# 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
  - 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

# 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<br>2,786 MW CHP in operation | Diablo Canyon in operation<br><br>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<br>301,480 GWh energy | 70,763 MW 1-in-2 No AAEE non-coincident peak load<br>322,218 GWh energy |
| California AAEE* | 9,418 MW non-coincident peak impact<br>39,779 GWh energy<br>CEC provided hourly profiles that usually have higher values in the late afternoon and early evening | 5,713 MW non-coincident peak impact<br>24,535 GWh energy<br>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<br>110,288 GWh energy | 40,986 MW installed capacity<br>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

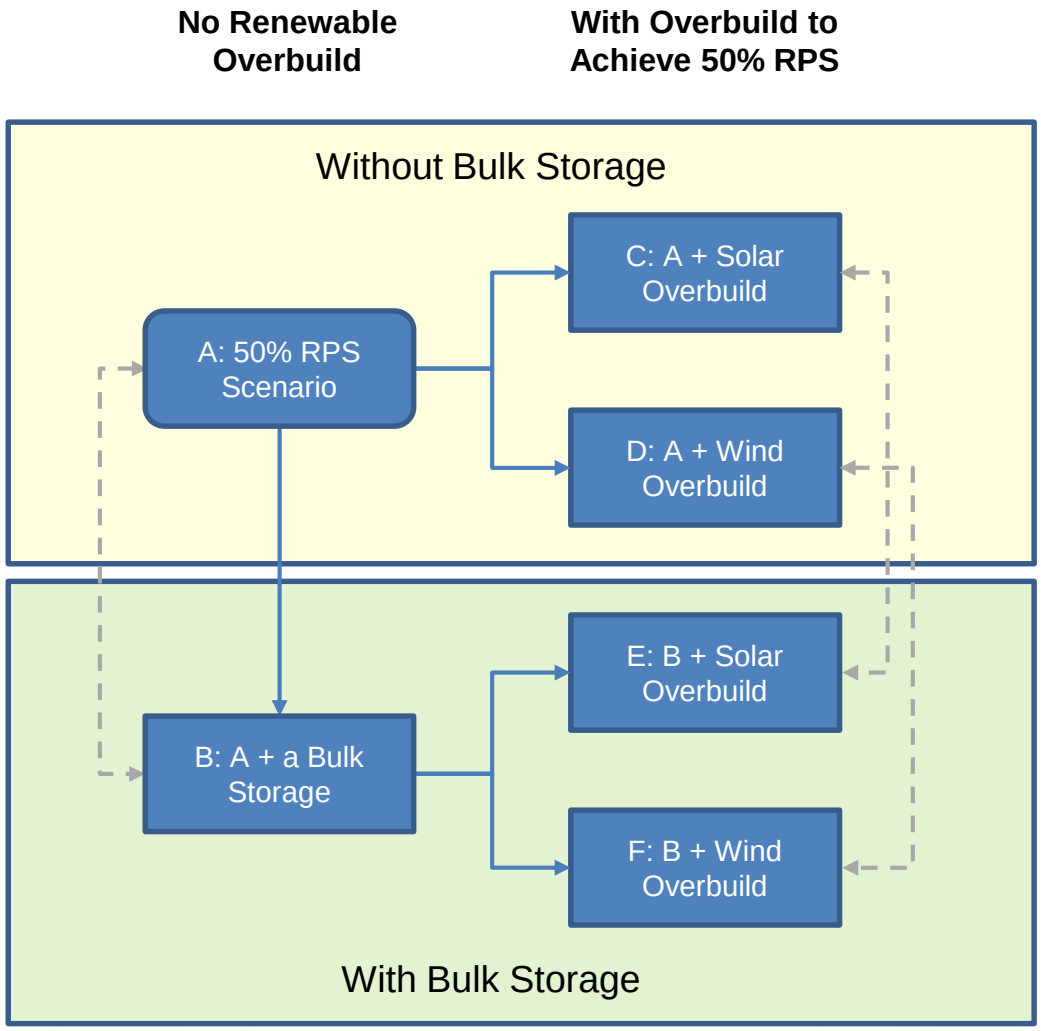
- Most of other assumptions for California are consistent with that in the study with 50% RPS in 2015-2016 TPP, including
  - Allowing renewable to provide load following-down up to 50% of the requirement
  - Enforcing a CAISO-wide frequency response requirement
- Assumptions for outside California are 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

