IRP Modeling Advisory Group Webinar

2019-20 IRP Proposed Reference System Plan

November 20, 2019

I. Introduction

Modeling Advisory Group (MAG) Background

- The MAG provides an open forum for informal technical discussion and vetting of data sources, assumptions, and modeling activities undertaken by CPUC staff to support the IRP proceeding (R.16-02-007)
- Participation in the MAG is open to the public, subject to the terms of the charter, and communication of events and materials is through the IRP proceeding service list
- Feedback received during and following MAG webinars and workshops inform staff work products that are later introduced into the formal record of the IRP proceeding

Purpose and Scope of Webinar

- Purpose:
  - To inform party comment on the November 6, 2019 ALJ Ruling on Proposed Reference System Portfolio and Related Policy Actions, staff will:
    - Present the Proposed Reference System Portfolio
    - Describe assumptions changes implemented since the October 8, 2019 IRP Preliminary Results workshop
    - Describe SERVM validation of RESOLVE portfolios

- Out of scope:
  - Recently adopted IRP Procurement Track Decision D.19-11-016, November 7, 2019.

Webinar Agenda

Item	Time *
I. Introduction, Purpose and Scope, Process for 2019 Reference System Plan Development	9:30 – 9:45am
II. Overview of Proposed Reference System Portfolio	9:45 – 10:15am
III. Modeling Changes Made Since 10/8/19 Preliminary Results Workshop	10:15 – 11:00am
IV. Description of SERVM Validation of RESOLVE Portfolios	11:00 – 12:00pm
Adjourn	

**Time allocated for agenda items includes Q&A*

Proposed schedule for 2019 IRP Reference System Plan

Step #	Activity	Estimated Date
1	Data Development	March-June 2019
2	Informal release: core model inputs + MAG presentation	June 2019
2a	Informal party comment on Step 2 content	July 2019
3	Input validation for RESOLVE & SERVM models	July 2019
4	Develop calibrated modeling results	July-Sept 2019
5	Informal release of complete RESOLVE model and draft results	October 2019
6	Formal release of Proposed 2019 IRP Reference System Plan	November 2019
7	Formal party comment on Proposed 2019 Reference System Plan	December 2019
8	Formal release of 2019 Reference System Plan Proposed Decision	February 2020
9	Formal party comment on 2019 Reference System Plan PD	March 2020
10	Commission Decision on 2019 Reference System Plan	March 2020
11	Transmittal of 2019 IRP portfolios to 2020-21 CAISO TPP	March 2020

II. Proposed Reference System Portfolio

Contents of Reference System Plan

- The Reference System Plan includes four key recommendations:
  - A GHG Planning Target of 46 million metric tons (MMT) to use for the electric sector in IRP that is consistent with 40% statewide reductions below 1990 levels by 2030.
  - A Reference System Portfolio – a single portfolio of resources that represents a least-cost, least-risk pathway to achieving the recommended GHG planning target and other SB 350 requirements.
  - A GHG Planning Price that represents the marginal cost of GHG abatement associated with the Reference System Portfolio and that will enable the CPUC and load-serving entities to consistently value both demand and supply-side resources.
  - Near-term Commission policy actions to ensure that the results from IRP modeling inform other CPUC proceedings and lead to the development or procurement of adequate resources.

IRP-Related Statutory Requirements

(All references are to the Public Utilities Code)

- Identify a diverse and balanced portfolio (454.51)
- Meet state GHG targets (454.52(a)(1)(A))
- Comply with state RPS (454.52(a)(1)(B))
- Ensure just and reasonable rates for customers of electrical corporations (454.52(a)(1)(C))
- Minimize impacts on ratepayer bills (454.52(a)(1)(D))
- Ensure system and local reliability (454.52(a)(1)(E))
- Strengthen the diversity, sustainability, and resilience of the bulk transmission and distribution systems, and local communities (454.52(a)(1)(F))
- Enhance distribution system and demand-side energy management (454.52(a)(1)(G))
- Minimize air pollutants with early priority on disadvantaged communities (454.52(a)(1)(H))

Steps Taken Since Preliminary Results Workshop to Determine Proposed RSP

- Core Policy Case Results for 46 MMT, 38 MMT, and 30 MMT GHG targets, as well as sensitivities on those cases, were included as part of the 2019 IRP Preliminary Results. These cases were updated as part of this 2019 IRP Reference System Plan presentation.
  - New sensitivities, including those focusing on near-term resource availability and offshore wind, are now also included.
- Multiple key updates to RESOLVE assumptions have occurred since the 10/8 workshop. The results of the core policy and sensitivity cases run with these new assumptions informed which portfolios should be validated for reliability, operability, and emissions using SERVM.
- Portfolios were then analyzed in SERVM, with the Proposed Reference System Portfolio being chosen from among those cases.

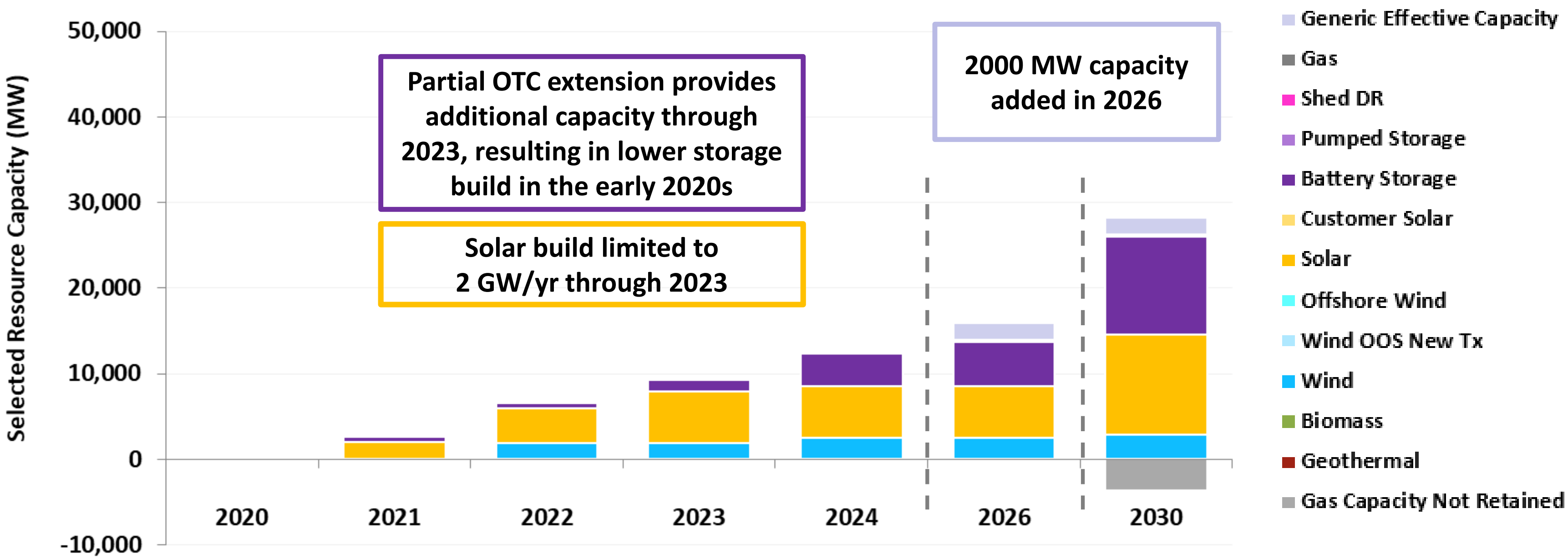
List of Modeling Changes Implemented Since Preliminary Results Analysis

- Added more modeling years to RESOLVE analysis, including 2021, 2023, and 2024.
- RESOLVE model was updated to more fully represent "nested" transmission constraint limits and associated transmission costs.
- Added constraints on availability for some candidate resources in RESOLVE (candidate Shed DR and solar PV).
- Allowed RESOLVE to build new transmission for 3 GW of out-of-state (OOS) wind resources as a default assumption.
- Implemented import capacity constraint in SERVM to match RESOLVE assumptions regarding import availability.

