A Bulk Energy Storage Resource Case Study updated from 40% to 50% RPS

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2015-2016 Transmission Planning Process

Purpose of the ISO bulk energy storage case study:

- To assess a bulk storage resource's ability to reduce
  - production cost
  - renewable curtailment
  - CO2 emission
  - renewable overbuild to achieve the RPS target
- To analyze the economic feasibility of the bulk storage resource
- To consider the locational benefits of known potential bulk energy storage locations in ISO footprint

Regarding the update to the bulk energy storage study (June 13 Stakeholder Call):

- Initial study with 40% RPS was conducted in the 2015-2016 planning cycle
- The ISO indicated that it will provide an update of the study with 50% RPS
- This material is that update
- The 2016-2017 planning cycle will include the large energy storage study using 2016-2017 updated assumptions

Update to 50% RPS – Study Assumptions

Summary of study assumptions

- The study was based on the bulk energy storage study with 40% RPS the CAISO conducted in 2015
- The 40% RPS based model was updated with the following new assumptions for California
  - A new load forecast, including AAEE and DG PV
  - A new RPS portfolio, increasing from 40% to 50%
  - Regulation and load-following requirements based on the new load, solar and wind generation profiles
  - A higher CAISO maximum net export limit

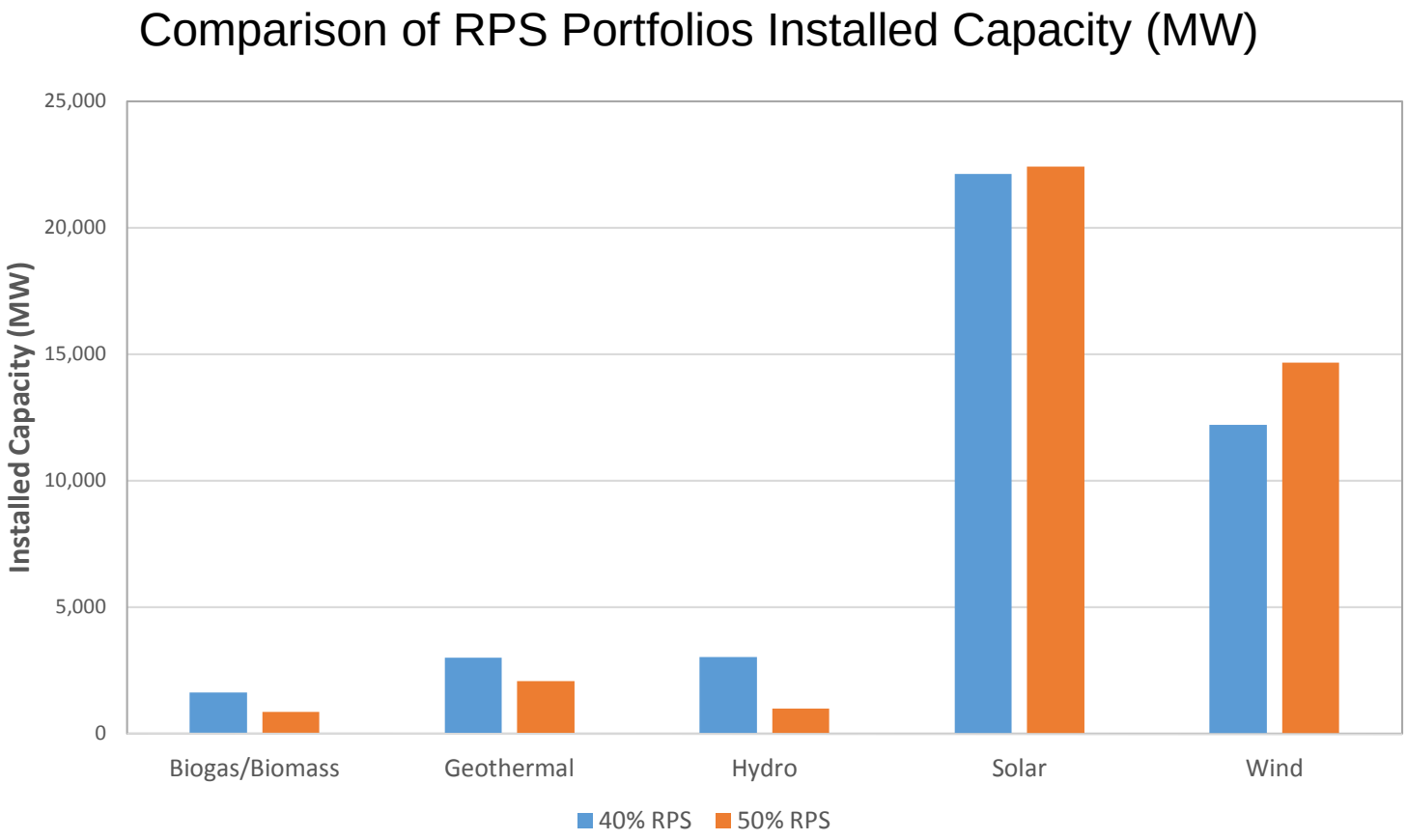
Summary of study assumptions (cont.)

