National Renewable Energy Laboratory
Innovation for Our Energy Future

Flexible Nuclear Power Plants with Thermal Energy Storage

Hybrid Energy Systems Workshop

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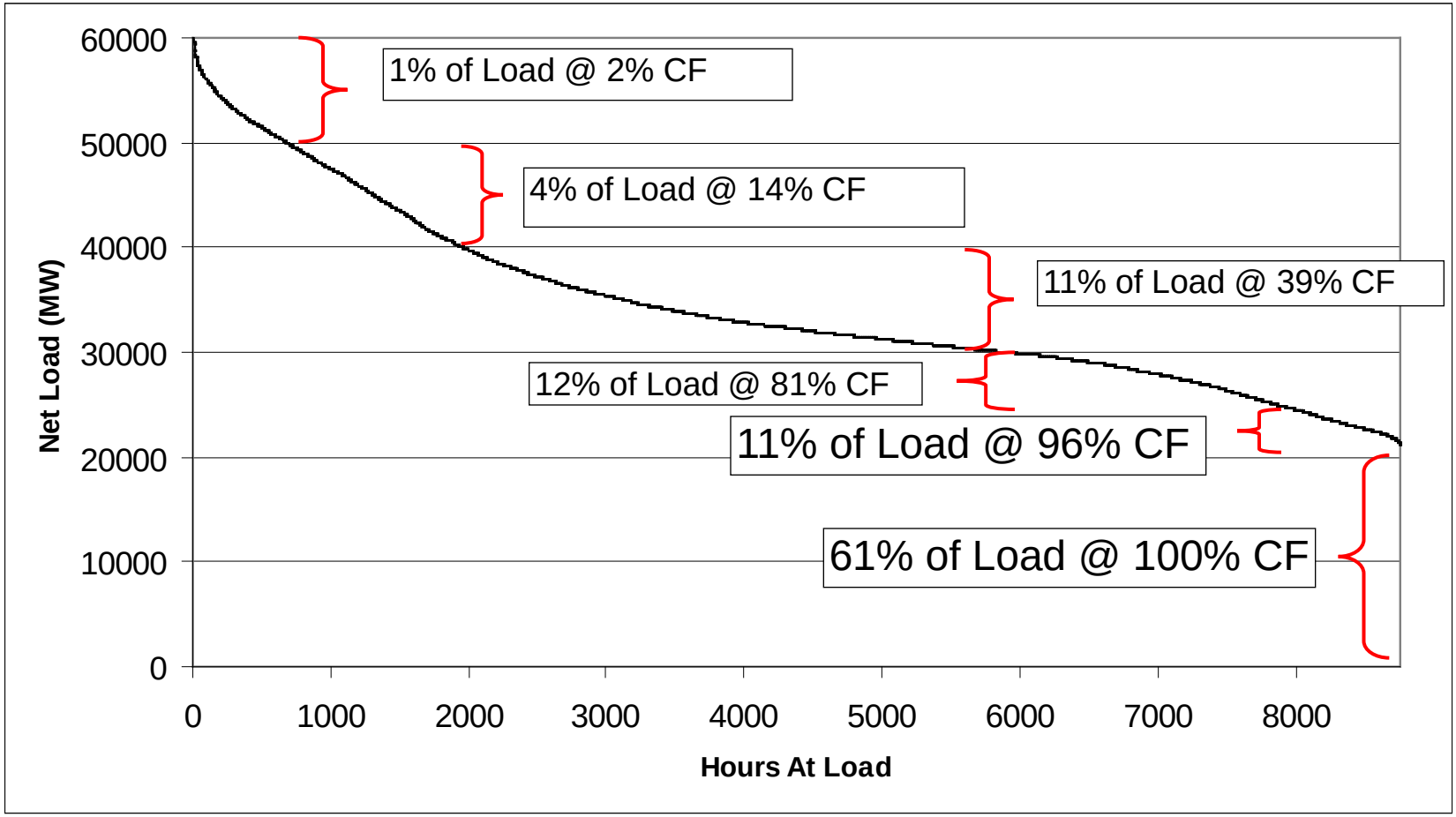
April 3, 2012

Overview

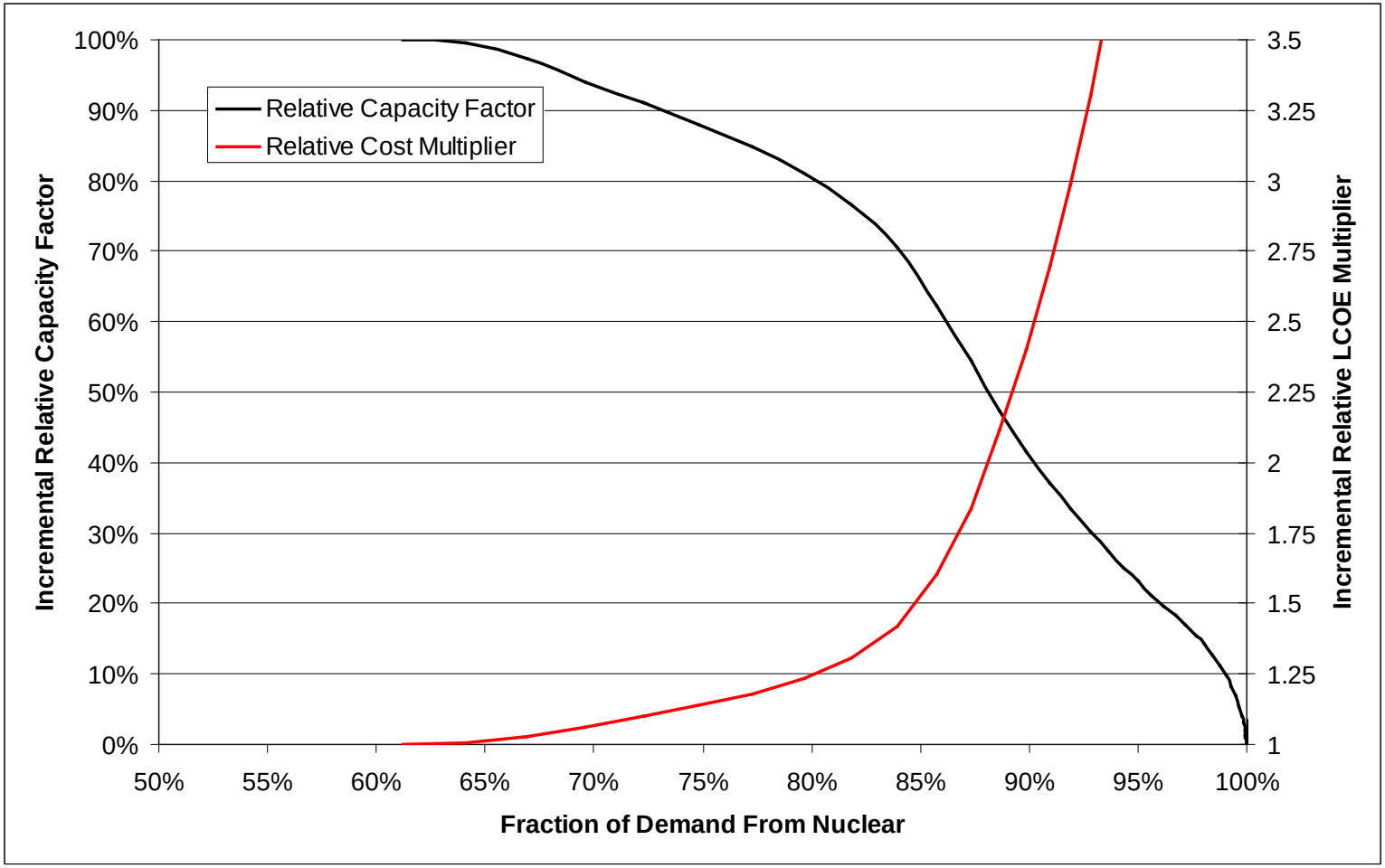
- The net load resulting from deployment of large amounts of solar and wind generation will be more variable
  - Requires more ramping and cycling of the balance of the system
- Baseload demand will be greatly reduced or eliminated
  - Capacity factor of traditional baseload plants will be reduced decreasing economic performance
- Use of thermal energy storage can increase ramping capability and increase reactor capacity factor

