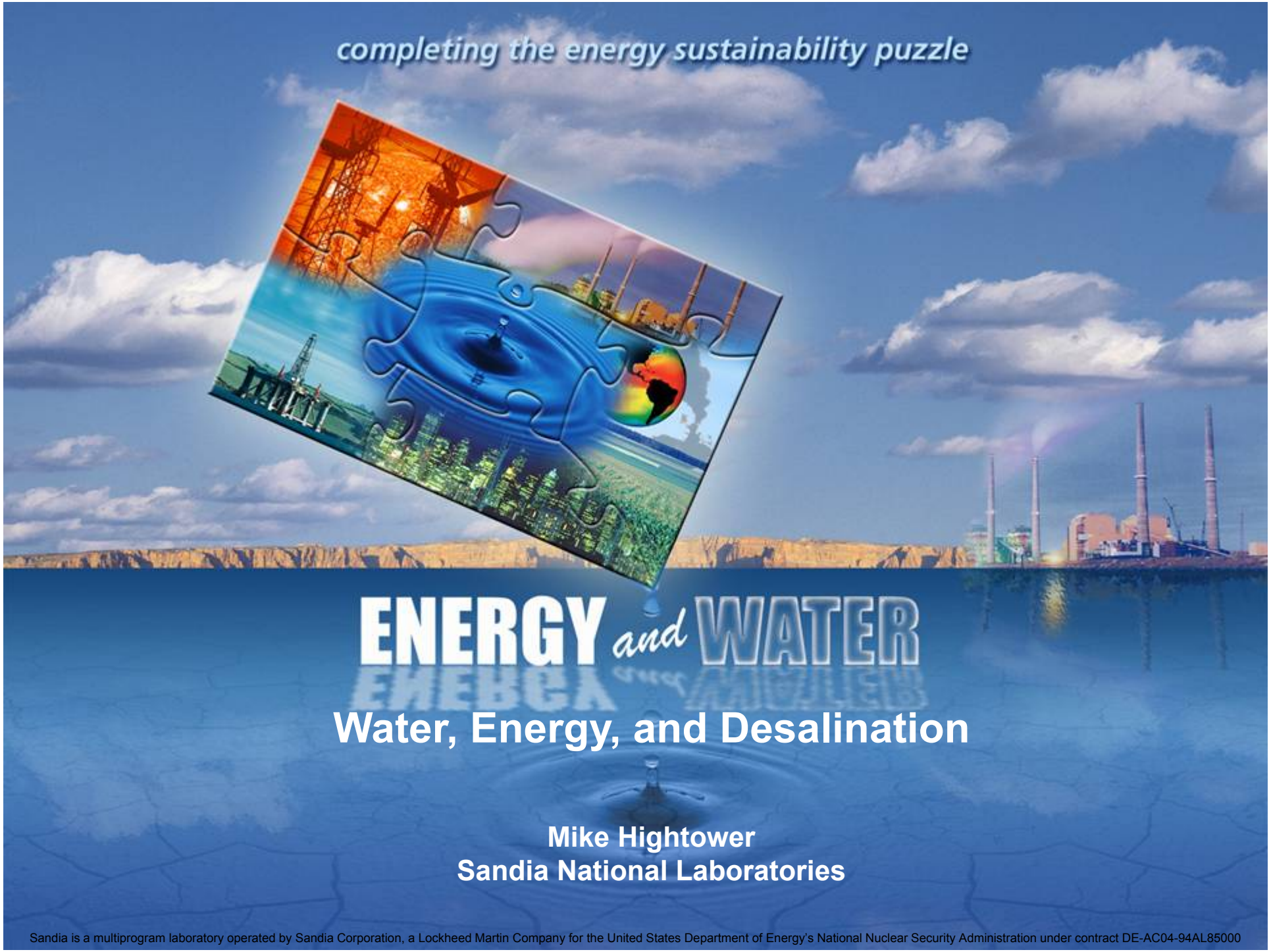


Water, Energy, and Desalination

Mike Hightower
Sandia National Laboratories

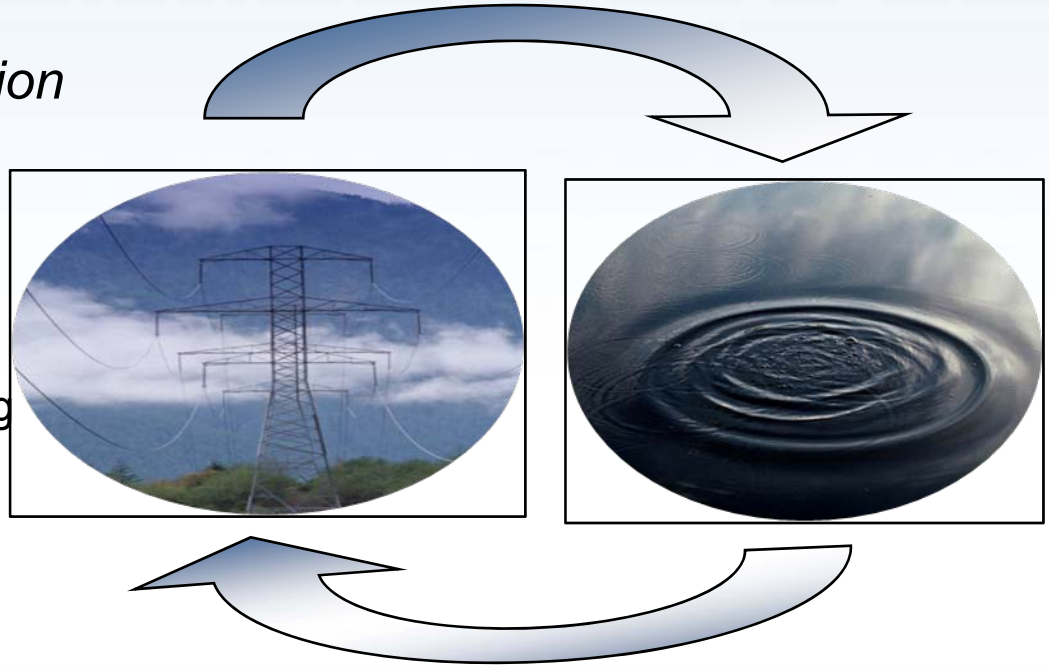
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000

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

ENERGY and WATER

Water Use and Consumption for Electric Power Generation

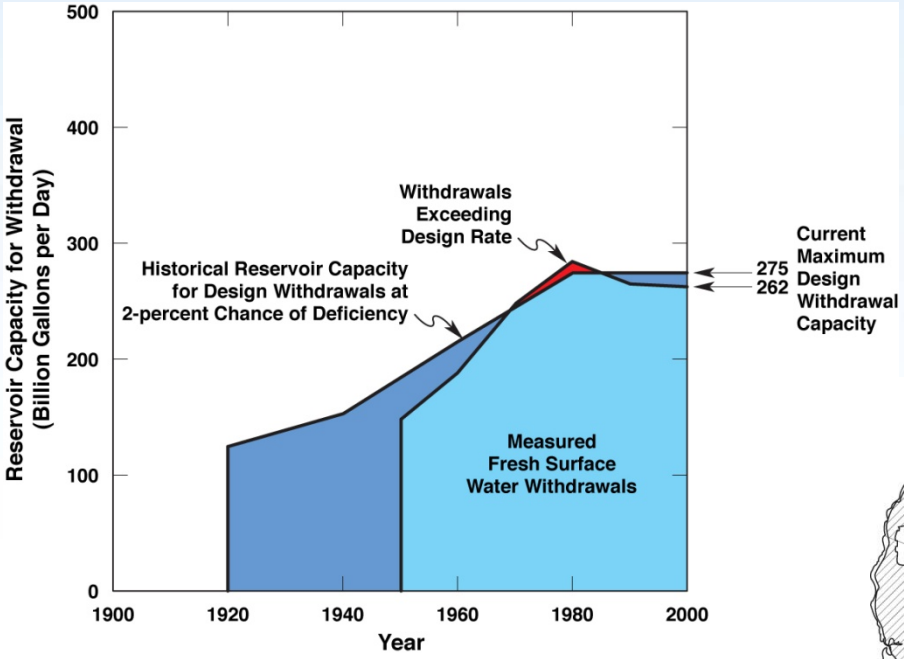
Plant-type	Cooling Process	Water Use Intensity (gal/MWh$_e$)		
		Steam Condensing		Other Uses
		Withdrawal	Consumption	Consumption
Fossil/ biomass steam turbine	Open-loop	20,000–50,000	~200-300	~30
	Closed-loop	300–600	300–480	
Nuclear steam turbine	Open-loop	25,000–60,000	~400	~30
	Closed-loop	500–1,100	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

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
- 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)	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 ‡

