American Chemistry Council

Public Comment
Trash Amendments
Deadline: 8/5/14 by 12:00 noon

RECEIVED
8-5-14
SWRCB Clerk

August 5, 2014

Jeanine Townsend, Clerk to the Board
State Water Resources Control Board
1001 I Street, 24th Floor
Sacramento, CA 95814

Re: American Chemistry Council Comment Letter – Trash Amendments

Dear Ms. Townsend:

The American Chemistry Council (ACC) appreciates the opportunity to offer comments on the draft amendments to the statewide water quality control plans to control trash. We applaud the Board's efforts to establish a uniform, statewide policy to reduce trash that flows into the state's waterways and want to recognize the Board's efforts to solicit input from affected stakeholders – both through the creation of the Public Advisory Group and through the various stakeholder meetings Board staff held throughout the state last year.

ACC supports policies that actually reduce the amount of trash that is improperly discarded and ends up in California's waterways. As drafted the proposal offers two pathways for compliance. Permittees could elect to install a network of full capture systems in storm drains (Track 1) or elect to use a combination of controls – both structural and institutional (Track 2).

ACC strongly supports the proposal to prioritize trash reduction by targeting high trash generating areas and the Track 1 structural controls that clearly are the most effective way to prevent all forms of trash from entering the state's waterways. The effectiveness of these types of infrastructure controls has been demonstrated in Los Angeles:

> *As of March 2012, the City has retrofitted 22,133 catch basins with trash capture or deflecting devices in the Los Angeles River Watershed as well as three netting systems certified as full capture devices have been installed strategically in the Watershed. With these structural devices alone, the City has reduced its trash discharge to the Los Angeles River by approximately 90%, several years ahead of the final TMDL compliance milestone.*[1]

ACC also recognizes that some approaches in Track 2 may be effective at reduced costs. But regardless of the approach adopted, the Board should require thorough monitoring that demonstrates equivalent effectiveness to Track 1 in reducing "trash."

However, as described in detail in our attached comments, ACC opposes the proposed Track 2 "regulatory source controls"—specifically product bans—as well as the proposed extensions of compliance deadlines for communities that adopt product bans. Product bans have not been demonstrated to be effective in reducing total trash, which is defined in the Draft Staff Report as "***all improperly discarded solid material*** from any

[1] *See* http://www.lacitysan.org/irp/documents/FINAL_IRP_5_Year_Review_Document.pdf, Section 3.4.2

production, manufacturing or processing operation, including, but not limited to, products, product packaging, or containers ***constructed of plastic, steel, aluminum, glass, paper, or other synthetic or natural materials***." (Draft Staff Report at 65)(emphasis added)

To quote from the Draft Staff Report:

> *Data from the City of San Francisco's Streets Litter Re-Audit report confirmed that eliminating all food-related polystyrene would simply change the type of litter found on our streets and in our waterways, and result in an increase in the non-polystyrene related litter items, thus* ***showing no overall reduction in litter (or trash to the waterways)****. (A-18)(emphasis added)*

Thus, product bans do not actually benefit the environment. Furthermore, studies show that alternatives can increase other environmental impacts including greenhouse gas emissions, energy use, water use and waste. These are important factors the Board is required by law to consider and should not overlook.

Our environmental concerns highlighted are also discussed in the expert report authored by Environmental Resources Planning and other supplemental information attached to our comments.

Further, ACC has several legal objections to the product ban proposals including:

1. Authorizing and incentivizing product bans or other regulatory source controls as a means to comply with the State's water quality control plan is arbitrary, capricious, and unsupported by the record because product bans are ineffective in reducing trash loads.

2. Authorizing and incentivizing municipalities to ban useful products as part of an MS4 NPDES permit would violate the Clean Water Act and is not authorized under its provisions.

3. The Proposed Amendments violate the California Environmental Quality Act.

4. By attempting to use the regulatory source control option to single out plastic and polystyrene products for local bans under the regulatory source control the proposal raises several constitutional concerns.

We further elaborate on these legal objections in our attached comments.

ACC is actively engaged in programs that demonstrably reduce trash. For example, in California ACC and member companies have promoted recycling, supported anti-litter education campaigns and community/school based instructional programs, and developed trash and recycling partnerships with California State Parks and Cal Trans. In addition ACC was instrumental in organizing 59 other plastic trade associations from 34 countries to launch a "Global Declaration" to keep plastic from becoming marine litter.[2] The most recent Progress Report for that work details more than 185 projects launched since December 2013 to prevent plastics from being discharged into the coastal or marine environment — a 90 percent increase in the number of projects since the Global Declaration was announced.

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[2] The Declaration of the Global Plastics Associations for Solutions on Marine Litter: Progress Report – 2014, *available at* http://plastics.americanchemistry.com/Education-Resources/Publications/Progress-Report-2014.pdf

We are committed to working with the Board to develop and implement a sound trash reduction policy that is balanced, economically and environmentally sustainable, and would provide real reductions in overall trash loads to the waters of this state. ACC thanks you in advance for considering our views. Should you have any questions or comments, please contact me at 916-448-2581 or tim_shestek@americanchemistry.com.

Sincerely,

Tim Shestek
Senior Director, State Affairs
American Chemistry Council

Attachments:

- Comments of the American Chemistry Council (August 5, 2014) and Exhibits
- ER Planning, Technical Assessment of California Statewide Water Quality Control Plans to Control Trash – June 2014 Draft Report (August 4, 2014)
- Declaration of Michael Levy (August 4, 2014)

Comments of the American Chemistry Council

"Proposed Amendments to Statewide Water Quality Control Plans to Control Trash and the Draft Staff Report, Including the Draft Substitute Environmental Documentation"

August 5, 2014

The American Chemistry Council Plastics Division ("ACC" or "ACC Plastics Division") appreciates this opportunity to comment on the State Water Resources Control Board's ("Board") Proposed Amendments to Statewide Water Quality Control Plans to Control Trash ("Proposed Amendments"), the Draft Staff Report, and the Draft Substitute Environmental Documentation ("SED").

ACC represents the leading companies engaged in the business of chemistry.[1] The ACC Plastics Division in particular represents the leading manufacturers of plastic resins—the raw material used to make consumer and other products of and with plastics. The Plastics Division's Packaging Team leads a variety of recycling initiatives and educational outreach programs, as does the Division's Plastics Foodservice Packaging Group, to educate the public about the benefits of plastic packaging including to protect the integrity and safety of goods; prolong the shelf life of packaged foods; and reduce greenhouse gas emissions, while delivering fuel savings, since it is more lightweight than alternatives.

The ACC Plastic Division actively works to implement environmental and sustainability initiatives for the plastics industry. These initiatives have included creating partnerships with governments and non-governmental organizations to prevent litter, reduce marine debris, and increase recycling. In California, ACC has been a strong supporter of AB 258, which was passed in 2007 to control and prevent the release of preproduction plastic pellets. AB 258 built on an existing program created by ACC and the Society of the Plastics Industry called Operation Clean Sweep in order to prevent spilled pellets from making their way into California's waters and the oceans. ACC also has sponsored over 700 recycling bins placed on California beaches and in state parks. ACC and partner organizations globally have announced approximately 185 projects to reduce marine debris since 2011.[2] ACC is dedicated to campaigning for an anti-litter ethic, which includes education on reducing and preventing litter.

INTRODUCTION

ACC supports reducing trash discharges from municipal separate storm sewer systems ("MS4s") to enhance water quality in California. ACC recognizes the Board's substantial effort to engage interested stakeholders through its Public Advisory Group, in which ACC has been an

[1] ACC members apply the science of chemistry to make innovative products and services that make people's lives better, healthier and safer. ACC is committed to improved environmental, health and safety performance through Responsible Care®, common sense advocacy designed to address major public policy issues, and health and environmental research and product testing. The business of chemistry is a $812 billion enterprise and a key element of the nation's economy. It is one of the nation's largest exporters, accounting for ten cents out of every dollar in U.S. exports. Chemistry companies are among the largest investors in research and development.

[2] The Declaration of the Global Plastics Associations for Solutions on Marine Litter: Progress Report – 2014, *available at* http://plastics.americanchemistry.com/Education-Resources/Publications/Progress-Report-2014.pdf.

active participant, as ACC and its members are essential stakeholders who would be impacted significantly by the Proposed Amendments.

The Proposed Amendments and supporting documentation are critical documents because they provide the blueprint that MS4 operators and MS4 national pollution discharge elimination system ("NPDES") permit writers would follow when controlling trash discharges from California MS4s. If adopted, the structural controls and non-structural measures that the Board has proposed—and in particular those that it would propose to incentivize—would be implemented at MS4s throughout the State.

ACC strongly endorses controls that have been documented to work to prevent discharges of trash—and measures that can be monitored to demonstrate the controls are in fact effective. We therefore support the Board's proposed "Track 1" that would provide for structural controls that are known and have been proven, through monitoring and data reporting, to effectively reduce trash discharges. We likewise would also endorse certain measures under the proposed "Track 2" that actually could reduce trash discharges, such as increased street sweeping, more trash receptacles, and enhanced trash collection.

However, we urge the Board not to retain the portion of the Track 2 proposal that authorizes so-called "regulatory source controls," and in particular any measures that would allow MS4s to comply with NPDES permit requirements by enacting bans on plastic bags and polystyrene foam food containers, as such product bans would be fundamentally flawed, ineffective, and unlawful. Indeed, the data are absolutely clear that banning these useful and lawful products would be ineffective at achieving the Board's goals of reducing trash and improving water quality. Moreover, promulgating a rule that would authorize and incentivize product bans is beyond the Board's authority under federal and state law.

As detailed below, ACC has four main concerns:

First, while reducing trash loads is an important goal that ACC supports, product bans directed at plastic bags and polystyrene foam food containers do not reduce trash and would not improve water quality. As a result, regulations, such as the Proposed Amendments, that authorize compliance by incentivizing product bans as a means to reduce trash discharges are arbitrary, capricious, and unsupported by the record. For one, bans are ineffective because the volume of potential trash is a very small share of the total trash at issue. As statistically significant litter surveys repeatedly demonstrate, plastic bags and polystyrene foam food containers are extremely small components of litter and are grossly overestimated by municipalities and other advocates who argue that product bans should be given preferential treatment in stormwater trash reduction programs. Further, empirical data based on statistically valid litter surveys establish that bans on plastic bags and polystyrene foam food containers do not reduce the total amount of trash that is discharged. Rather, at best, product bans cause businesses and consumers to substitute for plastic bags and polystyrene foam food containers with alternatives that result in the same or more litter.

Second, authorizing municipalities to ban useful products as part of an MS4 NPDES permit would be unlawful under the Clean Water Act ("CWA" or "Act"). The purpose of the CWA is to regulate and reduce pollutant discharges into waters of the United States, and NPDES permit conditions must have a direct nexus to the discharge of a pollutant. By contrast, product bans are ordinances that would regulate the upstream sale or distribution of a useful product that is used for its lawful, intended purpose. Congress did not expressly authorize product bans under the MS4 provisions, and it is unreasonable to infer that Congress implicitly authorized environmental agencies to use the CWA to regulate broad swaths of the U.S. economy in the name of pollution control far upstream from any potential discharges.

Third, the Proposed Amendments violate CEQA. The Draft Staff Report and Proposed Amendments make clear that bans on plastic bags and polystyrene foam food containers will frequently be included in MS4 permits. However, the SED does not include product bans as a reasonably foreseeable compliance option and, therefore, does not evaluate their environmental impacts or those of alternative approaches. This error is not harmless, as substitute products such as paper bags and bio-plastics have very significant environmental impacts.

Fourth, by using the regulatory source control option to single out plastic bags and polystyrene foam food containers for municipal bans, the proposal raises several constitutional concerns. The proposal would violate the dormant Commerce Clause by placing a significant economic burden on interstate commerce without providing any local benefit at all. The proposal would also violate the Equal Protection clause because there is no rational basis for singling out plastic bags and polystyrene foam food containers for bans when those bans would be ineffective. Finally, by failing to provide any standard to distinguish between effective and ineffective regulatory source controls, the Proposed Amendments violate the Due Process Clause and are void for vagueness.

BACKGROUND

A. Summary of the Proposed Amendments

The Board's mission is to "ensure the highest reasonable quality for waters of the state, while allocating those waters to achieve the optimum balance of beneficial uses."[3] To achieve this mission and provide comprehensive protection of the state's waters, the Board exercises authority over both water allocation and water quality. With respect to water quality, the Board exercises authority delegated to it from the state legislature in the Porter Cologne Act, California Water Code § 13000 *et seq.*, and from the federal government in the CWA, 33 U.S.C. § 1251 *et seq.* Under the CWA, each state is required to adopt water quality criteria for priority pollutants. 33 U.S.C. § 1313(c)(2)(B). States implement these criteria, in part, through NPDES permits. *Id.* § 1342.

The Board proposes to adopt a statewide water quality objective under which "no trash shall accumulate in state waters (or in areas adjacent to state waters) in amounts that would either adversely affect beneficial land uses, or cause nuisance." Draft Staff Report at 11; *see also id.* at D-1, E-1. This objective would be accomplished through "a conditional prohibition of discharge of trash directly into waters of the state or where trash may ultimately be deposited into waters of the State." *Id.* at 11. Trash is defined broadly under the proposal to include "[a]ll improperly discarded solid material from any production, manufacturing, or processing operation including,

[3] http://www.waterboards.ca.gov/about_us/water_boards_structure/.

but not limited to products, product packaging or containers constructed of plastic, steel, aluminum, glass, paper, or other synthetic or natural materials." *Id.* at D-10, E-10. For discharges subject to NPDES permits, such as MS4s, the conditional prohibition would be implemented through amendments to the MS4's existing NPDES permits.

The Proposed Amendments include two different permitting options or "Tracks" that an MS4 operator can follow in order to comply with the conditional prohibition on trash discharges. Under Track 1, an MS4 operator would "install, operate and maintain full capture systems for storm drains that capture runoff from priority land uses in their respective jurisdictions." Draft Staff Report at 13. Full capture systems are defined as "treatment controls (either a single device or a series of devices) that traps all particles that are 5 mm or greater, and has a design treatment capacity that is either: a) of not less than the peak flow rate, Q, resulting from a one-year, one-hour, storm in the subdrainage area, or b) appropriately sized to, and designed to carry at least the same flows as, the corresponding storm drain." *Id.*

Under Track 2, an MS4 operator "would develop and execute an implementation plan of any combination of controls, such as full capture systems, other treatment controls (e.g., partial capture devices and green infrastructure and low impact development controls (LID)), institutional controls, and/or multi-benefit projects to achieve the same performance results as Track 1 would achieve." *Id.* Among the institutional controls identified in Track 2 are "regulatory source controls," which are defined as "institutional controls* that are enforced by an ordinance of the municipality to stop and/or reduce pollutants at their point of generation so that they do not come into contact with storm water*." *Id.* at D-10, E-10. The Draft Staff Report specifically highlights "bans of single-use consumer products such as single-use carryout bags and expanded polystyrene foam" as regulatory source controls that municipalities could adopt. *Id.* at 16. Track 2 offers a degree of flexibility to MS4 operators, and the Board notes that "[t]he capital investment required to implement institutional controls is generally less than for full capture systems." *Id.* at 89.

Under both Track 1 and Track 2, MS4 operators would have to achieve full compliance with the Proposed Amendments within 10 years of the effective date of the NPDES permit that incorporated the Amendments. *Id.* at D-5, E-5. Because NPDES permits are revised every five years, the compliance date could be up to 15 years from the effective date of the final regulations. *Id.* The Board has proposed one exception to the compliance schedule: MS4 operators selecting the Track 2 compliance option will be given a one-year extension of compliance deadline for each "regulatory source control" they adopt, up to a total of three years. *Id.* at D-6, E-6. Once permits are in place, the Proposed Amendments also include broadly phrased monitoring and reporting requirements.

B. Likely Effect of the Proposed Amendments

ACC supports offering MS4 operators flexibility in achieving the state's water quality objectives for trash discharges into waterways, provided the alternatives incorporate measureable, effective tools for reducing the discharges. Although they can require a significant initial capital investment, the full capture devices included in Track 1 would clearly be effective at reducing trash discharges. Los Angeles, for example, recently reported that "[w]ith these structural devices alone, the City has reduced its trash discharge to the Los Angeles River by approximately 90%, several years ahead of the final TMDL compliance milestone."[4] By contrast, the Track 2 compliance option would allow MS4 operators to identify lower-cost alternatives to full capture devices that potentially could offer material reductions in trash discharges to waterways. Because full capture devices could also be incorporated into a Track 2 compliance approach, we would expect that virtually all MS4 operators would choose the Track 2 compliance option.

While Track 2 offers flexibility to MS4 operators, the content of the Board's final trash amendments will likely have significant influence over the content of the NPDES permitting conditions for trash discharges from MS4s. First, by defining the types of controls allowed under Track 2, the Board is thereby specifically authorizing the use of certain controls to comply with the CWA. Within the universe of permissible Track 2 compliance options, there will likely be widespread uniformity in permitting conditions, as permit writers and MS4 operators seek to identify the lowest-cost options that they believe could comply with the Board's final requirements. Thus, despite the fact that some flexibility would be offered in the Proposed Amendments, the Board's actions in effect would narrowly dictate the content of MS4 NPDES permit conditions for trash reduction.

That the proposal would control the likely content of MS4 permit conditions is particularly true with respect to "regulatory source controls." Not only would adopting a product ban be perceived as a low-cost compliance option for a municipality due to the lack of up-front capital costs, these regulatory source controls are the *only* Task 2 option that the Board has incentivized by offering to extend the compliance deadlines. Under these circumstances, it is reasonably foreseeable that most if not all municipalities would adopt product bans in order to receive the extensions of the compliance deadline offered by the Board's proposal. *See* Declaration of Michael Levy ¶ 6 (Aug. 4, 2014) ("Levy Decl.") (Exhibit A) ("Municipalities will enact product bans to avoid the capital costs associated with full capture structural controls and to obtain extensions of the compliance deadlines."). Further, the Draft Staff Report and Proposed Amendments make clear that plastic bags and polystyrene foam food containers will be the central focus of such municipal ordinances. In fact, these are the *only* "regulatory source controls" that are mentioned in either document. Given the history of such bans in California, it is likely that, if finalized, the Proposed Amendments would result in a *de facto* state ban on plastic bags and polystyrene foam food containers, as virtually every MS4 operator would include such regulatory source controls in its NPDES permit.

The likelihood of this outcome is further confirmed by the implementation of California's total daily maximum load ("TMDL") regulations for trash. *Id.* The Los Angeles Regional Water Quality Control Board has adopted a trash TMDL for Santa Monica Bay that includes a provision to extend compliance deadlines if municipalities adopt ordinances banning plastic bags, single use polystyrene food packaging, and smoking in public. 23 CA ADC § 3939.43. Municipalities have responded to these incentives by adopting the required bans. In Manhattan Beach, for example, the city's environmental program manager urged the city council to ban polystyrene foam food containers in order to obtain the three-year extension. Esther Kane, *Manhattan Beach City Council set to ban polystyrene food containers*, Easy Reader News (Aug.

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[4] City of Los Angeles, Water IRP 5-Year Review FINAL Documents, at 3-11(June 2012), *available at* http://www.lacitysan.org/irp/documents/FINAL_IRP_5_Year_Review_Document.pdf.

21, 2013) (Because of "Manhattan Beach's ban on plastic bags, impending ban on public smoking and this polystyrene ban, the city would be eligible for a three-year extension to meet the Board's Total Maximum Daily Load regulations.").[5] Other cities subject to the Santa Monica trash TMDL, such as Hermosa Beach have also adopted product bans after the TMDL was issued. *See* Hermosa Beach Municipal Code § 8.64.030. Thus, it is reasonable to expect that the Proposed Amendment would produce the same result, but on a statewide scale.

C. Economic Impact of a Ban on Plastic Bags and Polystyrene Foam Food Containers

Authorizing a *de facto* statewide ban on plastic bags and polystyrene foam food containers would have a significant impact on the industries that produce these products and on California's economy as a whole. Many of these products are produced in California and, therefore, produce economic significant value to Californians. Further, these products are manufactured at a lower cost than substitutes and, thus, provide economic benefits to consumers as well.

In a 2009 study, Keybridge Research evaluated the economic effects in California of a state-wide ban on polystyrene foam foodservice products, assuming the ban were complied with and enforced.[6] Keybridge found that the direct impact on polystyrene foam production facilities would include almost $430 million in reduced output and result in a loss of more than 1,500 jobs. *Id.* at 9. If indirect impacts on other entities in the polystyrene foam production chain are included, economic output would be reduced more than $1 billion and result in a loss of nearly 5,000 jobs. *Id.* Because polystyrene foam foodservice products are less expensive than substitute products, a ban will also have a negative effect on consumer purchasing power, which Keybridge estimated would reduce output by almost $600 million and result in more than 4,000 lost jobs. *Id.* at 15. Even when the economic benefits associated with producing alternative products are included, a ban on polystyrene foam foodservice products was projected to cause a nearly $1.4 billion net reduction in output and a net loss of approximately 8,000 jobs in California. *Id.* at 1. These impacts would be significant and would expand beyond the polystyrene manufacturing sector to affect retailers, grocers, restaurateurs, convenience stores, farmers, and others. While ACC's members would bear the brunt of such a ban, the impacts would be felt throughout California's economy, both in terms of indirect effects and a reduction on consumer purchasing power.

The effect of a state-wide ban on plastic bags would also be significant. According to the American Progressive Bag Alliance, there are 46 plastic bag manufacturing establishments in California.[7] These establishments employ more than 1,800 workers with an annual payroll of $75.8 million and total sales of more than $500 million. *Id.* A *de facto* statewide ban would

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[5] *Available at* http://www.easyreadernews.com/73829/manhattan-beach-city-council-set-to-ban-polystyrene-food-containers/.

[6] Keybridge Research, Quantifying the Potential Economic Impacts of a Ban on Polystyrene foam Foodservice Products in California (Nov. 18, 2009) (Exhibit A to Levy, Decl.).

[7] American Progressive Bag Alliance, Jobs by State: Plastic Bag Manufacturing (NAICS 326111) – Selected Statistics in 2012 by State (Exhibit B).

have a significant effect on the California market, which would assuredly cause dramatic harm to local plastic bag producing companies.

ARGUMENT

I. The Board Should Remove "Regulatory Source Controls" from Track 2 Because Including and Incentivizing Product Bans is Arbitrary, Capricious, and Not Supported by Substantial Evidence.

Board regulations such as the Proposed Amendments may be declared invalid if "[t]he agency's determination that the regulation is reasonably necessary to effectuate the purpose of the statute, court decision, or other provision of law that is being implemented, interpreted, or made specific by the regulation is not supported by substantial evidence." Cal. Gov. Code § 11350(b)(1). In legal challenges to a regulation, the reviewing court must determine "whether the action was arbitrary, capricious or entirely lacking in evidentiary support." *City of Arcadia v. State Water Resources Control Board*, 119 Cal. Rptr. 3d 232, 244 (Cal. App. 2010); *see also Light v. State Water Resources Control Board*, 173 Cal. Rptr. 3d 200, 224 (Cal. App. 2014) ("When a regulation is challenged on the ground it is not reasonably necessary to effectuate the purposes of the statute, our inquiry is confined to whether the rule is arbitrary, capricious, or without rational basis and whether substantial evidence supports the agency's determination that the rule is reasonably necessary" (internal citations and quotation marks omitted)).

ACC urges the Board to exclude "regulatory source controls," because the Board's proposal to authorize municipal bans on plastic bags and polystyrene foam food containers in Track 2 and to incentivize them by offering extended compliance deadlines fails under these standards. ACC supports measures that work. Yet, here, the Board offers no evidentiary support in the Draft Staff Report or elsewhere in the record to show that banning plastic bags and polystyrene foam food containers would be effective in reducing trash discharges. In fact the available evidence demonstrates that product bans are *not* effective at reducing municipal trash discharges. Thus, it would be arbitrary and capricious to authorize such product bans and to offer incentives for their adoption at the expense of other trash reduction options that are known and proven to be effective.

A. The Draft Staff Report Offers No Support for Regulatory Source Controls

Foremost, we urge the Board to remove "regulatory source controls" because there is no data or other evidence in the record to support including them in Track 2. Nowhere does the Draft Staff Report reference scientific study, data, or any other supporting materials whatsoever that demonstrate that product bans can reduce or eliminate trash discharges from MS4s. In fact the only evidence cited in the Staff Draft Report demonstrates that bans on plastic bags and polystyrene foam food containers—the sole regulatory source controls mentioned in the Draft Staff Report—would have no effect on overall trash discharges because replacement materials would simply be discharged in their place:

> The proposals to ban plastic bags and polystyrene food containers could result in the use of alternative materials with a variety of potential impacts. Data from the City of San Francisco's Streets Litter Re-Audit report confirmed that eliminating

> all food-related polystyrene would simply change the type of litter found on our streets and in our waterways, and result in an increase in the non-polystyrene related litter items, thus, showing no overall reduction in litter (or trash to the waterways) (City of San Francisco 2008). Without a ban on all plastic and paper carryout bags, a ban on only plastic bags would simply cause a shift back to paper.

Draft Staff Report at A-18. Thus, the record is "entirely lacking in evidentiary support" for the assertion that banning products can reduce trash discharges. *See City of Arcadia*, 119 Cal. Rptr. 3d at 244.

B. Existing Studies Demonstrate that Regulatory Source Controls Are Ineffective in Reducing Trash Discharges

Given the dearth of evidence in the administrative record, ACC retained a national expert, Steven Stein of Environmental Resources Planning LLC ("ER Planning"), to study the Proposed Amendments and existing literature regarding the effectiveness of product bans focused on plastic bags and polystyrene foam food containers in reducing trash discharges. ER Planning's report is included with these comments and incorporated here by reference. ER Planning, Technical Assessment of California Statewide Water Quality Control Plans to Control Trash – June 2014 Draft Report (August 2014) ("ER Technical Assessment") (Exhibit C). ER Planning found that "[n]o statistically-credible visible litter survey ever conducted in California or anywhere else supports the notion that material bans reduce overall litter." *Id.* at 21. In its analysis, ER Planning identified three primary flaws with the claim made by some that bans on plastic bags and polystyrene foam food containers would reduce or eliminate trash discharges from MS4s. ACC requests that the Board consider each of these, as we submit that each flaw is sufficient to demonstrate that product bans are ineffective and that it would be arbitrary and capricious to retain "regulatory source controls" as a Track 2 compliance option.

First, banning plastic bags and polystyrene foam food containers offers no real benefits because contrary to the conventional wisdom, the actual volume of these products in trash streams is extremely small. Ban proponents often make claims that erroneously rely on uncompressed trash volumes as opposed to volumes measured at natural density; this basic flaw can dramatically overestimate the volume of trash components with significant air space, such as plastic bags and polystyrene foam. ER Technical Assessment at 7-9. For example, the 2012 Bay Area Stormwater Management Agencies Association ("BASMAA") report erroneously used uncompressed volumes and overestimated the volume of plastic bags in trash by as much as 900%. *Id.* at 8. Relying on similar reports could cause municipalities to ban plastic bags or polystyrene foam food containers mistakenly believing the ban would materially reduce litter in water discharges, even though these bags and containers actually make up only a small portion of trash streams. An ER Planning comparison of 24 recent statistically valid litter surveys found that plastic bags comprised *only 0.5%* of the litter identified in the surveys. *Id.* at 15. In the same comparison, polystyrene foam food containers comprised *only 1.1%* of the trash stream. *Id.* at 11. This is consistent with the results of individual studies in California. *Id.* at 12, 13.

The implications of these surveys is clear: If plastic bags and polystyrene foam food containers do not comprise a significant portion of the overall trash stream, a municipal ban on the sale or distribution of these valuable products—even if fully implemented—could have no more than a negligible effect on trash volumes under the best of circumstances.[8] Thus, even if product bans were a legitimate way to reduce trash discharges (and we submit they are not), we urge the Board not to support bans of plastic bags and polystyrene food service containers under Track 2, as the bans would not be effective at improving water quality. Indeed, a municipality would be better served to focus on products that actually contribute substantially to trash streams in California. *See id.* at 10 (listing largest components of litter in San Francisco).

Second, statically valid studies have shown that local ordinances banning plastic bags and polystyrene foam food containers *do not* reduce the total amount of plastic bags and polystyrene foam food containers in trash streams. For example, ER Planning reports that studies taken in the three years after San Francisco's 2006 partial ban on plastic bags failed to show a statistically significant change in plastic bag litter. *Id.* at 21-22. Likewise, BASMAA's 2012 trash characterization failed to show a statistically significant difference in plastic bag and polystyrene foam litter between jurisdictions with and without material bans in place. *Id.* at 23-24. In fact, of the 216 municipalities in the BASMAA study, three of the six highest litter rates for polystyrene foam food containers were jurisdictions that had local ordinances banning those products. *Id.* Again, as these studies show that product bans are ineffective, the Board should remove bans from Track 2, as it would be arbitrary, capricious, and unreasonable for the Board to include, let alone incentivize, product bans as part of the proposed Track 2 compliance option.

Third, regardless, as the Draft Staff Report acknowledges, litter surveys demonstrate that local ordinances banning plastic bags and polystyrene foam food containers do not reduce the overall amount of trash in local waterways because, at best, product bans simply shift the content of that trash from one product to another through substitution. Draft Staff Report at A-18.[9] Comparative data show that when local bans are enacted, if there are reductions in plastic bags and polystyrene foam food containers, those products are replaced by other consumer products that are just as likely to be discarded and discharged into waterways. ER Technical Assessment at 25-26. In fact, trash surveys conducted before and after San Francisco banned polystyrene foam food containers show that any reductions in polystyrene foam litter were more than offset by increases in litter composed of paper and other plastic products that serve as substitutes, meaning that litter counts actually increased after the ban took effect. *Id.* (citing 59% increase in littered food service items and 45% increase in littered hot cups). A product ban that merely substitutes one type of trash for another is not and cannot be an effective means of reducing or eliminating trash from MS4 discharges. Further, in many cases, the alternative products used as substitutes for plastic bags and polystyrene foam food containers have greater potential impacts on the environment, considering lifecycle GHG emissions, water usage, and other factors. *See infra* Section III. Again, it would be arbitrary, capricious, and unreasonable to include or incentivize "regulatory source controls" that would substitute rather than reduce or eliminate the trash that is discharged from MS4s.

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[8] In many cases, municipalities create exceptions for small business, further reducing the potential effectiveness of bans on plastic bags and polystyrene food service containers. *Id.* at 19-20.

[9] The Proposed Amendments include a broad definition of trash that would encompass substitute products such as paper bags, paper cups, and bio-plastics. Draft Staff Report at D-10, E-10.

C. Viable Institutional Controls Have Been Proven to Be Effective and Should Be Incentivized Instead of Product Bans

The Proposed Amendments do not merely include product bans among the various institutional controls that municipalities can adopt under the Track 2 compliance option. Instead, the Proposed Amendments would create an incentive for municipalities to adopt product bans *over measures that are effective* by extending the compliance deadlines for municipalities that adopt product bans. As a result, if promulgated as proposed, it is very likely that municipalities selecting the Track 2 compliance option will overwhelmingly adopt bans on plastic bags and polystyrene foam food containers instead of other measures, in order to delay the relevant compliance deadlines. It would be arbitrary and capricious for the Board to include such incentives for product bans when, unlike bans, structural controls and established institutional controls (such as securing trash on collection trucks, street sweeping, increased collection bins, and increased frequency of collection) are actually shown to be effective in reducing trash discharges.

As an initial matter, as the public record establishes, it is beyond dispute that full capture devices and other structural controls have proved highly effective in reducing trash discharges under TMDL programs in California. For example, the City of Los Angeles recently asserted that, relying solely on strategically placed full capture devices, "the City has reduced its trash discharge to the Los Angeles River by approximately 90%, several years ahead of the final TMDL compliance milestone." LA IRP Review at 3-11. In light of the demonstrated effectiveness of full capture devices, ACC supports Track 1. In fact, given the effectiveness of full capture devices, there are compelling arguments for mandating the Track 1 approach.

ACC recognizes, however, that some municipalities may be pressed financially to implement only the full capture devices contemplated by the proposed Track 1 controls. Hence, ACC would support offering MS4s the flexibility of the combination of structural and institutional controls under Track 2; provided, that the Track 2 approach is limited to institutional controls that have proved effective in reducing trash discharges and are consistent with the law and the Board's legal authority. In addition to studying the effectiveness of bans on plastic bags and polystyrene foam food containers, ER Planning reviewed analyses of various institutional controls identified in the Proposed Amendments. In each instance, ER Planning concluded that these controls were actually effective in reducing trash discharges and, thus, offered significant advantages when compared to product bans. For example, ER Planning reports that properly securing trash on collection vehicles could reduce litter by 20% or more. ER Technical Assessment at 32. Likewise, studies have shown that more frequent street sweeping can reduce litter by 50%, *id.* at 31, and appropriately placed and conspicuously decorated trash receptacles have been shown to reduce litter by as much as 16.7%, *id.* at 30-31. Other effective institutional controls include focusing on high-density generation areas and enforcing existing anti-littering and illegal dumping ordinances. *Id.* at 29-30.

In light of these data, it would be arbitrary and capricious and fundamentally inconsistent with the purported purpose of the Proposed Amendments to provide incentives for municipalities to adopt bans on plastic bags and polystyrene foam food containers that may address, even under the best of scenarios, less than 1% of the total litter stream when there are structural and institutional controls that could produce significant, real reductions in trash. If the Proposed

Amendments are intended to eliminate or reduce trash discharges from MS4s, we urge the Board to incentivize effective controls, not ineffective ones, and to encourage municipalities to adopt the controls options that will reduce pollution to the maximum extent practicable in accordance with the Clean Water Act. Bans on plastic bags and polystyrene foam food containers clearly fail to meet this standard.

D. The Board Failed to Evaluate the Costs of Regulatory Source Controls

The arbitrary and capricious nature of the proposed authorization of product bans is exacerbated by the Board's failure to evaluate their full costs, as required by law. Although product bans have low up-front costs, ongoing monitoring costs must be incurred to ensure that the bans are effective in reducing trash discharges. However, the Board's staff made no attempt to evaluate those costs in the "Economic Considerations for the Proposed Amendments to Statewide Water Quality Control Plans to Control Trash." Draft Staff Report, Appendix C. While the Board asserts that it considered the costs "of reasonably foreseeable measures to comply with the proposed Trash Amendments," *id.* at C-2, it excluded product bans despite the high degree of likelihood that the bans would be adopted, if the amendments were issued as proposed. *See* Levy Decl. ¶ 6. Instead, the Board's analysis of institutional controls was limited to activities such as street sweeping, public outreach, and catch basin cleaning. *See, e.g.*, Draft Staff Report at C-25.

The failure to analyze the costs of product bans renders the entire proposal incomplete and, unless corrected, will prevent municipalities from properly weighing the costs and benefits of bans on plastic bags and polystyrene foam food containers. The primary benefit of the Track 2 compliance option is that it allows municipalities flexibility to select cost-effective measures to reduce trash discharges, so long as those measures perform as well as full capture systems. Critical to that analysis is an understanding of the costs associated with each control option. In fact, the Track 2 compliance option is only a viable option if the suite of Track 2 controls included in a MS4 NPDES permit can achieve the same trash reductions as full capture systems, but at a lower cost. Hence, it is critical that municipalities understand the costs associated with each control that could be included under Track 2 so that they can make an informed decision to proceed under Track 1 or Track 2 and, if necessary, choose among the various Track 2 control options. The lack of information regarding the costs of product bans is particularly troubling in light of the fact that these bans have been shown to be largely ineffective in reducing trash volumes. As a result, virtually any cost associated with product bans would be unreasonable in the face of uncertain and unlikely benefits.

Further, the cost to monitor the effectiveness of a product ban is not inconsequential. The Proposed Amendments would require Track 2 compliance options to perform as well as full capture systems with respect to trash reduction. Yet, while the Proposed Amendments include a clear monitoring requirement for Track 1, there is only a general requirement to conduct monitoring to show compliance under Track 2. *Id.* at D-6-7, E-6-7. Moreover, the proposal phrases the requirement broadly and does not offer any guidance to permit writers or municipalities regarding what a monitoring program for Track 2 would entail or any way to determine the costs. Yet, as ER Planning explains, the Board should rethink this approach. While full capture devices are well-known to be effective, Track 2 compliance options are more "risk-laden and unstructured," meaning that a "stricter and more extensive monitoring, testing and reporting" program is necessary. ER Technical Assessment at 27. For product bans, ER Planning asserts that an effective monitoring system "would be based on special surveys that would be conducted on an annual basis by independent third party professional firms." *Id.* Further complicating matters is the fact that "if multiple controls are put in place …, Permittees must validate the effectiveness of each control to help determine which components of their controls are driving any changes in the system." *Id.* Thus, a proper monitoring program will be complex, time consuming, and costly. The Board must evaluate and attempt to quantify this cost as part of its economic analysis.

II. The Board Should Also Remove the "Regulatory Source Controls" Provision Because the Clean Water Act Does Not Authorize the State Board to Use MS4 NPDES Permits to Ban Useful Products

ACC further urges the Board to remove "regulatory source controls" from the Track 2 compliance option because authorizing product bans would exceed the Board's authority under the CWA. The CWA authorizes the Board and NPDES permit writers to reduce discharges from MS4s to the maximum extent practicable ("MEP"). This squares with the purpose of the CWA, which is to regulate discharges of pollutants and the dischargers responsible for them. Congress did not, however, give the Board or NPDES permit writers the power to ban or to use the CWA to ban useful products. Congress never intended for the Board to look beyond those actually responsible for trash discharges and instead regulate the sale and distribution of useful products on the theory that a portion of those products may one day be discarded and then discharged into an MS4. A regulatory body should not—indeed cannot by law—assert authority over such a broad swath of the economy without a clear legislative mandate.

A. Regulation of MS4s Under the Clean Water Act

The regulation of MS4 discharges derives in part from the federal CWA. The purpose of the CWA is "'to restore and maintain the chemical, physical and biological integrity of the Nation's waters' by eliminating the discharge of pollutants into navigable waters." *City of Arcadia v. State Water Resources Control Board*, 38 Cal. Rptr. 3d 373, 379 (Cal. App. 2006) (quoting 33 U.S.C. § 1251(a)). The CWA seeks to accomplish this goal by imposing permit requirements on discharges of pollutants into waters of the United States. *See* 33 U.S.C. § 1311(a). Those who discharge pollutants from point sources must obtain national pollutant discharge elimination system ("NPDES") permits, which typically impose end-of-pipe effluent limitations based on technology-based standards or water quality-based standards. *Id.* § 1342. The technology-based standards included in conventional NPDES permits must be based on the best available technology economically achievable ("BAT").

Because end-of-pipe controls based on BAT proved more difficult to implement for stormwater discharges, Congress established revised NPDES permit requirements for stormwater discharges. *Id.* § 1342(p). For MS4 NPDES permits, Congress required "controls to reduce the discharge of pollutants to the maximum extent practicable." *Id.* §1342(p)(3)(B)(iii). This MEP standard can include "management practices, control techniques and system, design and engineering methods, and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants." *Id.*

B. The Board's Proposal to Authorize Product Bans Under the Track 2 Compliance Option Is Unlawful Under the CWA

1. The CWA does not authorize bans of useful products

The Board should remove the "regulatory source control" option from its proposal first and foremost because the CWA does not authorize agencies to use product bans to implement the stormwater discharge limits. Nothing in the language of the CWA or the MS4 permitting provisions suggests that Congress intended to authorize EPA, the States, and NPDES permit writers to ban useful products. As discussed above, the purpose of the CWA is to regulate and reduce discharges of pollutants, and this purpose is achieved by issuing permits to those who discharge pollutants. The 1987 amendments to the CWA created the MS4 permitting program in response to challenges posed by stormwater discharges. In doing so, Congress directed the use of "best management practices" ("BMPs) and "such other provisions as the Administrator or State determines appropriate for the control of such pollutants." 33 U.S.C. 1342(p)(3)(B)(iii). While the amendments expand *what* can be required of those who discharge stormwater, they do not expand *who* could be subject to regulation. Thus, there is no reason to believe that Congress authorized the Board to use the MS4 permitting program to use product bans to regulate those who sell or distribute useful products that someone might one day discard.

As a general rule, Courts are critical of agency interpretations that rely on implicit authorization to expand the agency's jurisdictional authority. *See, e.g., Continental Air Lines, Inc. v. Department of Transportation,* 843 F.2d 1444, 1449 n.4 ("Congress can reasonably be expected to be quite precise in defining critical jurisdictional terms going to the very power of the agency to regulate."). Instead, Courts frequently demand explicit Congressional authorization expanding an agency's jurisdiction. *E.g., Meghrig v. KFC Western, Inc.,* 516 U.S. 479, 484-85 (1996) (holding the Resource Conservation and Recovery Act did not implicitly authorize the government to recover response costs when the statute was silent and the authority to recover past costs was explicitly authorized in another statute); *New York State Bar Ass'n v. FTC*, 276 F. Supp. 2d 110, 134-35 (D.D.C. 2003), *aff'd sub. nom. Am. Bar Ass'n. v. FTC,* 430F.3d 457 (D.C. Cir. 2005) ("Courts have found that when Congress legislates in one area with explicit reference in a statute on an area of concern, but fails to reference that same subject matter in another statute, its silence is evidence that Congress did not intend for there to be applicability in the latter statute.").

Hence, as we urge the Board to recognize, when Congress sought to use its power to authorize an agency to regulate manufacturers or distributors by banning a particular product, Congress has stated its intent clearly and unambiguously. For example, under the Toxic Substances Control Act, EPA can "prohibit[] the manufacturing, process, or distribution in commerce of [a] substance or mixture" after finding that the substance or mixture "present[s] an unreasonable risk of injury to health or the environment." 15 U.S.C. § 2605. EPA can also cancel a pesticide registration upon a finding that the pesticide "causes unreasonable adverse effects on the environment." 7 U.S.C. § 136(d). These provisions, which give clear authority to ban the manufacture and sale of useful products based on the risks they pose to the environment stand in stark contrast to the MS4 provision which says nothing about banning useful products due to environmental concerns. "Where Congress knows how to say something but chooses not to, its silence is controlling." *In re Griffith*, 260 F.3d 1389, 1394 (11^{th} Cir. 2000) (en banc).

2. **As the core purpose of the Clean Water Act is to regulate actual discharges to waters of the United States, the stormwater management provisions of the Act cannot be interpreted to authorize bans of useful products**

Moreover, placed within the larger context of the fundamental purpose and framework of the CWA, it would be unreasonable to read the very general MEP standard as authorizing bans on useful and lawful products. For that additional reason, ACC urges the Board not to include "regulatory source controls" under Track 2.

As the Supreme Court has held, the legal framework in this regard is clear: "The meaning—or ambiguity—of certain words or phrases may only become evident when placed in context." *FDA v. Brown & Williamson Tobacco Corp.*, 529 U.S. 120, 132. Courts "must be guided to a degree by common sense as to the manner in which Congress is likely to delegate a policy decision of … economic and political magnitude to an administrative agency." *Id.* at 133. This is particularly true when the agency would intrude on fundamental aspects of our economy—including the ability for a lawful business to sell or distribute a legal product for use by consumers. Congress does not delegate decisions of "economic and political significance to an agency" in a "cryptic" fashion. *Id.* at 139. Instead, as the Supreme Court held earlier this year, "[w]hen an agency claims to discover in a long-extant statute an unheralded power to regulate 'a significant portion of the American economy,' [the courts] typical greet its announcement with a measure of skepticism. [The courts] expect Congress to speak clearly if it wishes to assign an agency decisions of vast 'economic and political significance.'" *Utility Air Regulatory Group v. EPA* 134 S. Ct. 2427, 2444 (2014). "Congress … does not alter the fundamental details of a regulatory scheme in vague terms or ancillary provisions—it does not, one might say, hide elephants in mouseholes." *Whitman v. American Trucking Associations*, 531 U.S. 457, 468 (2001); *see also Continental Air Lines, Inc. v. Department of Transportation*, 843 F.2d 1444, 1449, n.4 (D.C. Cir. 1988) ("Congress can reasonably be expected to be quite precise in defining critical jurisdictional terms going to the very power of an agency to regulate.")

The Supreme Court's recent decision in *UARG v. EPA* is a case in point. There, the Court rejected EPA's interpretation of the phrase "any air pollutant" when applying it to greenhouse gas emissions under the Prevention of Significant Deterioration ("PSD") program as it would have resulted in a 100-fold increase in the number of sources subject to EPA regulation. *UARG*, 134 S. Ct. at 2443. Notwithstanding the deference a court may in some cases give an agency charged with interpreting and applying a statute, according to the Court, EPA's approach was "unreasonable because it would bring about an enormous and transformative expansion in EPA's regulatory authority without clear congressional authorization." *Id.* at 2444.

Following these basic principles, it would be unreasonable to leap from general municipal stormwater management provisions that authorize "other provisions … for the control of such pollutants," to the wholesale bans of useful products as authorized and incentivized by the Proposed Amendments. For one, a product ban would be inconsistent with the core context of the CWA—to regulate and reduce *discharges* of pollutants into waters of the United States. *See, e.g.*, 33 U.S.C. § 1251(a) ("it is the national goal that the discharge of pollutants into navigable waters be eliminated …."). Hence, just like the reference to "any air pollutant" was limited by the broader context of the Clean Air Act in *UARG*, *UARG* 134 S. Ct. at 2440, the references to best management practices and "other provisions" to control pollutants must be read in context—any controls authorized under the MEP standard must be directed toward parties that have a direct nexus to the *discharge* of a pollutant into an MS4. There is no such nexus for product bans. The vast majority of plastic bags and polystyrene foam food containers that would be subject to bans are recycled or disposed of through other appropriate means. The manufacturers and distributors that would be targeted by bans on useful products that consumers use every day have no nexus to the discharge of a pollutant, and it is unreasonable to suggest that Congress would have delegated the authority to regulate them in so cryptic a fashion.

Further, had Congress intended for states to use the MS4 provisions to take the extraordinary step of banning a lawful and useful commercial product it certainly would have stated that authorization clearly and unambiguously, particularly in view of the extraordinary economic impacts that would result from authorizing bans of useful products. For example, as discussed above, a statewide ban on polystyrene foam food service items would result in economic losses of $1.4 billion in output and nearly 8,000 lost jobs. *See supra*, Background, Section B. Thus, the economic impacts of bans on these two products, the only targets listed in the Proposed Amendments, *e.g.*, Draft Staff Report at 7, 79, would be significant standing alone. However, as proposed, the potential product bans allowed under the guise of "regulatory source controls" in the Proposed Amendments are not limited to plastic bags and polystyrene foam food containers and are premised on the State Board having the authority to use the power of the CWA to ban any other useful product that may be found in an MS4's trash stream. Thus, a municipality could also obtain an extension of the compliance deadlines by adopting a ban on cigarettes, plastic and glass beverage containers, disposable diapers, or any other product identified by the Board as a component of Trash. *See* Draft Staff Report at 1. It is unreasonable to suggest that Congress intended to give EPA, the States, and NPDES permit writers the authority to regulate the entire retail economy as a means of limiting trash discharges into waters of the United States.

3. Using product bans is also inconsistent with guidance under the Clean Water Act.

Third, ACC would also urge the Board to reject "regulatory source controls," because this newly-claimed authority to regulate the sale and distribution of useful products would be inconsistent with the past practices of EPA, the States, and permit writers.

Under the Clean Water Act's "maximum extent practicable" standard, MS4 NPDES permitting requirements have focused on the core CWA purpose of regulating those responsible for the discharge of pollutants into waters of the United States. Specifically, as EPA has outlined in guidance, BMPs for MS4 operators may include a variety of structural controls, such as the construction of detention, retention, and filtration ponds.[10] In the context of trash reduction, consistent with the statutory direction to implement "best *management* practices" municipalities may, in addition to structural controls, be required to take steps to better *manage* the trash

[10] *See, e.g.*, EPA, Guidance Manual for the Preparation of Part 2 of the NPDES Permit Applications for Discharges from Municipal Separate Storm Sewer Systems § 6.4.

produced, such as to install and maintain trash receptacles and conduct regular street sweeping.[11] In addition, MS4 NPDES permits may direct a municipality to regulate other entities within their jurisdictions that are directly responsible for discharging pollutants into MS4s. For example, municipalities may adopt land use ordinances for construction projects in order to control sediment and other pollutants present at construction sites.[12] In the context of trash reduction, municipalities can adopt and enforce ordinances that prohibit littering.[13]

However, MS4 NPDES permits do not impose binding obligations on the upstream producers and distributors of useful products who lack a direct nexus to a pollution discharge. Nor does any guidance require, encourage or even suggest that states or municipalities ban lawful and useful products in order to comply with the Clean Water Act. Instead, at most, the MS4 NPDES permit writers may suggest to municipalities that they promote voluntary measures such as community outreach and public education to encourage manufacturers to produce and consumers to buy products with reduced packaging.[14] The Proposed Amendments would dramatically and unlawfully expand the scope of the MS4 NPDES permitting program beyond any previous guidance by allowing municipalities to impose binding product bans on manufacturers and distributors of useful products as a way to comply with the Clean Water Act. That level of intrusion into the marketplace through the Act would be unprecedented and we urge the Board to reject it.

III. The Board Should Also Exclude "Regulatory Source Controls" From Track 2 in Any Final Trash Amendments Because the Proposal Failed to Evaluate the Environmental Impacts of Product Bans As Required By CEQA

The SED included in the Draft Staff Report fails to comply with the CEQA because it does not evaluate the environmental impact of product bans. Even under the abbreviated CEQA review that the Board asserts is warranted here, there is a duty to consider all "reasonably foreseeable methods of compliance." There can be no debate that bans on plastic bags and polystyrene foam food containers are reasonably foreseeable, as the Proposed Amendments include bans within Track 2 and would incentivize municipalities to adopt them. Therefore, CEQA requires the Board to consider the environmental impacts of these bans, including the increased environmental impacts associated with substitute products.

A. CEQA Legal Background

CEQA informs government "decision makers and the public about the potential significant environmental effects of proposed activities." Cal. Code Regs., tit. 14 § 15002(a)(1). Through this process, both government and the public can "[i]dentify ways that environmental change can be avoided or significantly reduced … by requiring changes in projects through the

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[11] *.See, e.g.*, *id.* § 2.9; EPA, Water: Best Management Practices: Trash and Debris Management, *available at* http://water.epa.gov/polwaste/npdes/swbmp/Trash-and-Debris-Management.cfm.

[12] EPA, Water: Best Management Practices: Local Ordinances for Construction Site Runoff Control, *available at* http://water.epa.gov/polwaste/npdes/swbmp/Local-Ordinances-for-Construction-Site-Runoff-Control.cfm.

[13] *See* EPA, Water: Best Management Practices: Illegal Dumping Control, *available at* http://water.epa.gov/polwaste/npdes/swbmp/Illegal-Dumping-Control.cfm.

[14] EPA, Water: Best Management Practices: Trash and Debris Management.

use of alternatives or mitigation measures." *Id.* § 15002(a)(2)-(3). Under most circumstances, the agency must conduct an initial study of environmental impacts and then prepare a Negative Declaration or complete an Environmental Impact Report. *Id.* §§ 15002(f)(1), 15060(c), 15063(b)(1). As the Board explains in the Draft Staff Report, certain regulatory programs can be exempted from the requirements described above upon certification by the Secretary for Natural Resources. Pub. Res. Code § 21080.5. These exempted programs include, "[t]he Water Quality Control (Basin)/208 Planning Program of the State Water Resources control Board and the Regional Water Quality Control Boards." Cal. Code. Regs., tit. 14 § 15200(g).

However, actions certified by the Secretary for Natural Resources are not exempted entirely from CEQA. Pursuant to the Board's regulations, it must complete a SED for all actions exempted by the Secretary of Natural Resources. Cal. Code. Regs., tit. 23 § 3777. The SED must include, among other things, "[a]n environmental analysis of the reasonably foreseeable methods of compliance." *Id.* § 3777(b)(4). The analysis must identify the reasonably foreseeable methods of compliance and analyze any significant adverse environmental impacts, alternative compliance methods with less significant environmental impacts, and mitigation measures to reduce unavoidable impacts. *Id.*

B. Municipal Bans on Plastic Bags and Polystyrene Foam Food Containers Are Reasonably Foreseeable Compliance Options That the Board Must Include in the SED

There is no question that the adoption of local ordinances banning plastic bags and polystyrene foam food containers are reasonably foreseeable compliance options that municipalities will adopt in response to the Proposed Amendments. *See* Levy Decl. ¶ 6. Despite the data demonstrating that bans are not effective, *see supra* Section I.B., there is a strong likelihood that municipalities will view such product bans as a low-cost method of satisfying these obligations due to the lack of up-front capital costs. As outlined, the likely adoption of these product bans is further enhanced by the fact that the Board is proposing to incentivize their adoption by providing municipalities with an additional year to reach full compliance with the Proposed Amendments for each product ban that is adopted.

A review of the Draft Staff Report further confirms the likelihood that bans on plastic bags and polystyrene foam food containers will be adopted by municipalities. As regulatory source controls, product bans, are included in the definition of institutional controls, Draft Staff Report at D-8, E-8, and the Draft Staff Report consistently lists them alongside other institutional controls that could be adopted under Track 2, *see id.* at 70, 74, 89, 169.

Yet, despite the emphasis on product bans, the SED only includes increased street sweeping, enforcement of litter laws, and public education as "reasonably foreseeable methods of compliance." *See generally id.* at 97-159. The report excludes product bans from the SED and offers no explanation for doing so, despite the emphasis it places on them elsewhere in the Draft Staff Report as an incentivized compliance measure. Further, the Board appears to acknowledge that product bans are reasonably foreseeable by considering the environmental impacts that will be caused by extending the compliance deadlines for municipalities that adopt them. *Id.* at 159. By failing to evaluate the environmental impacts associated with local ordinances banning plastic bags and polystyrene foam food containers, the Board has violated CEQA.

C. Bans on Plastic Bags and Polystyrene Foam Food Containers Would Have Significant Adverse Environmental Impacts

The Board's failure to include product bans in the SED is not harmless. As described above, when municipalities ban plastic bags and polystyrene foam food containers, the banned products are replaced by alternatives. In many cases, the substitute products have greater environmental impacts than the plastic bags and polystyrene foam food containers they replace.

For example, a common alternative to polystyrene foam food containers is plastic made from biodegradable materials such as corn-based polymers, polylactic acid ("PLA") and polyhydroalkanoate ("PHA"), commonly referred to as bio-plastics. Increased use of bio-plastics as a result of bans on polystyrene foam food containers has the potential to cause serious environmental problems. If released into a watershed as litter, bio-plastics biodegrade under aerobic conditions and produce carbon dioxide, methane, nitrous oxide, hydrogen sulfide, and volatile organic compounds.[15] Production of these chemicals can have serious environmental consequences. First, eutrophication of surface waters can occur when nitrous oxide is converted to nitrates or ammonia[16] as well as from fertilizer runoff from corn production.[17] Eutrophication can cause "algal blooms" though the explosive growth of algae, periphyton attached to algae, and nuisance plant weeds.[18] Fish and wildlife are also impacted because decomposition of algal blooms depletes dissolved oxygen in surface waters, leading to hypoxic or anoxic conditions.[19] In addition, the increased amount of bio-plastics in the environment may cause some species to adopt them as a food source, which will ultimately disrupt the population dynamics between aquatic species. Beyond these localized impacts associated with the release of bio-plastics into the environment, lifecycle analyses have concluded that bio-plastics production results in greater emissions of greenhouse gases and other pollutants in comparison to polystyrene.[20]

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[15] Institute for Environmental Research and Education, Report to Mr. Michael Levy (Aug. 18, 2006) ("IERE (2006)") (Exhibit D).

[16] IERE (2006); Stein, S.R. (2006). Memorandum on biodegradable plastics. Senior Consultant, R.W. Beck, Inc., dated Aug. 18, 2006 (Exhibit E).

[17] Royte, E. Corn plastic to the rescue. Smithsonian Magazine, Aug. 2006 (Exhibit F).

[18] IERE (2006).

[19] *Id.*

[20] Gerngross, T.U. and S.C. Slater (2000). How green are green plastics? Scientific American, Aug. 2000: pp. 37-41 (Exhibit G); Gerngross, T.U. (1999). Can biotechnology move us toward a sustainable society? Nature Biotechnology, Vol. 17, June: pp. 541-544 (Exhibit H); Kurdikar, D., et al. (2001). Greenhouse gas profile of a plastic material derived from a genetically modified plant. Journal of Industrial Ecology, Vol. 4, No. 3: pp. 107-122 (Exhibit I).

Likewise, it is well documented that plastic bag bans result in large increases in the use of paper bags.[21] Paper bags have significantly greater lifecycle environmental impacts than plastic bags. A life cycle comparison by Bousted Environmental Consulting[22] in 2007 found that:

- Plastic bags require 70% less energy than paper;
- Plastic bags generate less than half the greenhouse gas emissions generated by paper;
- Plastic bags generate 80% less solid waste than paper; and
- Plastic bags use less than 5% of the water required for paper.

Other studies have confirmed that paper bags require more energy, emit more greenhouse gases, generate more solid waste and use more water than plastic bags.[23]

Moreover, the scope of these impacts cannot be dismissed as insignificant. This is not a case where a small municipality is banning the distribution of plastic bags from a select group of large retailers. *See Save the Plastic Bag Coalition v. City of Manhattan Beach*, 52 Cal 4th 155 (2011). In light of the regulatory incentives proposed in the Proposed Amendments and the low up-front capital costs of enacting local ordinances, adoption of bans on plastic bags and polystyrene foam food containers would be widespread in response to the Proposed Amendments. If adopted, the Proposed Amendments would likely result in a *de facto* statewide ban on plastic bags and polystyrene foam food containers would be substitution of other products such as paper bags and bio-plastics. At this scale, there is no question that the environmental impacts described above will be significant. Thus, to comply with CEQA, the Board must either remove product bans from the available compliance options under Track 2 or complete a new SED that appropriately evaluates the environmental impacts associated with them.

IV. Including Product Bans in the Proposed Amendments Raises Serious Constitutional Concerns

Including product bans among the Track 2 compliance options also raises serious constitutional concerns. Based on the Draft Staff Report, their inclusion under Track 2 would likely single out plastic bags and polystyrene foam food containers and effectively exclude them

[21] *See Save the Plastic Bag Coal. v. City of Manhattan Beach*, 52 Cal. 4th 155, 172 (2011) ("it is undisputed that the manufacture, transportation, recycling, and landfill disposal of paper bags entail more negative environmental consequences than do the same aspects of the plastic bag 'life cycle.'"); *Coal. to Support Plastic Bag Recycling v. City of Oakland*, Tentative Decision Granting Petition for Writ of Mandate, No. RG07-339097 (Cal. Sup. Ct. Alameda Apr. 17, 2008) (slip op.) at 8-9 (discussing studies).

[22] Bousted Consulting, Life Cycle Assessment for Three Types of Grocery Bags – Recyclable Plastic; Compostable, Biodegradable Plastic; and Recycled, Recyclable Paper, 2007 (Bousted Consulting (2007)) (Exhibit J).

[23] *See* Environmental Group Research Report, Proposed Plastic Bag Levy—Extended Impact Assessment, Volume 1: Main Report (2005) (Scottish government report finding that paper bags require more energy and water consumption while creating greater emissions of greenhouse gases and traditional air pollutants while increasing solid waste production); Boustead Consulting (2007) (Exhibit K) (finding that polyethylene plastic bags use less total energy, water and fossil fuels than recycled paper while also generating fewer greenhouse gas emissions and municipal solid waste).

from much of the California marketplace. Such a *de facto* ban across much of the State would have serious economic consequences both in California and across the United States. These consequences implicate a number of constitutional issues in light of the demonstrated ineffectiveness of such product bans in reducing trash discharges.

First, authorizing bans on plastic bags and polystyrene foam food containers implicates the dormant commerce clause because, among other reasons, "the burden imposed on [interstate] commerce is clearly excessive in relation to the putative local benefits." *Pike v. Bruce Church, Inc.*, 397 U.S. 137, 143 (1970).[24] As described above, including product bans in Track 2 will result in the widespread adoption of local ordinances banning plastic bags and polystyrene foam food containers. Levy Decl. ¶ 6. The current market for these products in California is extraordinarily large. While there are a number of California-based producers, a significant percentage of these products are manufactured in other states, and effectively banning these products in California will impose a significant burden on interstate commerce. These burdens are clearly excessive because bans on plastic bags and polystyrene foam food containers are ineffective, *see supra* Section I.B, and cannot be expected to provide any local benefit at all with respect to reduced trash discharges. As a result, imposing such burdens on interstate commerce would violate the dormant commerce clause.

Second, by singling out plastic bags and polystyrene foam food containers, the Proposed Amendments raise Equal Protection Clause concerns. The Fourteenth Amendment of the U.S. Constitution states that "No State shall … deny to any person within its jurisdiction equal protection of the laws." *See also* Cal. Const., art. I, § 7, subd. (a) (prohibiting denial of equal protection). "The concept of the equal protection of the laws compels recognition of the proposition that persons similarly situated with respect to the legitimate purpose of the law receive like treatment." *In re Eric J.*, 25 Cal. 3d 522, 531 (1979). Here, despite their comparatively minor contribution to trash discharges, *see supra* Section II.A, plastic bags and polystyrene foam food containers are singled out for differential treatment. Indeed, despite the wide array of materials that the Draft Staff Report notes are present in trash discharges, only these two products are mentioned in the context of product bans. The Board cannot offer any rational basis for this differential treatment, since the evidence clearly demonstrates that such bans are wholly ineffective and, therefore cannot serve a legitimate state purpose. *See Walgreen Co. v. City and County of San Francisco* 185 Cal. App. 4th 424 (Cal. Ct. App. 2010).

Third, by failing to include any standard or guideline that a permit writer may apply in determining which "regulatory source controls" may be included in an MS4 NPDES permit, the Proposed Amendments may be void for vagueness under the 5th and 14th Amendments of the U.S. Constitution. To satisfy the Due Process Clause, "[a] statute must be definite enough to provide a standard of conduct for it citizens and guidance for the police to avoid arbitrary and discriminatory enforcement." *People v. Townsend*, 62 Ca. App. 4th 1390, 1400 (Cal Ct. App. 1998). Even if some institutional controls can be an effective part of a trash reduction strategy, ACC has demonstrated that bans on plastic bags and polystyrene foam food containers are wholly ineffective in achieving that goal. However, the Board offers no guidance to permit writers on how to distinguish between potentially effective ordinances that could theoretically be

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[24] Product bans may also violate the dormant commerce clause if they discriminate, either on their face or by pracicla effect, against out of state manufacturers.

included in a NPDES permit and those that are ineffective and should be excluded from the program. Without some guidance for the municipalities that will seek to adopt ordinances to obtain extensions of compliance deadlines and for the permit writers that must evaluate the ordinances, the Proposed Amendments will be unconstitutionally vague.

In light of these serious constitutional concerns, the Board should reconsider its Proposed Amendments and exclude product bans entirely. Their inclusion in Track 2 offers no potential benefits in the form of trash reductions, and instead poses significant risks should these constitutional concerns be raised in a subsequent challenge. Thus, ACC urges the Board to focus solely on those institutional controls that have proven effective in the past and eliminate product bans as a compliance option under Track 2.

EXHIBIT A

I, Michael Levy, declare:

1. I am the Senior Director of the Plastics Foodservice Packaging Group, which is part of the Plastics Division of the American Chemistry Council. I have been in the chemical industry for 38 years and managed this group and its predecessors for 20 years. My responsibilities include understanding the economic, environmental, safety, and health benefits of products made from polystyrene foam products and other plastic packaging, as well as understanding the businesses that use them. My responsibilities also include understanding how regulatory actions affect businesses that use polystyrene foam products. Unless otherwise stated, I have personal knowledge of the facts set forth below.

2. Businesses use polystyrene foam to make products that promote health, safety, and a higher standard of living. Polystyrene foam is a lightweight, strong material that is ideal for storing and shipping food products. It also has outstanding insulation properties that make it ideal for storing hot foods and beverages. In addition, polystyrene foam costs less than alternative products and its use can reduce costs for both consumers and producers.

3. I have reviewed the Board's Draft Amendments to Statewide Water Quality Control Plans to Control Trash and the supporting Staff report. The draft amendments propose two compliance tracks to reduce trash discharges from municipal storm sewer systems. Under Track 1, municipalities would install and manage trash collection devices to collect trash before it is discharged from the municipal storm drains. Los Angeles has successfully reduced the trash in the Los Angeles River by installing such structural controls in order to comply with the Trash Total Maximum Daily Load ("TMDL").

4. Under proposed Track 2, municipalities would also be authorized to adopt institutional controls for trash reduction, including what the Board's proposal describes as "regulatory source controls." The Board proposes to define "regulatory source controls" to be

municipal ordinances that would ban the sale, distribution, and use of certain products. Polystyrene foam food service containers are one of the two products specifically referenced as a product that could be banned to satisfy the Board's proposed Track 2 option.

5. The draft amendments also propose to give municipalities an incentive to adopt product bans. A municipality would receive an extension of the final deadline to comply with the proposed amendments for each product ban or other regulatory source control adopted. Extensions are not offered for any other control option.

6. If the Board authorizes product bans under Track 2 and incentivizes them through extensions of the compliance deadline, I would expect that it would precipitate municipalities to enact bans on polystyrene foam food service products. I know this based on more than 35 years of experience in the foodservice plastics market. Municipalities will enact product bans to avoid the capital costs associated with full capture structural controls and to obtain extensions of the compliance deadlines. More than 75 municipalities in California have adopted bans on polystyrene foam food service products, and in several instances, including Manhattan Beach and Hermosa Beach, the municipalities adopted a ban in response to similar incentives included in Total Maximum Daily Load ("TMDL") regulations.

7. A number of the members of ACC's Plastics Foodservice Packaging Group and produce polystyrene foam food service products and supply them to California markets. These members would be directly harmed by the product bans that would occur if the draft amendments are adopted. Product bans would also harm the California economy as a whole, including agricultural and restaurant industries. A 2009 study prepared by Keybridge Research, LLC (copy attached here as Exhibit A) concluded that a statewide ban on polystyrene foam food service products would result in loss of $1.4 billion in output and cost the state nearly 8,000 jobs.

I declare under penalty of perjury under the laws of the State of California that the foregoing is true and correct.

Executed this 4th day of August, 2014.

Michael Levy

JESSICA HURWITZ
NOTARY PUBLIC
EXP.
9-14-2016
DIST [illegible] UMBIA

EXHIBIT A

KEYBRIDGE
RESEARCH

Quantifying the Potential Economic Impacts of a Ban on Polystyrene foam Foodservice Products in California

Prepared For:
Pactiv Corporation
American Chemistry Council

Prepared By:
Keybridge Research LLC

November 18, 2009

Executive Summary

For more than half a century, the foodservice industry has used food containers made from polystyrene (PS) foam. Despite the fact that PS foam foodservice products are generally much more affordable and have superior physical properties as compared to similar products made from other materials, legislators in California at both the state and local levels are considering banning the use of PS foam foodservice products by food vendors in the state.

In order to inform the public policy debate in California, this analysis provides a macroeconomic assessment of the impact that a PS foam foodservice product ban would have on the state, including direct and indirect effects on jobs, earnings, and output. Direct effects of the ban were calculated as the total losses and gains in output, earnings, and jobs resulting from decreased demand for California-made PS foam foodservice products and increased demand for California-made substitutes for PS foam foodservice products. Estimated direct effects also include losses in consumer purchasing power for other goods and services, as a result of consumers having to pay more for higher priced alternatives to PS foam foodservice products. Direct impacts on PS foam foodservice product manufacturers were based on confidential data provided to Keybridge Research by the operators of all PS foam foodservice product manufacturing facilities in California. Other direct impacts were based on manufacturing data provided by the U.S. Census Bureau and foodservice product price data from various sources.

