completing the energy sustainability puzzle

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ENERGY and WATER

Glenn Schrader & Ray Finley

University of Arizona & Sandia National Laboratories

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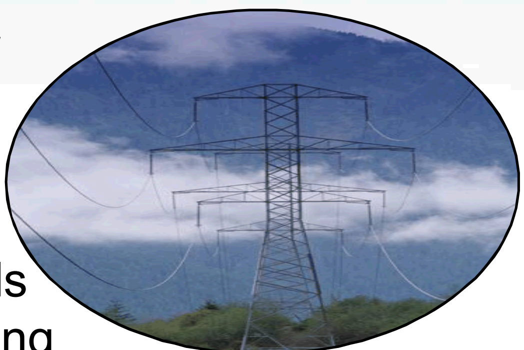
Energy and Water are … Interdependent

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

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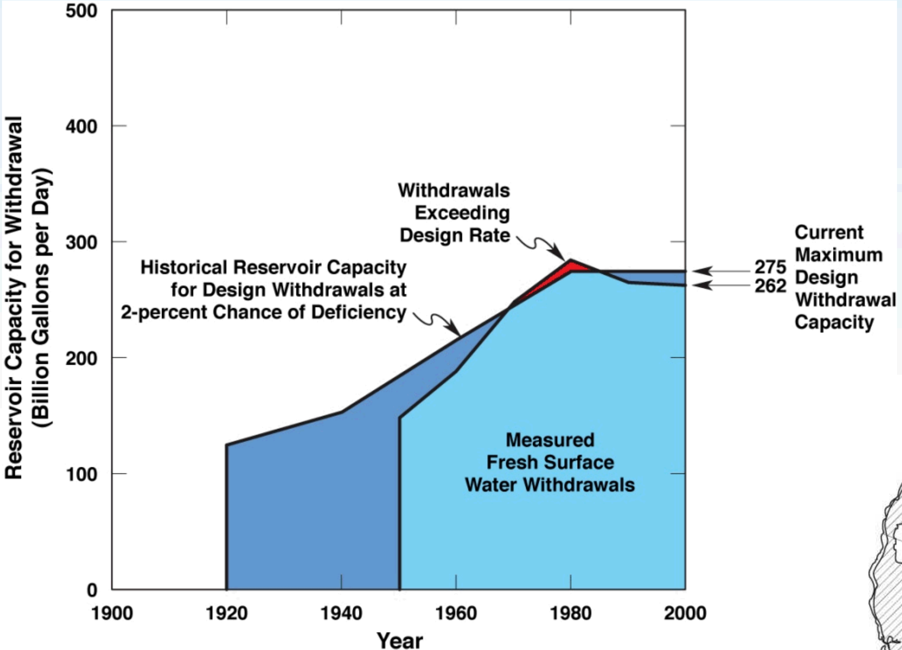
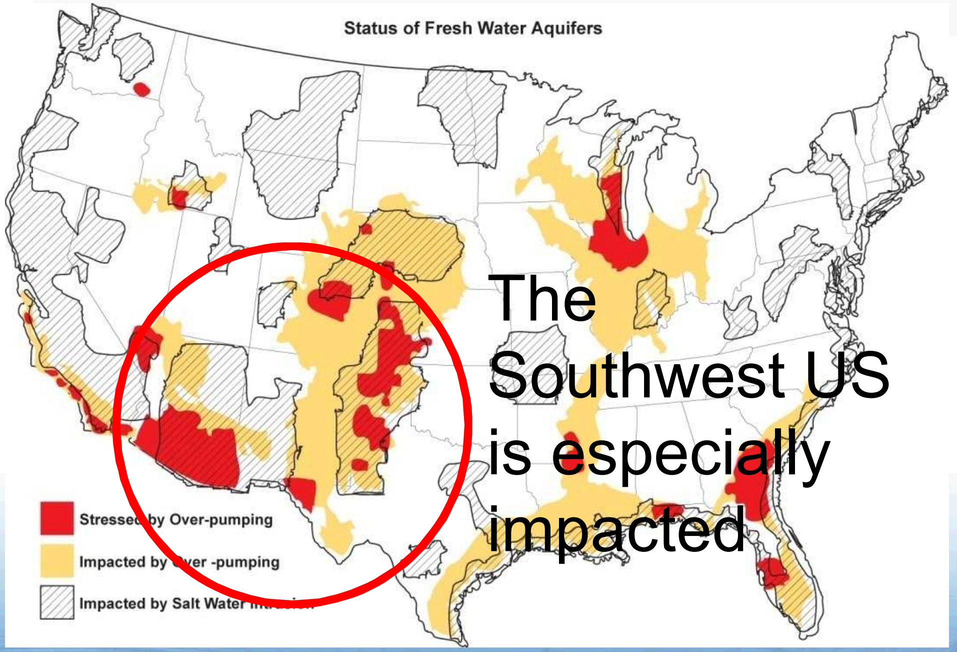
Growing Limitations on Fresh Surface and Ground Water Availability



(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

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



(Shannon 2007)