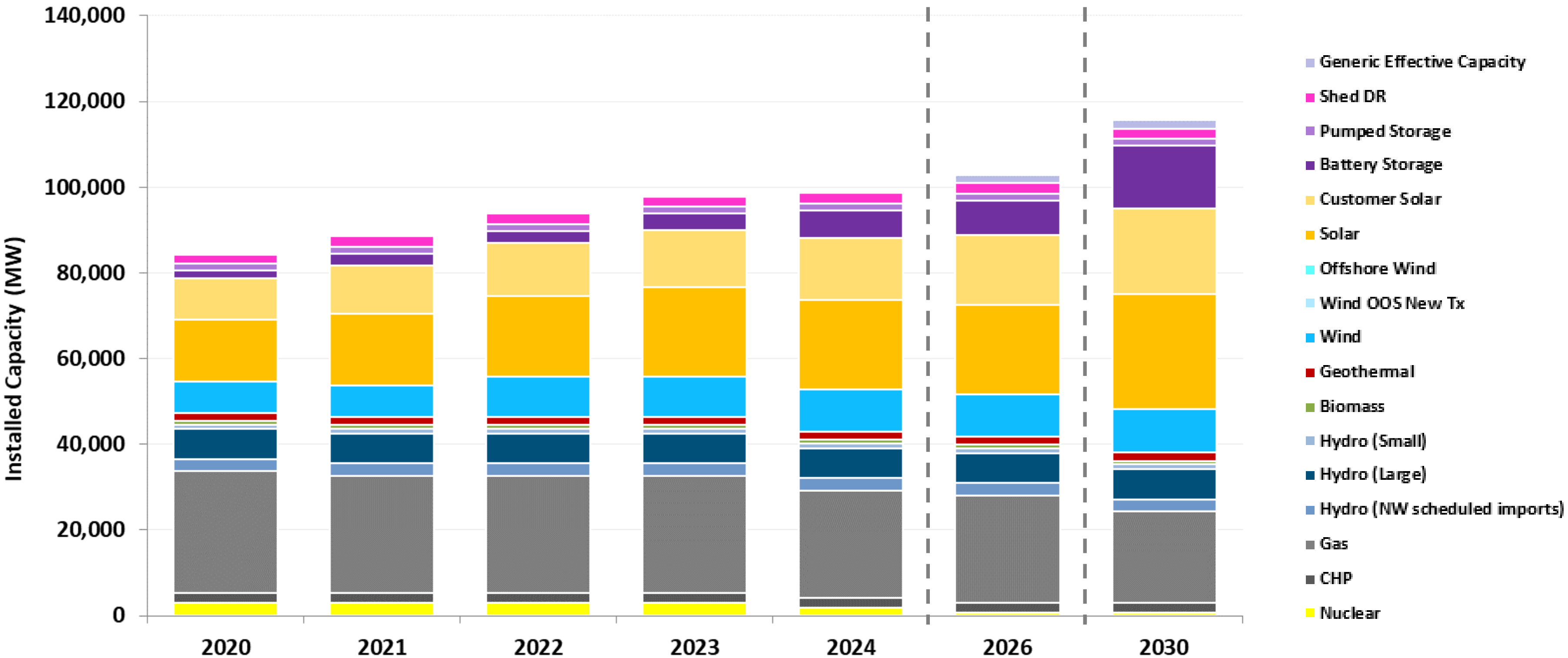
Description of Analysis of 46 MMT Default and Alternate Cases

- Analysis of the core policy cases, particularly the 46 MMT core policy case (now referred to as 46 MMT "Default"), compared to sensitivities with resource-build limitations and partial OTC extensions -- informed staff's decision-making regarding which cases to model in SERVM for production cost modeling.
- Two updated RESOLVE cases were selected for validation with SERVM, the 46 MMT Default, and the 46 MMT "Alternate", which differs from the 46 MMT Default in two ways and is included on slide 125 as the "Limited Near-term Solar and Partial OTC Extension" case:
  - Adjustment of candidate solar PV resource potential to implement a deployment limit of 2 GW/yr for candidate solar PV resources through 2023.
  - Inclusion of a partial extension of OTC generation capacity of 2,289 MW through 2023 and none thereafter.
- After SERVM analysis under new SERVM import constraints, Staff determined that an adjustment to the portfolio would likely be necessary for it to have sufficient reliability.

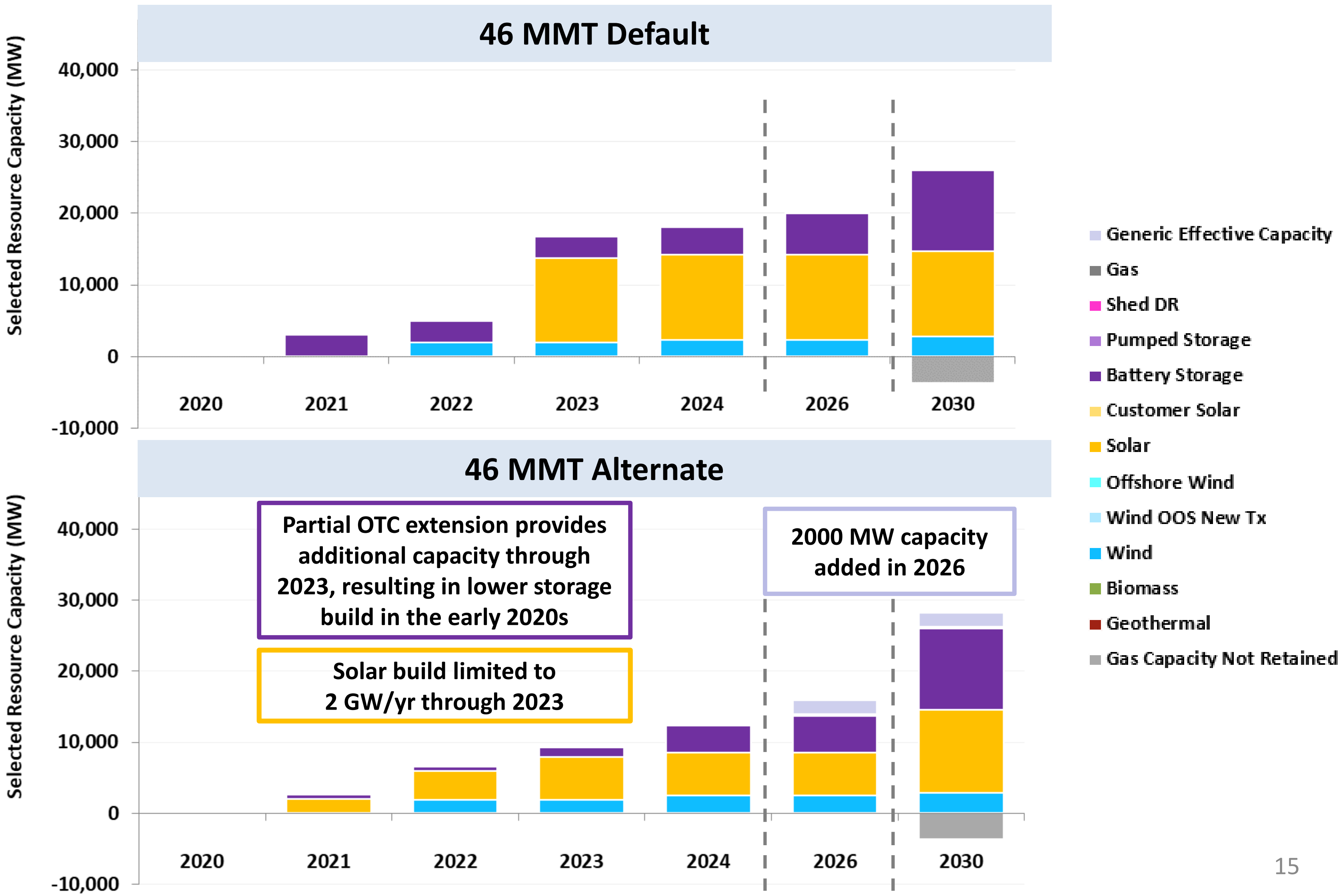
2019 IRP Proposed Reference System Portfolio, Selected Resources, with 2 GW Generic Effective Capacity Added in 2026, aka "46 MMT Alternate"



