Potential Impacts of Climate Change on Hydropower Generation in California

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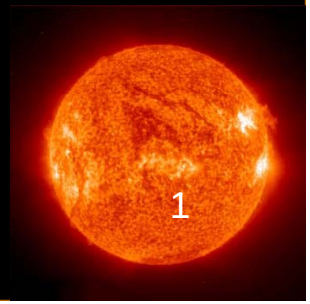
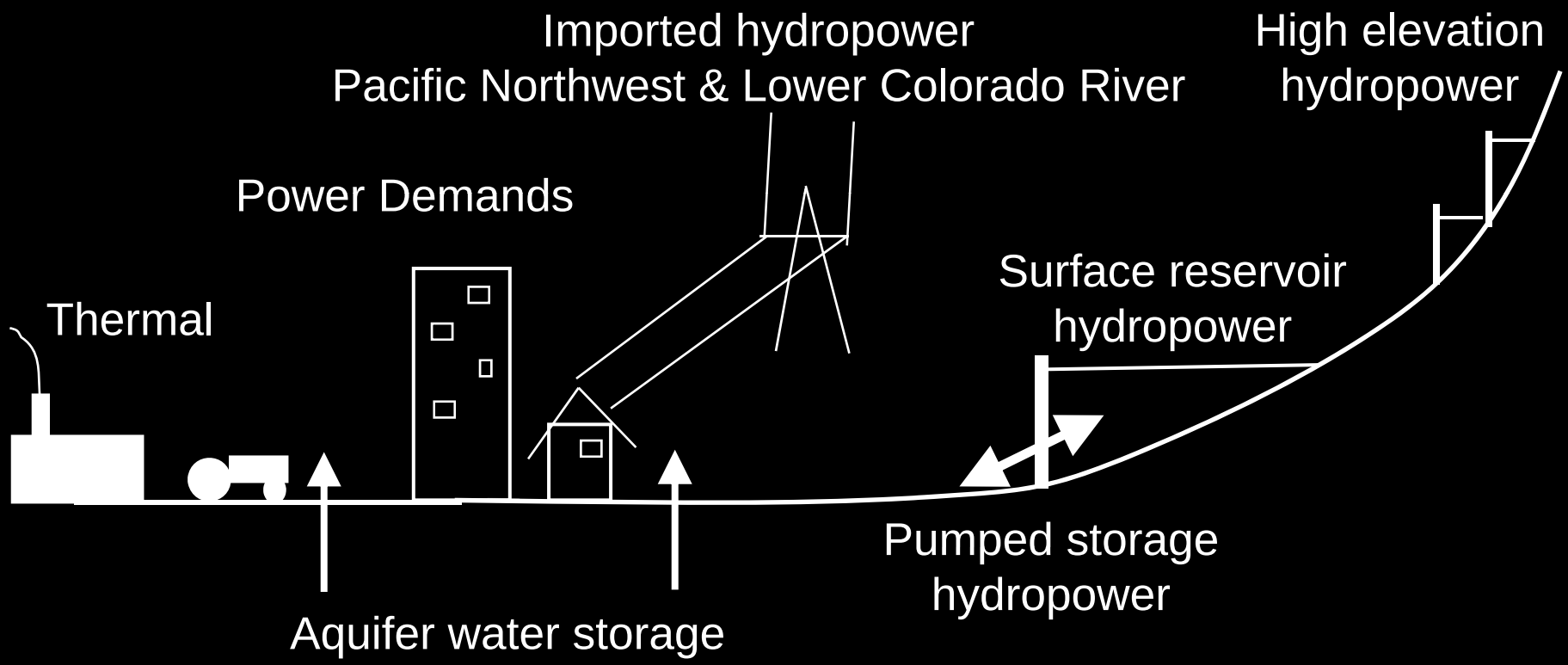


Outline

- Hydropower in California
- Effects on Low Elevation System
- Effects on High Elevation System
- Results
- Conclusions

Hydropower Systems



Hydropower and California

	1,000 GWH/yr, 2004
Hydropower Total	45.4
In-state Hydropower	*34.4*
High Elevation*	25.3
Low Elevation*	9.1
Pumped Storage	?
Imported Hydropower	*11*
PNW	9.5
LCR	1.5
Thermal	205.2
Other renewables	24.5
Total	**275.1**

