



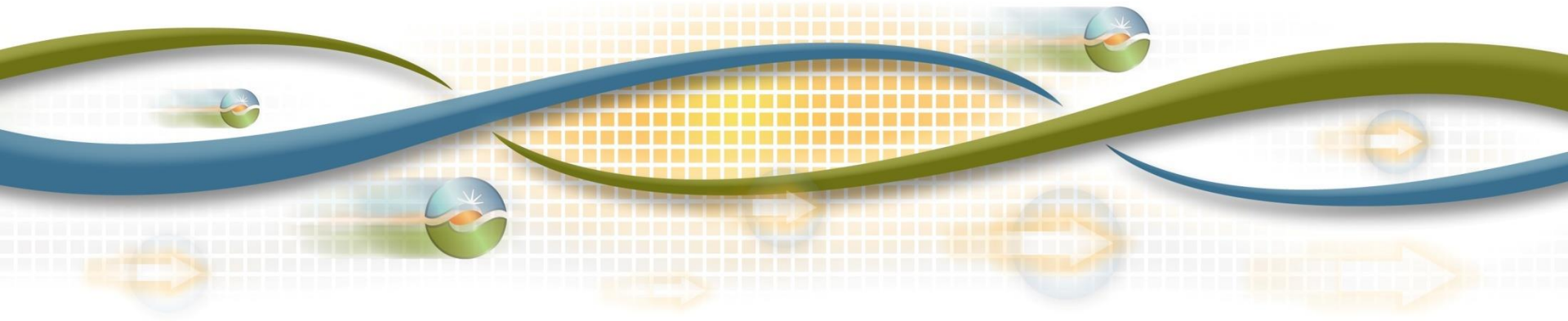
Integrating High Penetration Renewable Energy into the CAISO Market

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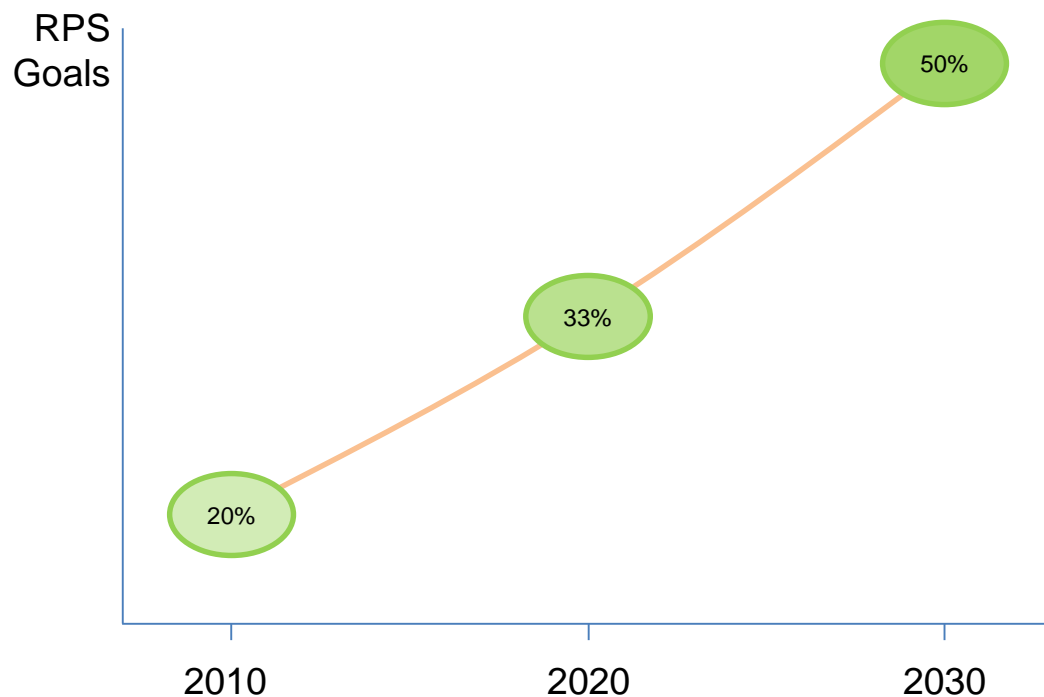
Principal, Market Development

DOE CSP SunShot Program Summit

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California SB 350 sets 50% Renewable Portfolio Standard (RPS) goal for 2030

