Plastic Clamshell Container Case Study

The Potential Impacts of Extended Producer Responsibility (EPR) in California on Global Greenhouse Gas (GHG) Emissions

California Department of Resources Recycling and Recovery

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Contractor's Report
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Acronyms

BEA	Bureau of Economic Analysis
BLS	Bureau of Labor Statistics
CalRecycle	California Department of Resources Recycling and Recovery
CIWMB	California Integrated Waste Management Board (now known as CalRecycle)
CO_2E	Carbon dioxide equivalent
EIO	Economic Input-Output analysis
EOL	End-of-life
EPR	Extended Producer Responsibility
EPS	Expanded Polystyrene (also known as Styrofoam)
GHG	Greenhouse Gas
GPPS	General-purpose Polystyrene
HDPE	High Density Polyethylene
IARC	International Agency for Research on Cancer
ISO	International Organization for Standardization
kg	Kilogram (1 metric ton = 1,000 kg, 1 kg = 2.205 lbs)
LCA	Life Cycle Assessment
MJ	Megajoule (about 948 BTUs)
MRIO	Multi-Region Input-Output Energy Use and GHG Emissions Model for California
NAICS	North American Industry Classification System (U.S. Census, 200x)
NCV	Net calorific value (same as lower heating value LHV)
PET	Polyethylene terephthalate
PLA	Polylactide
PP	Polypropylene
PPI	Producer Price Index
UCB	University of California, Berkeley
UCSB	University of California, Santa Barbara

Introduction

Background

This case study supports responsibilities of the Department of Resources Recycling and Recovery (CalRecycle, formerly the California Integrated Waste Management Board) under the California Air Resources Board's Scoping Plan to address greenhouse gas emissions through an Extended Producer Responsibility (EPR) approach.

EPR is a mandatory type of product stewardship that specifies, at a minimum, that a producer's responsibility for its product extends to post-consumer management of that product and its packaging. In practical terms, this means that a producer (manufacturer, brand owner, or an organization that represents its interests) designs, manages, and implements a product stewardship and recycling program. While there is government oversight, the product stewardship and recycling program is financed and operated by the private sector. EPR also is meant to provide incentives to producers to incorporate environmental considerations into the design of their products and packaging because they accrue the costs savings associated with design for recycling or end-of -life management.

The California Global Warming Solutions Act of 2006 (AB 32) requires greenhouse gas emissions to be reduced to 1990 levels by the year 2020. On Dec. 11, 2008, the California Air Resources Board approved the Scoping Plan to reduce the state's greenhouse gas emissions to 1990 levels by 2020. This plan includes a Recycling and Waste Management Measure for EPR. The aim of this climate action mitigation measure is to achieve high recycling and advance EPR to reduce emissions both in-state as well as within the connected global economy. This measure also aligns with CalRecycle's policy priority of advancing industry-led product stewardship (also known as Extended Producer Responsibility) in accordance with the EPR Framework adopted by the Waste Board in September 2007 and modified in January 2008 (CIWMB, 2008). One goal of product stewardship is to increases reuse and recycling of end-of-life products, which, in turn, can reduce greenhouse gas emissions by reducing the substantial energy use associated with the acquisition of raw materials in the early stages of a product's life cycle.

CalRecycle contracted with the University of California, Berkeley (UC Berkeley) and the University of California, Santa Barbara (UC Santa Barbara) with the objective of developing several scientifically-based approaches to analyze life-cycle environmental impacts of products, prepare case studies for selected products, and provide California-specific guidelines for determining if and when a product purchased with recycled content has reduced associated greenhouse gas emissions as compared to a similar product made from virgin materials. The four product case studies cover carpet, clamshells, mattresses and box springs, and single-use batteries.

Scope

This case study is concerned with the production and end-of-life management of single-use folding plastic containers, known as "clamshells," commonly used to contain food for take-out from restaurants. Expanded polystyrene foam (EPS) is a popular material choice for this product because of its low weight and cost and its thermal properties. However, EPS raises significant environmental concerns (see Appendix A). We consider containers made of EPS, general-purpose (crystalline) polystyrene (GPPS), polyethylene terephthalate (PET), polypropylene (PP), and polylactide (PLA). We assess each polymer with respect to several potential disposition pathways. Different pathways are mutually exclusive, i.e. only one pathway can be followed for a given end-of-life product. The different polymers have different possible end-of-life treatment options based on established markets for post-consumer plastic, and so the potential for greenhouse gas reduction can be expected to depend strongly on polymer type. This study assesses the energy and greenhouse gas implications of using different materials and end-of-life management methods (including in-state versus out-of-state recycling) for plastic clamshells. It does not study which EPR approaches and mechanisms would bring about which changes in clamshell design and end-of-life management.

Both types of LCA methodology—economic input-output LCA and process-based LCA (see Appendix B)—are used to estimate the greenhouse gas emission reductions that could be achieved through material substitution and increased recycling of clamshells.

Economic input-output LCA is used to calculate cradle-to-gate greenhouse gas emissions of manufacturing the product, forward logistics, and production processes avoided by recycling. 'Cradle-to-gate' here includes the greenhouse gas emissions of all upstream, or supply chain, activities and ends with the actual manufacturing of the product. Forward logistics refers to the shipment of products from the point of production to the point of consumption. The specific model used is the multi-region input-output life cycle assessment (MRIO-LCA) model developed by UC Berkeley. It employs economic input-output modeling techniques to separate purchases and greenhouse gas emissions into three regions; California, the rest of the United States, and the rest of the world.

The model is based on the single-region U.S. national economic input-output life cycle assessment (EIO-LCA) model developed by Carnegie Mellon University, which can be found at http://www.eiolca.net. Documentation on this website may be beneficial to readers new to economic input-output modeling. Both models use the North American Industry Classification System (NAICS), maintained by the U.S. Census Bureau, to partition the U.S. economy. NAICS is the standard classification used by federal statistical agencies for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. economy. The economic data that underlies the models is the 2002 benchmark input-output model maintained by the U.S. Bureau of Economic Analysis (Stewart et al., 2007).

Process-based LCA is used to estimate the energy demand and greenhouse gas emissions from product manufacturing (cradle-to-gate), forward logistics, and product end-of-life management. Generally, processes involved in product end-of-life management are landfill, reverse logistics, reprocessing operations such as disassembly, recycling and refurbishment, and the production processes avoided by secondary outputs from reuse and recycling activities. For each modeled process, the most appropriate process inventory is chosen from a wide range of public and proprietary life cycle inventory databases, including Ecoinvent, PE, and U.S. LCI, and literature. In some cases this has been complemented by primary data collection.

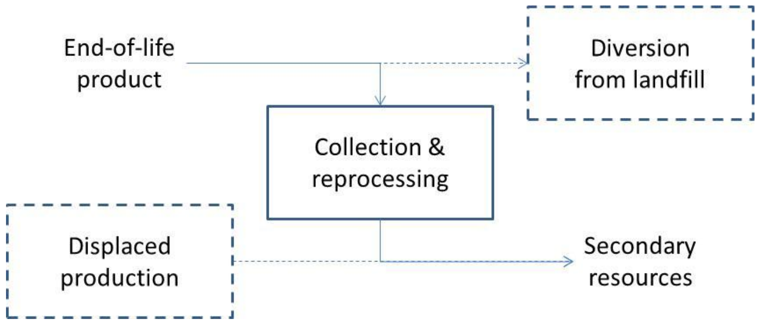

Figure 1: Analytical framework to assess greenhouse gas emissions reductions from reuse and recycling.

The greenhouse gas emission reductions from reuse and recycling are calculated as the greenhouse gas savings from avoided landfill and avoided primary production reduced by the added greenhouse gas emissions from reverse logistics and reprocessing (Figure 1). In life cycle assessment methodology, this method is typically called avoided burden approach or (consequential) system expansion. Avoided burdens are calculated independently with both the process model (as avoided processes) and the MRIO tool (as displaced economic activity). Avoided processes are modeled as negative energy requirements and greenhouse gas emissions. Displaced economic activity is modeled as negative economic demand in the MRIO tool. Because of the uncertainty inherent in estimating avoided burdens, the reported emissions reductions should be regarded as approximate. The way in which MRIO-LCA and process-based LCA is combined in the case studies is illustrated in Figure 2.

