A Bulk Energy Storage Resource Case Study with 40% RPS in 2024

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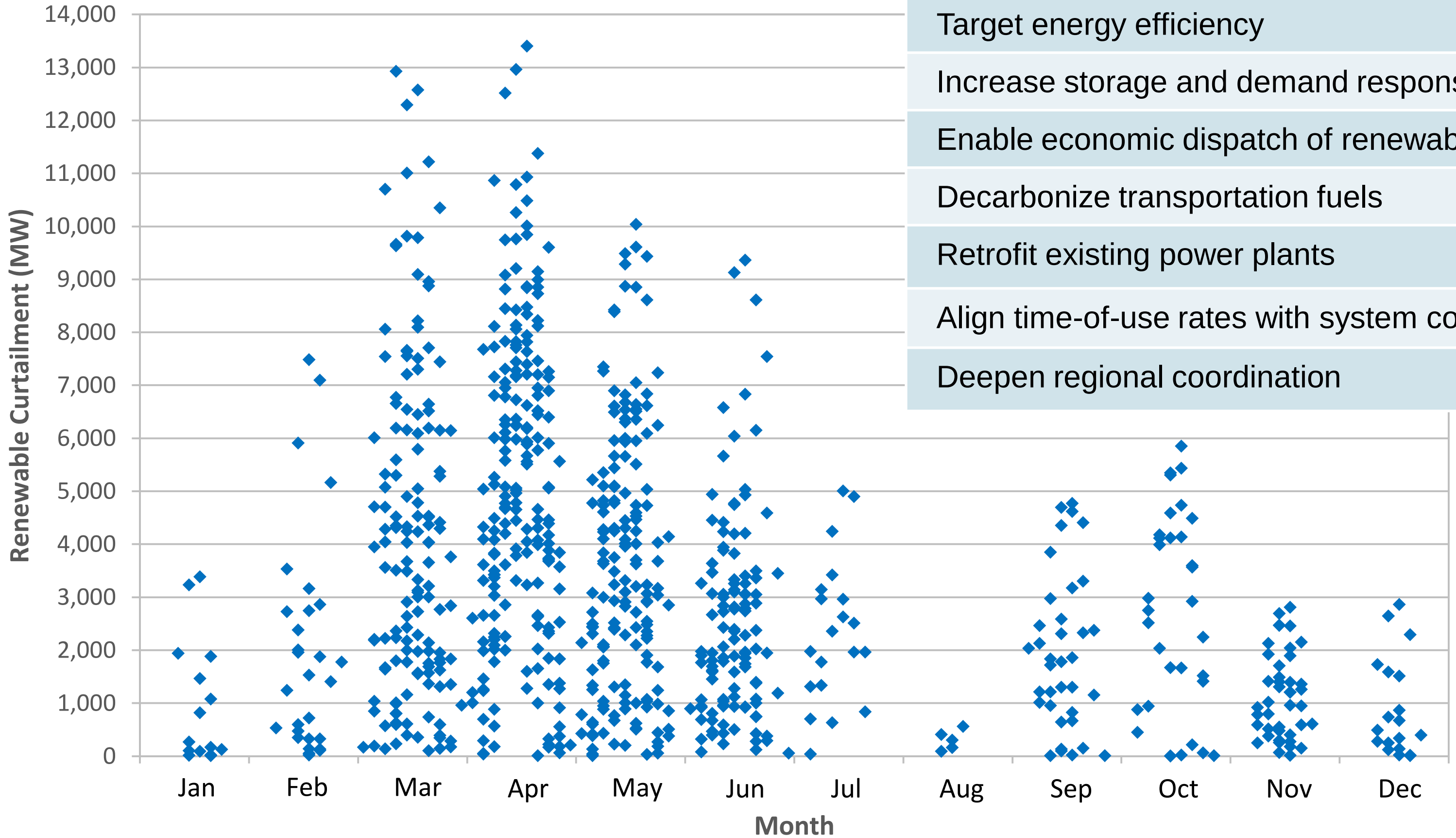
About the ISO bulk energy storage case study

- The study follows the CPUC 2014 Long-Term Procurement Plan (LTPP) Planning Assumptions and Scenarios
- In 2014 LTPP, the ISO studied four scenarios and one sensitivity
  - Trajectory scenario
  - High Load scenario
  - Expanded Preferred Resources scenario
  - 40% RPS in 2024 scenario
  - Trajectory without Diablo Canyon sensitivity case

The 2014 LTPP study identified large quantity of renewable curtailment in the 40% RPS scenario.



