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Sandia National Laboratories

The Energy-Water Utility Interface
Emerging Trends and Drivers

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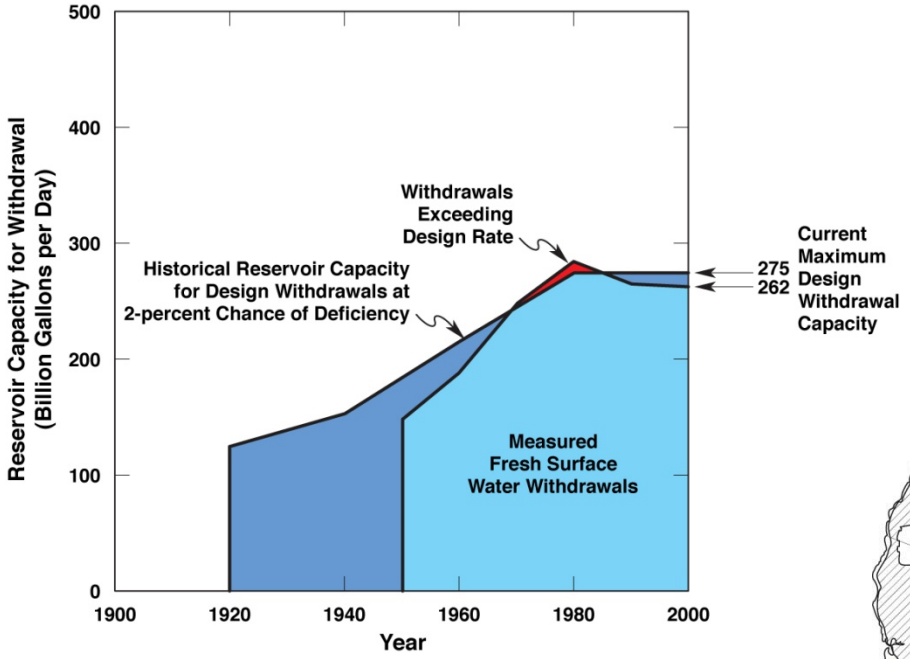
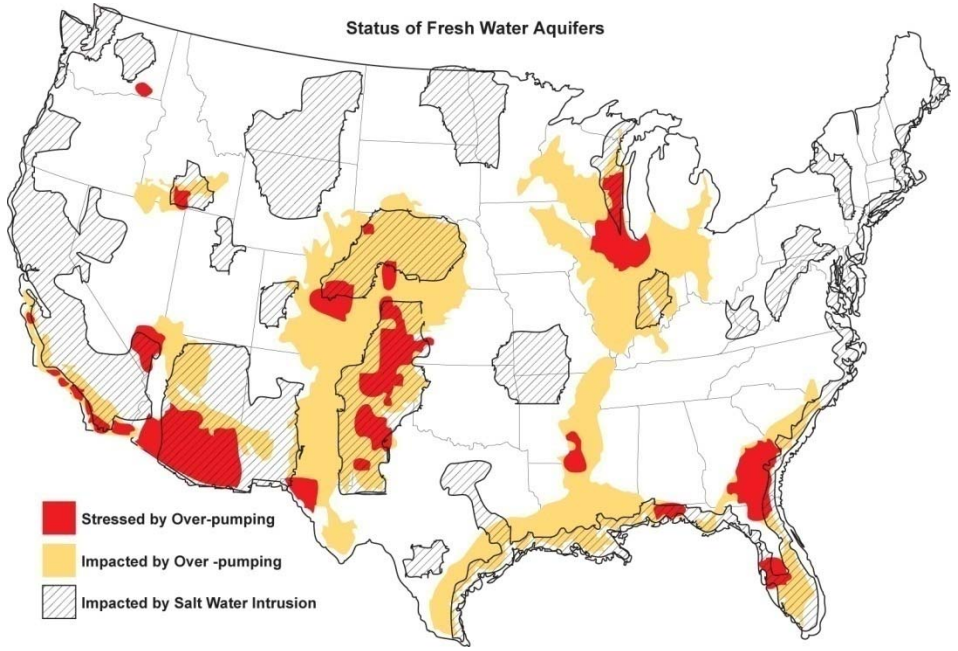
Growing Limitations on U.S. Fresh Surface and Ground Water Availability



