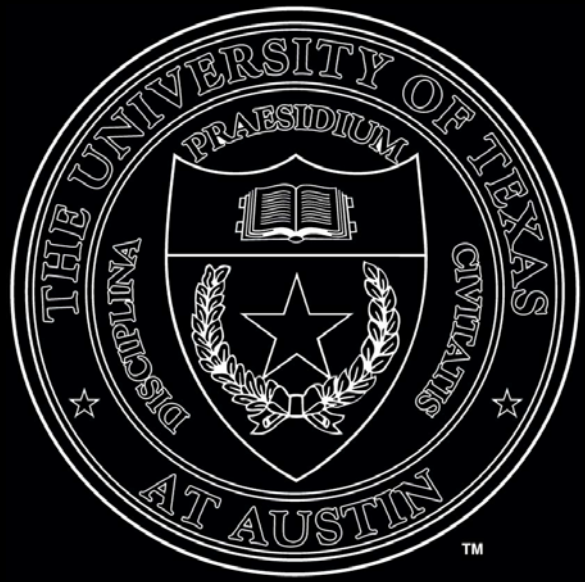

The Nexus of Energy & Water

MPC and Openlands
Chicago, Illinois

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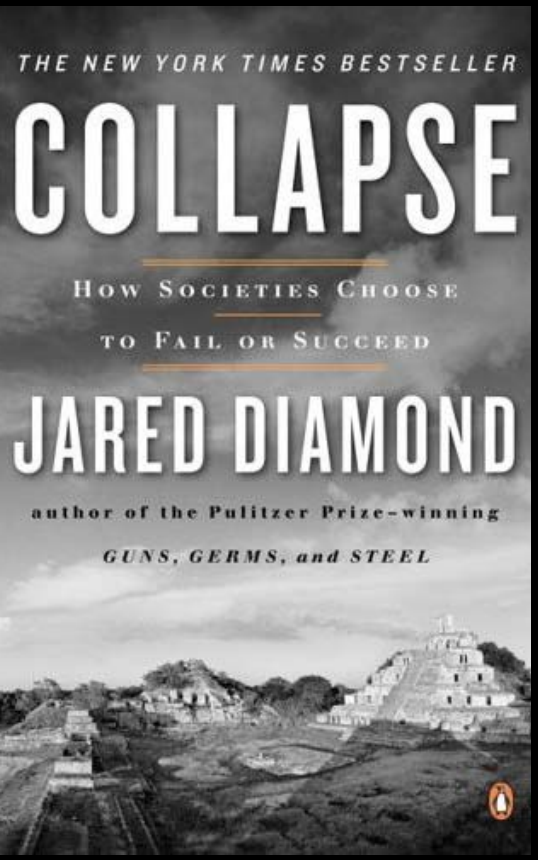
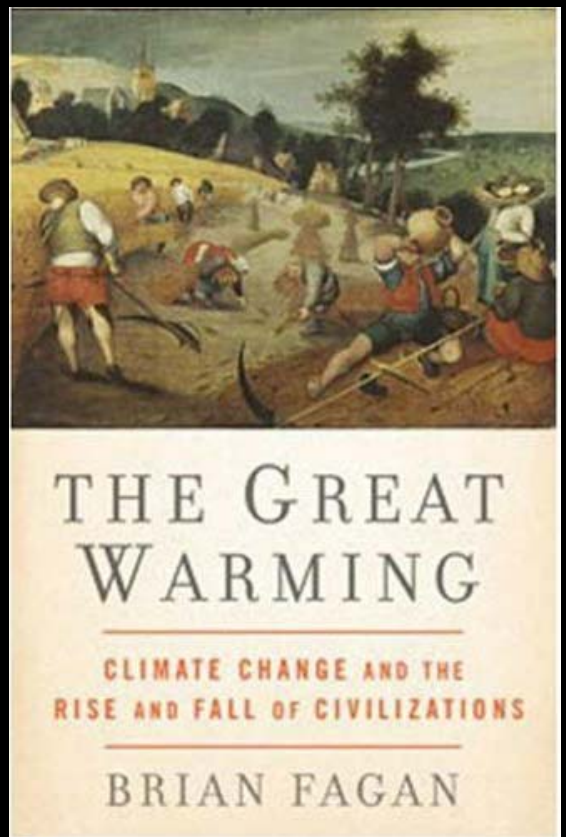
August 3, 2010

