completing the energy sustainability puzzle

ENERGY *and* WATER

Emerging International Issues and Challenges

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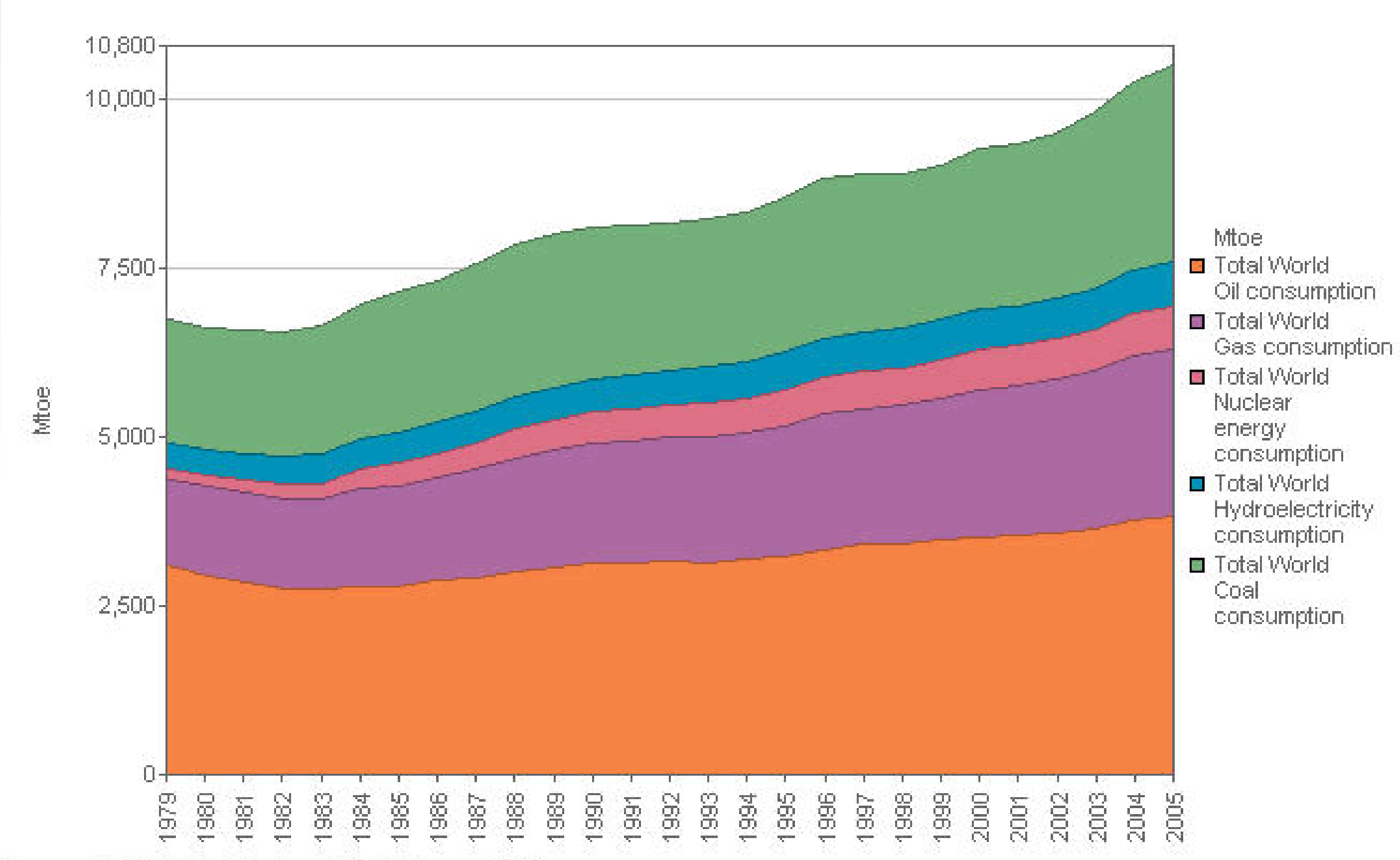
Energy-Water Connections