Indirect economic impacts include the ripple effects that these initial direct economic impacts have throughout the state economy. These include impacts resulting from changes in demand for material and labor inputs used during the manufacture of PS foam foodservice products and their substitutes, as well as changes in the purchasing power of employees working in those facilities. These indirect impacts were estimated using California-specific economic multipliers provided by the U.S. Department of Commerce's Bureau of Economic Analysis.

The overall impacts are the combined direct and indirect impacts. The main findings of the analysis include:

- Reduced demand for PS foam foodservice products in California and the resulting plant closures are estimated to bring about losses of more than $1 billion in California output, $222 million in California earnings, and 4,800 California jobs.
- Increased demand for PS foam product substitutes that are made in California is estimated to result in gains of just over $250 million in California output, $50 million in California earnings, and 1,200 California jobs.
- Reduced purchasing power of foodservice product consumers is estimated to reduce California output by about $600 million, California earnings by $169 million, and California employment by nearly 4,400 jobs.

Combining all of these effects, the study estimates the overall economic impact on the California economy, estimating overall losses of nearly $1.4 billion in output, $335 million in earnings, and almost 8,000 jobs. Furthermore, a supplementary analysis included in this report estimates that losses of tax revenue and the added cost of foodservice products for state-funded agencies will have significant and negative fiscal impacts on state budgets.

I. Introduction

Polystyrene (PS) foam has emerged in the past half century as a key building block of common consumer products and as a staple of modern societies. PS foam is a petroleum-based plastic resin that is remarkable for its affordability, light weight, resistance to moisture, and insulating properties. Although PS foam has a wide variety of applications throughout the economy, the foodservices industry in particular has benefited from its superior performance as a highly functional and low cost foodservices packaging material. Indeed, PS foam -based products, such as hot and cold beverage cups, plates, trays, containers, and hinged take-out boxes (clamshells), are used throughout the foodservices industry to increase efficiency, reduce costs, and maintain food freshness and quality.

The same properties that make PS foam products well-suited as a food packaging material, however, also make them a particularly challenging and highly visible form of litter when disposed of improperly, especially in marine environments. This creates an unfortunate situation in which popular perceptions of PS foam foodservice products are largely based on the highly visible and localized costs associated with their improper disposal, rather than the less visible and diffuse benefits associated with their production, use, and proper disposal.

Primarily due to such perceptions, some policymakers contend that a legislative ban on PS foam products in the foodservice industry is appropriate. However, an outright product ban is an exceptionally blunt policy instrument that must be wielded with extreme care. Public policies should be based on a balanced accounting of the intended costs and benefits, as well as recognition of potential negative unintended consequences. The extreme nature of a product ban heightens the policymaker's duty to perform due diligence including comparison of all the life cycle impacts of these products with possible substitutes and to search for alternative instruments that can achieve the same policy objectives at a lower cost. Otherwise a ban may simply solve one public policy problem while unintentionally creating another.

Given these considerations and recognizing that such legislation is currently under debate, the following analysis aims to quantify the potential economic impacts associated with banning the use of PS foam foodservice products in California. The goal of the analysis is to inform the public policy debate in California by evaluating how a ban may impact economic outcomes for a variety of stakeholders and the California economy as a whole.[1]

With this goal in mind, the analysis provides a macroeconomic assessment of the impact that a ban on PS foam foodservice products would have on California, including the direct and indirect impacts on jobs, earnings, and output associated with:

- Decreased production in the California PS foam industry,

[1] The analysis does not consider or attempt to quantify non-market outcomes, such as changes in energy or environmental outcomes, associated with such a ban.

- Increased production in California industries that manufacture replacement products, and
- Increased consumer costs due to the higher prices associated with replacement products.

A supplementary analysis included in Appendix C examines the impacts that increased foodservice product costs resulting from a PS foam foodservice product ban could have on state and local government budgets, including state agencies, school districts, and public universities.

II. Background: Polystyrene foam

Polystyrene is a commonly used petroleum-based plastic resin. At its most basic level, polystyrene is a polymer – that is, a macro molecule comprised of a long chain of styrene hydrocarbons that are linked together during a process called polymerization. Produced commercially for the first time in the 1930s, polystyrene has become one of the most popular types of plastic with a wide variety of applications, including toys, appliance casings, packaging materials, and office supplies.

Polystyrene foam has also been produced commercially for several decades. There are three types of processes used to make PS foam products:

1. Extrusion and thermoforming is a two-step process in which molten polystyrene and an expansion (blowing) agent are mixed to create foam material, which is extruded into sheets. The sheets are then thermoformed into the shape of the packaging product, then die-cut into commonly manufactured PS foam foodservice products like egg cartons, hinged containers (clamshells), dinnerware, and meat, poultry and produce trays;
2. Steam chest molding which involves the use of expanded polystyrene (EPS) beads. EPS contains an expansion agent, which is added to the beads either in the polymerization plant or in a separate impregnation process. This process is used to make most PS foam cups, as well as protective (cushion/transport) shape-molded PS foam products; and
3. Extruded board insulation involves expanding the polystyrene using an expansion agent, and extruding the polystyrene boards into a final product. Examples of this process are the Dow Styrofoam™ blue board insulation product used in building and construction applications.

PS foam is remarkable for its affordability, light weight, resistance to moisture, and superior ability to provide insulation. These unique properties lend themselves to several niche applications, including as insulation for heating systems, walls, or ceilings; protective packaging for electronics or as loose fill ("packing peanuts.") PS foam has also been deemed safe for use in contact with food by regulatory agencies including U.S. Food and Drug Administration (FDA) and has been used in foodservice products – cups, plates, takeout containers, trays, etc… – for more than five decades. For a variety of reasons, it is a uniquely well-suited material for use in these disposable foodservice containers:

- PS foam cups are significantly sturdier and more heat-resistant than either paper or hard plastic alternatives, and they do not conduct heat or lose their shape when holding hot beverages. This prevents the need to "double-cup" or use paperboard or corrugated sleeves, reducing waste and reducing costs.
- Food trays made from foam are light but sufficiently sturdy to hold heavy and even oily food products without tearing or leaking.
- Prepared hot and cold foods for sale by many food vendors are stored and sold in lidded foam containers that insure insulation and block air exposure, prolonging the life of foods and eliminating spoilage and waste.
- PS foam is inert and very stable, which are critical requirements in sanitary applications. Also, PS foam's chemical composition is not conducive to bacterial growth, which provides hygienic benefits to perishable foods stored in PS foam containers. These benefits are a major reason why PS foam foodservice products are so frequently used in hospitals, schools, nursing homes, cafeterias and restaurants where it is critical that the foodservice ware in contact with food be clean and hygienic.
- Polystyrene foam products are more affordable than both competing disposable food packaging materials and reusable dishes. Polystyrene foam cuts costs and increases operating efficiency when factoring in the additional resources required by "permanent ware", including equipment, labor, detergents, water and electricity resources to run dishwashers, and wastewater management.

III. Estimating Macroeconomic Impacts

The economic impact of a ban on PS foam foodservice products in California depends on a variety of factors, including:

- The extent to which PS foam product inputs are produced within the state,
- The ability of California's polystyrene foam industry to export its product or retool its factories to manufacture other products,
- The extent to which PS foam foodservice product substitutes can be manufactured within the state, and
- The cost differential between PS foam products subject to the ban and their substitutes.

The economic impact of a legislative ban on PS foam can be disaggregated into three effects: direct, indirect, and induced effects. The direct effects of a ban will include changes in output, earnings, and employment at PS foam product manufacturing facilities within the state and at manufacturing facilities that make alternative products. The resulting changes in production will lead to changes in demand for inputs used in those facilities, such as plastic resins, electric power generation, and engineering services. As a result there will be a number of indirect effects, including decreased output, earnings, and employment in upstream industries. Finally, changes in the earnings of employees working at affected facilities will impact their consumption of goods and services in the local community. These impacts are referred to as induced effects.

Furthermore, in addition to the direct, indirect, and induced impacts resulting from changes in demand for PS foam foodservice products and substitute products, a ban is likely to result in increased costs for downstream businesses and institutions, which will ultimately be passed through to consumers in the form of higher prices. Although the increased costs are likely to appear small on a per unit basis, the collective costs throughout California would likely be substantial – reducing the purchasing power of California households and decreasing demand throughout the broader economy.

The current study quantifies direct, indirect, and induced effects by performing three separate analyses:

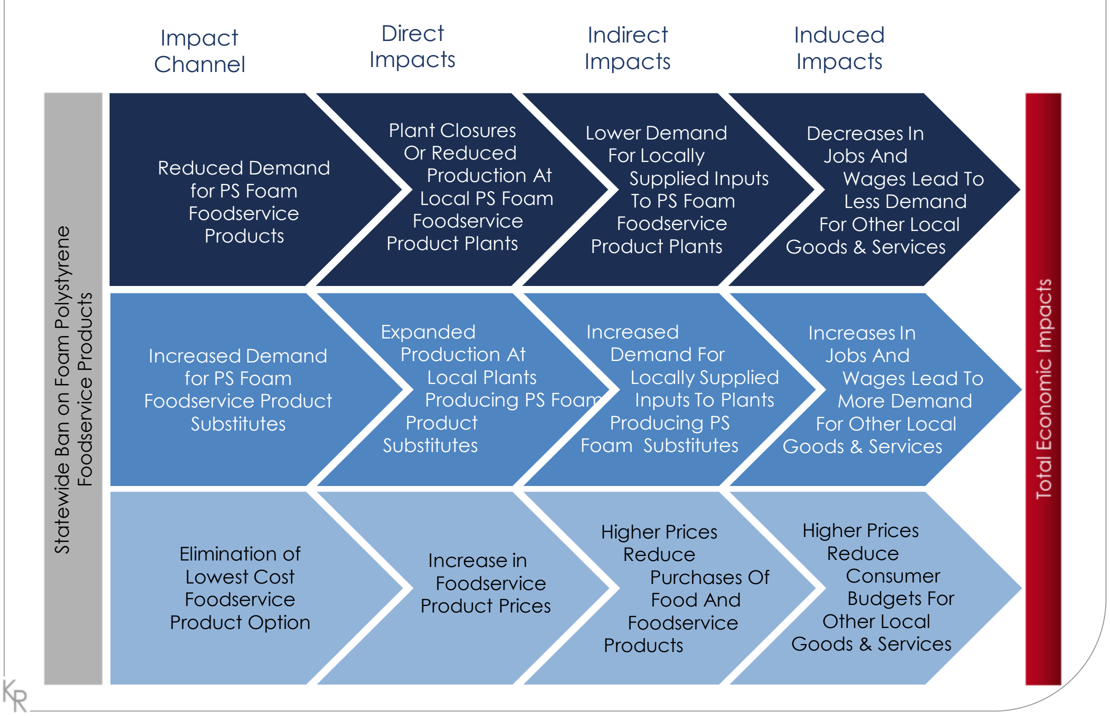
(1) An analysis of the impact of decreased final demand for PS foam products on the California polystyrene manufacturing industry and dependent industries within the state.

(2) An analysis of the impact of increased final demand for alternative products on competing California industries and dependent industries within the state.

(3) An analysis of the impact on the overall California economy due to increased costs associated with switching from PS foam products to alternative products.

The overall estimated impact on the California economy of a PS foam product ban is represented by the sum of these individual effects.

Figure 3.1: Both Positive and Negative Effects Of A Statewide Ban On PS Foam Foodservice Products Will Ripple Through the California Economy.



3.1 The Impact of Changes in Final Demand for Foam PS Products

3.1.1 Methodology

A state-wide ban on PS foam foodservice products is likely to result in either closure or significant downsizing of California-based PS foam product manufacturing facilities. This analysis assumes that a ban on PS foam foodservice products will result in the closure of facilities. The assumption is supported by a variety of economic realities:

- The cost per unit of PS foam foodservice products increases significantly when shipped over long distances. Consequently, PS foam product manufacturers tend to locate close to demand centers and most PS foam products manufactured in California are also distributed in California. If the California consumer base were diminished, existing California facilities are unlikely to competitively sell their PS foam products outside of the state.
- PS foam foodservice products constitute the majority of the output in the PS foam product manufacturing facilities, and the loss of such an important revenue stream would likely require plants to terminate all operations and product lines.
- Equipment used to produce PS foam foodservice products is highly specialized and efforts to retool facilities to produce products not subject to the ban would likely require full recapitalization.

To estimate the impact of plant closings, proprietary data was collected for California plants that would be affected by a ban on PS foam foodservice products. Assuming that these facilities would be forced to entirely terminate operation, the direct impact of the product ban is calculated as the loss of the direct output, earnings, and employment contributions made by these PS foam facilities to the California economy. Table 3.1 shows these estimated direct impacts.

Table 3.1 - Direct Impacts on PS Foam Foodservice Product Ban

Number of Severely Impacted California Facilities	6
Number of Employees	1578
Full Time	1408
Part Time	170
Household Earnings	$74,679,558
Output (Including some non PS Foam products)	$427,490,194

Source: Company Data

The ultimate impact of the ban, however, would extend much further than PS foam product manufacturing facilities. These facilities rely on a variety of inputs, the majority of which are supplied from other businesses within the California economy. As a result, the direct impact of plant closings would "ripple" throughout the economy, indirectly impacting upstream suppliers, downstream consumers, and the local communities that rely on those industries.

These indirect and induced impacts are estimated using "economic multipliers." The Regional Input-Output Modeling Systems II (RIMS II) from the U.S. Department of Commerce's Bureau of Economic Analysis (BEA) provides economic multipliers for output, employment, and earnings of nearly 500 different U.S. industries, including the polystyrene foam manufacturing industry. This study uses California-specific multipliers based on the RIMS II model.[2] These economic multipliers account for both indirect and induced impacts without distinguishing between them. Hence, this analysis also does not distinguish between indirect and induced and instead uses the term "indirect" to refer to both.

In instances in which sufficient data is available, the so-called "bill of goods" approach is the preferred method to calculate the overall impacts on output, earnings, and jobs.[3] This approach requires the decomposition of plant expenditures into key categories – such as compensation, healthcare benefits, electricity, real estate, truck transportation, and polystyrene resin – and a breakdown of the extent to which each of these inputs is purchased inside or outside the state.

Data on the decomposition of plant expenditures and the proportion of in-state and out-of-state purchases was provided directly by those companies with PS foam product manufacturing facilities within the state. When combined with the appropriate economic multipliers, such data allows for the quantification of the indirect impacts created as a result of spending in each individual expenditure category. These impacts are then summed to estimate total indirect economic impacts associated with PS foam plant closings.

To illustrate, of the $427 million in total revenue earned by the six foodservice product manufacturing facilities, about $311 million was spent on plant inputs that were sourced in California. These include labor, polystyrene resin, machinery, and electric power among others. The closure of the California PS foam foodservice product manufacturing facilities would not just peril the jobs and economic output of those plants. They would also lead to an approximate $311 million decrease in demand for inputs sourced in California, causing further job and output losses that will have their own indirect effects. The sum of all indirect effects is estimated by multiplying the initial decrease in demand in each of the expenditure categories by multipliers that are specific to those categories. Table 3.1 below shows a disaggregated breakdown of indirect impacts resulting from each category of reduced expenditures. Overall, the indirect impacts of the reduced demand for PS foam foodservice products on the California economy include about $600 million in reduced output, nearly $150 million in reduced earnings, and the loss of about 3,200 jobs.

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[2] See Appendix A for a more thorough description of the RIMS II model and multipliers.

[3] U.S. Bureau of Economic Analysis. *Regional Multipliers: A User Handbook for the Regional Input-Output Modeling System (RIMS II).* 1997.

Table 3.2: Detailed Expenditure Data and Indirect Economic Impacts of Reduced PS Foam Foodservice Manufacturing

NAICS code	Supplying Industry	California Expenditures	Output Multipliers	Indirect Output Impacts	Earnings Multipliers	Indirect Earnings Impacts	Jobs Multipliers	Indirect Jobs Impacts
H00000	Compensation of employees	$74,679,558	1.59	$118,792,772	0.450	$33,583,397	11.60	826
2211A0	Electric power generation, transmission, and distribution	$11,954,714	1.78	$21,308,082	0.416	$4,976,747	6.79	77
722000	Food services and drinking places	$215,000	2.44	$525,632	0.772	$165,894	32.97	7
525000	Funds, trusts, and other financial vehicles (proxy for pension contributions)	$2,183,755	3.16	$6,898,044	0.884	$1,929,784	15.26	32
622000	Hospitals (proxy for health insurance)	$7,084,690	2.53	$17,900,885	0.893	$6,329,462	19.34	131
7211A0	Hotels and motels	$671,134	2.15	$1,443,207	0.686	$460,532	19.70	13
221200	Natural gas distribution	$6,799,436	2.02	$13,736,221	0.392	$2,663,339	6.19	40
333220	Plastics and rubber industry machinery (proxy for depreciation)	$7,643,341	2.01	$15,385,281	0.518	$3,960,015	11.12	81
3221A0	Pulp, paper, and paperboard mills	$5,142,388	1.94	$9,991,146	0.400	$2,055,927	7.82	38
531000	Real estate	$3,147,886	1.75	$5,507,227	0.315	$990,640	9.39	28
H00000	Taxes on production and imports, less subsidies	$3,451,691	1.59	$5,490,605	0.450	$1,552,225	12.17	38
484000	Truck Transportation	$29,291,918	2.32	$67,869,374	0.647	$18,948,942	15.61	415
493000	Warehousing and storage	$8,322,434	2.28	$18,964,330	0.816	$6,793,603	21.73	164
221300	Water, sewage and other systems	$769,467	2.08	$1,604,031	0.572	$440,443	11.76	8
	Foam products manufacturing*	$149,795,730	1.99	$297,804,813	0.416	$62,380,900	8.70	1,303
	Total	$311,153,141		$603,221,650		$147,231,850		3,201

*The companies submitting data were unable to disaggregate all of their expenses. Any expenses that were not specifically assigned to other categories were included in the "Foam products manufacturing" category and the indirect impacts of those expenditures were estimated using multipliers for the "Foam products manufacturing" industry (NAICS 3261A0). The v alue shown in this table include those expenditures as well as expenditures in categories for which v alues were obtained from just one of the three companies. These v alues were lumped together in this table in order to protect company confidentiality. The multipliers shown for this category are weighted av erages of the actual multipliers

3.1.2 Results: The Direct & Indirect Impacts of Decreased Final Demand for PS foam Products

Aggregating both the direct and indirect impacts, the results indicate that the closure of the six plants involving three manufacturers that produce PS foam products in California would result in a decrease of more than $1 billion in California output, a decrease of $222 million in California earnings, and the loss of about 4,800 California jobs. Table 3.3 summarizes these impacts.

Table 3.3: The Direct and Indirect Negative Impacts of Decreased Final Demand for PS Foam Foodservice Products

	Direct Impacts	Indirect Impacts	Total Impacts
Output	$427,490,194	$603,221,650	$1,030,711,844
Earnings	$74,679,558	$147,231,850	$221,911,407
Employment	1,578	3,201	4,779

3.2 The Impact of Increased Final Demand for PS foam Product Substitutes

3.2.1 Methodology

Although a statewide ban on the use of PS foam foodservice products is likely to eliminate the manufacturing of those products in California, it will also likely increase the demand for alternative products and potentially increase production of alternative products within the state. Specifically, the ban may result in direct effects that include an increase in output, earnings, and employment at facilities in California that are manufacturing alternatives to PS foam foodservice products. These impacts will be determined by the overall increase in demand for those products and the ability of Californian industries to scale up production to meet an increase in demand.

Estimating Demand for Various PS foam Foodservice Product Substitutes

Three factors that will determine the value of new demand for PS foam product substitutes include:

(1) How demand for PS foam foodservice products will be redistributed among alternative products in the event of a ban,

(2) The price differential between PS foam products that are currently being consumed and substitute goods, and

(3) The demand price elasticity of the disposable foodservice products.

The first task is to estimate how demand for PS foam foodservice products will be redistributed among alternative products in the event of a ban. PS foam has a host of qualities that make it well-suited for use in a variety of foodservice needs. No other material suitable for use in single-use foodservice containers meets all of the needs that PS foam products meet. For example, rigid plastic containers lack the insulation properties of PS foam containers making them a poor substitute for PS foam hot beverage cups; coated paper is not rigid enough to be used in cafeteria trays; many PLA/starch materials melt when exposed to temperatures that are considered normal for hot foods and beverages. For these reasons and many others, a ban on PS foam would mean that a combination of alternative materials will be required to meet the functional needs of the foodservice industry.

This analysis assumes that the demand for PS foam foodservice products will be redistributed among alternative products in the following manner:

Table 3.4: Assumed Proportions of PS Foam Product Replacement Under an PS Foam Ban

	Other Plastics (Rigid PS, PP, APET)	Bagasse/Wheat Straw/Molded Fiber	Coated Paper	Aluminum	PLA/Starch/ Compostables
Cups	20%	…	70%	…	10%
Plates/Bowls	10%	40%	40%	…	10%
Clam Shells	30%	50%	10%	…	10%
School trays	…	60%	…	…	40%
Meat trays	10%	20%	10%	…	60%
Other 1pc/2pc containers	40%	20%	20%	10%	10%

Source: Estimates provide by Pactiv Corporation

The second task in estimating the impact of a shift in demand toward alternative products is to estimate the relative cost differences between existing PS foam foodservice products and their likely substitutes. Prices for PS foam foodservice products and substitute products were collected from multiple sources, including contracts between state agencies and foodservice supply vendors and PJP Marketplace (an online wholesaler of foodservice supplies). In all instances, price data for a particular PS foam product and its non-PS foam substitute were taken from the same source. The price differentials are given in Table 3.5. Prices for PS foam product substitutes are expressed as percentage markups from the price of the PS foam products that they would replace.[4]

Table 3.5: Relative Price Increases from PS Foam Product Substitutes

(Percentage Markup as Compared to PS Foam Alternative)

	Other Plastics (Rigid PS, PP, APET)	Bagasse/Wheat Straw/Molded Fiber	Coated Paper	Aluminum	PLA/Starch/ Compostables
Cups	131%	…	128%	…	259%
Plates/Bowls	90%	131%	44%	…	11%
Clam Shells	140%	214%	337%	…	279%
School trays	…	86%	…	…	292%
Meat trays	117%	115%	19%	…	205%
Other 1pc/2pc containers	108%	70%	132%	179%	182%

Source: Various contracts between state agencies and food service supply vendors and PJP Marketplace

The third task in estimating demand for PS foam product substitutes is to determine the price elasticity of demand for disposable foodservice products. In general, the cost of disposable food containers represents a small fraction of the overall cost of food and beverages. Therefore,

[4] A price markup of 100% means that the substitute product costs twice as much as an equally-sized PS foam product.

even a substantial increase in the price of disposable food containers is likely to only slightly impact the full price of a meal. This increase will reduce consumption to some extent as consumers on the margin will decide to reduce their consumption of meals whose prices are impacted by the ban, but disposable food container demand will be only marginally affected, indicating low demand elasticity.

The price elasticity of demand for these containers is also likely to be low at the institutional level. Restaurants and cafeterias need to serve take-out food and fast food in some kind of container. The majority of foodservice vendors who currently serve food in single-use PS foam containers are likely to react to a ban by switching to alternative single-use containers, as a more dramatic shift toward reusable dishes would have a much greater impact on their operations and their costs. Hence, at both the institutional and the consumer levels, it is likely that the price elasticity of demand is low. This study assumes a price elasticity of -0.1 meaning that a 100% price markup from a PS foam product to the substitute product would lead to a 10% reduction in the consumption (in units) of that item.[5]

Estimating California's Capacity to Produce PS foam Product Substitutes

To the extent that California can increase its production of PS foam substitutes in order to meet demand, some of the negative impacts on California's PS foam product manufacturing industry may be offset with positive impacts to California's manufacturers of PS foam product substitutes. However, California will not be able to simply scale up production in these industries. While there will be some ability to increase production at existing facilities if they are currently producing at less than full capacity, without significant investments in new manufacturing facilities – a prospect that California should not rely upon – it is likely that much of the increase in demand will be met by imports. Accordingly, this study does not assume that new facilities to produce PS foam substitutes will be built. It does make the assumption that existing California facilities that produce alternatives to PS foam foodservice products will be able to scale up production by 20%. Sensitivity analysis was conducted using the even more conservative assumptions, including the assumption that California could increase its production of PS foam alternatives by 50% and even 100% in order to meet increased demand.[6] The results of this sensitivity analysis are shown in Appendix B.

In order to estimate the change in output required to scale up PS foam substitute industries by 20% (or 50% or 100%), it is essential to know or estimate the current output of those industries in California. Such estimates were derived from a combination of reports and data published by the U.S. Census Bureau. The Census' *Industry Series* provides detailed manufacturing data for specific products (e.g. "pressed paperboard plates, dishes, spoons, & similar products") that are broken down at the state level. The *2007 Economic Census* provides detailed 2007 manufacturing data for specific products, but only at a national level. California's share of

[5] The sensitivity of this assumption was tested using elasticities of 0 and -0.2 and the results are shown in Appendix B.

[6] A conservative assumption is defined here as an assumption that is likely to reduce the overall negative economic impact estimated in this study.

national production was derived from various *Industry Series* reports and extrapolated onto the *2007 Economic Census* data. Data were then adjusted for inflation and an assumed annual industry growth rate of 1% in order to reflect California's 2008 production of these products. Table 3.6 shows the resulting estimates of California's 2008 production of PS foam substitute products.

Table 3.6: Estimated Current California Production of PS Foam Product Substitutes

Plastic	
Trays/containers/clamshell	$45,072,404
Dinnerware/Tableware	$317,834,294
Plastic cups	$480,837,130
Molded Fiber	
Trays/containers/clamshell/ plates/bowls	$49,822,226
Coated Paper	
Plates/bowls	$31,030,814
Paper cups	$130,557,931
Containers	$339,665
Clamshells	$34,815,872
Aluminum	
Containers	$21,008,409
PLA	
Plates/bowls	$0
Paper cups	$0
Containers	$0
Clamshells	$0

Source: Keybridge calculations based on U.S. Census Bureau data.

The increased estimates of output, earnings, and employment in California facilities that produce PS foam product substitutes represent positive direct impacts of a ban on PS foam foodservice products. The ripple or indirect effects of those positive impacts were estimated using a simpler approach than the "bill of goods" approach outlined in the previous section.[7] This simpler approach involves multiplying the estimated increase in output for each type of substitute good by an appropriate set of output, earnings, and jobs multipliers and then summing the effects.

3.2.2 Results: The Direct and Indirect Positive Impacts of Increased Final Demand for Polystyrene foam Product Substitutes

[7] This approach is recommended by the U.S. Bureau of Economic Analysis when data on plant expenses are unavailable. PS FOAM prospect substitute plant expenditure data is in fact unavailable and thus this simpler approach was used.

Under the assumption that California's manufacturing capacity for PS foam product substitutes could increase by 20%, the study concludes that paper cups, plates, and bowls are the only products for which increases in demand can be met through increased production in California. Increases in demand for other PS foam foodservice product substitutes would need to be met, at least in part, by an increase in imports (shipments to California from other states or foreign countries).

Using the simpler multiplier approach described above, the estimated additional output of California-made substitutes for PS foam products were multiplied by material-specific and California-specific final demand multipliers, ranging from 1.87 for coated paper to 2.05 for aluminum. The analogous earnings and employment multipliers were applied for earnings and jobs. The total positive impacts of increased demand for PS foam product substitutes include increases of more than $250 million in output, more than $50 million in earnings, and more than 1,200 jobs. The results of these impacts are summarized in Table 3.7.

Table 3.7: The Positive Impacts of Increased Final Demand for PS Foam Foodservice Product Substitutes

	Other Plastics (Rigid PS, PP, APET)	Bagasse/Wheat Straw/Molded Fiber	Coated Paper	Aluminum	PLA/Starch/ Compostables	Total
New Demand for Alternatives	$186,092,026	$220,578,355	$303,860,557	$18,615,087	$135,521,847	
Increase in California Production	$80,921,598	$9,964,445	$39,348,856	$4,201,682	$0	$134,436,582
Output Multipliers	*1.94*	*1.98*	*1.87*	*2.05*	*1.97*	
Total Increase in Output	**$156,874,611**	**$19,721,630**	**$73,664,994**	**$8,596,221**	**$0**	**$258,857,455**
Earnings Multipliers (per $ output)	*0.41*	*0.41*	*0.41*	*0.41*	*0.41*	
Total Increase in Earnings	**$33,153,579**	**$4,742,079**	**$16,994,771**	**$1,621,849**	**$0**	**$56,512,279**
Jobs Multipliers (per million $ output)	*9.12*	*10.24*	*8.59*	*7.85*	*9.81*	
Total Increase in Employment	**738**	**102**	**338**	**33**	**0**	**1,211**

Source: Keybridge calculations based on data from the U.S. Census Bureau data and the Foodservice Packaging Institute. Economic multipliers come from the U.S. Bureau of Economic Analysis RIMS II model.

3.3 The Impact of Increased Costs on Consumer Purchasing Power

Alternatives to PS foam products in California cost, on average, more than twice as much as their PS foam counterparts. As the cost of packaging materials are inevitably passed to final consumers, a ban on PS foam products would result in significant impacts on the purchasing power of California consumers. While consumers may only see a $0.10 or $0.20 increase in the price of a takeout meal, the cumulative costs will cause consumers, in aggregate, to have less money to spend on all other goods and services. Lost purchasing power not only lowers spending in other areas of the economy, but like demand for PS foam products and their alternatives, consumer spending has ripple effects throughout the economy.

3.3.1 Methodology

The key factors determining the direct impact of a PS foam ban on consumer purchases in other areas of the economy include the current consumption of PS foam products, the relative prices of PS foam products and their alternatives, and the price elasticity of demand for single-use foodservice products. Estimates of California consumption are based on the Foodservice Packaging Institute's 2004 Market Research Study on Foodservice Packaging Products. The study provided national consumption data in units for 2004. The data was scaled up to account for assumed growth of 1% per year since 2004 and California was assumed to represent a share of that consumption that is proportional with its share of the nation's population. Overall, the study estimates that Californians consumed about 7 billion polystyrene foam cups, plates, bowls, and other foodservice containers in 2008.

California PS foam consumption in dollars was calculated by multiplying consumption of each product type (e.g., cups) by the average prices for PS foam cups, bowls, plates and other containers as given on PJP Marketplace's website. Overall consumption of PS foam products in California is estimated to equal $320 million. Using the average price markups discussed in section 3.2 and an assumed price elasticity of -0.1, the increased consumption of PS foam substitute products that would occur under a ban was calculated to be almost $700 million. The difference between what is currently spent on PS foam products and what would be spent on PS foam substitutes represents the direct loss to consumers of having to pay more for a product that arguably has no additional value to them. The estimation of this direct loss is shown in Table 3.8.

Table 3.8: Estimating the Direct Consumer Impacts of Increased Costs of PS Foam Foodservice Product Substitutes

		Cups	Plates, Platters or Bowls	Hinged Containers	Cafeteria Trays	Total
Foam Polystyrene Foodservice Products						
2004 U.S. Consumption	million units	32,455	10,716	10,699	2,864	56,734
2008 U.S. Consumption	million units	33,773	11,151	11,133	2,980	59,037
2008 California Consumption	million units	4,053	1,338	1,336	358	7,084
Average Prices	cents per unit	3.7	2.5	8.7	5.5	
2008 California Consumption	million $	$150	$33	$116	$20	$319
Substitute Foodservice Products						
Average Prices	cents per unit	8.9	4.5	27.0	14.8	-
Price Elasticity		-0.10	-0.10	-0.10	-0.10	-
2008 California Consumption of Substitutes Under PS Foam Product Ban	million units	3,479	1,231	1,055	297	6,061
Cost of Alternatives	million $	$311	$55	$285	$44	$695
Loss of Consumer Purchasing Power	**million $**	**$161**	**$22**	**$169**	**$24**	**$376**

This direct impact on consumer purchasing power was then multiplied by California-specific RIMS II multipliers for household income in order to calculate the overall negative impacts that higher prices for disposable foodservice products would have on the California economy.

3.3.2 Results

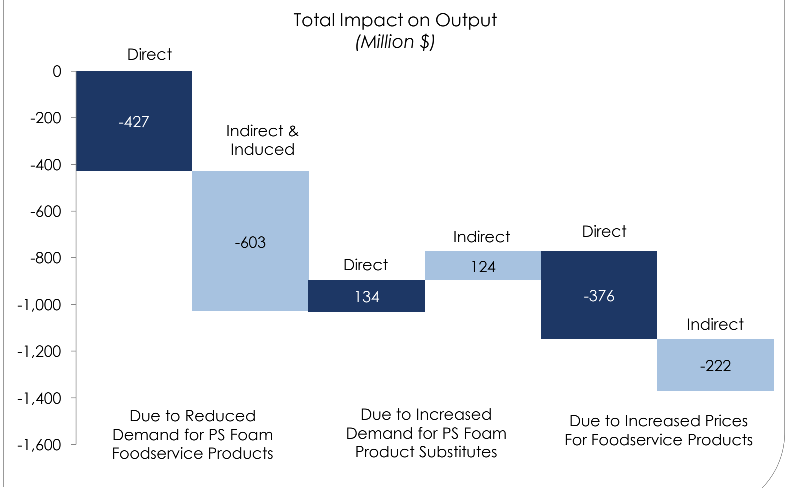
A ban on PS foam foodservice products in California is estimated to increase consumer spending on disposable foodservice products by about $376 million. That $376 million is disposable income that can no longer be spent on other consumer goods and services. As demand for those other goods is reduced, the California economy will suffer reductions in income, earnings, and employment. Like the negative and positive impacts of the ban discussed in previous sections, the direct impacts from reduced consumption of other goods have indirect or ripple effects that further reduce output, earnings, and employment. Overall, the reduced purchasing power of consumers is estimated to reduce California output by about $600 million, earnings by $169 million, and employment by nearly 4,400 jobs. Table 3.9 summarizes these results.

Table 3.9: The Total Negative Impacts of the Increased Cost of Disposable Foodservice Products

	Direct Impacts	Indirect Impacts	Total Impacts
Output	$376,105,356	$222,165,434	$598,270,789
Earnings	$106,327,138	$62,807,440	$169,134,578
Employment	2,743	1,620	4,363

3.4 Combined Macroeconomic Impacts

Figure 3.2: Estimated Macroeconomic Impact Of A State-wide Ban On PS Foam Foodservice Products



Source: Keybridge Research Calculations

The estimated macroeconomic impacts of banning PS foam foodservice products on the overall California economy is the sum of all of the components discussed above: the negative impact of decreased final demand for PS foam products, the positive impact of increased final demand for alternative products, and the negative impacts on California consumers due to the increased costs associated with switching from PS foam products to alternative products. These summed impacts on output in California are estimated at nearly $1.4 billion. The impacts on earnings are estimated to be $335 million and it is estimated that nearly 8,000 jobs would be lost as a result of such a ban. The results are summarized in table 3.10.

Table 3.10: Estimated Macroeconomic Impacts Resulting from a State-wide Ban on PS Foam Foodservice Products

	Output	Earnings	Employment
Negative Impacts Associated with Decreased Final Demand for FPS Foodservice Products	$1,030,711,844	$221,911,407	4,779
Positive Impacts Associated with Increased Final Demand for FPS Product Substitutes	$258,857,455	$56,512,279	1,211
Negative Impacts Associated with Increased Cost of Disposable Foodservice Products	$598,270,789	$169,134,578	4,363
Negative Impacts Associated with Increased Cost of Disposable Foodservice Products	**$1,370,125,178**	**$334,533,707**	**7,932**

3.5 Fiscal Impacts of a Ban on PS Foam Foodservice Products

The California state government and various governmental entities that it funds (e.g., school districts and public universities) will be significantly impacted by a statewide ban on PS foam foodservice products. The ban is likely to result in two types of fiscal impacts that will negatively affect the state government's budget. The first is the loss of tax revenues that would accompany any downsizing or disappearance of the state's polystyrene manufacturing facilities. In 2008, the operations of these six PS foam foodservice product manufacturing facilities contributed at least $6 million to the state in tax revenues. This includes direct taxes and fees paid to the state by the company as well as state income taxes withheld from employees who work at those facilities.[8] This estimate is likely to be a conservative one because not all of the companies were able to provide information for all of the different taxes that they paid and because not all employees have taxes withheld, particularly independent consultants working for the plants.[9] The significant downsizing or closure of these facilities would likely result in the loss of most of this revenue. Additionally, as the impact of the plant downsizings or closures ripple through the economy, the negative impacts on tax revenue are likely to be amplified as tax revenue losses from upstream and downstream industries are likely to outweigh increases in tax revenue collected from manufacturers of substitutes for PS foam foodservice products.

The second negative type of fiscal impact that a PS foam foodservice product ban is likely to have is due to the additional cost of foodservice products that public entities funded by the state will have to pay. As discussed earlier in the analysis, substitutes for PS foam foodservice products generally cost two to three times more than analogous PS foam products. This means that, like all California consumers of PS foam foodservice products, school districts, state agencies, and other state-funded entities that consume PS foam foodservice products will have to pay thousands or hundreds of thousands of dollars more for foodservice products. For example, in 2006, MB Public Affairs estimated the collective impact on the state's budget of higher foodservice product prices as a result of a PS foam ban to be approximately $59 million.[10] Appendix C includes an analysis that uses a similar methodology to the one used by MB Public Affairs in order to estimate the impact on state-funded entities for which data is available.[11] Looking at just four of the state-funded entities that responded to foodservice product purchase order requests, the estimated annual budgetary impact of increased foodservice product costs will be well into the millions of dollars.

Indeed, some public establishments have already been constrained by local PS foam product bans or government edicts that essentially ban PS foam products. The increased cost of PS

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[8] Direct taxes and fees paid to the state include sales and use taxes, corporate income and franchise taxes, property taxes, unemployment taxes, and licensing fees.

[9] State income taxes of employees and consultants that are not withheld are likely to far outweigh the amount of withheld taxes that get refunded to employees after filing.

[10] MB Public Affairs. 2006 Polystyrene & Replacement Cost Study for PFPG.

[11] Due to an insufficient number of responses to requests for purchasing orders and contracts from state funded entities under the California Public Records Act (CPRA), that analysis in Appendix C could not provide an updated statewide estimate of the fiscal impact that an PS foam foodservice product ban would have.

foam substitutes to those entities is already contributing to the massive budget shortfalls being experienced in the state. Between the loss of tax revenue and the added cost of foodservice products for state-funded agencies, the impact of a statewide ban on PS foam foodservice products is likely to be profound and negative.

IV. Conclusions for Policymakers

Polystyrene (PS) foam products are used in wide variety of applications and in such significant volumes because they are more affordable and because PS foam's physical properties make it more useful and efficient than competing materials in most of PS foam's applications. In addition to their widespread utility in industries such as foodservices, PS foam products are important to the California economy because PS foam products are made and used within the state. Because it is not cost effective to transport PS foam products out-of-state, the most likely result of a legislative ban on PS foam foodservice products is that California's six PS foam product-manufacturing facilities would close, leading to significant job losses and reductions in output and earnings.

The analysis shows that some of these losses can be offset through the increase in production of PS foam substitutes. However, it is likely that many of the replacement products would be manufactured outside of the state and it is unlikely that the increased production of those substitute products in California will be sufficient to offset the jobs, earnings, and output losses that would result from PS foam plant closures. Additionally, the negative impact of consumers having to pay higher prices for single-use foodservice products would virtually insure that the net macroeconomic impacts of such a ban will be negative and substantial. Included in those macroeconomic impacts are severe losses to state government budgets that are already under tremendous strain.

Overall, this study concludes that the impact of a PS foam foodservice product ban will have significant and negative net impacts on output, earnings, jobs, and consumer and government budgets in California.

Appendix A:
Description of RIMS II Multipliers

The use of multipliers is a common method for estimating the economic impacts associated with a change in public policy. This assessment uses multipliers provided by the U.S. Department of Commerce Bureau of Economic Analysis (BEA). The BEA publishes multipliers based on its Regional Input-Output Modeling Systems II (RIMS II). The RIMS II model provides multipliers for output, employment, and earnings in nearly 500 different U.S. industries.

RIMS II is based on an "input-output" accounting of the U.S. economy. Utilizing detailed data collected regularly by the Department of Commerce, the input-output matrix provides a complete picture of the inter-industry linkages within the economy. Consequently, RIMS II is well suited to estimate the impact that changes in one industry can have on other industries. The BEA can provide RIMS II multipliers for local regions (metropolitan areas, counties, or sub-state regions), individual states, or the nation. This assessment uses multipliers that are specific to California.

Appendix B:
Sensitivity Analysis Results for Macroeconomic Impact Assessment

In order to determine the sensitivity of the study's conclusions to key assumptions, a sensitivity analysis was performed. The analysis included alterations of assumptions about the price elasticity of foodservice product consumption and California's ability to scale up production of alternatives to polystyrene foam foodservice products. The purpose of the sensitivity analysis is to test whether the study's primary conclusion, that the macroeconomic impact of a PS foam foodservice product ban be significant and negative, holds under alternative and more conservative assumptions than those used in the study. The analysis can also confirm that the scale of the estimated impacts on output, earnings, and jobs in California is not dependent on those assumptions.

The first round of sensitivity analysis substitutes alternative demand elasticities of '0' and '-0.2' for the study's initial assumption of '-0.1'. This study used an elasticity of '-0.1' as its primary assumption to simulate demand that increases or decreases in direct proportion to price hikes or cuts in foodservice supply products. An elasticity of '0' signals that demand is perfectly inelastic to the price of foodservice products, and that consumers will not adjust their consumption patterns in response to more expensive foodservice supplies. Under such a scenario, consumption of PS foam and alternative material foodservice supplies remains constant even at higher prices, accruing benefit and revenue to those industries. However, this pattern of consumption leaves Californians with less disposable income to spend on other goods produced and sold in the state, and the negative consumer impact outweighs the positive impact resulting from increased demand for alternative products. The change in elasticity does not change the impacts resulting from the PS foam foodservice product plant closings. The overall impact is therefore, that even more output, income, and jobs are lost in the '0' elasticity scenario than those estimated in the study when a demand elasticity of '-0.1' was assumed.

Table B.1: Estimated Macroeconomic Impacts Resulting from a State-wide Ban on FPS Foodservice Products (Demand Elasticity of 0.0)

	Output	Earnings	Employment
Negative Impacts Associated with Decreased Final Demand for FPS Foodservice Products	$1,030,711,844	$221,911,407	4,779
Positive Impacts Associated with Increased Final Demand for FPS Product Substitutes	$278,345,473	$60,630,839	1,303
Negative Impacts Associated with Increased Cost of Disposable Foodservice Products	$822,761,650	$232,599,430	6,000
Negative Impacts Associated with Increased Cost of Disposable Foodservice Products	**$1,575,128,021**	**$393,879,999**	**9,477**

An elasticity of '-0.2' would suggest that consumer behavior is more price responsive to changes in the price of foodservice supplies than was assumed in the study. Under such a scenario, consumption of foodservice containers would decrease more significantly as a result of the ban because fewer consumers are willing to pay the higher price for PS foam substitutes. Local production of those alternative products would therefore not rise by as much as it would if the price elasticity were '-0.1'. However, this more responsive pattern of consumption leaves Californians with more disposable income as they reduce consumption of foodservice products and increase spending in other sectors of the state economy. Overall, the impact on consumption is larger than the impact due to decreased demand for PS foam substitutes. The overall macroeconomic impact is thus less negative in this scenario and the analysis's estimate of overall impacts would have been less negative if a more negative price elasticity were chosen. However, even when '-0.2' was assumed (probably an unrealistically conservative assumption), the overall impact on output was still nearly $1.2 billion.

Table B.2: Estimated Macroeconomic Impacts Resulting from a State-wide Ban on FPS Foodservice Products (Demand Elasticity of -0.2)

	Output	Earnings	Employment
Negative Impacts Associated with Decreased Final Demand for FPS Foodservice Products	$1,030,711,844	$221,911,407	4,779
Positive Impacts Associated with Increased Final Demand for FPS Product Substitutes	$239,369,438	$52,393,718	1,119
Negative Impacts Associated with Increased Cost of Disposable Foodservice Products	$373,779,929	$105,669,727	2,726
Negative Impacts Associated with Increased Cost of Disposable Foodservice Products	**$1,165,122,335**	**$275,187,415**	**6,386**

Further sensitivity analysis was conducted using more conservative assumptions regarding California industry's ability to increase its production of PS foam alternatives in response to a PS foam foodservice product ban.[12] The first round of sensitivity analysis assumes that Californian producers will increase alternative materials production capacity by 50%, as compared to 20% which was assumed in the main analysis. A second round of analysis assumes California producers will increase their production of PS foam substitutes by 100%.

Altering this assumption does not change the estimates of negative impacts due to the closure of PS foam foodservice product manufacturing facilities, nor does it alter the estimated impact on consumer budgets. The only impact that this change in assumptions can have is to increase the positive impacts that result from more local production of PS foam foodservice alternatives. The result is thus that there is a lower net impact on the California state economy. However, even under these generous assumptions providing for massive scale ups of non-PS foam foodservice product manufacturing in California, the overall macroeconomic effect is still negative and very significant, with losses in output still in the range of $1 billion and job losses in the range of 6,000-7,000.

[12] A conservative assumption is defined here as an assumption that is likely to reduce the overall negative economic impact estimated in this study.

Table B.3: Estimated Macroeconomic Impacts Resulting from a State-wide Ban on FPS Foodservice Products (Additional Capacity Increased by 50%)

	Output	Earnings	Employment
Negative Impacts Associated with Decreased Final Demand for FPS Foodservice Products	$1,030,711,844	$221,911,407	4,779
Positive Impacts Associated with Increased Final Demand for FPS Product Substitutes	$438,044,932	$97,090,177	2,044
Negative Impacts Associated with Increased Cost of Disposable Foodservice Products	$598,270,789	$169,134,578	4,363
Negative Impacts Associated with Increased Cost of Disposable Foodservice Products	**$1,190,937,702**	**$293,955,808**	**7,099**

Table B.4: Estimated Macroeconomic Impacts Resulting from a State-wide Ban on FPS Foodservice Products (Additional Capacity Increased By 100%)

	Output	Earnings	Employment
Negative Impacts Associated with Decreased Final Demand for FPS Foodservice Products	$1,030,711,844	$221,911,407	4,779
Positive Impacts Associated with Increased Final Demand for FPS Product Substitutes	$710,739,689	$158,938,831	3,317
Negative Impacts Associated with Increased Cost of Disposable Foodservice Products	$598,270,789	$169,134,578	4,363
Negative Impacts Associated with Increased Cost of Disposable Foodservice Products	**$918,242,944**	**$232,107,155**	**5,826**

Appendix C:
Estimating State & Local Budget Impacts

The California state government is a major purchaser of polystyrene (PS) foam products through the organizations and agencies that it funds. Many of the numerous state agencies, 32 public universities, and more than 1,000 public school districts in California provide on-site and/or take-out foodservices that require the use of disposable foodservice supplies. PS foam foodservice containers are widely used by the cafeterias and caterers that supply foodservices to these state agencies and public schools.

It is important for policymakers to have a full awareness of the costs and benefits of PS foam foodservice product use by these agencies before formulating legislation that could restrict or ban those products. The following assessment sheds light on the potential financial impact of a state-wide ban on PS foam foodservice products on one of the industry's largest set of consumers: state-run agencies and other entities receiving state funds.

Methodology

To assess the potential impact of a ban on PS foam foodservice products on state and local government budgets, public records were collected and cost comparisons run on a variety of PS foam and non-PS foam foodservice products, simulating the likely cost of replacing PS foam foodservice products used by state-funded foodservices with non-PS foam alternatives.

Data Collection

Requests were submitted under the California Public Records Act (CPRA) for: a) foodservice purchasing orders, b) contracts with disposable foodservice supply vendors, and c) contract usage reports. Twenty-eight total requests for documents and data for the 2007/2008 fiscal year were submitted to the following state-funded entities:

- Eight public K-12 school districts
- 31 state universities – 21 California State universities and 10 University of California universities
- Six state departments, including the Department of General Services (DGS)

CPRA requests were submitted between April 27, 2009 and July 21, 2009, with a total of 15 responses received between May and the beginning of September. Of those 15 responses, only four indicated the use of polystyrene foam products by that state agency, school, or school district, and contained data pertinent to the aims of this study. These include DGS, Modesto City Schools, San Diego Unified School District, and Corona-Norco Unified School District.

Impact Analysis

Based on the information yielded by CPRA requests, the likely impact of a ban on polystyrene foam was calculated for each of the three public school districts, and the various agencies using the DGS' contract.[13] Per unit prices for PS foam foodservice products found in the school and agency purchasing orders, as well as for non-PS foam foodservice products of comparable size and function were calculated using information available on the internet.

- Contract prices tended to be lower than those quoted on the internet, as vendors were obligated to submit bids to win state contracts. Additionally, larger contracts were often able to offer cheaper prices than smaller ones; DGS would typically pay less per unit for its food packaging than would the UCD coffee house. To avoid these biases, prices for both PS foam and non-PS foam items were taken from websites. Per unit prices were then scaled to match quantities in the purchase orders, providing a uniform basis of comparison across materials and contracts.
- The majority of prices were taken from www.pjpmarketplace.com, as it was consistently found to have the lowest listed price for foodservice disposables. Other websites were used only if PJP Marketplace did not carry an item found in one of the purchasing orders.
- For bio-based bagasse and polylactide (PLA) disposables, prices were taken from www.worldcentric.org.

Price differentials between each polystyrene foam item and its internet-available alternative[14] were calculated based on per unit prices. Mark-ups and mark-downs from PS foam foodservice products are displayed below in Table 4.1. PS foam foodservice products ordered by the three state entities during the 2007-08 fiscal year were replaced with the cheapest available, similarly sized alternative to calculate the likely state budgetary impact of a PS foam foodservice product ban.

Results

The study's findings indicate that the financial impacts on state and local government budgets are likely to be negative and significant if state-funded entities are forced to replace PS foam foodservice products with non-PS foam alternatives. Interestingly, of the 12 responses received from California public universities, not one used PS foam foodservice products during the 2007-8 school year. This suggests that were a ban to be enacted, its impact would be most strongly felt in school district and state agency budgets.

With the exception of a single item, PS foam foodservice products were found to be cheaper than disposable foodservice supplies made with other materials and ordered by UCD, Modesto,

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[13] A primary function of DGS is to provide purchasing agreements and contracts to any California state agency that does not wish to conduct its own procurement. The vast majority of state departments use DGS' "Disposable Foodservice Supplies" purchasing contract, which allows information on polystyrene foam use obtained from DGS to relatively accurately reflect the rate of use and cost of polystyrene foam disposables across state agencies.

[14] Prices for several items were not able to be found on the internet. Although these items are available through disposable foodservices manufacturers, manufacturer catalogues typically do not list prices for their products. For such items, prices were either estimated using price ratios of similar items as reference points, or the price for a similar but not identically sized item that could be found on the internet was used instead.

and DGS. Table 4.1 details the overwhelming price advantage that PS foam foodservice products have over non-PS foam alternatives.

Table C.1: Relative Price Increases from FPS Product Subsitutes

	Paper	Bagasse	PLA	Plastic
Cups (hot)				
4 oz	129%	153%	229%	…
8 oz	137%	268%	289%	…
Plates				
9"	61%	213%	…	90%
Bowls				
12 oz	21%	38%	90%	314%
22 oz	-14%	…	…	…
30 oz	86%	49%	11%	…
Clam Shells				
3 compt 9x9x3		209%		136%
3 compt 7-8x8-9x3		219%		144%
School Trays				
5 compartment	…	70%	…	…
6 compartment	…	102%	…	…
Other 1pc/2pc containers				
6 oz hot/cold	…	64%	…	…
8 oz hot/cold	166%	66%	300%	…
12 oz hot/cold	123%	75%	118%	…
16 oz hot/cold	108%	73%	129%	…

Each of the four institutions included in the study showed significant increases in their individual budgets for disposable foodservice products and janitorial services when alternative products were substituted for PS foam foodservice products. DGS' budget, by far the largest in terms of quantity of supplies purchased, increased by over 200% in response to the simulated ban on PS foam foodservice products. Modesto City Schools, San Diego Unified, and Corona-Norco's foodservice budgets all increased by roughly 70%.

The cumulative budgetary impact on these four state-funded entities alone totals over one and a half million dollars – $1,509,864.34. This figure clearly demonstrates the negative financial impact that banning the use of PS foam foodservice products would have on individual state-funded institutions. If all state-funded institutions' budgets were included, the impact of a PS foam foodservice product ban on California's state budget would likely be in the tens of millions of dollars range.

Table C.2: San Diego Unified Schools District Budgetary Impact

	FPS		Substitute	
Item	Per Unit Price	Est. Cost	Markup	Est. Cost
Tray, 5-compartment	$0.047	$940,000.00	70%	$1,598,000.00
Total	....	$940,000.00	....	$1,598,000.00
Budgetary Impact:				$658,000.00

Table C.3: Modesto City Schools Budgetary Impact

	FPS		Substitute	
Item	Per Unit Price	Est. Cost	Markup	Est. Cost
Bowl, 30 oz	$0.14	$4,278.00	11%	$4,748.58
Cup, 4 oz	$0.02	$3,043.00	129%	$6,968.47
Container, 16 oz	$0.05	$1,372.00	73%	$2,380.00
Container, 8 oz	$0.03	$4,680.00	66%	$7,751.25
Tray, 5 compt	$0.05	$171,268.00	70%	$291,520.00
Total	....	$184,641.00	....	$313,368.30
Budgetary Impact:				$128,727.30

Table C.4: Corona-Norco Unified School District Budgetary Impact

	FPS		Substitute	
Item	Per Unit Price	Est. Cost	Markup	Est. Cost
Tray, 5 compartment	$0.047	$141,000.00	70%	$239,700.00
Total	....	$141,000.00	....	$239,700.00
Budgetary Impact:				$98,700.00

Table C.5: DGS Budgetary Impact

	FPS		Substitute	
Item	Per Unit Price	Est. Cost	Markup	Est. Cost
Hinged Container 9x9x3	$0.092	$285,255.20	209%	881438.568
Hinged Container 7-8x8-9x3	$0.089	$3,293.00	219%	10504.67
Tray, 5 compt	$0.047	$6,345.00	70%	10786.5
Tray, 6 compt	$0.062	$16,275.00	102%	32875.5
Total	....	$311,168.20	....	$935,605.24
Budgetary Impact:				$624,437.04

Appendix D:
Project Team Members

Robert F. Wescott is President of Keybridge Research LLC. Dr. Wescott has nearly 30 years of professional experience working on macroeconomic, financial, and public policy issues. He served for four years as Special Assistant to the President for Economic Policy at the National Economic Council at the White House and as Chief Economist at the President's Council of Economic Advisers. From 1994-98 Dr. Wescott was Deputy Division Chief in the Research Department of the International Monetary Fund, where he did research on global economic risks and policy challenges. He also was an official in the Fund's European Department. From 1982-93, he was Senior Vice President and Chief U.S. Economist at WEFA Group (today IHS Global Insight), a private economic modeling and analysis firm, where he was responsible for all economic modeling, forecasting, and consulting operations. In 1989-90, he helped the University of Pennsylvania establish the International Centre for the Study of East Asian Development in Kitakyushu, Japan. Dr. Wescott holds a Ph.D. in Economics from the University of Pennsylvania.

Brendan Fitzpatrick is Senior Economist at Keybridge Research LLC. Mr. Fitzpatrick specializes in international economics and environmental policy. Prior to joining Keybridge, Mr. Fitzpatrick served in the Office of the Chief Economist of the World Bank, where he focused on development finance, aid effectiveness, environment, and the production of the 2006-08 Global Monitoring Reports. He also worked with USAID's Agriculture and Rural Enterprise Development team in Rwanda and worked in education and community development with Fundacion Rostro de Cristo in Ecuador. Mr. Fitzpatrick holds Bachelor's degrees in Bioengineering & Economics from the University of Illinois at Urbana-Champaign and a Master's degree in Public Administration in International Development from Harvard's Kennedy School of Government.

Mark W. McNulty is Director of Economic & Policy Analysis at Keybridge Research LLC. Mr. McNulty specializes in energy economics, environmental economics, and U.S. domestic policy. Before joining Keybridge, Mr. McNulty served as a consultant for U.S. financial institutions and rural development organizations, where he designed and implemented innovative financial products tailored to the needs of low-income consumers. From 2000-2001, he served as Staff Assistant for International Economics at the White House's National Economic Council, where he was responsible for research and analysis on global economic and financial risks. Mr. McNulty holds a bachelor's degree in Business Administration & Economics from Rhodes College and a Master's degree in Public Policy from Harvard's Kennedy School of Government.

EXHIBIT B

Jobs By State

PLASTICS BAG MANUFACTURING (NAICS 326111*) - SELECTED STATISTICS IN 2012, BY STATE					
	Number of Estabs	Number of Employees (Thous)	Annual Payroll ($ Mill)	Value of Industrial Shipments ($ Mill)	Capital Expenditures ($ Mill)
U.S. Total	380	30.9	1,303.7	9,456.2	268.1
Alabama	7	0.7	16.9	185.5	5.4
Alaska	0	0.0	0.0	0.0	0.0
Arizona	3	0.1	2.3	16.0	0.5
Arkansas	7	1.5	67.5	655.9	24.7
California	46	1.8	75.8	524.1	11.6
Colorado	2	0.1	4.3	30.1	0.9
Connecticut	1	0.1	4.2	28.9	0.8
Delaware	0	0.0	0.0	0.0	0.0
District of Columbia	0	0.0	0.0	0.0	0.0
Florida	10	0.4	16.0	107.9	7.1
Georgia	11	0.7	27.9	261.0	3.3
Hawaii	1	0.0	0.2	1.7	0.0
Idaho	2	0.1	4.1	28.7	0.8
Illinois	27	3.0	139.2	1,138.3	18.0
Indiana	9	1.0	46.4	274.6	8.0
Iowa	4	0.7	32.0	172.9	2.9
Kansas	2	0.2	9.0	62.9	1.8
Kentucky	5	0.6	27.1	300.8	12.1
Louisiana	6	0.3	8.9	59.1	1.7
Maine	1	0.1	4.1	28.6	0.8
Maryland	4	0.2	4.0	43.5	0.3
Massachusetts	8	0.4	19.1	103.6	2.7
Michigan	7	0.6	37.0	243.6	7.1
Minnesota	7	0.3	13.3	87.4	5.6
Mississippi	4	0.1	3.9	33.1	0.4
Missouri	6	0.5	22.9	122.1	2.5
Montana	0	0.0	0.0	0.0	0.0
Nebraska	0	0.0	0.0	0.0	0.0
Nevada	5	0.5	17.3	173.0	5.1

New Hampshire	3	0.2	5.9	42.5	1.2
New Jersey	17	0.6	24.6	178.0	6.4
New Mexico	0	0.0	0.0	0.0	0.0
New York	32	1.8	70.8	375.1	15.9
North Carolina	7	1.5	57.1	336.0	14.4
North Dakota	1	0.0	1.6	11.2	0.3
Ohio	17	1.0	45.3	244.8	8.5
Oklahoma	5	1.1	43.1	299.6	2.2
Oregon	4	0.1	4.0	28.1	0.3
Pennsylvania	18	2.0	80.4	501.9	9.3
Rhode Island	1	0.0	0.2	1.5	0.0
South Carolina	4	0.2	8.1	51.4	0.9
South Dakota	2	0.1	4.7	32.8	1.0
Tennessee	8	0.3	10.6	67.6	2.7
Texas	38	4.6	182.4	1,583.0	43.0
Utah	6	0.2	9.4	65.5	1.9
Vermont	1	0.0	0.2	1.7	0.0
Virginia	5	1.0	40.2	279.7	8.2
Washington	3	0.3	9.9	73.1	2.1
West Virginia	2	0.1	4.0	27.9	0.8
Wisconsin	21	1.9	97.6	571.7	24.4
Wyoming	0	0.0	0.0	0.0	0.0

* Definition: NAICS 326111 Plastics bag manufacturing. This U.S. industry comprises establishments primarily engaged in (1) converting plastics resins into plastics bags or (2) forming, coating or laminating plastics film and sheet into single wall or multiwall plastics bags. Establishments in this industry may print on the bags they manufacture.

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EXHIBIT C

Technical Assessment Report

California Statewide Water Quality Control Plans to Control Trash – June 2014 Draft

Conducted for

American Chemistry Council

by

Environmental Resources Planning, LLC
Gaithersburg, MD

August 2014

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Acknowledgments

Thanks to the communities and study authors for providing copies of the cited litter surveys as well as details about the methodologies and findings of these studies. The litter surveys cited in this report can be obtained either online, through the communities for which they were conducted or from the study authors themselves. Citations for each survey are included in the References section of this report.

Background

Littered items can easily find their way into stormwater systems. Rain can move these items into waterways causing aesthetic and functional issues.

California's State Water Resources Control Board and Regional Water Quality Control Boards (Water Boards) manage trash in stormwater primarily through Total Maximum Daily Loads (TMDLs) and permits.

The State Water Resources Control Board (State Water Board) has now proposed amendments to Statewide Water Quality Control Plans to Control Trash (Trash Amendments).

The provisions proposed in the Trash Amendments include six elements:

(1) Water quality objective,
(2) Prohibition of discharge,
(3) Implementation provisions,
(4) Time schedule,
(5) Time extension options for State Water Board consideration, and
(6) Monitoring and reporting requirements.

As proposed, the Trash Amendments would apply to all surface waters of the state, with the exception of waters under the jurisdiction of the Los Angeles Water Board that have trash TMDLs in effect prior to the effective date of the Trash Amendments.

Environmental Resources Planning, LLC (ER Planning), subject matter experts in the field of litter surveys and studies, conducted an evaluation of these documents at the request of the American Chemistry Council. ER Planning is the only private U.S. firm focusing exclusively on litter surveys and litter-related research studies. Field crews under our direction have surveyed more than 21 million square feet of roadways and recreational areas, including cities in California.

Although the time available to provide this analysis was limited, it is hoped that this examination of the Trash Amendments and the subsequent recommendations provided will be useful in helping stakeholders in California to craft programs that reduce the amount of litter and trash entering California stormwater systems and waterways more effectively.

Technical Assessment

Trash Characterization Methodologies

Litter can be measured by using weight, volume or counts. Counts can be either fresh litter counts or Visible Litter Survey tallies. Determining the most accurate and precise method of measuring litter and stormwater trash is of prime importance. An overview of each methodology is provided below.

1. Weight

Weight-based surveys require that all items are dried to the same level of moisture content to ensure consistency in weight measurements. Weights do not always reflect the offensiveness or impacts of littered items, nor do they lend themselves to baseline comparisons since advances in lighter packaging and thin-walling of products has been ongoing since the early 1990s. Weights are naturally biased toward heavier items such as metal construction debris and wood. Measuring litter accurately by weight has proven to be expensive for municipalities.

2. Volume

Volumetric surveys do not always account for the fact that the collection and removal of the components of litter tend to be similar and do not always correlate to size. Measuring litter accurately by volume has also proven to be inordinately expensive for municipalities.

Volumetric measures should also be avoided due to significant errors of accuracy measuring stormwater trash, as occurred with BASMAA in 2012 (Environmental Resources Planning, [ERP], 2012).[1]

Caltrans has recognized that measuring materials by volume noticeably increased the proportion of lightweight materials due to material densities.

> *"Another observation is the increased proportion of styrofoam [sic] compared to weight, due to its low density, and the reverse trend for the dense moldable plastics." (Caltrans, 2000, p. 6-6)*

In fact, this applies to all light, low-density components of litter and can be misleading when tallies are not also provided.

The Institute for Applied Research, a California firm that led more than 60 litter surveys, noted that volume is the least precise method of measuring litter.

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[1] The contractor used by BASMAA characterized trash by placing items in buckets measured by fullness without accounting for air space. This significantly overstated the volume and percentage of light materials such as PS foam food ware items and PR Bags in stormwater trash (Cascadia Consulting, email communications, February 28-29, March 1, 2012).

"The standard deviation of repeated measurements of the same litter measured by volume is 21.2% compared to 3-6% for all other methods of litter measurement". (Institute for Applied Research [IAR], 2007)

While this variability can decline as sample sizes grow, it always tends to be greater than with item counts (IAR, 2007).

Reproducible Field Measurements of Trash Load Volume

If volume is used as a measurement tool, it should always be accompanied by a tally to confirm accurate measurement. In addition, volume should always be measured using natural density to ensure accurate measurement.

Natural density is another term for bank density, a concept that has been historically used in the construction and landfill industries. Natural density is a more descriptive and intuitive term for a concept that addresses the problem of accurately measuring the volume of lighter materials.

One landfill engineer used the following example. Soil in its natural state would weigh about 3,400 pounds per bank cubic yard. When soil is excavated, it is in a less dense state than it was in its bank condition and only would weigh about 2,800 pounds per loose cubic yard. Once soil has been compacted, such as when it has been prepared for use as a clay liner, it becomes much denser and would weigh about 4,100 pounds per compacted cubic yard (Bolton, 1998).

Our firm conducted a pilot test using 2-gallon buckets to illustrate how this concept would have affected the volumetric measure of plastic retail bags (PR bags).

Figure 1 shows that when measuring loose or uncompressed volume, two plastic bags could be deemed as filling the bucket. The firm that conducted the first measure of trash for BASMAA Permittees indicated that they used this method to determine trash volume, which significantly overstates the portion of litter attributable to PR bags.

Figure 2 shows that, by compacting these bags, as many as 50 plastic bags could fit in the same bucket. This would understate the portion of litter attributable to PR bags.

Figure 3 shows that, using the natural volume or bank density of these items, 10 plastic bags fit in the same bucket. Notice how intuitive this method is and how it yields an accurate measure that avoids the two errors of precision shown in Figures 1 and 2.

The natural state for lighter, low-density components of trash consists of placing these items into a bucket and stopping at the point that compacting would be required to add more items.

Figures 1-3: Reproducible Field Measurements of Trash Loads

Figure 1	Figure 2	Figure 3
		
Loose (2)	**Compacted (50)**	**Natural Density (10)**

The characterization methodology used by BASMAA Permittees in 2012 measured volume by placing trash in buckets measured by fullness with no effort to address the significant amount of airspace present (Cascadia Consulting, email communications, February 28-29, March 1, 2012). This means the volume measured would have included a significant amount of air space that would cause the volumes and percentages of light materials such as polystyrene (PS) foam food service items and plastic bags to be overstated considerably. While in ER Planning's pilot, the volume would have been overstated by 500 percent, it is equally possible that, had there been just one loose bag counted, volume may have been overstated by 900 percent.

Others have documented the problems of trying to measure litter accurately and consistently using this type of methodology.

For example, when the Water Research Commission (WRC) of South Africa retained the Department of Civil Engineering at the University of Cape Town (UCT) to study the measurement of litter entering stormwater drainage systems, the study authors identified specific issues with the volume measurements of stormwater trash they observed (Marais).

1. The fullness of traps was inconsistently recorded.
2. The degree of fullness recorded was found in many cases to be almost completely arbitrary.
3. The volume derived from the degree of fullness of the trap was found to be an unreliable indicator of mass as the densities of the litter varied so widely.

Another pitfall of depending solely on volume measurements is that it creates a situation analogous to dead reckoning. The errors caused by allowing use of a flawed trash characterization methodology will be compounded if the State Water Board also allows Permittees to ban materials that are minute portions of litter. This will mislead Permittees into expecting significant reductions in litter that mathematically cannot occur from instituting such bans.

3. Fresh Litter Count

Fresh litter counts depend on collecting and bagging accumulated litter followed by a second survey which seeks to measure fresh litter that has accumulated over a given time period at each specific site. Without accounting for and differentiating the smaller sized items, the resulting data can be misleading. This method has also proved to be problematic as it cannot account for the inconsistent effect of winds, which can move littered items onto a site being surveyed from an area that was not being surveyed and had not been cleaned. Additionally, the level of winds in any given period of time may vary unpredictably, precluding the ability to produce credible data. This method requires two sets of surveys as well, usually 30 to 45 days apart, adding unnecessary project costs that are avoidable.

