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Consumer Product Life Cycle Assessment
Aveeno® Daily Moisturizing Lotion

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Consumer Product Life Cycle Assessment

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Executive Summary

This paper researches an attributional life-cycle assessment (ALCA) of a commonly used consumer product, specifically one bottle of 8-ounce Aveeno Daily Moisturizing Lotion. This LCA analyzed the impacts associated from cradle-to-grave processes of one bottle of Aveeno Daily Moisturizing lotion, including raw material extraction, raw material processing, manufacturing, packaging, distribution, use and end-of-life of both the lotion itself as well as the bottle. To successfully propose end-of-life management techniques, three different disposal options were analyzed: landfill disposal, incineration and recycling. All processes included in the system boundary were compared across three main midpoint impact categories: Fossil depletion, Freshwater depletion and Global Warming Potential. Results showed that transportation of the product outweighed all other processes in regard to the three impact categories. When all processes but transportation were considered, results showed that raw material extraction and processing was the significant contributor to the three impact categories. This LCA therefore proposes that Aveeno take advantage of local products to limit the need for excessive transportation. Furthermore, sustainable forms of transportation could be used to offset the product's overall environmental impacts. In regard to end-of-life disposal options, Aveeno could market recycling techniques to push forth the reuse of their plastic bottle. Considering costs, glass bottle use could also be considered to possibly implement a send-back and reuse option for consumers.

Introduction

An attributional life cycle assessment (ALCA) was performed of a 8 ounce Aveeno Daily Moisturizing Lotion. This lotion is one of the leading daily skin care products in the United States, with 2013 sales of $41.8 million, and 2010 unit sales of 2,200,920 ("Chain Drug Review," n.d.). The intent of this LCA is to provide relevant information to consumers, and manufacturers of skin care products. The results will inform consumers about the impact of disposal on the environment. The manufacturers of these products will have a better understanding of where the largest impacts associated with the manufacturing process of the lotion come from and what the best disposal option may be for the product container after its use by the consumer. Potentially, the product maker could alter or make the processes efficient used to manufacture the product and its container, or take steps to encourage more responsible disposal methods of the container. The results of the life cycle inventory are presented below, with special attention paid to the manufacture of the lotion and its container, made of HDPE plastic.

Methodology

The methodology used to create an LCA for one Aveeno Daily Moisturizing Lotion bottle incorporated traditional methods of data collection using well-known LCA databases such as EcoInvent, EIO/LCA, and EPA's WARM model. EcoInvent was invaluable and furthermore was the primary data source used for this LCA. The system boundary used for this LCA included all stages, from extraction of the raw materials needed to the end-of-life processes when discarding the bottle. Figure 1 below displays the system boundary used:

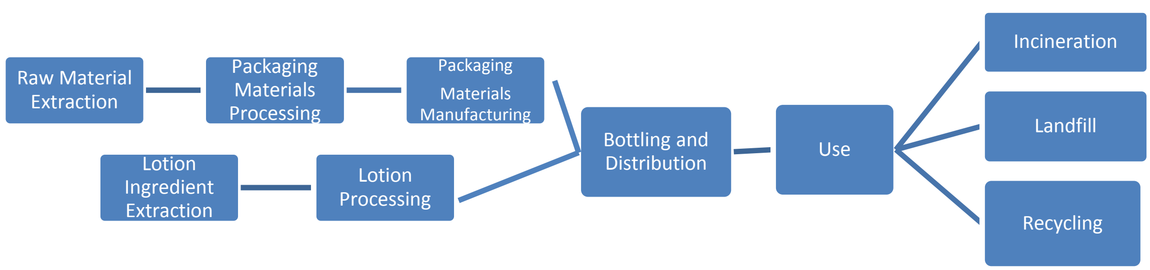

Figure 1: LCA System Boundary

The primary data obtained were the ingredients included in the lotion as well as their associated weights. Data for this was found through multiple phone calls to Johnson & Johnson, the makers of Aveeno Lotion, and through searches of the U.S. Patent Office's database. Further research into the U.S. Patent Office's database yielded a patent for nearly identical product to the Aveeno lotion analyzed. Furthermore, this patent also used Aveeno's formulation as their control. The patent listed the ingredients by percentage of weight, enabling the calculation of results to be done. Table 1 below shows the data of the different ingredients in the Aveeno lotion and their associated percentage:

Table 1: Aveeno Daily Moisturizing Lotion Major Ingredients and Quantitative Percentages

Ingredients	Percentage
Water	66.5%
Glycerine	18%
Dimethicone/Active Ingredient	1.3%
Petrolactum	0.6%
Isopropyl Palmitate	3.09%
Cetyl Alcohol	3%
Benzl Alcohol	0.5%
Colloidal Oatmeal	2%
Sodium Chloride	0.01%
Distearyldimonium Chloride	5%

In order to find data on the packaging alone, the 18-ounce Aveeno Daily Moisturizing Lotion bottle was separated into its various parts and individually weighed. Based off of labling on the bottle itself and assumptions made from various other data in regard to lotion packaging bottles, all plastic parts were assumedly made of high-density polyethylene plastic (HDPE). Table 2 below displays the weight of each lotion bottle packaging material in both ounces and kilograms.

