Climate Science Needs for Long-term Power Sector Investment Decisions

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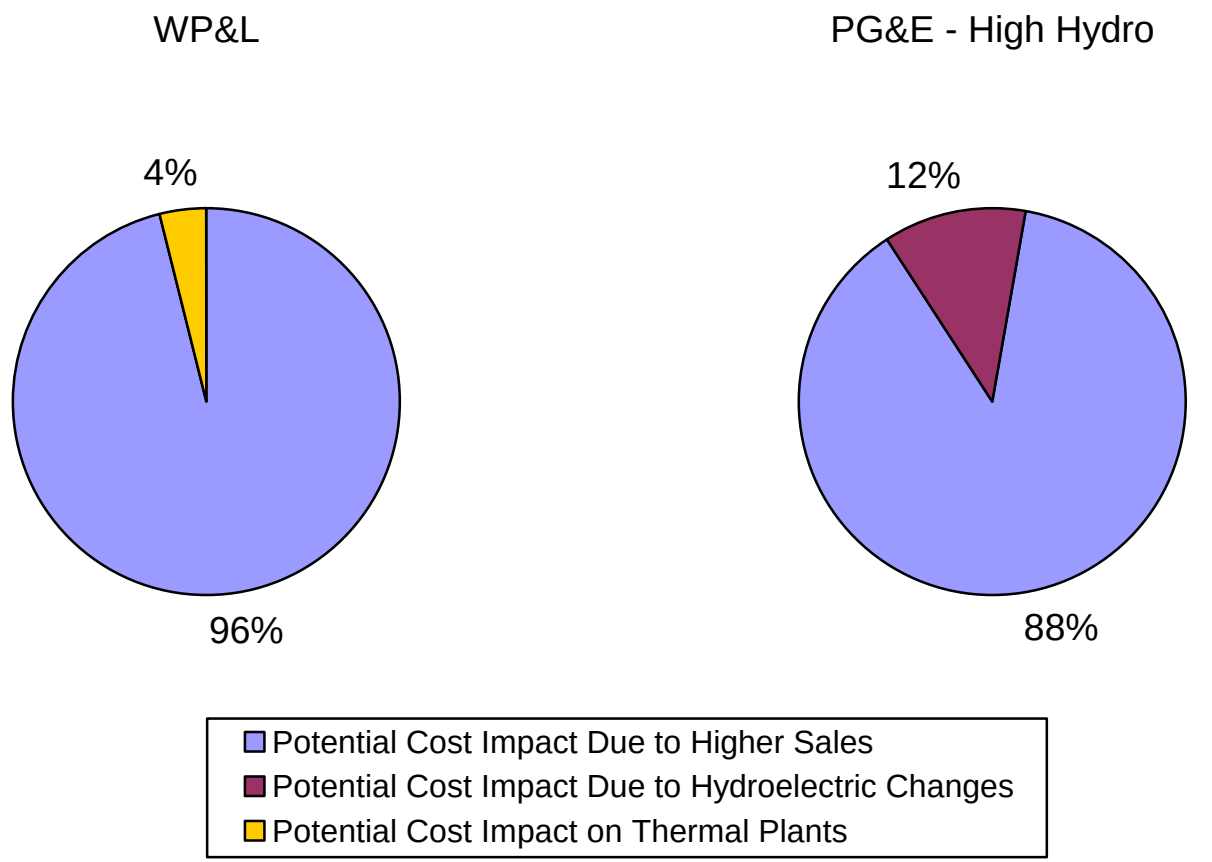
Power System Planners See a High-level of Uncertainty for Climate Change

- Temperature uncertainty
  - Time path of annual average temperature
  - Seasonal distribution of temperature changes
  - Distribution of changes by day types
    - Change in severity of extreme days
    - Change in number of extreme days
  - Change in number or intensity of extreme episodes
  - Regional distribution of changes
- Water for hydro generation and availability for cooling
- Change in frequency and intensity of storms
- Sea-level rise

EPRI/CRIEPI Study Examined Potential Effects of Climate on Electric Utilities

	HEPCo	WP&L	SOCO	PG&E	SRP	PP&L
DEMAND Change in Average Daily Temperature	X	X	X	X	X	X
SUPPLY Hydroelectric Impacts	X			X		
Storms and T&D Costs	X	X	X			
Cooling Water Temperature		X				
Combustion Air Temperature		X				
Drought (Fuel Supply, Cooling Water)		X	X			
Transmission Performance and Warmer Climate						X
Loss of Load Diversity Benefits						X
Sea Level Rise	X					