† 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

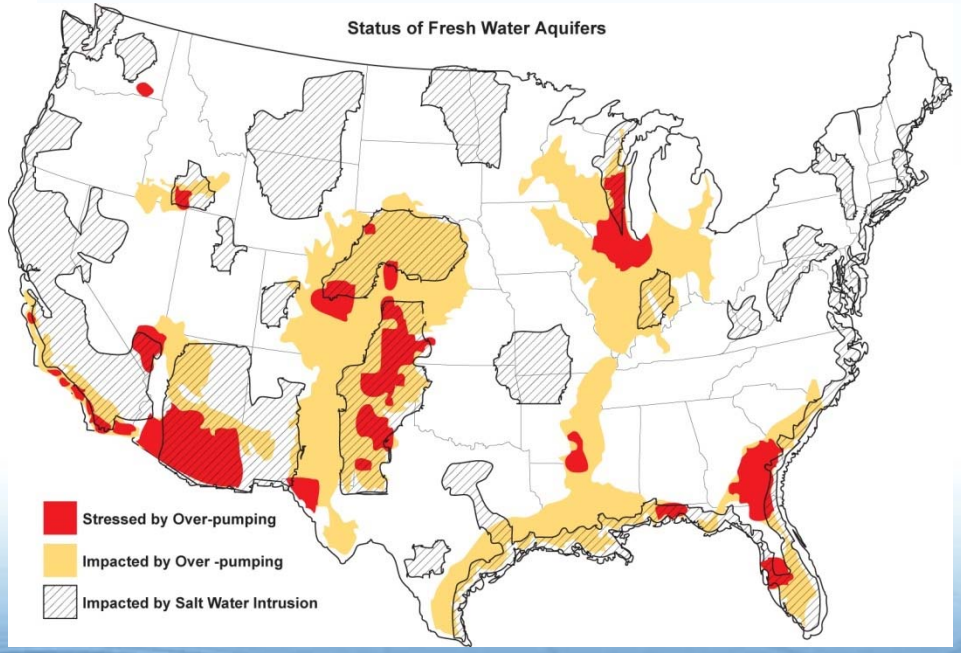
Growing Limitations on Fresh Surface and Ground Water Availability



(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)

