CIRCULAR ECONOMY IN QUEBEC

ECONOMIC OPPORTUNITIES AND IMPACTS

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S'ALLIER POUR LA PROSPÉRITÉ

Le développement durable en entreprise

Éco Entreprises Québec

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PREAMBLE

The Research Group on Globalization and Management of Technology (Polytechnique Montréal), in collaboration with the Institut de l'environnement, du développement durable et de l'économie circulaire at Université de Montréal (I-EDDEC), conducted a study on circular economy in Quebec as part of a mandate from the Conseil du patronat du Québec, the Quebec Business Council on the Environment and Éco Entreprises Québec.

The objective was to carry out a scientific and grey literature review to identify the economic and environmental impacts of circular economy, as well as the barriers and legislative levers that could serve in the transition toward a circular economy. The elaboration of case studies focused on five organizations that are active in Quebec's circular economy. A preliminary study to determine the economic sectors with strong potential in Quebec was also performed.

This report therefore discusses the first large-scale study on circular economy in Quebec and constitutes the first step in a two-fold research project. This initial phase pinpoints the province's economic sectors with significant circularity potential. The second will make it possible to specify the results through macroeconomic studies.

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ABBREVIATIONS AND ACRONYMS

3Rs	Reduction, reuse, recycling
3R-RD	Reduction, reuse, recycling, reclamation, disposal
BREF	Best available techniques reference document
CE	Circular economy
CIRAIG	International Reference Centre for the Life Cycle of Products, Processes and Services
CPQ	Conseil du patronat du Québec
CTTÉI	Centre de transfert technologique en écologie industrielle
C&T system	Cap-and-trade system
DIY	Do it yourself
EDDEC	Institut de l'environnement, du développement durable et de l'économie circulaire
ÉEQ	Éco Entreprises Québec
EPR	Extended producer responsibility
EU	European Union
GDP	Gross domestic product
GHG	Greenhouse gas
HDPE	High-density polyethylene
JIS	Japanese Industrial Standards
LCA	Life cycle assessment
LEED	Leadership in Energy and Environmental Design
MDDELCC	Ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques
NASA	National Aeronautics and Space Administration
PS	Polystyrene
QRMMP	Quebec Residual Materials Management Policy
REACH	Registration, Evaluation, Authorization and restriction of Chemicals
RoHS	Restriction of Hazardous Substances
RP	Resource productivity
VAT	Value added tax
WCI	Western Climate Initiative

SUMMARY

There is no doubt as to the negative impact that human activity exerts on the environment, and the international community has adopted a number of measures, such as the Paris Agreement, to minimize the medium-and long-term consequences. In Europe and Asia in particular, the concept of circular economy (CE) has become increasingly significant in view of this challenge. While calling for change to current business models, CE seeks greater efficiency in resource use and waste reduction. This report provides an analysis of relevant documentation and identifies the barriers and levers that could impact the transition toward a circular economy, whose potential benefits are also highlighted here. A number of sectors with significant potential in Quebec are brought to light, along with five case studies of organizations that already provide products and services within a circular economy.

This report adopts the following definition of *circular economy* set out by the *Pôle de concertation québécois sur l'économie circulaire*:

A production, exchange and consumption system which optimizes the use of resources at all stages of the life cycle 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 [1].

A range of strategies, mechanisms and tools may be adopted to develop a circular economy. They may be integrated in all production phases and are based on concepts such as the 3Rs: reduce, reuse, recycle.

A number of current tools and strategies may be coherently integrated into a CE from which five are presented here. The **functional economy** is based on selling performance or service rather than products themselves, often in economic sectors in which the products were previously available. The **sharing or collaborative economy** relies on new ways of organizing work and exchanges according to the principle of shared access to goods. It is generally driven by a digital platform that enables consumers and producers to have a direct contact and interchange their roles based on the products and services offered. **Remanufacturing, reconditioning and repair** are strategies that involve the restoration of products or product components that allow the product life extension. **Industrial symbiosis** brings together businesses in a same industrial area in which one organization's waste becomes another's input material. More widely known, **recycling** includes a series of operations to process recovered recyclable materials in an effort to reintroduce them into a new production cycle.

CE also integrates tools: material flow quantification and impact assessment methods and other means that are more focused on product development processes. In the first case, **input-output analysis** makes it possible to quantify the material flows on a given territory, while **life cycle assessment (LCA)** considers the environmental, social, cost and potential impact aspects of a product, service or process throughout its entire life cycle. In the second case, **ecodesign** accounts for environmental aspects as early as the product design phase and aims to reduce the negative impacts during the product's life cycle. Finally, **reverse logistics (reverse supply chain)** seeks to manage and optimize the flows from consumers to intermediates throughout the value chain back to the manufacturer.

POTENTIAL IMPACTS

The potential impacts of a CE remain relatively unknown. The vast majority of the studies that were reviewed highlight the potential economic and environmental benefits of CE.

The **environmental impacts** of CE include the reduction of the environmental impact generated by human activity. Studies on the topic have especially focused on greenhouse gas (GHG) reductions, specifically through waste management. Generally, they have shown that GHG emissions decrease by several percentage points according to the studied scenarios. The optimization of the use of primary and secondary resources may also reduce water, energy and fertilizer use and curb the need to extract raw materials.

Economic impact studies mainly tackle the impacts of CE on employment and economic activity. Most show that a CE can lead to GDP growth and job creation, which would compensate for losses in more traditional sectors. In addition, wasting fewer resources and adopting new consumption patterns could lead to savings for individuals and businesses.

However, while increased resource efficiency in a CE generates GDP growth, this growth can lead to a **rebound effect** which takes place when material efficiency gains are offset because they lead to greater consumption and environmental impacts.

BARRIERS AND LEVERS : ROLE OF PUBLIC POLICIES

The policies and the economic tools may be aggregated into three broad categories: regulation, tax system and government support. An overview is provided in the following table.

Regulation, tax system and other levers available to governments to foster CE

Regulation	End-of-life regulations	Residual materials management	▸ Using the life cycle approach ▸ Ban on landfill and incineration sites ▸ Ban on waste exports
		Resource efficiency	▸ Reuse and recycling ▸ Biodegradable materials processing ▸ Chemical fertilizer elimination/reduction ▸ Water management ▸ Extended producer responsibility (EPR)
	Environmental management	Industrial production	▸ Process, product and service improvements
		Hazardous substances	▸ Reduction in use ▸ Increase in control
		Renewable resources	▸ Increase in renewable energy sources ▸ Energy efficiency
	Standards	Ecodesign	▸ Setting minimum requirements
		Labelling	▸ Validation of product origin
		Standards	▸ Minimum quality guarantee
	Procurement policies	Public procurement	▸ Purchasing by government authorities based on responsible or green procurement policies
Tax system	Tax measures	Residual materials management	▸ Extended producer responsibility (EPR) ▸ Extended consumer responsibility ▸ Carbon market
		Taxation	▸ Landfill tax ▸ Ecotax (e.g. taxation of non-renewable resources)
Government support	Support and funding	Information	▸ Determination of best practices ▸ Awareness building among stakeholders
		Funding	▸ Direct funding ▸ Support in the search for funding ▸ Research and development support ▸ Waste exchange

Through **regulation**, the government directly influences the ways in which waste is managed. Above all, end of life disposal regulations aim to avoid the elimination of waste or create waste reduction at disposal sites. In some cases, regulations promote the ban or reuse of waste as a raw material. The policies implemented in the studied countries target specific activity sectors, the most common of which are construction, renovation and demolition waste and food waste, which all have significant recovery potential. Resource efficiency policies contribute to end of life efforts and essentially focus on reuse and recycling.

Environmental management involves a range of measures within industrial systems and processes. Industrial production legislation helps reduce the environmental impact of production. With regard to hazardous materials, Europe enacted the REACH regulations to better control the substances as early as the design stage. In an international effort to fight climate change, a number of countries are fostering the development of clean renewable energies, as well as energy efficiency.

Standards ensure quality and compliance and may be supported by governments. For instance, the European Union has adopted ecodesign guidelines. Labelling and standards help inform consumers and serve as communication and product differentiation tools. Finally, public public procurement require that certain purchases meet a series of environmental criteria, thus contributing to the implementation of the CE. Responsible procurement policies have been applied by the governments of Japan, Taiwan, South Korea, Malaysia and the United States.

In addition to regulation, governments may rely on certain **tax measures**, which, among other effects, introduce a cost to the externalities associated with resource development. With regard to waste management, the concept of extended producer responsibility (EPR) is based on the "polluter pays" principle and attributes the responsibility of the environmental impact of the end of life of products to the producers and sellers, while encouraging waste reduction. Incentive pricing systems (ex: Pay-as-you-throw [PAYT] schemes) make consumers more responsible through a charge on waste based on weight or volume. The carbon markets make it possible to negotiate and exchange GHG emissions trading. Taxation of waste sent to disposal sites is viewed as an incentive to reduce residues, recycle, reuse and recover, thus stimulate the development of new products and services.

Finally, government **support and funding** create a leverage effect, for example by informing target audiences about CE. By reducing the risks and reassuring investors with regard to the transition's viability, government support is the key to the success of the transition to a CE.

OTHER BARRIERS AND LEVERS

Other barriers and levers that are independent of government policy may impact the transition to CE. They are technological, economic and social in nature.

Technology constitutes both a barrier and a lever to the implementation of a CE. There is a range of innovations, especially those pertaining to more sustainable product uses. Unfortunately, 100% recycling is not possible owing to the energy that is required and inherent costs. In addition, materials and energy flows extend beyond geographic borders and are likely to lead to problem displacement and problem shifting that are difficult to assess. In addition, the impact of some technologies is only observable in the long term.

From an **economic** perspective, current business models require changes and need to be reviewed. For example, the functional economy makes it possible to extend the service life of products but also brings a number of organizations to question their business models. For these businesses, managing the transition to CE may present significant challenges. The lack of information and capacity to make projections may constitute an obstacle to adequately assess the profitability of investments in the medium and long term timeframes. Finally, lock-in and path dependency phenomena may also constitute limitations since the market will not necessarily retain the best solution but rather the one that is best aligned with current infrastructures.

On the **social** level, mindset changes from all economic actors are necessary, from politicians to businesses and consumers.

CIRCULAR ECONOMY IN QUEBEC

Quebec legislation includes certain practices that may be integrated into a CE. Even so, the government adopted the *Stratégie gouvernementale de développement durable 2015-2020* strategy, which incorporates the notion of CE and steers government bodies toward a green economy by identifying objectives for the fight against climate change.

A preliminary study of sectors with high circularity potential in Quebec highlights that among the most promising are agri-food and energy. Both sectors represent a high use value (production and consumption) of industries in terms of GDP. The metal production and construction sectors should also be considered. These preliminary findings are in alignment with the conclusions of CE impact studies particularly focused on industrial sectors.

A number of growing Quebec organizations are already active in the five CE strategies mentioned above. Among them, five organizations were chosen to be the focus of case studies. According to the stakeholders interviewed, the current trend is to reduce the environmental footprint through recycling, waste reduction and the sharing of goods. The transition is not necessarily simple and requires rethinking the supply of products and services.

CONCLUSION

An increasing number of states are turning to a circular economy to mitigate the environmental impacts of human activity. To this end, the different government authorities have a range of legislative and fiscal tools available to enable and facilitate the transition, some of which are described in this report.

The transition to a circular economy does not imply a decline in economic activity. On the contrary, the studies identified demonstrate that in addition to reducing the environmental impacts, circular economy could potentially increase employment, lead to GDP growth and develop new markets. However, businesses must rethink their business models as well as their production methods. For example, Xerox and Michelin undertook the process by selling the usage or the performance of their products (functional economy) and keeping ownership over them in addition to selling them as proposed by traditional business models. Indeed, this transformation yields numerous business opportunities for organizations.

The work accomplished in this report has led to the recommendations listed below, which are focused on two key aspects: extend and deepen knowledge and support for the market and organizations.

Extend and deepen knowledge

1. Circular economy is an emerging approach, and there is still a significant amount of basic and applied research that must be conducted to ensure that the transition generates the expected benefits as it takes place. For example, the European Union will dedicate one billion euros to circular economy research and innovation in 2018–2020 [97].

2. The sectors with high circularity potential in this study were essentially identified based on a review of international literature. The analysis should be further detailed by applying advanced methodologies described in this report. A better understanding of the characteristics that are specific to Quebec will facilitate the choice of priority strategies and sectors.

3. The potential economic impacts of a transition toward a circular economy described herein are also based on a review of international literature. Modeling for the Quebec context using specific data would be essential to better anticipate national impacts, for example in terms of GDP growth, job creation and greenhouse gas reduction.

Support for the market and organizations

4. Because Quebec market stakeholders (businesses, contracting authorities, legislators, etc.) and society at large are predominantly unfamiliar with the concept of circular economy, a broad awareness campaign and targeted training programs would ensure their participation to ensure their participation in a transition to a circular economy.

5. The transition to a circular economy should include support and incentive programs, as well as appropriate taxation and favourable legislation to be fully carried out to help boost public and private investment. A number of initiatives implemented in Europe and Asia could inspire future circular economy actions undertaken in Quebec.

6. Circular economy has significant entrepreneurial potential, as it can contribute to gains in terms of productivity, efficiency and profitability and stimulate research for innovation. The application of circular economy concepts in business models and processes with a view to advancement should therefore be driven by the development of strategies, analytical tools and financial and regulatory solutions to identify high-potential material flows and determine new uses and market opportunities for them.

1 INTRODUCTION TO CIRCULAR ECONOMY

There is no doubt as to the negative impact that human activity exerts on the environment, and the international community has adopted a number of measures, such as the Paris Agreement, to minimize the medium- and long-term consequences. In recent years, a number of strategies have been set out in an effort to tackle the issue, and the concept of circular economy is gaining momentum, particularly in Europe and Asia (mainly China and Japan). The circular economy is presented as an alternative solution to the *linear* economy, which is dominant (currently, less than 10% of material flows are closed-looped [2]) and consists in extraction, production, consumption and disposal. In light of the negative factors and impacts—environmental pollution, limited resource availability and the expansion of the middle class leading to a global increase in consumption—this unsustainable approach must be challenged.

The concept of circular economy (CE) seeks to account for the finiteness of resources and corporate and territory levels and of their circularization potential (i.e. their potential to reintegrate the economic system to avoid elimination). Still relatively new, CE brings together a number of scientific disciplines but has yet to have a clearly defined universal definition. Still, all the definitions that are currently in use have one thing in common: they consider a circular logic and optimized resource use through a range of strategies.

