Energy+Environmental Economics

Portfolio Development and Data Inputs for CAISO SB 350 Study

Arne Olson, Partner

About these slides

- **These slides represent an update to the draft data input assumptions presented at the public meeting on the SB 350 Regional Integration Studies on February 8, 2016**
  - Available at: https://www.caiso.com/Pages/documentsbygroup.aspx?GroupID=8163E112-AF86-4AEA-91AC-3F197148F219
- **Final renewable portfolio assumptions by scenario will be presented at the next public workshop and documented in the final report**

Study assesses the effect of regional markets on renewable procurement

Two major effects are tested:

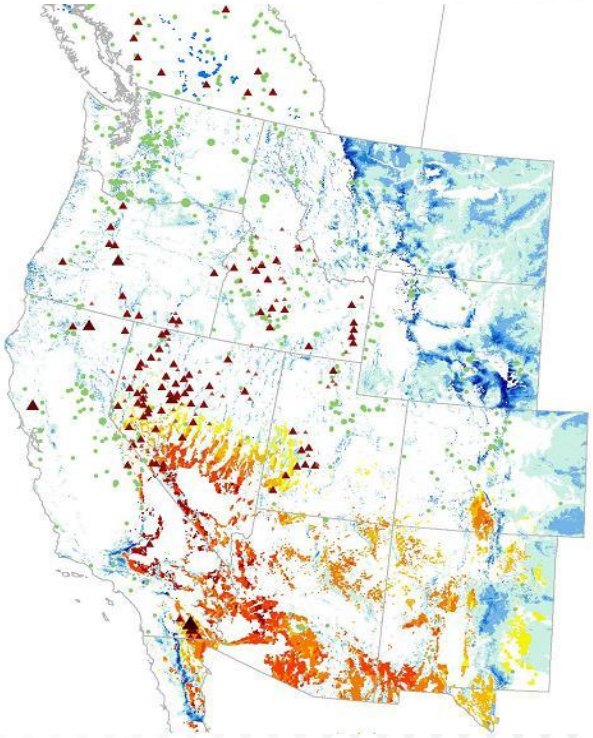
1. Effect of regional operations

- Increased access to latent flexible capacity across a broad, diverse region
- Increased ability to export surplus energy
- Could result in changes to least-cost portfolio

2. Effect of regional transmission tariff

- Reduces wheeling costs across the region
- Provides a mechanism for needed new transmission infrastructure to be studied and approved for inclusion in rates
- Provides access to high-quality wind in the Rockies and solar in the Southwest

Renewable Resource Potential in the West



Source: NREL

Three scenarios studied

1. **Current Practice Scenario**
   - Renewable energy procurement is largely from in-state resources
   - Limited quantity of out-of-state resources available, with delivery requirements assumed
   - No regional market to help reduce curtailment
2. **Regional market operations with current renewable energy procurement practices**
   - Assumes no increase in availability of out-of-state resources, but transmission wheeling charges are de-pancaked
   - Curtailment of renewables is reduced through better integration
3. **Regional market and renewable energy procurement**
   - Expands to regional renewable procurement with additional high-quality wind resources made available (requires new transmission)

RESOLVE Model Overview

- **Study uses E3's Renewable Energy Solutions (RESOLVE) Model to select optimal portfolio of renewables and other resources for each scenario for CAISO utilities**
- **RESOLVE minimizes the sum of investment and operating costs over a defined time period**
  - Investment decisions are made every 5 years between 2015 and 2030
  - Performs optimal dispatch over a representative set of operating days in each year
- **Selects least-cost combination of existing and new resources, subject to power system constraints:**
  - Meets energy, capacity and balancing needs
  - Complies with RPS (overbuilding renewable portfolio if necessary)

