
SCRIPPS
INSTITUTION OF
OCEANOGRAPHY
UCSD

Climate Forecasts for Improving Management of Energy and Hydropower Resources in the Western U.S.

NOAA CDEP & California Energy Commission

Scripps Institution of Oceanography

T. Westerling, T. Barnett, D. Pierce, E. Alfaro, A. Gershunov

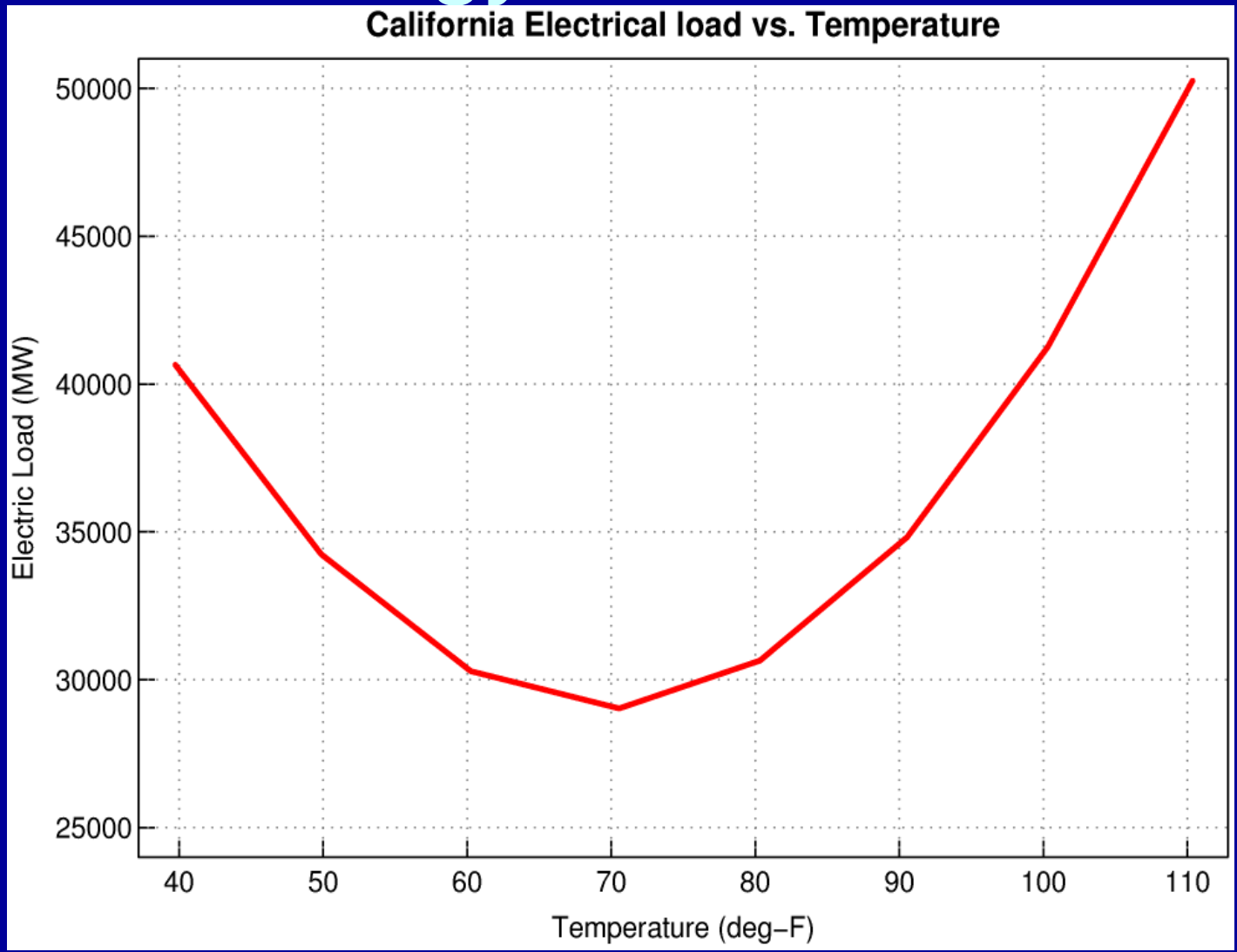
University of Washington

D. Lettenmaier, A. Hamlet, N. Voisin, A. Steinemann

PNNL

Ross Gutromson, Ning Lu

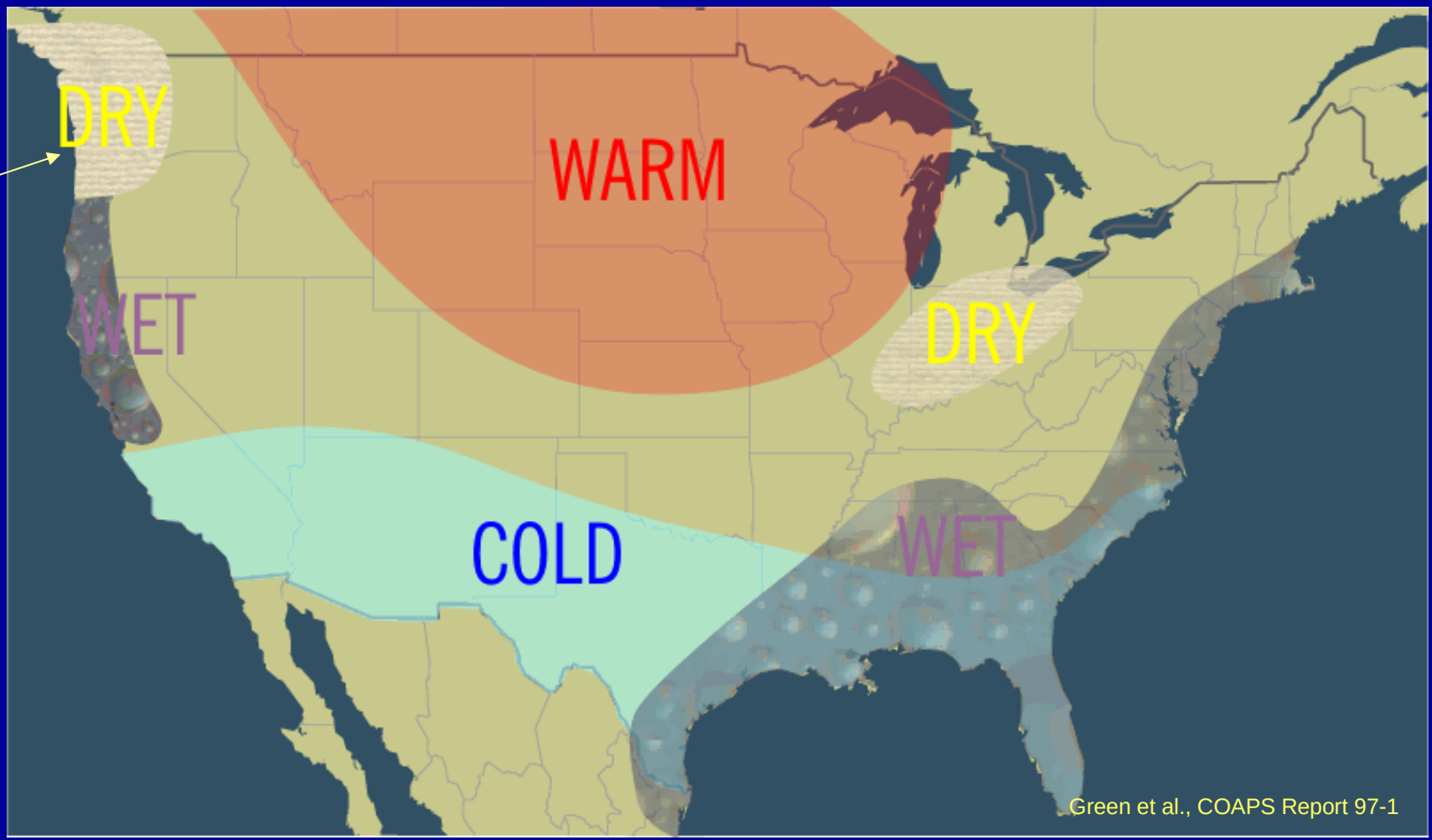
Climate & weather affect energy *demand*



