



Research on the Carbon Footprint of Bottled Water

Beverage Industry Environmental Roundtable, June 2012



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1.0 Introduction

Global awareness and concern regarding the impact of climate change continues to be a focal point as businesses seek to achieve better business in terms of reduced cost and risk while achieving positive impact on the world around them. As this issue advances on the list of global priorities, businesses in the beverage sector have already begun implementing strategies to reduce their Greenhouse Gas (GHG) emissions and thusly their impact on the global climate.

To continue to drive understanding of impacts and identify reduction priorities, the Beverage Industry Environmental Roundtable (BIER), whose membership includes representatives from the beverage alcohol, brewing, and non-alcoholic beverage sectors, has initiated research and analysis of select beverage product category carbon footprints.

BIER has focused on this particular line of research because it provides an excellent understanding of the significant drivers of carbon footprinting for beverages, and it supports BIER's broader goals of conducting data collection and quantification of beverage sector impacts on the environment (such as GHG emissions). As leaders of environmental stewardship in the beverage industry, BIER looks to support informed decision making through knowledge, data and experience sharing, conducting relevant research that will contribute to the various forums where hotspots identification, product category rules and metrics are being discussed and developed for different categories.

This carbon footprint analysis research will support key business decisions regarding where GHG reduction opportunities lie and the significance of their implementation within the beverage industry. Crafted as a series of five reports and accompanying emissions calculation workbooks, these analyses evaluate the carbon impacts of sourcing materials, production, distribution and use for five beverage categories – **beer**, **bottled water**, **carbonated soft drink**, **spirits** and **wine** – in Europe and North America. This report, presenting results regarding the carbon footprint assessment of **bottled water**, focuses on the key contributors of GHG emissions and the impact of aspect changes across the lifecycle of bottled water in Europe and North America.

As with any product carbon footprint or carbon quantification exercise, there are many factors, assumptions, and performance variables that can impact the calculated outcome for a given product or products. This is no different for beverages for which there are numerous categories, numerous varieties (specific stock keeping units (SKUs)), and varying production methods and recipes. These factors result in unique products within the beverage category that will inherently demonstrate varying carbon footprint values.

The ability to compare beverages, as well as their estimated carbon footprints, is very difficult at best. It is not the intention of this work to represent product comparisons. Rather, the intention is to provide perspective on the key drivers to beverage product footprints. The research conducted and shared herein is intended to be both a culpability analysis and a sensitivity analysis of the carbon impacts of select beverage categories. The purpose of the research is: 1) to identify those aspects of the



respective beverage value chain that contribute significantly to the overall carbon footprint; and 2) to evaluate the sensitivity of the carbon footprint to variations in material or process practice aspects (such as packaging material selection, distribution logistics, recycling rates, etc.) for which the beverage companies desired further investigation.

The carbon modeling and analysis is based, in a large part, on primarily data from and the performance experience of BIER member companies through their independent business analyses and evaluations, such as life cycle assessments and greenhouse gas (GHG) inventories.

One output of the process has been the development of a clearinghouse for secondary data resources, which facilitate the creation of a single directory of data resources for the beverage sector. This secondary data set will be included in the upcoming version of the *Beverage Industry Sector Guidance for Greenhouse Gas Emissions Reporting*.¹

¹ *Beverage Industry Sector Guidance for Greenhouse Gas Reporting, v. 2.0*, 2010, Beverage Industry Environmental Roundtable

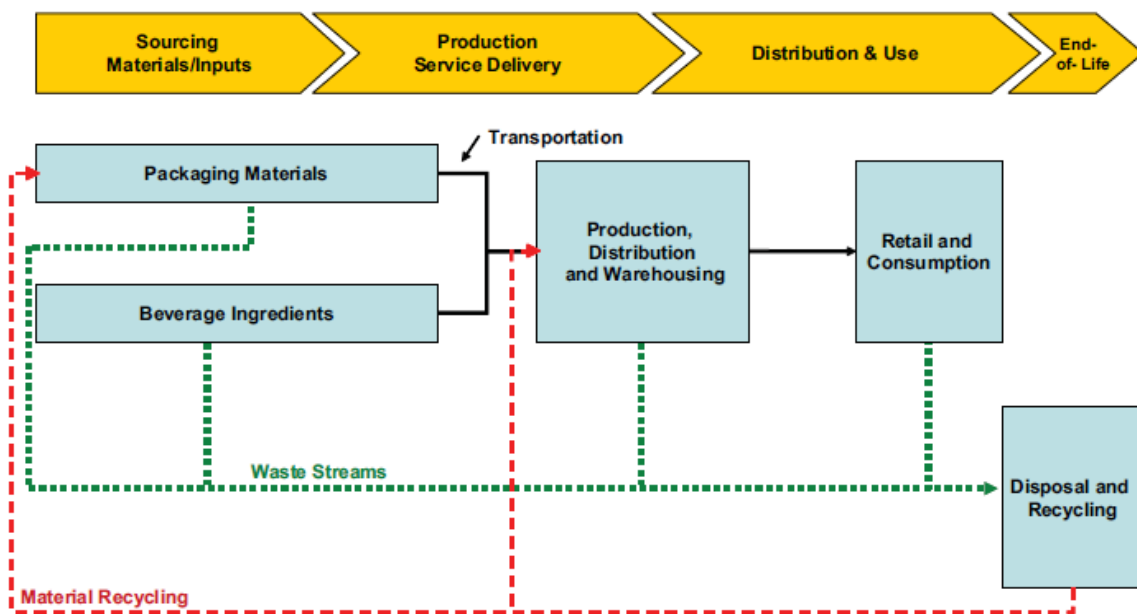


2.0 An Overview of Product Carbon Footprint

A product carbon footprint is an evaluation of GHG emissions across the life cycle of a product. All emissions within the value chain boundary of a specific product are accounted for and assigned to a functional unit, which could be a specific container, serving size, or case of product.