Why Baseload Makes Sense Now



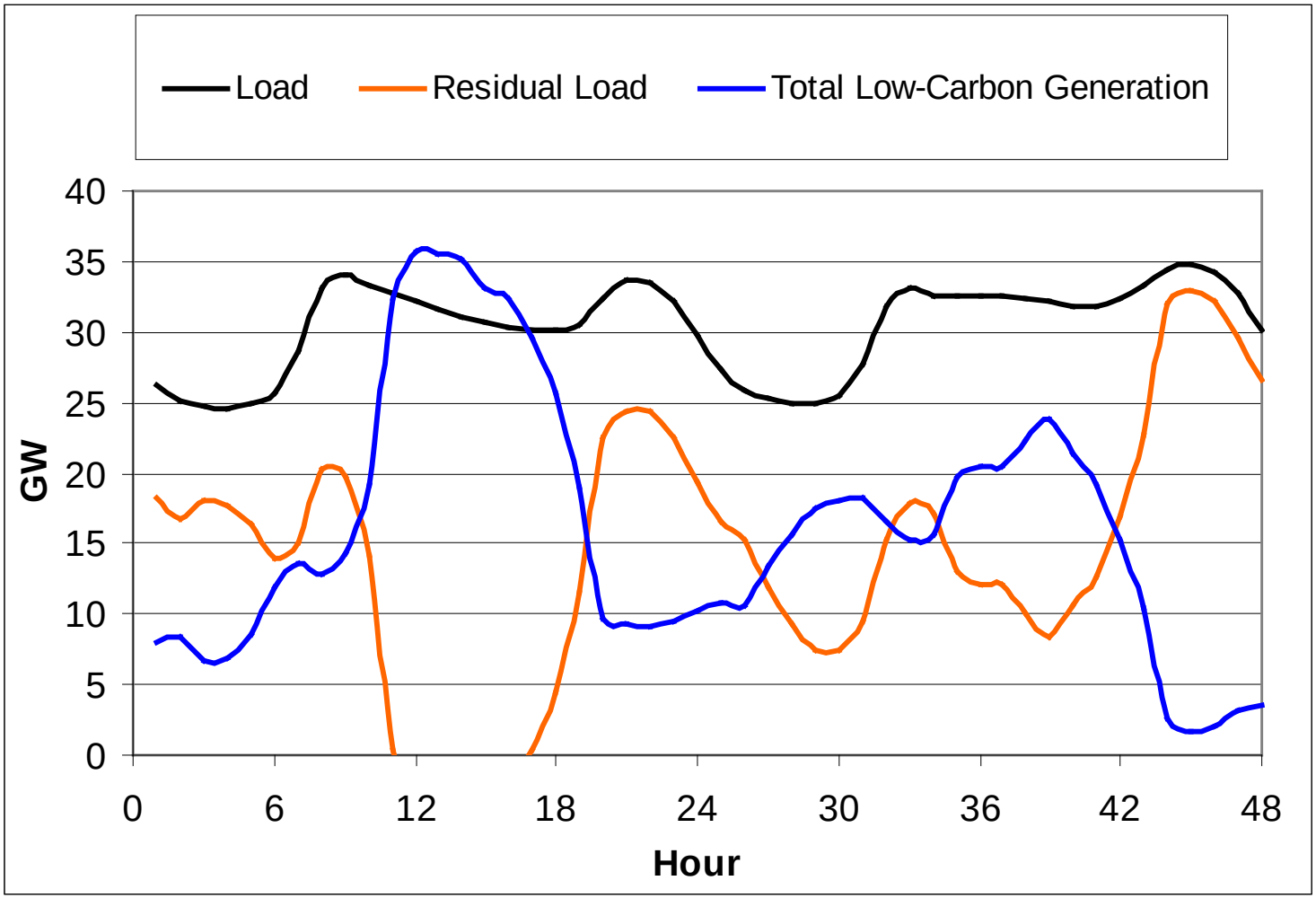
Load Duration Curve for ERCOT (2007) including Capacity Factor of Various Load Segments
>70% of total demand met by plants that can exceed >95% capacity factor