Source: www.caiso.com/docs/0900ea6080/22/c9/09003a608022c993.pdf

…and also energy *supply*

Typical effects of El Nino:



How is climate variability associated with anomalies in energy demand

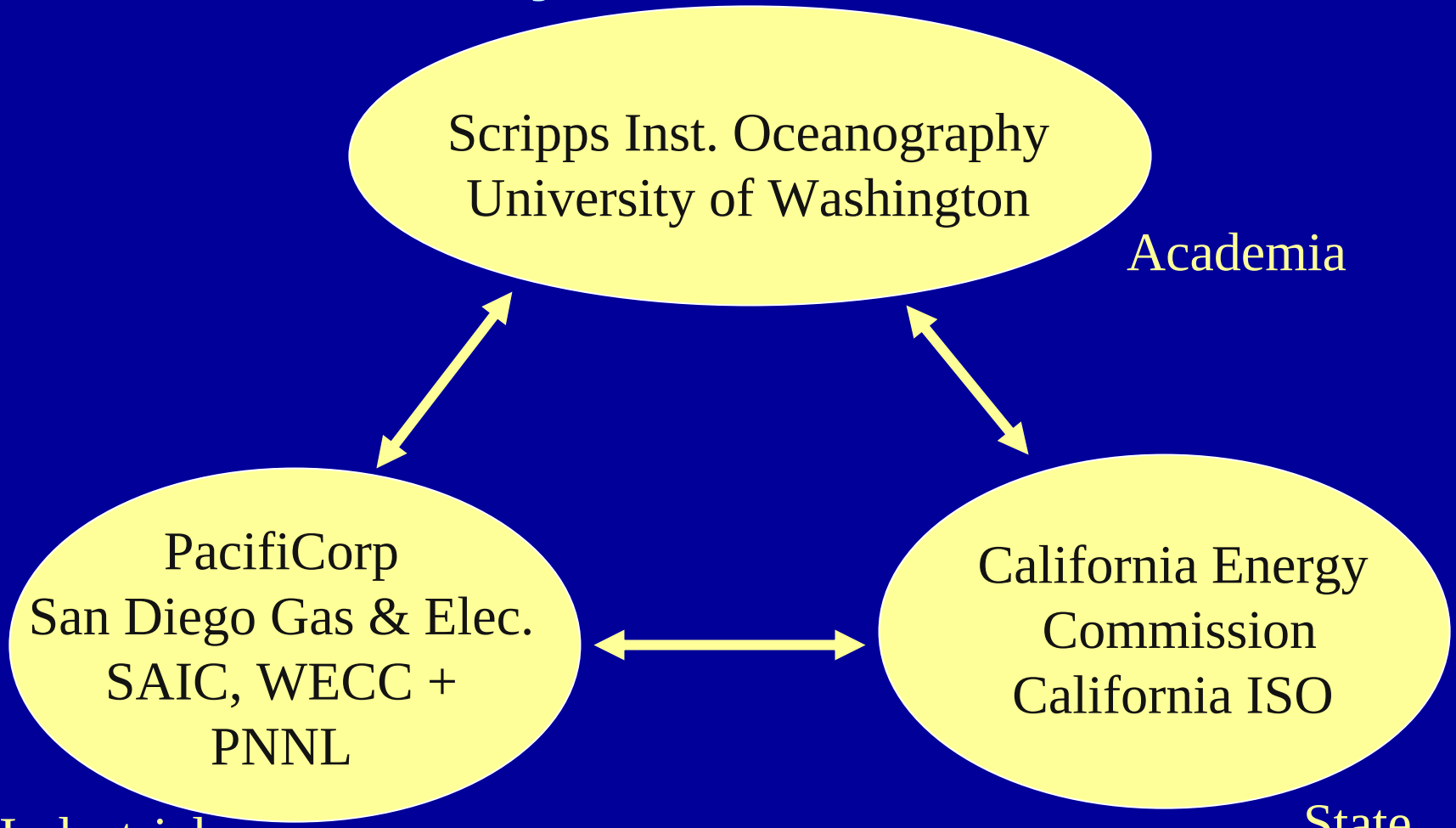
and potential hydropower?

Are these anomalies correlated?

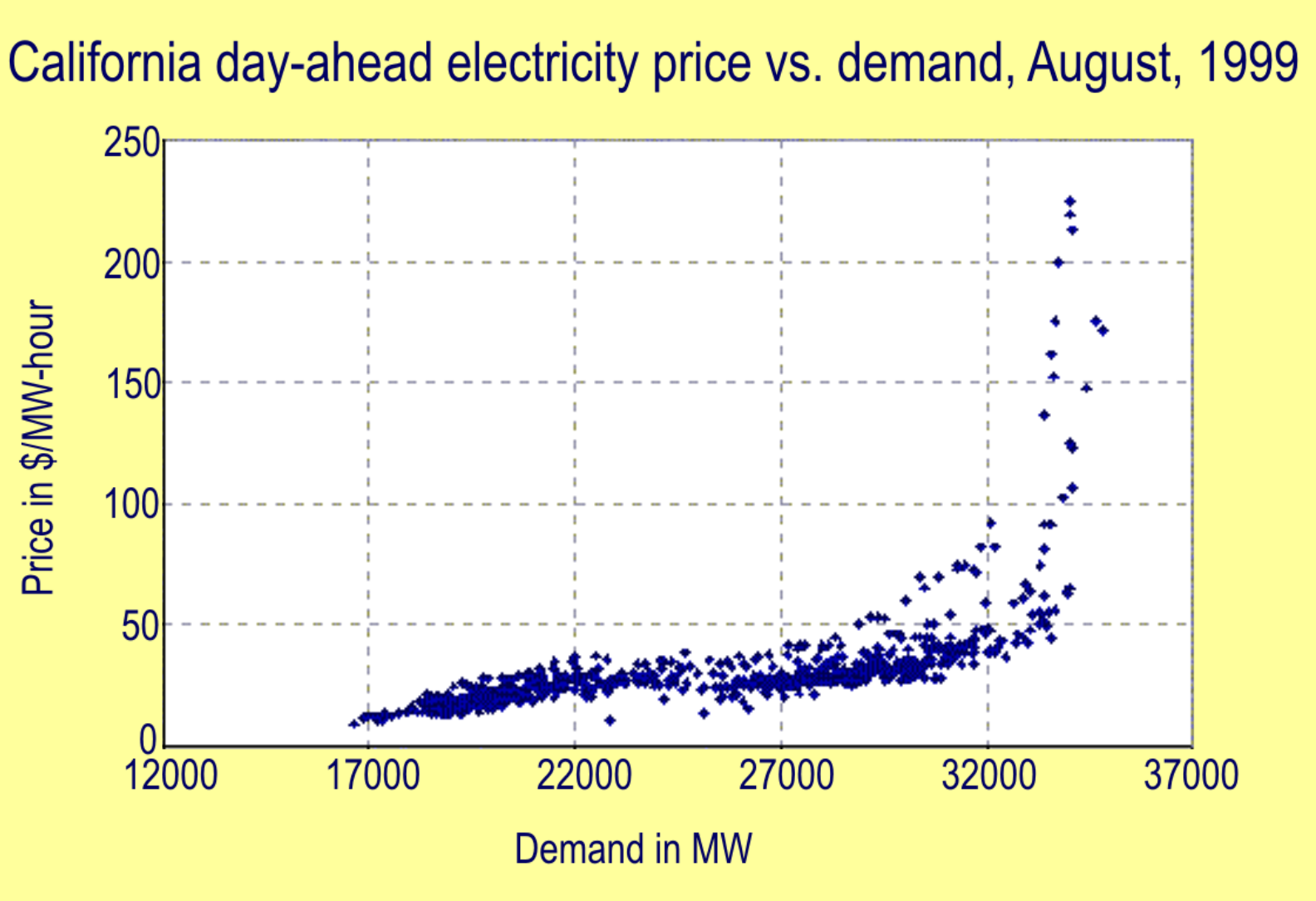
Across basins?

