Renewable Energy Development in the Southwest
Sustainability Challenges and Directions

Water and Land for Renewable Energy in the Southwest -
Focus on Concentrating Solar Power
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Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.

Electric Power Plant Major Location Selection Criteria

- A traditional thermoelectric power plant is located based on four major technical criteria:
  - Access to a fuel supply
  - Access to transmission capacity
  - Access to a water supply for cooling water
  - Airshed quality
- A renewable energy power plant is located based on similar technical criteria, plus:
  - Appropriate quality and appropriate areal extent of renewable or distributed resource (wind, geothermal, solar, biomass, hydro)
  - Managing intermittency of the resource (mostly wind and solar concerns)

Energy Sustainability – Development within Natural Resource Constraints

Natural Resources - Earth, Wind, Fire, and Water

Natural Resources Discussions – Often Narrowly Focused

Electric Car Example:

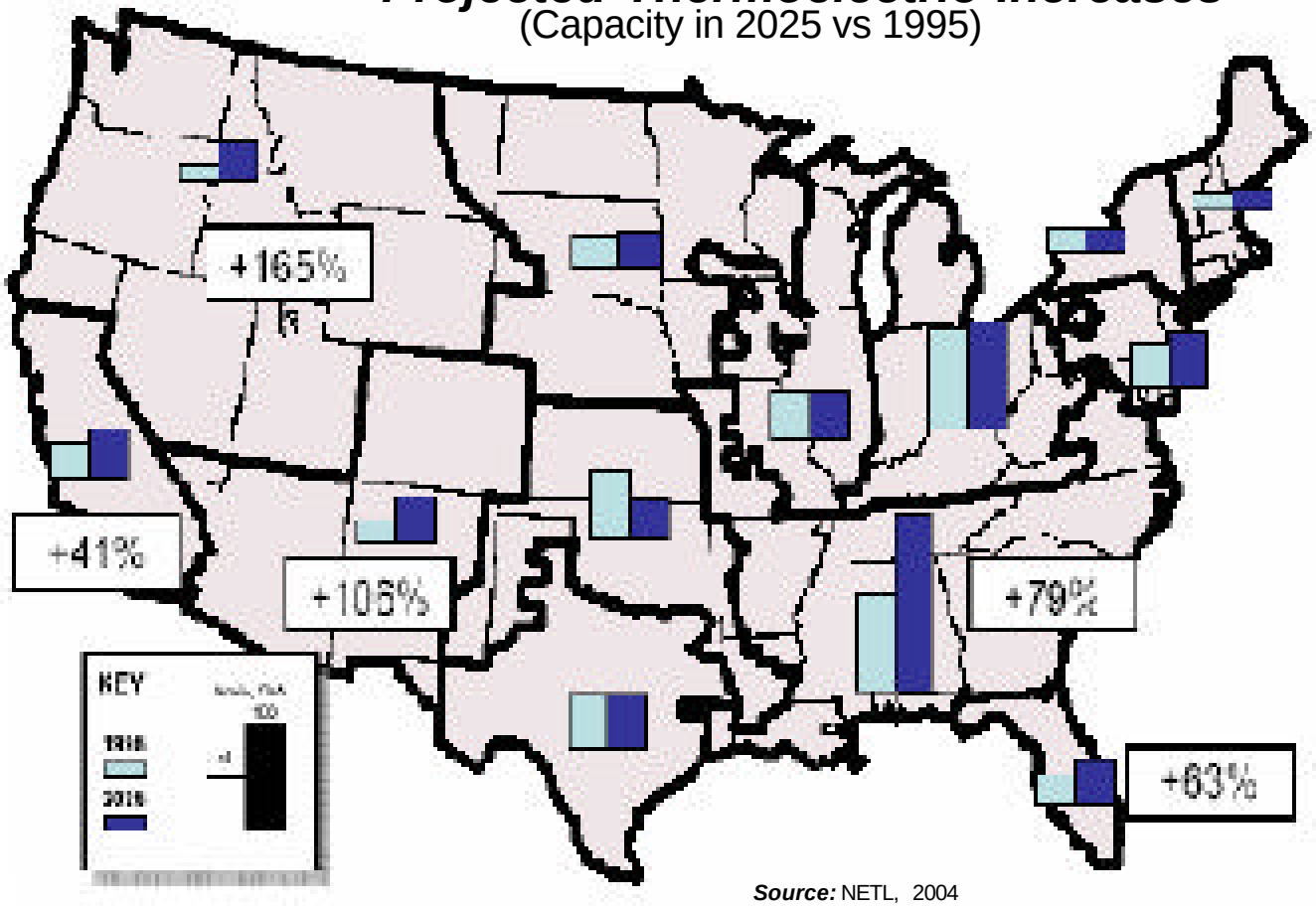
Hydrogen Car Example:

