2021

LIFE CYCLE ASSESSMENT OF COMMON DRINK PACKAGING

PREPARED BY TRAYAK LLC

IBWA
INTERNATIONAL BOTTLED WATER ASSOCIATION

TRAYAK
SUSTAINABILITY STARTS HERE

Trayak is a sustainability consulting & software solutions company helping companies to mainstream their Product and Package sustainability initiatives. Trayak provides the following services to their customers.

EcoImpact Software Platform

A cloud hosted, secure, globally available software application platform for R&D, Engineering and Sustainability professionals to assess and report the environmental impacts of their Products & Packaging. Create company, division, brand or region wide sustainability insight and rollup reports. Following solutions are offered.

COMPASS℠ – COMPARATIVE PACKAGING ASSESSMENT

The leading streamlined life cycle assessment (LCA) solution for packaging. View detailed environmental impacts using commonly used indicators. Easily and quickly evaluate current packaging portfolio and create a baseline. Establish practical sustainability goals. Compare alternatives and incorporate environmental feedback into design decisions. Analyze primary, secondary and tertiary packaging components. Simulate environmental impact based on different EOL scenarios.

COMPASS® – COMPARATIVE PRODUCT ASSESSMENT

The leading streamlined life cycle assessment solution is also available for products. View detailed environmental impacts using consumption and emission metrics. Easily and quickly evaluate products and create a baseline. Establish practical sustainability goals. Compare alternative designs and incorporate environmental feedback into design decisions. Simulate environmental impact based on different EOL scenarios. Create individual product environmental baseline reports.

SCORE® – EcoScoring- Track CSR GOALS

Customizable eco-scoring. Choose from a library of metrics and attributes and adapt them to your organization and your sustainability goals. Create simple visualization for making tradeoffs and enabling decisions that align with business goals. Create internal simple numerical scores for easy communication with stakeholders.

Expert Services

Trayak offers a range of consulting services that help customers start or accelerate their package/product sustainability initiatives. Trayak offers workshops and sustainable design training. Trayak offers insights into best practices and sustainability goal setting. Trayak offers services to analyze individual products/packages using LCA and SCORE. Trayak also offers reporting services to calculate environmental rollup across a product/packaging portfolio. Trayak provides additional services to interpret and translate the results into consumer-oriented metrics.

TABLE OF CONTENTS

TABLE OF FIGURES AND TABLES

1. EXECUTIVE SUMMARY

In 2020 the International Bottled Water Association (IBWA) reached out to Trayak LLC to conduct a Life Cycle Assessment of various packaged water formats. The results would be used to update the IBWA's graphic and LCA report. The five formats analyzed within this engagement are industry average: Polyethylene terephthalate (PET) water bottle, PET soda bottle, aluminum can, beverage carton, and a glass bottle. A standard container size of 500 mL was used to establish a reliable functional unit for this comparison.

The IBWA's primary goal is to determine the most sustainable option for packaged water through a third-party verified LCA. These results use industry average data to objectively determine the best packaging formats for water.

After the data was collected for all of the formats, the life cycle impact was calculated using Trayak's Comparative Packaging Assessment (COMPASS) methodology. The packaging systems were analyzed according to seven different environmental impact categories, and a detailed breakdown is provided for fossil fuel usage, GHG emissions, and water usage.

Critical to this engagement was collecting data for all of the packaging formats and establishing a reliable standard structure and packaging system for each. Within the LCA, the materials and processes were able to be modeled with industry average data from ecoinvent 3.5. The end of life of the packaging used specific data for the United States representing the likelihood that each packaging type and material format will be recycled, landfilled, or incinerated based on the current infrastructure.

The LCA results of the comparison between the five industry average water containers shows the PET water bottle as the least environmentally impactful option, and therefore the preferred container for packaged water. It produces the lowest environmental impact across the seven indicators measured, including fossil fuel use, greenhouse gas (GHG) emissions, and water use. The beverage carton was the second least impactful package across many of the seven indicators. The glass bottle was the most environmentally impactful container within this LCA across six of the seven indicators calculated.