The components of the product-level value chain include the GHG emissions associated with raw material inputs, transportation streams, manufacturing, and disposal/recycling of beverage materials. Aggregated GHG emissions from all activities related to a product from the extraction of basic raw materials, through manufacturing and distribution and including consumer use and end of life (recycling/disposal), are included in the product carbon footprint. Figure 1 presents a simplified process map of the value chain for a typical beverage product.

Figure 1. Beverage Process Map



3.0 Bottled Water Modeling

Modeling methodologies utilized in this analysis of the carbon footprint of bottled water followed those outlined in the *Beverage Industry Sector Guidance for Greenhouse Gas Emissions Reporting*.² This beverage industry guidance is aligned with the recognized protocols contained in *The Greenhouse Gas Protocol*³ and *Publicly Available Specification PAS 2050 – Specification for the Assessment of the Life Cycle Greenhouse Gas Emissions of Goods and Services*.⁴

The carbon footprint of bottled water was assessed utilizing an Excel spreadsheet-based modeling tool developed for this analysis. Table 1 shows the categories and processes of the value chain that were included in the analysis.

Table 1. Modeled Processes - Bottled Water

Category	Processes
Beverage Ingredients	Water
Packaging Materials *	PET Bottle
	Polypropylene Cap
	Paper Label
	Corrugated Tray
	LPDE Shrink Wrap
	Wood Pallet
Production and Warehouse	Electricity and Natural Gas
	Manufacturing Waste Disposal
Retail and Consumption	Electricity and Natural Gas (in-store refrigeration, lighting and climate control)
	Consumer Refrigeration
	Consumer Disposal
Transportation and Distribution	Road
	Rail
	Ocean

* multiple recycling methodologies were incorporated for packaging materials

Excluded processes are the following:

- Construction of capital equipment,
- Maintenance and operation of support equipment,
- Labor and employee transport, and
- Manufacture and transport of packaging materials not associated with final product.

² *Ibid.*,6

³ *The Greenhouse Protocol – A Corporate Accounting and Reporting Standard*, 2004, World Business Council for Sustainable Development

⁴ *Publicly Available Specification 2050:2011 – Specification for the Assessment of the Lifecycle Greenhouse Gas Emissions*, 2011, British Standards Institute



3.1 Beverage Format

The following beverage formats were analyzed:

- **Europe – 1.5 liter PET bottle; six-pack; shrink wrapped;** and
- **North America – 500 milliliter PET bottle; 24-pack; shrink wrapped corrugated tray.**

Carbon emissions from the modeled processes were normalized to these beverage formats, or functional units.

3.2 Analysis Methodology and Modeled Scenarios

The carbon emissions from the processes identified in Table 1 were calculated using data provided by BIER member companies and emission factors from recognized sources, such as IPCC⁵ and the ecoinvent⁶ databases. Where specific data was required for the analysis, but not readily available, assumptions were made based on engineering judgment.

Baseline emission scenarios were determined from data identified by BIER member companies as typical for the processes of concern.

The following specific value chain aspects were selected by BIER member companies for more detailed analysis to aid in understanding the sensitivities and impacts on the overall product carbon footprint:

- Primary package weight,
- Product cooling,
- Local electricity grid,
- Distribution assumptions, and
- Recycling methodology⁷ (see following box).

Low and high data values, as well as typical values (used for the baseline), for these select aspects were provided by BIER member companies, and the resulting impact to the overall footprint was assessed.

Recycling Allocation Methods

Closed loop approximation method - a recycling allocation method in which materials are recycled into the same product repeatedly - that is, material being recycled is used to displace virgin material input.

Recycled content method - a method in which a product's post-consumer waste materials are recycled into multiple products, including a portion of the same product, and the recycling process emissions are allocated to the life cycle that uses the recycled material.

⁵Guidelines for National Greenhouse Gas Inventories, 2006, Intergovernmental Panel on Climate Change

⁶ecoinvent data v 2.2, 2010, Swiss Centre for Lifecycle Inventories

⁷Greenhouse Gas Protocol – Product Life Cycle Accounting and Reporting Standard, 2011, World Resources Institute & World Business Council for Sustainable Development



Table 2 presents the ranges of these modeled process variables. When modeling a specific variable's range, all other process variables were held constant at their baseline value.

