2019-20 IRP: Calibration and Validation with SERVM production cost modeling

CPUC Energy Division

October 4, 2019

Purpose of Presentation

- Present process of modeling portfolios to be considered for the 2019 Reference System Plan, which involves use of a consistent dataset and two different models
- Present CPUC staff modeling results with SERVM model
- Make data available for stakeholders to review or conduct their own analysis

Content

1. Overview of IRP modeling tools and process
2. Overview of modeling inputs
   1. Electric demand forecast
   2. Baseline resources
3. RESOLVE - SERVM calibration results
4. Criteria pollutants analysis progress update

1. OVERVIEW OF IRP MODELING TOOLS AND PROCESS

Review of Objectives for IRP Analysis

Objective of IRP modeling: To develop an optimal portfolio of new resources to add to the existing fleet in the CAISO area to plan for:

- Achievement of long-term GHG reduction targets and other policy goals
- Maintaining reliability
- Keeping costs reasonable
- Accounting for uncertainty and expected energy market conditions (i.e., "real world" conditions)

- The role of the RESOLVE model in IRP is to select portfolios of new resources that are expected to meet our goals at least cost.
- The role of the SERVM model in IRP is to verify the reliability, operability, and emissions of resource portfolios generated by RESOLVE.
- Use of each model serves the overall objective of identifying optimal portfolios of resources under specific conditions that are suitable for use in guiding policy and procurement.

RESOLVE Model Review

- RESOLVE is a capacity expansion model designed to inform long-term planning questions around renewables integration.
- RESOLVE co-optimizes investment and dispatch for a selected set of days over a multi-year horizon in order to identify least-cost portfolios for meeting specified GHG targets and other policy goals.
- Scope of RESOLVE optimization in IRP 2019-20:
  - Covers the CAISO balancing area including POU load within the CAISO
  - Optimizes dispatch but not investment outside of the CAISO
    - Resource capacity outside of CAISO cannot be changed by the optimization
- The RESOLVE model used to develop the preliminary Reference System Plan results, along with accompanying documentation of inputs and assumptions, model operation, and results is available for download from the CPUC's website at: 2019-20 IRP Events and Materials

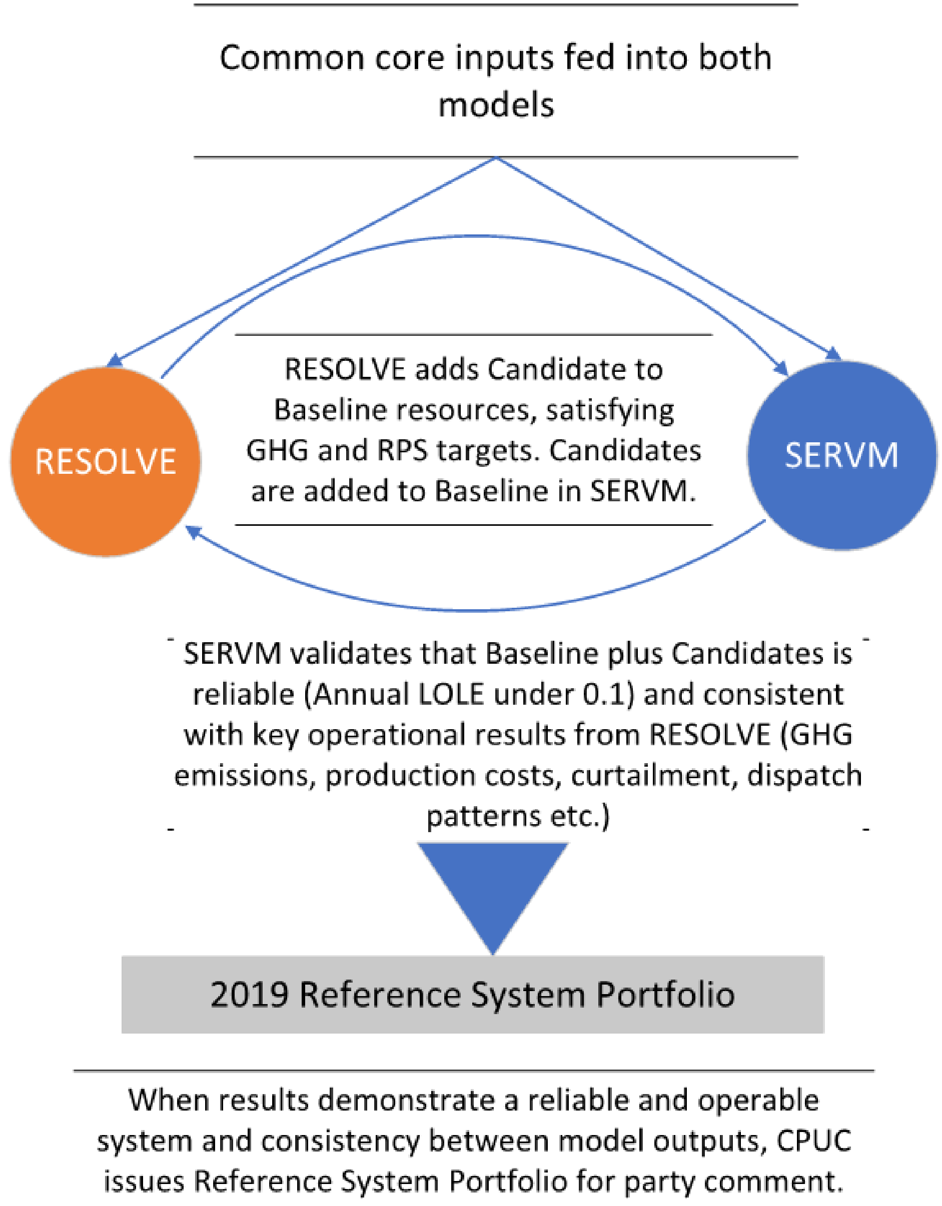
SERVM Model Review

The Strategic Energy Risk Valuation Model (SERVM)* is a probabilistic system-reliability planning and production cost model – primary objective is to reduce risk of insufficient generation to an acceptable level (e.g. security-constrained planning)

- Configured to assess a given portfolio in a target study year under a range of future weather (20 weather years), economic output (5 weighted levels), and unit performance (30+ random outage draws)
- Hourly economic unit commitment and dispatch
  - Reserve targets to reflect provision of subhourly balancing and ancillary services
  - Multiple day look-ahead informs unit commitment
  - Individual generating units and all 8,760 hours of year are simulated
  - Unit operating costs and constraints
- Pipe and bubble representation of transmission system
  - 8 CA regions, 16 rest-of-WECC regions
  - Includes region-to-region flow limits and hurdle rates as well as simultaneous flow limits