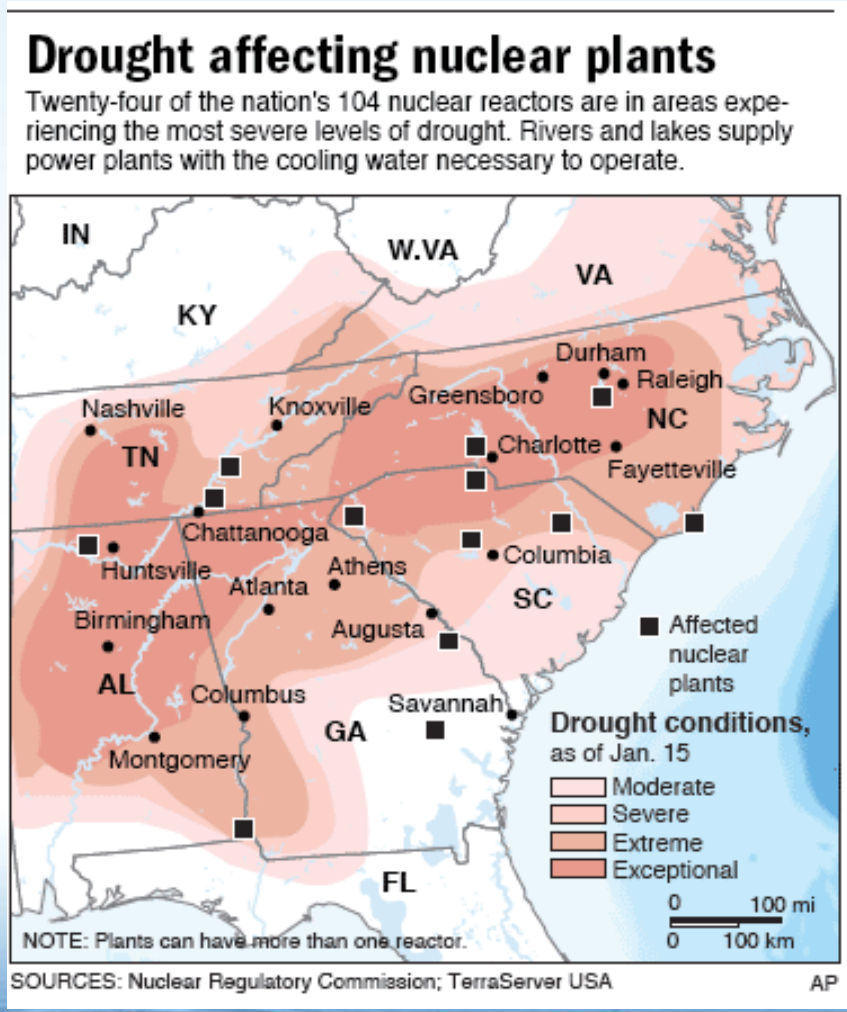
ENERGY and WATER

Contemporary Example: Southeast U.S. Drought Impact on Nuclear Power Production

Associated Press

Jan. 23, 2008

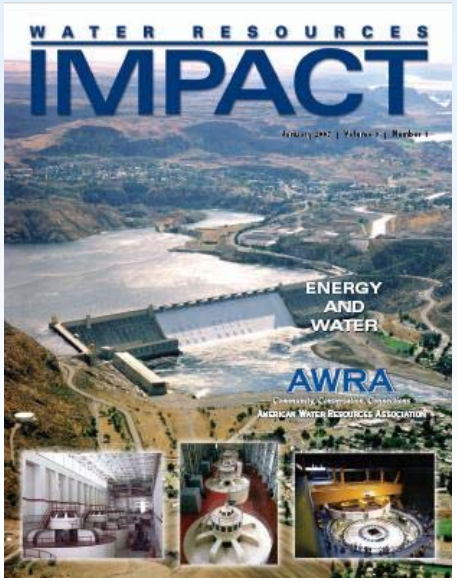
"LAKE NORMAN, N.C. - Nuclear reactors across the Southeast could be forced to throttle back or temporarily shut down later this year because drought is drying up the rivers and lakes that supply power plants with the awesome amounts of cooling water they need to operate."

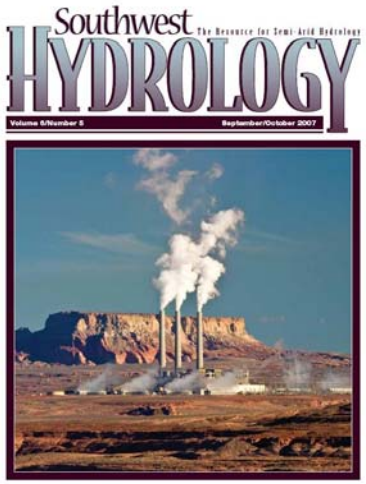


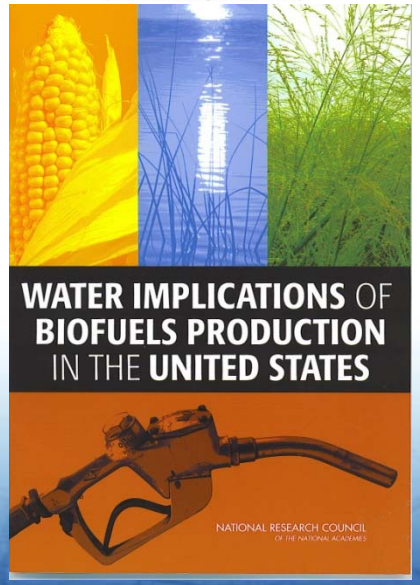
ENERGY and WATER

Emerging Interest in Energy and Water Issues and Challenges

- State and national water and energy groups
  - 30 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/NRC interest in energy debate and interdependencies research
- Growing international concerns and challenges
  - Europe, Australia, Asia, Canada







ENERGY and WATER

Energy-Water Regional Needs Workshops

- Congressionally funded and coordinated with DOE
- Coordinated by Sandia with support from all the national laboratories
- Needs driven research directions and solutions focus