2019 IRP Proposed Reference System Portfolio, Total Resources, with 2 GW Generic Effective Capacity Added in 2026, aka "46 MMT Alternate"



46 MMT Default and 46 MMT Alternate Resource Build Comparison



III. MODELING CHANGES MADE SINCE 10/8/19 PRELIMINARY RESULTS WORKSHOP

IMPLEMENTATION OF “NESTED” TRANSMISSION CONSTRAINTS

Transmission Capability and Cost Inputs for RESOLVE are Received from CAISO

- In accordance with a May 2010 MOU between CAISO and the CPUC
  - The CPUC, in coordination with the CEC, develops renewable resource portfolios used by CAISO in its annual transmission planning process (TPP)
  - The ISO provides the CPUC with transmission capability estimates for major renewable resource zones for the specific purpose of providing input into portfolio development as part of the CPUC's IRP process
- The ISO published a white paper on May 20, 2019 and held a stakeholder call on May 28, 2019 to describe
  - The components and interpretation of transmission capability estimation
  - Sources of information used for estimating transmission capability; and
  - Steps involved in estimation of transmission capability and conceptual upgrade information.
  - http://www.caiso.com/Documents/WhitePaper-TransmissionCapabilityEstimates-InputtoCPUCIntegratedResourcePlanPortfolioDevelopment.pdf

CAISO Data Sources

The primary source is generation interconnection studies; TPP studies is the supplementary source

1. **Current and past GIDAP studies (primary source of information)**
   - Lends itself particularly well to the transmission capability estimation effort
   - Amount of active generation in ISO's generation interconnection queue far exceeds the total generation resources that are typically selected as part of the portfolios
   - GIDAP assessments expose transmission constraints which typically would not be identified in the TPP assessments of generation amounts in the portfolios

2. **Current and past TPP studies**
   - ISO assesses the transmission impacts of renewable portfolios transmitted by the CPUC
   - Insights about the reliability impact of the portfolios on the transmission system, deliverability constraints that would limit portfolio resource deliverability and renewable curtailment observed in the production cost simulations
   - Act as a supplementary source of information for transmission capability estimation

California ISO

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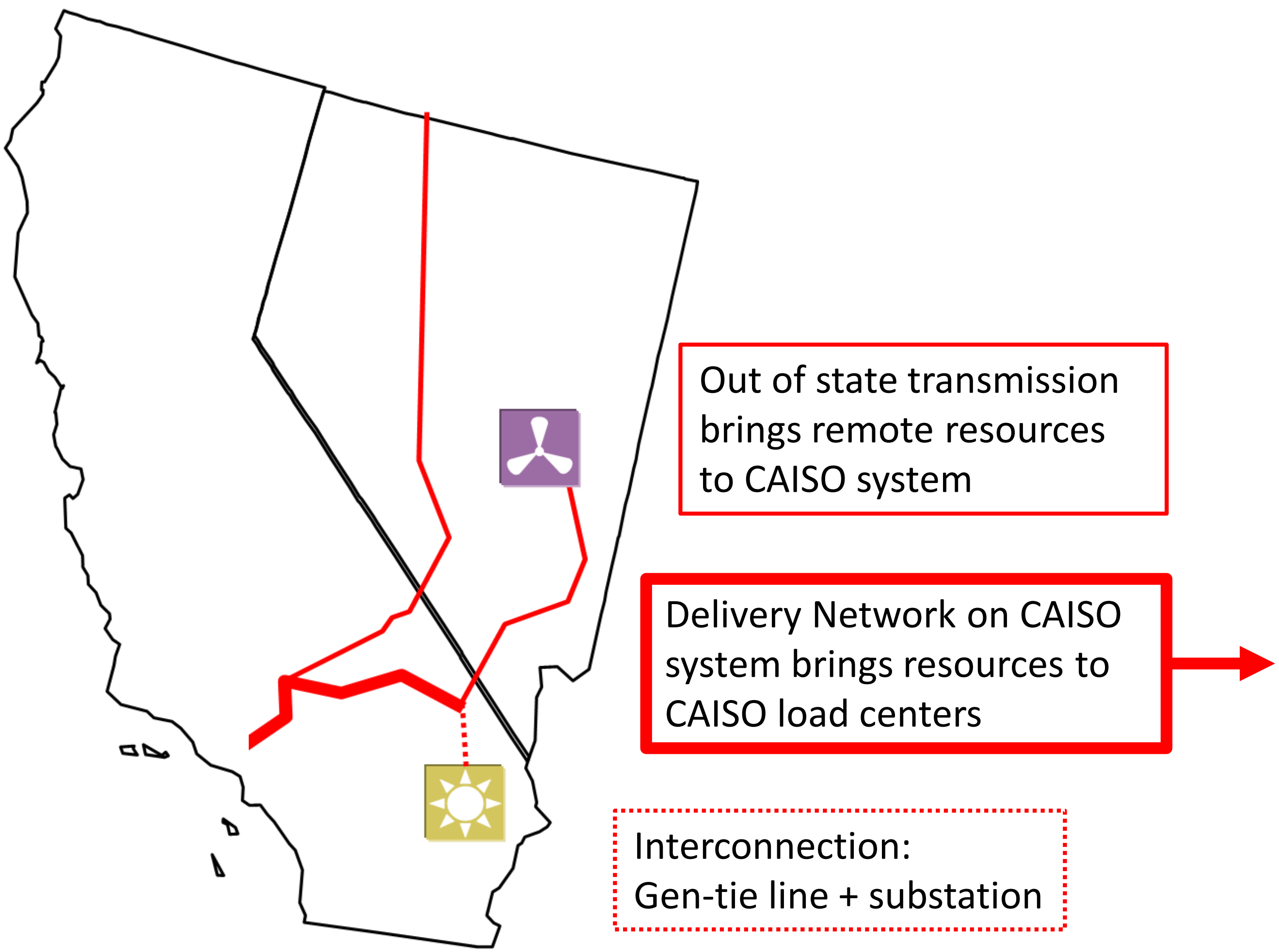
California ISO Public

