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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Bottled water
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.
Access to drinking water is a gender equity issue.
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
2. Condensation

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

3. Precipitation
   water releases from clouds as rain, sleet, snow, hail
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.
5. Runoff
precipitation that doesn’t infiltrate runs off into creeks and rivers.
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We are already exceeding global sustainability limits for climate change, nitrogen and phosphorus cycling, land use change, and biodiversity loss.

Source: Rockstrom et al.
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
3 Elements of a Water Footprint

$\text{H}_2\text{O}$

= BLUE WATER  GREEN WATER  GRAY WATER

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 dilute pollution
A water footprint can be calculated for all types of products

Products

- Potato: 287 l/kg
- Sheep meat: 10412 l/kg
- Cotton: 2495 l/shirt of 250 gram

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.

Water Use for Major California Crops

One head of broccoli: 5.4 gallons of water
One walnut: 4.9 gallons of water
One head of lettuce: 3.5 gallons of water
One tomato: 3.3 gallons of water
One almond: 1.1 gallons of water
One pistachio: 0.75 gallons of water
One strawberry: 0.4 gallons of water
One grape: 0.3 gallons of water

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

<table>
<thead>
<tr>
<th>Food item</th>
<th>Water footprint per unit of weight, L/kg</th>
<th>Nutritional content</th>
<th>Water footprint per unit of nutritional value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Green Blue Gray Total</td>
<td>Calories, kcal/kg</td>
<td>Protein, g/kg</td>
</tr>
<tr>
<td>Sugar crops</td>
<td>130 52 15 197</td>
<td>285 0.0 0.0</td>
<td></td>
</tr>
<tr>
<td>Vegetables</td>
<td>194 43 85 322</td>
<td>240 12 2.1</td>
<td></td>
</tr>
<tr>
<td>Starchy roots</td>
<td>327 16 43 387</td>
<td>827 13 1.7</td>
<td></td>
</tr>
<tr>
<td>Fruits</td>
<td>726 147 89 962</td>
<td>460 5.3 2.8</td>
<td></td>
</tr>
<tr>
<td>Cereals</td>
<td>1,232 228 184 1,644</td>
<td>3,208 80 15</td>
<td></td>
</tr>
<tr>
<td>Oil crops</td>
<td>2,023 220 121 2,364</td>
<td>2,908 146 209</td>
<td></td>
</tr>
<tr>
<td>Pulses</td>
<td>3,180 141 734 4,055</td>
<td>3,412 215 23</td>
<td></td>
</tr>
<tr>
<td>Nuts</td>
<td>7,016 1,367 680 9,063</td>
<td>2,500 65 193</td>
<td></td>
</tr>
<tr>
<td>Milk</td>
<td>863 86 72 1,020</td>
<td>560 33 31</td>
<td></td>
</tr>
<tr>
<td>Eggs</td>
<td>2,592 244 429 3,265</td>
<td>1,425 111 100</td>
<td></td>
</tr>
<tr>
<td>Chicken meat</td>
<td>3,545 313 467 4,325</td>
<td>1,440 127 100</td>
<td></td>
</tr>
<tr>
<td>Butter</td>
<td>4,695 465 393 5,553</td>
<td>7,692 0.0 872</td>
<td></td>
</tr>
<tr>
<td>Pig meat</td>
<td>4,907 459 622 5,988</td>
<td>2,786 105 259</td>
<td></td>
</tr>
<tr>
<td>Sheep or goat meat</td>
<td>8,253 457 53 8,763</td>
<td>2,059 139 163</td>
<td></td>
</tr>
<tr>
<td>Bovine meat</td>
<td>14,414 550 451 15,415</td>
<td>1,513 138 101</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Type of food</th>
<th>Calories (kcal)</th>
<th>L/kcal</th>
<th>L water</th>
</tr>
</thead>
</table>

Total =
<table>
<thead>
<tr>
<th>Item</th>
<th>Meat diet</th>
<th>Vegetarian diet</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kcal/day&lt;sup&gt;1&lt;/sup&gt;</td>
<td>L/kcal&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>Animal origin</td>
<td>950</td>
<td>2.5</td>
</tr>
<tr>
<td>Vegetable origin</td>
<td>2,450</td>
<td>0.5</td>
</tr>
<tr>
<td>Total</td>
<td>3,400</td>
<td>3.600</td>
</tr>
</tbody>
</table>
## Water footprint of a daily diet

