Foodprint:
Understanding the Connections Between Food and the Environment

Session 4

Freshwater Use

Session 5 Freshwater Use

Introduction to the water cycle
Planetary boundary for water use
Hidden water
Bottled water

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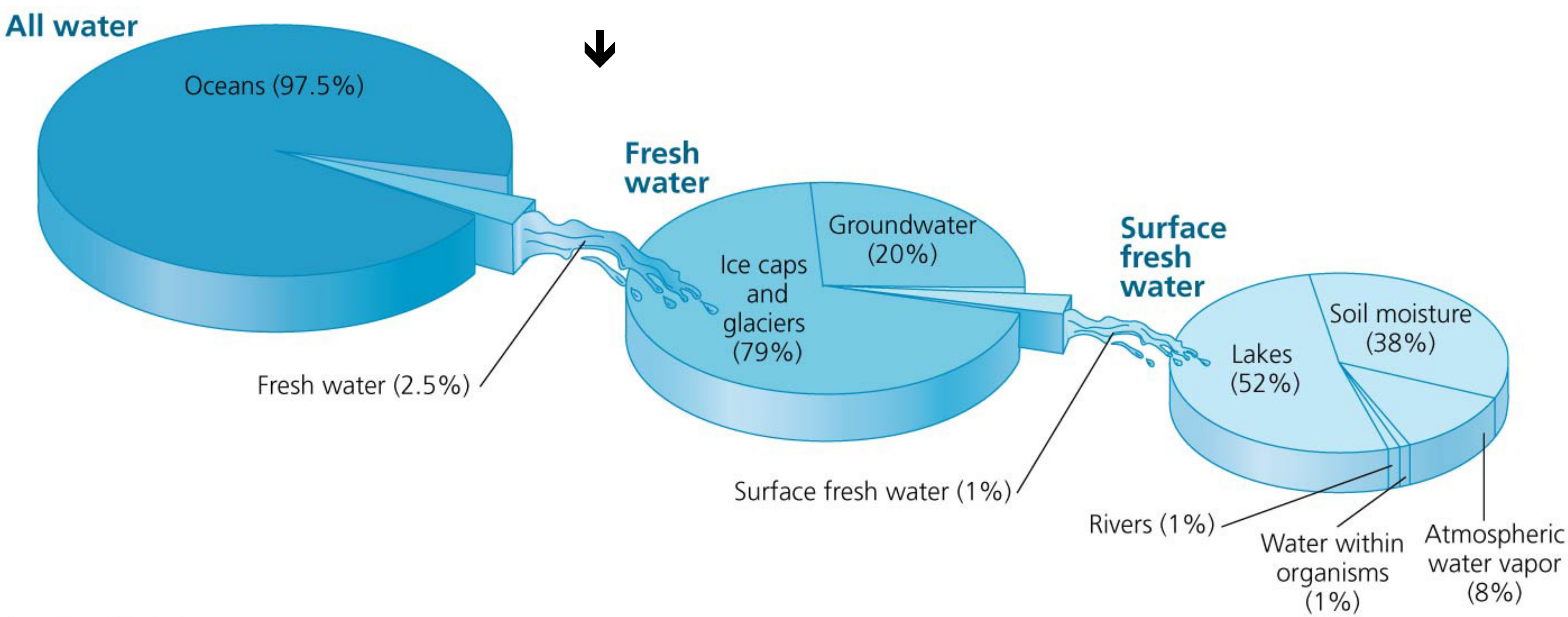
The Earth is covered in water, but…

Very little of this water is available freshwater

Fresh water = water that is relatively pure, with few dissolved salts—only 2.5% of total water



79% of freshwater tied up in glaciers & polar ice caps

Much groundwater is inaccessible

World Water Crisis

- Over 1 *billion* people lack access to clean, safe affordable drinking water.

- By 2025 two-thirds of the world's population is predicted to lack access to water.

- The World Bank has predicted that the wars of tomorrow will be fought over water.

- The problem is exacerbated by global warming which is spreading droughts.

Water delivery day India

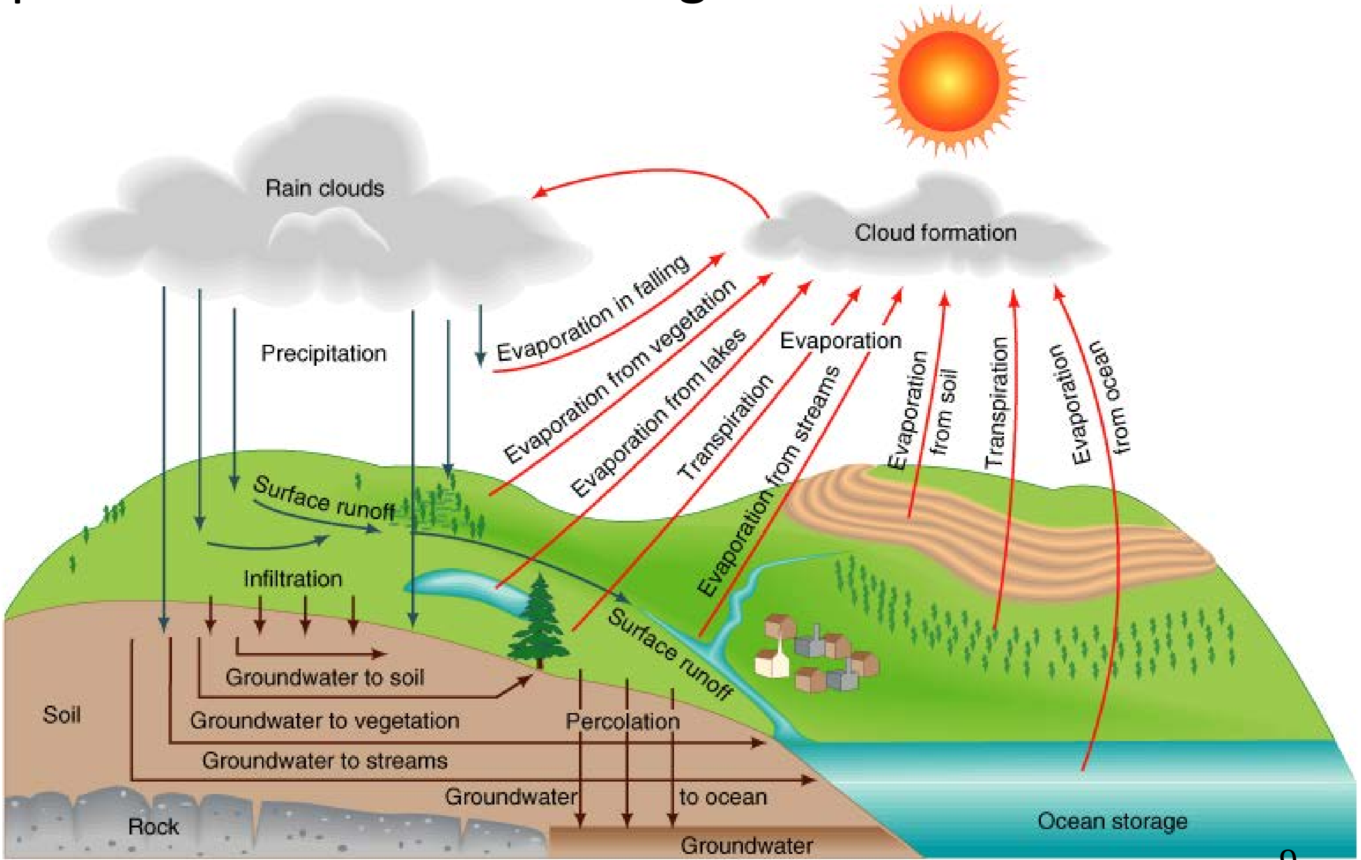
Access to drinking water is a gender equity issue.

The Hydrologic Cycle

1. Evapotranspiration

 Evaporation: radiant energy from the sun heats water, causing water molecules to become so active that some rise into the atmosphere as vapor

 Transpiration: plants take in water through roots and release it through leaves



Source: Modified after Council on Environment Quality and the Department of State, 1980, *The Global 2000 Report to the President*, vol. 2, Washington, DC.

