Climate Change and the Comparative Cost of Conserved Water via Electrical Cooling Options: A FEW Nexus Case Study in South Central Texas

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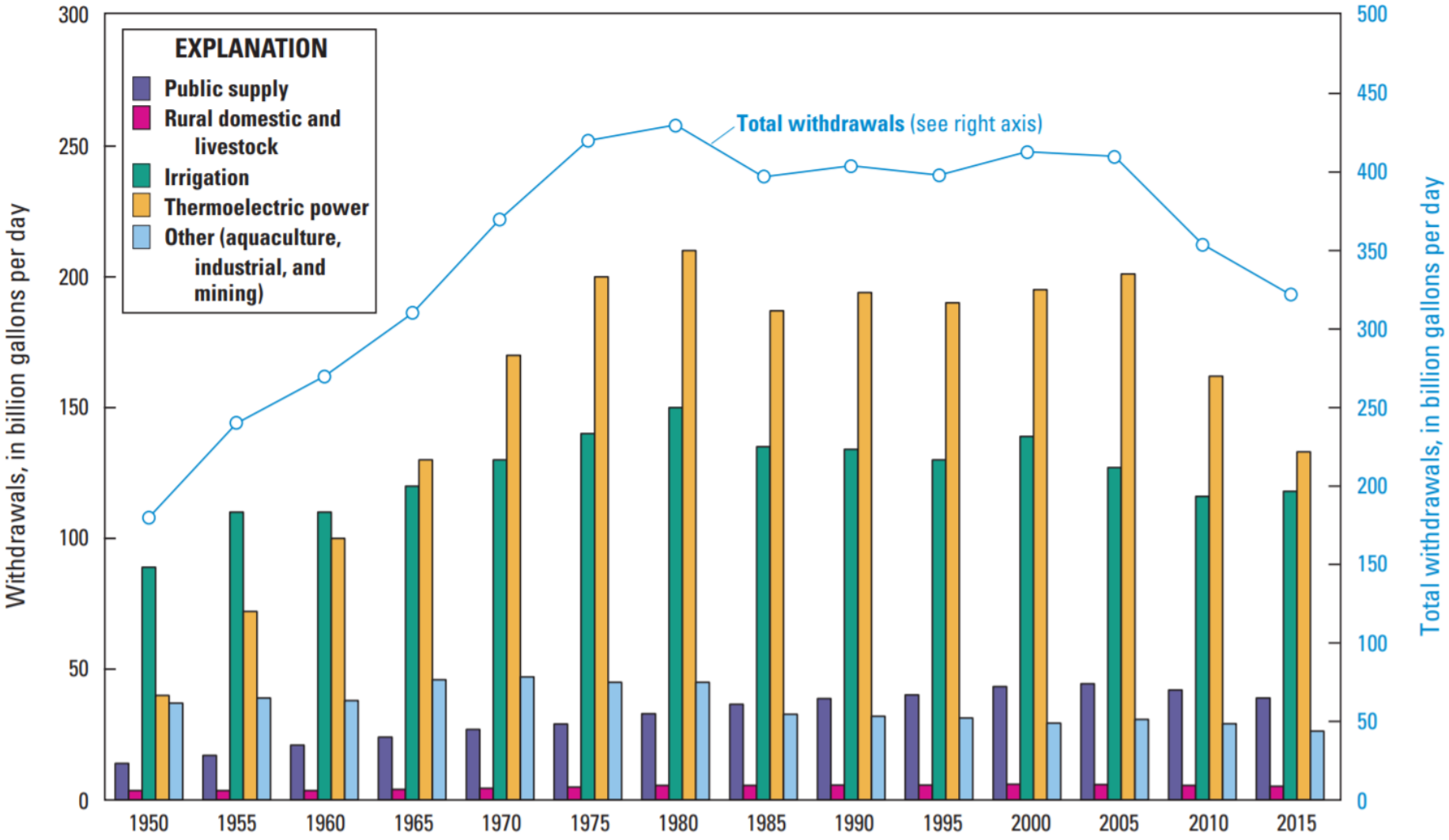
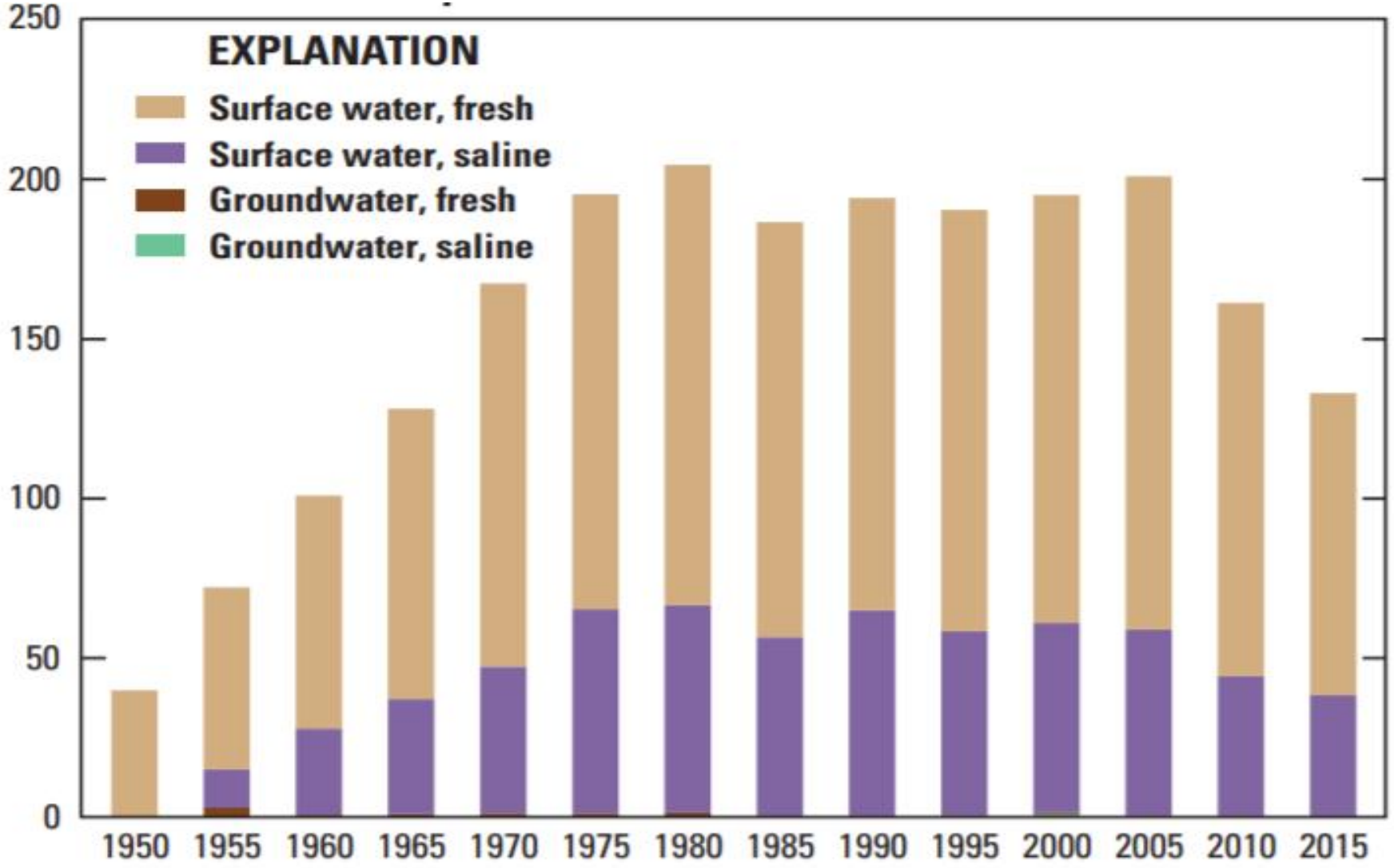
Water withdrawal by sectors



