IRP Modeling Advisory Group Meeting
Production Cost Modeling
with the Reference System Plan and the 2017 IEPR: Preliminary SERVM model results

July 13, 2018

California Public Utilities Commission

MAG Background

- The MAG provides an open forum for informal technical discussion and vetting of data sources, assumptions, and modeling activities undertaken by Energy Division 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

Overview of Presentation

- Purpose, status, and schedule
- Study Design:
  - Overall modeling method
  - Input data development
  - Definitions of studies
  - RESOLVE and SERVM inputs comparison
- Study Results:
  - "As found" study results
  - RESOLVE and SERVM outputs comparison
- Next steps

Purpose

- CPUC Energy Division's Energy Resource Modeling (ERM) section is conducting the Production Cost Modeling (PCM) activities described in the IRP decision (D.18-02-018), Attachment B (Guide to PCM in the IRP Proceeding)
  - Validate the PCM analytical framework with the SERVM model to prepare for modeling of the aggregated LSE plans
    - Aggregated LSE plans is the result of compiling resources assumed in individual LSE plans, removing duplication, assessing gaps, and reconciling with the baseline physical fleet, followed by aggregation into a total system portfolio
  - Other parties who also plan to model the aggregated LSE plans should work with Energy Division staff to compare and align inputs and modeling methods, and evaluate differences
  - Completing model calibration and vetting work up front should enable subsequent modeling of the aggregated LSE plans to focus more on that task, rather than validating models or characterizing differences between models

Modeling Activity Status

TASK	STATUS
Develop SERVM model dataset and configuration	Complete
Rerun RESOLVE model 42 MMT core case with 2017 IEPR inputs	Complete
Post draft Unified RA/IRP Inputs and Assumptions describing SERVM inputs and configuration	Complete
Conduct “as-found” studies	Complete
Post final Unified RA/IRP Inputs and Assumptions describing revised SERVM inputs and configuration	In-progress
Conduct calibrated loss of load and ELCC studies, and reserve margin calculations	In-progress
Produce draft report for ruling seeking comment	In-progress
Make revisions based on comment	Not started
Produce final report with any revised PCM guidelines	Not started

Key IRP Process Dates

ACTIVITY	DATE (2018)
MAG Webinar	**July 13**, 10am – 12pm
Filing Deadline for LSE Plans	**August 1**
Workshop in-person for LSEs to present filings	**August 7**
MAG In-Person Meeting	**August 10**, 10am – 3pm
Ruling seeking comment on SERVM studies and revised PCM guidelines	**Late August**
Ruling revising PCM guidelines for studying aggregated LSE portfolios	**Late September**
LSE portfolios aggregation process	**August – September**
SERVM studies on aggregated LSE portfolios	**September – November**

Study Design

Overall Modeling Method

- Probabilistic reliability planning approach (e.g. security-constrained planning) – primary goal is to reduce risk of insufficient generation to an acceptable level
- Uncertainty considered – weather, economic load forecast, unit performance
- Simulate hourly economic unit commitment and dispatch
  - With reserve targets to reflect provision of subhourly balancing and ancillary services
  - With assumed generation fleet and load forecast in target study year
  - Across probability-weighted range of uncertainties
- Pipe and bubble representation of transmission system
  - 8 CA regions, 16 rest-of-WECC regions

Strategic Energy Risk Valuation Model (SERVM)

- A system-reliability planning and production cost model designed to analyze the capabilities of an electric system during a variety of conditions under thousands of different scenarios
  - 35 historical weather year distribution (1980-2014)
  - 5 points of economic load forecast error
  - 35 x 5 = 175 probability-weighted ***cases***
  - Each ***case*** is run with tens or hundreds of unit outage draws creating thousands of iterations
  - Each iteration represents one realization of a year (8760 hours) of grid operations
  - Used for probabilistic loss-of-load studies, effective load-carrying capability (ELCC) studies, and forecasting production costs and market prices

Model outputs are probability-weighted distributions

- Outputs are reported as expected values (weighted average)
- Confidence intervals, percentiles, and full distributions can be extracted
  - To keep run times and file sizes manageable many outputs are aggregated up and/or only reported as an expected value
- Each weather year is equally weighted
- Economic load forecast error has varying probability

Magnitude of forecast error (percentage)	Probability of error occurring (percentage)
2.5% error	6.68% probability
1.5% error	24.17% probability
0% error	38.29% probability
-1.5% error	24.17% probability
-2.5% error	6.68% probability

- Weight for case with 1980 weather and economic load forecast error +1.5%: (1/35) x (0.2417) = 0.006906
- For “as-found” studies, each case is simulated with 50 equally weighted random draws of unit outages

Input Data Development

- Unified RA and IRP Inputs and Assumptions document describes data development, sources, and modeling methods in detail (download here*)
  - Generator unit data
  - Load forecast
  - Fuel and carbon prices
  - Load, wind, solar, and hydro shapes
  - Transmission topology and constraints
  - System operating constraints

* A draft document was posted in February 2018. An updated version describing the revised assumptions in the studies reported here will be posted soon.

Generator Unit Data

- CAISO Masterfile
  - Generator capacity, location, and operating costs and attributes
  - Unit-specific heat rates, ramp rates, startup profiles, minimum up/down times
- TEPPC 2026 Common Case v2.0
  - Non-CAISO generation data
- RPS contracts database
  - Planned projects not yet in CAISO Masterfile
- RESOLVE model output portfolio
  - Incremental resource portfolio based on IRP Reference System Plan 42 MMT scenario calibrated with the 2017 IEPR forecast
- Generator Availability Data System (GADS) database
  - Planned and forced outage data

Annual Load Forecast

- 2017 IEPR California Energy Demand Forecast for CA loads
  - Use "Single Forecast Set" mid demand, mid-mid AAEE, mid-mid AAPV
  - Annual consumption energy and peak demand used to scale and stretch weather-normalized synthetic hourly consumption load shapes
  - Annual installed capacity of "baseline BTM PV" plus AAPV used to create hourly BTM solar PV shapes
  - Annual load modifiers include growth from increased EV charging, AAEE savings, and load shifting from TOU rates
  - Non-PV self-generation is left embedded in the consumption load
- TEPPC 2026 Common Case v2.0 for non-CA load forecast

Annual Fuel and Carbon Prices

- All costs are in 2016 dollars
- Fuel prices are derived from the Energy Commission April 2018 NAMGAS model mid case
- Carbon adder on both in-state generation and CA import hurdle rates is based on the 2017 IEPR low carbon allowance price forecast
  - $27.37 per metric ton of CO2 in 2030, translates to a $11.71 per MWh hurdle rate adder on CA unspecified imports (emissions factor 0.428 metric ton per MWh)
  - RESOLVE model output GHG shadow price ($190 per metric ton of CO2 in 2030 + $27.37) is included in a sensitivity study of 2030 (no sensitivities for 2022 and 2026)
    - Recall that $190 is the shadow price resulting from updating RESOLVE to use the 2017 IEPR forecast, reported in the 3/29 MAG webinar

Hourly Profiles

	How developed	Sources
Load	Based on relationship between historical hourly load and weather	CAISO EMS, FERC Form 714, EIA Form 861, National Climate Data Center hourly weather
Wind	Based on relationship between historical hourly production and wind speed	NREL Western Wind Resources Dataset, NOAA hourly wind speed
Solar	Calculated production from historical irradiance and assumed technology configuration	NREL PVWatts tool, NREL National Solar Radiation Database; Tracking vs. Fixed assignment based on historical late-afternoon generation (existing units) or 75%/25% assumption (new units)
Hydro	Based on historical production	Form EIA-923: Power Plant Operations Report, CEC historical hourly monitoring
Load-modifiers	Used as-is	2017 IEPR hourly shapes for EV charging, TOU rates, AAEE savings

Transmission and System Parameters

- Operational constraints
  - Spinning and non-spinning reserves, load-following, and regulation as defined in Attachment B to D.18-02-018
  - Frequency response constraint consistent with definition in RESOLVE model
  - Minimum thermal generation requirements are replaced within CAISO by the frequency response constraint but minimum thermal generation requirement of 25% is set for non-CAISO areas.

