BASF

The Chemical Company

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

Compost Value Eco-Efficiency Analysis Final Report - June 2012

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Table of Contents

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 "Compost Value 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 Compost Value 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 Compost Value Eco-Efficiency Analysis (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. In this study, the EEA's measurement of the life cycle environmental impacts does not include the raw material extraction phase of the selected functional unit (Customer Benefit) of life cycle as defined in 3.8 of ISO 14040, since the raw materials are Municipal Solid Waste (MSW). At a minimum, BASF EEA evaluates the environmental impact of the production, use, and disposal of a product or process in the areas of energy and resource 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.

3.2. Preconditions:

The basic preconditions of this Eco-Efficiency Analysis are that all alternatives that are being evaluated are being compared against a common functional unit 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 below.

3.2.1. Environmental Burden Metrics:

For BASF EEA environmental burden is characterized using eleven categories, at a minimum, including: primary energy consumption, raw material 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 yellow represent the six main categories of environmental burden that are used to construct the environmental fingerprint, burdens in blue represent all elements of the emissions category, and green show air emissions.

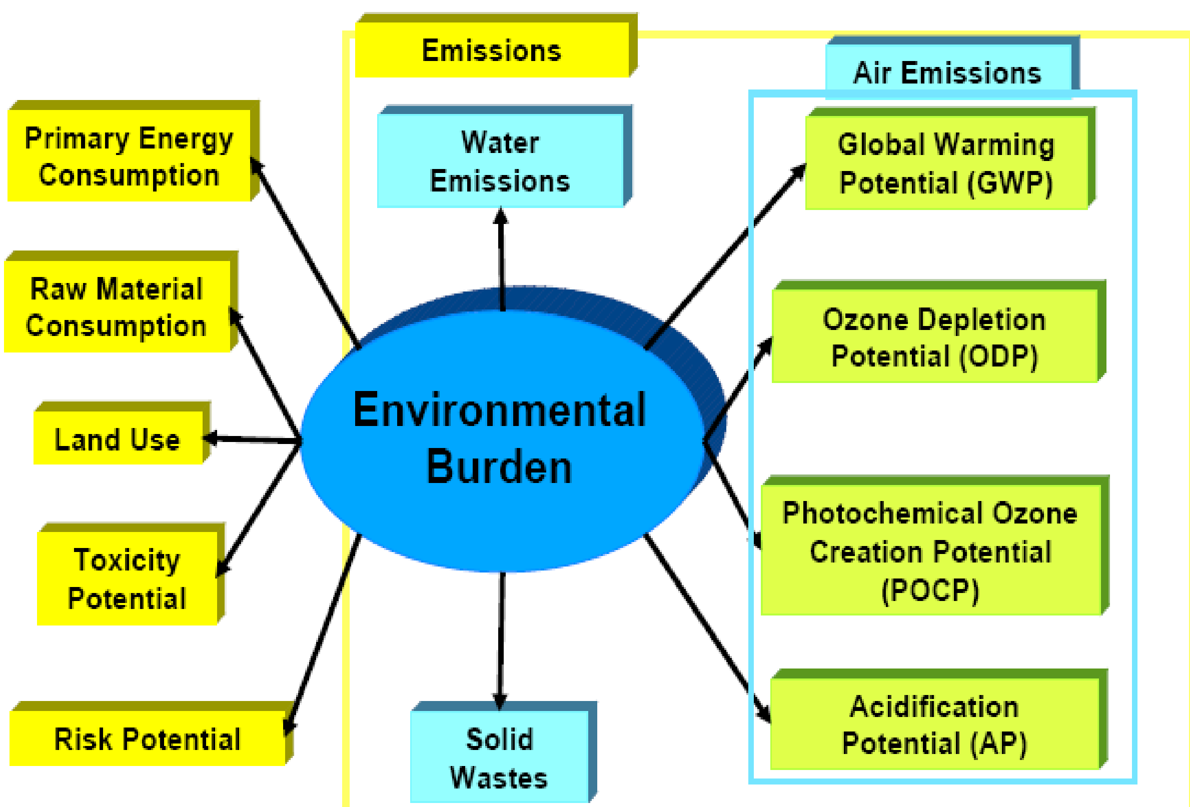

Figure 1. Environmental Impact categories

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. When different production methods are compared, the relevant costs include the purchase and installation of capital equipment, depreciation, and operating costs. 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.

3.3 Work Flow:

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

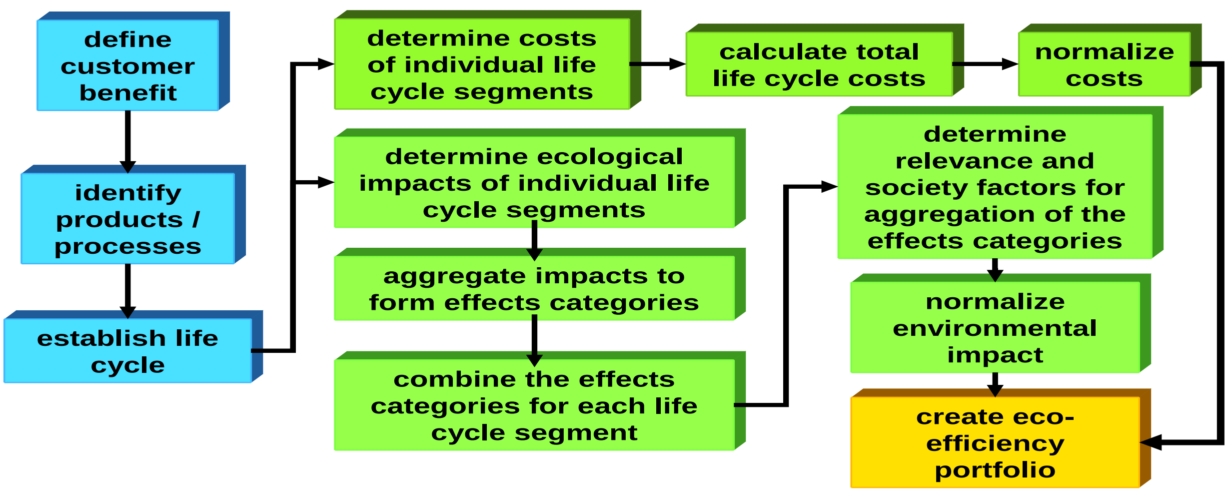

Figure 2. Overall process flow for BASF Compost Value EEA study

4. Study Goals, Context and Target Audience

4.1. Study Goals:

The specific goal defined for the Compost Value Eco-Efficiency Analysis is to quantify the differences in life cycle environmental impacts and total life cycle costs of composting Municipal Solid Waste (MSW) and the value from the composts. The differences between the alternatives will be the amount of organic MSW which is used for compost versus the amount that is put in landfill generating Landfill Gas (LFG) from this waste. The location for the study results will be from the United States.

The compost value will be quantified by evaluation of compost used in agriculture applications, LEED landscaping applications and in bio-remediation applications. The details of the value from each of these applications will be described in subsequent sections of the report (Section 6.1.1). In this analysis, the percentage of compost used in each sector was established at 50% in agriculture applications, 30% LEED landscaping applications and 20% bio-remediation applications. These percentages were established by the team at BASF for the base case. In the Base Case the varying amounts of compost evaluated in the alternatives was from zero compost up to 154,500 tons of compost, which is the total amount of compost generated from organic waste (assuming 50% organic feedstock to compost ratio) in 800,000 tons of MSW.

The compost value evaluated within each of these application areas are fertilizers use, water use, topsoil use and carbon sequestration. The value from organic MSW going to a landfill will be the electricity value from Landfill Gas (LFG) being utilized to generate MJ of electricity. This study also evaluates the benefits of composting MSW and the advantage this offers by extending the life of the landfill. Since the study is evaluating the value of compost, any value mentioned above from the compost alternatives is charged to the other alternatives as a lost opportunity value or trade-off. To explain this further, if fertilizer is the value of the compost, more fertilizer would need to be generated in the no compost alternative since the value of fertilizer is being used in the compost alternatives. The same applies to the compost alternatives where the creation of electricity comes from the LFG. Since material is not going to the landfill in the compost alternatives, there is a loss in potential electricity benefits of the LFG that has to be made up by creating electricity by some other source.

Study results will be used as a means to outline the advantages and disadvantages of compost as an alternative to disposal of organic waste in a landfill. This study will show the clear comparison between the environmental life cycle and total cost impacts of composting versus disposal of MSW in landfills. This study will also facilitate the clear communication of these results to key stakeholders in the waste disposal industry who are challenged with evaluating and making strategic decisions related to the environmental and total costs trade-offs associated with MSW disposal.

4.2 Design Criteria:

The context of this EEA study evaluates the environmental and cost impacts of compost being generated and the value of using compost, compared to organic MSW being disposed of in a landfill equipped to capture the LFG with electricity generation capabilities. The study design set the landfill capacity at 8 million tons on 90 acres, with the life expectancy of the landfill being 15 to 20 years. These parameters were set based on a Landfill Orientation Guide[1]. For the compost site the capacity was established as 40,000 tons per year on 15 acres, with a life expectancy of 50 years. The Base Case amount of MSW generated per year was established at 800,000 tons. This amount was established in order for the No Compost alternative to fill the landfill at just over 15 years. At this 800,000 tons MSW generation, the No Compost alternative would have 503,000 tons per year disposed of in a landfill (see Section 5.1 for calculation), of which almost 309,000 tons would be organic waste. In each of the alternatives, this organic waste amount is varied between the disposal in landfill and the use for compost. Varying the amount of MSW that is used for compost will show the value of the organic waste being used for compost instead of being disposed of in a landfill. The amount of compost evaluated will be from a 1 year time period with the potential value of the compost being from the compost amount. The maximum value of the compost over time is not evaluated. Additional values are also evaluated for the extension of the life of the landfill. If additional waste is being generated in the landfill that would shorten the 20 year life, then additional environmental and cost burdens would be placed on the landfill, since an additional landfill would need to be constructed.

This study will use documented data from universities, government agencies and municipalities dealing with the disposal of MSW. The data in the study will include general data such as landfill operations/emissions, compost production/emissions, electricity energy value from LFG, landfill construction, compost site construction, agricultural benefits, LEED landscaping benefits and bio-remediation benefits. The study will also look at transportation and equipment use in each of these areas.

The recycling rates were assumed to be constant for each alternative and were established at a fixed percentage based on the 2009 U.S. EPA study of MSW[2]. The percentage of MSW used in combustion processes to generate electricity was also held constant in each of the alternatives. The reason these were held constant was to be able to do a comparison of organic MSW being disposed of in a landfill or for being used for compost.

The study looks at a one year analysis for generation and values for each alternative waste diversion. The study assessment is regionally located and pertains to the United States. The drivers for the study are informational and can be associated with regulations for waste disposal as well as competitiveness for the organic waste. The innovation of the study is incremental but also points to the gap closure for comparing compost to LFG generation. The economic portion of the study is post consumer and in an emerging market. The analysis looks at multiple organic waste streams in several markets. Lastly, the analyisis evaluates the post consumer value of utilizing the organic waste. The study is informational driven and goals, target audience and context for decision criteria used in this study are displayed in Figure 3.

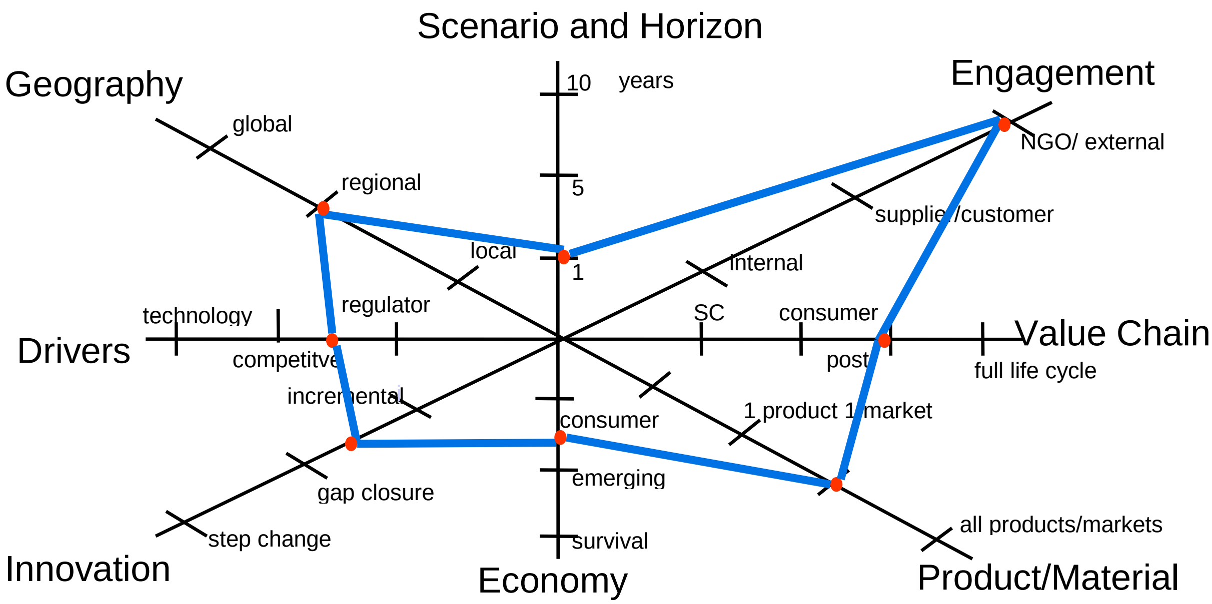

Figure 3. Context for Design Criteria of Compost Value Eco-Efficiency Analysis

4.3. Target Audience:

The target audience for the study has been defined as commercial landfill owners and municipalities that own and operate their own landfill or compost sites within North America. 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 (CB) applied to all alternatives for the Base Case analysis is disposal of 800,000 tons of Municipal Solid Waste (MSW) per year and sequential production and use for generating Landfill Gas (LFG) or Compost. This was established as the CB since each alternative will have varing amounts of organic waste that will go to landfill or for compost. This way there is a constant CB established for all the alternatives.

According to the 2009 U.S. EPA study of MSW[3], roughly 54.3% of all waste is discarded of in a landfill and 8.6% of all waste is composted. Of the remaining MSW, 25.2% is recycled and 11.9% is used in combustion with energy recovery. Figure 4 shows the management of the waste in these areas, whereas recycling and compost are combined in the Recovery section.

Leather and textiles were not raw materials for the compost due to the combustion with energy recovery needing raw materials to meet the 11.9%. Portions of wood, paper, plastic and rubber were also designated to the combustion with energy recovery, as well as miscellaneous MSW materials. Most of the rubber reported in the EPA report went to recycling, since most rubber material waste are used tires and these are being recycled to be used for alternative purposes.

The sum of the landfill waste and the compost waste is 62.9% and if all of this is put in a landfill, then using the CB of the amount of waste generated, roughly 503,000 tons of waste would be disposed of in a landfill. In this study, this is established as the No Compost alternative.