$CH_4 + 2H_2O \;?\; 4H_2 + CO_2$

Growth in Thermoelectric Power Generation

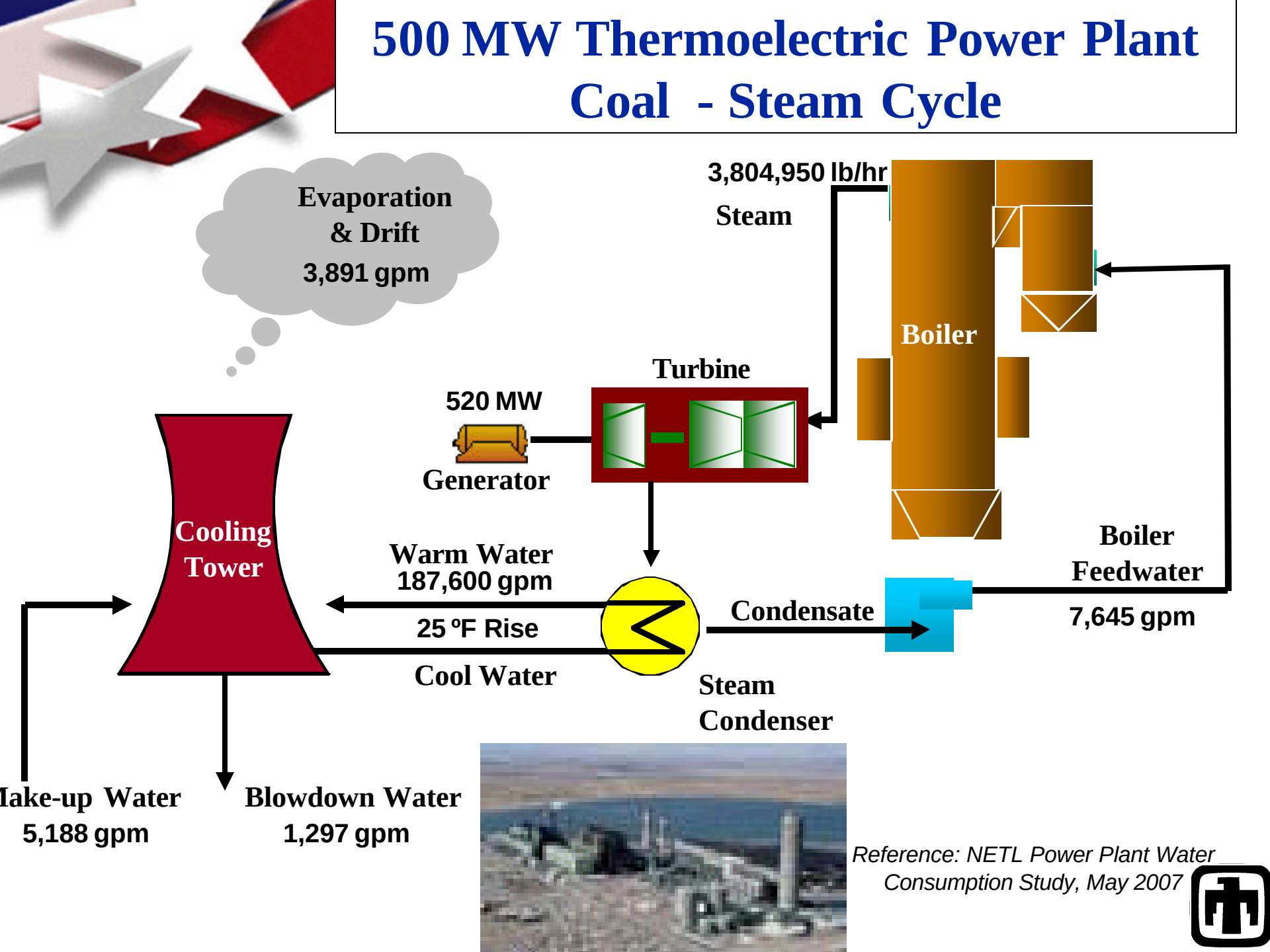
- Most growth in water stressed regions
- Most new plants expected to use evaporative cooling

Projected Thermoelectric Increases
(Capacity in 2025 vs 1995)



Source: NETL, 2004

500 MW Thermoelectric Power Plant
Coal - Steam Cycle



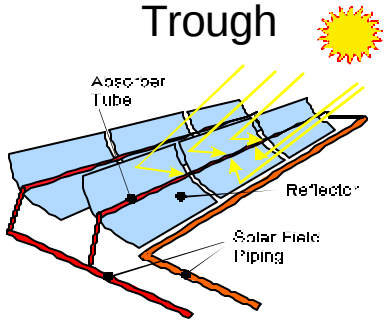
Reference: NETL Power Plant Water Consumption Study, May 2007

Concentrating Solar Power Technology

Steam Turbine Generator
Dispatchable, Integrates with Storage

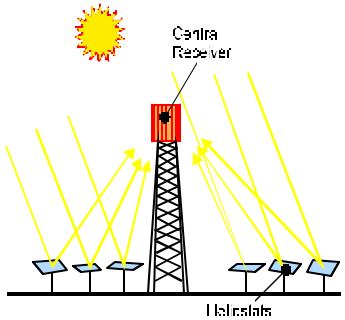
Stirling Engine-Alternator
High Efficiency, no Storage

Trough



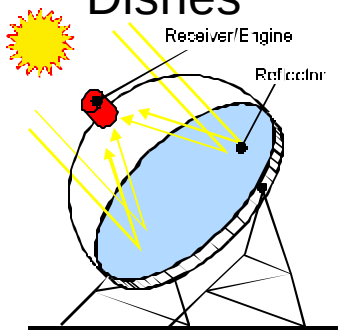
- Most cost effective >250MW
- Operating temp: 400C
- Annual efficiency: 14%