- Energy sector accounts for 8% of worldwide fresh water withdrawals
  - 40% of withdrawals in developed countries
  - 27% of non-agricultural fresh water consumption in the US – could quadruple by 2030 from electricity and biofuels demand
- Energy sector contributes to water quality issues
  - Traditional oil and gas produced water; biofuels, oil sands, oil shale, gas shale, and coal bed methane waste water; water drainage from coal and uranium mines; thermoelectric power plant emissions and impact on surface water quality
- Water and waste water sector energy use is expected to grow substantially
  - Growth in water treatment, new disinfection technologies, increased water transportation needs, etc. will increase energy intensity
  - Water and waste water sector energy use could grow from 3% to 10% of total demand by 2030
  - 30% of India's energy use is for ground water pumping

Past and Projected Global Increase in Energy Consumption



Source: BP Statistical Review of World Energy 2006

IEA projects 5,000 Mtoe increase between 2007 and 2030, Continuing the trend of the past 30 years

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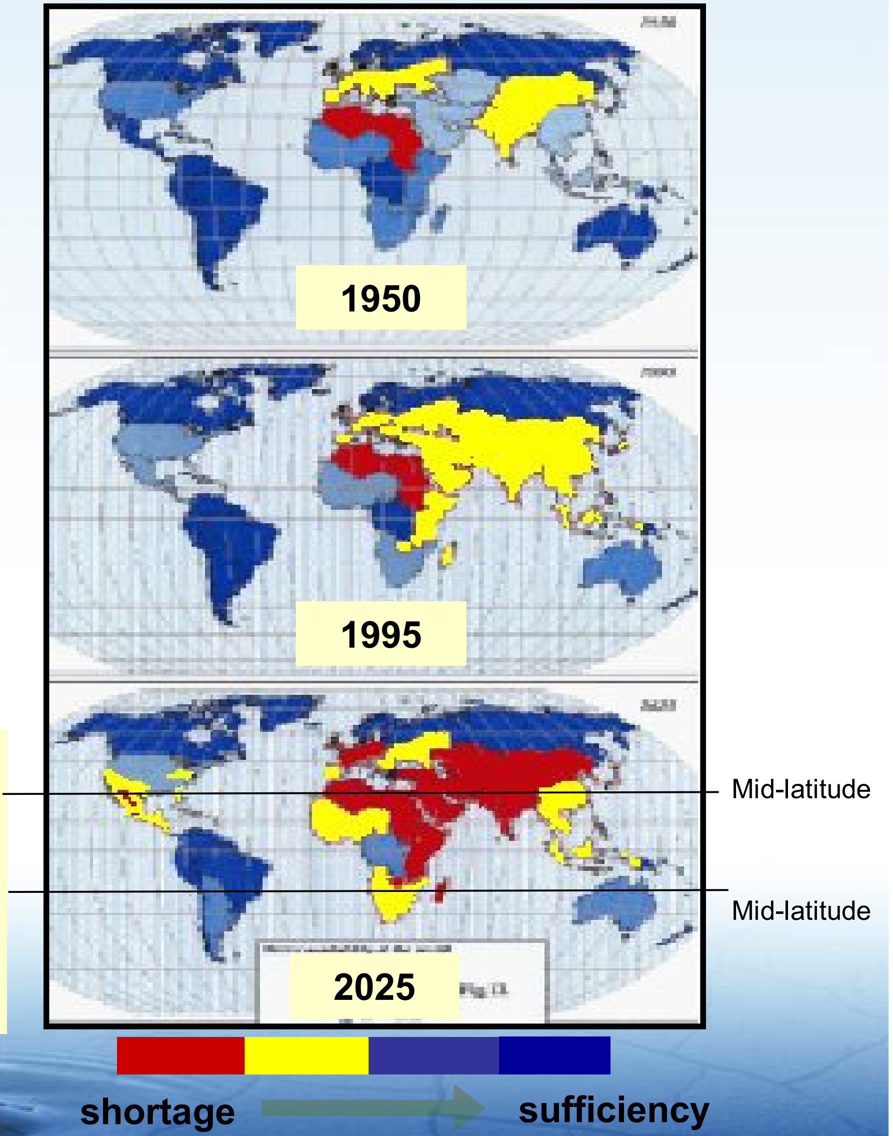
Over half the world's population will face severe water shortage in the next 50 years

- **By 2025,**
  - 20% more fresh water will be needed for irrigation worldwide, and
  - 40% more fresh water for domestic supplies to meet current per capita consumption
- **Exacerbated by climate change**

"Water promises to be to the 21st century what oil was to the 20th century: the precious commodity that determines the wealth of nations."