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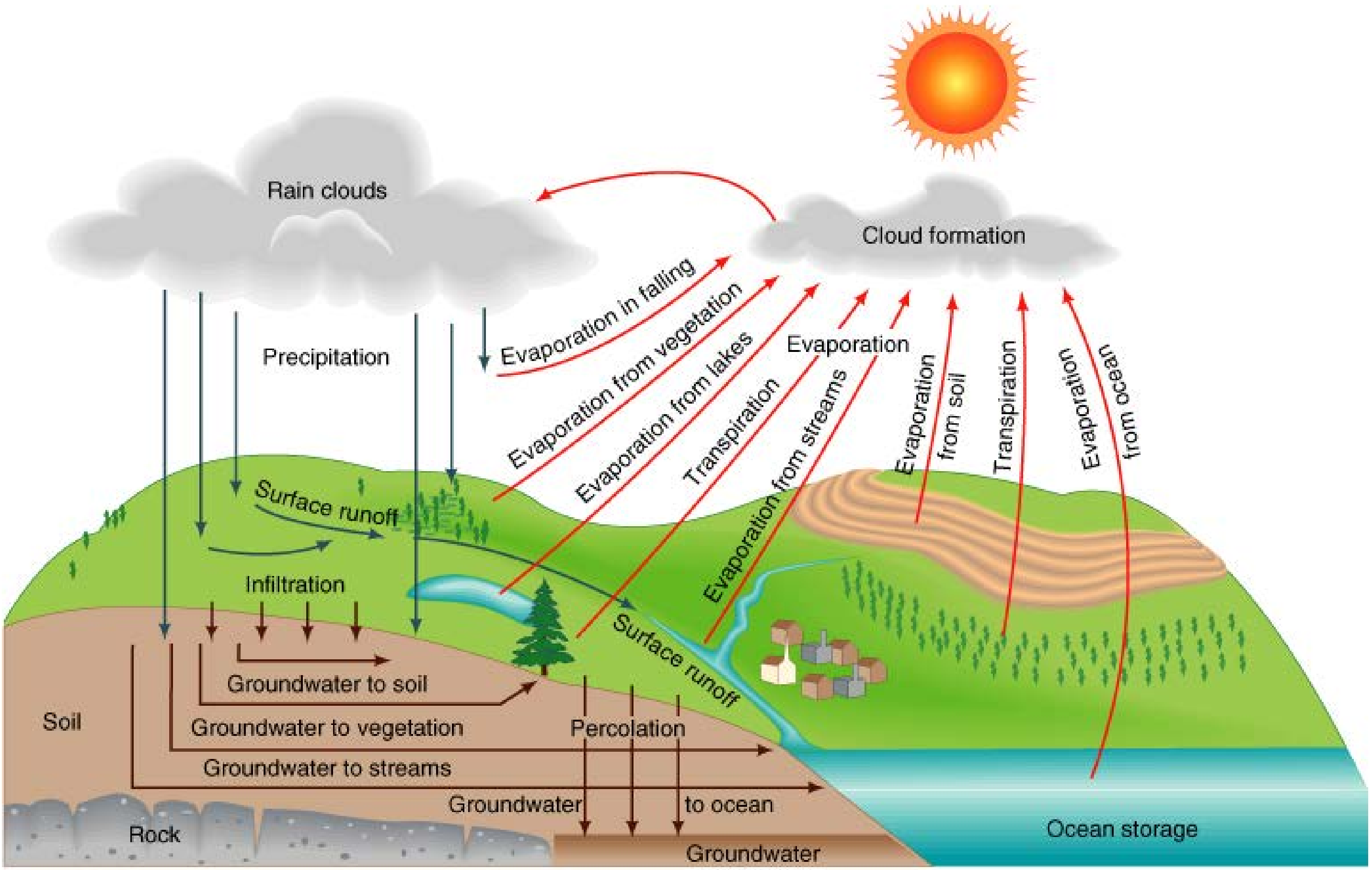
The Hydrologic Cycle

2. Condensation

water changes from vapor to a liquid. In cool air, water vapor condenses and forms clouds.



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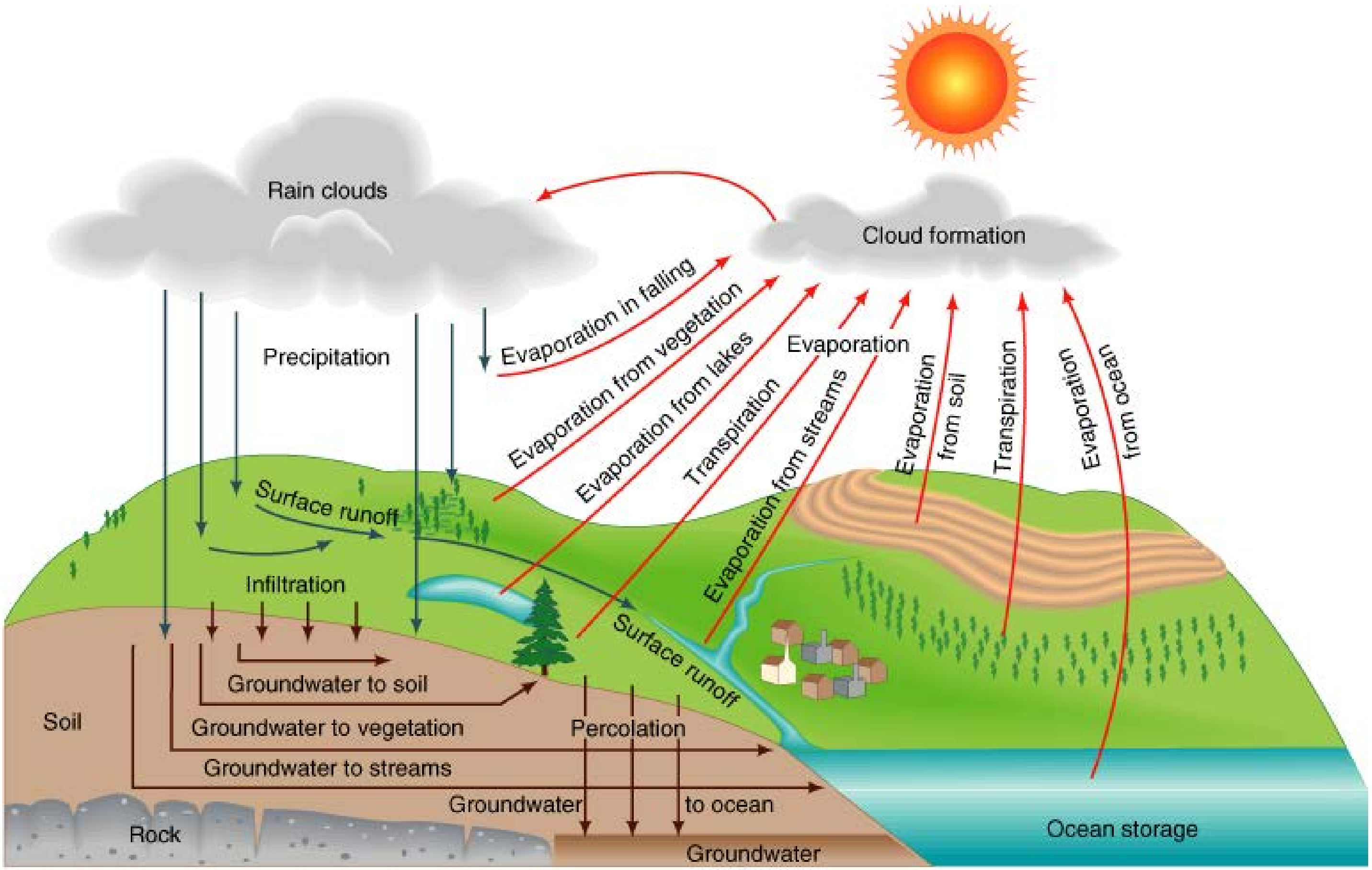
The Hydrologic Cycle

