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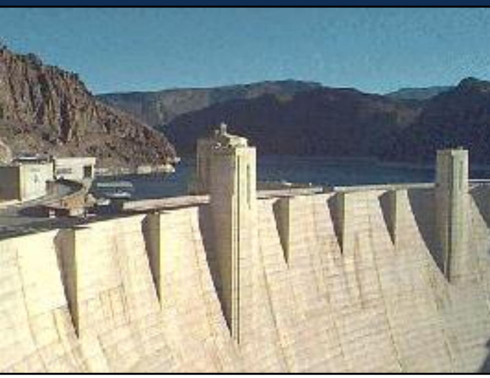

Energy and Water Interdependencies Issues and Trends in the Eastern U.S.

Mike Hightower
Sandia National Laboratories

Energy, Water, and the Environment in the Delaware River Basin
Rutgers EcoComplex , November 7, 2012

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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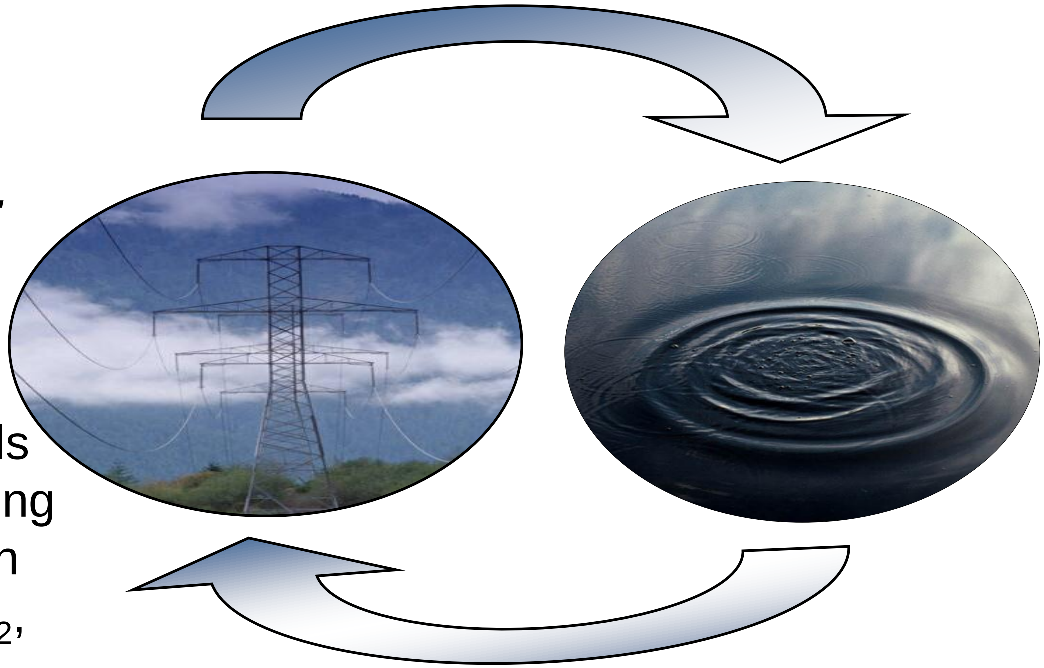
Energy and Water are … Interdependent

Water for Energy and *Energy for Water*

Energy and power production require water:

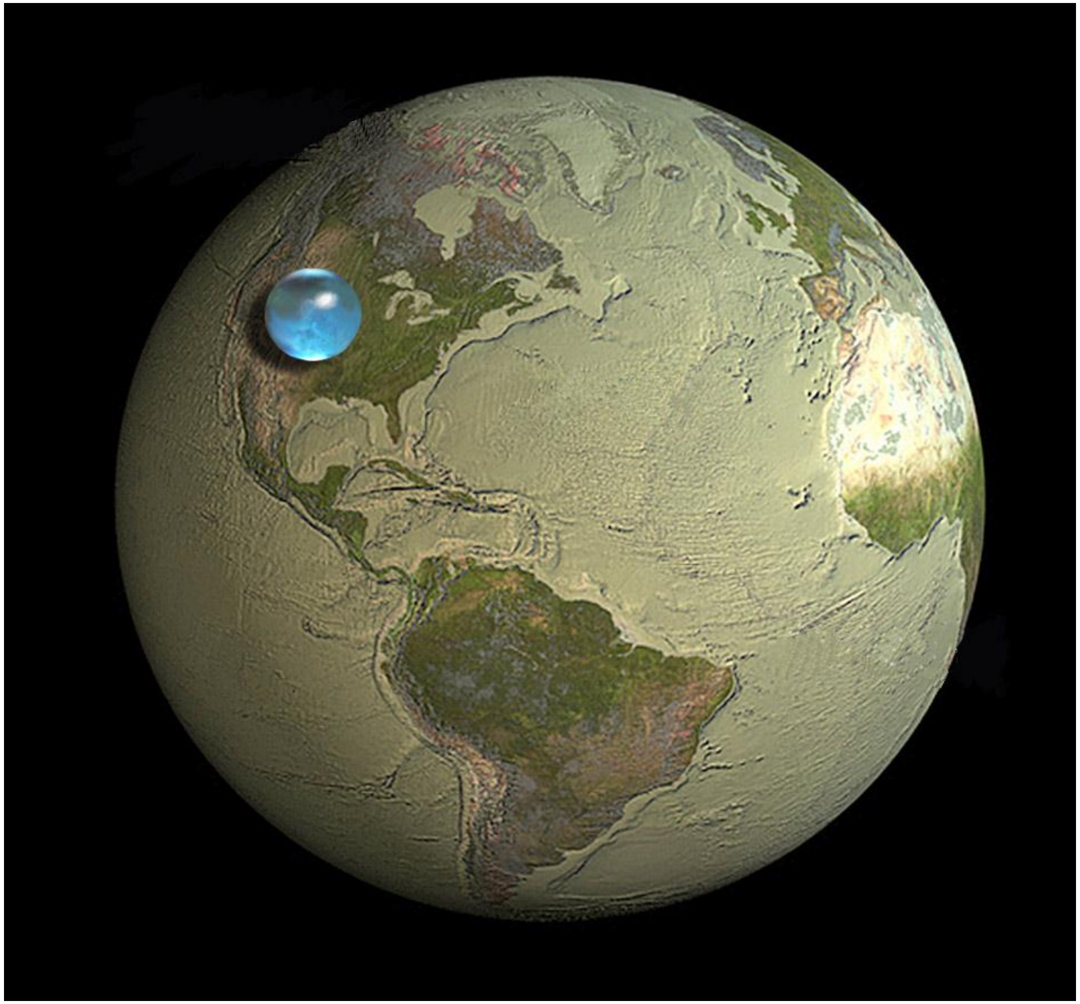
- Thermoelectric cooling
- Hydropower
- Energy minerals extraction/mining
- Fuel Production (fossil fuels, H_2, biofuels)
- Emission control



Water production, processing, distribution, and end-use require energy:

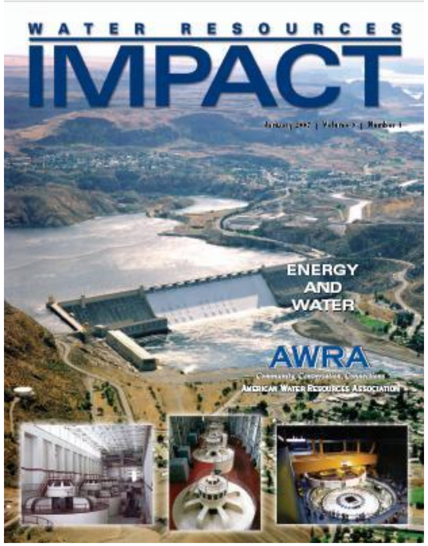
- Pumping
- Conveyance and Transport
- Treatment
- Use conditioning
- Surface and Ground water

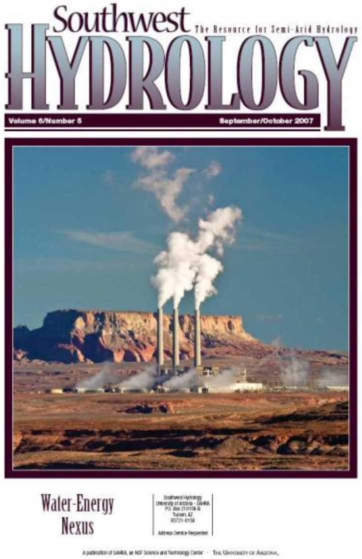
Total Amount of Water in the World - Should Water be a Priority Natural Resources Concern?