- Transmission topology, capacity limits, hurdle rates, and simultaneous flow constraints
  - Imports into CAISO limited by the CAISO Maximum Available Import Capability level derived for 2018 RA compliance and posted to the CAISO website
  - Import limits between other areas derived from TEPPC 2026 Common Case v2.0 for non-CAISO areas
  - CA is modeled as 8 regions
  - Rest of WECC outside CA is modeled as 16 regions

Simultaneous Flow Constraints

SERVM regions	Aggregation	Simultaneous flow constraint
• PGE_Bay • PGE_Valley • SCE • SDGE	CAISO	• Modeled as aggregate region – simultaneous import limit of 11,600 MW is applied near peak hours (hours where load is between 95% and 100% of peak) for all years • Net export limit of 5,000 MW is applied to all hours for all years • RESOLVE's net export limit increases slowly to 5000 MW in 2030
• IID • LADWP • PGE_Bay • PGE_Valley • SCE • SDGE • SMUD • TID	CA	• No simultaneous import or export limits applied to non-CAISO areas

Definition of Studies

Type of Study	3 Primary Studies: 2022, 2026, 2030	Sensitivity study: 2030 only
As-found	Study system "as found" and report typical performance metrics. "As found" is the baseline electric system plus new resources selected in the RESOLVE model using the 2017 IEPR.	Adds RESOLVE GHG shadow price ($190/metric ton CO2 in 2030) to CA generation fuel cost and CA import hurdle rates
Monthly calibrated loss-of-load	Remove existing generation until expected loss-of-load converges on desired monthly reliability target	
Monthly average portfolio ELCC for all utility-scale wind and solar	Remove wind and solar portfolio and incrementally add back perfect generation until expected loss-of-load converges on desired monthly reliability target. Ratio of total added perfect generation to removed wind and solar installed capacity is ELCC.	
Monthly reserve margin calculation	Calculate reserve margin using average portfolio ELCC as the NQC of all utility-scale wind and solar together	

RESOLVE and SERVM inputs and model comparison

- The RESOLVE and SERVM models both simulate hourly CAISO grid operation and can therefore be compared using common production cost model metrics such as annual production costs, emissions, import and export flows, curtailment, generation by resource type, month-hour dispatch patterns
- Model inputs and methods were aligned where feasible, but the two models have differences in structure and purpose, so results are expected to differ. The comparison exercise seeks to understand differences and reconcile where possible. Findings can be used to improve the accuracy of one or both models in future studies.

Structure and Purpose

- RESOLVE is an optimal investment and operational model
  - Co-optimizes fixed-costs of new investments and costs of operating the CAISO system within the broader footprint of the WECC electricity system over a multi-year horizon
  - Simplifies temporal and spatial resolution to manage model complexity and run-time
    - 37 independent representative days are simulated, each weighted such that daily outputs can be summed up to represent an operating year
    - Units are aggregated into classes, WECC transmission topology is aggregated into 6 regions, with 4 representing CA
  - Simplifications or averaging of operating performance of generation
  - Designed to solve for an optimal portfolio of new investments while satisfying a range of policy and operational constraints
- SERVM is a probabilistic reliability and production cost model
  - Optimizes least-cost unit commitment and dispatch of entire WECC
  - Over wide range of conditions (many different realizations of one chosen study year)
  - Simulates full sequential 8760 hours of a year
  - Requires generating fleet and load forecast to be pre-determined for the study year
  - Unit-level dispatch, WECC transmission topology is aggregated into 24 regions, with 8 representing CA
  - Operating performance of generation more detailed and by unit

CAISO generation capacity comparison

	TOTAL SERVM RESOURCES, MW			TOTAL RESOLVE RESOURCES, MW			SERVM minus RESOLVE, MW		
Resource Type	2022	2026	2030	2022	2026	2030	2022	2026	2030
Battery Storage	1,115	1,514	3,431	1,113	1,512	3,429	2	2	2
Biomass	676	676	676	1,107	1,107	1,107	-431	-431	-431
Geothermal	1,697	1,697	3,397	1,487	1,487	3,187	210	210	210
Nuclear	2,923	623	623	2,922	622	622	1	1	1
utility_scale_solar_pv	19,022	19,022	19,086	19,211	19,211	19,276	-189	-189	-190
Thermal	26,539	26,539	26,539	27,561	27,561	27,561	-1,023	-1,023	-1,023
Wind	7,969	7,969	9,070	7,816	7,816	8,917	153	153	153
BTMPV	12,301	16,727	20,759	12,758	17,454	21,573	-457	-727	-814
DR	1,754	1,754	1,754	1,752	1,752	1,752	1	1	1
Hydro	7,402	7,402	7,402	9,163	9,163	9,163	-1,761	-1,761	-1,761

- Totals include all generators serving CAISO load.
- Thermal includes CHP, CCGT, CT, reciprocating engine, and steam.
- Existing renewables based on contracted capacities reported in RPS Contracts Database.
- RESOLVE BTMPV based on calculated capacity from 2017 IEPR annual energy and an assumed capacity factor (that is slightly lower than assumed in the IEPR). Grossed up for T&D losses.
- SERVM BTMPV based on 2017 IEPR installed capacity. Grossed up for T&D losses.
- For the “Hydro” category, Hoover was excluded and pumped hydro storage was included in both models’ totals. Hoover is modeled in both models, but excluded from this capacity comparison.

Some Causes of Differences

- Thermal and renewable capacity levels differ partially due to SERVM dataset being updated more recently. SERVM sourced capacities from the CAISO Masterfile and TEPPC Common Case where possible, whereas RESOLVE generally sourced from a preliminary 2017 NQC List and an older Common Case version. Units may have been installed or retired. Many units retired in CAISO and across WECC since the RESOLVE dataset was compiled.
- RESOLVE tabulates capacity of hydro by totaling up individual hydro facilities. In SERVM, hydro is modeled as a combination of profiles – run of river, scheduled hydro, and emergency hydro. Each region gets a profile for each of the three types, equaling a bank of available energy, and a max capacity. These profiles are created monthly to correspond to 1980 through 2014 actual hydro generation patterns. For these reasons, hydro capacity is difficult to compare – hydro is often expected to perform at below maximum capacity in low hydro weather years.
- Differences were also related to units being modeled “in CAISO” versus “out of CAISO,” as explained further on the next slide

Modeling of generators located outside CAISO as "within" CAISO

- Both RESOLVE and SERVM model most renewable and specified import contracts (such as Palo Verde Nuclear Station) as internal to CAISO.
- The exception is dynamically scheduled conventional thermal generators, which are modeled as internal to CAISO in SERVM, and external in RESOLVE. These include Mesquite, Arlington, Yuma, and Griffith CCGT facilities which provide approximately 8 TWh of generation and 3.4 MMT of CO2 emissions per year.
- These units' generation is treated as unspecified imports into CAISO by RESOLVE, and would thus be subject to hurdle rates. As a result, RESOLVE would tend to dispatch them less compared to in-CAISO thermal units.
- Because SERVM models these units as internal to CAISO, it does not disfavor their use in this way, and dispatches them more compared to RESOLVE.

Impact of Generator Operational Differences

Higher heat rates (HR) and startup times in SERVM relative to RESOLVE lead to increases in fuel use (and emissions) in SERVM. SERVM data is sourced from CAISO Masterfile information .

Unit type	SERVM average HR in 2030 (MMBtu/MWh)	RESOLVE average HR in 2030 (MMBtu/MWh)
CCGT	7.57	6.91
CT	10.71	N/A (de minimis dispatch in 2030)
Cogen	9.21	7.61

SERVM Cogen heat rates derives from the CAISO Masterfile which does not separate fuel for useful heat vs. electricity production. This results in higher heat rates as some of the fuel goes towards useful heat. RESOLVE bases its Cogen heat rate only on fuel for electricity production.

Differences in startup times leads to more hours operating inefficiently in SERVM.

Unit Type	SERVM average hours in startup per start in 2030	RESOLVE average hours in startup per start in 2030
CCGT	1.53	1
CT	0.04	0
Cogen	0.31	N/A (must-run)

*All HR's reported here are based on actual operations: total fuel burn in study year / total MWh produced in study year

Modeling of renewables generators

- RESOLVE matches to a renewable unit's expected annual energy production and assigns a class average capacity factor. RESOLVE then reports out a "calculated" nameplate MW.
  - The "calculated" MW may differ from the unit's contract or nameplate MW because the unit's capacity factor may differ from the assigned class average.
  - The expected annual energy production for a renewable is used to scale RESOLVE's generation profile for that class so that the output annual energy reported by RESOLVE always matches.
- SERVM matches to a renewable unit's contract or nameplate MW.
  - The contract or nameplate MW for a renewable is used to scale SERVM's generation profile for that class. The output annual energy reported by SERVM may not match the unit's expected annual energy production.
    - Capacity factor implied by SERVM generation profile may differ from the unit's capacity factor.
    - SERVM generation profiles vary across 35 weather years.
    - For solar PV units, greater than unity inverter loading ratio (DC MW/AC MW) results in more energy production per assumed AC nameplate MW.

