THE NEXT WAVE OF CLIMATE ACTION

How **circularity** can contribute to emissions reductions in Canada

CANADIAN CLIMATE INSTITUTE
L'INSTITUT CLIMATIQUE DU CANADA

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March 2023

Executive summary

Worldwide interest in shifting to a circular economy in which "products are made to last longer, communities share resources and save money, and businesses are maintaining, reusing, remanufacturing and recycling materials to create more value for you and future generations," is growing rapidly (Government of Canada 2022a). Seventy-nine countries referenced adopting circular economy measures in their most recent submissions on Nationally Determined Contributions for meeting climate targets.

The interest in circular economy is logical given that numerous studies have found that current climate initiatives are not sufficient to keep warming below two degrees Celsius or to reach net zero goals. The 2021 *Circularity Gap Report* found that material handling and use accounted for 70 per cent of global greenhouse gas emissions. A shift to zero carbon energy sources or capturing carbon can address some, but not all, of these emissions.

Meanwhile, the 2023 *Circularity Gap Report* notes that, in the past 50 years, material extraction has more than tripled, so the problem of reducing the emissions associated with resource extraction, processing, and product lifecycles has been growing rather than shrinking. That's a concerning trend when studies have also found that five of nine key "planetary boundaries" have already been exceeded.

The Ellen MacArthur Foundation, a leading advocate for circular approaches, has suggested that adopting circularity measures in four key sectors (cement, steel, plastic, and aluminum) could reduce emissions by 40 per cent by 2050. For the agricultural and food sector, they suggest a reduction of close to 50 per cent is possible in the same timeframe by focusing on circular and regenerative practices.

Canada is at a nascent stage in adopting and implementing circular economy principles. This is not surprising given that Canada is a resource-rich country. But even here, it is running up against natural limits and concerns are growing about the impacts on air, water, land, and climate of a "take, make, waste" economy.

Shifting to renewable energy systems will require resources like metals and cement. Meeting this demand through increased resource extraction risks greater emissions and environmental impacts while potentially failing to fill critical gaps. By embedding circular principles in plans for meeting this demand, Canada can be better prepared to reduce impacts and ensure the country has the materials it needs.

Not surprisingly, countries like Japan that do not have significant natural resource wealth have long embraced circular principles, from promoting industrial symbiosis (sharing waste materials among co-located industries), to rigorously tracking material flows, and stripping away barriers to citizen participation in recycling and material recovery. Japan has developed a cultural commitment to maximizing value from resources that other countries can draw many lessons from.

Circularity goes far beyond improving recycling or capturing and reusing waste. It requires a much more sweeping change of industrial, commercial, and consumer mindsets and systems. There are a number of steps a true circularity approach will require including: Designing excess concrete or steel out of buildings, extending the life of products, shifting to "product as a service" models, ensuring materials and products are easy to recycle through better design and reduced contamination, and reducing the size of homes and vehicles. These are the kinds of steps a true circularity approach will require.

Measuring the climate impacts of circular approaches is still a work in progress. However, there are many academic and NGO studies of the potential for circularity to reduce emissions. The 2022 *Circularity Gap Report,* for example, suggests that by adopting its suggested circularity policies, resource demand can be reduced by 28 per cent and greenhouse gas emissions can be cut by 39 per cent.

But much of the emissions reduction potential of circularity remains hypothetical because even countries with strong circularity commitments, such as the Netherlands, Finland, and Scotland, are just beginning to implement their roadmaps for achieving greater circularity. China and Japan may have made greater advances due to rigorous commitments to reducing waste and reusing materials but these countries started this work before adopting their current circularity strategies.

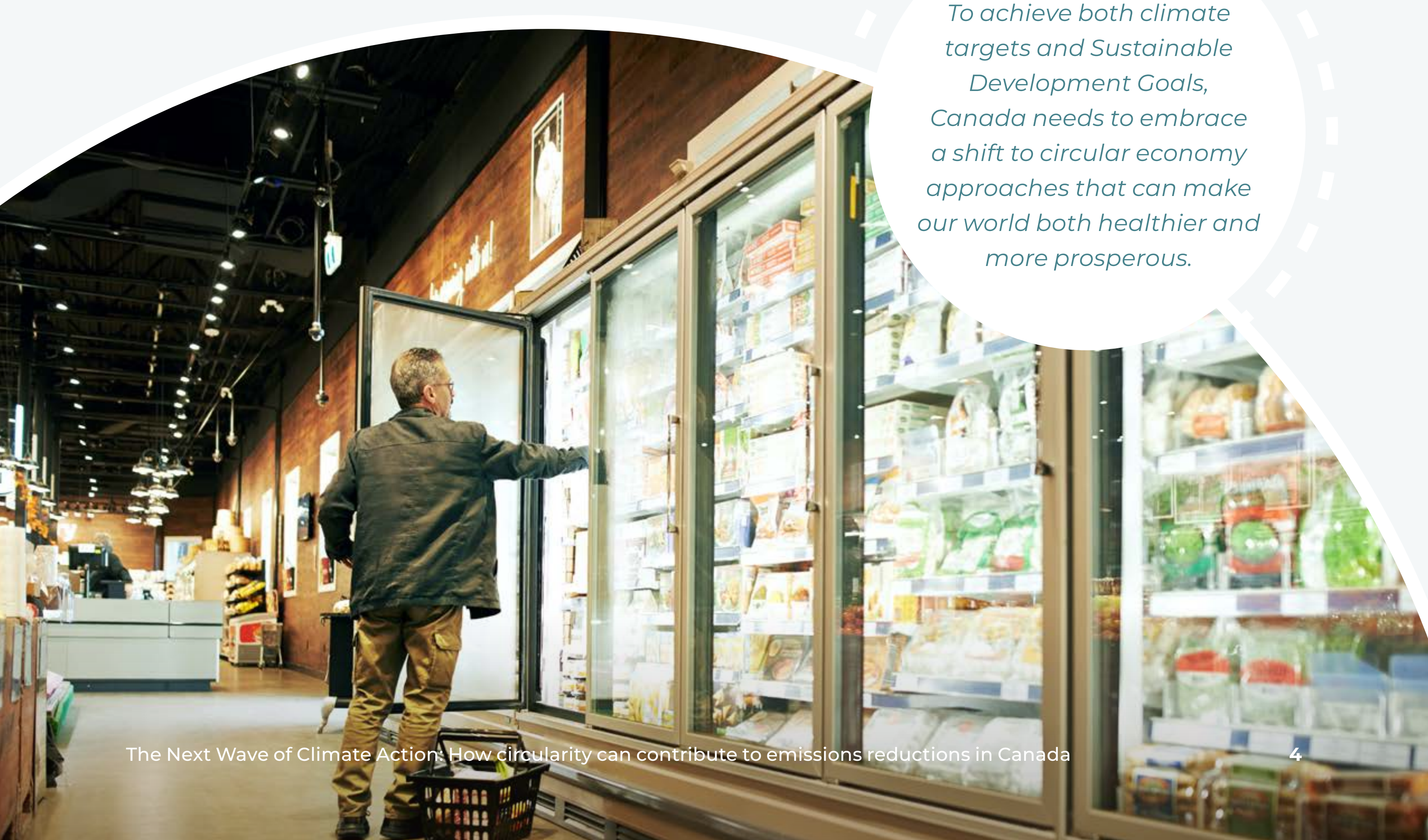
Measuring impact, meanwhile, also remains a work in progress as various international bodies work to standardize measurement approaches and build up a robust statistical framework for properly measuring the emissions outcomes of moving to greater circularity. Better tracking of materials flows, agreement on consumption- versus production-based accounting for emissions, and the ability to compile accounts at regional and national levels are all tasks that countries and international agencies continue to grapple with.

Developing a suite of policies and financial measures to incent circularity will also require that attention is paid to potential rebound or backfire effects, where adopting efficient or cost-saving circular approaches increases product demand or energy use, and results in unintended emissions increases.

There is little question, however, that the global economy must become more circular. The world is currently extracting more than 100 billion tonnes of resources from the Earth each year, a level of exploitation that is simply not sustainable. To achieve both climate targets and Sustainable Development Goals, Canada needs to embrace a shift to circular economy approaches that can make our world both healthier and more prosperous.

This report provides an overview of the current state of play when it comes to our understanding of the potential of circularity to reduce greenhouse gas emissions. While these approaches are not well developed in most countries today, there is no question that future development is likely to be rapid as countries begin to realize the potential of this next wave of climate action.

To achieve both climate targets and Sustainable Development Goals, Canada needs to embrace a shift to circular economy approaches that can make our world both healthier and more prosperous.



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Preface

Environment and Climate Change Canada commissioned this report from the Canadian Climate Institute to examine the potential of a shift to circular economic practices in helping Canada reach its goal of net zero emissions by 2050. We reviewed a mix of primary research and secondary reports summarizing the linkage between improved circularity in economic activities and emissions reductions. We also interviewed key Canadian stakeholders in a number of important emissions-intensive industries, including steel, cement, and plastics, as well as international experts.

This report presents an overview of current thinking around how to improve circularity and the resulting potential for emissions benefits. We focused on efforts that improve material and resource efficiency as a way to complement (and reduce the impacts of) a shift to non-fossil energy sources. We have not endeavoured to provide an absolute projection of what emissions reductions could be achieved by adopting circular practices in Canada. Rather, we have tried to describe the potential, based on both examples from other jurisdictions and examples and projections from within Canada.

The shift to a circular economy is a global phenomenon, but it is still in its very early stages. Countries (and blocs such as the European Union) are just beginning to put in place the policies and practices that they hope will encourage major shifts in economic practices and behaviours. Much of the current literature relies on projections of possible emissions reductions, but these are based on well-defined assumptions about anything from scope of behaviour change to material flow projections. They provide a strong indication of the value of pursuing circular practices—not just from an emissions reduction standpoint, but also for reducing impacts on natural systems, and more broadly for achieving the 17 Sustainable Development Goals outlined in the 2030 Agenda for Sustainable Development, as adopted by the United Nations in 2015.

Introduction

Interest in shifting toward a circular economy is growing rapidly worldwide. According to a summary produced by the U.K. nongovernmental organization WRAP (Waste and Resources Action Programme), 79 countries directly referenced circular economy in their Nationally Determined Contributions as of October 2022. Fifty-four other countries made reference to policies or actions that could contribute to circularity, but don't specifically refer to circularity (WRAP 2022).

This was formalized in the "G7 Berlin Roadmap on Resource Efficiency and Circular Economy" communiqué signed at the G7 Summit in Berlin in 2022, where the countries agreed to a statement outlining various steps to be taken to achieve circular economies. These steps focused on collaborating on developing more resource-efficient approaches including improving product design, shifting to product-as-a-service models (such as replacing individual vehicle ownership with car sharing services) and preventing greenwashing.

The reason for this growing interest is easy to understand. As many reports on circularity point out, a shift to zero carbon energy sources and/or carbon capture mechanisms alone will not be sufficient for most countries to meet their Nationally Determined Contributions and reach net zero greenhouse gas emissions by mid-century, as outlined in the Paris Agreement.

As the recent Working Paper from the World Resources Institute puts it, "Existing pledges and Nationally Determined Contributions (NDC) targets, even if fully achieved, are still not sufficient to meet the Paris climate goals. Considerable additional strategies and actions are urgently needed to close the emission gap" (Wang et al. 2022).

Similarly, the authors of a European Union report on the circular economy conclude, "In order to achieve its CO_2 emissions reduction targets, the E.U. will need to reduce CO_2 emissions associated with materials management because, on a global scale, this accounts for 67% of total global CO_2 emissions. Consequently, the circular economy is at the core of the European

Union's strategy for a climate neutral economy by 2050, as underlined in the 2019 European Green Deal" (Le Den et al. 2020).

In fact, there is a strong consensus that a shift to circularity is the critical "next wave" of climate action, building on a shift away from fossil fuels and efforts to capture emissions.

The Ellen MacArthur Foundation points out that there is a huge upside, beyond just emissions reductions, to shifting to circular economy practices, stating that circular measures could contribute to meeting 12 out of 17 UN Sustainable Development Goals (SDGs). The Canadian Council of Academics says it could help Canada meet 16 of 17 SDGs. Many authors point to the associated benefits of reducing pollutants, water waste, and biodiversity loss by adopting measures that reduce pressure for increased resource extraction and processing and for disposal of waste (EMF and Material Economics 2021; CCA 2021).

As the Organization for Economic Cooperation and Development (OECD) notes, "The per-kg environmental impacts of secondary materials are estimated to be an order of magnitude lower than those of primary materials. Policies that further ramp up the transition to secondary materials use and promote circularity will thus lead to overall reductions in environmental impacts" (OECD 2019).

Or as the 2023 *Circularity Gap Report* puts it "Ultimately, material extraction and use is a strong proxy for environmental damage—driving over 90% of total global biodiversity loss and water stress, for example" (Circle Economy and Deloitte 2023).

What is a circular economy?

There are many definitions of what the term means. The E.U. says simply that a circular economy is an economy "where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste is minimised" (Rehfeldt et al. 2020).

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The U.S. Environmental Protection Agency defines it as "an economy that uses a systems-focused approach and involves industrial processes and economic activities that are restorative or regenerative by design, enable resources used in such processes and activities to maintain their highest value for as long as possible, and aim for the elimination of waste through the superior design of materials, products, and systems (including business models)" (EPA 2021).

Québec Circulaire defines a circular economy as "a production, exchange and consumption system which optimizes the use of resources at all stages of the lifecycle of a good or a service, in a circular logic, while reducing the environmental footprint and contributing to the well-being of individuals and communities."

The Canadian Council of Academies, in turn, defines it as "a systemic approach to production and consumption for living within planetary boundaries that conserves material resources, reduces energy and water use, and generates less waste and pollution" (CCA 2021).

The Québec *Circularity Gap Report* offers an interesting framework for thinking about circularity as a cascading chain of actions. It suggests a "flow" focus, also suggested by the OECD, and Circularity along the following lines:

Narrow flows—use less: The amount of material used or greenhouse gases emitted in the making of a product or in the delivery of a service are decreased.

Slow flows—use longer: Resource use is optimized as the functional lifetime of goods is extended (for example, through improvements to durability or easier access to repair).

Regenerate flows—make clean: Fossil fuels, pollutants and toxic materials are replaced with regenerative sources, thereby increasing and maintaining value in natural ecosystems.

Cycle flows—use again: The reuse of materials or products at end-of-life is optimized, facilitating a circular flow of resources (Circle Economy 2021).

The Ellen MacArthur Foundation has identified three principles that form the basis of a circular economy model: eliminate waste and pollution, circulate products and materials, and regenerate nature.