3. Precipitation

   water releases from clouds as rain, sleet, snow, hail



Source: Modified after Council on Environment Quality and the Department of State, 1980, *The Global 2000 Report to the President*, vol. 2, Washington, DC.
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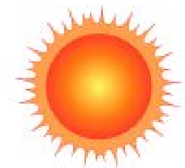
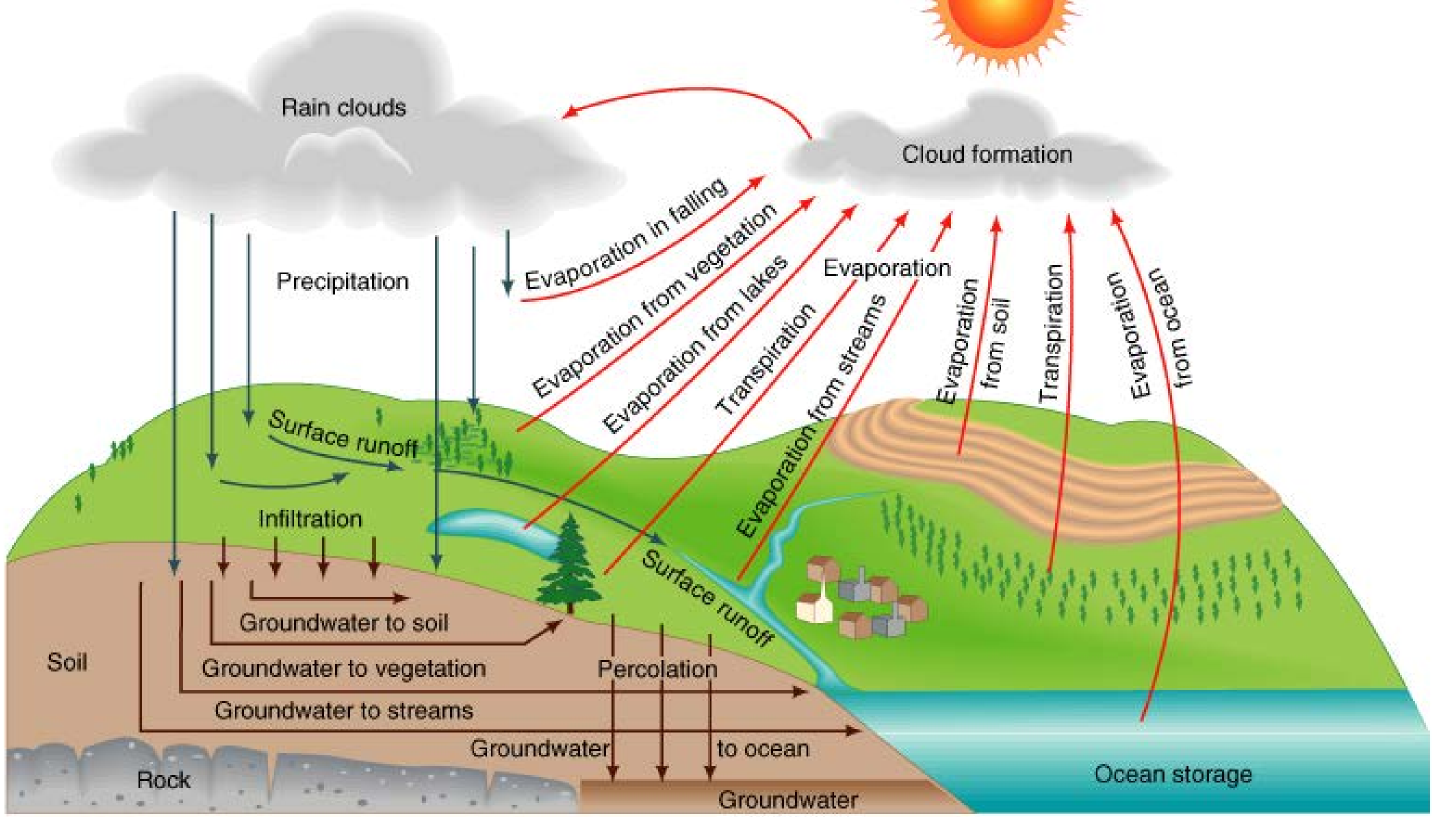
The Hydrologic Cycle

4. Infiltration

a portion of precipitation seeps into ground. Hits water table, where the spaces between rocks and particles are saturated. Groundwater moves slowly toward the ocean.





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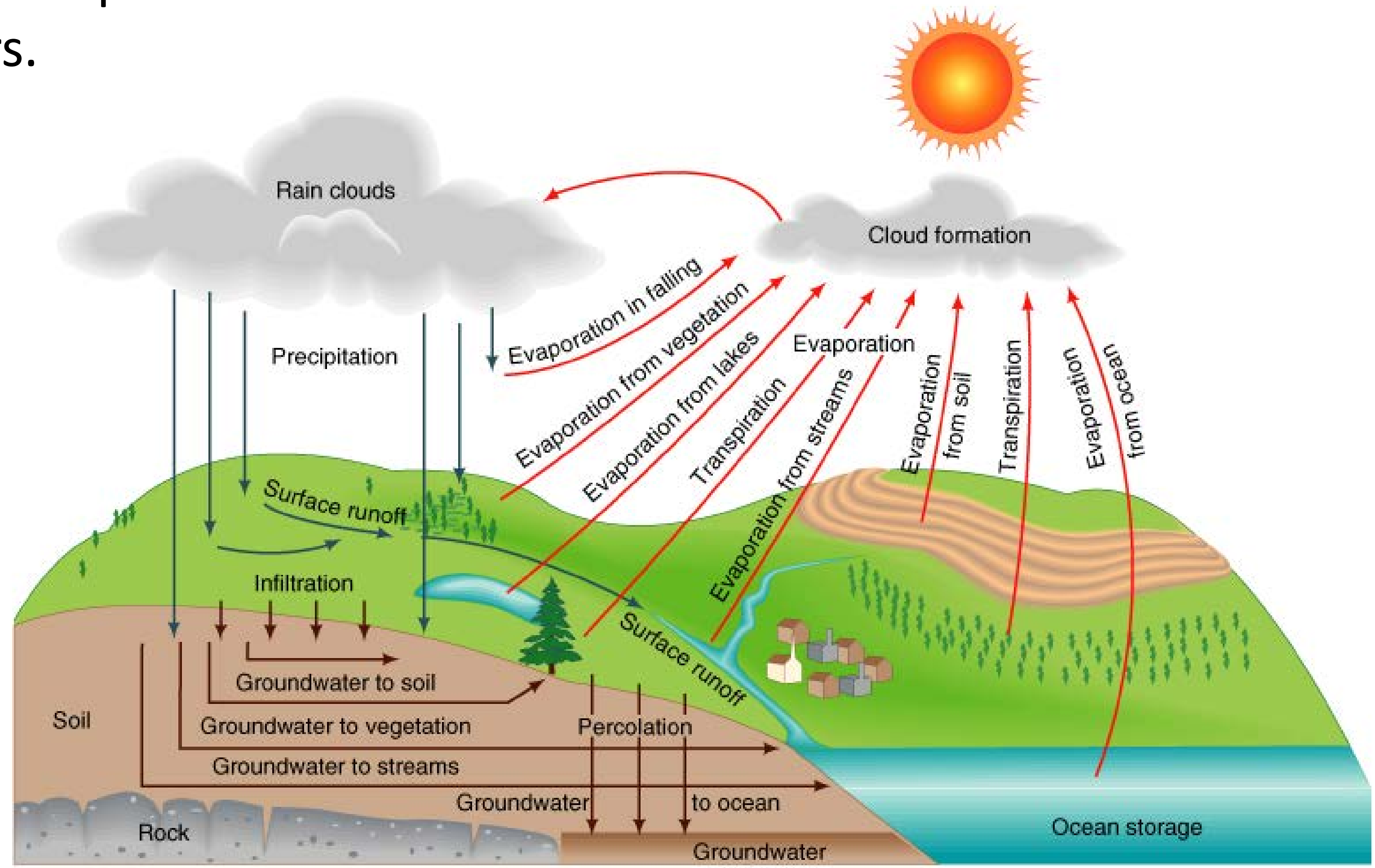
The Hydrologic Cycle

5. Runoff

precipitation that doesn't infiltrate runs off into creeks and rivers.



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Session 5 Freshwater Use

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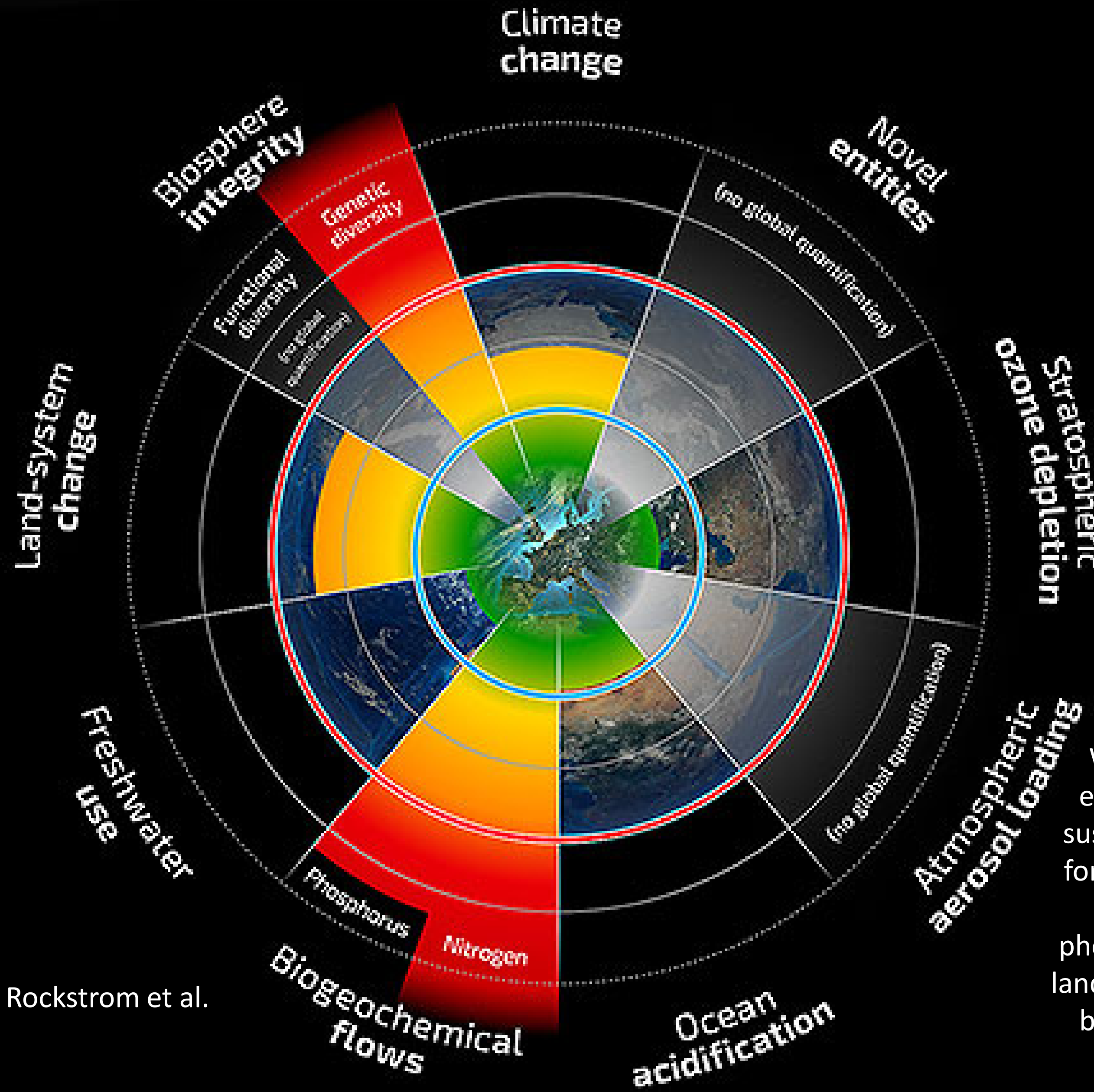
Planetary Boundaries: A Safe Operating Space for Humanity