Solutions
Target energy efficiency
Increase storage and demand response
Enable economic dispatch of renewables
Decarbonize transportation fuels
Retrofit existing power plants
Align time-of-use rates with system conditions
Deepen regional coordination

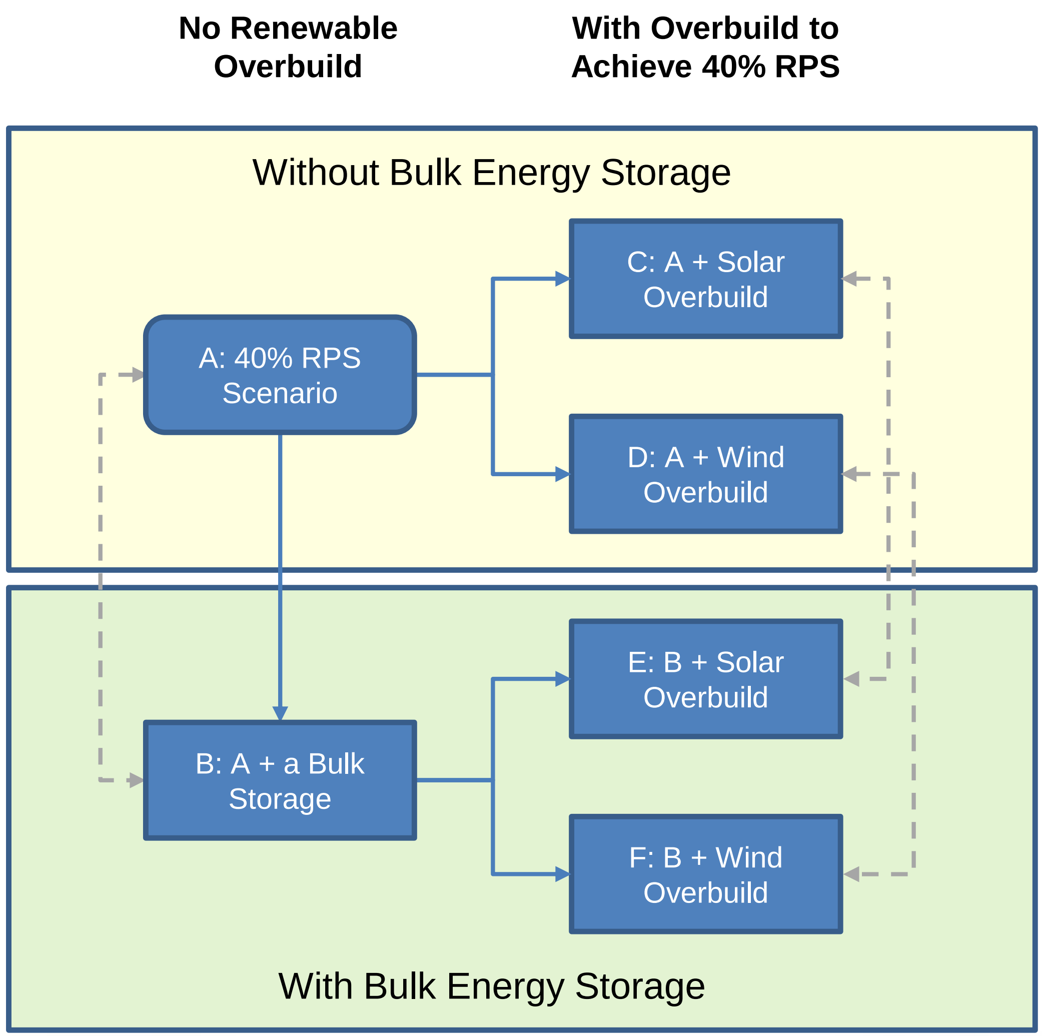
Purpose of the ISO bulk energy storage case study

- To explore solutions to curtailment of large quantity of renewable generation
- To assess a bulk storage resource's ability to reduce
  - production cost
  - renewable curtailment
  - CO_2 emission
  - renewable overbuild to achieve the 40% RPS target
- To analyze the economic feasibility of the bulk storage resource

Study approach

- Based on the 2014 LTPP 40% RPS in 2024 Scenario with renewable curtailment remaining unlimited
- Analyses compare two renewable build baselines, with and without the new bulk storage resource:
  - No overbuild of renewable resources
  - Overbuild renewables to achieve the 40% RPS target
- Overbuild of renewable with solar or wind
  - Demonstrate the benefits of more diversified RPS portfolios