Sustained Droughts Are Correlated with Collapsed Civilizations





Chinese dynasties

- **Tang (907 CE), Yuan, Ming**
- **Source: *Science (11/08)***

Roman empire

- **Source: American Geo. Institute (3/09)**

Meso America

- **Maya (900 CE)**
- **Source: *Science (11/08)***

Khmer Empire

- **Peaked in 13th century**
- **Source: *Nat Geo (July 2009)***

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Energy and Water Are the Two Critical Aspects to Modern Civilization

- **More critical than food:**
  - **modern food production requires energy & water**
- **More critical than healthcare:**
  - **top global public health problem: access to clean water & sanitation (e.g. wastewater treatment)**
- **More critical than law & order:**
  - **Katrina: lawlessness follows blackouts (food spoilage) and lack of water availability**

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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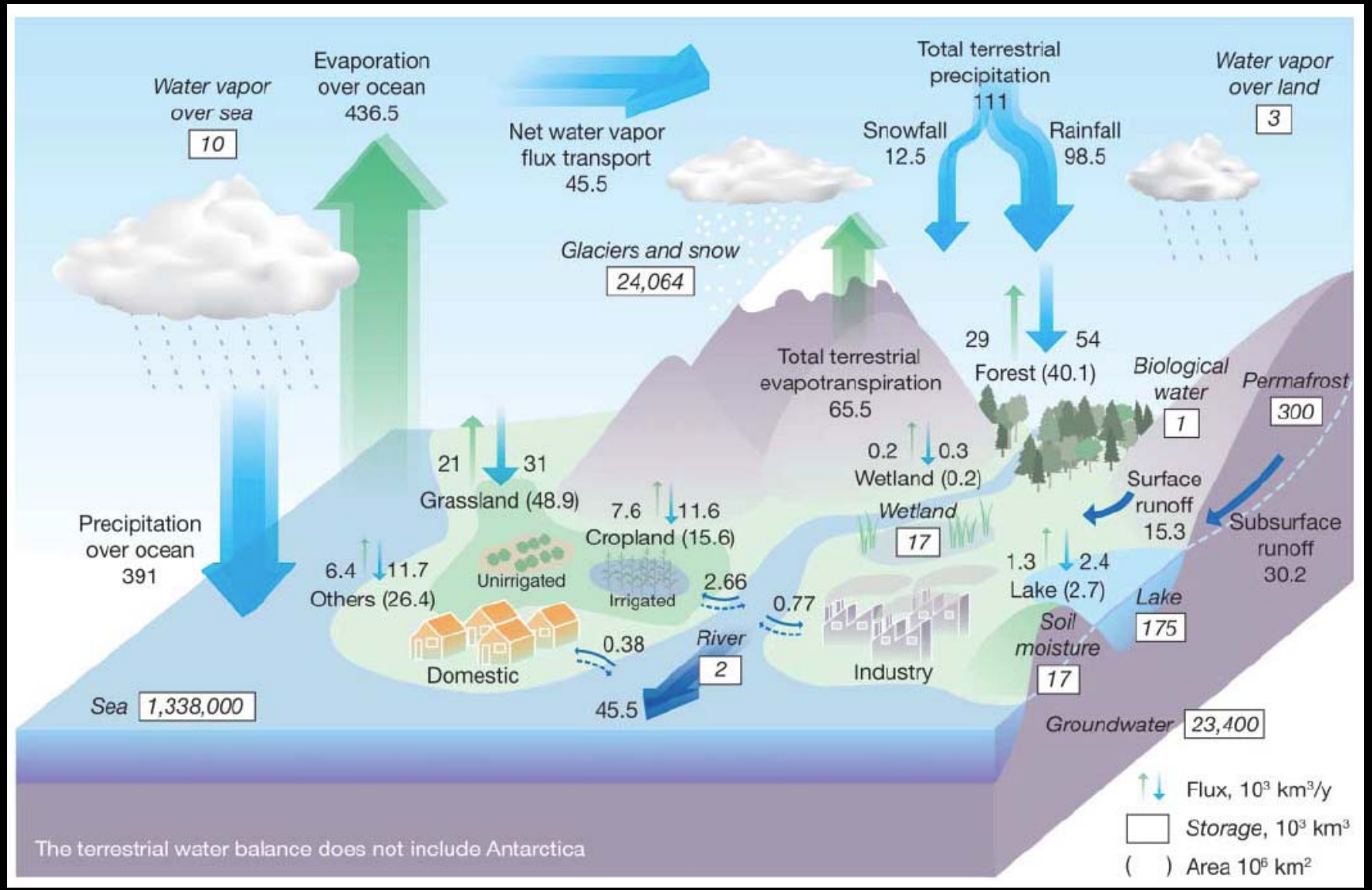
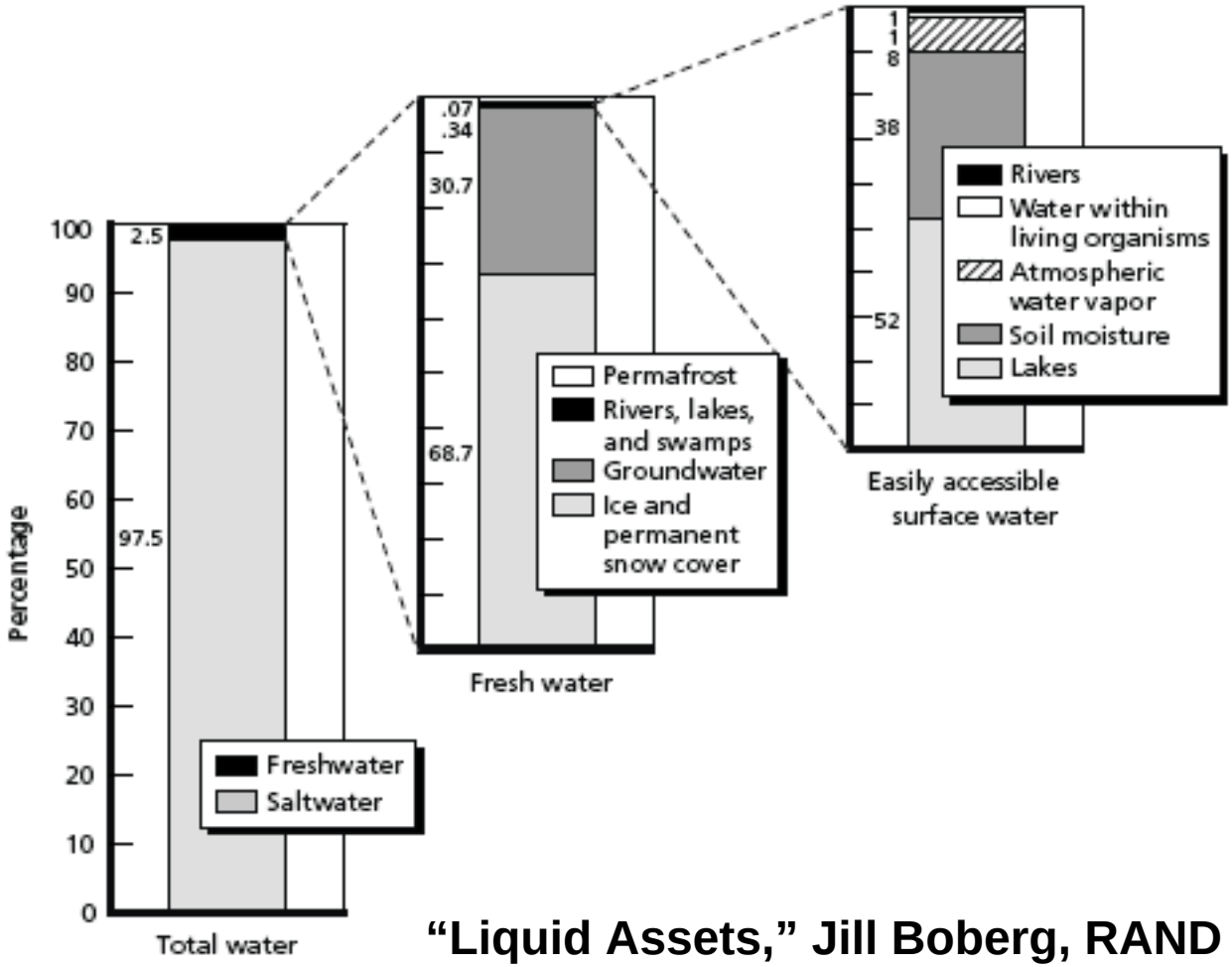
The Hydrological Cycle is Global



REVIEW: Global Hydrological Cycles and World Water Resources, Taikan Oki1,2,3*† and Shinjiro Kanae1,4*, Science, August 25, 2006