* Estimated Sources: CEC; McCann 2005

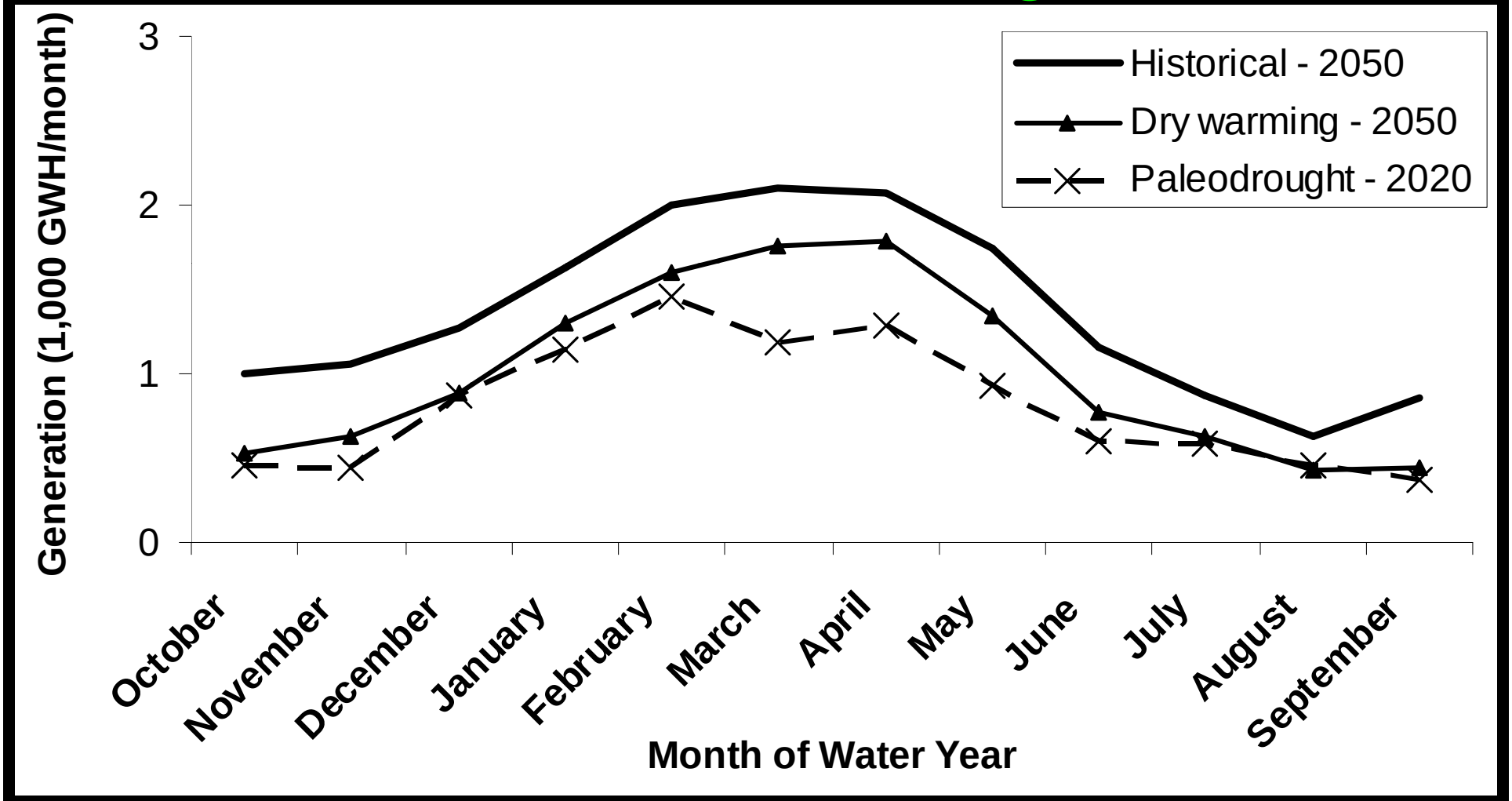
Climate Effects on Hydropower

1. Energy demand and prices
2. Timing of water availability
3. Quantity of water available
4. Availability of hydropower to import
5. Thermal generation efficiency
6. Environment sensitivity to hydropower operations