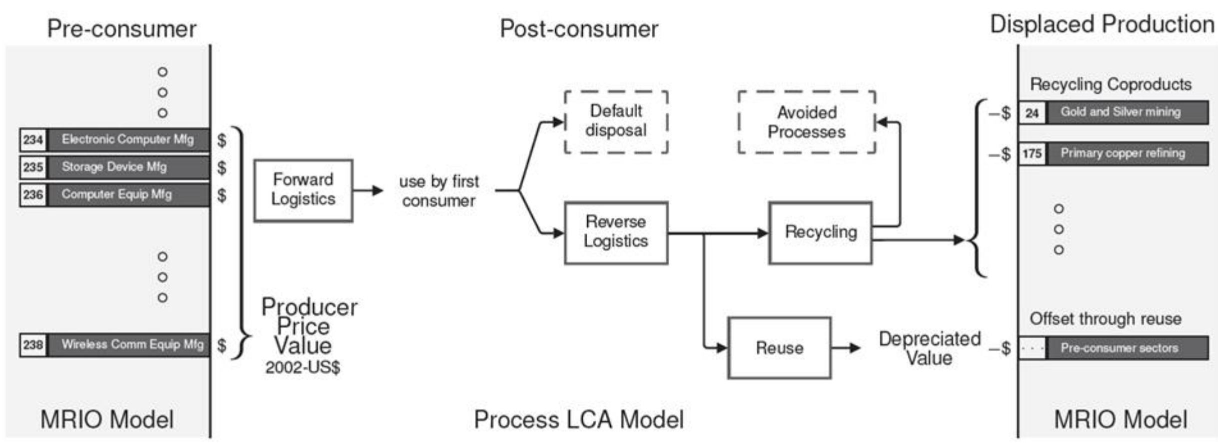

Figure 2: In the case studies, greenhouse gas emissions from product manufacturing and end-of-life management are calculated by combining MRIO-LCA with process-based LCA.

Product Description and Analysis

An industry report estimated that nationwide demand for foodservice clamshells was approximately $1.03 billion in 2010, of which $685 million was EPS foam and less than $15 million was PLA (Freedonia Group, 2011). Adjusting for inflation, this amounts to approximately $789 million in 2002. California's share of this amount can be estimated based on the number of restaurants in the state compared to the nation as a whole. According to the 2007 economic census, California restaurants contained a total of 3,114,660 seats, compared to 25,627,196 seats in the nation as a whole (U.S. Census Bureau, 2010). Thus, California is approximately 12.1 percent of the national market. The California market for clamshells in 2010 was therefore estimated to be $124 million to produce 1.54 billion clamshells. This is roughly $95 million in 2002 producer value.

Cradle to Clamshell

To develop the process life-cycle assessment model for this study, we selected a functional unit of 1,000 typical clamshell containers delivered to establishments in NAICS category 722000, “Food services and drinking places.” We investigated five different materials: expanded polystyrene (EPS) foam, general purpose polystyrene (GPPS, or clear PS), polyethylene terephthalate (PET), polypropylene (PP), and polylactide (PLA).

Table 1 shows parameters used to define the average clamshell, including estimates of purchaser cost per container and weight per container. Estimated environmental impacts from each product were obtained from both the MRIO model and process LCA. The process inventory data were taken from Ecoinvent 2.2 and include primary production of each polymer, transport of the polymer from resin production to clamshell production, and thermoforming the polymer into clamshells.

Table 1: Energy requirements and greenhouse gas emissions from production of a single clamshell using EIO and process-based LCA.

					EIO Results			Process Results	
			Cost ea.		Energy	GHGs	Weight	Energy	GHGs
Product	**Polymer**	**Sector**	**2011 Purch**	**2002 Prod**	**MJ**	**g CO_2E**	**g**	**MJ**	**g CO_2E**
Average Clamshell Container	EPS	326140	$0.08	$0.05	0.68	46.8	10	1.20	51.2
	GPPS	326110	$0.09	$0.06	0.99	69.7	11	1.14	49.2
	PET	326110	$0.23	$0.17	2.52	178.2	21	1.99	75.8
	PP	326110	$0.18	$0.13	1.98	139.5	20	1.80	56.5
	PLA	326110	$0.28	$0.20	3.07	217.0	18	1.70	33.3

The results in Table 1 highlight a significant discrepancy between economic input-output (EIO) results and process inventory results with respect to greenhouse gas emissions. For sector 326140 representing polystyrene foam, the EIO and process results are comparable, although process results are modestly higher. However, for sector 326110, representing GPPS, PP, and PET, the EIO model reports significantly higher greenhouse gas emissions than the process results. For PP and PET, the EIO discrepancy is more than a factor of two. Because of carbon sequestration in PLA production, which is not reflected in the EIO model, the discrepancy rises to a factor of five. This finding demonstrates that the MRIO-LCA results do not provide a reliable basis for comparison among different polymer materials within the same sector.

Focusing solely on process life-cycle assessment results, PLA is seen to have the lowest greenhouse gas impacts during the pre-consumer phase, again because of carbon sequestration associated with growing the corn feedstock. After PLA, the two types of polystyrene, expanded EPS and GPPS, are the next lowest, largely because they have the lowest mass.

Forward logistics

Forward logistics impacts can be derived from the EIO model using BEA statistics. The 2002 benchmark model reports costs for transportation between the producer and the purchaser. The input output data show that only transportation by truck (sector 484000) is significant. Following the premise of EIO-LCA, the monetary value of transport is used as a proxy for computing its environmental impact. The ratio of the value of the truck transportation cost to the value of shipments gives a dimensionless "transport share" of dollars spent on transport per dollar value of product. The transport share multiplied by the value of the product reports the value of transportation services delivered, which can be translated into environmental impact.
Table 2 shows estimates of the impacts from transporting a single clamshell based on EIO data.

Table 2: Impacts from forward logistics using benchmark EIO data.

Truck Transport	**484000**		**Impacts per 2002 US$ (Table 2):**			**18.9**	**1,329**
	Truck Transport – Share of Deliveries to 722000 (2002 US $million)				**Producer Value**	**Impacts per clamshell**	
Sector	**NAICS**	**Ship-ments**	**Truck Cost**	**2002 US $/$**	**2002 US$**	**MJ**	**g CO_2E**
Polystyrene foam product manufacturing	326140	**1,741**	32.3	0.0186	$0.05 EPS	0.016	1.14
Plastics packaging materials and unlaminated film and sheet manufacturing	326110	**362**	6.6	0.0183	$0.06 GPPS	0.022	1.57
					$0.17 PET	0.057	4.00
					$0.13 PP	0.045	3.13
					$0.20 PLA	0.069	4.87
Source:		BEA, 2008			Table 3		

Process inventory modeling can also be used to estimate truck transport impacts, in this case estimating the distance the products must be transported and using environmental data from the process model describing freight transport.

Table 3 shows estimates based on process inventory modeling. In this case, the distance shipped is used to determine the environmental impact. Shipping distances are taken from the 2007

Commodity Flow Survey (Bureau of Transportation Statistics, 2010; Table 12). The shipment distance for polylactide (PLA) is greater because the resin is assumed to be transported from the NatureWorks manufacturing facility in Blair, NE, and must therefore travel farther than average. The numbers are highly comparable to those in Table 2 and indicate that forward logistics may account for around 3-6 percent of pre-consumer greenhouse gas emissions.

Table 3: Impacts from forward logistics using process inventory data.