Definition of the study cases and expected takeaways



This study quantifies

- reduction of production cost, renewable curtailment and CO2 emission,
- quantity and cost of renewable overbuild
- cost and market revenue of the bulk storage resource

It does not quantify

- transmission impact

Assumptions of the new pumped storage resource

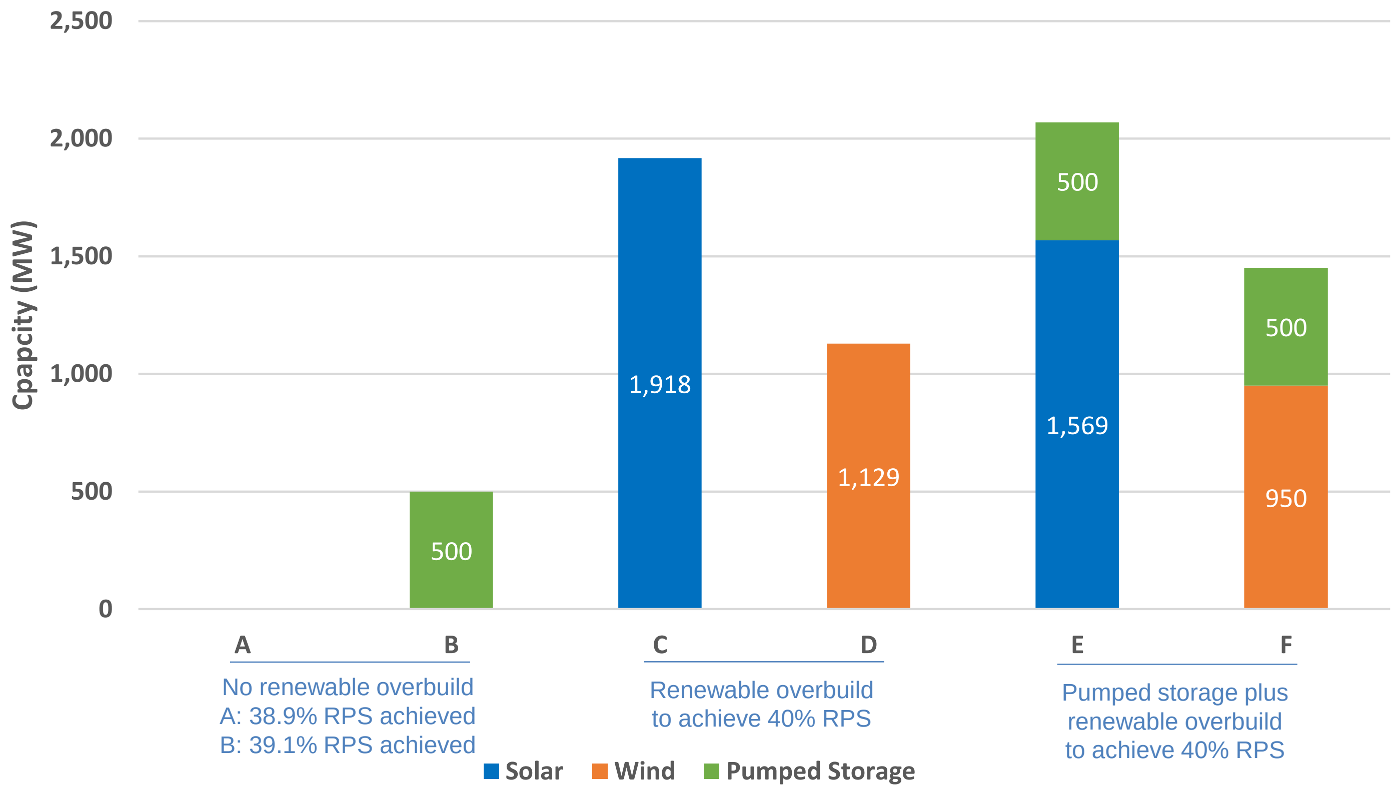
Item	Value
Number of units	**2**
Max pumping capacity per unit (MW)	**300**
Minimum pumping capacity per unit (MW)	75
Maximum generation capacity per unit (MW)	**250**
Minimum generation capacity per unit (MW)	5
Pumping ramp rate (MW/min)	**50**
Generation ramp rate (MW/min)	**250**
Round-trip efficiency	**83%**
VOM Cost ($/MWh)	**3**
Maintenance rate	8.65%
Forced outage rate	6.10%
Upper reservoir maximum capacity (GWh)	8
Upper reservoir minimum capacity (GWh)	2
Interval to restore upper reservoir water level	Monthly
Pump technology	**Variable speed**
Reserves can provide in generation and pumping modes	**Regulation, spinning and load following**
Reserves can provide in off modes	**Non-spinning**
Location	Southern California

