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Lower Snake River Dams Power Supply Replacement Analysis

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Study Goals

Use long-term, production cost model to compare two policy futures:

- Meet existing policy goals assuming Lower Snake River Dams* (LSRD) are not removed.
- Meet existing policy goals with LSRD removal.

Measure impacts associated with LSRD removal:

- Generating capacity mix required to meet clean energy laws with and without LSRD.
- Compare cost, timing, and emission impacts associated with LSRD removal.

* Lower Snake River Dams: Lower Granite, Little Goose, Lower Monumental, Ice Harbor

High Level Findings

- Significant capacity additions are required to meet clean energy laws (160 GW by 2045 in WPP).
- Replacement of LSRD requires an additional 14.9 GW of new renewable capacity.
- Cost of capacity to replace LSRD: $15 Billion NPV.
- If you double historical installation rates, clean energy targets cannot be met unit late 2050's to 2070's.
- Replacement capacity for LSRD is in addition to capacity required to meet existing laws. Replacing LSRD would further delay meeting clean energy laws by 3 to 5 years.
- Removal of LSRD in 2030 would result in increased carbon emissions until replacement resources are built in the 2050's to 2080's timeframe.

Approach

Clean Energy Targets

State	Target	Year
California	100%	2045
Colorado	100%	2040
Nevada	100%	2050
New Mexico	100%	2045
Oregon	100%	2040
Washington	100%	2045

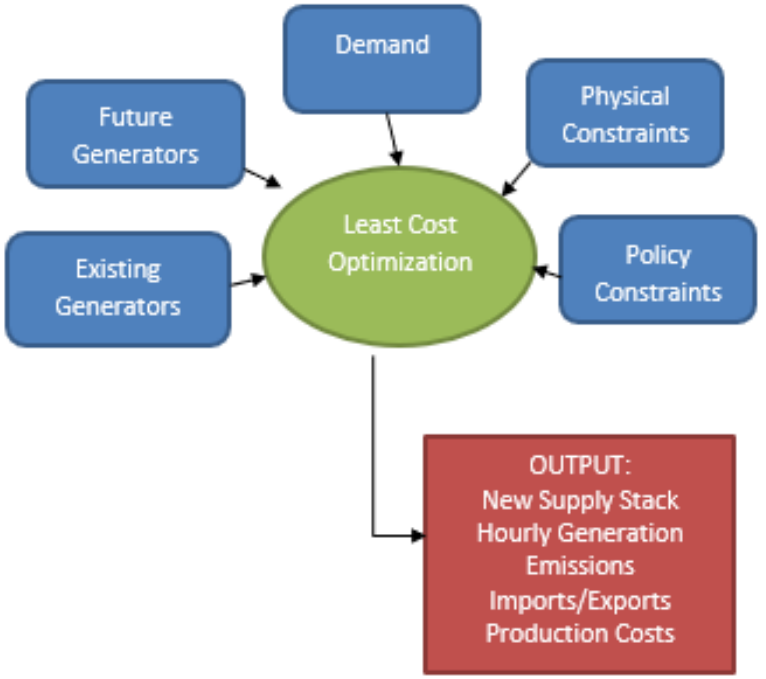
All policy goals implemented in model as Renewable Portfolio Standard, thereby less stringent in each case.

Linear glide path used for implementation from current state to future policy compliance