(Based on USGS WSP-2250 1984 and Alley 2007)

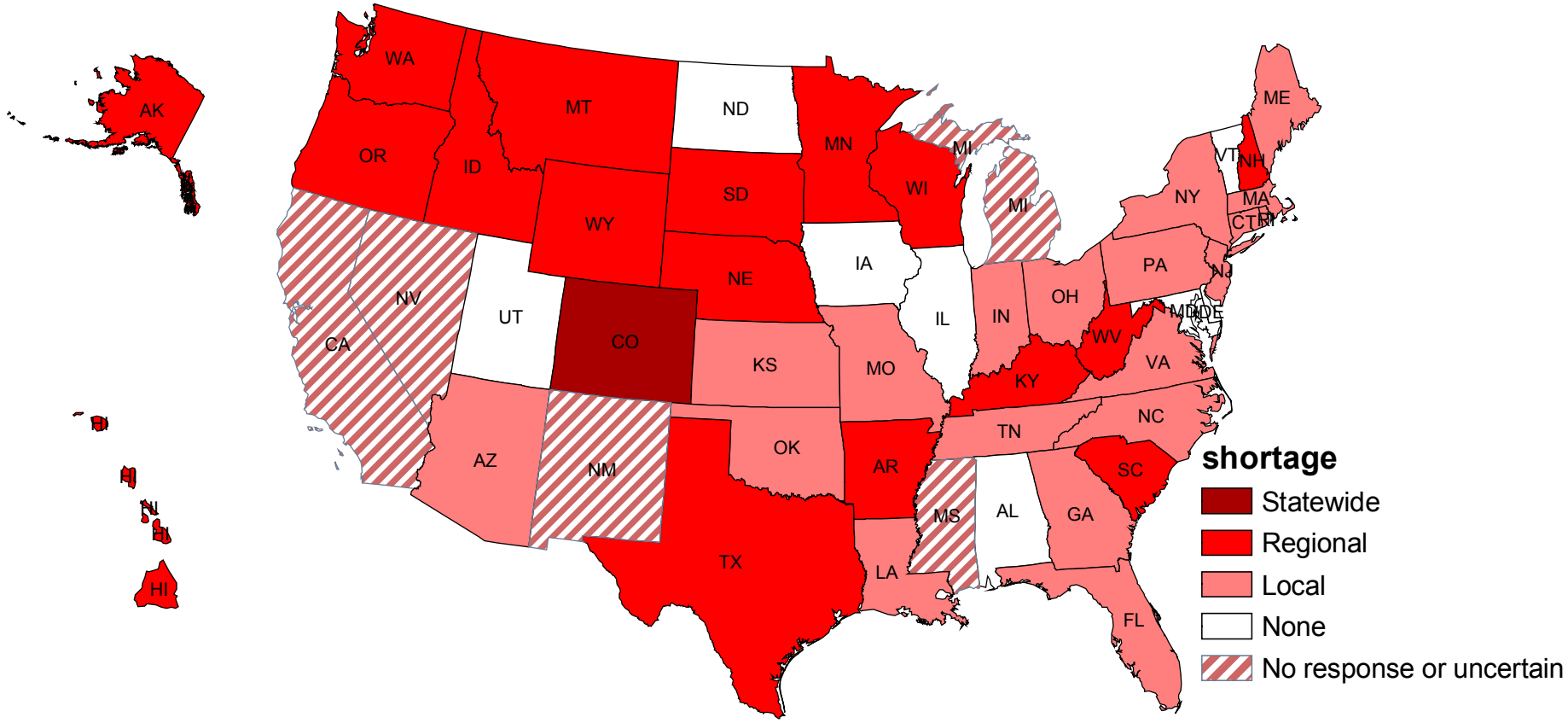
- Many major ground water aquifers seeing reductions in water quality and yield

- Little increase in surface water storage capacity since 1980
- Concerns over climate impacts on surface water supplies



