IRP Model Improvement and GHG Ground-truthing

IRP Modeling Advisory Group(MAG) Webinar
December 9, 2020

California Public
Utilities Commission

Agenda

Item	Time*
1. Introduction	9:30 – 9:50 am
2. Updated SERVM/RESOLVE Comparison	9:50 – 10:30 am
3. Comparisons Between Historical and Modeled CAISO GHG Emissions	10:30 – 11:30 am
4. SERVM Dispatch Data Study	11:30 – 12:00 pm
Adjourn	

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

1: Introduction

Logistics

- *Webinar slides* are available at the 2019-2020 IRP Events and Materials webpage under the "Modeling Advisory Group" section.
- The webinar will be recorded, with the recording posted to the 2019-2020 IRP Events and Materials webpage

Questions and Feedback

- We invite questions and feedback at the end of each section
- All attendees have been muted. **To ask questions:**
  - In WebEx:
    - Please "raise your hand"
    - WebEx host will unmute your microphone and you can proceed to ask your question
    - Please "lower your hand" afterwards
  - For those with phone access only:
    - Dial *3 to "raise your hand". Once you have raised your hand, you'll hear the prompt, "You have raised your hand to ask a question. Please wait to speak until the host calls on you."
    - WebEx host will unmute your microphone and you can proceed to ask your question
    - Dial *3 to "lower your hand"

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 / R.20 05 003)
- **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 **inform** staff work products that are later introduced into the formal record of the IRP proceeding

Purpose of the Webinar

- Inform stakeholders about recent IRP model improvements and the results of comparing actual and modeled GHG emissions and dispatch
  - Describe recent and planned updates to SERVM model and inputs to prepare for evaluating system reliability and emissions of aggregated LSE IRP portfolios
  - Present reliability and operational modeling results with completed improvements, and updated comparison to RESOLVE dispatch and emissions
  - Present a comparison between actual CAISO 2019 GHG emissions and modeled 2020 emissions in RESOLVE and SERVM
  - Deep-dive on SERVM dispatch patterns to assess realism and expected behavior under present (2020) and future (2030) grid conditions
- Provide opportunity for stakeholder feedback

Scope of the Webinar

- **In Scope:**
  - Updates to the SERVM model
  - RESOLVE and SERVM emissions vs. actual CAISO-reported emissions
  - SERVM hourly dispatch vs. CAISO hourly settlement

- **Out of Scope:**
  - IRP Proceeding including, but not limited to:
    - Order Instituting Rulemaking Scoping Memo
    - IRP Procurement Track
    - Preferred System Plan
      - LSE plan development/aggregation
    - 2021 Summer Reliability OIR

Background

- Staff used the RESOLVE capacity expansion model to design portfolios of new resources expected to meet electric system planning goals at least cost
  - RESOLVE simulates hourly dispatch of resources to meet electric demand and reports annual GHG emissions as part of its portfolio optimization
- Staff used the SERVM probabilistic reliability and production cost model to validate the reliability, operability, and emissions of resource portfolios generated by RESOLVE
- IRP Decision (D.)20-03-028 noted several differences between the two models – one key area to prioritize improvement is GHG emissions modeling
  - Adopted Reference System Portfolio modeling showed that SERVM's 2030 CAISO emissions were about 3.5 MMT higher than RESOLVE's
  - The Decision also noted that Commission staff would "compare actual CAISO-reported emissions with modeled emissions, in a continuing effort to ensure alignment between models and reality"

Questions?

2: Updated SERVM/RESOLVE Comparison

Performed by:
CPUC Energy Division: Energy Resource Modeling Section – Donald Brooks, Patrick Young, Mounir Fellahi

Completed SERVM Updates

- Wind shapes rebuilt using MERRA dataset from NASA
  - https://gmao.gsfc.nasa.gov/reanalysis/MERRA/FAQ/
  - Original wind shapes were developed from National Climate Data Center wind speed data which had bad or incomplete data in Alberta, East Riverside, and New Mexico
  - MERRA dataset is based on satellite data and more complete
  - Capacity factor increased in rebuilt wind shapes
- Updated SERVM software
  - Unit commitment logic improved, generally making CCGTs more flexible
  - Storage dispatch logic improved, linking current state of charge to ability to provide ancillary services
  - Various enhancements to input tables and output reports

Planned SERVM Updates – In Progress!

- Incorporate 2019 IEPR demand forecast
  - 2019 IEPR Workshops, Notices and Documents (ca.gov)
- Update burner-tip fuel price forecast (to June 2020 vintage)
  - Natural Gas Burner Tip Prices for California and the Western United States
- Update baseline generating fleet
  - Removal of redundant/erroneous units found during analysis comparing historical and modeled CAISO GHG emissions
  - Refresh additions and retirements based on most recent CAISO Master Control Area Generating Capability List and Mothball/Retirement List
  - Add newly contracted projects under development
    - Identified in September 2020 LSE IRP filings
    - Due to D.19-11-016 procurement order

SERVM Studies to Test Completed Updates

- Started with inputs and SERVM configuration identical to that described as final in D.20-03-028, the Reference System Plan decision
- Tested the impact of the new MERRA wind shapes and the newly updated SERVM software using the adopted 46 MMT and 38 MMT portfolios
  - Studied 2020 and 2030 with the 46 MMT portfolio
  - Studied 2030 with the 38 MMT portfolio
- Compared results before and after the updates

- Results presented here DO NOT include the 2019 IEPR or the portfolios being proposed for use in the 2021-22 CAISO Transmission Planning Process – those studies will be posted at a later date

Review of SERVM Metrics

Reliability Metrics

- Loss-of-Load Expectation (LOLE): expected frequency of events
- Loss-of-Load Hours (LOLH): expected duration of unserved energy
- Expected Unserved Energy (EUE): expected volume of unserved energy
- Loss-of-load events modeled to occur when operating reserves of 4.5% of hourly demand cannot be maintained (based on 3% spinning reserve and 1.5% regulation requirements)
- Electric system considered sufficiently reliable if probability-weighted LOLE <= 0.1, which corresponds to about 1 day in 10 years where firm load must be shed to balance the grid

Operational Metrics

- Annual energy by resource type, imports and exports, curtailment, storage dispatch, production cost, and emissions

