Research on the Carbon Footprint of Carbonated Soft Drinks

Beverage Industry Environmental Roundtable, June 2012

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 **carbonated soft drinks**, focuses on the key contributors of GHG emissions and the impact of aspect changes across the lifecycle of carbonated soft drinks 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]

---

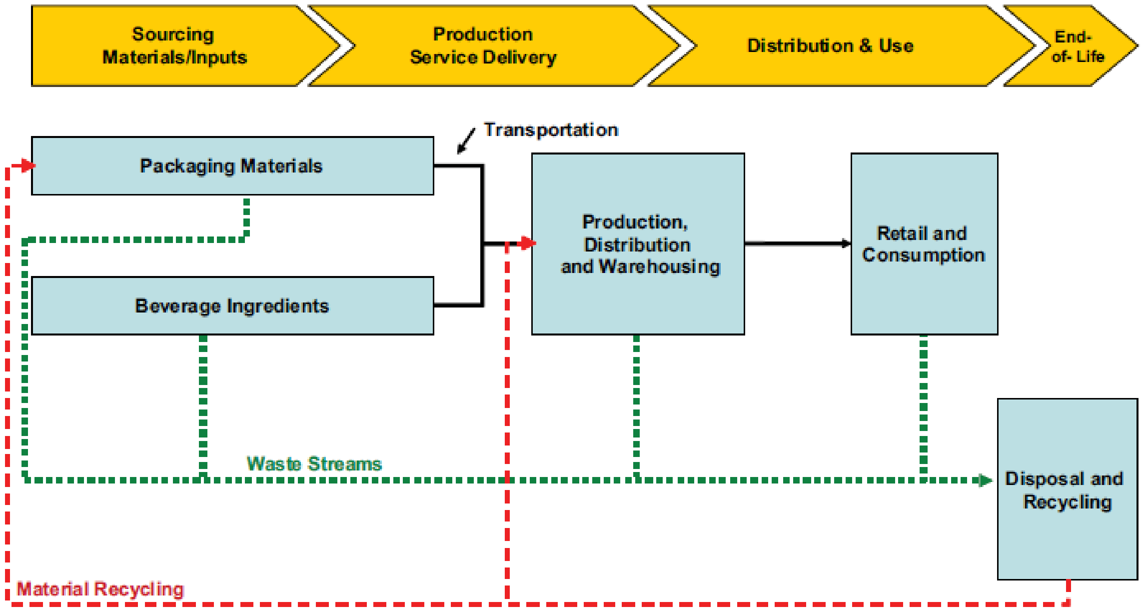
[1] *Beverage Industry Sector Guidance for Greenhouse Gas Reporting, v. 2.0*, 2010, Beverage Industry Environmental Roundtable

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 areas of the 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 Carbonated Soft Drink Modeling

Modeling methodologies utilized in this analysis of the carbon footprint of carbonated soft drinks 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 carbonated soft drinks 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 – Carbonated Soft Drink

Category	Processes	
Beverage Ingredients	Water	
	Sweeteners	
Packaging Materials *	PET Bottle	Aluminum Can
	Polypropylene Cap	Fiberboard Case
	HDPE Label	LPDE Shrink Wrap
	LPDE Shrink Wrap	Wood Pallet
	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

---

[2] *Ibid*., p 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

- Manufacture and transport of packaging materials not associated with final product.

3.1 Beverage Format

The following beverage formats were analyzed:

- **Europe – 1.5 liter PET bottle; six-pack; shrink wrapped**, and
- **North America – 355 milliliter aluminum can; 12-pack; cardboard case.**

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 processes identified in Table 1 were calculated using activity data provided by BIER member companies and emission factors from recognized sources, such as IPCC[5] and the ecoinvent[6] 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 determine their impacts on the overall product carbon footprint:

- Primary package weight -
  (Changing the weight of the bottle);
- Product cooling -
  (Changing the parameters for retail and domestic product cooling);
- Local electricity grid -
  (Changing the emissions factors);
- Variance in sweetener selection -
  (Changing brix value, source); and
- Recycling methodology -
  (Utilizing closed loop vs. recycled content allocation methods for packaging material[7] (see following box)

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.

