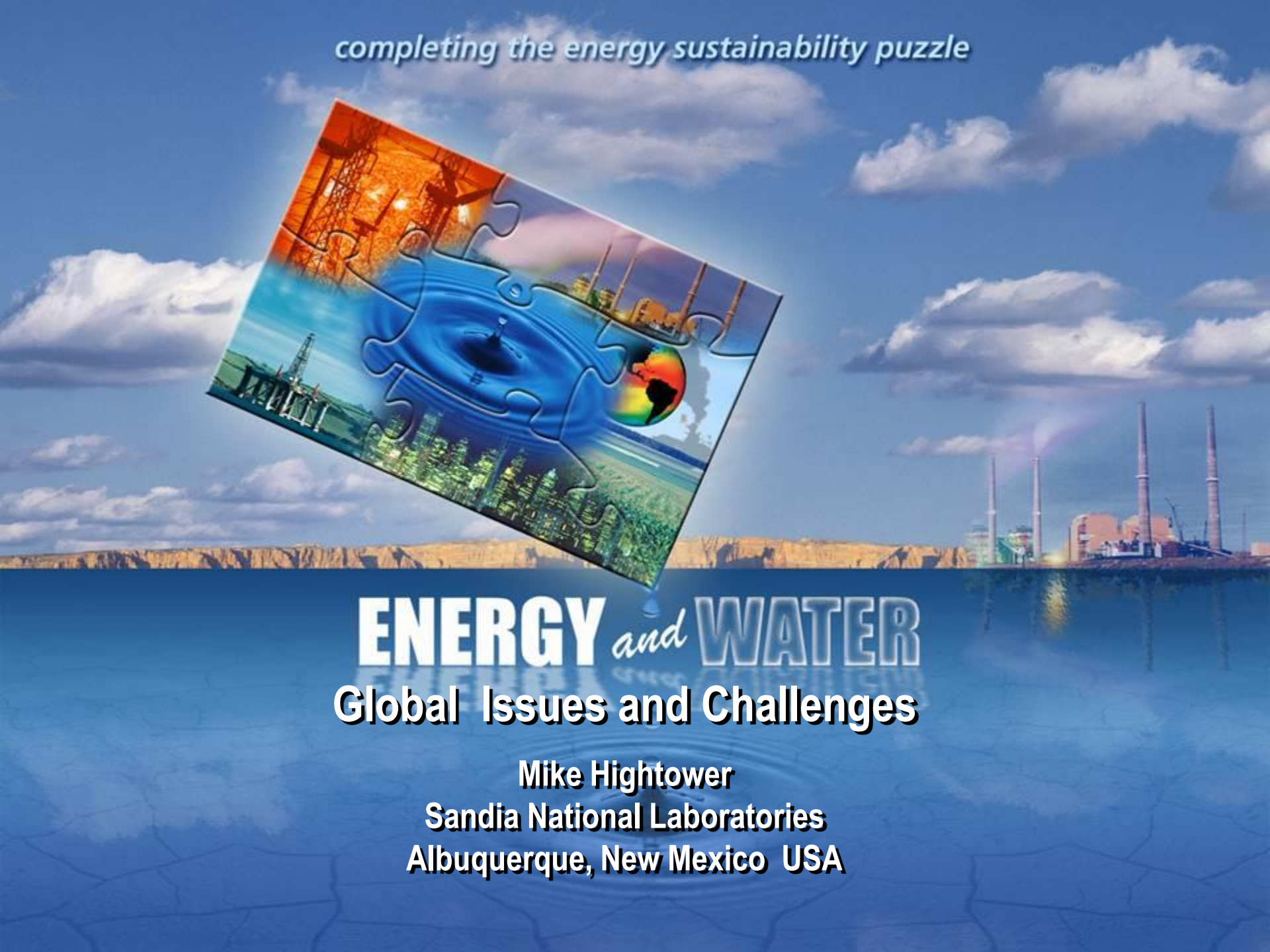