Freshwater Is A Small Part of the Total Supply



"Liquid Assets," Jill Boberg, RAND

There Are 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**

Energy and Water are Interrelated

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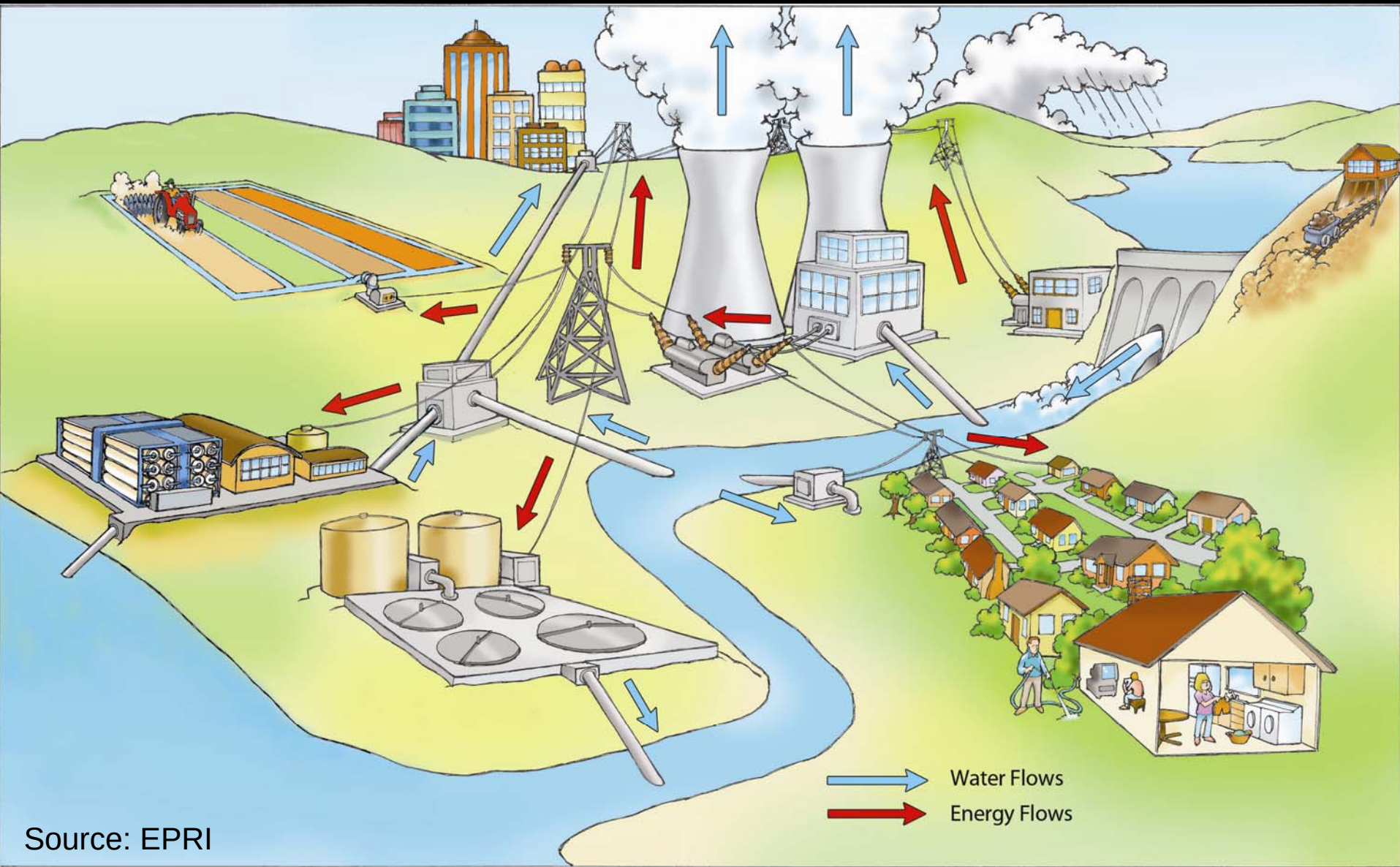
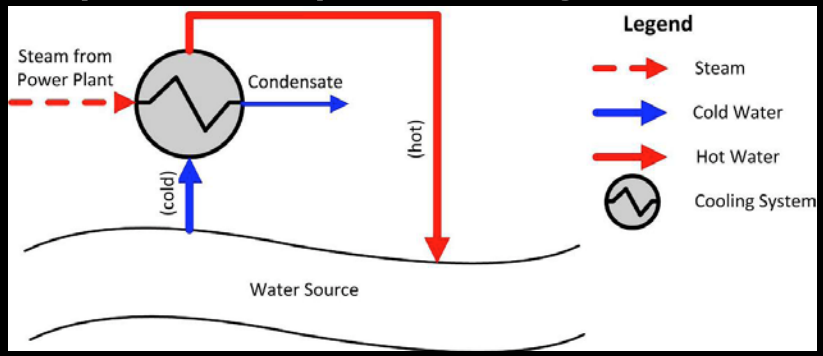
Energy and Water are Interrelated



