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Milestone Study on Bioplastics Waste Management in the US & Canada

Transforming Recycling and Solid Waste Management in the US & Canada

Executive Summary

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*Photo Credit – Cover: Planters made of recycled plastic bottles by Elizabeth Romo-Rabago from Ciclomanias. https://www.ciclomanias.com

1 Study Context and Scope

The CEC has commissioned this study as part of its Operational Plan 2021 Project "Transforming Recycling and Solid Waste Management in North America,"[1] with the goal of promoting circular economy and sustainable materials management approaches and bring economic and environmental benefits to the region. This project supports Canada, Mexico and the United States in their efforts to promote circular economy and sustainable materials management approaches to encourage eco-design and thus increase product and material reuse, recovery, and recycling rates.

This publication represents one of a series of three milestone studies which aim for better understanding of the opportunities in the recycling sector and secondary material markets for plastics, paper, and bioplastic waste. The content focuses on the US and Canada, and a separate set of these studies focused on Mexico will be available in the upcoming months. Building on the results of these milestone studies and on stakeholder input, the project will carry out pilot testing projects in a second phase designed to assess the feasibility of innovative technologies, policies, or practices for adoption at scale across North America.

The following report is the milestone study on bioplastics waste. It presents, in terms as comprehensive as the available data allow[2], a picture of the current state of bioplastics waste management, the barriers to circularity, and opportunities for overcoming these barriers. Information presented in this study is designed to support stakeholder collaboration and knowledge-sharing and provide policy makers with evidence-based recommendations for improving bioplastics waste management and circularity in Canada and the US. It does this by providing an overview of the value chain, market trends for production and demand, current and emerging policy trends, and considerations and best practice for waste management.

The scope of this milestone study is post-consumer bioplastics waste from residential and commercial sources, with a focus on packaging, including food service ware. The term "bioplastics" encompasses several materials groups. There are three main bioplastic groups covered in this report, depicted in Figure 1. They are distinct from conventional plastics in terms of raw material input and/or their ability to decompose naturally into harmless products within a reasonable timeframe (i.e., biodegrade). The three bioplastic groups are:

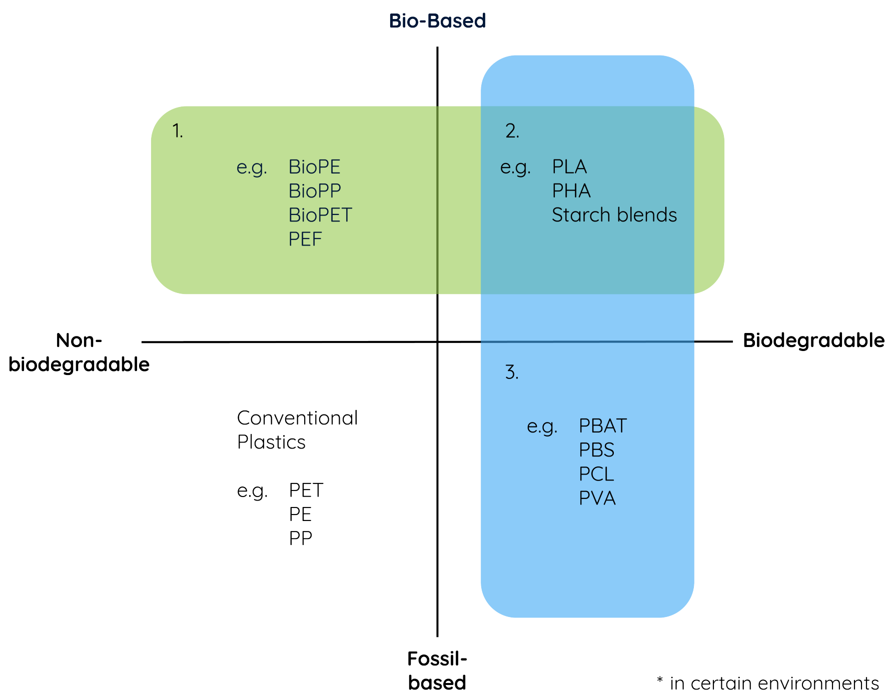
1. **Bio-based, non-biodegradable plastics** (e.g., bioPP, bioPET), encompassing plastics made from renewable raw materials ("bio-based") that do not biodegrade. These are often termed "drop-ins" because they have the same chemical structure as conventional plastic counterparts (e.g., PP, PET) and can be recycled alongside them in existing infrastructure.
2. **Bio-based, biodegradable plastics** (e.g., PLA, PHA), encompassing bio-based plastics that do biodegrade in relevant timescales, often only under specific conditions (e.g., at an industrial composting facility).

[1] CEC Operational Plan 2021 Project, "Recycling and Solid Waste Management in North America."
[2] This study considers the information and data available by December 2023.

