

*completing the energy sustainability puzzle*



# **ENERGY** *and* **WATER**

## **NEXUS of Water and Energy Issues, Trends, and Challenges**

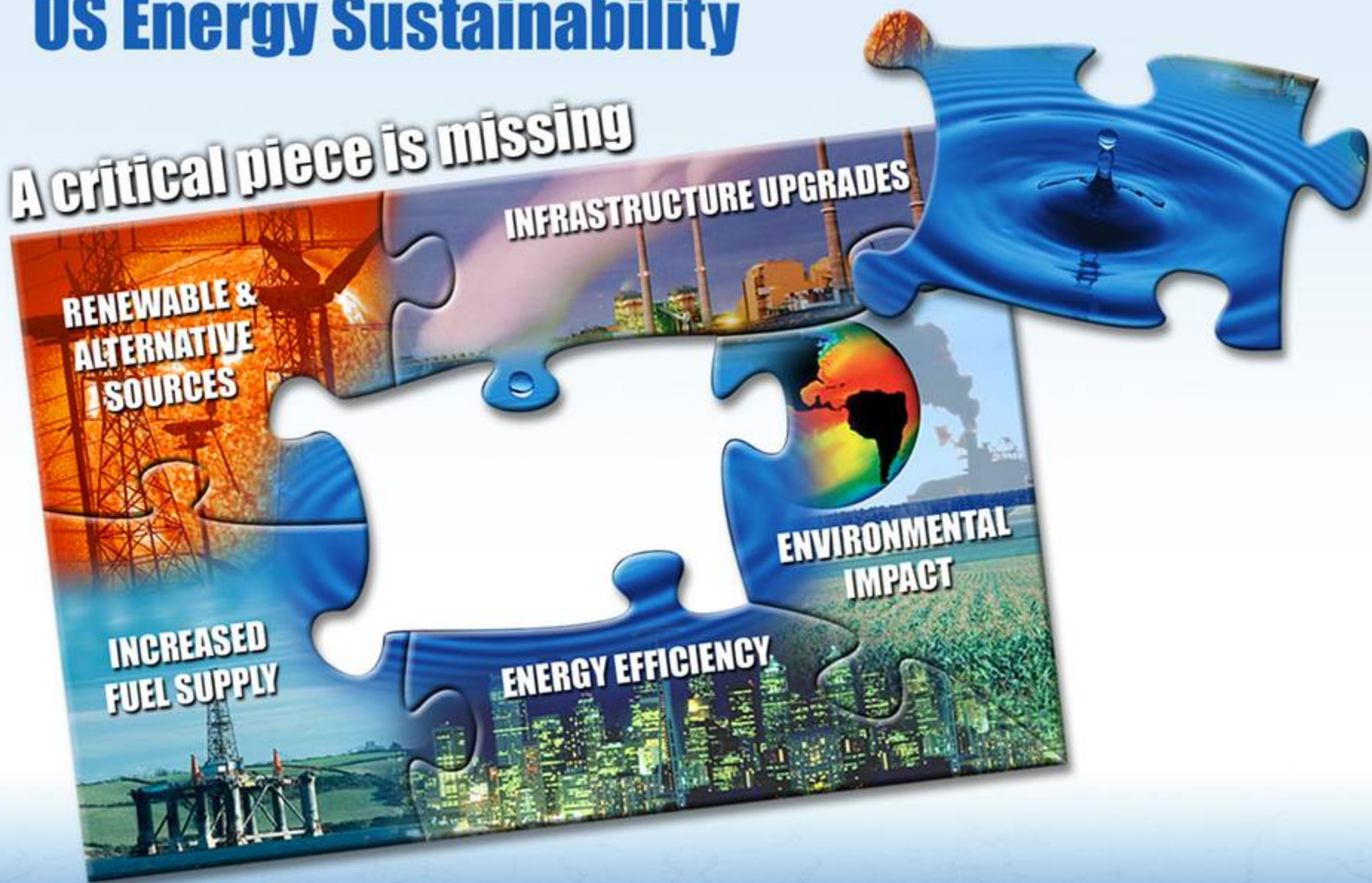
**Toyota Sustainable Mobility Seminar- Sept. 22 – 25, 2008**