---

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

[6] *ecoinvent data v 2.2*, 2009, Swiss Centre for Lifecycle Inventories

[7] *Greenhouse 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 (355 ml can)		
	Low		High	Low		High
PET Bottle (g)	39.9	41.5	46			
Aluminum Can (g)				10.4	13.9	17.4
Electrical Grid [a]						
Emission Factor (g CO2/kWh)	82.7	351	842.1	180.6	595.4	997.2
Warehouse Storage (days)	3	10	14	3	10	14
Sweetener Selection						
Emission Factor (g CO2/ g)	0.38	0.5	1.3	0.38	0.5	1.3
Product Cooling						
Retail						
Temperature (deg C)	7.0	5	3.0	7.0	5.0	3.0
Amount Cooled (%)	0	2.5	5	0	5	10
Domestic						
Storage Duration (days)	1	3	5	1	5	9

[a] Includes production, warehousing, retail, and domestic use

3.2.1 Data Sources and Assumptions

Data for primary package weight, retail and domestic product cooling and warehouse storage were provided by BIER members.

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 and 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 alternative sweeteners were supplied by BIER member companies. The low end of the range was represented by cane sugar, the high end by high fructose corn syrup, and the baseline factor was that of beet sugar.

Input of recycled PET to the bottle production process, which offsets the use of virgin PET, was assumed at 43 percent, based on BIER member input. The recycled content was conservatively assumed to be 3 percent.

The recycled aluminum content of the can was assumed at 68 percent based on an aluminum beverage can life cycle assessment.[8]

Detailed data references can be found in Attachment 1.

---

[8] *Life Cycle Impact Assessment of Aluminum Beverage Cans*, 2010, Aluminum Association, Inc.

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.

Table 3. Largest Contributors to Carbonated Soft Drink Carbon Footprint [a]

	Europe (1.5 liter PET bottle)		North America (355 ml can)	
	CO2e (grams)	Percent of Total	CO2e (grams)	Percent of Total
PET Bottle (1.5 L)	87.0	34.8%	NA	NA
Aluminum Can (355 mL)	NA	NA	137.8	68.9%
Sweeteners	81.8	32.7%	19.6	9.8%
Distribution Transportation	43.9	17.5%	17.9	9.0%
Retail Electricity & Natural Gas	9.1	3.6%	7.3	3.7%
Production	8.5	3.4%	2.9	1.4%
Electricity for Consumer Cooling	8.2	3.3%	4.3	2.2%
Others [b]	11.6	4.6%	10.1	5.1%
Total (grams CO2e per package)[c]	250	100%	200	100%
Total (grams CO2e per liter)	170		550	

[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.

As shown in the table, for the 1.5 liter Europe format, the total carbon footprint was calculated to be 251 grams of CO2e per 1.5 liter bottle. The PET bottle comprises 35 percent of the total product carbon footprint, followed by sweeteners (33%) and distribution transportation (17%). These three processes account for 85 percent of the total footprint.

In the North America format, the total carbon footprint is 195 grams of CO2e per 355 milliliter aluminum can. The aluminum can comprises 71 percent of the total product carbon footprint, followed by sweeteners (10%) and distribution transportation (9%). These three processes account for 90 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 PET bottle)[a]

	Range of Variation	
	CO2e (grams)	Portion of Total Footprint
PET Bottle Weight (closed loop approximation)	80 to 100	34% to 37%
PET Bottle Weight (recycled content)	110 to 130	45% to 48%
Local Electricity Grid	10 to 50	6% to 18%
Variance in Sweetener Selection	60 to 210	27% to 55%
Product Cooling Assumptions	10 to 30	4% to 12%

[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 (355 ml aluminum can)[a]