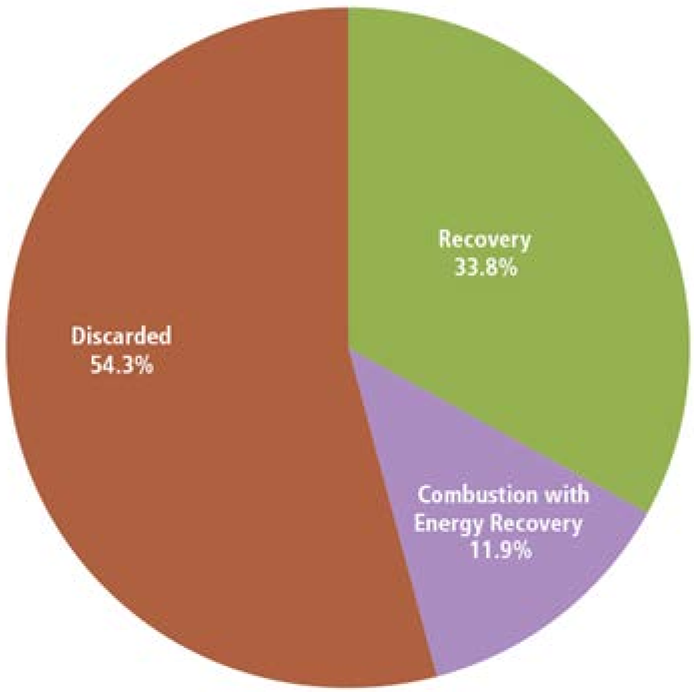

Figure 4. Management of U.S. MSW from U.S. EPA study, Figure 4, 2009[4]

5.2. Alternatives:

The product alternatives compared under this EEA study are (1) No Compost, which is the current organic MSW going to compost being disposed of in a landfill; (2) Compost I which is the current diversion of the organic MSW going to landfill and compost; (3) Compost II which is 50% extra diversion of organic waste from Compost I in each category for food scraps, yard trimmings, wood and paper; and (4) Compost III which is 100% diversion of organic waste generated from food scraps, yard trimmings, wood and paper. Table 1 shows the different alternative and the breakdown of the individual components in the landfill and compost processes, based on 2009 U.S. EPA study of MSW[5]. The values in the table show the percent total weight of the MSW components.

Table 1: Municipal Solid Waste breakdown for each alternative

PRODUCTION	No Compost	Compost I (Current)	Compost II (Additional 50%)	Compost III (100%)
Material to Landfill				
Food Scraps %	14.11	13.76	6.88	0.00
Yard Trimmings %	13.66	5.47	2.74	0.00
Wood %	5.39	5.39	2.70	0.00
Paper %	5.45	5.45	2.73	0.00
Plastic %	9.60	9.60	9.60	9.60
Metal %	5.63	5.63	5.63	5.63
Glass %	3.61	3.61	3.61	3.61
Rubber, leather, textiles %	5.02	5.02	5.02	5.02
Other %	0.34	0.34	0.34	0.34
Total Sum %:	62.84	54.30	39.26	24.22
Material to Composting				
Food Scraps %	-	0.35	7.23	14.11
Yard Trimmings %	-	8.19	10.93	13.66
Wood %	-	-	2.70	5.39
Paper %	-	-	2.73	5.45
Plastic %	-	-	-	-
Rubber, leather, textiles %	-	-	-	-
Total Sum %:	0.00	8.54	23.58	38.62
Material to Recycling				
Total Sum %:	25.22	25.22	25.22	25.22
Material to Combustion				
Total Sum %:	11.94	11.94	11.94	11.94
Total Sum %:	100.00	100.00	100.00	100.00

In the first 3 alternatives, there is some organic waste that is being disposed of in a landfill. Because of this, some LFG would be generated from the decomposition of this landfill waste. The LFG would be collected using underground piping and would be used as fuel to operate turbines in order to generate electricity. The amount of LFG is established based on U.S. EPA LFG Energy handbook[6] which states that 1 million tons of MSW produces roughly 432,000 cubic feet per day (cfd) of LFG. The organic waste in the MSW can not produce LFG immediately after it is disposed of in a landfill. The decomposition of the organic waste takes time and can produce LFG for over 20 to 30 years. However, in this study we are only evaluating the LFG generation for 1 year and the LFG being produced at the “Peak Year”. In the

Scenario section of this report (Section 8.4), the impact of LFG being generated over 30 years will be evaluated. Also in the U.S. EPA study, it states that LFG collection sites roughly recover only 75% of total LFG. In this study, we are using a collection factor of 100% to show the potentail value of the LFG if collection efficiencies can be improved. From the U.S. EPA LFG Energy handbook, the heating value of LFG is 500 BTU per standard cubic foot. Therefore, 1 million tons of MSW would produce roughly 288,000 MJ/d or 0.288 MJ/d for 1 ton of MSW.

Only 28.3% of landfills in the U.S. have LFG collections according to U.S. EPA data[7] from 2009. In the Base Case of this study, this value is used to calculate the potential collection value for the landfills in the U.S. For the 71.7% of landfills that did not have the collection capabilities for the LFG, the LFG would be released to the air and these values contribute to the air emissions.

The values of the LFG were only counted for a one year period just as the value of the compost was counted for just the initial application. It would have been difficult to try to get the full value of both the LFG and compost over 20 to 30 years and to do a justified comparison. This is why the LFG value was assumed to be at the peak release and the output from this peak is stated above.

5.3. System Boundaries:

The system boundaries define the specific elements of the production and use phases that are considered as part of the analysis. The "Production" phase of the LFG would be the transportation and disposal of the organic waste, decomposition into LFG, collecting the LFG and the emissions from the operations. The compost "Production" phase would be the transportation of the organic waste, compost operations, use of water and carbon sequestration or carbon sink from the operations of the compost process. The "Use" phase of the LFG would be the generation of electricity. The "Use" phase in the compost process would be the use of the compost which would give the compost value. For both systems boundaries the "Disposal" phase was not considered.

These particular system boundaries were selected because they encompass the entire life cycle of the MSW decomposing in a landfill or the MSW being used to generate compost and include all relevant parameters and elements. The justification for the use phase in both the LFG and the compost use was for the potential value of each and not the value seen by the consumer or end-user. The justification for elimination of the disposal phase is that there is no materials leftover in both of the processes.

The system boundaries for the LFG and the compost processes are shown in Figures 5 and 6, respectively.

There were no process steps that were excluded from this EEA evaluation since both processes were fully evaluated. In some of the alternatives (alternative 2 and 3), both processes are being evaluated. Each of the processes are quite different from each other since in one process a gas is being generated and the other a solid material is being generated, therefore no steps could be excluded in the study.

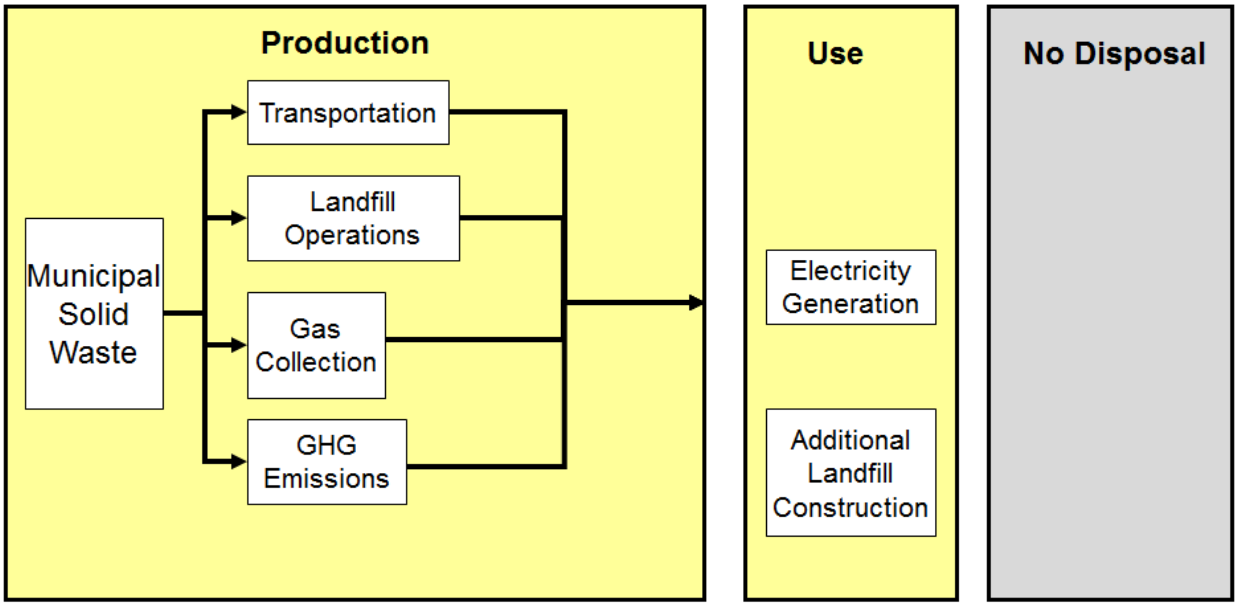

Figure 5. System boundaries – Landfill/LFG Process

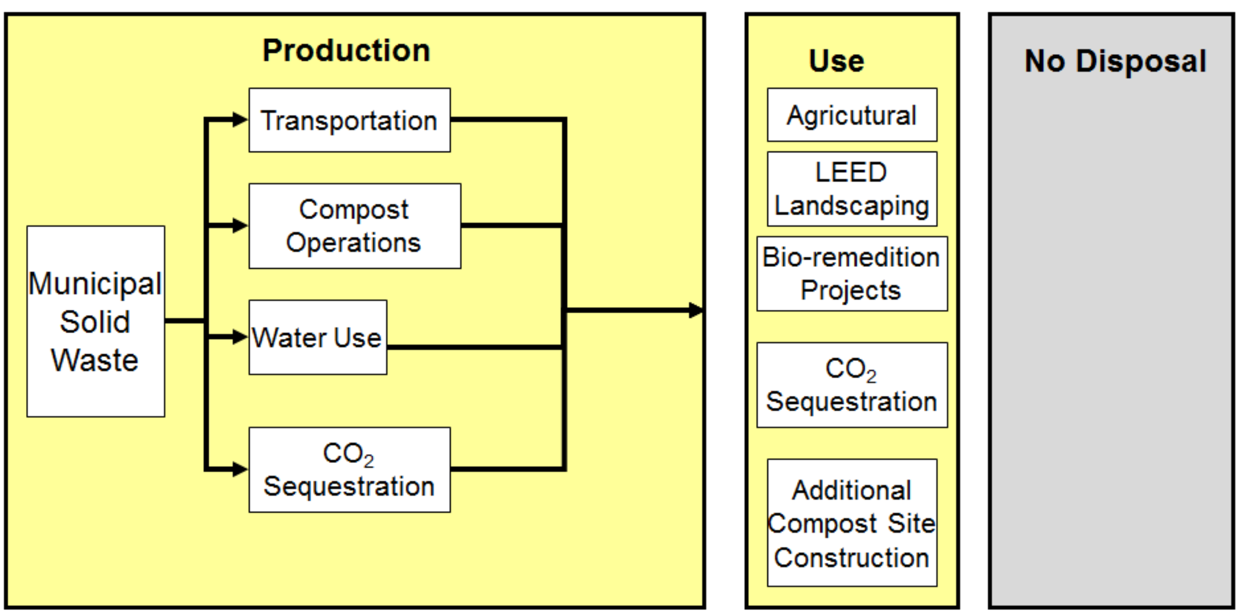

Figure 6. System boundaries – Compost Process

5.4 Scenario Analyses:

In addition to the base case analysis, additional scenarios will be evaluated to determine the sensitivity of the studies final conclusions and results to key input parameters. Scenario #1 evaluates 100% of all landfill sites capturing LFG within the U.S.; Scenario #2 evaluates the impact if the MSW generation was decreased by 25%; Scenario #3 evaluates the LFG generation over 30 years at the current % of landfill with collection capabilities; and Scenario #4 evaluates the LFG generation over 30 years at 100% of landfill with collection capabilities. The decrease in MSW generation would be through waste minimization efforts and the ratios could change between the waste materials, however in this scenario the ratio are held constant.:

- *Scenario #1:* 100% of all landfill sites capturing LFG for electricity generation.
- *Scenario #2:* 25% decrease in MSW generation and disposal.
- *Scenario #3:* LFG generation at peak production for 30 years at current landfill sites with colletion capabilities.
- *Scenario #4:* LFG generation at peak production for 30 years at 100% landfill sites with 100% collection.

6. Input Parameters and Assumptions

6.1. Input Parameters:

The data sources for the input parameters included all levels of government as well as universities and individual experts. The data sources are discussed in more detail in Chapter 7 of this document. The input values from this data are absolute values and the values are based on the input amounts of the MSW as discussed in Chapter 5.2 above. The values expressed in the results in each alternative is the tradeoff for each alternative based on the organic MSW being used for disposal in the landfill to create LFG or being used to make compost. For example, in the first alternative where there is no compost, the organic waste is all used for LFG generation thus there is a tradeoff for the compost value which is lost since there is no MSW for making compost. This is just the same for the Compost III alternative, where no MSW organic waste is used to generate LFG and so there is a loss of potential energy generation due to all the organic waste being used for compost.

In this study, there were three main sources for the data. The first source was the U.S. EPA 2009 MSW report used to determine the amounts, breakdown and availability of the MSW to be used for generating LFG or for making compost. The second source was the U.S. EPA LFG Energy Project Handbook which was used for the LFG production and data. The third source was the study published by Recycled Organics Unit of The University of New South Wales on compost. This study provided life cycle inventory and life cycle assessment values for the compost. The purpose of the Compost Value study is to show the value of the MSW organic waste being used for compost instead of disposal of MSW in a landfill and capturing the LFG. The decomposition of organic waste in a landfill to generate LFG takes time and is optimized after several years in a landfill. In this study, since the benefit of the compost can be realized in one year, the value of the LFG is assumed to be realized within the one year. This is unrealistic but in this study a conservative approach was evaluated for the LFG generation from organic MSW. The value of the compost could be greater compared to the LFG value, but this needed to be establish to get equal potential values. Also, the compost could have beneficial value over time thus having more value but this was not evaluated in this study.

6.1.1. Key Input Parameter Assumptions:

- One landfill and one compost site exist and the cost of these are from tipping fees and operational costs;
- 800,000 tons of MSW is generated per year;
- Life of landfill is 20 years and life of compost site is 50 years;
- Distance to landfill and compost sites are the same;
- Landfill and compost operations fuel use are the same;
- Landfill capacity is 8 million tons on 90 acres;
- Compost capacity is 40,000 tons on 15 acres;
- The LFG value is from the LFG generated in one year at peak generation;
- 100% of LFG is collected and used to generate electricity;
- Eco-toxicity of the compost was not evaluated in the Use phase;
- MSW to compost ratio is 50% based on professionals within the industry;
- Compost is used 50% in agricultural applications, 30% in LEED landscaping applications and 20% in bioremediation applications for remediating soil contaminated with heavy metals (Percentages determined by BASF).

6.1.2. Production Parameters:

Inputs for the transportation, operation and emissions for the landfill and compost operations were parameterized for each alternative. For the production and use of compost a credit for carbon sequestration (carbon sink) is given based on data from U.S. EPA[8]. The ratio for the carbon sequestration was 30% for the production and 70% for the use. Table 2 shows the amounts for each alternative based on the CB of 800,000 tons of MSW generated. Also in Table 2 are the input parameter values for 1 ton of MSW and the values used to calculate the amount in each alternative.

Table 2: Input data for Production of MSW in each alternative based on Customer Benefit

PRODUCTION	No Compost	Compost I (Current)	Compost II (Additional 50%)	Compost III (100%)	Input Parameter Value:	Input Units:
Landfill Operation and GHG Emissions						
MSW going to Landfill tons/CB	502,739.5	434,415.5	314,079.7	193,743.8		
Transportation distance miles	60.0	60.0	60.0	60.0	60	Miles
Transport fuel L/CB	180,986.2	156,389.6	113,068.7	69,747.8	6	mL/mile/ton
Landfill operation fuel L/CB	2,528,779.9	2,185,110.2	1,579,820.8	974,531.4	5.03	L/ton
Transport and Equipment operation use L/CB	2,709,766.2	2,341,499.8	1,692,889.5	1,044,279.2		
Fugitive CH4 Gas Emission kg/CB	693,310.0	466,578.5	168,666.7	0.0	1.49796	CH4 kg/ton/yr
Fugitive CO2 Gas Emssion kg/CB	2,045,994.2	1,376,897.7	497,744.2	0.0	4.4205588	CO2 kg/ton/yr
Compost Production and GHG Emissions						
Compost Production ton/CB	0.0	34,162.0	94,329.9	154,497.9		
Transportation distance miles	60.0	60.0	60.0	60.0	60	Miles
Transport fuel L/CB	0.0	24,596.6	67,917.6	111,238.5	6	mL/mile/ton
Compost Operation Fuel L/CB	0.0	343,669.7	948,959.1	1,554,248.5	5.03	L/ton
Transport and Equipment operation use L/CB	0.0	368,266.4	1,016,876.7	1,665,486.9		
Water addition L/CB	0.0	9,292,064.5	25,657,741.2	42,023,417.8	136	L/ton
Carbon Sequestration - CO2 eq. kg/CB	0.0	2,410,470.9	6,655,919.9	10,901,369.0	235.2	kg CO2/ton

Based on the CB, Table 3 shows the LFG energy value in each of the alternatives and the construction of additional landfills and compost sites if needed for each alternative. The input parameter values for calculating these values are also listed in this table.

