BASF
The Chemical Company

Submission for Verification of Eco-Efficiency Analysis Under NSF Protocol P352, Part B

Residential Food Waste Disposal Final Report – September 2014

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1. Purpose and Intent of this Guidance Document

1.1. The purpose of this submission is to provide a written report of the methods and findings of BASF Corporation's Residential Food Waste Disposal Eco-Efficiency Analysis, with the intent of having it verified under the requirements of NSF Protocol P352, Part B: Verification of Eco-Efficiency Analysis Studies.

1.2. The Residential Food Waste Disposal Eco-Efficiency Analysis was performed by BASF according to the methodology validated by NSF International under the requirements of Protocol P352. More information on BASF's methodology and the NSF validation can be obtained at http://www.nsf.org/info/eco_efficiency.

2. Content of this Guidance Document

2.1. This submission outlines the methodology, study goals, design criteria, target audience, customer benefits (CB), process alternatives, system boundaries, and scenario analysis for the Residential Food Waste Disposal EEA study, which will be conducted in accordance with BASF Corporation's EEA (BASF EEA) methodology. This submission will provide a discussion of the basis of the eco-analysis preparation and verification work.

2.2. As required under NSF P352 Part B, along with this document, BASF is submitting the final computerized model programmed in Microsoft® Excel. The computerized model, together with this document, will aid in the final review and ensure that the data and critical review findings have been satisfactorily addressed.

3. BASF's EEA Methodology

3.1. Overview:

BASF EEA involves measuring the life cycle environmental impacts and life cycle costs for product alternatives for a defined level of output. At a minimum, BASF EEA evaluates the environmental impact of the production, use, and disposal of a product or process in the areas of cumulative energy demand, resource and water consumption, emissions, toxicity and risk potential, and land use. The EEA also evaluates the life cycle costs associated with the product or process by calculating the costs related to, at a minimum, materials, labor, manufacturing, waste disposal, and energy consumption.

3.2. Preconditions:

The eco-efficiency methodology utilized in this study has been validated to the requirements of Part A of NSF P252 Validation and Verification of Eco-Efficiency Analyses. In addition, all alternatives that are being evaluated are being compared against a common Functional Unit (FU) or Customer Benefit (CB). This allows for an objective comparison between the various alternatives. The scoping and definition of the Customer Benefit are aligned with the goals and objectives of the study. Data gathering and constructing the system boundaries are consistent with the CB and consider both the environmental and economic impacts of each alternative over their life cycle or a defined

specific time period in order to achieve the specified CB. An overview of the scope of the environmental and economic assessment carried out is defined in this report.

3.2.1. Environmental Burden Metrics:

For BASF EEA environmental burden is characterized using twelve categories, at a minimum, including: cumulative energy demand, raw material consumption, water consumption, global warming potential (GWP), ozone depletion potential (ODP), acidification potential (AP), photochemical ozone creation potential (POCP), water emissions, solid waste emissions, toxicity potential, risk potential, and land use. These are shown below in Figure 1. Metrics shown in light blue represent the seven main categories of environmental burden that are used to construct the environmental fingerprint, while burdens in green represent all elements of the emissions category, and pink show the specific air emissions.

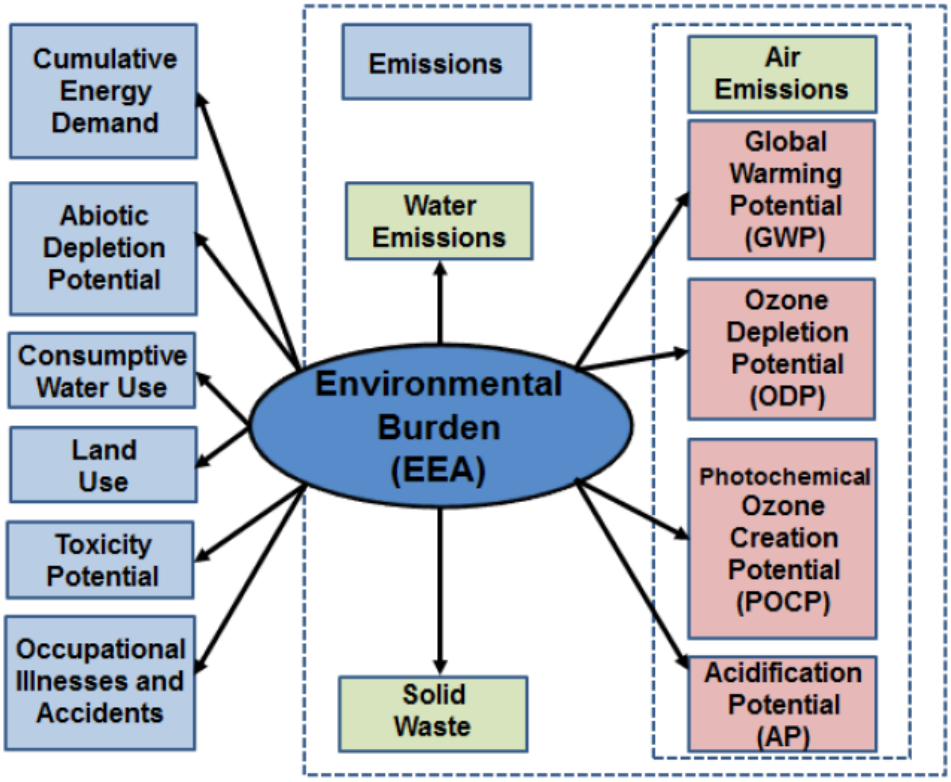


Figure 1. Environmental impact categories

3.2.2. Economic Metrics:

It is the intent of the BASF EEA methodology to assess the economics of products or processes over their life cycle and to determine an overall total cost of ownership for the defined customer benefit ($/CB). The approaches for calculating costs vary from study to study. When chemical products of manufacturing are being compared, the sale price paid by the customer is predominately used followed by any subsequent

costs incurred by the product's use and disposal. When different production methods are compared, the relevant costs include the purchase and installation of capital equipment, depreciation, and operating costs are analyzed. The costs incurred are summed and combined in appropriate units (e.g. U.S. dollar or euro) without additional weighting of individual financial amounts. The BASF EEA methodology will incorporate:

- the real costs that occur in the process of creating and delivering the product to the consumer;
- the subsequent costs which may occur in the future (due to tax policy changes, for example) with appropriate consideration for the time value of money; and
- costs having ecological aspect, such as the costs involved to treat wastewater generated during the manufacturing process.

3.2.3. Work Flow:

A representative flowchart of the overall process steps and calculations conducted for this Eco-Efficiency analysis is summarized in Figure 2 below.

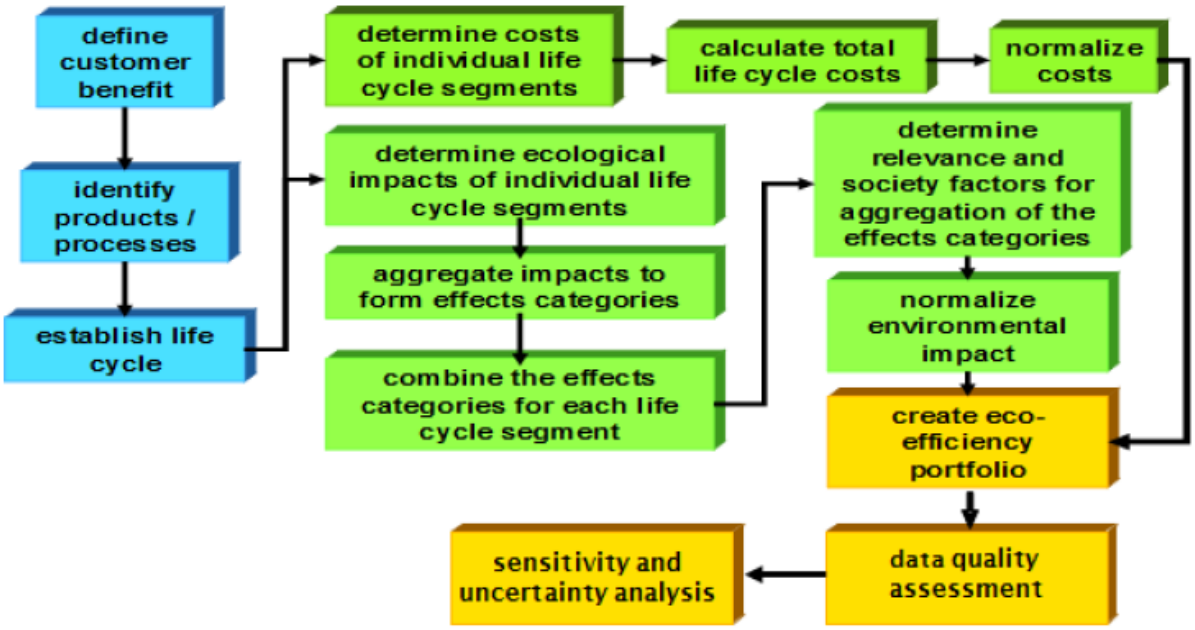


Figure 2. Overall process flow for Residential Food Waste Disposal EEA study

4. Study Goals, Context and Target Audience

4.1. Study Goals:

As shown in Figure 3, more food reaches landfills and incinerators than any other single material in municipal solid waste (MSW). In 2012 alone, more than 36 million tons of food waste was generated, with only five percent diverted from landfills and incinerators for recovery/composting[2]. Reducing the amount of food waste can significantly help the environment as well as provide economic and social benefits to society. Following the

EPA's Food Recovery Hierarchy (Figure 4), composting of food waste is a more preferred recovery option than landfilling/incineration. The benefits of compost are well known with environmental benefits ranging from reducing chemical fertilizer, water and pesticide usage, extending the life of municipal landfills and remediating contaminated or marginal soils. The overall environmental and economic benefits of composting versus traditional landfill disposal were analyzed and quantified in the 2012 Eco-efficiency analysis, "Compost Value Eco-efficiency Analysis" (June 2012)[3].

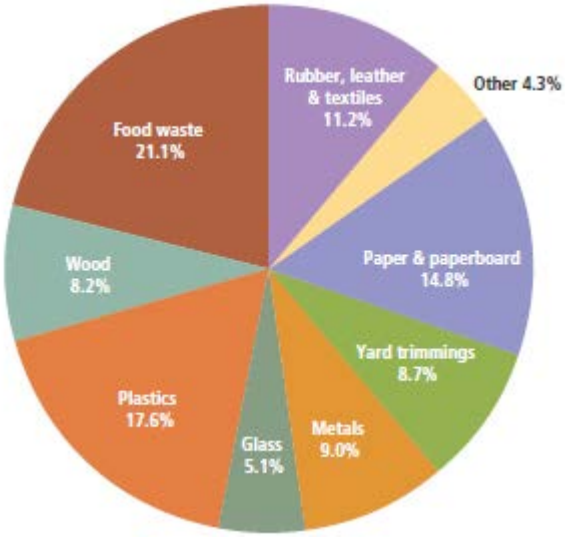


Figure 3: Total MSW discards by material 2012 (after recycling and composting) [2]

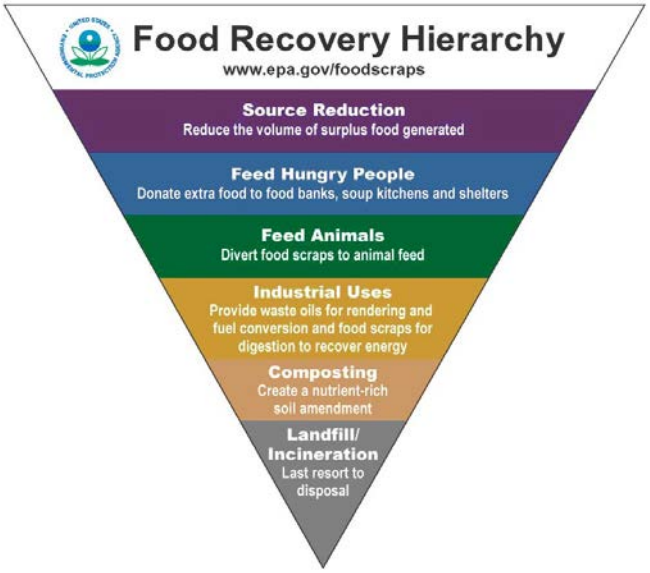


Figure 4: Food Recovery Hierarchy[1]

In a recent report by the Institute for Local Self-Reliance on the State of Composting in the United States[4], residential food waste collection in the U.S. has grown significantly in the past several years. Over 347 food scrap composting facilities were identified through surveys conducted with each state. In an earlier survey conducted by BioCycle[12], the

number of communities with collections programs has increased significantly in the last few years as well. There are now several hundred communities with source separated organics (SSO) programs, spreading across the majority of our states. While each community program described in BioCycle's report has its own method for residential food waste collection, several trends were apparent. The majority of communities that have established residential food waste collection programs, provide kitchen collectors to each household, and many encourage the use of approved compostable bags, to assist with the daily routine of collecting food scraps, and to increase both food scrap diversion rates as well as potentially increase overall participation rates. Each of these methods have their corresponding economic and environmental trade-offs and benefits, which will be objectively evaluated and compared in this study.

