Nestlé Waters North America

Project Report

Environmental Life Cycle Assessment of Drinking Water Alternatives and Consumer Beverage Consumption in North America

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Title	Environmental Life Cycle Assessment of Drinking Water Alternatives and Consumer Beverage Consumption in North America
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About Quantis:

Quantis specializes in Life Cycle Assessment (LCA) and related applications. The company was founded in 2009 and has its global headquarters in Lausanne, Switzerland. Its US office is based in Boston, Massachusetts and has additional offices in Montreal, Canada and Paris, France. The company provides the highest level of expertise in delivering state-of-the-art analysis and solutions for leading companies, governments and non-profit clients with an aim of creating a more sustainable world.

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Table of Contents

Executive Summary

Over the past several decades, the bottled water market in North America has experienced significant growth. Between 2002 and 2007 alone, the typical American's bottled water consumption rose by nearly 50% and has grown by more than 20-fold since 1977.[1] Concern has arisen that this growth, while meeting a consumer demand for health and convenience, may come with an added burden on the environment. Today, bottled water is a visible and ubiquitous consumer product and—given society's increasing environmental awareness—has become a charged symbol in the sustainability dialogue. As consumers have taken a larger interest in reducing the impacts of their lifestyles on the environment, some now believe that bottled water is environmentally inefficient, given a comparison to tap water which is readily available throughout the developed world. Campaigns have been launched to discourage the drinking of bottled water, retail outlets looking to have an environmentally friendly image have tried to steer consumers away from it, and a small number of municipalities have even contemplated banning its purchase for public functions.

Nestlé Waters North America (NWNA), the market leader in North America, has commissioned the present project to **better understand the environmental aspects of bottled water and available alternatives, and to explore ways to further reduce its own footprint.** The intentions of the project are to 1) identify and compare the environmental impacts of consuming bottled water and several prominent alternatives; and 2) identify the environmental impacts of a consumer's total beverage consumption and evaluating the influence of changing bottled water consumption habits**. The methodology applied here, life cycle assessment (LCA), is an internationally accepted method for measuring the environmental impact of products, services and other systems.** It includes a comprehensive scope, which ensures that environmental impacts are not simply being shifted to other parts of a system's life cycle or to other environmental impact categories. This study been peer-reviewed by an independent panel of LCA experts.

The bottled water alternatives that have been compared in high detail in this study include two NWNA products: a 500 ml "EcoShape" bottle[2] and a 3 liter bottle, as well as sports drinks, vitamin-fortified waters, water directly from a tap, tap water from a filtering pitcher, water from a water vending machine, and tap water in three reusable bottle material types (aluminum, plastic and steel). Comparisons are also made of the environmental impact of a consumer's total daily consumption (limited to three impact categories of water use, non-renewable energy use, and climate change impact), drawing on information produced elsewhere to include milk, coffee,

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[1] The Christian Science Monitor reports a 46% increase, from 20.1 gallons to 29.3 gallons per capita from 2002 to 2007 (September 8, 2008). Data from Beverage Marketing Corporation shows an increase of 2200% between 1977 and 2008 for the US. (http://www.nestle-watersna.com/Menu/AboutUs/Performance/Trended+Bottled+Water+Volume+Growth.htm).

[2] In 2009-2010, Nestlé Waters North America has introduced a further reduced-weight "EcoShape 2" bottled, weighing an average of 9.85 g, compared with its previously produced "EcoShape 1" bottle with an average weight of 12.2 g. For the present project, the "EcoShape" bottle that is considered is the newer, lower weight bottle.

beer, wine, juice, soda, and tea.[3] An overview comparison of the impacts associated with each of these beverages is provided in Figure A-1 below.

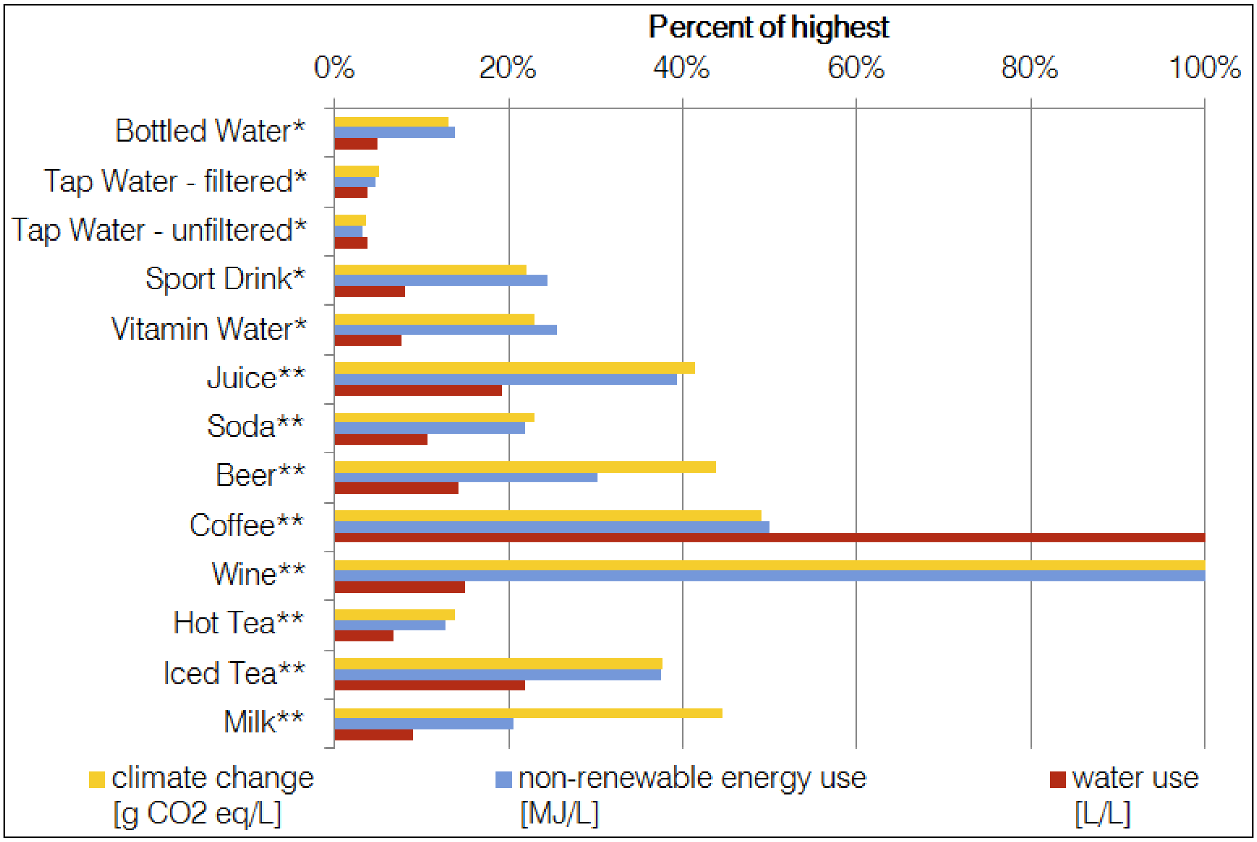

Figure A-1: Comparison of climate change impact, non-renewable energy use, and water use for a variety of beverage options (* indicates results from the present study; ** indicates results from public pre-existing sources, with the exception of iced tea, which is not publicly available).

Results of the climate change impact comparison of products are shown in the below figures. **Based on the baseline set of conditions used here, those systems based on consumption of tap water generally perform better from an environmental perspective than the bottled beverages.** However, there is significant variation within the categories of bottled and tap water examined and **sensitivity results show potential for wide variation within each of these categories**. The conclusions drawn are therefore subject to the conditions of consumer use and the specifics of beverage packaging and distribution. **It is therefore essential to consider the conditions of consumer behavior when comparing these systems** and to qualify conclusions based on the range of behaviors or other conditions under which they are applicable. Additionally, there are potentially both health and quality implications associated with bottled water alternatives, although these are outside the scope of this report.

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[3] Conclusions drawn on information from other sources (i.e., regarding milk, coffee, beer, wine, tea, soda and juice) cannot be made with the same certainty as for the beverage types directly studied here (bottled and tap waters, vitamin-fortified waters and sports drinks) due to a potential for inconsistencies in methodology, some of which are not fully documented in the pre-existing sources.

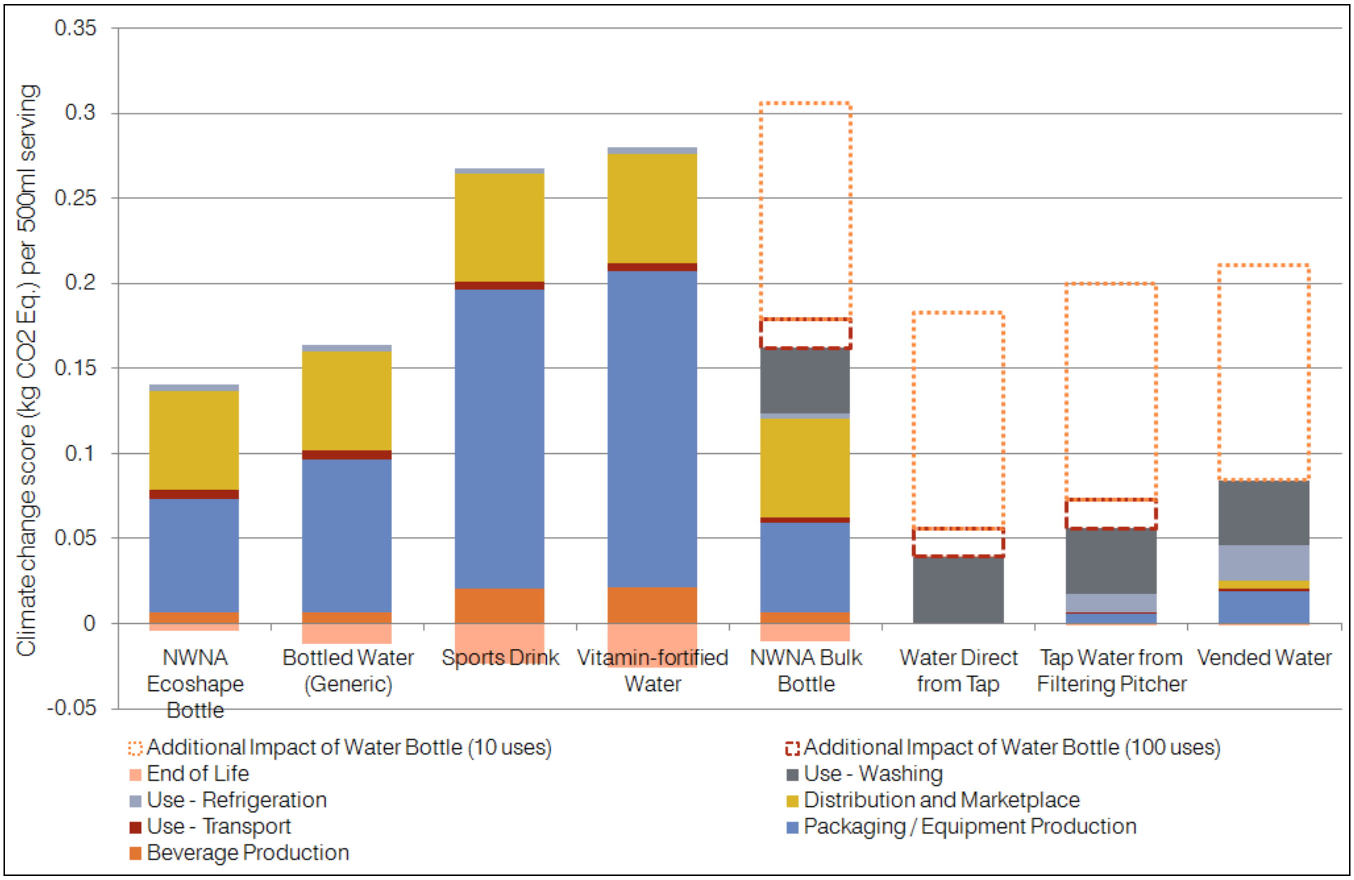

Figure A-2: Overview of results for climate change score of the various drinking water alternatives. Results are representative of other impact categories examined.

Within the bottled beverages considered, there is significant variation, with the two NWNA products examined—the EcoShape 500 ml water bottle and the 3 L bottle—performing roughly equivalently and significantly better than the sports drinks and vitamin-fortified waters. While some of this difference is due to the additives to these other beverages and is therefore inherent in the product categories, the largest portion of the difference is due to differences in packaging weight. Indeed, **the majority of the environmental benefit shown here for bottled waters versus other bottled beverages hinges on the assumption of a lower weight of PET bottle**, which is supported by the market research performed to support the present assessment. The influence of distribution distance is also shown to be important, but insufficient information is available to draw conclusions comparing beverage categories on this basis.

A range of sensitivity tests has been performed to identify the potential influence on the results of numerous assumptions that are unknown and/or variable with regard to consumption of tap and bottled water. Examples include the thickness of plastic bottles, distances products are transported, the number of times reusable bottles are used, the conditions of dishwashing and refrigeration, and many others. It is shown that variation in such factors lead to a very wide range in the environmental impact of water consumption. An assessment of reasonable upper and lower bounds based on these ranges of values shows that **choice between bottled and tap categories is just one of a large number of consumer choices and actions that affect the environmental impact of water consumption and that other choices and behaviors can be as or more important.** For both bottled and tap water, impact of consumption may vary by more than 10-fold among various options and behavior patterns. This indicates that it is necessary to communicate to consumers more information than just a comparison of bottled and tap options when seeking to assist them in making good environmental choices regarding their water/beverage consumption.

When examining the total beverage consumption impact of the typical American consumer**, it is shown that the contribution of beverage types to a consumer's total impact may be quite different than their contribution to the volume consumed**. For example, consumption of water of all types (both bottled and tap) provides 41% of beverage consumption, while producing only 12% of the associated impact on climate change. In comparison, the combination of milk, coffee, beer, wine and juice provide just 28% of the volume of beverages consumed but are associated with 58% of the climate change impact. These observations show that it is essential to consider the full scope of beverage consumption when considering impacts of any given product, as increases in consumption of one product are likely to result in the decrease of another product and *vice-versa*. In considering switching beverages, **there are both health-related and environmental considerations that should be considered, and the present project examines only the environmental aspects.** Figure A-3 illustrates a comparison of the contribution to volume of consumption and to environmental impact for each of the beverage categories examined.

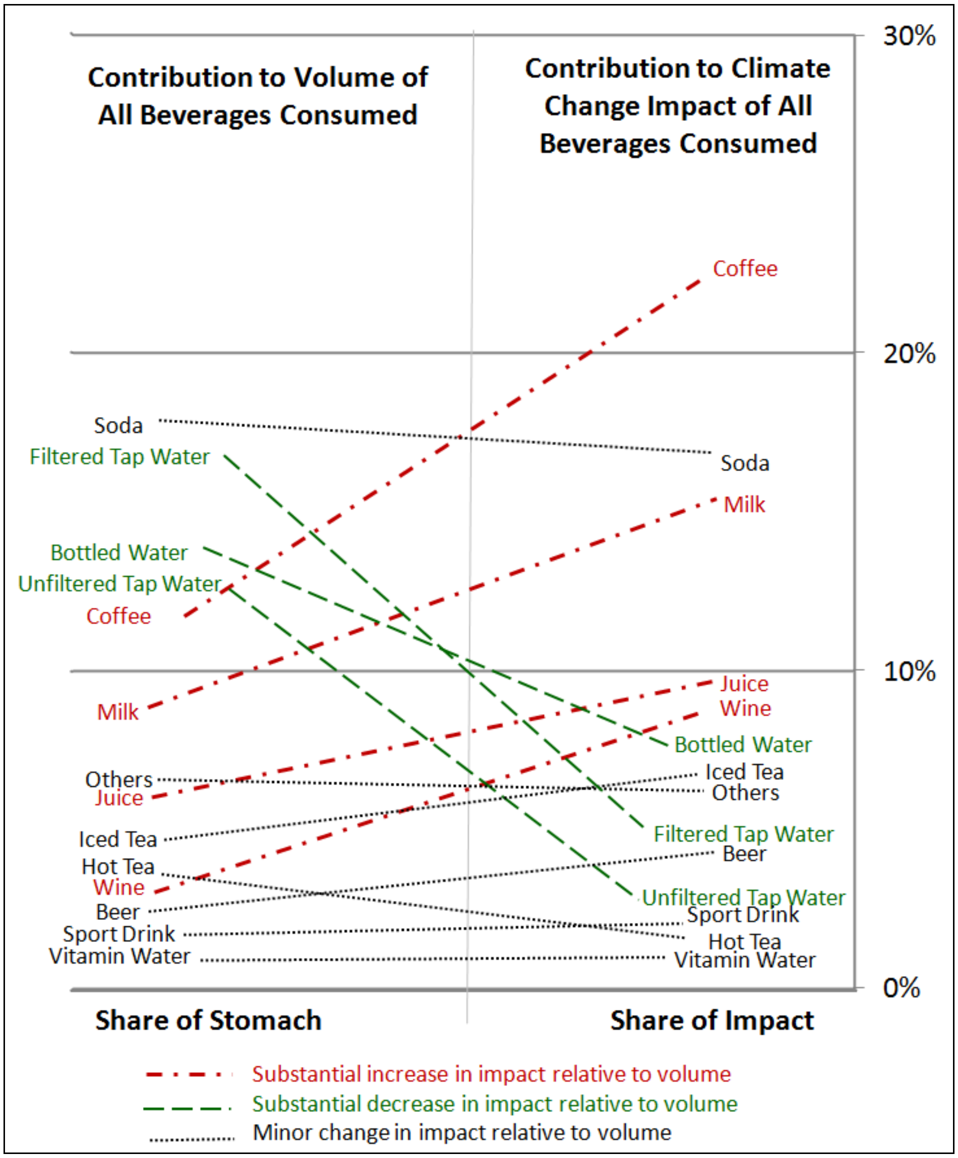

Figure A-3: Proportion of beverages by volume consumed by the typical American consumer and percent contribution to the climate change impact from beverage consumption. Beverages with a disproportionately large contribution to beverage consumption impact relative to volume and shown with red lines and those with a smaller impact are shown with green lines.

Surveys of consumers regarding their preferred alternative to bottled water in cases where it is not available were used as a basis to consider scenarios of increasing or decreasing consumption of bottled water. This information suggests that approximately 30% of bottled water drinkers will chose tap water when bottled is not available and the remainder will prefer another type of bottled beverage.[4]

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[4] Based on research performed for NWNA, as cited in the full report.

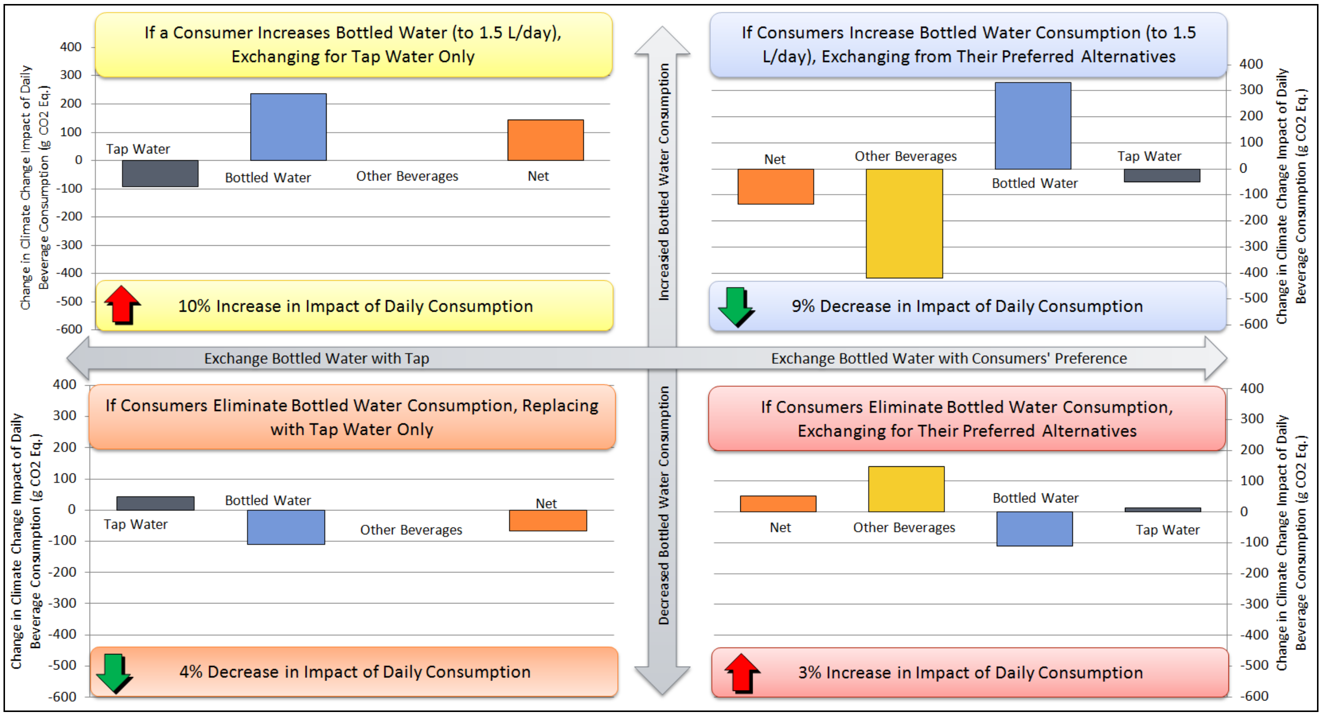

Figure A-4: Overview of results for climate change score of the various beverage consumption patterns. Results are generally representative of other impact categories examined.

The results from assessing changes under these conditions (Figure A-4) show that the unavailability of bottled water is unlikely to result in a net decrease in the environmental impacts of the consumer when considering the range of options that they are likely to switch to. **Conversely, similar consideration of cases where consumers drink more bottled water—and therefore less of other beverages—shows a potential for reducing the total environmental impact associated with providing a consumer's beverage consumption**. For example, increasing bottled water consumption to 1.5 L per day results in a decrease of approximately 9% in the climate change impact of the average consumer's beverage consumption. **An assessment was also made of the case where a consumer switches their consumption of bottled to tap water, resulting in a decrease of the impacts of that consumer's beverage consumption by approximately 4%.** Results of these scenarios regarding consumer switch cannot be considered statistically significant, but are illustrative of the importance to consider the full influence of shifts away from bottled water if they happen in a way that moves consumption to other bottled beverages, as may be expected based on the market research.

The results indicate that if bottled water is removed from consumer choice – and consumers remain free to choose among remaining alternatives based on their preference – it is unlikely that any environmental benefit will result. These results have important implications for methods of communicating with and guiding consumers, retailers and public officials in making beverage consumption choices that will reduce their impact on the environment. Combined with the results regarding the variability of direct product comparisons, they indicate that communications to consumers on choice of beverage consumption must be rich enough in information to convey a full understanding of the importance of both their choice of beverage, as well as their habits in consuming the beverage.

1. Introduction and Project Overview

1.1 Context

Over the past two decades, the bottled water market in North America has experienced significant growth. Concern has arisen that this growth, while meeting a consumer demand for health and convenience, may come with an added burden on the environment. Today, bottled water is a visible and ubiquitous consumer product and—given society's increasing environmental awareness—has become a charged symbol in the sustainability dialogue. As consumers have taken a larger interest in reducing the impact of their lifestyles on the environment, some now believe that bottled water is environmentally inefficient, given a comparison to tap water which is readily available throughout the developed world. Campaigns have been launched to discourage the drinking of bottled water, retail outlets looking to have an environmentally friendly image have tried to steer consumers away from it, and a small number of municipalities have even contemplated banning its purchase for public functions.

To better understand the environmental impacts of bottled water and available alternatives, Nestlé Waters North America (NWNA), the market leader in North America, has commissioned the present project with the intention of 1) identifying and comparing the environmental impacts of consuming bottled water and several prominent alternatives; 2) identifying the environmental impacts of a consumer's total beverage consumption and evaluating the influence of changing bottled water consumption habits; and 3) providing guidance to further improve the environmental performance of their products.

The methodology applied here, life cycle assessment (LCA), is an internationally accepted method for comparing the environmental performance of products, services and other systems (ISO 2006). It is characterized by a comprehensive scope, which ensures that environmental impacts are not inadvertently being shifted to other parts of a system's life cycle or to other environmental impact categories.

The bottled water alternates that have been compared in high detail include two NWNA products, a 500 ml "EcoShape" bottle and a 3 L bottle, as well as sports drinks, vitamin-fortified waters, water directly from a tap, tap water from a filtering pitcher, water from a water vending machine, and tap water in reusable bottles. Comparisons of a consumer's total daily consumption also draw on information produced elsewhere to include milk, coffee, beer, wine, juice, soda, and tea.

To ensure conformance with conventions in the field of LCA, this study has included a peer review by an external panel of experts. The comments from that review are included as an appendix.

The project is comprised of two main focuses: a comparison of specific drinking water alternatives and a comparison of beverage consumption habits of consumers. While the first of these two focuses draws upon new information compiled for this study, the second objective draws upon a combination of this new information as well as information that was assembled from other pre-existing sources. The references section below lists the key sources of information that are drawn upon to support the project.

1.2 Objectives

1.2.1 System Comparison Objectives

The objectives of the comparison of drinking water alternatives are:

- To comprehensively **determine the environmental impacts** over the whole life cycle of the product systems studied (see listing of systems in next section);
- To provide an assessment of the **influence of several key variables** or characteristics, such as the product inputs, production conditions, transport distances, packaging characteristics, consumer behavior and/or other aspects;
- To identify potential **areas for further focus in improving sustainability** performance of Nestlé Waters' products.
- To support **effective communication of the results**, including comparisons among the systems studied, both internally and externally.

For these products, comparisons will be made based on a wide range of environmental metrics, including climate change, non-renewable energy use, water use and more than a dozen other categories regarding the impact on resource consumption, human health and ecosystem quality.

For all systems being compared, it is intended that the comparison is relevant to the product systems being produced and consumed in the US at the present time (2009). Comparison of beverages produced or consumed elsewhere are not within the objectives of the study.

1.2.2 Consumption Pattern Comparison Objectives

The objectives of the comparison of beverage consumption patterns are:

- To **determine the environmental impacts** of the total beverage consumption of US consumers under various consumption patterns;
- To provide an assessment of **relative importance of various consumer choices, options, or behaviors**, such as including, omitting, increasing or decreasing the consumption of certain beverage categories;
- To identify **potential recommendations for consumers and public officials who want** to reduce the environmental impact of their beverage consumption.
- To support **effective communication of the results**, including comparisons among beverage consumption patterns, both internally and externally.

The comparisons among beverage consumption habits will be available only based on the metrics of climate change impact ("carbon footprint"), water consumption, and non-renewable energy use.

1.3 Systems to be Studied and Functional Unit

1.3.1 Systems Comparison Overview and Functional Unit

The product systems that have been compared in detail include the following:

1) NWNA's "EcoShape 2" bottle of water (0.5 L)
2) An industry average bottle of water (approx. 0.5 L)
3) A 20 oz industry average "sport drink"
4) A 20 oz industry average flavored vitamin-fortified water
5) Water from a refrigerated filtering pitcher
6) NWNA's "bulk" bottle of water (3 L)
7) Vended water[5]
8) Tap water (direct from tap, unfiltered)

For systems 5, 6, and 8, consideration is made of either a drinking glass or reusable water bottle, whereas for 7, only a reusable bottle is considered. The reusable bottle types considered include an aluminum bottle, a plastic bottle, and a steel bottle.

Although not purely water products, the vitamin water and sport drink have been selected for inclusion because market surveys conducted by NWNA (which are presented below) suggest a high propensity for consumers of bottled water to also choose such beverages and also due to a lack of any information in the public domain on environmental impacts of producing and consuming these products.

In LCA, a "functional unit" is used as the basis of study to ensure an even comparison is made of the impacts incurred for each product's fulfillment of an identical function. In the present case, the functional unit used is to quench an instance of thirst experienced by a consumer. To compare among the various beverages to be considered, it is assumed here that a single instance of thirst is equivalently reduced by providing a single **serving of 500 ml of hydration to the consumer**. This 500 ml serving will be the basis of comparison for all results shown comparing the drinking water alternatives.

It is important to note that in many cases, additional materials or activities are needed to meet this function. For example, in cases 5, 6 and 8 the production and/or washing of drinking glasses will be considered. In case 7, the production and operation of the vending machine is considered. In such cases,

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[5] Vended water refers to vending machines that dispense filtered, chilled water that is generally sources from a municipal water supply line. The water is dispensed into a user-provided bottle. For example products see www.watervend.com or www.aquapolar.com.

these additional materials and activities are considered within the system boundary, as they are needed to provide equivalent function[6].

Two of the systems studied, those produced by Nestlé Waters North America (eco-shape 500 ml bottle and bulk 3 L bottle), are based on detailed production information obtained from the manufacturer of these products. For the other systems, the results are not intended to represent the product of any single manufacturer, but rather to represent a typical product within these categories. To ensure a consistent assessment, care has been taken in selecting data that would represent each product to ensure that the greater detail available for NWNA does not lead to a bias for or against their products in the analysis. For example, because the shipping distances for NWNA are known with a high level of accuracy and the industry averages for other products are not, the distribution distances for NWNA have been used for all products to ensure a bias is not given in one direction or the other due to lack of information. In this case, the lack of information likely results in an underestimate of the impact of distributing competing beverages, as NWNA's distribution (being the leading water bottler in North America) should be among the lowest in the industry.

1.3.2 Consumption Pattern Comparison Overview and Functional Unit

Within the comparison of consumption patterns, data has been drawn from both the present project (for those produces that are included) and other existing sources of information. The following beverage types have been included in the comparison (with the source of information in parenthesis, citations are given in Table 6, found in Results 6.4):

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[6] In addition, some of the systems listed may be considered to provide additional function beyond that described by the functional unit. For example, a sport drink may be considered to also provide calorific value and electrolytes. Similarly, vitamin-fortified water also provides essential vitamins and minerals. While some might argue that such beverages have an added function beyond that of water, others may argue that in today's developed countries, added calories provide no positive function and may in fact have an added burden through costs such as those of weight-related health outcomes. To avoid such debates, we will maintain throughout the assessment of results the assumption that the beverages equally serve the "thirst quenching" function and that this is the function that most drives consumption. Indeed, the consumer research that will be presented below suggests that consumers may switch choices rather easily between calorie and non-calorie containing beverages and it is therefore not for calories that they are usually making a choice of beverages.

- Bottled Water (this project)
- Tap Water
  (filtered and unfiltered)
  (this project)
- Sport Drink (this project)
- Vitamin Water (this project)
- Juice (pre-existing information)
- Soda (pre-existing information)
- Beer (pre-existing information)
- Coffee (pre-existing information)
- Wine (pre-existing information)
- Tea (pre-existing information)
- Iced Tea (pre-existing information)
- Milk (pre-existing information)

This list is intended to represent a comprehensive—though by no means complete—selection of the beverages most prominently consumed by US consumers. The information to be used in all categories is intended to be representative of a typical product in that category, rather than specific to any given product.

A mixture of these beverages has been used to extrapolate various consumer beverage consumption patterns. These patterns include a "typical" US consumer based on national average consumption data and various alternate or modified consumption habits to show, for example, the impacts of drinking more or less of certain beverages, while maintaining the same total consumption.

The functional unit for comparing consumption habits is the quenching of a consumer's thirst over the course of a single day[7]. The amount of beverage necessary to provide this function is assumed to equal an average consumer's daily beverage intake, totaling 2849 ml as recommended by a recent US Beverage Guidance Panel (Popkin et al., 2006). Comparisons will therefore consist of examining alternative combinations of beverages to meet this function.

2. Methodology

LCA considers the potential environmental impacts (e.g., use of resources and the environmental consequences of releases) throughout a product's life cycle from raw material acquisition through production, use, end-of-life treatment, recycling and final disposal of the product (i.e., "cradle-to-grave"). LCA is an internationally respected and standardized practice and is a part of the ISO 14000 guidelines for environmental management systems (LCA guidelines are described by the ISO 14040 series). LCA has been used over the past several decades by a wide array of organizations for many uses, including

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[7] In addition to the nutritive function discussed in the prior section. Several of the beverages included here may also have a caffeine-related stimulatory function, or an alcohol-related function. As with nutrition, it is chosen here to consider only the thirst quenching function and to assume all beverages equally provide that function with an equal volume. Nevertheless, it may be important to consider that some beverages, such as coffees or sodas, may in fact dehydrate rather than hydrate and may therefore cause additional beverage consumption. Such physiological effects are not considered here due to a lack of information to allow for their consideration.

strategic planning, priority setting, product or process design or redesign, the selection and tracking of relevant indicators of environmental performance, marketing, eco-labeling, and more.

This study follows the LCA methodology as described in the ISO 14040/14044 standards. Because it contains comparative results that are intended to be suitable for public disclosure, the standard requires that the present assessment include an external peer review to ensure the compliance with the requirements of the standard. Such a review has been conducted and the panel comments and responses are included as an appendix.

It is important to note that the portion of the study involving the comparison of total consumer consumption habits is not intended to be a complete ISO-compliant LCA. It is rather a gathering of LCA-related information on beverages from the literature and an assessment that places it in the context of consumer choices. Because much of the information is sourced from the literature, it is not possible to comply with many aspects of the ISO LCA framework, such as a formal uncertainty assessment and a complete assessment of data quality and consistency for that portion of this report. It should be expected that some inconsistencies exist among the data and methodology used in the underlying sources of data used for that portion of the assessment.

Results have been calculated based on data and information collected from NWNA in combination with a wide array of data from leading LCA databases and the scientific literature. All information sources and methodological steps are documented here in the report and appendices to ensure maximum transparency of the final results.

The study will examine the extraction and processing of all upstream raw materials to produce the products and packaging components; the manufacturing process; distribution logistics; product use and packaging disposal. The work has been conducted using the Ecoinvent database and SimaPro software, with the use of MS Excel for compiling and examining results.

Each product under consideration in the product comparison (see listing in section 1.3.1) has been evaluated based on a wide range of environmental impact indicators, including:

- climate change impacts (measured in kg CO_2 equivalents, following the IPCC's most recent methodology),
- total use of non-renewable energy (measured in megajoules),
- water use (measured in liters and excluding water use from electric turbines),
- the seven midpoint environmental indicators under the US-based TRACI environmental impact assessment method (Tool for the Reduction and Assessment of Chemical Impacts), and
- the three additional endpoint indicators and twelve additional midpoint indicators under the IMPACT 2002+ system.

The use of two impact assessment methodologies is intended to provide a sensitivity check on the selection of impact assessment method. In total, this range of impact indicators gives a very complete assessment of the potential environmental harms or benefits offered by each of the systems. Both the IMPACT 2002+ and TRACI method have been published in leading scientific journals and have been used in a wide variety of life cycle assessment applications. Both can be considered to have wide international acceptance.

For the comparison of beverage consumption patterns, impacts have been considered only in regard to climate change, non-renewable energy use and water use. This limitation is due to the use of information from the literature to supplement the analysis for many beverages and the lack of adequate data for those beverages to support assessing each of the categories listed above.