Can integrated regional management use climate forecasts to reduce the cost of secure energy supplies?

Project Overview

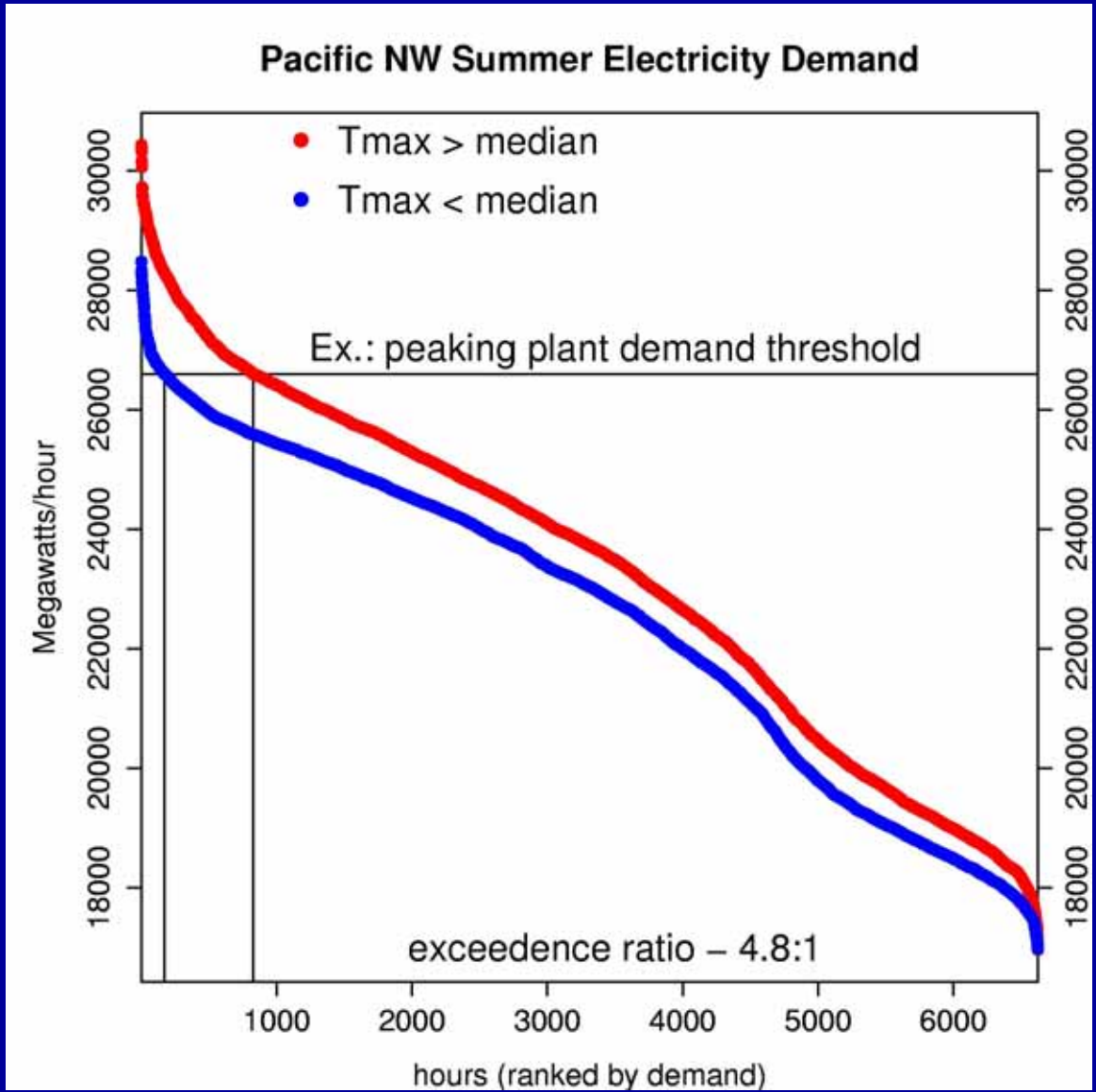


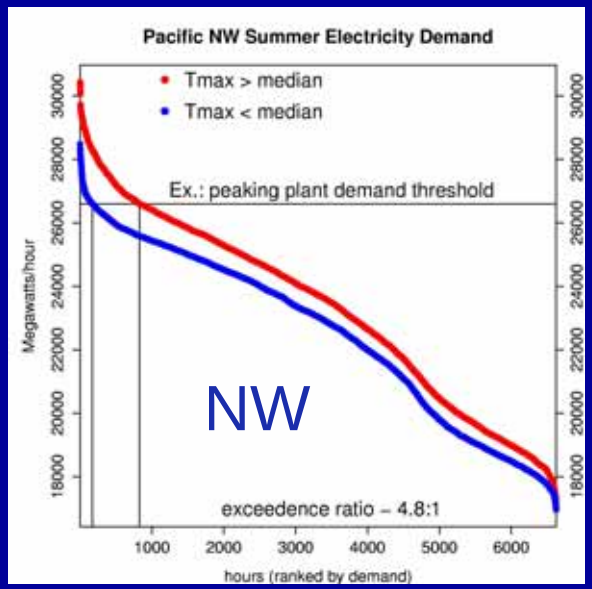
Price vs. Demand

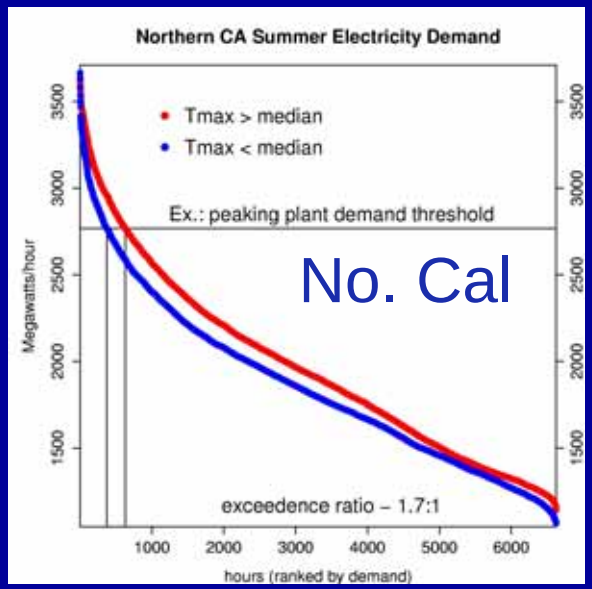


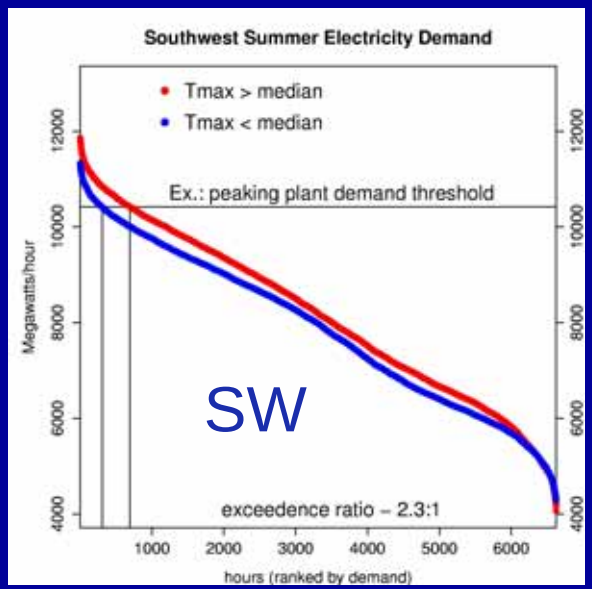
http://www.energy.ca.gov/electricity/wepr/1999-08/index.html

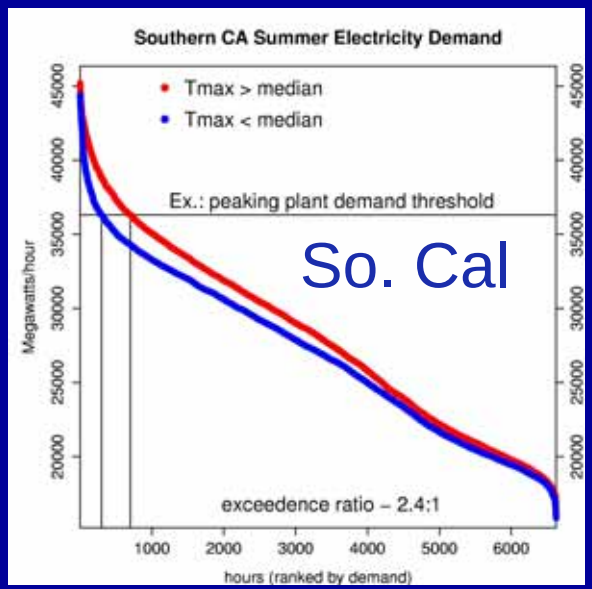
Pacific Northwest Summer Electricity Load Curves: JJA Tmax > or < median



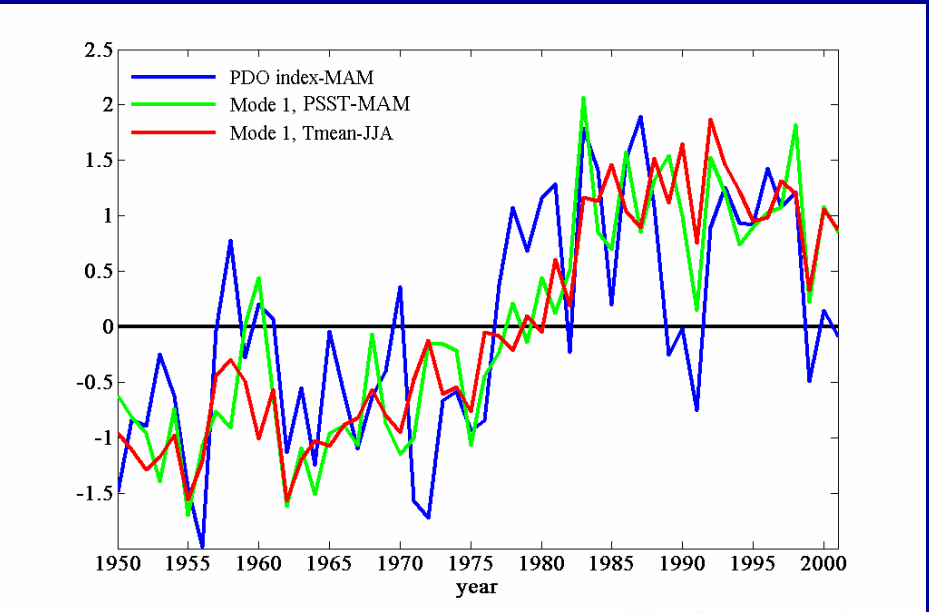

Pacific NW Summer Electricity Demand
Tmax > median
Tmax < median
Ex.: peaking plant demand threshold
NW
