Towards a Circular Plastics Economy:
Policy Solutions for Closing the Loop on Plastics

By:

Alexandra Carr
Éamonn Fetherston
Thomas Makled
Lauren Meyer

A project submitted in partial fulfillment of requirements
for the degree of Master of Science
(Environment and Sustainability)

University of Michigan
Ann Arbor

April 23, 2019

Faculty Advisor:
Dr. Shelie Miller

Client:
Amcor

Document Description

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Alexandra Carr, Éamonn Fetherston, Thomas Makled and Lauren Meyer
School for Environment and Sustainability
University of Michigan, Ann Arbor, Michigan

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School for Environment and Sustainability
University of Michigan
440 Church Street, Dana Building
Ann Arbor, MI 48109-1041
Phone: 734-764-6453
Web: https://seas.umich.edu/

ACKNOWLEDGEMENTS

We would like to acknowledge the many people who have made this research possible, to whom we are deeply grateful. At Amcor, we would especially like to thank David Clark, who allowed us to engage in this research in order to support Amcor's ambitions to facilitate a circular plastic packaging economy, and who provided valuable feedback throughout every step of this project. We learned a great deal throughout this process and are incredibly thankful for his mentorship. We would also like to recognize Gerald Rebitzer and Jennifer Bourgoin, who both provided helpful insights and guidance throughout our research.

At the University of Michigan, we would first and foremost like to thank Dr. Shelie Miller, who provided endless support and critically helpful feedback as our academic advisor. Additionally, we would like to thank Dr. Steve Yaffee, Dr. Jose Alfaro, Sara Goto, and Dr. Paula Lantaz, who all provided guidance and insights throughout our research. Last but not least, we would like to thank Jim Frey at Resource Recycling Systems, Inc., who helped orient us to the world of plastic packaging and recycling and who pointed us towards valuable research and information early on in our project.

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EXECUTIVE SUMMARY

Overview

Over the past 50 years, plastic has emerged as one of the most ubiquitous materials in modern society. In the form of packaging, plastic has provided us with immense convenience and utility, particularly with regards to food preservation, safety, and environmental impacts, compared to alternative materials. Against this backdrop, the combination of single-use plastic packaging and low recycling rates has led to a global plastic pollution crisis, yielding more intense public and governmental scrutiny towards plastics than ever before. Simultaneously, China's National Sword policy, which imposes strict contamination limits on imported recyclables and outright bans many popular plastic packaging types, has catalyzed immense disruption within the recycling ecosystem. Collectively, these disruptions have sharply reduced the availability of viable end markets for recycled plastic, ultimately leaving recyclers and governments around the world with nowhere to sell their plastic recyclables.

Given this confluence of events, plastic packaging stakeholders face a critical juncture in determining plastic's role within our society. Specifically, how can we sustainably produce, consume and dispose of plastic packaging in a manner that allows us to realize the material's vital value? In other words, how can the plastic packaging industry, policymakers, NGOs, and other involved stakeholders design and advocate for a more circular plastics economy?

This research seeks to answer this question based on the hypothesis that the use of public policies that facilitate the recovery and recyclability of plastics worldwide is critical for achieving the systemic changes required for the transition to a circular economy. As such, this research examines a wide array of policy tools around the world that have been implemented to reduce plastic pollution and increase plastic recycling rates, with the goal of providing the packaging industry and other stakeholders with insights and recommendations regarding the advantages and disadvantages of different policy options.

Policy Analysis

Our research focuses on two main types of policies: **Command-and-Control**, in which governments establish regulations with which the private sector and the public at large must comply, and **Market-Based**, in which governments use financial incentives to influence the actions of private firms and consumers. Our analysis further categorizes these policies based on their end goals: **increasing plastic recycling rates, reducing plastic consumption,** or **developing plastic recycling end markets**. Throughout this research, we evaluate policy tools within the context of both rigid and flexible packaging comprised of all types of plastic materials.

	Command-and-Control	Market-Based
Increasing Plastic Recycling Rates	▪ Product Take-Back Mandates ▪ Landfill/Disposal Bans	▪ Advanced Disposal Fees ▪ Deposit-Refund Systems ▪ Pay-As-You-Throw
Reducing Plastic Consumption	▪ Product/Material Bans	▪ Product Taxes
Developing Plastic Recycling End Markets	▪ Recycled Content Standards	▪ Virgin Resin Taxes ▪ Tradable Permits

Breakdown of policy tools examined in study.

In order to compare the advantages and disadvantages of the policies depicted above, we rely on evaluation criteria designed using decision science methods. The evaluation criteria are intended to represent some of the most salient issues encountered throughout our research, though they may not represent the full spectrum of criteria important to all stakeholders. Our criteria are grouped into four categories and attempt to answer some of the questions listed below:

- **Waste Management**
  How does the policy impact plastic recycling rates? How does it impact the quality of the plastics recyclables stream? Does it increase landfill diversion rates and reduce leakage points in the solid waste management stream?
- **Implementation & Operations**
  Can the policy be applied to multiple plastic materials, or is it particular to one? Does it have a level of administrative complexity appropriate to its goals and context? To what extent is it compatible with existing policies and practices, and is it scalable across multiple geographic contexts?
- **Funding & Economics**
  Does the policy have a stable and sustainable funding mechanism? Does it advance the price parity of post-consumer recycled plastics relative to virgin plastic materials?
- **Sociocultural Factors**
  Does the policy promote environmental justice, ensuring that the costs and benefits of plastics recycling are fairly distributed among different socioeconomic groups? Can the policy be adjusted to fit different sociocultural contexts, or is it particular to one?

Key Findings & Recommendations

Our analysis reveals the following key takeaways, which can be utilized by all stakeholders to inform future policy around the world:

1. **Voluntary, industry-led initiatives have an important role in addressing plastic pollution, but ultimately legislation passed by governments is still needed.**

   Industry-led initiatives are an important component in the transition to a circular plastics economy. However, they also have significant drawbacks, including a lack of transparency, accountability and harmonization between programs. This underscores the need for formal governmental legislation. Mandatory governmental policies are even more essential in developing countries, where the drivers of industry action on sustainability, such as consumer demand and citizen activism, are weaker.

2. **Deposit-refund systems are the most effective policy instrument for increasing plastic recycling rates.**

   Numerous academic studies and real world case examples indicate that deposit-refund systems are the most effective and economically efficient policy instrument for increasing recycling and reducing litter. Moreover, they also benefit recyclers and end users of recycled plastic by ensuring low levels of contamination and thus higher quality of the materials being recycled. Finally, they can be applied to a variety of products and materials and implemented in both developed and developing country contexts.

3. **Product bans and product taxes have mixed success in reducing plastic consumption and can present additional drawbacks.**

   Bans and taxes may be counterproductive in that product alternatives often present their own set of negative environmental impacts. Furthermore, the prevalence of plastic packaging can significantly challenge governance efforts, leading to inconsistent or absent enforcement. These circumstances may enable bribery, as well as the formation of black markets. Lastly, while bans and taxes promote pollution reduction, they do not support circularity and thus do not allow society to take advantage of the beneficial uses of plastics.

4. **The best policy for developing end markets for recycled plastic is unclear.**

   Tradable permits and virgin resin taxes are likely more economically efficient than recycled content mandates, but they lack adequate proof of concept. While both policy instruments have been applied successfully to other products and substances, further research is needed to explore their feasibility for plastic packaging.

5. **Establishing recycled plastic traceability systems can be an intermediate step in developing end markets for recycled plastic.**

   If governments lack capacity to implement and enforce command-and-control or market-based policies, they can consider recycled content disclosure requirements. Governments can work with recyclers, converters, and brands to establish post-consumer recycled content certificate schemes and standardize means of reporting.

6. **In addition to the above findings, the following best practices should be included in the development of new waste and recycling policies:**

   - Clearly define policies' **objectives** and **scope**
   - Take a systems-level, **life-cycle approach**
   - Prioritize **transparency** in cost structure and use of revenue
   - Develop fee structures that incentivize the use of **sustainable product design**
   - Prevent **anti-competitive activities** among producers, producer responsibility organizations and waste management firms
   - Identify and mitigate opportunities for **free-riding**
   - Develop independent and adequately funded **monitoring** and **enforcement** mechanisms
   - Foster **collaboration** across the value chain
   - Support immediately implementable **short-term solid waste management strategies** that do not jeopardize **long-term** sustainability

Ultimately, each policy instrument has its own advantages and disadvantages, and policy development must always be tailored to the specific objectives and context of the country in which it is being implemented. However, our findings indicate that, in general, policies that incorporate the use of economically efficient financial incentives and can feasibly be enforced are most effective at decreasing plastic pollution and increasing recycling rates. Additionally, the systemic nature of plastic pollution and recycling necessitates a combined suite of policy options that target multiple points of the plastic packaging value chain. Through the use of well-designed public policies, along with technological innovation, product redesign, infrastructural improvements and consumer education efforts, we can move our world closer to the creation of a circular plastics economy.

1. REPORT OVERVIEW

1.1. OBJECTIVES

The objective of this research is to provide the plastic packaging industry and its partners with insights and recommendations regarding public policy instruments that can be utilized to increase the circularity of plastic packaging. Specifically, we investigate a wide array of policy tools and their effectiveness towards improving recycling rates and reducing plastic pollution, with a complimentary goal of developing end markets for recycled plastic. Our analysis further identifies the economic, regulatory, infrastructural and political factors that shape the advantages and disadvantages of different policy options in various geographic contexts. Ultimately, we seek to inform and expand ongoing discussions by policy, industry and NGO stakeholders regarding global policy solutions that address plastic pollution and close the loop on plastics at large in order to create a new plastic economy.

1.2. RESEARCH SCOPE

This report examines the effectiveness of a range of public policy instruments, both proposed and currently implemented, to decrease plastic pollution, increase plastics recycling and develop end markets for recycled plastics. These policies encompass both "command and control" and "market-based" policies that target purchasing and disposal decisions made at different points of the plastic packaging value chain. "Information-based" policies, such as labelling and reporting requirements, are not exhaustively explored within this research. Similarly, policies focused on educating the public about proper recycling practices and encouraging pro-environmental behaviors are not included in our analysis. Although these policy tools are critical components of any successful waste reduction and recycling program, they are beyond the scope of this report, given its global scale and the difficulties of generalizing results from culturally-specific public education efforts across multiple cultural contexts.

Finally, analysis of the impacts of packaging design and the use of alternative materials on collection and recycling rates is also excluded from this report. Sustainable product design is increasingly being recognized as an essential strategy for transitioning to a circular economy. The Ellen MacArthur Foundation estimates that without fundamental redesign and innovation, about 30% of plastic packaging being produced today will never be reused or recycled (Ellen MacArthur Foundation, 2017). However, despite the importance of packaging design in relation to product recovery and recyclability, it is excluded from our analysis, given that our team lacks the technical expertise in packaging engineering and material science necessary to evaluate the tradeoffs between different design alternatives.

Finally, although plastics are used ubiquitously across many industries in a diverse array of applications, this report focuses exclusively on plastics used in packaging. The term “packaging” here is based on the definition provided by the Organization for Economic Co-Operation and Development (OECD), which “includes all materials of any nature (containers, wrappings, pallets) for the containment, handling and the delivery of any product, from raw materials to processed goods, from the producer to the user or consumer” (OECD, 1993). Based on this broad definition, this research considers both rigid and flexible packaging, comprised of both commonly used resins (i.e. PET, HDPE, LDPE, PP and PS) and newer, less common resins and composite materials—categorized in the United States as #7 for “Other” generically.

1.3. METHODS

1.3.1. Literature Review

Our analysis is primarily based on peer-reviewed, academic articles, with an emphasis on literature reviews and meta-analyses. In order to compare recycling rates and policy effectiveness across countries, we also utilize publicly available data on country demographics, waste volumes, recycling volumes, and other data points. These are primarily aggregated from sources such as the World Bank, or from individual countries’ public records. Available data per country often varies significantly, underscoring significant obstacles to more accurately track, compare, and understand variations in recycling rates globally. Indeed, for key countries included within the scope of our analysis, data is frequently lacking, dated, or published by unconventional sources that are not widely trusted.

Given the pace at which policy is evolving to address plastic packaging, our research also utilizes more current news content, including coverage of new policy initiatives, the public’s reaction towards plastic waste, and industry responses to the rapidly transforming landscape.

1.3.2. Policy Evaluation

In order to aid our analysis and provide a straightforward means of comparing different recycling policies, we rely on two tools from the decision sciences: the Analytical Hierarchy Process (AHP), which we use to categorize policy evaluation criteria (**Fig. 1**), and a consequence table (**Appendix 8.3**), a decision support tool used to compare alternative options across those criteria (Failing et al., 2012). The evaluation criteria used are not comprehensive—such a list is beyond the scope of this report—but they represent the most salient issues encountered throughout our research. As a whole, these criteria collectively aid in answering the question: *what does an effective plastics recycling policy look like?*

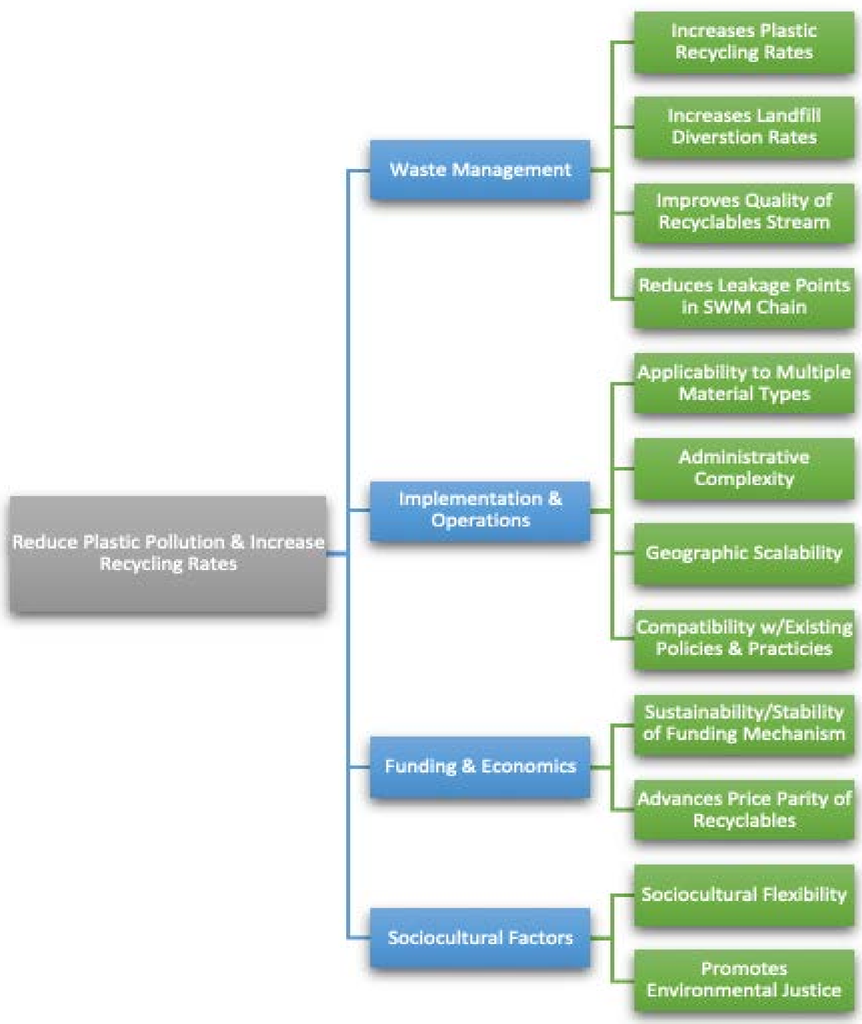

Fig. 1: *Policy evaluation criteria categorized via the Analytical Hierarchy Process.*

Using the AHP framework, the most salient evaluation criteria—which are primarily framed from the perspective of policy makers—are synthesized from our background research and grouped into four categories: *Waste Management, Implementation & Operations*, *Funding & Economics* and *Sociocultural Factors*. Detailed definitions for each policy evaluation criterion can be found in **Appendix 8.1.**

A simple, five-point constructed scale is used to evaluate the plastic recycling policies under consideration. Due to the broad spectrum of criteria, ranging from efficacy of funding mechanisms to promotion of environmental justice, a generic 'performance' indicator is used.

-2 - Strongly negative performance

-1 - Weakly negative performance

0 - Neutral performance/criterion does not apply to policy in question

1 - Weakly positive performance

2 - Strongly positive performance

Each policy is scored according to the evaluation criteria listed above. Scores are grouped under the AHP categories, and a normalized score on a -1 to 1 scale is calculated for each category. This allows for the categories to be composed of varying numbers of evaluation criteria, without unintentionally weighting the final score. A mean final policy score is calculated using the normalized category scores.

A description of the formulas used to produce these scores is provided below:

$$\frac{\textit{Sum of individual policy scores}}{\textit{Number of policies}} = \textit{Normalized category score}$$

$$\frac{\textit{Sum of normalized category scores}}{\textit{Number of categories}} = \textit{Final policy score}$$

AHP typically calls for the use of some form of weighting method to incorporate the relative importance of each evaluation criterion into the decision making process. However, we have omitted any such weights here. The relative importance of the evaluation criteria used here will doubtless vary depending on the specific stakeholder considering our policy recommendations. Omitting any weighting methods is our attempt to ensure that our policy evaluations are as impartial—and useful to multiple stakeholders with varying priorities—as possible.

A notable limitation of this model is that these scores still contain a degree of subjectivity, as the evaluation criteria were developed as a result of our background research process, and are thus potentially subject to any biases that arose during that process. Additionally, although we omitted any formal weighting scheme, the varying numbers of policies within each of the four categories affects the extent to which the performance of each individual policy influences the final policy score. This points to a need for future research to apply analytical frameworks that either incorporate a truly neutral scoring process, or to develop a system that explicitly acknowledges and justifies the use of this type of informal weighting.

A basic three-tone color scheme is used to address inconsistent levels of data availability encountered throughout our study. Large data gaps exist in plastics recycling studies specifically and waste management studies generally. This trend is exacerbated by the global scope of our study: even when robust data sources are available, they are often limited to a single country or region.

Red - Inconsistent/low data availability/quality

Amber- Moderate data availability/quality

Green - Robust/high data availability/quality

Visual representations of the consequences tables used to evaluate the recycling policies under consideration can be found in **Appendix 8.3.**

1.3.3. Research Limitations

One limitation we faced in the course of our research was the difficulty of comparing waste policies and their impacts across geographic regions. Metrics as simple as a national recycling rate were often not available or inconsistent across countries due to different data collection methods or time frames. This was a particularly persistent issue in researching policies implemented in developing countries.

Reliability and scarcity of quantitative data on waste management and recycling is especially problematic in the informal waste sector, wherein actors engage in waste management activities without formalized structures and legitimate recognition from governmental authorities. Under these conditions, there is little motivation or capacity to conduct the kind of in-depth studies needed to produce reliable data. Where data sources as available, recyclables are often treated as a single category, without disaggregation into distinct material flows. This presents difficulties in assessing the extent to which policies operating with informal sector actors increase plastic recycling rates specifically, as it is difficult to discern how much of the total recycling rates are composed of higher value materials like metals. Consequently, this lack of data limits the accuracy of estimating the impacts of policy initiatives aimed at decreasing pollution and increasing plastic recycling, as well as making comparisons across geographic regions.

In addition to these data gaps, evaluating different policy instruments in a comparative analysis was often challenged by the complexity and diversity of individual policies. Policies implemented under Extended Producer Responsibility (EPR) schemes were particularly difficult to form generalized conclusions about, because of the variation in policy design. In some cases, policies also overlapped with one another, as in the case of product take-back requirements, advance disposal fees and deposit-refund systems, which made it difficult to pinpoint the efficacy of individual policy instruments on their own. Moreover, isolating the impact of public policies from other factors like changes in consumption trends and other macroeconomic forces presented a significant obstacle, which adds a layer of uncertainty to our analysis.

Finally, the analytical capacity of this research was limited by the broadness of our scope, which explored waste policy development and implementation across the entire world. Given this massive scope, we fully recognize that we are forced to make numerous assumptions and generalizations in the course of our analysis. Much of our research sources are imbued with a developed, Western country perspective, both because of the personal backgrounds of the members of our research team and because the majority of peer-reviewed academic literature concerning environmental policy and waste management that we were able to access originates from these areas. Recognizing this potential for bias, we made an intentional effort to research waste management challenges, policies and other solutions also in place in South America, Africa, and Asia. However, we acknowledge that blind spots remain. As a result, we expect that our findings and recommendations will not hold true everywhere, and contradictory evidence likely exists.

Our objective with this report is not to provide an exhaustive analysis of the effectiveness of every policy that has been implemented worldwide to address plastic waste. Rather, our goal is to provide a general overview of what different types of policy tools exist that can be used to address the issue of plastic pollution, to compare their respective advantages and disadvantages, and to examine what additional factors contribute to the success or failure of sustainable end-of-life management. Through this high-level approach, we seek to contribute deeper understanding and nuance to the conversations currently taking place around the world amongst policymakers, citizens, NGOs and companies around plastic use and pollution.

2. INTRODUCTION TO PLASTICS

2.1 THE PLASTIC PACKAGING VALUE CHAIN

The plastic packaging value chain begins with the extraction and refinement of fossil fuels, such as oil, natural gas, and less frequently, coal. Currently, over 90% of the world's plastics are derived from fossil hydrocarbons (Center for International Environmental Law , 2017). Plastics may also be bio-based, though at only 4 million metric tonnes (Mt) annually, this represents a small percentage of global plastics production (Geyer, Jambeck & Law, 2017). Moreover, if production trends continue at current rates, the plastics industry may account for 20% of the world's oil consumption by 2050 (Ellen MacArthur Foundation, 2016).