As the benefits of composting have already been established, this eco-efficiency study will focus on identifying and comparing the various methods and practices associated with residential food waste collection and disposal. More specifically, this study will focus on the collection of residential food waste with and without the use of a compostable bag liner in the kitchen collectors/caddies and the outside waste toter. This study will also analyze the impacts associated with the cleaning of the collection containers. From this analysis one will be able to directly and comprehensively compare the benefits and trade-offs between a lined composting container with less required cleaning versus and unlined container which will require more frequent cleaning. More specifically, a comparison between the costs and impacts used to produce the compostable liner can be compared against the costs, materials and environmental impacts required to clean the containers. In addition, the study will highlight through a sensitivity analysis the additional benefits that can realized through the use of a compostable bag liner through increasing food waste diversion rates. Supported by the results from the 2012 Compost Value Eco-efficiency Analysis, the impacts required to eventually produce the compost from the collected food waste at a composting facility as well as the benefits derived from its use will be included in this analysis.

The study considered the use of compostable food waste collection bags in the United States market as a whole, with no specific focus on one region. Thus, average national data was used for key study input parameters.

The results of this study will be used as a basis to guide communities in the development of more eco-efficient composting programs as well as support the external marketing claims around the environmental and economic benefits of food waste collection in general and more specifically the use of compostable food collection bags. The results will also help inform and guide residential home owners on more eco-efficient practices related to the collection of food waste. The eco-efficiency methodology will facilitate clear communications of the study results to key stakeholders in the compostable waste industry, community and state leaders supporting compostable waste programs, and can also support the overall education and awareness on the topic of the responsible use of compostable food waste to the end use consumer/residential home owner.

This study will analyze the collection and management of food waste generated in one year by a representative residential community of 30,000 households. A general assumption is that the community has an existing food waste collection program, allows the use of compostable bags for collection and has an established composting facility.

4.2. Design Criteria:

The context of this EEA study compared the environmental and cost impacts for the disposal of food waste in a collection bin lined with an ecovio® compostable bag versus disposal of food waste in an unlined waste bin. The goals, target audience, and context for decision criteria used in this study are displayed in Figure 5.

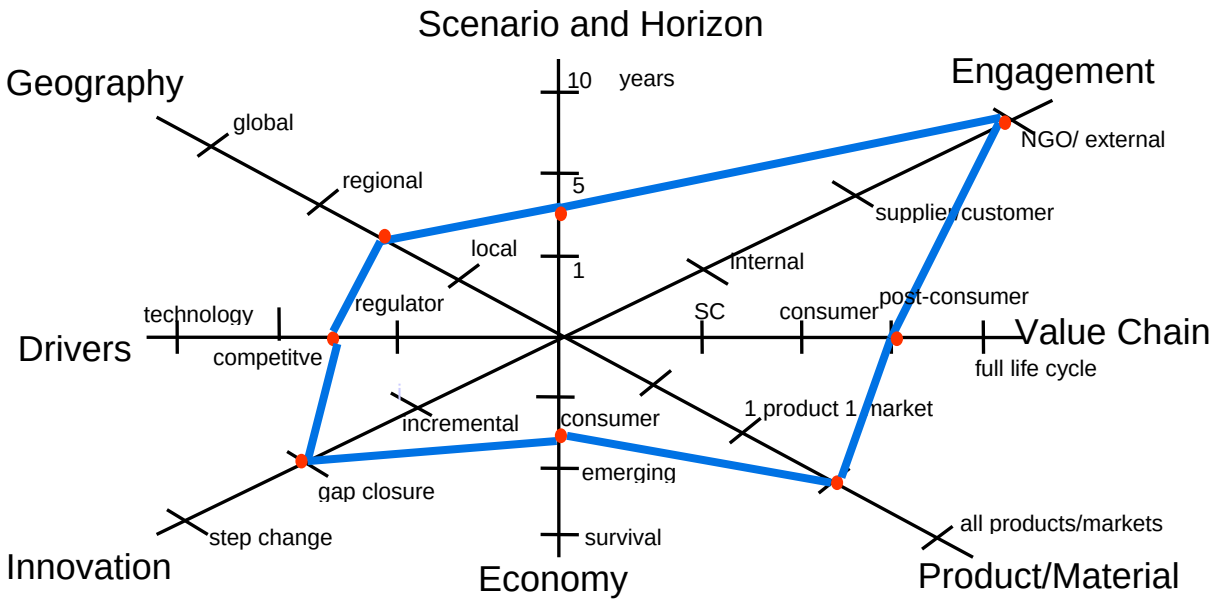


Figure 5: Context for Design Criteria for Food Waste Disposal Eco-Efficiency Analysis

4.3. Target Audience:

The target audience for this study has been defined as municipalities and cities interested in instituting a food waste collection program or enhancing the value of their current program. In addition, the results will be targeted to residential home owners as well as customers and distributors who supply to city waste managers, managers of waste diversion programs, the US Composting Council, and the Solid Waste Association of North America (SWANA). It is planned to communicate study results in marketing materials and at trade conferences.

5. Customer Benefit, Alternatives and System Boundaries

5.1. Customer Benefit:

The Customer Benefit (identified also as CB) or Function Unit (FU) applied to all alternatives for the base case analysis is the collection and management of food waste generated in one year by a representative residential community of 30,000 households. Each residential home will have both a kitchen caddy and larger outdoor waste toter for food waste collection and disposal. The above customer benefit was selected to best represent the potential benefits and trade-offs for various methods for collecting and disposing of food waste.

5.2. Alternatives:

The alternatives for the food waste disposal EEA to be analyzed and compared are: (1) disposal of food waste in waste bins (both the kitchen caddy and outdoor waste toter) lined with a compostable bag made from ecovio®, a compostable polymer with biobased content and (2) collection and disposal of food waste using unlined waste collection bins.

The key difference between the alternatives is the compostable plastic liner and the influence that has on the required cleaning frequency of the soiled collection containers. Liners will inherently keep the caddies and toters cleaner and thus reduce the overall cleaning frequency required for the collection bins. Conversely, unlined alternatives will accumulate more "yuck" within the container and warrant more frequent cleaning in order maintain sanitary conditions and reduce odor. Finally, the use of liners could also lead to higher overall food waste diversion rates per household.

5.3. System Boundaries:

The system boundaries define the specific elements of the production, use, and disposal phases of the life cycle that are considered as part of the analysis. For both alternatives the starting point for the analysis is the generation of the food waste with the end point being either the beneficial use of compost and/or the disposal of food waste in a landfill or incinerator. Impacts associated with the production of the food products were not considered. For alternative 1, the production phase of the life cycle includes the manufacturing, transport and purchase of the compostable bin liner. For both alternatives the impacts for producing the required amount of cleaning solution is included. The "use" phase of both alternatives includes the food waste collection, use of the compostable bag liners in the indoor kitchen caddy and outdoor toter and the cleanings of both the lined or unlined waste bins. Food waste generated that is not diverted to composting is disposed of with the normal municipal solid waste. The "disposal phase" includes the end of life treatment for the food waste as defined for each alternative as well as any logistical impacts associated with transportation. The system flow for food waste for alternative 1 which utilizes lined collection bins is depicted in Figure 6, while the system flow for food waste for alternative 2 which uses an unlined waste bin collection system is depicted in Figure 7.

As noted above, food waste not diverted for composting will be disposed of in the traditional household bin for disposal to landfill/incineration. Though the diversion rate of food waste into this bin will vary for each alternative, the bin cleaning frequency will be the same and thus will have an identical impact for each alternative and thus will be excluded from this analysis. However, for alternatives capturing more food waste through this bin, allowances were made to capture the increase in the number of polyethylene bags required.

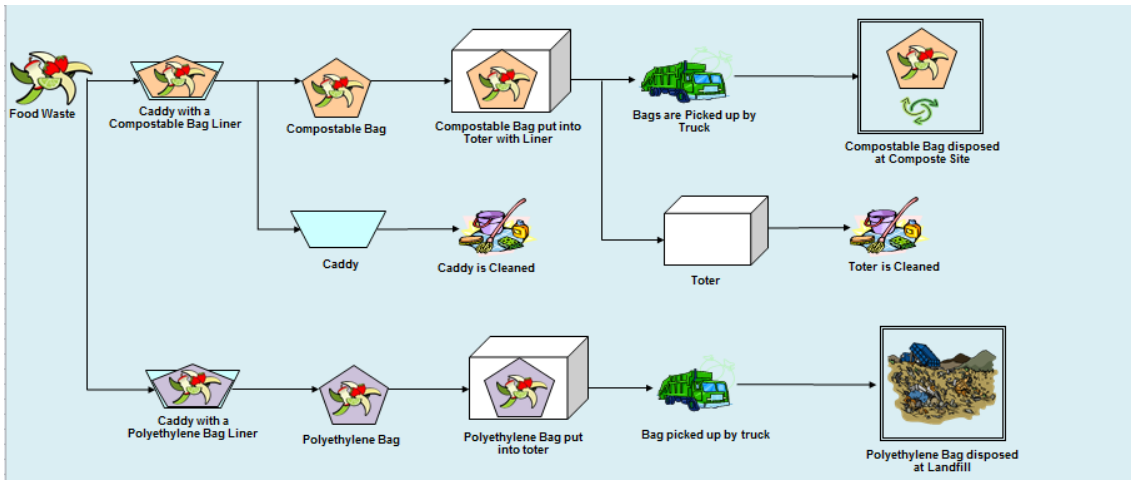


Figure 6. System flow for food waste disposal – alternative 1 (lined collection bins)

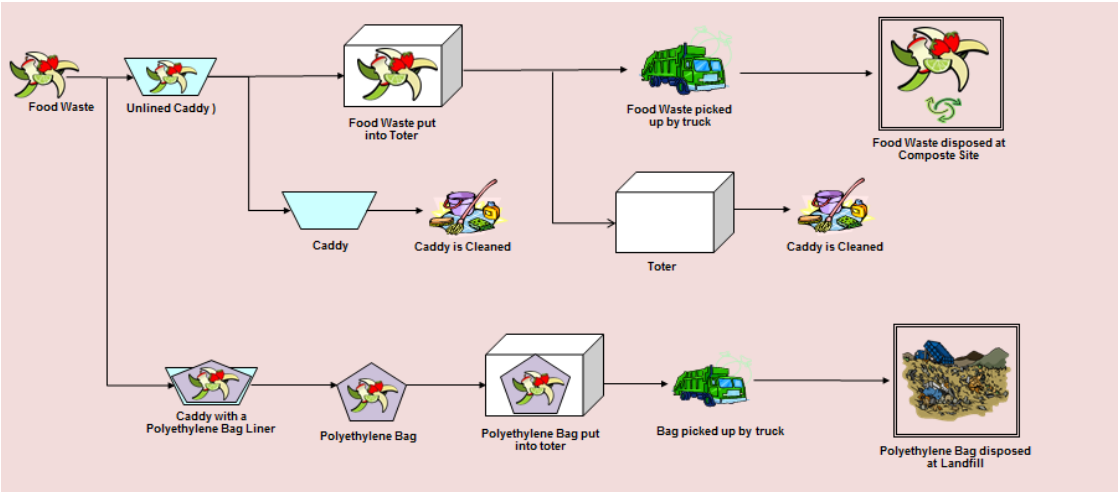


Figure 7. System flow for food waste disposal – alternative 2 (unlined waste bin)

5.4. Scenario Analyses:

In addition to the base case analysis, several additional scenarios were evaluated to determine the sensitivity of the study's final conclusions and results to key input parameters as well as to help focus the interpretation of the study results. Results will be presented and discussed in section 10.

5.4.1. *Scenario #1:*

Removal of the ecovio® compostable waste bag liner in the outdoor waste toter.

5.4.2. Scenario #2:

Cleaning of the unlined indoor waste caddy only one time per week as opposed to daily (base case).

5.4.3. Scenario #3:

Equal cleaning frequencies of the indoor waste caddy and the outdoor waste toter. Thus, monthly cleanings for alternative 1 (lined bins) and weekly for alternative 2 (unlined bins).

5.4.4. Scenario #4:

Same assumptions as Scenario #3 but variations in the washing requirements (water and detergent amounts) by 25%.

5.4.5. Scenario #5:

Increased diversion rates of food scraps from base case to 20% increase and 100% collection rate for the lined alternative.

6. Input Parameters and Assumptions

6.1. Input Parameters:

A comprehensive list of input parameters were included for this study and considered all relevant material and operational characteristic. Absolute input values as opposed to differential values were utilized.

6.2. General Information

6.2.1. Food Waste Generated, Diversion Rates, Overall Participation Rates

This study considered a representative residential community of 30,000 households which has an established composting facility and collection system. Values for food waste generation were derived from using data provided by both the 2012 EPA MSW characterization report[2] as well as the most recent US Census data[5]. The US Census reports a total waste generation per capita of 1.95 kg/day (4.3 pounds/day) of which 14.1% is food waste. Based on 2.6 persons/household this brings the total amount of food waste generation/household to around 0.73 kg (1.6 pounds)/day/household. Using the 2012 US EPA Municipal Waste Characterization Report[2], food waste made up 14.5% of the over 251 MM tons of MSW generated. Distributing this over the approximately 115 MM households in the United States in 2012, amounts to about 5.44 kg (12 pounds)/week/household or 0.77 kg (1.7 pounds/day)/household. Based on these closely related data samples, an average of 0.75 kg (1.65 pounds)/day/household will be used for this study.