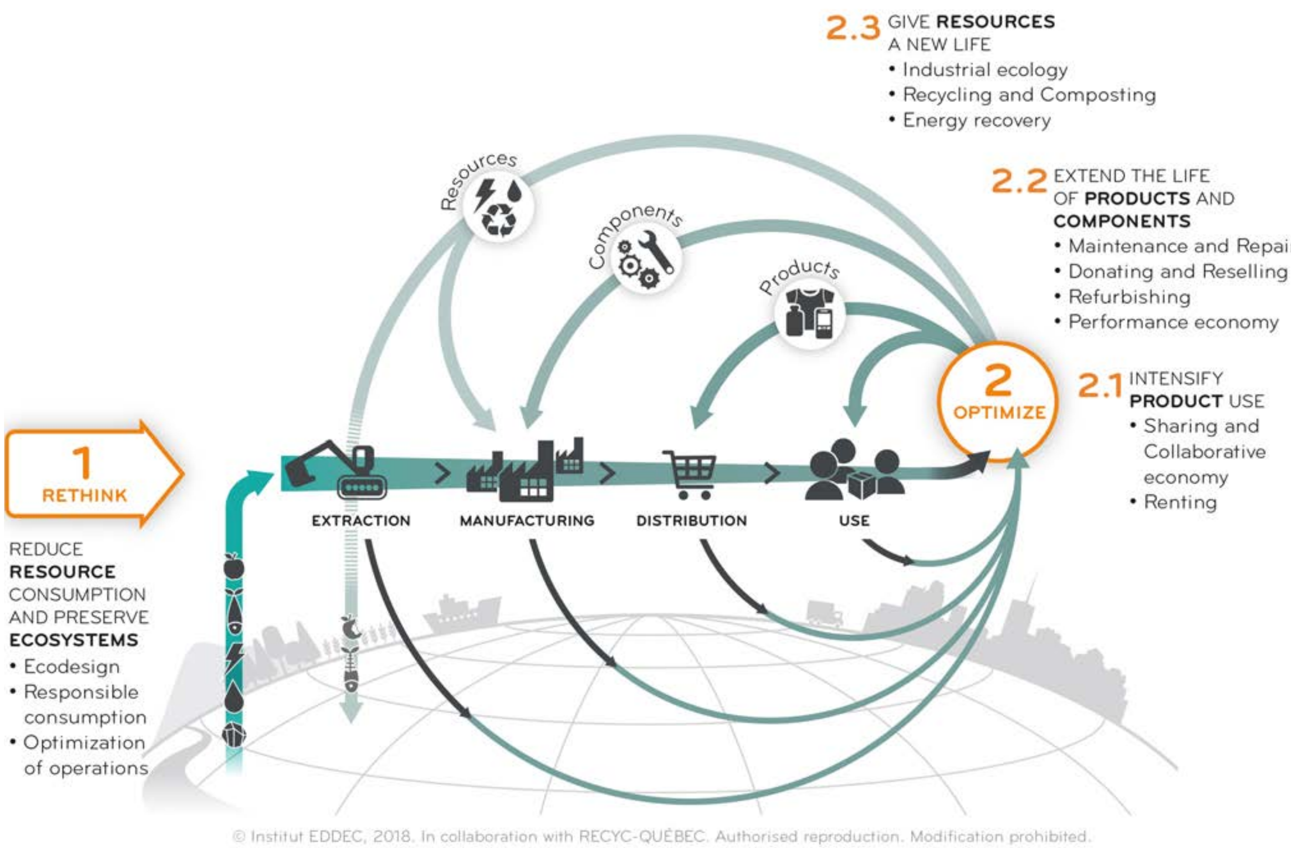
In August 2015, a committee of some 15 strategic stakeholders involved in the implementation of CE in Quebec was assembled. The committee is coordinated by Institut de l'environnement, du développement durable et de l'économie circulaire (Institut EDDEC) at Université Montréal. This report adopts the following definition of *circular economy* set out by the Pôle de concertation québécois sur l'économie circulaire (2016):

A circular economy is a production, exchange and consumption system which optimizes the use of resources at all stages in the life cycle 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 [1].

Figure 1 illustrates the concept of circular economy, as proposed by Institut EDDEC [3] (see additional figure in Annex 5.1).

Circular economy integrates a number of strategies and tools driven by factors including three well-known principles of environmental impact limitation: source reduction, reuse and recycling—commonly known as the 3Rs. As highlighted by Institut EDDEC, these strategies and tools may be integrated into all the stages in the production process: upstream (ecodesign) and during production (industrial ecology), distribution (service economy) and consumption (sharing economy).

FIGURE 1 – Diagram of a circular economy (Institut EDDEC)



1.1 KEY CIRCULAR ECONOMY STRATEGIES

As illustrated in Figure 1, circular economy coherently integrates several tools and strategies that already exist under isolated forms. This report presents five of these strategies: the service economy, the sharing economy, remanufacturing and reconditioning, industrial symbiosis and recycling.

The functional or performance **service economy** is based on selling product services rather than products themselves: the product's performance prevails over its possession, leading to the decoupling of added value and energy and raw materials consumption. For most organizations, this outlook brings about radical changes to the business model. Consider the initiative implemented by Michelin, which provides a tire use service to heavy vehicle fleet owners. As part of the service, Michelin retains ownership of its tires and, for a charge per kilometre, ensures all maintenance, remanufacturing and retreading and installs telemetry sensors on the tires to maintain optimal pressure. This practice leads to fuel savings and greenhouse gas (GHG) reductions and more than doubles the service life of the tires (2.5 times), generating key benefits for Michelin, which continues to own the products [4]. Xerox also provides customers with a photocopier use service. In Quebec, Chic Marie has developed a variant of the functional service economy model: rather than sell designer apparel, it offers a monthly clothing rental service.

The **sharing or collaborative economy** relies on products and services to optimize resource use [5]. Based on goods sharing, it is based on new types of work organization and exchange. It is generally driven by a digital platform that enables consumers and producers to contact each other directly and interchange their roles based on the products and services that are available. According to the Agence de l'Environnement et de la Maîtrise de l'énergie (ADEME), the system enables peers to exchange a product or service for their own use [4]. For example, in Montréal, members of La remise can access a work tool library. Other organizations, such as Crew collectif & café, FourmiliAire and Abri.co, provide coworking spaces, renting modular offices to self-employed workers.

Remanufacturing involves the refurbishment of a product through disassembly, cleaning, inspection, sorting, reconditioning and reassembly. **Reconditioning** makes it possible to make old components functional again [6], [7]. For example, equipment used in the energy sector has a service life of several decades that includes remanufacturing and reconditioning cycles. Indeed, the blades of wind turbines are reconditioned on a regular basis to be restored and ensure their performance [3].

Industrial symbiosis brings together businesses in a same industrial area in which one organization's waste becomes another's input or raw material. This system is mainly (but not only) based on geographic proximity [8], [9]. For example, in Quebec, the enterprise Loop helps reduce food waste by recovering fruits and vegetables deemed inadequate for sale in grocery stores by processing them into juice. The residual pulp is then used and integrated into the dog treats manufactured by Wilder & Harrier, Loop's business partner.

Finally, **recycling** consists in a series of operations to process recovered recyclable materials in an effort to reintroduce them into a new production cycle [4], [6]. The materials are reused either in a closed-loop system (i.e. reused in similar products) or an open-loop system (i.e. reused in other products). Polystyvert, for example, has developed a process to recycle polystyrene (PS) and reduce freight costs: it quickly dissolves PS by putting it in contact with an essential oil stored in a container left at the client's place of business, thus making it possible to transport ten times the volume of untreated PS while relying on similar mechanical properties.

1.2 MECHANISMS AND TOOLS TO IMPLEMENT CIRCULAR ECONOMY

Circular economy integrates a range of tools, including material flow quantification methods and impact assessment methods (input-output analysis, life cycle assessment) and tools that tend to focus on the product development process (ecodesign) or recovery in the value chain (reverse supply chain). Four such tools are presented here.

Input-output analysis is an economic modeling tools used to assess inputs and outputs in order to evaluate the possible interactions within an economy. For example, inputs may consist of imports or natural resource consumption, while outputs may be exports, pollution or waste [11].

Life cycle assessment (LCA) is a scientific method to assess production and consumption habits and accounts for a range of environmental, social or cost-related factors and potential impacts of a product, service or process throughout its life cycle, from raw materials extraction and processing to use, maintenance and end of life [12]. Life cycle standards developed by ISO (ISO 14 040 et ISO 14 044) ensure that all analyses are consistent internationally. In Quebec, the International Reference Centre for the Life Cycle of Products, Processes and Services (CIRAIG) specializes in LCA. Relying on a series of environmental indicators, the life cycle assessment conducted by the CIRAIG to compare traditional and electric vehicle performances in Quebec revealed that electric models provide many benefits in comparison to traditional ones. However, in a context in which the energy supply is not hydroelectricity and for total mileage of less than 150 000 km, the results suggest a standard vehicle is the sounder option [13].

Product **ecodesign** accounts for the environmental impact of a product from its design phase, notably by optimizing its use of resources and durability, including modularization and remanufacturing, component reuse and reduction in raw materials use [6], [14], [15]. Findings by Institut de développement de produits and Pôle Éco-conception showed that ecodesign had a neutral or positive effect on profits for 96% of 119 studied businesses—a trend that was confirmed in the long term [16].

Lastly, **reverse supply chain** helps optimize the flows from consumers to manufacturers and the intermediary links in the value chain, which is the opposite of the standard supply chain [6]. For example, Montréal-based Woodflame manufactures barbeques. After expanding its activities to the global market, it restructured its return service supply chain in different markets. While Canadian customers continue to return products directly to the manufacturer (reverse supply chain with same forward and backward logistics), European and American customers bring their products back to a nearby service centre that then repairs or reconditions them and returns them to their owners (reverse supply chain with different forward and backward logistics) [17].

In sum, circular economy aims at the more efficient use of extracted resources and the minimalization and even total abandonment of landfilling and incineration. By guaranteeing resource availability in a world in which resources are limited, CE also serves to ensure economic development [11], [18]–[21] [19], [22]. It therefore provides the opportunity to create new products and services and brings about the transformation of business models. This report presents of review of the CE literature and its potential impacts and also highlights certain barriers and levers to its widespread adoption. It includes an overview of some of the policies adopted in Quebec, identifies sectors with high circularity potential and outlines case studies of organizations that have implemented the approach in Quebec.

2 IMPACTS, BARRIERS AND LEVERS OF CIRCULAR ECONOMY

Circular economy has been the focus of a number of studies to assess the potential economic and environmental impacts. Research on the topic also explored current barriers and levers, notably from the perspectives of legislative frameworks, technological advances and awareness building among stakeholders in the economy.

2.1 POTENTIAL IMPACTS

The potential impacts of circular economy have been considered for a number of years, with varying results from one study to the next. The reason is that there are many approaches (microeconomic, macroeconomic, sectoral), combinations of analyses (by sector, product, material) and different interpretations of the concept that complexify impact analysis [5], [23], [24]. The deployment of CE is still in its earliest stages, and the quantitative models sometimes rely on simplification and several hypotheses without necessarily accounting for the many challenges of this economic transformation, such as the rebound effects [5]. Still, the vast majority of studies highlight the potential economic and environmental benefits of CE. The rebound effects reveal that CE may also yield negative impacts.

The studies reviewed here contain little discussion of the social impacts of circular economy. This may stem from the choice to distinguish the work from sustainable development research [19]. Even so, many studies assessed the net impact of CE on employment, which is positive and will be further developed in the section dedicated to economic impacts.

The following section provides an overview of a number of studies and an assessment of the potential impacts of a transition to CE. A more in-depth evaluation of the studies is available in Annex 5.5. The following table presents the activity sectors that were considered. Certain sectors—such as the construction sector—are cited more often than others.

TABLEAU 1 – Number of studies assessed per industrial sector (international)

Agriculture	2
Agri-food	10
Buildings and construction	13
Consumer goods	4
Chemical industry	3
Logging	3
Mining	4
Hospitality	1
Industrial	4
Pulp and paper	3
Plastics processing	1
Energy production	5
Consulting services	2
Public services	2
Textiles	2
Transport	4

In terms of CE strategies, the most commonly studied are reconditioning and repair (8 studies), recycling (7 studies) and reuse and recovery (4 studies).

2.1.1 Environmental impacts

Circular economy constitutes a potential source to reduce environmental impacts. The studies that were reviewed, which are all European, focus on greenhouse gas (GHG) reduction. They especially look at waste management with a focus on recycling and recovery. The studies also account for the economic impacts of CE on gross domestic product (GPD), which, for the most part, are estimated positive.

GHG reduction

- An analysis carried out for the Club of Rome on five European countries assessed the GHG reduction potential of CE. Three scenarios were set out: 1) 50% increase in the renewable energy share in the grid mix leading to a 50% reduction in GHGs; 2) 25% increase in energy efficiency, especially transport, leading to a 30% reduction in GHGs and 3) resource-efficient manufacturing leading to a 3 to 10% reduction in GHGs. Because the three scenarios are mutually supportive, their combination could potential reduce GHGs by 66% as compared to 2010 [25].
- A study by the Ellen MacArthur Foundation and McKinsey looked into the impact of CE in the transport, food and housing sectors in the European Union. Relying on an economic modeling methodology and 150 expert interviews, the results revealed a GHG reduction potential of up to 48% in 2030 and 83% in 2050 [26].
- Across the European food chain, approximately 31% of food is wasted [26]. In Canada, the figure is similar (30 to 40% according to RECYC-QUÉBEC). Reducing food waste would also serve to reduce the environmental impacts of agricultural land use from 28 350 to 47 520 km^2 in 2025 and from 38 070 to 56 970 km^2 in 2030. Based on the extent of these reductions, the potential GHG reductions total 56.5 to 96.5 million tonnes in 2025 and 74.6 to 115 million tonnes in 2030 [5], [27]. Reducing food waste is among the priorities of the European Commission [9].
- The revision of waste management regulations by the European Commission should lead to emissions reductions of some 424 to 655 million tonnes CO_2 eq. between 2015 and 2035 [5], [28]. These results are in keeping with those obtained by Eunomia Research & Consulting, which used an assessment method based on different scenarios related to waste, landfilling, packaging and packaging waste directives[29].
- A case study on the food and beverages, metal products and hospitality sectors considered optimized resource use, which could yield potential annual GHG reductions of 2 to 4% across Europe [5], [30].
- Recovering one tonne of steel or aluminum offsets the extraction of virgin materials and leads to average savings of 1.2 and 7.1 tonnes CO_2 eq. per tonne, respectively [9]. Recycled copper reduces theses emissions by 65% [31].
- Like additive manufacturing (3D), reconditioning could yield significant GHG reductions through technological development by increasing product performances by 70%. Standard machining methods yield an average of 40% [9].
- With a view to improve resource efficiency, a British study identified several waste reduction options and revealed that minimal investments could bring about a reduction of 29 million tonnes CO_2 eq. and savings of 23 billion sterling pounds [32].
- In Denmark, an analysis by the Ellen MacArthur Foundation [33] revealed potential GHG emissions reductions of between 3 and 7% in the food and beverages, buildings and construction, machinery, plastic packaging and hospital sectors (in order of circularity potential[1]) [5].

1 Role in the national economy in terms of contribution to gross added value, employability and growth and international competitiveness; circularity potential based on energy and material intensity, volume of waste generated and the amount of waste sent to landfill or incineration; estimate of reach to increase circularity.

- In the buildings sector, reconditioning and extending the service lives of infrastructures yield economic and environmental benefits. It was determined that an increase in the efficiency of material resources and waste reduction would have decreased CO_2 emissions across Britain by 1 638 kilotonnes in 2009 [32].
- It was estimated that GHG emissions in Europe would fall by between 247 and 303 million tonnes by 2020 [5], [27] through municipal waste recycling modeling.

Other environmental impacts

- A European study on the impact of increased resource efficiency through reductions in food waste and textile reuse revealed a potential reduction in water consumption of between 26.1 and 52.2 million litres through reuse, leading to a decrease in fertilizer use of 0.44 to 0.88 million tonnes in 2025 and in pesticide use of 0.58 to 1.02 million tonnes in 2030 for cotton production alone [5], [27]. Similarly, precision agriculture could potentially reduce the use of fertilizer and water by 20 to 30% to support the fight against soil and aquatic eutrophication [9].
- A high number of resource losses are attributable to non-optimized processes that lead to a corresponding increase in the need for raw materials. For example, 10 to 15% of infrastructure materials are not recovered during construction, and 54% of the materials generated in home demolition are landfilled. Cars are not in use 92% of the time, work spaces are empty 50 to 65% of the time and the average service life of manufactured products is 9 years. Adopting a circular economy could potentially reduce primary materials consumption by 32% in 2030 and 53% in 2050 [26].
- The Danish study cited above estimates that the adoption of a number of CE-specific measures would lead to a 5 to 50% reduction in primary resource use by 2035 [5], [33].