*Commercially licensed through Astrape Consulting: http://www.astrape.com/servm/

Iterative RESOLVE – SERVM Calibration Process



2019 Reference System Portfolio Development

- Common baseline data for IRP modeling were developed earlier in 2019 and presented on 6/17 to the Modeling Advisory Group. Data was posted on 6/28 to the Unified RA and IRP Modeling Datasets 2019 page.
- Baseline data aligned in RESOLVE and SERVM to maximum extent possible.
- Core policy portfolios were first developed in RESOLVE and then modeled in SERVM to test reliability, operability, similarity of resource dispatch, and emissions, validating that RESOLVE metrics are credible and complete.
- If results differed between models, changes were made to one or both models until key outputs were consistent (e.g. GHG emissions, dispatch patterns, curtailment, etc.). Several rounds of calibration were needed.
- A calibrated RESOLVE was then used to explore a wider range of sensitivities and scenarios.
- When the Proposed Reference System Portfolio is identified, staff will model it in SERVM for study years 2022, 2026, and 2030 to validate reliability throughout the IRP planning horizon.

Opportunities for Parties to Vet Staff Modeling or Conduct Their Own Modeling

- Staff posted the following information to the CPUC website:
  - Unified RA and IRP Modeling Datasets 2019 updates since the 6/17 Modeling Advisory Group webinar
  - New RESOLVE model, User Manual, and results for cases presented at 10/8 IRP workshop
  - IRP Inputs and Assumptions documentation
  - All of the above can be reached via the 2019-20 IRP Events and Materials page
- Parties may download and vet this information and conduct their own modeling and analysis
  - Develop modeling capacity now and update when Proposed Reference System Plan is identified later this month
  - Submit any modeling work as part of formal comments expected in November

Highlighting modeling milestones in 2019 IRP Reference System Portfolio Development Schedule

Step #	Activity	Estimated Date
1	Data Development	March-June 2019
2	**Informal release: core model inputs + MAG presentation [Data posted to website]**	**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 [RESOLVE model and guide, Inputs and Assumptions document, and updated SERVM datasets posted to website]**	**October 2019**
5a	**Stakeholders may perform analysis with RESOLVE, SERVM, or other model to test and validate portfolios (6 weeks)**	**October – November 2019**
6	**Formal release of Proposed 2019 IRP Reference System Plan [Modelers may update their analysis to focus on Proposed Reference System Portfolio]**	**October 2019**
7	**Formal party comment on Proposed 2019 Reference System Plan [Modelers may include analysis results]**	**November 2019**
8	Formal release of 2019 Reference System Plan Proposed Decision	January 2020
9	Formal party comment on 2019 Reference System Plan PD	January 2020
10	Commission Decision on 2019 Reference System Plan	February 2020
11	Transmittal of 2019 IRP portfolios to 2020-21 CAISO TPP	February 2020

2. OVERVIEW OF MODELING INPUTS

Key Updates to SERVM from Version Used in 2017-18 IRP Cycle

Staff performed a full data update at the beginning of the IRP cycle. Updates included:

- Updated weather-based hourly profiles to cover weather years 1998-2017: includes scheduled hydro, hourly electric demand, hourly wind and solar generation profiles as described at the 6/17 MAG
- Updated operating parameters for individual resources (and aggregated to RESOLVE categories) based on January 2019 CAISO MasterFile information and WECC 2028 Anchor Data Set Phase 2 V1.2
- Added the ability for storage to provide spinning and load following reserves (in addition to already providing regulation and frequency response)
- Updated forced and scheduled outage statistics from 2013-2017 GADS data
- Installed capacity adjustment to align CPUC-derived solar generation shapes with expected energy from IEPR BTM solar installations

Key Changes from 6/28/19 Core Inputs Data Release

During RESOLVE-SERVM calibration, staff updated some of the data posted to the CPUC website. Updates are posted to the Unified RA and IRP Modeling Datasets 2019 page:

- Transmission flow limits and hurdle rates in SERVM
- SERVM hydro profiles updated to cover 1998-2017 weather years (previous data was for 1980-2014)
- SERVM normalized hourly electric consumption profiles for 1998-2017 weather years
- Baseline generator unit list for both RESOLVE and SERVM
- SERVM normalized wind and solar shapes updated to account for more facilities matched to latitude/longitude locations and weather stations

2.1. ELECTRIC DEMAND FORECAST

Demand Forecast is a Core Modeling Input

- Per the Single Forecast Set agreement,* IRP uses the Energy Commission's 2018 Integrated Energy Policy Report (IEPR) Update Forecast as a core input
- Uncertainty in future electricity demand considered:
  - 1998-2017 weather scenarios and 5 weighted levels of load forecast uncertainty in SERVM
  - Sensitivity and scenario modeling (e.g. high load, high electrification) in RESOLVE
- IEPR forecast annual projections of electricity consumption and demand modifiers are used to scale corresponding hourly shapes in RESOLVE and SERVM
  - See 6/17 MAG presentation for further background on hourly shapes used by RESOLVE and SERVM; both models' shapes have been updated since the previous IRP cycle

* See: Final 2018 Integrated Energy Policy Report Update, Volume II- Clean Version

Electric Demand Modifiers are Modeled as Individual Resources

- RESOLVE and SERVM both model certain demand modifiers (aka demand-side resources/programs) as individual resources
  - Additional Achievable Energy Efficiency (AAEE), Time-Of-Use (TOU) rate effects, and Light-Duty Electric Vehicle (LDEV) load are each modeled individually with fixed hourly profiles
  - BTM PV (baseline committed + Additional Achievable PV) and BTM storage are modeled as resources with installed capacity
  - Other demand modifier components in the IEPR are left embedded in demand (Other Electrification, Climate Change effects, BTM CHP, Load Modifying Demand Response (LMDR))
- When backing demand modifiers out of demand forecast to model as resources on supply side:
  - Adjust for transmission and distribution (T&D) losses
  - Avoid enforcing Planning Reserve Margin on modeled demand increase due to backing out a demand modifier

IEPR-derived CAISO Area Demand Forecast Inputs Summary

Planning Area	PG&E		SCE		SDG&E		CAISO [5]	
Electric Demand Component [1]	**2020**	**2030**	**2020**	**2030**	**2020**	**2030**	**2020**	**2030**
Consumption, MW peak [2]	22,838	25,760	25,353	28,753	4,825	5,517	53,017	60,029
Managed non-coincident demand, MW peak	20,174	20,537	22,934	22,310	4,187	4,371	47,440	47,390
Consumption, GWh load [2]	111,274	123,640	110,047	123,337	22,123	24,691	243,444	271,668
Light-duty electric vehicles, GWh load	2,528	7,531	1,851	5,398	562	1,662	4,941	14,591
Time of use rate effects, GWh load [3]	-	23	-	13	0.03	2	0.03	38
Additional Achievable EE, GWh savings	2,939	12,949	2,881	14,108	572	3,029	6,393	30,086
Committed BTM PV installed capacity MW	5,493	10,269	3,476	7,292	1,504	2,458	10,473	20,020
Additional Achievable PV installed capacity MW	63	720	67	740	14	168	144	1,627
BTM storage installed capacity MW [4]	122	469	167	566	65	198	354	1,233