Table 3: LFG Energy value and construction information for landfill and compost sites based on CB

USE	No Compost	Compost I (Current)	Compost II (Additional 50%)	Compost III (100%)	Input Parameter Value:	Input Units:
LFG Energy Value						
Gas Recovery Value MJ/day/CB	52,612.3	35,406.6	12,799.4	0.0	0.288	MJ/d/ton
Elec. Generation MJ-yr/CB	19,203,476.6	12,923,410.6	4,671,772.0	0.0	365	d/yr
Additional energy base case MJ-yr/CB	0.0	6,280,066.0	14,531,704.6	19,203,476.6		
Additional energy - optimal recovery	0.0	0.0	0.0	0.0		
Landfill Construction						
Life expectancy Years	15.91	18.42	25.47	41.29	20	Life of landfill (years)
Land Use m2/Yr	22,888.385	19,777.776	14,299.207	8,820.637	4046.873	m2/Acre
Additional landfill sites #/CB	0.257	0.086	0.000	0.000		
Additional landfill waste tons/CB	2,054,790.9	688,310.8	0.0	0.0		
Compost Site Construction						
Compost sites		1.7	4.7	7.7	50	Life of compost site (yrs)
Land Use m2/Yr.	0.000	103,686.963	286,305.938	468,924.913	4046.873	m2/Acre
Additional Compost sites		0.7	3.7	6.7		
Additional compost tons	0.0	28,324.0	148,659.9	268,995.7		

Table 4 shows the value of using the compost in an agriculture application and these amounts are based on 50% of the compost available from the generation from organic MSW. The parameters evaluated are water, fertilizer and topsoil savings along with carbon sequestration. Transportation and handling of the compost are also considered in the use of compost.

Table 4: Agriculture values of using compost based on CB and Input parameter values

USE	No Compost	Compost I (Current)	Compost II (Additional 50%)	Compost III (100%)	Input Parameter Value:	Input Units:
Compost Value:						
Agriculture (irrigation, fertilizer, erosion)						
Compost Use:						
Transport Compost L/CB	0.0	6,149.2	16,979.4	27,809.6	6	mL/mile/ton
Handling & spreading Compost L/CB	0.0	16,397.8	45,278.4	74,159.0	0.96	L/ton
Total Transport and Equipment use L/CB	0.0	22,546.9	62,257.8	101,968.6		
Water Use:						
kL/CB	0.0	59,783.5	165,077.4	270,371.3	3.5	kL/ton
Additional water kL/CB	270,371.3	210,587.8	105,293.9	0.0		
Fertilizers Use:						
0.9% N kg/CB	0.0	303,173.7	837,139.2	1,371,104.7	0.009	
Additional N kg/CB	1,371,104.7	1,067,931.0	533,965.5	0.0		
0.3% P kg/CB	0.0	101,057.9	279,046.4	457,034.9	0.003	
Additional P kg/CB	457,034.9	355,977.0	177,988.5	0.0		
0.12% K kg/CB	0.0	77,477.7	213,935.6	350,393.4	0.0012	
Additional K kg/CB	350,393.4	272,915.7	136,457.9	0.0		
Topsoil Use:						
Topsoil tons/CB	0.0	1,483.1	4,095.2	6,707.2	1.45	tons/acre
Additional Topsoil tons/CB	6,707.2	5,224.2	2,612.1	0.0		
Transport, Handling and spreading topsoil L/CB	5,634.1	4,388.3	2,194.1	0.0		
Carbon Sequestration:						
CO_2 equivalent kg/CB	0.0	28,122.2	77,652.4	127,182.6	235.2	kg CO2/ton

The value of the compost used in LEED Landscaping is shown in Table 5 below and these amounts are based on 30% of the compost being used for this application. The parameters evaluated are water, fertilizer and topsoil savings along with carbon sequestration. Transportation and handling of the compost are also considered in the use of compost.

Table 5: LEED Landscaping values of using compost based on CB and Input parameter values

USE	No Compost	Compost I (Current)	Compost II (Additional 50%)	Compost III (100%)	Input Parameter Value:	Input Units:
LEED Landscaping (irrigation, fertilizer, erosion)						
Compost Use:						
Transport L/CB	0.0	3,689.5	10,187.6	16,685.8	6	mL/mile/ton
Handling & spreading L/CB	0.0	9,838.7	27,167.0	44,495.4	0.96	L/ton
Total Transport and Equipment use L/CB	0.0	13,528.2	37,354.7	61,181.2		
Water Use:	0.0	35,870.1	99,046.4	162,222.8	3.5	kL/ton
Additional water kL/CB	162,222.8	126,352.7	63,176.3	0.0		
Fertilizers Use:						
0.9% N kg/CB	0.0	181,956.5	502,428.0	822,899.5	0.009	
Additional N kg/CB	822,899.5	640,943.0	320,471.5	0.0		
0.3% P kg/CB	0.0	60,652.2	167,476.0	274,299.8	0.003	
Additional P kg/CB	274,299.8	213,647.7	106,823.8	0.0		
0.12% K kg/CB	0.0	18,600.0	51,359.3	84,118.6	0.0012	
Additional K kg/CB	84,118.6	65,518.6	32,759.3	0.0		
Pesticide Use:						
Herbicide Use ??						
Additional Herbicide	0.0	0.0	0.0	0.0		
Additional cost for Herbicide						
Biocide Use ??						
Additional Biocide	0.0	0.0	0.0	0.0		
Additional Cost for Biocide						
Topsoil Use:						
Topsoil tons/CB	0.0	10,248.6	28,299.0	46,349.4	2500	lbs/yd3
Additional Topsoil tons/CB	46,349.4	36,100.8	18,050.4	0.0	6	mL/mile/ton
Transport, Handling and spreading topsoil L/CB	30,034.4	23,393.3	11,696.6	0.0	0.96	L/ton
Carbon Sequestration:						
CO_2 equivalent kg/CB	0.0	16,873.3	46,591.4	76,309.6	235.2	kg CO2/ton

Table 6 shows the value of the compost used for bio-remediation applications and these amounts are based on 20% of the compost being used for this application. This parameter is based on using compost to cap contaminated soil[9] instead of using a water cap. The contaminated soil in this case was contaminated with a heavy metal. The model parameters evaluated were water savings, carbon sequestration and toxicity. Transportation and handling of the compost are also considered in the use of compost.

Table 6: Bio-remediation values of using compost based on CB and Input parameter values

USE	No Compost	Compost I (Current)	Compost II (Additional 50%)	Compost III (100%)	Input Parameter Value:	Input Units:
Bio-remediation						
Surface Cap - contaminated soil						
Compost Use:						
Transport L/CB	0.0	2,459.7	6,791.8	11,123.8	6	mL/mile/ton
Handling & spreading L/CB	0.0	6,559.1	18,111.3	29,663.6	0.96	L/ton
Area cover with Compost (15 cm thick) ft^2/CB	0.0	299,882.2	828,050.7	1,356,219.2	2500	lbs/yd3
Water (instead of compost) L/CB	18,899,534.1	14,720,538.2	7,360,269.1	0.0		
Transport water L/CB	1,500.0	1,168.3	584.2	0.0		
Carbon Sequestration:						
CO_2 equivalent kg/CB	0.0	11,248.9	31,061.0	50,873.1	235.2	kg CO2/ton
Toxicity: Pb decrease kg/CB	0.0	18,518.2	51,133.3	83,748.5	49.78	g/kg Pb
Pb toxicity impact kg/CB	83,748.5	65,230.3	32,615.2	0.0		

6.2. Costs

6.2.1. User Costs

User costs were evaluated for each alternative. User costs were entered based on the CB of 800,000 tons of MSW being generated. The production costs are the tipping fees charged by the landfill and compost sites, plus the transportation costs for fuel. There are also the costs per year from building the landfill or compost site based on disposal amounts, plus the equipment needed for these sites. If an additional landfill or compost site is needed, these amounts are proportional to the additional amount generated in each alternative. These costs are shown in Table 7. The cost analysis is based on data from from 2009 to early 2010 and the cost input data value is the same for all alternatives.

The value of the electricity generated by the LFG is also shown in this table and is charged to the compost alternatives as potential costs for additional electricity needed if organic MSW is composted.

Table 7: General Input data costs based on disposal of organic MSW in a landfill and construction of landfill or compost sites

PRODUCTION	No Compost	Compost I (Current)	Compost II (Additional 50%)	Compost III (100%)	Costs:	Units:
Landfill Operation and GHG Emissions						
Tipping fees $/CB	20,109,581.8	17,376,621.7	12,563,187.4	7,749,753.0	$40.00	$/ton
Cost of Fuel Transport $/CB	114,926.3	99,307.4	71,798.6	44,289.8	$0.64	$/L
Cost Landfill operation fuel $/CB	1,605,775.2	1,387,545.0	1,003,186.2	618,827.5	$0.64	$/L
Compost Production and GHG Emissions						
Tipping fees $/CB	0.0	1,024,860.1	2,829,897.9	4,634,935.8	$15.00	$/ton
Cost of Fuel Transport $/CB	0.0	15,618.9	43,127.6	70,636.4	$0.64	$/L
Cost Compost operation fuel $/CB	0.0	218,230.3	602,589.0	986,947.8	$0.64	$/L
Water Cost $/CB	0.0	5,449.8	15,048.3	24,646.7	$0.59	$/ kL
USE	**No Compost**	**Compost I (Current)**	**Compost II (Additional 50%)**	**Compost III (100%)**		
LFG Energy Value						
Cost for LFG Makeup (BC) $/CB	0.0	183,880.3	425,488.3	562,277.8	$0.03	$/MJ
Cost for LFG Makeup (OV) $/CB	0.0	0.0	0.0	0.0		
Landfill Construction						
Landfill start-up cost $/landfill	115,000,000.0	115,000,000.0	115,000,000.0	115,000,000.0	$115,000,000.00	$/Life of Landfill
Initial Landfill site $/year	7,226,881.0	6,244,723.4	4,514,895.5	2,785,067.5		$/year
Additional landfill cost $/yr	1,476,881.0	494,723.4	0.0	0.0		
Compost Site Construction						
Compost site start-up cost $/yr		24,050.0	24,050.0	24,050.0	$1,202,500.00	$/Compost site
Additional Initial compost site cost $		13,997.1	73,464.4	132,931.8		

Table 8 shows the cost values for each of the alternatives from the benefit of the MSW being composted. Again the cost value of the compost is charged to the landfill alternatives as potential costs for additional water, fertilizer and topsoil needed because compost is not being generated when organic MSW is being disposed of in a landfill. The cost of the compost in LEED landscaping is based on bags of compost costing roughly $2.00 per bag and 12.5 bags in a cubic yard. In the other applications, the compost would be bought in bulk, thus a much lower price.

Table 8: General Input data costs based on value of compost being generated from organic MSW instead of being disposed of in a landfill

USE	No Compost	Compost I (Current)	Compost II (Additional 50%)	Compost III (100%)		
Compost Value:						
Agriculture (irrigation, fertilizer, erosion)						
Compost Use:						
Compost costs $/CB	0.0	177,136.3	489,118.2	801,100.0	$7.00	$/yd3
Water Use:						
Additional water costs $/CB	158,572.7	123,509.7	61,754.9	0.0	$0.59	$/ kL
Fertilizers Use:						
Additional cost for N $/CB	634,821.5	494,452.1	247,226.0	0.0	$0.46	$/kg
Additional cost for P $/CB	224,861.2	175,140.7	87,570.3	0.0	$0.49	$/kg
Additional cost for K $/CB	190,964.4	148,739.1	74,369.5	0.0	$0.55	$/kg
Topsoil Use:						
Additional cost for Topsoil $/CB	37,560.6	29,255.3	14,627.7	0.0	$7.00	$/yd3
LEED Landscaping (irrigation, fertilizer, erosion)						
Compost Use:						
Compost costs $/CB	0.0	106,281.8	293,470.9	480,660.0	$7.00	$/yd3
Water Use:	0.0	35,870.1	99,046.4	162,222.8		
Additional water costs $/CB	95,143.6	74,105.8	37,052.9	0.0	$0.59	$/ kL
Fertilizers Use:						
Additional cost for N $/CB	381,002.5	296,756.6	148,378.3	0.0	$0.46	$/kg
Additional cost for P $/CB	134,955.5	105,114.6	52,557.3	0.0	$0.49	$/kg
Additional cost for K $/CB	45,844.6	35,707.6	17,853.8	0.0	$0.55	$/kg
Topsoil Use:						
Additional cost for Topsoil $/CB	926,987.2	722,015.1	361,007.6	0.0	$25.00	$/yd3
Bio-remediation						
Surface Cap - contaminated soil						
Compost Use:						
Compost costs $/CB	0.0	70,854.5	195,647.3	320,440.0	$7.00	$/yd3
Additional water costs $/CB	11,084.6	8,633.6	4,316.8	0.0	$0.59	$/ kL

* **Note:** All benefits of each alternative are charged to other alternatives as a lost opportunity cost.

7. Data Sources

7.1. Environmental:

The environmental impacts for this study were calculated from eco-profiles (a.k.a. life cycle inventories) for the individual components and for fuel usage. Life cycle inventory data for these eco-profiles were from several data sources, including

BASF, specific manufacturing data and customer supplied data. Overall, the quality of the data was considered medium. None of the eco-profile data was considered to be of low data quality. A summary of the eco-profiles is provided in Table 9.

Table 9: Summary of eco-profiles used in the Compost value EEA

Eco-Profile	Source, Year	Comments
Compost Value EEA		
Water	BASF well data, 1995	Boustead database[10]
Urea Fertilizer	Agrium, 2005	Boustead database[10]
DAP Fertilizer	Univ. of Minnesota., 2002	
K-Fertilizer	DE Avg., 1997	Boustead database[10]
Diesel Use - US	US Avg., 1996	Boustead database[10]
Topsoil	US date, 2000	Boustead database[10]
Electricity - US	US Avg. 2004	Boustead database[10]
Landfill site construction	Univ. of Montreal – Quebec, 2003	
Compost site construction	BASF, 2003	Boustead database[10]

7.2. Amounts and Costs:

The data sources for the amounts and costs of the individual components were obtained from various sources. A summary of the source of this data is provided in Table 10. The reference materials for this information can be found in Appendix A.

Table 10: Summary of data sources for amounts and costs

Parameter	Cost Source
Landfill operations	2009 Landfill tipping fees - Georgia
Compost operations	City of Ann Arbor, Michigan
Landfill Gas energy value	U.S. Environmental Protection Agency LMOP
Landfill Construction	Lancaster County Solid Waste Management
Compost Site Construction	Mountain Top Area SWANA
Compost Transport & Handling	Recycled Organic Unit – U. of NSW, USDA
Water savings	Recycled Organic Unit – U. of NSW, City of Detroit
N-P-K Fertilizers savings	Recycled Organic Unit – U. of NSW, USDA
Topsoil savings	Recycled Organic Unit – U. of NSW, commercial sources

8. Eco-Efficiency Analysis Results and Discussion

8.1. Environmental Impact Results:

The environmental impact results for the Compost Value EEA are generated as defined in Section 6 of the BASF EEA methodology. The results discussed in Section

8.1.1 through 8.3 (depicted in Figures 7 through 22) are for the Base Case only and do not represent any of the scenarios.

