Life Cycle Assessment of Tap Water: Analysis and Comparison with Mineral Water and other Beverages

Niels Jungbluth, Regula Keller, Alex König

Margrit-Rainer-Strasse 11c, CH-8050 Zürich

* Author to whom correspondence should be addressed; E-Mail: jungbluth@esu-services.ch;
Tel.: +044 940 61 32

Abstract: This article evaluates the environmental impacts of tap and mineral water in a broad context. The work is based on a study commissioned by the Swiss Gas and Water Association (SVGW). A first step is an investigation of the entire life cycle from water catchment/extraction to serving it up in a glass in a life cycle assessment (LCA). A variety of scenarios including different ways of tap water consumption in Switzerland as a beverage are assessed. They are compared with different scenarios for drinking mineral water and other beverages. The study shows that from an environmental point of view, tap water is preferable to other beverages if the investigated necessity is satisfying ones thirst. The study then broadens the view and evaluates the environmental importance of the total Swiss tap and mineral water consumption. It investigates the heating to get warm water in households and the treatment of used tap water. In this part of the analysis it is shown that other aspects such as waste water treatment and warming of water in households are much more relevant than the use of tap water (or mineral water) for drinking. Therefore switching from tap water to mineral water as a beverage contributes only a small potential for the reduction of total environmental impacts of consumption.

Keywords: life cycle assessment, tap water, beverage, mineral water, environmental impacts, global warming potential

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Abbreviation

CH	Switzerland
DE	Germany
FJ	Fiji
FR	France
IT	Italy
MW	Mineral water
PET	Polyethylene terephthalate
SVGW	Swiss Gas and Water Association
SWG	Seeländische Wasserversorgung
TW	Tap water
ZH	Zurich

1. Introduction

Drinking is a basic necessity. We should drink at least two litres of beverage a day. One option is water that can be provided to consumers directly from the tap or it can be bottled and transported home. Furthermore there are many more beverage options to satisfy thirst. But how can we satisfy this basic need in a manner that is as environmentally friendly as possible and what contribution can tap water make in this context?

Average tap water consumption in Switzerland has dropped slightly during the past couple of years, after rising slowly but steadily until well into the 1980s. Today 142 litres of tap water is consumed on average per person and day in private households in Switzerland [1]. Of this amount, only a small fraction is drunk.

The per capita consumption of bottled mineral water in Switzerland has grown continuously until 2003. From 2003 until 2007 it was stable at around 120 litres per year and capita. In 2011 it dropped and is currently amounting to 111 litres per year [2]. Imports of bottled water have more than tripled during the past decade, now accounting for almost one third of Swiss consumption of bottled water.

The most used method for investigating environmental impacts of products is a life cycle assessment (LCA). The environmental impact is examined throughout a product's entire life cycle from cradle to grave, i.e. from resource extraction, production and usage until the disposal of the product and production waste.

The first LCA studies on single tap water supplies in Switzerland have been elaborated in 1998 [3, 4]. ESU-services Ltd. investigated the environmental impacts of Swiss tap water and compared it with mineral water for the first time in an LCA in 2005 [5, 6]. In 2014 the Swiss Gas and Water Association (SVGW) has commissioned an in-depth update and extension of this study including many further beverages with reference to the year 2013 [7]. In this study several scenarios including home transportation of beverages and in-house distribution of tap water have been included. Furthermore, the study outlines the relevance of the environmental impact of water consumption in relation to the impacts of total private consumption in Switzerland. The study also investigates reduction potentials in different scenarios dealing with the reduction of water consumption or a shift in consumption patterns.

Several other studies have been published on the environmental impacts of tap water and on single other beverages. A good overview on LCA case studies for tap water is given e.g. in [8, 9]. Most of these studies focus on a comparison with mineral water. A comparison of all types of beverages has not been made so far to our knowledge.

In this article we provide further information related to different environmental aspects of tap water, mineral water and other beverages. The full LCA study in German summarized for this article with a special focus on the following themes:

- Tap water and water infrastructure
- Mineral Water and other beverages

Therefore the following questions are addressed in this article:

- What are the environmental impacts of tap water supply and which relevance has the infrastructure in this?

- How compare different beverages including tap and mineral water from an environmental point of view?
- How relevant is the drinking of tap and mineral water compared to the total impacts of tap water supply?
- How relevant is the heating of tap water compared to the heat water supply?
- How relevant is the treatment of used tap water compared to the total tap water supply?
- Which potentials for reduction of environmental impacts exist in these areas of private water consumption?

The LCA study for water is following most of the basic rules laid down in ISO 14040ff [10]. But there are some deviations from this standard, especially the use of a single score weighting for the impact assessment.

2. System boundaries

2.1. Comparison of tap water with mineral water and other beverages

The LCA investigates a range of different scenarios for the provision of tap water, mineral water and other beverages for drinking. The basis of this comparison is the functional unit of 1 kg of beverage available to consumers. For the definition of this functional unit only the provision of liquid, stilling ones thirst, has been taken as a necessity for the investigation. Beverages can supply many more functions, e.g. provision of further nutrients such as fats, proteins, vitamins etc. which are necessary for nutrition. They can therefore partly replace other food items like fruits ore meat. Some beverages such as coffee, wine or beer are also drunk for pleasure and thus fulfil an additional function besides nutrition. Thus, there might be further functions delivered by a beverage which are not addressed with the functional unit investigated in this study.