Source: Rockstrom et al.

We are already exceeding global sustainability limits for climate change, nitrogen and phosphorus cycling, land use change, and biodiversity loss.

Global freshwater planetary boundary

- The global freshwater cycle is officially part of the “Anthropocene”

- Humanity is the dominant force altering river flows globally

Global manipulations of freshwater cycle affect:

- Biodiversity
- Food security
- Health security
- The resilience of terrestrial and aquatic ecosystems
- Ecosystem functioning
  - Habitat
  - Carbon sequestration
  - Climate regulation

Global freshwater deterioration can affect human livelihoods through:

- Loss of soil moisture (green water) due to land degradation and deforestation
- Loss of runoff (blue water) necessary for human and aquatic use
- Impacts on climate regulation due to decline of moisture feedback of green water flows, affecting local and regional precipitation

Rockstrom et al, 2009

How was the freshwater boundary calculated?

The boundary must:

- safely **sustain enough green water flows for moisture feedback** (to regenerate precipitation)
- allow for the provisioning of terrestrial ecosystem functioning and services (e.g., carbon sequestration, biomass growth, food production, and biological diversity)
- secure the availability of blue water resources for aquatic ecosystems.

Rockstrom et al, 2009

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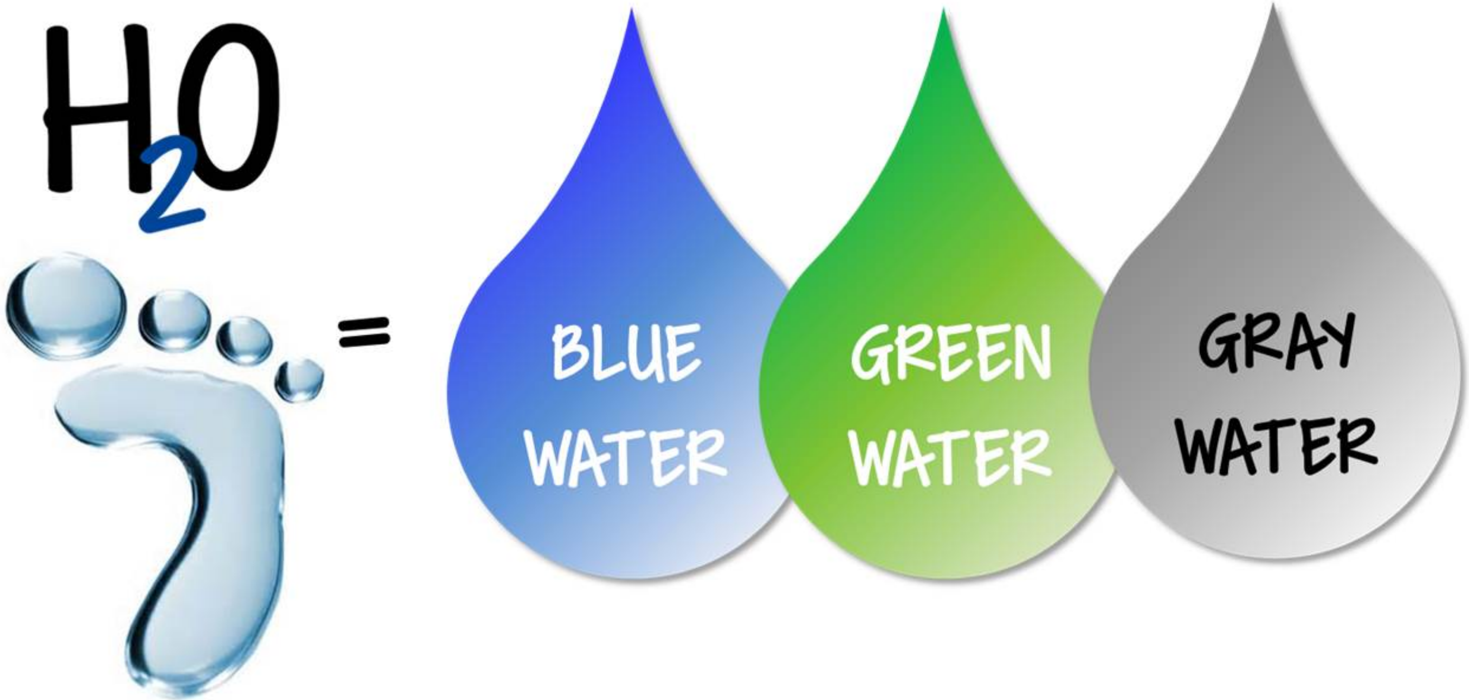
Food has "hidden water"



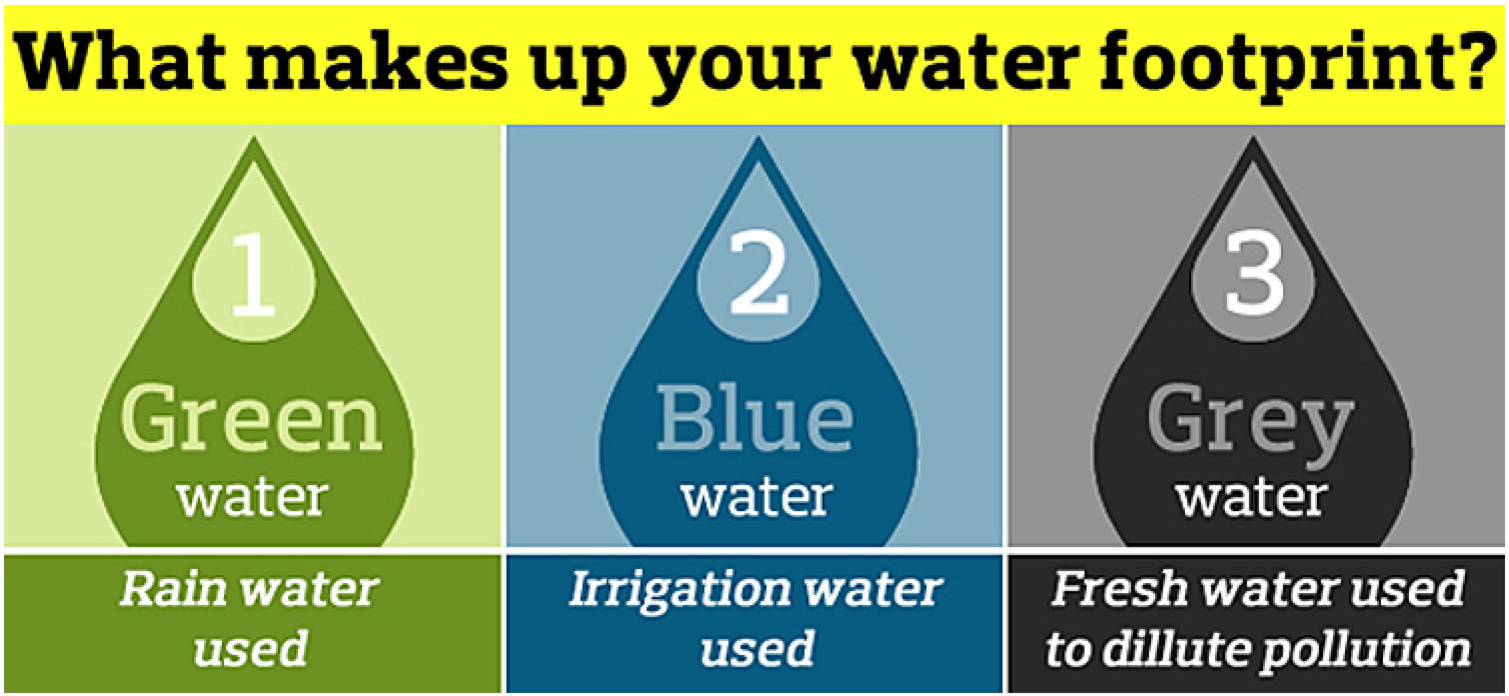
- Producing a quarter pound beef patty requires over 1,000 gallons of water

Images copyright.