Towers



- Most cost effective >250 MW
- Operating temp: 560C
- Annual efficiency: 18%

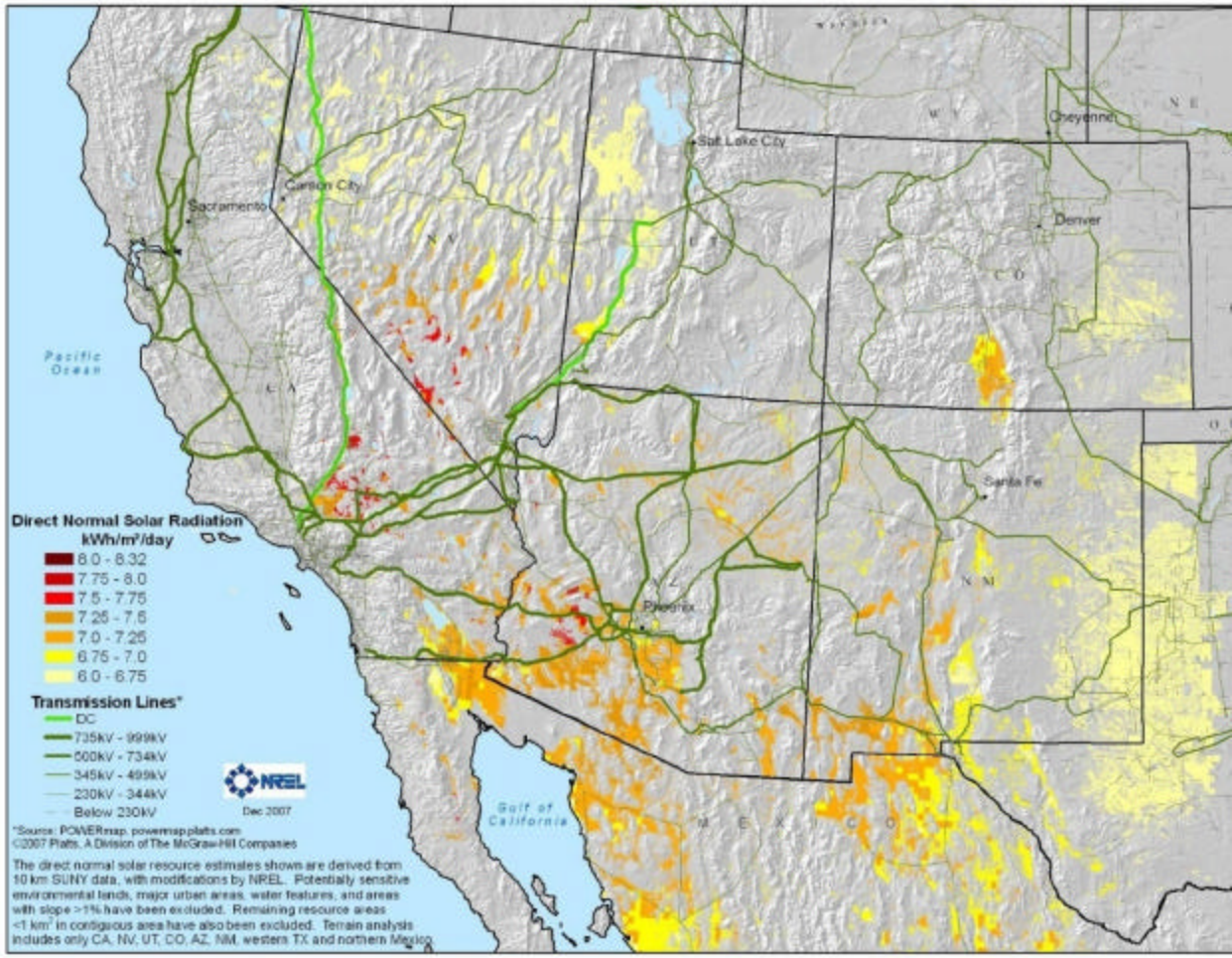
Dishes



- Modular 30 kW units – more flexibility in siting
- Operating temp: 800C
- Annual efficiency: 23%

Utility-scale Solar Energy Resources

- Filtered data
  - Available, flat, no environmental concerns, etc.
- Still tremendous resources at 6.75 kWh/m2/day
  - AZ 2.5 million MW
  - NM 1.9 million MW
  - CA 0.8 million MW
  - NV 0.7 million MW
- Significantly more resources at 6.0 kWh/m2/day



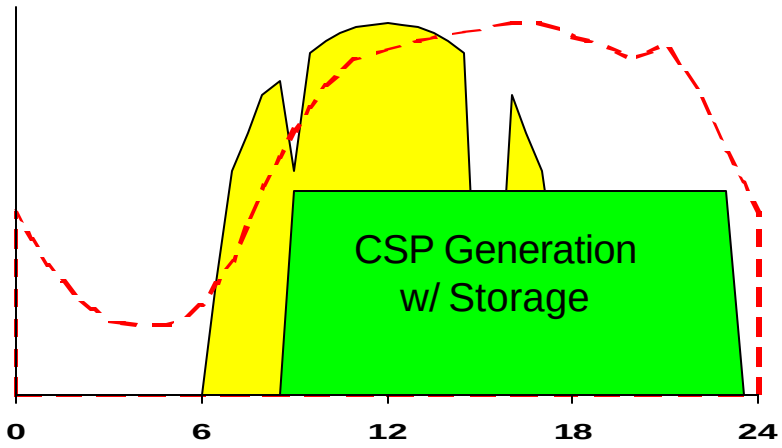
Utility-Scale Solar Opportunities and Needs

- Connected directly to transmission grid
  - Voltage > 69 kV
  - To date all PV systems are <69kV, though some are in planning
  - Kramer Junction Troughs are 115 kV
- As of August 2008 …
  - CSP
    - 3000 MW advanced stage of planning
    - 33,000 MW in CA ISO queue
    - 69,000 MW of applications to BLM
  - PV
    - 11,000 MW in CA ISO queue
    - 21,000 MW of applications to BLM
- Expected CSP needs in the Southwest– 6,000-10,000 MW