To summarize, circularity is about maintaining or improving human welfare while demanding less from the environment, using extracted and existing resources more efficiently (through alternative business models, design improvements and reuse, repair, refurbishment, remanufacturing and recycling), using more renewable or recyclable materials with less harmful co-products and pollutants, and powering the system with clean energy. It is a paradigm shift from the existing "take, make, waste" economic structure of today.

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Building on the shift to clean energy

Long-term circularity necessarily includes a shift to clean energy sources to drive circular flows, which is especially important for reducing impacts on climate, water, and local air pollutants. But given that phasing out fossil fuels or capturing their emissions are part of other government goals and existing policy, this report focuses elsewhere.

We are more interested in the opportunity to improve material efficiency as an additional tool for reducing emissions, whether that is by right-sizing or light-weighting vehicles and housing; shifting to product-as-a-service models; redesigning and simplifying products to eliminate waste and to make waste recovery and re-use more effective; changing consumer behaviour to shift (and reduce) energy and resource demands, including increase demand for and acceptance of products containing recycled materials or that have been refurbished; improving product durability and ease of repair; advancing new technologies for material recovery; or addressing the financial barriers to recovery, reuse and refurbishment.

This is only a partial list of the potential measures that a circular economy would be built around. The interplay among these measures is complex and important, but not deeply studied at this point. However, the clear theme is the focus on reducing demand for raw materials using a wide variety of means and then keeping the materials that are used in circulation for the longest time period possible.

As the IPCC notes, achieving a 50 per cent cut in emissions from industrial processes by 2050 will require much more than product innovation and recycling. In fact, it will require steps to reduce primary demand for materials and incentives to do so, including changes to greenhouse gas and resource taxation (IPCC 2022).

The IPCC also points out that another fundamental pillar of a circular economy will be a requirement to focus much more strongly on modifying consumer behaviour, a sector it notes gets much less attention in circular economy strategies than material efficiency and recycling. This focus on demand-side behaviour will require a resetting of consumer relationships with businesses, from being "consumers" to being users of services. The success of this transition will depend a great deal on the push and pull of prices and performance (IPCC 2022).

Canada is at a nascent stage of development in adopting circular measures. Most efforts to date are siloed in municipalities or provinces (notably Québec and British Columbia). The federal government has focused on a few specific initiatives, such as reducing plastic waste, including a ban on harmful single-use plastics and the development of minimum recycled content requirements. But as the authors of Québec 's *Circularity Gap Report* note:

> "Both Canada and the province of Québec lack concrete circular plans or goals; such as the E.U.'s *Circular Economy Action Plan* that sets out 54 actions across waste, landfill, reuse and recycling with end goals set for 2030 and 2035, or the Dutch government's goal of full circularity by 2050" (Circle Economy 2021).

What can circularity achieve?

Modelling is the primary methodology for measuring potential circularity impacts on climate pollution today. Modellers point to the difficulties of weak and missing data in many cases. And modelling the interplay of different measures is less common than modelling the impacts of individual actions or sectors. That said, modelling done by academics (for example, CIRAIG), consultants (for example, Deloitte, KPMG), and nongovernmental organizations (for example, WRI, PACE) finds that well-designed circular economy policies can have significant emissions impact, finding that a mix of circular economy measures can result in significant reductions in the order of 30-50 per cent from the emissions associated with current levels of material production, use, and disposal of products such as cement, steel, plastic, and food.

Given that circular economy measures have numerous co-benefits, from reducing resource scarcity to addressing toxics, while also creating new economic opportunities and employment, there is little question that interest in implementing circular economy is going to continue to rise. At this point, it is really just a question of whether Canada will be a leader or a follower in this trend.

While corporate interest in sustainability, increasing pressure to report (and reduce) Scope 3 emissions, and a growing shift to product-as-a-service business models can all incentivize companies to increase circularity efforts, relying on market mechanisms alone will likely not be sufficient. As the United Nations Environment Programme report on materials efficiency notes, "policy instruments can provide the much-needed stimulation" (Hertwich 2020).

Explicitly incorporating circular economy strategies into Nationally Determined Contribution calculations is a good starting point, and there is valuable guidance available for doing so, including from Deutsche Gesellschaft für Internationale Zusammenarbeit, which has proposed a generic process for countries to incorporate circular economy strategies into their domestic climate policies. As well, UNDP, UNEP, and UNFCCC have developed a guidance toolkit for policy makers to integrate circular economy and other sustainable production/consumption measures into their Nationally Determined Contributions (Hertwich 2020).

Japan, the Netherlands, Finland, China, and the European Union have all adopted relatively comprehensive national circularity programs. It may be time for Canada to do the same.

The emissions-reduction potential of circularity

There are numerous estimates of the emissions reduction potential of a shift to circular economy practices that range from the global to sectoral within countries. The Ellen MacArthur Foundation, for example, states that “applying circular economy strategies in just five key areas (cement, aluminium, steel, plastics, and food) can eliminate almost half of the remaining emissions from the production of goods—9.3 billion tonnes of CO_2e in 2050—equivalent to cutting current emissions from all transport to zero.” That is, circular economy actions can take us well beyond simply shifting to cleaner energy sources.

In fact, the Ellen MacArthur Foundation suggests that measures to switch to renewable energy address only 55 per cent of current global emissions. The remaining 45 per cent of emissions result from extracting resources, producing and distributing products (including food), providing services and disposing of waste, and it is here that a shift to a circular economy can help us close a large gap in current climate strategies (EMF and Material Economics 2021).

The 2022 *Circularity Gap Report* notes that “even if all original [Nationally Determined Contribution]s were fulfilled, the world would still warm up by 3.2-degrees this century and if we include all the updates ahead of COP26, the world would be on track for 2.4-degree warming this century” (Circle Economy 2022).

To keep warming below 2 degrees Celsius, the 2021 *Circularity Gap Report* calculates that the world needs to double the level of circularity from roughly 8.5 per cent of material currently being recovered and cycled back into production processes (Circle Economy 2021). However, global circularity has actually been declining and reached 7.2 per cent in 2022 according to the 2023 *Circularity Gap Report,* due to more and more materials going into long-term infrastructure such as buildings, roads, and durable goods (Circle Economy 2023). As the authors note, this trend indicates that efforts to reduce resource consumption through things like better design, behaviour change, or material substitution are going to be equally or more important than efforts to recover and reuse waste.

For Canada, achieving the needed level of circularity to stay within safe climate limits will be a bigger climb. Québec, for example, is currently considered to be 3.5 per cent circular based on current levels of material recovery and cycling. However, the province's Circularity Gap report projects that it is entirely possible for the province to triple its circularity with measures ranging from designing for circularity to changing procurement policies (Circle Economy 2021b).

The Energy Transitions Commission is equally bullish on the potential to scale up circularity and reduce emissions. Looking specifically at hard-to-abate sectors (steel, cement, and chemicals), it finds it possible to achieve net zero by 2050 at a cost to the global economy of 0.5 per cent of global GDP. It points out, "The technologies required to achieve this decarbonization already exist: several still need to reach commercial viability; but we do not need to assume fundamental and currently unknown research breakthroughs to be confident that net zero carbon emissions can be reached. Moreover, the cost of decarbonization can be very significantly reduced by making better use of carbon-intensive materials (through greater materials efficiency and recycling) and by constraining demand growth for carbon-intensive transport (through greater logistics efficiency and modal shift)" (ETC 2018).

In its analysis of circularity potential for the European Union, Deloitte found that for four key sectors (food, construction, vehicles, and electrical and electronic equipment) there is a potential for savings through "technically feasible and realistic circular economy strategies, between 13% and 66% (depending on the sector and the level of ambition of the circular economy scenarios) ... . On average, the potential savings on these four key sectors is around 33%" (Deloitte 2016).

Larger emissions reductions can be achieved by focusing on demand suppression or extended use measures compared to material recovery and reuse.

In its study of the potential for circularity measures in the automotive and electronic sectors in Canada, Environment and Climate Change Canada estimated reductions of 269,000 tonnes per year in the automotive sector and 339,000 tonnes per year in the electronics sector (Oakdene 2021). The UNEP Materials report found that across the G7, circular strategies could reduce emissions for vehicle production and disposal by 25 megatonnes of carbon dioxide equivalent (CO_2e) per year by 2025 (Hertwich 2020).

A common theme in circularity studies is the idea that larger emissions reductions can be achieved by focusing on demand suppression or extended use measures compared to material recovery and reuse. Essentially, reducing the need for material in the first place through a variety of measures, from avoiding "over-construction" in buildings to shifting to product-as-a-service models, can result in very significant emissions reductions.

As the ECCC study notes, "Emissions embedded in vehicles and electric and electronic equipment can be reduced by 43% and 45% respectively through recycling. But the potential may be significantly increased through product reuse and lifetime extension. Even with relatively conservative assumptions regarding the reuse of products, we demonstrated that the emissions of the electrical and electronic equipment and vehicle industries can be divided by 2 or 3 respectively" (Oakdene 2021).

A recent study by The Atmospheric Fund also found that adopting new design and procurement practices in the building sector could lead to large emissions reductions with little change to the building construction costs or timelines. They calculate that if these practices—from specifying low-carbon cement to eliminating parking spaces—were integrated across Ontario, the result would be avoided emissions of at least 1.5 megatonnes of CO_2e per year. The Atmospheric Fund study points out that for new buildings, embodied emissions are becoming a more and more important factor as the overall energy efficiency of buildings improves in response to building code changes and energy is increasingly sourced from renewable sources. The Atmospheric Fund also points to synergies between measures. Reducing the overall weight of a building by reducing common overstructuring approaches or by substituting lighter materials such as engineered wood for concrete can significantly reduce the concrete required in foundations, for example (Zizzo 2022).

The interplay between circularity measures and increasing use of renewable energy represents an interesting challenge for calculating emissions reductions from circularity measures. As Canada uses more zero-carbon energy to power industrial processes, it may seem like the value of circularity measures decreases from an emissions perspective. But as a number of researchers point out, even under these circumstances, circularity helps to reduce demand pressure on renewable energy systems that are going to be stretched by the rise of electrification in transportation and buildings helping to curb the demand for new materials required to build up even larger renewable energy systems.

As the Council of Academies note in their *Turning Point* report, "Transitioning to net-zero GHG emissions in Canada by 2050 while adopting EU27 circularity practices (Scenario 4) will increase the circularity rate to 20.3% but will have only moderate impacts on reducing material inputs and the circularity gap due to increased extraction and processing of new materials required to produce enough renewable energy to maintain the same energy demand" (CCA 2021). This finding points to the importance of ensuring new renewable energy development is done with a strong emphasis on circularity to avoid a surge in demand for resources and new waste streams.

Circularity measures not only reduce the amount of variable renewable power needed, but also the systemic backups needed to support variable renewable wind and solar, for example, more transmission, batteries, hydrogen, firm clean power sources like deep closed-cycle geothermal, nuclear or fossil generation with carbon capture and storage. Circularity can also play an important role in reducing demand for the metals needed in renewable energy systems or in electric vehicles, as well as the associated impacts of mining and transporting ores and metals.

A larger issue for demand reduction or a shift towards circularity approaches is their greater vulnerability to rebound effects. For example, many studies point to extending the useful life of buildings or electronics as a very high-impact circularity measure. The concern with this is that this may result in foregoing improved energy efficiency performance in newer products or buildings resulting in a "rebound" on emissions reductions. In extreme cases, where energy efficiency or circularity measures lead to higher emissions than before, perhaps due to increased productivity, these measures may backfire. Similarly, if the cost of recycled goods becomes lower through circular initiatives, but this results in increased product demand, a rebound in emissions can result (Koide, Murakami, and Nansai 2022). Some recovery-oriented processes, like chemical recycling of plastics, may also result in only marginal improvements in emissions if it takes large amounts of energy to break the waste down into reusable chemical building blocks.

The IPCC flags the issue of rebound in its discussion of circularity, noting that more study is needed on issues such as maintaining material quantity and quality through multiple reuse cycles and the significant amount of energy required to drive recycling processes (IPCC 2022).

Awareness of possible rebound and backfire effects can help shape effective responses—for instance, retrofitting older buildings to make them more energy efficient (and resilient) or improving local access to repair services. And as the UNEP report notes, “One important implication of the challenge of rebound is the need to consider policy instruments that not only induce improvements in efficiency, but also modulate demand (such as taxes and cap-and trade programs)” (Hertwich 2020).

Of course, much of what we think we know about the potential emissions-reduction benefits of shifting to a circular economy is based on economic modelling rather than real-world observations. With an average world circularity level below 10 per cent, the opportunities to study the real-world impacts of well-established circularity practices are few and far between. Even rarer is an opportunity to study the interplay among multiple measures when many exist only on paper. The importance of these interactions is stressed in a paper on “decarbonization benefits” that notes, “The interaction of the investigated [circular economy] actions is thus an important aspect to consider when modeling [circular economy] actions’ impacts, as they strongly depend on the specific action mix.” The authors go on to recommend that those assessing the potential impact of circularity measures look at four key criteria: impact, applicability, feasibility, measurability (Koide, Murakami, and Nansai 2022).

This is not to say that the models being used, mostly employing standard economic input-output models or lifecycle analysis, cannot be relied upon to paint an accurate picture of circularity potential. But a big limitation in these models is the availability of good data, and especially data on material flows.

As the Council of Canadian Academies notes, Canada’s data on material flows are particularly opaque. As they point out, “Canada does not currently track material flows in a comprehensive fashion (as the European Union does),” which makes it difficult to calculate current circularity rates based on material reuse and recovery (CCA 2021).

One expert interviewed for this study pointed out that another European advantage is the requirement for European businesses to report on much more than simple profitability. They pointed to initiatives like the Canadian Sustainability Standard Board as being useful to address this gap.

With an average world circularity level below 10 per cent, the opportunities to study the real-world impacts of well-established circularity practices are few and far between. Even rarer is an opportunity to study the interplay among multiple measures when many exist only on paper.

In its report on circularity on material efficiency, ECCC also notes the need for better circularity metrics and points to initiatives that could help address this, including Circulytics from the Ellen MacArthur Foundation, Circular Transition Indicators from the World Business Council for Sustainable Development, new guidelines from the FinanCE group, and guidelines from the International Organization for Standardization that are still under development (Smith 2020).

An interesting initiative in advancing measurement of impacts in Canada is the work of researchers from the International Reference Center for Life Cycle Assessment and Sustainable Transition (CIRAIG) on applying circularity modelling to the Québec steel sector. They have created a model based on material flow analysis that they believe builds on current lifecycle assessment approaches to quantify both direct and indirect emissions (for example, from production processes and emissions related to the material supply chain, respectively). They believe their model can be applied to emissions from any sector in any region to calculate both emissions and environmental effects (Binet et al. 2021).

