CARBON FOOTPRINT ANALYSIS OF MODERN SPIRITS BEVERAGES

Final Report

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CONFIDENTIAL

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CARBON FOOTPRINT ANALYSIS

I BACKGROUND AND INTRODUCTION

When husband-and-wife team Melkon Khosrovian and Litty Mathew first launched Modern Spirits in 2004, they handcrafted their line -- called Modern Spirits Artisan -- using conventional spirits and infused with local and exotic produce.

Soon, their unique and natural tasting products, like Celery Peppercorn and Grapefruit Honey, won many awards. Modern Spirits was named as one of the top 50 spirits in 2006 by *Wine Enthusiast* and “best of the tasting” by the *Wall Street Journal*. While Melkon and Litty would have liked to have taken all the credit, they learned their success hinged on some silent partners: their local farmers.

It turned out that several of their local farmers had begun converting their farms to organic, resulting in better quality produce. The couple noticed that their spirits began to taste better and better.

At that point, their minds were made. Organics held the key to make better tasting spirits. But as Melkon and Litty explored this new way of thinking, they realized that organic wasn’t just about flavor. As the couple began to connect the relationships between a bottle of spirits and the specific number of feet of farmland required to grow all the ingredients to produce that bottle…and the chemicals that organic farming helped keep out of that land and its nearby watersheds, they began to see organic as the starting point to something much bigger: sustainable spirits. And from that perspective, packaging became just as important as organic ingredients for the next stage of their products. They gave up their luxury glass bottles, laminated virgin paper labels and PVC capsules for a more sustainable aesthetic.

They applied this to their first green line, TRU organic vodkas and gin. Today, the company makes the largest portfolio of organic spirits in the world, with TRU vodkas and gin, CRUSOE rum, FRUIT LAB citrus, jasmine and hibiscus liqueurs and IXÁ tequila.

The portfolio’s packaging uses glass weighing 25% less than the average spirits bottle. Boxes are made from at least 35% post-consumer waste cardboard that fold together to eliminate the need for tape. Labels are made from 100% post-consumer waste recycled paper with soy based inks. The corks are recyclable and they’ve eliminated the plastic tamper-evident capsules altogether in favor of a simple paper strip.

As an added incentive to do more for the environment, Modern Spirits plants a tree for every bottle of TRU, CRUSOE, FRUIT LAB or IXÁ sold. Through Maine-based Sustainable Harvest, Modern Spirits has already helped plant more than 100,000 trees in the American rainforests.

The goal in creating these products was not merely to offset Modern Spirits’ own carbon footprint, but to create a product that would build awareness of environmental issues and the efforts that everyone should be making to address them. With the tree planting program, Modern Spirits attempts to offset its carbon in a very proactive manner by involving their consumers and the community.

In August 2008, Modern Spirits commissioned Four Elements Consulting, LLC to perform a carbon footprint (C-footprint) analysis of its TRU organic line of spirits. In 2011, Four Elements performed carbon footprints for three additional Modern Spirits products: CRUSOE rum, FRUIT LAB liqueur, and IXÁ tequila, and performed an update on TRU, based on the latest data and methodology. This report represents this current work.

A C-footprint analysis is the quantification of the greenhouse gases (GHGs) associated with the full life of a product or process. The goal of the C-footprint analysis is to provide a standards-based quantified carbon footprint of Modern Spirits’ beverages. The results may be used as follows:

- To provide data that will allow Modern Spirits to quantify and reduce or offset its GHGs associated with its products;

- To measure improvements over time;
- To enhance Modern Spirits' sustainability and environmental reporting with GHG-certified products;
- To educate Modern Spirits' customers and potentially assist in purchasing decisions;
- To potentially assist Modern Spirits' in business decisions.

Modern Spirits is already offsetting carbon production via its tree planting program. This analysis does not account for the carbon offsets due to the tree planting program.

This report is internal to Modern Spirits but, like the first C-footprint report for TRU, Modern Spirits intends to disclose the footprint and this report, or a portion of this report, on its website, to customers and other interested parties external to Modern Spirits.

II RESULTS: OVERALL CARBON FOOTPRINTS OF MODERN SPIRITS BEVERAGES

Based on the methodology, assumptions and modeling described in this report, the life cycle GHG emissions, in kilograms (kg) of carbon dioxide equivalents (CO2-eq) associated with one 750 ml bottle are found in Table 1.

Table 1 Total Life Cycle GHG Emissions per 750-ml Bottle

	TRU	CRUSOE	FRUIT LAB	IXA
Total (kg CO2-eq) per bottle	1.88	1.57	1.71	4.04

When looking at these totals, it is difficult to interpret what they mean, so contribution analyses are performed in order to understand the source of the GHG impacts. These are provided in the Results Section on page 12.

III METHODOLOGY AND STANDARDS

This C-footprint analysis adheres to the International Standardization Organization (ISO) standards on Life Cycle Analysis, i.e., ISO 140401 and ISO 14044,[2] since performing a carbon footprint is based largely on the principles of performing LCA. LCA is a tool for the systematic evaluation of the environmental impacts of a product through all stages of its life, which include extraction of raw materials, manufacturing, transport and use of products, and end-of-life management (e.g., recycling, reuse, and/or disposal).