Study Results

As-found study outputs

- Intended to assess operational performance of a given portfolio in a target study year, under a range of future weather and economic output
  - Given portfolio: RESOLVE 42 MMT core case aligned with 2017 IEPR
  - Three primary study years: **2022, 2026, 2030**
  - One sensitivity on the 2030 study year: Adds RESOLVE GHG shadow price ($190/metric ton CO2 in 2030) to CA generation fuel cost and CA import hurdle rates. The following slides label this sensitivity as "**2030+RGS**", short for "RESOLVE GHG Shadow price"
- Annual Loss-of-Load Expectation (LOLE) and normalized Expected Unserved Energy (EUE) is effectively zero for all studies – consistent with the projected system capacity reserve margin being several percent higher than 15 percent
- Reported on the following slides:
  - System balance and generation by resource class in 2030
  - Monthly generation by resource class, import and export flows, and curtailment
  - Hourly dispatch and market price for selected days
  - CO2 and criteria pollutant emissions
  - Annual RPS % for CAISO region
  - Comparisons with RESOLVE outputs

CAISO system balance in 2030

CAISO System balance verification, GWh	SERVM: 2030	SERVM: 2030+RGS	RESOLVE: 2030
Generation serving CAISO load, including BTMPV, direct imports, and excluding storage discharge, non-PV load modifiers	269,484	268,211	251,826
Non-PV load modifiers (net effect of AAEE, EV, TOU)	18,276	18,276	N/A
Imports_Unspecified	10,985	11,171	12,709
Load after reduction from non-PV load modifiers (net effect of AAEE, EV, TOU)	254,601	254,601	255,038
Non-PV Load Modifiers (net effect of AAEE, EV, TOU)	18,276	18,276	N/A
Exports_Unspecified	13,862	13,509	5,686
Battery and Pumped Storage Hydro losses (net of charge and discharge)	949	1,245	3,811
Curtailment	11,055	10,025	N/A

- Green items are “credits” that increase energy in a region, red items are “debits.” Total credits – total debits = 0
- RESOLVE generation amounts reported are after curtailment, whereas SERVM amounts are before curtailment
- RESOLVE uses the hourly net of charge and discharge (storage losses) for hourly energy balance. (Subhourly charge and discharge is separately tracked in RESOLVE.)
- RESOLVE models load as after reductions from non-PV load modifiers, whereas SERVM models load as before reductions from non-PV load modifiers, thus modeling the effect of non-PV load modifiers as a “generator”

CAISO Generation by Resource Class in 2030

Generation serving CAISO load by resource type in GWh. Includes in-region generation and direct (specified) imports.	SERVM: 2030	SERVM: 2030+RGS	RESOLVE: 2030
CCGT	71,208	70,887	69,371
CT	2,328	1,496	26
Steam	141	129	0
Coal	0	0	0
Biomass	1,931	1,899	6,792
BTMPV	42,621	42,621	36,295
Solar PV Fixed + Tracking	52,560	52,560	47,990
Wind	28,060	28,060	21,914
Scheduled Hydro Plus Run-of-River Hydro	28,490	28,490	25,317
Geothermal	23,729	23,709	24,357
Cogen	12,779	12,725	14,759
Nuclear	5,459	5,459	5,004
ICE	179	176	0
Non-PV Load Modifiers (net effect of AAEE, EV load, TOU)	18,276	18,276	N/A
Curtailment not included inline above	-11,055	-10,025	N/A
TOTAL	276,705	276,462	251,826

SERVM values are NOT net of curtailment, whereas RESOLVE values ARE. SERVM does not report curtailment on a resource-specific basis.

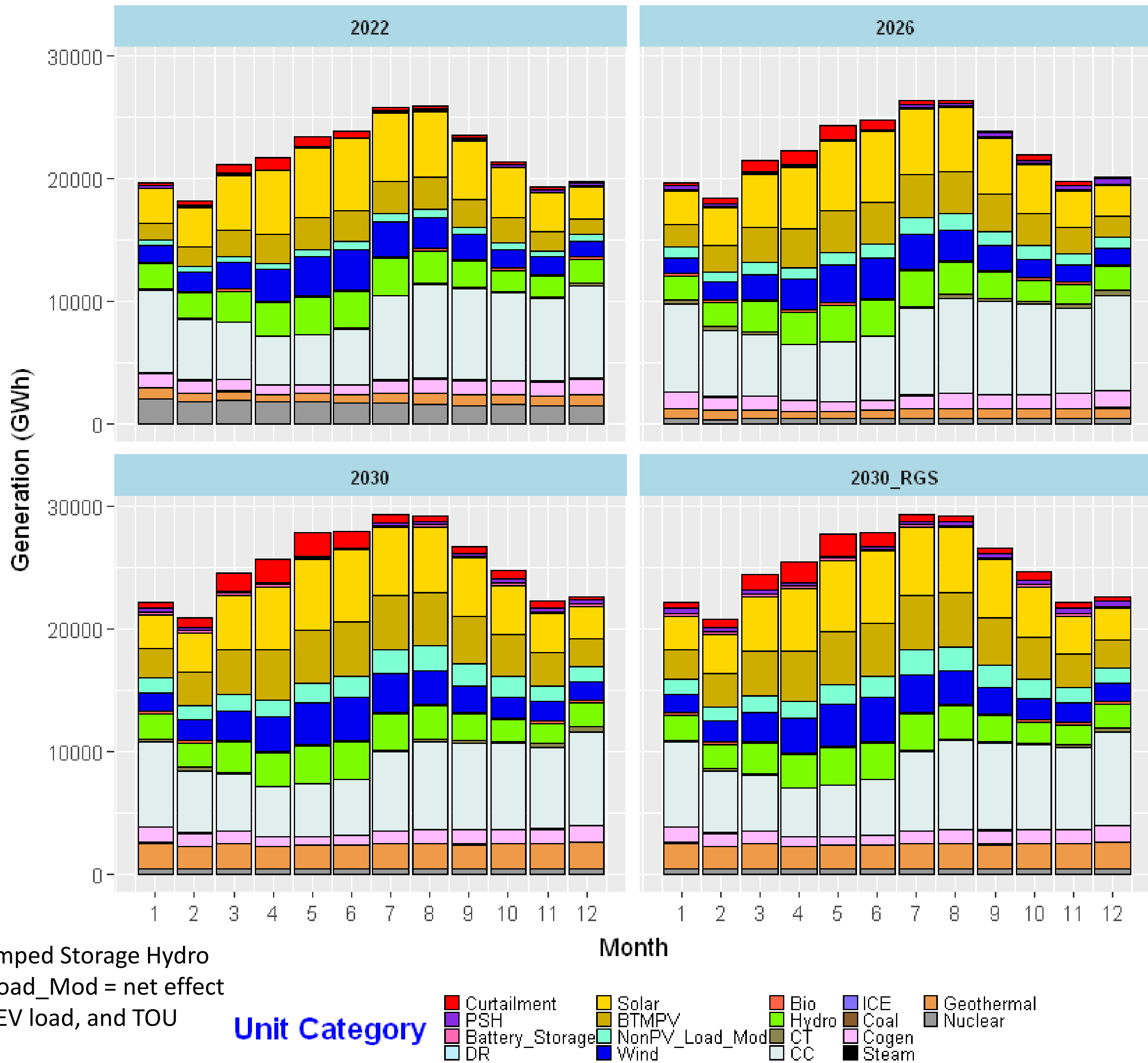
RESOLVE's wind value for CAISO does not include certain existing OOS wind generators with CAISO offtakers (1.8 GW capacity, 4.6 TWh energy), because these generators are not balanced by CAISO. These are considered in-CAISO by SERVM.

CAISO Storage Usage in 2030

Charges (-), discharges (+), or net storage loss, GWh, by resource type		SERVM: 2030	SERVM: 2030 + RGS	RESOLVE sum of hourly and subhourly: 2030
Pumped Storage Hydro	charge	-3,245	-4,608	-5,068
Pumped Storage Hydro	discharge	2,637	3,750	4,105
Battery Storage	charge	-2,314	-2,635	-6,656
Battery Storage	discharge	1,973	2,247	5,658
Pumped Storage Hydro	Net storage loss	-608	-857	-963
Battery Storage	Net storage loss	-341	-388	-998

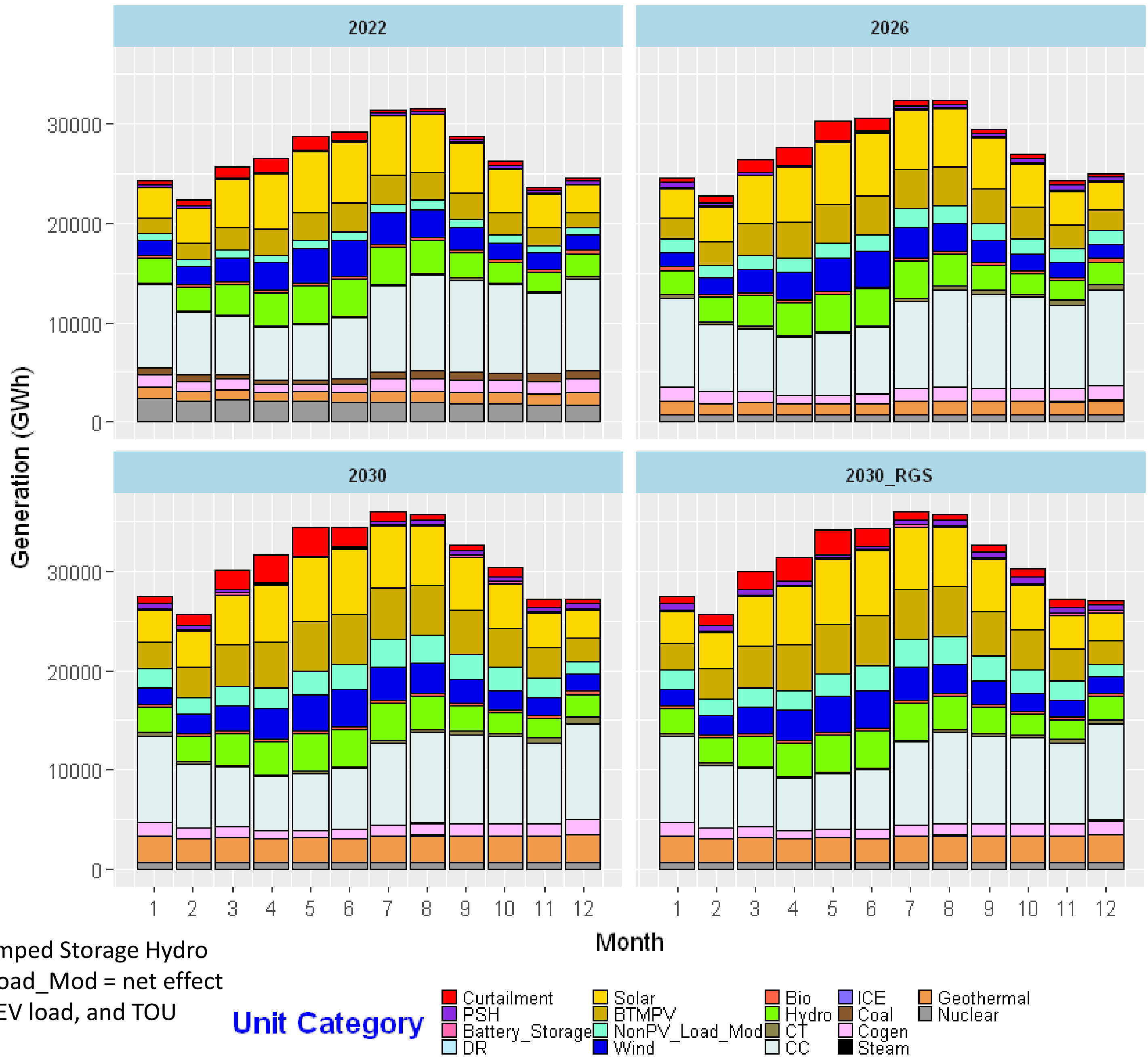
RESOLVE estimates the amount of charging and discharging to account for subhourly load following. This increases mileage on batteries above what is simulated in SERVM. We have tried to compare hourly battery dispatch to RESOLVE, but it is an imperfect comparison.