[1] All values are at the system level (includes gross up for losses)
[2] Consumption in this table is electric demand without the effects of all the other line items. Effects from IEPR projections of BTM CHP, load-modifying demand response, and other transportation electrification are left embedded in consumption.
[3] TOU effects have a tiny increase in annual energy while decreasing hourly demand during peak hours
[4] BTM storage capacity represents the amount projected in the IEPR. Additional BTM storage capacity is also modeled after considering recent data collected from LSEs and the CPUC storage procurement target (from AB 2514).
[5] CAISO includes Valley Electric Association in addition to the three major IOU TAC areas
Detailed data for production cost models are posted to the Unified RA and IRP Modeling Datasets 2019 page.

2.2. BASELINE RESOURCES

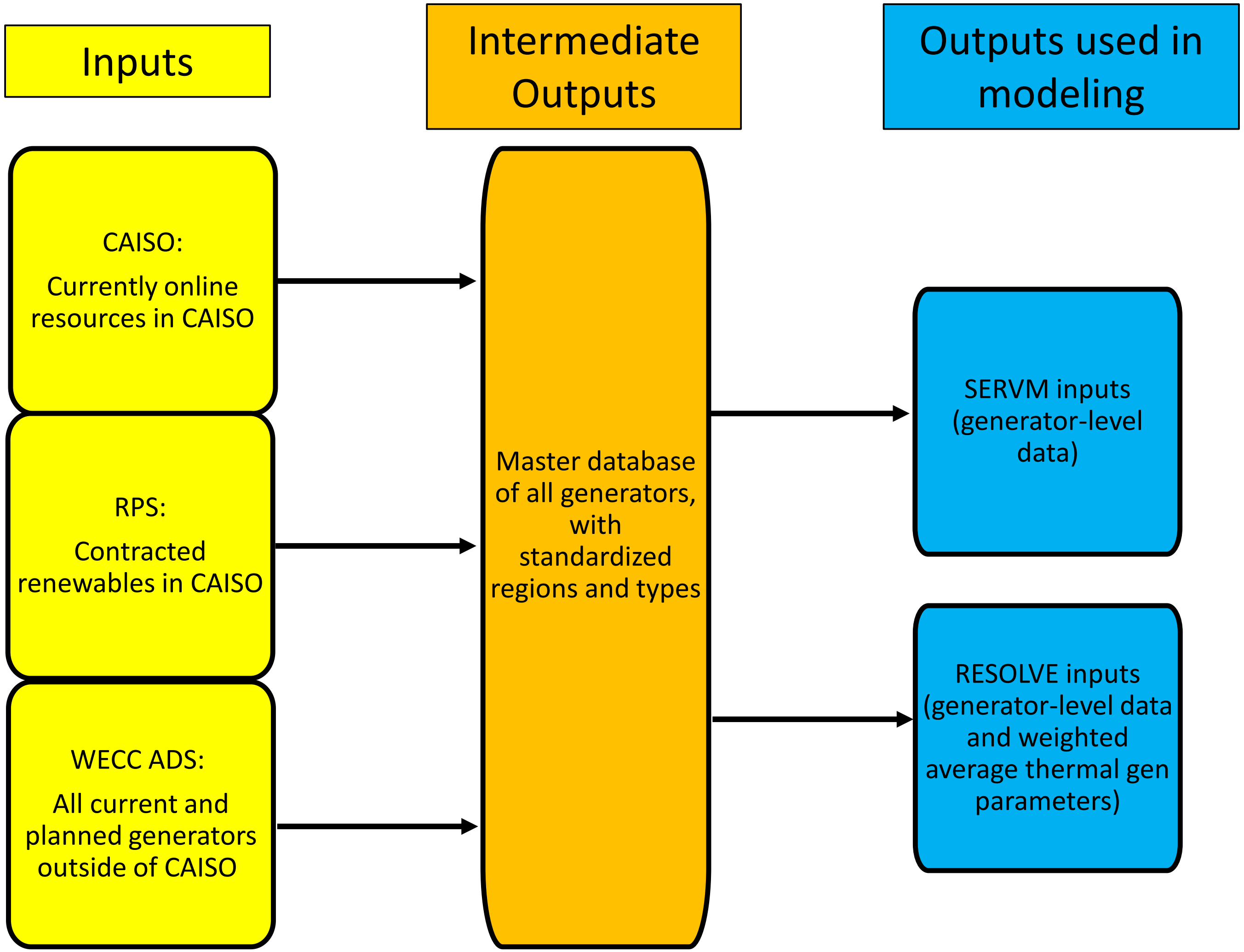
Defining “Baseline Resources”

- **Baseline resources** are resources that are included in a capacity expansion model run as an assumption rather than being selected by the model as part of an optimal solution.
- Within CAISO, the baseline resources are intended to capture:
  - Existing resources, net of planned retirements (e.g. once-through-cooling plants)
  - Future resources that are deemed sufficiently likely to be constructed, usually because of being LSE-owned or contracted, with CPUC and/or LSE governing board approval
    - e.g. CPUC- or LSE governing board-approved renewable power purchase agreements, CPUC storage procurement mandate (i.e., AB 2514)
  - Projected achievement of demand-side programs under current policy
    - e.g. forecast of EE achievement, BTM PV adoption under NEM tariff
- RESOLVE optimizes the selection of additional resources in the CAISO area needed to meet policy goals, such as RPS, a GHG target, or a planning reserve margin; these resources that are selected by RESOLVE are *not* baseline resources.
- SERVM and RESOLVE start with the same baseline. New candidates and economic retention are first selected by RESOLVE. The new portfolio is then added to SERVM so that both models have the same operating fleet.
- The baseline developed for 2019 IRP modeling includes data collected in the spring of 2019 and differs from the baseline used in the IRP's 2018 Preferred System Plan Decision (D.19-04-040).

