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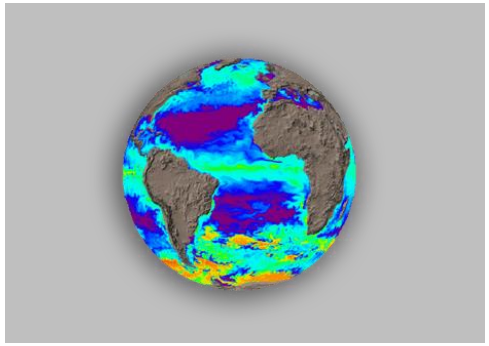


Energy, Water, Transportation Interdependencies and System-level Policy and Social Considerations

Mike Hightower

July 17, 2013 – Iowa State

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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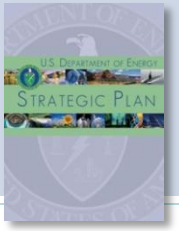
Energy Security, Reliability, and Sustainability Context

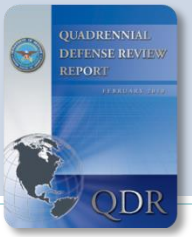
As currently Defined by federal stakeholders' authorities & responsibilities

DEPARTMENT OF ENERGY



2006 Strategic Plan

DEPARTMENT OF DEFENSE



Quadrennial Defense Review Report 2010

DEPARTMENT OF HOMELAND SECURITY

2008 Strategic Plan Protecting Critical Infrastructure

GOALS

- Diversify energy mix & reduce dependence on foreign petroleum
- Reduce green house gas emissions & other environmental impacts
- Create a more flexible, more reliable & higher capacity US energy infrastructure
- Cost-effectively improve energy efficiency of US economy

- Improve operational effectiveness
  - -Reduce energy demand
  - -Increase use of renewable energy supply
  - - Secure supplies for mission assurance
- Increase energy efficiency & protect against energy price fluctuations
- Reduce greenhouse gas emissions in support of US climate change initiatives

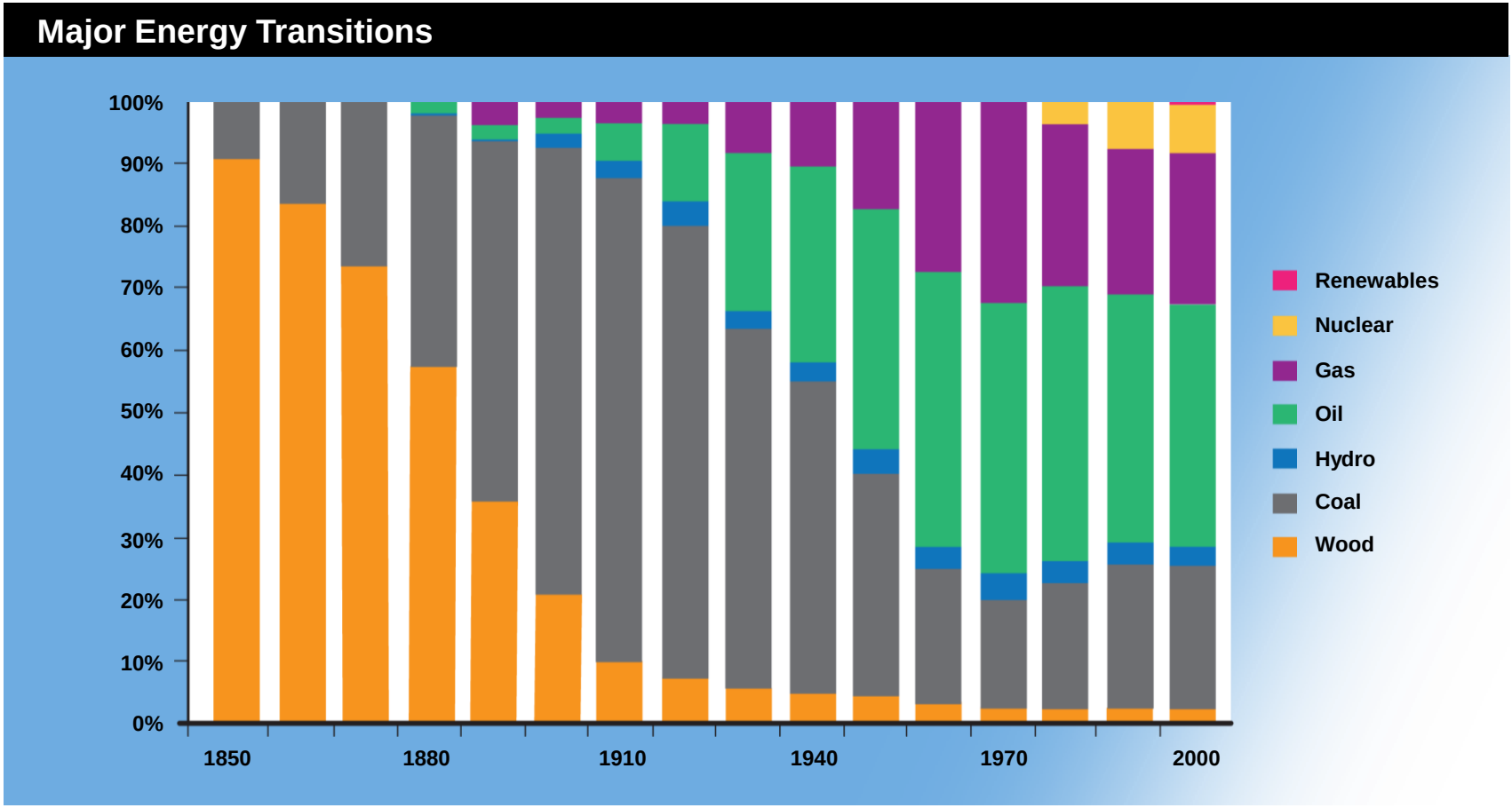
- Decrease vulnerability of critical infrastructure to bad actors both physical & cyber
- Improve national power grid mod/sim capability to address national scale threats
- Improve port and coastal security – climate change impacts
- DHS concerned with interdependencies: Transportation, Energy, Defense

All highlight focus of reliable, secure, resilient and sustainable energy approaches

"The times,…they are a changin .."

