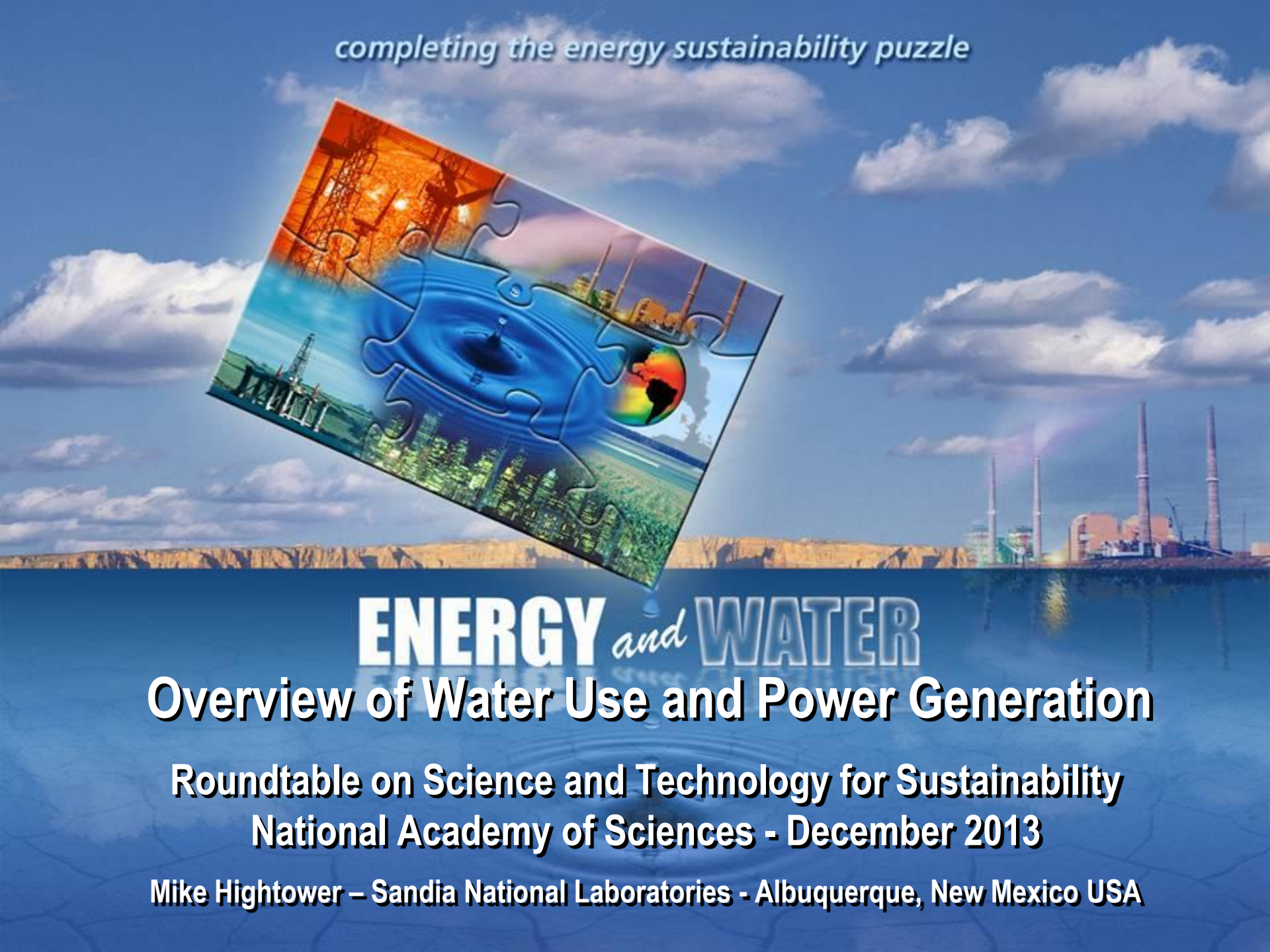
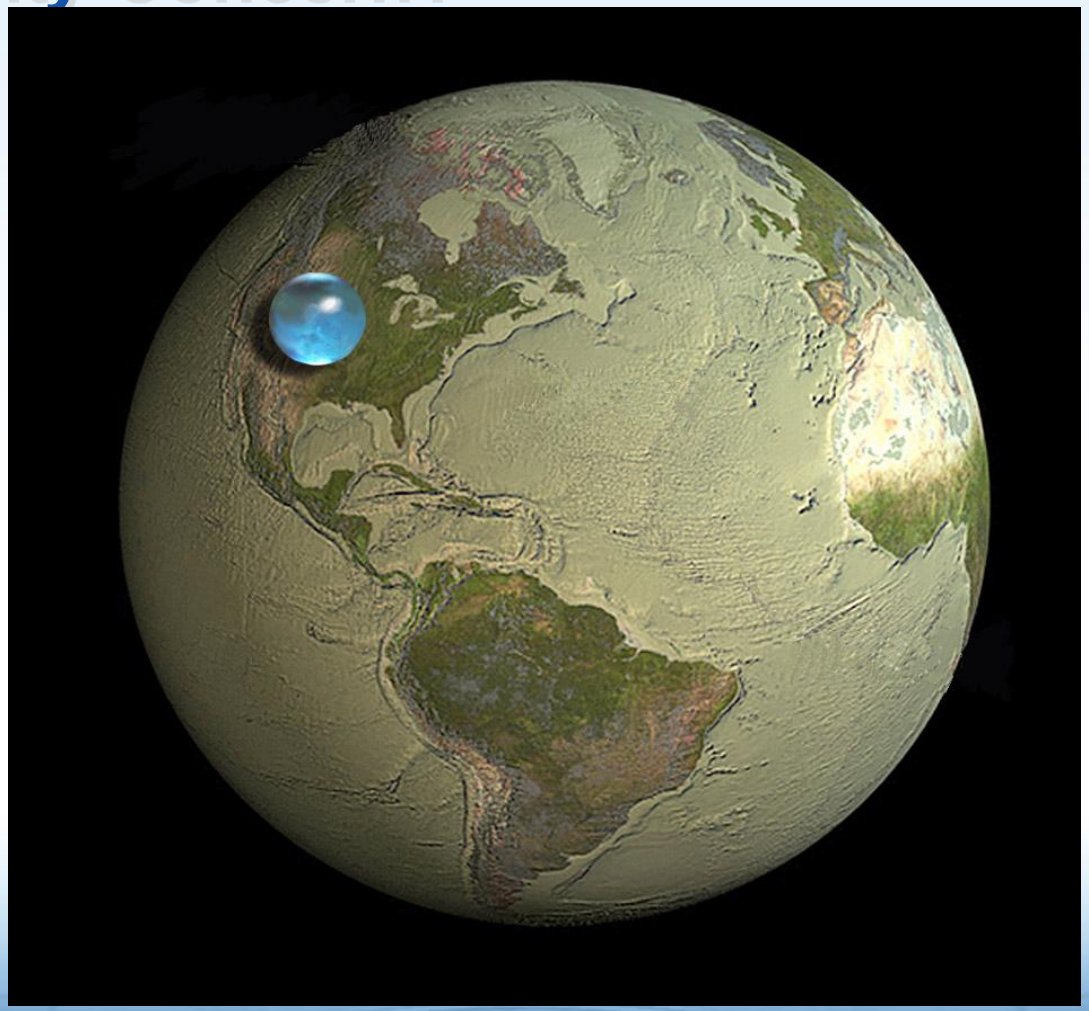