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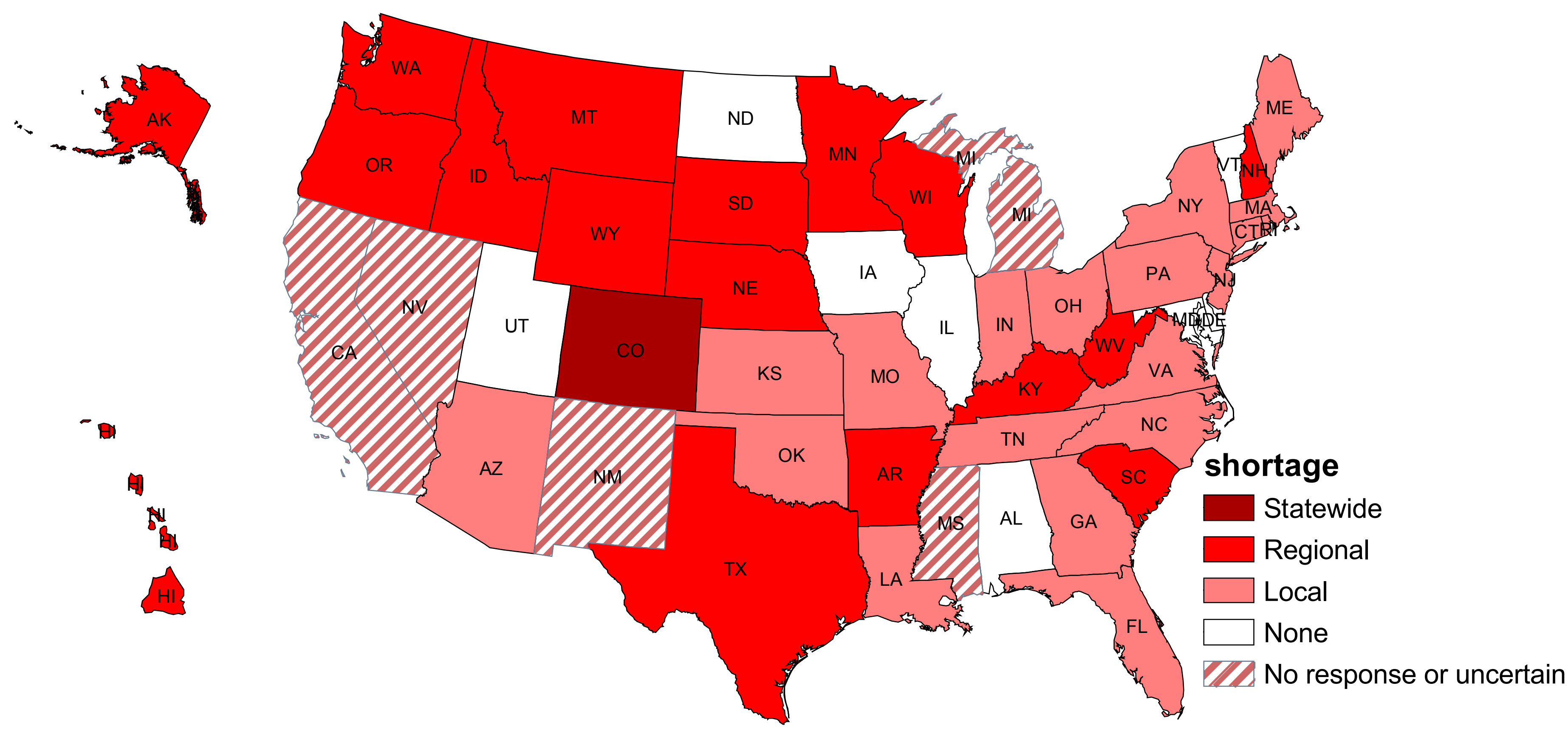
Most State Water Managers Expect Shortages Over The Next Decade Under Average Conditions



Source: GAO 2003

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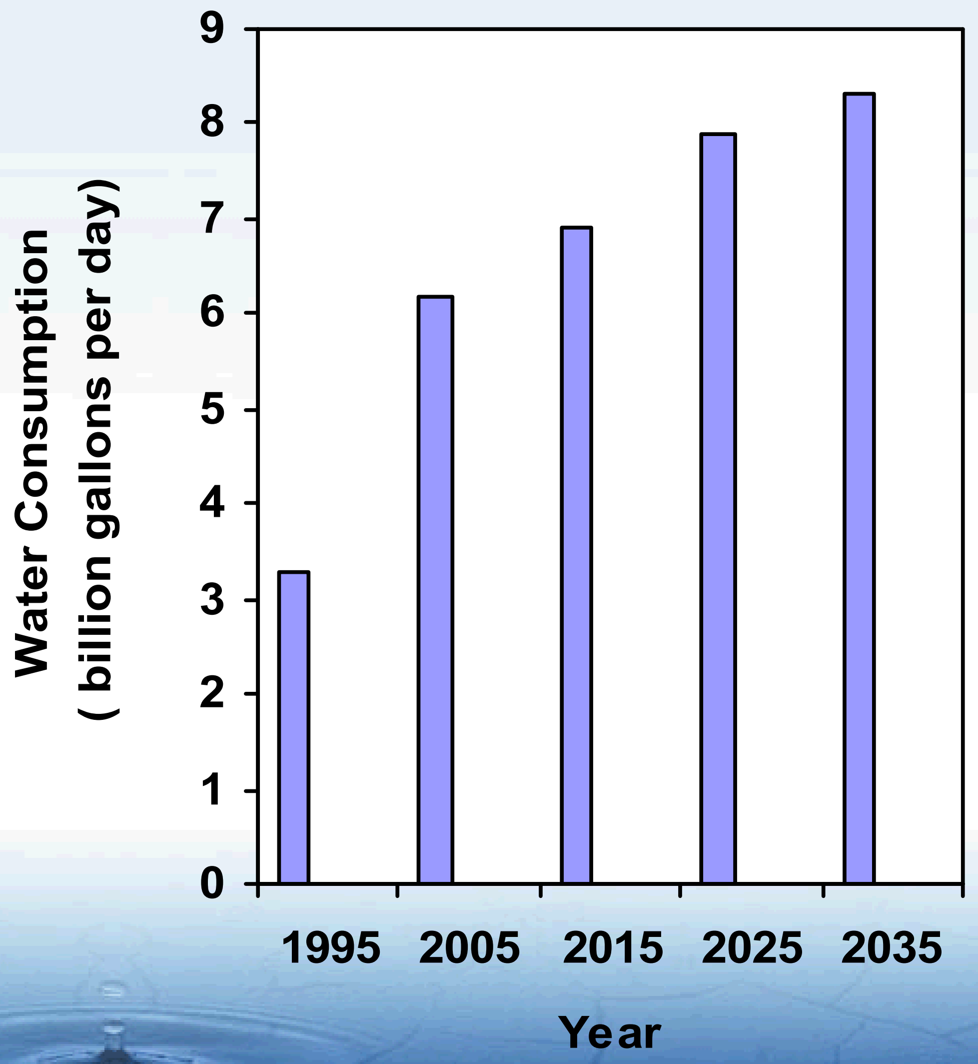
Water Demands for Future Electric Power Development

