



Research on the Carbon Footprint of Spirits

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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 presents results regarding the carbon footprint assessment of **spirits**. Given that detailed life cycle assessments and greenhouse gas emissions evaluations for the European spirits industry have been performed, particularly for Scotch whisky,¹ this document and the supporting emissions calculation tool focus on the key contributors of GHG emissions and show the impact of aspect changes across the lifecycle of whiskey in 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.

¹ *Scotch Whisky Life Cycle Assessment*, 2009, The Scotch Whisky Research Institute and The Scotch Whiskey Association



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*.²

² *Beverage Industry Sector Guidance for Greenhouse Gas Reporting, v. 2.0*, 2010, Beverage Industry Environmental Roundtable

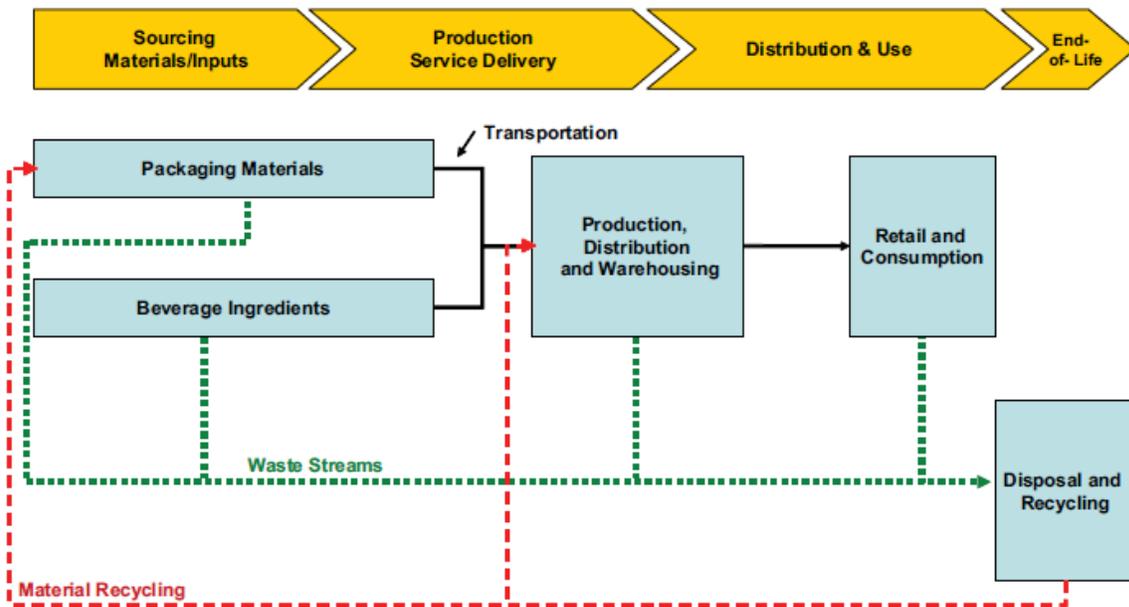


2.0 An Overview of Product Carbon Footprint

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 Spirits Modeling

Modeling methodologies utilized in this analysis of the carbon footprint of spirits followed those outlined in the *Beverage Industry Sector Guidance for Greenhouse Gas Emissions Reporting*.³ This beverage industry guidance is aligned with the recognized protocols contained in *The Greenhouse Gas Protocol*⁴ and *Publicly Available Specification PAS 2050 – Specification for the Assessment of the Life Cycle Greenhouse Gas Emissions of Goods and Services*.⁵

The carbon footprint of spirits 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 – Spirits

Category	Processes
Beverage Ingredients	Barley
	Corn
	Rye
	Water
Packaging Materials ^a	Glass Bottle
	PET Bottle
	Cap
	Cap
	Paper Label
	Paper Label
	Label Adhesive
	Label Adhesive
Production and Warehouse	Corrugated Cardboard
	Corrugated Cardboard
	LPDE Shrink Wrap
	LPDE Shrink Wrap
	Wood Pallet
	Wood Pallet
Retail and Consumption	Distillation
	Bottling
	Co-products - Agricultural Burden, Energy and Transportation
	Maturation (additional agricultural burden)
	Warehousing
Transportation and Distribution	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

³ *Ibid*, p. 6

⁴ *The Greenhouse Protocol – A Corporate Accounting and Reporting Standard*, 2004, World Business Council for Sustainable Development

⁵ *Publicly Available Specification 2050:2011 – Specification for the Assessment of the Lifecycle Greenhouse Gas Emissions*, 2011, British Standards Institute



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.