3 Elements of a Water Footprint

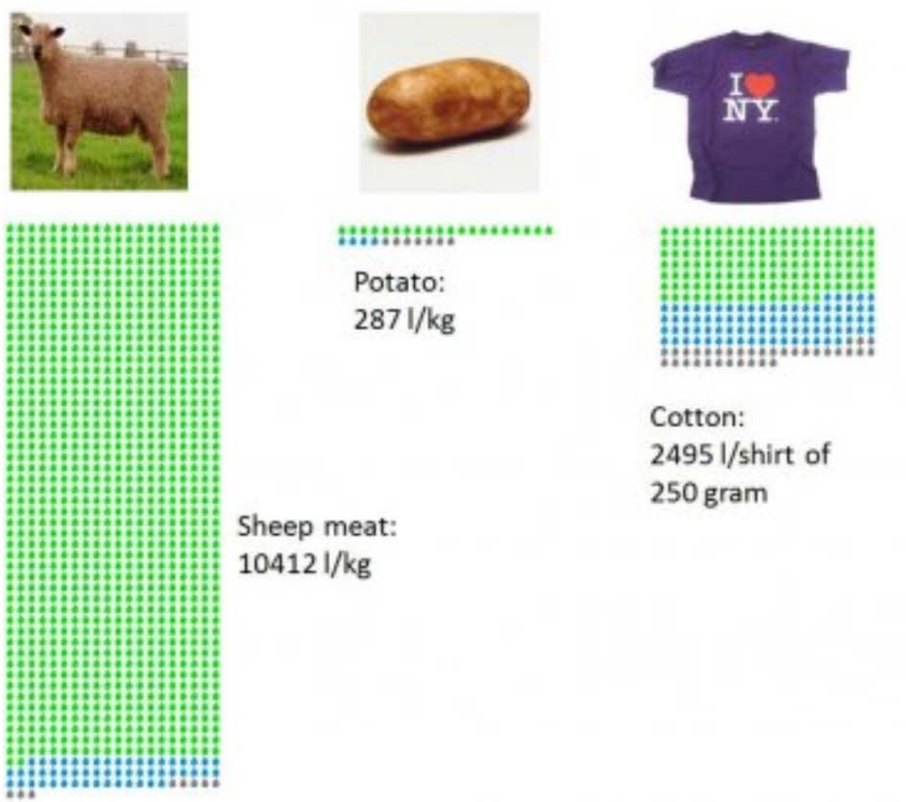


SOURCE: http://www.gracelinks.org/1336/water-footprint-concepts-and-definitions


What makes up your water footprint?
1
Green
water
Rain water used
2
Blue
water
Irrigation water used
3
Grey
water
Fresh water used to dillute pollution

A water footprint can be calculated for all types of products

Products



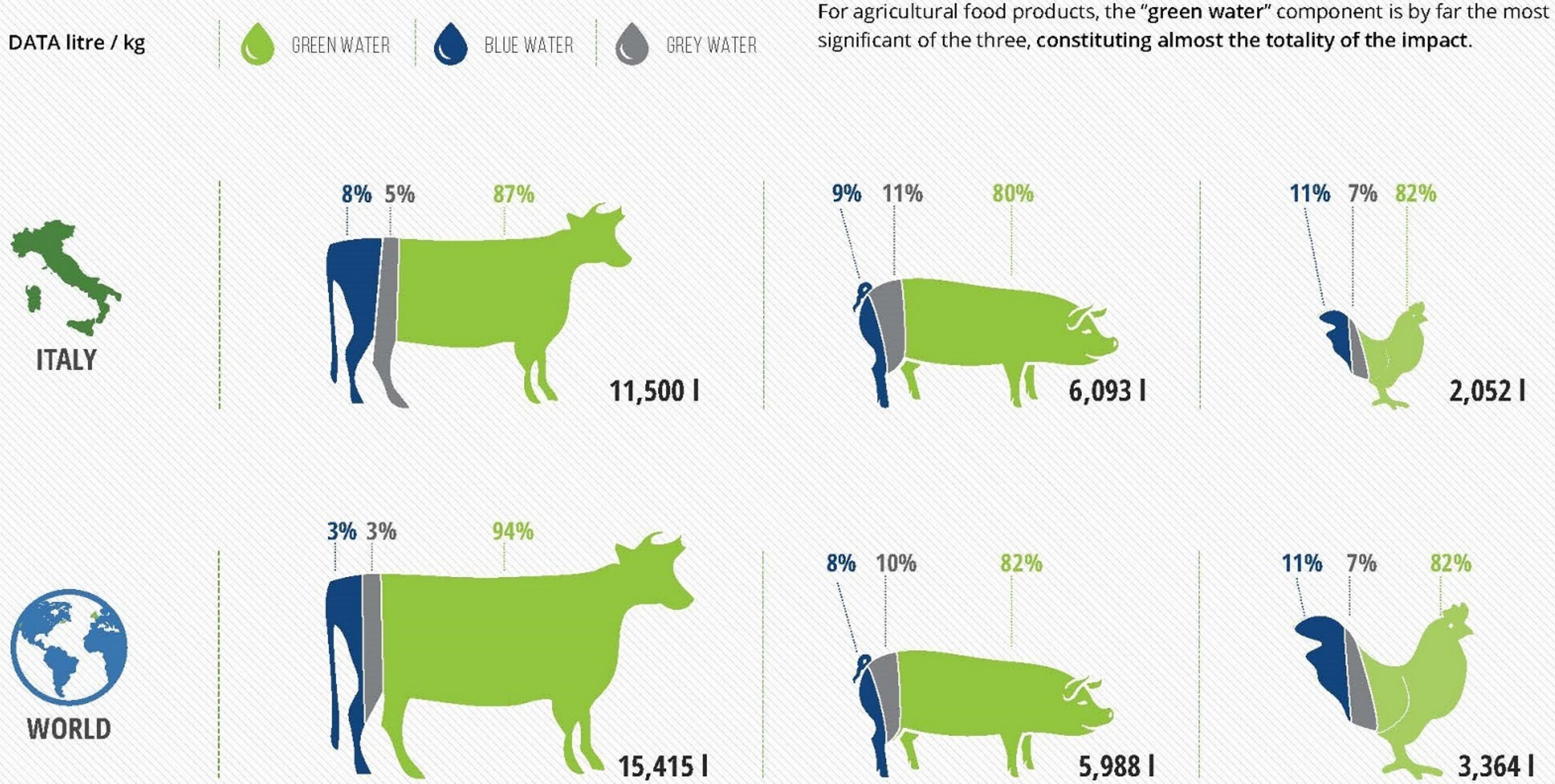
Comparison of product global water footprints and the share of green, blue and grey water. Source: http://www.waterfootprint.org