Overall, this LCA project provided IBWA members with quantitative data to determine the most sustainable container for packaged water. The LCA shows the preferred container to be the industry average PET 500 mL bottle.

1 PROJECT BACKGROUND

1.1 GOAL

This LCA is intended to determine the environmental impact of various beverage packaging systems to determine the most sustainable option for packaged water. The formats evaluated were PET water bottle, PET soda bottle, aluminum can, beverage carton, and a glass bottle.

1.2 SCOPE

The LCA of the industry average beverage containers was conducted using packaging system data collected by both an IBWA member and Trayak. In order to establish a reliable comparison, the IBWA member and Trayak collected data points from multiple brands for each format to create an industry average packaging system. To standardize varying compositions/structures depending on size of the container, a common size of 500 mL, or as close as possible, was used for all of the formats' primary package.

1.2.1 Functional Unit

The functional unit for an LCA designates the comparable unit that will be used throughout the study defining the quantity, quality, and duration of the product.

For this comparison, the functional unit was 500 mL of water. The water was assumed to be packaged effectively and meet typical commercial and regulatory standards for purity, taste, and quality.

All of the beverage containers are assumed to hold and protect the water with the same performance.

1.2.2 Boundary Conditions

This study is a cradle-to-grave assessment of industry average beverage containers. It includes impacts for raw material production and sourcing, manufacturing and refining, molding, and average end of life impact for the various components of the packaging systems.

The data used for each of the beverage packaging systems is detailed in Table 1 later in this report.

2 Data Collection of the Beverage Packaging Systems

In order to conduct the LCA, data needed to be collected for the various packaging systems. Each of the formats was considered as an entire packaging system: primary package, secondary package, and tertiary package. The primary package is defined as the saleable unit of the product. The secondary package is typically a case or a shipper used to bundle multiple primary packages. The tertiary package is a pallet and shrink wrap used to transport the cases to a retail store. For example, the PET water bottle, cap and label make up the primary package, the shrink film bundling multiple bottles is the secondary package, and the pallet and shrink wrap is the tertiary package.

The five formats analyzed through this LCA were a 500 mL PET water bottle, PET soda bottle, aluminum can, beverage carton, and a glass bottle.

2.1 PET Water Bottle

For the PET water bottle packaging system, Trayak and the IBWA member collected data from seven different brands. The average size of the bottle was 500 mL with an average case size of 24 bottles per pack with a nested configuration. The average cases per pallet was 84.

2.1.1 PET Water Bottle Primary Package

The average bottle was 8.30 grams made from PET using a blow molding process. The average cap was 0.77 grams made from HDPE with an injection molding process. The average label was 0.25 grams made from polypropylene with a film extrusion process. It was assumed there was an average post-consumer recycled (PCR) content of 3% for the PET.

2.1.2 PET Water Bottle Secondary Package

The average secondary packaging was 20.3 grams of plastic wrap made from low-density polyethylene (LDPE) using a film extrusion process.

2.1.3 PET Water Bottle Tertiary Package

For the tertiary package, a standard GMA, wood expendable pallet with the dimensions 48 x 40" was used. The structure of this pallet used data collected by Trayak. The average shrink wrap was 250 grams made from LDPE using a film extrusion process.

2.2 PET Soda Bottle

For the PET soda bottle packaging system, Trayak and the IBWA member collected data from five different brands. The average size of the bottle was 500 mL with a case size of 24 bottles per pack. The average cases per pallet was 60.

2.2.1 PET Soda Bottle Primary Package

The average bottle was 22.22 grams made from PET using a blow molding process. The average cap was 2.52 grams made from HDPE with an injection molding process. The average label was 0.41 grams made from polypropylene with a film extrusion process. It was assumed there was an average post-consumer recycled (PCR) content of 3% for the PET.