SERVM Reliability Results

	46 MMT original	46 MMT Merra	46 MMT Merra + NewServm	46 MMT original	46 MMT Merra	46 MMT Merra + NewServm	38 MMT original	38 MMT Merra	38 MMT Merra + NewServm
Study Year		2020			2030			2030	
LOLE (expected events/year)	0.1627	0.1597	0.1661	0.1084	0.0528	0.0935	0.1152	0.0498	0.0952
LOLH (expected hours of events/year)	0.3124	0.2862	0.2953	0.2574	0.1070	0.1262	0.2366	0.1052	0.1421
EUE (MWh)	270.5	224.7	244.7	597.5	241.8	122.8	457.7	214.4	149.2
annual load (GWh)	241,974	241,974	241,980	255,838	255,839	255,778	255,822	255,816	255,782
normalized EUE (%) *	0.0001118%	0.0000928%	0.0001011%	0.0002335%	0.0000945%	0.0000480%	0.0001789%	0.0000838%	0.0000583%

- MERRA wind shape update resulted in higher capacity factors for some wind resources, especially OOS wind. More impactful in 2030 when those portfolios included significant amounts of new OOS wind. Higher wind production contributed to higher reliability (Blue circle above).
- SERVM software changes slightly increased LOLE but reduced EUE – meaning events were slightly more frequent or longer but reduced in magnitude (Orange circle above). The increased LOLE may be attributed in part to storage charge state limiting provision of ancillary services.

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

SERVM Annual Energy Balance Results

Case	46 MMT Resolve	46 MMT original	46 MMT Merra	46 MMT Merra + NewServm	46 MMT Resolve	46 MMT original	46 MMT Merra	46 MMT Merra + NewServm	38 MMT Resolve	38 MMT original	38 MMT Merra	38 MMT Merra + NewServm
Study Year	2020				2030				2030			
Model	RESOLVE	SERVM	SERVM	SERVM	RESOLVE	SERVM	SERVM	SERVM	RESOLVE	SERVM	SERVM	SERVM
Category	CAISO Energy Balance (GWh)											
CHP	10,881	10,145	9,772	9,529	10,881	10,574	10,001	9,950	10,881	10,037	9,384	9,366
Nuclear	23,611	25,711	25,711	25,711	5,108	5,136	5,136	5,136	5,108	5,136	5,136	5,136
Hydro In-state	22,996	25,392	25,389	25,392	22,995	25,391	25,391	25,393	22,995	25,391	25,391	25,393
Hydro From NW	10,364	11,000	11,000	11,000	11,311	11,000	11,000	11,000	11,280	11,000	11,000	11,000
CCGT	51,970	45,267	41,702	41,540	38,564	48,420	42,134	44,556	38,822	41,736	32,955	35,116
Peaker	1,655	1,892	1,803	1,526	69	8,107	7,248	3,283	34	6,392	5,827	2,181
Reciprocating Engine	142	99	96	88	19	116	87	78	9	100	65	54
Coal	1,332	1,580	1,566	1,616	0	0	0	0	0	0	0	0
Steam	0	1,317	1,316	1,520	0	0	0	0	0	0	0	0
BTM PV	18,633	18,579	18,579	18,579	38,046	37,949	37,949	37,949	38,046	37,949	37,949	37,949
Solar	41,391	39,697	39,697	39,697	68,249	65,177	65,177	65,177	70,877	68,308	68,308	68,308
Wind	18,527	13,810	19,056	19,056	29,215	20,508	27,700	27,700	45,338	27,002	42,852	42,852
Geothermal	13,042	13,588	13,279	14,271	13,042	13,598	13,377	13,906	13,042	13,498	13,164	13,782
Biomass	6,778	6,206	5,957	6,140	6,764	5,339	5,192	5,484	6,764	5,192	4,866	5,278
Pumped Storage Roundtrip Losses	-303	-954	-936	-875	-1,478	-1,308	-1,300	-1,237	-1,876	-1,518	-1,491	-1,561
Battery Storage Roundtrip Losses	-348	-465	-448	-469	-2,705	-2,304	-2,266	-2,299	-3,095	-2,679	-2,592	-2,660
Curtailment	-1,181	-119	-306	-324	-5,541	-1,057	-2,029	-1,944	-6,696	-1,138	-2,493	-2,186
Imports (unspecified)	25,650	29,974	29,857	29,510	30,527	17,031	19,765	21,004	14,123	16,192	15,378	15,864
Exports	-2,096	-743	-1,116	-1,525	-6,316	-7,563	-8,617	-9,212	-6,693	-6,770	-9,867	-10,072
Load	242,188	241,974	241,974	241,980	257,010	255,838	255,839	255,778	257,010	255,822	255,816	255,782

Increased Wind Production and More CCGT Use

Case	46 MMT Resolve	46 MMT original	46 MMT Merra	46 MMT Merra + NewServm	46 MMT Resolve	46 MMT original	46 MMT Merra	46 MMT Merra + NewServm	38 MMT Resolve	38 MMT original	38 MMT Merra	38 MMT Merra + NewServm
Study Year	2020				2030				2030			
Model	RESOLVE	SERVM	SERVM	SERVM	RESOLVE	SERVM	SERVM	SERVM	RESOLVE	SERVM	SERVM	SERVM
Category	CAISO Energy Balance (GWh)											
CCGT	51,970	45,267	41,702	41,540	38,564	48,420	42,134	44,556	38,822	41,736	32,955	35,116
Peaker	1,655	1,892	1,803	1,526	69	8,107	7,248	3,283	34	6,392	5,827	2,181
Coal	1,332	1,580	1,566	1,616	0	0	0	0	0	0	0	0
Steam	0	1,317	1,316	1,520	0	0	0	0	0	0	0	0
BTM PV	18,633	18,579	18,579	18,579	38,046	37,949	37,949	37,949	38,046	37,949	37,949	37,949
Solar	41,391	39,697	39,697	39,697	68,249	65,177	65,177	65,177	70,877	68,308	68,308	68,308
Wind	18,527	13,810	19,056	19,056	29,215	20,508	27,700	27,700	45,338	27,002	42,852	42,852

- MERRA wind shape update significantly increased annual wind production and more closely matched with amounts modeled by RESOLVE (Blue circles above)
- Dispatchable gas generation was displaced by the higher wind production (Orange circles above)
- The SERVM software update resulted in more flexible CCGTs, thus CCGTs were used more and peakers were used less (Green circles above)
- The effect is more apparent in 2030 with a larger solar and wind fleet to balance around and no coal or steam units interacting with CCGT and peaker use