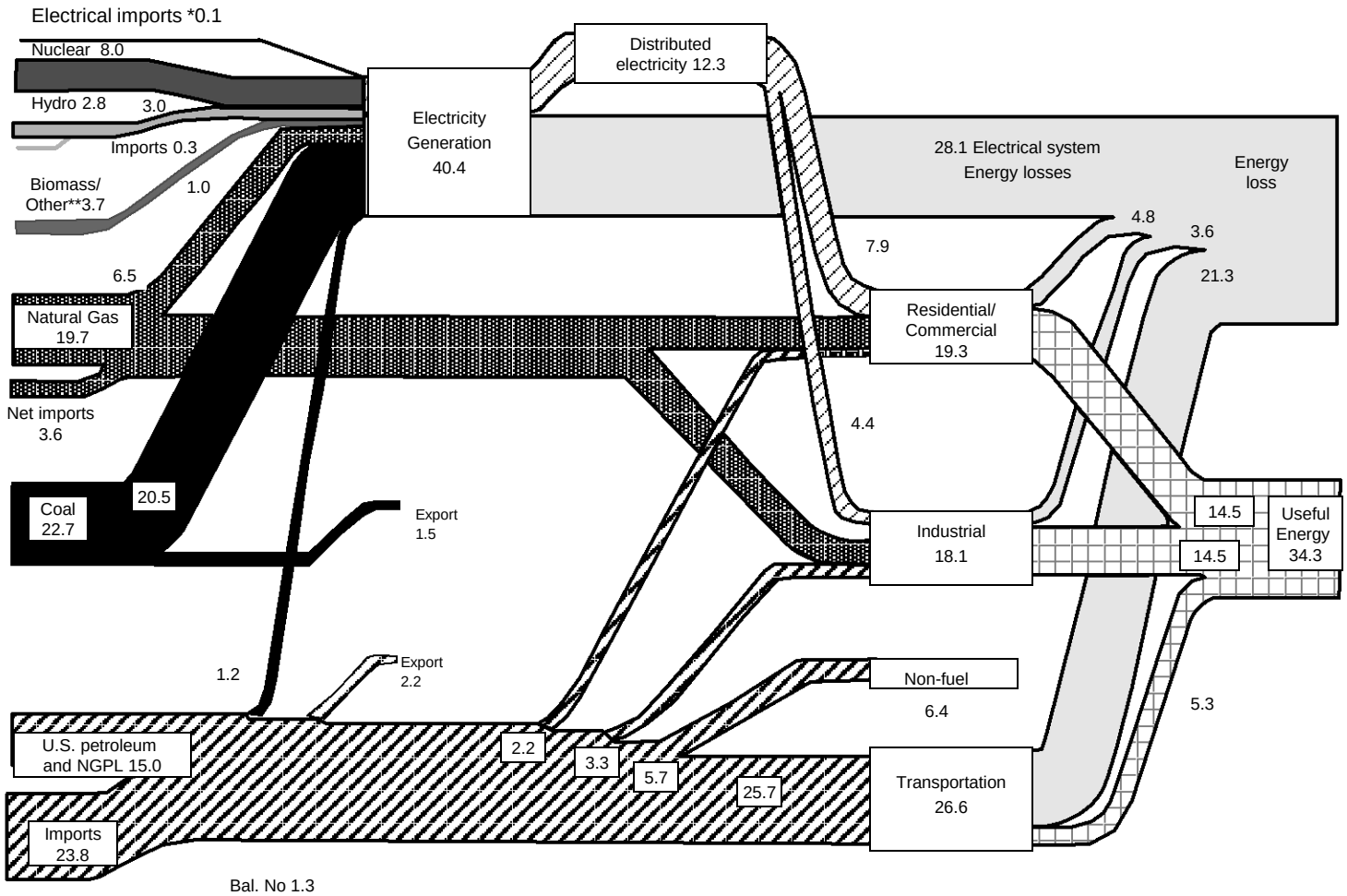
- Projected CO2 Emissions (million tons/yr)
  - 2010 U.S. 1600, China 3400, India 700, World 8400
  - 2020 U.S. 1800, China 4400, India 2100, World 11400
- By 2030 U.S. will be the largest oil producing nation, North American the second largest oil producing region
- Shale gas is everywhere….and lots of it?
  The new 'green chile' of energy resources?
- 75% of U.S. coal generating capacity is over 40 years old
- Is biofuels competing against the food supply – 28% of U.S. corn production and growing
- China PV manufacturer goes bankrupt, March 20, 2013

The World has Made Two Major Energy Transitions



Source: Energy Information Administration

FY 2000 U.S. Energy Use



Values in Quadrillion BTUs (quads) with Total Quads=100 in 2000

Source: Production and end-use data from Energy Information Administration. Annual Energy Review 2000
*Net fossil-fuel electronic imports
**Biomass other includes wood and waste, geothermal, solar, and wind.