8.1.1. Primary energy consumption:

Increasing the amount of organic waste to compost reduces the energy consumption. From Figure 7, the key driver for energy consumption is the landfill construction. If organic MSW is diverted away from the landfill, the life of the landfill is extended and an additional landfill is not needed. The energy demand from the equipment and materials needed to build an additional landfill is far greater than the energy value received from the generation of landfill gas.

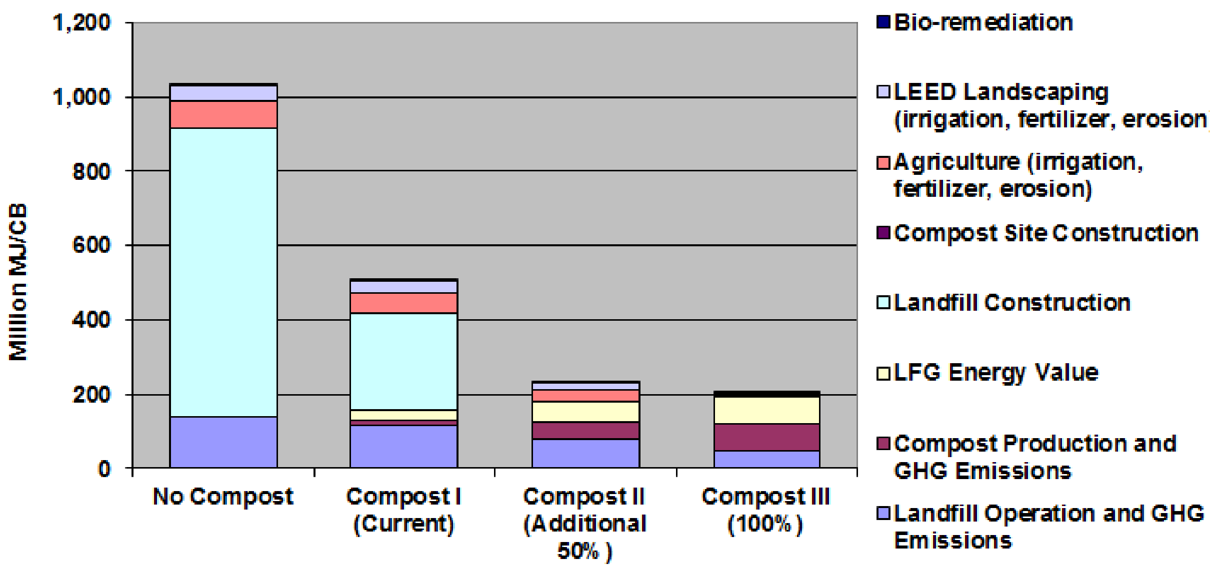

Figure 7. Primary energy consumption

8.1.2. Raw material consumption:

Figure 8 shows that the key driver for the raw material or resource consumption is dominated by the materials needed for an additional landfill.

Per the BASF 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. Sand is the main resource that dominates raw material consumption (apart from energy carriers like coal, lignite, oil and gas). The use of sand in the land operations and construction is significant. Figure 9 shows the overall use of individual raw materials for the different alternatives and the affect of having to build an additional landfill.

Landfill construction uses a lot of material to create barriers from leaching of the MSW waste into the ground surrounding the landfill. These materials consist of clay, gravel, sand, soil and plastic membranes. Also in order to collect the LFG, the landfill needs to be constructed with plastic piping to collect the gas. In the compost construction, the main raw materials are the concrete slab used as the base for the composting piles.

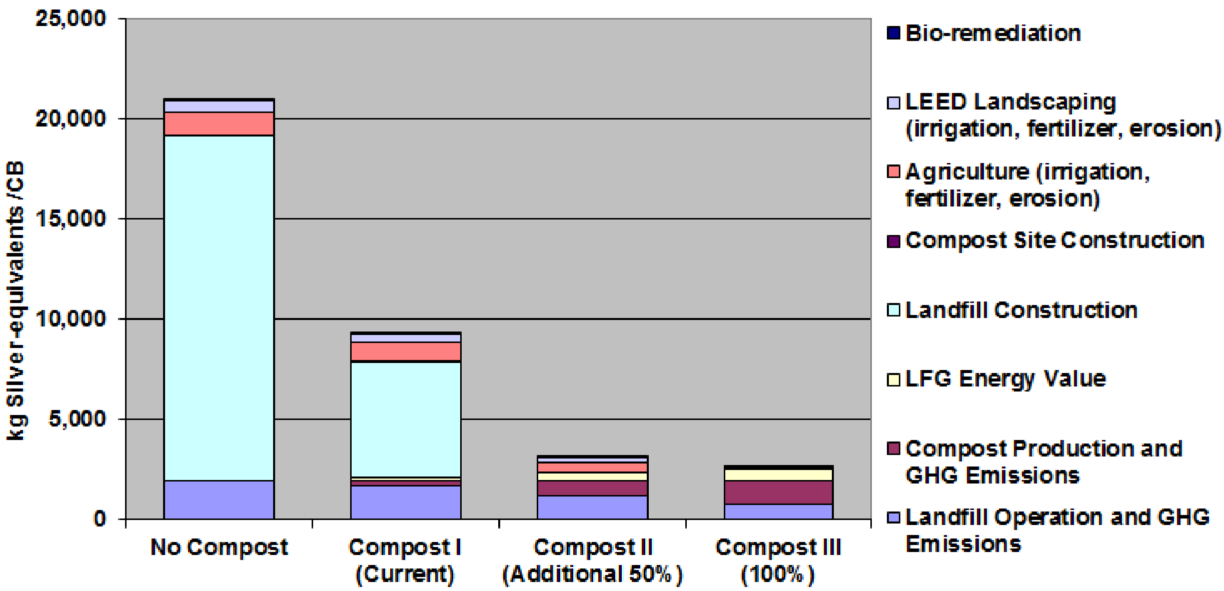

Figure 8. Raw Material consumption by Module

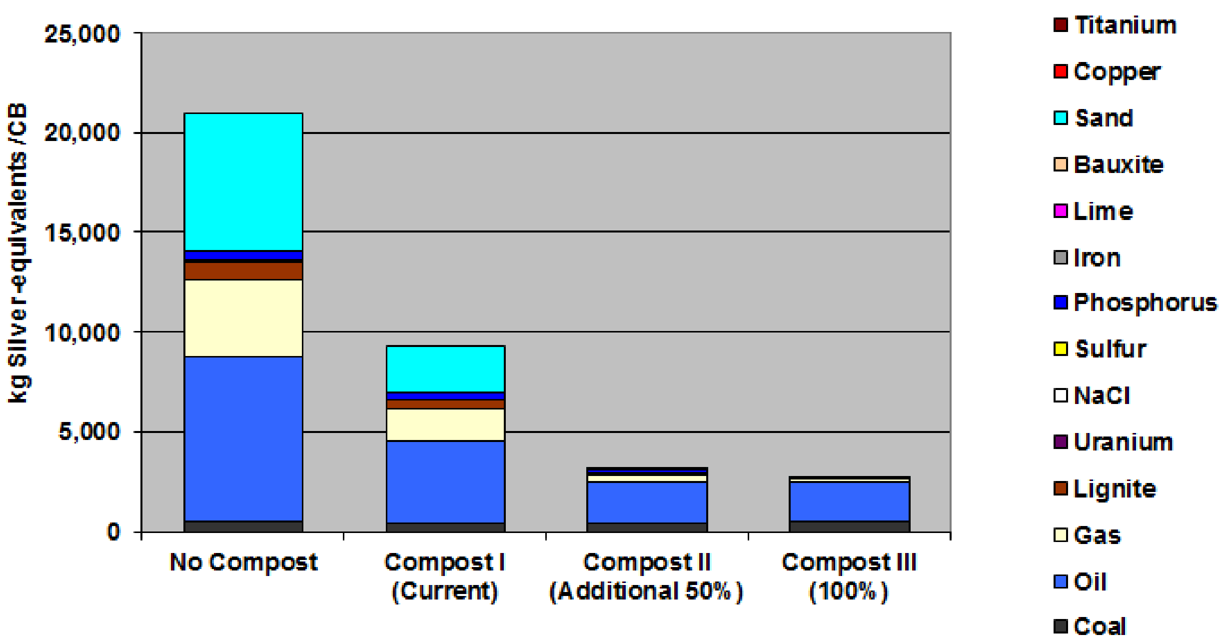

Figure 9. Raw Material consumption by Type

8.1.3. Air Emissions:

8.1.3.1. Global Warming Potential (GWP):

Global Warming Potential (GWP) highest emissions occurred in the landfill operations. This is significant in the alternatives where organic waste is not composted. When LFG is generated from organic waste, roughly 50% of this is carbon dioxide and 50% methane. If the methane is not captured, then this also contributes to GWP. GWP equivalents are calculated from the carbon dioxide, methane, halogenated hydrocarbons and nitrous oxide based on a 100 years time horizon. There is carbon sequestration in the compost process and from the use of the compost. In this study, 30% carbon sequestration credit is given in the production of compost and 70% in the use of the compost. Figure 10 shows the overall GWP emission for each of the alternatives and the carbon credit given in Compost II and Compost III.

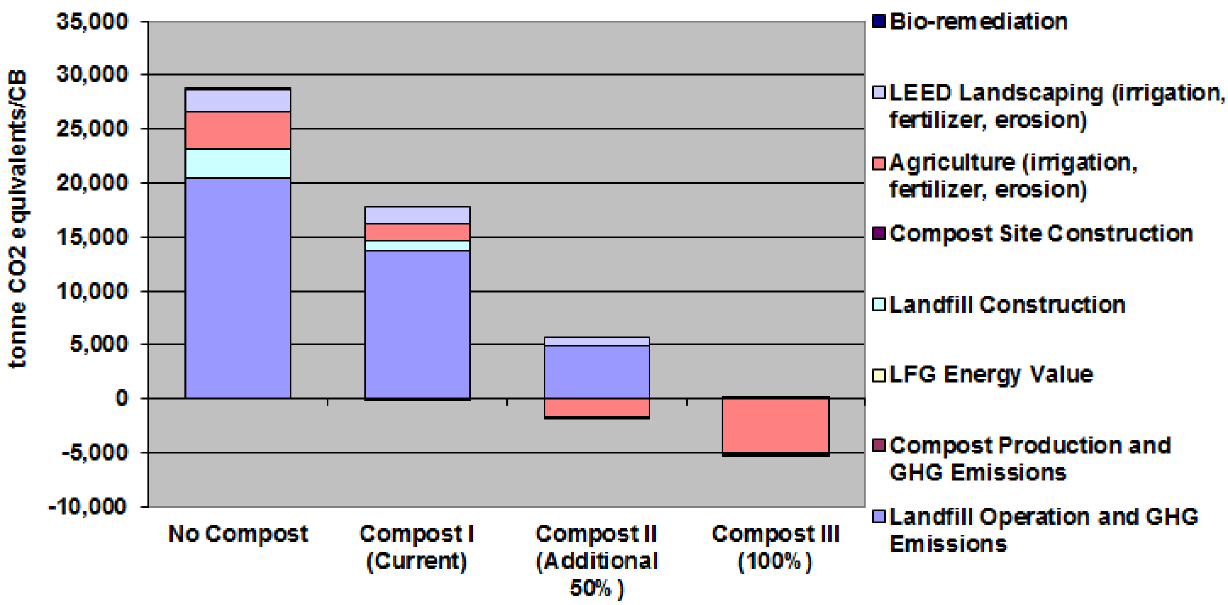

Figure 10. Global Warming Potential

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

Emissions with Photochemical Ozone Creation Potential are dominated by landfill operations, agricultural benefits and the LEED landscaping benefits of using compost. The main factors for POCP are the release of the methane gas in the landfill operations and the fertilizer benefits from using compost in agricultural and LEED landscaping. There is less fertilizer being needed in the less compost alternatives, thus less fertilizer needs to be produced. There is little POCP emissions in Compost III from the compost production. The environmental affect of the POCP is very minor in this study and the results of each alternative are shown in Figure 11.

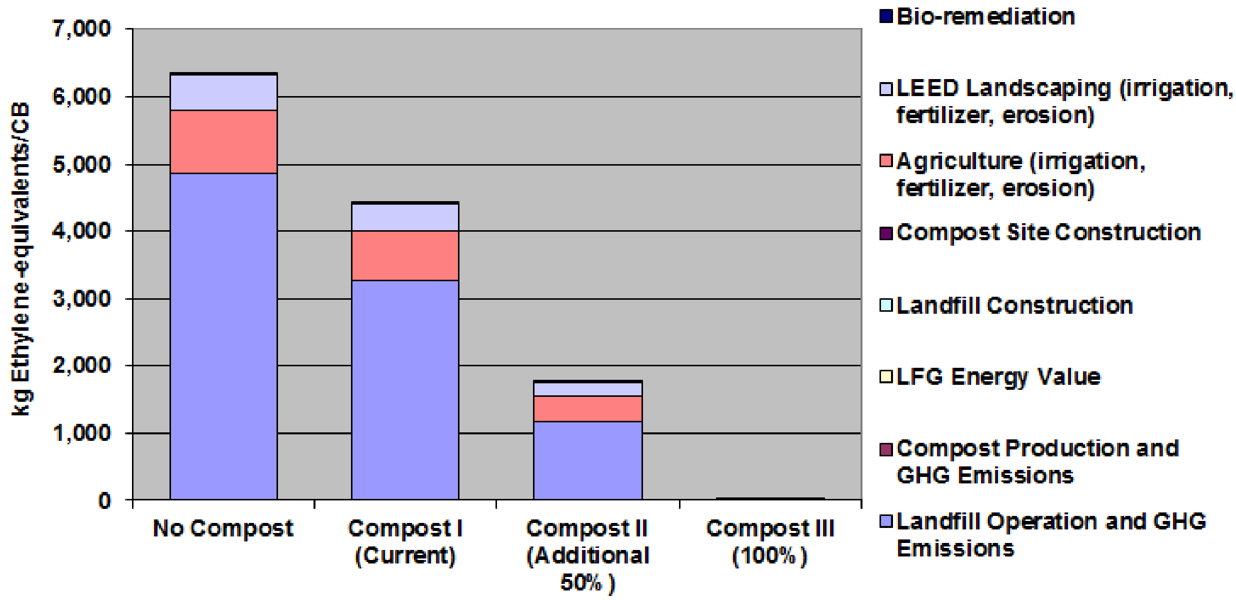

Figure 11. Photochemical Ozone Creation Potential

8.1.3.3. Ozone depletion potential (ODP):

Overall, the ODP emissions are very small and are dominated by the values of the compost. Again, since the Compost III alternative is the alternative all of the other values are based from there is very little ODP from this alternative. This environmental category has a very minor influence also and the results are shown in Figure 12.