**John A. Merson  
Sandia National Laboratories**



# US Energy Sustainability

A critical piece is missing



# Energy and Water are ... Interdependent



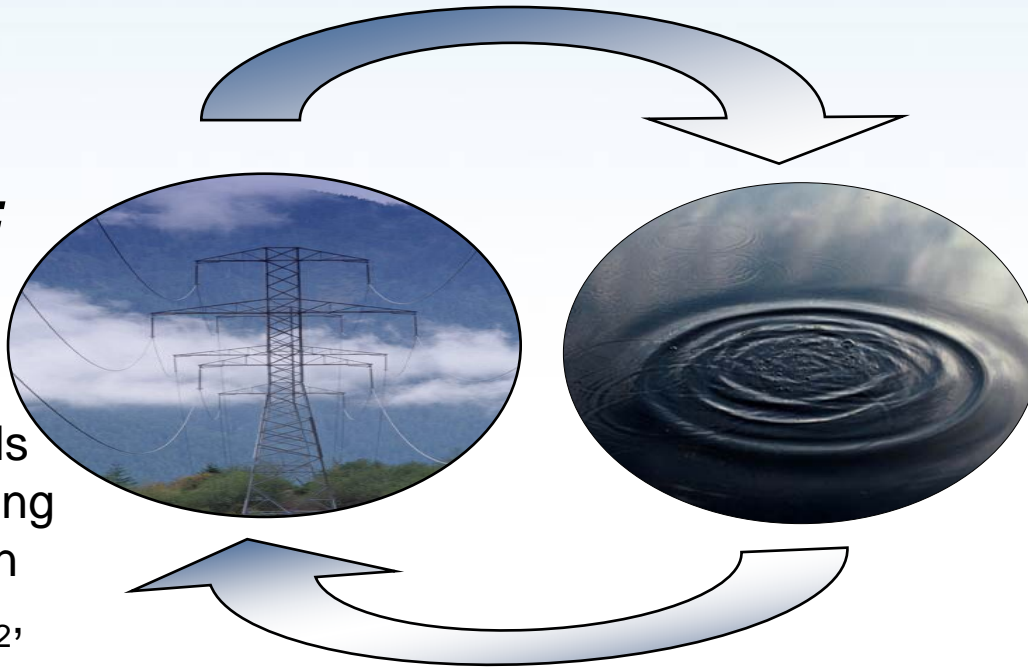
## Water for Energy

and

## Energy for Water

### ***Energy and power production require water:***

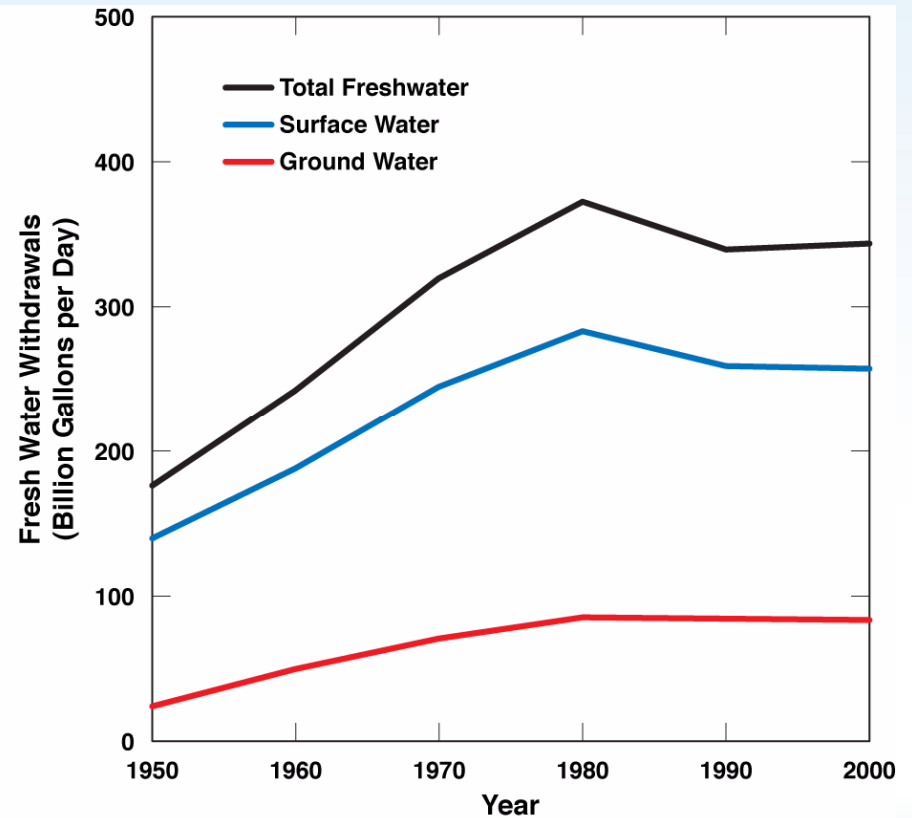
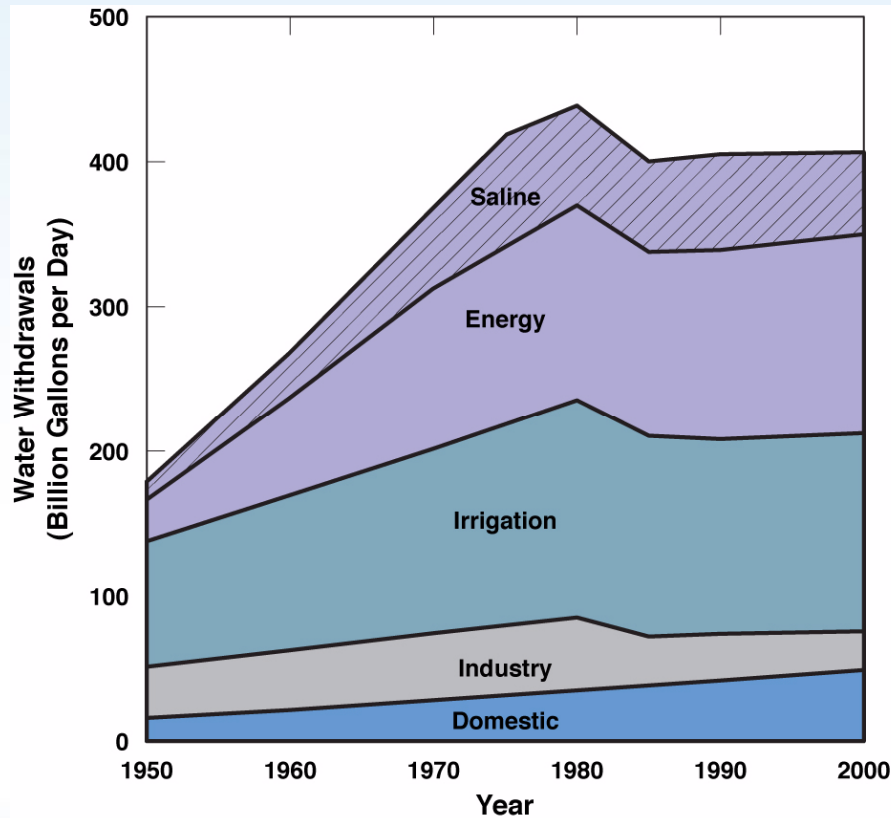
- Thermoelectric cooling
- Hydropower
- Energy minerals extraction/mining
- Fuel Production (fossil fuels, H<sub>2</sub>, biofuels)
- Emission control



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

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

# Water Withdrawal Trends by Sector



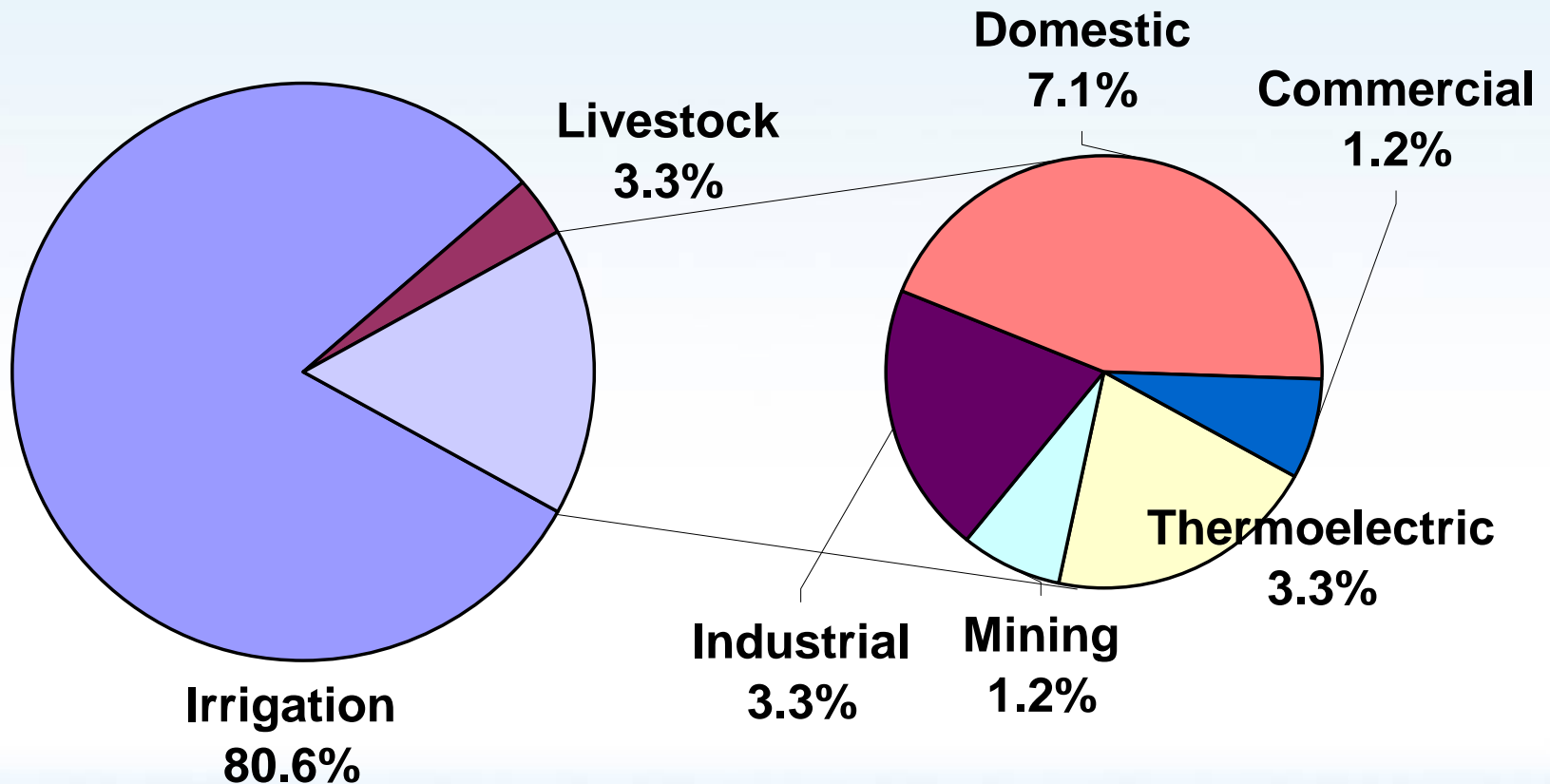
[USGS, 2004]