Monthly Generation by Resource by Year for CAISO

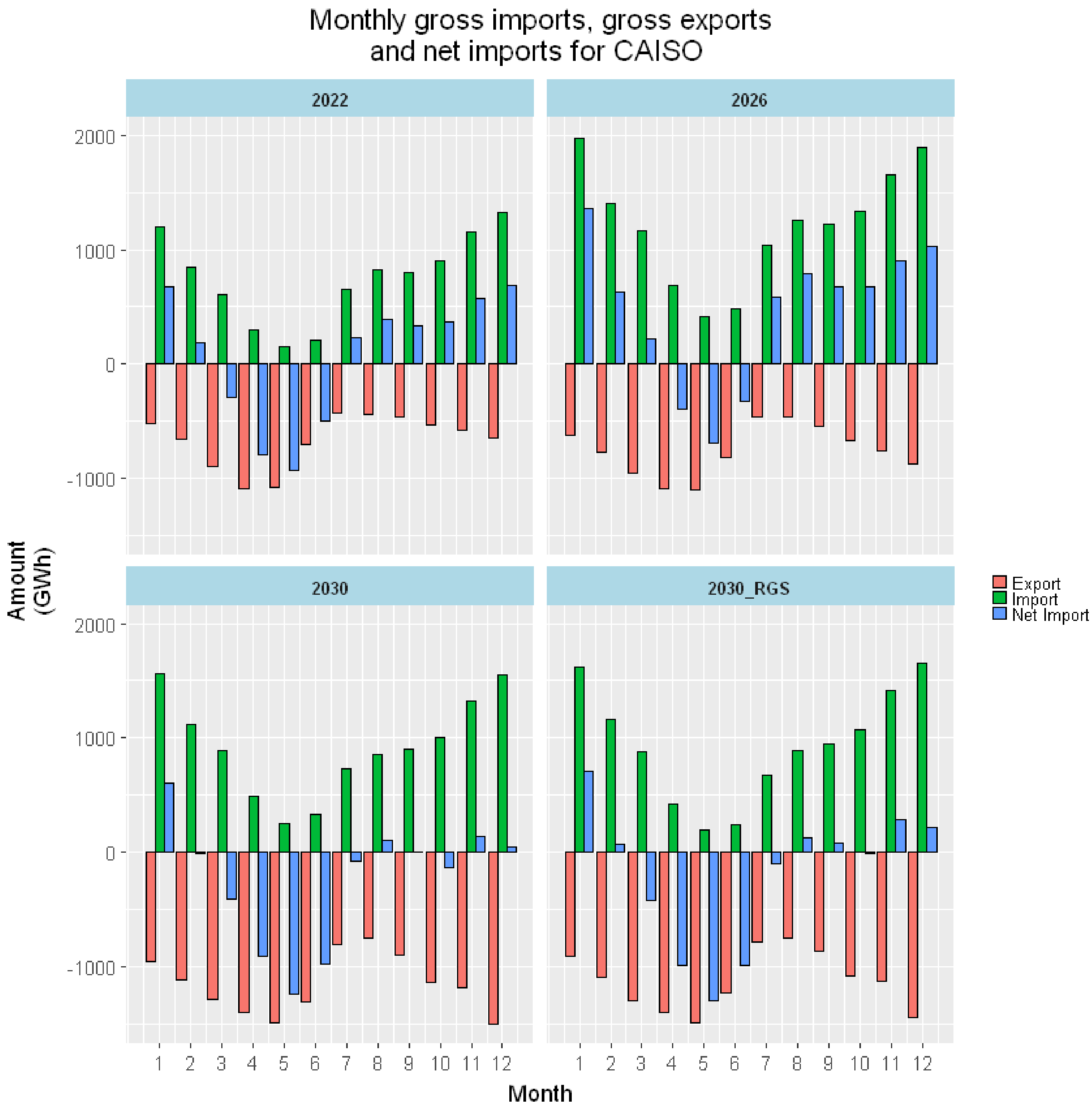


PSH = Pumped Storage Hydro
NonPV_Load_Mod = net effect of AAEE, EV load, and TOU

Monthly Generation by Resource by Year for CA

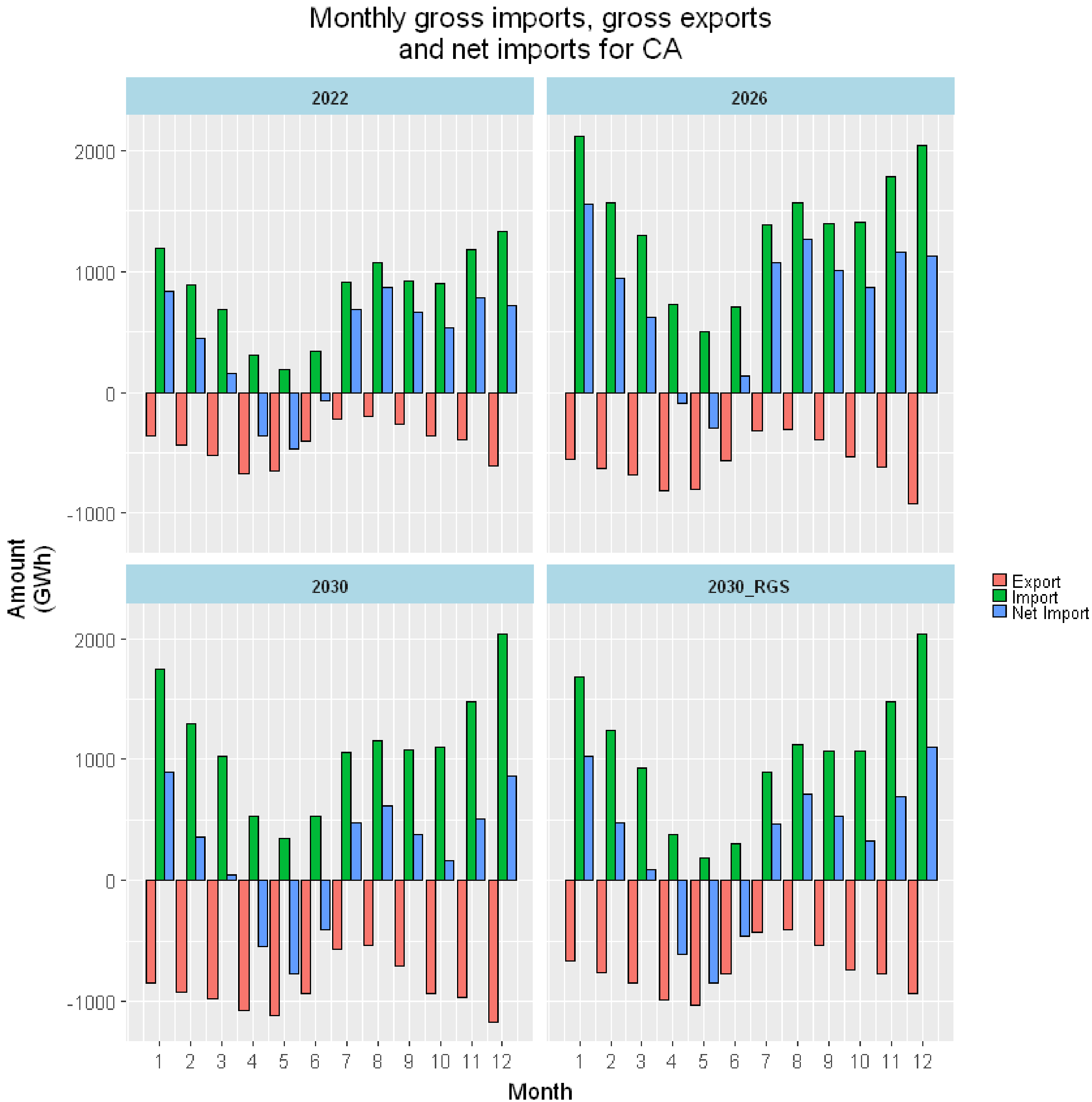


PSH = Pumped Storage Hydro
NonPV_Load_Mod = net effect of AAEE, EV load, and TOU



Unspecified imports and exports

Although we implemented a net export limit of 5,000 MW in any hour, this limit was binding on average less than one hour per month



Unspecified imports and exports.

