50% RPS Special Study– Out-of-state Portfolio Assessment Results and Next Steps

Sushant Barave

Regional Transmission Engineer - Lead

Regional Transmission

2016-2017 Transmission Planning Process Stakeholder Meeting

February 28, 2017

This is a follow up presentation to the 50% RPS special study results presented on February 17, 2017

A. <u>Background</u>:

- Objectives, assumptions and modeling

B. <u>Renewable curtailment and congestion results</u>:

- Key findings - OOS portfolio compared to In-state portfolios

C. <u>Reliability assessment</u>:

- Impact on CA system briefly discussed during February 17, 2017 stakeholder meeting
- Takeaways regarding snapshot identification

D. <u>Deliverability assessment</u>:

- Impact on CA system presented during February 17, 2017 stakeholder meeting

E. <u>Summary of Key Findings and Next steps</u>

Background: Objectives, Assumptions and Modeling

Incremental goal of OOS portfolio assessment compared to the In-state portfolio assessments

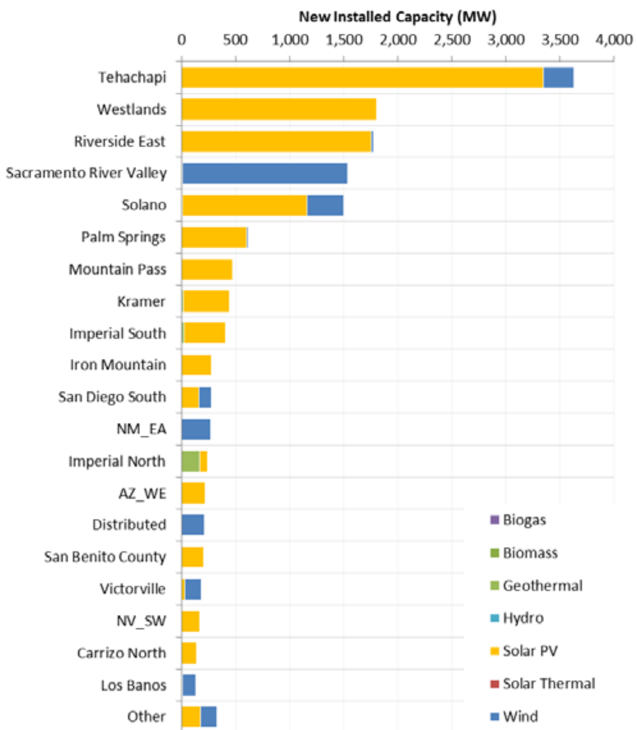
In addition to the primary objectives of the overarching 50% RPS special study, the OOS portfolio evaluation specifically aims to,

- *Examine the transmission implications of meeting part of the 50 percent RPS obligation by relying on renewable resources outside of California and foster a higher degree of coordination with regional planning entities for the OOS portfolio modeling and assessment*

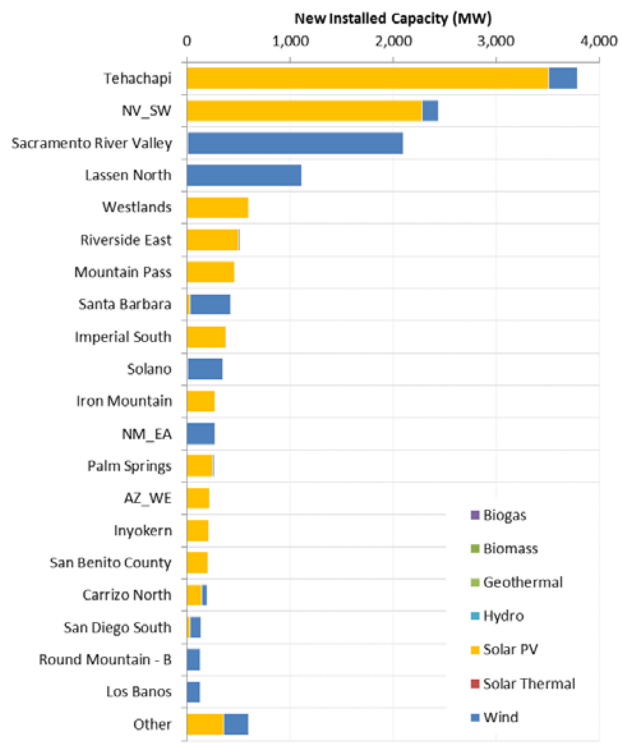
- does not provide basis for procurement/build decisions in 2016-17 TPP cycle;
- is intended to be used to develop portfolios for consideration by ISO in future TPP cycles; and,
- explores potential policy direction on various related issues but does not attempt to predict how those issues will ultimately be addressed.

OOS FCDS and EODS portfolios were almost identical; OOS portfolio size (MW) is smaller than the in-state portfolios

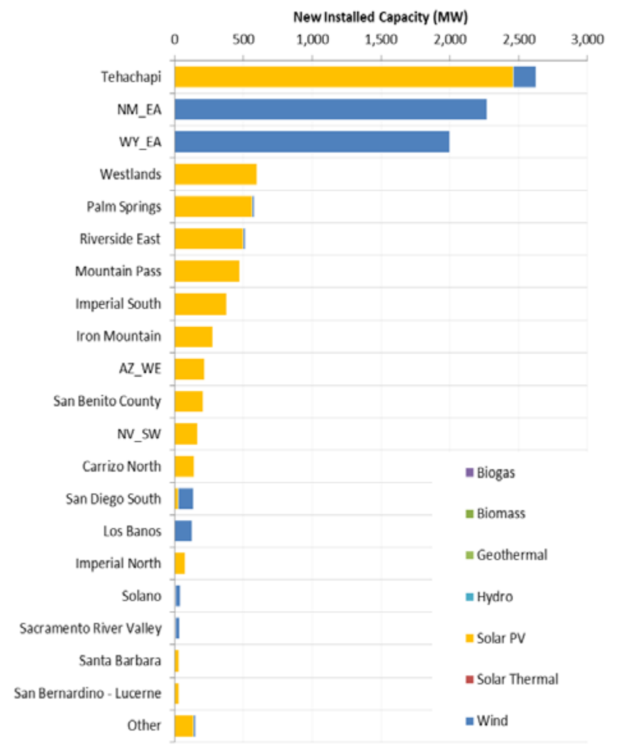
In-state FCDS



In-state EODS

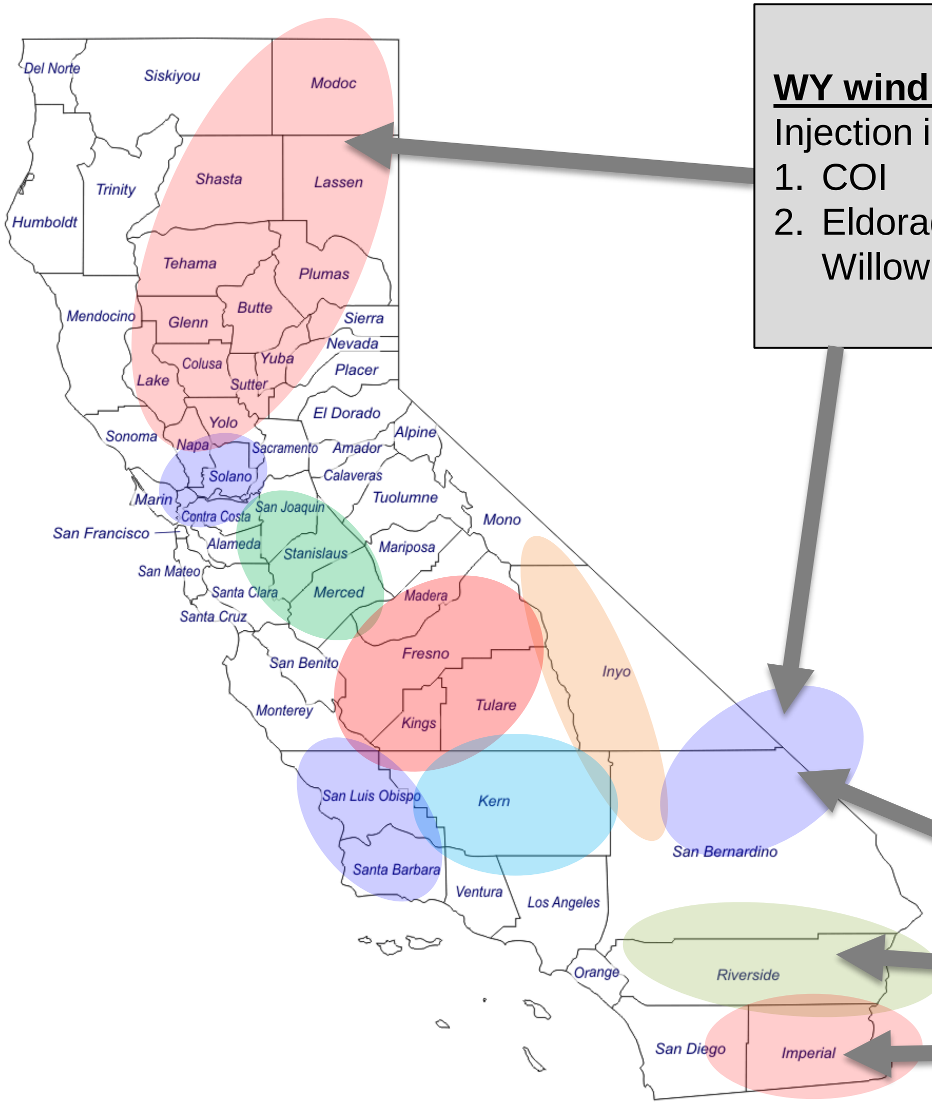


Out-of-state FCDS/EODS



Note - RPS calculator v6.2 was used to generate the portfolios

Expected injection points from out-of-state resources into CA over the existing network



WY wind resources (~2,000 MW)
Injection into CA could primarily utilize –
1. COI
2. Eldorado 500 kV, Mead 230 kV and Willow Beach scheduling points

NM wind resources (~2,000 MW)
Injection into CA could primarily utilize –
1. Palo Verde corridor

Out-of-state portfolio modeling was coordinated with the western planning regions

- NTTG and WestConnect provided resource location information for ~2,000 MW wind in WY and ~2,000 MW wind in NM
- Out-of-state portfolio models were shared with the western planning regions as part of the interregional coordination work
- NTTG provided transmission system contingencies to test the impact of the out-of-state portfolio on the affected part of the NTTG area
- Further coordination is expected on stressed scenario identification and reviewing study results