Thermoelectric power accounted for 41% of total water withdrawals

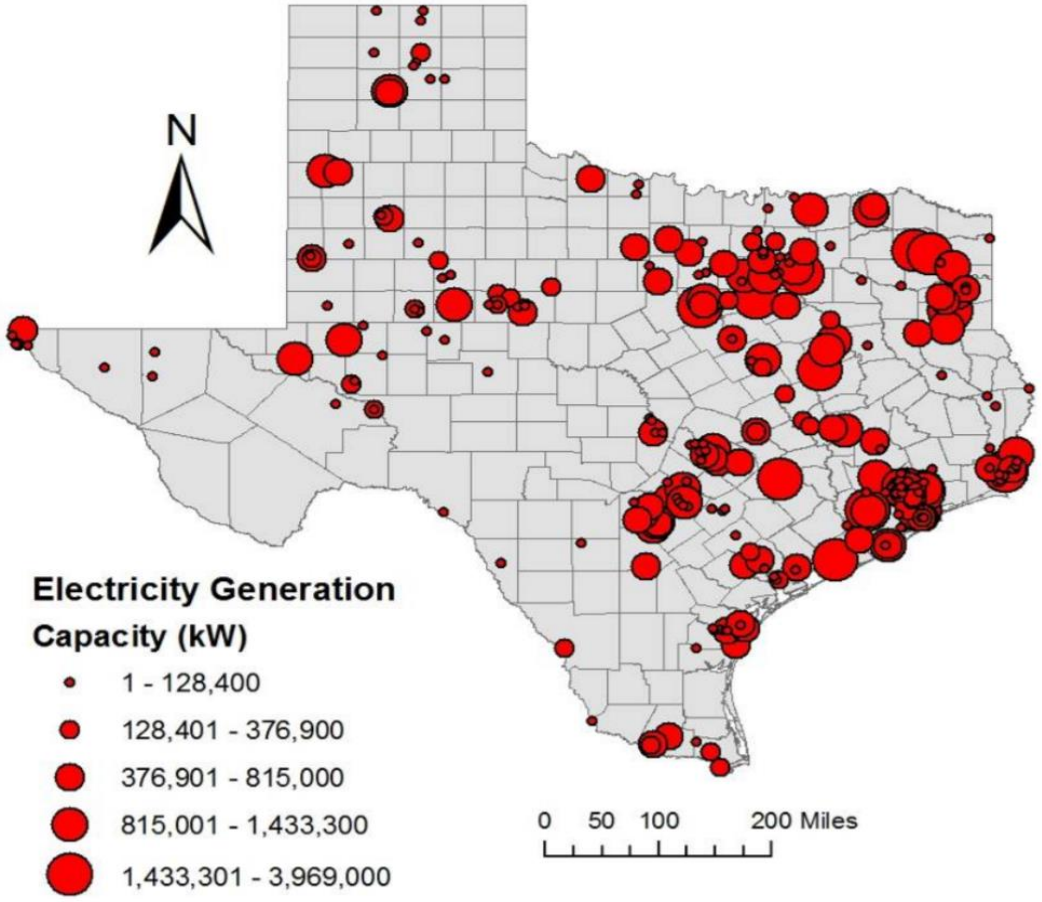
Source: https://pubs.usgs.gov/circ/1441/circ1441.pdf

Thermoelectric power water use source



- 72% surface water withdrawal from freshwater
- 34% of total freshwater withdrawals for all uses
- 97% of total saline surface water withdrawals for all uses