Master WECC-wide Baseline Generator List

- Aligning generator data in SERVM and RESOLVE is crucial for comparison and consistency between model outputs.
- The same baseline resources are assumed in the 46, 38, and 30 MMT Core Policy Cases
- As described at the 6/17 MAG, staff developed and posted a public dataset of baseline generators.
  - Updated as of 10/4 and available at the Unified RA and IRP Modeling Datasets 2019 page
  - Derived from the January 2019 version of CAISO Masterfile, the 2028 WECC ADS Phase 2 v1.2 (Anchor Data Set), and the CPUC RPS Contracts database
  - Includes technology types, zonal locations, contract information, in-service dates, and operational parameters for both models (heat rates, ramp rates, startup fuel/cost/time, etc.)
  - Confidential data aggregated or redacted before posting

Creating Master WECC-wide Generator List: Process Diagram



- Boxes represent datasets, arrows represent Python scripts that process the data
- Taken together, the yellow boxes represent the complete set of current and planned resources in the WECC
- Intermediate "master database" output is posted (redacting confidential portions)

WECC Baseline Installed Capacity by Type and RESOLVE Zone in August 2030, MW

	BANC	**CAISO**	IID	LDWP	NW	SW	Other WECC [4]	**TOTAL**
Biogas [1]	0	291	0	0	0	0	0	**291**
Biomass [1]	18	611	77	0	590	108	1,147	**2,551**
Combined Cycle	1,798	16,261	255	2,755	9,573	19,741	9,489	**59,873**
Cogeneration [2]	0	2,320	0	0	53	0	3,487	**5,860**
Coal	0	0	0	0	7,364	6,141	5,628	**19,132**
Geothermal	0	1,852	792	0	142	667	820	**4,273**
Hydro [6]	1,560	6,353	48	438	21,927	2,303	13,723	**46,351**
Nuclear	0	635	0	407	1,757	2,998	0	**5,797**
Peaker [2]	818	8,598	252	1,647	2,277	5,979	6,930	**26,501**
Pumped Storage [5]	0	1,599	0	1,460	500	220	543	**4,322**
Reciprocating Engine [2]	49	255	0	0	391	323	287	**1,306**
Solar [3]	146	14,783	166	948	2,661	1,912	1,175	**21,790**
Steam [2]	0	0	75	197	272	967	3,096	**4,606**
Wind	0	7,459	0	725	12,421	1,893	7,346	**29,844**
Battery Storage [7]	0	3,265	31	0	0	0	0	**3,296**
Demand Response	0	1,749	0	0	0	0	0	**1,749**
TOTAL [8]	**4,388**	**61,018**	**1,665**	**8,577**	**59,928**	**43,250**	**53,672**	**237,542**

This table shows August 2030 capacity without ambient derates (explained on next slide). Capacity varies by month due to intra-year planned retirements and the availability of demand response resources.

[1] Biogas is grouped with biomass for non-CAISO areas to reduce model complexity.

[2] In RESOLVE, certain non-CAISO area gas generator types are grouped with Peaker types to reduce complexity.

[3] BTM solar PV is not represented in the table above and is presented in the demand-side inputs section.

[4] “Other WECC” refers to areas that are within WECC but are not represented in RESOLVE, such as Alberta, British Columbia, and Colorado. RESOLVE models hydro from the NW separately. SERVM models each area explicitly.

[5] RESOLVE does not model pumped hydro storage in non-CAISO areas to reduce model complexity.

[6] Individual hydro units are not modeled in SERVM; the model uses region-wide profiles instead.

[7] Includes BTM storage assumed from all data sources (IEPR projection, AB 2514, LSE data request responses).

[8] Not shown in this table, RESOLVE also assumes small amounts of new renewables in non-CAISO zones to model compliance with known policy targets outside CAISO.

Ambient Derating of CAISO Combined Cycles and Combustion Turbines

- To account for the effects of summer heat on reliability, staff reduced the capacities of CAISO combined cycles and combustion turbines to their 2020 Draft NQC values (available here: http://www.caiso.com/Documents/2020DraftFinalNetQualifyingCapacityList.xls)
- In summer months these resources may show reductions in NQC relative to other months reflecting reduced output capability during hot weather conditions.
- The derate resulted in a loss of approximately 1,080 MW from the CAISO for August, as shown in the table below.

MW reduction due to ambient derate for August NQC values

	MW
CAISO Combined Cycle	507
CAISO Combustion Turbine	574
Total	1,081

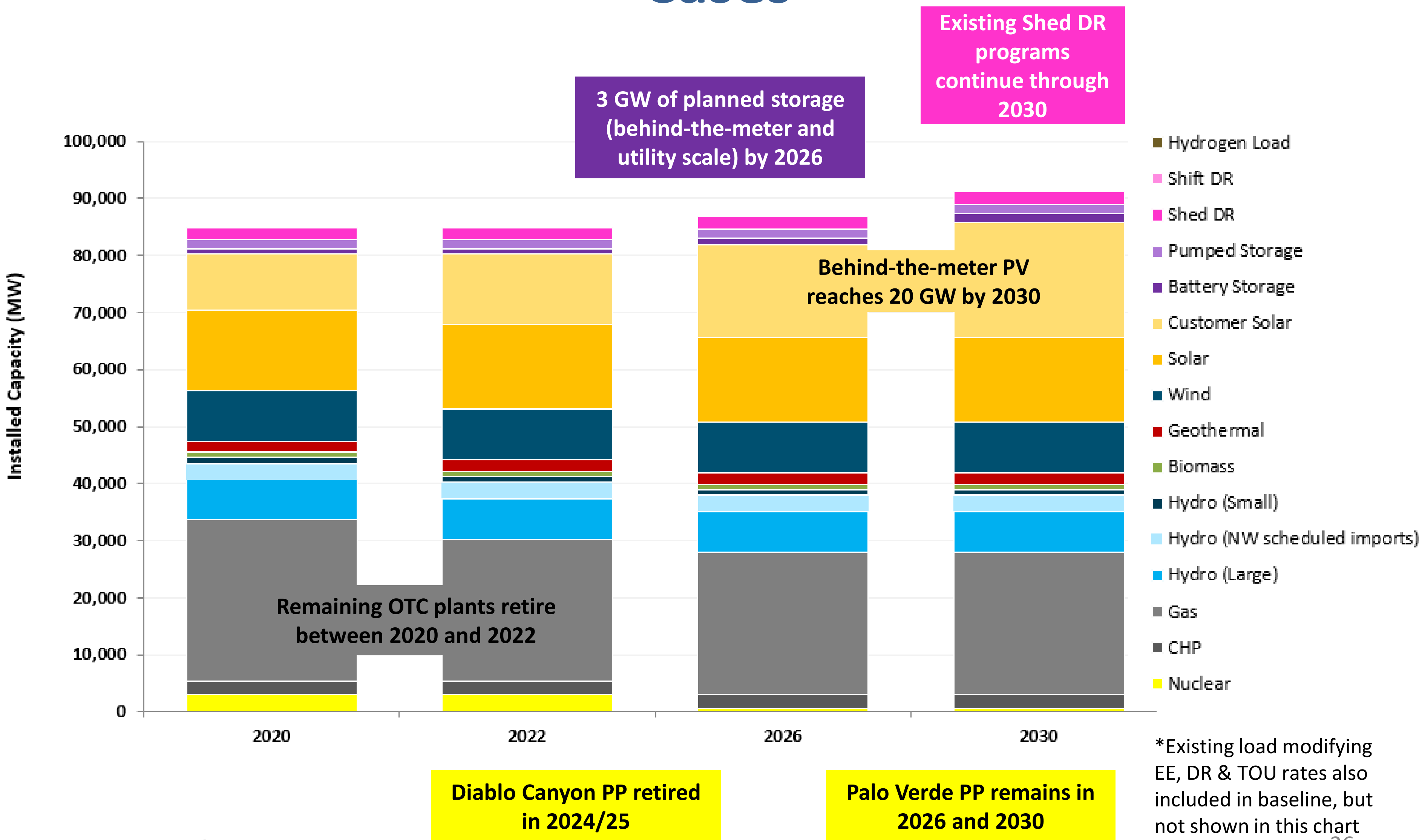
- Note that this loss is incremental to the capacity in the previous slides, which showed nameplate