	Range of Variation	
	CO2e (grams)	Portion of Total Footprint
Aluminum Can Weight (closed loop approximation)	100 to 170	65% to 75%
Aluminum Can Weight (recycled content)	90 to 150	54% to 66%
Local Electricity Grid	10 to 20	5% to 10%
Variance in Sweetener Selection	20 to 50	8% to 22%
Product Cooling Assumptions	10 to 20	4% to 8%

[a] *See note c in Table 3*

4.2.1 Primary Package Weight

Europe – Using the closed loop approximation recycling method, a weight change in the 1.5 liter PET bottle from a low of 39.9 grams to a high of 46 grams results in emissions that range from 34 to 37 percent, respectively, of the total footprint. Using the recycled content method, the same container weight change results in emissions from 45 to 48 percent of the total footprint. This reduction using the closed loop approximation is primarily due to the beneficial impact of using recycled PET to displace virgin material.

North America – Using the closed loop approximation method, the weight change in the 355 milliliter aluminum can from 10.4 grams to 17.4 grams results in emissions ranging from 65 to 75 percent of the total footprint, while with the recycled content method, the emissions range from 54 to 66 percent of the total footprint. This reduction is due to the reduced primary energy demand under the recycled content method.[9]

---

[9] *Life Cycle Impact Assessment of Aluminum Beverage Cans*, 2010, Aluminum Association, Inc.

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 and fraction of the product cooled.

Europe – The modeled variables showed a range from 9 to 33 grams of CO2 per bottle which equates to 4 to 12 percent of the total footprint.

North America - Impacts for North America ranged from 9 to 16 grams CO2 per bottle, which equates to 4 to 8 percent of the total footprint.

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 six to eighteen percent of the total footprint and for North America it represented five to ten percent of the total.

4.2.4 Sweetener Selection

Production and transportation of cane sugar versus high fructose corn syrup were modeled to illustrate the impact of changing sweetener. For Europe, this change results in an increase in the contribution to the total footprint from 27 to 55 percent, while for North America, the contribution increases from 8 to 22 percent.

4.2.5 Recycling Allocation

The application of the two recycling allocation methodologies to packaging materials can be seen in Attachment 1, in which the impacts are highlighted. For Europe, packaging material emissions are 99 g CO2 per 1.5 liter bottle when applying the closed loop approximation methodology versus 126 g CO2 per bottle when applying the recycled content methodology. The closed loop approximation methodology results in lower emissions due to the impact of replacement of virgin materials with recycled materials.

For North America, the values are 142 g CO2 per 355 milliliter aluminum can and 124 g CO2 for the closed loop and recycled content methodologies, respectively. This result is due to the higher reported emission factor for the recycled content approach. This reduction is due to the reduced primary energy demand under the recycled content method.

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 and aluminum 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 regional electricity grid factors, 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 Standard[11] 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, and related 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 baseline bottle format was estimated at 251 grams of CO2 per 1.5 liter bottle. The analysis identified the following as major contributors to the overall carbon footprint:

- PET bottle (35%),
- Sweetener (33%), and
- Distribution transportation (17%).

The overall carbon footprint for the 355 milliliter North American baseline can format was estimated at 195 grams CO2 per 355 milliliter aluminum can. The following were identified as the largest contributors:

- Aluminum can (71%),
- Sweetener (10%), and
- Distribution transportation (9%).

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

- Label,
- Wood,
- Water, and
- Warehousing.

Analysis of the select value chain aspects indicated that:

- Changes in 1.5 liter PET bottle weights for the Europe format result in emissions in the range of 34 to 37 percent of the total carbon footprint for the closed loop approximation recycling method and 45 to 48 percent with the recycled content method;
- Changes in 355 milliliter can weights with the North American format result in emissions that are from 65 to 75 percent of the total footprint with the closed loop approximation method and 54 to 66 percent of the total with the recycled content method;
- Product cooling for the Europe scenario could account for up to 12 percent of the total, and, for North America, up to eight percent of the total;
- Variations in the electricity grid could account for up to 18 percent of the total carbon footprint for the Europe format, and 10 percent for North America; and
- Utilization of the closed loop approximation recycling methodology results in a lower packaging emissions for the 1.5 liter PET soft drink package than the recycled content methodology (99 g CO2 vs. 126 g CO2) due to the benefit of recycled PET displacing virgin material. Use of the recycled content methodology results in lower emissions for the 355 milliliter aluminum can format than the closed loop approximation methodology (124 g CO2 vs 142 g CO2) due to the reduced primary energy requirement for recycled aluminum.