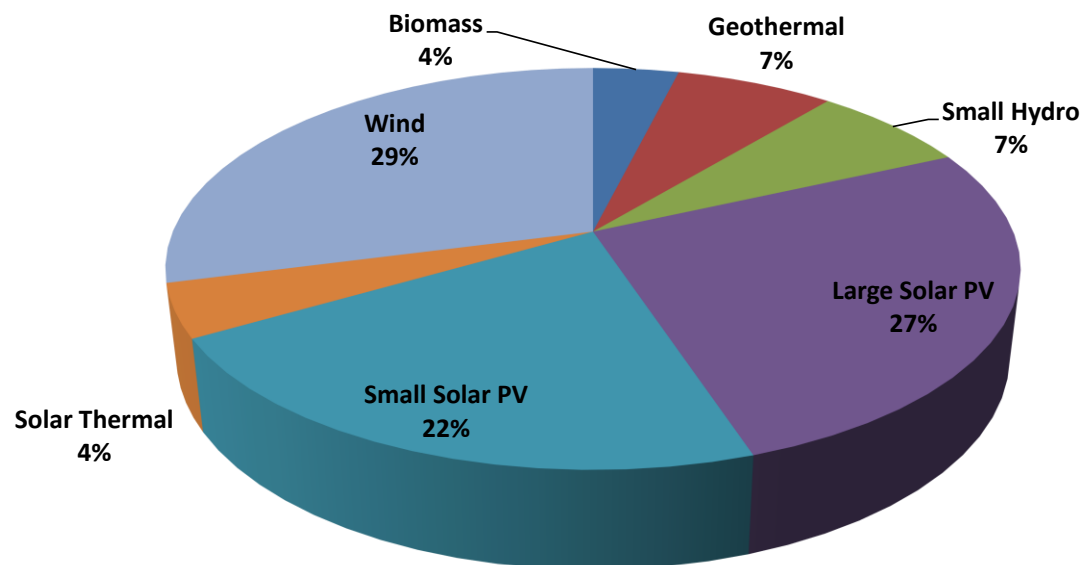


2013 actual 22.7%

2014 actual 25%

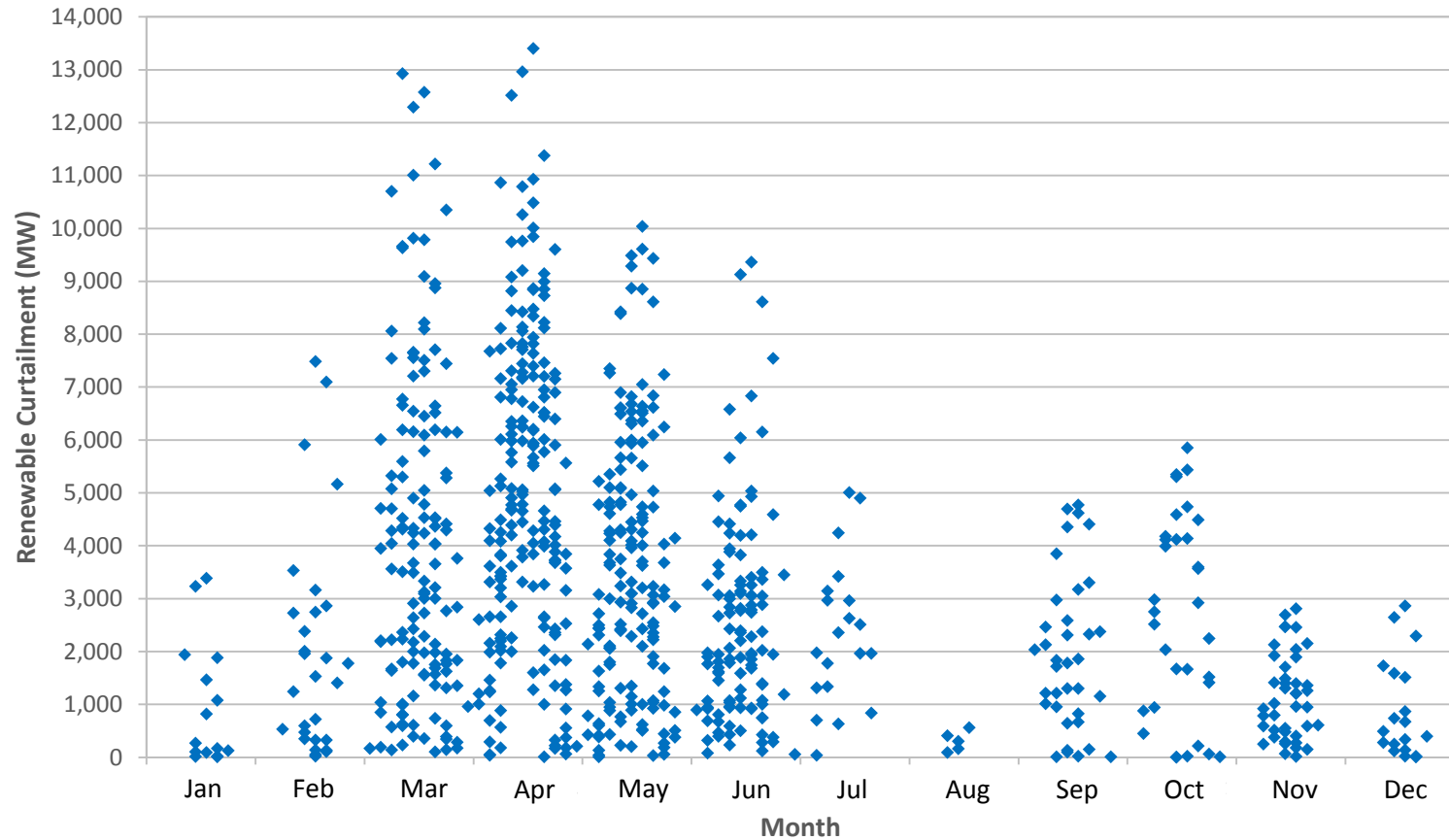
- RPS is calculated based on retail sales of electricity. It does not include distributed PV and hydro power plant greater than 30 MW

CAISO conducted studies to assess the impact of integrating high penetration renewable energy.