2.2.2 PET Soda Bottle Secondary Package

The secondary packaging was a film and paperboard tray that held four packs of six bottles grouped with a beverage ring. Each beverage ring was 4 grams made from LDPE. The film was 36 grams made from low-density polyethylene (LDPE) using a film extrusion process. The corrugated tray was 137 grams. It was assumed there was an average post-consumer recycled (PCR) content of 70% for all paperboard.

2.2.3 PET Soda Bottle Tertiary Package

For the tertiary package, a standard GMA, wood expendable pallet with the dimensions 48 x 40" was used. The structure of this pallet used data collected by Trayak. The average shrink wrap was pulled from the PET water bottle dataset which was 250 grams made from LDPE using a film extrusion process.

2.3 Aluminum Can

For the aluminum can packaging system, Trayak and the IBWA member collected data from eight different brands with varying size containers. There were two 500 mL cans, five 473 mL cans, and one 443 mL can. The palletization was taken from the 443 mL can with a case size of 12 cans per pack. The cases per pallet was 140.

2.3.1 Aluminum Can Primary Package

Looking through the data, the general expectation was that as can capacity increased, the can needed to be larger, so it would require more material and weigh more overall. However, there was a discrepancy in the data of the average masses of the cans with the smaller can weighing more than a larger can. The average mass for the 500 mL aluminum can + tab was 16.52 grams while the average mass for the 473 mL can + tab was 19.30 grams.

The data was combed through to identify an outlier. It was determined that one of the 500 mL masses was much lower (17.6% less) than the other 500 mL can and therefore should be omitted from the average mass calculations. With the outlier, the average mass of the seven cans (two 500 mL and five 473 mL) was 19.14 grams. Removing the outlier, changes the average mass of the six cans (one 500 mL and five 473 mL) to 19.74 grams.

Removing one of the 500 mL datapoints meant there was only one mass for the 500 mL container now. Trayak decided to take the overall average mass of the one 500 mL, five 473 mL cans, and one 443 mL can and model it as a 500 mL can within the LCA.

Overall, the average mass of the 500 mL aluminum can + tab was 19.74 grams made from aluminum using a production of aluminum can process. It was assumed there was an average post-consumer recycled (PCR) content of 68% for aluminum.

2.3.2 Aluminum Can Secondary Package

The average secondary packaging of the aluminum can was a paperboard tray with a plastic overwrap. The paperboard tray was 73.12 grams made from corrugated with a production of corrugated containers process. The plastic overwrap was 16.24 grams made from low-density polyethylene (LDPE) using a film extrusion process. It was assumed there was an average post-consumer recycled (PCR) content of 70% for all paperboard.

2.3.3 Aluminum Can Tertiary Package

For the tertiary package, a standard GMA, wood expendable pallet with the dimensions 48 x 40" was used. The structure of this pallet used data collected by Trayak. The average shrink wrap was pulled from the PET water bottle dataset which was 250 grams made from LDPE using a film extrusion process.

2.4 Beverage Carton

For the beverage carton packaging system, Trayak and the IBWA member collected data from three different brands. The average size of the carton was 500 mL with an average case size of 12 cartons per pack. The average cases per pallet was 120.

2.4.1 Beverage Carton Primary Package

An average beverage carton has a composition 54% paperboard, 15% polyethylene, 28% plant-based plastic, and 3% aluminum. This composition was modeled based on the mass percentages. The average carton was 21.82 grams made from solid unbleached sulfate board, linear-low density polyethylene, bio high-density polyethylene, and aluminum. The conversion processes of production of carton with offset printing, film extrusion, aluminum sheet rolling, and thermal lamination were used. The average cap, ring, and nozzle were 4.01 grams made of plant-based HDPE made using an injection molding process.

2.4.2 Beverage Carton Secondary Package

The average secondary packaging of the beverage carton was a paperboard case. The paperboard case was 182.50 grams made from clay coated news back (CCNB) corrugated with a production of corrugated containers process. It was assumed there was an average post-consumer recycled (PCR) content of 70% for all secondary paperboard.

2.4.3 Beverage Carton Tertiary Package

For the tertiary package, a standard GMA, wood expendable pallet with the dimensions 48 x 40" was used. The structure of this pallet used data collected by Trayak. The average shrink wrap was pulled from the PET water bottle dataset which was 250 grams made from LDPE using a film extrusion process.