Polymer resins comprise about 82% of plastic production; polyester, polyamide, and acrylic (PP&A) fibers and additives account for the remaining 12% and 6% of production, respectively (Geyer, Jambeck & Law, 2017). Polyethylene is the most common type of resin at 36% of global production, while polypropylene (PP), polyvinyl chloride (PVC), polyethylene (PET), polyurethane (PUR), and polystyrene (PS) comprise the majority of remaining production. The most common PP&A fiber is polyester, while plasticizers, fillers and flame retardants comprise the majority of additives (Geyer, Jambeck & Law, 2017).

Global plastics production operates on a massive scale: nearly 20,000 plastic bottles are manufactured every second, with a subsequent 1 million bottles bought every minute, and these numbers are expected to increase by 20% from 2017 to 2021 (Laville and Taylor, 2017). In total, Geyer, Jambeck & Law (2017) estimate that 8,300 Mt of virgin plastics have been produced to date, and that by 2050, the world will have produced 26,000 Mt of resins, 6,000 Mt of PP&A fibers, and 2,000 Mt of additives.

The packaging industry is the largest market for plastic, followed by the construction industry. Plastic packaging typically falls into two structural categories: rigid and flexible. The primary distinction between the two is that rigid packaging maintains its structural form whether filled or empty, while flexible packaging does not. Examples of rigid packaging include bottles, jugs, jars, tubes and clamshells. Examples of flexible packaging include pouches, chip bags, wrappers, sachets, and films. **Table 1** illustrates the resins most commonly used for various types of packaging applications.

Plastic Code	Resin	Packaging Applications	2015 World Consumption (Mt)
PET (#1)	Polyethylene terephthalate	Beverage bottles, salad domes, snack trays	32.7
HDPE (#2)	High-Density Polyethylene	Milk bottles, shampoo bottles, cleaning liquid jugs, freezer bags, ice cream containers	52.4
PVC (#3)	Polyvinyl Chloride	Cosmetic containers, commercial cling wrap	38.1
LDPE (#4)	Low-Density Polyethylene	Squeeze bottles, cling wrap, grocery and trash bags	64.4
PP (#5)	Polypropylene	Microwave dishes, ice cream tubs, chip bags, bottle caps	67.5
PS/EPS (#6)	Polystyrene/ Expanded Polystyrene	Cutlery, plates, cups, insulated food packaging	24.6
Other (#7)	Other	Encompasses a wide range of applications, including all bio-based plastic and multi-material composite packaging	127.2

Table 1: *Common Packaging Applications by Resin (United Nations Environment Programme, 2018; Credit Suisse, 2018)*

2.2 THE POSITIVE IMPACTS OF PLASTIC PACKAGING

Considerable media and public attention in recent years has focused on the negative impacts associated with plastic pollution, frequently coupled with calls for widespread use reduction and even bans of plastic packaging. However, the ubiquitousness of plastic packaging can be traced to the significant benefits it offers to both producers and consumers, in terms of functionality, aesthetics, cost, human health, and life cycle impacts.

2.2.1. Functional Benefits

Plastic packaging solutions provide numerous functional benefits for brand owners, end users, and other actors throughout the supply chain. Some of the most salient benefits can be grouped into three categories: *Distribution, Product Protection & Safety,* and *Convenience*.

Distribution: The use of plastic packaging in product distribution frequently allows producers to ship more product with less packaging material compared to alternative forms of packaging such as glass, metal, or wood. Products with plastic packaging typically have a lower package-to-product weight ratio than alternatives (Franklin Associates, 2018), resulting in reduced energy demand during transportation and distribution stages.

Although many of the distribution benefits of plastic packaging are realized most directly by the end consumer, certain forms of packaging provide value during business-to-business processes within the supply chain. Cartons and pallets, for example, allow smaller items to be grouped together and shipped in bulk quantities. Plastic-based fill packaging can reduce the likelihood of damage to fragile goods during distribution. The protection offered by plastic packaging solutions can help fulfill one of the core functions of any packaging material: to protect the product from the beginning of the supply chain to the end consumer.

Product Protection & Safety: For certain products, protection continues after the point of purchase. Food products, for example, benefit from plastic packaging that provides a barrier against exposure to chemical, biological, and physical impacts (Marsh & Bugusu, 2007). Resealability is a key feature that can further extend the shelf life of a product prone to degradation or spoilage. Tamper prevention, often used with medical or food products, is also a key benefit provided by plastic packaging. Most barriers can be broken, but packaging with tamper indicators can at least provide a warning to consumers that the integrity of the product contained within may have been compromised.

Convenience: The wide variety of form factors presented by plastic packaging deliver increased convenience to the end user compared to packaging comprised of alternate materials. In food products, resealability allows consumers to prolong a product's shelf life and subdivide into smaller portions without compromising the integrity of the packaging unit. The light weight of plastic packaging also allows consumers to enjoy products when and where they are most convenient.

Further, single-portion packaging like shampoo sachets and snack packets allow consumers to enjoy products on-the-go or while travelling, and they can also expose product categories to entirely new market segments. In developing countries, where low income levels exclude large portions of the population from purchasing certain consumer goods, goods in single-portion packaging available at a lower price point are becoming increasingly popular, as they allow consumers to sample a product they may otherwise be unable to afford in a larger form (Bhandare & Sundaresan, 2015).

2.2.2. Cost Benefits

Many of the aforementioned benefits are also a source of cost benefit for both producers and consumers of plastic packaging. For example, the light weight of plastic packaging compared to alternative materials presents two advantages. Plastic packaging solutions generally require fewer material resources on a per-unit basis, while also reducing the overall shipping weight of the product, which reduces energy costs. The benefits to be realized by the producer from these characteristics are self-evident, and these reduced costs can also be passed on to the consumer in the form of a lower price point at the point of sale. Packaging of food products also presents substantial cost savings, for producers and consumers alike, in the form of reduced food waste (Marsh & Bugusu, 2007).

2.2.3. Aesthetic Benefits

Packaging presents a valuable opportunity for conveying brand identity and product information. The physical design of a product's package—including size, shape, color, use of pictures/illustration, logos, etc.—provides extrinsic cues to consumers that allow them to infer material and affective characteristics about the product itself (Underwood & Klein, 2002). The malleability of plastic polymers allows brands to shape plastic packaging to reflect their brand identity. Color, shape, and subtle design touches like contours and ergonomic features are all effective means of linking product packaging to brand identity and intrinsic product characteristics (Pantin-Sohier, 2009). Plastic packaging solutions provide a higher level of flexibility in both of these attributes than alternative materials like glass, metal or cardboard/paperboard.

2.2.4. Human Health Benefits

Plastic polymers are inexpensive and lightweight, making them an extremely effective material for medical goods. Indeed, plastics can be used to safely package medical goods in sterile environments, and are often used in the production of vital medical supplies such as syringes and intravenous drips that have improved quality of life for much of the world's population (North & Halden, 2013).

Plastic packaging can also enhance human health through the provision of critical consumer goods. For example, bottled water provides a source of reliably clean and safe drinking water to communities with limited access to water resources or unsanitary conditions, such as developing countries or areas with infrastructure damaged by natural disasters.

2.2.5. Environmental Benefits

As public awareness of plastic litter increases, there has been a subsequent rise in calls to drastically reduce or eliminate the use of plastic goods worldwide. However, if one of the core underlying concerns of these initiatives is decreasing negative environmental impacts, the entire life cycle of materials must be taken into consideration, not just the end-of-life disposal.

Plastics generally have considerably lower life cycle impacts than alternative packaging materials like wood, glass or metal, which yield greater environmental burdens such as increased energy use, water consumption, solid waste by weight and volume, and greenhouse gas emissions (Franklin Associates, 2018). The energy and materials reductions realized in plastic packaging are largely due to the lower package-to-product weight ratio than alternative materials, resulting in lower energy and material inputs in manufacturing and distribution (Andrady & Neal, 2009).

2.3. THE NEGATIVE IMPACTS OF PLASTIC PACKAGING

2.3.1. Plastic Pollution

The documentation of rising levels of plastic pollution in recent years, both in marine ecosystems and on land, are catalyzing increased public attention towards plastic, and specifically, towards plastic packaging. In total, Parker (2018) estimates that roughly 8.3 billion metric tons of plastic has been produced, and that approximately 6.3 billion tons of that production has become plastic waste. Only 9% of that total has been recycled, while the remainder accumulates in landfills or elsewhere in the environment due to leakage. If current production, consumption, and recycling levels persist, it is estimated that there will be 12 billion tons of plastics in landfills by 2050 (Parker, 2018).

Ultimately, much of this plastic waste leaks into the ocean. The leading pollutants in the ocean include cigarette butts, plastic beverage bottles, plastic bottle caps, food wrappers, plastic grocery bags, plastic lids, straws and/or stirrers, glass beverage bottles, foam takeaway containers, and other plastic bags (Ocean Conservancy Group, 2017). It is estimated that between 5.3 and 14 million tons (on average, about 8 million tons) of plastics leak into the ocean annually from coastal regions alone. While some of this leakage has been attributed to waste from ships, a larger volume has been traced to litter, both in rivers and on land, which often gets blown or washed into the ocean (Jambeck et al., 2015). To date, it is estimated that there are over 150 million tons of plastics in the ocean, and that by 2050, there will be more plastics by weight than fish (Ellen MacArthur Foundation, 2017).

While data regarding the sheer volume of plastic waste has catalyzed public outcry, so, too has research seeking to better understand the impacts of this waste. A significant volume of research has sought to examine plastic's negative externalities on not only the environment, but also on human health and the economy. Critical to the magnitude of these externalities is the durability of plastic over time compared to other materials. Estimates of the time it takes for plastic to fully biodegrade range from 450 years to never (Parker, 2018).

The most common polymer types, such as polyethylene and polypropylene, have high molecular weights that make them essentially non-biodegradable (Shah, Hasan, Hameed & Ahmed, 2008). However, once these and other plastics enter the ocean, they are subjected to radiation, followed by thermal and/or chemical degradation, making the materials susceptible to biodegradation (Shah et al., 2008; Andrady, 2011). This degradation weakens the plastic, which can lead to the material's breakdown into smaller fragments, a process that can repeat indefinitely (Andrady, 2011).

Fragments smaller than 5 mm are often referred to as microplastics (Arthur, Baker & Bamford, 2009). While the presence of microplastics has been widely documented, the impacts of these microplastics on both the environment and human health are still being explored. The broad impacts of plastic waste to date, as well as the unknowns that researchers are seeking to better understand, have galvanized an increase in public discussion and scrutiny towards plastic, and plastic packaging in particular.

2.3.2. Environmental Impacts

The impacts of plastic waste on the environment have been long documented, perhaps most vividly through photography showing enormous volumes of plastics littered along coastlines, disrupting ecosystems and daily life for coastal communities around the world. Particularly impactful photographs have shown animals being choked and/or entangled by various plastic packaging items, serving as a lightning rod for environmentalists to speak out against plastic. Indeed, plastic waste has been cited as a cause of digestive tract blockage, appetite loss, altered feeding behavior, and even starvation and death (Barnes, Galgani, Thompson, & Barlaz, 2009; Ogonowski & Schur, 2018).

Beyond these documented impacts, research to better quantify and understand the impacts of plastic pollution—and microplastics in particular—on marine ecosystems is ongoing (Barnes, 2009). Several studies have found that plastic debris can distribute non-indigenous organisms to new locations; it can also absorb and transport persistent and bioaccumulative toxic pollutants (Engler, 2010). Plastics can play a role in increasing the persistence of these environmental contaminants (Teuten, Rowland, Galloway, & Thompson, 2007). There is also growing concern for plastic's dispersion of non-toxic additives, which are often mixed with resins in plastic packaging. The degree to which these dispersed additives can harm both marine biota and, via the food chain, humans, is an additional focus area of research (Andrady & Neal, 2009). Concern has grown over ingestion of plastic debris due to the largely unknown population-level impacts of microplastics. Emerging studies have correlated the consumption of microplastics to altered endocrine system functioning in fish, leading to questions regarding cancer, tumors, and other developmental disorders (Ocean Conservancy Group, 2017). Given the severity of these implications, the call for further research in this area is urgent.

Plastic waste has also impacted terrestrial systems, though research examining these impacts is less extensive than that examining marine environments. Research to date has identified that the plastic that eventually leaks into oceans is almost always produced, consumed, and disposed of on land (Jambeck et al., 2015). Accordingly, prior to entering aquatic ecosystems, plastic material almost always interacts with and potentially impacts land biota (Machado, Kloas, Zarfl, Hempel & Rillig, 2018). Early research has suggested that microplastics are ubiquitous in terrestrial systems—in fact, contamination might be 4-23 times larger than in oceans (Horton, Walton, Spurgeon, Lahive, & Svendsen, 2017). As such, similar concerns for terrestrial impacts have emerged, particularly in terms of critical ecosystem stakeholders such as plant pollinators, terrestrial fungi, and soil-dwelling invertebrates. Machado et al. (2018) have shown that the volume, composition, and physiochemical properties of plastic material can closely resemble the common terrestrial particulate material on which these organisms rely. As such, plastics have the potential to alter fundamental ecosystem processes and biodiversity. Additionally, microplastics can cause impacts on aspects of the biophysical environment such as geochemistry and ecotoxicology; these impacts can yield change in terrestrial organisms, potentially affecting their activity, growth, and reproduction (Machado et al., 2018).

Potentially compounding the harmful impacts described above, the average size of plastic particles appears to be decreasing, while the volume and spatial distribution on a global level is increasing (Machado et al., 2018). Given these findings, it is perhaps unsurprising that additional research has established that microplastics are available to every level of the food-web, from primary producers to trophic level organisms (Oliveira, Ribeiro, & Guilhermino, 2012). As this and other research emerges, the call to better understand the impacts of plastic waste grows louder, particularly in light of the fact that the impacts of previously generated plastic waste will be present for centuries, regardless of whether future pollution is curbed (Barnes et al., 2009).

2.3.3. Human Health Impacts

Just as research explores how the ingestion of plastic and specifically microplastics affect marine and terrestrial biota, a growing body of research is exploring how these same materials might impact the functioning of the human body, particularly potential altering of the endocrine system (Talsness, Andrade, Kuriyama, Taylor, & vom Saal, 2009). So far, researchers have identified microplastics in 114 aquatic species, half of which are currently consumed by humans. Additionally, humans aren't just encountering plastic in their food—they're also wearing it in their clothing, breathing it in the air, and drinking it in tap and bottled water (Ogonowski & Schur, 2018). Indeed, a recent study found microplastics present in over 90% of bottled water tested across eleven prominent brands across nine different countries, revealing the prevalence of microplastics in our daily lives (McCarthy, 2018).

Beyond the negative impacts posed by ingestion, plastic packaging also presents risk to humans in the form of plastic litter and leakage. Specifically, plastic bags and other flexible packaging items can clog waterways, particularly in urban areas, increasing risk of flooding and creating hotspots for mosquitoes and other insects, producing a dangerous breeding ground for infectious disease (UNEP, 2018). Additionally, researchers have begun to explore the possibility that microplastics, specifically the pellets that have now been banned in many countries, are being utilized as sites for laying eggs by insects, potentially increasing these insects' abundance and dispersion. Further research is needed to understand whether plastic is serving as a vector for species to reach new mobility ranges (Barnes et al., 2009).

2.3.4. Economic Impacts

Plastic waste also represents major negative economic impacts by impacting tourism, fishing and shipping industries, important contributors to GDP in many countries. In the Asia-Pacific region alone, it is estimated that the costs to these three industries totals roughly $1.3 billion annually. The costs of cleaning up plastic waste is also enormous: in Europe, it is estimated that countries spend about $838 million each year (UNEP, 2018). A growing number of entrepreneurial ventures such as The Ocean Cleanup have also emerged in recent years to help tackle plastic pollution in oceans, representing millions more in funds being mobilized to address plastic waste (McCarthy, 2018). Cumulatively, studies have estimated that global impacts of plastic waste in marine ecosystems causes $13 billion in damages annually (UNEP, 2018).

In developed countries with established waste management infrastructure, costly impacts from plastic waste are common at recycling facilities. Specifically, these facilities often receive plastic bags and other flexible plastic packaging that consumers assume are recyclable, leading to machinery blockages that are expensive and time-intensive to address (Romer, 2007).

2.3.5. Dependence on Fossil Fuels

Plastics currently account for between 4% and 8% of global oil consumption. Over 90% of plastics are derived from fossil fuel inputs (oil, natural gas, and less frequently, coal). If production trends continue at current rates, plastics could account for 20% of the world's oil consumption by 2050, and consume 15% of the world's annual carbon budget (CIEL, 2017-b; Ellen MacArthur Foundation, 2017).

Petrochemical production process: Five types of thermoplastics make up the majority (85-90%) of plastics produced: polyethylene (34.4%), polypropylene (24.2%), polyvinyl chloride or PVC (16.5%), polyethylene terephthalate or PET (7.7%), and polystyrene (7.3%) (CIEL, 2017-b;Plastics Europe Market Research Group, n.d.). Two primary chemical feedstocks are critical for these plastics: propylene, for polypropylene; and ethylene, for polyethylene, PVC, PET, and polystyrene. These feedstocks are especially important for the production of plastic packaging, as the majority of packaging is produced from these five thermoplastics, particularly polyethylene, polypropylene, and PET (CIEL, 2017-b).

These petrochemical feedstocks, or olefins, are by- or co-products of fossil fuel production. Most olefins are produced with natural gas liquids (NGL) or naphtha (from crude oil refining) (American Chemistry Council, n.d.). It is also possible to produce olefins from coal, although this is less common and has significant greenhouse gas impacts. China, with its abundant coal and limited natural gas, is investing in coal-to-olefin technology (CIEL, 2017-b).

Petrochemical Investment & Growth Trends

As the majority of plastics rely on oil and gas byproducts, it is often the case that fossil fuel companies have fiscal, ownership, and/or management roles in plastics production, and vice-versa. The chemical company DowDuPont describes its petrochemical operation as "one of the largest global producers of ethylene" (CIEL, 2017-b).

Recent advances in natural gas hydraulic fracturing, or "fracking," have spurred significant investment in new petrochemical infrastructure in the United States. In recent years, $164 billion has been planned for 264 new plastics facilities and expansion of existing infrastructure directly related (and often geographically connected) to shale-gas mining operations (CIEL, 2017-a). Cheap American natural gas exports are supporting new plastics facilities in Europe, while China is investing heavily in new plants to convert natural gas oil and methanol from coal into ethylene and propylene (CIEL, 2017-b).

Current production trends and recent investments underscore the significant interdependence of plastics and fossil fuel inputs. Cheap fossil inputs from the natural gas boom, as well as projections of continued oil dominance through the mid-21st century drive expectations of growth, availability, and continued demand for fossil feedstocks for petrochemical production over the next few decades. Globally, production capacity for ethylene and propylene is expected to grow by at least 33% within the next decade. The International Energy Agency's 2017 World Energy Outlook "New Policies Scenario" projects that 44% of the increase in crude oil consumption through 2040 will be for production of petrochemicals (IEA, 2017). ExxonMobil projects continued dominance of naphtha and NGLs as the primary plastic feedstocks through 2040 (CIEL, 2017-a).

Climate Change and Fossil Resource Availability

Projections of constrained resource availability, combined with efforts to mitigate global climate change and associated carbon regulations threaten the long-term affordability and ecological sustainability of petrochemical-based plastics. Plastics producers can expect significant changes to industry economics under most scenarios for mitigation of global climate change and declining fossil resource availability (CIEL, 2017-a).

In the short term (over the next few decades), climate regulations designed to limit global temperature rise below 2 degrees Celsius (or more recently, 1.5 degrees Celsius) may increase the costs of fossil fuel production and hasten the shift away from fossil fuels for energy production (United Nations Framework Convention on Climate Change, 2019). As fossil fuel production declines, plastics producers will have to bear more of the upstream costs to process fossil inputs and create the olefins needed for plastics production (American Fuel and Petrochemicals Manufacturers, n.d.). If demand for refined fuels for energy declines due to climate regulations, these costs will include disposal of excess unburnable hydrocarbons (CIEL, 2017-a). As a result, the aforementioned surge in petrochemical production capacity in the United States, Europe, and Asia could lead to a lock-in of new petrochemical infrastructure facing growing operations costs (CIEL, 2017-a).

An analysis by the Center for International Environmental Law notes that, as the costs of plastics are significantly determined by the costs of fossil fuels, plastics producers may consider three choices under growing climate and energy constraints: (1) take on a greater share of fossil fuel production and unused material disposal costs, (2) use different components of fossil fuels in production processes, or (3) use alternative feedstocks (CIEL 2017-c). While natural gas and crude oil feedstocks have carbon impacts, coal-to-olefin technology is far more carbon intensive and controversial even within industry. Olivier Thorel, VP of Global Intermediates and Ventures at Shell Chemicals described the technology as "massive CO2 machines that make chemicals as a sidestream" (CIEL, 2017-a).

In the long term, tightening supply and increasing costs of producing fossil resources due to resource depletion will likely constrain the fiscal and ecological viability of petrochemical plastics production. While global demand for fossil fuels remains strong, availability of high-quality fossil resources has declined since the mid-20th century. One way to measure declines in energy quality is "Energy Return on Investment," or EROI, a concept which compares the amount of resource energy extracted to the energy investment required to extract that resource (Ahmed, 2017). Between 1960 and 1980, while total fossil fuel production increased, the world average value of EROI for fossil fuel production declined from 35:1 to 15:1, and the rate of fossil fuel production has continued to decline. Notably, conventional oil production has, on average, plateaued since 2005, not exceeding 75 million barrels per day (Ahmed, 2017). Today, estimates of conventional oil EROI range from 1:1 to 18:1. Alternatives to conventional oil such as tar sands and shale oil & gas that are also important for plastics production have relatively low EROI estimates; tar sands average 4:1 and shale oil & gas average 2.8:1 (Ahmed, 2017).