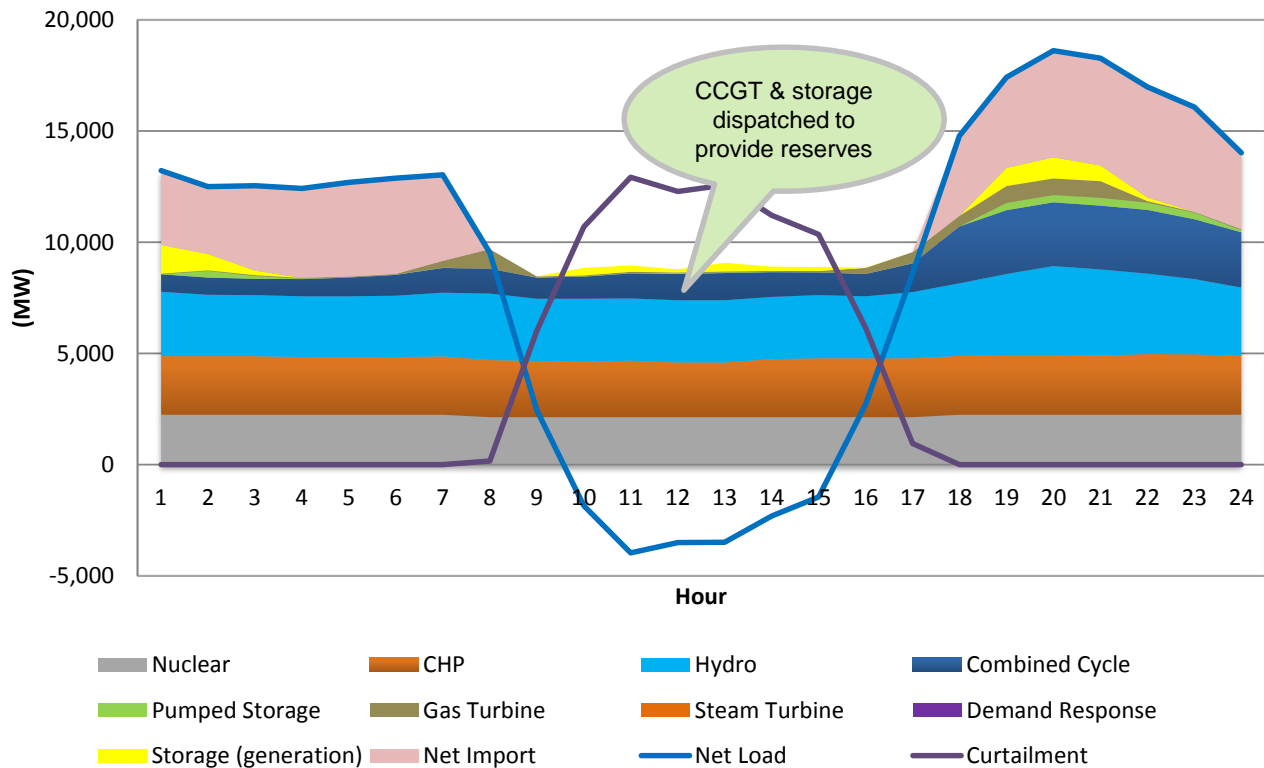


- A 40% RPS portfolio for 2024.
- Solar is more than 50% of the total 41,943 MW installed capacity.
- The portfolio excludes the 4,560 MW distributed PV.

The studies identified significant renewable curtailment at 40% RPS.



Energy balance on March 24, 2024 with 40% RPS



- Load includes energy used by pumped storages and battery storages
- $Net\ Load = (Load - Renewable\ Generation - DG\ PV\ Generation)$, which could be negative

Renewable integration solutions are being explored in three areas.

Area	Solution
Change Load	<ul style="list-style-type: none">• Improved Time of Use Rates• Targeted energy efficiency• Decarbonization of transportation fuels• Demand response
Change Supply	<ul style="list-style-type: none">• Storage• Diversified renewable portfolios• Economic dispatch of renewables• Retrofit of existing power plants
Collaborate Regionally	<ul style="list-style-type: none">• Participating in the CAISO Energy Imbalance Market by additional Balancing Authority areas• Joining the CAISO