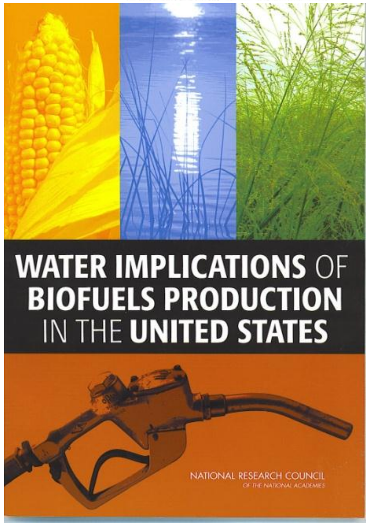


Energy and Water Issues and Concerns are Now Well Known

- National and international water and energy group direction
  - DOE Report to Congress 2006
  - World Energy Council 2010
  - World Council on Sustainable Development 2010
  - GAO 2009-2012
- Increased public media interest
  - NATURE, ECONOMIST 2008
  - National Security Journal 2010
  - National Geographic 2010
- Growing international interest
  - Europe, Australia, Asia, Canada, Africa, South America
- Economic Interest
  - Bloomberg 2012
  - World Bank 2012
  - World Economic Forum 2009

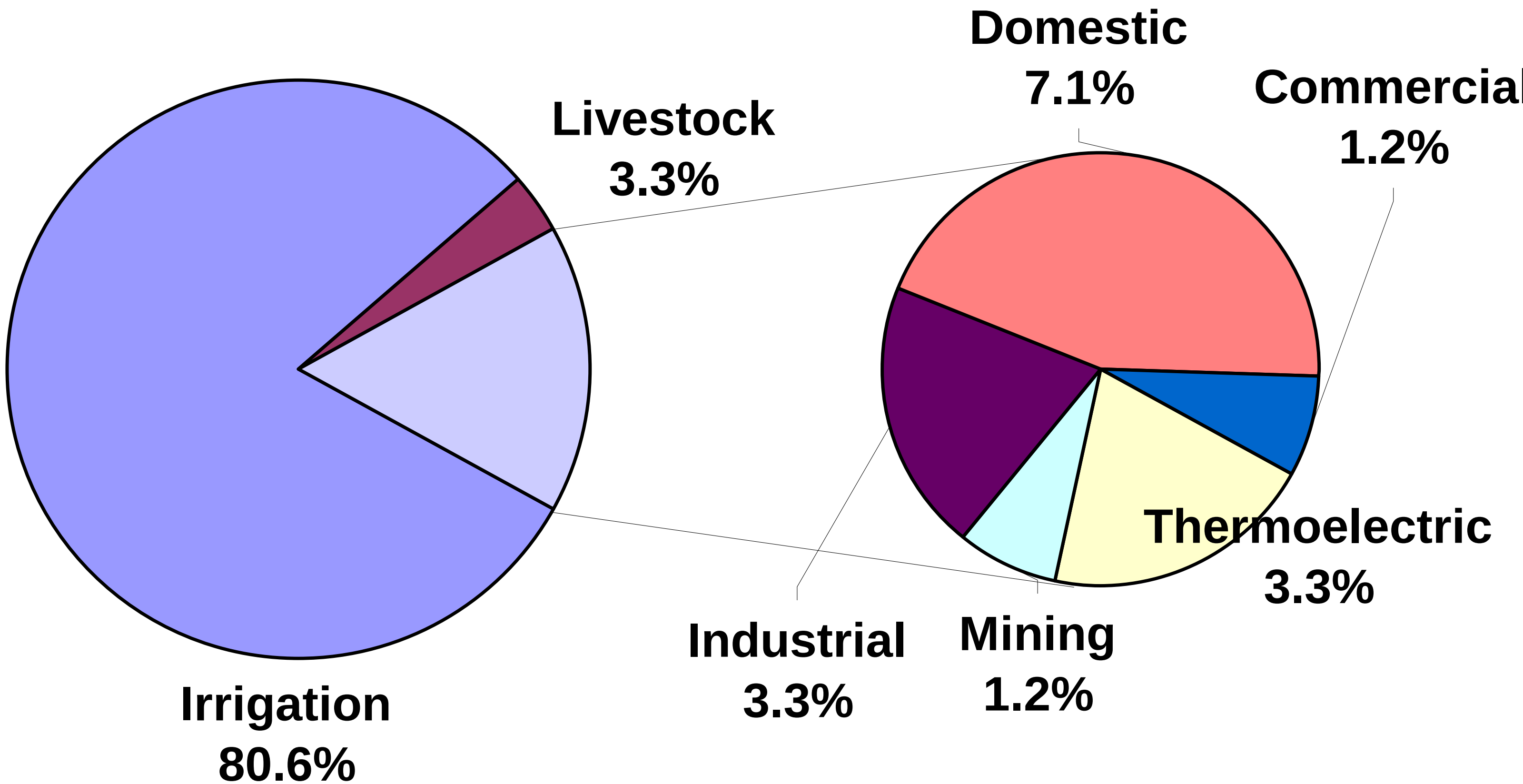






Water Consumption by Sector

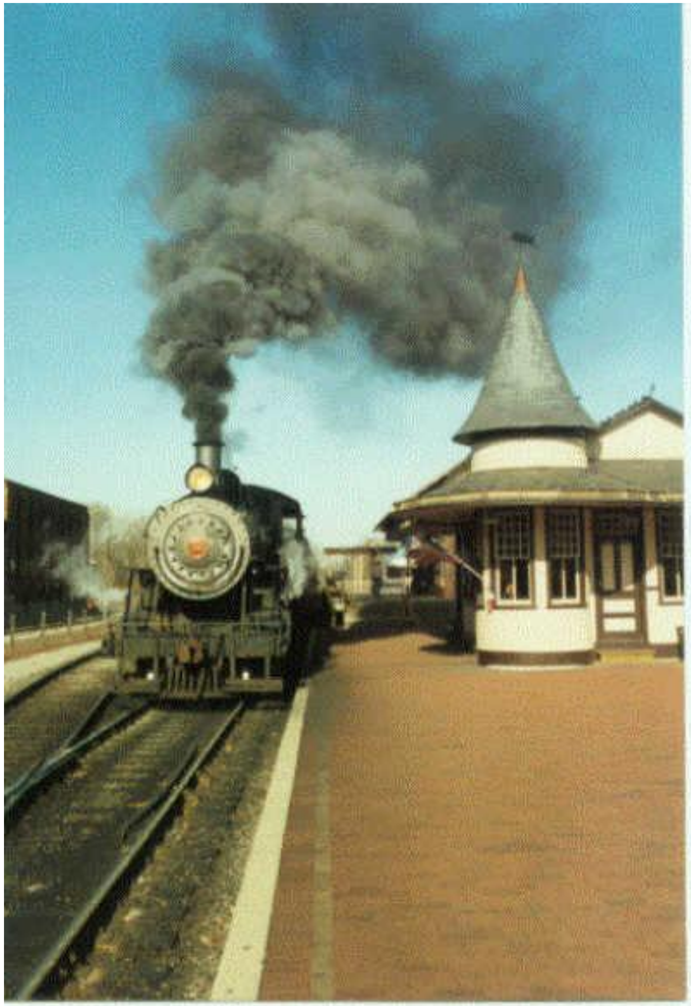
U.S. Freshwater Consumption, 100 Bgal/day



[USGS, 1998]

