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An Evaluation of Extended Producer Responsibility (EPR) as a Policy Option for Compostable Plastics in California

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An Evaluation of Extended Producer Responsibility (EPR) as a Policy Option for Compostable Plastics in California

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Introduction

In 2015, American's disposed of 137,700 tons of municipal waste in landfills, with the majority (DeSaulnier, 2011)of this being food (22%), plastics (18.9%) and, paper and paper board (13.9%) (United States Environmental Protection Agency, 2018b). The recycling rate has remained relatively steady between 2010-2015 at around 34% (United States Environmental Protection Agency, 2018b). State laws, local ordinances and business owner preferences appear poised to drive a change in the makeup of the municipal solid waste stream. This change is particularly evident when looking at the shift in the type of single-use, disposable food serviceware being used. Between 1988 and 2019 80 local ordinances have been put in place in California that ban expanded polystyrene (EPS) and/or other non-recyclable or non-compostable items from being used by restaurants for takeout food packaging (CA Against Waste, n.d.). It is becoming more common for a consumer to be served to-go food or beverage items in a plastic cup or container deemed "biodegradable" or "compostable". Business owners are embracing compostable plastics for their perceived environmental benefits, with the intent of being sustainable and also to stay competitive as the products become the norm (Meeks, Hottle, Bilec, & Landis, 2015). Although the type of material used to serve to-go food items may be changing in composition, the material will still go to a recycling center, compost center, landfill or other waste management operation for further processing and/or disposal.

In California, disposal of food and other organic materials such as leaves, grass, textiles and carpet make up 37% of the waste stream (Cascadia Consulting Group, 2016). Food is the largest material type disposed of, accounting for 18.1% of the disposal stream (Cascadia Consulting Group, 2016). In 2011, California enacted AB 341 which established the 75% diversion goal of waste from California landfills. California identified moving organics out of the landfill as one of six primary ways to meet the 75% recycling goal (CalRecycle, 2015). To help with the 75% diversion goal, California passed AB 1826 in 2013. AB 1826 requires local jurisdictions to provide organic recycling programs to businesses and multi-family residences of five or more dwellings. In addition, AB 1826 requires local businesses to participate in organics recycling (CalRecycle, 2018b). Nationally, composting has been on the rise with 1.94 million tons of food

composted in 2014 (5 percent of food) increasing to 2.10 million tons composted in 2015 (5.3 percent of food) (United States Environmental Protection Agency, 2018a).

One way to decrease food waste and increase the tonnage of food collected for composting is to make compostable food serviceware truly compostable so consumers can toss uneaten food and items used to eat it directly into the compost bin (Harmon, Hill, Baldwin, Marschall, & Ferrer, 2014). The compostable items, along with the uneaten food, can be diverted to a compost facility where they will degrade into carbon dioxide, water, inorganic compounds and biomass (US Composting Council, n.d.). The degradation of organic material results in compost, a valuable soil amendment that can be added back to the land to provide nutrients and energy for plants to grow (CalRecycle, 2018a).

The introduction of compostable plastic to the waste stream as single-use, disposable food serviceware has created end-of-life management challenges for composting facilities, recycling facilities and consumers to properly sort and identify this new material using traditional techniques (Harmon et al., 2014; US Composting Council, n.d.). One of the ways California has addressed items that are difficult to manage in the waste stream is to implement Extended Producer Responsibility (EPR) laws. EPR laws extend the responsibilities of producers, and all those involved in the product chain, to the end-of-life management of a product and its packaging. EPR laws assign primary responsibility to the producer who makes design and marketing decisions about a product (CalRecycle, n.d.-a). EPR laws shift the responsibility for end-of-life management of a product from the general public and ratepayers to the producers (CalRecycle, n.d.-c). There are currently five products in California that are managed by EPR laws: mercury containing thermostats, agricultural pesticide containers, paint, carpet, and mattresses (CalRecycle, n.d.-c).

Implementing EPR for compostable plastics now, while the product is emerging on the market, would help producers organize to address the end-of-life management challenges their products create. For this project I evaluate whether EPR in California is a viable option to

address the end-of-life management challenges identified for compostable plastics. I do this in three ways (1) review the main challenges identified for managing compostable plastics against the existing EPR laws to look for overlap in challenges California EPR laws have been used to address, (2) review compostable plastics in the context of the Product Selection Criteria used by California, (3) use the California EPR framework to lay out what an EPR program for compostable plastics could look like.

The outcome of the evaluations shows that EPR for compostable plastics would be successful in addressing two of the six challenges identified for compostable plastics: education and identification. When taken into consideration against other products in the waste stream, compostable plastics would not be a priority based on the initial product selection criteria provided by California. Compostable plastics as a material type meet the general requirements of an EPR program in California based on the California EPR framework.

Background

There can be a lot of confusion associated with the terms used to describe, label and inform consumers about biobased plastics. The definitions of four important terms used in this study are provided by the California Department of Resources Recycling and Recovery (CalRecycle) (Harmon et al., 2014):

> **Biobased:** Composed in whole, or in significant part, of biological products, renewable agricultural materials (including plant, animal, and marine materials), or forestry materials.
>
> **Biodegradable:** The ability of a substance to be broken down physically and/or chemically by microorganisms. The term has more detailed scientific and legal specifications, particularly in relation to elapsed time and environmental conditions.

Bioplastic: A plastic made from biobased, renewable materials; or a plastic that is biodegradable; or both. The term may not be well defined in common usage.

Compostable: As defined by ASTM in relation to bioplastics, material that undergoes biological degradation during composting to yield carbon dioxide, water, inorganic compounds and biomass at a rate consistent with other known compostable materials and leaves no visually distinguishable or toxic residues.

Greenwashing and false advertising have led to labeling laws for products sold in California claiming to be compostable that are not. California Senate Bill 567 prohibits the sale of plastic products labelled as compostable unless they meet the requirements of the ASTM 6400-12 standard (DeSaulnier, 2011). The ASTM 6400–12 standard for labelling plastics as compostable requires that the product break down at a rate consistent to other known compostable materials by aerobic degradation in commercial composting facilities to materials that do not diminish the value or utility of the resulting compost (Biodegradable Products Institute, n.d.; Harmon et al., 2014).

Compostable plastics may be made from plants or they can be made from petroleum (US Composting Council, n.d.). The company BASF manufactures a certified compostable plastic from petroleum under the trade name EcoFlex® (US Composting Council, n.d.). EcoFlex® has a special chemical structure allowing biodegradation by microorganisms and their enzymes while meeting the requirements of the compostability certification standards (BASF, n.d.). Compostable plastics made from petroleum are not reviewed in this study. In this study, the focus is on polylactic acid (PLA) and other biobased compostable plastics that are being used for single-use disposable takeout food serviceware. The petroleum based plastic EcoFlex® is mentioned here for completeness and to illustrate the complexity of compostable plastics.

Biobased plastics that are labelled as “biodegradable” may not meet all of the requirements to include them in a commercial composting system. Figure 1 illustrates the difference between compostable and biodegradable plastics (Gendell, n.d.). Biobased plastics that are classified as compostable degrade in a shorter period of time under the controlled environmental conditions of a commercial composting facility. Biobased plastics that are classified as biodegradable degrade under variable timeframes and environmental conditions.

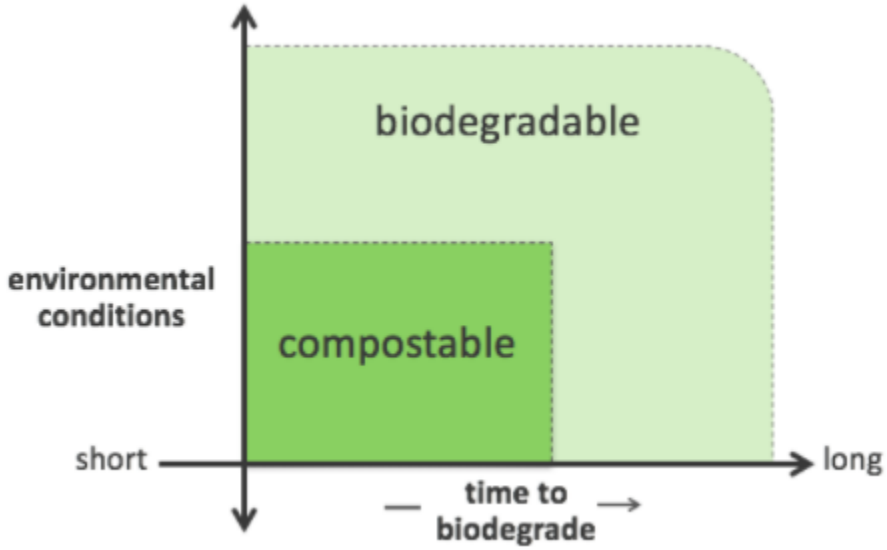

Figure 1. Categorization of compostable and biodegradable biobased plastics with regard to time and environmental conditions
Source: Gendell, A. (n.d.). Sustainable Packaging Coalition 101: Biobased, Biodegradable, Compostable.

