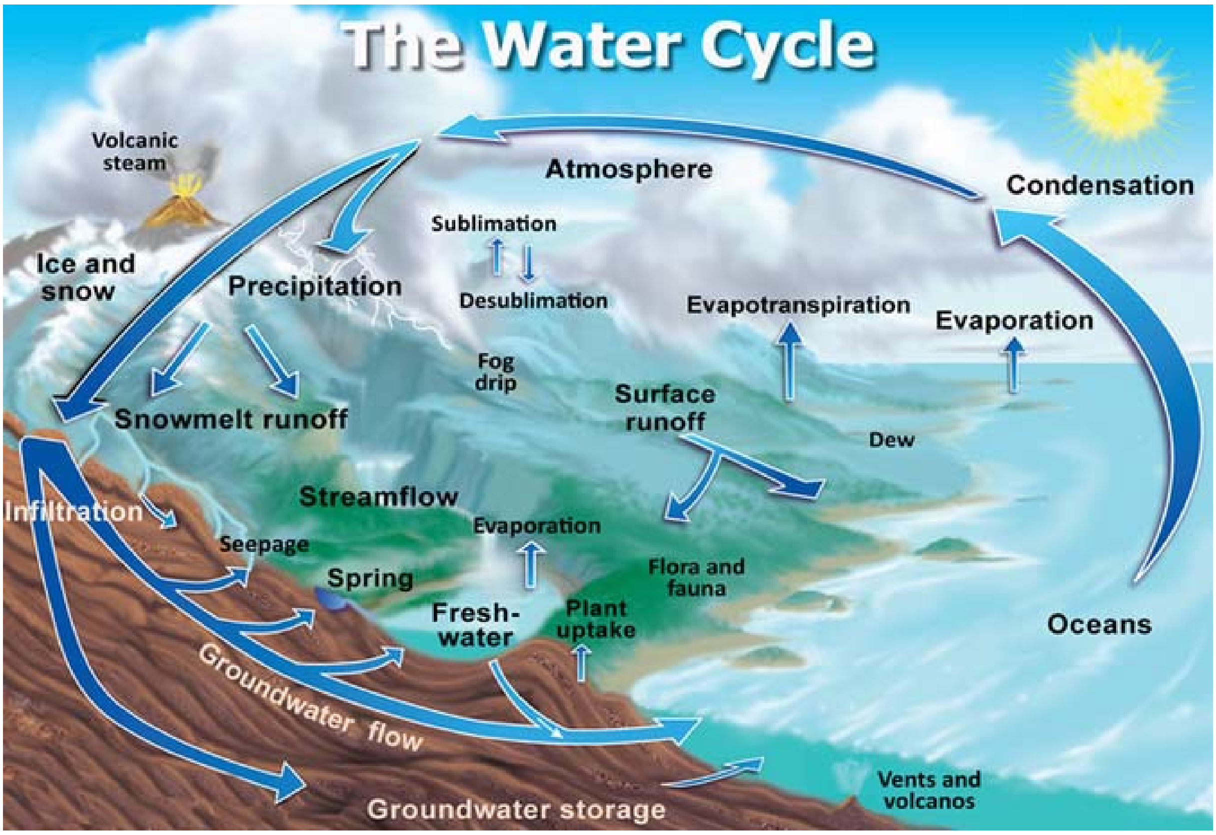
Water cycle

Water is not only the most important foodstuff, it is also needed in the home, for agriculture, lifestock, and industry. Global demand for water is rising as the world's population grows - and its consumption needs increase. This may intensify competition for water in some regions. At the same time, climate change is leading to changes in the global water balance.

Water is actually abundant on Earth - more than 1.3 billion cubic kilometers in total. But only a small part of it can be used as drinking water. Around 97% of the global water supply is saltwater, and only 2.6% is freshwater. Unlike other important raw materials - such as coal or crude oil - water as a resource cannot be "used up" on Earth, because water is part of a fairly rapid cycle. What can very well decrease, however, is the amount of clean water.