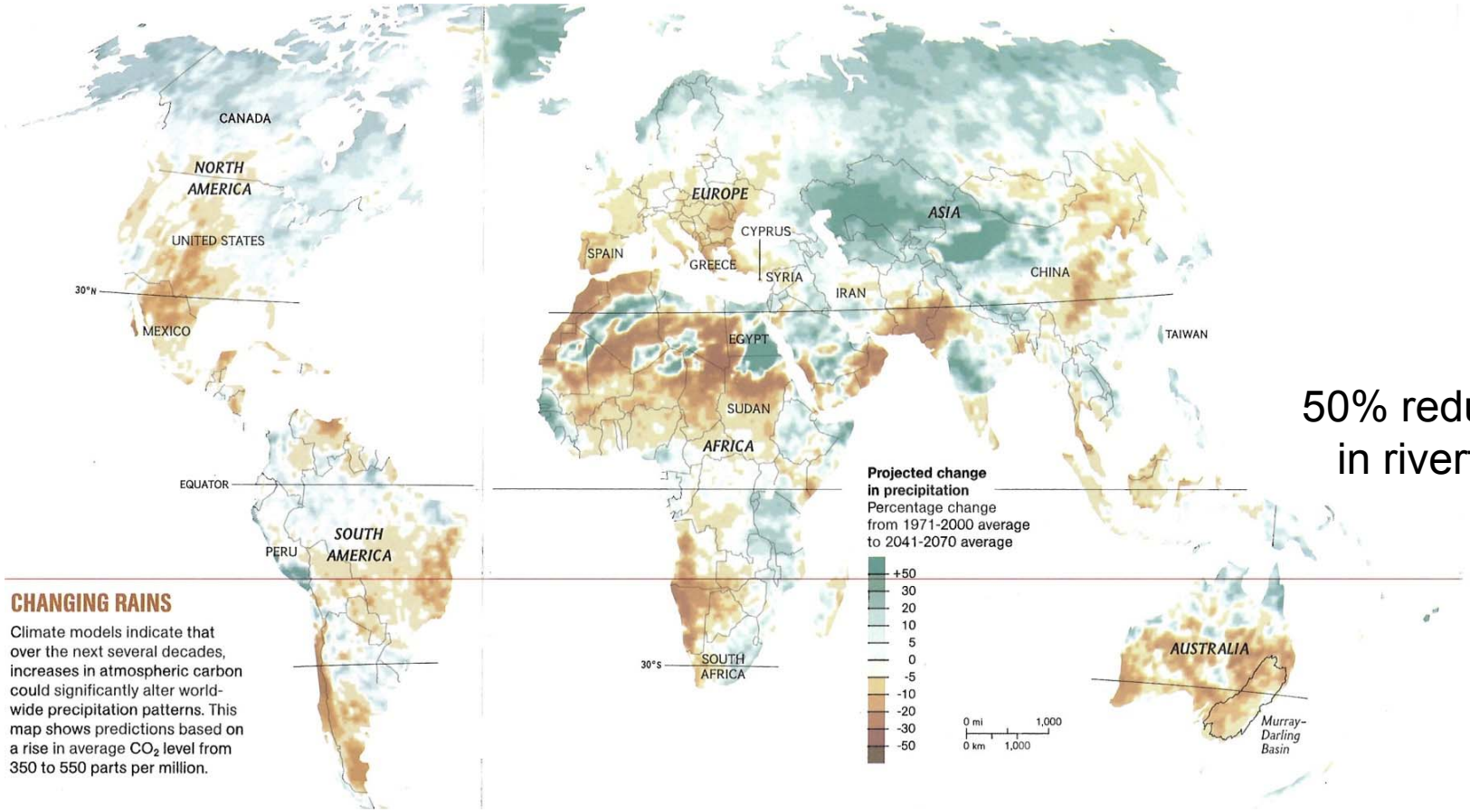
(Shannon 2007)

State Water Managers Expect Water Shortages Over The 2010 Decade Under Average Conditions



Source: GAO 2003

Climate Change Impacts on Water Availability and Energy Development



50% reductions in riverflows

"Water is where the climate change rubber meets the road"