Economic Challenge of Total De-Carbonization with Nuclear Only



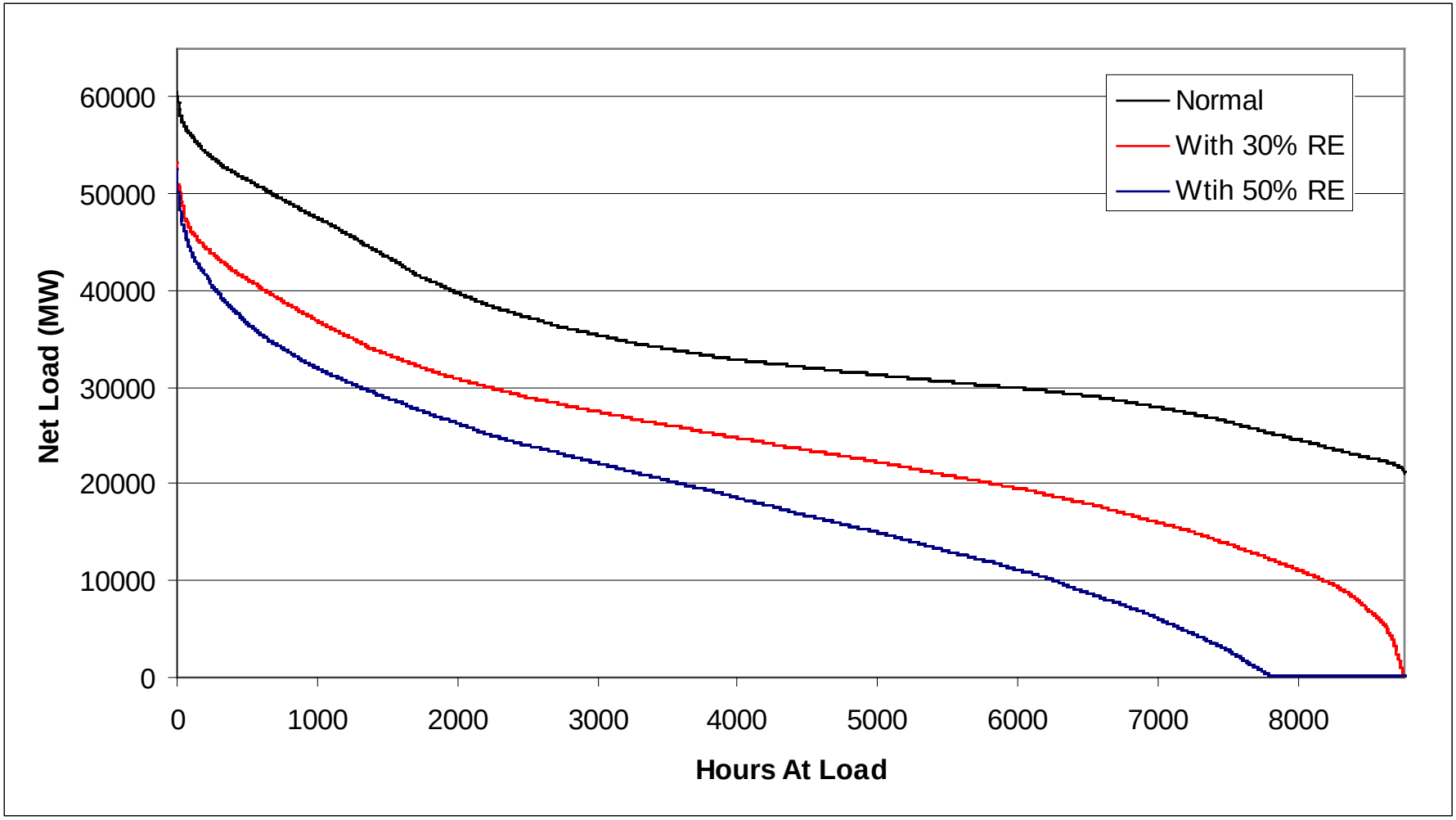
Incremental Capacity Factor and LCOE Multiplier of Nuclear Achieving De-Carbonized Scenarios

Impact of Renewables on Net Load



Two days in ERCOT (March 1-2). Renewables meets 50% of annual demand

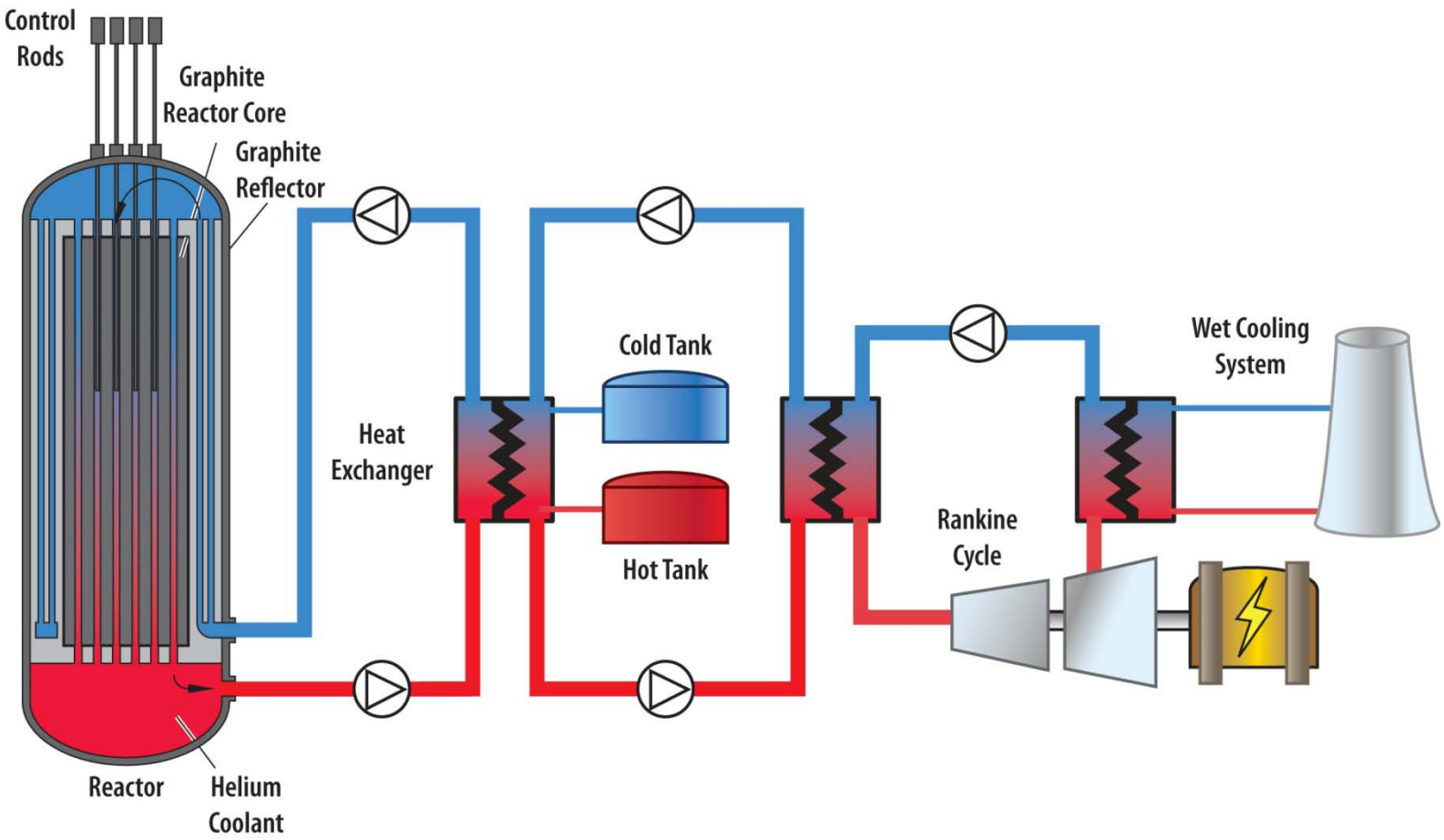
Impact of VG on Net Load Duration Curve



Nuclear Challenges and Possible Options

- Increase the ramp rates of nuclear load following
- Address the reduced capacity factor of the nuclear reactor
- Thermal storage?
  - Can shift energy to periods of high net demand
  - Can maintain nearly continuous reactor output
  - Utilize an oversized power block