On behalf of the Materials Management Branch Land and Chemical Division of the US EPA Region 5, the Econservation Institute issued a research reported[6] focused on best management practices in food scrap programs. The research focused on the practices of over 180 residential and commercial food scrap programs across the US for communities ranging in size from less than 200 to over 600,000. The report collected data on these programs and reported national average data for metrics such as food waste generation, diversion rates as well as overall participation per sector.

For established residential food waste collection programs the diversion rate of food scraps averaged between 14% - 17%. For elite, well established programs, the diversion rate could increase by 50% while lower performing programs could have diversion rates of 50% less.

Participation rates varied from a low of 10% to a high of 95% with the average being between 35% - 45%. Many factors influence participation rates with one variable being the "yuck"[6] factor. Many households may be turned off from food waste collection due to the potentially unattractive and smelly nature of the process. A best practice identified in the research showed that using bin liners such as bio-degradable plastic bags could help reduce the "yuck" factor and help increase overall participation and diversion rates.

As the focus of this study is on residential food waste collection practices and activities and not the benefits of composting in general, the base case analysis will set the residential participation rates and the diversion rates the same for both alternatives. Thus, the study will assume the national average participation rate of 40% and a food waste diversion rate of 15.5%. By doing this the study will reduce the number of contributing variables and allow a focused, objective comparison of the impacts and benefits of using a compostable bag for collection vs. using an unlined collection bin.

6.3. Product Information

6.3.1. Material Composition

For this study, standard industry sized waste containers and liners were used. The capacity (volume basis) of the indoor caddy was set at approximately 21 liters (2.5 gallons) while the outdoor toter bag's capacity was set at approximately 49 liters (13 gallons). The actual weights and type of materials used for the production of the ecovio® biodegradable liners were obtained through a detailed bill of materials (BOM) and from analytical laboratory reports. The liner for the indoor caddy weighed 8.5 grams and the outdoor toter liner had a mass of 24 grams. Full compositional data was provided to NSF International in support of this verification but is not directly included in this report in order to protect company confidential information.

6.3.2. Transportation - Logistics

The logistical impacts for movement of basic materials for manufacturing of finished products for use by the consumer as well as the logistics associated with disposal of the food waste were considered. The specific key logistical segments considered and their corresponding assumptions are presented in Table 1. Data sources related to the logistic profiles utilized in this study can be found in Table 4, Eco-profile Data Sources.

Transport	Location	Method of Transport	Distance (km)
ecovio® Resin Shipment	Germany to the USA	Sea Freight	5600
ecovio® Resin Shipment	USA Port to Mfg. Site	Truck	500
ecovio® and PE Bag	Manufacturing site to Warehouse	Truck	500
ecovio® and PE Bag	Warehouse to Retail	Truck	100
ecovio® and PE Bag	Retail to Home	Car	10
Food Waste	Home to Landfill	Truck	100
Food Waste	Home to Compost Facility	Truck	100
Food Waste	Home to Incineration	Truck	100
Compost	Compost Facility to Use	Truck	50

Table 1. Logistical Assumptions for Food Waste Disposal EEA

6.3.3. Polyethylene Garbage Bag

As not all food waste gets diverted to composting, some portion will be disposed of in the normal garbage and enter the traditional MSW stream. It was assumed that the food waste would be collected in a polyethylene bag. The standard kitchen garbage bag was assumed to have a weight of 10 grams and a carrying capacity of 33 kg (15 pounds). The alternative that required a higher amount of food waste to be diverted away from composting would be allocated additional polyethylene bags based on the amount diverted and the capacity of the bag.

Industry average data was used for the materials composition, manufacturing impacts, and emissions for the polyethylene bags. This analysis was conducted to produce a differential number of additional polyethylene bags needed between the two alternatives instead of an absolute value needed for each alternative.

6.4. Product Use Information

6.4.1. Food Waste Collection Bag Usage

This analysis assumed that each compostable waste bag would be replaced when it was approximately 50% filled (by volume). According to data collected by the EPA[9], the density of uneaten food and food preparation waste is 897.5 kg/m^3 (7.49 pounds per gallon). Using this value, a new bag would be replaced once it was filled with just over 4 kg (9 pounds) of food waste. Based on the study's base case assumptions around residential food waste generation and diversion rates, the compostable waste bag would be filled to less than capacity. Rather than allocating a portion of the bag, which would not be realistic from a practical perspective, the team modeled realistic home owner behavior, which is to dispose of bags in their entirety at the end of each week, assuming compost collection was weekly. If more than one bag would be required, the required bag quantities would be rounded to the nearest whole number.

6.4.2. Bin Cleanings

In order to minimize the "yuck" factor associated with food waste collection, collection bins are cleaned periodically with a water / cleaning solution mixture. The frequencies established by the study team based on expert judgment and field observations for bin cleanings are detailed in Table 2.

Table 2. Frequencies of Bin Washings for Product Use

Container	Lined bin	Unlined bin
Indoor caddy	weekly	daily
Outdoor toter	monthly	weekly

The indoor caddies are assumed to be cleaned with hot water. Energy (natural gas) required to heat the water in the hot water heater was considered in this analysis. The outdoor caddies are assumed to be cleaned with cold water. The amount of water and detergent used for each cleaning was determined by the eco-efficiency team as well as recommendations by a detergent manufacturer. They are highlighted in Table 3, below.

Cleaning of the caddy with the polyethylene liner which collects non-diverted food waste along with the remainder of household refuse was not considered in this analysis. The frequency of cleaning would not be impacted by the customer benefit and thus would be a common impact for each alternative and thus excluded from the analysis.

Table 3. Water and Detergent Use for Cleaning of Waste Bins

	Unlined Alternative		Lined Alternative	
	Indoor caddy	Outdoor toter	Indoor caddy	Outdoor toter
Hot water (l)	4		2	
Cold water (l)		40		20
Detergent (ml)	5.2	52	2.6	26

The eco-efficiency methodology accounts for all emissions into water bodies occurring during the cleaning process. An assumption for this study is that the households considered are connected to the municipal sewer system rather than to a septic system. Thus waste water generated through the cleaning of the waste bins is assumed to initially enter the sewer system and then enter a municipal waste water treatment facility where it would be treated and released into the environment.

6.5. Disposal Information

6.5.1. End of Life modeling

The amount of food waste collected for composting is found by applying the consumer participation rate and food diversion rate to the total food waste generated by the residential community. Half of the amount of food waste brought to compost is generated into useable compost, as detailed in BASF's "Compost Value Eco-Efficiency Analysis"[3]. Of the remaining food waste not collected for composting, it is collected and disposed of as garbage and enters the normal municipal solid waste (MSW) stream. Based on the latest figures from the EPA[8] 82% of municipal solid waste is disposed of at a landfill while 18% is disposed of through incineration with heat recovery.

6.5.2. Comprehensive Environmental profiles for compost and landfill disposal

BASF's "Compost Value Eco-Efficiency Analysis" study quantified the differences in life cycle environmental impacts and total life cycle costs of composting municipal solid waste and the resulting value from the compost versus traditional disposal of food waste into a landfill with the added benefit of landfill gas recovery. In order to incorporate the environmental burdens and credits into this study, a generic profile was established for compost and for food waste disposed of in a landfill. Though our study stayed consistent with the assumptions and modeling parameters of the "Compost Value EEA" slight modifications to the model were required. To be consistent with the scope of this study, the input tables were modified to only consider food scraps. In addition, the costs and environmental impacts of constructing compost facilities or landfills were removed as that is being addressed separately in this study. After these changes, all the environmental burdens and credits for alternative 1 ("no compost") in the Compost Value EEA study were aggregated and distributed across the amount of material going to landfill, thus establishing a comprehensive eco-profile for food waste to landfill. Similarly, all the environmental burdens and credits were summed for alternative 4 (compost III (100% compost)), and this was distributed across the amount of compost created for alternative 4, thus establishing a comprehensive eco-profile for compost.

Finally, to remain consistent with the approach in the "Compost Value Eco-Efficiency Analysis" study, we have allocated any benefits of incineration (i.e. heat recovery) for one alternative as a burden or lost opportunity for the competing alternative.

6.5.3. Landfill and Compost Facility Impacts

Though not reflected in the base case analysis as both alternatives are diverting the same amount of food waste from the municipal waste stream to composting, for the scenario analyses which address differences in food waste diversion, impacts on the service life for existing landfills or compost facilities were taken into consideration. For the alternative which caused diversion rates to either the landfill or the compost facility to increase and thus incrementally decrease the service life of that facility, economic and environmental impacts to account for this lost service life were allocated to that alternative.

6.6. Life Cycle Costs

The life cycle costs for each alternative were mostly comprised of material costs such as those for producing the ecovio® compostable bags or the traditional PE garbage bag as well as the cleaning costs associated with the water and detergent usage. In addition to the material costs, disposal costs in either the landfill or compost facility were included. Finally, as noted in section 6.5.3, any costs associated with decreasing the life of a landfill or costs associated with the construction of a new compost facility were included.

Current market pricing at major retailers (Target, Walmart) was used for the cost of the compostable indoor caddy and outdoor toter waste bags as well as the standard polyethylene waste bag. For the base case analysis, the prices were established to be $0.27/bag for the indoor caddy, and $0.55/bag for the outdoor toter and $0.21/bag for the standard polyethylene bag.

The BASF eco-efficiency team established for the base case analysis the price for the cleaning detergent to be $3.00/kg. Municipal water bills were referenced to establish representative pricing for water charges ($0.002/L) and municipal sewer charges ($0.001/L). Expenses for disposal and treatment of wastewater generated through cleaning of the waste bins was included in this cost analysis.

Current national average fuel costs[10] were utilized to calculate the logistics costs. The true cost of the material to landfill and the true cost of compost were derived from adjusting the total costs for alternatives 1 (no compost) and 4 (compost III,(100% compost)) in BASF's "Compost Value Eco-Efficiency Analysis" by removing the associated costs of construction for either a new landfill or compost facility and allocating the remaining costs across the amount of material sent to landfill or the amount of compost created. These costs were established as $55/ton for material to landfill and $50/ton, for material to a composting facility. Facility construction costs were established at approximately $14/ton for a landfill and $0.60/ton for a compost facility. Finally, national average data was used for the incineration tipping fee ($68/ton)[11].

7. Data Sources

7.1. Environmental:

The environmental impacts for the production, use, and disposal of the various alternatives were calculated from eco-profiles (e.g. life cycle inventories) for the individual system components (e.g. ecovio® compostable bags, polyethylene bags) and activities (e.g. waste bin washings, logistics) occurring over the life cycle defined for this analysis. Life cycle inventory data for these eco-profiles were from several data sources, including BASF and customer specific manufacturing data. Overall, the quality of the data was considered medium to high. None of the eco-profiles data was considered to be of low data quality. A summary of the eco-profiles is provided in Table 4.

Table 4. Eco-profile Data Sources

Eco-profile	Source, year	Comments
Ecovio® F 2341	BASF, 2013	
Polyethylene, LDPE	Plastics Europe, 2005	
Transport, Truck	Global / PE International, 2011	
Transport – Sea Freight	US Average / , 1996	Most reliable data available
Detergent	BASF BEST database, 2014	Typical liquid household detergent
Well Water	BASF BEST database, 2010	
Natural Gas	BASF BEST database, 2009	US Average
Food waste to Landfill	BASF EEA Study, 2012	Compost Value EEA Study
Food waste to Compost	BASF EEA Study, 2012	Compost Value EEA Study
Incineration of biomass with heat recovery	BASF BEST database, 2010	Germany
Waste water (post POTW)	RMIT, 2009	US
Waste water (direct to storm sewer)	BASF BEST database, 2005	US
Landfill construction	ecoinvent, 2010	
Compost facility construction	BASF BEST database, 2003	California

8. Eco-Efficiency Analysis Results and Discussion

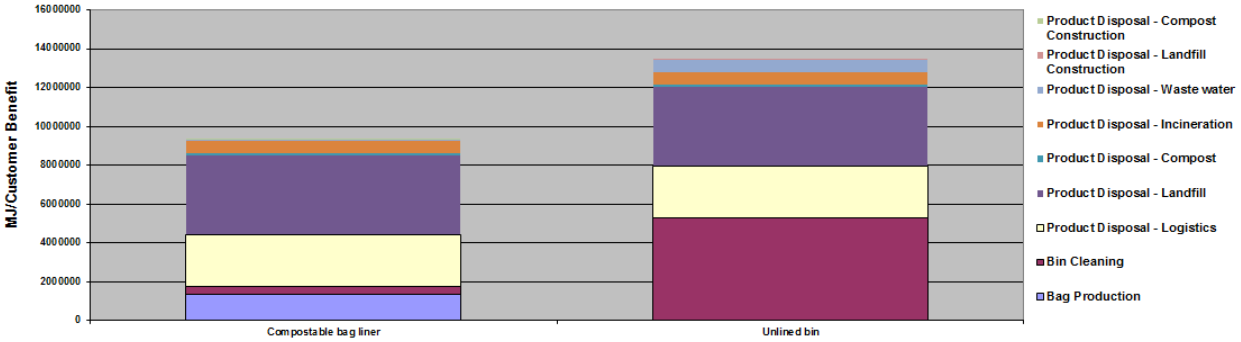
8.1. Environmental Impact Results:

The environmental impact results for the Compostable Food Waste Eco-efficiency analysis were generated as defined in Section 6 of the BASF EEA methodology. The results discussed in Section 8.1.1 through 8.1.9 are for the Base Case only and do not represent any of the scenarios.