Table 2: Aveeno Daily Moisturizing Lotion Parts and Associated Weights

Object	Weight (Ounces)	Weight (kg)
Bottle with Lotion	18	0.510291
Lotion	16.1	0.4564273
Whole Bottle	1.9	0.0538641
Top	0.40	0.0113398
Tube	0	0
Spout	0.30	0.00850486

Once all processes and their associated ingredients were determined, various sources (as mentioned above) were used to analyze these processes and produce results. Table 3 below displays each process analyzed in this LCA, the specific process chosen, and the source used to find that specific process.

Table 3: LCA Process Source Information

Processes	Processes used	Source
Raw Material Processing		
Glycerine production	Glycerine, from palm oil, at esterification plant, MY (kg)	EcoInvent
Palm Oil production	Palm kernel oil, at oil mill, MY (kg)	EcoInvent
Oatmeal production	Wheat IP, at feed mill	EIOLCA/EcoInvent
Benzyl alcohol production	Benzyl Alcohol, at plant RER	EcoInvent
Sodium Chloride production	Sodium Chloride, brine solution, at plant RER	EcoInvent
Cetyl alcohol production	Ethyoxylated Alcohol (AE3), palm kernel oil, at plant RER	EcoInvent
Petrolactum production	Chemicals organic, at plant, GLO (kg)	EcoInvent
Isopropyl Palmitate Production	Chemicals organic, at plant, GLO (kg)	EcoInvent
Distearyldimonium Chloride	Chemicals inorganic, at plant, GLO (kg)	EcoInvent
Dimethicone	Chemicals inorganic, at plant, GLO (kg)	EcoInvent
Manufacturing		
Water at manufacturing plant	Water, ultrapure, at plant/GLO with US electricity	EcoInvent/ LCI on Leave-on-skin products
Electricity at manufacturing plant	Electricity, production mix US,US,[kWh]	EcoInvent
Packaging		
HDPE Production	HDPE production	GREET Model
HDPE Bottle manufacturing	Injection molding RER, [KG]	EcoInvent
End-of-Life		
HDPE recycling	HDPE recycling	WARM
HDPE Combustion/incineration	HDPE Combustion/incineration	WARM
HDPE Landfilled	HDPE Landfilled	WARM

Process Descriptions

Raw material processing consisted of multiple steps. In regard to Glycerin production, vegetable glycerin is extracted from raw fats and oils, usually palm or coconut oil. The oils are split into crude fats under the combined action of water, temperature and pressure. Temperatures often exceed 400 degrees Fahrenheit and the oils are kept under pressure for 20 to 30 minutes. The water absorbs glycerol from the fatty acid phase of the oils. Then the glycerol is isolated, distilled and creates a standard 99 percent pure glycerin product (Hall, n.d.). Palm oil production (palm oil kernel) this oil is made from the kernel of the fruit, not the pulp. The industrial scale cultivation of palm requires large amounts of land and has led to widespread deforestation. Kernels are cleaned, crushed, "steam conditioned" to achieve uniformity of moisture, rupture cell walls, etc. The kernels are then pressed and filtered to extract the oil (Food and Agriculture Organization, n.d.). In regard to oatmeal production, oat is harvested with large combines using a "direct heading" method as soon as the crop is ripe. Oats are then ground and separated through mechanical means. The fourth process, benzyl alcohol, is synthesized by heating a mixture of benzyl chloride, sodium carbonate and water (Ostman, n.d.). Sodium Chloride is

produced from the electrolysis of brine. Cetyl alcohol is now manufactured through the reduction of ethyl palmitate (the waxy ester of palmitic acid) with metallic sodium and alcohol or under acidic conditions with lithium aluminum hydride as a catalyst (Encyclopedia Britannica, n.d.). Petrolactum iss a by-product of crude oil, and is produced during the oil refinery process.
Distearyldimonium Chloride is produced synthetically in a chemical plant. Dimethicone is a silicone-based substance, created from a series of complex chemical reactions (Hum, 2006).

Manufacturing consisted of two main processes: water at manufacturing plant and electricity at the manufacturing plant. Water at any manufacturing plant will be used in a huge variety of applications, from chemical processes to cooling, to assisting in mechanical processes and many others. Like water, electricity at a manufacturing plant will be applied to many things. For the product under study, electricity is notably used in catalyzing chemical reactions, in addition to its normal functions.