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 carbonated soft drinks identified several topics that would benefit from additional research in order to increase reliability and precision of results.

- Distribution -
  Detailed assessment of the impacts of actual distribution logistics and modal change options, since distribution transportation comprises a significant portion of the total carbon footprint of both product formats; 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

Carbonated Soft Drink – Europe

Beverage Ingredients	
Transport (Rail)	Based on European Average Conditions
Transport (Road)	DEFRA, 0.0946 kg/t-km for trucks over 16 tonnes; average of EURO3, EURO4, EURO5
Brix Value	BIER Member Input
Amount of Sweetener (g)	Assumed 160 grams
Beet Sugar	
Emission Factor	BIER Member Input
Distance Traveled (Rail)	Assumed 0 km
Distance Traveled (Road)	Assumed 120 km
Cane Sugar	
Emission Factor	BIER Member Input
Distance Traveled (Rail)	Assumed 0 km
Distance Traveled (Road)	Assumed 100 km
High Fructose Corn Syrup	
Emission Factor	BIER Member Input
Distance Traveled (Rail)	Assumed 0 km
Distance Traveled (Road)	Assumed 100 km
High Fructose Starch-Based Corn Syrup	
Emission Factor	BIER Member Input
Distance Traveled (Rail)	Assumed 0 km
Distance Traveled (Road)	Assumed 100 km
Water	
Emission Factor	Assumed .000271 gCO2e/g
Packaging Materials	
Transport (Rail)	Based on European Average Conditions
Transport (Road)	DEFRA, 0.0946 kg/t-km for trucks over 16 tonnes; average of EURO3, EURO4, EURO5
Plastics Bottle	
Emission Factor	Plastics Europe
Weight	BIER Member Input
Distance Traveled (Rail)	Assumed 0 km
Distance Traveled (Road)	Assumed 200 km
Bottle Label	
Emission Factor	Plastics Europe
Weight	BIER Member Input
Distance Traveled (Rail)	BIER Member Input
Distance Traveled (Road)	BIER Member Input
Cap - HDPE	
Emission Factor	Plastics Europe
Weight	BIER Member Input
Distance Traveled (Rail)	Assumed 0 km
Distance Traveled (Road)	Assumed 800 km
Plastics (LDPE Shrink Wrap)	
Emission Factor	Plastics Europe
Weight	BIER Member Input
Distance Traveled (Rail)	Assumed 0 km
Distance Traveled (Road)	Assumed 250 km
Wood Pallet	
Emission Factor	"Solid Waste management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks", 3rd Edition, September 2006, United States Environmental Protection Agency
Functional Unit (Pallet)	BIER Member Input
Weight of Pallet	BIER Member Input
Distance Traveled (Rail)	Assumed 0 km
Distance Traveled (Road)	Assumed 100 km

Carbonated Soft Drink – Europe (continued)

