The Nexus of Energy & Water

Ashlynn S. Stillwell

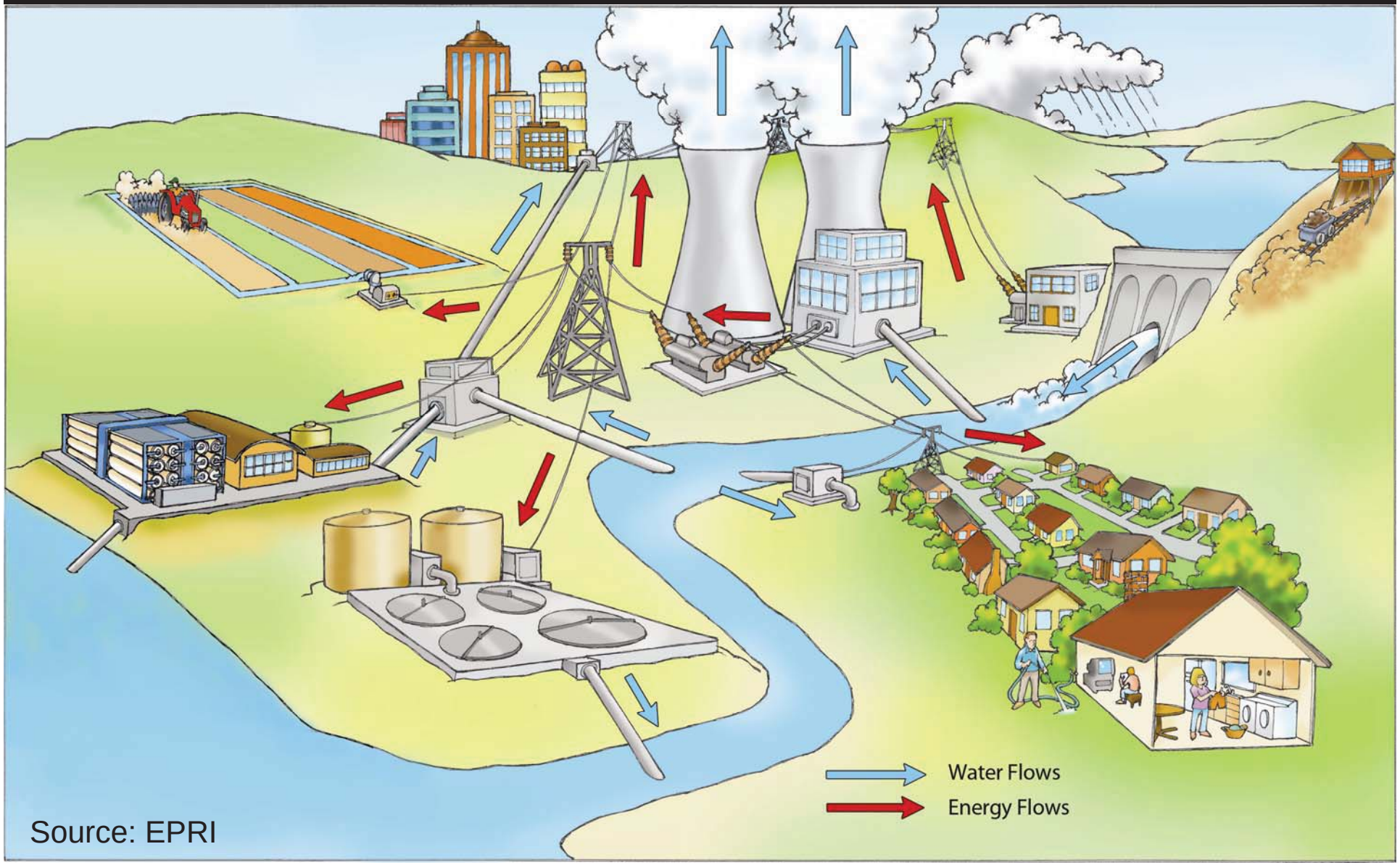
Rainwater Revival | Dripping Springs, TX
October 8, 2011

Energy and water are interrelated

- We use water for energy
  - Cooling during power generation
  - Liquid fuels production

- We use energy for water
  - Treatment and disinfection
  - Distribution
  - Heating

Energy and water are interrelated



Source: EPRI

Energy and water are also the two looming crises of the 21st century…

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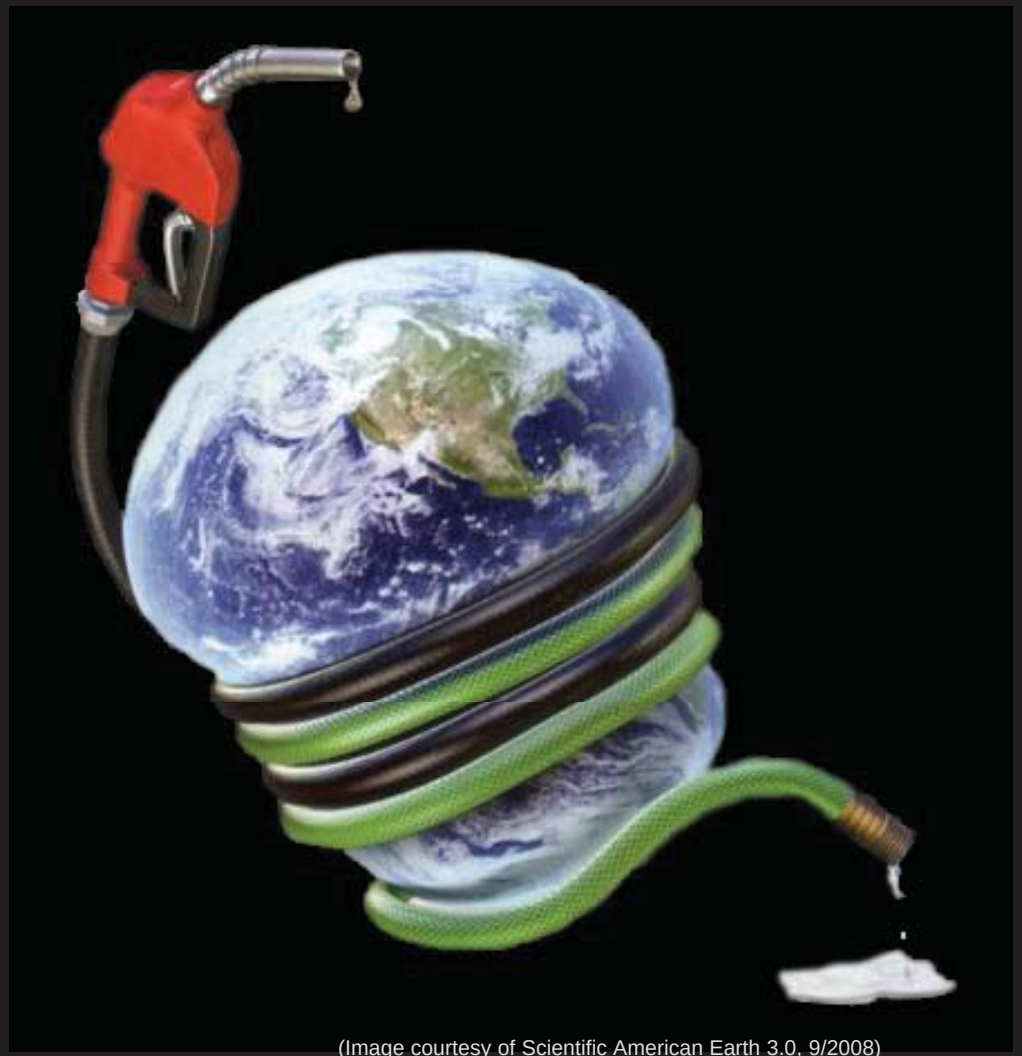
The Energy-Water Nexus: Can we solve both crises together?