4. Visible Litter Survey (VLS)

The VLS methodology uses a stratified random site selection process that is scientifically rigorous and reproducible. Littered items are identified and counted, but are not physically removed from the sample site. Large items are tallied separately from small items. This methodology makes better use of Permittees' resources by not requiring a second survey.

When dealing with issues similar to those in California, the Anacostia Watershed Society in Washington, D.C. noted the importance of a visible tally of littered items to supplement other data measurements.

> "*The tally count is an important indicator of trash impairment and should be used in conjunction with the total score to assist in site comparisons*." (Anacostia, p.8-5)

The WRC study authors noted the value of tallying littered items.

> *"Litter counts do however give a better indication of the aesthetic impact of lighter materials such as plastic bags and packaging…" (Marais, 2003)*

Trash Characterization Methodologies – Conclusion

VLS tallies have emerged as the de facto standard in California and across the U.S. and Canada. Keep America Beautiful utilized this method for their National Litter Survey (Keep America Beautiful [KAB], 2009). The State of Florida conducted six litter surveys between 1994 and 2001, all of them using the VLS methodology (Florida, 2002, p.10).

Every private firm whose work focuses on conducting litter surveys uses VLS tallies to do so, as did the Cities of San Francisco (2007, 2008 and 2009) and San Jose (2008 and 2009). This survey methodology, selected and used by California's own cities, is the only standard universally recognized by experts in this field.

Major Components of San Francisco Litter: 2007-2009

Table 1 shows the top 15 components of San Francisco litter by count as listed in Table 9 of the 2009 San Francisco Litter Survey. Neither PR bags nor PS foam cups were in the top 15 components of San Francisco litter (HDR, 2009).

Table 1 – Components of San Francisco Litter: 2007-2009

#	Large Litter	2009	2008	2007
1	Misc. Paper	552.5	317	570
2	No Brand Name Towels / Napkins	438.5	664	494.5
3	Printed material (newspapers, flyers, books etc.)	373.5	380	287
4	Misc. Plastic	219	185.5	342
5	Candy bar wraps	203	100	152
6	Tobacco other (packs, matches, cellophane)	177	144	109
7	Construction debris	169.5	102.5	31.5
8	Receipts (business forms, bus transfers, etc.)	167	166.5	203
9	Cup Lids, Pieces lids	160.5	96	100.5
10	Home Articles	151	127.5	145
11	Paper Food Wrap	122	51	32.5
12	Plastic packaging other	111.5	55.5	27.5
13	Gum wrappers	105.5	131	32
14	Foil materials / foil pieces	95.5	55.5	104.5
15	Paper Cups (Hot)	87	56.5	36

PS Foam Food Service Products in Litter

This section examines all litter surveys conducted in North America since 2000 that separately tallied PS foam food service products to determine the extent to which they are found in litter. Surveys included in this review met the following criteria:

1. Statistically-based quantification and characterization methodologies were used.
2. PS foam food service product components were specifically quantified.
3. Only surveys using VLS tallies were included to ensure comparability of results. The results from other studies are discussed separately.
4. Only surveys conducted since 2000 were included to ensure that the data evaluated is relevant.[2]

Table 2 – PS Foam Food Service Products in Large Litter

Survey	Year	Percent
Rhode Island	2014	1.7%
Edmonton	2013	0.8%
Texas	2013	2.8%
Toronto	2012	1.1%
Edmonton	2012	1.1%
Edmonton	2011	0.1%
Edmonton	2010	0.7%
Alberta	2009	0.7%
San Jose	2008	0.8%
Edmonton	2009	0.2%
KAB National	2009	1.7%
San Francisco	2008	1.1%
San Jose	2008	0.8%
San Francisco	2007	1.7%
Edmonton	2007	0.4%
Alberta	2007	1.1%
Toronto	2006	1.1%
Toronto	2004	1.0%
Peel	2003	0.5%
Durham	2003	0.6%
York	2003	0.3%
Toronto	2002	1.5%
Florida	2002	2.3%
Florida	2001	2.2%
Median Value		**1.1%**

[2] The 1980-81 California Litter Survey is referenced in the "Other Pertinent Litter Surveys" section since it represents the first statistically-based litter survey that tallied what it termed as "Styrofoam" items in California litter statewide.

Table 2 shows each of the 24 litter surveys evaluated by year and the percentage of items identified as PS foam food service products in large litter. These items were rarely observed in small litter, as discussed later in this report. The studies consistently show that PS foam food service products make up a small fraction of litter.

The 2009 KAB National Litter Survey characterized and quantified roadside litter on 288 sites nationwide using 65 separate categories. This survey concluded that all PS foam food service products constituted just 0.6 percent of roadside litter nationwide (KAB, 2009).

Street litter audits conducted in San Francisco showed that PS foam food service products constituted just 1.7 percent of large litter in 2007 (HDR, 2007) and just 1.1 percent in 2008 (HDR, 2008)**.** Those items were not identified as components of small litter.

The most recent comprehensive street litter audit of Toronto in 2012 surveyed 298 randomly selected sites and showed that PS foam food service products constituted just 1.1 percent of large litter (ERP, 2012).

A comprehensive statewide roadside litter study, funded by Florida Department of Environmental Protection, was conducted using 670 randomly selected sites in Florida and showed that all PS foam food service products constituted only 2.3 percent of litter in 2002 (Florida, 2002) and just 2.2% in 2001 (Florida, 2001). Those items were not identified as components of small litter.

PS Foam Food Service Products in Large Litter - Conclusion
Since the data in Table 2 consists of percentages from surveys representing a variety of population sizes and areas, the median is the appropriate measure for determining an average value. For the 24 VLS studies included, the median percentage of PS foam food service products in litter is 1.1 percent. Additional studies come to the same conclusion and are discussed below.

Ocean Conservancy – PS Food Service Items in Beach Litter
Ocean Conservancy sponsors beach cleanup days throughout the U.S. and internationally each year. Based on data from 2,609 U.S. sites surveyed in 44 states in 2013, PS food service items comprised 2.1 percent of all U.S. beach litter (Ocean Conservancy, 2014).

Other Pertinent Litter Studies
Other statistically based litter surveys quantified PS foam products in general, while not specifically identifying the food service portion. While these surveys are not directly comparable to those that broke out the food service portion, they still indicate that PS foam products in general comprise a small portion of litter. Therefore, by extension, the food service portion comprises even less.

2010 Northeast Litter Survey

The 2010 Northeast Litter Survey consisted of three separate and comprehensive statewide litter surveys conducted in Maine, New Hampshire and Vermont. A total of 288 sites were surveyed. All types of PS foam products were tallied, including food service products and packaging. Items specifically tracked included packaging peanuts and blocks; beverage cups, clamshells and plates; ice chests and other food insulating products; construction-related insulation sheets and pieces from retail, commercial and industrial sources.

The percentage of all PS foam products as components of litter in each state was identified:

- Maine: 1.3 percent
- New Hampshire: 1.4 percent
- Vermont: 1.5 percent (ERP 2010)

California 1980-81 Litter Survey

California's 1980-81 litter survey provides important insights into the contribution of PS foam materials to the litter stream in California over time. The California State Solid Waste Management Board underwrote the survey, which was led by Dr. Bruce Bechtol and Dr. Jerry Williams, Professors of Geography at California State University in Chico.

One-third of sites were monitored for large items only. The remaining sites were audited for all litter items larger than one square centimeter in size and formed the basis of litter composition in California. That study characterized PS food service and packaging items together and showed that all of these items, which it termed "Styrofoam", comprised between 2.1 percent and 2.6 percent of all litter (California Geographical Society, 1984).

PS Food Service Items in Litter - Survey Notes

Florida's litter surveys included a separate category for miscellaneous PS foam in large litter. The survey author noted that these items were chunks of PS, not food service items, which were categorized separately (John Schert, personal communications, 2012).

"Other PS Pieces", a minor portion of small litter, consisted primarily of broken pieces of items such as packaging materials or ice chest lids (Personal communications with John Schert, 2012), although it may have also included some pieces of PS foam food service products (Emy Mendoza/San Jose and Allan Mazur/Toronto, personal communications, 2012).

Toronto's 2004 survey noted that small litter is manufactured, in part, by mowing along roadsides before litter is removed, turning several larger pieces of litter into numerous small pieces (Toronto, 2004).

The 2010 Northeast Litter Survey, which surveyed all expanded PS products (packaging and food service) together, made similar observations (ERP, 2010). Thus, cleaning up litter before mowing can significantly reduce the amount of floatable items in litter.

Since the percentage of PS foam food service products in litter is low, the considerable time and financial resources expended to pursue this control measure is unlikely to achieve significant reductions of materials since they are not likely to exist at the levels implied.

PR Bags in Litter

PR Bag Data in Statewide and Citywide Litter Surveys

Statewide litter surveys that characterize litter using statistically based sampling methodologies consistently show that PR bags constitute a small portion of litter. This section relies on the same litter surveys and criteria as the PS foam food service section above.

Table 3 – PR Bags in Large Litter

Study	*Year*	*Percent*
Rhode Island	2014	0.5%
Edmonton	2013	0.0%
Texas	2013	2.0%
Toronto	2012	0.8%
Edmonton	2012	0.3%
Edmonton	2011	1.1%
Edmonton	2010	0.5%
Alberta	2009	0.0%
San Francisco	2009	1.5%
Edmonton	2009	0.3%
KAB National	2009	0.6%
San Francisco	2008	0.6%
San Jose	2008	0.4%
San Francisco	2007	0.6%
Edmonton	2007	0.4%
Alberta	2007	2.0%
Toronto	2006	0.1%
Toronto	2004	0.2%
Peel	2003	0.1%
Durham	2003	0.3%
York	2003	0.4%
Toronto	2002	0.6%
Florida	2002	0.5%
Florida	2001	0.7%
Median Value		**0.5%**

Table 3 shows each of the 24 litter surveys evaluated by year and the percentage of items identified as PR bags in large litter, typically less than 1.0 percent.

The 2009 KAB National Litter Survey characterized and quantified roadside litter on 288 sites nationwide using 65 separate categories. This survey concluded that all type of plastic bags constituted just 0.6 percent of roadside litter nationwide (KAB, 2009).

Percentages for categories such as plastic bags of all types constituted such a minute portion of roadside litter that they were not specifically addressed in the survey report.

Comprehensive citywide street litter audits were conducted in San Francisco before and after *PR Bag* use had been banned by the City at certain retail merchants. These surveys showed that PR grocery bags constituted only 0.59 percent of litter in 2007 (HDR, 2007) and 0.64 percent in 2008 (HDR, 2008). The percentage of PR grocery bags in litter actually increased slightly after the ban had been put into effect.

A comprehensive street litter audit conducted using 298 randomly selected survey sites in Toronto showed that PR grocery bags constituted only 0.1 percent of litter (MGM, 2006).

A comprehensive statewide roadside litter study, funded by Florida Department of Environmental Protection, was conducted using 670 randomly selected sites in Florida and showed that PR grocery bags constituted only 0.7 percent of litter in 2001 and just 0.5 percent of litter in 2002 (Florida, 2002). Similar surveys had been conducted in Florida in 1994, 1995, 1996 and 1997. In each of those years, PR bags constituted less than 1.0 percent of litter (Florida, 2002).

Litter surveys showing unusually high rates of littered items such as PR bags tend to be conducted by volunteers rather than professional staff. These surveys typically lacked stratified random sampling and standard statistical methods. At times, material categories were not consistent. While such studies have helped create the awareness of litter's impacts, their limitations have, in some cases, resulted in erroneous depictions of PR bags as a significant component of the overall litter stream.

Ocean Conservancy – PR Grocery Bags in Beach Litter

Ocean Conservancy sponsors beach cleanup days throughout the U.S. and internationally each year. For the first time, PR grocery bags were tallied separately in 2013. Based on data from 2,609 U.S. sites surveyed in 44 states, PR grocery bags comprised 2.1 percent of all U.S. beach litter (Ocean Conservancy, 2014).

For 35 of the 44 states, PR grocery bags comprised 2.9 percent or less. For 25 of the 44 states, plastic grocery bags comprised 1.9 percent or less (Nicholas Mallos, email communications, June 10, 2014) including California (1.7 percent), Oregon (1.4 percent) and Washington (0.9 percent).

Other states also showing that PR grocery bags comprised 1.9 percent or less of litter include: Alaska, Colorado, Connecticut, Delaware, Georgia, Hawaii, Kentucky, Maine, Massachusetts, Mississippi, New Hampshire, Nevada, Pennsylvania, Rhode Island, South Carolina, South Dakota, Texas, Vermont and Wisconsin (Nicholas Mallos, Personal communication, June 10, 2014).

PR Bags in Large Litter – Conclusion

Since the percentage of single-use plastic bags in litter is low, the considerable time and financial resources expended to pursue bans of this material as a regulatory source control will not achieve significant reductions of litter in large part because the litter surveys by California's own cities have proven that these items do not exist at the levels implied.

ER Planning 2013 Paper and Plastic Bag Litter Study

Characterization of All Plastic Bags in Litter

To accurately determine the types of plastic and paper bags found in litter, ER Planning conducted three separate citywide litter surveys between December 2011 and January 2012 in two California cities (Oakland and San Francisco) and in Washington, D.C. Each of these cities has taken a different approach to managing bag litter.

Field crews physically surveyed 180 sites (60 in each city), covering a total of 6.48 million square feet. In each city, field crews collected data for all types of plastic and paper bags including the source (e.g., convenience store) and brand label on each bag found in litter.

PR bags from grocery stores, pharmacies, convenience stores and take-out food outlets were each categorized separately. PR bags from all other retail stores such as Dollar Tree and Home Depot were categorized as *Other Retail Bags*.

Plastic bags were characterized by type, noting the source. Following discussions with the City of San Francisco Public Works and Environmental Health Departments, the following five guidelines were used:

1. Full and Properly Secured Trash Bags

Some full trash bags were properly tied. While they may not have met the requirement for a proper trash set-out, they were not deemed to have been littered and were excluded from this tally for that reason.

2. Empty Trash Bags

Empty or near-empty bags were deemed to have been littered since none of them were observed to be part of, or in close proximity to, a bona fide trash set-out. In addition, most of them were at least partially opened and/or seemed to have been blown about.

3. Partially Open Trash Bags

Several trash bags observed were open and had created litter. Field crews observed bags blowing about from similar set-outs. Thus, these bags were counted as litter.

4. Improperly Secured Trash Bags

In other cases, plastic bags filled with trash were left open and the contents were falling or blowing out, which created more litter. The bags themselves were not considered litter as they were substantially filled. However, if not collected and disposed of properly, they would continue to produce litter. In addition, they could very well become litter themselves, but had not done so yet. Inappropriate trash set-outs are a known cause of negligent litter.

5. Loose Trash Bags
Other bags, however, were carelessly set out in a manner that created opportunities for wind-blown litter, but were not littered yet. Other items from these set-outs had already become and were counted as litter.

Plastic Bags in Litter by Source and Type
Table 4 shows that sandwich bags were the most littered type of plastic bag in San Francisco (43 percent), while plastic bags from Other Retail stores were the highest in D.C. (24 percent) and Oakland (34 percent). Full and empty trash bags were a noticeable portion of littered plastic bags in all three cities (38 percent in San Francisco, 26 percent in D.C. and 12 percent in Oakland), averaging 19 percent overall.

Table 4 – All Littered Plastic Bags by Source and Type

Category	SF	DC	Oak	All
Trash - Full	18%	14%	7%	10%
Trash - Empty	20%	12%	5%	9%
Grocery	2%	10%	4%	5%
Other Retail	8%	24%	34%	29%
Pharmacy	0%	2%	4%	3%
Conv. Store	0%	5%	8%	7%
Take-out Food	8%	11%	6%	7%
Sandwich	43%	0%	6%	9%
Bulk Food	0%	22%	24%	21%
Subtotal	**100%**	**100%**	**100%**	**100%**

PR Bags in Litter – Branded and Unbranded
Some communities have chosen to exempt smaller and independent stores when crafting ordinances restricting the use of PR bags. The high percentage of unbranded PR bags observed in all three cities surveyed suggests that smaller, independent stores are the likely source for a significant number of these bags. Unbranded or "Thank You" bags are frequently used by smaller stores. Most large chains use bags with their logos.

Table 5 shows the percentage of PR bags in each city that were unbranded. The highest percentage of unbranded PR bags was observed in San Francisco (78 percent). Approximately half of the PR bags littered in Oakland (50 percent) and Washington D.C. (49 percent) were unbranded.

Cities that implement bag ordinances while exempting independent stores do so at their own peril, since more than half of all PR bags surveyed in these three cities represented bags used by independent stores (unbranded).

Table 5 – Unbranded PR Bags in Litter

City	Unbranded PR Bags	All PR Bags	Percent Unbranded
Oakland	75	149	50%
San Francisco	7	9	78%
Washington, D.C.	24	49	49%
All Cities	**106**	**207**	**51%**

Material Bans

The State Water Board notes that California communities have implemented numerous local ordinances banning certain consumer products, implying that those ordinances are effective in reducing overall littering in California (State Water Board [SWB], p. 7). The State Water Board goes further to specifically encourage bans of single-use carryout bags and PS foam food service products (SWB, p. 16) and highlights these bans throughout the document without providing any evidence that these bans are effective in reducing litter (SWB, p. 79).

The State Water Board even proposes to extend the compliance deadlines for Permittees who put these product bans in place (SWB, p. 158) as though material bans will automatically reduce litter effectively when all evidence from litter surveys conducted by California cities clearly prove that these bans have not reduced overall litter.

The State Water Board notes that the City of San Francisco banned the use of single-use plastic bags in grocery stores and pharmacies in 2006 (SWB, p. A-18). The City of San Francisco conducted three statistically-based litter surveys in 2007, 2008 and 2009. These surveys showed that PR bags and PS food service products were insignificant portions of litter. The City of San Jose conducted a statistically-based litter survey in 2008 and the results were virtually identical to those conducted in San Francisco.

No statistically-credible visible litter survey ever conducted in California or anywhere else supports the notion that material bans reduce overall litter.[3]

In fact, statistically-based surveys that have been conducted by cities in California prove precisely the opposite and prove two facts clearly:

1. PR bags and PS food service products are both insignificant portions of litter in these California cities, and
2. Material bans have never been shown to reduce overall litter.

Regarding the effect of San Francisco's ban on single-use plastic bags, "the city hasn't collected any litter data since the 2009 survey", according to Guillermo Rodriguez, a spokesman for the city's environment department (Santa Cruz, 2013). However, surveys conducted in 2008 and 2009 had shown no change in response to the ban.

[3] A San Jose memorandum implied that single-use plastic bags in the City's litter was reduced since the City's ban went into effect, citing post-ordinance data apparently collected by city staff in 2012. But their post-ordinance study only surveyed 31 sites, while the pre-ordinance study surveyed 107 sites (San Jose, 2012). Thus, results from these two surveys are not statistically comparable. San Jose further estimated an 11.9 percent reduction in stormwater trash and attributed this estimate solely to the City's ban on single-use plastic bags (san Jose, 2012b, p. 10-7), but the City's data used the flawed BASMAA trash characterization (San Jose, 2012a, p.5) and significantly overstated the volume of single-use plastic bags in its stormwater trash.

"San Francisco's ban effected no measurable change in plastic bag litter, at least in the first two years." (Santa Cruz, 2013)

The State Water Board admits that product bans simply change the type of litter and that San Francisco's litter surveys showed "no overall reduction in litter (or trash to the waterways)" (SWB, p. A-18). It goes on to admit that such bans could double the amount of greenhouse gas emissions, double energy use and quadruple the amount of waste caused by material substitutions (SWB, p. A-18).

Oddly, the State Water Board cites a University of California study and notes that

"Similarly, bans on polystyrene food containers would cause a shift to materials with other significant environmental impacts." (University of California at San Diego [UC-SD], 2006)

In fact, the University of California study goes on to state that:

"…Styrofoam cups are better than paper from an environmental standpoint…" (UC-SD, 2006)

Yet, despite acknowledging these risks and the significant environmental impacts they will likely have, the State Water Board proposes to encourage Permittees to enact these ineffective ordinances. The State Water Board should be able to reasonably foresee that material bans are an ineffective method of compliance.

Analysis of Litter Rates and Material Bans in Place

A statistical analysis of BASMAA's 2012 trash characterization showed that city bans on plastic grocery bags and PS foam food and beverage (F&B) products had statistically insignificant effects on the volume of PS foam F&B products in stormwater trash (ERP, 2012).

In these tables, sample size refers to the number of sites where trash was counted. The mean values represent the average amount, in gallons, of plastic grocery bags or PS foam F&B found at these sites measured in gallons without accounting for air space (i.e. uncompressed volumes) (ERP, 2012).

As shown in Table 6, the average volume of plastic grocery bags was only slightly lower where a city ban existed (0.14 gallons) than where one did not exist (0.19 gallons), and this difference was statistically insignificant.

The same was true for PS foam F&B, where the values were even closer (0.1 gallons where a ban existed and 0.15 gallons where no ban existed).[4]

If material bans had been effective, these values would have been much further apart.

Table 6 – Statistical Analysis: City Bans vs. No Bans

	Plastic Grocery Bags		PS Foam F&B	
Value	**Yes**	**No**	**Yes**	**No**
Sample Size (# of Sites)	110	105	110	105
Mean Value (gallons)	0.14	0.19	0.14	0.19

High Litter Rates in Cities with Bans in Place

Some of the sites with the highest volumes of plastic grocery bags and PS FF&B products were in cities that had bans of these items in place at the time that BASMAA's trash characterizations were conducted.

As shown in Table 7, half of the six sites with the highest volumes of PS FF&B products in litter had citywide bans in place at the time these characterizations were conducted.

[4] The highest trash volume, found on site RI01, was 42.84 gallons, while the second highest trash volume, found on site SP01 was only 18.27. Thus, site RI01 constituted an extreme outlier and, in accordance with good statistical practice, was excluded from the analysis.

Table 7 – High Litter Volumes with City Bans – PS Foam F&B Products

#	BASMAA Site ID	PS Foam F&B (gallons)	City	County	PS Foam F&B Ban (y/n)
1	RI01	3.56	Richmond	Contra Costa	y
2	SM07	1.67	San Mateo	San Mateo	
3	RI03	1.33	Richmond	Contra Costa	y
4	SL25	1.22	San Leandro	Alameda	
5	BR04	1.00	Brentwood	Contra Costa	
6	OK02	1.00	Oakland	Alameda	y

Similarly, as shown in Table 8, half of the six sites with the highest volumes (measured in gallons) of PR bags in litter also had citywide bans in place at the time these characterizations were conducted. These sites showed no relationship between the litter rates of PR bags or PS foam food service products and citywide bans that had been put into effect.

Table 8 – High Litter Volumes with City Bans – Plastic Grocery Bags

#	BASMAA Site ID	Plastic Grocery Bags (gallons)	City	County	Plastic Grocery Bag Ban (y/n)
1	RI01	4.00	Richmond	Contra Costa	y
2	SM12	1.33	San Mateo	San Mateo	
3	SP01	1.11	San Pablo	Contra Costa	y
4	SJ08	1.11	San Jose	Santa Clara	
5	SJ22	1.11	San Jose	Santa Clara	
6	SJ38	1.11	San Jose	Santa Clara	y

Substitution Effect

Since littering is a behavioral based problem, banning one material only means that another material will be used instead, but the littering problem is unaffected. This is clearly shown in litter survey data from three comprehensive litter surveys conducted in San Francisco (2007-2009).

PS food service items were banned by a November 2006 ordinance that took effect in June 2007. Since the 2007 field survey was conducted in April 2007, before the ban became effective since and trash accumulates over time, the 2007 data fairly represents pre-ban conditions.

Notice in each of the categories that litter was not reduced following the ordinance. In fact, litter for each category of food service item actually increased noticeably.

PS Foam Food Service Items and Substituted Materials

Table 9 summarizes the impact of substituting other materials for PS food service items by count. While the number of PS components was reduced by 30 percent, the number of paper components increased by 163 percent and the number of items made of other materials or other plastics increased by 253 percent.

Overall, the ban on PS food service items corresponded to an increase of 59 percent in the number of littered food service items as shown in Table 9.

Table 9 – PS Foam Food Service Items in San Francisco Litter

Littered Food Service Items	2007	2008	2009	Change	% Change
Polystyrene	67.5	45	47	-20.5	-30%
Paper	44.5	73.5	117	72.5	163%
Other Plastics/Other Materials	7.5	20	26.5	19	253%
Total	**119.5**	**138.5**	**190.5**	**71**	**59%**

PS Foam and Substituted Materials – Hot Beverage Cups

While the number of littered PS hot beverage cups was reduced by 36 percent, the number of littered paper hot beverage cups increased by 142 percent resulting in an overall increase of 45 percent in all littered hot beverage cups as shown in Table 10.

Table 10 – Hot Beverage Cups in San Francisco Litter

Littered Hot Cups	2007	2008	2009	Change	% Change
Polystyrene cups (foam)	43	31	27.5	-15.5	-36%
Paper Cups (Hot)	36	56.5	87	51	142%
Total	**79**	**87.5**	**114.5**	**35.5**	**45%**

The amount of fast food plates, clamshells and trays tallied were too small to analyze meaningfully by component.

Material Bans - Conclusion

If the State Water Board decides to allow material bans, despite the clear evidence that they are not effective in reducing overall litter, then such material bans should require rigorous demonstration, monitoring, and testing to assess whether the bans are effective at all in reducing litter.

Permittees must provide annual reports to their Water Board demonstrating, through the use of statistically credible surveys, that any material bans put in place have resulted in an actual net reduction of overall litter and stormwater trash.

The California Integrated Waste Management Board recommended in 2004 that California conduct a statewide litter survey to identify the types and amounts of litter (CIWMB, 2004).

Doing so now and thereby establishing credible baseline data, will provide sorely needed guidance before the State Water Board allows communities to impose material bans without any credible basis for doing so.

Compliance Monitoring

Proposed Tracks

Track 1 provides a clear trash abatement strategy requiring the use of full-capture systems, which have proven very effective in Los Angeles. Although it is clear and unambiguous, it demands full reporting by Permittees.

Track 2 is much more ambiguous, allowing Permittees to propose various regulatory controls, including material bans that have never been proven to effectively reduce litter. Despite the risk-laden and unstructured approach, there is no specific monitoring or testing required - only vague direction that Permittee demonstrate that its approach is effective.

Track 2 should require much stricter and more extensive monitoring, testing and reporting than Track 1 simply because Track 2 is innately ambiguous and therefore vulnerable to deficiencies and limitations that would not be present with Track 1.

How could compliance be credibly determined? Using the combination of controls described in the Trash Amendments would require more complex monitoring and more rigorous reporting than Track 1, rather than less.

If the State Water Board decides to go further and allow the use of material bans as an institutional control, then the Board must require Permittees to put a rigorous monitoring system in place to ensure that Permittees are achieving the mandated trash reduction and that those reductions are attributable to the material bans.

Such a monitoring system would be based on special surveys that would be conducted on an annual basis by independent third party professional firms with significant expertise in litter and/or stormwater trash. These firms should be selected by the State Water Board. The litter and/or stormwater surveys should utilize the methodology employed by both San Francisco (2007-2009) and San Jose (2008) with a similar reporting format to provide consistency.

In addition, if multiple controls are put in place such as material bans and enhanced street sweeping, Permittees must validate the effectiveness of each control and to help determine which components of their controls are driving any changes in the system. This would require a characterization and quantification survey of the materials captured by street sweeping equipment.

This will help the State Water Board and the Permittees ensure the credible data monitoring and reporting that Track 2, by its very nature, requires. To do less would constitute an abdication of responsibility on the part of the State Water Board and a failure to provide the guidance needed that will lead to the abatement of litter entering stormwater systems.

Los Angeles Exemption

The Trash Amendments propose to exempt waters within the jurisdiction of the Los Angeles Water Board (LAWB). LAWB adopted fifteen TMDLs with a numeric target of zero trash (SWB, p.22).

The LAWB has put significant controls in place using a clear strategy that has already proven to be extremely effective achieving a 90 percent reduction in trash well ahead of schedule.

> *As of March 2012, the City has retrofitted 22,133 catch basins with trash capture or deflecting devices in the Los Angeles River Watershed as well as three netting systems certified as full capture devices have been installed strategically in the Watershed. With these structural devices alone, the City has reduced its trash discharge to the Los Angeles River by approximately 90%, several years ahead of the final TMDL compliance milestone (Los Angeles, 2012).*

The successful trash reductions in Los Angeles demonstrate that full-capture structural controls are a proven method of significantly reducing trash discharges.

Other Institutional Controls

Certain aspects of the proposed Trash Amendments will help California communities address litter and stormwater trash more effectively.

High Density Generation Areas

The focus of efforts on high-density generation areas will help Permittees to apply their funding to areas that are most problematic and will likely provide the best opportunity to reduce littering efficiently and make the best use of their funding.

Anti-Littering and Illegal Dumping Enforcement

Enforcement of anti-littering and illegal dumping ordinances is a significant key to reducing litter. For example, States and communities can impose fines for vehicles traveling with untarped loads. Solid waste management facilities can also add surcharges for untarped loads.

Both of these strategies can help achieve significant reductions in litter. The State Water Board should encourage its communities and Permittees to enact and enforce such discharge-focused ordinances which direct their efforts to the specific sources of litter that each community seeks to reduce.

In an effort to reduce littering from untarped vehicle loads, waste management facilities in New York State institute surcharges for untarped vehicles. In addition, drivers are subject to fines of up to $1,000 by the New York State Department of Environmental Conservation for these violations. This best management practice can help reduce this source of litter.

George L. Kelling, Professor in the School of Criminal Justice at Rutgers University and a Research Fellow in the Kennedy School of Government at Harvard University, called attention to importance of enforcement with his landmark *Broken Windows* theory (Kelling, 1996).

Kelling was able to prove the correlation between enforcement and reductions in crime under the auspices of the Manhattan Institute (Sousa and Kelling, 2002). Kelling later applied that theory to the importance of enforcing anti-littering ordinances (Kelling, 2006).

An ongoing challenge of litter reduction strategies is the perceived reluctance of enforcement officials and courts to consider litter offenses a priority. Enforcement officers are tasked with significant responsibilities and littering is not commonly observed. However, when officers do observe littering, having programs and training in place can benefit enforcement officials.

In a speech given at the 2006 Governor's Litter Summit in Georgia, Kelling noted that people who commit offenses such as jumping subway turnstiles and littering have a higher than average rate of outstanding warrants. Thus, enforcement of anti-littering ordinances can provide useful tools to enforcement officers.

In a 1971 survey of 1,035 police departments across the U.S., 86 percent believed that enforcement could be effective if enforcement agencies and courts were trained on the implications of litter in their communities.

This sentiment was echoed in 2006 at Georgia's litter summit. When implemented with public education and cleanup efforts, enforcement can serve as an effective tool. Sentencing offenders to clean up litter was recommended.

Effective enforcement cannot be dependent on signs alone. Anti-litter signage without enforcement can result in higher litter rates as it tends to empower violators, sending a message that a community is powerless to control littering (KAB, 2007).

One factor in successful enforcement is the use of courts specifically designed to handle environmental offenses. The City of Memphis and Shelby County, TN is considered to be the national leader in the environmental court movement. The court handles caseloads relating to illegal dumping, littering and other environmental property issues, that might have otherwise fallen thru the cracks of the criminal justice system. This type of court is more supportive of environmental crimes and has higher conviction rates. More than 70 similar courts have been put in place nationwide (US Conference of Mayors, 1999).

The California Integrated Waste Management Board (CIWMB) recommended elevating littering to a civil offense:

> *"The Legislature should consider making litter a civil offense, to facilitate issuing litter tickets. Legislation could authorize financial incentives, perhaps from proceeds of violation tickets, to individuals and/or organizations that identify violators with appropriate proof (such as videotape or witness testimony) that results in tickets being issued." (CIWMB, 2004)*

Improved Trash Bin/Container Management

The effectiveness of improved trash receptacles was proven in several studies conducted by William C. Finnie, Ph.D. One study, testing the effect of decorated litter receptacles placed on each block of an urban area in Richmond, VA, found that litter was reduced by a statistically significant 16.7 percent (Finnie, 1973). A similar study of attractive receptacles in St. Louis found that liter was reduced by 14.7 percent (Finnie, 1973).

Finnie also found that conspicuously decorated trash receptacles at rest areas along highways reduced litter by 28.6 percent and that these reductions were apparent six miles from the receptacles. Similar results were obtained in subsequent studies by Dr. Scott Geller (Geller, 1982) as well as Cone and Hayes (Cone and Hayes, 1980).

Appropriately placed litter receptacles in commercial and public areas can also reduce littering rates. The City of Long Beach, CA used strategically placed receptacles to reduce litter in storm-water runoff. Receptacles were placed in business areas, bus stop and recreational areas (Long Beach, 2001).

According to the City's Storm Water Management Program Manual, approximately 1,000 litter receptacles were placed along public street frontage and serviced at least once per week. The city also placed approximately 2,100 litter receptacles in recreational areas and ensured that they were serviced regularly (Long Beach, 2001).

For litter receptacles to effectively reduce litter, internal municipal procedures must clearly ensure they are maintained in a timely manner. Since properly maintaining and emptying trash and litter receptacles can be time-consuming and expensive, public/private partnerships can help to alleviate these costs, provided there is proper oversight by the local government.

Overfilled receptacles that are not properly maintained create precisely the type of litter that is likely to enter stormwater systems.

Enhanced Street Sweeping in HD Areas

Focusing more extensive street sweeping efforts on high-density generation areas can help reduce litter entering stormwater systems.

> *"Frequent street cleaning can dramatically reduce the quantity of street litter reaching the drainage system – even where there is a generally adequate refuse removal service" (Armitage, 2001).*

A New York City study of street cleaning practices found that augmenting baseline street cleaning (mechanical sweeps twice per week) with manual sweeping of each block face once per day, six days a week reduced floatable litter 42 percent by count, 51 percent by volume and 64 percent by weight (HydroQual, 1996). Swedish scientists, evaluating the efficacy of street sweeping, found that the optimal efficiency was achieved by sweeping twice per week (German and Svensson, 2001).

Enhanced street cleaning should be implemented regardless of other reduction measures used since it can reduce the required maintenance of other technology-based controls.

Alternative Control Measures

In addition to the institutional controls identified in the State Water Board's proposal, we have identified a number of additional opportunities to reduce trash discharges that have been proved effective in other contexts.

Insufficient Securing of Collection Vehicle Loads

A nationwide litter survey found that insufficiently secured trash and recycling collection vehicles are a significant source of litter (ERP, 2010). Such vehicles along with untarped pickup trucks were estimated to be the source of 16.4 percent of the 51.2 billion pieces of roadside litter identified nationwide (KAB, 2009, p. 3-8). That study also found a significantly higher rate of litter on roadways within two to five miles of solid waste and recycling facilities than on other roadways (KAB, 2009, p. 3-21).

A pilot study of spillage from rear-loading trash collection vehicles in 2007 found that spills occurred at 202 (14.6 percent) of the crews' 1,385 residential trash collection stops. However, only 102 (slightly more than half) of these spills were cleaned up by the collection crew. The remaining 100 spills were left as litter. This meant that 7.2 percent of trash collection pickups resulted in litter that rains could wash into stormwater drains (ERP, 2009).

Other researchers confirm that trash collection vehicles deal with this problem.

> *"Even under ideal conditions, collecting hundreds of tons of refuse can be a messy business. A certain amount of spillage is unavoidable. However, in most situations collectors are able to 'clean up their mess.' Sometimes, inclement weather causes problems on collection day—wind is the primary culprit. In order to reduce litter, the local government should require that refuse containers have lids. Each collection vehicle should be required to carry a shovel, broom, and dust pan and remove litter associated with the refuse/recycling operation (Scarlett and Sloan, 1996)."*

The State of Florida, which conducted statewide litter surveys in 1994-1997 and 2001-2002, documented litter due to spills from front-loading trash collection vehicles in 2003. Researchers observed the collection of 337 commercial dumpsters over 1,277 miles and found that littering spills occurred at 28.8 percent spills at collection sites and on public streets or highways after 20.8 percent of trash pickups (Florida, 2003). Recycling collection vehicles were also found to be a source of litter for precisely the same reason (Florida, 1999).

San Francisco's departments of Public Works and Environmental Health reported in 2012 that, while collection vehicles are inspected, collection routes are not monitored for this type of spillage although this was discussed as a known source of litter nationwide (Dept. of Public Works and Dept. of Environmental Health, personal communications, 2012).

Recommendations

- Since the City of Los Angeles has achieved a 90 percent reduction in litter entering its stormwater system, it should be considered a model to be emulated by other California communities so other communities can achieve similarly successful litter abatement.
- Track 2 should be modified to preclude material bans due to a lack of credible evidence demonstrating their effectiveness in reducing overall trash.
- Track 2 should be less ambiguous overall and should require a level of reporting and monitoring at least equivalent to Track 1.
- Communities should focus their efforts on high-density generation areas when fiscal constraints preclude their ability to address stormwater controls community-wide.
- Due to known problems using volume-based quantification methodologies, the VLS methodology, considered by all experts in the field to be the standard for measuring litter, should always be used when quantifying litter and stormwater trash.
- Litter and stormwater trash surveys should always be performed by trained professionals and the methodologies used should always be transparent.
- Trash and recycling collection vehicle routes should be monitored to determine the extent to which they employ practices that contribute to litter that could enter stormwater systems.
- Innovative options for financing stormwater technology-based controls should be explored in order to assist Permittees that may have budgeting constraints.

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Appendix A - CV Brief

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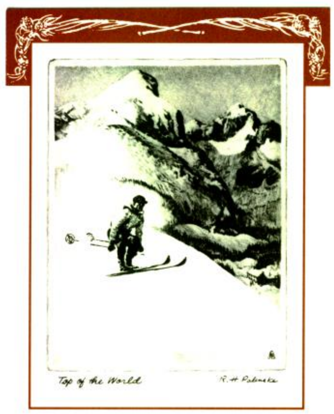

Steven R. Stein is Principal of Environmental Resources Planning LLC (ER Planning), North America's most experienced private firm in the field of litter–related and commodity characterization studies and litter's effects on our communities.

ER Planning's roots in the environmental field go back to the 1800s when Mr. Stein's grandfather worked in forestry and then, in 1913, in recycling. Steven has worked in the fields of recycling and solid waste management since 1972 for public, private, trade association and consulting.

His work with litter, which began in 1987, has been featured on ABC's Good Morning America and NPR as well as in the New York Times, National Geographic Magazine and Time Magazine. Field crews under his direction have physically surveyed litter along more than 21 million square feet of roadways and recreational areas.

ER Planning organized and sponsored the 2011 National Litter Forum, which focused on the role of litter abatement on restoring our nation's communities. Mr. Stein's firm provides pro-bono time to organizations such as Ocean Conservancy, assisting with projects regarding litter and marine debris.

Mr. Stein has worked on a considerable number of litter–related projects including the *Litter: Literature Review*, for which he was lead author in 2007. He led the design and implementation of Keep America Beautiful's National Litter Survey and Cost Study (2009) and the development of their Community Appearance Index, which focused on the impact of illegal signage, excessive outside storage, abandoned/junk vehicles and graffiti on local communities.

Mr. Stein has taught *Environmental Science* and *Ethics in Management* at the university level and was invited, as a subject matter expert on environmental issues and community dynamics, to participate in a study commissioned by the President in 2010.

Education

B.Sc., cum laude – *Environmental Studies,* Syracuse University and SUNY College of Environmental Science and Forestry (Joint Program). Focus of Studies: Waste Management and Environmental Law. Teaching assistant for Dr. Allen Lewis's Introduction to Environmental Studies course. Internship with New York State Department of Environmental Conservation.

M.Sc. – *Natural Resource Policy and Management,* Syracuse University and SUNY College of Environmental Science and Forestry (Joint Program). Focus of Studies: Macroeconomic relationship of Asian/U.S. recycling industries and evaluation of sustainable policy initiatives. Awarded New York SWANA Annual Scholarship Award for his research examining the implications of public policy intervention on the establishment of sustainable domestic recycling markets.

Ph.D. Coursework – Mr. Stein began a Ph.D. program in *Environmental Science* at SU/SUNY–ESF focusing on the influence of cultural archetypes on littering behavior and litter abatement, authoring a literature review of behavioral and litter quantification/characterization studies conducted between 1968 and 2006 and a paper evaluating the influence of cultural archetypes in America.

Selected Projects

- Technical Assessment Report: Analysis of California Statewide Water Quality Control Plans to Control Trash (June 2014 Trash Amendments) - Author (2014)
- 2014 Rhode Island Litter Survey – Project Manager, Author of subsequent report (2014)
- Maryland State Legislature – Testimony to the State Senate and House on the components of litter (2014)
- Paper, Plastic or Neither – Time magazine (2014)
- San Francisco Water Board – Measuring Compliance and Trash Load Reductions (2013)
- 2013 Texas Litter Survey – Project Manager, Author of subsequent report (2013)
- World Ocean Council – Research on food waste, carpet and mattress recovery (2012)
- 2012 Toronto Streets Litter Audit – Project Manager, Author of subsequent report (2012)
- Contribution of Polystyrene Foam Food Service Products to Litter – Author (2012)
- Our Beaches and Seas: Mechanics of Risk – Author, Speaker (2012)
- Multi–City Paper and Plastic Bag Litter Survey – Project Manager, Author of subsequent report (2012)
- World Ocean Council – Research on differentiation of Material Flows Methodology (2012)
- Technical Assessment Report: Analysis of BASMAA MS4s Stormwater Trash Reports - Author (2012)
- Sustainable Consumption Expert Roundtable, Johnson Foundation (2012)
- Ocean Conservancy: Beach Litter Survey Methodology Enhancements (2011)
- FoLAR: Los Angeles County Trash Biography – Peer Review (2011)
- National Litter Forum: Restoring Our Communities – Organizer and Sponsor (2011)
- Confidential Client – Expert witness research and report regarding litter and marine debris (2010)
- President's National Infrastructure Advisory Council: Optimization of [Community] Resources – Contributor (2010)
- 2010 Northeast Litter Survey – Three statewide litter surveys (Maine, New Hampshire, Vermont) – Project Manager, Author of subsequent report (2011)

- KAB National Affiliates Webinar: Litter – The Next Steps (2010)
- Bottled Water Study –Municipal Water Systems and Growth of the Bottled Water Industry (2010)
- Syngress/Elsevier Publishing – Honorariums (three) for Reviews to Publisher of Digital Forensics and Security Book Proposals (2010)
- Forensics Levels I,II and III – Towson University (2009-2010)
- KAB National Litter Survey/ Litter Cost Study – Project Manager, Lead Report Author (2009)
- BBC Advisor for planned series dealing with greenhouse gas emissions from landfills and other sources (2009)
- KAB Community Appearance Index Development – Project Manager (2007-2008)
- KAB National Litter Survey and Cost Study – Project Manager, Lead Author of subsequent report (2008–2009)
- KAB National Conference: 2009 National Litter Survey Results – Speaker (2009)
- KAB Campaign Partners Conference: National Litter Survey Results – Speaker (2009)
- National Geographic Magazine, Trash Register [Litter on Maryland Highways] (December 2008)
- The Impacts of Litter on Greenhouse Gas Emissions – Speaker, WASTECON (2008)
- Addressing Litter in a Changing World – Speaker, International Adopt–a–Highway Conference (2008)
- KAB: International Litter Research Forum, Invited Participant (2007)
- Litter: Literature Review –Lead Author (2007)
- Litter and Its Implications for Solid Waste Managers, WASTECON – Speaker (2007)
- Roadside Litter: Hazards on the Road, MSW Management Magazine – Co–Author (2007)
- Garbage, Litter & Trash, Kojo Nnamdi Show, WAMU – Interview (2007)
- State of Tennessee – Project Manager for statewide litter survey, Author of subsequent report (2007)
- The Truth about Recycling, The Economist – Contributor (2007)
- The New Gold Rush: Mining the Plastics Markets, Resource Recycling Magazine – Author (2007)
- State of Georgia – Project Manager for statewide litter survey, Author of subsequent report (2007)
- State of Georgia – Subject Matter Expert for litter–related web tool design team (2007)
- Debris Wreaks Havoc on the Road, ABC's Good Morning America – Interview (2007)
- Debris Wreaks Havoc on the Road, www.abcnews.com – Website Article (2007)
- Worsening U.S. Road Litter Threatens Lives, Voice of America – Interview (2007)
- Road Debris Causes 25,000 Accidents Annually, Urban Transportation Monitor – Interview (2007)
- Wake Up and Smell the Trash, Potomac Watershed Trash Summit Roundtable (2007)
- Highway Debris, Long an Eyesore, Grows as Hazard, New York Times – Interview (2007)
- US–Government Accountability Office – Assisted with GAO-07-37 report "Recycling: Additional Efforts Could Increase Municipal Recycling" (2007)

- Developed RFP for Tempe, AZ covering MSW and sludge disposal and recyclables processing (2007)
- New York State Dept. of Economic Development – Analysis of New York Scrap Tire Markets Update Reports (2006–07)
- Seattle Public Utility – White Paper: Mobilizing Resources for Disaster Response (2006)
- Potomac Watershed Initiative Trash Monitoring Protocol Subcommittee – Advisor, Led design of Potomac River trash survey (2006–2007)
- Ocean Conservancy's National Marine Debris Monitoring Program – Survey Director for Chincoteague Island, VA Site (2006–2007)
- American Plastics Council – Evaluated the impact of materials bans on environmental quality in California (2006–07)
- American Plastics Council – Evaluated the impact of "All-Plastic Bottles" and "Rural Recycling" initiatives on plastic recovery rates (2006)
- Confidential Client – Litter life-cycle research (2005–06)
- California Litter Survey of 77 Beaches – Project Manager (2005)
- Sweating the Litter Things: Recent Litter Survey Results, KAB National Conference – Speaker (2005)
- Sweating the Litter Things, Resource Recycling Magazine – Author (2005)
- What Litter Surveys Reveal about Bottle Bills, Federation of New York Solid Waste Associations Conference – Speaker (2005)
- Single–Stream (Compilation contributor), Resource Recycling Magazine (2005)
- Booz Allen – Lead Author for white paper on improving recycling measurements (2005)
- Alexandria, VA – Solid Waste Management Plan – Author (2005)
- Confidential Client – Expert Witness project – Comprehensive recycling facility audit (2005)
- Arlington, VA – Developed waste generation projections to support of flow–control issues (2005)
- Coca–Cola – Led the design team for development of a recycling program web tool (2004)
- Single-Stream: A Recycling Method That Cuts Both Ways, Resource Recycling Magazine (2004)
- Single-Stream: Shards and the Damage Done – Unanticipated Consequences of Single-Stream Recycling, NRRA Recycling Conference (2004)
- Single-Stream: Glass vs. Paper, New York Federation of Solid Waste Associations (2004)
- Who's Messing with New Jersey: Litter Survey Results, New Jersey Clean Communities Council (2004)
- What Litter Surveys Reveal About Bottle Bills, New Jersey Clean Communities Council (2004)
- New Jersey Litter Study – Project Manager, Author of subsequent report (2004)
- Recycled Paper Mill – Measured the impacts of contamination from incoming single-stream recyclables to the mill's landfill and maintenance costs (2004)
- Single-Stream Recycling: Capture & Residue, Maryland Department of the Environment (2003)

- Does Single-Stream Recycling Make Sense, NRRA Recycling Conference and Exposition (2003)
- Glass and Single-Stream Recycling, New York Federation of Solid Waste Organizations (2003)
- Pontiac, MI – Led development of collection RFP and on evaluation committee (2003)
- Presenting Recycling Economics to Public Officials and the Media, Maryland Recyclers Coalition Annual Conference (2003)
- Alexandria–Arlington Waste Disposal Trust Fund – Wrote Memo on Pending Federal Legislation and the Oneida–Herkimer Solid Waste Authority Flow Control Case – Author (2002)
- Recycling collection, processing and transport services RFPs – City of Fort Worth (2002)
- Issues Facing Paper Recycling, New York Federation of Solid Waste Organizations (2002)
- Fort Worth, TX – Developed recycling RFP and multi–year recycling revenue projection model (2002)
- GBB (Fairfax, VA) – Administrator of Windows Small Business Server and Microsoft Exchange Email Server (2001-2005)
- North Carolina Litter Study – Co-Author (2001)
- Metro–Nashville Government – Developed multi–year recycling revenue projection model (2001)
- Metro–Nashville Government –Transfer and disposal RFP and proposal evaluation (2001)
- Arlington County, VA Wastewater Treatment Plant – Analysis of Biosolids Management Practices and Alternatives Evaluations (2001)
- AF&PA (Washington, D.C.) – Developed and Published Flash Fax Summary Reports for 12 Leading Economic Indicators (2000-01)
- AF&PA – Worked with Dept. of Commerce to improve procedures for reporting Wood Industry Data (2001)
- Mass. State Legislature – Testified on the impact of container deposits on municipal recycling program revenues (2000)
- Creating a Successful Recycling Program, U.S. Conference of Mayors (2000)
- Municipal Curbside Recycling: Analyzing the Obstacles to Sustainability – Master's Thesis (1999)
- Municipal Recovery: A Success Story, International Recovered Paper IX (1998)
- Residential Mixed Paper Usage, New York State Federation Conference – Organizer (1998)
- Onondaga County, NY – Oversight for 30 recyclables and trash haulers and three MRFs (1990-1999)
- Onondaga County, NY – Site manager for Household Hazardous Waste Days (1992-1999)
- The Thinwalling Phenomena – Impact of Thinner Containers on Municipal Recycling Revenues, New York State Recycling Conference (1997)

- Curbing the Bottle Bill – Impact of Bottle Bills on Municipal Recycling Revenues, Bottle Bill: Sense or Cents Conference (1997)
- Onondaga County – Developed MRF Contingency Plan (1996)
- Auditing MRF Recyclables, New York State Recycling Conference (1996)
- Curbside Counting Lessons – Curbside Recyclables Characterization, New York SWANA (1996)
- Onondaga County, NY – Developed and implemented a stratified curbside recycling quantification and characterization study countywide (1996)
- Social Costs of Recycling – Indirect costs and benefits of curbside recycling, New York State Recycling Conference (1996)
- WiNet Waste and Recycling Information Software Workshop, New York State Dept. of Environmental Conservation Conference (1995)
- Onondaga County, NY – Designed and implemented "WiNet", an online recycling and solid waste information system (1995)
- Onondaga County, NY – Industrial and Medical Waste Audit. Project manager for three survey teams, documenting and analyzing the generation, handling and recovery of various components of all industrial process and medical waste facilities in Onondaga County, NY (1991-1992)
- Onondaga County, NY – Administrator and tech support for all agency workstations and network (1990-1999)
- CNY Environment – Research and analysis of drinking water quality in upstate New York comparing contamination issues from tap, well and filtered water sources (1989)
- New York State Dept. of Environmental Conservation – Organize and research FOIA data and requests as intern (1989)
- US–EPA Small Business Innovation Research Solicitation – Recovery and Reprocessing of Solid Municipal Wastes (1987)
- Plastic Recycling – Created one of the South's first all-plastic container recycling programs, accepting and grinding consumer and commercial plastic containers for recycling (1986)
- Developed program to sort out and recover recyclable materials from trash collected on "Trash–Bash Day" (1987)
- AT&T – Consultant to help increase recycling at AT&T's manufacturing plants (1987)
- Bossier City Clean Community Council – Developed newspaper recovery program in area 7-11 stores to benefit local Keep America Beautiful affiliate (1986)
- U.S. Air Force – Developed prototype drop–off recycling program to benefit the Air Force's Welfare and Morale Fund (1986)
- Assisted SWEPCO (Southwestern Electric Power Co.) with fund–raising recycling program to benefit St. Jude's Hospital (1986)
- Created markets for polycoated diaper liner trims from Kimberly–Clark plant (1986)
- Caddo Waste Trading – Primary broker and supplier of a variety of recycled paper grades to dry–felt roofing mill (1984-88)
- Managed Recycling Facility Operations that handled all grades of fiber as well as glass, aluminum and plastics for 7 years (1972-73, 1976-1979, 1984-88)

- American Bank –Design and implementation for one of the first U.S. online banking software systems (1984)
- American Bank – Computer programmer and Data Processing Manager (1982-84)
- American Bank – Author, Data Processing Security and Procedures Manual (1983)

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Institute for Environmental Research and Education

18 August 2006

Mr. Michael Levy
Executive Director
Polystyrene Packaging Institute
1300 Wilson Blvd.
Arlington, VA 22209

Dear Mr. Levy:

Per your request we are pleased to provide this report on the issues relating to biodegradation and composting of materials. Understand that this report is not comprehensive, partly because the intent is to provide an overview, but partly because these issues are not well understood, for they have not been studied in a comprehensive and technically rigorous fashion. Nevertheless, within these limits this report reflects the current and accurate state of knowledge of the environmental impacts of composting and biodegradation in a West Coast context.

Biodegradation is a natural process through which all non-autotrophic organisms obtain their energy and materials to grow. Optimizing the degradation of organic materials requires the following conditions:

- Heat (optimally 37ºC)
- Moisture
- Appropriate nutrient ratios (optimally, on a molar basis 106 Carbon:16 Nitrogen:1 Phosphorus)
- Adequate micronutrients
- Appropriate pH
- Small particles to increase surface areas for degradation
- Absence of materials that poison the degradation processes
- Appropriate microbial ecologies

Both the guts of animals and typical productive soils provide all these conditions, except that optimal heat is found only in mammals or in very warm climates. Although there is usually a resistant fraction that cannot be readily degraded, under optimal conditions most organic material can be degraded within 24 hours. However, optimal conditions rarely exist.

Most often when we speak of biodegradation, we are talking about the action of microorganisms acting in the natural environment, or in enhanced environments, such as compost facilities. The remainder of this report will focus on these situations.

Consider the case of a paper bag discarded in a roadside ditch. The ditch provides most of the conditions for optimal degradation, but there are still some elements that may be lacking. The bag is a rather large object when viewed from a microbial viewpoint. Its rate of degradation will be slowed as a consequence. Supposing that the ditch is dry—a paper bag in the desert could take years or even decades to degrade due to the lack of moisture. At the other extreme, suppose the bag were underwater and the water was stagnant. Here degradation would be slowed due to lack of oxygen. Under these conditions, the bag will be degraded anaerobically. This is a much slower process and has different biogeochemical outcomes.

Aerobic degradation of organic materials yields complete oxidation of the degradable fraction. Carbohydrates and hydrocarbons are converted to carbon dioxide (CO_2) and water. Proteins are converted to sulfate (SO_4^{2-}) nitrate (NO_3^-) and CO_2. Of course, a certain fraction of these natural polymers are incorporated into the living biomass of the microbes, but this is a small fraction, perhaps only ten percent. The energy of the degradation process fuels the biological processes of these organisms, and the waste heat can be considerable, reaching 37ºC or higher.

Under anaerobic conditions, the degradation is slower and less complete (although note that there are some materials that only degrade under anaerobic conditions). The necessary oxygen comes from the water, not from the dissolved oxygen, and the emissions are quite different. Carbon dioxide is formed from carbohydrates and hydrocarbons, but so is methane. Ammonia or nitrous oxide (N_2O) are formed instead of nitrate. Hydrogen sulfide (H_2S) is formed instead of sulfate[i]. The production of partially degraded volatile organic compounds (VOC's) is common. The proportion of undegraded, refractory material is larger and proportion of the total remaining biomass may be as much as 50 percent.

The environmental outcomes of these two degradation pathways are quite different. Under fully aerobic conditions, biomass degradation is climate neutral. The nitrogen produced is not volatile, although it does easily migrate in groundwater, and if the groundwater pathways permit it can migrate to rivers, lakes and marine environments. The sulfur is also water soluble, although sulfur is less likely to migrate.

Under anaerobic conditions, the climate change impacts can be quite substantial, since methane is about 20 times more potent than CO_2 as a greenhouse gas, and Nitrous oxide is about 300 times as potent as CO_2. The ammonia released is free in the atmosphere and can migrate to cause eutrophication in marine ecosystems. Although it is unlikely to reach concentrations high enough to cause toxic effects, the H_2S released has a most unpleasant rotten egg odor. Many of the VOC's are also odorants, with such evocative names as "putrescene."

In summary, aerobic decomposition may contribute to nitrates in the groundwater, which can cause blue baby syndrome, or under the right conditions can contribute to eutrophication. Anaerobic decomposition smells bad and can contribute to climate change and eutrophication.

The issue of eutrophication is an important one for the west coast marine environment. Recent work by Jane Lubchenco[ii] and her team indicates that the Oregon and Washington Coasts have been suffering anoxic events for the last five years. This can explain the fish kills experienced there. The entire west coast area is sensitive to oxygen depletion because the ancient seawater upwelled there by Eckman Transport is already low in oxygen. When wind patterns change, reducing natural upwelling, any additional nutrient loading can contribute to lower oxygen concentrations through eutrophication.

Several studies have looked at the biodegradability of plastics, using various approaches. Some general statements can be made. The issues of aerobic/anaerobic degradation apply to plastics as they do to all organic materials. Most plastics are very poorly degradable, with the exception of those specifically designed to biodegrade, e.g. PLA or starch derivatives. These appear to substantially degrade over weeks to months under aerobic conditions. This is the case whether one looks in composting systems or in degradation in the soil. Perhaps the most evocative study is one by the EU[iii] that concluded that a one percent addition of plastics to commercial composting facilities did not affect the composting process or the quality of the compost produced.

It is because of the undesirable outcomes caused by anaerobic decomposition that composting facilities attempt to maintain aerobic conditions. There is a great deal of literature and many websites focus on how to optimize composting, especially at the single family level. [iv] However, as attested by local ordinances requiring commercial composting facilities to be inside buildings, it is clear that at least part of the time composting facilities are operating anaerobically.

Nordictest (2002) provides estimates of the emissions to air and water[v] from ostensibly aerobic composting

- 1.5 to 10% of carbon emitted as methane
- 0.24 to 1.3 kg ammonia per tonne waste
- 0.08 to 0.17 kg nitrous oxide per tonne waste
- 0.8 to 1.7 kg VOC per tonne waste
- 2 to 20 grams COD per liter of runoff water
- 0.1 to 45 grams BOD per liter of runoff water
- 15 to 800 mg of ammonia-N per liter of runoff water

It is clear from these results that these supposedly aerobic facilities are operating at least partially anaerobically. The wide range of emissions probably reflect different ratios of aerobic versus anaerobic decomposition.

Most composting systems include some action to increase oxygen availability thus supporting aerobic rather than anaerobic decomposition. At home, one turns the compost pile. In commercial operations, the actions taken to maintain oxygen concentration high enough to support the aerobic decomposition tend to be energy intensive. The compost is turned using tractors or screws, or the composting is performed in cylinders that are tumbled. All of these approaches require either electricity or a fossil fuel source, with their concomitant emissions.

Adequate aeration is balanced by the metabolic rate. Cooler temperatures slow down metabolic rates and thus the tendency for using up all available oxygen. To a great extent, the composition of the compost determines the metabolic rate of the microorganisms, as the conditions of appropriate balance of macro and micronutrients is obtained. Assuring that there is not excess nitrogen will tend to slow down the metabolic rates and thus oxygen depletion. An excess of water reduces the ability of oxygen to diffuse through the composting mass, so a slight water deficit helps increase aeration. All of these actions slow down composting—and thus are not very attractive to commercial scale composting facilities.

Overall, composting is generally considered as a beneficial activity. Besides providing a disposal mechanism for organic wastes, its main purpose is to create compost. This soil additive increases water retention, decreases heavy metal toxicity, increases the availability of macro and micronutrients and generally increases the health and fertility of soils. No one would argue that the primary outcome of composting is a bad one. However, there are definite potential hazards that can occur as the result of the composting process itself, and these need to be managed in order not to cause environmental degradation.

Studies on the environmental impacts of composting have come to different conclusions about the environmental desirability of composting.

- In Denmark, a study of food waste disposal options compared incineration, gasification and composting found that composting was by far the worst approach.[vi]
- In Australia, a study showed that composting has many benefits, especially when considering the application of compost to soils.[vii]
- In Austria, a study of composting that captured the methane for energy recovery suggested an overall great benefit to composting.[viii]
- In Japan, a study that used anaerobic digestion found similar results to the Austrian study.[ix]

The materials being composted in these studies are very variable, affecting the balance of macro and micronutrients, and thus making comparisons difficult. The composting facilities found to be most environmentally advantageous were operated anaerobically and the methane produced was recovered for energy production. However, as noted above, anaerobic systems will certainly have more odors and eutrophication potential, too. To obtain the benefits of anaerobic composting requires enclosed systems with good capture mechanisms, and these increase the cost of the facility substantially.

Our search of the literature did not turn up good data that linked the parameters controlling composting to environmental outcomes in any systematic numerical way. It is not possible to develop a predictive model of the environmental outcomes of composting without this data.

To summarize, all organic materials, including plastics, can be biodegraded to a greater or lesser extent, but the rate of degradation is controlled by many factors, and we do not have numerical models to allow predictions of the environmental impact of biodegradation. The key issue is whether degradation is aerobic or anaerobic, for this single parameter has great impact on the greenhouse gas emissions, the emissions causing eutrophication, and the emissions of unpleasant odors. Studies examining the environmental impacts of composting have provided wide ranges of emissions estimates and mixed conclusions as to the desirability of this waste management method.

Qualitatively, biodegradation processes are well understood. Quantitatively, they are not. Nevertheless, our qualitative knowledge is sufficient to state that there are real environmental issues related to biodegradation, and that composting may not always be the preferred method for organic material disposal.

Please do feel free to contact me if you have any questions.

Yours truly,

Rita Schenck, Ph.D.
Executive Director, IERE

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EXHIBIT E

R·W·BECK

Biodegradable Plastics Memo
August 21, 2006

I am a consultant with R.W. Beck, a waste/water resources consulting firm. I have been asked by the Polystyrene Packaging Council to comment on a proposed policy affecting the use of both traditional and biodegradable plastics.

I understand that consideration is being given to bans on the use of petroleum-based plastic food service containers concurrently with a mandate for the use of biodegradable plastics as a solution to certain current litter and marine debris issues. As a professional working extensively with litter-related issues across the country, I am concerned that such an ambitious and untested policy, if mandated in a vacuum, could produce unforeseen problems.

Biodegradable plastics are typically starch-based. When substantial amounts of such plastics are littered and begin to break down, a substantial increase in the amount of biodegradable material in regional waterways could result, due to elevated BOD concentrations and unusually high nutrient levels. This could deplete the dissolved oxygen level in various bodies of water and likely lead to the proliferation of algal blooms and the subsequent decline of some regional aquatic ecosystems. These algae produce toxins that can pose significant public health concerns.

High levels of toxic algae appeared in blooms on the Klamath River in California during the summer of 2005. In response, the U.S. Environmental Protection Agency and the North Coast Regional Water Board joined other government agencies, warning residents and recreational users of the river to use caution when near such algal blooms. Widespread use of biodegradable plastics without significant reductions in litter could exacerbate such health issues.

Whatever issues may exist with conventional plastics will be exacerbated with biodegradable plastics, since they break down into smaller particles more quickly and are thus more available as a perceived food source by smaller organisms. As bio-based products start to degrade, these particles could more readily migrate into surface water via run-off. Once these substances are introduced into waterways, they could be inadvertently ingested by sensitive marine species more easily than sturdier petroleum-based counterparts.

As with other items found in litter, such as cigarette butts, littering incidents could increase due to an erroneous belief that starch-based plastics will benignly degrade, when in fact, the rate at which starch-based plastics will degrade is dependent upon different factors, including the amount of exposed surface area, the percentage of

R·W·BECK

starch in each item and seasonal/climatic conditions. Thus, the use of certain starch-based plastics could result in a disproportionate visual impact as a component of litter if they are littered with the expectation of quickly degrading. Food service items made from biodegradable plastics can persist for up to a year before degrading. If conditions are not optimal, some items may persist longer. This has been the case when products such as bio-based plastic shopping bags have become caught in shrubs or tree branches.

Biodegradable plastics typically contain prodegradant additives. These additives may visually seem to disappear, but actually persist in the environment rather than biodegrading, thus acting as a dispersal mechanism for catalytic metals. As these plastics begin to breakdown, carbon is converted from an inert form into atmospheric carbon, which contributes to greenhouse gases.

The ultimate impacts of the various degradable plastics will be partly dependent upon the polymer from which it has been manufactured and how it has been designed to degrade. Life-cycle assessments should be conducted on the manufacture, usage and disposal of starch-based plastic products to determine the extent of these environmental risks and whether the impacts they cause can be mitigated in a manner that is sustainable.

Other uncertainties exist regarding these issues. The bioavailability of starch-based plastics ingested by marine species is unknown, but should be determined.

It is fundamentally vital that credible analysis be conducted prior to the implementation of a new public policy, whose implications are so uncertain.

Steven R. Stein

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EXHIBIT F

Corn Plastic to the Rescue

Wal-Mart and others are going green with "biodegradable" packaging made from corn. But is this really the answer to America's throwaway culture?

By Elizabeth Royte

Thirty minutes north of Omaha, outside Blair, Nebraska, the aroma of steaming corn—damp and sweet—falls upon my car like a heavy curtain. The farmland rolls on, and the source of the smell remains a mystery until an enormous, steam-belching, gleaming-white architecture of tanks and pipes rises suddenly from the cornfields between Route 75 and the flood plain of the Missouri River. Behold NatureWorks: the largest lactic-acid plant in the world. Into one end of the complex goes corn; out the other come white pellets, an industrial resin poised to become—if you can believe all the hype—the future of plastic in a post-petroleum world.

The resin, known as polylactic acid (PLA), will be formed into containers and packaging for food and consumer goods. The trendy plastic has several things going for it. It's made from a renewable resource, which means it has a big leg up—both politically and environmentally—on conventional plastic packaging, which uses an estimated 200,000 barrels of oil a day in the United States. Also, PLA is in principle compostable, meaning that it will break down under certain conditions into harmless natural compounds. That could take pressure off the nation's mounting landfills, since plastics already take up 25 percent of dumps by volume. And corn-based plastics are starting to look cheap, now that oil prices are so high.

For a few years, natural foods purveyors such as Newman's Own Organics and Wild Oats have been quietly using some PLA products, but the material got its biggest boost when Wal-Mart, the world's largest retailer, announced this past October that it would sell some produce in PLA containers. The move is part of the company's effort to counter criticisms that it has been environmentally irresponsible. "Moving toward zero waste is one of our three big corporate goals for the environment," says Matt Kistler, vice president of private brands and product development for the retailer. Wal-Mart plans to use 114 million PLA containers a year, which company executives estimate will save 800,000 barrels of oil annually.

To make plastic packaging and containers from a renewable resource that can be returned to the earth as fertilizer sounds like an unmitigated good. Selling fruits and veggies in boxes that don't leach chemicals into landfills sounds equally wonderful. But PLA has considerable drawbacks that haven't been publicized, while some claims for its environmental virtues are downright misleading. It turns out there's no free lunch after all, regardless of what its container is made of, as I learned when I tried to get to the bottom of this marvelous news out of corn country.

At the NatureWorks plant in Blair, I don a hard hat, earplugs, gloves and protective eyewear and swear that I will snap no photographs. What can be revealed by my hosts is revealed: corn kernels are delivered and milled, dextrose is extracted from starch. Huge fermenters convert the dextrose into lactic acid, a simple organic chemical that is a by-product of fermentation (or respiration, in the case of the lactic acid that builds up in muscle tissue after intense activity). Industrial lactic acid is derived from many starchy sources, including wheat, beets and potatoes, but NatureWorks is owned by Cargill, the world's largest corn merchant, and so its lactic acid comes from corn. The compound is converted to lactide, and lactide molecules are linked into long chains or polymers: polylactic acid, PLA.

I did get a chance to see and touch the obscure object of my desire when some liquid PLA, with the color and shine of caramelized sugar, burst from a pipe and solidified in flossy strands on the steel-grated floor. The next time I saw the stuff, in a box in a warehouse, it had been crystallized into translucent white balls the size of peas: PLA resin. In the hands of fabricators, the pellets would be melted and reshaped into containers, films and fibers.