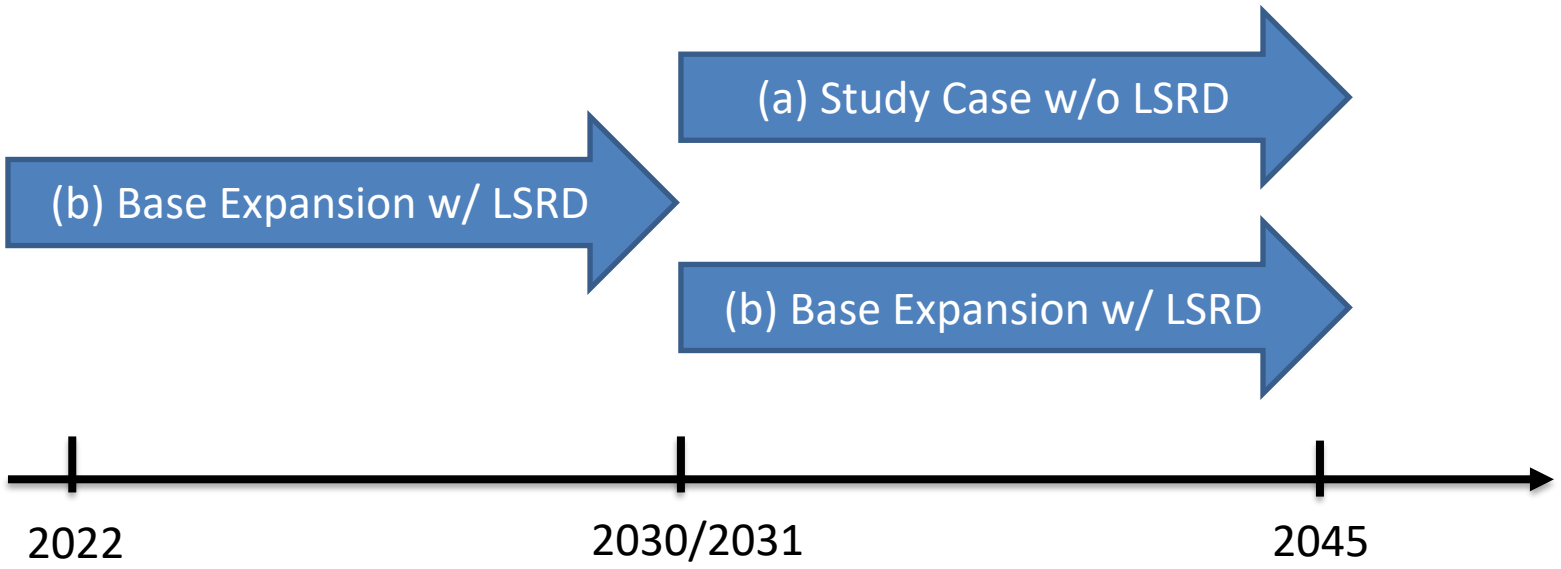
Additional annual emission constraint applied in Oregon and Washington

Production Cost Model

- Zonal Least Cost Optimization
  - Least cost solution to meet load subject to constraints such as:
    - Planning Reserve Margin (PRM)
    - Zonal transmission constraints
    - Renewable goals
    - New generator options
  - Widely used throughout the industry
    - PSEI, PGE, etc. use same commercial software (i.e., Aurora)



Study Approach



Impact of Removing LSRD = (a) – (b)

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“Pool” Topology for Capacity Sharing

- WECC wide model with five pools where:
  - Min. PRM defined
  - Commitment decisions
- Captures WRAP capacity sharing program
- Matches NERC reliability regions