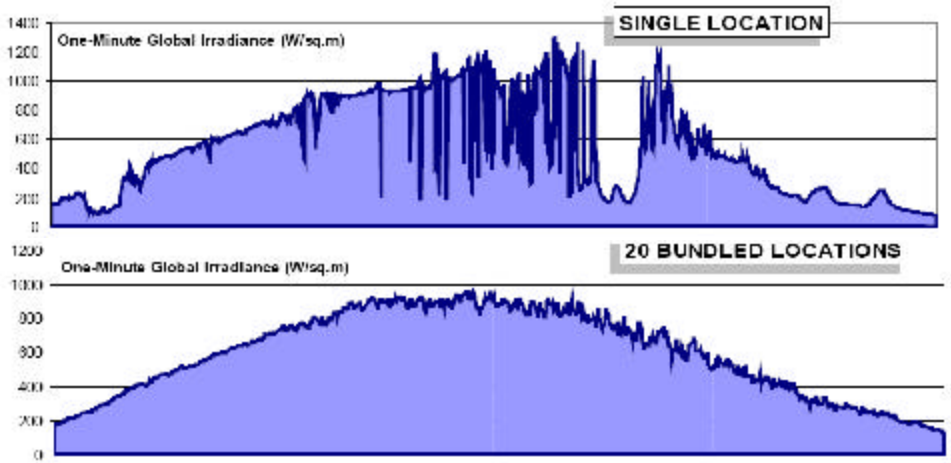
Options to Address Renewable Generation Intermittency and Capacity Factors

Solar Resource

Hourly Load



Molten Salt Storage + Natural Gas

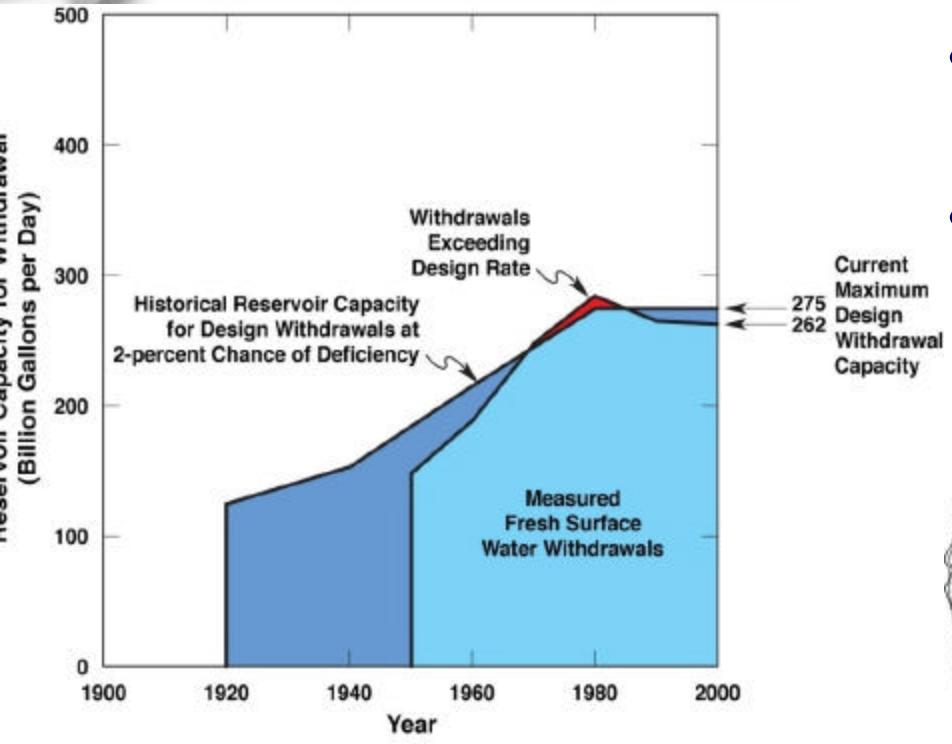


Geographic Diversity of Energy Generation

Electric Power Generation Land Requirements

Plant Type	Plant Size (MWh)	Land Area (acres)	Land Size	Unuseable Land Size	Capacity Factor
Coal/ biomass or gasification w/ steam turbine	500 - 1000 MW	640	1 mi X 1mi	All	.95
Nuclear Steam	500 - 1000MW	640	1 mi x 1 mi	All	.95
Natural Gas Combined-Cycle	200 -500 MW	320	0.7 mi x 0.7 mi	All	.95
Geothermal Steam	200-500 MW	320	0.7 mi x 0.7 mi	All	.95
Concentrating Solar	500 MW	3000	2.2 mi x 2.2 mi	All	0.3 - 0.4
	1000 MW	6000	2.8 mi x 2.8 mi	All	
Wind	500 MW	23000	6 mi x 6 mi	650 acres	0.3 - 0.4
	1000 MW	46000	8.5 mi x 8.5 mi	1300 acres	

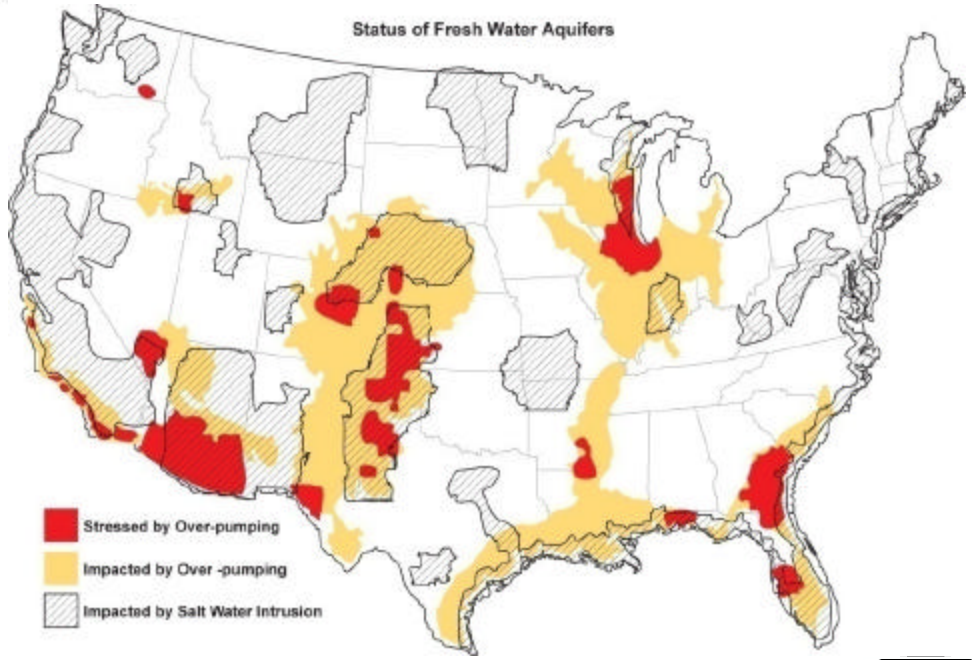
Growing Limitations on Fresh Surface and Ground Water Availability