Baseline Battery Storage Developed from Multiple Sources

- Sources to inform baseline storage resource capacity and assumptions: AB 2514 storage mandate, CEC's IEPR demand forecast, LSEs' April 2019 responses to CPUC Staff Data Request
- Further detail about these sources and the results are available within the Modeling Advisory Group (MAG) 6/17 presentation
- Subsequent to the MAG, staff posted further information about how the baseline storage data set for IRP modeling relates to counting conventions for the CPUC's Resource Adequacy program*

*See: https://www.cpuc.ca.gov/General.aspx?id=6442462047

CAISO Area Baseline Resources Included in All Cases



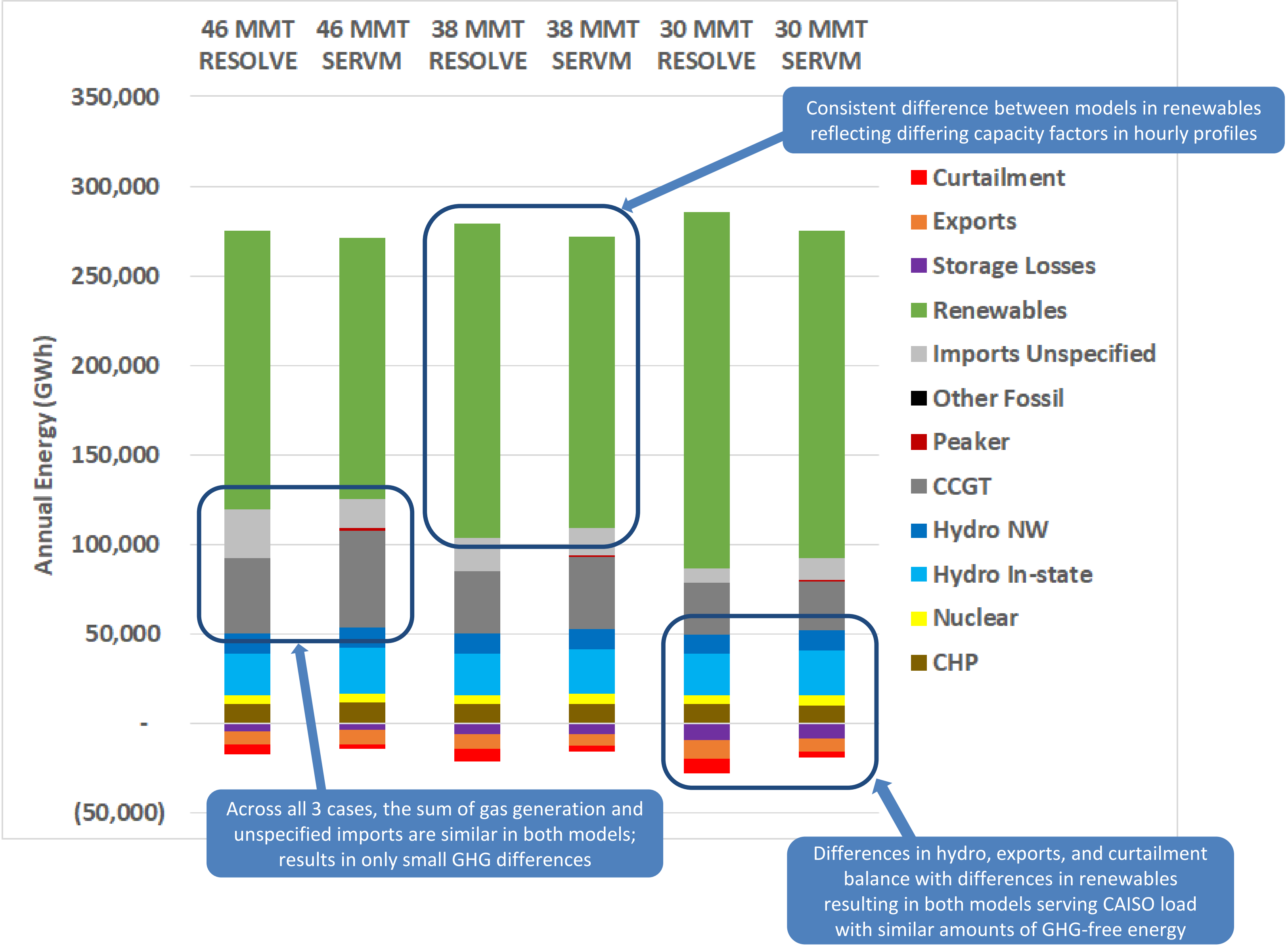
*Existing load modifying EE, DR & TOU rates also included in baseline, but not shown in this chart

RESOLVE – SERVM CALIBRATION RESULTS

Model Calibration Process

- Baseline resources in both models sourced from common datasets and aligned to 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.)
- If metrics between models differed, staff made changes to one or both models (increased/decreased capacity factor of wind, increased or decreased start times of CCGT, etc.) and reran to check calibration. If staff made changes to RESOLVE then a new portfolio of candidates is created, added to SERVM, and then rerun in SERVM.
- Staff eventually calibrated within reasonable bounds of GHG emissions and resource dispatch, and confirmed that the modeled baseline and new resource portfolio was reliable and operable
- Generation from different classes of generation were compared, and even though there were some differences in dispatch, the outcome of GHG emissions was close
- Staff then used the calibrated RESOLVE to explore additional sensitivities and scenarios as explained in the presentation of IRP Modeling Preliminary Results

