completing the energy sustainability puzzle

SAND2008-6249C

ENERGY and WATER

NEXUS of Water and Energy
Issues, Trends, and Challenges

Toyota Sustainable Mobility Seminar- Sept. 22 – 25, 2008

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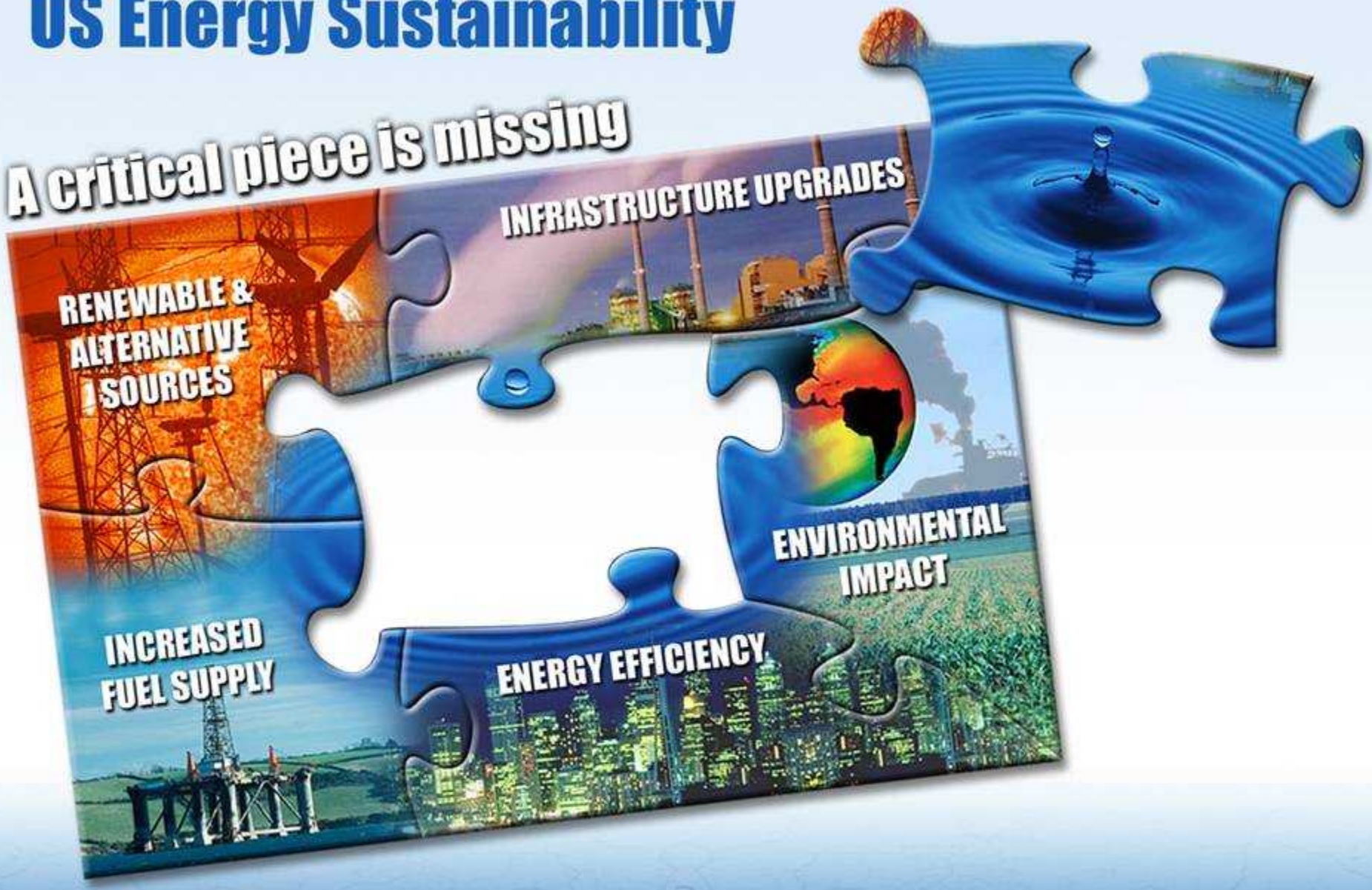
Sandia National Laboratories

