amounts.*
10. *Delta Institute. (2015). Extracting Value through Deconstruction.*
11. *Based on reuse assumptions outlined in Napier, T., Cochran, K., He, H. (nd). A Life-Cycle Approach to Reducing Residential Construction and Demolition Waste.*
12. *Calculation based on data from (3) and (4)*
13. *Calculation based on data from (3)*
14. *WRAP. ND. Waste Reduction Potential of Offsite Volumetric Construction. WAS003-003: Offsite Construction Case Study*
15. *Romain de Laubier , Arne Burfeind , Sebastien Arnold , Sven Witthöft , and Marius Wunder. (2019). The Offsite Revolution in Construction*
16. *McKinsey and Co. (2019). Modular Construction: From Projects to Products.*
17. *Gibb, A.F.G. (2001) Standardisation in construction, CRISP*
18. *Akbarnezhad, A., Ong., K.C.G., and Chandra, L.R. (2014). Economic and environmental assessment of deconstruction strategies using building information modelling. Automation in Construction, 37: pp 131-144*
19. *A.R. Chini (2005) Deconstruction and Materials Reuse – an International Overview, University of Florida*

Manufacturing

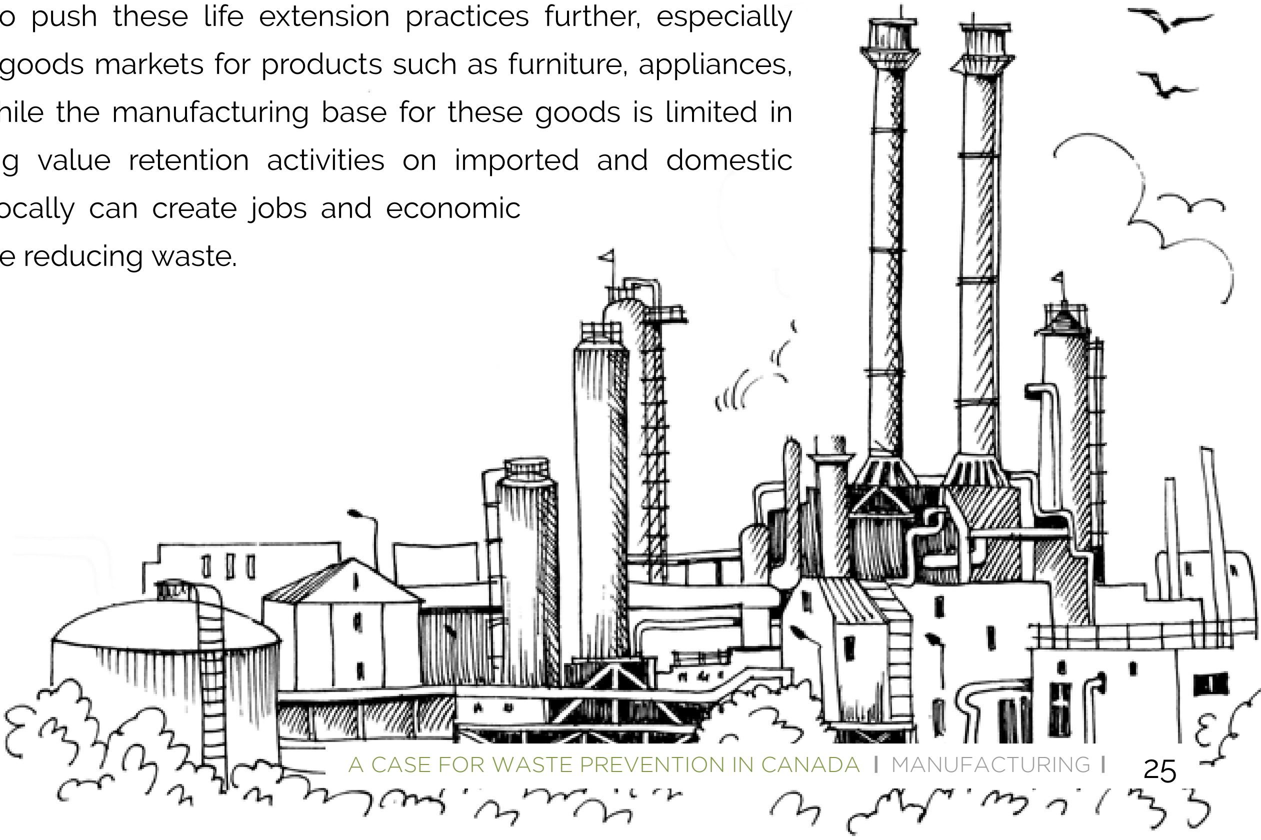
SECTOR IN CONTEXT

Canadian Government statistics show that the manufacturing sector generated sales income of nearly $688 billion in 2019[1]. A majority of this activity deals in the processing of food and natural resources such as seafood, wood, oil and gas, with clusters of engineering in aerospace, automotive and heavy-duty vehicles. Waste prevention in these sectors is ongoing, tackling obvious and diverse on-site primary production issues using at-hand techniques such as Lean Manufacturing.

With a rise in Extended Producer Responsibility – the concept of brand owners and manufacturers taking environmental responsibility for their products and the associated packaging throughout their lifecycles – attention is moving to how products can be serviced in the latter phases of their life for both economic and environmental gain.

This is already happening within sectors such as aerospace and automotive where parts and components routinely undergo recovery and remanufacturing for multiple lives.

The challenge is to push these life extension practices further, especially into the consumer goods markets for products such as furniture, appliances, electronics, etc. While the manufacturing base for these goods is limited in Canada, completing value retention activities on imported and domestic consumer goods locally can create jobs and economic value at home, while reducing waste.



CAUSES OF MANUFACTURING WASTE

Some Causes of Manufacturing Waste		
Point Along the Supply Chain Where Waste is Generated	**Design & Specification**	• Not understanding customers' needs • Customer needs are not clear • Designing products that cannot be repaired, upgraded or remanufactured/refurbished
	Procurement/ Feedstock Management	• Inaccurate forecast and demand information • Inaccurate inventory levels

	Production	• Poor quality control at the production level
		• Poor machine repair
		• Lack of proper documentation
		• Lack of process standards
		• Excessive processing due to:
		  • Poor communication
		  • Human error
		  • Slow approval process or excessive reporting
		• Unreliable processes
		• Unstable production schedules
		• Poor automation
		• Long or delayed set-up times
		• Overproduction of goods

	Distribution & Retail	• Inventory defects • Excessive transportation
	Demand & Use Management	• High consumer turnover of inexpensive and cheaply made furniture • Discarding repairable products
	Recovery & Extension	• No end of life/end of use value recovery

PROFILED INTERVENTIONS

Furniture Remanufacturing – Furniture remanufacturing is a sub-sector largely apparent in the commercial, industrial and institutional markets, harnessing the inherent durability of chairs, desks, cabinets and bedframes. However, there is an emergent market in more high-value home furnishing, often targeting the short-term rental market. Thus these extended life models are employing novel models for service and value delivery.

Facilitated Repair– Extending the life of goods, such as home appliances, can be problematic when the cost of labour for even a relatively simple repair presents a strong disincentive to the consumer. Facilitated home repair can allow manufacturers to meet their EPR obligations, service customer needs while obtaining income from spares and boost chances of repeat customers through customer satisfaction.

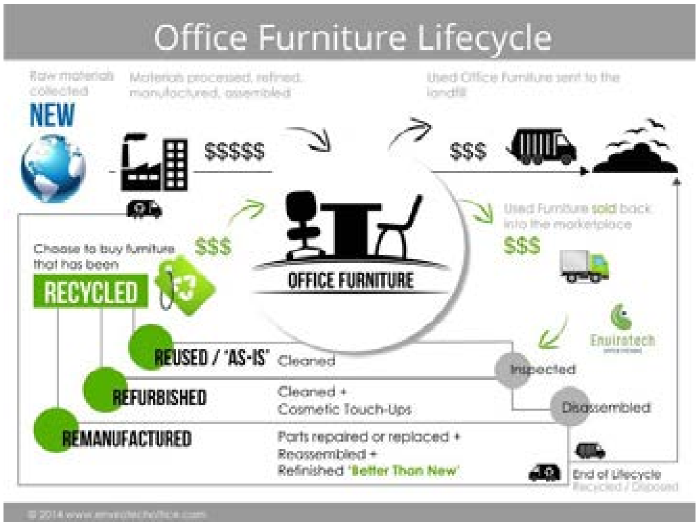
Intervention 1: Furniture remanufacturing

WHY REMANUFACTURING?

In Canada, it is estimated that 672,000 tonnes of furniture are thrown away each year[2]. Some of that furniture is recycled, but this waste of resources could be significantly reduced through remanufacturing and re-use. Environmental benefits go beyond a reduction in waste to landfill – taking figures from a number of studies including Dietz[3], CO2e savings through remanufacture are around 3.2 kg per kg of furniture for office products (on average). Plastics savings amount to around 0.1 kg/kg.

Of course, the informal re-use of furniture, via charities or through online platforms such as Kijiji, is common in Canada, however 'industrialized' remanufacturing and re-use has, until now, been on the decline in most developed countries. What has changed is the rise in environmental concerns related to the linear structure of these supply chains and the rise in waste related to fast furniture – cheap furniture that is not built to last.

Recently, global giant IKEA entered into a strategic partnership with the Ellen MacArthur Foundation to become a leader in the shift towards a circular business model for home furnishings. The initiative will include advocating for circular design – a cornerstone for enabling remanufacturing – as well as encouraging customers to care for, repair and pass on products in circular ways[4].



THE CASE FOR FURNITURE REMANUFACTURING

THE BOTTOM LINE

Several companies in Canada currently include reverse logistics, remanufacturing and resale of, primarily, office furniture as part of their business model. Davies Office, which operates in Canada and the USA, remanufactures office furniture to customer specifications. According to research conducted by the National Centre for Remanufacturing and Resource Recovery at the Rochester Institute of Technology[5], Davies remanufacturing process provides a variety of environmental benefits: Energy savings from the remanufacture of one office workstation uses 82% less energy than traditional manufacturing. Annually, their energy savings could power 342 typical households. Material savings in this sector primarily consists of wood, metals (steel and non-ferrous) and plastics.

IMPACT IN CANADA

It is estimated that around 10% of furniture in Canada is being remanufactured or refurbished[6]. Other countries, such as the UK show higher rates, particularly in the office furniture sector, at around 30%. This illustrates a clear potential for future growth. Future growth of 20% would enable:

- Firm revenues of up to $770 million[7];
- A GDP contribution of between $258 million and $$322 million[7,8]; and
- The creation of between 2,760 and 7,464 direct jobs[7,8].

Rype Office, a UK office furniture retailer, includes remanufacturing and creating furniture from waste in its business model. It's estimated that they saved their clients more than £1 million across 160 projects and reduced CO2e emissions by 1,036 tonnes of CO2e by remanufacturing 317 tonnes of furniture[10]. The firm also claims social benefits for their workforce but it is uncertain if these relate to operation policies around work and hiring or the remanufacturing itself.

An estimated **135,000**[9] **tonnes of waste** could be avoided if furniture remanufacturing grew by 20% in Canada

An estimated **13,500**[9] **tonnes of plastic waste** could be avoided if furniture remanufacturing grew by 20% in Canada

Up to **440,000**[9] **tonnes of CO2e** emissions could be avoided if furniture remanufacturing grew by 20% in Canada

CHALLENGES AND ENABLERS

CHALLENGES

- Increased accessibility of low-cost furniture is decreasing demand for value retention activities for both office and home furnishings[11].
- The price differential between new and second-life furniture may not be significant enough to drive more sustainable purchasing behaviour.
- Servitizing furniture may encourage rapid turnover - like clothes and cell phones, which have been criticized for their resource wastefulness – unless the manufacturer makes a genuine commitment to place furniture back into re-use.
- Well known consumer barriers to purchasing second-life consumer goods includes a perception that remanufactured products are of lower quality and consumer 'disgust' to purchasing a 'used' good[12]
- Furniture may not be designed for remanufacturing

ENABLERS

- Introducing EPR legislation for furniture that includes requirements for reuse, remanufacture and refurbishment
- Landfill bans
- Incentivizing remanufacture and reuse of furniture through preferential procurement policies by government and industry
- Removing taxes from remanufactured goods and services
- Designing and manufacturing durable furniture that can easily undergo multiple rounds of remanufacture and that can be upgraded to account for changing tastes

Intervention 2: Facilitated Repair

WHY REPAIR?

It's widely recognized that many otherwise valuable goods are disposed before end of life because they fail and repair seems like too costly an option. This is particularly a feature of goods well into their expected lifecycle where the user's perception is that buying a new item is more cost-effective.

Environmentally, though, this is a huge lost opportunity: A United Nations International Resource panel report of 2018[13] quantified the CO2e and material impacts of repair, showing them to be just a small fraction compared to new manufacture. Based on this, choosing repair over purchasing new would be the most environmentally beneficial option until very late in a product's life.

How can such value be liberated in a cost-effective manner? In short, assisting consumers to repair their own goods can eliminate the labour costs of repairs through standard channels. With appropriate support and using the advancement of internet resources, this is now possible.

Three components play a role: access to spare parts; access to repair guides; and community repair hubs.

Repair hubs are an increasingly common feature in other countries and there is precedent in Canada. Repair Café started in 2013 in Canada with one chapter in Calgary. Now there are 47 similar Café organizations in cities across the country.[14] These hubs provide a community of experience to be shared with the less confident home repairer, avoiding pitfalls and potential safety concerns. A survey of 317 repair cafes across 10 countries found kitchen and household appliances were the items most frequently brought to these hubs for repair.[15]

For-profit companies are also getting on board: Mobile Klinik, a chain of 80 stores that repair mobile devices in malls and Walmart locations across the country, was recently ranked as the 12th fastest growing company in Canada, with plans to have 200 more stores open by 2023.[16]

These initiatives can augment the increasing amount of repair instruction being put on-line to assist users, such as on iFixit, as well as repair tool kits and simple parts available for online purchase. Similarly, product-share libraries allow for the sharing of (especially) tools which would otherwise be unproductive for much of their lives. Such ventures have an added benefit of increasing community cohesion.

THE CASE FOR FACILITATED REPAIR

THE BOTTOM LINE

Reliable data on the amount of disposed goods which might actually be repaired for a full life is scarce. However, a major study of UK household attitudes to product life (E-SCOP, later re-analyzed by Cooper[17]) found that one-third of discarded appliances were still functional and of those that were broken, a third were classified as "in need of repair" as distinct from "broken beyond repair." Scaling to Canada, that is an estimated 430,000[18] appliances per year that could have been repaired rather than discarded.

Another UK study[19] assessed the condition of bulky items discarded at local authority waste facilities and concluded that 77% of upholstered furniture and 60% of domestic appliances could theoretically be refurbished and reused. This indicates a potential between 10 and 60% of discarded goods amenable to repair.

Within Canada, appliance repair currently contributes $922 million of output to the economy annually[7]. The current economic impact of appliance repair includes 3,330 direct jobs with a direct labour income of approximately $192 million[8]. Economic impacts of expanding repair are uncertain due to the multitude of business models for facilitating repair (such as third-party repair, tool café, OEM repair, repair knowledge providers or individual repair) and how the prevalence of these activities may cannibalize new product sales. However, lost revenue from new appliance sales may be substituted through parts sales to consumers and third-parties.

The case for facilitating the repair of appliances is strongest when considering social and environmental benefits. These benefits include:

- Likely higher employment per dollar spent in higher-skilled jobs, which is typical for value retention processes;[20] and
- Producing cultural capital including community cohesion through "informal exchanges of knowledge, skills, materials, goodwill and values.[20]

An estimated **10,000 tonnes*[18] of total material waste** could be avoided if repairable appliances in Canada were not discarded

[*] Assumes all appliances are recycled.