2.5 Glass Bottle

For the glass bottle packaging system, Trayak and the IBWA member collected data from four different brands with 500 mL glass bottles. The average case size was 12 bottles per pack. The average cases per pallet was 72.

2.5.1 Glass Bottle Primary Package

Looking through the data, it was determined that one of the 500 mL glass bottle masses was higher (29.6% more) than the average of the other 500 mL glass bottles and therefore should be omitted from the average mass calculations. With the outlier, the average mass of the four 500 mL glass bottles was 322.77 grams. Removing the outlier, changes the average mass of the three 500 mL glass bottles to 300.55 grams.

Overall, the average 500 mL glass bottle was 300.55 grams made from container glass. The average closure was 1.5 grams made from aluminum using the aluminum stamping process. The average plastic seal/liner was 0.46 grams made from LDPE with a film extrusion process. The label weight is assumed to be small (< 1 gram) and is included within the container weight. It was assumed there was an average post-consumer recycled (PCR) content of 52% for the glass.

2.5.2 Glass Bottle Secondary Package

The average secondary packaging of the glass bottle was a paperboard box. The paperboard box was 250.27 grams made from solid unbleached sulfate board with a production of carton with offset printing process. It was assumed there was an average post-consumer recycled (PCR) content of 70% for all paperboard.

2.5.3 Glass Bottle Tertiary Package

For the tertiary package, a standard GMA, wood expendable pallet with the dimensions 48 x 40” was used. The structure of this pallet used data collected by Trayak. The average shrink wrap was pulled from the PET water bottle dataset which was 250 grams made from LDPE using a film extrusion process.

***Table 1**: Average Mass and Packaging System Configuration of the Beverage Packaging Systems*

Beverage Packaging System	Primary Package						Secondary Package				
	Average Container Size	Average Container Mass	Average PCR Content	Average Closure Mass	Average Label Mass	Total Mass	Average Plastic Overwrap Mass	Average Box Mass	Average Pack Size	Average Cases/Pallet	Number of Primary Packages on Pallet
PET Water Bottle	500 mL	8.30 g	3%	0.77 g	0.25 g	9.32 g	20.3 g	NA	24	84	2016
PET Soda Bottle	500 mL	22.22 g	3%	2.52 g	0.41 g	25.15 g	Film - 36 g Bev ring – 4.44 g x 4	137 g	24	60	1440
Aluminum Can	500 mL	19.74 g	68%	NA	NA	19.74 g	16.24 g	73.12 g	12	140	1680
Beverage Carton	500 mL	21.82 g	0%	4.01 g	NA	25.83 g	NA	182.50 g	12	120	1440
Glass Container	500 mL	300.55 g	52%	1.5 g	Seal – 0.46 g	302.51 g	NA	250.27 g	12	72	864

3 Life Cycle Inventory (LCI)

The life cycle inventory data was used to construct the packaging system models within the LCA. The life cycle inventory data was broken down into four main phases: raw material, manufacturing, transportation, and end of life.

3.1 Material

The ecoinvent 3.5 database was used for all the materials within the beverage packaging systems. All of the materials were used as is, except for the corrugated and CCNB corrugated which are custom Trayak models. An average recycled content for some of the materials was determined through research. Aluminum cans have an average of 68% post-consumer recycled (PCR) content and plastic bottles have an average of 3% PCR content.[1] The paperboard containers are assumed to have an average PCR content of 70%.[2] The container glass is assumed to have an average PCR content of 52%.[3] All other components are assumed to be made from all virgin materials.

3.2 Manufacturing

The conversion processes for the various components use ecoinvent 3.5 data that has been regionalized to the United States by changing the electricity grids and water origins. The production of corrugated container, paper cutting, and production of aluminum can are all custom Trayak conversion processes.

3.3 Transport

Transportation impacts have not been considered within this LCA.