SERVM Annual GHG Emissions Results

Case	46 MMT Resolve	46 MMT original	46 MMT Merra	46 MMT Merra + NewServm	46 MMT Resolve	46 MMT original	46 MMT Merra	46 MMT Merra + NewServm	38 MMT Resolve	38 MMT original	38 MMT Merra	38 MMT Merra + NewServm
Study Year	2020				2030				2030			
Model	RESOLVE	SERVM	SERVM	SERVM	RESOLVE	SERVM	SERVM	SERVM	RESOLVE	SERVM	SERVM	SERVM
Category	CAISO GHG Emissions (MMtCO2/Yr)											
CAISO Generator Emissions	26.6	25.3	23.8	23.7	19.4	28.6	25.4	23.7	19.6	24.8	20.7	19.0
Unspecified Import Emissions	11.0	12.8	12.8	12.6	13.1	7.3	8.5	9.0	6.0	6.9	6.6	6.8
CAISO Emissions w/o BTM CHP	37.6	38.2	36.6	36.3	32.4	35.9	33.8	32.7	25.6	31.7	27.3	25.8
CAISO BTM CHP Emissions	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
CAISO Emissions w/ BTM CHP	43.1	43.7	42.0	41.8	37.9	41.4	39.3	38.2	31.1	37.2	32.8	31.3
Emissions delta relative to RESOLVE		0.59	-1.05	-1.29		3.49	1.44	0.31		6.09	1.66	0.23
	CAISO Generation and Imports (GWh)											
Zero-GHG	151,414	151,701	155,862	156,652	178,689	171,866	176,710	177,053	195,089	181,372	192,222	193,217
GHG-emitting	91,630	90,274	86,113	85,329	80,061	84,248	79,235	78,870	63,870	74,458	63,610	62,581

- Compound effect of SERVM improvements brings GHG emissions very close to RESOLVE's for study year 2030 (Blue circle above)
- In 2020 the two models diverge a bit more but are still relatively close

Conclusion and Next Steps

- Wind shape and SERVM software updates brought dispatch patterns and GHG emissions closer to RESOLVE
- Improvements are significant step forward to prepare models for next major round of analyses: evaluating the aggregate portfolio of all the LSE IRP filings
- Next Steps:
  - LOLE studies to assess system reliability of the portfolios proposed for use in the CAISO 2021-22 Transmission Planning Process
  - Baseline units update
  - Complete aggregation of all LSE IRP filings
  - LOLE studies of the aggregated portfolio to inform selection of the Preferred System Plan

Questions?

3:Comparisons Between Historical and Modeled CAISO GHG Emissions

Performed by:
E3 – Jimmy Nelson, Xiaoxuan Hou, Yuchi Sun, Charlie Duff, Aaron Burdick, Arne Olson
With guidance from CPUC IRP and Energy Resource Modeling

Introduction

- Modeled 2020 GHG emissions for the CAISO footprint in the IRP Reference System Plan are lower than 2019 GHG emissions calculated by CAISO
  - CAISO 2019: 49.3 $MMTCO_2$
  - RESOLVE RSP 2020: 37.6 $MMTCO_2$
  - SERVM RSP 2020 (updated): 36.6 $MMTCO_2$
- Goals of the comparison:
  - Explain sources and magnitude of emissions discrepancy
  - Suggest possible improvements to RESOLVE and SERVM modeling
- This analysis focuses on high-level conclusions – additional detail would be required to increase precision
- This analysis is an update to a similar comparison performed for the 2017-8 IRP process between CAISO 2017 actual and 2018 simulated by RESOLVE
  - Available at: https://www.cpuc.ca.gov/uploadedFiles/CPUCWebsite/Content/UtilitiesIndustries/Energy/EnergyPrograms/ElectPowerProcurementGeneration/irp/2018/IRP_MAG_webinar_2018-08-10_GHG_Accounting_CAISO_RESOLVE.pdf

Production Simulation vs. Actual Dispatch

- CAISO day-to-day operations include a full nodal unit commitment and dispatch algorithm. Dispatch decisions are made every five minutes on a plant-by-plant basis.
- Production simulations differ from reality in many ways:
  - Market participant behavior – bids not always priced at opportunity cost
  - Self scheduling
  - Perfect foresight
  - Generator and transmission outages
  - Contingencies
  - Weather-driven heat rate differences and de-rate factors
  - Weather-driven demand, hydro, and variable resource production
- Output from any production simulation model, such as the CPUC's SERVM model, will differ from actual dispatch in many ways, even if the loads are identical

RESOLVE vs. Other Production Simulation Models

- The RESOLVE model focuses on long-run capacity investment decisions
- RESOLVE is formulated to capture the major drivers of GHG emissions
  - One major benefit of this benchmarking analysis is to improve RESOLVE dispatch

To internalize the economics of unit commitment and dispatch within the investment framework, RESOLVE includes a simplified production simulation:

- Dispatch is simplified to aggregated plant types
- Unit commitment constraints are partially linearized
- 37 representative days per year are simulated (as opposed to 365)
- Dispatch decisions are made on an hourly level, with some representation of sub-hourly flexibility needs via reserve constraints
- Transmission constraints within CAISO are not included

Comparison Methodology

- GHG emissions and generation from technology classes are aggregated for:
  - CAISO 2019 historical ("CAISO 2019")
  - RESOLVE Reference System Plan in 2020 ("RESOLVE 2020")
  - SERVM Reference System Plan with updated wind shapes in 2020 ("SERVM 2020")
- CAISO 2019 GHG emissions and MWh production data was provided by CAISO
- E3 categorized CAISO gas generators to break out emissions and generation by technology (CCGT, peaker, and CHP)
- Differences in emissions rate (tCO_2/MWh) and annual generation (MWh) quantified
- Attribution of emission and generation differences between datasets is not precise and requires assumption of a counterfactual
  - Some differences may have multiple contributing factors

Technology Classes:

- Wind and Solar
- Biomass and Biogas
- Geothermal
- Nuclear
- Hydro (in CAISO)
- Hydro (imports)
- Coal imports
- Unspecified imports
- Exports
- CCGT
- Peaker (gas turbines, steam turbines, reciprocating engines)
- Combined Heat and Power (CHP)
- Storage (losses)

Waterfall Calculation Example: Difference in New Wind + Solar Generation

1. **Identify difference in datasets**

   RESOLVE 2020 includes ~7 TWh of generation from wind and solar plants not online in CAISO 2019, predominately from resources that come online in 2020

2. **Identify counterfactual**

   Counterfactual: renewables displace CAISO dispatchable gas (CCGT + peaker)