An estimated **7,200 tonnes[18] of plastic waste** could be avoided if repairable appliances in Canada were not discarded

CHALLENGES AND ENABLERS

CHALLENGES

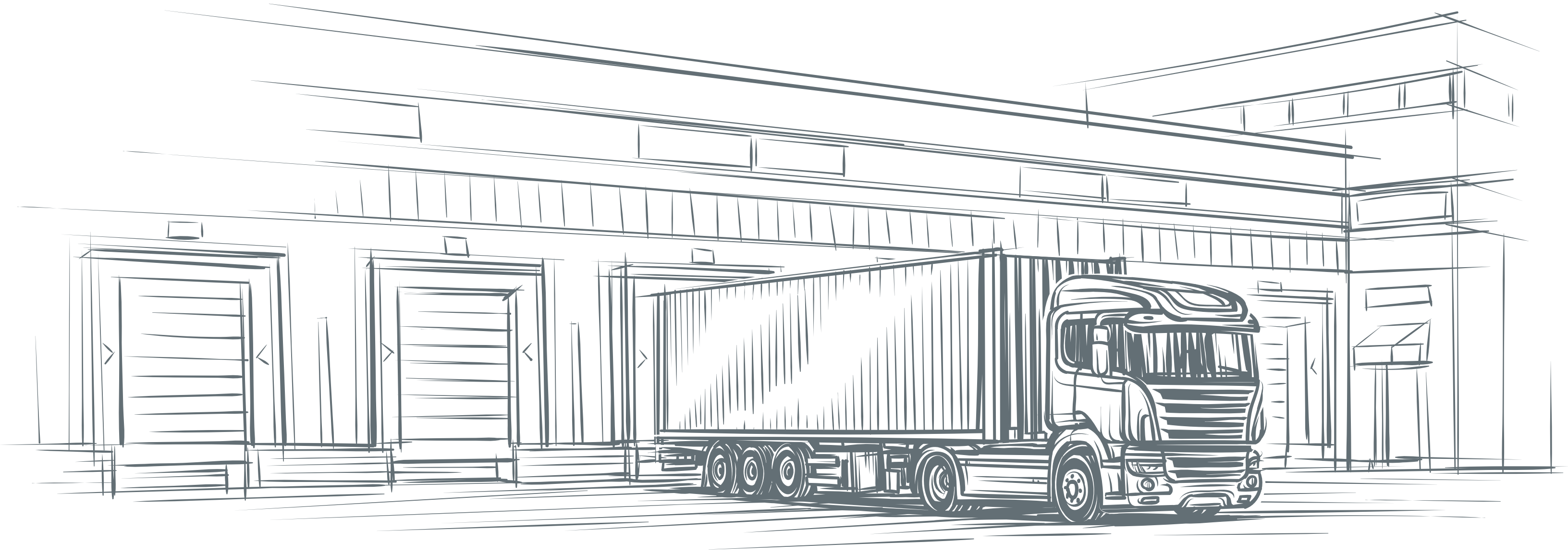
- Rightly there are concerns over the legal liabilities when consumers undertake own repair, particularly where there is a potential hazard to health. Action to clarify this was a key recommendation of the Montreal G7 Value Retention Workshop hosted by Canada in 2018.
- Manufacturers often use construction techniques which do not permit disassembly for repair without destroying (typically) the casing.
- Information necessary to make repairs is not readily available
- Parts necessary for repair are often unaffordable relative to the price of a new replacement
- Perceived intellectual property and security risks for firms

ENABLERS

- Online access to repair information and spare parts is core to the enabling of home repair. The internet has enabled a community of self-help and how-to information to be universally accessible.
- In other countries, there have been moves to embed the right to repair and the right of access to repair information and parts for a minimum guaranteed period.
- There is an emergent industry based on 3D printing using increasingly affordable print stations which can make to order one-off items for no-longer-made parts. This is particularly effective for plastic parts such as cogs, wheels, brackets and casings which – though small – can render devices defunct if broken.

OTHER OPPORTUNITIES FOR WASTE PREVENTION IN MANUFACTURING

- Implementing Lean Manufacturing Practices
- Implementing Designing for the Environment standards including Designing for Disassembly and Upgradability
- Improved demand forecasting
- Improved quality control at the production level
- Using standardized designs and components
- Ensuring appropriate storage and handling of production materials
- Develop and implement production waste management and prevention plans
- Reuse of surplus and salvaged materials
- Consumer education and awareness programs to help households identify and purchase products that can be remanufactured or repaired
- Establishment of harmonized Circular Economy legislation that includes national performance requirements and outlines minimum levels of reuse, remanufacture, refurbishment and repair for products



REFERENCES

1. *Statistics Canada. (2020). Table 16-10-0047-01: Manufacturers sales, inventories, orders and inventory to sales ratios, by industry.*

   https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=1610004701
2. *Extrapolated from data obtained from Morrisson Hershfield (2017) Assessment of Economic and Environmental Impacts of Mattress recycling in BC.*
3. *Dietz, A. (2005) Lifecycle Assessment of Office Furniture Products. Centre for Sustainable Systems University of Michigan*
4. *Ellen MacArthur Foundation (2020). Foundation Welcomes Ikea as Strategic Partner.*

   https://www.ellenmacarthurfoundation.org/news/foundation-welcomes-ikea-as-strategic-partner
5. *Rochester Institute of Technology. (nd). Davies Office Furniture Life Cycle Assessment.*

   https://www.daviesoffice.com/sustainability/benefits-of-office-furniture-remanufacturing
6. *Based on market size and end-of-life furniture flows in Bojczuk, K. et al. (2013) Furniture mass and product flow data to inform re-use market development in the UK, prorated to Canada.*
7. *Statistics Canada. (2018). Canadian Industry Statistics. Retrieved February 7, 2020, from Statistics Canada:*

   https://www.ic.gc.ca/app/scr/app/cis/search-recherche.
8. *Statistics Canada. (2020). Table 36-10-0594-01 Input-output multipliers, detail level. Retrieved February 8, 2020, from Statistics Canada: https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3610059401*
9. *Calculated based on data from (2) and (3).*
10. *European Circular Economy Stakeholder Platform. 2020. Rype Office applies the principles of circular economy and sustainability to office furniture. https://circulareconomy.europa.eu/platform/en/good-practices/rype-office-applies-principles-circular-economy-and-sustainability-office-furniture.*
11. *IBIS World. (Aug 2015) . Furniture Repair &; Reupholstery Market Research Report - NAICS 81142. http://www.ibisworld.com/*
12. *The Recycler. (2014). Study finds consumers perceive remanufactured goods as 'dirty'.*

    https://www.therecycler.com/posts/study-finds-consumers-perceive-remanufactured-products-as-dirty/
13. *Nasr et al. (2018) Redefining Value – The Manufacturing Revolution. Remanufacturing, Refurbishment, Repair and Direct Reuse in the Circular Economy*
14. *CBC News. (2020). Don't buy new, fix the old: The repair business is booming.*

    https://www.cbc.ca/news/business/climate-concerns-boost-interest-in-repairs-1.5482563
15. *Ellen Macarthur Foundation. 2016. Empowering Repair. Available at*

    https://www.ellenmacarthurfoundation.org/assets/downloads/ce100/Empowering-Repair-Final-Public1.pdf.
16. *The Globe and Mail. (2019) Report on Business: Canada's Top Growing Companies.*

    https://www.theglobeandmail.com/business/rob-magazine/article-canadas-top-growing-companies/
17. *Cooper, T. (2004) Inadequate life? Evidence of consumer attitudes to product obsolescence. Journal of Consumer Policy 27: 421–449.*
18. *Based on data scaled from Major Appliance Recycling Roundtable. (2019). 2018 Annual Report to the Director. https://www.marrbc.ca/documents/2018_MARR_Annual_Report.pdf*
19. *Anderson, C. (1999) Recycle, reuse, bury or burn? Bristol: The SOFA Project.*
20. *Wilson, Katherine. 2019. A 'repair economy' might fix more than just stuff. It could fix us as well. Available at*

    https://www.weforum.org/agenda/2019/06/mending-hearts-how-a-repair-economy-creates-a-kinder-more-caring-community

Healthcare

SECTOR IN CONTEXT

The healthcare sector is an essential service provider and a significant contributor to the Canadian economy. In 2016, this sector spent $264 billion dollars, or 11.6% of GDP[1], providing a variety of healthcare services primarily in institutional settings such as hospitals, long term care and rehabilitation facilities. The focus of the healthcare sector is the safe delivery of patient care. As such, waste can be a secondary concern, yet it has a large impact. Using an average waste intensity of 3.317 tonnes of waste generated per bed[2], Canada's 628 hospitals which have around 91,375 hospital beds[1], are expected to generate 303,000 tonnes of waste.

Healthcare operations not only present waste challenges; they have a high carbon impact too. It is estimated that the activities of Canada's healthcare sector contribute 33 million tonnes of CO2e emissions per year, making it among the top healthcare emitters globally per capita along with the US, Australia and Switzerland, as well as over 200,000 tonnes of other pollutants[4]. Approximately 71% of those emissions are embedded in the production, transport, use, and disposal of goods that the sector consumes[3].

Understanding that any waste prevention initiative undertaken within the healthcare sector must not come at the expense of the safe delivery of care, the suggested interventions in this chapter may require further research. There are a number of organizations currently working on waste prevention in healthcare including the Canadian Coalition for Green Health Care and the Canadian Association of Physicians for the Environment. Engagement with these organizations, and the healthcare sector in general, to identify a safe and practical approach to waste prevention in this sector is recommended.

SOURCES OF WASTE

The healthcare waste stream is diverse, including highly hazardous biomaterials, contaminated clothing and equipment, food waste, expired medication, office waste, electronics and construction debris (see Fraser Health waste composition as an example). Careful triage and consideration of alternative disposal routes have a role to play in minimizing waste and increasing value recovery, but there are also opportunities to reduce waste generation at its source.

A significant source of waste is the increased use and disposal of single-use medical devices as a result of concerns about the spread of blood-borne diseases, specifically HIV/AIDs in the 1980's[6]. For example, in North America, it's estimated that operating rooms alone are responsible for 20%- 33% of total hospital waste and estimates suggest that 47%–56% of operating room budgets are dedicated to supplies and materials[7].

Another source of waste includes underutilized and end of life or end of use medical equipment.

Average Annual Hospital Waste Profile in Canada

Waste Type	Total waste/material generated (tonnes)
General non-hazardous	44,425
Biomedical Waste	9228
Recyclable materials or other non-disposable wastes	
Cardboard and Paper	12,850
Batteries, E-Waste & Lights	610
Scrap metal	520
Scrap Wood & Pallets	960
Sharps	760
Organics	3,330
Blue Bin (plastic bottles, cans, etc)	6,100
Total waste/materials	**78,785**

Source: Canadian Coalition for Green Health Care, 2020

SOME CAUSES OF HEALTHCARE WASTE

		Causes of Healthcare Waste
Point Along the Supply Chain Where Waste is Generated	**Design & Specification**	• Designing equipment and devices for single use
	Procurement/Feedstock Management	• Poor demand forecasting (Expired Food and Medication) • Opened but unused single use medical devices
	Production	• Maintaining Paper records
	Demand & Use Management	• Food waste • Over prescribed medications • Underutilized assets
	Recovery and Extension	• Single Use Devices • End of Life Equipment

PROFILED INTERVENTIONS

Device Reprocessing - re-use is the single most effective tactic for reducing manufacturing waste simply through elimination of the need for new manufacturing. Reprocessing single use devices and/or purchasing reuseable items for reprocessing can significantly reduce material waste.

Equipment Servitization - Servitized contracts for equipment and infrastructure e.g. lighting. Improved outcomes and expenses can be achieved by servitizing at least components of building operation or equipment. Asset longevity and upgrading are often delivered via servitized systems, especially for complex equipment.

For infrastructure, lighting companies can supply and maintain lighting systems for a price per use, including energy and material costs, which incentivizes these companies to use long lived assets with high energy efficiency. 20% operational efficiency improvements (on top of any new technology benefits) are not uncommon.

Intervention 1: Single-Use Device (SUD) Reprocessing

Reprocessing a single use medical device encompasses cleaning, reconditioning, function testing, and disinfection or sterilization to ensure that a medical device can safely be reused[8].

WHY SUD REPROCESSING?

Reuse is the most basic tactic for avoiding waste and unnecessary recycling and the associated extraction of virgin materials to make new products. There are many medical products and equipment that are currently discarded after a single use that could potentially be safely cleaned and reused, however this case focuses on single use medical devices. While reuse is familiar in a home-use context, the reuse of healthcare equipment necessitates the careful selection of which devices to reuse and strict cleaning protocols to minimize the risk of spreading infection or disease.

Reprocessing SUDs substantially reduces waste production and disposal costs, and allows hospitals to "buy back" reprocessed medical devices for up to 50% less than new[7]. A lifecycle assessment comparing the environmental impacts of a single use medical device disposed after a single use versus one that was reprocessed found that, if reprocessing inputs are optimized, reprocessing offers global warming, human health and economic benefits over disposal after a single use[9].

A 2015 survey indicated that healthcare authorities in at least 5 provinces and territories in Canada did not reprocess any single use medical devices, and of those that did, the types of devices being reprocessed were limited[8]. Therefore, there is a significant opportunity to improve environmental and economic outcomes through single-use medical device reprocessing. While historically, some reprocessing of equipment was done in-house in Canadian hospitals, currently in Canada reprocessing can only be completed by an approved third party processor.

THE CASE FOR SUD REPROCESSING

Economic analysis for SUD reprocessing can be expected to vary by device as factors such as device cost, use frequency, reprocessing cost and risk influence feasibility. In a Montreal hospital, cost savings attributed to third-party reprocessing of a select list of SUDs ranged from $88,000 to $122,000 annually however, this estimate of cost savings did not consider the salary cost of a program manager. Therefore, the actual cost savings of such a program will be dependent on that cost[10]. A study conducted by the Canadian Agency for Drugs and Technology in Health[11] found that the cost of reprocessing equipment was 20%-30% of the cost of purchasing and using new single use devices. However, when the cost associated with the risk of an adverse event from reuse is considered, the cost benefit of reprocessing is less clear. This suggests that minimizing the risk of an adverse event from using a reprocessed device is key to determining its cost competitiveness.

A 2011 case study in the US found that the annual waste savings for 7 commonly reprocessed SUDs in a 500 bed acute care hospital was 11.36 tonnes[12]. Scaled to the Canadian context, with roughly 79,500 acute care beds[1], this roughly translates to waste reduction of over 1,800 tonnes of waste annually. Another study found that 512 kg of CO2e could be avoided by reprocessing SUDs used in a single laparoscopic hysterectomy[13]. With approximately 40,000 hysterectomy procedures performed per year[14], this amounts to 20,000 tonnes of CO2e avoided.

An estimated **1800 tonnes[15] of waste** avoided by reprocessing just 7 types of medical devices in Canada

An estimated **20,000 tonnes of CO2e** emissions[16] could be avoided by reprocessing SUDs from just one type of procedure in Canada

Comparative Marginal Costs of New and Reprocessed SUDs

Table 6: Results of economic model

Intervention	Cost per Patient			
	Device Cost	Cleaning Cost	Expected Cost of Adverse Events	Total Cost of Intervention
Catheter for angioplasty, base case • New SUD • Reused SUD	$250 $48	$0 $29	$0 $0	$250 $77
Catheter for angioplasty, break-even value for probability of adverse events • New SUD • Reused SUD	$250 $48	$0 $29	$0 $206	$250 $283
Laparoscopic cholecystectomy for base case values • New SUD • Reused SUD	$1,233 $246	$0 $15	$0 $0	$1,233 $261
Laparoscopic cholecystectomy break-even value for probability of adverse events • New SUD • Reused SUD	$1,233 $246	$0 $15	$0 $973	$1,233 $1,234

Source: Reprocessing of single-use medical devices: clinical, economic, and health services impact (11).