US Energy Sustainability



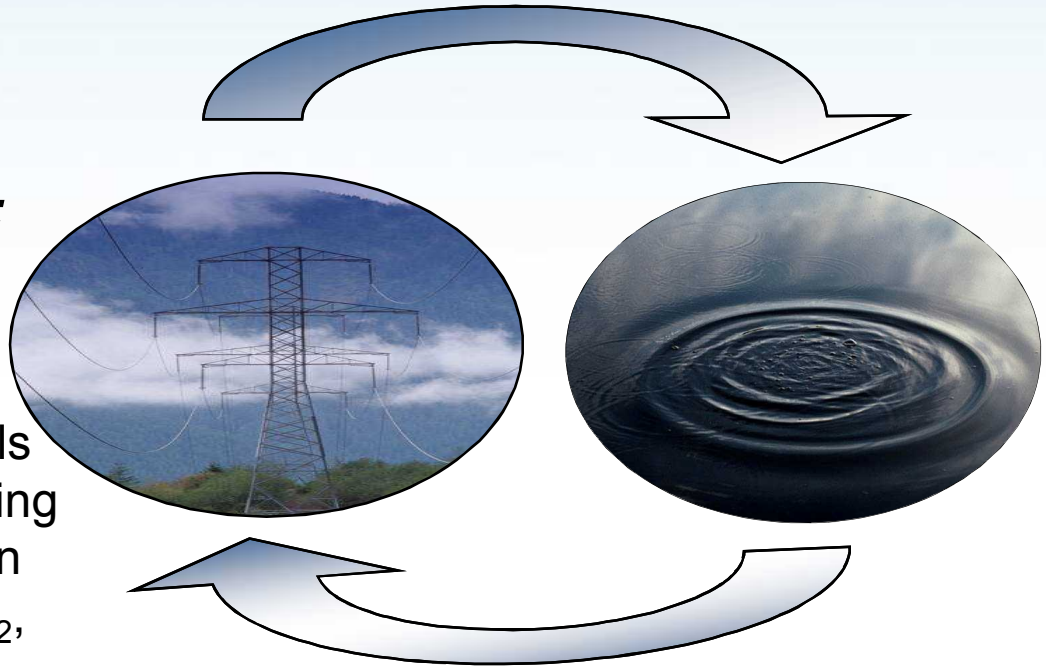
ENERGY and WATER

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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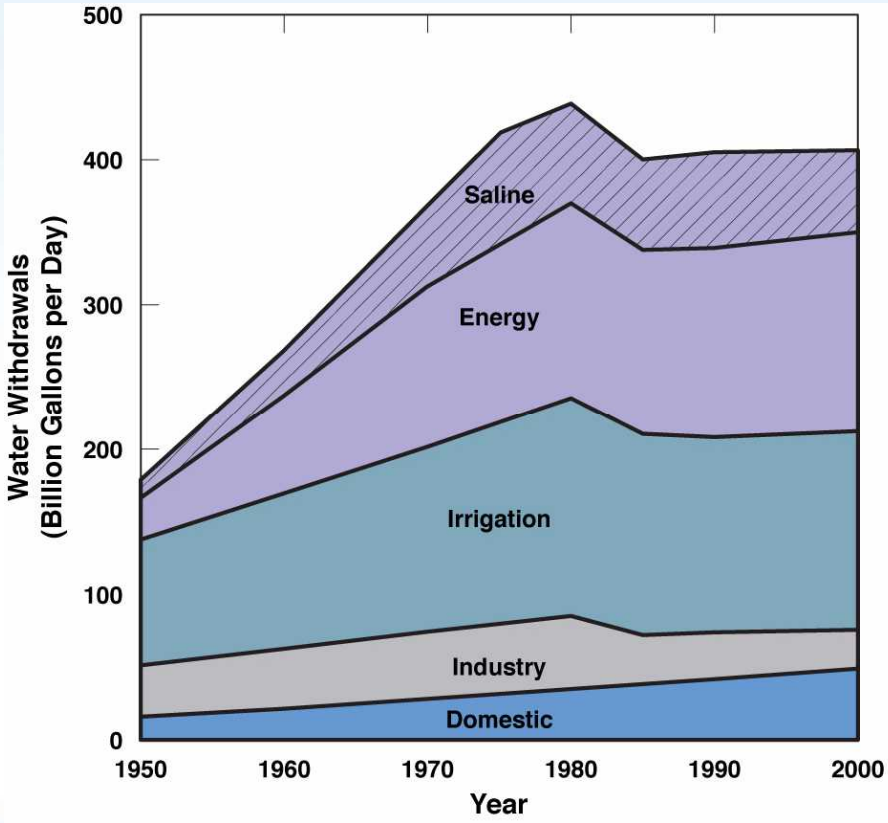
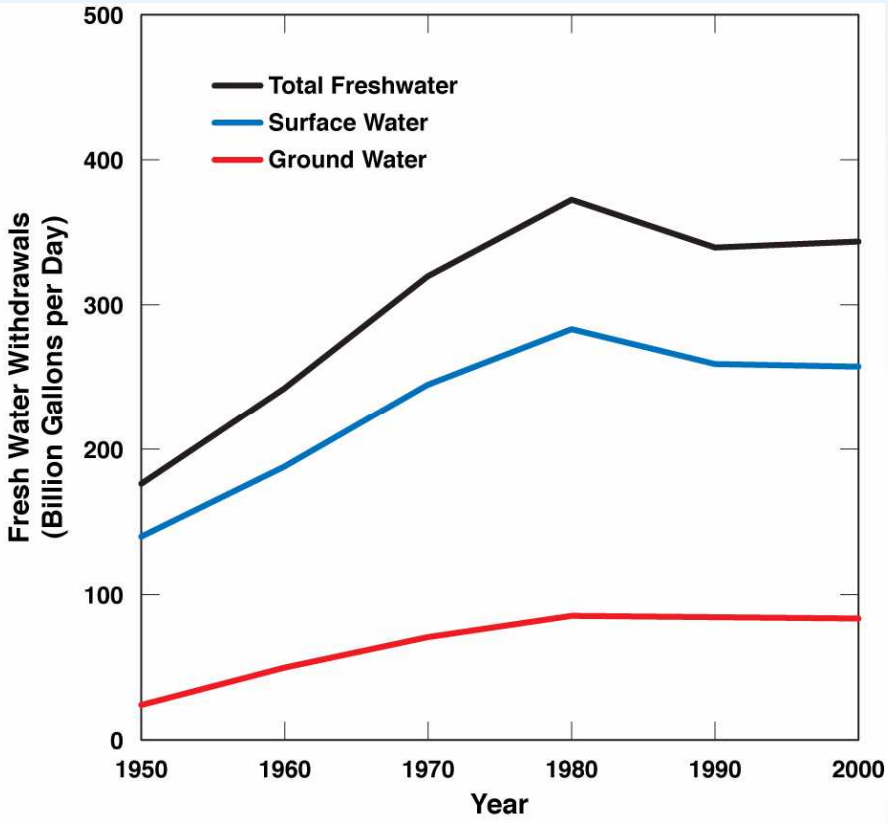
Water Withdrawal Trends by Sector

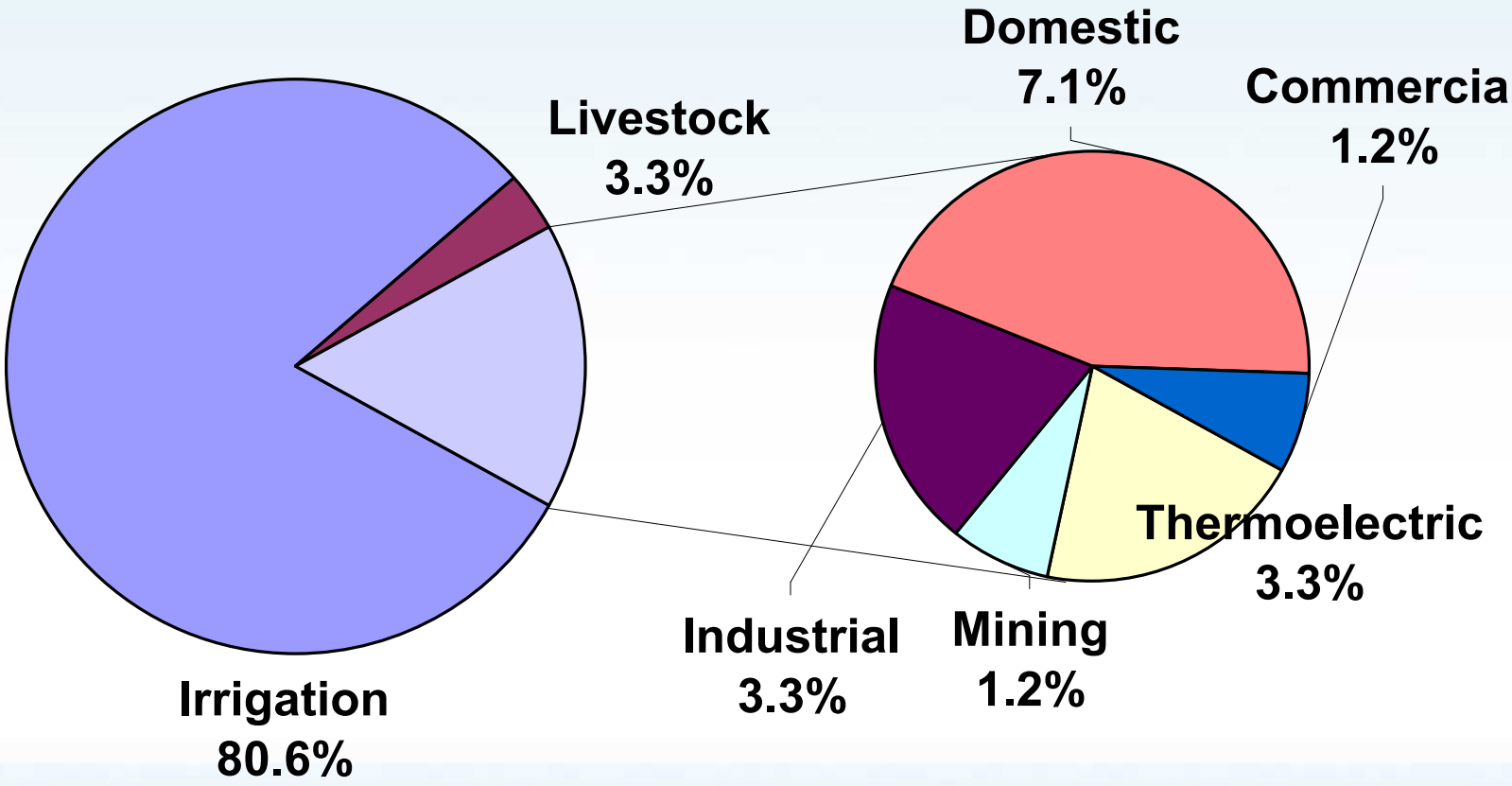




[USGS, 2004]