Biobased plastic products often look like conventional fossil-based plastics and can mistakenly be placed in a recycling bin or, if labelled as biodegradable, mistakenly be placed into a compost bin. Once these materials arrive at a processing facility they are either included as an appropriate material for the particular waste stream, identified as a contaminant and removed, or they pass through the system undetected leading to possible contamination later on in the process. Either way, these new materials are disrupting established recycling and compost operations and confusing consumers who want to properly dispose of them after use.

The confusion associated with biobased plastic disposal is of growing concern as the market for these products increases. Biobased plastics comprise approximately 1% of the approximately 320 million tons of plastics produced annually worldwide (European Bioplastics, 2017). Worldwide growth is projected to increase from 2.05 million tons in 2017 to 2.44 million tons in 2022 (European Bioplastics, 2017).

There are many types of biobased plastics commercially available and in development with a wide variety of properties and applications. Biobased plastics can be biodegradable or non-biodegradable. Biodegradable plastics are those that are degraded by naturally occurring microorganisms such as bacteria, fungi and algae (Harmon et al., 2014). Biobased plastics such as rubber and linoleum have been in use before fossil fuels were used to make plastics. Other biobased plastics such as Bio-PET (biobased PET (polyethylene terephthalate)) have the same chemical structure as traditional fossil based PET ("Biopolymers, Facts and Statistics 2016," 2016) but are sourced from biological materials like sugar cane (Harmon et al., 2014). These products are referred to as "drop-ins" because they can be recycled with their non-biobased counterparts (Alaerts, Augustinus, & Van Acker, 2018; "Biopolymers, Facts and Statistics 2016," 2016). The three commercially produced biodegradable plastics used for packaging and film include polylactic acid (PLA), polybutylene succinate (PBS), and polyhydroxyalkanoates (PHAs) (Williamson, 2010). Of these, PLA and PHA are compostable in commercial composting facilities. These materials have been developed in the last 30 years and contain chemical structures previously unknown in connection with plastics ("Biopolymers, Facts and Statistics 2016," 2016). PLA and PHA are considered the two most viable biobased plastic alternatives to conventional plastics (Chidambarampadmavathy, Karthikeyan, & Heimann, 2017).

PLA is the most common compostable plastic (Meeks et al., 2015). PLA makes up the largest market segment of all the biodegradable plastics (Markets and Markets, n.d.; Mordor Intelligence, n.d.). The global PLA market is expected to grow from 98.27 million U.S. dollar (USD), by revenue, in 2017, to 2,091.29 million USD by 2023, at a compound annual growth rate of 20.06% (Mordor Intelligence, n.d.). It is anticipated that between 2018 - 2025 market

demands for PLA will be driven by growing consumer awareness of sustainability, recyclability and green packaging (Grand View Research, 2017).

All of the PLA entering the market place will be composted, incinerated, or landfilled, if it doesn't become litter in the environment. In 2015, 60 thousand tons of PLA waste was generated in the U.S. with negligible amounts (less than 5,000 tons) recycled (United States Environmental Protection Agency, 2018b). Of this, 20 thousand tons were from plastic cups and plates, and 30 thousand tons were from non-durable goods, which are items with a life-time of 3 years or less such as disposable diapers, clothes and shoes (United States Environmental Protection Agency, 2018b). In addition, 10 thousand tons of PLA waste were from items like coatings, closures, lids, clamshells, egg cartons, and produce baskets (United States Environmental Protection Agency, 2018b). Table 1 puts the amounts of PLA in the waste stream in context of other plastic waste. As compostable products made from PLA begin to be generated in significant quantities to be included in waste characterization reports, an end-of-life management plan needs to be designed to ensure the material is properly handled and not destined for the landfill.

Table 1. Plastics in Products in Municipal Solid Waste, 2015

Product Category	Generation (Thousand tons)	Recycled (Thousand tons)	Recycled (Percent of generation)
Total Plastics in MSW, by resin			
PET	5,100	940	18.4%
HDPE	6,040	620	10.3%
PVC	890	Neg.	
LDPE/LLDPE	7,930	490	6.2%
PLA	60	Neg.	
PP	7,730	70	0.9%
PS	2,370	30	1.3%
Other resins	4,380	990	22.6%
Total Plastics in MSW	**34,500**	**3,140**	**9.1%**

Table 1 Source: United States Environmental Protection Agency. (2018b). Advancing Sustainable Materials Management: 2015 Tables and Figures (Table 8).

Over an 8-month time frame I collected the compostable plastic items that I received as single-use, disposable to-go serviceware from the California Bay Area. These items came from 7 brands or producers: Crown Poly, ECO-Products, Fabri-Kal GREENWARE, Novamont (for Mater-Bi items), Pacific Green Products, Stalk Market and World Centric. Each item contained some form of labeling indicating that it was compostable plastic. Other products such as TaterWare were also received with no indication on the product about compostability. As I received these items, I was often unsure whether the local composting facility was able to accept them. For example, while in Richmond, CA, the item would need to be placed in the trash but while in Berkeley or San Francisco the item could be placed in the compost bin, but when in Oakland I was unsure. Currently, producers and brand owners of these materials have no responsibility to ensure the materials can be properly identified and handled during the end-of-life stage of their products' life-cycle, which puts the burden on the municipalities.

Other countries are beginning to address biobased plastics in the waste stream. In 2018 the European Union put out a strategy for managing plastics which calls for three actions on biodegradable and compostable plastics to begin taking place in 2018: 1) "start work to develop harmonized rules on defining and labeling compostable and biodegradable plastics"; 2) "conduct a lifecycle assessment to identify conditions where their use is beneficial, and criteria for such application"; 3) start the process to restrict the use of oxo-plastics via REACH" (European Commission, 2018).

End-of-life Pathways for Compostable Plastics

Once a compostable plastic has been discarded by the consumer, there are several pathways it can travel. The item can be disposed of in the compost bin and delivered to a compost facility; it can mistakenly be included in the recycling bin where it is delivered to a recycling facility; it can be placed in a trash bin and delivered to a landfill or incinerator; or it can become litter in the

environment. The following sections describe these different pathways and issues associated with them.

Composting

California law requires bioplastics labeled as compostable to meet ASTM D6400-12 requirements for disintegration, biodegradation and ecotoxicity (Harmon et al., 2014). These are defined as follows:

- **Disintegration** – No more than 10 percent of the original dry weight of a product must remain after 12 weeks in a controlled composting test.
- **Biodegradation** – 90 percent of the organic carbon in the whole item or for each organic constituent must be converted to carbon dioxide within 180 days.
- **Ecotoxicity** – The product must have less than 50 percent of the maximum allowable concentrations of certain metals regulated by law in sludge or composts, and the test compost must be able to support germination of two different plant species at a rate at least 90 percent of that in a "blank" compost control sample.

A composting facility may have shorter processing times that those required by ASTM D6400-12. A 2010 survey by the Sustainable Packaging Coalition found that almost half (19/40) of U.S. compost facilities included in the survey had an active composting period of 70 days or less and some operations were as short as 14 days (Sustainable Packaging Coalition, 2010). Participants of the survey also noted that the ASTM methods were tested under laboratory conditions, not real-world conditions (Sustainable Packaging Coalition, 2010). The faster the compost facility can get the material in, process it and sell it, the more money they can make, especially when space is limited (Sustainable Packaging Coalition, 2010).