In this study, the entire life cycle of the beverage is traced from water catchment/extraction to serving it in a glass. Figure 1 shows a simplified flow charts for the main process stages involved in the supply of tap and mineral water. The life cycle of tap water as a beverage includes:

- water pumping during catchment and extraction
- treatment at the water works including chemicals used and necessary infrastructure
- central water storage
- distribution to the household via water pipes including the necessary infrastructure and energy use
- post-treatment of tap water at the consumption site (further purification in the house before the water reaches the tap)
- sanitary equipment, plumbing and house installations
- in some scenarios refrigeration, soda maker, boiling to make tea and coffee)
- pre-flow of tap water and treatment of this part of tap water that is not drunken in an effluent treatment plant

The life cycle of mineral water and other beverage includes

- production of agricultural raw materials like oranges, grapes, raw milk
- water catchment for mineral water

- tap water used for some beverages e.g. beer, coffee or ice tea
- processing (e.g. skimming of milk, pressing of oranges, brewing of beer, carbonation, etc.)
- bottling
- typical packaging materials and sizes including the production of the packaging
- distribution via wholesale and retail channels in the supermarket including cooling were necessary (e.g. milk)
- home transportation by average means of transportation with shares for cars, public transportation, bicycle
- chilling and boiling in the household
- disposal of packages by the household

The assessment for all beverages does not include the drinking receptacle (glass, cup) and the disposal of the flushed toilet water. It is assumed that these two stages do not differ for the different scenarios investigating the consumption of beverages. Treatment of effluents and disposal of wastes is included in all other process stages were relevant.

The LCA is conducted for the situation in Switzerland, which might deviate from the situation in other countries e.g. because of different structure of water works or different types of packages used for beverages. Thus all conclusions in this study are only valid for this country.

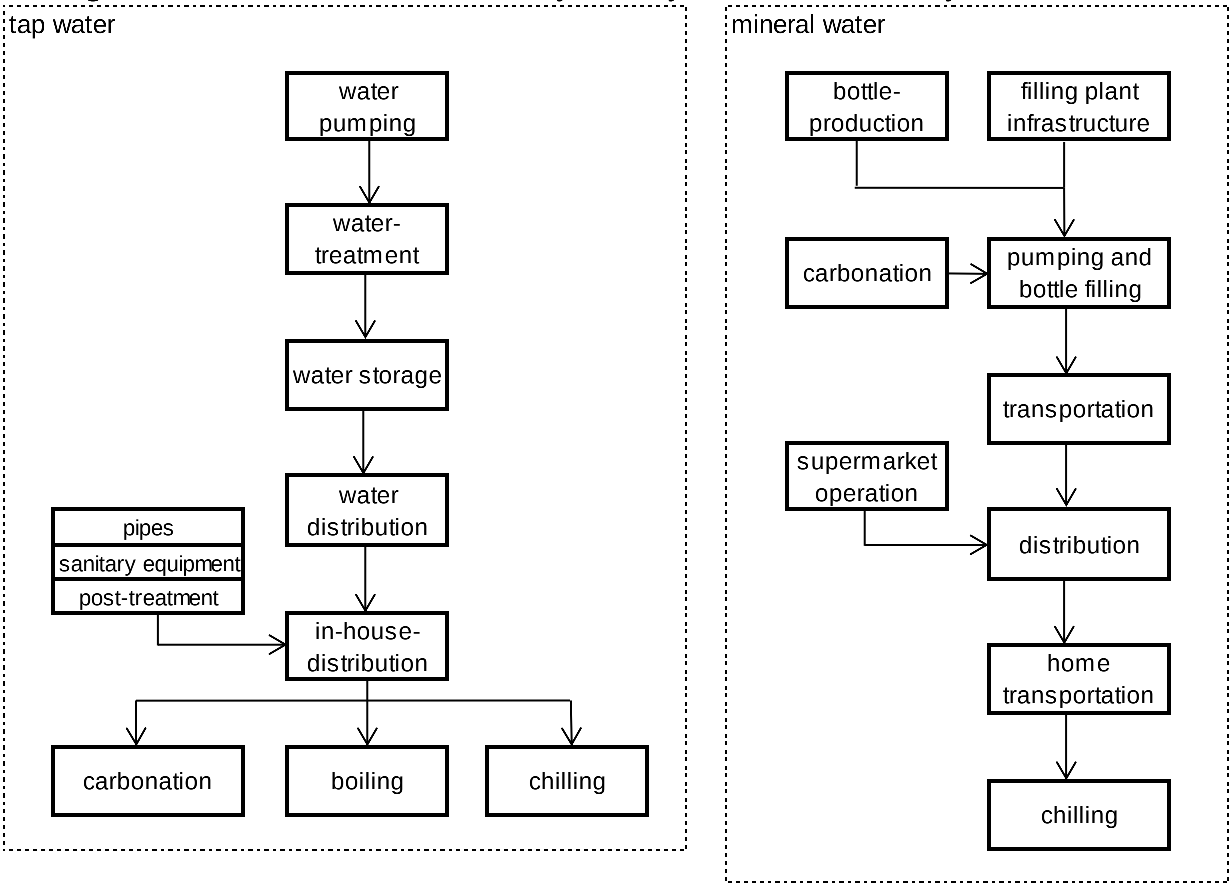

Figure 1. Overview on life cycle stages investigated for tap water and mineral water

2.2. Analysis of tap water in a broader context

In the analysis of tap water in a broader context some more issues are considered. One scenario evaluates the typical energy use for providing warm water in the household. Another scenario investigates the total impacts due to the treatment of polluted water from household. Furthermore it is evaluated which reduction potentials exist due to consumer choices e.g. for drinking tap instead of mineral water or using less warm water.

3. Life cycle inventory data

In the main study, life cycle inventory data is collected on material and energy flows for all essential process steps. All foreground data investigated for this study are documented in the background report [7] which is not published. All life cycle inventory data used for the assessments in this article are available with the ESU data-on-demand database [11] and with publicly available background data [12-14]. In the following sub-chapters the key assumptions are reported.