CAISO 2030 Energy Balance for 3 Core Policy Cases



Energy Balance Table for 3 Core Policy Cases

2030 CAISO Energy Balance (GWh)	46 MMT		38 MMT		30 MMT	
Category	**RESOLVE**	**SERVM**	**RESOLVE**	**SERVM**	**RESOLVE**	**SERVM**
CHP	10,881	11,769	10,881	11,148	10,881	10,395
Nuclear	5,108	5,136	5,108	5,136	5,108	5,136
Hydro In-state	22,995	25,391	22,995	25,391	22,995	25,391
Hydro From NW	11,222	11,000	11,160	11,000	10,908	11,000
CCGT	42,117	54,467	35,219	40,082	28,540	27,784
Peaker	76	1,306	-	883	-	604
Reciprocating Engine	37	173	18	111	11	63
Coal	-	-	-	-	-	-
Steam	-	-	-	-	-	-
BTM PV	38,046	37,949	38,046	37,949	38,046	37,949
Solar (pre-curtailment)	72,281	70,294	88,010	85,412	107,921	104,595
Wind (pre-curtailment)	25,002	19,092	29,755	21,000	31,347	21,533
Geothermal	13,042	13,254	13,042	13,403	14,808	13,716
Biomass	6,764	4,964	6,764	5,089	6,764	5,098
Pumped Storage Roundtrip Losses	(986)	(798)	(950)	(770)	(1,035)	(893)
Battery Storage Roundtrip Losses	(3,193)	(2,902)	(5,368)	(4,899)	(8,152)	(7,471)
Curtailment	(5,305)	(2,698)	(6,680)	(2,754)	(7,745)	(3,306)
Imports (Unspecified)	27,397	16,095	17,916	15,340	8,177	12,188
Exports	(7,637)	(7,992)	(7,994)	(7,017)	(10,519)	(7,263)
Load	257,010	256,497	257,010	256,502	257,010	256,515

Curtailment levels less different in absolute amounts than last year's modeling exercise – significant improvement. SERVM levels somewhat lower due to lower wind and solar generation.

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

GHG Emissions Table for 3 Core Policy Cases

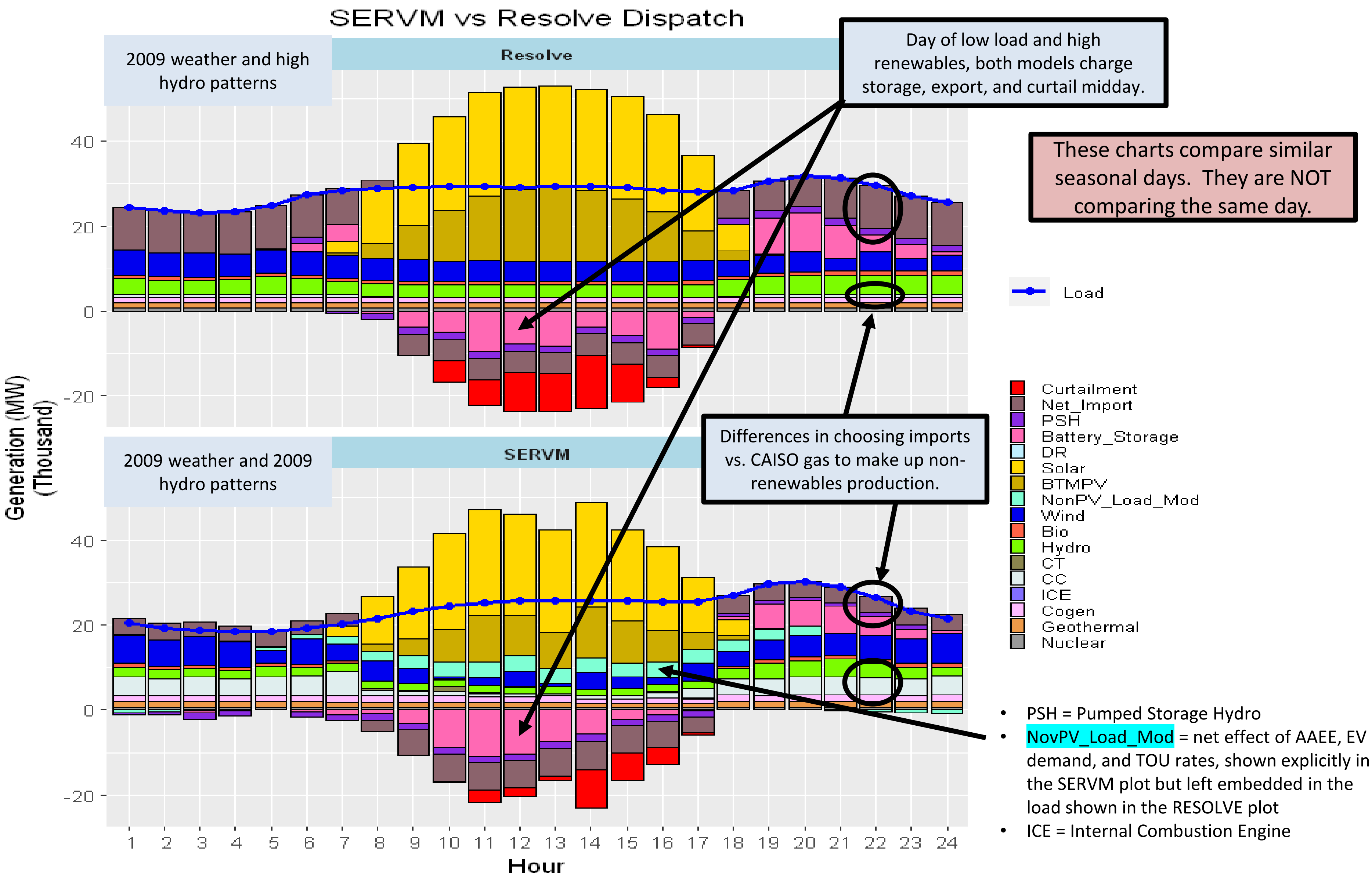
2030 CAISO Emissions (MMtCO2/Yr)	46 MMT Case		38 MMT Case		30 MMT Case	
	RESOLVE	SERVM	RESOLVE	SERVM	RESOLVE	SERVM
CAISO Generator Emissions	20.7	27.0	18.0	20.7	15.3	15.4
Unspecified Import Emissions	11.7	6.9	7.7	6.6	3.5	5.2
CAISO Emissions w/o BTM CHP	32.4	33.9	25.6	27.3	18.8	20.6
CAISO BTM CHP Emissions	5.5	5.5	5.5	5.5	5.5	5.5
CAISO Emissions w/ BTM CHP	**37.9**	**39.4**	**31.1**	**32.8**	**24.3**	**26.1**
Emissions Delta		1.50		1.66		1.85
2030 CAISO Generation and Imports (GWh)						
Zero-GHG	177,337	172,689	193,886	188,940	210,447	205,483
GHG-emitting	80,508	83,809	64,034	67,563	47,608	51,033

- Zero-GHG generation: Nuclear, Hydro from in-state and NW imports, Renewables net of storage losses, exports, 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.