CHALLENGES AND ENABLERS

CHALLENGES

- Patient safety concerns[17]
- Lack of Information or data regarding infection risk for each type of device[12,17]
- Lack of available services or infrastructure to reprocess SUDs in Canada[9,17]
- Some SUDs aren't designed for reprocessing
- Legislation or policies that prohibit the reprocessing of single use medical devices

ENABLERS

- Clear standards and processes for the reprocessing of single use medical devices
- Data on types of medical devices that can safely be reprocessed and reused
- A greater recognition of the negative environmental impact of the healthcare industry
- Data on the environmental and cost savings of reprocessing single use items

EMERGING

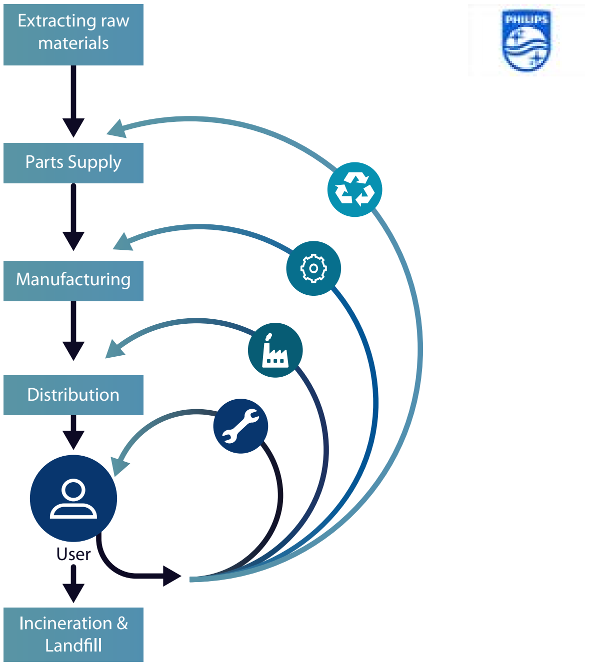
COVID-19 has led to a push to re-shore medical product supply chains. Due to higher labour costs in Canada relative to east Asian nations where medical supplies are currently produced, the healthcare sector may transition towards lower cost options such as reprocessing SUDs.

Intervention 2: Equipment Servitization

WHY SERVITIZATION?

Transitioning to a servitization model in healthcare - where equipment manufacturers retain ownership of the equipment and hospitals lease or pay for the services of the equipment rather than buy them outright - can provide environmental and economic benefits and improved healthcare operations through optimized equipment performance. There are benefits to this type of arrangement for both the end user and manufacturer. Offering its products as a service can allow a manufacturer to differentiate itself from its competitors, improve customer relationships and loyalty, increase revenue and retain equipment for remanufacturing and re-deployment for a second (profitable) life[18]. Customers can benefit through improved equipment performance and operational availability, lower up front investment requirements[16], and overall cost savings[19].

By retaining ownership of equipment, the equipment manufacturer is incentivized to design and construct long lived, durable products and to extend product life which can render significant environmental benefits including reduced waste. Further, remanufacturing - a controlled programme of disassembly, testing, remediation, upgrading and re-assembly before being placed back into service in like-new condition (including a warranty) - end-of-life healthcare equipment saves approximately 80% of the equipment's raw materials, resulting in less waste. Remanufactured equipment also costs 15-40% less than a new item[6] which can result in significant cost savings for the end user.



Source: Philips (https://www.philips.com/a-w/about/sustainability/circular-economy.html)

THE CASE FOR EQUIPMENT SERVITIZATION

Limited quantified data is available on the environmental benefits of servitization however a case study of MUJO, which manufactures specialized equipment for rehabilitation, found that servitizing their product allowed for a more efficient use of capital equipment and a lower volume of equipment manufactured. Lower manufacturing costs allowed them to bring manufacturing back to the UK[20]. The lighting as a service model – in which a lighting company installs, maintains and manages lighting throughout its lifecycle – can reduce electricity use for lighting by up to 50%.[21]

The benefits of end of use or end of life equipment re-use or remanufacture for top-end systems are proven including, 80% material savings and cost savings[21] between 15 and 40%, When delivered as part of a servitized product, customers also have reassurance that once products reach end of use through technical redundancy, they can be cascaded to less demanding applications, thus extracting even more (global) benefits.

IMPACT IN CANADA

This use of service models is a strong theme in healthcare waste reduction. A 2015 study[19] of waste reduction potential across selected sectors of the Danish economy identified that the use of servitization models in the procurement of hospital equipment, such as advanced diagnostic, IT or laboratory equipment, could lead to a net value recovery of $100-125 million per year by 2035. Denmark operates a public service healthcare model, so the learning is translatable to Canada. Scaled to the Canadian population, this could translate to $700-900 million of cost savings per year. While product servitization is a business model that is increasingly being considered within a number of sectors, including healthcare, further research to better understand how these types of contracts can positively or negatively impact the healthcare system may be needed.

An estimated **2.1 million GJ of energy**[22] would be saved per annum if all Canadian hospitals servitized their lighting

An estimated **1000 tonnes**[23] **of CO2e** emissions could be avoided per annum if Canada only purchased remanufactured MRI machines

An estimated **200 tonnes**[23] **of materials** would be reused per annum if Canada only purchased remanufactured MRI machines

CHALLENGES AND ENABLERS

CHALLENGES

- Aversion to change and risk aversion[24]
- Procurement barriers[24]
- Manufacturers not offering their products as a service
- Lack of formal decision-making processes for spending on health technology or service innovation[24]
- Lack of a top down Circular Economy strategy[25]
- The perception among decision makers that environmental, clinical and financial benefits cannot co-exist[25]
- Potential contractual concerns and the need for further research to determine how switching to equipment servitization might impact the healthcare system

ENABLERS

- Building awareness of the benefits of equipment servitization among healthcare decision makers
- Developing a Circular Economy strategy for healthcare and connecting its outcomes to federal and provincial climate change and zero plastic waste targets[25]
- Developing an ecosystem of innovation for public and private stakeholders can identify innovation and investment opportunities[24]
- Moving to a procurement process that includes consideration of the technology lifecycle[24]

OTHER OPPORTUNITIES FOR WASTE PREVENTION IN HEALTHCARE

- Transitioning to digital record keeping
- Virtual care reduces travel and – indirectly – unnecessary dressings and medications.
- SMART drug delivery reducing overall use, avoiding over-prescription, assisting patient medication conformance.
- Reducing recyclable and compostable materials being disposed of as a garbage
- Embedding environmental considerations into procurement decisions (Ex: purchasing plastic with recycled content, requesting the removal of unnecessary packaging, developing customized surgical kits and 'right-sizing'[25])

EMERGING

Asset sharing is one of the ways in which companies, organizations and individuals can create economic and social value in the circular economy and reduce waste through the efficient use of existing assets. By maximizing the utility of existing resources, the sharing economy can reduce the demand for new assets and all of the waste and energy that is inherent in the production, use and disposal of those assets throughout their lifecycle. FLOOW2 is a business to business (B2B) online sharing platform that enables companies and organizations to share their underutilized assets, including people, equipment and infrastructure. The company was started in Luxembourg in 2012 tackling global construction equipment, but rapidly expanded to sectors such as healthcare, manufacturing and heavy industry. The Canadian Coalition for Green Health Care is currently partnering with Floow2 to launch a healthcare sharing platform in Canada.

REFERENCES

1. Canadian Institute for Health Information (CIHI). Hospital Beds Staffed and In Operation, 2018–2019. https://www.cihi.ca/en/access-data-reports/results?f%5B0%5D=field_geographies%3A1947&f%5B1%5D=field_geographies%3A1980

2. Canadian Coalition for Green Health Care. (2020). 2018 GHS report Card.

3. Healthcare without harm. (nd). Findings: Health Care's Global Climate Footprint. https://noharm-global.org/sites/default/files/documents-files/5955/HealthCaresClimateFootprint_findings.pdf

4. Ekelman, M.J., J.D. Sherman and A.J. MacNeil. (2018) Life cycle environmental emissions and health damages from the Canadian healthcare system: An economic-environmental-epidemiological analysis

5. Fraser Health. (2019). Green Care 2018 Environmental Performance Accountability Report. https://bcgreencare.ca/sites/default/files/GreenCareEPAR_FH_VF_Oct-3-2019.pdf

6. Laustsen G. Reduce–recycle–reuse: guidelines for promoting perioperative waste management. AORN J 2007;85:717–22

7. Kagoma, Y., N. Stall, E. Rubinstein and D. Naudie. People, planet and profits: the case for greening operating rooms. CMAJ November 20, 2012 184 (17) 1905-1911; DOI: https://doi.org/10.1503/cmaj.112139

8. CADTH. (2015). Reprocessing of Single-Use Medical Devices: A 2015 Update. https://www.cadth.ca/reprocessing-single-use- medical-devices-2015-update

9. Unger, S. (2015). Sustainable Solutions for Medical Devices and Services. https://repository.asu.edu/attachments/163985/content/Unger_asu_0010E_15517.pdf

10. Bornstein, S., Butler, J. and Kean, R. (2010). The Reprocessing and Reuse of Single-Use Medical Devices in Newfoundland & Labrador. Project Report. Newfoundland and Labrador Centre for Applied Health Research (NLCAHR). Available at https://www.nlcahr.mun.ca/CHRSP/SUDS_full_web.pdf

11. Hailey D, Jacobs P, Ries N, Polisena J, Normandin S, Noorani H, Lafferty S, Gardam M. (2008). Reprocessing of single-use medical devices: clinical, economic, and health services impact. Ottawa, Canada: Canadian Agency for Drugs and Technologies in Health. Technology report number 105. https://www.cadth.ca/sites/default/files/pdf/htis/feb-2008/334B_Reprocessing-SUDs-Canada-Clinical-Economic_tr_e.pdf

12. Practice Greenhealth. (nd). Greening the OR Guidance Documents. The Business Case for Greening the OR. https://www.c4spgh.org/HCW1_Presentations/GOR_FullSet_Guidance%20Docs_Web_042711.pdf

13. Thiel, C., N.C.Woods, and M.M. Bilec. (2018). AJPH Research: Strategies to Reduce Greenhouse Gas Emissions from Laproscopic Surgery. https://ajph.aphapublications.org/doi/pdf/10.2105/AJPH.2018.304397

14. Zlomoslic, D. (2014). Canada's high hysterectomy rate under scrutiny. https://www.thestar.com/life/health_wellness/2014/06/10/canadas_high_hysterectomy_rate_under_scrutiny.html

15. Calculated based on data from (1) and (12).

16. Calculated based on data from (13) and (14)

17. Personal Communication. Ritche, D. and M. Dawson. Canadian Coalition for Green Healthcare. July 8, 2020.

18 Lead Innovation Management. 2019. Can Servitization Heal the Sick Hospitals? https://www.lead-innovation.com/english-blog/servitization-hospitals

19 Ellen McArthur Foundation. (2015). Potential for Denmark as a Circular Economy.

20 REBus. (2019). Service Agreements–good for health. http://www.rebus.eu.com/wp-content/uploads/2017/05/REBus-case-study-MUJO.pdf

21 Coronado, N. (Nd). Case Study I: Diamond Select Allura Xper FD20/10 Interventional X-ray system.
https://www.remanufacturing.eu/studies/fe7036c095524da69e15.pdf

22. Calculated based on data from (2), (19) and (20).

23. Calculated based on data from (21) and Statistica. (2018). Number of magnetic resonance imaging (MRI) units in selected countries as of 2017 (per million population).
https://www.statista.com/statistics/282401/density-of-magnetic-resonance-imaging-units-by-country/

24. MacNeil, M., M. Koch, A. Kuspinar, D. Juzwishin, P. Lahoux, P. Stolee. (2018). Enabling health technology innovation in Canada: Barriers and facilitators in policy and regulatory processes.
https://www.sciencedirect.com/science/article/pii/S0168851018305396#bib0190

25. Canadian Coalition for Green Health Care. (2020). Webinar: Introduction to the Circular Economy.
https://recordings.join.me/mxUl68ZK40Kr7PH3cX_XGg

Agriculture

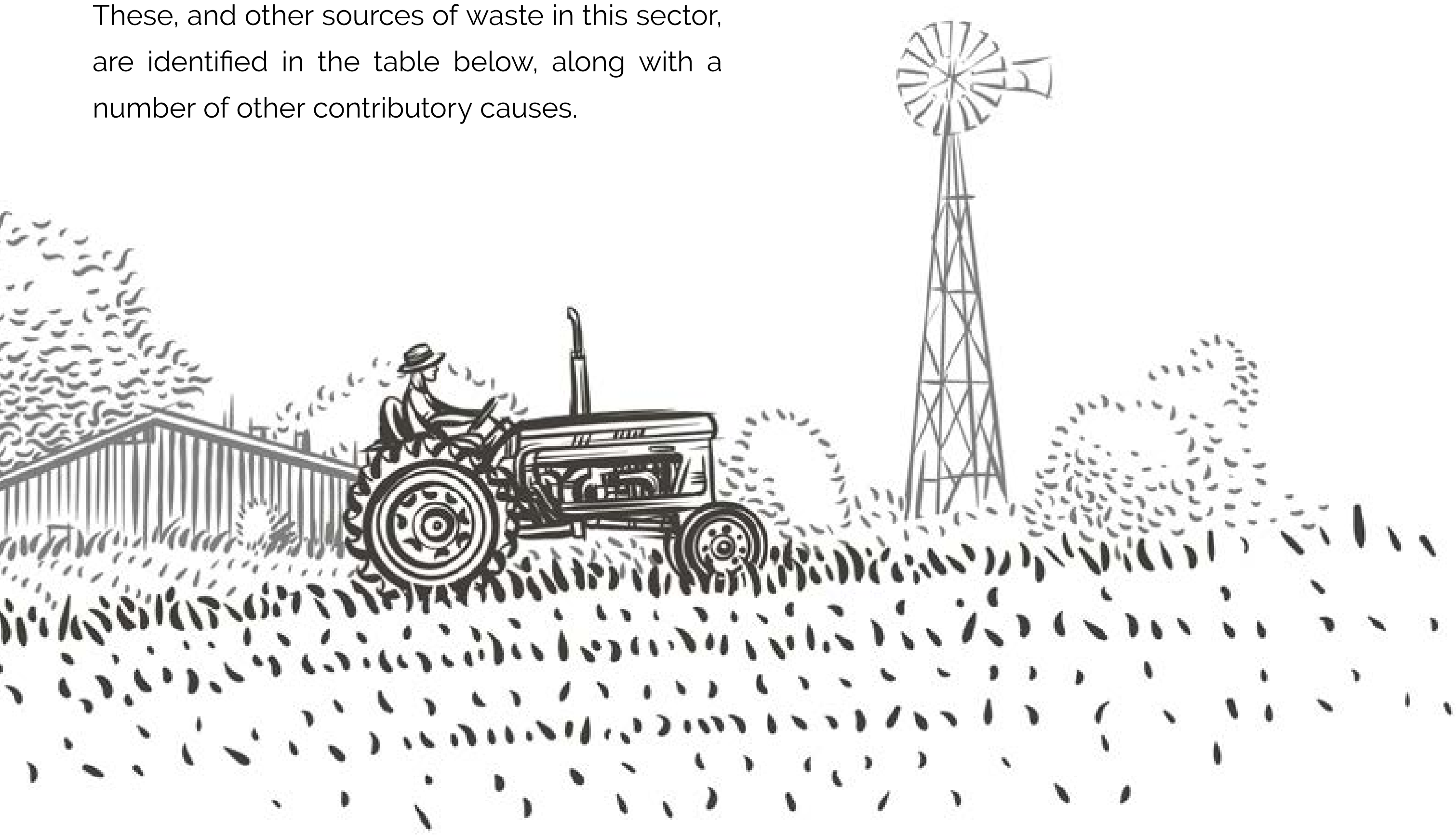
SECTOR IN CONTEXT

Agriculture is a fundamental part of Canada's economy. In 2016, this sector generated $112M in GDP and employed 2.3 million people across nearly 200,000 farms[1]. While modern agricultural practices have enabled societies to transition away from a subsistence way of life, these practices can result in negative environmental outcomes. Intensive agriculture can strip arable soil of vital nutrients, expedite for example soil erosion and cause groundwater and surface water contamination from excessive use of fertilizers and pesticides. Agricultural practices can also generate large amounts of GHG emissions and waste. It is estimated that this sector generates approximately 73.1 million tonnes[2] of CO_2e and 660,000 tonnes of avoidable food waste per annum in Canada[3] including 40,000 tonnes of plastic[4].

