Policy Brief: Diffusion of PHA Plastic to Protect Human Health

This policy brief prepared for **The Honourable Julie Dabrusin**, Minister of Environment and Climate Change and **The Honourable Mélanie Joly**, Minister of Innovation, Science and Economic Development Canada.

Briefing option 1: The Ministers require a briefing on specific innovation policy instruments and their potential role in supporting innovation to deliver SDG 3, target 3.9.

The brief contributes to **SDG 3:** Ensure healthy lives and promote wellbeing for all at all ages

- **Target 3.9:** By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination.

Due to the nature and authority over the instruments suggested, both Ministers are addressed.

Innovation for Sustainability

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Introduction

This brief discusses the acute global health consequences of plastic, particularly because of the immense pollution from single use plastic (SUP). Given the integration of plastic in Canadian lifestyles, consequences of our consumption actions echo overseas through waste shipments, which end up in the environment and circle back through bioaccumulation in the food system (Ferronato and Torretta, 2019). Although Canada recognizes the urgent need to curb plastic waste, policies have focused on reduced usage and recycling. A viable non-toxic and fully compostable (leaving behind no microplastics) alternative, polyhydroxyalkanoates (PHA) exists, however, challenges such as manufacturing cost and economic importance of the petrochemical industry in Canada have slowed diffusion (Mukherjee and Koller, 2023; Canadian Association of Petroleum Producers (CAPP), 2025) . A sociotechnical transition is necessary to combat the national and global health consequences of our actions. However, this transition requires policies to support PHA diffusion.

This brief will begin by reviewing the dangers plastic presents to human health and current policies in Canada. We then further examine the challenges around diffusion of PHA plastic along with theory and evidence including Edmondson, Kern and Rogge's (2019) co-evolutionary framework to analyze policy options and conclude with policy recommendations.

Framing

Modern convenience lifestyles have led to a significant amount of SUP that follows a linear take-make-dispose model. Canada contributes a disproportionate amount of plastic waste per person (Oceana Canada, 2020) which is often shipped overseas, where inadequate plastic waste management leads to spawning of vector-borne diseases (Landrigan *et al.*, 2025). Plastic pollution also releases a plethora of hazardous chemicals into the environment known to have serious health effects such as decreased fertility, developmental disorders and cancer, among others (Landrigan *et al.*, 2020). Increased cardiovascular risk also disproportionately affects regions with high plastic production sectors (Hyman *et al.*, 2025). Through pollution, these chemicals make their way into the environment, leading to bioaccumulation in the global food chain (Jambeck *et al.*, 2015; Ferronato and Torretta, 2019).

Heightened understanding of the harmful effects of plastic has led to sociopolitical shifts and investment in finding alternative technology for SUP (Song *et al.*, 2009). However, most alternatives still contain harmful chemicals (Zimmermann *et al.*, 2020). Only one alternative, PHAs are non-toxic, fully compostable and can be made from renewable biological resources (Bernard, 2014). Although the technology is available, policy support is lacking for widespread diffusion of PHAs.

The influence of oil and gas (OG) and petrochemical producers through economic strength and lobbying has perpetuated lock-in of the existing sociotechnical configuration (Edmondson, Rogge and Kern, 2020; Le Rouzic, 2020; Bauer and Fontenit, 2021). Fossil fuel, the key feedstock in traditional plastic (Kelly, 2021) is a major contributor to the Canadian economy (CAPP, 2025) and plastics manufacturing itself is a $35 billion industry (Environment and Climate Change Canada (ECCC), no date). However, when considering the economic costs of plastic in health and social-related losses annually which are estimated at 1.5 trillion USD (Landrigan *et al.*, 2025), the plastic industry may be a net-negative for the global economy (Trasande, 2025). Currently, the SUP market does not account for these externalities.

There is an opportunity for Canada to lead in commercialization of SUP alternatives with proper transition and policy support. However, to achieve sociotechnical transition towards Canada's zero plastic waste goals and protect human health globally, the current sociotechnical system needs to be reconfigured (Canadian Council of Ministers of the Environment (CCME), 2018; Trasande, 2025). Therefore, this brief will focus on policy recommendations addressing key barriers to innovation diffusion of PHAs including transition support of petrochemical and OG industries and cost competitiveness of PHAs.

Current Situation

Policies

Canada released a zero plastic waste strategy (ZPWS) in 2018 (CCME), which includes a SUP ban on six item types (ECCC, 2023). The plans largely focus on reduced usage and recycling, heavily relying on provincially controlled waste management programs (Tomchyshyn, 2022) such as extended producer responsibility (EPR) legislation. EPR shifts operational and financial responsibility for end-of-life waste management to producers. Guidance was released for national consistency, however, performance measures are left up to provinces causing variation in regulation, measurement and enforcement (Simpson, no date) and most provinces continue to receive failing grades for addressing plastic waste (Tomchyshyn, 2022).