“Pocket Guide” to renewable integration solutions

Category	Integration Solution	Findings
Net benefits even without renewable	<ul style="list-style-type: none"> Regional coordination 	<ul style="list-style-type: none"> More efficient dispatch and reduced renewable curtailment (http://www.caiso.com/informed/Pages/RegionalEnergyMarket/BenefitsofaRegionalEnergyMarket.aspx)
Low cost solutions with potentially large benefits	<ul style="list-style-type: none"> Time of use retail rates Sub-hourly renewable dispatch Renewable portfolio diversity 	<ul style="list-style-type: none"> Shifts energy consumption toward daylight hours Allows system to operate with fewer thermal resources during over-supply events Avoids curtailment by spreading renewable production over more hours of the year
Costs and benefits should be evaluated on specific project or program basis	<ul style="list-style-type: none"> Flexible loads and advanced DR Additional storage Gas retrofits New flexible gas resources 	<ul style="list-style-type: none"> Shifts energy consumption toward hours with over-supply, but cost and potential are unknown Reduces curtailment but requires significant investment Makes existing resources more flexible at a low cost Provides limited dispatch flexibility at a high cost
Valuable, though not as much for integration	<ul style="list-style-type: none"> Energy efficiency Conventional demand response 	<ul style="list-style-type: none"> Provides significant cost and GHG savings but may not reduce curtailment Provides cost savings but does not significantly reduce curtailment

Solutions with the highest identified renewable integration value

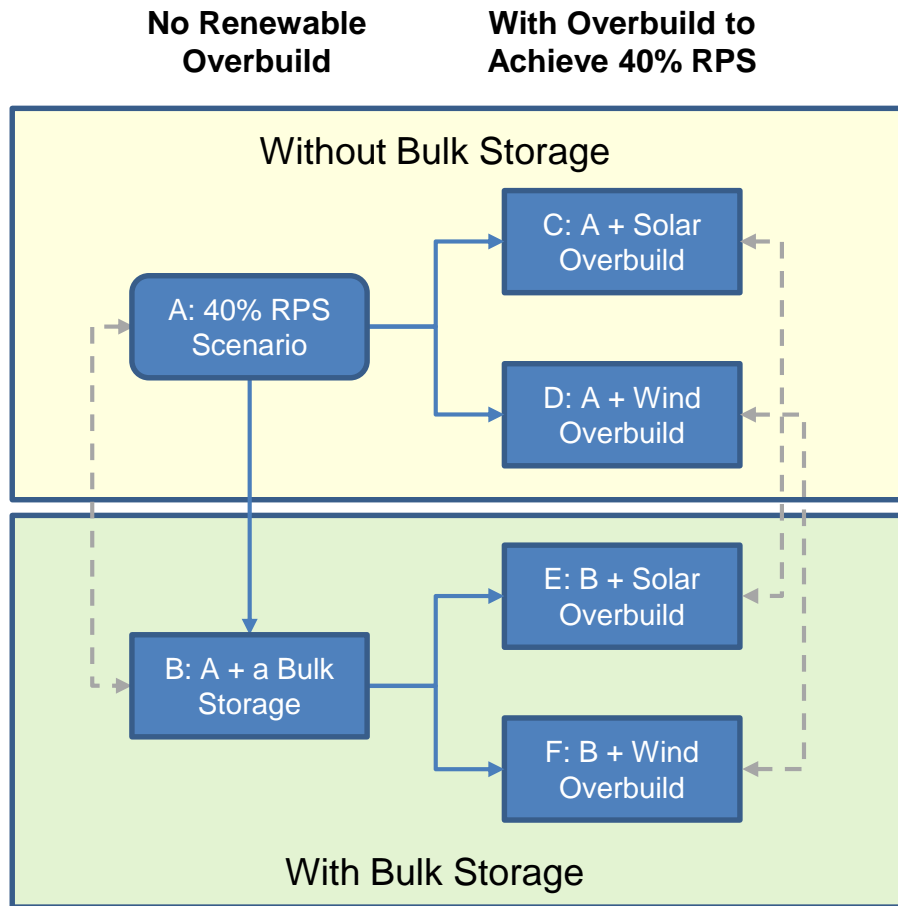


A CAISO special study on bulk energy storage

- To explore solutions to curtailment of large quantity of renewable generation
- To assess a bulk storage resource's ability to reduce
 - renewable curtailment
 - CO2 emission
 - production cost
 - renewable overbuild to achieve the 40% RPS goal
- To analyze the economic feasibility of the bulk energy storage resource