Climate and Hydropower Studies

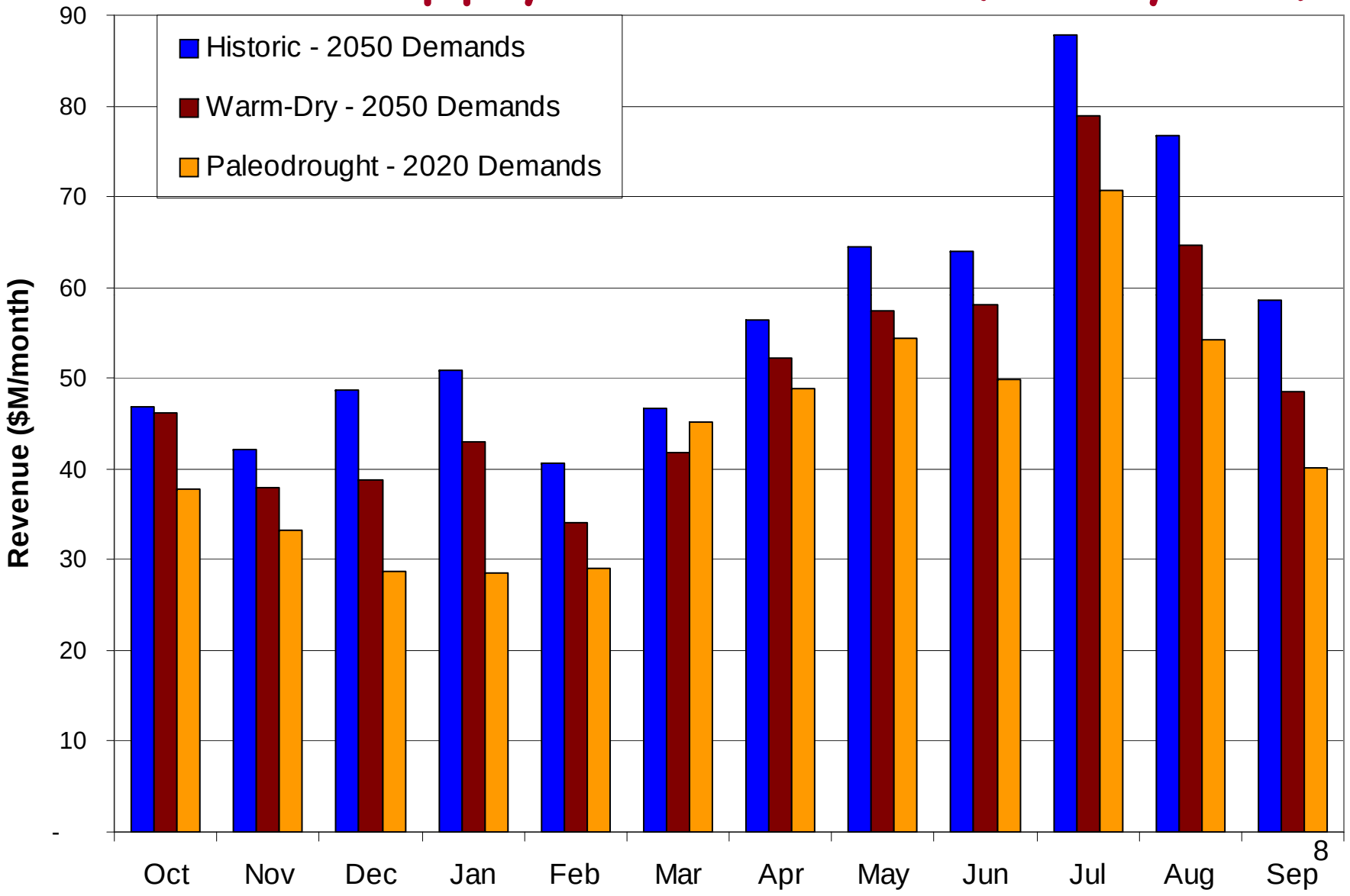
1. Low elevation production
   - DWR (CALSIM), UC Davis (CALVIN)
2. High elevation production
   - UC Berkeley (SMUD), UC Davis (EBOM)
3. Imported hydropower availability
   - Univ. of Washington
4. Electricity demands
   - UC Berkeley (Auffhammer)