Nat. Geo. April 2009 from IPCC

Dr. Bernie Zak, Sandia Sr. Climate Scientist, 2013

Water Use and Consumption for Electric Power Generation Alternatives

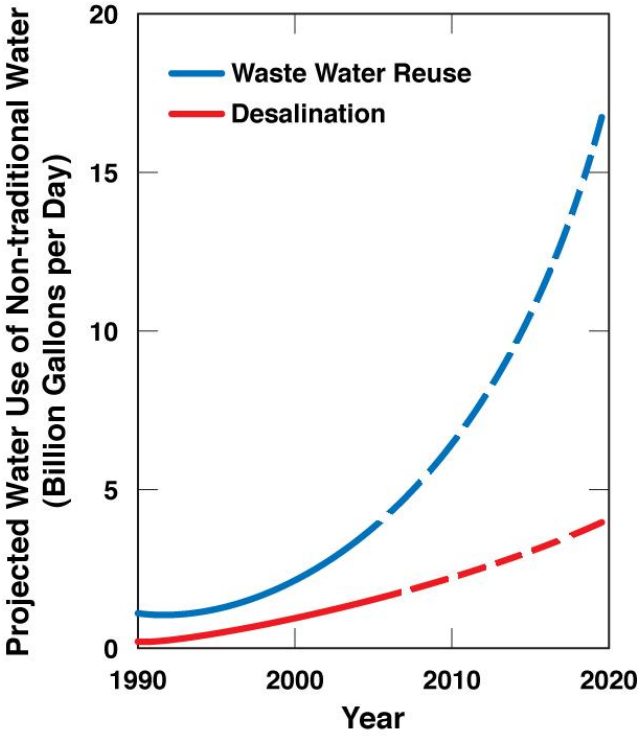
Plant-type	Cooling Process	Water Use Intensity (l/MWh$_e$)		
		Steam Condensing		Other Uses
		Withdrawal	Consumption	Consumption
Fossil/ biomass steam turbine	Open-loop	80,000–200,000	~800-1200	~120
	Closed-loop	1200–2400	1200–2000	
Nuclear steam turbine	Open-loop	100,000–240,000	~1600	~120
	Closed-loop	2000–4400	1600–2900	
Natural Gas Combined-Cycle	Open-loop	30,000–80,000	400	40
	Closed-loop	900	700	
Integrated Gasification Combined-Cycle	Closed-loop	800	700	600
Carbon sequestration for fossil energy generation	~80% increase in water withdrawal and consumption			
Geothermal Steam	Closed-loop	8000	2000-5500	200
Concentrating Solar	Closed-loop	3000	2900	40
Wind and Solar Photovoltaic	N/A	0	0	10