2.1.2 Economic impacts

Circular economy opens the door to the transformation of the economic model, and its impact may be apparent in terms of GDP, employment, investment and new market development [5]. The chiefly European studies especially focused on the impact on employment and economic activity, mainly with regard to GDP. For example, a study by the European Commission indicates that reducing resource consumption through more efficient material use by 1% could generate 12 to 23 billion euros in economic activity and lead to the creation of 100 000 to 200 000 jobs in Europe [9].

Economic activity

- The Club of Rome study looked at the economic impact of renewable energies, energy efficiency and resources. The authors predict GDP growth of at least 1.5%. However, investments equivalent to 3% of GDP are required to facilitate the transition to circularity and attain the results set out in the study [25].
- Technological advancements in Europe could enhance resource efficiency by 3% by 2030, which represents a benefit of 1 800 billion euros and a 7% positive contribution to GDP, especially in the transport, food and building sectors. In addition, the implementation of circular economy would have a positive impact on employment, mainly due to the increase in spending that would occur with the price declines in various economic sectors [26].
- Some studies calculated the economic value of GHG reductions in Europe. For example, in the recycling and reuse sector, the gain is assessed at between 2.5 and 12 million euros. The difference stems from the variation in the value attributed to a tonne of CO_2 from 10 to 40 euros (Ökopol, 2008 cited in [5]).
- A study evaluated the environmental and economic impacts of the adoption of alternative policies to enhance resource productivity (RP) in Europe by 2030. Three RP scenarios are proposed and compare the cost-effectiveness of different measures in terms of the impact on GDP based on the investments required to attain them. The modeling demonstrates that there is a slight potential to reduce GHG emissions and maintain a positive GDP [34], estimating 2 to 2.5% annual growth in European GDP. The costs incurred to attain the target RP level (2%) are lower than the economic benefits that are generated. However, beyond an increase of 2.5% in RP, additional efforts lead to net costs on GDP [34].
- A European study on resource efficiency in the food, beverage, metal products manufacturing and hospitality and food services sectors estimates the net annual benefits to be between 245 and 604 billion euros [30].
- The Danish study estimates that the nation's GDP could rise by 0.8 to 1.4% in the studied sectors (food and beverages, buildings and construction, machinery, plastic packaging and hospitals). The introduction of circularity principles could increase exports by 3 to 6% in 2035. In 2020, GDP growth is estimated at 400 million euros (0.1%) [33].
- A Finnish study assessed circular business opportunities at between 220 and 240 million euros/year in the pulp and paper sector. Most of Finland's exports are in the

equipment and machinery sectors, mainly for forestry and mining. The adoption of business models driven by a service economy and reconditioning could generated between 300 and 450 million euros per year. The study also provides an overview of the food sector and affirms that the potential annual savings from minimizing waste across the value total between 150 and 200 million euros [5] [35].

- A Scottish study evaluated the carbon impact of the national economy's materials consumption as part of an analysis of economic scenarios for 2050 [36]. The findings show that a circular Scottish economy could reduce territorial emissions by 11 million tonnes CO_2 per year by 2050 as compared to the business-as-usual scenario. As a whole, the study illustrates how the adoption of a circular economy could potentially reduce carbon emissions and consumption across the territory without stunting economic growth.

Employment

- The study for the Club of Rome revealed a job creation potential of 280 000 positions in the renewable energy sector in five countries. With regard to energy efficiency, the potential is 535 000 new jobs [25]. Finally, the implementation of resource efficiency measures could lead to 700 000 permanent jobs that are closely linked to a more intensive labour offer. The combination of these scenarios totals up to 1.28 million new positions.
- Another study indicates that the adoption of various European scenarios driven by circularity objectives, mainly in the textile and furniture sectors, could lead to a job creation potential of between 635 000 and 750 000 positions by 2025 and 710 000 to 870 000 by 2030. Also, in Europe, a 70% recycling rate for all materials could create 563 000 net jobs, including direct, indirect and induced jobs, for every 1 000 tonnes of recycled materials [5].
- The analysis of the impacts of the review of European Union waste management regulations included job creation figures based on different regulation application scenarios. The study estimates that between 136 000 and 178 000 full-time jobs, mainly in the recycling sector, could be created [28],[5].
- An employment study conducted in Denmark revealed that, as compared to the current growth scenario, the additional job creation potential is between 7 000 and 13 000 positions in 2035. In the shorter term, the impacts for 2020 are 1 300 to 1 400 new jobs [33].
- In Île-de-France, the evaluation of the impacts of end-of-life activities estimates job creation in sorting and recycling operations that is 10 times higher than in incineration and up to 30 times higher than in landfilling [9]. Another study indicates that sorting 10 000 tonnes of waste yields the potential to create 11 full-time positions, while the dismantling of complex used products could create 50. These two activities generate more positions than incineration, composting, methanization or landfilling. However, automation could impede job creation. ADEME projects that 2 500 to 5 000 of the 7 000 jobs in France in 2011 could be lost [37]. With regard to reuse and repair, the potential job creation is estimated at approximately 22 000 full-time positions in France [37].

- In the context of more efficient resource use, a study assessed the job creation and job market improvement potential of the development of a circular economy in the United Kingdom by 2030. Three circular scenarios were analyzed: no change, continuation of effort and current recycling and reconditioning activities and ambitious transformation. The study revealed a sustainable job creation potential for 2030 of approximately 517 000 gross jobs and a decrease of approximately 102 000 unemployed persons for the ambitious circular scenario. The results also reveal employment opportunities for unemployed and less literate people [38].
- The US Trade Commission affirmed that the reconditioning sector has experienced 15% growth, with 14 000 net jobs between 2009 and 2011, and now provides over 180 000 full-time positions (Deboutière et Georgault, 2015 cited in [37]).
- In the United Kingdom, remanufacturing helped reduce production costs by around 34% and double the number of jobs to 310 000 new positions. It also led to a 70% reduction in supply costs and a 20% reduction in sales prices. Annual revenue is estimated at between 5.6 and 8 billion sterling pounds [37].

Additional economic impacts

- Considering the required investments to facilitate the transition to a circular economy, and current costs may explain why the transition is moving at a relatively slow pace. For example, a Europe-wide study estimates that a reduction of 450 ppm of CO_2 emissions calls for investments totalling 108 billion euros to build an efficient reuse and recycling system, as well as 30 to 50 billion euros annually for the next 15 years. In addition, 31 billion euros would be required annually to reduce energy consumption by 1% and 2 200 billion until 2035 to replace eroding infrastructures and achieve decarbonization goals [5], [26].
- In the agriculture and agri-food sector, savings stemming from a 60% reduction in waste could total 73.4 billion euros for households by 2030 [27]. The hospital sector, which is responsible for 19% of Europe's food waste (89 million tonnes annually), could save 4 239 billion euros/year [31].
- Without stating a figure, recycling and recovery have the added benefit of reducing the vulnerability of organizations to variations in raw materials prices, which poses a risk to the long-term viability of businesses. Also, better resource use would certainly ensure future access to the resources that are required [9], [37].

2.1.3 Rebound effects

If, as suggested in certain studies, circular economy can generate GDP growth by enhancing resource efficiency, this growth may also generate rebound effects and reduce the expected environmental benefits [25], [39]. A rebound effect occurs when the savings yielded by increased efficiency in production and consumption lead to an increase in production and consumption [39], [40]—a phenomenon that is also known as the Jevons paradox and better known as the rebound effects of energy efficiency. In circular economy, the identification of a rebound effect implies determining whether the studied activity (e.g. recycling or remanufacturing) has a lower or greater impact per unit as compared to the primary production with which it is in competition. The issue is then to establish whether circularization leads to increases in production and consumption.

Two other noted mechanisms can trigger a rebound effect [39]. The first is the substitution of secondary products. In this case, under certain conditions, secondary products are insufficient substitutes to replace products made from original resources. The possibility of losing quality or value in recycling (e.g. brought about by degradation) makes it difficult to compare recycled and primary materials, leading to additional secondary goods production and not to substitution, thus reducing the positive impacts of recycling. Also, remanufactured goods may end up in different markets than new products, generating a global increase in product offer and therefore in total consumption.

The second mechanism is the effect of secondary goods on market prices, which ties into the fact that an increase in secondary production can impact prices. When this production is lower quality, prices are marked down in order to make the products more attractive as compared to higher quality items. This leads to an increase in production, sales and use, and consumers end up with greater purchasing power. They risk consuming more and, by the same token, spurring a rise in secondary production.

Currently, it is difficult to determine whether there is a rebound effect related to circular economy. A number of theoretical evaluations seem to indicate that some recycling and reconditioning activities may foster increases in production and consumption [41]–[43], while activities to extend the service lives of products through reuse, higher quality production and better materials selection could reduce the rebound effect and create employment.

2.2 BARRIERS AND LEVERS: THE ROLE OF PUBLIC POLICIES

A number of nations, including China, Japan, Germany and the Netherlands, have set out specific circular economy policies. They rely on governance systems and related policies that reflect the range of cultural, economic and environmental factors that are in place.

China has adopted a top-down governance model based on command and control instruments that may limit innovation, education, research and development and higher risk entrepreneurship [44]. The European, Japanese and American political systems are driven by market principles, and Europe has implemented a bottom-up approach in which initiatives and pressures chiefly stem from environmental, social and non-government organizations [45]. Japan relies on a strategy similar to China's with framework legislation that addresses a wide range of stakeholders and other actors. This structure is different from the systems in other nations, which often only have vertical application that is limited to industrial parks [14]. A diagram in Annex 5.2 illustrates an approach that reconciles the two governance strategies.

In sum, there are no set standards, and measures are divided into downstream (waste management) and upstream (prevention and reduction) approaches. See the following table for reference [14], [46].

TABLE 2 – Circular economy strategies in four nations

Nation	Importance afforded by governments
China	Waste prevention and reduction especially through clean technologies and reuse (industrial ecology)
Japan	Prevention through ecodesign Substitution of non-renewable resources by renewable ones
Germany	Waste prevention through efficient resource use including ecodesign Substitution of non-renewable resources by renewable ones
Netherlands	Waste management through life cycle to reduce environmental impacts

2.2.1 Policies to foster circular economy

The policies and economic tools presented in the following pages were taken from different initiatives and are reported in three broad categories: regulation, taxation and government support, as summed in the table below.

TABLE 3 – Regulation, tax system and other government levers to foster CE

Regulation	End-of-life regulations	Residual materials management	▸ Using the life cycle approach ▸ Ban on landfill and incineration sites ▸ Ban on waste exports
		Resource efficiency	▸ Reuse and recycling ▸ Biodegradable materials processing ▸ Chemical fertilizer elimination/reduction ▸ Water management ▸ Extended producer responsibility (EPR)
	Environmental management	Industrial production	▸ Process, product and service improvements
		Hazardous substances	▸ Reduction in use ▸ Increase in control
		Renewable resources	▸ Increase in renewable energy sources ▸ Energy efficiency
	Standards	Ecodesign	▸ Setting minimum requirements
		Labelling	▸ Validation of product origin
		Standards	▸ Minimum quality guarantee
	Procurement policies	Public procurement	▸ Purchasing by government authorities based on responsible or green procurement policies
Tax system	Tax measures	Residual materials management	▸ Extended producer responsibility (EPR) ▸ Extended consumer responsibility ▸ Carbon market
		Taxation	▸ Landfill tax ▸ Ecotax (e.g. taxation of non-renewable resources)
Government support	Support and funding	Information	▸ Determination of best practices ▸ Awareness building among stakeholders
		Funding	▸ Direct funding ▸ Support in the search for funding ▸ Research and development support ▸ Waste exchange

Table based on [31], [47]–[49] and completed based on [6], [9], [11], [14], [18], [21], [22], [31], [46], [49]–[55].

2.2.2 Regulation

Though regulation, a government may directly influence waste handling and management standards. While the policies presented here mainly constitute levers for CE development, there are also certain political barriers. According to a study conducted by the Wuppertal Institute for Climate, Environment and Energy, thinkstep and Fraunhofer [31], political barriers slow the emergence of economic opportunities that are in line with CE. The study identifies barriers, obstacles and legislative gaps that make potential CE markets inaccessible or underperforming. The constraints are not related to a specific policy but to a set of regulations. Also, to move beyond some of these barriers, it is important to restore balance between the different policies [56].

End-of-life regulations

End-of-life regulations are deployed in a range of strategies, including downstream waste management and upstream efficient resource use. Residual materials management chiefly aim to avoid disposal, reduce the volumes sent to landfills and, in certain case, ban or reuse the waste as raw materials. Europe, China and Japan apply variants of the 3Rs in their waste management laws. Japan undertakes standardization activities for waste processing, while China applies principles that are compatible with its production efforts. The Netherlands have adopted the life cycle approach to reduce the environmental impacts of materials [46].

Several countries and US states [55] prohibit the disposal of certain products and materials at landfill and incineration sites. In a number of cases, the bans are matched by complementary measures (taxation, in particular) [57]. The European Commission also seeks to toughen the detection of the illegal waste that crosses European borders by providing border agents with greater means [30].

All the policies of the studied countries target specific activity sectors, mainly the construction and food waste sectors, whose volumes and recovery potential are high. The construction sector accounts for the largest volume in the European Union, leading to the implementation of a voluntary construction and demolition waste management protocol [51]. In 2002, Japan adopted a law on the recycling of construction materials. Beyond construction, the Netherlands are targeting seven pilot sectors[2] to trigger a 20% reduction in environmental impacts over the life cycles based on factors including volumes (tonnes) of waste and pollution levels of toxic substances [46].

Resource efficiency policies make an overall contribution to all end-of-life efforts. The actions are driven by reuse and recycling and include laws on the recycling of containers and packaging, as well as appliances, vehicles, construction materials and food [11]. In 1991, Japan had already adopted a legislative structure for efficient resource use through targeted recycling policies. In Europe, the specific directives on waste from electrical and electronic equipment (WEEE) and end-of-life vehicles (ELVs) aim to make European producers responsible with regard to the guidelines and regulations related to their products and thus constitute extended producer responsibility-type measures (EPR) [6]. With regard to biodegradable materials, they are targeted in certain legislative frameworks. For example, the European Commission outlined actions against food waste in the Circular Economy Action Plan [51], and Japan passed a law to promote the use of recyclable food waste [46]. The EU also set out rules for the use and free

2 Textiles, cardboard, construction and demolition waste, aluminium, PVC, bulky household waste and food waste [22].

circulation of fertilizers made from primary and secondary materials (recovered nutrients) to foster the transformation of organic waste and by-products into economic opportunities. The EU also enacted regulations for the better integration of water reuse, planning and management [51]. Packaging, paper, cardboard, household appliances, batteries and accumulators and medications are among the other product categories to be commonly targeted by efficient resource regulations [9], [46], [49]. These laws generally impose restrictive measures and sometimes include extended producer responsibility mechanisms through the funding of collection and processing operations [46].

Environmental management

Environmental management comes in different formats and measures in industrial systems and processes. **Industrial production** legislation helps reduce the environmental impact of production. For example, in China, a clean production law is at the core of the nation's law to promote circular economy [14], which aims to ensure the ongoing improvement of economic efficiency and reduce environmental and human health impacts by reducing waste, pollution and the flow of non-renewable and hazardous inputs in industrial processes, products and services [51].

With a view to reduce the environmental footprints of products in the design stage, Europe implemented the REACH regulation to better control **hazardous substances** in Europe [58]. In addition, the European Commission adopted a proposal to review the RoHS directive on the restricted use of hazardous materials in electric and electronic equipment, which aims to replace certain hazardous substances [59].

As part of a collective effort against global warming, states are driven to reduce their greenhouse gas emissions, specifically through the development of **clean renewable energies** and energy efficiency. Feed-in tariff mechanisms foster investment, technological development and the supply of energy from renewable sources to reduce dependence on non-renewable and pollutant energy sources [22], [60].

Standards

Standards function as a type of assurance of quality or compliance according to set criteria and are used as levers to facilitate transactions between stakeholders. Standards may be issued by entities other than governments, such as industrial associations or non-government organizations (NGOs).