3. **Fossil-based, biodegradable plastics** (e.g., PBAT, PBS), encompassing plastics made of petrochemical raw materials that do biodegrade (unlike conventional plastics), often under specific conditions.

Oxo-degradable plastics are often misclassified as "biodegradable." These are materials of concern since they are modified conventional polymers with additives to accelerate fragmentation, leading to the generation of microplastic pollution. There is thus a recommendation to ban these materials across Canada and the US.

Figure 1. Material coordinate system of different types of bioplastics



Source: Adapted from (European Bioplastics 2022)

Biodegradable plastics must be certified compostable to even be considered for organic waste treatment (i.e., composting). Composting is the current formal treatment route for this material group, especially considering that most biodegradable plastics are not recyclable at scale. While all compostable plastics are biodegradable, not all biodegradable plastics are compostable.

It is important to distinguish between plastics certified compostable at home ("home compostable") and at industrial facilities ("industrially compostable"), where optimal conditions are maintained for biodegradation. Industrially compostable plastics are not always home compostable, due to the large variation in conditions seen during home composting. A third category to consider is "nature/marine biodegradable" plastics, referring to plastics claimed to be biodegradable in nature.

2 Research Method

The information presented in this milestone study was gathered through secondary research, analyzing existing relevant publications and databases, and primary research through consultation with key stakeholders in bioplastics waste management in each country.

In comparison to the more established paper and plastics markets, there was limited publicly available market and waste management data on bioplastics in Canada and the US during the time of study. This is due to bio-based and/or biodegradable plastics being relatively novel material groups, comprising a relatively small market share compared to conventional plastics. Particularly, there was a paucity of data related to bioplastics production, use, trade, waste generation, and end-of-life treatment. Figures related to bioplastics material flows and treatment capacity were based on the best available sources but should still be interpreted with caution. Additionally, there are constant developments in the bioplastics market and waste management sector with regards to product and technological innovation. Given this evolving landscape, information and data may be made available following publication of this study that were not accounted for at the time of writing.

3 Key Findings

3.1 Material Flows and Waste Management

3.1.1 Bioplastics Production and Future Market Trends

Market data on bioplastics is very limited, therefore the study relied on global production data by European Bioplastics. Canada and the US produce approximately 19% (about 420,000 tonnes) of global bioplastics annually, making it the third-largest producer of bioplastics, following Asia and Europe.[3]

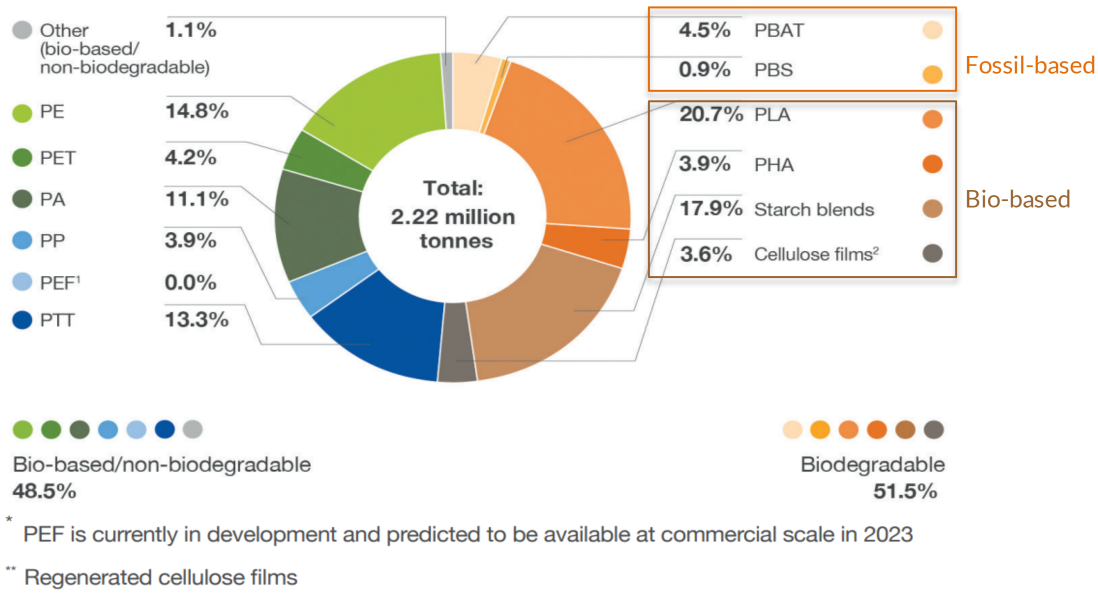
Approximately half of globally produced bioplastics are biodegradable, while the other half is bio-based non-biodegradable. Figure 2 demonstrates that the top bioplastic produced globally in 2022 was polylactic acid (PLA), followed by biodegradable plastics made from starch blends, bio-based drop-in polyethylene (bio-PE), polytrimethylene terephthalate (PTT), and bio-based drop-in polyamide (bio-PA). Globally, bioplastics are primarily produced for packaging (48% of total global production capacity), followed by fibres and consumer goods (15% and 14% of global production capacity respectively) (European Bioplastics 2022).