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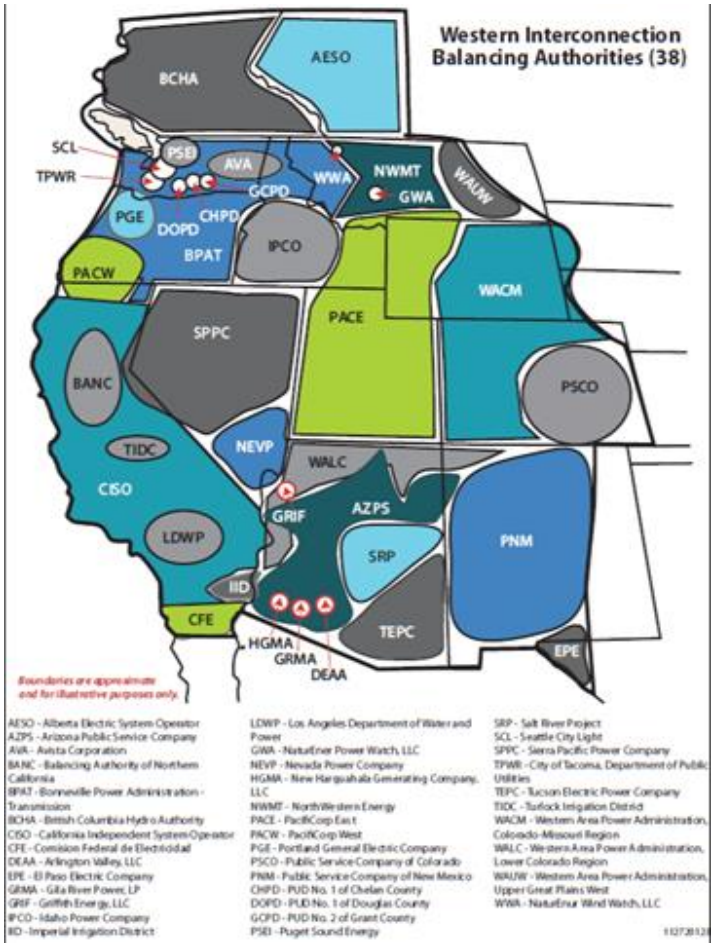
“Zone” Topology for Energy



- 41 zones broadly representing each Balancing Authority
- Transmission limits applied between zones
- Additional granularity in PNW separating East/West WA/OR; PacifiCorp East, and California

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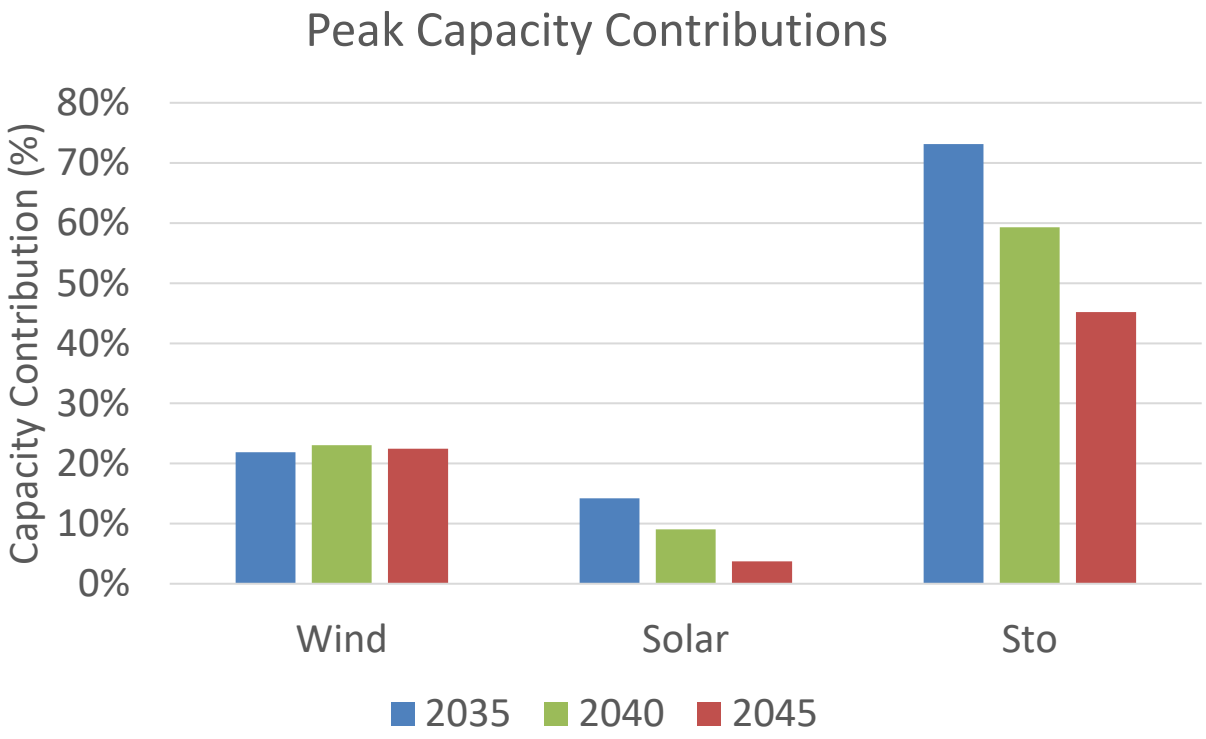
Generator Candidate Options