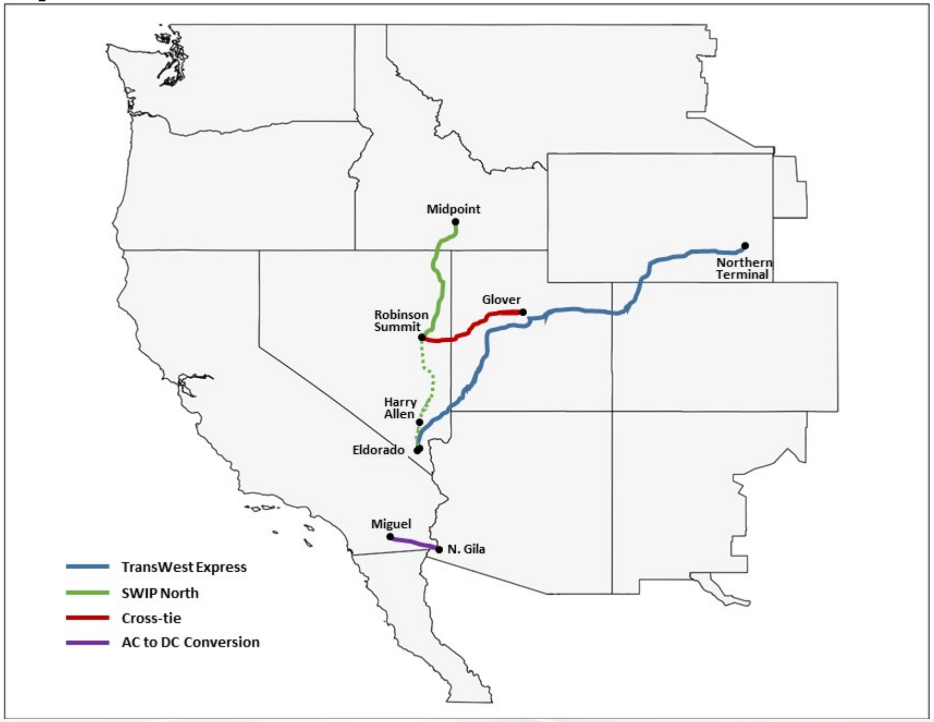
Interregional Transmission Projects

- ITPs were not modeled in the 50% RPS special study models
- The focus was on identifying system issues under existing transmission assumptions aligned with the TPP
- NTTG and WestConnect have completed the need evaluation during the current cycle of their ITP evaluation

Interregional Transmission Projects (ITPs)

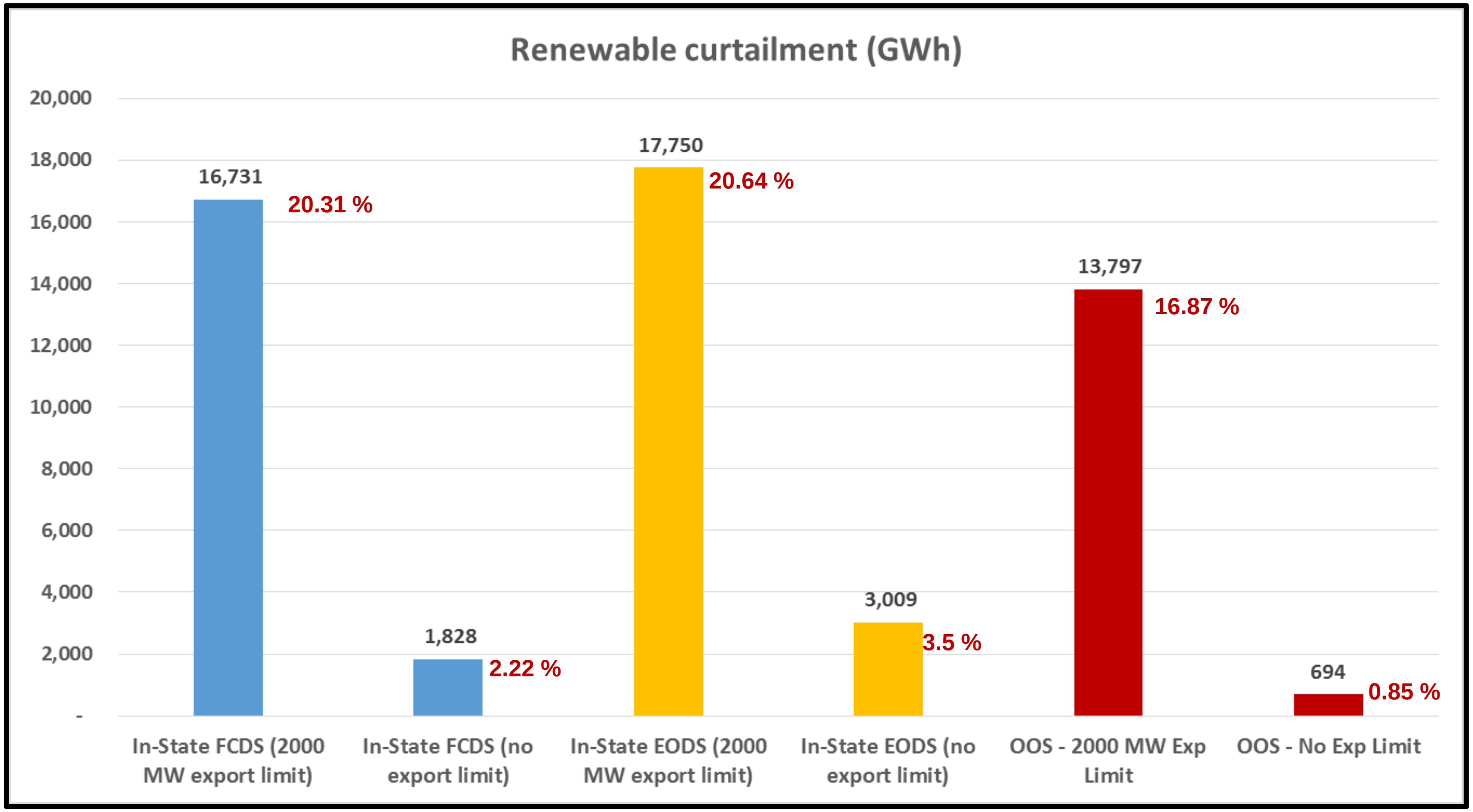
- TransWest Express
  - *California ISO*
  - *NTTG*
  - *WestConnect*
- SWIP North
  - California ISO
  - *NTTG*
  - *WestConnect*
- Cross-tie Project
  - California ISO
  - *NTTG*
  - *WestConnect*
- AC/DC Conversion Project
  - *California ISO*
  - *WestConnect*

Relevant Planning Region



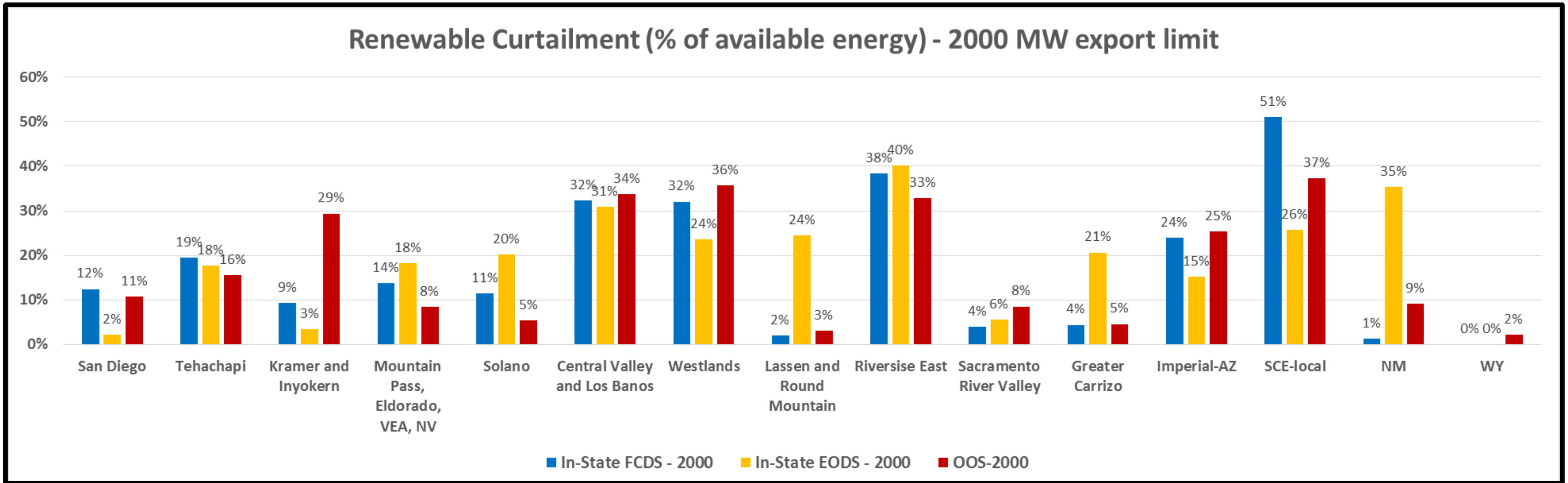
Renewable Curtailment and Transmission Congestion Summary

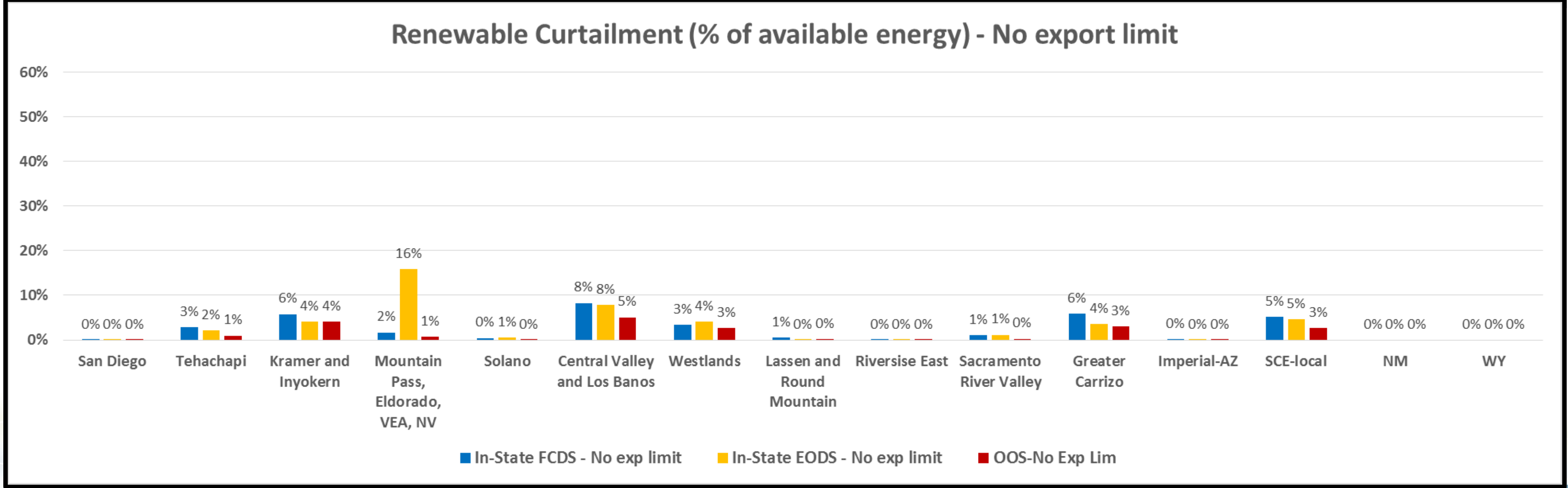
Total renewable curtailment by portfolio