- The 40% RPS based model was updated with the following new assumptions for California
  - Allowing renewable to provide load following-down
  - Removing the 25% local minimum generation requirements in the CAISO
  - Enforcing a CAISO-wide frequency response requirement
- Other updates for WECC based on the TEPPC 2024 Common Case v1.5 (from the May 12, 2014 pre-release version)

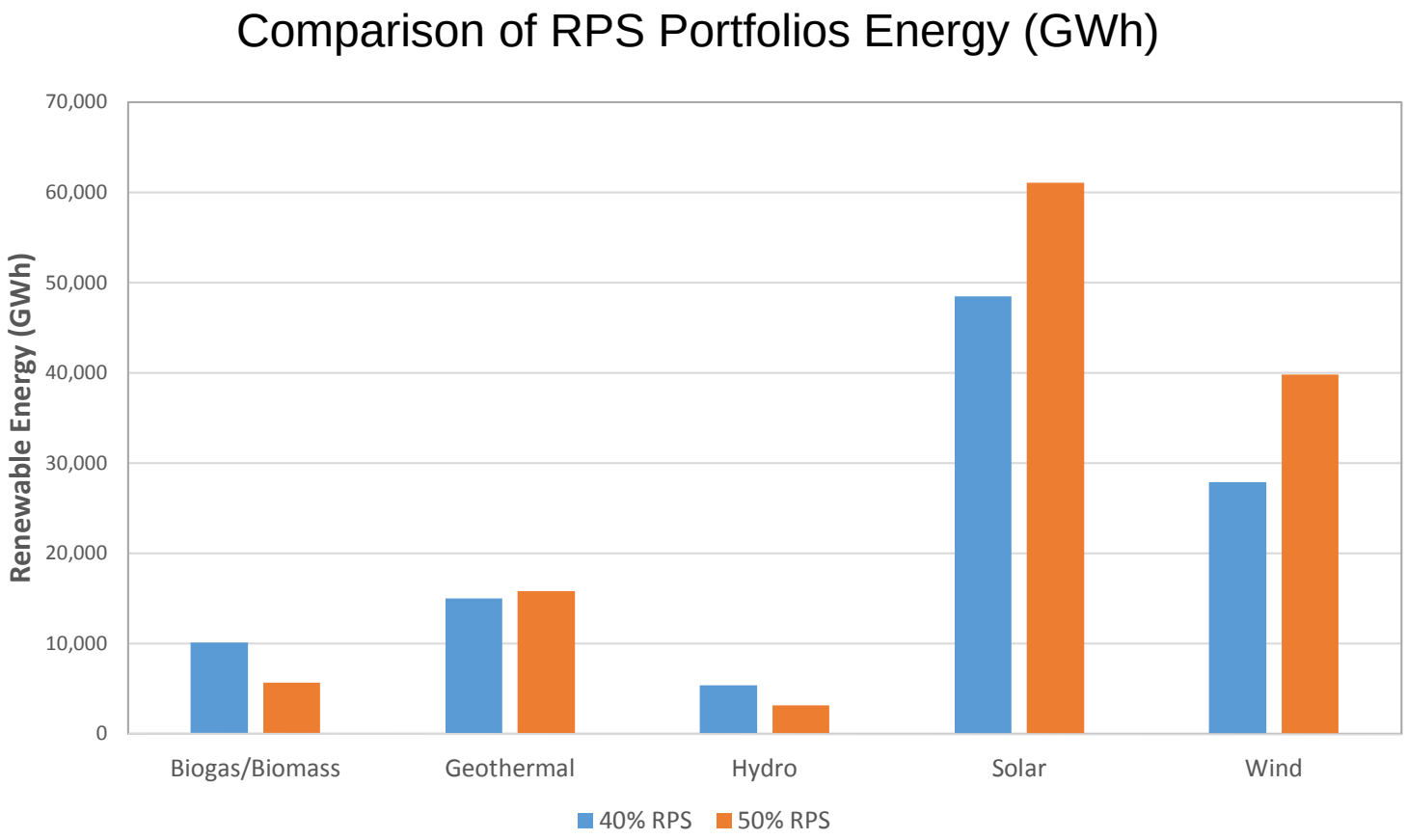
Specifics of the updates – from the 40% RPS to the 50% RPS study

- Update of CA load forecast, including AAEE and DG PV, from 2013 to 2014 CEC IEPR forecast, in which
  - DG PV capacity increased from 4,560 MW to 5,373 MW
- A CA 50% RPS portfolio the CPUC created for CAISO special studies (CA FCDS scenario, RPS Calculator v6.1, August 4, 2015)
  - Solar and wind has higher capacity factors than in the 40% RPS portfolio

Specifics of the updates – from the 40% RPS to the 50% RPS study (cont.)



Specifics of the updates – from the 40% RPS to the 50% RPS study (cont.)



Specifics of the updates – from the 40% RPS to the 50% RPS study (cont.)