Roadmap Regional Needs Workshops

ENERGY and WATER

Summary of Major National Needs and Issues Identified in Regional Workshops

Better resources planning and management

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

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

- Oil and gas produced water treatment for use
- Energy efficiency and assessment of impaired water treatment and use

www.sandia.gov/energy-water

ENERGY and WATER

National Trends in Desalination and Impaired Water Treatment

Increase in Number of Treatment Plants

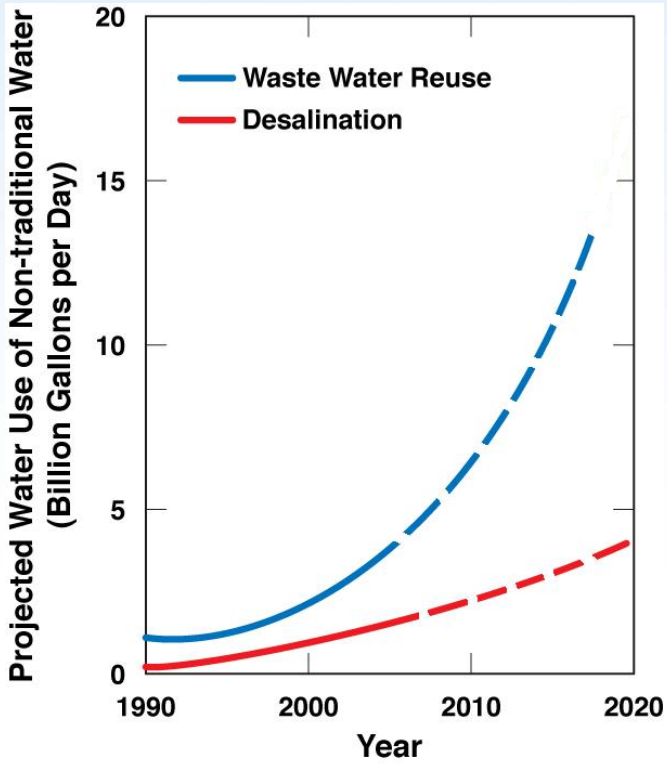
	<1993	<2003
Desalting	133	253
Low Pressure	1	218
– Micro Filtration	1	181
– Ultra Filtration	0	37
Total	134	461

Distribution of Treatment Plants

	<1993	2001
Number of States	13	37

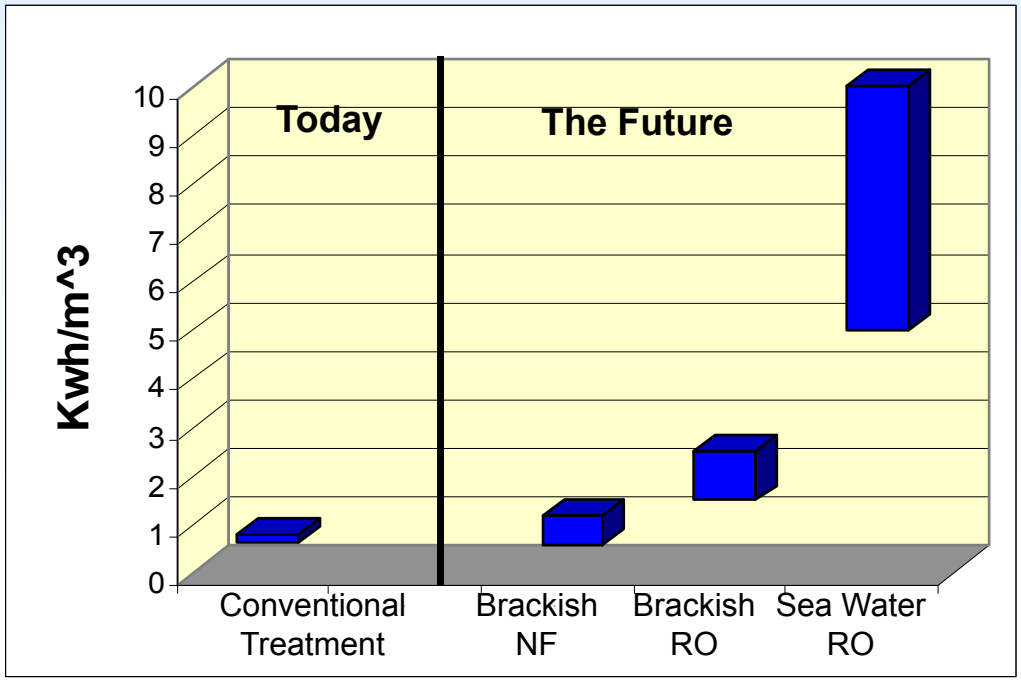
(Mickley, 2003)