Source: EPRI

There Are Two Main Cooling Approaches

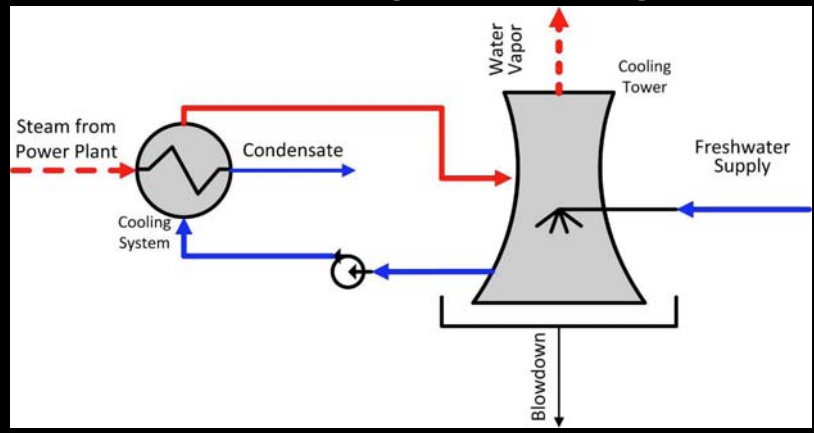
Open-Loop Cooling



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

[Source: Stillwell, 2009]

The Thermoelectric Power Sector is the Largest User of Water in the US

[Source: Stillwell, 2009]

	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

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Cooling Towers Are Large Structures

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

Biofuels Are Very Water-Intensive

[Source: King & Webber, 2009]

- **Processing/Refining**
  - **1-3 L_{H_2O}/ L_{fuel} for petroleum fuels**
  - **3-6 L_{H_2O}/ L_{fuel} for biofuels**
- **Growth/Production**
  - **~780 L_{H_2O}/ L_{fuel} for irrigated corn in the US**
    - **15 to 260 L_{H_2O}/ km for corn ethanol (withdrawals)**
    - **3 to 146 L_{H_2O}/ km for corn ethanol (consumption)**
  - **~510 L_{H_2O}/ L_{fuel} for irrigated soy in the US**
    - **~35 L_{H_2O}/ km for soy biodiesel (withdrawals)**
    - **~28 L_{H_2O}/ km for soy biodiesel (consumption)**

Water Quality

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Oil Spills Also Impact Water Resources

Santa Barbara Channel (1969)

Exxon Valdez (1989)

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Coal spills Happen, too--it's not just oil spills

The New York Times December 24, 2008

J. Miles Cary/Knoxville News Sentine

A Tennessee Valley Authority employee surveyed a home on Tuesday.

- "Coal Ash Spill Revives Issue of Its Hazards", NYT, 24 Dec 2008
  - The spill released about 300 million gallons of sludge & water
  - Much larger than Exxon Valdez

"…the spill reignited a debate over whether the federal government should regulate coal ash as a *hazardous* material. Similar ponds and mounds of ash exist at hundreds of coal plants around the nation…<snip>…the Edison Electric Institute estimated that the industry would have to spend up to $5 billion in additional cleanup costs if the substance were declared *hazardous*."

Coal Ash Spill Revives Issue of Its Hazards

J. Miles Carey/Knoxville News Sentinel, via Associated Press

Fifteen homes like this one in Harriman, Tenn., were flooded with fly ash sludge on Monday after a storage pond wall broke.

By SHAILA DEWAN
Published: December 24, 2008

The Water Sector Uses a Lot of Energy

Michael E. Webber, Ph.D.

The Water Sector Uses a Lot of Energy

- Energy is used to produce, move, heat and treat water
- Largest energy user in most municipalities
    - most WWTPs are municipally-owned
- 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