   Result: dispatchable gas generation would decrease by ~7 TWh

3. **Calculate difference in emissions**

   Calculation:
   Δ TWh
   * dispatchable gas tCO_2/MWh

   Result: ~7 TWh
   * ~0.4 tCO_2/MWh
   = <u>3.0 $MMTCO_2$</u>

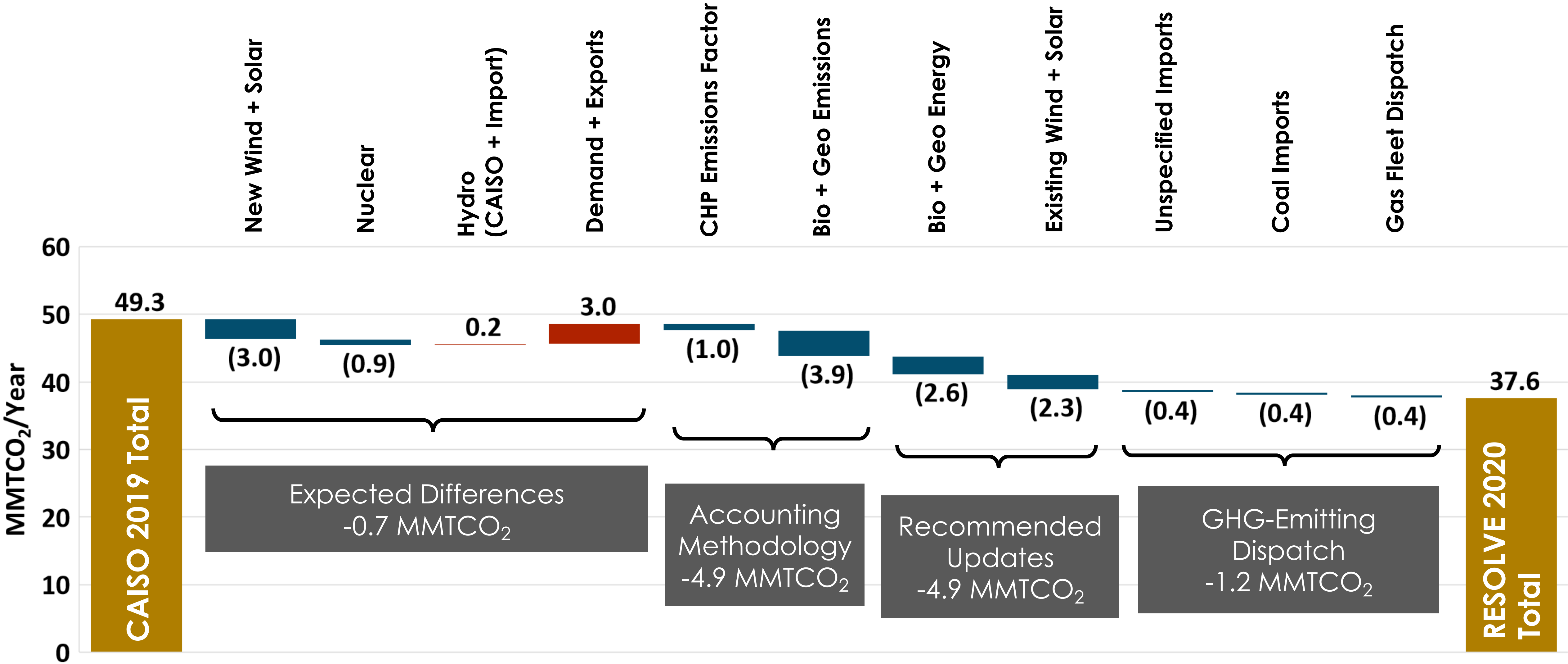
Categories of Differences

Differences between CAISO 2019 and RESOLVE or SERVM 2020 are placed into four categories to aid in formulating next steps:

1. **Expected Differences** – differences that could reasonably occur from year to year and do not necessarily need improvement beyond the usual cadence of updates to IRP inputs and assumptions.
2. **Accounting Methodology** – GHG accounting convention applied in CAISO reporting that differs from RESOLVE or SERVM accounting, which mirror CARB cap-and-trade accounting
3. **Recommended Updates** – differences in renewable and zero GHG energy production that are candidates for improvement
4. **GHG-Emitting Dispatch** – Differences resulting from coal, unspecified imports, and in-CAISO gas dispatch

3.1: Comparison Between CAISO 2019 and RESOLVE 2020

RESOLVE Emissions Comparison Waterfall



Note: Methodology used to quantify emissions differences is directional but not precise.

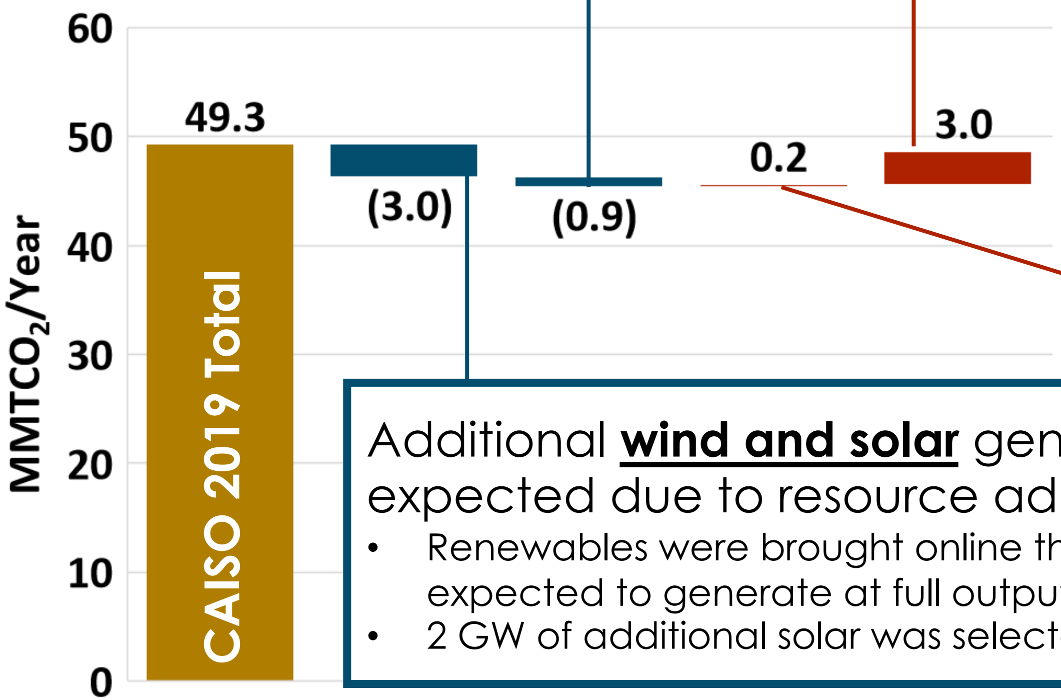
Expected Differences

Some level of difference is *expected* when comparing electricity generation and demand data from different years. The four categories of differences on this slide are within reasonable bounds and do not require additional updates beyond the standard cadence of IRP updates to inputs and assumptions.