3.4 End of Life

The end-of-life data was incorporated using the Environmental Protection Agency's report "Advancing Sustainable Materials Management: 2016 and 2017 Tables and Figures". This report details the likelihood that varying packaging types of a specific material will be recycled, landfilled, and incinerated based on the current infrastructure in the United States. Each component was designated an appropriate packaging type and this was used to determine the EOL percentage breakdown. Each of the materials has an impact for landfill and incineration regionalized according to the United States' electricity and water grids. The cut-off allocation method was used, so the end-of-life impact represents the impact of landfilling or incinerating the package component with no impact for recycling the component. The recycling impact is attributed to PCR material of a package.

---

[1] Data from the United States Environmental Protection Agency as referenced from https://www.reuters.com/article/us-environment-plastic-aluminium-insight/plastic-bottles-vs-aluminum-cans-wholl-win-the-global-water-fight-idUSKBN1WW0J5

[2] Data from the Corrugated Packaging Alliance's 2016 white paper "Corrugated Packaging – A Recycling Success Story"

[3] Data from the 2019 report "Recycled Content and Glass Packaging" from the European Container Glass Federation

4 Life Cycle Impact Assessment (LCIA)

The COMPASS® method is used to calculate the Life Cycle Impact Assessment (LCIA) for all packaging systems in this study. This method consists of seven indicators to provide a full picture view of the impact across different categories and considerations. The indicator descriptions are shown in the Appendix.

4.1 Comparing all Beverage Packaging Systems

After the models were complete, the beverage packaging systems were analyzed using the COMPASS® method. The Life Cycle Assessment results for seven indicators are shown in the spider web chart below. Each of the packaging systems is displayed as a different color and the value closest to the center represents the least impactful package option for that indicator. For example, the PET water bottle has the lowest greenhouse gas (GHG) emissions as well as the lowest water use.

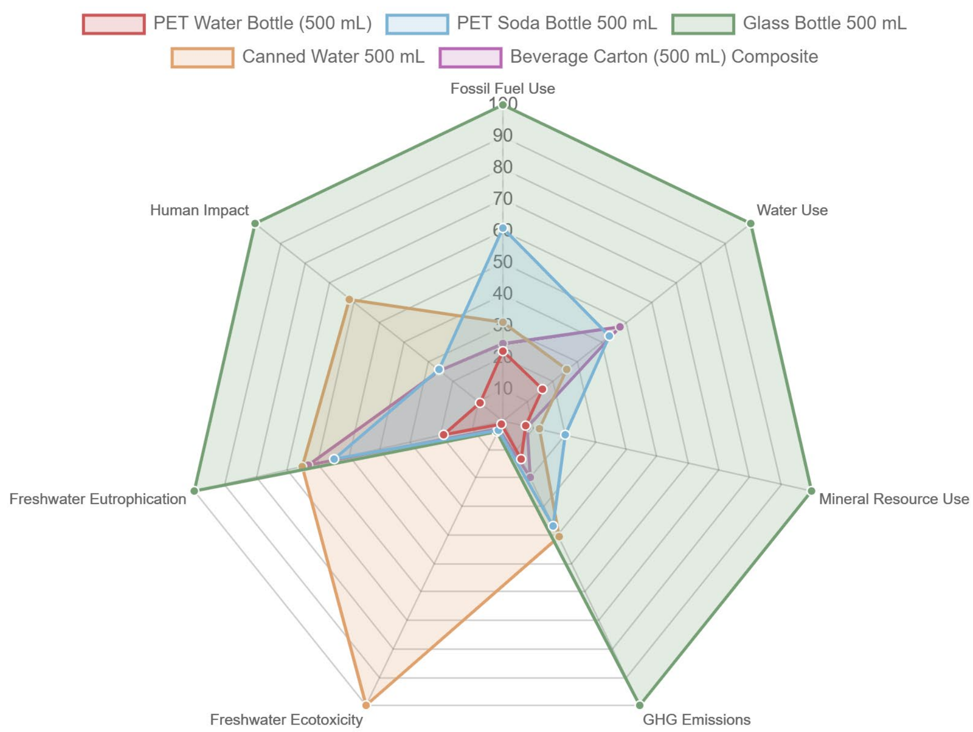


Figure 1. *Life Cycle Assessment Indicators Comparison Between Beverage Packaging Systems*