Packaging consisted of HDPE production and bottle manufacturing. HDPE is made by applying intense heat to petroleum to produce ethylene gas. These gas molecules then combine to form polymers and in turn produce polyethylene. This substance is finally forced through holes into long strings, which are ultimately cut and shaped to form granules. (Bottle2Bottle, n.d.) In regard to HDPE bottle production, the HDPE is heated to high temperatures and placed in two halves of a mold. Once cooled, compressed air is then blown into these molds to form the bottles. This final bottle is then cooled, shaped and tested for quality (Bottle2Bottle, n.d.).

Three end-of-life processes were focused on: HDPE recycling, HDPE incineration and HDPE landfilling. Also known as plastic #2, HDPE plastic is recycled traditionally: by cleaning, shredding and grinding. The plastic is then sold to the secondary scrap market or incorporated into new products on site (Perennial Park Products, 2014). In regard to HDPE incineration, typical "moving grate" solid waste disposal incinerators usually reduce the volume of waste by 80-85%, not including the by-product of ash, or recyclable metals recovered after incineration. This percentage can vary depending on the method of incineration. Waste is transported to the landfill for final disposal by truck. Waste is deposited in the working area of the landfill. Waste is covered in dirt, and a heavy clay and/or rubber liner prevents leachate from reaching the groundwater. Piping is usually included to deal with leachate. Decomposition of HDPE can take decades or longer.

Transportation of our product was assumedly handled by trucking in the United States. Furthermore, use of Google Scholar, and other sources such as LCI's known through outside work enabled data gaps to be addressed. This included electricity use during the manufacturing process. Aggregate data figured prominently in our data collection, as information on specific plants in the United States was lacking.

Results

Raw material sourcing and processing was the largest portion of energy requirements. Most of the energy required was used before the final mixing and production of the lotion. Palm oil production and Glycerine production from palm oil source was responsible for the majority of the impacts in the raw material processing stage, which is justified because the palm oil goes through a lot of processing stages starting from harvesting, sterilization, and processing of palm oil bunches. However, allocation of energy, emissions and water use weren't considered for the different co-products coming out of the oil mill (e.g. palm oil, palm kernel oil and palm oil meal). Please note that there were many data points for Glycerine production from different countries, and raw materials (e.g. Rape seed, soybean and vegetable oil) and the processes can vary in terms of efficiency.

When the transportation was added to the life cycle inventory of our results, all other impacts became very small. However, the transportation data used is comprised of an entire LCI for transportation. This includes construction of road infrastructure and maintenance as well as impacts from actual trucking. Also the transportation inventory was not normalized to the functional unit of the study; it was rather normalized to one truck traveling one way. More specific data must be gathered for this process to provide more inclusive results.

Impact Assessment

The LCI data from the EcoInvent was then characterized into three midpoint categories: Global Warming Potential (GWP), Freshwater Depletion and Fossil Depletion. For each of these three midpoint categories, hot spots were then identified. Each midpoint category and its associated hotspots are shown in Table 3 below:

Table 4: Midpoint Categories and Associated Hotspots

Midpoint Category	Associated Hotspots
Global Warming Potential (GWP)	• Raw Material Processing: CO_2 emissions from palm oil production and Glycerine production • Transportation: CO_2 emissions from trucks • Packaging: CO_2 emissions from Bottle production • End-of-Life: CO_2 emissions from Incineration
Freshwater Depletion	• Raw Material Processing: Water use from Glycerine production • Transportation: Embedded water during transportation (Maintenance and construction) • Packaging: Water use for HDPE Bottle manufacturing
Fossil Depletion	• Raw Material Processing: Energy use in Palm oil production and Glycerine production • Transportation: Oil for trucks • Packaging: Natural gas and oil for manufacturing of plastics

Cradle-To-Use

Figure 2 below displays the CO_2 emissions, water use and process energy emissions processing:

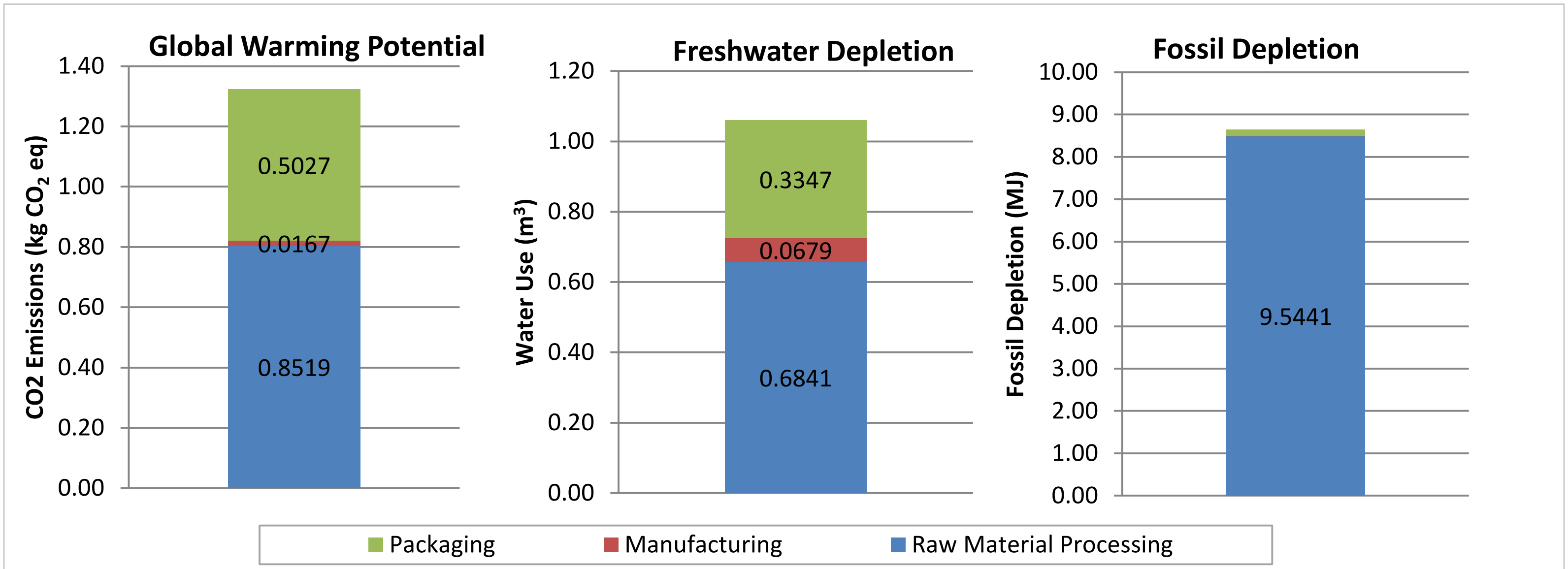

Figure 2: Process CO2 Emissions, Process Water Use, and Process Energy Emissions Graph

Figure 3 below represents a scenario built to display potential impacts from selected indicators. "Raw materials to Manufacturing Facility," shown in blue, represents transport distance from South Dakota to New Jersey. "Manufacturing Facility to Retail Store," shown in red, represents transport distance from New Jersey to Phoenix, Arizona.