Nuclear output lower in 2019 than modeled in 2020, likely due to Diablo Canyon outages.

Actual **demand** in 2019 was 5 TWh lower than was modeled in RESOLVE 2020 (based on 2018 IEPR).

Hydro generation difference (~10 %) between CAISO 2019 and RESOLVE 2020 is within normal annual variability. Less Northwest (Asset Controlling Supplier) imports and more in-CAISO hydro were observed in 2019; the impact of these two opposing factors roughly cancels out.



Additional **wind and solar** generation (~7 TWh) is expected due to resource additions in 2019 and 2020

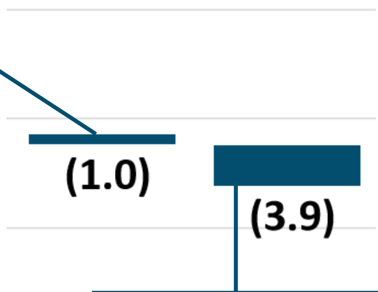
- Renewables were brought online throughout 2019 and 2020 are not expected to generate at full output in 2019 CAISO dispatch.
- 2 GW of additional solar was selected by RESOLVE in 2020.

Accounting Methodology

GHG accounting convention applied in CAISO reporting that differs from RESOLVE or SERVM accounting, which mirrors CARB cap-and-trade accounting

CAISO emissions rates for supply side Combined Heat and Power **(CHP)** are higher than RESOLVE (~0.5 vs. 0.4 tCO_2/MWh respectively), suggesting that there may be a difference in accounting for emissions from the heat and electric portions of CHP.

Recommendation:
Update emissions rates for CHP electricity using recent CARB data.



Recommendation: For next Reference System Plan analysis, report emissions with and without bio + geo emissions. No changes to GHG emissions constraint.

Biomass, biogas, and geothermal emissions are included in CAISO's emissions inventory. CARB requires reporting of bio + geo emissions, but emissions are exempt from the cap and trade program.

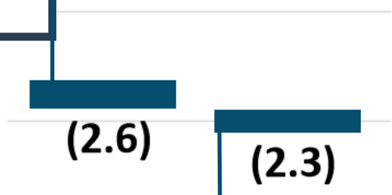
Reflecting cap and trade compliance obligations, RESOLVE does not include emissions from bio + geo.

Recommended Updates

Differences in renewable and zero GHG energy production that are candidates for improvement

<u>Biomass and geothermal</u> energy production significantly lower in 2019 than modeled in 2020.

<u>Recommendation:</u>
Update capacity factors based on recent trends, update capacity contracted to CAISO LSEs.



Energy production from existing (pre-2019) **<u>wind and solar</u>** resources higher in RESOLVE than was observed in 2019 CAISO data. Differences in installed capacity drive results; fleetwide capacity factor differences are relatively small.

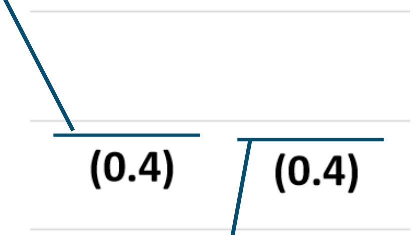
<u>Recommendation:</u>
Remove capacity from RESOLVE/SERVM baseline resources: 1.4 GW of solar and 0.3 GW of wind capacity was identified as redundant/erroneous.

GHG-emitting dispatch (Imports)

Differences resulting from coal dispatch and unspecified imports

CAISO 2019 includes ~1/4 more **unspecified imports** relative to RESOLVE 2020. CAISO dispatchable gas and unspecified import emissions factors are similar, leading to a small (0.6 MMT) difference in emissions.

Recommendation:
None – emissions difference is small.



Specified **Coal** imports were higher in 2019 than was modeled in 2020 by ~1 TWh

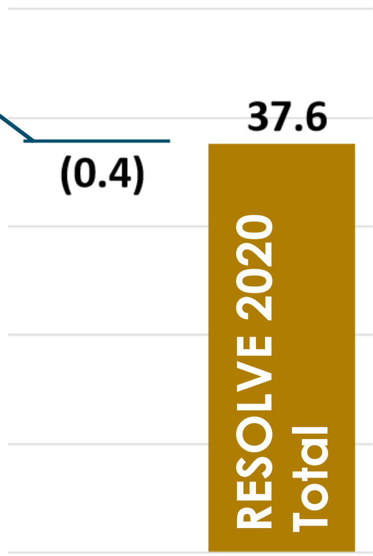
Recommendation:
Coal removed from resource portfolio by mid-2020s so closing the gap in coal emissions is not likely to result in large impacts in 2030 timeframe. Coal imports could be made be non-dispatchable in RESOLVE.

GHG-emitting dispatch (CAISO Gas)

Differences resulting from in-CAISO gas dispatch

- Some differences in **gas plant generation** exist even after accounting for differences in energy production and emissions rates from other resources, differences in demand and exports, etc.
- Differences in generation and emissions between different classes of gas generation (CCGT, peaker, and CHP) results in small (0.4 MMT) emissions differences - an improvement to the ~3.5 MMT gap in the 2017 vs. 2018 waterfall analysis.
- Peaker dispatch is lower in RESOLVE 2020 by ~4 TWh, but the emissions consequence of this difference is small due to the modest difference in efficiency between CCGT and peaker plants.

Recommendation:
For next RSP, investigate whether measures should be taken to increase peaker dispatch in simulations.