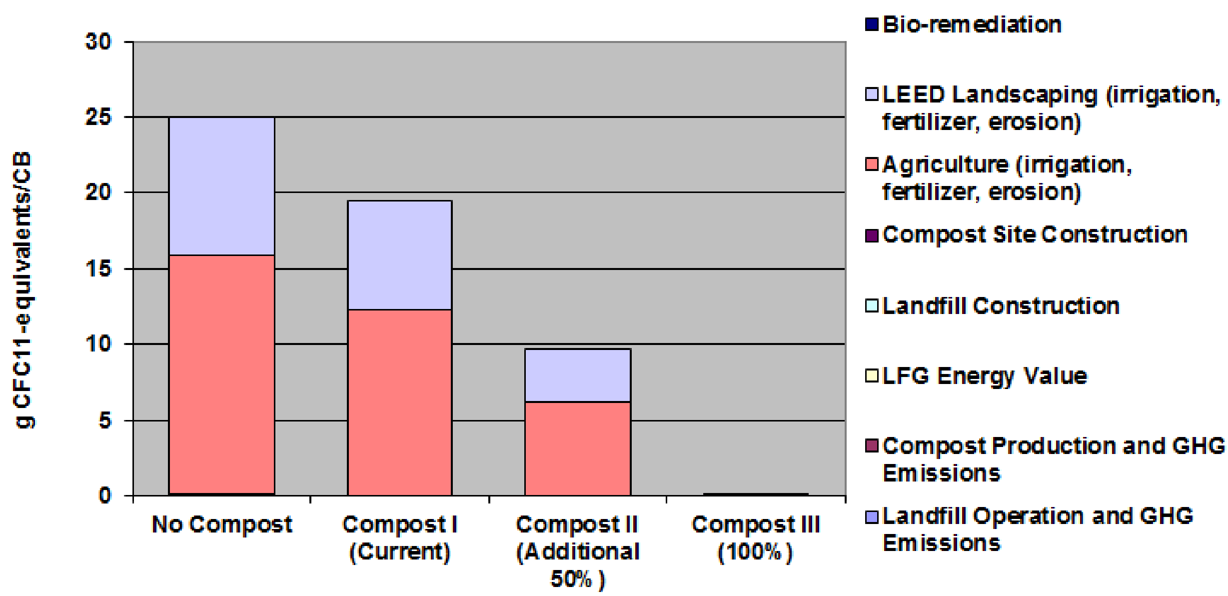

Figure 12. Ozone depletion potential

8.1.3.4. Acidification potential (AP):

It can be seen in Figure 13 that landfill operations and compost production contribute to the AP in each alternative, mainly from the diesel used in the operations. There is also AP from the NH_3- and NOx emissions from the fertilizer value of the compost in agriculture and LEED Landscaping. According to literature[11], 2% of N-fertilizers are emitted as NH_3 and 2% as NOx respectively.

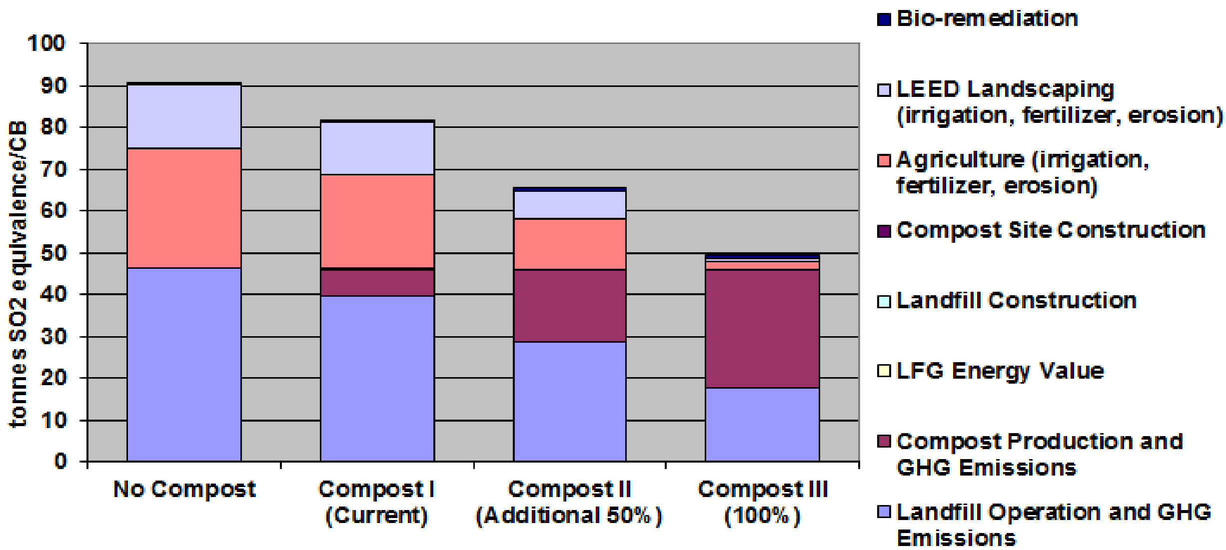

Figure 13. Acidification potential

Figure 14 below, shows the relative impacts of the four air emissions: GWP, AP, POCP and ODP. These values are normalized and weighted based on the calculation factors (see Figure 32 for the calculation factor percentage). The calculation factor is a calculation of the relative environmental factors and the social weighting factors.

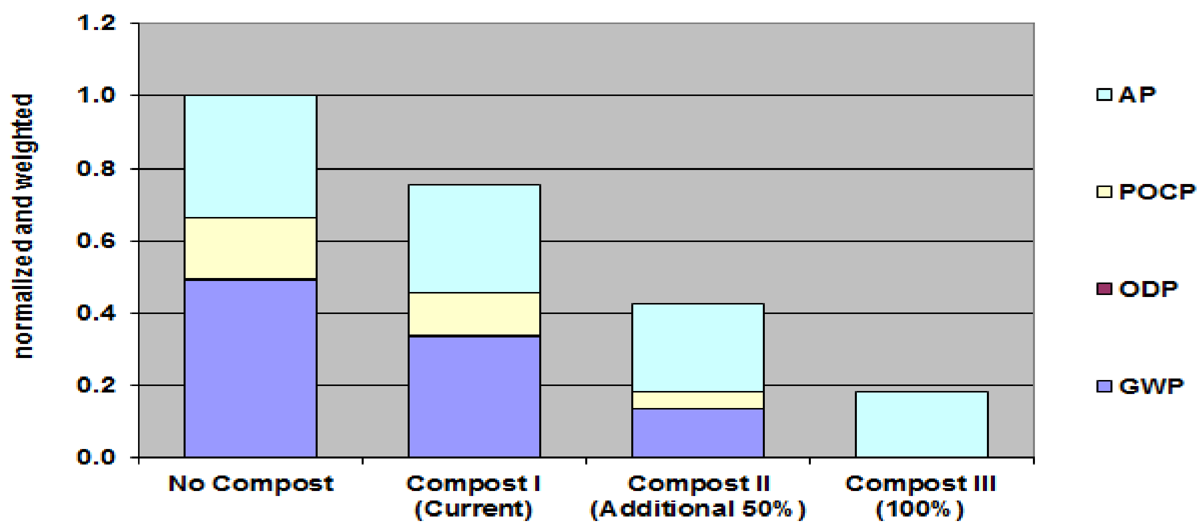

Figure 14. Overall Air Emissions

8.1.4. Water emissions:

This environmental category has a minimal affect on the overall results. Figure 15 displays that water emissions are dominated by landfill construction. This is attributed to the fuel usage and materials used in construction of a landfill. Agriculture and LEED Landscaping are minor contributors due to the fertilizer values of the compost. The day to day operations contribute to the water emissions, however the landfill construction overwhelms any other parameter. Reducing the amount of MSW that goes to a landfill can drastically reduce the water emissions as seen in Compost II and Compost III alternatives.

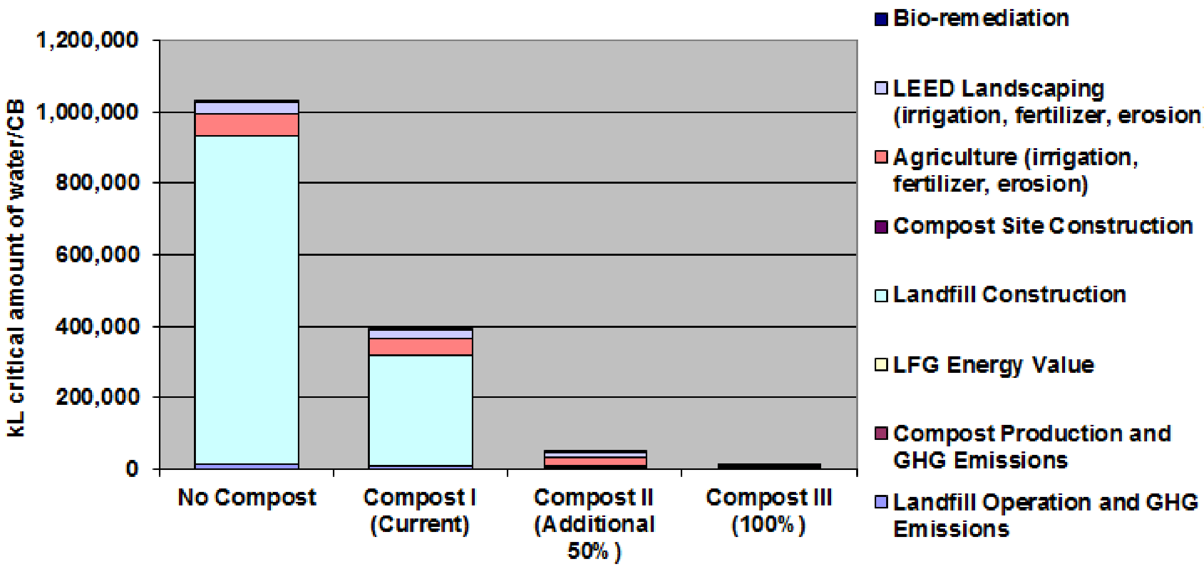

Figure 15. Water emissions

8.1.5 Solid waste generation:

Solid waste emissions have minor influence on the overall result. Solid wastes generated in landfill operations, compost production and landfill constructions are the dominating factors. The agriculture benefit due to the fertilizer value of compost and the electricity produced from LFG, have approximately the same impact based on the alternatives. This is due to the organic waste being used to generate LFG or being used as compost. Figure 16 displays the solid waste emissions for the four alternatives.

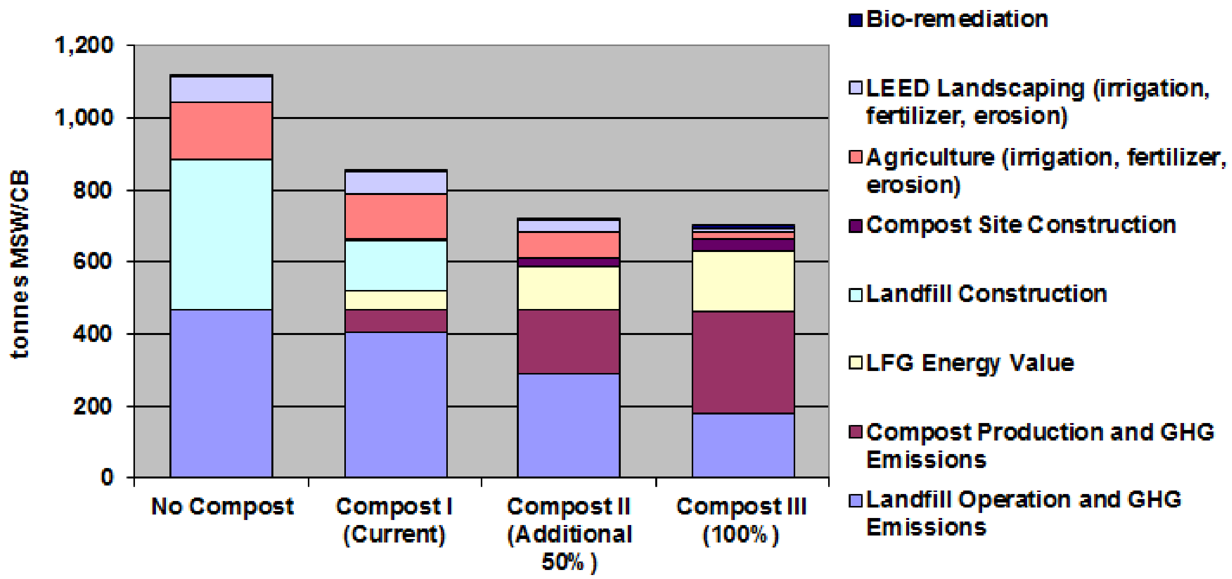

Figure 16. Solid waste generation

8.1.6 Land use:

As displayed in Figure 17, land use is assessed for each alternative. The land assessment is based on the hemeroby concept. This concept is a European approach and is a measurement of the total effects of human activities on the past and current land use. Different kinds of area use are weighted differently according to how much the use differs from "untouched land". The BASF process evaluates land use as pasture, fallow, bio-agriculture, conventional agriculture, sealed land, roads, tracks, and canals. The end result shows that agriculture and bio-remediation uses are the greatest value of the compost. The use of the compost in bio-remediation allows unusable land to be used as land and to support vegetation. The agricultural advantages is topsoil erosion and fertilizers use. As seen in the graph, the increase in organic MSW going to compost process leads to more land being used for compost production. Also shown in the graph is the value of compost used in bio-remediation projects.

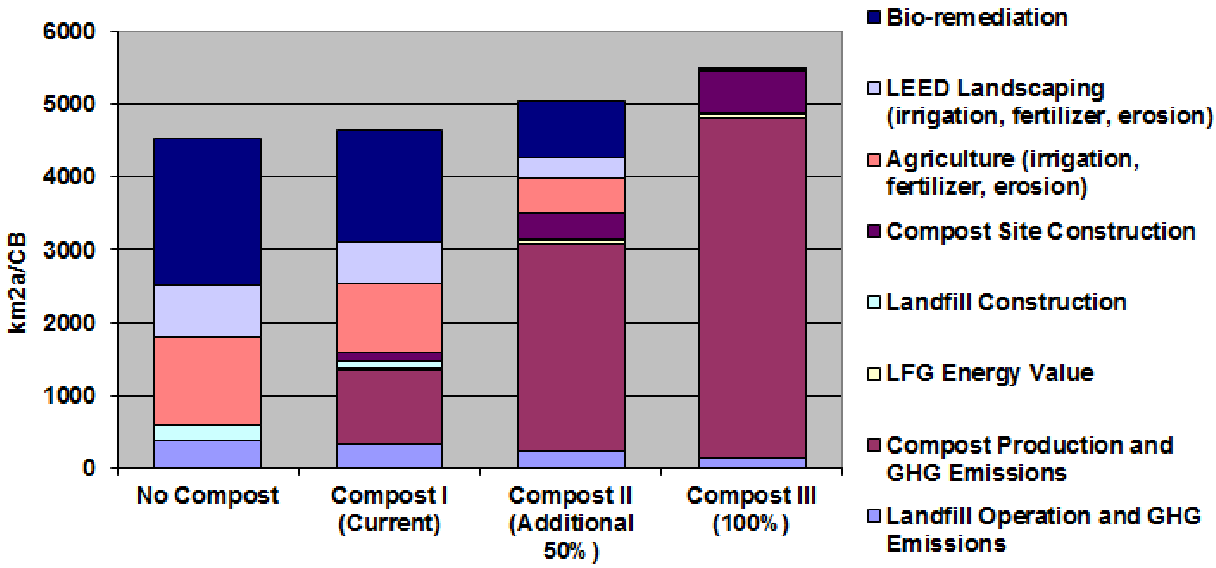

Figure 17. Land use – standard assessment

8.1.7 Toxicity potential:

The toxicity potential for use of compost is shown in Figure 18 for each of the modules. The major impacts are the compost value in reducing application of fertilizers in agriculture and LEED Landscaping. The value of the compost is clearly shown in the bio-remediation value since the compost can be used to reduce the toxicity of hazardous soil and can be also used as a soil cap. Ecotoxicity was not evaluated for the use phase since the study was looking at the value of the compost and not application of fertilizers or chemicals on the soil.

The use of nanoparticles were not evaluated in the chemical inputs for any of the alternatives, therefore the toxicity of nanoparticles was not evaluated in the study results.

Figure 19, shows the human toxicity potential at the life cycle phases for both the Production and Use phase for each alternative. The values have been normalized and weighted. Human toxicity potential is decreased since it is strongly influenced by the amount of fertilizers used. As seen by the chart, all the alternatives have the same toxicity potential in the Production phase. While in the Use phase, the toxicity potential decreases when more compost is generated based on reduction of fertilizers needed for the agriculture, LEED landscaping and bio-remediation applications.