Over the past several years, the demand for understanding the carbon footprint of products has grown exponentially. World Business Council on Sustainable Development (WBCSD) and World Resources Institute (WRI) have undertaken a multi-stakeholder process of developing new guidelines on supply chain and life cycle GHG accounting and reporting to standardize carbon footprinting.[3] These guidelines are in their final draft and as such are not formally available at this time. In the interim, a WRI/WBCSD technical working group "identified and confirmed the use of current best practices and standards including ISO 14040 and Publicly Available Specification (PAS) 2050" to be used for carbon footprinting.[4,5]

[1] ISO 14040:2006, the International Standardization Organization, Environmental management. Life cycle assessment. Principles and framework.

[2] ISO 14044:2006, Environmental management – Life cycle assessment – Requirements and guidelines.

[3] WBSCD and WRI, The Greenhouse Gas Protocol Initiative: Product Accounting & Reporting Standard, draft form, 2010.

[4] PAS 2050:2008, British Standards Institute, Specification for the assessment of life cycle GHG emissions of goods and services. Sponsored by Defra (UK's environmental agency) and Carbon Trust. PAS 2050 builds on the ISO 14040 standards on LCA.

[5] From a GHG Protocol newsletter, found at: http://www.ghgprotocol.org/ghg-protocols-product-and-supply-chain-initiative-launched-in-washington-dc-and-london.

Thus, in alignment with WRI and WBCSD, this carbon footprint assessment has been performed in accordance with the ISO 14040 series of standards on LCA and on PAS 2050. The study also follows CarbonFund.org's CarbonFree® Product Certification Carbon Footprint Protocol.

Meeting of PAS 2050 GHG Assessment Principals

The modeling of this study meets the five PAS principals on GHG assessments,[6] as follows:

- **Relevance:** This C-footprint analysis reflects the product life cycle GHG emissions for Modern Spirits' chosen inventory boundaries and will provide the information needed to meet Modern Spirits' C-footprint goals and objectives.
- **Completeness**: To the best of its ability, Modern Spirits has identified, accounted for and reported on all GHG emission sources and activities within the described life cycle boundaries. Any exclusions have been disclosed and justified.
- **Consistency:** Modern Spirits has produced the results using methodologies that will enable consistent calculations for future C-footprint analyses and meaningful benchmarking of products over time, if necessary.
- **Accuracy:** Any uncertainties and bias has been reduced as far as is practicable for LCA.
- **Transparency:** To the best of its ability, Modern Spirits has produced its C-footprint analysis in a factual and coherent manner. It has stated and disclosed relevant assumptions, and provides references to the accounting and calculation methodologies and data sources used.

IV Life Cycle of the TRU Organic Line – Scope Definition

Products Defined

TRU spirits are made from 100% organic wheat distillate and de-ionized water. The infusions of lemon, vanilla and the 14 aromatics of the gin occur in the most natural manner possible – maceration. The product contains real hand-zested organic lemon rind, real organic vanilla beans and real organic herbs and spices.

This analysis accounts for a weighted average of four TRU spirits' products, based on 2010 marketshare:

- TRU Straight: clean, smooth and well-rounded with a neutral finish ([redacted]%)
- TRU Lemon: crisp, vivid and true to the flavor of ripe citrus ([redacted]%)
- TRU Vanilla: sweet, floral aroma with hazelnut tones and a lingering finish ([redacted]%)
- TRU 2 Gin: full bodied with bold flavors and lots of complexity ([redacted]%)

CRUSOE rum is made from organic, fair trade sugarcane. FRUIT LAB hibiscus liqueur is made from hand-selected whole ingredients, including flowers, teas, and cane sugar. IXÁ tequila, which is produced in Jalisco, Mexico, is made with organic blue agave. More information on these products can be found on http://greenbar.biz.

These products share the same production operations (e.g., product blending, tank cleaning and sanitizing), bottling operations, packaging (bottle type, weight, labels), and shipping operations. Data used in this analysis is based on current (e.g., 2010) production. Since this carbon footprint consists of snapshots of the products over a year's period, the reader should understand that some of the data points are averages. For example, one average distribution distance is provided; actual distribution may vary depending on geographical location of customers.

System Boundaries - Life Cycle Stages Defined

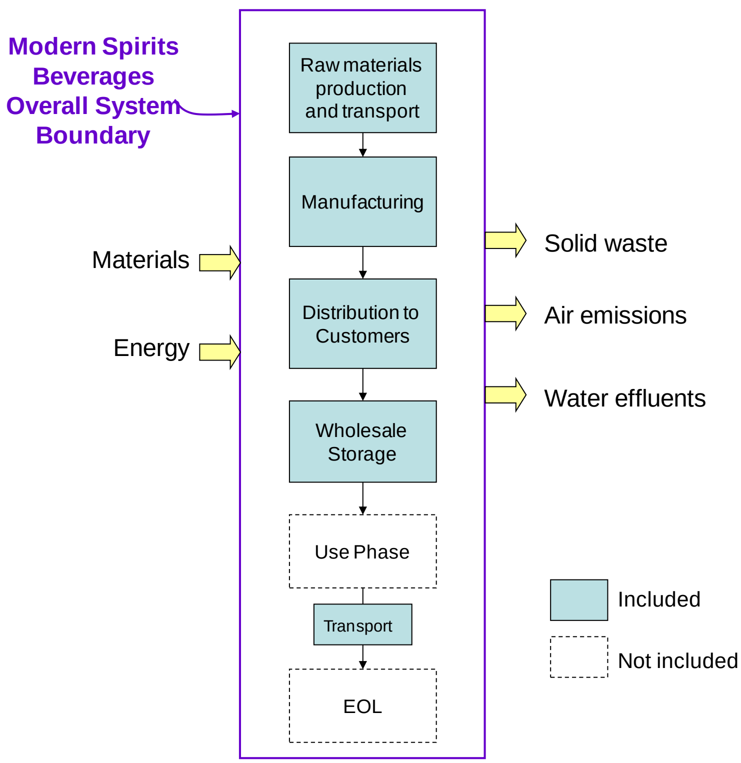
LCA is a tool used to comprehensively quantify and interpret the environmental inflows and outflows of a product or process system, and the system boundary for the product or process encompasses its entire life cycle. This C-footprint analysis includes four main life cycle stages of the product, described below and shown in the figure.