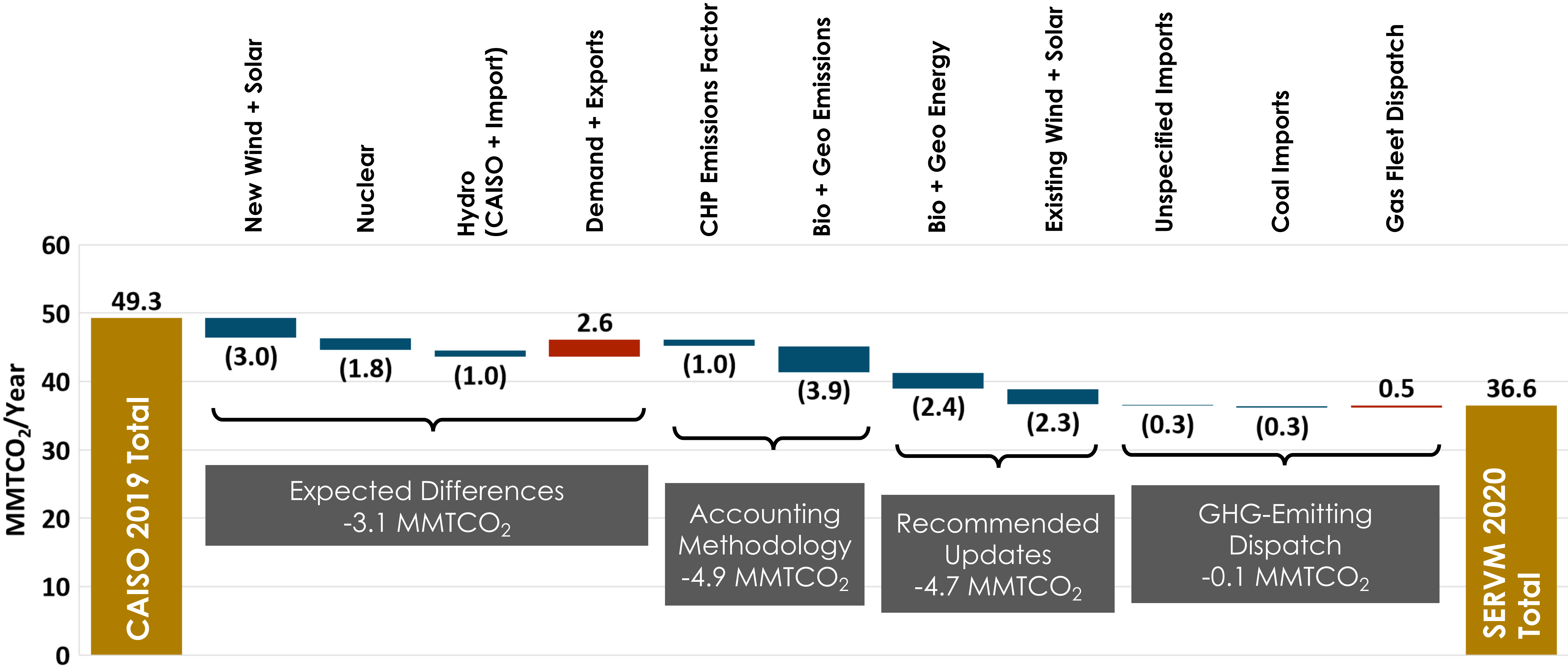


Status of updates from 2017 CAISO <> 2018 RESOLVE comparison

Potential updates identified in 2018	Implemented?	Notes
Include fuel consumption when starting CCGTs and peakers	Yes	RESOLVE includes a linearized version of unit commitment variables and constraints, allowing the model to estimate CCGT and peaker starts. Start emissions are calculated by multiplying a start emissions factor by the number of generator starts.
Impose additional operational constraints on resources providing reserves, potentially resulting in increased peaker utilization	No	Reserve limits not added. As a result of other updates, peaker dispatch in RESOLVE increased significantly from 0.2 TWh (2017/8) to 1.8 (2019/20).
Add specified coal imports in near-term	Yes	Intermountain coal imports were added, reducing the emissions gap from coal from 1.1 MMT (2017/8) to 0.4 (2019/20).
Model part of the CHP fleet as dispatchable and update installed capacity	Yes (partial)	Installed capacity was updated. CHP is modeled in RESOLVE as an inflexible baseload resource, but variation in production was captured by modeling CHP with a monthly-varying capacity factor based on historical production.
Compare historical and modeled renewable capacity factors	Yes	Capacity factors for baseline wind and solar updated to align with historical production for existing facilities.
Update demand forecast	Yes	IEPR forecast is updated each year.
Update CCGT heat rates / emissions factors	Yes	Gas heat rates updated, virtually eliminating the 1.9 MMT difference from CCGT Emissions Factors observed in 2017/8.

3.2: Comparison Between CAISO 2019 and SERVM 2020

SERVM Emissions Comparison Waterfall



Note: Methodology used to quantify emissions differences is directional but not precise.

SERVM vs. RESOLVE Waterfall

- Calibration between RESOLVE and SERVM performed in 2019 resulted in broad agreement between models on both GHG emissions and generation levels
- As a result, the differences observed in the CAISO <> RESOLVE comparison are generally also present in the CAISO <> SERVM comparison
- The largest emissions differences between RESOLVE and SERVM are observed in the Nuclear, Hydro, and Gas Fleet Dispatch categories; these differences are relatively minor (< 1 $MMTCO_2$/Yr) and do not merit further discussion here.
  - May be revisited while updating Inputs and Assumptions for next Reference System Plan
- Note that the version of SERVM used for this analysis includes new, higher capacity factor wind generation shapes than were used for the Reference System Plan analysis. The wind shape update helps to align SERVM wind output with historical capacity factors.

Conclusions

- While significant differences in modeling methodology exist between SERVM and RESOLVE, and between modeling and actual CAISO dispatch, most emissions discrepancies can be attributed to:
  - Differences in generation from zero/low GHG resources
  - Differences in demand
  - Accounting methodology
- After accounting for the above discrepancies, differences related to the dispatch of GHG-emitting resources are small – on the order of 1 $MMTCO_2$/Yr

- <u>Recommended near-term actions to update SERVM and RESOLVE:</u>
  - Reduce energy production from existing geothermal and biomass facilities
  - Remove certain wind and solar power plants from the list of baseline CAISO resources
- Both of the above recommended actions reduce the amount of energy available from existing zero/low GHG resources, potentially requiring additional zero/low GHG resources to meet GHG targets

Questions?

4: SERVM Dispatch Data Study

Performed by:
E3 – Xiaoxuan Hou, Jimmy Nelson, Charlie Duff, Aaron Burdick, Arne Olson
With guidance from CPUC IRP and ERM

Introduction

- High-level study of the SERVM production cost modeling
  - Goal: identify issues, if any, with SERVM dispatch of the CAISO system and propose solutions if necessary
  - General conclusion: the dispatch looks reasonable across a range of conditions, with a few remaining questions
  - Caveats:
    - Year difference: this study compares dispatch results between CAISO's actual 2019 operation and SERVM's 2020 operation, because simulation of year 2019 was out of scope. SERVM's 2020 system has more resources, including both planned additions and selected additions through RESOLVE capacity expansion modeling
    - Qualitative conclusions: the study was done through visualizing dispatch plots, therefore only results in directional and qualitative conclusions

Introduction (continued)

- Research questions
  - Is SERVM dispatch realistic across a range of conditions?
  - Does SERVM dispatch conform to expectations during loss of load events?
  - Does 2030 SERVM dispatch operation appear reasonable (with significant solar surplus and higher levels of battery storage)?