Consistent with the methodology's approach for assessing the human health impact 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 R-phrase and pre-chain toxicity potential scores[12] were provided to NSF International as part of the EEA model which was submitted as part of this verification.

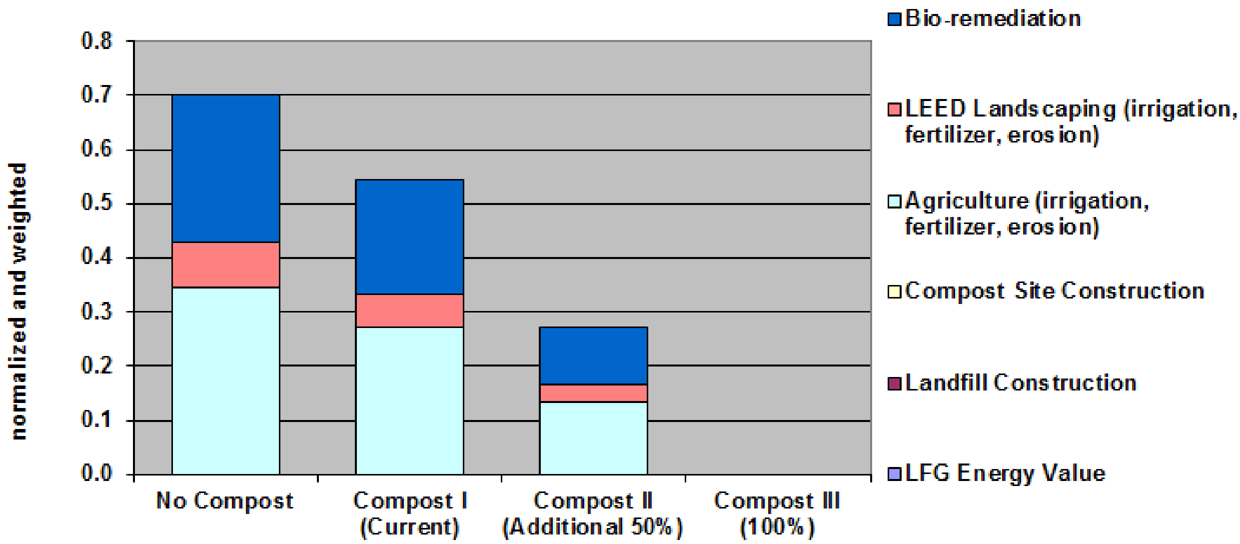

Figure 18. Toxicity potential by Module

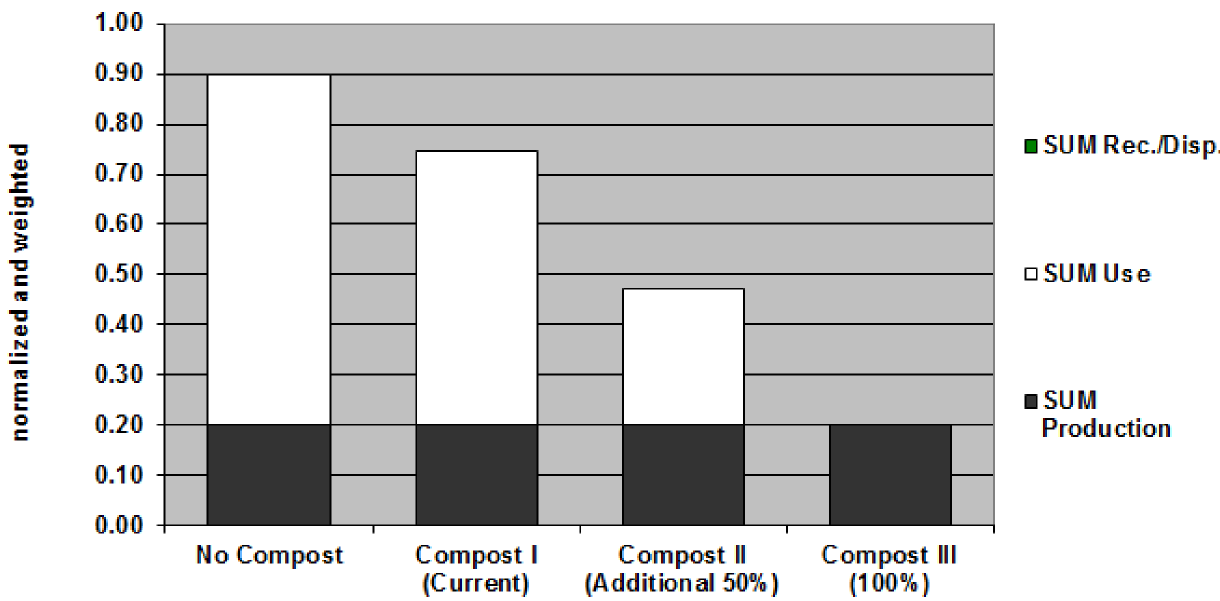

Figure 19. Toxicity by life-cycle process

8.1.8 Risk potential (Occupational Diseases and Accidents potential):

All the materials and activities accounted 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 and 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.

In Figure 20, the greatest Occupational Diseases and Working Accidents potential occurs in the landfill construction and in the value of compost in agriculture, mainly from the production of fertilizers. Working accidents are also associated to landfill construction since this takes a tremendous amount of moving of materials and soil. Figure 21 shows the distribution between Occupational diseases and Working accidents in this study. As can been seen in both figures, the Occupational Diseases are mainly being driven by the construction of a landfill.

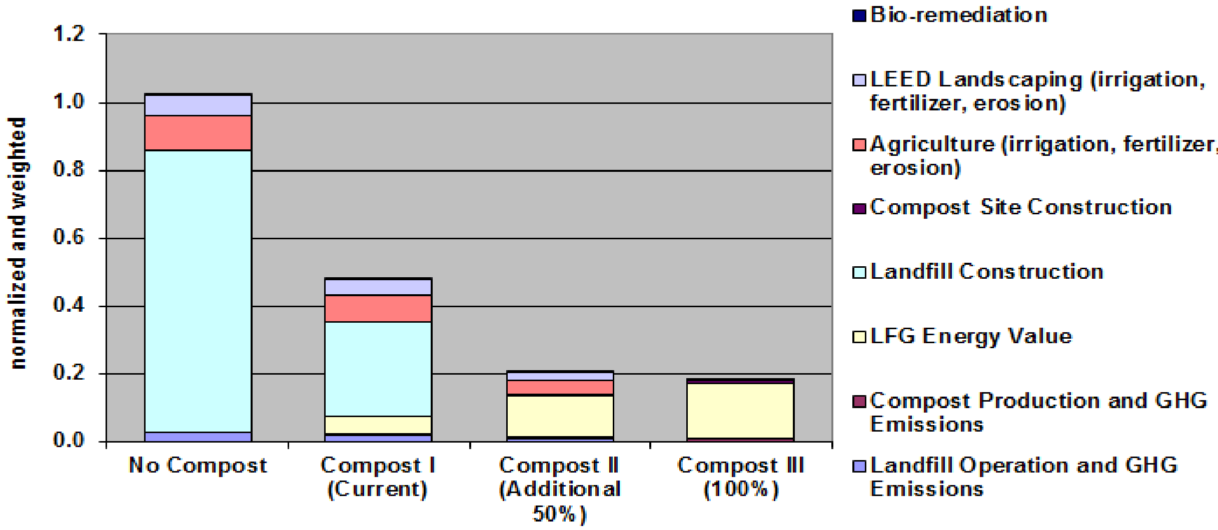

Figure 20. Occupational Illnesses and Accidents by modules

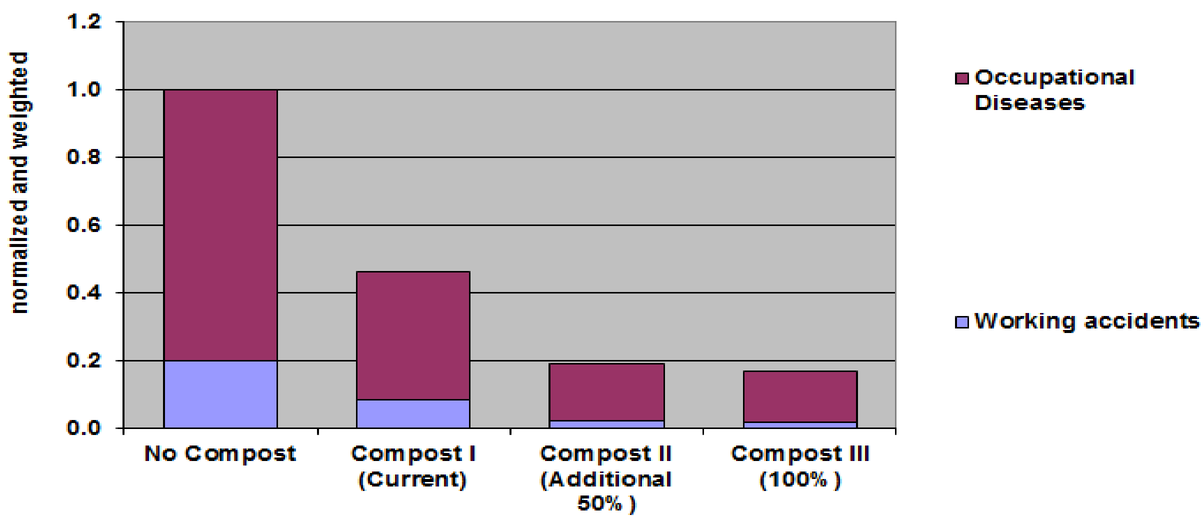

Figure 21. Overall Occupational Diseases and Working Accidents

8.1.9 Environmental Fingerprint:

Following different environmental impact categories in a normalized style and normalized and weighted with regards to emissions. The relative impact for all six of the environmental categories each alternative is shown in the Environmental Fingerprint, see Figure 22. A value of 1 represents the alternative with the highest impact in the concerning category, all other alternatives are rated in relation to 1.

As seen in the Environmental Fingerprint, the No Compost alternative has the greatest environmental impact in five categories, since this is established as 1 in the graph. The Compost III alternative has the greatest impact in the Land use and this is due to more compost sites being needed for the additional amount of waste being diverted to compost production. The Land use indicator has the least environmental impact on the total study at only 6% for the calculation factor, see Figures 29 and 30 in Section 10.1. Also, the Land use difference between the alternatives is very small with a difference of 18% amongst the alternatives as compared to the other indicators that have a difference of up to 87% amongst the alternatives in the other environmental categories.

As more organic waste is used for compost instead of going to the landfill, the environmental advantages of compost can be noticed in the following categories:

- Energy Consumption
- Emissions
- Resource Consumption
- Occupational diseases and working accidents

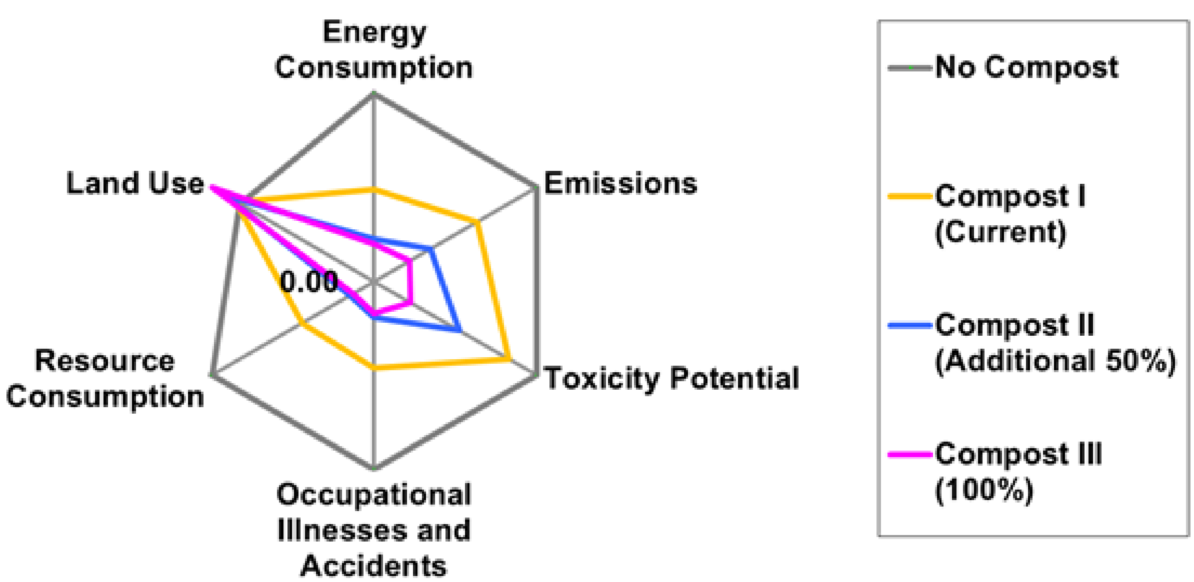

Figure 22. Environmental Fingerprint

8.2 Economic Cost Results:

The life cycle cost data for Compost Value 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 found that the landfill operations, compost operations and landfill construction costs are the driving factors in diverting organic waste to compost. The cost of the value of compost is not as great as the savings in production and in extending the life of a landfill. Figure 23 represents the graph of the costs for each of the alternatives based on the individual components.

The cost analysis is based on data from from 2009 to early 2010. Although this cost data may vary throughout the year, the input data is the same for all alternatives, but the amount will vary based amount of organic waste going to landfill and being used for compost.

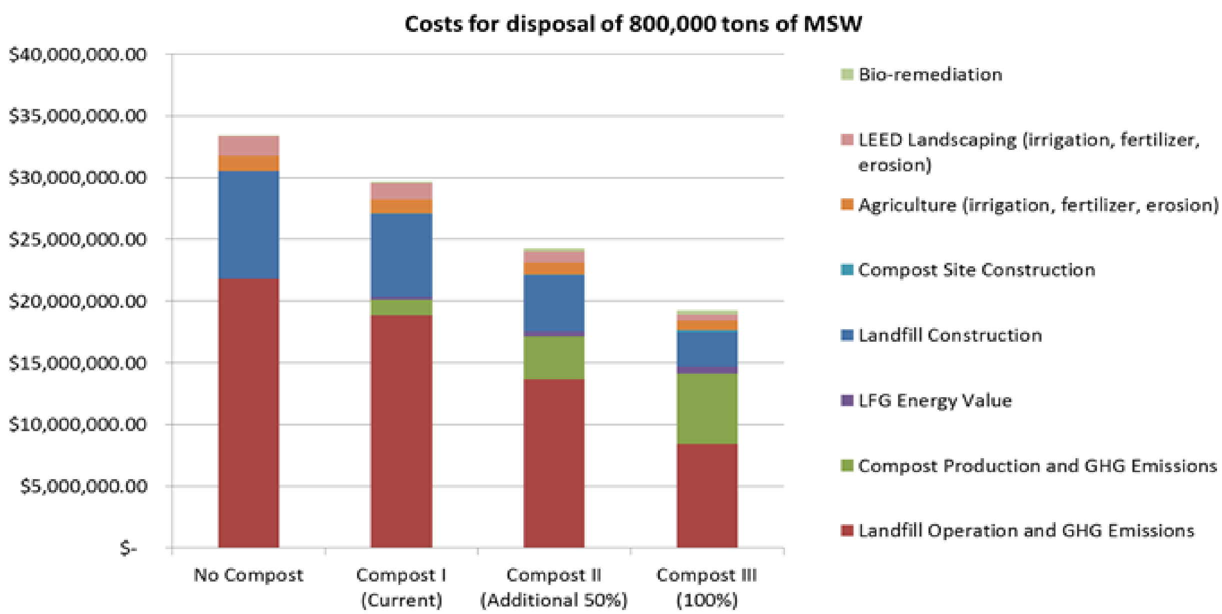

Figure 23. Life cycle costs modules

8.3 *Eco-Efficiency Analysis Portfolio*:

The Eco-Efficiency analysis portfolio for the Compost Value 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 a 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. The environmental relevance values utilized were last reviewed in 2007 and the social weighting factors were recently updated in 2009 by an external, qualified 3rd party.