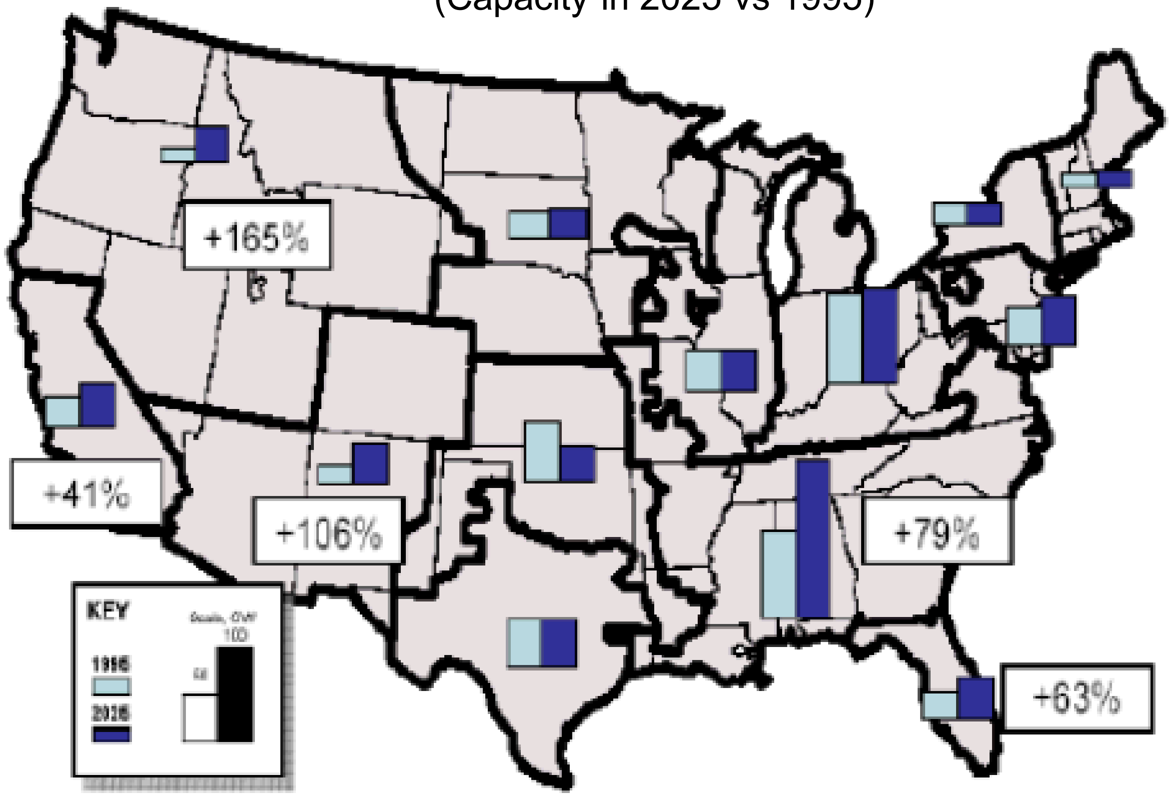
- Water demands could almost triple from 1995 consumption for projected mix of plants and cooling
- Carbon emission requirements will increase water consumption by an additional 1-2 Bgal/day



Regional Growth in Thermoelectric Power Generation

- Most growth in regions that are already water stressed
- Most new plants expected to use evaporative cooling because of EPA 316 A &B requirements