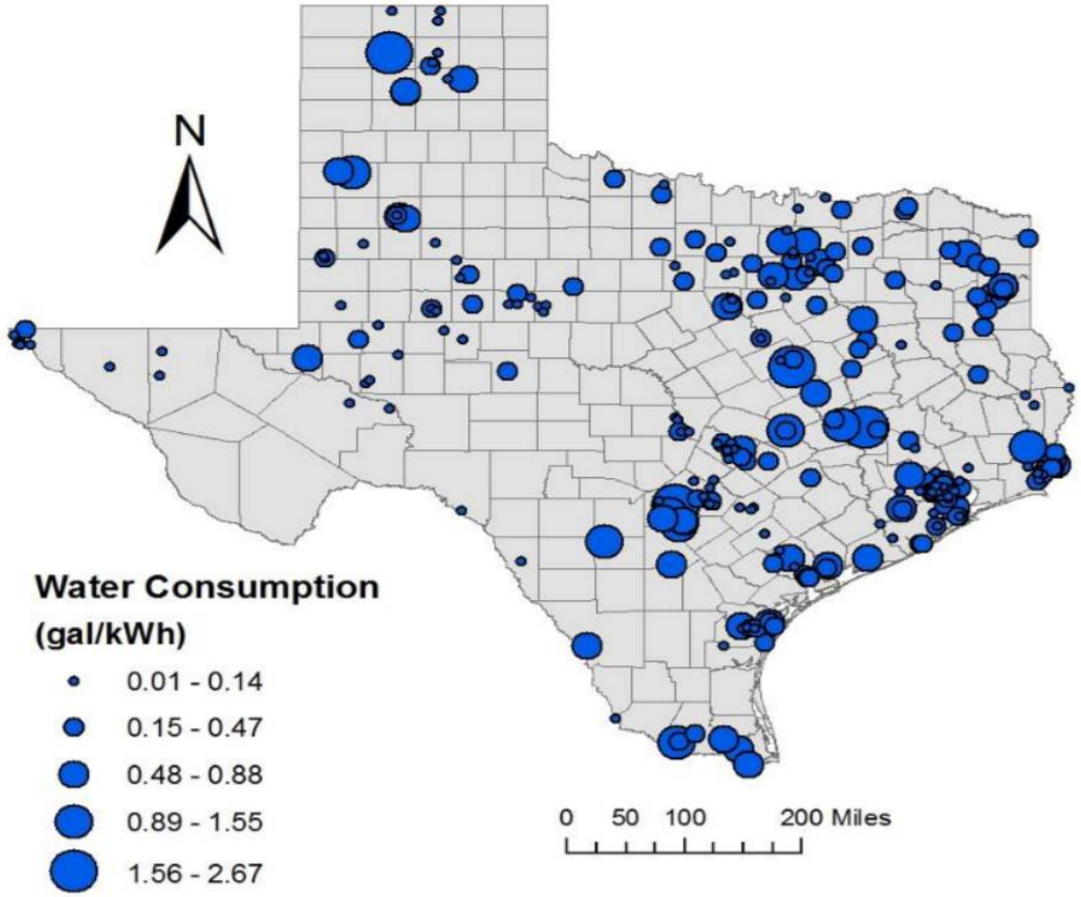
Electricity Generation from Texas Power Plants



Total electricity generation capacity is over 110 GW annually

Source: http://www.edf.org/sites/default/files/Energy_Water_Nexus_in_Texas_1.pdf

Water Consumption for Cooling for Texas Power Plants



- Texas Rivers flow to the Southeast
- Between 85% to 95% percent of water use in the plant are cooling water use
- Water consumption is enough for municipal use over 3 million people for a year