3.1 Beverage Format

The following beverage format, or functional unit, was analyzed:

- **North America – 750 milliliter glass bottle; 12-pack; corrugated cardboard.**

The analysis assumes a high-proof North American whiskey. It is not intended to represent a specific type or brand of spirit.

3.2 Analysis Methodology and Modeled Scenarios

The carbon emissions from the processes identified in Table 1 were calculated using activity data provided by BIER member companies and emission factors from recognized sources, such as IPCC⁶ and the ecoinvent⁷ 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:

- Raw material selection (emission factor),
- Distillation type (column vs. pot),
- Maturation (duration),
- Distribution assumptions (transportation modes),
- By- product processing (allocations),
- Primary package weight,
- Primary package material, and
- Recycling methodology⁸ (see box below).

⁶ *Guidelines for National Greenhouse Gas Inventories*, 2006, Intergovernmental Panel on Climate Change

⁷ ecoinvent data v 2.2, 2009, Swiss Centre for Lifecycle Inventories

⁸ *Greenhouse Gas Protocol – Product Life Cycle Accounting and Reporting Standard*, 2011, World Resources Institute & World Business Council for Sustainable Development



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.

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.

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

Table 2. Range of Modeled Process Variables

	North America		
	Low	Baseline	High
Raw Material Selection			
<i>Emission Factor (g CO₂e/g)</i>			
Barley	ND	0.421	ND
Corn	ND	0.434	ND
Rye	ND	0.342	ND
Primary Packaging Weight			
<i>Glass Bottle (g)</i>	385.0	450.0	595.0
Primary Packaging Material Selection			
<i>Glass Bottle (g)</i>		450.0	
<i>PET Bottle (g)</i>		50.0	
Distillation Type			
<i>Energy Use (MJ/liter of final product 80 proof)</i>			
Column	2.8	8.0	8.0
Pot	8.0	9.6	30.8
Bottling	0.2	0.6	1.5
Maturation			
<i>Storage Term (years)</i>	3.0	5.0	12.0
Transportation			
<i>Emission Factor (g CO₂/ ton-mile)</i>			
Road	143.2	143.2	143.2
Rail	3.4	23.2	54.1
Ocean	17.2	17.2	80.5

ND = No Data



3.2.1 Data Sources and Assumptions

Weights of the bottles and other packaging materials as well as data on energy use and raw material content and usage were provided by BIER members.

The generic grain recipe of 79 percent corn, 13 percent barley malt and 8 percent rye was provided by BIER members.

Emission factors for transportation of the finished product were based on railway trade organization data, global road transport data and ecoinvent database values and were utilized to illustrate the sensitivity of the change in mode of transportation on the overall footprint. Transport distances of 500 miles by road, 500 miles by rail, and 3000 miles by ship were assumed.

The emission factor for glass bottle production was taken from a European container glass life cycle assessment (LCA).⁹ The recycled glass content of the bottle was assumed at 54 percent based on this LCA.

Based on member input, a 2 percent annual loss of product was assumed during maturation.

Emission factors for PET bottles were obtained from PlasticsEurope's Eco-profile database¹⁰ for bottle-grade resin production and subsequent bottle conversion. The PET recycling rate (29%) was taken from NAPCOR's 2010 report on PET container recycling.¹¹ Input of recycled PET to the bottle production process, which offsets the use of virgin PET, was conservatively assumed at 3 percent.

Detailed data references can be found in Attachment 1.

⁹ *Life Cycle Assessment for Container Glass*, FEVE, 2010, The European Container Glass Federation

¹⁰ *Eco-profile for PET bottles*, 2010, PlasticsEurope

¹¹ *2010 Report on Post Consumer PET Container Recycling Activity – Final Report*, 2010, National Association for PET Container Resources



4.0 Results

The analysis results are presented by distillation type – column and pot – to illustrate the impact of the variable aspects on the total footprint of the two distillation processes.