Region-Technology	Size (MW)	Duration (hr)	Capacity Factor (%)	2023 Cost ($/kW)
West-Solar	100	-	16%	1,508
East-Solar	100	-	24%	888
East-Wind	150	-	35%	1,237
MT-Wind	150	-	40%	1,237
West-Storage	100	4	-	1,147
East-Storage	100	4	-	1,147
Hybrid Solar + BESS	100	4	-	1,306

Source: EGPS, NREL ATB - https://atb.nrel.gov/; EIA AEO

Notes: Declining cost curves applied in modeling;
Costs reflect ITC on solar and qualifying hybrid units.

Peak Capacity Credit



Notes: Wind/Solar peak credit determined by actual output in top 100 hours during simulation;
Storage peak credit specified as input based on capacity additions;
Peak capacity contribution sets the amount of capacity that can reliably serve the peak load.

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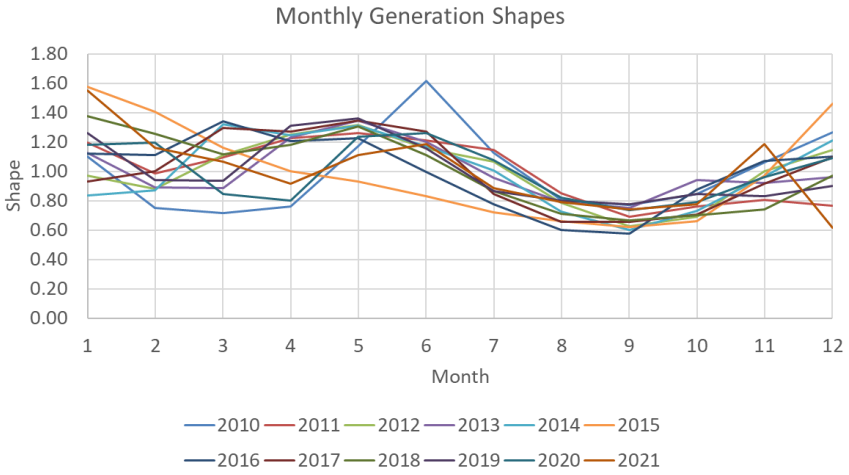
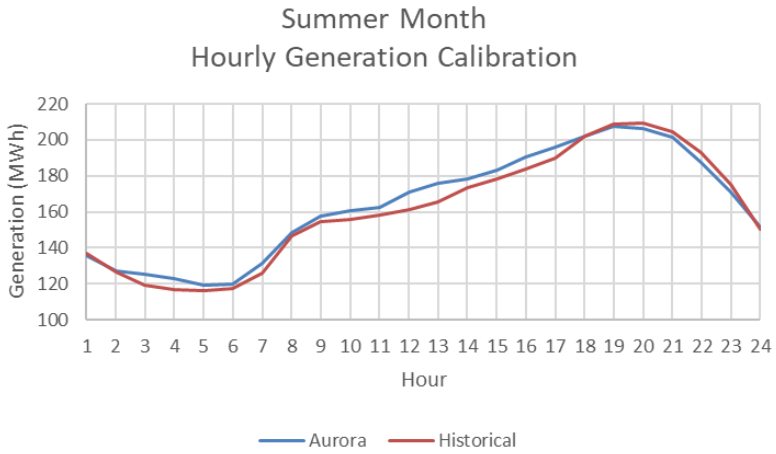
Hydro Modeling