The Canadian Plastics Innovation Challenges (CPIC) incentivizes innovation to address plastic waste, however, the projects funded vary depending on applications (ECCC, 2025). Although this is positive, per Kivimaa and Kern (2016), to allow a new sociotechnical regime to displace the old, more focus needs to be on policies to destabilize the existing regime.

Despite the ZPWS, Canada is far from achieving its net-zero plastic waste goals. Petrochemical and OG producers receive hundreds of millions of dollars in federal and provincial subsidies to build plants for plastic production (Rabson, 2018; Le Rouzic, 2020). Without new policies, plastic waste accumulation will continue.

Understanding PHAs

PHAs can be manufactured by converting a variety of biological raw materials as feedstock, including waste streams into carbon sources (Ganesh Saratale *et al.*, 2021). Microorganisms such as bacteria are used in a controlled environment to accumulate PHAs, the bacterial cells are then broken down to release the PHA, which is subsequently purified. Purified PHAs can be utilized for a variety of uses in a similar way to conventional plastics, including SUP (Ganesh Saratale *et al.*, 2021).

Government Options - Theory and Evidence

Being non-toxic, resulting in positive health and environmental impacts, PHAs are an eco-innovation. With the technology to replace SUPs (Mukherjee and Koller, 2023) , innovation diffusion is the system issue. According to Karakaya, Hidalgo and Nuur (2014), uncertainty in market conditions and return on investment (ROI) are main barriers to the diffusion of eco-innovations.

With cost of feedstock and complex processes such as the extraction and purification of PHAs, manufacturing costs may be up to six times higher than traditional plastic (Tan *et al.*, 2014; Yao *et al.*, 2025), creating difficulties to achieve economies of scale and compete with traditional plastics. Market failure to include harmful environmental and social externalities distorts competition and investment decisions for eco-innovation (Rennings, 2000). This creates barriers to scalability for eco-innovations, and the sociotechnical system remains unchanged.

According to Herrmann, Rhein and Sträter (2022), customers are willing to pay more for alternatives they perceive as sustainable, however, the same study also found that there is low willingness to pay (WTP) for alternatives where there is uncertainty around the sustainability benefits like bioplastics. This creates both lack of ROI and market uncertainty for companies to invest in PHAs.

In the diffusion phase, regulatory frameworks are key to normalize costs between eco-innovations and non-ecofriendly products (fossil-fuel based SUP) (Rennings, 2000). In this regard, with existing technology push, regulatory push is necessary to drive sufficient demand pull (Rennings, 2000).

A destabilization of the system is likely necessary to steer the transition towards sustainable alternatives (Kivimaa and Kern, 2016; Edmondson, Kern and Rogge, 2019). Regulatory policies to destabilize the current plastic production regime such as, a gradually increasing cap and trade system to limit virgin plastic production and increasing requirements for PHA (medium-long-term) plastic use in SUP goods either manufactured or imported into Canada will indirectly help diffusion of PHA. Capacity building initiatives such as training and apprenticeship programs will be required to support transitioning for current plastic industry workers.

Given waste management is a provincial responsibility, provinces will need to improve guidelines and national consistency of the composting element of waste collection programs. Canada has a great starting point with over 76% of households already doing some type of home composting (Statistics Canada, 2022). Composting provides a closed-loop waste system with PHA plastics able to decompose in home composting bins, and potential for waste streams to become a low-cost feedstock for PHA plastic, addressing some cost issues.

Lastly, creation of national certification standards for plastic alternatives would aid in building market trust and understanding, increasing customer WTP.

Although regulatory instruments are one vital tool for innovation diffusion, given the complex, systemic lock-in of plastic within the existing sociotechnical configuration a policy mix is needed to destabilize the interrelated components of this transition. See Table 1 for categories of policy instruments (includes current zero plastic waste instruments for reference).

Table 1 - adapted from (Borrás and Edquist, 2013).

	Definition	Current Instrument
Regulatory	Legal tools obliging actors to operate within a clearly defined framework	EPR legislation. SUP bans
Economic and Financial	Monetary (dis)incentives to support specific activities	EPR fees

		CPIC
Soft	Voluntary, often based on mutual exchange of information	

Policy mix suggestions consider Edmondson, Kern and Rogge's (2019) co-evolutionary framework which emphasizes the interdependent impacts of policy mix and sociotechnical systems. Policy effects (PE) which can be **resource** (distribution of resources like funding), **interpretive** (the way people interpret information) or **institutional** (policy interaction with sociotechnical institutional structure) impact sociotechnical change through influencing the behaviour of system actors (Edmondson, Rogge and Kern, 2020).