Load-Following Nuclear using TES



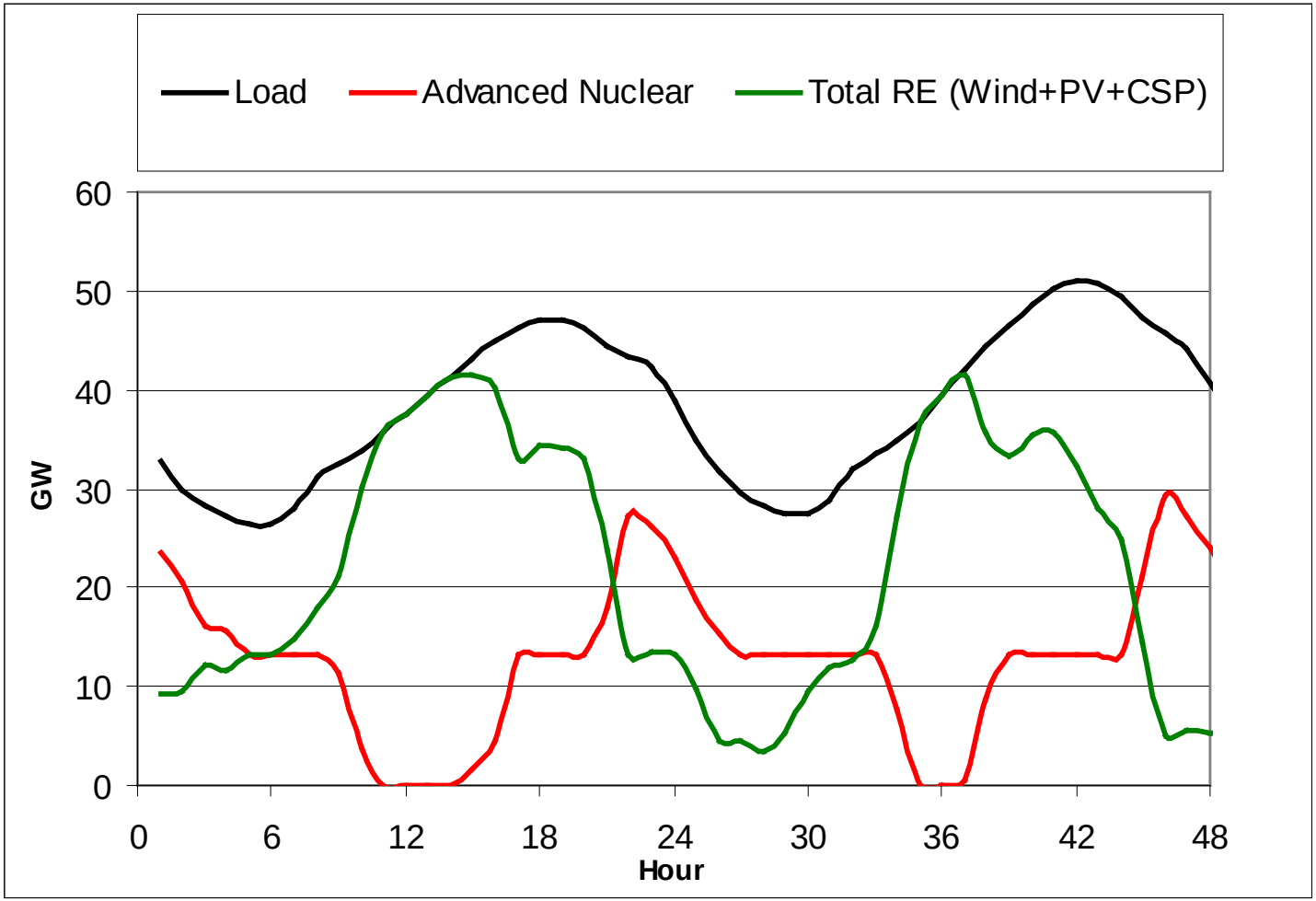
Why TES?

- High round trip efficiency (>95% in CSP plants)
  - Much higher than most electricity storage technologies
  - PHS: 72% U.S. avg, ~80% new)
  - Batteries: 60-85%
  - H2: <<50%
- Lower cost
- Big caveat – can only be used with thermal applications
  - Cant store wind, PV etc.