Assumptions of revenue requirements and RA revenue of the new resources

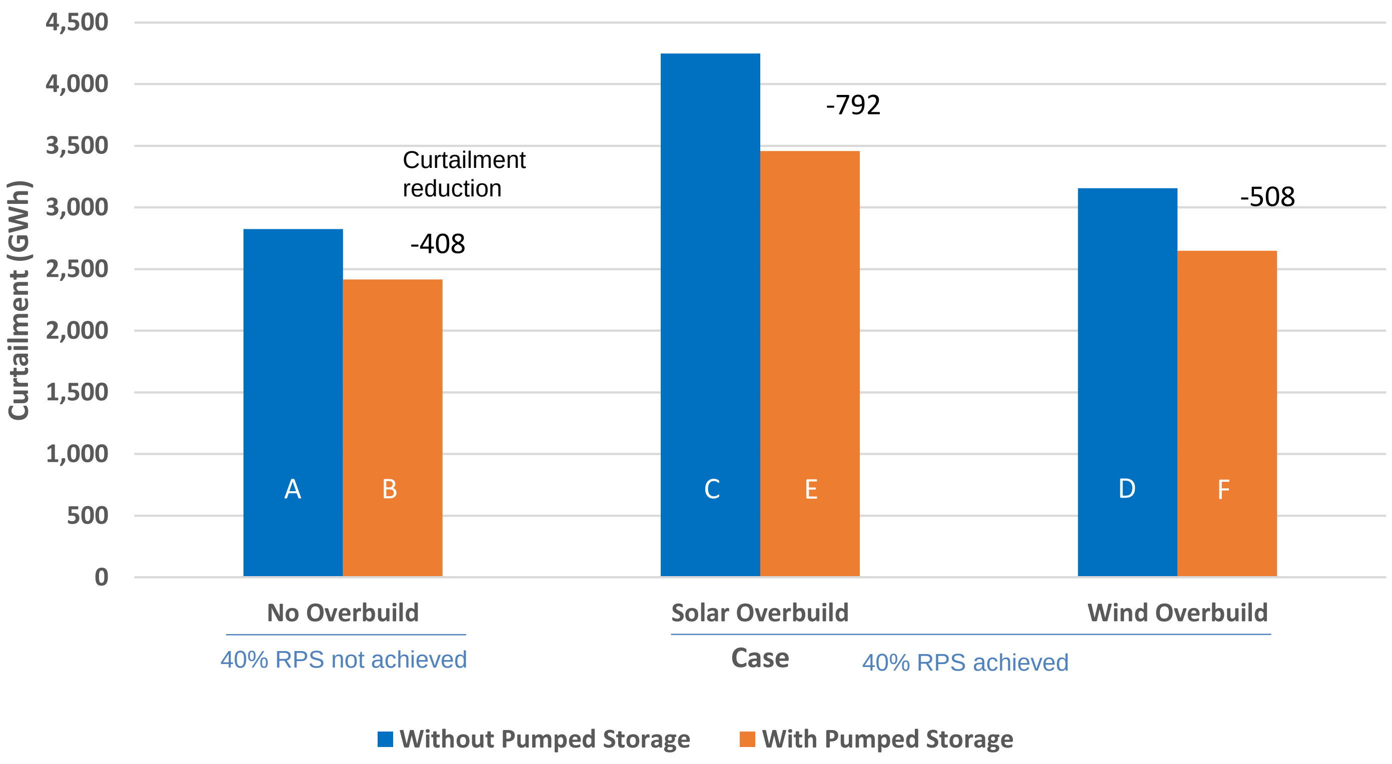
Item	Revenue Requirement ($/kW-year)		NQC Peak Factor [1]	RA Revenue ($/kW-year) [2]
	Generation Resource [3]	Transmission Upgrade [4]		
Large Solar In-State	327.12	22.00	47%	16.13
Large Solar Out-State	306.26	22.00	47%	16.13
Small Solar In-State	376.99	11.00	47%	16.13
Solar Thermal In-State	601.71	22.00	90%	30.89
Wind In-State	286.62	16.50	17%	5.83
Wind Out-State	261.13	72.00	45%	15.44
Pumped Storage In-State	383.62	16.50	100%	34.32