Background data

As to including background processes in the LCA, e.g. sewage disposal, packaging materials, transportation and construction materials, data is taken from the ecoinvent database v2.2 and updates publicly available [12-14]. Calculations for the LCA are made with the SimaPro software [15].

Foreground data for tap water supply

The following areas were taken as examples for tap water supply: an urban area (the city of Zurich (ZH)) and a rural area (Seeländische Wasserversorgung (SWG), a regional water supply facility located in the Canton of Bern). Furthermore the average supply in Switzerland (CH) is investigated. Data have been provided by these organizations and the SVGW.

Scenarios for tap water as a beverage

A series of scenarios were analyzed for the use of tap water as a beverage (Table 1). This always includes some losses with first running of tap water e.g. because of waiting for cooler or fresher water and for cleaning the containers. Scenarios 1 to 5 examine the impacts of consumer behavior (cooling in a refrigerator or water dispenser, soda maker) as based on the Swiss water supply. Various water supplies are compared with each another in scenarios 1, 6, 7. In scenario 8, boiled water is investigated. Scenario 9 considers warm water with 40°C used e.g. for hand washing and mixed from hot and cold water at the tap. Scenario 10 considers the delivery of water from the tap without the first running.

Table 1. Scenarios investigated for the provision of tap water as a beverage

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10
	TW, at tap, CH	TW, chilled, at tap	TW, carbonated, chilled, at soda device	TW, carbonated, at soda device	TW, chilled, at water dispenser	TW, at tap, SWG	TW, at tap, ZH	TW, boiling, at boiler	TW, 40°C, at tap	TW, direct at tap
Region	CH	CH	CH	CH	CH	SWG	ZH	CH	CH	CH
Provision	tap	tap	soda device	soda device	water dispenser	tap	tap	boiler	tap	tap
Carbonation	still	still	carbonated	carbonated	still	still	still	still	still	still
First running	no	yes	yes	yes	no	no	no	no	no	no
Temperature	unchilled	chilled	chilled	unchilled	chilled	unchilled	unchilled	boiling	40°C	unchilled

Scenarios for mineral water as a beverage

The consumption of bottled mineral water is examined using the following scenarios: production in Switzerland (CH) and imported from several different countries, 1.5-litre PET bottles, 1-litre glass returnable bottles and gallons accommodating 18.9 litres, carbonated or non-carbonated, refrigerated or unrefrigerated. These distinguishing features were used to create the scenarios shown in Table 2. They cover the possible spectrum between minimum and maximum values without taking into consideration every product available in a Swiss supermarket.

For bottled water in gallons, a distribution distance by van of 10 km to the consumer is assumed. The water is served via a water dispenser and might be drunk e.g. in office buildings. Scenario 13 models a minimum situation with local mineral water consumed directly after purchase in the shop (and thus no home transportation).

The data for pumping, filling and carbonization of mineral water is based on various environmental reports [16-23]. The LCA of packages is based on ecoinvent background data and literature [24-27]. For transporting mineral water to a shop in Berne (Switzerland), real transport distances for different well-known brands and origins have been investigated. The home transport is modelled with average data for purchasing in Switzerland considering the share and distance of common transport modes. The disposal of packages is assessed with standard scenarios. Packages which are not recycled are normally incinerated in Switzerland. According to the cut-off approach used in ecoinvent the recycling of packages (e.g. PET or glass bottles) is not considered as an environmental burden or benefit. In some scenarios also refillable bottles or containers are considered. In these cases the washing prior to refill is considered in the life cycle inventory analysis.

Table 2. Scenarios investigated for the provision of mineral water as a beverage

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
	MW, glass-RE, at restaurant	**MW, PET**	**MW, gallon, at office**	**MW, PET, carbonated**	**MW, PET, chilled**	**MW, PET, carbonated, chilled**	**MW, chilled, gallon, at office**
Production	CH	CH	CH	CH	CH	CH	CH
Transport truck [km]	162	162	162	162	162	162	162
Transport train [km]	42	42	42	42	42	42	42
Transport Schiff [km]	0	0	0	0	0	0	0
Distribution [km]	10	home transport	10	home transport	home transport	home transport	10
Carbonation	still	still	still	carbonated	still	carbonated	still
Temperature	unchilled	unchilled	unchilled	unchilled	chilled	chilled	chilled
Packaging	Glass-RE	PET-NON-RE	container	PET-NON-RE	PET-NON-RE	PET-NON-RE	container

	Scenario 8	Scenario 9	Scenario 10	Scenario 11	Scenario 12	Scenario 13
	MW, production mix CH	**MW, PET, Production FR**	**MW, PET, Production IT**	**MW, PET, Production GB**	**MW, PET, Production FJ**	**MW, PET, at shop**
Production	mix	FR	IT	UK	FJ	CH
Transport truck [km]	373	325	547	1204	510	50
Transport train [km]	45	0	130	0	0	0
Transport Schiff [km]	102	0	0	0	20330	0
Distribution [km]	home transport	home transport	home transport	home transport	home transport	none
Carbonation	Mix	still	still	still	still	still
Temperature	unchilled	unchilled	unchilled	unchilled	unchilled	unchilled
Packaging	PET/Glass	PET-NON-RE	PET-NON-RE	PET-NON-RE	PET-NON-RE	PET-NON-RE

RE Returnable bottle
MW Mineral water
NON-RE Non-returnable bottle
CH Switzerland
DE Germany
FJ Fiji
FR France
IT Italy

Background data for other beverages

The life cycle inventory analysis (LCI) for other beverages such as milk, orange juice, apple juice, beer, ice tea, black tea, coffee and wine is taken from the ESU data-on-demand database [11, 28-31]. The LCI includes the life stages as described in chapter 2.1. For milk, juices, beer and ice tea chilled scenarios are used. For all beverages, assumptions equivalent to those for mineral water are used concerning chilling and home transportation.