Simulations with REFlex

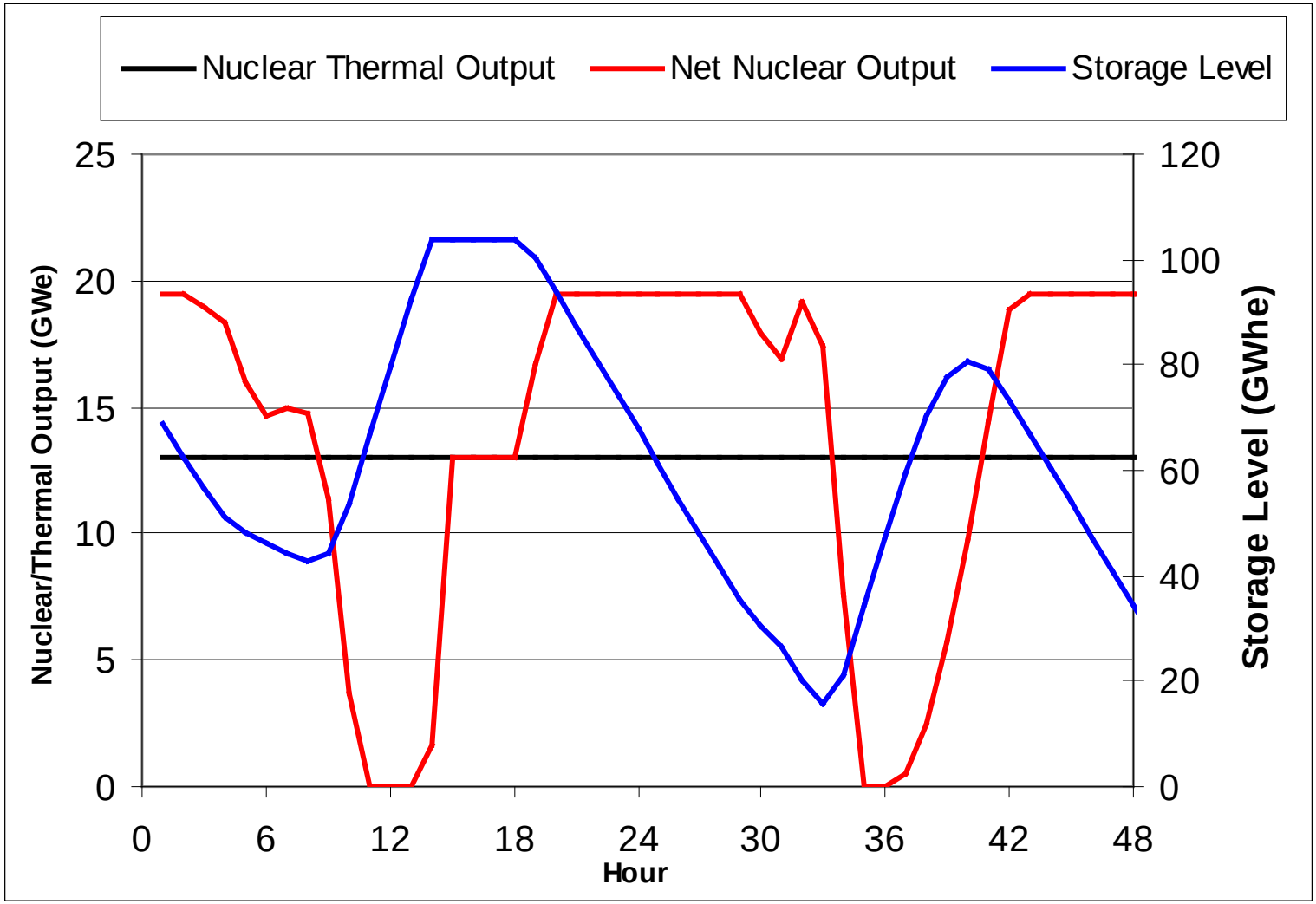
- Reduced form dispatch model
- Incorporates multiple energy storage technologies
- Identify reactor capacity factors at various penetrations
- Results for ERCOT
  - Simulation year 2005, 2006
  - Simulated wind and solar for same year

Advanced Nuclear Load Following



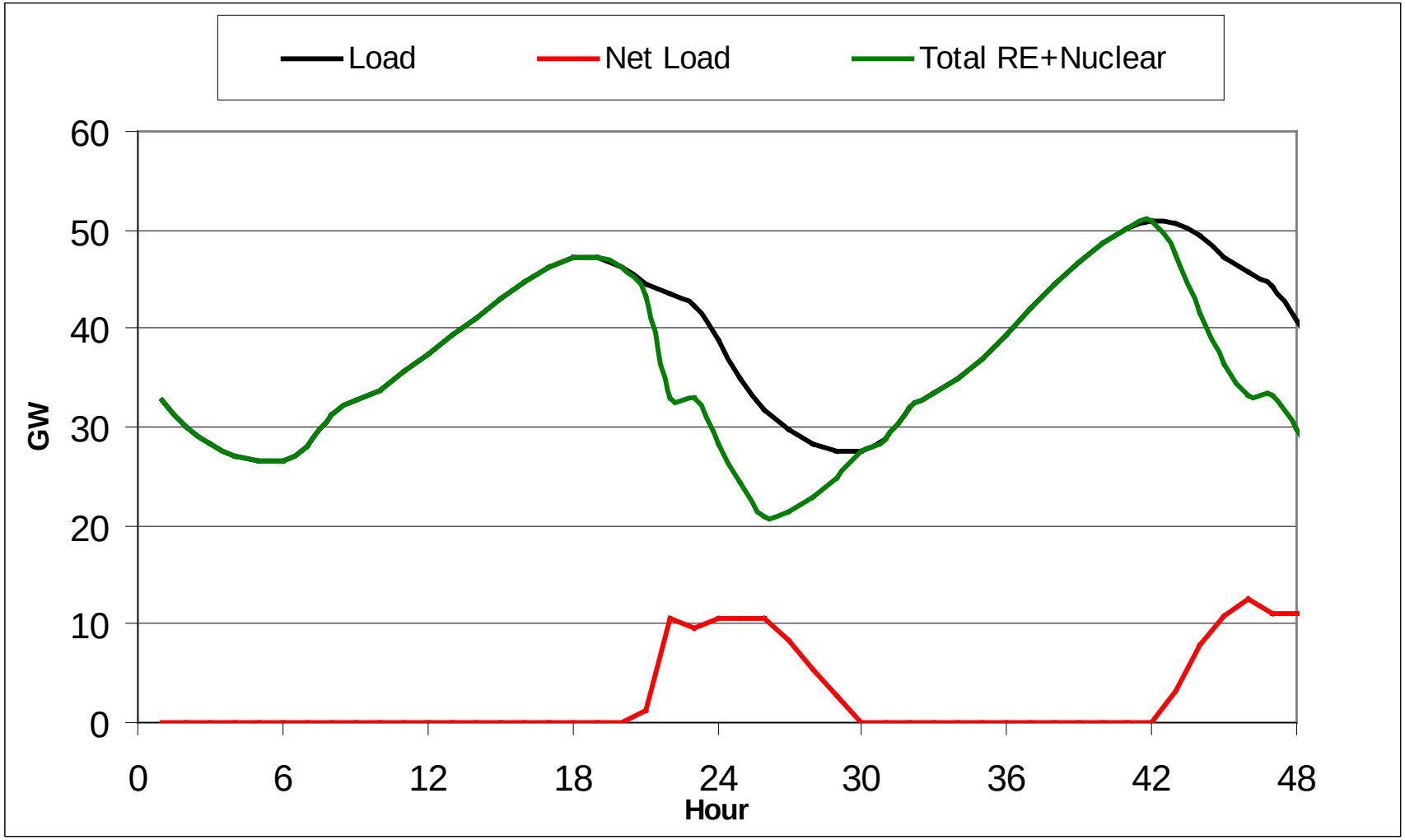
Example Output of a Nuclear/TES plant in a High VG Scenario in May