Production and Warehouse:	
CSD Emissions	NWNA Study: http://beveragelcafootprint.com/?page_id=205 Section 4.1; footnote 3
Production Emissions (Low) Local Electric Grid	France EF g CO2e/kWh IEA
Production Emissions (High) Local Electric Grid	UK average EF Source IEA
Electricity Use	For EU-27 in 2008 "CO2 Emissions from Fuel Combustion", International Energy Agency, 2010 edition
Warehouse	
Electricity Emission Factor	For EU-27 in 2008 "CO2 Emissions from Fuel Combustion", International Energy Agency, 2010 edition
Natural Gas Emission Factor	"Fuel Emissions Factor" spreadsheet, 2009, Energy Information Administration
Electric Use	NWNA Study: http://beveragelcafootprint.com/?page_id=205 Section 4.1; footnote 3
Natural Gas Use	NWNA Study: http://beveragelcafootprint.com/?page_id=205 Section 4.1; footnote 4
Area	Informed estimate
Storage Duration	BIER Member Input
Retail And Consumption	
Retail refrigeration	
"Chill to" temperature	5 deg C, BIER Member Input
Fraction chilled	2.5%, BIER Member Input
Volume	Informed estimate
Storage Duration(Days)	BIER Member Input
Refrigerant	R-404a refrigerant - GWP of 3922 (Revised Draft Analysis of US Commercial Supermarket Refrigeration Systems, 2005, ICF Consulting)
Cooler Size	140 in x 28 in deep x 28 in high usable storage (Hussmann, 2003, Data Sheet Set for P/N 0381957C, 12 foot cooler)
Annual Leak Rate	15 % Revised Draft Analysis of US Commercial Supermarket Refrigeration Systems, 2005, ICF Consulting
In-store lighting/heating	
*Average Annual kWh use of Retailer (kWh/SF*yr.)*	http://www.eia.doe.gov/emeu/consumptionbriefs/cbecs/pbawebsite/retailserv/retserv_howuseelec.htm
*Average Annual Natural Gas use of Retailer (therms/SF*yr.)*	http://www.eia.doe.gov/emeu/consumptionbriefs/cbecs/pbawebsite/retailserv/retserv_howuseelec.htm
SF of Product	Informed estimate
Residence Time (Days)	BIER Member Input
Electricity Grid (g CO2e/kWh)	For EU-27 in 2008 "CO2 Emissions from Fuel Combustion", International Energy Agency, 2010 edition
Natural Gas EF (g CO2e/therm)	"Fuel Emissions Factor" spreadsheet, 2009, Energy Information Administration
Domestic Refrigeration	
"Chill to" temperature	4.15 deg C, BIER Member Input
Fraction chilled	75%, BIER Member Input
Transportation and Distribution	
Road	DEFRA, 0.0946 kg/t-km for trucks over 16 tonnes; average of EURO3, EURO4, EURO5
Distance traveled by road	Assumed 300 km
Rail	Based on European Average Conditions
Distance traveled by rail	Assumed 0 km
Ocean	Ecoinvent 2.0
Distance traveled by ocean	Assumed 0 km

Attachment 1. Data Sources and Assumptions (continued)

Carbonated Soft Drink – North America

Beverage Ingredients	
Transport (Rail)	Based on 480 ton-miles/gallon diesel (American Association of Railroads)
Transport (Road)	Ecoinvent 2.0: transport, lorry >16t, fleet average/tmi/RER
Brix Value	BIER Member Input
Amount of Sweetener (g)	Assumed 38 grams
Beet Sugar	
Emission Factor	BIER Member Input
Distance Traveled (Rail)	Assumed 0 mi
Distance Traveled (Road)	Assumed 100 mi
Cane Sugar	
Emission Factor	BIER Member Input
Distance Traveled (Rail)	Assumed 0 mi
Distance Traveled (Road)	Assumed 100 mi
High Fructose Corn Syrup	
Emission Factor	BIER Member Input
Distance Traveled (Rail)	Assumed 0 mi
Distance Traveled (Road)	Assumed 100 mi
High Fructose Starch-Based Corn Syrup	
Emission Factor	BIER Member Input
Distance Traveled (Rail)	Assumed 0 mi
Distance Traveled (Road)	Assumed 100 mi
Water	
Emission Factor	Assumed .000271 gCO2e/g
Packaging Materials	
Transport (Rail)	Based on 480 ton-miles/gallon diesel (American Association of Railroads)
Transport (Road)	Ecoinvent 2.0 : transport, lorry >16t, fleet average/tmi/RER
Aluminum Can	
Emission Factor	Aluminum Association
Weight	BIER Member Input
Distance Traveled (Rail)	Assumed 0 mi
Distance Traveled (Road)	Assumed 350 mi
Plastics (LDPE Shrink Wrap)	
Emission Factor	Plastics Europe
Functional Unit (Uses per crate)	Average shrink wrap used 12 times, based on BIER Member Input
Weight	BIER Member Input
Distance Traveled (Rail)	Assumed 0 mi
Distance Traveled (Road)	Assumed 300 mi
Fiberboard Case	
Emission Factor	“Solid Waste management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks”, 3rd Edition, September 2006, United States Environmental Protection Agency
Functional Unit (Uses per case)	Average case used 12 times, based on BIER Member Input
Weight of Case	BIER Member Input
Distance Traveled (Rail)	Assumed 0 mi
Distance Traveled (Road)	Assumed 300 mi
Wood Pallet	
Emission Factor	“Solid Waste management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks”, 3rd Edition, September 2006, United States Environmental Protection Agency
Weight	BIER Member Input
Functional Unit (Uses)	BIER Member Input
Distance Traveled (Rail)	Assumed 0 mi
Distance Traveled (Road)	Assumed 300 mi