- Calibrated to 60-dam, historical hourly hydro production dataset in the PNW
  - Total annual generation based on 2020 actual production which was 100% of normal
  - Parsed annual generation into normal monthly generation by selecting a normal month for each month using data from the 2010 to 2021 time period.
  - Shape hourly generation based on shaping factors from historical hourly production (2018-2021)
- Outside PNW forecast is based on EIA 923





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Representation of LSRD

- Lower Snake River Dams Characteristics:
  - Nameplate capacity: 2900 MW†
  - Peaking capacity: 1844 MW*
  - Annual generation: 6,672 GWh
  - Monthly shaping: Selected normal month from 2010-2021 time period.
  - Hourly shaping: calibrated to 2018-2021

† Based on EIA

* This is the estimated Effective Load Carrying Capability or Net Qualifying Capacity.

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Study Differentiators

Input Assumption	EGPS; 2022	E3; 2022	Energy Strategies, 2022
Clean Energy Laws	100%	100%	NA, historical
Load Growth	P50, BAU	Electrification	NA, historical
Peaking Capacity of LSRD	1,844 MW	2,300 MW	1,000 MW
Market Purchases for Capacity	NA	NA	Allowed
Footprint / Dispatch	WECC	WECC	NA, one-for-one capacity
Cost of new Regional Transmission	No	Yes	No
Emerging Technologies	No	Yes†	No
Battery ELCC	80% declining to 50%	<10%‡	100%

† Most comparable scenario to this study includes off-shore wind

‡ At over 5 GW battery penetration

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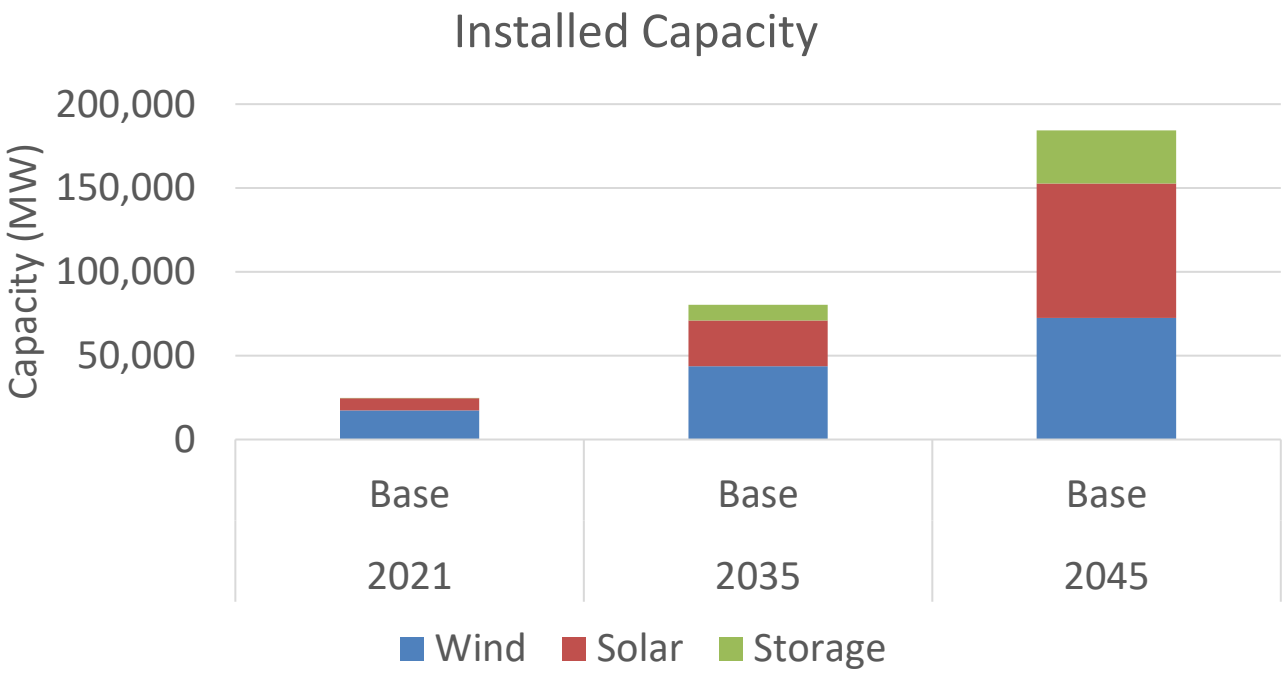
Results and Discussion