[1] References https://www.caiso.com/Documents/2012TACAreaSolar-WindFactors.xls and https://www.wecc.biz/Reliability/2024-Common-Case.zip
[2] Reference http://www.cpuc.ca.gov/NR/rdonlyres/2AF422A2-BFE8-4F4F-8C19-827ED4BA8E03/0/2013_14ResourceAdequacyReport.pdf
[3] References https://www.wecc.biz/Reliability/2014_TEPPC_GenCapCostCalculator.xlsm and https://www.wecc.biz/Reliability/2014_TEPPC_Generation_CapCost_Report_E3.pdf
[4] Reference http://www.transwestexpress.net/scoping/docs/TWE-what.pdf and the CAISO assumptions.

Capacity of renewable overbuild to achieve the 40% RPS target

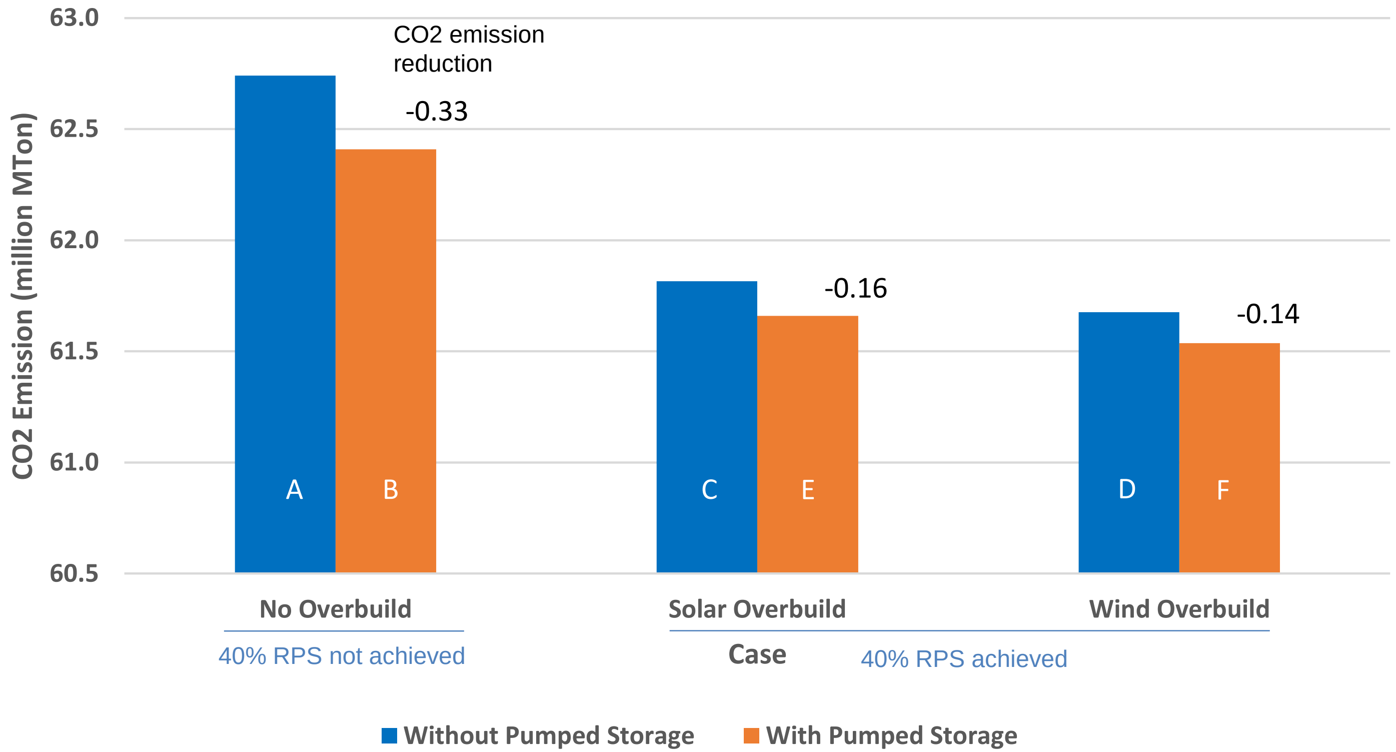


California renewable generation curtailment



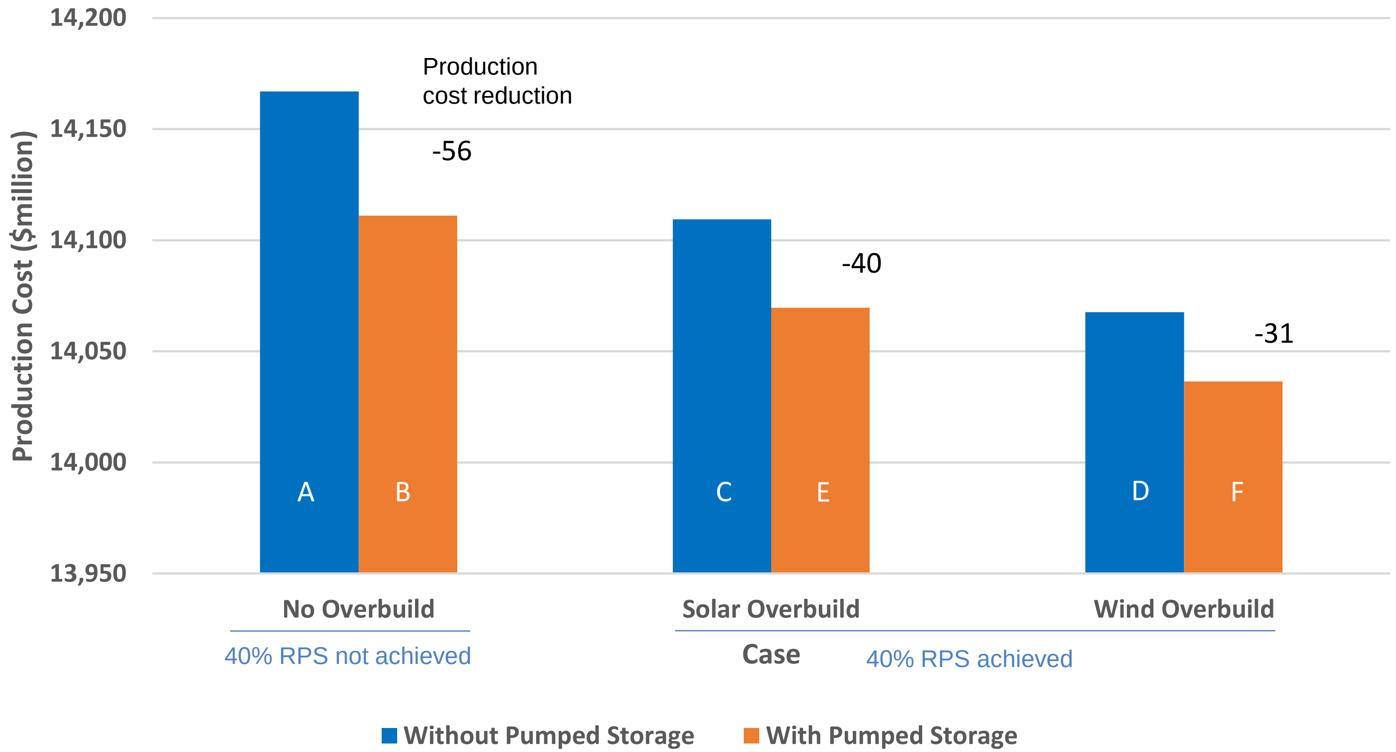
* Renewable generation is curtailed at -$300/MWh market clearing price (MCP).