8.1.1. *Cumulative Energy Demand*:

Cumulative energy demand, measured over the entire life cycle and depicted in Figure 8, shows that the unlined waste bin alternative uses a greater amount of energy over the defined life cycle than the alternative which uses a compostable waste bag to line waste bins. The gross energy consumption for the unlined waste bin alternative was about 13.4 million MJ per customer benefit and the compostable bag alternative consumed approximately 9.3 million MJ/CB. This is about a 30% reduction in energy consumption for the lined bin alternative. For the unlined alternative, the largest contributor to the energy consumption was the bin cleanings (almost 40%) followed by disposal to landfill and logistics. The compostable bag liner alternative's largest contributor was landfill disposal followed by logistics/transport. The production of the

bag contributed less than 15% of the total energy consumption for alternative 1.



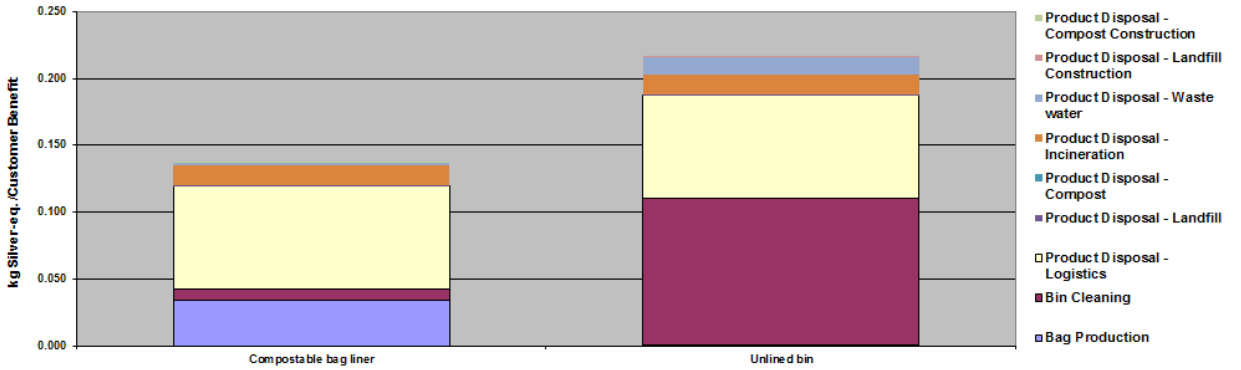
Significance: **MEDIUM** – Contributes 11% to the overall environmental impact. See Table 7 for summary of environmental impact relevance / significance factors.

Figure 8. Cumulative energy demand

8.1.2. Raw material consumption:

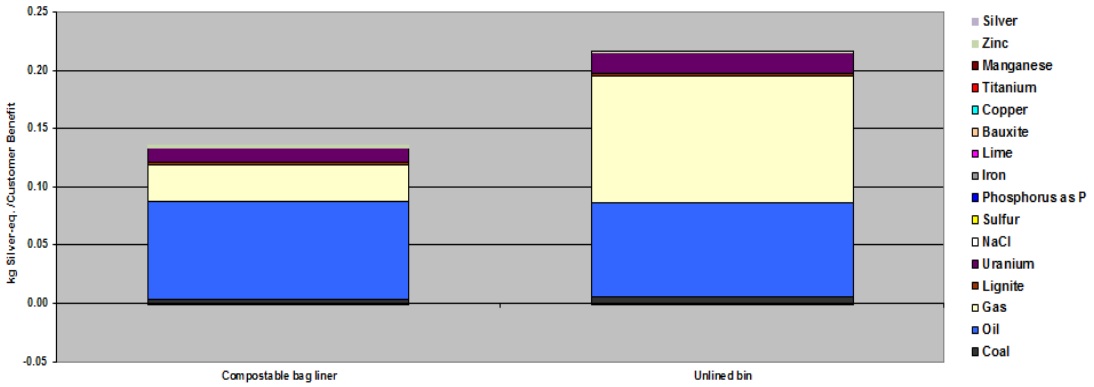
Figure 9 shows that the key drivers for raw material or resource consumption are the resources (detergents, fuels) required for washing the waste bins and the logistics activities required to transport the materials to their end of life. The lined waste bin alternative consumed about 35% less resources, then the unlined alternative. Through enabling less cleaning, the payback for the resources required to produce the compostable bag liner was over 3:1. In addition, the ecovio® compostable bag also benefited from the use of renewable feed stocks in its manufacturing.

Per BASF's EEA Methodology, individual raw materials are weighted according to their available reserves and current consumption profile. These weighting factors are appropriate considering the context of this study. As to be expected and indicated in Figure 10, fossil fuels such as oil and natural gas are the most significant resources consumed for either alternative.



Significance: **LOW** – Contributes 4% to the overall environmental impact. See Table 7 for summary of environmental impact relevance / significance factors.

Figure 9. Raw material consumption by module

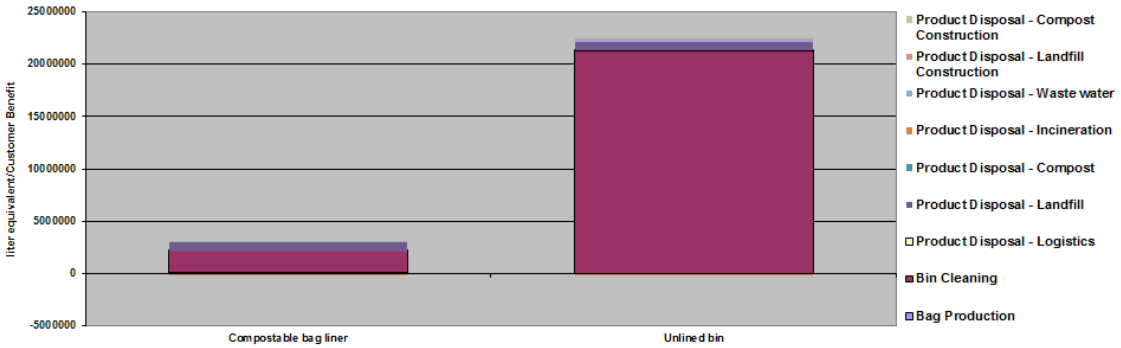


Significance: **LOW** – Contributes 4% to the overall environmental impact. See Table 7 for summary of environmental impact relevance / significance factors.

Figure 10. Raw material consumption by type

8.1.3. Consumptive Water Use

As expected, Figure 11 shows the largest contributor to consumptive water use for this study was the bin cleanings. By requiring more bin cleanings between collections, the unlined bin had the largest impact in this area. Under the base case assumptions, the compostable bag lined alternative reduced overall consumptive water usage by around 85%.



Significance: **HIGH** – Contributes 20% to the overall environmental impact. See Table 7 for summary of environmental impact relevance / significance factors.

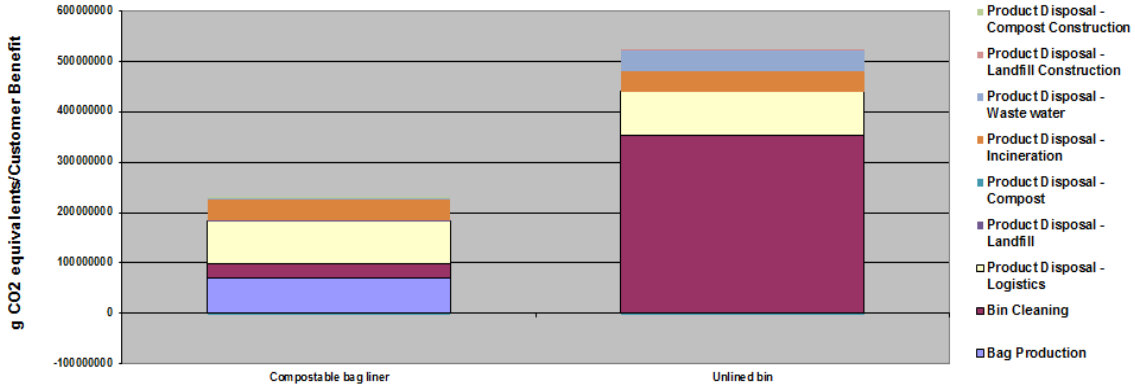
Figure 11. Consumptive water usage

8.1.4. Air Emissions:

8.1.4.1. Global Warming Potential (GWP):

Figure 12 shows that the highest greenhouse gas emissions or carbon footprint occurred in the unlined waste bin alternative with a value of 523 mtons of CO_2 equivalents per customer benefit. The compostable bag alternative had a carbon footprint of 229 mtons of CO_2 equivalents per customer benefit, a reduction of almost 60%. The largest contributor to global warming potential for the unlined

waste bin alternative was the combustion of fossil fuels during the waste bin cleaning process while the largest contributors for the compostable waste bag alternative were the production of the ecovio® bag and transportation to the disposal facilities. GWP is the most relevant air emission in this study.

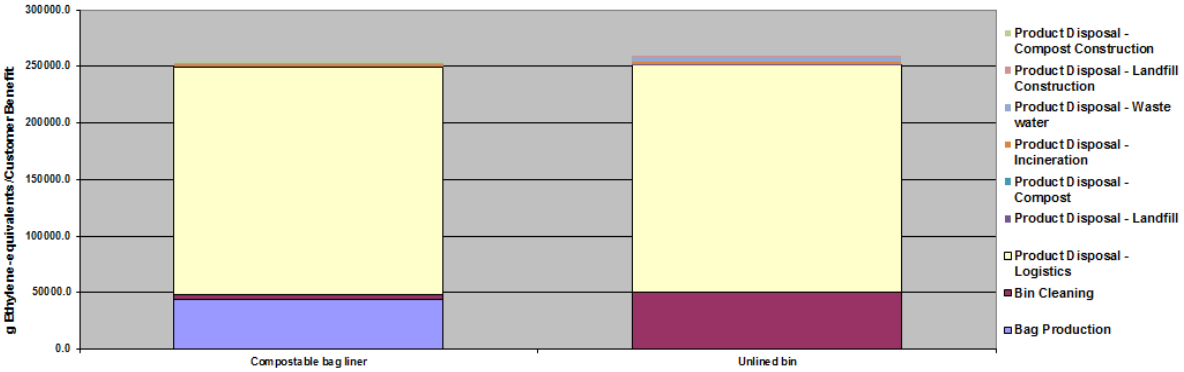


Significance: **LOW** – Contributes 3% to the overall environmental impact. See Table 7 for summary of environmental impact relevance / significance.

Figure 12. Global warming potential (GWP)

8.1.4.2. Photochemical ozone creation potential (POCP, smog):

Emissions with Photochemical Ozone Creation Potential (POCP) are dominated in both alternatives by the impacts of fuel consumption through transportation. Combustion of the fuel contributes to the emissions of methane and non-methane VOCs, two key smog contributors. Nitrogen oxides produced in the emissions of truck exhaust can also contribute to the formation of photochemical ozone (smog). Both alternatives have equal impacts in this category.



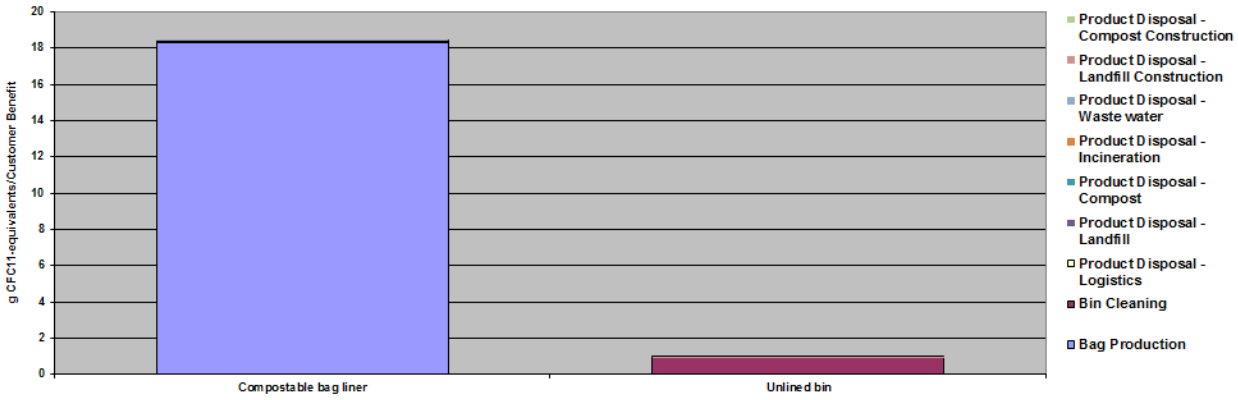
Significance: **LOW** – Contributes 2% to the overall environmental impact. See Table 7 for summary of environmental impact relevance / significance.