Energy uses 27 percent of all non-agricultural fresh water

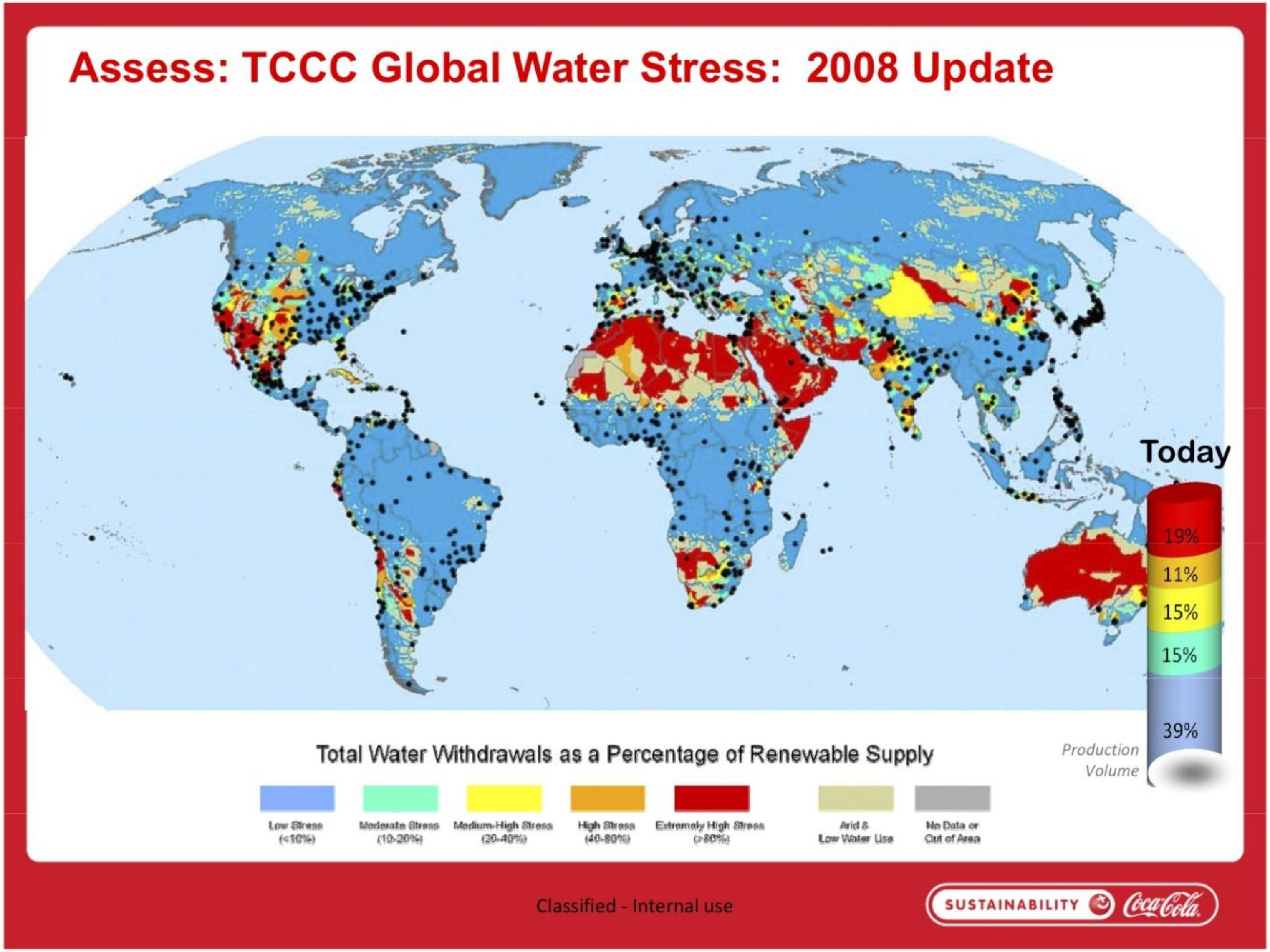
Presentation Overview



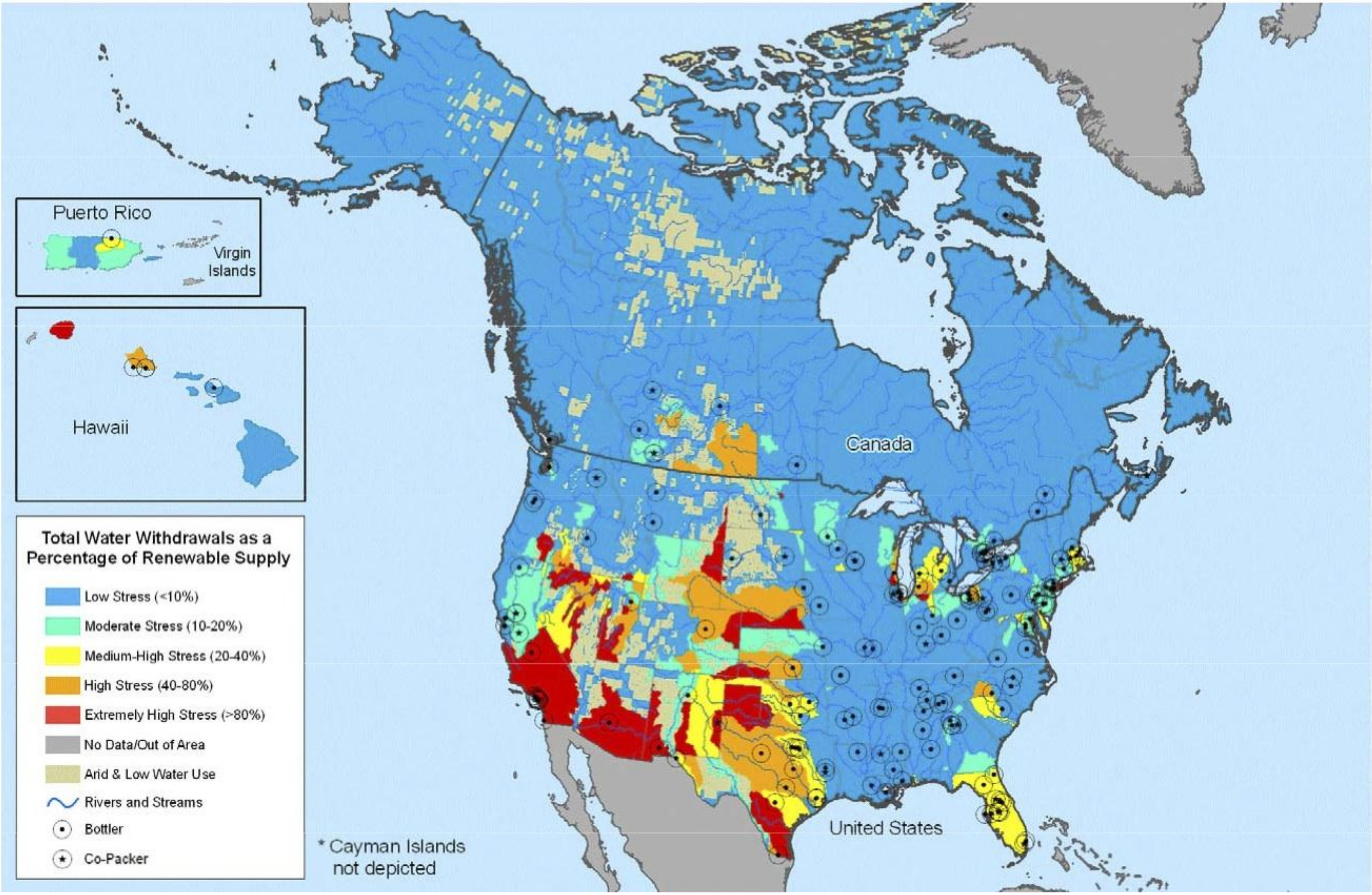
- Fresh water resources in the U.S. are already stressed
  - Many states are experiencing regional water shortages
- Climate aridity could reduce water supplies in mid latitudes by 25-50%
- Water demands for new energy development could be significant
  - Biofuels, oil shales, power plants, gas shales, enhanced oil recovery, carbon capture
- Integrated resources management is an element of a workable solution

THE TRAIN IS LEAVING THE STATION, TIME TO GET ON BOARD!

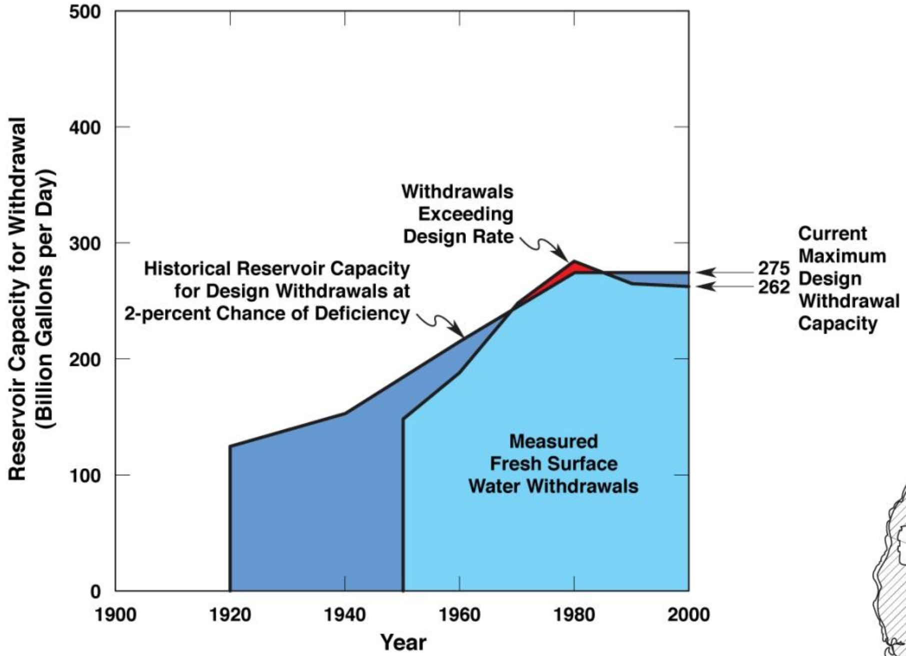
Water Issues and Stress – A Global Issue