Slide Source: http://www.caiso.com/Documents/TransmissionCapabilityEstimates-CPUC-IRP-PortfolioDevelopmentRedacted.pdf

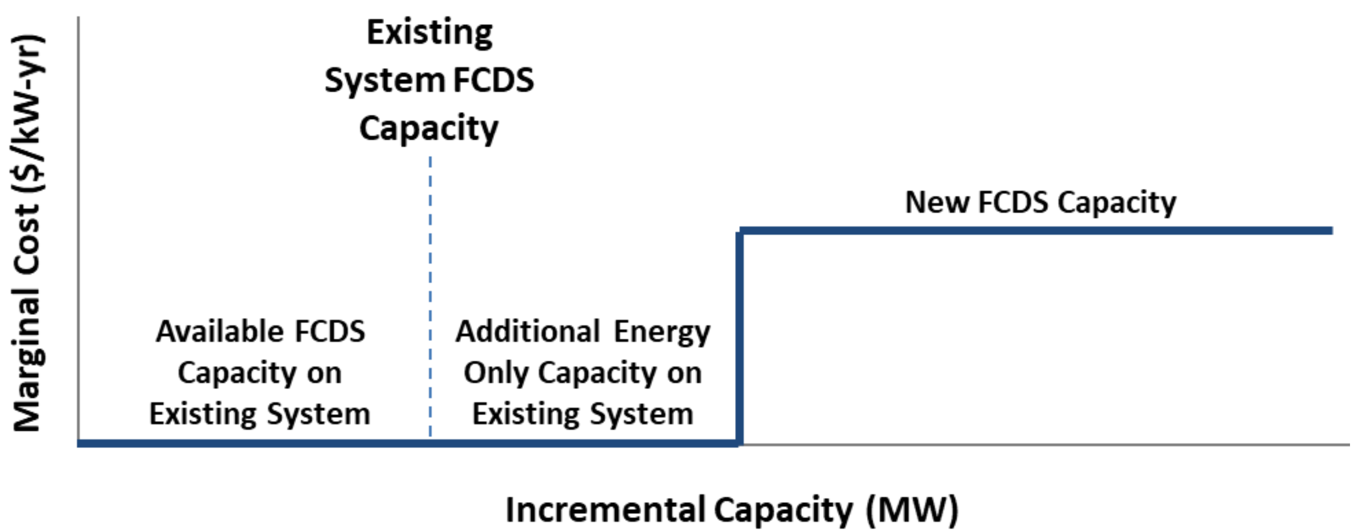
Transmission Interconnection for Renewable Resources in RESOLVE



Estimates received from CAISO include Delivery Network Upgrade costs and available capacity on the existing CAISO system

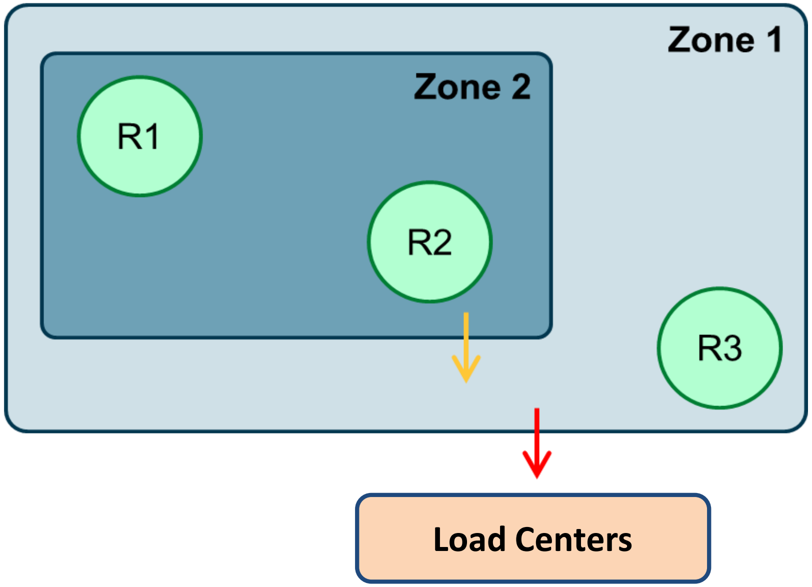
Fully Deliverable vs. Energy Only

- Candidate renewable resources in RESOLVE are selected as either:
  - **Fully deliverable (Full Capacity Deliverability Status, or FCDS)**
    - FCDS resources contribute to the Planning Reserve Margin; RESOLVE will typically prioritize FCDS for resources with a higher resource adequacy contribution.
  - Or **Energy only (Energy Only Deliverability Status, or EO)**
    - EO resources do not contribute to the Planning Reserve Margin