The impact that PLA has on compost communities has not been fully studied. Decaying matter includes specific microbial communities that are responsible for decomposition and include different types of bacteria, fungi, and actinomycetes (Campbell, 1990). The addition of PLA to

maturing compost for 2 months at 50° C changed the compost community by exhibiting a strong selection for *Thermomyces sp*, a minor species in a PLA free compost community (Karamanlioglu, Preziosi, & Robson, 2017). After the PLA degraded, the compost community returned to what was seen before the PLA was added, indicating that PLA causes a temporary change in compost communities and could change the dominant species (Karamanlioglu et al., 2017). These results suggest more research should be conducted to determine the impact on the composting process and compost quality (Karamanlioglu et al., 2017). As compostable plastic quantities increase in the compost waste stream, understanding the impact on compost microbial communities, quality and process will be important for using the finished product and adjusting operations to address potential impacts from the added material.

Under the National Organic Program (NOP) organic compost can contain plant and animal material and it can be made from other allowed feedstock materials (United States Department of Agriculture, 2011). The National List of Allowed and Prohibited Substances lists what can be used in and on organic crop production. The List includes non-synthetics that are not allowed and synthetic materials that are allowed for use in organic agricultural processes (United States Department of Agriculture, n.d.). Under the NOP, compostable plastics are not allowed to be used as feedstock because they fall under the "synthetic material" category (Fernandez-Salvador, 2012). In addition, the compostable plastic feedstock be genetically modified organisms (GMOs). GMOs are explicitly prohibited in organic farming by the U.S. Department of Agriculture (McEvoy, 2013). The National Organic Program (NOP) stipulates that any products labeled as "100% Organic", "Organic" or "Made with Organic "must be produced without prohibited methods, which includes GMOs (United States Department of Agriculture, n.d.). One reason composters do not want to accept compostable plastics isn't because they don't break down, it's because they can make more money selling certified organic compost (Oshins, n.d.).

Compostable plastics become a contaminant when the compost facility does not want to include the compostable plastics as part of the feedstock. Defined in California Code of

Regulations Title 14 Section 17852(a)(32) “Physical Contamination” or “Contaminants” mean human-made inert material contained within compostable material, digestate, or compost, including, but not limited to, glass, metal, and plastic (CalRecycle, n.d.-b). Contaminants must be removed from the composting process. The initial removal of contaminants from the composting process occurs during inspection of the load (Integrated Waste Management Consulting, 2009). If a load is judged to be overly contaminated, it will be redirected to the landfill (Integrated Waste Management Consulting, 2009). If accepted for composting the materials may then be sent through a pick-line where the material moves down a conveyor belt and people remove contamination they identify by sight (Integrated Waste Management Consulting, 2009). Compost is often screened to a specified maximum size (½ - ¼”) depending on the end product use (Integrated Waste Management Consulting, 2009). The screening can happen before or after grinding of the incoming material or before or after the curing stage (Integrated Waste Management Consulting, 2009). There are also machines designed to remove plastic contamination from compost (Integrated Waste Management Consulting, 2009). The machines usually work by pneumatic forces that draw air over the compost to pull out the plastic (Integrated Waste Management Consulting, 2009). The material separated from the final compost product can either be added to a new batch of compost or sent to the landfill (Integrated Waste Management Consulting, 2009). Compostable plastics cannot be visually distinguished from petroleum-based plastics except with appropriate labelling. If a compost operation chooses to keep compostable plastics as part of the feedstock, it is possible that the compostable plastics will be removed during the sorting process. Compostable plastics removed from the compost process increases the amount of material deposited in landfills.

Recycling

Another end-of-life pathway compostable plastics can follow is through the recycling stream for petroleum based plastics. Compostable plastics such as PLA and non-compostable PET (polyethylene terephthalate) are visually similar and cannot be distinguished from one another without the use of aids such as labelling or NIR (near infra-red) technology. A recycling incompatibility exists between PLA and PET (Alaerts et al., 2018). Small amounts (<0.1%) of PLA

can compromise the quality of the recycled PET (rPET) (Alaerts et al., 2018). Table 2 lists threshold concentrations of PLA and their impacts on PET resin. PLA has a lower melting point than PET by about 100°C, leading to degradation of the PLA when left in the prolonged high temperatures required for PET (Alaerts et al., 2018). The degradation of PLA causes yellowing of the PET(Alaerts et al., 2018). PLA has a lower softening point than PET, which can be a problem during the drying stage recycling process (Alaerts et al., 2018) after the material has been washed and flaked. The PLA flakes can become sticky which can foul the equipment and cause clumping of the PET flakes.

Table 2. Reported Threshold Concentrations for PLA in PET and Impacts

Concentration		Impact
%	ppm	
0.05	453	"No visual deviations in terms of colour and transparency"
0.05	453	"Not any significant difference in colour and haze"
<0.1	<1000	"Makes any rPET resin unsuitable"
0.1	1000	significant opacification of recycled PET
0.1	1000	PET recyclate unusable for many end-products
0.3	3000	"Lowers the onset of crystallization and retards recondensation"
>0.3	>3000	PLA causes yellowing of PET
2	20,000	Besides lower quality resin, also agglomeration and sticking to dryer walls
5	50,000	Besides lower quality resin, also agglomeration and sticking to dryer walls

Source: Alaerts, L., Augustinus, M., & Van Acker, K. (2018). Impact of Bio-Based Plastics on Current Recycling of Plastics. *Sustainability*, *10*(5), 1487.

To address PLA contamination of PET collected for recycling, companies can invest in different technological solutions. Optical recognition using Near-Infrared Spectroscopy (NIR) technology can be used to identify PET during material recovery (Alaerts et al., 2018). Pulses of air are used

to separate the the PET from the PLA once positive identification has been made with NIR. NIR is reported to be 86-99% efficient at identifying PET (Alaerts et al., 2018). Other options include the use of visible or chemical markers included during the manufacturing stage of the product's life-cycle or leveraging the lower softening temperature of PLA to separate it from PET using a hot conveyor belt or rotating drum (Alaerts et al., 2018). The inclusion of PLA in the market place is not without cost with regards to the recycling industry as they need to ensure they have a system in place to identify and remove PLA before it contaminates other materials. It would be appropriate for producers of compostable plastics to invest in research that supports methods used to identify PLA in the recycling stream. In addition, funds from an EPR program could be used to help recycling facilities invest in technology needed to identify and remove the PLA contaminant.

Landfill

The final resting place for much of American's trash is in a landfill. When organic materials are landfilled, they undergo aerobic (with oxygen) decomposition for about 1 year (US EPA E, n.d.). After 1 year, the oxygen is depleted and anaerobic microbes begin to break down the organic material producing landfill gas, a mix of roughly 50% methane and 50% carbon dioxide and small amounts of non-methane organic compounds (United States Environmental Protection Agency, n.d.). Methane is a greenhouse gas with heat trapping potential 28 to 36 times more potent than carbon dioxide over a 100-year time period compounds (United States Environmental Protection Agency, n.d.). As compostable plastics are rejected from recycling facilities, screened out of compost operations, or thrown in the trash by consumers they become part of the landfill and contribute to methane and carbon dioxide emissions. To keep compostable plastics out of the landfill and properly composted, the challenges associated with their identification must be addressed.

Litter in the Environment

The degradation of compostable plastics in nature, whether in soil or marine environments, is extremely variable and depends on the environmental characteristics of the area including the microorganisms present, pH, temperature, moisture, and oxygen content as well as the

chemical structure of the material, the polymer chain, crystallinity, and the complexity of polymer formula (Emadian, Onay, & Demirel, 2017). Compostable plastic films of PHA were tested in Hoa Lac, Vietnam where the PHA films biodegraded 98% while the same test was done in Dam Bai, Vietnam and resulted in only 48% degradation of the PHA films. This lower biodegradation rate at Dam Bai was attributed to the low pH of the Dam Bai soil at 5.48 (Emadian et al., 2017). The complex environmental conditions needed to successfully biodegrade compostable plastics make proper management of these materials even more important. As we work to mitigate the current damage being done by traditional plastic pollution in the environment, we do not need to contribute additional waste just because there is a promise of degradation under favorable conditions.