Capacity Mix (with LSRD) in WPP



160 GW of new capacity additions in WPP by 2045

- 55 GW new wind
- 73 GW of new solar
- 32 GW new battery storage

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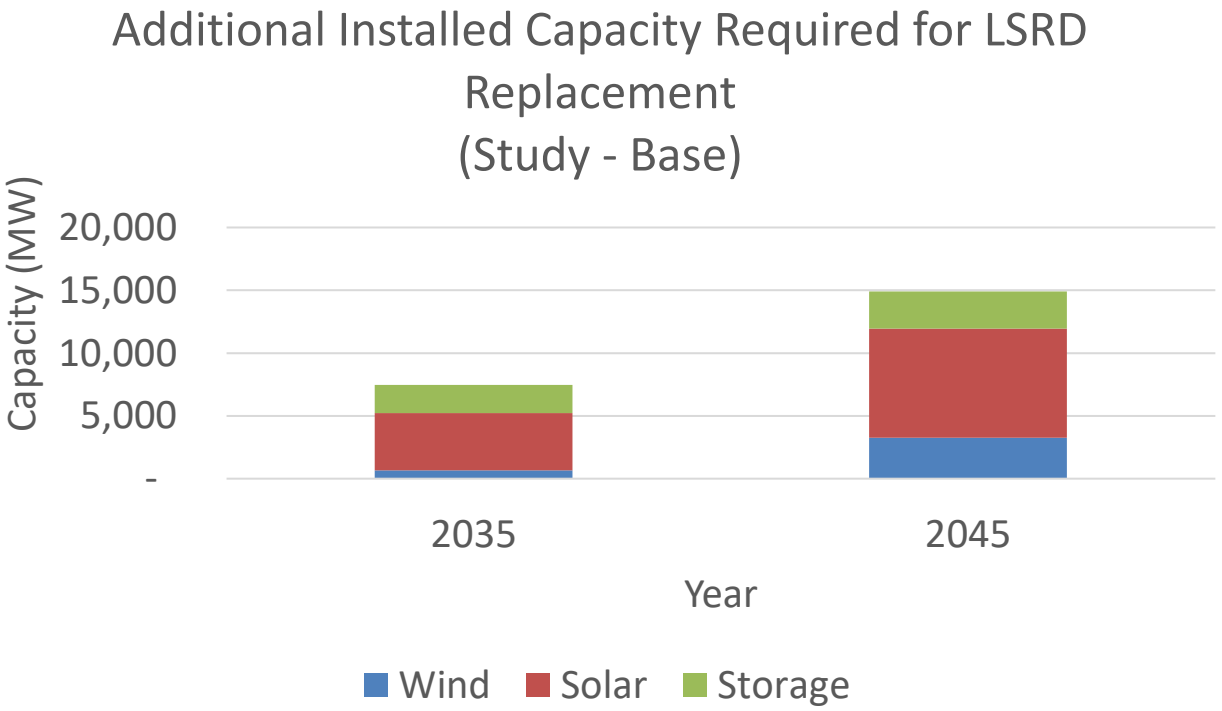
Replacement Capacity