The natural water cycle [John Evans and Howard Periman, USGS - http://ga.water.usgs.gov]

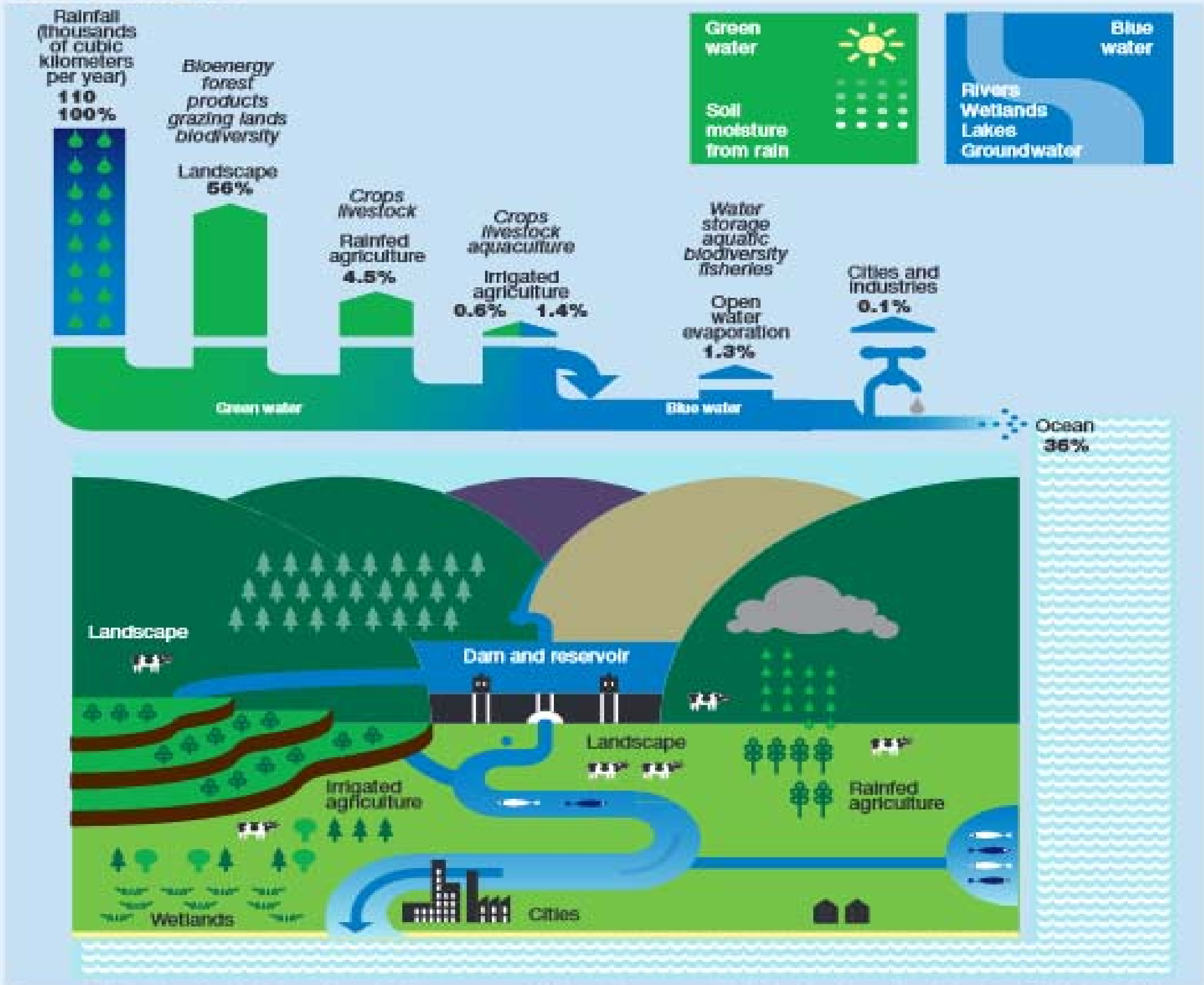
The amount of usable, clean water has already almost been reached. Therefore, the used water must be returned to circulation completely purified. But in many regions, water supplies are being used more than is sustainable in the long term. Worldwide, one third of the largest groundwater systems are threatened.