Impact of Climate Change on Demand Dominated All Other Pathways



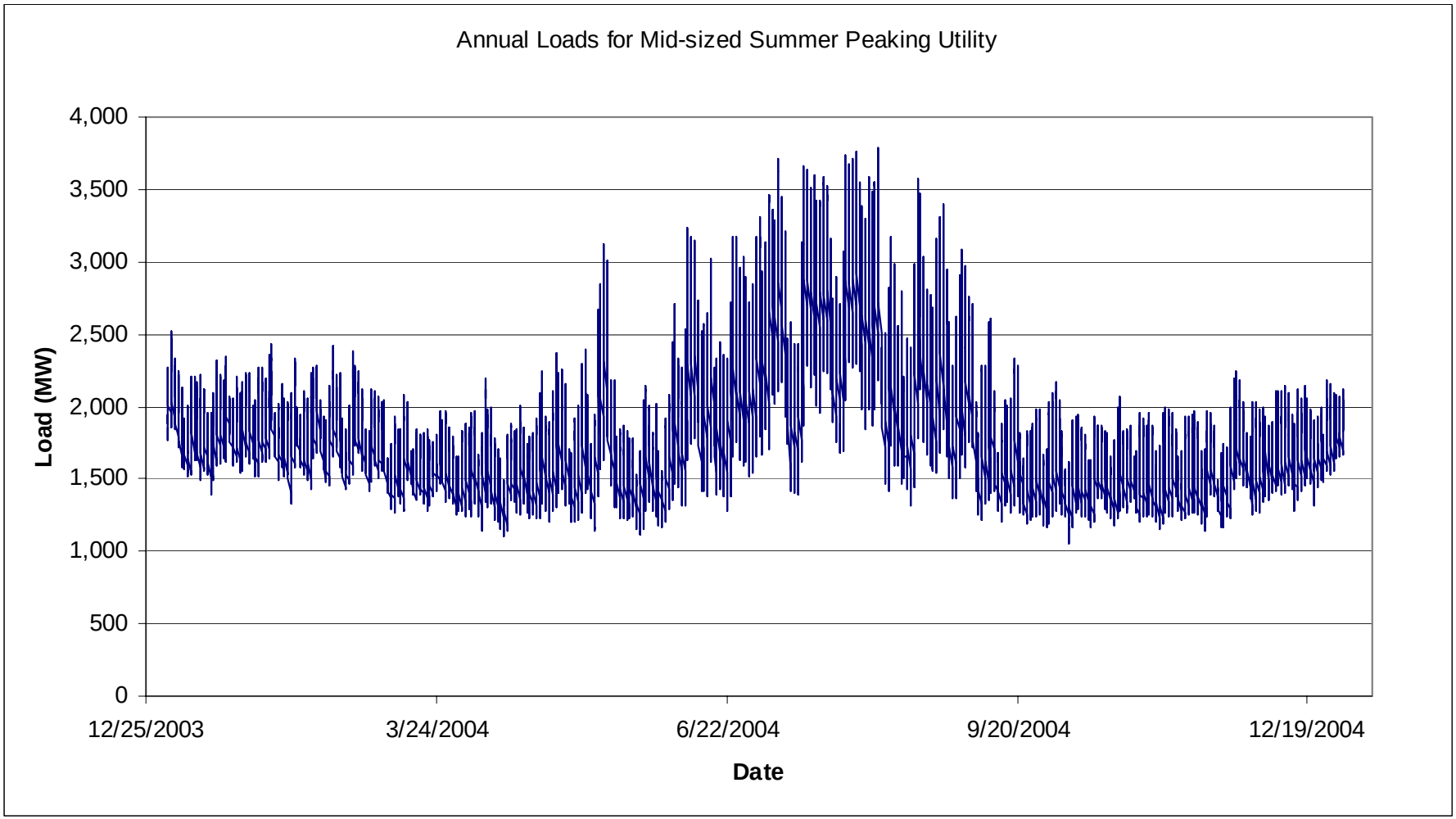
Temperature Change Scenarios Result in Large Effects on Loads, Generation and Total Costs