Assessment of Regional Water Stress in North America – DRB at Medium

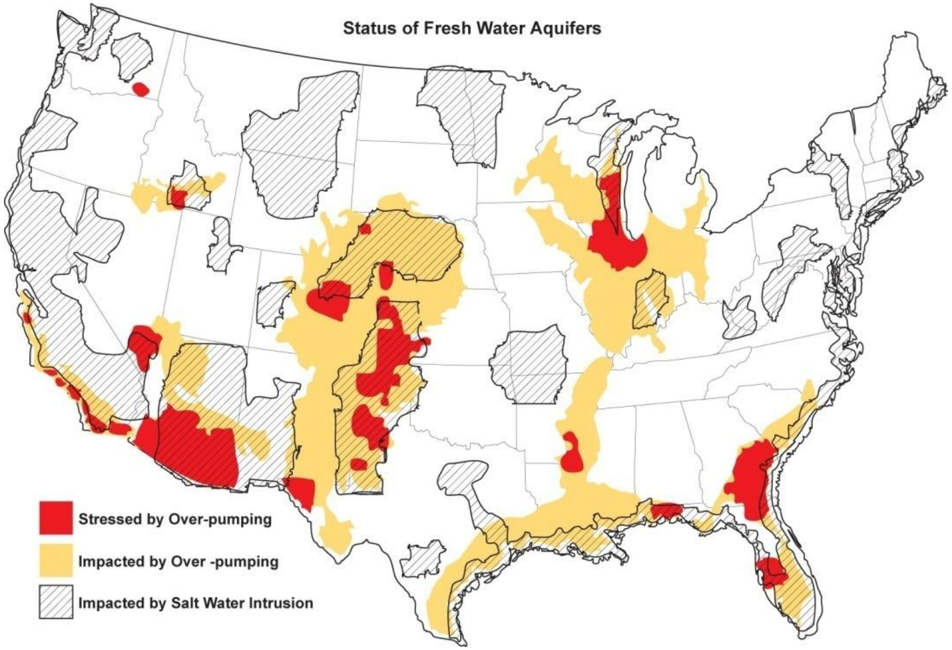


Growing Limitations on Fresh Surface and Ground Water Availability



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

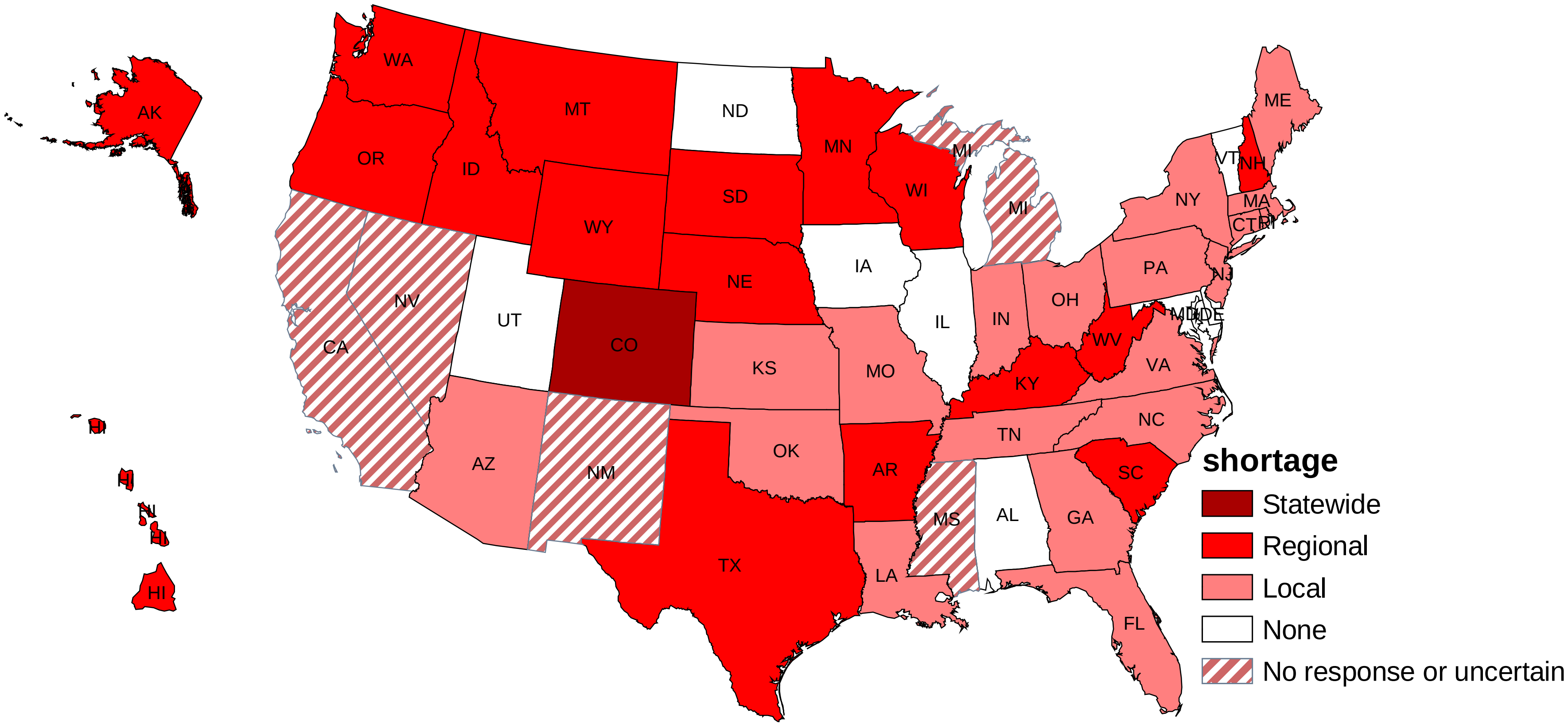
- Little increase in surface water storage capacity since 1980
- Concerns over climate impacts on surface water supplies



(Shannon 2007)

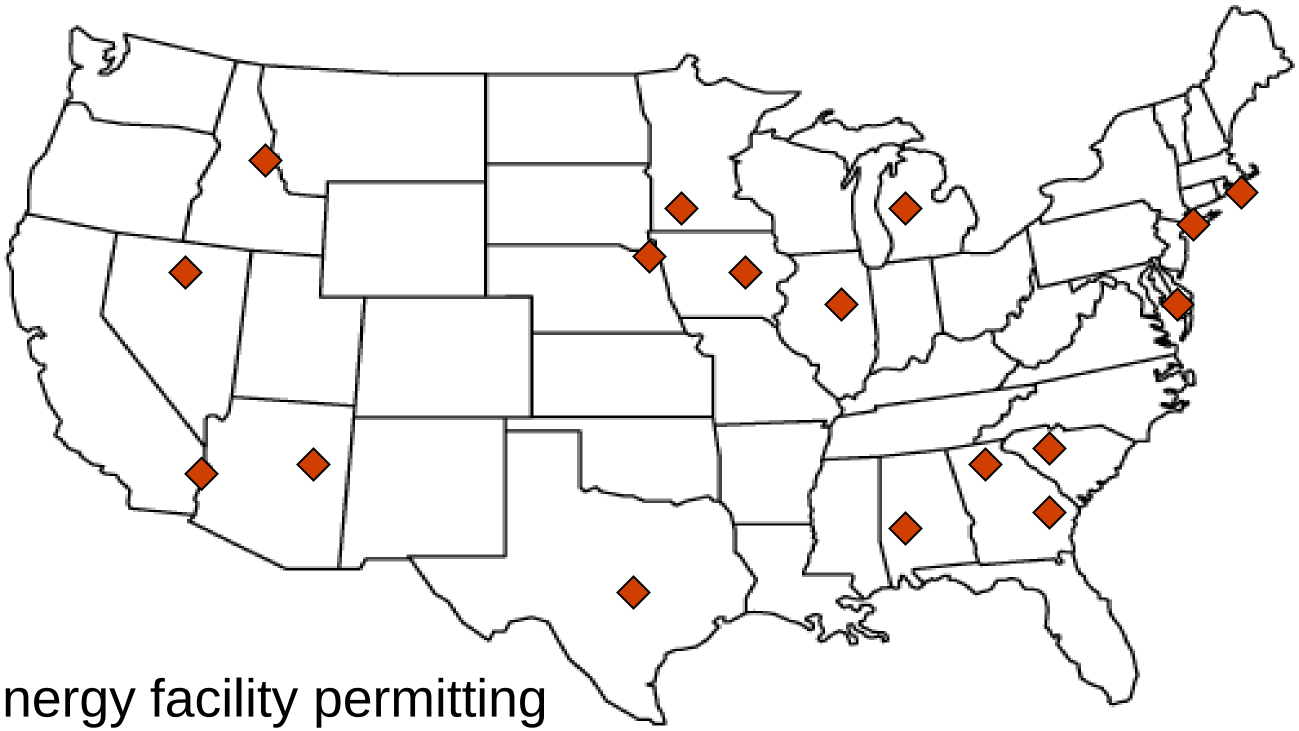
- **Many major ground water aquifers seeing reductions in water quality and yield**