Credit: USGS, Public domain. https://www.usgs.gov/special-topic/water-science-school/science/der-wasserkreislauf-water-cycle-german?qt-science_center_objects=0#qt-science_center_objects

Water availability

Although water is a renewable resource, it is not available everywhere in sufficient quantity and quality at all times. In areas with little precipitation, the lack of water limits agricultural yields, as does too much of it due to the climate. Sprinkling and irrigation require the presence of groundwater or surface water from rivers or lakes. Technical production processes as well as services of all kinds require water in various forms. Every use always results in water contamination and leads to water loss in natural vegetation.

Global water use



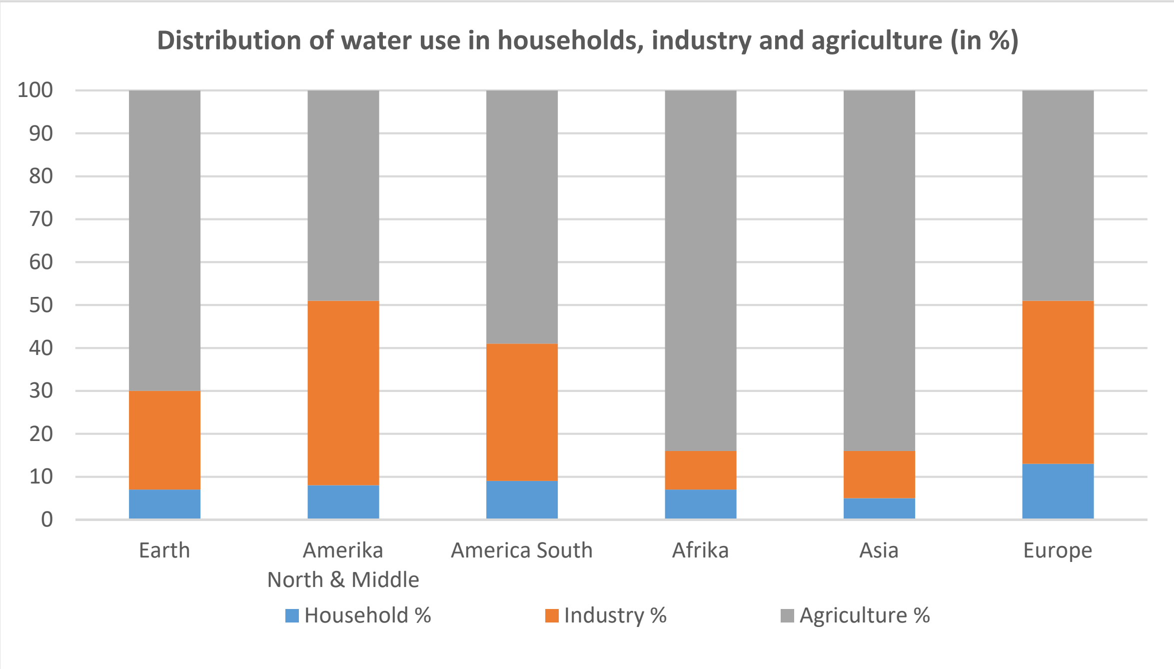
Source: Calculations for the Comprehensive Assessment of Water Management in Agriculture based on data from T. Oki and S. Kanae, 2006, "Global Hydrological Cycles and World Water Resources," *Science* 313 (5790): 1068–72; UNESCO–UN World Water Assessment Programme, 2006, *Water: A Shared Responsiblity,* The United Nations World Water Development Report 2, New York, UNESCO and Berghahn Books.

For an assessment of direct and indirect water consumption, the local availability of water is crucial. A high water footprint in water-rich regions is less problematic than in water-scarce regions or in desert areas. If the water footprint is too large, action must be taken. One solution is a targeted change in consumption and/or production conditions.