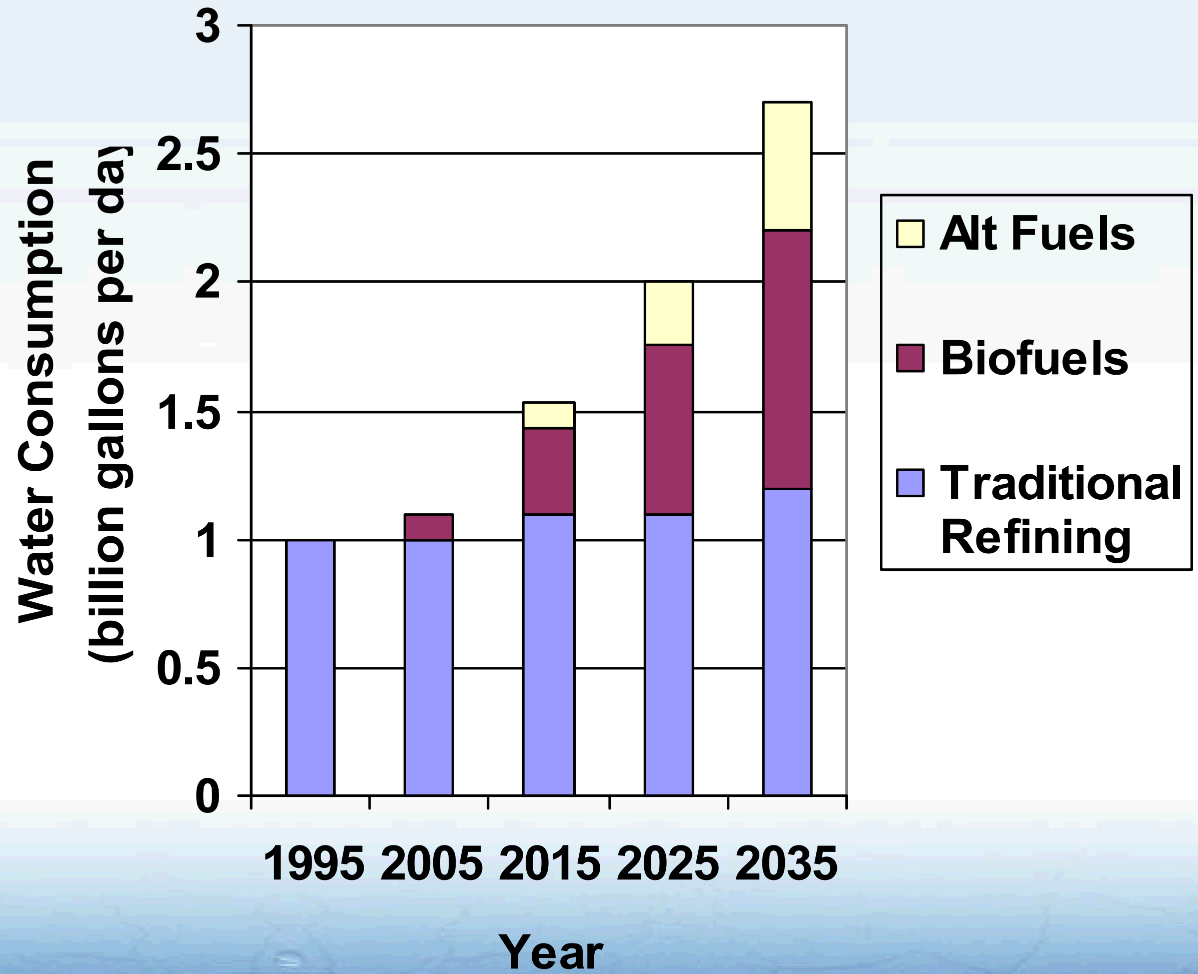
Projected Thermoelectric Increases
(Capacity in 2025 vs 1995)



Source: NETL, 2004

Emerging Water Demands for Alternative Fuels Development

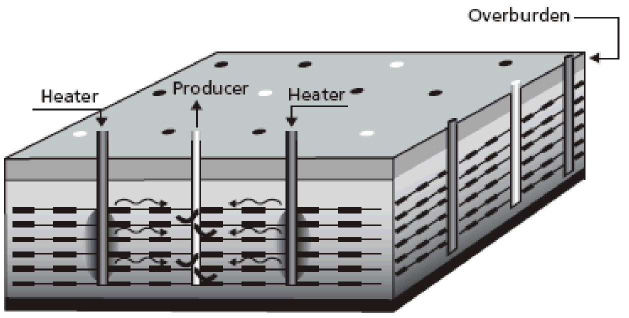
- Irrigation of even small percentage of biofuel acreage could increase water consumption by an additional 3-5 Bgal/day



Oil Shale development will be regional and impact water availability and quality

- Reserves are in areas of limited water resources
- Water needed for retorting, steam flushing, and cooling up to 3 gallons per gallon of fuel
- Concerns over *in situ* migration of retort by-products and impact on ground water quality

Figure 3.2
The Shell In-Situ Conversion Process



SOURCE: Adapted from material provided by Shell Exploration and Production Company.
RAND MG414-3.2