Advanced Nuclear Load Following



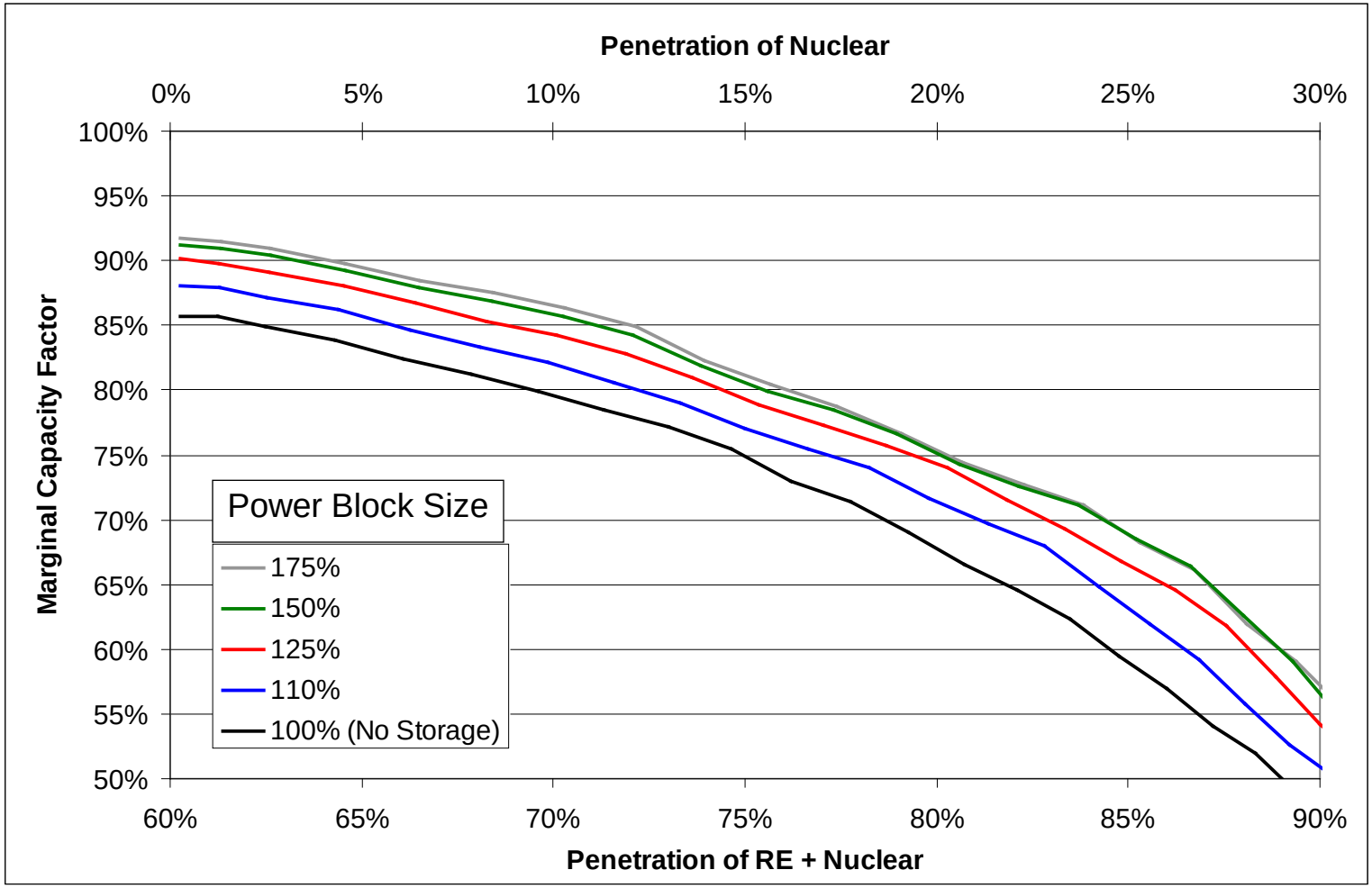
Dispatch of Thermal Energy Storage in a High VG Scenario in May

Advanced Nuclear Load Following



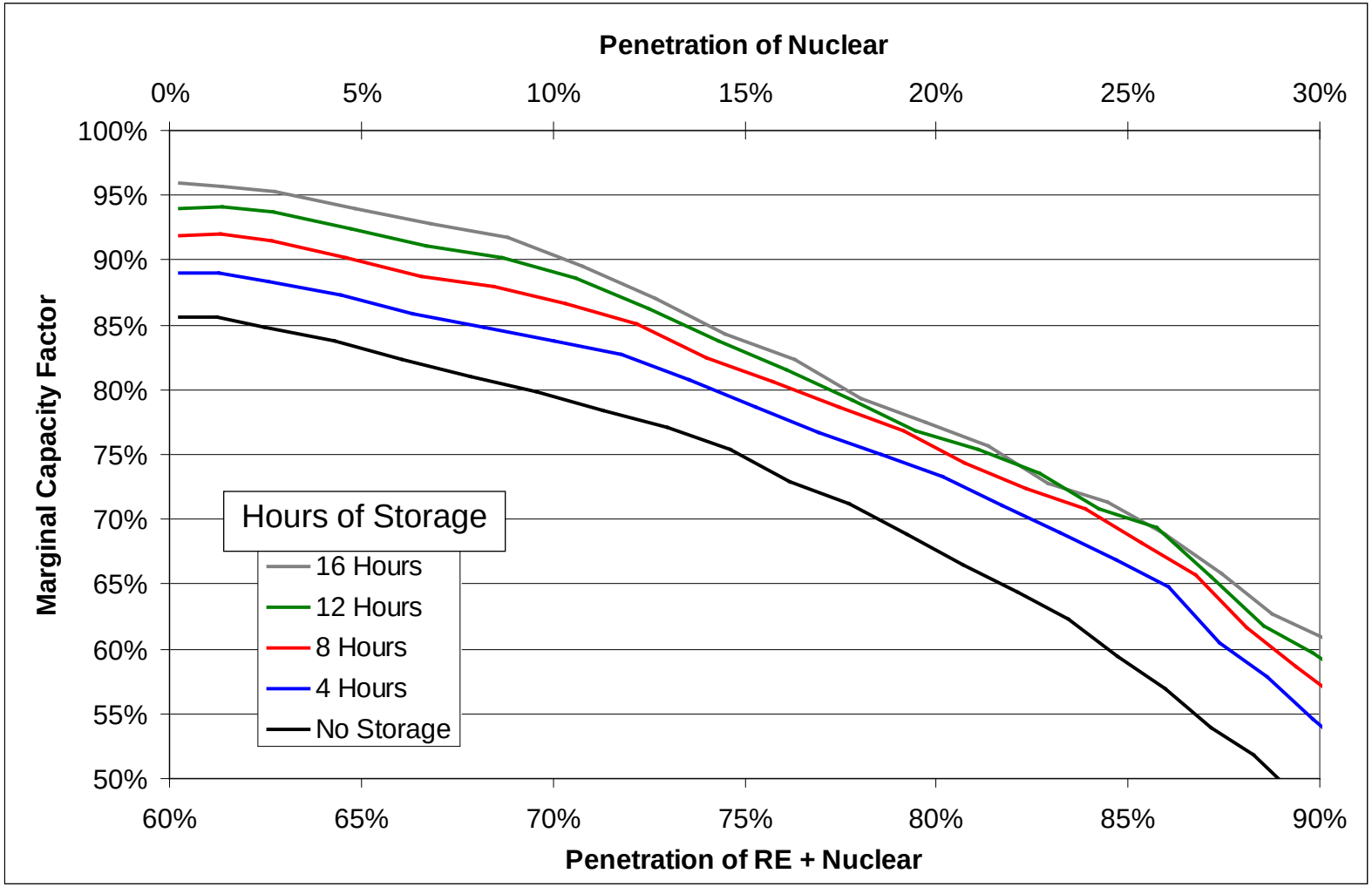
Dispatch of Renewables and Nuclear/TES in a High VG Scenario in May