Growing Use of Non-traditional Water Resources



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

Power Requirements For Treating

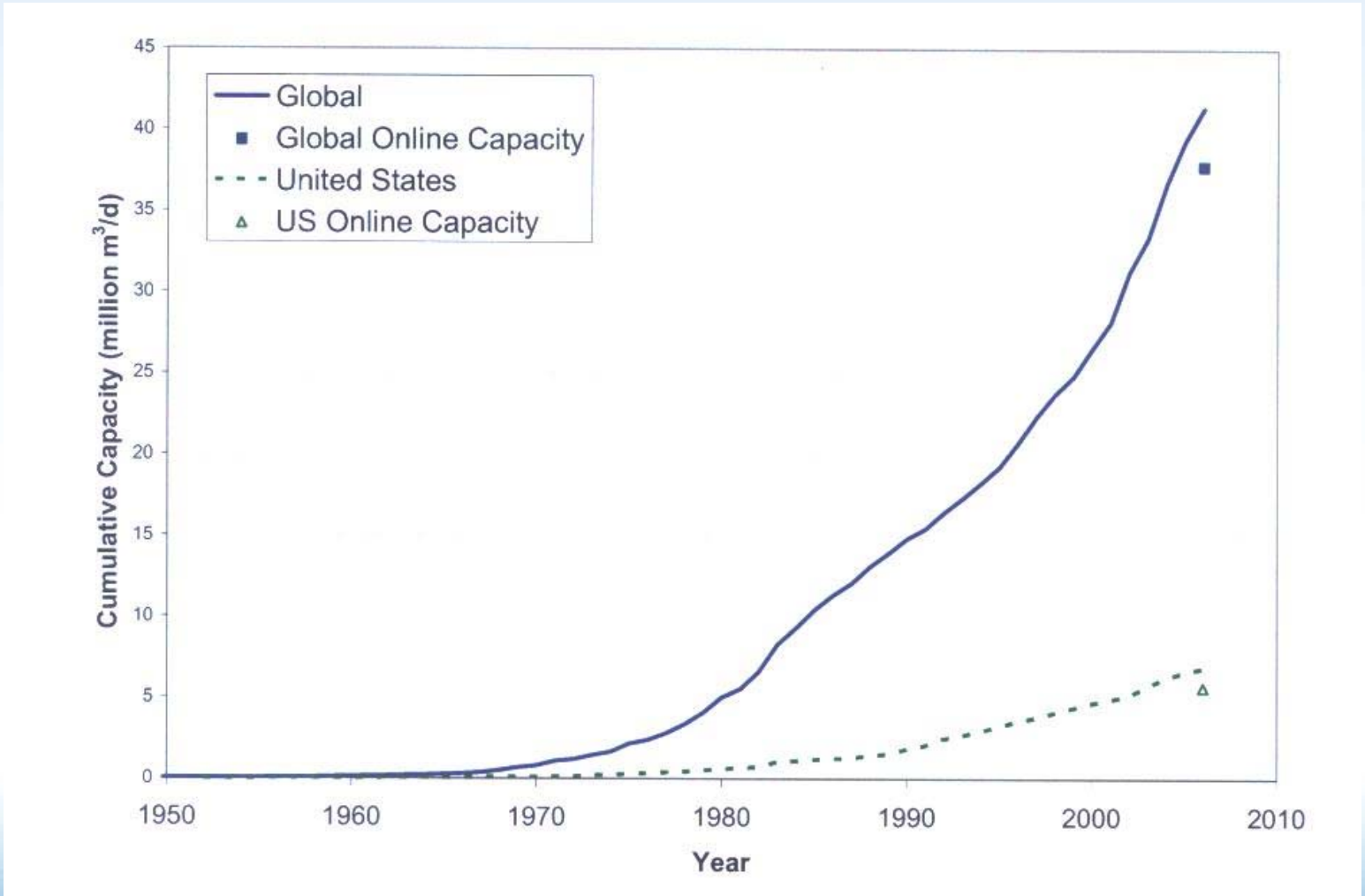


(Einfeld 2007)