A recent analysis by IHS Cambridge Energy Research Associates (CERA) suggests that while oil production will continue to increase through 2030-2040, the shift to harder to access, lower quality resources such as tar sands and shale means that "all categories of oil resource are now more expensive to develop, requiring high oil prices to generate an economic return" (Jackson & Smith, 2004). In other words, the era of cheap fossil fuels is ending, and this systemic transition will have far reaching consequences across all modern industrial sectors, especially petrochemicals and plastics production.

While fossil fuels are finite, attempts to predict peak oil production have been challenging. Hubbert's peak oil projections for the U.S. were initially accurate, but trends have not followed the curve neatly since (Ritchie & Roser 2018). Another way to visualize remaining fossil fuel reserves is the reserves to production ratio, or the quantity of resource reserve remaining divided by the current production rate. While this is useful as a static measure, production rates will continue to change with economic and technological change. Nonetheless, it is significant to note that at current consumption rates (based on 2015 figures), remaining reserves of coal are projected to last just 114 years, natural gas 52.8 years, and oil 50.7 years (Ritchie & Roser 2018).

Perhaps most important for assessing limits to fossil fuel production, and thus impacts on petrochemical plastics production, are global plans for climate change mitigation. A recent study by the Carbon Tracker Initiative estimated economic losses of $6.47 trillion over the next decade from investment in development of fossil fuel reserves that would be rendered unburnable by climate change regulations and shifts in industrial economics (CTI, 2013).

If today's known fossil fuel reserves were fully burned without carbon capture and storage technology, they would release 746 billion tonnes of carbon. A global "carbon budget" which represents the allowable carbon emissions to keep temperature rise at 2 degrees Celsius allows for 275 billion tonnes of carbon emissions. That leaves the fossil-fuel equivalent of 471 billion tonnes of carbon emissions as unburnable if climate change goals are to be met (Ritchie & Roser, 2018). It is widely recognized that meeting these goals would require leaving up to 80% of fossil fuel reserves in the ground (Ritchie & Roser, 2018).

The vast majority of plastics currently produced depend on fossil fuel inputs. As global energy markets shift away from fossil fuels and climate regulations hasten that shift, plastics producers will have to bear increasingly greater upstream costs for petrochemical production processes. Furthermore, plastics compete with many other industrial and manufacturing sectors for fossil resources—oil remains the "world's most important manufacturing commodity," essential for industries from pharmaceuticals to construction, electronics, clothing, and most significantly, modern agriculture (de Sousa, 2007). A sustainable plastics industry will likely find it necessary to enact significant shifts in fossil feedstocks and production processes, as well as the critical shift to a more circular, recycled resource-driven plastics economy.

2.4 THE CHALLENGES OF RECYCLING PLASTIC

As discussed above, plastic packaging in its current state of production, consumption and disposal poses enormous environmental, human health and economic risks. These risks are of such concern to the public that some environmental pundits call for ending society's use of plastic-based packaging all together. However, while the development and adoption of alternative packaging materials should certainly be explored, plastic as a material still offers a great deal of functional, financial and ecological advantages. Thus, an approach that develops solutions to the present issues associated with plastic packaging, while still allowing for the use of plastic as a packaging material, should be pursued as well.

One such approach that has been popularized globally by the Ellen MacArthur Foundation is the development of a circular plastics economy. In an ideal circular economy, material inputs are decoupled from nonrenewable resources and waste is eliminated. In the case of plastic packaging, this requires drastically improving end-of-life recovery and recycling rates and increasing the use of post-consumer recycled (PCR) content in new packaging products. If implemented successfully, this strategy of "closing the loop" on plastic packaging addresses both the issues of plastic leakage into the environment and the unsustainable dependence on finite fossil fuel resources. However, actually achieving a circular plastics economy is no simple matter. In addition to the global scale of the problem and the high complexity of plastic material flows, even the seemingly straightforward stages of collecting, sorting and recycling plastic face significant technical and economic challenges.

2.4.1. Technical Challenges

Most material recovery facilities (MRFs) depend on some level of manual sorting of materials, and in many developing countries, manual sorting may be the only sorting method available. However, while it's fairly easy for the naked eye to distinguish between major categories of materials like plastic, metal and glass, manually sorting between different types of plastic resins can be extremely difficult. The Ocean Conservancy (2015) estimates that at least 30% of packaging in the waste stream cannot be properly sorted without additional investment in optical sorting equipment capable of identifying specific polymers in the material. This limitation of manual sorting means that municipalities either have to invest in more sophisticated automated sorting technology or contend with contamination caused by incorrect sorting, which ultimately lowers the quality and economic value of the recycled materials produced.

However, even with the use of more advanced sorting technology, MRFs still encounter technical challenges with recycling plastic. One difficulty is that a great deal of current sorting equipment is designed to separate two-dimensional and three-dimensional products, with the assumption that paper-based materials are mainly two-dimensional, and plastic, metal and glass are mainly three-dimensional. However, with the growth of flexible plastic packaging, like pouches and sachets, which flatten into seemingly two-dimensional products in the recycling stream, more and more plastic ends up contaminating bales of mixed paper. Other problematic plastics are bags and films which can get tangled in a MRF's sorting equipment, causing costly delays as workers have to halt production to remove the materials. Finally, it is increasingly common for packaging to contain multiple layers of materials. While multi-material packaging can be beneficial in expanding the functionality of a packaging product and in enabling companies to save on transportation costs and greenhouse gas emissions through lightweighting, recycling technology has not kept pace with these innovations. It is difficult for recyclers to separate the thin layers of composite materials using traditional mechanical recycling methods. Innovations in chemical recycling may provide solutions to some of these challenges, but to date this technology is still relatively nascent.

2.4.2. Economic Challenges

Efforts to increase plastics recycling are also hindered by economic challenges. Certain types of plastic resins (e.g. PET and HDPE) are more valuable because they can be used in a variety of applications, and because their quality can be preserved through multiple cycles of use and recycling. However, in countries with the highest rates of plastic leakage into the environment, these high-value plastics only comprise 18% of the plastic waste stream. Meanwhile, low-value plastics such as films and composites make up an estimated 61% of the waste stream in these same countries (Ocean Conservancy, 2015). In order to ensure the economic feasibility of collection and sorting services, recyclers must either rely on the profits from selling high-value and medium-value plastics to cover the cost of recovering low-value plastics, or exclude low-value plastics from their operations all together.

This disparity of economic value by resin type is further exacerbated by differences in weight of the materials, which result in varying lengths of collection time, particularly when waste is being collected primarily by the informal sector. For example, an analysis by McKinsey estimated that it takes an informal waste picker on average 61 minutes to collect 1 kilogram of plastic bags, but only 21 and 37 minutes to collect a kilogram of HDPE and PET, respectively (Ocean Conservancy, 2015). Because of this combination of recycled plastic films' lower value as a commodity and the higher time-intensity of its collection, an informal waste picker might receive $3.70 for 10 hours spent collecting PET, but only $0.50 for 10 hours spent collecting plastic bags (Ocean Conservancy, 2015). In the interest of maximizing their return on time invested, waste pickers have a strong incentive to collect only high-value recyclables like PET and HDPE, leaving the low-value majority of plastics uncollected.

Finally, because plastic resins are sold on commodity markets, PCR plastic has to compete on price with virgin plastic. The price of virgin plastic is closely tied with the price of oil, and so any time the price of oil drops, the price of virgin plastic drops as well. This yields a subsequent decrease in market demand for PCR plastic. Even after collecting and successfully sorting plastic packaging, if recyclers cannot find customers to buy the materials as inputs for new products, the plastic will not be recycled and may even wind up being incinerated or landfilled to avoid storage costs.

3. CURRENT POLITICAL LANDSCAPE

3.1. Heightened Public Attention

The concept of sustainability in the plastic packaging industry has been subject to much change in recent years. Decades-long trends in pollution research have culminated in growing media attention and activist campaigns, shifts in legislation, industry consortiums, and multi-sector pledges. While the impetus for recycling is not new, plastics producers are finding that 21st century sustainability goals require renewed and deepened commitment across the value chain.

Plastics are a versatile material, valued for their durability, light weight, and affordability. However, plastic pollution is an urgent global environmental challenge. By 2017, a sweeping analysis of global plastics manufacturing in *Science Advances* estimated that between 4.8 million and 12.7 million tonnes of plastic enter the world's oceans every year (Geyer, Jambeck, & Law, 2017). The 2017 "New Plastics Economy" report by the Ellen MacArthur foundation and the World Economic Forum projects a near-quadrupling of plastics production by 2050, noting that there will be more plastic than fish in the ocean by midcentury under current insufficient waste management practices. Furthermore, 95% of the value of plastic packaging is lost to the economy after its first use—amounting to $80-120 billion annually—with only 14% of plastic packaging collected for recycling worldwide (Ellen MacArthur Foundation, 2017).

Global statistics do not tell the whole story, however. There are significant disparities in quality of recycling infrastructure and effectiveness of waste management policies across countries. In developing nations, solid waste collection rates are generally quite low, despite the fact that waste management is often the most costly item in municipal budgets. In 2018, The World Bank noted that overall municipal solid waste output is expected to grow by 70% by 2050 (Ellis, 2018). Given such regionally diverse challenges, varying levels of government support and stability, and global economic growth driving increased production and consumption of plastic packaging, the need to increase recycling rates and create a truly circular plastics economy is urgent.

3.2. Increase in Legislative Action

The world has taken note of the critical challenge posed by plastics pollution. The theme of UN World Environment Day 2018 was "Beat Plastic Pollution" (United Nations, 2018). Notably, the Royal Statistical Society of Great Britain named the amount of plastic produced that has never been recycled—90.5%—as its statistic of the year (Howard, Gibbens, Zachos, & Parker, 2019). The

European Union has pushed aggressively for enhanced recycling and circular policies. An EU-wide plastics strategy released in January 2018 calls for product redesign and enhanced recycling infrastructure, and the EU approved a sweeping ban on single-use plastics to apply to all EU nations by 2021 (European Commission, 2018; BBC News, 2018). The United Kingdom has also expressed intentions to ban single-use plastics, and a 2018 revised waste strategy requires companies to pay the full cost of collecting and recycling plastic packaging, and also proposes a tax on packaging with less than 30% recycled content (United Kingdom Department for Environment, Food & Rural Affairs, 2018). France's circular economy plan ambitiously aims to use 100% recycled plastics across the country by 2025 (Pyzyk, 2018b). Canada has pledged $65 million through the World Bank to address plastic waste in developing nations, and in 2018 announced plans to create a nationwide plastics strategy (Markets Insider, 2018a; Government of Canada, 2018).

The plastics policy landscape has been significantly impacted by China's "National Sword" program, which bans multiple categories of scrap materials imports to combat domestic pollution (Wong, 2017). Prior to the bans, China imported 45% of the world's recovered plastic. Chinese companies reported a 99.1% reduction in scrap plastic imports from 2017-2018, a shift from 12.6 billion pounds to 110 million pounds of material (Staub, 2019a; Pyzyk, 2018a). A study in *Science Advances* in June 2018 found that recyclers around the world are stockpiling and landfilling recovered plastics previously destined for China, and addressing this change will be a significant challenge for recyclers in years to come (Pyzyk, 2018b).

3.3. Growth of Public-Private Partnerships

Industries, governments, and NGOs are collaborating to address plastic pollution. In October 2018, Amcor was joined by global companies such as Unilever, PepsiCo, The Coca-Cola Company, and Veolia in committing to 100% reusable, recyclable, or compostable packaging by 2025 through the New Plastics Economy Global Commitment (Phipps, 2018). In December 2017, Dell Inc. and marine investment incubator Lonely Whale convened a cross-industry group, NextWave, to create a commercial-scale ocean-bound plastics supply chain (NextWave, 2017). In October 2018, the investment management firm Circulate Capital announced announced a $90 million investment from global companies to reduce ocean plastic leakage in Southeast Asia, with support from the Ocean Conservancy. (Markets Insider, 2018b; Circulate Capital 2018; PR Newswire 2018). In 2019, The Alliance to End Plastic Waste, a non-profit working with governments, finance, and NGOs, announced a $1.5 billion commitment from global companies including DowDuPont, ExxonMobil, Shell, BASF, Veolia, Proctor & Gamble, and Mitsubishi Chemical Holdings to support recycling infrastructure, new technologies, education, and cleanup of current contamination (Alliance to End Plastic Waste, 2019).

The challenges of achieving sustainability in the plastics economy are vast in scope, and so, too must be the responses. Existing commitments like those described above are ambitious, but eliminating plastic pollution, addressing human and environmental health concerns, and achieving a fully circular plastics economy will require worldwide collaboration from governments, industry, and the public.

4. POLICY CONSIDERATIONS

The merit of any policy solution is deeply dependent upon the context in which it is implemented. For policies seeking to increase plastic packaging recycling rates, it is particularly important that policymakers consider the context of waste management infrastructure, including the sophistication of collection, sorting, and recycling capabilities. Additionally, the effectiveness of any policy will also correlate to a variety of design considerations that policymakers must take into consideration. In this section, we seek to explore these important contextual factors and design decisions, beginning with the role that waste management infrastructure plays, and specifically, the many factors that determine this infrastructure's level of sophistication. Second, we examine how various policy design elements can be utilized to achieve specific objectives within different contexts.

4.1. WASTE MANAGEMENT CONSIDERATIONS

In evaluating various policy instruments and their potential effectiveness towards increasing plastic packaging recycling rates, policy makers must consider the sophistication of waste management infrastructure in a given location, as this varies widely across countries, states, and even municipalities. This sophistication often correlates to a broad variety of economic, political, and cultural factors, as well as the presence of specific waste management capabilities, such as collection services, single versus multi-stream recycling, waste to energy technology, and the informal sector. Ultimately, this sophistication dictates the types of policies that a government can support; many of the policies analyzed in this research rely on certain waste management capabilities, such as separate collection streams, that aren't available across all geographic contexts.

4.1.1. Level of Economic Development

At the broadest level, the sophistication of a country's waste management infrastructure depends upon its gross domestic product and overall economic stability. More developed countries often have the capital to support more robust collection systems, including the basic provision of waste management collection services at both the business and residential level. Alternatively, in many developing countries, these basic services are often lacking, or inconsistently available over time and across territories. Additionally, countries with higher GDP are often able to invest in more technologically advanced sorting capabilities that can support single-stream recycling schemes, whereas developing countries often lack the funds necessary to implement these sophisticated technologies. Lastly, a country's economic means will also impact that government's ability to enforce any waste management legislation, particularly for any "command-and-control" based policies that require human capital for regulatory and monitoring purposes.

4.1.2. Political Priorities and Cultural Support

The sophistication of waste management infrastructure also often correlates to a given region's political stability, as well as its dominant political priorities. At the most basic level, tremendous political instability can erode a government's ability to prioritize waste management as a policy focus. This is particularly relevant in developing countries where significant portions of the population face low standards of living, often leading governments to focus more urgently on the provision of basic services such as healthcare and access to electricity. In such cases, these priorities often precede demands for the provision or improvement of waste management services.

Cultural support for environmental initiatives is another important contextual factor that can impact the sophistication of waste management infrastructure. For example, communities with high cultural awareness towards environmental initiatives, or an advanced understanding of negative externalities associated with poor environmental services, may support or demand government investments in more sophisticated waste management infrastructure and services. Alternatively, regions with low awareness or high political polarization towards environmental initiatives may place less pressure on their government for these services.

Fragmentation of legislation is another contextual factor that can impact the sophistication of waste management infrastructure across regions. Competing priorities and/or inconsistent policies can undermine both a government's ability to pursue larger investments in waste management infrastructure, and at a more basic level, the community's cultural understanding of and support for waste management and recycling initiatives.

4.1.3. Waste Management Technological Sophistication

The practice of multi- vs. single-stream recycling is another contextual factor that impacts the sophistication of a region's waste management infrastructure. Specifically, in regions that support single-stream recycling, such as the U.S., there is a higher reliance upon sorting technologies and materials recovery facilities (MRFs), as these capabilities are necessary in order to separate and ultimately sell collected recyclables to end markets. Single-stream recycling can alleviate consumer confusion and is often viewed as a tool towards increasing recycling rates, but this reliance upon sorting technologies necessitates higher sophistication, and ultimately adds more complexity to the recycling value chain. Alternatively, multi-stream recycling necessitates higher consumer education and knowledge regarding material types and recycling practices.

4.1.4. Presence of Waste-to-Energy Capabilities

The existence of waste-to-energy capabilities is another critical factor to consider in assessing the best policy instrument to advance recycling rates in a given region. Governments typically invest in waste-to-energy capabilities in an effort to recover the value of waste as a source of energy. More specifically, waste-to-energy is often pursued by governments aiming to achieve waste reduction goals, manage scarce landfill resources, achieve renewable energy goals, or to reduce reliance on fossil fuel energy sources (Morris, 1996). In the context of plastic packaging, proponents of waste-to-energy credit the policy instrument as a practical, readily available tool towards capturing the value of the material, rather than allowing it to occupy space in landfills. Particularly in light of China's National Sword policy, which has challenged governments' abilities to identify end markets for their recyclables, waste-to-energy has been proposed as a viable, immediate option to reduce the landfilling of plastic packaging, particularly if recycling isn't feasible. Other proponents argue that it can be used in combination with recycling, and can provide value by diversifying a country's waste management strategy. From this perspective, waste-to-energy capabilities can play an important role within a sophisticated waste management system, and can theoretically support a wide variety of policy tools seeking to increase recycling rates.

However, the presence of waste-to-energy capabilities can also act as a barrier towards developing more sophisticated waste management infrastructure. Specifically, the ability of governments to utilize waste for energy production can remove or reduce incentives to sort and collect recyclables, potentially decreasing the volume of collected recyclables, which are critical to supporting recyclable end markets. In other words, the presence of waste-to-energy capabilities can detract from incentives that support the entire recycling ecosystem.

Waste-to-energy is also viewed by many as inherently non-circular, as the utilization of waste-to-energy technology prevents plastic packaging from ever being converted back into packaging (Malinauskaite et al., 2017). Instead, virgin resources must be procured to produce new plastic packaging. The predominant research consensus asserts that recycling conserves more energy than waste-to-energy mechanisms, even when taking recyclables' collection, sorting, and shipping into consideration (Morris, 1996). As such, policy makers must consider any existing reliance on waste-to-energy within the context of any policies seeking to increase plastic packaging recycling rates.

4.1.5. Participation of the Informal Sector

The presence of an informal sector is another critical component within waste management ecosystems. In many developing countries, municipal solid waste management (MSWM) programs lack the resources to adequately manage the quantities of solid waste produced daily in urban and rural areas, and informal sector actors address these shortcomings. The informal sector consists of individuals or groups performing waste management activities without formal government recognition, and at times in violation of local or state laws (Aparcana, 2017). **Table 2** summarizes the different stakeholders connected to the informal sector and their roles in resource recovery.

Stakeholder	Description
Itinerant waste buyers	Collect waste materials door-to-door, typically from homes
Street pickers	Collect waste materials from public spaces e.g. waste bins, dumpsters, illegal dumping sites
Dump and landfill workers	Sort and collect waste materials at dump/landfill site, frequently live at or near dump/landfill site
Middle men	Junk shop owners, intermediate processors, brokers and wholesalers, purchase from waste pickers and sell to recyclers/industry/exporters
Formal Recyclers/Industry/ Exporters	Domestic recycling, commercial industry, or exporters who represent the point at which recyclable materials transition from informal back into formal sector
Municipal/government entities	Oversee formal MSWM services

Table 2: *Major stakeholders in the informal sector (Scheinberg et al., 2010; Ezeah, Fazakerley, & Roberts, 2013).*

Informal waste sector workers—often referred to as waste pickers—play a significant role in collecting, separating, processing and transporting recyclable materials from solid waste streams that municipalities would otherwise be responsible for (Scheinberg et al., 2010). In some cases, these actors outperform formal systems in terms of overall recycling rates: some studies have shown recycling rates achieved by the informal sector as high as 20-30% in developing countries (Velis et al., 2012). While it is difficult to draw precise conclusions about the impact the informal sector has on recycling rates for plastic specifically, because of large gaps in data on informal recycling, available data suggests that high value plastics such as PET likely make up a significant portion of most informal recycling (Scheinberg et al., 2010). Moreover, waste pickers present an opportunity for low-tech, low-investment collection and sorting schemes that can bolster formal waste management. Low- and middle-income countries in particular benefit from this, since a disproportionately large percentage of their operating budgets are spent on MSWM (Medina, 2000).

Individual waste pickers are often constrained by a lack of financial, infrastructural and administrative resources. These constraints can be overcome through the formation of informal sector cooperatives, in which individual waste pickers organize into medium-to-large sized groups, allowing them to receive formal recognition from and enter into contracts with governmental and commercial entities, thus realizing greater incomes for their members (Aparcana, 2017; Wilson, Araba, Chinwah, & Cheeseman, 2009). Moreover, informal cooperatives increase the collective bargaining power of individual waste pickers. Especially among scavengers at open dump sites, monopsonistic markets—only one buyer, typically middle men—are common, and exploitation via underpricing of individual waste pickers is common (Medina, 2000). The collective bargaining power of cooperatives presents a possible solution to such exploitative practices, by helping workers receive larger margins on a per-weight basis (Wilson, Velis, & Cheeseman, 2006). Finally, informal waste cooperatives are better positioned to access capital to invest in the development of technological capacity. Increasing opportunities for vertical integration allows individual waste pickers to operate at a higher level in the recycling value chain and widen their margins even further (Wilson et al., 2006).