[6] PAS 2050, Section 4.1, which were adapted from ISO14064-1:2006.

- **Raw materials and transportation.** Examples of production inputs include ethanol, distilled water, vanilla, sugar, dried herbs, and packaging materials; Transport of the materials to the Modern Spirits facility is also included. Raw materials also encompass the agricultural processes to produce these inputs.
- **Manufacturing**. Manufacturing includes blending and bottling the products.
- **Distribution.** Distribution includes transporting products from the Modern Spirits facility to the distributor and then the customer, or directly to the customer.
- **Storage.** Storage includes storage at a wholesale distribution warehouse.
- **End-of-life**. Transport of the empty bottle to a glass recycling facility.

Use of the product, i.e., drinking and enjoying the beverage, is not included in this analysis. While transportation of the product to end-of-life fate is included, end-of-life impacts are not, with the assumption that the consumer sends the empty bottle to recycling. Note: one could argue that some consumers would not utilize recycling programs and would dispose of the bottle in the municipal solid waste (MSW) stream. However, more environmentally-conscious consumers who would purchase these organic products are more likely to take advantage of recycling programs. The recycling process itself is out of the boundaries of this study. It is assumed that within three years, the beverage is produced, distributed, and consumed.

Figure 1 Modern Spirits Beverages System Boundaries



Exclusion from the System Boundaries

Aside from the exclusions described in the previous section, the system boundaries exclude impacts for human activities such as employee commuting. Impacts for capital equipment are also excluded, as these impacts typically are negligible when allocated over the total quantity of product manufactured over the life cycle of the facilities and equipment.[7] Retail store impacts (heating, cooling, etc.) are not included, nor is transport of customers to and from the store to purchase the product.

[7] This is consistent with the PAS 2050 on excluding capital equipment.

ORGANIZATIONAL AND OPERATIONAL BOUNDARIES

For manufacturing operations, Modern Spirits chose to include emissions within the boundaries for which it has direct operational control, and has the ability to influence, set policies and control energy use and operations. All products except IXÁ are produced at the Modern Spirits facility, located in Monrovia, California. IXÁ is produced and bottled in Jalisco, Mexico, and is then sent to Monrovia for distribution to customers.

Modern Spirits is including scope 1 (direct facility emissions), scope 2 (indirect facility emissions), and scope 3 (i.e., other indirect emissions, which are a consequence of the activities of a company) emissions associated with the life cycle of these beverages. Operational boundaries are described below.

<u>Monrovia, California facility Scope 1 and Scope 2 Emissions</u>
Modern Spirits' direct emissions include a propane forklift used to unload and move packaging and other materials at the plant and a company-owned car used for occasional local deliveries and supply pick-ups. Modern Spirits' indirect emissions come from electrical energy used for processing and cooling the plant. There are no emissions associated with physical or chemical processing.

<u>Inclusion of Other Sources of GHGs: Scope 3 Emissions</u>
This C-footprint analysis accounts for scope 3 emissions upstream and downstream of the Modern Spirits operations. Other sources of GHG emissions in this analysis include:

- The upstream production of the raw materials that make up the Modern Spirits beverages and their packaging;
- The upstream production of the raw materials of IXÁ, its packaging and its manufacturing in Mexico;
- Transportation GHG impacts of all raw materials and the tequila to Monrovia;
- Distribution of the final products to the customer;
- Storage of the product; and
- Transportation of the bottle at end of life.

FUNCTIONAL UNIT

An LCA system is always defined by the function or service of the product it describes, so that results may be understood in relation to that function. A functional unit is defined so that products can be calculated on some quantitative basis. The function of Modern Spirits' beverages are to *provide an alcoholic beverage to responsible consumers over the age of 21 years.* The functional unit of the product has been defined as *one bottle of each beverage sold to a responsible consumer over the age of 21 years, amounting to 750-ml of beverage*.

CUT-OFF CRITERIA

ISO 14044 requires a cut-off criterion to be defined for the selection of materials and processes to be included in the system boundary. Several criteria are used in LCA practice to decide which inputs are to be studied, including mass, energy and environmental relevance.[8] The mass criterion was applied, and consistent with the "material emissions" threshold defined in PAS 2050, a cut-off goal of 99% of material inputs was defined. According to PAS 2050, a material contribution is "a contribution from any one source resulting in more than 1% of the total anticipated life cycle emissions of the product.[9]

Detailed information on the materials comprising the life of the product was collected, and every effort was made to include life cycle data for the production of these materials or to find suitable surrogate data (i.e., if data on that material was not available). A discussion as to the meeting of the cut-off criteria is found in the data quality section.