Most State Water Managers Expect Shortages by 2013 for Average Conditions



Source: GAO 2003

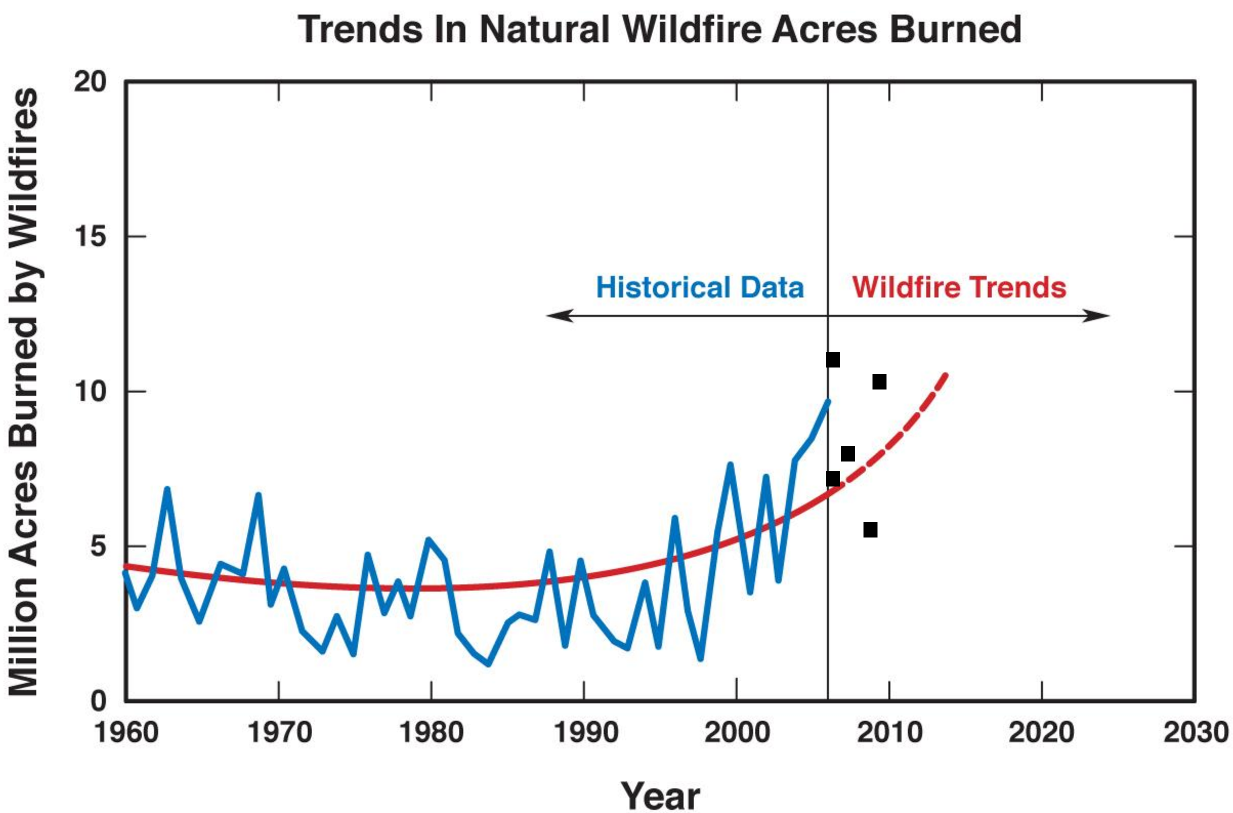
Water Availability Is Already Impacting New Energy Development



Recent energy facility permitting issues due to water availability

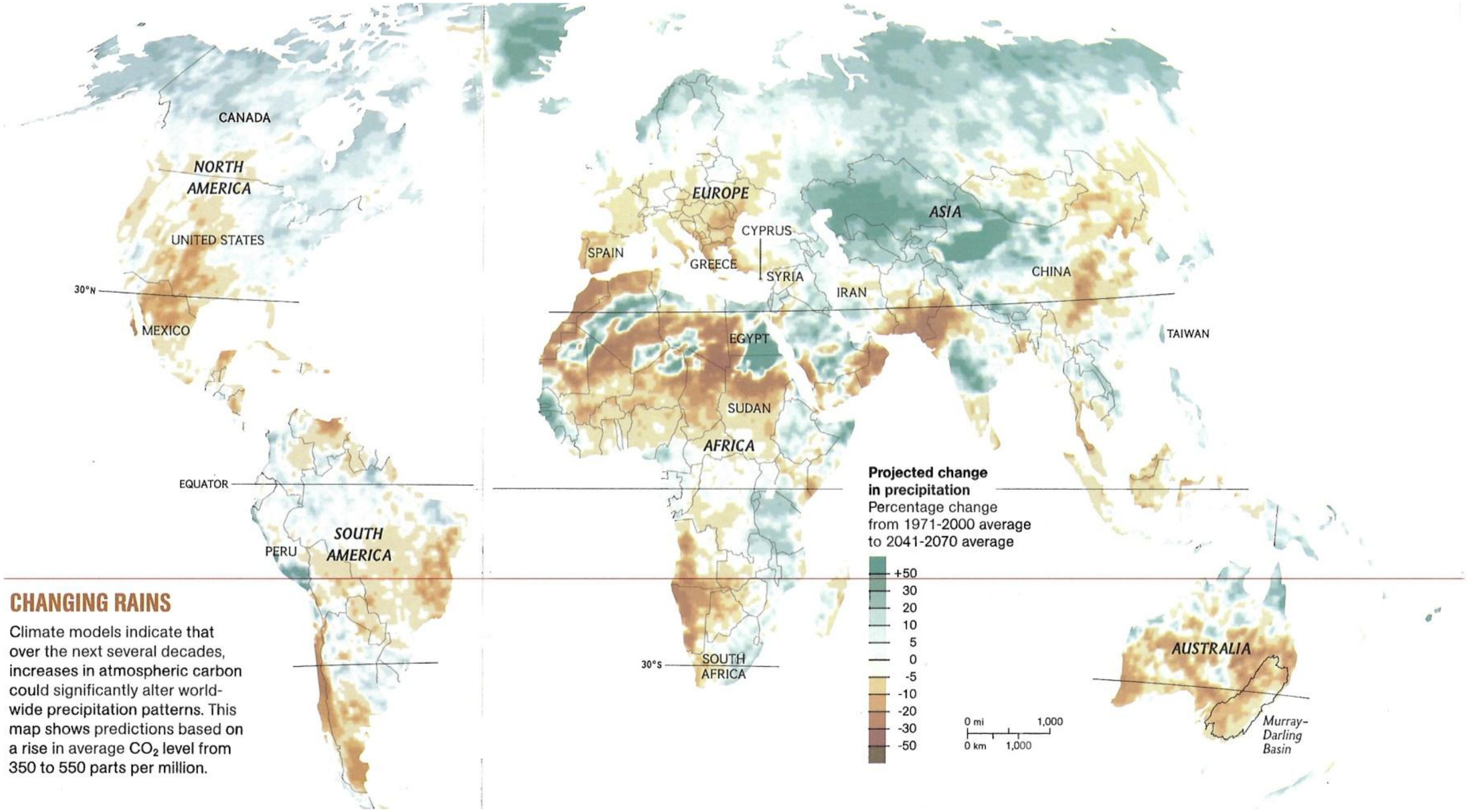
Changes in Water Availability will Impact Watersheds and Ecosystems

Current trends show that the number, size, and severity of wildland fires has grown significantly over the past four decades



Two sources contribute: forest management practices and climate change

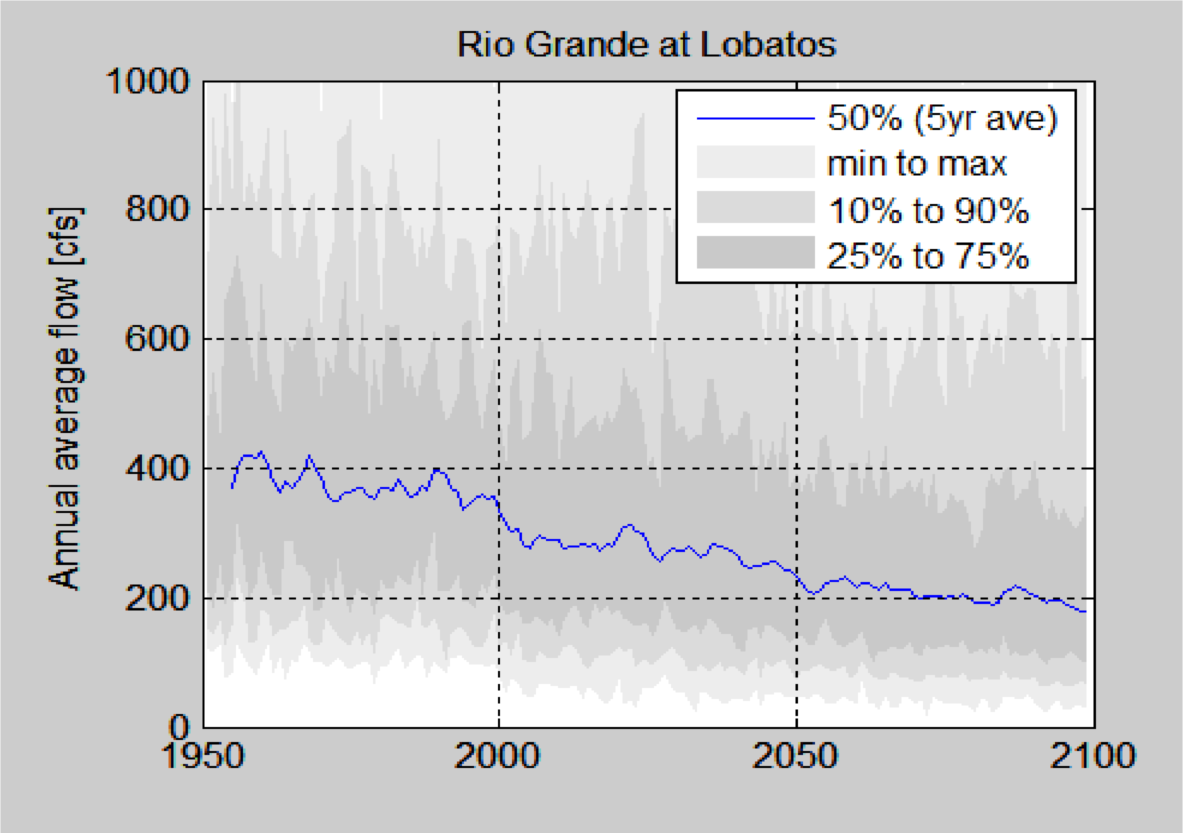
Climate Change will Impact Precipitation, Evapotranspiration, and Runoff



Nat. Geo. April 2009 from IPCC

Mid-latitude population belt will be strongly affected

Projected Rio Grande Flows through 2100



"Results are not predictions, but rather a starting point for dialogue and increased awareness of potential impacts of climate change."