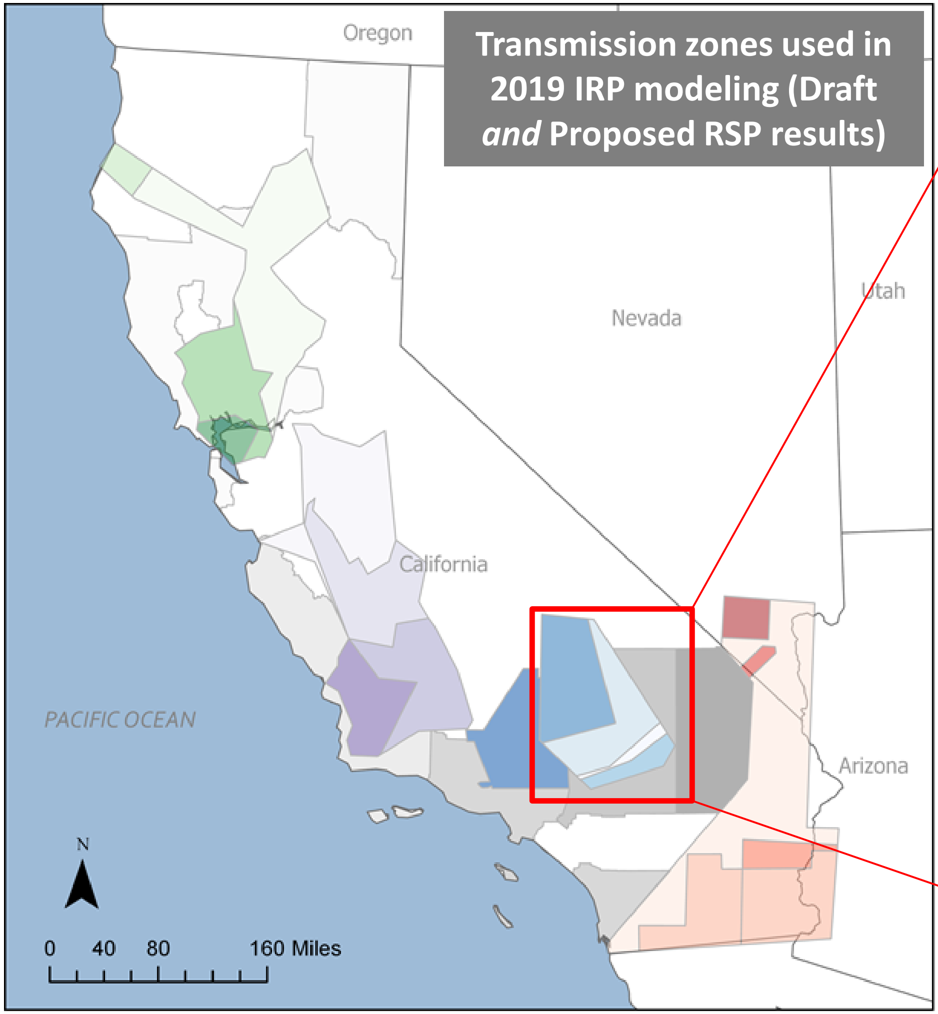
Nested Transmission Constraints

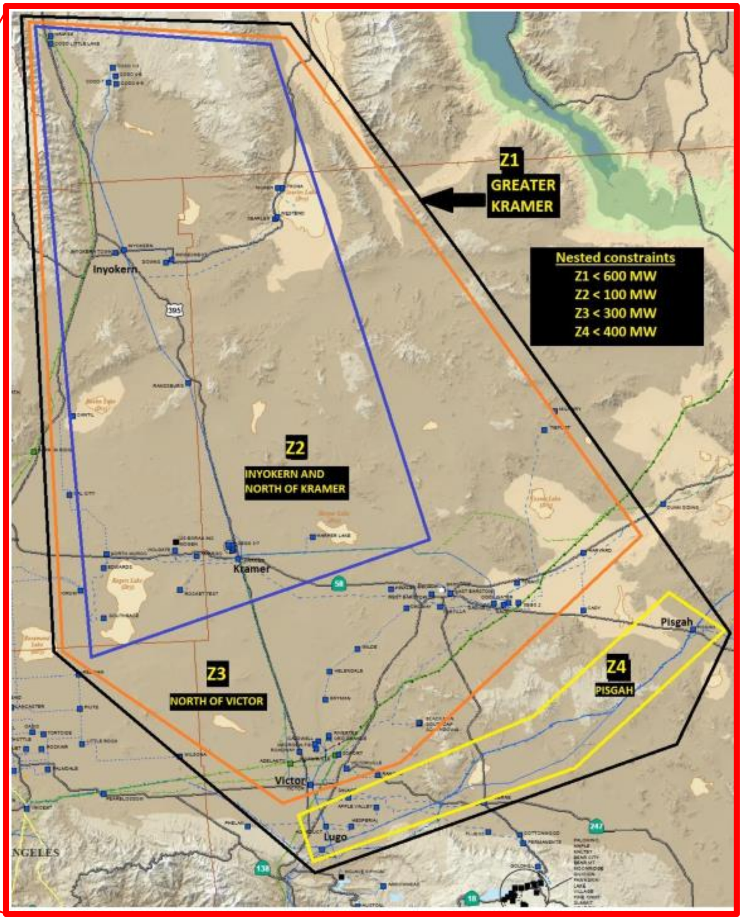
- CAISO has identified multiple layers of transmission constraints for many transmission zones. These “nested” constraints represent multiple concurrent limitations to delivering energy from renewable resource zones to load centers.
  - See: http://www.caiso.com/Documents/WhitePaper-TransmissionCapabilityEstimates-InputtoCPUCIntegratedResourcePlanPortfolioDevelopment.pdf
- While only one limit may be binding at a time, all limits must be modeled simultaneously to ensure that no limits are exceeded.



Reserving or building transmission along the yellow path allows a resource to be delivered from Zone 2 to Zone 1; transmission capacity along the red path is also needed to deliver generation from Zone 2 to CAISO load centers.

2019 IRP Resource Zones Updated to Incorporate Updated CAISO Transmission Constraints





"Nested" Constraints in Draft and Proposed RSP modeling

PreliminaryResults

- RESOLVE code could not directly simulate "nested" constraints
- RESOLVE inputs were modified to ensure that that none of the existing transmission system limits identified by CAISO were violated
  - Transmission capacity for subzones was allocated by prioritizing capacity for zones that have renewable resources with higher marginal capacity value
- Transmission costs based on full cost to build from subzone to load centers

Released 10/4/2019, available at:
https://www.cpuc.ca.gov/General.aspx?id=6442462824

Proposed RSP Results

- RESOLVE code was modified to directly represent "nested" constraints
- Allocation of transmission capacity between zones subzones not necessary with updated RESOLVE code
  - CAISO transmission limits used directly (with minor modifications)
- Transmission costs based on incremental cost to build from subzone to next "layer" of transmission constraint

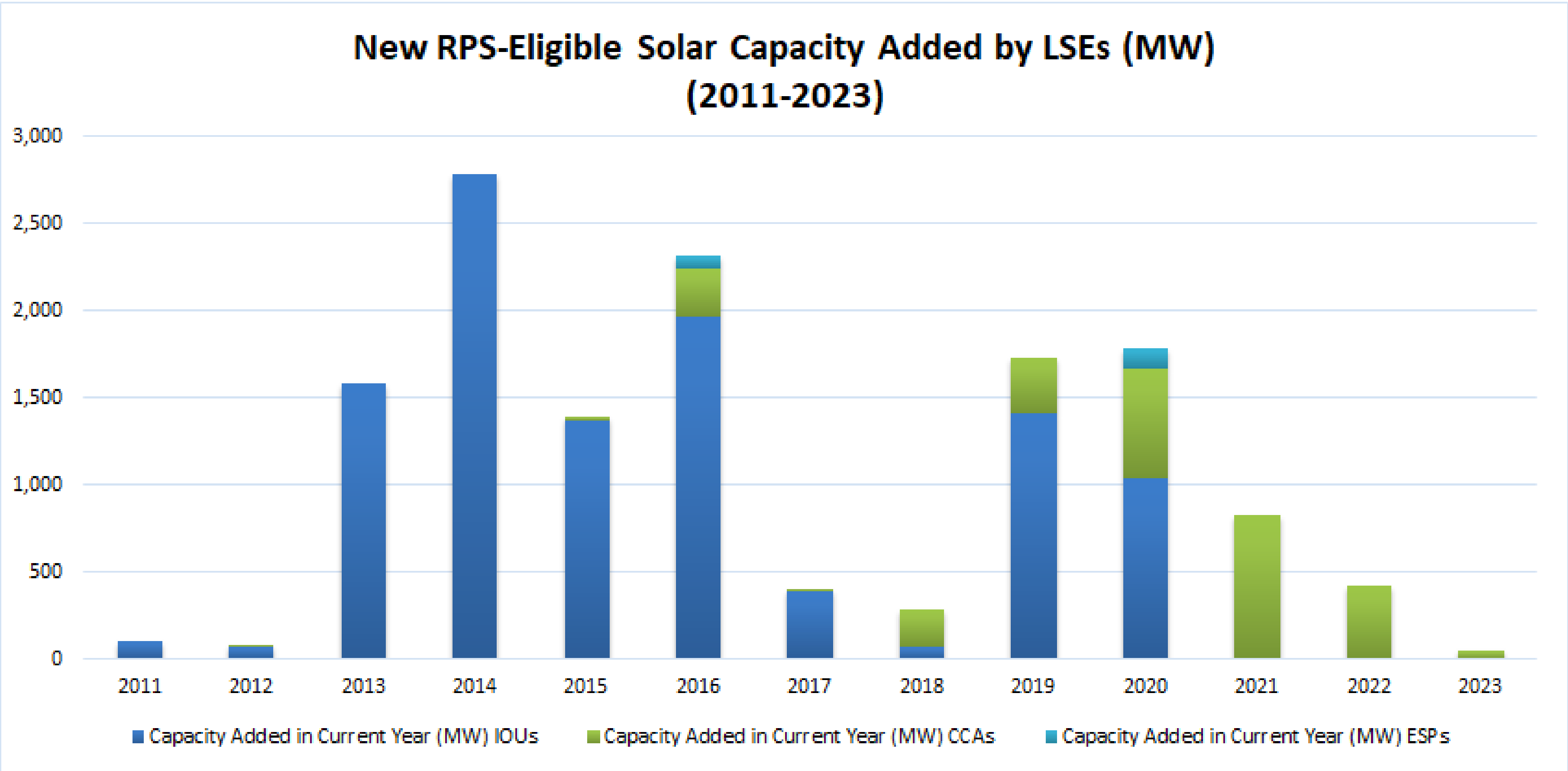
Released 11/6/2019, available at:
https://www.cpuc.ca.gov/General.aspx?id=6442463190