[8] ISO 14044, Section 4.2.3.3.
[9] PAS 2050, Section 3.33.

V Calculation Methodology and Tools

GHG Emissions and Sources

The main GHGs included in most GHG assessments are CO2, N2O, and CH4, which are usually fuel-combustion related. Other GHGs have been included in this assessment, and these are mostly found in the upstream material production inventories. A full list of the GHGs as well as their weighting factors are found in Appendix A.

Calculation Approach

The GHG emissions were calculated using a commercial LCA software tool, SimaPro 7.0.[10] SimaPro contains U.S. and European databases on a wide variety of materials in addition to an assortment of European- and U.S.-developed impact assessment methodologies, including the Intercontinental Panel on Climate Change (IPCC) 2007 factors (see Appendix A).[11] IPCC factors were used since its science on climate change and global warming potential weighting factors are the most globally-accepted.

The GHGs have been calculated on a 100-year time horizon CO2-equivalent basis. The life cycle inventory (LCI) output of GHGs from SimaPro are multiplied by their respective weighting factors to come up with a total GHG in CO2-eqs. A sample calculation converting inventory results to the total GHG is provided in Table 2.

Table 2: Sample Calculation

Selected GWP Flows	Weighting Factor	Sample LCI Result	Calculated GHG Result
Carbon Dioxide	1	2000	2000
Methane	25	15	375
Nitrous Oxide	298	0.04	12
		Total GHGs in CO2-equivalents →	**2387**

VI Carbon Footprint Analysis – Modeling and Assumptions

Data Collection

A detailed questionnaire was developed to collect product and process data from Modern Spirits' Monrovia facility, and included raw material inputs, process energy use, solid wastes, releases to air and water, and total product output. A similar set of data was asked of the facility in Mexico that produces the Tequila before it is shipped to Modern Spirits. Data were collected for the most recent time period in order to reflect current production practices and be representative of the products. In addition to the facility questionnaire, supplemental information was gathered for the life cycle stages following production, including distribution to customers, storage of the product and packaging.

[10] PRé Consultants: *SimaPro 7.0 LCA Software*. 2006. The Netherlands.
[11] Climate Change 2007. IPCC Fourth Assessment Report, The Physical Science Basis, found at: http://www.IPCC.ch/ipccreports/ar4-wg1.htm.

Life Cycle Stage Modeling and Assumptions

Upstream Materials Production

Raw Materials and Packaging

Data Tables. Table 3 through Table 7 provide the bill of materials (BOM) for each beverage, and Table 8 provides bottle-related packaging data.

Table 3 Contents of TRU Vodka

Ingredients	TRU Straight Per 350 gal	TRU Lemon Per 350 gal	TRU Vanilla Per 350 gal
Ethanol (wheat-based)	[redacted] gal	[redacted] gal	[redacted] gal
Water	[redacted] gal	[redacted] gal	[redacted] gal
Lemon	--	[redacted] lb	--
Vanilla bean	--	--	12 lb
Other	--	[redacted] [redacted]	[redacted] [redacted]

Table 4 Content of TRU 2 Gin

Ingredients	Per 20 liters
Ethanol (wheat-based)	[redacted] l
Water	[redacted] l
Lemons	[redacted] g
Vanilla bean	[redacted] g
Juniper berries	[redacted] g
Other dried herbs	[redacted] g

Table 5 Content of CRUSOE Rum

Ingredients	Per 350 gal
Ethanol (sugarcane-based)	[redacted] gal
Water	[redacted] gal
Other	[redacted] [redacted]

Table 6 Content of FRUIT LAB (Hibiscus)

Ingredients	Per 350 gal
Ethanol (sugarcane)	[redacted] gal
Water	[redacted] gal
Other	[redacted] [redacted]
Organic hibiscus flowers, dry leaf tea	[redacted] g

Table 7 Content of IXA

Ingredients	Per 350 gal
Ethanol (blue-agave)	[redacted] gal
Water	[redacted] gal

Table 8 Product Packaging per 750 ml Bottle

Material	TRU	CRUSOE	FRUIT LAB	IXA	Comments
Glass bottle (g)	620	600	600	588	
T-top synthetic cork no.7 recyclable (g)	8	7.8	7.8	5.3	Assume resin-based material
Paper label (g)	2	1.1	0.9	1.2	1000-label roll = 2kg (roll included paper label peels off and center board)
PETG Shrink capsule (g)	0	0	0	0	goes over the top of the cork - this is considered negligible, especially since it did not register a weight

Data Sources. The modeling of these materials comes from the U.S. LCI database, which is the most accepted set of U.S.-based LCI data on fuels, energy, and transportation,[12] the EcoInvent database,[13] and the SimaPro database. Where these sources of data did not contain information on certain materials used, a public search was made for alternative sources of LCI data on the materials, or else surrogate data was used. The Data Quality section provides more detailed information on the data in this study.