One of the most difficult aspects of measuring the emissions impact of circularity measures is how to account for emissions embodied in products or commodities that cross borders. Extending the life of an electronic device that is manufactured in a country with a high proportion of coal-fired electricity but exported to a country like Canada with a low-emissions system may be an excellent circularity measure, but accounting for actual emissions savings is challenging.

The European Union hopes to address this challenge, in part, with a carbon border adjustment mechanism (CBAM). As the World Resources Institute explains, “The EU … has proposed a phased implementation of carbon border tax between 2023 and 2026, where importers will eventually buy carbon certificates corresponding to the carbon price that would have been paid for their production, had the goods been produced inside the EU” (Wang et al. 2022).

The CBAM will initially apply only to iron and steel (including some downstream products such as nuts and bolts), cement, fertilizers, aluminum, electricity, and hydrogen, but is meant to eventually apply to all carbon-intensive goods.

However, as one expert noted in an interview with the Canadian Climate Institute, the E.U. is going to require much better data on product makeup, disposal, and emissions to make this system work, something it struggles with even within its own internal market, let alone with other countries. However, they note the European Statistical Agency is working to improve data collection to support the E.U.’s circularity strategy. In fact, the three-year initial implementation phase of the CBAM will be solely focused on data collection.

A consumption-based accounting model can also help to address these “split” emissions by focusing on how consumption within one jurisdiction drives emissions in another. As Deloitte notes in their study of European circularity potential, “An important consequence of using a consumption-based approach is that reported emissions are not all taking place in the European territory. If a product consumed in Europe is manufactured in China, the emissions associated with manufacturing are allocated to Europe; and if this same product is manufactured using minerals from Brazil, the emissions associated to the extraction and transportation of these minerals are allocated to Europe as well" (Deloitte 2016).

A consumption-based model can also provide a more accurate picture of a country's true circularity by capturing the emission impacts of the consumption of imported products. As one paper on methods for consumption-based accounting points out, current production-based models can be misleading: "For instance, the territorial emissions of the UK diminished from 1991 to 2004, while the impacts of satisfying UK consumption rose in the same period, a pattern typical for developed countries." A consumption-based system can be used to address this "burden shifting" (Tukker 2020).

The United Nations Environment Programme produced an interesting overview of natural resource use among G20 countries from both a production and consumption perspective. For Canada, it finds that from the consumption perspective, Canada demonstrates a relative decoupling of material footprint and environmental impacts from economic growth. However, it also points out that the costs of climate change impacts in Canada are more than double the G20 average (UNEP 2019).

The E.U. has made it clear that it intends to incorporate circularity in its Climate Plan, saying it will "promote strengthening the role of circularity in future revisions of the National Energy and Climate Plans and, where appropriate, in other climate policies." However, its Impact Assessment for updating targets in its current climate plan, which spells out steps to be taken to reach a more ambitious 50-55 per cent decrease in emissions by 2030, contains only a brief reference to circularity, noting the need to build on current efforts to capture emissions from landfill by focusing on "shifting towards waste as a material resource. Achieving circularity will thus not only reduce the need for disposal of remaining waste streams, it will also reduce the primary resource intensity of our economy and with it the associated industrial and energy emissions. Delivering on this is an integral part of the European Green Deal, as stressed in the Circular Economy Action Plan, but is not ensured under current legislation" (European Commission 2020b).

The E.U. Nationally Determined Contribution references increasing circularity in waste management but does not otherwise highlight circularity initiatives. Canada's Nationally Determined Contribution only mentions circularity in the context of provincial actions, pointing to the intention of the British Columbia provincial government to integrate circularity in its Clean B.C. plan (European Commission 2020c; Canada 2021).

And while many Nationally Determined Contributions reference circularity measures, the vast majority are referring to more limited measures to improve recycling, with product reuse, repair, and life extension being the next most frequently cited measures (WRAP 2022).

Circularity is not a "quick fix" for emissions or meeting other sustainability goals, but has transformative potential.

Measurement

Measuring the impacts of circularity measures on emissions can be challenging because of widely different methodologies, missing data sources, and different models used in different sectors and countries. These measures may also have long timelines that make ongoing tracking of outcomes and longer comparative timeframes necessary to fully understand the impacts of circularity measures. Circularity is not a "quick fix" for emissions or meeting other sustainability goals, but has transformative potential.

The Circular Economy Indicators Coalition is examining these challenges in an upcoming report. It will look at issues such as the differences between different approaches to data (for example, lifecycle vs. material flow) at regional, sectoral, and industry levels, and how these differences could be bridged to create a more seamless analysis of emissions reduction potential.

Researchers working on the project from the Platform for Accelerating the Circular Economy (PACE) note that much of the current analysis on circular emissions potential focuses on suites of actions applied to certain materials or sectors (for example, steel, cement, or transportation). This can be useful in determining the impact of a shift to circularity measures sector-wide, but does not necessarily help governments understand the impacts of a specific policy, they pointed out in a recent interview with the Canadian Climate Institute. They note that most of these models have been developed by either non-governmental organizations, academics, or consultants, and that the individual modelling approaches are often not shared in detail.

Eurostat is now at work on a new approach to more closely link circularity measures to emissions reductions. It is working on a decomposition analysis that it hopes will create a more uniform way of measuring emissions impact. In turn, this work has been taken up by the Dutch statistical agency (CBS) by applying the model to a longer analytical timeframe and comparing results to a more time-consuming statistical analysis. Early results suggest good correlation of outcomes.

Similarly, the European Environment Agency released a methodology for examining linkages in 2020. (Le Den 2020) But again, the usefulness of the methodology is very much determined by the availability of good underlying data. This data is particularly hard to come by for measures like product or building life extension, where estimation of emissions impact has seldom been previously attempted, note the PACE researchers.

Translating results from micro or sectoral levels to national levels can also be quite challenging, they note, due to different methodologies and data collection approaches. This means that translating results from these finer-scale initiatives to progress toward achieving national goals may not always be possible without significant further analysis. The Circular Economy Indicators Coalition will examine these challenges in detail in its upcoming paper.

A new source of finer-scale data may also emerge from companies reporting Scope 3 emissions. At this level, the Horizon Zero Initiative is focused on improving consistency and comparability in emissions reporting by developing new carbon accounting standards. As the Rocky Mountain Institute explains, there is a pressing need to develop more harmonized approaches: "First, and necessary to build a foundation for everything else, is the creation of open standards for the exchange of emissions data — to do for carbon accounting what the introduction of SWIFT banking standards did for international finance; what HTTP, HTML, CSS, and JavaScript did for the web; and what the shipping container did for international trade. Standardization can have profound effects."

The Rocky Mountain Institute points to the PACT format developed by the World Business Council for Sustainable Development and itself as an example of a technical standard that can expedite data sharing between different sectors. This sort of standardization could, in turn, help to create valuable building blocks for tracking of circularity impacts at higher levels by making it possible to more easily aggregate and compare data.

While these systems remain a work in progress, there are a handful of efforts to track the current impact of circularity initiatives. Eurostat has created a monitoring framework for circular economy actions across the E.U. It compiles indicators for production and consumption, waste management, secondary raw materials, and competitiveness and innovation.

The E.U. is currently revising its indicators and has been urged by nongovernmental organizations to expand the focus to better capture a circular economy hierarchy. Intervenors suggest that the following indicators be added in some form:

- Average duration of use of a product before the first repair;
- Average product lifespan until it can no longer be re-used or repaired;
- Share of products repaired rather than replaced;
- Share of second-hand products in total sales of manufactured goods in the E.U.;
- Share of non-repairable and non-reusable products that are repurposed (without being recycled);
- Average rate of equivalent secondary material in each product category;
- The share of raw materials used in the E.U. that are sourced from the circular economy (reusing, repurposing and recycling of materials already present in the territory) (EC2022 2022).

The OECD has an inventory of circular economy monitoring measures, but these are drawn from a small subset of countries, regions, and cities—mostly European. However, it does provide a good overview of the types of measures that are currently being tracked in various monitoring plans (OECD 2021).

The United Nations Economic Commission for Europe listed the following initiatives underway as of 2021 in its Terms of Reference for a Task Force on Measuring the Circular Economy (in which Canada is a participant):

- The "Bellagio process": the European Environment Agency in partnership with the Italian Institute for Environmental Protection and Research aim to build consensus on *what* to monitor and use best-practice examples as well as innovative ideas to identify shared principles on *how* to monitor;
- Eurostat's work related to the E.U. Monitoring Framework for the Circular Economy, including methodological development on measuring the circularity rate and improvements of Sankey diagrams;
- OECD's Expert Group on a New Generation of Information on Waste and Materials: This small expert group, in its work program for 2020-2021, was tasked with developing a conceptual framework for circular economy metrics for policy making, and preparing guidance on information and indicators needed for the transition to a resource-efficient and circular economy;
- The United Nations Committee of Experts on Environmental-Economic Accounting (UNCEEA) is working on a publication highlighting narratives and use cases for the SEEA's application to policy;
- Joint UNECE and FAO work exploring the issue of wood-based value chains in a circular economy;
- UNEP methodological work related to economy-wide material flow accounting in the context of sustainable production and consumption.

The Commission expects to finalize recommendations by the spring of 2023 (UNECE 2021).

The UNEP notes that more work needs to be done on tracking economic effects of circular economy measures, stating, “There are ways to represent material efficiency strategies in a simplified manner, through implementation curves and resulting reductions in materials demand within scenario models, such as those used in climate change mitigation research” (Hertwich 2020).

In Canada, the methodology developed by CIRAIG researchers can project potential savings from sectoral circularity measures. As the researchers note, “Our study expanded the scope of the analysis to account for the whole value chain of a material and provided a general framework and decision tree to guide a practitioner in applying it in any context to assess mitigation potential of circular economy strategies for any material in any region” (Binet et al. 2021).

Deloitte has suggested circularity measures for Canada in its 2019 report, *Economic Potential for Circularity in Canada,* that range from the economic value of materials recycled and reduction in use of raw materials to success in reducing jurisdictional complexity to social and health impact. Measures can be scored on a scale from “no impact” to “significant positive impact,” with an additional score given to indicate if an initiative has potential negative (rebound) effects, which allows potential trade-offs to be explored (Deloitte 2019).

Midsummer Analytics prepared an overview of many of these initiatives for ECCC in 2020 that contains actionable recommendations for addressing data gaps, from investing in the expansion of Statistics Canada Physical Flow Accounts to cover outputs of plastics, common air contaminants, sewage and nutrients, and household use of goods, to expanding tracking of product-as-a-service initiatives, starting with automobile sharing (Smith 2020).

Sectoral opportunities

In this section we look at the emissions-reduction potential of the circular economy, and challenges for key sectors in Canada: metals and mining (primarily steel), construction (primarily concrete), plastics and petro textiles, and food and organic waste. Some of these sectors (such as steel and cement) are considered hard-to-abate sectors, where potentials for emissions reductions from circularity practices are particularly significant opportunities. .

Metals

Metal recycling, particularly for steel, is a well-established practice, with 80-90 per cent of iron products recovered for recycling globally and global steel production relying on feedstocks of about 30 per cent scrap iron (Bataille 2020; SteelMint 2022). Canadian steel demonstrates high rates of recycling and also makes up a significant portion of the value of Canada's mineral exports (NRCan 2023). Canada produces about half as much scrap steel as it does steel, and, according to the Canadian Steel Producers Association, roughly 40 per cent of steel production in Canada relies on scrap iron (Kelleher 2020). Using secondary recycled scrap significantly reduces emissions from primary steel production, producing roughly one quarter of the emissions of producing steel from primary materials using average global electricity carbon intensity factors (from the use of electric arc furnaces) and standard practices (for example, preheating of scrap with fossil fuels). By using low-carbon electricity and not preheating with fossil fuels, those emissions reductions potentially drop to one-twentieth of conventional production (Baitalle 2020; Bataille 2021; Fennell 2022).

However, there is still a large role for circularity measures for metals with high rates of recycling. Steel recycling's biggest limiting factor, besides simple availability of scrap, is the quality of the end product when care is not taken to adjust for contaminants. Recycled steel is generally considered inferior and used for lower-value products (for example, “longs” and construction rebar rather than thin sheet “flats” for automobiles). This is largely due to contamination, particularly by copper or other alloys, in the feedstock scrap—for example, if copper wiring isn’t removed first due to lack of incentives to do so (Daehn 2017). Contamination is a common recycling challenge for a range of metals (Söderholm and Ekvall 2019).

Various strategies have been put forward for improving the quality of scrap metals, such as designing products for easier disassembly and separation of the component metals to lower contamination risks or limiting use of alloys in products (Sun, Lettow, and Neuhoff 2021). These would allow wider use of recycled metals, reducing emissions. Deloitte notes that steel production accounts for about half the emissions attributed to the automotive sector in Europe. In fact, they point out that steel is the major component in most large consumer appliances, making easier product disassembly along the steel supply chain an impactful opportunity (Deloitte 2016).

Others have suggested using materials more strategically, such as by only using the necessary amount of material, and substituting when appropriate. As the CIRAIG steel study notes, overspecification and use of only one or two types of structural beams is thought to lead to the use of about 50 per cent more steel than necessary in structures (Binet et al. 2021). Meanwhile, less conventional materials can be substituted if they offer superior outcomes. Engineered wood could be used in buildings, for example, and plastics are now much more common in automobiles. Wood is already a common construction material in Canada, but its use could be expanded in larger buildings where steel and concrete are dominant.

Another major problem with recycled metal is a lack of trust in the end product. Certification processes could be useful in addressing this issue if recycled metal products can be proven to meet higher standards.

Authors of a new study in *Nature* make the point that while efficiency in steelmaking has improved remarkably in recent decades, these improvements have now largely plateaued. Meanwhile demand for steel continues to rise, generating opportunities for new innovative practices to reduce emissions (Iannuzzi and Frankel 2022).

The *Nature* study points to a largely under-reported source of this demand: the need to replace corroded steel. They note that steel production accounted for almost 3,800 megatonnes of carbon dioxide globally in 2021, of which they estimate 560–1200 megatonnes could be associated with the replacement of corroded steel, or about 1.6 to 3.4 per cent of total global emissions. Adopting best practices for reducing corrosion (for example, expanding the use of stainless steel or coverage with paint and plastic liners) could therefore significantly reduce emissions from steel production by avoiding the need to replace corroded materials. They suggest that the need for steel to replace corroded materials could be reduced by 14–33 per cent by wider adoption of current best practices, and that this avoidance could be increased through new technologies.