International water management institute https://www.iwmi.cgiar.org/assessment/files_new/synthesis/Summary_SynthesisBook.pdf

Water use

Human demand for water has increased sixfold in the past 100 years, and it will increase worldwide, according to the United Nations World Water Report 2018. There are many reasons for the increase. Most notably, water demand is linked to population growth, economic development and changes in consumption patterns. According to UN estimates, between 9.4 and 10.2 billion people will live on Earth in 2050. During this period, global economic output is expected to grow by a factor of 2.5 at the same time.



At 86%, food and other agricultural products account for the largest share of global water demand. Irrigation accounts for the vast majority of this. The proportion of agricultural land that is irrigated worldwide has more than doubled since the 1960s. In addition to increasing mechanization, this has contributed to the fact that agricultural productivity has risen by a factor of 2.5 to 3 since 1950.

Water Use	Household	Industry	Agriculture
	%	%	%
Earth	7	23	70
Amerika North & Middle	8	43	49
America South	9	32	59
Afrika	7	9	84
Asia	5	11	84
Europe	13	38	49

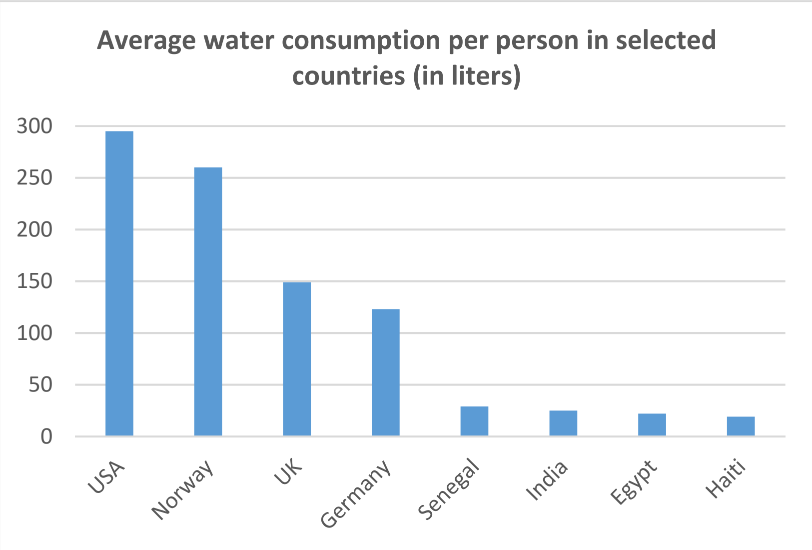
Industry, including energy production, and private households account for a much smaller share of global water demand than agriculture. The share of private households is only about ten percent, the share of industry only 20 percent of the water required worldwide.

Sources: http://www.waterfootprint.org/en/ I https://www.umweltbundesamt.de/themen/wasser/wasser-bewirtschaften/wasserfußabdruck#textpart-3

http://www.nature.com/articles/srep09306 I http://www.nature.com/articles/ncomms6012 I http://www.nature.com/articles/s41598-017-04182-x

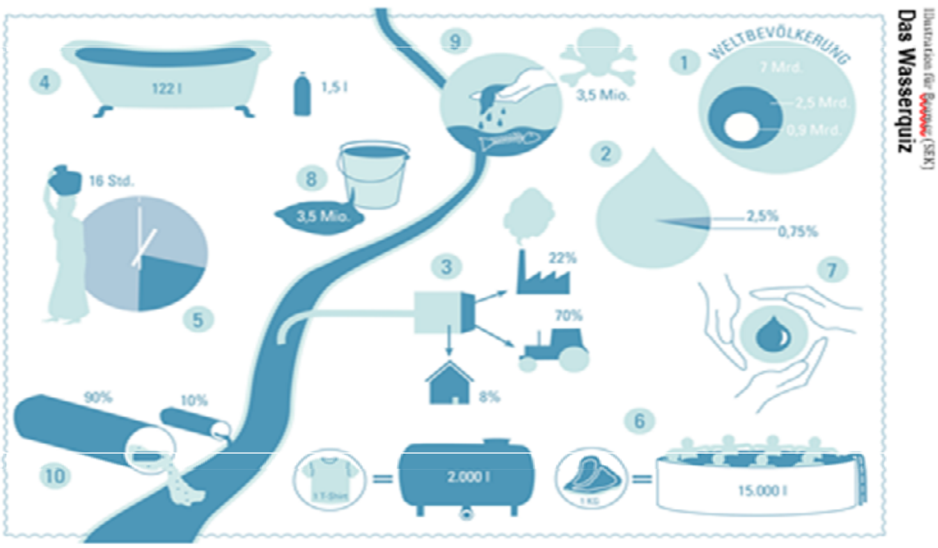
WS 1 Characteristics of personal water consumption