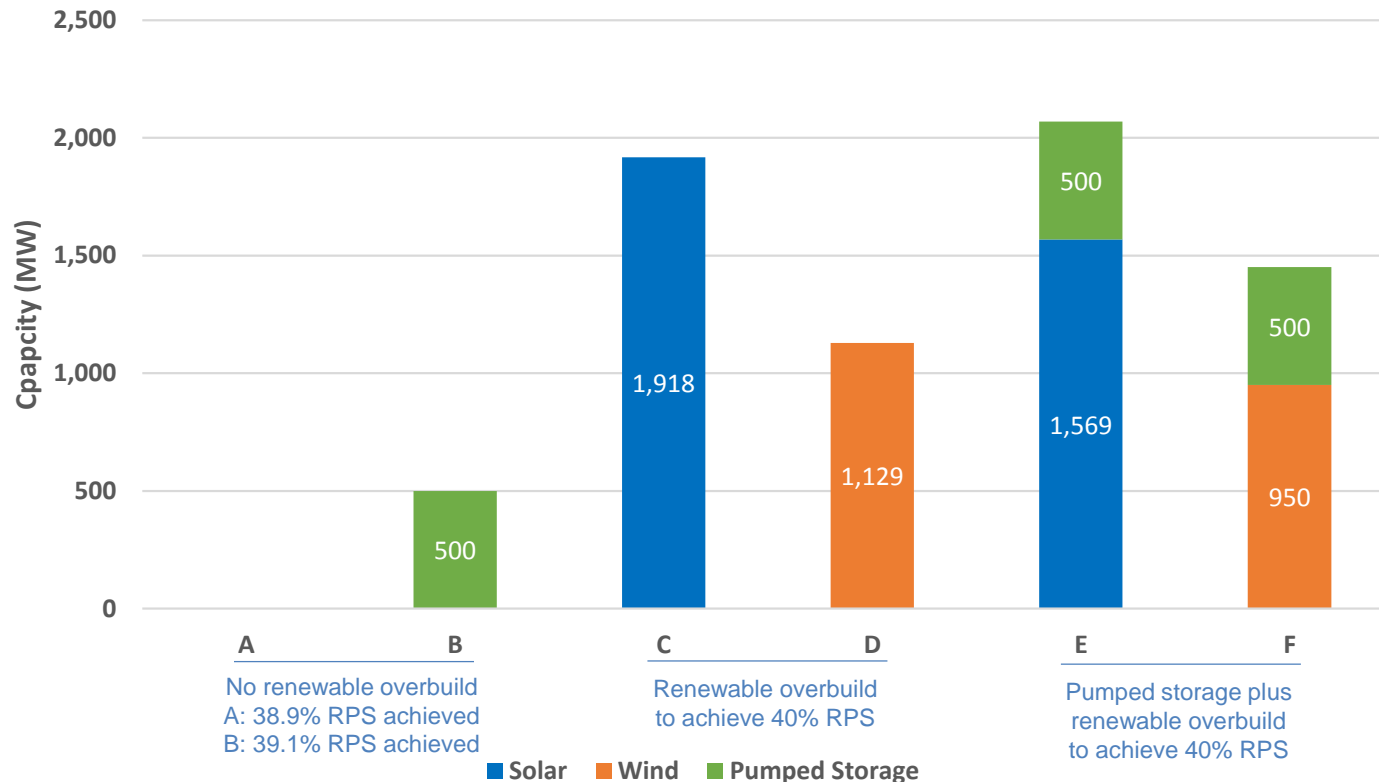
<http://www.caiso.com/Documents/Board-Approved2015-2016TransmissionPlan.pdf>
section 3.5