Overview of Water Use and Power Generation

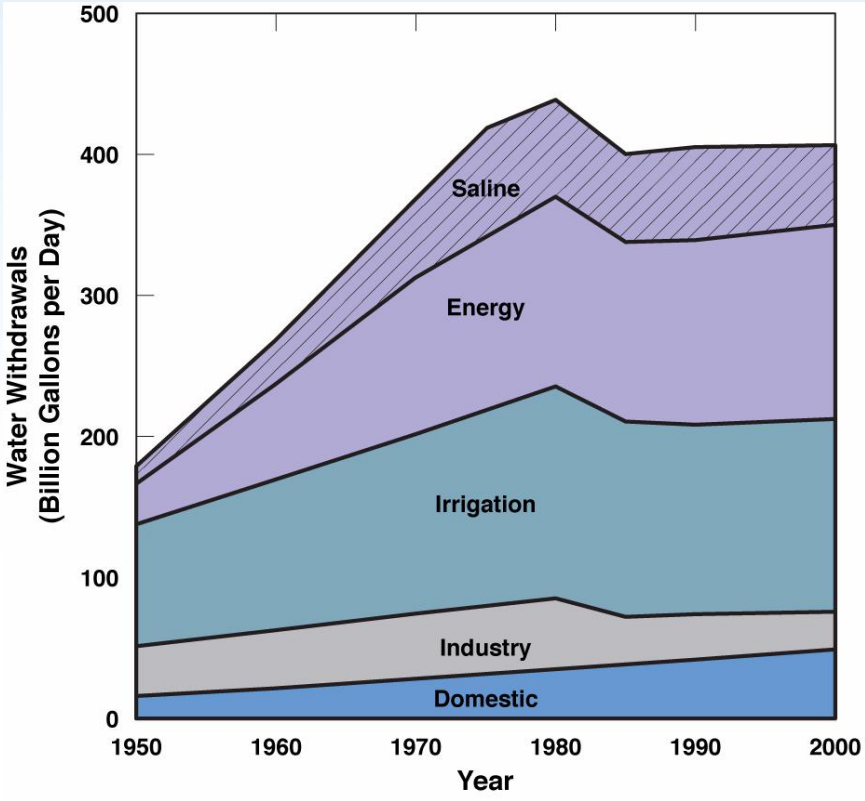
Roundtable on Science and Technology for Sustainability
National Academy of Sciences - December 2013