Water Consumption by Sector

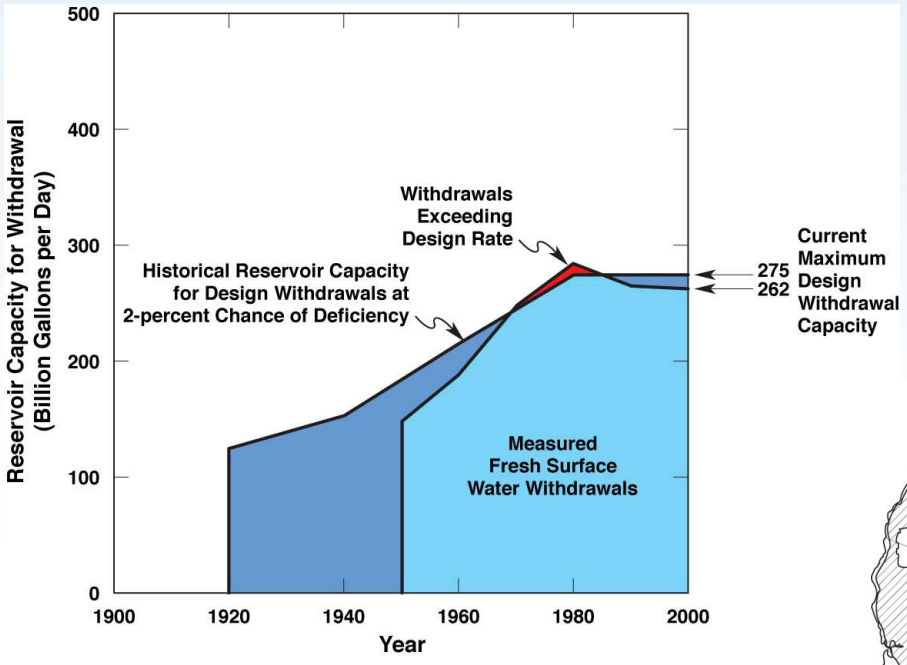
U.S. Freshwater Consumption, 100 Bgal/day



[USGS, 1998]

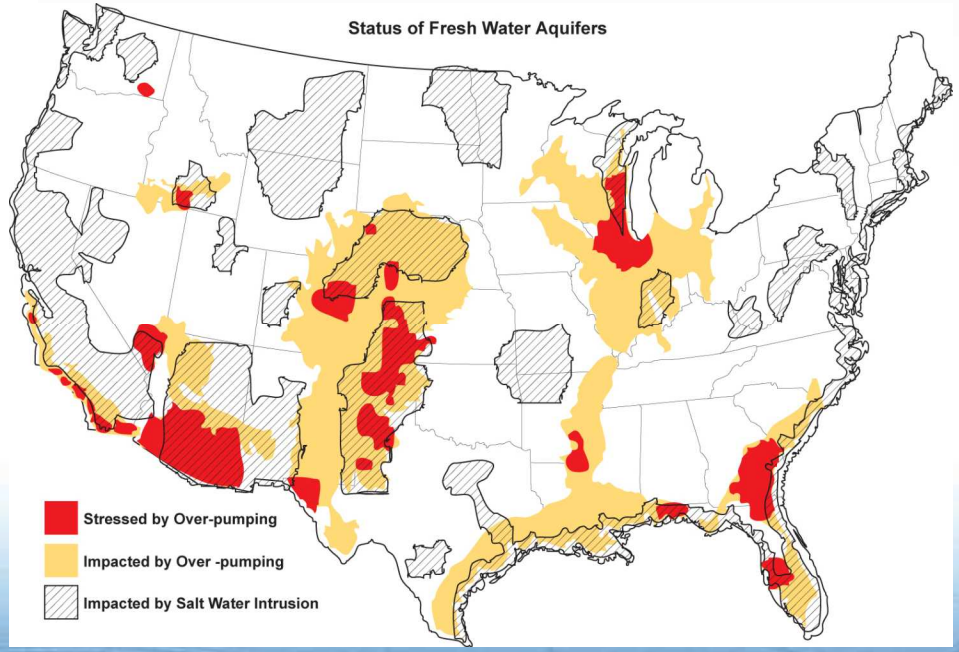
Energy accounts for 27 percent of non-agricultural fresh water consumption

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

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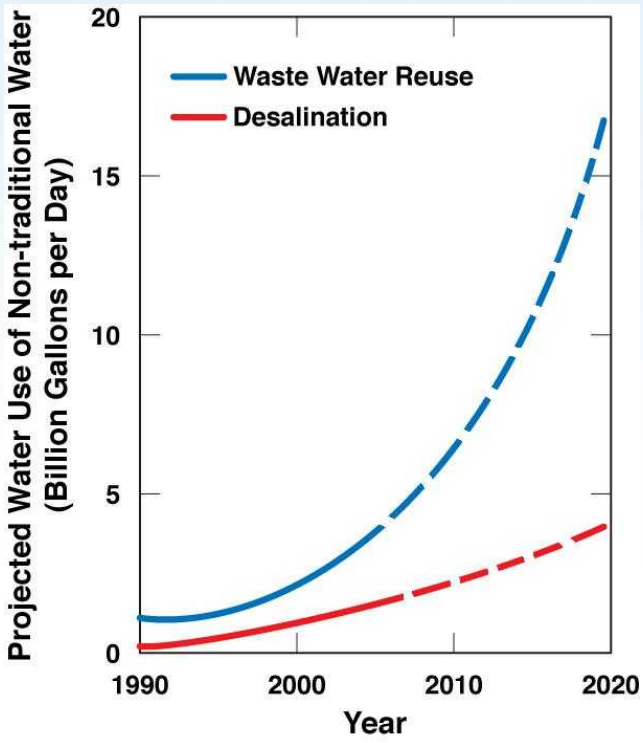
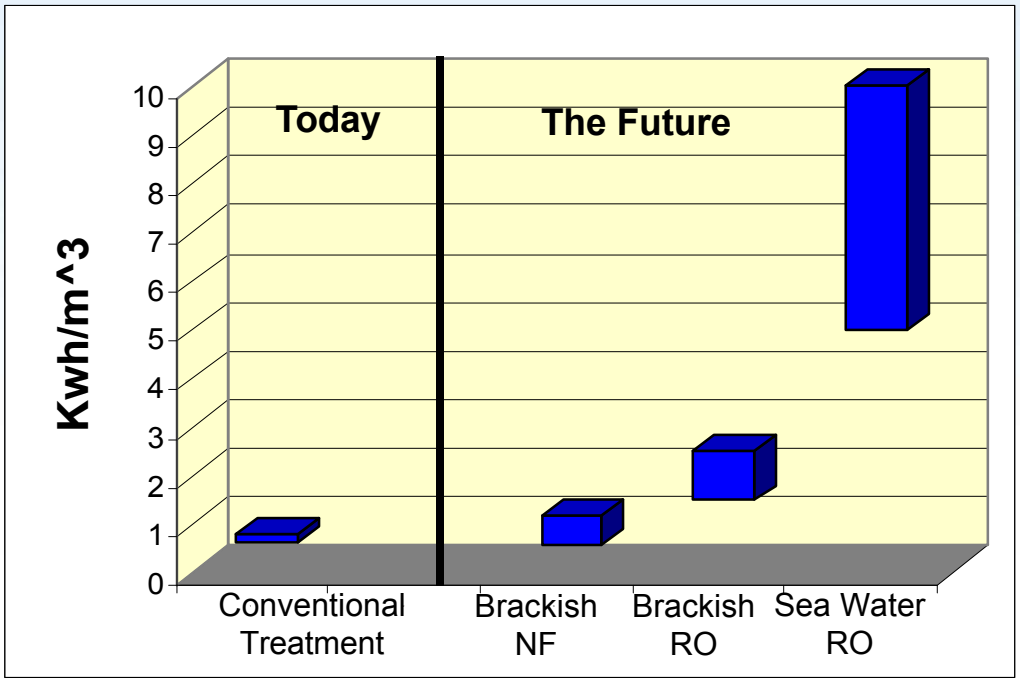
Growing Use of Non-traditional Water Resources



(From EPA 2004, Water Reuse 2007, 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