Personal daily water consumption varies greatly in selected countries depending on availability. In Germany, just under 120 liters of water are consumed daily for washing, cooking or brushing teeth. However, this is supplemented by around 4,000 liters of "virtual" water for the production of clothing, food, energy and mobility.



Water Use	daily per person
	Liters
USA	295
Norway	260
UK	149
Germany	123
Senegal	29
India	25
Egypt	22
Haiti	19

The Water Footprint Calculator can be used to calculate the **personal footprint:**
https://www.watercalculator.org/wfc2/q/household/



A water quiz provides information on daily water consumption.

Sources: http://www.waterfootprint.org/en/

https://www.umweltbundesamt.de/themen/wasser/wasser-bewirtschaften/wasserfußabdruck#textpart-3

Water quiz: German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, 3/2013, Creative Commons license CC-BY-NC-SA 3.0 https://www.umwelt-im-unterricht.de/wochenthemen/das-wasser-muss-fuer-alle-reichen/ II https://www.umwelt-im-unterricht.de/hintergrund/das-wasser-der-welt-eine-geteilte-ressource/

WS 2 Water consumption characteristics of selected food products

Water, especially clean drinking water, is increasingly perceived worldwide as a scarce and valuable commodity. Water is not only used for cooking or washing, but also in large quantities in the manufacture of products and food. The production of a cotton T-shirt requires about 3,000 L of water, the production of a car nearly 200,000 L of water. The production of a cucumber requires 141 liters of water, and one kilogram of beef contains around 16,000 L

Consequently, every product also indirectly contains a certain amount of water. This so-called "virtual" water is also referred to as the water footprint and is an indicator of the use of the resource (fresh) water.

How much water is in our food?

product	count	weigth [g]	water [L]
pudding		1,000	1,186
mayonnaise		250	1,732
salami		200	1,248
cheese (Gouda)		200	636
rice		80	193
flour		1,000	1,849
eggs	4	200	653
ham		200	865
plant-based burger patties	4	400	1,505
cheese grated		120	607
applesauce		600	493
margarine		80	543
garlic sauce		250	930
syrup		100	22
olive oil		100	1,443
yogurt		200	237
sugar		80	11
celery		200	77
peanutbutter		160	1,205
peanuts		60	238
soy bean sprouts		80	172
jam		80	218
cherry curd		200	237
eggs	1	50	163
paprika	1	200	76
tomato	1	100	21
onion	1	100	27
orange	1	150	84

product	count	weigth [g]	water [L]
sausages	4	400	2,395
carrots		1,500	293
baguette	1	400	643
eggs	8	400	1,306
green beans		800	438
ground beef		400	6,166
chop 1/2 & 1/2		200	2,140
macaroni noodle		400	740
lettuce		200	47
Pita bread small	4	400	643
potatoes		1,000	287
spinach		1,600	467
Pizza dough	4 portions	325	522
fries (deep chilled)		1,000	574
chocolade pudding		1,000	1,186
pancakes		800	2,024
apple pie		700	1,412
strawberies		500	173
ice cream		1,000	1,903
beef burger patties	4	400	6,166
sliced meat		1,000	10,412
sunflower oil		400	2,717
milk whole		1,000	1,054
milk low-fat		1,000	1,020
cucumber		400	141
cream		250	475
rice pudding		1,000	1,530

