Bottled Watershed: Carbon Footprint of Transporting Bottled Water

Sarin Strobush and Dr. Christina Hupy, Department of Geography & Anthropology

Abstract:

In 2008, the United States consumed over 8.5 billion gallons of bottled water, which equates to approximately 224 16oz bottles per person.[1] Growing concerns over climate change have popularized the idea of assessing an individual's carbon footprint. This project intends to calculate the carbon footprint of transporting bottled water from the source to grocery store locations in Eau Claire, Wisconsin. This task is accomplished by gathering bottling data, designing and creating a road network to calculate travel distances, and converting distances into a measure of carbon dioxide emissions using conversion factors. The information found in this investigation shows that the transportation of bottled water releases a substantial amount of carbon dioxide into the atmosphere.

Data:

The data used to begin the analysis were collected from bottled water bottles from grocery stores. To acquire bottling data, water brands were examined from the following stores: Walmart, Target, Gordy's County Market, and Festival Foods. At each of the stores, the city and zip code located on the label of each brand was recorded. On labels specifying a company name and city, internet search engines were used to find specific addresses. From the four stores, there were 14 different brands or addresses of domestic bottled water and 8 brands from overseas. In the case of the international brands, only city name was provided, therefore latitude and longitude coordinates were used. Tables 1 and 2 show the brands used in this analysis and the city of origin.

There are a few special cases for the brands that were chosen. First, Aquafina is on the list twice. This is because there were different addresses listed on Aquafina labels at different stores. Dasani is one of the largest bottled water brands in the United States, but it is not included in this project. None of the Dasani labels show any information on where they come from; they simply read "Bottled by Independent Bottlers under the Authority of the Coca-Cola Company". Also, some of the brands share addresses because they are bottled at the same place.

The transportation data used to create the network were obtained from the GIS Data Depot website. The roads for Europe and the United States were modified so they could be properly implemented in the network. Shipping routes were logically digitized based on actual marine routes.

Table 1

Brand	Address	City	State
Nursery	5660 New N. Side Drive, Suite 500	Atlanta	GA
Sam's Choice	702 Southwest 8th Street	Bentonville	AR
Chippewa Spring	600 East Park Avenue	Chippewa Falls	WI
Great Value	30 W Central St # 209	Chippewa Falls	WI
Kandiyohi	600 East Park Avenue	Chippewa Falls	WI
Festival Foods	15175 County Rd W	Crivitz	WI
Nicolet	15175 County Rd W	Crivitz	WI
Aquafina CO	3801 Brighton Boulevard	Denver	CO
Pure Life	900 Commerce Parkway W Dr	Greenwood	IN
Deja Blue	5301 Legacy Drive	Plano	TX
Water Joe	39 S Barrington Rd	South Barrington	IL
Ice Mountain	19275 8 Mile Road	Stanwood	MI
Smart Water	1720 Whitestone Expressway	Whitestone	NY
Aquafina KS	101 W 48th Street South	Wichita	KS

Table 2

Brand	City	Country	Latitude	Longitude
Evian	Évian-les-Bains	France	46.383333	6.583333
Perrier	Vergeze	France	43.744167	4.220833
Gerolsteiner	Gerolstein	Germany	50.223889	6.661389
Jana	Sveta Jana	Croatia	45.718889	15.596111
Fiji	Yaqara Valley	Fiji	-17.366667	178.15
S. Pellegrino	San Pellegrino Terme	Italy	45.833333	9.666667
VOSS	Vatnestrom	Norway	58.441111	7.955833
Icelandic Glacial	Selfoss	Iceland	63.933108	-20.997117

Source Locations of Bottled Water Brands

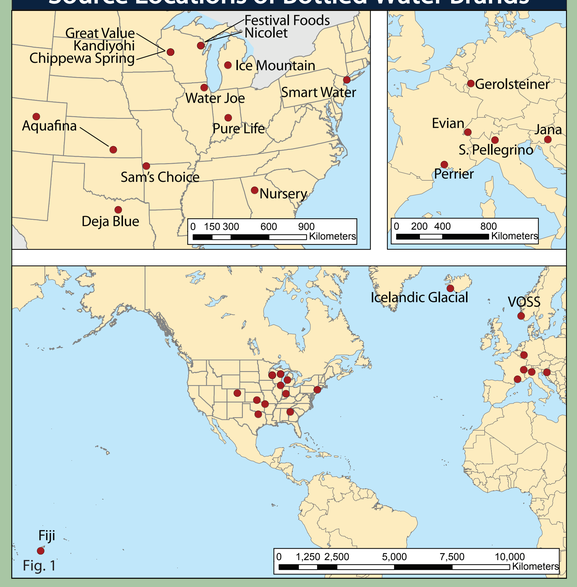


Fig. 1

Methods:

All of the addresses and coordinates were geocoded to create point locations to be analyzed in the network. In order to simplify routing operations, a single destination point was created by finding the mean center of the four grocery store locations in Eau Claire. A transportation network was created using major roadways in the United States and Europe, and digitized shipping lanes. Figures 2, 3, and 4 show the sources used in the network. Distances from the source locations to Eau Claire were found by adding the point locations of the bottled water brands to the network. The distances were converted to CO_2 emissions by implementing the following criteria:

> When traveling over land, bottled water will be transported via truck and if from overseas, by cargo ship.
> Energy use from a truck is 3.5 MJ (megajoule) per ton of cargo per km.[2]
> Energy use from a cargo ship is 0.37 MJ per ton of cargo per km.
> There are 137.79 MJ of energy in one gallon of diesel fuel.[3]
> CO_2 emissions from a gallon of diesel = 2,778 grams x 0.99 x (44/12) = 10,084 grams = 10.1 kg/gallon = 22.2 pounds/gallon[4]

Transportation Sources Used To Create Network

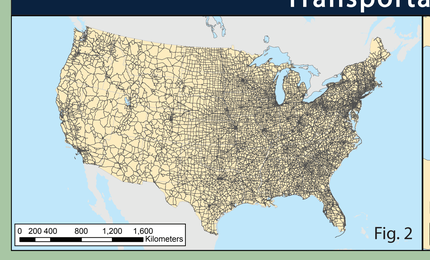


Fig. 2

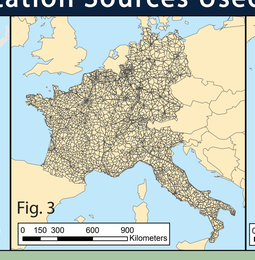
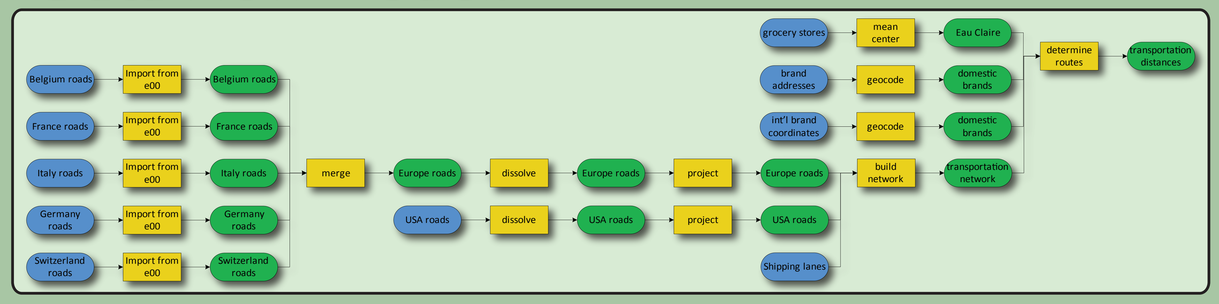


Fig. 3

Fig. 4

Figure 2- roadways in the United States
Figure 3- roadways in Europe
Figure 4- digitized shipping lanes

Data Flow Model:



Domestic Brand Routes

Fig. 5

International Brand Routes

Fig. 6

Results:

The routes found on the network are illustrated in Figures 5 and 6. In these images each "1" represents the starting point of the route for each brand and the "2" indicates the Eau Claire location used as described in the methods. All except one of the international brands are transported more than 10,000 km to reach the grocery stores in Eau Claire, Wisconsin, which in turn creates thousands of pounds of CO_2. Ten out of the fourteen domestic bottled water brands are shipped less than 1,000 km to grocery stores in Eau Claire. The transportation distances and CO_2 emissions for each brand are presented in Table 3. The distances in kilometers were converted to an energy cost unit in mega joules and then to CO_2 emissions in pounds. The resulting values represent the CO_2 emissions from transporting one ton of bottles for each brand. Jana water from Croatia had the highest emissions with 3328.45 lbs. This equals the amount of carbon that can be sequestered by almost 40 ten-year-old trees.[5]