Scenario evaluations have been used to examine the importance of several variables in the product comparison. These include a range of possible consumer behaviors regarding the use of the products, such as conditions of refrigeration, washing of glasses, and disposal routes for packaging, among others.

3. Data and Assumptions

3.1 Data sources for product comparisons

The following table compares data and assumptions that are used for each of the systems studied. For many items, the data or assumptions used are shown in parentheses or in footnotes. Additional information on data sources is also provided in the appendices. For several of the most important, most variable or most uncertain aspects, sensitivity tests have been conducted, as described in the results section of this report.

Table 1: Sources of information and assumptions for representing each of the systems compared

Life Cycle Stage	Information	EcoShape Bottle	3 L bottle	Sport, Vitamin and Generic Waters	Reusable Bottles	Home Filtering Pitcher	Vended Water	Tap Water
Water Production	Water Source	Groundwater from well (information provided by Nestle Waters		Assumed same as for Nestle Waters	Assumed same as for tap water			Based on mixture of sources for US municipal water
	Excess water production[8]	Assumed 30% lost in industrial processes (information provided by Nestle Waters)			Assumed 5% loss in filling bottle	Assumed 5% loss in filling pitcher	Assumed 5% loss in filling container	Assumed consumer wastes equal portion of water in filling glass
	Water Production Electricity[9] and Fuels	Information provided by Nestle Waters[10]		Assumed same as for Nestle Waters	Based on data from Ecoinvent database[11,12]			
	Use of filtration and treatment	Information provided by Nestle Waters (spring water has no significant treatment, with all components falling extremely below 1% of the mass (water		Assumed same as for Nestle Waters	Treatment depends on the water source being used.	Production of in-pitcher filters are included in Packaging and Equipment	Production of treatment equip. is included in Pkg./Equip. Prod., operation of machine is included	Based on data from Ecoinvent database

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[8] For tap water options, the Ecoinvent database, which has been used extensively in this study, assumes all tap water sources include a loss of approximately 12% as part of the municipal distribution system. This loss rate is also included in the tap water systems as part of the database. Confirmation or correction of the 12% figure for the US has not been undertaken here due to lack of adequate information. Reported rates for various municipalities in the US appear to range from lows of ~10% to highs of 30%, 40% or perhaps greater.

[9] For all stages of all products studied, it is assumed that electricity use reflects the average mixture of electricity production technologies supplying the US electrical grid, as represented in the Ecoinvent database. Within the background of process, the electricity grid used depends upon the geographic representation of the data that has been used.

[10] 0.01 kwh electricity, 0.002 MJ diesel, 0.007 MJ light fuel oil, 0.0002 kg LPG, 0.03 MJ natural gas, and 2E-7 kg propane per liter of water produced. Of the 0.084 kwh electricity per liter used for production (information provided by NWNA), 0.074 is assumed to be attributable to blow molding of bottles based on figures from Ecoinvent for blow molding. The remaining 0.01 kwh represents all other aspects of operating the bottling plant and are included in the Water Production stage of the life cycle. This value is just over the upper range for treatment and bottling provided by Gleick and Cooley (2009).

[11] Assumes 0.00039 kwh electricity per liter of water produced (data from Ecoinvent). Other references in the literature suggest values as high as 0.0049 kwh per liter electricity per liter (e.g., Vince et al., 2008), with others showing a value in between (e.g., 0.0016 kwh per liter in Elliot et al, 2003). Gleick and Cooley suggest a range as wide as 0.00003 kwh per liter to 0.007 kwh per liter.

[12] The Ecoinvent database assumes approximately a 12% loss of water in treatment and transmission. That is, for each 1 L delivered at the tap, 1.12 L must be pumped from the source.

Life Cycle Stage	Information	EcoShape Bottle	3 L bottle	Sport, Vitamin and Generic Waters	Reusable Bottles	Home Filtering Pitcher	Vended Water	Tap Water
		excluded) of the system))				Production	under Refrigeration	
	Amount of additives	Information provided by Nestle Waters (no additives for spring water)		Determined based on sampling of product labels, including 5% loss in production	Treatment chemicals, based on Ecoinvent database (e.g., chloride, peroxide			
	Characterization of water production facility or infrastructure	Information provided by Nestle Waters		Assumed same as for Nestle Waters	Based on data from Ecoinvent database			
	Characterization of water distribution system	N/A			Based on data from Ecoinvent database			
	Delivery distances to water production sites	Assumed that inbound distances are equal to outbound delivery distances provided by Nestle Waters (400 km)[13]		Assumed same as for tap water (water production) or assumed same as for NWNA products (other items, e.g., filtering pitchers)				Based on data from Ecoinvent database
Packaging and Equipment Production[14]	Drinking container materials and weights	Information provided by Nestle Waters and confirmed by samples of products. For 3 L bottle, drinking glass as in tap water is assumed		Determined based on samples of products (See tables below)	Determined based on samples of products (See tables below)	Assumed based on example product (glass, 223g) Same as tap water	Based on reusable bottles	Assumed based on example product (glass, 223g)
	Number of uses per container or equipment	1			100 (no supporting data)	600 (1.75L fills) (no supporting data)	30,000 (500 ml dispenses) (no supporting data)	N/A
	Production of resins and other	Based on data from Ecoinvent database. Upstream production activities are represented as in Ecoinvent.						

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[13] NWNA is the largest seller of bottled water in the US and has approximately 27 production sites, allowing coverage of the US geography with an average distribution distance of just under 400km. It is believed, based on input from their staff, that some other bottlers that are not using spring water, and may achieve somewhat shorter distances by locating more directly within major metropolitan areas. Smaller producers may have much larger transportation distances, extending into the thousands of kilometers if they are distributing nationally from a single or just a few production sites.

[14] This category includes production of primary and secondary packaging, drinking containers, the filtering pitcher, and the vending machine, and replacement filters. Where the term “drinking container” is used, this refers to a single-use bottle, a reusable bottle or a drinking glass, depending on the system in question.

Life Cycle Stage	Information	EcoShape Bottle	3 L bottle	Sport, Vitamin and Generic Waters	Reusable Bottles	Home Filtering Pitcher	Vended Water	Tap Water
	primary materials							
	Site of container formation	Formed at bottling plant. For 3 L bottle, glass produced as in tap water		Formed off-site (not at bottling location)	Formed at production site	Drinking glass same as tap water; pitcher formed at production site	Based on reusable bottles	Drinking glass from glass production site
	Composition and weights of filtering pitcher or vending machine	N/A				Based on sampling of product and product literature (see **Error! Reference source not found.**)	Based on product literature and correspondence with manufacturers	N/A
	Processing and energy for container formation	Based on Nestle Waters facility data		Based on data from Ecoinvent database				
	Transport of empty containers	N/A		200 km, volume limited, 20 ton truck	N/A			
	Secondary packaging	Cardboard tray with shrink wrap based on Nestle data, wooden pallet and stretch wrap	Cardboard box based on Nestle data, wooden pallet and stretch wrap	Assumed same as for EcoShape bottle	Packaged 8 per cardboard box, wooden pallet and stretch wrap	Drinking glass same as tap water; pitcher packaged in cardboard box	Bottle packaging same as for reusable bottles; No packaging considered for the machine.	Drinking glass packaged 6 per 250g cardboard box
	Count per pallet	Based on Nestle specifications		Assumed same product weight as for Nestle Eco-shape	Based on volume to fit on pallet	Same as tap water	Based on reusable bottles	No secondary packaging assumed for drinking glass
Transportation	Delivery distance for suppliers	Based on Nestle data		Assumed same as for Nestle products				
	Delivery distances from production facility to distribution center	Based on Nestle data		Assumed same as Nestle distances				No delivery

Life Cycle Stage	Information	EcoShape Bottle	3 L bottle	Sport, Vitamin and Generic Waters	Reusable Bottles	Home Filtering Pitcher	Vended Water	Tap Water
	Delivery distances from distribution center to retail	Based on Nestle data Assumed to be 400 km on weight-limited 21 ton truck					No retailer shipment	
	Transportation to consumers home	Assumed 11 km round-trip in passenger car, allocation of 1/20th of the shopping trip is made to the water purchased (assumed 12L of water per trip, 1 bottle per trip, 1 filtering pitcher per trip)					No transport home	
	Transportation to end-of-life	Assumed all materials travel 72 km by 20 ton truck to either landfilling, recycling or incineration.						
Retail	Shelf space occupied	Assumed, 0.02 m2	Assumed, 0.1 m^2	Assumed, 0.02 m^2	Assumed, 0.2 m^2	Assumed, 0.1 m^2	Assumed, 4 m2 (machine)	No marketing
	Shelf time	3 weeks at regional storage, 3 weeks at market					N/A	N/A
	Percent refrigerated at market	Assumed 0%			N/A		Energy of running operating machine is included in Refrigeration	N/A
Use, Refrigeration	Percent Refrigerated at home	Based on Nestle survey data		Assumed same as for Nestle products		Assumed 100% refrigerated	All water is chilled in machine (no chilling after vending considered)	Assumed 0% refrigerated[15]
	Time refrigerated	Assumed 4 days			Assumed 1 day		Stand-by and operating energy for the machine are included based on manufacturer's estimates	N/A
	Refrigerator efficiency	422 kwh electricity use per year[16]						
	Refrigerator allocation	Allocated based on volume within a 615 L refrigerator, assuming each item occupies 4x its physical volume.					Allocated all to drinking water	N/A
Use, Washing	Method of washing	Assumed no washing of drinking container	Home washing machine of drinking container	No washing of drinking container	Home washing machine of drinking container			

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[15] For water directly from the tap, it is assumed that it is not refrigerated, but rather the user wastes an additional functional unit (500 ml) running water before filling the drinking glass to get colder and/or fresher water.

[16] Based on type Whirlpool GR2FHM*V*O*, made in 2008, with top freezer; with total available volume: 615 L; and yearly consumption: 422 kWh/yr, www.energystar.gov.

Life Cycle Stage	Information	EcoShape Bottle	3 L bottle	Sport, Vitamin and Generic Waters	Reusable Bottles	Home Filtering Pitcher	Vended Water	Tap Water
	Washing machine efficiency	1.2 kwh energy use per cycle; 15 L water use per cycle (Kaenzig and Jolliet 2006)						
	Detergent use	10 g per load, liquid detergent (Kaenzig and Jolliet 2006)						
	Washing allocation	Glasses allocated as one of 40 items in washer. Bottles allocated as one of 20 items. Pitcher allocated as one of 10 items.						
	Frequency of washing	No washing	Glass washed after every 2 servings	No washing	Bottle washed after every 2 servings	Glass washed after every 2 servings; Pitcher washed every 10 servings	Bottle washed after every 2 servings	Glass washed after every 2 servings
End-of-life	Transportation to end-of-life	Included above under Transportation section						
	Percent recycled, primary material	Based on US EPA (2007) data for PET packaging(36.6%) and durable goods (30% for metals, 4.8% for plastics)drinking glass not recycled (3 L bottle)				Pitcher not recycled, drinking glass not recycled	Machine not recycled, bottle recycled as for reusable bottle	Glass not recycled
	Percent recycled, additional materials	Based on USEPA data for recycling of such materials						
	Percent incinerated	Based on UN data for US, approximately 20% of the amount not recycled						
	Percent landfilled	All materials neither recycled nor incinerated						
	Impacts / benefits occurring at end of life	Data from Ecoinvent is used to identify direct emissions and other impacts from the end-of-life processing, such as the burdens associated with the processing of recycled material. For recycling and incineration, an “avoided burden” approach is used to assign a benefit based on the impacts of otherwise providing the material or energy that is provided based on average supply technologies (not marginal technologies).						

While NWNA provided data for the systems that they manufacture, for other products, similar information is not available. In addition, for these other products, it is desirable for purposes of the comparisons that will be made among beverage consumption habits that the information be representative of product categories more so than specific products.

For these reasons, many characteristics of some of the systems being studied have been gathered based on examples of products that are available in the US marketplace within a product category. Information was taken from product labeling and literature, as well as by physical measurements of products themselves. The tables in Appendix 10.2 summarize the information that was obtained for these product categories.

It is possible that the greater use of primary information for NWNA's systems introduced a time-related difference in the data representing each technology. For example, the electricity use at the NWNA facilities is current, whereas even though the Ecoinvent database publication date is very current, the original collection of data for the database may have been several years in the past.

3.2 Data sources for beverage consumption habit comparisons

For the purpose of comparing the impacts associated with a consumer's total beverage consumption, information is needed on a wider variety of beverages than is being examined in the product-to-product comparisons made above, such milk, juice, sodas and other beverages. The information on these additional products is drawn from the best available sources.[17] Information will be taken only in regard to climate change impacts (as g CO_2 equivalents), primary non-renewable energy (as megajoules) and water use (as L of non-turbined water). These indicators have been selected both due to their relative importance and to the expected availability of data of high quality and reasonable consistency among methodologies used to classify these impact areas. Data presented in Appendix 10.2 presents the anticipated sources of information for each beverage type to be used in the beverage consumption habit comparison.

Results of 2009 research by TNS Worldpanel (www.tnsglobal.com) for NWNA showing the percent of beverage consumption in the US is provided below and will be the main data source used to provide the baseline estimate of consumer beverage consumption. Similar information is available, for example, in Storey *et al.*, who provide additional differentiation among age groups and demographics. The TNS Worldpanel data has been selected here because it is more aggregated, therefore representing an average of the population, and because it also includes water consumption, which is not included in the Storey *et al.* data. The results of that research are shown in Table 6 in Section 6.4, Beverage Consumption Habit Comparisons.

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[17] "Best available sources" is interpreted here to include components of geographic relevance, temporal relevance, scientific quality, transparency, and consistency with the methods and/or data used for other information sources. In some cases, such as beer, multiple sources of acceptable information were identified and the information has been compared to derive a reasonable mid-point result. Sources of information are indicated in Table .

Table 2: Beverage consumption of the average US consumer (data from TNS Worldpanel, collected for NWNA)

Beverage	%	Beverage	%	Beverage	%
Filtered tap water	16	Juice	5	Cocoa	0.6
Bottled water	13	Iced tea	4	Energy drinks	0.5
Unfiltered tap water	12	Alcohol	4	Smoothies	0.3
Hot coffee	11	Hot tea	2	Nutritional supp.	0.3
Regular soda	11	Fruit drinks	2	Soy milk	0.2
Dairy milk	8	Powdered bev.	1.9	Weight loss bev.	0.2
Diet soda	6	Sports drinks	1.4		

For determining changes in consumption habits, information has been collected for Nestle Waters by FRC (a marketing research firm, www.frcresearch.com) regarding what beverage options consumers will switch to if their first choice is not available. This information, shown in Table 3**Error! Reference source not found.**, can be interpreted to determine the influence on a consumer's beverage consumption if bottled water is not available. It indicates which beverages consumers are likely to switch to and from when changing consumption of bottled water. The information will be used to make predictions about the changes occurring in consumption of various beverages when the switch to or from various types of drinking water.

Table 3: Beverages consumers say they would switch to if bottled water is unavailable (Data from FRC, collected for NWNA)

Beverage	%	Beverage	%
Bottled water with vitamins / supplements	12	Fruit juice	7
Regular soft drink	12	Carbonated bottled water	6
Diet or caffeine free soft drink	7	Energy drink	3
Sports drink	8	Tonic, club or seltzer	2
Ready-to-drink iced tea	8	Tap water	32
Bottled water with flavoring / sweetener	7		

3.3 Data quality requirements

For the data obtained, data quality guidelines have been determined and checks have been made to determine the adequacy of the data used to meet the guidelines. For the product comparisons, the guidelines used are stated in the table below, along with a discussion of whether they have been met.

Data quality category	Requirement	Assessment
Temporal relevance	The data should be as current as possible and no older than ten years, with the majority of data being within five years. Exceptions should be noted.	The majority of data used for life cycle inventory (LCI) is from the Ecoinvent 2.01 database (published in 2007). Although underlying data within the data base is of varying ages, this is among the most current, if not the most current, source of comprehensive LCI data available. For data defining the amount of materials or processes used in each system (reference flows), data has been collected specifically for this study or taken from very recent sources, including studies conducted by NWNA and recent literature publications.

Data quality category	Requirement	Assessment
Geographic relevance	The data should be relevant to the geographic area of study, or to a geographic area with similar infrastructure and industrial technology. Greater exceptions may be made in the case of commodities whose global supply chains make the location upon which to judge relevance less clear. Exceptions should be noted.	The data regarding the reference flows has been assembled to be relevant to the US context. All products used to assess flows of materials have been examined based on those in the US market. The LCI data from Ecoinvent is largely produced to be specific to a European context. In many cases, the industrial technology between Europe and the US is similar. In some cases, such as electricity use or water use, where data might be particularly important data specific to the US, or that has been modified to better represent the US, has been used. Where data with better geographic relevance is available for some items (such as in NREL's US LCI), Ecoinvent has been used here in preference to maintain comparability among data sources and because of its greater comprehensiveness and temporal relevance.
Comprehens-veness	The life cycle inventory data should be as comprehensive as possible, including as much of the background systems as possible and including as broad as possible an inventory of chemical emissions and resource use.	The Ecoinvent database is in the top tier of data sources regarding comprehensiveness. The scope of background systems included is very broad. The number of chemical pollutants and types of resources uses included is very broad and among the best available.
Comparability	The data should be highly comparable among systems. In the case of life cycle inventory data, the majority of the data among systems should be taken from similar sources or databases, to ensure it has been produced in a similar manner and with common methods and assumptions. For data regarding the amount of materials and energy used, the data should be selected from sources of comparable accuracy. Where comparable accuracy is not available, data should be chosen so as to avoid data with large accuracy differences from determining the nature of the results.	The data has been assembled to be highly comparable. The LCI data among all systems is from the same data source (Ecoinvent), ensuring a very high level of comparability. For the data determining the reference flows, there is a potential concern in comparability when some systems represent products of a specific manufacturer and others represent industry average products, as is done here. In addition, the study has benefitted from a high level of detail for NWNA information and that high level of detail is not available across the industry categories of the non-NWNA products. To address this issue, in several cases, identical data has been used among systems to ensure that results are not being determined by data that is not of comparable accuracy or relevance. For example, the distribution distances for NWNA products (400km) have been used for all systems studied. Similarly, the production energy used at NWNA facilities has been assumed to be the same for manufacturers of other bottled beverages.
Transparency	The data should be from transparent, well-documented and available sources to allow others to further judge its quality and applicability.	The main source of LCI data, Ecoinvent, is commercially available for examination and use by others. Other sources of information used, such as to determine reference flows, are either previously available, or the relevant information has been disclosed in this report. Data specific to NWNA products is obtained from internal proprietary tools.
Accuracy	Data should be chosen that is as accurate as possible. To ensure the relevance of comparisons that are made, where differing accuracy of data may be available among systems, data should be chosen to first ensure comparability and then accuracy, using sensitivity tests or other means to judge the importance of such choices.	It is believed that the Ecoinvent database is among the most accurate data sources for LCI data. Regarding reference flows, the most important aspects for the bottled beverage systems are the weights of materials and transportation distances. The weights have been directly measured and therefore highly accurate. The distances are not knows with high accuracy and therefore they have been set equal among systems (as described above) and subjected to sensitivity testing. For the tap-water based systems, washing of dishes during use is important. The information on use of energy during washing has been chosen to be within what is a highly variable range, with upper and lower bounds tested as part of the sensitivity tests.

For the comparison of beverage consumption habits, data has been taken from the best available sources that could be found. With the exception of systems directly modeled in the present study, there is little ability to comprehensively judge the data quality. It is expected that there are significant differences in geographic relevance, comparability and transparency of the data used among the various types of beverages. This should be understood and considered when evaluating those results.

4. Scope and Detail of Systems Studied

4.1 System boundaries for product comparisons

The life cycles of the drinking water and alternative products to be compared have been divided into the following life cycle stages:

Water production: Pumping and treatment of the drinking water either at a municipal water plant or at a bottled beverage production facility. For systems where filtration or treatment is conducted at the home or point of use (e.g., the home water filter and vended water), the production and operation of those filtering systems is included in this stage. For those beverages containing additives, production of the additives is included in this stage. Transportation of all water production materials up to the point of manufacture are included in this phase.

Packaging / Equipment Production: Extraction of raw materials and production of the drinking container used in each system, including the disposable container for bottled beverage systems, the reusable bottles and drinking glasses used in various systems. Also included are the manufacture of items such as the filtering pitcher, the water vending machine and replacement filters for each. Transportation of all production materials for these components up to the point of manufacture are included in this phase.

Transportation: All transportation occurring in the system beginning with the immediate suppliers to the manufacturers of beverage products, drinking containers or filtering systems and ending with the transport of all materials to end-of-life. Also included are transportation of products from point of manufacture to point of sale and transport to the user's home.

Distribution and Marketplace: Activities related to marketing the products, including operation of retail outlets and/or coolers.

Refrigeration: Refrigeration of the water at the user's home. Commercial coolers are included in the Distribution and Marketplace stage listed above.

Washing of Drinking Containers: Washing of drinking containers, including drinking glasses and reusable bottles in between uses. Washing is assumed to take place in a dishwasher.

End-of-Life: Disposal of all materials by either landfilling, waste-to-energy or recycling. For disposal options that reflect a beneficial use of the material, these benefits are added to the system by expanding the system boundary to include the environmental burdens that are avoided by not needing to otherwise fulfill these functions. This includes the avoidance of electricity generation from waste-to-energy operations and avoidance of virgin material production from material recycling. At the end-of-life stage (and in all stages), emissions are included and equally evaluated regardless of the timing of their occurrence.

For each stage, process and materials have been included so as to provide as comprehensive a scope of study as is practicable. In all cases where information was readily available to be included, those materials or processes were included for consideration. Where parts of the systems exist that could have been identified, but for which adequate data did not readily exist, such materials or processes were excluded from consideration only if it could reasonably be expected that the environmental impacts of those components would be less than 1% of the total for the system in question. For example, grocery store price stickers, grocery bags, and receipts were not considered for purchased items, nor were the paper bills sent for the use of tap water. Business travel and employee commuting have been excluded. Prior internal assessments by Nestlé waters have shown them to be, in total, very close to the 1% cut-off. It is believed that all components contribution more than this 1% cut-off threshold have been included. In some cases (for example, wooden pallets used in shipping bottled water), it was not certain that the impact would be less than 1% and so they have been included to be able to ensure that items above the threshold were not excluded.

Figures 1-8 contain diagrams of the various systems, highlighting the aspects included within each stage, including the amount of many process or materials that are used *per functional unit* for each system. In some cases, the names and/or amounts of materials or processes that are of lesser importance have been omitted from these diagrams (but not from consideration in the study) for simplicity of presentation. A complete listing of the materials and processes included in each system is presented in the list of reference flows in the report appendix.

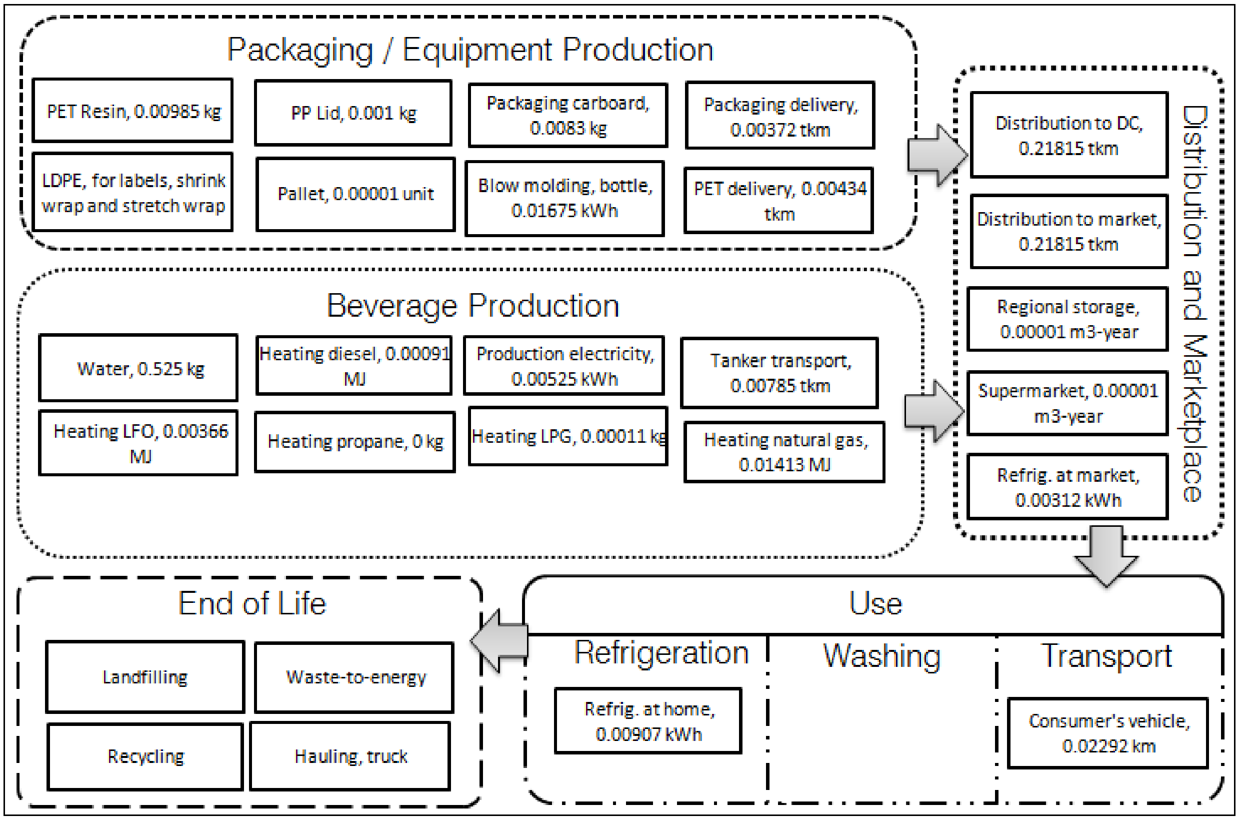

Figure 1: Boundary of system and stages for the EcoShape bottled water systems

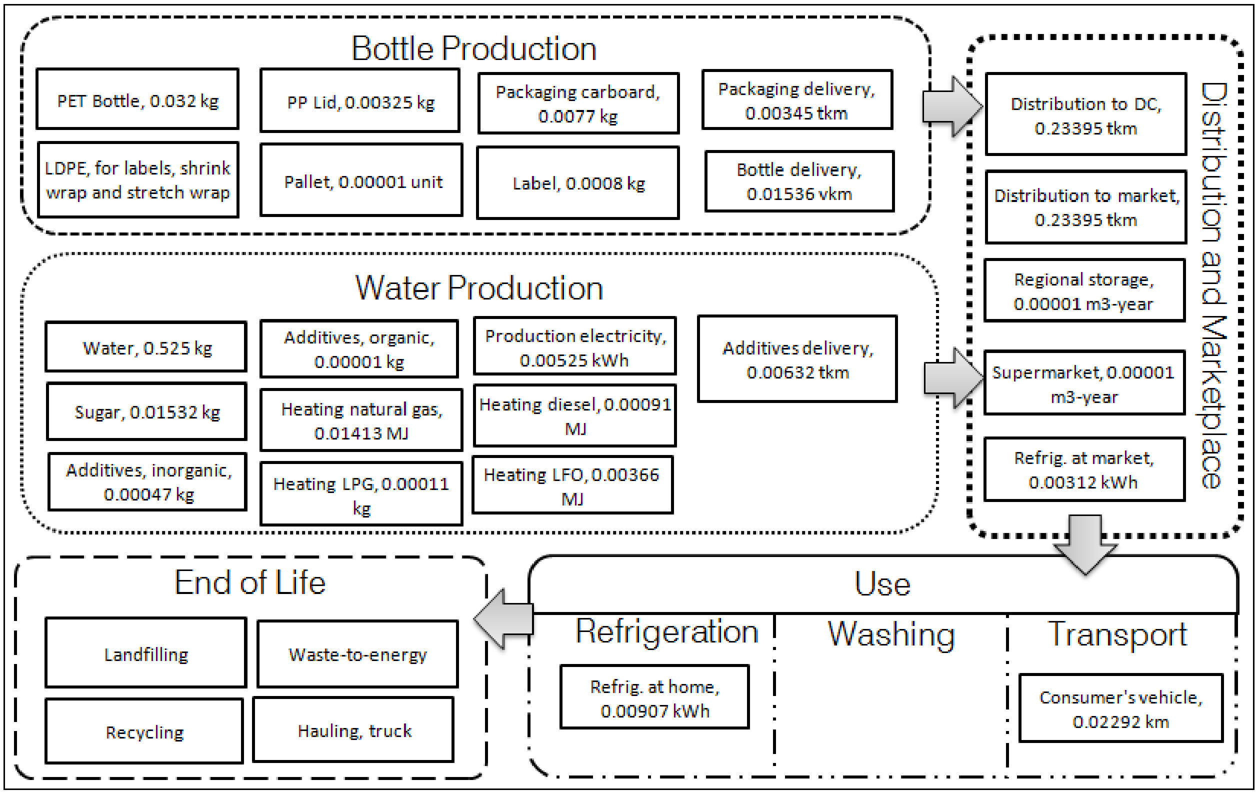

Figure 2: Boundary of system and stages for the sport drink system

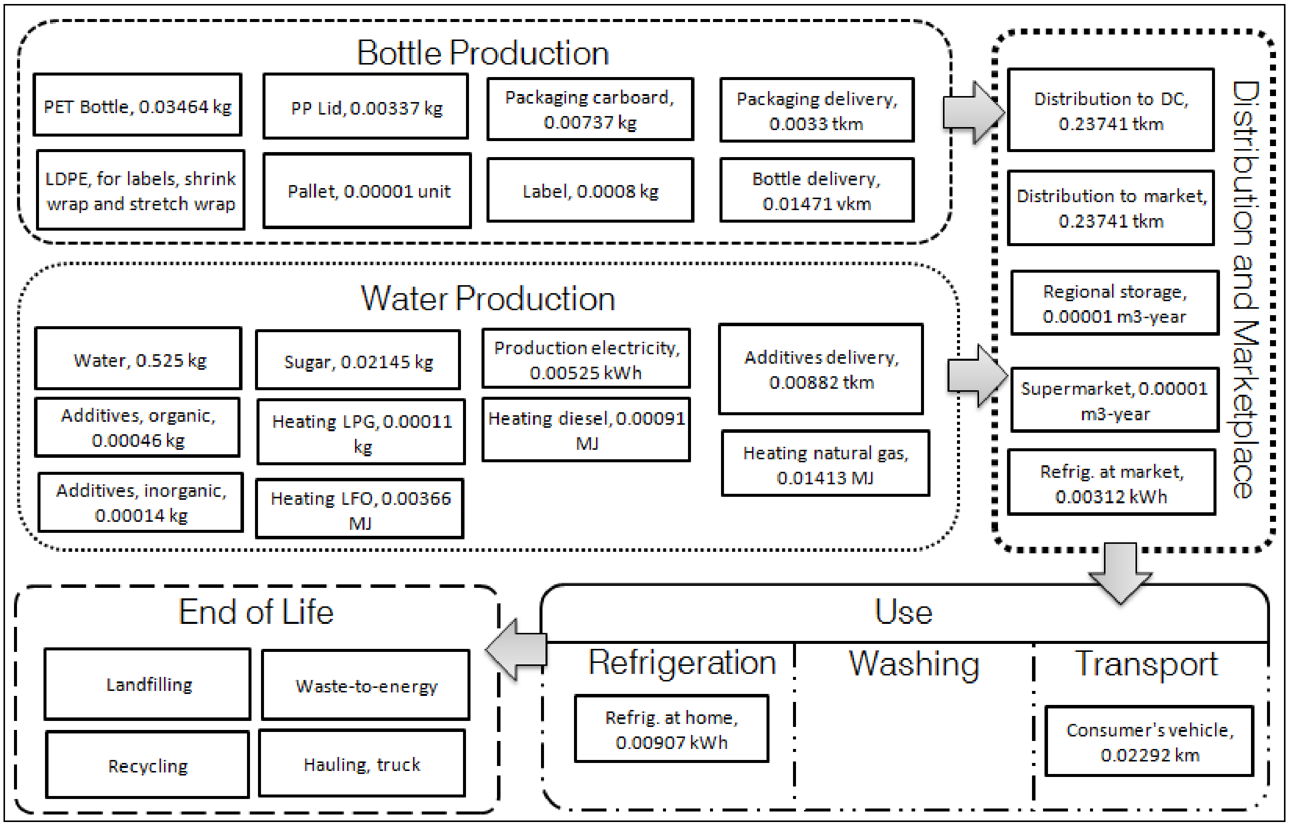

Figure 3: Boundary of system and stages for the vitamin-fortified water system

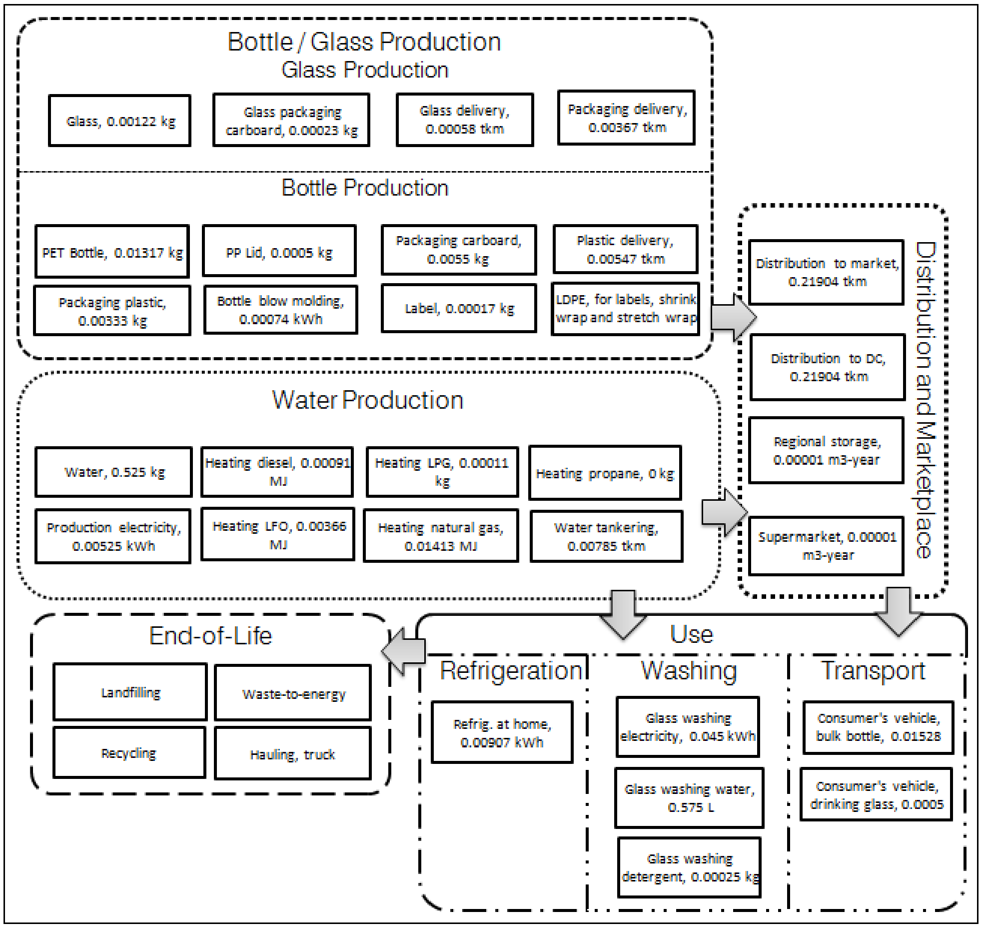

Figure 4: Boundary of system and stages for the 3 L bottle system

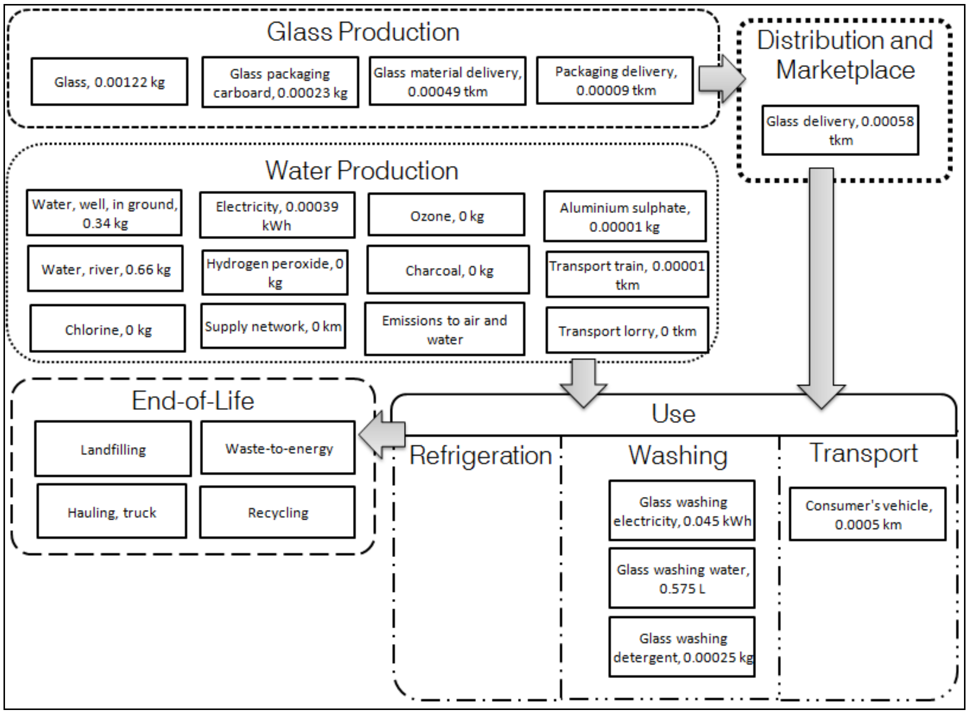

Figure 5: Boundary of system and stages for the tap water system

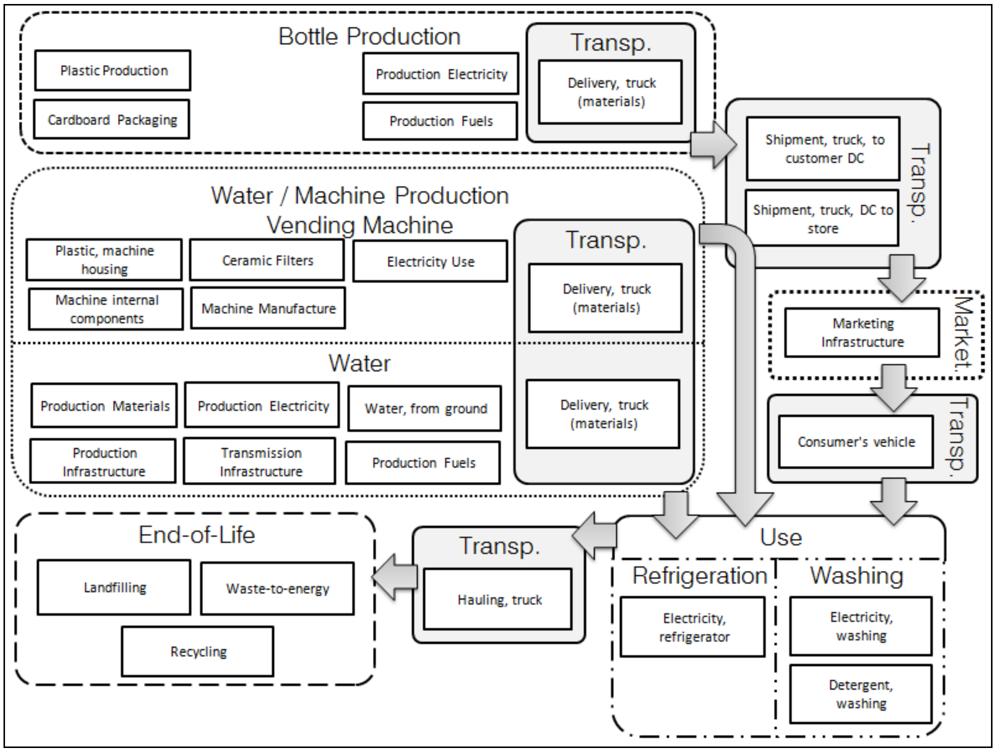

Figure 6: Boundary of system and stages for the vended water system, with plastic reusable bottle