The recognition of informal sector cooperatives as a legitimate organization by municipal authorities and local government can represent an important first step toward realizing the benefits described above. This recognition can provide informal actors with the ability to negotiate prices and contracts more effectively as a collective unit, and to demand benefits like basic healthcare and access to education (Ezeah et al., 2013). **Appendix 8.2** provides an in-depth examination of the role that the informal sector can play within a country's waste management infrastructure through a case study in Brazil.

4.2 POLICY DESIGN CONSIDERATIONS

4.2.1. Policy Goals

Policymakers must be clear about the primary goals of a recycling policy, and how it can be designed to best meet their priorities. In addition to the two common goals of reducing pollution and increasing the recovery of valuable resources, policymakers may also seek to reduce the costs of municipal waste management. This objective is pervasive in extended producer responsibility (EPR) policies, which shift the costs of managing products at the end-of-life from municipalities to producers. In theory, not only do EPR policies lower the costs incurred by municipalities for waste management, but they can also be used to create a sustained funding stream to manage the end-of-life for products not currently being collected at all. Additional recycling policy goals may include stimulating sustainable innovation in packaging design and encouraging consumer behavior changes.

It is important, however, for policymakers to be aware of potential conflicts between different goals. For instance, depending on the policy's cost structure, producers may choose to lightweight their packaging by using more multi-layered composite materials. This strategy could meet the goal of reducing the amount of waste as measured by weight, but in doing so, increase the costs of collection and recycling, because lightweight, multi-layer packaging has a lower value-to-weight ratio and is technically more difficult to separate for raw material reuse.

4.2.2. Reduction and Recovery Targets

When structuring waste policies that aim to reduce waste and increase recycling, policymakers must determine the ideal levels of these two goals. Not only does setting a target enable policymakers to measure the success of the instrument over time, but it also encourages policymakers and other stakeholders to think critically about balancing tradeoffs between effectiveness and economic efficiency. For example, policymakers might find that it is relatively low-cost to achieve a 90% recycling rate, but achieving the final 10% of recovery would drastically increase the costs associated with the policy and be better achieved through supplemental solutions.

In addition to establishing goals for waste reduction and recycling levels, policymakers also need to determine whether those targets apply to the aggregated volume of waste materials identified in the policy or to the volume of individual materials within the waste stream. In other words, does a policy with a 20% packaging waste reduction target refer to a 20% reduction in total waste or to a 20% reduction in bottle waste plus a 20% reduction in film waste, and so on? According to research by Palmer, Sigman, & Walls, M. (1997), there tend to be higher marginal costs associated with the latter scenario. However, if policymakers choose an aggregated waste reduction and recycling target in the former scenario, that might cause an increase in recycling for easily recyclable materials (like metals and rigid plastics) while having no effect on the disposal of difficult-to-recycle materials like flexible and multi-material plastics.

4.2.3. Selection of Products and Materials

A key component of any waste policy is establishing which packaging types and materials are subject to the policy and which should be exempt. Which plastic resins ought to be targeted? Should the policy also encompass glass, metal and cartonboard packaging? Do certain product categories, such as food and pharmaceutical drugs, face stricter packaging quality regulations that entitle them to exemptions?

4.2.4. Collection System

One of the most fundamental components of any waste management policy is the relationship between the policy instrument and the collection system and infrastructure in place. Adequate access to recycling collection services and infrastructure is obviously critical for any recycling policy to be successful. However, ensuring access alone is not sufficient. Policymakers must also consider what types of collection systems their policy instrument is best suited for. There are four major types of formal collection models: drop-offs at centralized material recovery facilities (MRFs) and landfills, reverse vending machines located at major retail hubs, curbside collection, and decentralized public recycling and trash receptacles.

Centralized MRFs and landfills are usually operated by a private contractor on behalf of a municipality. In a drop-off model, consumers are tasked with transporting their waste and recyclables to the centralized location themselves. When they arrive, their materials are sorted and weighed. The business models of drop-off centers varies. In Pay-As-You-Throw (PAYT) systems, consumers must pay a fee based on the volume of materials they bring. In other systems, consumers receive payment as remuneration for their recyclables. Drop-off centers are more common in rural locations or for specialized waste materials like electronic waste.

Reverse vending machines are kiosks in which consumers can deposit various types of recyclable materials. The kiosks not only provide storage for the used packaging, but modern machines are also capable of identifying and sorting the materials placed inside. The machine will rotate items to read their barcodes, using an omnidirectional UPC scanner, and then sort them into the correct bin internally. If the wrong type of material is entered into a machine, then it will be rejected and returned to the user (Thomas, 2012). By segregating materials automatically and preventing incorrect sorting of recyclables at the source, reverse vending machines ensure the collected materials have a drastically lower level of contamination than the mixed recycling streams collected in curbside programs, thereby increasing the economic value of those materials to recyclers. In addition to reducing the processing time and costs that would be incurred by retail store employees managing collection, reverse vending machines automatically store information about the type and amount of materials being collected and the funds being disbursed, which provides agencies managing the collection program with accurate data and insights into communities' recycling rates.

In municipal curbside collection programs, residents place waste outside in specially marked bins, and collection trucks come on a regular basis to pick up and transport that waste to the local MRF or disposal site. These hauling services can either be run directly by the municipality or private third-party contractors. In contrast to collection models such as reverse vending machines, source-point sorting of materials by consumers is not required in curbside collection models. While this creates added convenience for consumers, it also opens the door to higher levels of contamination in the recycling stream.

In addition to these formal collection models, another major form of collection is decentralized scavenging performed by informal waste pickers. The informal sector is characterized by small-scale, low-tech, labor-intensive collection, sorting, and processing of recyclable materials, frequently performed in developing countries and by traditionally marginalized social groups like women, children, the elderly, and migrants (Wilson et al., 2006). Workers are typically low-paid, and not formally recognized by municipal or other governmental bodies as members of the workforce at large. Physical working conditions are typically dirty and hazardous, with workers lacking adequate protective equipment exposed to sharp objects such as needles and other forms of biomedical waste; musculoskeletal, respiratory and gastrointestinal health issues are also common. On average, informal systems are responsible for diverting approximately 15% of waste from landfills and into recycling value chains (Aparcana, 2017). Although daily collection rates can vary widely, waste pickers represent significant sources of potential savings for municipalities by reducing the total volume of waste to be collected and managed.

It is important for policymakers to consider the collection system that is present in each country-specific context, as different waste management policies will better align better with some models than others. Deposit-refund schemes, for example, work by incentivizing consumers to return their recyclable materials for redemption at designated collection spots, either centralized drop-off sites or reverse vending machines. If consumers only have access to curbside collection, which does not allow for the return of deposits to individual households, this deposit-refund will be less effective. Likewise, PAYT would be an ineffective policy in locations where decentralized public bins are the predominant collection model, as the level of enforcement required would be unfeasible. Ultimately, a waste management policy must account for these different collection systems, and how they may aid or hinder the policy's incentive structure.

4.2.5. Fee Structure

In the effort to compel producers to internalize the externalities posed by plastic packaging at end-of-life, several types of waste policies involve imposing fees, to be paid either by the producer or the consumer at point-of-sale. Policymakers developing a policy's fee structure have to consider how high to set the fee and whether it should be universally applied to all products within the scope of the policy, or whether it should be tiered. In practice, it is common for the fee amount to vary depending on factors like packaging size, specific materials used, and the incorporation of sustainable product design features such as high PCR content. This last concept is known as eco-modulation. Products with lower environmental impacts across their lifecycle have lower fees imposed on them than products with higher impacts. Eco-modulation is becoming an increasingly common feature within waste policies, as Life Cycle Assessment (LCA) tools become easier for public and private stakeholders to use. Indeed, eco-modulation is now a required component of EPR schemes in Europe, under Article 8a of the revised Waste Framework Directive (Eunomia, 2018).

4.2.6. Allocation of Revenue

With any public policy that creates a new revenue stream, policymakers must determine how that revenue is used. In the case of waste policies, revenue can come both from fees paid by producers and by consumers, as well as from uncollected refunds in deposit-refund systems. This revenue could be allocated to a range of funding priorities, but the most common approach uses revenue to cover the program costs of managing the collection and processing of packaging at end-of-life.

Once these basic funding decisions are made, the question remains of how best to use leftover revenue. Some governments direct the remaining revenue to programs related to recycling, such as public education campaigns, clean-up events, and sustainable innovation research and development. In other programs, the remaining revenue goes into the government's general budget or is returned to the public in the form of tax refunds. Another potential use is environmental justice programs aimed at assisting segments of society adversely impacted by the policy. This concept is a frequent topic in discussions concerning other revenue-positive environmental policies such as carbon taxes. For example, environmental advocacy groups have proposed that lawmakers use the revenue from a carbon tax to provide job training in renewable energy installation to workers in the fossil fuel industry and to expand the earned income tax credit to low-income households who would be disproportionately impacted by increases in gas prices. There are analogous concerns over equity and justice in waste policies that must be addressed. For example, a portion of revenue could be allocated for assistance programs to vulnerable populations such as informal waste pickers and low-income households for whom small increases in the cost of basic packaged goods would present disproportionate financial hardships.

4.2.7. <u>Monitoring and Enforcement</u>

A fundamental component of any policy is how the governing agency plans to monitor compliance, enforce penalties and evaluate performance, once the policy has been put into place. Ideally, these mechanisms for monitoring and enforcement are consistently executed, regularly audited and adequately resourced, which requires an investment of time and funding.

4.2.8. <u>Trade Implications</u>

Some waste management policies, particularly those involving economic instruments, have the potential to affect trade across national and sub-national boundaries. If one country has implemented a waste policy that increases costs for domestic producers, but other countries have not, domestic producers may find themselves at a competitive disadvantage to foreign producers. However, as the

OECD (1993) indicates, this competitive disadvantage can be beneficial in the long-term for domestic producers if they are able to achieve technological innovation and enhanced brand value, thus positioning themselves at the leading edge of industry trends and potentially increasing their market share.

Policymakers concerned about impacts on domestic producers relative to foreign competitors can take advantage of border tax adjustments. A border tax adjustment levies an equivalent fee on imported goods entering the country and rebating charges for goods produced domestically that are subsequently exported, thus "leveling the playing field" for all products consumed in one country regardless of their point of origin. Border tax adjustments are permitted under the General Agreement on Tariffs and Trade (GATT), as long as the levies are applied equally to both domestically and foreign-product goods and there is no evidence of protectionism or favoritism toward Most-Favored Nations (OECD, 1993).

There are other implications for international trade associated with EPR policies specifically. For instance, if an EPR policy assigns not only financial responsibility to producers for the end-of-life handling of their goods, but also operational responsibility, this could require a level of on-the-ground program management which foreign producers are unwilling to deal with, thus incentivizing them to export to different markets. In this way, EPR policies may create non-tariff barriers that affect market entry decisions by foreign producers and thereby hinder market competition.

5. ANALYSIS OF POLICY INSTRUMENTS

Our analysis covers a wide array of policy instruments that can be utilized to reduce plastic packaging pollution and to increase plastic packaging recycling rates (see **Fig. 2-3**).

	Command-and-Control	Market-Based
Increasing Plastic Recycling Rates	▪ Product Take-Back Mandates ▪ Landfill/Disposal Bans	▪ Advanced Disposal Fees ▪ Deposit-Refund Systems ▪ Pay-As-You-Throw
Reducing Plastic Consumption	▪ Product/Material Bans	▪ Product Taxes
Developing Plastic Recycling End Markets	▪ Recycled Content Standards	▪ Virgin Resin Taxes ▪ Tradable Permits

Fig. 2: *Breakdown of policy tools examined in study.*

First, we analyzed a range of instruments that specifically target the increase of recycling rates, including both "command-and-control" policies, as well as "market-based" policies. "Information-based" policies, such as labelling and reporting requirements, are also important policy instruments that policymakers use to influence recycling rates. However, this report focuses exclusively on the first two types of policies, specifically product take-back mandates, product bans and landfill bans for "command-and-control" instruments and product taxes, advance disposal fees, deposit-refund systems and Pay-As-You-Throw for "market-based" instruments. In addition to policy tools that increase recycling rates, we also explored instruments that specifically target the development of recycling end markets, including recycled content standards, virgin resin taxes and tradable permits.

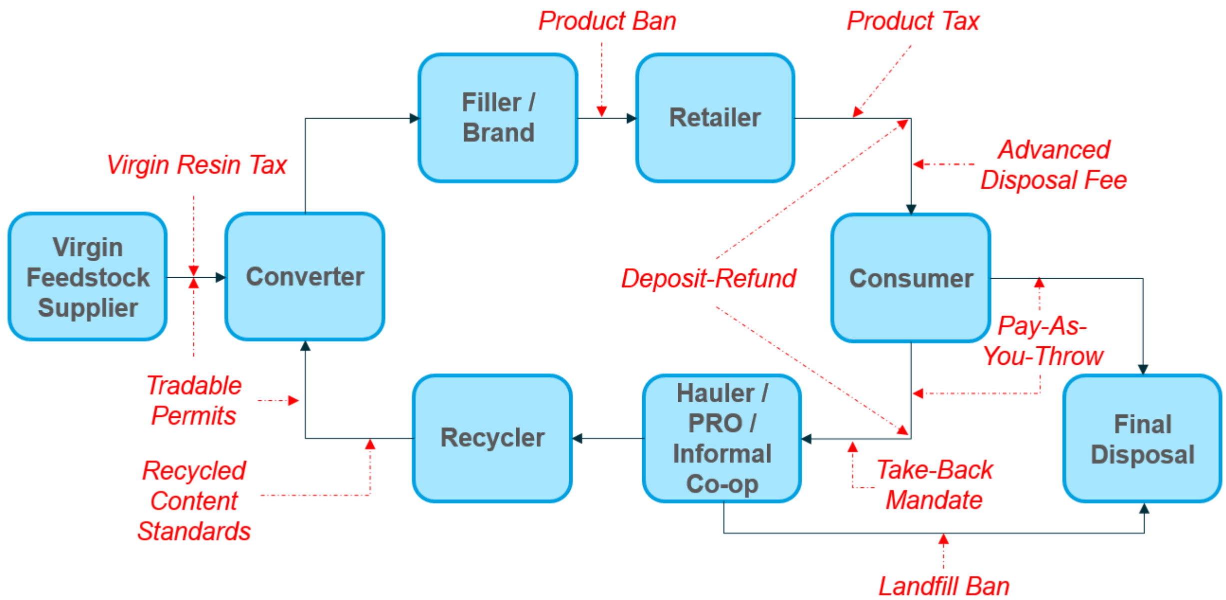

Fig. 3: *Map of each policy tool in relation to the plastic packaging value chain.*

5.1. POLICY INSTRUMENTS FOR INCREASING PLASTIC RECYCLING

5.1.1. <u>Landfill and Disposal Bans</u>

Overview

A landfill ban or disposal ban is a policy instrument that bans specific materials from entering a landfill. These bans have been examined by several governments for organic and biodegradable waste, as well as plastic packaging waste (Anapol, 2018; Fioretti, 2014). Bans are commonly applied to designated streams of waste, such as separately collected recyclables. Enforcement can take place at multiple junctures within the value chain, such as upon collection, or upon delivery to the landfill (CalRecycle, 2017). Enforcement can consist of manually surveying waste as it is collected or delivered and determining an appropriate punishment for offenders, such as a fine. Governments can narrow the scope of a landfill ban and arguably augment the feasibility of enforcement by imposing a ban only upon separately collected items, placing the onus of enforcement on waste haulers at collection points or sorting facilities. This method underscores the policy's potential reliance upon sophisticated collection and/or sorting streams (Simon, 2016).

Similarly, some governments have considered mandatory recycling policies, representing a slight divergence from pure landfill bans. This instrument places responsibility upon consumers and businesses to sort their recyclables from the rest of their waste, and designates the collector to enforce the mandate. Similar to landfill and disposal bans, a common means of enforcement involves surveying waste contents and imposing warnings and/or fines on individuals and businesses that fail to properly separate their recyclables (Kinney, 2016).

Policy Design Considerations

Fees: Fees can serve as a critical tool to ensure that consumers and waste management actors abide by bans. In deciding upon fee structures, policymakers must consider the amount that will properly incentivize actors to follow the ban, as well as how fees will be enforced and collected. Additionally, policymakers should consider how fees are communicated, as consumers' and waste actors' ability to learn about and understand the consequences of not complying with the ban plays a critical role in determining the success of the policy.

Enforcement: Enforcement is perhaps the most critical design consideration of a ban, as it determines whether actors feel properly incentivized to adhere to the ban. Depending on the policy structure, enforcement can fall upon various stakeholders. In countries with nationalized waste management systems, the government is often the primary enforcer, in that state-owned municipal waste management actors are responsible for providing and implementing sorting systems, and/or screening the waste that is collected and delivered to landfills. In countries in which waste management is privatized, this responsibility will fall upon private waste management actors in response to government policy. Private actors can include collectors or landfill operators operating independently or within a single organization.

Advantages of Landfill Bans:

Maintain opportunity to extract value of recyclables (as opposed to material bans): Perhaps the clearest advantage of landfill bans, disposal bans, and mandatory recycling laws is the opportunity to extract value from plastic packaging via recycling, rather than the outright ban of plastic packaging. As such, the policy will likely faces less industry resistance and oppositional lobbying efforts. Several stakeholders, particularly industry, see landfill bans as promising tools for increasing market incentives to support a strong recycling economy, in that a ban could increase and strengthen the flow of recyclable materials towards recycling markets. For example, trade associations such as PlasticsEurope have publicly declared their support for landfill bans on plastics in the EU, which has been debated within the EU Circular Economy Package (Simon, 2016).

Simplicity: Another advantage of landfill bans is their simplicity and clarity, which can further consumer understanding of and cultural awareness toward recycling. For example, despite the shortcomings of the aforementioned North Carolina legislation, the initiative arguably publicizes the government's focus on plastic packaging and the importance of recycling, which could shift cultural awareness and acceptance towards recycling.

Disadvantages of Landfill Bans:

Low Feasibility: A significant disadvantage of a landfill ban, disposal ban, or recycling mandate is the feasibility of enforcement. While governments can pursue a variety of enforcement mechanisms, most hinge upon evaluating waste streams to detect contamination conflicting with the ban or mandate. As such, this evaluation process is often time intensive and incurs high labor costs, and is thus difficult to scale to the volume of waste collected.

This lack of feasibility is observable in North Carolina, where the state legislature passed a house bill in 2005 to ban the landfill of rigid plastic bottles and other items by October of 2009 (General Assembly of North Carolina, 2005). However, the legislation does not define specific enforcement mechanisms. To date, government publishings indicate that enforcement is pursued by the North Carolina Division of Waste Management at disposal facilities such as landfills and transfer stations by surveying the disposed content. However, the legislation elaborates that any city or county can petition the department for a waiver from the prohibition, should it impose an economic hardship. Additionally, the legislation hinges upon a person knowingly disposing of the banned items, indicating that the Department can exercise leniency towards offenders who demonstrate a lack of awareness. These loopholes underscore the difficulty of defining structure around enforcement and holding offenders of the ban accountable.

Dependence on separately collected waste streams: Landfill bans imposed on separately collected waste streams present significant enforcement challenges for countries lacking separate collection streams. The process of separating waste without this pre-existing infrastructure is highly difficult to scale up from a cost perspective. In other words, without this infrastructure, landfilling is drastically less expensive, and landfills bans face difficulties in public support and funding (Simon, 2016). As such, particularly for broad policies that impact multiple municipalities, states, or countries, unique challenges and economic hardships are imposed upon regions lacking these separate collection streams compared to those with well-developed waste management infrastructure. These regions may also suffer from lower cultural understanding of or acceptance towards recycling, further complicating their ability to comply. This dependence upon separately collected waste streams is observable within the European Union, where the European Commission's Environment Directorate-General mandated the establishment of separate collection schemes for paper, metal, glass and plastic by 2015. Within the commission's Circular Economy Action Plan, the commission took aggressive steps by defining recycling targets for both municipal waste and packaging waste, and by proposing a landfill ban for paper, metal, glass, plastics and bio-waste that is separately collected by 2025. These initiatives tied to a broader goal of reducing packaging waste by 80% by 2030, as well as urban waste by 70% (Fioretti, 2014). In 2018, however, the EU commission's member states approved a set of measures that did not include any specific language regarding a landfill ban on separately collected items, instead focusing on increased recycling rates, decreased landfilling rates, the strengthening of separate collection streams, and various incentive and prevention measures (European Commission, 2018). This development likely underscores the difficulty of imposing landfill bans, particularly in those EU member states that have failed to establish separate collection streams and thus face steeper challenges in meeting recycling rate goals. Indeed, European lawmakers have acknowledged that countries lacking sophisticated waste management infrastructure face significantly steeper costs and other complex challenges in their efforts to support such legislation (Simon, 2016).

Negative externalities: Enforcing a landfill ban can lead to unintentional consequences such as increased illegal dumping, illegal burns, or increased support for waste-to-energy incineration schemes (CalRecycle, 2017). Illegal burns are a particularly significant concern, as they cause air pollution that can pose significant health risks to the population. Additionally, an increase in dumping and burning undermines one of the bans' principle advantages, in that these activities could restrain and even negatively impact recycling markets (Simon, 2016).

5.1.2. Product Take-Back Requirements

Overview

One way that governments have responded to the issue of plastic waste is by adopting Extended Producer Responsibility (EPR) policies, an approach that shifts the cost of managing products at the end-of-life from local governments to the producers. The primary goal of EPR is to internalize the currently externalized costs of plastic pollution to society and the environment by shifting the financial burden of waste management from municipalities to producers. Not only is this policy approach arguably more equitable, because it is in line with the "Polluter Pays" principle, but it also can serve as a more effective and economically efficient way to reduce waste and increase the recovery of plastic materials. While the term "Extended Producer Responsibility" can refer to policies that merely impose financial costs on producers without imposing direct responsibility for end-of-life management—for instance, advanced disposal fees, deposit-refund systems and product taxes—EPR is most often associated with the second approach.