Figure 13. Photochemical ozone creation potential (POCP)

8.1.4.3. Ozone depletion potential (ODP):

Both alternatives result in negligible ozone depletion potential. ODP is the least significant environmental emission and has an environmental relevance factor of 0.04% and contributes approximately 0.2% to the overall environmental impact. The compostable waste bag alternative produced the highest level, measured at

about 18g CFC equivalents/CB. Figure 14 indicates that the ODP comes predominately for the pre-chain chemistries involved in the precursor materials used in the ecovio® bag manufacturing process.

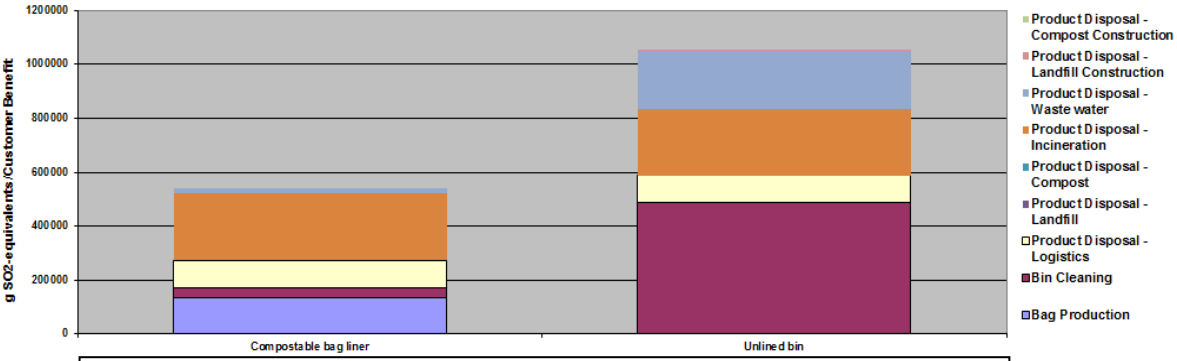


Significance: **LOW** – Contributes less than 1% to the overall environmental impact. See Table 7 for summary of environmental impact relevance / significance.

Figure 14. Ozone depletion potential (ODP)

8.1.4.4. Acidification potential (AP):

It can be seen in Figure 15 that the largest contributor to acidification potential was the unlined waste bin, with a net value of about 1.05 metric tons SO_2 equivalents/CB, mainly due to waste bin cleanings. The compostable waste bag alternative's value of around 0.54 meteric tons of SO_2 equivalents/CB was almost a 50% reduction.



Significance: **LOW** – Contributes almost 2% to the overall environmental impact. See Table 7 for summary of environmental impact relevance / significance.

Figure 15. Acidification Potential

Utilizing the calculation factors show in Table 7, Figure 16 shows the normalized and weighted impacts for the four air emissions categories (GWP, AP, POCP, and ODP) for each alternative. Overall, the unlined waste bin alternative had the greatest air emissions, almost twice those of the lined bin. The unlined alternative scored worst in the GWP and AP air emission categories and the compostable waste bag alternative scored worst in ODP. Both alternatives had similar POCP

impacts. GWP, AP, and POCP are the most relevant air emission categories for this eco-efficiency study. The ODP category was not considered relevant for this study.

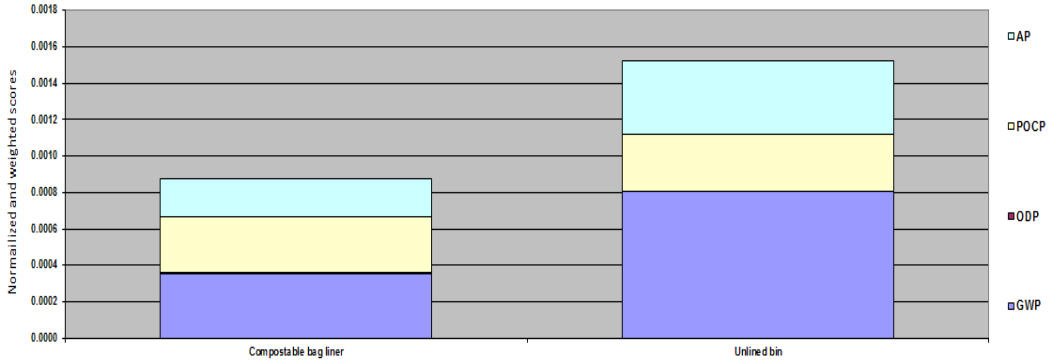
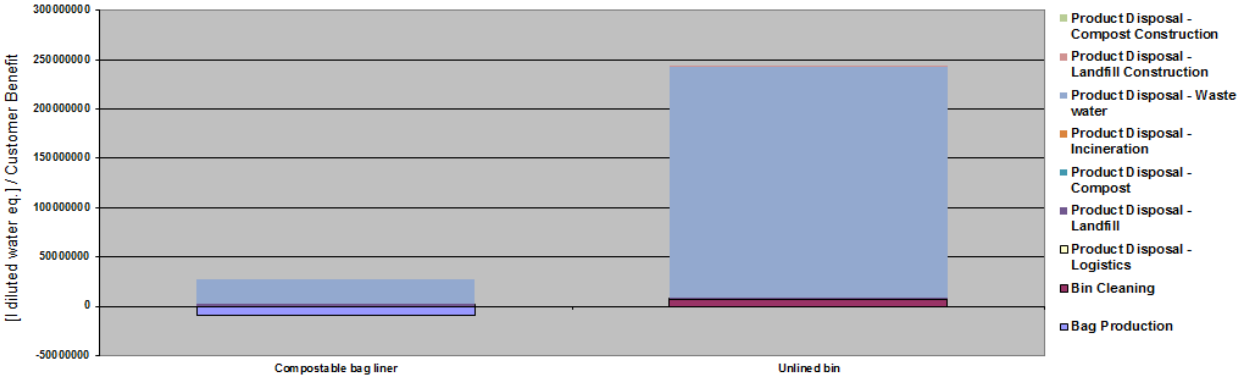


Figure 16. Overall air emissions

8.1.5. Water emissions:

Figure 17 displays that the overall water emission is highest for the unlined waste bin alternative with approximately 243,000,000 liters of grey water equivalents/CB. This is driven by the specific water emissions of COD, chlorides, phosphates and sulfates attributed to the washing detergent used to clean the waste bins and the waste water produced through bin cleanings. Decreased bin washings and overall reduction in organic matter being discharged into the POTW/storm sewer, enabled the lined bin alternative to reduce grey water emissions by over 90%.

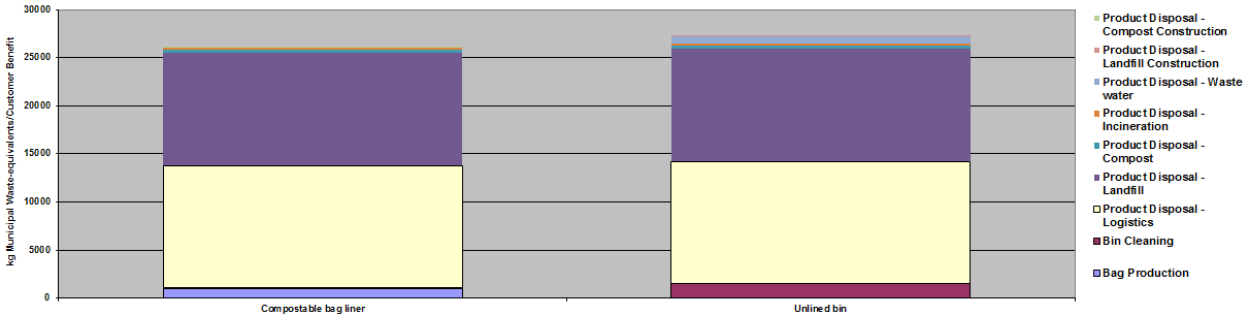


Significance: **HIGH** – Contributes 22% to the overall environmental impact. See Table 7 for summary of environmental impact relevance / significance.

Figure 17. Water emissions

8.1.6. Solid waste generation:

Solid waste emissions were dominated by the waste disposal to landfill and the solid waste generation associated with logistics/transport. Due to low overall diversion rates of food waste from landfill and the fact that both alternatives are transporting the same quantity of waste, regardless of its final destination the impact for each alternative is equivalent. Solid waste emissions are depicted below in Figure 18.

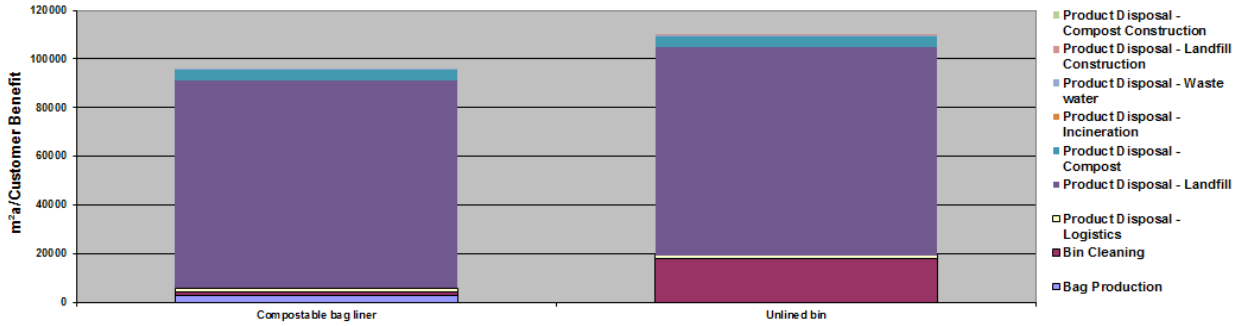


Significance: **LOW**– Contributes 2% to the overall environmental impact. See Table 7 for summary of environmental impact relevance / significance.

Figure 18. Solid waste generation

8.1.7. Land use:

Land use is assessed for each alternative and is based on the assessed impacts of land occupation and transformation. As displayed in Figure 19, the land use impacts are mostly influenced by bin cleaning and product disposal to landfill. Due to decreased bin cleaning activities, the lined alternative was able to reduce land use requirements by almost 13%.



Significance: **LOW** – Contributes 4% to the overall environmental impact. See Table 7 for summary of environmental impact relevance / significance.

Figure 19. Land use

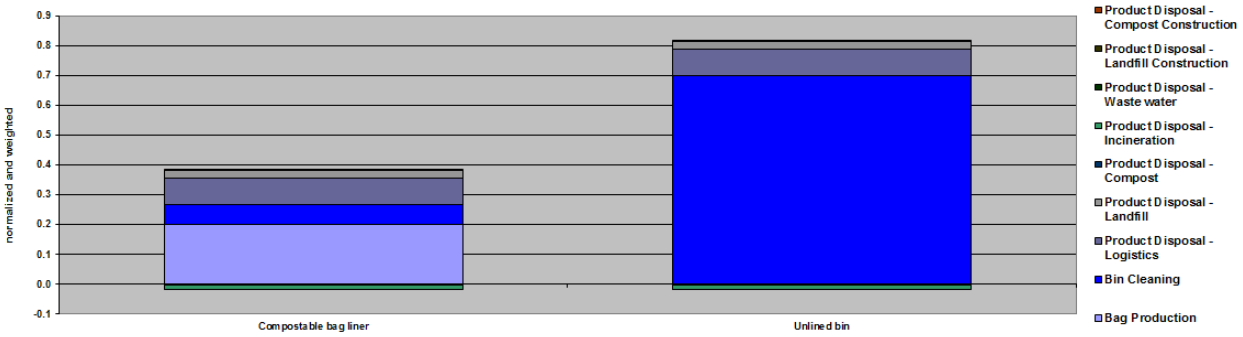
8.1.8. Toxicity potential:

The toxicity potential of the various materials manufactured and used as well as any associated activities with their use and disposal were analyzed for each alternative over their respective life cycle. Analysis of final products (i.e. ecovio® bag, PE bag, cleaning detergents, diesel fuel etc.) included a full analysis of the entire pre-chain of chemicals required during their manufacture and transport. During the use phase of the life cycle the human health impact potential consisted of the use of the bag liners and the washing activities. Toxicity potential in the disposal phase considered impacts from disposal and the associated logistics.

Nanoparticles were not included in the chemical inputs of any of the alternatives and were not evaluated in this study.

Inventories of all relevant materials were quantified for the three life cycle stages (production, use, and disposal). Consistent with BASF's EEA Methodology's approach of assessing the human health impact potential of these materials (ref. Section 6.8 of Part A Submittal), a detailed scoring table was developed for each alternative broken down per life cycle stage. This scoring table with all relevant material quantities considered as well as their H-phrase and pre-chain toxicity potential scores were provided to NSF International as part of the EEA model which was submitted as part of this verification. Figure 20 shows how each life cycle module contributed to the overall toxicity potential score for each alternative. The values have been normalized and weighted. The toxicity potential weightings for the individual life cycle phases were production (20%), use (70%), and disposal (10%). These standard values were not modified for this study from the standard weightings.