MEAT'S WATER FOOTPRINT

IN ITALY AND THE WORLD

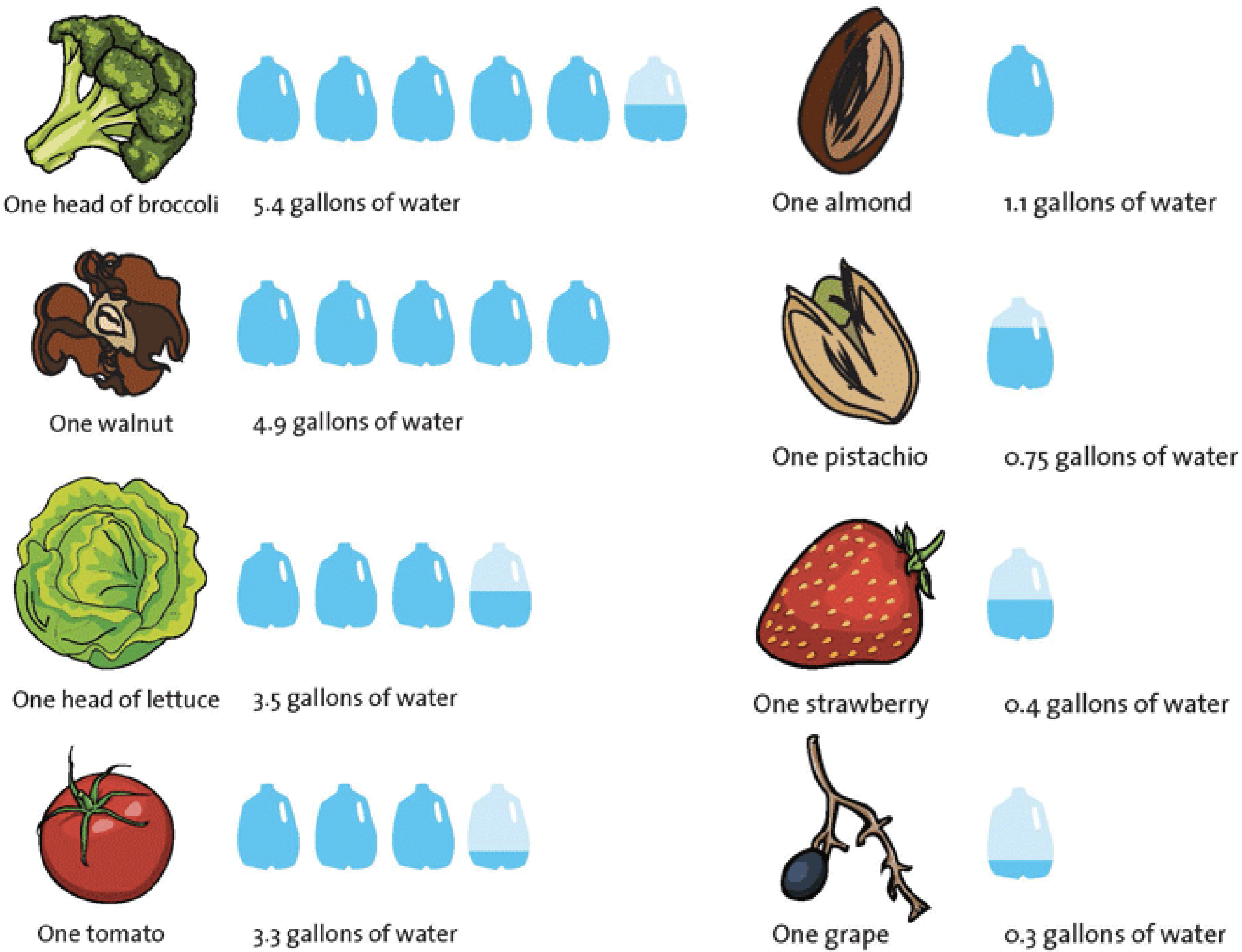
The **water footprint** is the sum of three contributions that are partly real and partly virtual: evapotranspirational water used by plants to live (**green water**), water effectively used by production processes or to irrigate the fields (**blue water**) and the water potentially needed to dilute and purify waste water (**grey water**).

For agricultural food products, the "**green water**" component is by far the most significant of the three, **constituting almost the totality of the impact**.



Source: Mekonnen, M. M., Hoekstra, A.Y. The Green, Blue and Grey Water Footprint of Farm Animals and Animal Products. Value of Water Research Report Series no.48, UNESCO-IHE, Delft, the Netherlands, 2010

Water Use for Major California Crops



http://www.motherjones.com/environment/2014/02/wheres-californias-water-going

How much water goes into making 1 L of soda?

340 - 620 L of water used for making 1 L of soda! –Twente Water Center

From Soda Politics, by Marion Nestle, reviewed in Nature Oct 2015

Why so high?

- Mostly from sugar cane production
- Varies greatly depending on where the sugar cane is grown.

Hoekstra 2012 studied water footprint of various diets

Table 1. The global-average water footprint of crop and animal products[1]

Food item	Water footprint per unit of weight, L/kg				Nutritional content			Water footprint per unit of nutritional value		
	Green	Blue	Gray	Total	Calories, kcal/kg	Protein, g/kg	Fat, g/kg	Calories, L/kcal	Protein, L/g of protein	Fat, L/g of fat
Sugar crops	130	52	15	197	285	0.0	0.0	0.69	0.0	0.0
Vegetables	194	43	85	322	240	12	2.1	1.34	26	154
Starchy roots	327	16	43	387	827	13	1.7	0.47	31	226
Fruits	726	147	89	962	460	5.3	2.8	2.09	180	348
Cereals	1,232	228	184	1,644	3,208	80	15	0.51	21	112
Oil crops	2,023	220	121	2,364	2,908	146	209	0.81	16	11
Pulses	3,180	141	734	4,055	3,412	215	23	1.19	19	180
Nuts	7,016	1,367	680	9,063	2,500	65	193	3.63	139	47
Milk	863	86	72	1,020	560	33	31	1.82	31	33
Eggs	2,592	244	429	3,265	1,425	111	100	2.29	29	33
Chicken meat	3,545	313	467	4,325	1,440	127	100	3.00	34	43
Butter	4,695	465	393	5,553	7,692	0.0	872	0.72	0.0	6.4
Pig meat	4,907	459	622	5,988	2,786	105	259	2.15	57	23
Sheep or goat meat	8,253	457	53	8,763	2,059	139	163	4.25	63	54
Bovine meat	14,414	550	451	15,415	1,513	138	101	10.19	112	153

[1]Source: Mekonnen and Hoekstra (2010). Reprinted with permission of the authors.

Hoekstra 2012

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Hoekstra 2012

Drinking water accounts for just 1% of water requirement for beef

Figure 4. Drinking water contributes only 1% to the total water footprint of beef (source: © 2011 iStockphoto.com/Skyhobo).

Hoekstra 2012

Water for feed crops accounts for 98% of water requirement for meat

Figure 3. Water to grow feed crops contributes about 98% to the total water footprint of animal products (source: © 2006 iStockphoto.com/Vladimir Mucibabic).

Hoekstra 2012

Hoekstra (2012) uses these numbers to calculate water footprint of different diets

- Choose the top three or four categories in your diet. Out of a total of say 2000 calories, write down how many calories you eat from each category.
- Find the multiplier for each item and multiply through.
- Add it all up!

Water footprint of a daily diet

Type of food	Calories (kcal)	L/kcal	L water

Total =

Table 2. The water footprint of 2 different diets in industrialized countries

Item	Meat diet			Vegetarian diet		
	kcal/day[1]	L/kcal[2]	L/day	kcal/day[3]	L/kcal[2]	L/day
Animal origin	950	2.5	2,375	300	2.5	750
Vegetable origin	2,450	0.5	1,225	3,100	0.5	1,550
Total	3,400		3,600	3,400		2,300

Water footprint of a daily diet

Type of food	Calories (kcal)	L/kcal	L water
Pulses	400	1.19	476
Fruits	500	2.09	1254
Vegetables	500	1.34	670
Cereals	600	0.51	204
Nuts	100	3.63	363

Total = 2967 L

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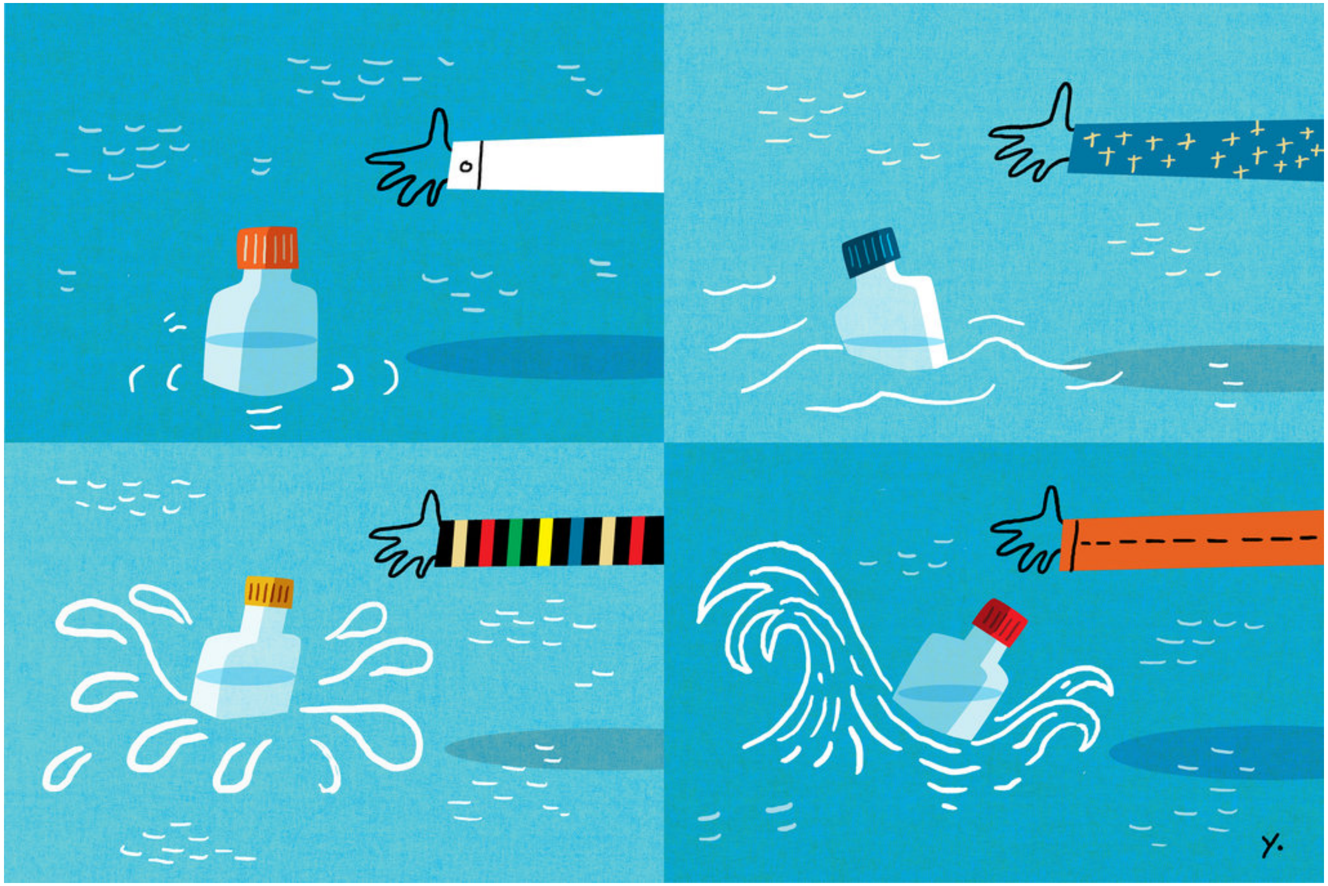
Bottled Water or Tap: How Much Does Your Choice Matter?