The majority of EPR schemes incorporate some level of a command-and-control policy called a product take-back requirement. Product take-back requirements assign firms the responsibility for managing their products at the end-of-life to ensure they are recycled or properly disposal of. To accomplish this, companies will often convene as an industry to establish a third-party organization, called a Producer Responsibility Organization (PRO), in order to collectively address logistics and compliance requirements. The first product take-back requirements were enacted in Germany in the early 1990s. Since that time, hundreds of similar policies have been established worldwide, targeting a number of waste materials including packaging, electronics, batteries, paint, tires and vehicles (OECD, 2016).

Policy Design Considerations

Recycling Targets: Product take-back requirements usually involve policymakers setting a collection and recycling target that the producers subject to the EPR scheme have to meet in order to be in compliance. This target is usually applied to the industry as whole, with the program management costs to individual companies being divided according to market share (OECD, 2016).

Governance: With regard to the governance structure for products' end-of-life management, there are several variations that policymakers can decide to make available as options for producers. Producers can directly manage the collection of their products themselves; they can establish their own individual Producer Responsibility Organization (PRO); and they can partner with other firms to work through one or more collective PROs serving their industry as a whole. Besides the benefit of reducing complexity for producers, contracting with PROs offers additional advantages in creating economies of scale, diffusing risk and providing consistency and convenience for retailers and consumers. PROs usually take the form of non-profit organizations, but can also be for-profit and quasi-governmental entities (OECD, 2016), which are usually required to register and be approved by the government.

Combination with other policy tools: One common characteristic about product take-back requirements as a policy is that they are often combined with additional policy instruments, such as advance disposal fees and deposit-refund systems. Policymakers may implement several policy tools within one overarching EPR scheme, so as to create additional funding sources for take-back initiatives and increase the effectiveness of the program through a more comprehensive approach. Even if policymakers do not combine product take-back requirements with other policy instruments themselves, producers may also voluntarily do so for similar reasons.

Advantages of Product Take-Back Requirements

Reduces costs to municipalities: One of the primary attractions of product take-back requirements is that they transfer the externalized costs of products' end-of-life management and plastic pollution from municipalities and the environment to the companies responsible for producing them in the first place. In this way, the cost of managing plastic waste is directly tied to the stakeholders benefiting from the products, rather than being shared across many stakeholders who receive no benefit from product use. Thus, not only does this shift reduce the financial burden on public budgets, it is also addresses a market failure.

Encourages sustainable product design: Because producers are financially responsible for the collection and recycling of their products, product take-back requirements can also create an explicit feedback loop to companies regarding the recyclability of their products. This in turn provides an incentive for firms to reduce this cost by redesigning their products so that they are less expensive to collect and recycle at high value. That said, many academic and policy reviews have found that the impact of product take-back requirements on product redesign is limited. It is generally agreed that the incentive established by the policy does contribute to sustainable design decisions, but ultimately other factors play a larger role in determining product design (OECD, 2016).

Disadvantages of Product Take-Back Requirements

Difficult to assess cost effectiveness: While producers and the PROs they partner with are required to report on their recycling rates, they do not necessarily have to disclose financial information regarding their operational costs associated with the take-back program. As a result, it is difficult to assess the cost effectiveness of product take-back programs compared with other policy options.

Risk of anti-competitive practices: There are legitimate concerns regarding anti-competitive behavior, based on historic cases of collusion. Specifically, these behaviors include price gouging and entry deterrence between producers, PROs and waste management companies (Kaffine & O'Reilly, 2013).

Outside of these advantages and disadvantages, however, it is difficult to evaluate the factors that influence the effectiveness of product take-back requirements and their attractiveness as a policy tool. This is due to the high diversity of EPR schemes in which product take-back requirements are often a single component. Consequently, it is hard to differentiate which outcomes are the result of a product take-back requirement alone and which are the result of the scheme's particular managing organization, collection model, or other policy tools operating concurrently.

5.1.3. Advance Disposal Fees

Overview

Advance Disposal Fees (ADFs) are similar to product taxes (see **Section 5.2.2**) in that one of their purposes is to internalize the negative environmental externalities associated with managing products at the end-of-life. However, ADFs go a step further in that the revenue gained from the fees is specifically allocated for waste collection and recycling, whereas the revenue from product taxes may simply be channeled into a government's general fund. Additionally, ADFs can target multiple points of the value chain. In some instances, fees are imposed upon producers (i.e. the brands) and in others, fees are imposed upon retailers. In practice, these fees are often then passed on to consumers through price increases. The use of ADFs to manage the end-of-life for packaging began in Germany in the early 1990s as a component of the government's der Grüne Punkt (Green Dot) EPR program (Bell, 2018). Today is it not uncommon for the funding mechanism of an EPR scheme to combine ADFs with product take-back mandates (OECD, 2016).

Policy Design Considerations

Fees: At the core of the concept of ADFs is the premise that these fees reflect the lifecycle costs associated with the end-of-life management of the products. This inherently implies the use of eco-modulation. Products that are more difficult and costly to recover and recycle (e.g. due to high material complexity) will have higher ADFs than products that are easier to recover. In Europe, ADFs for packaging range from 20-200 Euros/ton, with an average of 92 Euros/ton (OECD, 2016). Some countries have taken the additional step of including the use of post-consumer recycled (PCR) content in their definition of eco-modulation. For example, in France's EPR scheme for paper packaging, producers are eligible for a 10% reduction in their ADFs if they use at least 50% recycled content by weight, which they must demonstrate by submitting a certificate from their suppliers (Eunomia, 2018; Tencati et al., 2016). Although the use of PCR content in a product does not directly change the costs associated with its collection and processing, compared to products with virgin content, it can be argued that by creating demand for recycled materials, products with high PCR content indirectly improve the financial margins of end-of-life management and therefore merit a lower fee.

Product Substitutes: Similar to product taxes, increases in product prices caused by ADFs may incentivize consumers to switch to alternative products at a lower price point. Policy makers must account for the economic and environmental impacts such a shift might inflict.

Scale of Implementation: In another similarity to product taxes, it is preferable for ADF policies to be implemented on a national or multinational scale to prevent consumers from avoiding fees by purchasing products outside of the policy's jurisdiction.

Advantages of Advance Disposal Fees

Possesses many of the same advantages of product taxes: Like product taxes, ADFs can reduce demand for difficult-to-recycle products by increasing the cost to producers and consumers, which in turn lowers the volume of these materials entering the waste stream. ADFs are also not as prescriptive as command-and-control policies like product bans. While they change the incentive structures that inform producer and consumer purchasing decisions, they do not eliminate any product options, offering these groups flexibility over how they evaluate the various tradeoffs between different products. ADF policies are also able to leverage existing VAT tax reporting and collection systems at the point-of-sale, which keeps administrative costs low. Finally, the high level of public support for taxes that incentivize recyclability in plastic packaging in countries such as the United Kingdom suggest that ADFs are relatively politically feasible in the current climate of global concern over plastic pollution (Credit Suisse, 2018).

More economically efficient than product taxes: Because ADFs are specifically designed to incorporate eco-modulation into their fee structure to reflect the externalized costs of managing different products at the end-of-life, they are a more economically efficient form of Pigovian tax—a tax on negative externalities—than general product taxes.

Creates a stable funding source for waste management programs: The revenue from ADFs is specifically earmarked for the collection and processing of materials for recycling and proper disposal, providing municipalities with a stable source of funding for covering those program costs. This feature may be particularly attractive to municipalities that face financial barriers to implementing or expanding their waste services and infrastructure, as is the case in many developing countries.

Promotes equity: ADFs are in line with the "Polluter Pays" principle, which states that the stakeholders who are most responsible for generating environmental burdens—in this case plastic waste—should pay the costs of mitigating these burdens. Instead of distributing the costs of end-of-life management amongst the public in general, ADFs impose these costs onto the products' manufacturers and consumers who are directly responsible for generating the waste, which is a more equitable system.

Disadvantages of Advance Disposal Fees

Fails to impact disposal decision by consumer: Like product taxes, ADFs only influence the consumer's purchasing decision at the point-of-sale and does nothing to impact his disposal decision once the product has been used. In other words, apart from incentivizing source reduction, ADFs do not improve the likelihood that the packaging product will be recycled or properly managed at the end-of-life.

Difficult to internalize end-of-life costs accurately: One OECD report describes why the structure of ADFs includes economic inefficiencies:

> "It would be extremely difficult to determine the appropriate tax to place on the sale of any particular item to reflect the social cost of product disposal. The social cost of disposal depends upon how the consumer chooses to dispose of the product and this is impossible to determine at the point of purchase. Similarly, intervention at the point of purchase or manufacture may affect product uses which do not create any solid waste problem" (OECD, 1997).

May face industry resistance: Besides potential resistance from producers who do not want to see their products become more expensive to consumers or their profit margins decrease, policymakers may also experience a backlash from retailers who share similar concerns (Ocean Conservancy, 2015).

Risks stimulating demand for ecologically inferior alternatives: As mentioned above, if policymakers do not take a life cycle approach while evaluating the availability of different product substitutes, they risk incentivizing consumers to increase demand for products that could have worse environmental impacts.

5.1.4. Deposit-Refund Systems

Overview

Deposit-refund systems (DRSs) are a market-based policy that leverages two economic mechanisms rather than one. First, at the point of purchase, consumers pay a deposit fee on products that fall under the scope of the policy, such as products in plastic beverage containers. After consumption or use, consumers return the product's packaging to a collection center—often at the same retail locations where the product is sold. Once returned, the consumer is given either a full or partial refund of the original deposit. The nature of this two-part incentive structure means that consumers only experience a cost if they fail to recycle the product. As a result, DRSs much more closely target pollution from packaging waste at its source and are therefore considered to be a more economically efficient form of Pigovian tax than policies like ADFs that impose a cost on consumers regardless of the disposal outcome.

There is a long historical precedent for deposit-refund systems, which traditionally took the form of voluntary industry-driven programs. Because of the cost of manufacturing or purchasing new containers, it was common up until the mid-20th century for the beverage industry to sell their products in refillable containers, which they would incentivize customers to return after use by implementing a deposit-refund strategy. As packaging manufacturing costs decreased, however, and single-use, non-refillable containers became inexpensive, companies stopped their deposit-refund programs. More recently, interest in deposit-refund schemes has been revived in the wake of concern over the environmental issues caused by packaging waste, and governments in developed countries have increasingly begun to institute mandatory deposit-refund policies (Kulshreshtha and Sarangi, 2001).

Policy Design Considerations

Product Applications: Deposit-refund policies have primarily targeted the rigid beverage containers used for packaging by the alcohol, soda and bottled water industries. Historically, this packaging encompassed glass bottles and metal cans, but in recent decades has increasingly been expanded to include PET bottles, as well. Although some deposit-refund policies do include packaging used by the dairy and juice industries such as paper-based cartons, this is not as common (CMC Consulting, 2016).

Deposit: Deposit amounts commonly vary depending on the size of the container and the packaging material. Around the world, most deposits range from 0.05-0.20 USD, though in Denmark and Finland consumers pay deposits as high as 0.45 USD for containers larger than 1 Liter (CMC, 2018).

Refund: The second piece of the incentive structure is the refund paid to consumers upon the return of the targeted products at designated collection locations. The amount of money that consumers can redeem has a direct impact on recycling rates. In one recent example, the state of Oregon increased its deposit fee from 0.05 USD to 0.10 USD in 2017, and its recycling rate jumped from 59% to 82% in one year (CMC, 2018). In determining what amount of the original deposit should be returned, policymakers need to provide a refund high enough to incentivize consumers to return the products, while also ensuring that the costs of managing the deposit-refund program are being covered.

Additionally, it must be specified whether the refund is in the form of cash or credit for a product or service. Retailers participating in deposit-refund schemes will sometimes offer store credit instead of cash, while the city of Beijing offers public transit tickets or mobile phone minutes in exchange for recycled bottles (Martinko, 2014). Finally, in order to avoid consumers attempting to take advantage of this system, it is important that both the deposit amounts and refund amounts are universally applied across retail and collection locations. Otherwise, consumers are incentivized to buy products at whichever store charges the lowest deposits and return the packaging at stores that offer the highest refunds, leading to a loss of program revenue (OECD, 1993).

Collection System: Most countries with formal deposit-refund policies use reverse vending machines as their primary collection system, which are installed at retail stores and other high-traffic locations. Once the consumer has finished depositing her recyclable materials, the reverse vending machine automatically dispenses her refund, either in the form of a print receipt which can be redeemed at the retailer's check-out counter or via an electronic payment.

Scale of Implementation: Similar to product taxes and ADFs, deposit-refund systems are best suited for national or multinational implementation, rather than sub-national. Otherwise, it becomes difficult to prevent consumers from purchasing products in jurisdictions that do not charge the deposit and returning the products within jurisdictions that offer refunds, which can create revenue deficits.

Advantages of Deposit-Refund Systems

Highly effective at increasing recovery rates: Unlike product taxes and ADFs, deposit-refund systems influence consumers' disposal decisions by offering a direct financial incentive to recycle. This incentive structure has resulted in recycling rates of over 90% in at least six countries (CMC, 2018). One particularly remarkable example is Lithuania, which saw its recycling rate for PET bottles increase from 34% to 92% two years after implementation (Dundon, 2018). Additionally, studies have found in both the United States and in Australia that states with deposit-refund systems recycle plastics at more than twice the rate of states without such policies (Bragge, Wright, & Smith, 2016).

Reduces illegal dumping: The positive financial incentive provided by refunds can also significantly reduce consumers' motivation to engage in illegal dumping. In the U.S., for instance, states with deposit-refund systems for rigid beverage containers have reduced container litter by 70-84% and total litter by 34-47% (Container Recycling Institute, 2019).

Highly economically efficient: Pigovian taxes are generally considered to be more economically efficient the closer the tax is tied to the source of the externality, in this case plastic pollution. Thus, deposit-refund systems, which target the point-of-disposal along with the point-of-sale, are more efficient compared to policies that target the point-of-manufacture or point-of-sale alone. Moreover, while product taxes and ADFs impose blanket costs on consumers regardless of end-of-life disposal behavior, deposit-refund systems only impose a cost on consumers—through the unredeemed refund—who fail to recycle the product, thereby maximizing social welfare (Kulshreshtha and Sarangi, 2001). These theoretical assumptions are backed by an extensive swath of economic studies focused on EPR (Kaffine & O'Reilly, 2013). For example, one study found that in order to achieve the same 10% increase in recycling, policymakers would have to set a $45 per ton fee under a deposit-refund system, compared to an $85 per ton fee in an ADF scenario (Palmer et al., 1997). Thus, deposit-refund systems are regarded as highly cost-effective policy tools for waste management.

Improves quality of material stream for recycling: In order to receive the refund, consumers must segregate the target materials and return them to designated collection centers. Compared to commingled single-stream collection, this results in materials streams with lower levels of contamination. This yields higher quality feedstock inputs for new products, consequently increasing the value of PCR resins to recycling companies and end users.

Incurs moderately low program costs: Similar to product taxes and ADFs, policymakers implementing deposit-refund systems can take advantage of existing point-of-sale reporting and collection processes used for value-added taxes to enforce the initial deposit, which helps decrease the policy's administrative costs. Additionally, according to the OECD (1997), recycling programs like deposit-refund systems that rely on a "bring" model, i.e. have consumers bring their end-of-life materials to a collection center, usually involve lower administrative costs than programs that rely on a "collect" model (e.g. curbside pickup). Policymakers can go even further in keeping program costs low by investing in reverse vending machines, which automatically sort recyclable materials, track recycling and financial data, and disperse refunds.

Financially sustainable over long term in most cases: The revenue generated from unclaimed refunds and from offering partial refunds provides a stable funding source that can be used to cover program costs. While not all deposit-refund systems are revenue-positive or -neutral—California's Container Refund Value program is facing a structural deficit of $75 million (Toloken, 2018), possibly due to fraudulent refunds or to its more labor- and capital- intensive collection configuration—many other programs around the world have been able to finance themselves successfully over the long term. A study by a behavioral change research group at Monash University in Australia examined 40 established deposit-refund policies and found that, on average, these schemes had been in operation for 24.8 years (Bragge et al., 2016).

Widely supported by policy analysts and environmental groups: Based on the our literature review, it appears that the majority of academic analysts, governmental agencies and environmental groups believe deposit-refund systems to be the most effective policy tool for decreasing packaging pollution and increasing recycling rates (Barlaz and Loughlin, 2001; Container Recycling Institute, 2016; Gui, Atasu, Ergun, & Toktay, 2015; Kaffine & O'Reilly, 2013; OECD, 2016; Reloop, 2018; Walls, 2011).

Disadvantages of Deposit-Refund Systems

Less convenient for consumers: For consumers accustomed to recycling through curbside collection, deposit-refund systems that rely on drop-off collection centers are far less convenient. Policymakers can attempt to mitigate this obstacle by establishing collection centers in easily accessible and high-traffic locations, such as major retail stores and public transportation hubs. However, unless the financial incentive is quite high, deposit-refund systems often face lower recycling participation rates from the public as a whole (OECD, 1997). However, this does not indicate that the recycling rate itself is lower; rather, the stakeholders involved in recycling materials may shift and include more informal waste pickers.

Faces risk of fraudulent refunds: When deposit-refund systems are implemented in a piecemeal fashion, this presents the risk of fraudulent returns, in which consumers purchase products in states or countries with no or low deposits and then "return" them in neighboring states or countries with high deposits. With too few consumers paying the initial deposit, this problematic practice creates a funding gap for covering program costs. California, for example, recently charged five individuals with defrauding the state's recycling program of $80.3 million over several years (KPIX, 2018).

Possible risk of cannibalization: A frequent concern voiced against deposit-refund systems is the risk of siphoning high-value materials (such as PET) from the recycling stream, which could lower the overall value of the recyclable materials collected outside of the deposit-refund system, thereby jeopardizing the financial feasibility of recycling collection programs in general (Staub, 2019b). How significant this risk is, however, depends on two factors. The first factor is the extent to which the costs of maintaining public waste services are dependent on the sale of recyclables. Recycling programs in the U.S., for instance, are largely supported by property taxes, landfill tipping fees and user service subscription fees (Barlaz & Loughlin, 2001). The second factor is the percentage of the target materials segregated by consumers from the general waste stream. Some consumers may choose, out of convenience, not to collect their individual refund and instead commingle their waste materials with other recyclables, in which case recyclers can still redeem the refund on the materials themselves after collection (Barlaz & Loughlin, 2001).

Faces resistance from industry stakeholders: Particularly in the U.S. and Australia, Consumer Packaged Goods (CPG) companies have historically opposed efforts to implement deposit-refund systems. The crux of this resistance appears to a concern over the increased cost at the point-of-sale to consumers and the impacts of those costs on companies' market share, as well as philosophical opposition to regulatory mandates. More recently, however, there are signs of this industry opposition waning. Campaigns by environmental activist groups have successfully caused some companies like Coca-Cola to reverse course and come out in support of deposit-refund policies (Greenpeace, 2018), and the editor of industry newsletter *Plastic News*, Don Loepp, recently promoted the benefits of deposit-refund policies in an opinion article (Loepp, 2019).

5.1.5. Pay-As-You-Throw

Overview

Pay-As-You-Throw (PAYT) policies, also known as unit-based charges, impose a fee on consumers at the point-of-disposal. The fee varies with the volume of waste generated, providing a financial incentive for consumers to take steps towards reducing their waste, either by reducing their consumption of non-reusable products or by increasing recycling. This policy approach is an alternative to flat service fees or property taxes, which are not tied to the amount of waste being collected from each household. PAYT was first introduced in Austria in the 1940s, but did not garner broader interest until the 1970s. Today PAYT is quite common in many municipalities across Europe, Asia and North America and is slowly gaining traction in Africa.

Policy Design Considerations

Fees: A key component of implementing a PAYT policy is determining how high to set the fees. While policymakers may want to charge high fees in order to cover the costs of collection and management of waste materials, fees that are set too high may incentivize illegal dumping, so it is important to consider the public's willingness-to-pay threshold. Two additional considerations that policymakers have for designing PAYT fee structure are choosing between volume-based and frequency-based fees. With volume-based fees, individual households pay for a certain size bin or bag (sometimes marked by different colored tags), while with frequency-based fees, households pay for a certain frequency of collection via subscription. Policymakers can also decide between charging households by weight for all of their trash, or setting a maximum flat rate, and then charging any volume of waste generated above that by weight. Finally, how and when the fees are paid will depend on the particular municipality's waste collection model. For instance, if the municipality offers curbside collection, households may pay via a monthly or bi-monthly utility bill. If the municipality relies on drop-off centers, households instead pay directly at the center.

Use of Revenue: The fees collected under PAYT policies typically go straight to funding the collection and management of municipal solid waste.

Advantages of Pay-As-You-Throw

Can be very effective at reducing waste and increasing recycling: Multiple studies have shown that PAYT policies can be very effective at reducing municipal solid waste, particularly compared to programs that rely on flat rates and property taxes (Palmer et al., 1997).

Generates revenue that helps fund waste management services: The fees charged under PAYT policies create a stable source of revenue that supports municipal waste collection and management.

Promotes equity: Compared with policies involving the use of flat fees or property taxes to pay for waste management, PAYT is much more equitable in that households generating large amounts of waste pay more than households generating small amounts of waste. Thus, PAYT helps to eliminate free-riding and promotes environmental justice.

Disadvantages of Pay-As-You-Throw

Very difficult to enforce: Monitoring and enforcement for PAYT is very difficult, because waste streams are separated at the individual household level. In a McKinsey analysis of different waste management solutions, PAYT received a score of 1 out of 7 in terms of ease of implementation (Ocean Conservancy, 2015). This issue may be particularly challenging for policymakers in developing countries that have less funding available to carry out adequate monitoring and enforcement, and in countries that may face more widespread corruption.