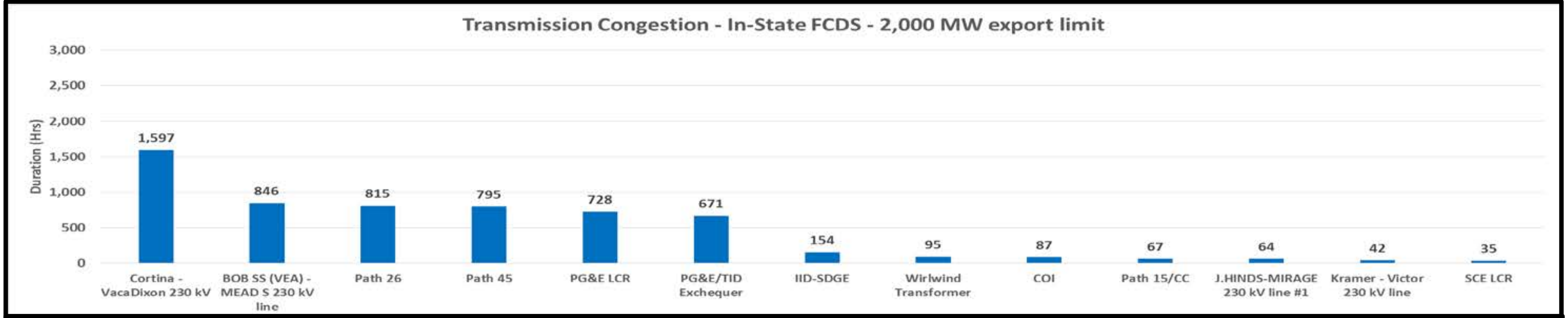
- **Export limits have a significant impact on the amount of renewable curtailment**
- **This indicates that most of the curtailment is over-supply related rather than transmission related regardless of the portfolio**
- **OOS portfolio shows the lowest curtailment (absolute and % of renewable potential) under the two bookend export limitations tested here**

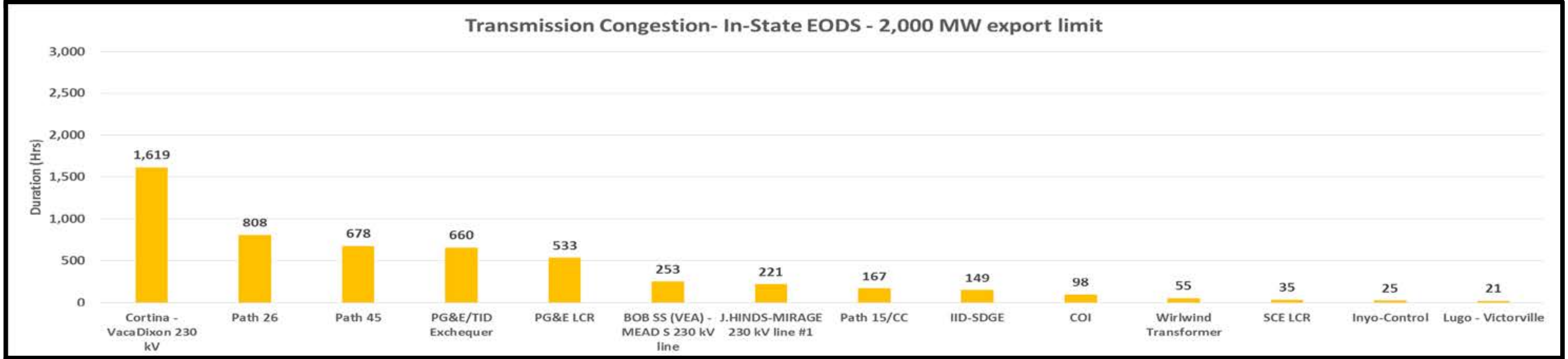
Relaxation of export limit resulted in a drastic reduction in total renewable curtailment across all portfolios

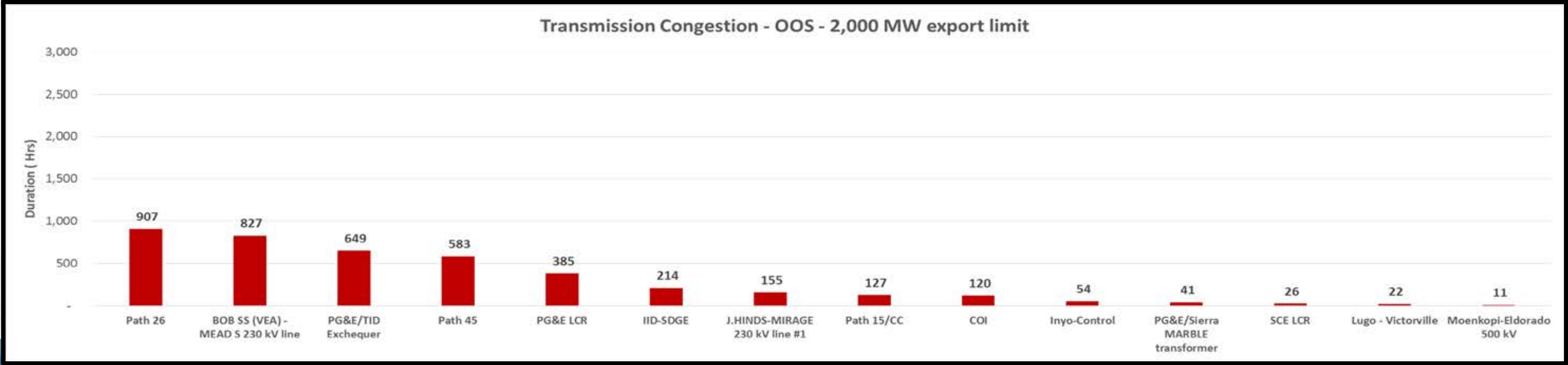




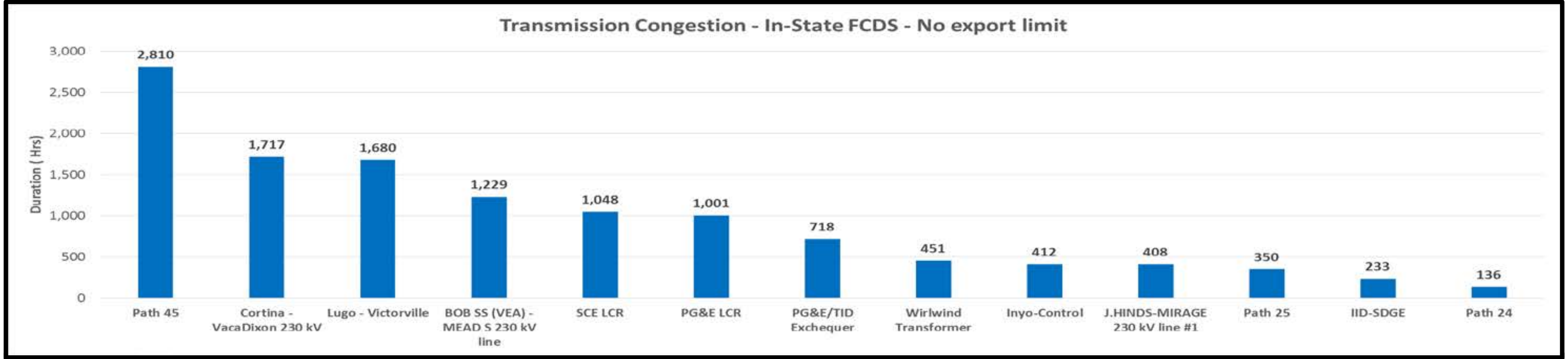
CA congestion with 2,000 MW export limit: OOS portfolio with showed the least amount of transmission congestion