While it is acknowledged that significant waste is generated at the food processing, retail and consumption stage, these wastes have been well characterized by NZWC and others in previous studies. Therefore, the focus of this chapter is on agricultural waste prevention which has not been as well studied. As with most sectors, some causes of waste in this sector are a result of forces beyond the control of the individual farmer and require action across the continuum of the value chain.

SOURCES OF WASTE

There are many sources of waste in this sector and vary based on specific crop or livestock type and farming system employed. However, for crops specifically, core sources of waste include the use of large tracts of land for growing, leaving food in field if it doesn't meet processor or retailers specifications, the over use of fertilizers, pesticides and irrigation water and the use of a large volume of plastics and other consumables in agricultural processes. These, and other sources of waste in this sector, are identified in the table below, along with a number of other contributory causes.



SOME CAUSES OF AGRICULTURAL WASTE

		Causes of Agricultural Waste
Point Along the Supply Chain Where Waste is Generated	Design & Specification	• Growing varietals that are poor for the growing conditions
	Procurement/ Feedstock Management	• Use and over-use of fuel oil and lubricants • Over-use of clean water, fertilizers and pesticides • Use and disposal of single use plastic • Tire use management and disposal • Scrap metal generation
	Production	• Poor process control on e.g. grain drying leading to spoiled product • Poor harvesting management and equipment • Nutrients from manures and silage effluent (livestock) • Weather and climate conditions
	Distribution and Retail	• Retail specifications that cause nutritious food to be left in field
	Demand & Use Management	• Consumer preference for unblemished foods that cause nutritious foods to be left in field

PROFILED INTERVENTIONS

Tackling 'Left In Field'

Around 6% of total avoidable food loss waste is attributable to growing and farming. Whilst small compared to wastes in food processing and consumption, the monetary and carbon impacts are still substantial. A significant fraction of this waste may be addressed by changing retail specifications to increase the scope of what is deemed acceptable for purchase and sale.

Precision Agriculture

A major component of arable farm costs relates to consumables, a large fraction being fertilizer and pesticides. These wastes arise because of both poor initial assessment of the soil needs, for example, and subsequently inefficient or untimely applications of treatments, more often resulting in over-dosing. The use of precision delivery techniques, including emergent drone technologies holds potential for reducing these types of waste while improving the overall health of the soil.

Building Integrated Agriculture

There are lost opportunities in agriculture where overall economies in energy use, including food miles and their consequent climate impacts, combined with opportunities to use non-field growing spaces with a higher intensity than conventional systems. In certain circumstances, the use of hydroponic and vertical farming systems in an urban environment can offer energy efficiencies and can free up land for traditional farm crops.

Intervention 1: Tackling 'Left-in-Field'

Left-in-Field is an otherwise viable crop which is left un-harvested.

WHY 'LEFT-IN-FIELD'?

It is estimated that over 660,000 tonnes of food produced in Canada each year are left unharvested[3]. Leaving unharvested nutritious food in the field is not unique to Canada – the EU has equivalent wastes of over 50 million tonnes – but it's an avoidable waste which can be tackled.

Major causes of left-in-field produce include:

- Buying standards and consumer expectations: Buyers and growers reject or accept crops based on perceptions of consumers' preferences, for example on size, shape, variability or blemish.
- Seasonal demand and price fluctuations: During plentiful harvests, prices may drop, disincentivizing the sale of additional volumes of the crop.
- Poor demand forecasting resulting in excess planting: Conservative over-planting to ensure demand can be met is common.
- Labour shortages: Shortages of labour may be a factor when choices between harvesting premium and second-grade crops need to be made.
- On farm spoilage: Poor handling and storage may lead to product spoilage at or near source.

Some harder to tackle reasons can arise as a result of perverse public policies. For example, some jurisdictions restrict gleaning – collecting food for donation – or control supply by private-public marketing orders.

THE CASE FOR TACKLING 'LEFT –IN-FIELD'

There are many good examples of how tackling this issue can yield savings: A study on Food Loss and Waste (FLW) in a potato supply chain in the UK found that changing from a 45mm to a 43mm screen would increase crop utilization by around 2% with annual savings of over $160,000 in a 50,000 tonne/ year operation. This was sufficient enough incentive to change farmer practice[5] indicating supply-chain actions are needed to address these issues.

A 500-member growing consortium, BC Tree Fruits, examined the specification of its normal 2nd grade apple cull which accounts for 20% of production – over 15,000 tonnes of fruit. Normally most are sent for juicing at little or no margin, but remarketing into a bespoke brand cider production joint venture allowed a high-grade value recovery of around 4,000 tonnes of fruit[6].

IMPACT IN CANADA

The value of lost crop, based on the price of food purchased at retail and at hotels, restaurants and institutional food service establishments, is estimated to be between $4,351 and $4,967 per tonne in Canada.[3]

Multiplier	Output (Bn)	GDP Contribution (Bn)	Jobs
Direct	$2.9	$1.4	9,370
Total [a]	$5.4	$2.7	20,964

a. The total multiplier measures the sum of the direct, indirect and induced multipliers. The induced multiplier measures the value of production driven by household expenditures associated with labour income (for example, wages) generated from the direct and indirect effects.

1.3 million tonnes of CO2e avoided if left in field crops were harvested instead[3]

84 million tonnes of water use avoided if left in field crops were harvested instead[3]

660,000 tonnes – the volume of food **waste avoided** if left in field crops were harvested instead[3]

CHALLENGES AND ENABLERS

CHALLENGES

- More focus on planning is required to forecast season demand.
- Some causes for crops being left-in-field are a result of complex supply chain issues and consumer demand which will require action across the value chain.
- For new product development, investment in on-farm technology and/or new partnerships may be needed.
- Conversations with purchasers regarding specifications changes can be difficult.
- Changes to legislation or public buying policy can be a long-haul and hard to achieve by lone actors.

ENABLERS

- Changing cosmetic requirements for primary food grading to widen the range of acceptability.
- Challenging buyer specifications, perhaps in new markets.
- Challenging regulations that encourage food waste e.g. the repeal of Quebec's act prohibiting sales on aesthetic grounds
- Enact tax credits which encourage donation of surplus food.
- Extending the shelf-life of surplus crops through additional processing.
- Improved supply-chain forecasting.

Intervention 2: Precision Agriculture Technologies

Precision agriculture technologies use a combination of sensing, remote and autonomous devices, communications, informatics and AI to deliver enhanced performance and reduce waste.

WHY PRECISION AGRICULTURE?

The application of liquid treatments to crops, both as nutrients and pest and disease control, is an embedded practice in modern day agriculture. It's easy to simply follow standard application formulae, but this can lead to over-dosing which results in a loss of money, a waste of resources and, potentially, a hazard to the eco-system. With fertilizer accounting for up to 60%[7] of arable farm costs, many farmers are interested in re-evaluating current practices.

Tools are now available which can significantly improve productivity while potentially reducing inputs. All require planning but start with an assessment of the pH, Nitrogen (N), Phosphorus (P), Potassium (K) and Magnesium (Mg) indices per plot: a case study from the UK's Defra[7] indicated that such assessments resulted in cost savings of around $22 per hectare and a reduction in nitrogen fertilizer use of approximately 100kg per hectare.

Easy access to computing and the advent of internet and drone-based informatics has expanded possibilities.

A 2016 report by PwC[8] highlighted three key benefits of using drone technologies:

- All-weather, on-demand crop supervision, immune from problems associated with the use of satellites.
- Soil and field analysis: using both spectral sensing and physical sampling these technologies can map and assess different plots. In addition, drones can be used to plant and fertilize.
- Health assessment: UV, visible and IR sensing reveals crop health and permits delivery of targeted pesticides and fertilizers.

THE CASE FOR PRECISION AGRICULTURE TECHNOLOGIES

Precision agriculture systems have moved beyond novelty and have high potential in a multitude of applications which may justify their relatively high current capital cost. For example, AgDrone systems decrease planting costs by 85 percent[9]. These systems shoot pods containing seeds and plant nutrients into the soil, providing the plant all of the nutrients necessary to sustain life. Ongoing monitoring of crops allows fertilizer and pesticides to be added only as needed rather than applied over the entire field as a preventative measure, thus reducing waste while improving production yields.

IMPACT IN CANADA

Reducing pesticide and fertilizer use can be expected to yield economic benefits (see table below). These benefits are dependent on what crop is farmed, the technology used and the size of farm.

Variable Rate Nutrient Application Technologies[10]	Variable Rate Pesticide Application Technologies[10]
• US studies (2000-2004) identified a net benefit of between \$11 and \$60 per ha annually using VR fertilizer application. • VR lime application studies (2000-2003) identified net benefits of \$5 to \$10 per ha over a three year period depending on methodology.	• Two studies (1996 and 2003) found that VRPA saved between \$26 and \$62 per hectare. • A 2007 study concluded integrating VR technology would generate herbicide savings of approximately 37% considering the additional fixed costs (the technology).

Approximately **395,000 m³ of irrigation water use avoided**[11] if all Canadian crop production used precision agriculture tools.

Approximately **9,900 metric tonnes of fertilizer use avoided**[12] **resulting in a reduction of 16,000 metric tonnes of CO2e avoided**[13] from fertilizer production if all Canadian crop production used precision agriculture tools.

Approximately **66,000 metric tonnes of the active ingredient in herbicides, pesticides and fungicides avoided**[14] if all Canadian crop production used precision agriculture tools.

CHALLENGES AND ENABLERS

CHALLENGES

- Regulatory, safety, privacy and insurance challenges associated with drone operation[16]
- Overall cost and lack of access to capital for initial investment[15]
- Lack of economies of scale for small farming operations
- IT infrastructure/internet speeds may not be sufficient in rural areas[15]
- Lack of training or necessary IT skills[15]
- The use of drones and other automated equipment in this application is an emerging technology and there still may be technological challenges to overcome to match the performance of other systems.
- Lack of information regarding the cost-benefits and performance benefits of the technology for the user.

ENABLERS

- Government incentives to encourage the adoption of precision agriculture technologies[15]
- Improved internet connection/speeds in agricultural areas[15]
- Dissemination and verification of performance and cost-benefits of the technology[15]

EMERGING

The University of Manitoba is developing Internet of Things (IoT) technologies for application in agriculture. IoT solutions enable the integration of intelligent assets - which are objects or devices that are capable of continuously monitoring their location, condition and availability in real time and communicate with the user or other devices via the internet[16]- to improve business processes.

Intervention 3: Building Integrated Agriculture

Building Integrated Agriculture (BIA) is agriculture using hydroponics in either a rooftop greenhouse or enclosed vertical farm.

WHY BIA?

Although not entirely novel, hydroponics have been recognized for their particular benefits in water-poor, energy rich environments. When arranged in multi-level 'vertical' farms, they offer even higher factor reductions in water use and productivities per unit area. When paired with renewable sources of electricity, clear benefits arise in situations where 'greenhouse crops' such as lettuces and tomatoes might relieve pressure on other crop land needs.

These circumstances do not appear at first sight to be an entirely natural fit for the Canadian situation, especially considering the limited effect on material wastes. However, with a growing emphasis on green cities and reduction of food miles, another proposition presents itself: integration of rooftop hydroponic farms into densely urbanized regions with synergistic benefits from thermal management and aesthetic value. Further, the valorization of otherwise unused space can increase building revenues and decrease reliance on agricultural lands. For the correct selection of crops, for example crops which would otherwise be hauled in from far away for all or a portion of the year, significant net carbon reductions are possible. For example, one kilogram of tomato's grown in a rooftop greenhouse or a rooftop vertical farm generates 2.4 kg and 1.1 kg less CO_2[17] respectively than tomatoes grown via traditional methods and imported.

THE CASE FOR BIA

Planned well, hydroponics integrated into urban rooftops or other urban settings, offers advantages compared to conventional agriculture. These arise from net carbon savings from crop transport and benefits to buildings through insulation and energy system synergies.

An MIT study[17] simulated BIA hydroponic greenhouses and container farms at tropical and high latitudes. It found, for example, that greenhouse-based systems would likely suit Canada, with between 60% and 80% reduction in GHGs. Container systems were viable with reductions of between 40% and 80% depending on local climate.

IMPACT IN CANADA

The economic feasibility of these systems remains uncertain in Canada[18]. High initial costs for real estate and energy provide a key barrier[18]. Once farms are established, cost savings may be apparent through:

- Reduced transportation costs[18]
- Reduced use of fertilizers, pesticides, water and other materials savings[18] and a reduction in land use; and,
- Significant yield increases per area of land for vertical farms due to the vertical stacking of growing space and the highly controlled climate/processes.[18]

The estimated economic returns for vertical or hydroponic farming are uncertain and time dependent as high fixed costs, like real estate, can be offset over time. It is expected pilot projects in major urban centres would be feasible[18].

Vertical and hydroponic farming can be expected to generate social benefits, including:

- Access to more local produce improving food security;
- Increased price certainty;
- Improved nutritional value; and,
- Land use efficiencies[18].

Hydroponic methods use approximately **92% less water**[19] than traditional agriculture **resulting in an estimated 145,000 m^3 of water saved**[20] if 10% of Canada's irrigated crops were produced using hydroponic methods rather than with traditional agricultural methods.

330,000 tonne of CO2e avoided[21] from reduced international shipping if just 10% of foreign crop production could be done domestically using hydroponic methods.

Up to a **50% reduction in building energy demand**[22] due to improved thermal regulation from the presence of the rooftop farm **resulting in a savings of 45.76 x 10^{15} Joules of energy** if 10% of buildings had a BIA[25].

CHALLENGES AND ENABLERS

CHALLENGES

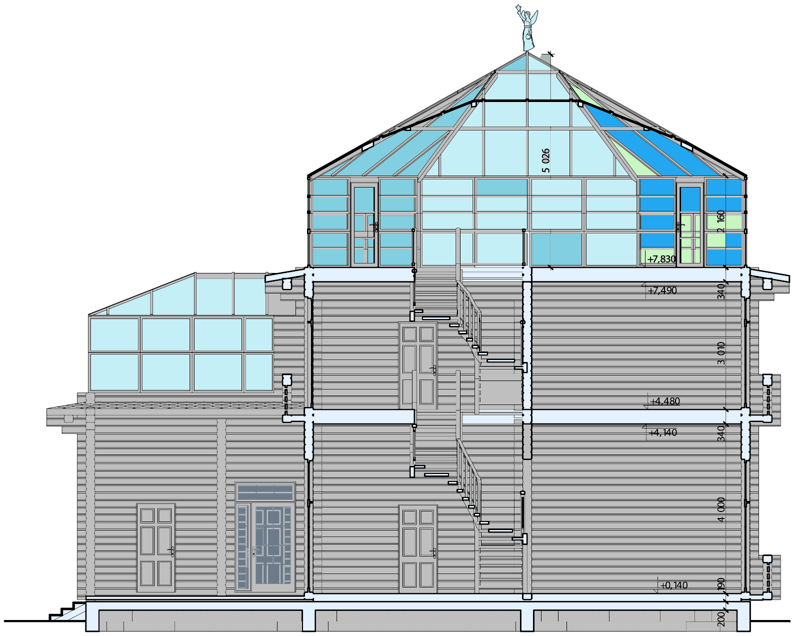
- Robust analysis is needed to ensure a profitable match of crop and farm type to urban setting, particularly to ensure proximity to consumers.
- Significant capital will be needed to install and establish an operating unit.
- Hydroponics is a distinct change in skill set from traditional agriculture, blending in elements of manufacturing, chemistry and crop health control.
- A reliable supply of (preferably renewable) electricity is needed to support the growth of crops.