Though the polymer, because of its low melting point, doesn't yet have as many applications as does the far more common plastic polyethylene terephthalate (PET), used to make soda bottles and some polyester fibers, the company has plans, as a large banner in the office proclaims, to "Beat PET!" In some ways, corn plastic is clearly easier on the environment. Producing PLA uses 65 percent less energy than producing conventional plastics, according to an independent analysis commissioned by NatureWorks. It also generates 68 percent fewer greenhouse gases, and contains no toxins. "It has a drastically different safety profile," says NatureWorks operations manager Carey Buckles. "It's not going to blow up the community."

For retailers, PLA has a halo effect. Wild Oats was an early adopter of the stuff. "Our employees loved the environmental message of the containers, that they came from a renewable resource, and our customers had a strong reaction when we told them they were compostable," says Sonja Tuitele, a Wild Oats spokesperson. The containers initially boosted the company's deli sales by 17 percent, she says, and the chain now uses six million PLA containers a year. Newman's Own Organics uses PLA packaging for its salad mixes. "We felt strongly that everywhere we can get out of petroleum products, we should," says Newman's Own CEO Peter Meehan. "No one has ever gone to war over corn."

Wal-Mart, which has begun using PLA containers in some stores, has also switched packaging on high-end electronics from PET to a sandwich of cardboard and PLA. "It has a smaller packaging footprint, it's completely biodegradable and it costs less," says Kistler. What Wal-Mart says about PLA's biodegradable nature is true, but there's an important catch.

Corn plastic has been around for 20 years, but the polymer was too expensive for broad commercial applications until 1989, when Patrick Gruber, then a Cargill chemist looking for new ways to use corn, invented a way to make the polymer more efficiently. Working with his wife, also a chemist, he created his first prototype PLA products on his kitchen stove. In the beginning, it cost $200 to make a pound of PLA; now it's less than $1.

The polymer has had to get over some cultural hurdles. In the mid-1980s, another bio-based plastic appeared on grocery store shelves: bags made from polyethylene and cornstarch that were said to be biodegradable. "People thought they would disappear quickly," recalls Steven Mojo, executive director of the Biodegradable Products Institute. They didn't. Will Brinton, president of Woods End, a compost research laboratory in Mt. Vernon, Maine, says the bags broke into small fragments of polyethylene, fragments that weren't good for compost—or public relations. "It was a big step backward for the biodegradability movement," he adds. "Whole communities abandoned the concept of biodegradable bags as a fraud."

According to a biodegradability standard that Mojo helped develop, PLA is said to decompose into carbon dioxide and water in a "controlled composting environment" in fewer than 90 days. What's a controlled composting environment? Not your backyard bin, pit or tumbling barrel. It's a large facility where compost—essentially, plant scraps being digested by microbes into fertilizer—reaches 140 degrees for ten consecutive days. So, yes, as PLA advocates say, corn plastic is "biodegradable." But in reality very few consumers have access to the sort of composting facilities that can make that happen. NatureWorks has identified 113 such facilities nationwide—some handle industrial food-processing waste or yard trimmings, others are college or prison operations—but only about a quarter of them accept residential foodscraps collected by municipalities.

Moreover, PLA by the truckload may potentially pose a problem for some large-scale composters. Chris Choate, a composting expert at Norcal Waste Systems, headquartered in San Francisco, says large amounts of PLA can interfere with conventional composting because the polymer reverts into lactic acid, making the compost wetter and more acidic. "Microbes will consume the lactic acid, but they demand a lot of oxygen, and we're having trouble providing enough," he says. "Right now, PLA isn't a problem," because there's so little of it, Choate says. (NatureWorks disputes that idea, saying that PLA has no such effect on composting processes.) In any event, Norcal says a future PLA boom won't be a problem because the company hopes to convert its composters to so-called anaerobic digesters, which break down organic material in the absence of oxygen and capture the resulting methane for fuel.

Wild Oats accepts used PLA containers in half of its 80 stores. "We mix the PLA with produce and scraps from our juice bars and deliver it to an industrial composting facility," says the company's Tuitele. But at the Wild Oats stores that don't take back PLA, customers are on their own, and they can't be blamed if they feel deceived by PLA containers stamped "compostable." Brinton, who has done extensive testing of PLA, says such containers are "unchanged" after six months in a home composting operation. For that reason, he considers the Wild Oats stamp, and their in-store signage touting PLA's compostability, to be false advertising.

Wal-Mart's Kistler says the company isn't about to take back used PLA for composting. "We're not in the business of collecting garbage," he says. "How do we get states and municipalities to set up composting systems? That is the million-dollar question. It's not our role to tell government what to do. There is money to be made in the recycling business. As we develop packaging that can be recycled and composted, the industry will be developed."

For their part, recycling facilities have problems with PLA too. They worry that consumers will simply dump

PLA in with their PET. To plastic processors, PLA in tiny amounts is merely a nuisance. But in large amounts it can be an expensive hassle. In the recycling business, soda bottles, milk jugs and the like are collected and baled by materials recovery facilities, or MRFs (pronounced "murfs"). The MRFs sell the material to processors, which break down the plastic into pellets or flakes, which are, in turn, made into new products, such as carpeting, fiberfill, or containers for detergent or motor oil. Because PLA and PET mix about as well as oil and water, recyclers consider PLA a contaminant. They have to pay to sort it out and pay again to dispose of it.

NatureWorks has given this problem some thought. "If the MRF separates the PLA, we'll buy it back from them when they've got enough to fill a truck," says spokeswoman Bridget Charon. The company will then either take the PLA to an industrial composter or haul it back to Blair, where the polymer will be broken down and remade into fresh PLA.

Despite PLA's potential as an environmentally friendly material, it seems clear that a great deal of corn packaging, probably the majority of it, will end up in landfills. And there's no evidence it will break down there any faster or more thoroughly than PET or any other form of plastic. Glenn Johnston, manager of global regulatory affairs for NatureWorks, says that a PLA container dumped in a landfill will last "as long as a PET bottle." No one knows for sure how long that is, but estimates range from 100 to 1,000 years.

Environmentalists have other objections to PLA. Lester Brown, president of the Earth Policy Institute, questions the morality of turning a foodstuff into packaging when so many people in the world are hungry. "Already we're converting 12 percent of the U.S. grain harvest to ethanol," he says. The USDA projects that figure will rise to 23 percent by 2014. "How much corn do we want to convert to nonfood products?" In addition, most of the corn that NatureWorks uses to make PLA resin is genetically modified to resist pests, and some environmentalists oppose the use of such crops, claiming they will contaminate conventional crops or disrupt local ecosystems. Other critics point to the steep environmental toll of industrially grown corn. The cultivation of corn uses more nitrogen fertilizer, more herbicides and more insecticides than any other U.S. crop; those practices contribute to soil erosion and water pollution when nitrogen runs off fields into streams and rivers.

NatureWorks, acknowledging some of those criticisms, points out that the corn it uses is low-grade animal feed not intended for human use. And it processes a small amount of non-genetically engineered corn for customers who request it. NatureWorks is also investigating better ways to segregate PLA in traditional recycling facilities, and it's even buying renewable energy certificates (investments in wind power) to offset its use of fossil fuels. But there's not much the company can do about the most fundamental question about corn plastic containers: Are they really necessary?

A few miles south of Blair, in Fort Calhoun, Wilkinson Industries occupies a sprawling, low brick building in a residential neighborhood. Wilkinson converts NatureWorks resin into packaging. In a warehouse-size room, the pellets are melted, pressed into a thin film and stretched into sheets that a thermoformer stamps into rigid containers—square, tall, rectangular or round. (PLA can also take the shape of labels, electronics casings, wrap for flowers, gift cards, clothing fiber and pillow stuffing.) "We're shipping trays to Google's cafeteria and to [filmmaker] George Lucas' studio in San Francisco," says Joe Selzer, a Wilkinson vice president. "We do trays for Del Monte's and Meijer stores' fresh cut fruit. And, oh yeah, we do Wal-Mart."

PLA amounts to about 20 percent of the plastic products made by Wilkinson. The rest is polystyrene and PET. "We'd like to see PLA be the resin of the future, but we know it never will be," says Selzer. "It's cost stable, but it can't go above 114 degrees. I've had people call me and say, 'Oh my god, I had my takeout box in my car in the sun and it melted into a pancake!'" Bridget Charon, sitting next to me, raises an eyebrow. Selzer continues. "Our number-one concern is PLA's competitive price, and then its applications. After that comes the feel-good."

Selzer leads us up a staircase to an interior room the size of a large pantry. It's crammed with samples of the 450 different containers fabricated by Wilkinson, which also stamps out aluminum trays. "Here's Kentucky Fried Chicken's potpie," Selzer says, pointing to a small round tin. "This plastic tray is for a wedding cake. This one's for crudités. This is for cut pineapple." (Wilkinson manufactured the original TV dinner tray, a sample of which resides in the Smithsonian Institution.) As I look around, I can't help thinking that almost all these products will be dumped, after just an hour or two of use, straight into a big hole in the ground.

Martin Bourque, executive director of the Berkeley Ecology Center, a nonprofit recycling organization, holds a dim view of PLA convenience packaging. "Yes, corn-based packaging is better than petroleum-based packaging for absolutely necessary plastics that aren't already successfully recycled, and for packaging that cannot be made of paper," he says. "But it's not as good as asking, 'Why are we using so many containers?'

My worry is that PLA legitimizes single-serving, over-packaged products."

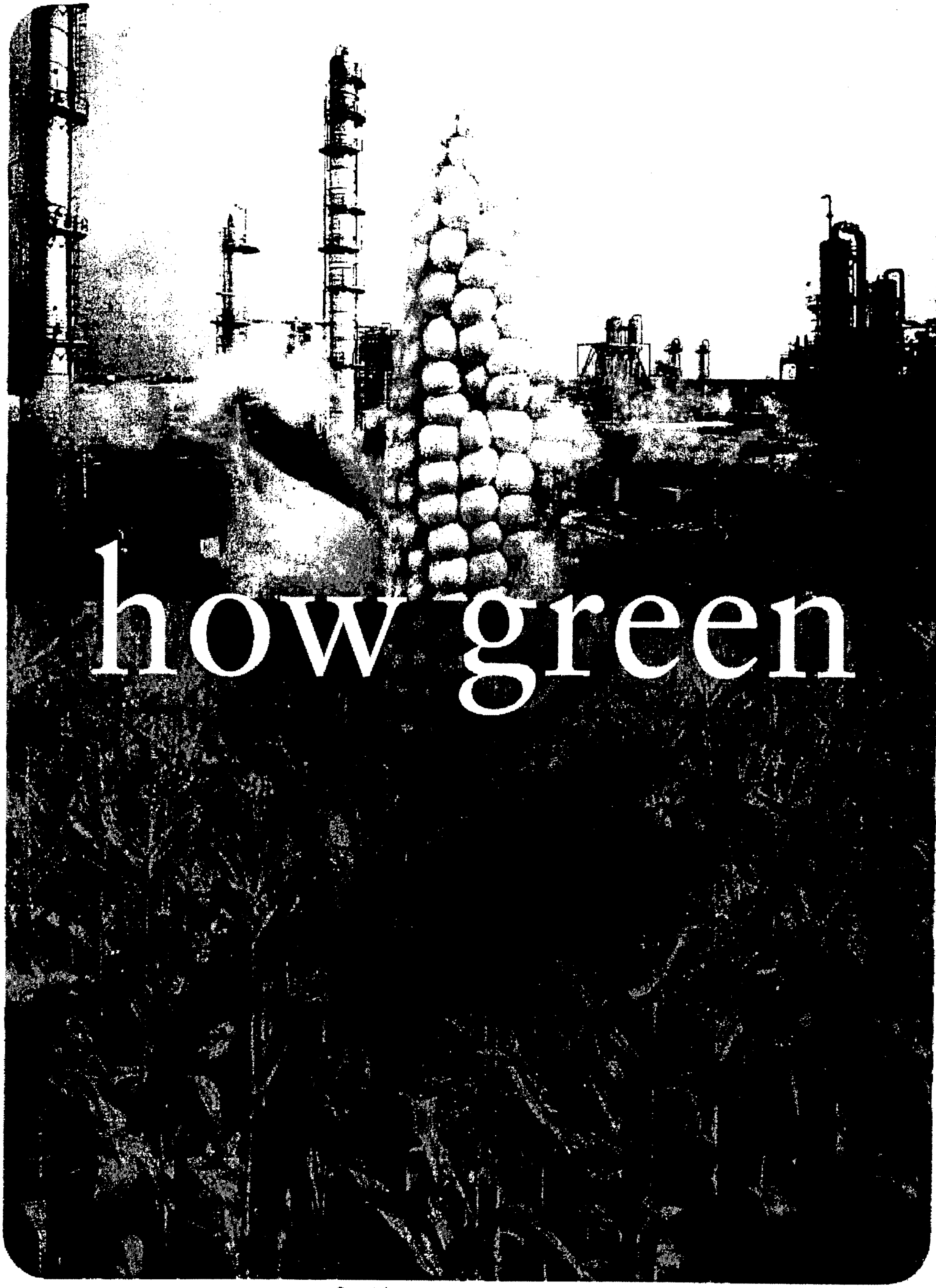
Many ecologists argue that companies should produce consumer goods that don't pollute the earth in their manufacture or disposal. In Cradle to Cradle: Remaking the Way We Make Things, the architect William McDonough writes about a future in which durable goods, like TVs and cars, are made from substances that cycle back into the manufacturing process, while packaging for short-lived products, like shampoo, will decompose back into the earth. NatureWorks says it wants to be part of that future. As the company's former CEO, Kathleen Bader, told Forbes magazine, "We're offering companies a chance to preempt embarrassing demands for responsible packaging. Brands that wait for legislative fiat will be left behind and exposed."

Eric Lombardi, president of the Grassroots Recycling Network and a leader in the international Zero Waste movement, takes a nuanced view of PLA's progress. He says it's "visionary" even to think about biologically based plastic instead of a petroleum-based one. True, he says, there are problems with PLA, "but let's not kill the good in pursuit of the perfect." He suggests that the difficulty disposing of PLA reflects a larger deficiency in how we handle trash. He's calling for a composting revolution. "We need a convenient, creative collection system with three bins: one for biodegradables, which we'll compost, one for recycling, and one for whatever's left."

Until such a system is in place, it's going to be hard to have cheap convenience packaging and feel good about its environmental effect—to have our takeout cake and eat it too. But the manufacture of PLA does save oil and generates far less air pollution. And we have to start somewhere.

Elizabeth Royte, a resident of Brooklyn, is the author of Garbage Land: On the Secret Trail of Trash.
Photographer Brian Smale is based in Seattle.

EXHIBIT G


how green

It is now technologically possible to make plastics using green plants rather than nonrenewable fossil fuels. But are these new plastics the environmental saviors researchers have hoped for?

by Tillman U. Gerngross and Steven C. Slater

are green plastics?

Driving down a dusty gravel road in central Iowa, a farmer gazes toward the horizon at rows of tall, leafy corn plants shuddering in the breeze as far as the eye can see. The farmer smiles to himself, because he knows something about his crop that few people realize. Not only are kernels of corn growing in the ears, but granules of plastic are sprouting in the stalks and leaves.

This idyllic notion of growing plastic, achievable in the foreseeable future, seems vastly more appealing than manufacturing plastic in petrochemical factories, which consume about 270 million tons of oil and gas every year worldwide. Fossil fuels provide both the power and the raw materials that transform crude oil into common plastics such as polystyrene, polyethylene and polypropylene. From milk jugs and soda bottles to clothing and car parts, it is difficult to imagine everyday life without plastics, but the sustainability of their production has increasingly been called into question. Known global reserves of oil are expected to run dry in approximately 80 years, natural gas in 70 years and coal in 700 years, but the economic impact of their depletion could hit much sooner. As the resources diminish, prices will go up—a reality that has not escaped the attention of policymakers. President Bill Clinton issued an executive order in August 1999 insisting that researchers work toward replacing fossil resources with plant material both as fuel and as raw material.

With those concerns in mind, biochemical engineers, including the two of us, were delighted by the discovery of how to grow plastic in plants. On the surface, this technological breakthrough seemed to be the final answer to the sustainability question, because this plant-based plastic would be "green" in two ways: it would be made from a renewable resource, and it would eventually break down, or biodegrade, upon disposal. Other types of plastics, also made from plants, hold similar appeal. Recent research, however, has raised doubts about the utility of these approaches. For one, biodegradability has a hidden cost: the biological breakdown of plastics releases carbon dioxide and methane, heat-trapping greenhouse gases that international efforts currently aim to reduce. What is more, fossil fuels would still be needed to power the process that extracts the plastic from the plants, an energy requirement that we discovered is much greater than anyone had thought. Successfully making green plastics depends on whether researchers can overcome these energy-consumption obstacles economically—and without creating additional environmental burdens.

Traditional manufacturing of plastics uses a surprisingly large amount of fossil fuel. Automobiles, trucks, jets and power plants account for more than 90 percent of the output from crude-oil refineries, but plastics consume the bulk of the remainder, around 80 million tons a year in the U.S. alone. To date, the efforts of the biotechnology and agricultural industries to replace conventional plastics with plant-derived alternatives have embraced three main approaches: converting plant sugars into plastic, producing plastic inside microorganisms, and growing plastic in corn and other crops.

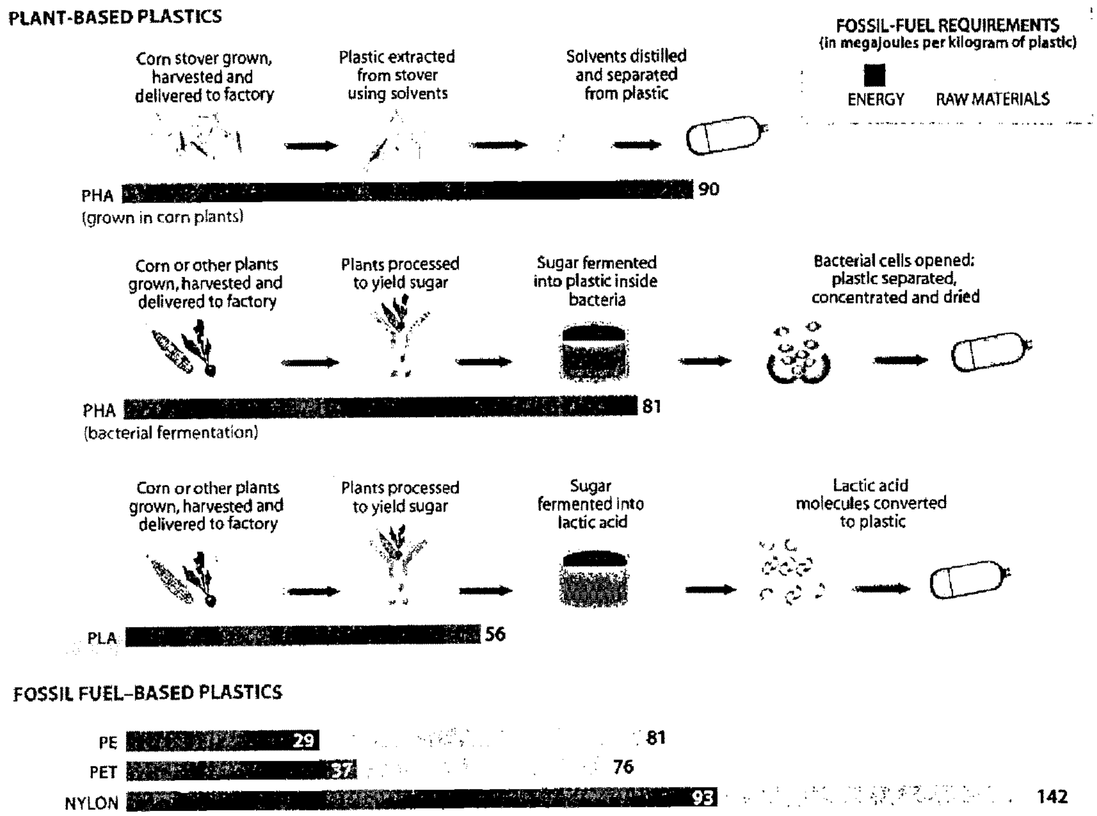
Cargill, an agricultural business giant, and Dow Chemical, a top chemical firm, joined forces three years ago to develop the

GROWING PLASTICS in plants once seemed to be an innovative way to lessen the global demand for fossil fuels.

TOM DRAPER DESIGN

PRODUCTION AND ENERGY DEMANDS

Plant-derived plastics require more energy to produce—and thus result in higher emissions of greenhouse gases associated with burning fossil fuels—than do many of their petrochemical counterparts.



first approach, which turns sugar from corn and other plants into a plastic called polylactide (PLA). Microorganisms transform the sugar into lactic acid, and another step chemically links the molecules of lactic acid into chains of plastic with attributes similar to polyethylene terephthalate (PET), a petrochemical plastic used in soda bottles and clothing fibers.

Looking for new products based on corn sugar was a natural extension of Cargill's activities within the existing corn-wet-milling industry, which converts corn grain to products such as high-fructose corn syrup, citric acid, vegetable oil, bioethanol and animal feed. In 1999 this industry processed almost 39 million tons of corn—roughly 15 percent of the entire U.S. harvest for that year. Indeed, Cargill Dow earlier this year launched a $300-million effort to begin mass-producing its new plastic, NatureWorks™ PLA, by the end of 2001 [*see box on page 40*].

Other companies, including Imperial Chemical Industries, developed ways to produce a second plastic, called polyhydroxyalkanoate (PHA). Like PLA, PHA is made from plant sugar and is biodegradable. In the case of PHA, however, the bacterium *Ralstonia eutropha* converts sugar directly into plastic. PLA requires a chemical step outside the organism to synthesize the plastic, but PHA naturally accumulates within the microbes as granules that can constitute up to 90 percent of a single cell's mass.

In response to the oil crises of the 1970s, Imperial Chemical Industries established an industrial-scale fermentation process in which microorganisms busily converted plant sugar into several tons of PHA a year. Other companies molded the plastic into commercial items such as biodegradable razors and shampoo bottles and sold them in niche markets, but this plastic turned out to cost substantially more than its fossil fuel–based counterparts and offered no performance advantages other than biodegradability. Monsanto bought the process and associated patents in 1995, but profitability remained elusive.

Many corporate and academic groups, including Monsanto, have since channeled their efforts to produce PHA into the third approach: growing the plastic in plants. Modifying the genetic makeup of an agricultural crop so that it could synthesize plastic as it grew would eliminate the fermentation process altogether. Instead of growing the crop, harvesting it, processing the plants to yield sugar and fermenting the sugar to convert it to plastic, one could produce the plastic directly in the plant. Many researchers viewed this approach as the most efficient—and most elegant—solution for making plastic from a renewable resource. Numerous groups were (and still are) in hot pursuit of this goal.

In the mid-1980s one of us (Slater) was part of a group that isolated the genes that enable the bacteria to make plastic. Investigators predicted that inserting these enzymes into a plant would drive the conversion of acetyl coenzyme A—a compound that forms naturally as the plant converts sunlight into energy—into a type of plastic. In 1992 a collaboration of scientists at Michigan State University and James Madison University first accomplished this task. The researchers genetically engineered the plant *Arabidopsis thaliana* to produce a brittle type of PHA. Two years later Monsanto began working to produce a more flexible PHA within a common agricultural plant: corn.

So that plastic production would not compete with food production, the researchers targeted part of the corn plant that is not typically harvested—the leaves and stem, together called the stover. Growing plastic in stover would still allow farmers to harvest the corn grain with a traditional combine; they could comb the fields a second time to remove the plastic-containing stalks and leaves. Unlike production of PLA and PHA made by fermentation, which theoretically compete for land used to grow crops for other purposes, growing PHA in corn stover would enable both grain and plastic to be reaped from the same field. (Using plants that can grow in marginal environments, such as switchgrass, would also avoid competition between plastic production and other needs for land.)

The Problem: Energy and Emissions

Researchers have made significant technological progress toward increasing the amount of plastic in the plant and altering the composition of the plastic to give it useful properties. Although these results are encouraging when viewed individually, achieving both a useful composition *and* high plastic content in the plant turns out to be difficult. The chloroplasts of the leaves have so far shown themselves to be the best location for producing plastic. But the chloroplast is the green organelle that captures light, and high concentrations of plastic could thus inhibit photosynthesis and reduce grain yields.

The challenges of separating the plastic from the plant, too, are formidable. Researchers at Monsanto originally viewed the extraction facility as an adjunct to an existing corn-processing plant. But when they designed a theoretical facility, they determined that extracting and collecting the plastic would require large amounts of solvent, which would have to be recovered after use. This processing infrastructure rivaled existing petrochemical plastic factories in magnitude and exceeded the size of the original corn mill.

Given sufficient time and funding, researchers could overcome these technical obstacles. Both of us, in fact, had planned for the development of biodegradable plastics to fill the next several years of our research agendas. But a greater concern has made us question whether those solutions are worth pursuing. When we calculated all the energy and raw materials required for each step of growing PHA in plants—harvesting and drying the corn stover, extracting PHA from the stover, purifying the plastic, separating and recycling the solvent, and blending the plastic to produce a resin—we discovered that this approach would consume even more fossil resources than most petrochemical manufacturing routes.

In our most recent study, completed this past spring, we and our colleagues found that making one kilogram of PHA from genetically modified corn plants would require about 300 percent more energy than the 29 megajoules needed to manufacture an equal amount of fossil fuel–based polyethylene (PE). To our disappointment, the benefit of using corn instead of oil as a raw material could not offset this substantially higher energy demand.

Based on current patterns of energy use in the corn-processing industry, it would take 2.65 kilograms of fossil fuel to power the production of a single kilogram of PHA. Using data collected by the Association of European Plastics Manufacturers for 36 European plastic factories, we estimated that one kilogram of polyethylene, in contrast, requires about 2.2 kilograms of oil and natural gas, nearly half of which ends up in the final product. That means only 60 percent of the total—or 1.3 kilograms—is burned to generate energy.

Given this comparison, it is impossible to argue that plastic grown in corn and extracted with energy from fossil fuels would conserve fossil resources. What is gained by substituting the renewable resource for the finite one is lost in the additional requirement for energy. In an earlier study, one of us (Gerngross) discovered that producing a kilogram of PHA by microbial fermentation requires a similar quantity—2.39 kilograms—of fossil fuel. These disheartening realizations are part of the reason that Monsanto, the technological leader in the area of plant-derived PHA, announced late last year that it would terminate development of these plastic-production systems.

Growing PHA in corn stover would enable both grain and plastic to be reaped from the same field.

The only plant-based plastic that is currently being commercialized is Cargill Dow's PLA. Fueling this process requires 20 to 50 percent fewer fossil resources than does making plastics from oil, but it is still significantly more energy intensive than most petrochemical processes are. Company officials anticipate eventually reducing the energy requirement. The process has yet to profit from the decades of work that have benefited the petrochemical industry. Developing alternative plant-sugar sources that require less energy to process, such as wheat and beets, is one way to attenuate the use of fossil fuels. In the meantime, scientists at Cargill Dow estimate that the first PLA manufacturing facility, now being built in Blair, Neb., will expend at most 56 megajoules of energy for every kilogram of plastic—50 percent more than is needed for PET but 40 percent less than for nylon, another of PLA's petrochemical competitors.

The energy necessary for producing plant-derived plastics gives rise to a second, perhaps even greater, environmental concern. Fossil oil is the primary resource for conventional plastic production, but making plastic from plants depends mainly on coal and natural gas, which are used to power the corn-farming and corn-processing industries. Any of the plant-based methods, therefore, involve switching from a less abundant fuel (oil) to a more abundant one (coal). Some experts argue that this switch is a step toward sustainability. Missing in this logic, however, is the fact that all

GREEN PLASTIC GETS PRACTICAL

Patrick Gruber, vice president of technology for Cargill Dow, answers questions about his company's new plant-derived plastic.

How will NatureWorks™ PLA compete with petrochemical plastics?

NatureWorks™ PLA combines several attributes into a single family of plastics. Its glossiness and ability to retain twists and folds better than its petrochemical counterparts, for example, appeal to companies that are developing PLA for candy wrappers and other kinds of consumer packaging. PLA also offers fabric manufacturers a natural fiber that can compete with synthetics, such as nylon, in both performance and ease of processing. Overall, industry sources have identified several billion pounds of market potential for PLA in areas such as apparel, activewear, hygiene products, carpet fibers and packaging.

What are the environmental advantages of PLA?

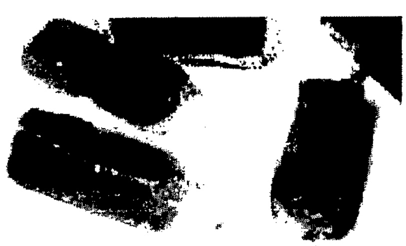
Because we use plant sugar rather than fossil fuels as the raw material for PLA, its production consumes 20 to 50 percent fewer fossil resources than do conventional plastics. PLA can be broken down into its original chemical components for reuse, or it can be recycled. One of our customers already plans to use PLA in recyclable carpet tiles. PLA will also biodegrade, much in the way that paper does, in municipal composting facilities. For these reasons, PLA will reduce society's dependency on fossil fuels while providing products that fit current disposal methods. These clear environmental benefits of PLA are a bonus—we believe that people will buy this plastic primarily because it performs well and can compete with existing technologies.

Do these benefits offset the fact that the energy required to produce PLA is greater than that needed to produce some petrochemical plastics?

It is important to realize that our PLA-manufacturing technology is only 10 years old and has yet to profit from the nearly 100 years during which petrochemical-plastic manufacturing has been improving. Even our first manufacturing facility, now being built in Nebraska, will use only 40 percent of the fossil-fuel energy that is required to power the production of conventional nylon. As our scientists and engineers optimize the production of PLA, we expect to reduce the energy requirements of our second and third manufacturing facilities, targeted for construction as early as 2004, by as much as 50 percent.

Do you plan to address what Gerngross and Slater call "the environmental shortcomings" of PLA?

Yes. Not only are we developing production methods that require less energy, we are also investigating more efficient ways to generate energy, including cogeneration and use of renewable fuels such as plant material, or biomass. We are also pursuing alternative raw materials for PLA. Using fermentable sugars from corn stover would allow a second crop to be harvested from the same land used to grow corn grain. PLA can also be derived from wheat, beets and other crops best suited to particular climates.



CANDY WRAPPERS are just one of the products that companies plan to manufacture from Cargill Dow's new plant-based plastic when it hits the market in late 2001.

fossil fuels used to make plastics from renewable raw materials (corn) must be burned to generate energy, whereas the petrochemical processes incorporate a significant portion of the fossil resource into the final product.

Burning more fossil fuels exacerbates an established global climate problem by increasing emissions of greenhouse gases, such as carbon dioxide [see "Is Global Warming Harmful to Health?" by Paul R. Epstein, on page 50]. Naturally, other emissions associated with fossil energy, such as sulfur dioxide, are also likely to increase. This gas contributes to acid rain and should be viewed with concern. What is more, any manufacturing process that increases such emissions stands in direct opposition to the Kyoto Protocol, an international effort led by the United Nations to improve air quality and curtail global warming by reducing carbon dioxide and other gases in the atmosphere.

The conclusions from our analyses were inescapable. The environmental benefit of growing plastic in plants is overshadowed by unjustifiable increases in energy consumption and gas emissions. PLA seems to be the only plant-based plastic that has a chance of becoming competitive in this regard. Though perhaps not as elegant a solution as making PHA in plants, it takes advantage of major factors contributing to an efficient process: low energy requirements and high conversion yields (almost 80 percent of each kilogram of plant sugar used ends up in the final plastic product). But despite the advantages of PLA over other plant-based plastics, its production will inevitably emit more greenhouse gases than do many of its petrochemical counterparts.

The Answer: Renewable Energy

As sobering as our initial analyses were, we did not immediately assume that these plant-based technologies were doomed forever. We imagined that burning plant material, or biomass, could offset the additional energy requirement. Emissions generated in this way can be viewed more favorably than the carbon dioxide released by burning fossil carbon, which has been trapped underground for millions of years. Burning the carbon contained in corn stalks and other plants would not increase net carbon dioxide in the atmosphere, because new plants growing the following spring would, in theory,

CARGILL DOW

absorb an equal amount of the gas. (For the same reason, plant-based plastics do not increase carbon dioxide levels when they are incinerated after use.)

We and other researchers reasoned that using renewable biomass as a primary energy source in the corn-processing industry would uncouple the production of plastics from fossil resources, but such a shift would require hurdling some lingering technological barriers and building an entirely new power-generation infrastructure. Our next question was, "Will that ever happen?" Indeed, energy-production patterns in corn-farming states show the exact opposite trend. Most of these states drew a disproportionate amount of their electrical energy from coal—86 percent in Iowa, for example, and 98 percent in Indiana—compared with a national average of around 56 percent in 1998. (Other states derive more of their energy from sources such as natural gas, oil and hydroelectric generators.)

Both Monsanto and Cargill Dow have been looking at strategies for deriving energy from biomass. In its theoretical analysis, Monsanto burned all the corn stover that remained after extraction of the plastic to generate electricity and steam. In this scenario, biomass-derived electricity was more than sufficient to power PHA extraction. The excess energy could be exported from the PHA-extraction facility to replace some of the fossil fuel burned at a nearby electric power facility, thus reducing overall greenhouse gas emissions while producing a valuable plastic.

Interestingly, it was switching to a plant-based energy source—not using plants as a raw material—that generated the primary environmental benefit. Once we considered the production of plastics and the production of energy separately, we saw that a rational scheme would dictate the use of renewable energy over fossil energy for many industrial processes, regardless of the approach to making plastics. In other words, why worry about supplying energy to a process that inherently requires more energy when we have the option of making conventional plastics with much less energy and therefore fewer greenhouse gas emissions? It appears that both emissions and the depletion of fossil resources would be abated by continuing to make plastics from oil while substituting renewable biomass as the fuel.

We did not immediately assume that these plant-based technologies were doomed forever.

Unfortunately, no single strategy can overcome all the environmental, technical and economic limitations of the various manufacturing approaches. Conventional plastics require fossil fuels as a raw material; PLA and PHA do not. Conventional plastics provide a broader range of material properties than PLA and PHA, but they are not biodegradable. Biodegradability helps to relieve the problem of solid-waste disposal, but degradation gives off greenhouse gases, thereby compromising air quality. Plant-based PLA and PHA by fermentation are technologically simpler to produce than PHA grown in corn, but they compete with other needs for agricultural land. And although PLA production uses fewer fossil resources than its petrochemical counterparts, it still requires more energy and thus emits more greenhouse gases during manufacture.

The choices that we as a society will make ultimately depend on how we prioritize the depletion of fossil resources, emissions of greenhouse gases, land use, solid-waste disposal and profitability—all of which are subject to their own interpretation, political constituencies and value systems. Regardless of the particular approach to making plastics, energy use and the resulting emissions constitute the most significant impact on the environment.

In light of this fact, we propose that any scheme to produce plastics should not only reduce greenhouse gas emissions but should also go a step beyond that, to reverse the flux of carbon into the atmosphere. To accomplish this goal will require finding ways to produce *non*degradable plastic from resources that absorb carbon dioxide from the atmosphere, such as plants. The plastic could then be buried after use, which would sequester the carbon in the ground instead of returning it to the atmosphere. Some biodegradable plastics may also end up sequestering carbon, because landfills, where many plastic products end up, typically do not have the proper conditions to initiate rapid degradation.

In the end, reducing atmospheric levels of carbon dioxide may be too much to ask of the plastics industry. But any manufacturing process, not just those for plastics, would benefit from the use of renewable raw materials *and* renewable energy. The significant changes that would be required of the world's electrical power infrastructure to make this shift might well be worth the effort. After all, renewable energy is the essential ingredient in any comprehensive scheme for building a sustainable economy, and as such, it remains the primary barrier to producing truly "green" plastics. ■

The Authors

TILLMAN U. GERNGROSS and STEVEN C. SLATER have each worked for more than eight years in industry and academia to develop technologies for making biodegradable plastics. Both researchers have contributed to understanding the enzymology and genetics of plastic-producing bacteria. In the past two years, they have turned their interests toward the broader issue of how plastics manufacturing affects the environment. Gerngross is an assistant professor at Dartmouth College, and Slater is a senior researcher at Cereon Genomics, a subsidiary of Monsanto, in Cambridge, Mass.

Further Information

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EXHIBIT H

Can biotechnology move us toward a sustainable society?

A case study of biodegradable polymer production from agricultural feedstocks casts doubt on the premise that alternative biological processes always offer environmental benefits over conventional manufacturing processes.

Tillman U. Gerngross

The sustainability of a society based on finite fossil resources is the subject of ongoing scientific and political debate. One aspect of this debate, besides exploring alternative energy sources, is the challenge to provide chemical commodities (fuels, lubricants, adhesives, solvents, paints, materials, etc.) to an advanced consumer society, without depleting nonrenewable resources. An approach that has recently gained popularity advocates the use of biological (fermentation) processes to produce chemical commodities from agricultural feedstocks[1]. Fueled by advances in the area of metabolic engineering, an array of products, ranging from polymers to polymer intermediates and industrial dyes, can now be produced by fermentation. With numerous such biological approaches currently under consideration, it is pertinent to analyze whether the proposed processes have the intended effect of sparing nonrenewable resources and benefiting the environment.

Fermentation-based processes offer intuitive advantages, such as aqueous processing environments, nontoxic waste, and most importantly the use of renewable, nonfossil feedstocks. In most cases, however, these benefits have not been critically weighed against an overall inventory of materials and energy required to generate a given product. This article offers a side-by-side comparison of a biological versus a conventional petrochemical plastic manufacturing process to illustrate the complexity of choices confronting society and the commodity biotechnology industry in the coming years.

Weighing the alternatives

Much has been made of the environmental shortcomings of conventional, fossil oil–based polymers, such as polyethylene, polypropylene, and polystyrene. While these polymers offer good material properties at a low price, their environmental impact and manufacture has traditionally been viewed in a negative light. As a result, much effort has been dedicated to developing alternative plastic materials that are both biodegradable and produced from renewable resources, preferably of agricultural origin.

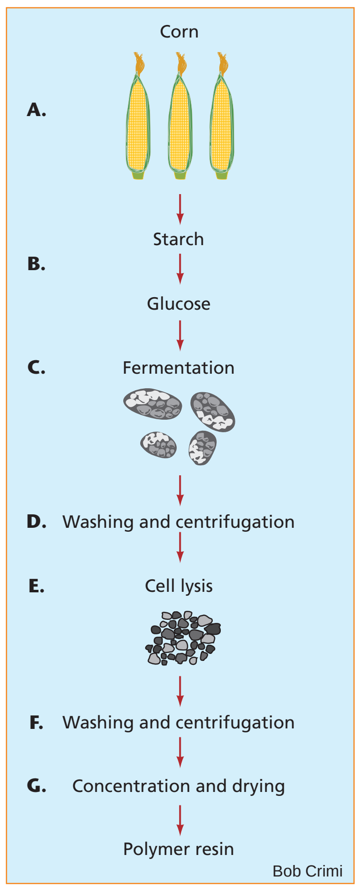

Figure 1. The analyzed multistep PHA production process. (A) Growing and harvesting corn. (B) Processing of corn to yield glucose. (C) Sterilizing the medium and conducting a fermentation process by which glucose is converted to PHA (note cells containing PHA polymer in the form of intracellular inclusions). (D) Recovering the biomass containing the polymer and washing it by centrifugation. (E) Disrupting the cell wall and releasing the polymer from the cells. (F) Washing the polymer by centrifugation. (G) Drying the polymer slurry to a powder that can be processed to a final consumer product.

Of the various alternative polymers developed to date, polyhydroxyalkanoates (PHAs), a class of aliphatic microbial polyesters, have been considered among the leading candidates to replace conventional plastics on a large industrial scale[2]. Like their petrochemical counterparts, PHAs are moldable, water insoluble, thermoplastic polymers. The most common PHA, poly-3-hydroxybutyrate (PHB), is a stiff, high-melting-point aliphatic polyester similar to many industrial polyolefins. Unlike polyolefins, however, PHAs can be synthesized by microorganisms, which can produce and store the polymer in the form of intracellular inclusions at levels exceeding 80% of the cell dry mass (see Fig. 1). These microbial polymers can be made entirely from glucose in a fermentation process and, in addition to offering favorable material properties, are completely biodegradable. Thus, the replacement of conventional plastics with PHAs has been promulgated as a desirable approach to solid-waste management and sustainable polymer production[3,4].

A cradle-to-grave analysis

Several factors contribute to the environmental impact and the degree of sustainability of a given product or material. In many instances, however, environmental impact is the result, not of the product per se, but rather of the consumption of raw materials and the release of waste products generated during manufacture. Thus, a "cradle-to-grave" analysis, which incorporates manufacturing practices, energy input/output, and overall material flows, is a good benchmark for assessing environmental impact and sustainability[5,6].

Contrary to the widespread belief that PHAs are a sustainable alternative to polymer production, a surprisingly high latent energy content is associated with their fermentative production. By considering the utilities required to make glucose from corn, it is possible to estimate that a PHA fermentation process consumes 22% more steam, 19-fold more electricity, and 7-fold more water than a conventional process for producing polystyrene. While only polystyrene is directly derived from fossil oil, both polystyrene and PHAs require energy in their manufacture. As

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Table 1. Direct raw material requirements for the production of polystyrene versus PHA.

	Raw material requirement (per kg polymer)	
Item	Polystyrene	PHA
Glucose	None	3.33 kg[a]
Petroleum fractions	1.78 kg[b]	None
Inorganic salts	20 g[b]	149 g[c]
Water	4 L[b]	26 L[d]

[a]The yield of PHA on glucose in bacterial fermentations is 30%. [b]Petroleum fractions serve as a feedstock and as an energy source in the manufacture of polystyrene. The production of 1 kg of polystyrene requires a total of 2.26 kg of fossil fuels, of which 0.48 kg can be directly assigned to the production of steam and electricity. Of the remaining 1.78 kg, which serve as feedstocks, a fraction is recycled and also used as an energy source. For details, see refs 5,6. [c]Inorganic salts are required for the fermentation process in the form of potassium phosphate, sodium phosphate, ammonia, phosphoric acid, and trace elements[18]. In the subsequent energy analysis, only the energy to produce ammonia is taken into account (which is about 109 g/kg polymer). [d]Water is required to fill the fermenter and for four washes. It does not include cooling water, which is expected to be recycled through a chiller or a cooling tower.

Table 2. Energy required to produce raw materials for the production of PHA.

Item	Energy (kJ) required requirement (kJ/per kg of raw material)
Glucose	8,129[a]
Inorganic salts	30,135[b]
Water	5.6[c]

[a]Energy to produce 1.52 kg of corn grain (60% starch) and process the grain to yield 1 kg of glucose minus energy for coproducts (33% of corn milling energy). Calculation: 1.52 kg × 2,442 kJ/kg (ref. 11) + 4417 kJ/kg (corn wet milling) = 8,129 kJ. The entire corn wet milling industry consumed 147 trillion kJ of energy by combusting externally purchased fossil fuels or buying external electrical power[13]. In the same year, a total of 33.66 million tons of corn grain were processed[19]. Thus, the average energy input can be estimated to be about 4,375 kJ/kg processed corn grain, and therefore the production of 1 kg of dextrose from 1.52 kg of corn grain (starch content 60%) consumes about 6,650 kJ (ref. 20). Of that energy, 33% (2,194.5 kJ) is reallocated to the production of coproducts (corn meal, etc.), leaving 4,417 kJ/kg for glucose. In addition, two engineering firms (Nofsinger, Kansas City, MO, and Process Systems, Memphis, TN) active in the construction of corn wet mills were contacted to confirm these estimates. We obtained values ranging from 3,718 kJ to 5,631 kJ for the production of 1 kg of glucose from corn grain. [b]Energy to produce 1 kg ammonia, which is used in the fermentation to control pH and provide nitrogen[21]. [c]Energy to filter and pump water to point of use[22].

Table 3. Energy requirement for fermentative production of PHA from glucose.

	Energy requirement (per kg PHA)		
Item	Electricity (kWh)	Steam (kg)	Fossil fuel equivalent[a] (kg)
Fermentation			
Media sterilization[b]	None	0.45	0.02
Agitation[c]	0.32	None	0.09
Aeration[c]	1.27	None	0.35
Cooling[d]	0.76	None	0.21
Downstream			
Centrifugation and washing[e]	0.50	None	0.14
High-pressure homogenization[f]	1.97	None	0.54
Centrifugation and washing[e]	0.50	None	0.14
Evaporation[g]	None	0.33	0.02
Spray drying[h]	None	2.00	0.10
Total	**5.32**	**2.78**	**1.59**

[a]Amount of fossil fuel (kg) consumed to generate the electricity and steam listed in the same row. In 1997, the US average for producing 1 kWh of electrical power, from all power sources (including geothermal, hydroelectric, nuclear, and alternative power generation), required the direct combustion of 0.272 kg of fossil resources (83% coal, 13% natural gas, and 3.5% petroleum)[8]. Thus, the conversion of electricity to fossil fuel equivalent was carried out as follows: electrical energy (kWh) × 0.272 (kg/kWh) = fossil fuel equivalent (kg). The conversion of steam to fossil fuel equivalent was as follows: steam (kg) × heat of evaporation of water (2,400 kJ/kg) / heat of combustion of natural gas (47,219 kJ/kg) = fossil fuel equivalent (kg). Calculation assumes 100% efficiency, the use of natural gas for steam generation, and no heat loss. [b]Medium is continuously sterilized to 143°C for 30 s; 68% of energy is recaptured through a heat exchanger and used to pre-warm the incoming medium[23]. [c]Agitation and aeration for this type of aerobic fermentation with very high cell densities is estimated to require 5 W/L of power input. Power, delivered by mechanical agitation and compressed air, totals 1.59 kWh/kg of PHA[24]. [d]Cooling assumes the use of a fully jacketed 114,000 L fermenter (height to diameter ratio of 3 to 1) that has additional cooling coils on the inside, providing a total cooling area 266 m^2 or 2.32 m^2 per m^3. Under the assumed production schedule (a 48 h culture that yields 190 g/L of biomass), approximately 17.6 W/L or a total of 2 million J/s (ref. 23) must be removed. Coolant is provided through cooling towers and chillers (coefficient of performance of 5.0), which deliver about 48,700 kJ and 18,000 kJ of cooling per kWh input, respectively[22]. [e]For centrifugation, see ref. 15. Energy input was reduced by 50% to reflect the energy savings from our higher solids content. [f]For cell disruption, see ref. 15. [g]Evaporation is performed with a triple-effect evaporator. A preconcentrated slurry containing 30% solids is concentrated to 50% solids. This step requires the evaporation of 1.33 kg of water and requires 0.33 kg of steam per kg PHA. [h]The final polymer slurry is spray dried to yield a powder of the polymer. The energy required for spray drying is generally about twice the amount of the water that has to be evaporated from the slurry. Thus, about 2 kg of steam are required to remove 1 kg of water, leaving 1 kg of dry polymer powder.

most energy is generated by combusting fossil resources[7] (in the US at least), both polymers also have a latent fossil fuel content. This suggests that, despite the use of renewable agricultural feedstocks, fermentative PHA production consumes significantly more energy, releases more net greenhouse gases[8], and therefore is no more sustainable than conventional petrochemical polymer production.

The balance of power

By compiling an energy and feedstock inventory of a "theoretical" large-scale PHA process and a conventional polystyrene process, it is possible to determine the environmental benefits of substituting a petrochemical process with a biological process.

Only a minor fraction (less than 4%) of crude oil is refined into intermediates that serve as feedstocks for the polymer industry (the rest being used for production of transportation fuels and heating oil). Analysis of the polystyrene production process reveals an energy requirement that is equivalent to the consumption of 1 kg of fossil oil for each kilogram of polystyrene[6]. In other words, the synthesis of 1 kg of polystyrene requires a total of 2.26 kg of fossil oil (1 kg of fossil fuel to generate energy and 1.26 kg of fossil fuel to serve as feedstocks for polymer production; see Table 1 footnote).

Production of PHAs, on the other hand, is based on corn, which is one of the more energy-intensive agricultural crops. Corn production in the US accounts for about 44%, 44%, and 55% of total fertilizer, insecticide, and herbicide use, respectively[9]. Several researchers have attempted to quantify the energy required to till, irrigate, fertilize, and harvest corn, estimating that the process consumes between 2,226 and 6,722 kJ per kilogram of corn grain[9–11]. By incorporating primary energy usage patterns of US farms, this translates into the combustion of between 50 and 160 kg of fossil fuels per ton of corn grain[12].

Subsequent processing of the corn also involves energy expenditure. On transfer to a wet mill, it must be fractionated and processed to yield gluten meal, oil, starch, and sugars (mainly glucose and fructose). In 1991, the average energy needed to process 1 kg of corn grain was about 4,375 kJ (see Table 2), which equates to the combustion of 130 kg of fossil fuels per ton of processed grain[13].

Several fermentation-based PHA processes have been described[14–16]. Although they differ in the choice of microorganism and other process characteristics, all share the fol-

Table 4. Energy and fossil fuel equivalents (FFEs) required in the production of polystyrene versus PHA.

Item	Energy and FFE (per kilogram polymer)			
	polystyrene		PHA	
	Energy	FFE[a]	Energy	FFE[a]
Production of raw materials	See below[b]	1.78 kg[b]	31,218 kJ[c]	0.80 kg
Utilities				
Steam[d]	7.0 kg	0.4 kg	2.78 kg	0.14 kg
Electricity[e]	0.30 kWh	0.08 kg	5.32 kWh	1.45 kg
Total		**2.26 kg**		**2.39 kg**

[a]Fossil fuels required to produce the energy and raw material in the corresponding energy column, taking into account the primary fuel usage patterns for each industry. For corn wet milling, energy is generated from natural gas (37%), coal (48%), and petroleum (10%)[11]. For each megajoule of energy currently consumed by the corn wet milling industry, 370,000 kJ are generated by combusting 7.84 kg of natural gas, etc. Petroleum, coal, and gas have a heat of combustion of 42,000 kJ/kg, 25,788 kJ/kg, and 47,218 kJ/kg, respectively. For other conversions, see Table 3. [b]Feedstock required to produce 1 kg of polystyrene from crude oil. The feedstock for direct polymer synthesis is included, as well as a fraction that is lost in the process and recycled for energy generation. As this type of process does not allow a clear allocation of feedstocks, energy numbers include both feedstock and process energy. The analysis does not, however, include the itemized steam and electricity energy listed below (see also ref. 6). [c]Energy (including steam and electrical power) to produce glucose, ammonia, and water. Calculations: 3.33 (yield of PHA on glucose) × 8,128 kJ (see Table 2) + 4,028 kJ (energy to produce 0.109 kg of ammonia) + 120 kJ (energy to provide 26 L of process water) = 31,218 kJ. [d]The production of 1 kg of steam requires the combustion of 0.058 kg of residual fuel oil during PS production. Fermentation for PHA most likely will use natural gas for steam generation and therefore requires only 0.0508 kg of gas to produce the same amount of steam. [e]For conversion of kWh to FFE, see Table 3.

lowing features: they can yield very high PHA concentrations, commonly above 100 g/L; biological polymer synthesis is an exothermic process and therefore requires external cooling; 2.4 kg of carbon dioxide are emitted per kilogram of polymer produced during the fermentation; all processes are aerobic and therefore require considerable aeration and agitation; cell wall disruption is required to release the polymer from the microorganism; between 0.15 and 0.3 kg of biological waste are generated per kilogram of polymer; and approximately 3.33 kg of glucose are required to produce 1 kg of PHAs (see Table 1).

Using an optimistic high-cell-density PHA fermentation as a basis for analysis, a 48 h culture would produce an impressive 190 g/L biomass, of which 150 g/L would be PHA (79% polymer content). Assuming recovery of 100% of the polymer produced in the fermentation, this would require 2.39 kg of fossil resources (gas, oil, and coal) to produce 1 kg of PHAs.

The hard facts

As the analysis above indicates, the amount of fossil fuel (2.39 kg) required to produce 1 kg of PHAs exceeds that (2.26 kg) required to produce an equal amount of polystyrene (see Tables 3 and 4). While the consumption of fossil resources does not differ greatly between the two processes, the emissions reveal a discouraging fact: PHA production requires the combustion of the entire 2.39 kg for energy production, whereas polystyrene production combusts only 1 kg of the 2.26 kg fossil fuel required for its manufacture, the balance being used as a feedstock.

The energy consumption estimates used in the analysis above are very conservative and far below those of other researchers who have assigned energy requirements to PHA fermentation processes[15]. In fact, van Wegen and co-workers[15], who analyzed the fermentation process alone and assigned energy values that were 57% and 467% greater than those used in the present analysis for electricity and steam, respectively. If their values were used, the net effect would be fairly drastic, resulting in an overall fossil fuel consumption of 3.73 kg per kilogram of PHAs.

Conclusions

For the particular system studied, the replacement of conventional polymers with fermentation-derived PHAs does not appear to be a useful approach if a sustainable production of polymers is the desired outcome. Other benefits such as the biodegradability and biocompatibility of PHAs could justify the expense of considerable fossil resources; however, those benefits would have to be quantified and evaluated separately. For example, the usefulness of biodegradability itself has been put into question because the degradation of biodegradable materials, such as paper in landfills, is not only slow[17], but also results in greenhouse gas emissions (methane and carbon dioxide) as well as leachates with increased biological oxygen demand. Proper incineration, on the other hand, produces less harmful greenhouse gases and, more importantly, allows the partial recovery of energy expended during manufacture.

The production of PHAs using corn as a feedstock with current fermentation technology is thus of questionable environmental benefit, even under rather favorable assumptions. Although biological processes that use renewable resources certainly have the potential to conserve fossil resources, this case study demonstrates that such an approach can also have the reverse effect. Therefore, future assessments of biological processes must not only incorporate the use of raw materials (which are mostly renewable), but also address the indirect consumption of nonrenewable energy sources required for the process.

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EXHIBIT I

Greenhouse Gas Profile of a Plastic Material Derived from a Genetically Modified Plant

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Summary

This article reports an assessment of the global warming potential associated with the life cycle of a biopolymer (poly(hydroxyalkanoate) or PHA) produced in genetically engineered corn developed by Monsanto. The grain corn is harvested in a conventional manner, and the polymer is extracted from the corn stover (i.e., residues such as stalks, leaves and cobs), which would be otherwise left on the field. While corn farming was assessed based on current practice, four different hypothetical PHA production scenarios were tested for the extraction process. Each scenario differed in the energy source used for polymer extraction and compounding, and the results were compared to polyethylene (PE). The first scenario involved burning of the residual biomass (primarily cellulose) remaining after the polymer was extracted from the stover. In the three other scenarios, the use of conventional energy sources of coal, oil, and natural gas were investigated. This study indicates that an integrated system, wherein biomass energy from corn stover provides energy for polymer processing, would result in a better greenhouse gas profile for PHA than for PE. However, plant-based PHA production using fossil fuel sources provides no greenhouse gas advantage over PE, in fact scoring worse than PE. These results are based on a "cradle-to-pellet" modeling as the PHA end-of-life was not quantitatively studied due to complex issues surrounding the actual fate of postconsumer PHA.

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Introduction

Production of plastics worldwide consumes about 270 million metric tons[1] of fossil fuel each year (Gerngross and Slater 2000), 120 million tons as feedstock and another 150 million tons as process energy. Although conventional plastics such as polystyrene and PE have very good material properties, their reliance on fossil resources as a raw material, their lack of biodegradability, and their contribution to a growing solid waste stream (in particular, in the United States) have been historically cited as potential long-term shortcomings. Finding alternatives that are made from renewable resources and are biodegradable has thus become the focus of intense research efforts (Gerngross and Slater 2000).

Background on Biopolymers Production

Among the biopolymers having commercial potential, poly(hydroxyalkanoates) (PHAs) have been viewed as particularly promising, and diverse PHA production pathways have been studied and compared (Gerngross and Slater 2000). PHAs are natural products produced by many bacterial species for carbon and energy storage, and many types of PHA with diverse physical properties can be produced by growing the bacteria on an appropriate feedstock. Indeed, PHA production via bacterial fermentation has been performed commercially, most notably for production of poly(3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV), commercialized under the trade name Biopol™. Biopol™ has been used to make plastic bottles and to coat paper. Greenpeace, an environmental advocacy organization, produced a credit card made of this polymer. However, PHBV production was recently discontinued because manufacture based on fermentation cannot compete economically with petrochemical processes used to produce conventional plastics such as PE (Gerngross and Slater 2000).

Despite the economic difficulties associated with PHA production, one might think that the environmental benefits would justify higher cost and provide chances for success in the market place. After all, the polymer is derived from a renewable resource (sugar from corn starch) and products made from PHBV are completely biodegradable. However, earlier work has shown that PHA production based on fermentation is not a sustainable process (Gerngross 1999). In fact, when considering the energy and material requirements for corn farming and wet milling, fermentation, and polymer recovery, a rather discouraging picture emerges. All major environmental indicators such as carbon emissions, air acidification, eutrophication, and depletion of natural resources show that fermentative PHA production has considerably more negative environmental impact than conventional plastic production. These counterintuitive findings demonstrate the need for a comprehensive life-cycle assessment prior to dedicating significant resources to the development of a new technology.

Efforts to produce PHAs have since focused on synthesizing the polymer in agricultural crops modified by using genetic engineering techniques, followed by recovery of the polymer by extraction with organic solvents. Producing PHAs in plants was expected to allow more economical performance compared to petrochemical polymers because it eliminated the requirement for a fermentation process. Getting a plant to synthesize PHAs involves the stable introduction of several microbial genes into the plant. These genes encode for the biosynthetic conversion of acetyl-CoA, a naturally occurring metabolic precursor, and likely additional plant metabolites, into a polyester of high molecular weight.

Several types of plants, including the laboratory organism *Arabidopsis thaliana* (Nawrath et al. 1994; Poirier 1992), and the crops *Brassica napus* (Houmiel et al. 1999; Slater et al. 1999), *Glycine max* and *Zea maize* (Gruys et al. n.d.) have been successfully engineered to produce the simple polymer poly(3-hydroxybutyrate). In addition, both *Arabidopsis* and *Brassica* have also been engineered to produce the commercial product PHBV (Slater et al. 1999), albeit at a low polymer content. Analysis of potential production systems led to three plants in which commercial production appeared economically attractive. These were, in order of decreasing economic and increasing technical viability, switchgrass, sugar cane, and corn. Switchgrass grows to very high biomass density on marginal land, and has been extensively investigated as a potential source of biomass fuel (Department of Energy 1998). However, the genetics of switchgrass are complex and poorly characterized, and an efficient system for making transgenic plants is not currently available. Sugar cane can be genetically modified, but is also an extremely poorly understood genetic system. Thus, corn was chosen as a model because it can be both genetically modified and well characterized. The polymer is produced in genetically engineered corn in which grain is harvested in a traditional manner, and polymer is extracted from the corn stover (stalks, leaves, and cobs). Although the technical and economic aspects of PHAs obtained through transgenic crops are increasingly understood, the impact of their life cycle on the environment is less known.

This paper presents the greenhouse gas profile associated with the production of such a polymer, derived from research at the Monsanto company. This profile has been assessed from a life-cycle perspective, that is, accounting for the life-cycle stages including corn farming, extraction of polymer, and compounding. The end-of-life step has been excluded from the quantitative modeling, due to the wide variety of uses applicable to PHA and their corresponding end-of-life possibilities. End-of-life considerations and their potential influence on the results are nevertheless presented, from a qualitative viewpoint only.

Modeling

This section describes the life-cycle steps of PHA production taken into account in the calculation of the greenhouse gas profile of PHA. A special focus is placed on farming. Two different options for allocating greenhouse gas emissions to stover and grain are analyzed. Then, various scenarios are described according to the nature of the energy required for extraction and compounding. A comparative scenario describing PE production is finally detailed.

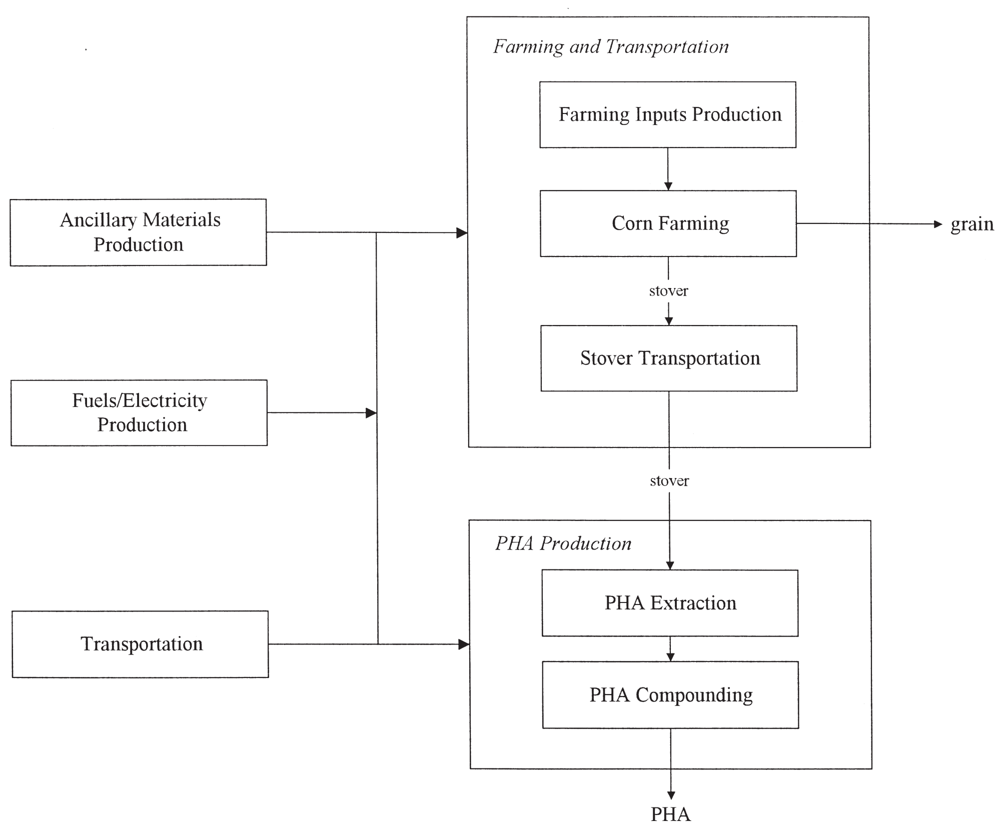

Figure 1 Overview of the system boundaries defined for the PHA production system

System Boundaries

The greenhouse gas profile has been calculated for the production inputs used during farming, as well as PHA extraction and polymer compounding as detailed in figure 1. The different end-of-life options—landfilling, composting, and incineration—are discussed from a qualitative viewpoint only, as explained in the background section.

Allocation of Burdens to Harvested Stover

Both grain and stover are intentionally co-produced through the farming of engineered corn. The impacts associated with farming (use of fertilizers, direct emissions from the field, etc.) have to be distributed to both corn grain and stover. The allocation procedure in the study follows the ISO 14041 standard, which deals with the inventory phase of the life cycle. According to this procedure, it is recommended to extend the stover production system to include the production of all co-products, that is, stover and grain. When using this allocation approach, also called system extension, the full farming impacts of growing the genetically engineered corn (including grain/stover separation) is attributed to harvested stover only (around 60% of total stover) but the impact due to producing the same quantity of conventional corn grain is subtracted (see figure 2). Conventional-corn farming requires less input (fertilizer, energy, land, etc.) than engineered-corn farming to produce the same amount of grain. We assume a 5% grain yield loss for corn producing PHA. In essence, the system extension approach is designed to burden the PHA-containing stover with only the incremental impact due to the slightly lower yield per acre associated with the production of genetically engineered corn.

The system extension is used as the baseline approach in the study, accordingly to ISO recommendations (ISO 14041 1998). Nevertheless, additional calculations using a different approach are performed in order to test the sensitivity of the overall results to the allocation method. Allocation issues have sometimes proved contentious and critical to the outcome of life-cycle studies, and a careful analysis of alternate allocation methods was an important component of this study.

In the second allocation approach, the farming impacts are partitioned between grain and stover based on an "underlying relationship" (ISO 14041 1998)—a physical relationship when possible—that exists between these co-products. Applied to corn, an immediate relationship to consider between grain and stover is the one between their relative mass. The allocation procedure in that case partitions each total input and output according to the relative dry mass of each co-product harvested from the field. The use of mass partitioning reflects the assumption that any considered input such as a single fertilizer (or output such as a single air emission) is really consumed (or generated) by each co-produced part of the plant in the ratio dictated by its relative mass. As these physiological relationships are not known for sure, another type of relationship between grain and stover is actually discussed below.

Economic value of both co-products, when available, is another potential factor on which the allocation can be based, partitioning each total input and output according to the relative monetary value of each co-product. Nevertheless, this partitioning factor cannot be used in the study, as stover is usually considered to have no commercial value, and is almost never harvested. Even in the rare case of actual harvest and further use, an appropriate commercial value of the stover is difficult to determine as market pricing strongly depends on local, and highly variable, conditions. In an attempt to avoid these obstacles, one might consider deducing the stover economical value from the assessment of the potential saving that farmers achieve when they leave the stover on the field, "using" it as a potential chemical and physical soil improvement agent for the next season. Due to remaining difficulties associated with this economic assessment,[2] the mass-based partitioning is kept as the only possible alternative option to system extension, and is shown in figure 3.

PHA Extraction Energy Scenarios

The extraction process requires steam and electricity that can be generated by various primary energy sources, either biomass or fossil fuels. In the biomass scenario, retained as the

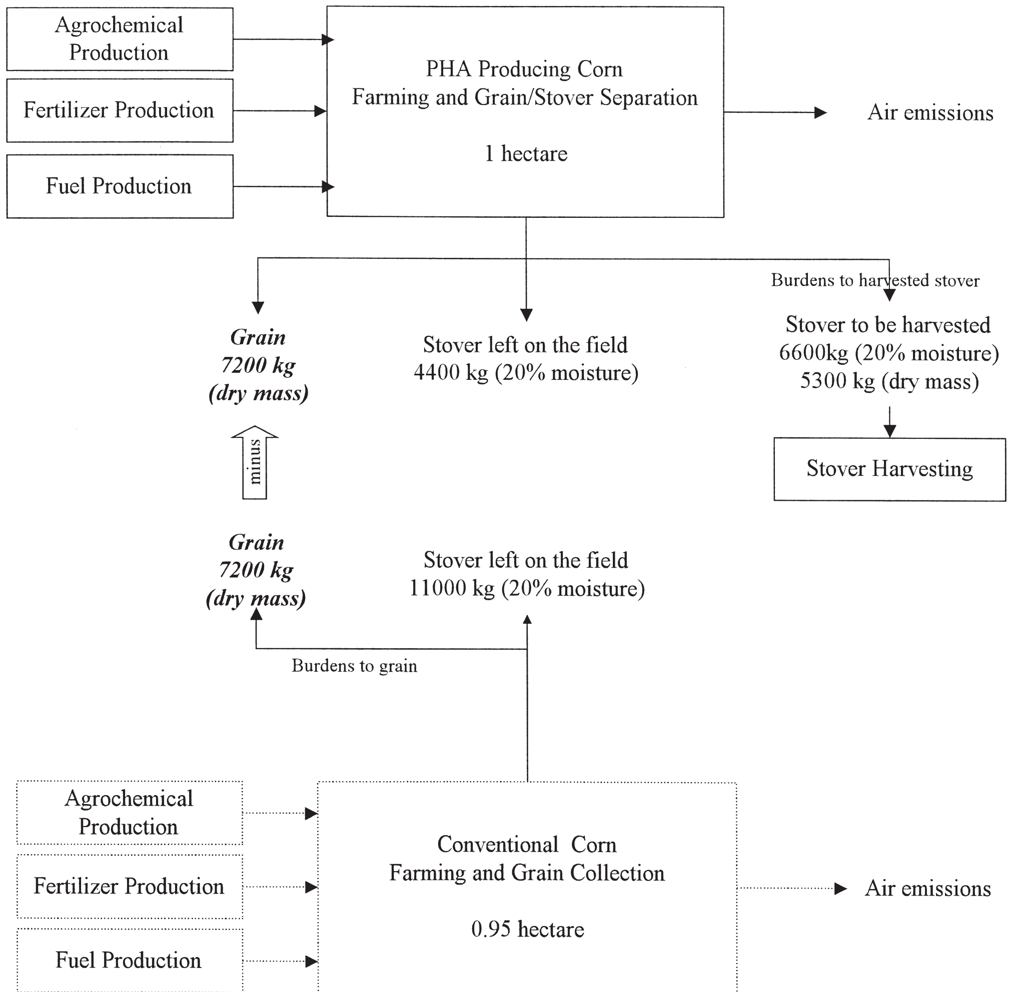

Figure 2 Extending the system boundaries

baseline case, a boiler burns the residual biomass that stover yields after PHA has been extracted. The PHA production process uses steam and electricity generated by biomass burning and the surplus unused steam is converted to electricity and sold. In order to account for this net production of electricity, the impacts due to electricity production from an alternate source (e.g., electricity from grid) have been subtracted from the system. This "biomass burning" modeling is shown in figure 4.