- CA solar and wind hourly profiles with new shapes developed by the CAISO based on NREL raw data
  - Solar shapes spread wider in summer months
- CAISO max net export limit increased from 0 MW to 2,000 MW
- Renewable providing load following-down up to 50% of load following-down requirement
  - Resulting in additional curtailment of renewable energy that was not counted in this study yet

Specifics of the updates – from the 40% RPS to the 50% RPS study (cont.)

- Removal of the 25% local minimum generation requirement for the CAISO, SCE and SDG&E
- A CAISO-wide 376 MW frequency response requirement that can be met by the combination of battery storage and online CCGT

Specifics of the updates – from the 40% RPS to the 50% RPS study (cont.)

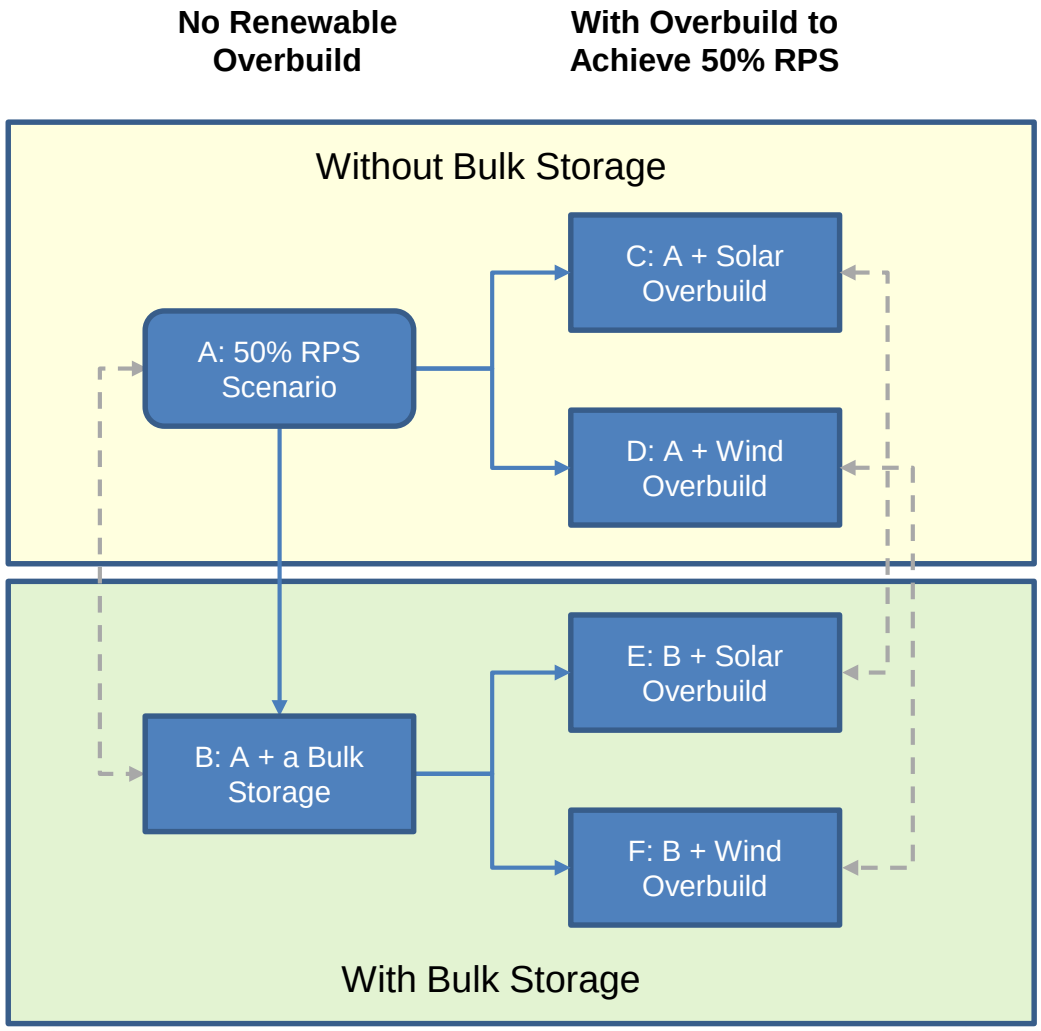
- Other updates for whole WECC based on the TEPPC 2024 Common Case v1.5 (from the May 12, 2014 pre-release version), including
  - Load forecast and renewable portfolios for areas outside CA
  - Fuel prices, specifically (~25%) higher gas price and lower coal price
  - Higher hydro energy, mostly in July – October

Update to 50% RPS – Study Approach

Study approach

- Using the 2014 LTPP 40% RPS in 2024 Scenario with
  - The updates described in the previous section
  - Renewable curtailment remaining unlimited
- Analyzing two renewable build baselines, with and without a new bulk energy storage resource,
  - No overbuild of renewable resources
  - Overbuilding renewables to achieve 50% RPS target
- Overbuilding only solar or wind to 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, which represents the bulk energy storage