In Canada and the US, packaging applications make up an even larger share of bioplastic use, followed by agriculture, consumer goods and textiles (Grand View Research 2022). The split of bioplastic types in Canada and the US is currently unknown. Major bioplastic producers in Canada and the US are NatureWorks, Danimer Scientific, Green Dot Bioplastics, and Plant PET Tech Collaborative, which produce PLA, PHA, starch blends, and bioPET respectively. No estimates on

[3] Based on data from (European Bioplastics 2022).

COMMISSION FOR ENVIRONMENTAL COOPERATION import and export tonnages were made in this study, as there is no publicly available import and export data for bioplastics overall nor according to type.

Figure 2. Global production capacities of bioplastics in 2022 by material type



Source: Adapted from (European Bioplastics 2022).

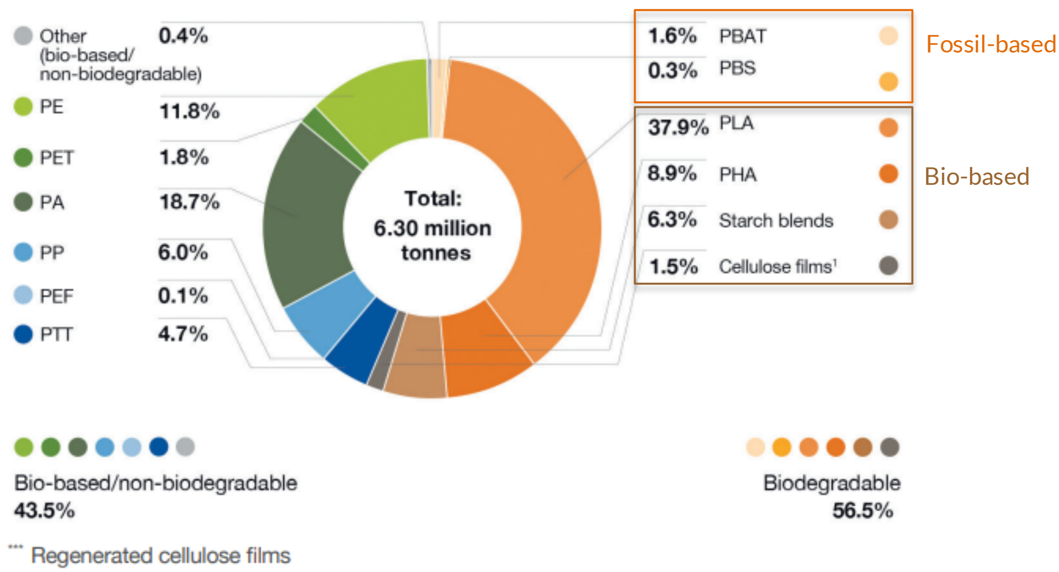
Historic bioplastic global production data from the last six years do not provide a clear indication of market trajectory. Between 2017 and 2022, there has been a shift from bio-based drop-ins representing the majority of bioplastic production (~60% in 2017) to a ~50% split between bio-based drop-ins and biodegradable plastics in 2022.[4] It is unclear whether this trend will continue. In 2022, there was a major (45%) increase in bio-based drop-in production, a trend which may continue, potentially causing the bio-based drop-in market to become dominant again. This is possible considering that manufacturers are increasingly exploring using bio-based drop-ins to reduce virgin fossil content in products, as an alternative to the use of recycled content.

Most predictions estimate that the bioplastics market in Canada and the US will reflect the global bioplastics market and grow at a compound annual growth rate of approximately 10% up to 2030 (Fortune Business Insights 2021, Grand View Research 2022, Research and Markets 2021). Overall, packaging and food service ware are expected to continue to be the main application for bioplastics. European Bioplastics' projections of global bioplastics production capacities estimate there will be an increase to 6.3 million tonnes produced by 2027 (European Bioplastics 2022) (see Figure 3). PLA is expected to continue to dominate production, globally and in Canada and the US since NatureWorks, headquartered in the US, currently has the highest production capacity for PLA. Bio-PE and bio-PA are expected to continue to be highest in demand by 2027 within the bio-

[4] Based on calculations using production figures from the following sources: (European Bioplastics 2022); (European Bioplastics 2021); (European Bioplastics 2019); and (European Bioplastics 2018).

based drop-in market segment. The automotive industry is the main source of demand for bio-PAs (nylons), often used to reduce vehicle weight as an alternative to glass fiber (Eunomia Research & Consulting 2020).