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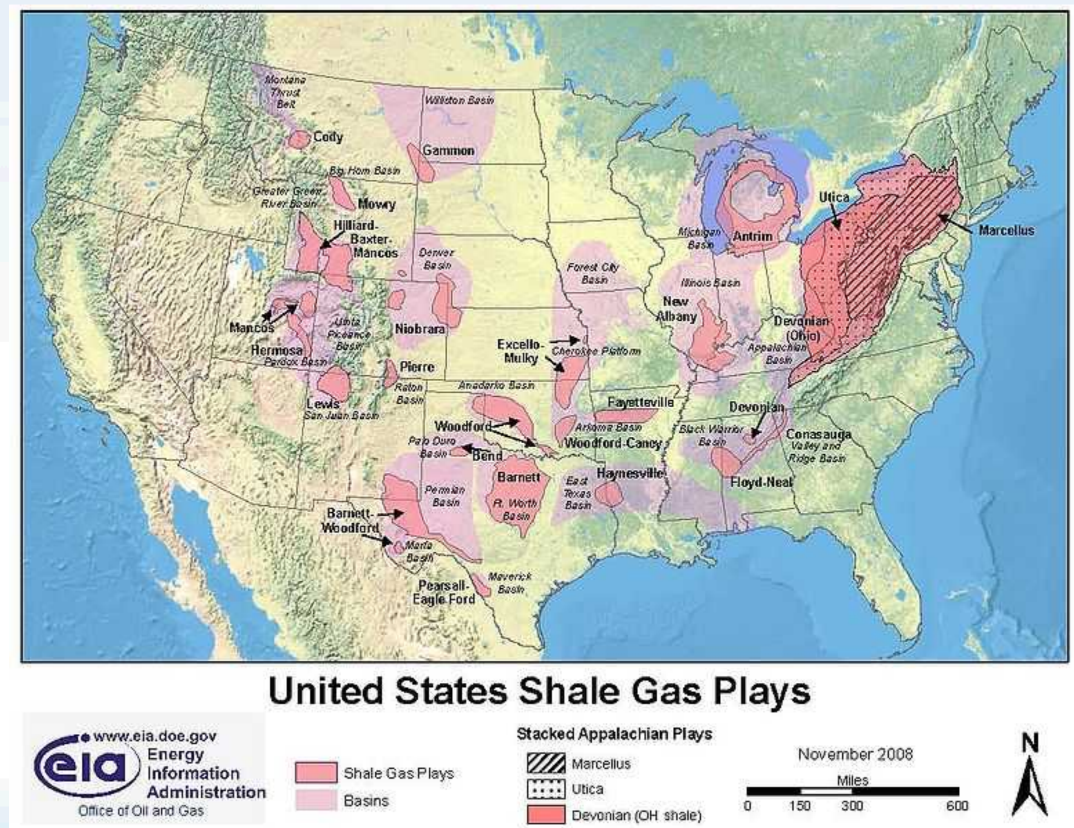
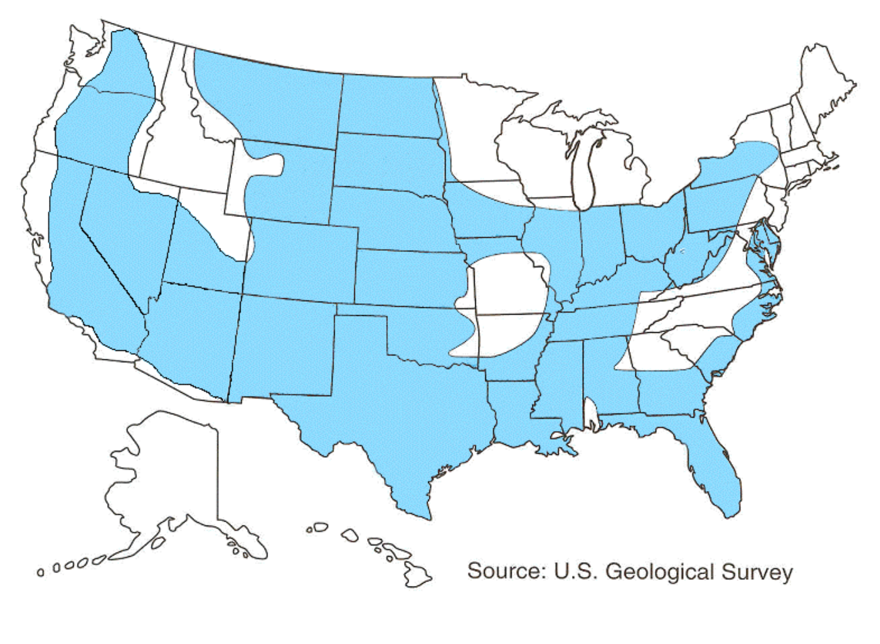
Gas Shale development could be extensive and impact water availability and quality

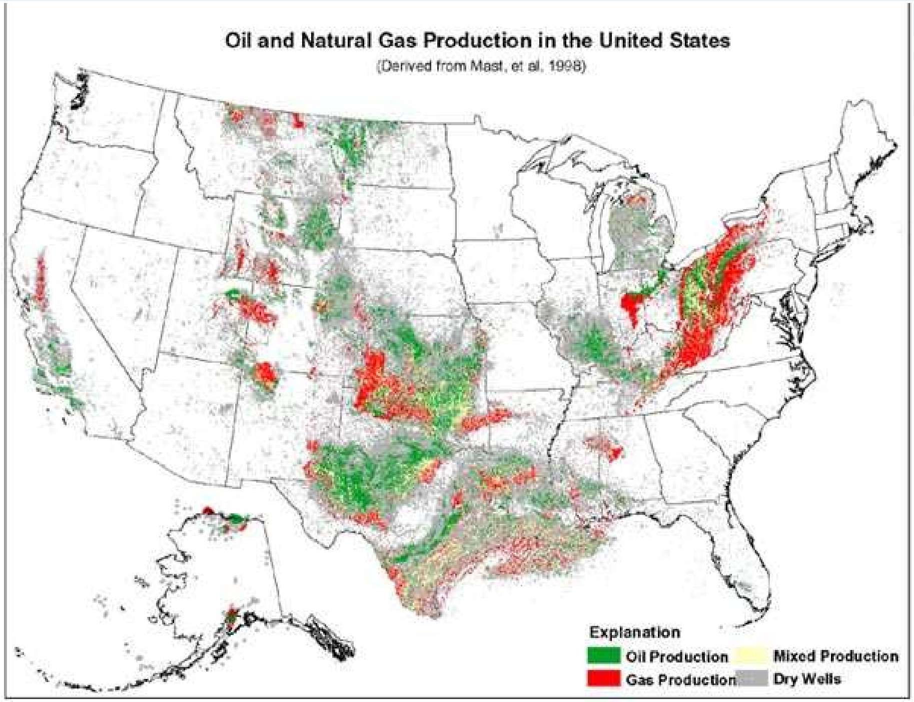
- Water is used in drilling, completion, and fracturing
- Up to 3 million gallons of water is needed per well
- Water recovery can be 20% to 70%
- Recovered water quality varies – from 10,000 ppm TDS to 100,000 ppm TDS
- Recovered water is commonly injected into deep wells if available