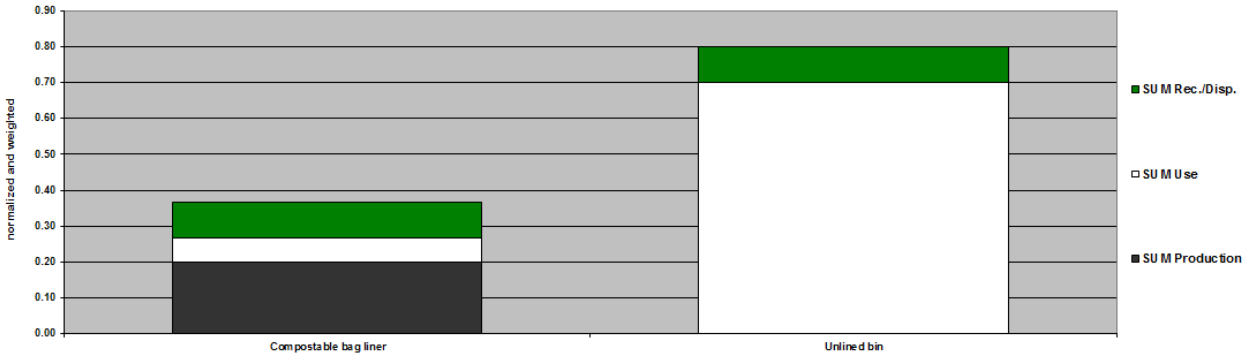
The module which influenced toxicity potential to the largest degree was bin washing. The unlined alternative, which had more frequent and higher bin washing requirements, scored the highest in overall toxicity potential. The major influencing factor for the lined alternative was the manufacturing of the bin liner. Smaller contributions to the overall toxicity potential for both alternatives were made from transport (i.e. combustion exhaust) and product disposal in landfill.



Significance: **HIGH** – Contributes 19% to the overall environmental impact. See Table 7 for summary of environmental impact relevance / significance.

Figure 20. Toxicity potential – modules

Figure 21 shows how the toxicity scoring is distributed across the various life cycle stages. Consistent with the discussion above, the use phase is the most significant for the unlined bin alternative, accounting for almost all of the toxicity potential points. All three phases of the life cycle contribute appreciably for the unlined alternative but overall by enabling reductions in cleaning and the use of detergents, the lined alternative achieved over a 50% reduction in overall toxicity potential when compared to the unlined alternative.



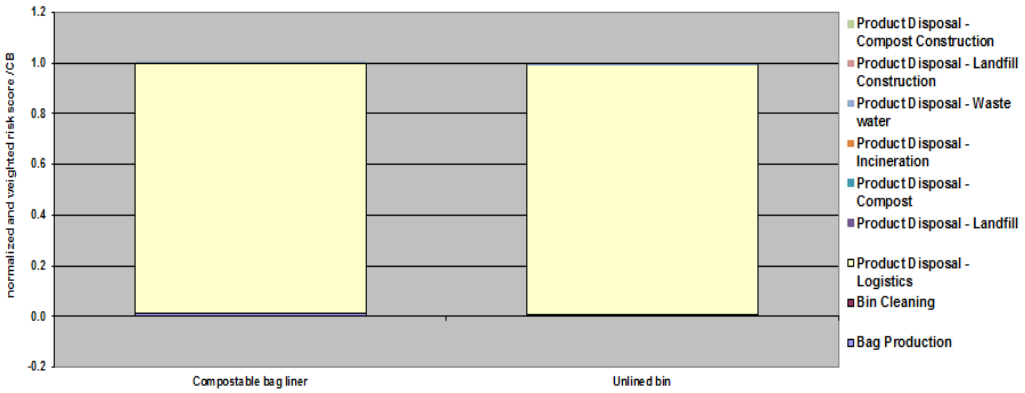
Significance: **HIGH** – Contributes 19% to the overall environmental impact. See Table 7 for summary of environmental impact relevance / significance.

Figure 21. Toxicity potential – life cycle phases

8.1.9. Risk potential (Occupational Diseases and Accidents potential):

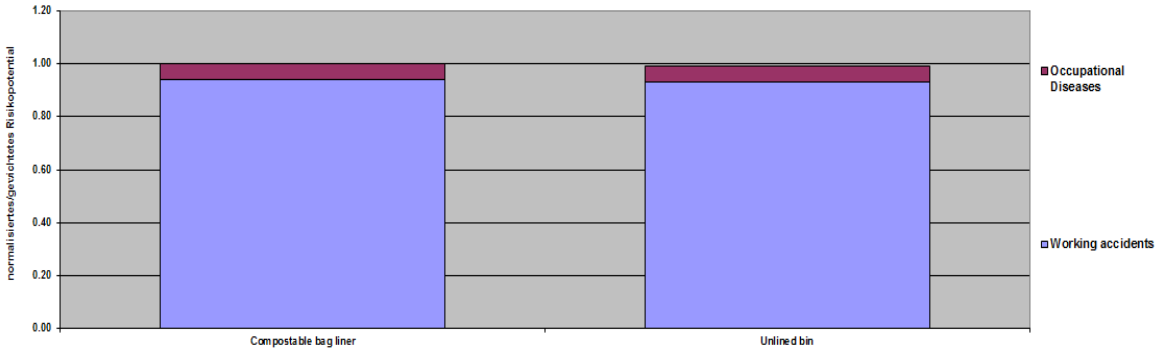
The risk category in BASF EEA, includes assessment of the physical hazards during the production, use and disposal phases of the defined life cycle as well as consideration for the risk of explosions, flammability, storage accidents, worker illnesses and injury rates, malfunctions in product filling/packaging, transportation accidents and any other risks deemed relevant to the study. The risk potential is established using quantitative government and industry data (e.g. working accidents and occupational disease using industry related data) as well as expert judgment. All the materials and activities account for in the various life cycle stages were assigned specific NACE codes. NACE (Nomenclature des Activities Economiques) is a European nomenclature, which is very similar to the NAICS codes in North America. The NACE codes are utilized in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the business economy and is broken down by specific industries. Specific to this impact category, the NACE codes track, among other metrics, the number of working accidents, fatalities, illnesses, and diseases associated with certain industries (e.g. chemical manufacturing, petroleum refinery, inorganics, etc.) per defined unit of output. By applying these incident rates to the amount of materials required for each alternative, a quantitative assessment of risk is achieved.

Figure 22 shows that the risk category for this study is dominated by the risks associated with the logistical activities associated with product disposal. As both alternatives have similar logistical activities there is no differentiation between the alternatives. Figure 23 shows that the risk category is equally split between occupational diseases and working accidents. As depicted, working accidents were the most relevant risk category for each alternative. No unique risk categories were identified for this study so the standard weighting between working accidents and occupational illnesses was maintained.



Significance: **MEDIUM** – Contributes 11% to the overall environmental impact. See Table 7 for summary of environmental impact relevance / significance.

Figure 22. Risk potential (occupational illnesses and accidents) – per module



Significance: **MEDIUM** – Contributes 11% to the overall environmental impact. See Table 7 for summary of environmental impact relevance / significance.

Figure 23. Risk potential – per category

8.1.10. Environmental Fingerprint:

Following normalization or normalization and weighting with regards to the emissions categories, the relative impact for all seven of the main environmental categories for each alternative is shown in the environmental fingerprint, Figure 24. A value of "1.0" represents the alternative with the highest impact in the referenced category; all other alternatives are normalized against this value and given a normalized value less than 1.0. Positions closer to the center of the fingerprint reflect lower impact in that specific environmental category.

As presented in the previous discussions of the individual impact categories and depicted in the environmental fingerprint, the compostable waste bag alternative demonstrated reduced overall environmental impacts in four categories while having equal impact to the unlined bin in the risk and land use categories. The key factor influencing the reduced overall environmental impact is impact related to the production of the compostable bag were significantly less than the impacts required by the more frequent cleaning operations of the unlined alternative. More specifically, by using the bin liner and reducing the cleaning requirements, significant reductions in

consumptive water use, detergent usage as well as fuel requirements to heat the cleaning water were realized. All these factors contributed to the lined alternative having a 55% lower overall environmental impact when compared to the unlined alternative.

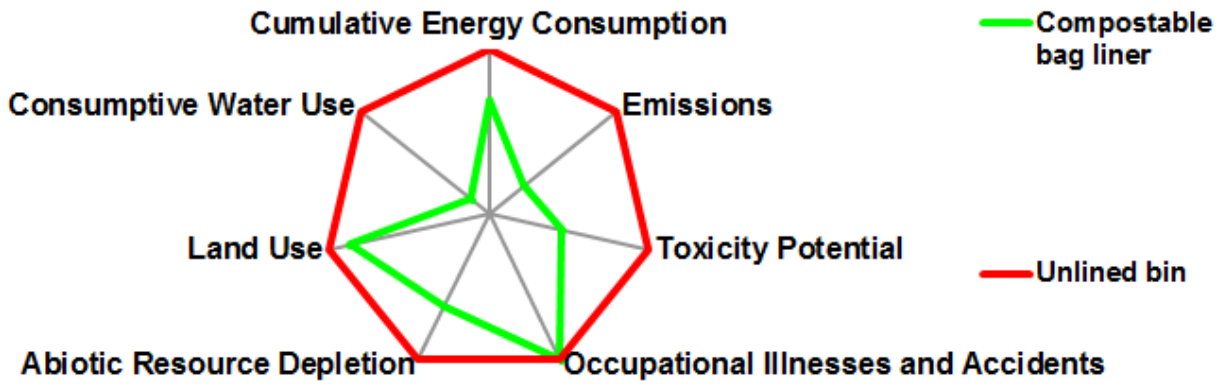


Figure 24. Environmental fingerprint

8.2. Economic Cost Results:

The life cycle cost data for the Compostable Food Waste EEA are generated as defined in Section 7 of the BASF EEA methodology and described in Section 6.2, above. The results of the life cycle cost analysis are depicted in Figure 25 and demonstrate that the alternative with the lowest life cycle costs was the unlined waste bin alternative. This difference was driven by the fact that the additional cost for the compostable bag liner was higher than the costs savings it was able to achieve through reduced cleaning activities. Costs associated with product disposal and transport were generally equivalent between the alternatives.

Overall, the life cycle costs for the compostable waste bag alternative was around 20% higher than the unlined alternative. The base case analysis for this study shows that there is financial incentive to use an unlined waste bin for compostable food waste disposal.

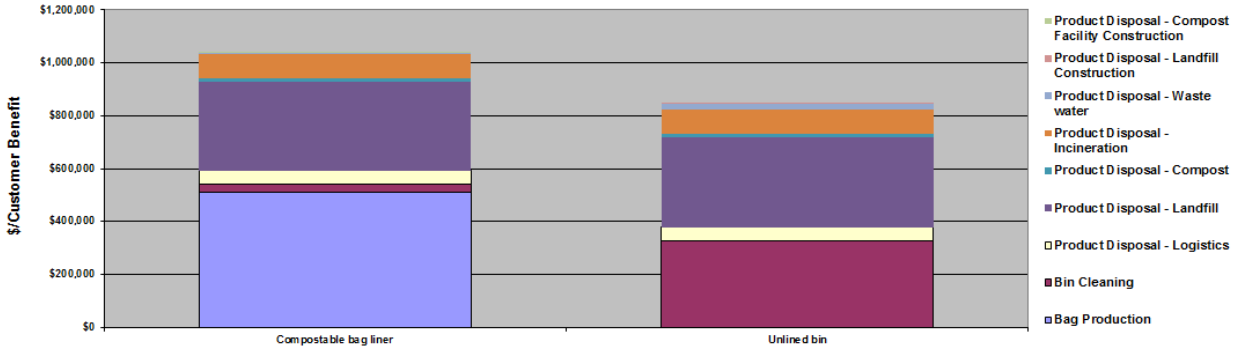


Figure 25. Life cycle costs - modules

8.2.1. Eco-Efficiency Analysis Portfolio:

The eco-efficiency analysis portfolio for the Compostable Food Waste EEA has been generated as defined in Section 9.5 of the BASF EEA methodology. Utilizing relevance and calculation factors, the relative importance of each of the individual environmental impact categories are used to determine and translate the fingerprint results to the position on the environmental axis for each alternative shown. For clearer understanding of how weighting and normalization is determined and applied please reference Section 8 of BASF's Part A submittal to P-352. Specific to this study, the worksheets "Relevance" and "Evaluation" in the EEA model provided to NSF as part of this verification process should be consulted to see the specific values utilized and how they were applied to determine the appropriate calculation factors. Specific to the choice of environmental relevance factors and social weighting factors applied to this study, factors for the USA (national average) were utilized, as this was the intended target market/audience for the use of the materials. The environmental relevance values utilized were last updated in 2013 and the social weighting factors were last updated in 2011 by an external, qualified third party organization.

Figure 26 displays the eco-efficiency portfolio for the base case analysis and shows the results when all seven individual environmental categories are combined into a single environmental score and combined with its respective life cycle cost impact. Because environmental impact and cost are equally important, the most eco-efficiency alternative is the one with the furthest perpendicular distance above the diagonal line moving in the direction of the upper right hand quadrant. The results from this study find that alternative 1 which utilized an ecovio® compostable bag for collection and disposal of food waste was more eco-efficient than alternative 2 which did not use a bin liner. Although the compostable food waste bag alternative had a higher life cycle cost, its superior environmental profile enabled it to be the most eco-efficient alternative. The eco-efficiency advantage was approximately 13%.