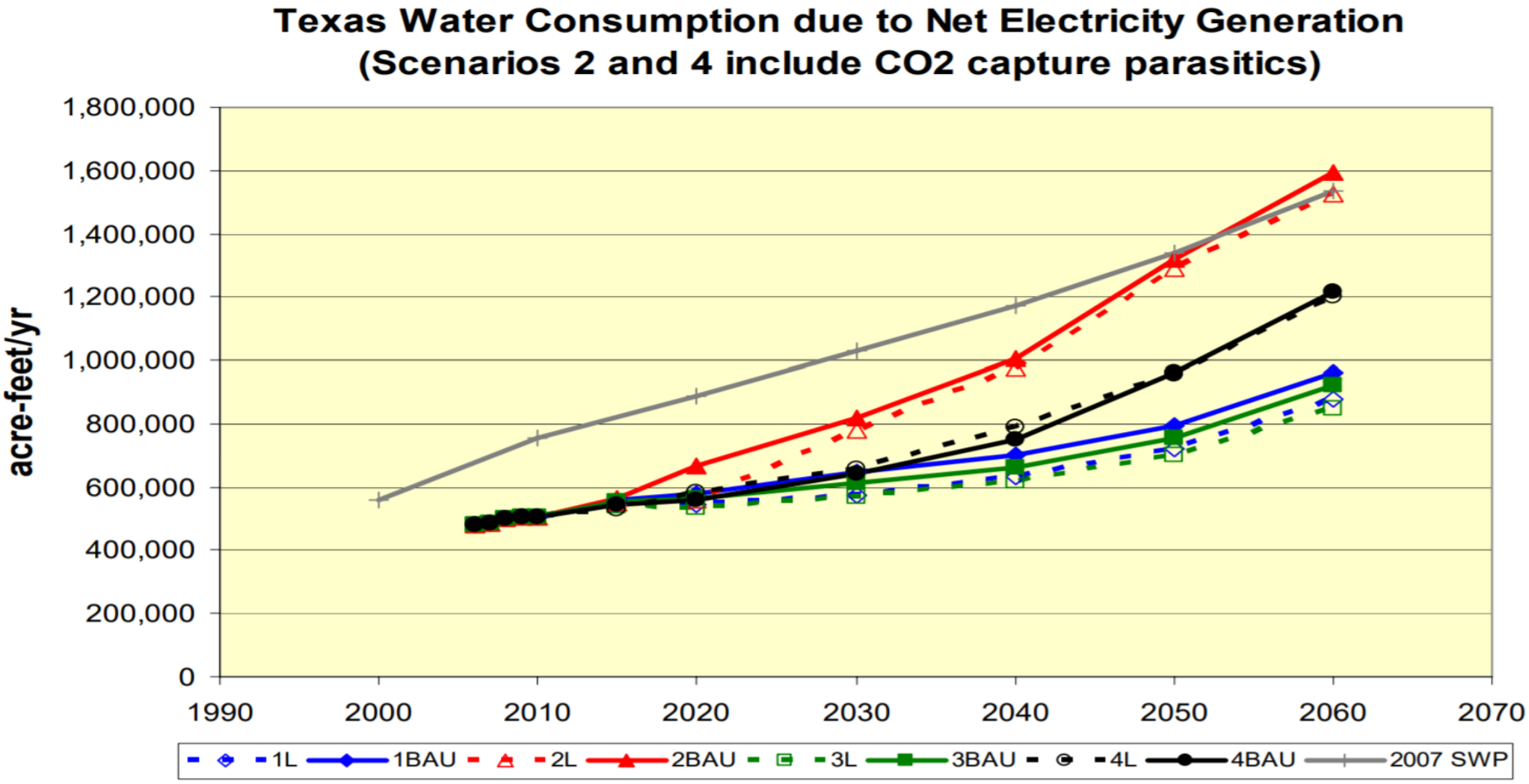
Source: http://www.edf.org/sites/default/files/Energy_Water_Nexus_in_Texas_1.pdf

Characterization of simulated scenarios for projected electricity generation

Scenario	Annual Electric Growth	Natural Gas Prices	Carbon Capture Implemented
1L	Low	High	No
1BAU	BAU	High	No
2L	Low	High	Yes
2BAU	BAU	High	Yes
3L	Low	Low	No
3BAU	BAU	Low	No
4L	Low	Low	Yes
4BAU	BAU	Low	Yes

Source: http://www.twdb.texas.gov/publications/reports/contracted_reports/doc/0704830756ThermoelectricWaterProjection.pdf

Future water use for power production



Source:
http://www.twdb.texas.gov/publications/reports/contracted_reports/doc/0704830756ThermoelectricWaterProjection.pdf

Cooling Options Overview

- **Once-through:**
  - withdrawn large volumes of water
  - absorbs heat from the steam
  - discharges back to river at higher temperature
- **Recirculating:**
  - use cooing tower to expose water to ambient air
  - consumptive water use is large
- **Dry cooling:**
  - large capital cost
  - efficiency penalties
  - reduce water use

Cooling Options Retrofit

Retrofitting power plant cooling systems can be very complex!

- Once-through → Recirculating
- Once-through → Dry
- Recirculating → Dry

Disadvantage:

- Expensive - $12.5 billion to retrofit the 39 Texas once-through systems
- Premature retirement of multiple plants
- Hinder power producer's ability to meet the electric demands

Advantage:

- Alleviate plant vulnerabilities to drought
- Save water consumption

Literature

Cooling system technologies in thermal power plants

- Stillwell, A.S., and M.E. Webber. 2013. “Novel methodology for evaluating economic feasibility of low-water cooling technology retrofits at power plants.” *Water Policy; Oxford* 15(2):292–308.