NEAR-TERM RESOURCE AVAILABILITY

Description of Near-Term Resource Availability Limitations

- Many "real-world" factors make it challenging to ramp up resource deployment quickly.
  - Logistics of training and re-locating staff, upstream supply chain limitations, siting and permitting lead times, etc.
- Near-term limits on resource buildout will limit the capacity of resources available to be procured by LSEs, and should be represented in IRP modeling when possible.
- However, it can be analytically challenging to predict a feasible level of near-term deployment.
- Near-term resource availability limitations were placed on two resource types in RESOLVE since the 10/8 Preliminary Results workshop:
  - Shed Demand Response (default):
    - To reflect lead time required to ramp up shed DR availability, total potential is phased in linearly between 2020 and 2025.
    - Shed DR potential limitation is now a default assumption.
  - Candidate resource solar PV (sensitivities, including 46 MMT Alternate):
    - Availability limited to 2GW/yr for candidate solar through 2023.
    - Candidate BTM PV resources included under this assumption.
    - Baseline BTM PV adoption is taken directly from IEPR and is not affected.

Historic and Planned Solar PV Build in California



- Represents data compiled from:
  - RPS Database, last updated 11/15/19
  - RPS Compliance Reports, last updated 8/1/19

IMPLEMENTATION OF IMPORT CAPACITY CONSTRAINT IN SERVM

Implementing an Additional Simultaneous Import Constraint Due to Limits on Firm Import Capacity

- Both RESOLVE and SERVM model a 11,665 MW CAISO simultaneous import limit covering all hours. In any hour, the import flow into CAISO cannot exceed this limit.
- RESOLVE also models a separate Planning Reserve Margin (PRM) constraint where the portfolio must always have enough effective capacity to meet a 15% PRM. As a default, RESOLVE assumes that 5,000 MW of imports can count towards effective capacity to meet Resource Adequacy (RA) requirements.
  - In a future where non-CAISO areas are less willing to provide RA for CAISO entities, RESOLVE assumes only 2,000 MW of firm imports that can count towards RA
- SERVM does not model a PRM constraint like RESOLVE. To reflect a constraint on firm imports that can count towards RA, staff added a second CAISO simultaneous import limit of 5,000 MW that would apply for all hours where gross electric demand is higher than the 95th percentile. This approximates the stressed hours of the year that the RA program is intended to cover.
  - Previously presented SERVM results did not include this second constraint. As will be explained later in this presentation, this is a key constraint that can contribute to loss-of-load events.

IV. DESCRIPTION OF SERVM VALIDATION OF RESOLVE PORTFOLIOS

Review of Model Calibration Process

- Inputs for both models were sourced from common datasets and aligned to the maximum extent possible
- Staff set RESOLVE to the desired GHG target and generated a portfolio of candidate resources
- Staff added the new resource portfolio to SERVM, ran the model, and extracted key metrics (GHG emissions, production costs, LOLE, energy production by resource categories, etc.)
- Both models were adjusted and run iteratively until GHG emissions and resource dispatch were reasonably aligned, and SERVM confirmed the modeled electric system was reliable and operable
- Staff aligned GHG emissions in RESOLVE and SERVM under a range of GHG reduction targets: see details in the Calibration presentation from the 10/8/19 workshop
- Staff used the calibrated RESOLVE to explore additional sensitivities and scenarios as explained in the Proposed Reference System Portfolio presentation
- The reliability of the Proposed Reference System Portfolio was assessed with SERVM for years 2022, 2026, and 2030

Review of SERVM Metrics

- Staff validates the reliability of RESOLVE portfolios through Loss-of-Load Expectation (LOLE) studies with SERVM
  - Output metrics include expected frequency of events (LOLE), expected duration of unserved energy (Loss-of-Load Hours or LOLH), and expected volume of unserved energy (Expected Unserved Energy or EUE)
  - Staff considered the electric system sufficiently reliable if the probability-weighted LOLE was less than or equal to 0.1. This corresponds to about 1 day in 10 years where firm load must be shed to balance the grid.
- Staff also validates operations and emissions through the same studies since SERVM is also a production cost model
  - Annual energy by resource type, imports and exports, curtailment, storage dispatch, and emissions were compared to RESOLVE

SERVM Assessment of Updated RESOLVE Cases

- As discussed in the Proposed Reference System Portfolio presentation, a couple of key updates in RESOLVE cases modeled have occurred since the 10/8/19 workshop that determined which portfolios should be validated for reliability, operability, and emissions using SERVM.
  - RESOLVE implementation of nested transmission constraints and various small updates/corrections to inputs
  - Near-term resource availability studies
- Two updated RESOLVE cases were selected for validation with SERVM, the 46 MMT Default, and the 46 MMT Alternate.
- In addition, staff revised SERVM's modeling of import constraints to approximate a future where firm imports that can be counted upon for resource adequacy are limited, consistent with RESOLVE's PRM constraint.
  - As will be shown on the following pages, this additional constraint materially affects the reliability assessment in SERVM.