- Data sources
  - SERVM updated Reference System Plan runs for 2020 and 2030
    - Note that SERVM dispatch modeling and input data has been updated since release of Reference System Plan
  - CAISO hourly settlement data from 2019
    - Aggregated by resource type to enable comparison between SERVM and CAISO dispatch

SERVM Dispatch Comparison (2020) to CAISO Historical Operations (2019)

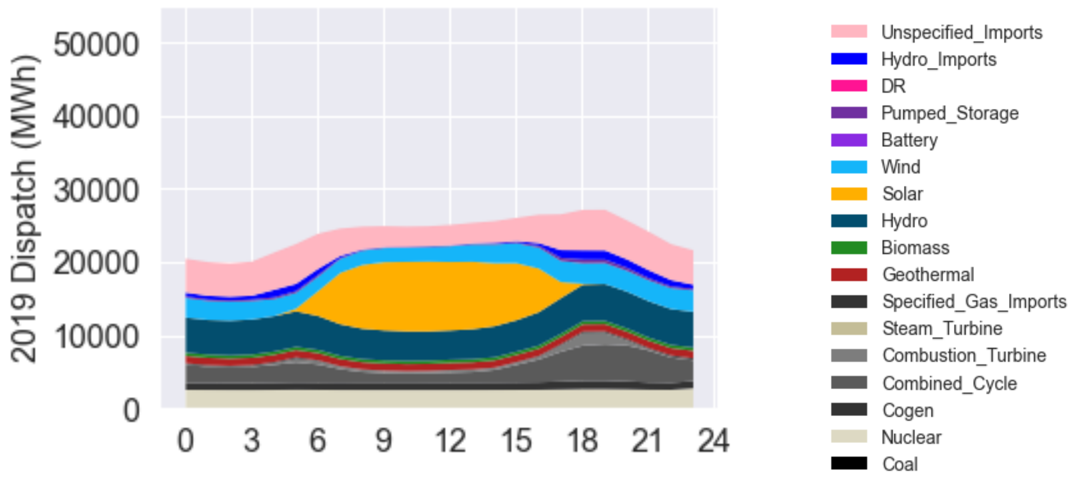
- Is SERVM dispatch realistic across a range of conditions?
  - **Generally, yes. However, additional calibration may be needed for SERVM's utility scale solar shapes**

- Does SERVM's dispatch of CCGT vs. peaker align with CAISO historical dispatch during ramping hours?
  - **For ramping needs, CAISO relies more on CT, while SERVM uses a combination of CT, CCGT, and ST**

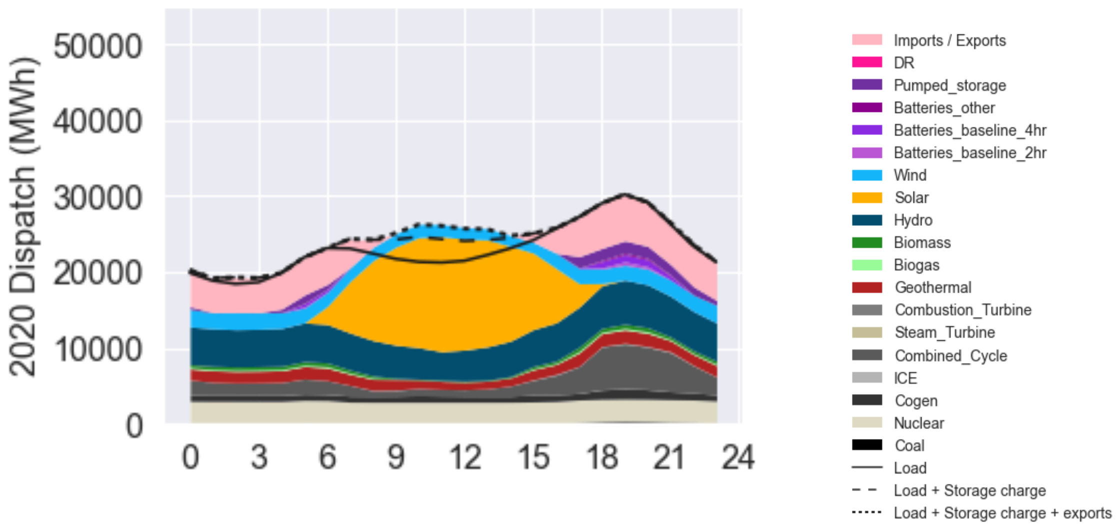
Spring Dispatch

- Renewables:
  - SERVM seems to have a different solar shape than CAISO
  - SERVM data reflects ~3.5 GW more solar capacity (1.5 GW extra planned + 2 GW selected). The 1.5 GW extra planned capacity will be removed from SERVM as soon as possible
- Imports / Exports:
  - SERVM relies on imports for ramping during sunrise and sunset
    - The same dynamic is likely seen in CAISO operations, but is not shown below because detailed CAISO export data was not available
      - CAISO imports are **not** net of exports; SERVM imports are net of exports

CAISO Monthly Average Dispatch: April 2019



SERVM Monthly Average Dispatch: April 2020

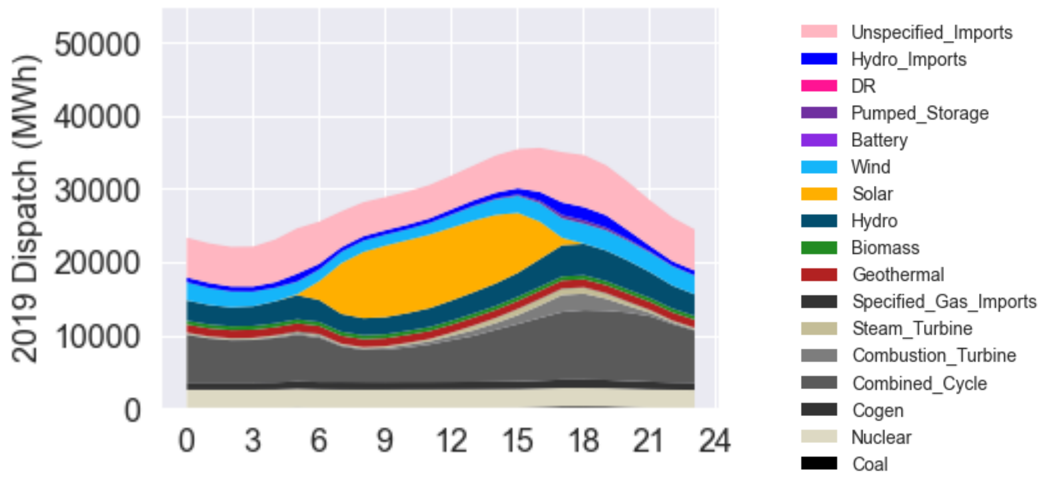


Note: Behind-the-meter resources have been netted out from the load side.