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

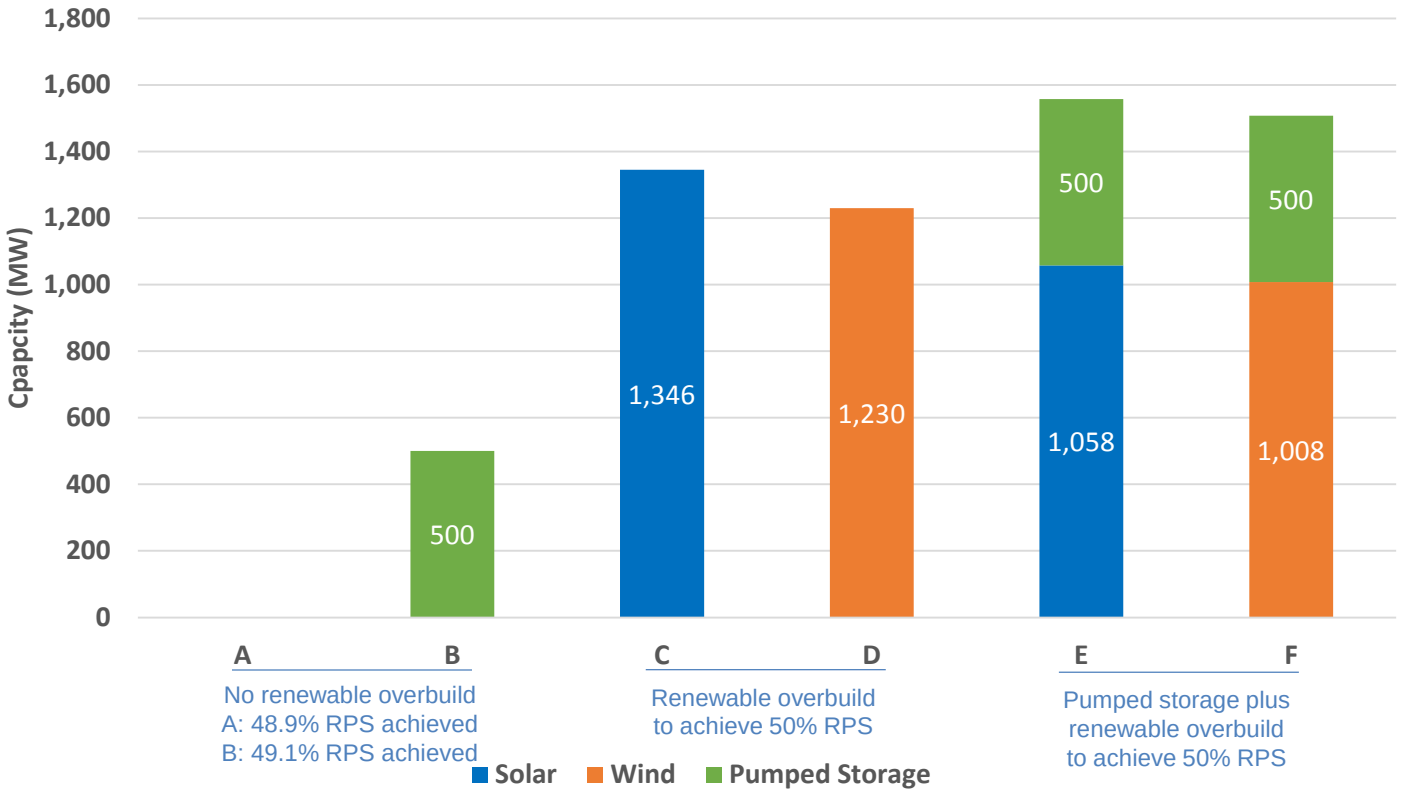
Assumptions of revenue requirements and RA revenue of the new resources