4. Impact assessment

Within this article, the environmental impacts are assessed according to the ecological scarcity method 2013. This method evaluates the inventory results on a distance to target principle. The calculation of the eco-factors is based on one hand on the actual emissions (actual flow) and on the other hand on Swiss environmental policy and legislation goals (critical flows). The weighting is therefore based on the Swiss environmental policy goals, whereby global and local impact categories are normalized to Swiss conditions. Final results of the impact assessment are presented in eco-points [32].

In addition to this, the total results of all scenarios are separately presented according to the global warming potential [33]. It has to be noted that presenting comparative LCA results with such a full weighting of different types of environmental impacts is not allowed according to ISO 14040 [10, 34] but it is very common in Switzerland. Therefore it is also recommended for communicating LCA results to consumers [35]. In the figures presented in this article, the total results with the ecological scarcity method are split showing the contribution of single indicator. Therefore also the importance of single indicators like the global warming potential can be estimated and compared to each other.

Within the detailed study [7], the results are also presented and discussed according to the cumulative energy demand [33, 36].

4.1. Share of life cycle stages

Figure 2 compares the direct provision of tap water with tap water chilled and carbonated for consumption as a beverage. The house installation is responsible for about 40% of the impacts. The post-treatment of tap water in the house (house installations, further purification) accounts for about 9% of total impacts. Sanitary equipment and pipes are other important factors for the house installation. Energy use for central treatment and pumping and also the distribution network are additional important stages in the provision of tap water.

This picture changes totally if carbonation and chilling are included in the assessment. These two processes contribute each 40 - 50% to the total impacts. Thus the relative importance of process stages and the total impacts vary with the way how tap water is used and consumed.

For average mineral water according to scenario 8, home transportation has a share of 40% of total impacts (Figure 4). Here a car transport of 4.5 km for 12 kg of purchases is the most important factor in the average scenario for home transportation. The transport between source and supermarket, which is about 500 km in average, accounts for one quarter of the environmental impacts of average mineral water.

Chilling and the bottle each account for one fifth of the total impacts. The type of packaging can influence the environmental impacts of beverages. For short distances, it is preferable to use a refillable bottle. For longer distances, PET bottles might be better due to their lower weight compared to glass bottles. Impacts of transportation are not linear with the distance. The mode of transportation is very relevant. The impacts of mineral water from Fiji were expected to be much higher, but since it is assumed that the bottles are transported for the main part of the distance with very efficient container ships, the difference is not that big. The long distance transport from Fiji to Genoa has about the same impacts as a truck transport over 1’400 km. Carbonized mineral water has only slightly higher impacts than still water.

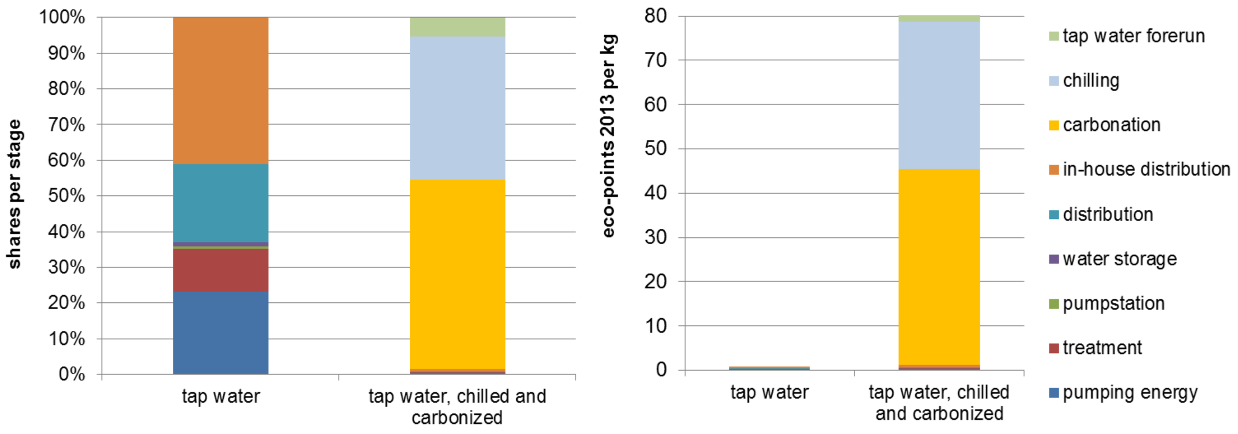

Figure 2. Share of process stages in the provision of tap water for total environmental impacts according to the ecological scarcity method 2013

4.2. Comparison of tap water supplies

Figure 3 compares some scenarios for tap water. The description starts at the bottom. The first 3 scenarios for ZH, CH, SWG compare the provision of tap water in different supply areas and only including the public supply network. Impacts between different tap water suppliers in Switzerland differ. A relevant factor is the length of the distribution network and differences in the electricity consumption. Impacts at the provider SWG are slightly higher as this it supplies a rural area with a higher demand for infrastructure than the supply in the city of Zurich.

The scenario “tap water, direct at tap” includes the in-house infrastructure and post treatment as evaluated in Figure 2. The rise of impacts compared to tap water at house is due to the inclusion of in-house distribution. The upper 3 scenarios compare the provision of tap water as a beverage and have higher impacts due to the assumed pre-flow of tap water before filling it in the glass.