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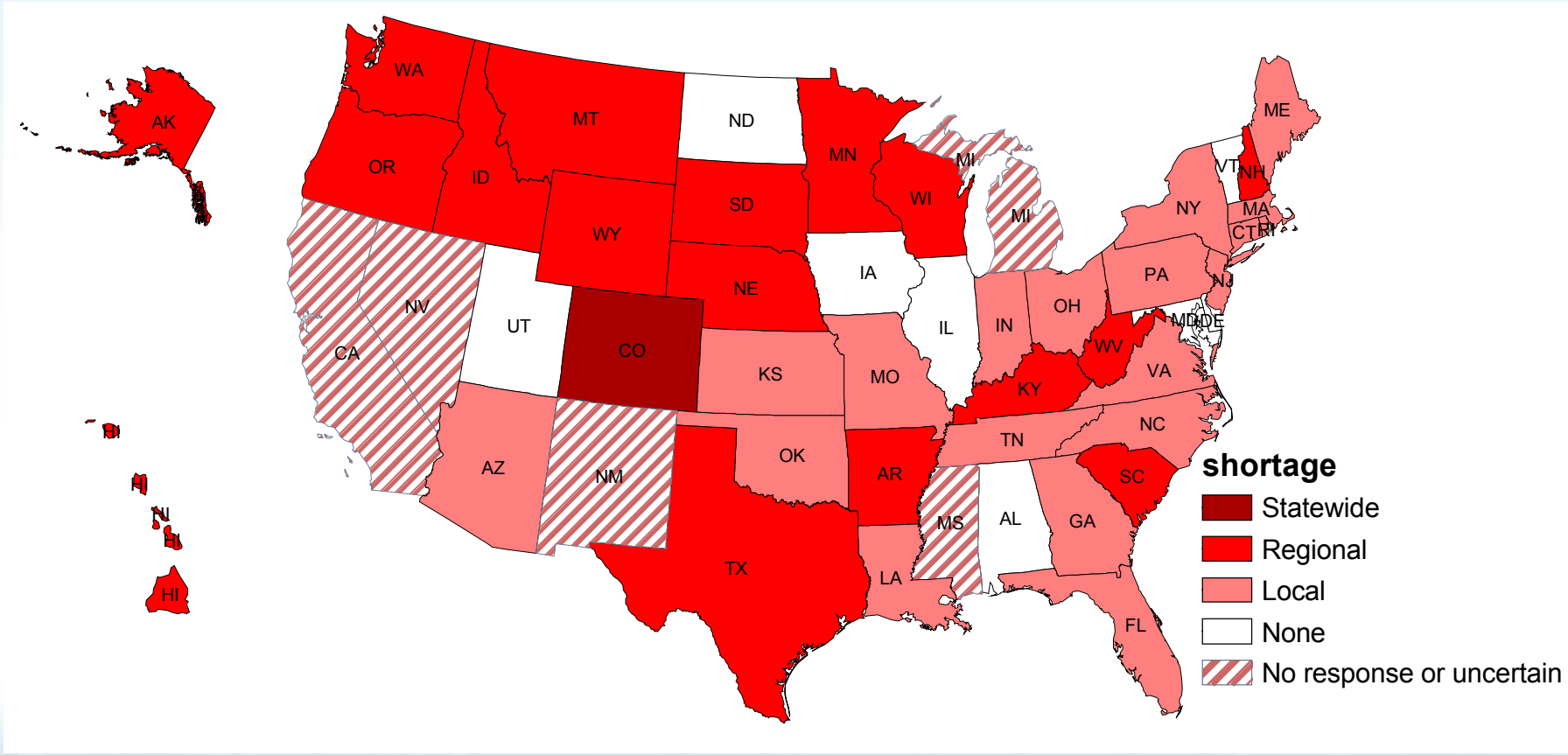
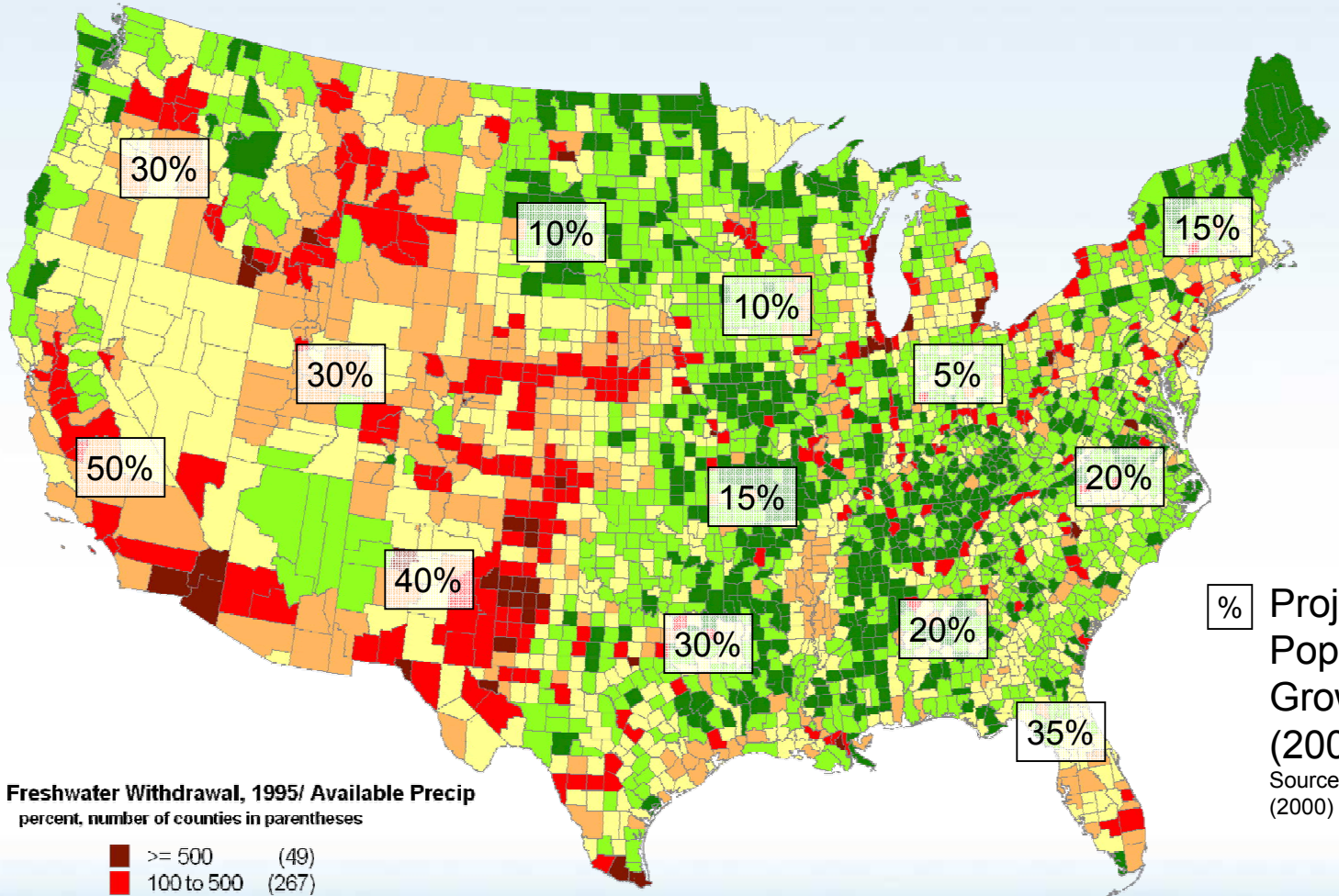
Most State Water Managers Expect Shortages Over The Next Decade Under Average Conditions



Source: GAO 2003

Water challenges are nationwide



% Projected Population Growth (2000-2020)

Source: Campbell (2000)