Truck Transport		Impacts per kg·km:			0.002	0.139
					Impacts per clamshell	
		Weight	Distance	Freight	Energy	GHGs
Product	**Polymer**	**g**	**km**	**kg·km**	**MJ**	**g CO_2E**
Average Clamshell Container	EPS	10	1050	10.6	0.021	1.48
	GPPS	11	1050	11.6	0.023	1.61
	PET	21	1050	22.0	0.044	3.05
	PP	20	1050	20.5	0.041	2.85
	PLA	18	2650	47.3	0.095	6.57

Product End-of-Life Management

Recycling of post-consumer plastic waste is challenging because different plastics must be cleaned of contaminants and separated from one another in order for reclaimed material to be valuable in primary plastic applications (Al-Salem et al., 2009). Separation of a single type of plastic from commingled recyclables is costly and is only economical when the resulting material stream is large enough and has adequate consistency to establish and maintain market demand. All of the polymers discussed in this report are recycled to varying degrees; however, in food contact applications only polyethylene terephthalate (PET) is commonly recycled.

All five polymers are regarded as inert in landfills (PE Americas, 2009). This means the only greenhouse gas impacts from landfill are associated with collection and with the landfill’s operation. Below, the end-of-life modeling decisions for each polymer are described in detail.

Reverse Logistics and Reclamation

All products are assumed to be generated as end-of-life waste in a widely distributed manner. We assume recycled clamshells enter a commingled recycling stream, either at the point of consumption (60 percent) or through residential curbside recycling collection (40 percent). Our model of disposable packaging reverse logistics and recycling is based on our prior work on polyethylene terephthalate (PET) bottles for CalRecycle (Kuczenski and Geyer, 2011, 2012). The polymers are sorted from non-polymer waste at a materials recovery facility and transferred to a reclamation facility, where they are granulated, cleaned, and separated from one another based on density and other physical characteristics.

The reclamation process is based on inventory data for polyethylene terephthalate (PET) bottle recycling published in the U.S. Life-Cycle Inventory database (Franklin Associates, 2010; U.S. LCI, 2011). We apply the same process for all recycled polymers—that is, general purpose polystyrene (GPPS), PET, and polypropylene (PP)—even though the data apply to PET recycling, because the existing process already accommodates the separation of different polymers and can be considered to be adaptable to different polymer mixes. Burdens are allocated between the different plastic streams based on mass.

EPS foam

Expanded polystyrene (EPS) foam is the most abundant material used to make clamshells. Because of the low density of EPS foam packaging, recycling of food-contaminated foam products is not considered to be economical (CIWMB, 2004). EPS foam recycling is common only for loose fill packing materials and protective durable-goods packaging (AFPR, 2009). Food service EPS items are currently not accepted (AFPR, 2012). Pilot-scale operations exist to recycle food-grade EPS containers, although they are presently restricted to high-volume institutional consumers, and participants must maintain densification equipment for reducing the volume of collected waste prior to pick-up. The resulting recycled EPS is used to make decorative moldings and picture frames (DART Container Corporation, 2012). No process inventory information is available for these operations and so they cannot be included in the present study.

EPS has high calorific content and could potentially be combusted to produce energy. In the absence of inventory data for recycling operations, we consider waste EPS incineration with electricity generation as a possible best use of the material. We assign EPS the energy density of 48 MJ/kg. The efficiency for production of electric power from municipal waste incineration in Swiss facilities ranges from 5-22 percent, and the average is 13 percent (Doka, 2003). We assume an electric power conversion efficiency of 22 percent to reflect the performance of a modern facility in California. The resulting electricity can be assumed to displace primary electricity production. We model two end-of-life pathways: (a) avoiding U.S. grid-average electricity production and (b) displacing $0.13/kWh activity in sector 221100, “Electric power generation, transmission, and distribution.”

PET

A mature market exists for post-consumer polyethylene terephthalate (PET) bottles, in part through the support of beverage container deposit programs (Kuczenski and Geyer, 2010). However, post-consumer PET material streams do not typically include non-beverage-bottle PET packaging such as clamshells. Plastics recycling industry actors are working to introduce PET clamshell recycling jointly at the materials recovery facility and reclaimer level (Schedler and Eagles, 2011). We assume PET clamshells could be introduced to the existing PET recycling stream with minimal technical complexity. Because PET is already widely recycled, we assume it finds beneficial use as a polymer. We model the upgrade of the R-PET resulting from clamshell recycling to solid state pellet using U.S. LCI data. We model two end-of-life pathways for the resulting R-PET: (a) avoiding the production of primary PET polymer and (b) displacing $1/kg activity in sector 325211, “Plastics material and resin manufacturing.”

GPPS and PP

At present, general purpose polystyrene (GPPS) and polypropylene (PP) are generally only recycled as components of a mixed-plastic stream which is processed into synthetic lumber, railroad ties, garden equipment, or other low-value products (American Chemistry Council, 2009). Recycled PP from certain product systems is used to replace primary resin; however, this is not common for food applications.

The polyethylene terephthalate (PET) recycling process results in a separate material stream of low-density olefins, including PP and polyethylene, which can be sold for further use. Although PP presently comprises a small fraction of the PET bottle stream, separation of PP from PET should be straightforward in principle using existing technology because of the significant difference in density of the two polymers. GPPS may be more suitable for recovery than EPS in a mixed plastic material stream, although sorting of GPPS from PET may present technical challenges. For the purposes of this case study, we assume that PP and GPPS are equally separable from PET in commingled waste and enter the recovered mixed polymer stream together. We use the same reclamation process inventory for GPPS and PP as for PET, though we omit the pelletization process. We assume the resulting recovered mixed polymer granulate is used to manufacture synthetic lumber. We describe the resulting product alternately as (a) avoiding the production of natural lumber for outdoor use and (b) displacing $0.60/kg economic activity in sector 321100, "sawmills and wood preservation."

PLA

Polylactide (PLA) is recyclable in principle into its constituent monomer, lactic acid, although the low volume of the PLA material stream presents a challenge to efforts to sort it at a materials recovery facility (Verespej, 2010). PLA is considered to be a highly problematic contaminant in the PET stream because the two materials are difficult to distinguish (National Association for PET Container Resources, 2011). No process inventory data are available to describe the process of lactic acid recovery from postconsumer PLA.

PLA is distinct from the other polymers in its greenhouse gas characteristics because it is a bio-based material and because it is compostable. Because PLA is made from corn, atmospheric carbon is drawn into the material during photosynthesis. Thus, according to life cycle assessment methodology, PLA production is conventionally assigned a "credit" that partially offsets the greenhouse gas emissions from polymer production. This leads to PLA production having much lower net greenhouse gas emissions per kilogram than synthetic materials from cradle-to-gate. At the end of the product life cycle, if the polymer degrades, the carbon taken up during crop production is released back into the atmosphere and the greenhouse gas credit is negated. However, if the polymer is assumed to remain intact and not biodegrade, then the atmospheric carbon is effectively sequestered.

We model PLA in terms of two disposal options: landfill and composting. PLA is not compostable in a natural compost pile, though it will degrade in municipal and commercial composting facilities. PLA is assumed to release its full carbon content as CO_2 during composting. The question of PLA's ultimate behavior in landfill has not been answered rigorously, but an emerging consensus holds that it remains inert in a modern sanitary landfill (Bohlmann, 2004; Kolstad et al., n.d.). Thus, the PLA behaves similarly to the other poylmers. If degradation were to occur under the anaerobic conditions typical to sanitary landfills, it would generate methane, which could either be released to the atmosphere or captured and combusted for energy. However, this possibility is not considered in this report.

Life-Cycle Assessment Results

Table 5 and Figure 3 show the results of our modeling for each polymer under each disposition route with regard to greenhouse gas emissions. Table 5 and Figure 4 show the results for energy requirements. In the figures, each polymer is represented as a cluster of bars. The leftmost bar (orange) shows pre-consumer impacts; the rightmost bar (gray) shows best-case greenhouse gas emissions if the products are diverted from landfill and processed in-state according to the above scenarios.