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

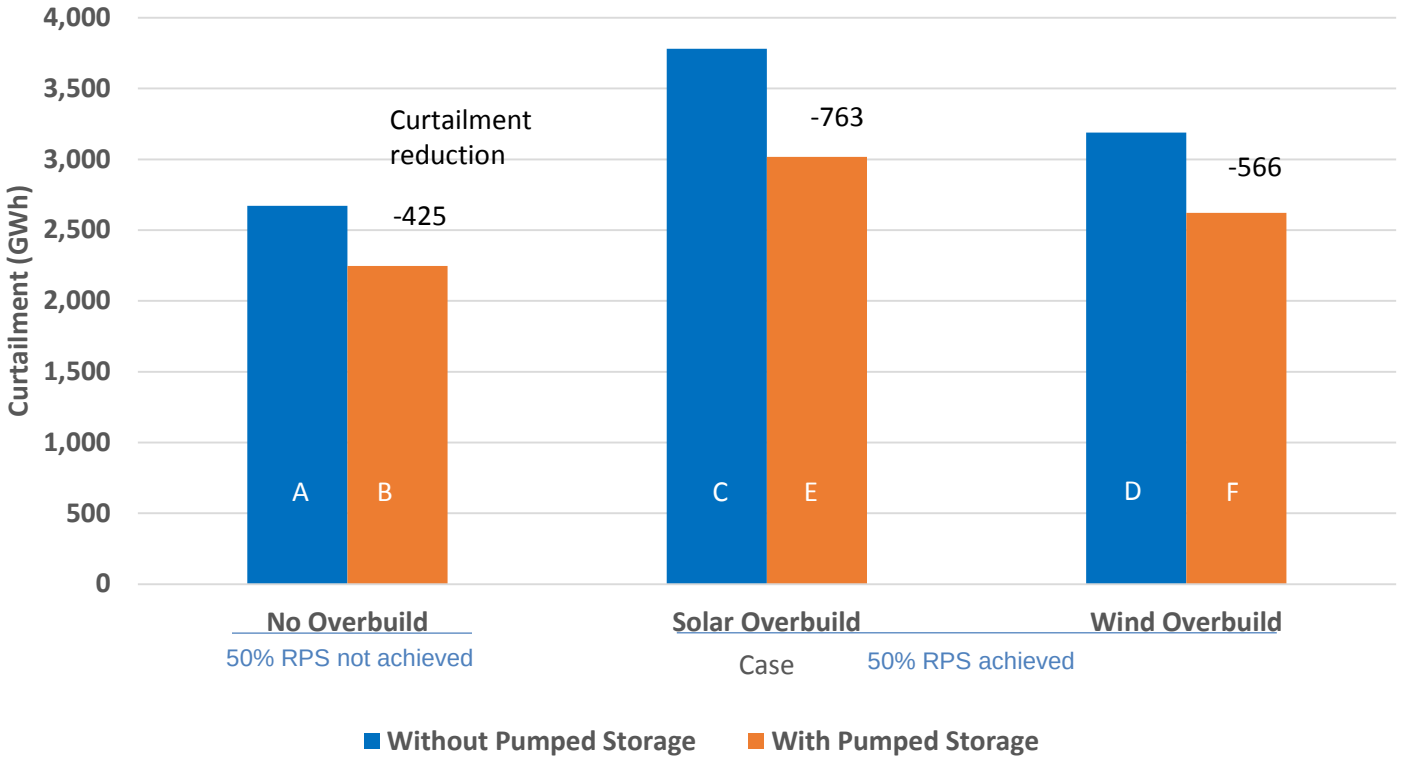
[1] References https://www.caiso.com/Documents/2012TACAreaSolar-WindFactors.xls and https://www.wecc.biz/Reliability/2024-Common-Case.zip
[2] Reference http://www.cpuc.ca.gov/NR/rdonlyres/2AF422A2-BFE8-4F4F-8C19-827ED4BA8E03/0/2013_14ResourceAdequacyReport.pdf
[3] References https://www.wecc.biz/Reliability/2014_TEPPC_GenCapCostCalculator.xlsm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