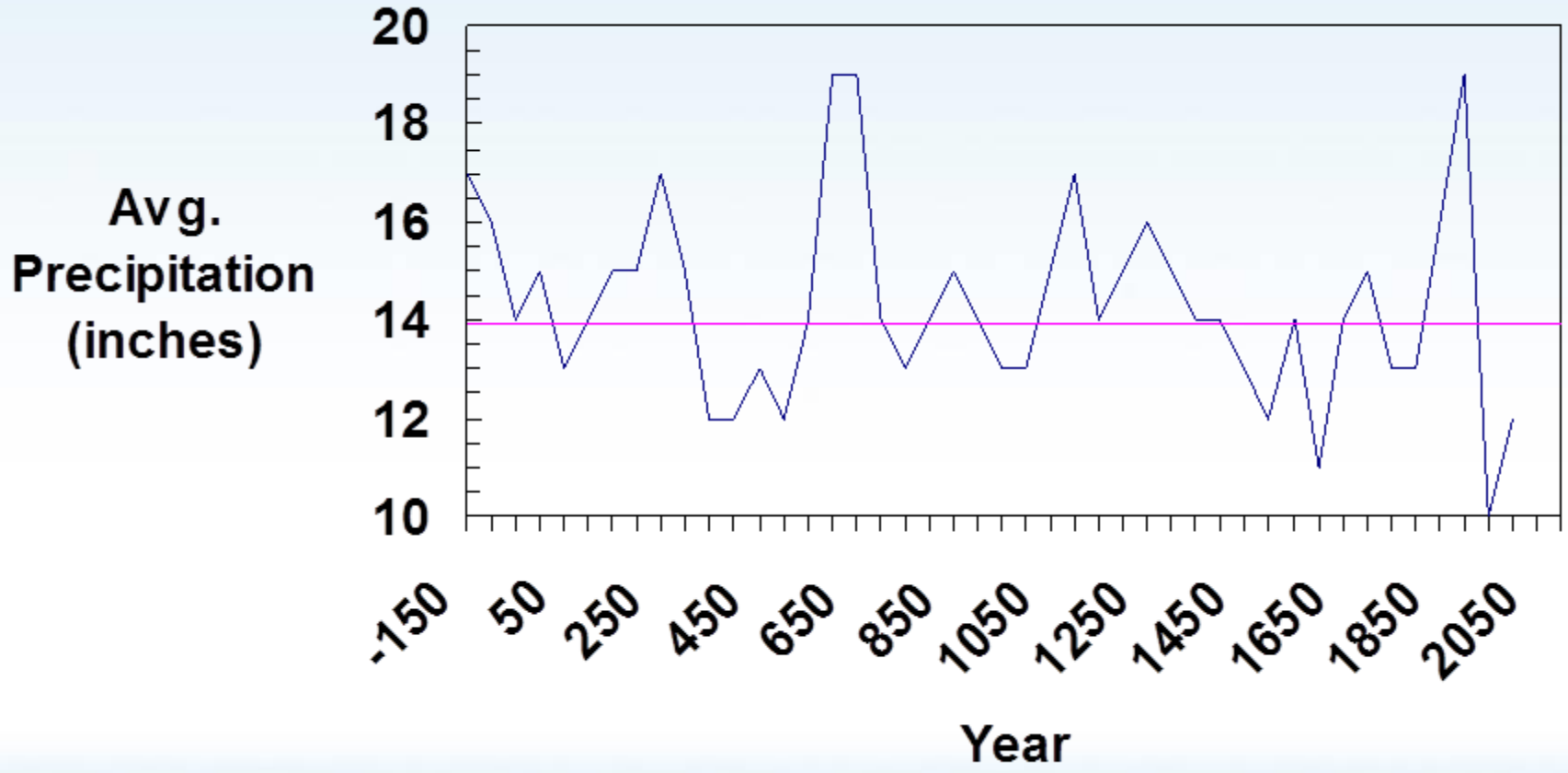