ENABLERS

- Greening of cities, reduction of food-miles and increased amenity for citizens are concepts gaining in credibility.
- There has been a burst of developments in both plant genetics and horticultural systems which demonstrate potential.
- Rapid developments in both renewables and low-energy lighting are swinging the economics in favour of hydroponics.
- The capital cost of installing and operating a unit can be reduced through the potential heat and energy savings.

EMERGING

Lufa Farms, a Canadian company, built and operated the world's first commercial rooftop farm in Montreal, Quebec. They currently have four locations, totalling approximately 300,800 sq ft, which produce lettuce, herbs, leafy greens, microgreens, peppers, tomatoes and eggplant for local consumption. Based upon their results to date, they estimate that they would only need to convert the rooftops of 19 average-sized shopping centres to grow sufficient vegetables to feed all of Montreal![23] Through rainwater capture and the recirculation of water and nutrients in their closed-loop system, they indicate that they are able to save 50% more water than comparable operations without such a system[23]. They also use half the energy of a ground-level greenhouse and do not use synthetic pesticides[23].



OTHER SOLUTIONS TO WASTE PREVENTION IN THE AGRICULTURE SECTOR

- Donate surplus or second grade food[1]
- Create new markets for second grade crops[1]
- Process by-products and organic waste through bio-refineries to develop valuable co-products
- Process cosmetically flawed produce into other products
- Improve crop rotation to reduce fertilizer use

Photo: Sausage developed through cellular agriculture

EMERGING SOLUTION

Cellular agriculture is the emerging field of producing animal products from cell cultures, rather than from an animal itself, using advances in biotechnology, tissue engineering, molecular biology and fermentation. Products currently in development include milk, eggs, chicken and fish. A number of studies are currently underway to determine if this method of production will result in improved environmental outcomes, include reduced lifecycle emissions, waste and land use.

REFERENCES

1. *Government of Canada. Taking Stock: Reducing Food Loss and Waste In Canada. https://www.canada.ca/en/environment-climate-change/services/managing-reducing-waste/food-loss-waste/taking-stock.html*
2. *Government of Canada. (2020). Greenhouse Gas Emissions. https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/greenhouse-gas-emissions.html*
3. *Gooch, M., Bucknell, D., LaPlain, D., Dent, B., Whitehead, P., Felfel, A., Nikkel, L., Maguire, M. (2019). The Avoidable Crisis of Food Waste: Technical Report; Value Chain Management International and Second Harvest; Ontario, Canada.*
4. *Friesen, B. (2018). Agricultural Waste Management in Canada. United States, New Zealand and Australia. http://cipa-plasticulture.com/wp-content/uploads/2018/06/Agri-management-North-America_BFriesen_final.pdf*
5. *WRAP. (ND). Getting maximum value from its potato crop can save The Co-Operative Group up to 600,000 a year. https://wrap.org.uk/sites/files/wrap/Coop%20Potatoes%20Pathfinder%20Project_Case%20Study.pdf*
6. *CEC. 2017. Characterization and Management of Food Loss and Waste in North America. Montreal, Canada: Commission for Environmental Cooperation. 289 pp*
7. *Defra (2006) Saving money by reducing waste - Waste minimisation manual: a practical guide for farmers and growers*
8. *PwC (2016) Clarity from above: PwC global report on the commercial applications of drone technology*
9. *Mikhailova S., "Using Ex-military Drones to Plant Trees", http://www.huffingtonpost.com/pro-journo/using-ex-military-drones_b_8414532.html*
10. *Balafoutis, Athanasios, Bert Beck, Spryos Fountas, Jurgen Vangeyte, Tamme van der Wal, Iria Soto, Manuel Gomez-Barbero, Andrew Barnes and Vera Eory. 2017. Precision Agriculture Technologies Positively Contributing to GHG Emissions Mitigation, Farm Productivity and Economics. MDPI Sustainability.*
11. *Calculated based on data from Statistics Canada. Table 38-10-0240-01 Irrigation volume by crop type (x 1,000). 2018 Data: Irrigated crops only - assumes other field crops are watered only by rainwater and Kumar. R, V.P. Singh, V.J. Jhajharia, and D Mirabbasi. (2020). Agricultural Impacts of Climate Change*
12. *Calculated based on data from Statistics Canada. Table 32-10-0038-01 Fertilizer shipments to Canadian agriculture and export markets, by product type and fertilizer year, cumulative data (x 1,000) and Bryce, E. (2019). Here's How Precision Agriculture Could Help Farmers Reduce Their Fertilizer Use. Anthropocene Magazine.*
13. *Calculated based on data from (13) and Cowie, A. 2004. A Review of Greenhouse Gas Emission Factors for Fertiliser Production. Research and Development Division, State Forests of New South Wales.*
14. *Based on data from Statistics Canada. Table 32-10-0209-01 Type of pesticides used on farms (2017 Data); Simon, M. (2016). The Future of Humanity's Food Supply Is In the Hands of AI. Wired Magazine; Soberon, M., A. Bravo and C.A. Blanco. (2016). Strategies to Reduce Insecticide Use in Agricultural Production. Reference Module In Food Science; Liu, Y., M.R. Langemeier, I. Small, L. Joseph and W.E. Fry. (2017). Risk Management Strategies Using Precision Agriculture Technology to Manage Potato Late Blight. Crop Economics, Production & Management.*
15. *Agriculture and Agri-Food Canada. (2017). Hitting the Target: Benefits and Barriers to Precision Agriculture in Canada.*
16. *Aminusoft Corporation. (2018). Alive Solutions: Precision Agriculture.*
17. *Benis et al. (2017) Building-Integrated Agriculture (BIA) In Urban Contexts: Testing A Simulation-Based Decision Support Workflow, MIT*
18. *Banerjee, Christian and Adenaeuer, Lucie. 2014. Up, Up and Away! The Economics of Vertical Farming. Journal of Agricultural Studies, Vol. 2, No. 1.*
19. *Barbosa, G.L., F.D.A. Gadelha, N. Kublik, A. Proctor, L. Reichelm, E. Weissinger, G.M. Wohlleb, and R.U. Halden. (2015). Comparison of Land, Water, and Energy Requirements of Lettuce Grown Using Hydroponic vs. Conventional Agricultural Methods*
20. *Calculated based on data obtained from (19) and tatistics Canada. Table 38-10-0240-01 Irrigation volume by crop type (x 1,000). 2018 Data (Irrigated crops only - assumes other field crops are watered only by rainwater).*
21. *Calculated based on data from Statistics Canada, J. Wang and A-R Mamane. (2019). Household food consumption and Canadian greenhouse gas emissions, 2015 and M. Kissinger. (2012). International trade related food miles – The case of Canada. Food Policy.*
22. *Calculated based on 2014 data from Natural Resources Canada, Table 1 – Building characteristics, energy use and energy intensity by primary activity, 2014 and (18)*
23. *Lufa Farms.(2020). About Us. https://montreal.lufa.com/en/about*

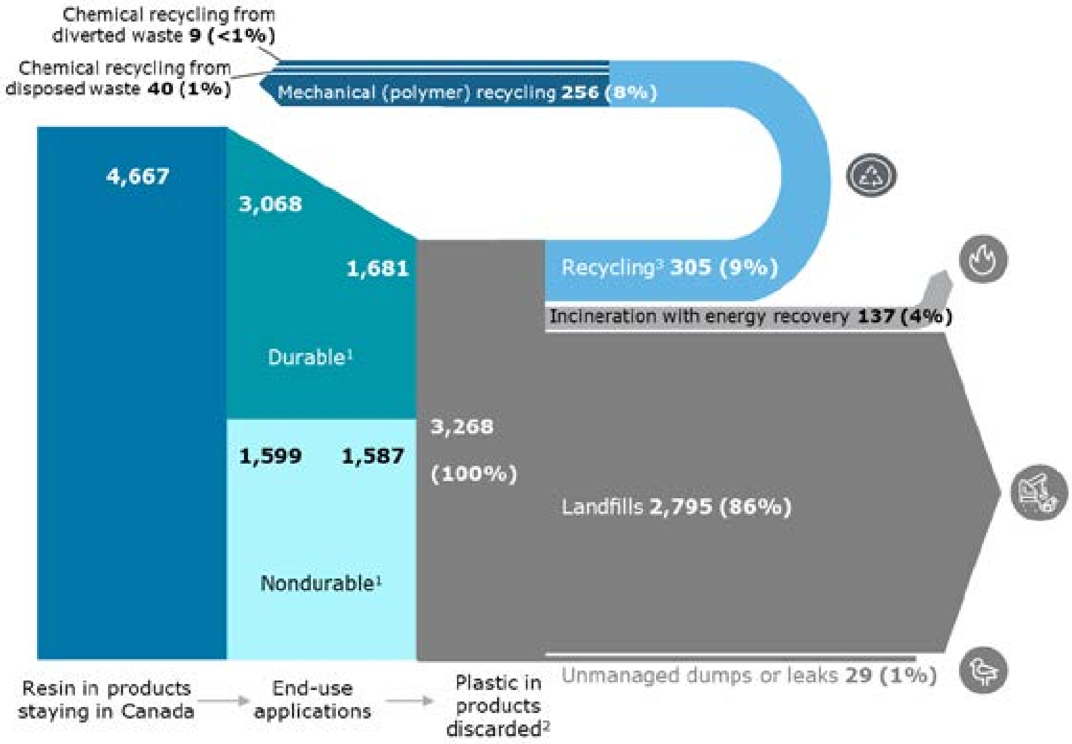
Plastics Sector

SECTOR IN CONTEXT

In 2017, the plastics manufacturing industry in Canada employed 89,000 people, generated $25 billion in sales (excluding resin sales) and produced $15 billion of plastic for the domestic market[1]. An additional $12 billion of plastic was imported.

In 2016, Canadians discarded 3,268 kt of plastics, with approximately 86% of that plastic going to landfill and approximately 1% leaking into the environment. The approximate value of this unrecovered plastic was $7.8 billion.[1]

Plastic Waste Material Flows in Canada per annum, in kt (2016)



Source: Deloitte. (2019). Economic Study of the Canadian Plastic Industry, Markets and Waste- Summary Report. Government of Canada, Environment and Climate Change Canada

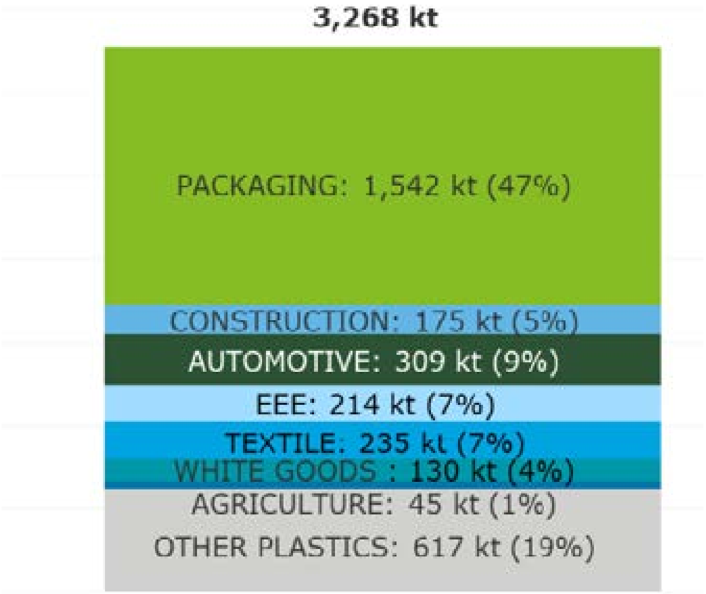
SOURCES OF WASTE

Single use plastics (SUPs) have become ubiquitous in western society because of its utility, versatility, light weight and relatively low cost. While plastics provide many benefits across nearly every industry, the large volume of SUPs disposed, and the resultant negative social and environmental impacts, has gained significant attention worldwide, in no small part due to the efforts of the Ellen MacArthur Foundation which brought attention to the problem of marine plastics. As a result, governments and the packaging industry are facing pressure from the public to drastically reduce the use of unnecessary plastics, ensure proper end-of-use management and enable a circular economy.

Packaging is the primary use and source of plastic waste in Canada. 47% of discarded plastics in Canada are in the form of packaging,1 most of which contains only virgin plastic and has been designed for a single use. In 2016, 77% of plastic packaging waste, or approximately 1,187 kt, was sent to landfill or leaked to the environment[1], which can be hazardous to wildlife especially

as it breaks down to form readily ingestible microplastics. Reducing plastic waste and improving collection systems are two ways to tackle this problem.

Plastic Waste In Products Discarded In Canada (kt)



Source: Deloitte. (2019). Economic Study of the Canadian Plastic Industry, Markets and Waste- Summary Report. Government of Canada, Environment and Climate Change Canada

** EEE = Electronics and Electronic Equipment*

SOME CAUSES OF PACKAGING WASTE

		Causes of Packaging Waste
Point Along the Supply Chain Where Waste is Generated	Design & Specification	• Design for single use[2] • Design is not aligned with the capabilities of available recycling technologies (ex. multi-material products, additives, etc.) and recyclability is not always prioritized in packaging design. • Lack of consistent regulatory intervention forcing higher reuse and diversion rates including end of life responsibility[1,3] • Contract length can deter investment and reduce recycling capacity[1]
	Procurement/ Feedstock Management	• Lack of a secondary market limits the use of recycled plastics[1,3] • Low virgin material prices[1] • Undifferentiated market for recycled and virgin plastics[4]
	Production	• Subsidized virgin resin production[3]
	Distribution & Retail	• Use of plastics for branding and other forms of over packaging goods • Lack of public awareness on product lifecycles and designed recyclability • A large portion of plastic packaging is imported and is not aligned with the capacities of local recycling infrastructure.
	Demand & Use Management	• Lack of public awareness on recycling requirements, processes and results[1,4]
	Recovery and Extension	• Leakage into the environment[1] • Poor sorting by consumers[1,3] Due to a lack of education and differences in sorting instruction between jurisdictions • Low collection rates from the Industrial, Commercial and Institutional (ICI) sectors • Lack of infrastructure for end of life recovery[1] • Sorting is often not market viable[1] • Information asymmetries between collection, sorting and recycling stages[4] • The output of sorting centres often doesn't match the needs of local companies for recycled plastics

PROFILED INTERVENTIONS

Optimizing packaging design – Eliminating unnecessary plastic packaging should be the first step producers take to reduce overall plastic consumption and waste. Optimization of packaging design to reduce material inputs should be undertaken while keeping in mind the required technical performance of the packaging and downstream trade offs.

Designing for Reuse – Plastic packaging is commonly designed to be discarded. The redesign of plastic packaging and business models to allow for the reuse of packaging, in areas and markets where the net impacts of such a transition are positive, can significantly reduce plastic waste.

Minimum Recycled Content Mandates– Using recycled plastic content reduces the environmental impacts associated with single use plastic packaging that cannot be mitigated through elimination or reuse and reduces reliance on virgin resins.