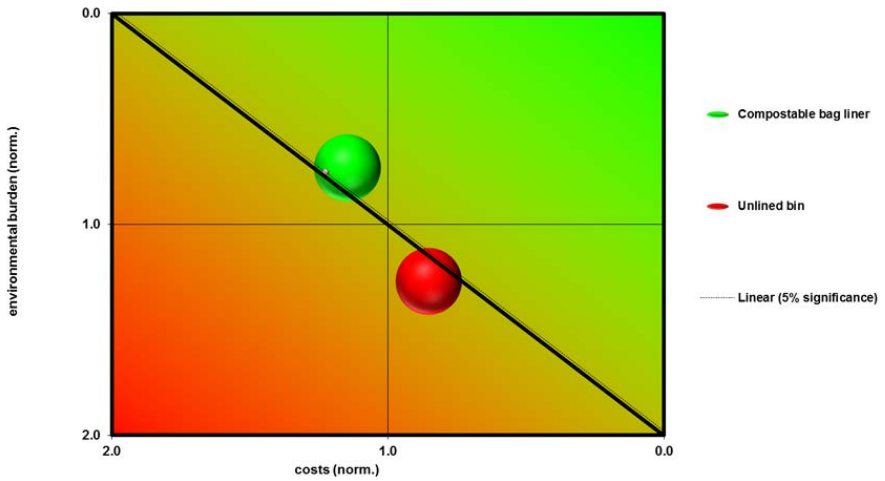


Figure 26. Eco-efficency portfolio base case analysis – food waste disposal

8.3. Scenario Analysis:

8.3.1. Scenario 1: Removal of the ecovio® compostable waste bag as a liner for the outdoor waste toter

This scenario looks at the impact of only using a compostable waste bag as a liner for the indoor waste caddy and removing the liner for the outdoor waste toter. The eco-efficiency team felt that many residential home owners would not find it necessary to place a bin liner in the outdoor waste toter if the food waste is already being disposed of in a compostable waste bag. The outside toter bag is almost 3x the weight of the indoor bag and twice the cost. As discussed in the base case analysis, the key cost contributor as well as environmental impact for alternative 1 comes from the compostable bag liner. Figure 27 shows the improved eco-efficiency positioning of the lined bin alternative relative to the unlined alternative. By only including the compostable bag in the inside caddy, the eco-efficiency advantage of alternative 1 was increased from 13% to almost 55%.

As shown in Figure 28 (environmental fingerprint), there are obvious environmental savings of using fewer bags, but there is also a significant economic benefit. As you can see in Figure 29, the total life cycle costs of alternative 1 are now 18% lower than the unlined alternative. A dramatic improvement relative to the base case analysis.

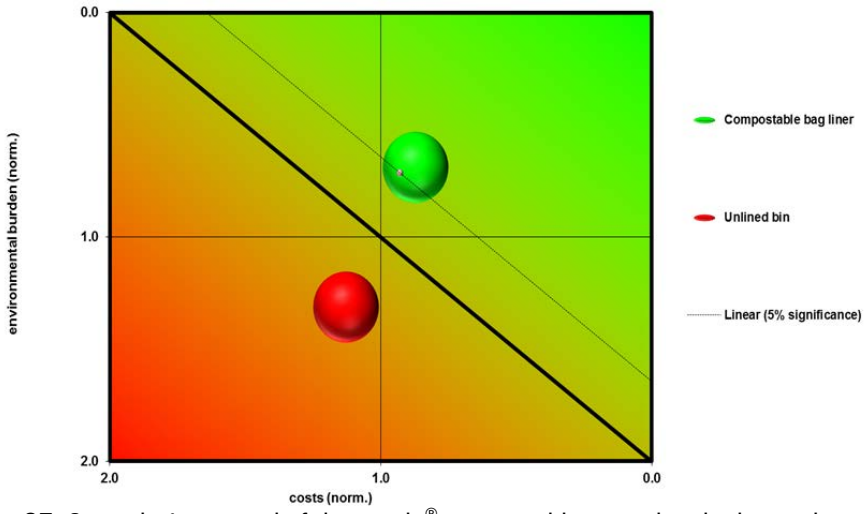


Figure 27. Scenario 1: removal of the ecovio® compostable waste bag in the outdoor waste toter

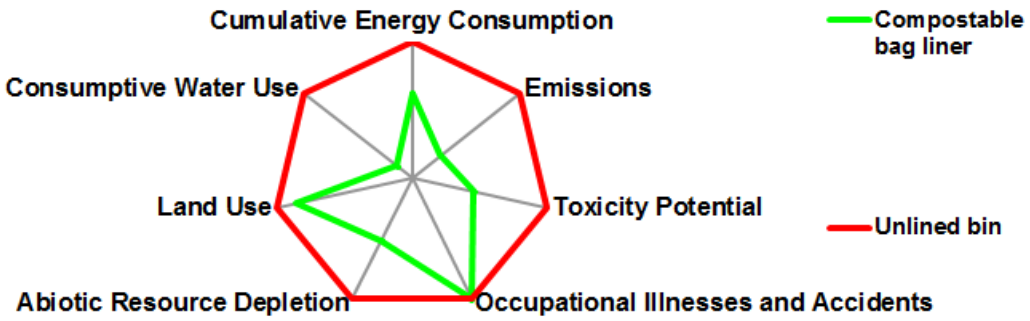


Figure 28. Environmental fingerprint

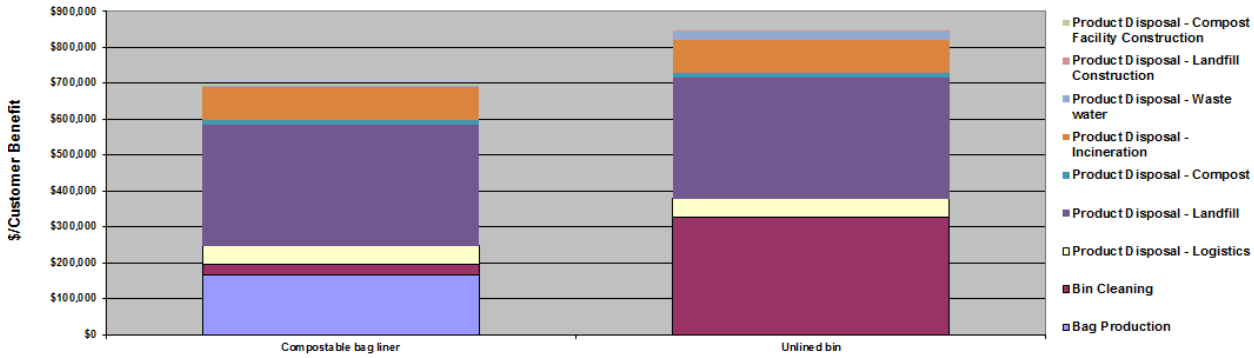


Figure 29. Total cost analysis for scenario 1

8.3.2. Scenario 2: Cleaning of the unlined indoor waste caddy only one time per week

This scenario analysis evaluates the impacts of cleaning the unlined indoor waste caddy only one time per week. By reducing bin cleanings from daily to weekly, the homeowner would be able to clean both bins together. Reduced bin washings will decrease the environmental and economic impacts associated with cleaning the caddy. Figure 30 shows the new eco-efficiency portfolio for scenario 2. The eco-efficiency of the unlined alternative improves significantly and leads the lined alternative by around 10% as opposed to trailing by 13% in the base case.

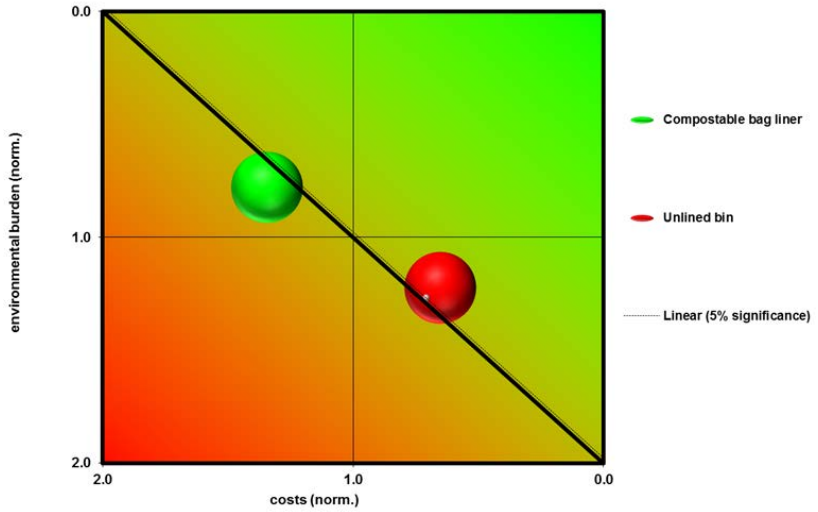


Figure 30. Scenario analysis 2: Reduced cleaning of the unlined indoor waste caddy to only one time per week

8.3.3. Scenario 3: Equal cleaning frequencies of the indoor waste caddy and the outdoor waste toter

This scenario is a variation of Scenario 2 and modifies the frequency of waste bin washings so that both lined containers for alternative 1 are cleaned on a monthly basis and the unlined bins of alternative 2 are cleaned on a weekly basis. This scenario benefits both alternatives as longer cleaning frequencies reduces cost and overall environmental impact. As shown in Figure 31, the unlined alternative is now the most eco-efficient about a 10% improvement over the lined alternative.

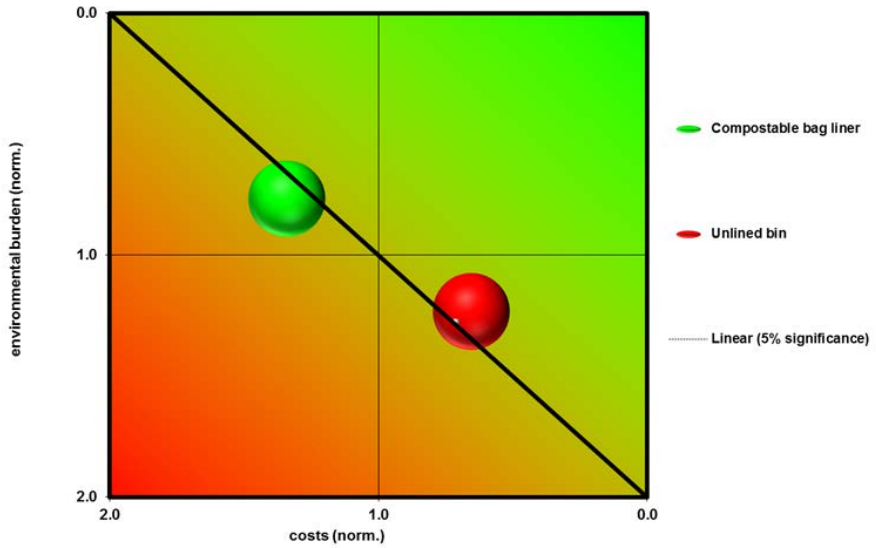


Figure 31. Scenario analysis #3: Monthly cleanings for lined bins and weekly cleanings for unlined collection bins

8.3.4. Scenario 4: Equal cleaning frequencies of the indoor waste caddy and the outdoor waste toter with adjustments to the detergent and water usage (+/- 25%).

This scenario is a variation of the base case analysis and modifies the amount of water and detergent used to clean the waste bins. Though the base case analysis modeled customary cleaning practices of a homeowner, this scenario looks at an extremely scaled down approach to cleaning the waste bins and a more enhanced cleaning approach. The first case would reflect the very minimum cleaning requirements in order to maintain the waste bins in an acceptable / sanitary condition while the second case would reflect a case where more extensive cleaning is required or the homeowner inadvertently uses more detergent/water than is minimally required. The first variation benefits the unlined alternative more as it has higher cleaning requirements over the defined life cycle. As shown in Figure 32, the lined alternative increases its eco-efficiency and now both alternatives are equivalent. For the variation where an increase in detergent and water usage is modeled, Figure 33 shows the lined alternative increasing its eco-efficiency advantage over the unlined alternative to 25%.