Low Elevation Hydropower Seasonal Generation Changes

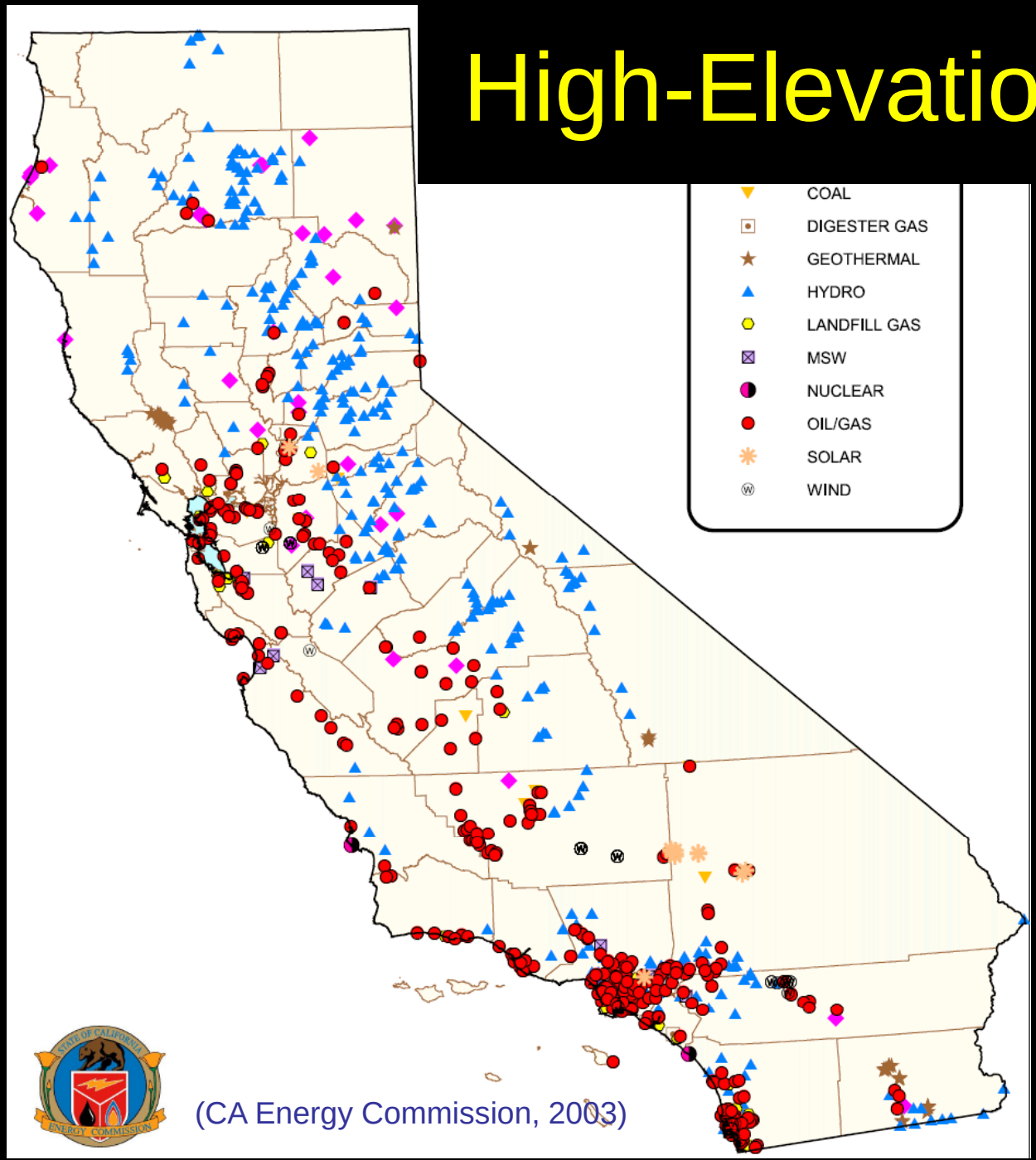


Major water supply reservoirs in system optimization model

Average Hydropower Benefits at Water Supply Reservoirs ($M/year)