Roach et al.

KEY CLIMATE CHANGE IMPACTS ON THE ENERGY SECTOR

- Warming will be accompanied by decreases in demand for heating energy and increases in demand for cooling energy. The latter will result in significant increases in electricity use and peak demand in most regions.
- Energy production is likely to be constrained by rising temperatures and limited water supplies in many regions.
- Energy production and delivery systems are exposed to sea-level rise and extreme weather events in vulnerable regions.
- Climate change is likely to affect some renewable energy sources across the nation, such as hydropower production in regions subject to changing patterns of precipitation or snowmelt.

Ref: U.S. Global Change Research Program
2009 – Impacts by Sectors

Summary of Major National Needs and Issues Identified in Regional Workshops

Better resources planning and management

- Integrated regional energy and water resource planning and decision support tools
- Infrastructure and regulatory and policy changes for improved energy/water efficiency
- Improved water supply and demand characterization, monitoring, and modeling

Improved water and energy use efficiency

- Improved water efficiency in thermoelectric power generation
- Improved biofuels/biomass water use efficiency
- Reduced water intensity for emerging energy resources

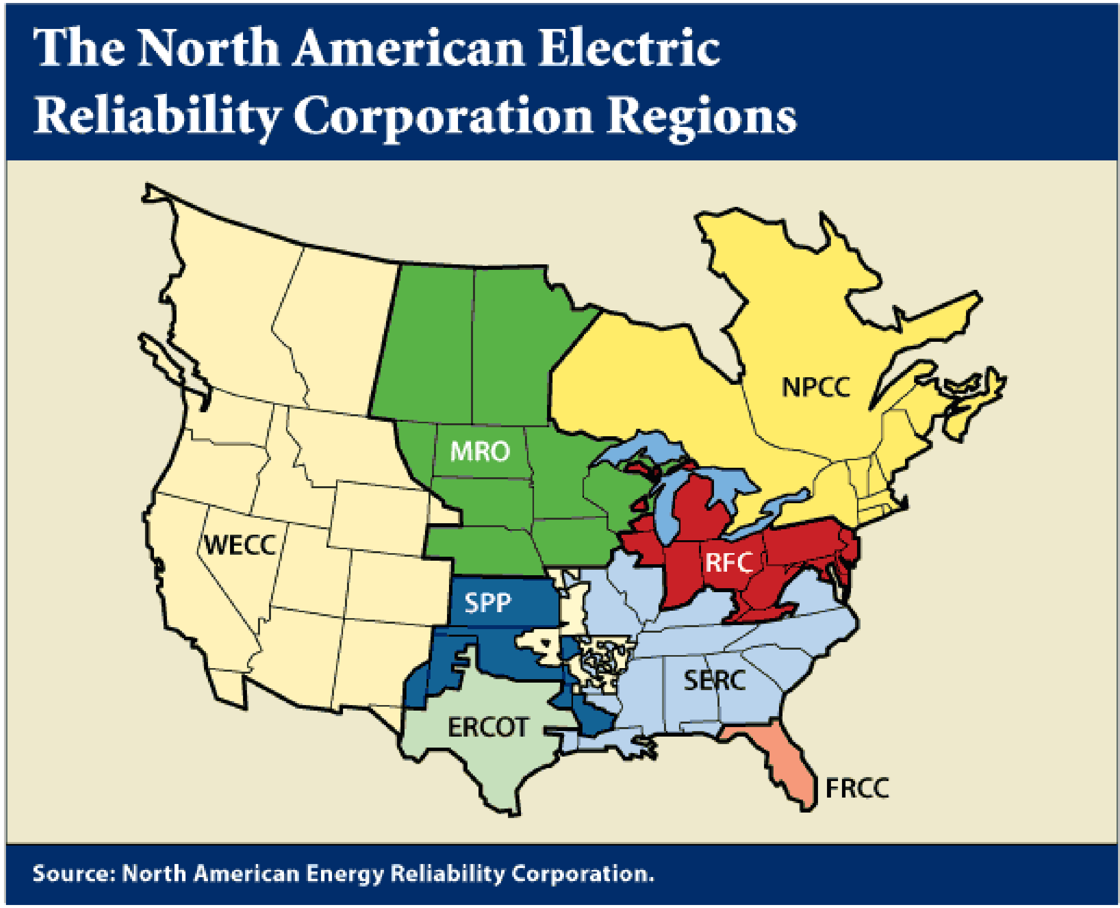
Development of alternative water resources and supplies

- Oil and gas produced water treatment for use
- Energy efficiency and assessment of impaired water treatment and use

www.sandia.gov/energy-water

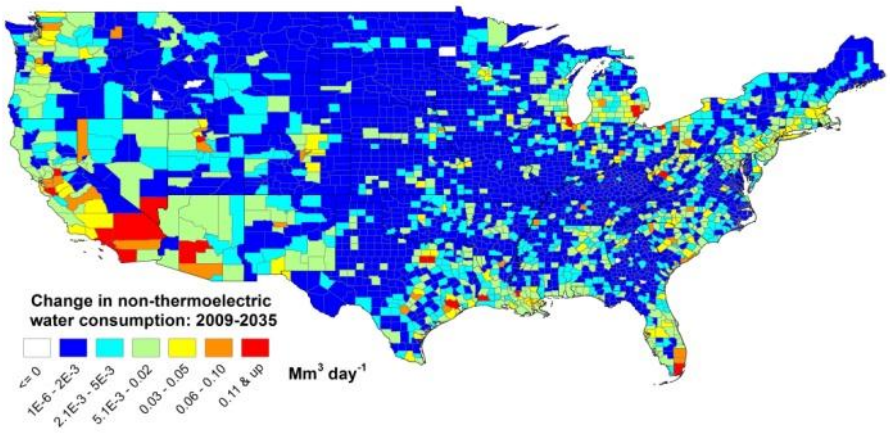
Regional Energy Transmission and Energy Water Planning Underway

- WECC and ERCOT are conducting long-range transmission planning (20 yrs.)
  - Siting of new power plants, new transmission capacity
- Great Lakes Council, California
- Delaware and Susquehanna River Systems
- World Bank looking at many developing regions

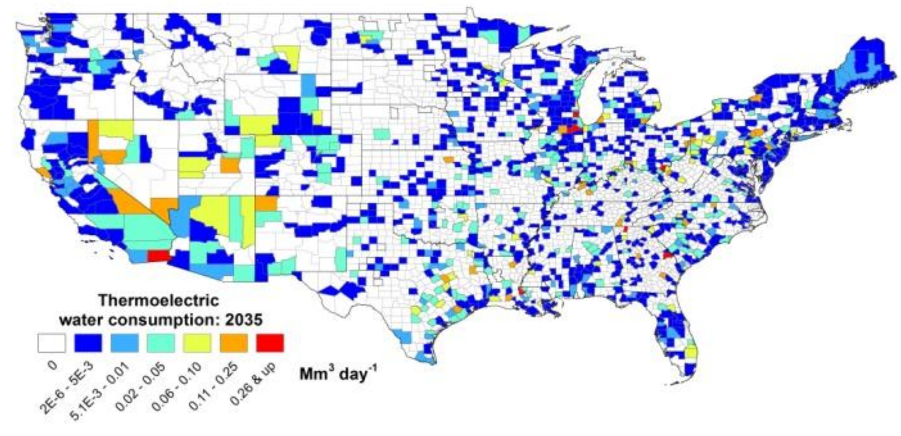


Place Matters: Water Demand Growth

Growth in Non-Thermoelectric Consumption 2010-2030



Growth in Thermoelectric Consumption 2010-2030



Water Use and Consumption for Electric Transportation Alternatives is and Issue

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	~85% 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