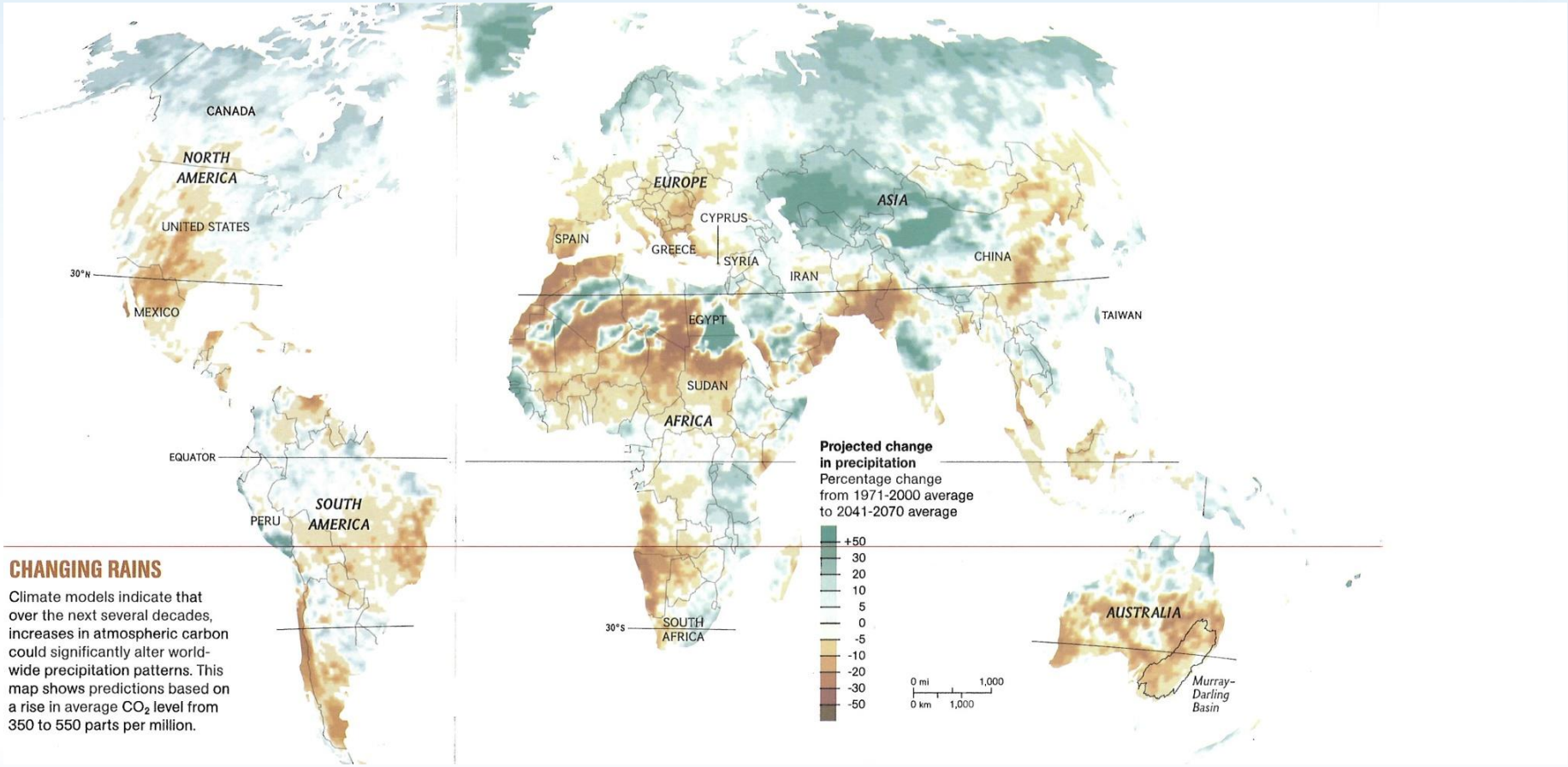
Global Issues and Challenges

Mike Hightower
Sandia National Laboratories
Albuquerque, New Mexico USA