Fortune Magazine, May 15, 2000



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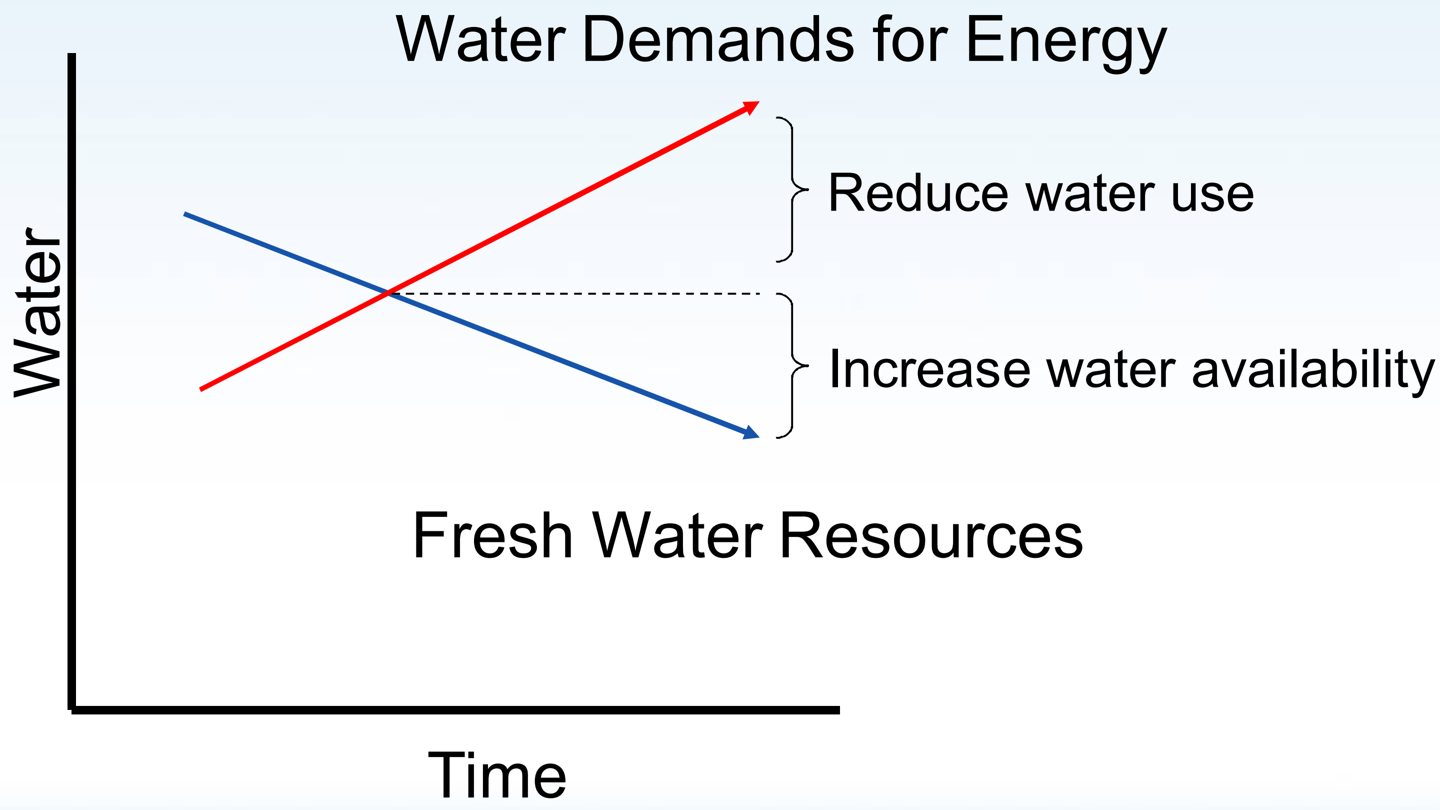
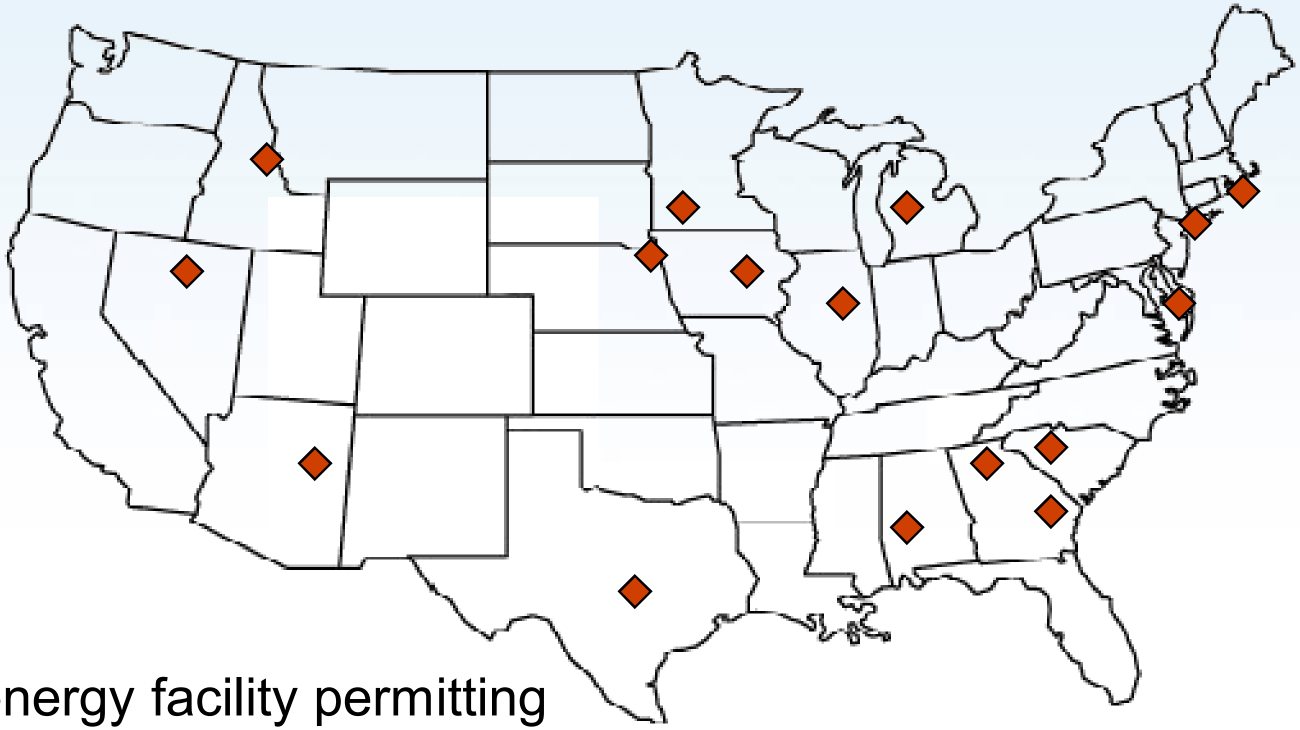
Trends in Fresh Water Availability and Energy Demands for Water