Figure 3. Global production capacities of bioplastics predicted for 2027 (by material type)



Source: Adapted from (European Bioplastics 2022).

3.1.2 Quantities and Types of Bioplastics Entering Waste Streams

Due to lack of data, it is difficult to accurately determine the quantities and types of bioplastics entering specific waste streams in Canada and the US. This is due to the novelty of the material group, their small market share, their largely indiscernible appearance from conventional plastics, and a lack of targeted data collection in waste streams.

This study assumes that the quantities of bio-based non-biodegradable plastics entering waste streams are the same as the quantities produced. It also assumes that these plastics will be recycled, incinerated, landfilled or lost to the environment in similar proportions to what currently happens to conventional plastics. Based on these assumptions, this study estimates 7,000 tonnes of bio-based non-biodegradable plastics in North America will be recycled[5]. For biodegradable plastics, this study estimates that 19,600 tonnes of compostable plastics are sent to organics treatment facilities that accept biodegradable plastic material. This estimate is based on 2016 data on US food waste collection tonnages, the acceptance of compostable plastics in US food waste collection schemes, and organic waste composition data.

[5] For detailed waste flows of conventional plastics please refer to the CEC Plastic Milestone Study.

In total, 25,510 tonnes of bio-based and/or biodegradable plastic are estimated to be either sent for mechanical recycling, or industrial composting, although some biodegradable plastics are likely removed at industrial composting facilities along with contaminants (e.g., conventional plastics). Therefore, there is likely to be a maximum recovery rate of ~6% for North America for all bioplastics. However, this may be an overestimate, as there are poor accounts of material flows, and this assessment assumes treatment facilities are processing the material they accept in the same way as conventional plastics or organic waste.

3.1.3 Bioplastics Waste Treatment Capacity

Bio-based drop-ins are recycled alongside conventional plastics using existing infrastructure (see CEC Plastics Milestone Study for more detail on conventional plastic recycling capacity). Though certain biodegradable and compostable plastics are technically recyclable, currently they are not collected, sorted, and recycled in practice and at scale in Canada and the US. Therefore, they are considered unrecyclable, in practice. Biodegradable and compostable plastics contaminate the conventional plastics recycling stream and need to be recycled separately. However, the relatively small volumes of these plastics placed on the market do not make their collection, sorting, and separation for recycling economically viable, and no recycling happens at scale.

The appropriate end-of-life route for compostable plastics is collection with organics waste, ideally food waste, and treatment at industrial composting and anaerobic digestion (AD) facilities. Though some facilities may be technically able to treat certified industrially compostable plastics, many facilities remove any material the looks like plastic due to contamination concerns. According to the only updated comprehensive dataset available at the time of writing, only 12% of 1,029 composting facilities in the US accepted "compostable products", which includes, but is not limited to, "biodegradable plastics" (Green Blue 2023). In 2021, Canada had an estimated total organic waste processing capacity of 5.7 million tonnes per year (EREF 2021), though the processing capacity compostable plastics at these industrial composting and AD facilities is likely to be lower.

Even if compostable plastics were more widely collected and accepted by composting and AD facilities, there is a limit in total processing capacity to treat annual organics waste generation in both the US and Canada. Current facilities would have insufficient capacity to treat a significant increase in industrially compostable plastic waste, which provides no nutritional benefit to compost nor digestate.

3.2 Current Policy

Policy and regulation are key to changing waste and recycling practices to increase material circularity and transition to a circular economy. Currently there is no uniform approach to policy for managing bioplastics waste between Canada and the US.

In the US, waste management is largely handled on a state level, leading to patchwork policies. When it comes to biodegradable plastics, US state legislation is more focused on the labeling of biodegradable plastic products than on the banning of the material. State and local single-use plastic (SUP) bans tend to vary, with some states including biodegradable plastics in bans, and others encouraging the use of certified compostable plastics as alternatives to conventional SUPs.

However, the US federal government undeniably supports the production of bio-based products, as seen by the USDA's BioPreferred Program. The program legally requires the government and its contractors to give procurement preference to bio-based products (both biodegradable and non-biodegradable) (USDA 2023).

In Canada, waste and recycling regulations are primarily established by individual provinces and territories, while management is led by municipal authorities. The Government of Canada has authority when there is the potential for pollution from waste and it is responsible for waste management on federal land. In its efforts to tackle plastic pollution, from conventional, bio-based, and biodegradable plastics, the federal government has enacted the Single-use Plastics Prohibition Regulations (SUPPR) (Government of Canada 2022). Additionally, the government is drafting regulations for recyclability and compostability labelling rules for plastics and developing a federal plastics registry for reporting data (Government of Canada 2023).