Water Production, Treatment and Distribution Requires Energy

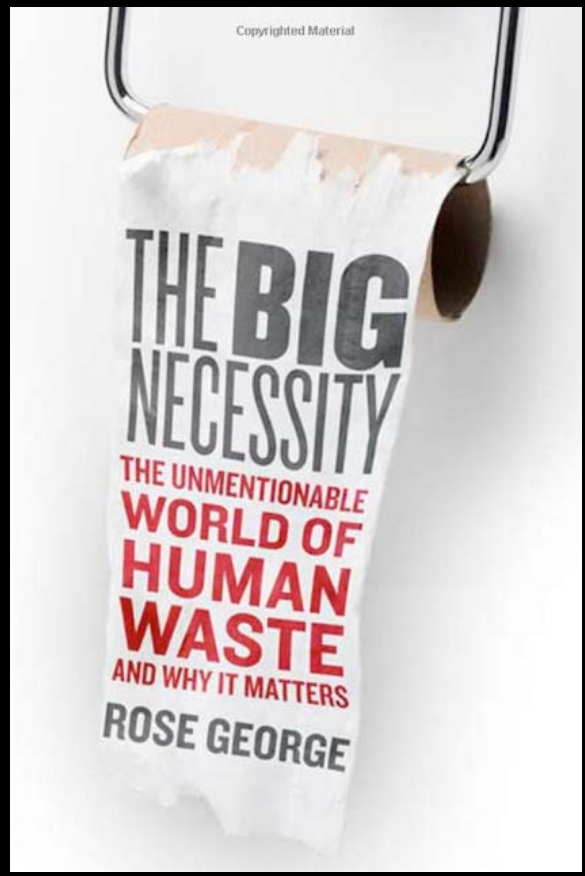
Source/Treatment Type	Energy Use [kWh/Mgal]
Surface Water	1,400
Groundwater	1,800
Brackish Groundwater	3,900-9,750
Seawater	9,780-16,500

[Source: Stillwell, 2009]

Wastewater Treatment Requires Energy

[Source: Stillwell, 2009]

Treatment Type	Energy [kWh/Mgal]
Trickling Filter	955
Activated Sludge	1,300
Advanced Treatment w/o Nitrification	1,500
Advanced Treatment w/ Nitrification	1,900