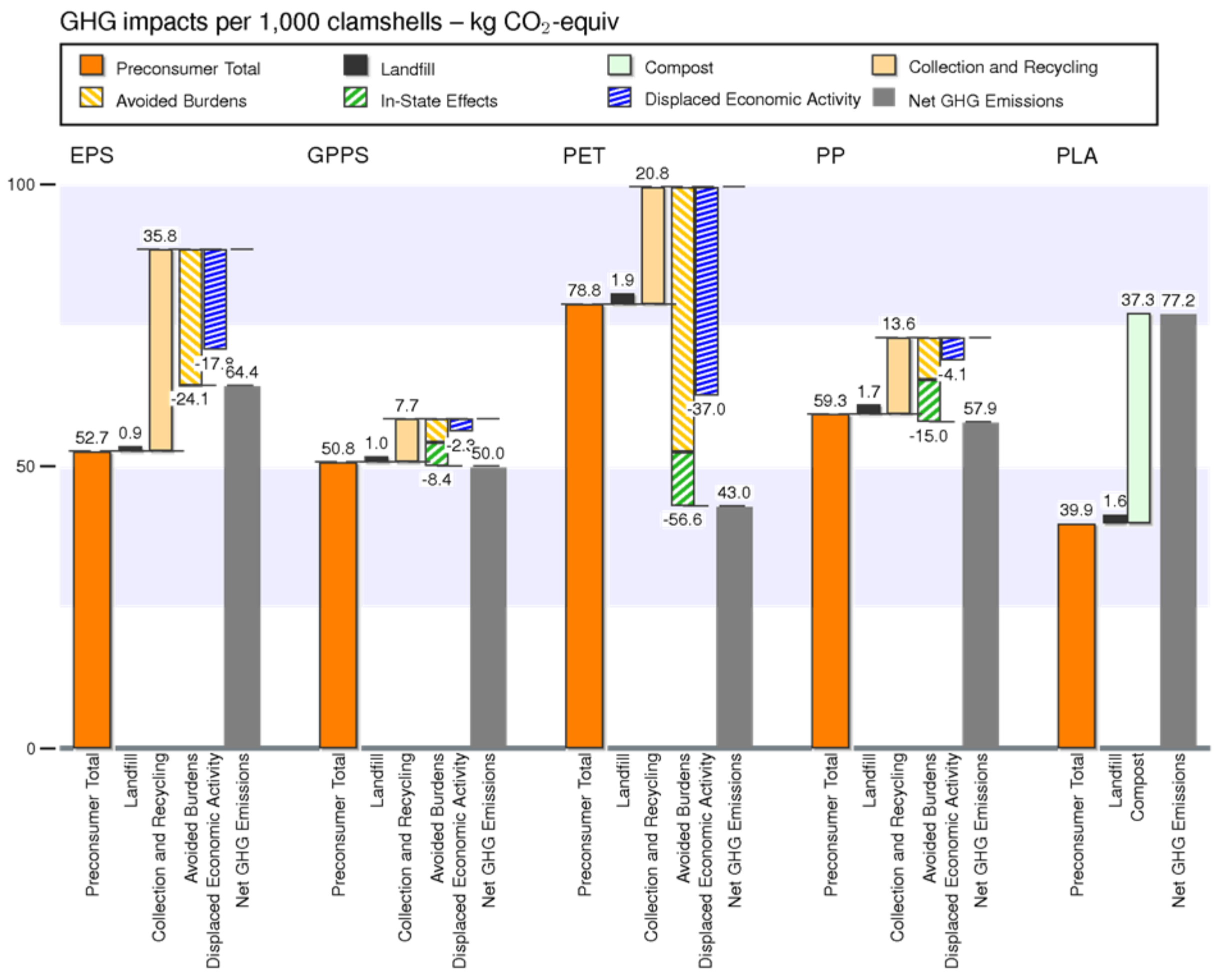

Figure 3: Greenhouse gas emissions from meeting the functional unit for each polymer.

Table 4: Life-cycle greenhouse gas emissions for different polymers for different dispositions.

Life Cycle GHG Impacts kg CO_2E per 1,000 clamshells	EPS Foam		GPPS		PET		PP		PLA
	10 kg, $46		11 kg, $65		21 kg, $165		20 kg, $129		18 kg, $201
Stage									
Cradle-to-clamshell: EIO – 326140*	46.8								
Cradle-to-clamshell: EIO – 326110*			69.7		178		139		217
* EIO figures are not included in the total									
Cradle-to-clamshell: Process	51.2		49.2		75.8		56.5		33.3
Forward Logistics	1.5		1.6		3.1		2.9		6.6
Pre-consumer Subtotal:	52.7		50.8		78.8		59.3		39.9
Landfill (no recovery)	0.9		1.0		1.9		1.7		1.6
No-recovery Total:	53.6		51.8		80.7		61.1		41.5
Reverse Logistics	0.6		0.7		1.3		1.2		1.1
Landfill of Processing Waste	0		0.20		0.37		0.35		0.0
Postconsumer Processing	35		6.8		19.2		12.1		37.8
EOL Pathway:	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(c)
Avoided Landfill	-0.9	-0.9	-1.0	-1.0	-1.9	-1.9	-1.7	-1.7	-1.6
Avoided Burdens	-23.2		-3.2		-45.1		-5.8		
Displaced Economic Activity		-17.8		-2.3		-37.0		-4.1	
Recovery Total:	--		54.3	55.2	52.7	60.8	65.5	67.1	--
In-State Effects	--		-4.2	-4.2	-9.6	-9.6	-7.5	-7.5	--
In-state Recovery Total:	64.4	69.9	50.0	50.9	43.0	51.2	57.9	59.5	77.2

The "no-recovery total" represents the default disposition. End-of-life pathway (a) indicates environmental benefits through avoided process burdens; End-of-life pathway (b) indicates environmental benefits through displaced economic activity. For polylactide (PLA) only, end-of-life pathway (c) indicates composting. The different pathways are mutually exclusive. "In-state effects" indicate avoided freight transport in both forward and reverse directions, and use of the California electric grid instead of the national average.

Table 5: Life-cycle energy demand for different polymers for different dispositions.

Life Cycle Energy Demand MJ per 1,000 clamshells	EPS Foam		GPPS		PET		PP		PLA
	10 kg, $46		11 kg, $65		21 kg, $165		20 kg, $129		18 kg, $201
Stage									
Cradle-to-clamshell: EIO – 326140*	675								
Cradle-to-clamshell: EIO – 326110*			991		2532		1982		3083
* EIO figures are not included in the total									
Cradle-to-clamshell: Process	1198		1142		1990		1799		1701
Forward Logistics	21		23		44		41		95
Pre-consumer Subtotal:	**1219**		**1166**		**2034**		**1840**		**1796**
Landfill (no recovery)	3		3		7		6		6
No-recovery Total:	**1222**		**1169**		**2040**		**1846**		**1802**
Reverse Logistics	9		10		18		17		16
Landfill of Processing Waste	0		1		1		1		0
Postconsumer Processing	87		105		294		187		0
EOL Pathway:	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(c)
Avoided Landfill	-3	-3	-3	-3	-7	-7	-6	-6	-6
Avoided Burdens	-349		-205		-1225		-364		
Displaced Economic Activity		-320		-28		-499		-50	
Recovery Total:	**--**		**1073**	**1250**	**1116**	**1842**	**1675**	**1990**	**--**
In-State Effects	--		-61	-61	-137	-137	-108	-108	--
In-state Recovery Total:	**963**	**993**	**1012**	**1189**	**979**	**1705**	**1568**	**1882**	**1806**

The "no-recovery total" represents the default disposition. End-of-life pathway (a) indicates environmental benefits through avoided process burdens; End-of-life pathway (b) indicates environmental benefits through displaced economic activity. For polylactide (PLA) only, end-of-life pathway (c) indicates composting. The different pathways are mutually exclusive. "In-state effects" indicate avoided freight transport in both forward and reverse directions, and use of the California electric grid instead of the national average.