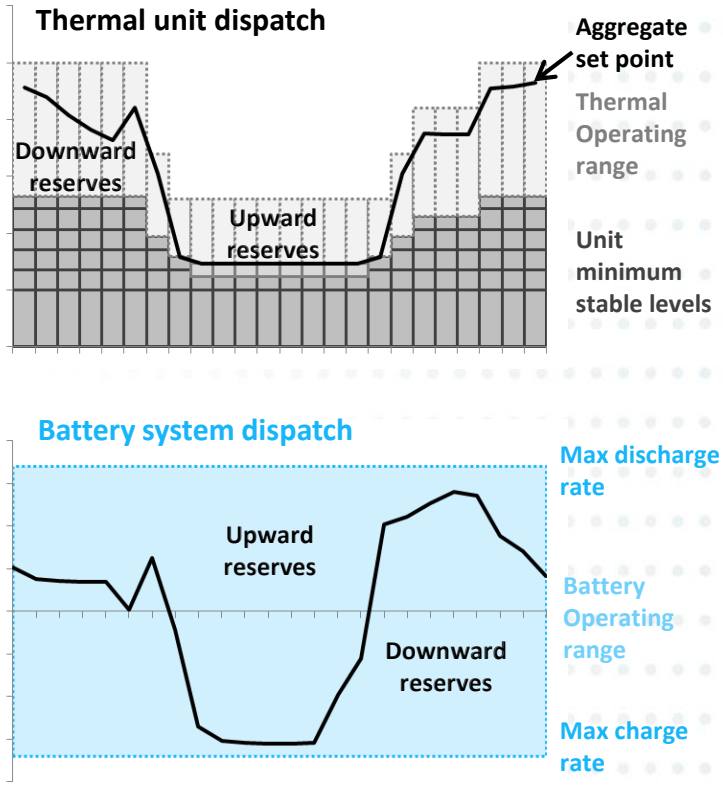
Cost analysis in RESOLVE model

- **RESOLVE selects least-cost combination of renewable resources and integration solutions**
  - Selects portfolio of solar, wind, geothermal, biomass, and small hydro
  - Adds integration solutions such as energy storage and flexible conventional resources in combination with renewable portfolio to minimize total cost over analysis period
- **Resources are added to meet RPS target, overbuilding renewable portfolio if necessary**
  - Renewables are curtailed if the output cannot be consumed in California or exported to neighboring systems due to oversupply or insufficient power system flexibility
  - Renewable contracts are treated as sunk costs and fully compensated for curtailed output
  - Resources added to portfolio if necessary to replace curtailed output
    - Renewable curtailment implicitly valued at replacement cost, which increases geometrically with curtailment

Detailed hourly model brings operational challenges into investment decisions

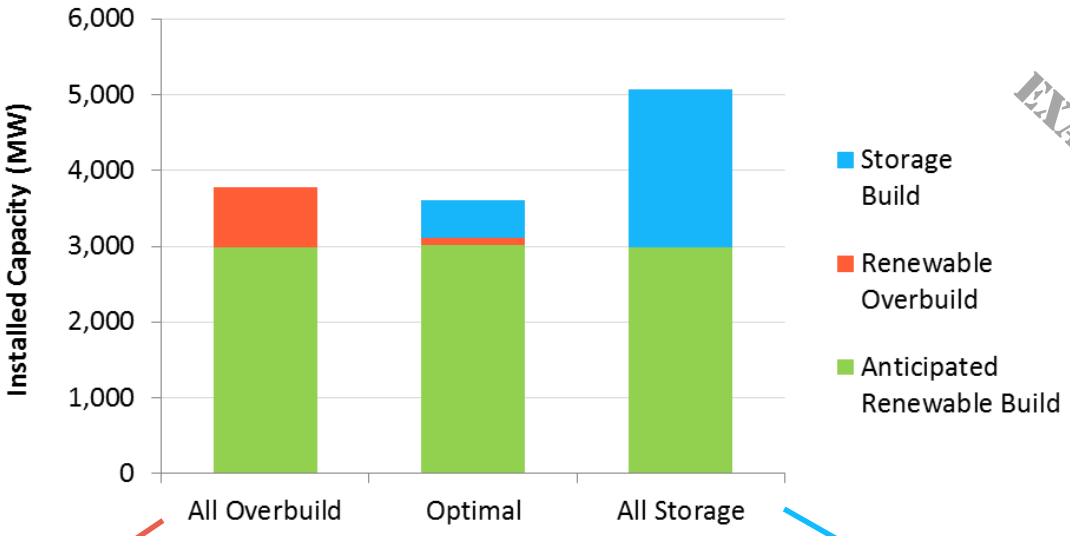
- **For each year in the simulation, a subset of days are selected and weighted to reflect long-run distributions of:**
  - Daily load, wind, and solar
  - Monthly hydro availability
- **Dispatch is modeled using linear optimization to establish:**
  - Upward and downward operating reserve constraints
  - Renewables can provide downward reserves at cost of sub-hourly curtailment

Simulates economic dispatch on each day subject to technical operating constraints



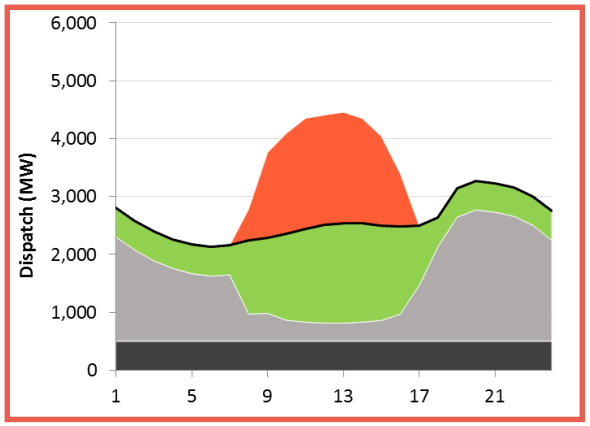
Optimal portfolio balances solutions with overbuild