Table 2. Range of Modeled Process Variables

	Europe (1.5 l bottle)			North America (500 ml bottle)		
	Low	Baseline	High	Low	Baseline	High
PET Bottle (g)	24	29.3	35.8	9	13.5	19
Product Cooling						
<i>Retail</i>						
Temperature (deg C)	7	5	3	7	5	3
Amount Cooled (%)	1	1	1	1	3	5
Storage Duration (days)	1	1	2	1	1	2
<i>Domestic</i>						
Amount Cooled (%)	10	30	50	10	30	50
Storage Duration (days)	1	1	3	1	3	10
Electrical Grid ^a						
<i>Emission Factor (g CO2/kWh)</i>	82.7	351.0	842.1	180.6	595.4	997.2
<i>Warehouse Storage (days)</i>	5	14	28	10	14	28
Transportation						
<i>Emission Factor (g CO2/ ton-km)</i>						
Road	53	94.6	253			
Rail	2.13	7.1	34			
Ocean	10.7	10.7	50			
<i>Emission Factor (g CO2/ ton-mi)</i>						
Road				85	143.2	408
Rail				3	23.2	54
Ocean				17	17.22	80

^a Includes production, warehousing, retail, and domestic use

3.2.1 Data Sources and Assumptions

Data for bottle weights, retail and domestic product cooling, and warehouse storage were provided by BIER members. Emission factors for PET bottles were obtained from PlasticsEurope's Eco-profile database⁸ for bottle-grade resin production and subsequent bottle conversion.

⁸ Eco-profile for PET bottles, 2010, PlasticsEurope



The electricity grid emission factor ranges were selected to assess the sensitivity of changes in the regional generation mix on the overall footprint. In Europe, the grid factor for France was selected to represent the low end of the range; the United Kingdom was selected for the high end, with the baseline represented by the average grid factor for the European Union (EU-27).

For North America, the highest factor for the United States (WECC Rockies) was used for the high end of the range, Canada for the low, and the U.S. average for the baseline.

Emission factors for transportation of the finished product were also assumed and utilized to illustrate the sensitivity of the change in mode of transportation on the overall footprint. For example, the low end of the rail transport variable was represented by the factor for electric locomotives and the high end by the factor for diesel locomotives, with the European average being the baseline value. Similarly, the low end of the road transport range was an average factor from a life cycle inventory and the high end was a factor specific to 3.5 to 16 tonne trucks. Transport distances of 400 kilometers by road and rail were assumed.

The recycling rate for PET bottles in Europe (43%) was obtained from BIER members, and in North America the recycling rate (29%) was taken from NAPCOR's 2010 report on PET container recycling.⁹ Input of recycled PET to the bottle production process, which offsets the use of virgin PET, was conservatively assumed at three percent.

Detailed data references can be found in Attachment 1.

⁹ 2010 Report on Post Consumer PET Container Recycling Activity – Final Report, 2010, National Association for PET Container Resources



4.0 Results

4.1 Baseline

The largest contributors to the carbon footprint for the two beverage formats under the baseline scenario are shown in Table 3. Details of the modeling calculations can be found in Attachment 1.

As shown in the table, for the 1.5 liter Europe format, the total carbon footprint was calculated to be 162.7 grams of CO₂e per 1.5 liter bottle. Distribution transportation comprises 39 percent of this total product carbon footprint, followed by the PET bottle (37%) and the corrugated packaging tray (11%). These three processes account for 87 percent of the total footprint.

In the North America format, the total carbon footprint is 82.8 grams of CO₂e per 500 milliliter bottle.

Table 3. Largest Contributors to Bottled Water Carbon Footprint ^a

	Europe (1.5 l bottle)		North America (500 ml bottle)	
	CO ₂ e (grams)	Percent of Total	CO ₂ e (grams)	Percent of Total
PET Bottle	60.8	38.0	31.0	38.8
Distribution Transportation	63.1	39.4	23.6	29.5
Corrugated Tray	18.0	11.2	4.5	5.6
Production Electricity & Natural Gas	8.5	5.3	4.1	5.1
Cap	2.7	1.7	2.7	3.4
Electricity for Consumer Cooling	2.4	1.5	2.0	2.5
Label Adhesive	2.3	1.4	2.3	2.8
Retail Electricity & Natural Gas	2.1	1.3	10.0	12.5
Others ^b	0.1	0.1	-0.1	-0.1
Total (grams CO ₂ e per package) ^c	160	100	80	100
Total (grams CO ₂ e per package)	100		160	

^a Baseline scenario

^b Individually less than one percent

^c Given the uncertainty inherent to secondary data points utilized in conducting these analyses, all "Total" values have been rounded to the nearest 10's value for Tables 3,4, and 5 in this report.

The PET bottle comprises 38 percent of this total, followed by distribution transportation (29%) and retail electricity and natural gas (12%). These three processes account for 78 percent of the total footprint.



4.2 Specific Value Chain Aspects

Table 4 shows the influence of varying the selected value chain aspects from low to high values and the resultant impact on the total carbon footprint for the Europe format. Each of these aspects is discussed below.

Table 4. Impact of Changes to Select Value Chain Aspects – Europe (1.5 l bottle)^a

	Range of Variation	
	CO2e (grams)	Portion of Total Footprint
PET Bottle Weight (closed loop)	50 to 70	33% to 42%
PET Bottle Weight (recycled content)	70 to 100	44% to 54%
Product Cooling	0 to 10	1% to 8%
Local Electricity Grid	10 to 30	4% to 16%
Distribution Assumptions	30 to 180	26% to 64%

^a See note c in Table 3

Table 5 shows the influence of varying the selected value chain aspects from low to high values and the resultant impact on the total carbon footprint for the North America format. Each of these value chain aspects is discussed below.