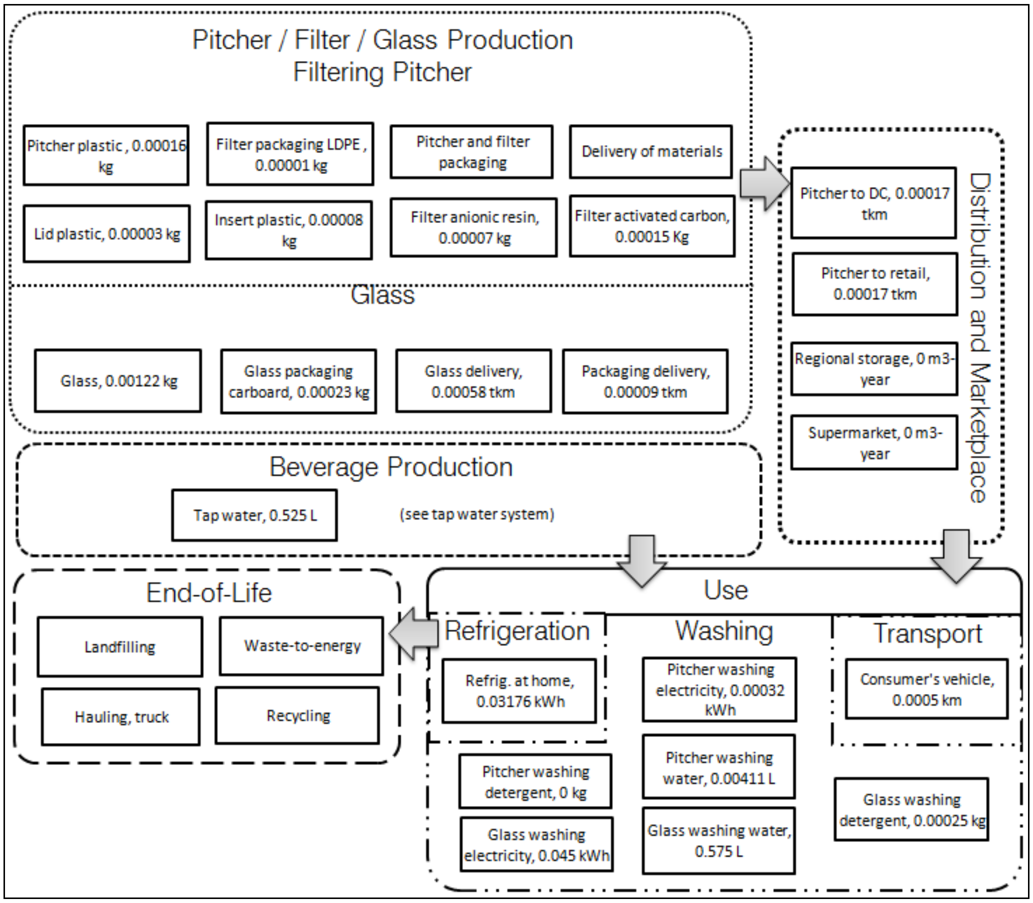

Figure 7: Boundary of system and stages for the filtering pitcher system

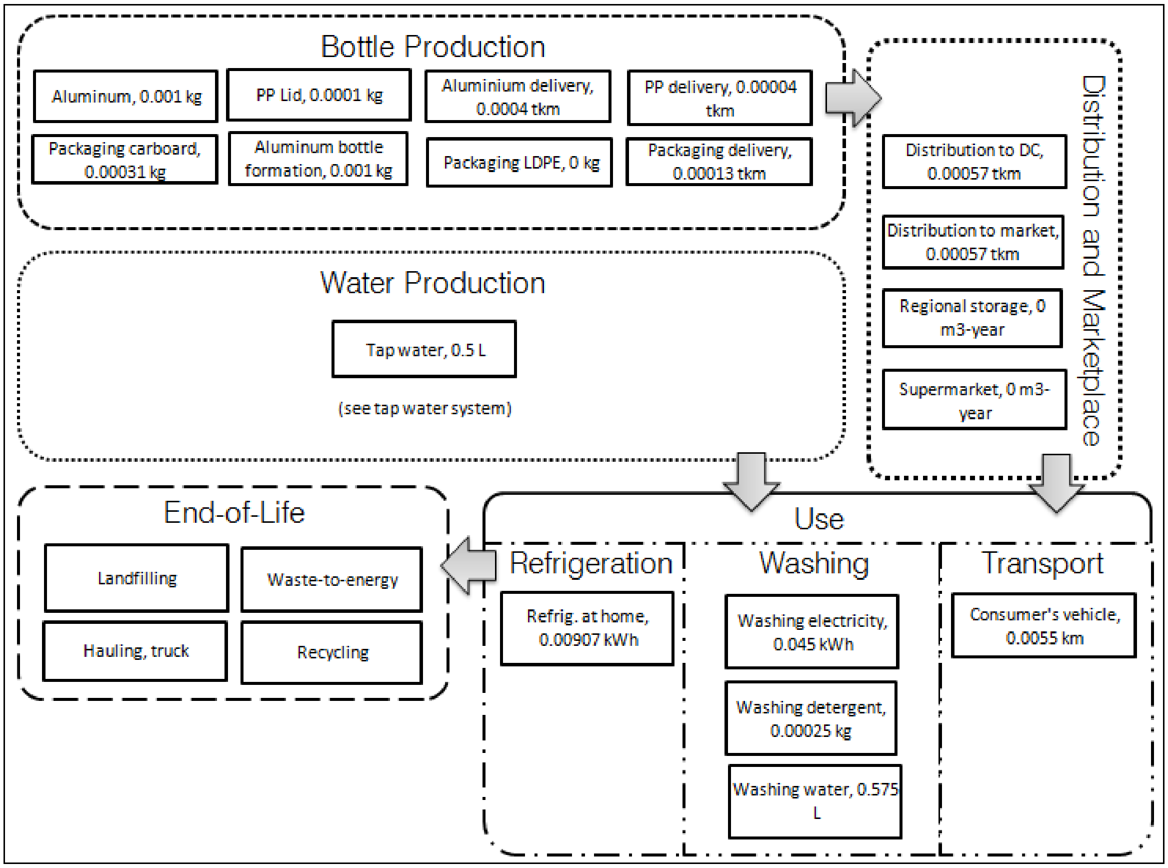

Figure 8: Boundary of system and stages for the reusable bottle systems (using example of aluminum)

4.2 System boundaries for beverage consumption pattern comparison

The system boundary for the beverage consumption comparison is intended to include all impacts associated with producing and providing the beverages consumed by a consumer in a single day, based on the proportions consumed among the population. This includes the same general scope as shown in the prior section for the product comparisons. In particular, it includes the production of the beverage itself, including raw material ingredients, production of the packaging, transportation, distribution and retail operational, use and end of life. In several cases information is drawn from literature-derived sources, and it is not possible to ensure a completely consistent scope among all the beverages. Sources of information have been chosen that provide as close as is feasible a scope to that outlined in the above section for the production comparison.

The purpose of this analysis is to place the impacts of beverage consumption within the context of consumer behavior and to examine how the complexities of consumer choices may influence the effectiveness of certain efforts to influence or constrain consumer choices of beverages. It is further meant to provide a more meaningful context to the comparative influence of each type of beverage by representing them based on typical amounts consumed. As an example, wine and spirits are shown to be highly impacting on a per-volume basis, but are not consumed in large amounts and are therefore a rather minor influence on the beverage-related environmental "footprint" of a typical consumer.

4.3 Beverage consumption habit comparisons

Within consumption habit comparisons, scenarios have been conducted that consider various changes in the baseline consumption habit in response to hypothetical choices of consumers or external conditions. These include: (1) the case where the consumer eliminates bottled water consumption and replaces it based on the information from the consumer survey; (2) the case where the consumer eliminates bottled water and replaces it with tap water only (all bottled water is switched to tap water); (3) the case where the consumer increases their daily bottled water consumption and thereby reduces consumption of other beverages based on the consumer survey; and (4) the case where the consumer eliminates tap water and replaces it with bottled water only (all bottled water is switched to tap water).

5. Scenarios and Sensitivity Tests

5.1 Product comparisons

Within the product comparisons, several scenarios will be conducted to explore the importance of information that is either uncertain or highly variable. The aspects to be tested will be determined based upon consideration of the preliminary results and with suggestions from the external review panel. Some options might include, for example:

Number of uses per bottle: It is anticipated that the behavior of the user of reusable bottles will have a substantial influence on the impact of these systems. The consumer can influence the number of uses of his bottle. A set of scenarios have been run to show the variation in impacts from a low number of uses to a high. The bottles are assumed to be used 1, 3, 10, 30, 100, 300, and 1000 times (the baseline results assume 100 uses). There is no reference that could be found to support this number. In practice, some bottles will be used very infrequently (<10 times), while others will be used very frequently and for a long period (1000 uses or more). These reuse assumptions apply to the reusable bottles only. Bottles from the single-serving beverages are assumed to be used only once.

Distribution distances of products: Because the product transportation stage of the life cycle is a major contributor of impact for many of the systems, a series of scenarios were run to consider product distribution with differing transportation distances from factories to distribution center and from distribution center to retail. These scenarios include distribution distances of 400 km (baseline scenario, based on the distribution network of NWNA), 100 km, 1000 km and 3000 km.

Allocation of consumer's shopping trip: When consumer's shopping is included in a system, there is a methodological choice that must be made regarding how to apportion the impact of consumer's vehicle per purchased product. There is no reference available to justify one choice or another and the allocation will depend upon the amount purchased, as well as the choice of the basis for the allocation (e.g., mass, cost, number of items, urgency of need). To test the importance of this methodological choice, several allocation approaches have been applied as scenarios. The baseline scenario throughout this report allocates 5% of the vehicle's impact to the purchased item (one 24-pack pack of single-serving bottles, six 3 L bottles, one reusable bottle or one filtering pitcher). In addition, scenarios are conducted that include allocating 1%, 3%, 10%, 30% and 100% of the impact to the purchased product.

Container recycling rates: It is uncertain how dependent the results of the bottled systems may be on the rate at which the PET bottles are recycled at their end of life. To explore this question, a range of options from 0% to 100% recycling are considered. In addition to changes in the average rate of recycling for the population, it is possible to consider the difference between 0% and 100% to be representative of the effect of recycling an individual bottle or not recycling it, or one consumer changing the behavior from no recycling to all recycling.

Percent of product refrigerated: There may be wide variation and uncertainty regarding what percent of bottled beverages are refrigerated (and for how long). To examine these questions, scenarios are conducted regarding the percent refrigerated, varying from 0% to 100%. In addition to the percent of product refrigerated, the sensitivity shown here may also be interpreted to be representative of time refrigerated or any other factor that would be linearly related to the electricity use attributed to refrigeration, such as the energy demand of the refrigerator. The baseline scenario has assumed 100% of bottles are refrigerated for an average of 2.4 days (a timeframe based on NWNA market research and that includes those bottles not refrigerated)

Efficiency of washing: As with refrigeration, the conditions of dish washing are variable and the average condition is uncertain. To examine the sensitivity to this activity, scenarios are conducted adjusting the energy used by the dishwasher (including the energy to heat water). Scenarios range from 1.0 kwh per load to 2.2 kwh per load, spanning the range in values shown for current models in Hoak et al., 2008. The baseline is 1.8 kWh, which is the prior standard for qualifying for US EPA's Energy Star Program.

Source of electricity: The default assumption has been that electricity used in manufacturing processes, refrigeration and dishwashing is based on the mixture of technologies supplying the US electrical grid. Electricity production may vary by region and some may argue for consideration of a regional grid for certain locations. Others may argue that because it is the so-called "marginal" technologies supplying the grid that respond to changes in electricity use, it may be more realistic to assume all electricity is from coal or natural gas when evaluating actions. To examine these issues, a set of scenarios has been conducted altering the "carbon intensity" of the grid from between 0.2 and 1.2 kg CO2 eq. per kwh, which spans the range of the more efficient regional grid mixes in the us and the carbon intensity of coal-based power plants.

6. Results

Complete results for each of the chosen indicators for each life cycle stage are provided in the appendices. In the sections below, the discussion will prominently feature the Climate Change impact category, with additional mention of other indicators in situations where the findings are particularly noteworthy. The focus on climate change is for simplicity of presentation and is not intended to place exclusive emphasis on this impact category. Where results differ significantly for other impact categories that have been studied, such differences are noted in the discussion. A specific section is included below for presentation of results from the other systems.

6.1 Product comparisons

6.1.1 Overview

The total climate change score for the baseline scenario for each system is shown in Figure 9. The 3 L bottle, filtering pitcher, vended water and tap water generally require a drinking container to be used in the system. For each of these systems except the vended water, use of a drinking glass has been assumed in the baseline results shown in Figure 9. For the vended water (from a water vending machine), because this system is most often encountered when the consumer is outside their home or workplace, it is assumed that a reusable bottle is used.[18]

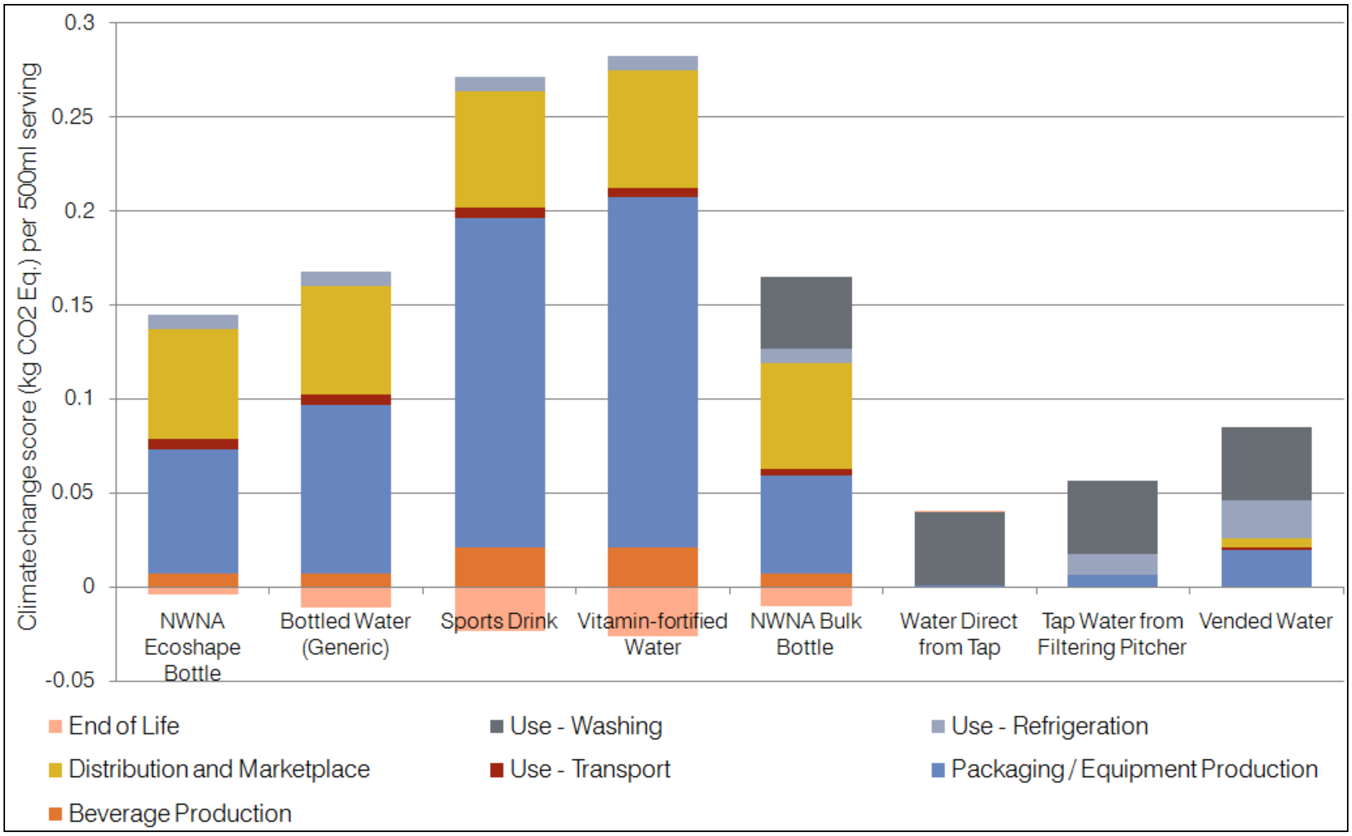

Figure 9: Total Climate Change Impacts by Life Cycle Stage for the Main Beverage Scenarios (per 500 ml functional unit)

The climate impact of the single-use bottled beverages range between roughly 2 and 5 times that of the non-bottled options. Among the bottled options, the sports drink and vitamin-fortified water are more than 50% more impacting for climate change than the EcoShape bottle.

While the inclusion of sugars and other additional ingredients contributes to the greater impact of those beverage systems, it is primarily a substantial increase in the amount of packaging materials (the PET bottle) that causes the magnitude of larger impact of the sports drink and bottled water. It is important to note, therefore, that the majority of the difference shown among these systems is due to the specific

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[18] Where reusable water bottles are included in the results of each drinking water system, it is represented as an average value among bottles of plastic, steel and aluminum, as described earlier in the report.

characteristics of the products currently on the market, rather than an inherent difference in the products. While the size of the 3 L bottle allows for an additional saving in impact in comparison to the EcoShape bottle, this advantage is nearly offset by the added need to wash a drinking container to be used with the 3 L bottle.

Within the tap water-based systems, the direct consumption of tap water (assumed in the baseline to be unrefrigerated) shows the lowest impact. The filtering pitcher and vended water are between 1.5 and 2 times as impacting as the direct tap water. This increase is primarily due to the added equipment needed (including the pitcher, machine, and filters for each), and the electricity used in cooling the water.

Each of the tap water-based options shown above will require in most instances a drinking container (as will the 3 L bottle). Rather than the drinking glass that has been assumed in the baseline results above, and a more suitable comparison to the utility of a single-serving bottle would be a reusable drinking bottle, of which a wide variety are available on the market.

The following figure illustrates the potential importance of such variability by showing the tap water impacts with the use of a reusable bottle added, showing the difference between an aluminum bottle that is used 100 times and one that is used 10 times.

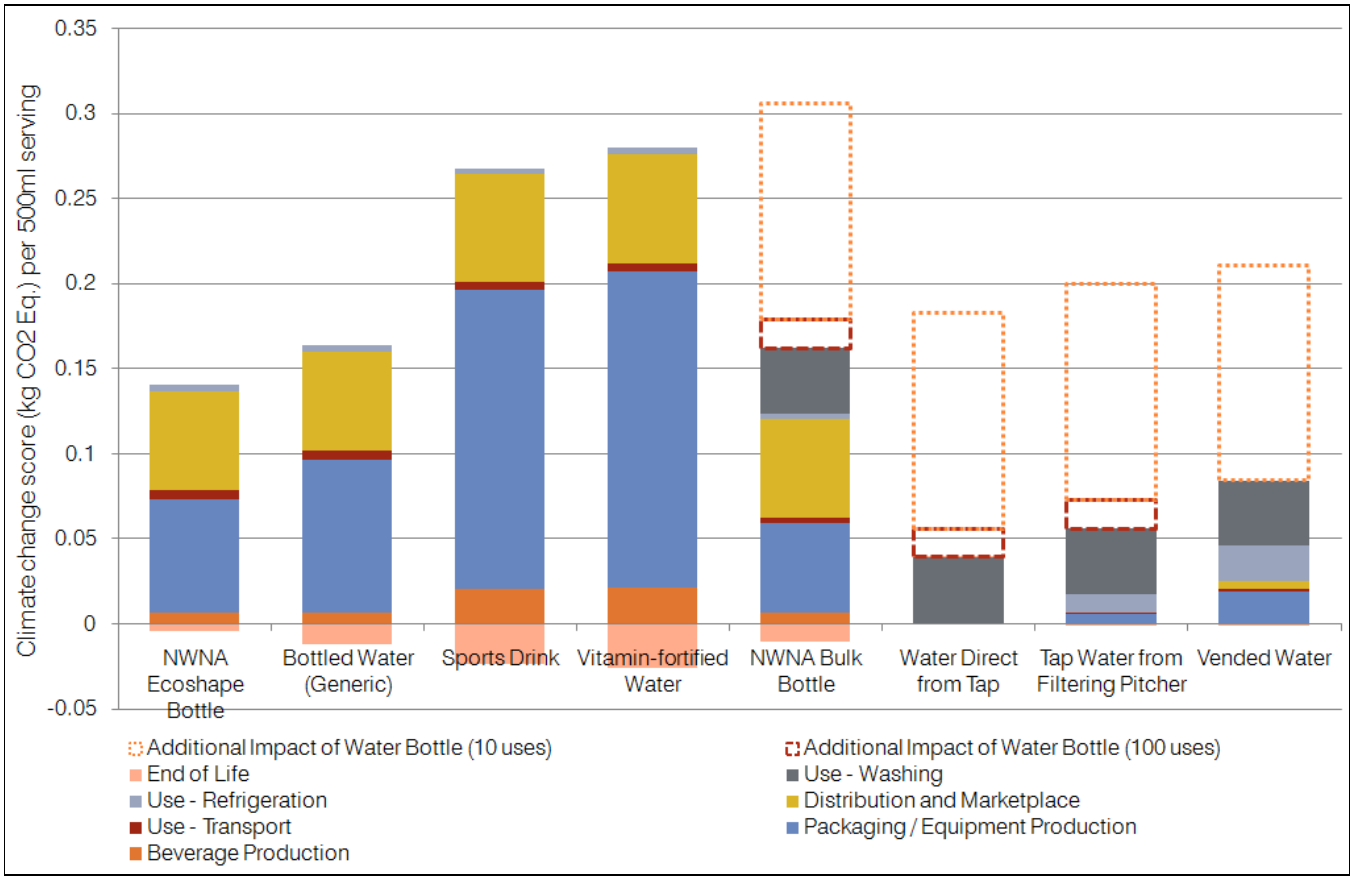

Figure10: An illustration of the influence of number of uses for reusable water bottles

The results show the important influence of the type of drinking container used for tap water and, perhaps more importantly, the number of times that the container is used. This relationship will be explored further below as part of the analysis of scenarios. (see Figure 15 in Section 6.3, Scenarios, Sensitivity Tests & Uncertainty Assessments).

6.1.2 The Results in Perspective

It can be informative to place the results of assessing such products within the context of other everyday items and activities to allow for a clearer understanding of the importance of each system and the difference between them. The results of 137 g of CO_2 equivalents for an EcoShape bottle, 253 g for a vitamin water and 40 g for tap water may not mean much to the typical consumer. Using information provided by the US EPA[19], the following comparisons have been made to other aspects of a consumer's everyday life:

Table 4: Comparison of benchmarks with climate change impact of water consumption

	Water directly from tap	Water from filtering pitcher in reusable bottle	NWNA EcoShape bottle	Vitamin-fortified water
Climate change score for 4 500 ml servings per day annually (kg CO_2 eq.)	58.4	106	200	369
Number of propane containers for home barbeque	1.1	2.0	3.7	6.8
Number of miles driven by car	150	280	520	970
Years of continuous operation of a 100W lightbulb	0.09	0.17	0.31	0.58

These comparisons are shown, along with the additional beverages that are included below in the comparison of total beverage consumption habits, in Figure 11 below. Seeing results within the perspective of other common aspects of a consumer's lifestyle may help give perspective to the level of importance of this topic versus other actions a consumer might consider to reduce their impact on the environment.

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[19] Comparisons are based on data from US EPA (www.epa.gov/RDEE/energy-resources/calculator.html)

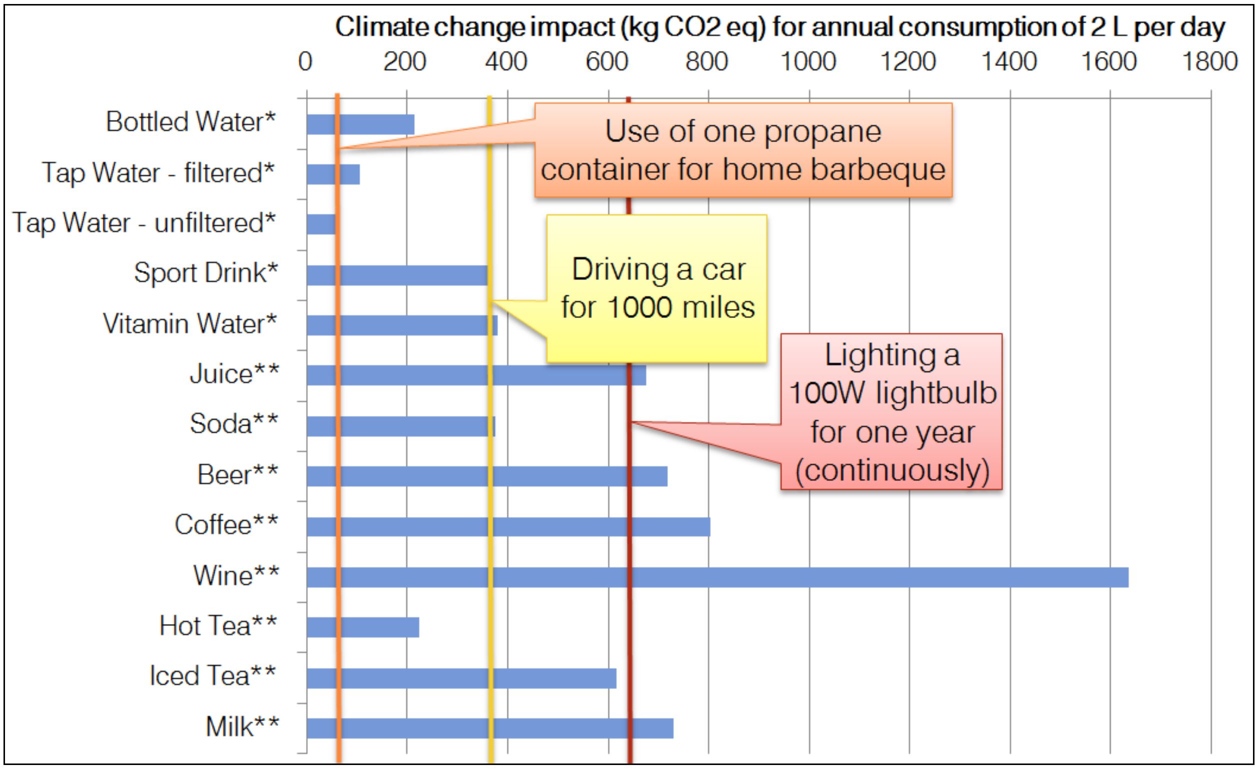

Figure 11: Climate change score (kg CO2 eq per year) for annual consumption of four daily 500 ml servings of each beverage (* indicates results from the present study; ** indicates results from pre-existing sources).

6.1.3 Contributions by Life Cycle Stage

Detailed descriptions and figures showing the contribution of the various life cycle stages to the beverages studied are provided as an appendix.

5.2 Assessment of Additional Impact Categories

For simplicity, the results shown in Section 6.1 refer primarily to the impact category of climate change. However, it is important to consider also the results of other environmental impact categories to identify cases where the conclusions drawn within the climate change category may not be consistently supported by other indicators of environmental impact. Figures 12 - 14 below show the results for each of the additional categories of environmental impact that have been examined. These include the midpoint and endpoint indicators of the IMPACT 2002+ system (including water use), the indicators of the TRACI system and indicators for total materials used and wastes generated. The impact assessment methodology is described in more detail in Section 2, Methodology, and in the appendix.

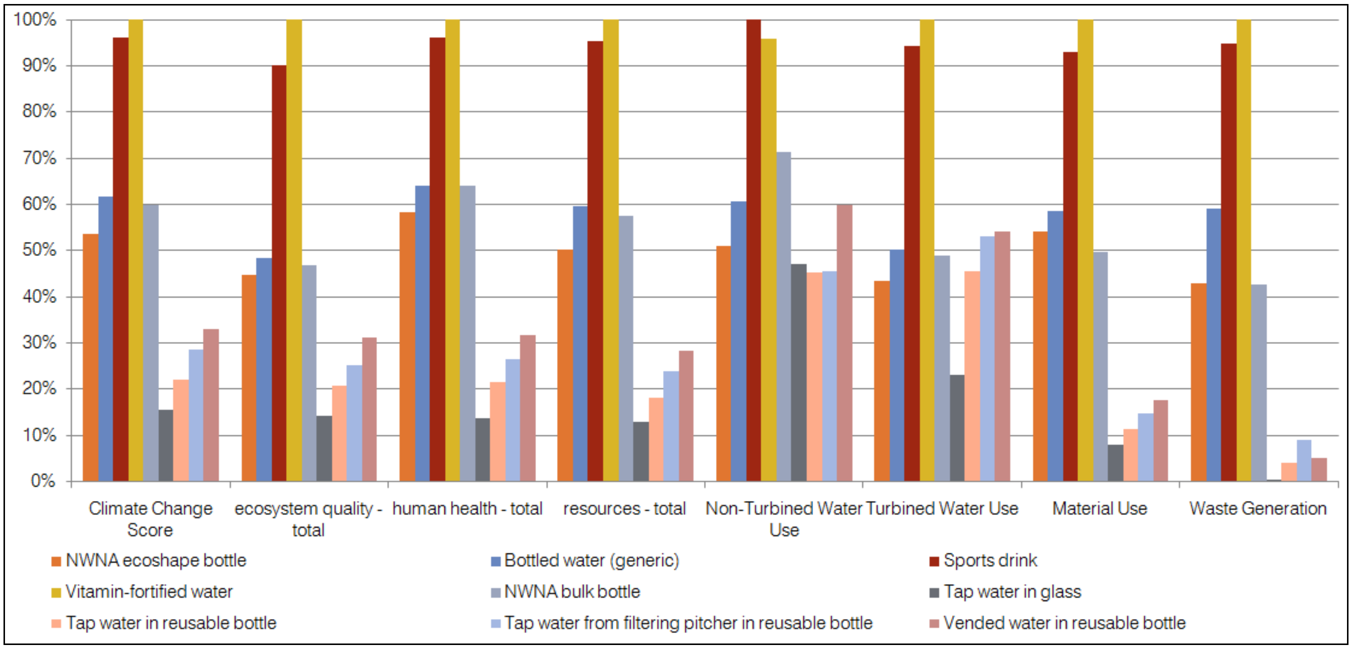

Figure 12: Results for the endpoint indicators of the IMPACT 2002+ system, water use, material use and waste generation. All are shown as a percentage of the highest impacting system in each category, based on providing one 500 ml serving.