EXAMPLE PORTFOLIO

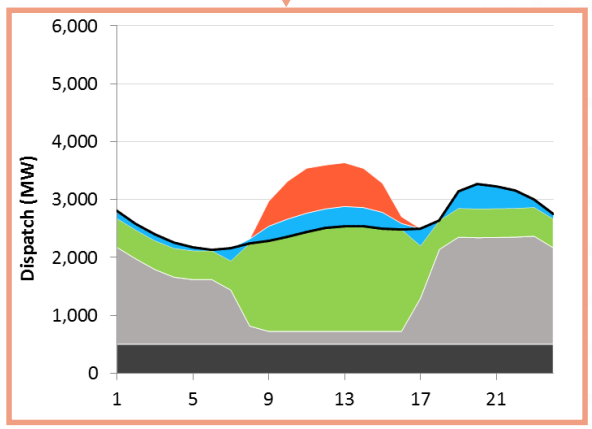


EXAMPLE PORTFOLIO

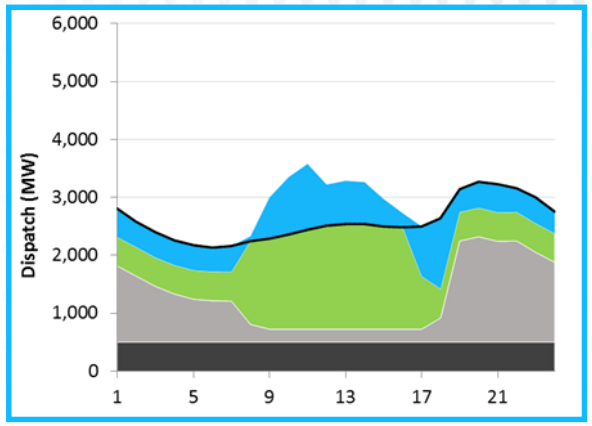
All Overbuild



Mix of Overbuild and Storage



All Storage



RESOLVE considers many different solution types

+ RESOLVE selects optimal mix of technologies based on installed costs and operational value

Integration Solution	Examples of Available Options	Assumptions & Data Sources *
Energy Storage	• Batteries: 1-, 2-, 4-, or 8-hour • Pumped Storage: 12-hr, 24-hr	• Literature review
Demand Response	• Existing & new demand response programs	• Based on 2016 LTPP assumptions
New Flexible Gas Plants	• Simple cycle gas turbines • Reciprocating engines • Flexible combined cycle gas turbines	• WECC/E3 capital cost study
Renewable Dispatch	• Scheduled & real-time renewable curtailment	• Dynamic downward dispatch of renewable resources to help meet within-hour flexibility needs • Curtailed renewables must be replaced to ensure RPS compliance

* Details of assumptions and data sources will be included in the SB350 report.