The study cases are defined as

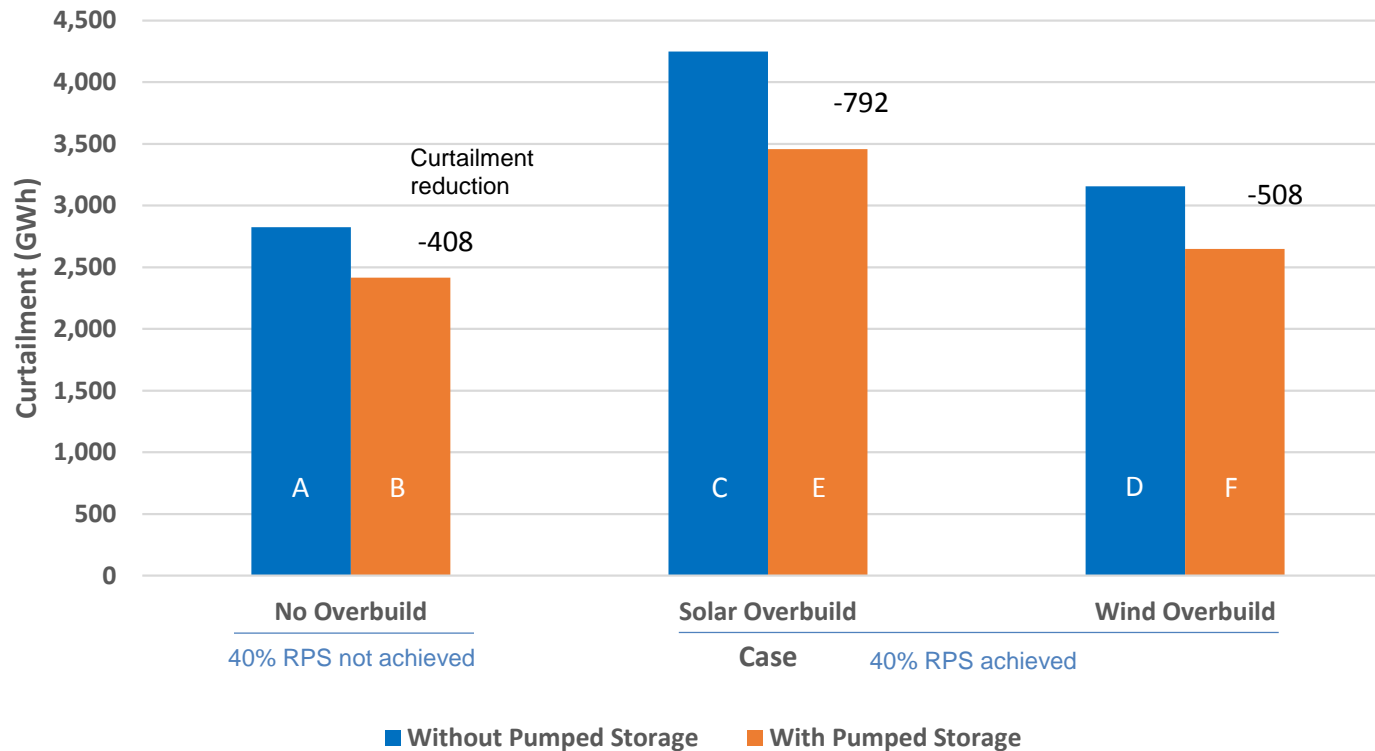


- Based on the 2014 LTPP 40% RPS in 2024 Scenario allowing unlimited renewable curtailment
- Using a new 500 MW fast and flexible pumped storage as the bulk energy storage resource
- Overbuilding solar or wind resources to achieve the 40% RPS goal