Table 5. Impact of Changes to Select Value Chain Aspects – North America (500 ml bottle)^a

	Range of Variation	
	CO2e (grams)	Portion of Total Footprint
PET Bottle Weight (closed loop)	20 to 40	29% to 46%
PET Bottle Weight (recycled content)	20 to 50	35% to 53%
Product Cooling	0 to 30	5% to 29%
Local Electricity Grid	10to 40	8% to 35%
Distribution Assumptions	10 to 70	18% to 53%

^a See note c in Table 3

4.2.1 Bottle Weight

Europe – Using both closed loop approximation and recycled content allocation methods, a weight change in the 1.5 liter PET bottle from a low of 23 grams to a high of 35.8 grams results in emissions that range from 29 to 53 percent of the total footprint, respectively.

North America – Similarly, the weight change in the 500 milliliter bottle from nine grams to 19 grams results in emissions ranging from 32 to 51 percent of the total footprint.



The difference between the two recycling schemes for the changes in package weights is significant. For Europe, the recycled content method results in an impact that is 15 grams of CO₂e greater than the closed loop approximation method at both the low and high ends of the weight range. This equates to a change of 11 percent in the total footprint.

In North America the recycled content method results in an impact that is eight grams of CO₂e greater than the closed loop approximation method at the high end of the weight range. This is almost 7 percent of the total carbon footprint.

4.2.2 Product Cooling

Carbon emissions result from energy usage for retail and domestic refrigeration. Variables that were changed in the modeling include the “chill-to” temperature, storage duration, fraction of the product cooled, and electricity grid emission factor.

Europe – The modeled variables showed a range from 1.9 to 12.6 grams of CO₂ per bottle, which equates to 1 to 8 percent of the total footprint.

North America - Impacts for North America ranged from 3.8 to 29.9 grams CO₂ per bottle, which equates to 5 to 29 percent of the total footprint. This impact is significantly larger than that of the European scenario due to longer storage times, greater fraction cooled in retail facilities and higher emission factors for electricity generation.

4.2.3 Local Electricity Grid

Emissions from electricity usage for production, warehousing, retail and consumer usage were calculated using the assumed range of regional electricity grid factors as described above in Section 3.2.1. For Europe the impact from the change in the grid factors represented 4 to 16 percent of the total footprint, and for North America it represented 8 to 35 percent of the total. Most of this difference is accounted for by the higher percentage of renewable generation in Europe.

4.2.4 Distribution Transportation

Modeling of distribution of the final product to the retailer and consumer included transport by truck and rail. The key parameter is the emission factor, with truck emission factors significantly greater than those of rail on a mass per unit distance basis. The factors within each mode of transportation also vary significantly depending on the specificity of the vehicle itself.

The range of values modeled resulted in impacts for Europe that were 26 to 64 percent of the total footprint and 18 to 53 percent of the total footprint for North America. The large range in impacts results from a similar range in emission factors for road transport, indicating the importance of utilizing factors that most accurately represent actual transportation scenarios.



4.2.5 Recycling Allocation

The application of the two recycling allocation methodologies to packaging materials can be seen in Attachment 2, in which the impacts are highlighted. For Europe, packaging material emissions are 86 g CO₂ per 1.5 liter bottle (53% of the total) when applying the closed loop approximation method versus 105 g CO₂ per bottle (58% of the total) when applying the recycled content allocation methodology.

For North America, the values are 43 g (52% of the total) and 49 g CO₂ (55% of the total) per 500 milliliter bottle for the closed loop approximation and the recycled content methodologies, respectively. In both bottle formats, the closed loop methodology results in lower emissions due to the impact of replacement of virgin materials with recycled materials.

4.3 Quality and Uncertainty

The quality of the results is determined by the quality of the data obtained from BIER members and the quality and uncertainty of the emission factor data selected. For example, where primary data was provided by BIER members, such as container mass, the data is high quality with little uncertainty. Similarly, carbon emission data for the life cycles of PET containers is well documented in comprehensive LCA studies. It should be noted that these sources of secondary data refer to "industry average" emission factors and do not reveal the differences or reflect the "bandwidth" of the varying performance of suppliers, nor the regional differences that exist.

Contrast this with the obvious uncertainties associated with both domestic and retail product cooling practices. Multiple variables exist such as temperature, storage times, storage duration, fraction of product cooled, consumer habits, etc. Coupled with factors for the regional electricity grid, as opposed to specific local electricity providers, all lend uncertainty to carbon estimates from these activities.

Data uncertainty was assessed applying the methodology and guidance provided by the Greenhouse Gas Protocol.¹⁰ This guidance was published in support of the Product Standard¹¹ and the Value Chain (Scope 3) Standard.¹²

The assessment, which is detailed in Attachment 3, utilized data quality indicators of precision, completeness, temporal representativeness, geographic representativeness, and technological representativeness, relating them to established uncertainty factors based on data quality criteria. Using these uncertainty factors to calculate the square of the geometric mean then yields a statistical representation of the data uncertainty. Attachment 3 details this assessment.

¹⁰ *Quantitative Inventory Uncertainty*, 2011, Greenhouse Gas Protocol

¹¹ WRI & WBCSD, *op. cit.*

¹² *Greenhouse Gas Protocol – Corporate Value Chain(Scope 3) Accounting and Reporting Standard*, 2011, World Resources Institute & World Business Council for Sustainable Development



5.0 Conclusions

The overall carbon footprint for the European 1.5 liter bottle format was estimated at 163 grams of CO₂ per 1.5 liter bottle. The analysis identified the major contributors to the overall footprint as the following:

- Distribution transportation (39%),
- PET bottle (37%),
- Corrugated tray (11%), and
- Production energy use (natural gas and electricity) (5%).