RESOLVE: KEY DATA INPUTS

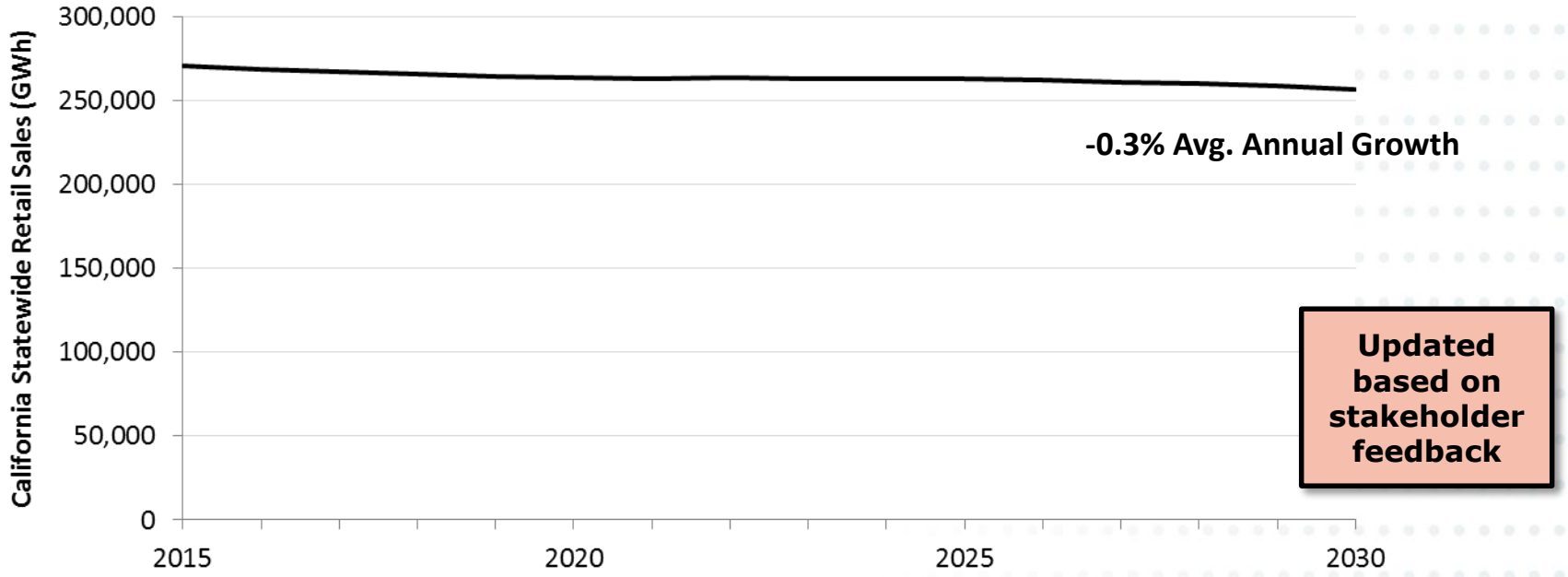
Summary of Updates to Assumptions

- **Load forecast**
  - Updated to CEC 2015 IEPR mid-AAEE (rooftop PV higher, EVs lower)
- **Statewide analysis rather than focus on California ISO**
- **Renewable resource costs**
  - Reduced solar PV & geothermal costs based on stakeholder feedback
- **Battery costs**
  - A number of adjustments based on stakeholder feedback and additional literature review:
    - Added inverter replacement, 15% adder to total price for installation and EPC, reduced fixed O&M, reduced capital cost, adjusted lifetime and replacement time, etc.
- **Other**
  - Hydro and storage can provide frequency response

Retail Sales Assumptions - Statewide

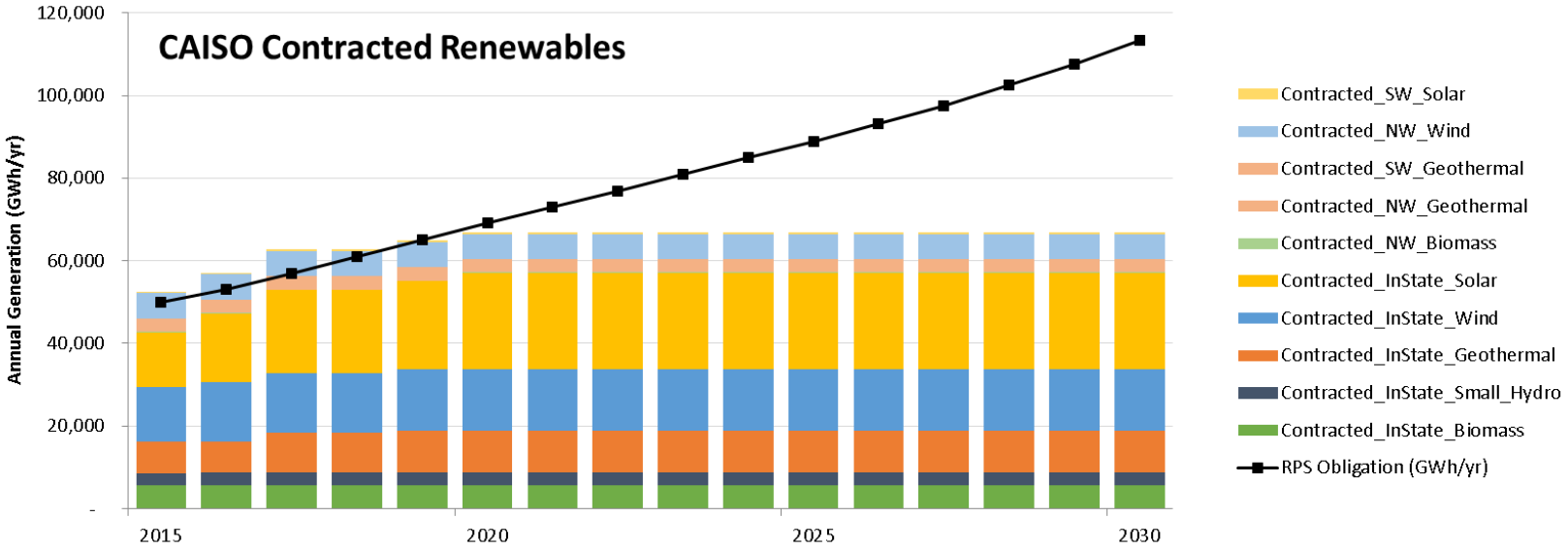
+ Statewide retail sales forecast

- CEC's 2015 IEPR California Electricity Demand Mid Baseline + Mid AAEE
- Doubling of the energy efficiency goals per SB 350 will be tested as a sensitivity; implementation and interpretation of the doubling of energy efficiency is currently under discussion at state agencies