Update to 50% RPS – Summary of Results

Capacity of renewable overbuild to achieve the 50% RPS target

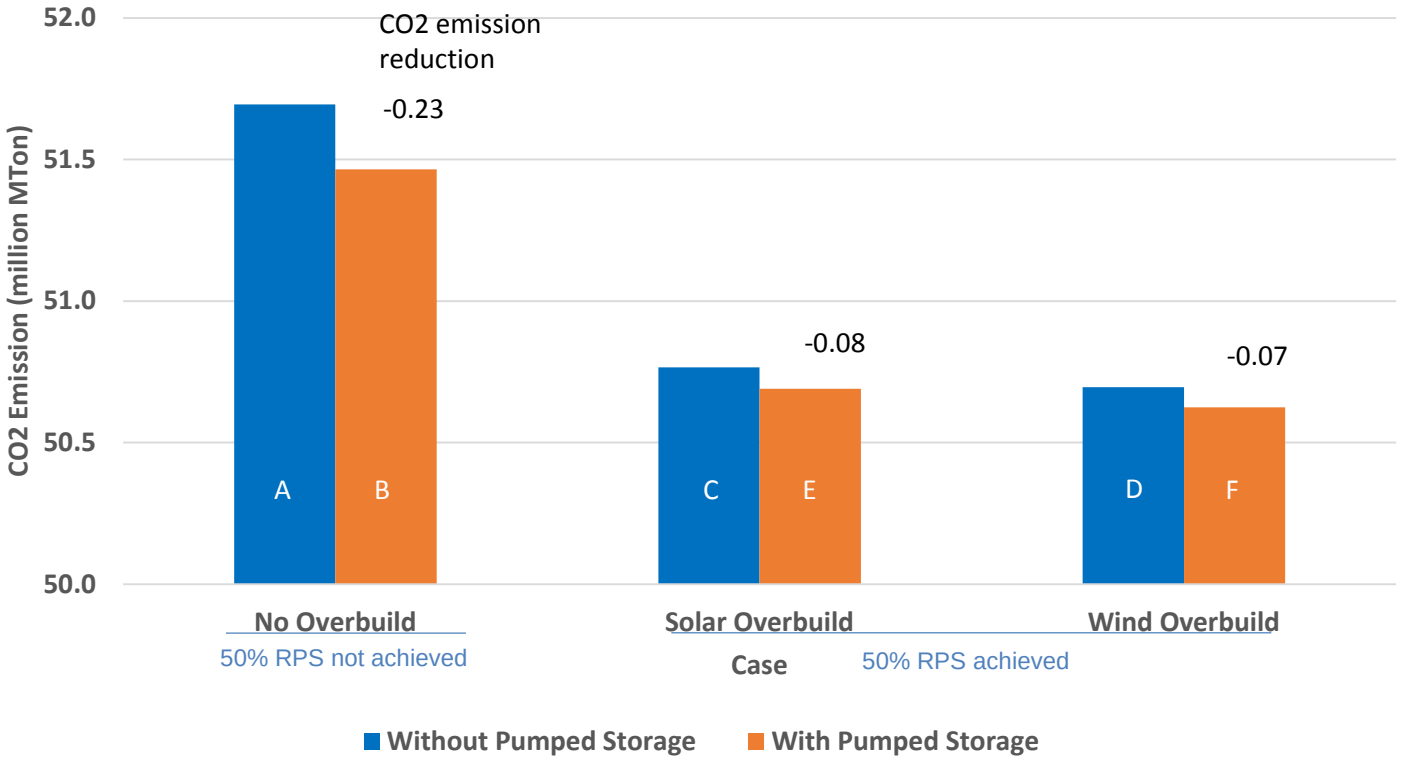


California renewable generation curtailment (50% RPS)



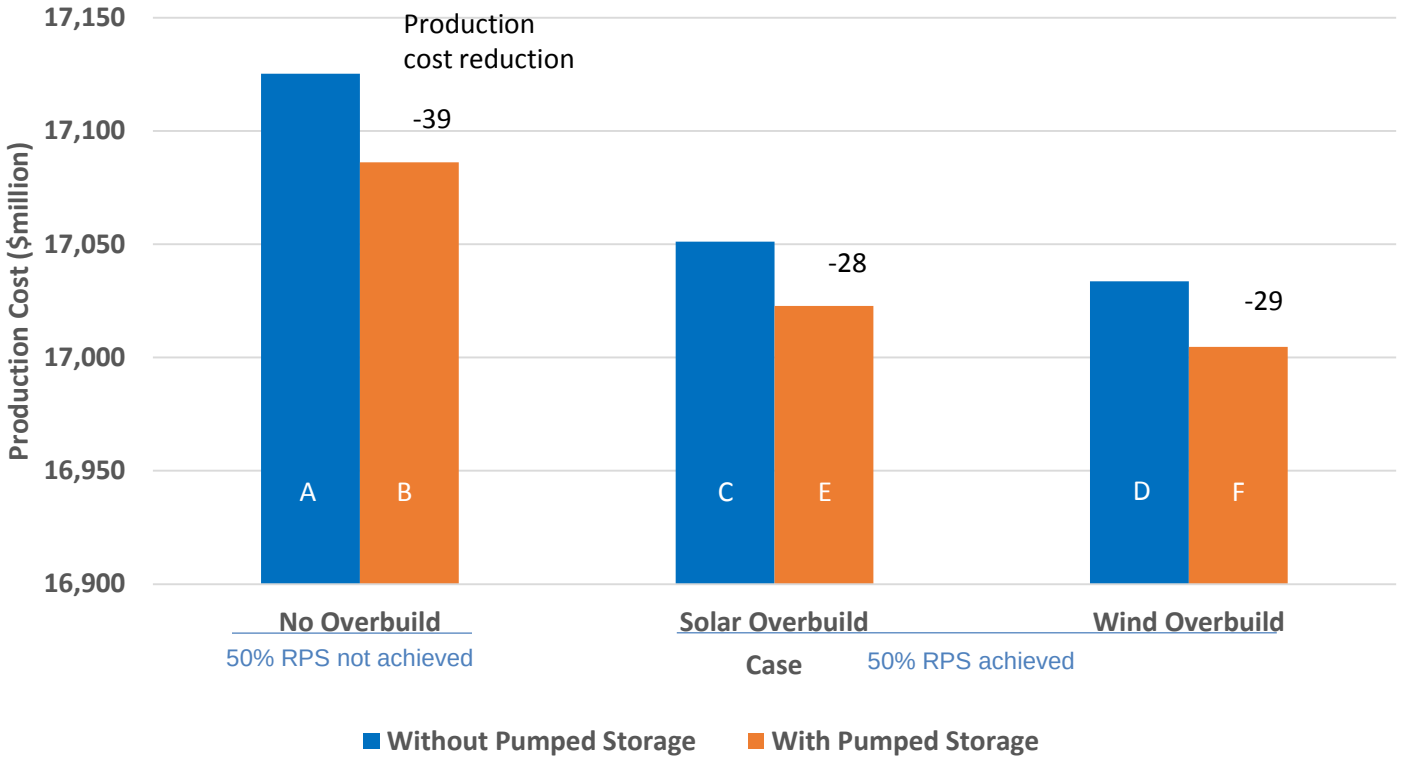
* Renewable generation is curtailed at -$300/MWh market clearing price (MCP).