Southwest U.S.Precipitation Patterns Based on Tree Ring Data



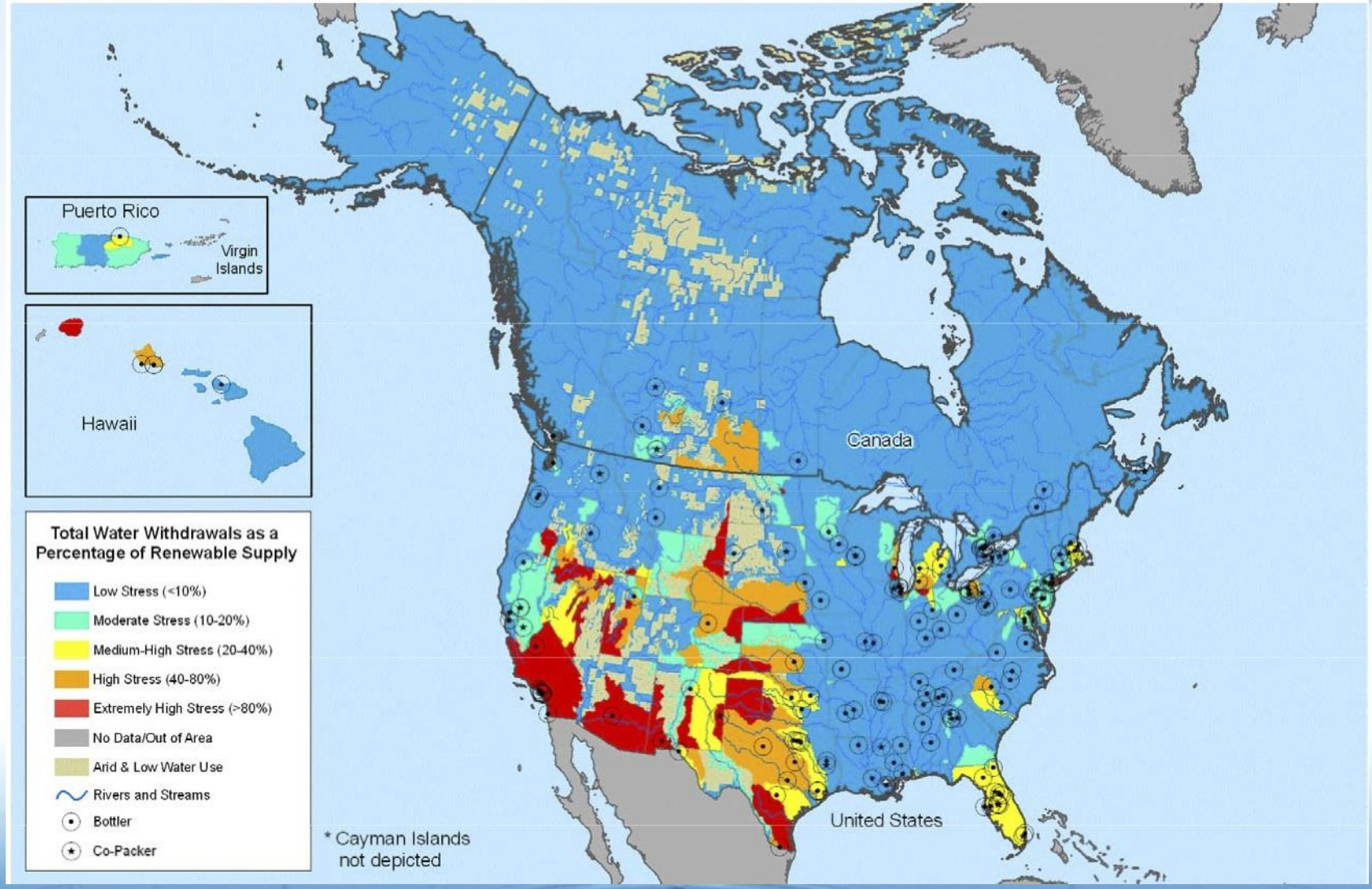
Climate Change will Impact Precipitation, Evapotranspiration, and Runoff