Carbonated Soft Drink – North America (continued)

Production and Warehouse:	
CSD Emissions	NWNA Study: http://beveragelcafootprint.com/?page_id=205 Section 4.1; footnote 3
Production Emissions (Low) Local Electric Grid	Canada Average EF IEA
Production Emissions (High) Local Electric Grid	WECC Rockies EF US EPA eGRID 2010
Electricity Use	g/kWh, eGRID USEPA Average 2008
Warehouse	
Electricity Emission Factor	g/kWh, eGRID USEPA Average 2008
Natural Gas Emission Factor	"Fuel Emissions Factor" spreadsheet, 2009, Energy Information Administration
Electric Use	NWNA Study: http://beveragelcafootprint.com/?page_id=205 Section 4.1; footnote 3
Natural Gas Use	NWNA Study: http://beveragelcafootprint.com/?page_id=205 Section 4.1; footnote 4
Area	Informed estimate
Storage Duration	BIER Member Input
Retail And Consumption	
Retail refrigeration	
"Chill to" temperature	5 deg C, BIER Member Input
Fraction chilled	5%, BIER Member Input
Volume	Informed estimate
Storage Duration(Days)	BIER Member Input
Refrigerant	R-404a refrigerant - GWP of 3922 (Revised Draft Analysis of US Commercial Supermarket Refrigeration Systems, 2005, ICF Consulting)
Cooler Size	140 in x 28 in deep x 28 in high usable storage (Hussmann, 2003, Data Sheet Set for P/N 0381957C, 12 foot cooler)
Annual Leak Rate	15 % Revised Draft Analysis of US Commercial Supermarket Refrigeration Systems, 2005, ICF Consulting
In-store lighting/heating	
*Average Annual kWh use of Retailer (kWh/SF*yr.)*	http://www.eia.doe.gov/emeu/consumptionbriefs/cbecs/pbawebsite/retailserv/retserv_howuseelec.htm
*Average Annual Natural Gas use of Retailer (therms/SF*yr.)*	http://www.eia.doe.gov/emeu/consumptionbriefs/cbecs/pbawebsite/retailserv/retserv_howuseelec.htm
SF of Product	Informed estimate
Residence Time (Days)	BIER Member Input
Electricity Grid (g CO2e/kWh)	g/kWh, eGRID USEPA Average 2008
Natural Gas EF (g CO2e/therm)	"Fuel Emissions Factor" spreadsheet, 2009, Energy Information Administration
Domestic Refrigeration	
"Chill to" temperature	4.19 deg C, BIER Member Input
Fraction chilled	75%, BIER Member Input
Transportation and Distribution	
Road	Ecoinvent 2.0 : transport, lorry >16t, fleet average/tmi/RER
Distance traveled by road	Assumed 300 mi
Rail	Based on 480 ton-miles/gallon diesel (American Association of Railroads)
Distance traveled by rail	Assumed 0 mi
Ocean	Ecoinvent 2.0
Distance traveled by ocean	Assumed 0 mi