Case Definitions

	RESOLVE	SERVM	RESOLVE	SERVM
Name of case in RESOLVE Near-Term Resource Availability Study	**46 MMT**		**46 MMT limited near-term solar and partial OTC extension**	
Name of case in Ruling	**46 MMT Default**		**46 MMT Alternate**	
OTC extension assumption	None	None	2,289 MW [a]	2,241 MW
Near-term solar build limit	None	N/A	Yes	N/A
Imports to count towards RA (the PRM constraint)	5,000 MW	N/A	5,000 MW	N/A
Import limit during peak load conditions	N/A	Both None and 5,000 MW were modeled [b]	N/A	5,000 MW
Import limit for all other hours	11,665 MW	11,665 MW	11,665 MW	11,665 MW

[a] RESOLVE extended half of aggregate OTC capacity to 2023, whereas SERVM extended specific units to 2023, hence the small difference

[b] This case was modeled both with and without the additional import constraint in SERVM

RESOLVE Selected Resources for each Case

Selected Resource Summary		46 MMT Default			46 MMT Alternate		
	Unit	2022	2026	2030	2022	2026	2030
Biomass	*MW*	-	-	-	-	-	-
Geothermal	*MW*	-	-	-	-	-	-
Solar	*MW*	-	11,807	11,807	4,006	6,006	11,774
Wind	*MW*	1,950	2,372	2,837	1,950	2,550	2,837
Wind OOS New Tx	*MW*	-	-	-	-	-	-
Offshore Wind	*MW*	-	-	-	-	-	-
Battery Storage	*MW*	2,960	5,796	11,376	624	5,193	11,384
Pumped Storage	*MW*	-	-	-	-	-	-
Shed DR	*MW*	222	222	222	222	222	222
Gas Capacity Not Retained	*MW*	-	-	*(3,682)*	-	-	*(3,704)*

Reliability Results for the 46 MMT Default Case

	46 MMT Default w/ no import limit during peak load conditions			46 MMT Default w/ 5,000 MW import limit during peak load conditions		
	2022	*2026*	*2030*	*2022*	*2026*	*2030*
LOLE (expected outage events/year)	**0.000**	**0.000**	**0.005**	**0.220**	**0.108**	**0.166**
LOLH (hours/year)	0.000	0.000	0.007	0.505	0.191	0.268
LOLH/LOLE (hours/event)	0.000	0.000	1.509	2.300	1.758	1.613
EUE (MWh)	0.0	0.0	14.3	456.9	251.1	763.6
annual load (MWh)	247,335,870	253,489,278	256,512,173	249,710,160	253,487,073	256,497,901
normalized EUE (%) *	0.000000%	0.000000%	0.000006%	0.000183%	0.000099%	0.000298%

- 46 MMT Default case was studied in SERVM without the new import constraint. Consistent with earlier studies presented in the 10/8/19 workshop, LOLE was well below 0.1.
- When the 5,000 MW import constraint was added, LOLE increased to above 0.1.
- Given similarity in RESOLVE selected resources between the 46 MMT Default and 46 MMT Alternate cases (see previous page's comparison), staff expected a SERVM study with the 46 Alternate case as-is from RESOLVE would also result in LOLE > 0.1.

* Normalized EUE = EUE/annual load expressed as a percent

Reliability Results for the 46 MMT Alternate Case

	46 MMT Alternate w/ 5,000 MW import limit during peak load conditions		
	2022	*2026*	*2030*
LOLE (expected outage events/year)	**0.070**	**0.056**	**0.016**
LOLH (hours/year)	0.097	0.094	0.032
LOLH/LOLE (hours/event)	1.390	1.668	1.955
EUE (MWh)	94.5	114.9	43.9
annual load (MWh)	247,331,018	253,492,922	256,512,296
normalized EUE (%)	0.000038%	0.000045%	0.000017%
Generic effective capacity added only to SERVM	**0**	**2,000 MW**	**2,000 MW**

- Rather than study the 46 MMT Alternate case as-is from RESOLVE, staff added 2,000 MW of generic effective capacity only to SERVM, for the purposes of validating reliability
- Addition of 2,000 MW of generic effective capacity in 2026 and 2030 decreased LOLE to below 0.1 for each year, meeting the threshold for sufficient reliability
- No capacity was added to 2022 since the assumption about partial OTC extension provided sufficient effective capacity in the near-term
- Generic effective capacity was modeled as a perfectly dispatchable peaker with zero-emissions. In reality, the additional capacity could be realized through firm imports, batteries paired with solar, geothermal, more economic retention of existing thermal generation, demand response, or other.

Explanation of Reliability Results

- The PRM constraint in RESOLVE (intended to ensure sufficient effective capacity) and SERVM's reliability assessment appear to be slightly uncalibrated – RESOLVE does not build quite enough effective capacity to ensure no more than 0.1 LOLE. Possible reasons:
  - Effective Load Carrying Capability (ELCC) of wind and solar in RESOLVE (used to count contribution towards meeting PRM constraint) was not based on SERVM analysis
  - Wind ELCC in RESOLVE is somewhat higher than most recent SERVM analysis in the RA proceeding shows
  - The battery storage ELCC curve implemented in RESOLVE may be too generous in quantifying the effective capacity of storage. The RA import constraint implemented in SERVM results in higher capacity need at stressed hours and storage may be less effective at filling that incremental capacity need.
  - Different load, wind, and solar shapes between models
- Although it is challenging to use two different models, uncovering this disconnect demonstrates the utility of two different models each designed for a specific objective of the IRP process
- Both IRP models succeeded at what they were designed to do:
  - RESOLVE selected the least-cost portfolio to satisfy various constraints
  - SERVM tested the reliability of that portfolio