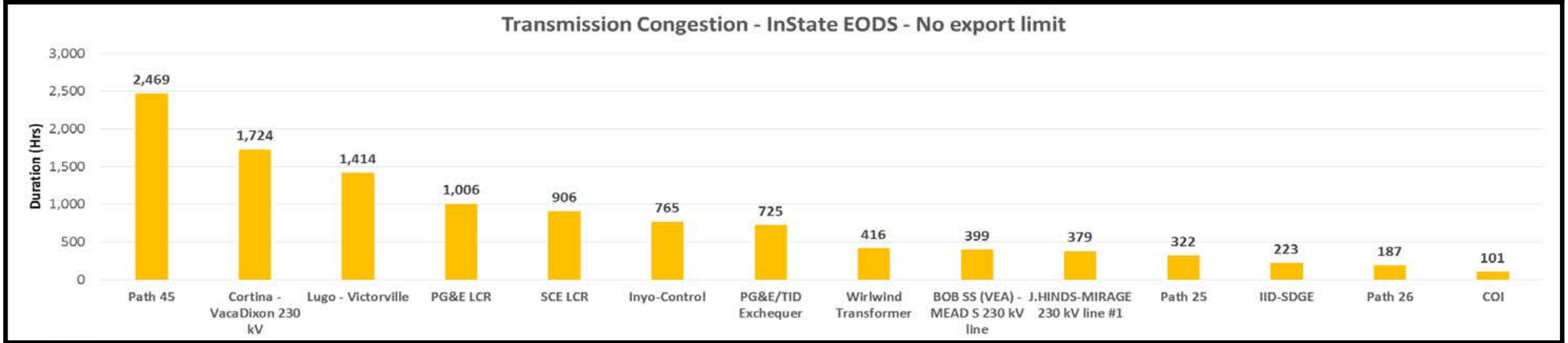


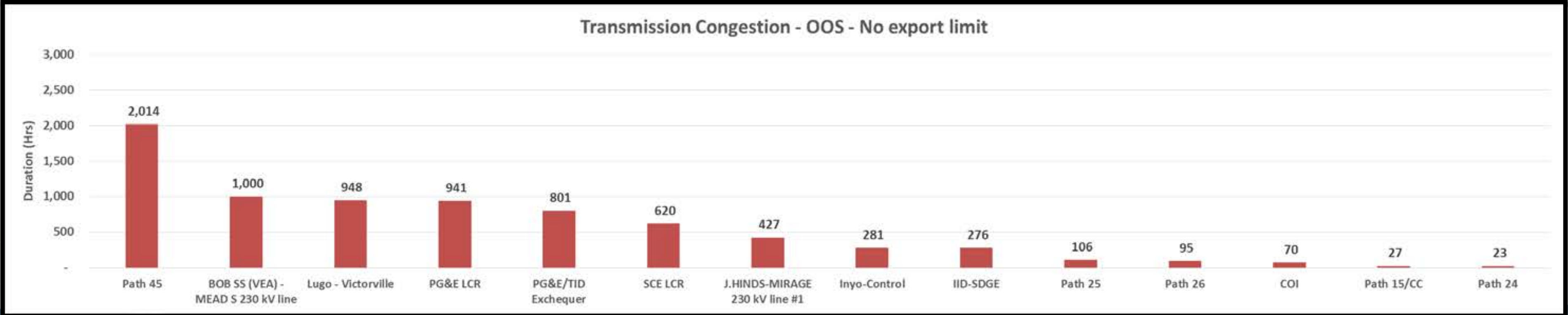




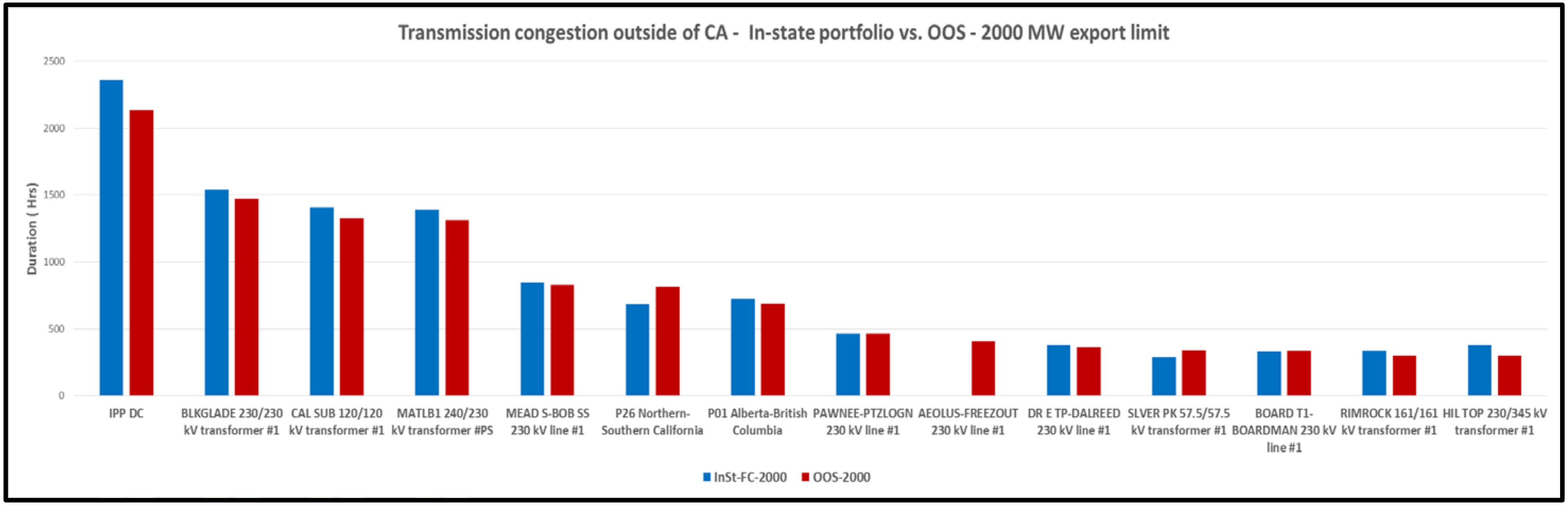
CA congestion with export limit relaxation: OOS portfolio with showed the least amount of transmission congestion





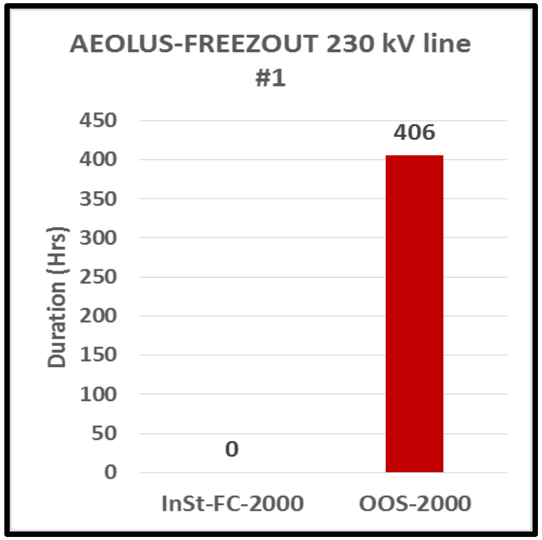


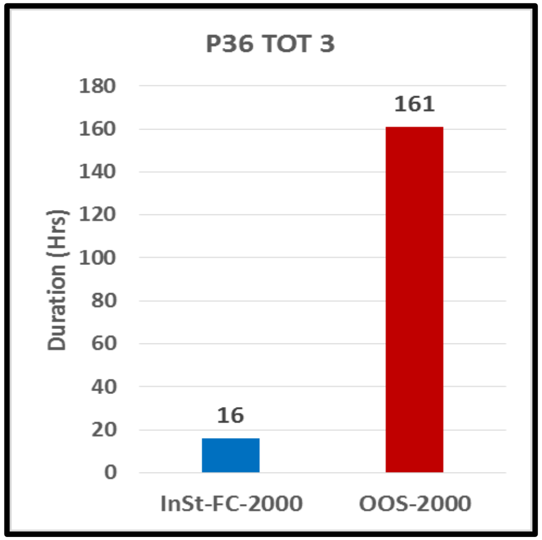
Congestion outside of CA: No significant change in the most heavily congested paths

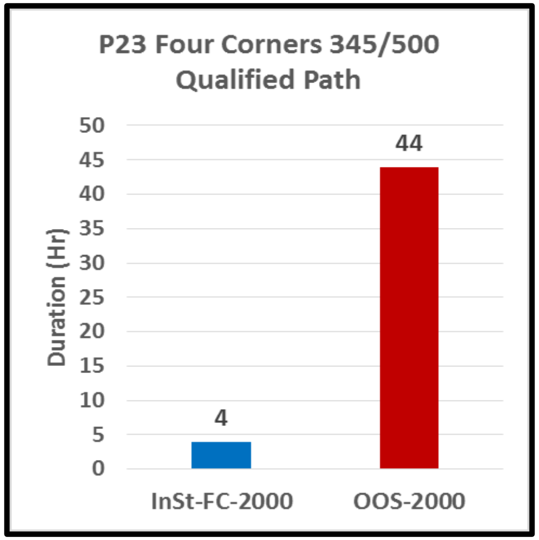


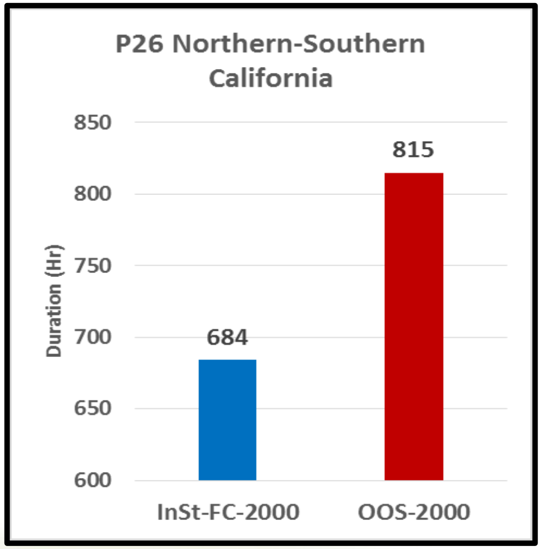
- Comparison of In-state and OOS portfolio from a prism of congestion outside of CA
- Barring a few constraint, no major changes observed (more details on the next slide)
- Constraints that experienced significantly more congestion are summarized on the next slide.

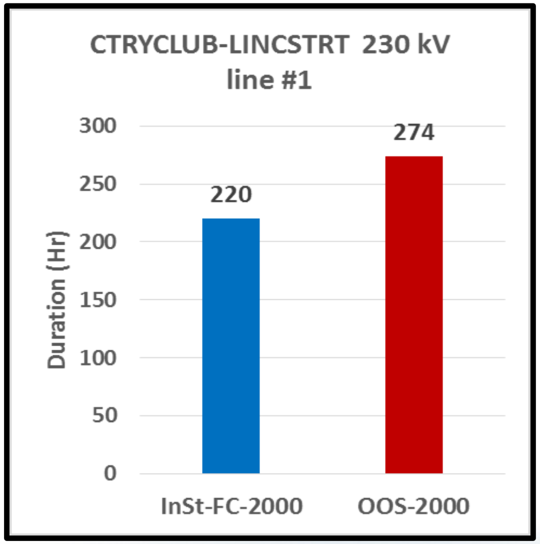
Congestion outside CA: Constraints that experienced significant increase in congestion (In-State vs OOS portfolio)

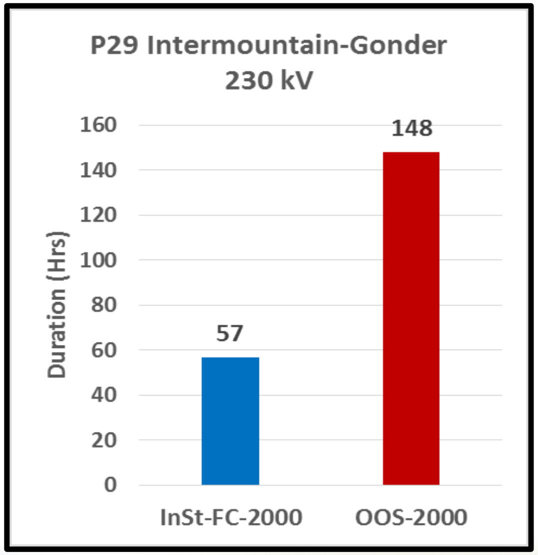












Reliability Snapshot Assessment

Power flow snapshots were selected based on stressed conditions from a CA system perspective

GridView Simulations

8760 Hours of production cost simulation results

Subset of hours with the maximum renewable potential (dispatch + curtailment)

Prior study experience and engineering judgement

Within this subset, selected hours with reasonably **stressed major path flows from CA system perspective**

Special considerations e.g. high COI and high WY wind

Scenario	Northern CA	Southern CA
In-state FCDS	None (focus was on deliverability assessment)	March 18 – Hr 13
In-state EODS	March 19 – Hr 19	March 18 – Hr 13
Out-of-state FCDS/EODS	**June 15 – Hr 05 (High COI and high WY wind)**	**November 29 – Hr 12**

Summary of impact of the OOS portfolio on CA transmission during the selected snapshots

- Very few resources were selected in the Northern CA system in the OOS portfolios, so no major reliability issues were identified

- Major overloads in Southern CA system –

Scenario	Limiting Element	Contingency	Type	Comment
In-State & **OOS**	Mead - Bob SS 230kV Line	Eldorado 500/230kV Bank 5	T-1	Existing Ivanpah RAS not sufficient. Pre-contingency curtailment (~1300 MW)
In-State-EODS, In-State-FCDS, **OOS**	MIDWAY-WIRLWIND 500kV (Path 26)	Base Case	N-0	Series compensation on P26 may need to be revisited for S->N flows. ~1300 MW curtailment needed.
In-State-EODS, **OOS**	MAGUNDEN - ANTELOPE 230kV 1	MAGUNDEN - ANTELOPE 230kV 2 & ANTELOPE - PARDEE 230kV 1	N-1-1	~2500MW curtailment after the first N-1 without Big Creek Gen ~1150 MW curtailment after the first N-1 asusming Big Creek Gen is available