In 2005, the European Union adopted an **ecodesign** directive that provides a framework of minimum energy efficiency requirements [61]. In the 2016–2019 Ecodesign Working Plan, the regulatory review also focused on standards pertaining to issues including energy efficiency and the recycling of electronic devices [51]. China and Japan rely on more stringent standards that are often paired with the use of environmental labels to identify and differentiate high-performance products [46].

Labeling makes it possible to provide information to consumers based on set criteria [14]. In some cases, labels serve as communication and product differentiation tools or describe a product's features in compliance with certain laws.

To foster the reuse and extension of the service lives of products, Japan and Europe have adopted **standards** for recycled products and for products (new and used) sold online. The Japanese Industrial Standards Committee (JIS) has implemented measures to standardize the use of recycled products and facilitate their distribution and use [46], [62]. In Europe, the Circular Economy Action Plan, which aims to protect consumers, provides warranties on consumer goods and promotes the sale of sustainable and repairable products for up to two years following sale or delivery [51].

Procurement policies

Finally, with regard to regulations, governments may adopt procurement policies requiring that public sector organizations select products that meet certain environmental criteria. In Europe, government procurement accounts for 19.9% of GDP [63], and the impact of procurement policies is significant. Green procurement policies are also applied by the governments of Japan, Taiwan, South Korea, Malaysia and the United States [49]. In the United States, NASA and the Pentagon have made service offers for the purchase of material goods based on green procurement a priority [22].

2.2.3 Tax system

In addition to policy, governments rely on **tax measures** that attach a cost to the externalities associated with resource development to stimulate more efficient and effective use of resources in an effort to reduce waste and pollution.

Since the adoption of the German packaging law in 1992, the concept of extended producer responsibility (EPR) has been integrated into a number of environmental policies around the world [55]. Based on the polluter pays principle, the concept attributes the responsibility of the environmental impact at the end of a product's life to the producer or seller and promotes the reuse, recycling, disposal and reduction of waste (i.e. product circularity) [14], [55], [64]. Japan and Quebec have developed curbside recycling programs for recyclable packaging and containers, whose end of life is funded by businesses in order to offset the collection fees incurred by municipalities and collectors. For citizens, an incentive-based pricing systems (ex: Pay-as-you-throw schemes [PAYT]) similar to EPR encourages waste reduction and higher recycling rates [54]. Based on the weight or volume of curbside waste, the system makes consumers responsible [55]. In 2010, just over 25% of US cities had implemented this system, which is also in effect in Switzerland, Germany, Italy, Denmark, the Netherlands, Spain [65] and Quebec in the municipalities of Potton and Beaconsfield [66].

The carbon markets, each with their own specific features, make it possible to negotiate and exchange GHG emission rights in an effort to reduce the environmental impact of major polluters [67]. Participants are attributed GHG permits on a nation by nation basis. A cap on emission units in CO_2 equivalent with which target organizations must comply is set. These businesses must reduce their emissions by, for example, changing their processes through the implementation of green technologies or reducing their energy consumption. If they fail to observe the threshold, they must purchase emission units on the carbon market. Since 2015, the number of emission permits has been cut by 1 to 2% per year to compel major polluters to reduce their GHG emissions.

Governments also rely on **taxation**. The call to tax landfilled waste is often viewed as having an incentive effect to recycle, reuse and recover, which should promote the development of new products and services. Under its Environment Action Programme, the European Union has set out a zero waste policy objective to tighten the targets to reduce the volumes of biodegradable material sent to landfill [14]. According to some authors, a review of the current taxation system would make it possible to adapt the tax system to the economic changes brought about by circular economy. They suggest taxing non-renewable and fossil resources and adjusting the value added tax (VAT) [21], [22], [25], [31], [45]. Walter R. Stahel [22] advocates a tax system that promotes a loop economy leading to an increase in the number of jobs and wealth creation while using fewer resources. Imposing a tax on non-renewable resources would exert pressure to reduce the use of energy and materials, including rare earths, and the pollution generated by extraction and production. In addition, within a circular economy, abolishing the values added tax (VAT) on products that are reintegrated into the economy would help correct certain market imperfections [31].

Of the current measures, extended producer responsibility and taxation of materials sent to disposal sites are the most commonly used.

2.2.4 Support and funding

Other government levers may contribute more or less directly to the creation of conditions that support the transition to a circular economy. Among these conditions is the availability CE-related **information** for target audiences. The European Commission adapted its sector-specific *Best Available Techniques References Document* (BREFs) by integrating information on circular economy. Japan adopted a similar approach for communities and businesses [46]. In Europe, the programs used as tools build awareness, share information and create a space for collaboration and resources in the transition to a CE. Germany, for its part, launched an innovative technologies platform that involves the efficient use of resources [24].

Some levers take the form of **funding** or assistance in obtaining funding. Government support for the transition is central to the success of the process since it reduces risks and ensures that investments are in line with economic development and environmental objectives [18]. In Europe, a platform that brings together the European Commission, the European Investment Bank and stakeholders in the financial and corporate sectors was implemented to support greater CE awareness-building efforts among businesses and spark the interest of investors in circular projects [29]. The European HORIZON 2020 research and development program supports circular initiatives and provides organizations with access to technological services and advanced manufacturing installations to support clean production [51]. Considered to be the Netherlands' key green economy development tool, the Green Deal program facilitates the creation of innovative projects in society, supports the implementation of circular projects and eliminates a number of barriers to the attainment of a green economy [46]. Under the program, the government's role is to lift the regulatory and legislative barriers, standards, authorizations and permits that slow the development of a green economy. In Japan, the Eco-Town program facilitates the development of industrial symbiosis by funding local communities and financing loans through the Development Bank of Japan. The waste exchanges, which function much like funding, are especially useful and necessary to generate industrial symbiosis. Indeed, Japan created waste exchange programs to stimulate industrial symbiosis—an approach that has been used in Europe since the 1970s and in the Netherlands in particular under the Green Deal [46].

2.3 OTHER BARRIERS AND LEVERS

There exists a range of technological, economic and social barriers and levers [21]. Independent of governments, they impact the transition to a circular economy. See Annexe 5.4 for summary tables.

2.3.1 Technological barriers and levers

Technology may constitute both a barrier and a lever. Supported by circular strategies and objectives, a number of innovations have already taken shape, specifically with regard to the more sustainable use and reuse of products and the transformation of product-related services. Indeed, standard product and service design approaches must be reconsidered since there is innovation potential in all life cycle phases.

With regard to life cycle, there are many examples of the range of benefits of technological advancement[3]. For instance, establishing new advanced quality standards and implementation sophisticated technologies may make recycled materials more appealing and possibly rival primary materials [31]. Based on a product's use and nature, technology may help accelerate the transition to a circular economy in which reconditioning and reuse lead to the integration of marginal progress as a complementary activity to the manufacturing sector [69]. The service economy could therefore provide a response to the concerns related planned obsolescence, which consumes natural resources [5].

But there are limits to technological change. Complete recycling is impossible from the physical perspective, as noted by mathematician and economist Nicholas Georgescu-Rogean [40]. Indeed, thermodynamics imply that, beyond a certain level, recycling consumes too much energy and renders the process inappropriate. Also, recycling will always remain incomplete due to energy and resource losses. Geographic dispersion, recycling operations, materials losses and wear are other examples of limitations. In addition, a number of everyday technologies and devices are made from rare materials that current recycling technologies are not always able to process [69], [70].

Because the planet itself is a closed set, there are spatial and temporal limitations. Material and energy flows across geographic boundaries can cause displacement issues that must be minimized [71]. For example, reducing the environmental impacts in a regional system may lead to direct and indirect adverse impacts in another part of the system (through the supply chain or life cycle). Developing countries are severely affected by environmental and social impacts. Also, at this time, it is difficult to determine the long-term environmental impacts of certain human activities [40].

3 Improved resource productivity, greater cost reductions, increased accuracy of operations (less water and fertilizer use in agriculture), better environmental performance (resource consumption and environmental impacts) [22], [49], resource efficiency (better use through reuse) [21] [68] and more effective waste processing [49].

2.3.2 Economic barriers and levers

A number of changes and revisions to current business models are required to integrate CE strategies [69]. Accenture has identified a number of technologies that foster new business models. They have changed business practices across the value chain and merge the physical and digital on a broad scale, favouring circular economy development [23]. Digitization supports the sharing of information in real time between users, machines and management systems, making it possible to establish a relationship beyond the point of sale and facilitating actions such as information transfers to customers. The implementation of engineering technologies, which are essentially physical and technical, is activity based. In terms of hybrid technologies, they lie at the midpoint between digitization and engineering, providing access to information and physical goods and material flows.

The functional service economy, which allows to extend the service lives of products, seems to constitute an interesting approach, making it possible to internalize the costs of waste and risks and secure resources for an organization or national economy through better resource control [22]. However, the approach challenges the business model of many entities, which are then forced to rethink proven principles that have led to success for many years. It may be difficult to change the status quo, opt for new capabilities and perhaps realize that their business offer is not sustainable in the long term [72] [56]. For users and clienteles, cybersecurity remains the most significant area of concern with regard to the sharing and service economies [73].

Among the other economic obstacles, the vision held by shareholders, which is often focused on the short term and corporate governance, does not enable investments as part of a transformation that will only yield results in the medium and long terms. Executives may also have reservations with regard to new business proposals, specifically those that impact confidence in the reliability of new models and the confidentiality of information (IMSA, 2013 cited in [45]).

Transition management is challenging for businesses, which are concerned with cannibalization (goods sales substituted by value sales), the redefinition of roles in the value and supply chains and the more direct relationship with consumers, to name only a few. Also, an organization that seeks transformation may face resistance from stakeholders that prefer the status quo [45] or do not grasp the changes.

Beyond business models, non-renewable energy and raw materials market prices are sometimes higher than recycled materials prices [31], particularly because the environmental costs in the extraction phase are not taken into account [45]. Recycling also involves additional costs, such as materials processing to reach a quality comparable to the original materials and the development of collection systems and infrastructures, which may be higher than the value of the material to be recovered. Government support, whether financial or political (e.g. EPR), may counter the effects of the barriers to the implementation of a circular economy [49].

Change may also be limited by the lock-in effect and path dependency [40], since the market will not necessarily retain the optimal solution. On the contrary, the market is likely to retain the most common or popular solution or the one that is best adapted to current infrastructures, thus slowing the market penetration of ensuing innovation. Also, significant investment is often required to fund infrastructures, systems and process and related networks, making it difficult and even impossible to implement CE solutions.

A number of studies affirm that there is a need to coordinate the international market (i.e. states and national policies). While the internal efforts made by states help ensure the transition to a circular economy, they remain insufficient. Still, resource and supply chain exchanges cross national borders [45], [48], [49]. This coordination could, for example, involve the establishment of independent international systems to organize flows, including the centralization and sharing of information, labeling, impact assessment and standardization [45], [49]. With regard to environmental policies in key sectors and standardization, international coordination would help set common rules to guarantee competitiveness in all countries, thus facilitating transactions on major markets and providing several investment opportunities [49].

2.3.3 Social barriers and levers

Change of mindset is needed in every segment of society, from policies to businesses and consumers.

It may be difficult for by-products and new products from secondary resources to gain market foothold in light of their provenance, the lack of information on their advantages and prices that do not always seem justified [31]. Information sharing and awareness building among consumers is therefore required. Fortunately, reuse and the services to extend service lives are increasingly perceived as smart and sound resource management rather than signs of lower quality [69].

Labeling is a simple solution to differentiate products and services that contribute to CE. The system encourages the quick adoption of practices by businesses and may yield rewards [15][25]. Among its proposals to facilitate transition, Institut Montaigne [9] includes the implementation of an awareness-building program for citizens and industrial consumers, the promotion of public procurement and local incentive measures mainly pertaining to recycling.

As an awareness-building tool, training also plays a key role in preparing future professionals for the concept of CE [18], [45], and investments in such programs are required (information programs to increase efficiency) [21]. In addition, some studies note the need for new skills and tailored training programs aimed at specific sectors, activities and technologies [9], [38].

3 CIRCULAR ECONOMY IN QUEBEC

Quebec has integrated circular economy strategies and tools into its legislation. In addition, a number of the province's economic sectors show good potential for circularization. They are briefly presented at the end of this section. Finally, organizations are already working to implement the five strategies highlighted in this study: the service economy, the collaborative economy, recycling, remanufacturing and reconditioning and industrial symbiosis.

3.1 CIRCULAR ECONOMY POLICIES

Quebec has adopted regulations and policies to reduce the environmental impact of economic and human activities. Certain policies are described in this section, which is not exhaustive. Some of these are included in a timeline in Annex (5.3) to illustrate their evolution.

3.1.1 Regulation

The government of Quebec has enacted a strategy that guides several regulations and goes beyond simple legislation. For example, the Government Sustainable Development Strategy 2015–2020 expresses Quebec's vision and commitments, guides public administration toward a green economy and sets out objectives in the fight against climate change. It also stresses the support of government departments and organizations in the development of green and responsible business practices and models. The objective is to ensure that 30% of Quebec businesses have undertaken a sustainable development approach by 2020 through actions including the development of circular economy and industrial ecology systems [74]. Among the activities outlined in the 2015–2020 sustainable development action plan is ecoresponsible management, which calls for a range of actions in the transport, building and IT sectors, and the development of ecoresponsible procurement policies and tender specifications [75]. A range of waste management rules, standards and tax tools help support Quebec's approach to minimize its environmental impact.

End-of-life regulations

- The Quebec Residual Materials Management Policy (QRMMP) is a policy of the *Environment Quality Act* and chiefly aims to eliminate waste according to the 3R-RD principles: 1) source reduction, 2) reuse, 3) recycling, 4) reclamation and 5) disposal. The strategies and measures that have been implemented are in line with three challenges: end resource waste, help attain the objectives of the Climate Change Action plan and Quebec's former energy strategy, which is now the 2030 energy policy, and make waste management stakeholders accountable [76]–[78].

- Section 4 of the *Regulation respecting the landfilling and incineration of residual materials* provides a framework for materials whose elimination is prohibited. The Quebec Residual Materials Management Policy sets out organic materials categories that are banned from disposal in order to lower their volumes and increase recycling and recovery rates [57], [79].

- The *Regulation respecting the recovery and reclamation of products by enterprises*, which has been in effect since 2011, and the 2011–2015 action plan are both derived from the Quebec Residual Materials Management Policy. The regulation assigns responsibility to the businesses that market certain products (e.g. oils, coolants, antifreeze, their filters and containers, electronic devices, paints and their containers, mercury lamps and batteries). Manufacturers, producers, owners and users of brands and first suppliers must implement their own recovery and reclamation programs or adhere to end-of-life management programs developed by organizations recognized by RECYC-QUÉBEC. This regulation is based on the principle of extended producer responsibility [80], [81].

- Similarly, businesses that place containers, packaging and printed matter on the market in Quebec are responsible for the end of life of the products and must make contributions to fund municipal curbside recycling services [71]. Private not-for-profits Éco Entreprises Québec (ÉEQ) and RecycleMédias, which are designated by RECYC-QUÉBEC, support the compensation plan for curbside recycling between the businesses targeted by the *Environment Quality Act*, municipalities, sorting centres and other stakeholders [83].

- The 2011–2015 action plan of the Quebec Residual Materials Management Policy targets waste management in the construction, renovation and demolition (CRD) sector, as well as the recycling and reclamation of certain types of waste [53], [77], [78].

Environmental management

- The 2030 energy policy, which was announced in 2016, aims to reduce GHG emissions by 37.5% as compared to 1990 by curbing the use of petroleum products, eliminating thermal coal, increasing renewable energy production by 25% and bioenergy by 50% and improving energy efficiency by 15% [84].