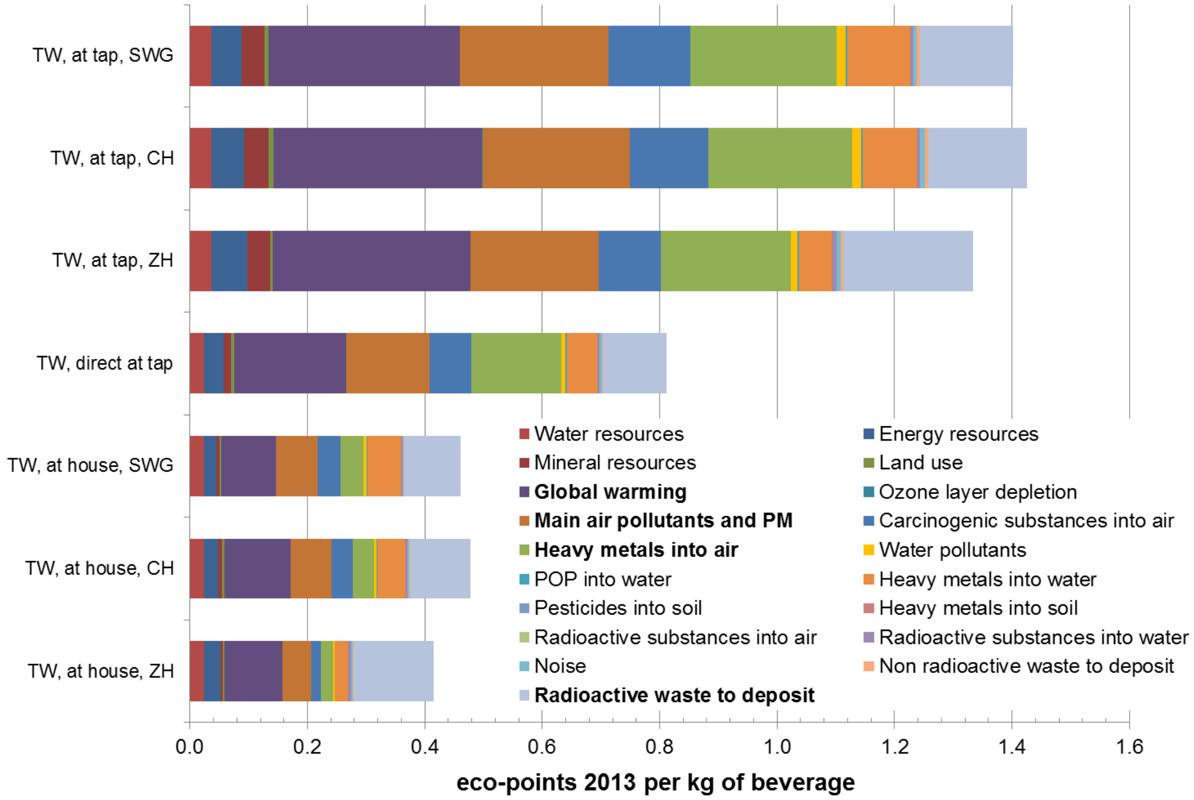

Figure 3. Comparison of different scenarios for tap water with the ecological scarcity method 2013 (ZH – Zürich, CH – Switzerland, SWG – Seeländische Wasserversorgung, TW – tap water). The impact categories with highest values are in bold.

4.3. Comparison of carbonized water

The comparison of carbonized beverages in Figure 3 shows clear advantages for the use of soda devices to carbonize tap water compared to the purchase of carbonated mineral water. The main aspects for mineral water are transports and bottles. This is also visible in Figure 3, were the air emissions of trucks cause considerable impacts in the areas of global warming and main air pollutants. A prerequisite for the reduction of environmental impacts with a soda device is its usage frequency. Here it was calculated with 2 litres per day and a life time of the device of 5 years. It the device is used less frequently, the impacts would be higher.