California CO2 emission



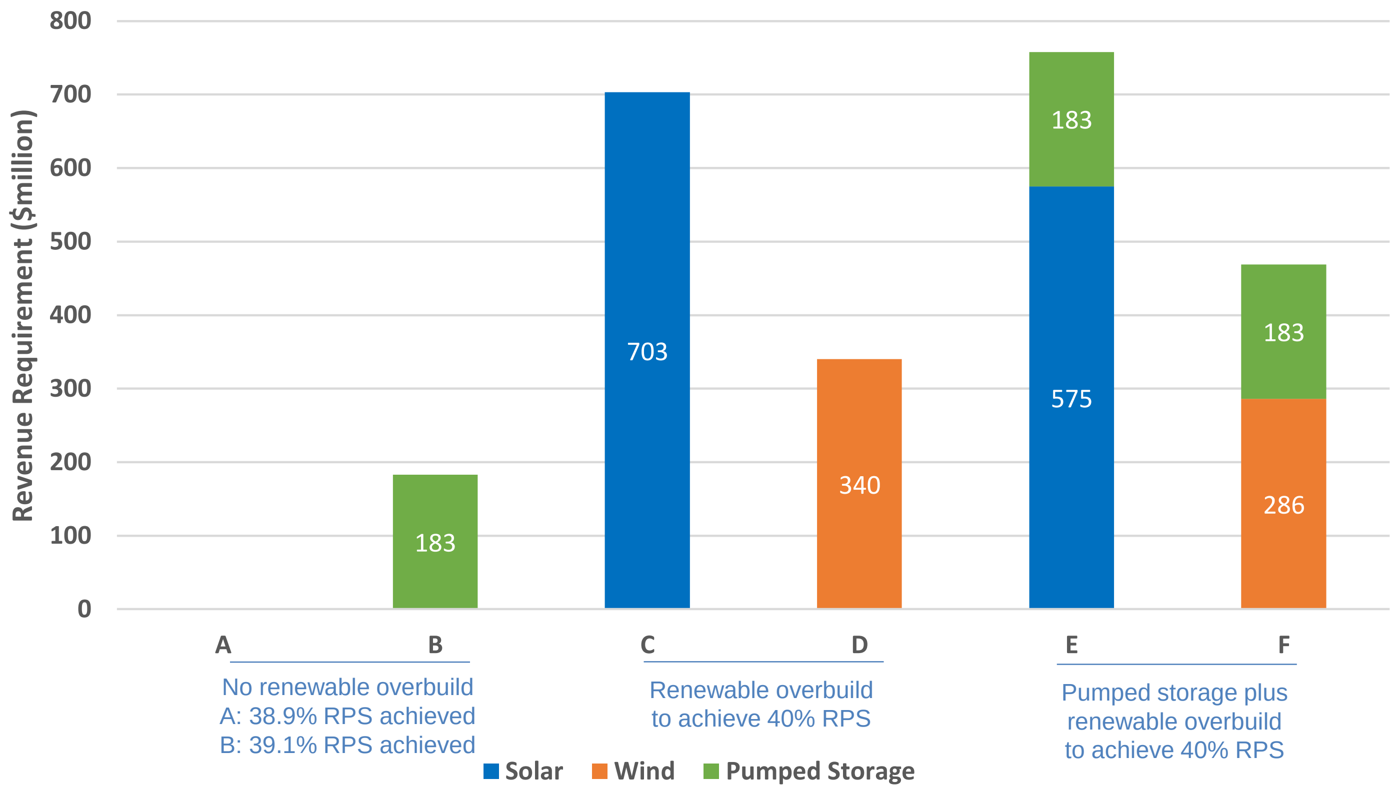
** California CO_2 emission includes the emission from energy net import.