Standards

- The *Regulation respecting the energy efficiency of electrical or hydrocarbon-fuelled appliances* came into effect in August 2017. It requires that manufacturers, distributors, wholesalers and those that sell or rent appliances disclose the information on the products' energy efficiency, in accordance with regulatory requirements [85].

Taxation

- Since 2013, Quebec has been part of the Western Climate Initiative (WCI) carbon market. In 2014, the province linked its cap-and-trade system for greenhouse gas emission allowances (C&T system) with California's, creating North America's largest carbon market. Ontario joined on January 1, 2018, making WCI the largest carbon market in the world after the European Union's. Quebec's C&T system targets organization that release[4] over 25 000 metric tonnes of CO_2 eq. per year and includes the industrial, electricity and fuel and fossil fuel distribution sectors[5]. Since late 2017, Quebec businesses that emit between 10 000 and 24 999 tonnes of CO_2 eq. annually may choose to enrol in the C&T system on a voluntary basis. The funds amassed through the emissions auction are invested in Quebec's Green Fund and earmarked for initiatives under the dedicated 2013–2020 Climate Change Action Plan [87].

- The *Regulation respecting the charges payable for the disposal of residual materials*, which came into effect in June 2006, aims to reduce the amounts of waste that are eliminated, extend the service lives of disposal sites and fund waste management plans. Operators are required to pay disposal charges for each metric ton of waste received [82].

- Under the *Regulation respecting the charges payable for the disposal of residual materials*, the sums collected are distributed according to the terms of the program to redistribute the charges and the agreements between the MDDELCC and the organizations that represent municipalities. The sums are made available as grants to municipalities according to criteria such as population and regional performance. They also fund the residual materials management activities of the Ministry and the program to process organic materials through methanization and composting [88].

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4 An emitter is a person or municipality that operates a business that distributes at least 200 litres of fuel within the meaning of protocol QC.30 of Schedule A.2 of the Regulation respecting mandatory reporting of certain emissions of contaminants into the atmosphere (Q-2, r.15) [86].

5 For more information, refer to Schedule A.2 of the Regulation respecting mandatory reporting of certain emissions of contaminants into the atmosphere (Q-2, r.15)

Support and funding

- The Green Fund is one of Quebec's main sources of sustainable development funding. The sums collected through the different programs are used to protect the environment, preserve biodiversity and fight climate change. The Green Fund derives its revenues from the auctioning of its GHG emission units under the C&T system, the charges for waste disposal and water use and the federal government transfers for dams [89], [90]. Other elements that are not related to environmental protection also contribute to the Green Fund: annual duties from industrial depollution attestations, fines and penalties for violations of the *Environment Act* and environmental permit fees [91].

- RECYC-QUÉBEC provides several funding opportunities through calls for proposals for source reductions and waste outlets (industrial, commercial and institutional) and recycling and reclamation initiatives [92]. The organization also implements programs to facilitate regional transitions to a circular economy.

- The Centre de transfert technologique en écologie industrielle (CTTÉI) and Synergie Québec support the development of industrial symbiosis and provide tools to facilitate development across the province [93], [94].

3.2 IDENTIFICATION OF SECTORS WITH HIGH GROWTH POTENTIAL

A number of studies apply theoretical models and assessment metrics to estimate the impacts identified in the literature. At the macro level, there is a range of evaluation methods, including approaches based on input-output analysis that are used to create circularity indicators. This type of tool has reached an adequate level of maturity to directly assess material flows in an economy, in a broad sense. Input-output analysis may also be applied at an intermediate scale (e.g. to evaluate industrial symbiosis within industries) and for additional symbiosis efficiency assessments (e.g. energies, labour intensity). At the micro level, current indicators are not standardized or adequately established. Linder et al. [95] propose a circularity indicator based on quality criteria pertaining to a product's reused and original materials contents and to the activities required to reintegrate these materials. While there are other indicators, they do not aggregate the results into a single indicator that considers the units of measurement and all the circular loops [95].

A preliminary analysis to identify sectors with high potential in Quebec was conducted by combining results from the literature and the 2014 Supply and Use Tables released by Statistics Canada. The sectors were selected based on a review of studies on the impacts of CE. In total, 12 studies focusing on a number of economic sectors were used and the sectors with the most mentions were selected. The industry and resource (products and services) aggregates were evaluated based on their value-in-use of the industries in terms of percentage of GDP to highlight their significance to Quebec's economic context. The aggregation and identification of consumption types, which include intermediate industrial consumption and end demand by sectors, are based on data found in the literature. The results are presented in Table 4.

The agri-food (22.29%), energy (16.63%), construction (14.66%) and metal products (12.48%) sectors are significant in terms of GDP percentage. These four sectors therefore hold good circularization potential since major environmental and economic gains seem possible.

Though the recyclable materials (7.49%), textile (3.52%), agricultural and forestry (2.00%) sectors carry less relative weight in Quebec, there are still possible gains (e.g. in terms of water savings and forest resource optimization).

The assessment serves to emphasize the junctions between the international studies and key sectors in Quebec's economy. A more in-depth evaluation is required for a sector-specific perspective to determine the sectors with short-, medium- and long-term circularization potential. Further research is also required to identify the most promising sub-sectors and the significance of the impact of their circularization on the province's economy.

Cascades produces, converts and markets paper packaging products. It is the leading recycled paper collector in Canada. More widely known for recovering paper products, Cascades also collects other materials, including plastic and metal. In 2016, the corporation reclaimed over 440 000 metric tonnes of materials in North American alone.

Source cascades.metrio.net/indicators/matieres_residuelles/indicators/matieres_residuelles_brutes

Since 2007, **Groupe Bellemare** has operated a sorting centre that recovers and reclaims recyclables from construction, renovation and demolition projects, including wood, concrete, cardboard, gypsum, glass, shingles, metal and plastic. Groupe Bellemare recycles and reclaims 100 000 metric tonnes of material annually.

Source www.groupebellemare.com

Sanimax recovers and reclaims agri-food industry by-products. It processes meat by-products, fats, used cooking oils and other organic materials into high-quality inputs for a range of industrial sectors, diverting nearly two billion kilograms of by-products from landfills.

Source http://sanimax.ca

Cette évaluation a l'avantage de mettre en évidence les points de jonction entre les études internationales et les secteurs clés de l'économie québécoise. Une analyse plus approfondie serait requise pour identifier, au sein même de ces secteurs, ceux qui ont un potentiel de circularisation à court, à moyen et à long terme. Davantage de recherche serait aussi nécessaire afin de cerner quels sous-secteurs seraient à privilégier et de déterminer l'importance de l'impact de leur circularisation sur l'économie de la province.

TABLE 4 – Quebec activity sectors with high growth potential

Product category per industry	Number of studies on the topic (of the 12 studies[6])	Significance of products in intermediary production and consumption (GDP %)
Agri-food[7]	8	22.29 %
Energy[8]	3	16.63 %
Construction[9]	8	14.66 %
Metal and electronic products[10]	5	12.48 %
Recyclable materials[11]	6	7.49 %
Textile[12]	3	3.52 %
Metals, minerals and chemical products[13]	6	3.02 %
Agriculture and forestry[14]	7	2.00 %

Source Daméco et Statistique Canada

6 The studies are [25], [26], [29] à [36], [38], [64].

7 *Goods-producing industries:* grain and oilseed milling, sugar and confectionery product manufacturing, fruit and vegetable preserving and speciality food manufacturing, dairy and meat product manufacturing, seafood product preparation and packaging, bakeries and tortilla manufacturing, other food manufacturing, soft drink and ice manufacturing, breweries, wineries, distilleries, tobacco manufacturing.

8 All producing and intermediate industries

9 *Goods-producing industries and intermediate consumption:* residential building construction, non-residential building construction, engineering construction (for transportation, oil and natural gas, electric power, communications and others), repair construction and other activities of the construction industry.

10 *Goods-producing industries:* cutlery, hand tools and other fabricated metal product manufacturing, architectural and structural metals manufacturing, boiler, tank and shipping container manufacturing, hardware manufacturing, spring and wire product manufacturing, machine shops, turned product, and screw, nut and bolt manufacturing, coating, engraving, heat treating and allied activities, agricultural, construction and mining machinery manufacturing, industrial machinery manufacturing, commercial and service industry machinery manufacturing, ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing, metalworking machinery manufacturing, engine, turbine and power transmission equipment manufacturing, other general-purpose machinery manufacturing,

11 *Intermediate consumption:* plastic product manufacturing, pulp, paper and paperboard mills, converted paper product manufacturing, printing and related support activities. *Goods-producing industries:* plastic product manufacturing.

12 *Intermediary consumption:* textile and textile product mills, clothing and leather and allied product manufacturing.

13 *Goods-producing industries:* iron ore mining, gold and silver ore mining, copper, nickel, lead and zinc ore mining, other metal ore mining, stone mining and quarrying, sand, gravel, clay, and ceramic and refractory minerals mining and quarrying, pesticide, fertilizer and other agricultural chemical manufacturing.

14 *Goods-producing industries:* crop production, greenhouse, nursery and floriculture production, aquaculture, forestry and logging, fishing, hunting and trapping, support activities for crop and animal production, support activities for crop and animal production, for forestry and logging.

For the past 20 years, **Granules LG** has manufactured wood pellets and bioenergetic firelogs from first- and second-stage wood processing residues. Entirely owned by Indigenous investors, Granules LG specializes in heating from biomass—a renewable resource—and animal bedding.

Source https://granuleslg.com/fr

Enerkem processes non-recyclable waste into biofuel, reducing dependence of fossil fuels and GHG emissions. It also transforms waste into renewable chemical products that are used in hundreds of commercial and industrial applications.

Source http://enerkem.com

Developed in Quebec, **Netlift** is part of the sharing economy. A mobile smartphone application that relies on an advanced digital platform to plan commutes, Netlift puts empty seats in personal vehicles to use and serves to expand the public transit system by providing a more personalized service through a multimodal approach.

Source https://www.netlift.me

3.3 CASE STUDIES OF ORGANIZATIONS THAT ARE ACTIVELY CONTRIBUTING TO QUEBEC'S CIRCULAR ECONOMY

A number of Quebec businesses and organizations provide products and services that are in line with at least one circular economy strategy. To highlight this expertise, the authors met with four businesses and a college centre for technology transfer in fall 2017. They all specialize in specific products and services through CE-driven approaches.

The authors conducted one-hour interviews with a representative from each organization. The interviews were divided into two parts. The first focused on the organization itself and the second on CE. The meetings led to the development of the five case studies presented here. The comments are those expressed by the representatives.

3.3.1 RECYCLING: Soleno & Soleno

Soleno is family-owned Quebec business. Since 1977, it has specialized in storm water management collection pipe systems essentially manufactured from high-density polyethylene (HDPE), as well as nonwoven geosynthetic textiles. With some 370 employees in four business units—Soleno, Soleno Services, Soleno Textile and Soleno Recyclage—the organization operates plants in Quebec and New Brunswick. Since its foundation, it has been keenly aware of its local social impact and has demonstrated its strong commitment to its community through the years.

This case study is specifically focused on Soleno Recyclage, which recycles and conditions HDPE used for domestic and industrial purposes. Located in Yamachiche, the plant is run through a partnership created in 2014 with Groupe RCM, a social economy enterprise that provides employment for persons with functional limitations. Soleno currently employs 65 individuals through the partnership. In 2015, Soleno received the Écoresponsable certification from the Conseil des industries responsables for all its divisions.

Products, services and markets

Soleno Recyclage receives HDPE from sorting centres and other business partners, including its own plants. After sorting and washing, the material is conditioned, extruded and shipped as granules to Soleno plants to be used to manufacture new polyethylene drainage systems.

As a whole, Soleno covers four major activity sectors: residential, natural resources, agricultural redevelopment and infrastructure, commercial and institutional. Operating in a local market in which transport costs and efficiency are key drivers of competitiveness, Soleno has built a client base that is mainly located in eastern Canada and the northeastern United States.

Developments in research and standards have expanded Soleno's markets. For example, agronomy researchers showed that a properly drained field will have better yields, leading to a rapid return on the investments to install the drains. Part of the organization's growth stems from awareness building, communication and scientific research. Soleno contributes to research projects on a regular basis.

Competition varies from one activity sector to the next but the main competitor for infrastructure projects is an alternative product—concrete pipes—which are chosen for several applications despite the longer service life of HDPE pipes. Soleno also faces competition from other Canadian and American manufacturers in its major markets.

Circular economy strategy

The prevailing circular economy strategy at Soleno is recycling. The organization recovers HDPE containers that it conditions and then uses as raw material to manufacture drains. This sourcing practice enables Soleno to expand its independent access to raw material and is a response to the 2008 economic crisis in which a number of its suppliers collapsed. The plant requires some 100 million plastic containers annually.

Soleno also relies on industrial symbiosis at the internal (extrusion plant waste is sent to Soleno Recyclage) and external levels with several partners. At each site, Soleno has implemented a collection system for recyclable materials (e.g. cardboard and metal) that are then transferred to other organizations for recycling. In addition, some companies send their HDPE waste to Soleno's recycling plant. These practices and the partnerships with sorting centres provides Soleno Recyclage with a continuous supply of raw material.

Economic, environmental and social impacts

Through recycling, industrial symbiosis and a number of other approaches, Soleno generates significant economic, environmental and social impacts in Quebec. The organization is clearly focused on becoming an industry leader and developing sustainable local solutions.

There are many economic benefits. Through local purchasing, Soleno decreases its transport costs and thus lowers the purchase price of the raw material, provides a competitive edge and enables the company to better control raw material volumes and prices. According to the Soleno representative, from the economic and social perspectives, the company's actions serve to create direct and indirect jobs at the local level and generate higher revenues for businesses and governments. Hiring persons with functional limitations helps support a labour force whose members have difficulty finding positions. Finally, recycling materials locally reduces environmental impacts by minimizing waste and avoiding the extraction and processing of original materials.

Issues

The key issue faced by Soleno pertains to the manufacturing standards set out for its products, which are highly restrictive and require polyethylene of a specific quality. This complicates recycling since the quality of the material that is received is not always adequate. Current standards also prevent Soleno from entering certain markets in which concrete pipes are given priority—a practice that is difficult to justify.

The industrial sector remains a challenging one, as evidenced by the collapse of the recycling plants that came before Soleno. Indeed, that is one of the reasons why the organization chose to create its own recycling plant. Another challenge is access to materials to be recycled. In Quebec, roughly 60% of the company's needs are met, and Soleno must look outside the province for the remaining 40%. But if Quebecers recycled more, the company could meet all its procurement needs locally. Other trends also impact Soleno's access to raw material, including exports by brokers that send recyclables to other countries and the fact that biodegradable containers are not recyclable.

These supply and export challenges cause the prices of the materials to be recycled to constantly fluctuate and vary the supply costs of Soleno's other plants, which constitute Soleno Recyclage's client base.

3.3.2 REMANUFACTURING AND RECONDITIONING: Pools and Spas Poseidon

Pools and Spas Poseidon has been in business for 15 years. It primarily provides pool and spa maintenance services, including opening and closing. For the past few years, Poseidon has also provided spa remanufacturing and reconditioning services. When it was founded, the company had nearly a dozen clients. Today, it has a team of 15 to 45 employees (depending on the season) and serves over 2 000 clients. Poseidon responds to an average of 8 000 calls per year on a territory that covers the South Shore, Montréal, Westmount and Town of Mount Royal.

Products, services and markets

Through the years, Poseidon has added professional pool and spa repair and renovation and specialized spa (high performance and quality and energy efficient) sales services to its pool maintenance services. It then expanded its after-sale services to better support its customers—an activity that complements the sales and installation expertise of major retailers. Poseidon also launched a spa rental services based on practices in the US market. Its turnover is spread: 80% from the residential market and 20% from the institutional market.