The overall carbon footprint for the North American 500 milliliter bottle was estimated at 83 grams of CO₂ per 500 milliliter bottle. The following were identified as the largest contributors:

- PET bottle (38%),
- Distribution transportation (29 %),
- Retail energy use (electricity and natural gas) (12%), and
- Corrugated tray (5%).

De minimis sources - that is, those with emissions of less than one percent of the total - were:

- Shrinkwrap,
- Wood,
- Water,
- Warehousing, and
- Domestic product cooling.

Analysis of the select value chain aspects indicated that:

- Changes in bottle weights result in emissions in the range of 30 to 50 percent of the total carbon footprint;
- Product cooling for the North America scenario could account for up to 30 percent of the total, but, for Europe, up to 8 percent of the total. The difference is due to longer storage times, greater fraction cooled in retail facilities and higher emission factors for electricity generation;
- Variations in the electricity grid could account for up to 21 percent for North America, but only 12 percent for Europe due to the higher percentage of renewable generation in Europe;
- The mode of transport and choice of emission factor for distribution transport can have a significant effect on distribution emissions. Road transport emissions are greater than those resulting from rail transport. Emission factor choice for both modes of transport can significantly vary by the type of vehicle (e.g. electric versus diesel rail transport); and
- Utilization of the closed loop approximation method for packaging materials results in a lower impact (three to five percent) on the total carbon footprint than the recycled content methodology.



These analysis results can be utilized to support discussions on the variability of carbon impacts from similar products, supply chain carbon contributions, and prioritization of reduction opportunities.

6.0 Topics for Further Study

Analysis of the literature, available measurements, activity data, emission factors, and modeling methodologies utilized in this investigation of the carbon footprint of bottled water identified several topics that would benefit from additional research in order to increase reliability and precision of results:

- **Electricity Emission Factors -**
Evaluation of the carbon implications of utilizing specific electricity emission factors that represent the local grid mix and show the impact of renewables;
- **Distribution -**
Detailed assessment of the impacts of actual distribution logistics and modal change options; and
- **Data Quality -**
A more detailed look at activity and emission factor data quality and uncertainty would identify opportunities for improvement in quality for those activities that are significant contributors to the carbon footprint and would increase the reliability of the results thereby improving confidence in any decision-making based on those results.



Attachment 1. Data Sources and Assumptions

Bottled Water – Europe

Beverage Ingredients	
Water	
<i>Emission Factor</i>	Assumed .000271 gCO ₂ e/g
Packaging Materials	
<i>Transport (Rail)</i>	Based on European Average Conditions
<i>Transport (Road)</i>	DEFRA, 0.0946 kg/t-km for trucks over 16 tonnes; average of EURO3, EURO4, EURO5
PET Bottle	
<i>Emission Factor</i>	Plastics Europe
<i>Weight</i>	BIER Member Input
<i>Distance Traveled (Rail)</i>	Assumed 0 km
<i>Distance Traveled (Road)</i>	Assumed 0 km
PP LID	
<i>Emission Factor</i>	Plastics Europe (Used PET as Proxy)
<i>Weight</i>	BIER Member Input
<i>Distance Traveled (Rail)</i>	Assumed 250 km
<i>Distance Traveled (Road)</i>	Assumed 250 km
Paper Label	
<i>Emission Factor</i>	“Solid Waste management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks”, 3rd Edition, September 2006, United States Environmental Protection Agency
<i>Weight</i>	BIER Member Input
<i>Distance Traveled (Rail)</i>	Assumed 0 km
<i>Distance Traveled (Road)</i>	Assumed 400 km
Label Adhesive	
<i>Emission Factor</i>	Plastics Europe
<i>Functional Unit (Uses per returnable bottle)</i>	Informed estimate
<i>Weight of Bottle</i>	BIER Member Input
<i>Distance Traveled (Rail)</i>	Assumed 0 km
<i>Distance Traveled (Road)</i>	Assumed 400 km
Corrugated Tray	
<i>Emission Factor</i>	“Solid Waste management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks”, 3rd Edition, September 2006, United States Environmental Protection Agency
<i>Functional Unit (Uses per Tray)</i>	Average corrugated tray used 6 times, based on BIER Member Input
<i>Weight of Tray</i>	BIER Member Input
<i>Distance Traveled (Rail)</i>	Assumed 0 km
<i>Distance Traveled (Road)</i>	Assumed 400 km
Wood Pallet	
<i>Emission Factor</i>	“Solid Waste management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks”, 3rd Edition, September 2006, United States Environmental Protection Agency
<i>Functional Unit (Pallet)</i>	Average pallet used 16800 times, based on BIER Member Input
<i>Weight of Pallet</i>	BIER Member Input
<i>Distance Traveled (Rail)</i>	Assumed 0 km
<i>Distance Traveled (Road)</i>	Assumed 150 km



Bottled Water – Europe (continued)

