When looking at sustainability metrics the building industry has typically focused on energy and water independently. This is reflected in standardized metrics like energy use intensity (EUI) and water use intensity (WUI) but in practice water and energy use in a building is more complex than this. Water and energy are intertwined in intricate and often overlooked ways. This presentation works to show how water use and energy use are interlinked from source to site. This includes the water use intensity of electrical production, building system water.
Learning Objectives

At the end of this course, participants will be able to:

1. Participants will gain knowledge of the issues with water scarcity both globally and locally and they will understand how energy and water usage are interlinked.
2. Upon completion, participants will be able to identify the full carbon footprint of water usage in a building.
3. Participants will be able to quantify what consumes water in a building from source to site.
4. Upon completion, participants will be able to apply a concept for a passive water house setting a water budget that drastically reduces water and carbon emissions tied to the water usage.

Why Water Matters

“All the water that will ever be is, right now” – National Geographic

Take ALL the WATER on the planet and ALL the ATMOSPHERE and convert their volume into spheres. That is all we have...
Current Major Potable Water Use

Why Water Matters

**It's all about the people...**

As the world’s population continues to grow, now at a rate of about 10,000 per hour, the same finite water resources are going to have to go farther and be treated wisely. In order to meet our future water needs, simple solutions are needed that are both economical and environmentally friendly.

Global footprints

Global footprints of different foods

- 24,000 litres: 1 kg of chocolate
- 15,500 litres: 1 kg of beef
- 4,400 litres: 1 kg of olives
- 1,500 litres: 1 kg of sugar
- 140 litres: 1 cup of coffee
Water and Oil Do Mix

“The total amount of energy embedded in our use of bottled water can be as high as the equivalent of filling a plastic bottle one quarter full with oil.” ~ Pacific Institute

Water-related use of electricity is about 19% of the total State of California electricity use. Since population growth drives demand for both resources, water and energy demand are growing at about the same rate.
In 2005 the annual water-related energy use in the United States was equivalent to at least 521 million MWh or 13% of 2007 electricity consumption. Residential water heating comprises the largest share of water-related carbon emissions.

Thermoelectric power is 48% of all water withdrawals and 39% of freshwater withdrawals.

Water consumed to produce one megawatt-hour of electricity, which is enough to power three homes for an hour:
- 672 gallons
- 687 gallons
- 786 gallons

Withdrawal: 0.2 – 42.5 gal/kWh
Consumption: 0.1 – 0.8 gal/kWh
Water Energy Nexus

Many plants reuse the water, but some of it – up to 10% in some cases – evaporates in the process.

Nuclear power plants use as much as 20% less water, but they’re more expensive to build.

Coal and nuclear plants work the same way. All plants get water from wells, rivers or the ocean, and some use recycled water.

<table>
<thead>
<tr>
<th>Type</th>
<th>Withdrawals (gal/kWh)</th>
<th>Consumption (gal/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermoelectric (National Avg.)</td>
<td>21</td>
<td>0.5</td>
</tr>
<tr>
<td>Thermoelectric (once-through)</td>
<td>40</td>
<td>0.25</td>
</tr>
<tr>
<td>Thermoelectric (with cooling tower)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Hydroelectric</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Aggregate National Average</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

Water Versus Energy

Rainwater

Water Efficient Fixtures

Greywater

Stormwater

Potable water

Sewage & runoff

EUI

SF/YR
Estimated Use of Water in the United States by Sector, 2000

- Thermoelectric: 48%
- Irrigation: 34%
- Public Supply: 11%
- Industrial: <1%
- Self-Supply Domestic: <1%
- Mining: <1%
- Livestock: <1%
- Aquaculture: <1%
Energy Intensity of Water

Generic Energy Intensity of Water Supply Types

Energy Intensity (kWh/MG)

Water Supply Type

Surface Water (Gravity Fed)  Groundwater  Brackish Groundwater  Desalinated Seawater  Recycled Water

Energy Intensity of Water

Energy Intensity of Water

Thermoelectric, freshwater

Withdrawal (gallons per day)

Year


Energy Intensity of Water

EPRI - Water use for Electricity Generation and Other Sectors

Energy Intensity of Water

Toto Toilet - US Average

Total

Wastewater Discharge

Wastewater Collection and Treatment

Water Distribution

Water Treatment

Water Supply and Conveyance

Based on River Network Data and using the average size home in the USA
Leakage Rates

Water lost due to supply system leakage is estimated to be on the order of 10% of total supply, or 5.48 billion gallons daily.

A national program aimed at reducing system loss could achieve a 5% reduction in leaks, equal to 0.5% of total water supply.

Water Leakage

This would save 270 MGD of water and 313 million kWh of electricity annually.

Equal to the electricity use of over 31,000 homes & 225,000 metric tons of CO2 emissions could be avoided.

Leakage Rates

- Every day, nearly 6,000,000,000 gallons of treated water is lost through leaks
- Leaky, aging pipes & outdated systems are wasting an estimated 14-18% of the daily use in the USA

Saving Energy With Cooling Towers
### Water Versus Energy

**Building Cooling**

- Passive removal
- Energy consumed
- Water consumed
- Natural Ventilation
- Electrical Energy in Compressor
- Evaporating Water

Choose your destiny

#### Heat removed

**What effects water usage in buildings?**

- Toilet: 31%
- Clothes Washer: 12%
- Shower: 15%
- Faucet: 11%
- Other Domestic: 9%
- Bath: 1%
- Dishwasher: 1%
- Leaks: 1%
- Outdoor Use: 2%

EPA - 1999 Single-Family Home Daily Water Consumption by End Use (Gallons per Capita)