	2050
Change in Summer Temp – Highest Scenario	+9.7 Degrees (F) Summer Ave. +14.4 Degrees (F) Peak Day
Change in Peak Demand–Range	-2 to +63 percent
Change in Total Electricity Energy Demand	-1 to +8 percent
Increase in Capacity Additions	+16 to 70 percent
Costs Per Utility	+100 to 800 million 1990 dollars
Percent Change in Rates	0 to +5 percent

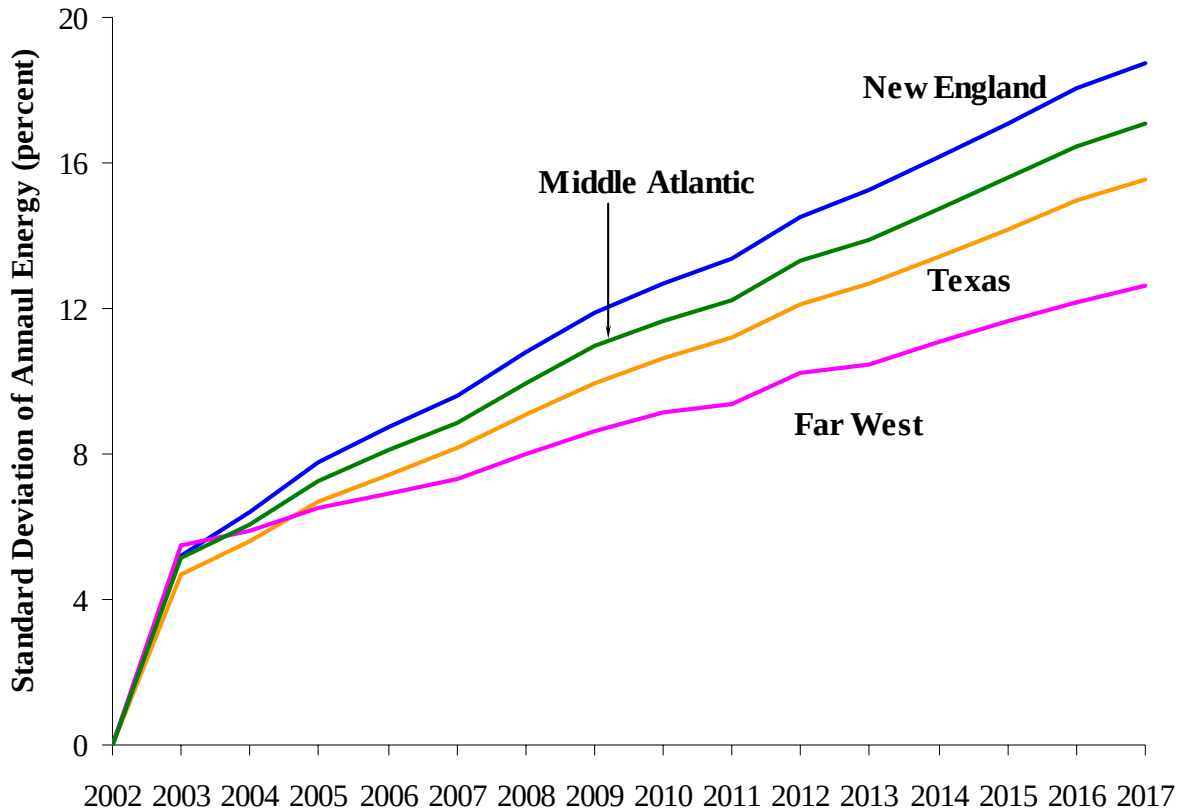
Utility Planning Priorities

- Avoiding poor reliability due to inadequate generation or transmission
- Avoid launching uneconomic generation due to
  - Unanticipated high construction cost
  - Poor fit with transmission system
  - Fuel/emission price changes
  - Poor fit for load shape

Loads Highly Variable by Hour, Day and Season



Load Uncertainty a Key Challenge for Generation Planning



- The standard deviation of forecasted loads jumps in first year due to weather uncertainty and then rises over time due to uncertainty in economic growth

Generation Planning Practice (integrated regulated utilities)