Water Availability Is Already Impacting New U.S. Energy Development



◆ Recent energy facility permitting issues due to water availability

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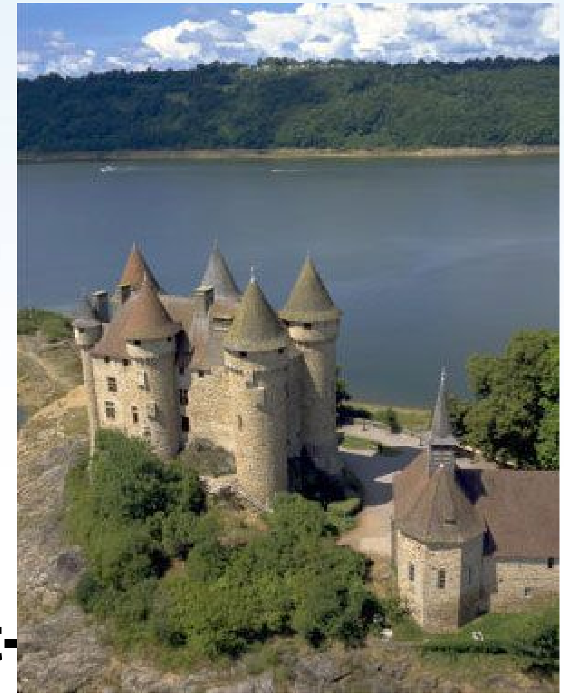
2003 Heat Wave Impact on French Electric Power Generation

- Loss of 7 to 15% of nuclear generation capacity for 5 weeks
- Loss of 20% of hydro generation capacity
- Large-scale load shedding and shut off transmission to Italy
- Sharp increase of spot-market prices: 1000 to 1500 $ / MWh for most critical days