3.3 Key Barriers to Circularity

Table 1 summarizes, at a high-level, the barriers to bioplastics circularity, within Canada and the US, according to value chain stages and bioplastic material group. The red, amber, and green coloring (RAG rating) represents the degree of barrier severity to circularity, with red representing the greatest barriers and green the least severe barriers.[6] Where the term "biodegradable plastic" is used, this encompasses both bio-based and fossil-based biodegradable plastics. Similarly, "bio-based" encompasses both biodegradable and non-biodegradable plastics, except when noted otherwise. Finally, "bioplastics" encompasses all material groups (bio-based biodegradable, bio-based non-biodegradable, fossil-based biodegradable). See Figure 1 above for a visual explanation of these material groups.

Table 1 shows that, across Canada and the US, there are barriers to circularity at all stages of the value chain for both biodegradable and bio-based plastics. The product design, collection, sorting, and composting value chain stages for biodegradable plastics pose the greatest barriers to circularity, requiring investment in infrastructure expansion, education, and research. Bio-based plastics face the greatest barriers in upstream stages, with respect to sustainable feedstock production, requiring the development of policy and more stringent standards.

[6] In the full study, the color coding is simply red for the left two columns that outline the challenges and barriers to circularity; green for the right two columns that outline the suggested solutions.

Table 1. Barriers to bioplastics circularity in Canada and the US, according to value chain stage

Stage	Country	RAG rating	Material Group	Reason for RAG Rating
Product Design	 		Bioplastics	Bio-based and biodegradable plastics are designed and used for inappropriate product applications, often as alternatives to conventional plastics, due to lack of awareness and guidance. Using bioplastics for inappropriate product applications can increase the chance of inappropriate disposal by the consumer or lack of circular waste management route.
Collection			Biodegradable	There is an absence of or limited access to organics/food waste collection schemes, and limited acceptance of compostable plastics in these collection programs, where they are provided. According to available data, 43% of residents in 1,000 of the largest US cities (~40% of the US population) did not have access to composting programs of any kind in 2023 (GreenBlue 2023). Engaging in composting programs seems to rely on environmentally motivated residents to pay for their own service: a higher proportion of residents (25%) having access to privately-run curbside services compared to municipally run services (14%) (GreenBlue 2023). Furthermore, only 23% and 8% of residents had access to privately- and municipally run curbside programs respectively that accept any form of compostable packaging, though this is not limited to compostable plastic (GreenBlue 2023). A 2021 BioCycle survey of composting programs found that of the 265 municipally run programs responding, only 14% of them accepted compostable plastic foodservice items and packaging (BioCycle 2021).
			Bio-based, non-biodegradable	In the US, there is inequitable access to recycling collections.
			Biodegradable	Food waste collection schemes tend to reject industrially compostable plastics largely due to contamination issues at industrial composting facilities (e.g., from incomplete biodegradation, contamination with conventional plastics). At the time of writing, of 12 large municipal organic waste collection programs assessed, only four programs truly accept industrially compostable plastic bin liners/bags to help capture food waste. The remaining programs prohibit all forms of compostable plastic or allow them in the waste stream but treat compostable plastics as contaminants and landfill them regardless.

Stage	Country	RAG rating	Material Group	Reason for RAG Rating
			Bio-based, non-biodegradable	Though many residents have access to conventional plastic recycling collections (the formal stream for collecting recyclable bio-based drop-ins), there is still lower access to recycling collections for certain plastic polymers and/or packaging types (e.g., multi-material films).
Sorting and Recycli	 		Bio-based, non-biodegradable	There is a lack of infrastructure available to sort and recycle "difficult to recycle" polymers and product designs.
Collection, Sorting, and Recycling	 		Biodegradable (recyclable)	Recyclable biodegradable plastics contaminate conventional plastic recycling streams and must be recycled separately. For example, PLA acts as a contaminant in PET streams at very low levels (approximately 1%) (Niaounakis 2019). However, the low volumes of material currently placed on the market make the collection, sorting, and recycling of a separate stream inefficient, expensive, and financially unsustainable (Beeftink, et al. 2021). Collection, sorting, and recycling of recyclable biodegradable plastics (e.g., PLA) is thus absent across Canada and the US. There is also a lack of specialist infrastructure to recycle certain recyclable bioplastics like PLA.
Sorting and Composting			Biodegradable	There is limited treatment capacity for food waste in the US, especially residential food waste, compared to other types of organic waste like yard waste. According to available data, of the total organic waste processed between 2015 and 2016, only 8.7% of it was food waste (BioCycle 2017). Composting facilities' sorting systems, which are often manual, cannot distinguish industrially compostable plastics from conventional plastics, due to their similarity in appearance. This often leads to the rejection and landfilling of the material due to incomplete biodegradation, contamination issues (e.g., with conventional plastics and of compost), certification for compost used in organic farming, and the lack of nutritional value compostable plastics provide. For example, the US composting industry has been raising public concern on the suitability of compostable plastics in the organics waste stream. Oregon composters released a joint statement in early 2019 on why compostable packaging poses a risk to facilities (Oregon Composters 2019). In the US, approximately 12% of composting facilities accepting organic waste accept compostable products (which is not limited to compostable plastics) (Green Blue 2023).