Non-traditional Water Resource Availability

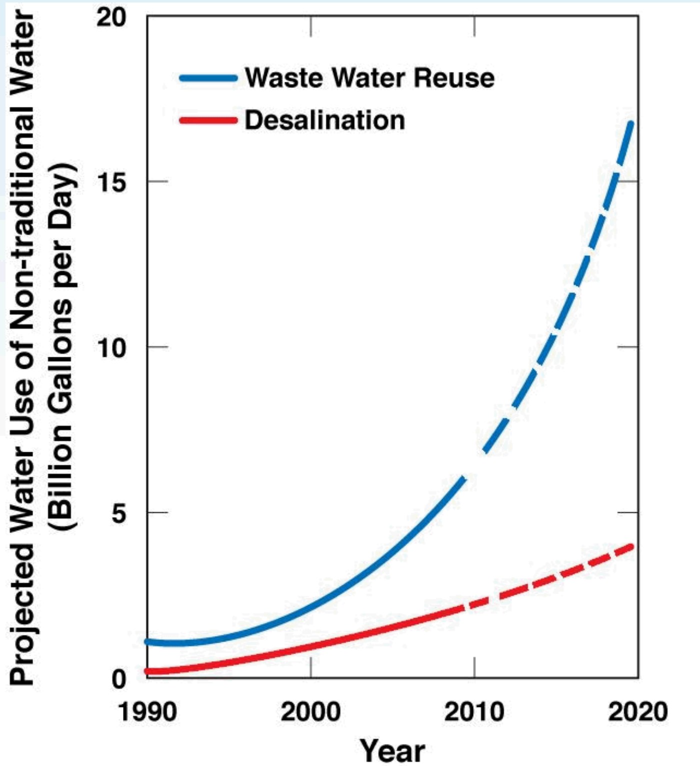


Saline Aquifers



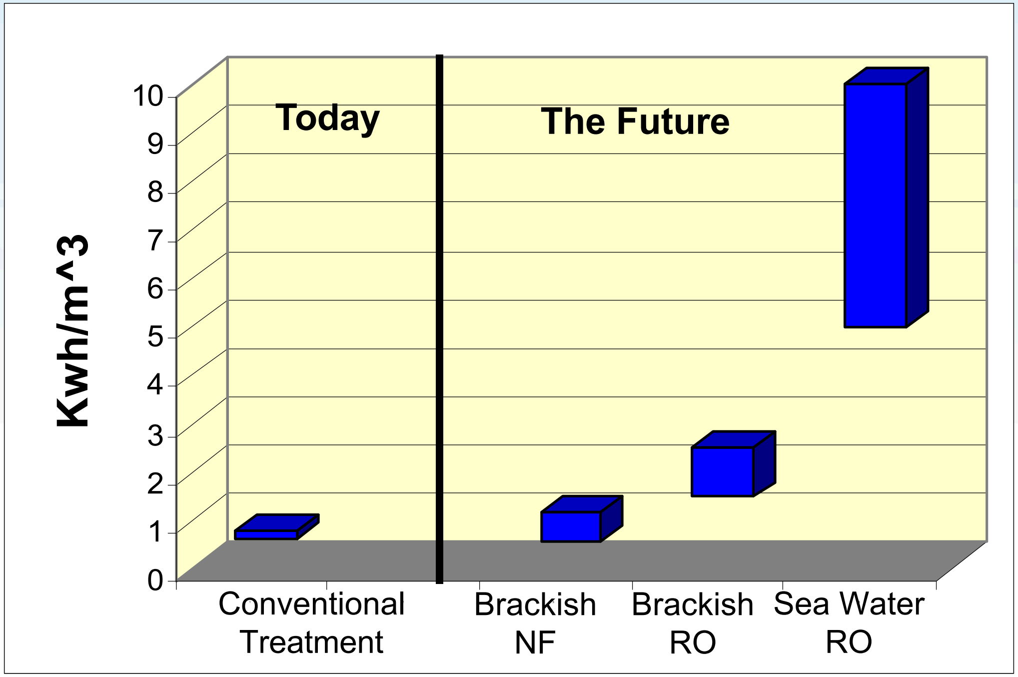
Oil and Gas Produced Water

Growing Use of Non-traditional Water Resources



(Modified from Water Reuse 2007, EPA 2004, Mickley 2003)

Power Requirements For Treating



(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 and WATER

What are the “special” challenges and opportunities faced by the arid southwest ?

- Economic/population growth?
- Climate change impacts on energy-water?
- Infrastructure planning for contingencies?
- Water Management Technologies (e.g. IWRM)?
- Changes in water quality/sediment load?
- Biofuels?
- New water treatment technologies/materials?
- New cooling technologies?

Summary of Major National Needs and Issues Identified in Regional Workshops

Better resources planning and management

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

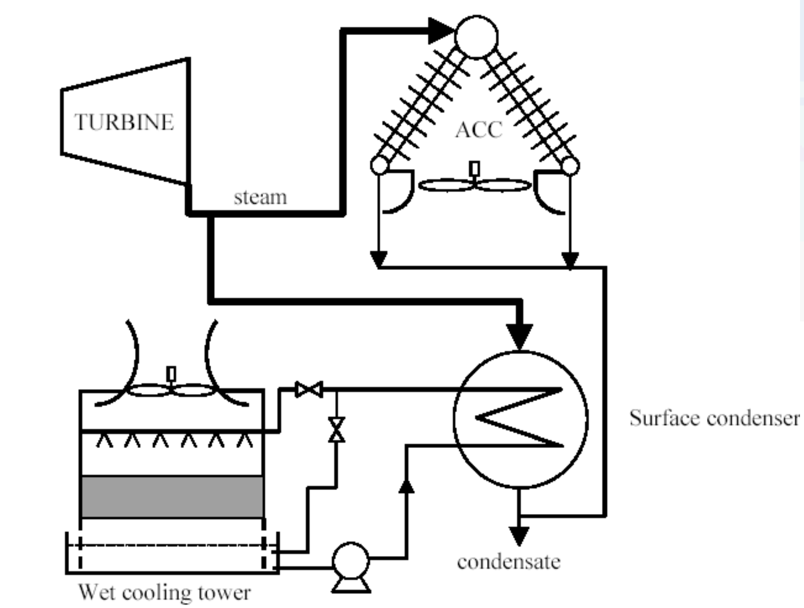
Improved water and energy use efficiency