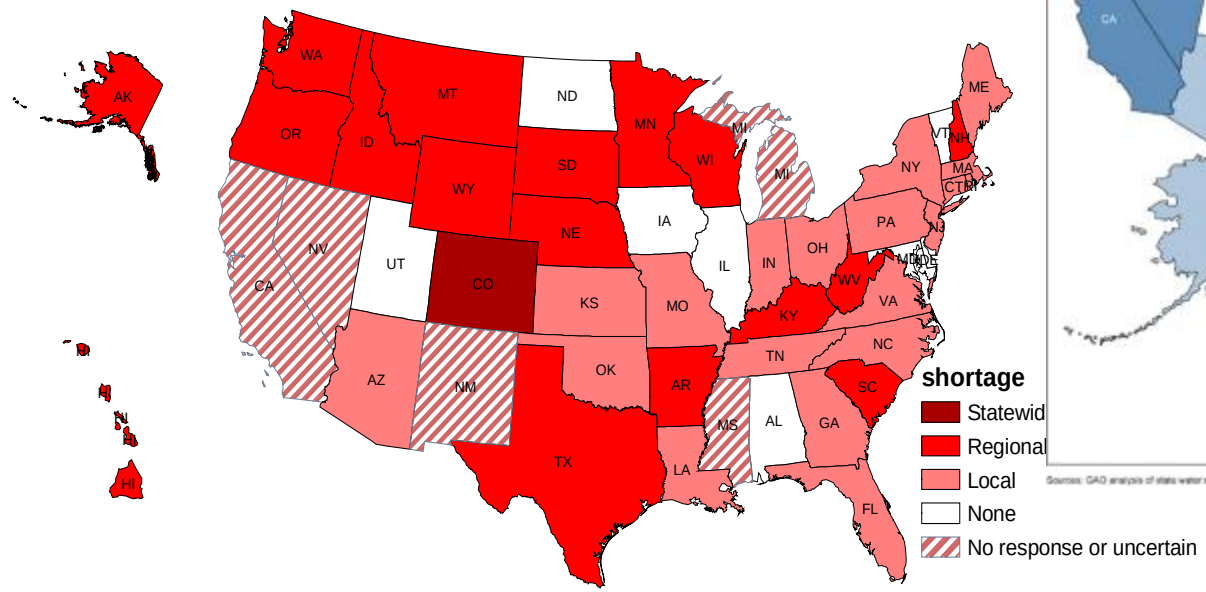
Nat. Geo. April 2009 from IPCC

Mid-latitude population belt will be strongly affected

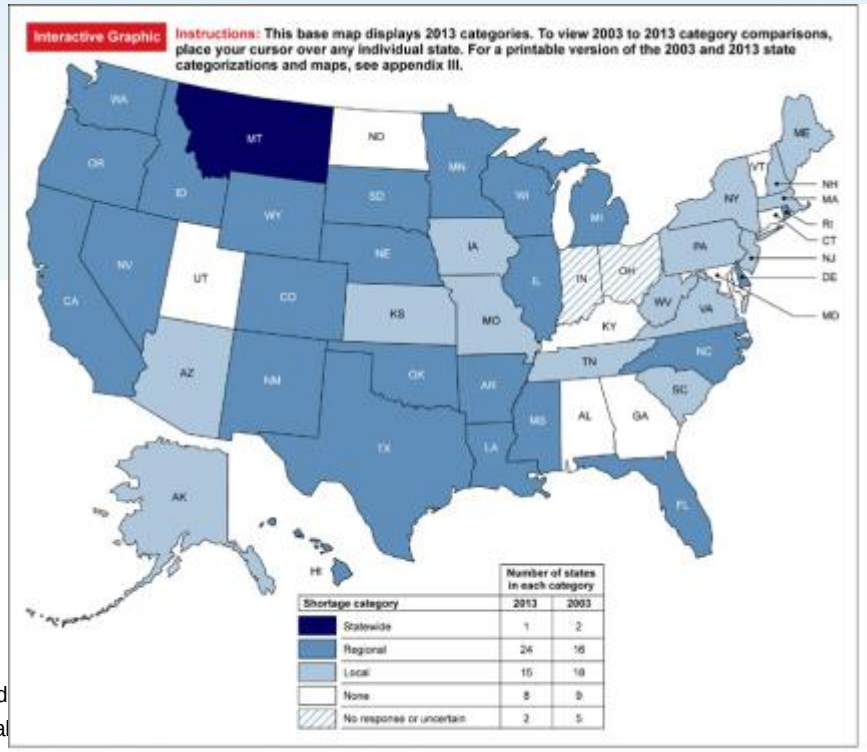
Assessment of Regional Water Stress in North America



