

completing the energy sustainability puzzle

# ENERGY and WATER

## Groundwater and Energy – Challenges and Opportunities

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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<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

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## Growing Limitations on Fresh Surface and Ground Water Availability

Reservoir Capacity for Withdrawal (Billion Gallons per Day)

Year

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

Status of Fresh Water Aquifers

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

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

(Shannon 2007)

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## Regional Growth in Thermoelectric Power Generation

Projected Thermoelectric Increases (Capacity in 2025 vs 1995)

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

KEY

Source: NETL 2004

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## Water Use and Consumption for Electric Power Generation

Plant-type	Cooling Process	Water Use Intensity (gal/MWh <sub>e</sub> )		
		Steam Condensing		Other Uses Consumption
		Withdrawal	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	~60% 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 Demands for Future Electric Power Development

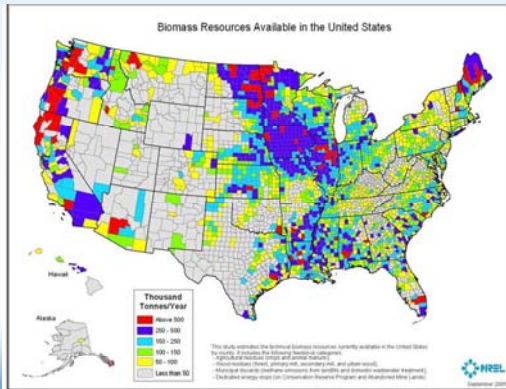
- Water demands could almost triple from 1995 consumption for projected mix of plants and cooling
- Carbon emission requirements will increase water consumption by an additional 1-2 Bgal/day

Water Consumption (billion gallons per day)

Year

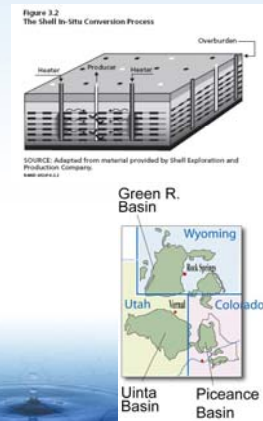
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## Biomass and Water Use Impacts Will be Regional



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

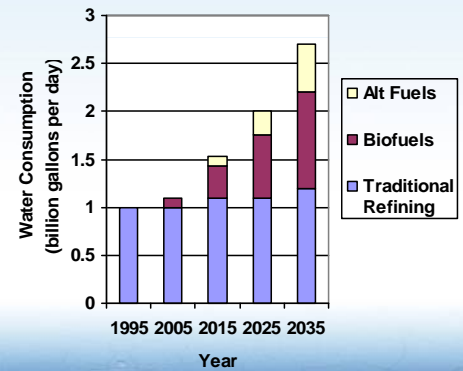


## Water Demand/Impact of Transportation Fuels

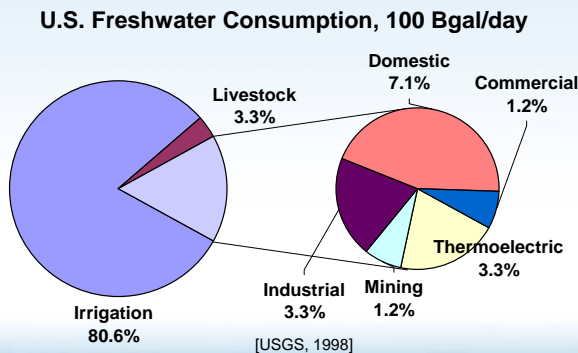
Fuel Type and Process	Relationship to Water Quantity	Relationship to Water Quality	Water Consumption		
			Water consumed per-unit-energy [ gal / MMBTU ] †	Average gal water consumed per gal fuel	
Conventional Oil & Gas	Water needed to extract and refine; Water produced from extraction	Produced water generated from extraction; Wastewater generated from processing;	Oil Refining	7 - 20	~ 1.5
			Oil Refining	2 - 3	~ 1.5
			Oil Refining	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
Oil Shale	Water needed to extract and refine; Water for processing; Energy crop impacts on hydrologic flows	Wastewater generated; Water quality benefits of perennial energy crops	Ex situ retort	13800 - 60000	~ 6500*
			In situ retort	24 - 150 †† (ethanol)	~ 2 - 6 ††
			Ex situ retort	14 - 90 †† (diesel)	~ 2 - 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)	1 - 9 †	~ 2 †
			Hydrogen RE Electrolysis	15 - 40 †	~ 3 †
			Hydrogen (NG Reforming)	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 †