In the alternative scenarios, the energy sources are fossil fuels. Therefore, the dried stover obtained after the PHA extraction is not burned nor used beneficially in any other way. Instead, all environmental burdens of the extraction are placed on the PHA and none are placed on the extraction residue that is considered as waste. The "fossil fuel burning" modeling is shown in figure 5.

All data for natural gas, coal, and oil, as well as electricity production come from Ecobalance's DEAM™ database, reflecting average production conditions in the United States (Ecobalance 1999).

Comparison with PE

Because PHA presents similar material properties as PE and can replace it in various appli-

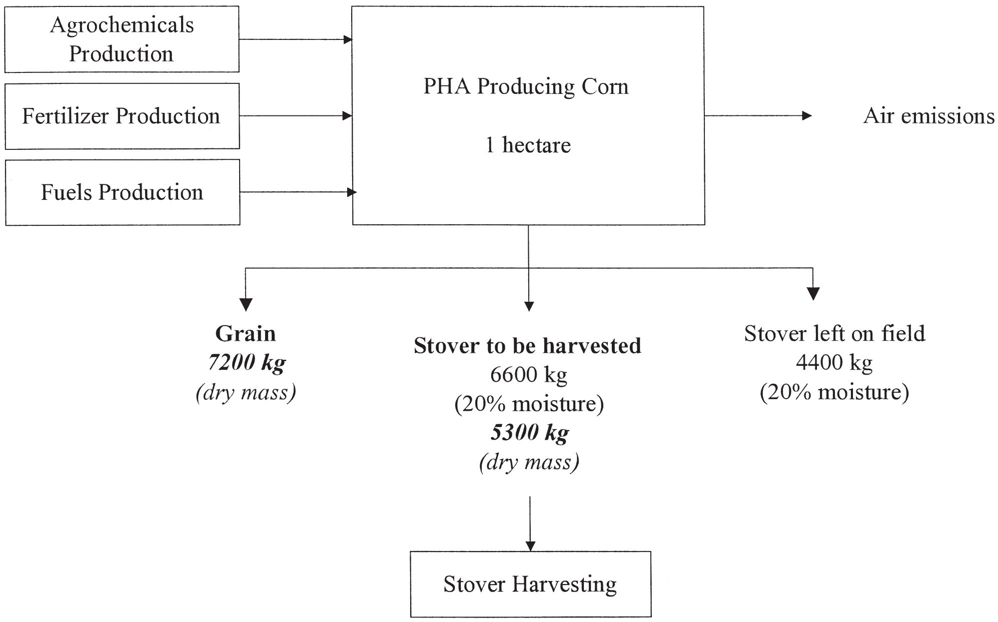

Figure 3 Allocation of burden based on dry mass produced

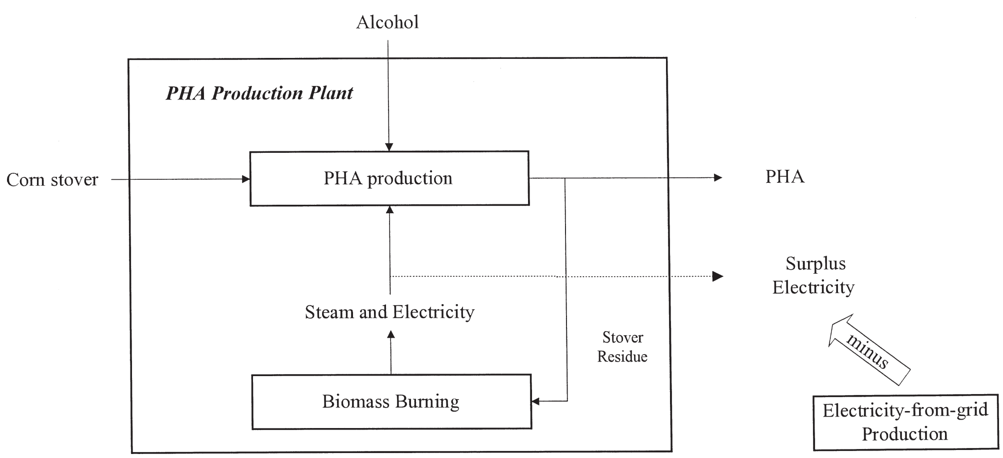

Figure 4 Biomass Scenario

cations (Holmes 1988), a comparison of the two polymers is included in the study. Therefore, in addition to each of four PHA production scenarios, a greenhouse gas profile is calculated for PE production, both for low-density PE (LDPE) and high-density PE (HDPE). The PE production systems include extraction of raw material, processing of crude oil and natural gas, petroleum refining, ethylene polymerization, and PE separation (EPA 2000).

Global Warming Potential Calculation

The flows contributing to global warming potential and their respective coefficients—for a time horizon of 100 years—from the Intergovernmental Panel on Climate Change (IPCC 1998) are displayed in table 1.

The calculation is performed for six different scenarios based on the allocation approach, system extension or partitioning, and the source of

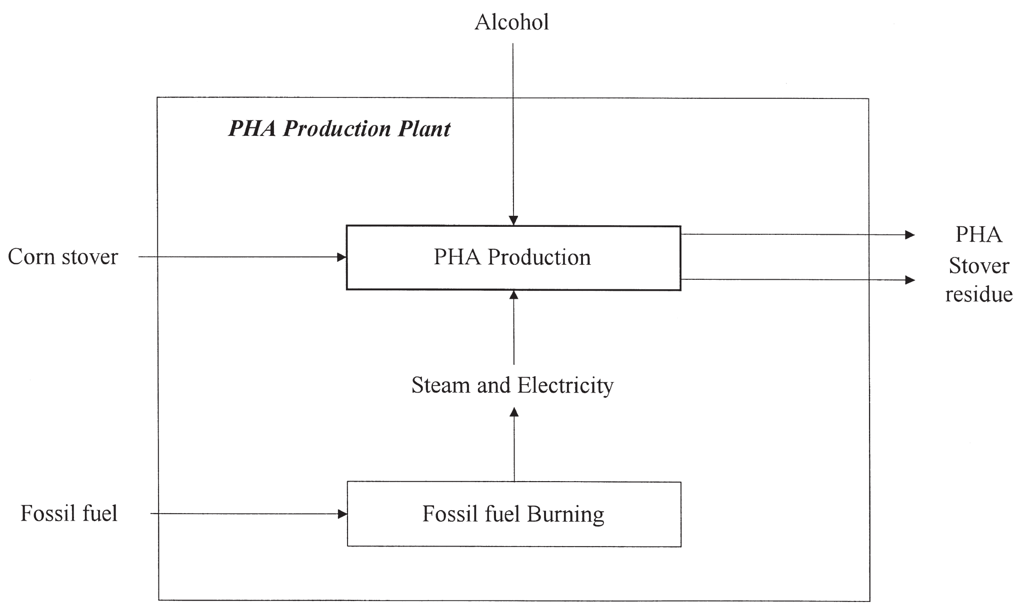

Figure 5 Fossil fuel Scenarios

energy for extraction, as listed in table 2.[3] Both allocation approaches are applied to the biomass and the natural gas scenarios, and only the system extension to the coal and oil scenarios.[4]

Data Sources

Farming Inputs and Outputs

The farming model takes into account corn yield parameters of genetically engineered corn as derived from Monsanto's own assumptions. In particular, grain corn value is chosen based on current farming situations and is assumed to reach 8,950 kg/ha (143 bushels/acre). Although on the high side of the U.S. national average, this grain yield is realistic for the most productive part of the United States and is congruent with Monsanto's expectations for PHA yield. Taking into account the ratio of stover harvested, and that of dry content grain/stover, stover yield reaches 5,300 kg/ha (dry weight) based on 8,950 kg of grain/ha. Good farming practice requires that at least 40% of the stover be left on the field to prevent erosion and provide organic matter for the following season, so only 60% of the output stover is assumed harvested (Nielsen 1995). Based on an approximate 20% water content at harvesting time, harvested stover wet weight is 6,600 kg/ha, corresponding to 5,300 kg/ha dry weight. Regarding corn producing PHA, we assume a 5% grain yield loss. Table 3 summarizes the farming yield assumptions used to build the model.

Table 1 Elementary flows in global warming indicator and corresponding coefficient

Elementary flows	*Coefficients*
CO_2 (fossil and biomass)	1
CH_4	24
N_2O	360

Much of the data regarding farm production inputs are provided in a study from the Economic Research Service (ERS) of the United States Department of Agriculture (USDA) (Shapouri et al. 1995). Such farm production data include energy (diesel, gasoline, electricity, and natural gas) as well as fertilizers and other chemicals consumption, and are based on USDA's 1991 Farm Costs and Returns Survey. More recent numbers regarding cost and returns are available but the corresponding ERS study had not been updated at the time of this assessment. The data encompass the nine major U.S. states producing corn for ethanol (Illinois, Indi-

Table 2 Scenario listing

		Allocation approach	
	Energy source	*System extension*	*Mass-based partitioning*
1	Biomass	Biomass, System extension	not applicable
2	Biomass	not applicable	Biomass, Partitioning
3	Natural gas	Natural gas, System extension	not applicable
4	Natural gas	not applicable	Natural gas, Partitioning
5	Coal	Coal, System extension	not applicable
6	Oil	Oil, System extension	not applicable

Table 3 Corn yield parameters

Parameters	*Data source or formula*	*Units*	*Values*
Figures for grain and stover (regular corn)			
Grain yield (15.5% water content)	Derived from current situation	bu/ac	142.6
Grain density	Nielsen 1995	lb/bu	56
Grain yield	142.6 · 56 · 0.4536/0.1047	kg/ha	8,950
Grain dry content	Nielsen 1995	(kg/kg)	0.845
Ratio of dry grain to dry stover	Monsanto's data	(kg/kg)	55/45
Stover yield (dry basis)	55/45 · 8,950 · 0.845	kg/ha	9,244
Figures for harvested stover (regular corn)			
Stover harvest rate	Nielsen 1995	(kg/kg)	0.6
Harvested stover (dry basis)	9,244 · 0.6	kg/ha	5,546
Figures for modified corn			
Grain yield loss	Monsanto's data	(kg/kg)	0.05
Corn grain	8,950 · 0.95	kg/ha	8,503
Harvested stover (dry basis)	5,546 · 0.95	kg/ha	5,269
Figures for stover (modified corn, 20% water content)			
Stover water content when harvested	Monsanto's assumption	(kg/kg)	0.2
Harvested stover	5,269/(1–0.2)	kg/ha	6,586

ana, Iowa, Minnesota, Nebraska, Ohio, Michigan, South Dakota, and Wisconsin). The average grain yield in this ERS study is 7,700 kg/ha (122 bu/ac) for 1991, which is below the objective of 8,950 kg of corn grain per hectare. In order to take into account this projected higher grain yield, the farming inputs as found in the ERS study are scaled up to 8,950 kg/ha. Even though there is not always a direct relationship between high inputs and high yield, the same increasing factor—8,950/7,700, for example, 16% increase—is conservatively applied to all inputs. Furthermore, as will be shown in the results, farming is often a minor contributor to global warming potential of the PHA life cycle. Therefore, the bias due to scaling up does not change the final results of the study.

Table 4 describes the inputs that are used in this study. The energy requirement figures include the following farming steps: growing seed, land preparation and plowing, planting, weeding, chemicals distribution, irrigation, and grain/stover separation (grain harvest step). The pre-production steps related to the input production (raw material extraction, refining, etc.) are derived from Ecobalance's DEAM™ database. The greenhouse gas emissions related to the production of fertilizer, agrochemicals, and fuel are included in the calculations, along with those corresponding to the combustion of fossil fuel in farm equipment.

Table 4 Farming inputs

Fertilizers and agrochemicals	*Units*	*Data*
Nitrogen as N	kg/ha	163
Phosphate as P_2O_5	kg/ha	76
Potash as K_2O	kg/ha	69
Lime	kg/ha	315
Agrochemicals (unspecified)	kg/ha	5.1
Energy requirements		
Diesel oil + Gasoline	l/ha	111
Electricity	kWh/ha	96

Although tilling practices and residue management are well-established factors affecting the soil organic content (Duiker and Lal 1999; Lal 1997), and as such are important to greenhouse gas considerations, no specific data have been identified as to which tilling practice is likely to accompany 60% stover removal. Therefore, the carbon sequestration in soils attributable to tilling practices because of the export of 60% of the stover is not included in the modeling. Additionally, the effect of tilling practices depends on soil and climate conditions, which are beyond the scope of this study. Finally, and most important, the farming contribution (fertilizer, agrochemicals, and fuel use) to global warming potential is minimal compared to that of PHA extraction (see Results section). All those reasons lead us to assume in the study that harvesting 60% of the stover does not change the fertilizer, agrochemicals, and fuel requirements nor the soil carbon content (beyond the net exportation of carbon corresponding to the mass of harvested stover) compared to leaving 100% of the stover in the field.

The CO_2 plant intake related to the corn growth is estimated from the stover carbon content. This latter is assumed to approximate 50%, based on the composition of sugar cane bagasse (sugar cane residues), as both plants have a similar cellulosic content (Broder and Barrier 1990; EPA 1997).

Nitrous oxide emissions related to farming are more difficult to evaluate. In addition to small emissions due to the operation of farm equipment when applying fertilizer, a major source of nitrous oxide emissions is the nitrogen fertilizer itself (part of the nitrogen applied to the soil is transformed into N_2O through microbial processes). These emissions from the soil, however, are not necessarily specific to corn raising as they are generated even in absence of fertilization and/or any cultivation. In this study, the nitrous oxide emission from the soil directly related to the quantity of nitrogen fertilizer used is taken into account, whereas the unspecific emission from the field is excluded. No well-documented and internationally recognized method is available to model these N_2O emissions from field-derived fertilizer use. The method chosen for this work (Conrad 1983) is based on field measurements of nitrogen fertilizer losses rather than chemical reactions, as used in other models. It evaluates the N_2O emission to the air to 5.1 g per kg of nitrogen applied. It should be mentioned that N_2O contribution to the overall greenhouse gas impact does not reach 1%. No significant changes are expected in the overall results if another method is used.

PHA Production Inputs and Outputs

PHA preparation from the dried stover includes a two-step solvent extraction (Kurdikar et al. 1998). The materials and utilities requirement data (table 5) are derived from engineering estimates made by Monsanto, and are based on extraction of PHA using a C_4-C_{11} alcohol (Kurdikar et al. 1998). The model built for C_4-C_{11} alcohol is based on butanol production with the consumed amount of C_4-C_{11} alcohol, and includes the energy requirements for compressed air.

The compounding step produces PHA pellets ready to be sold to processors. These PHA pellets are comparable to the PE resin modeled in the study. The final compounding step that processors might perform on resin, either PHA or PE, is not included in the study.

In the baseline scenario, the dried stover (after PHA extraction) is burned for steam and electricity generation, and the surplus steam is converted to electricity to be sold. The projected CO_2 emission from the stover combustion is displayed in table 6. Emissions data specific to burning dried corn stover were not readily found. Therefore, available emissions data related to bagasse-fired boilers were used instead (Air Chief, EPA 1997). Heating values (on a dry basis) of bagasse and corn are quite similar, approximately

Table 5 Expected inputs of PHA production from modified corn stover

Raw PHA extraction	*Unit per kg PHA*	*Value*
Stover (dry basis)	in kg	6.8
Alcohol (losses)	in kg	0.08
Steam	in kg	12.5
Electricity	in MJ elec	8.8
Stover residue (dried, after PHA extraction)	in kg	5.8
PHA compounding		
Electricity	in MJ elec	2.4
Titanium oxide (TiO_2)	in kg	0.003

17 MJ/kg for dry corn stover (Ontario Ministry of Agriculture, Food and Rural Affairs, OMAFRA) as is their composition (Janick 1990).

PE Production

Data on PHA production were compared to data on the production of PE, both LDPE and HDPE. Data assumptions related to PE production are found in the EPA data set for Plastic Materials (2000). These EPA data include polymerization data from the Association of European Plastics Manufacturers (Boustead 1993, 1997), based on 36 European plants producing 4.5 million tons of PE of all grades. A weighted average is used for LDPE and HDPE, respectively. These European process data are combined with U.S. data regarding the energy supply (electricity grid and the actual average for steam). Results in this work are given per kilogram of PE resin; in other words they do not include final compounding, which is consistent with what was done for PHA. This exclusion from the model is reasonable as the differences in final compounding recipes between PE and PHA are very slight and are expected to generate only minimal changes in the greenhouse gas profile of both polymers. The influence of polymer density, however, is taken into account as it could affect the comparison between PE and PHA. Densities are on average 0.93, 0.95, and 1.2 for LDPE, HDPE, and PHA, respectively. Replacement of PE by PHA could be volume-based in some applications, or mass-based in others (mixed situations being also possible). Therefore, the graphical results for both LDPE and HDPE show the range obtained from volume-based (favorable to PE) to mass-based (favorable to PHA) calculations, both to be compared to PHA results given per 1 kg of biopolymer.

Table 6 Characteristics for corn stover-boiler

Heating value of stover	in MJ/kg of dry stover	17.6
CO_2 emission factor	in g/kg of dry stover	1,560

Results

The following section presents the overall global warming potential for several scenarios, biomass and natural gas being analyzed in further detail. Unless otherwise noted, all scenarios are analyzed using the system extension approach (see Modeling section). The results of a sensitivity analysis comparing this approach to mass-based partitioning are also presented. For all scenarios, the greenhouse gases derive from both the farming and processing steps, but are primarily the result of processing. Among the greenhouse gases relevant to this study, CO_2 (whether from biomass or fossil fuels) is the primary greenhouse gas in all scenarios, both in quantity of CO_2 and in global warming impacts, overshadowing CH_4 and N_2O (as displayed for the biomass scenario). Furthermore, in all results, the harvested stover is assumed to release its embedded carbon through burning (biomass scenario) or natural degradation (stover residue in fossil fuel scenarios). The nonharvested stover is not included in the accounting, as its CO_2 uptake is assumed, according to standard carbon accounting practices, to equal its CO_2 releases during long-term degradation.

Biomass Scenario

The overall generation of greenhouse gas through the production of PHA in a biomass scenario equals –4,000 g CO_2 eq/kg PHA (first column of figure 6) with CO_2 being the major contributor, as shown in table 7.

Figure 6 displays a breakdown by farming steps (corn growth and fertilization) and by process

Table 7 Relative contribution of greenhouse gases to global warming impact in biomass scenario. Negative values indicate CO_2 absorption or credit

Per kg PHA	CO_2	CH_4	N_2O
Emission in g	–4,000	2	0.06
Coefficient	1	24	360
Contribution in g CO_2 eq	–4,000	48	21

steps (extraction and compounding). The corn plant absorbs around 12,500 g CO_2 eq/kg PHA produced, which is mostly released when the stover is burned for energy generation (9,000 g CO_2 eq/kg PHA). The difference (3,500 g CO_2 eq/kg PHA) corresponds to the carbon embedded in the PHA (2,000 g CO_2 eq/kg PHA based on carbon content) and in the ash from the boiler (1,500 g CO_2 eq/kg PHA due to incomplete combustion). In addition, the surplus electricity generated in the biomass scenario yields a small greenhouse gas credit (e.g., offset of grid electricity). The end-of-life of the ash has not been modeled in the study, but its most probable fate is disposal in a landfill, unless its composition is appropriate for application on farming land (depending on the mineral composition of the ash). Even though it is not clear what the degradability of this boiler-generated ash might be, either for landfill or land application, global warming potential corresponding to this waste is not expected to exceed 1,500 g CO_2 eq/kg PHA. Based on this conservative consideration, the overall global warming impact becomes –2,500 g CO_2 eq/kg PHA.

Natural Gas Scenario

When natural gas is used as the energy source for the extraction/compounding process, the stover residue is still assumed to release over time 100% of its carbon to the atmosphere (around 10,500 g CO_2 eq/kg PHA). In addition, the extraction and compounding steps combined release around 5,500 g CO_2 eq/kg PHA through steam and electricity production. The overall process generates a net greenhouse effect of approximately 3,800 g CO_2 eq/kg PHA as shown in figure 7.

All Scenarios

In figure 8 all scenarios are compared. All fossil fuel scenarios appear to have a higher global warming potential. The biomass scenario on the contrary shows a much better profile, with a greenhouse gas credit from surplus electricity production and CO_2 sequestration in the biopolymer.

Sensitivity Analysis of Allocation Approaches of Farming to Stover

Figure 9 presents the results of a sensitivity analysis comparing the system extension to the

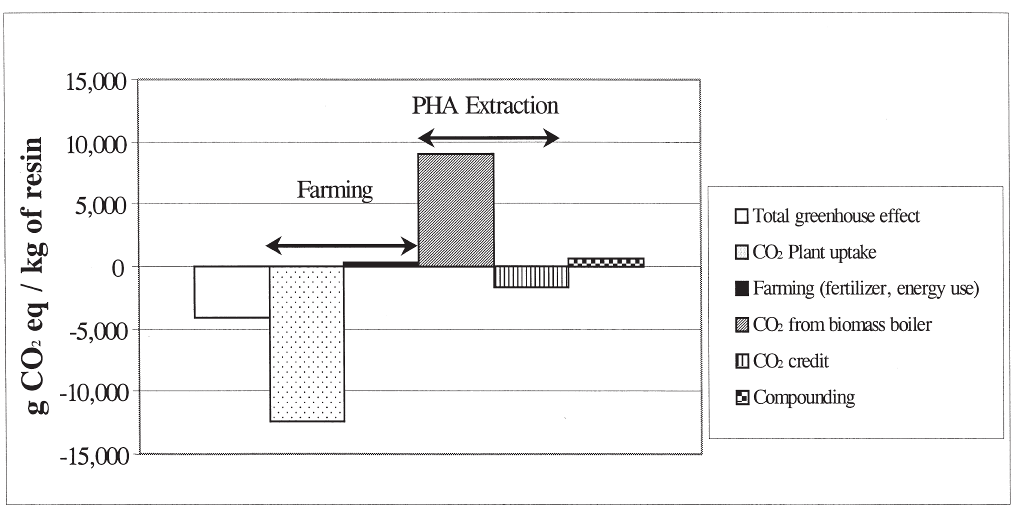

Figure 6 Global warming potential for PHA biomass scenario

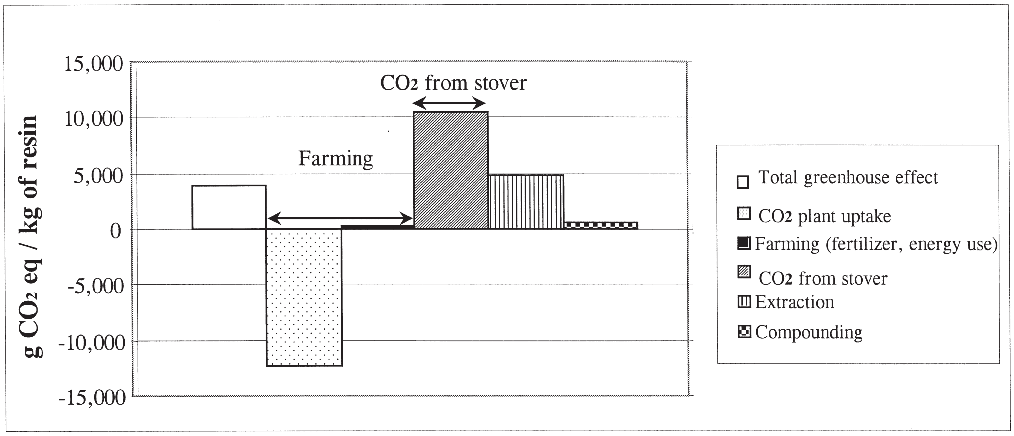

Figure 7 Global warming potential for fossil fuel scenarios

mass-based partitioning approach (see Modeling section) for the biomass and natural gas scenarios only. In the system extension approach, the greenhouse gas generation from stover alone is obtained by subtracting that of conventional-corn farming (including grain collection) from that of engineered-corn farming (including grain/stover separation). In the partitioning approach, the environmental burdens are distributed between grain and stover based on the respective dry mass harvested. The partitioning scenarios lead to an overall PHA global warming potential 20% higher than those obtained through system extension. For emissions related to the farming step, partitioning puts a burden to the harvested stover approximately eight times higher than that determined by the first approach. But, when considering the overall system, which in addition to farming encompasses PHA extraction and production, this ratio is highly reduced.

End-of-Life Considerations

After the polymers have been produced, processed, and used, they are discarded as municipal solid waste, then routed according to different waste management options, each of these presenting their own greenhouse gas implications (EPA 1998). A quantitative study of the greenhouse gas implications of various end-of-life practices was excluded from the scope of the project. This section attempts to qualitatively address greenhouse gas implications for different end-of-life options, for PHA and PE, respectively.

Implications for PHA:

- When PHA is composted, most of its CO_2 is released, which alters its greenhouse gas profile. The production of a valuable compost material could offset the production of another compost material. The subtracted alternative compost production could possibly provide PHA with some CO_2 credit but this effect is not clear, as the materials usually used for compost production (such as yard clippings) are considered to sequester their CO_2 for a longer period of time compared to what is known for PHA. The net impact from both PHA degradation and alternative compost production is unknown but would most probably be around 2,000 g CO_2 eq per kg of composted PHA (according to PHA carbon content).
- Incineration would increase PHA's CO_2 emission by 2,000 g CO_2 eq per kg of incinerated PHA based on its 50% carbon content. However, corresponding heat recovery and production of electricity (offsetting grid electricity) would generate a CO_2 credit. Based on PHA heating value (18 MJ/kg), and with an energy yield assumed to be 20% for electricity recovery, around 1,000 g of net CO_2 eq per kg of incinerated PHA would be released through PHA incineration.
- Landfilling would present a mixed picture for PHA products. Part of the biomass carbon contained in PHA would decompose

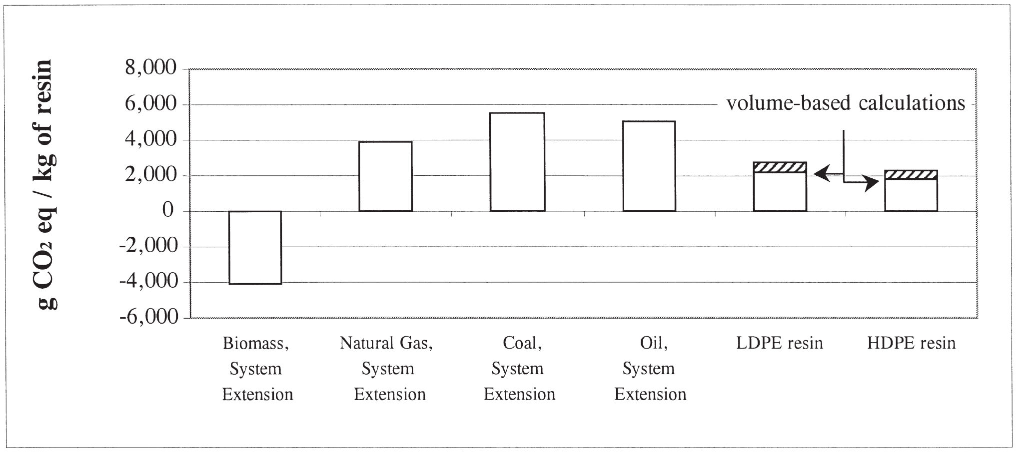

Figure 8 Global warming potential for PHA biomass and fossil fuel, and PE scenarios. The volume-based line in PE columns shows the influence of PE smaller densities compared to that of PHA, in volume-based applications. To manufacture PE products with the same volume as the PHA product, smaller quantities of PE resin are required compared to PHA, which generates smaller overall PE global warming potential than in case of mass-based applications (line topping the column).

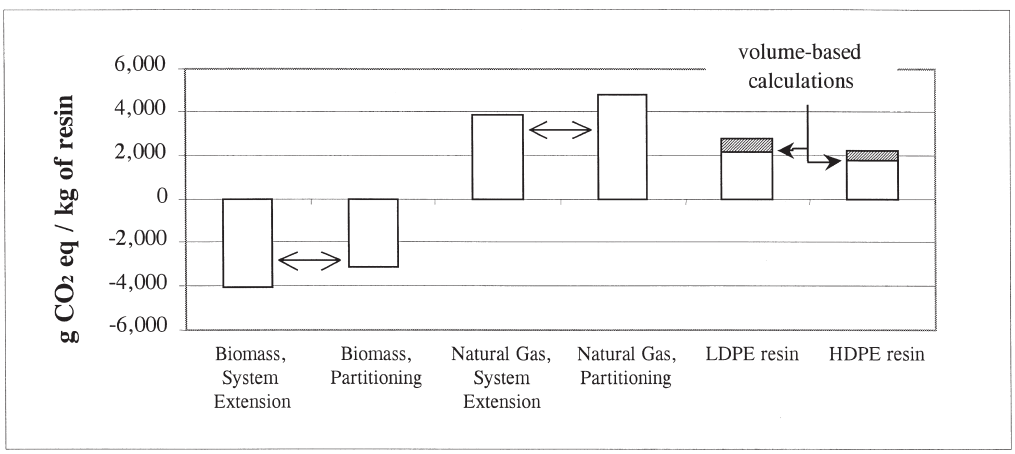

Figure 9 Global warming potential for PHA biomass and natural gas scenarios, with system extension and partitioning approaches, and PE. The volume-based line in PE columns shows the influence of PE smaller densities compared to that of PHA, in volume-based applications. To manufacture PE products with the same volume as the PHA product, smaller quantities of PE resin are required compared to PHA, which generates smaller overall PE global warming potential than in case of mass-based applications (line topping the column).

and be emitted both as CO_2 and CH_4. While the CO_2 emission will simply add to PHA's greenhouse gas profile, the influence of CH_4 emissions will vary depending on the landfill technology. In a landfill where captured gas is beneficially used (i.e., in a turbine, engine, or boiler), the generated CH_4 will eventually result in a CO_2 credit from the offset of the production of fossil energy. The absence of CH_4 recovery on the landfill will have an adverse effect on the PHA profile.

- Recycling could be a significant component of PHA's waste management, but the absence of data does not allow specific expectations.

Implications for PE:

- Composting is not applicable to PE.
- Incineration would increase the direct CO_2 emission from PE, probably to a higher extent than for PHA, because of PE's higher carbon content (around 85% for PE). The CO_2 credit from electricity production would likely be higher for PE than for PHA as its heating value is higher (42 MJ/kg vs. 18 MJ/kg for PHA). Based on PE heating value, and with an energy yield assumed to be 20% for electricity recovery, around 1,000 g of net CO_2 eq per kg of PE incinerated would be released through PE incineration.
- Landfilling will not alter PE's greenhouse gas profile, as it is essentially inert.

Based on these end-of-life implications, the relative performance of PHA compared to that of PE is not straightforward. Nevertheless, the overall global warming potential of each polymer, considering the worst end-of-life option for PHA (composting) and the best end-of-life option for PE (incineration), should be around –2,000 g CO_2 eq per kg of PHA in a biomass scenario, and between 2,500 and 3,000 g CO_2 eq per kg of PE (all PE densities and applications included). PHA with a biomass scenario shows a more favorable profile than PE. PHA remains more favorable than PE if 100% of the CO_2 sequestered in the boiler ash is released, which is highly hypothetical.

The outcome of the comparison of PHA to PE regarding the end-of-life step of their life cycles cannot be determined more precisely at this point of the analysis for the following reasons:

- Based on the previous qualitative considerations, it is apparent that opposite factors could affect the greenhouse gas profile of PHA leading to a variable position of PHA over PE inside each end-of-life option.
- Also, PE and PHA probably will not follow the same end-of-life pathways. For instance, PHA is likely to be targeted, at least initially, in niche markets where composting would be the preferred end-of-life option.

Conclusion

This study evaluates the greenhouse gas impact of producing plastic from (mostly) atmospheric CO_2 using metabolically engineered corn. The production system capitalizes on existing farming infrastructure and requires no petroleum for polymer feedstock. Therefore, the impacts were initially hypothesized to be minimal. However, polymer extraction and compounding are extremely energy-intensive, so processing energy dominates the environmental impact of the overall scheme. This means that a low-impact product is possible, but only if the processing energy is itself renewable. Use of traditional fossil fuels results in an overall greenhouse gas impact that is worse than the greenhouse gas impact from PE production. In the PHA process analyzed here, the copious residual biomass generated during plastic extraction provides a ready source of biomass energy. Thus, it is the use of biomass power, not renewable feedstock, that makes the product preferable to PE from a greenhouse gas perspective. The use of renewable resources to produce the PHA plastic itself compared with the use of nonrenewable feedstock to produce PE has the added benefit of sustainability.

With only a few exceptions, biomass power has failed to gain a foothold in energy production. The existing infrastructure makes fossil fuels relatively inexpensive and easily available, so they are the most likely energy source for a manufacturing process. Sugar production from sugar cane is one instance in which biomass fuel is consistently exploited. In sugar production, as in the PHA process outlined above, the biomass fuel (sugar cane bagasse) is a readily available by-product of the sugar. Thus, the fuel is harvested and transported to the plant along with the final product. This provides fuel at a very low cost, and it is burned to power sugar extraction and purification. Most of the waste, which would otherwise require disposal, is burned and so eliminated. The biomass energy option is currently available to the corn processing industry, but it is not used (Department of Energy 1994). Convenience, additional infrastructure requirements, and cost are cited in justifying the use of fossil energy in corn processing over a renewable energy source. It is noteworthy in this context that corn-farming states use coal disproportionately in electricity generation.

Harvesting fuel as a co-product in this PHA production scenario makes biomass energy fairly inexpensive and efficient, as it is in sugar production. However, there is no particular reason that the energy derived from corn stover must be used for PHA extraction. In fact, one could argue from a global warming perspective that it might be better to simply burn the stover, and use the energy to power production of PE. All CO_2 generated would be recaptured in the next growing season, and PE (if landfilled) would provide a carbon sink that would minimize greenhouse gas emissions. Nonrenewable oil depletion for PE feedstock is the primary disadvantage to this scenario from a sustainability perspective. This scenario would weigh the negative impact of oil depletion versus the positive impact of reduced greenhouse gas emissions. The balance of this equation would be expected to shift as oil becomes a scarcer resource.

A truly sustainable system for plastics production would require renewable feedstock, renewable fuels used in harvesting and transportation, and renewable energy for production of agricultural inputs and for polymer extraction and processing. It would also minimize the consumption of energy in general. Renewable energy on this scale will require redistribution of infrastructure to exploit renewable fuels, and it will be many years before this becomes both technically and economically feasible. However, much work is ongoing and it appears clear that such a switch will eventually be essential as environmental concerns increase and fossil fuels, particularly oil, become scarce.

Notes

1. 270 million metric tons = 296 million short tons or 270 million megagrams (Mg). Unless otherwise indicated, tons as used in this article refers to metric tons.
2. The cost of displaced fertilizer and fuel (for mechanical equipment) between "stover left on the field"-scenario and "stover harvested"-scenario could theoretically serve as a base of the calculation. The overall effect of stover removal on farming practices in general, however, and on future yields in particular, is a complicated issue that is still being addressed by experts. Studies are underway but so far, no consensus has emerged. On the one hand, stover removal tends to reduce carbon buildup in the soil, and leads to long-term yield loss, presumably by acting on mineral retention in soil components. Similarly, tillage favors biodegradation and tends to reduce carbon sequestration (as no quantitative data on how stover removal affects tilling practices are identified at this point, it is not possible to include this aspect in the study). On the other hand, within a more short-term view, stover removal diminishes plant pests' infestation as less stover debris means less refuge for pests and therefore allows for a better crop yield the next year with subsequent increased carbon sequestration. Also, especially in northern parts of the United States, removal of stover is actually recommended as it accelerates the ground warm-up after winter. But, as no model that we have identified has integrated these contrary effects yet, the intricate calculation of stover economical value has not been performed in this study, according to its scope.
3. In the six scenarios listed in table 2, 60% of the stover is assumed to be removed and processed (see data on farming inputs and outputs for explanation of that percentage). Another scenario would be to harvest 100% of the grown stover and to return the residual organic matter to the field after the stover has been processed for PHA. Since farmers might be reluctant to use stover residues that potentially contain traces of solvent (from the PHA extraction process), such a scenario is not modeled in this study.
4. The natural gas scenario receives more attention in the study compared to that of coal and oil because it is considered "cleaner" based on the favorable air acidification potential corresponding to its extraction and combustion taken together compared to that of coal or oil.

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EXHIBIT J

BOUSTEAD CONSULTING & ASSOCIATES

"FINAL REPORT"

Life Cycle Assessment for Three Types of Grocery Bags - Recyclable Plastic; Compostable, Biodegradable Plastic; and Recycled, Recyclable Paper

Prepared for the Progressive Bag Alliance

Chet Chaffee and Bernard R. Yaros
Boustead Consulting & Associates Ltd.

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EXECUTIVE SUMMARY

In the pursuit to eliminate all that is not green, plastic seems to be a natural target. Its widespread use in products and packaging, some say, has contributed to environmental conditions ranging from increased pollution to overloaded landfills to the country's dependence on oil. In response, some cities have adopted legislation that bans plastic grocery bags made from polyethylene in favor of bags made from materials such as cloth, compostable plastics, or paper.

But will switching from grocery bags made from polyethylene to bags made from some other material guarantee the elimination of unfavorable environmental conditions? We know that every product—through its production, use, and disposal—has an environmental impact. This is due to the use of raw materials and energy during the production process and the emission of air pollutants, water effluents, and solid wastes.

More specifically, are grocery bags made other materials such as paper or compostable plastics really better for the environment than traditional plastic grocery bags? Currently, there is no conclusive evidence supporting the argument that banning single use plastic bags in favor of paper bags will reduce litter, decrease the country's dependence on oil, or lower the quantities of solid waste going to landfills. In addition, there is limited information on the environmental attributes of compostable plastics and how they fare against traditional plastic grocery bags or paper bags.

To help inform the debate about the environmental impacts of grocery bags, the Progressive Bag Alliance contracted with Boustead Consulting & Associates (BCAL) to conduct a life cycle assessment (LCA) on three types of grocery bags: a traditional grocery bag made from polyethylene, a grocery bag made from compostable plastics (a blend of 65% EcoFlex, 10% polylactic acid or PLA, and 25% calcium carbonate), and a paper grocery bag made using at least 30% recycled fibers. The life cycle assessment factored in every step of the manufacturing, distribution, and disposal stages of these grocery bags. It was recognized that a single traditional plastic grocery bag may not have the same carrying capacity as a paper bag, so to examine the effect of carrying capacity, calculations were performed both on a 1:1 basis as well as an adjusted basis (1:1.5) paper to plastic.

BCAL compiled life cycle data on the manufacture of polyethylene plastic bags and compostable plastic bags from the Progressive Bag Alliance. In addition, BCAL information on the compostable plastic resin EcoFlex from the resin manufacturer BASF. BCAL completed the data sets necessary for conducting life cycle assessments using information extracted from The Boustead Model and Database as well as the technical literature. BCAL used the Boustead Model for LCA to calculate the life cycle of each grocery bag, producing results on energy use, raw material use, water use, air emissions, water effluents, and solid wastes.

The results show that single use plastic bags made from polyethylene have many advantages over both compostable plastic bags made from EcoFlex and paper bags made with a minimum of 30% recycled fiber.

	Impact Summary of Various Bag Types (Carrying Capacity Equivalent to 1000 Paper Bags)		
	Paper (30% Recycled Fiber)	**Compostable Plastic**	**Polyethylene**
Total Enegy Usage (MJ)	2622	2070	763
Fossil Fuel Use (kg)	23.2	41.5	14.9
Municipal Solid Waste (kg)	33.9	19.2	7.0
Greenhouse Gas Emissions (CO2 Equiv. Tons)	0.08	0.18	0.04
Fresh Water Usage (Gal)	1004	1017	58

When compared to 30% recycled fiber paper bags, polyethylene grocery bags use less energy in terms of fuels for manufacturing, less oil, and less potable water. In addition, polyethylene plastic grocery bags emit fewer global warming gases, less acid rain emissions, and less solid wastes. The same trend exists when comparing the typical polyethylene grocery bag to grocery bags made with compostable plastic resins—traditional plastic grocery bags use less energy in terms of fuels for manufacturing, less oil, and less potable water, and emit fewer global warming gases, less acid rain emissions, and less solid wastes.

The findings of this study were peer reviewed by an independent third party with significant experience in life cycle assessments to ensure that the results are reliable and repeatable. The results support the conclusion that any decision to ban traditional polyethylene plastic grocery bags in favor of bags made from alternative materials (compostable plastic or recycled paper) will result in a significant increase in environmental impacts across a number of categories from global warming effects to the use of precious potable water resources. As a result, consumers and legislators should re-evaluate banning traditional plastic grocery bags, as the unintended consequences can be significant and long-lasting.

Introduction

In the national effort to go green, several states, counties, and cities are turning their attention to plastic grocery bags made from polyethylene because of the perception that plastic bags contribute to local and global litter problems that affect marine life, occupy the much needed landfill space with solid waste, and increase U.S. dependence on oil.

To address these environmental issues, and perhaps in seeking to follow the example of other countries such as Australia and Ireland, legislators in several cities across the United States have proposed or have already passed ordinances banning single use polyethylene plastic grocery bags in favor of bags made from alternative materials such as cloth, paper, or compostable plastic. Legislators state that they believe that these new laws and proposals will reduce litter, reduce the use of fossil fuels, and improve the overall environmental impacts associated with packaging used to transport groceries.

Before we examine whether plastic bags cause more environmental impacts than the alternative materials proposed, we should first consider the most commonly proposed alternatives, which tend to include: cloth bags, compostable plastic bags, and paper bags.

Reusable cloth bags may be the preferred alternative, but in reality, there is no evidence that most, or even a majority of, customers will reliably bring reusable bags each time they go shopping.

Compostable plastic bags, although available, are in short supply as the technology still is new, and therefore cannot currently meet market demand. So it appears that the proposed laws banning plastic grocery bags may simply cause a shift from plastic bags to the only alternative that can immediately supply the demand—paper bags.

Therefore, is legislation that mandates one packaging material over another environmentally responsible given that all materials, products, and packaging have environmental impacts? The issue is whether the chosen alternatives will reduce one or several of the identified environmental impacts, and whether there are any trade-offs resulting in other, potentially worse, environmental impacts.

To help inform the debate on the environmental impacts of grocery bags, and identify the types and magnitudes of environmental impacts associated with each type of bag, the Progressive Bag Alliance contracted Boustead Consulting & Associates (BCAL) to conduct a life cycle assessment (LCA) on single use plastic bags as well as the two most commonly proposed alternatives: the recyclable paper bag made in part from recycled fiber and the compostable plastic bag.

Life cycle assessment is the method being used in this study because it provides a systems approach to examining environmental factors. By using a systems approach to analyzing environmental impacts, one can examine all aspects of the system used to produce, use, and dispose of a product. This is known as examining a product from cradle (the extraction of raw materials necessary for producing a product) to grave (final disposal of the product). LCA has been practiced since the early 1970s, and standardized through several organizations including SETAC (Society of Environmental Toxicology and Chemistry) and ISO (International Standards Organization). LCA studies examine the inputs (resources and energy) and outputs (air emissions, water effluents, and solid wastes) of each system and thus identifies and quantifies the effects of each system, providing insights into potential environmental impacts at local, regional, and global levels.

To compile all the information and make the calculations, BCAL uses the Boustead Model and Database. The Boustead Model and Database is an LCA software model with a database built over the past 25 years, containing a wide variety of data relevant to the proposed study. Dr. Boustead has pioneered the use of life-cycle methods and has conducted hundreds of studies, including those for the plastics industry; which have been reviewed by US and European industry as well as life-cycle practitioners.

Study Goal

According to ISO 14040, the first steps in a life cycle project are defining the goal and scope of the project to ensure that the final results meet the specific needs of the user. The purpose of this study is to inform the debate on the environmental impacts of grocery bags, and identify the types and magnitudes of environmental impacts associated with each type of bag. In addition, the study results aim to inform the reader about the potential for any environmental trade-offs in switching from grocery bags made from one material, plastic, to another, paper.

The life cycle assessment was conducted on three types of grocery bags: a traditional grocery bag made from polyethylene, a grocery bag made from compostable plastics (a blend of 65% EcoFlex, 10% polylactic acid or PLA, and 25% calcium carbonate), and a paper grocery bag made using at least 30% recycled fibers. It is important to note that the study looked at only one type of degradable plastic used in making grocery bags, which is the bag being studied by members of the Progressive Bag Alliance. Since this is only one of a number of potential blends of plastic that are marketed as degradable or compostable, the results of this study cannot be used to imply that all compostable bags have the same environmental profile.

Scope

The scope of the study is a cradle to grave life cycle assessment which begins with the extraction of all raw materials used in each of the bags through to the ultimate disposal of the bags after consumer use, including all the transport associated with the delivery of raw materials and the shipping and disposal of final product.

The function of the product system under study is the consumer use and disposal of a grocery bag. The functional unit is the capacity of the grocery bag to carry consumer purchases. A 1/6 BBL (Barrel) size bag was selected for all three bags in this study because that is the commonly used bag in grocery stores. Although the bags are of equal size, previous studies (Franklin, 1990) pointed out that the use of plastic bags in grocery stores was not equal to the use of paper bags. According to Franklin (1990), bagging behavior showed that plastic to paper use ranged from 1:1 all the way to 3:1, depending on the situation. In contrast, data collected by the Progressive Bag Alliance shows that plastic and paper bags are somewhat equal in use once the baggers have been properly trained. In this study BCAL used both 1:1 and 1.5:1 plastic to paper ratios, allowing for the possibility that it still takes more plastic bags to carry the same amount of groceries as a paper bag. The 1.5:1 ratio equates to 1500 plastic bags for every 1000 paper bags.

BCAL prepared LCA's for the three types of grocery bags. The data requirements for BCAL and for the Progressive Bag Alliance are outlined below.

1. *Recyclable Paper Bag LCA………The following operations are to be included in the analysis:* To start, BCAL provided data on the extraction of fuels and feedstocks from the earth, including tree growing, harvesting, and transport of all materials. BCAL added process operations in an integrated unbleached kraft pulp & paper mill including recycling facility for old corrugated containers; paper converting into bags; closed-loop recycling of converting bag waste; packaging and transport to distribution and grocery stores; consumer use; and final disposal. Data for most of the above operations in one form or another are in the Boustead Model and Database. Weyerhaeuser reported that its unbleached kraft grocery bag contains about 30% post consumer recycled content and the use of water-based inks[1]. Therefore, in this study BCAL used 30% recycled material. This is also somewhat reflective of current legislation where minimum recycled content in paper bags is required (see Oakland City Council Ordinance requiring 40% recycled material). In the operations leading to final disposal BCAL estimated data for curbside collection and generation and recovery of materials in MSW from government agencies and EPA data, which for 2005 showed paper bag recycling at 21%, paper bag MSW for combustion with energy recovery at 13.6%, resulting in 65.4% to landfill[2]. The following final disposal options will also be considered: composting and two landfill scenarios.

2. *Recyclable Plastic Bag LCA……..The following operations are to be included in the analysis:* The extraction of fuels and feedstocks from the earth; transport of materials; all process and materials operations in the production of high and low density polyethylene resin[3]; converting PE resin into bags; packaging and transport of bags to distribution centers and grocery stores; consumer use; and final disposal. In the operations leading to final disposal, BCAL estimated data for curbside collection and generation and recovery of materials in MSW from government agencies and EPA data, which for 2005 showed plastic bag recycling at 5.2 %, plastic bag MSW for combustion with energy recovery at 13.6%, resulting in 81.2% to landfill[2]. The following final disposal options will also consider two landfill scenarios.

   Data for the converting operation was collected specifically from a member of the Progressive Bag Alliance that makes only plastic grocery bags. The data obtained, represents the entire annual production for 2006. All waste is reprocessed on site, so that is how the calculations were conducted. All inks are water-based, and the formulas provided. The production and supply of all PE resin is based on materials produced and transported from a Houston based supplier. The corrugated boxes were included as made from recycled material to reflect the fact that the supplier to the PBA member reported using between 30% and 40% post consumer recycled fiber[1].

3. *Degradable Plastic Bag (EcoFlex and PLA mix) LCA………The following operations are to be included in the analysis:* The extraction of fuels and feedstocks from the earth; production and transport of materials for all process and materials operations in the production of polylactide resin; EcoFlex from BASF (data provided by BASF)[4]; and calcium carbonate, converting the EcoFlex/PLA resin mixture into bags; packaging and transport of bags to distribution centers and grocery stores; consumer use; and final disposal. Again, most of the above operations are contained in the Boustead Model and Database. The production data for PLA was obtained from NatureWorks[5] and the data for EcoFlex was obtained from BASF[4]. Both NatureWorks and BASF use the Boustead Model for their LCA calculations, so the data BCAL requested and received was compatible with other data used in the study. In addition, BCAL sent its calculated results to BASF for confirmation that the data and the calculations on bags made from the EcoFlex compostable resin was accurate. BASF engineers confirmed that BCAL's use of the data and the calculated results were appropriate. In the operations leading to final disposal, BCAL estimated data for curbside collection and generation and recovery of materials in MSW from government agencies and EPA data[3], which for 2005 showed plastic bag recycling at 5.2 %, plastic bag MSW for combustion with energy recovery at 13.6%, resulting in 81.2% to landfill[2]. The following final disposal options will be also be considered: composting and two landfill scenarios.

   Data for the converting operation of the EcoFlex/PLA resin mixture was collected at the same PBA member facility during a two-week period at the end of May 2007. The production and supply of the PLA polymer is from Blair, NE. The production and supply of Ecoflex polymer is from a BASF plant in Germany. The trial operations at the PBA member's facility indicate that the overall energy required to produce a kilogram of EcoFlex/PLA bags may be lower than the overall energy required to produce a kilogram of PE bags, based on preliminary in-line electrical measurements conducted by plant engineers. However, these results still are preliminary, and need to be confirmed when full scale operations are implemented. As a result, this study will assume that the overall energy required to produce a kilogram of EcoFlex/PLA bags is the same as the overall energy required to produce a kilogram of PE bags. The plastic bag recycling at 5.2 %, will be assumed to go to composting. The inherent energy of the degradable bags has been estimated from NatureWorks and BASF sources.

The following are some detailed specifications for the LCA study:

	Recyclable Plastic	Degradable Plastic	Recyclable Paper
Size/type	1/6 BBL	1/6 BBL	1/6 BBL
Length (inches)	21.625	22.375	17
Width (inches)	12	11.5	12
Gusset (inches)	7.25	7.25	6.75
Gauge (Mil)	0.51	0.75	20 lb /1000 sq ft
Film Color	White	White	Kraft
Material	HDPE (film grade blend)	Degradable Film Compound (EcoFlex/PLA mix)	Unbleached Kraft Paper
Jog Test (strokes)	45	20	n/a
Tensile Strength (lb)	50	35	n/a
Weight per 1000 bags in lbs	13.15 (5.78 kg)	34.71 (15.78 kg)	114 (51.82 kg)

Human energy and capital equipment will not be included in the LCA; detailed arguments for this decision are presented in the proposal appendix.

Methodological Approach

BCAL followed the sound scientific practices as described in ISO 14040, 14041, and 14042 to produce the project results. BCAL is well versed in the requirements of the ISO standards as Dr. Ian Boustead has and continues to be one of the leading experts participating in the formation of the ISO standards. The procedures outlined below are consistent with the ISO standards and reflect BCAL's approach to this project.

Calculations of LCAs

The Boustead database contains over 6000 unit operations on the processes required to extract raw materials from the earth, process those materials into useable form, and manufacture products. These operations provide data on energy requirements, emissions and wastes.

The "Boustead Model" software was used to calculate the consumption of energy, fuels, and raw materials, and generation of solid, liquid, and gaseous wastes starting from the extraction of primary raw materials. The model consists of a calculating engine that was developed 25 years ago and has been updated regularly based on client needs and technical innovations. One important consequence of the modeling is that a mass balance for the entries system is calculated. Therefore, the resource use and the solid waste production are automatically calculated.

Fuel producing industry data are available for all of the OECD countries and some non-OECD countries. The United States and Canada are further analyzed by region; the US is divided into 9 regions and Canada is sub-divided in 5 regions, corresponding to the Electric Reliability Council. For both the US and Canada, there also is a national average. Since the whole of the Model database can be switched from one country to another, any operation with data from outside the US can be adjusted for energy from non-US energy inputs to “USA adjusted” energy inputs. Assuming that the technology is the same, or very similar, this allows BCAL to fill any data gaps with data from similar operations in non-US locations.

Another important aspect of calculating LCAs is the use of allocation procedures when differentiating the use of energy and raw materials associated with individual products within a single system. In many cases, allocation methods that defy or at the very least, ignore sound scientific practice (such as economics) have been used when they benefit clients. These types of errors or biases are important to avoid as they are easily discovered by peer reviewers or technical experts seeking to use the results in subsequent studies (such as building applications), which unfortunately can cause the rest of the work to be discounted due to unreliability. BCAL has considerable experience in this arena having published several technical papers on the appropriate allocation principles in the plastics industry. Utilizing sound scientific principles and objective measures to the greatest extent possible, BCAL has been able to avoid most problems associated with allocation decisions and produce accurate and reliable LCA data for a wide variety of plastics. Proof of this is the widespread use of PlasticsEurope data (produced by Boustead Consulting) in almost every life cycle database available worldwide as well as in life cycle studies in numerous product and building applications.

Calculated data are readily aggregated and used to produce the final LCA data set which includes the impact assessment step of LCA. These resulting data sets address specific environmental problems.

Using LCA data….BCAL scientific viewpoint

Life cycle assessment modeling allows an examination of specific problems as well as comparisons between systems to determine if there are any serious trade-offs between systems. In every system there are multiple environmental parameters to be addressed scaling from global to local issues. No single solution is likely to address all of the issues simultaneously. More importantly, whenever choices are being made to alter a system or to utilize an alternative system, there are potential trade-offs. Understanding those trade-offs is important when trying to identify the best possible environmental solution. Hopefully, decisions to implement a change to an existing system will consider the potential trade-offs and compromises. While LCA can identify the environmental factors and trade-offs, choosing the solution that is optimal is often subjective and political. Science can only help by providing good quality data from which decisions can be made. The strength of the proposed LCA assessment system is that these unwanted side effects can be identified and quantified.

A life cycle assessment can:

1. Quantify those parameters likely to be responsible for environmental effects (the inventory component of life cycle analysis).

2. Identify which parameters are likely to contribute to a specific environmental problem (characterization or interpretation phase of impact assessment). An example would be identifying that carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are greenhouse gases.
3. Aggregate the parameters relating to a specific problem (the valuation or interpretation phase of impact assessment). An example would be producing carbon dioxide equivalents for the components of greenhouse gases.

LCA derived data provide a compilation of information from which the user can address specific problems, while also examining potential trade-offs. For example, if interested in addressing specific conservation issues such as the conservation of fossil fuels, the user would examine the mass and energy data for only coal, oil, and natural gas; and ignore the other information. If the user would like to examine the potential impacts the grocery bag system has on global warming, acid rain, and municipal solid waste one can address these issues both individually and cooperatively by examining the specific parameters which are likely to contribute to each. In so doing, the user can strive to achieve the optimum reduction in each parameter because of a better understanding of how these parameters change in association with the grocery bag system as a whole and each other individually.

Data Sources and Data Quality

As noted above, data sources included published reports on similar materials, technical publications dealing with manufacturing processes, and data incorporated into the Boustead Model and Database, most of which has been generated through 30 years of industrial studies on a wide range of products and processes.

ISO standards 14040, 14041, and 14042 each discuss aspects of data quality as it pertains to life cycle assessments. In general, data quality can be evaluated using expert judgment, statistics, or sensitivity analysis. In LCA studies, much of the data do not lend itself to statistical analyses as the data are not collected randomly or as groups of data for each input variable. Instead, most LCA data are collected as single point estimates (i.e., fuel input, electricity input, product output, waste output, etc). Single point estimates are therefore only able to be evaluated through either expert judgment or sensitivity analysis. Since the reliability of data inevitably depends upon the quality of the information supplied by individual operators, BCAL used its expert judgment to carry out a number of elementary checks on quality. BCAL checked mass and energy balances to ensure that the data did not violate any of the basic physical laws. In addition, BCAL checked data from each source against data from other sources in the Boustead Model and Database to determine if any data fell outside the normal range for similar products or processes.

Data reporting

To enhance the comparability and understanding of the results of this study, the detailed LCA results are presented in the same presentation format that was used for the series of eco-profile reports published by the Association of Plastics Manufacturers in Europe

(APME). A set of eight tables, each describing some aspect of the behavior of the system, shows the results of the study. Five tables in the data set are useful in conservation arguments and three tables are indications of the potential pollution effects of the system.

The performance of the grocery bag systems is described by quantifying the inputs and outputs to the system. The calculation of input energy and raw materials quantifies the demand for primary inputs to the system and these parameters are important in conservation arguments because they are a measure of the resources that must be extracted from the earth in order to support the system.

Calculation of the outputs is an indication of the potential pollution effects of the system. Note that the analysis is concerned with quantifying the emissions; it does not make any judgments about deleterious or beneficial properties.

The inputs and outputs depend on the definition of the system—they are interrelated. Therefore, any changes to the components of the system means that the inputs and outputs will likely change as well. One common misconception is that it is possible to change a single input or output while leaving all other parameters unchanged. In fact, the reverse is true; because a new system has been defined by changing one input or output, all of the inputs and outputs are expected to change. If they happen to remain the same, it is a coincidence. This again illustrates the fact that common perceptions about environmental gains from simple changes may be misleading at best, and detrimental to the environment at worst.

Increasingly there is a demand to have the results of eco-profile analyses broken down into a number of categories, identifying the type of operation that gives rise to them. The five categories that have been identified are:

1. Fuel production
2. Fuel use
3. Transport
4. Biomass
5. Process

Fuel production operations are defined as those processing operations which result in the delivery of fuel, or energy; to a final consumer whether domestic or industrial. For such operations all inputs, with the sole exception of transport, are included as part of the fuel production function.

Fuel use is defined as the use of energy delivered by the fuel producing industries. Thus fuel used to generate steam at a production plant and electricity used in electrolysis would be treated as fuel use operations. Only the fuel used in transport is kept separate.

Transport operations are easily identified and so the direct energy consumption of transport and its associated emissions are always separated.

Biomass refers to the inputs and outputs associated with the use of biological materials such as wood or wood fiber.

LCA RESULTS TABLES

RECYCLABLE PAPER BAG SYSTEM

The results of the LCA for the recyclable paper bag system are presented below, each describing some aspect of the behavior of the systems examined. In all cases, the following tables refer to the gross or cumulative totals when all operations are traced back to the extraction of raw materials from the earth and are based on the consumer use and collection of 1000 bags. The subsequent disposal operations of recycling, composting, incineration with energy recovery and landfill are not included in these results tables and will be discussed separately.

Table 1. Gross energy (in MJ), required for the recyclable PAPER bag LCA. Based on consumer use & collection of 1000 bags. Totals may not agree because of rounding.

Fuel type	Fuel prod'n & delivery	Energy content of fuel	Transport energy	Feedstock energy	Total energy
Electricity	461	185	3	0	649
Oil	17	143	30	1	191
Other	15	777	1	990	1783
Total	493	1105	34	991	2622

Table 2. Gross primary fossil fuels and feedstocks, expressed as energy (in MJ), required for the recyclable PAPER bag LCA. Based on consumer use & collection of 1000 bags. Totals may not agree because of rounding.

	Fuel prod'n	Fuel use	Transport	Feedstock	Total
Coal	229	94	1	0	324
Oil	23	150	33	1	207
Gas	113	278	0	0	391
Hydro	15	6	0	-	21
Nuclear	90	36	0	-	127
Lignite	0	0	0	-	0
Wood	0	533	0	988	1521
Sulfur	0	0	0	2	2
Hydrogen	0	0	0	0	0
Biomass (solid)	18	7	0	0	24
Recovered energy	0	-1	0	-	-1
Geothermal	0	0	0	-	0
Unspecified	0	0	0	-	0
Solar	0	0	0	-	0
Biomass (liqd/gas)	1	0	0	-	1
Industrial waste	1	0	0	-	1
Municipal Waste	3	1	0	-	4
Wind	0	0	0	-	0
Totals	493	1105	34	991	2622

Table 3. Gross primary fossil fuels and feedstocks, expressed as mass (in milligrams), the recyclable PAPER bag LCA. Based on consumer use & collection of 1000 bags. Totals may not agree because of rounding.

Crude oil……………..	4,591,000
Gas/condensate………	7,432,000
Coal………………….	11,210,000
Metallurgical coal…...	25,900
Lignite …………….	79
Peat ………………….	444
Wood (50% water)…..	274,000,000
Biomass (incl. water)…	2,880,000

Table 4. Gross water resources (in milligrams) required for the recyclable PAPER bag LCA. Based on consumer use & collection of 1000 bags. Totals may not agree because of rounding.

Source	Use in process	Use in cooling	Totals
Public supply	3,895,000,000	-	3,895,000,000
River/canal	5,260	1,920	7,190
Sea	8,490	1,092,000	1,100,000
Unspecified	14,600,000	2,910,000	17,500,000
Well	200	50	250
Totals	3,909,000,000	4,000,000	3,913,000,000

Note: total cooling water reported in recirculating systems = 404.

Table 5. Gross other raw materials (in milligrams required for the recyclable PAPER bag LCA. Based on consumer use & collection of 1000 bags. Totals may not agree because of rounding.

Raw material	Input in mg
Air	4,080,000
Animal matter	0
Barites	211
Bauxite	469
Bentonite	51
Biomass (including water)	0
Calcium sulphate (CaSO4)	0
Chalk (CaCO3)	0
Clay	46,300
Cr	31
Cu	0
Dolomite	792
Fe	64,800
Feldspar	0
Ferromanganese	59
Fluorspar	9
Granite	0
Gravel	239
Hg	0
Limestone (CaCO3)	385,000
Mg	0
N2	6,050
Ni	0
O2	1,180
Olivine	608
Pb	395
Phosphate as P205	147,000
Potassium chloride (KCl)	7
Quartz (SiO2)	0
Rutile	0
S (bonded)	1
S (elemental)	233,000
Sand (SiO2)	101,600
Shale	1
Sodium chloride (NaCl)	712,000
Sodium nitrate (NaNO3)	0
Talc	0
Unspecified	0
Zn	14

Table 6. Gross air emissions (in milligrams) resulting from the recyclable PAPER bag LCA. Based on consumer use & collection of 1000 bags. Totals may not agree because of rounding.

Air emissions/mg	Fuel prod'n	Fuel use	Transport	Process	Biomass	Fugitive	Total
Dust	32,900	4,440	1,930	89,000	-	-	128,000
CO	59,500	16,300	23,000	21,900	-	-	121,000
CO2	43,100,000	22,600,000	2,330,000	1,066,000	-63,600,000	-	5,507,000
SOX	168,000	166,000	6,030	239,000	-	-	579,000
NOX	151,000	86,400	26,500	600	-	-	264,000
N2O	<1	<1	-	-	-		<1
Hydrocarbons	49,000	16,000	7,300	60	-		72,300
Methane	266,000	16,200	10	3,500	-		286,000
H2S	<1	-	<1	2,750	-	-	2,750
Aromatic HC	6	-	98	1	-	-	105
HCl	6,440	42	4	622	-		7,110
Cl2	<1	-	<1	<1	-		<1
HF	242	2	<1	<1	-		244
Lead	<1	<1	<1	<1	-		<1
Metals	25	105	-	<1	-		131
F2	<1	-	<1	<1	-		<1
Mercaptans	<1	<1	<1	802	-	-	802
H2	124	<1	<1	91	-	-	215
Organo-chlorine	<1	-	<1	<1	-		<1
Other organics	<1	<1	<1	<1	-		1
Aldehydes (CHO)	-	-	-	13	-		13
Hydrogen (H2)	152	-	-	3,130	-		3,280
NMVOC	2	-	<1	<1	-		2

Table 6B. Carbon dioxide equivalents corresponding to the gross air emissions (in milligrams) resulting from the recyclable PAPER bag LCA. Based on consumer use & collection of 1000 bags. Totals may not agree because of rounding.

Type/mg	Fuel prod'n	Fuel use	Transport	Process	Biomass	Total
20 year equiv	59,850,000	23,690,000	2,400,000	1,330,000	-63,560,000	23,710,000
100 year equiv	49,460,000	23,060,000	2,400,000	1,190,000	-63,560,000	12,550,000
500 year equiv	45,200,000	22,800,000	2,400,000	1,130,000	-63,560,000	7,970,000

Table 7. Gross water emissions (in milligrams), resulting from the recyclable PAPER bag LCA. Based on consumer use & collection of 1000 bags.. Totals may not agree because of rounding.

	Fuel prod'n	Fuel use	Transport	Process	Total
COD	55	-	35	396,000	396,000
BOD	14	-	<1	75,000	75,000
Acid (H+)	11	-	<1	1	13
Al+compounds as Al	<1	-	<1	<1	<1
Ammonium compounds as NH4	19	-	2	<1	22
AOX	<1	-	<1	<1	<1
As+compounds as As	-	-	<1	<1	<1
BrO3--	<1	-	<1	<1	<1
Ca+compounds as Ca	<1	-	<1	19	20
Cd+compounds as Cd	-	-	<1	-	<1
Cl-	25	-	35	10,400	10,400
ClO3--	<1	-	<1	97	97
CN-	<1	-	<1	<1	<1
CO3--	-	-	3	30	34
Cr+compounds as Cr	<1	-	<1	<1	<1
Cu+compounds as Cu	<1	-	<1	<1	<1
Detergent/oil	<1	-	2	3	6
Dichloroethane (DCE)	<1	-	<1	<1	<1
Dioxin/furan as Teq	-	-	<1	-	<1
Dissolved chlorine	<1	-	<1	<1	<1
Dissolved organics (non-HC)	23	-	<1	<1	23
Dissolved solids not specified	1	-	9	3,700	3,710
F-	<1	-	<1	<1	<1
Fe+compounds as Fe	<1	-	2	<1	3
Hg+compounds as Hg	<1	-	<1	<1	<1
Hydrocarbons not specified	<1	<1	2	<1	3
K+compounds as K	<1	-	<1	<1	<1
Metals not specified elsewhere	3	-	<1	3,060	3,060
Mg+compounds as Mg	<1	-	<1	<1	<1
Mn+compounds as Mn	-	-	<1	<1	<1
Na+compounds as Na	10	-	22	7,510	7,540
Ni+compounds as Ni	<1	-	<1	<1	<1
NO3-	1	-	<1	76	78
Organo-chlorine not specified	<1	-	<1	6	6
Organo-tin as Sn	-	-	<1	-	<1
Other nitrogen as N	3	-	<1	7,950	7,950
Other organics not specified	<1	-	<1	<1	<1
P+compounds as P	<1	-	<1	879	880
Pb+compounds as PB	<1	-	<1	<1	<1
Phenols	<1	-	<1	<1	<1
S+sulphides as S	<1	-	<1	344	344
SO4--	<1	-	8	1536	1,544
Sr+compounds as Sr	-	-	<1	<1	<1
Suspended solids	2,850	-	3,870	219,800	226,500
TOC	<1	-	<1	<1	<1
Vinyl chloride monomer	<1	-	<1	<1	<1
Zn+compounds as Zn	<1	-	<1	<1	<1

Table 8. Generation of solid waste (in milligrams resulting from the recyclable PAPER bag LCA. Based on consumer use & collection of 1000 bags. Totals may not agree because of rounding.