Iannuzzi and Frankel go on to propose the adoption of a certification system they call "a total energy and CO2 (TECO2) rating," which would include the total energy required to produce the material and manufacture the final product, as well as the resulting lifecycle emissions, including those from corrosion. If procurement efforts were to focus on the TECO2 rating, avoiding corrosion would become an important component of project management and construction approaches. One such approach would be wider use of rust-resistant alloys. While the use of such alloys would increase the energy intensity of production, it would also result in much longer material lifetimes, thereby producing a net reduction in lifecycle emissions.

This is an example of how both new technologies and certification systems could combine to drive circular approaches to critical infrastructure decisions—a crucial intervention given the large amount of metals and minerals of all kinds required for everything from a shift to green energy, to a build-out of transit, to addressing current infrastructure deficits.

One expert interviewed for this study noted that low demand for recycled products and low prices for non-recycled materials deny producers an incentive to expand recycling efforts. Similarly, current tax treatments are a disincentive to using recycled materials. Smart Prosperity notes, "the marginal effective tax rates on the scrap and waste sector were found to be higher than the mining sector, and final products using recycled materials taxed more heavily on average than those using virgin materials. The largest difference was for metal products" (Cairns 2020).

This may change with growing demand for metals due to the growth of the electric vehicles and renewable energy industries, as will opportunities to source end-of-life metals from solar panels, wind turbines, and batteries. However, consideration will need to be given to product design to improve recyclability. For example, solar panels could be designed to reduce the use of silver, which would also help reduce the cost of panels. And panels could be constructed with plastic coatings that make recycling easier than the ones currently in use (Cairns 2021).

As another example, while Teck has a long-established lead-acid battery recycling operation in Trail, British Columbia, an entirely new facility would be required to recycle lithium ion batteries. Such a facility would also require a steady supply of end-of-life batteries in quantities the western Canadian market alone probably could not supply. That in turn points to the need to develop better policies to ease cross-border shipments of materials like batteries. It will also require the development of a battery recycling "ecosystem," with smelting being the last step after battery disassembly or shredding. Developing clusters that can feed materials to these new recycling processes and that can uptake the resulting recovering products will be critical.

Initiatives to reduce emissions from the steel sector have focused heavily on shifting to zero emissions power, fuel substitution, and carbon capture. But currently, electric arc furnaces produce a lower-quality steel because they run on partially contaminated scrap. We learned from one expert interview that large quantities of high-carbon-intensity steel are imported

Many consumer electronic components are literally glued together for durability, a condition that also complicates repair.

into Canada from places such as China. These factors point to the value of reducing steel demand via circularity in higher-end uses such as automobiles, appliances, and buildings.

Electronics are also a major potential source of metals for recovery or for demand reduction via circularity. But recovering metals from electronics presents a number of challenges, according to the U.S. National Institute of Standards and Technology (NIST), which explains that while the volume of electronics, batteries, and solar panels is rapidly increasing, the products themselves contain progressively lower concentrations of high-value materials (for example, precious and critical metals), which makes recovery more challenging and expensive (Schumacher 2021).

There is also a trade-off between the types of materials that can be recovered, NIST adds. Bulk recovery through shredding is useful for recovering high-content materials such as glass, aluminum, steel, and copper, but much less useful for recovering precious and critical metals, particularly with the purity needed to reintroduce them directly into the supply chain (for example, solar-grade silicon).

This problem is exacerbated by the design of many consumer electronic products, where components are literally glued together for durability, a condition that also complicates repair (Schumacher 2021).

The E.U. is responding to this challenge with an Ecodesign Directive under its circularity action plan, which will set standards for energy efficiency and durability, reparability, upgradability, maintenance, reuse, and recycling.

Europe is already well ahead of Canada in recovering consumer electronics. According to the Canadian Construction Association, "in 2016, Canada recycled less than 14% of the total electronic waste generated that year. In 2019, 17.4% of e-waste was recycled globally, and world-leading Europe recycled 42.5% of its e-waste" (CCA 2021).

Shifting to a product-as-a-service model as a way of reducing emissions from the replacement of electronic goods like computers and printers is a strategy that HP Canada has been exploring. Their internal study of the effectiveness of a shift to providing things like computers as a "service" rather than a retail product found that "[product-as-a-service] systems outperform conventional retail systems across all environmental categories" (HP 2020).

For computers, for example, the study found that product-as-a-service models reduce greenhouse gas emissions by 25 per cent and improved resource efficiency by 28 per cent. Even larger benefits were delivered by the company's Instant Ink program, which resulted in greenhouse gas emissions being reduced by 73 per cent, resource efficiency improved by 73 per cent, and water use reduced by 70 per cent. Essentially, the program gives HP an incentive to rethink its product approach, with the company pointing to things like higher-capacity cartridges, less packaging, and higher recycling rates along with improved distribution efficiency driving these savings (HP 2020).

What is not driving these savings are current extended producer responsibility programs, noted one expert interviewed for this study, who also sees a need for stronger government procurement efforts for "green" products and services. In particular, governments need to do more to spark demand for recycled plastics, they noted in an interview with the Canadian Climate Institute.

The Québec government, in consultation with CIRAIG, has looked at the potential for circularity in the province's mining industry, and highlighted 13 strategies that could enhance recovery of iron, copper, and lithium. These ranged from "mining" urban waste to accelerating car-sharing services. However, the challenge for Québec as with most mineral-producing regions of Canada, is that the vast majority of the metals mined in the province are exported, so adopting these strategies within the province will have only a minimal impact on Québec's emissions.

Cement and construction

The construction sector is a major source of emissions, but mostly from the embodied emissions in the products used to construct buildings rather than from construction activities themselves.

Both Deloitte and the UNEP estimate that a suite of circular strategies applied to construction could reduce emissions by around one third. UNEP notes, "In 2016, the recycling of building materials saved 15 to 20 per cent of the emissions in the primary production of materials for residential buildings in the G7. Under optimistic assumptions, improved recycling could save an additional 14 to 18 per cent" (Hertwich 2020). Deloitte states, "further product reuse strategies need to be implemented to reach more significant reductions (up to 34% with our assumptions)" (Deloitte 2016).

The potential for redesign and smarter procurement to significantly reduce the embodied emissions in buildings was highlighted in a recent report by The Atmospheric Fund that found that "Substituting the best available materials in just five categories could achieve reductions of 50-75%, at little to no additional cost" (Zizzo 2022).

Both Deloitte and the UNEP estimate that a suite of circular strategies applied to construction could reduce emissions by around one third.

The Global Cement and Concrete Association's *Concrete Future* roadmap report foresees 22 per cent of total emissions reductions coming from efficiency in design and construction, which includes reuse of materials, and still allocates the bulk of emissions reductions to a switch to zero-carbon electricity and carbon capture. They note, "The primary means of unlocking design levers is ensuring that reduction of CO_2 emissions becomes a design parameter in addition to the current parameters of quality, cost, speed and specific project client requirements" (GCCA 2021).

They also point out that captured carbon dioxide can be used in new product development, including the manufacture of artificial aggregates, curing concrete and carbonation of recycled concrete. These processes are largely still under development, including by Nova Scotia-based Carbon Cure.

In the shorter term, efforts to reduce the emissions intensity of cement are focused largely on decarbonizing energy sources through a switch to renewable and waste energy and carbon capture. There are, however, other steps that can be taken. Up to 50 per cent of the "clinker" in cement production, the most CO_2 intensive element in the manufacturing process, can be replaced with substitute cementitious materials, including waste materials such as fly ash and blast furnace slag and naturally occurring volcanic pozzolan minerals. Fly ash and furnace slag may, however, both become more scarce as the world shifts away from coal-fired power and conventional steel production. The Global Cement and Concrete Association suggests that an alternative may lie in recovering materials from old quarries and mine sites, noting, "activating low-grade minerals and quarry wastes to produce calcined clays, can provide a sustainable new stream of cementitious materials with global potential."

In fact, it should be possible to completely offset any decline in fly ash or blast furnace slag with limestone calcined clay cements, according to LC3. Using the "Limestone Calcined Clay" process, one third ground limestone and two thirds ground calcined clays, which are available globally, can replace up to 50 per cent of clinker in most cements without degrading performance and can eliminate up to half the emissions from cement making. (LC^3 2023) Currently, cement production accounts for 1.5 per cent of Canada's total greenhouse gas emissions, or 11.2 megatonnes in 2019 (ISED 2022).

The Québec *Circularity Gap Report* notes, "in Canada, 3.4 million tonnes of construction materials are sent to landfill on a yearly basis, comprising approximately 1.8 million tonnes of embodied CO_2e. If the construction sector were to prioritize disassembly over demolition—reusing up to 85% of materials—emissions could be axed by as much as 1.3 million tonnes CO_2e per year and waste volumes cut by 2.5 million tonnes" (Circle Economy 2021b).

Among that waste is reinforced concrete, where efforts to reduce steel corrosion would reduce the need to not only replace steel but to replace even more emissions intensive concrete (Iannuzzi and Frankel 2022).

Optimizing concrete specification is another example of a way to combine both design and technology measures in a circular way to reduce emissions. Well-made concrete that requires more energy to produce could be further limited to building parts where compression strength is required and avoided where it is not.

The federal government's *Greening Government Strategy* committed to diverting 90 per cent of all construction waste from landfills on federal projects, as well as reducing the embodied carbon in major government construction projects by 30 per cent and conducting lifecycle assessments by 2025 (CCA 2021). However, as populations grow and renewable energy infrastructure rapidly expands, demand for materials will also grow. As the UNEP report notes, "Looking at a clean energy scenario, cement use in the electricity system almost doubles, while iron and copper consumption would increase by approximately 10 per cent until 2050" (Hertwich 2020).

Some of the strongest circularity measures for the construction sector are reducing material usage in buildings through improved design or by reducing floor area and extending the life of existing structures, while also making new ones easier to disassemble and recover materials. It is projected, for example, that lightweight design could reduce the weight of load-bearing elements in buildings by 40 per cent (Circle Economy 2021b). But these are long time horizon actions for having widespread impact on emissions.

Substituting wood for concrete is something many circularity studies consider, although use of wood is already widespread in the Canadian construction sector, particularly for residential construction. Efforts to substitute wood have to consider what level of harvest can be reasonably sustained without impairing the ability of forests to absorb carbon and support biodiversity. As the Energy Transitions Commission notes "To replace 25% of the 6.4 billion m^3 of concrete used each year with timber would require an increase of global forest cover of about 14%—a land area representing 1.5 times the size of India" (ETC 2018).

In its study of how circularity could reduce cement production emissions, the E.U. found, "In the high ambition scenario, the applied circular economy actions thus reduces the overall emissions of the construction sector related to cement/concrete manufacturing, transport and use by about 58% (91.45 Mt)" (Rehfeldt et al. 2020).

The study goes on to say, “Among the circular economy actions with the strongest individual contribution are the use of new cement types for pre-cast concrete elements (23.49 Mt), increased use of timber as building material (19.01 Mt) and reduced space use in buildings (18.91 Mt offices and 5.31 Mt residential buildings)” (Rehfeldt et al. 2020).

In an interview with the Canadian Climate Institute, one expert noted that reprocessing of construction materials to recover aggregates and unreacted cement is entirely possible. With aggregates in particular, they noted that the industry recognizes that new quarries are emissions intensive and extremely difficult to get regulatory approval for, which is generating interest in using recycled aggregate. However, the expert also explained that there are many provincial and municipal regulatory barriers limiting the use of recycled aggregate. Meanwhile, reusing unreacted cement recovered from reclaimed concrete avoids the need for the energy-intensive process of creating cement as a precursor to producing concrete.

The interviewee said that beyond carbon pricing, what would help jumpstart initiatives to produce new, lower-carbon products and to recycle existing materials would be an effective carbon contract for differences that would give the industry the certainty it needs to proceed with initial projects. Efforts will also be needed to shift demand to these new products, which currently lags behind efforts to increase supply.

There is no question in the interviewee’s mind that other jurisdictions will embrace efforts to produce lower-carbon products, which puts pressure on the Canadian industry to compete.

Plastics and petro textiles

Plastics are an area ripe for circularity. Currently, even basic recycling of just a fraction of post-consumer plastic products is at very low levels worldwide.

As Energy Transitions Commission notes, “While claims are often made that, for instance, the EU achieves 30% plastics recycling, the true figure is only about 10%. Moreover, it can be argued that most current recycling does not achieve ‘closed loop’ recycling into equally high quality and high-priced plastic products (for instance, polyethylene terephthalate (PET) bottles recycled into PET bottles), but downcycling into lower value plastics (for instance black pots). With radical changes to the way in which plastics are used and handled, 28% of all plastics demand could be eliminated or substituted, while 25% of all plastics could be recycled and 2% re-used, delivering a 56% reduction in global lifecycle emissions from plastics” (ETC 2018).

ECCC’s own study of plastic waste in Canada reported, “The Canadian plastics economy is mostly linear, with an estimated nine percent of plastic waste recycled, four percent incinerated with energy recovery, 86 percent landfilled, and one percent leaked into the environment in 2016.”

British Columbia has recently made significant headway in recovering post-consumer plastic waste for recycling in-province in response to the closure of offshore processing options. The province now has a "blue box" plastics recovery rate of 57 per cent (as of 2021). But how this recovered plastic is actually being used is not clear, and much of it is still likely being downcycled.

Almost half of the plastic waste in Canada comes from packaging (47 per cent), but there are also significant amounts coming from end-of-life automobiles (9 per cent), textiles (7 per cent) and electronic equipment (7 per cent), according to ECCC. Interestingly, the construction sector is now a very large user of plastics, consuming 26 per cent of plastic put into the market. Much of this plastic is embedded in buildings and appliances that remain in use, but this will become a growing source of plastic waste in the future. Extending building life therefore has become an important circularity strategy for not just concrete and steel, but plastics as well (Deloitte and Cheminfo 2019).

There are two major hurdles to plastics recycling. The first is a lack of adequate municipal infrastructure. Industry may have an incentive to help municipalities address this problem through extended producer responsibility programs, but it will be difficult to ramp up recycling without better collection and sortation systems.

The second hurdle is the very mixed nature of plastic waste, with various different polymers used or combined in different products and then mixed with "plasticizers," colourings, and other additives. This huge product spectrum makes high-level recycling difficult as there is little purity in the products entering the system. This may account for the wide range in emissions reductions achieved by recycling different plastics, with the Chemistry Industry Association noting that these can range from 5 to 95 per cent lower emissions compared to processes using primary materials.