4.1 Baseline

The largest contributors to the carbon footprint for the baseline scenario are shown in Table 3.

Table 3. Largest Contributors to Spirits Carbon Footprint ^a

	Column Distillation		Pot Distillation	
	CO2e (grams)	Percent of Total	CO2e (grams)	Percent of Total
Pot Distillation			1195.7	40.3
Column Distillation	992.3	36.1		
Glass Bottle (750 mL)	559.4	20.4	559.4	18.8
Maturation (Additional Ag Burden)	138.8	5.1	160.5	5.4
Warehousing	283.5	10.3	283.5	9.5
Corn	240.4	8.8	240.4	8.1
Transportation	185.5	6.8	185.5	6.2
Barley	95.3	3.5	95.3	3.2
Bottling	74.4	2.7	74.4	2.5
Electricity	62.1	2.3	62.1	2.1
Corrugated Cardboard	57.4	2.1	57.4	1.9
Others	60.9	2.2	55.8	1.9
Total (Closed Loop) ^c	2750	100	2970	100

^a Closed loop 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 column distillation process, the total carbon footprint was calculated to be 2745 grams of CO2e per 750 ml bottle. Of this total, distillation is the largest component (36%) of the total product carbon footprint, followed by the glass bottle (20%), warehousing (10%), and corn production and transport (9%). These processes account for 76 percent of the total footprint.

For the pot distillation process, the total carbon footprint is 2971 grams of CO2e per 750 milliliter bottle. Of this total, distillation is the largest contributor (40%). The glass bottle comprises 18 percent of the total, followed by warehousing (10%), and corn (8%). These processes account for 77 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 column distillation. Each of these aspects is discussed below.

Table 4. Impact of Changes to Select Value Chain Aspects – Column Distillation^a

	Range of Variation	
	CO2e (grams)	Portion of Total Footprint
Column distillation	350 to 990	17% to 36%
Maturation	80 to 360	3% to 12%
Distribution assumptions	170 to 470	6% to 16%
By-product processing ^b	-40	-2%
Primary packaging weight	480 to 730	18% to 25%
Primary packaging material	140 to 560	5% to 17%

^a See note c in Table 3

^b Due to the lack of significant data at the time of these analyses, a single value (vs. range) was assigned for the estimation of by-product impacts. It is BIER's intention to amend these analyses periodically and as additional data becomes available.

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 pot distillation. Each of these aspects is discussed below.

Table 5. Impact of Changes to Select Value Chain Aspects – Pot Distillation^a

	Range of Variation	
	CO2e (grams)	Portion of Total Footprint
Pot distillation	990 to 3820	36% to 68%
Maturation	90 to 410	3% to 13%
Distribution assumptions	170 to 470	6% to 14%
By-product processing ^b	-40	-1%
Primary packaging weight	480 to 730	17% to 23%
Primary packaging material	140 to 560	4% to 16%

^a See note c in Table 3

^b Due to the lack of significant data at the time of these analyses, a single value (vs. range) was assigned for the estimation of by-product impacts. It is BIER's intention to amend these analyses periodically and as additional data becomes available.



4.2.1 Raw Material Selection

Production and transport of corn, barley malt and rye make up 13 percent of the total carbon footprint for column distillation and 12 percent of the total for pot distillation based on the baseline agricultural emission factor data provided. As this data is universally recognized, no additional data was provided for alternative factors; thus a range was not modeled.

4.2.2 Primary Packaging Weight

The impact from a change in 750 ml glass bottle weights of 385 to 595 gram glass bottles resulted in an impact that is approximately 17 to 25 percent of the total footprint.

4.2.3 Primary Packaging Material

The impact of a 50 gram 750 ml PET bottle versus a 450 gram 750 ml glass bottle was assessed. The PET bottle production resulted in an impact that is four percent of the total footprint, compared to the glass bottle's impact that is 17 percent of the total.

4.2.4 Distillation

The contribution from column distillation varied from 17 percent to 36 percent of the total carbon footprint and the contribution from pot distillation varied from 36 percent to 68 percent of the total.