Bort-les-Orgues Réservoir



Normal conditions in August

August 27, 2003

Summary of Major U.S. Needs and Issues Identified in Regional Workshops

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

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

Water Use and Consumption for Electric Power Generation Alternatives

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	400
	Closed-loop	900	700	
Integrated Gasification Combined-Cycle	Closed-loop	800	700	600
Carbon sequestration for fossil energy generation	~65% 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

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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] †	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;		
- 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

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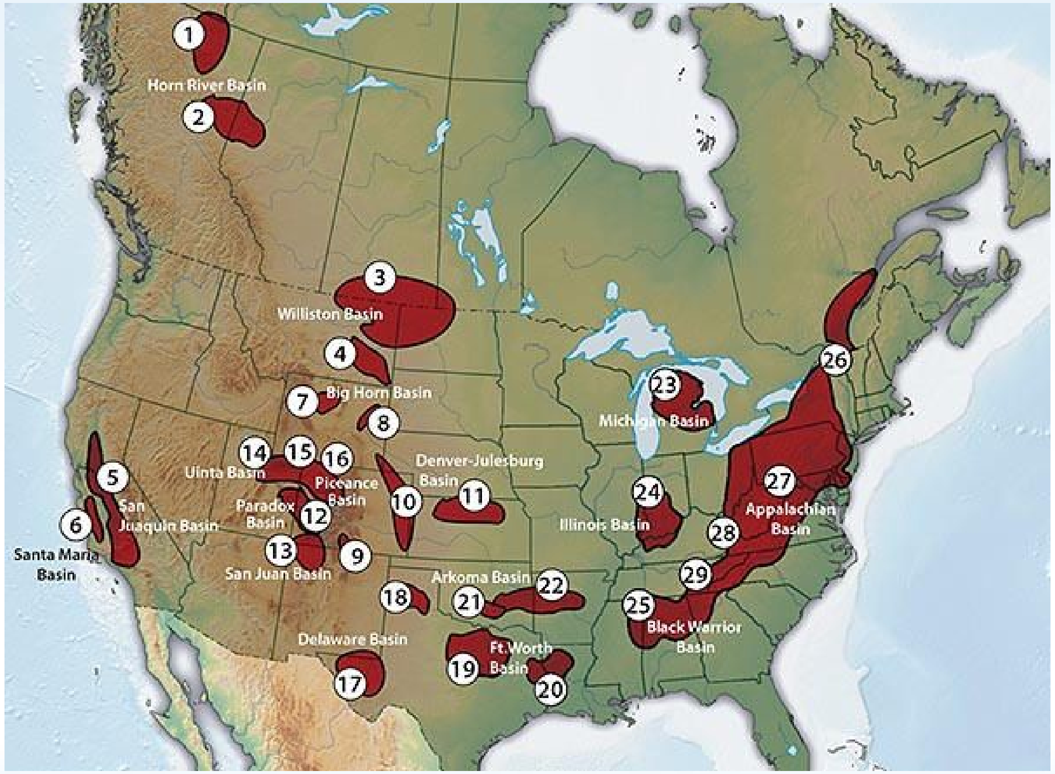
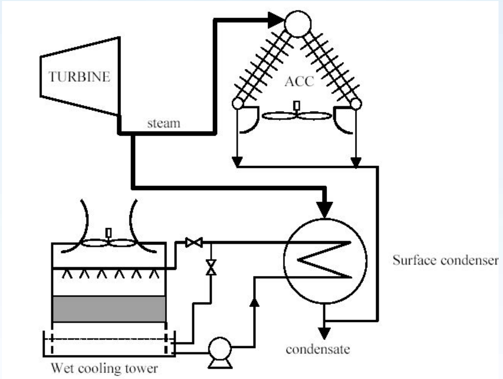
Shale gas development could be limited by water availability and quality issues

- **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 disposal or treatment can be problematic in some areas**