In Quebec, which is different from the European market, the pool and spa sector does not officially recognize pool specialists. To adequately train its employees, Poseidon had to develop its own technical training programs based on the research and experience it has acquired since its founding. With a view to keep its trained and skilled labour force during the off season, the company began to explore the remanufactured spa market.

As spas become increasingly popular in the mid 2000s, the remanufactured spa market grew significantly. But since then, many owners have sought to get rid of their spas. Poseidon purchases used spas in good condition, which are often higher end models, and then reconditions them to extend their service life.

The company believes that the remanufactured spa market is still relatively new and will grow in the years to come. It expects an increase in sales since a remanufactured spa costs some 50% less than a new model. The stronger US dollar may also contribute to the growth since most spas are manufactured in the United States and spa prices in Canada will rise. Poseidon offers a two-year warranty with the purchase of a remanufactured spa to remove any quality doubts customers may have. The warranty also constitutes an added value that competitors such as classified platforms such as Kijiji and eBay do not provide.

Circular economy strategy

The prevailing circular economy strategy at Poseidon is remanufacturing and reconditioning. The company recovers used spas and remanufactures them to meet current standards. The spas are therefore restored or even improved as compared to the initial product with new components (pipes, filtration system, etc.) and the addition of new technologies or features (e.g. energy efficiency). Finally, spa rental is part of the service economy and enables consumers to enjoy a spa without having to purchase one.

Economic, environmental and social impacts

Remanufacturing enables Poseidon to keep its trained and qualified labour force throughout the year in an economic sector that is usually seasonal. The company lowers its employees' unemployment rate and employees benefit from the opportunity to hone their skills. The activity also helps generate additional profits and contributes to better materials efficiency and a more circular economy.

The potential environmental impacts of providing large durable products that generally end up in a landfill with a second life are significant. Spas are made of a number of materials, including some that may constitute environmental hazards. A remanufactured spa may function for an extra 10 to 15 years and lead to energy savings through the addition of more advanced technologies. It is important to note that the pool and spa sector has made great strides in terms of the use of chemicals that are less harmful to the environment.

Because Poseidon carries out its activities on a relatively limited territory, it minimizes the travel time of its technicians. Wait times and fuel consumption are also reduced, and the company can answer a higher number of calls in less time. This strategy fosters profitability and helps provide employees with good working conditions.

Issues

The key issue for Poseidon is the preservation of its skilled labour force, which has received adequate training on maintenance and reconditioning operations. Seeing as the company has developed its own techniques to provide quality service, retaining the employees it has trained is critical to the continuation of its activities.

In addition, Poseidon is often contacted to pick up a spa at no or low cost to the company. There is ample supply, and Poseidon chooses its spas based on quality and the repairs that are required. However, these purchases require warehousing space since the company only remanufactures spas in winter. In summer, technicians carry out maintenance work on a full-time basis.

3.3.3 SERVICE ECONOMY: AutoPartage

For the past several years, AutoPartage[15] has provided self-service vehicles in six Montréal boroughs. It operates a fleet of 450 vehicles that are used daily by 50 000 members. The company also provides services in a number of cities in North America and Europe.

Products, services and markets

AutoPartage provides self-service vehicles: within the city's designated zones, the vehicles may be used at any time and left at the user's destination. Each vehicle has a universal parking sticker valid in all parking areas in the participating boroughs, including Côte-des-Neiges, Hochelaga-Maisonneuve, Plateau-Mont-Royal and Rosemont.

Members may use a vehicle at any time and are billed according to the amount of time they use it (by the minute, hour or day). The vehicles are borrowed through a smartphone application created by AutoPartage. Members log in to their account to find a vehicle parked nearby, reserve it and unlock it. AutoPartage is responsible for service, maintenance and gas.

The local and international clienteles are primarily urban and comfortable using technology and have chosen not to own a vehicle or not to purchase a second one. The AutoPartage services are in line with the trend to adopt a multimodal lifestyle in which individuals combine different modes of transportation, alternating between public transit (commuter trains and subways), bicycle (Bixi or personal), walking and taxi. The phenomenon has been coined mobility as a service and requires considerable user flexibility, as well as a shift in mindset in the context in which owning a vehicle is no longer such a strong sign of social status.

AutoPartage is consistent with this trend and provides a practical and flexible service that is complementary to other means of transportation for short distances in urban areas or longer distances outside city centres. Within a market that is expanding in Quebec's urban areas and around the world, the company is preparing for the arrival of autonomous vehicles, which it intends to add to its fleet. AutoPartage's main competitor is privately-owned cars.

Circular economy strategy

The service provided by AutoPartage is in line with circular economy since the dominant strategy is the service economy in which a product's use, rather than its ownership, is the focus, making it possible, in this particular case, to optimize vehicle use. A customer may access a vehicle that he/she does not own and which will be paid for based on use time. In exchange, the customer is certain that the vehicle has undergone proper maintenance and is safe to drive in all seasons. In this sense, trust remains key to the success of AutoPartage. Other circular economy strategies (maintenance, vehicle repair) are the responsibility of AutoPartage.

15 Fictitious name. The company asked to remain anonymous.

Economic, environmental and social impacts

A number of academic studies have explored car sharing services, and AutoPartage has been able to better identify the benefits of its service offer.

According to the studies cited during the interview, each self-service vehicle takes 7 to 11 vehicles off the roads, reducing GHG emissions by between 10 and 14 metric tonnes per year for each self-service vehicle. In addition, the use of each vehicle is optimized since, unlike privately-owned cars that are parked most of the time, the AutoPartage vehicle makes several trips on a given day. AutoPartage expects this optimization to increase with the arrival of autonomous cars since vehicles will drive themselves into the areas where demand is highest.

Also, customers who rely on a car-sharing service are more aware of the costs of using a vehicle since they are billed based on use. The link between use and cost is less direct for car owners, who, on average, spend $8 000/year on their vehicle. Car-sharing customers would have to spend $700/month to incur the same sum, which does not represent the actual use of AutoPartage members, who rather rely on a range of modes of transportation. In doing so, they delay the purchase of a vehicle or avoid the purchase of a second one.

Car sharing seems to directly contribute to more active modes of transportation. Studies show that customers walk more, especially since they are not in the habit of driving small distances.

Issues

AutoPartage's capacity to provide interesting mobility services to its customers directly depends on population density, thus making expansion outside of urban zones a challenge.

In addition, AutoPartage is facing a number of (essentially municipal) regulatory issues. Access to the universal parking stickers that allow users to park the vehicles in boroughs across Montréal is limited. This factor explains why the service is currently only available in certain areas. With regard to provincial and federal regulations, AutoPartage expects that it will have to raise awareness among elected officials and citizens of the autonomous cars that will be on the roads in Quebec and Canada in the medium term.

Finally, AutoPartage must also make itself better known, though this is less and less the case. Self-service vehicles remain relatively new and are lesser known outside Montréal's more central districts.

3.3.4 INDUSTRIAL SYMBIOSIS: CTTÉI

The Centre de transfert technologique en écologie industrielle (CTTÉI) is the college centre for technology transfer (CCTT) of Cégep de Sorel-Tracy. The 49 CCTTs conduct applied research within the Réseau Trans-tech network. Their mandate is to support the technological and social innovation of businesses through research, support, information and technical training.

The CTTÉI employs some 15 people and aims to improve the performances of businesses and communities through research and development driven by innovative industrial ecology approaches and technologies. It helps recover industrial waste, identify and enhance clean processes and create industrial symbioses. The case detailed here is especially focused on this type of service.

Products, services and markets

The CTTÉI has supported industrial symbiosis since 2008 and provides consulting services across Quebec. The development of a symbiosis hinges on business meetings, site visits, information gathering and input (demand materials) and output (waste) databases to identify possible complementary links to prioritize and communicate at information sessions and networking workshops. Local facilitators who are advised and accompanied by the CTTÉI orchestrate the symbioses.

The CTTÉI generates a significant amount of communications and information on industrial symbiosis, including the Synergie Québec[16] guide and website. These local links are brought together in a community of practice to discuss local issues and possibly establish synergies that extend beyond a given territory.

The CTTÉI may also be called upon to assess a production process (e.g. by analyzing waste generated) or determine potential outlets or eco-product options. In one instance, the CTTÉI was approached by a company seeking to increase its recycled materials content to meet LEED standards. This type of research enables businesses to develop new markets for their waste and rethink their dependence on raw materials.

The CTTÉI's clientele is quite diverse and ranges from companies to municipalities and industrial parks. The centre works with several small and medium businesses, as well as major GHG emitters that are impacted by the carbon market.

There is increasing demand for industrial symbiosis. Recent waste management plans now account for industrial waste, and symbiosis constitutes a tool to reduce volumes. Also, the CTTÉI is leading a project to use big data and AI tools to facilitate networking between industrial inputs and outputs to generate more symbioses. In addition, while landfilling costs remain low, they continue to increase, thus motivating businesses to look to other options. Finally, the interest in industrial symbiosis is also buoyed by organizations that want to reduce their environmental footprint.

16 https://www.synergiequebec.ca/

Circular economy strategy

The CTTÉI is a key catalyst of the circular economy strategy to create industrial symbioses. These symbioses may also lead to reuse: the cardboard boxes and barrels that can no longer be used in aerospace—a sector in which standards are particularly rigorous—may be transferred to agricultural farms. In addition, the CTTÉI has observed that businesses in which symbiosis is more mature have begun to undertake remanufacturing and reconditioning initiatives.

Economic, environmental and social impacts

The CTTÉI representative who was interviewed for this study affirmed that when a material is diverted from landfill as part of a symbiosis and reused with minimal transport, there is a direct reduction in the environmental impacts of the organizations that can lead to economic and social gains. Symbiosis therefore serves to preserve the value of a material that has been extracted and processed. The implementation of new processes to transform the material generates value, economic activity and employment with a lesser environmental impact.

The CTTÉI is working to develop tools to quantify the potential economic, environmental and social impacts of industrial symbiosis to highlight the economic, social and environmental benefits to put forward in order to encourage more organizations to contribute.

Issues

Symbiosis faces human, regulatory, technological and financial issues. For the CTTÉI, human contact is key to a successful symbiosis: managers must know each other and develop a minimum level of trust before agreeing to share information that may be confidential. Indeed, waste transfers can raise certain apprehensions, especially with regard to confidentiality and trade secrets. Businesses are concerned that competitors will become aware of their waste volumes and then know which processes are used at the plant. In addition, the implementation and sustainability of symbiosis depends on local contacts and the mobilization of community actors.

Regulations vary according to material and technology. Because the material is the priority over the industrial sector, businesses are not subject to the same standards. A material that is considered a contaminant in one sector will not be perceived as such in another. This constitutes a major challenge to the integration of waste into manufacturing. Also, current technologies and processes do not yet support the development of certain types of waste, thus limiting the opportunities for exchanges between organizations. These constraints increase the complexity of the implementation of symbioses.

Symbiosis is also impeded by financial challenges, including the lack of financial incentives, landfilling costs that remain low and precarious long-term funding. Indeed, funding is especially fragile at the start of a symbiosis, when businesses are often reticent to contribute without short-term returns on their investments. A number of expenses must be incurred (database development, workshops, visits, etc.) before a symbiosis is developed. There are also market roadblocks with regard to waste volumes, since it may be difficult to find a taker for certain materials whose volumes are too low.

3.3.5 SHARING ECONOMY: La Remise

La Remise, a non-profit solidarity cooperative, is Queec's first tool library. It was created in June 2015 in the Villeray neighborhood in Montréal by Villeray en Transition, an organization that takes action on local environmental issues. The cooperative is managed by volunteers, who are members and oversee the operations and activities for 2 000 members.

Products, services and markets

La Remise provides three types of services. The first, its primary mission since its founding, is providing access to a varied library of tools—including carpentry, construction, bicycle and vehicle mechanics, kitchen and gardening tools—that members can borrow for up to seven days. Tool loans are the most popular service and account for 50% of La Remise's activities. The second service is access to workshops, which are available for personal carpentry and furniture-making projects. Specialists are on hand to advise and support members in their projects and their use of specialized tools. Finally, as part of the third service, La Remise provides technical training by specialist members (bicycle mechanics, woodworking, sewing and electronic repairs).

La remise requires that new members enrol ($10) and select one of two types of memberships: a yearly membership that provides unlimited access to the tools library with an annual loan limit or a pay-per-use membership for occasional loans based on a points system (each tool is assigned a points value). Once a member has spent all the points on his/her membership card, he/she must purchase a new one. Finally, the fee to access the workshops is based on the number of hours of use. The training sessions, some of which are free, are priced according to topic.

La Remise experienced rapid growth through word of mouth among members of a community that is concerned about economic and environmental impacts and is also interested in accessing creative spaces through services that are in line with the current do-it-yourself (DIY) trend and zero waste movement. There is also the fact that small apartments provide little space to store tools such as saws and drills that are rarely used. The clientele is mainly made up of young adults from the surrounding neighborhoods of Villeray, Ahuntsic and Rosemont-La-Petite-Patrie.

The concept gained traction in other cities across Quebec and as far as Europe. La remise provides support to other organizations seeking to develop a similar offer. It trades its tool loan service for a range of local products and invests in expertise sharing with other tool libraries. Eventually, La Remise aims to develop partnerships with local hardware store suppliers and the city's trade schools.

Circular economy strategy

The services provided by La Remise are in keeping with circular economy through the cooperative's sharing economic strategy. The tools shared by the library and workshops are made available to members at a low cost, and there is an emphasis on expertise sharing among members. In this sharing approach, strategies to maintain, repair and replace outdated components and extend the service lives of tools help keep the material (tools and others) functional for as long as possible. Most of the tools were donated.

Through La Remise, the personal projects and activities undertaken by members are also in line with CE strategies. For example, the cooperative noted that approximately 50% of the lumber used in the workshop was recovered and reused. Other member projects may involve reconditioning and remanufacturing (e.g. to repair or remanufacture old furniture).

Economic, environmental and social impacts

The cooperative defines itself as a type of smart and responsible economy in which loans substitute purchases. The business model was developed to be financially autonomous so that the cooperative does not have to depend on grants or any other type of funding. Also, for La Remise, the learnings it fosters enable members to become more independent and resilient, which can constitute an economic driver. This social aspect of knowledge sharing in a meeting space helps empower the community and promotes self-fulfillment through manual activities for a range of clienteles, including women and persons with low incomes.

The activities led by La Remise help reduce goods consumption through shared use, optimize resource efficiency and reduce the environmental footprint from a life cycle perspective. In addition, the services that are provided limit planned obsolescence through repair and access to sustainable products.

Issues

Despite the advantages for volunteers, certain administrative positions with La Remise are subject to a high turnover and depend on the availability of the volunteer workforce. The cooperative is currently exploring the issue to find a long-term solution.

It would certainly be more difficult to develop this type of system outside highly populated areas, since the distance factor could lead people to purchase their own tools and materials. La Remise benefits from the fact that housing size limits personal tool storage options.

3.3.6 Case study findings

The five case studies presented here demonstrate that there are organizations within Quebec's economy that are contributing to a circular economy in a dynamic manner.

With the exception of the CTTÉI, which operates in a research setting, few of the organizations that are profiled were familiar with the term circular economy, which some saw as an idea to generate wealth using waste or give a second life to a used item. The reduction in the use of raw materials through recycling and change in consumption habits (e.g. vehicle or tool sharing) were also raised. After being informed of the definition of circular economy, all representatives were of the opinion that it held good economic potential for Quebec. They affirmed that there should be a standard definition of CE and common vocabulary to provide a framework for the province's efforts.

The interviewees agreed that mindsets are changing and that consumers are increasingly concerned with their environmental impact. In this sense, the expansion of the service and sharing economy and remanufacturing and reconditioning is rooted in the trend and encourages organizations to rethink their business models. While Quebecers are familiar with recycling, the process could be better optimized and developed across the province. The transition to CE also involves a willingness by consumers to better understand the composition and provenance of products. The local purchasing movement, which reduces carbon footprints, could potential create a virtuous circle from an economic perspective. Indeed, buying locally supports local markets and direct and indirect jobs (tertiary services, revenue from income and sales taxes, etc.). In sum, for the representatives who were interviewed, these trends can create potential markets for Quebec businesses, provided that the offer is attractive in terms of pricing and accessibility.