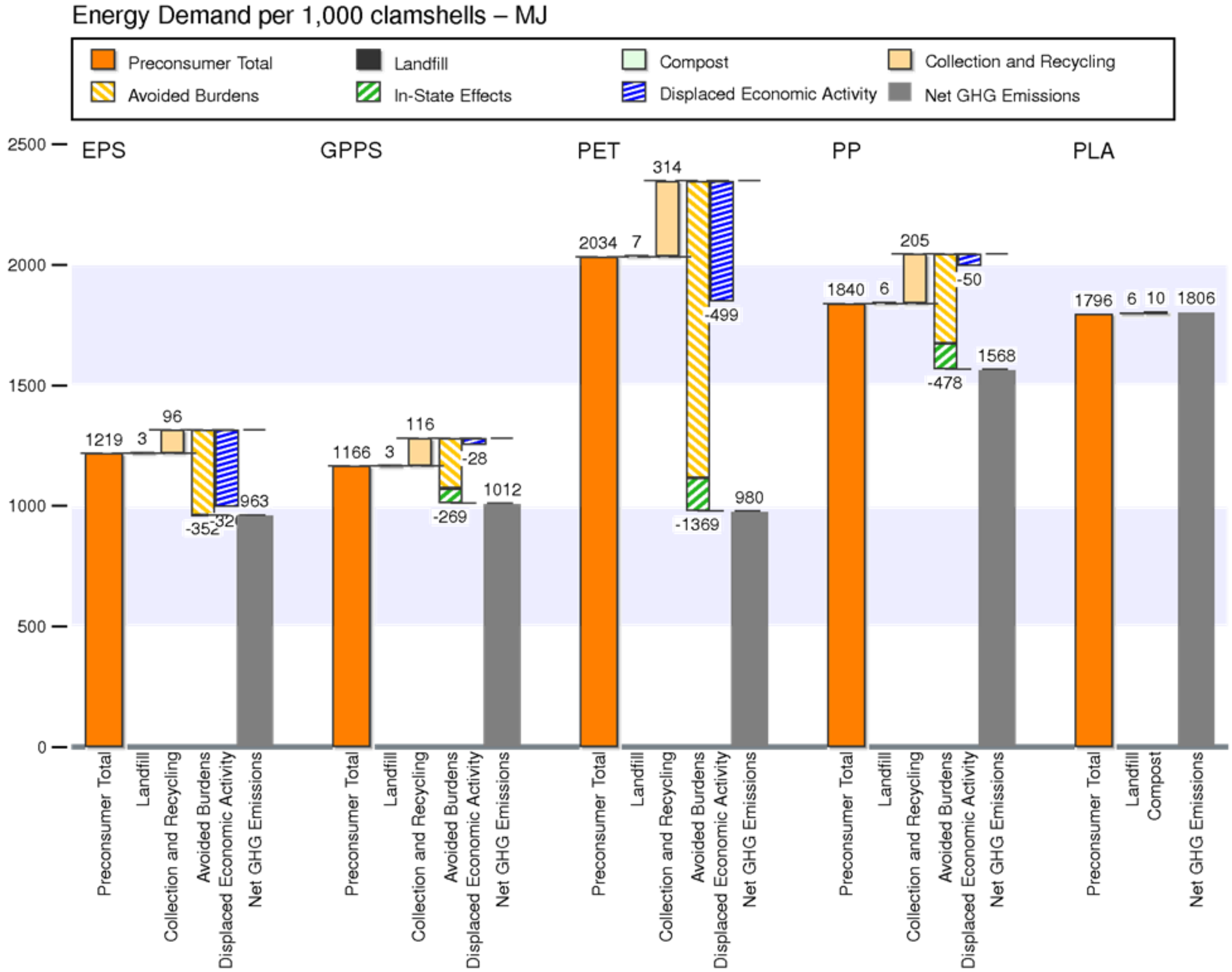

Figure 4: Energy demand from meeting the functional unit for each polymer.

The first notable result is that under the default (no-recovery) disposition, polylactide (PLA) clamshells have the lowest greenhouse gas impacts. This is due to the assumption that the polymer remains inert in landfill, sequestering the atmospheric carbon taken up during corn cultivation for feedstock. If the PLA container is composted at the end of its life, however, then the sequestered carbon is released. Thus the PLA compost route has greenhouse gas emissions that are comparable to the most carbon-intensive synthetic polymer, polyethylene terephthalate (PET).

Polystyrene (PS) products—expanded polystyrene (EPS) foam and general purpose polystyrene (GPPS)—generate relatively low impacts per functional unit compared to the other petrochemical polymers. This is because the impacts of plastic production are generally proportional to mass, and PS products can be manufactured with very low mass. GPPS is comparable to EPS in impacts under the no-recovery scenario. PET has the highest energy requirements and greenhouse gas emissions associated with delivering the functional unit. The initial reverse logistics (e.g. curbside recovery) and landfilling do not contribute greatly to greenhouse gas emissions, each accounting for 1-3 percent of life-cycle impacts.

Due to our assumption that EPS foam cannot be recycled, and that its highest use is to be incinerated for energy recovery, both EPS recovery options result in a net increase in greenhouse gas emissions. This is true even with favorable assumptions regarding the energy content of EPS and the electrical conversion efficiency of the prospective waste-to-energy plant. These findings do not reflect the possible source separation and recycling of EPS foam.

Although PET has the highest pre-consumer impacts of the alternative polymer choices, it also has the lowest impacts under the assumption of in-state recycling. This is because PET is the only material that is already closed-loop recycled, and so the avoided burden credit from primary PET displacement is notably larger than the avoided burdens for other polymers. Recycling of general GPPS and polypropylene (PP) amounts to very little net change in greenhouse gas emissions, although there are modest reductions in energy requirements. This is due to the low carbon intensity of the products displaced by mixed polymer waste.

The two recycling methodologies—avoided burden and displaced economic activity—show comparable greenhouse gas reduction results, though those obtained through displaced economic activity are uniformly smaller. The economic activity reductions are entirely dependent on the assigned value of the economic activity being displaced ($1/kg for polyethylene terephthalate (PET), $0.60/kg for synthetic lumber), a parameter with large uncertainty. In both cases where polymers are assumed to displace miscellaneous wood products, the overall end of life treatment path results in a negligible change in life cycle greenhouse gas emissions versus the polymer's default disposition.

Our results also show that if polymers are reclaimed in the state of California, the potential for avoided emissions due to transportation is significant, amounting to up to 10 percent of life cycle emissions. In-state benefits include shortened shipping distances that result from localization of processing activities within the state, and effects from the use of electric power drawn from the California grid versus the national average. Realizing these benefits requires that (1) polymers are reclaimed in California rather than out of state, and (2) the products of the reclamation process are also converted into products sold in California.

Opportunities for Life-Cycle Emissions Reductions

Material selection and End-of-Life management scenarios

Greenhouse gas emissions are determined by the demand for the product, the product's material composition, life cycle logistics, and end-of-life treatment. The 2010 California market for clamshells was estimated to comprise 1.54 billion units. We assume that reducing market demand is not a viable strategy. Under estimated market conditions, the life cycle greenhouse gas emissions for the clamshell product system in 2010 totaled 87.7 kt (Gg, thousand metric tons) CO_2E.

We modeled a number of different material choices under four end-of-life scenarios: landfill, recycling, in-state recycling, and composting. The following scenarios are considered:

- Business as usual (66 percent expanded polystyrene (EPS) foam; 11 percent each general purpose polystyrene (GPPS), polyethylene terephthalate (PET), and polypropylene (PP); 1 percent polylactide (PLA) [*];
- 100 percent EPS foam;
- No EPS foam (25 percent each GPPS, PET, PP, and PLA);
- 100 percent PET;
- 100 percent PLA

Figure 5 shows life-cycle greenhouse gas emissions results for the different scenarios. Each scenario assumes the entire California market demand was met with the specified material and given the specified end-of-life treatment. Thus, the achievable greenhouse gas reductions will be smaller than those depicted on the graph. The life-cycle greenhouse gas emissions for partial collection rates can be obtained by interpolating between the default and recycling scenarios. For instance: recycling 50 percent of PET bottles would lead to life-cycle greenhouse gas emissions of 102.4 kt CO_2E (50 percent of the way from 124 kt to 80.9 kt).