(Image courtesy of Scientific American Earth 3.0, 9/2008)

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The hydrological cycle is global

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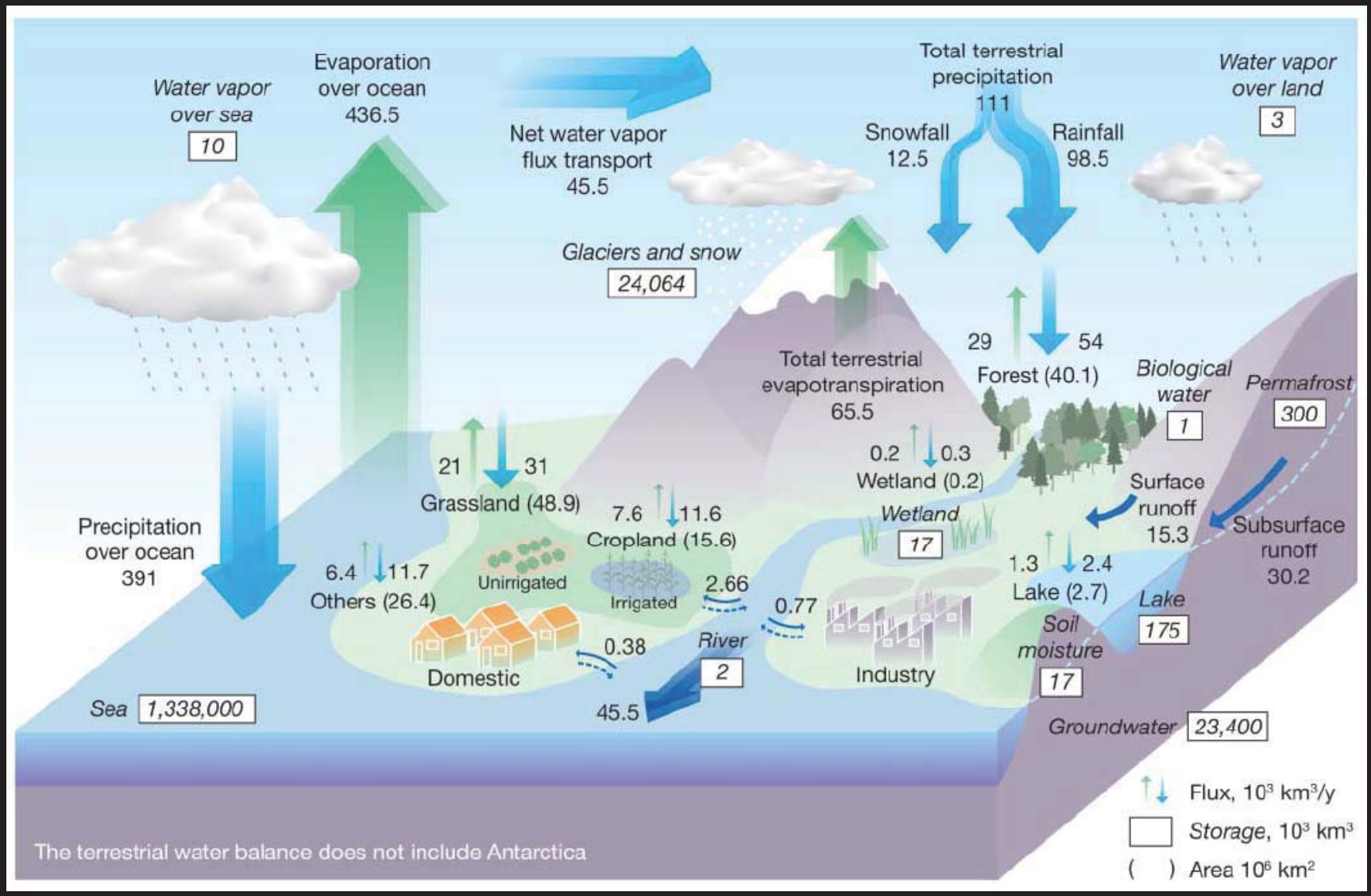
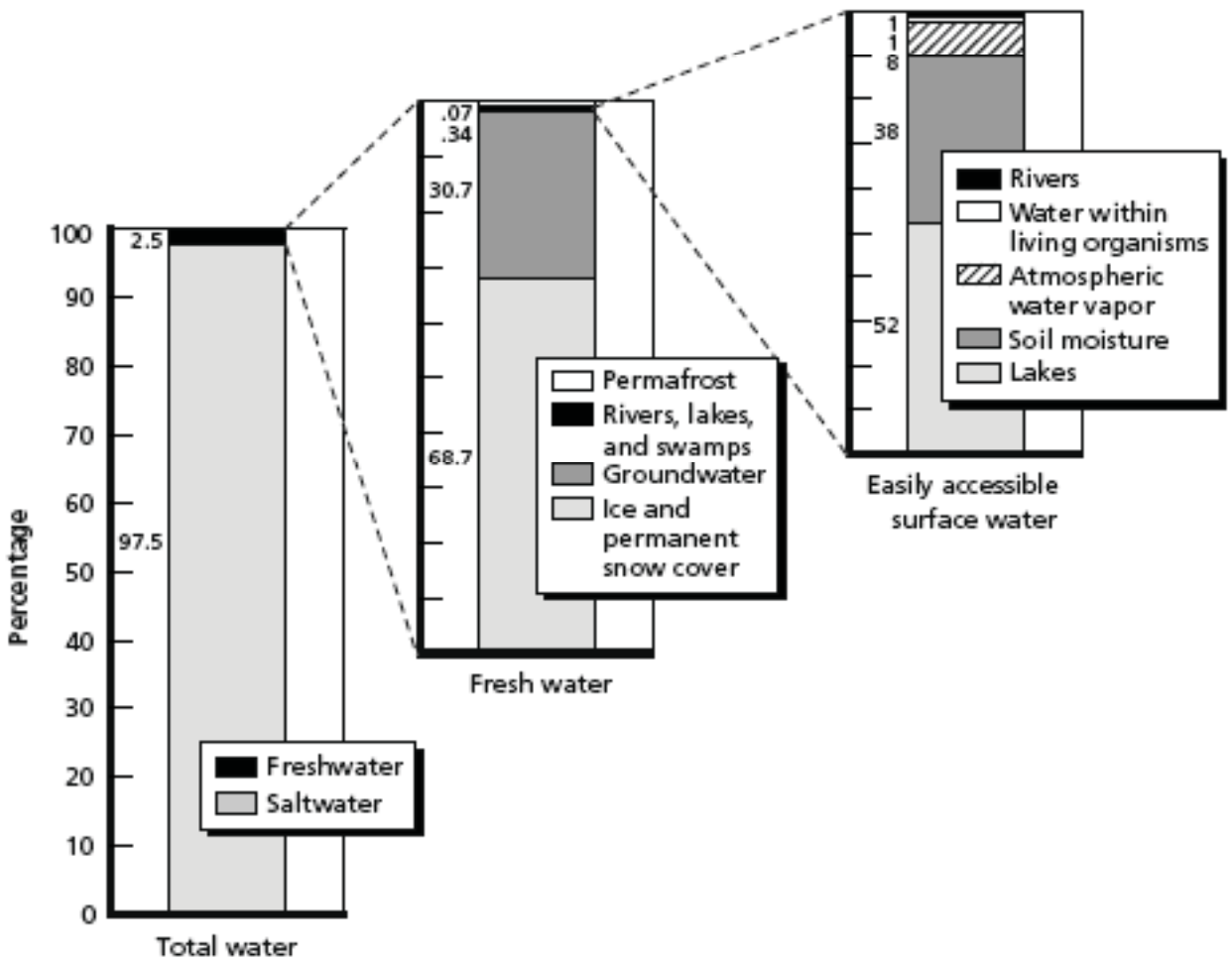
The hydrological cycle is global