Extended Producer Responsibility (EPR)

One environmental policy approach that could be used to address the end-of-life management stage of compostable plastics is EPR. The Organization for Economic Co-operation and Development (OECD) defines EPR as "an environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of a product's life-cycle." EPR aims to accomplish two goals: 1) to shift the end-of-life responsibility upstream, from municipalities to the producers and 2) to influence product design that takes the environment into consideration (Organization for Economic Co-operation and Development, 2001). Many countries and states within the United States have adopted successful EPR programs for products that pose challenges at the end-of-life stage of their life-cycle. These programs include the Green Dot program adopted by Germany, one of the first EPR programs to successfully address excessive packaging waste, and California's adoption of EPR for mercury thermostats, agricultural pesticide containers, paint, carpet, and mattresses. The successes of these EPR programs might be able to guide the implementation of an EPR policy to address end-of-life management of compostable plastics.

EPR is often intertwined with product stewardship. Both are mechanisms for responsible management of products at the end of their life-cycle. The main difference between the two is

that with EPR the end-of-life management of a product is the responsibility of the producer (brand owners, first importers or manufacturers), funding is provided by the producers, and the cost may be internalized as a factor of production or passed on to consumers. With product stewardship, the end-of-life management can be allocated to a local government and is funded by environmental fees and public funds, and the responsibility is usually not allocated to the producers (Government of Canada, n.d.). Similarly, in California a program is not considered an EPR program if it uses large public resources to implement the program (CalRecycle, n.d.-c). California has product stewardship programs for electronic waste, pharmaceuticals, sharps, motor oil and tires which often include a producer take-back component or a requirement to reduce harmful substances (CalRecycle, n.d.-c).

Designing an EPR program for compostable plastics now, while they comprise just 1% of the market, is desirable because there are no established disposal habits, pathways, or conventions for compostable plastics that would be disrupted. Compostable plastics *are* disrupting established systems used to manage recycling and compost when they are an unwanted material and considered a contaminant. Requiring EPR at the beginning of this product's introduction and assimilation into the economy would help mitigate the externalities that are arising from companies not being held responsible for the end-of-life management of the products they produce. EPR for compostable plastics would provide structure, organization and resources that are needed to implement a working end-of-life waste management strategy.

EPR in the United States

The United States does not currently have a nationwide EPR or product stewardship program for any product (CalRecycle, n.d.-c), which has led some states to adopt EPR/product stewardship legislation for themselves. States with the highest number of EPR/product stewardship programs include California and Vermont with eight programs each and Maine with seven programs (Product Stewardship Institute, 2018). 30 other states have at least one EPR program and 17 states have no EPR programs (Product Stewardship Institute, 2018).

California's experience and leadership implementing EPR/product stewardship programs puts it in an excellent position to implement EPR for compostable plastics.

EPR in California

In 2007, California's Integrated Waste Management Board (now CalRecycle) adopted a set of strategic directives to reduce the amount of resources being wasted in California (CalRecycle, n.d.-d). Strategic Directive 5 is focused on Producer Responsibility and states that it is a core value of CalRecycle to promote producer responsibility of products in order to promote responsible stewardship and environmental sustainability (CalRecycle, n.d.-c). Strategic Directive 5 gave CalRecycle the ability to seek statutory authority to implement producer responsibility and implement producer-financed and producer-managed programs (CalRecycle, 2018c).

To help implement Strategic Directive 5, California developed the guidance document "Overall Framework for Extended Producer Responsibility in California" to provide a flexible and comprehensive approach in the development of EPR programs for products that have a significant impact on the environment. The EPR framework document defines EPR as:

> Extended Producer Responsibility (EPR) is the extension of the responsibility of producers, and all entities involved in the product chain, to reduce the cradle-to-cradle impacts of a product and its packaging; the primary responsibility lies with the producer, or brand owner, who makes design and marketing decisions.

The EPR framework document identifies key elements common among EPR approaches. These include: Policy Goals, Guiding Principles, Definitions, Roles and Responsibilities, Governance, Product/Product Categories Covered, Program Effectiveness and Measurement.

Each product or product category has specific needs when implementing an EPR or product stewardship program depending on the needed infrastructure, consumer and producer education, and recycling/reuse opportunities making it unrealistic to set up a producer

responsibility program for each product or product category (CalRecycle, 2007a). California has laws for five products that meet the basic requirements of producer responsibility: mercury thermostats, pesticide containers, paint, carpet and mattresses. The details of the EPR laws are compared to the main 6 challenges surrounding compostable plastics to identify commonalities that can be resolved with EPR programs.

Assessment of California EPR programs for Application to Compostable Plastics EPR

Methodology

In order to determine whether compostable plastics are a good candidate for EPR legislation in California, three evaluations were conducted. The first evaluation looks at the five existing California EPR laws for mercury thermostats, agricultural pesticide containers, paint, carpet, and mattresses to determine whether the EPR laws for these products address similar end-of-life product management challenges seen with compostable plastics. The end-of-life product management challenges for compostable plastics are identified in two reports. The first set of challenges comes from the US Composting Council report “Compostable Plastics 101: An Overview of Compostable Plastics”. The second set of challenges comes from the CalRecycle report “Biobased and Degradable Plastics: Understanding New Packaging Materials and their Management in California”. The challenges from the US Composting Council and CalRecycle reports were combined together to create a group of six end-of-life management challenges for compostable plastics. Of the three evaluations, Evaluation 1 is the most definitive with outcomes grounded in existing EPR laws that address compostable plastic challenges.

The second evaluation reviews compostable plastics using 2007 CalRecycle criteria and procedures used to select priority products from the waste stream for product stewardship laws. The priority product selection criteria and procedures are described in the report “Analysis of Priority Product Selection”. The priority product selection criteria is composed of categories and associated questions. The answers are used to assign a rate of “high”, “medium” or “low” based on the evaluator(s) assessment of the answers. The scores for compostable

plastics are based off of my assessment and consideration on how compostable plastics answer the question. I use the rate I assigned for each criteria and compare them to the compostable plastics ratings for the priority products chosen in 2007. The criteria for Evaluation 2 was originally designed by CalRecycle to evaluate products prevalent in the waste stream. EPR for compostable plastics is different in that it is a preventative approach that aims to to address the challenges of compostable plastics *before* they become prevalent in the waste stream. As such, Evaluation 2 is not as defensible as Evaluation 1.

The third evaluation looks at compostable plastics through the lens of California's guidance document for implementing product stewardship laws "A Framework for an Extended Producer Responsibility System in California". Evaluation 3 populates the framework that should be followed in California when establishing an EPR program. Evaluation 3 looks at whether compostable plastics can address the elements needed to establish an EPR program. Evaluation 3 is a hypothetical review that uses the elements outlined in the Framework as an exercise to see whether an EPR program could be designed for compostable plastics using available information about the product. Several parts of Evaluation 3 were not completed as they pertained to details such as definitions, roles and responsibilities. These details are variable based on how the EPR program is set up and what the specific components are. Developing an EPR program for compostable plastics would take a group of experts from multiple disciplines. Exercise 3 represents a starting point from which a compostable plastic EPR program could begin to be discussed.

The three evaluations assess whether compostable plastics are a good candidate for EPR legislation. Evaluation 1 is the most definitive and provides the basis for the recommendations in this study. Evaluation 2 and Evaluation 3 were valuable in assessing that it is not inconceivable to develop a compostable plastics EPR program.

EVALUATION 1: REVIEW OF EXISTING CALIFORNIA EPR LAWS TO INFORM HOW TO ADDRESS CHALLENGES IDENTIFIED FOR COMPOSTABLE PLASTICS

The six challenges identified by the US Composting Council (USCC) and CalRecycle for compostable plastics are listed below with a brief description of each challenge.

1. **Identification and Labeling Challenges (USCC) and Sorting (CalRecycle)** – Labeling needs to be used that easily and readily distinguishes compostable from non-compostable materials so that consumers can engage in correct source separation and material recovery facilities (MRFs) and composters can reliably identify and sort the material.

2. **Enforcement and Legislation (USCC)** – The United States does not have any enforcement or legislation at the federal level that mandate clear definitions for claims of compostability, biodegradability or biobased products. The Federal Trade Commission (FTC) does have "Green Guides" which provide guidelines for non-deceptive environmental marketing claims but these guidelines are are not independently enforceable. A company can be held accountable for unfair or deceptive advertising practices of a product under section five "Unfair or Deceptive Practices" of the FTC Act, using the "Green Guides" as a basis for the violations.