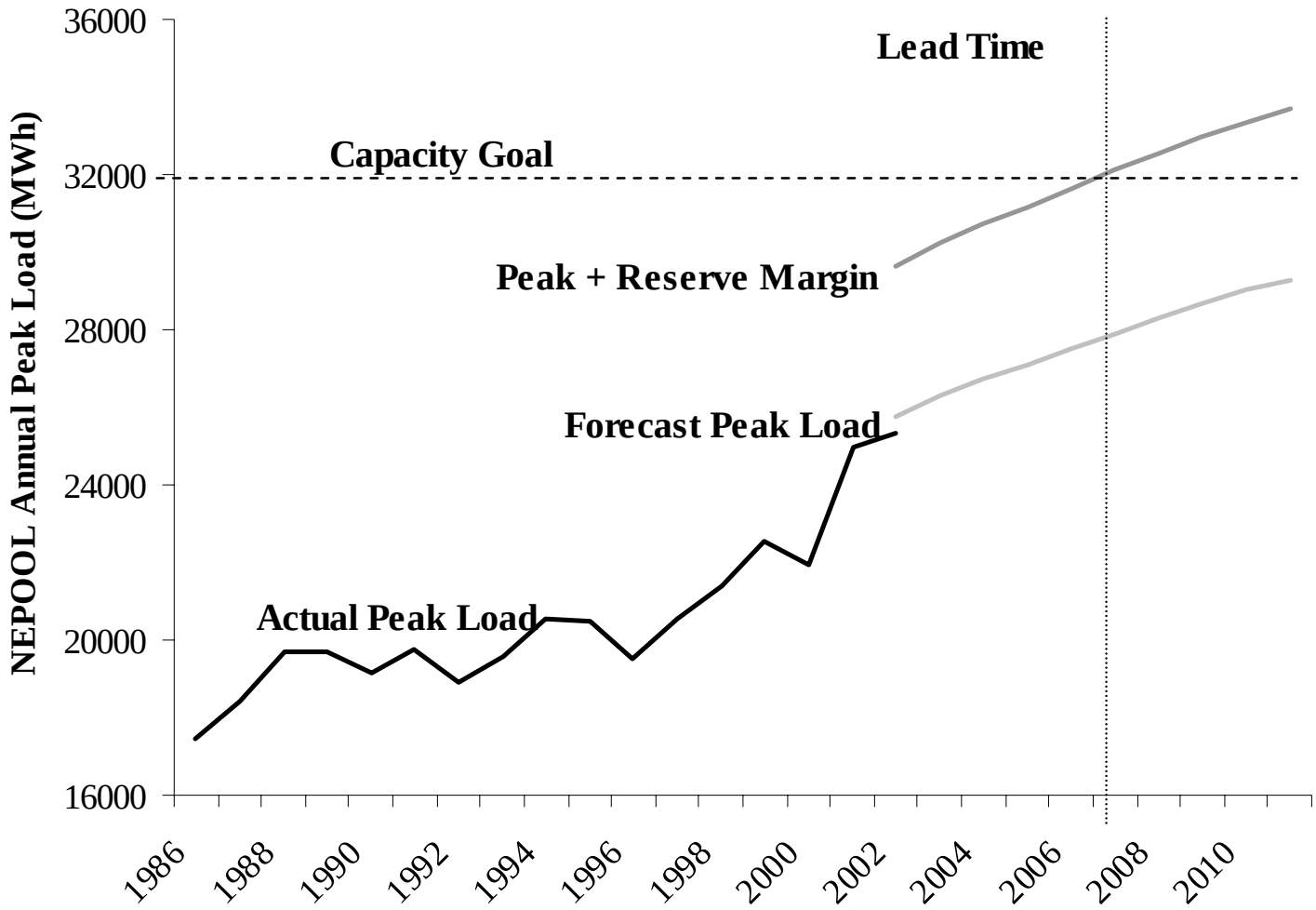
- Assess load growth rate
  - Observe loads and weather
  - Create weather-adjusted load history
  - Forecast weather-adjusted load growth rate
    - System level and/or by “load pocket”
- Develop plan for immediate needs
- Review plan with stakeholders and execute

Challenge – separating climate change signal from noise

Finding Climate Change Signals in the Noise

- What changes planners care about
  - Season (summer/winter/shoulder)?
  - Time of day (day/night, min/max temp changes)?
  - Where (micro regions/service territory/broad regions)?
  - How soon, how much?
- Possible changes highly uncertain
- High level of underlying variability
- How can planners “know” of changes requiring response?