The interviewees also identified a number of industry-specific and broader obstacles.

- While the concept of CE remains unfamiliar, citizens and businesses must still be encouraged to recycle at the office, for example, even though these habits are ingrained at home.
- The low costs to landfill and develop certain raw materials do not support the adoption of all CE strategies (e.g. recycling, remanufacturing or industrial symbiosis).
- Quebec lacks incentive measures to foster the purchase of products with recycled content. The province could, for example, provide purchasing compensation to develop the market given that it can be more expensive to use recycled materials as compared to raw materials, especially since externalities are not taken into account when determining the cost of primary materials. In addition, citizens are also unfamiliar with the containers and packaging that should be recycled, leading to higher collection, sorting and conditioning costs. In all these cases, the initial investments to implement recycling are significant.
- The economic, social and environmental impacts of greener products and services often go unrecognized. Further studies are required to convince businesses of the cost-effectiveness.
- Government support (e.g. funding or credits) to develop a recycling infrastructure or industrial symbiosis could accelerate the development of a circular economy.

- Municipal, provincial and federal policies are not always consistent or evolve too slowly to facilitate the implementation of new CE products and services, creating legislative obstacles that impact some of the organizations that were the focus of the case studies by preventing them from supplying products and services to other sectors, regions or public agencies.
- In industrial symbiosis, a lack of trust between stakeholders can impede the development of CE.
- In many cases, the development of new CE business models depends on population density. Because they are less populated, outlying areas must be more innovative in order to capitalize on the benefits.

Despite these barriers, the representatives who were interviewed believe that there are many opportunities for businesses seeking to integrate the principles of circular economy. These prospects may stem from the development of materials that are currently sent to landfills, as well as the creation of new manufacturing processes to generate innovative products and services.

4 CONCLUSION

An increasing number of organizations are turning to circular economy to mitigate the environmental impact of human activity. Indeed, the different government authorities have a range of legislative and taxation tools to foster and facilitate the transition, some of which are described in this report.

The transition to circular economy is not synonymous with a decline in economic activity. Quite the opposite, the studies reviewed indicate that, in addition to reducing the environmental impact, circular economy could potentially increase employment, lead to GDP growth and promote new market development. However, businesses must rethink their models and production modes. For example, Xerox and Michelin undertook this process by adding product access service sales to their product sales. Indeed, a number of business opportunities will arise as the transformation gets underway.

The work to draft this report led to the recommendations listed below, which are focused on two key aspects: knowledge enhancement and support for organizations.

Knowledge enhancement

1. Circular economy is an emerging approach, and there is still a great deal of basic and applied research required to ensure that the transition generates the expected benefits. For example, the European Union will dedicate 1 billion euros to circular economy research and innovation in 2018-2020 [97].

2. The sectors with high circularity potential identified in this study were essentially identified based on a review of international literature. This review could be further detailed by applying the advanced methodologies described here. A more in-depth understanding of Quebec's distinctive characteristics will facilitate the choice of priority strategies and sectors.

3. The potential economic impacts of a transition to CE described here are also based on a review of international literature. Modeling for the Quebec context using specific data is essential to better anticipate national impacts, for example in terms of factors such as GDP growth, job creation and reduction in GHG emissions.

Support for the market and businesses

4. Because Quebec market stakeholders (businesses, contracting authorities, legislators, etc.) and society as a whole are relatively unfamiliar with circular economy, a broad awareness-building campaign and targeted training programs are required to ensure their participation in the transition to circular economy.

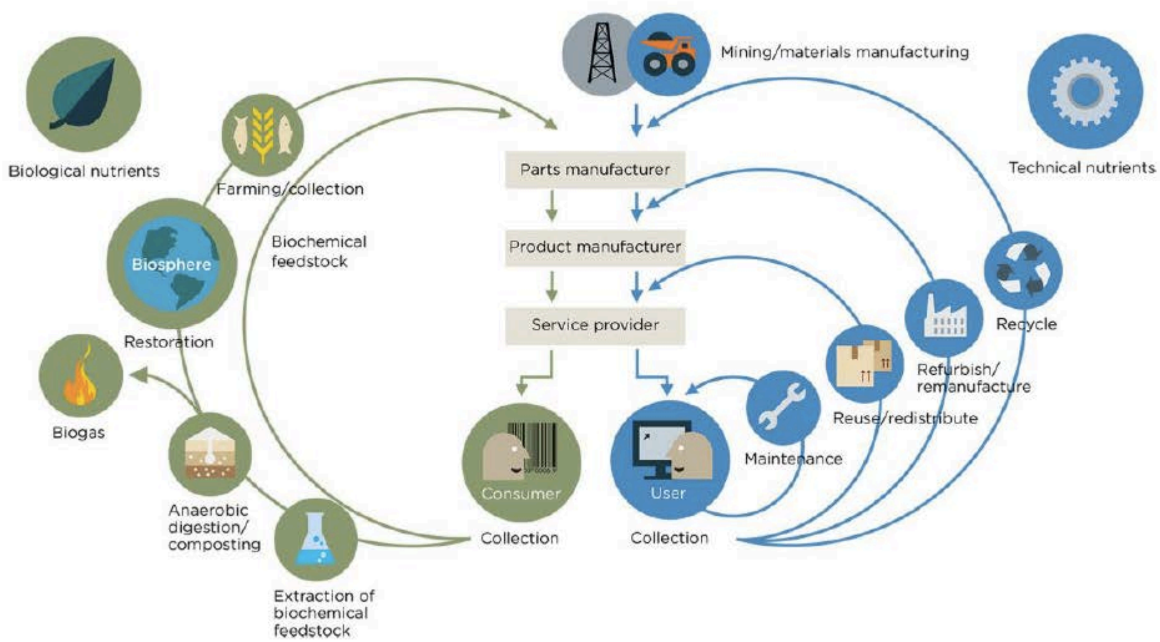
5. The transition to circular economy should include support and incentive programs, as well as appropriate taxation and favourable legislation, to be fully carried out and better foster public and private investment. A number of initiatives implemented in Europe and Asia could inspire future actions undertaken in Quebec.

6. Circular economy has significant entrepreneurial potential, as it can contribute to gains in terms of productivity, efficiency and profitability and stimulate research and innovation. The use of circular economy in business models and processes with a view to advancement should therefore be driven by the development of strategies, analytical tools and financial and regulatory solutions to identify high-potential material flows and new uses and market opportunities for them.

5 ANNEXES

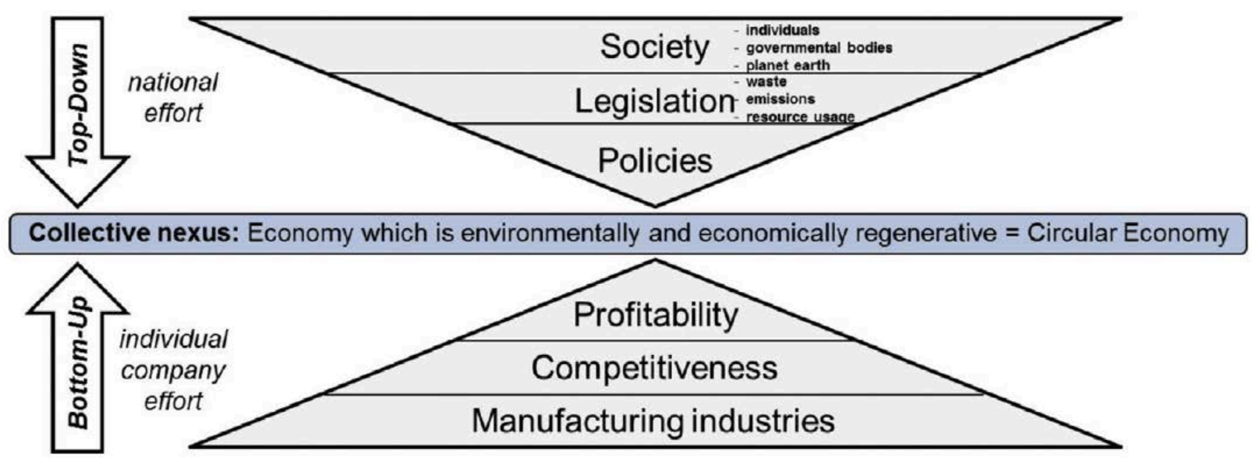
5.1 DIAGRAM OF A CIRCULAR ECONOMY BY THE ELLEN MACARTHUR FOUNDATION

FIGURE 2 – Diagram of a circular economy (Ellen MacArthur Foundation) [25]

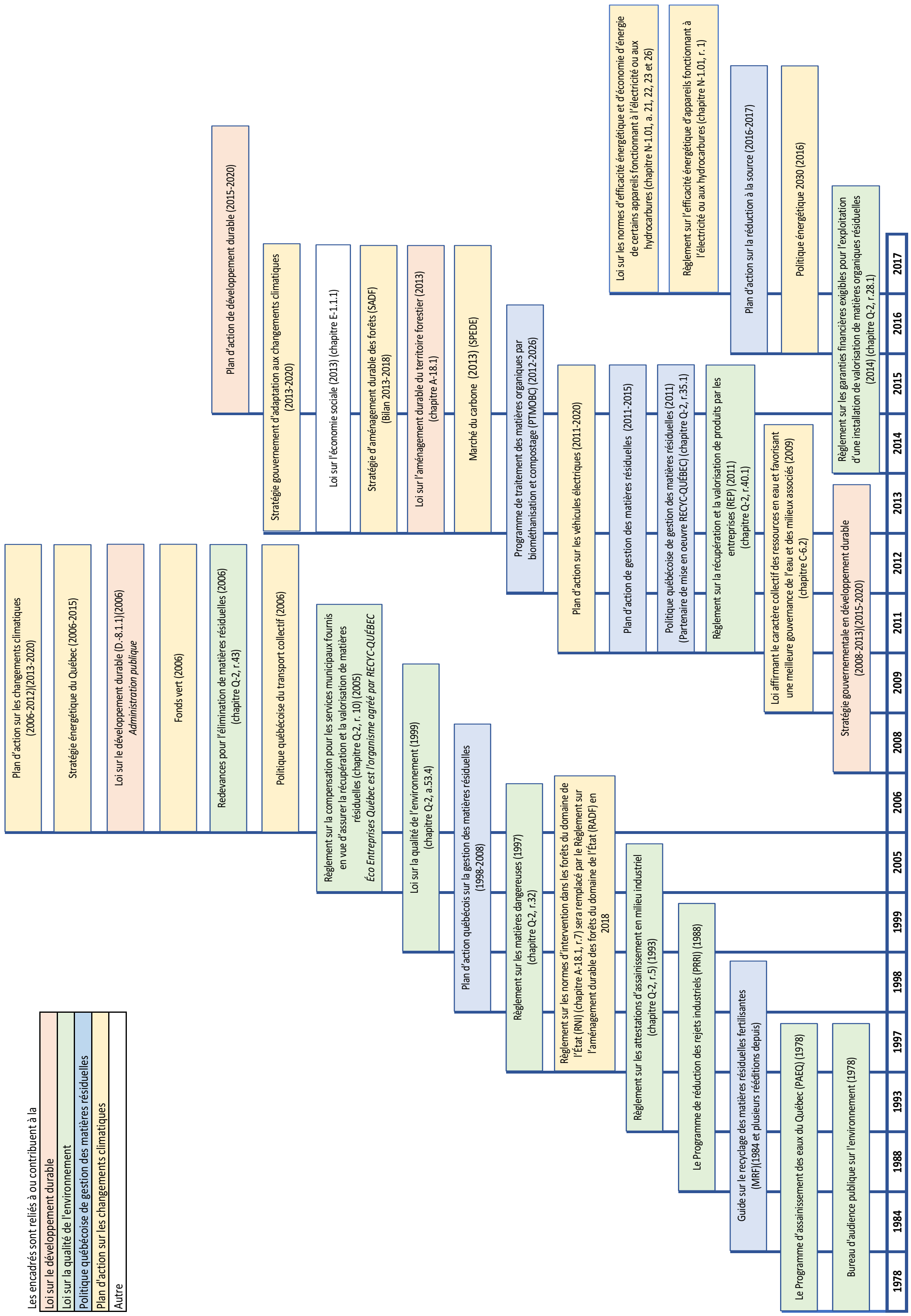


5.2 CIRCULAR ECONOMY IMPLEMENTATION PROPOSAL

FIGURE 3 – Proposal to implement circular economy through a top-down and bottom-up approach [5]



5.3 MAPPING OF QUEBEC POLICIES



Non-exhaustive compilation

5.4 BARRIERS AND LEVERS (NOT POLICY RELATED)

The tables provide an overview of barriers and levers (see legend)

LEGEND	Lever
	Barrier
	Hybrid

5.4.1 Technological barriers and levers

Innovation	**Technological advancement**	Lever
	Increased resource productivity, cost reductions, increased environmental performance, operational accuracy [8]–[10]	Lever
	Increased efficiency [11]	Lever
	Better waste processing [9]	Lever
	Higher quality of recycled materials [5]	Lever
	Acceleration of marginal technological advancements through reuse and remanufacturing [1]	Lever
	Collaborative economy and adaptation to change [12]	Lever
	Digital technologies and engineering to support business models [13]	Lever
	Use of rare earths in technologies [1]	Barrier
	Intellectual property [14], [15]	Hybrid
	Biomimicry innovation [5], [6]	Lever
	Product design [45]	Hybrid
	Compromise to foster innovative design (with policies) [31]	Hybrid
Physical	**Thermodynamic limits**	Barrier
	Inability to reach 100% recycling [5], [26]	Barrier
	Strategy to extend product service life (does not guarantee a less significant environmental impact) [16]	Barrier
	Physical scale of the economy (should be limited in the context of economic growth) [16], [22]	Lever
	Spatial and temporal limits [16], [23]	Barrier
	Geographic dispersion of supply chains [45]	Barrier
	Geographic dispersion of products for a service economy by manufacturers [14]	Barrier
	Complexity of the materials to be recycled [45]	Barrier

5.4.2 Economic barriers and levers

Economic	**Technology and infrastructure path dependency and lock-in** [9], [16]
	Market prices [3], [5]
	Expensive options [3], [9], [16]
	Significant upfront investment [3]
	Economies of scale for effective processes and cost-effective leading-edge technologies [16]
	High planning and management costs [3]
	Funding and risk management tools to support investment and R&D [2]
	Coordination on the international market [3], [9], [17]
	International and geopolitical competition [5], [18], [19]
	New business models
	Based physical product retention and the sustainable use of products through resource efficiency [69]
	Application in a context with high population density (functional service and collaborative economy) [18]
	Materials exchanges limited by reverse logistics capacity [45]
	Need for a long-term vision by businesses (limit to the development of new circular business models) [45]
	Functional service economy
	Concern about cannibalization (value added growth: service value) [72]
	Change in network relationships [72]
	Complementary skills required [72]
	Change in relationship terms [72]