Expected Water Shortages by State



GAO 2003



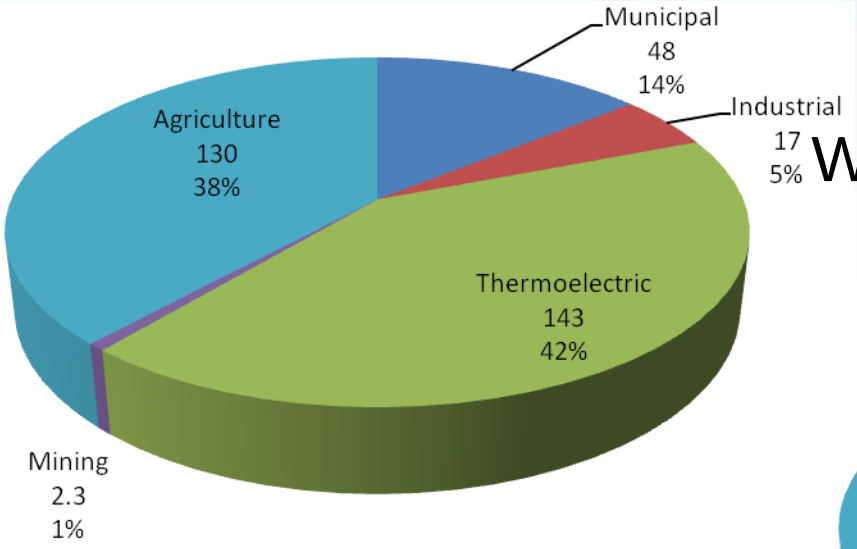
GAO 2013

Water stress is increasing nationally

ENERGY and WATER

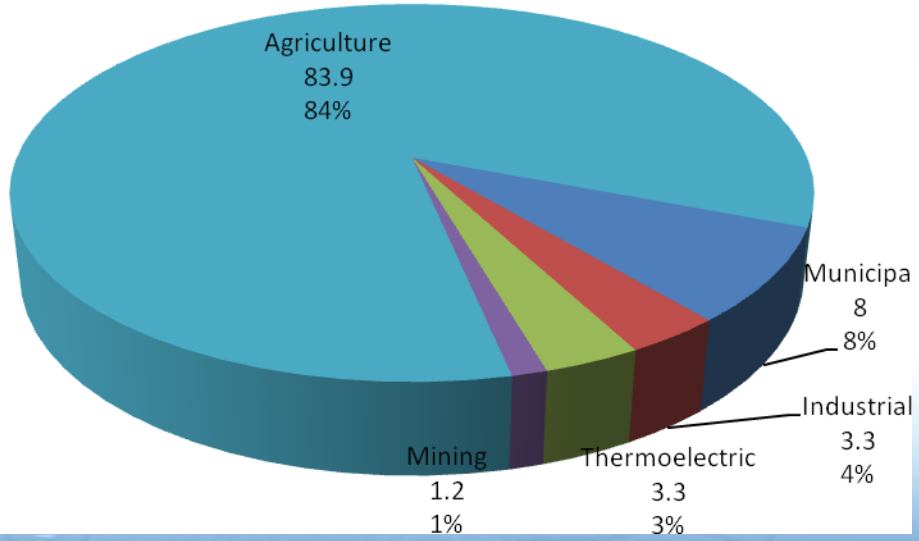
Water for Energy

Water Withdrawal (1,290 Mm^3/d)