Water Consumption for Different Transportation Fuel Alternatives

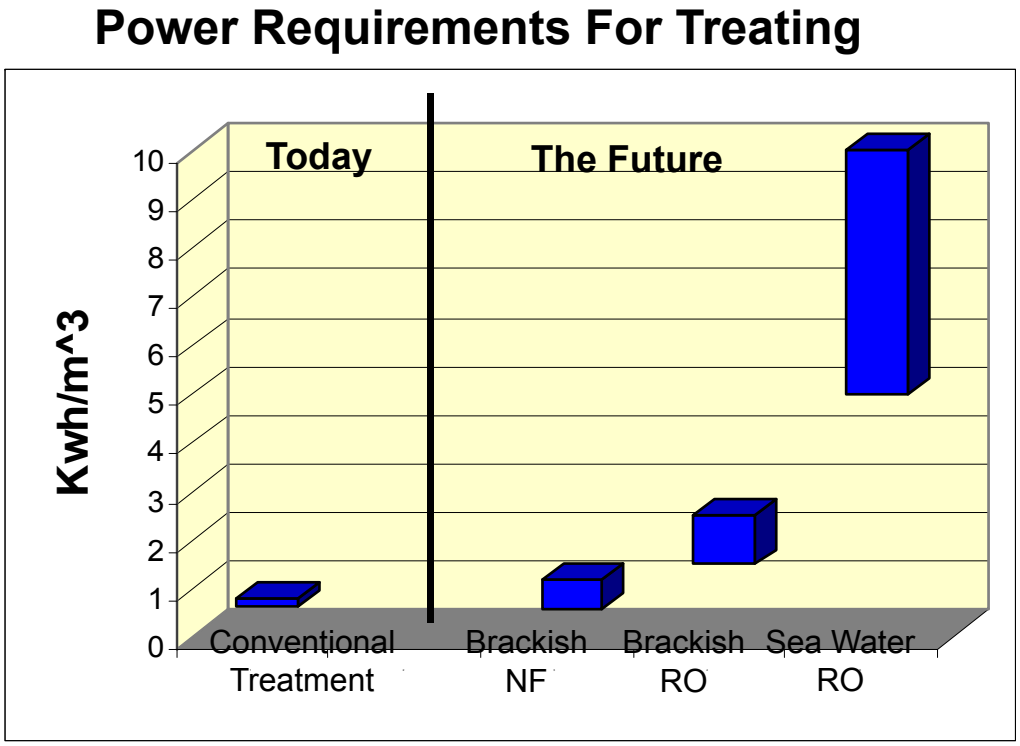
Fuel Type and Process	Relationship to Water Quantity	Relationship to Water Quality	Water Consumption	
			Water consumed per-unit-energy [gal / MMBTU] †	Average gal water consumed per gal fuel
Conventional Oil & Gas	Water needed to extract and refine; Water produced from extraction	Produced water generated from extraction; Wastewater generated from processing;		
- Oil Refining			7 – 20	~ 1.5
- NG extraction/Processing			2 – 3	~ 1.5
Biofuels	Water needed for growing feedstock and for fuel processing;	Wastewater generated from processing; Agricultural irrigation runoff and infiltration contaminated with fertilizer, herbicide, and pesticide compounds		
- Grain Ethanol Processing			12 - 160	~ 4
- Corn Irrigation for EtOH			2500 - 31600	~ 980*
- Biodiesel Processing			4 – 5	~ 1
- Soy Irrigation for Biodiesel			13800 – 60000	~ 6500*
- Lignocellulosic Ethanol and other synthesized Biomass to Liquid (BTL) fuels	Water for processing; Energy crop impacts on hydrologic flows	Wastewater generated; Water quality benefits of perennial energy crops	24 – 150 ‡§ (ethanol) 14 – 90 ‡§ (diesel)	~ 2 - 6 ‡§ ~ 2 - 6 ‡§
Oil Shale	Water needed to Extract / Refine	Wastewater generated; In-situ impact uncertain; Surface leachate runoff		
- In situ retort			1 – 9 ‡	~ 2 ‡
- Ex situ retort			15 - 40 ‡	~ 3 ‡
Oil Sands	Water needed to Extract / Refine	Wastewater generated; Leachate runoff	20 - 50	~ 4 - 6
Synthetic Fuels	Water needed for synthesis and/or steam reforming of natural gas (NG)	Wastewater generated from coal mining and CTL processing		
- Coal to Liquid (CTL)			35 - 70	~ 4.5- 9.0
- Hydrogen RE Electrolysis			20 – 24 ‡	~ 3 ‡
- Hydrogen (NG Reforming)			40 – 50 ‡	~ 7 ‡

† Ranges of water use per unit energy largely based on data taken from the Energy-Water Report to Congress (DOE, 2007)
* Conservative estimates of water use intensity for irrigated feedstock production based on per-acre crop water demand and fuel yield
‡ Estimates based on unvalidated projections for commercial processing; § Assuming rain-fed biomass feedstock production