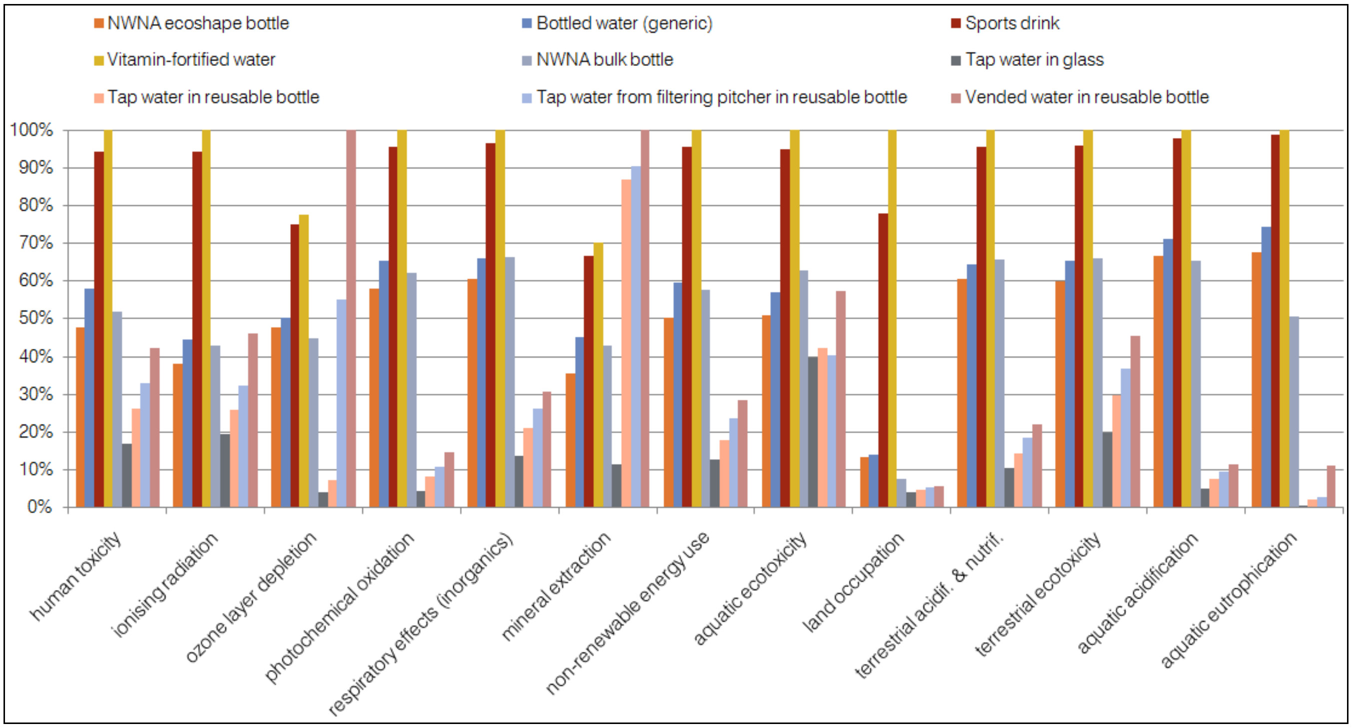

Figure 13: Results for the midpoint indicators of the IMPACT 2002+ system. All are shown as a percentage of the highest impacting system in each category, based on providing one 500 ml serving.

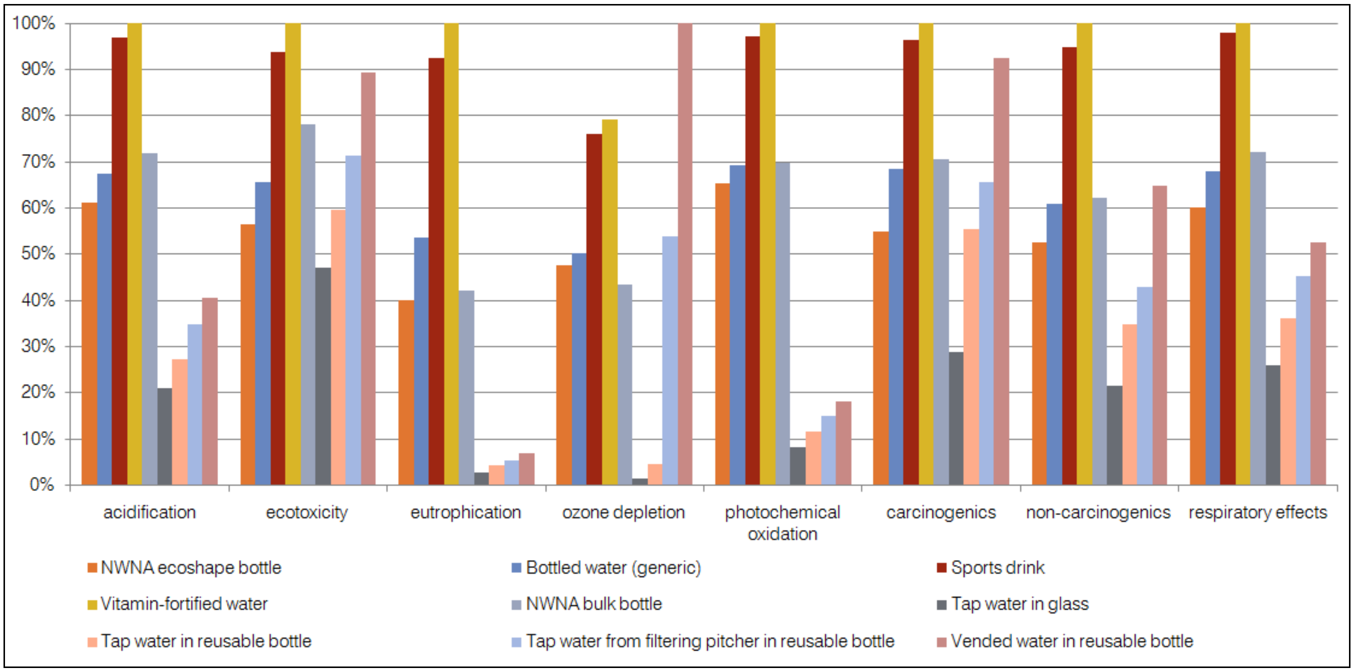

Figure 14: Results for the indicators of the TRACI system. All are shown as a percentage of the highest impacting system in each category, based on providing one 500 ml serving.

The large majority of the impact categories considered support the conclusions that have been reached above, with the tape water options out-performing the packaged beverage options. Within the bottled water options, the general hierarchy of the EcoShape bottle and 3 L bottle performing better than the generic bottled water, which performs better than the vitamin waters and sports drinks. Within the tap water options, the hierarchy of water directly from the tap consistently scores best, with the use of a reusable bottle[20] and filtering pitcher adding additional impact and vended water performing the worst among these options.

Within the mid-point indicators, there are some significant exceptions to the findings. For a handful of impact indicators, including mineral extraction, ozone layer depletion and several indicators of human or ecological toxicity, the results are of the tap water systems are shown to be either very close to or in some cases exceeding the impact of the bottled water systems. This is not the case for water consumed directly from the tap, but only for those situations where the reusable bottles are used. It is the metals in the reusable bottles (and in the vending machine) that are causing the prediction of high impacts in these categories.

An advantage of the IMPACT 2002+ system is its integration of the various midpoint factors dealing with human health and ecosystem quality, providing a scientifically-based assessment of the overall effects on human health and the ecosystem. The endpoint factors resulting from combining these midpoint categories are shown in Figure 12. It is shown that for the human health and ecosystem quality endpoints, even though there are some mixed results within the midpoint categories, the overall trend among systems is quite consistent with the findings for climate change.

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[20] In all results shown in this section, the reusable bottle is represented as an even mix of plastic, aluminum and steel options and is assumed to be used 100 times.

One important exception to this general finding is shown for water use, and particularly the non-turbined water use (which excludes the water used for electricity generation). **This consumptive use of freshwater is shown to have nearly equivocal results between the bottled water and tap water options. It should be noted that the water consumption indicator for the tap water systems is likely to be highly dependent on the rate of loss of water in municipal water systems.** The rate for the US has been assumed to be 12% following the Ecoinvent database, but we have not been able to confirm this number with reliable US sources and the actual loss rate may be much higher. The vitamin and sport water products remain higher for these categories partly due to the additional use of water in raising sugar.

In total, the evaluation of these other impact categories suggest that the general conclusions drawn in the preceding sections (and below) for climate change are valid for a wide range of environmental impact categories. However, they also point out a few places where some caution might be taken in interpreting the results and suggest a potential need to further explore the results with regard to metal-containing products. Further evaluation of water use as an indicator might also be appropriate to better understand what conclusions might be reached on this issue. Additional detail on these additional categories of environmental impact are provided in an appendix.

6.3 Scenarios, Sensitivity Tests and Uncertainty Assessment

As described in Section 5.1, numerous sensitivity tests and scenarios have been examined to examine the responsiveness of the results to varying conditions and to explore the strength of the findings to alternative assumptions. The results of these assessments are presented and discussed below.

6.3.1 Number of uses per bottle

To examine the variation in results depending on number of uses per reusable bottle, scenarios have been conducted in which this number of uses was varied between 1 and 1000 uses. Figure 15 shows the results of these scenarios for the climate change score.

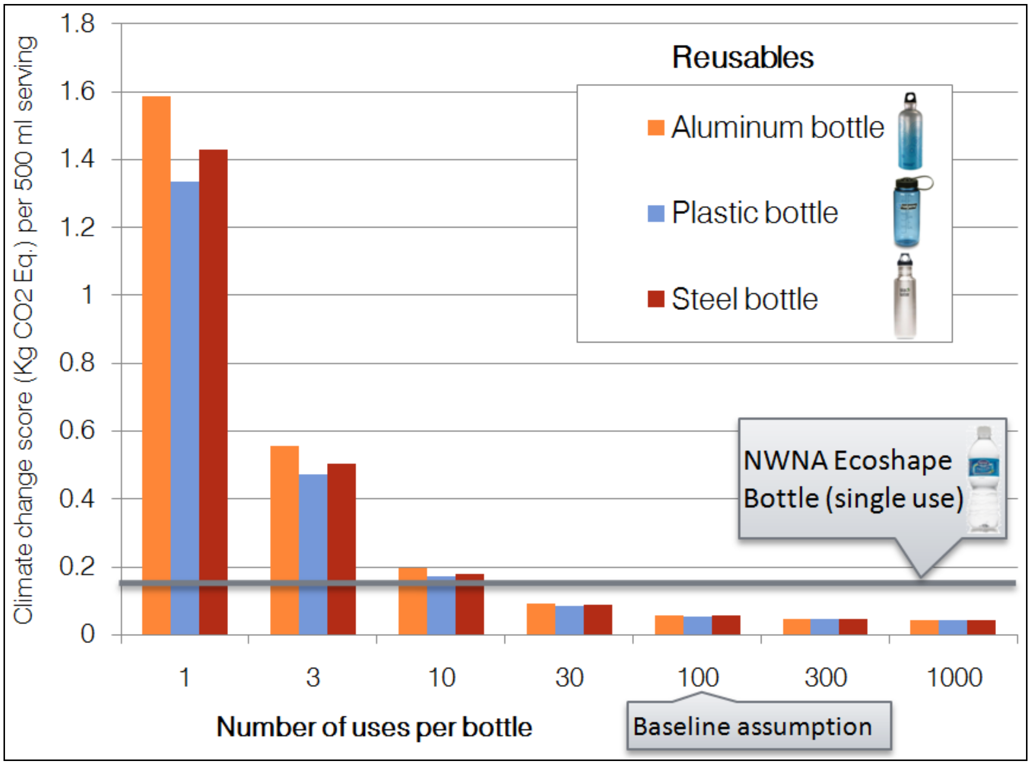

Figure 15: Climate change score for the life cycle of providing 500 ml of drinking water in a reusable bottles of varying number of uses (100 uses has been assumed in the baseline results).

Increasing the number of uses is shown to improve the performance of the reusable bottles. It is shown that above 100 uses per bottle, the impacts of bottle production become very small in comparison to other aspects of the life cycle and a 10-fold further increase to 1000 uses provides only a minor improvement in the impact per use. However, under 100 uses, the rate of change of impact per use is rather steep and especially so below 10 uses. It is possible to consider the question of how many times a reusable bottle must be used to provide a better environmental performance than a bottled water product. For purposes of comparison, the climate change impact of the NWNA EcoShape bottle is shown in Figure 15 as a horizontal line. It appears that the break-even point for use of a reusable bottle is between 10 and 20 uses, with some variation depending on the type of bottle. Further variation would result from consumer behaviors, such as conditions of washing the bottle.

6.3.2 Distribution distances of products

To examine the variation in results depending on distribution distances of products, scenarios have been conducted in which this distance was varied between 100 km and 2000 km.[21] Figure 16 shows the results of these scenarios for the climate change score.

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[21] The baseline assumption for distribution distance of all systems is 400km to the customer's distribution center, This is based on NWNA internal data and other systems have been assumed to be equivalent to avoid providing an advantage or disadvantage where high quality data regarding the distribution networks of other manufacturers is not available. 100 km is selected as a minimum based on what is expected might be achieved by some competitors with

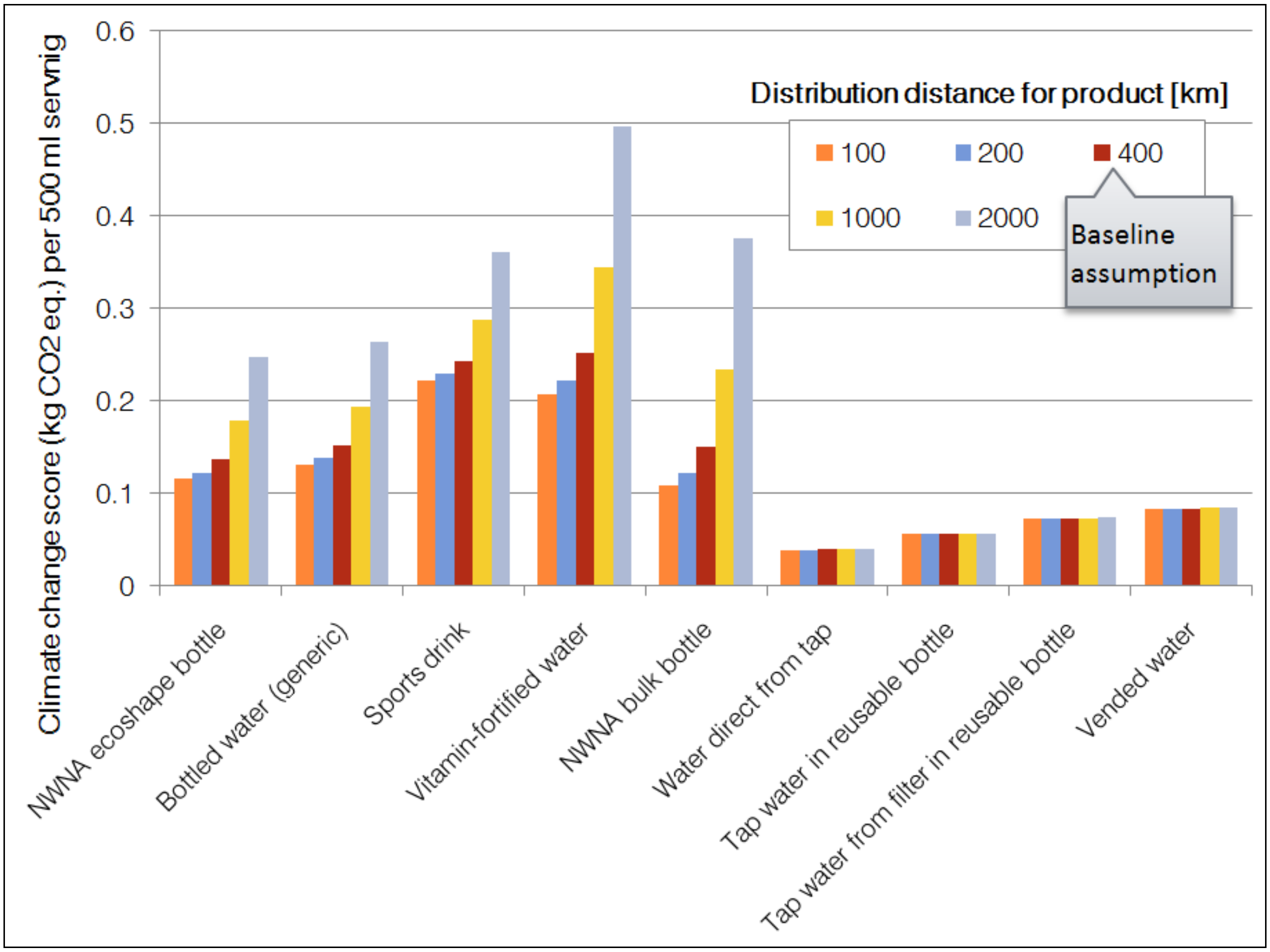

Figure 16: Climate change score for all systems of varying distribution distances of the products (400 km has been used in the baseline results).

It is clear from the results of the sensitivity assessment that the results for the bottled water systems are highly sensitive to variations in product transportation distance. The impacts of the products on the market might therefore vary above or below the values shown in this report depending on the distances of shipment from each producer and certainly on a per-bottle basis, the impacts will vary widely, with a potential for impacts from small bottled water producers that ship nationally (or internationally) to be much higher than that represented here. This might be interpreted to imply that (along with light weight packaging), the density of the production network may be a primary determinant of impacts among products in this category. Brands and formats that sell at high volumes may therefore allow denser networks and lesser transportation impact than brands with smaller sales volumes covering the same geographical market.

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a very local delivery system (chosen with input from NWNA). 2000 km is chosen to represent a feasible average delivery distance for a company that produces in one location and distributes nationwide.

6.3.3 Allocation of consumer's shopping trip

A set of scenarios were created to examine alternative methodological or information choices for allocating impacts of consumer's shopping, for example to represent cases of purchasing more or less products at the same time. Whereas the baseline scenario allocates 5% of the impact of the consumer's trip to the market to each product (e.g., one 24-pack of bottles), the alternate scenarios allocate 1%, 3%, 10%. 30% and 100% of the consumer's vehicle impact to the product. For example, if allocating evenly among the number of products purchased, the 5% allocation would represent the case where 20 total items are purchased. If allocating by value purchased, it assumed the items are one twentieth the total value, and so on. The results of the alternative scenarios, spanning 1 to 100% allocation are shown in Figure 17.

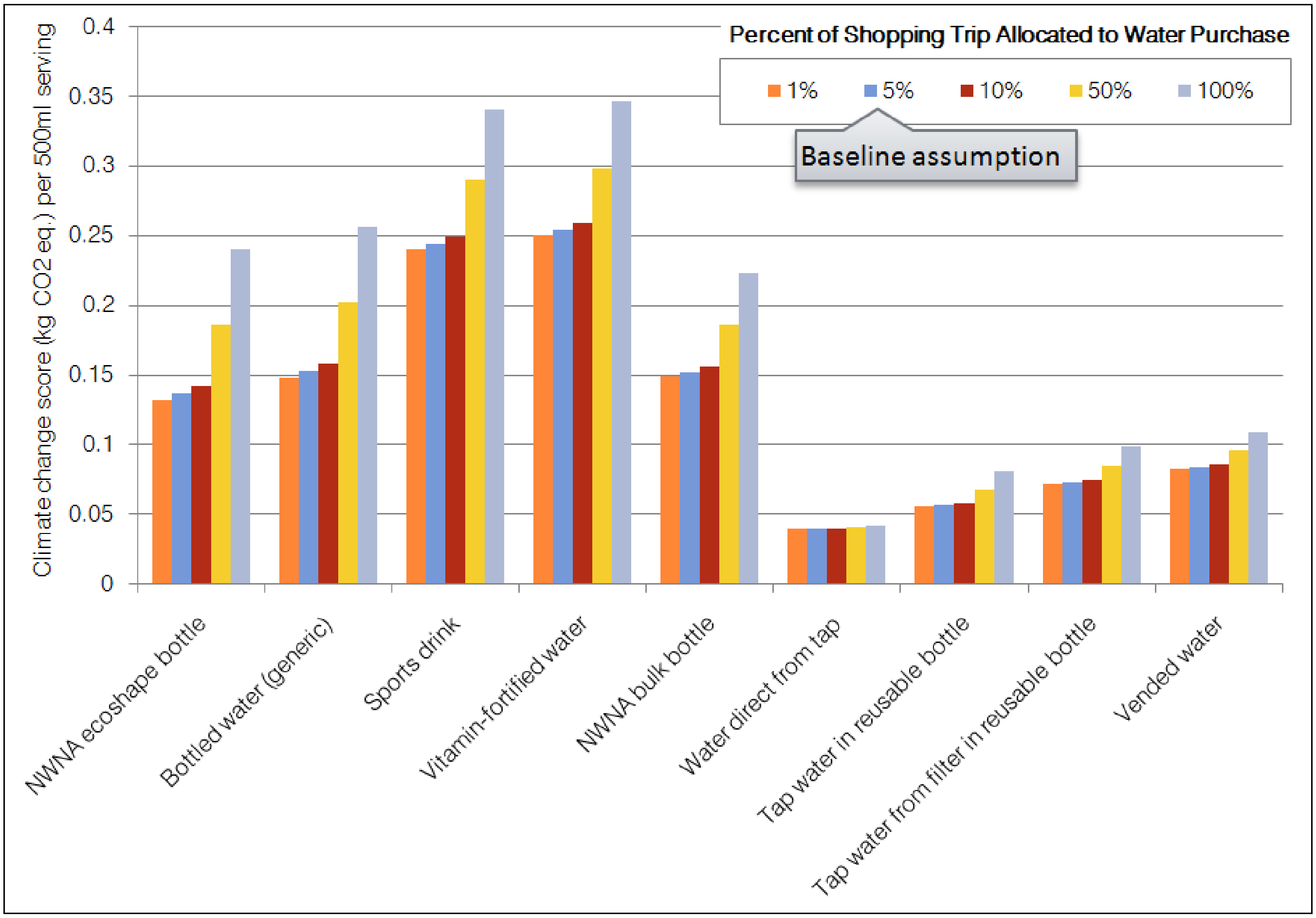

Figure 17: Climate change score for all systems of varying allocation of the consumer's shopping trip to the products (5% has been used in the baseline results).

While the influence on the results is modest for most of the scenarios examined, it is clear that in the case of 100% allocation, the consumer shopping trip becomes important. It could therefore be concluded that for these systems, if the allocation remains 10% or lower, the influence of changing this factor is quite small. Above 30%, the influence begins to become quite important. This scenario can also be considered to represent the general level of sensitivity to alternative distances to the marketplace (or even efficiency of the automobile used). For example, the case of doubling the allocation factor to 10% from 5% will produce the same result as doubling the assumed distance driven while keeping the allocation at 5%. This therefore suggests that at very long distances to the marketplace, the impact of the shopping trip can be an important factor.

6.3.4 Container recycling rates

All of the systems contain some components that can be recycled. To assess the importance of recycling rate, scenarios were run in which the recycling rates for all recyclable materials that reach the consumer are recycled at rates varying from 0% to 100%. Figure 18 presents the results of these scenarios alongside the baseline ("default") results for each system. The present study has used an approach that represents as an environmental benefit (by preventing an impact) the effect of providing usable materials or energy through recycling or waste-to-energy conversion and assigns this benefit to the system providing the material.

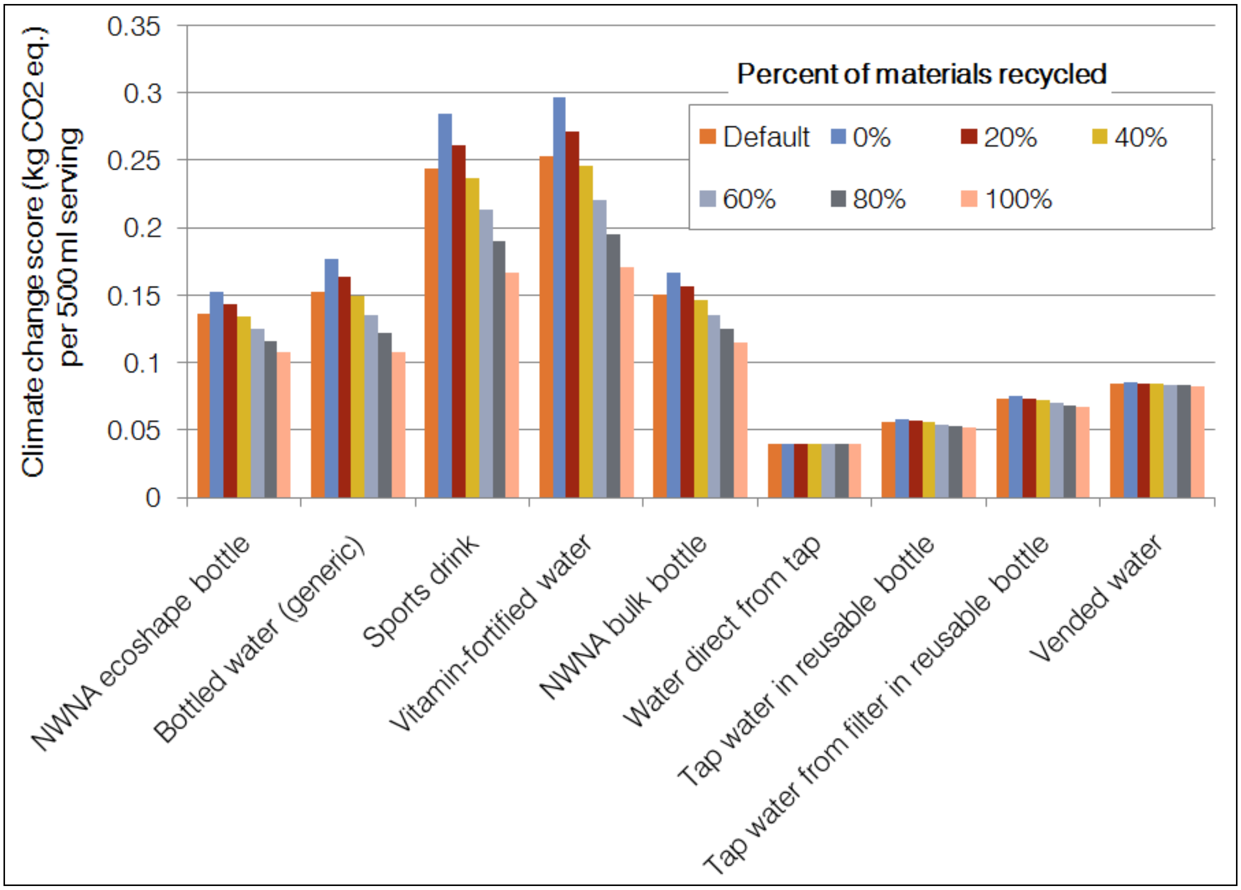

Figure 18: Influence of the rate of consumer material recycling on the total climate change impact of each system

The recycling rate has a large influence on the single-use bottled beverages and on the aluminum bottle. For example, the 100% recycling rate is between one third and one quarter lower for each of these systems than the 0% recycling rate with regard to climate change impact. In addition to representing alternative versions on an average societal recycling rate for these containers, this set of scenarios can also be seen to represent individual beverages consumed by an individual consumer. The results imply, for example, that a consumer might decrease their climate change impact of consuming a bottled beverage by 25% or more if they recycle the bottle rather than place it in the waste bin.

6.3.5 Conditions of refrigeration

A set of scenarios has also been run to determine the potential importance of a variety of assumptions that must be made regarding the refrigeration of bottled and tap water. For bottled water, twelve refrigeration scenarios have been conducted to consider upper and lower bounds of refrigeration, as well as a moderate case and also a no refrigeration option for both the retail and consumer parts of the life cycle. For tap water, scenarios of no refrigeration, an upper and lower bound and moderate case have been examined. For the refrigeration scenarios the use of a filtering pitcher combined with a drinking glass was used. The following table shows the assumptions made in each of these cases.

Table 5: Parameters of the consumer refrigeration scenarios

Parameter	Units	Low Assumption	Mid	High Assumption
Commercial refrigeration of bottled water				
Commercial refrigerator efficiency[22]	kWh/L-year	1	2	6
Portion of refrigerator volume occupied		1/2	1/3	1/4
Time refrigerated	Days	0.125	2	7
Refrigeration energy use (per 500ml)	kWh	0.000342	0.0164	0.230
Consumer refrigeration of bottled water (at home or office)				
Consumer refrigerator efficiency[21]	kWh/L-year	0.5	2	8
Portion of refrigerator volume occupied		1/2	1/4	1/10
Time refrigerated	Days	0.125	2.4	7
Refrigeration energy use	kWh	0.000171	0.0263	0.767
Consumer refrigeration of tap water (in filtering pitcher, at home or office)				
Consumer refrigerator efficiency[21]	kWh/L-year	0.5	2	8
Portion of refrigerator volume occupied		1/2	1/4	1/10
Time refrigerated	Days	0.125	2.4	2
Refrigeration energy use	kwh	0.000171	0.0263	0.219

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[22] Ranges of refrigerator efficiencies have been determined based on information available from the US EPA's energy star program (www.energystar.gov) on several hundred existing refrigerators qualifying under their program, along with the application of a 30% factor to account for non-qualifying refrigerators (a statistic also from Energy Star). This information has been used to develop approximate upper and lower bounds for refrigerators.

Figure 19 shows the results of these scenarios.

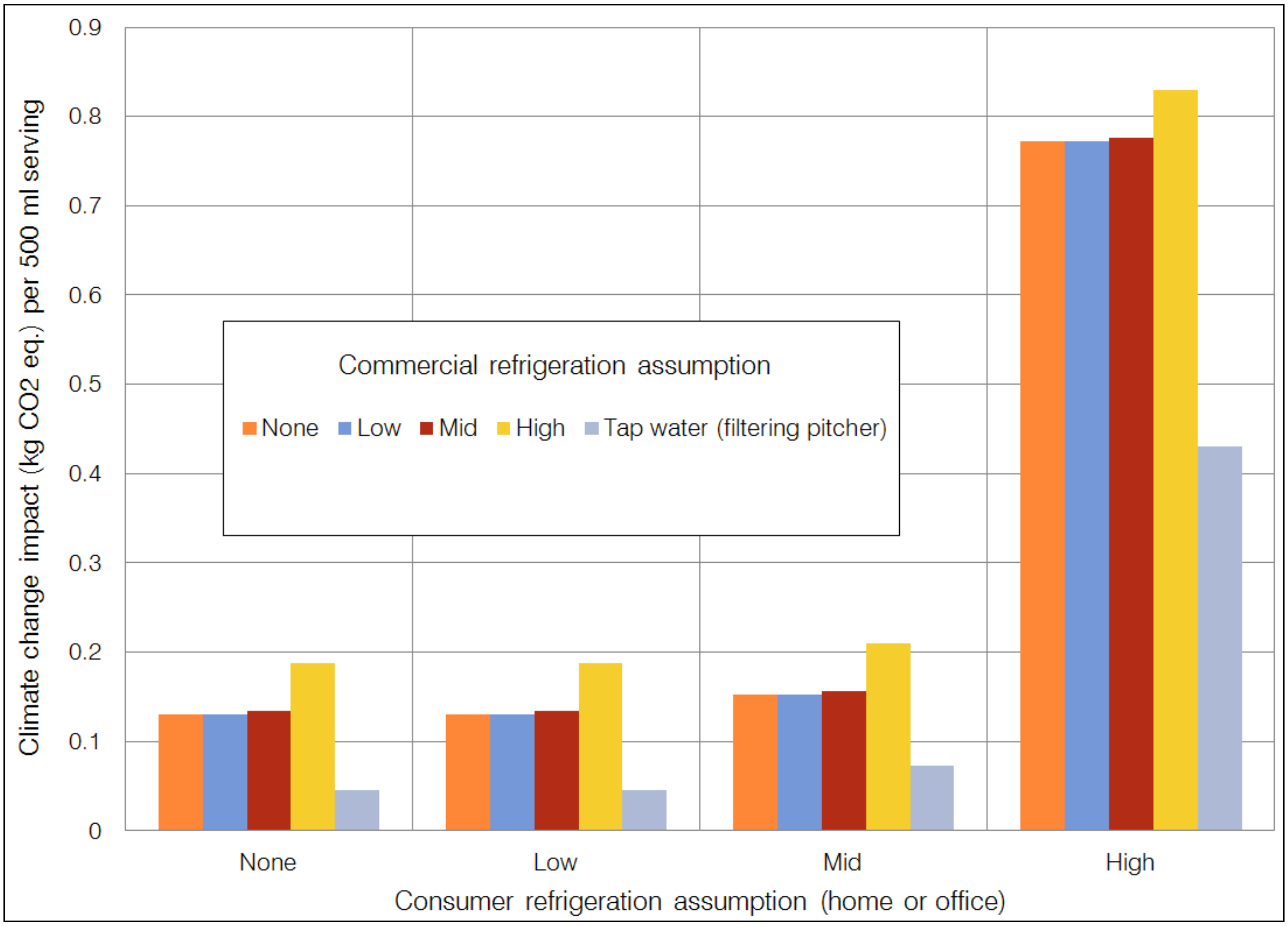


Figure 19: Variation in climate change score with refrigeration assumptions

The potential clearly exists for refrigeration to exert an important influence on the results. However, an extreme influence is seen only in the case where high assumptions are made for several of the parameters. Within the low and moderate cases, only a small influence is seen on the overall results. Note from the table above that the combined variation in the parameters results in a variation of more than 1000-fold between the low and high assumptions and more than 10-fold between the mid and high assumptions.

6.3.6 Conditions of drinking container washing

As with refrigeration, a set of scenarios have been conducted to examine the sensitivity of the results to the assumed efficiency of dishwashing.