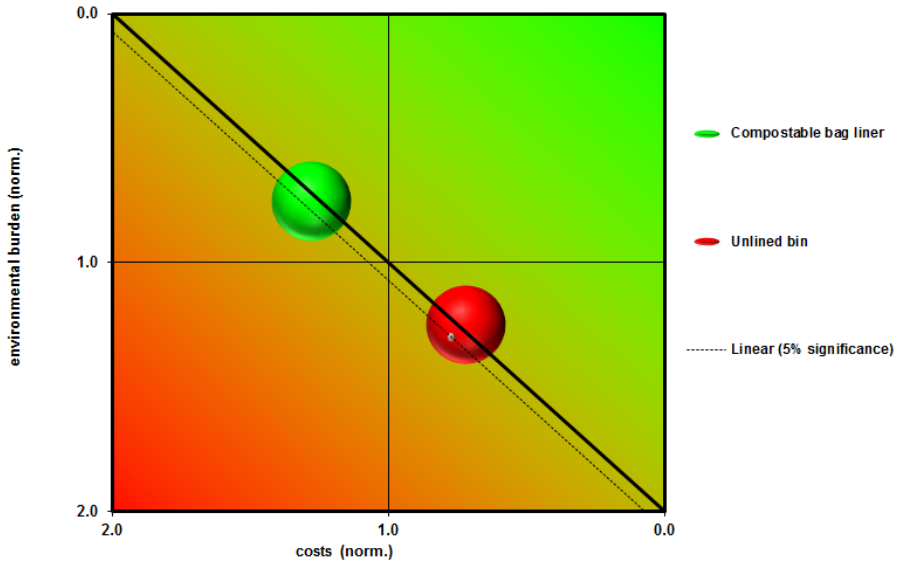


Figure 32. Scenario analysis #4: Minimum cleaning requirements to maintain collection bins in sanitary condition

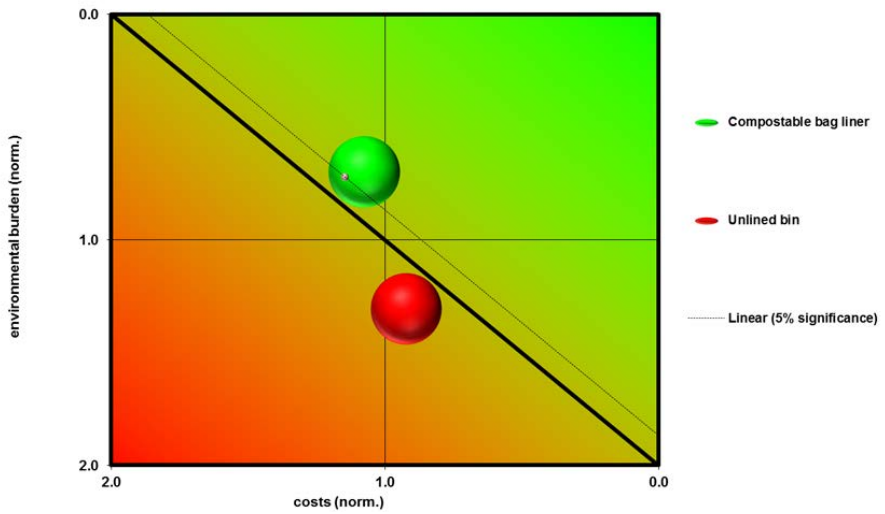


Figure 33. Scenario analysis #4: Enhanced cleaning requirements (25% increase in detergent & water usage)

8.3.5. Scenario #5: Increased diversion rate of food scraps to 19% and 100%

As discussed in this report's introduction, this eco-efficiency study wanted to focus on the eco-efficiency benefits and trade-offs of using a compostable bag as a liner for food waste collection containers. Specifically, do the impacts and costs of the bag outweigh the environmental benefits achieved by reducing the cleaning frequency of the collection bins. This study was not looking to confirm the benefits of composting as this has been well documented in earlier eco-efficiency studies[3]. That said, studies[7] have shown that the use of liners in food waste collection bins can increase the collection rate/diversion rate of food waste. This scenario analysis looks at an increase in food scrap diversion rate by 20% for alternative 1 and a future vision case of 100% food scrap diversion for alternative 1.

Figure 34 shows that there is a slight eco-efficiency improvement for alternative 1 when the food scrap diversion rate is increased from the base case assumption of 15.5% to around 19%, a 20% increase. This modest increase in food scrap diversion was able to increase the eco-efficiency of alternative 1 by around 8%. Thus the lined alternative is now 14% more eco-efficient than the unlined alternative. For a more visionary scenario (Figure 35), if all the food scraps are diverted from landfill to compost for alternative 1, alternative 1 significantly improves its life cycle costs and further improves its environmental profile leading to an eco-efficiency advantage over the unlined alternative of 30%. Thus, for the same amount of impacts, alternative 1 was able to drive enhanced benefits through the generation of additional compost.

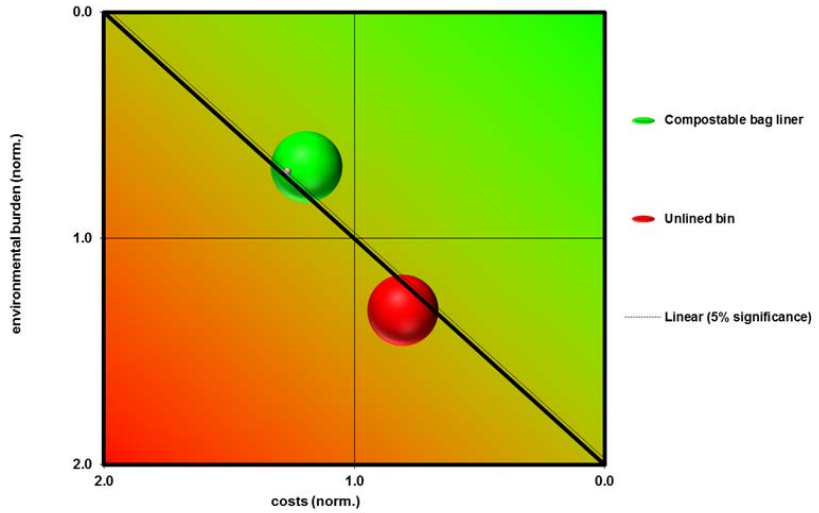


Figure 34. Scenario Analysis #5: Increased diversion rate of food waste by 20% for the lined alternative

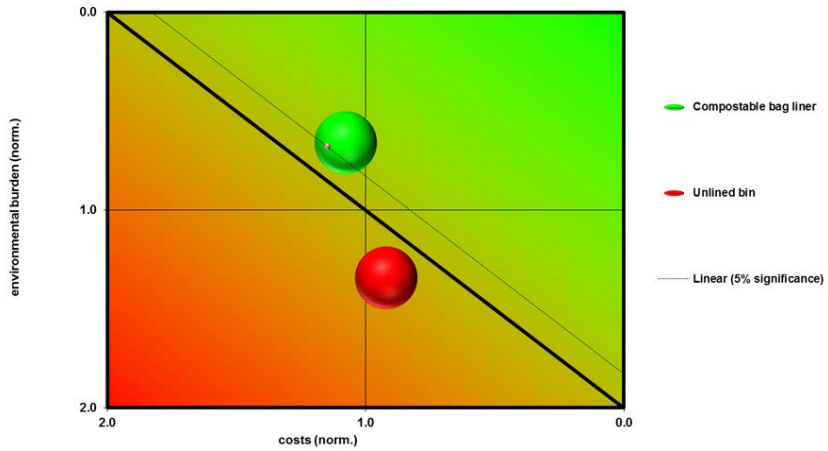


Figure 35. Scenario Analysis #5: Increased diversion rate of food waste to 100% for the lined alternative

9. Data Quality Assessment

9.1. Data Quality Statement:

The data used for parameterization of the EEA was sufficient with most parameters of medium to high data quality. Moderate data is where industry average values or assumptions pre-dominate the value. No critical uncertainties or significant data gaps were identified within the parameters and assumptions that could have a significant effect on the results and conclusions. Table 5 provides a summary of the data quality for the EEA. Table 6 lists the data sources for the life cycle inventory data.

Parameter	Quality Statement	Comments
ecovio® F2341	High	Known formulation based on BASF company data.
Food Waste Disposal Statistics	High	Most recent EPA MSW statistics as well as data from the 2012 US census.
Washing Impacts	Medium – High	Usage figures for water and detergent based on comparable EEA study on commercial food waste disposal. Eco-profile of detergent based on current technology using industry average data
Benefits / Impacts of Compost	High	3rd party verified eco-efficiency study of similar scope
Impacts of material to Landfill	High	3rd party verified eco-efficiency study of similar scope
Bag Weights	Medium – High	Data from Manufacturer
Logistics	Medium – High	Truck: PE international data; Ship: Boustead database. Assumed values are reasonable given study context and goals.
Incineration	Medium	Best available data but reasonable considering the study context and goals.
Waste water	Medium	Amount and composition based on BASF data as well as comparable LCA study. Assumed values are reasonable given the scope and goals of the study.
Disposal Costs	Medium – High	National average data as well as 3rd party eco-efficiency study of similar scope
Material (bag) Costs	Medium – High	National average consumer price.
Landfill / Compost Facility Costs	Medium – High	National average data report by government agencies and trade industry data

Table 5. Data quality evaluation for EEA parameters

Eco-profile	Source, year	Comments
Ecovio® F 2341	BASF, 2013	
Polyethylene, LDPE	Plastics Europe, 2005	
Transport, Truck	Global / PE International, 2011	
Transport – Sea Freight	US Average / , 1996	Most reliable data available
Detergent	BASF BEST database, 2014	Typical liquid household detergent
Well Water	BASF BEST database, 2010	
Natural Gas	BASF BEST database, 2009	US Average
Food waste to Landfill	BASF EEA Study, 2012	Compost Value EEA Study
Food waste to Compost	BASF EEA Study, 2012	Compost Value EEA Study
Incineration of biomass with heat recovery	BASF BEST database, 2010	Germany
Waste water (post POTW)	RMIT, 2009	US
Waste water (direct to storm sewer)	BASF BEST database, 2005	US
Landfill construction	ecoinvent, 2010	
Compost facility construction	BASF BEST database, 2003	California

Table 6. Life cycle inventory data sources

10. Sensitivity and Uncertainty Analysis

10.1. Sensitivity and Uncertainty Considerations:

A sensitivity analysis of the final results indicates that the economic impacts were slightly more influential or relevant in determining the final relative eco-efficiency positions of the alternatives. This conclusion is supported by reviewing the BIP Relevance (or GDP-Relevance) factor[13] calculated for the study. The BIP Relevance indicates for each individual study whether the environmental impacts or the economic impacts were more influential in determining the final results of the study. For this study, the BIP Relevance indicated that the economic impacts were slightly more influential in impacting the results than the environmental impacts (reference the “Evaluation” worksheet in the Excel model for the BIP Relevance calculation).

As the data quality related to the main cost contributors identified in Table 5 were of medium to high quality, we were confident in the final conclusions indicated by the study.

Though the economic impacts were the most significant, the environmental impacts still influence the overall eco-efficiency of each alternative. A closer look at the analysis (Table 7) indicates that the impact with the highest environmental relevance were water emissions followed by consumptive water use and energy consumption. This is to be expected, as previous discussions showed waste bin washing impacts are very significant. The frequency of bin washings is the key assumption that impacts these key categories. Data quality related to this information was also strong at a level of medium to high quality.

The calculation factors (Table 7), which consider both the social weighting factors and the environmental relevance factors, indicate which environmental impact categories were having the largest effect on the final outcome. Calculation factors are utilized in converting the environmental fingerprint results (Figure 24) into the final, single environmental score as reflected in our portfolio (Figure 26). The impacts with the highest calculation factors were water emissions, consumptive water use and toxicity potential. The input parameters that were related to these impact categories have sufficient data quality to support a conclusion that this study has a low uncertainty.

The social weighting factors had an influence in adjusting the relative weightings of a few impact categories namely energy consumption, resource consumption and water emissions. Higher societal relevance for energy and resource consumption helped increase their respective weighting relative to the other key impact categories. In addition, the lower social weighting value for water emissions helped to decrease its overall weighting compared to the other key impact categories.

Environmental Impact Category	Environmental Relevance Factor	Social Weighting Factor	Calculation Factor	Significance
Water Emissions	57%	8%	22%	HIGH
Consumptive Water Use	23%	15%	20%	HIGH
Toxicity Potential	NA	19%	19%	HIGH
Cumulative Energy Consumption	8%	14%	11%	MEDIUM
Risk Potential	NA	11%	11%	MEDIUM
Abiotic Resource Depletion	1%	15%	4%	LOW
Land Use	2%	7%	4%	LOW
Global Warming Potential	4%	2%	3%	LOW
Solid Waste	1%	5%	2%	LOW
Acidification Potential	2%	2%	2%	LOW
Summer Smog (POCP)	2%	1%	2%	LOW
Ozone Depletion Potential	0%	1%	0%	LOW
Total	100%	100%	100%	

Scale:	
HIGH	>19%
MEDIUM	10 - 19%
LOW	<10%

Table 7. Environmental relevance factors, social weighting factors, calculation factors and significance used in the sensitivity and uncertainty analysis

10.2. Critical Uncertainties:

There were no significant critical uncertainties from this study that would limit the findings or interpretations of this study. The data quality, relevance, and sensitivity of the study support the use of the input parameters and assumptions as appropriate and justified.

11. Limitations of EEA Study Results

11.1. Limitations:

The eco-efficiency analysis results and the conclusions are based on the specific comparison of the production, use, and disposal phases, for the described customer benefit, alternatives, system boundaries and specific study assumptions. Transfer of these results and conclusions to other production methods or products is expressly prohibited. In particular, partial results may not be communicated so as to alter the meaning, nor may arbitrary generalizations be made regarding the results and conclusions.

12. References

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[2] Municipal Solid Waste Characterization Report 2012 Fact Sheet. United States Environmental Protection Agency. See Table 1, Page 6.

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[13] Saling, P., et al., “Eco-Efficiency Analysis by BASF: The Method,” International Journal of Lifecycle Assessment, 7 (4), pp. 203-218 (2002).