Research Program Needs for Electric Power Sector

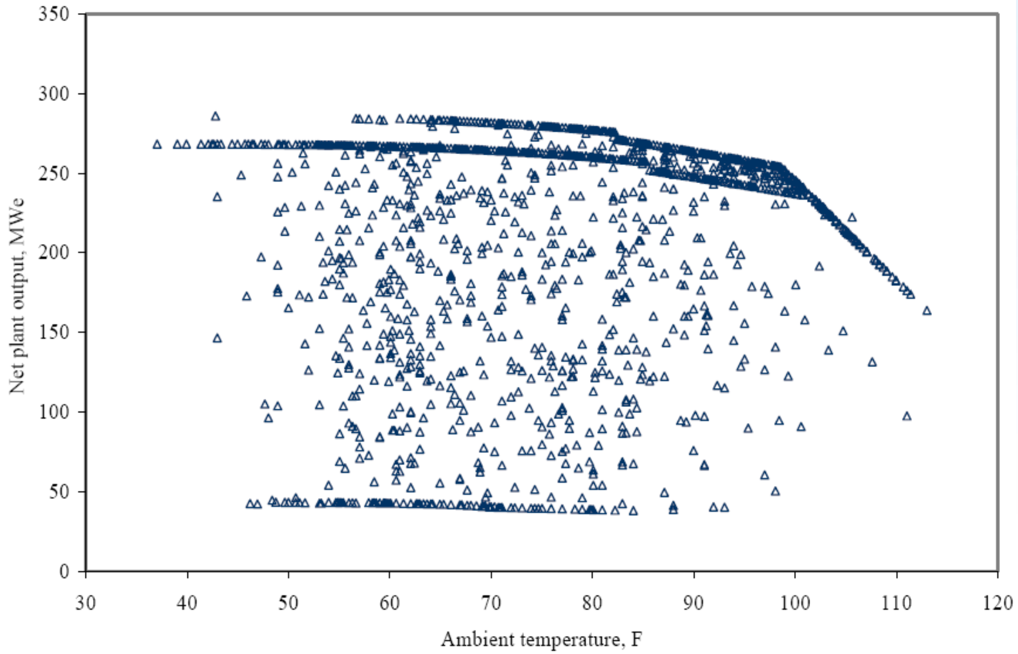


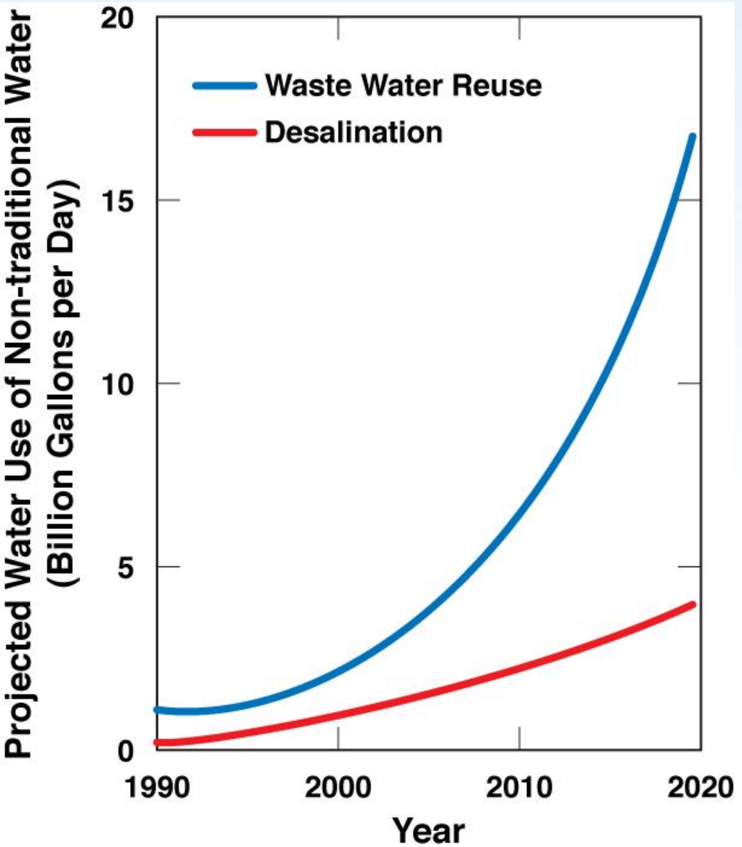
Figure 5 Net Plant Output as a Function of Ambient Temperature; Dry Heat Rejection

Dry Cooling Performance

- Improve dry and hybrid cooling system performance and cost
- Improve ecological performance of intake structures for hydro, once-through, and ocean cooling
- Improve materials and cooling approaches compatible with use of degraded water
- Electric grid infrastructure upgrades to improve low water use distributed technology integration

Emerging Cooling Trends

- Relook at coastal power plants and sea water cooling
  - Costs, reliability, of 17,000 MW retrofit of California coastal power plants to evaporative/hybrid fresh water cooling
  - Texas consideration of large coastal power plants with sea water cooling - reducing fresh water demands at low ecological cost
- Relook at EPA 316b that significantly increases water consumption to allow mitigation
- Growing use of waste water for cooling and hybrid cooling for power plants
- Move from concentrating solar to PV, wind, and natural gas



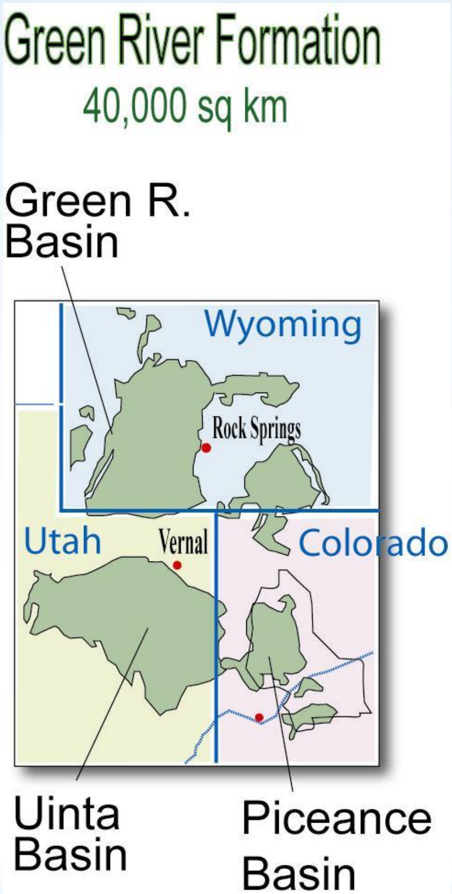
ENERGY and WATER

Water Consumption for Different Transportation Fuel Alternatives

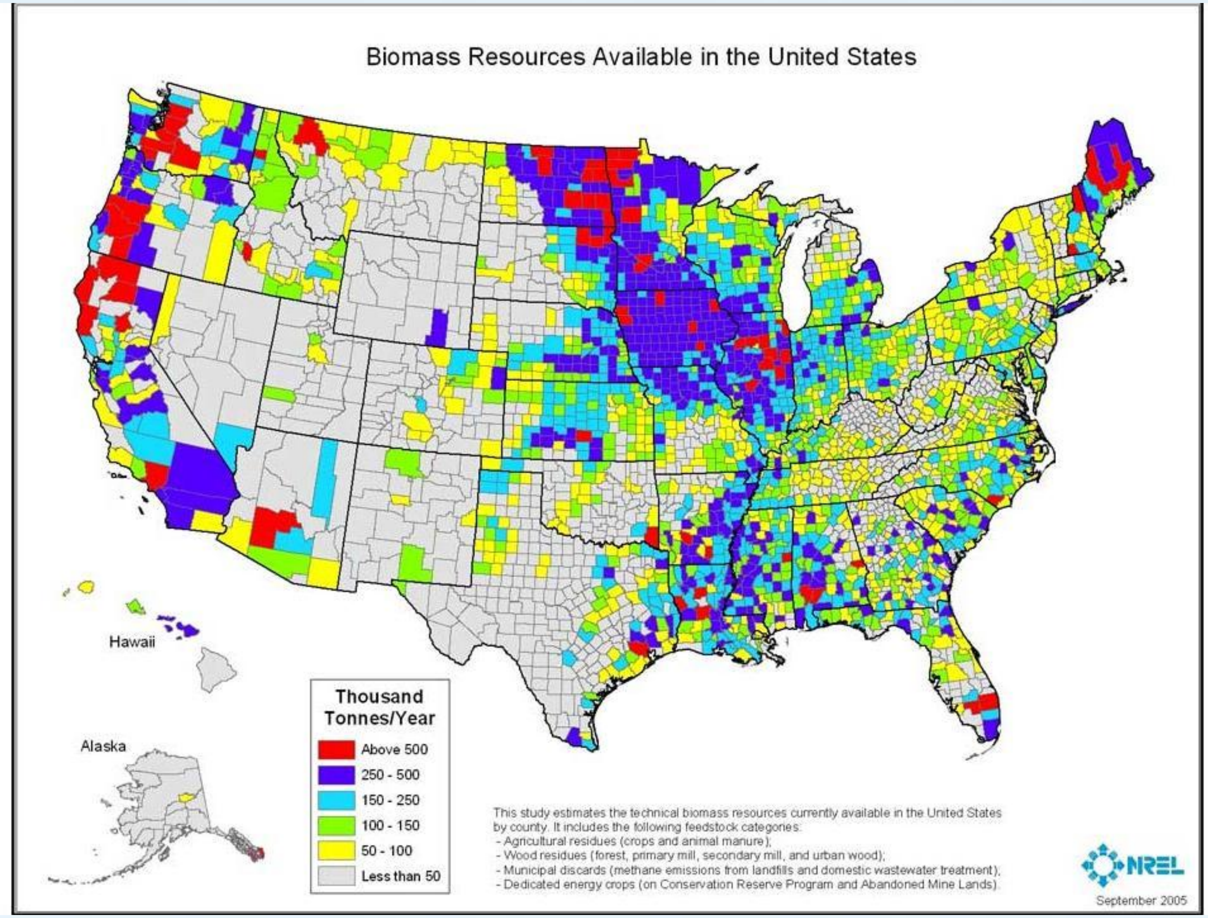
Fuel Type and Process	Relationship to Water Quantity	Relationship to Water Quality	Water Consumption	
			Water consumed per-unit-energy [gal / MMBTU] †	Average gal water consumed per gal fuel
Conventional Oil & Gas	Water needed to extract and refine; Water produced from extraction	Produced water generated 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)			
- Coal to Liquid (CTL)		Wastewater generated from coal mining and CTL processing	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