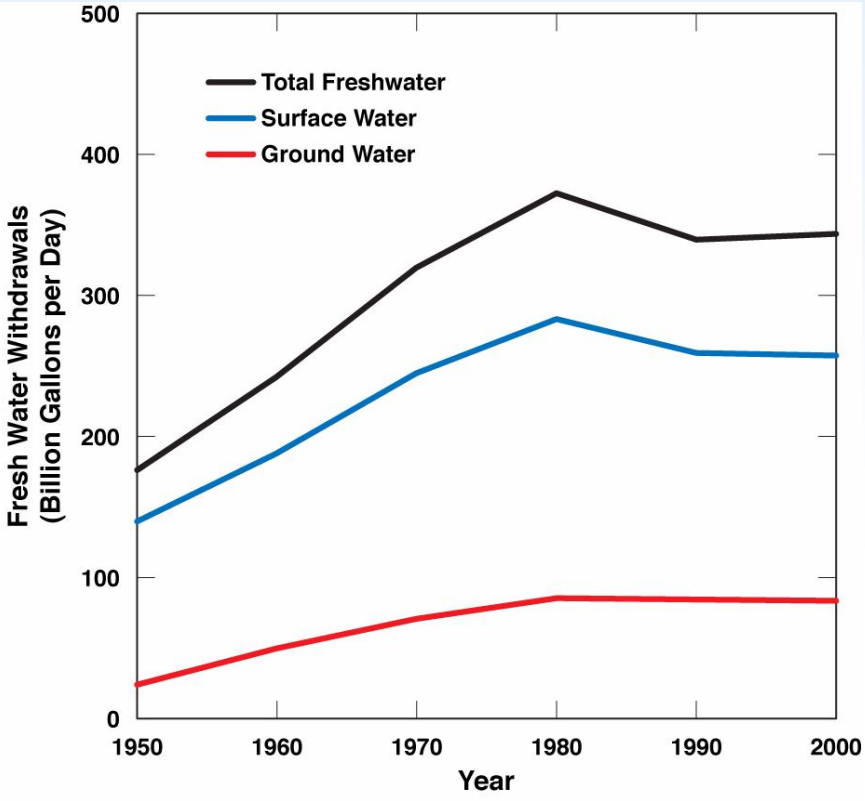
Mike Hightower – Sandia National Laboratories - Albuquerque, New Mexico USA

Total Amount of Water on Earth - Should Water be a Priority Natural Resource and Sustainability Concern?



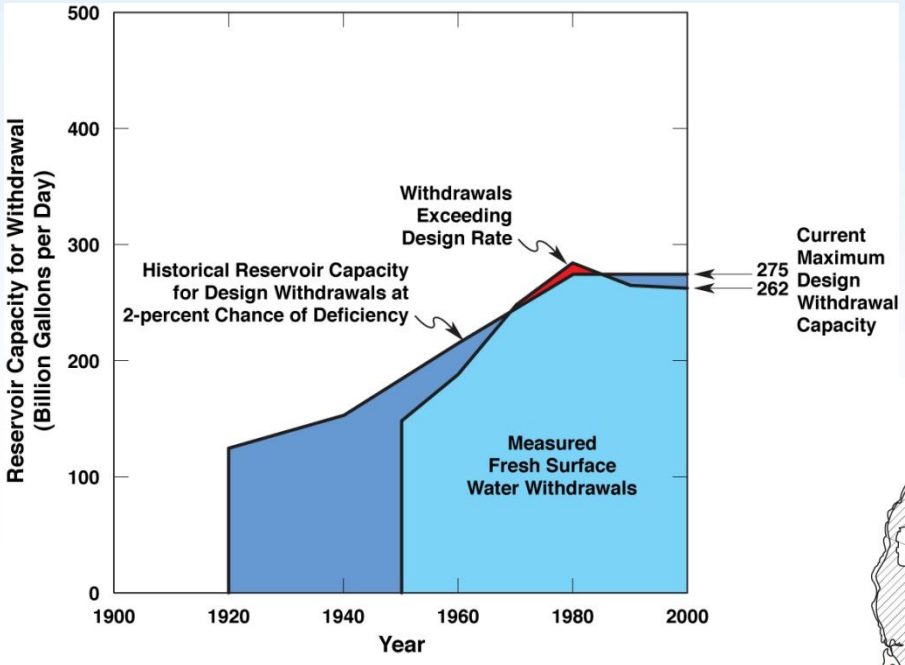
U.S. Water Withdrawal Trends





National Water Withdrawals for Energy (% of total)
Developed countries ~40%, Developing Countries ~10%