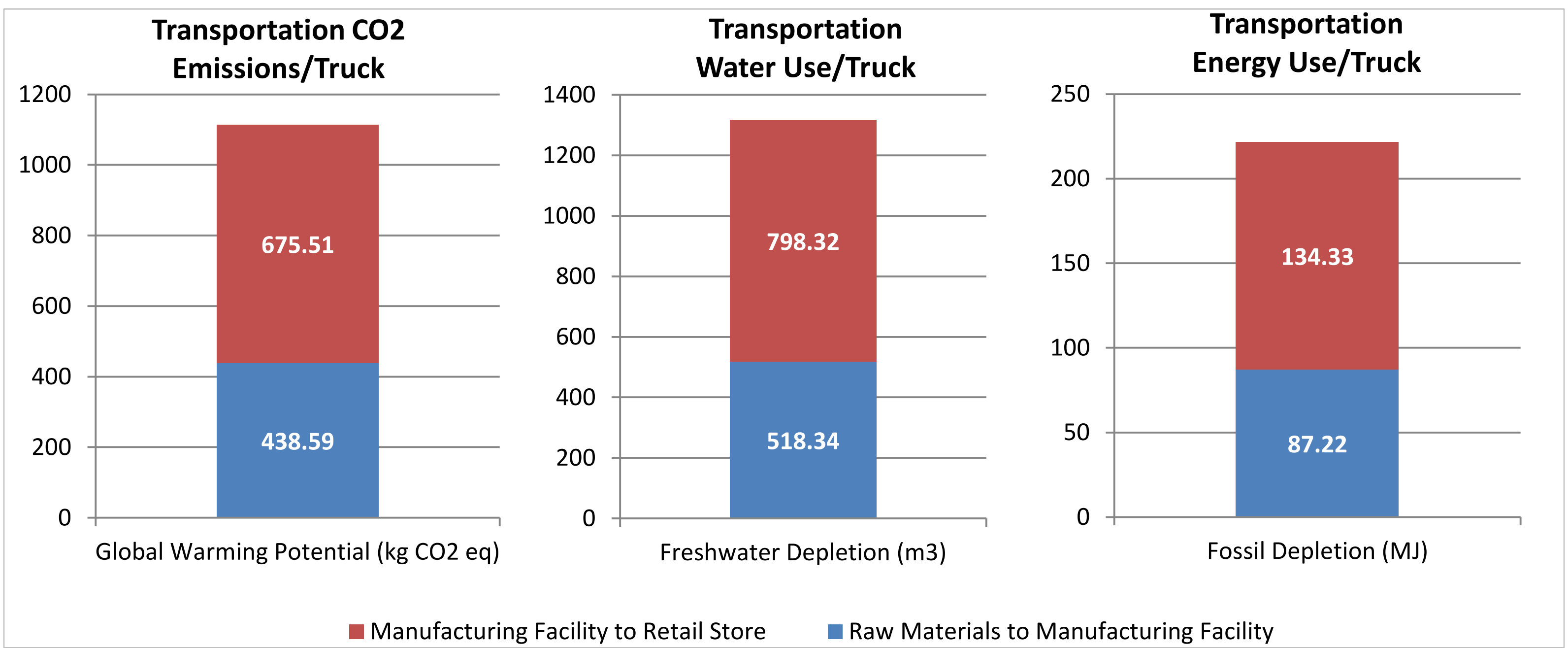

Figure 3: Transportation and Associated Trucking Impacts

End-Of-Life

Figure 4 below displays four different end-of-life options and their associated carbon dioxide emissions:

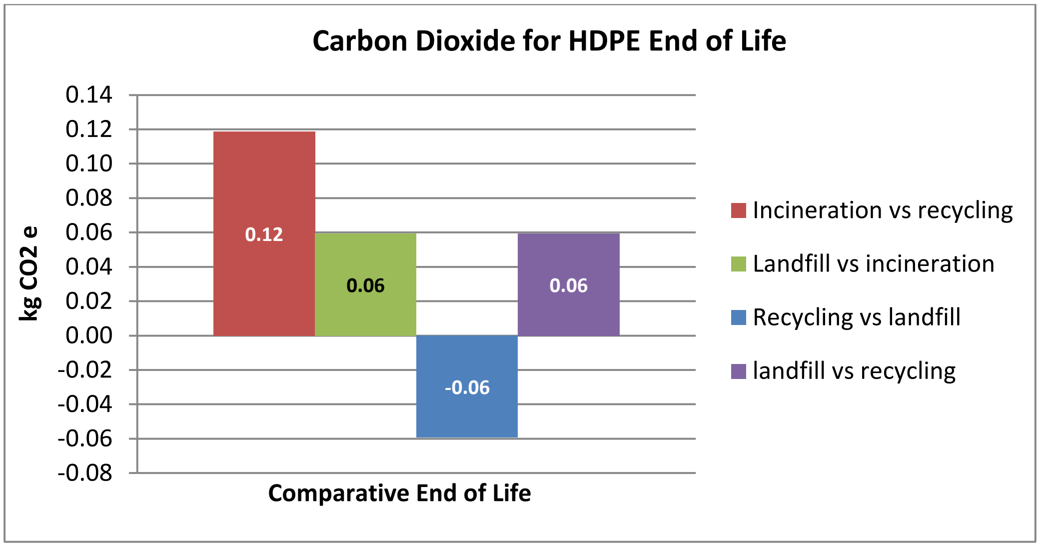

Figure 4: End-of-Life Process- CO_2 Emissions

Figure 5 below displays the same four end-of-life options shown in Figure 3 and their associated energy usage in MegaJoules.