From Figure 1, it can be concluded that the PET water bottle is the least impactful packaging system for water across all of the indicators, with the beverage carton a close second in terms of fossil fuel use, mineral resource use, and freshwater ecotoxicity. The glass bottle is the most impactful packaging system for nearly all of the indicators with the aluminum can having the strongest freshwater ecotoxicity impact.

4.2 Breakdown of Beverage Packaging Systems

To further understand the environmental impact of the beverage packaging systems, below is an analysis specific to fossil fuel use, water use, and GHG emissions. The various phases of the beverage packaging systems lifecycles are shown in a stacked bar graph. Overall, raw material is the largest contributor to environmental impact. This reflects the importance of material choice, but another important consideration is the quantity of material used. The poor performance of the glass bottle can be attributed to the fact that the container itself uses several times more mass than the other materials considered. This means that even if the impact of producing one gram of glass is low, a 300g glass container will still have a bigger footprint than a 20g plastic container. Similarly, the PET water bottle uses noticeably less material than the other packages, which likely contributed to its low impact across the board.

4.3 Simple Indicator Savings

The environmental savings for the average PET water bottle compared to the other beverage packaging formats can be converted to simple indicators.

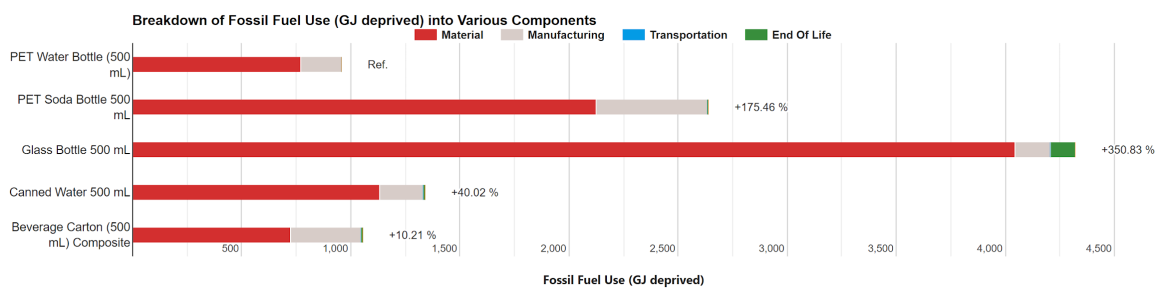
4.3.1 Fossil Fuel Consumption Savings

If one million 500mL PET soda bottles were replaced with PET water bottles, it would save 1,681 GJ deprived across the entire life cycle. This is equivalent to the energy in 275 barrels of oil.

If one million 500mL glass bottles were replaced with PET water bottles, it would save 3,362 GJ deprived across the entire life cycle. This is equivalent to the energy in 549 barrels of oil.

If one million 500mL aluminum cans were replaced with PET water bottles, it would save 383.5 GJ deprived across the entire life cycle. This is equivalent to the energy in 63 barrels of oil.

If one million 500mL composite beverage cartons were replaced with PET water bottles, it would save 97.8 GJ deprived across the entire life cycle. This is equivalent to the energy in 16 barrels of oil.