EPRI 2003

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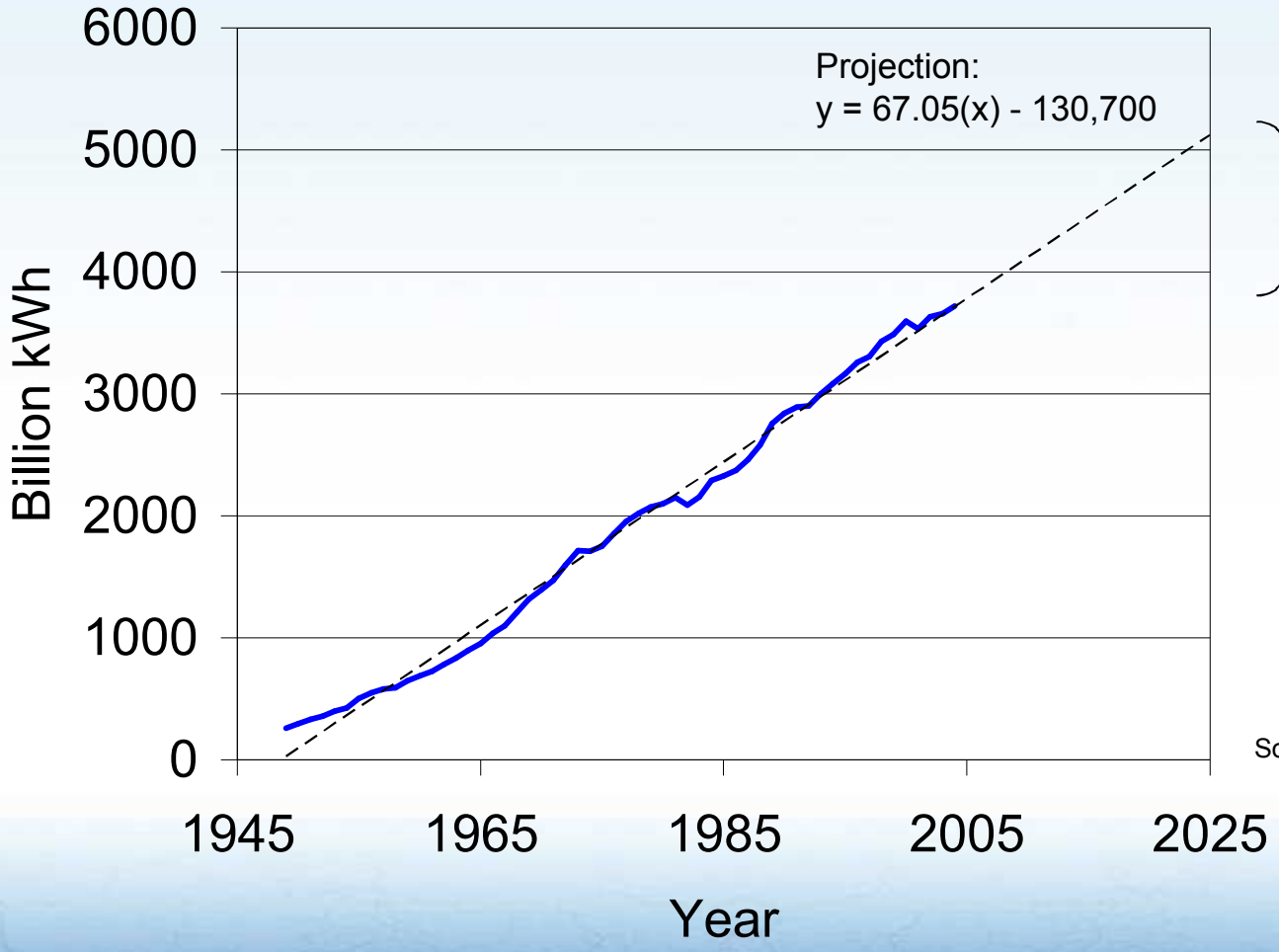
The U.S. will need 50% more electricity by 2035

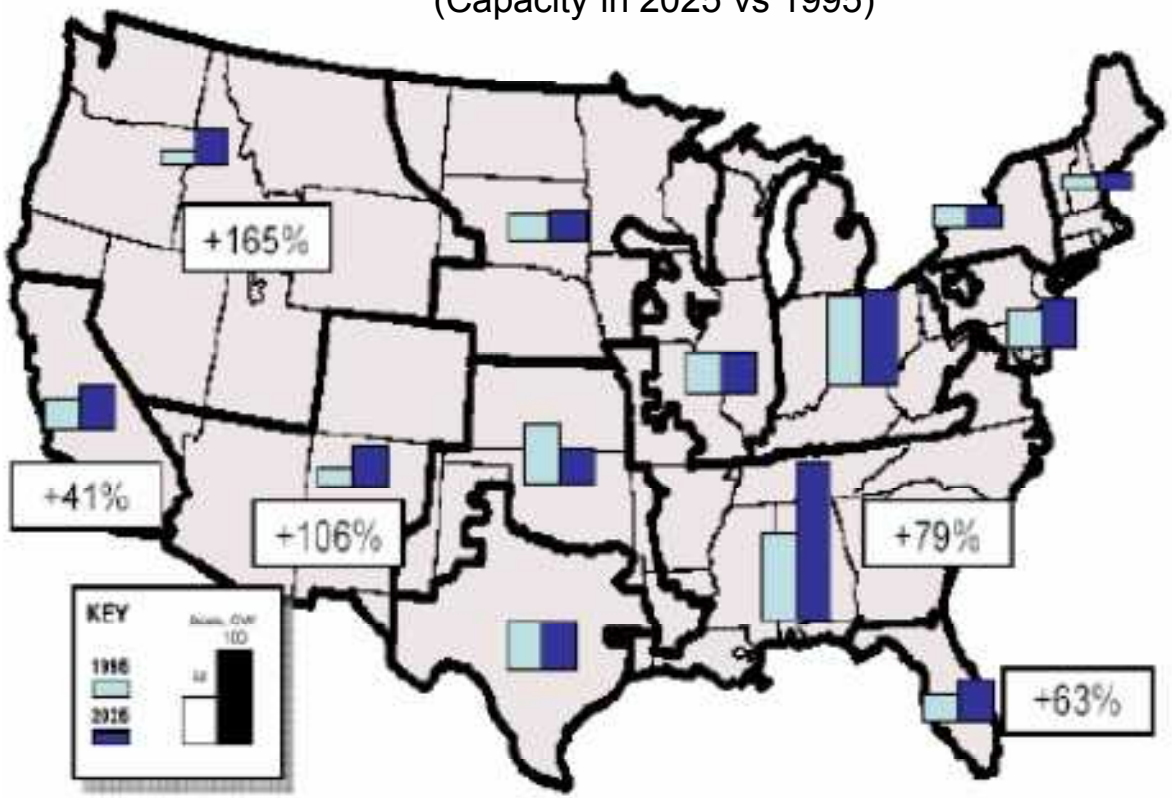


Source: DOE/EIA-0384(2004)

Growth in Thermoelectric Power Generation

- Most growth in water stressed regions
- Most new plants expected to use evaporative cooling

Projected Thermoelectric Increases
(Capacity in 2025 vs 1995)