14.9 GW of new capacity additions to replace LSRD by 2045

- 3.3 GW new wind
- 8.7 GW of new solar
- 2.9 GW new battery storage

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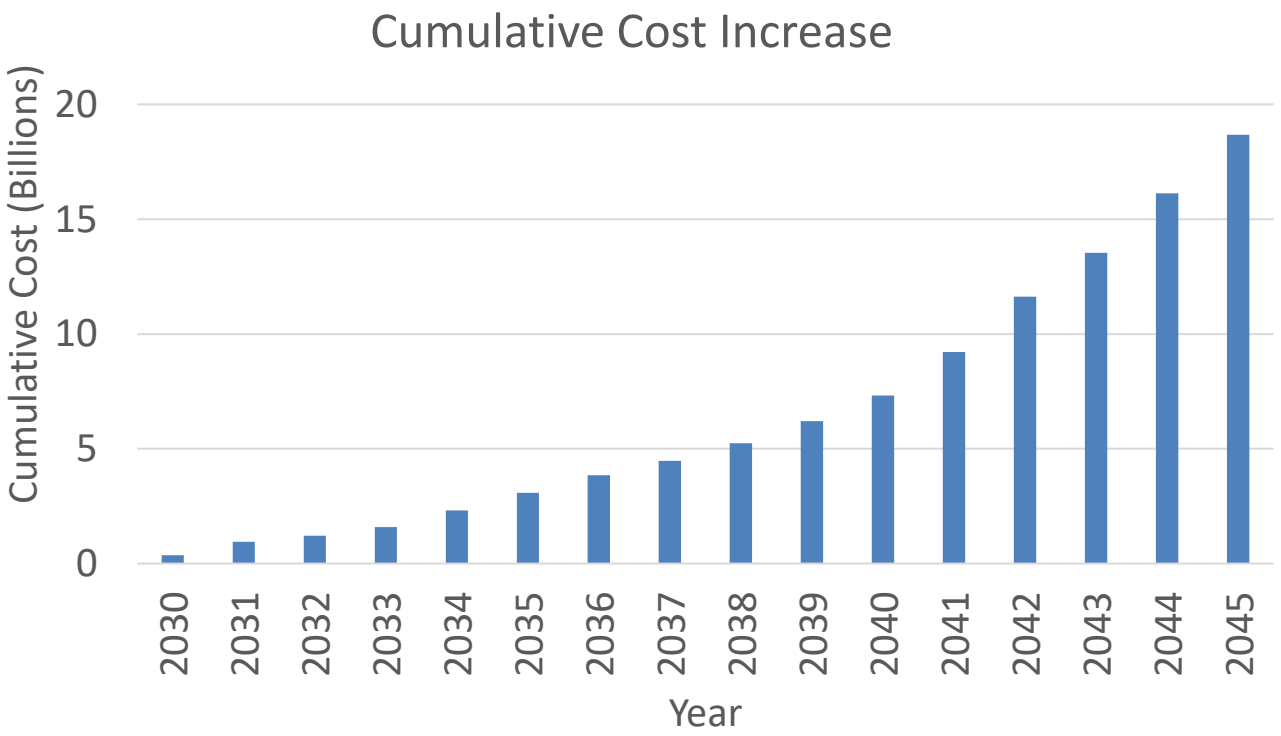
Replacement Costs