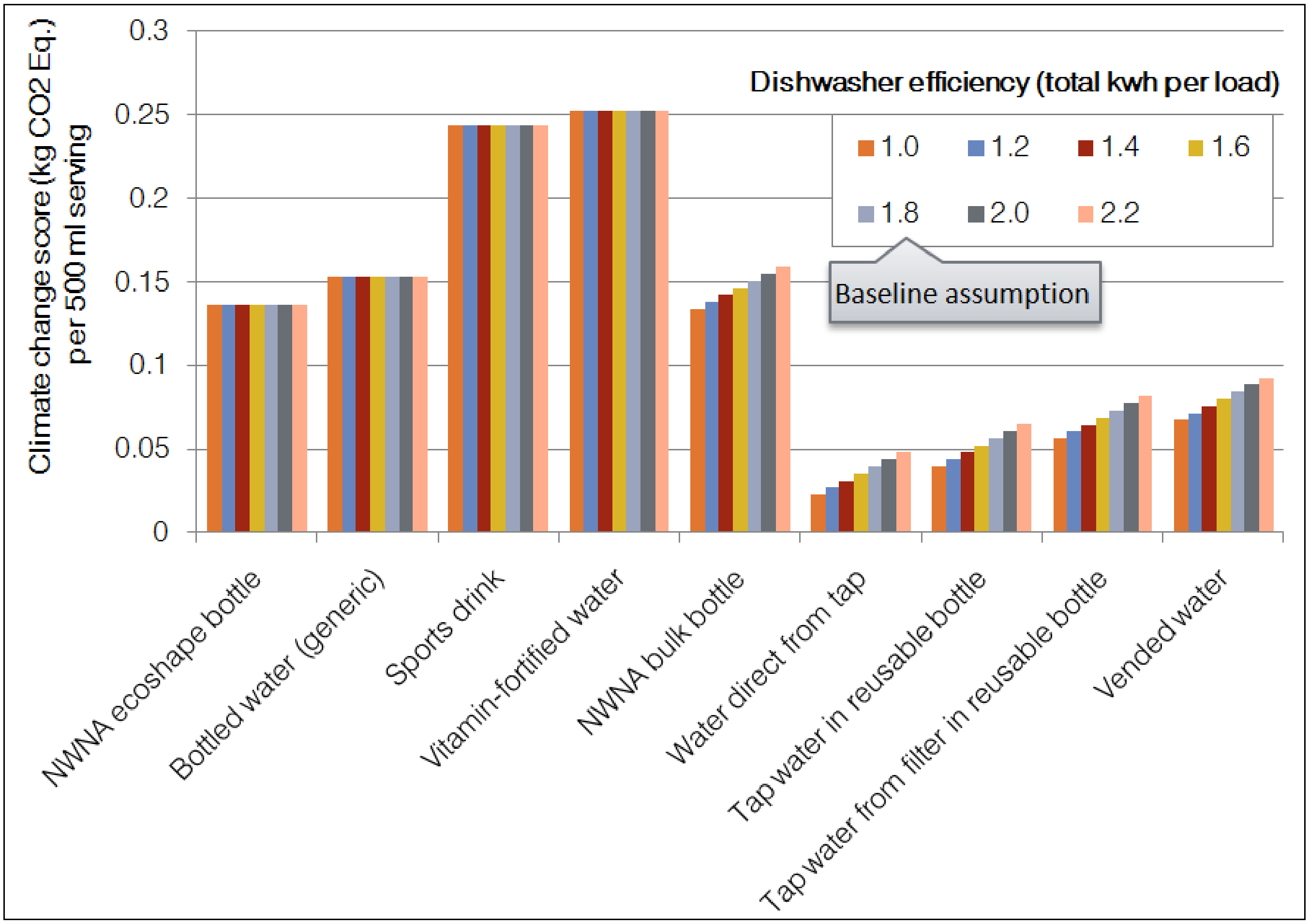


Figure 20: Influence of the dishwasher efficiency on the total climate change impact of each system (baseline results have assumed 1.8 kwh per load; electricity use includes heating of water)

Clearly, there is no effect of dishwashing habits on the single-serving bottles, which are not washed. For the systems that do involve washing of dishes, the efficiency of the dishwasher is shown to be a highly important factor, with the difference between high a low-efficiency washers producing a doubling or more of the climate change impact associated with tap water consumed directly from the faucet. It could be expected that other factors that influence the impact from washing, such as the number of uses of items between washes and the allocation of the washing load to the items washed, will also have a substantial influence.

6.3.7 Weight and distribution distance of single-use bottles

It is clear that the difference in bottle weight is a major cause of the differing impact among the single-serving water and single-serving sport drink and vitamin fortified waters. Within the bottled water category, there is a variety of bottle weights on the market, ranging at least to four-fold the weight of the EcoShape bottle for a similar capacity. Similarly, it is expected that there will be a wide range of distribution distances among bottled water options, whether in regard to average distances of various manufacturers or in regard to the actual distances for individual bottles a consumer may encounter in the marketplace.

To further clarify the importance of bottle weight and distribution distance, a set of scenarios have been conducted within the bottled water system to examine the influence of this and characterize the variation it might cause in extrapolating results to other bottled waters. Figure 21 shows the results of these scenarios, highlighting the first-generation EcoShape, the second-generation EcoShape (phased in during 2009 and the bottle design on which this study is based), and the "generic" bottled water shown in many of the above results.

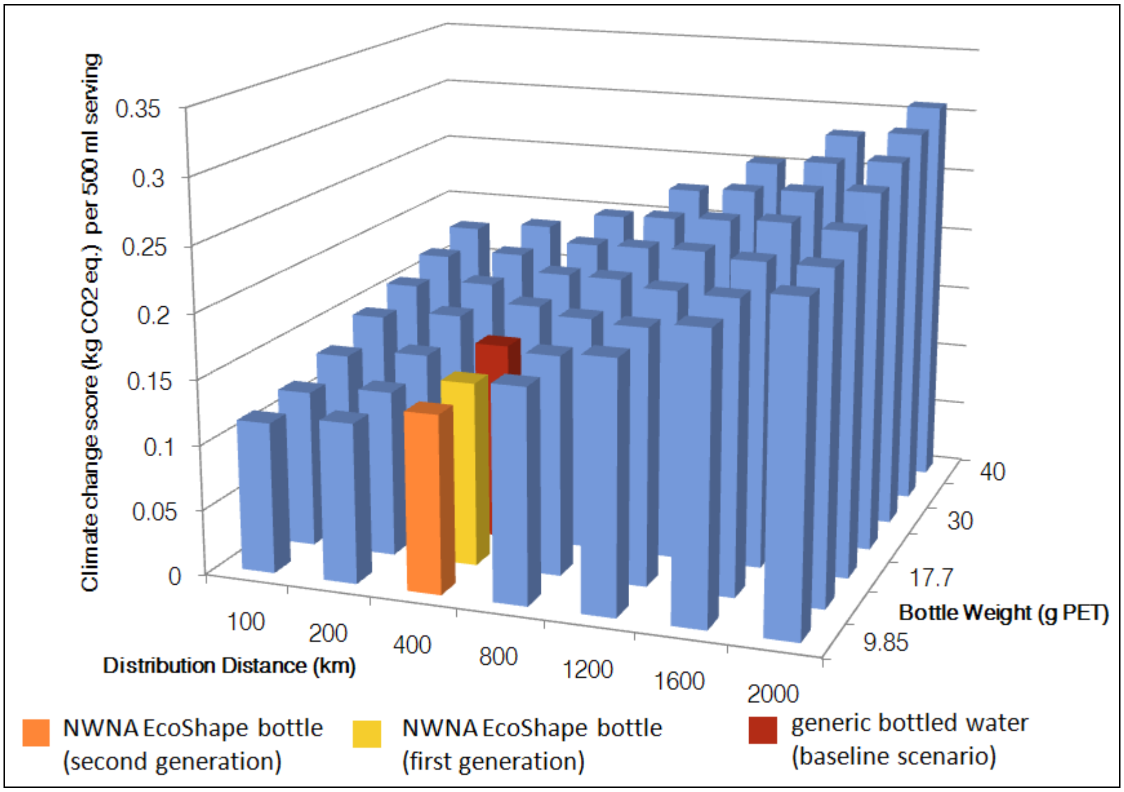


Figure 21: influence of bottle PET weight and distribution distance on the total climate change impact of the bottled water system

These are clearly important aspects of the environmental impact of bottled water products. The results suggest that the 500 ml PET bottled water products that a consumer finds in the market may differ in their environmental impact by 3-fold. The present results do not consider options of overseas transport, or use of other packaging, such as glass, which would very likely have larger impact.

The results here indicate that, in addition to the transportation distance, the weight of plastic is likely to be among the most important aspects differentiating various bottled water products on the market. This result suggests that the emphasis NWNA has placed on developing lighter bottles has addressed one of the most effective aspects for improving environmental performance. Informing consumers of the importance of bottle weight in determining the environmental impact of their bottled water consumption may be an effective means of enabling them to make more environmentally preferable choices. Similarly, communicating the benefit of purchasing locally bottled water may also enable consumers to make better-informed choices, although they may have more difficulty assessing the distances travels based on product appearance and labeling.

6.3.8 Electricity production

The baseline scenarios used throughout this study have assumed that all electricity used is drawn from the average of production technologies supplying the US electrical grid. Given the interconnectedness of the grid and the intention that the study represent typical US conditions, this is believed to be a reasonable assumption. Nevertheless, some may argue that in cases where the site of use of electricity can be identified, it may make more sense to assume a more local mix of technologies, such as the production within a given state or region. Others may also argue that it makes most sense to assume that any use of electricity that might be increased or decreased will be drawn from the marginal technologies (such as coal) that can easily respond to fluctuations in demand. Finally, some may be interested to understand the potential for improvement in environmental profiles through an increasing use of renewable technologies.

To represent these considerations, scenarios have been conducted on a range of “carbon intensities” of the electrical production, ranging from a low of 200 g CO_2 per kWh (representing a mixture with a very large percentage of renewable energy) to a high of 1200 g CO_2 per kWh (approximating production at a coal-fired power plant). The baseline scenarios shown above have assumed a US national average of 837 g CO_2 per kWh (based on the US supply mix from the Ecoinvent database). The results of these scenarios are shown in Figure 22.

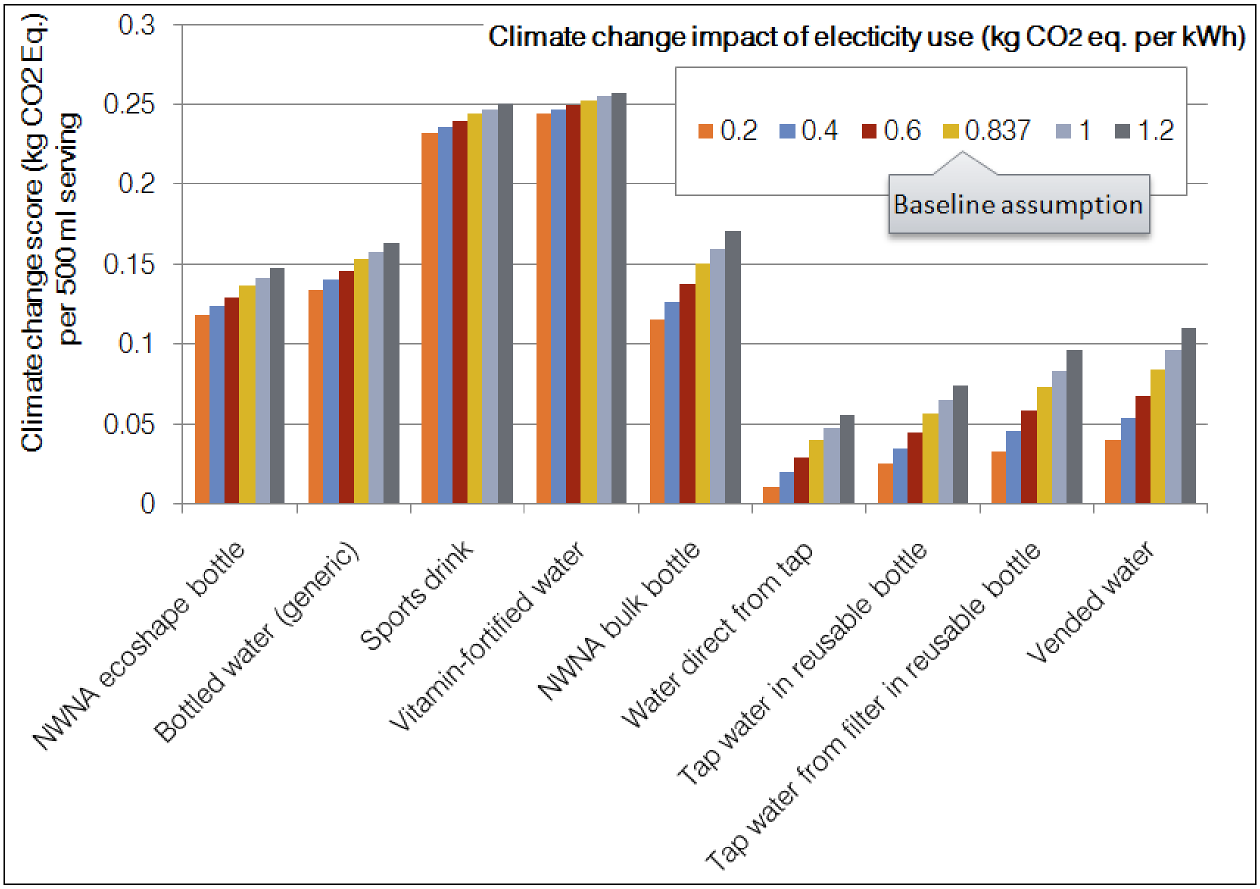


Figure 22: Influence of the “carbon intensity” of the electrical grid on the total climate change impact of each system (baseline results have assumed 0.835 kg CO_2 per kwh)

The results indicate a high level of importance for this assumption for those systems where washing of dishes is an important factor, and especially for water consumed directly from the tap, due to the dominance of dishwashsing – and the importance of energy use to heat washing water - in the impacts of that scenario. The bottled single-serving beverages also show sensitivity to this factor, but to a lesser extent than the tap water systems and the 3 L bottle.

6.3.9 Upper and lower bounds

As shown in the sections above, there are a large number of variables for which the results of each system show a high degree of sensitivity. It is difficult to see from an assessment of each variable in isolation which are the most important and how they might combine to show an upper or lower bound of the impact of each system. Scenarios have therefore been conducted to show the result of combining many scenarios at once, using the ranges of values from the above sections. Figure 23 shows the upper and lower bound determined for the bottled water systems, while Figure 24 shows the upper and lower bound for tap water systems. Figure 25 shows a comparison of these upper and lower bounds. Please note that the scales differ on each graph.

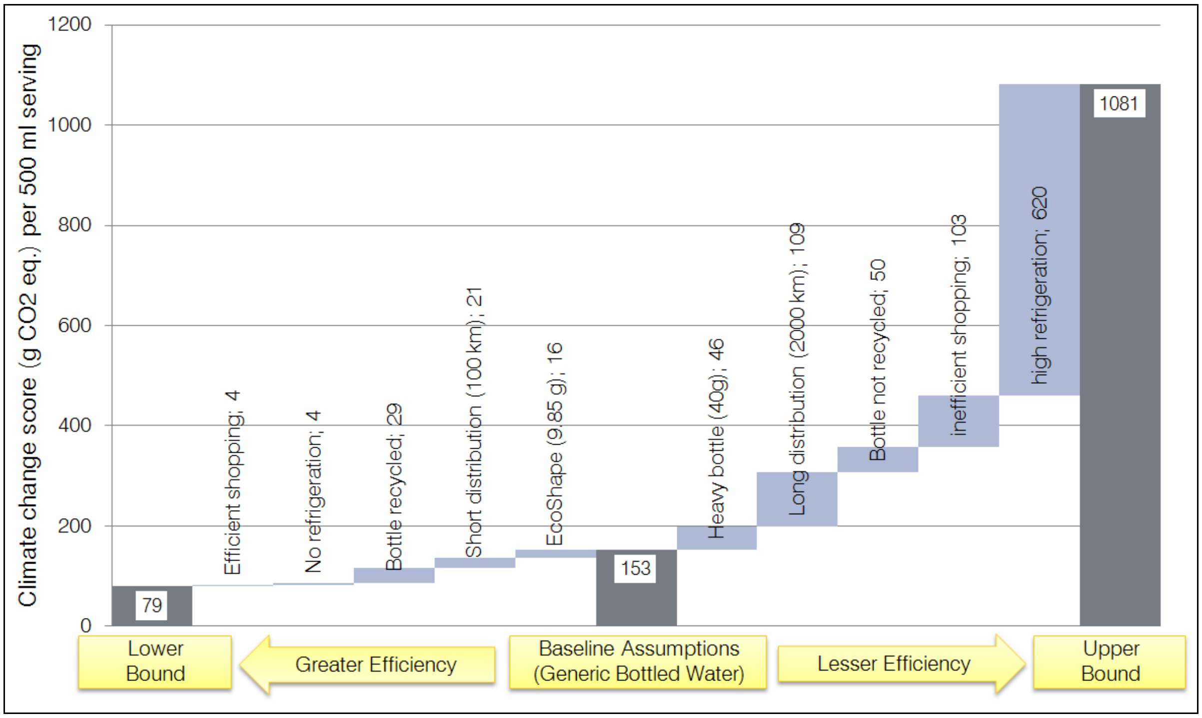


Figure 23: Upper and lower bound of impact for bottled water systems, illustrating the contribution of each incremental change in assumptions, product characteristic or behaviour.

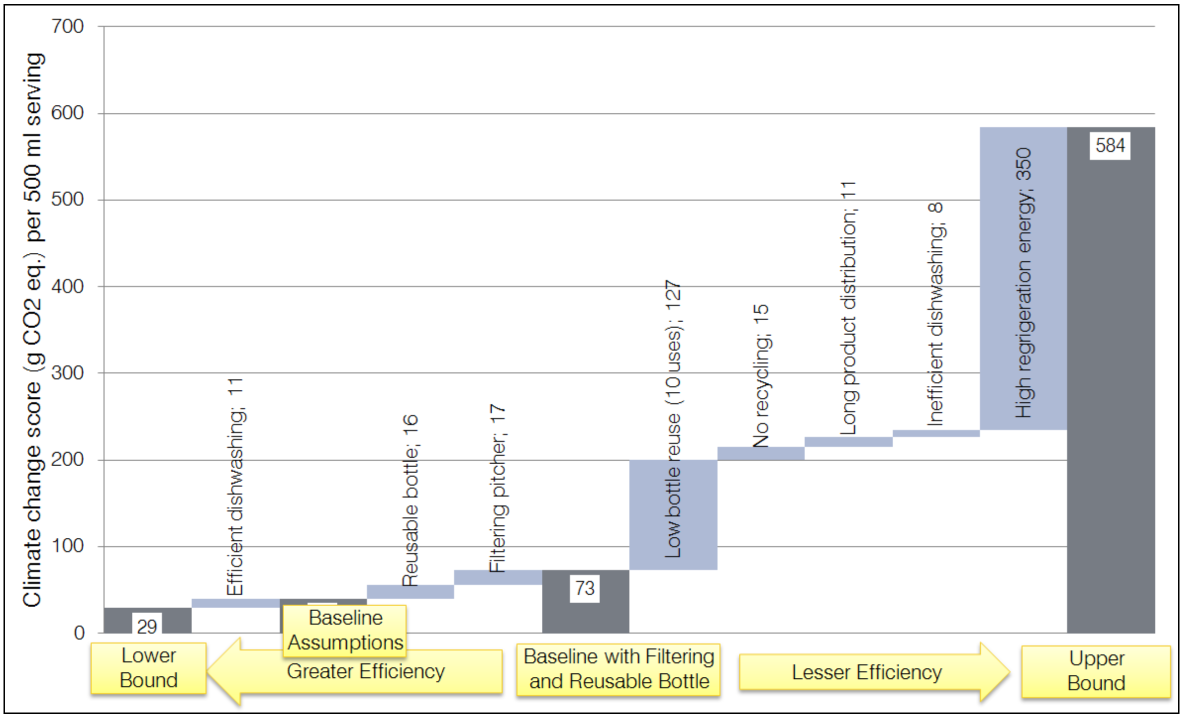
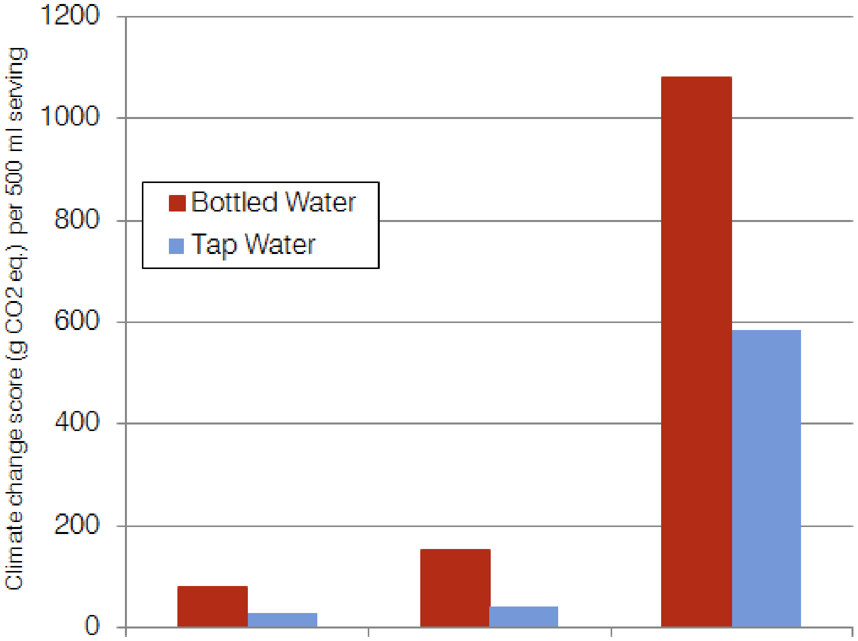


Figure 24: Upper and lower bound of impact for tap water systems, illustrating the contribution of each incremental change in assumptions, product characteristic or behaviour.



	Assumption	Lower Bound	Baseline	Upper Bound
Tap	*Drinking Container*	Drinking glass, used 365 times	Reusable bottle, used 100 times	Reusable bottle, used 10 times
	Filtering	Not filtered	Filtered using pour-over pitcher	Filtered using poor-over pitcher
	Consumer Refrigeration (per 500 ml, see Table 4)	0.00017 kWh	0.026 kWh	0.22 kWh
	Dishwasher efficiency (per load)	1 kWh	1.8 kWh	2.2 kWh
	Product distribution (all products)	100 km	400 km	2000 km
Bottled	*Consumer shopping habits*	11km trip for 100 items	11km trip for 20 items	11 km trip for water only
	Commercial Refrigeration (per bottle, see Table 4)	0.00034 kWh	0.016 kWh	0.23 kWh
	Consumer Refrigeration (per bottle, see Table 4)	0.00017 kWh	0.026 kWh	0.77 kWh
	Consumer recycling	0%	30%	100%
	Product distribution (all products)	100 km	400 km	2000 km
	Bottle plastic weight (PET)	9.85 g (EcoShape)	17.7 g	40 g

Figure 25: Comparison of the upper and lower bound in climate change impact for bottled and tap water, based on the upper and lower bound assumptions used in the sensitivity tests

For both bottled and tap water systems, it is clear that a very wide range of impact is possible within the set of possible factors examined here. For both bottled water and tap water, there is a greater than factor-of-ten difference between the lower and upper bound. These upper and lower bounds should not be taken as absolute, as not all potential variables or possible assumptions have been tested. For example, for tap water, an assumption that the reusable bottle is used only once would result in an impact more than 6-fold the upper bound shown (see Figure 15). The situations shown here have been selected as relatively high and low values to reflect likely real-world use, but not the absolutely highest or lowest that might exist.

For the bottled beverages, it is shown that bottle weight, distribution distance, recycling and the efficiency of consumer shopping are all highly important variables that can significantly impact the outcome. For the tap water systems, the rate of reuse of the reusable bottle is clearly the most significant variable that is tested here. Efficiency of dishwashing, use of filtering pitchers, recycling and product distribution are also shown to have some importance. It should be noted that the importance of recycling and product distribution are themselves subject to variability based on the number of uses of reusable bottles.

These upper and lower bound estimates show that there is very significant variation in the impacts incurred for each system and that these bounds are strongly influenced by factors outside the consumer's direct control, but also by aspects within their direct control. They therefore emphasize the importance of a thorough communication to consumers on the influence of their product choices and behaviors.

6.2 Beverage consumption habit comparisons

As described above, this study draws on several sources of information to estimate the range of environmental impacts for the various types of beverages that make up the total beverage consumption of the typical consumer. These beverages include bottled water, tap water, filtered tap water, sports drinks, vitamin waters, juices, sodas, beers, wines, coffees, teas (hot and iced), and milk. The information on environmental impacts of the beverages has been obtained from a variety of sources, including the present study, and has already been described. The total impacts caused by these beverages in the areas of climate change, use of non-renewable energy, and use of water are shown in Table 6 and Figure 26.

Table 6: Sources and Information Regarding the Impacts of Beverages

Beverage	Percent of US Consumption[23]	Primary Data Source(s)	Non-renewable energy (MJ/L)	Climate Change score (gCO_2eq/L)	Non-turbined water use (L/L)
Tap Water (unfiltered)	12%	This study, based on a adaptation of data from Ecoinvent.	1	79	6
Bottled Water	13%	This study (representative of EcoShape, bulk and generic)	6[24]	300	8
Filtered Tap Water	16%	This study	2	112	6
Soft Drink	17%	Carlsson et al. 2003	8	480	16
Juice	5%	Carbon Trust 2008 and 2009	15	890	30
Sport Drink	1%	This study	10	495	13
Vitamin Water	0.3%	This study	10	513	12
Hot Coffee	11%	Humbert et al. 2009 (values consistent with Buesser and Jungbluth 2008)	20	1100	280 (including 250 of irrigation)[25]

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[23] Percentages of consumption based on research performed by TNS Worldpanel for Nestle Waters North America in 2009.

[24] For purposes of comparison, a recent study by Gleick and Cooley (2009) has given a range of 5.6 to 10.2 MJ per L of bottled water.

[25] Note that the water use included here is only that drawn from ground or surface water sources and does not include rain water that may contribute to crops' transpiration, which may be an important consideration in those systems containing sugar, coffee,

Teas (Hot and Iced	6%	Tea bag LCA, Ecointesys 2008 and Iced tea LCA, Ecointesys 2008 (weighted average)	10	667	26
Beer	2%	The Climate Conservancy, Sidel 2008, WWF 2009	20	920	24
Wine/Spirits	2%	Ardente 2006	39	2200	75
Milk	8%	Guignard et al., 2009.	8	1400	16
Other	6%	Represented as Soft Drink	8	520	14

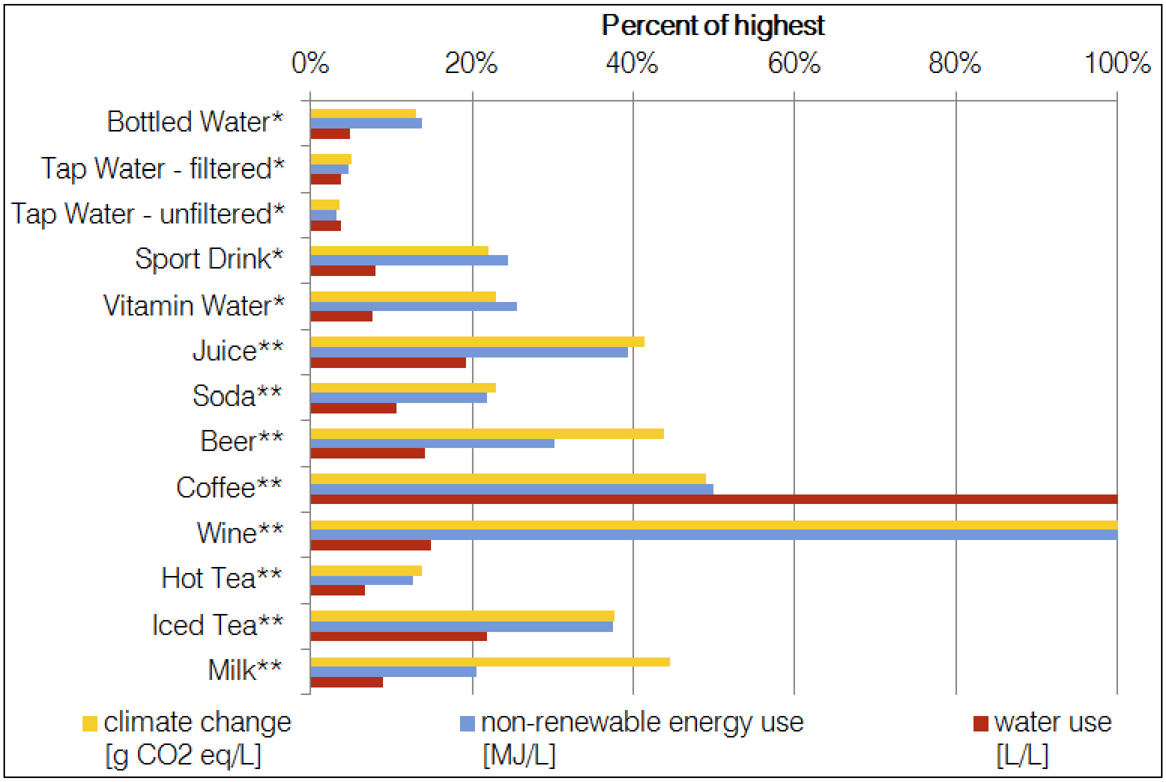

Figure 26: Environmental impacts per 500 ml serving of various beverages (* indicates results from the present study; ** indicates results from pre-existing sources).

It is clear from the numbers shown that there is wide variation in the impact produced by consuming various types of beverages. For each of the impact types there is a range of at least 30-fold between the most and least impacting beverages. This range suggests that, while the varied data sources used will result in some uncertainty or inconsistency due to methodological aspects of each study, the range of differences among beverages is likely to be sufficient to achieve meaningful results in making comparisons among beverage consumption habits. It is interesting to note that while impacts for many beverages tend to follow a similar pattern among the various impact categories examined, there are some that have characteristics that cause a higher or lower relative impact in some categories than in others. For example, milk shows a relatively higher impact for climate change than for other impacts due to the emission of methane from cows, while coffee shows a relatively high impact in water use due to crop irrigation demands.

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tea or other agricultural products . For example, Chapagain et al., 2009, estimate the total water needed to produce a 1 L portion of coffee at over 1000 L when rainwater transpiration is also considered.

It is possible to use this information in combination with the average consumer beverage consumption information presented above to estimate the contributions of each beverage type to the total environmental impact of consuming beverages for the typical consumer. The results of this assessment for climate change are shown in Figure 27. Such a weighted average can provide an informative perspective for consumers in considering and understanding the environmental aspects of their beverage consumption as a whole. It can also allow consideration of the impacts of shifts in consumption habits or beverage availability.

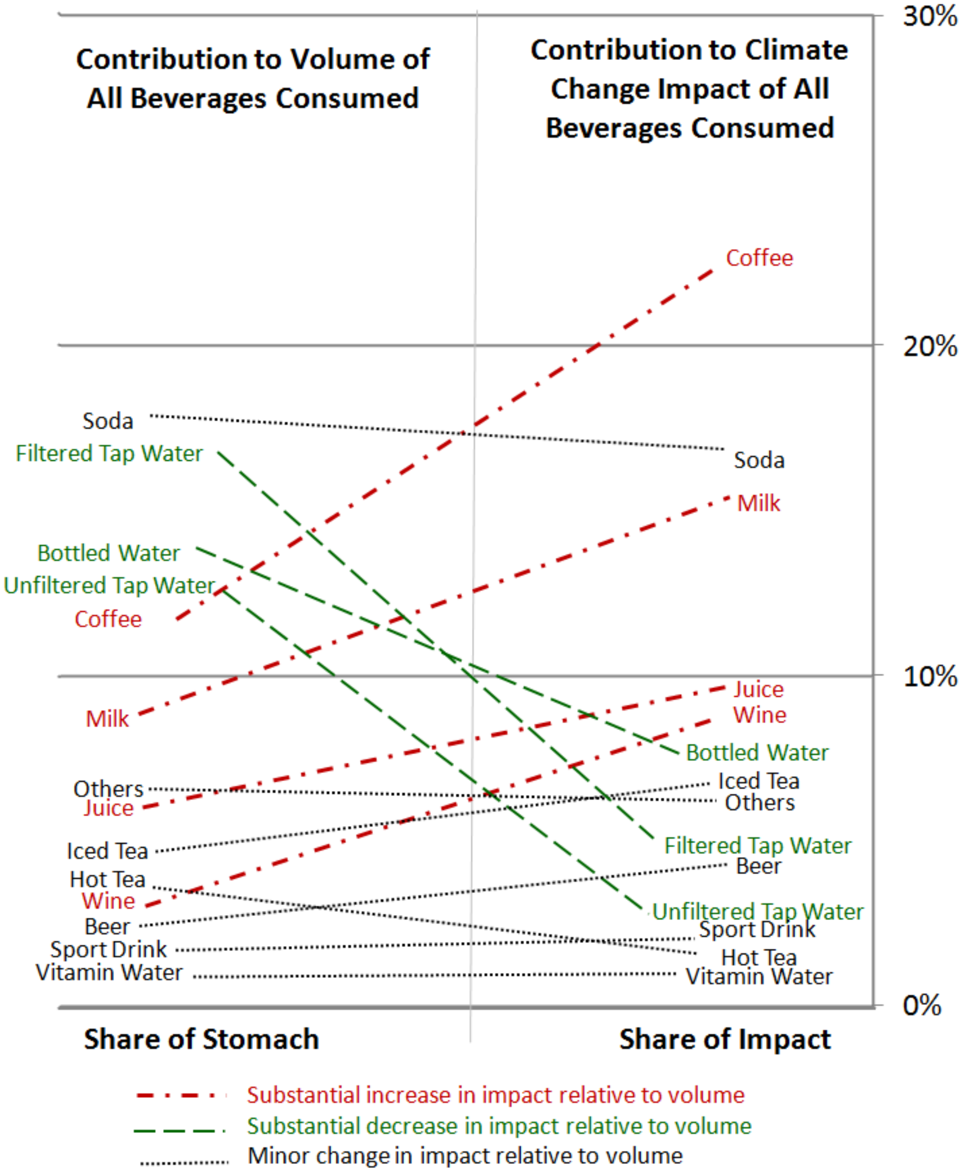
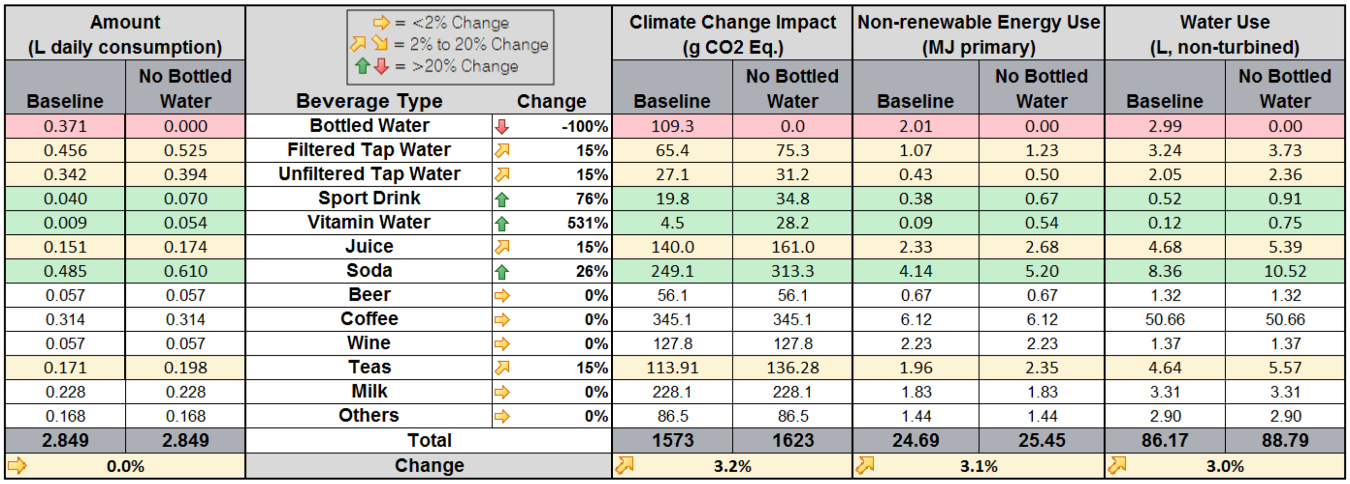


Figure 27: Proportion of beverages by volume consumed by the typical American consumer and percent contribution to the climate change impact from beverage consumption. Beverages with a disproportionately large contribution to beverage consumption impact relative to volume and shown with red lines and those with a smaller impact are shown with green lines.