Existing & Contracted Renewable Resources

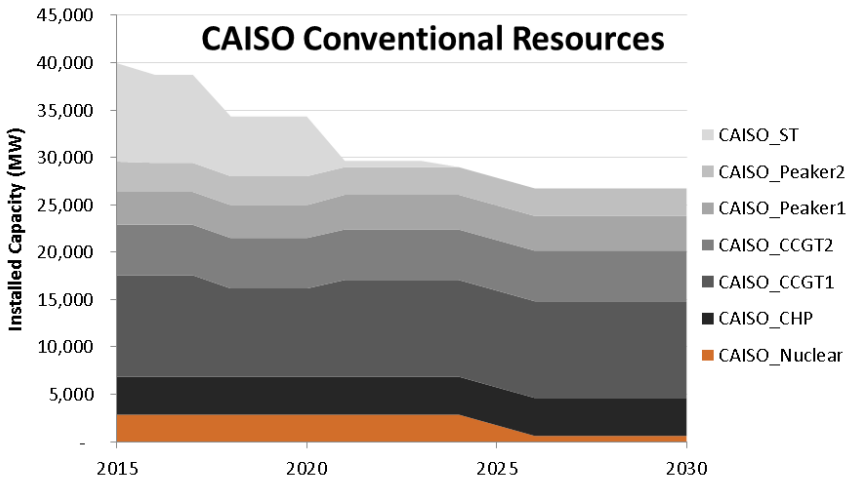
- Existing and contracted renewables for IOUs are from the RPS Calculator v6.1, Municipal utility existing and contracted renewables are from TEPCC 2024 data
- 18 GW of rooftop PV statewide by 2030 based on extrapolation of CEC 2015 IEPR "mid" forecast



Conventional Generator Additions and Retirements

+ Retirements

- Nuclear: Assumes retirement of Diablo Canyon in 2025
- California Once-through-cooling (OTC) units are retired per 2014 LTPP thermal stack assumptions



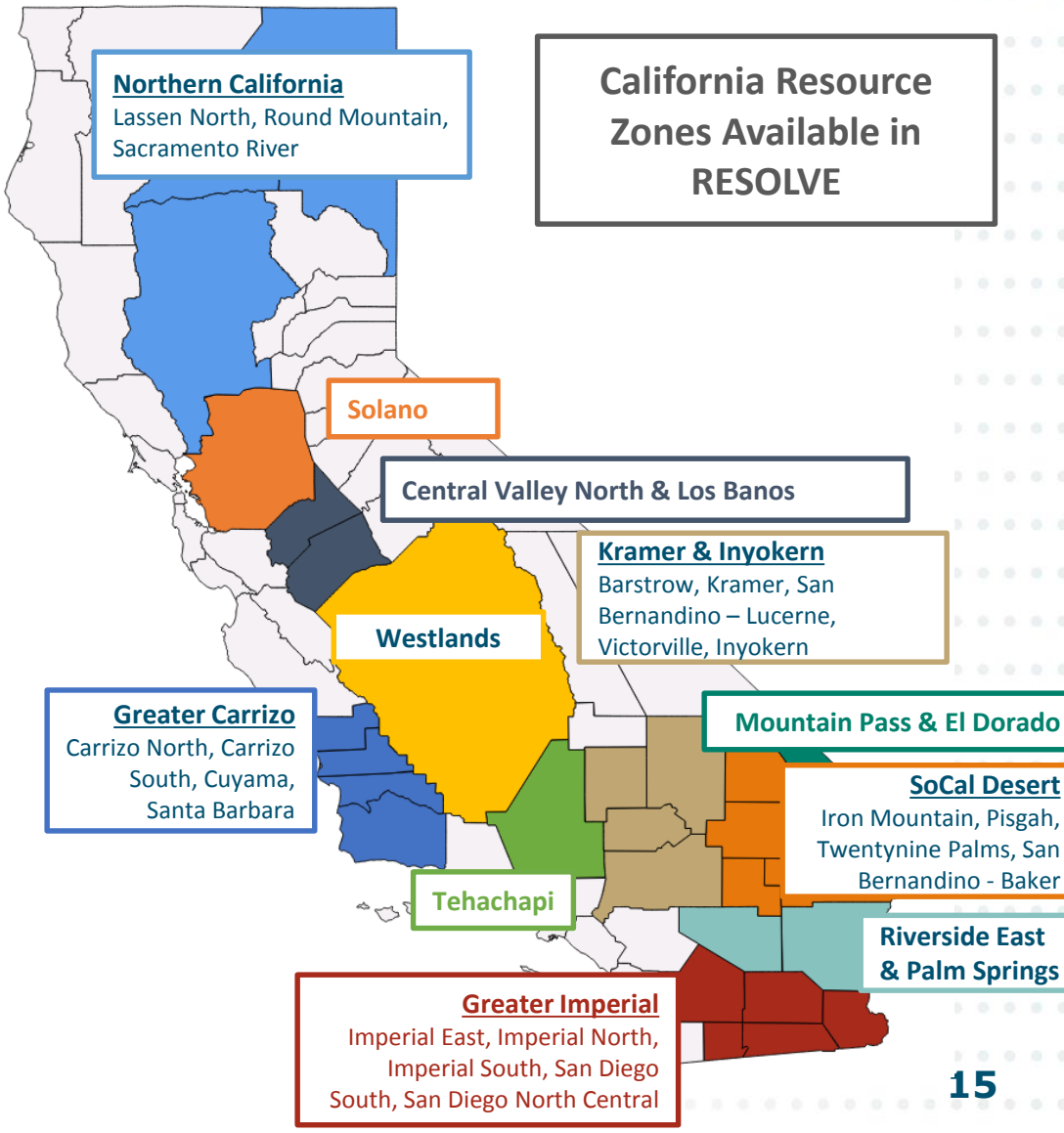
- Out of state coal retirements are based on announced retirements (including retirements assumed in PacifiCorp IRP)