(Based on USGS WSP-2250 1984 and Alley 2007)

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

- Little increase in surface water storage capacity since 1980
- Concerns over climate impacts on surface water supplies



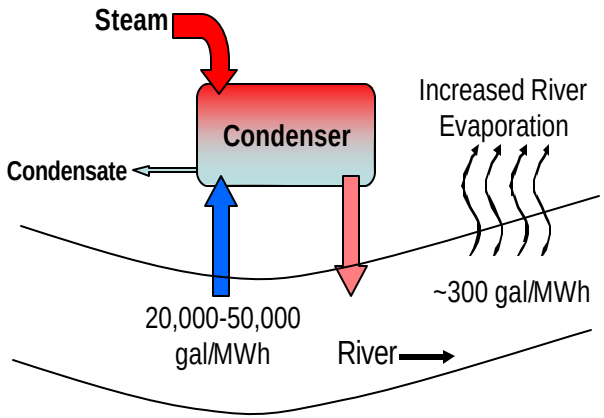
(Shannon 2007)

Electric Power Generation Water Consumption

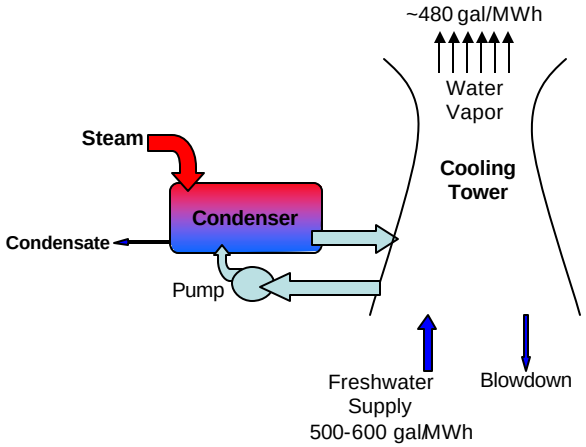
Plant-type	Cooling Process	Water Use Intensity (gal/MWh$_e$)		
		Steam Condensing[a]		Other Uses[b]
		Withdrawal	Consumption	Consumption
Fossil/ biomass steam turbine[c]	Open-loop	20,000–50,000	~200-300	~30-90[d,i]
	Closed-loop	300–600	300–480	
	Dry	0	0	
Nuclear steam turbine[c]	Open-loop	25,000–60,000	~400	~30[d]
	Closed-loop	500–1,100	400–720	
	Dry	0	0	
Natural Gas Combined-Cycle[c]	Open-loop	7,500–20,000	100	10[e]
	Closed-loop	~230	~180	
	Dry	0	0	
Coal Integrated Gasification Combined-Cycle[c]	Closed-loop	200	170	150[c,e]
	Dry	0	0	150[c,e]
Geothermal Steam[f]	Closed-loop	2000	1350	NA
Concentrating Solar[g,h]	Closed-loop	750	740	10
	Dry	10	0	10
Wind and Solar Photovoltaics[j]	N/A	0	0	1-2
Carbon sequestration for fossil energy generation				
Fossil or biomass[k]	All	~30% increase in water withdrawal and consumption		

Electric Power Generation Cooling Options

Once-Through Cooling



Closed-Loop (Evaporative) Cooling



Dry-Cooled Power Plant

Dry and Hybrid Cooling Issues and Opportunities

- 90% Less water consumption
- 6 % loss in production
- 20% reduced capacity at hottest hours
- 10% increase in capital cost
- 1-2 ¢ /kWh increase in cost of power