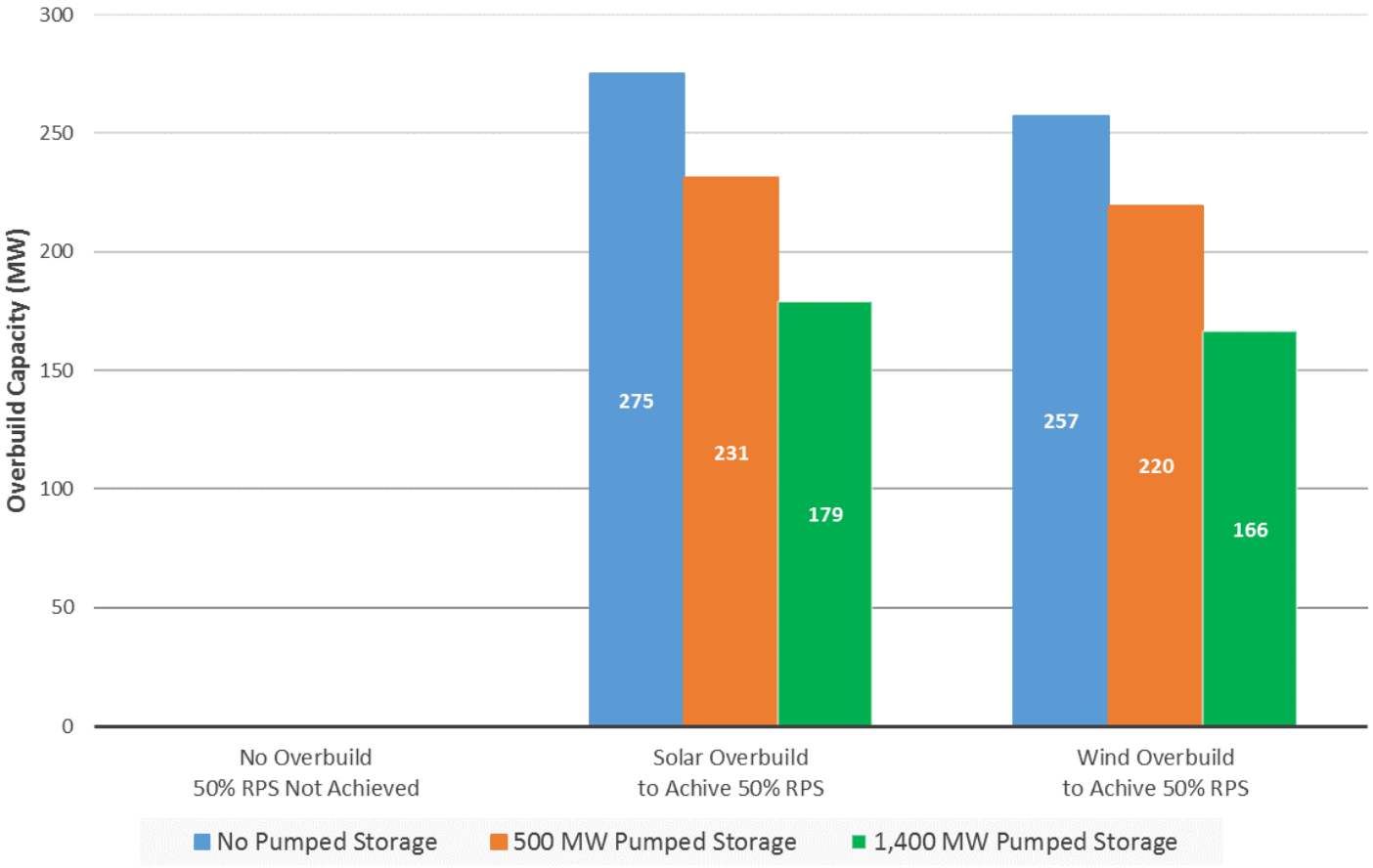
[6] CPUC 2015 RA Report http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=6442452221