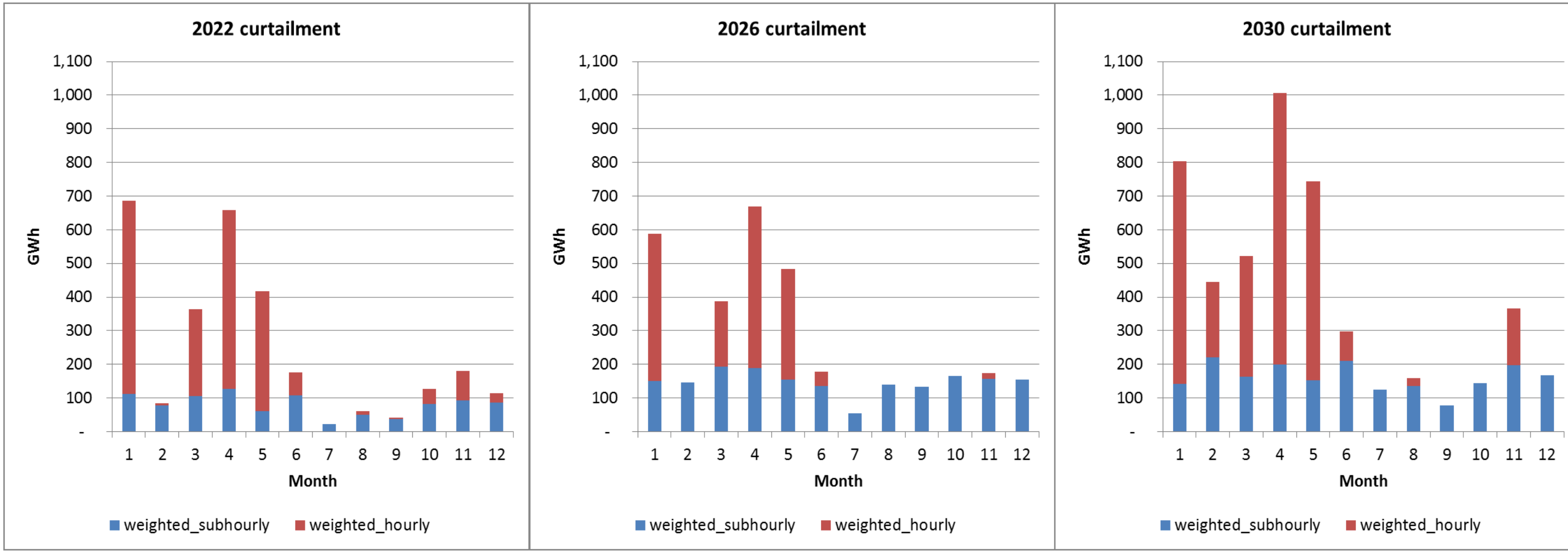
Comparing with the preceding slide, the CAISO area appears to export some of its excess to other CA areas as well as OOS. CAISO appears to mostly import from OOS since CA imports generally exceeds CAISO imports.

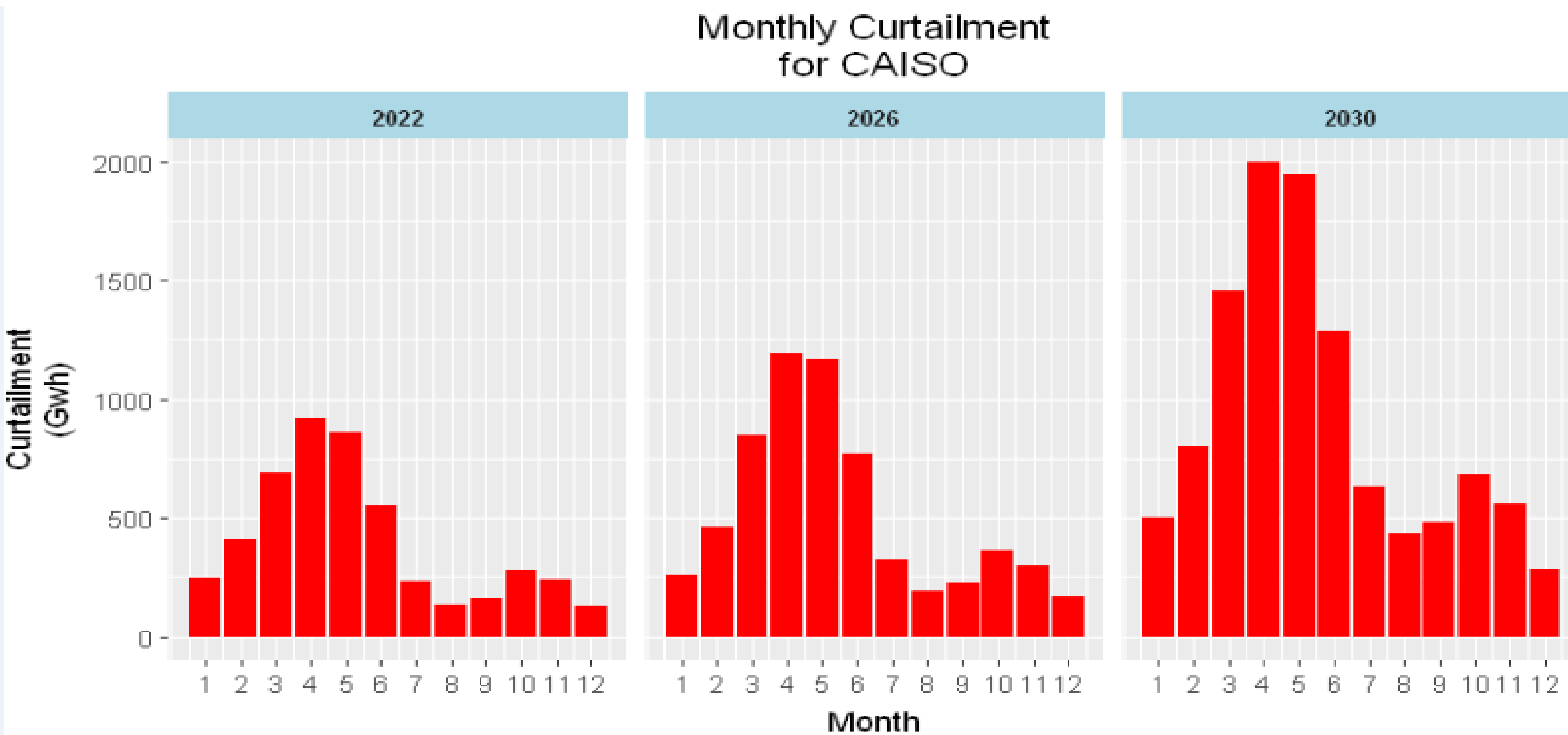
Monthly CAISO curtailment comparison with RESOLVE

- RESOLVE reports scheduled (hourly) curtailment which is generally due to excess production, and estimates subhourly curtailment, generally due to downward load following and regulation provision
- Breakout of monthly curtailment in RESOLVE is a very gross estimate since the day-weighting scheme was designed to represent high and low load days within a year, but not within individual months
  - One of RESOLVE's 37 representative days is a January day with relatively high weight. That day also happened to have high curtailment, thus overestimating the amount of January curtailment due to the high day weight.