California CO2 emission (50% RPS)



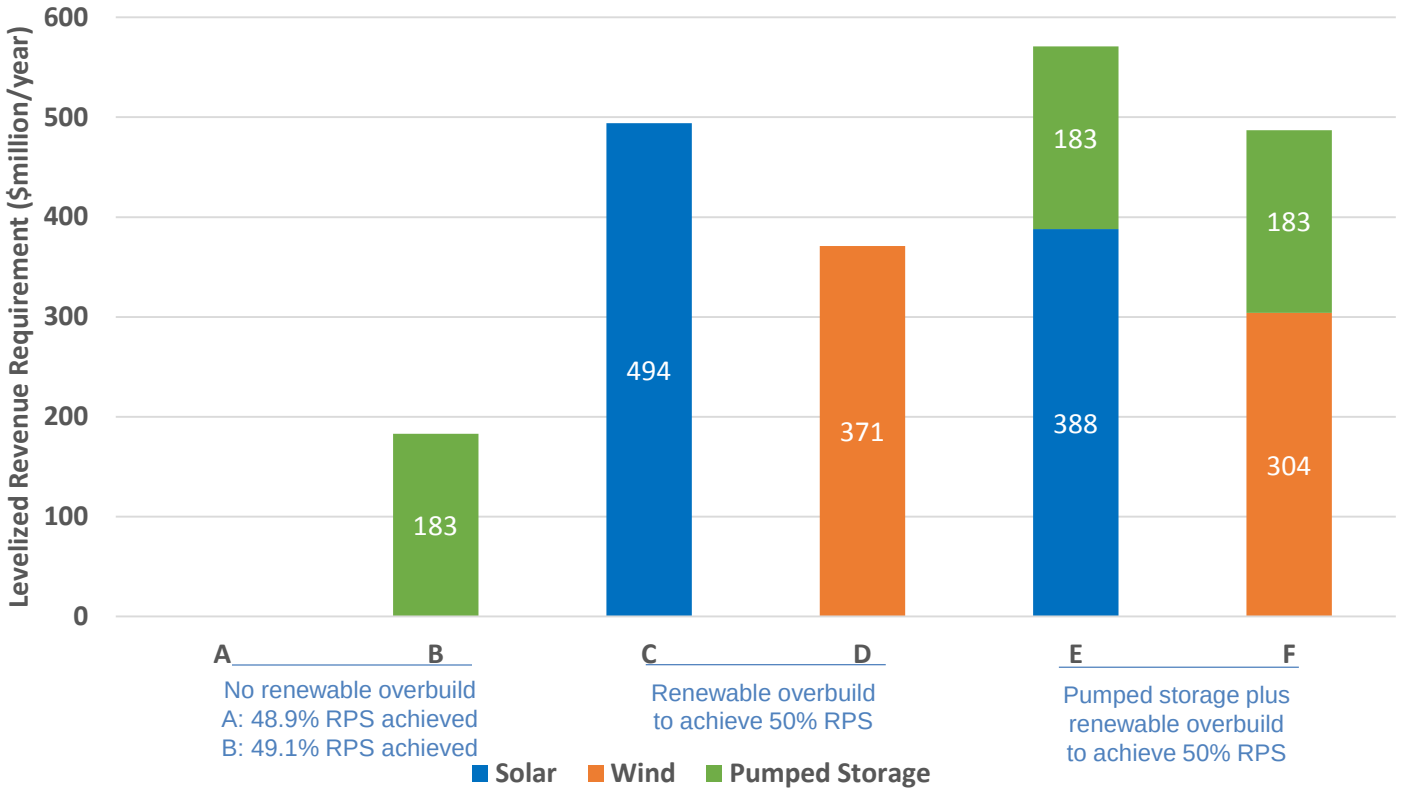
** California CO2 emission includes the emission from energy net import.

WECC annual production cost (50% RPS)