Extensive North American Reserves



Research Program for Electric Power Sector



Hybrid Wet-Dry Cooling

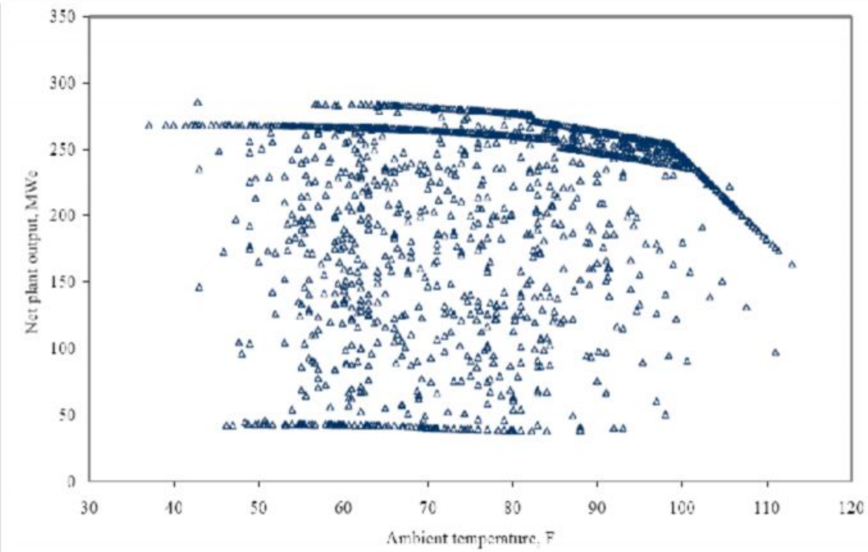
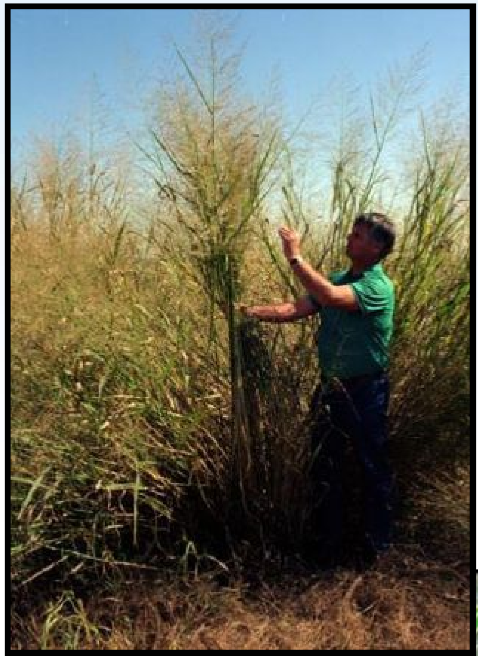
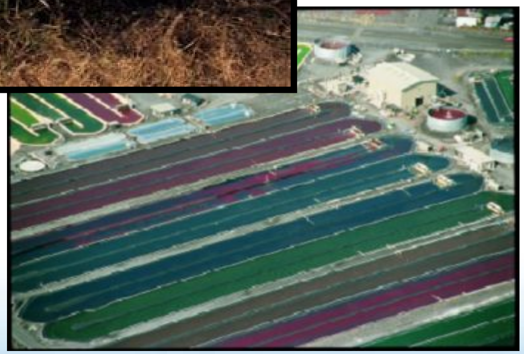


Figure 5 Net Plant Output as a Function of Ambient Temperature: Dry Heat Rejection

- 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

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, oil shale, oil sands, etc.

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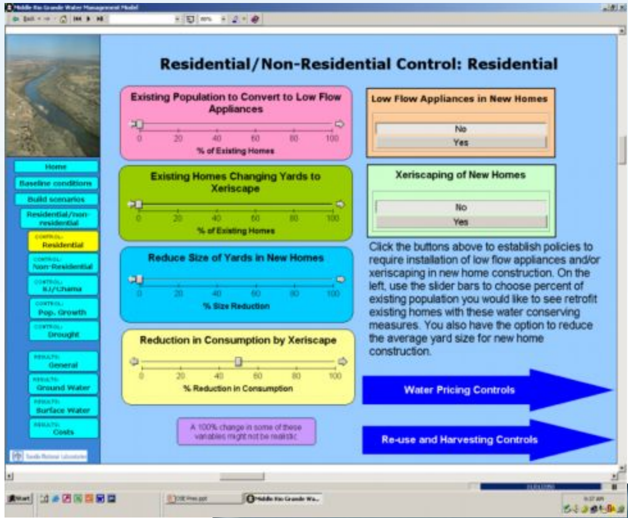
Research and Development Program for Integrated Resources Management



- 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

Summary of Global Energy and Water Issues and Challenges

- **Across the globe, energy demand is rising while fresh water resources are becoming more limited**
- **This is causing increased stress on natural resources – water, land, and energy**
- **Economically and environmentally sustainable development will require innovation in how energy, water, and land resources are developed, used, and managed in the future**