Growing Use of Non-traditional Water Resources



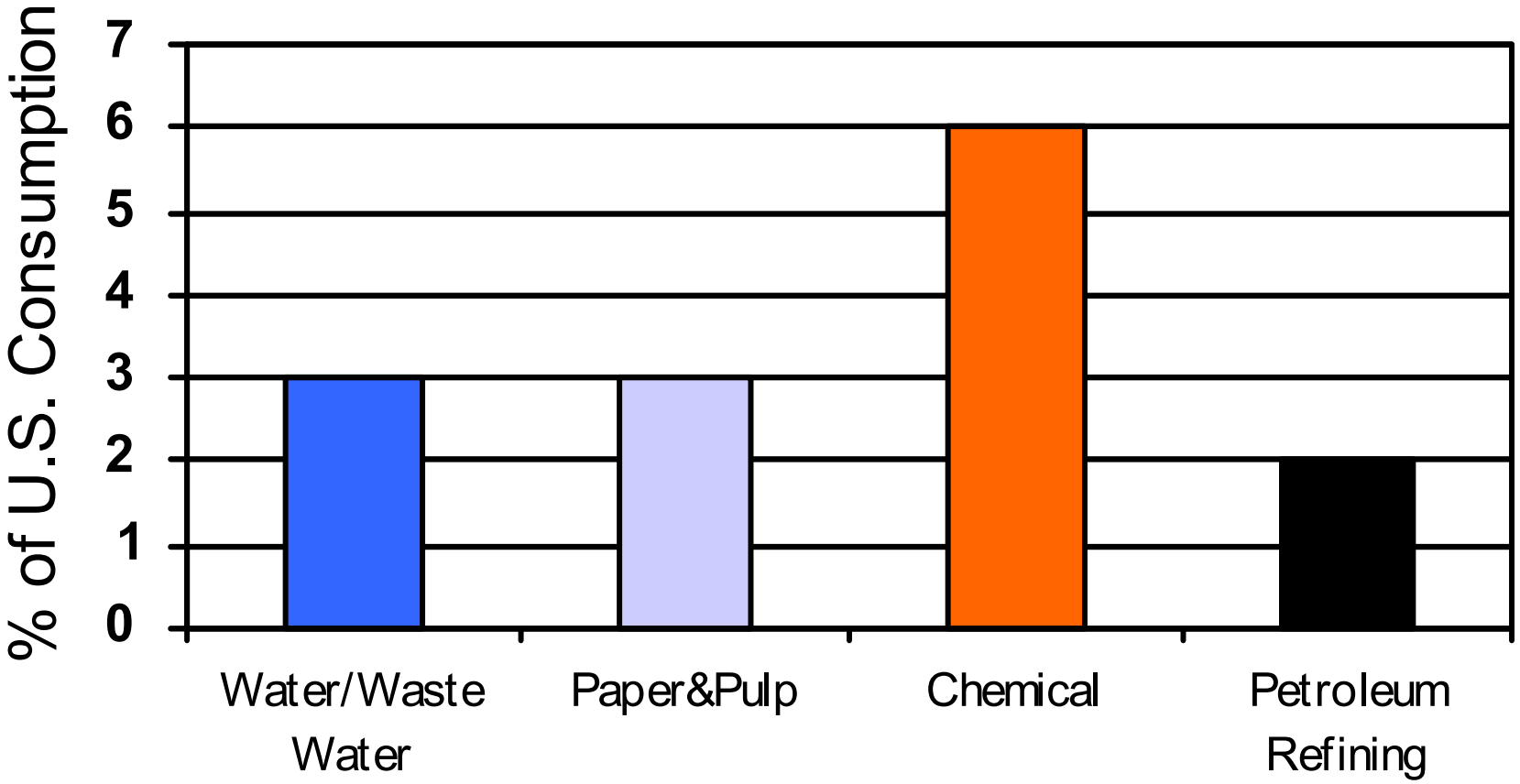
(From EPA 2004, Water Reuse 2007, Mickley 2003)



(Einfeld 2007)

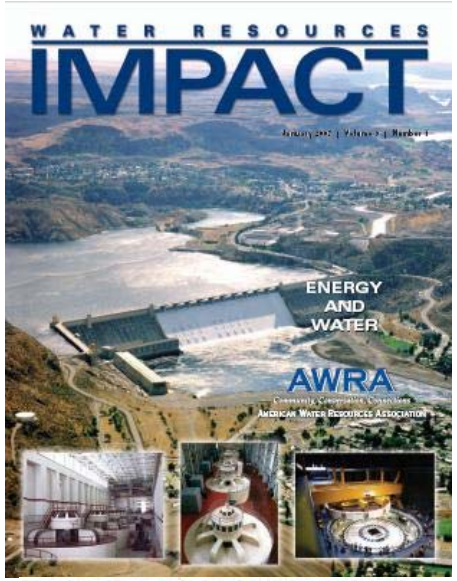
- Desal growing at 10% per year, waste water reuse at 15% per year
- Reuse not accounted for in USGS assessments
- Non-traditional water use is energy intensive