Solid waste (mg)	Fuel prod'n	Fuel use	Transport	Process	Total
Construction waste	<1	-	<1	<1	<1
Inert chemical	<1	-	<1	275	276
Metals	<1	-	<1	1,350	1,350
Mineral waste	2,590	-	38,500	1889,000	230,000
Mixed industrial	-26,300	-	1,550	22,900	-1,860
Municipal solid waste	-383,000	-	-	-	-383,000
Paper	<1	-	<1	<1	<1
Plastic containers	<1	-	<1	-	<1
Plastics	<1	-	<1	389	390
Putrescibles	<1	-	11	<1	11
Regulated chemicals	67,500	-	3	85	67,600
Slags/ash	921,000	5,290	15,000	5,380	947,000
Tailings	81	-	1,290	4	1,380
Unregulated chemicals	51,200	-	51	820	52,040
Unspecified refuse	55,300	-	<1	282,000	337,000
Waste returned to mine	2,202,000	-	1,420	345	2,203,000
Waste to compost	-	-	-	1,290,000	1,290,000
Waste to incinerator	1	-	18	16	35
Waste to recycle	<1	-	<1	2,544,000	2,544,000
Wood waste	<1	-	<1	306,000	306,000
Wood pallets to recycle	<1	-	<1	-	<1

RECYCLABLE PLASTIC BAG SYSTEM

The results of the LCA for the recyclable plastic bag system are presented below, each describing some aspect of the behavior of the systems examined. In all cases, the following tables refer to the gross or cumulative totals when all operations are traced back to the extraction of raw materials from the earth and are based on the consumer use and collection of 1000 bags and 1500 bags. The subsequent disposal operations of recycling, composting, incineration with energy recovery and landfill are not included in these results tables and will be discussed separately.

Table 9A. Gross energy (in MJ), required for the recyclable PLASTIC bag LCA. Based on consumer use & collection of 1000 bags. Totals may not agree because of rounding.

Fuel type	Fuel prod'n & delivery	Energy content of fuel	Transport energy	Feedstock energy	Total energy
Electricity	103	42	3	0	148
Oil	2	35	7	156	199
Other	2	37	0	123	162
Total	106	114	11	279	509

Table 9B. Gross energy (in MJ), required for the recyclable PLASTIC bag LCA. Based on consumer use & collection of 1500 bags. Totals may not agree because of rounding.

Fuel type	Fuel prod'n & delivery	Energy content of fuel	Transport energy	Feedstock energy	Total energy
Electricity	154	63	5	0	222
Oil	3	53	11	233	299
Other	2	55	1	185	242
Total	159	171	16	418	763

Table 10A. Gross primary fossil fuels and feedstocks, expressed as energy (in MJ), required for the recyclable PLASTIC bag LCA. Based on consumer use & collection of 1000 bags. Totals may not agree because of rounding.

	Fuel prod'n	Fuel use	Transport	Feedstock	Total
Coal	43	21	1	0	65
Oil	5	37	8	155	206
Gas	23	46	1	116	186
Hydro	4	2	0	-	6
Nuclear	26	11	1	-	38
Lignite	0	0	0	-	0
Wood	0	3	0	7	9
Sulfur	0	0	0	0	0
Hydrogen	0	0	0	-	0
Biomass (solid)	3	1	0	0	4
Recovered energy	0	-7	0	-	-7
Geothermal	0	0	0	-	0
Unspecified	0	0	0	-	0
Solar	0	0	0	-	0
Biomass (liqd/gas)	0	0	0	-	0
Industrial waste	0	0	0	0	0
Municipal Waste	1	0	0	-	1
Wind	0	0	0	-	0
Totals	106	114	11	279	509

Table 10B. Gross primary fossil fuels and feedstocks, expressed as energy (in MJ), required for the recyclable PLASTIC bag LCA. Based on consumer use & collection of 1500 bags. Totals may not agree because of rounding.

	Fuel prod'n	Fuel use	Transport	Feedstock	Total
Coal	65	31	2	0	98
Oil	8	56	12	233	309
Gas	35	69	2	175	279
Hydro	6	3	0	-	9
39	16	1	1	-	57
Lignite	0	0	0	-	0
Wood	0	4	0	10	14
Sulfur	0	0	0	0	0
Hydrogen	0	0	0	-	0
Biomass (solid)	4	2	0	0	6
Recovered energy	0	-11	0	-	-11
Geothermal	0	0	0	-	0
Unspecified	0	0	0	-	0
Solar	0	0	0	-	0
Biomass (liqd/gas)	0	0	0	-	0
Industrial waste	0	0	0	0	0
Municipal Waste	1	0	0	-	1
Wind	0	0	0	-	0
Totals	159	171	16	418	763

Table 11A. Gross primary fossil fuels and feedstocks, expressed as mass (in milligrams), required the recyclable PLASTIC bag LCA. Based on consumer use & collection of 1000 bags. Totals may not agree because of rounding.

Crude oil……………..	4,571,000
Gas/condensate………	3,065,000
Coal………………….	2,259,000
Metallurgical coal…...	6,060
Lignite …………….	670
Peat ………………….	7,920
Wood (50% water)…..	809,000
Biomass (incl. water)…	498,000

Table 11B. Gross primary fossil fuels and feedstocks, expressed as mass (in milligrams), required the recyclable PLASTIC bag LCA. Based on consumer use & collection of 1500 bags. Totals may not agree because of rounding.

Crude oil……………..	6,857,000
Gas/condensate………	4,598,000
Coal………………….	3,388,000
Metallurgical coal…...	9,100
Lignite …………….	1,010
Peat ………………….	11,900
Wood (50% water)…..	1,212,000
Biomass (incl. water)…	746,000

Table 12A. Gross water resources (in milligrams) required for the recyclable PLASTIC bag LCA. Based on consumer use & collection of 1000 bags. Totals may not agree because of rounding.

Source	Use in process	Use in cooling	Totals
Public supply	31,900,000	1,230,000	33,150,000
River/canal	4,970,000	2,520,000	7,480,000
Sea	819,000	58,600,000	59,400,000
Unspecified	5,120,000	105,400,000	110,600,000
Well	425,000	66,000	138,000
Total	43,250,000	167,800,000	211,100,000

Table 12B. Gross water resources (in milligrams) required for the recyclable PLASTIC bag LCA. Based on consumer use & collection of 1500 bags. Totals may not agree because of rounding.

Source	Use in process	Use in cooling	Totals
Public supply	47,900,000	1,850,000	49,700,000
River/canal	7,460,000	3,780,000	11,200,000
Sea	1,230,000	87,900,000	89,100,000
Unspecified	7,680,000	158,000,000	166,000,000
Well	638,000	99,000	207,000
Total	64,900,000	252,000,000	317,000,000

Table 13A. Gross other raw materials (in milligrams required for the recyclable PLASTIC bag LCA. Based on consumer use & collection of 1000 bags. Totals may not agree because of rounding.

Raw material	Input in mg
Air	1,436,000
Animal matter	<1
Barites	343
Bauxite	111
Bentonite	231
Calcium sulphate (CaSO4)	22
Clay	235
Cr	7
Cu	<1
Dolomite	184
Fe	15,000
Feldspar	<1
Ferromanganese	14
Fluorspar	3
Granite	<1
Gravel	56
Hg	<1
Limestone (CaCO3)	542,000
Mg	<1
N2	823,000
Ni	<1
O2	110,000
Olivine	141
Pb	87
Phosphate as P205	743
Potassium chloride (KCl)	252
Quartz (SiO2)	0
Rutile	272,000
S (bonded)	13
S (elemental)	1,520
Sand (SiO2)	935
Shale	63
Sodium chloride (NaCl)	51,200
Sodium nitrate (NaNO3)	0
Talc	<1
Unspecified	<1
Zn	266

Table 13B. Gross other raw materials (in milligrams required for the recyclable PLASTIC bag LCA. Based on consumer use & collection of 1500 bags. Totals may not agree because of rounding.

Raw material	Input in mg
Air	2,154,000
Animal matter	<1
Barites	515
Bauxite	166
Bentonite	347
Calcium sulphate (CaSO4)	33
Clay	353
Cr	10
Cu	<1
Dolomite	276
Fe	22,600
Feldspar	<1
Ferromanganese	21
Fluorspar	4
Granite	<1
Gravel	83
Hg	<1
Limestone (CaCO3)	812,000
Mg	<1
N2	1,235,000
Ni	<1
O2	165,000
Olivine	212
Pb	131
Phosphate as P205	1,120
Potassium chloride (KCl)	379
Quartz (SiO2)	0
Rutile	408,000
S (bonded)	20
S (elemental)	2,270
Sand (SiO2)	1,400
Shale	94
Sodium chloride (NaCl)	76,700
Sodium nitrate (NaNO3)	0
Talc	<1
Unspecified	<1
Zn	399

Table 14A. Gross air emissions (in milligrams) resulting from the recyclable PLASTIC bag LCA. Based on consumer use & collection of 1000 bags. Totals may not agree because of rounding.

Air emissions/mg	Fuel prod'n	Fuel use	Transport	Process	Biomass	Fugitive	Total
Dust (PM10)	6,340	540	430	7,000	-	-	14,300
CO	10,800	48,900	5,110	2,570	-	-	67,400
CO2	8,570,000	5,390,000	551,000	953,000	-427,000	-	15,030,000
SOX as SO2	35,700	9,130	2,000	3,640	-	-	50,500
H2S	<1	-	<1	14	-	-	14
Mercaptan	<1	<1	-	4	-		4
NOX as NO2	28,500	10,000	6,060	870	-	-	45,400
Aledhyde (-CHO)	<1	-	<1	<1	-	-	<1
Aromatic HC not spec	1	-	22	380	-	-	403
Cd+compounds as Cd	<1	-	<1	-	-		<1
CH4	40,900	1,660	3	20,700	-	-	63,300
Cl2	<1	-	<1	29	-	-	29
Cr+compounds as Cr	<1	-	<1	-	-	-	<1
CS2	<1	-	<1	<1	-		<1
Cu+compounds as Cu	<1	-	<1	-	-	-	<1
Dichlorethane (DCE)	<1	-	<1	<1	-	<1	<1
Ethylene C2H4	-	-	<1	-	-	-	<1
F2	<1	-	<1	<1	-	-	<1
H2	68	2	<1	754	-	-	824
H2SO4	<1	-	<1	<1	-	-	<1
HCl	1,220	95	<1	3	-	-	1,320
HCN	<1	-	<1	<1	-	-	<1
HF	46	1	<1	<1	-	-	47
Hg+compounds as Hg	<1	-	<1	<1	--	-	<1
Hydrocarbons not spec	7,430	920	1,670	13,100	-	-	23,100
Metals not specified	6	5	<1	3	-	-	14
Methylene chloride CH2	<1	-	<1	<1	-	-	<1
N2O	<1	<1	<1	-	-	-	<1
NH3	<1	-	<1	8	-	-	8
Ni compounds as Ni	<1	-	<1	-	-	-	<1
NMVOC	<1	-	<1	993	-	-	994
Organics	<1	<1	<1	367	-	-	367
Organo-chlorine not spec	<1	-	<1	<1	-	-	<1
Pb+compounds as Pb	<1	<1	<1	<1	-	-	<1
Polycyclic hydrocarbon	<1	-	<1	<1	-	-	<1
Sb+compounds as Sb	-	-	<1	-	-	-	<1
Vinyl chloride monomer	<1	-	<1	<1	-	<1	<1
Zn+compounds as Zn	<1	-	<1	<1	-	-	<1

Table 14B. Carbon dioxide equivalents corresponding to the gross air emissions (in milligrams) resulting from the recyclable PLASTIC bag LCA. Based on consumer use & collection of 1000 bags. Totals may not agree because of rounding.

Type/mg	Fuel prod'n	Fuel use	Transport	Process	Biomass	Total
20 year equiv	11,100,000	5,590,000	566,000	2,280,000	-427,000	19,200,000
100 year equiv	9,550,000	5,530,000	566,000	1,470,000	-427,000	16,700,000
500 year equiv	8,900,000	5,500,000	566,000	1,140,000	-427,000	15,700,000

Table 14C. Gross air emissions (in milligrams) resulting from the recyclable PLASTIC bag LCA. Based on consumer use & collection of 1500 bags. Totals may not agree because of rounding.

Air emissions/mg	Fuel prod'n	Fuel use	Transport	Process	Biomass	Fugitive	Total
Dust (PM10)	9,500	811	644	10,500	-	-	21,500
CO	16,100	73,400	7,670	3,850	-	-	101,000
CO2	12,900,000	8,082,000	826,000	1,429,000	-640,000	-	22,550,000
SOX as SO2	53,500	13,700	3,000	5,460	-	-	75,700
H2S	<1	-	<1	21	-	-	22
Mercaptan	<1	<1	-	6	-		6
NOX as NO2	42,700	15,100	9,090	1,310	-	-	68,100
Aledhyde (-CHO)	<1	-	<1	<1	-	-	<1
Aromatic HC not spec	2	-	33	570	-	-	604
Cd+compounds as Cd	<1	-	<1	-	-		<1
CH4	61,400	2,490	4	31,090	-	-	95,000
Cl2	<1	-	<1	43	-	-	43
Cr+compounds as Cr	<1	-	<1	-	-	-	<1
CS2	<1	-	<1	<1	-		<1
Cu+compounds as Cu	<1	-	<1	-	-	-	<1
Dichlorethane (DCE)	<1	-	<1	<1	-	<1	<1
Ethylene C2H4	-	-	<1	-	-	-	<1
F2	<1	-	<1	<1	-	-	<1
H2	102	2	<1	1,130	-	-	1,240
H2SO4	<1	-	<1	<1	-	-	<1
HCl	1,830	142	1	5	-	-	1,980
HCN	<1	-	<1	<1	-	-	<1
HF	69	2	<1	<1	-	-	71
Hg+compounds as Hg	<1	-	<1	<1	--	-	<1
Hydrocarbons not spec	11,100	1,380	2,510	19,700	-	-	34,700
Metals not specified	9	7	<1	5	-	-	21
Methylene chloride CH2	<1	-	<1	<1	-	-	<1
N2O	<1	<1	<1	-	-	-	<1
NH3	<1	-	<1	12	-	-	12
Ni compounds as Ni	<1	-	<1	-	-	-	<1
NMVOC	<1	-	<1	1,490	-	-	1,490
Organics	<1	<1	<1	551	-	-	551
Organo-chlorine not spec	<1	-	<1	<1	-	-	<1
Pb+compounds as Pb	<1	<1	<1	<1	-	-	<1
Polycyclic hydrocarbon	<1	-	<1	<1	-	-	<1
Sb+compounds as Sb	-	-	<1	-	-	-	<1
Vinyl chloride monomer	<1	-	<1	<1	-	<1	<1
Zn+compounds as Zn	<1	-	<1	<1	-	-	<1

Table 14D. Carbon dioxide equivalents corresponding to the gross air emissions (in milligrams) resulting from the recyclable PLASTIC bag LCA. Based on consumer use & collection of 1500 bags. Totals may not agree because of rounding.

Type/mg	Fuel prod'n	Fuel use	Transport	Process	Biomass	Total
20 year equiv	16,700,000	8,390,000	849,000	3,420,000	-641,000	28,800,000
100 year equiv	14,300,000	8,300,000	849,000	2,210,000	-641,000	25,100,000
500 year equiv	13,400,000	8,250,000	849,000	1,710,000	-641,000	23,600,000

Table 15A. Gross water emissions (in milligrams), resulting from the recyclable PLASTIC bag LCA. Based on consumer use & collection of 1000 bags. Totals may not agree because of rounding.

	Fuel prod'n	Fuel use	Transport	Process	Total
COD	9	-	8	5390	5,410
BOD	2	-	<1	543	545
Acid (H+)	4	-	<1	9	13
Al+compounds as Al	<1	-	<1	4	4
Ammonium compounds as NH4	5	-	<1	11	17
AOX	<1	-	<1	<1	<1
As+compounds as As	-	-	<1	<1	<1
BrO3--	<1	-	<1	<1	<1
Ca+compounds as Ca	<1	-	<1	20	20
Cd+compounds as Cd	-	-	<1	-	<1
Cl-	3	-	8	3,060	3,070
ClO3--	<1	-	<1	15	15
CN-	<1	-	<1	<1	<1
CO3--	-	-	<1	181	182
Cr+compounds as Cr	<1	-	<1	<1	<1
Cu+compounds as Cu	<1	-	<1	1	1
Detergent/oil	<1	-	<1	39	40
Dichloroethane (DCE)	<1	-	<1	<1	<1
Dioxin/furan as Teq	-	-	<1	-	<1
Dissolved chlorine	<1	-	<1	<1	<1
Dissolved organics (non-HC)	3	-	<1	44	47
Dissolved solids not specified	2	-	2	947	952
F-	<1	-	<1	<1	<1
Fe+compounds as Fe	<1	-	<1	<1	<1
Hg+compounds as Hg	<1	-	<1	<1	<1
Hydrocarbons not specified	26	<1	<1	3	30
K+compounds as K	<1	-	<1	11	11
Metals not specified elsewhere	<1	-	<1	54	55
Mg+compounds as Mg	<1	-	<1	<1	<1
Mn+compounds as Mn	-	-	<1	<1	<1
Na+compounds as Na	2	-	5	3,136	3,143
Ni+compounds as Ni	<1	-	<1	<1	<1
NO3-	1	-	<1	13	13
Organo-chlorine not specified	<1	-	<1	<1	<1
Organo-tin as Sn	-	-	<1	-	<1
Other nitrogen as N	<1	-	<1	46	47
Other organics not specified	<1	-	<1	<1	<1
P+compounds as P	<1	-	<1	7	7
Pb+compounds as PB	<1	-	<1	<1	<1
Phenols	<1	-	<1	10	10
S+sulphides as S	<1	-	<1	2	2
SO4--	<1	-	2	4,097	4,098
Sr+compounds as Sr	-	-	<1	<1	<1
Suspended solids	573	-	861	78,300	79,800
TOC	<1	-	<1	60	60
Vinyl chloride monomer	<1	-	<1	<1	<1
Zn+compounds as Zn	<1	-	<1	<1	<1

Table 15B. Gross water emissions (in milligrams), resulting from the recyclable PLASTIC bag LCA. Based on consumer use & collection of 1500 bags. Totals may not agree because of rounding.

	Fuel prod'n	Fuel use	Transport	Process	Total
COD	14	-	12	8,080	8,110
BOD	3	-	<1	814	817
Acid (H+)	6	-	<1	13	19
Al+compounds as Al	<1	-	<1	5	5
Ammonium compounds as NH4	7	-	<1	17	25
AOX	<1	-	<1	<1	<1
As+compounds as As	-	-	<1	<1	<1
BrO3--	<1	-	<1	<1	<1
Ca+compounds as Ca	<1	-	<1	30	30
Cd+compounds as Cd	-	-	<1	-	<1
Cl-	5	-	11	4,590	4,610
ClO3--	<1	-	<1	22	22
CN-	<1	-	<1	<1	<1
CO3--	-	-	1	272	273
Cr+compounds as Cr	<1	-	<1	<1	<1
Cu+compounds as Cu	<1	-	<1	2	2
Detergent/oil	<1	-	<1	59	60
Dichloroethane (DCE)	<1	-	<1	<1	<1
Dioxin/furan as Teq	-	-	<1	-	<1
Dissolved chlorine	<1	-	<1	1	1
Dissolved organics (non-HC)	4	-	<1	66	70
Dissolved solids not specified	3	-	3	1,420	1,430
F-	<1	-	<1	<1	<1
Fe+compounds as Fe	<1	-	<1	<1	<1
Hg+compounds as Hg	<1	-	<1	<1	<1
Hydrocarbons not specified	39	<1	<1	4	45
K+compounds as K	<1	-	<1	16	16
Metals not specified elsewhere	1	-	<1	81	83
Mg+compounds as Mg	<1	-	<1	<1	<1
Mn+compounds as Mn	-	-	<1	<1	<1
Na+compounds as Na	3	-	8	4,700	4,710
Ni+compounds as Ni	<1	-	<1	<1	<1
NO3-	<1	-	<1	19	19
Organo-chlorine not specified	<1	-	<1	<1	<1
Organo-tin as Sn	-	-	<1	-	<1
Other nitrogen as N	1	-	<1	69	70
Other organics not specified	<1	-	<1	<1	<1
P+compounds as P	<1	-	<1	10	10
Pb+compounds as PB	<1	-	<1	<1	<1
Phenols	<1	-	<1	15	15
S+sulphides as S	<1	-	<1	3	3
SO4--	<1	-	3	6,150	6,150
Sr+compounds as Sr	-	-	<1	<1	<1
Suspended solids	860	-	1,290	117,500	119,600
TOC	<1	-	<1	90	90
Vinyl chloride monomer	<1	-	<1	<1	<1
Zn+compounds as Zn	<1	-	<1	1	1

Table 16A. Generation of solid waste (in milligrams resulting from the recyclable PLASTIC bag LCA. Based on consumer use & collection of 1000 bags. Totals may not agree because of rounding.

Solid waste (mg)	Fuel prod'n	Fuel use	Transport	Process	Total
Construction waste	<1	-	<1	<1	<1
Inert chemical	<1	-	<1	3,446	3,446
Metals	<1	-	<1	301	301
Mineral waste	974	-	8,564	324,200	333,700
Mixed industrial	-11,800	-	345	5,520	-5,950
Municipal solid waste	-79,800	-	-	22,500	-57,300
Paper	<1	-	<1	<1	<1
Plastic containers	<1	-	<1	-	<1
Plastics	<1	-	<1	53,600	53,600
Putrescibles	<1	-	2	7	10
Regulated chemicals	9,040	-	<1	4,720	13,800
Slags/ash	180,000	4,460	3,330	1,660	189,000
Tailings	16	-	287	1,048	1,350
Unregulated chemicals	6,810	-	11	7,190	14,000
Unspecified refuse	7,350	-	<1	62,900	70,200
Waste returned to mine	443,000	-	316	872	444,400
Waste to compost	-	-	-	9,290	9,290
Waste to incinerator	<1	-	4	4,370	4,380
Waste to recycle	<1	-	<1	33,200	33,200
Wood waste	<1	-	<1	2,330	2,330
Wood pallets to recycle	<1	-	<1	298,000	298,000

Table 16B. Generation of solid waste (in milligrams resulting from the recyclable PLASTIC bag LCA. Based on consumer use & collection of 1500 bags. Totals may not agree because of rounding.

Solid waste (mg)	Fuel prod'n	Fuel use	Transport	Process	Total
Construction waste	<1	-	<1	<1	<1
Inert chemical	<1	-	<1	5,170	5,170
Metals	<1	-	<1	452	452
Mineral waste	1,460	-	12,800	486,000	501,000
Mixed industrial	-17,700	-	517	8,280	-8,930
Municipal solid waste	1119,700	-	-	33,800	-85,900
Paper	<1	-	<1	<1	<1
Plastic containers	<1	-	<1	-	<1
Plastics	<1	-	<1	80,400	80,400
Putrescibles	<1	-	4	11	14
Regulated chemicals	13,600	-	<1	7,080	20,600
Slags/ash	270,000	6,680	4,990	2,480	284,000
Tailings	24	-	430	1,570	2,030
Unregulated chemicals	10,200	-	17	10,800	21,000
Unspecified refuse	11,030	-	<1	94,300	105,400
Waste returned to mine	665,000	-	475	1,310	667,000
Waste to compost	-	-	-	13,900	13,900
Waste to incinerator	<1	-	6	6,560	6,560
Waste to recycle	<1	-	<1	49,800	49,800
Wood waste	<1	-	<1	3,500	3,500
Wood pallets to recycle	<1	-	<1	447,000	447,000

THE COMPOSTABLE PLASTIC BAG SYSTEM

The results of the LCA for the compostable plastic bag system are presented below, each describing some aspect of the behavior of the systems examined. In all cases, the following tables refer to the gross or cumulative totals when all operations are traced back to the extraction of raw materials from the earth and are based on the consumer use and collection of 1000 bags and 1500 bags. The subsequent disposal operations of recycling, composting, incineration with energy recovery and landfill are not included in these results tables and will be discussed separately.

Table 17A. Gross energy (in MJ), required for the COMPOSTABLE PLASTIC bag LCA. Based on consumer use & collection of 1000 bags. Totals may not agree because of rounding.

Fuel type	Fuel prod'n & delivery	Energy content of fuel	Transport energy	Feedstock energy	Total energy
Electricity	221	103	1	0	325
Oil	29	279	36	1	345
Other	15	277	1	417	710
Total	265	659	38	418	1380

Table 17B. Gross energy (in MJ), required for the COMPOSTABLE PLASTIC bag LCA. Based on consumer use & collection of 1500 bags. Totals may not agree because of rounding.

Fuel type	Fuel prod'n & delivery	Energy content of fuel	Transport energy	Feedstock energy	Total energy
Electricity	331	154	2	0	487
Oil	44	418	54	1	518
Other	22	416	2	625	1065
Total	398	988	57	627	2070

Table 18A. Gross primary fossil fuels and feedstocks, expressed as energy (in MJ), required for the COMPOSTABLE PLASTIC bag LCA. Based on consumer use & collection of 1000 bags. Totals may not agree because of rounding.

	Fuel prod'n	Fuel use	Transport	Feedstock	Total
Coal	113	48	1	0	161
Oil	34	281	37	1	353
Gas	44	301	1	360	705
Hydro	7	2	0	-	9
Nuclear	62	11	0	-	74
Lignite	0	0	0	-	0
Wood	0	7	0	18	26
Sulfur	0	0	0	0	0
Hydrogen	0	0	0	0	0
Biomass (solid)	6	2	0	39	47
Recovered energy	-2	-5	0	-	-8
Geothermal	0	0	0	-	0
Unspecified	0	0	0	-	0
Solar	0	0	0	-	0
Biomass (liqd/gas)	0	0	0	-	0
Industrial waste	1	0	0	-	1
Municipal Waste	1	0	0	-	1
Wind	0	11	0	-	11
Totals	265	659	38	418	1,380

Table 18B. Gross primary fossil fuels and feedstocks, expressed as energy (in MJ), required for the COMPOSTABLE PLASTIC bag LCA. Based on consumer use & collection of 1500 bags. Totals may not agree because of rounding.

	Fuel prod'n	Fuel use	Transport	Feedstock	Total
Coal	169	72	1	0	241
Oil	51	422	55	1	529
Gas	65	451	1	540	1,057
Hydro	11	3	0	-	14
Nuclear	94	17	0	-	111
Lignite	0	0	0	-	0
Wood	0	11	0	27	38
Sulfur	0	0	0	0	0
Hydrogen	0	0	0	0	0
Biomass (solid)	9	4	0	58	71
Recovered energy	-4	-8	0	-	-11
Geothermal	0	0	0	-	0
Unspecified	0	0	0	-	0
Solar	0	0	0	-	0
Biomass (liqd/gas)	0	0	0	-	0
Industrial waste	1	0	0	-	1
Municipal Waste	1	1	0	-	2
Wind	0	16	0	-	16
Totals	398	988	57	627	2,070

Table 19A. Gross primary fossil fuels and feedstocks, expressed as mass (in milligrams), required the COMPOSTABLE PLASTIC bag LCA. Based on consumer use & collection of 1000 bags. Totals may not agree because of rounding.

Crude oil……………..	7,840,000
Gas/condensate………	14,020,000
Coal………………….	5,760,000
Metallurgical coal…...	17,000
Lignite …………….	0
Peat ………………….	7
Wood (50% water)…..	2,210,000
Biomass (incl. water)…	986,000

Table 19B. Gross primary fossil fuels and feedstocks, expressed as mass (in milligrams), required the COMPOSTABLE PLASTIC bag LCA. Based on consumer use & collection of 1500 bags. Totals may not agree because of rounding.

Crude oil……………..	11,760,000
Gas/condensate………	21,030,000
Coal………………….	8,630,000
Metallurgical coal…...	25,000
Lignite …………….	0
Peat ………………….	10
Wood (50% water)…..	3,310,000
Biomass (incl. water)…	1,480,000

Table 20A. Gross water resources (in milligrams) required for the COMPOSTABLE PLASTIC bag LCA. Based on consumer use & collection of 1000 bags. Totals may not agree because of rounding.

Source	Use in process	Use in cooling	Totals
Public supply	2,540,000,000	19,200,000	2,560,000,000
River/canal	3,870	1,690,000	1,700,000
Sea	13,100	2,710,000	2,720,000
Unspecified	36,600,000	6,270,000	42,900,000
Well	564,000	49	564,000
Totals	2,580,000,000	29,900,000	2,607,000,000

Table 20B. Gross water resources (in milligrams) required for the COMPOSTABLE PLASTIC bag LCA. Based on consumer use & collection of 1500 bags. Totals may not agree because of rounding.

Source	Use in process	Use in cooling	Totals
Public supply	3,810,000,000	28,800,000	3,840,000,000
River/canal	5,810	2,540,000	2,550,000
Sea	19,650	4,065,000	4,080,000
Unspecified	54,900,000	9,410,000	64,350,000
Well	846,000	74	846,000
Totals	3,870,000,000	44,900,000	3,910,000,000

Table 21A. Gross other raw materials (in milligrams) required for the COMPOSTABLE PLASTIC bag LCA. Based on consumer use & collection of 1000 bags. Totals may not agree because of rounding.

Raw material	Input in mg
Air	1,460,000
Animal matter	0
Barites	1,700
Bauxite	4,000
Bentonite	99
Calcium sulphate ($CaSO_4$)	<1
Clay	34,200
Cr	19
Cu	0
Dolomite	513
Fe	47,300
Feldspar	0
Ferromanganese	38
Fluorspar	3
Granite	0
Gravel	155
Hg	0
Limestone ($CaCO_3$)	4,230,000
Mg	0
N_2 for reaction	17,900
Ni	0
O_2 for reaction	1,030
Olivine	394
Pb	260
Phosphate as P205	12,300
Potassium chloride (KCl)	23,000
Quartz (SiO_2)	0
Rutile	0
S (bonded)	401,000
S (elemental)	23,700
Sand (SiO_2)	22,400
Shale	2
Sodium chloride (NaCl)	261,000
Sodium nitrate ($NaNO_3$)	0
Talc	0
Unspecified	0
Zn	9

Table 21B. Gross other raw materials (in milligrams) required for the COMPOSTABLE PLASTIC bag LCA. Based on consumer use & collection of 1500 bags. Totals may not agree because of rounding.

Raw material	Input in mg
Air	2,190,000
Animal matter	0
Barites	2,550
Bauxite	6,010
Bentonite	148
Calcium sulphate ($CaSO_4$)	<1
Clay	51,300
Cr	28
Cu	0
Dolomite	769
Fe	71,000
Feldspar	0
Ferromanganese	57
Fluorspar	5
Granite	0
Gravel	232
Hg	0
Limestone ($CaCO_3$)	6,350,000
Mg	0
N_2 for reaction	26,800
Ni	0
O_2 for reaction	1,550
Olivine	591
Pb	390
Phosphate as P205	18,400
Potassium chloride (KCl)	34,500
Quartz (SiO_2)	0
Rutile	0
S (bonded)	602,000
S (elemental)	35,500
Sand (SiO_2)	33,600
Shale	3
Sodium chloride (NaCl)	392,000
Sodium nitrate ($NaNO_3$)	0
Talc	0
Unspecified	0
Zn	14

Table 22A. Gross air emissions (in milligrams) resulting from the COMPOSTABLE PLASTIC bag LCA. Based on consumer use & collection of 1000 bags. Totals may not agree because of rounding.

Air emissions/mg	Fuel prod'n	Fuel use	Transport	Process	Biomass	Fugitive	Total
Dust (PM10)	9,120	520	1,500	42,200	-	-	53,400
CO	16,000	4,900	16,900	4,100	-	-	41,900
CO2	13,860,000	2,620,000	2,580,000	41,800,000	-4,230,000	-	56,600,000
SOX as SO2	54,900	7,210	21,100	192,000	-	-	275,000
H2S	0	0	1	40	-	-	41
Mercaptan	0	0	0	11	-		11
NOX as NO2	50,000	8,260	24,500	221,500	-	-	304,000
Aledhyde (-CHO)	0	0	0	0	-	-	0
Aromatic HC not spec	2	-	67	4	-	-	74
Cd+compounds as Cd	0	-	0	-	-		0
CFC/HCFC/HFC not sp	0	-	0	0	-		0
CH4	59,600	1,060	98	224,000	-	-	284,000
Cl2	0	-	0	0	-	-	0
Cr+compounds as Cr	0	-	0	-	-	-	0
CS2	0	-	0	0	-		0
Cu+compounds as Cu	0	-	0	-	-	-	0
Dichlorethane (DCE)	0	-	0	0	-	0	0
Ethylene C2H4	-	-	0	-	-	-	0
F2	0	-	0	0	-	-	0
H2	38	0	0	226	-	-	264
H2SO4	0	-	0	0	-	-	0
HCl	2,140	6	3	871	-	-	3,020
HCN	0	-	0	0	-	-	0
HF	81	0	0	0	-	-	81
Hg+compounds as Hg	0	-	0	0	--	-	0
Hydrocarbons not spec	13,800	1,720	6,400	100	-	-	22,000
Metals not specified	8	4	0	0	0	-	12
Molybdenum	-	-	-	1	-	-	1
N2O	0	0	0	53,100	-	-	53,100
NH3	0	-	0	39	-	-	39
Ni compounds as Ni	0	-	0	-	-	-	0
NMVOC	0	72	410	46,400	-	-	46,900
Organics	0	0	0	119	-	-	119
Organo-chlorine not spec	0	-	0	16	-	-	16
Pb+compounds as Pb	0	0	0	0	-	-	0
Polycyclic hydrocarbon	0	-	0	0	-	-	0
Titanium	-	-	-	119	-	-	119
Vinyl chloride monomer	0	-	0	0	-	-	0
Zn+compounds as Zn	0	-	0	0	-	-	0

Table 22B. Carbon dioxide equivalents corresponding to the gross air emissions (in milligrams) from the COMPOSTABLE PLASTIC bag LCA. Based on consumer use & collection of 1000 bags. Totals may not agree because of rounding.

Type/mg	Fuel prod'n	Fuel use	Transport	Process	Biomass	Total
20 year equiv	17,630,000	2,700,000	2,640,000	70,200,000	-4,230,000	89,000,000
100 year equiv	15,300,000	2,660,000	2,640,000	62,640,000	-4,230,000	79,000,000
500 year equiv	14,300,000	2,640,000	2,400,000	51,600,000	-4,230,000	67,000,000

Table 22C. Gross air emissions (in milligrams) resulting from the COMPOSTABLE PLASTIC bag LCA. Based on consumer use & collection of 1500 bags. Totals may not agree because of rounding.

Air emissions/mg	Fuel prod'n	Fuel use	Transport	Process	Biomass	Fugit ive	Total
Dust (PM10)	13,700	780	2,260	63,400	-	-	80,100
CO	24,000	7,360	25,300	6,150	-	-	62,900
CO2	20,800,000	3,930,000	3,880,000	62,700,000	-6,340,000	-	84,900,000
SOX as SO2	82,400	10,800	31,600	288,000	-	-	413,000
H2S	0	0	2	60	-	-	62
Mercaptan	0	0	0	17	-		17
NOX as NO2	74,900	12,400	36,700	332,000	-	-	456,000
Aledhyde (-CHO)	0	0	0	0	-	-	0
Aromatic HC not spec	3	-	101	7	-	-	111
Cd+compounds as Cd	0	-	0	-	-		0
CFC/HCFC/HFC not sp	0	-	0	0	-		0
CH4	89,500	1,590	147	335,000	-	-	426,000
Cl2	0	-	0	0	-	-	0
Cr+compounds as Cr	0	-	0	-	-	-	0
CS2	0	-	0	0	-		0
Cu+compounds as Cu	0	-	0	-	-	-	0
Dichlorethane (DCE)	0	-	0	0	-	-	0
Ethylene C2H4	-	-	0	-	-	-	0
F2	0	-	0	0	-	-	0
H2	57	0	0	339	-	-	397
H2SO4	0	-	0	0	-	-	0
HCl	3,220	8	5	1,310	-	-	4,540
HCN	0	-	0	0	-	-	0
HF	121	0	0	0	-	-	122
Hg+compounds as Hg	0	-	0	0	--	-	0
Hydrocarbons not spec	20,600	2,580	9,590	150	-	-	33,000
Metals not specified	13	5	0	0	0	-	18
Molybdenum	-	-	-	2	-	-	2
N2O	0	0	0	79,600	-	-	79,600
NH3	0	-	0	59	-	-	59
Ni compounds as Ni	0	-	0	-	-	-	0
NMVOC	1	108	615	69,600	-	-	70,300
Organics	0	0	0	178	-	-	178
Organo-chlorine not spec	0	-	0	24	-	-	24
Pb+compounds as Pb	0	0	0	0	-	-	0
Polycyclic hydrocarbon	0	-	0	0	-	-	0
Titanium	-	-	-	178	-	-	178
Vinyl chloride monomer	0	-	0	0	-	-	0
Zn+compounds as Zn	0	-	0	0	-	-	0

Table 22D. Carbon dioxide equivalents corresponding to the gross air emissions (in milligrams) from the COMPOSTABLE PLASTIC bag LCA. Based on consumer use & collection of 1500 bags. Totals may not agree because of rounding.

Type/mg	Fuel prod'n	Fuel use	Transport	Process	Biomass	Total
20 year equiv	26,400,000	4,050,000	3,960,000	105,300,000	-6,350,000	134,000,000
100 year equiv	23,000,000	3,990,000	3,960,000	94,000,000	-6,350,000	119,000,000
500 year equiv	21,500,000	3,960,000	3,600,000	77,400,000	-6,350,000	101,000,000

Table 23A. Gross water emissions (in milligrams), resulting from the COMPOSTABLE PLASTIC bag LCA. Based on consumer use & collection of 1000 bags. Totals may not agree because of rounding.

	Fuel prod'n	Fuel use	Transport	Process	Total
COD	15	2	57	59,700	59,800
BOD	4	-	4	3,190	3,200
Acid (H+)	2	-	0	0	4
Al+compounds as Al	0	-	0	2	2
Ammonium compounds as NH4	5	-	2	0	7
AOX	0	-	0	10	10
As+compounds as As	-	-	0	0	0
BrO3--	0	-	0	0	0
Ca+compounds as Ca	0	-	0	201	201
Cd+compounds as Cd	-	-	0	-	0
Cl-	7	-	670	27,500	28,100
ClO3--	0	-	0	2	2
CN-	0	-	0	0	0
CO3--	-	-	2	5	7
Cr+compounds as Cr	0	-	0	0	0
Cu+compounds as Cu	0	-	0	0	0
Detergent/oil	0	-	2	3	5
Dichloroethane (DCE)	0	-	0	0	0
Dioxin/furan as Teq	-	-	0	-	0
Dissolved chlorine	0	-	0	0	0
Dissolved organics (non-HC)	6	-	0	0	6
Dissolved solids not specified	2	-	6	59	67
F-	0	-	6	0	6
Fe+compounds as Fe	0	-	1	20	22
Hg+compounds as Hg	0	-	0	0	0
Hydrocarbons not specified	0	0	1	334	337
K+compounds as K	0	-	0	2	2
Metals not specified elsewhere	0	-	0	52	52
Mg+compounds as Mg	0	-	0	2	2
Mn+compounds as Mn	-	-	0	0	0
Na+compounds as Na	3	-	15	1,270	1,290
Ni+compounds as Ni	0	-	0	0	0
NO3-	0	-	0	1,910	1,910
Organo-chlorine not specified	0	-	0	0	0
Organo-tin as Sn	-	-	0	-	0
Other nitrogen as N	0	-	0	4,300	4,300
Other organics not specified	0	-	0	0	0
P+compounds as P	0	-	0	41	41
Pb+compounds as PB	0	-	0	0	0
Phenols	0	-	0	0	0
S+sulphides as S	0	-	0	5	5
SO4--	0	-	5	6,287	6,290
Sr+compounds as Sr	-	-	0	0	0
Suspended solids	945	-	2,660	396,000	399,000
TOC	0	-	15	2,460	2,480
Vinyl chloride monomer	0	-	0	0	0
Zn+compounds as Zn	0	-	0	0	0

Table 23B. Gross water emissions (in milligrams), resulting from the COMPOSTABLE PLASTIC bag LCA. Based on consumer use & collection of 1500 bags. Totals may not agree because of rounding.

	Fuel prod'n	Fuel use	Transport	Process	Total
COD	22	2	86	89,500	89,600
BOD	6	-	6	4,790	4,800
Acid (H+)	4	-	0	1	5
Al+compounds as Al	0	-	0	3	3
Ammonium compounds as NH4	7	-	2	1	11
AOX	0	-	0	15	15
As+compounds as As	-	-	0	0	0
BrO3--	0	-	0	0	0
Ca+compounds as Ca	0	-	0	302	302
Cd+compounds as Cd	-	-	0	-	0
Cl-	10	-	1,010	41,200	42,200
ClO3--	0	-	0	2	2
CN-	0	-	0	0	0
CO3--	-	-	3	7	10
Cr+compounds as Cr	0	-	0	0	0
Cu+compounds as Cu	0	-	0	0	0
Detergent/oil	0	-	2	4	7
Dichloroethane (DCE)	0	-	0	0	0
Dioxin/furan as Teq	-	-	0	-	0
Dissolved chlorine	0	-	0	0	0
Dissolved organics (non-HC)	9	-	0	1	10
Dissolved solids not specified	2	-	10	89	101
F-	0	-	9	0	9
Fe+compounds as Fe	0	-	2	31	33
Hg+compounds as Hg	0	-	0	0	0
Hydrocarbons not specified	1	1	2	501	505
K+compounds as K	0	-	0	3	3
Metals not specified elsewhere	0	-	0	76	76
Mg+compounds as Mg	0	-	0	3	3
Mn+compounds as Mn	-	-	0	0	0
Na+compounds as Na	4	-	23	1,900	1,930
Ni+compounds as Ni	0	-	0	0	0
NO3-	0	-	0	2,860	2,860
Organo-chlorine not specified	0	-	0	0	0
Organo-tin as Sn	-	-	0	-	0
Other nitrogen as N	0	-	0	6,440	6,440
Other organics not specified	0	-	0	0	0
P+compounds as P	0	-	0	62	62
Pb+compounds as PB	0	-	0	0	0
Phenols	0	-	0	0	0
S+sulphides as S	0	-	0	7	7
SO4--	0	-	8	9,430	9,440
Sr+compounds as Sr	-	-	0	0	0
Suspended solids	1,420	-	3,990	594,000	599,000
TOC	0	-	23	3,690	3,710
Vinyl chloride monomer	0	-	0	0	0
Zn+compounds as Zn	0	-	0	0	0

Table 24A. Generation of solid waste (in milligrams) resulting from the COMPOSTABLE PLASTIC bag LCA. Based on consumer use & collection of 1000 bags. Totals may not agree because of rounding.

Solid waste (mg)	Fuel prod'n	Fuel use	Transport	Process	Total
Construction waste	0	-	0	0	0
Inert chemical	0	-	0	5	5
Metals	0	-	0	822	822
Mineral waste	1,110	-	26,500	405,000	433,000
Mixed industrial	-12,800	-	1,100	2,620	-9,080
Municipal solid waste	-130,000	-	-	205,000	75,000
Paper	0	-	0	0	0
Plastic containers	0	-	0	-	0
Plastics	0	-	0	1,580	1,580
Putrescibles	0	-	7	1	8
Regulated chemicals	18,400	-	4,830	133	23,400
Slags/ash	308,000	660	10,300	2,690,000	3,009,000
Tailings	27	-	15,900	284	16,300
Unregulated chemicals	14,000	-	0	82,400	96,400
Unspecified refuse	15,100	-	0	171,700	186,800
Waste returned to mine	731,000	-	980	108	732,100
Waste to compost	-	-	-	25,400	25,400
Waste to incinerator	0	-	12	67	80
Waste to recycle	0	-	0	32,500	32,500
Wood waste	0	-	0	6,370	6,370
Wood pallets to recycling	0	-	0	812,700	812,700

Table 24B. Generation of solid waste (in milligrams) resulting from the COMPOSTABLE PLASTIC bag LCA. Based on consumer use & collection of 1500 bags. Totals may not agree because of rounding.

Solid waste (mg)	Fuel prod'n	Fuel use	Transport	Process	Total
Construction waste	0	-	0	0	0
Inert chemical	0	-	0	6	6
Metals	0	-	0	1,230	1,230
Mineral waste	1,660	-	39,800	608,000	649,000
Mixed industrial	-19,200	-	1,650	3,940	-13,600
Municipal solid waste	-195,000	-	-	308,000	113,000
Paper	0	-	0	0	0
Plastic containers	0	-	0	-	0
Plastics	0	-	0	2,380	2,380
Putrescibles	0	-	11	<1	11
Regulated chemicals	27,600	-	7,250	199	35,100
Slags/ash	462,000	985	15,500	4,035,000	4,510,000
Tailings	40	-	23,900	427	24,400
Unregulated chemicals	20,900	-	52	124,000	145,000
Unspecified refuse	22,600	-	0	258,000	280,000
Waste returned to mine	1,097,000	-	1,470	162	1,098,000
Waste to compost	-	-	-	38,000	38,000
Waste to incinerator	0	-	18	101	120
Waste to recycle	0	-	0	48,800	48,800
Wood waste	0	-	0	9,550	9,550
Wood pallets to recycling	0	-	0	1,220,000	1,220,000

Final Disposal Solid Waste Options: Recycling, Combustion with Energy Recovery, Landfill and Composting

Recycling

A major goal of recycling is to reduce the generation of solid waste. The bag making process for grocery bags generates paper and plastic waste. The majority of this waste, known as mill waste, is recycled internally. Therefore, in this study BCAL treated mill waste as a closed loop recycling effort that returned the waste to the production process.

All of the grocery bags are recyclable to other paper and plastic products. EPA data from 2005 show that 21% of the kraft paper grocery bags are recycled and 5.2 % of the plastic grocery bags are recycled. The allocation decision for these recycled materials is that the recycled materials are not burdened with any inputs or outputs associated with their previous manufacture, use, disposal prior to recycling.

BCAL used this allocation approach, and treated the recycled materials as diverted waste. Diverted waste, like raw materials, are burdened with their intrinsic feedstock value and are subsequently burdened with the resource use, energy consumption, and environmental releases associated with their collection, cleaning and reprocessing, use, and disposal. Therefore, the inherent feedstock energy value of the recycled material is assigned to the diverted waste.

With respect to the degradable plastic bags, BCAL assumed that initially the same rate that applies to recycling of standard plastic bags (5.2%) would be appropriate for the rate sent to composting. This reflects a conservative approach using only data that currently reflect consumer behavior with regard to plastic bags. It is expected that the percentage of degradable plastic bags sent to composting will actually be higher once they are made available and collection can occur within municipalities, making it easier for the general consumer to send these bags through a different route of disposal. Recycling of plastic bags is currently low. This may be for a number of reasons, not the least of which appears to be the lack of infrastructure and poor consumer awareness about the inherent recycleability of plastic bags.

Solid Waste Combustion With Energy Recovery

In previous years, a controlled burning process called combustion or incineration was used solely to reduce volume of solid waste. However, energy recovery became more prevalent in the 1980s. Therefore, today, most of the municipal solid waste combustion in the US incorporates recovery of energy. EPA data from 2005 show that 13.6% of MSW was combusted with energy recovery.

The gross calorific values for the various grocery bags are estimated as follows:

For kraft paper bags	17.7 MJ/kg
For recyclable plastic bag	40.0 MJ//kg
For degradable plastic bag	19.6 MJ/kg

These materials are used as fuels in the waste to energy plants, however the thermal efficiencies for mass-burn WTE plants varies from 15% to 23% in the newer plants.[6] This study used 23% thermal efficiency for energy recovery.

Assuming complete combustion, the resulting estimated CO2 emissions are:
For kraft paper bags 1,650,000 mg/kg paper bag
For recyclable plastic bags 3,150,000 mg/kg recyclable plastic bag
For degradable plastic bags 1,360,000 mg/kg degradable plastic bag

The recovered energy (23% thermal efficiency) is as follows:
For kraft paper bags 4.07 MJ/kg paper bag
For recyclable plastic bags 9.20 MJ/kg recyclable plastic bag
For degradable plastic bags 4.51 MJ/kg degradable plastic bag

Therefore, using the above information, the following table is prepared on the basis of 1000 grocery bags and shows the recovered energy and resulting carbon dioxide emissions when 13.6% of the 1000 grocery bags are combusted with energy recovery.

Table 25. Recovered energy (MJ) and resulting carbon dioxide emissions (mg) when 13.6% of the 1000 grocery bags are combusted with energy recovery.

	Kraft Paper Bag	Recyclable Plastic Bag	Degradable Plastic Bag
Recovered energy	28.7 MJ	7.2 MJ	9.7 MJ
CO2 emissions	11,640,000 mg	2,150,000 mg	2,920,000 mg

Table 25 shows that the kraft paper bag has the highest recovered energy and the highest CO2 emissions. The recyclable and compostable plastic bags have significantly lower recovered energy and CO2 emissions.

Solid Waste to Landfill

A landfill has various phases of decomposition. Initially, aerobic decomposition will take place where oxygen is consumed to produce carbon dioxide gas and other by-products. During the first phase of anaerobic decomposition, carbon dioxide is the principal gas generated. As anaerobic decomposition proceeds toward the second phase, the quantity of methane generated increases until the methane concentration reaches 50% to 60%. The landfill will continue to generate methane at these concentrations for 10 or 20 years, and possibly longer[7].

Methane emissions from landfills in the United States were estimated at 8.0 million metric tons in 2001. In addition, 2.5 million tons were recovered for energy use and 2.4 million tons were recovered and flared. Therefore, more than 60% of the methane produced in landfills is not recovered.[8]

The precise fate of paper deposited in a landfill site is unknown. Paper may decompose entirely in a short space of time or it may remain intact for long periods.[9] This depends on a variety of factors such as temperature, pH, the presence of bacteria and nutrients, the composition of the waste and the form of the paper-shredded paper is much more likely to decompose than is a whole telephone book. To account for this variability, two scenarios were used to calculate emissions associated with the disposal of paper bags (both adjustment for 40% of the recovered methane noted above). The first scenario is a worst-case scenario that follows the basic decomposition reaction for cellulose and the second scenario is one that estimates carbon sequestration for paper in MSW landfills.

Scenario 1 for Paper Bags

The basic decomposition reaction for cellulose is well known and follows the form of:

$$C_6H_{10}O_5 + H_2O = 3CH_4 + 3CO_2 \quad (1)$$

It is therefore expected that only one half of the carbon present in kraft paper bags will result in methane formation during decomposition. Typically carbon represents 45% of the mass of paper. Thus, the carbon content of 1 kg of paper will be 0.45 kg. That proportion giving rise to methane, assuming 100 % decomposition, would then be 0.225 kg. Based on this, the mass of methane produced would be 0.30 kg and the corresponding mass of the coproduct carbon dioxide would be 0.83 kg.

Scenario 2 for Paper Bags

Although cellulose decomposition in landfill is well documented, there remains significant uncertainty in the maximum extent of cellulose decomposition that can be realized under landfill conditions. Several studies indicate that significant carbon sequestration occurs in landfills because of the limited degradation of wood products. In one study[10 a] carbon storage factor (CSF) was calculated that represented the mass of carbon stored (not degraded) per initial carbon mass of the component. For the following MSW paper refuse components the CSF was calculated: old newsprint = 0.42 kg C sequestered, coated paper = 0.34 kg C sequestered, and old corrugated = 0.26 kg C sequestered.

For this scenario the partial decomposition that the paper bags go through is assumed to be aerobic or the initial anaerobic phase, resulting principally in carbon dioxide emissions. In this scenario, we have assumed that the paper bags are similar to old corrugated, and therefore have assigned the same value of 0.26 kg C sequestered. Given that 0.26 kg of the kraft paper bag is assumed to be sequestered, 0.74 kg of the kraft paper bag results in carbon dioxide emissions of 1.23 kg.

Recyclable plastic bags are not considered to degrade in landfills, suggesting that all the inherent feedstock energy and emissions will be sequestered. Therefore, there are no carbon dioxide or methane emissions associated with the recyclable plastic bags sent to landfills.

Many types of biodegradable polymers are available to degrade in a variety of environments, including soil, air, or compost. The biodegradable products degrade under aerobic conditions to carbon dioxide and water in the presence of oxygen. The biodegradable, compostable plastic bags in this study are made from a blend of Ecoflex and PLA. Ecoflex is made from aliphatic-aromatic copolyester blended with equal amounts of starch. According to information provided by BASF, Ecoflex meets the requirements for biodegradable polymer classification based on European, US, and Japanese standards because Ecoflex can be degraded by micro-organisms.[11] PLA is a biodegradable polymer made from corn and is converted completely to carbon dioxide and water by micro-organisms. In addition, compostable plastic bags have been found to degrade as designed within an allowable timeframe in appropriate composting facilities[13]. In composting facilities, decomposition of biodegradable plastic bags made from a blend of Ecoflex and PLA are expected to release primarily carbon dioxide emissions and water. However, if sent to a landfill, biodegradable plastic will either not degrade at all, or may follow similar pathways as paper bags (a combination of both aerobic and anaerobic degradation). BCAL treated these bags in both ways in this study to examine all possibilities.

Solid Waste Composting

The biodegradable, compostable plastic bags in this study have demonstrated biodegradation in several standardized tests in several countries. Ecoflex and PLA meet US, European, Australian, and Japanese standards by degrading in 12 weeks under aerobic conditions in a compost environment and by breaking down to carbon dioxide and water. The extent of the degradation for Ecoflex was 2 to 6 months in compost depending upon temperature, and for PLA was 1 to 3 months in compost depending upon temperature. [11] Therefore, in the composting environment, decomposition of biodegradable plastic bags made from a blend of Ecoflex and PLA is expected to degrade over time with the release primarily of carbon dioxide emissions and water.

LCA Calculations of Environmental Impacts

As noted under the section on LCA methodology, life cycle assessment modeling allows an examination of specific problems as well as comparisons to determine if there are any serious side effects to any of the systems under study. In every system there are multiple environmental parameters to be addressed scaling from global to local issues, and no single solution is likely to address all of the issues simultaneously. In addition, almost every change to a system creates trade-offs, and it is the identification of these trade-offs that is important when trying to determine the best solution for any given problem.

To reiterate, a life cycle assessment can:

1. Quantify those parameters likely to be responsible for environmental effects (the inventory component of life cycle analysis).
2. Identify which parameters are likely to contribute to a specific environmental problem (characterization or interpretation phase of impact assessment). An

example would be identifying that carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are greenhouse gases.

3. Aggregate the parameters relating to a specific problem (the valuation or interpretation phase of impact assessment). An example would be producing carbon dioxide equivalents for the components of greenhouse gases.

The LCA calculations provide a compilation of information from which the user can address specific problems such as the conservation of fossil fuels, global warming, acid rain, and municipal solid waste. In addition, the user also is able to determine what trade-offs exist between systems and to examine the specific parameters which are likely to contribute to these problems. In so doing, the user can strive to achieve the optimum reduction in each parameter because of a better understanding of how these parameters change in association with each grocery bag system.

GLOBAL WARMING

One important issue that is currently being addressed using LCA studies is an examination of the contribution that industrial systems make to climate change. The work of the Intergovernmental Panel on Climate Change (IPCC)[12] provides a framework for aggregating data on those air emissions that are thought to be significant contributors to global warming. The aggregated effect of any system can be summarized as a parameter known as Global Warming Potential (GWP) or carbon dioxide equivalent. Any gaseous emission that is thought to contribute to global warming is assigned a value equal to the equivalent amount of CO_2 that would be needed to produce the same effect. Multiplying each gaseous emission by its CO_2 equivalent allows the separate effects of different emissions to be summed to give an overall measure of global warming potentials.

The major greenhouse gases of importance in this eco-profile are carbon dioxide, methane and nitrous oxide. The results tables provided previously (see Section on LCA Results) showed the global warming impacts (with carbon dioxide equivalents) up to the collection of the grocery bags.

The following table estimates the global warming impacts just from the collection and disposal of the grocery bags.

As discussed previously, two scenarios will be considered for the kraft paper bags, the first is a worst-case scenario that follows the basic decomposition reaction for cellulose and the second scenario is one that estimates carbon sequestration for paper in MSW landfills.

The recyclable plastic bags will not degrade in the landfill; all the inherent feedstock energy and emissions will be sequestered. Therefore, there are no carbon dioxide emissions from recyclable plastic bags in landfills.

In the landfill, decomposition of biodegradable plastic bags made from a blend of Ecoflex and PLA is expected to degrade over time with the release primarily of carbon dioxide emissions and water.

Table 26A. Greenhouse gas emissions. 20-year carbon dioxide equivalents (in milligrams) resulting from the disposal of 1000 grocery bags.

Disposal process	Paper bag with “worst case scenario” of methane emissions	Paper bag with “sequestered scenario” of carbon dioxide emissions	Recyclable plastic bag	Degradable plastic bag With 100% aerobic decomposition in landfill	Degradable plastic bag with 50% aerobic & 50% anaerobic decomposition in landfill (using the same pathway as described for paper bags)
Recycling	21% recycled & burden is transferred	21% recycled & burden is transferred	5.2% recycled & burden is transferred	5.2% recycled to composting & burden is transferred	5.2% recycled to composting & burden is transferred
Incineration with energy recovery 13.6%	11,640,000	11,640,000	2,150,000	2,920,000	2,920,000
Landfill 65.4% paper, 81.2% plastic	412,000,000	41,300,000	0	17,400,000	129,400,000
Total disposal related emissions	423,640,000	52,940,000	2,150,000	20,320,000	132,320,000

Table 26A shows that after disposal, the recyclable plastic bag has the lowest greenhouse gas emissions. The paper bag with the “sequestered scenario” has more than 15 times the greenhouse gas emissions of the recyclable plastic bag. The paper bag with the “worst-case scenario” has more than 200 times the greenhouse gas emissions of the recyclable plastic bag. The degradable plastic bag has more than 9 times the greenhouse gas emissions of the recyclable plastic bag.

Table 26B. Greenhouse gas emissions. 20-year carbon dioxide equivalents (in milligrams) resulting from the disposal of 1000 kraft paper grocery bags and 1500 recyclable plastic and degradable plastic grocery bags.

Disposal process	Paper bag with "worst case scenario" of methane emissions	Paper bag with "sequestered scenario" of carbon dioxide emissions	Recyclable plastic bag	Degradable plastic bag With 100% aerobic decomposition in landfill	Degradable plastic bag with 50% aerobic & 50% anaerobic decomposition in landfill
Recycling	21% recycled & burden is transferred	21% recycled & burden is transferred	5.2% recycled & burden is transferred	5.2% recycled to composting & burden is transferred	5.2% recycled to composting & burden is transferred
Incineration with energy recovery 13.6%	11,640,000	11,640,000	3,230,000	4,380,000	4,380,000
Landfill 65.4% paper, 81.2% plastic	412,000,000	41,300,000	0	26,100,000	194,000,000
Total disposal related emissions	423,640,000	52,940,000	3,230,000	30,500,000	198,000,000

Table 26B shows that even using 1.5 plastic bags to 1 paper bag, after disposal, the recyclable plastic bag has the lowest greenhouse gas emissions. The paper bag at a 1 to 1.5 use ratio, with the "sequestered scenario," has more than 10 times the greenhouse gas emissions of the recyclable plastic bag. The paper bag with the "worst-case scenario" has more than 130 times the greenhouse gas emissions of the recyclable plastic bag. The degradable plastic bag has more than 9 times the greenhouse gas emissions of the recyclable plastic bag with the 100% aerobic decomposition and more than 60 times the greenhouse gas emissions of the recyclable plastic bag with the 50% aerobic decomposition/50% anaerobic decomposition.

Table 27A. Carbon dioxide equivalents (in milligrams) resulting from all operations just prior to the disposal of 1000 grocery bags.

	Recyclable and Recycled Paper bag* (from Table 6B)	Recyclable plastic bag (from Table 14B)	Degradable plastic bag (from Table 22B)
20 year CO2 eq.	23,710,000 mg	19,200,000 mg	89,000,000 mg

*It should be noted that these emissions include the "credit" when carbon dioxide was absorbed during tree growing.

Table 27A shows that from all operations just prior to disposal, the resulting CO2 equivalents are more than 20% greater for the paper bag compared to the recyclable plastic bag. From all operations just prior to disposal, the resulting CO2 equivalents for the degradable plastic bag are the highest about 4 times greater than the recyclable plastic bag.

Table 27B Carbon dioxide equivalents (in milligrams) resulting from all operations just prior to the disposal of 1000 kraft paper grocery bags and 1500 recyclable plastic and degradable plastic grocery bags.

	Recyclable and Recycled Paper bag* (from Table 6B)	Recyclable plastic bag (from Table 14B)	Degradable plastic bag (from Table 22B)
20 year CO2 eq.	23,710,000 mg	28,800,000 mg	134,000,000 mg

*It should be noted that these emissions include the "credit" when carbon dioxide was absorbed during tree growing.

Table 27B shows that from all operations just prior to disposal, the resulting CO2 equivalents are more than 20% greater for the recyclable plastic bag compared to the paper bag. From all operations just prior to disposal, the resulting CO2 equivalents for the degradable plastic bag are the highest about 4 times greater than the recyclable plastic bag and 5 times greater than the paper bag.

Now, adding the greenhouse gas emissions from tables 26 and 27 the total LCA cradle-to-grave greenhouse gas emissions for the production, use, and disposal of 1000 grocery bags are given in Table 28.

Table 28A. Total LCA cradle-to-grave CO2 equivalents (in milligrams) for the production, use, and disposal of 1000 grocery bags:

	Paper bag with "worst-case scenario" of methane emissions	Paper bag with "sequestered scenario" of carbon dioxide emissions	Recyclable plastic bag	Degradable plastic bag With 100% aerobic decomposition in landfill	Degradable plastic bag with 50% aerobic & 50% anaerobic decomposition in landfill
20 year CO2 eq	447,350,000	76,650,000	21,350,000	109,300,000	221,300,000
100 year CO2 eq	202,200,000	65,490,000	18,850,000	99,300,000	134,800,000
500 year CO2 eq	90,410,000	60,910,000	17,850,000	87,320,000	92,100,000

Table 28A shows that the recyclable plastic bag has the lowest the total cradle-to-grave CO2 equivalents. The paper bag with the "sequestered scenario" has more than 3.5 times the total cradle-to-grave CO2 equivalents of the recyclable plastic bag. The paper bag with the "worst-case scenario" has more than 20 times the total cradle-to-grave CO2 equivalents of the recyclable plastic bag. The degradable plastic bag has more than 5 times the total cradle-to-grave CO2 equivalents of the recyclable plastic bag.

Table 28B. Total LCA cradle-to-grave CO2 equivalents (in milligrams) for the production, use, and disposal of 1000 kraft paper grocery bags and 1500 recyclable plastic and degradable plastic grocery bags.

	Paper bag with "worst-case scenario" of methane emissions	Paper bag with "sequestered scenario" of carbon dioxide emissions	Recyclable plastic bag	Degradable plastic bag With 100% aerobic decomposition in landfill	Degradable plastic bag with 50% aerobic & 50% anaerobic decomposition in landfill
20 year CO2 eq	447,350,000	76,650,000	32,030,000	164,000,000	332,000,000
100 year CO2 eq	202,200,000	65,490,000	28,300,000	149,000,000	202,000,000
500 year CO2 eq	90,410,000	60,910,000	26,800,000	131,000,000	138,000,000

Table 28B shows that even using 1.5 plastic bags to 1 paper bag, the recyclable plastic bag has the lowest the total cradle-to-grave CO2 equivalents. The paper bag, at a 1 to 1.5 use ratio, with the "sequestered scenario," has about 2.3 times more total cradle-to-grave CO2 equivalents of the recyclable plastic bag, depending upon the time horizon. The paper bag with the "worst-case scenario" has more than 20 times the total cradle-to-grave CO2 equivalents of the recyclable plastic bag. The degradable plastic bag has more than 5 times the total cradle-to-grave CO2 equivalents of the recyclable plastic bag.

STRATOSPHERIC OZONE DEPLETION

The stratospheric ozone layer occurs at an altitude of between 10-40 km. The maximum generation of ozone (O3) occurs at the outer layer, where oxygen molecules (O2) react with atomic oxygen. The presence of other compounds, particularly halogenated compounds, promotes the decomposition of this ozone in the presence of strong ultra-violet radiation.

In this study there were no identified ozone depleting chemicals associated with the bag systems studied, and therefore no contributions to stratospheric ozone depletion.

ACID RAIN

The production of acid rain in the northeastern United States is recognized as a regional problem. Acid rain results when sulfur and nitrogen oxides and their transformation products return from the atmosphere to the earth's surface. The major source of acid rain is the emission of these pollutants from coal powered electricity generating plants.

The following data were extracted from the results tables. There are no data available for SOX and NOX emissions after disposal.

Table 29A. Acid rain emissions (in milligrams of SO_2 and NO_2) resulting from all operations just prior to disposal 1000 grocery bags.

Acid rain emissions mg	Paper bag	Recyclable plastic bag	Degradable plastic bag
SOX	579,000 mg	50,500 mg	275,000 mg
NOX	264,000 mg	45,400 mg	304,000 mg

Table 29A shows that the recyclable plastic bag has the least SOX and NOX emissions. The paper bag has more than 10 times the SOX emissions compared with the recyclable plastic bag and more than 5 times the NOX emissions compared with the recyclable plastic bag. The degradable plastic bag has more than 5 times the SOX and NOX emissions compared with the recyclable plastic bag.

Table 29B. Acid rain emissions (in milligrams of SO_2 and NO_2) resulting from all operations just prior to disposal for 1500 recyclable plastic bags and degradable plastic grocery bags.

Acid rain emissions mg	Paper bag	Recyclable plastic bag	Degradable plastic bag
SOX	579,000 mg	75,800 mg	413,000 mg
NOX	264,000 mg	68,100 mg	456,000 mg

Table 29B shows that even using 1.5 plastic bags to 1 paper bag, the recyclable plastic bag has the least SOX and NOX emissions. The paper bag, at a 1 to 1.5 use ratio, has more than 7 times the SOX emissions compared with the recyclable plastic bag and almost 4 times the NOX emissions compared with the recyclable plastic bag. The degradable plastic bag has more than 5 times the SOX and NOX emissions compared with the recyclable plastic bag.

MUNICIPAL SOLID WASTE

Another widespread environmental issue concerns the generation and disposal of municipal solid waste. The mineral wastes from mining, the slags and ash wastes from oil and gas production and utility coal combustion, and regulated chemical wastes are generally managed by regulation and permits that exclude these wastes from the municipal solid waste stream. The type of wastes in mixed industrial wastes can contribute to the municipal solid waste problem. If, as in this study, there is an interest in focusing on the municipal solid waste problem, the results on mineral wastes, slags & ash, and regulated chemicals can be ignored. Selecting only the solid waste resulting from just the disposal of grocery bags in landfill, one can prepare the following table 30A considering disposal of 1000 grocery bags and table 30B considering disposal of 1000 kraft paper grocery bags and 1500 recyclable plastic and degradable plastic grocery bags. The table reflects the waste that is landfilled as 65.4% paper bags and 81.2% plastic bags.

Table 30A. The municipal solid waste (in mg) resulting from just the disposal of grocery bags in landfill. Based on 1000 grocery bags but only 65.4% of paper bags are landfilled and 81.2% of plastic bags are landfilled.