It has been suggested that recycling could be improved by using AI systems to help sort waste streams, better labelling of plastics so recyclers can better sort incoming streams, and simplification of product makeup by banning certain additives or standardizing a common number of additives (Sun, Lettow, and Neuhoff 2021; BASF 2020)

There is also interest in developing chemical recycling processes where the plastics are broken down into their original polymers, which can then be used to produce any number of products. However, development of chemical recycling processes is still at an early stage and there is concern about how energy intensive the process could be. As researcher Xi Sun notes, "it is still uncertain to what extent mixed and contaminated plastic waste can be recovered in chemical recycling processes, thus the purity of waste inputs is likely to remain important" (Sun, Lettow, and Neuhoff 2021).

Similarly, there has been hope that extended producer responsibility programs would lead to progress on recycling plastic waste, but to date, the evidence is that there is little incentive in these programs for producers to invest deeply in higher quality recycling. In fact, one of the greatest shortcomings of the programs is that they mostly emphasize end-of-life recovery and have not spurred any significant interest in redesigning products to reduce waste in the first place (for example, simplifying product makeup, reducing packaging, or substituting other materials).

As Sustainable Prosperity notes, “To date provinces have implemented their own [extended producer responsibility (EPR)] programs, resulting in a patchwork of product stewardship, partial EPR, and full EPR programs, covering different materials and [using] different definitions, reporting mechanisms, and governance structures. Further, existing EPR programs in Canada have not been designed for environmental improvements in products necessary for a circular economy” (Jagou 2021).

ECCC’s review of plastics in Canada recommended a number of different circularity measures, including a focus on extending the life of durable goods (for example, appliances), which contain some of the hardest-to-recycle plastics, by improving levels of reuse, repair, and remanufacturing.

California recently passed a bill that will require State approval for recyclability labelling on plastics (the “chasing arrows”). The goal is to reduce misleading claims about the recyclability of products and to make it easier for recyclers to understand the composition of products by improving accuracy (California Governor 2021). While such regulations are also being considered in Canada, the chemical industry feels they are premature in the absence of better recycling infrastructure.

With the Canada-wide Strategy on Zero Plastic Waste seeking to reduce the amount of plastic waste produced per capita in Canada by 30 per cent from 2014 to 2030, adopting circular approaches that reduce the use of plastics in the first place will play an important role (ECCC 2022).

Along with durable goods, one of the hardest-to-crack areas of plastic use when it comes to recycling is textiles. The rise of fast fashion has led to a dramatic increase in textile waste. As NIST reports, “According to U.S. EPA data, textiles comprised 5.83% of the total municipal solid waste (MSW) stream generated in the U.S. in 2018 (roughly 17 million tons), a linear increase of 80% on a per tonnage basis since 2000. This is a drastic increase compared to the overall waste stream which increased only 20% over the same timeframe” (Schumacher 2022).

While most of these textiles are not produced in Canada, demand in Canada is driving emissions from an industry that is now dominated by the production of petro-fibres, often in countries with high-carbon power systems. For municipalities, dealing with the resulting waste is also becoming a larger and larger burden.

Fast fashion emissions are also being heavily driven by a shift to online sales. Fashion Takes Action notes that one retailer reported that as much as 40 per cent of clothing bought online

is returned. This represents significant transportation emissions. Plus, few retailers have the capacity to properly deal with these returns (restocking or off-selling) and a high percentage is simply landfilled. Fashion Takes Action notes that changing "duty drawback" provisions in the Customs Tariff and the Financial Administration Act would reduce the incentive for retailers to destroy returned goods that were imported for sale in Canada in order to claim a duty refund (Drennan 2021).

Extending use of clothing is a first step for circularity in textiles. Fashion Takes Action reports that, in a survey done for beauty brand Maybelline of 2,000 women in the U.K., the respondents reported wearing clothing items on average seven times before disposing of the garment. The Ellen MacArthur Foundation notes that if the average number of uses per garment were doubled, greenhouse gas emissions associated with textile production and transport would be 44 per cent lower (Wang et al. 2022).

Similarly, the Council of Canadian Academies notes, "Increasing the circularity of textiles would also have positive environmental impacts, as textiles production is responsible for generating more annual GHG emissions than all international flights and maritime shipping combined" (CCA 2021).

Currently, the preferred method of dealing with used textiles is to try to divert them to resale through thrift shops. But only a small fraction of even the donated goods that make it to these stores are eventually resold. The vast majority ends up being sold to sorters who may separate out natural fibres for "ragging" and send the rest overseas.

As NIST says about U.S. collection efforts, "a majority of the 15% of textile products collected are exported to low income regions for resale, although there is skepticism regarding the sustainability and benefit of this practice" (Schumacher 2022).

There are attempts underway to make better use of used textiles. In Canada, Loop Industries (Terrebonne, Québec) has developed a technology to depolymerize PET plastic and polyester fibre, including plastic bottles, packaging, carpets, and textiles, according to Fashion Takes Action.

Other examples cited by Fashion Takes Action are Jasztex in Montreal, which converts non-woven fabrics into insulation material, blankets, or filters. In the U.S., Shear Composites bonds the shredded fibres from old denim with a bio-based resin to create sheet material or compression-molded items used in furniture, countertops and work surfaces, plates, and even jewelry.

Collaborations to advance textile recovery currently exist in Ontario, Nova Scotia, and Québec: the Ontario Textile Diversion Collaborative, the Association for Textile Recycling in Nova Scotia, and MUTREC in Québec.

Still, almost all recycled fibre found in textiles today comes from PET bottles. As the beverage industry shifts to higher-value bottle-to-bottle recycling, this source could decline and the need to recover fibres directly from textiles could grow.

Food and organic waste

According to the National Zero Waste Council, a third of all the food produced and delivered in Canada is never eaten. The Commission for Environmental Cooperation, meanwhile, estimates that Canada generates roughly 13 megatonnes of food waste each year (CEC 2017).

Reasons for food waste noted by the Commission for Environmental Cooperation include:

- overproduction by processors, wholesalers, and retailers;
- product damage;
- lack of cold-chain infrastructure (refrigeration during transportation and storage);
- rigid food-grading specifications;
- varying customer demand; and
- market fluctuations.

Recovering nutrients like phosphorus and nitrogen from organic waste and wastewater is a valuable strategy, as phosphorus and nitrogen are the highest onsite contributors to climate change from grain farming. The emissions embodied in grains are, in turn, the largest share of emissions from milk and dairy production.

Agriculture Canada attributes the agricultural sector's emissions to three main sources: enteric fermentation (24 megatonnes of carbon dioxide equivalent), crop production (24 megatonnes), and on-farm fuel use (14 megatonnes). It notes that agriculture was responsible for approximately 10 per cent of Canada's greenhouse gas emissions in 2019 (73 megatonnes).

The E.U. has estimated that bio-waste could substitute up to 30 per cent of inorganic fertilizers, adding that today, only 5 per cent of bio-waste is recycled and used as fertilizers.

The Ellen MacArthur Foundation points to the value of regenerative agricultural practices in reducing emissions, noting that if 80 per cent of the world's cropland adopts practices such as zero till, intercropping, and cover crops, it could lead to an annual carbon benefit of 2,500 megatonnes of carbon dioxide equivalent; while managed grazing on half of the world's suitable pastureland could lead to a net annual carbon benefit of 1,400 megatonnes in 2050.

The report adds, "Furthermore, nutrient cycling, through practices such as composting and applying manure, can improve the productivity of soils by improving water retention, reintroducing soil microbes and adding nutrients, thereby reducing demand for chemical fertilisers and irrigation on degraded soils. This reduces emissions from fertiliser production and emissions associated with the energy use for irrigation" (EMF and Material Economics 2021).

Many studies of food waste talk about changing consumer behaviour. In particular, they favour encouraging consumers to shift diets away from high-emission products such as meat. But as one expert noted in an interview with the Canadian Climate Institute, these types of consumer behaviour changes can take time and present higher uncertainty. Interestingly, Statista reports that per capita meat consumption fell by 13 per cent in Canada between 2000 and 2021, with per capita consumption of beef falling by 31 per cent over the same period, so there is some evidence that this shift is underway, perhaps in response to a combination of climate and health messaging (Shahbandeh 2022).

According to pollster Angus Reid, younger generations are much more interested in this sort of dietary shift. Its polling found that Canadians between the ages of 18 and 34 are considerably more likely than their older peers to have tried these products, with close to 60 per cent having done so. Seventy percent of this age group believe plant-based meat substitutes are not a fad and will continue to grow in popularity, a very different perspective than older generations (Angus Reid 2019).

An example of a successful effort to reduce food waste through behavioural "nudging" is found in a study of a waste reduction pilot from London, Ontario, in 2017. With a theme of "Reduce Food Waste, Save Money," the program provided participants with simple tools to reduce food waste, ranging from preformatted shopping lists to fridge magnets (at the time, there was no central organic waste collection in the community). The actual physical waste from a set of participating households was compared to waste from control households that were given no prompts. Remarkably, food waste from the participating households declined by 30 per cent and then stayed level over the following two years, which coincided with the start of COVID pandemic and a large surge of food waste in the control households (Everitt 2022).

While recovering nutrients from food waste and other organic sources fits with Canada's goal of reducing absolute levels of greenhouse gas emissions arising from fertilizer application by 30 per cent below 2020 levels by 2030, efforts to reduce food waste and make higher use of

waste food products can also contribute to lowering emissions in other ways (Government of Canada 2022b).

For example, the Commission for Environmental Cooperation estimates, "GHG emissions savings from rescuing food for human consumption are about 20 times more than those from recovering for animal consumption, and more than 40 times higher than those from recycling alternatives [for example, composting]."

Efforts to increase sales of imperfect produce or to make best-before labelling on products clearer can contribute to keeping still-edible food from being wasted or even recycled at a lower net climate benefit. In Québec, the Québec Agrifood Innovation Centre has undertaken research on optimizing meat packaging to prevent losses and extend shelf life, while the Supermarket Recovery Program encourages retailers across the province to donate surplus produce to food banks. The province has also repealed regulations that had banned the sale of fruits and vegetables not meeting strict aesthetic standards (Circle Economy 2021b).

The Ivey Business School examined the potential for up-cycling food waste from two sectors in Ontario: spent grain (a by-product of brewing) and fruit and vegetable residues (leftover material from canning and juicing). It found that these materials could be used in products such as cookies, crackers, edible powders, and flavourings, although the bulk of these materials continue to be landfilled or used as animal feed. From an emissions perspective, however, the results of the study were not straightforward, with some upcycling activities having the risk of producing more emissions than conventional disposal. However, most of the case studies showed emission benefits on par with animal feeding (Gualandris 2022).

The authors pointed to a number of factors that affected emissions performance, from the methods used to reduce moisture in spent grains to the quality of the residuals being incorporated in new products and the distance between the waste producer and the manufacturer.

The Québec *Circularity Gap Report* notes that "wet waste" is a large proportion of material headed for disposal in the province. It notes that organic waste is the largest unrecovered waste stream in the province: "about two-thirds of the 5.8 million tonnes of eliminated waste consists of organic waste, including wet waste, municipal and industrial sludges and agricultural waste."

The report suggests a number of alternative uses for this material, from the creation of "eco briquettes" to energy generated from anaerobic digestion. Québec is investing $1.2 billion over the next 10 years in organic waste recovery with a goal of having 70 per cent of all organic household waste composted by 2030.

The Ellen MacArthur Foundation points to examples from Europe of combined energy and biosolids recovery benefits: "[Wastewater treatment plants] in Aarhus and Odense in Denmark have both demonstrated they can generate twice as much energy as they consume by collecting the biogas released by the anaerobic digestion of sludge. Further carbon benefits are achieved as the nutrient-rich biosolids left over from this process can be spread over local farmers' fields."

Currently, efforts to reduce food waste are largely being driven by grocery retailers, noted one expert in an interview with the Canadian Climate Institute. With narrow profit margins, reducing waste and creating new product opportunities ("ugly vegetables," for example) is seen as an opportunity to grow revenue, they noted. But while the economic motive is driving the sector to reduce waste, it also opens the door to greenwashing of products and waste claims due to an absence of regulation, the interviewee added.

Using agricultural or forest residues to create alternatives to plastics in particular is an area of growing interest. The federal government's Domestic Plastic Challenge, for example, is helping companies scale-up the production of bio-based plastics that are compostable under standard composting conditions. It has made a $1 million investment in BOSK Bioproducts Inc. to develop a highly compostable and cost-effective new bioplastic made from paper mill sludge and wood fibre residue that could be used in areas like 3D printing, food packaging, plastic bottles, and containers for cosmetics.

With narrow profit margins, reducing waste and creating new product opportunities ("ugly vegetables," for example) is seen as an opportunity to grow revenue.

However, the use of “waste” materials from natural forests must be carefully examined both in terms of impact on biodiversity and forest nutrient cycles. For example, a recent meta-analysis of scientific papers on the impact of the removal of “slash” from forestry operations found that this can reduce soil carbon (i.e. and increase atmospheric CO_2) by as much as 24 per cent (James et al. 2021).

The ban on single-use plastics as part of the federal government’s plastics waste reduction strategy has led many restaurants to source new materials such as takeout containers and cutlery made from natural materials. As the *Globe and Mail* reports, “Restaurateurs can choose from a wide variety of new options made from materials including bamboo, oats, corn, rice and paper” (Saba 2023).

Canada is getting onboard with producing products using a wider range of agricultural inputs through its funding of Bioindustrial Innovation Canada under the Canadian Agricultural Adaptation Program. The country’s first Bioeconomy Strategy was published in 2019. It notes, ”the bioeconomy is an important component of circular economy activities in Canada, especially where biotechnology can enable the transformation of biomass that would otherwise not be fully utilized into useful products” (Bioindustrial Innovation Canada 2019).

The strategy also points out, “Canada’s bioeconomy will be driven by a ‘Green Generation’ where consumer demand for more sustainably-sourced products will push the market toward more validated sustainable biomass supply. Biomass industries will transform their resource management and development practices for production, conversion and management to meet customer and consumer demands and more fully utilize all aspects of feedstocks” (Bioindustrial Innovation Canada 2019).

In fact, the strategy sees competition for biomass stocks heating up and a need to ensure highest and best use for these stocks, including greater emphasis on higher value-added products, such as automotive parts, aviation fuels, or chemical feedstocks. The strategy has many recommendations that are similar to those found in more generic circular economy guides, including improving intelligence on biomass (and residue) availability, using government procurement to support new product development, and undertaking proper lifecycle assessment to develop a clear picture of the potential benefits of a shift to bio-products.