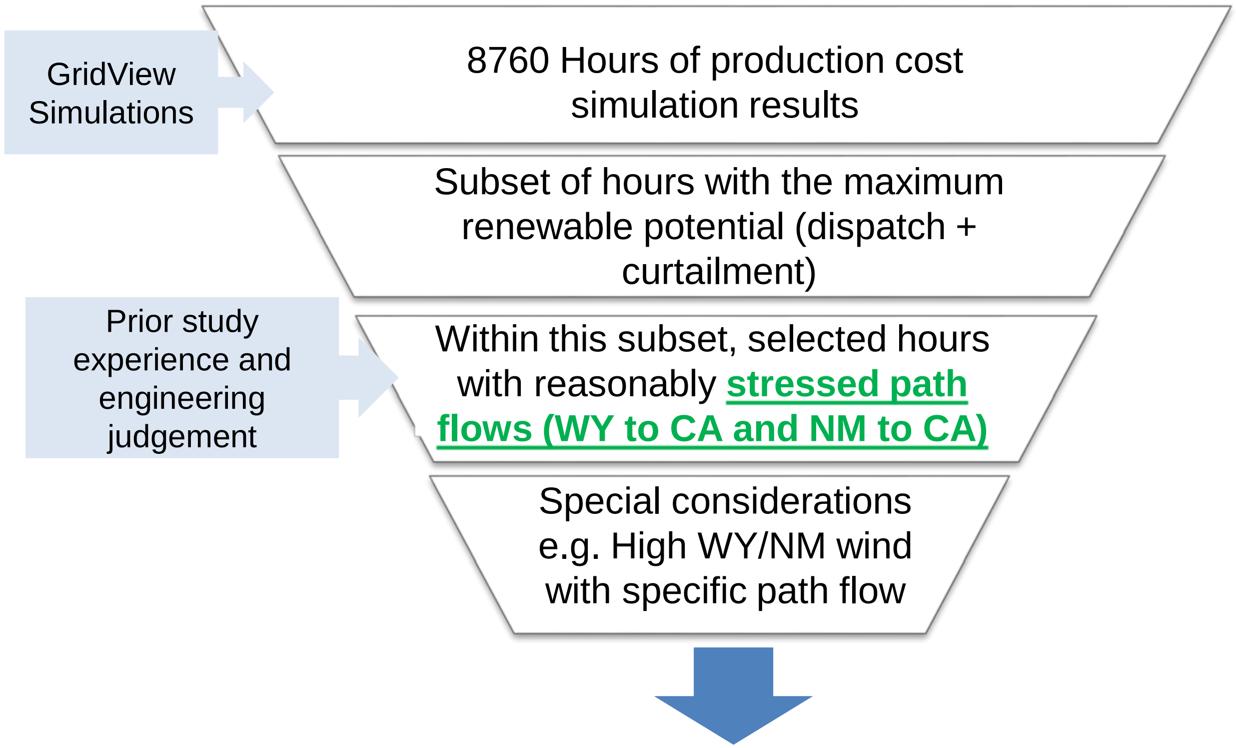
- OOS portfolio was the least severe one in terms of adverse reliability impact on the CA transmission system; the curtailment numbers in the table above are for the worst overloads (In-state EODS)

Evaluation of transmission system outside of CA: Additional production simulation modeling is needed to identify potential constraints

- Contingencies provided by NTTG were tested against the reliability snapshots identified based on stressed path flows from CA system perspective and high renewable potential
- Several 230 kV overloads were observed in WY system in the vicinity of the new wind resources

- The snapshots were based on 2015-2016 TPP and path flow modeling was focused on the CA system; unable to identify the most stressed snapshot for paths outside of CA using this data
- The production cost simulation results presented here will help refine the snapshot identification moving forward for evaluating impact on transmission system outside of CA
- Input from the Western Planning Regions (WPRs) and stakeholders will be crucial

Additional production simulation modeling is needed to identify transmission constraints outside of CA



- **The production cost models used in 2015-2016 TPP were not the ideal ones to identify the most stressed snapshot for paths outside of CA.**
- **Snapshot identification approach needs to be targeted towards stressed snapshot for paths outside of CA .**
- **Need input from stakeholders and from the western planning regions (WPRs)**

Scenario	Region A	Region B
Out-of-state FCDS/EODS	**One or more snapshots**	**One or more snapshots**

Deliverability Assessment

(Impact on CA system presented during
February 17, 2017 stakeholder meeting)

Out-of-state import deliverability evaluation (MIC)

- Evaluated whether MIC expansion is needed for out-of-state renewables
- Large amount of wind resources in NM and WY
- Sufficient import capacity for NM and WY wind resources

	NM	WY
50% exceedance factor	40.27%	40.76%
Wind Capacity	2200	2000
MIC Need	885.94	815.20
Scheduling Point	PVWEST	ELDORADO500 & MEAD230 & WILLOWBEACH
Remaining Import Capacity after ETC and Pre-RA in 2026	1821	925
MIC Expansion	0	0
Current MIC	3254	1753
Total Target MIC	3254	1753

Summary of Key Findings and Next Steps

Summary of conclusions for OOS portfolio assessment portion of the 50% RPS special study

Assessment	Key findings pertaining to OOS portfolio
Production Cost Simulation	• <u>Curtailment:</u> OOS portfolio shows the lowest curtailment (absolute and % of renewable potential) under the two bookend export limitations • <u>Transmission congestion:</u> OOS portfolio showed the least amount of intra-CA congestion; increase in congestion outside of CA • <u>Further coordination with WPRs is expected on stressed scenario identification and reviewing study results</u>
Reliability Assessment	• OOS portfolio was the least severe one • No major issues in the Northern CA system due to lower amount of resource selection • One potential issue in Southern CA observed in all portfolios • <u>This year's production cost simulations will help identify more severe snapshots for the system outside of CA</u>
Deliverability	• Evaluated the need for MIC expansion and found no major deliverability issues from injection point into CAISO BA to CAISO loads (Presented during February 17, 2017 stakeholder meeting #4))

Next steps regarding the ITP evaluation portion of the 50% RPS special study

- Share the results with the Western Planning Regions and identify specific stressed snapshots for evaluating the system outside of CA
- Additional production cost analysis (with more clarity on OOS resource assumptions)
- Work with the Western Planning Regions to identify important contingencies to test the out-of-state portfolio on the affected part of the WPR areas
- Once major transmission issues are identified using stressed scenarios and snapshots for the system outside of CA, test the effectiveness of ITPs in mitigating these issues
- Coordinate with WestConnect on their study and findings out “High Renewables” scenario that models a California 50% out-of-state case

Questions?

Bulk Energy Storage Resource Case Study – Update with the 2016 LTPP Assumptions

Shucheng Liu
Principal, Market Development

2016-2017 Transmission Planning Process Stakeholder Meeting
February 28, 2017

Purpose of the ISO bulk energy storage case study

- To assess a bulk storage resource's ability to reduce
  - production cost
  - renewable curtailment
  - CO_2 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

History of the bulk energy storage studies

- Initial study with 40% RPS was conducted in the 2015-2016 planning cycle[1]
- It was then updated with a 50% RPS portfolio and some other changes[2]
- This is another update of the study with new assumptions and two sizes of bulk energy storages

[1] http://www.caiso.com/Documents/Board-Approved2015-2016TransmissionPlan.pdf
[2] http://www.caiso.com/Documents/BulkEnergyStorageResource-2015-2016SpecialStudyUpdatedfrom40to50Percent.pdf

Study Assumptions

Summary of study assumptions

- This study is based on the Default Scenario of the CPUC 2016 LTPP/TPP Assumptions and Scenarios[3]
- There are some major changes in the assumptions compared to the study with 50% RPS in 2015-2016 TPP
  - Retirement of non-dispatchable generation resources
  - Dispatchability of CHP resources
  - Lower load forecast and higher Additional Achievable Energy Efficiency (AAEE)
  - Lower RPS energy
  - Higher renewable curtailment prices

[3] Reference: http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M162/K005/162005377.PDF

Comparison of assumptions that may affect the results of this study notably

Assumption	This Study	2015-2016 TPP 50% RPS Study
Changes in non-dispatchable generation resources	Diablo Canyon nuclear plant (2,300 MW) is retired 2,786 MW CHP in operation	Diablo Canyon in operation 4,684 MW CHP in operation
Dispatchability of CHP resources*	50% of the 2,786 MW CHP is dispatchable	All 4,684 MW CHP is non-dispatchable
California Load forecast	64,009 MW 1-in-2 No AAEE non-coincident peak load 301,480 GWh energy	70,763 MW 1-in-2 No AAEE non-coincident peak load 322,218 GWh energy
California AAEE*	9,418 MW non-coincident peak impact 39,779 GWh energy CEC provided hourly profiles that usually have higher values in the late afternoon and early evening	5,713 MW non-coincident peak impact 24,535 GWh energy No hourly profile, offsetting load proportionally to the hourly load values

Comparison of assumptions that may affect the results of this study notably (cont.)

Assumption	This Study	2015-2016 TPP 50% RPS Study
CA RPS portfolio	36,776 MW installed capacity 110,288 GWh energy	40,986 MW installed capacity 125,307 GWh energy
Price of renewable generation curtailment*	-$15/MWh for the first 200 GWh, -$25/MWh for additional 12,400 GWh and -$300/MWh thereafter	-$300/MWh for all curtailment
Hydro condition	2005 hydro generation	2005 hydro generation
ISO maximum net export capability	2,000 MW	2,000 MW

Additional sensitivity analyses will be conducted to address the uncertainties in some of the assumptions.

- Because of the uncertainties in some of the assumptions, the ISO will conduct additional sensitivity analyses on at least the following assumptions
  - Dispatchability of CHP resource
  - Level of AAEE
  - Prices of renewable curtailment