   On a state level, California requires that products meet California Public Resources Code (CPRC) Section 42359-42359.8 stating that claims of compostability be met with competent and reliable evidence using ASTM standards. This is enforced by the California Attorney General.

   An example of CPRC Section 42359-42359.8 being enforced in California can be seen in two high profile cases brought against Walmart and Amazon for selling products with false advertising claims of biodegradability or compostability. Walmart paid $940,000 in 2017 to settle claims that it had wrongly sold items labeled as "biodegradable" or "compostable" and stated that "We are pleased to resolve this matter with the California District Attorneys and are appreciative of them as they have worked with us on this issue. Sustainability is a priority for us, and we have

been recognized as a retail leader in this space". Of this settlement, $50,000 will go to pay for the testing of products claimed as biodegradable or compostable (Shen, 2017). Similarly, Amazon settled a 1.5-million-dollar claim in 2018 for selling items falsely labeled as "biodegradable" or "compostable" to California consumers. Amazon immediately took steps to stop the sale of these products once they had been contacted by prosecutors. An additional $50,000 will be paid by Amazon to support the testing of products labeled as compostable or degradable (Paben, 2018). These lawsuits show that creating laws to support compostable plastics, enforcing the laws and including penalties for non-compliance is an important factor to successfully address challenges complicating compostable plastics in the marketplace.

3. **ASTM Standards need Refining (USCC) and Compostability Standards (CALRECYCLE)** The ASTM standards need to be refined to be more in line with what actually happens at composting facilities. Current ASTM standards specify that something can be considered compostable if the material breaks down in a commercial facility within 180 days. In reality, most compost facilities finish their composting process within 120 days, with most finishing the compost process in less than 100 days(US Composting Council, n.d.). One solution suggested by USCC in their report is the development of multiple test methods to test for biodegradability under different operating procedures common to the commercial composting facilities (US Composting Council, n.d.).

4. **Consumer Education (USCC) –** Consumers are not going to be able to properly manage compostable plastics without an understanding of compost processes and a basic understanding of the terminology for bioplastic, biobased, biodegradable, and compostable. The USCC report suggests that consumer education be aligned with guidance from well-respected, non-governmental organizations such as the U.S.

Composting Council, the National Research Council, and the Sustainable Packaging Institute.

5. **National Organics Program (NOP) Impacts (USCC) and Organic Certification (CALRECYCLE) -** The U.S. Department of Agriculture created the National Organics Program (NOP) to provide rules and regulations for products certified as organic. One rule is that compost feedstock used on organic agriculture must be free from a NOP list of "unacceptable synthetics". Third party organic compost certifiers will not certify compost as organic from facilities that include compostable plastics in their feedstock.

6. **Bioaccumulation (CALRECYCLE):** A concern is that compostable plastics may contain potentially toxic chemicals, additives or byproducts that have been added as product enhancements. The product enhancements from compostable plastics could accumulate in the soil over time and bioaccumulate in soil organisms. The bioaccumulation occurs when organisms living in the soil have direct exposure to the medium, or by consumption of food containing the chemicals, over long periods of time.

Table 3 lists the six compostable plastic challenges across the top row of the table and the existing EPR laws in the first column. The second row provides a brief description of the compostable plastic issue. Each of the EPR laws is reviewed to see whether the law was used address similar challenges to those identified for compostable plastics.

Table 3. Comparison of compostable plastics challenges and current California EPR laws

	Identification and labeling Challenges (USCC) Sorting (CALRECYCLE)	**Enforcement and Legislation (USCC)**	**ASTM Standards need Refining (USCC) Compostability Standards (CALRECYCLE)**	**Consumer Education (USCC)**	**National Organics Program (NOP) Impacts (USCC) Organic Certification (CALRECYCLE)**	**Bioaccumulation (CALRECYCLE)**
Compostable Plastic Challenges / **Existing California EPR Laws**	Identifying the correct materials. Compostables and regular plastics can look alike.	No federal level enforcement or legislation for claims of compostability, biodegradability or biobased. CAL has compostability labeling laws.	The standards are not designed to work with a real facility. Most process in less time. The requirements for bioplastic to be considered compostable are laid out in this standard but most commercial facilities process in less time.	Basics on how composting works and teach a common vocabulary.	Are compostables a synthetic material? For now they are considered one.	Could additives added to compostables accumulate in the soil and up the food web over time?
Mercury Thermostats: AB 2347	The law specifically targets Hg containing thermostats. Educational materials provide pictures and guidelines on how to tell if	Federal legislation exists. The Code of Federal Regulations, 40 CFR part 273.9 lists mercury thermostats as universal hazardous waste.		Education is required by the EPR law. First 2.5 years of the law required public service announcements, establishment of a public internet website with templates of information that could be downloaded; On-going educational		Law identifies that methyl mercury bioaccumulates and biomagnifies and is a neurotoxin.

	the thermostat contains mercury.			effort requires design of signage to be displayed by retailers, wholesalers, HHW facilities; provide written materials and downloadable templates targeting consumers about the laws around disposal, provides list of collection locations, directions on how to handle old thermostats, advertising, materials to use as direct communication during purchase of a new thermostat.		
Pesticide Container: SB 1723	Law is for agricultural use pesticide containers 55 gallons or less made out of rigid, non-refillable HDPE. HDPE can be identified by the recycle symbol with the #2 inside. (Department of Pesticide Regulation, 2011).	By existing law, to sell pesticides in California you have to register and the product must be in a sealed or closed registrant's container or package.	Container recycling program must be certified by a third party to be ANSI/ASABE Standard S596 compliant for recycling pesticide containers.	No specific requirements for consumer education are written in the law. The Ag Container Recycling Council (ACRC) provides information about how to recycle the containers on their website. The ACRC stewardship organization existed before the EPR law. They are a non-profit, industry funded, pesticide container recycling stewardship organization (Ag Container Recycling Council, n.d.).		

				The ACRC represents 90% of the containers recycled in California (California Department of Pesticide Regulation, n.d.).		
Paint: Public Resources Code Section 48700--48706	The law specifies that it applies to interior and exterior "Architectural paint" sold in 5 gallons or less used for commercial or homeowner use. Law also includes list of what it does not includes such as aerosol spray paint.	Existing California regulation: Paint is a household hazardous waste that is banned from disposal in the trash (CalRecycle, n.d.-e).		Requires education and outreach to inform retailers, consumers and contractors about source reduction and recycling by using signage, written materials, and downloadable templates.		
Carpet: Chapter 681, Statutes of 2010 (Perez, AB 2398)	The law defines what the term "carpet" means, what constitutes carpet and what does not.	Cited in the EPR law: California Integrated Waste Management Act of 1989 requires CalRecycle to work towards waste reduction by reducing,		Requires education. Includes signage, written materials, templates for retailers to download, and promotional activities and materials		

		reusing and recycling resources used in California to the maximum extent possible to conserve natural resources in a cost effective manner (AB 2398).				
Mattresses: SB 254,	The law includes a definition for a mattress as well as a list of items that are not mattresses such as sleeping bags and pillows.			Law requires consumer, manufacturer and retailer education. Education was specifically addressed by the stewardship organization Mattress Recycling Council. They created a consumer focused website <ByeByeMattress.com> that includes consumer education materials for retailers to use and they launched a public service announcement (PSA) campaign using print, TV, radio and outdoor ads (Mattress Recycling Council California, LLC, 2018) pg. 73. The stewardship organization has a Program		

				Operations Manual for recyclers to follow called: California Mattress Recycling Program COLLECTION GUIDELINES. This includes color pictures on acceptable and non-acceptable mattresses, including how to identify bed bugs and how to discard of infested mattresses. (Mattress Recycling Council California, LLC, 2018) Appendix D.		