# Water Consumption by Sector



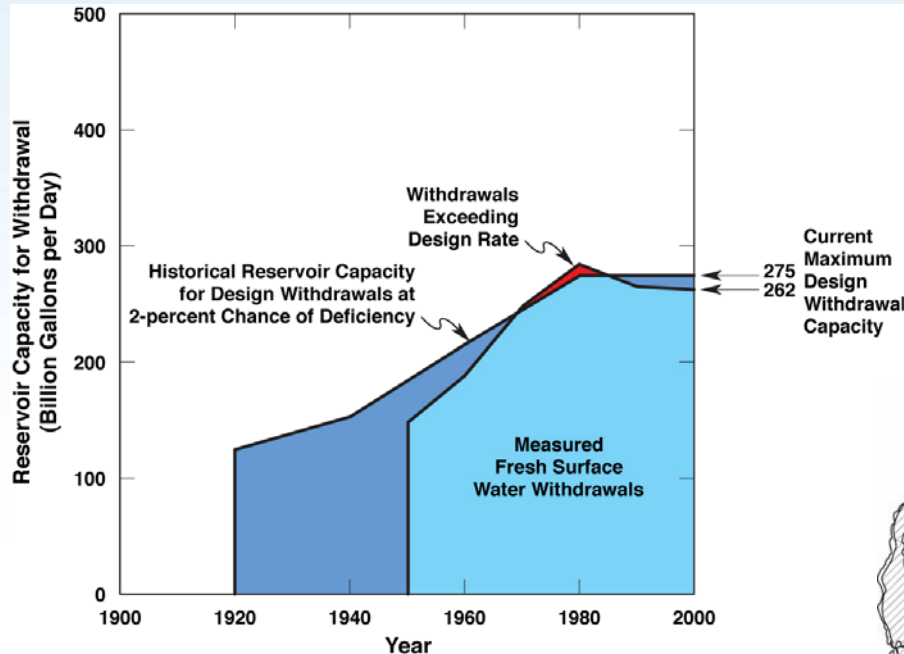
**U.S. Freshwater Consumption, 100 Bgal/day**



[USGS, 1998]

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

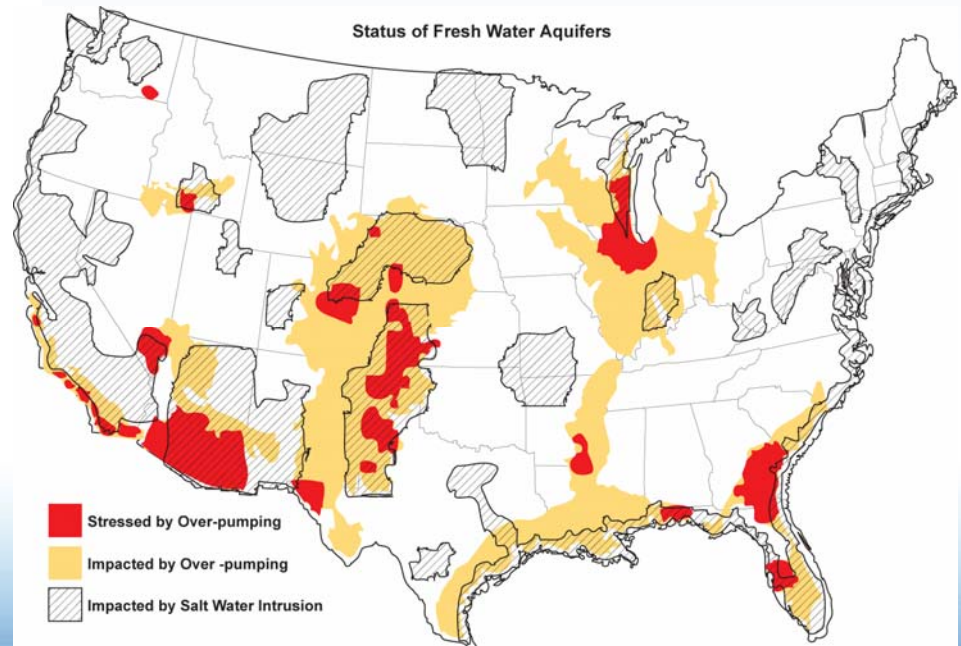
# Growing Limitations on Fresh Surface and Ground Water Availability



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

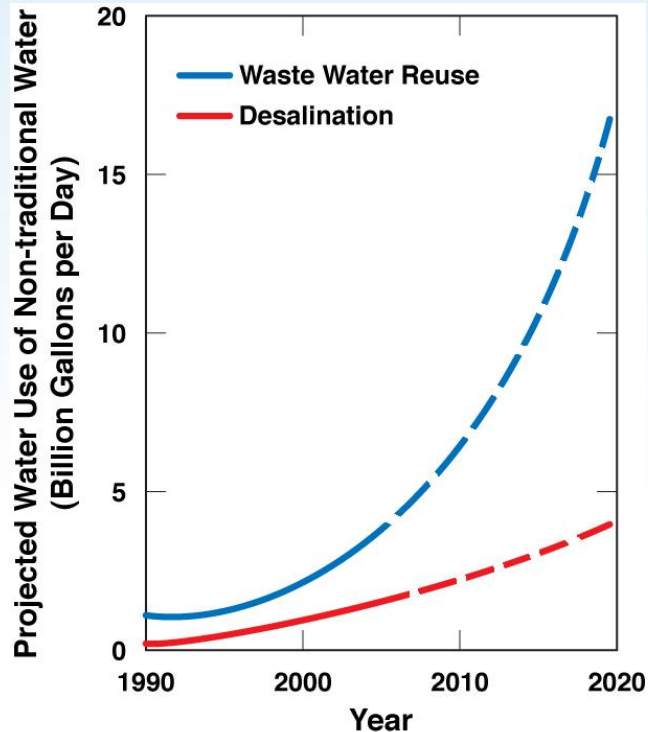
- Many major ground water aquifers seeing reductions in water quality and yield

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



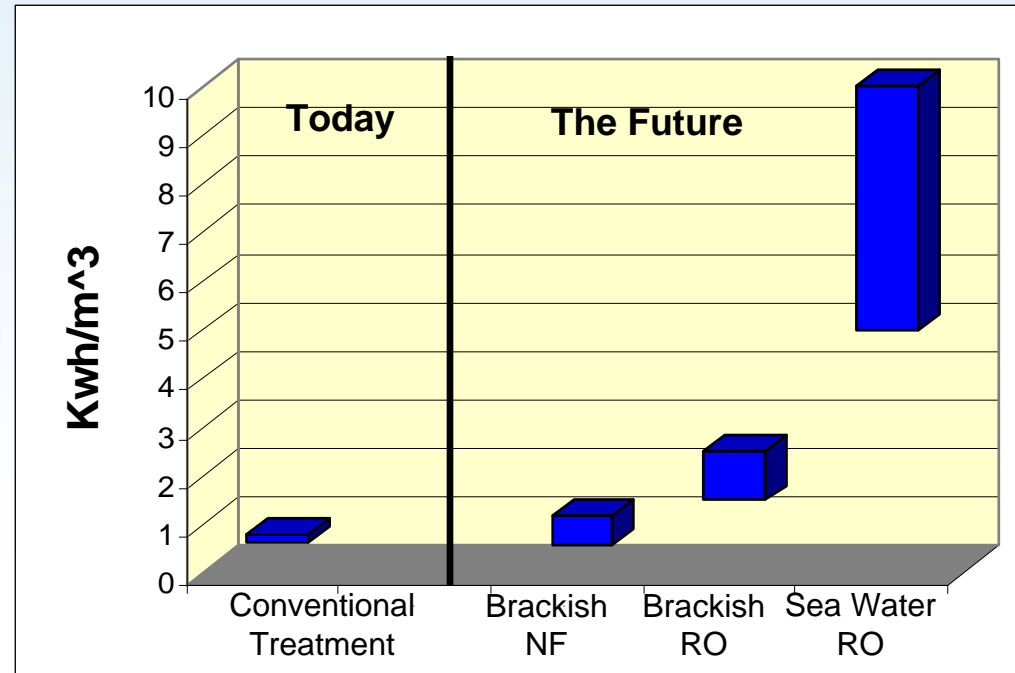
(Shannon 2007)