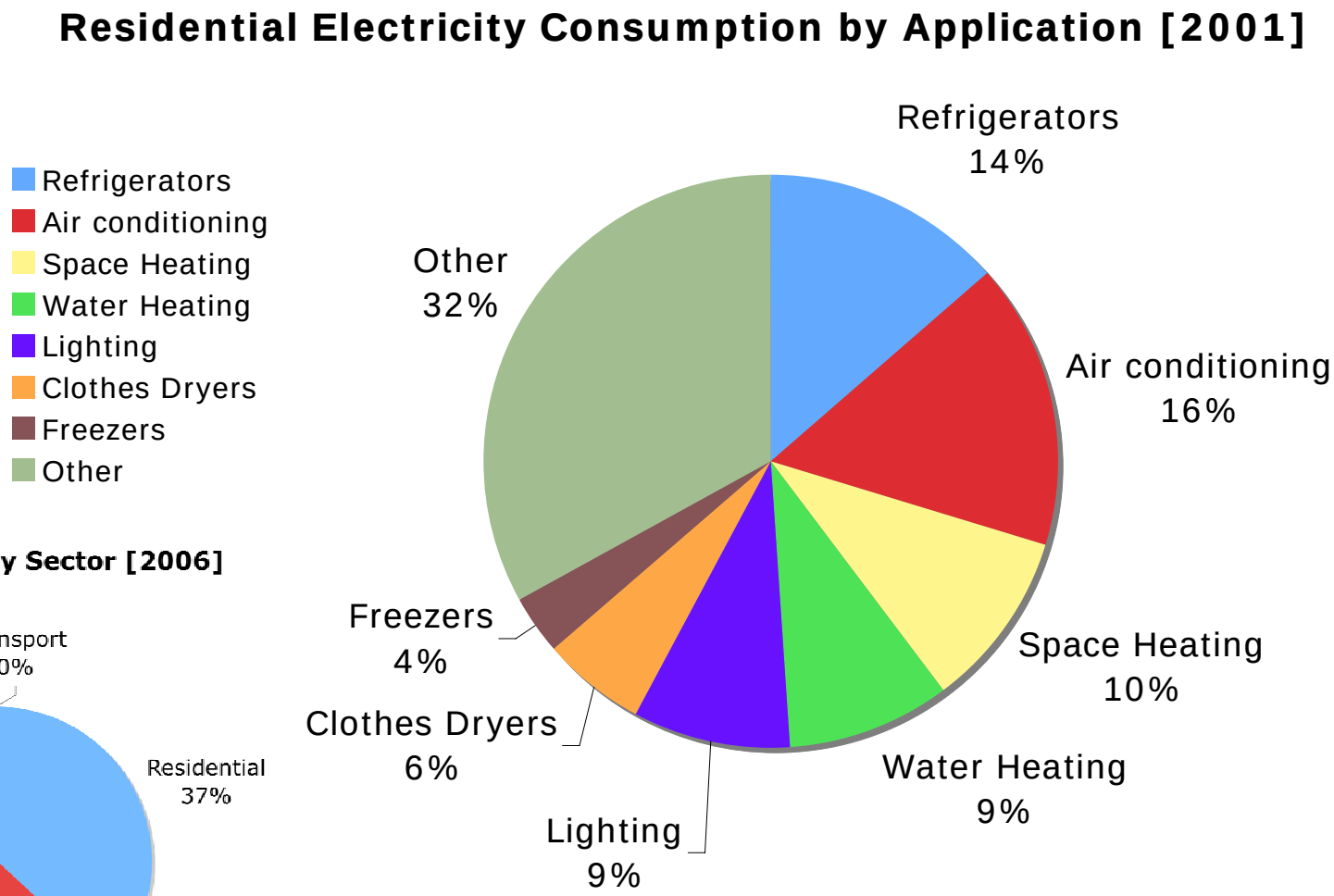


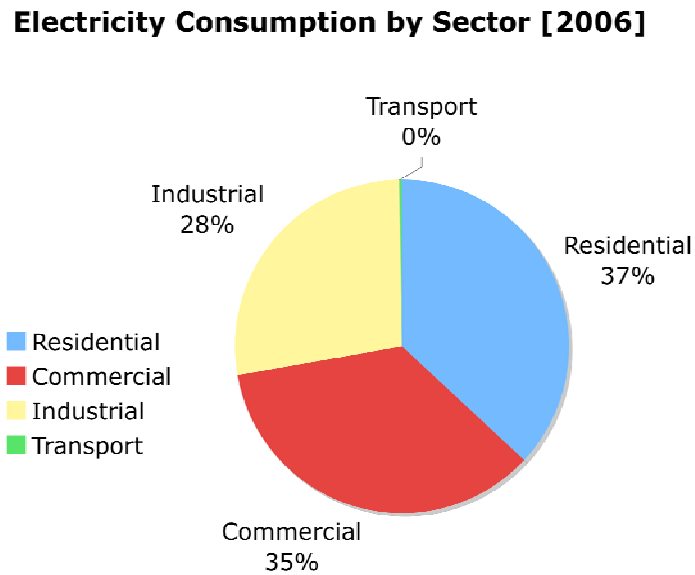
Advanced treatment with nitrification, followed by water treatment, is less energy-intensive than desalination

Reclaimed water: “toilet to tap” (Singapore, ISS,…)

Water Heating Is One of the Single Largest Users of Residential Electricity in the USA

Source:
U.S. DOE





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Americans 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

Credit: Evelyn Webber 2009

- **Texans consume ~150 gallons of drinking water per person per day**
- **Texans consume >25 MMBTU per capita annually to heat, treat and move drinking water**

The Energy-Water Relationship Is Already Under Strain

Michael E. Webber, Ph.D.

The Energy-Water Relationship Is Already Under Strain

- **Record heat wave in France in 2003**
  - **nuclear power plants dialed back because of inlet water temperatures (less cooling capability) and rejection water temperature limits**

- **"Droughts could close nuclear power plants: Southeast water shortage a factor in huge cooling requirements"**
  - ***Associated Press*, January 23, 2008**

- **Civil War Between Georgia and Tennessee?**
  - **"Georgians want access to Tennessee water"**
  - ***The Tennessean*, February 8, 2008**
  - **move the border 1 mile north to give GA access to the Nickajack Reservoir on the dammed Tennessee river**

"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.com, 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*, 1/29/2008**

Trends Imply That Strain in the Energy-Water Relationship Will Be Exacerbated

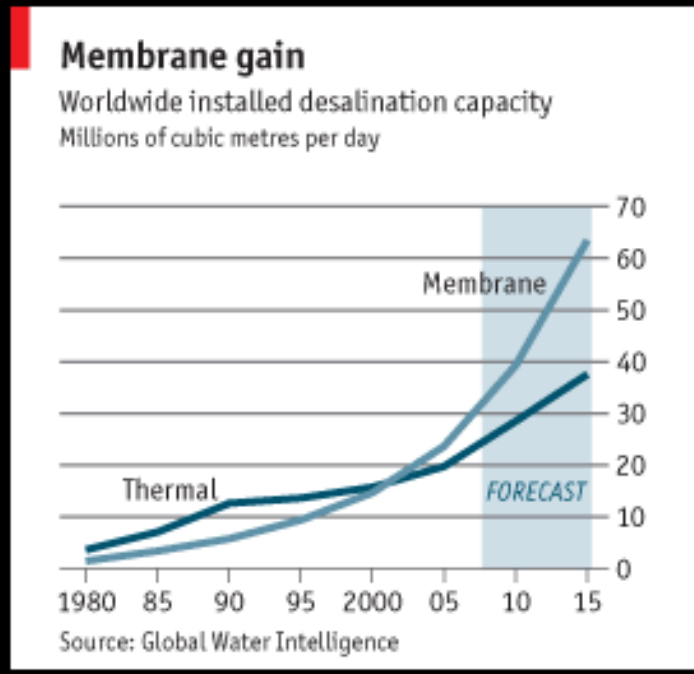
Michael E. Webber, Ph.D.