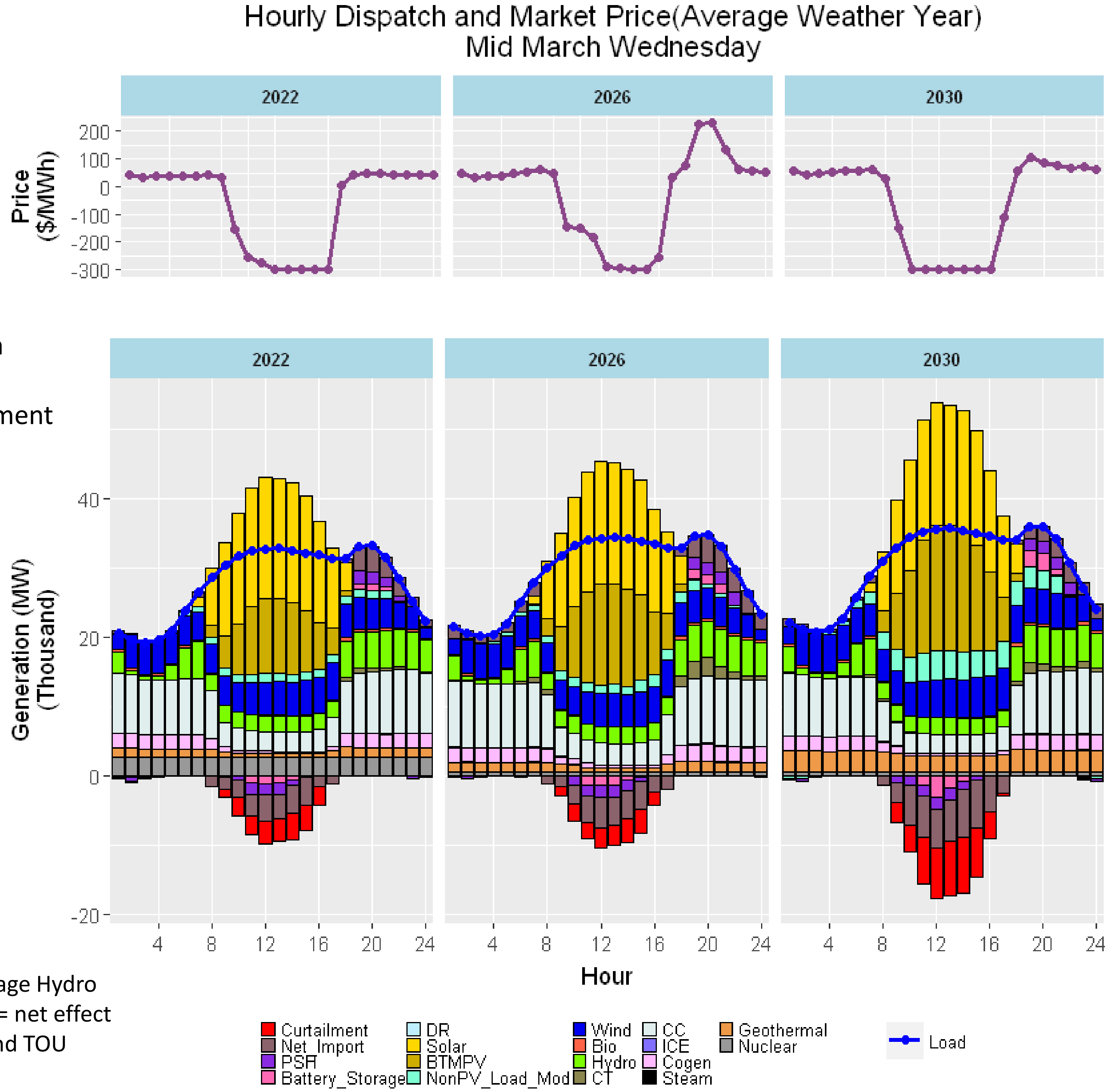
- SERVM reports only hourly curtailment, subhourly effects were not explicitly simulated
- SERVM curtailment overall is nearly twice as much as reported by RESOLVE, likely due to SERVM's thermal generation being modeled as less flexible and not fully turned off during excess supply conditions midday

- The next slide compares monthly curtailment extracted from RESOLVE results (top row) and monthly curtailment reported by SERVM (bottom row), for the CAISO area.


2022 curtailment
2026 curtailment
2030 curtailment
GWh
Month
weighted_subhourly
weighted_hourly


Monthly Curtailment
for CAISO
2022
2026
2030
Curtailment
(Gwh)
Month

50th percentile March weather (1989, case 43 of 175)