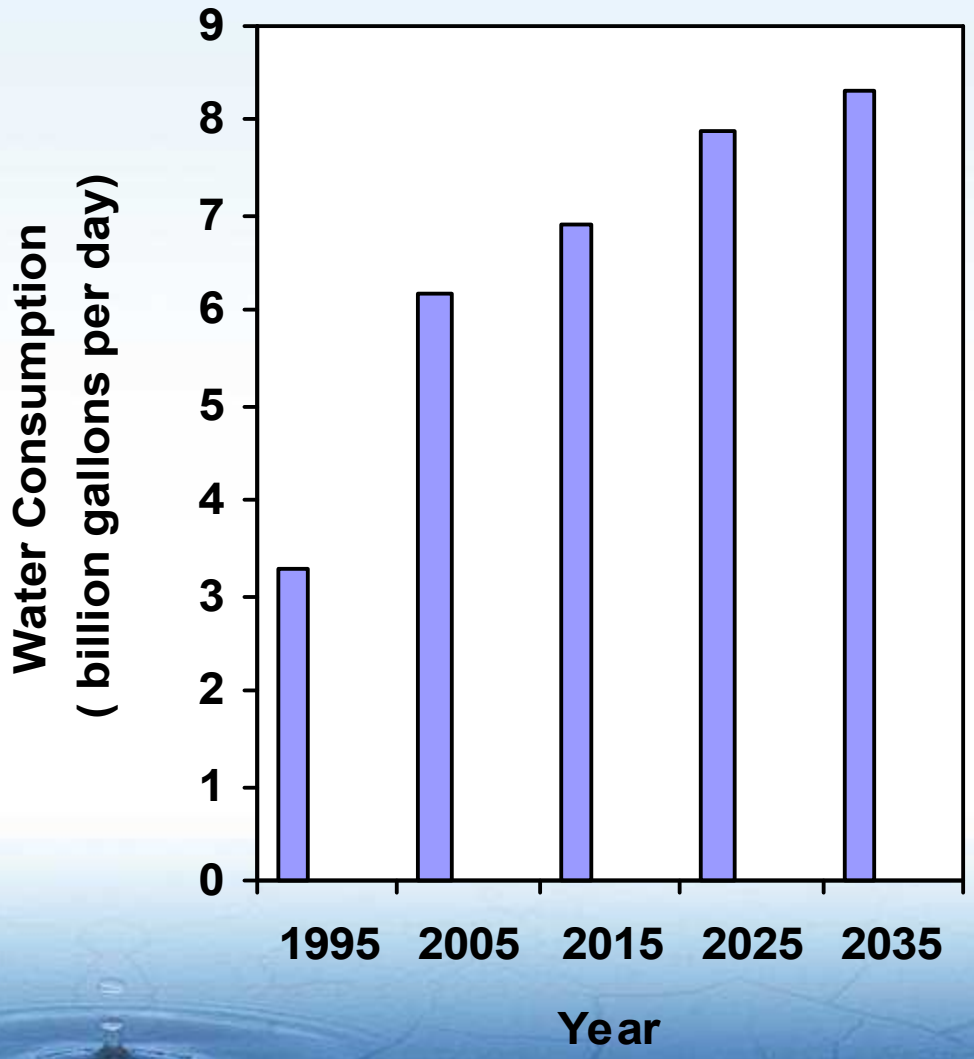


Source: NETL, 2004

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

Source: NETL 2006

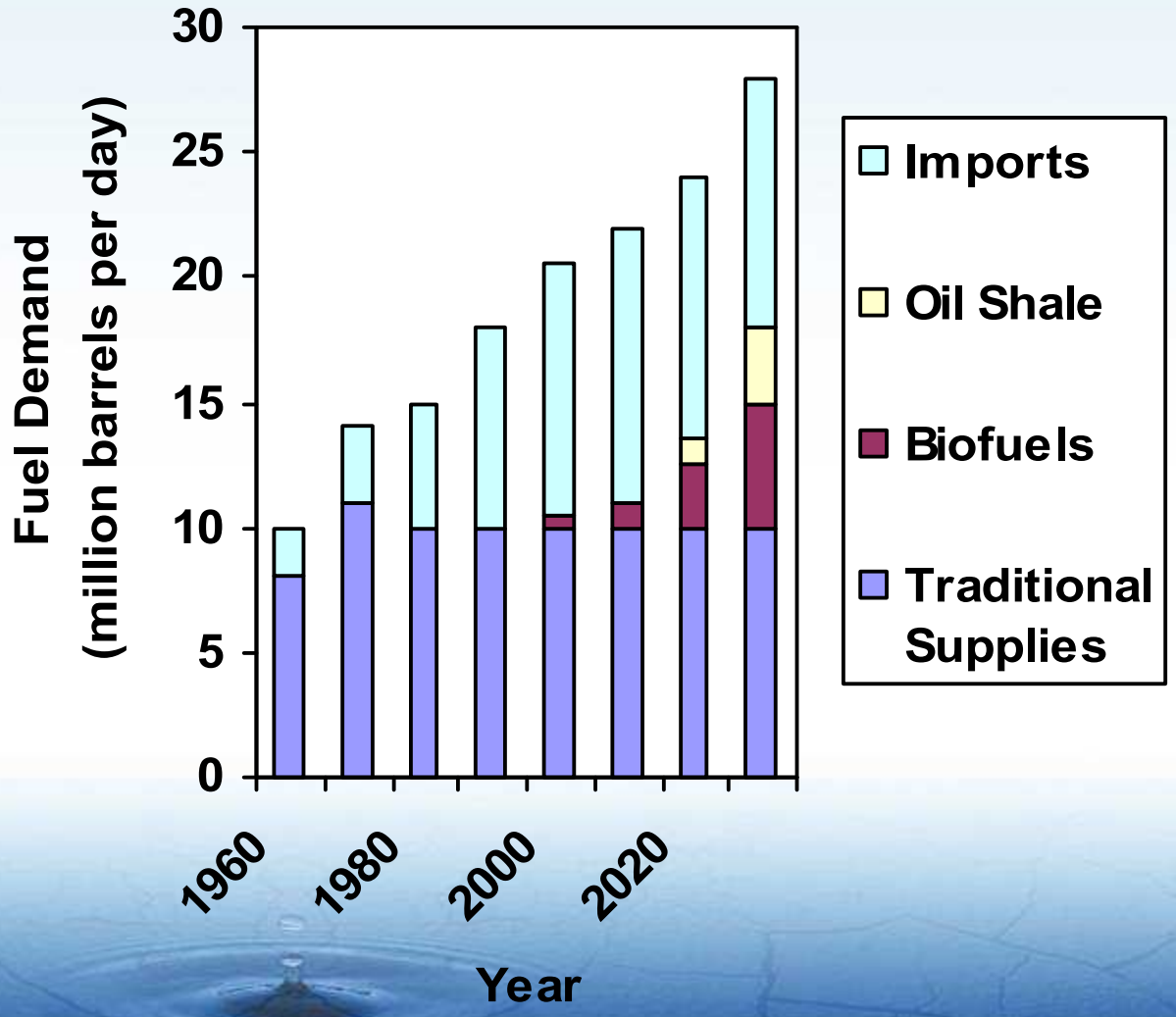


Water Use and Consumption for Electric Power Generation

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	15-36
	Closed-loop	300–900	300–714	
Nuclear steam turbine	Open-loop	25,000–60,000	~400	36
	Closed-loop	800–1,100	~720	
Natural Gas Combined-Cycle	Open-loop	7,500–20,000	100	10-20
	Closed-loop	230	408	
Integrated Gasification Combined-Cycle	Closed-loop	360-540	200-510	130
Carbon sequestration for fossil energy generation	~25% increase in water withdrawal and consumption			
Geothermal Steam	Closed-loop	2190	1640-1750	50
Concentrating Solar	Closed-loop	850-1125	750-920	10-53
Wind and Solar Photovoltaic	N/A	0	0	1

The U.S. will need 33% more Transportation Fuels by 2030

- Fuel use will increase despite gains in efficiency
- Current initiatives for domestic alternatives like oil shale and biofuels
- Major hydrogen use will be post 2030