Attachment 2. Baseline Carbon Footprint Summary – Carbonated Soft Drink[a]

	Baseline							
	EUR Closed loop		*EUR Recycled Content*		*NA Closed loop*		*NA Recycled Content*	
Upstream								
Packaging Materials	**98.94**	**40%**	**126.08**	**45%**	**142.31**	**71%**	**123.52**	**69%**
PET Bottle (1.5 L)	86.96	35%	113.69	41%	NA			
Aluminum Can (355 mL)	NA				137.82	69%	119.33	66%
Cap (Polypropylene)	6.61	3%	6.86	2%	NA			
Fiberboard Case	NA				2.32	1%	1.96	1%
Label (HDPE)	1.19	0%	1.23	0%	NA			
Plastic	NA				2.23	1%	2.30	1%
Plastic (LDPE Shrink Wrap)	4.51	2%	4.65	2%	NA			
Wood	-0.33	0%	-0.34	0%	-0.07	0%	-0.07	0%
Beverage Ingredients	**82.19**	**33%**	**82.19**	**29%**	**19.63**	**10%**	**19.63**	**11%**
Sweeteners	81.82	33%	81.82	29%	19.54	10%	19.54	11%
Carbon Dioxide	0.00	0%	0.00	0%	0.00	0%	0.00	0%
Water	0.37	0%	0.37	0%	0.09	0%	0.09	0%
Upstream Totals	**180**	**70%**	**200**	**70%**	**160**	**80%**	**140**	**80%**
Controlled								
Production	**8.49**	**3%**	**8.49**	**3%**	**2.88**	**1%**	**2.88**	**2%**
Production	8.49	3%	8.49	3%	2.88	1%	2.88	2%
Warehousing	**0.01**	**0%**	**0.01**	**0%**	**0.00**	**0%**	**0.00**	**0%**
Warehousing	0.01	0%	0.01	0%	0.01	0%	0.01	0%
Controlled Totals	**10**	**0%**	**10**	**0%**	**0**	**0%**	**0**	**0%**
Downstream								
Retail	**9.69**	**4%**	**9.69**	**3%**	**7.63**	**4%**	**7.63**	**4%**
Electricity and Natural Gas	9.09	4%	9.09	3%	7.34	4%	7.34	4%
Fugitive Refrigerants	0.60	0%	0.60	0%	0.29	0%	0.29	0%
Use	**8.19**	**3%**	**8.19**	**3%**	**4.32**	**2%**	**4.32**	**2%**
Electricity	8.19	3%	8.19	3%	4.32	2%	4.32	2%
Distribution	**43.85**	**18%**	**43.85**	**16%**	**17.91**	**9%**	**17.91**	**10%**
Transportation	43.85	18%	43.85	16%	17.93	9%	17.93	10%
Downstream Totals	**60**	**30%**	**60**	**20%**	**30**	**20%**	**30**	**20%**
Grand TOTAL	**250**	**100%**	**280**	**100%**	**200**	**100%**	**180**	**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:
U_1 = uncertainty factor for precision
U_2 = uncertainty factor for completeness
U_3 = uncertainty factor for temporal representativeness
U_4 = uncertainty factor for geographic representativeness
U_5 = 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 - CSD Baseline

	Precision	Completeness	Temporal Representativeness	Geographic Repesentativeness	Technological Representativeness	Geometric Std Deviation ^{2}
Beverage Ingredients	Good	Good	Good	Good	Good	1.26
Packaging Materials	Good	Good	Good	Good	Good	1.26
Production and Warehouse	Good	Fair	Good	Good	Good	1.26
Retail and Consumption	Fair	Fair	Fair	Fair	Fair	1.60
Transportation and Distribution	Poor	Poor	Fair	Fair	Fair	1.89