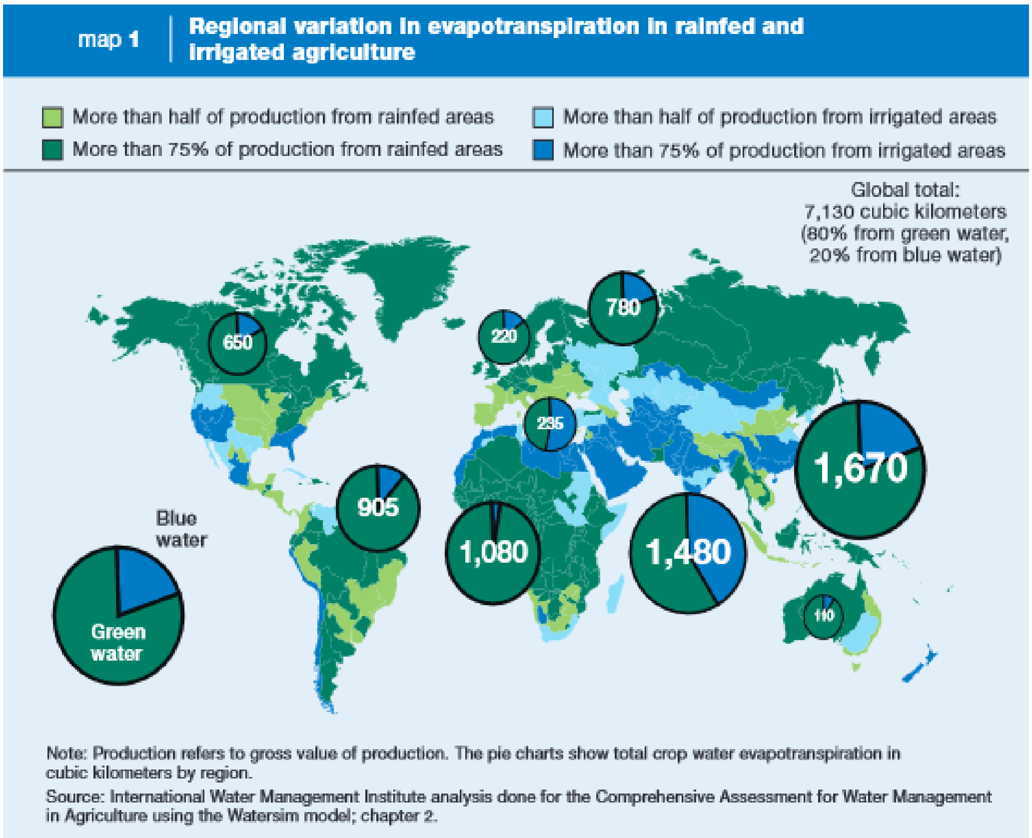
TASKS:

- As an example, compare the water requirements for the production of different foods.
- How are water resources distributed worldwide?
- How can water consumption be reduced?

Sources: http://waterfootprint.org/media/downloads/Zutaten.pdf I Virtual water hidden in the shopping basket at www.umwelt-im-unterricht.de

WS 3 Characteristics of water consumption in agriculture using the example of wheat

In terms of agricultural production, water has a particularly high influence on the level of yields that can be achieved. In the event of a water shortage, the use of artificial irrigation systems is necessary. Depending on the technique used - flooding, spraying, drip technique in the open or in the greenhouse - evaporation rates of up to 70 % can be expected. The water sources used for this purpose (e.g. groundwater, desalinated seawater) must also be taken into account when calculating the water footprint of a product.



There are major regional differences in wheat cultivation. On global average, 1,827 L of water are needed to produce 1 kilo of wheat.

- 70 percent is precipitation water (green),
- 19 percent comes from irrigation (blue) and
- 11 percent is referred to as gray water. This is polluted by fertilizers and pesticides during wheat cultivation and is therefore unusable for other purposes.