In Manitoba, the Pembina Fibreshed project is promoting the use of flax, which is widely grown in the province, to produce linen, a material it notes can be composted, unlike petro textiles. The project is providing farmers with seed for flax varieties suitable for making linen at no cost. They are also looking at promoting growing Japanese indigo to create a natural blue dye (LeGal 2022).

What other countries are doing

Many countries are exploring the potential of a shift to a circular economy as an opportunity to reduce greenhouse gas emissions and other environmental harms. In this section, we briefly review initiatives underway with some of Canada's largest trading partners and economic peers, including how increased circularity is factored into key climate policies.

European Union

The E.U. has a wide range of initiatives underway to improve circularity in member countries. These are largely spelled out in its *Circular Economy Action Plan*, which is a central piece of its Green Deal initiative (European Commission 2020a).

Key pieces of the *Action Plan* include development of a sustainable product policy legislative initiative. According to the *Plan*, "The core of this legislative initiative will be to widen the Ecodesign Directive beyond energy-related products so as to make the Ecodesign framework applicable to the broadest possible range of products and make it deliver on circularity."

Some of the more unique initiatives envisioned under the plan include:

- "mobilising the potential of digitalisation of product information, including solutions such as digital passports, tagging and watermarks;
- rewarding products based on their different sustainability performance, including by linking high performance levels to incentives."

Recognizing the need for better data on material flows and other circularity aspects, the plan also calls for establishing, "a common European Dataspace for Smart Circular Applications with data on value chains and product information."

The E.U.'s data goals include:

- analyze how the impact of circularity on climate change mitigation and adaptation can be measured in a systematic way;
- improve modelling tools to capture the benefits of the circular economy on greenhouse gas emissions reduction at E.U. and national levels;
- promote strengthening the role of circularity in future revisions of the national energy and climate plans and, where appropriate, in other climate policies.

Better information can also be used to, "step up efforts, in cooperation with national authorities, on enforcement of applicable sustainability requirements for products placed on the EU market, in particular through concerted inspections and market surveillance actions."

This is an important action given that, as one expert mentioned in an interview with the Canadian Climate Institute, current enforcement of standards in the E.U. is weak and requirements are often very general.

In terms of linking circularity actions to emissions performance, the E.U. is, "assessing options for further promoting circularity in industrial processes in the context of the review of the Industrial Emissions Directive, including the integration of circular economy practices in upcoming Best Available Techniques reference documents."

Very relevant to Canada, where small and medium-size enterprises (SME) dominate the economy, the E.U. is also looking to help the SME sector improve circularity through knowledge sharing and training. Its *SME Strategy* will foster circular industrial collaboration among SMEs building on training, advice under the Enterprise Europe Network on cluster collaboration, and knowledge transfer via the European Resource Efficiency Knowledge Centre.

The *Action Plan* recognizes the need for better integration of circularity measures into Climate Plans stating: "In order to achieve climate neutrality, the synergies between circularity and reduction of greenhouse gas emissions need to be stepped up.

The Commission will:

- analyze how the impact of circularity on climate change mitigation and adaptation can be measured in a systematic way;
- improve modelling tools to capture the benefits of the circular economy on greenhouse gas emission reduction at EU and national levels;
- promote strengthening the role of circularity in future revisions of the National Energy and Climate Plans and, where appropriate, in other climate policies."

The E.U. *Action Plan* lists more than 50 actions to be taken to improve circularity. An Annex to the plan sets out deadlines for development of the supporting policies.

United States

At a national level, the U.S. Environmental Protection Agency (EPA) is developing a national recycling strategy with a focus on improving circularity. It states that the "EPA is also committing to develop a new goal to reduce the climate impacts from materials use and consumption, which will complement existing national goals on recycling and the reduction of food loss and waste. The EPA plans to collaborate across all levels of government, including tribal nations, and with public and private stakeholders to achieve these ambitious goals" (EPA 2021).

It recognizes the need for better metrics to assess success in achieving its goal: The EPA intends to work with interested stakeholders to develop standardized definitions, measurement methodologies, baselines, and targets for future metrics and the National Recycling Goal.

The National Renewable Energy Laboratory in the U.S. has also developed an ambitious research program with a strong focus on circularity to address the material demands inherent in the shift to green energy systems. It describes its vision as, "a future in which energy materials are manufactured more efficiently, built to last longer, and designed for reuse and recycling on retirement to ensure that resources and supply chains for the clean energy transition are secure and sustainable" (NREL n.d.).

Some states are also implementing early steps on increasing circularity. California recently approved a new $15 billion climate action plan that specifically allocates $270 million to promote circular economy measures. According to a government media release, this funding will be used to raise demand for recyclables and attract green industry to California and will include funding to support the work of CalRecycle's new Office of Innovation in Recycling and Remanufacturing. Additional funds will support organic waste infrastructure, food recovery efforts and composting, remanufacturing, and recycling infrastructure, including investments in disadvantaged communities.

Washington state has passed an Industrial Symbiosis Law that will enhance efforts to turn waste into resources for new products. The law directs the state to facilitate waste exchange through a variety of measures including: creating an inventory of waste resources, creating material flow data collection systems, supporting the creation of sharing hubs, developing environmental and health performance metrics, and educating businesses about waste exchange opportunities (BioCycle 2021).

At a city level, New York City is working with the Ellen MacArthur Foundation to reduce the 200 million pounds of clothing sent to the landfill each year, while also working with design and architecture firms to reduce the waste created by the city's building sector through voluntary *Zero Waste Design Guidelines* (NYCEDC 2021).

The Inflation Reduction Act and Bipartisan Infrastructure Law that are the centerpieces of the Biden administration's climate policies, do not have a strong circular economy focus, but the Department of Energy has enhanced case-by-case lending powers for potential circularity projects that also meet the mitigation and industrial policy goals of the Act. It provides incentives for improving home energy efficiency, including installing heat pumps, and for more efficient appliances, but is mostly focused on a shift to cleaner energy sources. Government summaries of the Infrastructure Law say that investments in new infrastructure must address climate change mitigation and resilience, but it is not clear how policies will reinforce these requirements.

China

In 2021, China released its Development Plan for the Circular Economy (Bleischwitz 2022).

The plan sets the following goals for 2021-2025:

- "Increasing resource productivity by 20 percent compared to 2020 levels.
- Reducing energy consumption and water consumption per unit of GDP by 13.5 percent and 16 percent, respectively, compared to 2020 levels.
- Reaching a utilization rate of 86 percent for crop stalks, 60 percent for bulk solid waste, and 60 percent for construction waste.
- Utilizing 60 million tons of waste paper and 320 million tons of scrap steel.
- Producing 20 million tons of recycled non-ferrous metals.
- Increasing the output value of the resource recycling industry to RMB 5 trillion (US$773 billion)."

One key strategy for China is the development of "eco-industrial parks" where waste materials from one industry or process can be shared with another (also called industrial symbiosis, an approach pioneered by Kalundborg, Denmark, where 14 public and private companies have been working to cycle waste and waste energy since 1972).

China first adopted a Circular Economy Promotion Law in 2008, but it had a simpler "Three Rs (reduce, reuse, recycle)" type focus. The new plan outlines a broader range of strategies for achieving circularity, including promoting green design and remanufacturing.

A research paper in the journal *Resources, Conservation and Recycling* finds that China has been relatively successful in improving material efficiency, noting that, "Our data analysis shows a remarkable success of decoupling GDP from resource use in China over the last twenty years, a strong relative decoupling leading to a doubling of resource productivity in China" (Bleischwitz 2022).

China's climate plan, Action Plan for Carbon Dioxide Peaking Before 2030, integrates circular concepts in many sections (for example, using more steel scrap and clinker substitutes in cement) but also directly acknowledges the need for circular approaches:

> "**The action for promoting circular economy in carbon mitigation purpose** Focusing on resource utilization as a key factor, we will push ahead with the development of the circular economy, and work toward an all-around improvement in the efficiency of resource utilization. In the process, we will fully leverage synergistic effects between efforts to reduce resource consumption and cut carbon emissions."

It also calls for developing industrial parks "in a circular manner" and making better use of "bulk waste" like fly ash and straw, taking an "internet +" approach to recycling, and improving household recycling (NDRC 2021).

Japan

In 2000, the Basic Act on Establishing a Circular Society was passed in Japan with a requirement to establish plans that are updated every five years (the fourth plan was published in 2018).

Japan has achieved very high recycling rates for many products: 93 per cent for air conditioners, 86 per cent for liquid crystal and plasma display televisions, 79 per cent for refrigerators and freezers, 90 per cent for washing machines and dryers, 69 per cent for glass bottles, 85 per cent for PET bottles, 92 per cent for steel cans, and 94 per cent for aluminum cans. This is perhaps not surprising for a country that is not rich in natural resources and highly dependent on material imports (Benton and Hazell 2015).

In 2022, the Japanese government set a goal of expanding the size of the domestic circular economy market to over 80 trillion yen by 2030 from the current 50 trillion yen. To achieve this outcome, the government wants to double the amount of plastics collected by companies and local governments by 2030, strengthen measures to reduce food waste to four million tons or less, promote the recycling of rare and other metals, and shift from materials derived from fossil fuels to biomass materials (METI 2020a).

The Institution of Environmental Sciences suggest the success factors in the Japanese system include:

- **Collaboration:** Japanese business culture emphasizes collaboration; the result is a comprehensive approach, both to measurement and to action.

- **Consumer-friendly collection:** the system for collecting old appliances for recycling is so comprehensive and easy to use that it is harder not to recycle them. Old appliances are collected by retailers either in store or when delivering a new appliance. For old IT equipment, the manufacturer can be requested to collect it by local authorities from the doorstep or it can be taken to any post office to be returned to them.
- **Consumers pay fees up front:** for electronics, the cost of transport and recovery is paid for at the point of purchase, meaning that the customer does not have any disincentive to participate when a product comes to the end of its life.
- **Recycling infrastructure is co-owned:** the law requires consortia of manufacturers to run disassembly plants, ensuring they directly benefit from recovering materials and parts. Companies therefore invest for the long term in recycling infrastructure. And because they own both manufacturing and recovery facilities, companies send product designers to disassembly factories to experience the frustrations of taking apart a poorly designed product. Some companies even put prototypes through the disassembly process to make sure they are easy to recover" (Benton 2015).

Japan is also encouraging entrepreneurs to address circularity with companies that do everything from renting umbrellas to "de-branding" used clothing for resale.

Of Japan's "14 Priority Areas for Carbon Neutrality by 2050" circularity is part of the Home/Office cluster where resource circulation is a focal area. Circularity is indirectly referenced in other areas, including "wooden skyscrapers" and "carbon recycling" in cement and plastics, but is otherwise not a central feature (METI 2020b).

Netherlands

The Dutch have set a goal of having a completely circular economy by 2050, with an interim goal of halving the consumption of primary raw materials by 2030. The government has outlined "five transition agendas" covering biomass and food, plastics, manufacturing, construction, and consumer products, with detailed plans for each that cover actions needed, the role of government, and budgets (Hanemaaijer et al. 2021; MIWM 2021).

The Netherlands has developed some interesting tools for helping to spur interest in circularity when it comes to infrastructure procurement: DuboCalc and the CO_2 Performance Ladder. As the U.N. Materials study explains, "DuboCalc assesses the environmental impacts of the "product" (infrastructure), while the CO_2 Performance Ladder assesses the GHG impacts of work processes."

DuboCalc is a lifecycle-based software tool that quantifies a wide range of the environmental impacts of construction materials. Using DuboCalc, all embedded environmental impacts of material use can be estimated for the entire product lifecycle, from raw material extraction and production, to demolition and recycling. For evaluation of infrastructure, use-phase energy consumption can be calculated.

Based on the materials used, DuboCalc calculates a single value for all of the environmental effects called the environmental cost indicator value, based on the costs of preventing emissions.

The Dutch National Climate Agreement released in 2019 embeds the concept of circularity throughout all sections of the plan, from shifting to circular construction approaches and adopting circular agriculture practices, to developing procurement processes that incent circularity (EZK 2019).

It offers a number of insights into the challenges of reaching its circularity goals, including creating industrial clusters (symbiosis) for the reuse of materials. It points to efforts to enhance material sharing among five Dutch regions and, on a finer scale, to how, "Mechanical recycling in Rotterdam-Moerdijk, for example, which includes waste-to-chemicals/circular plastic production/biomass, is one of the options that illustrates how climate policy and the circular economy can reinforce one another."

Importantly, the plan recognizes that, "The success of the system transition and the creation of an entirely new type of industry not only requires a supply, but equally requires a demand for sustainably produced products."

With this economic development perspective in mind, the plan points to the country's Integral Knowledge and Innovation Agenda as a roadmap for how it will focus on priority growth markets, noting that, "targeted action may be needed that will take a different shape for each of the development phases of the growth market."

Finland

Finland adopted a national roadmap for transitioning to a circular economy in 2016. While the country has dramatically reduced waste going to the landfill, it has largely done so by diverting waste to energy-from-waste facilities while actual post-consumer waste levels have continued to rise.

Sitra, Finland's Innovation Fund, has played a central role in leading efforts around the circular economy (Sitra was created in 1967 but its current endowment largely resulted from the donation of Nokia stock by the Finnish parliament in 1992). It has invested in companies such as Swappie, a company that refurbishes old cellphones, with a focus on assuring consumers of the quality of refurbished goods. Sitra, in its own words, "acts as a think tank, promoter of experiments and operating models and a catalyst for co-operation. In being accountable to Parliament, our future-oriented work is funded with returns on investments based on endowment capital received originally at the behest of Parliament."

In line with Finland's strong emphasis on education as a key tool for advancing circularity, Sitra focuses on not just enterprises, but on the health of democratic structures and building a vision for a green future: "We renew and develop democratic structures, procedures and means of participation and interaction, among other things. We especially focus on investigating how network-based approaches and algorithm and data-based ways of acting and influencing can be harnessed to support democracy, engagement and co-operation" (Järvinen and Sinervo 2020).

It has also led to an innovative project focused on lifestyle/behaviour change, where the emphasis is not on a personal "carbon footprint" but on "building a good life that is sustainable." The program has engaged one in five Finns in considering 100 different actions to make their lifestyles more sustainable. The program encourages citizens to develop a personal plan that Sitra says on average results in a 30 per cent cut in lifestyle-related greenhouse gas emissions (Hot or Cool Institute 2021).

Finland creates regular Medium-term Climate Change Policy Plans to implement its Climate Change Act. The latest plan was submitted to the country's legislature in the fall of 2022 and contains many actions and measures with a circular focus (Ministry of the Environment 2022).