By TATIANA SCHLOSSBERG OCT. 20, 2016

What's your daily plastic habit doing to the planet? Take this quiz and find out.



How much more energy do you think it takes to bottle water, transport it and refrigerate it compared to getting it from the tap?

- ❑ 2X as much
- ❑ 100X as much
- ❑ 1000 X as much
- ❑ 2000 X as much

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- ❑ 1000 X as much
- ❑ 2000 X as much

So, despite that, **how many people in the United States do you think drink water from a bottle occasionally or as their main source of water?**

- ❑ 10 percent
- ❑ 25 percent
- ❑ Around 35 percent
- ❑ About 50 percent

So, despite that, **how many people in the United States do you think drink water from a bottle occasionally or as their main source of water?**

- ❑ 10 percent
- ❑ 25 percent
- ❑ Around 35 percent
- ❑ About 50 percent

About how many plastic bottles of water do you think were sold in the United States last year? (Hint: About 320 million people live here.)

- ❑ 300 million
- ❑ 1.6 billion
- ❑ 25.3 billion
- ❑ 49.4 billion

About how many plastic bottles of water do you think were sold in the United States last year? (Hint: About 320 million people live here.)

- ❑ 300 million
- ❑ 1.6 billion
- ❑ 25.3 billion
- ❑ 49.4 billion

Now tell us how many plastic bottles of soda you think the average American bought last year.

- ❑ 10
- ❑ 27
- ❑ 81
- ❑ 62

Now tell us how many plastic bottles of soda you think the average American bought last year.

- ❑ 10
- ❑ 27
- ❑ 81
- ❑ 62

What percentage of plastic bottles do you think is collected for recycling in the United States?

- ❑ None
- ❑ 32 percent
- ❑ 50 percent
- ❑ 75 percent

What percentage of plastic bottles do you think is collected for recycling in the United States?

- ❑ None
- ❑ 32 percent
- ❑ 50 percent
- ❑ 75 percent

Just under a third is right, even though the type of plastic most commonly used to make bottles is one of the easiest and most efficient to recycle. [11]

About a quarter of all the plastic produced is plastic packaging, the kind we think of as disposable, meant to be discarded after a single use. **How much of this kind of plastic do you think is collected for recycling globally?**

- ❑ 2 percent
- ❑ 14 percent
- ❑ 32 percent
- ❑ 50 percent

About a quarter of all the plastic produced is plastic packaging, the kind we think of as disposable, meant to be discarded after a single use. **How much of this kind of plastic do you think is collected for recycling globally?**

- ❑ 2 percent
- ❑ 14 percent
- ❑ 32 percent
- ❑ 50 percent

It's **14 percent**, and another 14 percent is burned.

What percentage of plastic packaging do you think ends up in landfills?

- ❑ 10 percent
- ❑ 72 percent
- ❑ 30 percent
- ❑ 40 percent

What percentage of plastic packaging do you think ends up in landfills?

- ❑ 10 percent
- ❑ 72 percent
- ❑ 30 percent
- ❑ 40 percent

Where do you think the rest of the plastic packaging ends up?

- ❑ Just … **around**.
- ❑ **The ocean**.
- ❑ **The ocean and other places**.

Where do you think the rest of the plastic packaging ends up?

- ❑ Just … **around.**
- ❑ **The ocean.**
- ❑ **The ocean and other places.**

All of those answers are kind of right. Globally, 32 percent of plastic packaging is mismanaged, and a lot of that gets into the ocean.

The energy required to treat and transport 1 liter of bottled water is equivalent to the energy in what volume of gas?

The energy required to treat and transport 1 liter of bottled water is equivalent to the energy in what volume of gas?

250 mLs!

This is enough gas for a car to travel how many miles?

IOP PUBLISHING ENVIRONMENTAL RESEARCH LETTERS
Environ. Res. Lett. 4 (2009) 014009 (6pp) doi:10.1088/1748-9326/4/1/014009

Energy implications of bottled water

P H Gleick and H S Cooley

Pacific Institute, 654 13th Street, Oakland, CA 94612, USA

Estimates energy needs for production, transport and use of bottled water

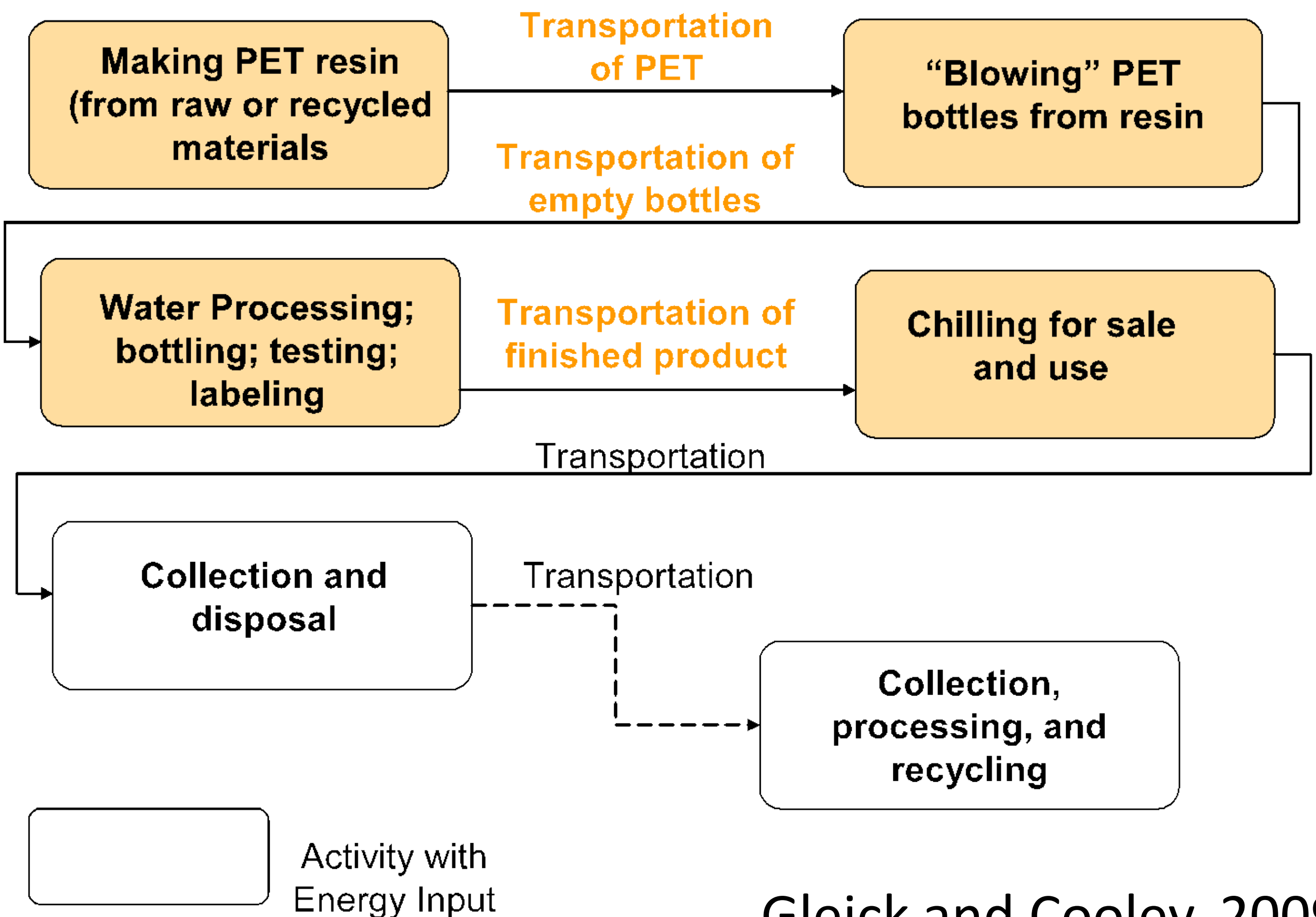
No one life cycle assessment can be made due to big differences in sources, bottling, and transportation