Findings

Table 4. EPR Laws that address Compostable Plastic Challenges

	Identification and labeling	Enforcement and Legislation	Compostability Standards	Consumer Education	National Organics Program (NOP)	Bioaccumlation
Mercury Thermostats: AB 2347	**X**	**X**		**X**		**X**
Pesticide Container: SB 1723	**X**	**X**	**X**			
Paint: PRC 48700--48706	**X**	**X**		**X**		
Carpet: AB 2398	**X**	**X**		**X**		
Mattresses: SB 254,	**X**			**X**		

EPR laws addressed challenges similar to those compostable plastics have half (15/30) of the time (Table 4.). Each compostable plastic challenge is discussed in the context of how the EPR laws addressed the similar challenges.

Identification, labeling, and sorting of compostable plastics: While the average consumer can identify paint, carpet and mattresses, each EPR law provides definitions of what the names mean under the law. For example, the paint law defines architectural paint as "interior and exterior architectural coatings, sold in containers of five gallons or less for commercial or homeowner use, but does not include aerosol spray paint or coatings purchased for industrial or original equipment manufacturer use." Mercury containing thermostats are more difficult to identify and the law requires educational materials be made available that provide pictures and guidelines on how to identify them. Pesticide containers are the most closely related product to compostable plastics, being made from plastic, and the law defines them as being "rigid, non-refillable, high-density polyethylene (HDPE) containers of 55 gallons or less"
that can be identified by a recycling symbol with a resin code #2 on the inside when displayed by the manufacturer (Department of Pesticide Regulation, 2011).

Enforcement and legislation about compostability claims: None of the 5 EPR laws address issues of false advertising about the performance of the products or their inherent properties. Laws and legislation exist outside of the EPR laws and cover different aspects of the products. For example, mercury thermostats and paint both have existing laws banning these products from being disposed of in landfills. Pesticides cannot be sold except by a registered party and in the registrant's sealed or closed containers. California passed SB 567 in 2011 requiring any product labeled as "compostable" to meet ASTM 6400-12 standards for compostability, which shows some progress in addressing this challenge.

Refining ASTM and compostability standards: For the existing EPR laws, there does not appear to be situations where standards don't reflect real situations. There is one standard for

recycling pesticide containers, the American National Standard Institute (ANSI)/ American Society of Agriculture and Biological Engineers (ASABE) Standard S596 which exists outside of the EPR law and describes how to safely recycle pesticide containers. The pesticide container EPR law cites this standard and requires that all recycling programs follow it. In addition, the recycling program must be certified by a third party as being in compliance with the recycling standards.

Consumer Education: Consumer education plays a big role in existing EPR laws. All of the California EPR laws except for pesticide containers explicitly require consumer education. These laws have well developed requirements for consumer education which take the form of signage, pamphlets, campaigns, printable templates for retailers, advertising on TV and radio, websites and public service announcements. Some campaigns like Bye Bye Mattress have in-depth branding that include easily recognizable cartoon characters. Others like PaintCare have easily recognizable logos to brand their message. The requirements for recycling mercury thermostats include providing pamphlets that tell consumers how to identify the items and where to take them.

Consumer outreach concerning proper disposal of a product is often done when a consumer purchases the item new. For example, when you purchase a new mattress, a recycling fee is added to your receipt and the consumer is told that there is no fee to have the old mattress removed at the time of delivery, or if the consumer prefers, they can drop it off at a designated recycling center for free. The pesticide container recycling law includes education for the consumer but it is a special case in that the law applies to a special sector of people who are registered to purchase agricultural pesticides and not the general population of consumers.

Organics Certification: This challenge is unique to compostable plastics. Unlike other materials under EPR legislation, the process of recovering compostable plastics by composting involves the material completely degrading into component elements.

Bioaccumulation: The EPR law for mercury-containing thermostats is the only law covering a material known to be a neurotoxin that bioaccumulates and biomagnifies. Proper end-of-life management of the mercury in these devices is intended to protect the environment and human health.

This analysis shows that compostable plastics have two unique challenges: refining ASTM and compostability standards to include real world operations; and the National Organics Program inclusion of compostable plastics as an "unacceptable synthetic". The two distinct areas where EPR for compostable plastics would be most effective are consumer education and identification, labeling, and sorting.

Evaluation 2: Product Criteria Evaluation and Rating for Product Stewardship in California

In 2007 CalRecycle (previously California Integrated Waste Management Board) published their methodology and findings of a priority product assessment in the report '*Analysis of Priority Product Selection'.* The study was conducted to rate each product or product category in the waste stream. The goal was to determine which products had the greatest environmental and human health impacts in the waste stream. The products with the greatest impacts got priority consideration for producer responsibility programs. The assessment used both quantitative data, such as tons disposed, and qualitative data such as descriptions of whether there is stakeholder concern. A set of nine criteria were used, three primary criteria to determine whether the product or product category was a viable candidate, and six secondary criteria to further evaluate the product or product category. Each product was given a rating of "high", "medium" or "low" for each criteria. The products with the greatest number of "high" scores were determined to be the best candidates for producer responsibility programs. The criteria used to evaluate the products in the 2007 waste stream was used to evaluate compostable plastics. Table 5 includes the two criteria sections, primary and secondary. For each level of criteria, the name and definition from the CalRecycle report is given in the first two columns. An evaluation of how compostable plastics meet the criteria is shown in the third column, and the rating ("high", "medium" or "low") indicates how well I assess the product meets the criteria.

Table 5. Product Criteria Evaluation and Rating

Primary Criteria			
Criteria Name	**Criteria Definition**	**Evaluation of product against criteria to determine rating**	**Rating (High/Medium/Low)**
Significant End –of-Life impacts	Does the product either contribute significantly to the overall total amount of solid waste disposed or does it represent an environmental or human health hazard?	No, but if compostable plastic EPR existed compost facilities would be poised to support organics diversion goals. Food waste and scraps comprise 18% of the material disposed of in California landfills each year, equivalent to 6 million tons (https://www.calrecycle.ca.gov/organics/food). California has a policy goal to source reduce, recycle and compost 75% of waste generated by 2020 (AB 341). Moving organics out of the landfill is one of 5 priority strategies for achieving the 75% goal (AB341 Report to the Legislature). AB1383 establishes goals to reduce disposal of organic waste by 50% by 2020 and 75% by 2025. Compostable plastics have been identified as a way to increase the diversion of food waste from the landfill and toward compost facilities (Harmon et al., 2014). EPA Facts and Figures for 2015 Plastics = 13.1% of total 2015 U.S. Municipal Solid Waste Stream before recycling, composting and combustion. Food = 15.1% of total 2015 U.S. Municipal Solid Waste Stream before recycling, composting and combustion.	Low
Feasibility	Is there a clearly identifiable producer? Is information available or can information be gathered in a	Yes. Compiling a list of compostable plastic producers and brand owners could be done within a reasonable amount of effort. Many private sector, compostable plastic brand owners (e.g., Eco-Products and World Centric) express concern for the planet and	High

	reasonable amount of time or with a reasonable amount of effort to determine infrastructure, distribution, producers, etc. Potential for private sector participation in voluntary product stewardship programs and activities.	society as is evidenced by being Certified B Corps, promoting alternative options to conventional plastic products and offering BPI certified compostable product lines. It is in the best interest of the companies to address the issues surrounding the infrastructure and other laws that hinder compostable plastics from living up to their full potential.	
Opportunities exist for new effort	Is the market currently dealing with this product? Do we need to create a new market? Is another agency better suited to deal with this product? Are other programs already in place for this product?	Yes, the compost facilities are having to deal with this product. This is a growing product category with no federal regulations. California has labeling laws for labeling a product as "compostable" but there are no laws excluding sale of the products in areas without proper compost facilities available. The disposal options in a community do not always match consumer intention when purchasing the product. This contributes to increased contamination at the compost facility and recycling facility which potentially reduces revenue.	Med
Secondary Criteria			
Difficult to manage/bulky	Does the product require significant amount of effort to disassemble, transport,	Compostable plastics are difficult to manage because they have specific time and temperature requirements to break down and they are a potential contaminant if they enter the recycling center and are included with PET recycling.	Med