The carbon uptake to produce the biobased products (e.g., the wheat, herbs, etc.) has not been included in the model, as the product is a short-lived product (i.e., the carbon content in the beverage is not "captured" permanently). It should be noted that this one of the reasons for re-calculating TRU; one difference between the new TRU carbon footprint and the previous is that previously, the biobased carbon in the product was modeled as sequestered. Additionally, there is a small amount of product loss during manufacturing, calculated to approximately 0.1%.

Transportation of Materials to the Modern Spirits Facility

Transportation of each of these materials by truck and car to Modern Spirits was modeled as part of the upstream production stage.

MANUFACTURING

Energy Usage – TRU, CRUSOE, and FRUIT LAB

Manufacturing data includes the following:

Propane forklift. Propane is used to haul materials at the plant. Even though Modern Spirits borrows this forklift, it is still accounting for the GHG emissions generated from its use. Total usage has been estimated by Modern Spirits as approximately 30 hours per year. With a 33-lb propane tank providing approximately 8 hours of use, their total propane consumption is 124 lbs per year.

Gasoline-powered vehicle. Modern Spirits has adopted a weekly pickup/delivery route using a gasoline-powered company-owned car that averages 50 miles round trip. On a yearly basis, this amounts to 1300 miles. This mileage is divided between the pick-up of supplies (herbs in the Hibiscus FRUIT LAB) and deliveries.

Electricity. Electricity is used for:

- Pumping alcohol for blending;
- Bottling machine;
- Air conditioner;
- Labeling machine; and
- Capsule shrinking machine.

[12] Found at: http://www.nrel.gov/lci/.

[13] Generally reputed to be current, representative data on processes and chemicals, the EcoInvent database is a for-purchase database developed by the Swiss Center for Life Cycle Inventories. EcoInvent is used in conjunction with other databases in the SimaPro software. More information can be found at www.ecoinvent.org.

Electricity data was collected from utility bills for the period of November 10, 2009 through November 9, 2010, and amounts to 17,099 kWh. During that period, a total of 76,355 750-ml bottles of spirits were produced. Therefore, electricity usage per bottle equated to 0.22 kWh per bottle.

Table 9 summarizes the total energy use for each energy source and the associated quantity per bottle.

Table 9 Energy use and production – all products at Modern Spirits

Energy Source	Quantity	Usage per Bottle
Electricity (kWh)	17,099	0.22
Propane (lbs)	124	0.0016
Car usage (mi)	1300	0.017

<u>Energy Usage – IXÁ</u>

The processes at the Tequila plant include the following:

- Steaming the agave in a clay oven
- Crushing/shredding the softened agave
- Collected juices pumped into fermentation tanks
- Fermenting (temperature-controlled?)
- Pumping into stills
- Distillation
- Blending of tequila distillate and water
- Bottling and packaging

The table below summarizes the energy use per bottle of tequila produced. This data is primary data from the Mexican producer.

Table 10 Energy use – IXÁ

Energy Source	Usage per Bottle
Electricity (kWh)	0.13
Diesel fuel (liters)	Approx. 0.75
Propane (lbs)	0.0004

<u>Other Manufacturing Impacts</u>

Ancillary materials for cleaning. Each 350-gallon batch of spirits produced involves cleaning a tote twice as well as cleaning the pumps and bottling equipment. This equates to 2 cups each of citric acid and chlorinated trisodium phosphate. Additionally, the following are used:

- one cup of dishwashing detergent to clean the stainless bowls, stirring paddles etc,
- one cup of clothes detergent to clean the infusion bags and dish cloths, and
- one cup of environmentally-friendly detergent (Simple Green) to mop the floors.

These materials were included in the manufacturing stage of the model, and were modeled on a per bottle basis. Data sets for these materials came from the EcoInvent and SimaPro databases.

Air Emissions. No GHGs besides fuel combustion-related emissions are released from this facility.

Recovered material. A total of 15% of the used lemons are given away to family and friends, and this reuse of materials is not included in the model.

Waste. Some of the ingredients in TRU and FRUIT LAB listed in the tables above are added only for their flavor. So essentially, after their ingredients are added to the ethanol and water, they are disposed of. This model takes into account the disposal and GHG-related emissions of the portion of lemons (not reused), vanilla, juniper berries, hibiscus, and other herbs. First, their usage per bottle was calculated. Then a carbon-equivalent emissions factor from an EPA study on GHGs from landfills was applied,[14] as follows.

Total weighted average biomass discarded per 750-ml bottle	0.029 kg, or 2.9 E-5 metric ton (MT)
Food discards total emission factor from an average U.S. landfill	0.209 metric ton carbon-eq. (MTCE)
Total C-eq. per 750-ml bottle	5.9 E-6 MTCE
Total CO2-eq. per 750-ml bottle TRU beverages	**2.2 E-5 MT, or 0.022 kg**
Total CO2-eq. per 750-ml bottle FRUIT LAB	**1.4 E-5 MT, or 0.014 kg**

The EPA study takes into account:

- Net GHG emissions from methane generation from food discards in the landfill;
- Carbon storage from the food discards; and
- Transportation CO2 emissions from transport of the material to the landfill.

Additionally, the U.S. average landfill accounts for the average of emissions from: landfills without any landfill gas (LFG) recovery, landfills with LFG recovery and flaring, and landfills with LFG recovery and production of electricity with the LFG. The "food discards" category was used, as these ingredients fit most appropriately into that category in this study.