Alternative Transportation Fuels and Water Use Impacts are Often Regional



Oil Shale

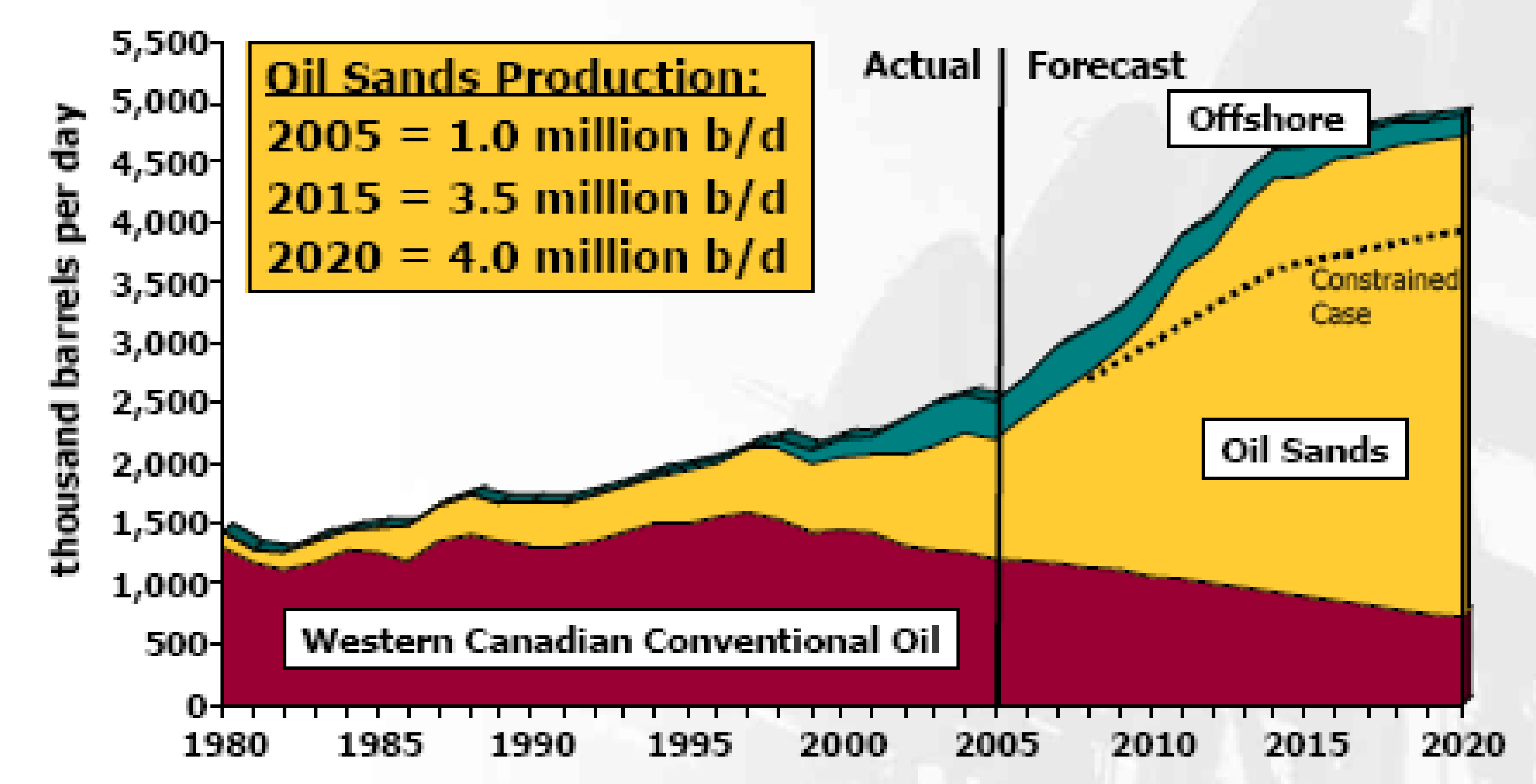


Cellulosic Biomass

ENERGY and WATER

Canadian Oil Sands Production

Increasing Regional and Global Interest and Supplies

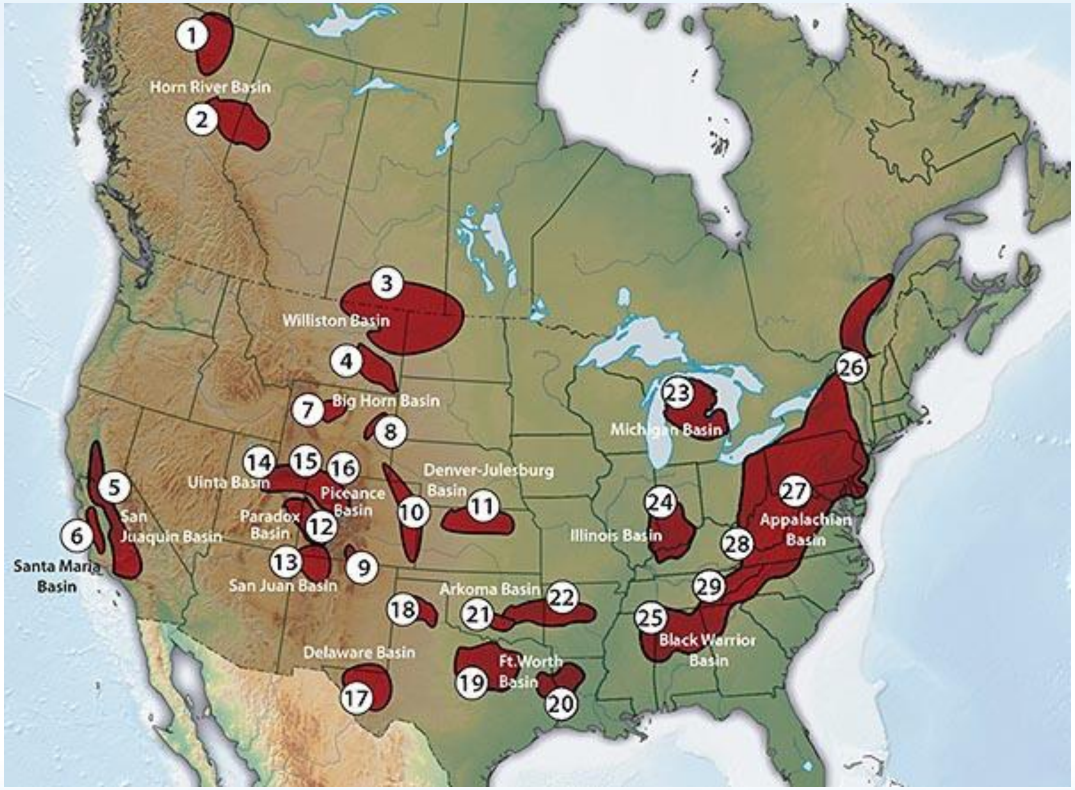


Canadians addressing constrained oil sands production through new technologies, use of brackish water, and water recycling

Shale gas is extensive in North America, but development limited by water issues

- Water is used in drilling, completion, and fracturing
- 2-5 million gallons of water is needed per well
- Water recovery can be 20% to 70%
- Recovered water quality varies – from 10,000 ppm TDS to 100,000 ppm TDS
- Recovered water disposal or treatment can be problematic in some areas
- Well pads can be up to 5 km apart

Extensive North American Reserves



ENERGY and WATER

Relative Water Use of Gas Shale Development

Water Use per Unit Energy (gallons/MMbtu)	
Natural Gas Extraction	1-2
Coal Gasification	50-100
Coal Liquefaction	20-50
Insitu Oil Shale	2-10

- **Average shale gas well yield – 2-6 BCF**
- **Gas shale fracking has high water use efficiency if use renewable water supplies**
- **Renewable water availability could become the limiting factor for gas shale development**

ENERGY and WATER