	Paper bag	Recyclable plastic bag	Degradable plastic bag
Municipal solid waste mg	33,900,000	4,690,000	12,800,000

Table 30A shows that the recyclable plastic bag has the least municipal solid waste. The paper bag has more than 7 times the municipal solid waste compared with the recyclable plastic bag. The degradable plastic bag has almost 3 times the municipal solid waste compared with the recyclable plastic bag.

Table 30B. The municipal solid waste (in mg) resulting from just the disposal of grocery bags in landfill. Based on 1000 kraft paper grocery bags but only 65.4% of paper bags are landfilled and 1500 plastic grocery bags of which 81.2% of plastic bags are landfilled.

	Paper bag	Recyclable plastic bag	Degradable plastic bag
Municipal solid waste mg	33,900,000	7,035,000	19,200,000

Table 30B shows that even using 1.5 plastic bags to 1 paper bag, the recyclable plastic bag has the least municipal solid waste. The paper bag, at a 1 to 1.5 use ratio, has almost 5 times the municipal solid waste compared with the recyclable plastic bag. The degradable plastic bag has almost 3 times the municipal solid waste compared with the recyclable plastic bag.

CONSERVATION OF FOSSIL FUELS

Conservation problems are concerned with the depletion and possible exhaustion of raw materials and fuels. With continued use, the finite supply of raw materials, and especially fossil fuels will one day be exhausted. The conservation of fossil fuels: coal, oil ,and natural gas is an important global environmental issue. It is therefore important to ensure that these resources are used with the maximum efficiency and the minimum of waste.

Table 31A. The gross fossil fuels and feedstocks, expressed as energy (MJ) required for the production, use, and disposal of 1000 grocery bags.

Energy in MJ	Paper bag	Recyclable plastic bag	Degradable plastic bag
Coal	324	65	161
Oil	207	206	353
Gas	391	186	705
Totals	922	457	1,219

Table 31A shows that the recyclable plastic bag uses the least fossil fuels and feedstocks. The paper bag uses more than 2 times the fossil fuels and feedstocks compared with the recyclable plastic bag. The degradable plastic bag used more than 2 1/2 times the fossil fuels and feedstocks compared with the recyclable plastic bag.

Table 31B. The gross fossil fuels and feedstocks, expressed as energy (MJ) required for the production, use, and disposal of 1000 kraft paper grocery bags and 1500 recyclable plastic and degradable plastic grocery bags.

Energy in MJ	Paper bag	Recyclable plastic bag	Degradable plastic bag
Coal	324	98	242
Oil	207	309	530
Gas	391	279	1,058
Totals	922	686	1,830

Table 31B shows that even using 1.5 plastic bags to 1 paper bag, the recyclable plastic bag uses the least fossil fuels and feedstocks. The paper bag, at a 1 to 1.5 use ratio, uses 34% more fossil fuels and feedstocks compared with the recyclable plastic bag. The degradable plastic bag used more than 2 1/2 times the fossil fuels and feedstocks compared with the recyclable plastic bag.

LOCAL & REGIONAL GRID ELECTRICITY USE

The US recently has experienced severe problems related to its local and regional grid electricity. Because of these recent “blackouts,” “brownouts,” and electricity interruptions, the need for appropriate conservation measures can be argued.

Table 32A. The electrical energy (MJ) required for the production, use, and disposal of 1000 grocery bags.

	Paper bag	Recyclable plastic bag	Degradable plastic bag
Electrical energy MJ	649	148	325

Table 32A shows that the recyclable plastic bag uses the least electrical energy. The paper bag uses more than 4 times the electrical energy compared to the recyclable plastic bag. The degradable plastic bag used more than 2 times the electrical energy compared with the recyclable plastic bag.

Table 32B. The electrical energy (MJ) required for the production, use, and disposal of 1000 kraft paper grocery bags and 1500 recyclable plastic and degradable plastic grocery bags.

	Paper bag	Recyclable plastic bag	Degradable plastic bag
Electrical energy MJ	649	222	488

Table 32B shows that even using 1.5 plastic bags to 1 paper bag, the recyclable plastic bag uses the least electrical energy. The paper bag, at a 1 to 1.5 use ratio, uses almost 3 times the electrical energy compared with the recyclable plastic bag. The degradable plastic bag used more than 2 times the electrical energy compared with the recyclable plastic bag.

WATER USE & PUBLIC SUPPLY

Parts of the US continue to be plagued by periodic drought conditions. During these times, laws and regulations concerning water conservation are enforced. Since public water supply issues have been identified as a problem, the following table has been prepared to compare public water supply used for the production, use, and disposal of 1000 grocery bags.

Table 33A. Public water supply (in mg) used for the production, use, and disposal of 1000 grocery bags.

	Paper bag	Recyclable plastic bag	Degradable plastic bag
Public water supply (in mg)	3,895,000,000	31,150,000	2,560,000,000

Table 33A shows that the recyclable plastic bag uses the least public water supply. The paper bag uses more than 125 times the public water supply compared with the recyclable plastic bag. The degradable plastic bag used more than 80 times the public water supply compared with the recyclable plastic bag.

Table 33B. Public water supply (in mg) used for the production, use, and disposal of 1000 kraft paper grocery bags and 1500 recyclable plastic and degradable plastic grocery bags.

	Paper bag	Recyclable plastic bag	Degradable plastic bag
Public water supply	3,895,000,000	46,700,000	3,840,000,000

(in mg)			

Table 33B shows that even using 1.5 plastic bags to 1 paper bag, the recyclable plastic bag uses the least public water supply. The paper bag, at a 1 to 1.5 use ratio, uses more than 80 times the public water supply compared with the recyclable plastic bag. The degradable plastic bag used more than 80 times the public water supply compared with the recyclable plastic bag.

SUMMARY AND CONCLUSIONS

Recent efforts by legislators to ban traditional plastic bags on the basis of environmental impact have reignited the debate surrounding single-use grocery bags, and whether there are any environmental trade-offs in switching from bags made with polyethylene to bags made from alternative materials.

This life cycle assessment was commissioned to examine the overall environmental impacts associated with the typical single-use polyethylene plastic grocery bag, compared with grocery bags made from compostable plastic resin and grocery bags made from 30% recycled paper.

Life cycle assessment is a useful analytical tool because it allows for the examination of an entire production system from cradle to grave, thus examining the full range (global, regional, and local impacts) of environmental issues at once rather than examining individual components of a system or individual products or processes. This broad picture analysis is important because environmental effects range from global (greenhouse gases), to regional (acid rain/solid waste) or local (toxic releases) impacts. And while there often is excellent information on local environmental effects, few complete data sets are available to understand the contributions production systems are making to global and regional environmental problems.

These study results confirm that the standard polyethylene grocery bag has significantly lower environmental impacts than a 30% recycled content paper bag. This supports conclusions drawn from a number of other studies looking at similar systems.[14, 15, 16] In addition, this report also shows that the typical polyethylene grocery bag has fewer environmental impacts than a compostable plastic grocery bag made from a blend of EcoFlex (BASF), polylactic acid, and calcium carbonate, when compared on a 1:1 basis, as well as when the number of bags is adjusted for carrying capacity so that the comparison is 1.5:1. Surprisingly, the trend is the same for most of the individual categories of environmental impacts. No one category showed environmental impacts lower for either the compostable plastic bag or the paper bag.

This study did not examine the impacts associated with reusable cloth bags, so no comparison was made between the cloth bags and single-use polyethylene plastic bags. In other studies, however, cloth bags were shown to reduce environmental impacts if consumers can be convinced to switch. The problem is that there are few examples where entire cities, counties, or countries have been successful in changing consumer behavior from the convenience of using bags provided by retail establishments to bringing their own bags to the store each time they shop. There is no question that a percentage of consumers do, and will use reusable cloth grocery bags, but the vast majority of consumers still appear to use the freely available bags provided by retail establishments. So, if consumer behaviors are not appearing to change, banning one type of single-use bag will simply mean that it is replaced by another type of single-use bag.

Given the above-stated assumption, it is clear that the replacement bags will either be compostable plastic bags or paper bags, as proposed legislation tends to stipulate these as the preferred alternatives. But can these alternative materials meet the legislative objectives, which often include: the reduction of litter, the need to reduce dependence on fossil fuels, and the need to reduce solid wastes? Taking the latter two objectives first, one can use the LCA results in this report to see if the above stated objectives are being met.

In the case of reducing dependence on overall energy, it is clear (see Table 34) that neither the life cycle of compostable bag nor paper bag provides a reduction in overall energy use. The standard polyethylene plastic grocery bag uses between 1.8 and 3.4 times less energy than the compostable and paper bag systems, respectively.

Table 34. Gross Energy by Activity (MJ)

	Fuel prod'n (total)	Fuel use (total)	Transport (total)	Feedstock (total)	Total
Paper Bag (1000 bags)	493	1105	34	991	2622
Compostable Plastic Bag (1000 bags)	265	659	38	418	1380
Compostable Plastic Bag (1500 bags)	398	988	57	627	2070
Polyethylene Plastic Bag (1000 bags)	106	114	11	279	509
Polyethylene Plastic Bag (1500 bags)	159	171	16	418	763

Table 35 demonstrates that in terms of fossil fuel use, including oil, the compostable plastic bag system does not provide any benefit. The compostable plastic bag system appears to use more oil than either of the other two bag systems, varying from 1.7 to 2.57 times more oil than either the plastic bag or paper bag systems, respectively. The paper bag system would appear to be able to provide a slight improvement, but only if the plastic bag system actually uses 1.5 bags for every 1 bag in the paper system. If this assumption cannot be supported, then the paper bag system would not provide even a slight advantage.

Table 35. Gross Fossil Fuel Use (kg)					
	Paper Bag (1000 bags)	Compostable Plastic Bag (1000 bags)	Compostable Plastic Bag (1500 bags)	Polyethylene Plastic Bag (1000 bags)	Polyethylene Plastic Bag (1500 bags)
Coal	11.2	5.8	8.7	2.3	3.4
Oil	4.6	7.8	11.8	4.6	6.9
Gas	7.4	14.0	21.0	3.1	4.6

These results may appear to some to be counterintuitive, but both compostable plastic and paper bags require more material per bag in their manufacture. This results in greater use of fuels in the extraction and transport of raw materials for the manufacture of the bags, as well as greater energy in bag manufacturing and greater fuel use in the transport of the finished product from the manufacturer to retail establishments. Although standard polyethylene plastic bags are made from oil, the added requirements of manufacturing energy and transport for the compostable and paper bag systems far exceed the raw material use in the standard plastic bag system.

The results of this study also show that the standard polyethylene single-use plastic grocery bag's contribution to the solid waste stream is far lower than either the paper bag system or the compostable bag system. This is not surprising considering both the compostable bag and paper bag systems require more material per bag. The increase in solid wastes has become an important global issue as populations multiply and developing countries become wealthier, consuming more material goods. Currently, more land is being devoted to the disposing of solid wastes, and the lack of proper containment in solid waste facilities is causing problems in terms of soil contamination and water pollution.

Table 36. Municipal Solid Waste (kg)				
Paper Bag (1000 bags)	Compostable Plastic Bag (1000 bags)	Compostable Plastic Bag (1500 bags)	Polyethylene Plastic Bag (1000 bags)	Polyethylene Plastic Bag (1500 bags)
33.9	12.8	19.2	4.7	7.0

This study was not designed to address the issue of litter, so no specific calculations were conducted on the effect of the various bag systems on litter. However, there are some interesting points that can be made with regard to meeting the objective of reducing litter by switching to alternative materials in the grocery bag system. The summary of results discussed above on energy use and solid waste already illustrate that reducing litter through a change in the grocery bag system will lead to greater use in energy and greater amounts of solid wastes. Those who believe that this is an acceptable trade-off must also understand that there are additional, and perhaps far more serious, environmental impacts that will result if plastic bags are supplanted by either compostable plastic bags or paper.

One of these serious environmental impacts is global warming. The study showed that switching from single-use polyethylene plastic grocery bags to either paper or compostable plastic grocery bags may increase the emission of greenhouse gases and therefore contribute to global warming (See Table 37). Based on these results, it appears that the trade-off for reducing litter is an increase in global warming, which if not curbed, is expected to cause problems for decades and to affect marine, freshwater, and terrestrial habitats, and species globally. If one of the major concerns about litter is its accumulation in marine habitats and its negative effect on sea life, it would hardly seem justified to address the effects of litter with a grocery bag system that can cause significant harm to not only the same habitats, but to all other habitats as well.

Table 37. Global Warming Potential (CO2 Equivalents in tons)				
	Paper bag with "sequestered scenario" of carbon dioxide emissions (1000 bags)	Compostable plastic bag With 100% aerobic decomposition in landfill (1500 bags)	Compostable plastic bag with 50% aerobic & 50% anaerobic decomposition in landfill (1500 bags)	Polyethylene Plastic Bag (1500 bags)
Production	0.03	0.15	0.15	0.03
Disposal	0.05	0.03	0.22	0.00
Total	0.08	0.18	0.37	0.04

Another increasingly important issue is the protection of water sources around the globe. Concerns have been raised over the long-term availability of water to support the expanding population's need for drinking, manufacturing, and agriculture. Table 38 shows the use of freshwater resources for each of the grocery bag systems studied. The standard polyethylene plastic bag uses significantly less water, compared with the paper or compostable grocery bag systems. Paper grocery bags use approximately 1 gallon of water for every bag, compared with the plastic bag system, which uses only .008 gallons per bag or 1 gallon for every 116 bags. Compostable grocery bags do not appear to provide any improvement over paper bags, and use far more water than the standard polyethylene plastic bag. It appears, therefore, that in switching to a paper bag or compostable plastic bag system to combat a litter problem, consumers will have to accept another significant trade-off—the increase in use of valuable water resources.

Table 38. Gross Freshwater Resources (gallons)					
	Paper Bag (1000 bags)	Compostable Plastic Bag (1000 bags)	Compostable Plastic Bag (1500 bags)	Polyethylene Plastic Bag (1000 bags)	Polyethylene Plastic Bag (1500 bags)
Public Supply	1000	660	1000	8	13
Other	4	12	17	32	45

Other environmental factors that show similar trends are the emission of acid rain gases and water pollutants. In both cases, paper bag and compostable bag systems show larger amounts of pollutants emitted into the environment than those emitted by the plastic grocery bag system. Similarly, there are other environmental matters that are important to consider when making a decision on which systems to implement. Paper bag systems use a completely different resource base—wood fiber—than the plastic bag system. If the wood fiber does not come from sustainably managed forest systems or from agricultural wastes, it may cause a trade-off that is unacceptable to consumers. Forests are important ecosystems that support a wide variety of life, and disrupting these ecosystems in the name of reducing litter is an effect that deserves further contemplation.

The study results support the conclusion that any decision to ban traditional polyethylene plastic grocery bags in favor of bags made from alternative materials (compostable plastic or recycled paper) will be counterproductive and result in a significant increase in environmental impacts across a number of categories from global warming effects to the use of precious potable water resources.

Addressing the issue of increasing litter with bans on plastic grocery bags may be counterproductive as this study has not considered many other mitigating circumstances that may lead to even greater differentials between plastic grocery bags and those made from either paper or compostable plastics.

Increased recycling rates for plastic bags, better bagging techniques at retail, and secondary uses of plastic grocery bags such as waste disposal could all further reduce the environmental impacts of plastic grocery bags. In addition, getting consumers to change their behavior so that plastic bags are kept out of the litter stream would appear to be more productive in reducing the overall environmental impact of plastic bags including litter.

This study supports the conclusion that the standard polyethylene grocery bag has significantly lower environmental impacts than a 30% recycled content paper bag and a compostable plastic bag. An LCA report and its findings can be used to demonstrate that an environmental impact analysis needs to take into account the entire picture, and when dealing with a product that is likely to be replaced by another, the trade-offs in the environmental impact of the replaced alternative should also be given a critical analysis.

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APPENDIX 1 – PEER REVIEW

Background

Dr. Overcash conducted the peer review and is a Professor of Chemical Engineering, as well as a Professor of Biological and Agricultural Engineering at North Carolina State University. Dr. Overcash has developed an in-depth national research program in life cycle research, developing the new areas for utilization of the life cycle tools. Dr. Overcash has led the effort in life cycle inventory techniques for manufacturing improvement and product change. Dr. Overcash has contributed to life cycle studies in energy production, electroplating, solvent selection, pharmaceutical processes, life cycle assessment comparisons, paper industry, and textiles. He has been active in European life cycle efforts and reviews of research in this field.

All of the suggestions and recommendations made by Dr. Overcash have been reviewed and incorporated in this report. Below is the Peer Review Report provided by Dr. Overcash.

Review of Draft Report
Life cycle assessment for three types of grocery bags – recyclable plastic; compostable, biodegradable plastic; and recycled, recyclable paper

By Dr. Michael Overcash
September 2, 2007

This report provides both a sound technical descriptions of the grocery bag products and the processes of life cycle use. The functional unit has a range to accommodate differences in customer use found to exist. These differences did not prove to change the resulting low environmental impact choice. The discussion of the limitations of the life cycle impact assessment is very important and the readers should use these observations. The following detailed review is divided into technical and editorial segments.

The conclusions regarding the relative environmental impact when using a life cycle view are consistent with previous studies and need to be reinforced in the policy arena. The policies to discourage plastic bags may have more to do with litter than the overall environment. Whatever the goals of the policy makers, these need to be far more explicit than general environmental improvement, since the life cycle story is consistent in favor of recyclable plastic bags. It is possible that the emphasis of another report might be that the full benefit of plastic bags is even higher when large recycling is in place.

Technical

1) p.3 last paragraph BBL is not defined
2) Table 3 at 5.78 kg functional unit this mass reflects the 50% water in wood. However this wood is lignin and cellulose and so only about 50% of the solid material ends up in paper bag, so this should be 274,000,000 mg

3) Table 5 These occur in all the raw material Tables
   a. Biomass is double counted as it appears also in Table 3 while wood does not appear both places
   b. Limestone is listed twice, here and as chalk
   c. N2 and O2 are listed twice as air and constituents of air
4) Table 7 This is an unusually high COD:BOD ratio, it might need to be checked
5) Table 9B Elec = 103 This did not change from Table 9A, while all the other values did change reflecting the differences in number of bags.
6) p.34 line 4 under Solid Waste This identifies steam or electricity as possible energy recovery mechanisms, but Table 25 is only electricity. Steam would have a much higher recovery value
7) p.41 2nd line From the data in Table 28A this ratio is more like 3.5 and not 2.5
8) p. 42 3rd line From the data in Table 28B it is hard to see any ratio as high as 13

Editorial

1) p1 2nd line world for governments
2) p4 last para, 3rd line represent
3) whole document the conventional style is that data are plural, but throughout this documents that is mostly not followed. A search for the word data and inserting the correct verb will fix this.

EXHIBIT K

Environment Group Research Report

Proposed Plastic Bag Levy - Extended Impact Assessment

Volume 1: Main report

2005

Research Report 2005/06

Proposed Plastic Bag Levy - Extended Impact Assessment Final Report

Volume 1: Main Report

Final Report

James Cadman, Suzanne Evans
Mike Holland (ERMC)
Richard Boyd (Metroeconomica)

AEA Technology Environment

Scottish Executive 2005
Environment Group Research Report 2005/06

Contact

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- Scottish Executive Waste Strategy Team
- Carrier Bag Consortium
- Convention of Scottish Local Authorities (CoSLA)
- Friends of the Earth Scotland
- Scottish Retail Consortium
- Scottish Environment Protection Agency (SEPA)

Glossary

ARA	Australian Retailers Association
BRA	Belgian Retail Association
BRC	British Retail Consortium
CBC	Carrier Bag Consortium
CoSLA	Convention of Scottish Local Authorities
Defra	Department for Environment, Food and Rural Affairs (London)
ERM	Environmental Resources Management
HDPE	high density polyethene (polyethylene)
INCPEN	Industry Council for Packaging and the Environment
KSB	Keep Scotland Beautiful
LCA	Life cycle assessment
LDPE	low density polyethene (polyethylene)
LEAMS	Local Environmental Audit and Management System
MCS	Marine Conservation Society
NO_x	nitrogen oxides
ONS	Office of National Statistics
RMIT	Royal Melbourne Institute of Technology
SME	small-to-medium enterprise
SRC	Scottish Retail Consortium
SWAG	Scottish Waste Awareness Group
UCD	University College Dublin
VOC	volatile organic compound
WRAP	Waste and Resources Action Programme

Executive Summary

Mike Pringle MSP has tabled a Members Bill in the Scottish Parliament to impose an environmental levy on lightweight plastic carrier bags as provided by shops and other retail outlets. It is understood that this would cover all bags made partially or completely of plastic, with the exception of those used for directly packing of fresh meat, fish, fruit and other foods.

This brief study, commissioned by the Scottish Executive and undertaken by AEA Technology Environment and associates, has addressed the likely impacts of such a levy and variants of it on:

- The environment.
- Consumers.
- Business.
- Waste.
- Local authorities.

Advocates of a levy on plastic bags cite the main benefits as being reduced littering (including marine litter), reduced use of resources and energy, lower pollutant emissions and increased public awareness of environmental issues.

Opponents argue that lightweight plastic carrier bags are hygienic, convenient and durable, that they are often reused for other purposes, that they form only a small part of the litter stream and that they have a lower overall environmental impact than paper bags. They also claim that a levy would impact unfairly on poorer households and would lead to job losses in Scotland (from reduced plastic bag manufacturing and importing).

The study has considered these and other arguments for and against a levy, quantifying the probable effects wherever possible. It considered a range of different scenarios:

- Scenario 0: No levy, i.e. business as usual.
- Scenario 1A: A levy of 10p on plastic but not paper bags, covering all businesses (as proposed in the Bill).
- Scenario 1B: A levy of 10p on plastic but not paper bags, covering all businesses except small and medium sized enterprises (SMEs) and charities.
- Scenario 2A: A levy of 10p on plastic and paper bags, covering all businesses.
- Scenario 2B: A levy of 10p on plastic and paper bags, covering all businesses except SMEs and charities.

A wide range of evidence has been used to inform the study. This includes experience from the PlasTax in Ireland and voluntary schemes in the UK along with results from life cycle analysis (LCA) studies from France and Australia.

The study does not make a judgement on whether, on balance, such a levy should be introduced, but provides evidence on the main effects expected under each of the four levy scenarios.

Overall Effects

A levy would cause a set of interacting effects. The study is predicated on evidence that a levy would stimulate a switch away from use of plastic bags (by typically 90%). If only plastic bags were to be levied (scenarios 1A and 1B), then studies and experience elsewhere suggest that there would be some shift in bag usage to paper bags (which have worse environmental impacts). This study is based on this experience of behaviour change.

In each of the areas considered – environment, consumers, business, waste and local authorities - there would therefore be a complicated set of effects, but in general:

Environment The environmental impact of each of the four levy scenarios was assessed using 8 indicators. These include energy, water, waste and litter. Under the levy as proposed (scenario 1A) 5 out of the 8 indicators show an improvement.

There are different impacts under each levy scenario. In particular, including paper bags increases the potential environmental benefits of a levy (e.g. scenario 2A or 2B) where all 8 indicators improve.

In all cases the changes in environmental indicators due to a levy are modest (i.e. 1% or less) in comparison to overall environmental impacts from other activities in Scotland (as shown in Table A3.7).

Consumers Consumers act to reduce the financial impact by switching away from use of carrier bags. This limits the detrimental financial impact for consumers to a maximum of £10 per person per year.

Business The impacts would be positive for food retailers, and detrimental for non-food retailers and other businesses such as plastic bag manufacturers.

Waste Under scenarios 1A and 1B waste increases due to a switch from plastic to paper bags. When paper bags are included in the levy (e.g. scenario 2A or 2B) waste arisings fall. The greatest increase, 5,409 tonnes, is for scenario 1A, while the greatest decrease, 4,993 tonnes, is for scenario 2A. These should be compared against total household waste arisings of 2,094,872 tonnes pa [SEPA], a 0.26% increase and a 0.24% decrease respectively.

In all scenarios litter reduces, but plastic bags are only a small percentage of reported litter.

Local authorities There will be set-up costs and on-going costs to administer the levy. In general the revenue from the levy is expected to cover the on-going administration costs. However there are important differences between the on-going costs and revenues between local authorities. For example smaller authorities could receive lower revenues without a proportional reduction in administration costs.

Impacts on the Environment (Section 4 in the main report)

The study used an LCA approach to evaluate the changes in a range of different environmental indicators (e.g. energy use, water use, waste etc). The analysis shows that there would be an environmental benefit for some of the indicators depending on what consumers choose to use were a levy to be introduced.

In all scenarios where the levy is applied, consumption of non-renewable energy, atmospheric acidification and formation of ground level ozone and the risk of litter would be considerably less than the current situation.

In scenarios 2A and 2B, where the levy is applied to paper bags as well as plastic bags, these environmental benefits increase. In addition there are reduced impacts in terms of consumption of water, emissions of greenhouse gases and eutrophication of water bodies (rivers, lakes, etc.). This is because paper bags have a higher environmental impact in these categories relative to plastic bags.

As these results depend on key assumptions we undertook a sensitivity analysis to assess how this changes the results. This shows that scenarios 1A and 1B, which increase use of paper bags, are more sensitive to key assumptions than scenarios 2A and 2B. Excluding SMEs in the levy (scenarios 1B and 2B) accentuates the impacts.

For each of the environmental indicators used in this study we have assessed the total impact from all activities in Scotland. This analysis shows that the environmental benefits in all indicators from a levy are modest (i.e. 1% or less) when compared to overall environmental impacts from other activities in Scotland.

Impacts on consumers (Section 5 in the main report)

Consumers would obviously have to pay the levy itself overtly, on levied bags they continue to use, but the true additional financial burden of a levy on consumers in Scotland depends on a number of other factors as well. This draws upon experience from Ireland of the change in behaviour and therefore bag use. The total cost was calculated from the amount of levy paid for carrier bags, the relative hidden costs of plastic and paper bags[1], the costs of buying additional heavyweight plastic carrier bags (so-called 'bags for life'), the costs of buying additional bin liners, and additional VAT.

The cost to the consumer also depends on whether or not certain costs (in particular the 'hidden costs/savings') are passed on to the consumer by the retailer.

This leads to a wide range of estimated costs to the consumers, depending on assumptions. In Scenarios 1A and 1B (no levy on paper bags) the estimates ranges from £7.41 to £10.58 per year. In Scenarios 2A and 2B (levy on paper bags as well) the range is from about £2.50 to £6.11 per year.

[1] Hidden costs cover the purchase, transport and storage of bags by a retailer, normally passed on to consumers through the price of goods.

Including paper bags in the levy would therefore reduce the financial burden. Indeed this has a bigger effect on the range than whether or not SMEs are included.

The estimates of financial impact on consumers should be compared with average household expenditure in Scotland, this is £365 per week.

<u>Impacts on business (Section 5 in the main report)</u>

a) Retailers

After taking set-up and administrative costs into account, the food retail industry would benefit from net cost savings from the proposed bag levy. Savings would result from having to buy far fewer plastic carrier bags (now usually given away for free[2]), while sales of 'bags for life' and bin liners would increase.

However, this would not be the case for non-food retailers (e.g. clothing), as experiences in the Republic of Ireland following the introduction of the so-called PlasTax has seen a more pronounced shift to paper bags in these stores.

In terms of systems needed to comply with the proposed levy, larger retailers are expected to find this easier, having computerised systems and greater resource available. Smaller retailers may well not have computerised systems and the levy would thus represent a greater burden

b) Other business

There are an estimated 15–20 manufacturers, importers and distributors of plastic carrier bags in Scotland, most of which are SMEs. All will be affected by the proposed levy. It is believed that the imposition of a plastic bag levy in Scotland would lead to job losses, as it is considered unlikely that plants that currently manufacture plastic carrier bags would switch to alternative products (e.g. production of bin liners). Losses have been estimated at between 300 to 700 direct jobs, with further indirect jobs being affected (e.g. in support and distribution services).

<u>Impacts on Waste (Sections 4 and 5 in the main report)</u>

In all four levy scenarios, the total number of carrier bags (lightweight and heavyweight plastic and paper) used in Scotland per year would decline as a result of the levy. However, if paper carrier bags are not subject to the levy (as in scenarios 1A and 1B), the total tonnage of all carrier bags used and requiring disposal actually increases by 5,409 tonnes for scenario 1A (the proposed levy). Scenario 2A (including paper in the levy) would yield the greatest reduction in the tonnage of waste relative to current levels (a reduction of 4,993 tonnes per year). For comparison, in 2002/03 household waste in Scotland was 2,094,872 tonnes [SEPA] and 5,409 tonnes extra represents a 0.26% increase, whilst 4,993 tonnes less equates to a 0.24% decrease.

---

[2] Some stores in independent initiatives already charge for their lightweight carrier bags.

This analysis suggests some potential for an increase in solid waste generation for scenarios that favour a switch to paper bags. This is due to different assumptions about the relative weight of plastic and paper bags, and the fact that the LCA looks at solid waste impacts throughout the bag life cycle rather than just the end-of-life disposal phase.

Impacts on local authorities (Section 6 in the main report)

To determine the costs of set up and administration for local authorities would require a detailed specification of the systems and wider discussions. Our preliminary estimates suggest that the application of the levy to all businesses could cost Scottish local authorities, collectively, about £3–4 million to set up and £3.5 million per year to manage. This would reduce to £1.5–2.5 million to set up and £1.75 million per year to manage if the levy was applied selectively, i.e. based on retailer size or function.

These costs could be more than offset by revenues from the levy estimated at £7.75 million per year for all businesses and £5.5 million per year if applied selectively. However, smaller local authorities could receive lower revenues without a proportional reduction in administrative costs.

The Convention of Scottish Local Authorities (CoSLA) has reservations about the duty of collection falling to the local authorities and its concerns regarding the magnitude and potential administrative costs of the Levy, which they believe needs a full investigation.

Alternatives to the levy (Section 3 in the main report)

In addition to the assessment of the impacts of the levy scenarios, the study examined the details of alternatives to the levy.

The Carrier Bag Consortium (CBC) has developed a draft voluntary code to develop waste reduction and reuse initiatives and to continue product engineering to make further savings in the production, transportation and storage of plastic carrier bags. This has been submitted to the Voluntary Code of Conduct working group set up by the British Retail Consortium (BRC) and the Scottish Retail Consortium (SRC).

A voluntary approach has already been adopted in Australia, where use of carrier bags fell by 20.4% between 2002 and 2004.

Report Structure

This summary provides a brief introduction to the analysis methodology and results of the study. The main sections of the report are:

Volume 1

Section 1 reviews the context for the study.

Section 2 sets out background information on the various types of carrier bags and why they would be subject to a potential levy and reviews experience in Ireland.

Section 3 presents an assessment of the views for and against a levy based on experiences from around the world and from a variety of stakeholders.

Section 4 presents the life cycle assessment (LCA) analysis undertaken for different plastic bag levy scenarios.

Section 5 analyses the impacts a levy would have on consumers and businesses.

Section 6 gives a brief review and commentary on levy collection and its potential impact on local authorities.

Section 7 presents our conclusions.

Volume 2

Appendix 1 reviews international experience.

Appendix 2 provides details of the retail context.

Appendix 3 provides detail information on the LCA approach including the sensitivity analysis.

Appendix 4 provides graphs on the distribution of revenue to local authorities.

Both volumes include a glossary and a full set of references.

Contents

1 Report Context

Mike Pringle MSP (www.mikepringlemsp.com) tabled a Members Bill in the Scottish Parliament for a Member's Bill to enable local authorities in Scotland to impose an environmental levy on specified plastic bags [Pringle]. If passed, this legislation would cover all plastic bags provided by retailers at point-of-sale or from other outlets. The inspiration for this bill was taken from the experience of the plastic bags levy (the so-called PlasTax) in the Republic of Ireland.

The Scottish Executive commissioned this brief study from AEA Technology Environment and associates in order to investigate and assess the range of environmental, business and consumer impacts related to the proposal to introduce a plastic bag levy in Scotland. In doing so, other potential options or variants on the proposed levy have also been researched.

In this study, we used the Irish definition of a lightweight plastic carrier bag, i.e. 'any bag made wholly or in part of plastic, suitable for use by a customer at point of sale in a supermarket, service station or retail outlet'. Heavier weight plastic carrier bags, the so-called 'bags for life', costing more than €0.70 (around £0.48) are excluded from the Irish levy.

This Volume of the report is structured as follows:

Section 2 sets out background information on the various types of carrier bags and why they would be subject to a potential levy.

Section 3 presents an assessment of the views for and against a levy based on experiences from around the world and from a variety of stakeholders.

Section 4 presents the life cycle assessment (LCA) analysis undertaken for different plastic bag levy scenarios. As well as the bill tabled by Mike Pringle, we assessed scenarios that looked at the effect of applying the levy to paper bags as well as plastic bags and focusing only on larger retailers. No new LCA was undertaken for this report. Instead, the results from other suitable LCAs were adapted with Scottish data to show the relative environmental effects of a levy or variants thereof.

Section 5 analyses the impacts a levy would have on consumers and businesses.

Section 6 reviews and comments on levy collection and impacts on local authorities.

Section 7 presents our conclusions.

Volume 2 of the report contains the following Appendices:

Appendix 1 reviews international experience.

Appendix 2 provides details of the retail context.

Appendix 3 provides details on the LCA approach including the sensitivity analysis.

Appendix 4 provides graphs on the distribution of revenue to local authorities.

References are designated in square brackets, e.g. [CBC].

2 Introduction

The estimates for the number of lightweight plastic carrier bags issued in the UK vary from 8 billion [Defra 2003] to 10 billion [WRAP 2005]. From these, a range of 690–860 million has been estimated for use in Scotland based on population statistics. The calculations and assumptions behind this range are given in Section 4.3. The estimated cost of these bags to UK retailers also varies. Some sources suggest the cost to UK retailers is around £1 billion per year [BBC, WRAP 2004b], whereas the Carrier Bag Consortium (CBC) suggests that, based on the unit price of bags, the cost is closer to £64–80 million.

2.1 The Different Types of Carrier Bags

Most outlets currently provide free lightweight bags[3] made from conventional polyethene (polyethylene) plastic or bags made from degradable plastic (some outlets do make a charge[4]). Most major supermarket retailers also offer heavyweight reusable bags known as 'bags for life', for which they charge a small sum. Some shops also provide paper bags free of charge. The main types of carrier bags are described below; Table 2.1 summarises their key features.

Disposable High-Density Polyethene (HDPE) Bags

These plastic bags offer a thin, lightweight, high strength, waterproof and reliable means of transporting shopping. Research and development by the industry has reduced the average weight of such a bag by 60% compared with 20 years ago, while retaining the same strength and durability. Such bags are currently found in supermarkets and other food retail outlets.

Disposable Low-Density Polyethene (LDPE) Bags

These bags are currently given away free by many UK retailers (e.g. clothing shops). Like their HDPE counterparts, they are made from a by-product of oil refining.

Reusable Low-Density Polyethene (LDPE) Bags,

These are heavier gauge plastic carrier bags, often called 'bags for life'. Retailers charge for these (typically around 10p). The intention is that the customer uses them repeatedly and then returns them to the store for recycling when they are worn out, receiving a free replacement. Such bags are offered in many UK supermarkets.

[3] Throughout this report, the term 'lightweight' plastic carrier is used to describe 'disposable' plastic carrier bags available at the checkout as opposed to reusable bags such as 'bags for life'. Bags will vary in size depending upon products purchased. We understand, and have taken into account, the fact that lightweight plastic carrier bags are often reused for a second purpose.
[4] For example, Lidl and B&Q (see Appendix 2).

Paper Bags

The paper bags issued by shops range from very simple ones for small items (e.g. from newsagents and greengrocers) to larger ones (e.g. issued by fashion and shoe retailers). Some paper bags have plastic handles or plastic coatings. Under the terms of the Irish definition of plastic carrier bags (i.e. a bag with a plastic content), it is assumed that paper bags with a plastic content would be subject to the levy.

It is a misconception that paper bags are environmentally friendly because they are biodegradable. The increased volume of waste and the impact of their manufacture and transportation all need to be taken into account.

Polypropylene Bags

Polypropylene[5] has many uses for producing rigid and flexible containers, as well as furniture, and is also derived from oil resources. Non-woven polypropylene bags are available at shops such as Marks and Spencers in the UK, where they retail at more than £1. They are strong and durable and, like 'bags for life', are intended to be used many times.

Woven polypropylene bags are available at J Sainsbury in the UK as well as in the Republic of Ireland at Tesco and Dunnes stores. Woven bags are produced by stretching the polypropylene in production to form "fibres", the result is a stronger bag.

Degradable Bags

Bags that can be broken down by chemical or biological processes are described as degradable. Intuitively, degradable bags are expected to be environmentally friendly and a number of retailers are actively pursuing this option. Thus, there is often some surprise when reports suggest that degradable bags are not such an 'environmentally friendly' option. Waste management protocols emphasise the need to prevent, reduce, reuse, recycle and then recover energy. Encouraging disposal via degradation runs counter to this approach.

It can also be difficult to agree whether a particular type of bag is degradable or not. This could become significant if biodegradable bags were to be exempt from the levy.

Types of degradable bags

There are two main kinds of degradable bags[6].

- **Biodegradable** bags are made from natural starch sources such as maize and synthetic polyesters that degrade through the enzymatic action of micro-organisms (bacteria, fungi and algae), essentially rotting down like vegetable matter. However, starch-based biodegradable carrier bags are not available in significant numbers in the UK. They would only be covered by a potential levy on plastic carrier bags if they contained some plastic (some do for bag-strengthening reasons).

[5] Correct chemical name is polypropene.
[6] Biodegradable bags can be properly classified by how they decompose (either by microbes or through heat, ultraviolet light and water) and by the material they are made from (e.g. natural starch sources such as maize or wheat, or synthetic polymers from oil). Blended materials are also available, e.g. starch with HDPE or polyester [RMIT].

- **Bioerodable** bags are made from synthetic plastics (oil-based) with trace degradation initiators (HDPE with an approximately 3% content of heavy metals such as manganese and iron[7]) and, as such, would be covered by a plastic bags levy. They bioerode primarily by oxidation and erosion of the plastic through the action of light and heat until very small particles of plastic remain (these often degrade biologically). It is reported that, in an anaerobic environment, the degradation process is halted for some types of bioerodable bags [RMIT, Symphony Plastic Technologies].

Concerns Regarding Bioerodable Bags

- **Recycling.** Conventional polyethene plastic bags (HDPE and LDPE) can be recycled into new products such as other bags and solid items such as ‘plastic’ wood (known as plaswood). It will be difficult to keep the different kinds of bag apart (HDPE and LDPE bags for recycling and bioerodable bags for composting), especially if both are available in the same community. Inevitably, bioerodable bags will get into this plastic bag waste stream and thus contaminate the recyclate. If the resulting recycled item contains a certain percentage derived from bioerodable bags, it will have inherently lower functional properties (i.e. it will start to degrade when in contact with water, ultraviolet light, etc.). This could have serious implications if the recycled plastic is used for pipes for water, gas supply or as fencing posts or seats [RMIT]. Some types of bioerodable bags[8] are reported not to damage the overall value of the reclaimed material as the degradant initiator is destroyed during reprocessing.

- **Shelf-life and storage.** Bioerodable bags may start to decompose early if exposed to high temperatures, light or moisture. This compromises their carrying ability, though vacuum packaging is reported to prevent this [Symphony Plastic Technologies].

- **A solution to littering problems.** This claim is felt to send the wrong message to the consumer, i.e. it is acceptable to discard these bags because they will eventually rot down. The argument is that consumers should be informed of the need to reuse bags to reduce litter and resource consumption [RMIT]. In addition, the Marine Conservation Society (MCS) reports that any littered bioerodable bags based on HDPE will still cause problems to wildlife as they will break down into smaller pieces that can be ingested [MCS 2005]. This is questioned by Symphony Plastic Technologies, which suggests that degradation to carbon dioxide, water and humus is likely and that, should an animal ingest these smaller pieces, the degradation process will actually continue in its gut.

[7] Also copper, nickel, cobalt and cerium as well as photoactive compounds such as ferrocene.
[8] Oxo-biodegradable plastic bags produced by Symphony Plastic Technologies plc.

- **Provision of appropriate conditions for planned benign degradation.** Bioerodable bags are designed to decompose through the action of sunlight, water, stress and, ultimately, the enzymatic action of microbes in an aerobic environment. Where degradable bags are simply disposed of alongside other 'household waste' and then landfilled (like most household waste in Scotland [SEPA]), then the necessary conditions to allow degradation may well be absent and thus the environmental 'benefits' lost.

Certification and Labelling

Manufacturers of degradable polymers have signed a voluntary agreement with the European Commission to use environmentally friendly polymers in packaging that *"will effectively guarantee a biodegradability standard for products such as plastic bags, cups and plant pots, enabling them to be turned into compost and soil improvers."* The agreement includes a certification and labelling scheme to help consumers and manufacturers identify products made from degradable polymers [EU Commission].

Key Features of Carrier Bags

Table 2.1 summarises some of the key features of the various types of carrier bags available, including their costs and relative sizes compared with conventional lightweight plastic carrier bags.

Table 2.1 Key features of carrier bags

Bag type	Features	Average cost to the retailer per thousand bags *	Average weight per thousand bags (kg)*	Relative bag storage volume**	Recyclability
Lightweight plastic carrier	Light, strong, durable, effective when wet	£7.47	8.4	1	Yes – but not all stores have facilities
'Bag for life'	Light, strong, durable, effective when wet	£60.88	47.4	4	Yes – system of replacement actively encouraged
Fully degradable plastic bag	Light, strong, durable, effective when wet	£6 to £8	6.5	1	Degradable under the right conditions. Problematic if contaminate conventional plastic recycling.
Paper, without handles §	Convenient	£50	51	8	Yes – kerbside collections available
Paper, with handles §	More appealing to customers e.g. for shoes and clothes	£220	124	10	Yes – kerbside collections available but can be more problematic due to mixed materials
Non-woven polypropylene	Durable, strong, effective when wet	£333.33	138.7	20	Not at present
Woven polypropylene	Durable, strong, effective when wet	£433.33	226	20	Not at present

* Data provided by CBC and Symphony Plastic Technologies plc. Based on average price of an average bag.
**The relative volume of bags (to a conventional lightweight bag) is important for transportation and storage units required compared with plastic carrier bags.
§ The average weight of all paper bags available is 99g (arithmetic mean of 51, 81 and 166g). The values of 51g and 99g are used in the LCA in Section 4 for various analysis sensitivities.

2.2 Summary of the Irish Experience

A key motivator for the introduction of a levy on plastic bags in Scotland is the experience from the Republic of Ireland, where a levy known as the PlasTax was introduced in 2002. We consulted the Department of Environment, Heritage and Local Government in the Republic of Ireland for its views on the introduction and operation of the PlasTax. The Department said:

- The PlasTax was primarily an anti-litter measure with the secondary aims of increasing public awareness and changing behaviour. Introduction of the levy coincided with introduction of Ireland's Waste Strategy.
- No documented evidence is available showing a reduction in visible litter in the Republic of Ireland because of the levy. The Department has commented that *"littering of plastic carrier bags is no longer a problem"*.
- Approximately €1 million are raised each month from the levy.
- The decrease in bag usage was initially 90% and is now 95%.
- The main cost to retailers was updating their software so that till receipts would itemise the sale of plastic carrier bags.
- Theft was reported to increase at the outset but, when the Department investigated these claims, they were unable to substantiate them.
- Some increased control measures were introduced to stop trolleys being taken away from stores.
- Although use of paper bags has increased, it is not felt that their exclusion from PlasTax has been to the detriment of the scheme. Paper bags are reported as being used mainly by fashion and shoe shops. The grocery sector has switched largely to reusable bags.
- The advertising campaign, which was high profile and intensive, was considered a successful element in smoothing introduction of the levy.
- There are approximately 30,000 accountable persons registered in the Republic of Ireland. An accountable person is responsible for submitting the required information to the Revenue Commissioners.
- Compliance levels are reported to be very good. There is a facility for 'estimating levy liability' if retailers fail to submit returns or if the return is considered too low.
- There have not been any prosecutions. Any retailer not complying with the law has been visited, their non-compliance verified and a warning issued.

- Funds have been used to support waste recycling infrastructure, ongoing running costs and the introduction of dedicated staff to enforce waste legislation (with a particular focus on illegal waste dumping).

- An independent review of the scheme will be undertaken during 2005, three years after its introduction.

- A voluntary code was considered but the advice received suggested that this would be less effective.

3 The Arguments For and Against a Levy

The focus on plastic bags, in particular, is supported by:

- The high volume used.
- The perception that they are generally supplied 'free of charge'.
- The fact that they are a secondary form of packaging.
- The assertion that they add to litter in a highly visible manner.
- Their persistence in the environment.
- The view that they are potentially easy to replace.
- The view that they represent an 'easy target for visible success'.

3.1 The Arguments For a Levy

A bill for levy for certain plastic carrier bags in Scotland has been presented by Mike Pringle MSP [Pringle] following the introduction of the Irish PlasTax as a means of altering behaviour to help protect the environment. A further benefit stressed by Mike Pringle is the reduction of litter while encouraging the reuse of plastic bags. He argues that many plastic bags are not reused but end up in landfill sites or, worse still, as litter on the streets of Scotland.

Proponents of a levy cite the following potential benefits:

- Reduced resource consumption.
- Reduced energy consumption.
- Reduced emissions of greenhouse gases.
- Less litter.
- Increased public awareness of environmental issues in general.
- Strong message to change behaviour.

A Throwaway Society

Mike Pringle asserts that plastic bags contribute significantly to our throwaway culture of waste and argues that their use needs to be curbed, resulting in benefits for both the environment and business. He hopes that, by extension, people would be encouraged to think more about the other products and services they use and become more aware of reuse and recycling issues in general.

The proponents of a levy suggest that plastic carrier bags are only used twice at the most – to take purchases home and then, largely, for rubbish disposal. As such, they argue that plastic carrier bags are a needless waste of resources. This waste includes both the crude oil by-product resource from which the bags are made and the transport resources to deliver them from the manufacturing site[9] to the retail outlets where they will ultimately be distributed.

[9] Approximately 90% of plastic carrier bags used in the UK are imported from the Far East/China [CBC, Pringle].

Recycling levels for plastic carrier bags are low in Scotland and supporters of the levy argue that those that are not disposed of responsibly could increase the problems of litter. They often quote the sight and impact of wind-blown bags caught in trees and bushes to illustrate this point.

Litter and Damage to Wildlife

Further problems with littered carrier bags, especially in marine environments, are also cited. The Marine Conservation Society (MCS) conducts annual surveys every September in the UK to collect and remove litter from beaches. During this work, the MCS catalogues the amounts and types of litter found. The results are given in the MCS's Beachwatch reports [MCS 2003, MCS 2004, Independent].

In 2003, the survey covered 135 km of UK coastline and, in 2004, this rose to 145 km. Table 3.1 presents the survey data relevant to plastic bags. This category includes supermarket carrier bags as well as other kinds of plastic bags.

Table 3.1 MCS beach litter survey results

Year	Total number of plastic bags collected	Percentage of total litter	Plastic bags per km of coastline
2003	5,831	2.10%	43.2
2004	5,592	2.03%	38.5

The results show a drop of 4% from 2003 to 2004 in the numbers of plastic bags of all kinds collected. However, it is difficult to say whether this figure is statistically significant as it will depend on which beaches were visited.

It is also stated that a range of marine life such as whales, dolphins and turtles are severely injured or killed because they ingest or become entangled in plastic – as many as a million birds and 100,000 marine mammals worldwide every year [Envt Canada, MCS 2005]. One of the reasons given for why marine wildlife consume plastic bags is that they may mistake them for jellyfish, a main source of food for marine mammals. The consequence of this error is that the bags block the throat preventing normal feeding [Envt Canada, MCS 2005]. In 2004, the helpline run by Scottish Society for the Prevention of Cruelty to Animals (Scottish SPCA) received nine calls relating to animals that had become trapped in plastic bags, this is 0.01% of all calls taken. The Scottish SPCA note that the number of calls received will only represent a fraction of the actual number of wild animals who become entangled.

A survey undertaken in the Bay of Biscay during the early 1990s reported that plastic bags of all kinds, including lightweight plastic carrier bags that had been washed out to sea from land-based sources, accounted for 95% of all litter in sub-surface tows [Galgani].

Charting Progress - An Integrated Assessment of the State of UK Seas [Defra 2005] states:

> *"Marine litter can pose a hazard to beach users and recreational water users. Fish, seals, cetaceans and seabirds can become trapped (e.g. in sections of discarded fishing nets and plastic or rubber rings). They can also ingest plastic particles and objects, which can be fatal. Marine litter can also degrade the aesthetic quality of the environment, particularly in tourist areas."*

Clearly, this is not all due to plastic carrier bags as they make up only a proportion of this litter.

3.2 The Arguments Against a Levy

A number of organisations have lobbied against imposing taxes on plastic bags in many countries. These include the CBC in the UK, the Australian Retailers Association (ARA) and the Belgian Retail Association (BRA).

The Benefits of the Plastic Carrier Bag

The advantages highlighted by proponents of plastic carrier bags [ARA, CBC, EuroCommerce] include:

- Hygiene.
- Convenience.
- Reliability/efficacy/durability (paper bags often rip and are 'double-bagged').
- They can be reused for other purposes in and around the home, e.g.
    - as bin liners;
    - for storing shoes;
    - for collecting pet mess.
- Their disposal results in lower greenhouse gas emissions compared with disposal of bioerodable bags of paper, starch or plastic origin.
- There are lower environmental effects compared with paper bags in terms of production and transport as plastic bags use fewer resources, take up less volume and weigh less.

Hygiene is an important issue and, as is the case in Republic of Ireland, bags for wrapping fresh meat, fish, poultry and loose fruit would need to be excluded and remain free of charge because of their hygienic functional role[10].

Negligible Impacts on the Waste Stream

Plastic films, which include carrier bags and other plastic packaging, make up 4.37% of the household waste stream on average[11] in Scotland [SEPA]. To put these figures in context, paper and card makes up almost 25% of the household waste stream by weight while putrescibles (e.g. waste food) nearly 32%. Furthermore, plastic bags alone constitute about 0.3% of the municipal waste stream in the UK [HM Treasury].

The amount of municipal solid waste (household and commercial waste) collected by local authorities across Scotland for disposal in 2002/03 was 2,589,702 tonnes[12]. Using the UK data, 0.3% of the municipal waste stream by weight equals 7,769 tonnes per year of plastic bags. Any reduction in the amount of plastic bags disposed of would have very little effect on the overall waste disposal figures. Further analysis of the waste issues is provided in sections 4.6 and 5.2.

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[10] It is a statutory requirement under the Food Safety (General Food Hygiene) Regulations 1995 SI 1763 that meats are packed appropriately before supply to the customer.
[11] Range of 1.84–6.08% for 2002/03 [SEPA]
[12] Scottish local authorities collected a total of 3,345,458 tonnes of controlled waste (household, commercial and industrial) for disposal or recycling in 2002/03 [SEPA].

One of the aims of the EU Landfill Directive is to reduce the amount of biodegradable municipal waste going to landfill. The imposition of a levy that excluded paper bags is expected to increase the number of paper bags used and disposed. Although some would be recycled by consumers (e.g. through kerbside collections), there would ultimately be more paper bags going to landfill where they would degrade giving off greenhouse gases.

Single Trip or Multi-trip?

The Scottish Waste Awareness Group (SWAG) survey *Public Attitudes to Reduce, Reuse, Recycle in Scotland* (2001) stated that:

> "*The number of people engaging in this range of practices [reuse] was limited, the most commonly practised behaviour was the reuse of materials. This was achieved primarily through the reuse of plastic bags (84% of respondents), although the majority of these were ultimately used as bin liners"*. [SWAG]

A Waste Watch study for the UK reported that 54% of people questioned said that they reuse plastic carrier bags, with secondary reuse as bin liners a typical example [Waste Watch]. This study states that:

> "*Recent research suggests that four out of five people reuse products. Plastic bags and glass jars or bottles are reused by around half the public and plastic containers or bottles by one in five."*

Both the SWAG and Waste Watch studies suggest that a proportion of respondents reuse lightweight plastic carrier bags, often as bin liners. If so, the majority of bags would only be reused once. It must also be made clear that, when the SWAG survey states that 84% of respondents reuse bags, this does not mean that 84% of bags are reused. What it means is that 84% of people reuse some of their carrier bags at some point; a similar logic applies to the results of the Waste Watch study.

A more recent study undertaken by the Waste and Resources Action Programme (WRAP) found that, of the 1,048 people interviewed, 59% said they reuse all their lightweight plastic bags with a further 16% saying they reuse most of them [WRAP 2005]. The main use by far was as a surrogate bin liner, though other uses were reported such as other shopping, collecting pet mess or carrying other things when going out.

Litter Culprits?

A Local Environmental Audit and Management System (LEAMS) report by Keep Scotland Beautiful (KSB) states that the main items of litter in Scotland are:

- Cigarette litter (cigarette ends, matches, matchboxes, cigarette packaging) found at 70% of sites inspected.
- Confectionary litter (sweet wrappers, chewing gum wrappers and crisp packets) found at 50% of the sites inspected.
- Drinks-related litter (cans, bottles, cups, straws and lids) found at 34% of sites.
- Fast food packaging litter (fish & chip wrappers, polystyrene cartons, burger wrappers, plastic cutlery) found at 10% of sites.

Even though those plastic carrier bags that are littered are visible and persistent in the environment, the report did not mention them specifically [KSB].

Windblown plastic litter in the environment is often from other plastic sources such as the agricultural wrappings for hay bales, etc. [CBC]. WRAP has commented that a reduction in plastic bags used would not result in a noticeable improvement in the overall litter situation [WRAP 2004a].

These results have been echoed elsewhere in the UK by ENCAMS[13]. Its surveys have also shown that the main littering problems in England are from smoking products, food and drinks containers (plastic and glass) and dog mess, with the most prominent commercial litter coming from elastic bands dropped by postmen [ENCAMS].

A further recent survey conducted in England, commissioned by the Industry Council for Packaging and the Environment (INCPEN) and carried out by ENCAMS collected 37 carrier bags out of a total of 58,041 items, which equates to 0.064% of all items of litter found [INCPEN-ENCAMS]. The chief culprits were confirmed as chewing gum and cigarette ends. The data show that lightweight plastic carrier bags are not major contributors to reported land litter in Scotland.

A Finite Resource

Plastic bags are made from a by-product of crude oil refining. Supporters of plastic bags would argue that they maximise the benefits from a finite resource, rather than flaring off the excess gases (including ethene) produced by the crude oil cracking process.

Behavioural Change?

Countries that have not introduced a levy have argued that it is people's littering behaviour which needs to be changed and that this will not necessarily come about from the imposition of a levy [ARA]. The Belgian Retail Association agrees; it believes that the main problem and cause of litter is not in the plastic bag per se, but the public's behaviour in simply discarding it rather than disposing of it properly. Education and awareness raising are seen as the key to the litter problem rather than levying the use of lightweight plastic carrier bags [EuroCommerce].

Job Losses

Those against the levy argue that it will lead to job losses in an industry that has successfully developed and optimised its product to provide an efficient and effective means of transporting goods from place of purchase to the home. This topic is discussed in more detail in Section 5.2.

[13] The Keep Britain Tidy Group

3.3 The Voluntary Approach

The introduction of a levy at a UK level was reviewed and rejected in 2003. The Department for Environment, Food and Rural Affairs (Defra) has stated that *"...we have no current plans for a plastic bag tax, but the Government keeps all taxation under review"* [Defra 2003, Hansard 2004]. Various voluntary mechanisms are currently being investigated.

WRAP is working with the British Retail Consortium (BRC) on a 'reusable bags' project. The aim of this project is to achieve a united approach across retailers through the creation of a retail partnership. This will provide a high level exposure of 'reusable bags' to the consumer at most retail outlets. It is hoped that the 'reusable bags' concept can be presented more effectively to consumers, actively encouraging behavioural change in a self-sustaining way that will avoid the introduction of a levy. Actions under consideration include:

- In-store awareness promotions.
- High visibility of store 'reusable bags'.
- Loyalty points for carrier bag reuse.
- Staff training in carrier bag advice.
- Checkouts without lightweight carrier bags.
- A pilot project in Edinburgh and Bristol in Autumn 2005.

In addition, BRC and the Scottish Retail Consortium (SRC) have formed a working group to look at the possibility of developing a voluntary code of conduct. They will be working with members and other key stakeholders including the CBC. The CBC has submitted a draft Voluntary Code on Best Environmental Practice for the Provision, Use and Disposal of Plastic Retail Carrier Bags for consideration by the working group. While the draft code is not yet available, the CBC note that the draft proposal outlines plans for:

- Encouraging industry and retailers to work together to find ways of further reducing energy, material and environmental impacts in the production, transportation and storage of plastic carrier bags.
- Active support and participation in waste reduction and reuse initiatives.
- Development of new schemes to promote recycling.
- A commitment for separate film collection for degradable bags.
- Development of a customer information campaign.
- An independently audited scheme to monitor, measure and report success.

The CBC strongly supports a voluntary approach for Scotland and the UK as a whole. It suggests that reusable bags should be offered, but that free, disposable lightweight plastic carrier bags should also be available so that consumers can make their own choice.

The imposition of a levy in Australia was considered and then postponed for two years (until the end of 2004) to see if the voluntary take-up of reusable bags and increased rates of recycling could reduce the number of lightweight plastic carrier bags by a target of 50%. A report from the Australian consultants Nolan-ITU published in March 2005 states that bag usage fell by 20.4% between 2002 and 2004 through the voluntary code of conduct agreed by retailers [Nolan-ITU].

This reduction is broken down into supermarkets reducing usage by 25% and non-supermarket retailers reducing usage by 10–15%. This result shows that a voluntary scheme can have a significant effect, given the support and time to get its message across. The Australian Government is determined to continue this trend to the extent of reducing use to 50% by the end of 2005 and ultimately phasing out plastic bag use completely by 2008 [Aus Govt].

3.4 Other Alternatives to a Levy for Reducing the Impacts of Plastic Bags

Degradable bags have been suggested as a possible solution. The issues surrounding their disposal, recycling and littering implications are discussed in Section 2.1.

Other ways of reducing usage include promoting the **reuse** of lightweight plastic bags, the purchase of thicker 'bags for life' or rigid boxes as well as recycling plastic bags (either within shops or by local authorities). These alternatives are all fully feasible and in operation, but have only had a small uptake so far.

Recycling is one option for polyethene plastics as a way of reducing their environmental burdens. This would be achieved through replacing raw materials (virgin polymer) with recycled polymer (see Dixons case study below), as well as reducing the (albeit very small) load on landfill at their end-of-life. Recycling of all plastic films – not just carrier bags – currently stands at 300,000 tonnes per year in the UK [CBC].

Dixons plc, in association with Nelson Packaging introduced the UK's first **fully recycled carrier bag** in 2003 [Dixons]. Rather than being sent to landfill, waste plastic collected from commercial back-of-store and post-consumer in-store sources in the UK is used to make bags for Dixons. An independent LCA of these bags has been undertaken by Nottingham University. This estimates that every tonne of recycled bags produced saves around 1.8 tonnes of oil compared with a tonne of bags made from virgin material [Nottingham]. Dixons argues that using recycled material to produce plastic carrier bags not only reduces the environmental burden directly (through the use of less crude oil by-products and less waste being discarded), but it also educates the consumer to some extent.

Some retailers have adopted **voluntary charging**. Lidl currently charges 5p per bag in its UK stores. B&Q has piloted a scheme in its shops in Scotland at the same level, while IKEA charges 5p per lightweight plastic carrier bag at its Edinburgh store with good success (see Appendix 2 for more details). There is a similar story in Australia where European companies based there such as Aldi and IKEA already charge for their bags [RMIT], although this is a voluntary approach rather than mandatory. Consequently, some shoppers are already aware of, and accustomed to, the idea of paying for carrier bags for their goods.

Where incineration is the main disposal method in preference to landfilling, carrier bags offer high calorific values equal to or greater than that of oil. Hence, energy can be recovered from the bags and put back into the national electricity grid. This would reduce the need for conventional fossil fuels for power – again albeit by a small degree. However, there are currently only two energy-from-waste incinerators in Scotland [SEPA].

4 Life Cycle Assessment

A number of LCAs have been undertaken that compare the environmental impacts of the reusable, plastic, degradable and paper bags typically available in high street shops. The studies have been carried out in the USA, France and Australia (see Appendix 3 for a full list). No studies have been carried out based on data from Scotland or the UK.

We reviewed the studies and identified the French study (carried out by Ecobilan for the retailer Carrefour) as the most relevant to the situation in Scotland (the rationale used for this selection is presented in Appendix 3). We believe that the information available from this study is sufficient to provide a good indication of the likely life-cycle environmental impacts of changing plastic bag usage in Scotland. The Carrefour study (as it will be referred to in this report) is used in the following analysis.

4.1 Stages of the LCA for this Report

The analysis proceeds through the following stages:

1. Development of scenarios that will influence the numbers and types of bag used.
2. Quantification of the number of bags of each type (lightweight plastic, reusable plastic, paper, and bin liners) used under each scenario.
3. Review of the Carrefour study to extract the most relevant data for application in Scotland.
4. Sensitivity analysis – designed to test the robustness of base case results to plausible variations on the assumptions made.

4.2 Plastic Bag Levy Scenarios

Table 4.1 gives details of the five scenarios investigated for this study, including ‘business as usual’.

Table 4.1 Scenarios investigated for this study

Scenario	Summary	Description
0	Current situation	Business as usual
1A	As in the proposed Bill	Based on the introduction of a levy on all lightweight plastic carrier bags including degradable plastic bags, but NOT paper bags. It includes all distribution points: shops, petrol stations, charity shops, on-street promotional give-aways, etc.
1B	As in the proposed Bill, but excluding small-to-medium enterprises (SMEs), charities and promotions	Recognises the logistical problems of collecting a levy from all retail outlets. It assesses the extent of the environmental gain for the anticipated large-scale additional effort. The idea is to focus on the larger companies that use the greatest amount of bags and have the resources to enable them to comply more readily with a levy.
2A	As in the proposed Bill + paper bags	Based on applying the levy to all lightweight carrier bags including plastic, degradable plastic and paper. Includes all distribution points: shops, petrol stations, charity shops, on-street promotional give-aways, etc. Recognises that the levy is aiming to achieve behavioural change and encourage the use of re-usable bags and not simply a switch to, for example, paper bags.
2B	As in the proposed Bill + paper bags but excluding SMEs, charities and promotions	This scenario is the same as scenario 2A, but excludes SMEs, charities and promotions. Like scenario 1B, it looks at the extent of the environmental benefits without the logistical problems of trying to police and enforce the levy across the board.

4.3 Consumption Data Used to Quantify Environmental Impacts

To understand plastic bag consumption, we used published data to produce consumption figures for the different scenarios in conjunction with data on the impacts on consumers (see Section 5). These figures were derived as follows.

Existing Lightweight Carrier Bag Usage

- A Defra report stated that 8 billion plastic bags were used in the UK in 2000 [Defra 2003].
- Other sources [BBC, WRAP 2005] put this figure at 10 billion per year, from which it has been stated that Scotland's consumption is 1 billion plastic carrier bags per year [Pringle]. This estimate presumes an approximate factor of 10%.
- There are no actual figures available for the consumption of plastic bags in Scotland. Therefore, we used population statistics [Stats Scot, Stats UK] to scale UK bag

consumption data to Scotland. Population statistics show that 8.6% of the UK's population lives in Scotland.

- Average annual lightweight plastic carrier bag use in Scotland is estimated at 775 million[14].
- In consultation with the BRC and its members, it was agreed that reusable bag consumption ('bags for life') constitutes an additional 1%[15].
- There were no statistics available on the level of consumption of paper bags[16]. We estimated that paper bag consumption is about 5% of all plastic carrier bag consumption[17].

Consumer Behaviour

In essence, the success of the levy will depend upon consumers' wish to avoid paying the levy and the consequent reduction in the use of plastic carrier bags. If fewer people pay the levy, less revenue will be generated.

If a levy is introduced and does not include paper bags, it is anticipated that there will be an increased take-up of paper bags as well as 'bags for life'. Our estimate of the take-up of alternative carrier bag options is based on 'assumed percentage reductions' as used in Australian [DEH] and South African [FRIDGE] studies.

Our interpretation of consumer behaviour is based on the following assumptions:

- A levy would be charged at £0.10 per bag on lightweight plastic or paper carrier bags. This would lead to a 90% reduction in demand for each type of carrier bag, based on the experience in the Republic of Ireland.

- Under scenarios 1A and 1B (in which paper bags are not subject to the levy), it is assumed that of consumers not purchasing a lightweight plastic carrier bag:
  - 30% will not require any type of carrier bag ('no bag');
  - 45% will switch to heavyweight plastic carrier bags (or similar);
  - 25% will switch to paper carrier bags[18].
- Under scenarios 2A and 2B (which include paper bags in the levy base), it is assumed that of consumers not purchasing a lightweight plastic bag:
  - 42.5% of consumers will not require any type of carrier bag;
  - 57.5% of consumers will switch to heavyweight carrier bags (or similar)[19].

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[14] Calculated using population scaling on the upper and lower UK bag consumption figures: 8.6% of 8 billion equals 690 million bags, while 8.6% of 10 billion equals 860 million. The average of these two numbers is 775 million.

[15] Waitrose quoted as 1–2%; J Sainsbury's at 0.3%.

[16] Paper bags are normally used in the non-food retail sector for clothing, shoes, etc.

[17] From consultation with BRC.

[18] It is assumed that 30% of the total reduction in the use of lightweight plastic and paper carrier bags is transferred to 'no bag', as adopted for a 15 cent levy in the Australian report [DEH]. The remaining 70% reduction is assumed to be split between paper carrier bags and heavyweight plastic carrier bags. Using information from the UK Expenditure and Food Survey 2002/03 [ONS], we calculated expenditure likely to require a carrier bag and then split it according to (a) those retail categories (e.g. footwear, clothing, etc.) thought most likely to accommodate a switch to paper carrier bags (as seen in the Republic of Ireland) and (b) those retail categories (e.g. food, beverages, etc.) most likely to accommodate a switch to heavyweight plastic carrier bags. On this basis, 36% of total household expenditure is sourced from (a) and 64% from (b). It has therefore been assumed that 25% is transferred to paper carrier bags (i.e. 36% × 70% = 25%) and 45% is transferred to heavyweight plastic carrier bags (i.e. 64% × 70% = 45%).

- Under scenarios 2A and 2B, the estimated reduction in paper bags is assumed to result in a 70% switch to heavyweight carrier bags (or similar).

- It has been assumed that a typical heavyweight carrier bag is used 20 times before replacement[20]. Therefore, the 45% of consumers who choose to switch to a heavyweight carrier bag will purchase five such bags in place of 100 lightweight carrier bags. This gives a 1/20th ratio for calculating the numbers of heavyweight carrier bags used under the levy scenarios.

- Spending at SMEs has been assumed to account for 30% of total household expenditure[21]. In order to exclude SMEs from being subject to the levy, we have simply reduced total expenditure by households on items likely to involve the acquisition of a carrier bag (of any type) by 30%.

Bin Liner Consumption

- We included bin liner consumption to account for the displacement effect of people switching to or using additional purpose-made bin liners instead of carrier bags in the event of a levy.

- As no UK or Scotland specific data were available for current bin liner use, Irish data were used and scaled for Scotland along population ratios. An Australian study [DEH] reports a 77% increase bin liner consumption in the Republic of Ireland, from around 91 million to 161 million , following the introduction of the PlasTax. We have assumed a similar 77% increase in bin liner use for Scotland, i.e. from 118 million/year currently to 208 million/year post-levy[22].

- We have not included black refuse sacks and disposable nappy sacks as information on the relevant sales volumes was not available. In addition, there were no statistics available for bags made of polypropylene in Scotland. Although retailers felt that a levy would instigate an increase in sales of kitchen swing bin liners, they did not feel that it would alter their sales of black refuse sacks to any great extent [Nolan-ITU Pty Ltd, personal communication].