These results reflect the wide variation of distillation operations in the industry. The type of distillation utilized is highly dependent on the product and not interchangeable. For example, Scotch malt whisky utilizes pot distillation, and Scotch grain whisky is made in column stills. A blended whisky contains portions of both. Many other small batch spirits (e.g. bourbons, rums, and tequilas) are produced in pot stills, which offer more flexibility within the process.

Production volume and efficiency objectives are also drivers. Where high capacity and lower cost per unit output is the objective, column distillation would be utilized.

4.2.5 Maturation

Impact from the variation in the duration of maturation was modeled by determining the additional amount of raw materials required to compensate for evaporative losses occurring during the varying maturation times. Modeling a change in maturation duration from 3 years to 12 years results in a range of contribution to the total footprint from 3 to 13 percent, respectively.

Final product characteristics are dependent on specific maturation times. The specific characteristics, such as flavor profile, that give a spirit its desired identity can only be achieved by definitive maturation times. Thus, changing established maturation times would adversely affect any distilled spirit.



4.2.6 By-product Processing

Economic allocation of emissions to by-products was assessed utilizing the methodology detailed in the BIER sector guidance.¹² The emissions associated with the by-products - raw materials and their transport and production operations (e.g. dewatering) - are allocated to the by-product based on economic values of the primary product and the by-products.

The allocation of emissions associated with spent grains (distillers' dried grains and stillage) resulted in CO₂ reductions of 2 percent and 1 percent of the total whiskey footprint for the column and pot distillation scenarios, respectively.

4.2.7 Distribution Transportation

Modeling of distribution of the final product to the retailer and consumer included transport by truck, rail, and ship.

The transport impact on the total footprint ranged from 6 to 16 percent for a product produced using column distillation and 6 to 14 percent for a product from pot distillation.

4.2.8 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. Emission factors for glass production that reflect only the use of recycled material in the production process are unavailable. Thus the same factor referenced in Section 3.2.1, and its inherent recycled content, was used for both methodologies. The assessment of the two recycling allocation methodologies to packaging materials showed an insignificant impact for both the glass and PET bottles.

The PET emission factor for the two methodologies only differs by 2 percent, and the bottle is only 3 percent of the total carbon footprint. Thus, the difference in the two recycling methodologies on the overall footprint is insignificant.

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 glass 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.

¹² Beverage Industry Environmental Roundtable, *op cit.*, p. 60



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, 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.¹³ This guidance was published in support of the Product Standard¹⁴ and the Value Chain (Scope 3) Standard.¹⁵

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.

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

¹⁴ WRI & WBCSD, op. cit.

¹⁵ *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

For the column distillation process, the total carbon footprint was calculated to be 2745 grams of CO₂e per 750 milliliter bottle. The analysis identified the major contributors to the overall carbon footprint of the bottle as the following:

- Distillation (36%),
- Glass bottle (20%),
- Warehousing (10%), and
- Corn production and transport (9%).

For the pot distillation process, the total carbon footprint is 2971 grams of CO₂e per 750 milliliter bottle. The analysis identified the major contributors to the overall carbon footprint of the bottle as the following:

- Distillation (40%),
- Glass bottle (19%),
- Warehousing (10%), and
- Corn production and transport (8%).

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

- Rye,
- Wheat,
- Retail electricity and natural gas,
- Lid,
- Bottle Label,
- Label Adhesive,
- Water,
- Plastic (LDPE Shrink Wrap),
- Caramel,
- Fugitive Refrigerants, and
- Wood.

Analysis of the select value chain aspects indicated that:

- Agricultural raw material production and transport comprise 13 percent of the total carbon footprint;
- Emissions from energy use for distillation account for the majority of the total footprint, with the pot distillation having the capability of contributing from 36 to 68 percent of the emissions, based on the reported large range of energy use (eight to 31 megajouleJ per liter of production). Column distillation could contribute from 17 to 36 percent, resulting from energy use of three to eight MJ per liter;
- A change in maturation duration from three years to 12 years results in a change in the contribution to the total footprint of 3 percent to 13 percent;
- Allocation of the emissions associated with by-products had a two percent impact on the total footprint. In the future, BIER intends to expand its analysis of by-products as significant data



becomes available through other studies. BIER will look to incorporate a range of performance to reflect the various methods of by-product disposal; and

- The glass bottle contributed 17 percent to the total footprint, while the PET bottle contributed 4 percent.