Table 3

Brand	Distance (km)	Ocean Distance (km)	Energy Cost Cargo Ship (MJ)	Land Distance (km)	Energy Cost Truck (MJ)	Total Energy Cost (MJ)	Gallons of Diesel	CO_2 Emissions (lbs)
Jana	12958.1	7889.6	2919.15	5068.5	17739.75	20658.90	149.93	**3328.45**
S. Pellegrino	12193.8	7889.6	2919.15	4304.2	15064.70	17983.85	130.52	**2897.46**
Fiji Water	13795.6	9732.2	3600.91	4063.4	14221.90	17822.81	129.35	**2871.52**
Gerolsteiner	11723.4	7889.6	2919.15	3833.8	13418.30	16337.45	118.57	**2632.20**
Evian	11717.6	7889.6	2919.15	3828	13398.00	16317.15	118.42	**2628.93**
Perrier	11641.5	7889.6	2919.15	3751.9	13131.65	16050.80	116.49	**2586.02**
VOSS	12369.7	10060.7	3722.46	2309	8081.50	11803.96	85.67	**1901.79**
Icelandic Glacial	9973.9	7664.9	2836.01	2309	8081.50	10917.51	79.23	**1758.97**
Smart Water	2340.7	0	0	2340.7	8192.45	8192.45	59.46	**1319.92**
Nursery	1997.9	0	0	1997.9	6992.65	6992.65	50.75	**1126.62**
Deja Blue	1984.1	0	0	1984.1	6944.35	6944.35	50.40	**1118.84**
Aquafina, CO	1983.8	0	0	1983.8	6943.3	6943.3	50.39	**1118.67**
Sam's Choice	1456.6	0	0	1456.6	5098.1	5098.1	37.00	**821.38**
Aquafina, KS	1453	0	0	1453	5085.5	5085.5	36.91	**819.35**
Ice Mountain	1139.1	0	0	1139.1	3986.85	3986.85	28.93	**642.34**
Pure Life	1070	0	0	1070	3745	3745	27.18	**603.37**
Water Joe	614	0	0	614	2149	2149	15.60	**346.24**
Festival Foods	461.5	0	0	461.5	1615.25	1615.25	11.72	**260.24**
Nicolet	461.5	0	0	461.5	1615.25	1615.25	11.72	**260.24**
Great Value	28.4	0	0	28.4	99.4	99.4	0.72	**16.01**
Chippewa Water	27.4	0	0	27.4	95.9	95.9	0.70	**15.45**
Kandiyohi	27.4	0	0	27.4	95.9	95.9	0.70	**15.45**

Conclusion:

Buying bottled water has a potentially huge impact on the environment. The range of effect from brand to brand is vast with 3300 lbs. of carbon dioxide produced from transporting Jana to just 15 lbs. from Chippewa Spring Water. The emissions found in this study are produced only from the transportation of the water. Other sources of emissions include the production of plastic bottles and energy costs of treating the water. Consumers need to consider the environmental impact of bottled water. If purchasing bottled water, be aware of where it is produced and choose a brand originating closer to home.

There are a number of unexplored avenues in regards to this research. Another matter to contemplate is the quality of the water. Nursery Water is advertized as being better for young children than tap water. The source for this brand is the municipal supply in Atlanta, Georgia. Is bottled water significantly different than tap water? Future research inquiries include assessing the quality of the water.

References:

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[3] "Bioenergy Conversion Factors." Bioenergy Feedstock Information Network (BFIN) Administration Site. <http://bioenergy.ornl.gov/papers/misc/energy_conv.html>.
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[4] "Emission Facts: Average Carbon Dioxide Emissions Resulting from Gasoline and Diesel Fuel US EPA." US Environmental Protection Agency. <http://www.epa.gov/otaq/climate/420f05001.htm>.
[2] Gleick, P. H., and H. S. Cooley. "Energy Implications of Bottled Water." Environmental Research Letters 4.1 (2009) IOPScience.
[5] "Greenhouse Gas Equivalencies Calculator." US Environmental Protection Agency. <http://www.epa.gov/cleanenergy/energy-resources/calculator.html>.