We combined the assumptions and data discussed above to give the annual bag and bin liner consumption shown in Table 4.2 for the different scenarios.

[19] It is assumed that, of those consumers who transferred to paper bags under Scenarios 1A and 1B, half now transfer to heavyweight plastic bags and half transfer to 'no bag'. We made this assumption because no other suitable evidence was available. Thus, the total proportion of the reduction in lightweight carrier bags now transferred to heavyweight bags is equal to 57.5% (i.e. 45% + (50% × 25%)).

[20] Taken from the Carrefour study [Carrefour].

[21] This is based on share of turnover in SIC(92)52, i.e. the retail trade with less than 250 employees, as determined by the Institute of Retail Studies, University of Stirling. Hence, in scenarios 1B and 2B, the levy is assumed to apply to 70% of the retail base in scenarios 1A and 2A. By adjusting the retail base in this fashion, it has been assumed that a £1 expenditure equals a £1 turnover and that the number of bags issued per £ expenditure at a SME equals the number of bags issued per £ expenditure at a non-SME. This is a crude assumption, but necessary without any data available.

[22] Scaled for population [CSO.ie2005, Stats Scot]

Table 4.2 Estimated annual carrier bag consumption under the different scenarios[23]

	Total number of bags consumed under each scenario (millions/year)[24]				
	0	**1A**	**1B**	**2A**	**2B**
Plastic carrier bag (HDPE, lightweight)	775	78	287	78	287
Plastic reusable bag (LDPE, heavyweight)	8	23	19	29	23
Paper bag (single use)	39	213	161	4	14
Total bags used	**822**	**314**	**467**	**111**	**324**
Bin liners	*118*	*208*	*181*	*208*	*181*

It is predicted that:

- Under scenarios 1A and 2B, there would be a drop in lightweight plastic carrier bag usage of 697 million/year.
- This decrease would not be so profound if SMEs were excluded (scenarios 1B and 2B) when it would be 488 million/year.
- If paper bags were not included in the levy, there would be annual increases of 174 million paper bags under scenario 1A and 122 million bags under Scenario 1B.
- 'Bags for life' would only increase by 11–21 million/year due to them being reused 20 times.
- Bin liner consumption would increase by 90 million/year if SMEs were included in the levy (scenarios 1A and 2A), or 63 million/year if not (scenarios 1B and 2B).

We combined these data on bag consumption with information on the life-cycle environmental impacts of different types of bags to determine the relative environmental impacts of each scenario in Scotland (Sections 4.5–4.7).

4.4 Relevant Results from the Carrefour LCA

The assumptions and scope of the Carrefour analysis are summarised in Appendix 3.

The Carrefour study considered four types of carrier bag:

- HDPE bags made from virgin polymer (lightweight plastic carrier bags).
- Reusable LDPE bags made from virgin polymer ('bags for life').
- Paper bags made from recycled fibres.
- Biodegradable starch-based bags.

[23] Numbers calculated as described in Section 4.3.
[24] Example calculations. For lightweight carrier bags under scenario 1B: (30% × 775) + (70% × 10% × 775) = 287. For heavyweight carrier bags under scenario 2A: 8 + [(775 –78) × 58% × 5%] + [(39 – 4) × 70% × 5%] = 29

We have not considered biodegradable starch-based bags in the analysis of the Scottish situation because they are not thought to be used in any great numbers. Numbers for plastic bioerodable bags (made from HDPE polymer with trace degradant additives) are used at a few outlets, but considerably more conventional HDPE bags are used. We have assumed that the environmental life-cycle impacts of bioerodable bags are comparable to conventional plastic bags as they are both made from HDPE, albeit with a small addition of degradation-promoting compounds. The consumption of bioerodable bags is included within the consumption of lightweight plastic bags.

The Carrefour study examined energy, resource use and pollutant emissions over the whole lifecycle of the bags, i.e. it included production of the raw materials, manufacture of the bags, transport of the bags to the retailer, and disposal at the bags' end-of-life. For plastic bags, for example, the lifecycle begins with extraction and refining of oil and the production of plastic, pigments ink and glue.

In the Carrefour study, the lightweight plastic bags are manufactured in Malaysia, Spain and France, and the heavyweight 'bags for life' are manufactured in France. Paper bags made from recycled paper are produced in Italy for Carrefour. It has been assumed that the bags are produced from old newspapers/magazines.

The Carrefour study examined both incineration and landfilling of bags at the end of their life. For the base case, we selected data that reflect landfilling of the bags as a large proportion of all waste is sent to landfill in Scotland[25]. However, we have also performed a sensitivity analysis that considers an alternative waste management strategy (see below).

The Carrefour study assessed the environmental impact of the energy use, resource use, waste generation and pollutant emissions from the lifecycle of each type of bag by examining their contribution to eight environmental indicators (see Appendix 3). Table 4.3 shows the environmental indicator score for each of the different types of bags, relative to the lightweight plastic bag, for the base case with all material sent to landfill at the end of the lifecycle.

The lightweight plastic bag has been given a score of 1 in all categories as a reference point. A score greater than 1 indicates that another bag ('bag for life' or paper) makes more contribution to the environmental problem than a lightweight plastic bag when normalised against the volume of shopping carried. A score of less than 1 indicates that it makes less of a contribution, i.e. it has less environmental impact than a lightweight plastic bag.

The indicators take account of emissions which occur over the whole lifecycle. They can therefore occur in different locations depending on where different parts of the lifecycle are located. For global environmental problems such as climate change, the location of the emission is not important in assessing the potential environmental impact. For other regional or local environmental impacts, however, it can be significant. For example, the impact of eutrophication of a water body will depend on the water characteristics. This is a well-known limitation of lifecycle impact assessment methodology: LCA quantifies the potential risk of environmental damage rather than actual harm.

[25] 88.2% was landfilled in 2002/03. Only 2.2% was incinerated, 5.9% was recycled, 2% was composted and the remaining 1.7% was treated by other means [SEPA].

Table 4.3 Environmental impacts of different types of carrier bag relative to a lightweight plastic carrier bag[26]

Indicator of environmental impact	HDPE bag (lightweight)	Reusable LDPE bag (used 2x)	Reusable LDPE bag (used 4x)	Reusable LDPE bag (used 20x)	Paper bag (single use)
Consumption of non-renewable primary energy	1.0	1.4	0.7	0.1	1.1
Consumption of water	1.0	1.3	0.6	0.1	4.0
Climate change (emission of greenhouse gases)	1.0	1.3	0.6	0.1	3.3
Acid rain (atmospheric acidification)	1.0	1.5	0.7	0.1	1.9
Air quality (ground level ozone formation)	1.0	0.7	0.3	0.1	1.3
Eutrophication of water bodies	1.0	1.4	0.7	0.1	14.0
Solid waste production	1.0	1.4	0.7	0.1	2.7
Risk of litter[27]	1.0	0.4	0.4	0.4	0.2

There are two key stages in the overall production process as laid out in the LCA:

i) Winning the raw materials from nature (e.g. drilling for and then refining crude oil) and converting them into commodities (e.g. polyethene granules).
ii) Manufacturing the bags themselves from these commodities.

The Carrefour study concluded that, for all bags, the main environmental impacts come from the first of these stages, i.e. the extraction and production of the materials (polyethene and paper) that are then used to make bags. The second stage (i.e. the manufacture of the bags themselves) is generally of less importance though not negligible. The study found that transport contributed very little to the environmental impacts. The end-of-life phase also makes a significant contribution to some indicators – most notably, the production of solid waste.

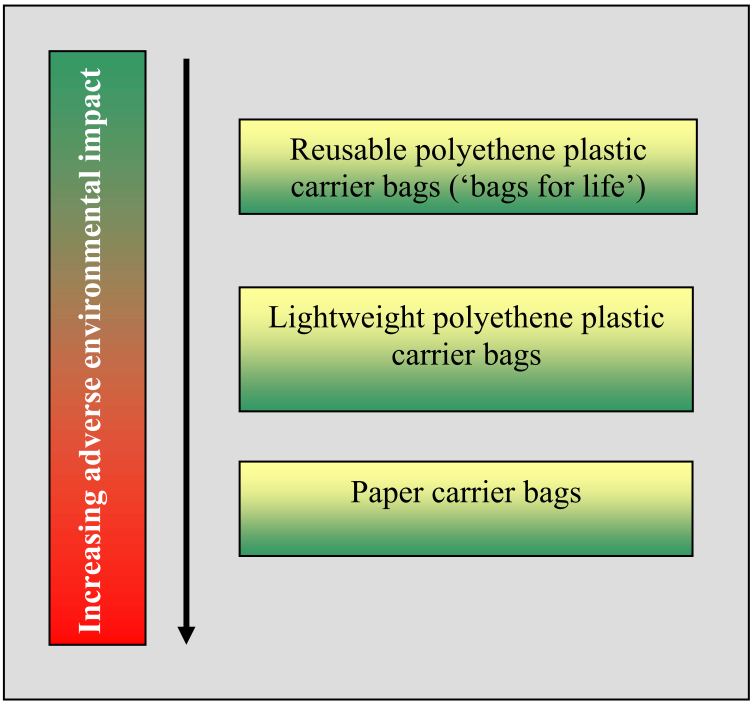
The overall conclusion from the Carrefour study was that reusable plastic bags (so-called ‘bags for life’) are more sustainable than all types of lightweight carrier bags (plastic, paper, or degradable) if used four times or more (columns 4 and 5 in Table 4.3), offering the greatest environmental benefits over the full lifecycle of any bags used.

[26] From Table 18 in the Carrefour study. Numbers *greater* than one indicate a *greater* environmental impact compared with lightweight plastic carrier bags and numbers *less* than one indicate a *lesser* environmental impact**.**
[27] The Carrefour study used the terms ‘strong’, ‘medium–weak’ and ‘weak’ to describe the risk of littering for each of the bags. We interpreted these terms numerically as 1.0, 0.4 and 0.2, respectively, in order to be able to show graphically how the risk of littering may change under the different levy scenarios.

Figure 4.1 summarises these findings. Paper carrier bags have a bigger environmental impact than lightweight plastic bags in all categories apart from risk of litter. Paper bags have a particularly high impact on the environment in terms of[28]:

- Eutrophication of water bodies (rivers, lakes, etc.) due to pollutants released to water during the manufacture of the paper.
- Water consumption.
- Greenhouse gas emissions
- Production of solid waste.

Figure 4.1 Summary of the environmental impacts of different carrier bags from the Carrefour LCA



[28] As noted in Appendix 3, the scores against these environmental indicators reflect potential risk than actual harm. Some indicators such as eutrophication are very site-specific in terms of actual impact, depending on the level of wastewater treatment employed and the state of the receiving environment. Others (e.g. climate change impacts from greenhouse gas emissions) are not site-specific.

4.5 Applying the Results to Scotland

We used data from Table 4.2 on plastic bag and bin liner consumption in conjunction with the relative environmental impact scores in Table 4.3 to assess the relative environmental impacts of the four levy scenarios compared with the current situation (scenario 0, 'business as usual'). We used the assumption from the Carrefour study that a reusable bag is reused 20 times[29].

To allow an assessment of the predicted change in bin liner consumption, it was assumed that the lifecycle impact of manufacturing bin liners is the same as for HDPE carrier bags per unit weight[30]. This is an approximation, which may overestimate the environmental impact of bin liners, and hence underestimate the benefits of the four levy scenarios. More details about the calculations are given in Appendix 3.

The results of the base case comparison are shown in Figure 4.2. The base case applies the results from the Carrefour study (Table 4.3) directly to the bag use data in Table 4.2. This implicitly accepts the use of French data on bag weights and volumes. The results give the percentage change in the environmental impact score for each of the levy scenarios compared with the current situation (scenario 0). In all scenarios where the levy is applied, consumption of non-renewable energy, atmospheric acidification, the formation of ground level ozone and the risk of litter fall considerably compared with the current situation.

In scenarios 1A and 1B where paper bags are exempt from the levy, the impacts are greater than the current situation for the consumption of water and eutrophication. However, they are approximately equivalent for the emission of greenhouse gases and the production of solid waste. This is due to a trade-off between the impacts from the additional paper bags consumed and the environmental benefits from the reduction in the use of lightweight plastic bags. The overall environmental impact from scenarios 1A and 1B is therefore predicted to remain very similar to today's situation. This is because the benefits of reducing plastic carrier bag use are displaced by the increased use of paper bags.

It is only in scenarios 2A and 2B, where the levy is applied to paper as well as plastic carrier bags, that consumption of water, emission of greenhouse gases, eutrophication of water bodies and production of solid waste are significantly reduced. This is because paper bags have a high score in these environmental categories relative to plastic bags (see Table 4.3 and Table A3.1 in Appendix 3).

In all cases, the environmental benefits increase (and environmental impacts reduce) when SMEs are included in the levy.

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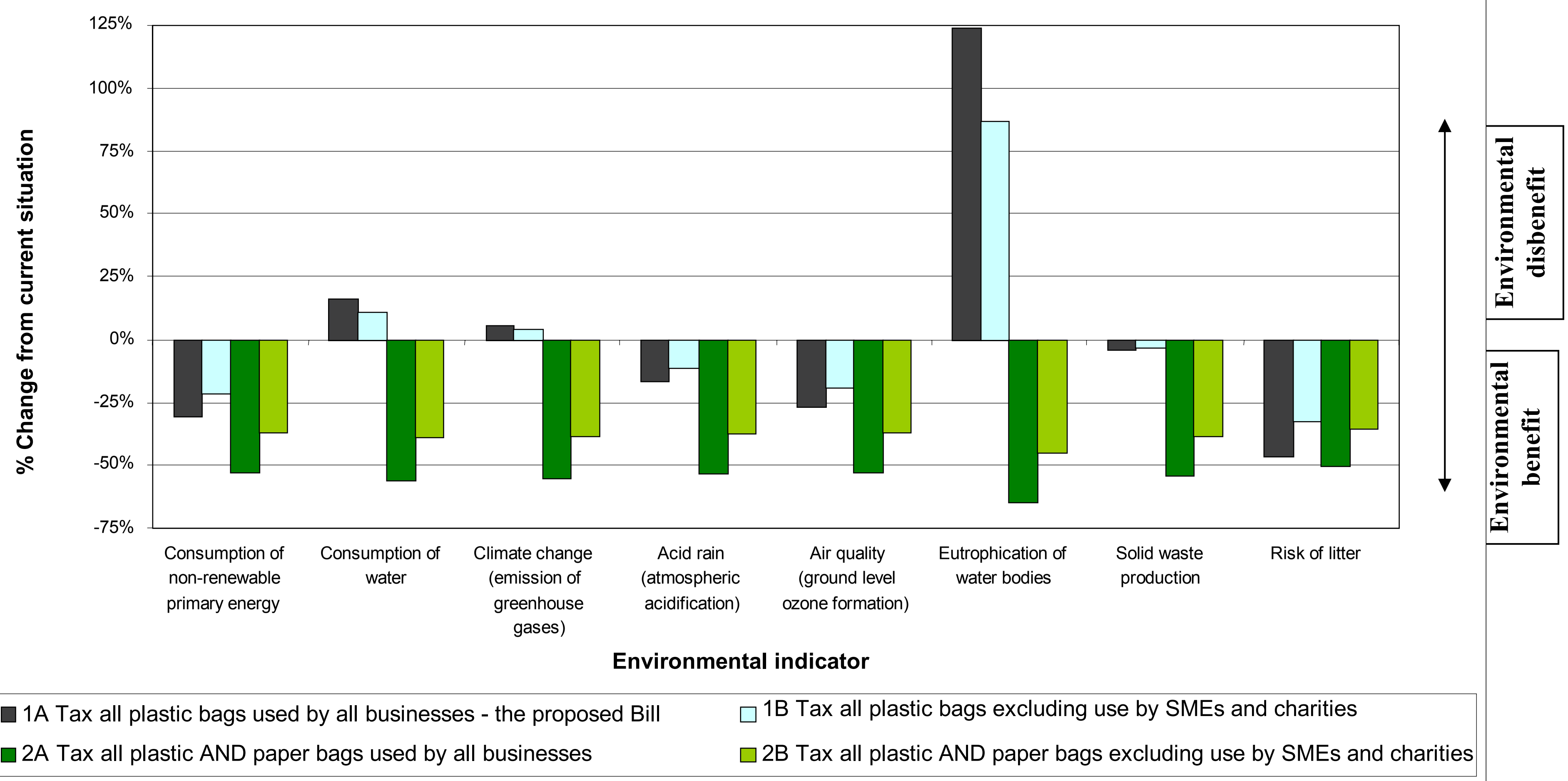
29 For comparison, the Australian study assumed that reusable 'bags for life' are reused around 52 times before being recycled, i.e. once a week in a given year [Nolan-ITU].

30 On average, bin liners weigh 15g each and lightweight plastic carrier bags 8g each. Thus, the environmental impacts of a bin liner were assumed to be 1.9 (=15/8) times greater than a lightweight plastic bag, giving an approximate ratio of 2:1. We have used this ratio throughout our analysis.

Figure 4.2 Change in environmental indicators due to a levy



Key assumptions: In scenarios 1A and 1B, there is a 25% switch from lightweight plastic bags to paper bags. In scenarios 2A and 2B, there is a 90% reduction in paper bag use.

These environmental effects will occur at different locations around the globe depending on where the raw materials are derived, where the bags are manufactured and how far they have to travel. The bulk of plastic bags for the Scottish market are made in the Far East and imported, whereas Scotland has a considerable paper bag manufacturing sector. Furthermore, some of the effects (e.g. ground level ozone formation) are more localised and some are regional (e.g. the consumption of water and emission of acidic gases), while others such as climate change resulting from fossil fuel combustion are global problems.

While we believe these broad messages about relative environmental impacts are applicable to the Scottish situation, there are differences between France and Scotland that mean that specific environmental impacts will differ. This is due to inherent France-specific assumptions in the original LCA work such as the characteristics and usage of bags, and to differences in the environmental impacts of manufacturing and waste disposal in the two countries. In particular, we note the following differences between the assumptions made in the French LCA and the situation in Scotland:

- The Carrefour study assumed that plastic bags weigh 6g as opposed to 8g in Scotland.

- The French study states that the paper checkout bags used by Carrefour weigh 52g. Paper checkout bags[31] in Scotland weigh 51g [CBC]. In the LCA base case, the Carrefour value was taken as representative for Scotland as it was assumed that checkout bags would be more affected by a levy, in terms of numbers and nationwide coverage, than boutique paper carriers with handles. In the sensitivity analyses (see below), the test used the average weight of 99g for all types of paper bags.[32]

- The Carrefour study assumed that a plastic bag has a volume of only 14 litres while a paper bag has a volume of 20.5 litres. This means fewer paper bags are required for the same amount of shopping. For Scotland, however, we would expect no significant difference on average in the volume of shopping carried in the two types of bag. One reason for this is the tendency for ‘double bagging’, where customers use two paper bags instead of one because they are concerned that a single paper bag may rip open.

- The Carrefour study takes for its base case an average waste management scenario for France, i.e. 45% of paper bags being recycled, 25% being incinerated and 26% landfilled. For the base case in this study, we used one of the Carrefour sensitivity analyses in which all waste is sent to landfill; this is much closer to the current Scottish position where 88% of waste is landfilled[33] [SEPA].

[31] Information provided by the CBC showed that there are three kinds of paper bags in general used in Scotland, depending on size and whether they have handles or not. These weigh 51g (checkout bag, no handles), 81g (carrier bag with handles) and 166g (carrier bag with handles). The arithmetic mean of these is 99g.

[32] This analysis suggests some potential for an increase in solid waste generation for scenarios that favour a switch to paper bags. This is due to different assumptions about the relative weight of plastic and paper bags, and the fact that the LCA looks at solid waste impacts throughout the bag life cycle rather than just the end-of-life disposal phase.

[33] Most recent published data (2002/03).

Various sensitivity analyses are presented in Appendix 3 to demonstrate the robustness of results against these factors. These analyses are:

- Sensitivity analysis 1: Assume paper bags weigh 99g instead of 52g.
- Sensitivity analysis 2: Assume on average that paper and plastic bags are used to carry the same volume of shopping.
- Sensitivity analysis 3: Assume lightweight plastic bags weigh 8g instead of 6g.
- Sensitivity analysis 4: Combined effects of sensitivity analyses 2 and 3.
- Sensitivity analysis 5: Assume the same split across recycling, incineration and landfill as in France.

The main results of the sensitivity analyses are:

- Repeating the analysis using a higher bag weight or 'effective' volume of paper bags led to a significant worsening in the performance of scenarios 1A and 1B for all categories except for 'risk of litter'. The categories of solid waste generation and acid rain, for which a small benefit was originally recorded under the base LCA (Carrefour, 100% of end-of-life bags landfilled), became a disbenefit (to a lesser extent for acid rain). The effect on solid waste generation is driven by the greater weight of paper bags compared with plastic bags (this feeds directly through to waste generation at the end of the lifecycle) and by the waste produced during paper production.

- Such effects are counteracted to a large degree by the assumption that lightweight plastic bags in Scotland are 8g compared to 6g in France.

- The assumptions on alternative waste management strategies (sensitivity analysis 5) have little effect on the results.

- The results for scenarios 1A and 1B are affected significantly by the sensitivities explored. This is as a result of encouraging people to switch from plastic bags to paper. Whereas, the results for scenarios 2A and 2B, where paper bags are also subject to the levy, show little change. In all cases studied and for all environmental indicators, scenarios 2A and 2B improved on the business as usual case by between 30% and 70%. The most restrictive scenario (2A, where all outlets including SMEs and charities are subject to the levy) shows a uniform improvement over scenario 2B of around 16% relative to business as usual.

It is important to recognise that the scores from the LCA represent *potential risk* and not actual environmental damage. Quantification of actual damage would require an impact pathway assessment that traces emissions from source to exposure to the quantification of impacts from specific industrial and waste management facilities. Such analysis is outside the scope of this report. It is noted, however, that some categories of effect are much more site-sensitive than others. For example, eutrophication of water bodies is only a problem where effluents are discharged untreated to a nutrient-sensitive water body. Climate change impacts, in contrast, are not sensitive to the site of the greenhouse gas release.

4.6 Displacement of Plastics in Scotland

In this section, we calculate the changes in tonnages of materials consumed in the scenarios based on the bag numbers data from Table 4.2 and the unit weights[34] for bags given in Table 4.4.

Table 4.4 Unit bag weights used in this study

	Weight (grams per unit)
Lightweight plastic carrier bags	8
Paper bags	51
Heavyweight plastic carrier bags	47
Bin liners	15

Table 4.5 shows the estimated changes in the weight of carrier bags (tonnes) used across Scotland in scenario 1A compared with the current pre-levy situation (scenario 0). Note that paper bags are not subject to the levy in scenario 1A.

Table 4.5 Change in annual consumption of materials for scenario 1A*

Bag	Pre-levy consumption (tonnes)	Expected post-levy consumption (tonnes)	Expected absolute change[35] (tonnes)	Expected % change
Lightweight plastic carrier bags	6,200	620	-5,580	-90%
Heavyweight plastic bags; 'bags for life'	364	1,102	+738	+203%
Bin liners	1,764	3,122	+1,358	+77%
Total for polyethene	**8,328**	**4,844**	**-3,484**	**-42%**
Total for paper	**1,976**	**10,869**	**+8,893**	**+450%**

* Numbers have been rounded so may not add up exactly. Negative numbers mean less material used and positive numbers mean more material is used.

For Scotland, there would be a saving of 5,580 tonnes of polyethene from 90% fewer lightweight plastic carrier bags being used. This has to be balanced, however, against the increase in 'bags for life' and bin liners – a total of 2,096 tonnes. Taken together, these data show an estimated net decrease of 3,484 tonnes of polyethene consumed per year in Scotland. Paper bag usage would increase under this scenario by 8,893 tonnes per year.

The summary information for all four levy scenarios is summarised in Table 4.6.

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[34] Data from CBC and SRC. For paper bags the checkout bag weighing 51g was used for consistency with the LCA base case. If the average weight of 99g, see footnote 31, was used then the waste implications would be greater.

[35] As stated earlier, data on black refuse sacks and disposable nappy sacks were not available. **If these figures were included, the net decrease in resource consumption would be less.**

Table 4.6 Change in annual consumption of materials for all four levy scenarios across Scotland

	1A: Proposed levy	1B: Proposed levy excluding SMEs	2A: Proposed levy + paper bags	2B: Proposed levy + paper bags excluding SMEs
Decrease in polyethene consumption (tonnes)*	-3,484	-2,439	-3,214	-2,250
Change in paper consumption (tonnes)*	+8,893	+6,225	-1,779	-1,245
Net change (tonnes)	**+5,409**	**+3,786**	**-4,993**	**-3,495**

* Does not account for black refuse sacks or nappy bags.

In summary, it is predicted that polyethene amounts would reduce across all four levy scenarios, but that paper amounts would increase in scenarios 1A and 1B and decrease in scenarios 2A and 2B.

If paper carrier bags are not subject to the levy (as in scenarios 1A and 1B), the total tonnage of carrier bags used actually increases. This is because shoppers will switch from the relatively lighter plastic carrier bags to the much heavier paper carriers. Where paper is included in the levy, both show a decrease in the overall tonnage of waste material (paper and plastic) needing disposal. Scenario 2A, where paper and all businesses are levied, shows the best overall reductions (4,993 tonnes) relative to the situation today. Scenario 1A performs worst – waste actually increases by 5,409 tonnes per year.

4.7 Conclusions on Lifecycle Impacts

This study has used an existing published lifecycle study from France to gain an indication of the relative lifecycle environmental impacts of different types of bag. This has then been combined with estimates of changes in bag use under four levy scenarios to examine the resulting changes in environmental impacts from bag usage.

Using the Carrefour study introduces an element of uncertainty into the results owing to national differences between Scotland and France affecting the lifecycle, i.e. the way in which electricity is generated, the amount of transport required and final disposal methods.

However, based on the results of our various sensitivity analyses, we believe the pattern of environmental impacts described in the Carrefour study will be similar to those in Scotland. It is our view that the results described above are sufficiently relevant to Scotland to serve as a useful guide to decision-making on policies concerning carrier bags. However, for the reasons presented above**,** the findings in this report cannot be used for a precise quantification of environmental impacts. This would require a full lifecycle analysis based on the Scottish situation, which is outside the scope of this study.

The main conclusions from our analysis are:

- The analysis shows that there would be an environmental benefit for some of the indicators depending on what consumers choose to use were a levy to be introduced.

- More specifically, the biggest environmental improvement is seen in scenarios 2A and 2B where paper bags are included in the levy. These occur for all environmental indicators

- In scenarios where paper bags are excluded, the environmental benefits of reduced plastic bag usage are negated for some indicators by the impacts of increased paper bag usage. This is because a paper bag has a more adverse impact than a plastic bag for most of the environmental issues considered. Areas where paper bags score particularly badly include water consumption, atmospheric acidification (which can have effects on human health, sensitive ecosystems, forest decline and acidification of lakes) and eutrophication of water bodies (which can lead to growth of algae and depletion of oxygen).

- Heavyweight, reusable plastic bags (the so-called ‘bags for life’) are more sustainable than all types of lightweight plastic carrier bags **if used four times or more.** They give the greatest environmental benefits over the full lifecycle.

- Paper bags are anywhere between six to ten times heavier than lightweight plastic carrier bags and, as such, require more transport and its associated costs. They would also take up more room in a landfill if they were not recycled.

- The analysis demonstrates that SMEs and paper bags should be included to maximise the potential environmental benefit of the levy. The inclusion of paper bags in the levy makes a greater contribution to maximising environmental benefits than inclusion of SMEs.

5 Impacts on Consumers and Business

Our base assumptions (i.e. scenario 0) are as shown in Table 5.1 and stated below.

Table 5.1 Bag consumption by type in Scotland

Bag type	Annual consumption (millions)	Per capita consumption
Plastic carrier	775	153
Paper	38.75	8
Multi-use	7.75	2
Total	**821.5**	**163**

- The population of Scotland is taken as 5,062,011 (from the 2001 census) and the grossed number of households as 2.14 million. This is 2.33 people per household.
- The UK Expenditure and Food Survey 2002/03 [ONS] states that total weekly expenditure in Scotland averaged £365 per household. Of this figure, approximately £110 per week is spent on goods that are likely to be sold with the option of acquiring a carrier bag[36].
- It has been assumed that a £ spent by lower income households requires the same number of bags for purchases as a £ spent by higher income households[37].
- The two largest sources of carrier bags are 'food' and 'clothing' retailers, followed by 'catering services' (e.g. takeaway).
- Current consumption of bin liners is around 118 million per year.

5.1 Determining the Financial Burden on Consumers

We made the following assumptions concerning unit costs:

- A levy would be set at £0.10 on each bag. We derived the amount that would be paid from this value and the numbers of bags used as given in Table 4.2. We have accounted for the fact that, under scenarios 1B and 2B, SMEs are not included in the levy base.
- Consumers are currently not charged for carrier bags[38]. This cost element to retailers (which includes the purchase, transport and storage costs of the bags) is known as the 'hidden' cost and is accounted for. It is passed on to the consumer, embedded within the price of goods.

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[36] We assessed the categories within the survey and made a judgement on whether a carrier bag might be required for purchases, e.g. insurance and holidays would not, but household goods and hardware would.

[37] In reality it is more likely that a £ spent by a lower income household buys more goods and this requires more bags than a £ spent by higher income households, since the price paid per unit by the latter will be higher. Sufficiently detailed data were not available however to accommodate this complexity.

[38] Except in some stores such B&Q and Lidl (see Appendix 2).

- The 'hidden' cost of lightweight plastic carrier bags to the retailer is £7.51 per 1,000 bags[39].
- The 'hidden' cost of paper carrier bags to the retailer is £163.69 per 1,000 bags[40].
- Heavyweight plastic carrier bags (or similar) are assumed to sell for £0.65 per bag[41].
- A bin liner is assumed to cost £0.05 per liner. This is the unit price averaged over ten products sold by Tesco.
- For scenarios 1A and 1B, it has been assumed that the additional 'hidden' costs incurred by stores are passed on to consumers as they increase due to additional purchase, transport and storage of paper carrier bags.
- Spending at SMEs has been assumed to account for 30% of total household expenditure[42]. In order to exclude SMEs from being subject to the levy, we have simply reduced total expenditure by households on items likely to involve the acquisition of a carrier bag (of any type) by 30%.

The total additional financial burden incurred by Scottish consumers as a result of the levy is therefore made up of the elements shown in Equation 5.1.

Equation 5.1 Financial burden to consumers

Total additional financial burden of levy
=
Payment of the levy on each levyable plastic carrier bag consumed post-levy
+
'Hidden' cost of carrier bags
+
Cost of **buying additional heavy use carrier bags** (or similar)
+
Cost of **buying additional bin liners** (or similar)
+
Payment of net **additional VAT**[43]

[39] Derived from data provided by the CBC and survey data reported by researchers from University College Dublin [UCD]. The average cost of lightweight carrier bags to the retailer is £7.47 per 1,000 excluding storage and transport [CBC].

[40] Derived from data provided by the CBC and survey data reported by researchers from UCD. The average cost of paper bags to the retailer is £163.33 per 1,000 [CBC]. The switch to paper bags is largely assumed to be by the clothing and shoe retailers.

[41] It is recognised that shoppers will have a wide range of options with an equally wide range of unit costs (e.g. currently from £0.10 for a 'bag for life' to £2.00 for an unbleached cotton carrier bag purchased privately). CBC suggested a range from 65p to £1.50; we used the lower figure. In addition, only those bags sold for more than €0.70 (approximately £0.48) are excluded from the levy in Republic of Ireland.

[42] Based on share of turnover in SIC(92) 52 retail trade with less than 250 employees determined by the Institute of Retail Studies, University of Stirling. Hence, in scenarios 1B and 2B, the levy is assumed to apply to 70% of the tax base in scenarios 1A and 2A. By adjusting the tax base in this fashion, it has been assumed that: a £ expenditure = a £ turnover and the number of bags issued per £ expenditure at a SME = the number of bags issued per £ expenditure at a non-SME. This is a crude assumption, but necessary without any data to the contrary.

[43] HM Revenue and Customs levy VAT on environmental taxes such as the climate change levy, the aggregates levy, the landfill tax and the oil duties. It is expected that the proposed carrier bags levy would likewise be subject to VAT.

We calculated the total additional financial burden to consumers for the four levy scenarios using:

- Equation 5.1.
- Bag use data under the scenarios from Table 4.2.
- The assumptions outlined above.

Table 5.2 shows how the numbers were derived for scenario 1A.

Table 5.2 Incremental cost to consumers of the levy under scenario 1A

Cost element for Scottish consumers in an average year	**Annual cost under scenario 1A (£ million)**
Amount of levy paid by consumers (= local authority revenue)	7.75
Additional 'hidden' cost of bags	23.31
Cost of additional heavyweight bags	10.20
Cost of additional bin liners	4.34
Additional VAT	7.98
Total additional financial burden of scenario 1A in Scotland	**53.58**
Total additional financial burden of levy per person	**£10.58/person/year**

Table 5.3 shows the results for all four levy scenarios. The greatest effect on the results is from the additional 'hidden' costs, which can vary significantly. In the first instance, we have assumed that, for all four scenarios, any additional 'hidden' costs or savings are passed on to the consumer (see columns 2–5).

The 'hidden' costs increase significantly for scenarios 1A and 1B as, despite fewer plastic bags being used, far more paper carriers are being used. However, costs go down in the scenarios (2A and 2B) where paper is included in the levy (i.e. *hidden cost savings*), as both paper and plastic carrier bag use declines in these cases. At the discretion of the retailer, these savings could be passed on to the consumer, thus reducing the financial load on consumers (see columns 4 and 5). We have added to Table 5.3 the resulting costs in scenarios 2A and 2B assuming that the retailer does not pass on any savings they may accrue (see shaded columns 6 and 7).

Table 5.3 Incremental cost of the levy to consumers for all scenarios, with sensitivity on 'hidden' costs

	Scenario					
	1A	**1B**	**2A**	**2B**	**2A – sensitivity**	**2B – sensitivity**
	'Hidden' costs or savings passed on to consumers				*'Hidden' savings **not** passed on to consumers*	
Total additional financial burden of levy in Scotland (£ million/year)	53.58	37.51	18.05	12.63	30.91	21.64
Total additional financial burden of levy per person (£ /person/year)	10.58	7.41	3.57	2.50	6.11	4.27

The scale of the estimates of financial burden can be gauged by reference to the results in the UK Expenditure and Food Survey 2002/03 [ONS]. This shows that average weekly household expenditure is £365. Our examination of the categories of expenditure shows that £110 of this is likely to require use of a carrier bag. This can be compared with an annual cost of the levy of between £3.57 and £10.58 per person.

Based on data from the annual UK Expenditure and Food Survey 2002/03 [ONS], it is estimated that the costs given in Table 5.3 will represent a higher proportion of final income for households with lower incomes than for higher income households. Excluding paper bags from the levy base increases the financial burden (compare 1A with 2A and 1B with 2B), more than excluding SMEs (compare 1A with 1B and 2A with 2B).

5.2 Impact on the Business Sector

The proposed levy on plastic carrier bags will affect the economy as well as the environment. Our conclusions on the business and industry effects of the proposed levy are based on:

- Contact with industry.
- Examination of raw data.
- Evidence from previous studies on similar measures worldwide.

Scotland and the Plastic Carrier Bag Industry

CBC estimates that there are 15–20 plastic manufacturers, importers and distributors in Scotland, most of which are SMEs. We have validated this estimate through study of the online Applegate directory of plastics companies in the UK [Apgate]. The geographical distribution of these businesses shown in Table 5.4 indicates their wide distribution in Scotland. Both importers and/or distributors of carrier bags, as well as manufacturers, will be affected by the levy. In the Republic of Ireland, one manufacturer closed after PlasTax was introduced.

Table 5.4 Plastics and plastic bag manufacturers, importers and distributors in Scotland by postcode

Postcode	Total plastic	Plastic bags
AB	11	1
DD	8	1
DG	5	1
EH	22	4
FK	6	1
G	36	3
HS	0	0
IV	4	2
KA	9	0
KW	1	0
KY	11	3
ML	6	1
PA	5	0
PH	0	0
TD	5	0
Total	**129**	**17**

Smaller enterprises are considered more likely to suffer greater impacts from a levy as it is anticipated that they have less capacity to adapt. Discussion with industry suggests most of the bin liners produced in the UK are manufactured in England. It is considered unlikely that production could be switched to Scotland to compensate for some of the lost plastic carrier bag production.

Industry estimates that anywhere between 300 to 700 direct jobs could be lost in Scotland alone as a result of a levy being imposed on lightweight plastic carrier bags [CBC]. This estimate is made up of:

- Some 400 jobs at BPI's Greenock plant.
- Some 100 or so jobs at Simpac's plant in Glasgow.
- Jobs at other smaller manufacturers and importers that would either have to:
  - close;
  - move operations to elsewhere in the UK (as in Simpac's case to Hull) or abroad;
  - diversify where possible into other plastic film products.

Another important company that would be affected by a levy is Smith Anderson in Fife[44], which manufactures large volumes of paper bags from both virgin and recycled sources.

There would also be knock-on effects elsewhere in an industry that employs around 2,500 people in the manufacture, import and distribution of carrier bags and around 12,000 in the wider plastic films sector in the UK.

[44] www.smithanderson.com

Paper Sector

The extent to which lightweight plastic carrier bags may be replaced by paper carrier bags is an issue of contention. In the Republic of Ireland, some sectors (e.g. fashion and shoes) have switched to paper bags [BRC]. In the scenarios where paper bags are excluded from the levy (1A and 1B), a 25% switch to paper carrier bags has been assumed. A move towards greater use of paper carrier bags would have consequences for those sectors involved in their manufacture, transport, waste management and import. As mentioned above, Smith Anderson is a major company in the paper recycling and bag manufacturing industry in Scotland.

Retail Sector

The estimated cost to UK supermarkets of giving away lightweight **plastic** carrier bags is reported in Section 2 (see Table 2.1).

Evidence from Republic of Ireland and BRC suggests that the food retail industry would benefit from net cost savings from a levy after taking set-up and administrative costs into account. Savings would result from having to buy far fewer plastic carrier bags, which are then given away for free, while sales of 'bags for life' and bin liners would increase [BRC, ERM, UCD].

However, this would not be the case for non-food retailers. Evidence from the Republic of Ireland from those retailers that switched to paper bags (mainly 'high street' non-food retailers) suggests that greater storage space and more frequent deliveries are now required. This has increased their overhead costs for material purchase and transport by over four-fold [BRC]. There are also different consumption patterns between food and non-food retailers. For the former, people often shop regularly and can thus plan to take reusable bags with them. For the latter, it is often more of an impulse purchase [WRAP 2005].

Larger retailers are expected to find it easier to implement the system needs for compliance as they tend to have computerised systems and greater resources available. There will be a cost associated with administration of the levy, but the experience in the Republic of Ireland suggests that the effects were generally positive or neutral [UCD].

The levy would represent a greater burden to smaller retailers (e.g. newsagents, butchers, etc.) as they may not have computerised systems. As a minimum, it is anticipated that retailers will need to have an auditable system for:

- Recording carrier bags sales.
- Accounting for bags in stock.
- Reconciling sold versus stock remaining.
- Submitting records (quarterly in Republic of Ireland).
- Submitting payments.

Shoplifting and Theft

Theft, as an unwanted side effect of introducing a levy, is often raised as a problem for retailers. Although levels of theft were initially reported to have risen in the Republic of Ireland, they have since gone back to pre-levy levels and are even dropping further (information from the Department of Environment, Heritage and Local Government, Republic of Ireland).

The reported levels of 'shrinkage' (the industry term for theft) are calculated each year in the EU [Retail Research]. Table 5.5 shows shrinkage in percentage terms of turnover for 2003 and 2004 for the UK and Republic of Ireland. It is evident that both countries saw a drop in retail theft between 2003 and 2004.

Table 5.5 Changes in retail theft as a percentage of overall turnover for the UK and Republic of Ireland

Retail Shrinkage (as % of turnover)	2003	2004
UK	1.69%	1.59%
Republic of Ireland	1.35%	1.34%

Increased trolley and basket theft has been highlighted by some as a potential cost to industry caused by people wishing to save on paying for bags. Five months after the introduction of the PlasTax, the Retail, Grocery, Dairy and Allied Trades' Association (RGDATA) for the Republic of Ireland reported that 50 baskets per month were disappearing from shops at a total cost of €450/month.

Impacts for Waste Management

This section uses the changes in the weight and volume of bags under each levy scenario to assess the changes in waste arisings, changes in waste management costs and changes in waste volumes. Note that this is only part of the total waste due to carrier bags, the total waste impact (including waste in the winning of raw materials and production, which will often take place outside of Scotland) is considered in more detail in the LCA and is presented in Figure 4.2 and Appendix 3.

The change in consumption of materials under each levy scenario is considered in section 4.6. To assess the impacts on waste management we then need to add in details of the waste disposal routes.

In 2002/03[45], 88.2% of all waste arisings in Scotland were disposed of to landfill, 2.2% were incinerated, 5.9% were recycled, 2% were composted and the remaining 1.7% was treated by other means [SEPA].

[45] SEPA informed us that recycling rates for 2003/04 were 12.3% nationwide (data to be published in June 2005). However, 2002/03 SEPA statistics were used for consistency.

For plastic bags we have assumed that there is a low level of recycling of post-consumer bags and that this would not change significantly if a levy were introduced. Thus, for the purpose of this calculation, all plastic bags would eventually be landfilled or incinerated[46]. We assumed that 97.6% of plastic bags were landfilled and 2.4% were incinerated[47]. It was not possible to estimate the quantity of lightweight plastic carrier bags or heavyweight plastic carrier bags going to each disposal route[48]. Instead, we applied the shares of landfill and incineration in total waste disposal equally to each.

For paper bags we were able to account for recycling in the calculations of waste management using Scottish waste statistic [SEPA][49]. Paper comes under the heading of ‘paper and card’ in SEPA data. As paper bags are not accounted for separately in SEPA waste statistics, we assumed that recycling rates for paper bags are the same as “paper and card”. We made the following calculation:

- 24.26% of household ‘bin’ waste in Scotland is paper and card.
- 2,094,872 tonnes of household (controlled) waste were collected in 2002/03.
- This means that 508,216 tonnes of paper and card were collected from household waste for disposal (to landfill or incineration).
- 67,660 tonnes of paper and card were collected separately for recycling.
- Therefore, 13.3% of paper and card was recycled (67,660 tonnes/508,216 tonnes).
- The remaining paper is either landfilled (84.6%) or incinerated (2.1%)[50].

We estimated the change in paper bags waste for each disposal route using:

- Our calculation ratios for landfilling, incineration and recycling of paper in Scotland.
- The net total change in annual paper consumption (and hence waste production) under the four levy scenarios given in Table 4.6.

The amounts shown in Table 5.6 represent changes in the disposal of residual household waste and recycling in an average year under each of the levy scenarios.

Table 5.6 Estimated annual changes in waste disposal routes for residual waste in Scotland under the different scenarios

Scenario	Disposal route (tonnes per year)			
	Landfill	Incineration	Recycling	Net change
1A	4,122	103	1,184	**5,409**
1B	2,886	72	829	**3,786**
2A	-4,640	-116	-237	**-4,993**
2B	-3,248	-81	-166	**-3,495**

46 Plastic *films* are recycled in large amounts, though this is mainly back-of-store packaging, estimated at 300,000 tonnes per year [CBC]. There is very little post-consumer recycling of plastic carrier bags and there are very few facilities to do so. For example, the recycling rate for lightweight carrier bags in Australia in 2002 was 2.7% [DEH].

47 Step 1: 88.2% (landfilled) + 2.2% (incinerated) = 90.4%. Step 2: 88.2% / 90.4% = 97.6%

48 The facility is known to exist in many food retail outlets for the take-back and recycling of heavyweight bags-for-life, but no data on the level or rate of this was available.

49 Recycling of paper bags was not considered for the LCA in Section 4 due to the assumptions in the Carrefour study. This will lead to a difference in the results presented here with those in section 4 under the ‘solid waste’ environmental indicator.

50 13.3% of paper is recycled. This leaves 86.7% going to another route. 97.6% will be landfilled: 97.6 % × 86.7% = 84.6% overall. 2.4% will be incinerated: 2.4% × 86.7% = 2.1 % overall.

Table 5.7[51] shows estimated changes in landfill and incineration costs for household waste in Scotland as a whole, under each levy scenario. Costs increase under scenarios 1A and 1B, while costs decrease under scenarios 2A and 2B. These cost increases or decreases apply to local authorities who are responsible for household waste disposal.

Table 5.7 Estimated changes in waste management costs for Scotland due to the levy[52]

Scenario	Cost (£ per year)		
	Landfill	Incineration	Total
1A	227,000	7,000	**233,000**
1B	159,000	5,000	**163,000**
2A	-255,000	-8,000	**-263,000**
2B	-179,000	-5,000	**-184,000**

The amount of solid waste generated can also be quantified in terms of volume. The Carrefour study only gives information on weight for the full life cycle, though it is clear that this is dominated by the end of life stage. Using data on relative bag storage volume from Table 2.1 it is possible to estimate the relative difference in volume of material sent for disposal (see Table 5.8), though this ignores wastes generated at stages other than end of life disposal. Results show a significant increase for scenarios 1A and 1B for volume relative to the base case. For scenarios 2A and 2B, however, the volume of bags disposed of relative to the base case falls significantly.

Table 5.8 Estimated changes in waste volumes in Scotland due to the levy

Change in Volume – assuming 50 g paper bag occupying 8 times the volume of HDPE lightweight bags					
As % of base case	100%	167%	148%	20%	44%

Charities

In a submission to Mike Pringle MSP, the Association of Charity Shops expressed its belief that the ability of some charity shops to operate successfully would be jeopardised by the proposed levy[53]. The Association is also concerned that donations by the public would become difficult, as donated stock delivered to shops is usually in plastic carrier bags. These bags are then reused for customer purchases.

[51] Figures have been rounded.

[52] Savings based on landfill costs of £55/tonne and incineration costs of £65/tonne. The unit costs include collection, transfer and gate fees (including landfill tax in the case of landfill). However, it has not been possible to separate the fixed from the variable elements of the costs. Given the relatively small scale of the changes in waste tonnages, only the latter will be saved. The cost savings will therefore tend to be overestimates. However, landfill costs are likely to rise during the same period as a result of the landfill tax escalator.

[53] Response by the Association of Charity Shops to consultation paper issued by Mike Pringle MSP.

6 Administration of the Levy

The mechanism by which local authorities would administer the levy falls within an exception to the reservations in the Scotland Act 1998 (Section A1, Part II, Schedule 5 Fiscal, economic and monetary policy). This states that local taxes to fund local authority expenditure fall within devolved competence. It is this exception which is being investigated by Mike Pringle MSP. We have not considered the validity of this exception, but have considered some of the implications for administering the levy should the Bill proceed.

6.1 System Requirements

A system will be required which will allow for:

- Monies to be collected from 'retailers' and held in a local authority account.
- Keeping records of customer transaction.
- Auditing and inspection.
- System checks and interrogation re anticipated income, documentation files and generation of customer queries.
- Development of an appeals system.
- Development of systems to pursue debt and non-payment.

Businesses would need advice on:

- How the levy would operate.
- Definitions of what types of bags the levy covered.
- What information they would be required to submit, e.g. stock of bags at outset, stock remaining at end of submission period and records of bags sold.
- How and when the monies collected should be transferred (ideally electronically) to the administration body.
- The penalties for non-compliance.

System in the Republic of Ireland

In the Republic of Ireland, businesses submit quarterly returns. There are separate and distinct roles and bodies for collection and enforcement. Payment is by electronic debiting of the retailer's bank account. An online system that allowed this, the Revenue Online System (ROS), was in place prior to the introduction of the PlasTax.

So far, there has been one prosecution for non-compliance. Any retailer not complying with the legislation has been visited, their non-compliance verified and a warning issued. Warnings have been issued to a few hundred out of around 50,000 retailers [communication from Terry Sheridan, the Department of Environment, Heritage and Local Government, Republic of Ireland].

The basic administrative requirements are:

- An opening stock take of plastic bags when the levy is introduced.
- A record of plastic bag purchases.
- A record of plastic bags supplied to customers where the levy applies.

The records must differentiate between:

- Those plastic bags used to contain fresh meat, fish, poultry, fruit, vegetables and other foods that are not otherwise packed, or ice
- Other plastic shopping bags.

The role of enforcement is separate and is undertaken by the local authorities. It involves:

- Visiting retail outlets and talking to retailers.
- Carrying out initial spot checks.
- Monitoring implementation.
- Ensuring that the levy is passed on in full to customers.
- Ensuring that exemptions are not being abused.
- Checking tills to confirm that customers are being charged the €0.15 levy for plastic bags where applicable.
- Taking appropriate action where it has been established that the levy has not been charged to customers, e.g. issuing letters informing retailers of obligations under the regulations and following up where necessary. Following up on any complaints from the public.

The Revenue Commissioners are responsible for:

- Identification of accountable persons[54].
- Processing returns and payments received from accountable persons.
- Carrying out verification checks relating to the accuracy of returns.
- Pursuing accountable persons who fail to deliver returns and payments within the statutory time limits.
- Raising estimates where returns are not received or where liability is under stated.
- Dealing with appeals against estimates raised.

To minimise compliance costs on retailers, checks carried out by the Revenue Commissioners are, insofar as possible, incorporated with checks carried out in relation to tax liabilities.

[54] An accountable person is responsible for submitting the required information to the Revenue Commissioners.

6.2 Impact on Local Authorities

CoSLA has recorded its reservations about the duty of collection falling to the local authorities and its concerns regarding the magnitude and potential administrative costs of the levy, which it believes require a full investigation.

We consulted two local authorities and considered three options for implementation of the levy:

- Option 1: Blanket application of the levy

  While applying the levy on a blanket basis ensures consistency of application, data from Australia [DEH] suggest that the collection of the levy from small retailers could give marginal returns given the cost of collection and estimated segmentation of bag distribution. Consequently, we also considered:

- Option 2: Selective application of the levy based on retailer size or function.

- Option 3: Selective application of the levy based on rateable value.

As a possible option for making the best use of resources that would support the Scottish Executive's Efficient Government Initiative, we invited the local authorities consulted to consider the benefits and workability of setting up a central billing body to administer the levy on behalf of all authorities. It should be noted, however, that this is not presented as a formal proposal and it is one about which CoSLA has voiced concerns.

The results from these consultations should not be taken as the whole story for Scotland, but as indicative of the potential costs.

Option 1: Blanket Application of the Levy

The levy will apply to all retailers in Scotland (52,690)[55] and all other outlets distributing bags as part of a business transaction (e.g. exhibiters). This will undoubtedly create a very significant administrative burden for local authorities, as they will have to administer the levy including collection, policing and penalising of defaulters.

Feedback from discussions with the Assessor to the Lothian Valuation Board has been made available to this study. In essence, a national billing body could establish a database of all subjects liable to the levy. Since this would be sourced to valuation roll data, any analysis of levies imposed and collected could be easily calculated for an individual local authority area. Businesses would need to account directly to the billing body. The most efficient process would be self-assessment similar to the collection of VAT, with legislation enabling the billing body to check the records of any individual businesses for accuracy, etc. The self-assessment would also need to be accompanied by payment to streamline the bureaucracy involved and again legislation would be required to encourage compliance, e.g. fines for late payment, etc. The main administrative efforts would be to keep name and address details up-to-date and to police the return of the prescribed information and levy payments.

[55] Total number of retailers in the all-Scotland Valuation Roll from April 2005. There were 52,690 properties classified by the assessors as 'shops'.

CoSLA is also concerned that, if the levy were successful in its aim of reducing plastic bag usage, expenditure on collecting and enforcing the levy might exceed income and local authorities might have to look to the Executive to cover a funding shortfall. CoSLA believes that additional funding from the Scottish Executive would be required for start-up and has commented that the estimated costs would require detailed analysis.

In the absence of any available detailed analysis, we undertook a **simplistic** estimation of costs of this option using the assumptions given in Table 6.1. This suggests average indicative set-up costs of around £3 – 4 million, and enforcement and ongoing management costs of around £3.5 million per year.

Table 6.1 Simple cost estimates for option 1 (blanket application)

Activity	Cost calculation	Estimated cost
Education campaign		£1 – 2 million
Set-up	1 person for 1 year plus support (£60,000 × 32 local authorities)	~£2 million
Ongoing management	0.5 person/year/local authority (0.5 × 32 × £40,000 = £0.64 million) Billing body team (4 × £40,000 = £0.16 million)	~£1 million
Enforcement/policing	1 person/local authority plus support and travel (£40,000 × 32) + (£20,000 × 32) = £1.92 million Plus legal advice (£0.75 million)	~£2.5 million

Option 2: Selective Application of the Levy Based on Retailer Size or Function

A second option would be to apply the levy based on retailer size. One option for this is to use the EU definition of an SME as the defining point beyond which the levy is applied. The current EU definition of SME is a business with a turnover of €50 million or less. Although this presents a sound solution in terms of practicality, no data are unfortunately readily available to local authorities at present. It would, therefore, have to be sourced from UK Revenue and Customs (formerly HM Customs and Excise). It is also uncertain whether these data would be available at local authority level.

Making a simplistic estimation of costs again for discussion purposes, this option is estimated to require potentially lower set-up costs because less ‘contact’ will be required as a consequence of working with fewer retailers. Similar ongoing annual management costs and less policing and enforcement costs to option are anticipated, as we would expect the major retailers to comply readily with the legislation.

Table 6.2 suggests average indicative set-up costs of £1.5 – 2.5 million and enforcement and ongoing management costs of £1.75 million per year.

Table 6.2 Simple cost estimates for option 2 (selective application based on retailer size)

Activity	Cost calculation	Estimated cost
Education campaign		£1 – 2 million
Set-up	0.25 person for 1 year plus support (0.25 × £60,000 × 32 authorities)	~£0.5 million
Ongoing management	0.5 person/year/local authority (0.5 × 32 × £40,000 = £0.64 million) Billing body team (4 × £40,000 = £0.16 million)	~£1 million
Enforcement/policing	0.25 person/local authority plus support and travel (0.25 × £40,000 × 32) + (£5,000 × 32) = £0.48 million Plus legal advice (£0.25 million)	~£0.75 million

Option 3: Selective Application of the Levy Based on Rateable Value or Square Footage

Another option, which was suggested by the local authorities consulted, would be to apply the levy based on either the rateable value of the retail outlet or its square footage. These are data held by all local authorities and which could be used as the basis for allocating the levy. While the rateable value approach would allow small retailers to be exempt, it could present consistency difficulties in terms of varying rateable values both within and between local authority areas.

6.3 Revenue by Local Authority

Based on average use assumptions (see Table 4.2), each person in Scotland is predicted to pay the amounts shown in Table 6.3. This table also shows the calculated revenue for the whole of Scotland.

Table 6.3 Cost per person per year for levied carrier bags[56]

Scenario	Cost per person per year for all bags	Revenue total in Scotland per year
1A	£1.53	£7.75 million
1B	£1.07	£5.43 million
2A	£1.61	£8.14 million
2B	£1.13	£5.70 million

Revenues are slightly higher from scenarios 2A and 2B than from 1A and 1B because paper bags are also subject to the levy in these cases.

Table 6.4 shows the flow of revenue predicted in Table 6.3 against the costs incurred to set up and run a levy collection scheme. Option 1 (blanket levy) and associated costs have been used together with scenario 1A (the proposed levy) and associated revenue. Table 6.4 shows the set up costs in the year before introduction (year 0) and that from the first year of operation onwards, net revenue is estimated at £4.25 million per year. Under Mike Pringle's Bill, this would be available for environmental schemes across Scotland [Pringle].

56 Assumes full payment of the levy.

Table 6.4 Estimated costs versus revenue in Scotland (Scenario 1A, Option 1)

	Cash flow (£ million) in year:			
	0	**1**	**2**	**3**
Set-up costs[57]	-3.50	0	0	0
Annual costs	0	-3.50	-3.50	-3.50
Revenue	0	7.75	7.75	7.75
Net	-3.50	4.25	4.25	4.25
Cumulative	*-3.50*	*0.75*	*5.00*	*9.25*

Analysis for other scenarios and options shows that:

- More revenue would be generated for scenario 2A because paper bags would be included. However, the costs (Option 1 blanket levy) would be the same, so the annual balance would be greater.
- If SMEs were excluded (Option 2 and scenarios 1B or 2B), there would be lower set-up and ongoing management costs but also lower revenue.
- If plastic carrier bag use fell to 5% of pre-levy volumes, half the revenue estimated in Table 6.4 would be generated. If it is assumed that the 90% reduction is for the first year of operation only and that consumption then drops to 95% of pre-levy amounts[58], revenue could be expected to fall to around £3.8 million per year. Likewise, if the reduction in carrier bag use is less than anticipated, the revenue generated will be greater.

By applying the costs per person given in Table 6.3 to population data by local authority, it is possible to get some feel for the amount of levy revenue likely to be raised by each authority under each of the scenarios (see Appendix 4)[59]. As expected, the higher the population within a local authority, the more revenue it would collect from the levy. Hence, under all four levy scenarios, the City of Glasgow would raise by far the most revenue (from just under £620,000 per year under scenario 1B to just under £930,000 per year under scenario 2A). Some of the islands (e.g. Orkney and Shetland) would collect as little as £21,000–24,000 per year under scenario 1B.

Comparing these figures with the costs outlined in Tables 6.1 and 6.2 shows that there would be disproportionate costs between local authorities, with a net financial gain to the larger ones but a net cost to the smaller ones. This disparity could be addressed by a national billing body.

[57] The timescale for set-up is unknown.
[58] As in Republic of Ireland (see Section 2.2).
[59] In our calculations, however, we assumed that every individual across Scotland is essentially identical in terms of bag-using behaviour. In addition, the amount of revenue raised by a local authority will be a function of, among other things, the age profile and socio-economic characteristics of its population (and in turn their behaviour as consumers), and not just its total population. Furthermore this ignores the impact of consumers making purchases at outlets not located in the local authority in which they reside.

6.4 Conclusions on the Administration of the Levy

Of the three options presented, Option 1 seems most complicated and will have the greatest resource and cost implications. It is also difficult to envisage a simple and cost-effective policing mechanism. Options 2 and 3 offer a simplified approach, involving less resources and an anticipated reduced requirement for policing. We predict there would be a net gain financially from a levy in all situations, whether or not coverage is restricted.

Having discussed the practical implementation of Option 1 (blanket application of the levy) with two local authorities, their view was that there are clear administrative difficulties and significant costs associated with this course of action. Blanket application was considered to require dedicated staff within each local authority area to administer the levy in terms of informing business of its existence and to carry out subsequent policing of the levy. Such staff would still be required even if a central billing body were set up to collect the revenue.

A discrete billing body was considered a logical option for collecting revenue. This body would be responsible for:

- Collating returns from all retailers.
- Collecting funds.
- Allocating monies by local authority (money must be spent locally to satisfy the requirement in Mike Pringle's Bill for devolved competence).

The success of this model would depend on a high level of trust between retailers and the billing body, i.e. it is assumed that no responsible retailer would wish to be seen to be avoiding its tax liabilities. All businesses liable to pay the levy would be identified and informed of their new duty. The billing body would then expect to be provided, electronically, with information regarding the number of bags distributed and the subsequent levy owing. Most significant retailers in Scotland possess electronic stock systems, which should allow them to transfer information on bag usage easily to the billing body. Billing could be carried out on a monthly or quarterly basis, as required. Electronic data submission by smaller retailers may be more problematic.

It is expected that the cost of running a plastic bag levy collection scheme could be recouped from the revenue generated. It is therefore expected that this cost would not be added to local authority expenditure.

Such a model seems to sit well with local government efficiency initiatives by encouraging shared resources between councils. Discussions with the local authority representatives suggested that such a body could function with around four staff. This would allow the maximum benefit to be accrued from the levy. However, CoSLA is known to have concerns about the shared resource option and is unlikely to support this approach without a more detailed financial appraisal.

As each authority would generate different levels of revenue, a range of 'contributions' to the billing body might be necessary. Otherwise, some authorities would be paying disproportionately.

7 Conclusions

Mike Pringle MSP has stated that the levy *“aims to alter people's behaviour to help protect the environment”.*

Environmental Impact

Our analysis suggests that environmental benefits will be achieved if consumers switch from lightweight plastic bags to reusable bags. In all scenarios where the levy is applied, consumption of non-renewable energy, atmospheric acidification, the formation of ground level ozone and the risk of litter fall considerably compared with the current situation.

However, our analysis also suggests that, in all circumstances, paper bags have a greater negative environmental impact than conventional plastic carrier bags. If paper bags are excluded from the levy, as currently proposed, we estimate that paper bag usage will increase by 174 million bags per year to 213 million per year. This will have associated environmental implications in terms of increased energy use, transport costs, storage space and waste disposal.

The scenario analysis suggests that including both paper bags and SMEs in the levy (scenario 2A) would lead to greater environmental benefits. It would offer more overall savings in bag use and generate more revenue than the levy proposal to include all retailers but exclude paper bags (scenario 1A).

The levy as proposed is estimated to reduce annual lightweight plastic carrier bag use by 697 million bags. However, there would be an increase in annual demand of 15 million ‘bags for life’, 90 million bin liners and 174 million paper bags. This would result in an estimated decrease of 3,484 tonnes of polyethene used in Scotland per year **but** an increase of 8,893 tonnes of paper per year[60].

Greater environmental benefits will be achieved if paper bags are also subject to the levy. There would be an annual reduction in lightweight plastic carrier bag use of 697 million bags and an increase in ‘bags for life’ by 21 million and bin liners by 90 million, but a decrease in paper bag use of 35 million per year. These savings would result in an estimated decrease of 3,214 tonnes of polyethene used in Scotland per year **and** a decrease of 1,779 tonnes of paper per year.

Although under all levy scenarios there would be a resulting decrease in litter, the fact that plastic bags account for less than 1% of land litter suggests that this would have a minor impact on the overall litter problem in Scotland. The same argument also holds for any reduction in the amount of plastic carrier bag waste going to landfill.

We undertook a sensitivity analysis to examine how the environmental indicators for the levy scenarios change in response to changes in the assumptions used. This shows that environmental indicators for the levy scenarios that include paper bags (scenarios 2A and 2B) are much more robust to changes in the assumptions.

[60] These estimates do not take into account any increased demand for refuse sacks, as we were unable to source data on current sales levels or the likely increase in demand.

An education and awareness campaign, as used in Republic of Ireland, is seen as beneficial to the introduction of a levy to reinforce to consumers the waste hierarchy's principles:

- To reduce waste.
- Reuse where possible.
- Recycle when reuse is not possible.
- Recover energy.
- And only then to dispose of the item.

Costs to Consumers

Consumers would obviously have to pay the levy itself overtly, on levied bags they continue to use, but the true additional financial burden of a levy on consumers in Scotland depends on a number of other factors as well.

The cost to the consumer also depends on whether or not certain costs (in particular the 'hidden costs/savings') are passed on to the consumer by the retailer.

This leads to a wide range of estimated costs to the consumers, depending on assumptions. In Scenarios 1A and 1B (no levy on paper bags) the estimates ranges from £7.41 to £10.58 per year. In Scenarios 2A and 2B (levy on paper bags as well) the range is from about £2.50 to £6.11 per year. To put this into context the average Scottish household spends some £365 per week [ONS].

Impacts on Industry

An estimated 300 to 700 jobs could be lost in Scotland alone as a direct result of a levy being imposed on plastic carrier bags [CBC]. Knock-on effects would also be felt elsewhere in an industry that employs around 2,500 people in carrier bags manufacture, import and distribution, and around 12,000 in the wider plastic films sector in the UK.

Impacts on Local Authorities

CoSLA has a number of operational concerns, particularly regarding the magnitude of the proposed levy and any proposal for a joint collection body. If the levy were successful in its aim of reducing plastic bag usage, expenditure on collecting and enforcing the levy might exceed income. Local authorities could then be expected to look to the Scottish Executive to cover a funding shortfall. CoSLA also believes that additional funding would be required for set up the administrative systems and that detailed analysis of the potential costs is required.

Impacts on Charities

In a submission by the Association of Charity Shops to Mike Pringle MSP, the Association voiced its belief that the ability of some shops to operate successfully would be jeopardised by the levy. The Association is concerned that donations by the public would become difficult, as donated stock is usually delivered to shops in plastic carrier bags. These bags are then reused for customer purchases.

Impacts on Larger Retailers

After taking set-up and administrative costs into account, the food retail industry would benefit from net cost savings from a bag levy. Savings would come from having to buy far fewer plastic carrier bags that are given away for free, while sales of 'bags for life' and bin liners would increase [ERM, UCD].

However, this would not be the case for non-food retailers. Evidence from the Republic of Ireland from those retailers that switched to paper bags (mainly 'high street' non-food retailers) suggests that greater storage space and more frequent deliveries are now required. This has increased overhead costs for material purchase and transport by over four-fold [BRC].

There are also different consumption patterns between food and non-food. For the former, people often shop regularly and can thus plan to take reusable bags with them. For the latter however, it is often an impulse purchase [WRAP 2005]. Overall, retailers feel it would be fairer if all bag materials (not just plastic) and all businesses (small or large) were levied UK-wide.

In terms of system needs for compliance, it is envisaged that larger retailers will find this easier, having computerised systems and greater resource available. There will be a cost associated with administration of the levy, but experience in the Republic of Ireland suggests that the effects were generally positive or neutral [UCD]. In general, costs are considered modest and, in some cases, are less than the savings the retailers enjoy from buying fewer lightweight plastic carrier bags. Although there have been some reports of problems with increased theft, it is understood that, after an initial rise in theft, retailers state that levels returned to those before the introduction of the levy.

Impacts on SMEs

The levy would represent a greater burden to smaller retailers (e.g. newsagents, butchers, etc.) because they are less likely to have computerised systems. As a minimum, it is anticipated that retailers will need to have an auditable system recording carrier bags sales, account for bags in stock, reconcile sold versus stock remaining, submit records (quarterly in Republic of Ireland) and submit payment.

Revenue Generated

In an average year, the levy is expected to generate an estimated:

- £7.75 million under scenario 1A (proposed levy).
- £5.43 million under scenario 1B (proposed levy excepting SMEs, charities and promotions).
- £8.14 million under scenario 2A (proposed levy plus levy on paper bags).
- £5.70 million under scenario 2B (proposed levy plus levy on paper bags and excluding SMEs, charities and promotions).

Costs to Introduce

To determine the costs of set up and administration for local authorities would require a detailed specification of the systems and wider discussions. In the absence of any assessments on costing, we generated some estimates based on simplistic assumptions. We did this largely to prompt discussion on this matter. Our calculations suggest indicative set-up costs of around £3 – 4 million, and enforcement and ongoing management costs of around £3.5 million per year.

Alternatives to the Levy

Lightweight plastic carrier bags have undergone considerable design engineering to produce a lightweight, strong and reliable means of transporting goods from the place of purchase to the home.

A draft voluntary code to develop waste reduction and reuse initiatives and to continue product engineering to make further savings in the production, transportation and storage of plastic carrier bags has been proposed and submitted by the CBC to the Voluntary Code of Conduct Working Group set up by the BRC and the SRC. The voluntary approach has been adopted in Australia, where a reduction in use of 20.4% has been achieved.

In addition, WRAP is working with BRC on increasing the uptake of 'bags for life', with the aim of reducing the use of lightweight plastic carrier bags and improving recycling rates.

These two projects present an alternative to the levy and a means of altering consumer behaviour – a fundamental aim of the levy proposed by Mike Pringle MSP.

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do a little change a lot

Small changes in the way we perform everyday tasks can have huge impacts on Scotland's environment.

Walking short distances rather than using the car, or being careful not to overfill the kettle are just two positive steps we can all take.

This butterfly represents the beauty and fragility of Scotland's environment. The motif will be utilised extensively by the Scottish Executive and its partners in their efforts to persuade people they can do a little to change a lot.

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