- Improved water efficiency in thermoelectric power generation
- Improved biofuels/biomass water use efficiency
- Reduced water 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

Research Program for Electric Power Sector



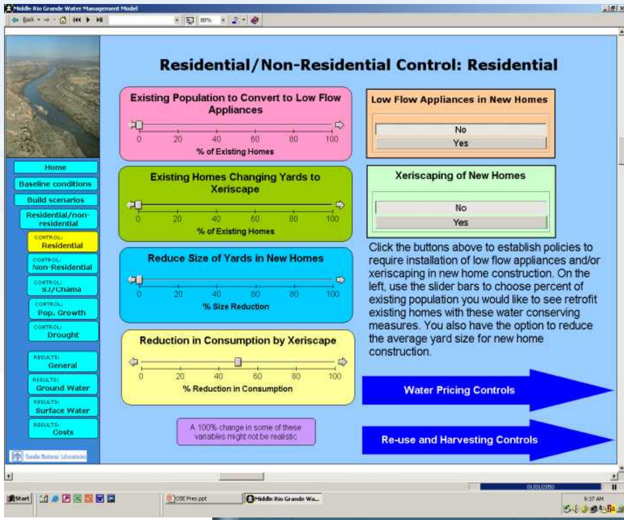
Hybrid Wet-Dry Cooling System

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

Research Program for Alternative Fuels Sector

- Reduce water use for cooling in biofuels and alternative fuels production
- Reduce water use in processing
- Develop low fresh water use technologies such as algal biodiesel
- Assess non-traditional water use for fuels applications
- Assess hydrologic impacts of large cellulose biofuels scale-up and oil shale

Research and Development Program for Integrated Resources Management



- – Accelerate water resources forecasting and management
- – Evaluate impacts of climate variability and improve hydrological forecasting
- – Improve common decision support tools
- – Develop system analysis approaches for: Co-location of energy and water facilities, improved national transmission capabilities to support renewables, distributed generation of biofuels

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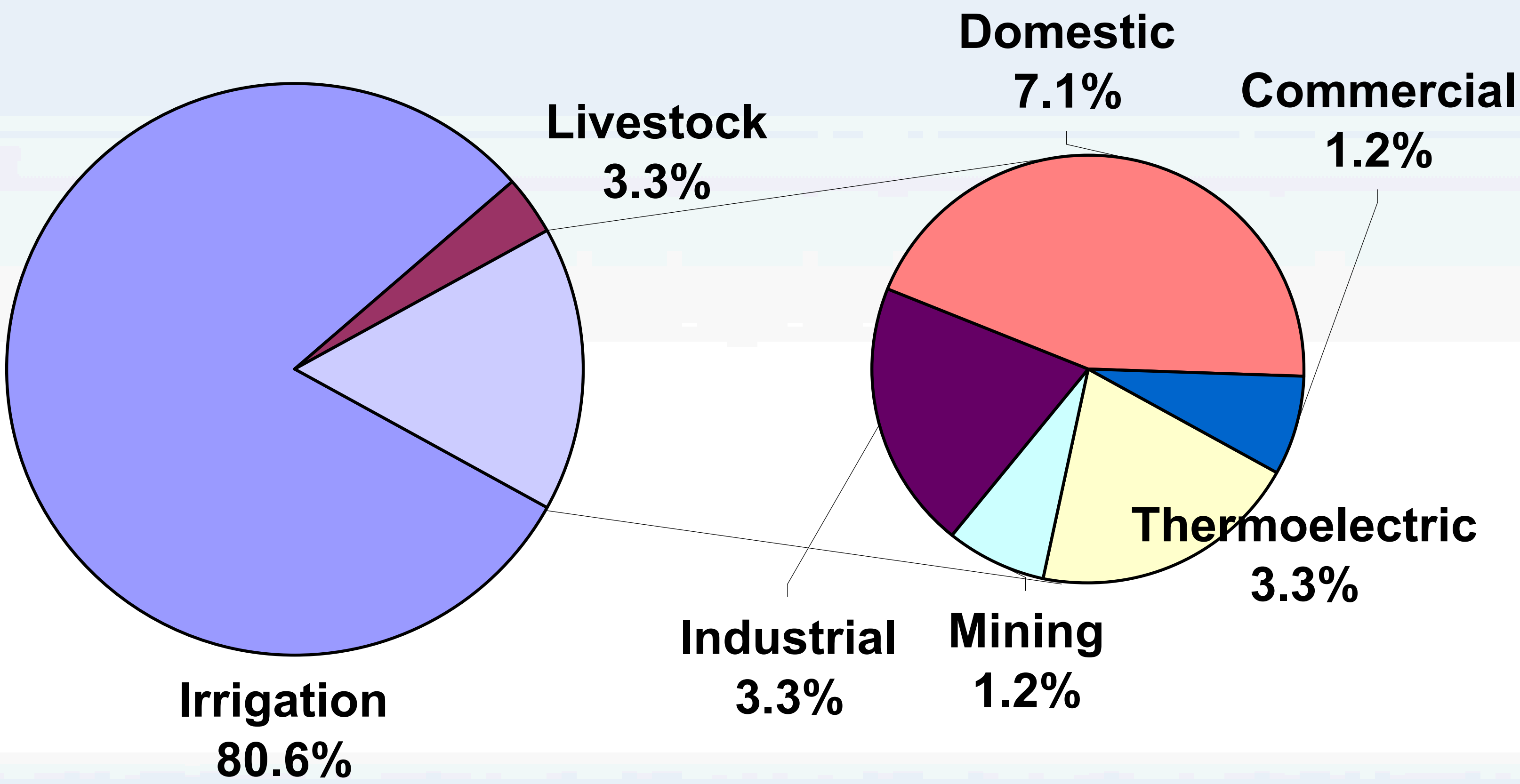
Backup Slides