Energy Generation and Delivery – A More and More Complex System to Manage

Sandia National Laboratories

Resource Dependencies

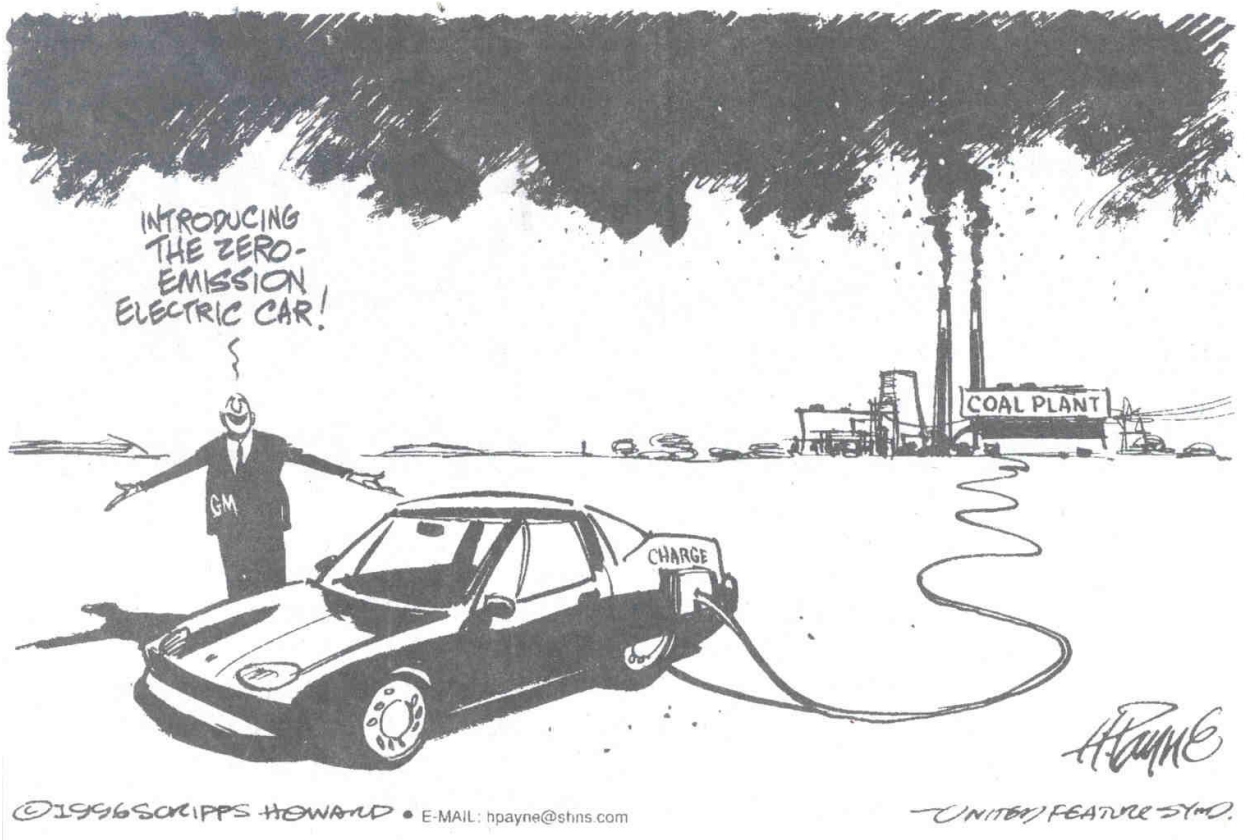
- Air
- Fuel
- Land
- Water
- Capital

Infrastructure Dependencies

- Transmission and distribution
- Fuel development and transportation
- Water
- Telecom
- Government

Energy Policies and Regulations Must be System Focused

Electric Car Example:

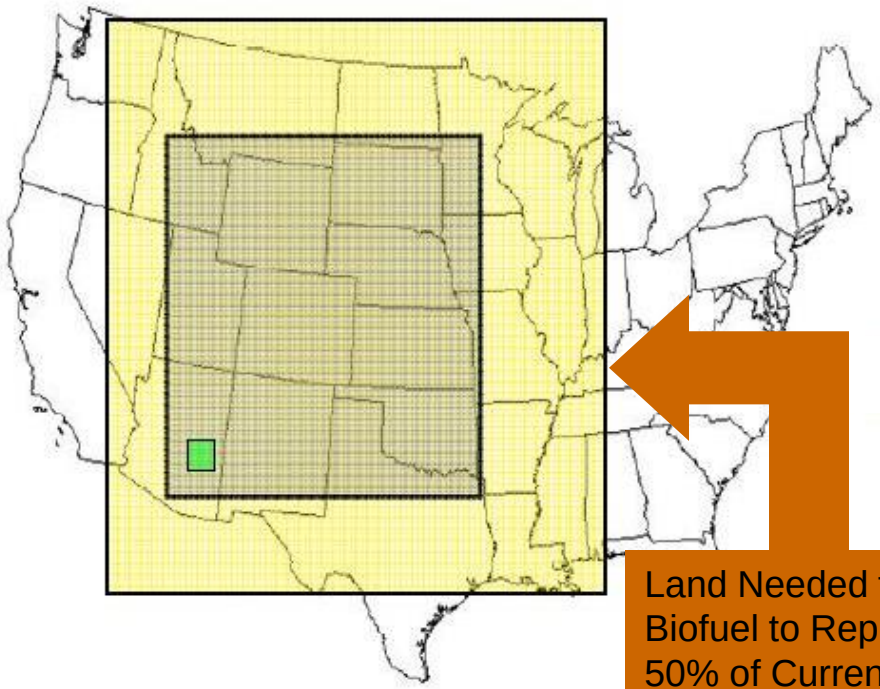


Hydrogen Car Example:

$$CH_4 + 2H_2O + \text{energy} > 4H_2 + CO_2$$

Biofuels and Natural Resources Systems Evaluations

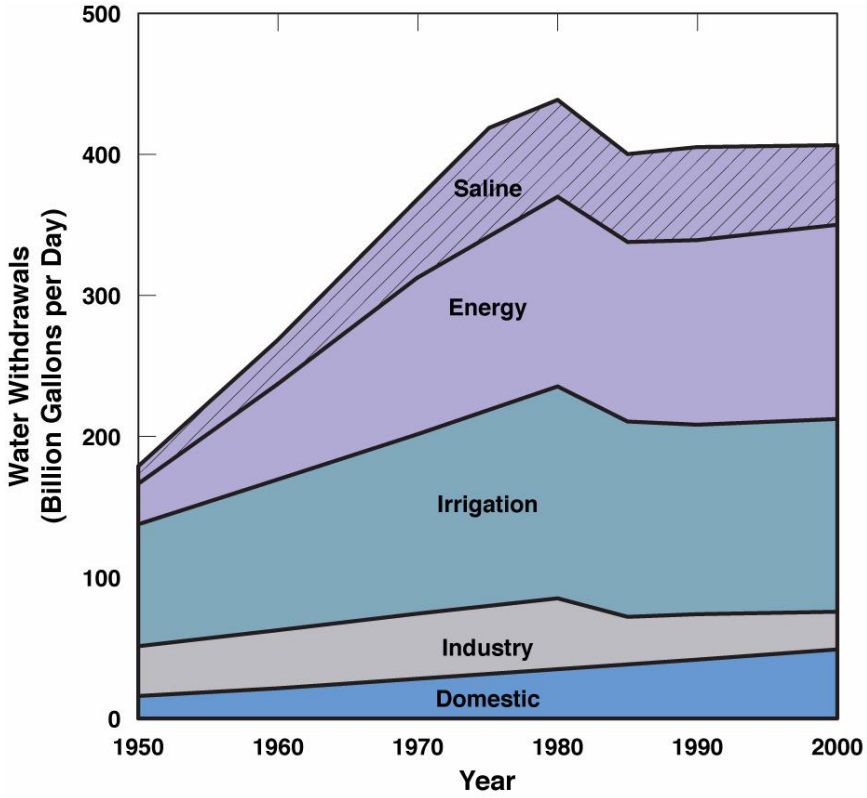
Gallons of Oil per Acre per Year	
Corn	18
Soybeans	48
Safflower	83
Sunflower	102
Rapeseed	127
Oil Palm	635
Micro Algae	1000 - 7000

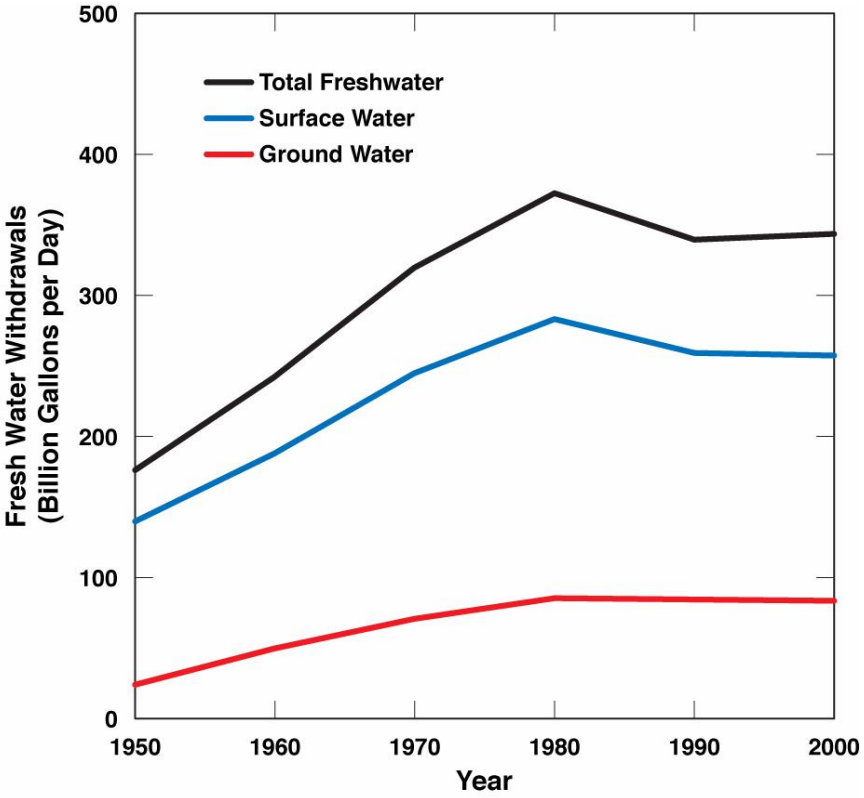


Land Needed for Biofuel to Replace 50% of Current Petroleum/Diesel using oil from:

Corn
Soybean
Algae

U.S. Water Withdrawal Trends

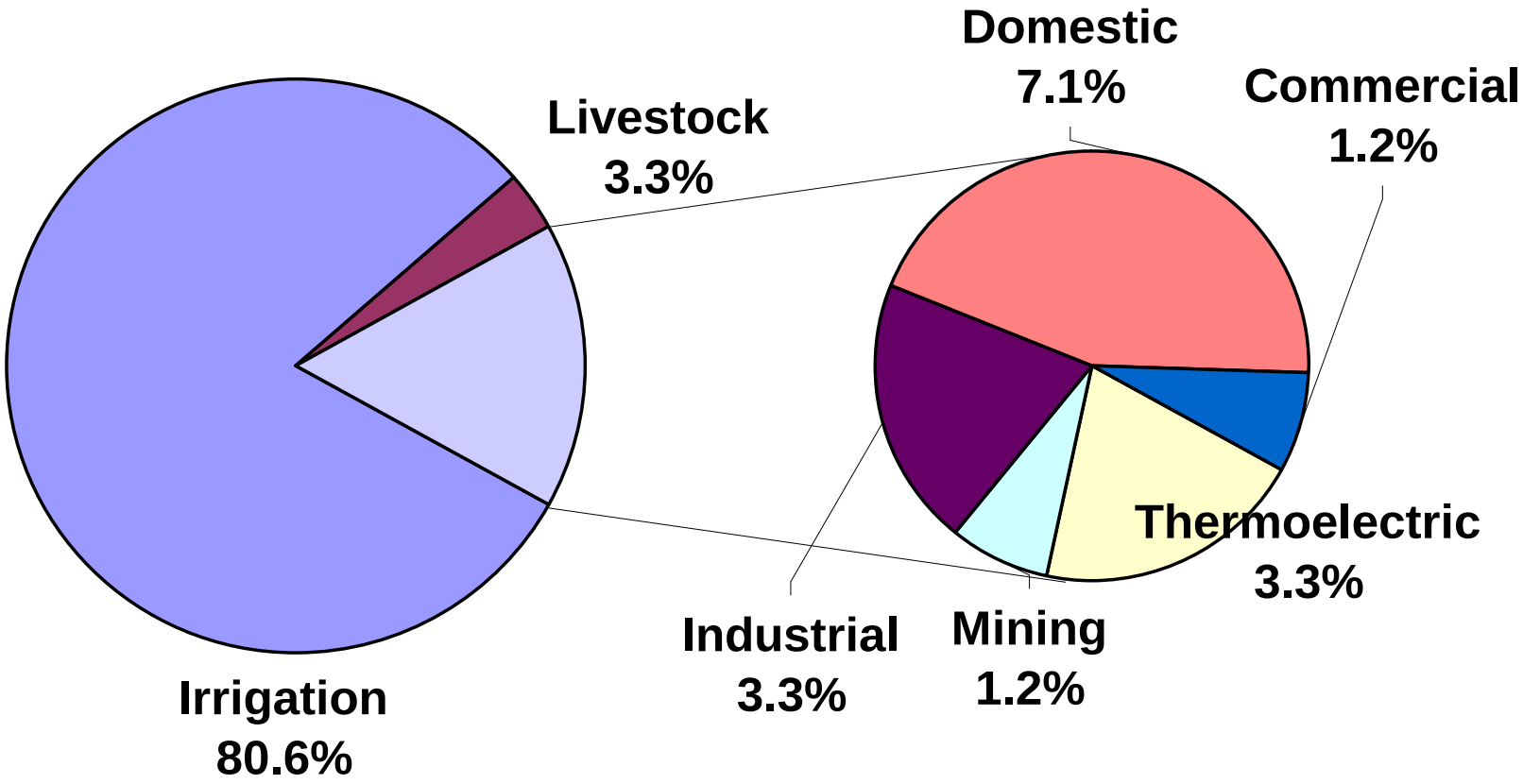




The energy sector is the largest water withdrawal sector in the U.S.

Water Consumption by Sector

U.S. Freshwater Consumption, 100 Bgal/day



[USGS, 1998]

Energy uses 27 percent of all non-agricultural fresh 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	~80% increase in water withdrawal and consumption			
Geothermal Steam	Closed-loop	2000	450-1350	50
Concentrating Solar	Closed-loop	750	740	10
Wind and Solar Photovoltaic	N/A	0	0	1-2

Water Consumption of Transportation Fuels

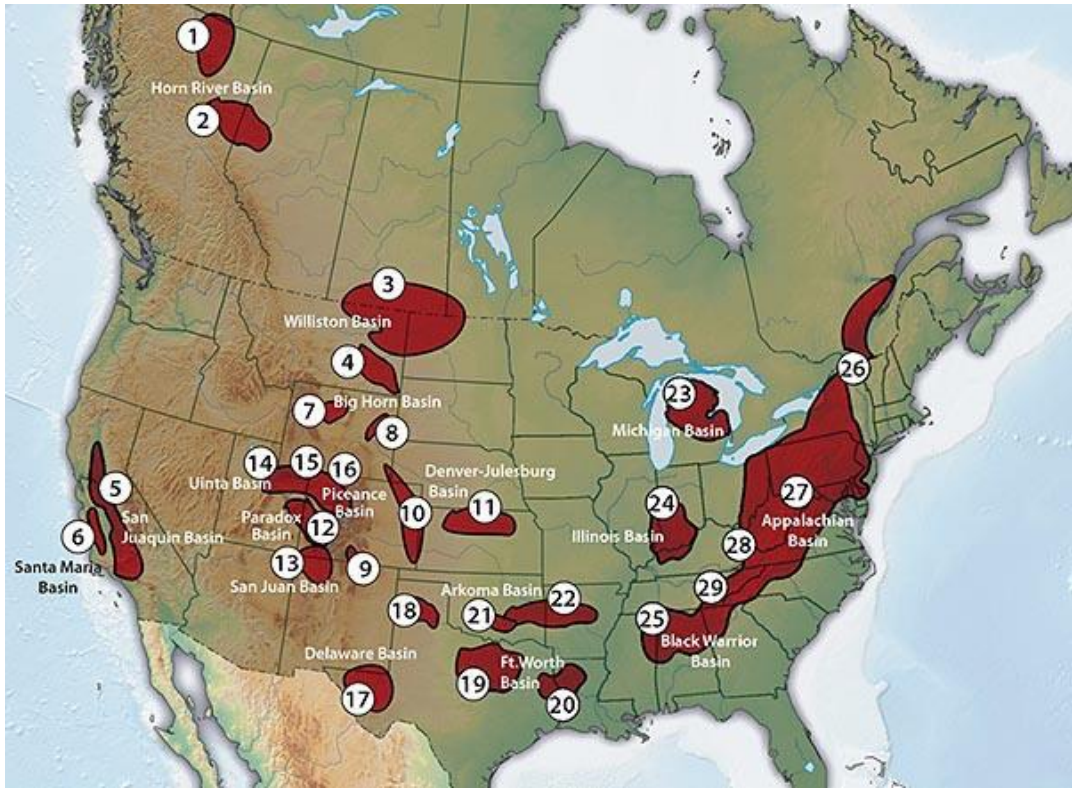
Fuel Type and Process	Relationship to Water Quantity	Relationship to Water Quality	Water Consumption: Water consumed per-unit-energy [gal / MMBTU] †	Water Consumption: Average gal water consumed per gal fuel
Conventional Oil & Gas	Water needed to extract and refine; Water produced from extraction	Produced 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)	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