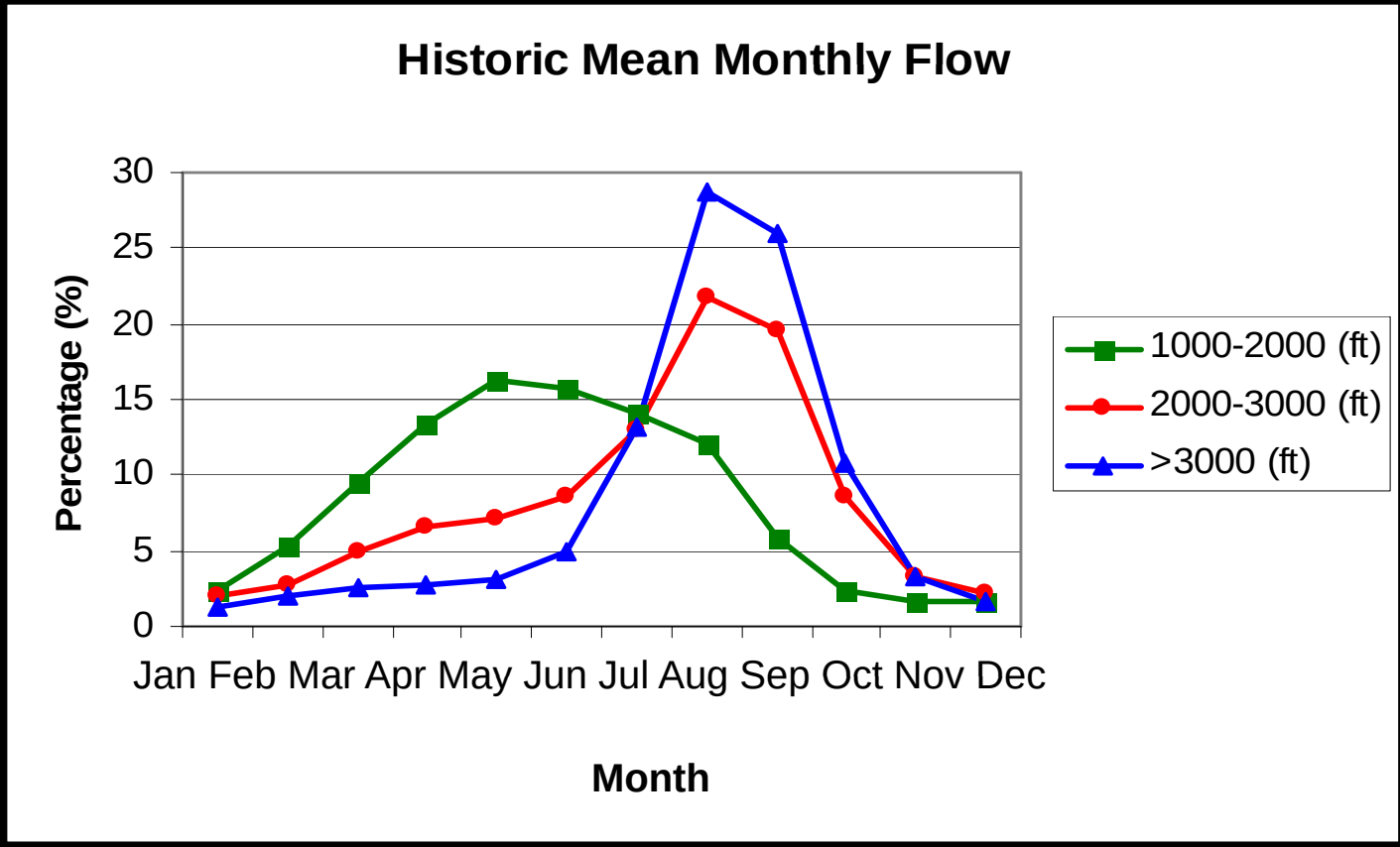
High-Elevation System



(CA Energy Commission, 2003)

- 156 High-elevation power plants
- Snowpack helps
- High-head, little head-storage effect
- Limited storage or flow data!!

High-Elevation Runoff (Snowpack Effect)