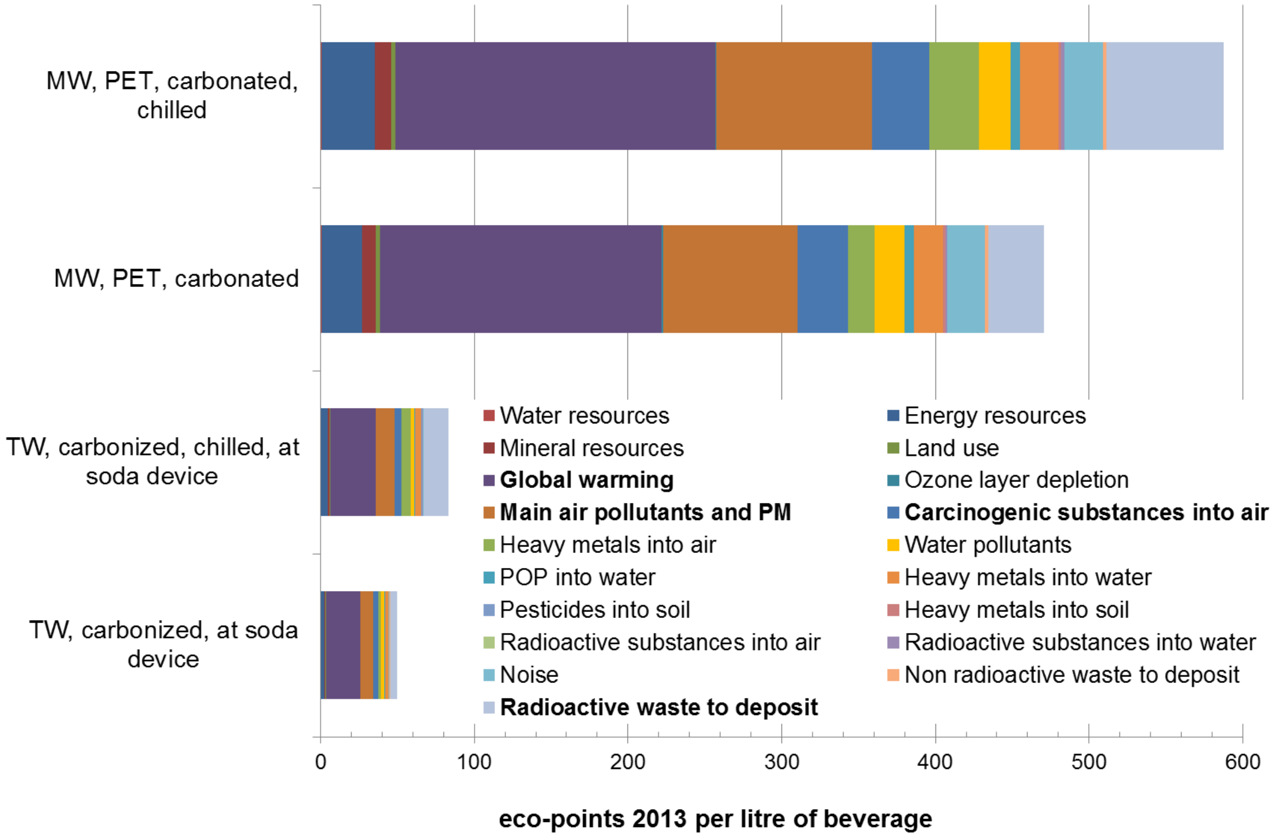

Figure 3. Comparison of different scenarios for the provision of carbonized water with the ecological scarcity method 2013 (MW – mineral water, TW – tap water). The impact categories with highest values are in bold.

4.3. Comparison of still beverages

Tap water is also the most environmentally friendly option even if it is compared with a range of different still beverages (Figure 4).

The average mineral water causes impacts that are about 450 times higher than the impacts of Swiss tap water. Environmental impacts of tap water without carbonation are remarkable lower compared to the carbonized version. For mineral water, there is not a large difference between the still and carbonized option.

Most other beverages cause higher impacts than the mineral water. Black tea prepared from boiling tap water is an option with impacts between tap and mineral water. Coffee has considerable higher impacts per litre than tea due to the higher impacts in its agricultural production and the necessary processing. For all beverages produced from agricultural raw materials, the impacts are higher than for mineral water since impacts from agriculture have to be added to those of packaging and transportation. The highest impacts have been found for red wine (more than 9500 eco-points per kg). This is mainly due to the use of copper and pesticides in the grape production.

It has to be kept in mind that the beverages compared here can fulfil sometimes additional functions. While tap and mineral water mainly satisfy the thirst, other options might also provide nutritional value (e.g. vitamins in fruit juice or proteins in milk). Alcoholic beverages are rather used for pleasure.

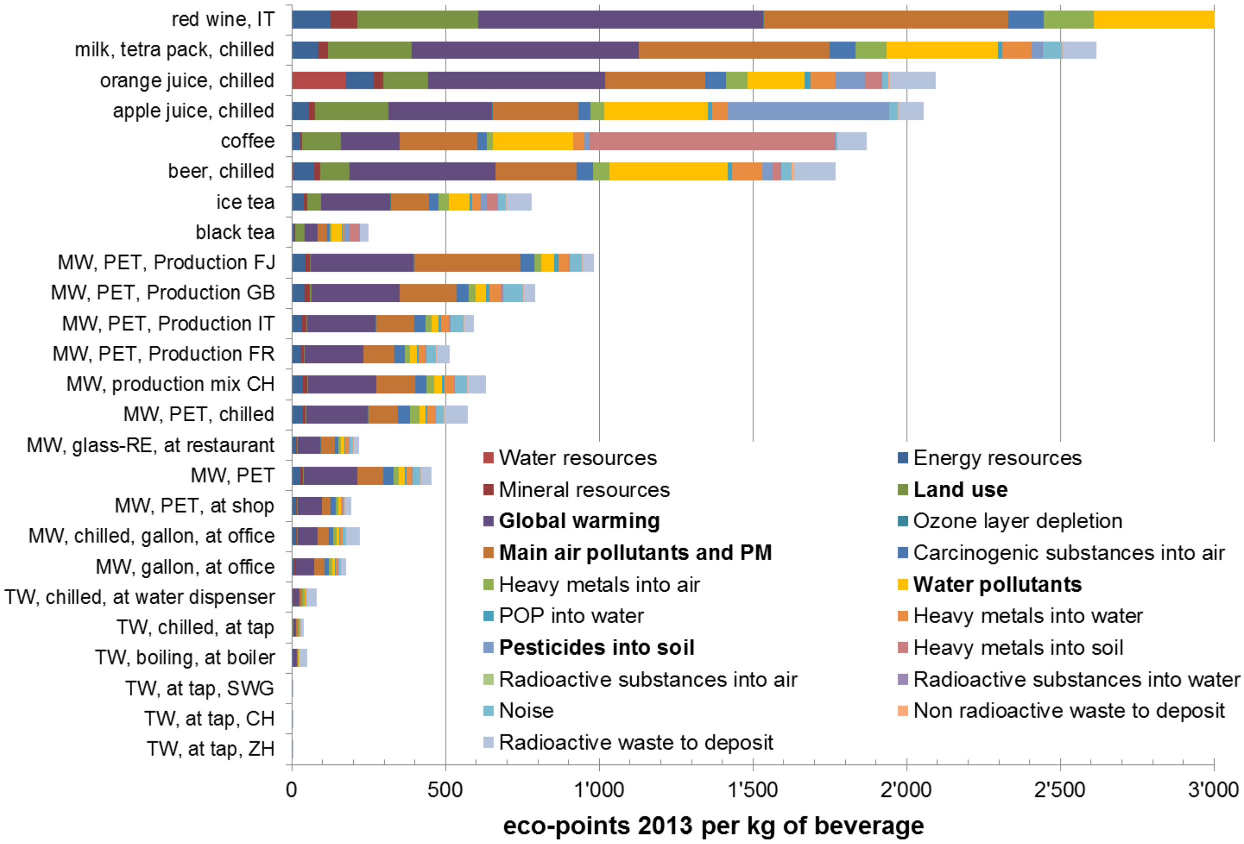

Figure 4. Comparison of different scenarios for the provision of still beverages with the ecological scarcity method 2013. The impact categories with highest values are in bold. Red wine out of scale (about 9500 eco-points).