# Growing Use of Non-traditional Water Resources



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

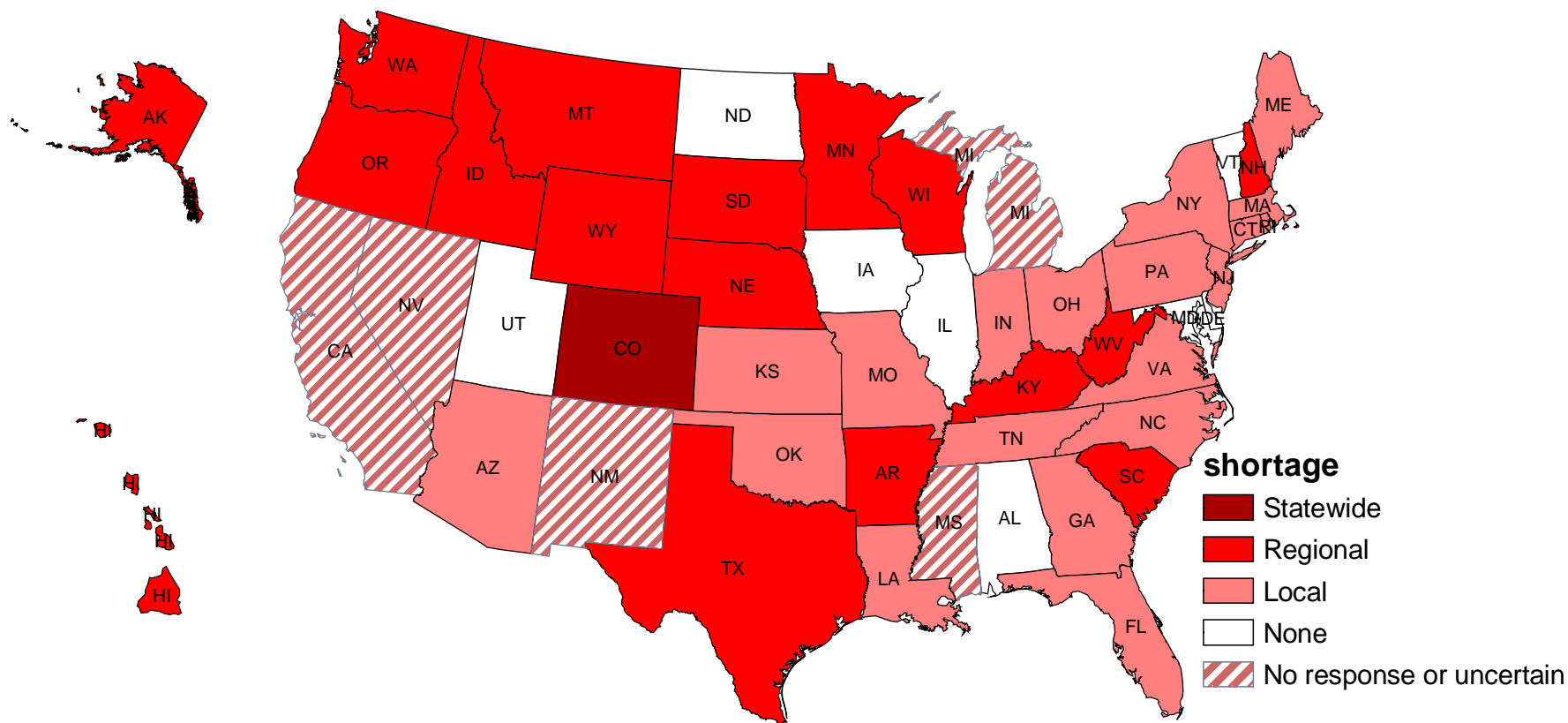
## Power Requirements For Treating



(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

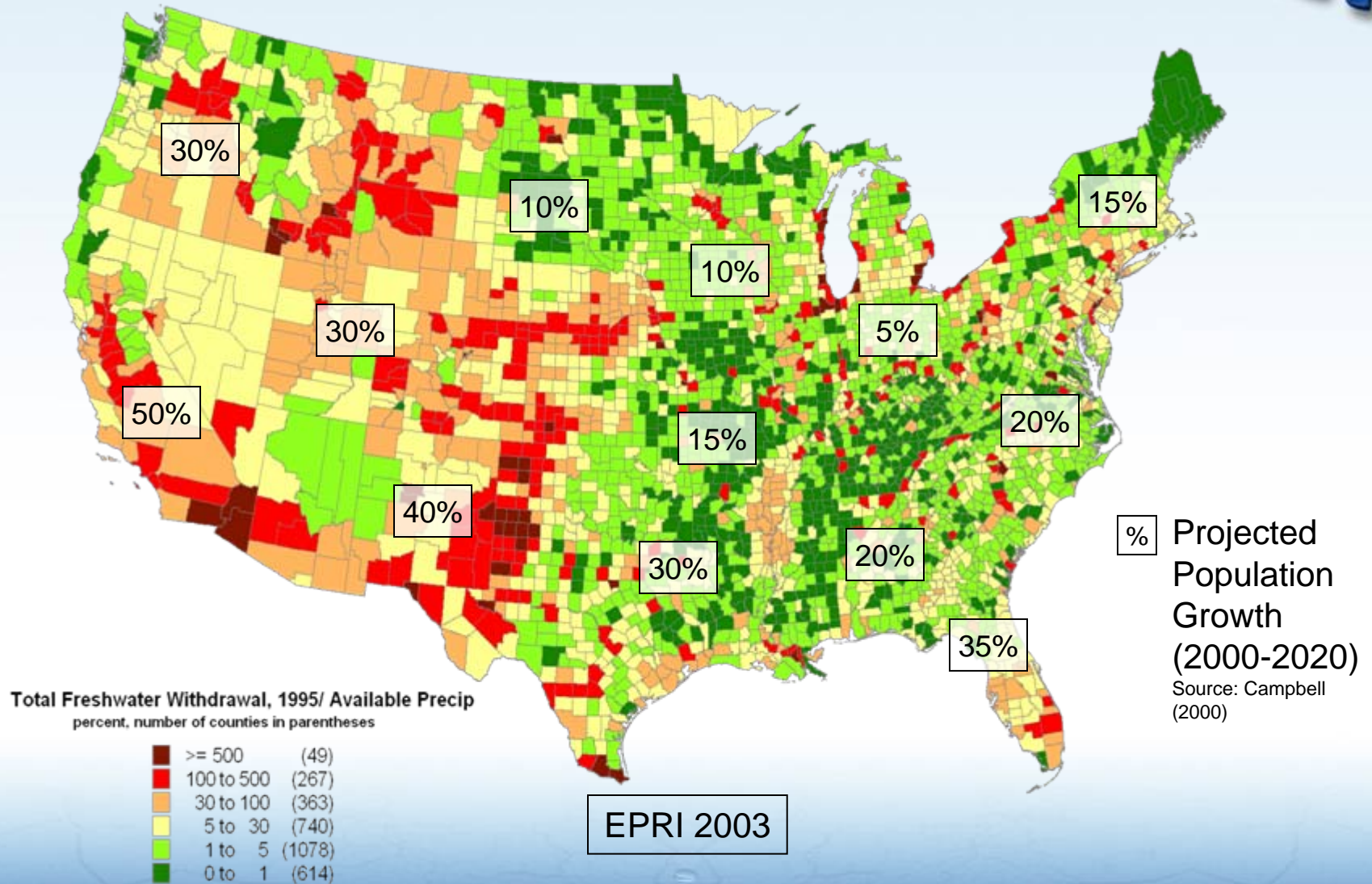
# Most State Water Managers Expect Shortages Over The Next Decade Under Average Conditions