As illustrated in in Figure 27, there are some beverages whose contribution to climate change impact is disproportionately higher than their contribution by volume, and other beverages whose contribution is lower. Those beverages with a substantially higher contribution to climate change include milk, wine, coffee, beer, and juice. While these beverages contribute a combined 28% to the volume consumed, they together contribute 60% of the climate change impact. The increase in contribution from these beverages for climate change impact is the result of a similar decrease in the proportionate contribution primarily of the water products. **Whereas all water types contribute just over 40% to the total volume of beverages consumed, they represent just over 10% of the total climate change impact resulting from beverage consumption. The difference is most pronounced for tap water, whose nearly 30% contribution to consumption results in just under 5% of climate change impact. A substantial, but less dramatic comparison is seen for bottled water, which contributes 13% to consumption, but only 7% to impact.**

With this information on environmental impacts, it is possible to consider scenarios of alternative beverage consumption patterns that might reflect such things as differing behavior patterns of various consumers, the influence of decision by marketplaces and public entities regarding which options to stock, or the effects of marketing efforts to influence the consumption habits of the population as a whole.

In constructing and evaluating such scenarios, it is important to recognize the various components of decision making and available options that may influence the choice of beverages. For considering what beverages consumers will choose to replace bottled water, information has been used that was gathered for NWNA through consumer surveys. This information indicates what beverages bottled water drinkers will chose to consume in cases where bottled water is not available. This information can be used to produce a scenario where consumer shift from bottled water to these alternate choices. It could be considered to represent such cases as a workplace cafeteria not including bottled water in its cooler, a municipality banning the purchase of bottled water for its employees or at public meetings, or the influence on consumer of messages that stigmatize bottled water consumption without informing on the impacts of other beverages. The results of such a shift away from bottled water to other beverages is shown in Figure 28.

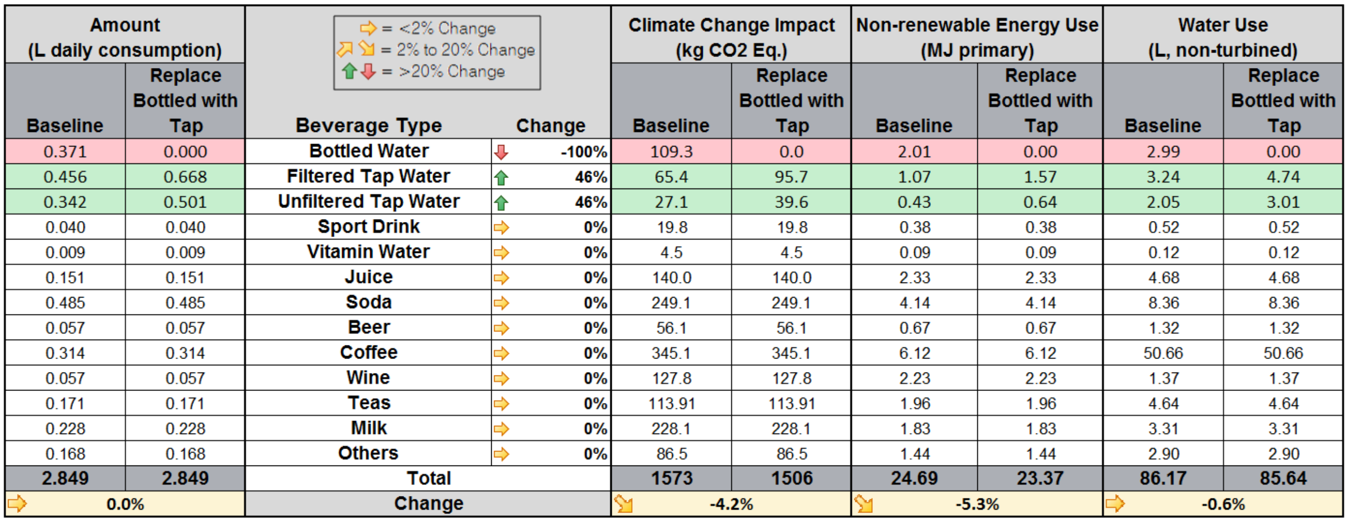


Amount (L daily consumption)		⇨ = <2% Change ⇗ ⇘ = 2% to 20% Change ⇧ ⇩ = >20% Change		Climate Change Impact (g CO2 Eq.)		Non-renewable Energy Use (MJ primary)		Water Use (L, non-turbined)	
Baseline	**No Bottled Water**	**Beverage Type**	**Change**	**Baseline**	**No Bottled Water**	**Baseline**	**No Bottled Water**	**Baseline**	**No Bottled Water**
0.371	0.000	**Bottled Water**	⇩ **-100%**	109.3	0.0	2.01	0.00	2.99	0.00
0.456	0.525	**Filtered Tap Water**	⇗ **15%**	65.4	75.3	1.07	1.23	3.24	3.73
0.342	0.394	**Unfiltered Tap Water**	⇗ **15%**	27.1	31.2	0.43	0.50	2.05	2.36
0.040	0.070	**Sport Drink**	⇧ **76%**	19.8	34.8	0.38	0.67	0.52	0.91
0.009	0.054	**Vitamin Water**	⇧ **531%**	4.5	28.2	0.09	0.54	0.12	0.75
0.151	0.174	**Juice**	⇗ **15%**	140.0	161.0	2.33	2.68	4.68	5.39
0.485	0.610	**Soda**	⇧ **26%**	249.1	313.3	4.14	5.20	8.36	10.52
0.057	0.057	**Beer**	⇨ **0%**	56.1	56.1	0.67	0.67	1.32	1.32
0.314	0.314	**Coffee**	⇨ **0%**	345.1	345.1	6.12	6.12	50.66	50.66
0.057	0.057	**Wine**	⇨ **0%**	127.8	127.8	2.23	2.23	1.37	1.37
0.171	0.198	**Teas**	⇗ **15%**	113.91	136.28	1.96	2.35	4.64	5.57
0.228	0.228	**Milk**	⇨ **0%**	228.1	228.1	1.83	1.83	3.31	3.31
0.168	0.168	**Others**	⇨ **0%**	86.5	86.5	1.44	1.44	2.90	2.90
2.849	**2.849**	**Total**		**1573**	**1623**	**24.69**	**25.45**	**86.17**	**88.79**
⇨ **0.0%**		**Change**		⇗ **3.2%**		⇗ **3.1%**		⇗ **3.0%**	

Figure 28: Results of a switch from bottled water to other beverages consumers claim they would drink in cases where bottled water is not available.

As other beverages are consumed instead of bottled water, the total volume consumed remains constant. Approximately one third of the bottled water volume is shifted to tap water, while the remainder is distributed among other beverages. The climate change impact resulting from this scenario shows an increase in the impact from beverage consumption of 2 - 3%. When considering the amount of uncertainty in making such assumptions, this shift amount of difference might be regarded as being essentially the same as no change. **This suggests that the unavailability of bottled water to consumers is unlikely to result in a notable net decrease in climate change impacts from their consumption habits. The environmental benefits produced by those consumers who chose tap water as a replacement are more than offset by the increase in impact caused by consumers who choose other, more impacting, beverages.**

It is also informative to consider the case of individual consumers, whose choices can be identified more clearly than the population average. It is possible to consider, for example, a scenario of an individual consumer whose beverage consumption represents the average consumption described above and who then decides to shift all their bottled water consumption exclusively to tap water. The results of such a scenario are shown in Figure 29.

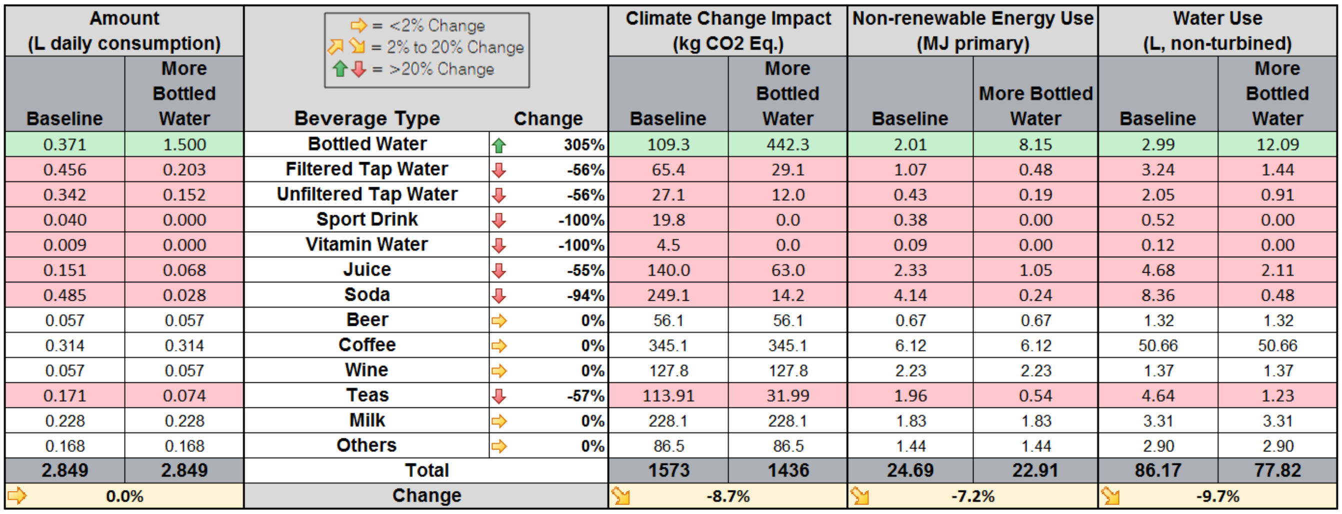


⇨ = <2% Change
⇗ ⇘ = 2% to 20% Change
⇧ ⇩ = >20% Change

Amount (L daily consumption)					Climate Change Impact (kg CO2 Eq.)		Non-renewable Energy Use (MJ primary)		Water Use (L, non-turbined)	
Baseline	Replace Bottled with Tap	Beverage Type	Change		Baseline	Replace Bottled with Tap	Baseline	Replace Bottled with Tap	Baseline	Replace Bottled with Tap
0.371	0.000	**Bottled Water**	⇩	**-100%**	109.3	0.0	2.01	0.00	2.99	0.00
0.456	0.668	**Filtered Tap Water**	⇧	**46%**	65.4	95.7	1.07	1.57	3.24	4.74
0.342	0.501	**Unfiltered Tap Water**	⇧	**46%**	27.1	39.6	0.43	0.64	2.05	3.01
0.040	0.040	**Sport Drink**	⇨	**0%**	19.8	19.8	0.38	0.38	0.52	0.52
0.009	0.009	**Vitamin Water**	⇨	**0%**	4.5	4.5	0.09	0.09	0.12	0.12
0.151	0.151	**Juice**	⇨	**0%**	140.0	140.0	2.33	2.33	4.68	4.68
0.485	0.485	**Soda**	⇨	**0%**	249.1	249.1	4.14	4.14	8.36	8.36
0.057	0.057	**Beer**	⇨	**0%**	56.1	56.1	0.67	0.67	1.32	1.32
0.314	0.314	**Coffee**	⇨	**0%**	345.1	345.1	6.12	6.12	50.66	50.66
0.057	0.057	**Wine**	⇨	**0%**	127.8	127.8	2.23	2.23	1.37	1.37
0.171	0.171	**Teas**	⇨	**0%**	113.91	113.91	1.96	1.96	4.64	4.64
0.228	0.228	**Milk**	⇨	**0%**	228.1	228.1	1.83	1.83	3.31	3.31
0.168	0.168	**Others**	⇨	**0%**	86.5	86.5	1.44	1.44	2.90	2.90
2.849	**2.849**	**Total**			**1573**	**1506**	**24.69**	**23.37**	**86.17**	**85.64**
⇨ **0.0%**		**Change**			⇘ **-4.2%**		⇘ **-5.3%**		⇨ **-0.6%**	

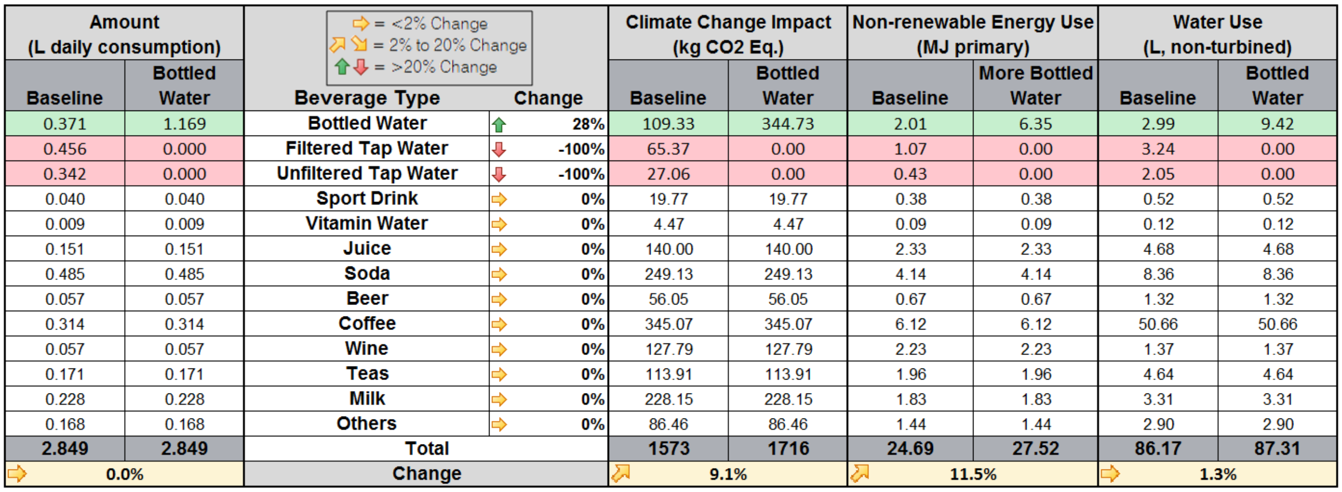
Figure 29: Changes in consumption volume and climate change impact resulting from a switch of all bottled water to all tap water

The result of the switch is a decrease in climate change impact of approximately 5%, with a lesser decrease for water use. It is possible to also consider the case of a consumer increasing their consumption of bottled water. This could be considered as occurring as a shift from the range of beverages that consumers state they are likely to shift to/from bottled water, or occurring as a shift exclusively at the expense of tap water. Figure 30 shows the results for increasing bottled water consumption to 1.5L per day, drawing the extra amount from the range of beverages consumers expressed that they would switch to or from in the consumer survey. Figure 31 shows the case of increasing bottled water consumption by only switching tap water to bottled water, with no change in the consumption of other beverages.



Amount (L daily consumption)		⇨ = <2% Change ↗ ↘ = 2% to 20% Change ⇧ ⇩ = >20% Change		Climate Change Impact (kg CO2 Eq.)		Non-renewable Energy Use (MJ primary)		Water Use (L, non-turbined)	
Baseline	More Bottled Water	Beverage Type	Change	Baseline	More Bottled Water	Baseline	More Bottled Water	Baseline	More Bottled Water
0.371	1.500	Bottled Water	⇧ 305%	109.3	442.3	2.01	8.15	2.99	12.09
0.456	0.203	Filtered Tap Water	⇩ -56%	65.4	29.1	1.07	0.48	3.24	1.44
0.342	0.152	Unfiltered Tap Water	⇩ -56%	27.1	12.0	0.43	0.19	2.05	0.91
0.040	0.000	Sport Drink	⇩ -100%	19.8	0.0	0.38	0.00	0.52	0.00
0.009	0.000	Vitamin Water	⇩ -100%	4.5	0.0	0.09	0.00	0.12	0.00
0.151	0.068	Juice	⇩ -55%	140.0	63.0	2.33	1.05	4.68	2.11
0.485	0.028	Soda	⇩ -94%	249.1	14.2	4.14	0.24	8.36	0.48
0.057	0.057	Beer	⇨ 0%	56.1	56.1	0.67	0.67	1.32	1.32
0.314	0.314	Coffee	⇨ 0%	345.1	345.1	6.12	6.12	50.66	50.66
0.057	0.057	Wine	⇨ 0%	127.8	127.8	2.23	2.23	1.37	1.37
0.171	0.074	Teas	⇩ -57%	113.91	31.99	1.96	0.54	4.64	1.23
0.228	0.228	Milk	⇨ 0%	228.1	228.1	1.83	1.83	3.31	3.31
0.168	0.168	Others	⇨ 0%	86.5	86.5	1.44	1.44	2.90	2.90
2.849	2.849	Total		1573	1436	24.69	22.91	86.17	77.82
⇨ 0.0%		Change		↘ -8.7%		↘ -7.2%		↘ -9.7%	

Figure 30: Changes in consumption volume and climate change impact resulting from a switch to bottled water (increasing to 1.5 L per day) from other beverages based on consumer preferences



Amount (L daily consumption)		⇨ = <2% Change ↗ ↘ = 2% to 20% Change ⇧ ⇩ = >20% Change		Climate Change Impact (kg CO2 Eq.)		Non-renewable Energy Use (MJ primary)		Water Use (L, non-turbined)	
Baseline	Bottled Water	Beverage Type	Change	Baseline	Bottled Water	Baseline	More Bottled Water	Baseline	Bottled Water
0.371	1.169	Bottled Water	⇧ 28%	109.33	344.73	2.01	6.35	2.99	9.42
0.456	0.000	Filtered Tap Water	⇩ -100%	65.37	0.00	1.07	0.00	3.24	0.00
0.342	0.000	Unfiltered Tap Water	⇩ -100%	27.06	0.00	0.43	0.00	2.05	0.00
0.040	0.040	Sport Drink	⇨ 0%	19.77	19.77	0.38	0.38	0.52	0.52
0.009	0.009	Vitamin Water	⇨ 0%	4.47	4.47	0.09	0.09	0.12	0.12
0.151	0.151	Juice	⇨ 0%	140.00	140.00	2.33	2.33	4.68	4.68
0.485	0.485	Soda	⇨ 0%	249.13	249.13	4.14	4.14	8.36	8.36
0.057	0.057	Beer	⇨ 0%	56.05	56.05	0.67	0.67	1.32	1.32
0.314	0.314	Coffee	⇨ 0%	345.07	345.07	6.12	6.12	50.66	50.66
0.057	0.057	Wine	⇨ 0%	127.79	127.79	2.23	2.23	1.37	1.37
0.171	0.171	Teas	⇨ 0%	113.91	113.91	1.96	1.96	4.64	4.64
0.228	0.228	Milk	⇨ 0%	228.15	228.15	1.83	1.83	3.31	3.31
0.168	0.168	Others	⇨ 0%	86.46	86.46	1.44	1.44	2.90	2.90
2.849	2.849	Total		1573	1716	24.69	27.52	86.17	87.31
⇨ 0.0%		Change		↗ 9.1%		↗ 11.5%		⇨ 1.3%	

Figure 31: Changes in consumption volume and climate change impact resulting from a switch of all tap water to bottled water

The switch to 1.5 L of bottled water per day based on the consumer survey data shows a resulting decrease of 5% to 9% in the impact categories examined. In the case of drinking more bottled water exclusively at the expense of tap water, there is an increase in the impact of beverage consumption of roughly 12% (though a lesser increase, 2%, in the case of water use impacts).

Figure 32 summarizes the results of the various scenarios of changes within a consumer's beverage consumption habits.

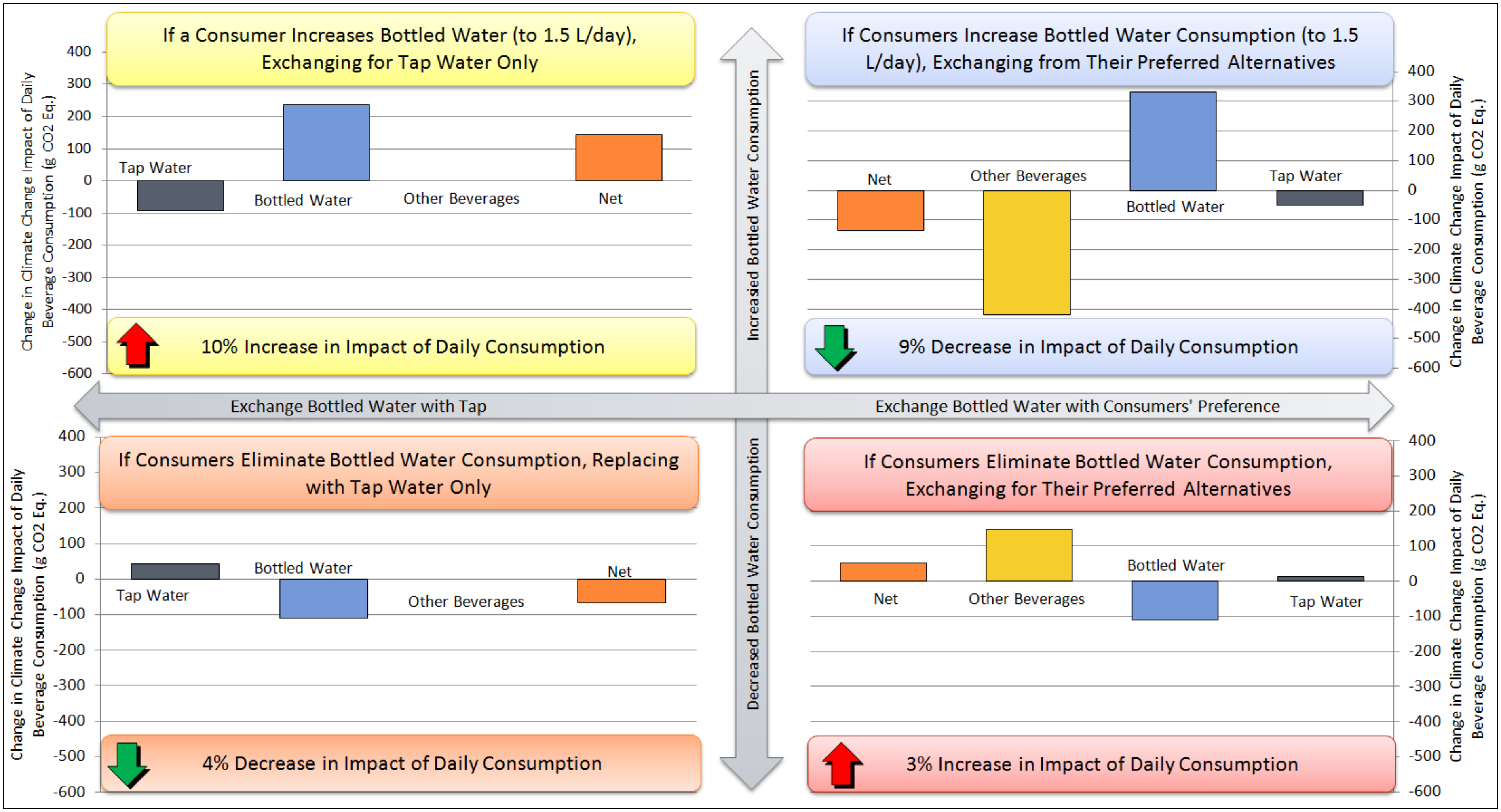


Figure 32: Summary of results for increasing or decreasing the bottled water consumption of the average US consumer.

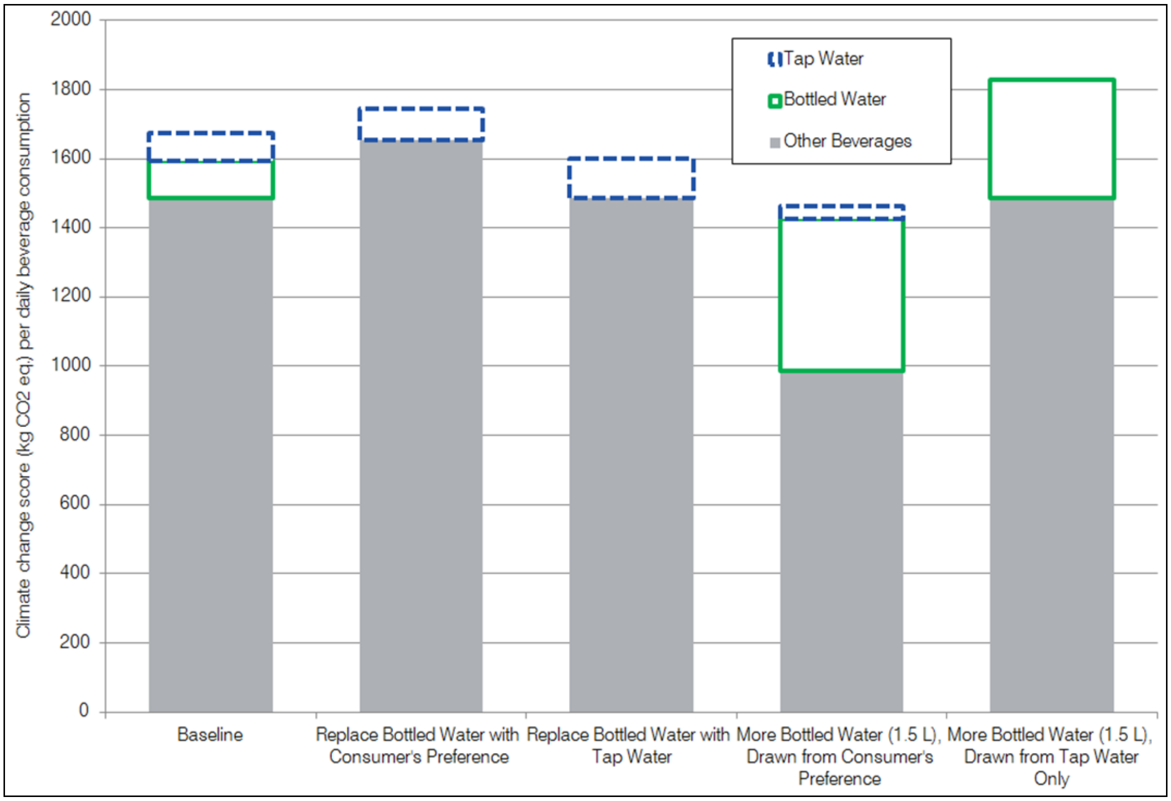


Figure 33: Summary of results of the scenarios changing consumer beverage consumption habits (climate change results).

The results of these scenarios suggest several important conclusions when considering individual consumer choices regarding beverages or choices of retailers, governments, or others that might impact what choices are available. It is clear that consideration of what beverages one is switching to or from when they increase or decrease the consumption of bottled water is of great importance.

In cases where bottled water consumption is shifted to tap water consumption, a net benefit in environmental impacts results. However, if considering a change that influences the general population to forego a choice of bottled water, a shift away from bottled water results in distribution of that consumption to a range of different beverages (including some to tap water, based on survey data of consumer choices) and a net increase in environmental impact is predicted to result. Because the magnitude of the changes in the results shown here cannot be considered to be scientifically significant, the conclusion is best phased as follows:

> *While tap water provides some environmental benefits versus bottled water, if the general public is influenced to avoid a choice of bottled water or prevented from choosing bottled water, it is unlikely that this influence will result in a benefit for the environment.*

It is therefore important to consider the full complexity of consumer beverage choice and behavior when contemplating communications intended to influence environmental impact of such behavior or when contemplating constraints on consumer choices.

7. Study limitations

The appendix material and section 4.3 contain summary information regarding assessment of the quality and consistency of information used to support the results shown here. Overall, the quality and consistency of the information is sufficient to meet the goals of the study.

There are several limitations in the current study that should be reiterated and that might be made a focus of future work in this area. As shown in the sensitivity tests performed, many of the most important factors determining the impact of drinking water systems are highly variable and typical consumer behaviors or product characteristics are not always known with certainty. With regard to the assessment of bottled drinking water and bottled water alternatives, it is clear from the results of sensitivity tests that many factors, especially regarding consumer behaviors, can largely affect the magnitude of the impact within systems, and even affect the comparisons among systems. Further examination of these behaviors and other factors may be of interest both to better identify accurate "average" behaviors, as well as to support better understanding among consumers of these behavioral influences.

For many of the systems studied here, the goal has been to provide estimates of a typical product within the marketplace, but not to identify specific products. Improved accuracy in comparison among products within a category (e.g., sports drinks, filtering pitchers, reusable bottles), would require more detailed collection of information for each of those products. Some of the information used to represent the NWNA products is more current than equivalent information used on other systems, which is drawn from literature sources or databases. The most prominent example of this is the energy use at the beverage bottling plants in comparison to the energy use of tap water production. More transparent reporting by all beverage companies (in addition to manufacturer or related items such as filters or reusable containers), would benefit the public discussion on beverage sustainability.

For the comparison of beverage consumption habits, it is desirable to have more detailed and transparent information on the life cycle impact of the various beverages considered. Further confirmation of the information used to predict the beverage switching habits of consumers is also desirable, as many of the conclusions from that portion of the study hinge on those assumptions. The assessment done here has been founded on an assumption that increasing consumption of one beverage will result in an equivalent decrease of volume of another assumption based on a simplified conception of the causes leading to consumption of beverages. Further physiological knowledge of the causes and effects of beverage consumption might be able to identify more complex relationships based the hydrating—or even dehydrating—effects of certain beverages.

8. Summary of Findings

The goals of this study have been to 1) compare the total life cycle environmental impacts of the NWNA EcoShape bottle and 3 L bottle with several categories of bottled drinking water alternatives; 2) compare the total environmental impacts of the beverage consumption of a typical consumer and examine the influence of changes in those consumption habits; and 3) provide information to allow Nestlé Waters North America to improve environmental performance of their products.

Comparison among bottled water alternatives reveals several important conclusions. Based on the baseline set of conditions used here, those systems based on consumption of tap water will generally perform better from an environmental perspective than the bottled beverages. The results of the sensitivity tests suggest that this difference is subject to the conditions of use. Factors such as the number of times a reusable bottle is used, conditions of refrigeration and dishwashing are sufficiently important to alter the magnitude—or even the direction in extreme cases—of this comparison. Additional variability occurs within the bottled beverage categories, due especially to the factors of packaging material weight and distribution distances.

It is therefore important to consider the conditions of consumer behavior when comparing these systems and to qualify conclusions based on the range of behaviors under which they are applicable. Examination of many scenarios in the present study suggest that under most conditions, the tap water systems provide an environmental advantage and it is only cases of specific consumer behavior, such as using a reusable bottle less than 5 times or washing dishes very inefficiently that might be reversed.

Within the tap water systems, there is important variation in the environmental impact depending on the equipment and drinking containers used. A comparison of water consumed directly from the tap versus that from a filtering pitcher or water vending machine shows a difference of at least two-to-three-fold in the total impact, with an even larger range likely to result when considering upper-bound and lower-bound assumptions. Under the baseline assumptions, the more impacting tap water systems (e.g., vended water) are approximately a factor of 2 less impacting than bottled water, depending on the type of environmental impact in question.

There is significant variation between the bottled beverages considered, with the two NWNA products examined (the EcoShape 500 ml water bottle and the 3 L bottle) performing roughly equivalently and significantly better than the sports drinks and vitamin-fortified waters. While some of this difference is due to the additives to these other beverages and is therefore inherent in the product categories, the largest portion of the difference is due to differences in packaging weight. Much of this advantage might therefore disappear in cases of either bulk packaging or if manufacturers of these products reduced packaging weight to the level of the EcoShape bottle. The influence of distribution distance is also shown to be important, but insufficient information is available to draw conclusions comparing beverage categories on this basis. It can be said that bottled beverages with long distribution distances are very likely to be much worse performing from an environmental perspective than those with shorter distribution networks. It is therefore reasonable to conclude that the impacts shown for the EcoShape bottle, with has the lightest packaging in the industry, is formed and filled at the same plant, and is produced by the manufacturer with the densest network represents an approximate lower bound for current products in the single-serving bottled water category.

The comparison of the EcoShape bottle and the 3 L bottle show a roughly equivalent level of environmental impact for these two systems. Because of the thinness of PET obtained in the EcoShape bottle, the 3 L bottle has only a slight advantage in material efficiency despite its 6-fold larger size. This advantage is roughly offset by the added impact of washing the drinking glass that is assumed to be used with the 3 L bottle.

The results of a test of the sensitivity of the weight of PET in the water bottle suggest that NWNA's focus on decreasing the weight of the bottle has been a highly valuable effort from an environmental perspective. The current product footprint suggests that further weight decreases, along with further improvements in the transportation logistics network, are the most likely activities to improve the environmental performance of NWNA's products. In addition to decreasing weight, other means of reducing the impact of packaging material production could be pursued. Such means might include use of recycled resins, use of bioplastics, working with suppliers on their environmental performance, and other options. None of these alternatives have been considered in this project specifically and warrant their own investigation to ensure a strategy is selected that will result in the best environmental profile.

The variation among the water alternatives studied in detail here (nearly a factor 10 difference) is small in comparison to the range in impacts for other beverage types found in examining other sources of information, where a greater than 30-fold difference is observed between the least impacting and most impacting beverages. When examining the total beverage consumption impact of the typical American consumer, it is found that those beverage types that produce the greatest portion impact associated with beverage consumption are different than those that are most prominent in volume consumed. For example, consumption of water of all types accounts for 41% of beverage consumption, while producing only 12% of the associated impact on climate change. In comparison, the combination of milk, coffee, beer, wine and juice provide 28% of the volume of beverages consumed but are associated with 60% of the climate change impact. These observations show the importance of carefully considering the full scope of beverage consumption when considering impacts of any given product, as increases in consumption of a product are likely to result in the decrease of another product and *vice-versa*.

Surveys of consumers regarding their preferred alternative to bottled water in cases where it is not available were used as a basis to consider scenarios of increasing or decreasing consumption of bottled water. This information suggests that approximately 30% of bottled water drinkers will choose tap water when bottled is not available and the remainder will prefer another type of bottled beverage**. The results indicate that if bottled water is removed from consumer choice – and consumers remain free to choose among remaining alternatives based on their preference – it is unlikely that any environmental benefit will result.** Conversely, similar consideration of cases where consumers drink more bottled water shows a potential for reducing the total environmental impact associated with providing a consumer's beverage consumption. For example, tripling bottled water consumption to 1 L per day results in a decrease of between 5% to 10% in the climate change impact of the average consumer's beverage consumption.