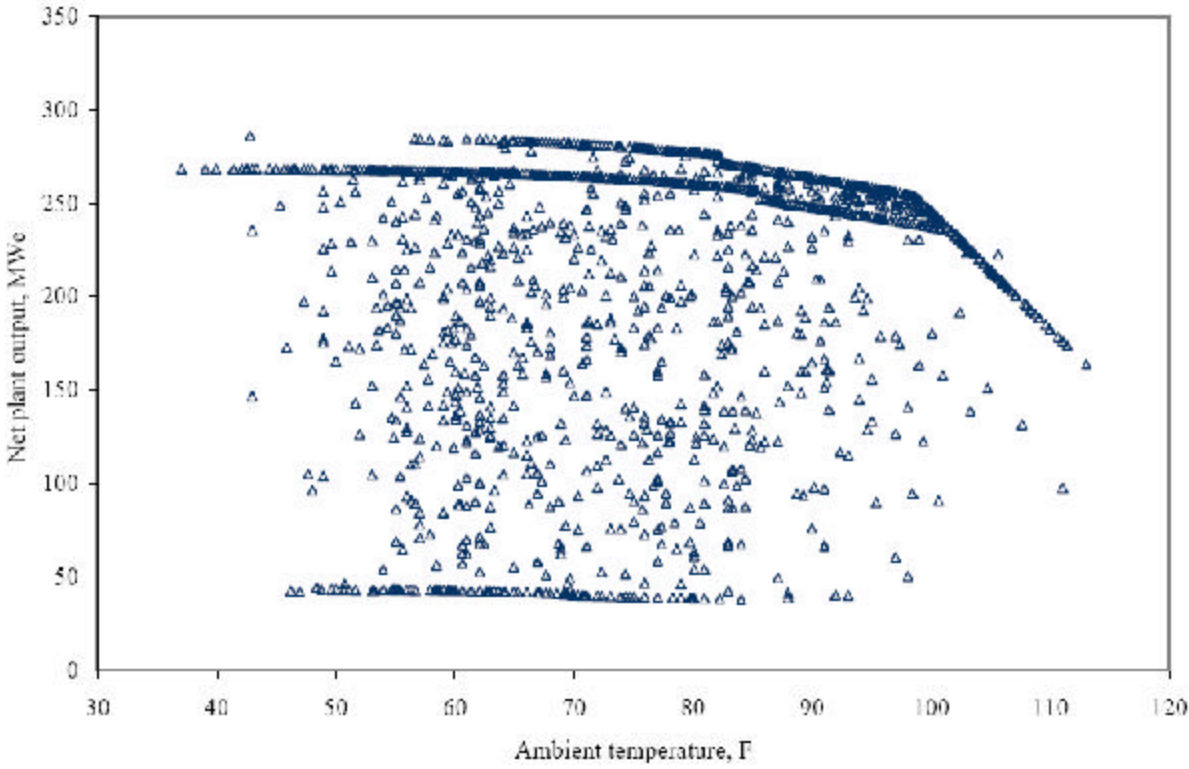
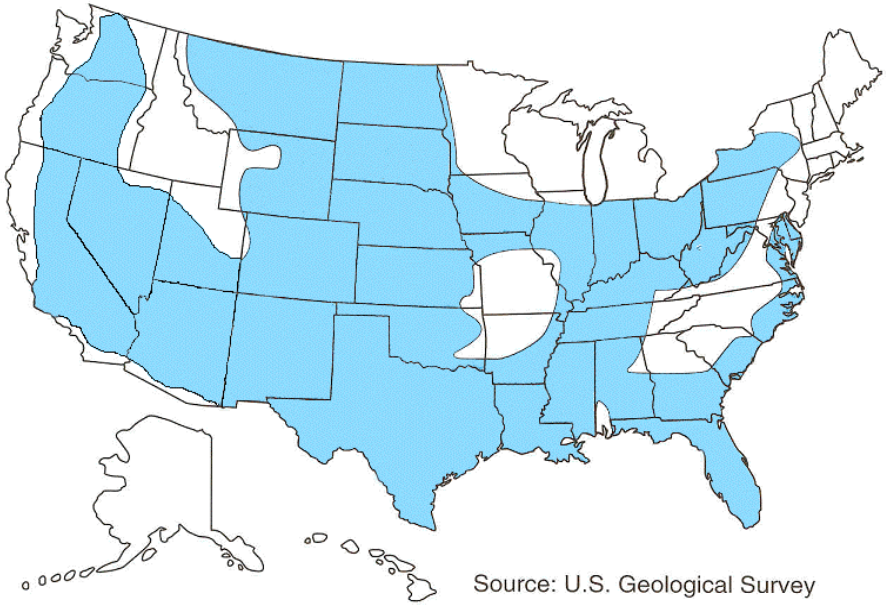


Figure 5 Net Plant Output as a Function of Ambient Temperature; Dry Heat Rejection

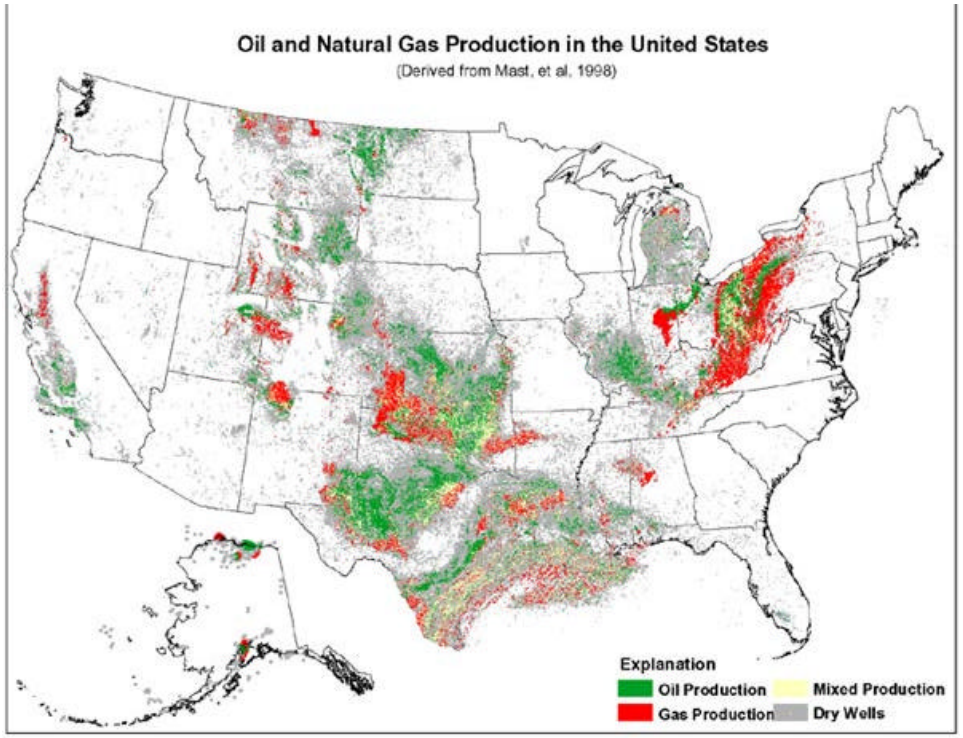
Growing use of non-traditional water for cooling