Production and Warehouse:	
<i>Bottled Water Emissions</i>	NWNA Study: http://beveragecafootprint.com/?page_id=205 Section 4.1; footnote 3
<i>Production Emissions (Low) Local Electric Grid</i>	France EF g CO ₂ e/kWh IEA
<i>Production Emissions (High) Local Electric Grid</i>	UK average EF Source IEA
<i>Electricity Use</i>	g/kWh, EU-27 "CO ₂ Emissions from Fuel Combustion", International Energy Agency, 2010 edition
Warehouse	
<i>Electricity Emission Factors</i>	For EU-27 in 2008 "CO ₂ Emissions from Fuel Combustion", International Energy Agency, 2010 edition
<i>Natural Gas Emission Factor</i>	"Fuel Emissions Factor" spreadsheet, 2009, Energy Information Administration
<i>Electric Use</i>	NWNA Study: http://beveragecafootprint.com/?page_id=205 Section 4.1; footnote 3
<i>Natural Gas Use</i>	NWNA Study: http://beveragecafootprint.com/?page_id=205 Section 4.1; footnote 3
<i>Area</i>	Informed estimate
<i>Storage Duration</i>	BIER Member Input
Retail And Consumption	
Retail refrigeration	
<i>"Chill to" temperature</i>	5 deg C, BIER Member Input
<i>Fraction chilled</i>	1%, BIER Member Input
<i>Capacity</i>	Informed estimate
<i>Storage Duration (Days)</i>	BIER Member Input
<i>Refrigerant</i>	R-404a refrigerant - GWP of 3922 (Revised Draft Analysis of US Commercial Supermarket Refrigeration Systems, 2005, ICF Consulting)
<i>Cooler Size</i>	140 in x 28 in deep x 28 in high usable storage (Hussmann, 2003, Data Sheet Set for P/N 0381957C, 12 foot cooler)
<i>Annual Leak Rate</i>	15 % Revised Draft Analysis of US Commercial Supermarket Refrigeration Systems, 2005, ICF Consulting
In-store lighting/heating	
<i>Average Annual kWh use of Retailer (kWh/SF*yr.)</i>	http://www.eia.doe.gov/emeu/consumptionbriefs/cbecs/pbawebiste/retailserv/retserv_howuseelec.htm
<i>Average Annual Natural Gas use of Retailer (therms/SF*yr.)</i>	http://www.eia.doe.gov/emeu/consumptionbriefs/cbecs/pbawebiste/retailserv/retserv_howuseelec.htm
<i>SF of Product</i>	Informed estimate
<i>Residence Time (Days)</i>	BIER Member Input
<i>Electricity Grid (g CO₂e/kWh)</i>	For EU-27 in 2008 "CO ₂ Emissions from Fuel Combustion", International Energy Agency, 2010 edition
<i>Natural Gas EF (g CO₂e/therm)</i>	"Fuel Emissions Factor" spreadsheet, 2009, Energy Information Administration
Domestic Refrigeration	
<i>"Chill to" temperature</i>	3.3 deg C, BIER Member Input
<i>Fraction chilled</i>	30%, BIER Member Input



Bottled Water – Europe (continued)

Transportation and Distribution	
<i>Road</i>	DEFRA, 0.0946 kg/t-km for trucks over 16 tonnes; average of EURO3, EURO4, EURO5
<i>Road High</i>	0.2534 kg/tkm for trucks 3.5 - 16 tonnes based on Ecoinvent data for EURO3, EURO4, and EURO5
<i>Road Low</i>	Recommended emissions factor for articulated truck
<i>Distance traveled by road</i>	Assumed 400 km
<i>Rail</i>	Based on European Average Conditions
<i>Rail High</i>	Ecoinvent Transport Report (No 14), Table 6-17 shows 33.6 g CO2/tkm for diesel trains
<i>Rail Low</i>	Ecoinvent Transport Report (No 14), Table 6-17 shows 2.13 g CO2/tkm for electric trains
<i>Distance traveled by rail</i>	Assumed 400 km
<i>Ocean</i>	Ecoinvent 2.0
<i>Ocean High</i>	Recommended high end range emissions factor
<i>Ocean Low</i>	Ecoinvent 2.0
<i>Distance traveled by ocean</i>	Assumed 0 km



Attachment 1. Data Sources and Assumptions (continued)

Bottled Water – North America

Beverage Ingredients	
Water	
<i>Emission Factor</i>	Assumed .000271 gCO ₂ e/g
Packaging Materials	
<i>Transport (Rail)</i>	Based on 480 ton-miles/gallon diesel (American Association of Railroads)
<i>Transport (Road)</i>	Ecoinvent 2.0 : transport, lorry >16t, fleet average/tmi/RER
PET Bottle	
<i>Emission Factor</i>	Plastics Europe
<i>Weight</i>	BIER Member Input
<i>Distance Traveled (Rail)</i>	Assumed 0 mi
<i>Distance Traveled (Road)</i>	Assumed 0 mi
PP LID	
<i>Emission Factor</i>	Plastics Europe (Used PET as Proxy)
<i>Weight</i>	BIER Member Input
<i>Distance Traveled (Rail)</i>	Assumed 0 mi
<i>Distance Traveled (Road)</i>	Assumed 250 mi
Paper Label	
<i>Emission Factor</i>	"Solid Waste management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks", 3rd Edition, September 2006, United States Environmental Protection Agency
<i>Weight</i>	BIER Member Input
<i>Distance Traveled (Rail)</i>	Assumed 0 mi
<i>Distance Traveled (Road)</i>	Assumed 250 mi
Label Adhesive	
<i>Emission Factor</i>	Plastics Europe
<i>Weight of Bottle</i>	BIER Member Input
<i>Distance Traveled (Rail)</i>	Assumed 0 mi
<i>Distance Traveled (Road)</i>	Assumed 250 mi
Corrugated Tray	
<i>Emission Factor</i>	"Solid Waste management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks", 3rd Edition, September 2006, United States Environmental Protection Agency
<i>Functional Unit (Uses per Tray)</i>	Average corrugated tray used 6 times, based on BIER Member Input
<i>Weight of Tray</i>	BIER Member Input
<i>Distance Traveled (Rail)</i>	Assumed 0 mi
<i>Distance Traveled (Road)</i>	Assumed 250 mi
Wood Pallet	
<i>Emission Factor</i>	"Solid Waste management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks", 3rd Edition, September 2006, United States Environmental Protection Agency
<i>Weight</i>	BIER Member Input
<i>Functional Unit (Uses)</i>	Average pallet used 27210 times, based on BIER Member Input
<i>Distance Traveled (Rail)</i>	Assumed 0 mi
<i>Distance Traveled (Road)</i>	Assumed 100 mi