2005

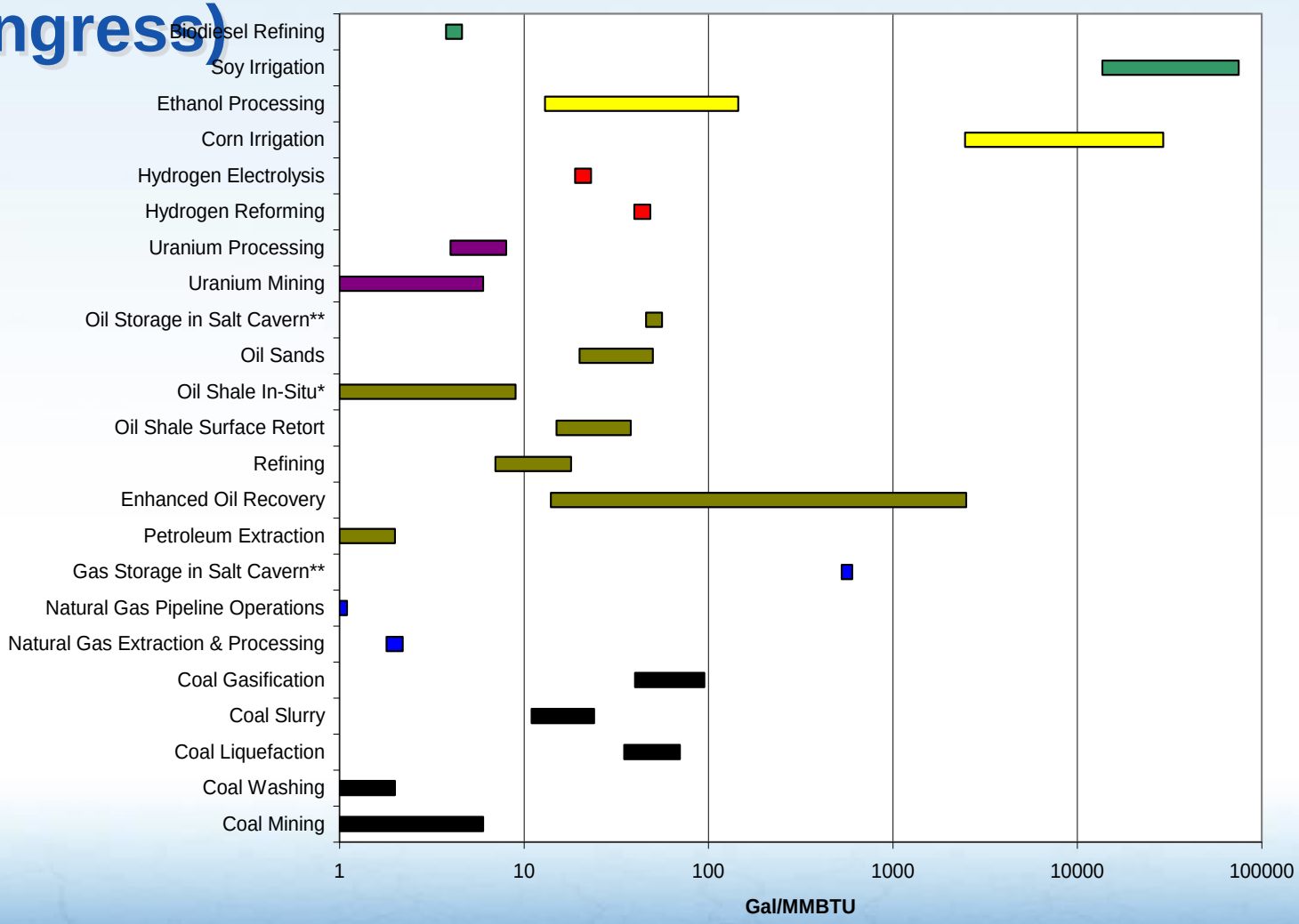


~4 Mm^3/d Consumed in Mining and Fuel Processing

Water Consumption (390 Mm^3/d)
1995



Water Consumption for Energy Extraction, Mining, and Processing (2006 Report to Congress)