Hours with Expected Unserved Energy (EUE) Occur in the Evening

46 MMT Alternate + 2,000 MW Generic Effective Capacity

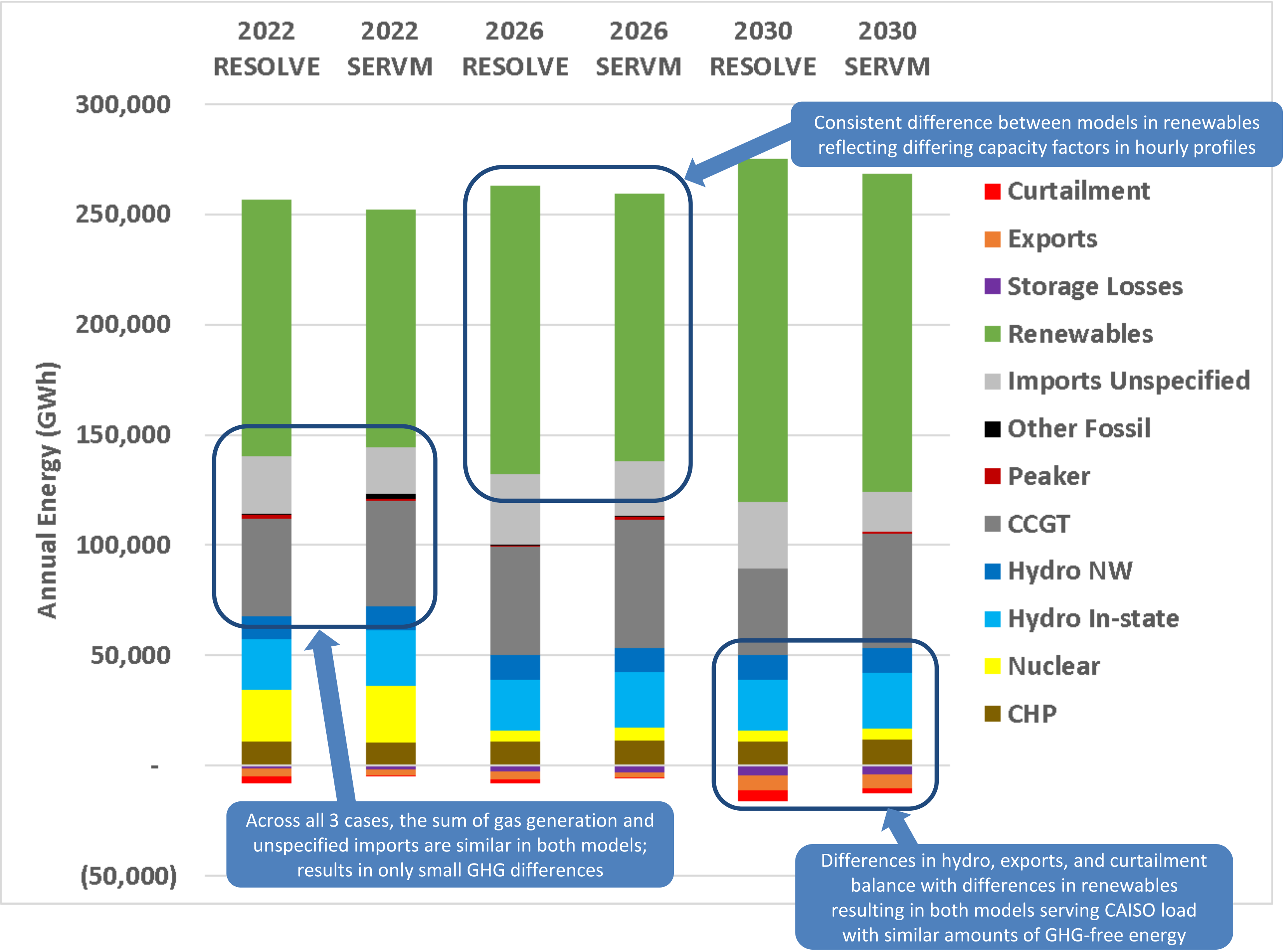
EUE (MWh), 2022												
Hour Ending	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.48	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	2.07	18.60	2.57	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	17.75	12.00	2.61	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	16.56	7.94	0.81	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	1.33	0.00	0.00	0.00	0.00	0.00

EUE (MWh), 2026												
Hour Ending	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.06	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.36	10.59	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	9.71	7.89	0.62	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	32.00	23.54	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	2.95	16.72	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	1.76	5.67	0.00	0.00	0.00	0.00

EUE (MWh), 2030												
Hour Ending	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.18	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.72	12.50	0.23	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	1.40	21.03	0.68	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.25	0.70	0.00	0.00	0.00

- Heat maps illustrating the month-hour where Expected Unserved Energy (EUE) occurs is an intuitive way of showing <u>when</u> loss-of-load events are likely to occur and quantifying the likely <u>magnitude</u> of those events
- Likely LOLE and EUE hours are consistently in the summer <u>evening hours of 6-9pm</u> and shift later for each study year – an expected outcome as solar PV penetration shifts the peak hour later in the evening

CAISO Energy Balance for 46 MMT Alternate + 2 GW Generic Effective Capacity



Energy Balance Table for 46 MMT Alternate + 2 GW Generic Effective Capacity

46 MMT Alternate Case						
CAISO Energy Balance (GWh)	2022	2022	2026	2026	2030	2030
Category	RESOLVE	SERVM	RESOLVE	SERVM	RESOLVE	SERVM
CHP	10,881	10,280	10,881	11,523	10,881	11,638
Nuclear	23,611	25,711	5,108	5,563	5,108	5,136
Hydro In-state	22,996	25,392	22,996	25,391	22,995	25,391
Hydro From NW	10,421	11,000	11,179	11,000	11,298	11,000
CCGT	44,097	47,581	49,092	57,956	38,986	52,139
Peaker	1,641	855	684	1,485	99	798
Reciprocating Engine	127	120	52	152	31	131
Coal	525	1,336	-	-	-	-
Steam	-	1,029	-	-	-	-
BTM PV	23,291	23,225	30,631	30,556	38,046	37,949
Solar	48,913	47,106	54,425	52,847	70,654	68,281
Wind	24,158	18,830	25,980	18,830	26,842	19,491
Geothermal	13,042	13,137	13,042	13,502	13,042	13,567
Biomass	6,778	5,631	6,778	5,611	6,764	5,181
Pumped Storage Roundtrip Losses	(525)	(912)	(576)	(831)	(963)	(797)
Battery Storage Roundtrip Losses	(674)	(731)	(1,966)	(2,026)	(3,573)	(3,231)
Curtailment	(2,886)	(416)	(2,043)	(402)	(5,080)	(2,335)
Imports (unspecified)	26,160	20,970	32,337	24,857	30,228	17,915
Exports	(3,770)	(2,811)	(3,583)	(2,659)	(6,617)	(6,320)
Load	247,401	247,331	253,790	253,493	257,010	256,512

SERVM curtailment lower due to lower wind and solar generation.

Storage utilization is similar between models – improvement from last year's modeling.

GHG Emissions Table for 46 MMT Alternate + 2 GW Generic Effective Capacity

46 MMT Alternate Case						
CAISO GHG Emissions (MMtCO2/Yr)	2022	2022	2026	2026	2030	2030
	RESOLVE	SERVM	RESOLVE	SERVM	RESOLVE	SERVM
CAISO Generator Emissions	22.9	25.3	23.5	28.4	19.5	25.7
Unspecified Import Emissions	11.2	9.0	13.8	10.6	12.9	7.7
CAISO Emissions w/o BTM CHP	34.1	34.3	37.4	39.0	32.4	33.4
CAISO BTM CHP Emissions	5.5	5.5	5.5	5.5	5.5	5.5
CAISO Emissions w/ BTM CHP	39.6	39.8	42.9	44.5	37.9	38.9
Emissions Delta		0.21		1.64		0.96
CAISO Generation and Imports (GWh)						
Zero-GHG	165,356	165,161	161,971	157,382	178,514	173,311
GHG-emitting	83,431	82,171	93,047	95,972	80,226	82,621

- Zero-GHG generation: Nuclear, Hydro from in-state and NW imports, Renewables net of storage losses, exports, and curtailment
- GHG-emitting generation: CHP, CAISO gas, Unspecified Imports

The sum of CAISO gas and unspecified imports in both models is similar. The relative amounts of CAISO gas and unspecified imports vary between models and across cases, but the differences generally net each other out for each case resulting in similar emissions between models.

The net amounts of zero-GHG energy serving CAISO loads are similar.

Conclusions of SERVM Analysis of Proposed Reference System Portfolio

- SERVM and RESOLVE remain sufficiently calibrated in terms of projecting GHG emissions. The models differ by less than 2 MMT CO2e for each study year.
- The Proposed Reference System Portfolio (the RESOLVE 46 MMT Alternate Case, plus 2,000 MW of generic effective capacity) was found to be a sufficiently reliable and operable portfolio for the CAISO electric system through 2030
- Both IRP models succeeded at what they were designed to do:
  - RESOLVE selected the least-cost portfolio to satisfy various constraints
  - SERVM tested the reliability of that portfolio