The results show that under the business-as-usual scenario, collecting and recycling 100 percent of non-EPS clamshells would reduce greenhouse gas emissions by 3.5 kt, or about 4 percent, with an additional 3.7 kt reduction available if the recycling occurred in-state.

PLA disposed to landfill would provide the lowest greenhouse gas impacts due to the assumption that the polymer remains inert and thus sequesters atmospheric carbon. Net greenhouse gas emissions could be reduced by up to 24 kt (27 percent) if all clamshells were made of PLA and all were landfilled at the end-of-life. However, frequently PLA is marketed as a “green” material due to its biodegradability. Under the 100 percent composting scenario, PLA would lead to a net increase in emissions of around 31 kt, or 35 percent.

[*] Under business as usual, EPS foam is assumed to be always landfilled and never recycled.

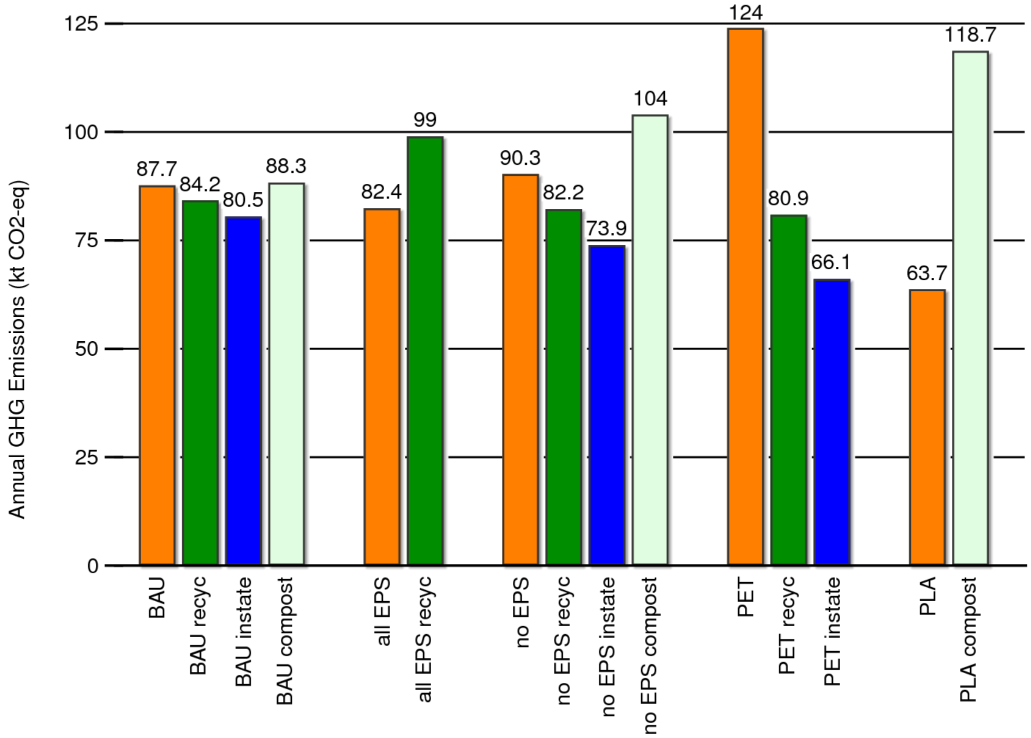

Figure 5: Life cycle greenhouse gas emissions for the California clamshell product system, 2010.

If EPS was phased out and the market demand was met with an even mix of the other polymers, emissions would slightly increase; however, if these clamshells were recycled, then a net reduction could be obtained. A collection and recycling rate of 32 percent would be sufficient for the avoided burdens of recycling to break even with the increase in pre-consumer impacts. If all recycling occurred in-state, then the break-even point is reached with only a 15 percent collection rate.

PET has the highest impacts if it is not recycled; however, extensive recycling of PET could lead to a net reduction in greenhouse gas impacts. A collection rate above 95 percent would have to be obtained for PET clamshells to lead to a net improvement over EPS foam; however, if the recycling was performed in-state, the break-even collection rate falls to 72 percent.

Light-weighting or right-sizing of containers could lead to possible improvements. These improvements would be directly proportional to the reduction in mass of the average container. If the mass of PET clamshell containers were reduced by 20 percent, the break-even collection rate versus EPS clamshells falls to 50 percent; the break-even rate for in-state recycling would fall to 36 percent.

If recycling of EPS foam became viable, emissions could be considerably reduced relative to the 100 percent EPS scenario. However, the benefits would materialize only if the EPS foam displaced primary polystyrene production.

Reverse Logistics

Because clamshell containers are disposable products produced with high volume, distributed collection of post-consumer containers is appropriate. A straightforward option is for clamshell container collection to be integrated into existing recovery and take-back routes for packaging waste, especially commercial and residential curbside commingled recycling collection. An EPR strategy using this approach would benefit from the existing network of businesses and materials recovery facilities, which already process large quantities of consumer waste. However, a curbside integration approach would also be saddled with the shortcomings of the existing system, particularly the prevalence of a single commingled recycling stream with a small polymer fraction.

Bales of post-consumer waste containing clamshells would need to have a positive market value in order for collection and sorting at materials recovery facilities to be viable. The CRV program was considered effective in raising the value of polyethylene terephthalate (PET) bottle bales because bales of redeemed bottles were regarded as being relatively uncontaminated (NewPoint Group, 2007). A similar program may have utility for clamshells if reclaimers can be convinced that clamshell bales result in a valuable material stream. When reclamation facilities are located in California, the potential benefits are substantial because of avoided transportation. This creates the opportunity for a considerable synergy in program design, because reclamation facilities could reprocess post-consumer material into clamshells (or lower-value products) sold into California. Materials recovery facilities might be easily convinced to sort bales that had a ready market of local reclaimers willing to buy. Facilities exist in California which produce PET clamshells for food applications entirely or partially from recycled PET bottles (Global PET, Perris, CA; Peninsula Packaging; Exeter, CA).

Design for Recycling

Given the challenges of recovering clamshells, superior product design is design that supports the production of a viable secondary material stream, i.e. design for recycling. The most significant design decision is the choice of polymer. Because the polyethylene terephthalate (PET) recycling stream is already mature, near-term programs may find it advantageous to leverage this existing market. Furthermore, PET thermoformed containers are already in widespread use outside of the clamshell market, so recycling programs that could accommodate this material stream as well would expand the scope of potential improvement. Olefins, which include polypropylene (PP) as well as the various forms of polyethylene, can be easily separated from PET by density because they are lighter than water while PET is denser than water. The density of general purpose polystyrene (GPPS) is very close to water, making it difficult to separate from the other polymers. Thus a stream which excludes GPPS would appear to be easier to sort into recyclable components.

In designing a clamshell product, the use of adhesives, labels, and resin additives should be kept to a minimum. Ideally, the selection of additives should be done in concert between package manufacturers and reclaimers. Contaminants which would impair the use of recycled polymers in food contact applications should be avoided. Recyclable products should also be visually distinguishable from non-recyclable products, on a basis such as color or shape, in order to assist manual and automatic sorting at the materials recovery facility.

The state could advance the development of a recycling infrastructure for clamshells by requiring manufacturers to provide price support for post-consumer clamshells between use and reclamation. As long as demand for thermoform containers is anticipated to grow, there will be an opportunity for reducing environmental impacts through increasing thermoform recycling. The amount of potential benefit increases as the recycled polymer is put to higher use. This is visible in the net greenhouse gas reductions modeled for PET recycling.

Both recovery and reclamation activities would require support until the material cycle is better established. This support could be given in the form of a fee paid by the producer or distributor, or a container deposit paid by the consumer, whose value is dependent on the container's compatibility with the recycling infrastructure. Clamshells which are made from recycled content or which meet design guidelines could be exempted from the program. Because products could be designed whose entire life cycles occur within California, CalRecycle could have considerable flexibility in involving and incentivizing stakeholders. As a greater proportion of clamshells are recycled and end-use markets are established, the need for price support will decline.