Cooling system retrofits in the US power plants

- Tidwell, V.C., J. Macknick, K. Zemlick, J. Sanchez, and T. Woldeyesus. 2014. “Transitioning to zero freshwater withdrawal in the U.S. for thermoelectric generation.” *Applied Energy* 131:508–516.

Mitigate water use in energy sector by fuel switching or water use fees

- Grubert, E.A., F.C. Beach, and M.E. Webber. 2012. “Can switching fuels save water? A life cycle quantification of freshwater consumption for Texas coal- and natural gas-fired electricity.” *Environmental Research Letters* 7(4):045801.

Water use for new thermal power plants in regulatory changing environment

- Zhai, H., E.S. Rubin, and P.L. Versteeg. 2011. “Water Use at Pulverized Coal Power Plants with Postcombustion Carbon Capture and Storage.” *Environmental Science & Technology* 45(6):2479–2485.

Thermal power plants vulnerability to climate change

- Schaeffer, R., A.S. Szklo, A.F. Pereira de Lucena, B.S. Moreira Cesar Borba, L.P. Pupo Nogueira, F.P. Fleming, A. Troccoli, M. Harrison, and M.S. Boulahya. 2012. “Energy sector vulnerability to climate change: A review.” *Energy* 38(1):1–12.

Data

Power plant characteristics:

- EIA Form 860 – generator, boiler, cooling systems and air emission control
- EIA Form 923 – power generation, fuel consumption, operational cooling water,
- EGRID – capacity factor, heat rate
- EIA cooling water – data quality is of concern

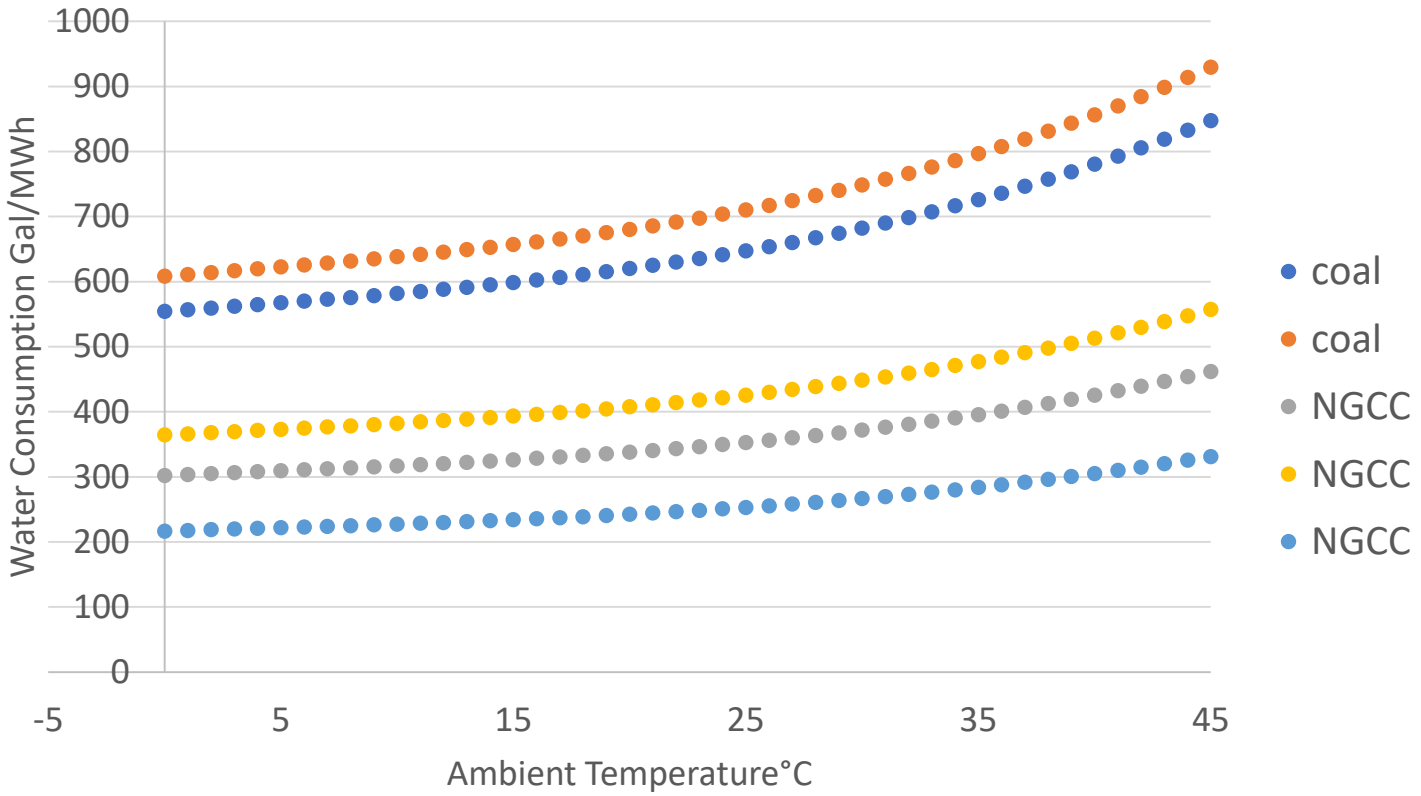
Capital and operating cost of cooling system:

- Integrated Environmental Control Model

Water consumption:

- Delgado, A., and H.J. Herzog. 2012. “Simple model to help understand water use at power plants.” *Cambridge, MA: Massachusetts Institute of Technology*.

Estimation of Water consumption



- Selected plants with large capacities
- Coal plant consumption > NGCC plant consumption
- Consumption increases as ambient temperature increase
- Consumption is greatly reduced by dry cooling option

Fuel type	Retrofit transition	Number of plants	Total consumption saved annually (acft)
Coal	Recirculating to dry	4	31088
NGCC	Once-through to recirculating	2	-829
	Once-through to dry	2	1688
	Recirculating to dry	7	19457

Retrofit Cost of Water Saving

Plant	Water Saved (acft/mwh)	Retrofit Cost ($/acft)
Victoria	1.156	2048.995
Guadalupe Generation Station	1.307	2180.907
Arthur Von Rosenberg	1.028	2283.795
Sam Rayburn	1.744	2433.016
Corpus Christi Energy Center	0.777	2722.205
Rio Nogales Power Project	1.083	2946.372
Ingleside	0.454	3030.412
Gregory	0.442	3649.355
Formosa Utility Venture Ltd	0.289	5205.849
J K Spruce	2.272	6220.188
J T Deely	2.579	9539.464
San Miguel	2.913	4261.315
Coleto Creek	2.071	5044.511

- Individual plants retrofit from recirculating to dry cooling
- Retrofit cost of coal plant > retrofit cost of NGCC plant
- Average cost of retrofitting NGCC plant is $2933/acft
- Average cost of retrofitting coal plant is $6266/acft
- The higher temperature, the lower retrofit cost
- Retrofitting once-through to recirculating will actually consume more water

Texas Water Development Board Water Projects

- Municipal conservation projects
  - lowest average cost of water saving
- Use out region water as supply
  - Sea desalination project – unit cost $2713/acft
- Surface water
- Off channel reservoir
- Reuse
- Aquifer storage and recovery
- Develop ground water

Comparisons

water saving strategies	available projects	average cost($/acft)	number of retrofit chosen	number of retrofit chosen under rcp8.5	min_cost($/acft)	max_cost($/acft)
municipal conservation	6	589	0	0	470	770
reuse projects	8	749	0	0	458	1500
ground water projects	28	1285	4	5	135	2554
surface water projects	2	1979	1	2	1886	2072
off-channel reservoir	5	1091	4	4	140	2561
aquifer storage and recovery	4	1286	0	0	585	1835
outside water projects	6	2034	5	6	867	2803
coal_retrofit		6266			4261	9539
ngcc_retrofit		2933			2049	5206

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Thank you!