# Definition of the study cases

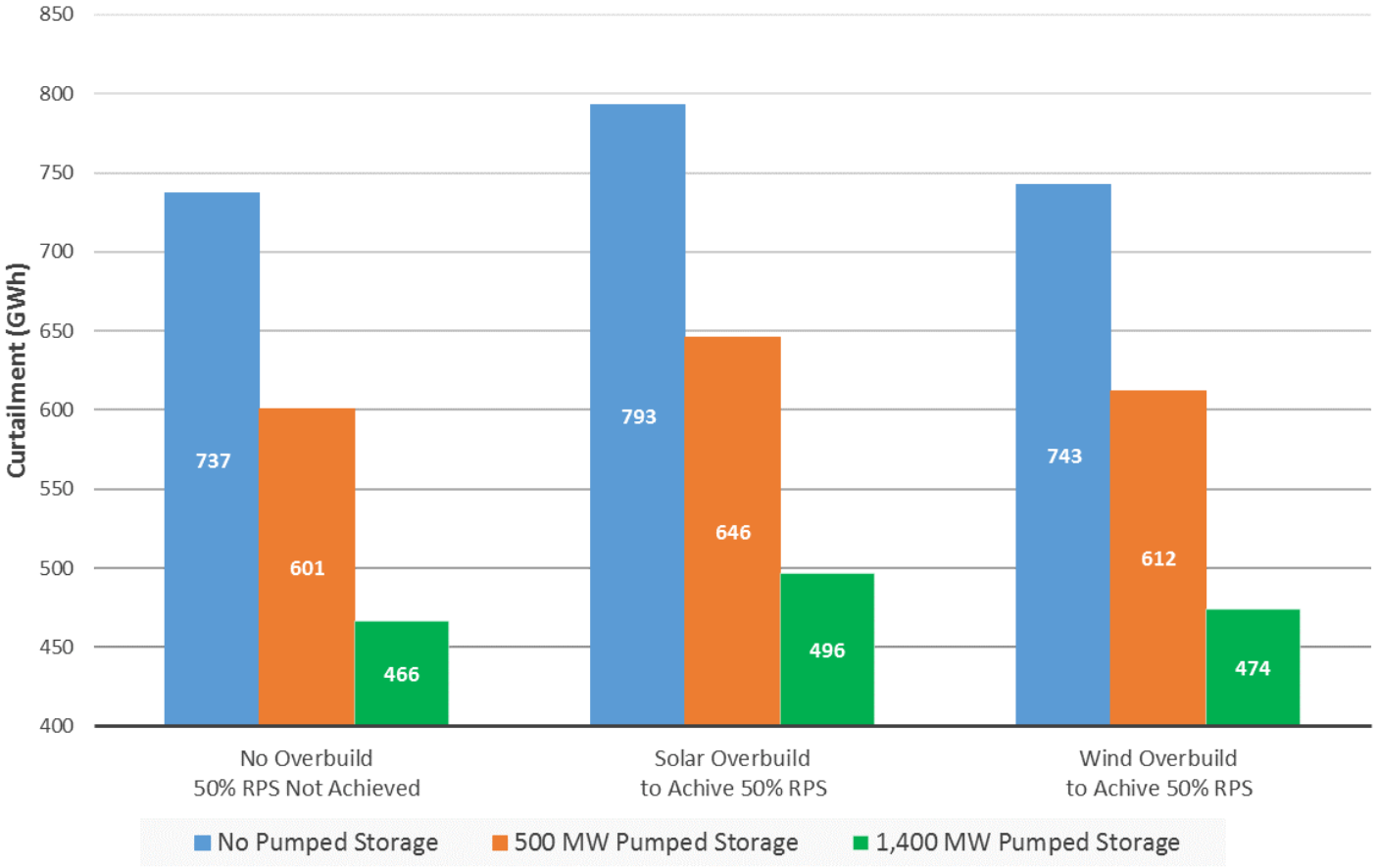
| Case | Definition |
|---|---|
| **A** | Base Case, no pumped storage and no renewable overbuild |
| **B500** | Base Case plus a 500 MW pumped storage resource |
| **B1400** | Base Case plus a 1,400 MW pumped storage resource |
| **C** | Base Case with solar overbuild |
| **D** | Base Case with wind 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