#### What effects water usage in buildings?

**Domestic Water Use Per Capita (gal/day)**

- National avg.: 88 gal/day
- Alabama: 108
- Alaska: 113
- Arizona: 111
- Arkansas: 110
- California: 109
- Colorado: 108
- Connecticut: 107
- Delaware: 106
- District Of Columbia: 105
- Florida: 104
- Georgia: 103
- Hawaii: 102
- Idaho: 101
- Illinois: 100
- Indiana: 99
- Iowa: 98
- Kansas: 97
- Kentucky: 96
- Louisiana: 95
- Maine: 94
- Maryland: 93
- Massachusetts: 92
- Michigan: 91
- Minnesota: 90
- Mississippi: 89
- Missouri: 88
- Montana: 87
- Nebraska: 86
- Nevada: 85
- New Hampshire: 84
- New Jersey: 83
- New Mexico: 82
- New York: 81
- North Carolina: 80
- North Dakota: 79
- Ohio: 78
- Oklahoma: 77
- Oregon: 76
- Pennsylvania: 75
- Rhode Island: 74
- South Carolina: 73
- South Dakota: 72
- Tennessee: 71
- Texas: 70
- Utah: 69
- Vermont: 68
- Virginia: 67
- Washington: 66
- West Virginia: 65
- Wisconsin: 64
- Wyoming: 63
- Puerto Rico: 62
- U.S. Virgin Islands: 61
- TOTAL: 60

---

<table>
<thead>
<tr>
<th>Building Component</th>
<th>Passive house (certified)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air leakage @ 50 pascal pressure (measured by blower-door test)</td>
<td>≤ 0.6 ACH</td>
</tr>
<tr>
<td>Space Heating (Annual heat requirement)</td>
<td>≤ 15 kWh/m²/yr (4.75 kBtu/sf/yr)</td>
</tr>
<tr>
<td>Primary Energy</td>
<td>≤ 120 kWh/m²/yr (38.1 kBtu/sf/yr)</td>
</tr>
<tr>
<td>Total Site Energy</td>
<td>&lt;42 kWh/m²/yr (13.3 kBtu/ ft²/yr)</td>
</tr>
<tr>
<td>Ventilation system with heat recovery efficiency</td>
<td>≥ 75% efficiency with low electric consumption @ 0.45 Wh/m³</td>
</tr>
</tbody>
</table>

---
What effects water usage in buildings?

Municipal per capita water use

Toilet Clothes Washer Shower Faucet Other Domestic Bath Dishwasher Leaks Outdoor Use

EPA - 1999 Single-Family Home Daily Water Consumption by End Use (Gallons per Capita)

Residential Water Use

Water Energy Nexus

The energy embedded at end-use from water heating alone accounts for 74% of total water related energy use.

LEED Residential

<table>
<thead>
<tr>
<th>Fixture</th>
<th>Baseline flush or flow rate</th>
<th>Estimated fixture usage</th>
<th>Estimated water usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shower (per compartment)</td>
<td>2.5 gpm</td>
<td>6.15 minutes</td>
<td>15.4 gallons</td>
</tr>
<tr>
<td>Lavatory, kitchen faucet</td>
<td>2.2 gpm</td>
<td>5.0 minutes</td>
<td>11 gallons</td>
</tr>
<tr>
<td>Toilet</td>
<td>1.6 gpf</td>
<td>5.05 flushes</td>
<td>8 gallons</td>
</tr>
<tr>
<td>Clothes washer</td>
<td>9.5 WF</td>
<td>0.37 cycles @ 3.5 ft³ (@0.1 m³)</td>
<td>15.1 gallons</td>
</tr>
<tr>
<td>Dishwasher</td>
<td>6.5 gpc</td>
<td>0.1 cycles</td>
<td>0.7 gallons</td>
</tr>
</tbody>
</table>
**Watch Water**

- Passive House Source EUI 30
- Efficient Fixtures + Typ. Outdoor Use EUI 3

**Water Use for Electricity**

- Water Use for Source EUI of 30 kBtu/SF/yr

**Sustainable Water Use**

What is the most sustainable approach to water?

**Centralized treatment**
### Decentralized treatment

#### Non-water discharging containment systems
- Composting toilets
- Inverting toilets
- Evaporation systems

#### Primary treatment systems
- Septic tanks

#### Suspended growth
- Sequencing batch reactors
- Membrane bioreactors

#### Attached growth
- Recirculating biotrons
- Intermittent sand filters
- Fabric/synthetic filters

#### Hybrid
- Moving bed biofilm reactor

#### Natural
- Constructed wetlands

---

#### Table 1: Selected Decentralized Treatment Technologies

<table>
<thead>
<tr>
<th>Footprint</th>
<th>Operation Energy</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composting toilets &amp; Constructed wetlands</td>
<td>Small - Large</td>
<td>Zero - Low</td>
</tr>
<tr>
<td>Constructed wetland</td>
<td>Small - Large</td>
<td>Zero - Low</td>
</tr>
<tr>
<td>Recirculating biotrons</td>
<td>Medium</td>
<td>Low - Medium</td>
</tr>
<tr>
<td>Membrane bioreactors</td>
<td>Small - Medium</td>
<td>High</td>
</tr>
</tbody>
</table>

---

- The compost bins are filled with wood chips and contain a spindle with a series of tines, which is manually spun for aeration by a building engineer.
- A fan also pulls air through the system and out through the roof.
- The center expects a year and a half will pass before the first batch of compost needs to be removed.
Additional References

- http://living-future.org/clean-water-healthy-sound
- http://www.rivernetwork.org/resource-library/carbon-footprint-water

Questions?

This concludes The American Institute of Architects Continuing Education Systems Course

Passive House Northwest  education@phnw.org