Intervention 1 : Optimizing Packaging Design

Eliminating unnecessary packaging and designing the remaining packaging to achieve the desired technical performance while reducing the volume and complexity of material inputs and keeping downstream trade offs in mind.

WHY OPTIMIZING PACKAGING DESIGN?

While plastic packaging serves an important function a large volume of unnecessary packaging is consumed and disposed of globally due to poor packaging design, over design and over application.

Over-packaging can be described as a product that is wrapped in more packaging than is necessary to protect the product and can occur for many reasons including a company's marketing strategy – designing packaging to make the product look larger than it is, to catch the consumers eye or to display the desired marketing messaging – and the production of standardized, one-size-fits-all packaging options by packaging suppliers. The problem of over-packaging has become particularly acute due to the rise of e-commerce, where pre-packaged products are wrapped and boxed again for transport, often in over-sized boxes filled with bubble wrap to prevent the product from shifting around during transport. This leads to excess waste, excess cost for materials and transport and, often, consumer frustration.

Forward-thinking companies are beginning to find ways to reduce their packaging while still protecting their product against damage, contamination and theft. For example, Amazon recognized that, for many of the products that they sell online, the packaging required to catch consumers' attention and prevent theft and damage in a physical retail store is not required. They have worked with product suppliers, through their Frustration Free Packaging Program, to reduce product packaging by shipping their products 'naked' - the shipping box is the primary packaging - or where this not possible, simplifying the packaging used. This has reduced packaging waste[5] and shipping costs[6].

THE CASE FOR OPTIMIZING PACKAGING DESIGN IN CANADA

IMPACT IN CANADA

EcoloPharm, a Canadian firm, uses eco-design principles to minimize the environmental footprint of the pharmacy packaging that they sell. For example, the Ecolo-Vial is a redesigned prescription pill bottle that uses 30% less plastic and 52% less CO2e than traditional pill bottles[7]. Since 2009, Ecolo-Vials have avoided the generation of 130,000 tonnes of plastic and 190,000 tonnes of CO2e[8]. They are also recyclable and made in Canada.

Changing perceptions of environmental stewardship is driving economic activity in Canada and abroad. In an international study, Unilever found one third of consumers are choosing to buy from brands believed to be doing social or environmental good.[9] This will drive firms to be more environmentally conscious. Economic benefits of eco-design initiatives will vary by firm. A 2011 study considering 30 Quebec and French firms found 90% of firms had the same (53%) or higher (37%) unit margins for eco-designed products relative to current offerings.[10] While this is a small sample, it indicates firm-level economics can be positively impacted by eco-design. Significant environmental benefits of eco-design in Canada could also be realized.

Source: EcoloPharm[7]

An estimated **462, 000 tonnes[1] of plastic** use could be avoided per annum if all packaging used in Canada could be optimized to reduce plastic inputs by 30%

An estimated **469,000 tonnes[11] of CO2e** could be avoided per annum if all packaging used in Canada could be optimized to reduce plastic inputs by 30%

CHALLENGES AND ENABLERS

CHALLENGES

- 45% of plastics products consumed in Canada are imported[1]
- Conflicting eco-design principles and downstream trade offs can make optimizing packaging design difficult
- A lack of data regarding which materials and techniques will have the biggest impact on waste reduction and environmental impacts can make optimization difficult
- Packaging redesign can require engagement of the entire packaging supply chain

ENABLERS

- Increased consumer preference for more environmentally sustainable goods and products
- Plastic packaging bans for unnecessary plastics and those with eco-responsible alternatives
- Better understanding and more common use of lifecycle assessments as a tool to contextualize product optimization and redesign
- Mandated packaging design requirements

Intervention 2: Plastic Packaging Reuse

Redesigning plastic packaging and business models to enable a system that reuses currently disposable plastic packaging

WHY PLASTIC PACKAGING REUSE?

Redesigning plastic packaging to be used again for its original purpose could significantly reduce plastic waste when coupled with business models that support reuse. Studies suggest that there are financial and environmental benefits to packaging reuse including a yearly cost savings for businesses of up to 30% [12], improved brand loyalty, improved customer satisfaction, and a reduction in packaging waste[13]. The Ellen MacArthur Foundation (EMF) has estimated that replacing 20% of global SUP packaging with reusable packaging could save 6 million tonnes of material and be a $10 Billion USD economic opportunity[13]. Scaled to Canadian plastics packaging consumption and disposal, this could represent a material savings of 308,000 tonnes and a financial opportunity of $773 million[1].

The four business-to-consumer reuse models identified by the EMF include:

- Refill at home – Customers purchase a product with a reusable container and refill it with compact refills purchased online or at a retail store (examples include SodaStream, consumer and cleaning products including laundry detergent, shampoo, soap, etc);
- Refill on the go – Customers purchase a reusable container and refill it at a retail store (examples include bulk stores and packaging free stores, travel mugs for coffee);
- Return from home- Logistics providers pick-up empty packaging/containers at customers home and returns it to the retailer for reuse (examples include Loop which is being piloted in Canada in 2020 through Loblaws)
- Return on the Go - Customers return reusable packaging/containers to the point of sale or other participating vendors (examples include Regoo's reusable and returnable to-go coffee cup program in Toronto as well as La Tasse program in Quebec.)

THE CASE FOR PLASTIC REUSE

One example of a return on the go business model that is gaining traction in Canada is an open-return coffee cup program that allows customers to take their to-go coffees in a reusable cup that can be returned for cleaning and reuse at any participating coffee shop. A life cycle assessment of environmental impacts for reusable versus disposable coffee cups conducted by the International Reference Centre for Life Cycle of Products, Services and Systems (CIRAIG) in Quebec found that reusable (polypropylene, polycarbonate and stainless steel) coffee mugs were less energy intensive and resulted in fewer CO2e emissions than their disposable counterparts (paper cups with polyethylene liner and polystyrene cover) when reused 50, 110 and 220 times, respectively[14]. The one area where reuse is not an environmentally superior option is for water consumption which increases significantly due to the requirement to wash the mugs after each use.[14]

IMPACT IN CANADA

It is estimated that Canadians use 4.2 billion disposable coffee cups per year[15], therefore replacing single use coffee cups with a refill-on-the-go model could generate significant triple bottom line benefits. For example, restaurants and cafes could save between $0.13 and $0.17 per cup, which would amount to $109 - $142 million of savings annually if an additional 20% of single use coffee cups were replaced by reusable cups.[15,16]

An estimated

2,600 tonnes [17,*] of plastic waste

could be avoided per annum in Canada if an additional 20% of disposable coffee cups were replaced by reusable stainless steel cups

An estimated

16,600 tonnes [17,*] of waste

could be avoided per annum in Canada if an additional 20% of disposable coffee cups were replaced by reusable stainless steel cups

An estimated

45,000 tonnes of CO2e [18,]**

could be avoided per annum in Canada if an additional 20% of disposable coffee cups were replaced by reusable stainless steel cups

[*] *Calculation assumes that single use cups are not recycled and that end of life reusable cups are recycled*

[**] *Calculation assumes reusable cups are reused 350 times.*

CHALLENGES AND ENABLERS

CHALLENGES

- Reverse logistics, including developing a deposit and refund system and preparing packaging for reuse, is not a core competency for most businesses that have traditionally focused on forward logistics.
- Underdeveloped reverse logistics supply chains and the geographic spread of communities in Canada could lead to higher costs for circular business models that aren't local.
- Public health concerns with reuse models due to Covid-19 and other communicable diseases.
- Motivating users to carry and return or clean and reuse their reusable containers.

ENABLERS

- Increased consumer and regulatory awareness of the magnitude of the plastic waste issue and stakeholder pressures.
- Incentivizing local reuse loops.
- Actionable intelligence on the size of the opportunity for financial benefits and waste prevention.
- Plastic waste bans.
- Packaging design regulations
- Consumer and business incentives for reuse.
- Better communication regarding the low risk of Covid-19 transmission associated with reusing containers that have been properly cleaned with detergent and water[19].
- Stronger engagement through the value chain to encourage the use/procurement of reusable packaging

EMERGING

Packaging-free stores are gaining traction in Canada. These stores allow customers to bring-their-own containers to package and purchase bulk goods. This allows consumers to buy only the amount of product they need or can afford. Many packaging free stores also sell reusable alternatives to common single use items and work with suppliers to reduce waste along the supply chain.

Intervention 3: Minimum Recycled Content

Redesigning plastic packaging and business models to enable a system that reuses currently disposable plastic packaging and reduces reliance on virgin feedstocks

WHY MINIMUM RECYCLED CONTENT?

While the elimination of unnecessary plastics and the implementation of reuse systems, (where packaging can be reused multiple times) are environmentally preferable, using recycled content for plastic packaging that cannot be avoided or reused can reduce the environmental impacts associated with plastic production and use.

Recycled content mandates, whether instituted by governments or private entities, increase the economic incentives to engage in recycling and, thus waste prevention.[3,20] These initiatives are commonly involuntary demand side initiatives where governments or firms mandate a portion of plastics packaging is derived from recycled material.[3] In 2018, the Government of Canada, through the Canadian Council of Ministers of the Environment (CCME) approved, in principle, the Canada-Wide Strategy on Zero Plastic Waste which includes the option of implementing Minimum Recycled Content legislation[4]. In addition, a number of global companies, including Unilever and Walmart, have announced their own post-consumer recycled content commitments for packaging.

Key benefits of recycled content mandates include:

- Improved financial performance for recycling operations;[1]
- Improved socio-economic outcomes including jobs;[1]
- Accelerated market adoption;[20]
- Reduced financial risk for early adopters;[20]
- Elimination of the free-rider problem borne by voluntary initiatives;[20]
- Aid in establishing a secondary market for recycled plastics and improve quality of recycled plastics stock;[20]
- Improved collection of plastics, potentially resulting in the reduced leakage of plastics to the environment where they may breakdown into problematic microplastics
- Material savings;[1] and,
- Reduced GHG emissions.[1]

EMERGING

Groupe d'Action Plastiques Circulaires/ Circular Plastics Taskforce is a coalition of plastics producers, end users and industry stakeholders in Quebec that are developing a roadmap, and piloting identified interventions, for a circular economy for plastics in Quebec. Transferable learnings will be applied in other areas of Canada. See www.gapc.ca for more details.

THE POLICY CASE FOR MINIMUM RECYCLED CONTENT

Increased recycled content in Canadian plastic packaging should result in socio-economic and environmental benefits. Under the assumptions of the Deloitte study of Canada's plastics market, achieving a 90% diversion rate results in better economic performance, more jobs and improved environmental outcomes, when considering all sectors.[1]

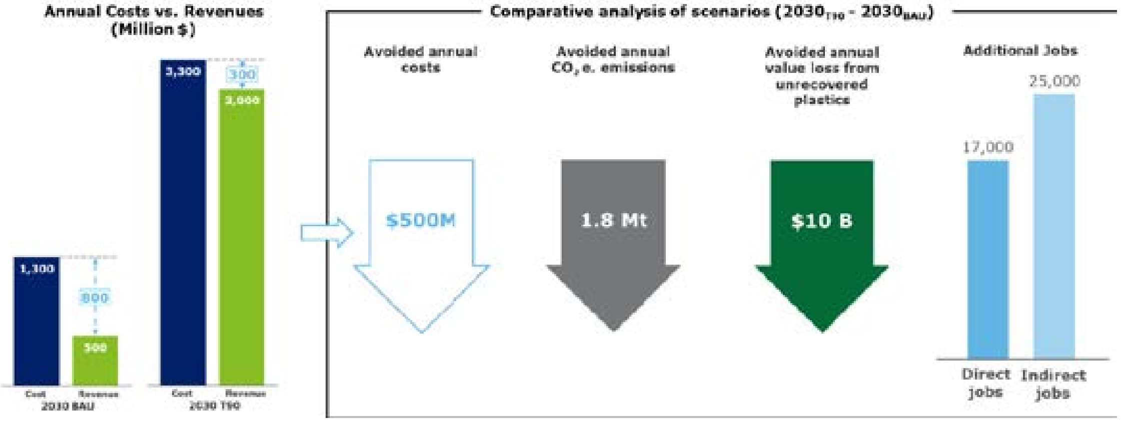
IMPACT IN CANADA

The calculation defining net impact assumes 10% of total benefits (as described in the figure below) could be attributed to a minimum recycled content policy for packaging.* Based on these assumptions, net economic impacts can be estimated to include:

- $50 million of avoided costs (net revenue would still be expected to be negative).[1]
- 1,000 to 2,700 direct jobs with an indirect jobs multiplier of 1.5 jobs.[1]
- $1 billion worth of recovered material. [1]

An estimated **180,000 tonnes[1] of CO2e emissions** avoided based on a 30% minimum recycled content policy

An estimated **465,000 tonnes[1] of plastic waste** avoided based on a 30% minimum recycled content policy



Source: Deloitte, 2019

*This assumes a 30% minimum recycled content policy for packaging where one third of plastics end of use is for packaging as was the case in 2016. This aligns with the European Union's policy for single use plastic bottles, which mandates plastic bottles must contain 30% recycled content by 2030 and targets a 90% diversion rate.

CHALLENGES AND ENABLERS

CHALLENGES

- 45% of plastics products consumed in Canada[1] are imported and we are a small market, making unilateral policy action difficult.
- Fossil fuel subsidies may reduce virgin resin material costs, skewing the packaging market.
- Underdeveloped reverse logistics and supply chains may be prohibitive in designing effective policy.
- Difficult to recycle materials and complex, proprietary plastic compositions

ENABLERS

- Private sector firms including brand owners and retailers, are pursuing minimum recycled content policies aligned with the agenda of the EMF's Plastic Pact.
- Consumer preferences are changing towards more environmentally sustainable goods and products.
- Government actors are active in studying plastic waste reduction options including minimum recycled content policies.
- Investment in infrastructure to support the secondary market including sorting and processing.
- Landfill bans or increasing the cost of landfilling plastics
- Product design mandates (including imported plastics)
- Advanced sorting and recycling technologies

EMERGING

BASF Canada is deploying a pilot project in British Columbia called reciChain which uses blockchain technology to track, trace and share data on plastic materials in the value chain. The intent of the initiative is to improve the transparency of the plastics value chain in order to increase the opportunities to revalorize plastic waste, to increase stakeholder accountability and to provide a mechanism against which to verify compliance with minimum recycled content mandates.

THE BUSINESS CASE FOR MINIMUM RECYCLED CONTENT

Globally, the cost to recycle plastics is highly variable and a substantial fraction of recycling operations are not profitable. The earnings generated by recyclers will vary by geography, resin, application type and volume. Only 20% of global recycling operations are considered to be value generating when oil is $60 (USD) per barrel and approximately 50% of operations generate profit below the investment viability threshold.[21] McKinsey rates this industry as 'emergent' and indicates that increasing the scale of diversion and recycling could be a key to better economic returns.[21]

IMPACT IN CANADA

In Canada, targeting a 90% diversion rate is estimated to reduce the total net loss for recycling operators by $500 million.[1] Businesses may also generate non-financial value, such as environmental and social benefits consistent with the policy case.

CHALLENGES AND ENABLERS

CHALLENGES

- Typical business models are linear leading to disposal.
- Underdeveloped reverse logistics supply chains leading to higher costs for circular business models.
- Lack of a secondary market for recycled plastics
- Low prices of virgin resins
- Low bale quality for recycled plastics
- Poor packaging design from a recyclability standpoint
- Lack of economies of scale in sorting[1]

ENABLERS

- Increased consumer awareness and stakeholder pressures
- Recycling technology improvements making recycling more economical.
- Government interest and investment in increased circularity may reduce the market barriers for businesses including incentivizing a secondary market and economies of scale.
- The development of a secondary market.
- Incentives for recycling. For example, in Quebec, recycled content in some types of packaging can result in a reduction in EPR costs for concerned companies.
- Bans or design restrictions.