Labor implications

A recent report by the Container Recycling Institute attempted to estimate the job impacts from beverage container collection (Morris and Morawski, 2011; hereafter "CRI, 2011"). The findings are reported in terms of jobs per 1,000 tons (907 t) of material handled by curbside fleets, materials recovery facilities, transfer stations, and reclamation facilities. Thus, they should be adaptable to the clamshell product system. Another report by the Tellus Institute and Sound Resource Management also estimated the employment impacts of reuse and recycling (Tellus Institute and Sound Resource Management, 2011). The estimated job increases found in the reports are shown in Table 6:

Table 6: Job impacts from curbside recycling of plastics.

Operation	Jobs created per 1,000 tons average / median	Reference
Automated Curbside Recycling	0.77 / 0.79	CRI, 2011, Appendix 1.3
	1.67	Tellus, 2011, Table 5
Transfer Station	0.28 / 0.22	CRI, 2011, Appendix 1.5
Primary processing (MRF)	0.73 / 0.64	CRI, 2011, Appendix 1.9
	2.00	Tellus, 2011, Table 5
Secondary processing	2.78 / 2.27	CRI, 2011, Appendix 1.1
	10.30*	Tellus, 2011, Table 5
Avoided Operation	Jobs lost per 1,000 tons average / median	Reference
Transport to Landfill	0.48 / 0.35	CRI, 2011, Appendix 1.7
	0.56	Tellus, 2011, Table 5
Landfill Disposal	0.06 / 0.05	CRI, 2011, Appendix 1.13
	0.10	Tellus, 2011, Table 5
Primary Plastic	0.51 / 0.36	CRI, 2011, Appendix 2.8
	Not quantified	Tellus, 2011
	0.28 / 0.22	CRI, 2011, Appendix 1.5
Net Job Creation:	**3.51 / 3.16**	**CRI, 2011**
	**	**Tellus, 2011**
Indirect Job Creation Factor	1.39-1.61	CRI, 2011, Page 31

* This number includes jobs from reclamation and manufacturing with reclaimed materials combined.
** Because manufacturing jobs are included in the Tellus estimate for secondary processing, and because the Tellus report did not quantify jobs lost in primary plastics production, it is not possible to estimate net job creation from that report.

Employment at existing facilities can corroborate the jobs estimates for reclamation. A recently completed facility in Riverside, owned by Carbonlite, has a reported capacity of 37,500 tons and employs 100 people, equaling roughly 2.7 jobs per 1,000 tons (Verespej, 2012). The Peninsula Plastics facility in Turlock has an annual capacity of 25,000 tons and employs 60, or 2.4 jobs per 1,000 tons (Californians Against Waste, 2012b). Global PET in Perris employs 150 people in its combined reclamation and thermoforming plant with a 30,000 ton capacity, or 5 jobs per 1,000 tons for both reclamation and manufacturing (ibid.).

The method for computing net job creation from recycling is similar to the method for computing net greenhouse gas emissions, as described in Figure 1. Specifically, jobs created through diversion and reclamation, less jobs "lost" through avoided activities such as landfill and primary plastics production, equals the net change in jobs. Jobs from manufacturing of clamshells with recycled plastics should not be counted because of the assumption that recycled-content clamshells would displace equivalent clamshells made from primary plastics.

In the scenarios depicted in Figure 6, the mass of material in the clamshell product system in California ranges from 15-32 kt, which is about 16,900-35,500 (short) tons. Thus, according to the CRI numbers the net job creation from clamshell recycling through automated curbside collection amounts to 53-125 jobs. This quantity rises to about 75-200 jobs when indirect effects are included. This number accounts for jobs lost due to avoided primary production. The Tellus Institute report makes considerably higher job creation estimates, but does not provide enough information to exclude clamshell manufacturing jobs or deduct jobs from primary plastics production. The Tellus report also did not estimate indirect job creation, nor provide a multiplier. However, making the assumption that reclamation and manufacture each contribute equally to employment, and assuming primary plastics production jobs are proportionate in both reports, one could estimate the net job creation to be six to nine jobs per 1,000 tons, or roughly double the number according to the CRI report. Assuming the CRI multiplier for indirect job creation, this would amount to 150-400 jobs created through clamshell recycling.

Conclusion

Clamshell containers represent a low-volume material system with potential for modest reductions in life cycle greenhouse gas emissions. Any approach to greenhouse gas emissions reduction in the clamshell system is predicated on establishing a preferred end-of-life management mechanism for clamshells. Non-recyclable polymers, or polymers whose recycling does not reduce greenhouse gas emissions, should be landfilled; recyclable polymers should be separated from the waste stream and recycled. Once materials are separated for recycling, keeping the material stream in California has additional benefits, both economic and environmental. An EPR program could help motivate manufacturers to establish these situations.

The existing dominant product, expanded polystyrene (EPS) foam, has lower pre-consumer greenhouse gas emissions per functional unit than higher-grade polymers. Although it has undesirable qualities in other areas of environmental performance, particularly litter dispersal, polystyrene represents a fairly low-carbon option. If EPS could also be recycled in a way that reduced demand for primary polymer production, then the material's already low greenhouse gas intensity could be reduced further. The existence of pilot programs to recycle EPS is encouraging; however, these programs are currently low-volume and not closed-loop, and thus their potential for environmental benefit at a larger scale is unclear.

A shift to an alternative polymer would probably entail an increase in net greenhouse gas emissions, unless the material is recycled. The benefits of recycling would be most likely to materialize if the material were closed-loop recycled to remain in the food-grade polymer market, especially if it remained within the California market. If EPS was phased out and replaced with an even mix of the other polymers, a recycling rate of roughly 30 percent or greater would lead to a net reduction in greenhouse gas emissions.

This reduction is achieved partly through the lower greenhouse gas intensity of some polymer choices—general purpose polystyrene (GPPS) and polylactide (PLA)—in combination with the substantial benefits of recycling polyethylene terephthalate (PET). If new markets developed for recycled polymers which made them more attractive and /or caused them to displace more greenhouse gas-intensive primary production (such as displacing polymer production rather than lumber production), a net emissions reduction could be achieved with a lower recycling rate.

PLA has the potential to be the lowest-carbon alternative if it is considered to sequester atmospheric carbon in landfill; however, this contrasts with the public image of the product as biodegradable. PLA that degrades in compost will release considerable amounts of stored carbon to the atmosphere. Thus, while the widespread adoption of PLA may address some of the environmental concerns regarding EPS, greenhouse gas emissions reduction would not be among them unless PLA was aggressively landfilled.

PET has the highest pre-consumer impacts, due in part to its higher container mass, but shows great improvement under a recycling scenario. The potential benefits from a shift to PET within the clamshell market are very closely tied to container light-weighting. However, increased recycling of rigid PET could also have benefits outside the clamshell market. Because closed-loop recycling of PET is already established and because of the growing demand for foodservice PET, there could be significant improvement potential if these other products could also be recycled along with clamshells.

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Appendix A: Concerns about EPS

Expanded polystyrene foam (EPS) is a popular material choice for this product because of its low weight and cost and its thermal properties. However, EPS raises significant environmental concerns. Polystyrene food products are a significant source of litter and marine debris (CIWMB, 2004). Because of their low density and high brittleness, EPS containers are disproportionately likely to be dispersed into waterways or the ocean, where they can easily be mistaken for food by marine organisms (California Ocean Protection Council, 2008).

Styrene, the chemical building block of polystyrene polymer, is classified in Group 2B “Possibly carcinogenic to humans,” by the International Agency for Research on Cancer (IARC, 2002). A public health risk analysis commissioned by the plastics industry and conducted by the Harvard Center for Risk Analysis in 2002 found “suggestive” but inconclusive evidence of risk to human health from styrene exposure (Cohen et al., 2002). Efforts by the California Office of Environmental Health Hazard Assessment to include styrene on the list of hazardous chemicals known to the state of California under the Safe Drinking Water and Toxic Enforcement Act (known as Proposition 65) have encountered legal resistance.