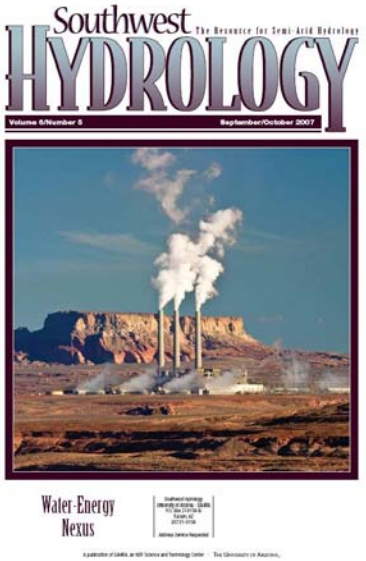
Energy Demands for Water and Waste Water Supply and Other Sectors

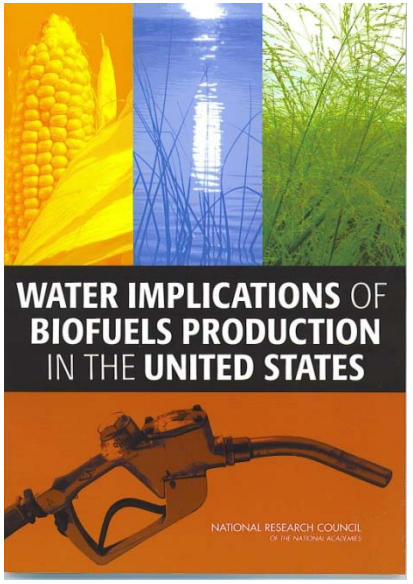


Emerging Interest in Energy and Water Issues and Challenges

- State and national water and energy groups
  - 100 invited presentations since 2007 on energy and water challenges
  - Research and regulatory groups considering future energy and water needs
- Increased media interest
  - NATURE, ECONOMIST, Bloomberg, Goldman Sachs, National Geographic
  - Technical magazines
- NSF/NAS/NRC interest in interdependencies research
- Growing international concerns and challenges
  - Europe, Australia, Asia, Canada, Africa, Middle East
- United Nations, World Bank







Energy Water Studies in the U.S.

- Energy Water Interdependencies - Report to Congress by Sandia and other national laboratories in January 2007 raised interest and concerns
- Review of Energy Water issues by multiple U.S. agencies
  - Government Accountability Office had five reports from 2009 through 2012
  - Congressional Research Service – 2010, 2013, 2014
  - U.S. Geological Survey - 2013
- Many universities, economic, and scientific groups looked at energy water issues – 2009 through 2012
    - University of Texas, American Society of Mechanical Engineers, Union of Concerned Scientists, Johnson Foundation, National Geographic, Nature, Forbes

Drove international energy water studies

World Business Council (2009), World Energy Council (2010) etc.

Current Energy Water Directions in the U.S.

- National Science Foundation Energy Water Research Roadmap - 2014
- Department of Energy Research Roadmap – 2014
- General Accountability Office/National Research Council Energy Water Research Roadmap – 2014
- Electric Power Research Institute Energy Water Research Program - 2012
  - Advanced cooling technology research program
  - $16M advanced cooling technology utility-scale demonstration facility
- Oil and gas industry hydraulic fracturing research program on frac water reuse and recycling – started 2012
- ASME water conservation guide for cooling – 2013
- WEF and WERF energy water program 2011

Summary of Major Directions and Trends in Energy Water Planning

- Better resources planning and management
  - Improved water supply characterization, monitoring, and modeling
  - Integrated regional energy and water resource planning and decision tools
  - Framework for infrastructure, regulatory, and policy integration for improved energy/water efficiency planning
- Improved water and energy use efficiency
  - Improved water efficiency in thermoelectric power generation
  - Improved biofuels/biomass water use efficiency
  - Reduced water use intensity for emerging energy resources
- Development of alternative water resources and supplies
  - Non-traditional and oil and gas produced water use and reuse
  - Improved energy efficiency for non-traditional water treatment and use
- Reduce energy use in the water sector
  - Co-location, energy recovery