[Oki & Kanae 2006]

Freshwater is a small part of the total supply

Figure 2.1
Earth's Supply of Water



SOURCE: Hinrichsen, Krchnak, and Mogelgaard (2002).

RAND MG358-2.1

[Boberg, RAND]

Four main points to remember

1. **Energy and water are interrelated**
   - **we use energy for water and water for energy**
2. **The energy and water relationship is already under strain**
   - **constraints in one resource introduce constraints in the other**
3. **Trends imply these strains will be exacerbated**
   - **Population growth increases total demand**
   - **Economic growth increases per capita demand**
   - **Global climate change intensifies the hydrological cycle**
   - **Policy shifts towards increasing water-intensity of energy and energy-intensity of water**
4. **There are different policy actions that can help**
   - **Policy engagement on energy/water nexus is warranted**

The energy sector uses a lot of water

- **Thermoelectric power sector is the largest user of water in the US**
  - **48% of total water withdrawals**
  - **39% of freshwater withdrawals** [USGS]
- ***Withdrawal*: 0.2 - 42.5 gal/kWh**
- ***Consumption*: 0.1 - 0.8 gal/kWh**

Also need water for production and refining of transportation fuels…

Michigan City, IN
Credit: M. Webber, 8/09

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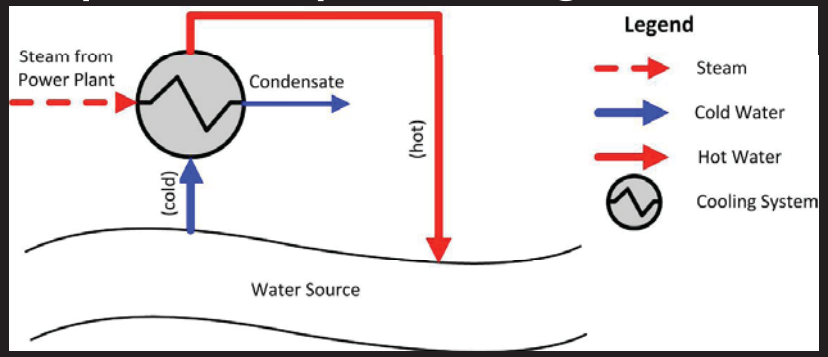
There are two main cooling approaches for power plants

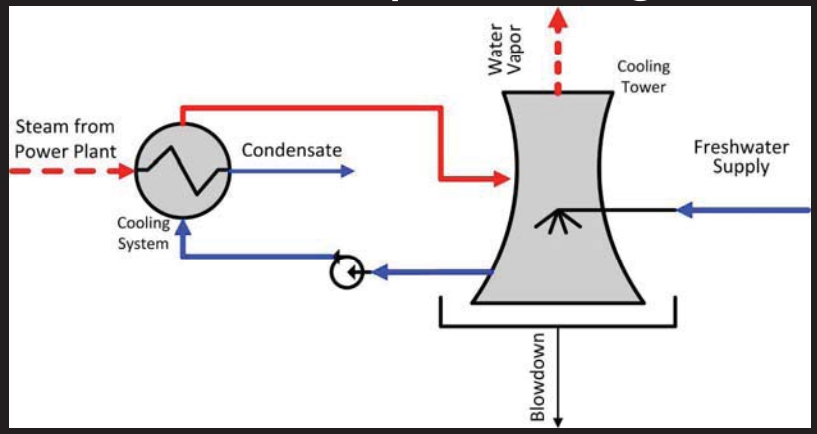
Open-Loop Cooling



Most water that is withdrawn is returned…but at a higher temperature

Withdraws more, consumes less

Closed-Loop Cooling



Most water that is withdrawn is consumed

Withdraws less, consumes more

[Stillwell *et al.* 2009]

Thermoelectric power is the largest user of water in the U.S.

	Closed-Loop (cooling tower)		Open-Loop	
Fuel	**Withdrawals [gal/kWh]**	**Consumption [gal/kWh]**	**Withdrawals [gal/kWh]**	**Consumption [gal/kWh]**
Nuclear	**1.0**	**0.7**	**42.5**	**0.4**
Solar CSP	**0.8**	**0.8**	**N/A**	**N/A**
Coal	**0.5**	**0.5**	**35.0**	**0.3**
Natural Gas (combined cycle)	**0.23**	**0.18**	**13.8**	**0.1**
Natural Gas (combustion turbine)	**negligible**	**negligible**	**negligible**	**negligible**

Consumption: ~0.1 to 0.8 gal/kWh

Withdrawals: ~0.2 to 42.5 gal/kWh

[Stillwell *et al*. 2011]