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**
- **Long-haul pipelines and inter-basin transfer**
  - **China, India, Texas**
- **Desalination plus long-haul transfer**



Economist, June 7, 2008

We Are Moving Towards More Water-Intensive Energy

- **Nuclear power, Solar CSP**
  - **Note:** also choosing water-lean energy forms
    - 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)**

[Source: King & Webber, 2009]

Transportation sector becomes major water user

- **This analysis shows water for LDVs**
  - **2005 ~ 1,200 Bgal/yr (3% US total)**
    - **Petroleum part is ~400 Bgal/yr**
  - **2030 ~ 2,700 Bgal/yr (7% US total)**
- **US Total water consumption**
  - **36,500 billion gallons in 1995 (USGS, 1998)**
- **Comparisons**
  - **Thermoelectric sector ~ 3% – 4%**
  - **Irrigation ~ 80%**
    - ***Biofuels are now a <u>subset</u> of irrigation***

[Source: King & Webber, 2010]

There Are Some Solutions Being Developed

- ***Pecan Street Project:***
  - **$30M smart grid demonstration project in Austin, TX (DoE, NSF, City of Austin,…)**
    - **with the local utility & 11 corporate partners**
  - **Smart Grid (for electricity) and Smart Water**
- ***Conservation and Reuse* in the residential sector**
- ***Energy Recovery from WWTPs***
- ***Dry-cooling To Spare Water Rights In TX***
- ***Incorporating water into grid planning***
  - **$4M study with the DoE**

There Are Policy Pitfalls At The Energy-Water Nexus

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Example of Disaggregated Energy and Water Policymaking In the USA

- **Funding and oversight mechanisms are separate**
  - **Energy planners assume they have the water they need**
  - **Water planners assume they have the energy they need**
- **Multitude of agencies, committees, etc. w/o clear authority**
- **Hierarchy of policymaking is dissimilar**

  ***Energy*: top-down**
  - **powerful federal energy agencies**

  ***Water*: bottom-up**
  - **powerful local water agencies**

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Water Data Are Sparse, Error-prone, and Inconsistent in the USA

- **USGS data-collection is infrequent**
  - **last survey on water consumption: 1995**
  - **last survey on water withdrawals: 2000 (2005)**

- **Errors in national databases (Egrid, etc.)**
  - **differences between state and federal reporting**
  - **different units**
    - ***East*: gallons**
    - ***West*: acre-feet**
  - **unclear definitions:**
    - **use vs. withdrawal vs. consumption vs. diversion**

Timescales Do Not Match for Energy and Water Policymaking

- **Water**
  - **Water plans are 50-100 years**
    - **Austin, TX debated a water plant for 40 years**
  - **Water data are backwards-looking**

- **Energy**
  - **Energy plans are 2-30 years**
  - **Energy data are backwards- and forward-looking**

There Are Policy Opportunities At The Energy-Water Nexus

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There Are Energy/Water Policy Tools Available

- **Collect, maintain and make available accurate, updated and comprehensive water data**
  - **IEA/EIA for energy data, who for water data?**
- **Conduct integrated policymaking**
- **Establish federal policy role for water *quantity***
  - **For example, EPA is in charge of water *quality***

There Are Energy/Water Policy Tools Available

- **Invest heavily in water-related R&D to match increases in energy-related R&D**
- **Focus bioenergy R&D on biofuels feedstocks that do not require freshwater irrigation (e.g. algae)**
- **Support reclaimed water use at powerplants, industry and agriculture**
- **Fund R&D for dry cooling systems at powerplants**
  - **Infrastructure swap-outs**

Good news: energy conservation and water conservation are synonymous

"Turn off the water, Daddy. The scientists need time."
– Evelyn Webber, 8 years old, March 2007

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

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