DISTRIBUTION TO CUSTOMERS

Shipping Information

For all products analyzed, the shipping distance to customers was estimated based on Modern Spirits' general sales information. Since over half of their sales stay on the west coast and less than half is distributed to the eastern U.S., the average estimated distance came to 1500 miles. The product is shipped by truck. For IXÁ, transportation of the finished Tequila product by truck to Modern Spirits from Mexico was accounted for in addition to IXA's distribution to customers.

Shipping Materials

Shipping materials include the following:

Table 11 Product Shipping Materials per 750 ml Bottle

Material	**TRU (576 btls/plt)**	**CRUSOE (528 btls/plt)**	**FRUIT LAB (432 btls/plt)**	**IXÁ (600 btls/plt)**	**Comments**
Shipping box, adjusted on per bottle basis (g)	54	48	94	53	At least 35% recycled.
Stretch wrap around pallets[15], adjusted on per-bottle basis (g)	0.94	1.0	1.2	0.89	Approximately 20 m2 polyethylene per pallet

plt = pallet

STORAGE

Modern Spirits rents storage space in New Jersey for a small portion of their production. Storage was calculated on a per-bottle basis: at 6 bottles per box, with one box approximately 0.5 cubic feet, the total stored space for one box equated to 0.083 cubic feet. The dataset from EcoInvent on Wholesale Warehouse (+20 degrees C) was used, which accounted for these temperature-controlled conditions.

[14] Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks, Chapter 6, Exhibit 6-6, found at: http://epa.gov/climatechange/wycd/waste/downloads/chapter6.pdf
[15] Note: pallets were not modeled as these are re-used many times.

VII RESULTS – CONTRIBUTION ANALYSES

Contribution analyses were performed in order to understand the source of the GHG impacts in the life cycle of each of the beverages. Table 12 through Table 15 present the breakdown of each life cycle stage as they contribute to the overall total of each beverage.

The reader should be reminded that packaging materials (e.g., the glass bottle), distribution to customers and the warehouse, shipping materials, storage, and end-of-life modeling and assumptions are very similar for each of the 750-ml bottles of beverages. The same is true for manufacturing data for TRU, CRUSOE, and FRUIT LAB. The reason for the differences in percentages in the following tables come from the difference in the bill of materials, which end up shifting the percentages.

Table 12 TRU Spirits Life Cycle GHGs, kg CO2-eq per 1 750-ml Bottle

Total (kg CO2-eq) per bottle	Production		Manufacturing		Distribution		Storage	End-of-Life
	Bill of Materials	Packaging Materials	Energy	Ancillary Materials	Shipping - Truck	Shipping Materials		
1.88	23%	31%	10%	1%	20%	3%	12%	0.2%

Production of materials in TRU represents 54% of the footprint, with a majority of that from production of packaging materials. Distribution by truck amounts to 20% of the total footprint, and storage at a warehouse makes up 12%. Manufacturing energy makes up only 10% and materials used for shipping the product make up 3%. Ancillary materials and the end of life contribute a small percentage of the footprint.

Table 13 CRUSOE Rum Life Cycle GHGs, kg CO2-eq per 1 750-ml Bottle

Total (kg CO2-eq) per bottle	Production		Manufacturing		Distribution		Storage	End-of-Life
	Bill of Materials	Packaging Materials	Energy	Ancillary Materials	Shipping - Truck	Shipping Materials		
1.57	13%	36%	8%	0%	25%	3%	14%	0.3%

Production of materials in CRUSOE represents approximately 50% of the footprint, with most of that from production of packaging materials. Distribution by truck amounts to 25% of the total footprint, and storage at a warehouse makes up 14%. Manufacturing energy makes up less than 10% and materials used for shipping the product make up 3%.

Table 14 FRUIT LAB Liqueur Life Cycle GHGs, kg CO2-eq per 1 750-ml Bottle

Total (kg CO2-eq) per bottle	Production		Manufacturing		Distribution		Storage	End-of-Life
	Bill of Materials	Packaging Materials	Energy	Ancillary Materials	Shipping - Truck	Shipping Materials		
1.71	15%	33%	8%	1%	24%	5%	13%	0.3%

Production of materials in FRUIT LAB represents 48% of the footprint, with most of that from production of packaging materials. Distribution by truck amounts to 24% of the total footprint, and storage at a warehouse makes up 13%. Manufacturing energy make up 8% and materials used for shipping the product make up 5%.

Table 15 IXA Tequila Life Cycle GHGs, kg CO2-eq per 1 750-ml Bottle

Total (kg CO2-eq) per bottle	Production		Manufacturing		Distribution		Storage	End-of-Life
	Bill of Materials	Packaging Materials	Energy	Ancillary Materials	Shipping - Truck	Shipping Materials		
4.04	0.4%	14%	62%	0%	17%	1%	6%	0.1%

The contribution analysis for IXÁ looks different from the other three sets of results. In the other results, the production of ethanol was included in the bill of materials for those products. For IXÁ, the ethanol production data is included at the tequila plant, thus the energy to produce the ethanol is accounted for in manufacturing (not as an upstream bill of material). Nonetheless, this energy contribution is high, representing 62% of the total or 2.5 kg CO2-eq; manufacturing energy alone exceeds the total C footprints of the other beverages. The manufacturing data received from the IXA facility was confirmed to be high, and that IXA comes from a smaller operation that may not be as efficient as larger producers. In addition to energy use to produce the tequila, other main contributors include shipping from Mexico to Monrovia, CA, and then to Modern Spirits' customers (17% or 0.69 kg CO2-eq) and packaging (14% or 0.57 kg CO2-eq).