An assessment was also made of the case where a consumer switches their consumption of bottled to tap water. This case results in a decrease of the impacts of that consumer's beverage consumption by approximately 5%, with a likelihood of variation depending upon their exact consumption profile and the conditions of the bottled and tap water consumption.

While the difference shown are not substantial enough to conclude that removing bottled water from consumer choice causes an increase in impact, the results that it is unlikely to result in a definitive environmental benefit and highlight the importance of considering the resulting choices that will be made by consumers when they are steered away from bottled water.

The findings shown here may have important implications in the context of the information consumers receive regarding bottled water and the actions proposed or taken by some municipalities or organizations limiting availability of bottled water. The relationships shown here illustrate the importance of consumer actions, such as shopping, refrigeration, washing, container reuse and recycling on the impacts of both bottled and tap water. This suggests an importance of communicating a detailed set of information to those consumers who are interested to reduce the impact of their water consumption to help them understand which aspects of their behavior are important in addition to the choice of bottled versus tap water. As noted earlier, related issues of tap water quality or health concerns related to consuming tap water or other beverages are outside the scope of this study.

The comparison of many types of beverages and potential for consumers to increase impacts when moving away from bottled water to other beverages suggests a danger in stigmatizing bottled water as an environmental offender in a way that is not shared by other non-water beverages, most or all of which have a larger environmental impact than bottled water. For each consumer that chooses non-water beverage rather than bottled water in part to avoid a potential image of not being environmentally conscientious is very likely having exactly the opposite effect that messages suggesting avoiding bottled water have been intended to produce. Because the potential increase in impact by switching from bottled water to, for example, milk or coffee is greater than the decrease of switching from bottled to tap water, even if a minority of consumers are influenced by these messages to choose non-water beverages, they could still result in more harm than good. These finding suggest the importance of carefully considering the effects of information that is provided to the public and to ensure that complete and accurate information is communicated to help consumers make choices that match their desire to be responsible consumers.

Choices by retailers or governments that limit or eliminate availability of bottled water, without any limits on other beverages or education to encourage tap water, seem unlikely to produce a decrease in environmental impacts of beverage consumption. Because these actions act equally on all consumers rather than resonating only with “concerned” consumers, they are even more likely than advertising campaigns to move would-be bottled water consumers toward other beverages rather than, as is likely intended, to tap water. Such findings underscore the importance of considering the influence on total consumption habits when seeking to direct consumers toward or away from certain products.

The results suggest that, when informing concerned consumers about the most effective means of reducing the environmental impacts of their beverage consumption, it is appropriate to recommend consumption of tap water in preference to bottled beverages. One should further communicate the important influence that the consumer has regardless of which beverages they are consuming through activities such as refrigeration, dishwashing, recycling, etc. It is also important when discussing bottled water to acknowledge that in comparison to other bottled beverages, it represents a good environmental choice in those cases where tap water is not available or is not a desired choice by the consumer. Within the bottled beverage category, consumers could be enabled and encouraged to choose those products with low packaging weight and short distribution distances. Finally, it is important to assist consumers in understanding the range of environmental impacts possible within both the bottled and tap categories and that achieving a low impact is a more nuanced decision than simply a choice of bottled or tap water.

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10. Appendices

10.1 Contributions by Life Cycle Stage

Details descriptions and figures showing the contribution of the various life cycle stages to the beverages studied are provided as an appendix.

10.1.1 Beverage Production

Figure 32 shows the contributors to the climate change impacts during the Beverage Production stage for the bottled beverage systems. The total life cycle climate change impact is also shown for context on a second axis (note that the scale of this axis is 10-fold that shown for the results within the Beverage Production stage). Production of bottled water by other manufacturers has been assumed here to be within the range shown for Nestlé Waters due to the absence of more specific industry data on production.

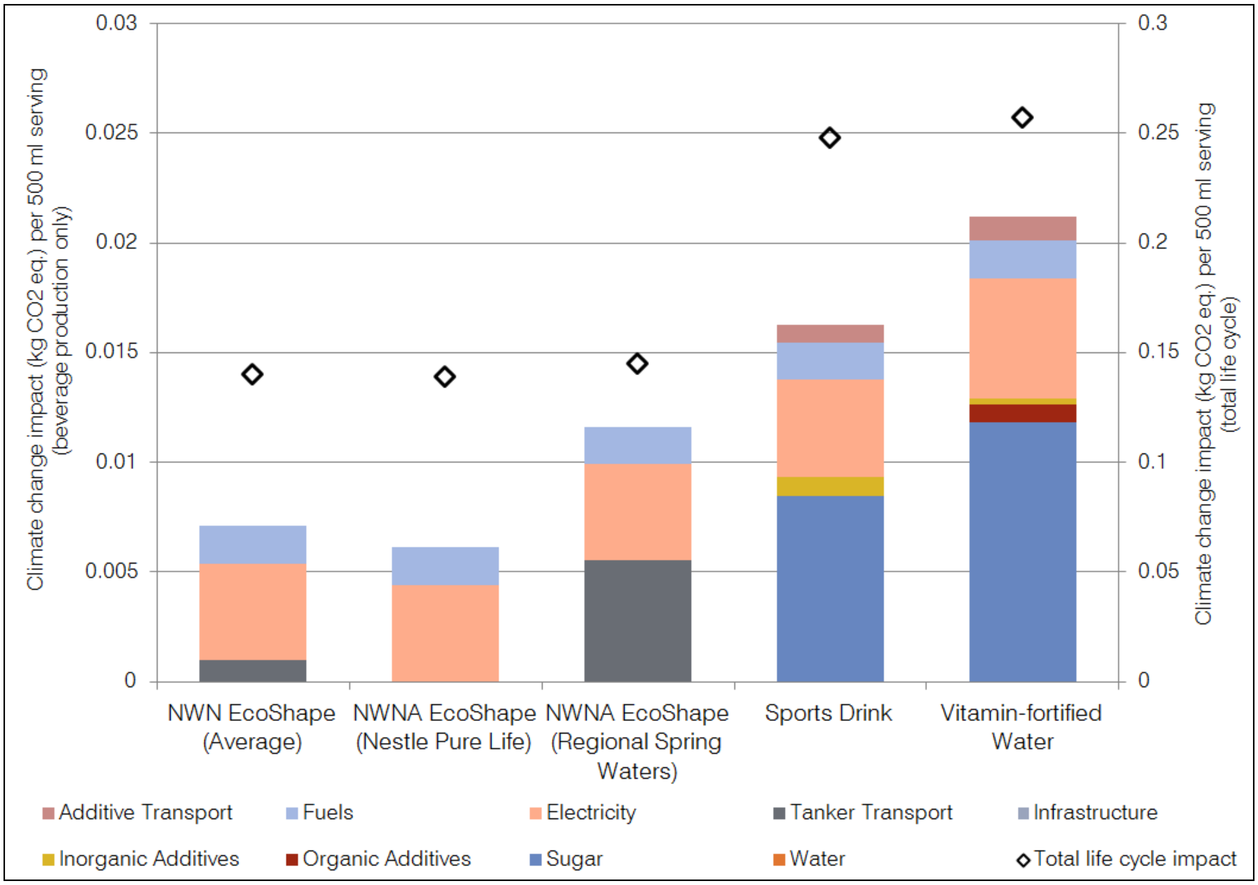

Figure 34: Climate Change Impact for the Beverage Production Stage of the Bottled Beverage Systems (per 500 ml serving)

The beverage production impacts for the sport drink and vitamin-fortified water are shown to be roughly 2 to 3 times that of the water products. The primary determinant of the difference within beverage production for these products is sugar, with other additives resulting in a much smaller contribution. It should be noted that fuels and electricity for the other bottled beverage production have been based on the NWNA data and can be expected to vary among manufacturers.

Within bottled water, results are shown for both the Nestle Pure Life product, in which water is filtered and then re-mineralized, and for regional spring waters, which undergo only very minimal treatment. Materials used in water treatment for both products are very minimal and have been omitted from the scope. Another important difference among these two products is that movement of water by tanker truck from the site of the spring to the site of bottling is common for regional spring water (occurring for more than 1/3 of Nestlé's regional spring waters), whereas movement by tanker never occurs for the Nestle Pure Life water. As seen in Figure 11, the use of tinkering is important for the results within the Beverage Production state, causing the regional spring water to have a higher environmental impact than Nestle Pure Life. However, because Beverage Production is only a minimal contributor to the total impact throughout the product lifecycle, the result is only a minor difference (2%) in the total climate change impact of the two water types.

Figure 35 shows the beverage production impact for tap water.

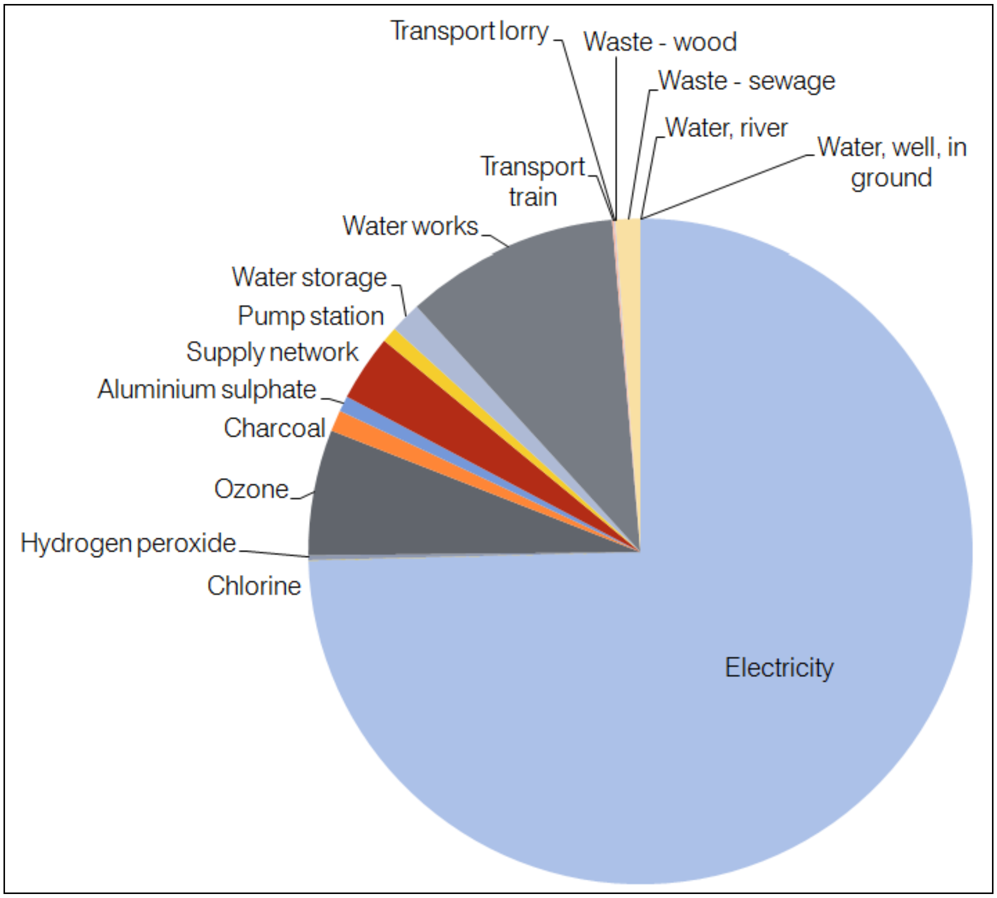

Figure 35: Contributors to the Climate Change Impact for the Beverage Production Stage of Tap Water (total = 0.00044 kg CO2 equivalents per functional unit)

Note that the impacts of beverage production here are slightly less than one tenth of those shown for beverage production of bottled water in Figure 11. The major contributor to tap water production impact is the use of electricity, with other aspects being of less significant importance, which agrees with conclusions found elsewhere (e.g., Vince et al, 2008).[26]

10.1.2 Packaging and Equipment Production

Figure 36 shows the contributors to the Drinking Container Production stage for each of the bottled beverage systems.

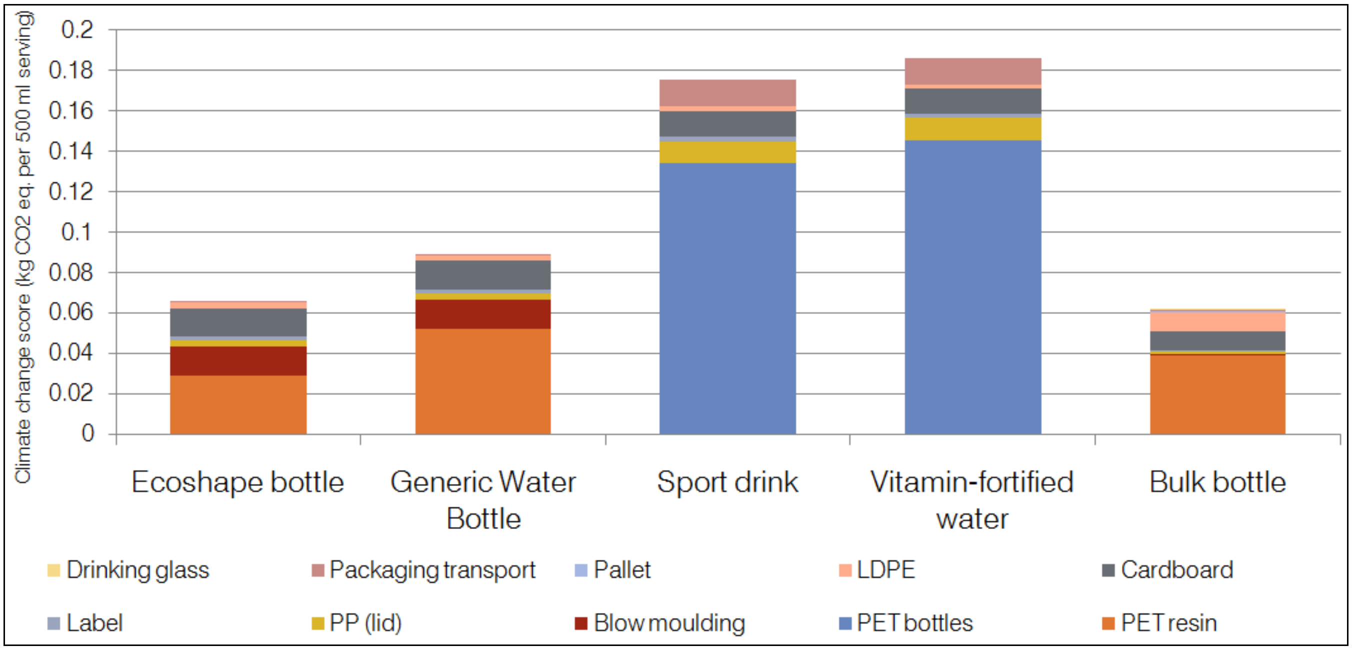

Figure 36: Climate Change Impact of Container Production for the Bottled Beverage Systems (per 500 ml functional unit)

The EcoShape and 3 L bottle perform substantially better than the sport drink and vitamin fortified water, primarily due to a lesser use of PET per amount of water served. While the EcoShape bottle achieved this by use of a lighter weight bottle with a similar size, the 3 L bottle provides a greater product to packaging ratio by taking advantage of its larger size.

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[26] The comparison between the impacts of producing the water itself for bottled and tap water is subject to important uncertainties and variability. The tap water production energy will vary considerably based on the location and treatment technologies used (at least a factor of 10, Vince et al., 2008). The information used to assign impacts of electrical production of bottled water are very accurate in regard to the total impact of the system, but contain an important uncertainty affecting the water production itself. The total electricity use of the bottling plants (0.084 kwh per liter) cannot be precisely divided among the water treatment, facility operation and blow molding, which occurs on-site. Here, we have therefore used energy use information from Ecoinvent to estimate the amount of electricity needed for the blow molding (0.074 kwh per liter) and assigned the remaining electricity to water treatment and facility operation (included in the category Beverage Production). It should be noted that an underestimate in the electricity for blow molding of 0.01 kwh per liter (<15%), which may be feasible given the thinness of the EcoShape bottle, would result in an overestimation of the Beverage Production contribution by 100-fold (although it would not change the total impact for the bottled water system). It is therefore advisable not to reach conclusions regarding the comparison of beverage production alone among the tap and bottled water systems.

Figure 37 shows the climate change impact for the production of the reusable bottles, based on one functional unit.

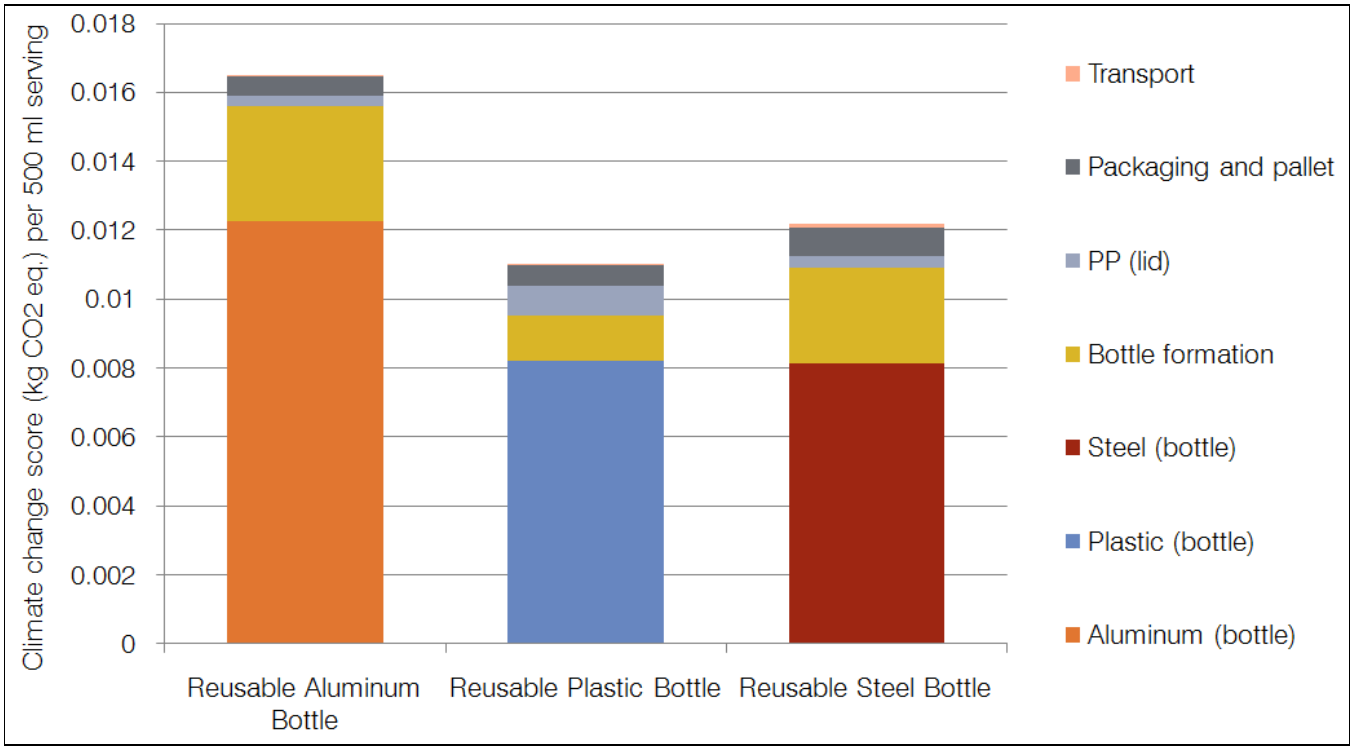

Figure 37: Climate Change Impact of Container Production for Reusable Bottles (per 500 ml functional unit). Note that 100 uses per bottle are assumed.

The impact of the reusable plastic bottle is shown to be less than for the reusable metal bottles. However, the difference shown is such that variation in characteristics may be sufficient to reverse that trend. In addition, the number of uses over the lifetime of bottles of each material may not be equal. It is therefore not possible to conclude whether one material is preferable to another.

Figure 38 shows the contribution of various components to the climate change impact of the Packaging/ Equipment Production stage of the life cycle for the filtering pitcher system.

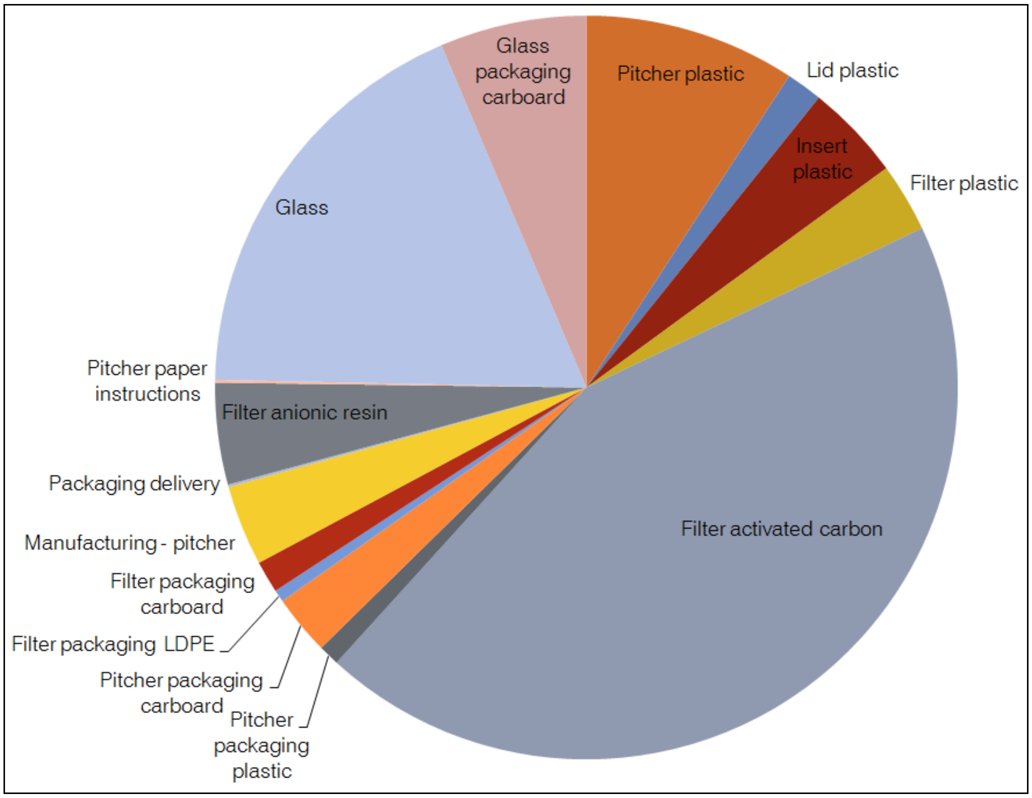

Figure 38: Contribution to climate change impact of the Packaging / Equipment Production Stage for the Filtering Pitcher (total impact per functional unit is 0.017 Kg CO2 Eq.)

The results suggest that the replacement filters are the most significant contributor to the equipment and container-related impact of the filtering pitcher system, most notably due to the activated carbon within the filters. It should be noted that the ratio of filter-related impact to pitcher-related impacts will depend upon the length of use of the pitcher (which is assumed here to be a total of 600 uses (e.g., 300 uses per year for 2 years).

Figure 39 shows the equipment-related climate change impact for the vended water system.

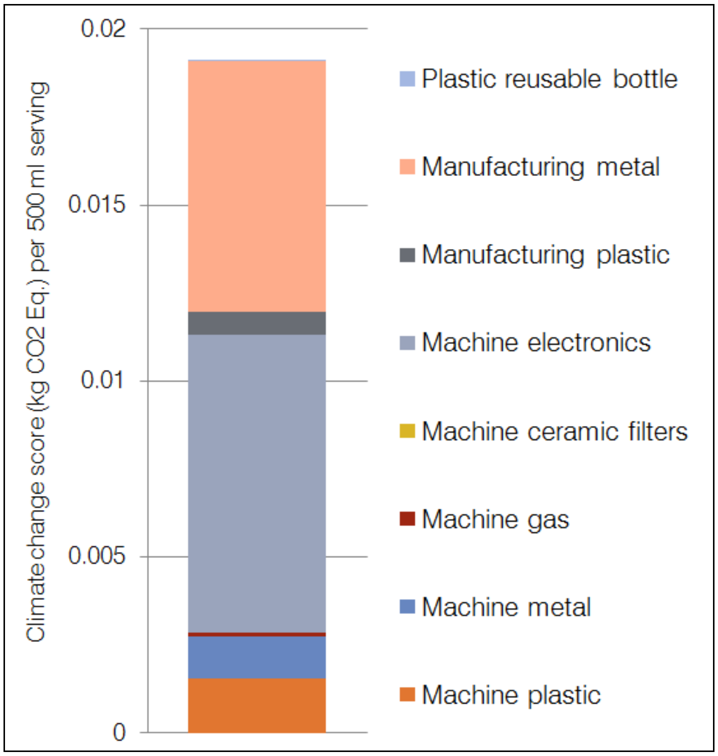

Figure 39: Climate Change Impact for Equipment Production of the Vended Water System (per 500 ml functional unit).

Several components of the machine are shown to be important contributors. Is should be reiterated that the machine is represented here based on general assumptions about its material contents and vending machines on the market are likely to vary considerably in their material contents and manufacture.

10.1.3 Distribution and Marketplace

For the bottled beverage systems, the transportation of products to the marketplace is an important contributor to the impact of the product (see figure 9). For each system, the climate change impact at this stage ranges from 55 to 60 g CO2 equivalent, which represents between a fifth and a third of the total impact, depending on the system. Because of the important impact of diesel truck emissions on human respiratory health, this stage is an even more important contributor to human health impacts, contributing slightly more or less than half the impacts in this category over the lifecycle (depending on the product in consideration). For the other systems, delivery of the products to marketplace is much less important, contributing only 0.2 g CO2 equivalents or less per functional unit.

Transportation to the consumer's home is estimated to be rather small for all systems. For the bottled beverage systems, a value of between 3 and 5 g CO2 equivalents per functional unit are estimated. For the reusable bottle systems, this value is estimated to be less than 2 g CO2 equivalents per functional unit. For the filtering pitcher and 3 L bottle, the impact is estimated to be less than 0.2 g. As discussed in the sensitivity section below, this life cycle stage has a potential to be an important contributor in cases where the consumer is driving large distances to buy the water and little else, but in typical conditions, such as those assumed in the baseline assumptions, the impact of this shopping trip is only a small contributor to the lifecycle impact of any of the systems.

10.1.4 Use – Refrigeration

Refrigeration of products is estimated to be a modest contributor to the impacts of each system, with a potential for a more important contribution under alternative consumer practices. In cases where refrigeration at home occurs, it is estimated here to contribute just less than 4 g CO2 equivalent per functional unit. This represents between 1 and 2% of the impacts of the bottled systems and between 5 and 10% of the impacts of the tap-water based systems. The vended water system is estimated to have a higher contribution, of approximately 20 g CO2 equivalents per functional unit at this stage (all electricity consumption by the vending machine is included in this "refrigeration" stage), just over one quarter of the total for this system. As is shown in the scenarios, the refrigeration stage is highly dependent on a variety of assumptions and in extreme cases could become the most significant portion of the life cycle of both tap and bottled waters.

10.1.5 Use – Drinking Container Washing

For those systems involving washing of dishes (all but the single-serving, single-uses bottles), this stage is an important contributor to impacts, providing approximately 25 g CO2 equivalents per functional unit for the washing of bottles or glasses. This stage provides the major contribution of impact for many of the systems and is the large majority of impact for unrefrigerated and unfiltered tap water. The filtering pitcher also requires washing of the pitcher, raising the impact at this stage to 30 g CO2 equivalents per functional unit for this stage. Because of the importance of this stage in several of the systems, variability in consumer behaviors in washing will lead to significant variation in the impacts of consuming tap water among consumers.

10.1.6 End-of-Life

As seen in in Figure 9, the impact or benefit derived at end-of-life is very small for most of the systems. While the influence of end-of-life is extremely small for the tap-water based systems, it ranges from 3 to 10 g CO_2 equivalents of *benefit* for the bottled water systems, representing between 1 and 5% the total impact of these systems.[27] The sport drink and vitamin-fortified waters show a higher end-of-life benefit due to their higher use of plastic material. The impact regained at end-of-life from PET recycling, based on the assumptions used here, is shown to be just under one fifth of the impact of producing the PET bottles and is highly influenced by the assumed rate of recovery of these bottles in the US. The benefit obtained at end-of-life represents several percent of the total impact for the bottled water systems.

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[27] The benefit or impact identified at end-of-life will depend highly on the method chosen for representing the activities at end-of-life and, for end-of-life routes that both eliminate wastes and produce useful products or energy, determining how those activities are distributed among the systems providing the waste and those using the materials. The method used here follows the "avoided burden" approach at end of life and is discussed in section 2.

10.2 Characteristics of the Systems Studied

Table 7: Characteristics of Sport Drinks

Sport Drinks	Sample 1	Sample 2	Sample 3	Sample 4	Average Product
Size	502mL	591mL	591 mL	473 mL	539 mL
Bottle Weight and Material	37g, PET	32g PET	40g PET	40 g PET	37g PET
Label Weight and Material	<1g, LLDPE	<1g, LLDPE	<1g LLDPE	2g LLDPE	1g LLDPE
Lid Weight and Material	3g, PP	3g, PP	3g PP	5g PP	3.5g PP
Ingredients	Purified/distilled water, pure cane sugar, natural black raspberry flavor, electrolytes (magnesium lactate, calcium lactate, dipotasium phosphate, potassium chloride), citric acid, vitamin E acetate, vitamin A palmitate, folic acid, zinc cluconate, rosemary extract, d-ribose	Water, natural flavors, citric acid, salt, potassium citrate, sucralose, sodium citrate, potassium phosphate, acesulfame potassium, red 40, niacinamide, pyroxidine rabic line e, cyanocobalamin	Water, high fructose corn syrup, sucrose syrup, citric acid, natural flavors, salt, sodium citrate, monopotassium phosphate, gum rabic. Glycerol ester of wood rosin, red 40, blue 1.	Filtered water, organic evaporated cane juice, natural flavors, salt, citric acid, magnesium lactate, potassium phosphate	See table below
Nutritional Info (per bottle)	Calories: 73.5, Potassium: 197.4mg, sugars: 18.9g, Calcium: 8% USRDA, Magnesium: 25% USRDA, Vitamin A: 12% USRDA, Zinc: 21% USRDA	Sodium: 137.5 mg, potassium: 87.5mg, niacin (B3): 10% USRDA, vitamin B6: 10% USRDA, vitamin b12: 10% USRDA	Calories: 130, Sodium: 270 mg, Potassium: 75mg, sugars: 34g	Calories: 90, Sodium: 260 mg, Potassium: 700mg, carbohydrates: 22g, sugars: 10g, iron: 2%USRDA, magnesium: 6%USRDA	See table below

Table 8: Characteristics of Vitamin Water

Vitamin Water	Sample 1	Sample 2	Sample 3	Sample 4	Average Product
Size	591mL	591mL	591 mL	480 mL	563 mL
Bottle Weight and Material	39g, PET	40g PET	38g PET	39 g PET	39g PET
Label Weight and Material	<1g, LLDPE	<1g, LLDPE	<1g LLDPE	3g LLDPE	1g LLDPE
Lid Weight and	3g, PP	3g, PP	4g PP	5g PP	4g PP

Material					
Ingredients	Purified water, sugar, natural flavors, citric acid, vitamin C, potassium citrate, modified corn starch, calcium lactate, calcium gluconate, magnesium lactate, vitamin E acetate, acacia gum, calcium disodium EDTA, zinc gluconate, vitamin A palmitate, beta carotene, Epigallocatechin gallate, magnesium gluconate, soy lecithin	Reverse osmosis water, cane sugar, rabic line fructose, natural flavor, citric acid, ascorbic acid, fruit and vegetable juice (less than 1%), berry and fruit extract, magnesium lactate, gum rabic, niacin, pantothenic acid, ester gum, vitamin E acetate, monopotassium phosphate, calcium lactate, pyridoxine hydrochloride, cyanocobalamin	Water, sucrose syrup, citric acid, natural flavors, salt, sodium citrate, potassium citrate, vitamin C, sucralose niacinamide (vitamin B3), calcium disodium EDTA, calcium pantothenate (vitamin B5), vitamin E acetate, pyridoxine hydrochloride (vitamin B6), acesulfame potassium, vitamin B12.	Purified water, cane sugar, fructose, vitamin C, citric acid, natural flavors, magnesium lactate gluconate, Okinawa deep sea minerals, zinc amino acid chelate, pyridoxine hydrochlorate, calcium pantothenate (vitamin B5),niacin, manganese gluconate, glycine, aspartic acid, chromium polynicotinate, folic acid, cyanocobalin.	See table below
Nutritional Info (per bottle)	Calories: 150, sugars: 30g, calcium: 4% USRDA, Magnesium: 4% USRDA, Vitamin A: 50% USRDA, Zinc: 6% USRDA, vitamin c: 250%, vitamin E: 50%	Calories: 150, Sugars: 32.5g, Vitamin C: 100 % USRDA, Vitamin E: 25% USRDA, Vitamin B3: 100% USRDA, Vitamin B6: 100% USRDA, Vitamin B12: 100% USRDA, Vitamin B5: 100% USRDA, Berry and fruit polyphenols, 50mg	Calories: 25, Sodium: 85 mg, carbohydrates: 7g, sugars: 5g, vitamin C: 30%USRDA, vitamin E: 25%USRDA, niacin: 60%USRDA, vitamin b6: 60%USRDA, vitamin b12: 10% USRDA, pantothenic acid: 60% USRDA	Calories: 100, Sodium: 60 mg, Potassium: 200mg, sugars: 25g, vitamin C: 1660%USRDA, calcium: 6%USRDA, , niacin: 25%USRDA, vitamin b6: 500%USRDA, folate: 4%USRDA, vitamin b12: 420%USRDA, pantothenic acid: 25%USRDA, Magnesium: 15% USRDA, Zinc: 13% USRDA, Manganese: 25% USRDA, Chromium: 8%USRDA	See table below

To estimate an average 500 ml single-serving bottle weight representing the range of products on the marketplace, NWNA was able to provide existing research regarding weights of various bottles on the market. Measurements of more than 50 brands are provided in the table below. An average weight of 17.7 g PET was determined by taking an equally weighted average of these values.