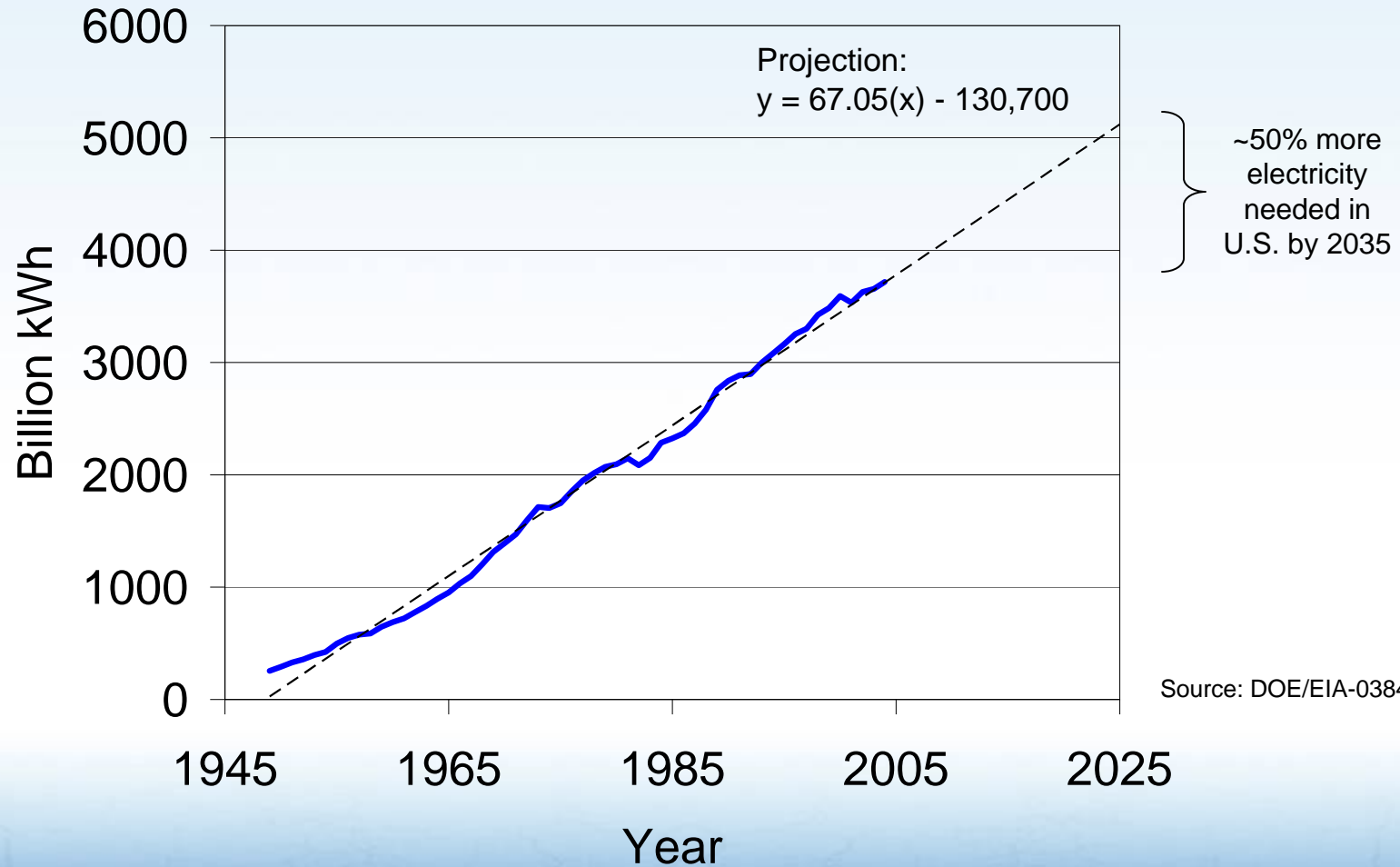
Source: GAO 2003



# Water challenges are nationwide



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

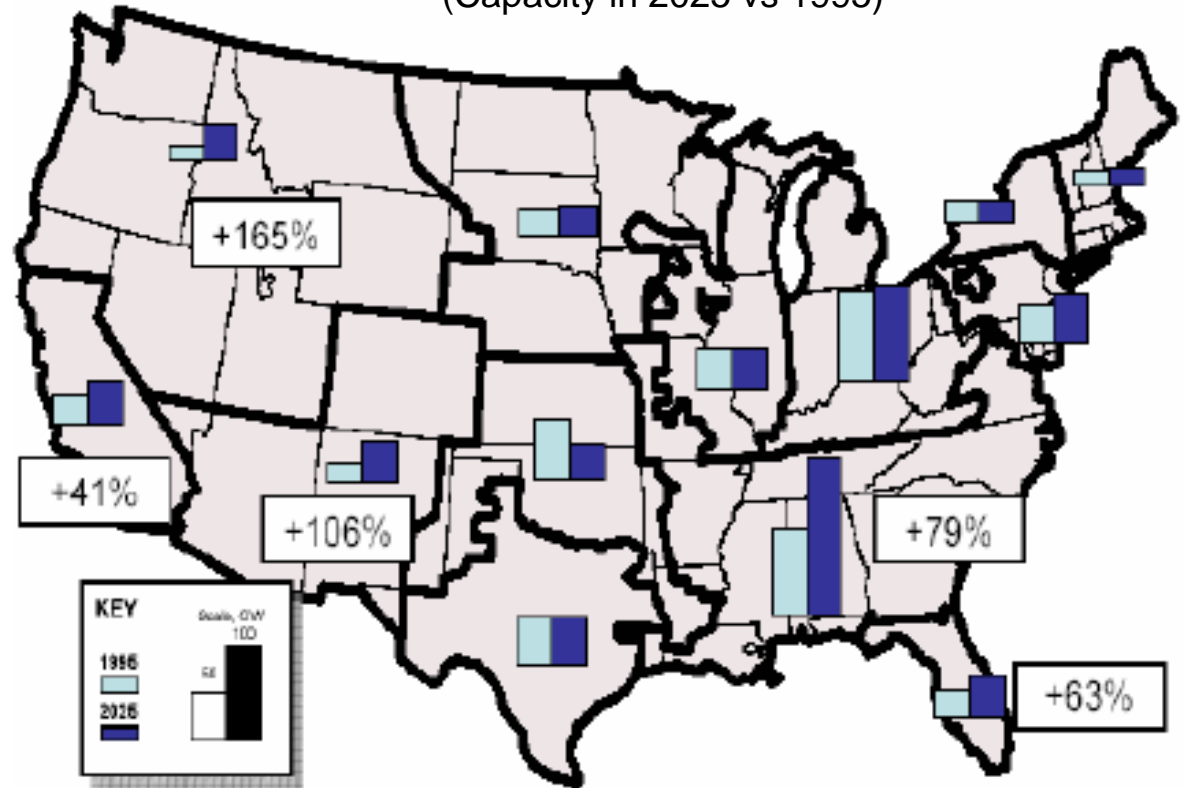


# Growth in Thermoelectric Power Generation



- 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

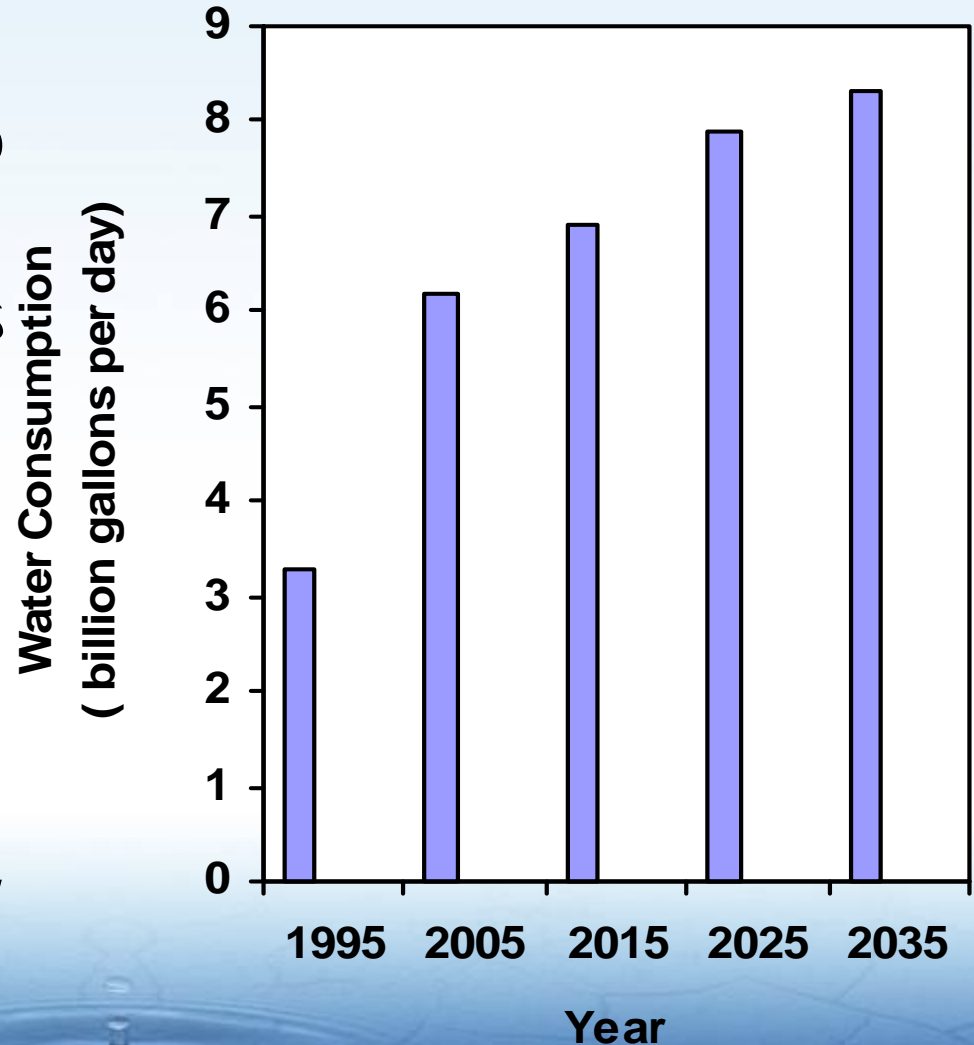


# Water Demands for Future Electric Power Development



Source: NETL 2006

- 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