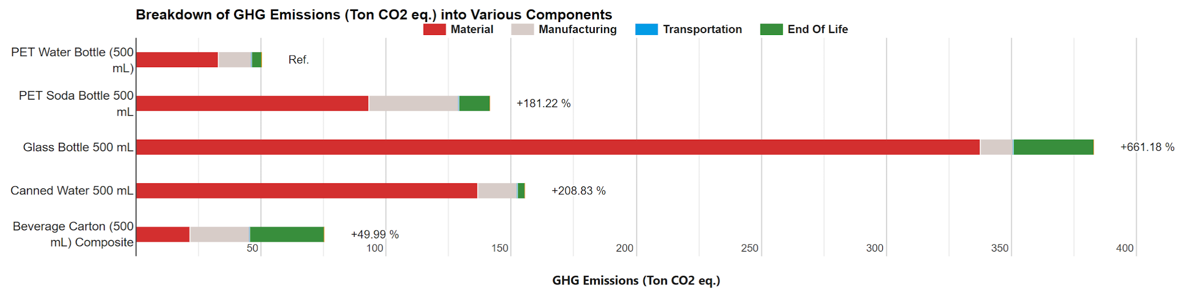
4.3.2 Greenhouse Gas Emissions Savings

Replacing one million PET soda bottles with PET water bottles would save 91.2 kg CO_2 eq across the entire life cycle. This is the equivalent to the GHG emissions from 19.5 passenger vehicles over a year.

Replacing one million glass bottles with PET water bottles would save 332.6 kg CO_2 eq across the entire life cycle. This is the equivalent to the GHG emissions from 71.2 passenger vehicles over a year.

Replacing one million aluminum cans with PET water bottles would save 105.1 kg CO_2 eq across the entire life cycle. This is the equivalent to the GHG emissions from 22.5 passenger vehicles over a year.

Replacing one million composite beverage cartons with PET water bottles would save 25.2 kg CO_2 eq across the entire life cycle. This is the equivalent to the GHG emissions from 5.4 passenger vehicles over a year.



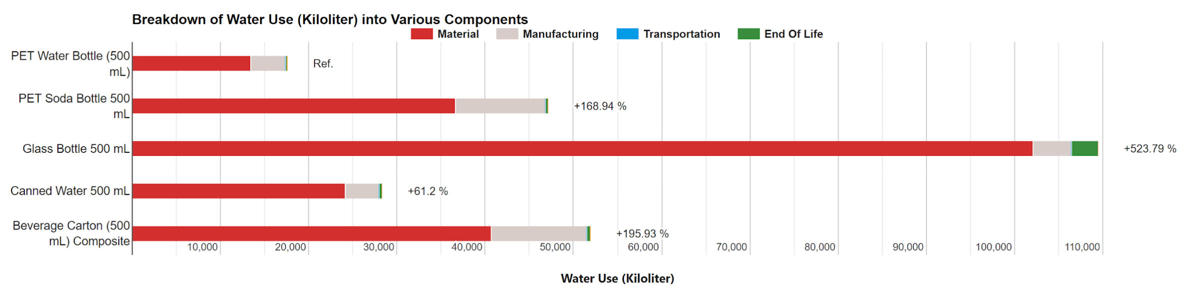
4.3.3 Water Consumption Savings

Per million bottles, 7.83 million gallons eq of water can be saved by replacing PET soda bottles with PET water bottles. This is enough water for 1,248 people to shower every day for an entire year.

Per million bottles, 24.28 million gallons eq of water can be saved by replacing glass bottles with PET water bottles. This is enough water for 3,868 people to shower every day for an entire year.

Per million bottles, 2.84 million gallons eq of water can be saved by replacing aluminum cans with PET water bottles. This is enough water for 452 people to shower every day for an entire year.

Per million bottles, 9.08 million gallons eq of water can be saved by replacing composite beverage cartons with PET water bottles. This is enough water for 1447 people to shower every day for an entire year.



5 Interpretation and Conclusions

5.1 Study Limitations

The results from this study must be looked at in the context of the limitations of this study. While the most comprehensive and equal functional unit was utilized in this comparison, Trayak recognizes that assumptions were built into the model based on research and input from IBWA members.

This LCA focused on industry average packaged water and determining the least environmentally impactful option. This study assumes each of the containers is single use.

As a result of limited and assumed data, this study is intended to be used as directional guidance to help inform decisions and understand environmental impact for IBWA members.

5.2 Conclusions

The purpose of this Life Cycle Assessment was to model and compare different styles of beverage bottles in order to assess their environmental impact. This will assist IBWA members in making informed decisions about material selection and package design in order to reduce the impact of their products. Several types of 500mL beverage containers were analyzed, including PET water bottles, PET soda bottles, glass bottles, aluminum cans, and composite beverage cartons.