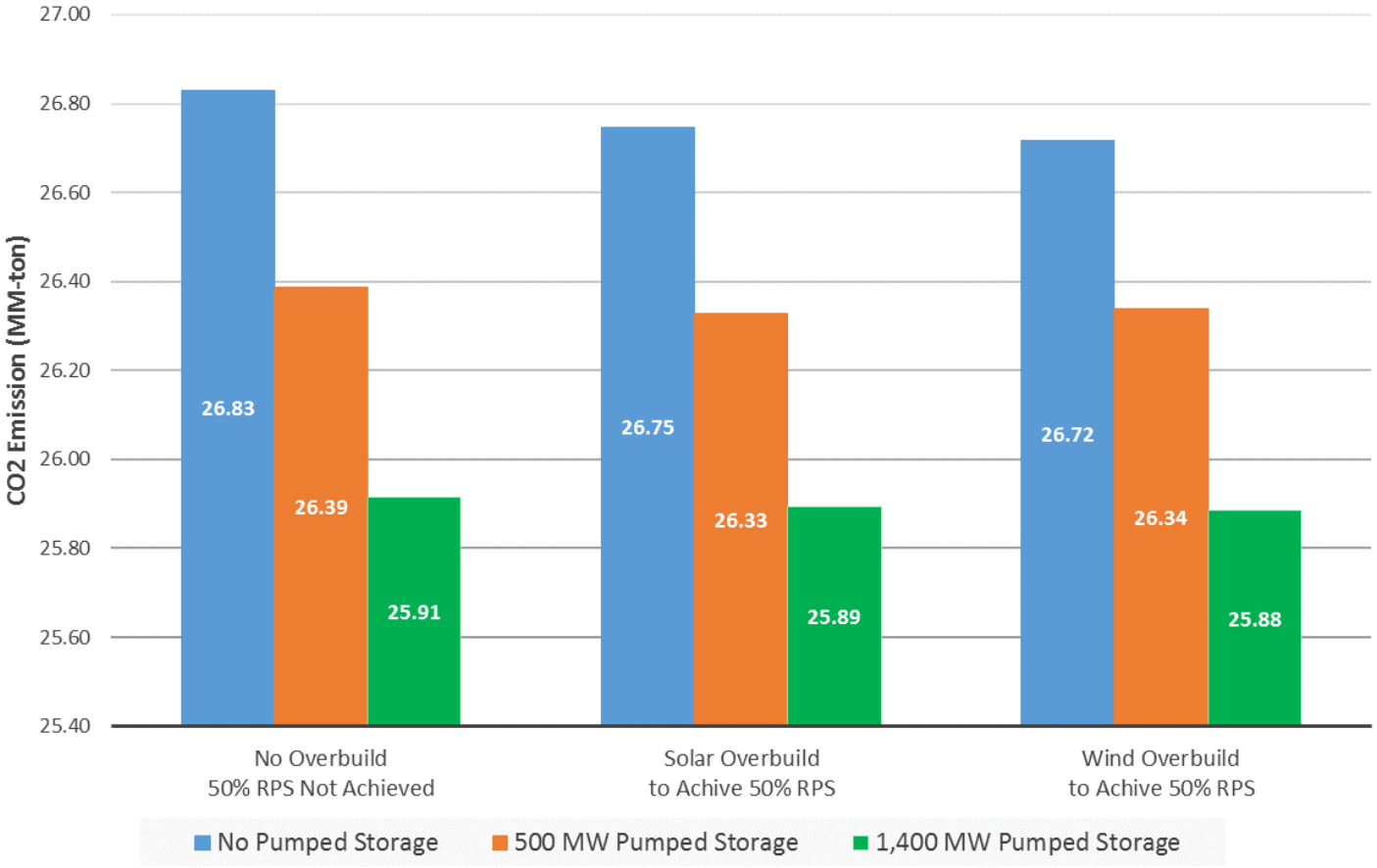


# California renewable generation curtailment



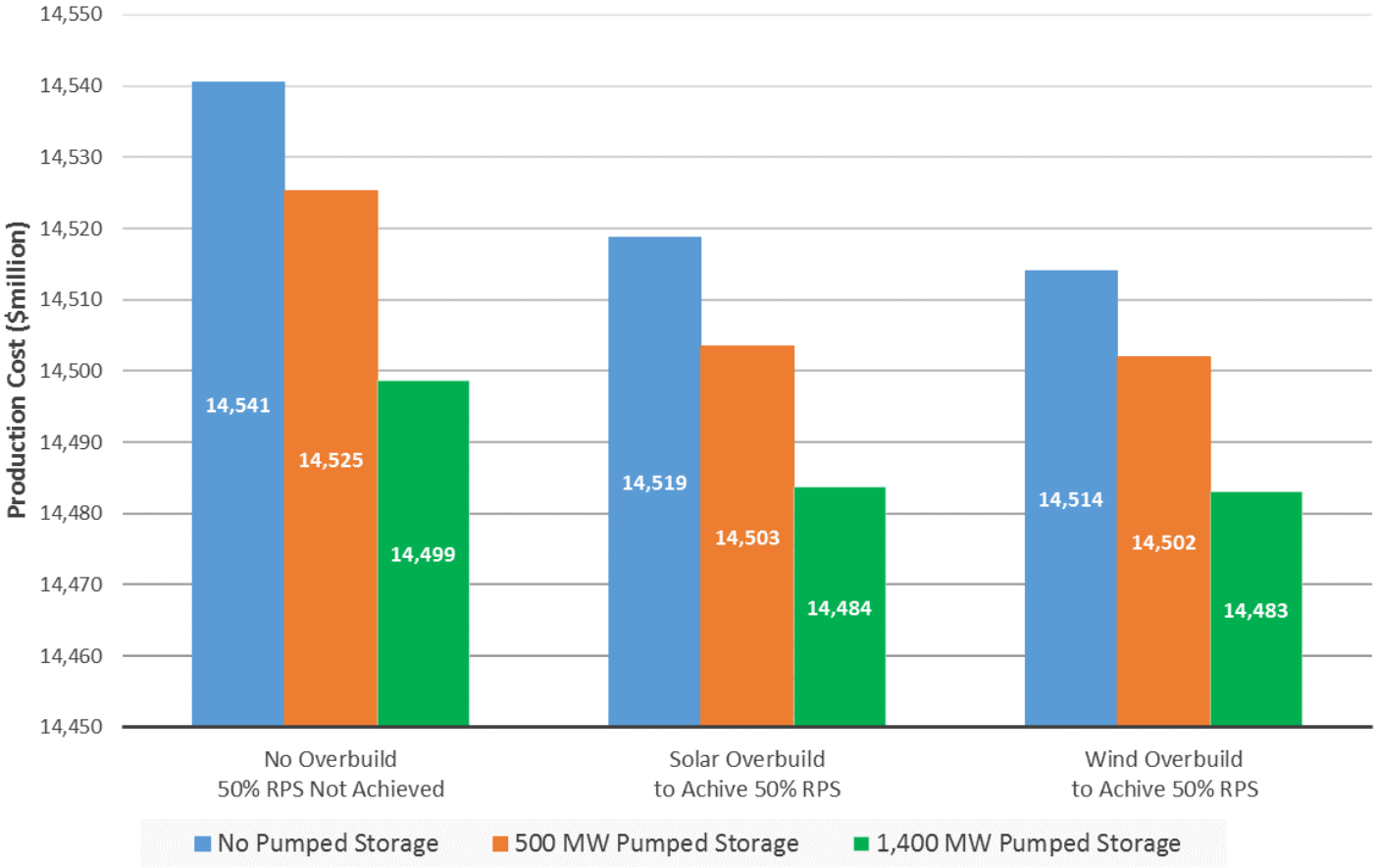

Renewable curtailment price is assumed as -$15/MWh for the first 200 GWh and -$25/MWh for additional 12,400 GWh.