+ Additions

- RESOLVE adds new capacity if resource adequacy needs are not met with preferred resources
  - No new capacity additions are triggered

Overview of In-State Resource Potential

- **Initial renewable resource supply curve developed based on RPS Calculator 6.1, adjustments made based on stakeholder feedback**
  - Model includes extensive data on renewable resource potential and performance in California, as well as transmission cost and availability provided by CAISO
  - Renewable cost assumptions adjusted from Black & Veatch assumptions based on stakeholder feedback
- **In-state resource potential:**
  - Solar: 11,000 MW
  - Geothermal: 1,800 MW
  - Wind: 3,000 MW



Renewable Resource Costs

- **Renewable resource cost assumptions are based on the CPUC's RPS Calculator v.6.1, then modified based on stakeholder feedback to reflect current renewable market**
- **Pro-forma cash flow model translates costs into estimated PPA prices**
- **Costs are location-specific and incorporate differences in local costs of materials and labor**

Category	Geothermal	Solar PV*	Wind
Capital Cost ($/kW)	**$4,759**	**$2,174**	$2,031
Interconnection Cost ($/kW)	$260	$200	$136
Fixed O&M ($/kW-yr)	$313	$32	$33

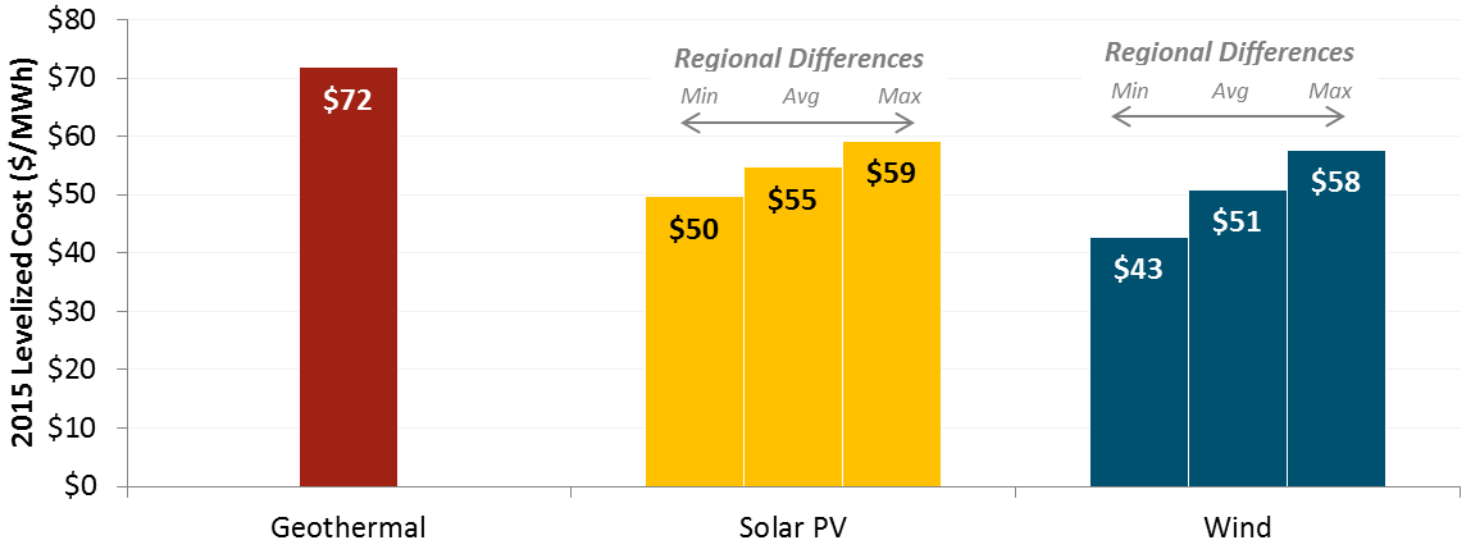
Notes: Costs represent an average plant installed in California in 2015; costs are expressed in 2015 $; solar PV costs are expressed with respect to AC capacity