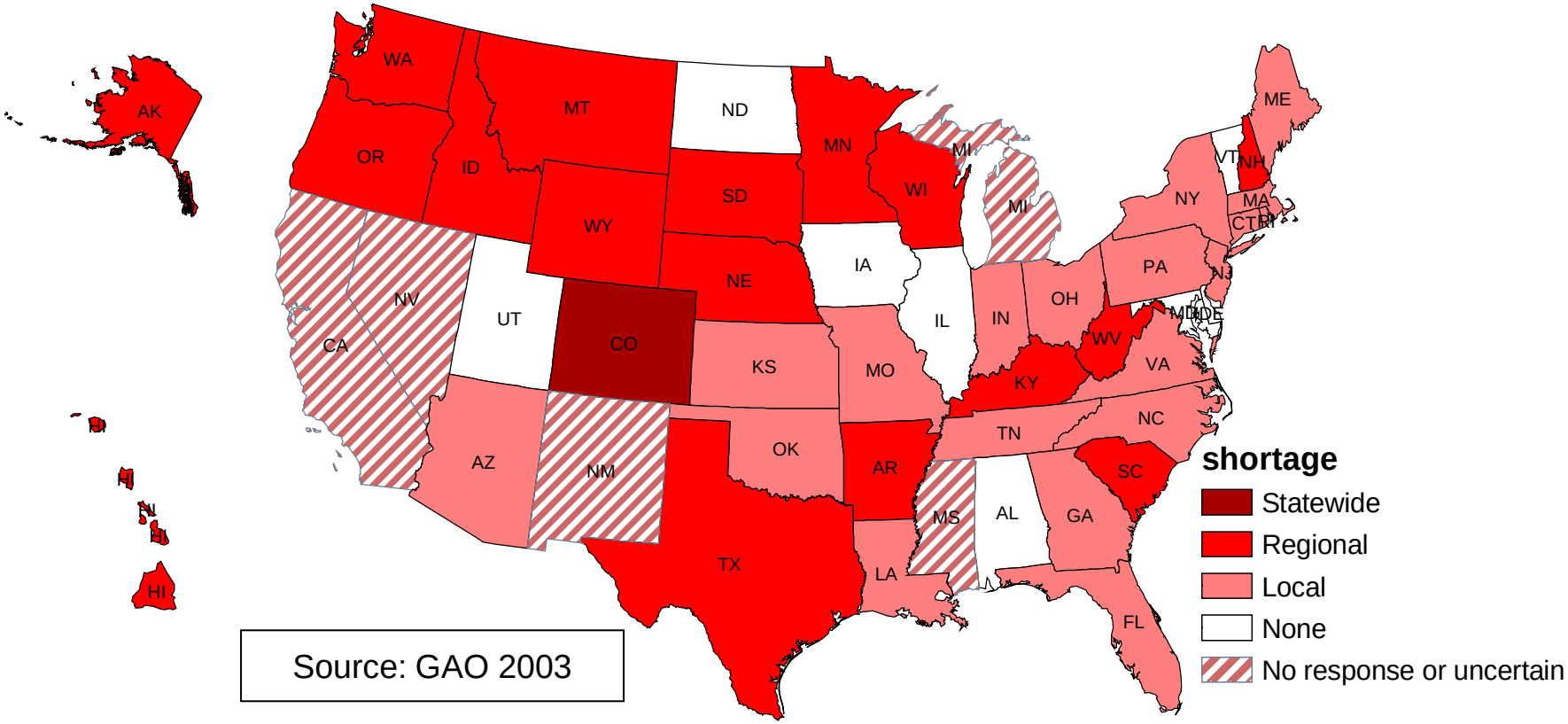
Shale gas is extensive in North America, but development limited by water issues

- Water is used in drilling, completion, and fracturing
- 2-5 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
- Well pads can be up to 5 km apart