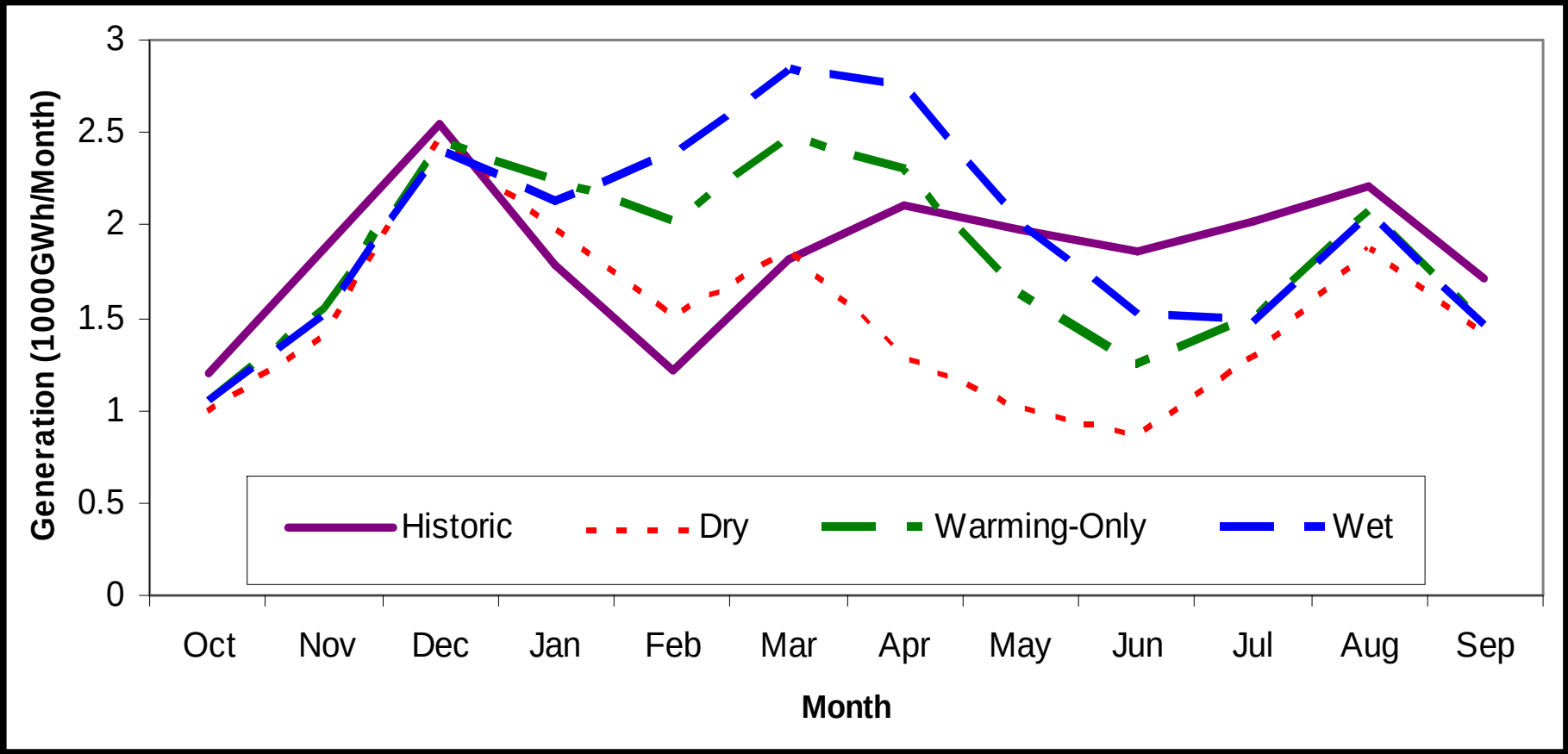


High-Elevation Model Results

137 of 156 hydropower plants

1985 – 1998 period

Monthly High Elevation Generation

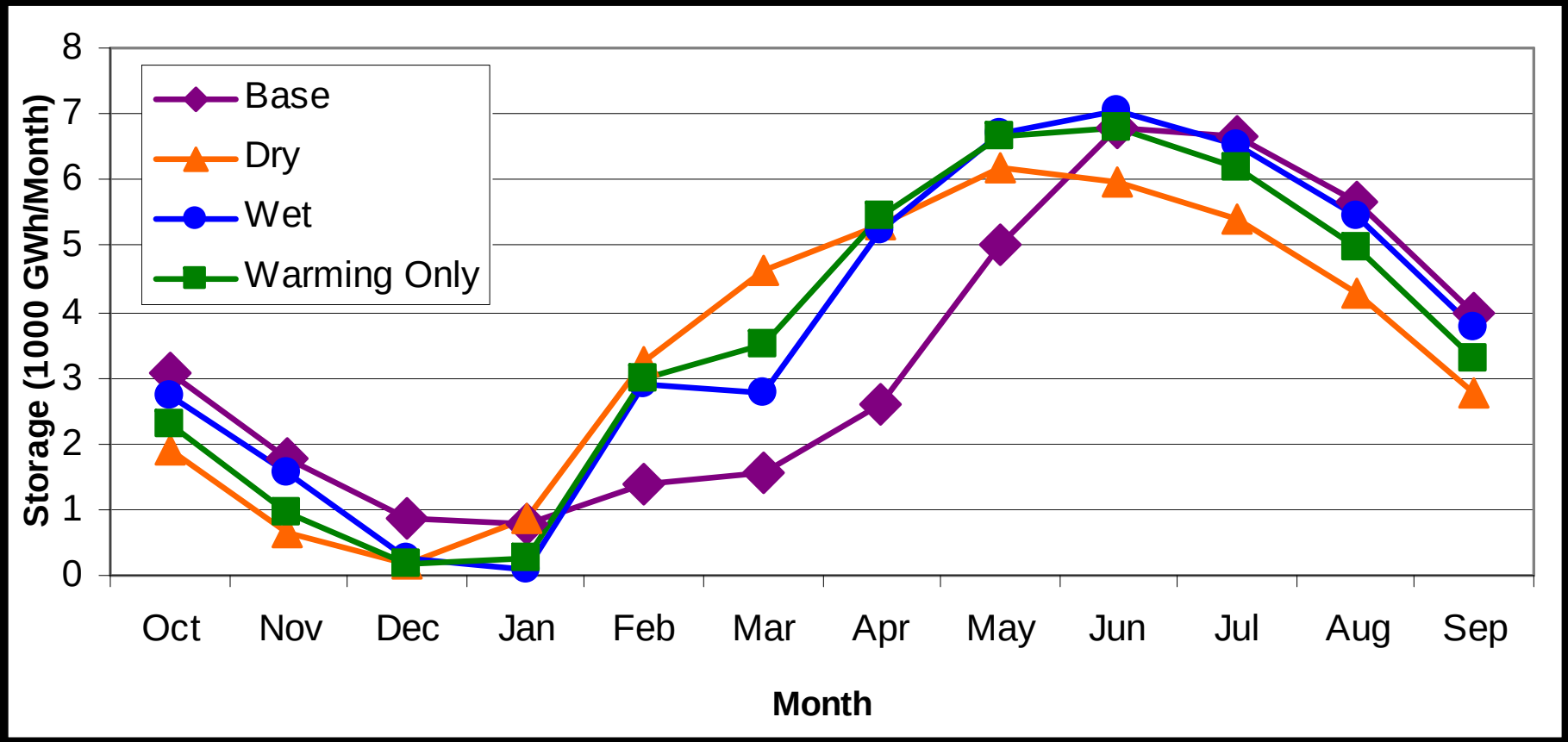


High Elevation Model Results

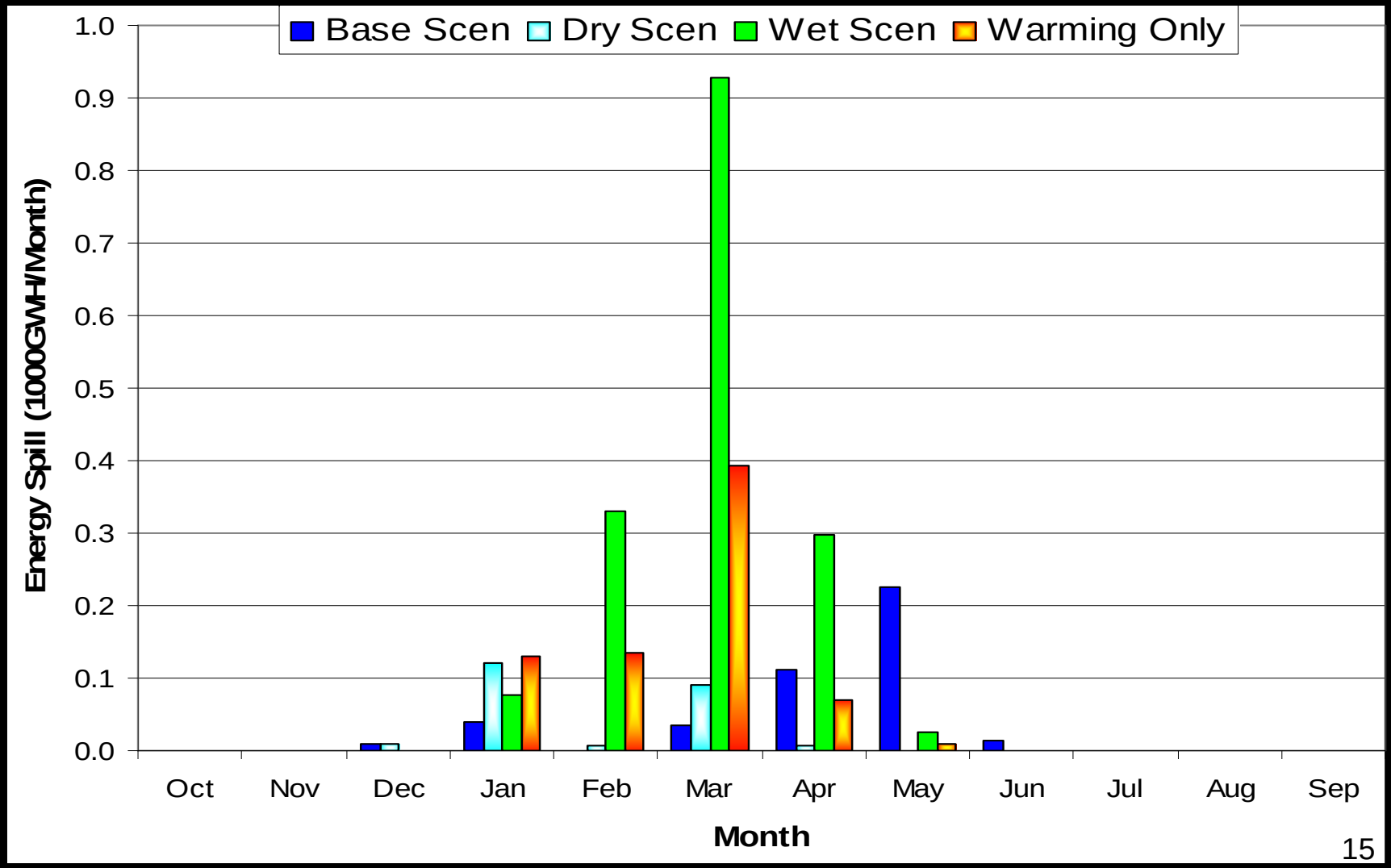
	Scenario			
	Base	***Dry (-20%)***	***Wet (+10%)***	***Warming-Only***
Generation (1000 GWH/yr)	22.3	17.9	23.6	22.0
Generation Change with Respect to the Base Case (%)		- 19.8	+ 5.8	- 1.3
Spill (MWH/yr)	130	96	1,112	410
Spill Change with Respect to the Base Case (%)		- 26.2	+ 755.5	+ 215.6
Revenue (Million $/yr)	1,509	1,292	1,528	1,475
Revenue Change with Respect to the Base Case (%)		- 14.4	+ 1.2	- 2.3