PE

Resource

Significant funding support to transition the Canada's petrochemical industry, ensure cost competitiveness of PHA plastic and encourage innovation diffusion will be required. This can be achieved through economic and financial instruments such as the introduction of government backed, low-no interest loans and subsidies for PHA manufacturing facility construction to ramp down of fossil products with ramp-up of PHA plastic production.

Given waste management is a provincial responsibility, other resource options include working with provinces to reduce EPR fees for PHA plastics while increasing fees and non-compliance fines for non-PHA plastics.

Interpretive

Given consumer hesitation to trust bioplastics (Herrmann, Rhein and Sträter, 2022), to build consumer trust, soft instruments like campaigns will be needed to educate consumers about PHA plastic and new certification standards and confirm dangers of traditional plastic.

Institutional

Working with the petrochemical industry to reform the power dynamics of the current sociotechnical system with transitional supports discussed above.

Effective rollout of **resource** and **institutional** transitions will also tie into positive petrochemical and OG **interpretation** of the new policy mix.

Feedback

Feedback throughout the policy development and execution phases comes in the form of **sociopolitical** (contains three dimensions: cognitive - perception by key actors; constituency – rallied support or dissention; agenda – consideration of alternatives by actors), **administrative** (design of bodies in charge of policy) or **fiscal** (do costs raise concern). These forms of feedback contribute to feedback loops that are created from the interfacing of the system elements which also include PE, exogenous conditions (like economic and political conditions) and policy subsystem (actors involved in the system, like the industries discussed above) that determine the success of the policy mix in assisting the transition (Edmondson, Rogge and Kern, 2020).

Maintaining positive feedback loops (virtuous cycle) is crucial for a successful transition (Edmondson, Rogge and Kern, 2020). Consequently, to achieve all dimensions of positive **sociopolitical** feedback, care must be taken to engage diverse actors in validating policy mix recommendations and implementation approaches. It is vital to include the experienced PHA bioscience community, industry workers and OG and petrochemical producers given their influence and destabilization of the current plastic industry. Having the right policy supports and design of bodies administering the policy is key to maintaining a virtuous cycle.

To address **fiscal** feedback, financing can come from cap-and-trade system proceeds, EPR fees and re-purposing of subsidies currently made to the industry for other OG and petrochemical related projects.

With the importance of **administrative** feedback, a diversified working group should be set up to discuss supporting workers, and production set up for cost-effective PHA production. Certain biotech tools have shown promise in making manufacturing more cost effective (Chen *et al.*, 2020).

For long-term success and to maintain political credibility, policy mixes need to have clear, consistent outcomes (Edmondson, Rogge and Kern, 2020) and be flexible to respond to accompanying sociotechnical changes over time (Song, Rogge and Ely, 2023).

Therefore, policy recommendations are guided by the following outcomes:

1) Influence increased PHA production by building manufacturing capacity to diversify fossil-dependent industries to support sociotechnical transition.
2) Form product markets for PHA
3) Build end-consumer awareness of and trust in PHA

Policy Recommendations and Conclusion

To achieve diffusion of PHA as a SUP alternative, the current sociotechnical system must be reformed. A virtuous cycle must be maintained (Edmondson, Rogge and Kern, 2020), and the serious health consequences of plastic must be acknowledged. The following policy mix recommendations consider maintaining a virtuous cycle per Edmondson, Kern and Rogge's (2019) co-evolutionary framework that maximizes sociotechnical transformation success over the short-medium and long-term.

Recommendations are categorized by desired outcomes and are a complementary addition to Canada's current zero plastic waste policies.

Outcome 1

- Introduce a gradually increasing cap and trade system along with requirements for PHA SUP as production increases.
- Create interdisciplinary and multi-industry working group to set recommend production set up for cost-effective PHA production as well as create certification standards for plastic alternatives.

Outcome 2

- Government backed low-no interest loans and subsidies for PHA manufacturing facility construction.

- Work with provinces to reduce EPR fees for PHA plastics while increasing fees and non-compliance fines for non-PHA plastics.

- Provide funding for training and apprenticeship programs for workers to transition to new plant work producing PHA.

- Work with provinces to improve guidelines and consistency of composting element of waste collection programs across the country.

Outcome 3

- Build campaigns including informational signage in grocery and convenience locations.

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