exceedence ratio – 4.8:1
Megawatts/hour
hours (ranked by demand)


Northern CA Summer Electricity Demand
Tmax > median
Tmax < median
Ex.: peaking plant demand threshold
No. Cal
exceedence ratio – 1.7:1
Megawatts/hour
hours (ranked by demand)

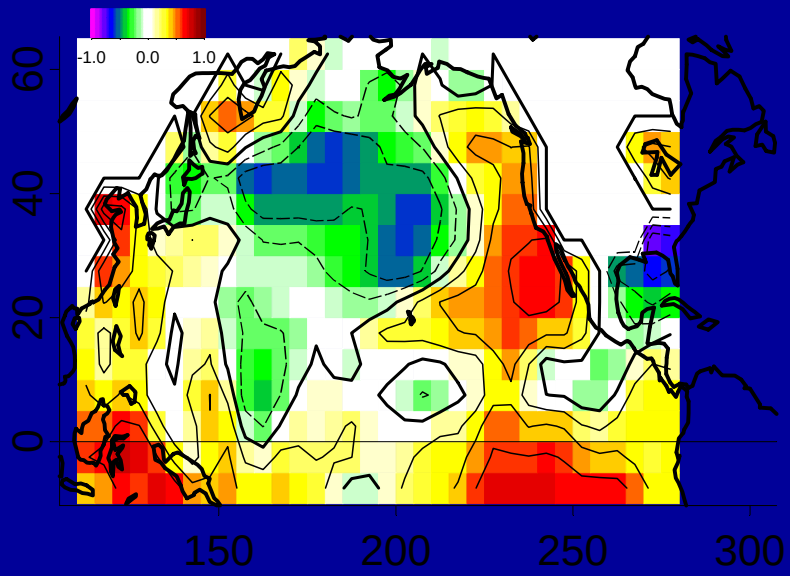

Southwest Summer Electricity Demand
Tmax > median
Tmax < median
Ex.: peaking plant demand threshold
SW
exceedence ratio – 2.3:1
Megawatts/hour
hours (ranked by demand)


Southern CA Summer Electricity Demand
Tmax > median
Tmax < median
Ex.: peaking plant demand threshold
So. Cal
exceedence ratio – 2.4:1
Megawatts/hour
hours (ranked by demand)