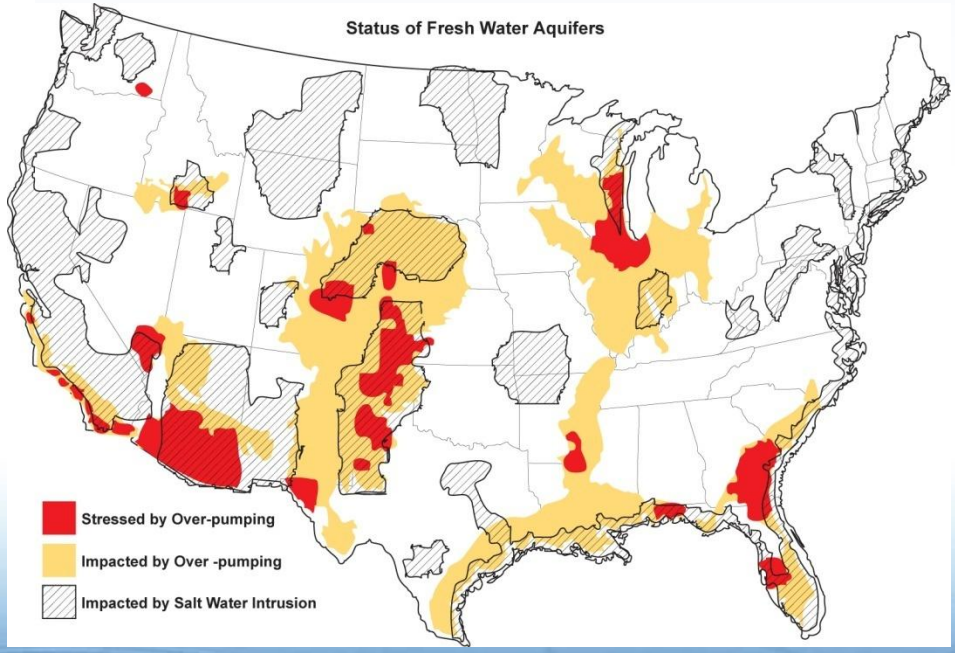
Growing Limitations on Fresh Surface and Ground Water Availability