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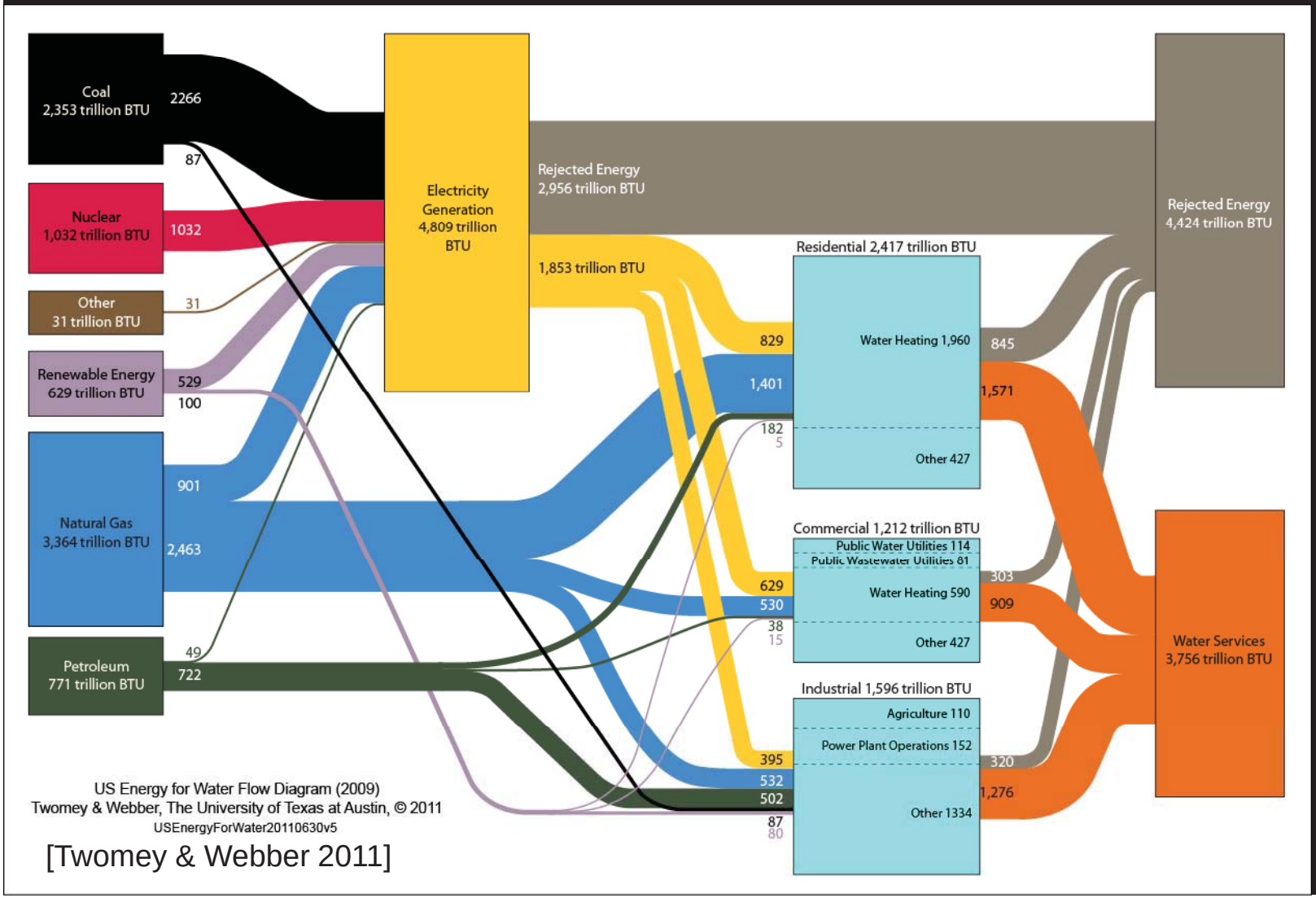
We use water from a variety of sources for a variety of purposes with a variety of energy requirements



[Twomey & Webber 2011]

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The water sector uses a lot of energy

- **Energy is used to produce, move, heat, and treat water**
  - **About 5% just for residential & commercial sectors**
  - **250-300 MMT of CO_2 emissions (~5% of total)**
- **California is an extreme example**
  - **CA spends ~19% of its electricity on water**
    - **Primarily for end-use**
    - **SoCal uses a lot of energy for conveyance**
  - **similar story wherever water is scarce**

[Twomey & Webber 2011, CEC 2005]

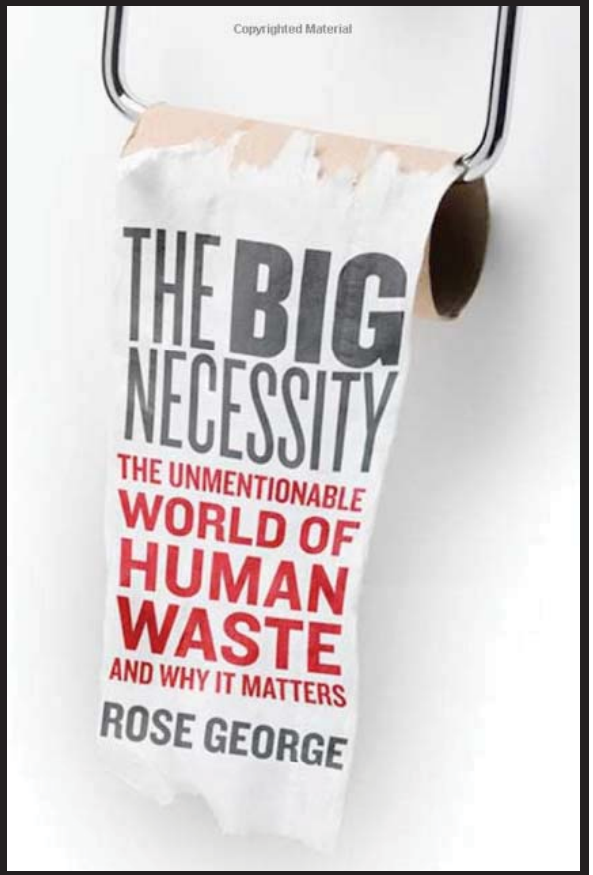
Water/wastewater collection, treatment, and distribution requires energy

	Source/Treatment Type	Energy [kWh/Mgal]
Water	Surface Water	1,400
	Groundwater	1,800
	Brackish Groundwater	3,900-9,750
	Seawater	9,780-16,500
Wastewater	Trickling Filter	955
	Activated Sludge	1,300
	Advanced Treatment w/o Nitrification	1,500
	Advanced Treatment w/ Nitrification	1,900

[Stillwell *et al*. 2011]

Wastewater treatment requires energy

- **Sanitation differentiates**
  - **Healthy & wealthy = sanitation**
  - **Sick and poor = no sanitation**
- **Reclaimed water**
  - **Advanced treatment is less energy-intensive than desalination**
  - **“toilet to tap” (Singapore, ISS,…)**



The energy-water relationship is already under strain

The energy-water relationship is already under strain

- **Water Constraints Become Energy Constraints**
  - ***Heat Waves:*** **thermal pollution limits can constrain power plant operation**
  - ***Droughts:*** **water scarcity can prohibit power plant operation or fuels production**

- **Energy Constraints Become Water Constraints**
  - ***Blackouts*** **disrupt water treatment & distribution**

The energy-water relationship is already under strain

- **Record heat wave in France in 2003 caused nuclear power plants to dial back because of water temperature limits**
- **"Droughts could close nuclear power plants: Southeast water shortage a factor in huge cooling requirements"**

  [*Associated Press*, 1/23/08]
- **Power generation reductions for at least one Texas power plant due to falling cooling reservoir levels**

  [*Houston Chronicle*, 8/25/11]
- **Civil War Between Georgia and Tennessee?**
  - **"Georgians want access to Tennessee water"**
  - **move the border 1 mile north to give GA access to the Nickajack Reservoir on the dammed Tennessee river**

  [*The Tennessean*, 2/8/08]

"Las Vegas Running Out of Water Means Dimming Los Angeles Lights"

Worst 10-year drought in recorded history

Hoover Dam provides electricity to 750,000 people in LA

[*Bloomberg*, 2/26/09]

A white "bathtub ring" on canyon walls at Lake Mead National Recreation Area in July shows mineral deposits left by higher levels of water near the Arizona Intake Towers at the Hoover Dam. (Ethan Miller, Getty Images)