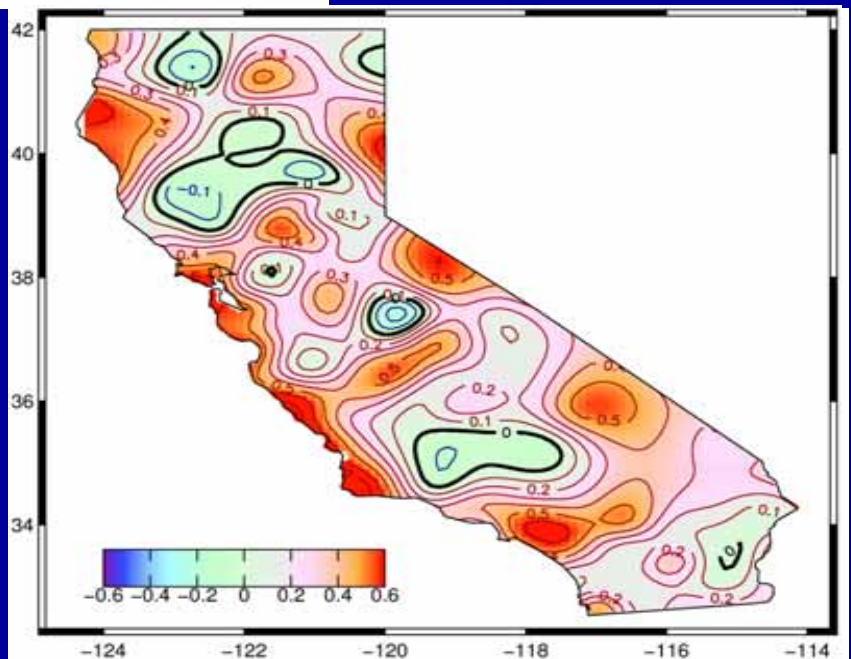
Relationship PDO => California Summertime Temperatures



Correlations, Mode 1-PSST, MAM



Correlations, Mode 1-Tmean, JJA =>



Management Strategies conditional on a T forecast

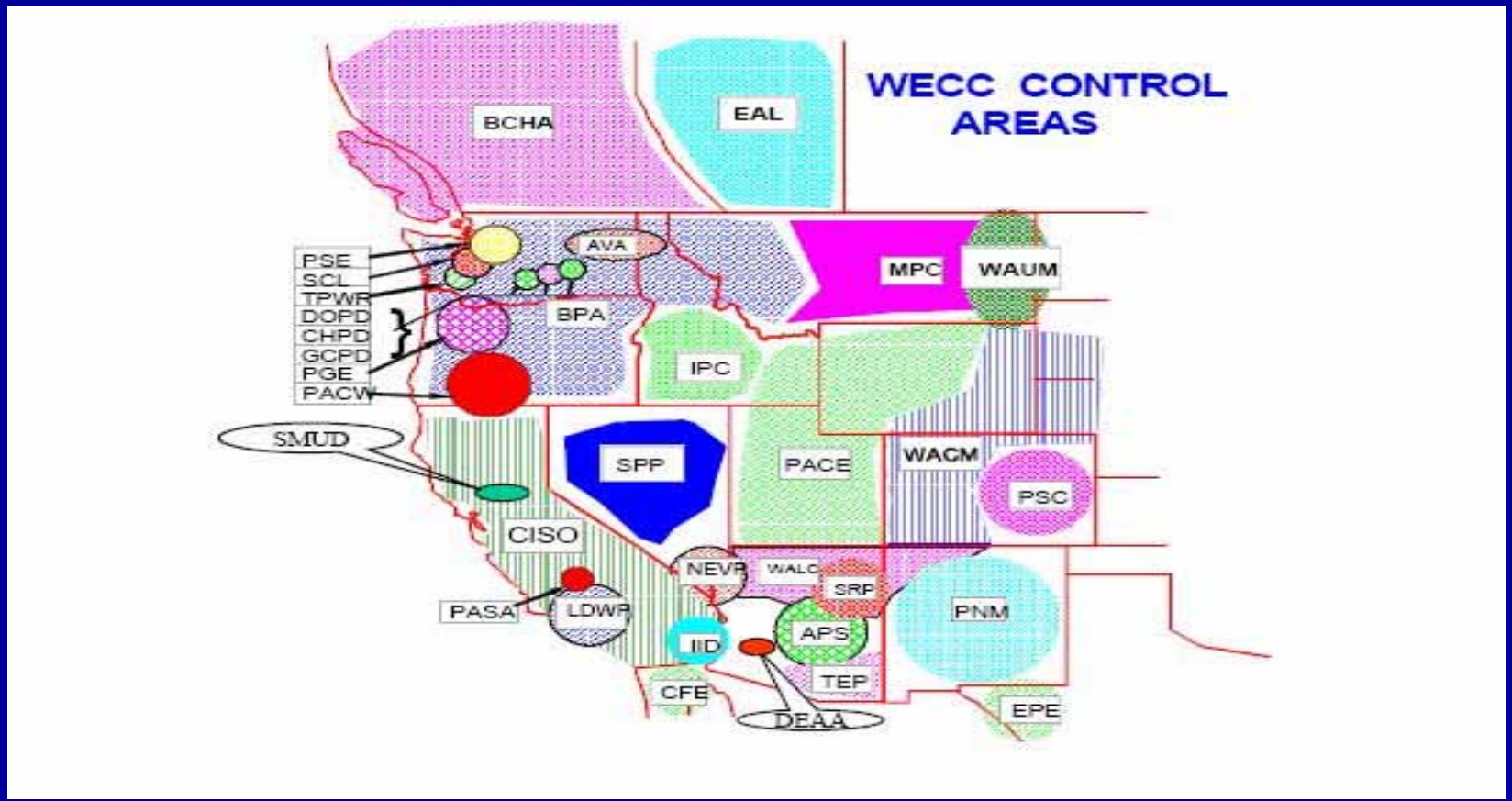
Demand:

- curtailment
- variable pricing

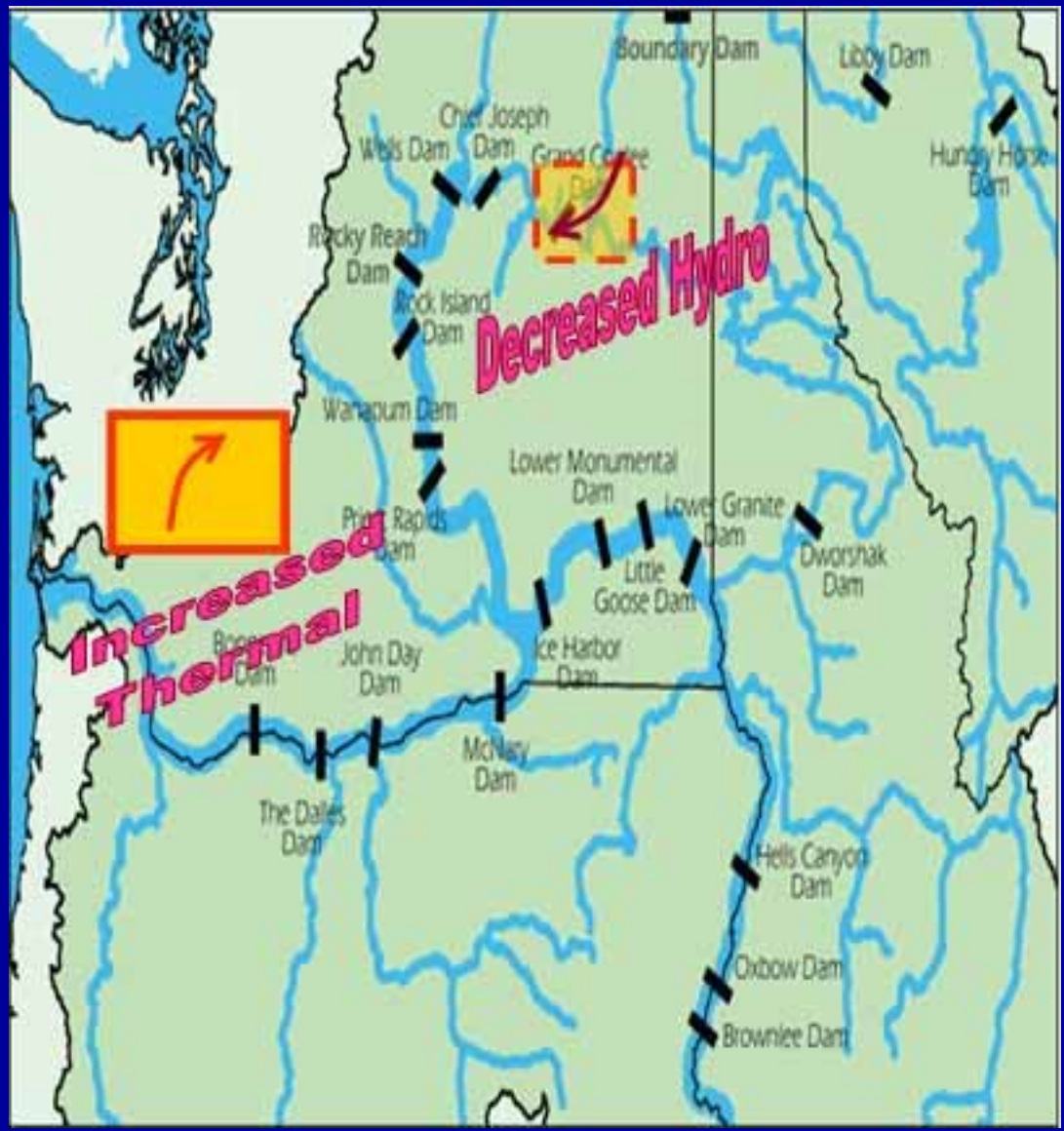
Supply:

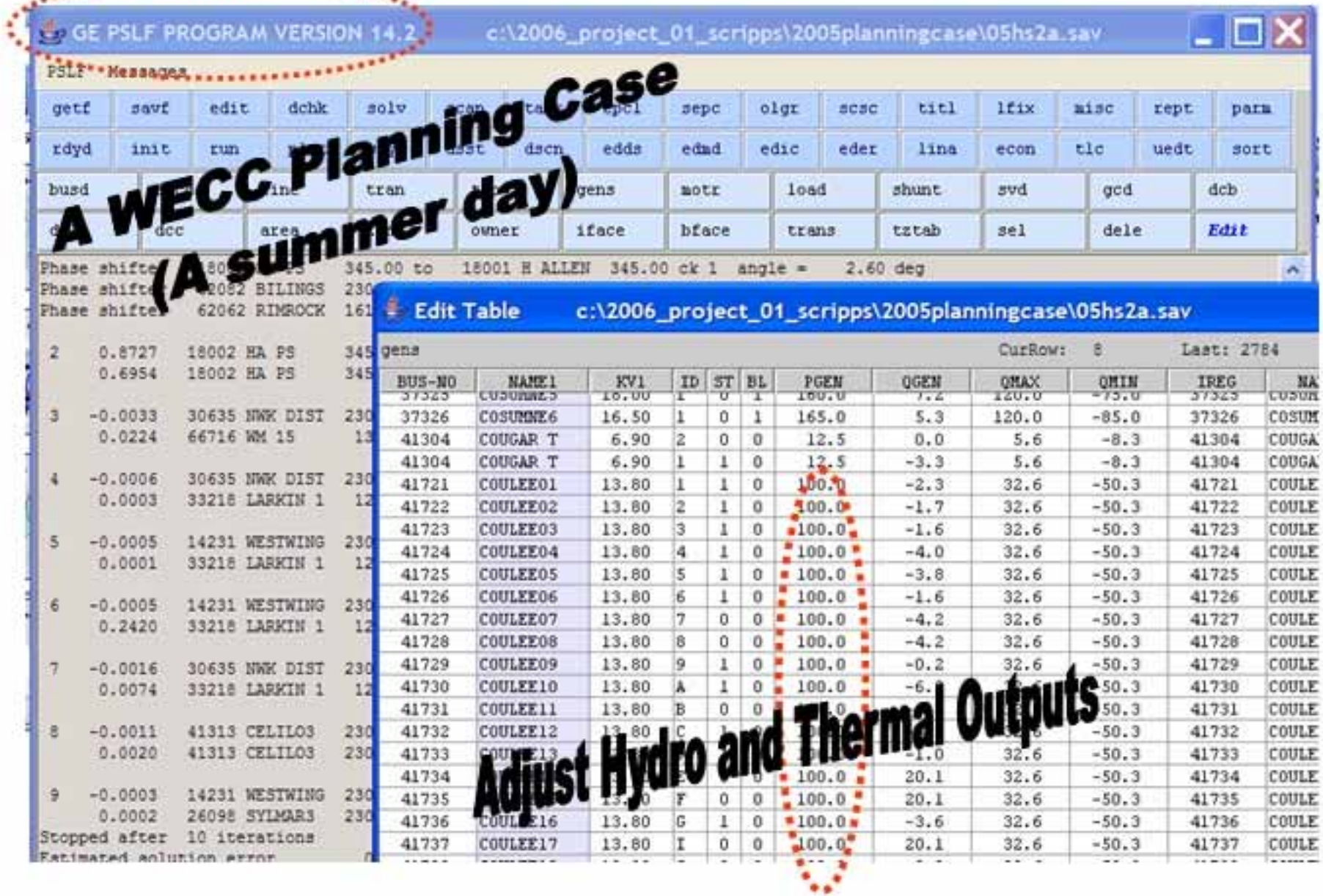
- forward contracts

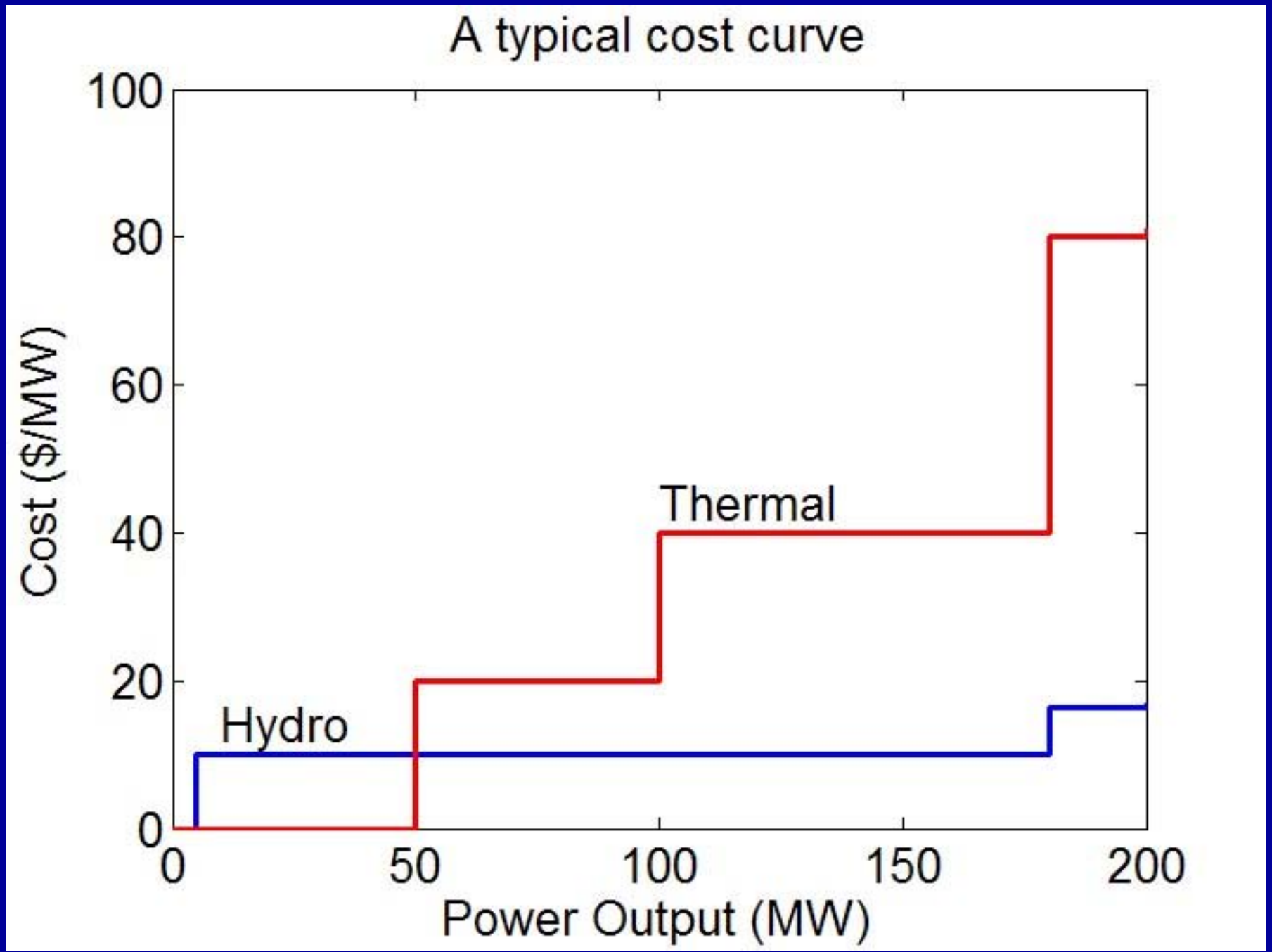
WECC Control Areas




A Summer Case
Top Attractions in the Pacific Northwest
(Click place names for more information)
B.C. Hydro
Puget Sound Energy (Thermal)
The Hydro plants
Prince Rupert
Gwaii Haanas N.P.
Inside Passage
British Columbia
Whistler
Kamloops
North Cascades N.P.
Ross Lake N.R.A.
Victoria
Vancouver
Seattle
ALBERTA
SASKATCHEWAN
Missoula
Montana
Billings
Big Hole Battlefield
Little Bighorn Battlefield
Bighorn Canyon N.R.A.
WYOMING
Yellowstone N.P.
Craters of the Moon
Idaho
Boise
Sawtooth N.R.A.
Hells Canyon N.R.A.
CALIFORNIA
NEVADA
UTAH
NORTH DAKOTA

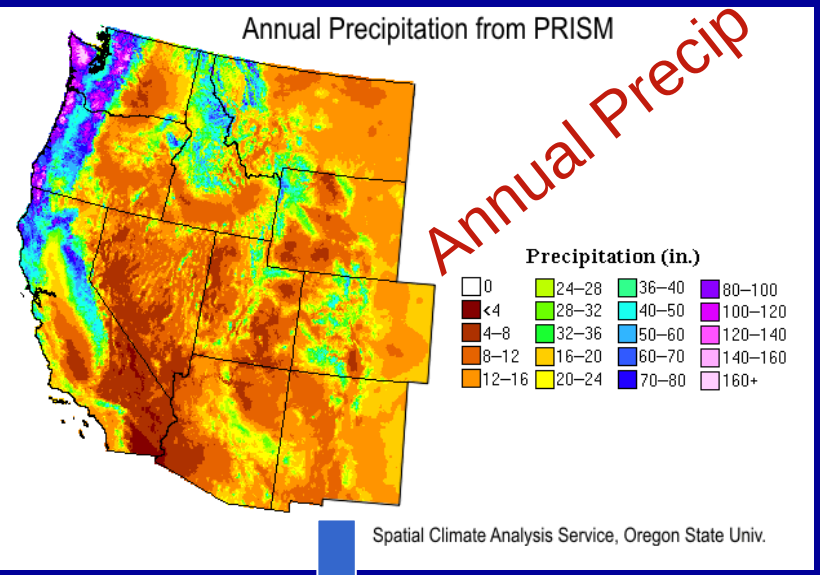

Boundary Dam
Libby Dam
Chief Joseph Dam
Wells Dam
Grand Coulee Dam
Hungry Horse Dam
Rocky Reach Dam
Rock Island Dam
Decreased Hydro
Wanapum Dam
Lower Monumental Dam
Lower Granite Dam
Priest Rapids Dam
Little Goose Dam
Dworshak Dam
Increased Thermal
John Day Dam
Ice Harbor Dam
McNary Dam
The Dalles Dam
Hells Canyon Dam
Oxbow Dam
Brownlee Dam