(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

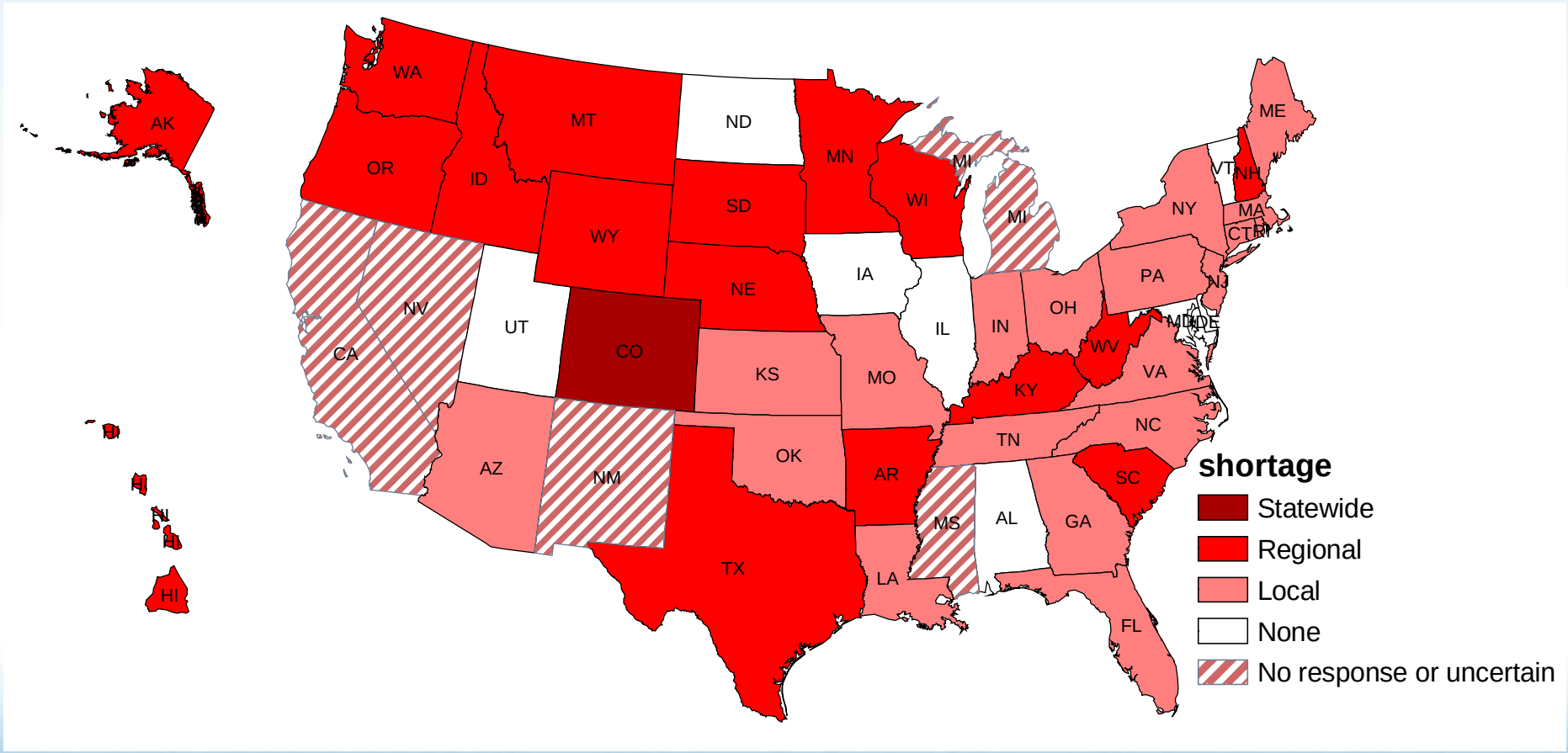
- Many major ground water aquifers seeing reductions in water quality and yield



(Shannon 2007)

ENERGY and WATER

Most State Water Managers Expected Water Shortages Over The Past Decade Under Average Conditions



Source: GAO 2003

ENERGY and WATER

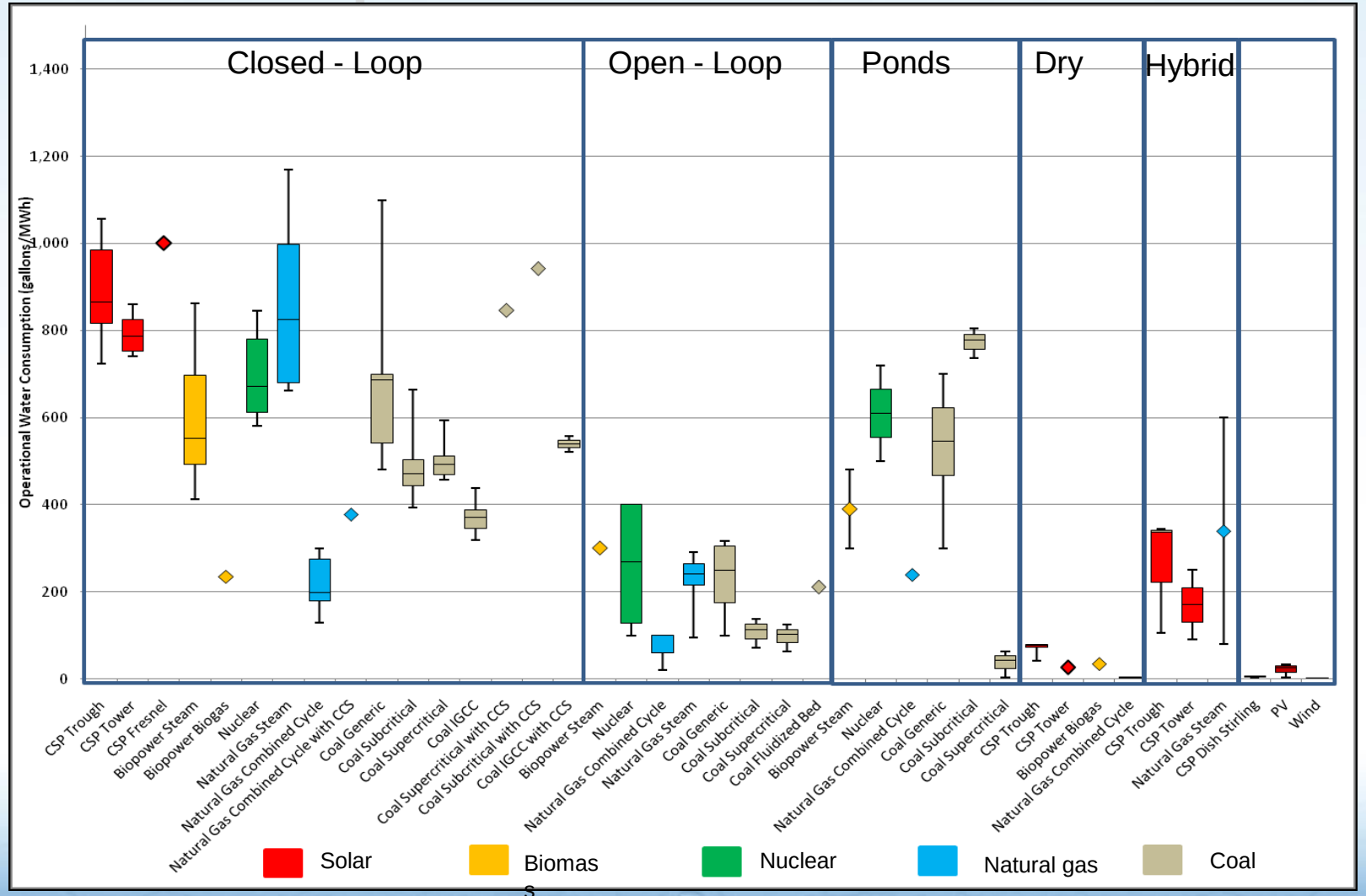
Water Availability Has Been Impacting New Energy Development