Identifying Likely Configuration

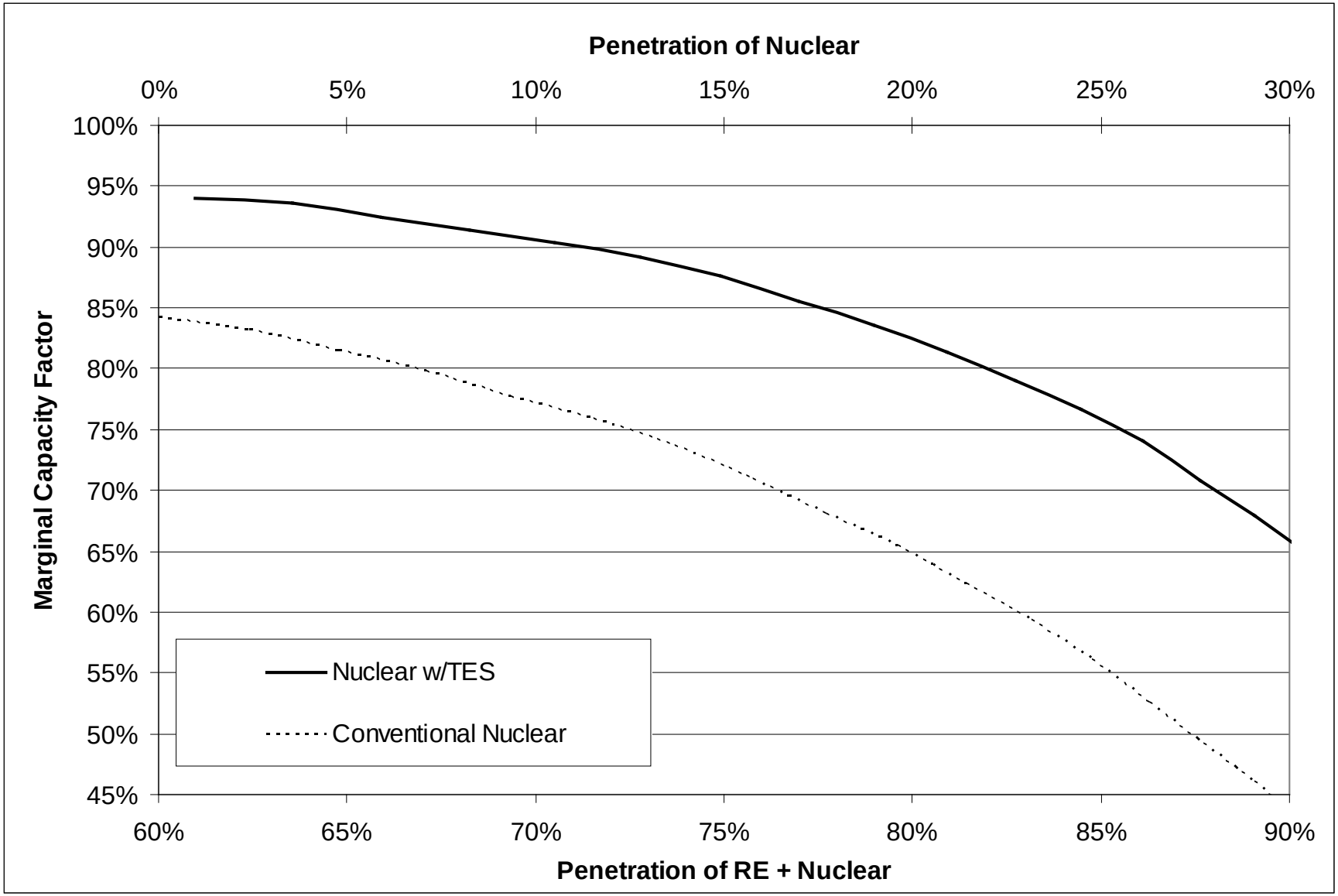


Renewables meets 60% of annual demand. The relative contribution of wind, PV, and CSP is 65%, 20%, and 15% respectively, with CSP having 8 hours of thermal storage.