ENERGY and WATER

Water Use and Consumption of Electric Power Generation Alternatives

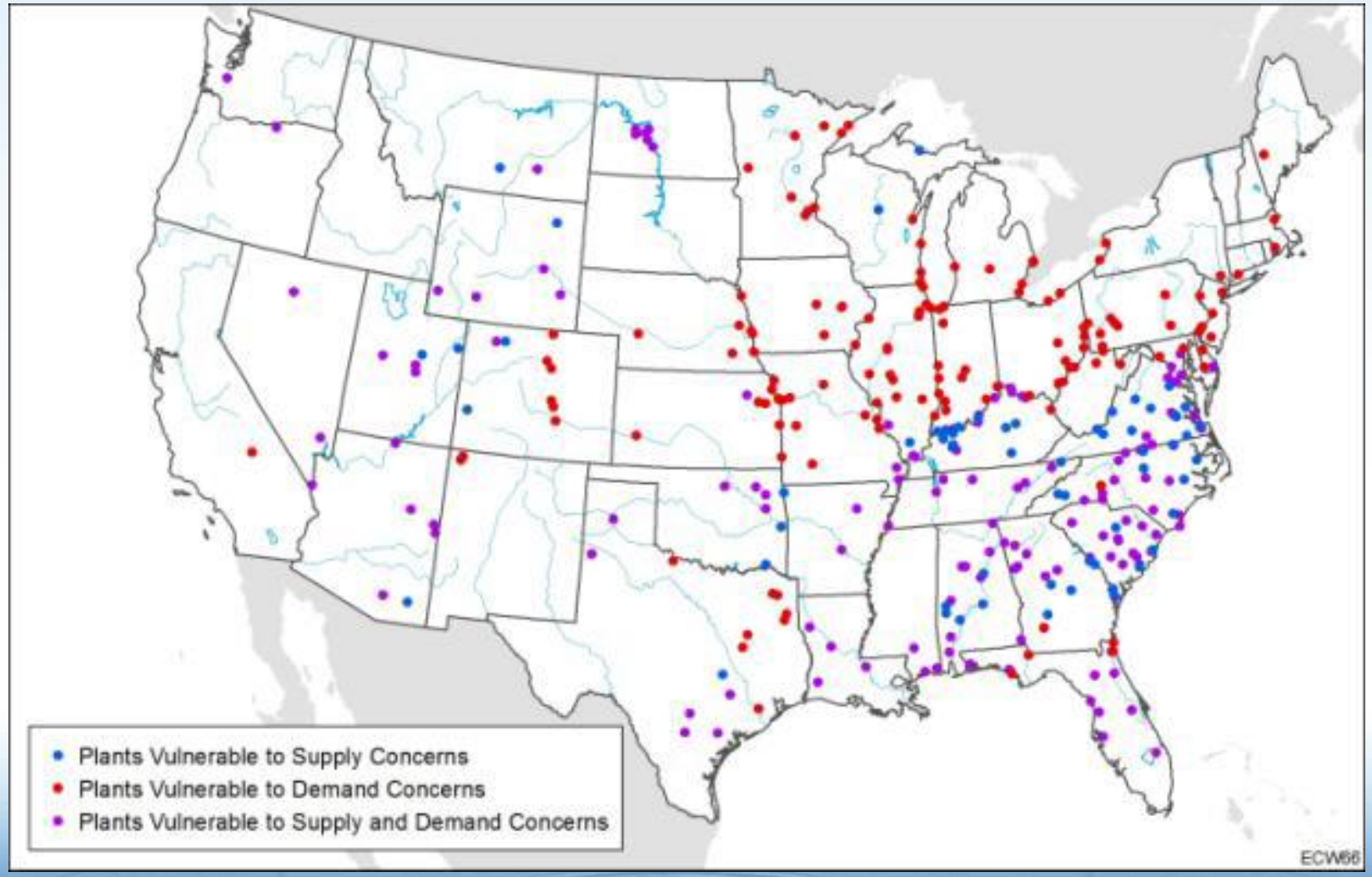
Plant-type	Cooling Process	Water Use Intensity (l/MWh$_e$)		
		Steam Condensing		Other Uses
		Withdrawal	Consumption	Consumption
Fossil/ biomass steam turbine	Open-loop	80,000–200,000	~800-1200	~120
	Closed-loop	1200–2400	1200–2000	
Nuclear steam turbine	Open-loop	100,000–240,000	~1600	~120
	Closed-loop	2000–4400	1600–2900	
Natural Gas Combined-Cycle	Open-loop	30,000–80,000	400	40
	Closed-loop	900	700	
Integrated Gasification Combined-Cycle	Closed-loop	800	700	600
Carbon sequestration for fossil energy generation	~70-90% 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

Water Consumption of Transportation Fuel Alternatives

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

Coal Power Plants with Potential Water Supply and Demand Concerns



DOE Energy Water Program Plan

- **Technology RDD&D**
  - Thermoelectric Cooling Improvements
  - Waste Heat Recovery in Energy Systems
  - Process Water Use Efficiency and Quality
  - Alternatives to Fresh Water Use in Energy Production Using Advanced Materials and Processes
  - Traditional and Non-traditional Hydropower Improvements
  - Desalination Improvements
  - Net-Zero Municipal Wastewater Treatment
  - Sensors
  - Deployment
- **Analysis and Modeling**
  - Integrated Analytical Platforms
  - Decision Support Tools
- **Policy Framework**
- **Stakeholder Engagement**
- **International Diplomacy**