Australia

The closing off of China for imports of waste materials has had a dramatic impact on Australia, which is now racing to develop domestic material recovery capacity. The country has set a goal of an 80 per cent recovery rate for waste by 2030 along with a halving of food waste.

To this end, it has established a $A250 million Recycling Modernisation Fund, which it believes will drive, "a $[A]1 billion of investment in recycling infrastructure and drive a billion-dollar transformation of Australia's resource recovery industry. The RMF will modernise Australia's recycling infrastructure increasing our circular economy capabilities by finding innovative solutions for onshore recycling and supporting remanufacturing of products with recycled content (DCCEEW 2022).

Australia is struggling to catch up with many other jurisdictions when it comes to adopting a circular economy. This has been attributed to such factors as regulatory gaps, insufficient infrastructure, and immature policies (Environment and Communications References Committee 2018).

Scotland

Scotland is developing an ambitious roadmap for shifting to a circular economy. It released this roadmap for consultation in the spring of 2022 with a goal of achieving a fully circular economy by 2045 (Minister for Green Skills, Circular Economy and Biodiversity 2022).

Scotland's 2020 Climate Change Plan sets out emission "envelopes" for each economic sector. For the waste sector, emissions must be reduced by one-third by 2025 to stay within the envelope. More broadly, all sectors must reduce emissions sufficiently to meet Scotland's national goal of achieving a 75 per cent emissions reduction by 2030.

While the waste sector only accounts for three per cent of Scotland's emissions, consumption of materials, goods, and services makes up approximately 80 per cent of emissions. This is why Scotland has embedded circular economy principles in its Climate Plan including:

- **Responsible Consumption,** where people and businesses demand products and services in ways which respect the limits of our natural resources. Unnecessary waste, in particular food waste, will be unacceptable in Scotland.
- **Responsible Production,** where a circular economy is embraced by the businesses and organisations that supply products, ensuring the maximum life and value from the natural resources used to make them.
- **Maximising Value from Waste and Energy,** where the environmental and economic value of wasted resources and energy is harnessed efficiently" (Energy and Climate Change Directorate 2020).

Circular economy goals are also embedded in the country's economic transformation strategy, its Environment Strategy for Scotland and in its standalone Circular Economy Strategy.

An interesting Scottish initiative is the Scottish Institute for Remanufacturing, which provides research and financial support for companies interested in developing new circular businesses.

The country has also undertaken more detailed Material Flow Accounts to build on its previous efforts to calculate the country's carbon footprint. It describes the purpose of these accounts simply: "If Scotland wants to end its role in the climate emergency, it needs to dramatically reduce the amount of materials used in its economy" (Zero Waste Scotland 2021).

Barriers and policy approaches

Circularity challenges for Canada

The Council of Canadian Academies notes a number of Canada-specific challenges to adopting circularity practices.

To begin with, as a country with a large resource extraction sector, circularity may seem counter intuitive. One of Canada's strengths is in the production of raw materials, which circularity seeks to reduce. However, there are many ways in which circularity can complement this strength.

First, the shift to renewable energy sources and other green technologies such as electric vehicles is going to create new demand for metals in particular (for example, copper for wiring, lithium for batteries, nickel for alloying, cobalt and rare earths for general purpose electronics). Being able to quickly meet this need is going to require better recovery of metals to accompany the slower development of new mineral bodies. Expertise in smelting and metals processing, and evolving expertise in mineral recovery from mining waste, can all be used to complement conventional mining activities. Similarly, the substitution of things like mass timber or manufactured wood panels for concrete in the building sector may represent a shift from one resource sector to another, but not a net loss.

Many Canadian reports point to the challenge inherent in Canada's thinly spread population and vast distances. But the flipside of this challenge is that Canada's population is also highly concentrated, with 70 per cent of the population living in large urban areas. As the Canadian Construction Association notes, this offers an opportunity for a more iterative and distributed development of circular economy measures, where initiatives get off the ground locally and then are taken up more widely (CCA 2021).

In fact, the National Zero Waste Council (NZWC), created in 2013, comprises Canada's six largest metropolitan regions: Metro Vancouver, Toronto, Montreal, Halifax, Calgary, and Edmonton, with a mandate to advance circular approaches at the municipal level. The NZWC, in turn, launched the Canadian Circular Cities and Regions Initiative in 2021 in collaboration with the Federation of Canadian Municipalities, RECYC-QUÉBEC, and the Recycling Council of Alberta, to advance circular economy knowledge and capacity in the Canadian local government sector.

Given that some circular measures can be energy intensive—such as chemical recycling of plastics or production of recycled steel—Canada's largely zero-carbon electricity system provides an advantage as it can maximize the benefits of measures that may result in more marginal improvements in countries with higher-carbon power systems. How long this advantage will last is a key question as other countries embrace a shift to zero-carbon power. Working for Canada is that most of our power comes from reliable, clean, "on-demand" sources like hydro and nuclear, and additions of solar and wind save this firm power for when it is most needed. Translated another way, if Canadian governments and industries plan wisely, the country is unlikely to experience the same challenges as other countries as it has sufficient firm clean power supplementing variable renewables.

Actions by the U.S. have a large impact on Canada, which currently sends a large proportion of our plastics, e-waste, and textiles south of the border for processing (CCA 2021). As a comparatively small market, it may make sense to continue to "collectivize" these waste streams for processing in larger American hubs, or it may be better to develop stronger domestic capacity to deal with these materials. But cross-border trade in materials will continue under a circular model and barriers will need to be addressed. For example, creating cross-border regional exchanges for recycling things like electric vehicle batteries may be the best path forward, rather than only relying on the smaller Canadian market.

Interestingly, the B.C. government reports that greenhouse gas emissions associated with consumer recycling programs in the province "declined by 20.7% [in 2021] primarily due to a reduction in marine shipments to overseas end markets and increased efficiencies of internal material movements." So, there are emission benefits of keeping processing closer to where waste is produced if volumes warrant (Tuck 2021).

Sustaining circularity benefits

One of the key conclusions of many circularity studies is that more attention needs to be paid to the interplay between measures and potential "rebound" effects. There is, for example, a strong consensus that early intervention measures, such as a shift to product-as-a-service models or downsizing housing stocks, can have larger emissions impacts than downstream activities such as recycling. Extending product lifetimes, expanding efforts to repair or refurbish products, or even increasing sales of used products (a form of non-destructive

recycling), are all seen as having greater emissions reduction and environmental benefits than recovering materials from end-of-life products.

However, there are a number of caveats. As one report on material recovery notes, all products that involve energy use are subject to trade-offs when it comes to extending product life due to improved energy efficiency in newer models. Extending the use of less efficient devices may not always be the best choice. Similarly, repair and refurbishment services need to take into account the energy involved in transporting goods back and forth to repair depots. Lifecycle analysis will be important to understanding where greater circularity can have the most impact (Koide 2022).

In the race to adopt circularity and/or clean energy measures, countries may also come up against some unexpected barriers. For example, the availability of cement clinker substitutes, such as fly ash in cement, may decline dramatically as coal-fired power is phased out and requires a shift to different substitutes such as a mix of ground limestone and heat-treated clays. Similarly, the use of PET from recycled bottles in the textile industry may decline as beverage producers seek to close the loop on bottle-to-bottle recycling or shift to bio-based plastics.

As well, where hard-to-abate processes such as steel or cement manufacturing are successfully shifted to zero-carbon energy sources, the emissions value of circular measures such as incorporating more recycled materials may decline. However, by reducing the overall energy demand of processes, circularity measures may still make an important contribution by extending the availability of renewable energy more widely (for example, requiring less of a finite supply for these energy-intensive processes) and reducing the emissions involved in extracting raw materials, such as aggregates or iron ore.

It is also important to consider time frames when it comes to circularity. Some measures, such as extending product life, expanding repair services, or improving recycling, can be implemented fairly rapidly with the right policy and market signals. Others, such as improving the recovery of material from demolished buildings or changing consumer eating habits, will take much longer to have an impact. However, given that many of these longer-term measures can deliver significant emissions reductions, they should be considered worthy investments.

The transition from a take-make-waste system to a circular economy is going to require major changes in everything from public attitudes to financial structures and infrastructure. However many countries, including Canada, are only at a nascent state of development in implementing these new approaches and have focused climate efforts on a shift away from fossil fuels rather than the more holistic approaches required by a broad shift to circularity.

The U.N. Environmental Programme (UNEP) sums up the current limitations of approaches to circularity well:

“Policies related to material efficiency have traditionally focused on recycling, while other equally or more promising strategies have typically not been the focus of either resource- or climate-oriented policies. In other cases, material efficiency strategies have either been the subject of limited policy development (as with the use of mass timber in construction), or such strategies have not been a policy focus at all (as with shared housing or mobility). Rigorous quantitative ex-post policy evaluation is uncommon. Thus, in many cases, knowledge of policy efficacy is simply very limited, making judgments difficult as to how to best use policy to realize the benefits indicated by the modelling” (Hertwich 2020).

Recycling steel is a well-established process. But the incentives to improve processes to create higher-value end products, such as thin sheet steel for cars, are currently minimal and compete with cheap and well-developed but carbon-intensive processes. Manufacturers have no incentive to design products for easier disassembly to reduce contamination, recyclers have little incentive to develop new processes to limit contamination, and steel producers have little incentive to increase recycled content because there is little market demand for products with recycled content. In fact, such content can create concerns about product quality and suitability.

Changing these conditions will require multiple measures, from making it more costly to put landfill construction waste and other goods, to creating certification systems to increase public trust in refurbished or recycled goods.

As one expert noted in an interview with the Canadian Climate Institute, even when consumers do want to make “greener” purchase decisions, it can be very difficult to understand trade-offs between different product aspects (for example, a refurbished refrigerator vs. a new more energy efficient model).

Rigorous certification programs that are based on lifecycle analysis can help with this problem. The E.U., for example, is using its Ecodesign Directive to try to drive producers toward producing more sustainable products, such as with simplified packaging that is easier to recycle or that uses less material to begin with (Sun, Lettow, and Neuhoff 2021). In Finland, the company Swappie does not just refurbish cellphones, it certifies their performance because it recognizes that consumer trust (and preference) is a major barrier to the sale of refurbished and recycled goods.

In France, Italy, Spain, Sweden, and the Netherlands, disposal fees are assessed according to sortability, recyclability, and the existence of sorting instructions on products, while California is requiring pre-clearance of plastic products with recycling labels. These are the kinds of stronger extended producer responsibility policies that are needed to spur product redesign rather than just increased recycling.

As the UNEP notes, when it comes to circularity, “design is a crucial point of intervention.” Design can be influenced by numerous codes and standards that can either increase circularity or create barriers. In textiles, for example, “new material only” requirements for things such as mattress filling creates a disincentive for textile recycling. Similarly, weak material content labelling regulations make it difficult to properly sort textiles as disclosure is often incomplete or inaccurate. The National Institute of Standards and Technology (NIST) notes that “more than 40% of garment labels contain inaccurate fiber composition information. Additionally, current labeling is designed for the consumer, not circular partners, and is often removed prior to reaching post-consumer stakeholders.” They add that, “a digital passport in which a garment is equipped with a permanent digital identifier such as a Quick Response (QR) code, Radio Frequency Identification (RFID) tag, watermark, or Near-field Communication (NFC) technology” could make sorting much easier (Hertwich 2020).

This sort of “digital passport” system can be extended to products beyond textiles and would also help to fill data gaps on the fate of most materials. As many studies note, current material tracking systems are simply not robust enough to fully support material exchange and reuse systems and to assess the success of circularity initiatives. Fortunately, a number of companies are experimenting with better tracking technologies, such as a pilot project by BASF to use blockchain to better track the fate of plastics in B.C. (BASF 2020).

NIST points out, for example, that recyclers are going to need much better information to deal with the coming wave of used batteries, many of which will be coming from much different sources than today as the green transition builds. They point out that, “A key principle of the circular economy is to extend product and component life for as long as possible through reuse and repair. However, recyclers have little to no information about batteries entering their facility, specifically, cathode chemistry, form factor, history (for example, use cycles), or remaining charge rate. This hinders recyclers’ ability to choose the appropriate pathway for recovery. Additionally, the feasible reuse of batteries is impeded by a lack of performance metrics, best practice guides, or concrete financial data” (Schumacher 2021).

Enhancing material exchange

Both Ontario and Québec have established material exchange systems for industry.

In Québec, the Centre de transfert technologique en écologie industrielle (CTTÉI) is working to reduce manufacturing waste levels by championing industrial symbiosis. The Centre conducts research on how to reuse waste products and acts as a consultant while enhancing information exchange through its Synergie Québec guide and website. The CTTÉI boasts a wide clientele, from companies and municipalities to industrial parks, and aids its partners in "identifying eco-product options, refining processes and developing symbioses" (Binet et al. 2021).

The Ontario Materials Marketplace similarly positions itself as, "More than a static materials exchange," noting that "listings, user capabilities and conversations on the Materials Marketplace are actively monitored, and reuse opportunities are identified and pushed to qualified companies as recommendations." It also acts as a facilitator between companies and works with them to overcome barriers to material exchange. The marketplace is also integrated with similar American initiatives to facilitate cross-border material exchange.

While these exchanges often point to cost savings on waste disposal, it is going to take deeper policies to drive wider uptake and reduce waste creation. As one interviewee noted in an interview with the Canadian Climate Institute, the cement industry is very interested in recycling aggregates, but is often stymied by municipal building or procurement requirements.

Using codes, standards, and pricing

Building codes are the kind of tool that is ripe for promoting circularity. As UNEP notes, building design is heavily shaped by building codes, although awareness of lower carbon materials and design approaches that are already approved is also critical as The Atmospheric Fund notes.

In fact, in its report The Atmospheric Fund warns against spending large periods "piloting" new approaches and instead urges policies to spark quick uptake. Instead of pilot programs, it urges governments to, "Start with quantification and benchmarking (perhaps for two years, starting in 2022 or 2023), then bring in limits or caps on embodied emissions intensity (embodied emissions per square meter). The caps should lower over time (again, every two years), with the future caps and effective dates being published years in advance to signal industry and provide a clear roadmap" (Zizzo 2022).

Carbon pricing can be a key tool in driving circularity by creating a financial incentive to extend product use, redesign products and processes to use lighter or fewer materials, or recover materials. In its study of upcycling food waste, the Ivey Business School notes that a higher carbon price can make a significant impact on the desirability of using recovered materials, but the range of impact can still be very large: "With a carbon price of $170/tonne, the value of the avoided carbon for a tonne of bakery production would be between $7-$191. This would equate to $700-$19,100 per year in cost savings or additional earnings for a mid-sized bakery operation, which is between three and 84 per cent of its annual profit" (Gualandris 2022).