* Solar PV costs on a $/kW AC basis (modeled as single-axis tracking with an inverter loading ratio of 1.30)

Updated based on stakeholder feedback

Modeled California PPA Prices for 2015 Delivery

- **Levelized Cost of Electricity for wind, solar, and geothermal calculated from assumptions of cost, performance, financing, and tax credits**



- **Wind and solar PPA prices vary by location due to differences in cost and capacity factors**

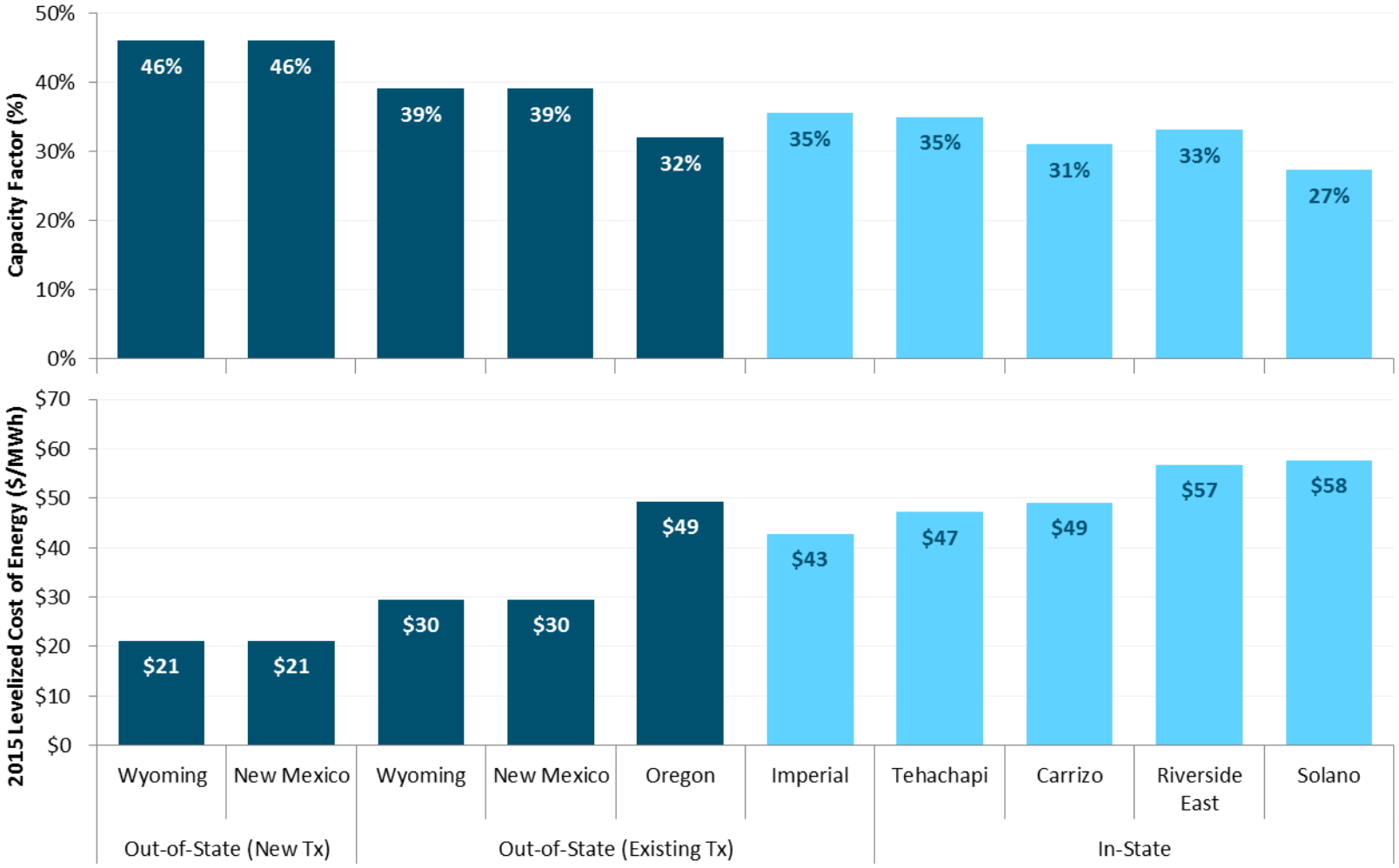
Updated based on stakeholder feedback

Impacts of federal tax credits are included, updated from real to nominal levelized values

Solar costs are relatively uniform throughout Southwest region

Assumptions: single axis tracking solar PV with an inverter loading ratio of 1.3, impacts of federal tax credits are included, updated from real to nominal levelized values