# Water Use and Consumption for Electric Power Generation

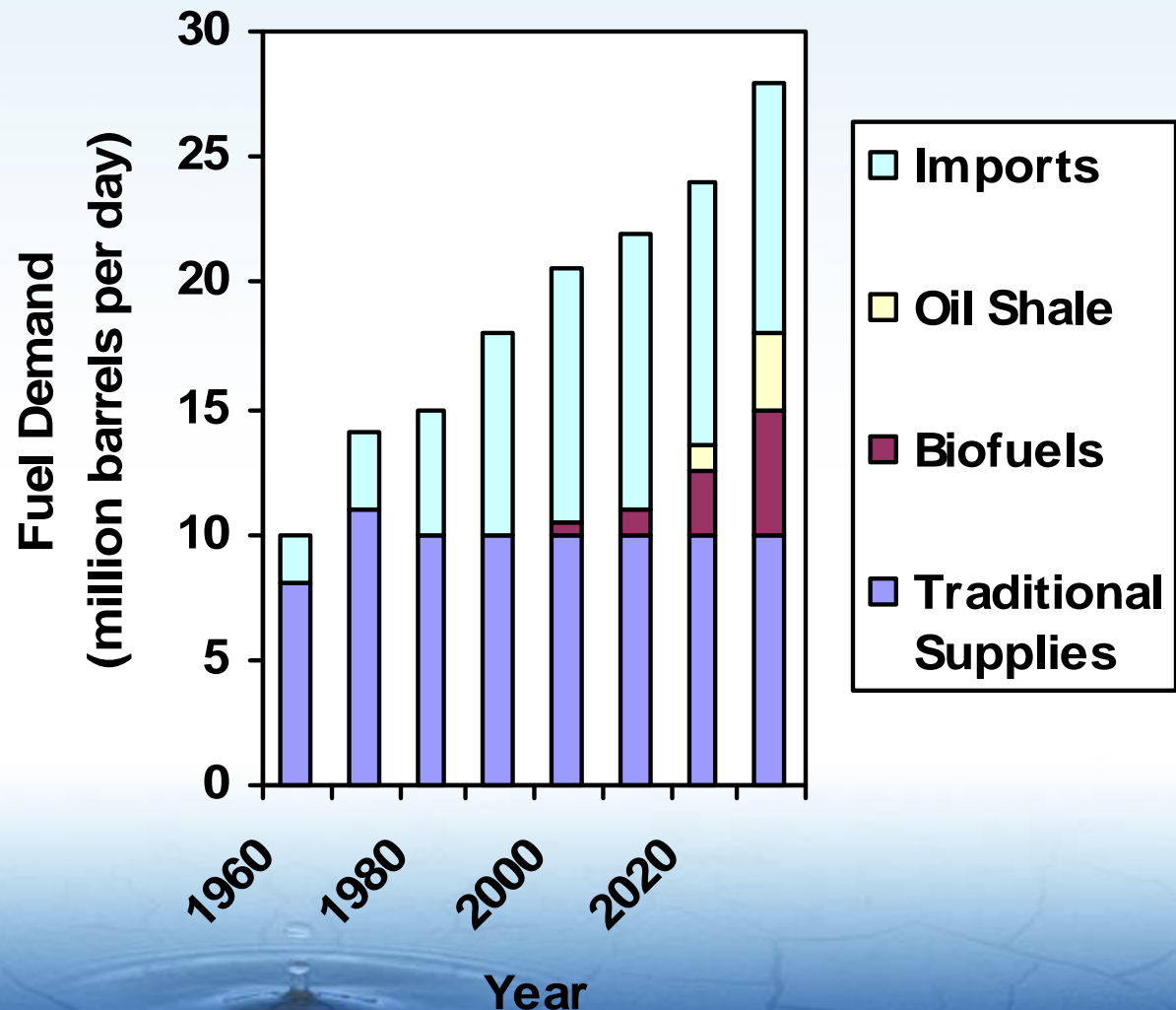


Plant-type	Cooling Process	Water Use Intensity (gal/MWh <sub>e</sub> )		
		Steam Condensing		Other Uses
		Withdrawal	Consumption	Consumption
Fossil/ biomass steam turbine	Open-loop	20,000–50,000	~200-300	15-36
	Closed-loop	300–900	300–714	
Nuclear steam turbine	Open-loop	25,000–60,000	~400	36
	Closed-loop	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