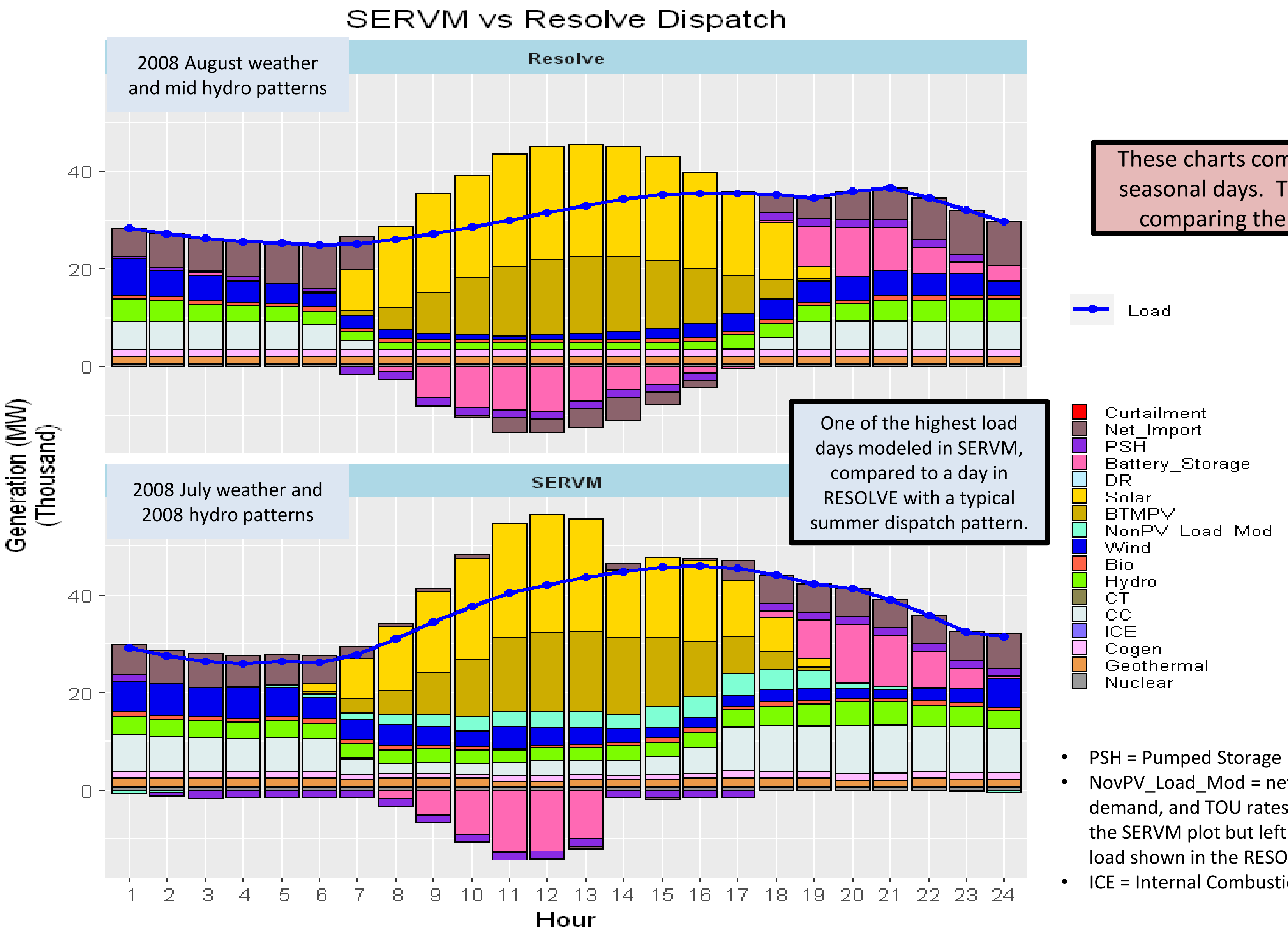
The net amounts of zero-GHG energy serving CAISO loads are similar.

Comparison of Dispatch Patterns – 2030 March day, 46 MMT Case



- PSH = Pumped Storage Hydro
- NovPV_Load_Mod = net effect of AAEE, EV demand, and TOU rates, shown explicitly in the SERVM plot but left embedded in the load shown in the RESOLVE plot
- ICE = Internal Combustion Engine

Comparison of Dispatch Patterns – 2030 summer day, 46 MMT Case



These charts compare similar seasonal days. They are NOT comparing the same day.

- PSH = Pumped Storage Hydro
- NovPV_Load_Mod = net effect of AAEE, EV demand, and TOU rates, shown explicitly in the SERVM plot but left embedded in the load shown in the RESOLVE plot
- ICE = Internal Combustion Engine

Reliability Assessment of Core Policy Cases

- Staff performed Loss-of-Load Expectation (LOLE) reliability assessments of the core policy cases
  - Annual LOLE study over 20 weather years (1998-2017) and at five levels of economic/demographic forecast error. The CAISO area is reliable in 2030 with a probability-weighted LOLE of less than 0.1 in the Core Policy Cases.
  - Staff also demonstrated that with the projected penetration of storage and renewables in 2030, the system was "energy sufficient" - meaning that consecutive days of low renewable production did not lead to more loss-of-load.
  - When the Proposed Reference System Portfolio is identified, staff will conduct LOLE reliability assessments on that portfolio for study years 2022, 2026, and 2030 to cover the IRP planning horizon.
  - These LOLE studies are not statements of how much firm capacity is needed to maintain reliability. In other words, staff did not estimate firm capacity requirements by removing capacity until the LOLE metric just meets 0.1.