	or neutralize? Difficult to manage products cost local governments considerable amounts of money and represent a large portion of illegally dumped items. These products would benefit greatly from a Product Stewardship Program.	The compostable plastic PLA, considered one of the most viable bio-based plastic alternatives to petroleum based plastics (Chidambarampadmavathy et al., 2017), is often used to make products traditionally made with PET resin. Identifying PLA products from PET products cannot be done by eye unless appropriate visual indicators are included on the product such as labeling (Alaerts et al., 2018). PLA and PET have a very severe recycling incompatibility and when PLA is included with PET it can cause changes in the the characteristics of the recycled resin such as discoloration (Alaerts et al., 2018). NIR waste sorting technology coupled with pneumatic sorting can be used to positively identify PET and separate them from PLA (Alaerts et al., 2018; TOMRA Sorting Solutions, 2017). When petroleum plastics are included in a compost bin they have to be removed manually, screened out or removed using machines that use pneumatic forces to remove plastic from compost.	
CIWMB (currently CalRecycle) is appropriate agency	Is the CIWMB the primary agency responsible for this product? Or should another agency or agencies take the lead on this? We should focus mostly on products which fall directly under our responsibility.	CalRecycle is responsible for organic materials management for the state. Compostable plastics are an organic material disposed of with other organic materials.	High
Increasing or steady usage trend	Is product usage holding steady or increasing? If the	Yes product usage is increasing but slowly and bioplastics are about 1% of the worldwide plastics market (European Bioplastics, 2017).	Low

	product is being slowly phased out of use anyway, there is little use in pursuing it with this kind of program.		
Stakeholder concern	The cost to local governments and ratepayers for the handling and recycling/disposal of the products.	The compost facility or the recycling facility is burdened with the cost to deal with these materials when they unwanted. They often must implement new procedures and/or purchase new technology to identify these materials and remove them from the process. How the facility deals with the additional cost will be facility dependent. Some are privately owned while others are owned by local governments.	Med
Life-cycle impacts	The toxicity of the product throughout its lifecycle and its relevance to solid waste reduction, and hazardous waste and water quality pollutant reduction priorities.	Compostable plastics are made from renewable resources helping to move away from dependence on fossil fuels. This product may help divert more food to compost and away from landfill.	Low
Potential for lifecycle improvement	Is there some interest in private-sector to pursue environmentally-friendly technology related to this product? Can improved design reduce the negative lifecycle impacts?	Yes. This product gets a large part of it's market value from the end-of-life management possibilities inherent in the compostability of the product. When consumers find out that the product may not be composted in their community or only at certain places it can damage the products reputation for being an Earth friendly alternative. Brand owners will be interested in maintaining the Earth friendly reputation the product has.	High

Findings

The 9 criteria used by CalRecycle in 2007 to evaluate products and product categories for potential producer responsibility programs are used here to assess how compostable plastics stand up as a candidate for producer responsibility. Based on the outcome of this evaluation, shown in Table 5, compostable plastics would not be recommended for priority product selection for an EPR program because compostable plastics do not pose a large enough threat to the environment or human health. Under the 'Primary Criteria' section, compostable plastics rated "high" for 'Feasibility', "medium" for 'Opportunities Exist for New Effort' and "low" for 'Significant End-of-Life Impacts'. During CalRecycle's evaluation, products that received at least one "high" rating in the 'Primary Criteria' section continued on to be evaluated using the 'Secondary Criteria'. Since compostable plastics received one "high" under the 'Primary Criteria' section they qualify to be evaluated using the 'Secondary Criteria'. Under the 'Secondary Criteria', compostable plastics received the rate of "high" twice, once for 'CIWMB (now CalRecycle) is appropriate agency' and again for 'Potential for lifecycle improvement'. The products identified by CalRecycle as good candidates for product stewardship programs were rated "high" three to four times in the secondary criteria. CalRecycle noted that the products were evaluated based on solid waste management issues and that some of the products may fair differently if evaluated with other criteria important to other agencies, such as pharmaceuticals showing up in surface water. In addition, CalRecycle noted that getting stakeholder input would be a valuable part of the process and should be included when this evaluation is done on a longer time scale (CalRecycle, 2007b). For compostable plastics, many of the challenges are unique to this product and stakeholder input could make the difference in establishing the relevance of needing a producer responsibility program for proper end-of-life management. The criteria for Evaluation 2 was originally designed by CalRecycle to evaluate products prevalent in the waste stream. This evaluation may not adequate to determine whether an EPR program should be established for new materials (like compostable plastics) entering the waste stream. EPR for compostable plastics is a preventative approach that aims to to address the challenges of compostable plastics *before* they become prevalent in the waste stream.

EVALUATION 3: REVIEW OF CALIFORNIA'S EPR FRAMEWORK FOR SETTING UP PRODUCT STEWARDSHIP PROGRAMS

The report "Overall Framework for Extended Producer Responsibility in California" outlines nine key elements to be addressed when establishing a product stewardship plan in California. The Framework is used here to evaluate whether EPR could be adopted for compostable plastics.

Element 1: The Framework requires that the goals of the EPR policy be clearly stated.

Application: The goals of the compostable plastic EPR policy are to: improve identification of compostable plastics for consumers, compost facilities and recycling facilities and communicate to consumers whether the material can be included in the local organics cart. Education about proper disposal and making products easily identifiable reduces contamination that occurs when the products are disposed of incorrectly in recycling bins or in areas that cannot accommodate compostable plastics in the compost operation.

Element 2: The Framework lays out guiding principles of what to include in the stewardship plan.

Application: Each brand owner is responsible for developing or participating in an approved stewardship plan that focuses on education and identification for proper disposal.

The stewardship plan includes mapping and designing educational materials for each compost MRF-Shed that brand owners sell product in. The MRF-Shed is the geographic community that funnels recyclables to the same material recovery facility (MRF) (The Recycling Partnership, 2018). For example, a map can show the areas that funnel all compost to one facility, and a two color coding system can be used to indicate whether that facility accepts compostable plastics or just food and/or green waste.

Product design should include industry approved standard visible identification for compostable plastics sold in California such as color coding and visual disposal instruction such as the 'How to Compost' label. Technological identifiers should be reviewed for use such as marker technology or digital watermarks that facilities can rely on to accurately identify the material.

Element 3: The framework delineates that end-of-life management of a product is a producer's responsibility.

Application: Brand owners of compostable plastics are aware that their products may not perform in a compost facility the way they intend. Many facilities operate in shorter time periods than are needed to break down compostable plastic and are at odds with the time indicated within the standard ASTM D6400-12. Regardless, it is still the responsibility of brand owners to work on addressing incompatibilities with the existing system, their products, and their claims of compostability.

Element 4: The framework describes how the EPR law is expected to protect the environment.

Application: The EPR for compostable plastics protects the environment by reducing amounts of single-use disposable items in landfills, reducing food waste, reducing methane gas generated during anaerobic degradation of compostable plastics in landfills, and contributes to an increase in renewable resources being used to produce single-use disposable items instead of fossil fuels.

Element 5: The framework provides that consumers should have easy access to collection locations.

Application: Not all compost facilities will be able to process compostable plastics. Mandatory, standard labeling of the items and signage at disposal locations will increase proper disposal. An option would be to maintain an online website that shows which MRF-Sheds accepts compostable plastics providing retailers who want to purchase

compostable plastics a resource to understand how the compostable plastics will be handled for their area.

The stewardship plan includes details on how the EPR program will be funded. There are several economic and market based EPR policy instruments that could be established for compostable plastics, including Advanced Disposal Fees (ADF) and Upstream Combination Tax/Subsidy (UCTS). An ADF is based on the cost to collect, identify and process the material and is added to the purchase price of the product (OECD, 2016). UTS is paid by the producers and is used to finance the treatment of the waste (OECD, 2016). The UTS provides an incentive for producers to redesign products so that treatment of the waste is less costly (OECD, 2016).

Element 6: The framework stipulates that the system must be set up to get results.

Application: The results of the compostable plastics EPR can be measured by an annual audit of compost and recycling facilities reporting on increased or decreased contamination and unwanted material, adjusted to account for the increase in production and use over time. The audit should be conducted by a third-party nonprofit organization paid for out of funds collected to implement the producer responsibility program.

Elements 7, 8, and 9 cover definitions, roles and responsibilities and are not described here due to the exploratory nature of this analysis. A summary of elements 7, 8, and 9 are included for completeness of understanding the Framework.

Element 7: The framework defines key terms for EPR, Producer, Cradle to Cradle Impacts, Product stewardship Program and Stewardship Organization.