Table 9: 500 ml water bottle weights sampled from the US marketplace

Brand	Bottle weight (w/o cap)	Brand	Bottle weight (w/o cap)
NWNA Eco-Shape Bottle (generation 1)	12.37	Kroger	15.59
Savalas	11.14	Shop Rite	15.59
Niagara	12.60	Volvic Spring Water	16.91
Costco	12.73	Evian	17.05
Food Lion	12.77	Publix	17.06
Crystal Springs	12.79	Spring!	17.11
Crystal Geyser	12.91	HEB	17.12
Albertsons Natural Spring Water	12.99	Walgreens-Pure American	17.18
Absopure	13.11	Odwalla	17.21

Sunset Foods-Centrella Spring	13.11	Drug Mart-Aqua Pura Purified Water	17.47
Albertsons Purified Drinking Water	13.12	Spring! By Dannon	17.52
Hannafrod Spring Water	13.15	CVS Spring Water-Pop Cap	18.58
Meijer	13.15	Deja Blue	19.05
Stater Bros. Pure Water	13.16	Deja Blue - Pop Cap	19.12
Safeway-Refreshe Purified Drinking Water	13.31	Iceland Springs	20.13
Diamond Springs	13.50	Evamor	20.63
Safeway-Refreshe Spring Water	14.02	Aquafina	21.50
Rite Aid (Crystal Lake)	14.14	Ethos Water	21.56
WalMart (Great Value)	14.32	Aqua Panna S. Pellegrino Natural Spring Water	23.16
Roxanne Mountain Spring Water	14.35	Gerolsteiner	23.64
Sparkletts	14.52	80 Degrees North	23.72
Acadia	14.78	Tynant Spring Water	23.94
Walgreens-Spring Water	14.94	Iceland Pure	24.00
7-Eleven	14.98	Isbre	24.03
Dasani	15.07	Penta	25.68
Aquafina (New)	15.12	Fiji	26.10
CVS Spring Water	15.15	SEI (Metromint on Cap)-Spring Water	34.56
Wild Oats-Whole Foods	15.52	Voss	41.30

Table 10: Characteristics of filtering pitcher

Filtering Pitcher	Sample 1	Sample 2	Average Product
Capacity	1.75 L	1.75 L	1.75 L
Pitcher Weight and Material	349 g styrene acrylonitrile copolymer	309 g styrene acrylonitrate copolymer	329 g styrene acrylonitrile copolymer
Insert Weight and Material	157g PP	163 g PP	160g PP
Lid Weight and Material	71g PP	49 g PP	60g PP
Filter housing weight and material	17g PP	20 g PP	18.5g PP
Filter internal weight and material	87g total contents (activated carbon and anion exchange resin combined)	65 g total contents (activated carbon and anion exchange resin combined)	76 g, assumed to be 2/3 activated carbon and 1/3 anion exchange resin[28]
Pitcher lifetime	Assumed to be used 600 times (e.g., 300 uses per year for 2 years)		
Water treated per filter	40 gallons	50 gallons	45 gallons
Primary pitcher packaging	Not sampled	196 g cardboard, 10 g paper, 44 g PVC	196 g cardboard, 10 g paper, 44 g PVC
Primary filter packaging	Each in 2g LDPE bag; 5 in 62g cardboard box	Each in 2g LDPE bag; 1 in 22g cardboard box	2 g LDPE bag per filter; 17 g cardboard per filter

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[28] Product packaging states that the filter contains both activated carbon and an anion exchange resin. No information could be found indicating what percentage of each is contained in the filter.

Table 11: Characteristics of Plastic Reusable Bottle

Plastic Reusable Bottle	Sample 1	Sample 2	Average Product
Capacity	1000 mL	500 mL	750 mL
Bottle Material and Weight	161g Polycarbonate	51 g Polycarbonate	106 g Polycarbonate
Cap Material and Weight	18g PP	35 g PP	26 g PP

Table 12: Characteristics of Aluminum Reusable Bottle

Aluminum Reusable Bottle	Sample 1	Average Product
Capacity	1000 mL	750 mL
Bottle Material and Weight	133g Aluminum	100 g Aluminum
Cap Material and Weight	12g PP	10g PP

Table 13: Characteristics of Steel Reusable Bottle

Steel Reusable Bottle	Sample 1	Sample 2	Average Product
Capacity	800 mL	500 mL	750 mL
Bottle Material and Weight	177g steel	98g steel	155 g steel
Cap Material and Weight	3g PP	17 g PP	10 g PP

10.2.1 Sports Drink and Vitamin Water Ingredients

The ingredients of the two products sports drink and vitamin water are quantified using information on the product labels. The labels contain are presented in the previous section 4.1. The following table shows the method of estimating quantities of sugar and the different organic and inorganic ingredients. [29]

Table 14: Amount of sugars, organic and inorganic ingredients in the sport drinks

Sport Drinks	Sample 1	Sample 2	Sample 3	Sample 4	Average Product
Sugar					
Sugar	19 g		34 g	10 g	21 g
Organic ingredients					
Carbohydrates				20 mg	20 mg
Vitamin A – USRDA[30]: 0.9 mg	0.1 mg				0.1 mg
Vitamin B3 (niacin) – USRDA: 16 mg		2 mg			2 mg
Vitamin B6 – USRDA: 1.3 mg		0.1 mg			0.1 mg
Vitamin B12 – USRDA: 0.0024 mg		0.0002 mg			0.0002 mg
Inorganic ingredients					
Zinc – USRDA: 11 mg	2 mg				2 mg
Sodium – USRDA: 1500 mg		140 mg	270 mg	260 mg	220 mg
Iron – USRDA: 8 mg				0.2 mg	0.2 mg
Potassium – USRDA: 4700 mg	197 mg	88 mg	75 mg	700 mg	265 mg
Calcium – USRDA: 1000 mg	80 mg				80 mg
Magnesium – USRDA: 420 mg	105 mg			25 mg	65 mg

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[29] Because specific data is not available on the impacts of producing individual vitamins, flavorings and other additives, these have been represented in the life cycle inventory based on information for generic organic or inorganic chemicals, depending on the nature of each additive. For any given additive, this information is believed to be accurate within a factor of ten and somewhat more accurate than that for a total of several additives, as errors in either direction will cancel out. The results indicate that, using this data and climate change as an example, these additives represent less than 0.4% of the total impact for the vitamin-fortified water and much less than 0.1% for the sports drink. Therefore, even in the case of a factor 10 underestimate, the result on the whole vitamin water system would be underestimated by only a few percent and the sports drink by less than a percent. The percent error produced in the case of an overestimate is much less.

[30] Source : http://fnic.nal.usda.gov

Table 15: Amount of sugars, organic and inorganic ingredients in the vitamin-fortified waters

Vitamin Water	Sample 1	Sample 2	Sample 3	Sample 4	Average Product
Sugar					
Sugar	30 g	33 g	5 g	25 g	23 g
Organic ingredients					
Carbohydrates			7 mg		7 mg
Polyphenols		5 mg			5 mg
Vitamin A – USRDA[31]: 0.9 mg	0.5 mg	0.5 mg			0.5 mg
Vitamin B3 (niacin) – USRDA: 16 mg		16 mg	10 mg	4 mg	10 mg
Vitamin B6 – USRDA: 1.3 mg		1 mg	1 mg	7 mg	3 mg
Vitamin B12 – USRDA: 0.0024 mg		0.0024 mg	0.0002 mg	0.0101 g	0.0042 mg
Vitamin C – USDRA: 90 mg	230 mg	90 mg	30 mg	1490 mg	460 mg
Vitamin E – USDRA: 15 IU = 2/3 mg	5 mg	3 mg	3 mg		3 mg
Vitamin B5 (pantothenic acid) – USDRA: 5 mg		5 mg	3 mg	1 mg	3 mg
Vitamin B9 (folate) – USDRA: 0.4 mg				0.02 mg	0.02 mg
Inorganic ingredients					
Zinc – USRDA: 11 mg	0.7 mg	0.7 mg		1.4 mg	0.9 mg
Sodium – USRDA: 1500 mg			90 mg	60 mg	70 mg
Iron – USRDA: 8 mg					
Potassium – USRDA: 4700 mg				200 mg	200 mg
Calcium – USRDA: 1000 mg	40 mg	40 mg		60 mg	50 mg
Magnesium – USRDA: 420 mg	20 mg	20 mg		60 mg	30 mg
Manganese – USRDA: 2.3 mg				0.6 mg	0.6 mg
Chromium – USDRA: 0.35 mg				0.003 mg	0.003 mg

10.2.3 Vended water machine

Different sources of data have been used and different assumptions have had to be made to assess the vended water. The main data are collected in the following table.

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[31] Source : http://fnic.nal.usda.gov

Table 16: Assumed Characteristics of the Vended Water Machine Systems

Vended water machine	Data	Source
Machine weight and dimensions	200 lb, 30'' x 30'' x 72''	correspondence with Watervend, a water vending machine distributor
Machine material	83 kg steel 14 kg plastic 1 kg Freon 0.5 kg electrical components 0.3 kg filter	Assumption
Machine electricity consumption	375 Watts on vend mode 15 Watts on idle mode	correspondence with Watervend
Filter	one filter to change every 14,000 vends	correspondence with Watervend
Numbers of vends	30,000 vends / machine lifetime (5 years), equivalent to 16 vends / day. One 500 ml bottle filled per vend.	Assumption
Vends time	30 seconds	correspondence with Watervend
Maintenance	Every 2 month, 30 times per machine lifetime, 25 km covered by car.	Assumption

10.3 Explanation of Impact Assessment Methods

The conclusions of the study have primarily been based on an assessment of the impacts the home has in contributing to global climate change. Just as there is a danger in basing environmental impacts on a surrogate measure like waste generation, there is also a danger in basing decisions on only one category of environmental impact. It is quite possible that actions that will achieve improvements in this one category could have important detriments in other categories. The group has therefore evaluated several additional impact assessment metrics that represent other types of impact categories.

The IMPACT 2002+ methodology has an advantage in that it uses scientific principles to evaluate a wide variety of human health and ecosystem impacts into single metrics for these categories. For simplicity, the results for these metrics, along with the results for resource depletion and nonrenewable energy use from that methodology, have been included in the scorecard. Because it has greater geographic relevance for the United States (IMPACT 2002+ is configured for Europe), the U.S. EPA's Tool for the Reduction and Assessment of Chemical Impacts (TRACI) has also been used and the results are shown in Section 6.3.

Descriptions of each of the impact metrics that have been used here are provided below:

Climate Change is represented based on the International Panel on Climate Change's 100-year weightings of the global warming potential of various substances (IPCC, 2007). Substances known to contribute to global warming are weighted based on an identified global warming potential expressed in grams of CO_2 equivalents. Because the uptake and emission of CO_2 from biological sources can often lead to misinterpretations of results, it is not unusual to omit this biogenic CO_2 from consideration when evaluating global warming potentials. Here, we have followed the recommendation of the PAS 2050 product carbon footprinting guidance in not considering either the uptake or emission of CO_2 from biological systems and correcting biogenic emissions of other gasses accordingly by subtracting the equivalent value for CO_2 based on the carbon content of the gas (BSI, 2008).

Nonrenewable Primary Energy Use accounts for the consumption of fossil and nuclear resources but excludes sources of renewable energy at all stages of the life cycle and in all upstream processes. This metric is expressed here in megajoules. It is assessed here based on the IMPACT2002+ methodology (Jolliet et al., 2003).

Human Health impact can be caused by the release of substances that affect humans through acute toxicity, cancer-based toxicity, respiratory effects, increases in UV radiation, and other causes. An evaluation of the overall impact of a system on human health has been made following the human health end-point in the IMPACT 2002+ methodology (Jolliet et al., 2003), in which substances are weighted based on their abilities to cause each of a variety of damages to human health. These impacts are measured in units of disability-adjusted life years (DALYs), which combine estimations of morbidity and mortality from a variety of causes.

Ecosystem Quality can be impaired by the release of substances that cause acidification, eutrophication, toxicity to wildlife, land occupation, and a variety of other types of impact. An evaluation of the overall impact of a system on ecosystem quality has been made following the Ecosystem Quality end-point IMPACT 2002+ methodology (Jolliet et al., 2003), in which substances are weighted based on their ability to cause each of a variety of damages to wildlife species. These impacts are measured in units of potentially disappearing fractions (PDFs), which relate to the likelihood of species loss.

Resource Depletion is caused when nonrenewable resources are used or when renewable resources are used at a rate greater than they can be renewed. Various materials can be weighted more heavily based on their abundance and difficulty to obtain. An evaluation of the overall impact of a system on resource depletion has been made following the resources end-point in the IMPACT 2002+ methodology (Jolliet et al., 2003), which combines nonrenewable energy use with an estimate of the increased amount of energy that will be required to obtain an additional incremental amount of that substance from the earth based on the Ecoindicator 99 method. These impacts are measured in megajoules (MJ).

Carcinogens are chemicals believed to contribute to the incidence of human cancers through release into the environment and subsequent human exposure. The weightings applied here are those from the TRACI methodology (Bare, 2003). These impacts are measured in kilograms of benzene equivalents.

Non-carcinogens are chemicals whose release to the environment is believed to contribute to the incidence of human morbidity or mortality through chronic health effects other than cancer. The weightings applied here are those from the TRACI methodology (Bare, 2003). These impacts are measured in kilograms of toluene equivalents.

Respiratory effects are the result of releasing chemicals to the environment that cause acute harm to human respiratory systems and that may contribute to morbidity or mortality through these pathways. The weightings applied here are those from the TRACI methodology (Bare, 2003). These impacts are measured in kilograms of $PM_{2.5}$ equivalents.

Acidification is the lowering of pH in natural water bodies through the release of acidifying substances to air, land, or water. The weightings applied here are those from the TRACI methodology (Bare, 2003). These impacts are measured in moles of H^+ equivalents.

Ecotoxicity is the harm to wildlife, including all types of flora and fauna, through toxic effects of environmental pollution. The weightings applied here are those from the TRACI methodology (Bare, 2003). These impacts are measured in kilograms of 2, 4-D equivalents.

Eutrophication is the lowering of dissolved oxygen in natural water bodies through an increase in the amount of nutrients (such as phosphorous and nitrogen) in the water body, promoting excessive growth of microorganisms. The weightings applied here are those from the TRACI methodology (Bare, 2003). These impacts are measured in kilograms of nitrogen equivalents.

Ozone depletion is the decrease in ozone in the stratosphere, where it serves to block UV rays from penetrating the atmosphere. The weightings applied here are those from the TRACI methodology (Bare, 2003). These impacts are measured in kilograms of CFC-11 equivalents.

Photochemical oxidation is the creation of oxidizing compounds in the troposphere from environmental pollution (usually the release of nitrogen oxides and volatile organic compounds), also commonly called smog. The weightings applied here are those from the TRACI methodology (Bare, 2003). These impacts are measured in kilograms of NO_x equivalents.

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The following appendices are in an MS Excel file, available upon request

10.4 Overview of Results

10.5 Reference Flow Summary

10.6 Summary of Quality and Consistency Checks

10.7 Details of Reference Flows

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10.8 Uncertainty Assessment

To test the certainty of the results, an uncertainty assessment has been performed. The approach taken is to determine the uncertainty distributions of each system and of the ratios of the systems based on the uncertainty of input parameters. The uncertainty in ratios is a critical metric to assess because it accounts for the interdependence of some aspects of the uncertainty among systems.

The analysis has been made following the method of Hong *et al.* (2009). In brief, the uncertainty of each system is considered to be comprised of uncertainty in the quantities of: 1) the reference flows; and 2) the emission factors (or factor of other types of impacts) that are used to determine the life cycle inventory based on the reference flows. The uncertainties in these two types of input parameters can be used to determine the overall level of uncertainty based on the equation:

$$(\ln GSD_y)^2 = S_1^2(\ln GSD_1)^2 + S_2^2(\ln GSD_2)^2 + \ldots + S_n^2(\ln GSD_n)^2$$

GSD_y is the geometric standard deviation of the result. GSD_1 is the geometric standard deviation of the first input (e.g., a reference flow or emission factor) and S_1 is the sensitivity of the result to that factor. The sensitivities are defined as the percent response in the output to modification to the input and are identical to the percent contributions of the process in question to the overall result.

The GSDs of the reference flows have been determined based on the pedigree matrix approach of Frischknect *et al.*, 2005. The guidance of Frishknect *et al.* 2007 has been used to estimate the pedigree components. Uncertainty in the emission factors for climate change have been determined either based on Monte Carlo modeling in SimaPro software based on the Ecoinvent 2.01 database, or by assigning a conservative estimate of GSD=2 as an approximate upper bound for global warming potential. Where such conservative assumptions are used, they will tend to overestimate the uncertainty, making it more difficult to show the significance of differences.

The distributions of the probability for the climate change impact for systems studied are shown in Figure 40. The steel reusable bottle is shown as an example of the reusable bottle category.

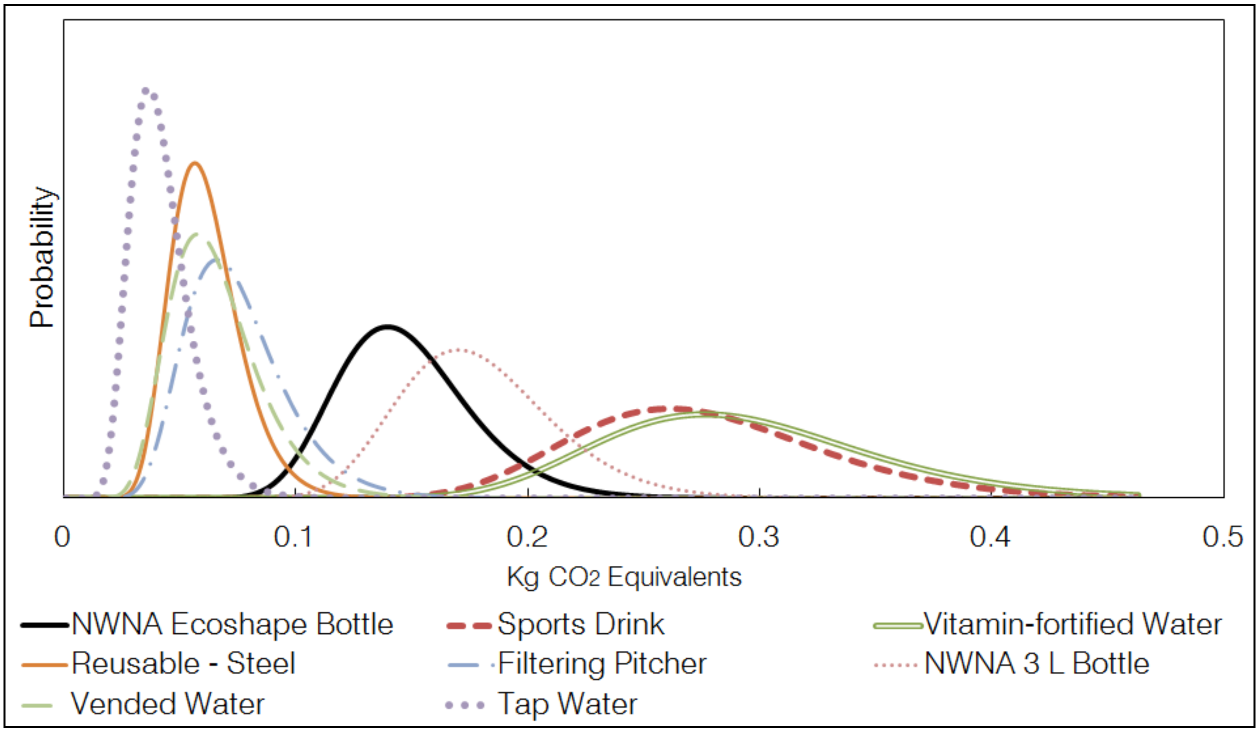

Figure 40: Probability distributions of the climate change impacts of the systems studied

Figure 40 shows while the sport drink and vitamin water are shown to be more impacting than the bottled water products, their uncertainty range overlaps substantially with the bottled waters. Similarly, although the bottled waters are shown to be more impacting that the filtering pitcher, reusable bottle and vended water, there is also substantial overlap of uncertainty ranges in these comparisons. As will be discussed below, a further step that assesses the uncertainty of the comparisons among systems will show that these comparisons are indeed significant.

Drawing comparisons based on the results in Figure 40 overestimate the uncertainty in comparisons among the systems because some aspects of the uncertainty in the systems is uncertainty in the same information and while it contributes to the certainty of results of each system, it does not contribute as substantially to the uncertainty of the comparison among systems.

In addition to determining the uncertainty of the result for each system, Hong *et al.* (2009) also present a method for assessing the uncertainty of the ratios of the results for two systems. This allows a statement of confidence in the conclusion that one system has a greater impact than another. This is performed using the following formula:

$$(\ln GSD_{\frac{A}{B}})^2 = \sum_i^l S_{A_i}^2 (\ln GSD_i)^2 + \sum_{j=l+1}^m S_{B_j}^2 (\ln GSD_j)^2 + \sum_{k=m+1}^n (S_{A_k} - S_{B_k})^2 (\ln GSD_k)^2$$

S_{Ai} and S_{Bj} are the deviations of the independent processes or scenarios A and B, respectively. S_{Ak} and S_{Bk} are the sensitivities of common parameters for scenarios A and B, respectively. GSD_i and GSD_j are the geometric standard deviations of the independent processes or scenarios A and B. respectively GSD_k is the geometric standard deviation of common parameters for both scenarios.

The results are shown graphically in Figure 41

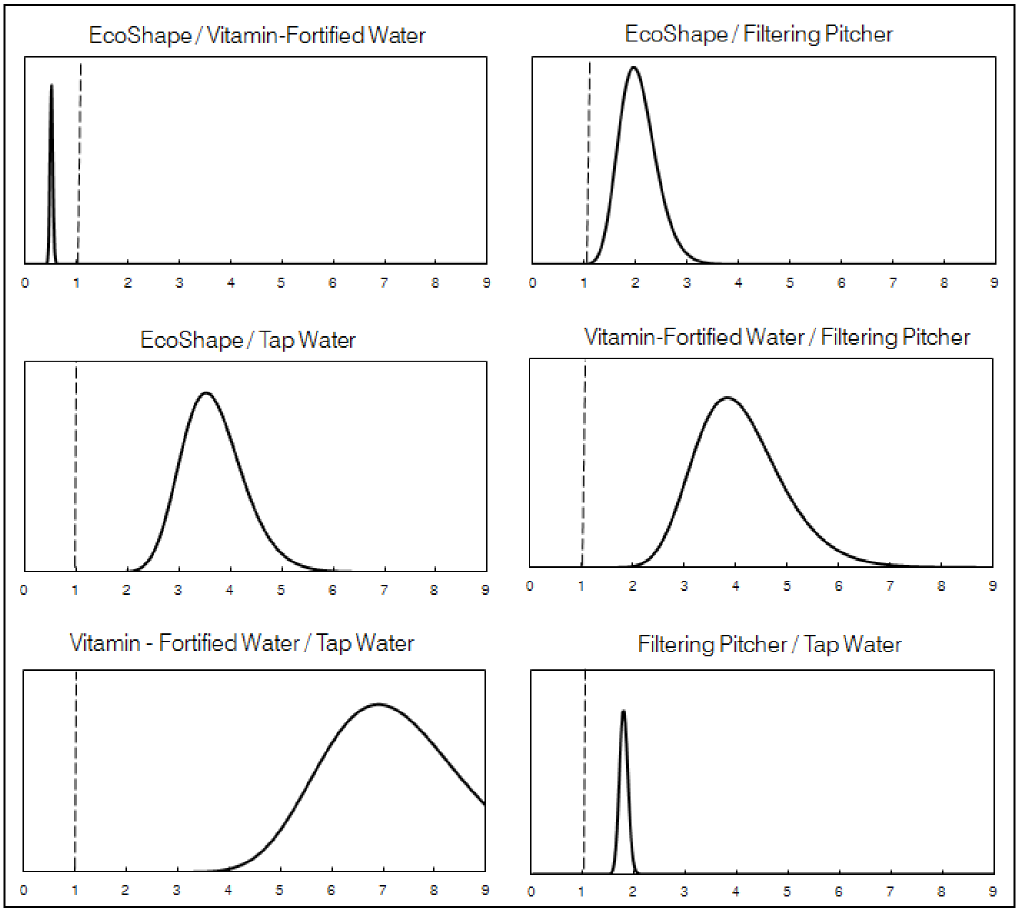

Figure 41: Results of uncertainty assessment, showing ranges of uncertainty for the ratios of the total global warming potential of the four systems compared

The result shows that many of the trends observed in Figure 41 above are indeed statistically significant once the shared uncertainties among systems are accounted for. In particular, the results of the uncertainty assessment indicate that the vitamin-fortified water and sport drinks are more impacting than the bottled waters, that the bottled waters are more impacting than filtered tap water (filtering pitcher) and that the filtering pitcher is more impacting that water directly from the tap. It should be noted that the uncertainty assessment shown above is presented only for climate change impact and the significance of results may vary for other impact types.

11 External Peer Review and Responses

11.1 Critical Review by Panel of External Experts

In the capacity of the original study commissioner, Nestlé Waters North America commissioned a panel of external experts to review the *Environmental Life Cycle Assessment of Drinking Water Alternatives and Consumer Beverage Consumption* study. The following is a report of the review results of the *Draft for External Peer Review* version by the review panel.

Panel Members

The panel comprised of the following members:

Thomas P. Gloria, Ph.D. (Chair)
Managing Director, Industrial Ecology Consultants
Lead Faculty, Bainbridge Graduate Institute

Dr. Michael Z. Hauschild, Ph.D.
Professor, Dept. of Management Engineering, Technical University of Denmark

H. Scott Matthews, Ph.D.
Associate Professor, Civil and Environmental Engineering, Carnegie Mellon University

Critical Review Objectives

Per International Organization of Standardization (ISO) 14044:2006(E) *Environmental management – Life cycle assessment – Requirements and guidelines*, the critical review process included the following objectives to ensure conformance with applicable standards:

- The methods used to carry out the LCA were consistent with the applicable international standards
- The methods used to carry out the LCA were scientifically and technically valid
- The data used were appropriate and reasonable in relation to the goal of the study
- The interpretations reflected the limitations identified and the goal of the study, and
- The study report was transparent and consistent.

Review Results

The review results of the *Draft for External Peer Review* version of the study are as follows. Overall the LCA practitioners accomplished a significant amount of work in a very short period of time. Aspects of the study that stand out as commendable include:

- A fair and balanced assessment of different drinking water systems approaches;
- The use of market research data to generate future scenarios;
- The definition of a meaningful and novel functional unit – the ability to quench one's thirst;
- The careful definition of congruent boundaries to assess the disparate systems;
- The documentation of allocation assumptions;
- The use of limited data to generate a comprehensive life cycle inventory;
- The generation of multiple impact assessment results; and,
- The interpretations of the results appear to be generally consistent with expected results by the review panel.

General areas in need of improvement include the following:

(1) The practitioners should include uncertainty analysis or at least a semi-quantitative estimate of uncertainties of the overall results for at least climate change impact scores to reveal which differences are significant. Also, be aware of co-variation, as it will inherently be present among the water types as they represent similar or identical systems.

(2) Although sensitivity analysis was by and large completed, several important assumptions were made without documented justification. The reviewers felt that this was a key area to ensure appropriate interpretation of the results of the study. By way of example, the format of Figure 11: An illustration of the influence of number of uses for reusable water bottles, is needed throughout to ensure that the reader clearly understands the potential variability of results.

(3) Although the LCA practitioners clearly point out that the discussion of results is framed in the context of contribution to climate change, this is too narrow a selection of impact categories for a comparative study according to ISO standards 14040 and 14044 for the purposes of external communication. In the draft analysis, results have been obtained for a comprehensive set of impact categories (and are presented in the Appendix) and the LCA practitioners should further interpret the results as part of the narrative of the report.

(4) As stated in the goal and scope of the study, it is intended to be used for external and or published comparative assertions, as such, per ISO 14044, Section 6.3, the LCA commissioners should include the involvement of interested parties in the review process. Interested parties are those affected by the conclusions drawn from the LCA study, such as government agencies, non-governmental organizations (NGOs), competitors and affected industries. For example, manufacturers of the filtered water pitcher should be involved in a third party review prior to the publishing of the results of the study. In addition, the documentation of the study would need significant improvement to cover the following areas to conform to the ISO Standards, notwithstanding that uncertainty analysis needs to be completed and sensitivity analysis requires further justification as stated above:

a) analysis of material and energy flows to justify their inclusion or exclusion;

b) assessment of the precision, completeness and representativeness of data used;

c) description of the equivalence of the systems being compared;

d) description of the critical review process;

e) an evaluation of the completeness of the LCIA;

f) a statement as to whether or not international acceptance exists for the selected category indicators and a justification for their use;

g) an explanation for the scientific and technical validity and environmental relevance of the category indicators used in the study;

h) the results of the uncertainty and sensitivity analyses; and,

i) evaluation of the significance of the differences found.

(5) In general data quality is not addressed by the report. Clearly state the data quality requirements, and if appropriate, bring attention to potential bias associated with basing the study on current, accurate primary data (such as data representative of the EcoShape bottle) versus secondary data (for many of the alternatives) that may be of lesser quality due to its broad geographical representation and timeliness.

(6) The cut-off criteria for data collection need to be explicitly stated as part of the study.

(7) If consistent with the intent of the study, clearly state that the system boundary is for water produced and consumed in the US. And if it is the case that data used to complete the study is not representative of this boundary definition, clearly state that this is so.

(8) It was evident that one of the studied product systems, an industry average plastic single use bottle comparable to the EcoShape bottle was not included in the study. It may be appropriate to do so to illustrate the significance or lack thereof, of the differences between the overall results for the two product systems.

Additional detailed technical and editorial comments and recommendations were submitted by the review panel and can be made available upon request. The LCA study practitioners should provide responses to all substantial, non-editorial review comments as an annex to this report.

Conclusion

On the basis of the process to review this study the review panel concludes that the study generally conforms to the applicable ISO standards as an internal comprehensive study. With the careful consideration and incorporation of items 1-8 listed above, particularly item 4 the inclusions of a review a broader panel of external interested parties, this study can be disclosed to the public.

Thomas P. Gloria, Critical Review Panel Chair

9 November 2009

Newton, Massachusetts

11.2 Responses to the Comments of the Critical Review Panel

Responses from the study's authors to each of the comments regarding "general areas in need of improvement" from the panel of critical reviewers are presented below in italics.

(1) The practitioners should include uncertainty analysis or at least a semi-quantitative estimate of uncertainties of the overall results for at least climate change impact scores to reveal which differences are significant. Also, be aware of co-variation, as it will inherently be present among the water types as they represent similar or identical systems.

> *A section regarding uncertainty has been included as an appendix that examines the uncertainty in the comparisons among systems. The methodology chosen is able to distinguish among uncertainty that is common among the systems, therefore accounting for the concern for co-variation. It is performed only for the climate change indicator. The results indicate that, for that indicator at least, many of the directional results seen within the study are significant when uncertainty is accounted for.*

(2) Although sensitivity analysis was by and large completed, several important assumptions were made without documented justification. The reviewers felt that this was a key area to ensure appropriate interpretation of the results of the study. By way of example, the format of Figure 11: An illustration of the influence of number of uses for reusable water bottles, is needed throughout to ensure that the reader clearly understands the potential variability of results.

> *The depiction of reusable water bottle based on multiple rates of reuse, as was done in the original figure 11 has been applied in several additional figures here and to more systems. To better show the additive nature of the sensitivity, additional figures have been made with several sensitive parameters varied at once (see section 6.3.9).*

(3) Although the LCA practitioners clearly point out that the discussion of results is framed in the context of contribution to climate change, this is too narrow a selection of impact categories for a comparative study according to ISO standards 14040 and 14044 for the purposes of external communication. In the draft analysis, results have been obtained for a comprehensive set of impact categories (and are presented in the Appendix) and the LCA practitioners should further interpret the results as part of the narrative of the report.

> *We fully agree that the original analysis, while presenting results of other indicators did not adequately feature them in the body of the report, nor give them adequate discussion. Additional figures and discussion have been added to the main body of the report regarding the other impact indicators that have been examined. The appendix with results for each indicator has been retained.*

(4) As stated in the goal and scope of the study, it is intended to be used for external and or published comparative assertions, as such, per ISO 14044, Section 6.3, the LCA commissioners should include the involvement of interested parties in the review process. Interested parties are those affected by the conclusions drawn from the LCA study, such as government agencies, non-governmental organizations (NGOs), competitors and affected industries. For example, manufacturers of the filtered water pitcher should be involved in a third party review prior to the publishing of the results of the study. In addition, the documentation of the study would need significant improvement to cover the following areas to conform to the ISO Standards, notwithstanding that uncertainty analysis needs to be completed and sensitivity analysis requires further justification as stated above:

> *Regarding the inclusion of interested parties, we have been informed that it is the intention of NWNA to post the information from this project in an online format that includes the*

ability for any interested party to make comments and discuss the assumptions, results, and the topic of sustainability in the beverage industry. Potentially, comments and information submitted through such a forum could lead to further improvements of the present analysis or to further research in this topic area. .

a) analysis of material and energy flows to justify their inclusion or exclusion;

See below regarding cut-off criteria.

b) assessment of the precision, completeness and representativeness of data used;

See below regarding data quality requirements.

c) description of the equivalence of the systems being compared;

Such a discussion was included and had not been modified.

d) description of the critical review process;

Documentation of the critical review has been included.

e) an evaluation of the completeness of the LCIA;

Documentation of the results of the LCIA have been improved and a statement was added evaluating the completeness.

f) a statement as to whether or not international acceptance exists for the selected category indicators and a justification for their use;

A statement has been added regarding the international scientific use and acceptance of the methods chosen.

g) an explanation for the scientific and technical validity and environmental relevance of the category indicators used in the study;

The category indicators are explained and their technical basis is addressed in an appendix section and the cited documentation

h) the results of the uncertainty and sensitivity analyses; and,

An assessment of uncertainty has been added as an appendix.

i) evaluation of the significance of the differences found.

An evaluation of the significance is included in the assessment of uncertainty mentioned immediately above.

(5) In general data quality is not addressed by the report. Clearly state the data quality requirements, and if appropriate, bring attention to potential bias associated with basing the study on current, accurate primary data (such as data representative of the EcoShape bottle) versus secondary data (for many of the alternatives) that may be of lesser quality due to its broad geographical representation and timeliness.

A longer discussion of data quality requirements has been added, including a table summarizing the requirements used and results of checks on those requirements. Further comments were added about the consideration of differing accuracy of data and how this was handled and the prioritization of comparability above accuracy.

(6) The cut-off criteria for data collection need to be explicitly stated as part of the study.

Further discussion has been added (Section 3.1) describing the use of a 1% cut-off threshold for the exclusion of materials or processes for which data was not readily available for its inclusion. Where data was known, falling below the threshold was not used as justification for exclusion.

(7) If consistent with the intent of the study, clearly state that the system boundary is for water produced and consumed in the US. And if it is the case that data used to complete the study is not representative of this boundary definition, clearly state that this is so.

Mention of this was added in Section 1.2. An evaluation of geographic relevance of the data used was included as part of the data quality evaluation that is mentioned above.

(8) It was evident that one of the studied product systems, an industry average plastic single use bottle comparable to the EcoShape bottle was not included in the study. It may be appropriate to do so to illustrate the significance or lack thereof, of the differences between the overall results for the two product systems.

Based on this suggestion, an additional system has been added to the results to reflect and industry average 500ml PET bottled drinking water. With the exception of an adjustment to the weight of the plastic bottle, which has been selected as 17.7 g PET, other aspects have been kept the same for this system (e.g. secondary packaging, manufacturing process, distribution) because of an inability to provide a more accurate industry average. Additional testing of the sensitivity of the bottle weight and distribution distance has been made to illustrate the range of products on the market. Also added has been a distinction among bottled waters that are sourced from regional springs and waters that are not spring-sourced (such as the Nestlé Pure Life product line) to illustrate the potential importance of the movement of water by tanker truck.