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

EUE (MWh), 46 MMT case												
Hour Ending	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.13	7.47	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.12	11.88	21.30	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	27.73	3.82	0.00	0.00	0.00	0.00

EUE (MWh), 38 MMT case												
Hour Ending	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
8	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.66	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00
20	0.00	1.25	0.00	0.00	0.00	0.00	0.00	1.05	0.00	0.00	0.00	0.00
21	0.00	0.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

- Hours of EUE indicate <u>when</u> loss-of-load events occur and quantify the <u>magnitude</u> of those events.
- Total EUE for all 3 core policy cases was very small, consistent with the finding that LOLE was well under 0.1 for each case.
- No appreciable EUE was observed in the 30 MMT case so no table is shown for it.
- Likely LOLE and EUE hours are consistently in the <u>evening hours of 6-9pm</u>

Remaining Issues

Some differences in dispatch between models remain and were not reconciled – the net effect of differences did not lead to a significant emissions difference between models

- Differences in resource-specific annual amounts of zero-GHG-emitting energy
  - Wind capacity factor materially lower in SERVM (19 TWh in SERVM vs. 25 TWh in RESOLVE for the 46 MMT case in 2030) – related to SERVM's wider range of wind weather years
  - In-state hydro energy was slightly higher in SERVM as well (25 TWh in SERVM vs. 23 TWh in RESOLVE for the 46 MMT case in 2030) – related to SERVM's wider range of historical hydro years
  - Differences tend to cancel each other out and do not cause emissions to differ significantly
- Differences in how RESOLVE and SERVM dispatch thermal resources
  - SERVM dispatches units individually with unit-specific heat rates and constraints, RESOLVE dispatches units in relatively uniform unit sizes with weighted-average heat rates and constraints
  - The combination of effects contributes to differences in thermal dispatch and use of unspecified imports
- SERVM produces significant intrahour import and export energy, presumably buying and selling reserves and economic energy transactions.
  - Upon comparison with current EIM market operation (using CAISO OASIS data) staff concluded that it was safe to assume that the volume of transactions in SERVM were not meant to serve CAISO load, and staff has netted unspecified imports and exports each hour (not over the day, week, or year) and reported the hourly netted unspecified imports in the energy balance.
- SERVM did not create a special "CAISO NW hydro zone" like in RESOLVE to estimate the amount of NW imports that is zero-GHG hydro
  - Staff assumed that 11 TWh of imports were attributable to NW Hydro and adjusted total unspecified imports downwards to allocate 11 TWh to NW hydro in accounting. The 11 TWh was selected to reflect what RESOLVE was estimating as the amount of NW hydro. This is similar to the NW Hydro adjustment used in last cycle's modeling.

RESOLVE – SERVM Calibration Takeaways

- SERVM validated that the 3 Core Policy portfolios produced by RESOLVE are reliable, operable, and meet the GHG emissions objective
  - CAISO area GHG emissions in 2030 differ between models by less than 2 MMT
  - Considering the new resources added and economic retirements assumed by 2030, reliable CAISO system operation is maintained (a loss-of-load event is expected to occur less than once in 10 years)
- RESOLVE sensitivities outside the Core Policy Cases are likely to also be consistent with the SERVM and RESOLVE calibrated modeling results
- This calibration process can be repeated for future IRP cycles. Staff achieved sufficient calibration between the models in this IRP cycle.
- RESOLVE and SERVM are both useful and accurate models
  - Both models are robust in doing what they are designed to do and both models are necessary to have confidence in IRP modeling results

CRITERIA POLLUTANTS ANALYSIS PROGRESS UPDATE

Criteria Pollutants Overview

- Statute directs the Commission's IRP process to ensure that LSEs "minimize localized air pollutants and other greenhouse gas emissions, with early priority on disadvantaged communities "(PU Code 454.52 (a)(1)(H)).
- In the 2017-2018 IRP cycle, staff estimated NOX and PM2.5 emissions from power plants by applying a single emissions factor (emissions per mmbtu of fuel burn or per MWh) each for:
  - Hot starts,
  - Warm starts,
  - Cold starts, and
  - Normal operation between Pmin and Pmax.
- Staff then separated the results by disadvantaged community (DAC) and non-DAC areas.
- In workshops and comments in the 2017-2018 IRP cycle, parties expressed a desire to improve the accuracy and locational granularity of these estimates.

Criteria Pollutants Proposed Improvements

- Energy Division staff is in the process of making the following improvements to criteria pollutant accounting:
  - Count emissions from all emitting generation in California (including natural gas, geothermal, biomass, and biogas plants).
  - Calculate emissions by ARB basin for more locational granularity.
  - Where available, use plant-specific criteria pollutant emissions data (which maps NOx, SO2, and PM2.5 to levels of MW output from the plant) from EPA.
- The SO2, NOX and PM2.5 emissions associated with the Proposed Reference System Portfolio would be reported with its release later this fall.
  - Staff proposes to post lookup tables to enable cross-referencing between EPA plant information, ARB air basin, and CPUC identifiers, and can post those publicly in the near future. Where appropriate, staff will redact confidential generator-level information (e.g. factors derived from CAISO settlement data).
- Staff proposes to incorporate hourly criteria pollutant data in the Clean System Power calculator tool (formerly Clean Net Short tool) for LSE planning (See Staff Proposal for 2019-2020 Filing Requirements)

Criteria Pollutants: Proposed Methodology

- Map all generators from the CPUC public generator list to their ARB ID and EPA ID.
- Get emissions data for each plant.
  - If a plant has measured EPA data, use that data.
  - If plant does not have EPA data (e.g. geothermal, biomass, many cogen plants), assign reasonable factor based on historical 2017 emissions from CARB data.
  - If plant does not exist yet (e.g. Alamitos repower), assign it a proxy.
- Where EPA data is available, calculate average emissions factors in startup vs normal operations.
    - Note: CAISO Pmins are confidential, so staff used public EIA Pmin data to determine the cutoff between startup and normal operation.
    - EPA data is public and can be posted.
- Apply these factors to the fuel burn of the power plants from the Reference System Portfolio. The result will be criteria pollutant emissions by power plant.
- Aggregate the results to air basin and DACs and include results of analysis in release of 2019 IRP Reference System Plan.
  - Note that staff will aggregate results from air basins with small numbers of generators in them to preserve confidential generator-level data.

Data Sources

- Generator-specific curves mapping emissions to fuel burn at different power plant levels of operation from EPA, where available, from ftp://newftp.epa.gov/DMDnLoad/emissions/hourly/monthly/2019/
  - EPA data is mostly steam plants, combustion turbines, and combined cycles. The dataset has no information regarding geothermal, biomass, and biogas, and only approximately 150 MW of cogeneration plant data.
  - Many combined cycles do not have data for the steam unit, though they do have data for the combustion turbines.
- 2017 historical emissions by generating facility, from CARB pollution mapping tool from https://ww3.arb.ca.gov/ei/tools/pollution_map/
- SERVM output from model runs with the Reference System Plan (forthcoming)
- EIA Form 860 for information about the generators and their subunits. https://www.eia.gov/electricity/data/eia860/