But while some broader fiscal measures such as carbon pricing may be beneficial for spurring circularity, they are not likely to be sufficient on their own to address all the current barriers to circular practices, from public perceptions of refurbished goods being inferior quality, and preference for larger vehicles or housing, to shifting to product-as-a-service models, improving material information systems, and incenting product and packaging simplification.

UNEP recommends a wider array of fiscal policies to address circularity, including building certification, green public procurement, virgin material taxes, recycled content mandates, and removal of virgin material subsidies.

It adds that, "Virgin materials taxes, as distinct from royalty payments associated with resource extraction, are not widely used with the exception of modest levies on construction minerals. While politically challenging, reduction of subsidies for virgin resources is likely to provide dual benefits—increased material efficiency and government revenues" (Hertwich 2020).

Similarly, Sustainable Prosperity notes examples of "taxes and user fees initiated specifically to support circularity include Sweden's reduced value-added tax (VAT) on repairs for a range of products and China's VAT policy which offers tax refund opportunities for products containing recycled content" (Cairns 2020).

The Council of Canadian Academies points out that Canada is currently under-using policies to drive circularity, noting, for example, that "policies such as landfill bans are under-used in Canada. For example, though Electronics Product Stewardship Canada has recommended province-wide landfill bans for electronics, they have largely been implemented only at the municipal level, if at all, with electronics banned from all municipal landfills in Newfoundland and Labrador, Nova Scotia, and Prince Edward Island only" (CCA 2021).

But while bans can be effective, it is important to ensure that there are fully sustainable alternatives in place. Consumers will need help to shift to products that actually lead to lifecycle improvements.

Similarly, it is important to consider how policies may be evaded, intentionally or unintentionally. Automotive fuel performance standards have indeed led to a drop in light duty passenger car emissions in Canada, but this gain has been offset by a shift to heavier vehicles. Similarly, large single-occupancy electric vehicles may be a less desirable solution than promoting sharing smaller vehicles and transit (Saxifrage 2022).

Turning intentions into action

The CCA *Turning Point* report outlines a broad series of policies that Canada could adopt or adapt to further circularity, with the following summary of policy-oriented findings:

- The transition towards a circular economy will require significant financial investments. In addition to private investment, public financial incentives—such as tax policies, disposal fees, transfer payments, and procurement—are needed to support and enhance circular supply and business models.
- New technologies, improved product design, eco-labelling, and the development of circular economy standards and certifications are key to enabling the transition towards a circular economy.
- Awareness campaigns, educational curricula that incorporate circular economy principles, and skills training or retraining for workers will help the public engage with the circular economy.
- Trade is an essential consideration in supporting a transition towards a circular economy both domestically and globally, given current globalized systems of production and consumption. As a relatively small player in many global value chains, Canada's circular economy approach would benefit from coordination with international initiatives.
- Extended producer responsibility programs are a widely used policy lever that can theoretically help to advance a circular economy. However, existing extended producer responsibility programs in Canada are often narrow, fragmented, and underdeveloped, leading to limited effectiveness in practice (CCA 2021).

Government procurement can be a useful way to support a shift to circularity. The federal government has taken steps in this direction with its *Greening Government Strategy*.

But as *Roadmap to Net Zero Carbon Concrete by 2050* notes, "Challenges remain in some markets, particularly with governments that have traditionally been slower to adopt lower-carbon products" (ISED 2022).

Smart Prosperity notes in a recent opinion piece in the *National Observer* that there is very large potential to use preferential treatment for low-carbon materials in public procurement to lower emissions, stating, "The production of materials used in public infrastructure creates at least eight million tonnes of carbon emissions every year—equal to the pollution caused by 1.7 million gas-fuelled cars. When private construction is included, the figure rises to almost 28 million tonnes annually—50 per cent of Canada's electricity generation emissions" (Kaiser 2022).

Smart Prosperity acknowledges that the bulk of infrastructure spending is at the municipal and provincial levels, with federal purchases making up less than one per cent of infrastructure spending in Canada. But it also notes that this is direct spending and the federal government has large leverage through its funding "partnerships" with lower levels of government.

The B.C. government, meanwhile, sees circularity as an opportunity to address social equity by creating widespread economic opportunities. But it notes that this requires workforce training and community support, noting, "Creating accessible and effective training programs will decrease negative consequences on vulnerable communities. To stimulate market demand for this kind of labour, the B.C. government can act as an early adopter and first mover through incentives and procurement policies" (Tuck 2021).

Building a roadmap

In terms of building a roadmap that sets out goals and policies for shifting to a circular economy, the World Resources Institute offers the following set of objectives to guide policy:

1. Shift consumption patterns.
2. Stimulate product circularity from the design phase.
3. Incorporate circularity across clean energy value chains.
4. Integrate circular economy strategies into national climate policies and plans.
5. Incentivize cross-border greenhouse gas emissions reductions.
6. Connect circular economy metrics with climate change impacts.
7. Increase transparency and comparability in modelling methodologies.
8. Apply systemic and context-specific impact assessment to inform decision-making.
9. Investigate the role of the circular economy in climate change adaptation (Wang et al. 2022).

An interesting approach for advancing on these objectives is offered by Smart Prosperity in their examination of how Canada's successful clean technology innovation efforts could be harnessed to advance circularity (Cairns 2020).

They note that, "Canada does not have dedicated government research institutions or programs with explicit, broad circular economy goals. It does however have ongoing research programs that could contribute to meeting circular objectives. One example is the ‘Mining Value from Waste’ pilot project run by CanmetMINING within Natural Resources Canada (NRCan), which aims to develop technologies to extract value and reduce liability from tailings by recovering valuable metals and using the wastes as resources in other applications. Another example is recent federal funding directed towards the bioeconomy.”

Current policies, such as extended producer responsibility programs, are simply not spurring innovation, Smart Prosperity notes, and calls for examination of a wider array of policies that consider full product lifecycles and that addresses, “the second use phase, take-back systems, design for disassembly, reparability, reusability, planned obsolescence, and recyclability. Standards can require a certain proportion of recycled and renewable material in new products. Product labeling can be a communication and product differentiation tool to shift consumer preferences towards circular products. Regulations to extend product warranty periods or coverage and thereby extend the service life of products can also incentivize consumer uptake and encourage repair over replacement” (Cairns 2020).

Japan offers a good lesson in the value of making material efficiency a cultural norm, by stripping away barriers for both businesses and consumers and by building a culture of cooperation where material recovery or reduction is highly valued. As a country with a dense population and small land area, these characteristics have evolved somewhat naturally in Japan, but they have also been driven by government actions and societal expectations. With many Canadians increasingly concerned about our impact on climate and nature, the time may be ripe to follow in Japan’s footsteps.

We cannot achieve the emissions reductions necessary to avoid the worst impacts of climate change without embracing circularity.

Conclusion

The evidence about the necessity of shifting to circular economic approaches is clear: We cannot achieve the emissions reductions necessary to avoid the worst impacts of climate change without embracing circularity.

The math is relatively simple. Direct emissions from energy use account for less than half of the emissions that are destabilizing our climate. The rest are a result of harvesting resources, turning them into products, and disposing of unwanted goods. Changing the paradigm for this activity from take-make-waste to fully circular is therefore going to be critical to reduce this second tranche of emissions.

Resource-rich North America lags Europe, Scandinavia, China, and Japan in starting down the circular path. But even with a wealth of resources, Canada is coming up against natural system limits and the growing impacts of a climate emergency. Citizens, meanwhile, are asking companies and governments for more sustainable approaches thanks to growing recognition that current practices are hugely wasteful and ultimately quite costly—financially, socially, and for the liveability of the planet.

Circularity offers us an important—and fairly robust—toolset for reducing emissions and other environmental impacts. Deciding which of these tools fit best for individual circumstances will be one of the challenges for governments. For example, shifting from personal vehicle ownership to car sharing may be a good strategy for a country with a highly urbanized population. But it will not address the fact that this is also a country with higher than average travel distances, which will require other tactics to address.

By focusing us more strongly on resource efficiency, circularity also helps us see new opportunities, whether that is reducing corrosion in steel and therefore making better use of infrastructure dollars, or redeploying end-of-life electric vehicle batteries to support rapidly growing sources of intermittent power.

In fact, embedding a circular world view in our efforts to shift to renewable energy systems will be critical to avoid the creation of a huge new waste stream and to meet the surge in demand for metals and other materials created by the shift to wind turbines, solar panels, and batteries. It is also a lot faster to develop better steel-scrap supply chains or recover copper from used electronics than it is to build new mines.

That said, it is important to note that some of the highest impact circularity measures are not focused on material recovery but on reducing material demand. Whether it is reducing food waste or changing construction practices to reduce steel and concrete consumption, these "upstream" measures can have some of the biggest emissions reduction benefits. However, these upstream measures also come with a higher degree of uncertainty and, in some cases, longer lag times (for example, extending building life).

Fundamentally, however, circularity does not require the creation of a vast new ecosystem of policies and processes. It requires, as with current climate action strategies, better alignment of policies and financial measures with goals, whether that is building codes that encourage leaner building practices, better material labeling requirements, or landfill bans for organics and electronics. On the financial side, there is the usual mixture of a need to reduce disincentives (for example, higher taxes on scrap metals or duty refunds for landfilled clothing) and to create incentives (for example, sales tax reductions for goods with high recycled content). At a more fundamental level, changing mindsets may be a longer-term project, but emulating the tight business collaboration culture and stringent efforts to reduce consumer barriers to material recovery demonstrated by Japan are goals worth pursuing.

Canada's federated structure creates challenges in creating a well-coordinated shift to circular practices. But the federal government does, as with current climate efforts, have a central role to play in setting objectives and creating leading policies. The Zero Plastic Waste Agenda and Bioeconomy Strategy are examples of ways that the federal government is already helping to lay the groundwork for circularity. Federal procurement is becoming more aligned with circularity through the *Greening Government Strategy*, but could be even more impactful by integrating circularity requirements in infrastructure spending. In fact, using the policy structure that has been developed around clean technology innovation could provide a useful scaffold for building out a circularity strategy. Many jurisdictions are now embracing circularity as not just an emissions reduction opportunity, but as an economic development policy. Scotland, for example, sees circularity as having a central role in its National Strategy for Economic Transformation and sets as a first objective Scotland becoming, "an international benchmark for how an economy can transform itself, de-carbonise and rebuild natural capital whilst creating more, well-paid and secure jobs and developing new markets based on renewable sources of energy and low carbon technology."

This focus on economic opportunity is also strongly echoed in Europe's Green Deal and its Circular Economy Action Plan. The overarching goal for both inter-linked initiatives is "achieving a cleaner and more competitive Europe" and the bloc clearly sees early adoption of circular principles as a major economic opportunity to develop new markets, products and services.

There are, in fact, any number of strategies where the federal government could lead, such as in developing better data tracking and data linkages between sectors and regions, design regulations for vehicles and appliances to enhance lifespan, repairability and retaining value in the recycling process, restricting plastics or packaging to a simpler set of material compositions for common usages, investigating the potential for electronic and appliance deposit and return systems and how to improve and expand extended producer responsibility programs, and preparing for new demands for new types of infrastructure, such as for electric vehicle battery or solar panel recycling.

At a more cultural level, changing mindsets from seeing resources as infinitely available (despite growing indications that our natural wealth is in steady decline) to understanding they are a finite resource that must be carefully stewarded, is a key challenge for Canada and where it can learn from countries like Japan, where this has been translated into a rigorous commitment to reducing barriers to circularity.

On the industrial circularity front, consideration should be given to the potential advantages of co-locating heavy industry to share energy and waste streams and to enhance access to energy storage, green hydrogen, and waste heat.

Of course, tracking and measuring impact will be key to success and here Canada is behind. Greater effort is going to be needed to track material flows in order to understand the impacts of circular initiatives. It will also be useful as Canada considers measures like carbon border adjustments or consumption-based accounting. Fortunately, Canada has an opportunity to benefit from work being done in this space by everyone from the ISO to the European Statistical Agency.

As the federal government sets about updating its Emissions Reduction Plan, a focus must be on the potential for circularity to "close the gap" between necessary emissions reductions and actions identified to date. Putting resources into building the data framework for properly understanding circularity potential in Canada would be a good first step.

There is really no question that Canada needs to follow in the footsteps of circular economy leaders. To remain competitive in a climate-constrained world, circularity is going to be critical. Therefore, embracing the challenge of closing the circularity gap between Canada and global leaders while achieving the levels of circularity needed to keep warming in check is going to be an essential task for the next decade.

Acknowledgments

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We consulted with circular economy experts from industry, academia, and independent research institutes, and non-governmental organizations across Canada and Europe. Interviews of 30 to 45 minutes in length were carried out with the experts listed below.

	Organization	Experts
Industry	Canadian Steel Producers Association	Catherine Cobden, President and CEO
	Cement Association of Canada	Sarah Petrevan, Vice-President, Sustainability Division
	Chemistry Industry Association of Canada	Christa Seaman, Acting Vice-President Plastics Division
	HP Canada	Frances Edmonds, Head of Sustainable Impact
Academia	Carleton University	Dr. Leanne Keddie, Assistant Professor, Accounting
	Polytechnique Montreal, CIRAIG	François Saunier, Deputy Director
Independent Research Institutes	German Economic Research Institute (DIW Berlin)	Xi Sun, Research Associate
Government	Smart Cities Office	Andrew Telfer, Circular Opportunity Innovation Launchpad (COIL) and Development Lead; Barbara Swartzentruber, former and founding Executive Director; David Messer, Executive Director
NGOs	Circular Economy Leadership Canada	Paul Shorthouse, Managing Director
	Smart Prosperity Institute	Shahid Hossaini, Research Associate
	World Resources Institute	Ke Wang, PACE Program Director; Lotte Holvast, PACE Program Manager; Renilde Becqué, Senior International Sustainability and System Change Advisor

Chris Bataille, Adjunct Professor at Simon Fraser University, a researcher with the Institut du Développement Durable et de Relations Internationales (IDDRI.org), reviewed the draft document.

Two experts from an industry organization were also interviewed and have chosen to remain anonymous.

Recommended citation:

Cundiff, Brad, Calvin Trottier-Chi, Rick Smith, Marisa Beck, and Chris Bataille. 2023. The Next Wave of Climate Action: How circularity can contribute to emissions reductions in Canada. Canadian Climate Institute.

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

Environment and Climate Change Canada   Environnement et Changement climatique Canada

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