VII DATA QUALITY REQUIREMENTS AND EVALUATION

This study adheres to the ISO standards on data quality to help ensure consistency, reliability, and clear-cut evaluation of the results. The following sections describe the study's data quality in accordance with ISO 14044.[16]

REPRESENTATIVENESS

Representativeness includes the following:

- Time/temporal coverage – describes the age of data and the minimum length of time (e.g., one year) over which data are collected;
- Geographical coverage – describes the geographical area from which data for unit processes are collected to satisfy the goal of the study; and
- Technological coverage (or the technology mix) – describes the technology mix of the data sets, which may include weighted average of the actual process mix, best available technology, or worst operating unit.

Detailed and current information on Modern Spirits' materials, energy and fuel use at manufacturing, distribution, and other life cycle aspects of the beverages were provided. The data are based on Modern Spirits' technologies and practices, and the data sets are for the most part based on U.S. data*. Therefore, these beverages can be considered representative.

***Note on geographical coverage of the data sets**: In LCA it is quite common to use a mix of data sets from different geographical locations, for several reasons. First, data for all materials is not always available for all geographies. Also, available data from a preferred geographical location may be very poor in quality (may be outdated, based on faulty emissions factors, based on old or non-representative technologies, based on one plant or a representative sample, etc.). Finally, an alternative geography or data set may be used because it is better than no data at all. In order to minimize an LCA's margin of error associated with data based on a different geographical location, it is Four Elements' practice to customize the data sets to the preferred geographical location.

CONSISTENCY

Consistency is a qualitative understanding of how uniformly the study methodology is applied to the various components of the study. Consistency was maintained in the handling of the various aspects of this study. A single person at Modern Spirits provided and reviewed the data for the study. The consultant performed the data analysis and aggregation in a consistent manner with other LCA or carbon footprint analyses.

REPRODUCIBILITY

The level of detail and transparency provided in this report allow the results of this study to be reproduced by another practitioner, using similar material and process data sets.

PRECISION

Precision represents the degree of variability of the data values for each data category. The raw materials for the product line were based on actual quantities in the products, so there was not any variability in the data. The manufacturing data was very precise and there was not much variability in the data.

[16] ISO 14044 Section 4.2.3.6

COMPLETENESS

ISO 14044 section 4.2.3.6 defines completeness as the "percentage of flow that is measured or estimated."[17] This study can be considered complete since most, if not all data provided was based on measured or estimated data. In terms of inclusion of production data of the raw materials, the cut-off criteria of 99% was exceeded. Some of the data for the ingredients in the TRU Gin were not included due to lack of available production data. This amounted to 2.8% of the total mass of gin inputs (excluding water), yet 0.5% of the total product line since gin accounts for 18% of the TRU product line.

SOURCES OF DATA

Both primary and secondary data are used in modeling the beverages. Primary data (collected directly from Modern Spirits) are the preferred, highest quality data for life cycle modeling. Primary data were gathered for the manufacture of their products and Modern Spirits provided data pertaining to other aspects of the product. Primary data was also used for the production of the Tequila. With regards to secondary data, from a practical standpoint it is impossible to collect actual process data for each of the thousands of unit processes included in a complete life cycle model so the use of secondary data in an LCI is normal and necessary. Secondary data is applied to production of material inputs, production and combustion of fuels used for process energy, and transportation energy throughout the life cycle. This study used the best data that were available.

LIMITATIONS AND UNCERTAINTY

Because the quality of secondary data is not as good as primary data, the use of secondary data becomes an inherent limitation to the study. Secondary data may cover a broad range of technologies, time periods, and geographical locations. Because hundreds of data sets are linked together and because it is often unknown how much the secondary data used deviate from the specific system being studied, quantifying data uncertainty for the complete system becomes very challenging. As a result, it is not possible to provide a reliable quantified assessment of overall data uncertainty for the study. Also, the methodology for performing carbon footprints is still in its infancy, so there could be changes to the approaches taken in this study.

[17] ISO 14044:2007, Section 4.2.3.6.