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 spirits identified several topics that would benefit from additional research in order to increase reliability and precision of results:

- Recipe -
Comprehensive evaluation of the carbon implications of varying the grain recipe;
- 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 References and Assumptions - Spirits

Beverage Ingredients	
<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
Barley	
<i>Seed Production</i>	Ecoinvent 2.0
<i>Transport of Barley (Rail)</i>	BIER Member Input, 500 mi
<i>Transport of Barley (Road)</i>	BIER Member Input, 100 mi
<i>Barley Malting</i>	Created in Sima Pro using BIER Member Input
<i>Transport of Malt (Rail)</i>	BIER Member Input, 1500 mi
<i>Transport of Malt (Road)</i>	BIER Member Input, 15 mi
Corn	
<i>Seed Production</i>	Ecoinvent 2.0
<i>Distance Traveled (Rail)</i>	BIER Member Input, 500 mi
<i>Distance Traveled (Road)</i>	BIER Member Input, 15 mi
Rye	
<i>Seed Production</i>	Ecoinvent 2.0
<i>Distance Traveled (Rail)</i>	BIER Member Input, 1500 mi
<i>Distance Traveled (Road)</i>	BIER Member Input, 15 mi
Wheat	
<i>Emission Factor</i>	Wheat not included in Whiskey, BIER Member Input
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, 2011)
<i>Transport (Road)</i>	Ecoinvent 2.0 : transport, lorry >16t, fleet average/tmi/RER
Glass Bottle	
<i>Emission Factor</i>	FEVE The European Container Glass Federation
<i>Weight</i>	BIER Member Input
<i>Glass Bottle- Low Weight</i>	BIER Member Input
<i>Glass Bottle- High Weight</i>	BIER Member Input
<i>Distance Traveled (Rail)</i>	Assumed 0 mi
<i>Distance Traveled (Road)</i>	Assumed 400 mi
Alternative Packaging (Plastics 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 200 mi
Bottle 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 350 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 500 mi



Attachment 1. Data References and Assumptions – Spirits (continued)

Cap - HDPE	
<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 125 mi
Plastics (LDPE Shrink Wrap)	
<i>Emission Factor</i>	Shrink wrap impact not material based on BIER Member LCA
Corrugated Cardboard	
<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 Cardboard used 12 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 500 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 Wood Pallet is used 672 times, based on BIER Member data
<i>Distance Traveled (Rail)</i>	Assumed 0 mi
<i>Distance Traveled (Road)</i>	Assumed 500 mi
Production and Warehouse:	
<i>Pot Distillation</i>	BIER Member Input
<i>Column Distillation</i>	BIER Member Input
<i>Energy Use</i>	BIER Member Input
<i>Electric Emission Factor</i>	g/kWh, eGRID USEPA Average 2008
Co-Products	
<i>Transport Emission Factor</i>	Ecoinvent 2.0: transport, lorry >16t, fleet average/tmi/RER
<i>Mass (g/750 mL)</i>	BIER Member Input
<i>Value of Co-Products (USD/g)</i>	BIER Sector Guidance
<i>Value of Whiskey (USD/750 mL)</i>	BIER Sector Guidance
<i>Distance Traveled</i>	BIER Member Input
Warehousing	
<i>Annual Warehouse Energy Consumption</i>	BIER Sector Guidance
<i>Emission Factor</i>	g/MJ, eGRID USEPA Average 2008
Maturation	
<i>Storage Term</i>	BIER Member Input
<i>Annual Loss</i>	BIER Member Input



Attachment 1. Data References and Assumptions – Spirits (continued)

Retail And Consumption	
Retail 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>	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>	N/A
<i>Fraction chilled</i>	N/A
Ice for Consumption	
<i>Cubes per Serving</i>	2 Cubes, BIER Member Input
<i>Fraction Served on Ice</i>	50%, BIER Member Input
Transportation and Distribution	
<i>Road</i>	Ecoinvent 2.0: transport, lorry >16t, fleet average/tmi/RER
<i>Road High</i>	0.2534 kg/tmi 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 500 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 CO2/tmi for diesel trains.
<i>Rail Low</i>	Ecoinvent Transport Report (No 14), Table 6-17 shows 2.13 g CO2/tmi for electric trains
<i>Distance traveled by rail</i>	Assumed 500 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 3000 mi