Figure 24 displays the Base Case (BC) Eco-Efficiency portfolio, which shows the results when all six individual environmental categories are combined into a single relative environmental impact and combined with the life cycle cost impact. Because environmental impact and cost are equally important, the most eco-efficient alterative is the one with the largest perpendicular distance above the diagonal line and the results from this study find that Compost III (100% Organic Diversion) is the most eco-efficient alternative due to its combination of lower environmental burden and having the lowest life cycle cost.

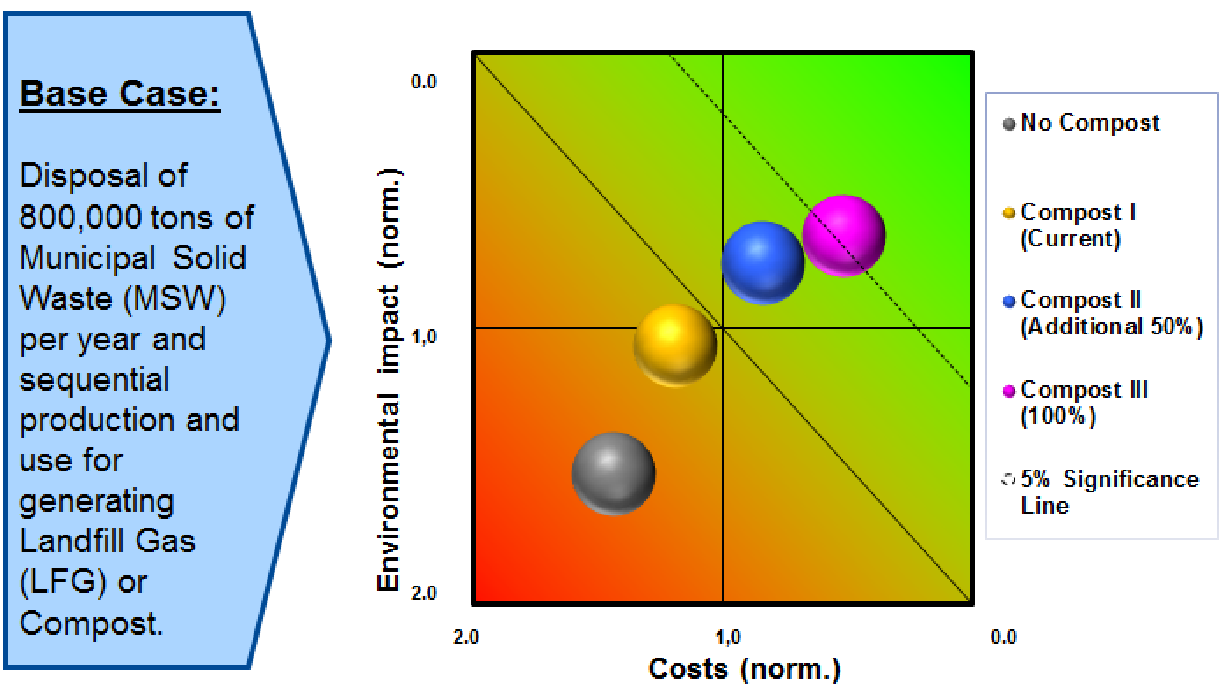

Figure 24. Eco-Efficiency Portfolio Base Case – Compost Value

8.4 Scenario Analysis:

8.4.1. Scenario #1: 100% of all landfill sites capturing LFG for electricity generation

In this scenario analysis, if 100% of all landfills had Landfill Gas (LFG) recovery, this would be slightly better for eco-efficiency than what is being done currently with organic waste being composted. However, if just 50% more of the organic waste is used for compost, then this is more eco-efficient than trying to capture the LFG from all landfills. The problem with LFG is that about 50% of the LFG is CO_2 and limited by the value to generate electricity. Also, the other 50% is methane which is considered a Greenhouse Gas and contributes to GWP. Figure 25 shows the Eco-Efficiency Portfolio results of Scenario #1 and Figure 26 shows the Environmental Fingerprint of Scenario #1.

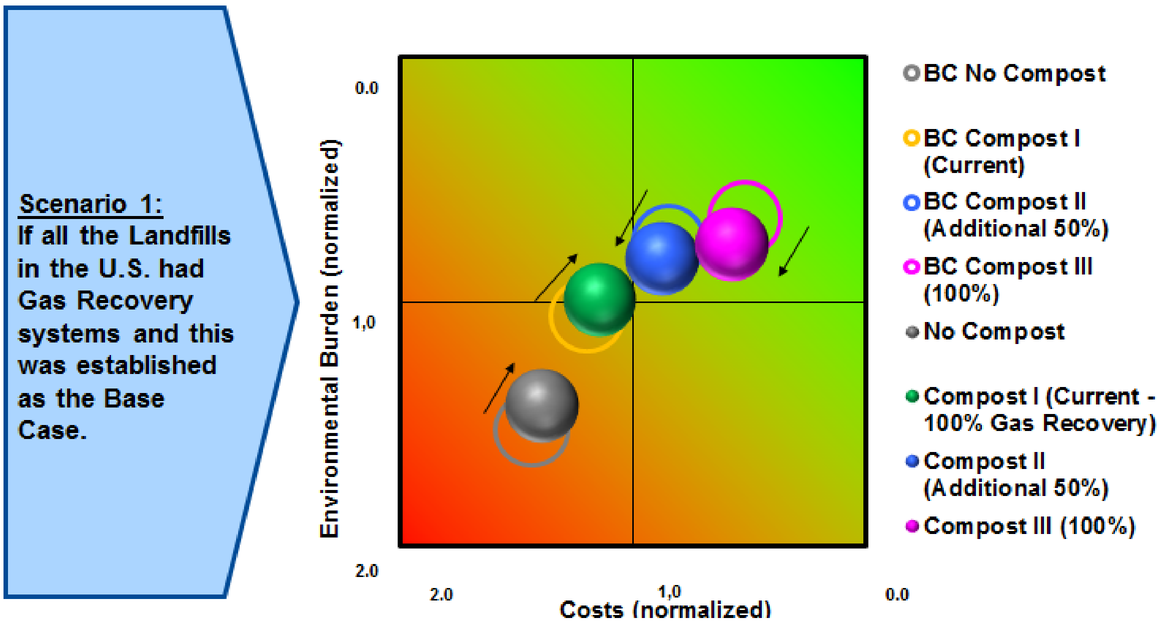

Figure 25. Scenario #1: 100% of all landfill sites capturing LFG

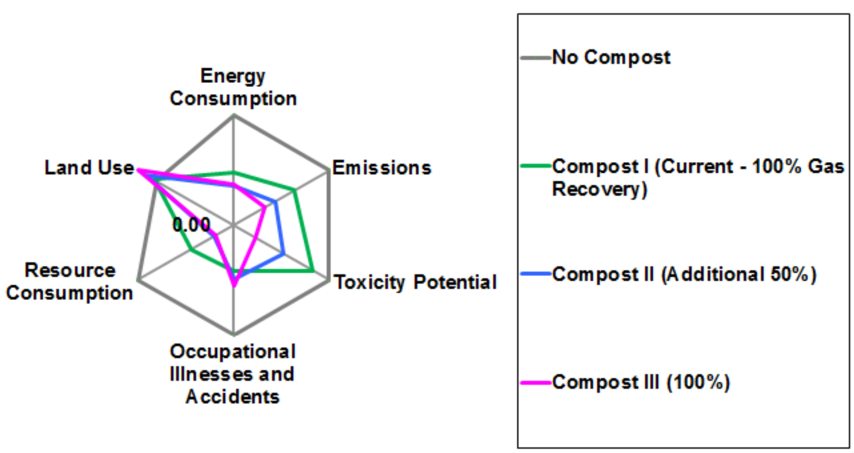

Figure 26. Environmental Fingerprint of Scenario #1

8.4.2. Scenario #2: 25% Decrease in MSW generation and disposal

For this scenario analysis, decreasing the amount of waste generated would benefit the landfill, since this would help to extend the life of the landfill. However, decreasing the amount of MSW generated and composting all the organic waste would still be a much more eco-efficient alternative than to capture the LFG from organic waste in a landfill. In this scenario the alternatives with more compost have less environmental advantages due to the fact that less organic waste is available and less value is generated in these alternatives. Figure 27 shows the Eco-Efficiency Portfolio results of Scenario #2 and Figure 28 shows the Environmental Fingerprint of Scenario #2.

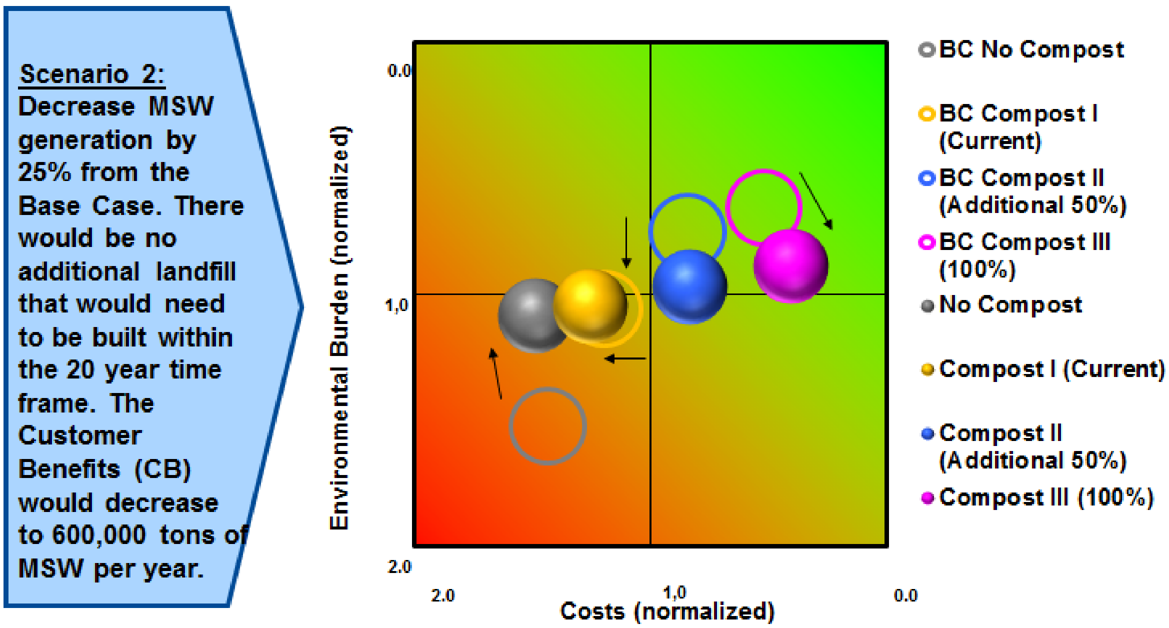

Figure 27. Scenario #2: 25% Decrease in MSW generation and disposal

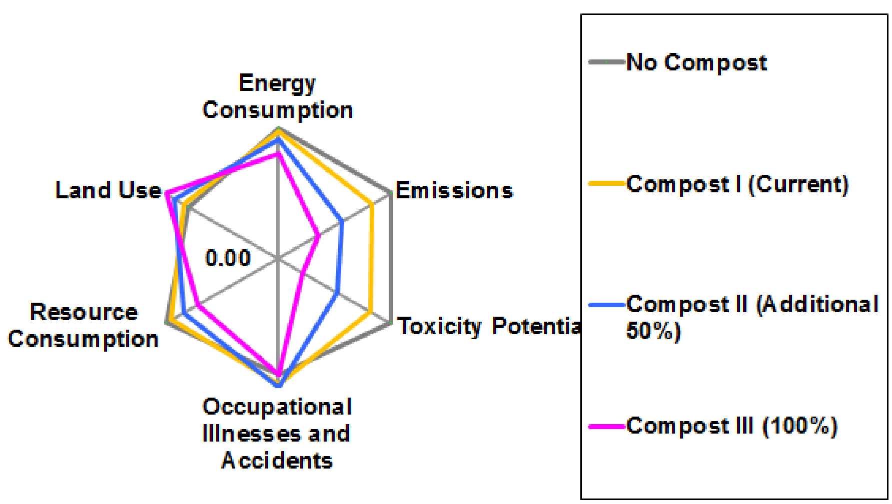

Figure 28. Environmental Fingerprint of Scenario #2

8.4.3. Scenario #3: LFG generation at peak production for 30 years at current landfill sites with colletion capabilities.

For this scenario analysis, if the current landfills collected Landfill Gas (LFG) at peak amount for 30 years, this would show the eco-efficiency of all the alternatives. Composting is still better in this analysis, but there is not as large of an advantage. In this analysis, the compost value is only seen for 1 year and additional benefits of the compost are not evaluated. The assumption of all LFG being collected and that it would produce at peak for 30 years is not realistic but shows ultimate value of the LFG. Figure 29 shows the Eco-Efficiency Portfolio results of Scenario #3 and Figure 30 shows the Environmental Fingerprint of Scenario #3.

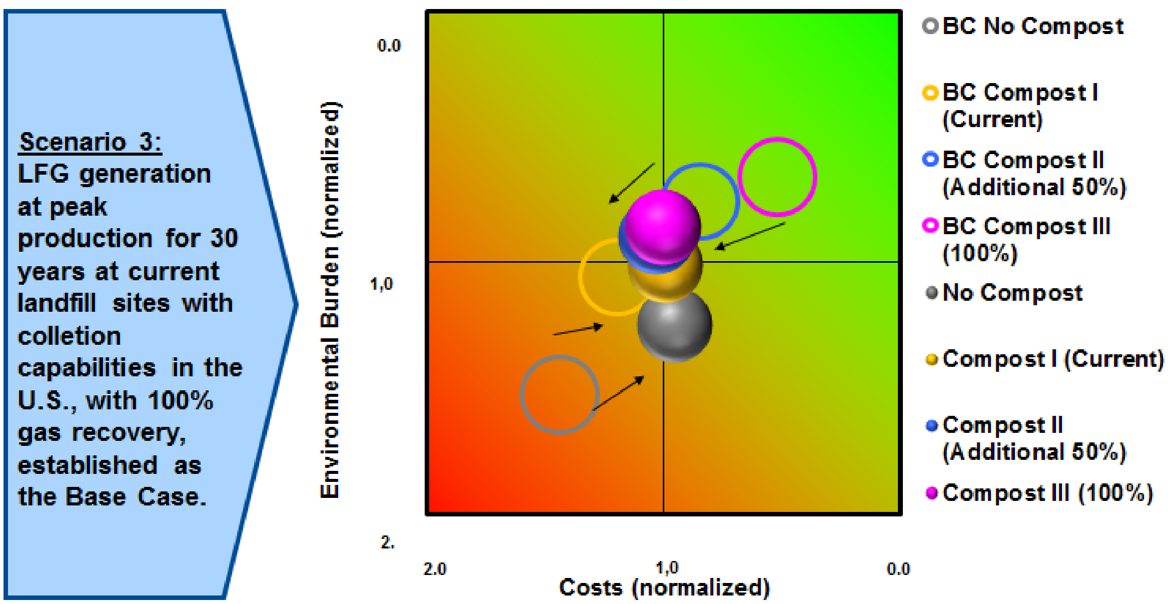

Figure 29. Scenario #3: 25% Decrease in MSW generation and disposal

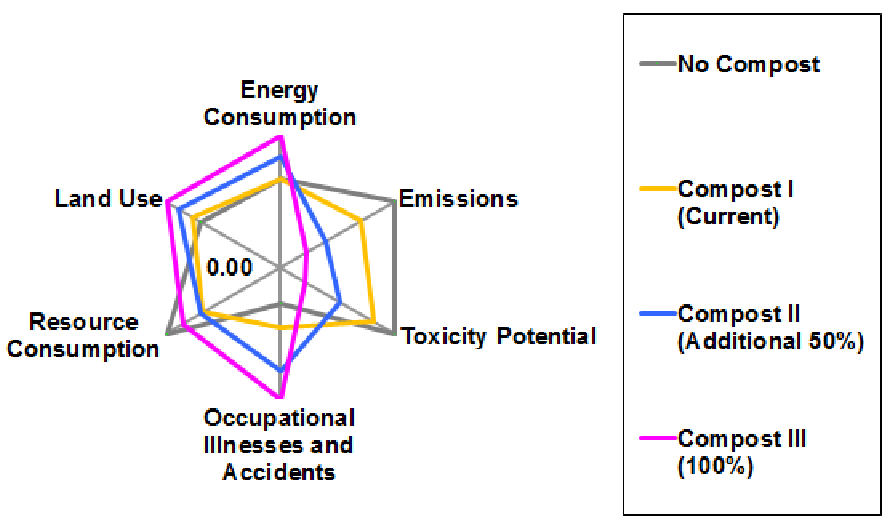

Figure 30. Environmental Fingerprint of Scenario #3

8.4.4. Scenario #4: LFG generation at peak production for 30 years at 100% landfill sites with 100% collection.

This scenario analysis is smiliar to the Scenario #3 analysis but takes into consideration that all landfills in the U.S. have capability of collecting LFG at peak amount for 30 years. In this analysis, LFG generation is better than composting and the value of the alternatives is opposite of the Base Case. Figure 31 shows the Eco-Efficiency Portfolio results of Scenario #4 and Figure 32 shows the Environmental Fingerprint of Scenario #4.