VIII Appendix - GHG weighting factors

Weighting factors used for the Calculations in this Life Cycle GHG Inventory

Greenhouse Gas	CO2-eq
1-Propanol, 3,3,3-trifluoro-2,2-bis(trifluoromethyl)-, HFE-7100	297
Butane, 1,1,1,3,3-pentafluoro-, HFC-365mfc	794
Butane, perfluoro-	8860
Butane, perfluorocyclo-, PFC-318	10300
Carbon dioxide, fossil	1
Carbon dioxide, land transformation	1
Chloroform	31
Dimethyl ether	1
Dinitrogen monoxide (nitrous oxide)	298
Ethane, 1-chloro-1,1-difluoro-, HCFC-142b	2310
Ethane, 1-chloro-2,2,2-trifluoro-(difluoromethoxy)-, HCFE-235da2	350
Ethane, 1,1-dichloro-1-fluoro-, HCFC-141b	725
Ethane, 1,1-difluoro-, HFC-152a	124
Ethane, 1,1,1-trichloro-, HCFC-140	146
Ethane, 1,1,1-trifluoro-, HFC-143a	4470
Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	1430
Ethane, 1,1,2-trichloro-1,2,2-trifluoro-, CFC-113	6130
Ethane, 1,1,2-trifluoro-, HFC-143	353
Ethane, 1,1,2,2-tetrafluoro-, HFC-134	1100
Ethane, 1,2-dibromotetrafluoro-, Halon 2402	1640
Ethane, 1,2-dichloro-1,1,2,2-tetrafluoro-, CFC-114	10000
Ethane, 1,2-difluoro-, HFC-152	53
Ethane, 2-chloro-1,1,1,2-tetrafluoro-, HCFC-124	609
Ethane, 2,2-dichloro-1,1,1-trifluoro-, HCFC-123	77
Ethane, chloropentafluoro-, CFC-115	7370
Ethane, fluoro-, HFC-161	12
Ethane, hexafluoro-, HFC-116	12200
Ethane, pentafluoro-, HFC-125	3500
Ether, 1,1,1-trifluoromethyl methyl-, HFE-143a	756
Ether, 1,1,2,2-Tetrafluoroethyl 2,2,2-trifluoroethyl-, HFE-347mcc3	575
Ether, 1,1,2,2-Tetrafluoroethyl 2,2,2-trifluoroethyl-, HFE-347mcf2	374
Ether, 1,1,2,2-Tetrafluoroethyl methyl-, HFE-254cb2	359
Ether, 1,1,2,3,3,3-Hexafluoropropyl methyl-, HFE-356mec3	101
Ether, 1,1,2,3,3,3-Hexafluoropropyl methyl-, HFE-356pcc3	110
Ether, 1,1,2,3,3,3-Hexafluoropropyl methyl-, HFE-356pcf2	265
Ether, 1,1,2,3,3,3-Hexafluoropropyl methyl-, HFE-356pcf3	502
Ether, 1,2,2-trifluoroethyl trifluoromethyl-, HFE-236ea2	989
Ether, 1,2,2-trifluoroethyl trifluoromethyl-, HFE-236fa	487
Ether, 2,2,3,3,3-Pentafluoropropyl methyl-, HFE-365mcf3	11
Ether, di(difluoromethyl), HFE-134	6320
Ether, difluoromethyl 2,2,2-trifluoroethyl-, HFE-245cb2	708
Ether, difluoromethyl 2,2,2-trifluoroethyl-, HFE-245fa1	286
Ether, difluoromethyl 2,2,2-trifluoroethyl-, HFE-245fa2	659
Ether, ethyl 1,1,2,2-tetrafluoroethyl-, HFE-374pc2	557
Ether, nonafluorobutane ethyl-, HFE569sf2 (HFE-7200)	59
Ether, pentafluoromethyl-, HFE-125	14900

Hexane, perfluoro-	9300
HFE-227EA	1540
HFE-236ca12 (HG-10)	2800
HFE-263fb2	11
HFE-329mcc2	919
HFE-338mcf2	552
HFE-338pcc13 (HG-01)	1500
HFE-347pcf2	580
HFE-43-10pccc124 (H-Galden1040x)	1870
Methane	25
Methane, biogenic	22
Methane, bromo-, Halon 1001	5
Methane, bromochlorodifluoro-, Halon 1211	1890
Methane, bromodifluoro-, Halon 1201	404
Methane, bromotrifluoro-, Halon 1301	7140
Methane, chlorodifluoro-, HCFC-22	1810
Methane, chlorotrifluoro-, CFC-13	14400
Methane, dibromo-	1.54
Methane, dichloro-, HCC-30	8.7
Methane, dichlorodifluoro-, CFC-12	10900
Methane, dichlorofluoro-, HCFC-21	151
Methane, difluoro-, HFC-32	675
Methane, fluoro-, HFC-41	92
Methane, fossil	25
Methane, iodotrifluoro-	0.4
Methane, monochloro-, R-40	13
Methane, tetrachloro-, CFC-10	1400
Methane, tetrafluoro-, CFC-14	7390
Methane, trichlorofluoro-, CFC-11	4750
Methane, trifluoro-, HFC-23	14800
Nitrogen fluoride	17200
Pentane, 2,3-dihydroperfluoro-, HFC-4310mee	1640
Pentane, perfluoro-	9160
PFC-9-1-18	7500
PFPMIE	10300
Propane, 1,1,1,2,2,3-hexafluoro-, HFC-236cb	1340
Propane, 1,1,1,2,3,3-hexafluoro-, HFC-236ea	1370
Propane, 1,1,1,2,3,3,3-heptafluoro-, HFC-227ea	3220
Propane, 1,1,1,3,3,3-hexafluoro-, HCFC-236fa	9810
Propane, 1,1,2,2,3-pentafluoro-, HFC-245ca	693
Propane, 1,1,3,3-tetrafluoro-, HFC-245fa	1030
Propane, 1,3-dichloro-1,1,2,2,3-pentafluoro-, HCFC-225cb	595
Propane, 3,3-dichloro-1,1,1,2,2-pentafluoro-, HCFC-225ca	122
Propane, perfluoro-	8830
Propane, perfluorocyclo-	17340
Sulfur hexafluoride	22800
Trifluoromethylsulfur pentafluoride	17700