Extensive North American Reserves

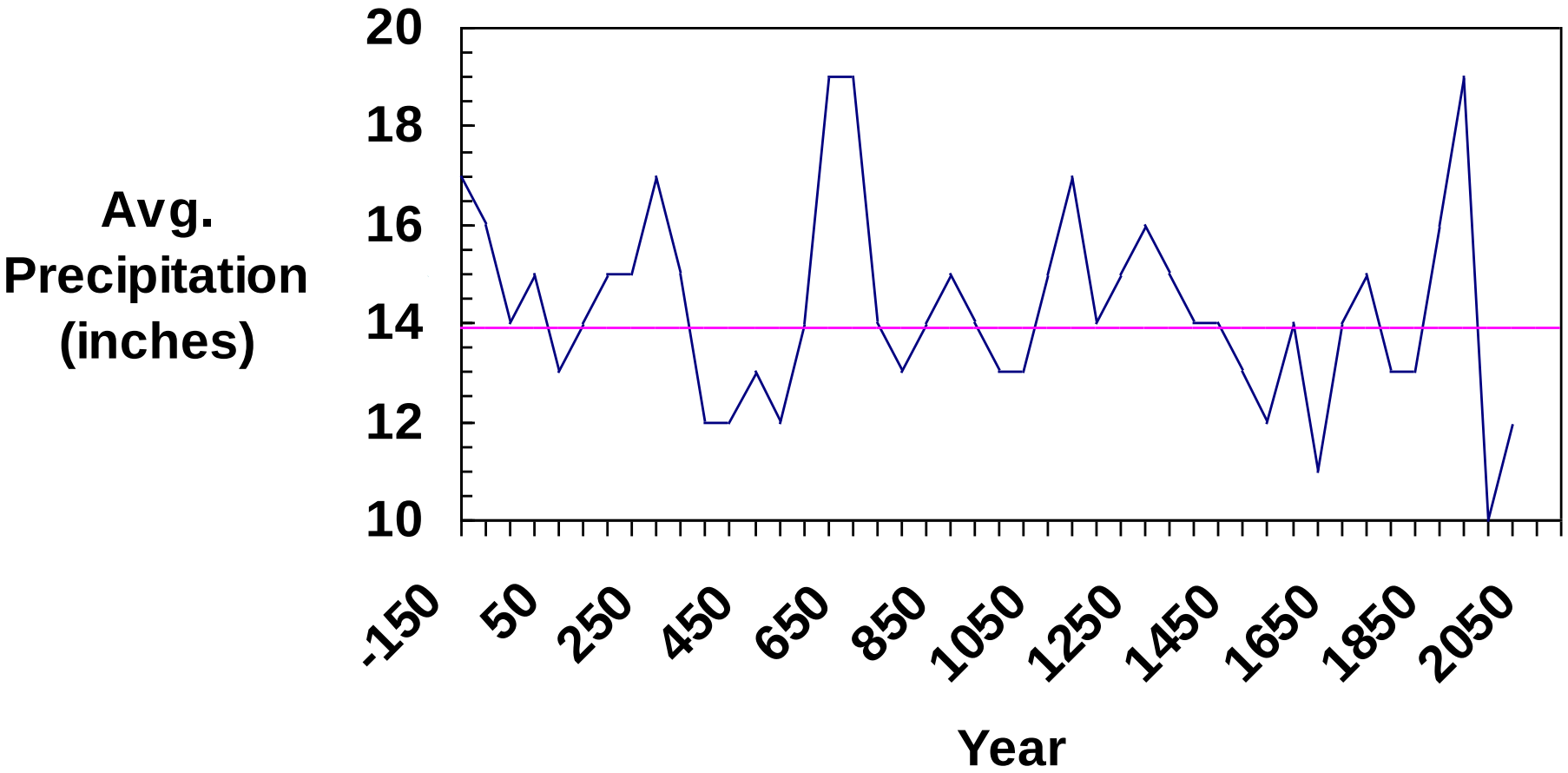


Most State Water Managers Expect Some Shortages by 2013 Under Average Conditions

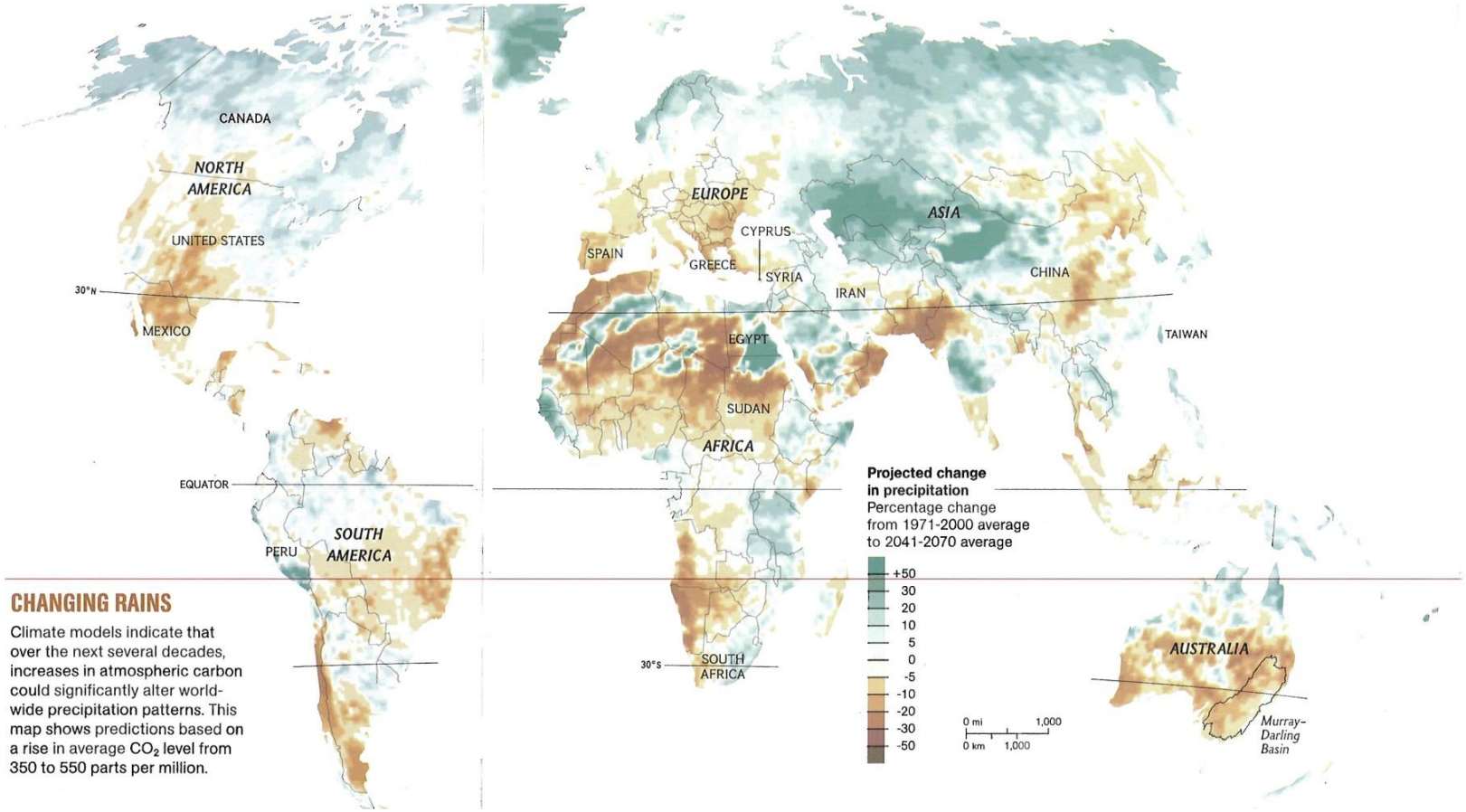


Source: GAO 2003

Southwestern U.S Precipitation History



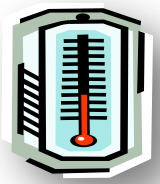
Climate Changes will Impact Precipitation and Regional Water Supplies and Resources



Nat. Geo. April 2009 from IPCC

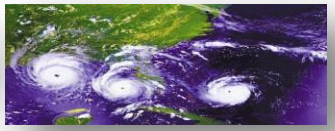
Mid-latitude population belt will be strongly affected

Climate Impacts on the Energy Sector



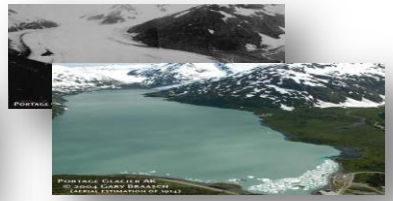
Temp Increase

Droughts & Floods



More Frequent Bigger Storm Events

Rising Sea Level



Snow Cover Shrinking

Impacts on…

Resource Production

- Competition for access to water
- Increased production interruptions
- Early season delays
- Pad damage
- Precipitation impact on biofuels

Transport & Terminals

- Damage to shore-line facilities
- Increased shipment interruptions
- Increased ice-load variation
- Reduced barge and other shipping seasons

Refining

- Reduced access to water
- Increased flooding
- Loss of peak cooling capacity

Pipelines

- Thaw subsidence and frost jacking
- Increased setbacks
- Loss of capacity in existing pipelines

Electricity Generation

- Competition for access to water