EMERGING

Chemical recycling, which breaks plastics down to their basic molecules, can work in concert with mechanical recycling to accept low quality or mixed quality inputs that cannot be recycled mechanically for technical, market or economic reasons. This can increase the market viability of recycling operations and de-risk these investments. Several companies in Canada, such as Pyrowave, Loop Industries and GreenMantra, are currently leading the way in this technology.

OTHER SOLUTIONS FOR PLASTIC PACKAGING WASTE PREVENTION

- Removing fossil fuel subsidies
- Taxing virgin plastic resin
- Single use item bans (straws, films, etc.) for unnecessary plastics or where eco-responsible alternatives exist.
- Legislated packaging design requirements
- Consumer education on recycling
- Ban on difficult to recycle plastics
- Mandating that all plastics entering the economy be recyclable based on common eco-design criteria and standardized packaging types
- Aligning sorting and recovery instructions across all Canadian municipalities and regions
- Investing in new and upcoming technologies to increase recovery and recycling rates

REFERENCES

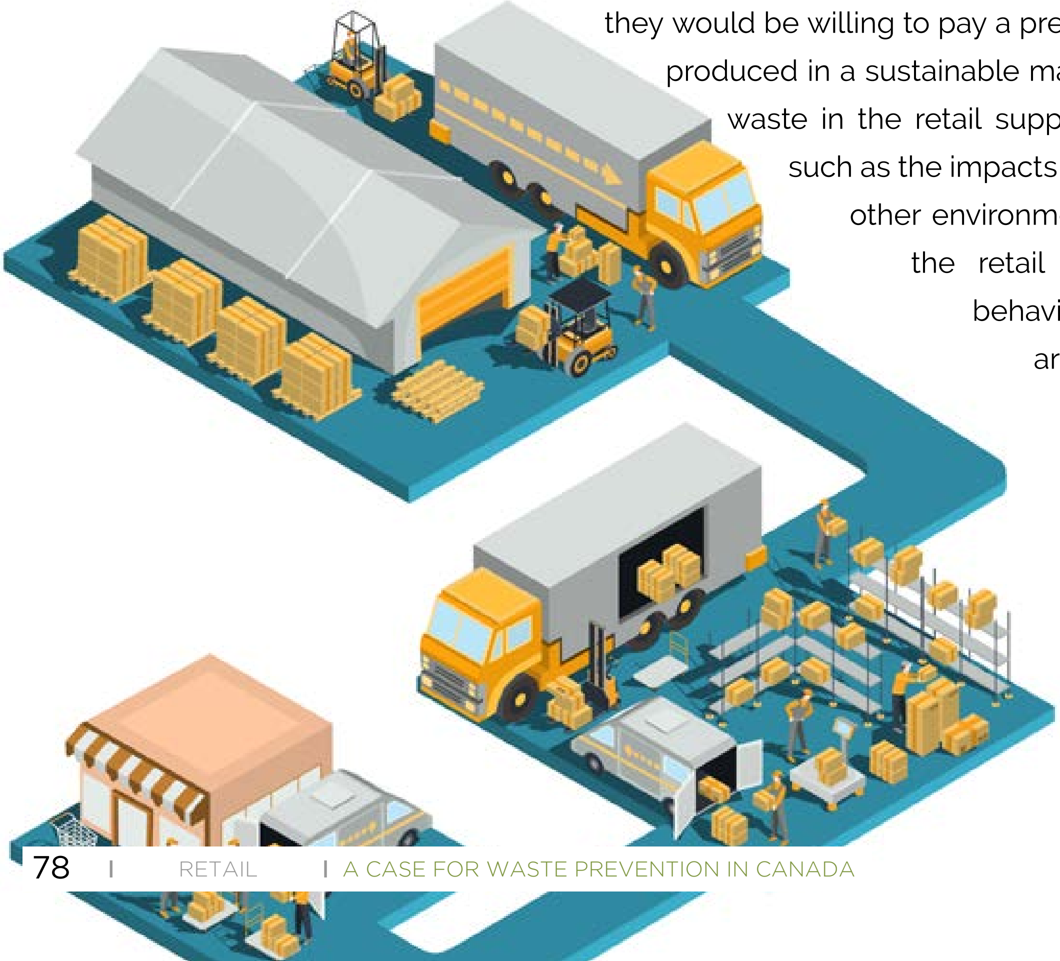
1. *Deloitte. 2019. Economic Study of the Canadian Plastic Industry, Markets and Waste- Summary Report. Government of Canada, Environment and Climate Change Canada. http://publications.gc.ca/site/eng/9.871296/publication.html*
2. *World Economic Forum, Ellen MacArthur Foundation and McKinsey & Company. (2016). The New Plastics Economy – Rethinking the future of plastics. http://www.ellenmacarthurfoundation.org/publications*
3. *Smart Prosperity Institute. (2019). A Vision for a Circular Economy for Plastics in Canada: The Benefits of Plastics Without the Waste and How We Get It Right. https://institute.smartprosperity.ca/sites/default/files/report-circulareconomy-february14-final.pdf*
4. *CCME. 2019. Canada-Wide Action Plan on Zero Plastic Waste Phase 1. PN 1289. https://www.ccme.ca/files/Resources/waste/plastics/1289_CCME%20Canada-wide%20Action%20Plan%20on%20Zero%20Plastic%20Waste_EN_June%2027-19.pdf*
5. *Amazon. (2020). Frustration Free Packaging. https://www.aboutamazon.com/planet/improving-packaging*
6. *Amazon. (2018). Amazon Frustration-Free Packaging Program Certification Guidelines. https://d39w7f4ix9f5s9.cloudfront.net/42/8b/1a59177d4db29f580118ca35c861/amazon-frustration-free-packaging-program-certification-guidelines-v10.1__2019_FINAL.pdf*
7. *EcoloPharm Inc. (2019). Ecolo-Vial medication Vial. https://www.ecolopharm.com/en/products/eco-friendly-vials/*
8. *Éco Entreprises Québec (2020). Ecolo-Vial: the eco-responsible prescription bottle. http://www.optimeco.ca/en/initiatives-examples?details=359*
9. *Lacy, Peter and Wesley Spindler. 2019. Sustainable packaging is good for profits as well as the planet. World Economic Forum. https://www.weforum.org/agenda/2019/01/most-plastic-packaging-is-unrecycled-that-has-to-change/.*
10. *Plouffe, Sylvian, Paul Lanoie, Corinne Berneman and Marie-France Vernier. Economic Benefits tied to Ecodesign. Journal of Cleaner Production. https://proyectaryproducir.com.ar/public_html/Seminarios_Posgrado/Material_de_referencia/Economic%20benefits%20tied%20to%20ecodesign.pdf*
11. *Kissinger, M., Sussman, C., Moore, J. and Rees, W. (2013). Accounting for Greenhouse Gas Emissions of Materials at the Urban Scale-Relating Existing Process Life Cycle Assessments Studies to Urban Material and Waste Composition. Low Carbon Economy, 2013,4, 36-44.*
12. *Jager, J.K. and Peeters, W. (2020). The Untapped Business Potential of Reusable Packaging: How Collaboration is key for moving toward a reusable packaging paradigm. https://www.circle-economy.com/blogs/the-untapped-business-potential-of-reusable-packaging*
13. *Ellen MacArthur Foundation. (2020). Reuse: Rethinking Packaging. https://www.ellenmacarthurfoundation.org/assets/downloads/Reuse.pdf*
14. *CIRAIG. (2014). Rapport Technique. Analyse du Cycle de Vie de Tasses Reutilisables et de gobelets a café a usage unique. http://ciraig.org/wp-content/uploads/2020/05/CIRAIG_RapportACVtassesetgobelets_public.pdf*
15. *Calculated based on data from CBC News. (2018). Quebec's Green Party proposes deposit system for reusable 'to-go' coffee cups https://www.cbc.ca/news/canada/montreal/reusable-coffee-cups-green-party-1.4776056#:~:text=Single%2Duse%20cups%20used%20by%20Canadians%20annually&text=Tyrrell%20said%20%22people%20are%20%5Busing,they're%20not%20recyclable.%22 and Kelleher Environmental. (2009). City of Toronto Hot Drink Strategy Research on Behaviour Change. http://kelleherenvironmental.com/wp-content/uploads/2012/07/kell_env_hot_drink_report_behaviour_change.pdf*
16. *Fisher, Laura. 2008. Signalling Change: Studying the Effect of Price Signals on Disposable Hot Beverage Cup Consumption. http://www.recyclingadvocates.org/wp-content/uploads/2016/03/Fisher2008_DisposableCupThesis.pdf*
17. *Calculated based on data obtained from (15) and Linaghan, M. (Nd.) Disposable Coffee Cups- Why are they a problem and What Can be Done? https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwj_9ePf0ajuAhUeIDQIHSNTBfIQFjAAegQIAhAC&url=https%3A%2F%2Fwww.sustainabilityexchange.ac.uk%2Ffiles%2Fy_a_problem_and_what_can_be_done_presentation_-_michael_lenaghan_zero_waste_scotland_-_28_11_17.pptx&usg=AOvVaw3FabbG2P1gLmyzcebmOVub*
18. *Calculated based on data obtained from (14) and (15).*
19. *Multiple Authors. (Nd.) Health Expert Statement Addressing Safety of Reusables and COVID-19. https://storage.googleapis.com/planet4-international-stateless/2020/06/26618dd6-health-expert-statement-reusables-safety.pdf*
20. *Carriere, Chantal and Beavers Horne, Rachael, The Case for a Legislated Market in Minimum Recycled Content for Plastics (January 1, 2020). Environmental Law Reporter, Vol. 50, No. 1, 2020. Available at SSRN: https://ssrn.com/abstract=3533450 or http://dx.doi.org/10.2139/ssrn.3533450*
21. *Gao, W., T. Hundertmark, T. Jan Simons, J. Wallach and C. Witte. 2020. Plastics recycling: Using an economic-feasibility lens to select the next moves. McKinsey. Available at https://www.mckinsey.com/industries/chemicals/our-insights/plastics-recycling-using-an-economic-feasibility-lens-to-select-the-next-moves.*

Retail

SECTOR IN CONTEXT

The retail sector plays a critical role in the Canadian economy – providing Canadians with the products they want and need every day. In 2019, this sector generated $102 billion in GDP1 and employed over 2 million people across Canada2. As a result of Covid- 19, growth in this sector has been affected and consumer behaviours have changed as well – with more than half of Canadians saying that they are now more likely to buy online than visit brick and mortar retailers3. A shift in consumer spending has a negative effect on the volume of unsold goods in stores that will need to be managed and, in some cases, disposed. Further, increasing numbers of online retail purchases can come with a corresponding increase in product returns – due to the difficulty of assessing the suitability of certain products online – resulting in a number of negative externalities, including increased traffic, emissions and waste.

A recent survey found that Canadian consumers are concerned about the sustainability of the retail sector – with many indicating that they would be willing to pay a premium price for goods that are produced in a sustainable manner4. While some causes of waste in the retail supply chain are well recognized, such as the impacts of fast fashion and packaging, other environmental impacts associated with the retail sector and the purchasing behaviours of Canadian consumers are not well publicized.



SOURCES OF WASTE

Sources of waste within retail are many, diverse and relatively well-recognized. They arise from inefficiencies in internal processes, such as overordering, manufacturing or process waste, shifts in consumer behaviour, poor product design, including the production of low quality goods, over packaging of goods and handling during forward and reverse logistics. Methods to tackle these issues are listed later in this section.

A growing feature of retail waste arises from increasing product returns and the reverse logistics required to process them, particularly driven by the growth in online retail. These present large economic and environmental burdens for retailers and the economy in general. It is estimated that worldwide, consumers returned $640 billion USD5 ($880 billion6 CAD) of goods in 2015, 4.4% of the total value of global retail sales5. For some sectors, such as publishing and greetings cards, up to 20% of products will be returned7. In other sectors such as Clothing, up to 10% of in-store purchases are returned8, and up to 50% of online purchases9.

Retailers, who traditionally have a forward-focused supply chain, are frequently ill equipped to handle the large quantity of products involved. As a result, retailers have found it easier to recycle, landfill or incinerate large proportions of product returns9,10,11. Large sales events are often opportunities to offer major rebates on overstock, but reselling is not always a path considered by retailers. Nevertheless, 30% of all returned products end up in landfill7 – an estimated 2 million tonnes per year in the US alone9. Exact figures for Canada are not available, but it is estimated that many Canadian retailers are facing similar issues.

Product returns can broadly be classified as 'uncontrollable' and 'controllable'. As this suggests, retailers have little sway over the former, at least in the short term. But the latter can be tackled by retailers and are the subject of this case study. Further, while an estimated 48% of returned products are in original condition and could be resold at full price, often these products are sold at discounted prices resulting in financial losses for retailers.

There are some unique conditions in Canada to recognize when analyzing the retail sector. The emergence of Extended Producer Responsibility frameworks for packaging, electronics and other consumer products are beneficial to the sustainability of supply chains. But a considerable challenge within the Canadian retail landscape is important to note: the majority of items sold in Canada are imported. Imported goods face different federal customs tariffs that may be contributing to waste. In some cases, the challenges are exacerbated by federal tax regulations that may incentivize destruction of unsold goods rather than return to country of origin or reuse, resale and repurpose options.

SOME CAUSES OF RETAIL WASTE

		Causes of Retail Waste
Point Along the Supply Chain Where Waste is Generated	**Design & Specification**	• Over-ordering and over production is common in supply.
	Procurement/Feedstock Management	• Stockpiling of materials at production input or output wastes money and risks spoilage of non-durable products.
	Production	• Over packaging of products (primary and tertiary) • Un-optimized design and production • Inefficient processes and equipment • Using 'subtractive' manufacturing and standardized material sizes leading to excess cut offs • Mass producing standardized goods rather than producing customized goods that are a better fit for customers
	Demand & Use Management	• Unpurchased or overstocked goods • The production and sale of cheap or low quality goods encourages over-consumption and increases the need to replace goods more often due to low durability
	Recovery &Extension	• Under utilization of value retention processes to extend the life of products. • Retailers using returns processes that are not fit for purpose leading to the disposal of returned products. • Damaged products during return processes

	Distribution & Retail	• Damaged products in transit and storage
		• Increased product returns due to:
		  • Mis-purchasing, where customers don't get exactly the item they wanted or expected
		  • Over-ordering or buyers remorse , where customers routinely order a variety of sizes, colours or styles with the intent of returning a fair fraction.
		• 'Regret' purchasing arises because of the ease of 'click and buy' with subsequent change of heart leading to the return of no-fault goods.

PROFILED INTERVENTIONS

Mass Customization – One cause for returned goods is that the purchased good either doesn't meet customers needs or expectations. Producing goods on demand to customer specifications may be one way to reduce returns due to poor fit, lower than expected quality or performance etc. thus reducing the environmental impacts of producing, distributing, returning and disposing unwanted goods.

Optimized Reverse Logistics – Fit for purpose reverse logistics services can provide the data and analysis required to identify the best resale option for returned products in order to maximize product resale.

Intervention 1:
Mass Customization

Mass customization is a technology-assisted production process, using virtual prototyping, 3D body scanning and computer aided design and manufacture, that allows customers to modify the traditional mass production process to produce customized products on demand.

WHY MASS CUSTOMIZATION?

Purchasing is the starting point from which product use, or lack of use and end-of-life issues flow. Making this experience as effective, efficient and 'lean', is core to cost and waste reduction. Benefits flow back upstream in avoided manufacture and resource extraction.