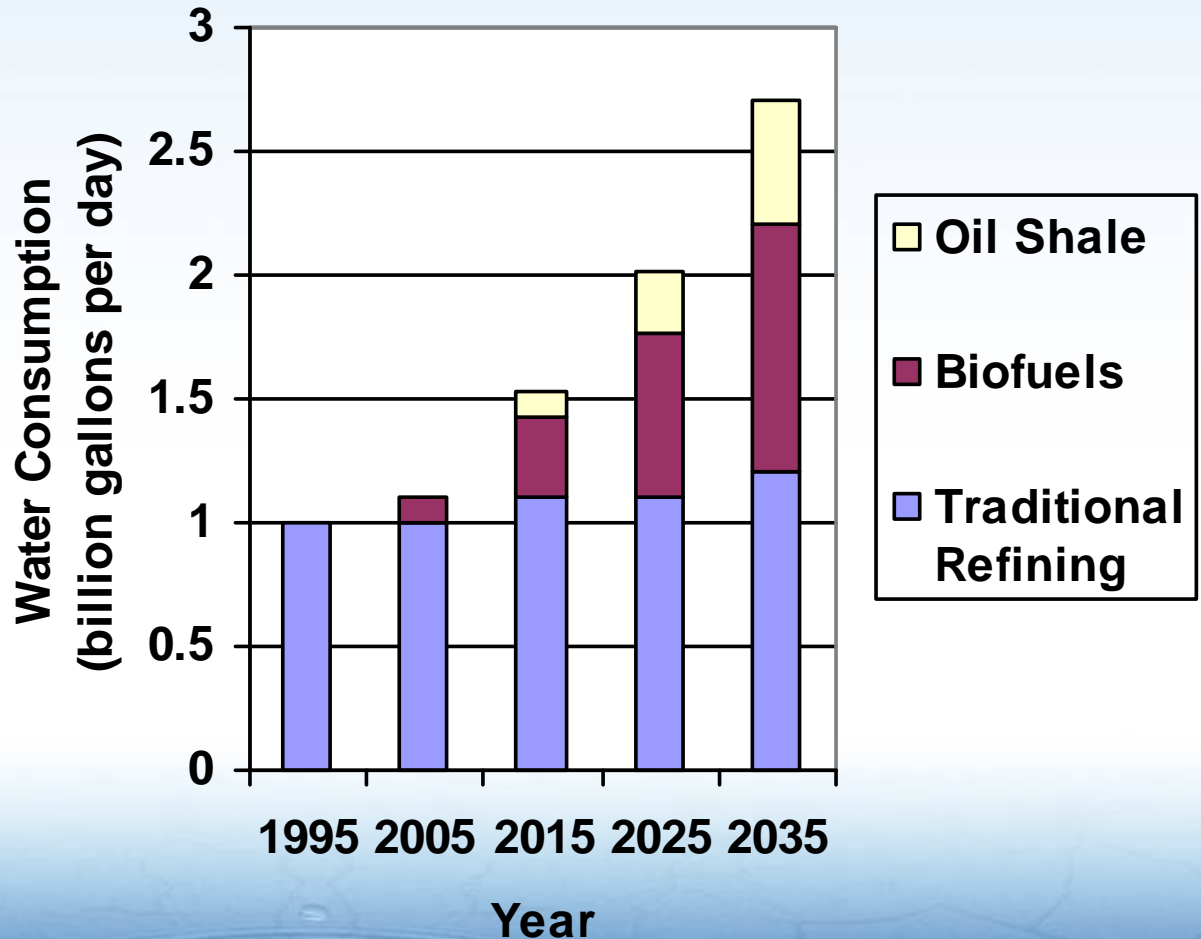




# Emerging Water Demands for Alternative Fuels Development



- 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
<b>Conventional Oil &amp; Gas</b> - Oil Refining - NG extraction/Processing	Water needed to extract and refine; Water produced from extraction	Produced water generated from extraction; Wastewater generated from processing;	1 - 2.5
			0.2
<b>Biofuels</b> - Grain Ethanol Processing - Corn Irrigation for EtOH - Biodiesel Processing - Soy Irrigation for Biodiesel - Lignocellulosic Ethanol and other synthesized Biomass to Liquid (BTL) fuels	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
			~ 980*
			~ 2
	Water for processing; Energy crop impacts on hydrologic flows	Wastewater generated; Water quality benefits of perennial energy crops	~ 6500*
			~ 2 - 6 ‡ ~ 2 - 6 ‡
<b>Oil Shale</b> - In situ retort - Ex situ retort	Water needed to Extract / Refine	Wastewater generated; In-situ impact uncertain; Surface leachate runoff	1.2 - 2.3
			2.1 - 5.2
<b>Oil Sands</b>	Water needed to Extract / Refine	Wastewater generated; Leachate runoff	2 - 6.9
<b>Synthetic Fuels</b> - Coal to Liquid (CTL) - Hydrogen RE Electrolysis - Hydrogen (NG Reforming)	Water needed for synthesis and/or steam reforming of natural gas (NG)	Wastewater generated from coal mining and CTL processing	0.9 - 2.7
			~ 3 ‡
			6.4

† Ranges of water use per unit energy largely based on data taken from the Energy-Water Report to Congress (DOE, 2007)

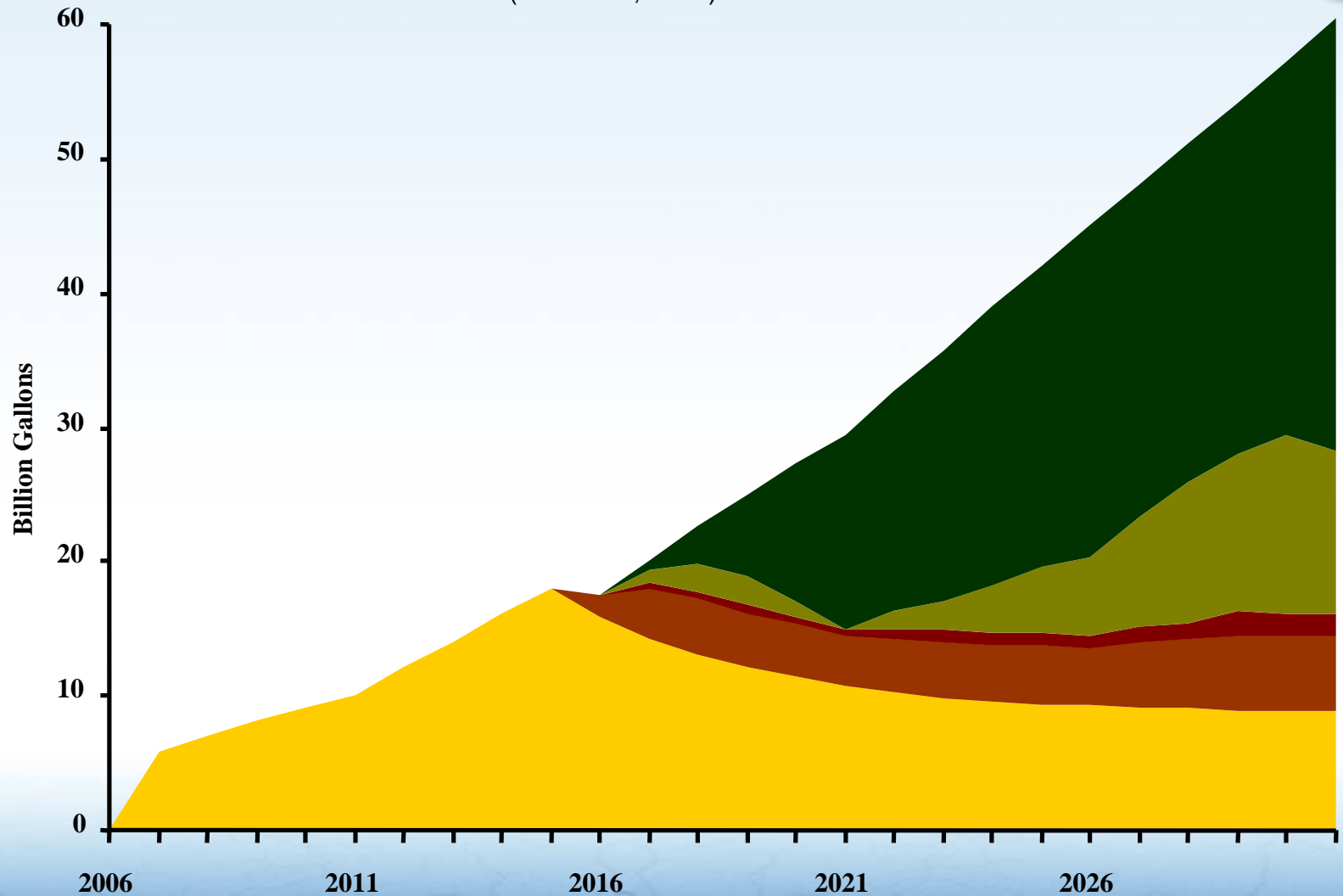
\* Conservative estimates of water use intensity for irrigated feedstock production based on per-acre crop water demand and fuel yield