The PET water bottle shows lower environmental impact than the other containers across each of the considered indicators. Much of this benefit is derived from the low material usage compared to the other container types, with the average PET water bottle considered using less than half of the material weight of the other container types. Lower material usage means less impact from material extraction, manufacturing, and ultimately results in less material entering landfills or needing to be recycled. In contrast, the glass bottle had higher impact in nearly every category than the other container types. This is likely due to high material usage; the average glass bottle considered weighs more than ten times as much as the other containers in this study.

The results provide a reliable comparison between various styles of beverage containers and help illuminate the key environmental savings when choosing a more efficient container style. These savings were calculated in terms of simple indicators to tell a more informative story. The analysis and the identified trends can be useful in determining focus areas to reduce environmental footprint in the future.

6 APPENDIX

1.1 COMPASS METHODOLOGY AND INDICATOR DEFINITIONS

CONSUMPTION

- **Fossil Fuel Consumption (MJ-eq deprived)**: Total quantity of fossil fuel consumed throughout the life cycle reported in mega joules equivalents deprived. Since it requires different quantities of these fossil fuels to generate one-unit MJ, this measure uses MJ-eq to aggregate them, uses the Impact World+ method, and assumes fossil resources mainly used for energy purposes. Fossil fuels include coal, petroleum, and natural gas. Inputs for nuclear fuel such as uranium are accounted for in the MINERAL CONSUMPTION metric.
- **Water Consumption (Liters eq)**: The relative available water remaining per area in a watershed after the demand of humans, aquatic ecosystems, and manufacturing process has been met. This metric accounts for water scarcity and the result represents the relative value in comparison with the average liters consumed in the world. Essentially, the total water consumed to make the package is multiplied by the region's scarcity factor which will either increase or decrease the water usage value based on the scarcity or excess availability of water in a specific region, respectively. Ex. If the water consumption of making a package is 2 L and it is being considered in a water abundant region, the water use value would be calculated as less than 2 (maybe 1.7 L eq). But if the package is being considered in a water scarce region the value would be calculated as greater than 2 (maybe 2.4 L eq)
- **Mineral Consumption (kg deprived)**: This indicator uses the material competition scarcity index from de Bruille (2014) as a midpoint indicator and the factor represents the fraction of material needed by future users that are not able to find a reliable substitute for the mineral. It is expressed in units of kilograms of deprived resource per kilogram of resource dissipated. It considers mineral scarcity and viable substitutes.

EMISSIONS

- **GHG Emission – with Carbon Uptake (kg CO_2 eq)**: The total quantity of greenhouse gases (GHG) emitted throughout the lifecycle reported in kilograms of CO_2 equivalents. This calculation follows the latest IPCC 2013 method and considers climate feedback loops.
- **Human Impacts (Total) (DALY)**: The quantity of environmental emissions resulting in particulate, cancer & toxic non-cancer impacts to humans released throughout the lifecycle. The metric reports these three measurements in Disability Adjusted Life Years (DALY). Calculated using Impact World+ and considers severity factors of any adverse effects.
- **Freshwater EcoToxity (CTUe)**: The quantity of environmental emissions resulting in aquatic toxic impacts released throughout the lifecycle reported in Comparative Toxic Unit ecosystem (CTUe). CTUe corresponds to a fraction of disappeared species over a cubic meter of freshwater (or marine water) during one year. This is a measure of ecotoxicity impact of chemical releases to air, water, and land using aquatic toxicity factors and is calculated using characterization factors from USEtox 2.0.

- **Freshwater Eutrophication (kg PO4-eq)**: Eutrophication is the increase in chemical nutrients that results in excessive plant/algal growth and decay resulting in an anoxic condition in freshwater systems. Typically, these are emissions of phosphorus compounds released during the production of materials. It is reported in phosphate (PO4) equivalents and is calculated with Impact World+ characterization factors.