Wind cost is significantly lower in WY and NM



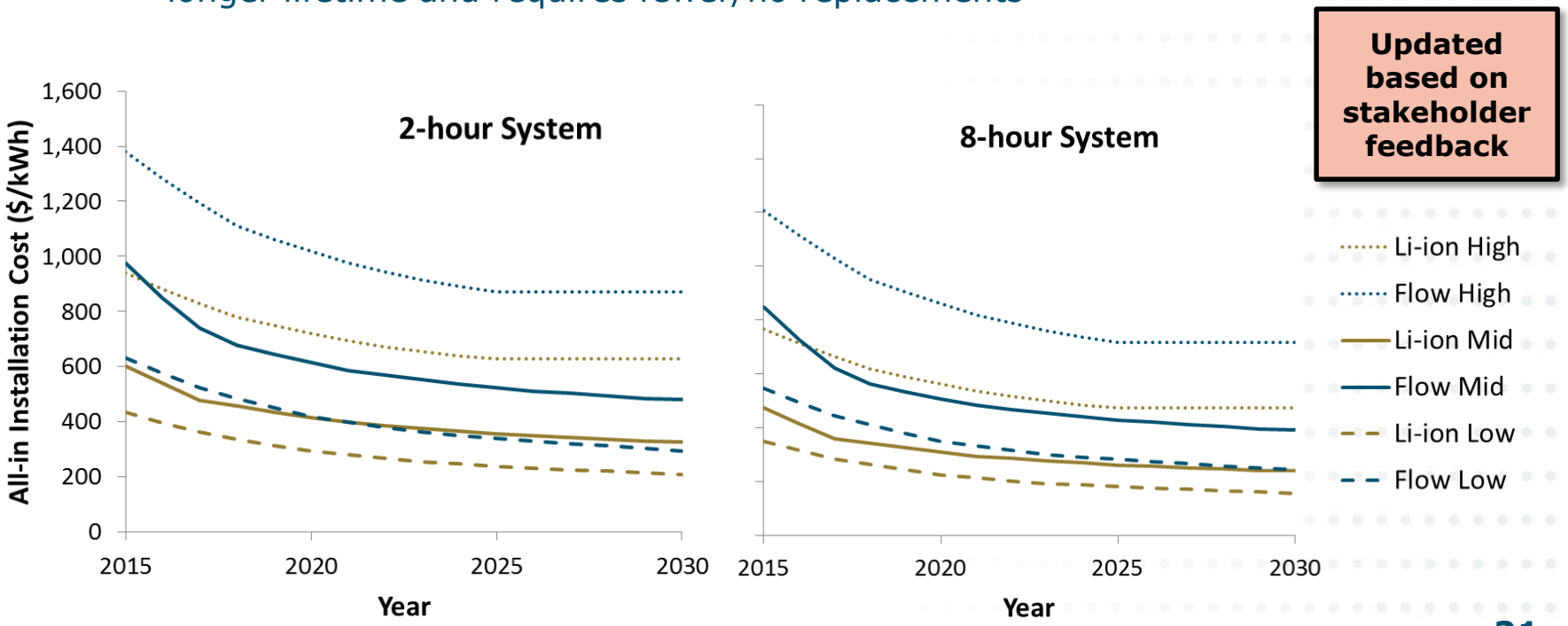
Impacts of federal tax credits are included, updated from real to nominal levelized values

PPA prices change over time

- **Power purchase agreement prices are projected through 2030 based on long-term industry trends:**
  - **Capital cost reductions:** technological improvement expected to reduce renewable resource costs
  - **Long run financing:** financing costs expected to increase over time due to rising interest rates
  - **Property tax exemption:** the exemption of solar facilities from California property tax is not available to facilities installed after 2024
  - **Federal tax credit sunsets:** Federal PTC and ITC phase out by 2019 for wind and by 2021 for solar and geothermal
    - Solar PV & geothermal eligible for 10% ITC after 2021

Storage costs decline significantly over study horizon

- **RESOLVE selects least-cost storage type, capacity and duration**
  - Three types of storage modeled: Li-ion, flow batteries, pumped storage
- **Battery cost estimates are based on literature review and quotes from manufacturers, updated based on stakeholder feedback**
  - Installed cost of Li-ion is lower even at long durations, but flow battery has longer lifetime and requires fewer/no replacements



Renewable integration solutions assumed in all scenarios

- Time-of-use rates that encourage daytime use
- 5 million electric vehicles by 2030 with near-universal access to workplace charging
- Renewables providing operating reserves
- Storage and hydro providing operating reserves and frequency response
- 500 MW of pumped storage manually added
- 500 MW of geothermal manually added
- 5,600 MW of out-of-state renewable resources available to be selected on a least-cost basis
- Unlimited storage available to be selected on a least-cost basis