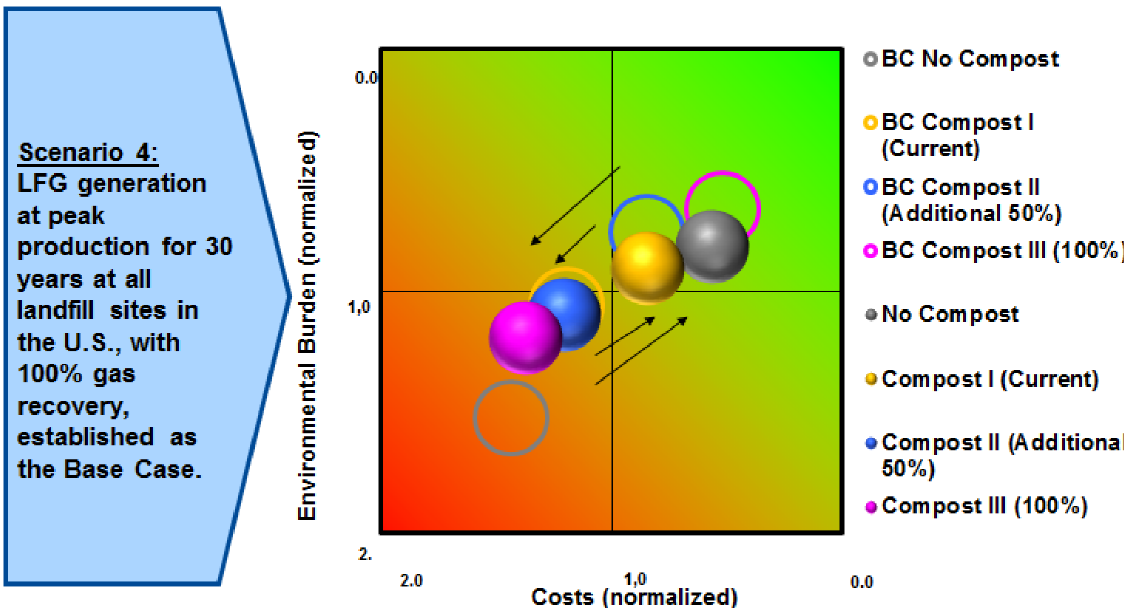

Figure 31. Scenario #4: 25% Decrease in MSW generation and disposal

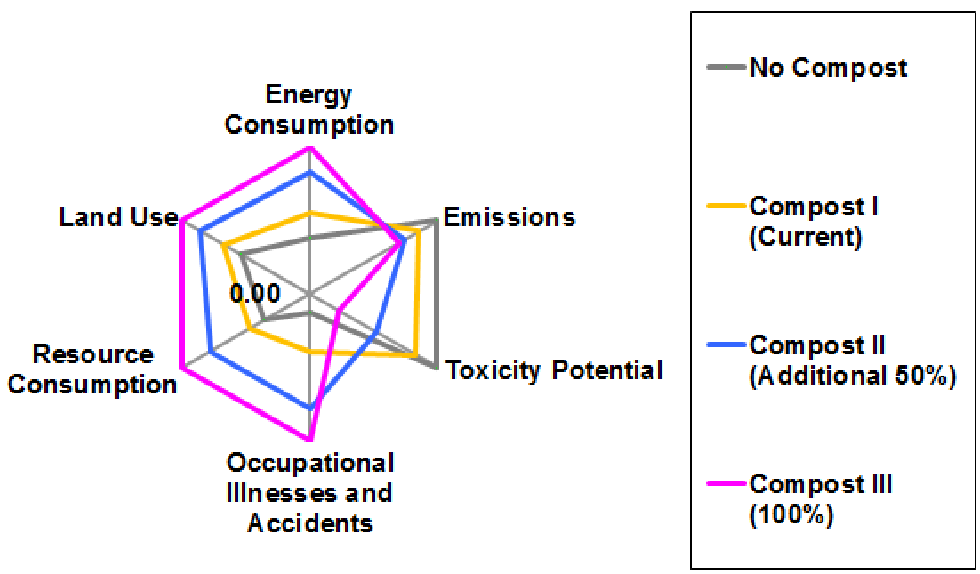

Figure 32. Environmental Fingerprint of Scenario #4

9. Data Quality Assessment

9.1. Data Quality Statement:

The data used for parameterization of the EEA was sufficient with most parameters of moderate to high data quality. Moderate data is where industry average values or assumptions pre-dominate the value. No critical uncertainties were identified within the parameters and assumptions that could have a significant effect on the results and conclusions. The data is from compost assessments throughout the world. There are a few sources with data before 2007, see Appendix A for data sources and years. Table 11 provides a summary of the data quality for the EEA.

Table 11: Data quality evaluation for EEA parameters

Parameter	Quality Statement	Comments
Life Cycle Inventories	Mod.-High	Boustead V. 5.0.12 Public Internet data Published presentation
Compositional Data	High	U.S. EPA University studies
Data for Alternative	High	U.S. EPA
Production and Application impacts	Moderate	University studies
Life Cycle Costing	Mod.-High	Published data Industry rates Public rates
Toxicity Potential	Mod.-High	Toxipo data files
Risk Data	Moderate	NACE Codes

10. Sensitivity and Uncertainty Analysis

10.1. Sensitivity and Uncertainty Considerations:

A sensitivity analysis of the final results indicates that the economic impacts were more influential or relevant in determining the final relative eco-efficiency positions of the alternatives. This conclusion is supported by reviewing the GDP Relevance factor calculated for the study. The GDP 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 GDP Relevance indicated that the economic impacts were significantly more influential in impacting the results than the environmental impacts (reference the "Evaluation" worksheet in the Excel model for the GDP Relevance calculation).

As the data quality related to these main contributors were of high to moderate high quality and scenario variations were run related to them (see Section 8.4), this strengthened our confidence in the final conclusions indicated by the study. A closer look at the analysis (see Figure 33) indicates that the impact with the highest environmental relevance was resource consumption, followed by energy consumption and toxicity potential. This is to be expected, as the study dealt with the production being the disposal of MSW and materials needed in building and daily operations of a landfill. Although emissions was a very small part of the overall environmental impact, air emissions were the most important in the emissions category. More specifically, AP and GWP are considered the two most important air emissions. The calculation factors (Figure 34), which considers both the social weighting factors and the environmental relevance factors, indicates which environmental impact categories were having the largest affect on the final outcome. Calculation factors are utilized in converting the environmental fingerprint results (Figure 22) into the final, single environmental score as reflected in our portfolio (Figure 24). The impacts with the highest calculation factors were similar to the environmental relevance factors, with regards to the six main impact categories.

The calculation factors were slightly higher for land use and emissions than in the relevance factor, while resources decreased in the calculation factor compared to relevance factor. 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 considered for this study did influence some minor reprioritization of the impact categories represented in the emissions and air emissions sub-categories.

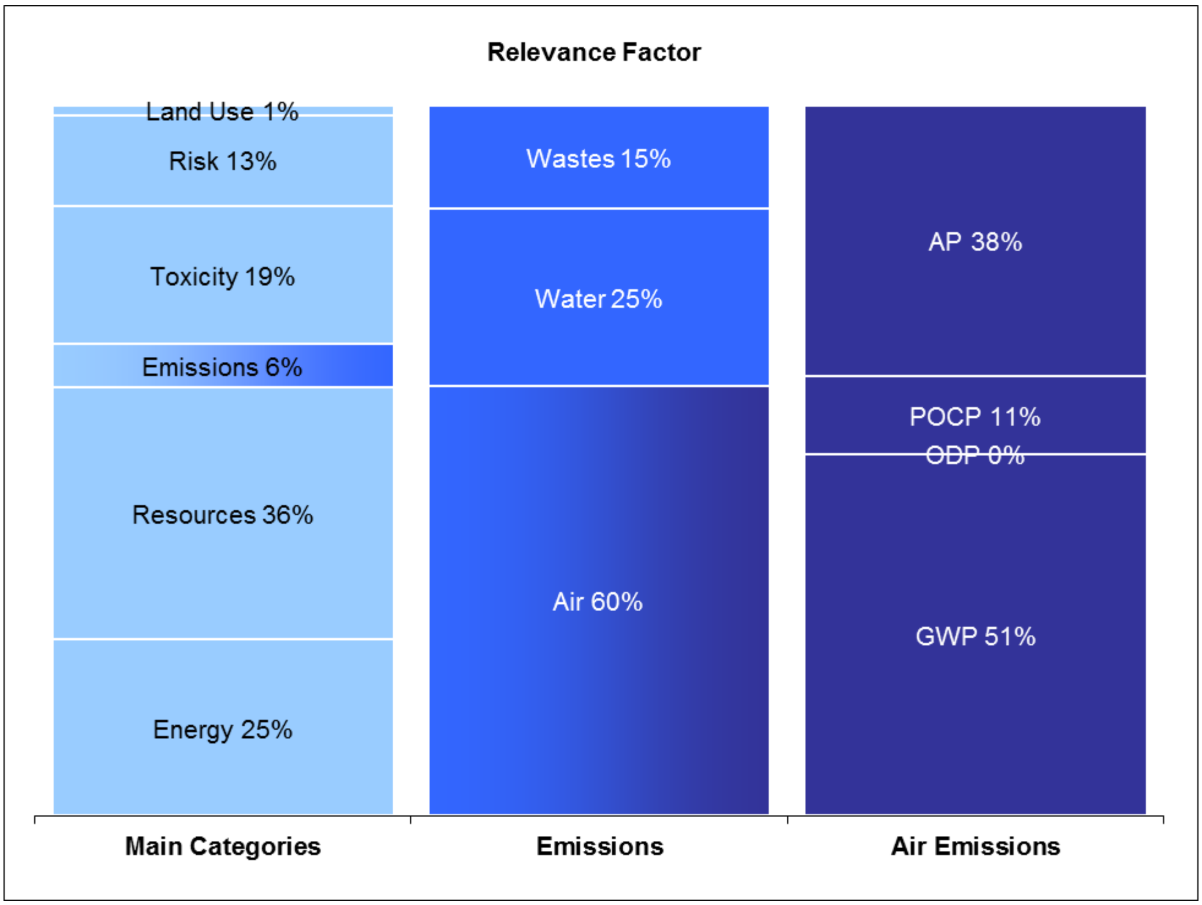

Figure 33. Environmental Relevance factors that are used in the sensitivity and uncertainty analysis

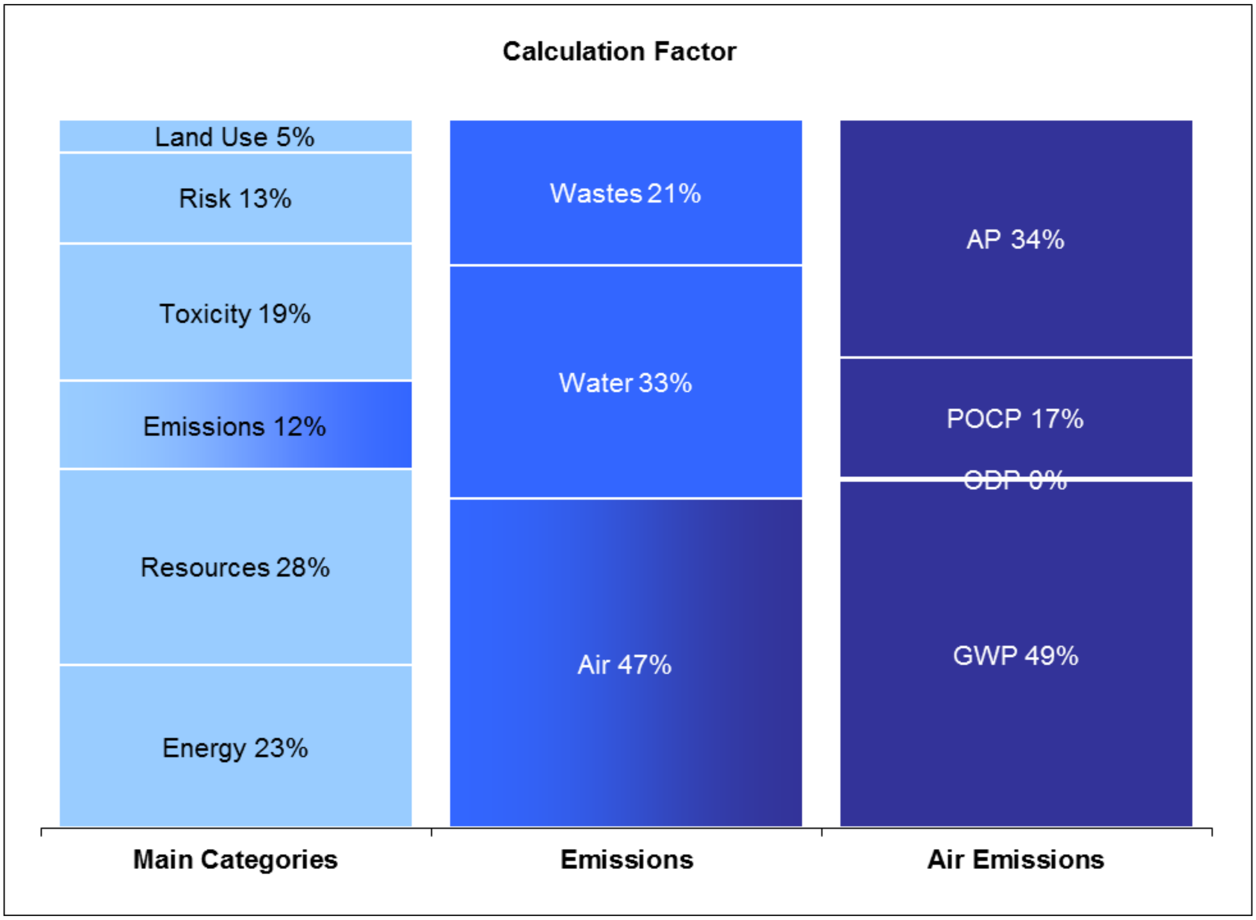

Figure 34. Calculation factors that are used in the sensitivity and uncertainty analysis

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:

These Eco-Efficiency analysis results and its conclusions are based on the specific comparison of the production, for the described customer benefit, alternatives and system boundaries. 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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Appendix A:

Data Sources used for input data:

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