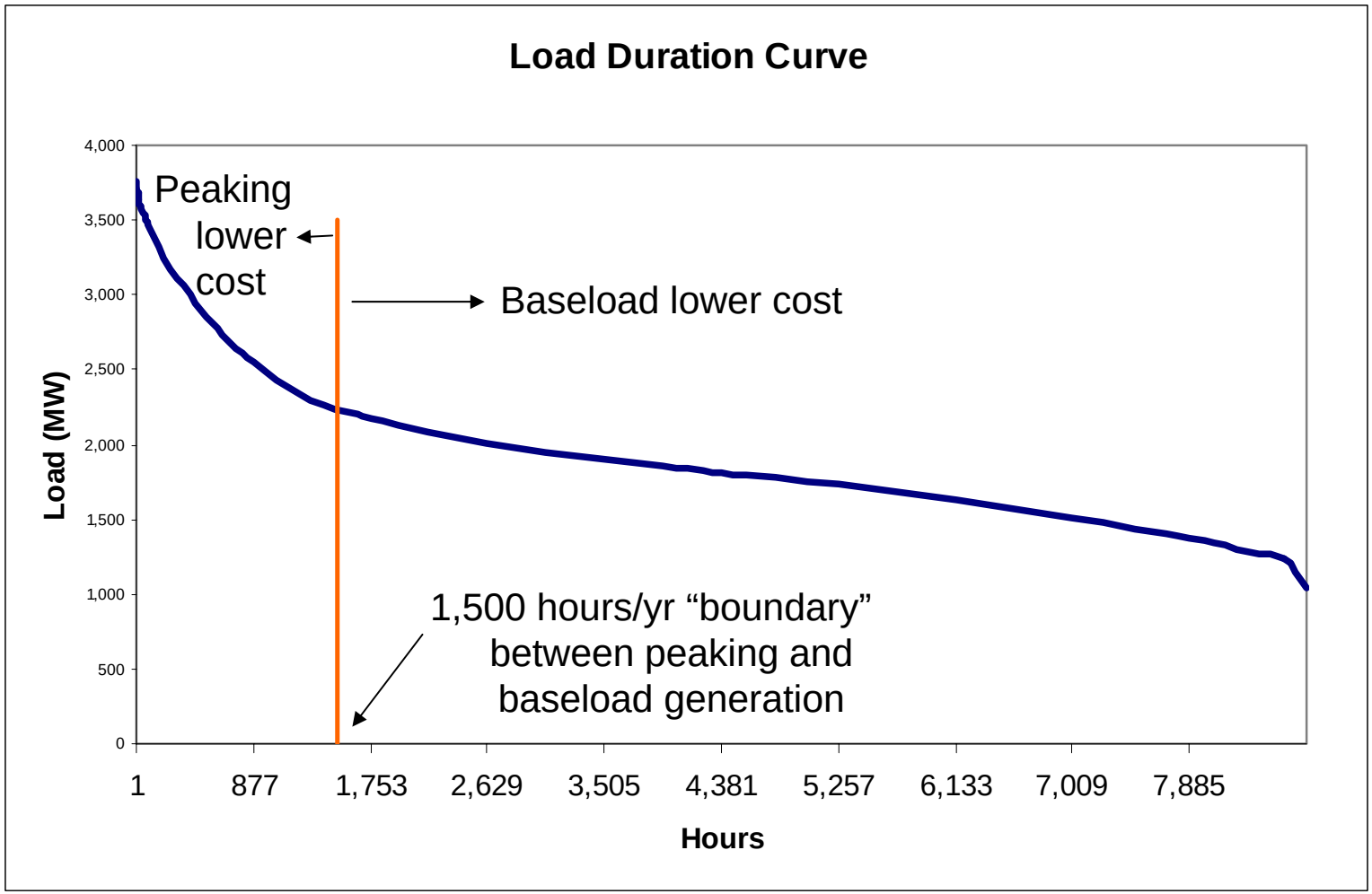
Planning Reserve Margins Help Avoid Reliability Risk Due to Uncertainty