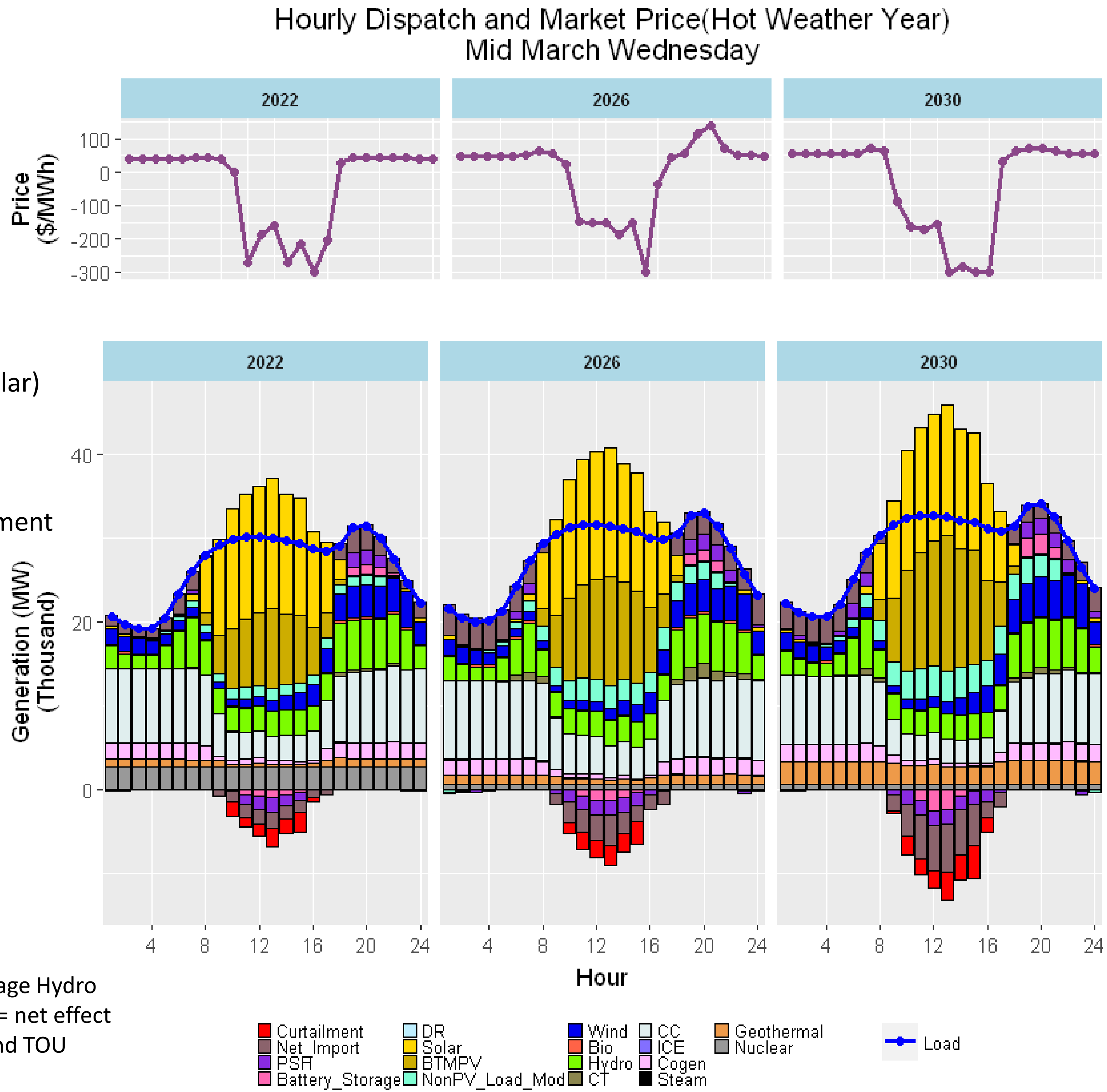


A spring day with negative midday price and curtailment in all years

PSH = Pumped Storage Hydro
NonPV_Load_Mod = net effect of AAEE, EV load, and TOU

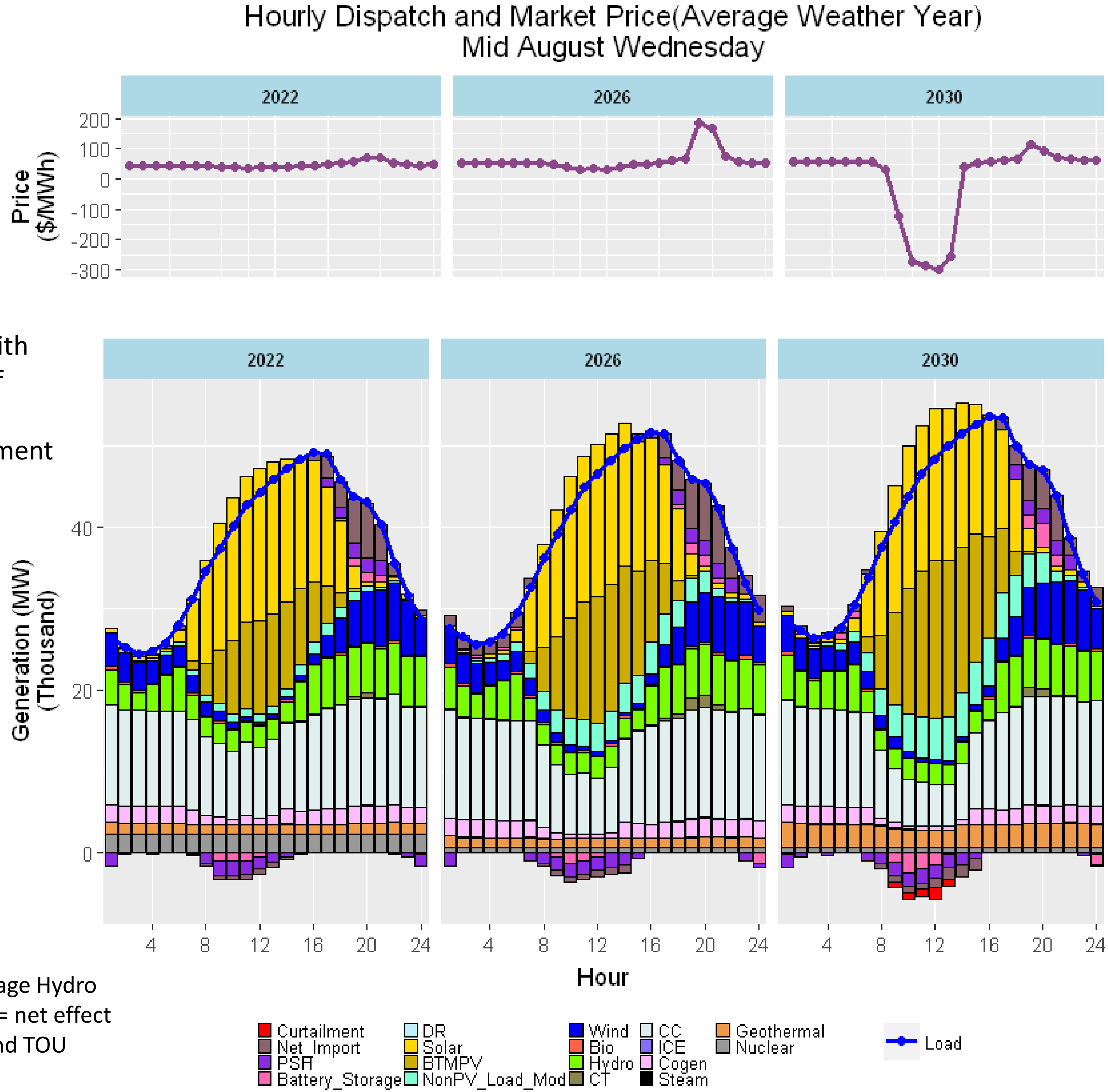
90th percentile March weather (2004, case 118 of 175)

A hot (perhaps cloudy w/ less solar) spring day with somewhat less negative midday price and curtailment



PSH = Pumped Storage Hydro
NonPV_Load_Mod = net effect of AAEE, EV load, and TOU

50th percentile August weather (1986, case 28 of 175)

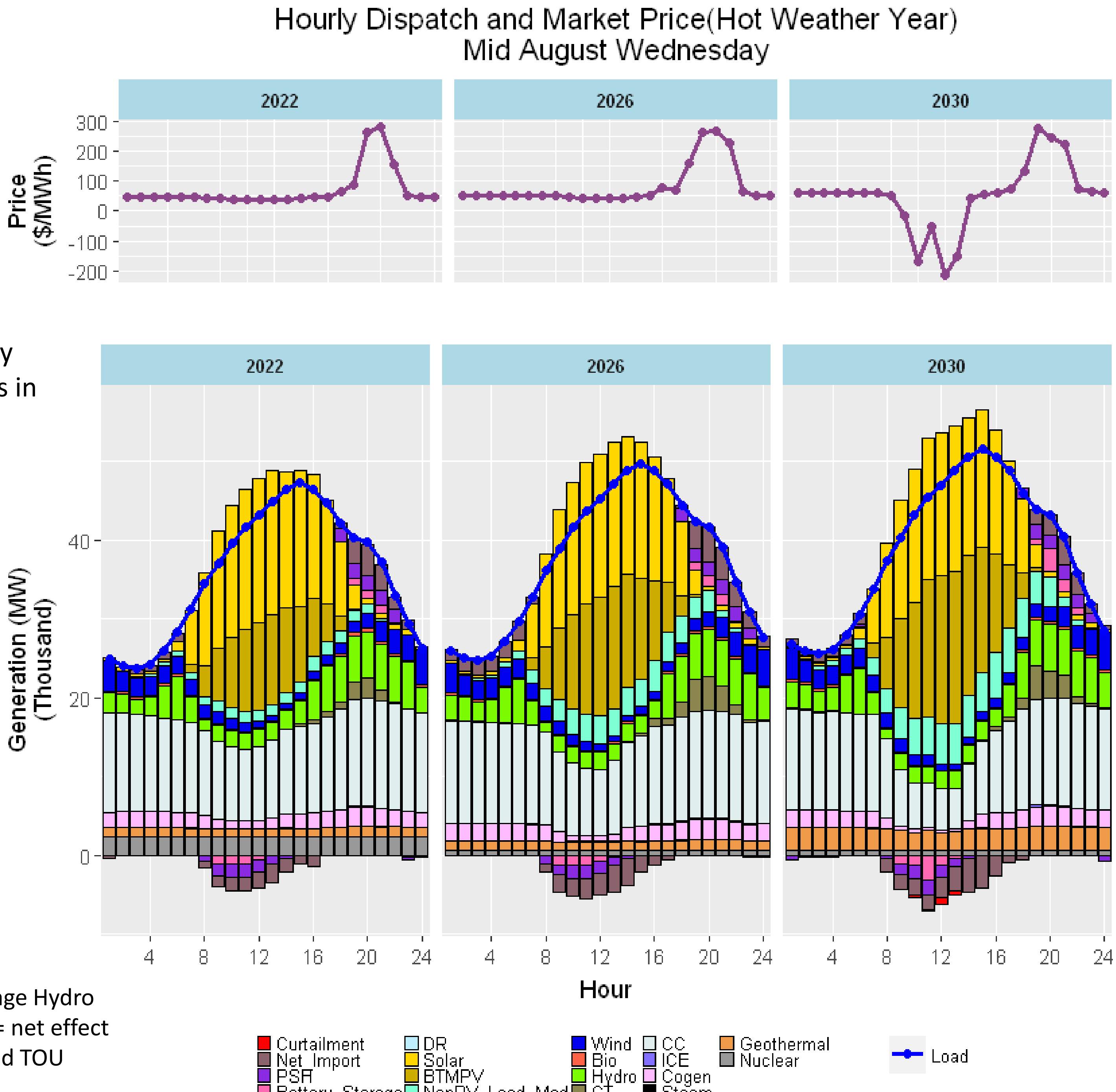


A summer day with small amounts of negative midday price and curtailment in 2030

PSH = Pumped Storage Hydro
NonPV_Load_Mod = net effect of AAEE, EV load, and TOU

90th percentile August weather (2009, case 143 of 175)

A hot summer day with higher prices in the 6-9pm hours



PSH = Pumped Storage Hydro
NonPV_Load_Mod = net effect of AAEE, EV load, and TOU

Refresher: IRP GHG Planning Targets

- D.18-02-018 adopted an electric sector 42 MMT in 2030 planning target, statewide
- This translated to a 34 MMT in 2030 planning target for the CAISO footprint, assuming CAISO share of electric sector emissions is about 81%
- RESOLVE does not count BTM CHP emissions as part of electric sector emissions, whereas CARB's California Greenhouse Gas Emissions Inventory and Scoping Plan does. SERVM follows the same counting convention as RESOLVE, excluding any emissions from BTM CHP (generally the non-PV self-generation component of the IEPR demand forecast).

Annual CO2, NOx, PM2.5 emissions*

CAISO	Units	2022	2026	2030	2030+RGS
CO2	MMT	37.4	43.4	38.2	37.6
NOx	Metric ton	4,100	4,393	4,114	3,933
Steady-state	Metric ton	3,758	3,916	3,651	3,558
Starts	Metric ton	342	477	462	375
PM2.5	Metric ton	2,109	2,204	2,056	2,019

California	Units	2022	2026	2030	2030+RGS
CO2	MMT	46.6	53.1	48.1	46.8
NOx	Metric ton	7,368	5,475	5,245	4,999
Steady-state	Metric ton	6,896	4,820	4,591	4,453
Starts	Metric ton	472	655	654	546
PM2.5	Metric ton	3,240	2,724	2,594	2,537

*CO2 emissions are from all generation to serve load including unspecified imports. NOx and PM2.5 emissions are from in-state generation and specified imports only.