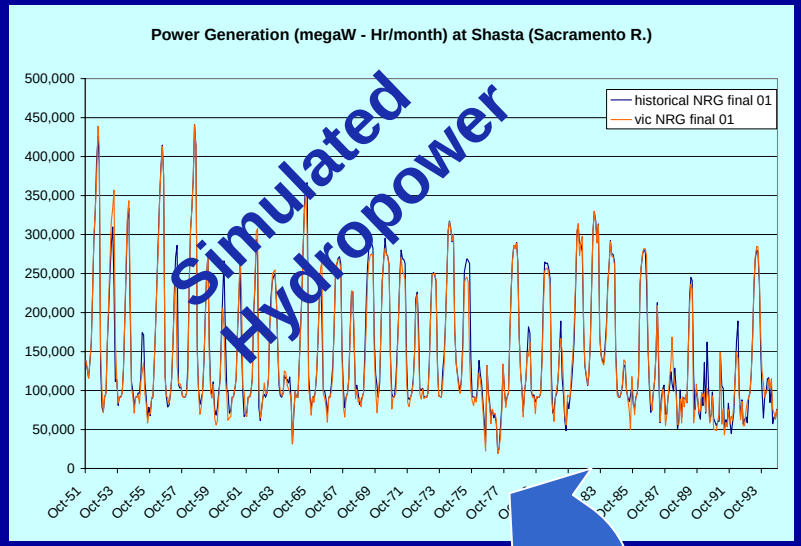

GE PSLF PROGRAM VERSION 14.2
c:\2006_project_01_scripps\2005planningcase\05hs2a.sav
PSLF Messages
getf savf edit dchk solv scan sepc olgr scsc titl lfix misc rept parm
rdyd init run dscn edds edmd edic eder lina econ tlc uedt sort
busd tran gens motr load shunt svd gcd dcb
dcc area owner iface bface trans tztab sel dele Edit
A WECC Planning Case
(A summer day)
Edit Table c:\2006_project_01_scripps\2005planningcase\05hs2a.sav
gens CurRow: 8 Last: 2784
BUS-NO NAME1 KV1 ID ST BL PGEN QGEN QMAX QMIN IREG NA
37326 COSUMME6 16.50 1 0 1 165.0 5.3 120.0 -85.0 37326 COSUM
41304 COUGAR T 6.90 2 0 0 12.5 0.0 5.6 -8.3 41304 COUGA
41304 COUGAR T 6.90 1 1 0 12.5 -3.3 5.6 -8.3 41304 COUGA
41721 COULEE01 13.80 1 1 0 100.0 -2.3 32.6 -50.3 41721 COULE
41722 COULEE02 13.80 2 1 0 100.0 -1.7 32.6 -50.3 41722 COULE
41723 COULEE03 13.80 3 1 0 100.0 -1.6 32.6 -50.3 41723 COULE
41724 COULEE04 13.80 4 1 0 100.0 -4.0 32.6 -50.3 41724 COULE
41725 COULEE05 13.80 5 1 0 100.0 -3.8 32.6 -50.3 41725 COULE
41726 COULEE06 13.80 6 1 0 100.0 -1.6 32.6 -50.3 41726 COULE
41727 COULEE07 13.80 7 0 0 100.0 -4.2 32.6 -50.3 41727 COULE
41728 COULEE08 13.80 8 0 0 100.0 -4.2 32.6 -50.3 41728 COULE
41729 COULEE09 13.80 9 1 0 100.0 -0.2 32.6 -50.3 41729 COULE
41730 COULEE10 13.80 A 1 0 100.0 -6.
41731 COULEE11 13.80 B 0 0
41732 COULEE12 13.80 C
41733 COULEE13
41734 100.0 20.1 32.6 -50.3 41734 COULE
41735 13.80 F 0 0 100.0 20.1 32.6 -50.3 41735 COULE
41736 COULEE16 13.80 G 1 0 100.0 -3.6 32.6 -50.3 41736 COULE
41737 COULEE17 13.80 I 0 0 100.0 20.1 32.6 -50.3 41737 COULE
Adjust Hydro and Thermal Outputs
Phase shifte 345.00 to 18001 H ALLEN 345.00 ck 1 angle = 2.60 deg
Phase shifte 62062 BILINGS 230
Phase shifte 62062 RIMROCK 161
2 0.8727 18002 HA PS 345
0.6954 18002 HA PS 345
3 -0.0033 30635 NWK DIST 230
0.0224 66716 WM 15 13
4 -0.0006 30635 NWK DIST 230
0.0003 33218 LARKIN 1 12
5 -0.0005 14231 WESTWING 230
0.0001 33218 LARKIN 1 12
6 -0.0005 14231 WESTWING 230
0.2420 33218 LARKIN 1 12
7 -0.0016 30635 NWK DIST 230
0.0074 33218 LARKIN 1 12
8 -0.0011 41313 CELILO3 230
0.0020 41313 CELILO3 230
9 -0.0003 14231 WESTWING 230
0.0002 26098 SYLMAR3 230
Stopped after 10 iterations
Estimated solution error


A typical cost curve
100
80
60
40
20
0
Cost ($/MW)
Thermal
Hydro
0
50
100
150
200
Power Output (MW)

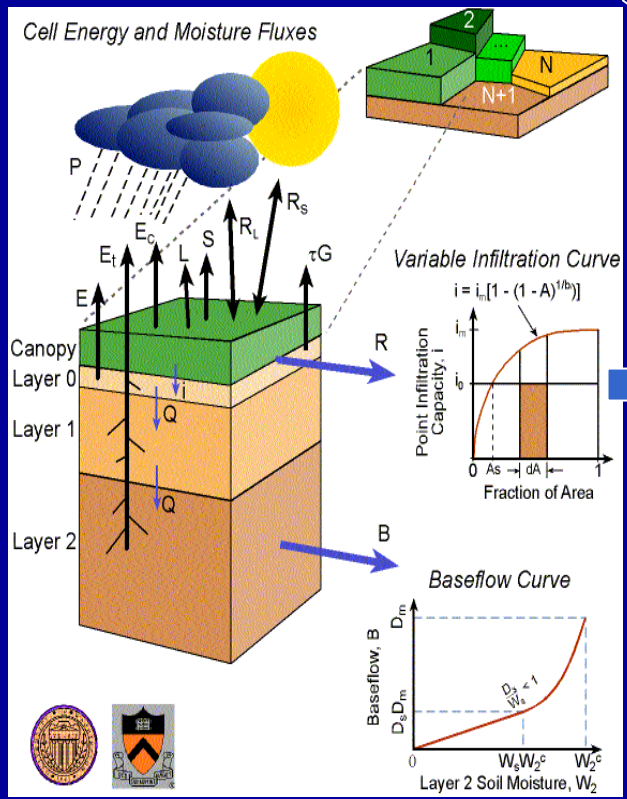
Replacing Reduced Hydro with Thermal Generation
(Peak Summer Day - WECC Planning Scenario)

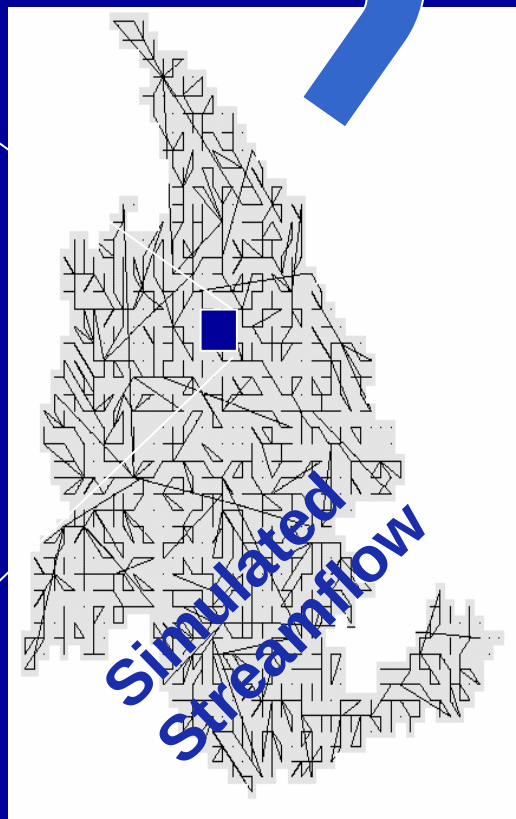
Scenario	Hydro (Coulee)	Thermal (PGE)	Net Gain/Loss
Base	1800 MW	1443 MW	na
- 10%	1620 MW	1614 MW	-$5,198
- 20%	1440 MW	1794 MW	-$13,670
- 30%	1260 MW	1974 MW	-$32,316





Simulated Hydrology





Management Strategies conditional on a Streamflow/ Hydropower forecast

Demand:

⇓curtailment (advance warning)

⇓⇑variable pricing

Supply:

⇓forward contracts

⇓conserve cheaper hydro supply

⇑export hydro

Why aren’t climate forecasts used?

- *Probabilistic in nature* – sometimes unfamiliar
- *Lack of understanding* of climate forecasts & benefits
- *Language and format* of climate forecasts is hard to understand – need to be translated
- *Aversion to change* – easier to do things the traditional way
- *Institutional rigidities* – narrow performance targets
- *Risk management* – system designed to be insensitive to climate variability