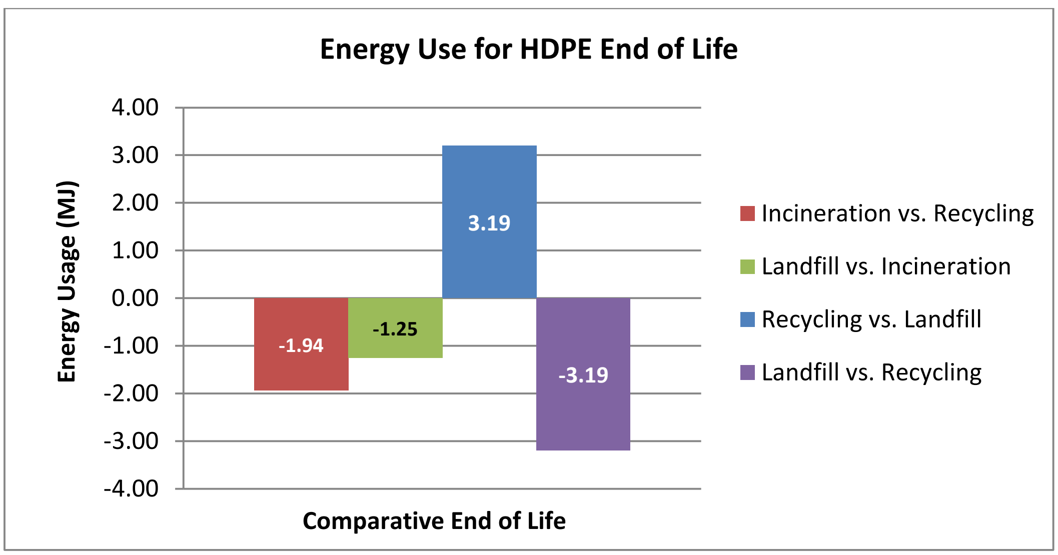

Figure 5: End-of-Life Process- Energy Use

EcoInvent does not have specific water usage values for HDPE or any other plastic, so water usage values were therefore estimated using an average value from EIO-LCA. Using their estimated 990 kilogallons per $10,000,000 spent, 0.0035m^3 of water were calculated as being used during the waste management process of one bottle of Aveeno Daily Moisturizing hand lotion. This calculation is shown in the *Appendix* as well.

Discussion

Figure 2 shown above in the *Results* section displays the data for three main processes (raw material processing, packaging and manufacturing) among the three main midpoint categories analyzed: Global Warming Potential (GWP), Freshwater Depletion and Fossil Depletion. When looking at all three graphs at once, it can be seen that the raw material processing process, shown in blue, dominates the three individual graphs. In regard to GWP, Freshwater Depletion and Fossil Depletion, the raw material processing process makes up 62%, 62.95%, and 98.38% of the total, respectively. Packaging is the second-highest contributor to each of the three midpoint categories, while manufacturing processes result in being very insignificant.

Figure 3 shown above in the *Results* section was not normalized to the functional unit of the LCA study, one bottle of Aveeno lotion, because it was difficult to allocate energy requirements, carbon emissions, and water use to the single unit. A scenario analysis was performed, in which the function of transportation and the distances were assumed. In regard to "Raw material production," the functional unit was assumedly trucking from the Midwest to New Jersey, and in regard to "Manufacturing Facility to Retail," the functional unit was assumedly trucking from New Jersey to Phoenix, Arizona. The midpoint categories, Global Warming Potential (GWP), freshwater depletion and fossil depletion, were large in comparison to the other life cycle stages because the LCI chosen from EcoInvent for transportation includes construction and maintenance of the roads along with the trucking impacts.

As shown in Figure 4 regarding carbon dioxide emissions for HDPE end-of-life, different process options for the end-of-life of the lotion bottle were compared. This graph shows that recycling would be the best option, since it has a negative impact value compared to all the other processes. A negative impact value is possible to to the recycling process associated with the bottle. If the plastic bottle is recycled, it can be used to create a new product versus being placed in a landfill. This avoids the emissions released when developing a new product from raw materials.

Figure 5 shown above in the *Results* section displays four different options for HDPE end-of-life and their associated energy use values. In regard to energy use, landfilling would be the best option due to its significantly low energy use value (-3.1949 MJ). Recycling has the highest rate of energy use due to the energy demand of the facilities and equipment needed to sort the materials. In comparison to landfilling or incinerating an item, which both have relatively low energy use rates, it makes sense that a recycling facility would require greater energy. The amount of water used as an indicator is difficult to quantify with the current data that exists for end-of-life processes. The calculation comes from the amount of money spent for a specific amount of water at a waste management facility to be scaled down to one bottle.

Uncertainty and Quality Assessment

Uncertainty was continually seen throughout this life cycle assessment, as it was largely unavoidable. Limitations on certainty were mainly due to the fact that specific data for this product's manufacturing process is considered "proprietary information," and is therefore difficult to find. Therefore, aggregate data on processes observed in Europe and Asia was used.

Other challenges were unique to the sourcing decisions made by Aveeno. During conversations with representatives of Aveeno, it became known that the origin of the ingredients in the product varied depending on factors such as the growing season, convenience of availability, and the prevailing market price at the time of purchase. It was therefore determined that using data that described cultivation, harvesting, and manufacturing of ingredients could be taken from a variety of overseas sources without critically compromising the relevance and accuracy of the data.

Other uncertainties were due to simple data gaps. For example, no data was found on the cultivation of oats used in the manufacturing process of colloidal oatmeal. As a substitute, wheat was used, since the harvesting method is virtually identical to that of oat. A series of assumptions were made in an attempt to collect the necessary data (as dictated by the system boundary) while still preserving an acceptable level of quality.