- **The surface of Lake Mead has dropped 100 feet in six years. If it drops 50 feet lower, Las Vegas could lose an intake that supplies 40 percent of its water. Simultaneously, "Hoover Dam stops generating electricity"** [*Denver Post*, 1/29/08]

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Trends imply that strain in the energy-water relationship will be exacerbated

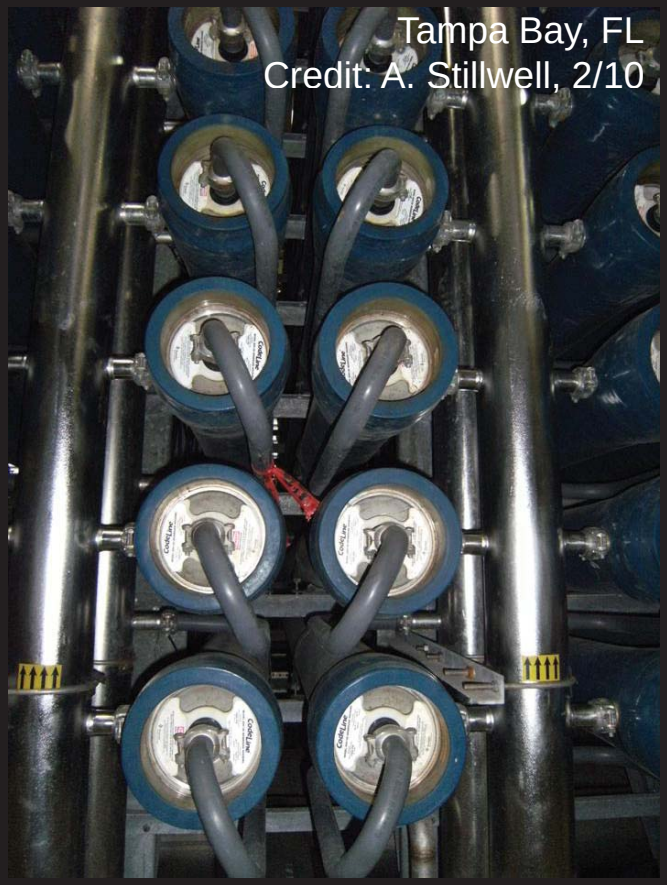
Trends imply that strain in the energy-water relationship will be exacerbated

- **Population growth**
  - **drives up total demand for energy & water**
- **Economic growth**
  - **drives up per capita demand for energy & water**
    - **might be counteracted by efficiency**
- **Climate change**
- **Policy choices**
  - **movement towards energy-intensive water and water-intensive energy**

We are moving towards more energy-intensive water

- **Stricter water/wastewater treatment standards**
- **Deep aquifer production**
- **Desalination**
  - **Worldwide capacity to double by 2025**
  - **Middle East, London, San Diego, TX**

  [*Economist*, 6/7/08]
- **Long-haul pipelines and inter-basin transfer**
  - **China, India, Texas**
- **Desalination plus long-haul transfer**



Tampa Bay, FL
Credit: A. Stillwell, 2/10

We are moving towards more water-intensive energy

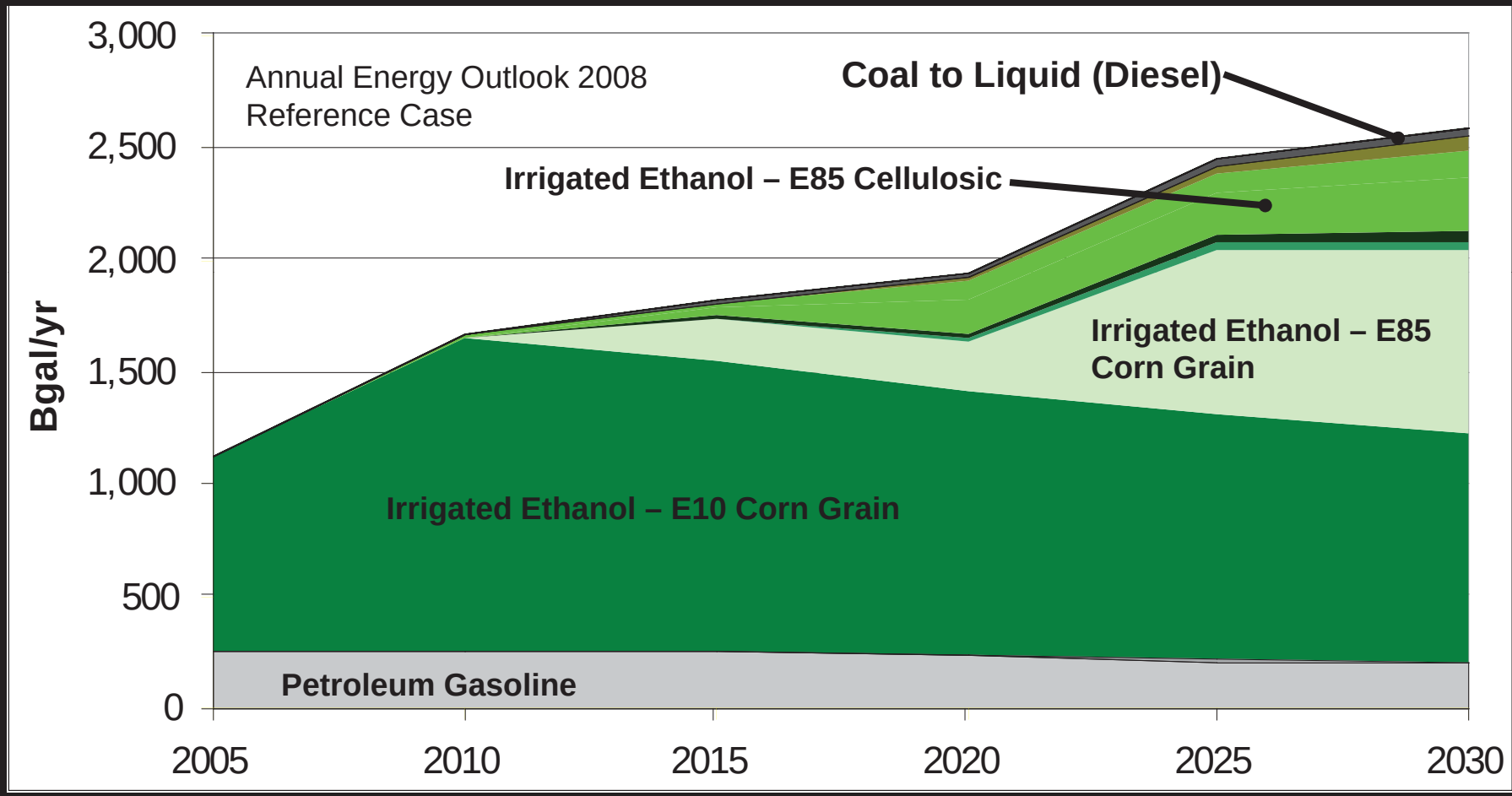
- **Nuclear power, Solar CSP**

(Note: we are also choosing water-lean energy forms, like solar PV, wind, natural gas)