Other assumptions

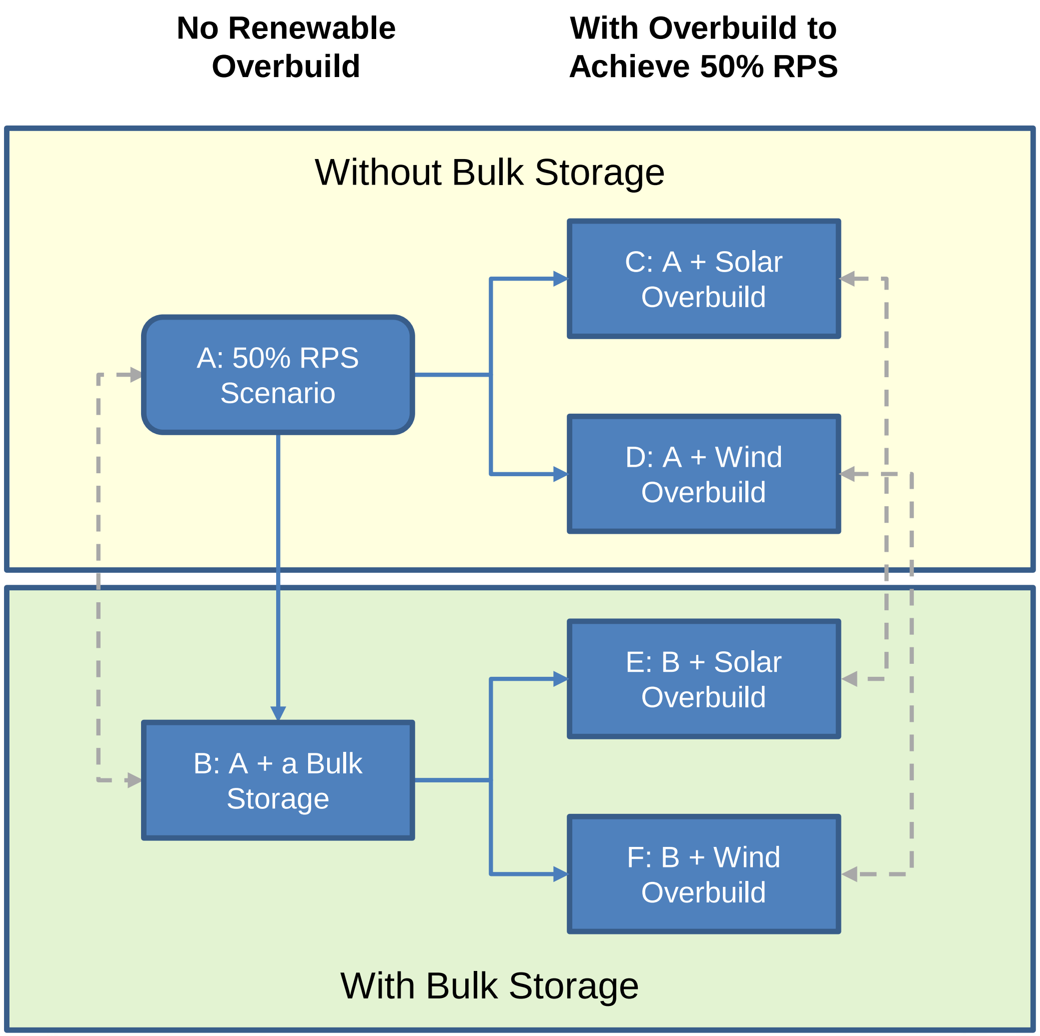
- Most of other assumptions for California are consistent with that in the study with 50% RPS in 2015-2016 TPP, including
  - Allowing renewable to provide load following-down up to 50% of the requirement
  - Enforcing a CAISO-wide frequency response requirement
- Assumptions for outside California are from the TEPPC 2026 Common Case v1.5 (October 21, 2016 release)

Study Approach

Study approach

- 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 explore the benefits of more diversified RPS portfolios
- Modeling two bulk energy storage sizes, 500 MW and 1,400 MW, separately

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 500 MW 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, pumping and generation)	**1.5**
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 the 1,400 MW new pumped storage resource

Item	Value
Number of units	**4**
Max pumping capacity per unit (MW)	**422**
Minimum pumping capacity per unit (MW)	75
Maximum generation capacity per unit (MW)	**350**
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, pumping and generation)	**1.5**
Maintenance rate	8.65%
Forced outage rate	6.10%
Upper reservoir maximum capacity (GWh)	18.8
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 for revenue requirements and RA revenue calculation

Item	Generation & Transmission Costs (2016$/kW-year) [4]	NQC Peak Factor [5]	RA Revenue ($/kW-year) [6]
Large Solar In-State	242.19	47%	16.53
Large Solar Out-State	183.17	47%	16.53
Small Solar In-State	334.80	47%	16.53
Solar Thermal In-State	551.55	90%	31.66
Wind In-State	239.14	17%	5.98
Wind Out-State	223.88	45%	15.83
Pumped Storage In-State	407.91	100%	35.18

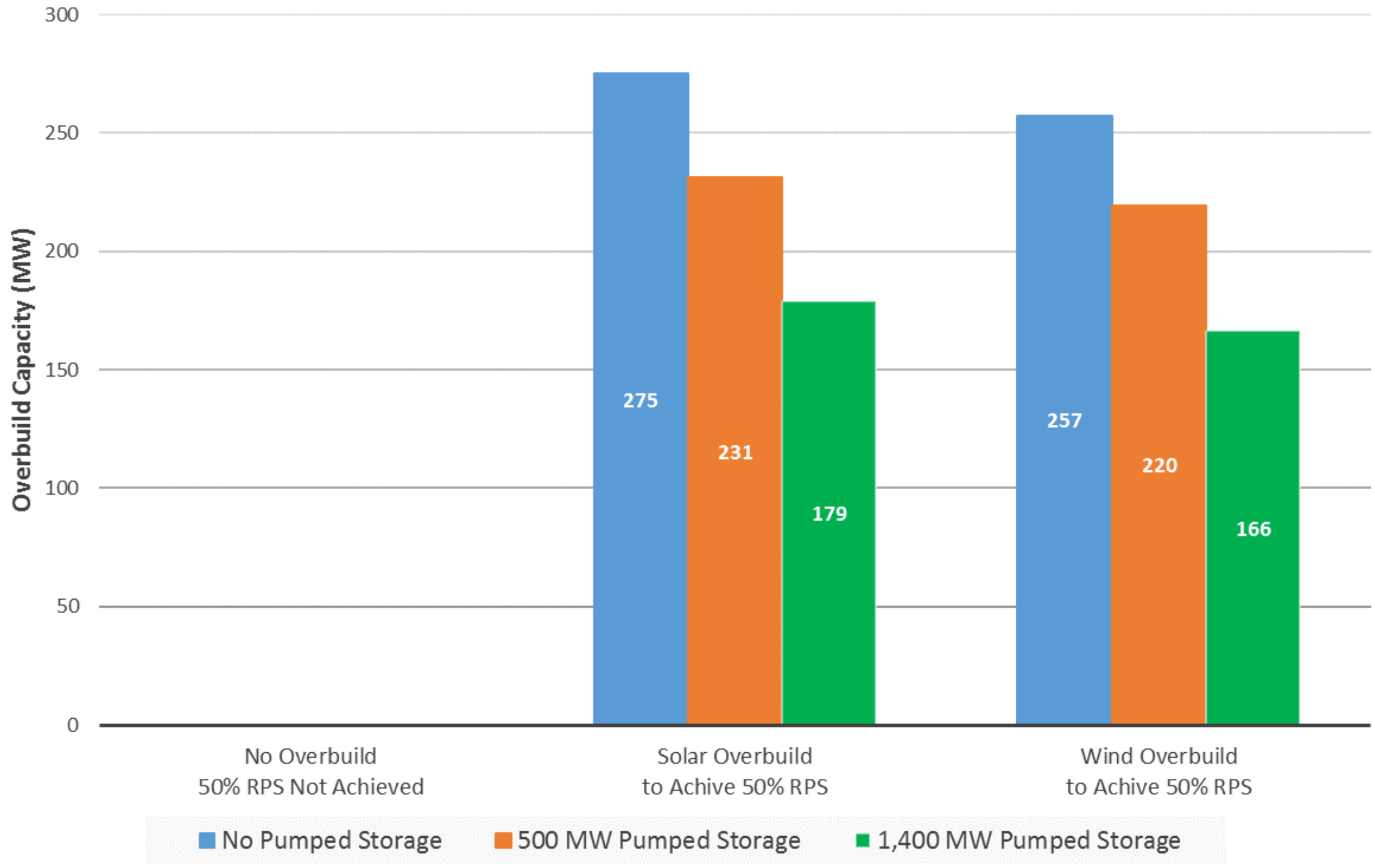
[4] Draft2017 IRP Assumptions http://www.cpuc.ca.gov/uploadedFiles/CPUC_Website/Content/Utilities_and_Industries/Energy/Energy_Programs/Electric_Power_Procurement_and_Generation/LTPP/DRAFT_RESOLVE_Inputs_2016-12-21.xlsx
[5] https://www.caiso.com/Documents/2012TACAreaSolar-WindFactors.xls and https://www.wecc.biz/Reliability/2024-Common-Case.zip
[6] CPUC 2015 RA Report http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=6442452221

Definition of the study cases

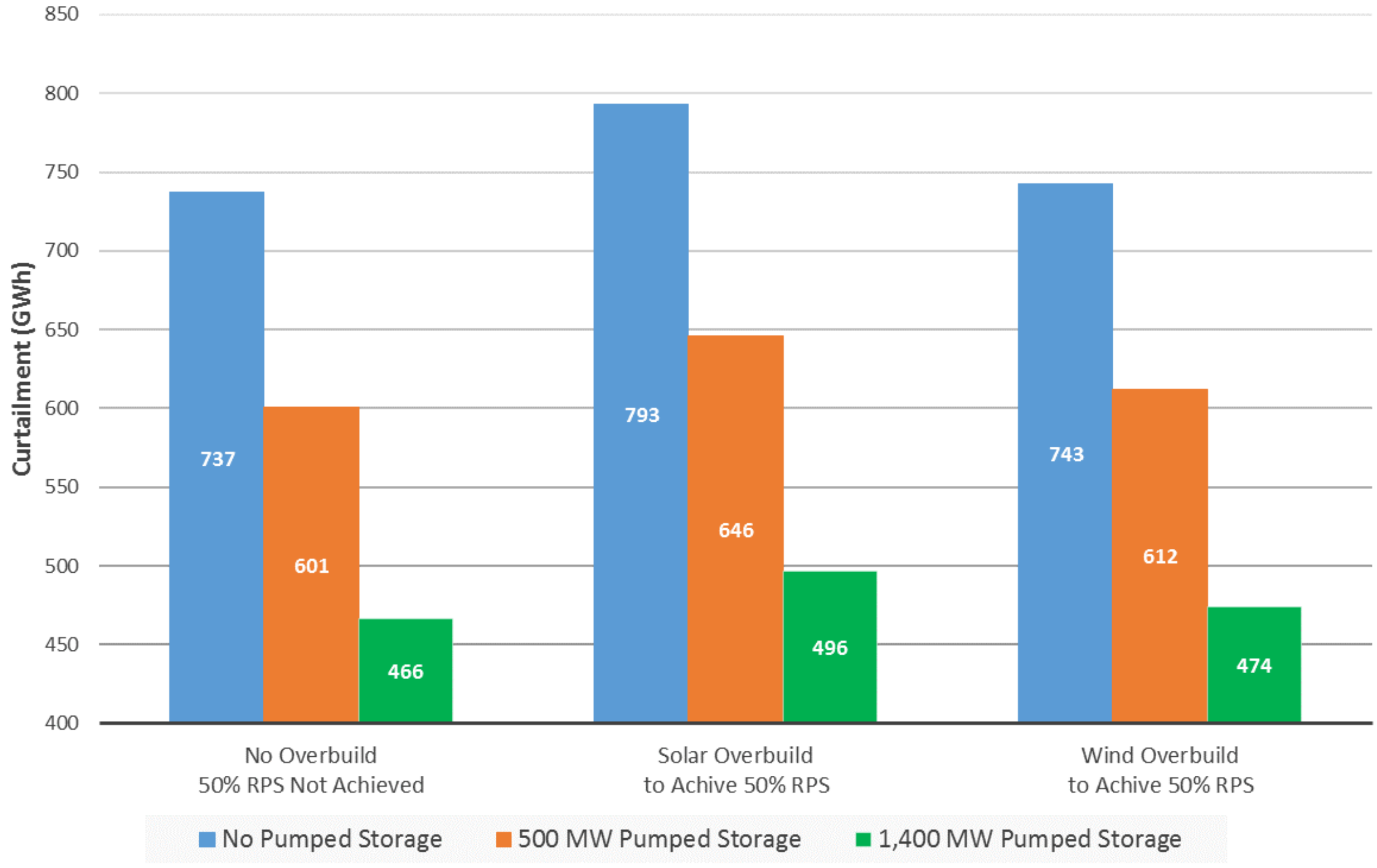
Case	Definition
A	Base Case, no pumped storage and no renewable overbuild
B500	Base Case plus a 500 MW pumped storage resource
B1400	Base Case plus a 1,400 MW pumped storage resource
C	Base Case with solar overbuild
D	Base Case with wind overbuild
E500	Base Case with solar overbuild and a 500 MW pumped storage resource
E1400	Base Case with solar overbuild and a 1,400 MW pumped storage resource
F500	Base Case with wind overbuild and a 500 MW pumped storage resource
F1400	Base Case with wind overbuild and a 1,400 MW pumped storage resource