Additional challenges were presented in the collection and calculation of transportation data. As of this writing, transportation results were not normalized to the functional unit due to difficulty allocating energy requirements, carbon emissions, and water use to a single bottle of lotion. An informal scenario analysis was performed, in which transportation distances and mode were assumed. Trucking was assumed to be from the Midwest to New Jersey, and from New Jersey to Phoenix, AZ. The production of oats was also used as the placeholder for other raw materials. More data on the other raw materials and their transportation loads is still missing. As mentioned, transportation data also included processes and impacts outside the scope of the study, and more specific data is needed, as well as a careful examination of cutoff and allocation options.

Because the location of the manufacturing facilities was unknown, average data for transportation loads was used and calculated using the WARM database for the three end-of-life options, and by determining typical distances that ingredients would travel. (Oats are typically harvested in the upper Midwest, and leading states for the production of oats include Iowa, Minnesota, and South Dakota. Average impacts for trucking from South Dakota to New Jersey were used, where the lotion is blended and prepared for sale). Also worthy of mention are the potential ecotoxicity concerns with the lotion itself, and its entry into the wastewater stream. Little is currently known about these impacts, and they are worthy of deeper study. The final LCA report will feature a more formalized quality assessment and uncertainty review to supplement this preliminary review.

Despite the large number of average data sources and necessary assumptions, the results in this life cycle assessment confidently represent the processes and impacts of an average lotion sold in the United States, at least. The results can in fact represent most such lotions, as insight gained through examination of patents indicates that most of these products are extremely similar in their basic ingredient makeup, and their proportions.

Pedigree Matrix

The five pedigree matrices below were made due the significance of their related processes in this LCA. Below is a pedigree matrix made for the overall LCA:

Table 5: Pedigree Matrix- Overall LCA

Indicator Score	1	2	3	4	5
Reliability of Source			The data found was for specific processes, but processes specific to our product weren't found		
Completeness				Some of the data was out of date, and some of it used substitute processes. The data was representative, but was only found from a handful of sources. The majority of the data was obtained from only one source, usually found on EcoInvent.	
Temporal Differences					Some of the data was recent, but much of it, on palm oil for example, was from a study undertaken from 1999 to 2003. Large portions of our data suffered this set back.
Geographical Differences			Most data was from Europe or Asia, using similar processes and subject to global market forces. Values are assumed to be similar to material production domestically, as globalized markets encourage uniformity in sourcing.		
Further Technological differences		Processes described in the LCA match those studied. However, data was from different enterprises and areas. Technology processes were normalized to the system studied as best they could be, though processes are very similar regardless. The impact loads were mostly accounted for using LCA methodology.			

The score for this pedigree matrix is 17. Overall, the data is reliable and relevant, as it mostly comes from EcoInvent, as well as other established databases that describe similar or identical processes. However, there were serious issues with the age of the data, and the lack of multiple sources for the various processes. Completeness and age were the two biggest weaknesses in the data.

Below is a pedigree matrix that was made solely for the end-of-life process associated with this LCA:

Table 6: Pedigree Matrix- End-of-Life Scenario

Indicator Score	1	2	3	4	5
Reliability of Source			Data based on measurements, but was average and does not specify specific sites or disposal method for the type of material under study (HDPE plastic)		
Completeness					The data is not specific enough, and was from only one source. It is largely unknown if the data is representative of end of life impacts.
Temporal Differences	The WARM and EIO data was current.				
Geographic Differences		Although the data was average, the processes examined were domestic, albeit from a larger area. The area under study was included, and the same currency was used in calculations.			
Further technological differences.					Data was averaged, and not for the specific process under study. Technology used for end of life HDPE disposal was largely unknown, and assumed to be average.

The score for this end-of-life pedigree matrix is 16. Because of the nature of the WARM tool, data is representative and aggregated on a national scale.

Table 7: Pedigree Matrix- Transportation

Indicator Score	1	2	3	4	5
Reliability of Source	The data was gathered scientifically from verified sources on EcoInvent.				
Completeness			Data was representative and complete for the impacts of the operation of trucks, but was taken from Europe.		
Temporal Differences				The data is nine years old, and represents average "lorry" operation for 2005	
Geographic Differences				Data was from Europe, which has similar cost conditions, but uses a different currency.	
Further Technological Differences				The data was relevant to the system under study, but it is unknown if engines in Europe are comparable to those in the U.S. Additionally, it is unknown if trucks in Europe undertake "long-haul" routes as the often do in the U.S.	

This transportation pedigree matrix had an overall score of 16. Overall, the data for this process was old, averaged, and from a different continent than the one under study.