Palo Verde – largest Nuclear Power Plant in the US, uses waste water for cooling

Non-traditional Water Resource Availability

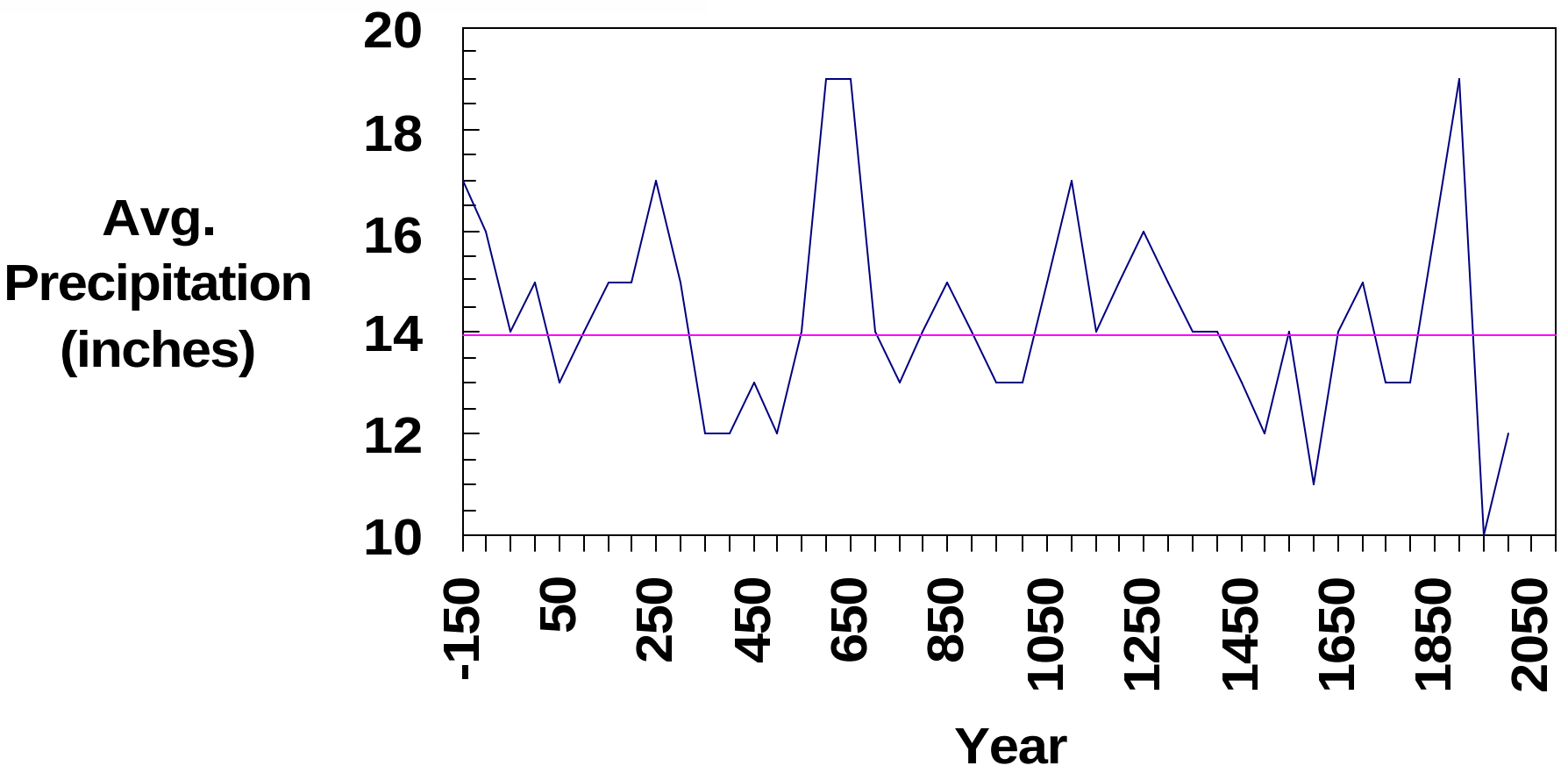


Saline Aquifers



Oil and Gas Produced Water

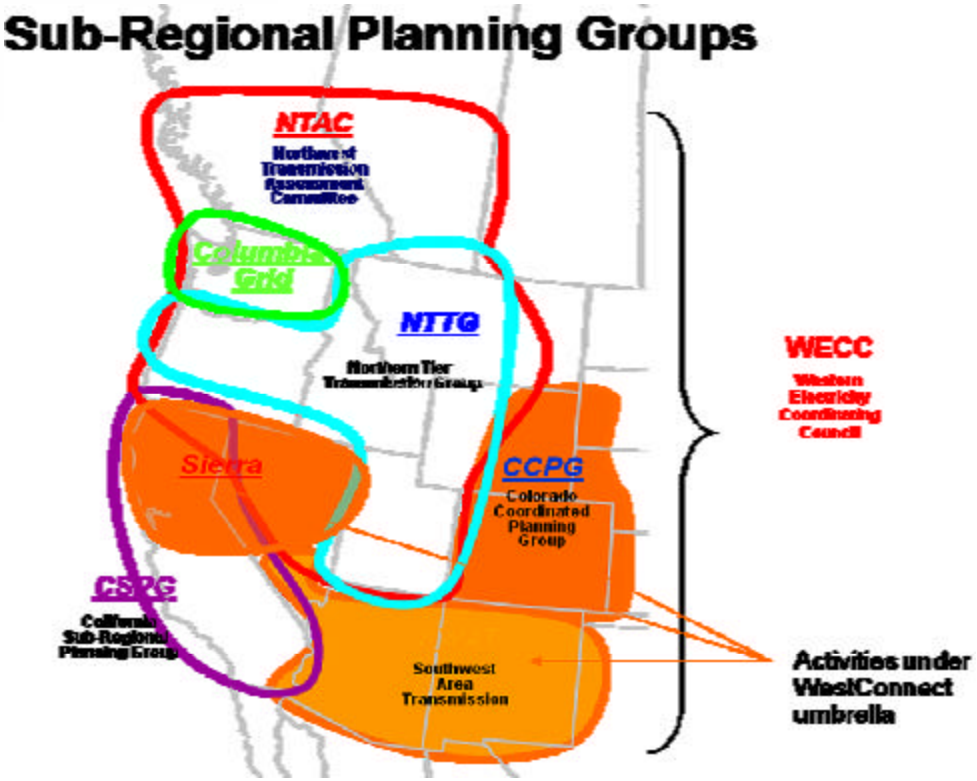
Southwest Climate History



Green House Gas Issues and Challenges

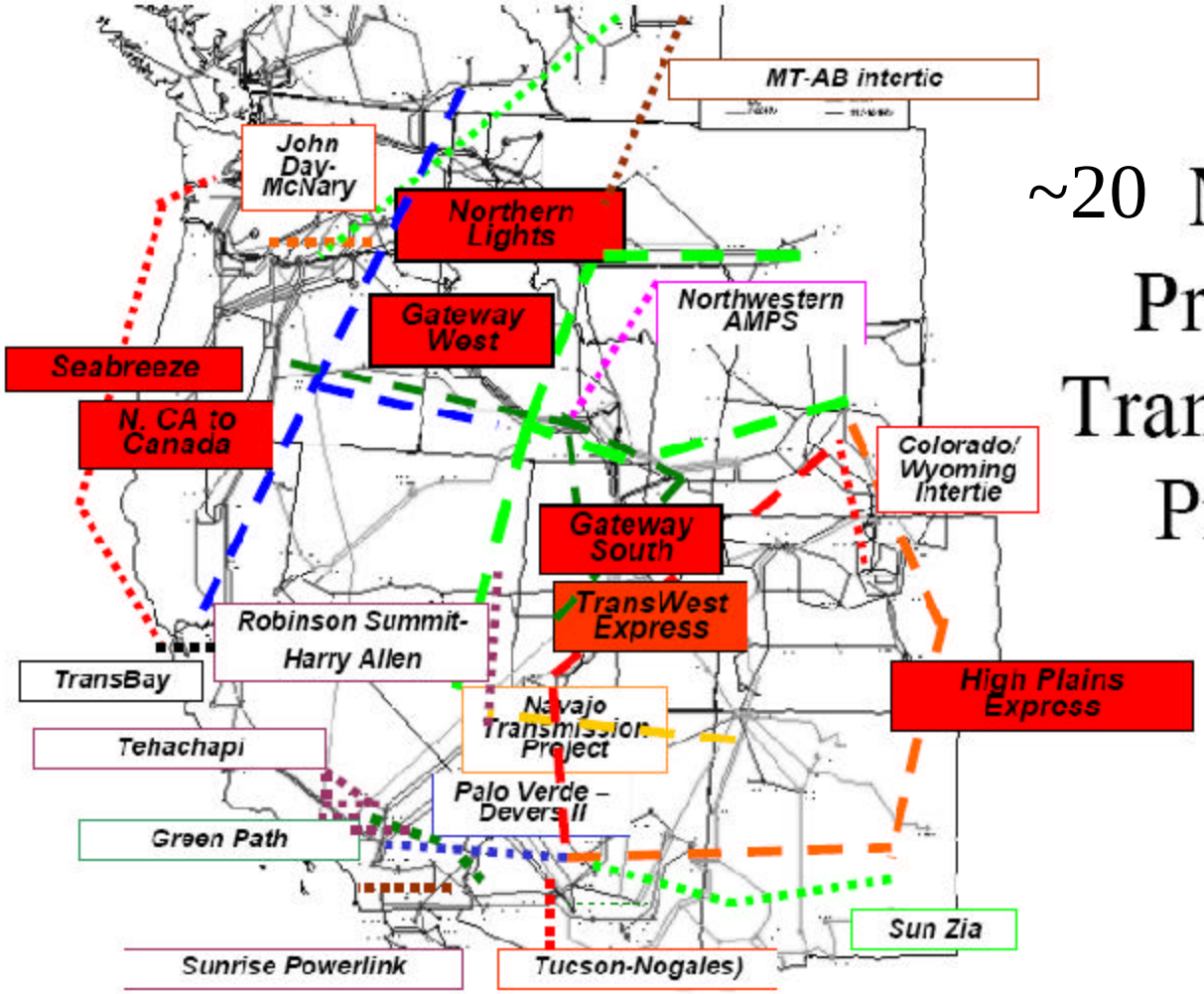
- Global Energy Consumption/person
  - US – 800 kwh/mo (30% of worlds energy consumption)
  - India – 25 kwh/mo
  - China – 15 kwh/mo
- Global Transportation, vehicles/1000 people
  - US – 800
  - India – 60
  - China – 70
- Projected CO2 Emissions (million tons/yr)
  - 2010 U.S. 1600, China 3400, India 700, World 8400
  - 2020 U.S. 1800, China 4400, India 2100, World 11400

In contrast to other regions in the United States, transmission planning in WECC is quite decentralized



FERC can now approve proposed new transmission lines in key corridors identified by DOE if states fail to do so within 1 year

The majority of lines under development are meant to access coal and wind, but several could access solar projects



~20 Major Proposed Transmission Projects

European Energy Vision - Desertec CSP a Major Element