Capacity of renewable overbuild to achieve the 40% RPS goal

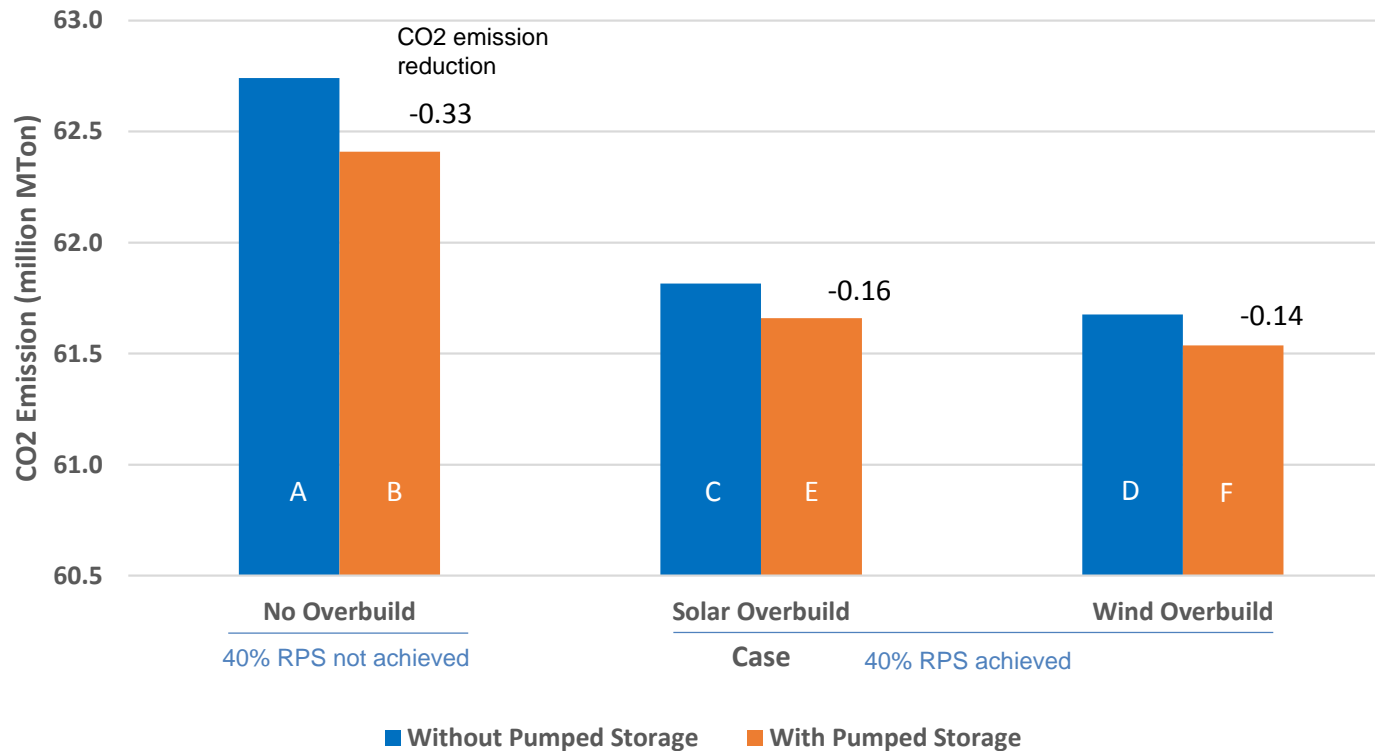


California renewable generation curtailment



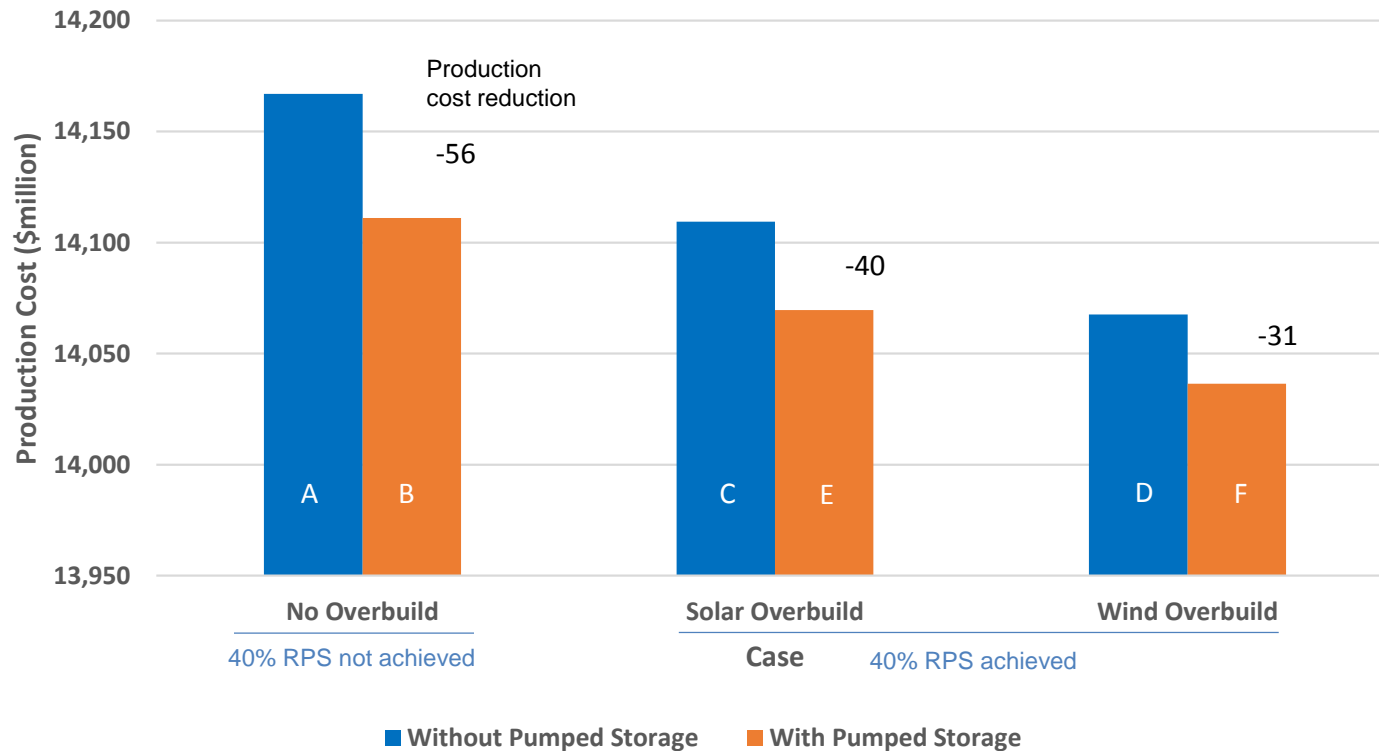
- Renewable generation is curtailed at $-\$300/\text{MWh}$ market clearing price (MCP).

California CO2 emission



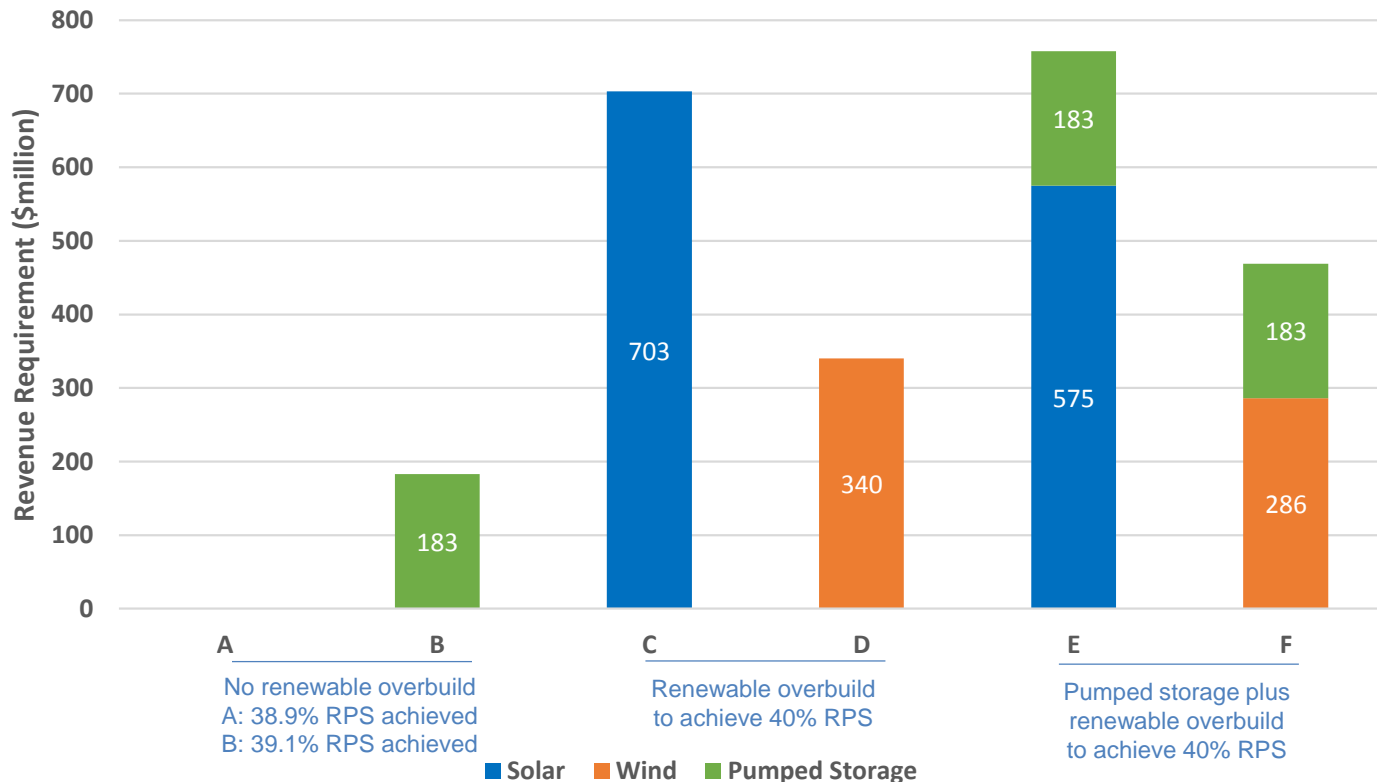
- California CO2 emission includes the emission from energy net import.
- CO2 emission cost can be calculated using \$23.27/m-ton price.