- **Future transportation fuels are especially thirsty**
  - **Unconventional fossil fuels (2-4x worse)**
  - **Natural Gas (better to 1-2x worse)**
  - **Electricity (2-3x worse)**
    - **Good with wind/solar PV, worse with nuclear**
  - **Hydrogen (1-500x worse)**
    - **Good with wind/solar PV, worse with nuclear**
  - **Biofuels (1-1000x worse)**

[King & Webber 2009]

Federal policy essentially mandates increases in water consumption for transportation fuels

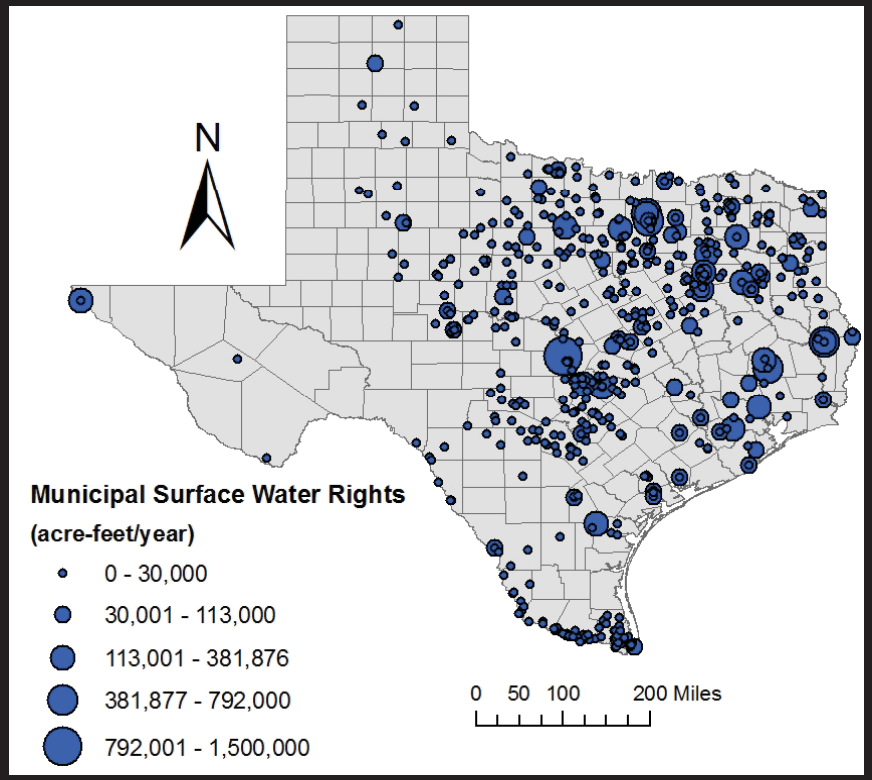


[King *et al*. 2010]

The view from Texas is particularly interesting

Rights to surface water in Texas vary with geography

Municipal Water Rights (ac-ft/yr)



- **Large cities and river authorities hold large rights**
- **Availability for new water rights depends on existing allocations**

[Data from TCEQ]

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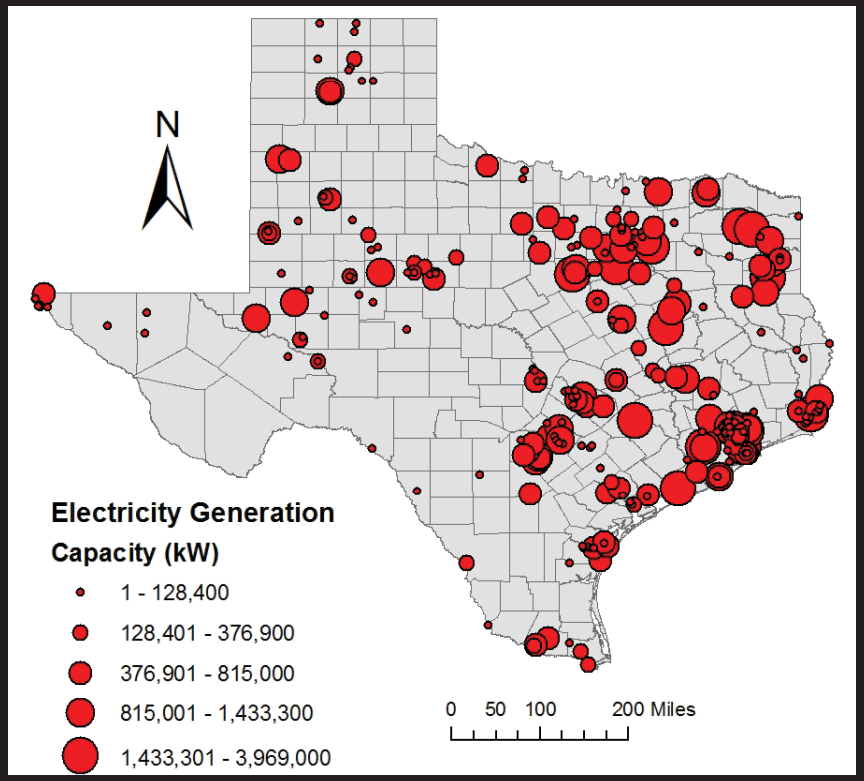
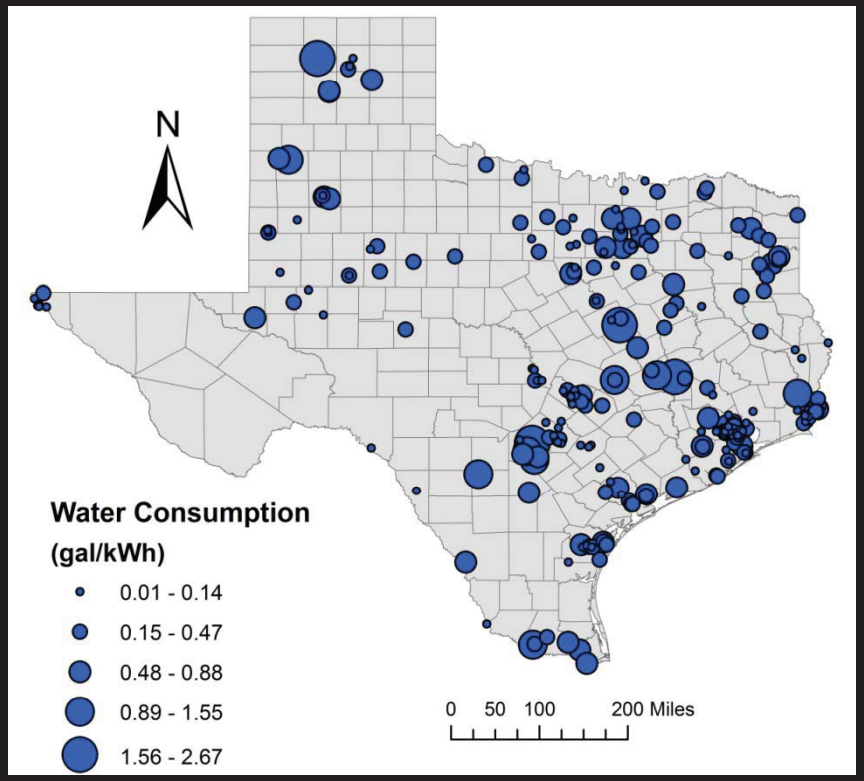
Large power plants are large water users