‡ Estimates based on unvalidated projections for commercial processing; § Assuming rain-fed biomass feedstock production

# Projected Ethanol Production by Feedstock



(Ref: NRC, 2007)

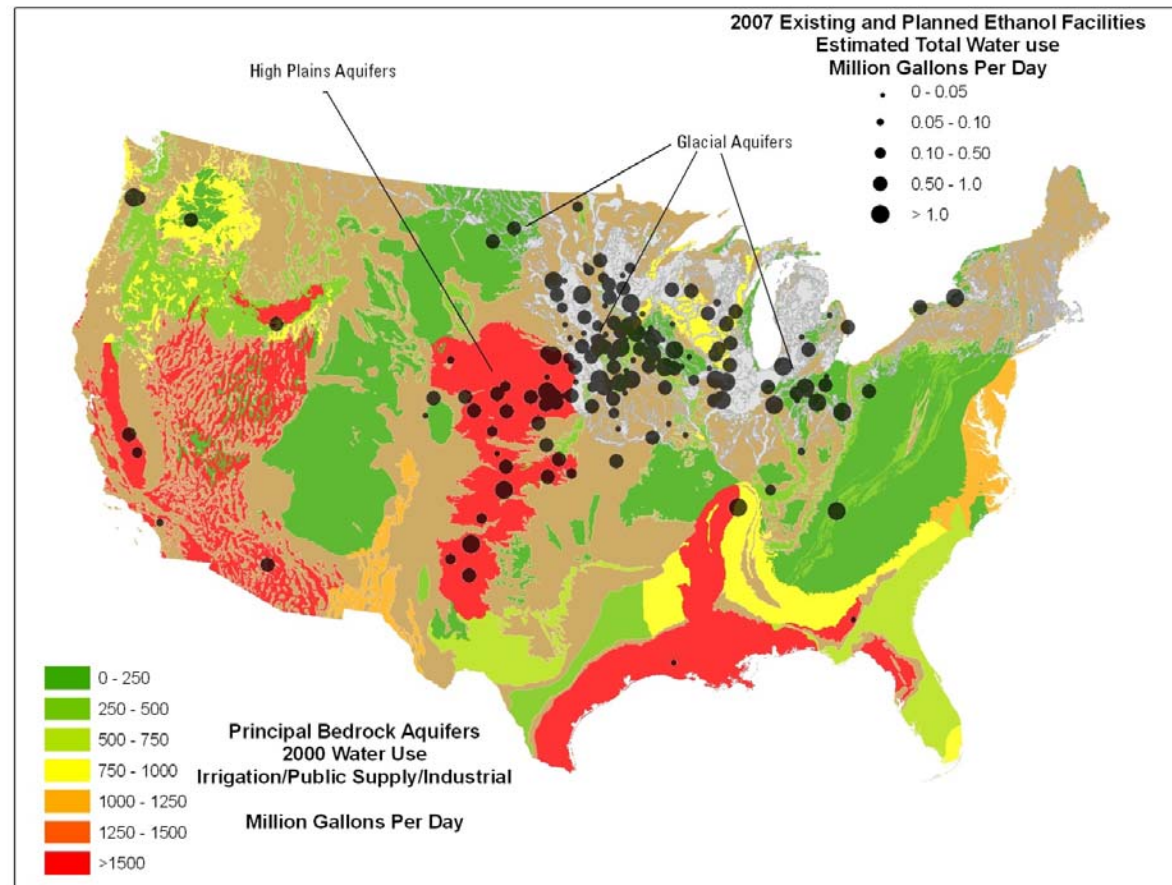




# Ethanol Production Growth and Feedstock Irrigation Issues

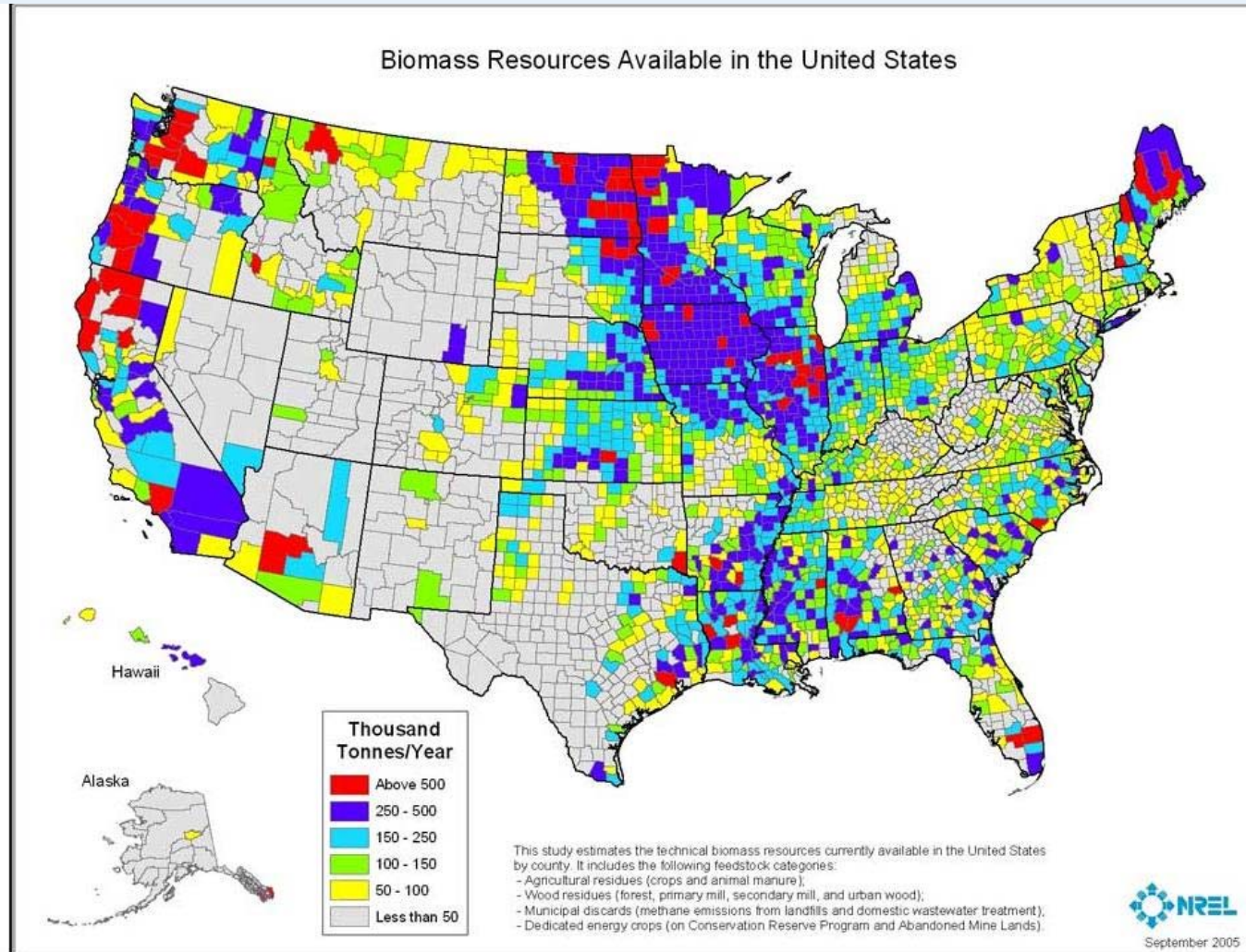


- Irrigated corn requires 2000-4000 gal/bushel
- Move to cellulosic ethanol will move production south and east
- Amount of irrigation needed for fuel reliability of dedicated energy crops is uncertain
- Concerns over ethanol production plant impacts on groundwater quality and availability



Ref: Schnoor, ACS, 2008

# 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

Green River Formation

40,000 sq km

Green R.  
Basin



Uinta  
Basin

Piceance  
Basin





# QUESTIONS