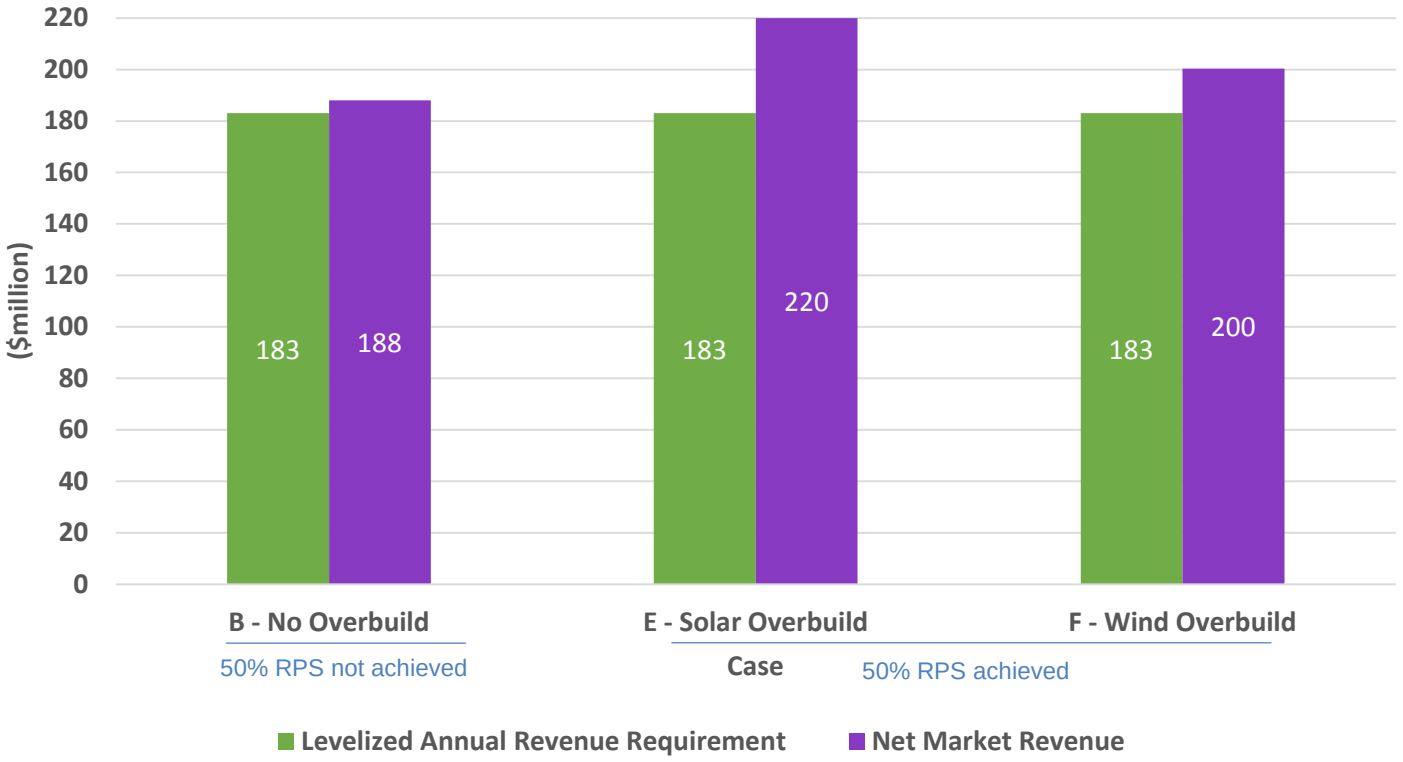


**** Production cost includes start-up, fuel and VOM cost, not CO2 cost.

Renewable overbuild and pumped storage levelized annual revenue requirements (50% RPS)



Pumped storage levelized annual revenue requirement and net market revenue of 2024 (50% RPS)



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

Preliminary results by case – 50% RPS

	50% RPS	Without Pumped Storage		With Pumped Storage		
Case	A	C	D	B	E	F
Renewable Curtailment (GWh)*	2,673	3,781	3,188	2,247	3,018	2,622
CA CO2 Emission (Million Ton)**	51.69	50.77	50.70	51.47	50.69	50.62
CA CO2 Emission ($ mil)***	1,203	1,181	1,180	1,198	1,180	1,178
Production Cost ($ mil)****						
WECC	17,125	17,051	17,034	17,086	17,023	17,005
CA	4,016	3,990	3,963	3,959	3,938	3,913
Renewable Overbuild and Pumped Storage Capacity (MW)						
Solar		1,346			1,058	
Wind			1,230			1,008
Pumped Storage				500	500	500
Levelized Annual Revenue Requirement of Renewable Overbuild and Pumped Storage ($ mil)						
Solar		494			388	
Wind			371			304
Pumped Storage				183	183	183
Pumped Storage Net Market Revenue ($ mil)*****				188	220	200

* 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.

Some observations

- From 40% RPS to 50% RPS, in all cases,
  - Renewable curtailment is lowered
  - Less renewable overbuild is required
  - CO2 emission is reduced
  - Production cost is increased
  - Wind overbuild is still more efficient than solar overbuild
  - The pumped storage brings comparable benefits
  - It can meet its levelized revenue requirement from net market revenue in three cases

Some observations (cont.)

- Lower renewable curtailment due to
  - 2,000 MW higher maximum net export limit
  - Allowing renewable to provide load following-down
  - New solar shapes and higher solar capacity factor that reduce energy concentration in midday
- Less renewable overbuild required as
  - Lower renewable curtailment
  - Higher solar and wind capacity factors in the 50% RPS portfolio

Some observations (cont.)

- Reduced CO2 emission because of
  - More renewable energy (40% to 50% RPS)
  - Lower load forecast (net by AAEE) and higher DG PV
- Increased production cost caused by
  - Higher gas price forecast

Some observations (cont.)

- Compared to solar, wind overbuild has
  - Less required overbuild capacity to achieve 50% RPS
  - Lower curtailment, CO2 emission and production cost
- As in the 40% RPS study, the pumped storage brings benefits to the system in reduction of
  - Overbuild needed to achieve the 50% RPS target
  - Renewable curtailment
  - CO2 emission
  - Production cost

Some observations (cont.)

- The pumped storage resource has net market revenue sufficient to meet its levelized revenue requirement in all three cases, mostly due to
  - Higher gas price that leads to higher energy and ancillary service prices
  - Therefore higher net revenue from moving energy from hours with curtailment to hours with high demand and from providing ancillary services and load-following

California ISO

The End