Summary of Study Results

Capacity of renewable overbuild to achieve the 50% RPS target

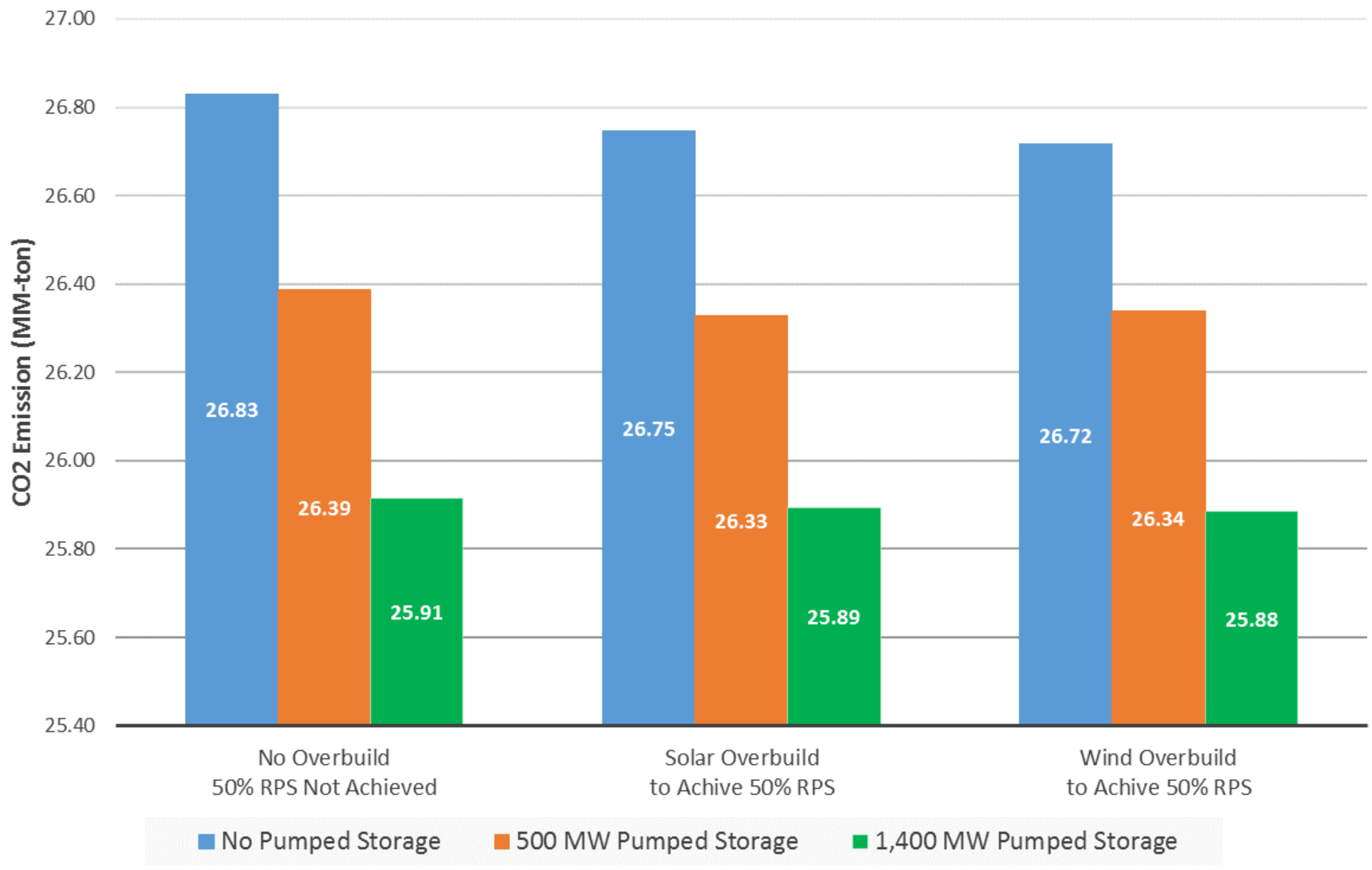


California renewable generation curtailment



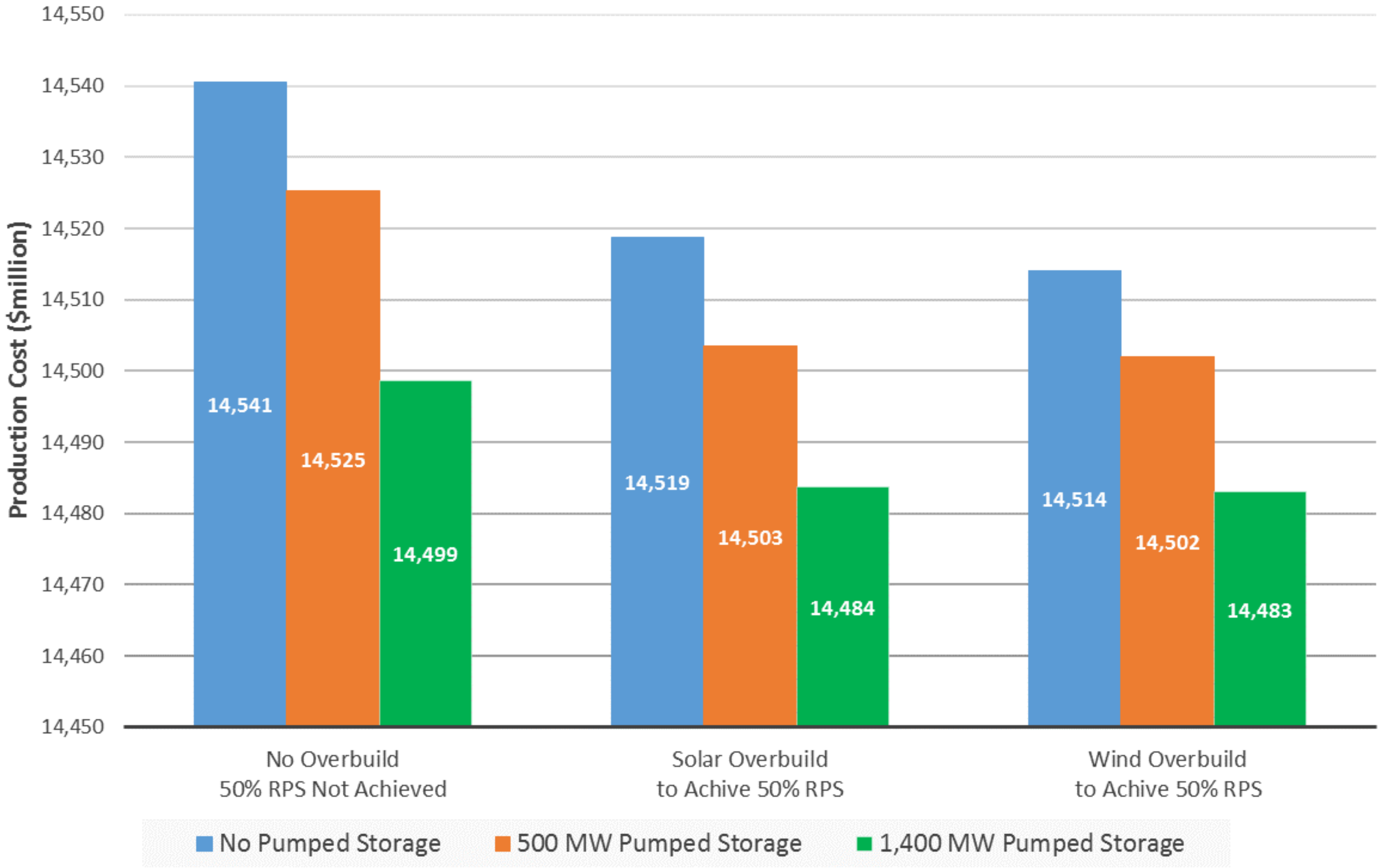
Renewable curtailment price is assumed as -$15/MWh for the first 200 GWh and -$25/MWh for additional 12,400 GWh.

California CO2 emission (50% RPS)



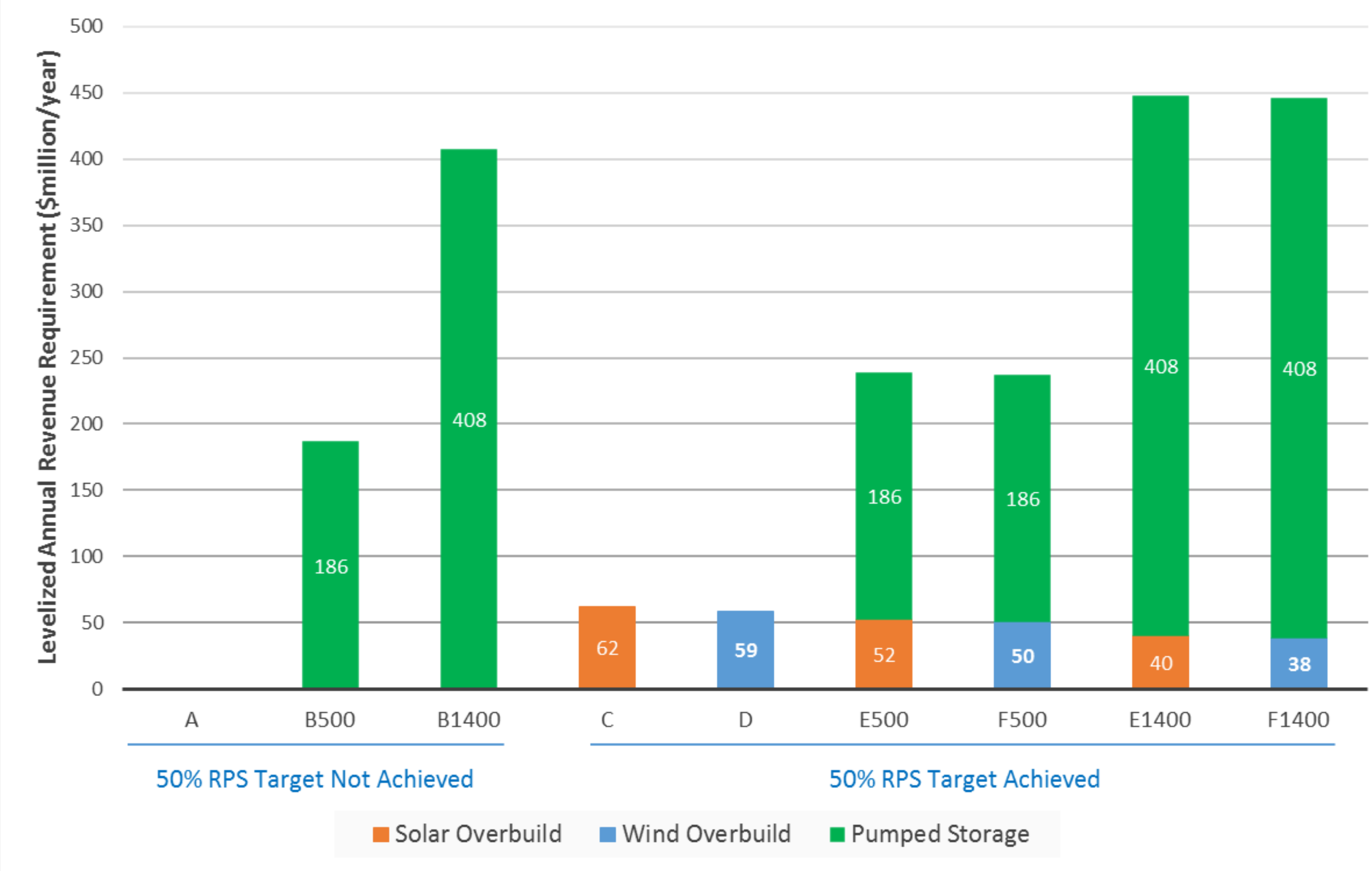
CA CO2 Emission includes the CO2 emission from net import