A key reason for product returns, especially for products purchased online, is that products, once received, either do not meet customer needs or expectations. This is especially pertinent for online clothing retail where clothing fit, material feel, colour and quality are difficult to tangibly assess when purchasing online. This can lead to ordering the same product in a number of sizes and colours, for example, in an effort to find the right fit. Online fashion retailers indicate that up to 17% of on-line sales are being returned for these reasons[8].

Customizing some types of products to match customer's needs and expectations can improve customer satisfaction and reduce over purchasing and returns. In addition, manufacturing customized products on demand can reduce the problem of overstocked goods that can arise from poor demand forecasting during the mass production process[15]. Often, these unsold goods are directed to landfill. The Ellen MacArthur Foundation estimates that, for clothing alone, 1 million tonnes of unsold product goes to landfill or incineration globally every year[15].

An example of mass customization is the start up company, unspun, which uses 3D body scans of customers' bodies, done through a phone app at home or at unspun's facility, to manufacture a pair of customized, bespoke jeans for each client[16]. The cost is around $200 USD with the potential to become more affordable as demand grows and technologies mature[16]. While the premium cost may be a barrier for many, researchers suggest that a growing number of customers are willing to pay extra for high-quality, durable, personalized products[14].

THE CASE FOR MASS CUSTOMIZATION

Mass customization is viewed as an emerging business model in the retail trade. Bain and Company has found that while less than 10% of consumers have tried customized products, 25%-30% are interested in doing so.

While the variety of products and sectors within the retail trade and lack of available data on this emerging opportunity make quantifying the economic potential of mass customization difficult[17], studies suggest that consumers are willing to pay 20% more than standard equivalents for customized products[17]. This could represent a potential $19 billion market opportunity for Canada[*]. There are also qualitative benefits for brands from these activities such as increased loyalty[17].

EMERGING

Clothing leasing services are one way that people can keep their wardrobes fresh and up to date without having to purchase and, eventually, discard their garments. Canadian companies such as dresst and Sprout Collection, are online clothing leasing services that allow subscribers to rent their clothing. Both have extensive styles to choose from and the subscription fee includes free round-trip shipping and dry cleaning. When combined with reusable shipping packaging, this business model can benefit the environment by reducing the volume of clothing purchased and landfilled and by encouraging the production of high quality, durable clothing.

[*] Assumes 15% of 2019 Canadian retail revenue ($615 billion[18]) were new customized purchases based on from the survey data gap between custom purchases and those interested (25% interested less 10% currently purchasing customized products). A 20% premium is then applied to these transactions

THE CASE FOR MASS CUSTOMIZATION

IMPACT IN CANADA

Research suggests that mass customization can provide environmental benefits including[14]:

- Increased customer attachment to products, thus extending the use phase of products and reducing premature disposal and new purchasing;
- A reduction in over purchasing and subsequent returns;
- A reduction in unsold inventory and the subsequent storage and transportation required for inventory; and,
- Enabling the potential for repair and reuse business models as a result of having direct contact with consumers.

Additional benefits may arise if mass customization incentivizes modular, upgradeable designs and personalization options including the selection of sustainably sourced or recycled materials.

An estimated **42,500 tonnes of waste[18]** could be avoided per annum if mass customization reduced product returns by 15% in Canada

An estimated **281,000 tonnes of CO2e emissions[18]** from landfill could be avoided per annum if mass customization reduced product returns by 15% in Canada

CHALLENGES AND ENABLERS

CHALLENGES

- Requires alterations to business models throughout the supply chain which can be complex and expensive[20]
- Requires the development of new skills and the purchase of new technology which can be complex and costly[20]
- Highly customized products can increase the cost and complexity of production
- Consumers may be concerned about the amount of personal data that is being provided during the customization process[21]
- A subset of consumers may not be willing to wait for the production of, or pay a premium price for, customized products[21]
- Environmental benefits of mass customization can be reduced if economies of scale are not achieved or personalization of products is too complex[22]

ENABLERS

- Online retail platforms, digital technology and modern production processes, such as 3D printing[20,21]
- Consumer demand - interest in purchasing personalized retail products, such as clothing, shoes, furniture and electronics, has been found to be as high as 53% for some product categories and approximately 20% of those interested in personalized products are willing to pay a premium price and share data[21]
- Providing customization options that reduce manufacturing complexity can reduce the cost of personalized products[21]

Intervention 2: Improved reverse logistics

Reverse logistics involves activities associated with the backward movement of products through the supply chain.

WHY IMPROVED REVERSE LOGISTICS?

The ballooning of returns from increased online purchases has overwhelmed many retailers who have simply outsourced the bulk of the issue to their existing forward supply chain agents. While these external processes are typically separate from the forward logistics flows, using different software, planning and infrastructure, oftentimes the reverse logistic process is so mismatched that product returns sit in a warehouse without being remarketed (if not immediately disposed) because of a lack of appropriate decision processes for how to manage returned products[23]. As a result, it is estimated that a full 30% of returns end up in landfill which may represent 7% of the retailer's bottom line[23]. Employing fit for purpose processes to handle reverse logistics in a manner that triages returns to optimize cost and material recovery has become critical.

There are now software and solution providers that can provide fit for purpose reverse logistics services and provide the data and analysis required to identify the best resale option for returned products to maximize product resale volumes and prices.

As an example, Optoro is a US based reverse logistics solutions provider that uses a data-driven returns management solution that processes returned goods, identifies resale options and then sells returned products to the most profitable and eco-friendly destination among outlet and secondary channels[24]. For some clients, Optoro has improved the operational efficiency of the returns process by 100% and increased revenue recovery by 70%[25]. On average, their clients were able to reduce waste to landfill in their reverse supply chain by over 30%, reduced emissions by more than 20% and donated $6.9 million USD (~$9.3 million CAD) of inventory to charity partners[24].

CoreCentric has developed a product returns process for domestic appliances that integrates remanufacturing and repair services to capture value from defective and returned products[26]. The company collaborates with some of the largest retailers and consumer goods manufacturers in the world, operating both large repair programmes and redistribution and resale channels[27]. CoreCentric's infrastructure is allowing for products to have a longer effective life and therefore a higher utility and value. Benefits include:

- Diversion of more than 1,000,000 service parts and 400,000 products from the landfill every year[27]
- Conservation of 85% of the material and energy used to create new products[27]
- Retention of 80% of retail value[26]

Waste during forward logistics – though generally well-tackled – is not without issues. For example, errors in stock-picking and damage in transit are still prevalent and point to issues which could be tackled by improved tagging and checking, and via better (reusable) packaging and more rigorous delivery agent performance, checking and validation.

INFORMATION

In Canada, a number of businesses such as Mariner Auctions, hold online auctions to sell off overstock and retail return items and misguided freight for some of the world's largest retailers.

THE CASE FOR IMPROVED REVERSE LOGISTICS

Reverse logistics is a core competency in the transition to a circular economy. Enabling the reuse, repair, refurbishment, remanufacture and sharing of goods in a way that is both economical and reduces the negative environmental impacts associated with the reverse movement of products will be critical.

Improved reverse logistics, that harnesses data analytics and other advanced analysis and decision making tools and processes, can reduce logistics and processing costs, increase value recovery and improve customer response time[28]. One estimate suggests that improved reverse logistics can save retailers approximately 20% of the cost on each returned item and improve margins between 3% and 15%[28].

IMPACT IN CANADA

Using Optoro's performance as a case study for improved reverse logistics, it can be assumed that firms can recover 70% of the 7% net profit lost due to returns. Based on Canada's 2019 retail sales of approximately $615 billion with a net profit of $31 billion, the potential benefits of improved reverse logistics in Canada could include an additional 1.5 billion in net revenue and an additional 4,500 jobs (based on available labour rates)[29,30,31]. Anticipated environmental benefits include waste reductions and avoided emissions.

An estimated **85,00 tonnes of waste**[32] could be avoided per annum in Canada if all retailers used advanced reverse logistics

An estimated **375,000 tonnes of CO2e emissions**[32] could be avoided per annum in Canada if all retailers used advanced reverse logistics

CHALLENGES AND ENABLERS

CHALLENGES

- Companies, regulators and consumers inattention to, or lack of awareness of, the costs and environmental impacts associated with product returns[33]
- Reverse logistics may not be a core competency of the traditional retail supply chain
- Lack of an appropriate performance management system to measure the performance of a company's reverse logistics processes[33]
- The cost to upgrade reverse logistics systems and train personnel may be cost prohibitive, especially for SME's
- A lack of willingness in the industry to share product returns and damages data, information and experiences which leads to:
- The inability to benchmark performance against industry or learn from others' best practices

ENABLERS

- Employing returns packaging that facilitates ease of use and decision making by return logistics personnel
- Collecting and analyzing returns data to identify the primary reasons for return and/or cause of damage and implementing changes in the product supply chain to mitigate the cause of returns, if possible
- Implementing a performance measurement system to measure the performance of reverse logistics processes including the development of key performance indicators including value recovery and waste reduction metrics
- Utilizing advanced data analytics to support decision making and handling processes
- Outsourcing reverse logistics to specialized solutions providers
- Regulations that reduce the ability of firms to dispose of unsold, but viable, goods in landfills.

OTHER SOLUTIONS TO WASTE PREVENTION IN THE RETAIL SECTOR

- Encouraging, product rental versus sales business models
- Incentivizing end of life/ end of use product recovery for value retention or recycling through EPR legislation, landfill bans, etc
- Educating consumers about the environmental impacts of their product choices and consumption habits and how they can reduce their impact
- Enabling, and normalizing, the sharing economy
- Improving product durability and quality for a prolonged use cycle
- Packaging free retail options
- Packaging optimization
- Reusable/ returnable packaging

EMERGING

New technologies such as augmented reality and virtual reality can give consumers a better understanding of their prospective purchases in greater detail by allowing them to view products in situ or otherwise in 3D space. For the fashion industry in particular, new software such as Virtusize[34] and fit analytics[35] used by companies such as ASOS and Patagonia has allowed consumers to get a better understanding of the fit of their items before they purchase them, circumventing the need to order multiple sizes to try on at home.

REFERENCES

1. 1. Statistics Canada. (2020). Table 36-10-0434-03 Gross domestic product (GDP) at basic prices, by industry, annual average (x 1,000,000). https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3610043403
2. Statistics Canada. (2020). Table 14-10-0201-01 Employment by industry, monthly, unadjusted for seasonality. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1410020101
3. Deloitte. (2020). Covid – 19: Voice of Canadians and impact to retailers.
4. PwC Canada. (2020). Environmental sustainability becoming a business imperative https://www.pwc.com/ca/en/industries/retail-consumer/environmental-sustainability-becoming-a-business-imperative.html
5. Cheng, A. (2015). Consumers Return 642.6 billion in Goods Each Year. https://www.marketwatch.com/story/consumers-return-6426-billion-in-goods-each-year-2015-06-18
6. 2015 exchange rate of 1 USD – 1.278711 $CAD
7. KPMG. 2017. Future Proof Your Reverse Logistics. Available from: https://assets.kpmg/content/dam/kpmg/au/pdf/2017/future-proof-reverse-logistics.pdf
8. Bertram, R.F. and Chi, T., 2018. A study of companies' business responses to fashion e-commerce's environmental impact. International Journal of Fashion Design, Technology and Education, 11(2), pp.254-264. Available from: https://www.tandfonline.com/doi/pdf/10.1080/17543266.2017.1406541?needAccess=true&
9. Renwick, D. (2020). The Hidden Environmental Costs of Your Free Holiday Returns. https://www.theguardian.com/environment/2020/jan/02/as-americans-send-back-millions-of-holiday-gifts-theres-a-hidden-environmental-cost
10. Calma, J. (2019). Free Returns come with an environmental cost. https://www.theverge.com/2019/12/26/21031855/free-returns-environmental-cost-holiday-online-shopping-amazon
11. Saltzman, A. (2017). Here's what really happens to all those gifts you return to the store. https://www.cbc.ca/news/business/christmas-gifts-returns-1.3932253
12. Statistics Canada. (2020). Retail sales increase in May. https://www150.statcan.gc.ca/n1/daily-quotidien/200721/cg-a001-eng.htm
13. Digital Commerce 360. (2020). US ecommerce sales grow 14.9% in 2019. https://www.digitalcommerce360.com/article/us-ecommerce-sales/#:~:text=Total%20retail%20sales%20increased%203.8,through%20all%20channels%20jumped%204.1%25.
14. Dissanayake, D.G.K. (2019). Does Mass Customization Enable Sustainability in the Fashion Industry? https://www.intechopen.com/books/fashion-industry-an-itinerary-between-feelings-and-technology/does-mass-customization-enable-sustainability-in-the-fashion-industry-
15. Ellen MacArthur Foundation. A New Textiles Economy. https://www.ellenmacarthurfoundation.org/assets/downloads/publications/A-New-Textiles-Economy_Full-Report.pdf
16. https://unspun.io/pages/aboutus
17. Abraham, Mark, Robert Archacki, Josep Esteve González, Stefano Fanfarillo, and Kerckhove Jean-Francois Van. 2019. The Next Level of Personalization in Retail. Boston Consulting Group. Available at https://www.bcg.com/publications/2019/next-level-personalization-retail.
18. Calculated based on data from (9), (12) and (13)
19. Statistics Canada. 2020. Retail Trade, December 2019. Available at https://www150.statcan.gc.ca/n1/daily-quotidien/200221/dq200221a-eng.htm.

20. European Commission. (2013). Advanced Manufacturing: Mass Customization.

21. Deloitte. The Deloitte Consumer Review: Made – to- order: the rise of mass personalization. https://www2.deloitte.com/content/dam/Deloitte/ch/Documents/consumer-business/ch-en-consumer-business-made-to-order-consumer-review.pdf

22. Pourabdollahian, G. F. Steiner, O.H. Rasmussen and S. Hankammer. (2014). Impact Factors of Mass Customization on Sustainability.

23. Phillips, E.E. (2015). Do Customers Have A 'Constitutional Right' to Return Stuff Ordered Online? https://www.wsj.com/articles/do-customers-have-a-constitutional-right-to-return-stuff-ordered-online-1430490642

24. Optoro (nd). Impact Report 2019. https://info.optoro.com/hubfs/Optoro%202019%20Impact%20Report.pdf

25. Optoro. (2019). Go Beyond Liquidation with a Returns Optimization Platform. https://optoro-corp.s3.amazonaws.com/2019-GoBeyondLiquidation-Infographic.pdf

26. CoreCentric Solutions. (2020). Product Returns Management. https://www.corecentricsolutions.com/services/product-returns-management/

27. Ellen MacArthur Foundation. (2017). Case Studies. CoreCentrics Solutions – A Second Life: returns management, parts recovery and product repairs. https://www.ellenmacarthurfoundation.org/case-studies/a-second-life-returns-management-parts-recovery-and-product-repairs

28. Bain & Company. 2017. How Reverse Logistics Improves Retail Performance. Available at https://www.bain.com/insights/reverse-logistics-infographic/.

29. Statistics Canada. Table 20-10-0008-01 Retail trade sales by province and territory (x 1,000)

30. Statistics Canada. 2020. Retail Trade, December 2019. Available at https://www150.statcan.gc.ca/n1/daily-quotidien/200221/dq200221a-eng.htm.

31. Statistics Canada, tables 20-10-0066-01 and 20-10-0068-01, Annual Retail Trade Survey

32. Calculated based on data from (12), (13) and Optoro. (Nd). Environmental Impact https://www.optoro.com/impact/environmental-impact/

33. Sharma, S.K., B.N. Panda, S.S. Mahapatra and S. Sahu. (2011). Analysis of Barriers for Reverse Logistics: An Indian Perspective http://www.ijmo.org/papers/18-T0023.pdf

34. http://www.virtusize.com/site/

35. https://www.fitanalytics.com/

zeroWASTE

NATIONAL ZERO WASTE COUNCIL

An Initiative of Metro Vancouver