Stage	Country	RAG rating	Material Group	Reason for RAG Rating
			Biodegradable	In 2021, Canada (excluding Quebec) had an estimated total organics processing capacity of 5.7 million tonnes per year, though technologies able to process food waste made up almost 3.1 million tonnes per year of that capacity (EREF 2021). Nevertheless, composting facilities' sorting systems, often cannot distinguish industrially compostable plastics from conventional plastics and there is likely a limited capacity to treat industrially compostable plastics alongside food waste due to the tendency of facilities to reject the material over contamination concerns. According to available data at the time of writing, in Canada there is only one composting facility that accepts compostable plastic packaging (Green Blue 2022). Consultation with stakeholders suggests that GreenBlue's data may not capture all facilities that accept and process compostable plastic products and packaging, however at the time of writing no other current and comprehensive dataset is publicly available.
Policy			Bioplastics	There is patchwork policy on bioplastics management, labelling, waste management, and SUP bans, confusing producers and businesses and limiting the advancement of a circular economy at a national level. SUP bans and policies do not prioritize the implementation of reuse and refill systems, perpetuating single-use consumption. There is also unclear policy and guidance on appropriate bioplastic alternatives to SUPs covered within bans (according to product application). The lack of clarity makes it difficult for businesses to procure truly sustainable alternatives to conventional SUPs and risks perpetuating single-use consumption. There is a lack of data monitoring and reporting requirements for bioplastics, limiting the amount of data available on bioplastics production, consumption, and end-of-life treatment. This lack of data limits the ability to develop strategies that effectively manage bioplastics in a circular economy.

Stage	Country	RAG rating	Material Group	Reason for RAG Rating
			Bioplastics	The SUPPR and associated guidance do not provide detailed guidelines on selecting appropriate bioplastic alternatives to the SUPs covered within a ban. The proposed labelling regulations for SUPs and plastic packaging (not yet adopted) addresses compostability and recyclability claims but not bio-based content claims. The widespread implementation of reuse and refill systems (over single-use consumption) is not prioritized in policy. There is a lack of data monitoring and reporting requirements for bioplastics, limiting the amount of data available on bioplastics production, consumption, and waste generation. This lack of data limits the ability to develop strategies that effectively manage bioplastics in a circular economy.
	 		Bio-based	There is a lack of policy and enforceable standards that ensure feedstock for bio-based plastic production is sustainably sourced and that any negative environmental impacts associated with feedstock sourcing and production for bio-based plastics are mitigated.
			Bio-based, non-biodegradable	Lack of incentives and policy signaling to increase use of recycled content, and production of recyclable, bio-based drop ins specifically.
			Bio-based, non-biodegradable	While the BioPreferred program incentivizes public procurement of bio-based plastics (both biodegradable and non-biodegradable), there is a lack of incentives and policy signaling to increase production of recyclable, bio-based drop ins specifically and the use of recycled content.
Standards	 		Industrially compostable	Standards for industrially compostable plastics exist but are often criticized by composters for their unrealistic testing conditions and the lengthier biodegradation timeframes employed than is relevant to composters.
			Home compostable	No home compostability standard exists in the US or Canada. Home composting conditions are extremely variable, making it difficult to test home compostable plastics against a standard.
			Nature/ marine biodegradable	No nature/marine biodegradable standard exists (in Canada and the US nor internationally). This is due to the large variation in real-world conditions, making any such standard meaningless.

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Stage	Country	RAG rating	Material Group	Reason for RAG Rating
	US		Bio-based	The US has bio-based content standards. However, there is variation in the approach to calculating bio-based content across standards internationally. Depending on the approach used, the calculated and certified bio-based content for the same product can vary significantly (Willemse and van der Zee 2018). This means bio-based content is not comparable across products and makes it difficult to determine the environmental benefit of using one product over another.
	Canada		Bio-based	No bio-based content standard currently exists in Canada.

4 Recommendations to Increase Circularity

The following section summarizes the key recommendations for improving bioplastics material circularity, based on the barriers to circularity identified in this study. Key recommendations are grouped according to bioplastic material group and overarching approach (policy, education, research and innovation).