Attachment 2. Baseline Carbon Footprint – Spirits^a

	Column Distillation				Pot Distillation			
	Baseline							
	Closed Loop		Recycled Content		Closed Loop		Recycled Content	
Upstream								
Packaging Materials	625.81	23%	624.55	23%	625.81	21%	624.55	21%
Glass Bottle (750 mL)	559.41	20%	559.41	20%	559.41	19%	559.41	19%
Bottle Label	3.60	0%	3.60	0%	3.60	0%	3.60	0%
Label Adhesive	0.74	0%	0.74	0%	0.74	0%	0.74	0%
Cap	4.83	0%	4.70	0%	4.83	0%	4.70	0%
Corrugated Cardboard	57.45	2%	56.34	2%	57.45	2%	56.34	2%
Plastic (LDPE Shrink Wrap)	0.00	0%	0.00	0%	0.00	0%	0.00	0%
Wood	-0.22	0%	-0.23	0%	-0.22	0%	-0.23	0%
Beverage Ingredients	357.23	13%	357.23	13%	357.23	12%	357.23	12%
Barley	95.32	3%	95.32	3%	95.32	3%	95.32	3%
Corn	240.41	9%	240.41	9%	240.41	8%	240.41	8%
Rye	21.37	1%	21.37	1%	21.37	1%	21.37	1%
Wheat	0.00	0%	0.00	0%	0.00	0%	0.00	0%
Caramel	0.00	0%	0.00	0%	0.00	0%	0.00	0%
Water	0.12	0%	0.12	0%	0.12	0%	0.12	0%
Upstream Totals	980	40%	980	40%	980	30%	980	30%
Controlled								
Production	1066.69	39%	1066.69	39%	1270.10	43%	1270.10	43%
Pot Distillation	0.00	0%	0.00	0%	1195.68	40%	1195.68	40%
Column Distillation	992.27	36%	992.27	36%	0.00	0%	0.00	0%
Bottling	74.42	3%	74.42	3%	74.42	3%	74.42	3%
Co-Products	5.60	0%	5.60	0%	5.60	0%	5.60	0%
Spent Grain Allocation	-43.35	-2%	-43.35	-2%	-43.35	-1%	-43.35	-1%
Energy + Transportation Inputs	48.95	2%	48.95	2%	48.95	2%	48.95	2%
Warehousing	283.50	10%	283.50	10%	283.50	10%	283.50	10%
Warehousing	283.50	10%	283.50	10%	283.50	10%	283.50	10%
Maturation	138.83	5%	138.83	5%	160.45	5%	160.45	5%
Maturation (Additional Ag Burden)	138.83	5%	138.83	5%	160.45	5%	160.45	5%
Controlled Totals	1500	60%	1500	60%	1720	60%	1720	60%
Downstream								
Retail	20.21	1%	20.21	1%	20.21	1%	20.21	1%
Electricity and Natural Gas	20.21	1%	20.21	1%	20.21	1%	20.21	1%
Fugitive Refrigerants	0.00	0%	0.00	0%	0.00	0%	0.00	0%
Use	62.07	2%	62.07	2%	62.07	2%	62.07	2%
Electricity	62.07	2%	62.07	2%	62.07	2%	62.07	2%
Distribution	185.47	7%	185.47	7%	185.47	6%	185.47	6%
Transportation	185.47	7%	185.47	7%	185.47	6%	185.47	6%
Downstream Totals	270	10%	270	10%	270	10%	270	10%
Grand Total	2750	100%	2740	100%	2970	100%	2970	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*,¹⁶ 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 reflects 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.

¹⁶ *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 - Spirits Baseline

	Precision	Completeness	Temporal Representativeness	Geographic Representativeness	Technological Representativeness	Geometric Std Deviation ²
Beverage Ingredients	Fair	Fair	Good	Good	Good	1.40
Packaging Materials	Good	Good	Good	Good	Good	1.27
Production and Warehouse	Fair	Fair	Fair	Good	Good	1.64
Retail and Consumption	Fair	Fair	Fair	Fair	Fair	1.60
Transportation and Distribution	Poor	Poor	Fair	Fair	Fair	1.88