WECC annual production cost

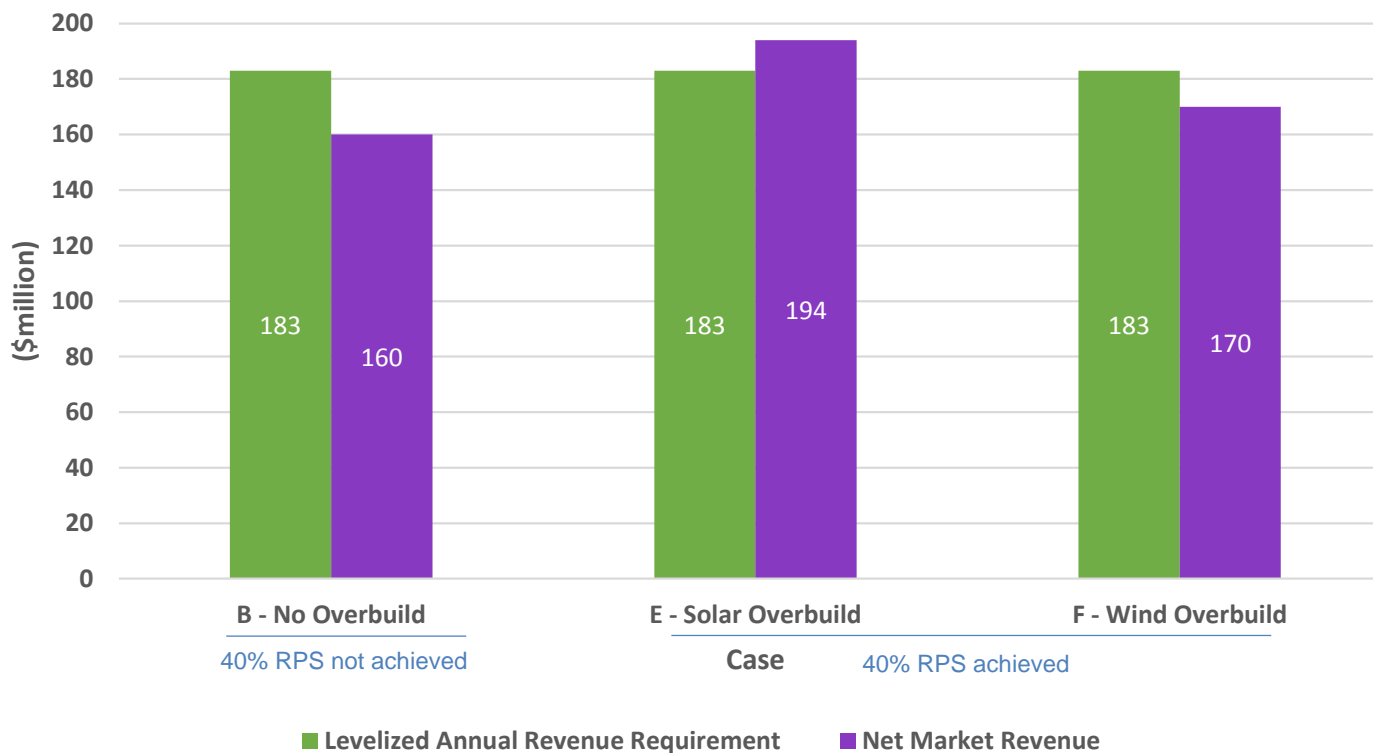


- Production cost includes start-up, fuel and VOM cost, not CO2 cost.

Levelized annual revenue requirements of the renewable overbuild and pumped storage resource



Pumped storage levelized annual revenue requirement vs. net market revenue of 2024



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