Table 8: Pedigree Matrix- Glycerine Production

Indicator Score	1	2	3	4	5
Reliability of Source	The data was gathered scientifically from verified sources on EcoInvent.				
Completeness	The data is complete. It was taken from plants in Malaysia and globally, and the study period was adequate				
Temporal Differences					The study period was from 1996 to 2003. The data is old.
Geographical Differences		The study focused on Malaysia. However, palm oil is global market, and the location of the processing facility has little effect on the market price. The system under study is included by default in this global market.			
Other Technological Differences		The data is representative of this process, but did not include the specific system under study.			

The score for this pedigree matrix is 11. This was the strongest data source, with the only glaring weakness being the age of the data used.

Table 9: Pedigree Matrix- HDPE Production

Indicator Score	1	2	3	4	5
Reliability of Source	The data was gathered scientifically from verified sources on EcoInvent.				
Completeness	The data is provided by the plastics industry in Europe. 24 manufacturers contributed data. A few processes were not examined. For example, recyclable wastes produced, or dioxin released to the water. The data was gathered from an adequate number of sites in a relevant period of time.				
Temporal Differences					The data is almost fifteen years old. The study period was 1999-2000.
Geographic Differences				Data was from Europe, which has similar cost conditions, but uses a different currency.	
Other Technological Differences		Processing for the product under study wasn't found. Different enterprises used very similar processes for production of HDPE. Similar accounting systems were assumed as well.			

The score for this HDPE pedigree matrix is 13. Although the data was from a different continent, and there were issues with age, this data was deemed to be reliable and complete.

Conclusion

The purpose of this ALCA of Aveeno Daily Moisturizing Lotion is to inform manufacturers and consumers about the various impacts associated with one daily-use product and its packaging materials. The impacts identified include the amount of water used, energy used, and carbon dioxide emitted from the cradle-to-grave processes associated with both the bottle and its contents. Based on the results of this LCA, various suggestions can me made to the manufacturers of this product as well as the consumers in regard to their disposal behaviors of the product. The manufacturing process should be significant to the manufacturers since the greatest impacts come from the manufacturing process itself.

Based on the transportation aspects of this LCA, it is shown that impacts related to transportation are the highest when compared to all other processes. Therefore, solutions should be implemented to lower transportation rates and in turn, lower CO_2 emissions, overall costs and water use. More efficient truck routes could be considered to reduce overall miles traveled. Furthermore, different storage techniques within these trucks could be considered to move a greater product quantity at one time. End-of-life processing was significant to this LCA, as recycling versus both incineration and landfilling significantly lowered related CO_2 emissions. To push forth this idea to consumers, Aveeno could implement different, more progressive marketing campaigns. Different labeling strategies could be considered as well, such as providing clear messages on the bottle that it is recyclable, or making the recyclable symbol on the bottom of the bottle more apparent. These labels could be used to educate the users that the bottle can and should be recycled. Overall, it is hoped that environmental awareness as well as personal awareness of commonly used products such as lotion can come from this life cycle assessment.

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Appendix

I. Waste Management Water Usage Calculation

$$\frac{990\ kgal}{\$10{,}000{,}000} * \frac{\$9.74}{1\ bottle} * \frac{1000\ gal}{1\ kgal} * \frac{1\ m^3}{264.1729\ gal} = \mathbf{0.0035\ m^3\ water/bottle}$$

II. Pedigree Matrix Key

Table 3 – Pedigree matrix for managing cost data quality issues in eco-efficiency

Indicator score	1	2	3	4	5
Reliability of source	Verified data based on measurements	Verified data partly based on assumptions or non-verified data based on measurements	Non-verified data partly based on assumptions.	Qualified estimate (e.g. by industrial expert)	Non-qualified estimate or unknown origin
Completeness	Representative data from a sufficient sample of sites over an adequate period to even out normal fluctuations	Representative data from a smaller number of sites but for adequate periods	Representative data from an adequate number of sites but from shorter periods	Representative data but from a smaller number of sites and shorter periods or incomplete data from an adequate number of sites and periods	Representativeness unknown or incomplete data from a smaller number of sites and/or from shorter periods
Temporal differences	Less than 0.5 years of difference to year of study	Less than 2 years difference	Less than 4 years difference	Less than 8 years difference	Age of data unknown or more than 8 years of difference
Geographical differences	Data from area under study, **same currency**	Average data from larger area in which the area under study is included, **same currency**	Data from area with slightly **similar cost conditions, same currency, or with similar cost conditions, and similar currency**	Data from area **with slightly similar cost conditions, different currency**	Data from unknown area or area with very **different cost conditions**
Further technological differences	Data from enterprises, processes, and materials under study	Data from processes and materials under study from different enterprises, **similar accounting systems**	Data from processes and materials under study but from different technology, **and/or different accounting systems**	Data on related processes or materials but same technology	Data on related processes or materials but different technology