Can incentivize illegal dumping: Unfortunately, because enforcement is so difficult, it is not uncommon for PAYT policies to inadvertently incentivize consumers to dump their waste illegally in an attempt to avoid the policy's fees. Moreover, this problem is not just limited to individual households. Waste haulers who have to pay their own version of PAYT fees through landfill tipping fees will sometimes dump some of their loads after collection, so that their trucks will be charged less per weight upon arrival. The Ocean Conservancy estimates that illegal dumping by waste haulers in China, the Philippines, Vietnam, Thailand and Indonesia results in 700,000-900,000 metric tons of plastic leakage every year, about 10% of total plastic leakage overall (Ocean Conservancy, 2015). To combat this, policymakers may need to consider strategies for increasing oversight of trucking routes, for instance by recording departure and arrival times and implementing GPS tracking. Mitigating illegal dumping on the individual household level is much more challenging, though campaigns to educate the public about the negative impacts of dumping and instill cultural norms around recycling may help.

Can lead to increased contamination of the recycling stream: PAYT policies can also incentivize consumers to place their waste in recycling bins, if recycling services are offered for free or at a lower cost in their municipality. This practice is extremely problematic: the overall amount of waste being generated is not reduced, and the waste contaminates the recycling stream, which increases processing costs for recyclers and lowers the quality of materials (Barlaz & Loughlin, 2001).

Lacks incentives for producers to participate in waste reduction efforts: Because PAYT only focuses on the consumer at the point-of-disposal, there is very little impact on producers and the decisions they make regarding the recyclability of their products. Thus PAYT policies fall short of leveraging the resources available to companies for innovating new products and business models.

5.2 POLICY INSTRUMENTS FOR DECREASING PLASTIC CONSUMPTION

5.2.1 Product Bans

Overview:

The outright banning of plastic packaging items has grown in popularity as a policy approach in recent years, often spurred by frustrated municipalities reacting to enormous plastic litter and/or leakage into waterways, and further encouraged by vocal environmental advocates. Additionally, in more developed countries with sophisticated municipal solid waste management infrastructure, bans can be a tool towards meeting waste reduction goals imposed by higher levels of government (Romer, 2007). The ultimate goal of bans is often to address the economic, environmental, or human health impacts caused by plastic. For example, in India, 25 different states have imposed some sort of plastic packaging ban, largely stemming from the negative externalities that the government is confronting due to plastic packaging pollution within the country (Chitnis, 2015).

Product bans typically target specific plastic resins and/or products, such as plastic bags, styrofoam, straws, etc. Municipalities, states, and countries around the world have enforced bans through a variety of mechanisms, including fines and jail time. Among the most common enforcement tactics are fining the manufacturers of the banned items, the vendors who are caught distributing said items, and the consumers who purchase these items. Additionally, some governments have gone so far as to conduct raids, shut down manufacturers, and even jail repeat offenders (Parvaiz, 2018; Sampathkumar, 2019). Governments have allocated varying degrees of funding toward enacting this legislation, yielding a wide array of results discussed below.

Advantages of Product Bans:

Decreases plastic consumption: The most obvious advantage of product bans is the reduction of plastic consumption, and thus, a reduction in the negative externalities that can result from plastic production and leakage. However, as the disadvantages section details, these advantages hinge upon the effectiveness of a product ban, which is not guaranteed due to consumer confusion, difficulty of enforcement, and more.

Simplicity: One of the clearest advantages of a ban is its simplicity, particularly compared to other complex schemes that require additional administrative costs and coordination across multiple stakeholders for implementation and enforcement. Because a ban is mandated by a government and relies less on other stakeholders' input and participation, the process of crafting and passing the policy can be relatively straightforward and streamlined.

Disadvantages of Product Bans:

Difficulty of enforcement: Given the ubiquity of plastic packaging, it is extremely difficult for governments to fund and supply the proper human capital necessary to track plastic packaging across an entire economy, and to enforce punishments for all offenders (Parvaiz, 2018). In the event that enforcers are unable to punish every offense, they can choose to punish select actors, but it is uncertain whether this will influence the broader community to obey the ban. These difficulties are evident in India, where lax enforcement and a lack of resources available for the government to enforce the ban have been documented. Out of the 25 states that have imposed plastic bans, some go so far as to completely ban the manufacturing, supply, and storage of specific plastic items such as polyethylene bags. However, given the wide demand for and availability of these items, it is difficult and costly for India to properly enforce such a ban. Additionally, the government lacks an independent auditing or validation system to track the effectiveness of enforcement, underscoring the uncertain results of bans (Parvaiz, 2018).

Environmental impacts of substitute materials: Another disadvantage of a ban is that, depending on the degree of flexibility and immediacy of the enactment of legislation, businesses can be forced to secure alternatives that may have higher life cycle costs than plastic, particularly in terms of water use, land use, and carbon emissions (Tullo, 2016). The materials that businesses commonly replace plastic with often don't offer the same functionality, particularly in terms of food preservation and carbon emissions reductions during the transportation of goods (Gray, 2018).

Uneven distribution of impacts: Some material alternatives to plastic are more costly for producers, which can disproportionately impact small business owners that lack the capital to make the switch from plastic to glass. Additionally, as previously mentioned, the difficulty of enforcing a ban can lead to the punishment of only a select portion of offenders, leading to a perceived injustice between those who avoid detection and those who are punished.

Consumer confusion due to geographic inconsistency: Bans can be difficult to decipher and enforce, due to inconsistencies across borders (Sampathkumar, 2019). For example, while the aforementioned 25 Indian states all ban target common items like plastic bags and plastic utensils, many of them differ with regards to which specific packaging items are banned, as well as whether the ban is full or partial. While some states impose a total ban on polyethylene bags, others impose the ban only on bags thinner than 50 microns, which authorities commonly test via touch (Parvaiz, 2018). Given this variation, consumers and businesses are often unclear on specific rules, compromising both consumers' and businesses' ability to comply (Xanthos & Walker, 2017). Larger companies with global supply chains often struggle to decipher which products are allowed where. Even if businesses are able determine where packaging items are legal vs. illegal, the country's citizens can lack clarity, leading to the transport of goods across state borders without understanding or acknowledging differing bans (Parvaiz, 2018).

Illicit externalities: The imposition of a ban and the subsequent desire to avoid punishment can result in bribery between public officials, individuals and businesses, particularly those businesses who rely upon or derive profitability from plastic packaging. In extreme cases, a black market can emerge for the banned items (Pilgrim, 2015). For example, in India, where plastic packaging manufacturers have been shut down in certain states as a result of the ban, certain banned plastic items are often trafficked in from other states lacking that same ban (Parvaiz, 2018).

5.2.2 Product Taxes

Overview

Product taxes (also known as product charges) are taxes either placed on retailers—who can then pass the cost onto consumers—or imposed directly on the consumer at the point of sale. The purpose of such a tax is to internalize the negative externalities caused by a particular product and to provide a financial disincentive to consumers to purchase it. A product tax may be applied to packaging products that are particularly difficult to recycle. To date, the most common packaging applications affected by this policy tool are lightweight plastic grocery bags and Styrofoam cups, with laws taxing these products passed in a number of countries and sub-national regions worldwide (UNEP, 2018).

Policy Design Considerations

Tax Rate: Policymakers have the option of either establishing a static tax rate, in which the consumer pays a set amount per product, or a variable tax rate, in which the consumer pays a percentage of the value of the product. In nearly all real world cases, however, it appears that the static rate is the preferred option, with consumers paying as low as 0.015 USD per bag in Indonesia and as high as 0.56 USD per bag in Denmark (UNEP, 2018). In some countries, the tax rate varies between retailers. In this scenario, policymakers establish a minimum tax rate, and then retailers may choose to set their own rate above that. Finally, policymakers may also incorporate eco-modulation into the law so that the tax rate is tiered based on the use of ecologically superior product attributes, such as PCR content and lower material complexity. This tiering thus provides a financial incentive for producers to invest in more sustainable product designs.

Country	Tax Rate (USD per plastic bag)
Bulgaria	$0.10
Cyprus	$0.06
Denmark	$0.56
Fiji	$0.05
Greece	$0.09
Indonesia	$0.02
Ireland	$0.26
Israel	$0.03
Malaysia	$0.05
Malta	$0.18
Netherlands	$0.30
Portugal	$0.12
Romania	$0.06
Vietnam**	$1.76

**Tax rate per kilogram

Table 3: *Sample of countries with product taxes on plastic bags (UNEP, 2018)*

Use of Revenue: The revenue collected from product taxes typically goes into the government's general fund, though it can be earmarked for waste, recycling and other environmental programs.

Product Substitutes: As the cost to consumers for single-use plastic bags increases, it is important for policymakers to consider which alternatives this change may incentivize consumers to adopt instead. This is an important consideration for two reasons. First, the policy may face significant resistance from the public if no affordable alternatives to the taxed product exist, which can not only result in a political backlash, but can also undermine the policy's effectiveness by encouraging black market trade. Second, policymakers must account for the tradeoffs incurred by alternative products from a life cycle perspective. For instance, reusable bags may present upstream environmental impacts that are not as visible to consumers. Policymakers should make an effort to avoid causing new or increased environmental harms by passing a product tax.

Scale of Implementation: Product taxes in general are better suited for national or multinational implementation, rather than local implementation, because if consumers can easily access the same products in locations outside of the policy's jurisdiction and thus avoid paying the higher price, the policy will not be as effective.

Advantages of Product Taxes

Can be highly effective at reducing demand for problematic products: A number of countries such as the U.K., Greece and China experienced 60-86% decreases in plastic bag consumption shortly after implementation of a plastic bag tax. Ireland in particular stands out as a highly successful example, decreasing its consumption of plastic bags by over 90% within one year (UNEP, 2018; Convery, McDonnell, & Ferreira, 2007).

Low administrative costs: In addition to generating revenue, product taxes also benefit from having relatively low administrative costs. Because the product tax is often imposed at the cost of sale, it is possible for policymakers to integrate the required reporting and tax collection processes into existing value-added tax (VAT) collection systems. A study by Convery et al. (2007) estimated that the administrative costs associated with Ireland's plastic bag product tax comprised about 3% of the revenue generated by the policy.

Offers greater flexibility over product bans: As a market-based solution, product taxes give retailers and consumers more flexibility to choose between different product alternatives that best meet their needs, compared with an outright ban that eliminates certain product options.

High levels of public support in some countries: With public concern about plastic pollution at an all-time high worldwide, environmental policies that raise costs to consumers like product taxes are more politically feasible than they may have been historically. In 2018 for instance, the British government requested public input for how to best address plastic waste. The request received 162,000 responses, which was the largest response to any consultation in the treasury department's history. Of these responses, 40,000 called for a tax that incentivized recyclability in plastic packaging (Credit Suisse, 2018).

Disadvantages of Product Taxes

Fails to impact disposal decision by consumer: While product taxes can reduce the volume of plastic products entering the waste stream, the policy is only directed at influencing the consumer's purchasing decision and does nothing to impact his disposal decision once the product has been used. In other words, apart from incentivizing source reduction, product taxes do not improve the likelihood that the packaging product will be recycled or properly managed at the end-of-life.

Not always successful at lowering demand: In several developing countries such as Vietnam and Zimbabwe, product taxes have been largely ineffective, and plastic bags are still widely used. In Zimbabwe, plastic bags are simply smuggled into the country from Mozambique (UNEP, 2018). These failures suggest that, in the face of limited product substitutes that are affordable to consumers and inadequate policy enforcement, product taxes can be an ineffective policy tool in certain market and regulatory contexts.

Faces barriers in extending to other packaging applications: Product taxes do not work for every packaging type. A 25 pence tax on single-use coffee cups in the U. K. has had surprisingly little impact on consumers, and the British government is reportedly planning to repeal it (Gabbatiss, 2018).

Additionally, there are significant differences between plastic bags and CPG packaging, which presents challenges in applying a product tax to the latter. For one, the decision of which product to use in the case of plastic grocery bags is made by the consumer, whereas the decision of which product to use in the case of CPG packaging is made by the brand. Additionally, the product functionality and quality requirements of CPG packaging for protecting and prolonging food and pharmaceuticals, pose difficulties for brands attempting to find substitute products.

Does not necessarily allocate revenue toward waste management: The revenue generated by the tax typically goes into the government's general budget, rather than being specifically allocated to fund the collection and end-of-life management of the products targeted by the tax. Thus, if one of the government's stated goals is to support the expansion of waste infrastructure and services and lower the financial burden on municipalities of ongoing waste management efforts, product taxes fall short.

Faces public and industry resistance: In countries such as Indonesia and Brazil, product taxes on plastic bags have faced high levels of resistance both from industry stakeholders and from the public (Langenheim, 2017; ICIS 2011).

Risks stimulating demand for environmentally inferior alternatives: As mentioned above, if policymakers do not take a life cycle approach when evaluating the availability of different product substitutes, they risk incentivizing consumers to increase demand for products that could have worse environmental impacts.

5.3. POLICY INSTRUMENTS FOR DEVELOPING RECYCLED PLASTIC END MARKETS

In addition to policies and waste management strategies that decrease plastic pollution and increasing recycling rates downstream, there are also a number of policies that target upstream of the plastic packaging value chain by influencing producers' sourcing decisions, particularly around the use of post-consumer recycled content (PCR). Just because plastic is collected and recycled does not mean that the recycler will be able to sell it to manufacturers who can reuse the material to make new products. Without stable end markets, recyclers are at times forced to either stockpile the materials, or find alternative end-of-life channels such as waste-to-energy or even landfilling. This challenge has become particularly urgent in light of China's National Sword policy. Half of the world's scrap plastic was previously being exported to China, and National Sword reduced that number by 99.1% (Ocean Conservancy, 2015; Staub, 2019a), with the result that governments across the globe are currently scaling back their recycling programs or freezing them altogether (Corkery, 2019). Thus, in order to create a truly circular plastics economy, governments must also explore policies that can support the development of end markets for recycled plastic. Furthermore, besides improving the economic feasibility for recyclers to sort and process plastic packaging for material recovery, increasing the use of PCR plastic in packaging also has enormous societal benefits in the form of energy and greenhouse gas savings, compared to the use of virgin plastic.

These benefits have already been recognized by government, industry and NGO stakeholders alike. Green procurement programs, in which public agencies are required or encouraged to leverage their purchasing power to purchase goods with higher PCR content, have been adopted in many countries and states worldwide, such as Australia and California. Major corporations too have been setting voluntary commitments to increase their use of PCR in their products and packaging. The most high-profile example of this was the New Plastics Economy Global Commitment in 2018, orchestrated by the Ellen MacArthur Foundation in partnership with members of the New Plastic Economy. One of the key principles the commitment encompasses is the decoupling of plastic use from the consumption of finite resources, and signatories are subsequently expected to set goals for increasing the percentage of PCR resins in their products. The 275 signatories collectively represent 20% of global plastic packaging production and include CPG giants such as Coca-Cola, Colgate-Palmolive, Danone, Henkel, Nestlé, PepsiCo and Unilever, who have each set targets of sourcing 20-50% PCR content within the next decade (Phipps, 2018).

However, despite this admirable leadership and momentum, there are still multiple systemic barriers to the sourcing and use of PCR resins for the production of plastic packaging. These barriers include:

- The market failure to account for the externalized costs of virgin plastic compared with PCR plastic
- Constrained supply of PCR resins
- High search costs
- Need to meet credible traceability and verification requirements

- Quality concerns
- Aversion to risk

To address these challenges and support the development of recycled plastic end markets, there are a number of policy tools that policymakers can consider.

5.3.1. Recycled Content Standards

Overview

Recycled content standards are a command-and-control policy that requires producers to achieve a minimum percentage of PCR content in their packaging. The most common material targeted by recycled content standards is paper, but in the early 1990s, three states in the United States—Wisconsin, California and Oregon—enacted the first policies that specifically targeted rigid plastic containers. Since then, it does not appear that any additional state or national governments worldwide have passed recycled content standards for plastic packaging. However, in 2018, a coalition of 35 European organizations and companies, including EuRIC, the EU's industry association for recyclers, and FEAD, the EU's industry association for the waste management industry, called on the European Union to incorporate a 25% recycled content mandate for plastics into its Plastics Strategy (Messenger, 2018). This rise in support may indicate that recycled content standards are once again under serious consideration by global policymakers as a policy tool.

Policy Design Considerations

Products and Materials Targeted: Policymakers designing recycled content standards face many decisions regarding what types of materials, products, industries and distribution channels to include within the policy's scope. Reloop, an international environmental think tank, advocates for recycled content standards to target products and industries that are less consumer-facing, which face fewer quality restrictions—i.e. initially exempting food or pharmaceutical products given the heavy regulation within these industries. The group also recommends initially targeting PET packaging, given that there is a relatively robust market for recycled PET in many countries around the world (Reloop, Position Paper, 2018).

Recycled Content Minimum: One of the most fundamental features of a recycled content standard is the minimum required level of PCR. In the United States, the minimum target is 10% for Wisconsin (ISSA, 2005) and 25% for California and Oregon (CalRecycle, 2019; Oregon DEG, 2007). More recent conversations in Europe and Australia indicate that a 25-30% minimum is under consideration for new recycled content standards (Credit Suisse, 2018). Alternatively, other approaches policymakers could take to set the recycled content minimum include varying the minimum by material or product type, and/or designing the minimum to increase over time (Reloop, Position Paper, 2018).

Verification of Recycled Content: Policymakers must establish consistent and straightforward mechanisms for companies to demonstrate their compliance with the standards. For instance, policymakers can set up registers of certified PCR suppliers and development channels for the dispersal of "secondary materials certificates" awarded at the point-of-sale to packaging manufacturers (Eunomia, 2018).

Advantages of Recycled Content Standards

Ensures that companies adhere to their PCR content goals: While companies that establish and achieve voluntary PCR content goals arguably deserve recognition, there is always the risk that these companies can renege on their commitments, should the price of virgin plastics drop below the price of PCR plastics. This risk was illustrated by the UK dairy industry, which formerly set a collective target of sourcing 10% recycled HDPE in their containers by 2010, with increased targets of 30% by 2015 and 50% by 2020. After the industry achieved its first two targets, the price of crude oil declined sharply, leading to a subsequent drop in the price of virgin plastics. Consequently, many companies in the dairy industry walked back from their commitments in 2014 (Eunomia, 2018). A mandated recycled content standard offers a solution towards ensuring that producers meet a minimum level of PCR content regardless of fluctuations in the price of oil.

Establishes greater consistency and certainty of demand for recyclers: The recycling industry can face enormous financial challenges due to the discrepancy in elasticity between supply and demand. Specifically, demand for recycled plastics is highly price-sensitive and variable, due to global fluctuations in the price of oil. Alternatively, the supply of recycled plastics is relatively inelastic, as recyclers will contract with municipalities to receive their recovered materials over multi-year periods. By stabilizing market demand for PCR plastics, recycled content standards could thus increase demand certainty and financial viability for recyclers.

Potentially straightforward to implement: One of the biggest concerns regarding policies that mandate or incentivize increased use of recycled content is how regulators will go about monitoring and enforcement. However, opportunities exist for policymakers to overcome this obstacle. Specifically, given that the information about a product's recycled content constitutes a product claim, policymakers have an opportunity to take advantage of existing government-managed verification processes and resources that regulate fraudulent claims. Even in developing countries with limited regulatory resources, McKinsey analysts evaluating a number of policy options rated recycled content mandates as 5 out of 7 with regard to ease of implementation (Ocean Conservancy, 2015).

May experience industry support: Given that many large packaging and CPG companies are already proactively establishing recycled content goals for themselves, mandated recycled content standards are arguably aligned with the industry's dominant momentum. Moreover, recycled content standards could potentially make it easier for packaging manufacturers and brands alike to achieve their PCR goals. It is risky for individual converters to commit to sourcing high quantities of PCR resins when competitors have the ability to procure cheaper virgin resins and potentially gain a competitive advantage with corporate buyers. However, a mandate that applies to all companies within the industry could mitigate this risk by leveling the playing field. Additionally, policymakers could also help lower search and transaction costs for producers by publishing lists of PCR resin suppliers, like the California Department of Resources Recycling and Recovery has done (CalRecycle, 2019).

Proof of concept exists: In the United States, California, Oregon and Wisconsin have all implemented recycled content standards for plastic packaging. However, despite the long period of time that these policies have been in place, it is difficult to assess their impact. Not only did Wisconsin's policy set a low minimum of 10% to begin with, it also permitted manufacturers to include pre-consumer recycled content in order to demonstrate compliance, which does not generate demand for recyclers (ISSA, 2005). In Oregon, the state's recycled content standards only take effect if the statewide recycling rate falls under 25%. Accordingly, since the state has managed to exceed a 25% recycling rate, its recycled content policy has never been enforced (ODEQ, 2007).

Similarly, there is a lack of available information regarding the success of California's recycled content standards for plastic packaging, despite having registered over 1,600 manufacturers by 2015 and publishing annual enforcement reports (CalRecycle, Enforcement Report, 2014 and 2015). However, data are available for a similar policy in the state that targets newsprint. In a 2010 progress report, CalRecycle reported that 49.8% of newsprint sold in California was "recycled-content newsprint" (RCN)—which was made from 40% of higher waste paper fibers—all but achieving its 50% goal. Moreover, the report found 70% of printers and publishers to be in compliance, with the remaining 30% claiming exemptions (CalRecycle, 2010). In other states as well, recycled-content standards for newsprint have been successful (Barlaz and Loughlin, 2001), indicating that recycled-content standards in general have merit as a policy tool.

Disadvantages of Recycled Content Standards

Lack of flexibility with regard to sourcing constraints: In setting a mandated percentage of recycled content that producers must use in their packaging, recycled content mandates offer little flexibility to companies that may face a range of sourcing constraints. For example, by requiring a minimum level of PCR content, producers are hindered in their ability to respond to fluctuations in resin price, which poses potential risks to their margins. Industry stakeholders have also voiced concerns about the availability of an adequate supply of PCR resins that can meet their quality specifications, particularly for food, beverage and medical packaging applications.