- 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

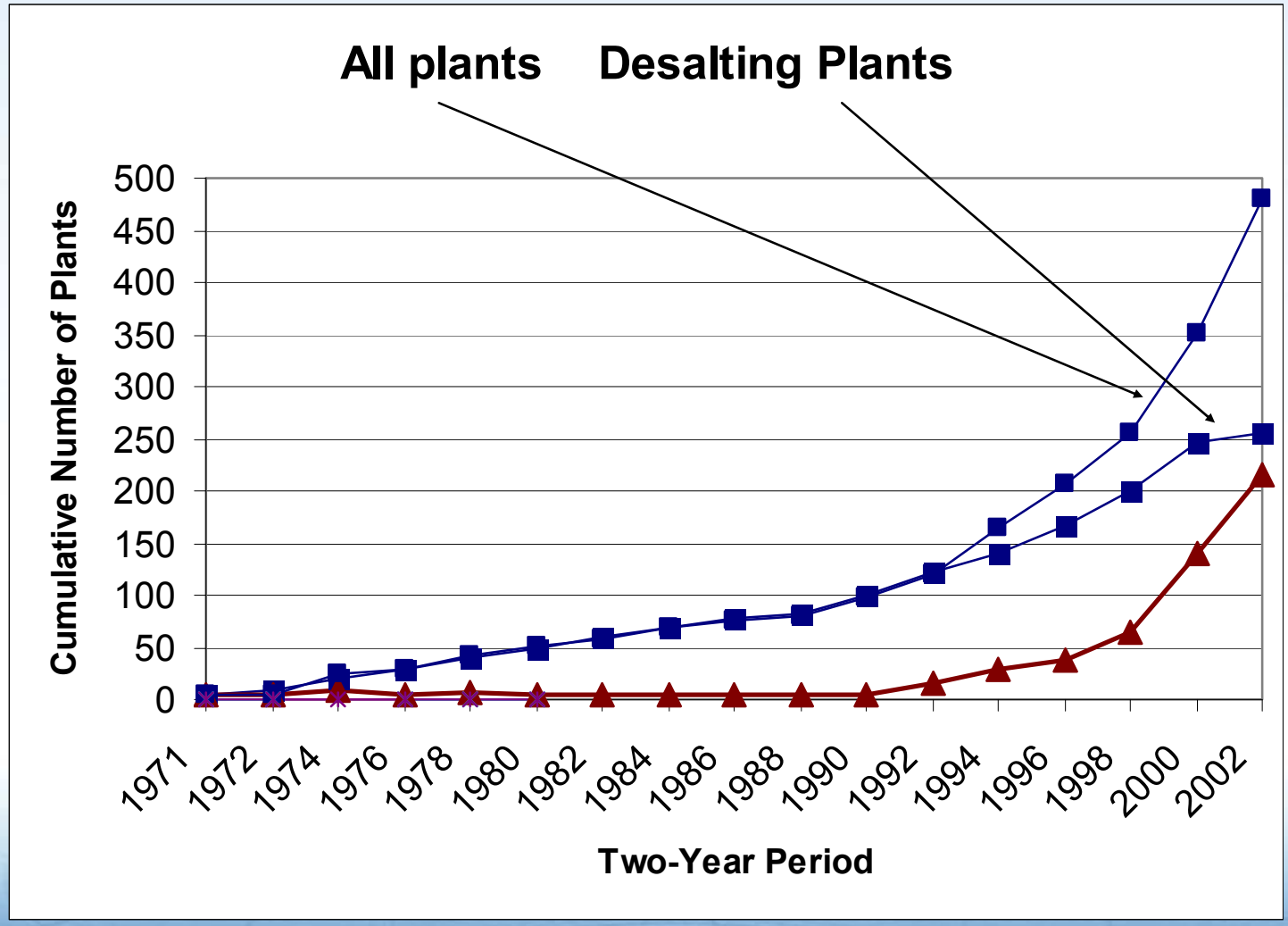
ENERGY and WATER

Desalination Capacity Growth Trends



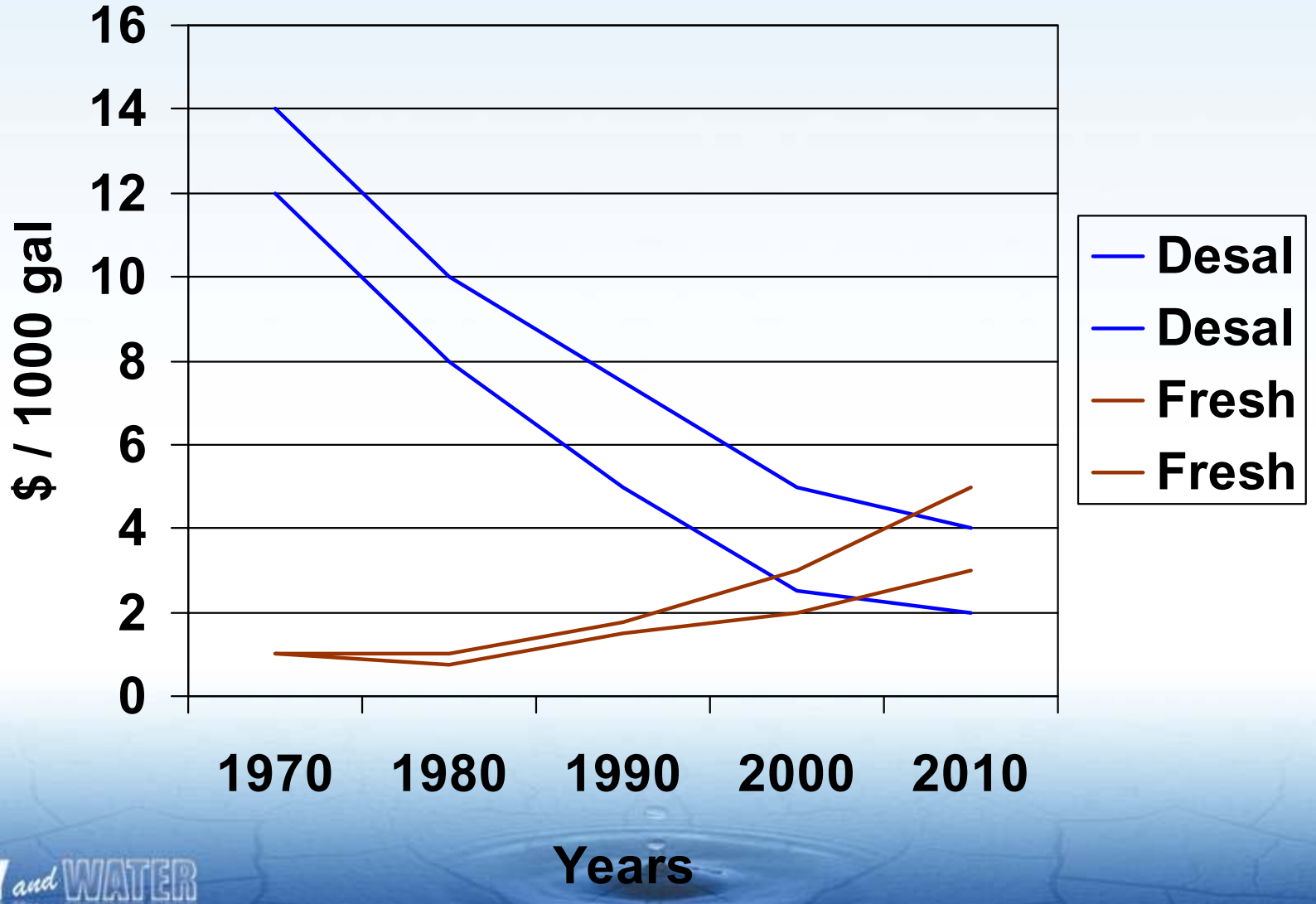
(NAS, Desal Roadmap 2008)

Growth in U.S. Membrane Treatment Plants



(Mickley, 2003)

Trends in Desalination and Fresh Water Costs



ENERGY and WATER

Sandia Water Treatment Thrusts

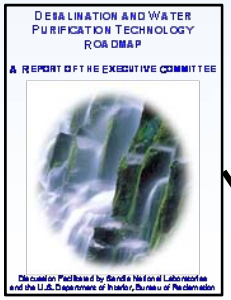
Fundamental Research
- Structure/properties of water at surfaces & confined spaces
- Theory and simulation of water-membrane interactions
- Novel materials development

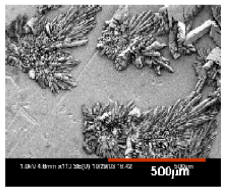
Desalination
- Nanostructured membranes
- Biofouling prevention and control
- Membrane module fluid dynamics
- Sensors
- Water re-use applications
- RO concentrate minimization and management
- Beneficial uses of produced water

Contaminant Removal
- Development of novel As adsorbent media
- Testing and evaluation of As remediation technologies
- Pathogen and virus adsorbent media
- Photocatalytic oxidation

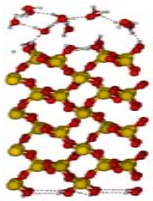
Sandia's Desalination Program

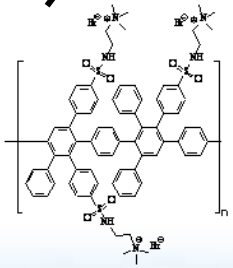
Roadmapping





Near-term research





Long range research

BoR's Brackish Groundwater National Desalination Research Facility (BGNDRF), Alamogordo, NM

ENERGY and WATER