Water Consumption by Sector

U.S. Freshwater Consumption, 100 Bgal/day



[USGS, 1998]

Energy uses 27 percent of all non-agricultural fresh water

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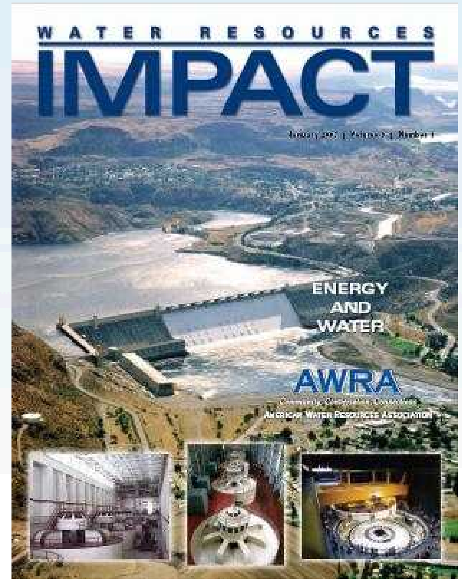
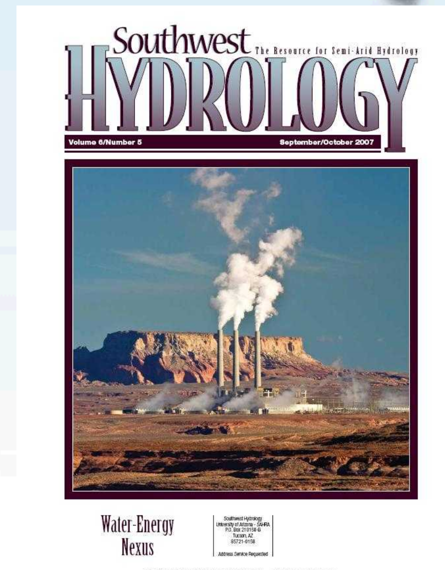
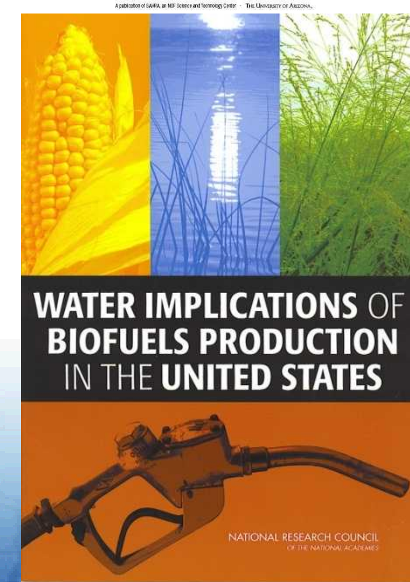
Emerging Interest in Energy and Water Issues and Challenges

- State and national water and energy groups
  - 24 invited presentations in FY07 and 08 on energy and water challenges
  - Research and regulatory groups considering future energy and water needs
- Increased media interest
  - NATURE, ECONOMIST
  - Technical magazines
- NSF/NAS interest in energy debate and interdependencies research
- Growing international concerns and challenges
  - Europe, Australia, Asia, Canada







Water Use and Consumption for Electric Power Generation

Plant-type	Cooling Process	Water Use Intensity (gal/MWh_e)		
		Steam Condensing		Other Uses
		Withdrawal	Consumption	Consumption
Fossil/ biomass steam turbine	Open-loop	20,000–50,000	~200-300	~30
	Closed-loop	300–600	300–480	
Nuclear steam turbine	Open-loop	25,000–60,000	~400	~30
	Closed-loop	500–1,100	400–720	
Natural Gas Combined-Cycle	Open-loop	7,500–20,000	100	7–10
	Closed-loop	230	180	
Integrated Gasification Combined-Cycle	Closed-loop	200	180	150
Carbon sequestration for fossil energy generation	~25% increase in water withdrawal and consumption			
Geothermal Steam	Closed-loop	2000	1350	50
Concentrating Solar	Closed-loop	750	740	10
Wind and Solar Photovoltaic	N/A	0	0	1-2

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Water Demand/Impact of Transportation Fuels

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				
- Oil Refining	Water needed to extract and refine; Water produced from extraction	Produced water generated from extraction; Wastewater generated from processing;	7 – 20	~ 1.5
- NG extraction/Processing			2 – 3	~ 1.5
Biofuels				
- Grain Ethanol Processing	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	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				
- In situ retort	Water needed to Extract / Refine	Wastewater generated; In-situ impact uncertain; Surface leachate runoff	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				
- Coal to Liquid (CTL)	Water needed for synthesis and/or steam reforming of natural gas (NG)	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

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Biomass and Water Use Impacts Will be Regional