- energy facility permitting issues due to water availability

Water Use and Consumption for Electric Power Generation Alternatives

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	300–500	
Nuclear steam turbine	Open-loop	25,000–60,000	~400	~30
	Closed-loop	500–1100	400–750	
Natural Gas Combined-Cycle	Open-loop	7,500–20,000	100	10
	Closed-loop	225	175	
Integrated Gasification Combined-Cycle	Closed-loop	200	175	150
Carbon sequestration for fossil energy generation	~80% increase in water withdrawal and consumption			
Geothermal Steam	Closed-loop	2000	1000-2500	50
Concentrating Solar	Closed-loop	750	750	10
Wind and Solar Photovoltaic	N/A	0	0	10

NREL Detailed Electric Power Water Consumption - 2011



Source: Macknick, J., R. Newmark, G. Heath, and K. Hallett, 2011: A Review of Operational Water Consumption and Withdrawal Factors for Electricity Generating Technologies. *NREL Technical Report*, **NREL/TP-6A20-50900**

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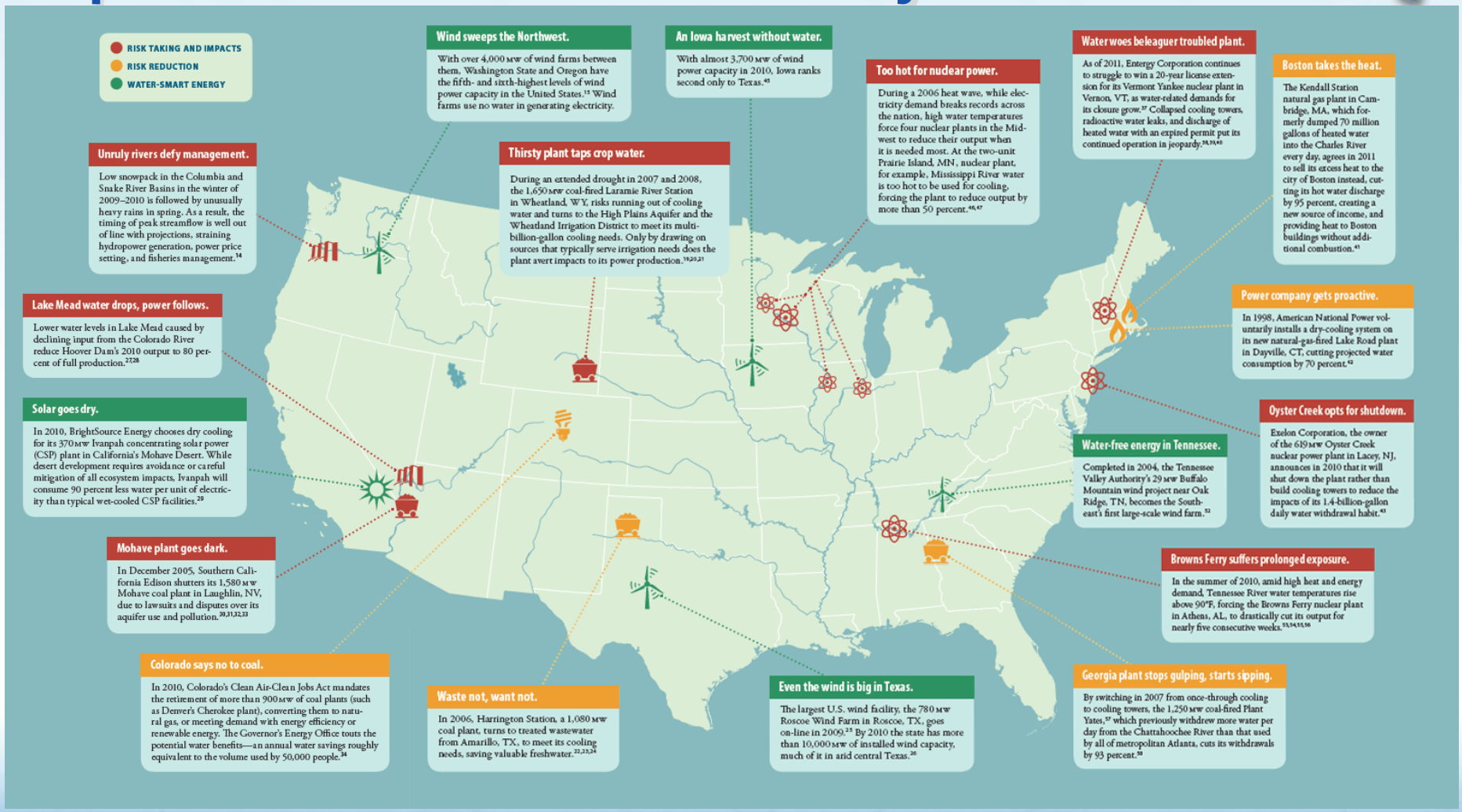
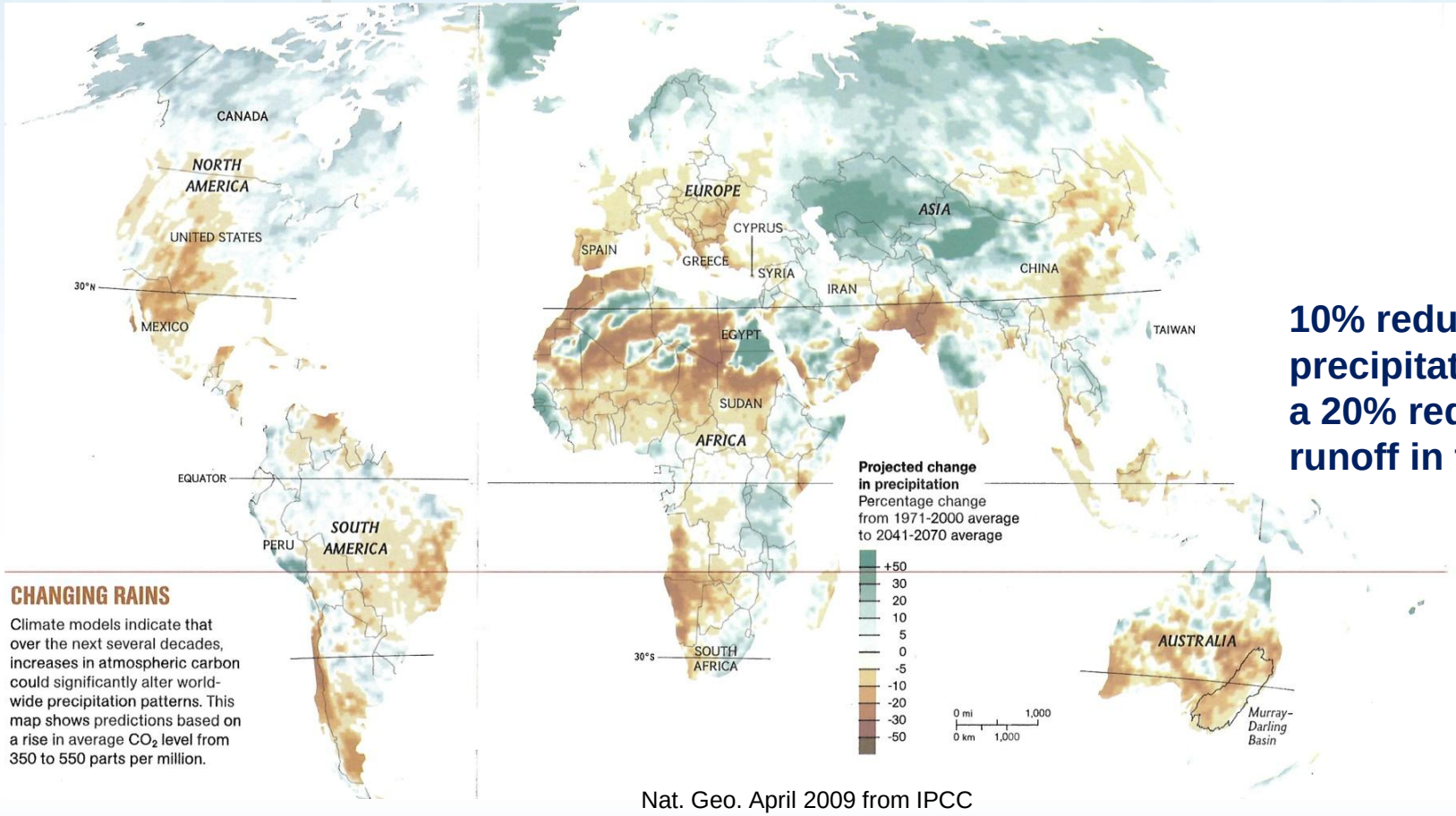
Union of Concerned Scientists – Water Impacts on Electric Power Study - 2011