## 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

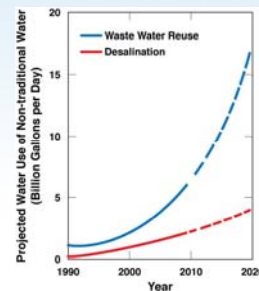


## Water Consumption by Sector – Emerging Competing Energy Sector Demands



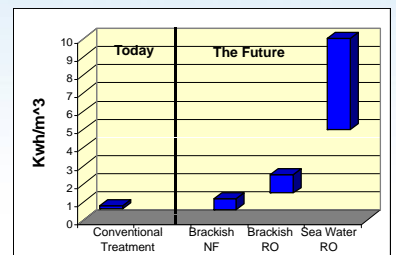
Energy uses 27 percent of all non-agricultural fresh water

## 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

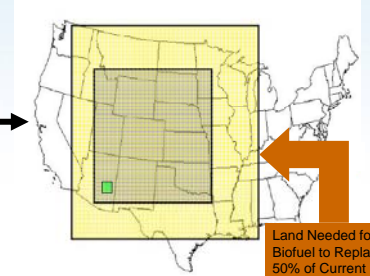
## Energy Requirements of Various Water Resource Options

Water Supply Options	Energy Demand (kWhr/kgal)
Fresh Water Importation (100-300 miles)	10-18
Seawater Desalination w/Reverse Osmosis	12-20
<b>Brackish Groundwater Desalination</b>	
Reverse Osmosis Treatment	7-9
Pumping and concentrate management	1-3
<b>Total</b>	<b>8-12</b>
<b>Aquifer Storage and Recovery</b>	
Pre-treatment (as needed)	3-4
Post-treatment (as needed)	3-4
Pumping	2-3
<b>Total</b>	<b>5-11</b>

## Agricultural Biofuels Land Demands

Algae has potential advantages over corn, cellulosic materials, and other crops as an alternative to petroleum-based fuels

Gallons of Oil per Acre per Year	
Corn	18
Soybeans	48
Safflower	83
Sunflower	102
Rapeseed	127
Oil Palm	635
Micro Algae	1000 - 7000



Land Needed for Biofuel to Replace 50% of Current Petroleum/Diesel using oil from:  
 Corn  
 Soybean  
 Algae

Wastewater use for algae is being investigated

## Growing use of non-traditional water for thermoelectric power plant cooling



Palo Verde – largest Nuclear Power Plant in the US, uses waste water for cooling

## Water Pumping and Treatment for Novel Energy Storage

- Water pumping and treatment considered to support renewable energy use
- Detailed matching of wind energy, water demand, and water storage by hour
- Several applications have shown overall savings on water treatment and delivery costs

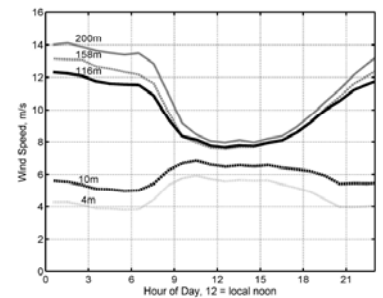


Fig. 78. Average diurnal evolution of the observed wind speed at each height level at Lubbock, Texas.

## Summary of Major Needs Identified in Regional Energy Water 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