Generation Capacity (kW)



Water Consumption (gal/kWh)



Texas consumes 157 billion gallons of water to produce 400 billion kWh annually (more than any other state)

[Data from TWDB]

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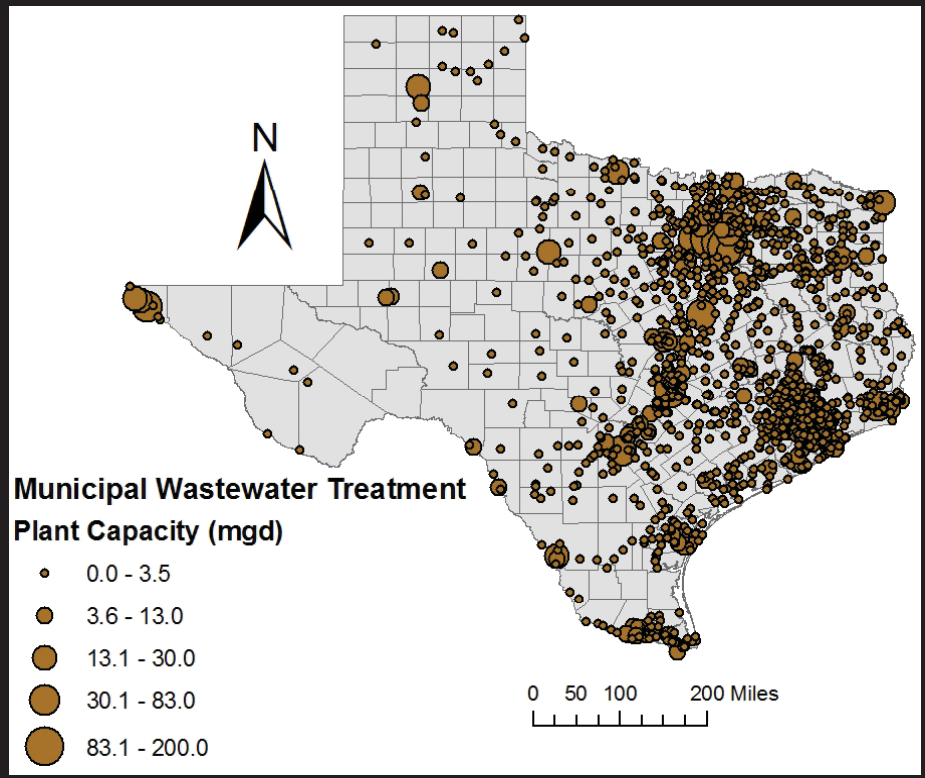
Large wastewater treatment plants are near large populations

- **Wastewater treatment alone requires 25% more energy per volume than water treatment and distribution combined**
- **Unit energy kWh/Mgal varies widely with plant size**

Wastewater Treatment (MGD)



[Data from TCEQ, EPA]

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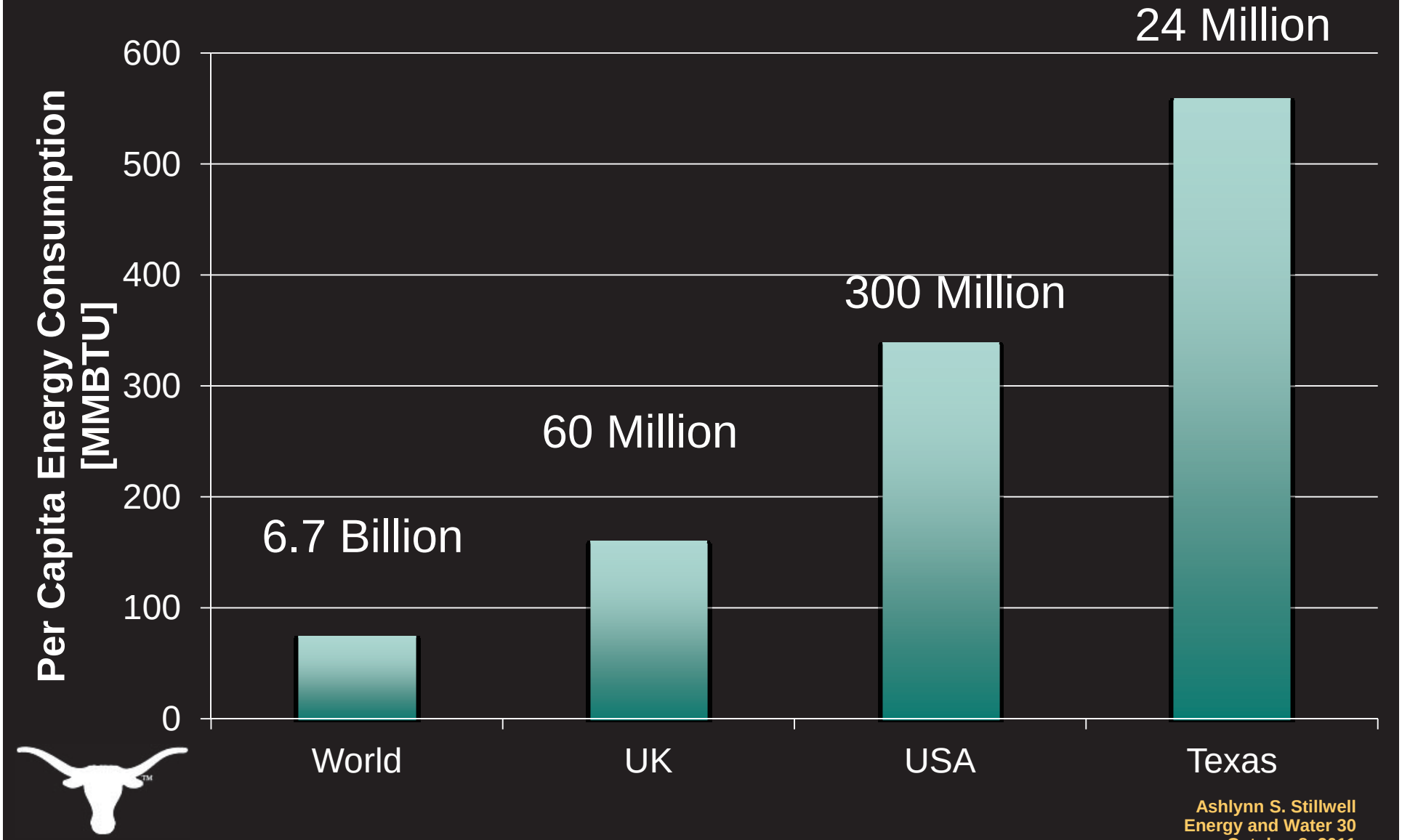
Annual per capita energy consumption varies from 75 (global) to 560 (Texas) MMBTU