Source: Union of Concerned Scientists. "The Energy-Water Collision: Power and Water at Risk." Fact Sheet. June 2011. http://www.ucsusa.org/assets/documents/clean_energy/ew3/power-and-water-at-risk-with-endnotes.pdf

Climate Change will Impact Precipitation, Evapotranspiration, and Runoff



10% reduction in precipitation equals a 20% reduction in runoff in the SW

Nat. Geo. April 2009 from IPCC

"Water is where the climate change rubber meets the road"

Dr. Bernie Zak, Sandia Sr. Climate Scientist, 2013

ENERGY and WATER

Summary of Major National Needs and Issues Identified in Regional 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

Major Research and Technology Directions in the Electric Power Sector

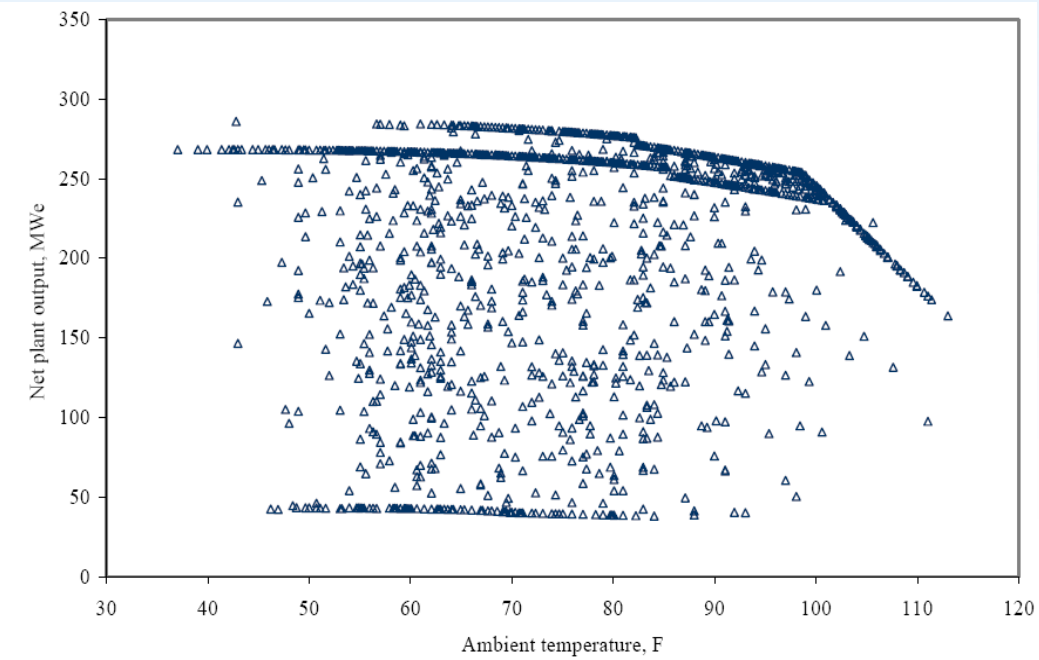


Figure 5 Net Plant Output as a Function of Ambient Temperature; Dry Heat Rejection

Dry Cooling Performance

- Improve dry and hybrid cooling system performance and reduce 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
- Consider co-location benefits

Other Agencies are Taking Note of Water and Electric Power Issues

- **EPA**
  - 316b regulations on cooling
- **USGS/EIA**
  - Power plant water use and consumption data collection improvement
- **COE/BOR/TVA/BPA**
  - Hydropower availability and balancing ability
- **United Nations**
  - 2014 is the year of Energy and Water