WECC annual production cost



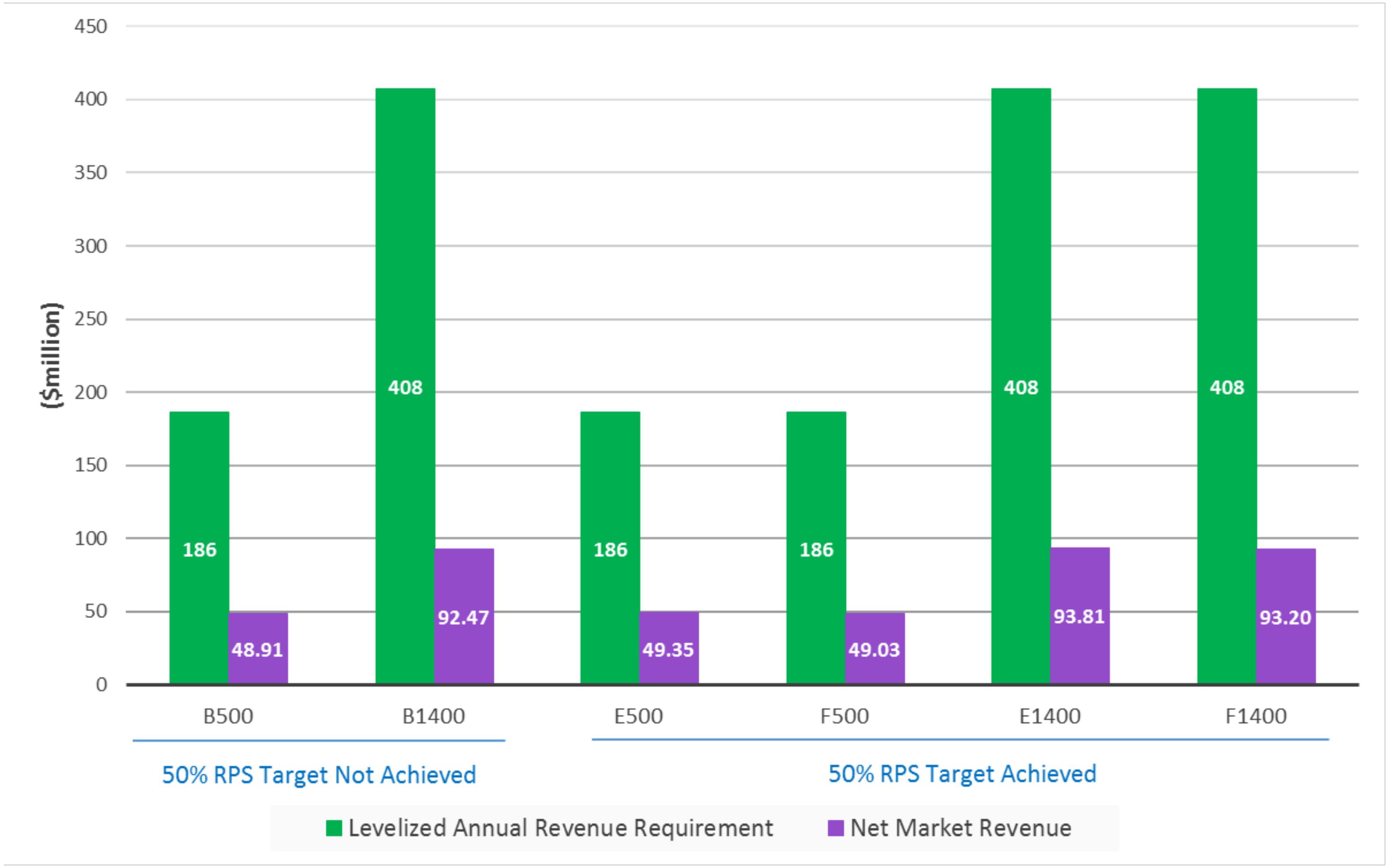
Production cost includes start-up, fuel and VOM cost, but not CO2 cost.

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



Cost of the 1,400 MW pumped storage is discounted by 20% based on economies of scale assumption

Pumped storage levelized annual revenue requirements and net market revenues of 2026



Net Market Revenue is revenue from energy, reserves and load following minus cost of energy and operation

Summary of annual results by case

	No Pumped Storage			500 MW Pumped Storage			1,400 MW Pumped Storage		
Case	**A**	**C**	**D**	**B500**	**E500**	**F500**	**B1400**	**E1400**	**F1400**
Renewable Curtailment (GWh)	737	793	743	601	646	612	466	496	474
Curtailment Frequency (hours)	292	320	305	251	268	253	211	219	207
CA CO2 Emission (MM-ton)	26.83	26.75	26.72	26.39	26.33	26.34	25.91	25.89	25.88
CA CO2 Emission ($million)	606	604	604	596	595	595	585	585	585
Production Cost ($million)									
WECC	14,541	14,519	14,514	14,525	14,503	14,502	14,499	14,484	14,483
CA	2,999	2,989	2,986	2,952	2,945	2,946	2,900	2,898	2,897
Renewable Overbuild and Pumped Storage Capacity (MW)									
Solar		275			231			179	
Wind			257			220			166
Pumped Storage				500	500	500	1,400	1,400	1,400
Levelized Annual Revenue Requirement of Renewable Overbuild and Pumped Storage ($million/year)									
Solar		62.11			52.17			40.43	
Wind			58.89			50.41			38.04
Pumped Storage				186.37	186.37	186.37	407.61	407.61	407.61
Sum		*62.11*	*58.89*	*186.37*	*238.54*	*236.78*	*407.61*	*448.04*	*445.65*
Pumped Storage Net Market Revenue ($million)				48.91	49.35	49.03	92.47	93.81	93.20

Notes:
1. Renewable curtailment price is assumed as -$15/MWh for the first 200 GWh and -$25/MWh for additional 12,400 GWh.
2. CA CO2 Emission includes the CO2 emission from net import.
3. CO2 cost is $22.59/M-ton.
4. Production cost includes start-up, fuel and VOM cost, but not CO2 cost.
5. Net Market Revenue is revenue from energy, reserves and load following minus cost of energy and operation.

Findings of system benefits

- Compared to the study with 50% RPS in 2015-2016 TPP, results of this study show significantly lower renewable curtailment, mainly due to
  - Retirement of Diablo Canyon and non-dispatchable CHP resources
  - Dispatchability of 50% of CHP resources
  - Lower load forecast together with higher AAEE, and the resulted lower renewable energy needed to achieve the 50% RPS target

Findings of system benefits (cont.)

- Because of low renewable curtailment, the effectiveness of the pumped storage resources in reducing renewable curtailment, CO_2 emission and production costs is limited
- Besides lower curtailment, the net market revenues of the pumped storages are also affected by the higher renewable curtailment prices

Findings of system benefits (cont.)

- The net market revenue of the pumped storage resources provides only a portion of the levelized annual revenue requirements
- Developing pumped storage resources would need other sources of revenue streams, which could be developed through policy decisions

Findings of system benefits (cont.)

- The following annual system cost reductions (benefits) are not included in the net market revenue, but may be attribute to the pumped storage resources

	500 MW Pumped Storage		1,400 MW Pumped Storage	
Case	**E500**	**F500**	**E1400**	**F1400**
CA CO2 Emission ($million)	-9.45	-8.50	-19.25	-18.79
Production Cost ($million)				
WECC	-15.30	-11.96	-35.03	-30.96
CA	-44.05	-39.59	-91.49	-89.01
Levelized Annual Revenue Requirement of Renewable Overbuild ($million/year)				
Solar	-9.94		-21.68	
Wind		-8.48		-20.85

Next steps

- The results of the study are sensitive to the assumptions, especially those listed in the tables on slide 6 and 7
- There are uncertainties in some of these assumptions
- The conclusions about the benefits and costs of the pumped storage resources could change should the assumptions change in the future
- The ISO will conduct sensitivity analyses at least on
  - Dispatchability of CHP resource
  - Level of AAEE
  - Prices of renewable curtailment

Bulk Energy Storage Resource Special Study– Locational Benefits

Robert Sparks
Manager, Regional Transmission - South
Regional Transmission

2016-2017 Transmission Planning Process Stakeholder Meeting
February 28, 2017

Overview of Locational Benefit Analysis

- The ISO undertook additional analysis to assess the locational benefits of large energy storage
- Assessment considering known potential sites:
  - Lake Elsinore,
  - Eagle Mountain,
  - San Vicente

Locational Assessment for Eagle Mountain Storage Project

- Eagle Mountain is located in the Riverside renewable zone
- Riverside renewable zone could be potentially congested due to large amount of renewable development in the area
- Preliminarily screening to identify congestion benefits of locating the Eagle Mountain storage project in the Riverside Renewable zone was performed using the ISO’s 2016-2017 production cost models (PCM) with 50% renewable portfolios

Locational Assessment Results for Eagle Mountain Storage Project

- The Eagle Mountain storage project was modeled into ISO's 2016-2017 production cost models (PCM) with 50% renewable portfolios
  - In-state FCDS
  - In-state EODS
  - Out-of-state FCDS/EODS
- The Eagle Mountain pumped storage project did not significantly reduce any of the identified congestion
- The ISO has identified marginal transmission line loss improvements

Locational Assessment for Lake Elsinore and San Vicente Projects

- Lake Elsinore and San Vicente are located in the San Diego load center
- The San Diego load center requires local generation capacity to reliability serve the San Diego area load
- Both Lake Elsinore and San Vicente storage projects would be interconnected at locations that would be effective in meeting the San Diego area local capacity needs
- A sensitivity of transmission line loss analysis shows no line loss benefits, as the pumped storage generation appears to displace local gas-fired generation that does not require “charging”
- The local capacity benefits would be subject to future procurement decisions.