- Increased peak demand and loss of peak cooling capacity
- Increased flooding
- Increased wind and solar variability

Transmission

- Damage to lines from storm events, temperature increases, and floods
- Increased congestion

Ref: Jan Dell, CH2MHill

Proposed Electric Power Sector Research Program

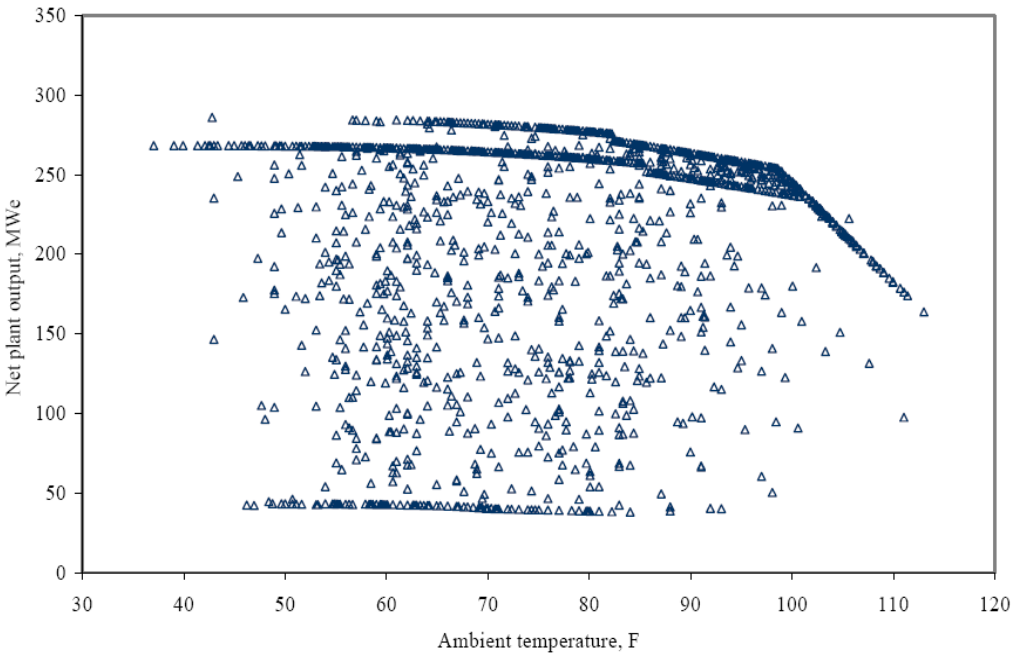


Figure 5 Net Plant Output as a Function of Ambient Temperature; Dry Heat Rejection

Dry Cooling Performance

- Improve dry and hybrid cooling system performance and 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

NYC After Tropical Storm Sandy
Energy Reliability and Resiliency Contrast

Susceptibility to outages varies based on selected optimization parameters

Natural Resource Sustainability for Energy System and Social Surety and Resiliency

- **Many regions in the U.S. and the world will be negatively impacted by climate change and natural resource degradation and overuse in many infrastructures**
- **The natural resources that support energy generation and development, could be negatively impacted by climate, ecosystem, and other environmental changes**
- **System-level evaluation approaches, policies, and regulations focused on resource conservation will be required for sustainable, reliable, and resilient economic growth and social stability in the future**