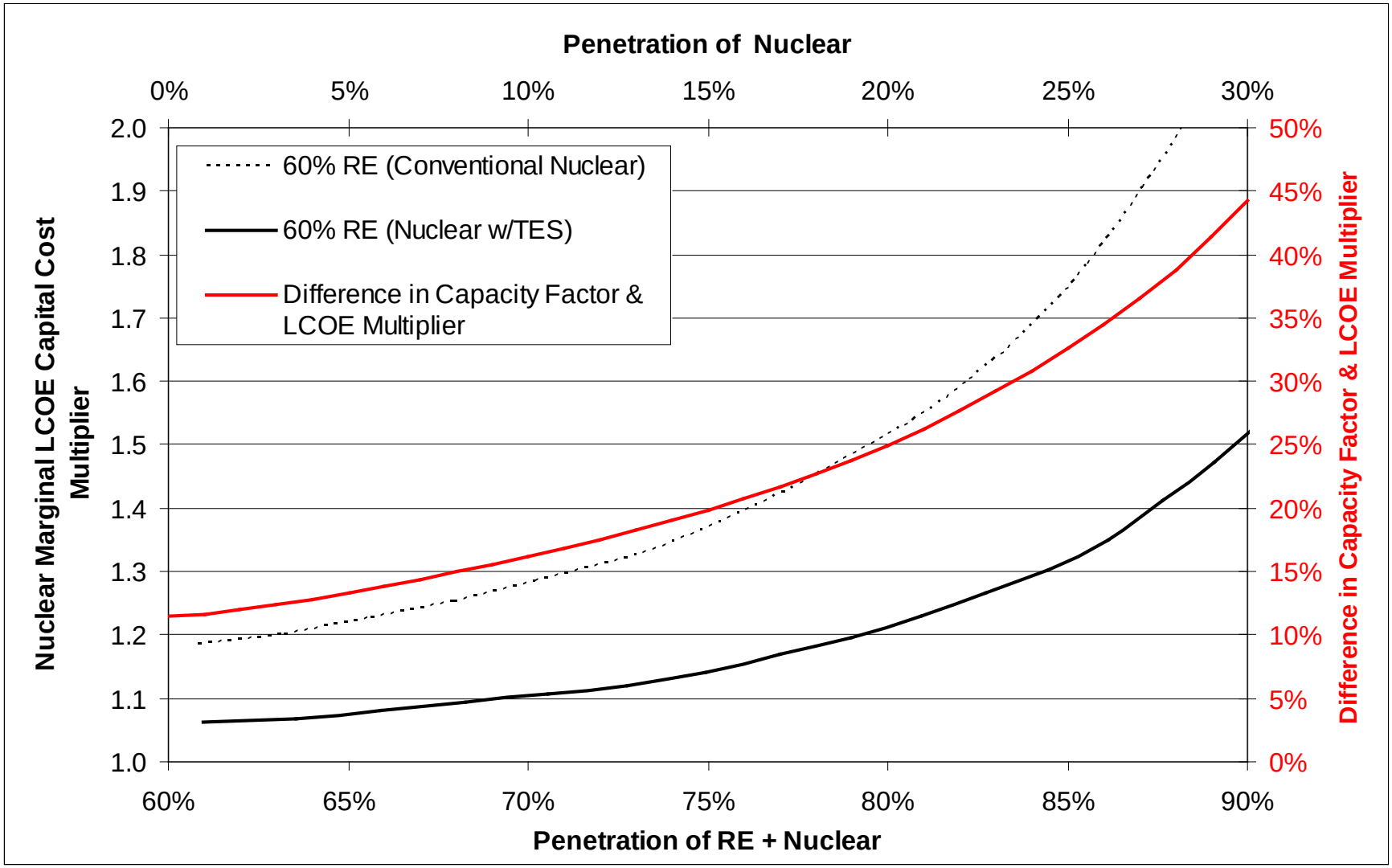
Identifying Likely Configuration



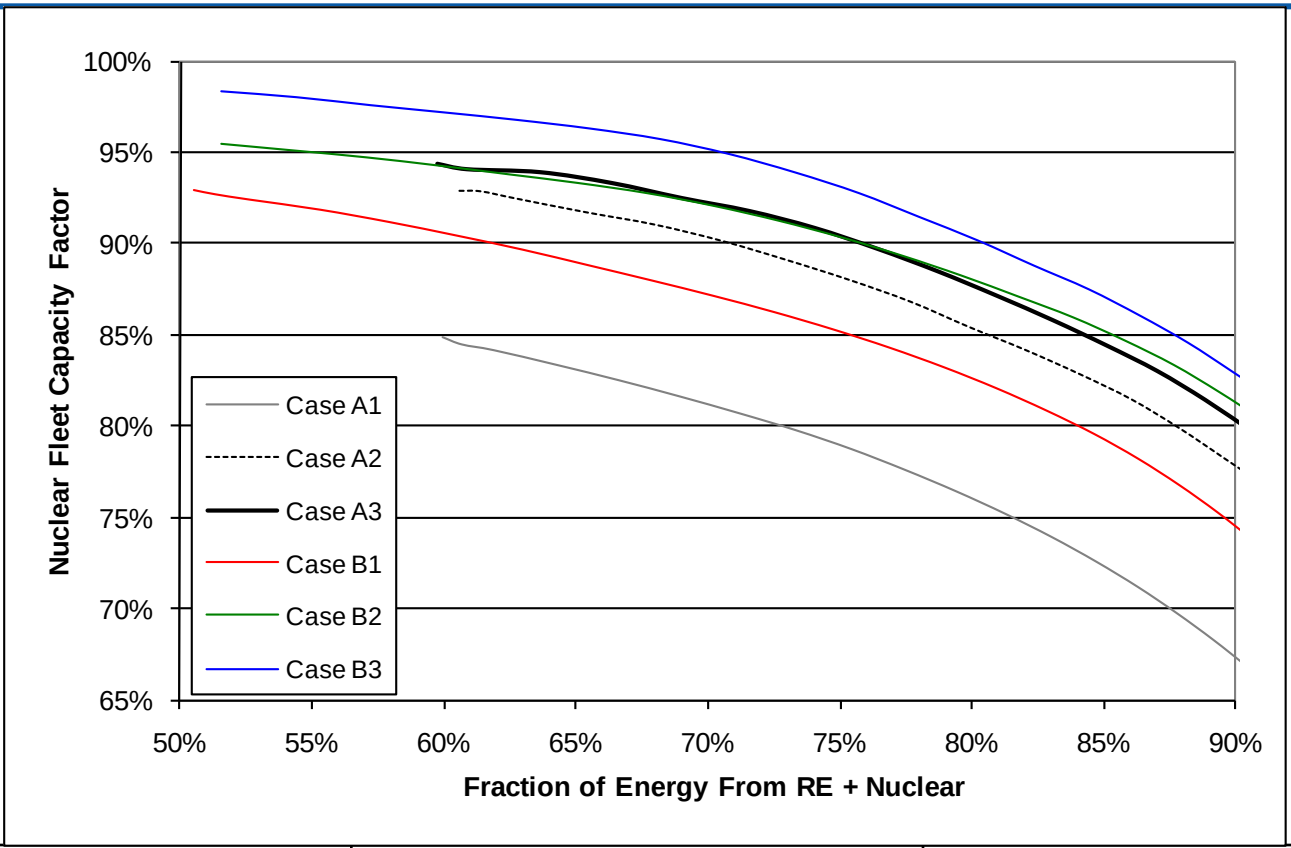
Marginal Capacity Factor



Difference in Capital Cost



Fleet Capacity Factors in High RE/Nuclear Scenarios



Case Number	% Energy From Renewables	Mix of Renewables (Wind/PV/CSP)	% Nuclear Plants w/TES
A1	60	60% / 25% / 15%	0
A2	60	65% / 20% / 15%	100%
A3	60	60% / 25% / 15%	100%
B1	50	60% / 25% / 15%	0
B2	50	60% / 25% / 15%	50%
B3	50	60% / 25% / 15%	100%

Questions?