4.1 Oxo-degradable Plastics

Oxo-degradable plastics are often considered biodegradable; however, they do not truly biodegrade and instead rapidly fragment into harmful microplastics. This makes oxo-degradable plastics unsuitable for composting, due to contamination issues, as well as reuse and recycling, due to their fragmentation into microplastics at faster rates than conventional plastics. Oxo-degradable plastics must thus be treated with residual waste (e.g., landfilled and/or incinerated with energy recovery), making it an unsuitable material for a circular economy. Therefore, banning or restricting the sale of oxo-degradable plastics at a federal level is recommended.

4.2 Both Bio-based and Biodegradable Plastics

Policy

In both Canada and the US, bio-based and biodegradable plastics face challenges related to the use of misleading claims on products, limited data availability, and lack of clarity or consistency in policy. Additionally, bio-based and biodegradable plastics are often used for product applications that are unlikely to be recycled or composted, or are used for applications that cause issues (e.g., contamination) within recycling and composting facilities. The added environmental benefit of using a bioplastic material in that product, over conventional plastic, can thus be reduced or, sometimes, entirely negated. Key policy recommendations that address these overarching barriers include:

- Making bio-based content and compostability standards legally enforceable at a federal level, to reduce the use of misleading claims on products.

- Adopting federal labelling regulations to ensure consistent product labelling, thereby also reducing instances of misleading claims.
- Implementing extended producer responsibility (EPR) environmental policies with a modulated fee structure (i.e., eco-modulation) to incentivize businesses to use bioplastic materials in appropriate product applications. EPR is an environmental policy in which producers bear the financial responsibility for managing the packaging they place on the market at end-of-life.
- Collecting data from treatment facilities and providing government support for data monitoring (e.g., through grants) to better understand bioplastic waste material flows.
- Developing incentives and/or requirements for waste reporting and performing waste characterizations, thus improving the availability of bioplastics waste data.
- Mandating or incentivizing the implementation of reuse systems (e.g., funding schemes, pilot schemes, tax breaks), instead of promoting the use of single-use bioplastic alternatives to conventional plastics. This will encourage advancements in the circular economy and limit single-use consumption overall.

In the US, SUP (single-use plastic) policy remains inconsistent at a national level and the promotion of alternative materials, such as bioplastic SUPs, also varies state by state. Restricting or prohibiting the sale of SUPs at the federal level would further encourage a transition to a circular economy. Similarly, disincentivizing the production and procurement of SUPs (e.g., through EPR, taxing businesses) could also further promote circular economy practices.

Education

In both Canada and the US, there is a general lack of awareness among businesses and consumers on the realities of bioplastic production and waste management. Investing in educational campaigns and activities can address barriers related to lack of awareness. For example, governments can:

- Provide businesses with tools for transitioning to reuse systems.
- Fund awareness raising campaigns for consumers and business on sustainable management requirements for bio-based and biodegradable plastics.
- Develop and provide best practice guidance to policymakers, businesses, and consumers, with scenarios and applications in which bio-based and/or compostable plastics provide the most added value as alternatives to conventional plastics.
- Establish guidance for waste reporting and performing waste characterizations.

4.3 Biodegradable Plastics

Policy

Policy for biodegradable plastics can be leveraged to improve their proper disposal, effective sorting, and safe treatment at industrial composting facilities or in home composting. Key recommendations to address these barriers across Canada and the US include:

- Developing national home compostability standards to ensure products labelled as "home compostable" tested against a credible standard and certified to fully biodegrade in relevant timeframes, into harmless substances.

- Adopting federal labelling regulations and funding consumer awareness raising campaigns to reduce instances of consumer confusion during disposal.
- Developing and adopting stricter industrial composting standards to better reflect real-world conditions and improve acceptance of certified industrially compostable plastics at industrial facilities.
- Aligning industrial composting standards across Canada and the US to account for sales of industrially compostable plastics across countries.

In the US, there is low or inequitable access to food waste collection. Additionally, there is a limited capacity or lack of infrastructure for processing food waste. Implementing policies that increase funding for the expansion of food waste collection and industrial composting infrastructure (e.g., through government grants, federal funding schemes, EPR) can address these barriers.

Education

Biodegradable plastics are often used in inappropriate product applications. Producers have designed these biodegradable plastics for products that are not associated with or appropriate for disposal in the food waste stream. This generates consumer confusion during disposal, leading to the disposal of biodegradable plastics in an inappropriate waste stream (e.g., the recycling stream). In both Canada and the US, producers and consumers would thus benefit from educational tools including:

- Producer guidance and toolkits on product design, including designing for product applications in which certified compostable plastics provide the most added value. Determining beneficial use of certified compostable plastics can be determined by conducting life-cycle analyses and effectively synthesizing the research across products.
- Consumer guidance and tools on sorting household waste and disposing of biodegradable plastics in the appropriate waste stream.