The look at 3 site-species examples

Gleick and Cooley (2009) compare:

- 1) Local bottled water produced and used on Los Angeles
- 2) Water bottled in the South Pacific and transported by cargo ship to Los Angeles
- 3) Water from France transported in various ways to Los Angeles

Gleick and Cooley looked specifically at activities (and transportation steps) in orange



Gleick and Cooley, 2009

Drinking water treatment methods vary greatly in energy needs

Table 2. Energy requirements for water-treatment methods.

Treatment technique	Energy use (kWh_e/million liters)	Data source
Ozone		
Pre-oxidation (pre-treatment)	30	SBW Consulting, Inc (2006)
Disinfection	100	SBW Consulting, Inc (2006)
Ultraviolet (UV) radiation (medium pressure)		
Bacteria	10	SBW Consulting, Inc (2006)
Viruses	10–50	SBW Consulting, Inc (2006)
Microfiltration/ultrafiltration	70–100	SBW Consulting, Inc (2006)
Nanofiltration (source TDS = 500–1000 ppm)	660	AWWA (1999)
Reverse osmosis		
Source TDS = 500 ppm	660	AWWA (1999)
Source TDS = 1000 ppm	790	AWWA (1999)
Source TDS = 2000 ppm	1060	AWWA (1999)
Source TDS = 4000 ppm	1590	AWWA (1999)
Seawater desalination (reverse osmosis)	2500–7000	National Research Council (2008)

Gleick and Cooley, 2009

“Purified water” has lower transportation costs

- ‘purified water’ is usually produced by treating and packaging municipal water in major demand centers close to markets.
- These products are bottled at local bottling plants spread across the country near major urban areas, with deliveries to local markets.
- The Coca-Cola Company, the PepsiCo, and other major bottlers produce treated municipal waters in many major cities for local distribution, often at the same plants producing soft drinks and other beverages.

Gleick and Cooley, 2009

Bottled water energy costs by km and by scenario

Cargo ship/ocean ($MJ\ t^{-1}\ km^{-1}$)	Air cargo ($MJ\ t^{-1}\ km^{-1}$)	Rail ($MJ\ t^{-1}\ km^{-1}$)	Heavy truck ($MJ\ t^{-1}\ km^{-1}$)	Medium truck ($MJ\ t^{-1}\ km^{-1}$)
0.37	15.9	0.23	3.5	6.8

Scenario	Medium truck (km)	Heavy truck (km)	Rail (km)	Cargo ship (km)	Total energy cost ($MJ\ l^{-1}$)
Local production	200 (local delivery)	0	0	0	1.4
Spring water from Fiji	100 (local delivery)	0	0	8900 (Fiji to Long Beach)	4.0
Spring water from France	100 (local delivery)	600 (Evian to Le Havre)	3950 (New York to Los Angeles)	5670 (Le Havre to New York)	5.8

Gleick and Cooley, 2009

Total energy requirement for bottled water

	Energy intensity ($MJ_{(th)}\ l^{-1}$)
Manufacture plastic bottle	4.0
Treatment at bottling plant	0.0001–0.02
Fill, label, and seal bottle	0.01
Transportation: range from three scenarios	1.4–5.8
Cooling	0.2–0.4
Total	5.6–10.2

Gleick and Cooley, 2009

Let’s check that gas calculation

- 1 gallon gas = 131.8 MJ
- 1 gallon = 3.785 L

Let’s check that gas calculation

- 1 gallon gas = 131.8 MJ
- 1 gallon = 3.785 L
- 5.6 mJ * (1 gal/131.76 MJ) * (3.785 L/gal)

  = 0.16 L
- 10.2 mJ * (1 gal/131.76 MJ) * (3.785 L/gal)

  = 0.29 L
- The calculation checks out!!!

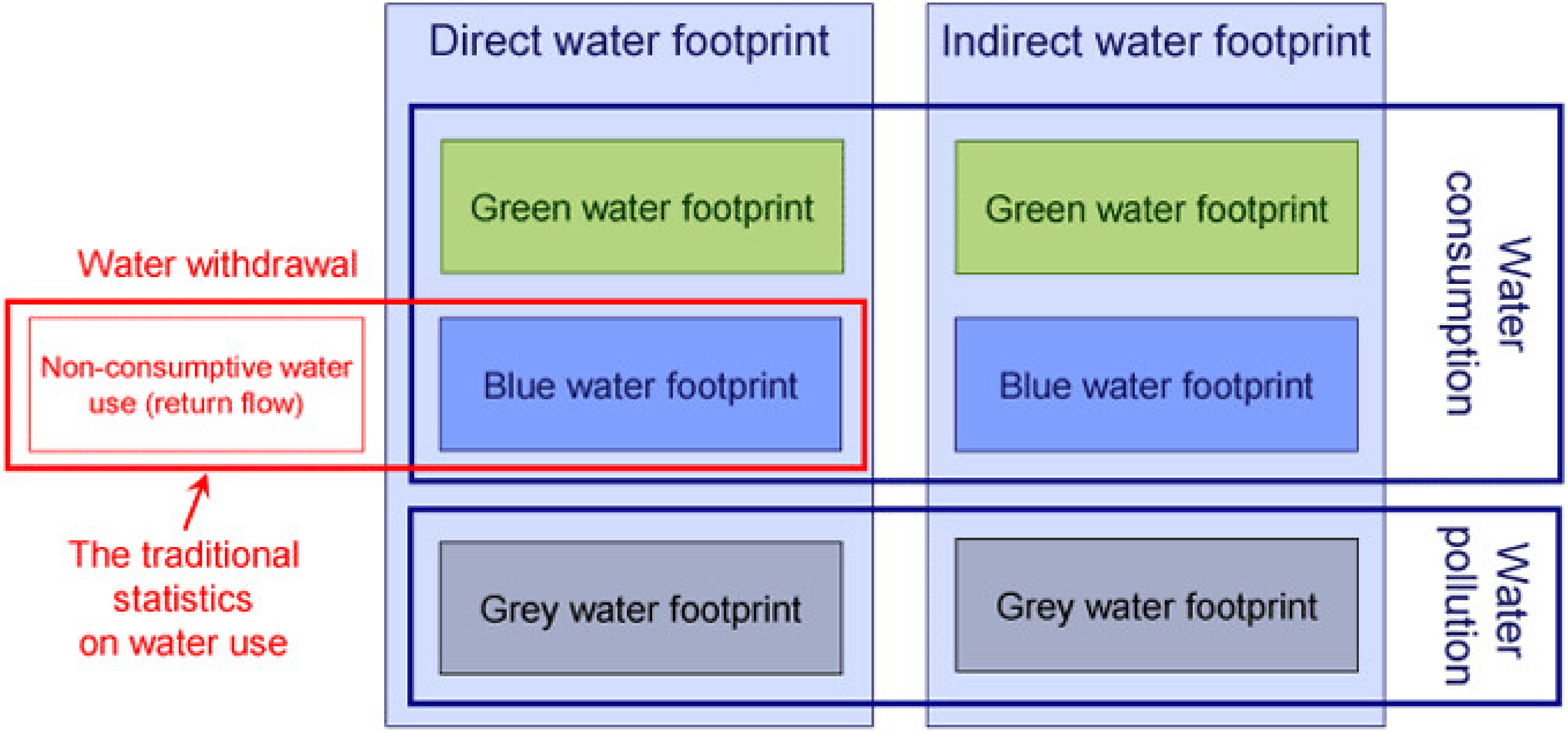
Main findings from Gleick and Cooley

- For water transported short distances, the energy requirements of bottled water are dominated by the energy used to produce the plastic bottles.
- Long-distance transport, however, can lead to energy costs comparable to, or even larger than, those of producing the bottle.
- All other energy costs—for processing, bottling, sealing, labeling, and refrigeration—are far smaller than those for the production of the bottle and transportation.

Gleick and Cooley, 2009

- Extra slides

Components of a water footprint



[A.Hekstra et.al. (2009), Water Footprint Manual State of the Art 2009, Water Footprint Network]