May experience industry opposition: Although recycled-content mandates have the potential to provide industry stakeholders with several benefits, opposition may emerge towards the policy for several reasons. First, even if their' sourcing goals are aligned with policymakers' goals, companies may resent encroachment on their autonomy regarding purchasing decisions. Additionally, by mandating that the entire packaging industry meet a recycled-content minimum level, the policy could weaken companies' ability to generate positive publicity from previous efforts to establish their own recycled-content goals.

5.3.2. Virgin Resin Taxes

Overview

Virgin resin taxes are material input taxes imposed on either packaging manufacturers or brands for the purchase of virgin plastic resins. When imposed on packaging manufacturers at the point-of-manufacture, the tax is based on the volume of virgin resin purchased, so that the price per ton of virgin plastic increases. When imposed on brands, the tax may instead be based on all packaging that contains more than a stated limit of virgin plastic content.

This policy tool is not widespread in plastic packaging applications. However, in 2018, both France and the United Kingdom announced that their governments would implement virgin resin taxes. The UK's policy, which applies to all plastic packaging that does not include at least 30% recycled content, is planned to go into effect in 2022, and will be part of a larger reform effort within the country's Packaging Producer Responsibility System (Plastic News Europe, 2018).

Policy Design Considerations

Location of Tax in Value Chain: Virgin resin taxes can target either packaging manufacturers or brands. However, environmental research organizations like Eunomia advocate for imposing the tax on the former for two reasons. First, it is extremely difficult to determine the amount of virgin versus PCR content in packaging once it has been mixed together and processed into its later-stage product forms. Thus, from a traceability and enforcement standpoint, it is simpler to apply the instrument to packaging manufacturers, since they possess the necessary data regarding the amount of virgin and PCR plastics they're consuming in their operations in the form of purchase orders. Additionally, as the buyer of virgin and PCR resins, packaging manufacturers are the decision-makers that are most directly affected by increases in the cost of virgin resins, which, from a policy design perspective, increases the instrument's level of effectiveness.

Virgin Content Threshold: If policymakers choose to target brands and apply the virgin resin tax to finished products, it may not be technically or politically feasible to apply the tax to all products that contain any amount of virgin plastic content. A more pragmatic approach is instead to establish a maximum virgin resin content threshold and apply the tax to products that exceed it. For example, the United Kingdom is proposing to tax plastic packaging that contains more than 70% virgin content—i.e. less than 30% post-consumer recycled content (Plastic News Europe, 2018).

Tax Rate: A key component of virgin resin taxes that policymakers must decide on is how to structure the tax rate. For instance, the tax can either be a flat rate (e.g. $100/ton) or variable based on market price. Given plastic's high level of price volatility, a variable tax may be more appropriate than a flat tax. For virgin resin taxes applied at the brand level, proposed rates have varied between 5% and 10% (Credit Suisse, 2018). Additional factors that can influence a policy's tax rate include funding requirements, willingness-to-pay and the estimated cost of negative societal externalities, though this last factor can be very difficult to calculate at the individual polymer level.

Use of Revenue: Finally, as with any revenue-generating policy instruments, policymakers must determine what to allocate the revenue towards. Revenues from a virgin resin tax could feed into the government's general fund, for instance, or it could be earmarked for specific environmentally-related programs such as PCR content monitoring and enforcement programs.

Verification of Recycled Content: Similar to recycled content standards, policymakers must establish consistent and straightforward mechanisms for companies to demonstrate their compliance with the standards.

Advantages of Virgin Resin Taxes

Increases the price competitiveness of PCR plastic: By increasing the cost of virgin plastic, virgin resin taxes can improve the price competitiveness of PCR resins. This change could be particularly helpful for companies interested in setting sustainability commitments to use more PCR content, in that the tax could make the business case easier to justify to the broader organization.

Offers producers greater flexibility than recycled content standards: Unlike the mandate set by recycled content standards, virgin resin taxes allow producers to maintain a higher level of decision-making power over their plastic sourcing decisions. While virgin resin taxes incentivize companies to decrease their use of PCR, the policy does not outright prohibit it, giving companies greater flexibility in balancing sustainability with other factors such as quality, cost and existing supplier relationships.

Generates revenue to cover program costs: Virgin resin taxes generate revenue, which policymakers can utilize not only to cover the administrative costs associated with the policy, but also to fund initiatives that further develop end markets for PCR plastic. For example, excess revenue could be used for programs that provide financial and technical support to plastics recyclers to expand their operational capacity.

Disadvantages of Virgin Resin Taxes

Faces challenging implications from international trade: One of the biggest challenges facing virgin resin taxes is the economic disparity between imported products and domestically produced that are subject to a domestic tax. In response, a Border Tax Adjustment has been proposed, with an end goal of leveling of the playing field to ensure that domestic producers remain price competitive with foreign competitors. However, it is very difficult to determine the level of virgin plastic versus PCR plastic in finished packaging products, which makes effectively applying a Border Tax Adjustment a challenging concept (Eunomia, 2018).

Potential pushback from industry stakeholders: Because a virgin resin tax will increase costs for producers, it seems likely that some industry stakeholders will oppose the policy, particularly if the tax revenue is used to fund programs unrelated to plastics recycling (Credit Suisse, 2018).

May incentivize lightweighting over increasing PCR: One concern that implementing a virgin resin tax may raise is that, rather than incentivizing producers to reduce their virgin content by substituting in recycled content, firms will instead pursue a strategy of lightweighting their packaging. Lightweighting—that is, using less material in the packaging overall—would not only reduce the cost of taxes that companies would pay for virgin resins, but would also enable companies to reap additional benefits like reduced freight costs. While lightweighting can have ecological advantages such as lowering freight-related emissions, it nevertheless does not increase demand for recycled plastic and can even exacerbate recycling challenges by increasing the production of difficult-to-separate multi-material layers.

Lacks proof of concept for plastic packaging: While the concept of a material input tax is not necessarily new, there does not appear to be any cases in which this policy tool has been applied specifically to virgin plastic versus recycled plastic inputs. Without real world case examples, it is difficult to make conclusive statements about the feasibility and effectiveness of virgin resin taxes.

5.3.3. Tradable Permits

Overview

The concept of tradable permits is based on the same policy mechanism as "cap and trade" schemes for regulating hazardous emissions. In the case of plastic packaging, the "cap" is the percentage of virgin resin content within a product. Companies that are able to cap the proportion of virgin plastic resins used in their products and use a higher proportion of PCR content earn credits, also referred to as permits, which they can then sell to other companies that face greater difficulty in capping their use of virgin resin content. Governments can also issue their own permits in the event of an insufficient number of privately-owned permits on the marketplace.

Tradable permits are similar to virgin resin taxes in that they are both market-based instruments that increase the price of virgin plastic. However, there is a key difference between the two policies in that taxes provide price-control, while tradable permits provide quantity-control. In other words, within a virgin resin tax scheme, the government sets the price of virgin plastic, and the market determines the optimal quantity purchased, whereas within a tradable permits scheme, the government sets the quantity of virgin plastic purchased, and the market determines the optimal price. Theoretically, both policy tools can be used to achieve the same outcome. However, in instances of high uncertainty regarding the marginal benefits or marginal costs of pollution abatement, the two policies can differ in their economic efficiency (Yohe, 1978). Moreover, both instruments have additional economic and political considerations that will influence the effectiveness and overall success of implementation.

Tradable permits in cap and trade schemes have been used for decades as a pollution control instrument for reducing harmful gaseous emissions, such as carbon dioxide in the European Union, South Korea, China, and New Zealand, and sulfur dioxide in the United States. Based off of these historical precedents, however, it appears that tradable permits have only ever been applied to industrial discharges (i.e. system outputs), and the application of this policy tool towards reducing raw materials (i.e. system inputs) such as virgin plastic resins has not been attempted. Consequently, the discussion of tradable permits as a policy instrument for increasing demand for PCR plastic in this report is based primarily off of hypothetical explorations by environmental think tanks such as Eunomia (2018).

Policy Design Considerations

Location of Tax in Value Chain: Similar to virgin resin taxes, policymakers must decide at what point along the value chain to implement tradable permits. The policy tool could be applied towards packaging manufacturers or brands.

Cap Limit: In designing a policy with tradable permits, policymakers can either require permits to be purchased to cover any use of virgin resin content or to allow the use of virgin content up to a specified threshold, after which companies must purchase permits. The level at which the material is capped will depend on factors such as the availability and substitutability of PCR resins and the buy-in of industry stakeholders.

Size of Market: The establishment of a marketplace for trading virgin resin permits raises the question of who can and must participate in the marketplace. Ideally, a large number of companies both on the selling and buying side can increase competition and drive greater efficiency. However, governments are constrained by the resources needed to monitor the companies involved, which theoretically becomes less financially and logistically feasible as more companies participate. To strike the right balance, policymakers may set parameters based on firm size or specific sub-sectors in order to establish which companies should be included.

Permit Transaction Process: Another critical element of a tradable permits policy is the process through which permits are actually traded. In some cases, companies have to go through a governmental agency, while in others, companies can trade directly B2B, which can facilitate quick transactions (Schmalensee and Stavins, 2017).

Use of Revenue: Finally, in the event of the governing agency issuing its own limited number of permits, policymakers must decide how to allocate the revenue generated by the sale of these permits. For example, as mentioned within other policy instrument design considerations, revenues could be allocated towards covering program-related costs or deposited directly into a general fund.

Verification of Recycled Content: Similar to recycled content standards, policymakers must establish consistent and straightforward mechanisms for companies to demonstrate their compliance with the standards.

Advantages of Tradable Permits

Ensures consistency of demand for recyclers: As companies theoretically investigate avenues to reduce the cost of their permit purchases and instead earn revenue through selling permits, they will begin to use more and more PCR plastic content. This increase in market demand gives recyclers greater certainty of finding end users, and thus greater financial stability.

Supports industry commitments to PCR goals: Similar to virgin resin taxes, tradable permits can be a source of motivation for companies to set and follow through with public sustainability commitments to increase their use of PCR content. For companies that are proactive about sourcing high levels of recycled plastic in their products, this investment brings in new revenue opportunities through the sale of permits to competitors. Additionally, because the policy would apply to all or most stakeholders within the packaging or CPG industry, companies may feel a collective pressure to keep up with the progress made by their peers so as to avoid falling behind.

Offers producers greater flexibility than recycled content standards: Like other market-based instruments discussed in this report, tradable permits preserve companies' autonomy in making product design and sourcing decisions. Despite the financial incentive to seek alternative materials in the form of permit requirements, producers may still determine that these costs are outweighed by the advantages of continuing to use virgin plastics in the short-term.

More economically efficient than other policy tools: Assuming a sufficiently large market, companies will possess differing capabilities with regard to transitioning from virgin content to PCR content. The firms for which increasing their use of PCR resins is relatively inexpensive can subsequently be rewarded for doing so by selling credits to competitors. Not only does this market heterogeneity give producers flexibility and opportunities for competitive advantage, it also benefits society, in that the costs of reducing virgin resin content are being carried out in the most economically efficient manner (Schmalensee and Stavins, 2017). Thus, compared to recycled content standards and virgin resin taxes, tradable permits arguably come closer to maximizing social welfare.

More responsive to inflation than virgin resin taxes: Because the market establishes the price of the virgin resins under quantity-control policy instruments like tradable permits, it can respond more easily to inflation and adjust the cost of a permit accordingly. In contrast, the cost of virgin resins under a tax policy is established by the government, and thus not as adaptive to inflation, potentially leading to a tax that is disproportionately higher or lower than intended (Lyon, 2018).

Generates revenue to cover program costs: If the governing body issues permits for sale, it can use the revenue generated to help cover the costs of managing the program, as well as other environmental programs and funding priorities.

Disadvantages of Tradable Permits

Requires high degree of regulatory capacity: Tradable permits necessitate a higher degree of regulatory capacity than most other policy tools. Not only does the governing body have to engage in a variety of verification, monitoring and enforcement activities to track how much virgin plastic content producers are using, but it also has to establish and manage the trading of permits between producers. This complexity can be challenging for governmental agencies, particularly if they are inadequately resourced or face issues like corruption.

Challenging implications for trade: Tradable permits face similar challenges as virgin resin taxes with regard to international trade. Because it is very difficult to ascertain the level of virgin versus recycled content in plastic products once they are manufactured, the PCR certificates and other forms of verification are essential for companies to demonstrate compliance. However, these verification programs may not be available to foreign producers in their countries of origin, which presents the challenge of monitoring the firms' levels of virgin plastic content and the assessing the number of permits it can buy or sell.

Lacks proof of concept for plastic packaging: As mentioned above, it appears that cap and trade schemes have only been applied to industrial emissions such as carbon dioxide and sulphur dioxide, and therefore discussions about using tradable permits as a tool to cap virgin plastic use and increase market demand for PCR plastic remain hypothetical. As a result, although case examples exist in which tradable permits successfully achieve desired pollutions reductions (Schmalensee and Stavins, 2017), it is difficult to draw conclusions about the feasibility and effectiveness of this policy instrument for virgin resin content in plastic packaging.

6. KEY FINDINGS AND RECOMMENDATIONS

6.1. Policy Analysis Results

Using the decision support tools outlined earlier in this report, each of the above policy instruments was scored and compared according to a range of evaluation criteria using a constructed performance scale. Those criteria were aggregated into four broader groups: *Waste Management*, *Implementation & Operations*, *Funding & Economics*, and *Sociocultural Factors*. Individual criteria scores within each category were normalized to create an overall category score on a -1 to 1 scale.

For example, *Waste Management* encompasses four evaluation criteria: *Increases plastic recycling rates, Increases landfill diversion rates, Improves quality of recyclables stream,* and *Reduces leakage points in solid waste management chain.* Each policy is scored according to these criteria on a -2 to 2 scale. These individual criteria scores are then used to create a normalized category score on a -1 to 1 scale that reflects the policy's performance in terms of *Waste Management* as a whole. This process is repeated for each category. A Final Policy Score was then calculated by finding the mean of each policy's performance according to those four Normalized Category Scores. The results of this scoring system, including Normalized Category Scores and Final Policy scores, are summarized in **Fig. 4**. A more detailed visualization of the scoring process and results, including each policy's score on each evaluation criterion, can be found in **Appendix 8.3**.

	Command-and-Control Policy Alternatives			
	Increasing Recycling Rates		Reducing Plastic Consumption	Developing End Markets
	Product Take-Back Mandates	Landfill/ Disposal Bans	Product/ Material Bans	Recycled Content Standards
Waste Management	0.375	0.250	-0.250	0.375
Implementation & Operations	0.250	-0.125	0.250	0.000
Funding & Economics	0.500	0.000	-0.750	0.250
Sociocultural Factors	0.250	0.000	-0.500	0.250
Final Policy Score	**0.344**	**0.031**	**-0.313**	**0.219**

	Market-Based Policy Alternatives					
	Increasing Recycling Rates			Reducing Plastic Consumption	Developing End Markets	
	Advance Disposal Fees	Deposit-Refund	Pay-As-You-Throw	Product Taxes	Virgin Resin Taxes	Tradable Permits
Waste Management	0.375	0.875	0.125	0.125	0.250	0.375
Implementation & Operations	0.375	0.375	-0.125	0.750	-0.125	-0.125
Funding & Economics	0.500	0.250	0.250	0.500	0.750	1.000
Sociocultural Factors	0.250	0.250	0.000	0.000	0.250	0.250
Final Policy Score	**0.375**	**0.438**	**0.063**	**0.344**	**0.281**	**0.375**

Fig. 4: *Final policy scores for the recycling policies analyzed, grouped into Command-and-Control Policy Alternatives and Market-Based Policy Alternatives*

Policies were compared and contrasted using their Final Policy Scores (highlighted in green in **Fig. 4**). There are considerable differences among the scores of policies aimed at Increasing Recycling Rates, with values ranging from 0.031 to 0.438. Policies aimed at Developing End Markets for PCR materials are more consistent in their performances, ranging from 0.219 to 0.375. Although they are not the primary focus of this report, two policies aimed at Reducing Plastic Consumption—Product/Material Bans & Product Taxes—were also evaluated because they have emerged as prevalent policies aimed at addressing plastic waste issues. These policies showed the broadest range of performance, from -0.313 to 0.344, respectively.

This scoring process is not intended to be used as an absolute indicator, but rather as a means of applying a systematic framework to our policy analysis. Although the list of evaluation criteria used includes the most salient factors that we encountered in our research, it is by no means comprehensive, and is potentially subject to judgmental biases that arose during our largely qualitative research process. As such, it is more accurate to view these scores as guidelines for structuring our recommendations. With these caveats in mind, we base our recommendations on the results generated by this process, focusing on those policies that scored the highest relative to other policies with the same aims: Deposit-Refund Systems, Virgin Resin Taxes, and Tradable Permits. However, due to some practical limitations that our analysis tool failed to incorporate, our recommendations for policies aimed at Developing End Markets are not directly derived from this scoring system.

6.2. Key Findings and Recommendations

Our analysis yielded several key findings and recommendations, both regarding individual policy instruments, as well as general best practices regarding to policy development and waste management strategies. The most salient takeaways include:

Key Finding: *Voluntary industry-led initiatives play an important role in addressing plastic pollution, but mandatory government-led policies are still needed.*

A growing contingent of companies are recognizing the need to respond to the massive challenges posed by plastic leakage into the environment. In recent years, hundreds of major corporations have set ambitious goals and taken substantive action to improve the sustainability of their packaging and to reduce plastic pollution. While this demonstration of sustainability leadership is admirable, voluntary commitments are structurally flawed as a solution towards environmental and social issues caused by plastic packaging pollution. Ultimately, there is a need for governments to instate mandatory public policies, which can address the structural flaws inherent to voluntary commitments.

One of the most critical shortcomings that mandatory policies can address is the lack of accountability that often accompanies voluntary industry commitments. Without standardized and public reporting requirements, it can be difficult for the public to discern which companies are taking concrete steps to improve their environmental impacts and which are merely engaging in greenwashing. Moreover, without the accountability that legislation entails, companies may be tempted to walk back from voluntary commitments, if implementation proves to be more complicated or expensive than anticipated. To this end, mandatory public policies can also create more favorable economic conditions for companies to pursue sustainability strategies. By leveling the playing field and internalizing environmental costs, mandatory policies can financially incentivize businesses to invest in post-consumer recycling efforts and make sustainable product innovations more compelling.

Mandatory policies can also serve as a tool to coordinate and harmonize industry efforts to advance sustainability. If every individual company pursued a different approach for reducing plastic waste with a resulting plethora of disposal requirements, this fragmentation could cause significant confusion on the part of consumers, as well as deprive companies from leveraging opportunities for economies of scale. It should be noted, however, that governmental legislation can also lack harmonization, not only between countries, but even within countries as well. Policy fragmentation poses major challenges for national and multinational companies that have to navigate compliance across different jurisdictions. To mitigate this risk, policymakers should solicit industry input during the policy development process to understand the extent of the regulatory complexity companies are being asked to navigate. Ideally, efforts should also be made to harmonize newly proposed policies with existing policies, while also balancing the needs of policymakers' constituents in differing contexts.

Finally, it is important to note that mandatory public policies are particularly important in developing countries. Two of the key sources of motivation behind industry-led environmental initiatives are consumer demand for more sustainable products and brands, as well as pressure from activist and watchdog organizations. These drivers are often weaker in developing countries and therefore fail to provide the necessary impetus that companies often need to set and meet voluntary commitments (Blackman, 2010).

Recommendation: *Policymakers should encourage industry-led initiatives and public-private partnerships, but not in place of pursuing mandatory policy solutions.*

Industry-led initiatives and public-private partnerships represent enormous opportunities for the development and implementation of sustainable solutions at scale. Coalitions like the New Plastics Economy, the Trash Free Seas Alliance and the Alliance to End Plastic Waste are engaged in crucial work that has already driven immense progress, and policymakers should continue to support the development of more voluntary cross-sector efforts such as these. However, as previously discussed, voluntary commitments can also fall short of achieving the progress needed to address crises such as plastic pollution, and policymakers should pursue bold, mandatory policy solutions in concert with these industry-led efforts.

Key Finding: *Deposit-refund systems are the most promising policy tool for decreasing pollution and increasing recycling rates.*

Among the policy instruments examined in this report, deposit-refund systems are the top-performing policy. Most notably, deposit-refund systems are highly effective at reducing litter and increasing recycling rates, as demonstrated by numerous studies and real world case examples. Additionally, deposit-refund systems internalize the cost of pollution and waste in an economically efficient manner, only imposing costs on consumers when they fail to recycle products. For refunds that are uncollected or only partially refunded, deposit-refund systems also generate their own source of funding to cover program costs. Deposit-refund systems also increase the quality of the materials collected for recycling by encouraging consumers to segregate materials into separate streams, thus avoiding contamination from other materials. Finally, deposit-refund systems can be applied in a variety of economic and cultural contexts. Successful state-run and industry-run deposit-refund programs exist in both developed and developing countries around the world.

"*Theoretical models have shown that alternative waste disposal policies, such as virgin materials taxes, advance disposal fees, recycled content standards, and recycling subsidies are inferior to a deposit-refund.*" –Margaret Walls, **Resources for the Future**

"*In selecting policies within the EPR framework, multi-instrument policies, such as deposit/refund, are likely to be more efficient than single instrument policies such as an advance disposal fee.*" –Daniel Kaffine and Patrick O'Reilly, **OECD**

"*The industry should support state and national bottle bills since bottle-deposit programs have proved effective in collecting a clean, valuable recycling stream.*" –Don Loepp, **Plastics News**

Recommendation: *Implement deposit-refund systems for high-value recyclables (e.g. PET bottles) and explore the feasibility of extending this policy to low-value materials as well.*

Deposit-refund systems already have a strong track record of success with high-value plastic packaging such as PET and HDPE. This presents a significant opportunity for reducing plastic pollution, as two of the ten most common forms of marine pollution are PET bottles and bottle caps. Thus, deposit-refund systems could act as a significant lever in reducing two of the most prevalent forms of plastic in the environment.