Utilities Use a Mix of Peaking and Baseload Generation to Minimize Costs

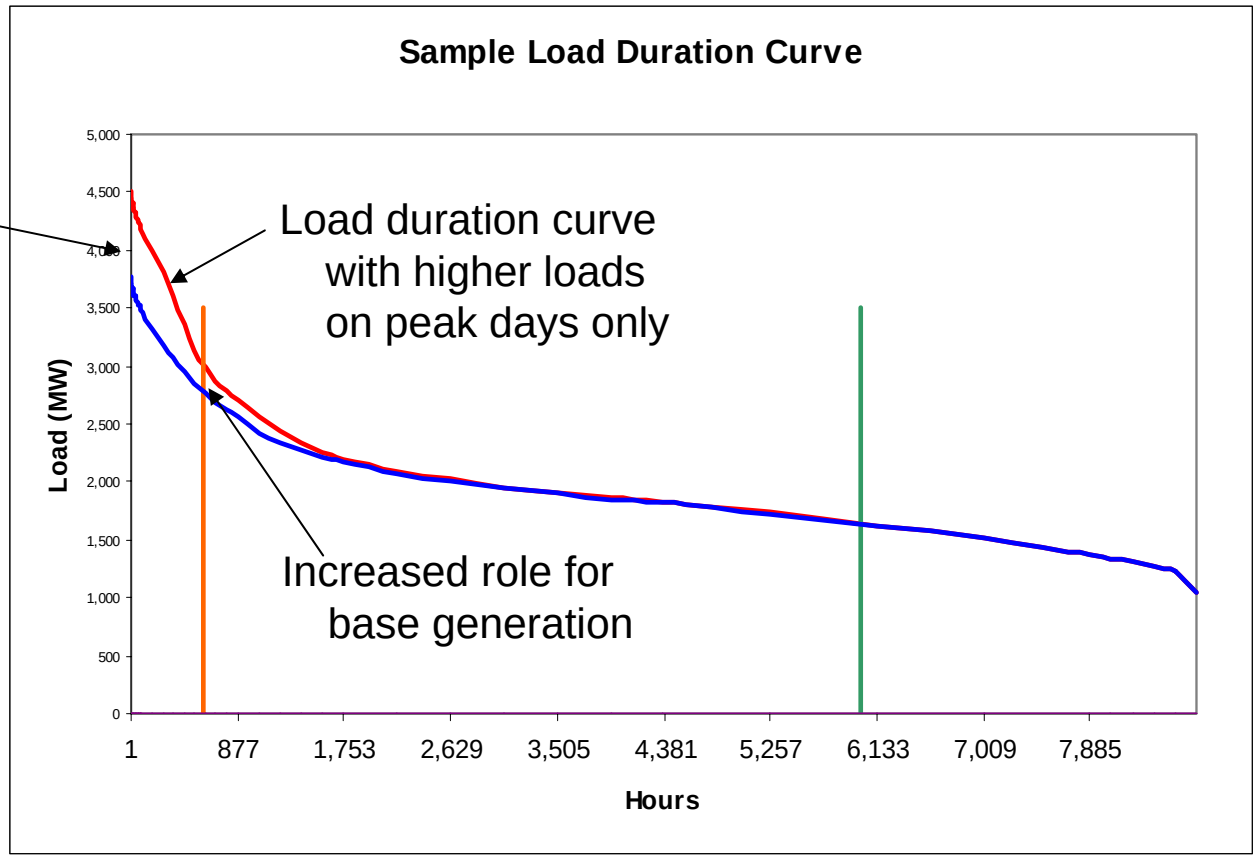
- Peaking units – gas CTs and CCs
  - Low fixed costs (capital + FO&M)
  - Higher operating costs (fuel + emissions + O&M)
  - 1-3 year lead times
  - Most economic for loads < 1,500 hours/year
- Baseload units – coal, nuclear
  - High fixed costs
  - Lower operating costs
  - 4-10 year lead times
  - Most economic for loads > 1,500 hours/year

Least-cost Generation Mix Depends on Load Shape and Generation Economics



If Temperature Increases Concentrated in Summer Season Change Least-cost Mix

Increased role for peaking generation



- Fuel price uncertainty has much larger effect on mix than climate change uncertainty

Insights

- Lead times for new generation short compared to potential temperature changes that occur gradually
- Growing power system has many opportunities to adapt to changing load patterns due to climate change
- However, identifying climate change-driven shifts in load patterns extremely difficult
- Information tracking local climate variation over time may help planners adapt to changes more effectively