5.4.3 Social barriers and levers

Education	**Awareness building** (consumers and businesses)
	Some by-products and new products from secondary resources cannot enter the market because of their provenance [5]
	Lack of awareness and sense of urgency among organizations [3]
	Training
	Integration of the CE concept into training and educational programs (leadership, in businesses, MBAs, economy, engineering, policy design and political science) [3]
	Better consideration of the labour force, a creative and skilled problem-solving resource [1]
	Preparation of future professionals for the concept of CE and its practices and understanding [2]
	Investment in education and employment services to prepare the market for the next economy [20]
	Investments in information programs to expand advancements in energy efficiency [20]
Political	Government incentives support the linear economy, and circularity is not efficiently integrated into innovation policies. Competition regulations block collaborations between businesses. Recycling policies are not efficient enough to yield high quality. [3]
	Remove the legislative barriers and provide access to funding to encourage experimentation, innovation and redesign [3]
	Foster the development of new technologies with the support of public authorities [18]
	Account for sector differences and foster public-private cooperation to better counter and lift political barriers [18]
	Assess progress using reliable indicators for imports and local production while accounting for the life cycles of products [18]
Consumer and producer behaviours	**Change of mindset** [21], [49], [69]
	Consumption habits
	E-commerce [64]
	Change in the choices made by consumers [9], [25], [64], [69]
	Organizational status quo [72]
	Cultural barriers to the adoption of a functional service economy [72]
	Governance issues relating to responsibility and property [45]
	No system to exchange information but trust and confidentiality issues limit these exchanges
	Shareholder concerns are often short term and dominate corporate governance [45]
	Resistance by key stakeholders seeking the status quo [45]
	Use of circular performance indicators by governments, investors and businesses can encourage the value chain to become more circular [45]
	Inter-organizational and intra-organizational management strategies

5.5 REVIEW OF THE LITERATURE ON CIRCULAR ECONOMY IMPACTS

TABLE 5 - Review of the literature on circular economy impacts

Study	Scope of the study	Methodology	Potential impacts	Reference
Wijkman & Skånberg (2015) [25]	Assess the environmental and economic benefits of renewable energies and increased resource efficiency. **Location:** Five European countries: Finland, Sweden, Netherlands, Spain and France **Sectors:** - Fossil fuels (reduction) - Renewable energies (noted potential of bio mass) - Recycling and materials efficiency - 40 sectors in 3 categories based on the model (primary, secondary, tertiary).	The study is based on a material flow model of 40 sectors, inputs/outputs. Three strategies were considered (decoupling) for projection horizon 2030 (base year 2010): 1) 25% increase in energy efficiency 2) 50% increase in the renewable energy share in the grid mix 3) 25% increase in materials efficiency, replacement of 50% of original materials by recycled materials and two-fold increase in product service lives.	**Economy:** All strategies create jobs and have positive impacts on GDP. However, combining the three yields higher potential to create jobs in each country and requires an approximate investment of 3% of GDP until 2030: 75 000 jobs in Finland, 100 000 jobs in Sweden, 200 000 jobs in the Netherlands, 400 000 jobs in Spain and 500 000 jobs in France. **Environment:** Combining the three strategies could reduce GHG emissions by approximately 66% across all countries: 66% in Sweden and France, 68% in Finland, 67% in the Netherlands and 69% in Spain.	[5]
Ellen MacArthur Foundation & McKinsey Center for Business and Environment (2015) [26]	**Location:** Europe **Sectors:** Transport, food systems and buildings.	Economic modeling and information gathered from 150 interviews. Several factors taken into account, including materials reuse, renewable energy, nutrient flows, biological and technical materials management and the optimization of product performance and efficiency.	**Economy:** 3% increase in resource productivity by 2030, which translates to total annual benefits of 1 800 billion euros and a 7% increase in GDP. **Environment:** Up to 40% reduction in GHG emissions by 2030 and up to 83% by 2050. In a number of sectors, raw materials consumption could decrease by up to 32% by 2030 and 53% by 2050.	[5]

EEB (2014) [27]	Impacts of increased resource efficiency on reductions in GHG emissions and water, fertilizer, pesticide and land use. **Location:** Europe **Sectors:** Food, textiles and furnishings (furniture).	The analysis of three scenarios (modest, moderate and ambitious) for potential EU objectives with regard to GHG emissions (CO2) and water, fertilizer, pesticide and land use. The calculation of the economic impacts is based on hypotheses on the number of jobs created per thousand tonnes of reused textile and furniture. The water savings are based on hypotheses on reduced water use leading to textile reuse. The estimations for the use of land not used in agriculture are based on the hypothesis of a direct link between reduced food waste and reduced primary food production (estimates from industry and NGOs).	**Economy:** Depending on the level of ambition, approximately 635 000 to 750 000 additional jobs created until 2025 and 710 000 to 870 000 jobs until 2030. **Environment:** 56.5 to 96.5 million tonnes GHG could be avoided until 2025 and 74.6 to 115.0 million tonnes until 2030. The potential water savings total 26.1 to 52.2 million litres in 2025 and 34.8 to 60.9 million litres in 2030. Avoided use of fertilizer and pesticide: 0.44 to 0.88 million tonnes by 2025 and 0.58 to 1.02 million tonnes by 2030. Land use for agricultural purposes is estimated at 28 350 to 47 520 km^2 by 2025 and 38 070 to 56 970 km^2 by 2030.	[5]
European Commission (2015) (Study completed by Eunomia Research & Consulting in 2014) [28]	Impacts on GHG emissions and employment following the implementation of the EU's proposed waste regulations. **Location:** Europe	Model the impacts of the implementation of various municipal solid waste recycling objectives and consider the packaging waste and landfill diversion objectives.	**Economy:** Based on the scenario, the complete implementation of the proposed waste legislation could create 136 000 and 178 000 full-time jobs by 2025. **Environment:** Reduction of 424 to 617 million tonnes CO2 eq. over 2015–2035.	[5]
Lawton et al. (2013) [30]	Environmental benefits of materials efficiency (resources) . **Location:** Europe **Sectors:** Food and beverages (manufacturing), metal-based products manufacturing, hotels and restaurant.	The results are based on case studies of specific businesses and are therefore not representative of the average company.	**Environment:** Potential annual GHG emissions reduction of between 2 and 4%.	[5]

Technopolis Group et al. (2016) [31]	Analysis of legislative and regulatory barriers that limit circularity potential in certain sectors. **Location:** Europe **Sectors:** Packaging, food, electronic and electrical equipment, transport, furnishings, buildings and construction	Evaluation of legislative and regulatory barriers based on studies of cases in the value chain with circularly potential and priority sectors (based on literature and 1 500 contributions and sorting by criteria).	**Opportunities behind legislative and regulatory barriers:** Savings of 15% on the price of raw materials through palladium recycling. Europe exports the equivalent of 115 million euros of precious metals in catalytic converters annually. **Food redistribution:** Food waste generated by the hospital sector is estimated at over 4 billion euros/year. **Recovery of manure nutrients:** 1.14 billion euros in opportunity costs annually (20% of manure is processed as waste). **Plastic recycling:** 700 million euros for plastic packaging. **Medical equipment reconditioning:** 20% price reduction that represents savings of 100 to 500 million euros annually. Nearly 30% of revenues are reduced. **Battery recycling:** 50 to 100 million euros. **Electronic equipment reuse:** A 2% increase in the use of used products could lead to cost savings of up to 3 billion euros.	[31]
Oakdene Hollins (2011) [32]	Assessment of resource efficiency and waste reduction performances and economic opportunities. **Location:** United Kingdom **Sectors:** Energy, transport (freight), services, industrial. **Waste and resources:** non-metallic chemical/ mineral, industrial metals, electricity and public utilities, construction. **Water:** public utilities and other offers.	This study is based on earlier studies (quantification of savings at no or low cost associated with efficient resource use and the conversion of financial savings into emissions savings) by assessing the UK's performances since 2006 through savings and evaluating resource efficiency. The study covers a broader context in order to identify savings opportunities (measures/ interventions) that are not limited to one year (ease of implementation). Statistical data were also used to consider the study objectives (audit and case studies).	The values of the no- or low-cost resource efficiency savings for 2009 are estimated to be a reduction of 29 million tonnes CO_2 and represent savings of 23 billion pounds (18 billion for waste and 4 billion for energy efficiency). Additional savings opportunities over a reimbursement (costs) for more than 1 year are estimated at 33 billion pounds.	[5]
Ellen MacArthur Foundation (2015) [33]	Economic and environmental benefits of circular economy. **Location:** Denmark **Sectors:** Food and beverages, construction and real estate.	Combination of data from the national statistical authority and expert opinions and guidance to provide a quantitative or semi-quantitative assessment of impacts. Estimation of the carbon footprint by evaluating the variation in carbon emissions divided by status quo model emissions.	**Economy:** GDP growth between 0.8 and 1.4%, creation of 7 000 to 13 000 additional jobs, 3 to 6% increase in net exports. **Environment:** Potential reduction of 3 to 7% in Denmark's carbon footprint. Potential reduction in original resource consumption of 5 to 50% by 2035.	[5]

Bastein et al. (2013)	Economic benefits of circular economy and policies required for transition. **Location:** Netherlands **Sectors:** Metals and electricity (17 product categories), waste flows (34 targeted), biorefinery technologies and activities, biogas extraction and household waste.	Assessment of the impacts of increasing circularity in the metallurgy and electricity sectors and use of biomass waste flow use. The results are then scaled to the entire Dutch economy to estimate the economic impacts.	**Economy:** Potential to create added value of 7.3 billion euros/year and approximately 54 000 jobs. The current value of the circular economy for the 17 product categories in the metallurgy and electricity sector is 3.3 billion euros, and the Netherlands could reach an annual additional market value of 573 million euros. The use of the 34 most significant waste material flows already represent a value of 3.5 billion euros. An estimated investment of 4 to 8 billion euros on new technologies could create an added value of 1 billion euros/year for the circular economy in the biorefinery, biogas extraction and household waste sorting sectors.	[5], [26]
Ökopol (2008)	Impacts of recycling activities on GHG emissions. **Location:** Europe	**Use of different scenarios** i) Modest: Current recycling rate (from 2005) supposing constant growth of 1.1%/year ii) Average: 65% recycling rate by 2020 iii) Ambitious scenario based on waste production per inhabitant and per kg and maintenance of recycling rates similar to those in the moderate scenario	**Environment:** Reduction of 247 to 330 million tonnes CO_2.	[5]
Cambridge Econometrics & BIO Intelligence Service (2014) [34]	Potential impacts of various resource productivity targets (GDP per raw materials consumption unit). **Location:** Europe **Sectors:** Main materials categories analyzed by default (Eurostat material flows): biomass, metals, minerals and fossil fuels. **Materials** - Ferrous and non-ferrous metals - Construction and industry minerals - Forestry - Food - Animal feed - Biomass - Fossil fuels	Quantitative analysis of economic and environmental impacts of an increase in primary resource productivity (RP) using the E3ME macroeconomic model. The model is used to analyze detailed links between economies, materials, the environment and energy in 33 countries (28 EU nations and 5 others). In the study, RP is defined as GDP per unit of raw materials consumption. The scenarios in the report are based on different resource productivity objectives for the 33 countries, from modest increase in RP (1%/year) to ambitious increase (3%/year). In the 2014–2030 period, this leads to an increase in RP of approximately 15% for the modest scenario and 50% for the ambitious one. The study presumes that the policies that enhance RP fall into three categories: market instruments such as taxation, measures supported through private funding such as recycling and public investments to increase efficiency. The revenue from the instruments based on the market are meant to be used to fund investments. The remainder is allocated to lowering labour income taxes.	**Economy:** Increased RP between 1 and 3%/year. The results indicate that an annual productivity increase of 2% could create 2 million additional jobs and have a positive impact on GDP up to 2030. A 2 to 2.5% increase would also positively impact GDP. **Environment:** A 3% increase in RP could lead to greater emissions reduction up to 2030 and to higher costs with a negative impact on GDP.	[5], [26]

SITRA (2016) [35]	Impacts of circular economy in Finland. **Location:** Finland **Sectors:** Machinery and equipment, forest industry, food waste, real estate, private consumption and secondary goods markets and nutrient recycling.	The study relies on estimates by Sitra & McKinsey (2015) of resource flows and value creation combined with estimates by the Ellen MacArthur Foundation (2013a). Among the sources used by Sitra & McKinsey (2015) are Eurostat and national authority statistics.	**Economy:** The value of the circular economy could potentially reach 2 to 3 billion euros by 2030.	[5]
Pratt & Lenaghan (2015) [36]	Assessment of materials consumption on carbon emissions considering territorial boundaries and country-specific consumption. **Location:** Scotland **Materials:** - Chemical and industrial materials - Construction materials - Ferrous and non-ferrous metals - Food and plants - Glass - Medical equipment - Household goods - Machinery - Minerals - Mixed metals - Paper - Plastic - Rubber - Textile - Vehicles - Lumber	The results are based on a material flow model that includes the number of tonnes of materials consumed, waste management data and emissions factors based on consumption boundaries (exports excluded). The study sets out four circularity scenarios compared to 2012: status quo, resource efficiency, slow economic growth and circular economy. The model excludes trade among UK nations through simplification that may impact the results.	**Environment:** The circular economy scenario could lead to potential reductions of 50% in materials consumed and 11 million tonnes CO_2 eq. in 2050 (base year is 2012). **Economy:** The circular economy scenarios could lead to GDP growth of 2.2% annually. The slow economic growth scenario leads to higher reductions in CO_2 but lower GDP growth (0.2%/year).	[36]
Friends of the Earth (2010)	Impacts of recycling activities in employment. **Location:** Europe	Applies conversion coefficients for jobs per 1 000 tonnes of recycled materials from UK to EU recycling data to estimate the potential.	**Economy:** The EU's recycling objective of 70% could create 563 000 new net jobs. This figure includes new direct, indirect and induced jobs.	[5]
European Commission SWD (2015) [28]	Analysis of the impacts of the European directive on waste (regulation). **Location:** Europe		62 million tonnes CO_2 eq.	[102]

Morgan & Mitchell (2015) [38]	The job creation potential in a UK that practices efficient resource use in its reuse, open- and closed-loop recycling, biorefinery, repair and reconditioning and services activities. **Location:** United Kingdom **Sectors:** - Reuse activities: used goods retail (store) - Open- and closed-loop recycling: recycling and waste, waste and scrap metal wholesalers - British biorefinery market as a whole - Repair, reconditioning and services: rental	Three 2030 scenarios developed: no initiatives, current development rate and transformed economy (circular economy). The study opted for a quantitative and qualitative analysis of labour in Britain. The approaches are as follows: — Analysis of the British job market as a whole — Analysis of the requirements of circular economy activities in Great Britain based on proxy data from statistics, studies and expert opinion — Assessment of circular economy developments — Development of three scenarios of three trajectories of the evolution of circular economy (induced activities and impacts on the job market) — Results	**Economy:** The circular economy strategy (ambitious) could potentially create 200 to 520 new gross jobs and reduce unemployment by 50 000 to 100 000 people. **Social:** The circular scenario compensates for job losses in positions qualified as intermediate. The demand for intermediate jobs would be high in a circular economy. There is potential to reduce regional unemployment in areas with the highest unemployment rates and contribute to reducing regional disparities through circular activities.	[5], [26]
Ellen MacArthur Foundation & SYSTEMIQ (2017)	**Location:** Europe **Sectors:** Transport, food and buildings.	Investment opportunities are quantified based on the investment measures identified through documentary research and interviews with experts.	**Economy:** Investment opportunity of 320 billion euros by 2025.	[5]
Ellen MacArthur Ellen MacArthur Foundation (2015)	**Location:** Global **Sectors:** electric vehicles (shared and autonomous), reduction in food waste, food and its value chain, passive houses, urban planning and renewable energies.		17 000 million tonnes CO_2 in 2030.	[102]
Circle Economy, Ecofys (2016)	**Location:** Global **Sectors:** Recovery and reuse activities and activities to extend product service lives, sharing and service models, circular design and digital platforms.		7 500 million tonnes CO_2 in 2030.	[102]
BIO for European Commission (2011)	**Location:** Europe **Sectors:** Recycling		176 million tonnes CO_2 eq. (regulatory targets). 278 million tonnes CO_2 eq. (technical potential).	[102]
CDC Climat for Eco-Emballages (2015)	**Location:** France **Sector:** Packaging recycling		2.1 million tonnes CO_2 eq. in 2013.	[102]

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