Element 8: The framework requires that the EPR law define roles for the stakeholder groups including producers, retailers, consumers, California government, local government, haulers and collectors, recyclers, dismantlers, processors, and advisory committees & working groups.

Element 9: The EPR law should assign each stakeholder group responsibilities for oversight and continual improvement, information needs/requirements, physical management of products and component materials (cradle to cradle), financial management of end-of-life responsibilities.

Findings

The evaluation demonstrates that developing an EPR program for compostable plastics would be a valuable place to begin to address some of the key challenges associated with end-of-life management of compostable plastics. An EPR program could strengthen consumer confidence in the product to be properly managed after use.

Discussion

Three evaluations were conducted to assess how compostable plastics fit as a contender for EPR legislation. The first evaluation reviewed the five existing California EPR laws to see whether any of them have similar challenges as compostable plastics. The findings indicated that all existing EPR laws addressed two of the challenges identified for compostable plastics: (1) Identification, labeling, and sorting; (2) consumer education.

Addressing ASTM standards for compostability and organics certification are challenges unique to compostable plastics and beyond the ability of an EPR program to control but brand owners can actively participate in efforts to revise the standards and organics certification.

The second evaluation used the primary and secondary product review criteria to evaluate compostable plastics to see how they rate for EPR product selection. Compostable plastics did not receive enough high ratings to have been selected by CalRecycle for initial EPR programs. This was due to things like lack of toxicity, the relatively small quantity generated and the relatively low cost for dealing with the contamination compared to other products. The CalRecycle priority product selection criteria is based on ranking prevalent items in the waste stream. Compostable plastics are not a prevalent item in the waste stream. EPR for compostable plastics is presented here as a preventative approach that aims to to address the challenges of compostable plastics *before* they become prevalent in the waste stream.

In the decades following the initial 2007 CalRecycle priory product selection there have been efforts to address packaging in the waste stream. Beginning in 2016 CalRecycle was tasked with developing a comprehensive, mandatory policy model for managing packaging to reduce packaging waste from this material (CalRecycle, 2017). In October 2017 CalRecycle released the '*CalRecycle Packaging Reform Workshop Background Document'* which detailed the current priority packaging selection process. The screening evaluated the different fiber and plastic packaging types based on 6 waste related and 2 environment related criteria (CalRecycle, 2017). Table 6. Final Listing and Rank of Prioritized Packaging for California shows degradable plastics tied for fourth place priority with thermoforms and wood. Compostable plastics are beginning to show up in screening efforts aimed at managing waste.

Table 6. Final Listing and Rank of Prioritized Packaging for California

Fiber		Plastic	
Rank	Material	Rank	Material
1	Uncoated corrugated cardboard	1	Film plastic
1	Waxed cardboard	2	Expanded polystyrene
1	Aseptic containers and cartons	3	Pouches
4	Wood (pallets and crates)	4	Thermoforms (e.g., PET, PVC, PL, and PLA)
5	Other miscellaneous paper	4	Degradable plastics (e.g., PLA and PHA)
		6	PET containers
		7	Plastic 3-7 containers
		8	HDPE containers

Source: CalRecycle. (2017). CalRecycle Packaging Reform Workshop Background Document.

The third evaluation looked at compostable plastics in terms of the EPR framework guidelines put out by CalRecycle. It was apparent when reviewing the framework criteria that an EPR program could be set up for improving education and identification of compostable plastics and that doing so would lead to positive benefits such as clear disposal guidance based on where you live.

Existing EPR programs in California target bulky or toxic consumer items that do not fit within the traditional multi-stream collection system which limits access to proper disposal and strains education efforts. Current waste management infrastructure. Similarly, compostable plastics do not fit within the current system EPR provides a cohesive and organized way to approach the specific end-of-life management needs of compostable plastics. The challenges identified now will only magnify as future sales and applications increase. Setting up and implementing an EPR program for compostable plastics now, before compostable plastics become a prevalent material in the waste stream, will reduce cost and frustration when dealing with the product in the future.

Based on the outcome from these three evaluations there are eight clear action to be taken for improved end-of-life management of compostable plastics.

Action Area Recommendations

1. Establish an Extended Producer Responsibility (EPR) program for compostable plastics. The projected market growth and known challenges associated with proper end-of-life management of compostable plastics make this product an excellent choice for EPR legislation. EPR can provide a platform and level playing field from which the challenges are addressed. This new class of materials, newly included in the waste stream, needs an organized, thought-out path to follow as it moves through the end-of-life process. The challenges identified by the USCC and CalRecycle will continue to exist and will become more impactful as the product becomes more established.
    - Under the EPR program, stakeholder groups could be appointed that would work to address areas of importance as mandated under the EPR law. The stakeholder groups would be responsible for outlining steps to evaluate specific challenges, researching the challenges, and reporting the findings for further direction from CalRecycle. The stakeholder groups would include experts from relevant fields, industry representatives, recycling and composting operators, waste managers, the public and others.

2. Information based instruments will be critical for the future end-of-life management success of compostable plastics and should be implemented under an EPR program. Information based instruments communicate to consumers, waste managers and compost operators and include labelling, reporting, waste separation rules, and materials contained in products(OECD, 2016). The following information based actions could be implemented under an EPR program:
    - Map the compost MRF-Sheds. A MRF-Shed map shows all areas that funnel their materials to the same facility (Figure 2). The MRF-Shed map would indicate whether the compost facility accepts compostable plastic or just food and/or green waste. The MRF-Shed map would be used to educate counties, cities, institutions, business owners and consumers on whether the compost bins in their area accept compostable plastics. A MRF-Shed specific map could be included with each order of compostable plastic products so that those purchasing them can understand the real disposal option available in their area.

Figure 2. Cincinnati Area MRF-Shed for Rumpke Waste and Recycling
Source: The Recycling Partnership. (2018). Regional Cooperation to Harmonize Recycling Programs - Tools and Tips.

- Create a public education campaign for compostable plastics. The campaign would use signage, pamphlets, packaging, a website, public service announcements and other communication avenues. A public education campaign should provide education on the difference between compostable, biodegradable, and biobased products. The campaign should include how to identify the different types of biobased items with specific focus on how to confidently identify that an item is compostable plastic.
- Establish and use standardized, consistent visual labeling. Existing labels include the How2Compost label by the Sustainable Packaging Coalition, the GreenStripe used on Eco-Product items, the Biodegradable Products Institute label, and many more. Visual labeling should be easy to see, easy to understand and clearly recognizable. The EPR program should establish a universal label and require its use on all compostable items.

3. The EPR program should mandate investment in research to develop technological identification such as fluorescent marker technologies or digital watermarks that increase the ease of identification once an item is being sorted from other materials for processing.
4. The EPR program should fund research to evaluate whether there is a case to petition the National Organics Program (NOP) to add compostable plastics to the national list as an allowed synthetic. An example of a study that supports the addition of compostable plastics to the "acceptable synthetics" list was conducted by the European Bioplastics Association. The study found that most companies use feedstock from non-GMO crops or offer

GMO-free options to produce bioplastics but that even when GMO crops are used to produce bioplastics, the multi-stage processing and high heat of production remove all traces of genetic material (European Bioplastics Association, n.d.). Scientific studies have pointed to composting as a safe way to dispose of GMOs. Biodegradable plastics are accepted by the Canadian Organics Program and the European Organics Program in their feedstocks (US Composting Council, n.d.). Reclassifying compostable plastics as an "allowed synthetic" on the NOP list in the United States would increase the acceptance of compostable plastics at compost facilities and divert more compostable plastics away from landfills.

5. An EPR program should review the ASTM standards and determine the best way to address them. As an example, the EPR program could require producers and compost facility operators to negotiate a target compostability standard that satisfies all stakeholders. This may require producers to work on their formulations to enable compostable plastics to biodegrade faster while compost facilities may need to agree to a standard minimum amount of time that they will allow material to process. If stakeholder compostability standards can be agreed upon, the ASTM standards for compostability could be revised to represent the stakeholder terms.
6. An EPR program should provide a financial support system for facilities needing to invest in new equipment or upgrade existing equipment to properly identify and sort compostable plastics.
7. An EPR program should finance research to understand how compostable plastics impact the microbial communities and the quality of the resulting compost.

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