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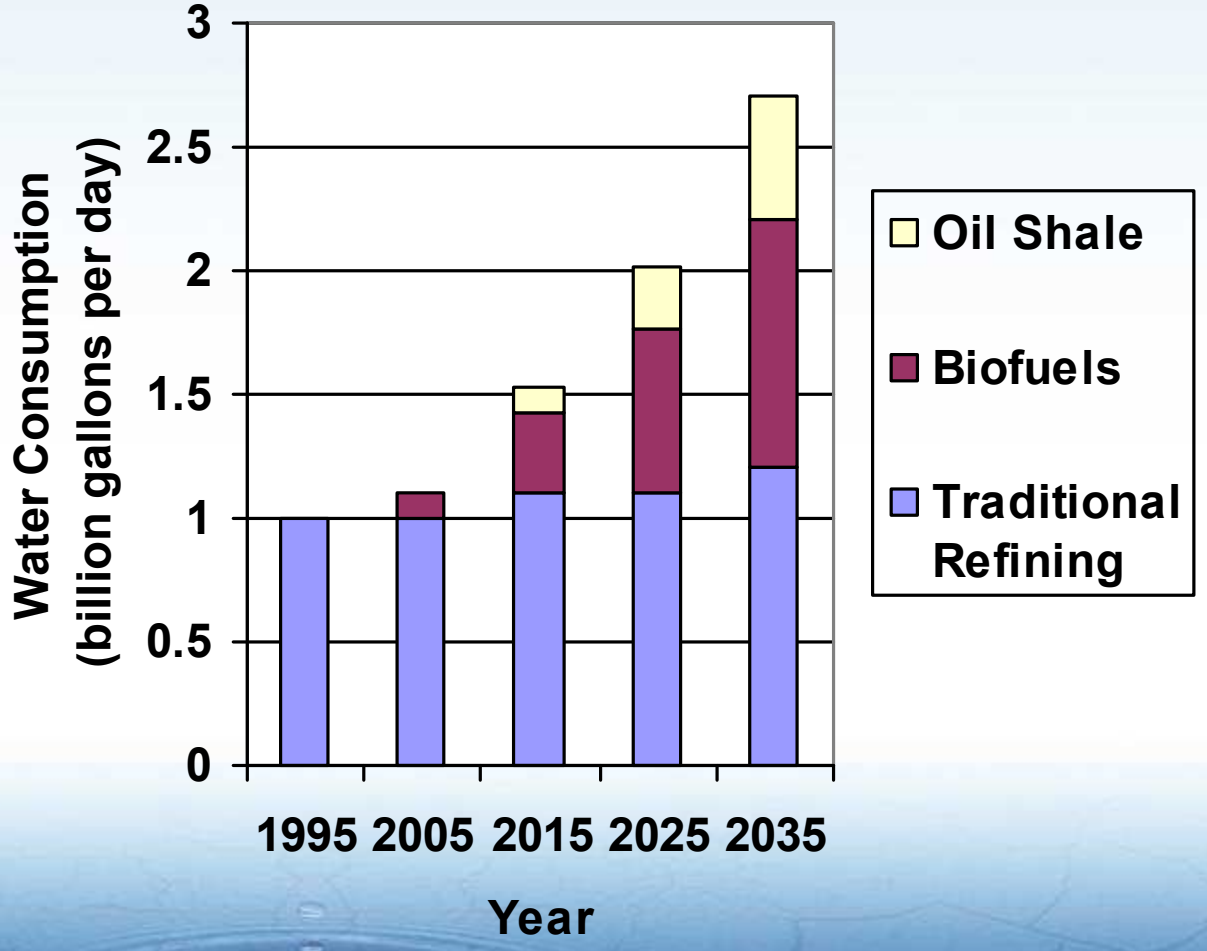
Emerging Water Demands for Alternative Fuels Development

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



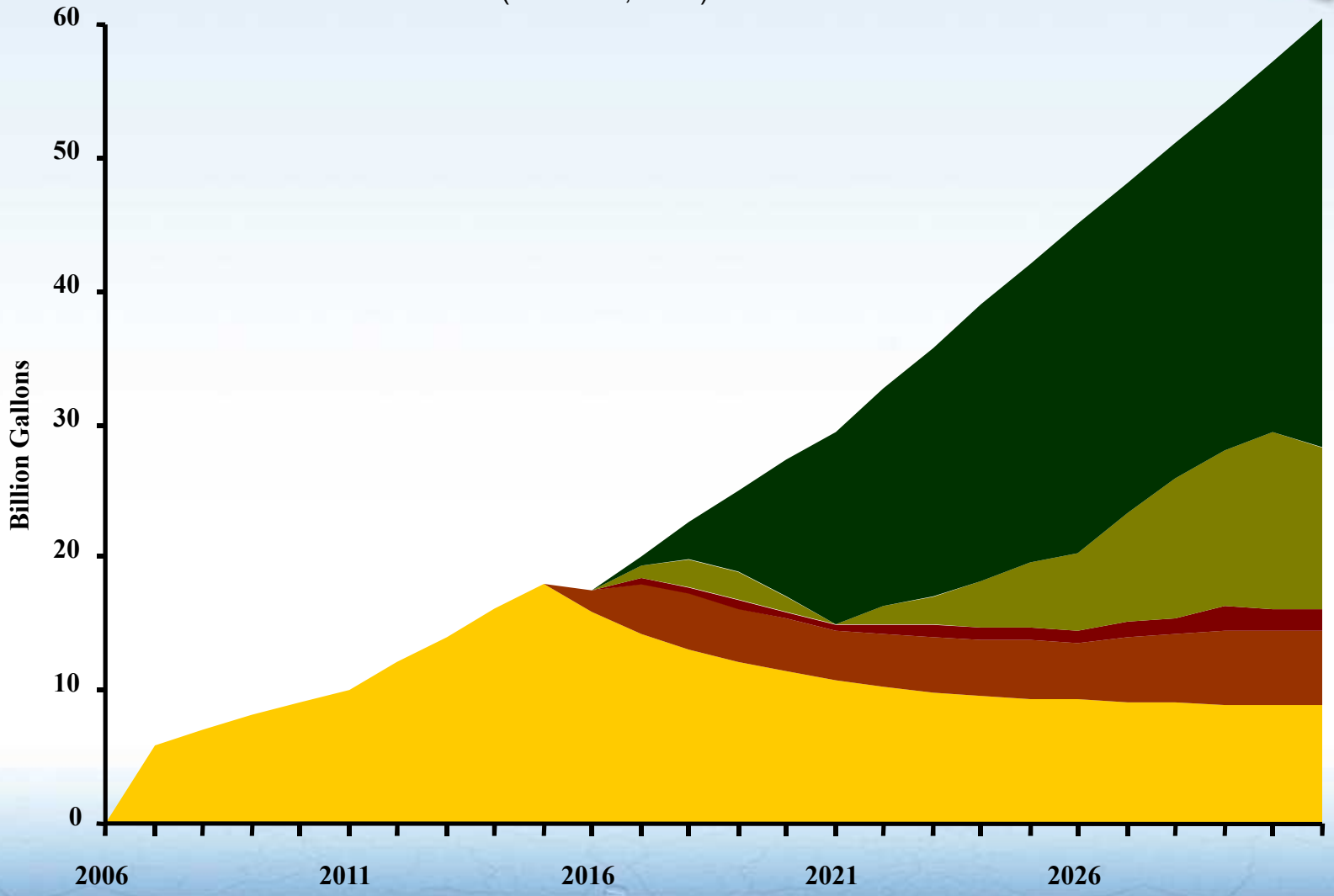
Water Demand/Impact of Transportation Fuels

Fuel Type and Process	Relationship to Water Quantity	Relationship to Water Quality	Water Consumption 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;	1 - 2.5
- Oil Refining			0.2
- NG extraction/Processing			
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	3 - 7
- Grain Ethanol Processing			~ 980*
- Corn Irrigation for EtOH			~ 2
- Biodiesel Processing			~ 6500*
- Soy Irrigation for Biodiesel			
- 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	~ 2 - 6 ‡§ ~ 2 - 6 ‡§
Oil Shale	Water needed to Extract / Refine	Wastewater generated; In-situ impact uncertain; Surface leachate runoff	1.2 - 2.3
- In situ retort			2.1 - 5.2
- Ex situ retort			
Oil Sands	Water needed to Extract / Refine	Wastewater generated; Leachate runoff	2 - 6.9
Synthetic Fuels	Water needed for synthesis and/or steam reforming of natural gas (NG)	Wastewater generated from coal mining and CTL processing	0.9 - 2.7
- Coal to Liquid (CTL)			~ 3 ‡
- Hydrogen RE Electrolysis			6.4
- Hydrogen (NG Reforming)			

† Ranges of water use per unit energy largely based on data takenfrom the Energy-Water Report to Congress (DOE, 2007)
* Conservative estimates of water use intensity for irrigated fœdstock 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