WECC annual production cost

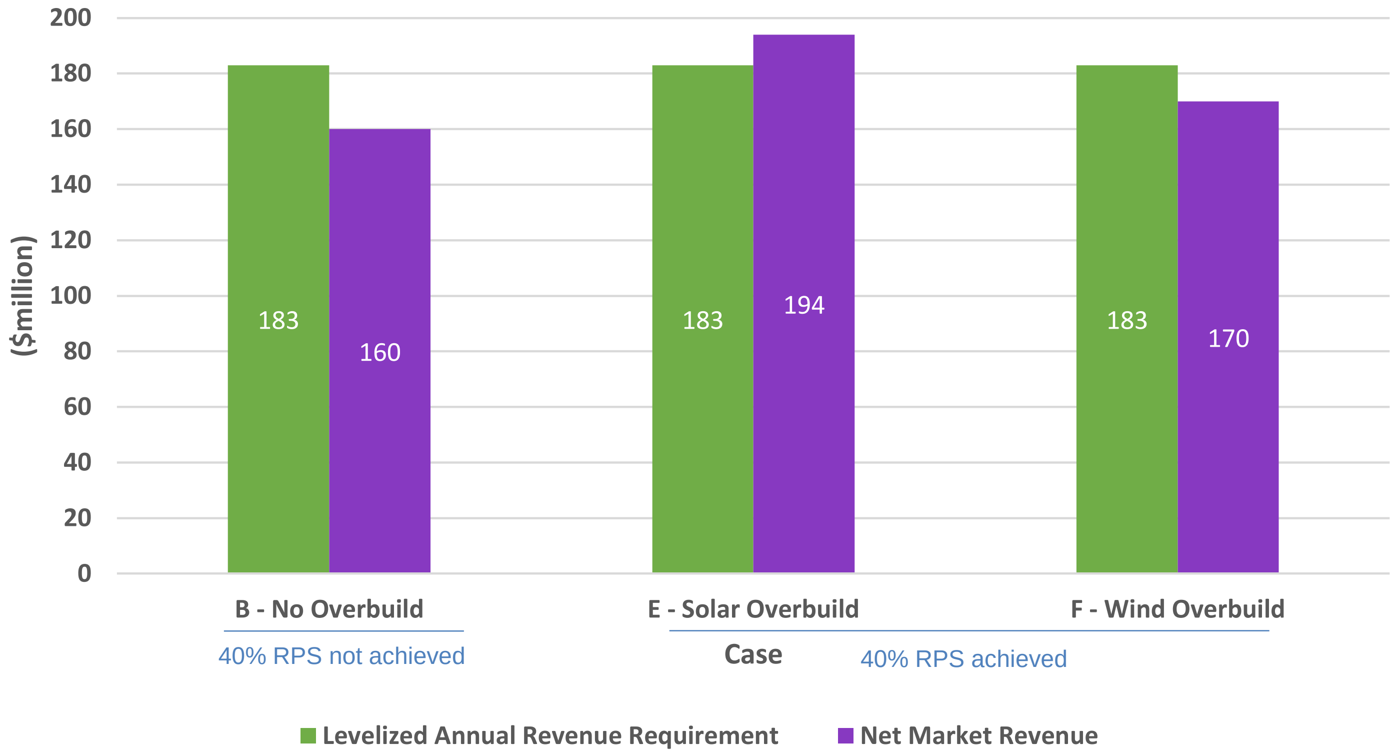


**** Production cost includes start-up, fuel and VOM cost, not CO2 cost.

Renewable overbuild and pumped storage levelized annual revenue requirements



Pumped storage levelized annual revenue requirement and net market revenue of 2024



***** Net revenue is revenue from generation, reserves and load following minus cost of operation and energy consumed.

Some observations

- Original 40% RPS portfolio is solar-dominant (53% in capacity)
- Wind overbuild increases diversity of the RPS portfolio and shows more benefits than solar overbuild
  - Requires less overbuild than solar due to less incremental curtailment from the overbuild
  - Has lower CO2 emission and production costs than solar due to less steep ramping

Some observations (cont.)

- Bulk storage brings benefits in all cases
  - Reduced curtailment, CO_2 emission, production costs and overbuild of renewables to achieve the 40% RPS target
- Bulk storage is better utilized with solar-dominant RPS portfolio than more diversified
  - Capturing more renewable curtailment in midday
  - Moving more energy to the evening and morning
  - Reducing more production cost and CO_2 emission

Some observations (cont.)

- Bulk storage benefit to cost ratios dependent on
  - Storage costs
  - Mix of renewable resources
  - Renewable curtailment price
  - Other assumptions

Summary of study results

	Without Pumped Storage			With Pumped Storage		
Case	A	C	D	B	E	F
Renewable Curtailment (GWh)*	2,825	4,249	3,157	2,417	3,457	2,649
CA CO2 Emission (Million Ton)**	62.74	61.82	61.68	62.41	61.66	61.54
CA CO2 Emission ($ mil)***	1,460	1,438	1,435	1,452	1,435	1,432
Production Cost ($ mil)****						
WECC	14,167	14,109	14,068	14,111	14,070	14,037
CA	3,866	3,826	3,795	3,803	3,779	3,751
Renewable Overbuild and Pumped Storage Capacity (MW)						
Solar		1,918			1,569	
Wind			1,129			950
Pumped Storage				500	500	500
Levelized Annual Revenue Requirement of Renewable Overbuild and Pumped Storage ($ mil)						
Solar		703			575	
Wind			340			286
Pumped Storage				183	183	183
Pumped Storage Net Market Revenue ($ mil) *****				160	194	170

* Renewable generation is curtailed at -$300/MWh market clearing price (MCP)
** Includes the CO2 emission from net import.
*** Calculated using $23.27/m-ton price.
**** Includes start-up, fuel and VOM cost, not CO2 cost.
***** Net revenue is revenue of energy, reserves and load following minus cost of energy and operation.

California ISO

Thank you.

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