$19 Billion Nominal / $15 Billion NPV costs to replace LSRD from 2030 to 2045

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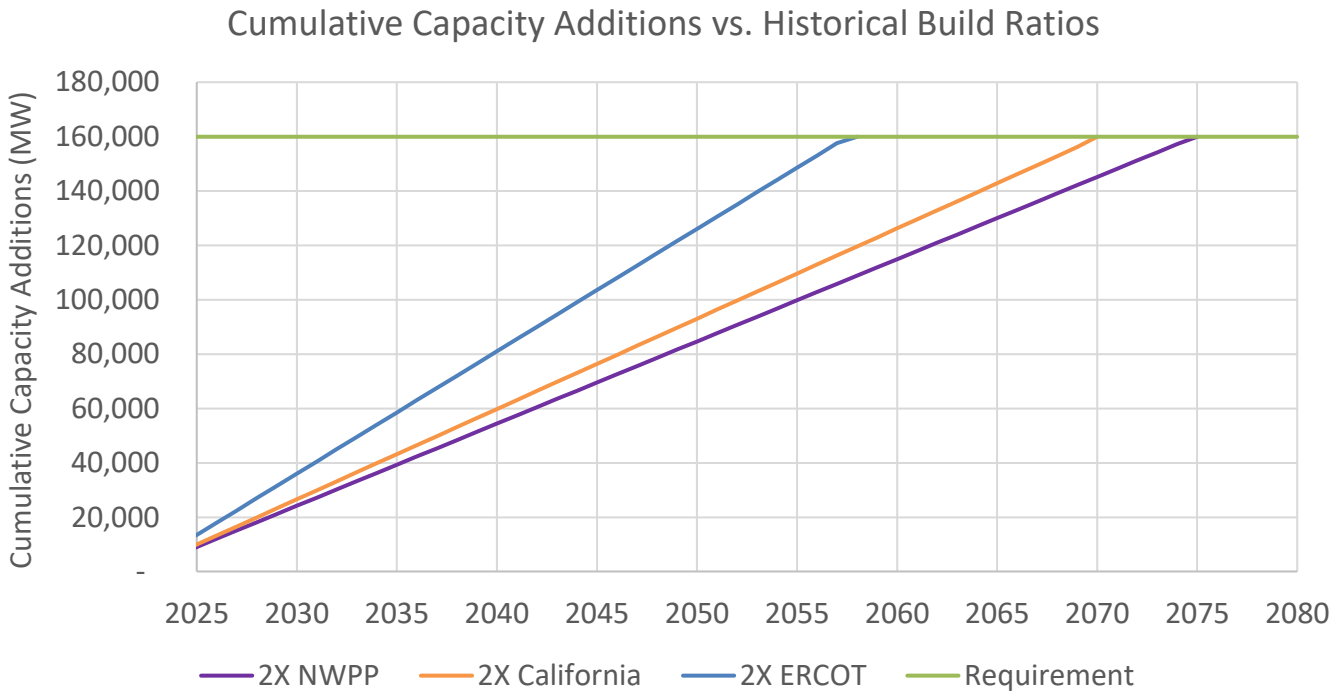
Delay in Meeting Clean Energy Laws



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Delay in Meeting Clean Energy Laws

Annual Average Renewable Capacity Additions in WPP to meet Study Case			
	Using WPP Historic Buildout Pace	Using CA Historic Buildout Pace	Using ERCOT Historic Buildout Pace
Annual average renewable capacity additions from 2007 – 2021 (MW)	1512	1661	2326
Estimated achievement of clean energy laws if double the historic pace of capacity additions (Year)	2076	2071	2057
Added emissions due to delay (MMT)‡	136	114	55
Estimated achievement of clean energy laws and replacement of LSRD if double the historic capacity additions (Year)	2081	2076	2060
Added emissions due to delay for replacement of LSRD (MMT) ‡	8.5	8.5	5.1

‡Based on average emission rate from 2030 to 2045

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Study Assumptions Which Understate Replacement Capacity and Costs

- Load growth will likely be higher.
  - Electrification is very likely to cause higher load growth
- Capacity contribution of LSRD may be higher.
  - WPP WRAP estimates of peak capacity contribution for hydro is likely higher than the 1844 MW modeled.
- Capacity contribution of batteries may be over-stated.
  - Battery peak capacity contribution is likely lower than assumed in this study.
- Cost of new regional transmission
  - E3 found a significant cost driver and uncertainty was cost of new regional-scale transmission
  - We did not consider regional transmission expansion and associated costs

Study Assumptions Which Overstate Replacement Capacity and Costs

- New generating technology
  - Not-yet commercial technology such as off-shore wind, hydrogen, small nuclear reactors were not considered.

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Thank you