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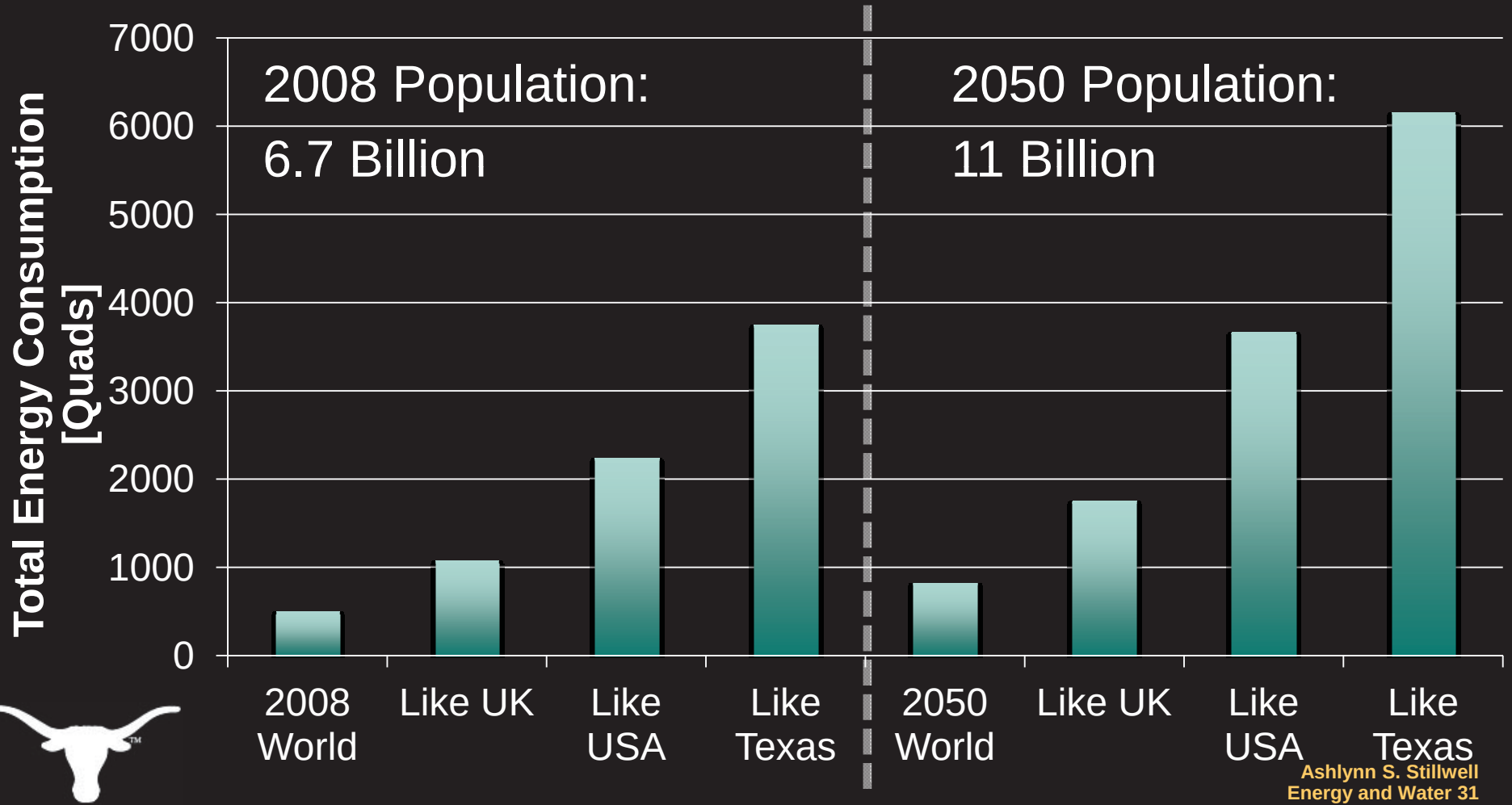
Total energy consumption will increase if the world changes per capita consumption to match the UK, USA, or Texas



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We consume vast sums of energy on water

Public restrooms usually use high quality drinking water to flush the toilets

Dogs also get the highest quality drinking water

- **Texans consume ~135-250 gallons of drinking water per person per day**
- **Water is often free or cheap at point of use**

Credit: Evelyn Webber 2009

Rainwater harvesting is one way to reduce strain on the energy-water relationship

- **Offsets use of energy-intensive drinking water**
- **Reduces pumping costs by providing a distributed water supply**
- **Can match intended use with water quality**
- **Reduces surface runoff and associated stormwater treatment**

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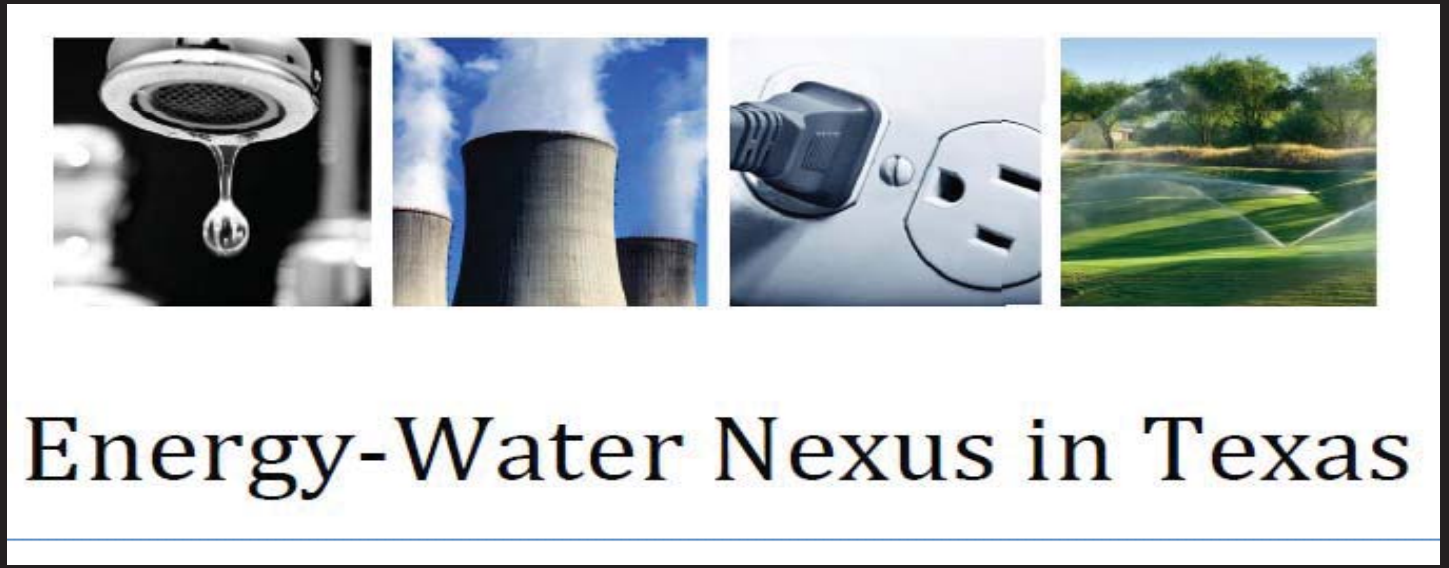
Good news: energy conservation and water conservation are synonymous

- **Conserving water will conserve energy**
- **Conserving energy will conserve water**

Energy-Water Nexus in Texas report



http://www.edf.org/documents/9479_Energy-WaterNexusinTexasApr2009.pdf

Questions?

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