Bottled Water – North America (continued)

Production and Warehouse:	
<i>Bottled Water Emissions</i>	NWNA Study: http://beveragelcafootprint.com/?page_id=205 Section 4.1; footnote 3
<i>Production Emissions (Low) Local Electric Grid</i>	Canada Average IEA
<i>Production Emissions (High) Local Electric Grid</i>	WECC Rockies EF. US EPA eGRID 2010
<i>Electricity Use</i>	g/kWh, eGRID USEPA Average 2008
Warehouse	
<i>Electricity Emission Factors</i>	g/kWh, eGRID USEPA Average 2008
<i>Natural Gas Emission Factor</i>	"Fuel Emissions Factor" spreadsheet, 2009, Energy Information Administration.
<i>Electric Use</i>	NWNA Study: http://beveragelcafootprint.com/?page_id=205 Section 4.1; footnote 3
<i>Natural Gas Use</i>	NWNA Study: http://beveragelcafootprint.com/?page_id=205 Section 4.1; footnote 4
<i>Area</i>	Informed estimate
<i>Storage Duration</i>	BIER Member Input
Retail And Consumption	
Retail refrigeration	
<i>"Chill to" temperature</i>	5 deg C, BIER Member Input
<i>Fraction chilled</i>	3%, BIER Member Input
<i>Capacity</i>	Informed estimate
<i>Storage Duration (Days)</i>	BIER Member Input
<i>Refrigerant</i>	R-404a refrigerant - GWP of 3922 (Revised Draft Analysis of US Commercial Supermarket Refrigeration Systems, 2005, ICF Consulting)
<i>Cooler Size</i>	140 in x 28 in deep x 28 in high usable storage (Husmann, 2003, Data Sheet Set for P/N 0381957C, 12 foot cooler)
<i>Annual Leak Rate</i>	15 % Revised Draft Analysis of US Commercial Supermarket Refrigeration Systems, 2005, ICF Consulting
In-store lighting/heating	
<i>Average Annual kWh use of Retailer (kWh/SF*yr.)</i>	http://www.eia.doe.gov/emeu/consumptionbriEFs/cbecs/pbawebwebsite/retailserv/retserv_howuseelec.htm
<i>Average Annual Natural Gas use of Retailer (therms/SF*yr.)</i>	http://www.eia.doe.gov/emeu/consumptionbriEFs/cbecs/pbawebwebsite/retailserv/retserv_howuseelec.htm
<i>SF of Product</i>	Informed estimate
<i>Residence Time (Days)</i>	BIER Member Input
<i>Electricity Grid (g CO2e/kWh)</i>	g/kWh, eGRID USEPA Average 2008
<i>Natural Gas EF (g CO2e/therm)</i>	"Fuel Emissions Factor" spreadsheet, 2009, Energy Information Administration
Domestic Refrigeration	
<i>"Chill to" temperature</i>	3.3 deg C, BIER Member Input
<i>Fraction chilled</i>	30%, BIER Member Input



Bottled Water – North America (continued)

Transportation and Distribution	
<i>Road</i>	Ecoinvent 2.0: transport, lorry >16t, fleet average/tmi/RER
<i>Road High</i>	0.2534 kg/tkm for trucks 3.5 - 16 tonnes based on Ecoinvent data for EURO3, EURO4, and EURO5
<i>Road Low</i>	Recommended emissions factor for articulated truck
<i>Distance traveled by road</i>	Assumed 250 mi
<i>Rail</i>	Based on 480 ton-miles/gallon diesel (American Association of Railroads)
<i>Rail High</i>	Ecoinvent Transport Report (No 14), Table 6-17 shows 33.6 g CO ₂ /tkm for diesel trains
<i>Rail Low</i>	Ecoinvent Transport Report (No 14), Table 6-17 shows 2.13 g CO ₂ /tkm for electric trains
<i>Distance traveled by rail</i>	Assumed 250 mi
<i>Ocean</i>	Ecoinvent 2.0
<i>Ocean High</i>	Recommended high end range emissions factor
<i>Ocean Low</i>	Ecoinvent 2.0
<i>Distance traveled by ocean</i>	Assumed 0 mi