Additionally, some governments are exploring extending the deposit-refund model to other forms of packaging that have historically been more difficult to recycle, such as flexible plastic packaging. In Canada, the provinces and territories of Alberta, British Columbia, Newfoundland & Labrador, Northwest Territories and Prince Edward Island currently include flexible drink pouches and bag-in-a-box products in their deposit-refund systems, charging deposit fees of 0.05-0.25 CAD per pouch (CMC, 2018). Similarly, in India, the state of Maharashtra recently proposed establishing a deposit-refund system for flexible milk pouches, charging 50 paise per pouch (Times of India, 2018).

Even if there are limited end market opportunities for all low-value plastics to be recycled, simply collecting these materials so that they can be properly managed would prevent waste from leaking into the environment. Thus, deposit-refund systems still present benefits for low-value materials, despite concerns that these materials cannot yet be recycled in a truly circular way.

Recommendation: *Implement deposit-refund systems on a national or multinational scale to reduce fraudulent redemptions and partner with border enforcement agencies.*

As described earlier in this report, one of the challenges of implementing deposit-refund policies is the risk of fraudulent returns—that is, consumers purchasing products in locations that do not charge deposits and returning them in different locations that offer refunds. This free-riding practice is problematic, in that it can cause major funding deficits in the deposit-refund program, as seen in California. To combat this risk, policymakers should aim to implement deposit-refund systems on a national scale rather than a piecemeal, local approach, launch public education campaigns to inform the public about what constitutes a legitimate return, and partner with border enforcement agencies to better regulate organized criminal activity. Additionally, national governments (e.g. within the

European Union) should ideally seek to collaborate with neighboring countries to harmonize deposit-refund systems in order to reduce differences between deposit and refund rates that may incentivize consumers to engage in fraudulent returns.

Key Finding: *Product bans and product taxes both have mixed success in reducing plastic consumption and present additional drawbacks.*

Both product bans and product taxes have the potential to lower the consumption of plastics and thus reduce the volume of plastic waste that must be managed at the end-of-life. However, the results of case studies in which these policy tools have been employed are mixed. Factors such as the lack of capacity and resources for enforcement and the presence of black markets severely undermines the effectiveness of product bans, while the effectiveness of product taxes is dependent on the tax being set at a sufficiently high rate. Additionally, the success of both policies is hindered in situations where manufacturers and consumers lack access to product alternatives that can provide equivalent levels of functionality and value. Moreover, even when these policy tools are effective at reducing plastic consumption, they may inadvertently incentivize increases in demand for products that come with their own set of negative impacts, which may even represent a larger environmental burden than the products they are replacing. Finally, in focusing on plastics reduction rather than circularity, product bans and product taxes cause society to forgo the benefits of plastic use which remain significant in a large number of markets and communities worldwide.

Key Finding: *At this time, there is no conclusively superior policy instrument for increasing demand for PCR plastic.*

In comparing the different policy options designed to increase demand for post-consumer recycled plastics, we were unable to conclude that any one policy is clearly superior. Rather, all of the instruments that we examined presented notable benefits and tradeoffs. Recycled content standards have been successfully implemented in multiple geographies and offer recyclers more certainty with regard to market demand for PCR resins than market-based policies. However, recycled content standards do not offer brands and packaging manufacturers a great deal of flexibility and do not consider other factors and barriers to change that these industry stakeholders face in their procurement decisions, such as cost, material quality and existing supplier relationships.

Virgin resin taxes and tradable permits, on the other hand, are less prescriptive. While both increase the costs of virgin resins to producers, they still offer flexibility in their purchasing decisions. In some cases, virgin resin taxes and tradable permits may even support companies' sustainable procurement strategies by increasing the price competitiveness of PCR resins compared to virgin resins. Additionally, applying the concept of "cap and trade" to virgin resins under a tradable permit policy stimulates competition between producers by offering companies that are capable of using high levels of PCR content new revenue opportunities from the sale of permits. Finally, virgin resin taxes and some tradable permit policies generate revenue that policymakers can use to further environmental objectives such as expanding waste collection services and investing in new recycling technologies.

However, unlike recycled content standards, the use of virgin resin taxes and tradable permits to drive demand for PCR in plastic packaging appears to be largely theoretical and lacks adequate proof of concept. Additionally, the regulatory bandwidth required to manage a tradable permit scheme may seem excessively complex to some governments, particularly when accounting for international trade and the challenges of ascertaining the level of PCR content in the finished product stage.

Finally, for all three policies, questions remain regarding their potential impact on the existing supply of PCR resins. A sudden increase in demand is likely to catalyze an increase in the price of PCR resins in the short-term, with implications not only for the packaging industry, but also for other industries that source PCR plastics in their products.

Recommendation: *Build traceability systems within the PCR supply chain to meet future disclosure requirements.*

Regardless of which instrument policymakers believe will be best suited to meet the objective of increasing demand for PCR plastic, all three policy tools require a minimum level of monitoring and enforcement capacity for ensuring compliance. Thus, an intermediate step that policymakers should consider is to develop tracking and reporting systems for PCR resins in the plastics value chain, which will form the basis of compliance requirements included in future policies. For example, policymakers can work with recyclers, packaging manufacturers and brands to establish PCR certificate schemes with standardized means of reporting and verifying PCR content, as advocated by Eunomia, a British recycling think tank (Eunomia, 2018). Additionally, policymakers can officially register PCR suppliers and list them on public databases, which would lower the search and vetting costs incurred by producers. Tracking and reporting systems such as these are critical towards the successful implementation of any policy involving PCR disclosure requirements.

Recommendation: *Explore the feasibility of market-based policies such as virgin resin taxes and tradable permits with further research.*

As more policymakers, academics and industry stakeholders recognize the importance of increasing demand for PCR plastics as an essential component of a circular plastics economy, research and popular dialogue surrounding these two market-based policies is still evolving. In order for policymakers to make informed decisions in the future, additional research and pilot programs are needed to better understand the feasibility of both virgin resin taxes and tradable permits.

Recommendation: *Incorporate the following general best practices into the development of new waste and recycling policies.*

The OECD's 2016 report "Extended Producer Responsibility: Updated Guidance for Efficient Waste Management" lists the following best practices in developing EPR policies, which can be extended generally to most of the waste and recycling policies considered in this report:

- Clearly define the policy's objectives and scope
- Take a systems-level, life-cycle approach
- Prioritize transparency in cost structure and use of revenue
- Incorporate eco-modulation into fee design so that costs reflect actual end-of-life management for specific products
- Prevent anti-competitive activities among producers, PROs and waste management firms
- Identify and mitigate opportunities for free-riding
- Develop independent and adequately funded monitoring and enforcement mechanisms
- Foster collaboration across the value chain

Key Finding: *Addressing rudimentary gaps in waste management infrastructure and services in high-leakage countries will provide immediate reductions in plastic pollution in the environment.*

Over 80% of global plastic pollution in the ocean comes from land-based sources. About 75% of this amount is from uncollected waste, while the remaining 25% is the result of mismanaged waste post-collection due to issues such as a lack of proper controls during transportation or at landfills, the proximity of landfills to waterways, and illegal dumping (Ocean Conservancy, 2015). Moreover, over half of ocean-bound plastic comes from just five rapidly developing countries—China, Indonesia, the Philippines, Thailand and Vietnam (Ocean Conservancy, 2015)—for which the challenges of uncollected and mismanaged waste are even more pronounced. Very basic measures that are immediately implementable, such as increasing the number of public waste bins, installing fences and other controls around disposal sites, optimizing collection routes and altering incentive structures to reduce illegal dumping, can be immensely impactful towards stemming some of the largest points of leakage. The Ocean Conservancy estimates that the combination of short-term strategies like these and medium-term investments in larger infrastructure projects in the five countries listed above would reduce plastic leakage by 45% worldwide over 10 years (Ocean Conservancy, 2015).

Recommendation: *Supplement the implementation of policy tools with investments in a combination of simple, short-term and ambitious long-term infrastructure and technology solutions.*

In addition to pursuing the enactment of public policies to decrease plastic pollution and increase recycling rates, governments must also expand waste and recycling infrastructure and services. In particular, governments should prioritize both short-term initiatives, such as trash fences and public waste bins, and long-term strategies like investing in large-capacity collection and processing facilities. Technological innovation in circular materials science, packaging design, distribution models and material recovery should also be encouraged.

Recommendation: *Recognize the agency of informal waste workers and partner with them to develop equitable solutions, such as establishing informal sector cooperatives.*

As previously discussed, the informal sector often provides critical value to the waste management ecosystem. In some developing countries, informal actors have been shown to outperform formal systems in terms of overall recycling rates by as high as 20-30% (Velis et al., 2012). While inconsistencies in data collection make it difficult to draw precise conclusions about the impact that the informal sector has specifically on plastic packaging recycling rates, it is impossible to dismiss the value that they provide to governments in the form of stemming some plastic leakage. Particularly in countries lacking the funds to invest in collection services and sorting technologies, supporting and investing in the informal sector presents a low-tech, relatively inexpensive opportunity to bolster waste management.

Given that individual waste pickers are often constrained by a lack of financial, infrastructural and administrative resources, policymakers and industry stakeholders should consider supporting the formation of informal sector cooperatives. A cooperative can serve as a tool for these actors to gain formal recognition from governmental and commercial entities, to enter into formal contracts, and to ultimately realize greater incomes (Aparcana, 2017; Wilson et al., 2009). Additionally, informal cooperatives can increase these actors' collective bargaining power, which can help informal actors combat exploitative practices.

***Recommendation**: Avoid investments in capital intensive waste-to-energy projects, even though they may represent appealing short-term solutions.*

Several key stakeholders within the plastic packaging ecosystem, ranging from policymakers to businesses, view waste-to-energy technologies as a solution towards combating plastic pollution, particularly in light of the shortage of end markets resulting from China's National Sword policy. Some of these arguments are based on the premise that waste-to-energy still captures the value of plastic packaging, as opposed to letting these items occupy space in landfills. Other arguments highlight that waste-to-energy can and has co-existed with recycling in certain countries around the world.

Despite these arguments, in order to achieve a circular plastics economy, any investments in established incineration technologies represent significant challenges to recycling, and thus should be avoided. This recommendation stems from the reality that waste-to-energy technologies as they stand today—that is, excluding emerging technologies like chemical recycling that hold immense opportunity for plastic packaging recycling—are inherently non-circular, in that they prevent plastic materials from being converted back into packaging (Malinauskaite et al., 2017). Instead, virgin resources must be procured in order to produce new plastic packaging, which demands more energy than recycling, even when taking recyclables' collection, sorting, and shipping into consideration (Morris, 1996). Lastly, and perhaps most importantly, waste-to-energy schemes threaten the entire recycling ecosystem, in that these capabilities ultimately weaken incentives to sort and collect recyclables, thus decreasing the volume of collected recyclables and ultimately starving recyclable end markets.

7. CONCLUSION

The purpose of this study was to analyze the advantages and disadvantages associated with different policy tools that governments can use to reduce plastic leakage into the environment, increase plastic recycling rates and develop end markets for recycled plastic. Our findings suggest that deposit-refund schemes hold the most potential as a policy tool for minimizing pollution and increasing recycling. With regard to increasing demand for recycled plastic by developing end markets, our research revealed that recycled content standards are a viable option for policymakers. Market-based instruments such as virgin resin taxes and tradable permits also hold immense potential, although further research is required to assess the feasibility of their application to plastic packaging. Ultimately, however, the systemic nature of plastic waste and recycling necessitates a combined suite of policy options that must always be tailored to the specific objectives and context of the country in which they are being implemented.

There are no simple solutions to addressing the global challenge of plastic pollution. However, we hope that our research into the benefits and tradeoffs associated with different policy tools will inform and add nuance to the conversations currently taking place around the world amongst policymakers, citizens, NGOs and companies about solutions. Through the use of well-designed public policies, along with technological innovation, product redesign, infrastructural improvements and consumer education efforts, we can move our world closer towards the creation of a circular plastics economy.

8. APPENDICES

8.1. Description of Decision Support Tool Criteria

Waste Management

The effectiveness of any new recycling policy is highly contingent upon its function within the broader waste management system. These evaluation criteria assess key factors relating to the efficacy of recycling policy in terms of its role as part of a broader waste management scheme.

Increases plastic recycling rates

Does the policy have a direct impact on plastic recycling rates? If so, does it increase or decrease rates? Increased rates can be achieved through a variety of methods; this seeks only to determine the end result of the policy vis-a-vis overall recycling rates in the country in which the policy has been implemented.

Increases landfill diversion rates

Does the policy directly impact landfill diversion rates? The amount of landfilled materials—measured either by weight or volume—is not a direct indicator of a change in recycling, as other waste disposal methods such as composting and waste-to-energy can affect landfill diversion rates. However, increasing diversion rates can be one component of a systematic approach to increasing plastics recycling.

Improves quality of recyclables stream

The market value of recyclable materials is highly contingent upon the quality of the materials. 'Quality' can be a measure of contamination rates from biological factors like food/beverage residue or non-recyclable solid materials, as well as the extent to which a stream is composed of a single material. The characteristics of a particular recycling systems and the policies under which it operates will determine the appropriate interpretation of 'quality.'

Reduces leakage points in solid waste management chain

Leakage can occur at a number of different points in the solid waste management chain, from the point of collection all the way to the end point of the system (e.g. landfill or Material Recovery Facility).

Implementation & Operation

Effective plastics recycling policies must account for potential obstacles to implementation and continued operations, including issues of scope, administrative efficacy, and compatibility with systems already in place.

Applicability to multiple material types

In order to be successful at a broad scale, policies must be applicable to multiple recyclable plastic materials. Accordingly, they must take into account the inherent differences presented by different recyclable plastic materials in terms of the variety of polymers used and other physical characteristics such as weight and volume.

Administrative complexity

Does the policy have the appropriate level of complexity? Effective policies will call for the level of administrative complexity required to achieve set recycling goals, while avoiding overly convoluted structures that place an undue burden on the parties responsible for implementation and continued execution. This applies to higher-level municipal managers as well as those closer to end users in the recyclable material supply chain. This issue is of particular importance in developing countries with less advanced recycling/waste management systems.

Geographic scalability

Is the policy locally specific, or is it scalable across the country and regional level? Although context-specific considerations should be taken into account in the formulation of any new recycling policy, the impact of a policy is linked to its ability to be applied in more than one geographic area.

Compatibility with existing policies and practices

Although some degree of innovation is advantageous in many cases, new recycling policies must be at least somewhat compatible with existing policies and practices in order to be implemented successfully. Factors impacting compatibility include existing infrastructure, market trends, and habitual consumer behaviors. This criterion relates to the concept of 'buy in' for government, industry and the end consumer: the success of a policy hinges on the extent to which the actors involved in its implementation 'buy in' to the new program. A new policy that does not attempt to achieve compatibility with existing structures will create barriers to its own implementation, thus making successful adoption less likely.

Funding & Economics

Adequate and sustainable funding sources represent one of the greatest hurdles facing policy makers seeking to increase recycling rates. In order to succeed and produce a sizable impact in the long term, recycling policies must include adequate and realistic funding mechanisms.

Sustainability/stability of funding mechanism

In order for any recycling policy to be effective on a continuing, long-term basis, it must have a reliable funding mechanism in place. Depending on their structure and goals, different policies will demand different funding approaches, such as fees collected for specific uses/programs or taxes directed into a general fund. However, key areas across all recycling policies that demand sufficient funding sources include installation/startup costs, operations costs, and administrative costs.

Advances price parity of recyclables

The market cost of post-consumer recycled plastic materials compared to virgin resins has a considerable effect on the viability of many recycling policies, whether those costs are realized by government, industry, or the consumer. Those policies that move recycled feedstocks toward price parity with virgin feedstocks will increase the likelihood of a reliable, sustainable source of funding.

Sociocultural Factors

Just as producers of consumer goods adopt different strategies for different markets, shaped by the sociocultural values and norms of their target audience, so, too must plastic recycling policies account for these same factors. Plastic recycling policies must consider not just the end of life of plastic goods, but the human lives affected by that point in the supply chain.

Promotes environmental justice

Recycling policies that promote environmental justice will include explicit measures ensuring that the costs and benefits of plastics recycling are justly and fairly distributed among different socioeconomic groups, and will move toward internalizing costs that have historically been externalized. This is of particular importance in developing countries, and among traditionally marginalized communities such as children, the elderly, women, and disabled persons.

Sociocultural flexibility

Can the policy be adjusted to fit different sociocultural contexts? This evaluation criteria addresses the issue that there is no one-size-fits-all plastics recycling policy. Different contexts call for different solutions, especially when comparing developed countries with advanced recycling and waste management systems to developing countries with more rudimentary systems. Particularly in areas where there is a significant informal recycling sector, the implementation of any new recycling policies must take into account potential impacts and intersections with existing recycling and waste management systems. Failure to do so can result in system inefficiencies, redundant processes, and in some cases strong community resistance that can even result in physical violence.

8.2. Case Study: The Informal Sector in Brazil

Due to the issues of data quality and availability described above, it is difficult to make broad statements about the impact/effectiveness of the informal sector on plastics recycling rates in general, and of informal sector cooperatives specifically. However, a number of notable case studies have been cited as examples of the benefits presented by cooperatives, including Brazil.

Although the quality of its SWM infrastructure is highly variable across the country, in 2010, legislation officially recognized waste picking as an occupation nationwide, allowing the informal sector to be included in government statistics. As of 2017, 65.7% of municipalities have formalized working arrangements with waste picker cooperatives (Resource Recycling Systems, 2018). The number of active waste picker cooperatives in Brazil grew by 25% from 2003-2013, although many operate under arrangements with municipalities lacking any legal contract (Resource Recycling Systems, 2018). Despite inconsistent arrangements with municipal authorities, there are numerous success stories from waste picker cooperatives in Brazil. Coopamare, based in Rio de Janeiro, collects half of the total amount of solid waste collected by São Paulo's municipal services, at a lower cost, and pays its members twice the national minimum wage (Medina, 2000). Unfortunately, much of the literature concerning cooperatives in Brazil focuses on social justice issues and working conditions of waste pickers, making it difficult to relate these statistics on the growth of cooperatives to plastics recycling rates.

8.3. *Detailed Policy Analysis Results*

8.3.1. *Command-and-Control Policy Alternatives*

		Command-and-Control Policy Alternatives			
		Increasing Recycling Rates		**Reducing Plastic Consumption**	**Developing End Markets**
		Product Take-Back Mandates	Landfill/ Disposal Bans	Product/ Material Bans	Recycled Content Standards
Waste Management	Increases plastic recycling rates	1	1	-1	0
	Increases landfill diversion rates	1	1	1	1
	Improves quality of recyclables stream	0	1	-2	1
	Reduces leakage points in solid waste management chain	1	-1	0	1
	Normalized Category Score	**0.375**	**0.25**	**-0.25**	**0.375**
Implementation & Operations	Applicability to multiple material types	2	0	1	-1
	Administrative complexity	-2	-1	1	-1
	Geographic scalability	2	1	1	2
	Compatibility with existing policies and practices	0	-1	-1	0
	Normalized Category Score	**0.25**	**-0.125**	**0.25**	**0**
Funding & Economics	Sustainability/stability of funding mechanism	2	-1	-1	-1
	Advances price parity of recyclables	0	1	-2	2
	Normalized Category Score	**0.5**	**0**	**-0.75**	**0.25**
Sociocultural Factors	Promotes environmental justice	1	0	-1	1
	Sociocultural flexibility	0	0	-1	0
	Normalized Category Score	**0.25**	**0**	**-0.5**	**0.25**
	Final Policy Score	**0.34375**	**0.03125**	**-0.3125**	**0.21875**

8.3.2. *Market-Based Policy Alternatives*

		Market-Based Policy Alternatives					
		Increasing Recycling Rates			**Reducing Plastic Consumption**	**Developing End Markets**	
		Advance Disposal Fees	Deposit-Refund	Pay-As-You-Throw	Product Taxes	Virgin Resin Taxes	Tradable Permits
Waste Management	Increases plastic recycling rates	1	2	2	1	0	0
	Increases landfill diversion rates	1	1	2	0	1	1
	Improves quality of recyclables stream	0	2	-1	0	0	1
	Reduces leakage points in solid waste management chain	1	2	-2	0	1	1
	Normalized Category Score	**0.375**	**0.875**	**0.125**	**0.125**	**0.25**	**0.375**
Implementation & Operations	Applicability to multiple material types	2	2	2	2	-1	-1
	Administrative complexity	-1	-1	-2	2	-2	-2
	Geographic scalability	2	2	-1	2	2	2
	Compatibility with existing policies and practices	0	0	0	0	0	0
	Normalized Category Score	**0.375**	**0.375**	**-0.125**	**0.75**	**-0.125**	**-0.125**
Funding & Economics	Sustainability/stability of funding mechanism	2	1	1	2	1	2
	Advances price parity of recyclables	0	0	0	0	2	2
	Normalized Category Score	**0.5**	**0.25**	**0.25**	**0.5**	**0.75**	**1**
Sociocultural Factors	Promotes environmental justice	1	1	0	0	1	1
	Sociocultural flexibility	0	0	0	0	0	0
	Normalized Category Score	**0.25**	**0.25**	**0**	**0**	**0.25**	**0.25**
	Final Policy Score	**0.375**	**0.4375**	**0.0625**	**0.34375**	**0.28125**	**0.375**

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