Because of litter and public health concerns, numerous California municipalities have enacted bans on the use of EPS takeout containers (Californians Against Waste, 2012a), and a statewide ban is under consideration by the state Legislature (SB 568 (Lowenthal), 2011). EPR has been put forth as a strategy to reduce the generation of expanded polystyrene foam (EPS) food packaging litter in the absence of more widespread engagement with the issue by manufacturers and consumers (California Ocean Protection Council, 2008).

Appendix B: Process versus Economic Input-Output LCA

There are two major methods for performing life cycle assessment (LCA), process and economic input-output (EIO-LCA). Process LCA uses a model of the sequence of processes involved in a product's life cycle to estimate environmental impacts. The life-cycle impact is calculated as the sum of the impacts of all the individual processes.

Process LCA enables very accurate modeling of individual processes, but suffers from the fact that for practical reasons and data limitations only the most important processes of a product life cycle are included, while the rest is excluded. This is also called the cut-off problem in process LCA.

In contrast, EIO-LCA uses a standard input-output model of the entire economy which has been extended with estimates of sector-wide environmental interventions. Using the EIO model avoids the truncation error inherent to process LCA; however, it suffers from poor specificity and potentially poor accuracy for products that are not representative of their sector as a whole. The only factors that determine environmental impact under an EIO-LCA model are economic sector and producer price, so comparisons between products within the same sector will depend strictly on their relative cost. Thus, economic sectors that vary widely in incurred environmental impacts per dollar value of product will tend to be more poorly modeled by the tool.

Sectors with a relatively higher level of homogeneity in their included activities or produced outputs will be more aptly modeled (Lenzen, 2000). EIO-LCA also does not take into account the use or post-consumer phases of a product life cycle. A hybrid approach is intended to take advantage of the strengths of both methods (Suh and Huppes, 2002). Input-output LCA is used to account for upstream or "supply chain" impacts for which sectoral averages are an appropriate proxy, and process LCA is used to describe detailed processes pertaining to the product system under study where greater specificity is needed than input-output LCA provides.

Appendix C: EIO Data for Clamshell Containers

Clamshell containers, like other specialty products, are particularly challenging to model using economic input-output (EIO) analysis due to the diversity of products included in each economic sector. Because the model is based on the 2002 benchmark EIO accounts (Stewart et al., 2007), our NAICS specifications refer to the 2002 NAICS, although there were no observed differences between the 2002 and 2007 NAICS codes with relevance to our model.

We assume that plastic clamshells are purchased by restaurants and subsequently given to consumers. Table 7 shows macroeconomic statistics that were used to estimate the purchase of plastic clamshells by NAICS sector 722000, "Food services and drinking places." The total economic output of this sector in 2002 was $468.7 billion. The table describes, from left to right, the economic sector to which clamshell production was assigned; total economic output from those sectors; the consumption of products from those sectors by sector 722000 in both producer prices and purchaser prices; and adjustments for inflation. The estimates of economic output come from the EIO accounts (U.S. Bureau of Economic Analysis, 2008) and inflation adjustments come from sector-specific producer price indices maintained by the Bureau of Labor Statistics (BLS) (U.S. Bureau of Labor Statistics, 2012). The value adjustment ("Value Adj.") in the final column is the product of the producer-to-purchaser markup and the 2003-2011 inflation adjustment. This value is used to determine 2002 producer prices from 2011 purchaser prices. Sector 32619A, "Other plastics product manufacturing," is included in the table for comparison.

Table 7: Macroeconomic indicators for economic sectors involved in the production of clamshells. Note: 2002 PPI values were not available.

		Producer Value (2002 US $million)		Purchaser Value (2002 US $million)		PPI Adjustment		
Sector	**NAICS**	**Output**	**to 722000**	**to 722000**	**Markup**	**2003 PPI**	**2011 PPI**	**Value Adj**
Plastics packaging materials and unlaminated film and sheet manufacturing	326110	28,524	362	**386**	6.6%	100	130.7	**1.394**
Polystyrene foam product manufacturing	326140	6,119	1,741	**1,983**	13.9%	100	151.5	**1.726**
Other plastics product manufacturing	32619A	75,893	1,141	**1,403**	22.9%			
Source:		BEA, 2008				BLS, 2012		

Expanded polystyrene (EPS) products are represented in the NAICS code 326140, "Polystyrene foam product manufacturing." This category encompasses all EPS foam products, including clamshells as well as loose fill packaging "peanuts," protective packaging for shipment of durable goods, building insulation, and automotive components. The 2010 Annual Survey of Manufacturers by the U.S. Census indicates that packaging (NAICS 7-digit code 3261402) made up only 30 percent of the value of shipments from sector 326140 nationwide in 2010 (U. S. Census, 2011). Food packaging products, classified under the informal NAICS 8-digit category 32614021, are a subset of the 30 percent. However, economic input-output data are not available at that level of detail. Because all products in sector 326140 are approximately the same material, it is more likely that environmental data in the EIO model will be representative of all products in the sector. Since food service deliveries make up a proportionately greater share of the sector's output, the EIO tool should more aptly model the EPS foam clamshell product system.

Other plastic foodservice packaging products are represented in NAICS category 326110, "Plastics packaging materials and unlaminated film and sheet manufacturing." This category includes containers made of general purpose polystyrene (GPPS) as well as polyethylene terephthalate (PET), polypropylene (PP), and other polymers. It also includes a wide variety of other plastic products, including plastic bags, shrink wrap, and other film and sheet. Deliveries to the food service sector are a very small fraction of the sector's total output, about 1.3 percent. Because this sector likely includes a wide variety of products made of many different polymers, and because such a small fraction of these products are within the scope of the present study, it is possible that the environmental data from the EIO model will be unrepresentative of the clamshell product system. Products made of polylactide (PLA), in particular, will not manifest in the EIO model because PLA was not produced on an industrial scale in 2002 (Vink et al., 2003).

From Table 7, it is evident that nationwide, food service establishments in 2002 procured significantly more polystyrene foam products ($1.983 billion) than non-foam plastics packaging products ($386 million) or other plastics products ($1.403 billion). The polystyrene foam sector also delivered a larger share of its output to the food service sector than the other two sectors. Although foam products here include food service items such as cups and dishes, as well as non-disposable items, the implication is that food service establishments make greater use of polystyrene foam for packaging than other types of plastics.

Table 8 shows results from the MRIO model for sectors relevant to the investigation. The figures indicate the energy requirements and greenhouse gas emissions associated with one dollar of economic activity in each sector. The origin sectors are the economic sectors that produce clamshells. The destination sector, "Food services and drinking places," is the sector of final consumption. Displaced activity sectors are areas of economic activity whose outputs may be displaced through the recycling of clamshells. Total economic demand, energy use, and greenhouse gas emissions are the impacts computed by the EIO model.

Table 8: Economic impact, energy requirements and greenhouse gas emissions by sector per dollar of economic activity (in 2002 producer value), from the MRIO model.

		Producer Value	Total Economic Demand	Energy Use	GHG emissions
NAICS	**Sector Name**	**2002 US$**	**2002 US$**	**MJ**	**g CO_2E**
	Origin sectors				
326110	Plastics packaging materials and unlaminated film and sheet manufacturing	$1	$2.56	15.3	1,080
326140	Polystyrene foam product manufacturing	$1	$2.45	14.6	1,010
32619A	Other plastics product manufacturing	$1	$2.36	10.9	765
Destination Sector					
722000	Food Services and Drinking Places	$1	$1.91	7.36	506
Displaced Activity Sectors					
221100	Electric power generation, transmission, and distribution	$1	$1.59	82.6	4,592
321100	Sawmills and wood preservation	$1	$2.76	9.08	752
325211	Plastics material and resin manufacturing	$1	$2.98	24.9	1,844
Related Sectors					
420000	Wholesale Trade	$1	$1.50	2.84	176
484000	Truck Transportation	$1	$2.00	18.9	1,329