4.4. Comparison of beverages according to global warming potential

In Figure 5 the results of the different water and beverage scenarios are revealed according to the global warming potential. Therefore it can be shown that there are no significant changes in the result according to this impact assessment method except for the result of coffee. Different from the other scenarios, the total environmental impact of coffee is highly influenced by the heavy metal emissions in the cultivation stage. Since this is not reflected by the global warming potential, its result for coffee is notably lower in comparison to other options.

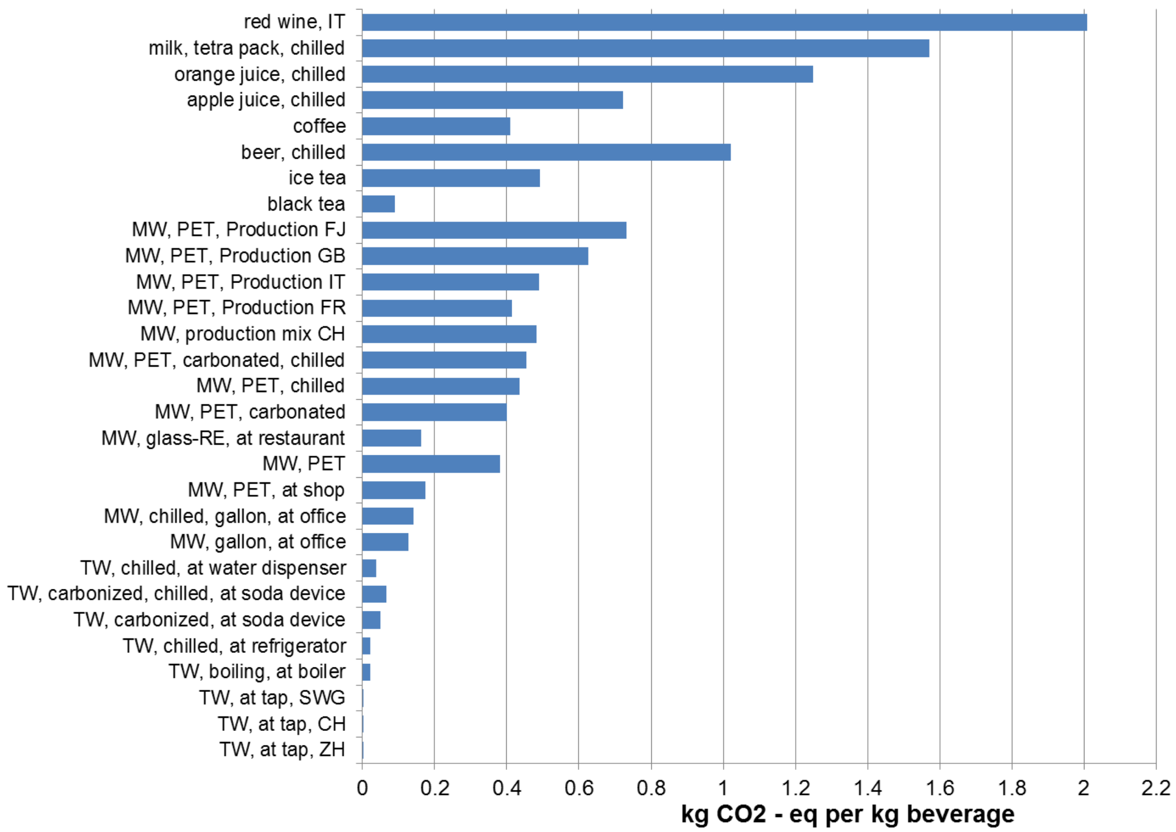

Figure 5. Comparison of different scenarios for the provision of beverages according to the global warming potential (kg CO_2-eq per kg)

4.5. Relevance of beverages and water compared to total consumption

In order to provide a broader view on the theme "water", some additional analyses are made in the following. The next question addressed is the environmental relevance of private water consumption as a beverage and for all other purposes compared to the total environmental impacts of consumption in Switzerland. Table 3 shows the environmental impacts of water related issues in relation to the total environmental impacts caused per capita in Switzerland [37]. In this case we use the ecological scarcity method 2006 instead of the version 2013 in order to allow comparability with former investigations about impacts of production and consumption [38]. This assessment shows the relevance of the present consumption of warm and cold tap water. For the amount of tap water consumed the daily consumption of 142 litres is used as a basis. Warm water accounts for about 50 litres per day and capita. The total amount of water used is also assumed to be treated in an effluent treatment plant.

The evaluation shows that the waste water treatment is more relevant from an environmental point of view than the tap water supply. Also warm water heating in the household is more relevant than the supply of tap water.

About 111 litres of mineral water are consumed per Swiss person in the year 2011 [2]. Mineral water and tap water consumption have about equal impacts, because the much higher amount of tap water consumption levels with the higher specific impacts of mineral water, i.e. impact per kg. The "water-related" impacts account for about 2.4% of total environmental impacts due to the consumption patterns of Swiss households.