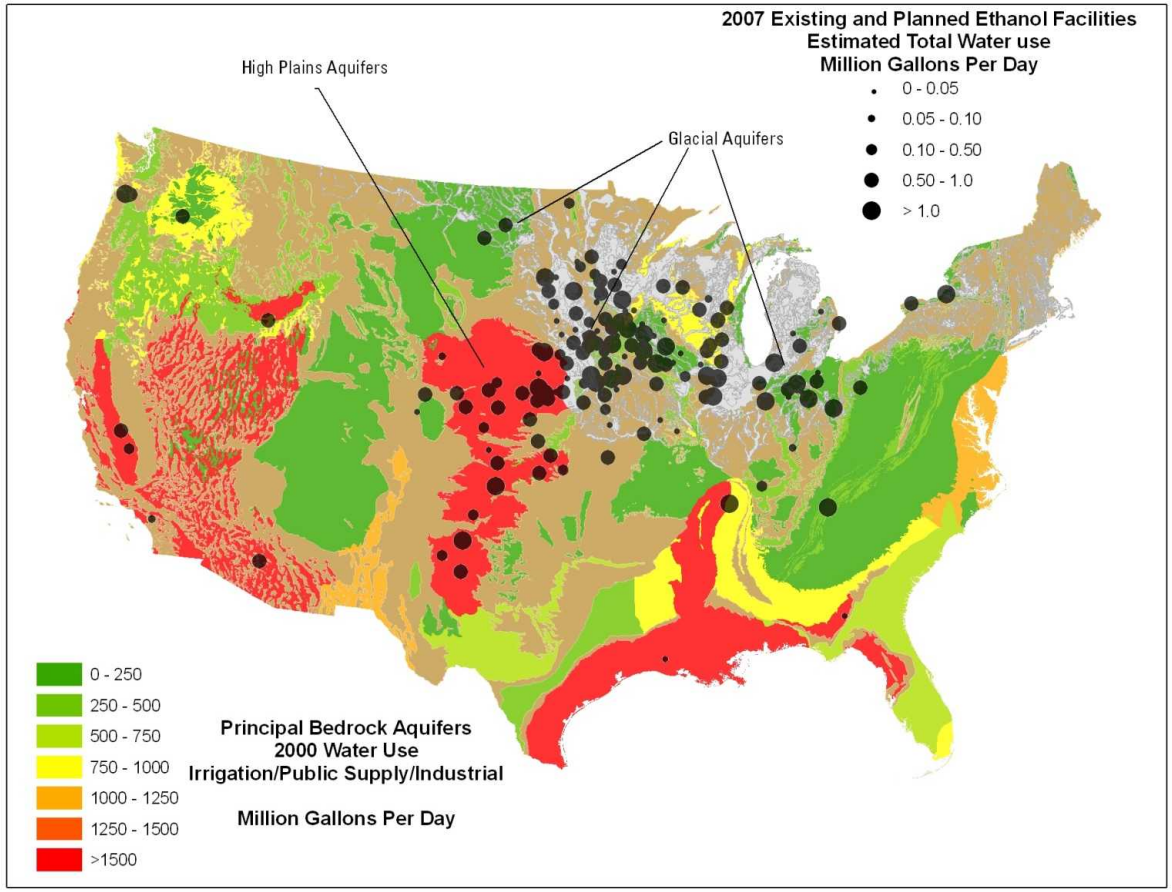
Projected Ethanol Production by Feedstock

(Ref: NRC, 2007)



Ethanol Production Growth and Feedstock Irrigation Issues

- Irrigated corn requires 2000-4000 gal/bushel
- Move to cellulosic ethanol will move production south and east
- Amount of irrigation needed for fuel reliability of dedicated energy crops is uncertain
- Concerns over ethanol production plant impacts on groundwater quality and availability



Ref: Schnoor, ACS, 2008

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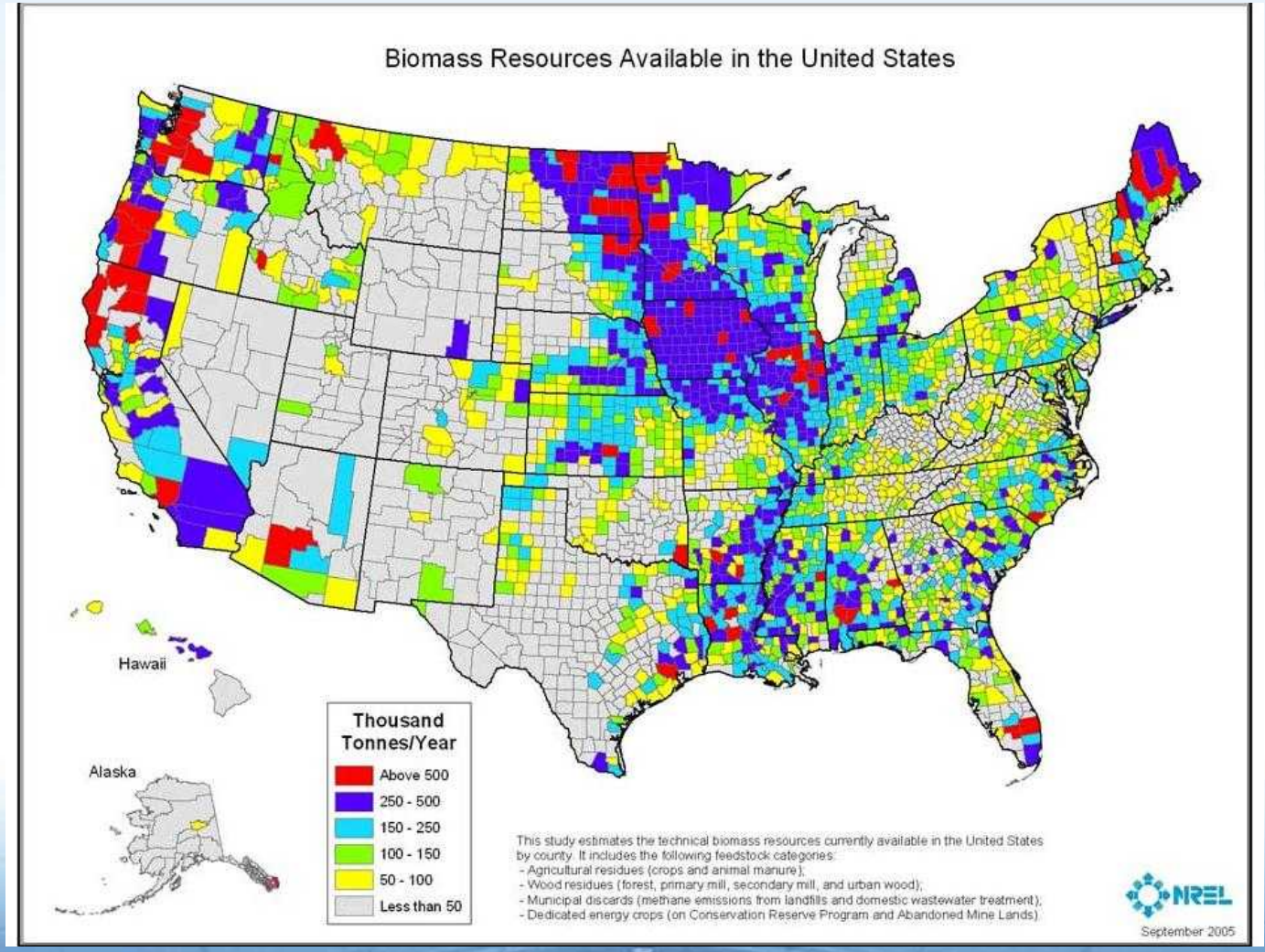
Biomass and Water Use Impacts Will be Regional



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 2-5 gallons per gallon of fuel
- Concerns over *in situ* migration of retort by-products and impact on ground water quality

QUESTIONS