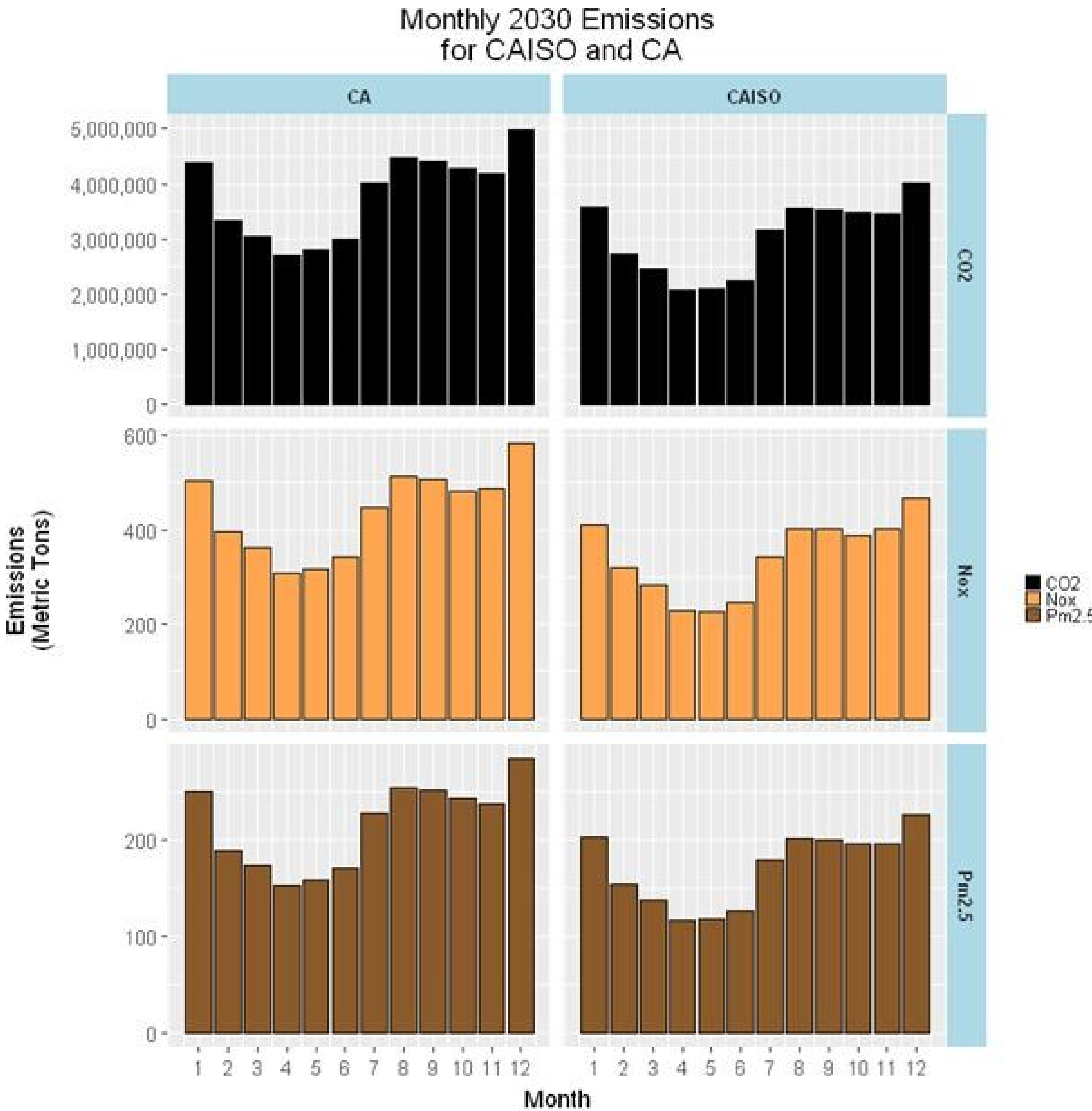
Details: 2030 California NOx, PM2.5 emissions*

NOx emissions in metric tons, by operation state and resource type						
	CC	CT	Coal	Cogen	ICE	Steam
steady state	3,135	335	-	1,071	40	10
hot start	154	36	-	4	2	0
warm start	54	310	-	23	17	0
cold start	18	29	-	5	2	0
total	3,362	709	-	1,103	61	10

PM 2.5 emissions in metric tons, by resource type						
	CC	CT	Coal	Cogen	ICE	Steam
steady state	2,062	130	-	387	8	7

*NOx and PM2.5 emissions are from in-state generation and specified imports only, for the 2030 study (not the sensitivity)

The Sept 2017 Proposed Reference System Plan analysis estimated NOx from CCs in steady state as roughly 2,700 metric tons in 2030, statewide. The SERVM analysis here estimates 3,135 metric tons in 2030, statewide. SERVM's higher number is due to multiple factors: inclusion of specified fossil imports, some of SERVM's CCs were assigned higher NOx emissions factors based on technology, CCs run a bit more in SERVM than in RESOLVE.



CO2 emissions are from all generation to serve load including unspecified imports. NOx and PM2.5 emissions are from in-state generation and specified imports only.

The monthly pattern of emissions correlates with higher use of CCGTs and unspecified imports in winter months and lower use of CCGTs and unspecified imports in spring months.

Comparison to RESOLVE in 2030 CAISO CO2 Emissions

Emissions breakout for all generation serving CAISO load, MMT CO2	SERVM: 2030	SERVM: 2030+RGS	RESOLVE
Gross unspecified imports	4.7	4.8	5.4
Gross direct imports: thermal resources located out of CAISO but serving CAISO load (Arlington, Griffith, Mesquite, Intermountain)	3.4	3.4	0.0
In-CAISO thermal generation	32.9	32.2	31.4
NW Hydro Credit	-2.8	-2.8	-2.8
Total	**38.2**	**37.6**	**34.0**

- Higher emissions in SERVM likely due to multiple factors including:
  - Explicit inclusion of specified fossil imports (whereas in RESOLVE some of that is co-mingled with unspecified imports but probably dispatched to serve CAISO less due to import hurdles)
  - Higher levels of in-state thermal generation, higher heat rates overall, and more time spent in higher heat rate operating states

CAISO area RPS% calculation comparison		**RESOLVE**	**SERVM**
Metric	***Unit***	**2030**	2030
T&D Losses	*%*	7%	7%
Pumping Loads - not grossed up for losses	*GWh*	8,781	8,781
Customer_PV (btmpv)	*GWh*	36,295	42,621
System Load after non-btmpv load-modifiers & before btmpv reductions	*GWh*	255,038	254,601

Metric	***Unit***	**2030**	2030
Delivered RPS Renewables after Scheduled Curtailment	*GWh*	109,136	101,949
Non-Modeled RPS Renewables (AESO wind mainly)	*GWh*	2,655	
RPS Spent Bank	*GWh*	8,441	8,441
Storage Losses Subtracted from RPS	*GWh*	1,961	949
Scheduled Curtailment	*GWh*	2,923	11,055
Subhourly Curtailment	*GWh*	1,936	
RPS-bound Retail Sales	*GWh*	193,929	187,661
Curtailment (scheduled and subhourly)	*% of RPS Renew.*	4.2%	9.8%
Curtailment and Storage Losses	*% of RPS Renew.*	5.9%	10.6%
Delivered Effective RPS Percentage - Excl. Spent Bank	*% of Retail Sales*	55.6%	53.8%
Spent Bank	*% of Retail Sales*	4.4%	4.5%
Delivered Effective RPS Percentage - Incl. Spent Bank	*% of Retail Sales*	60.0%	58.3%

Next Steps

Takeaways - Model Comparison Implications

Significant progress has been made developing the SERVM model dataset and exercising Energy Division's production cost modeling process

Differences between SERVM and RESOLVE that merit additional investigation:

- Renewable installed capacity and renewable resource production shapes
- Sub-hourly and operational reserve modeling
- CCGT operational constraints (uptime, downtime, start and stop profiles, etc.)
  - An important question for IRP modeling is whether the future CAISO CCGT fleet will be able to turn off as the sun comes up and turn back on as the sun goes down.
- CCGT heat rate differences between SERVM and RESOLVE
- Cogeneration heat rate differences and the allocation of emissions between heat and power

Potential future RESOLVE updates:

- Include fuel consumption when starting CCGTs and peakers, potentially resulting in increased peaker dispatch
  - RESOLVE currently includes start costs for CCGTs and peakers, but does not include start fuel
- Model part of the cogeneration fleet as dispatchable
- Update RESOLVE thermal capacity with latest available information

What staff needs at the conclusion of this round of production cost modeling

- Refinements to the SERVM dataset and the PCM process must be finalized prior to modeling the aggregated LSE plans (approximately Sep-Nov, 2018)
- Improvements to the RESOLVE model will be scoped out, selected, and implemented over the coming months prior to the start of Reference System Plan modeling for the next IRP cycle

Modeling Activity Estimated Completion

TASK	Estimated Completion Date
Post final Unified RA/IRP Inputs and Assumptions describing revised SERVM inputs and configuration – including workbooks	End of July
Finish calibrated loss of load and ELCC studies, and reserve margin calculations	End of July
Present results of above at August MAG meeting	August 10
Complete draft report for ruling seeking comment	Late August
Complete final report for ruling with any revised PCM guidelines	Late September
Post aggregated LSE portfolio datasets for PCM	Late September
Complete SERVM studies with aggregated LSE portfolios	Late November

Questions?

- Thank you for your participation and please contact ERM section staff with any comments or questions you have.

Contacts:
Donald Brooks – donald.brooks@cpuc.ca.gov
Patrick Young – patrick.young@cpuc.ca.gov
Frederick Taylor-Hochberg – frederick.taylor-hochberg@cpuc.ca.gov
Mounir Fellahi – mounir.fellahi@cpuc.ca.gov

Important links:
IRP Events and Materials
Modeling Advisory Group
ERM Projects
ERM Data