From one kilogram of wheat grains, 790 g of flour (about 80%) can be milled. The rest is grain husks, which are utilized in animal feed production.
From 1 kg of flour, 1.15 kg of bread can be baked. A Kaiser roll (60 g) has a water footprint of 40 L, a baguette (300 g) 155 L, a mixed bread 1,608 L/kg.

Of the water used for total crop production worldwide, wheat production alone takes up about 15%.

Sources and raw data using the example of grain production
faostat, proplanta, agrifoodprint and https://eplca.jrc.ec.europa.eu/uploads/ConsumerFootprint_BoP_Food.pdf,)
Waterfoodprint Organization https://waterfootprint.org/en/
International water management institute https://www.iwmi.cgiar.org/assessment/files_new/synthesis/Summary_SynthesisBook.pdf

WS 4 The relationship between LCA and Water Footprint.

In the LCA of a product or service, the water footprint plays an indicative role in the assessment. The availability of product-relevant resources and their measurable environmental impacts enable identification of particularly high water requirements or contamination within a production process. Consequently, these should always lead to improvements in production conditions.

The results of a life cycle assessment can be used to optimize processes and reduce environmental impacts. While a life cycle assessment examines various environmental impacts, there are also studies that focus on individual aspects of environmental impacts. These include, for example, the ecological footprint, the CO_2 footprint and the land footprint[3].

Consequently, every product also indirectly contains a certain amount of water. This so-called "virtual" water is also referred to as water footprint and is an indicator for the use of the resource (fresh) water. Virtual water can be divided into three categories:

- **green water** = is rainwater that is stored in the soil and absorbed and evaporated by plants.
- **blue water** = is freshwater that is taken from surface and groundwater but not returned as part of the natural cycle. The irrigation of gardens and fields or technical cooling water systems leads to the consumption of blue water.
- **gray water** = describes the amount of water that is polluted during the life cycle of a product as a result of its production, transport and use or consumption. For example, the application of fertilizers or the use of medicines releases pollutants into the environment that lead to the contamination of water bodies.
- **water footprint describes water use in CUBIC METERS/YEAR [m^3 /a].**

There is disagreement when it comes to calculating the water footprint:
For the LCA, the water footprint is to be determined according to ISO 14046 and is to quantify the potential environmental impacts related to water. The consumption of "green water" is less considered. It is seen as a consequence of land use change and considered together with the impacts of this, in the categories provided (Gerbens-Leenes et al. 2021, p. 3). The category of "gray water" is also treated differently. In LCAs, the impacts of pollutants are considered separately in categories such as eutrophication and ecotoxicity.

Other scientists define the water footprint of a product as the volume of freshwater used to produce it. According to A.Y. Hoekstra and M.M. Mekonnen of UNESCI-IHE, the water footprint is calculated in such a way that the consumption of "green water" has a major impact on the calculations, however. For the water footprint, on the other hand, "gray water" is referred to as the amount of water that would be needed to dilute polluted water to the extent that valid water quality standards are achieved (Gerbens-Leenes et al. 2021, p. 3).

This results in different weightings with respect to virtual water.

Poore & Nemecek 2018: Poore, J., Nemecek, T., Reducing food's environmental impacts through producers and consumers, 2018, Reducing food's environmental impacts through producers and consumers | Science (sciencemag.org)). [10.06.21]

Mekonnen, M.M., Hoekstra, A.Y.. A global assessment of the water footprint of agricultural products,2012, https://doi.org/10.1007/s10021-011-9517-8) [10.06.21].

Hoekstra, A.Y., Virtual water trade, Proceedings of the International Expert Meeting on Virtual Water Trade, Research Report Series No. 12, IHE Delft.

Gerbens-Leenes et al. 2021: Gerbens-Leenes, W.; Berger, M.; Allan, J.A. Water Footprint and Life Cycle Assessment: The Complementary Strengths of Analyzing Global Freshwater Appropriation and Resulting Local Impacts. Water 2021, 13, 803. https://doi.org/10.3390/w13060803 [10.06.21]