Research and Innovation

Certain knowledge gaps pertaining to biodegradable plastics persist. In both Canada and the US, there is limited knowledge on the extent to which product labelling can reduce consumer confusion. Funding research into this can provide insight on how best to label products. Furthermore, an argument for using certified industrially compostable plastic is to increase food waste capture. However, there is limited research on and evidence of a positive relationship between industrially compostable plastic and food waste capture within both the Canadian and US context. Funding research on industrially compostable plastics and food waste diversion may provide opportunities for policymakers to incentivize designing for food waste capture.

Additionally, certain barriers in sorting and related to facility acceptance of biodegradable plastics can be improved upon through funding research and development on:

- Sorting technology for novel biodegradable polymers, to aid in distinguishing between conventional and biodegradable plastics and thus reduce contamination at recycling and composting facilities.
- Improving the compostability and nutritional value of industrially compostable plastics, which may help increase composting facility acceptance of the material.

4.4 Bio-based Plastics

Policy

Bio-based plastics are produced from renewable feedstock and their greatest circularity barriers are related to unsustainable production and sourcing of feedstock. In both Canada and the US, the environmental impacts of upstream production may be partially addressed by developing and enforcing national standards and guidelines for sustainable resource production and incorporating direct and indirect land-use change as a measurement criterion.

Bio-based content claims are currently incomparable within and across countries, due to varying measurement approaches being used. Aligning these measurement approaches across Canada and the US could ensure that products are comparable and allow consumers and businesses to make more informed purchases.

In Canada, a key policy recommendation would be to adopt a national bio-based content standard, something which is currently lacking.

Research and Innovation

To address research gaps on the environmental impacts of bio-based plastics throughout their lifecycle, key recommendations include funding and promoting:

- Research into direct and indirect land-use change associated with the production of renewable feedstock in a bioeconomy and for bio-based plastics.
- Research into the indirect impacts of agricultural production of feedstock.
- Research and development into sustainable agriculture practices and the use of more sustainable feedstock for producing bio-based plastics, such as second and third generation feedstock, which would reduce the demand for arable land.

4.5 Bio-based, Non-biodegradable Plastics (Drop-ins)

Policy

A separate set of key recommendations are made for bio-based non-biodegradable plastics (bio-based drop-ins) due to their ability to be recycled alongside conventional plastic counterparts in existing recycling infrastructure. This material group could thus potentially provide benefits in the case of achieving net-zero. The following key recommendations would encourage the market growth of bio-based drop-ins and improve the demand for bio-based recyclate across Canada and the US:

- Set virgin fossil-based plastic content reduction targets to provide flexibility for producers to incorporate recycled content and/or bio-based content.
- Increase policy signaling to drive investment into the bio-based drop-in sector. For example, this could be accomplished through taxes on conventional plastics, using a certain fossil content and through establishing public sector procurement programs for bio-based drop-ins.

- Set increasing recycled content targets to stimulate national demand, not only for virgin bio-based content but also for recycled content, generating greater environmental savings in a circular economy.
- Fund the expansion of sorting and recycling infrastructure to overcome recycling challenges in the "difficult to recycle" products and formats.
- Implement EPR, requiring producers to fund collection and recycling of bio-based drop-ins (and conventional plastics). The EPR should require producers to pay higher fees for non-recyclable product designs to encourage more reusable and recyclable product designs.

In the US, where accessibility to recycling collections is low or inequitable, implementing EPR can also improve residents' accessibility to collections, given that producers are incentivized to fund infrastructure expansion to meet mandated targets. Similarly, US states may benefit from implementing a deposit-refund system (DRS), to improve accessibility to recycling collections. A DRS places a monetary deposit on a product, paid by the consumer at the time of purchase, which is then refunded when the consumer returns the product to a designated location for reuse and/or recycling. Implementing a DRS can help to increase the volume of plastic bottles collected domestically and thereby improve high quality recycling feedstock availability (for both conventional plastics and bio-based drop-ins).

Education, Research, and Innovation

In addition to the policy recommendations above, both the Canadian and US governments can invest in education and research to optimize product design for reusability and recyclability and overcome barriers in recycling "difficult to recycle" products. For example, the governments can provide guidance to producers on designing products for reusability and recyclability. Similarly, funding research and development into sorting and recycling technologies that overcome "difficult to recycle" polymers, formats, and designs.

5 Conclusion

The findings from these milestone studies on paper waste, plastics waste and bioplastics waste will provide key input for defining and developing appropriate pilot projects in Phase II of the Commission for Environmental Cooperation's Operational Plan 2021 Project, "Transforming Recycling and Solid Waste Management in North America."

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