It has to be noted that Table 3 (and Table 4) only consider the central warm water supply, but not cooking of water e.g. for tea, coffee or meals nor heating of rooms. Also heating of water in washing machines and dish washers is not yet included in this assessment. Taking this into account, impacts of tap water heating would even be higher than assumed here.

Table 3. Relevance of water related impacts compared to total environmental impacts of consumption in Switzerland. Eco-points 2006 for the present situation, share of eco-points and amounts of water consumed.

eco-points 2006 per person and year	present situation	share	amount (litre/a)
tap water use	40'128	0.2%	51'830
water heating	174'648	0.9%	17'276
waste water treatment	201'243	1.0%	51'830
consumption of mineral water	63'053	0.3%	111
total impacts related to water	**479'072**	**2.4%**	**-**
total impacts of consumption	20'000'000	100%	-

4.6. Reduction potentials

The annual environmental impacts due to the use of tap and mineral water are shown in Table 4 together with possible reduction potentials. The methodology for calculating the reduction potentials has been developed by ESU-services for different projects [39, 40]. The highest reduction potential could be achieved by a 25% reduction of the tap water consumption using e.g. water saving installations and appliances. By doing so, the total environmental impacts in Switzerland could be reduced by 0.5%. Drinking tap water instead of mineral water would reduce the total impacts by about 0.3%. A reduction of the warm water consumption by 25% (replaced by cold water) could potentially reduce the total impacts by 0.4%. Adding these different options would lead to a potential reduction of 1.1% of total environmental impacts per person (or 47% of the water related impacts).

Table 4. Reduction potentials of different behavioral changes related to water consumption

eco-points 2006 per person and year	present situation	saving water	tap instead of mineral water	cold instead of warm water	combination of options
In relation to the impacts related to water	479'072	-20%	-13%	-18%	-47%
In relation to total environmental impacts	20'000'000	-0.48%	-0.31%	-0.44%	-1.12%

4.7. Comparison to previous study

Comparing the results of the updated study with the first version published in 2006 [6] shows generally higher results for tap water and mineral water. This is not caused by an increase of certain energy or material uses in the life cycle but mainly due to a more complete investigation of environmental impacts. For tap water, the installations in the house have been investigated in more detail. For mineral water, the study shows that the home transportation is a quite relevant factor which so far has not been considered sufficiently in the previous study. Thus the higher impacts compared to the former study are not an indicator for a worse situation.

5. Conclusions

In this article we evaluated the environmental impacts of water in a broad context. Therefore we investigated its use as beverage, but also evaluated the importance of the total tap and mineral water consumption, heating for warm water in households and treatment of used tap water.

Tap water is the most environmentally friendly beverage if compared for the function of stilling ones thirst. Unchilled and still mineral water causes about 450-times the environmental impacts of drinking tap water. Cooling and carbonation increases the environmental impacts of tap water considerable, but still it causes less impacts than the comparable mineral water options bought in a shop. Thus carbonation in a soda device is the recommended option if the consumers like this type of water more. For such positive results the device should be used frequently (at least for 1 kg a day) and over a reasonable period (more than five years) in order to pay-back the environmental investment for its production.

The origin and thus transports are more relevant than the packaging of mineral water. Thus, mineral water coming from nearby is preferable compared to mineral water transported over longer distances. Refillable bottles and containers only make sense if they are not transported over long distances. Bringing purchased beverages home can be very relevant if a car is used for transportation.

The agricultural production of raw materials is often the main impact for other beverages such as milk, fruit juice or wine. These impacts have to be added to the impacts of packaging and transportation and therefore these options have higher impacts than tap and mineral water. But they serve often also further function such as nutrients or pleasure.

The consumption of tap and mineral water is responsible for only a very small share of total impacts due to Swiss final consumption. Thus, a replacement of mineral water with tap water or reducing the use of tap water would only slightly decrease the total environmental impacts caused by Swiss inhabitants. But, food and beverages often lead to discussions about general environmental aspects and can raise interest in environmental issues. The recommendations for shorter transport distances, less use of private cars or efficient cooling are valid for all types of food purchases and not only relevant for the consumption of water.

Considering the general water use at home, a very relevant aspect is the heating of warm water in households. A reduction of the used warm water (e.g. taking a shower instead of a full bath, lower temperatures for washing and hand washing with cold water) can reduce the environmental impacts much more than a reduction of the cold water use.

For the operators of water supply networks and for house owners the following recommendations can be derived from this study. The infrastructure and especially the distribution network are quite relevant for the water supply. Installations in the consumer's house also have a remarkable share of the total impacts due to tap water supply. Thus, environmentally friendly materials and processes should be used during construction and maintenance of this infrastructure. Further important issues are the electricity use for pumping and the loss of water. Losses of water increase the impacts per m^3 of water sold. Internal use e.g. for public water sources are counted as losses in this study. This makes it difficult to directly compare the different water suppliers investigated in this study.

The system boundaries of this study are only valid for Switzerland. The situation in other countries might be quite different. Thus, e.g. the impacts form electricity use and the necessary pumping energy for tap water differs between different countries. The distance between the water source and the consumer can be different. Also systems used for beverage bottles are not the same. In Germany, e.g., a refill system for PET-bottles is common while this is not known in Switzerland.

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Author Contributions

Niels Jungbluth drafted the first version of this paper and has the overall responsibility for the research project. Alex König elaborated many parts of the full LCA and helped for the revision of the paper. Regula Keller gave feedback in different stages of this study and the preparation of the paper.

Conflicts of Interest

The authors declare no conflict of interest.

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