<table>
<thead>
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<th>L/kcal</th>
<th>L water</th>
</tr>
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<tr>
<td>Pulses</td>
<td>400</td>
<td>1.19</td>
<td>476</td>
</tr>
<tr>
<td>Fruits</td>
<td>500</td>
<td>2.09</td>
<td>1254</td>
</tr>
<tr>
<td>Vegetables</td>
<td>500</td>
<td>1.34</td>
<td>670</td>
</tr>
<tr>
<td>Cereals</td>
<td>600</td>
<td>0.51</td>
<td>204</td>
</tr>
<tr>
<td>Nuts</td>
<td>100</td>
<td>3.63</td>
<td>363</td>
</tr>
</tbody>
</table>

Total = 2967 L
Introduction to the water cycle
Planetary boundary for water use
Hidden water
Bottled water
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
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
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?
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.
Drinking water treatment methods vary greatly in energy needs

Gleick and Cooley, 2009

<table>
<thead>
<tr>
<th>Treatment technique</th>
<th>Energy use (kWhₑ/million liters)</th>
<th>Data source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ozone</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disinfection</td>
<td>100</td>
<td>SBW Consulting, Inc (2006)</td>
</tr>
<tr>
<td><strong>Ultraviolet (UV) radiation (medium pressure)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Microfiltration/ultrafiltration</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nanofiltration (source TDS = 500–1000 ppm)</td>
<td>660</td>
<td>AWWA (1999)</td>
</tr>
<tr>
<td><strong>Reverse osmosis</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Source TDS = 500 ppm</td>
<td>660</td>
<td>AWWA (1999)</td>
</tr>
<tr>
<td>Source TDS = 1000 ppm</td>
<td>790</td>
<td>AWWA (1999)</td>
</tr>
<tr>
<td>Source TDS = 2000 ppm</td>
<td>1060</td>
<td>AWWA (1999)</td>
</tr>
<tr>
<td>Source TDS = 4000 ppm</td>
<td>1590</td>
<td>AWWA (1999)</td>
</tr>
<tr>
<td>Scawater desalination (reverse osmosis)</td>
<td>2500–7000</td>
<td>National Research Council (2008)</td>
</tr>
</tbody>
</table>
“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

<table>
<thead>
<tr>
<th>Cargo ship/ocean (MJ t⁻¹ km⁻¹)</th>
<th>Air cargo (MJ t⁻¹ km⁻¹)</th>
<th>Rail (MJ t⁻¹ km⁻¹)</th>
<th>Heavy truck (MJ t⁻¹ km⁻¹)</th>
<th>Medium truck (MJ t⁻¹ km⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.37</td>
<td>15.9</td>
<td>0.23</td>
<td>3.5</td>
<td>6.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Medium truck (km)</th>
<th>Heavy truck (km)</th>
<th>Rail (km)</th>
<th>Cargo ship (km)</th>
<th>Total energy cost (MJ L⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local production</td>
<td>200 (local delivery)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1.4</td>
</tr>
<tr>
<td>Spring water from Fiji</td>
<td>100 (local delivery)</td>
<td>0</td>
<td>0</td>
<td>8900 (Fiji to</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Long Beach)</td>
<td></td>
</tr>
<tr>
<td>Spring water from France</td>
<td>100 (local delivery)</td>
<td>600 (Evian to Le Havre)</td>
<td>3950 (New York to Los Angeles)</td>
<td>5670 (Le Havre to New York)</td>
<td>5.8</td>
</tr>
</tbody>
</table>

Gleick and Cooley, 2009
## Total energy requirement for bottled water

<table>
<thead>
<tr>
<th>Activity</th>
<th>Energy intensity (MJ\textsubscript{th} l\textsuperscript{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacture plastic bottle</td>
<td>4.0</td>
</tr>
<tr>
<td>Treatment at bottling plant</td>
<td>0.0001–0.02</td>
</tr>
<tr>
<td>Fill, label, and seal bottle</td>
<td>0.01</td>
</tr>
<tr>
<td>Transportation: range from three scenarios</td>
<td>1.4–5.8</td>
</tr>
<tr>
<td>Cooling</td>
<td>0.2–0.4</td>
</tr>
<tr>
<td>Total</td>
<td>5.6–10.2</td>
</tr>
</tbody>
</table>

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

Direct water footprint
- Green water footprint
- Blue water footprint

Indirect water footprint
- Green water footprint
- Blue water footprint

Water withdrawal
- Non-consumptive water use (return flow)

The traditional statistics on water use

Water consumption

Water pollution