# California CO2 emission (50% RPS)



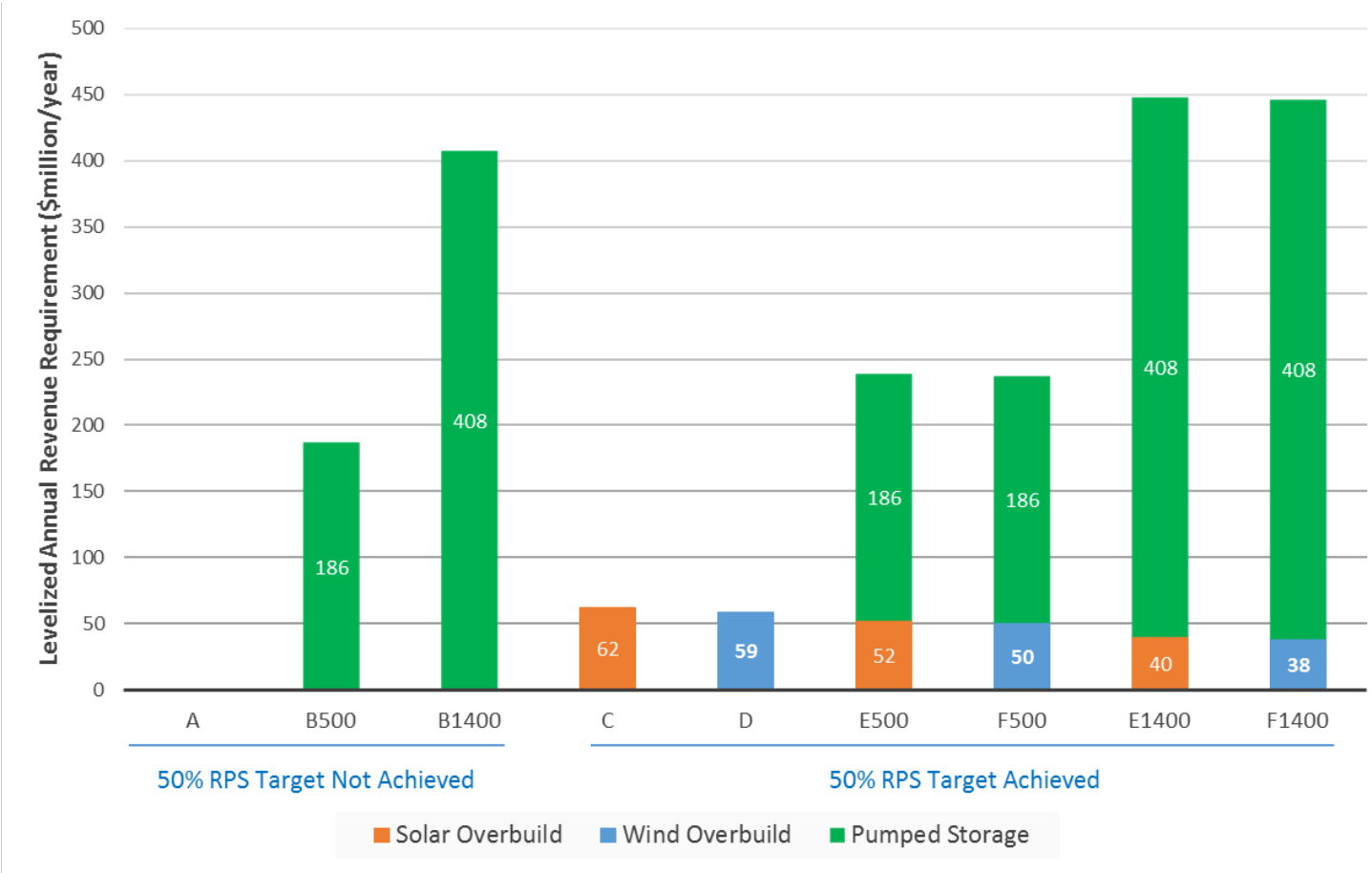

CA CO2 Emission includes the CO2 emission from net import

# 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, CO2 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