Attachment 2. Baseline Carbon Footprint Summary – Bottled Water^a

	Baseline							
	EUR Closed loop		EUR Recycled Content		NA Closed loop		NA Recycled Content	
Upstream								
Packaging Materials	85.83	50%	104.48	58%	42.81	54%	48.50	54%
PET Bottle (500 mL)	60.84	36%	79.71	44%	31.04	39%	36.67	41%
PP Lid	2.69	2%	2.76	2%	2.71	3%	2.77	3%
Label	1.62	1%	1.62	1%	1.62	2%	1.62	2%
Label Adhesive	2.27	1%	2.34	1%	2.27	3%	2.34	3%
Corrugated Tray	17.99	11%	17.62	10%	4.50	6%	4.41	5%
Plastic (LDPE Shrink Wrap)	0.76	0%	0.78	0%	0.74	1%	0.77	1%
Wood	-0.34	0%	-0.35	0%	-0.08	0%	-0.08	0%
Beverage Ingredients	0.63	0%	0.63	0%	0.21	0%	0.21	0%
Water	0.63	0%	0.63	0%	0.21	0%	0.21	0%
Upstream Totals	90	50%	100	60%	40	50%	50	60%
Controlled								
Production	8.49	5%	8.49	5%	4.05	5%	4.05	5%
Production	8.49	5%	8.49	5%	4.05	5%	4.05	5%
Warehousing	0.03	0%	0.03	0%	0.02	0%	0.02	0%
Warehousing	0.03	0%	0.03	0%	0.02	0%	0.02	0%
Controlled Totals	10	10%	10	10%	0	0%	0	0%
Downstream								
Retail	2.20	1%	2.20	1%	10.15	13%	10.15	11%
Electricity and Natural Gas	2.14	1%	2.14	1%	9.97	12%	9.97	11%
Fugitive Refrigerants	0.06	0%	0.06	0%	0.18	0%	0.18	0%
Use	2.37	1%	2.37	1%	1.98	2%	1.98	2%
Electricity	2.37	1%	2.37	1%	1.98	2%	1.98	2%
Distribution	63.10	37%	63.10	35%	23.58	29%	23.58	26%
Transportation	63.10	37%	63.10	35%	23.58	29%	23.58	26%
Downstream Totals	70	40%	70	40%	40	50%	40	40%
Grand Total	170	100%	180	100%	80	100%	90	100%

^a Given the uncertainty inherent to secondary data points utilized in conducting these analyses, all “Total” values have been rounded to the nearest 10’s value.

Impact of applying Closed Loop Approximation and Recycled Content recycling allocation methodologies



Attachment 3. Uncertainty Determination

Data uncertainty was assessed applying the methodology and guidance provided in the Greenhouse Gas Protocol document, *Quantitative Inventory Uncertainty*,¹³ that was published in 2011 in support of the Product Standard and the Value Chain (Scope 3) Standard.

This assessment utilizes a pedigree matrix approach in which qualitative data quality indicators (precision, completeness, temporal representativeness, geographic representativeness, and technological representativeness (see Box)) are related to uncertainty ranges for various parameters.

Precision/Reliability: the degree to which the sources, data collection methods, and verification procedures used to obtain the data are specific to the process in question and are dependable

Completeness: the degree to which the data are statistically representative of the process

Temporal representativeness: the degree to which the data reflect the actual time (e.g., year) or age of the process

Geographical representativeness: the degree to which the data reflect actual geographic location of the processes within the inventory boundary (e.g. country or site)

Technological representativeness: the degree to which the data reflect the actual technology(ies) used in the process

An uncertainty factor is assigned to the five data quality indicators and four data quality criteria - very good, good, fair, and poor. These uncertainty factors are shown in Table A3-1.

Table A3-1. Uncertainty Factors based on Data Quality Ratings

	Very Good	Good	Fair	Poor
Precision	1.00	1.10	1.20	1.50
Completeness	1.00	1.05	1.10	1.20
Temporal Representativeness	1.00	1.10	1.20	1.50
Geographic Representativeness	1.00	1.02	1.05	1.10
Technological Representativeness	1.00	1.20	1.50	2.00

These uncertainty factors are used to calculate the total uncertainty, expressed as the square of the geometric standard deviation (95 percent confidence interval), as shown in the following equation.

¹³ *Quantitative Inventory Uncertainty*, 2011, Greenhouse Gas Protocol



$$SD_{g95} \cong \sigma^2_g = \exp \sqrt{[\ln(U_1)]^2 + [\ln(U_2)]^2 + [\ln(U_3)]^2 + [\ln(U_4)]^2 + [\ln(U_5)]^2}$$

Where:

U₁ = uncertainty factor for precision

U₂ = uncertainty factor for completeness

U₃ = uncertainty factor for temporal representativeness

U₄ = uncertainty factor for geographic representativeness

U₅ = uncertainty factor for technological representativeness

The large variability in data sources and quality within several process categories were pooled to arrive at an aggregate data quality rating for the category. For example, one member may have provided actual measured data while another member provided proxy data for the same process.

Table A3-2 shows the data quality ratings for the modeled process categories for the baseline and the resulting uncertainties (geometric standard deviations).

Table A3-2. Data Quality Ratings and Resulting Standard Deviations - Water Baseline

	Precision	Completeness	Temporal Representativeness	Geographic Representativeness	Technological Representativeness	Geometric Std Deviation ²
Beverage Ingredients	Fair	Fair	Fair	Fair	Good	1.40
Packaging Materials	Good	Good	Good	Good	Good	1.26
Production and Warehouse	Good	Fair	Good	Fair	Good	1.28
Retail and Consumption	Fair	Fair	Fair	Fair	Fair	1.60
Transportation and Distribution	Poor	Poor	Fair	Fair	Fair	1.88