average of results over 1985-1998 period

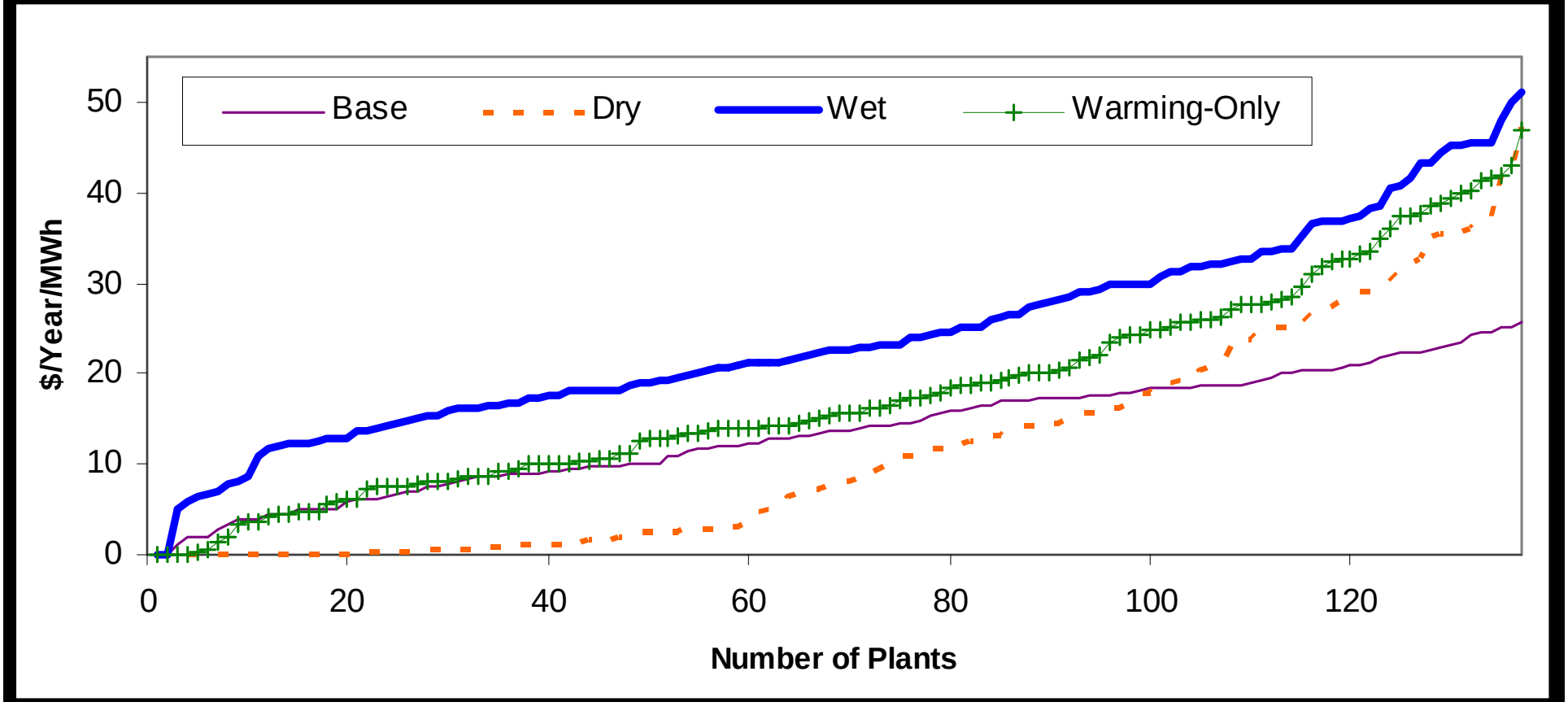
Average total end-of-month energy storage (1985-1998)



Average monthly energy spill (1985-1998)



Benefit of Expanding Storage Capacity



Hydropower Conclusions

1) Warming shifts snowmelt to winter and reduces total runoff some. Precipitation changes are less certain.

2) Drier conditions proportionally reduce generation. Wetter climates produce less increases in generation, from spills.

3) Warming alone affects generation mostly by increasing evapotranspiration, and less by seasonal shift of inflows.

4) Seasonal flow shifts from warming increase spills, reduce generation a little, and reduce revenues a little more.

5) Energy prices and reduced availability of hydropower imports from Northwest might be most important

6) Storage capacity often becomes less valuable with drier conditions (since reservoirs fill less frequently).

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