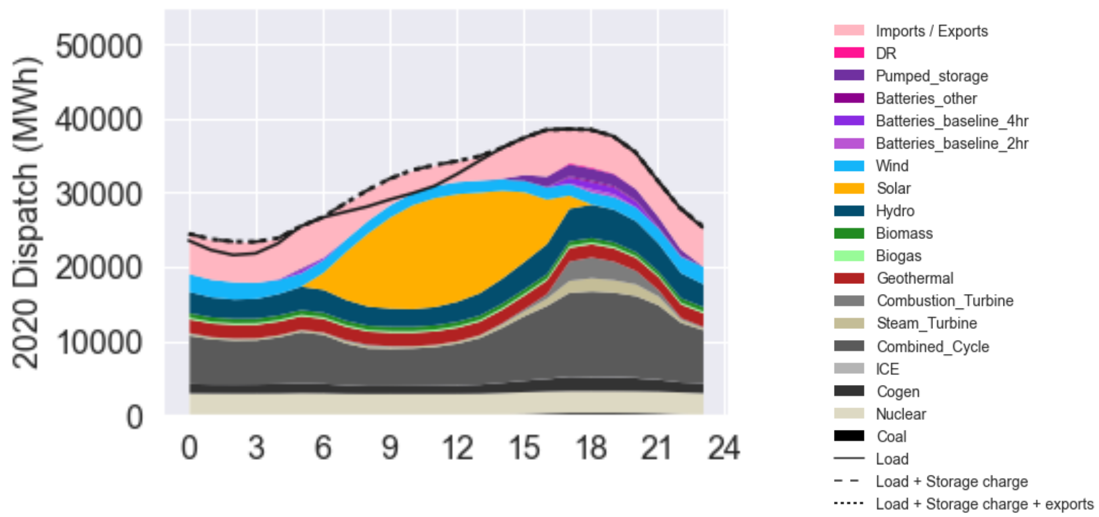
Summer / Fall Dispatch

- SERVM dispatch generally aligns with CAISO, with slightly steeper evening ramping met by gas peakers (CT + ST), as well as batteries
- SERVM dispatch reflects ~2 GW more battery storage capacity (1 GW planned + 1 GW selected) due to rapid battery growth between 2019 and 2020

CAISO Monthly Average Dispatch: September 2019



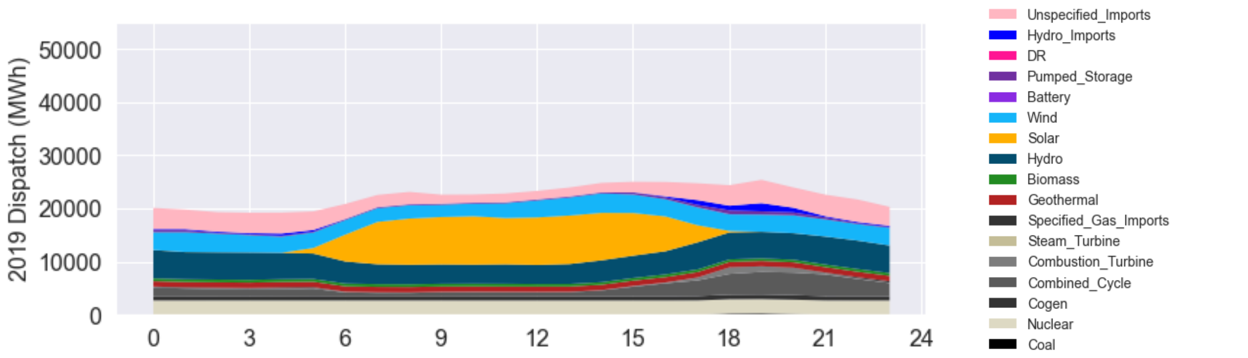
SERVM Monthly Average Dispatch: September 2020



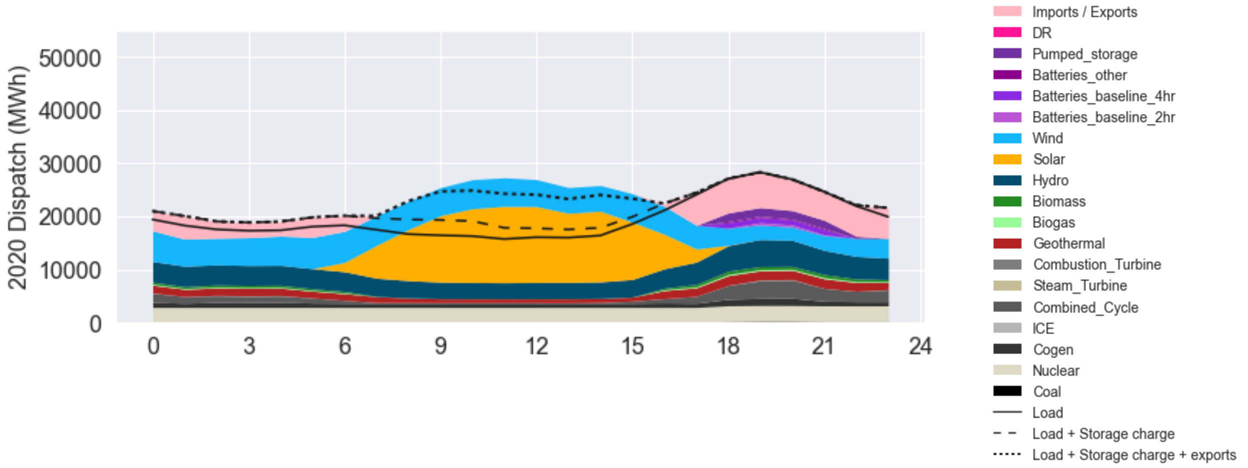
Note: Behind-the-meter resources have been netted out from the load side.

Spring High Curtailment / Ramping Day Dispatch

CAISO High Curtailment Day



SERVM High Curtailment Day



Note: Behind-the-meter resources have been netted out from the load side.

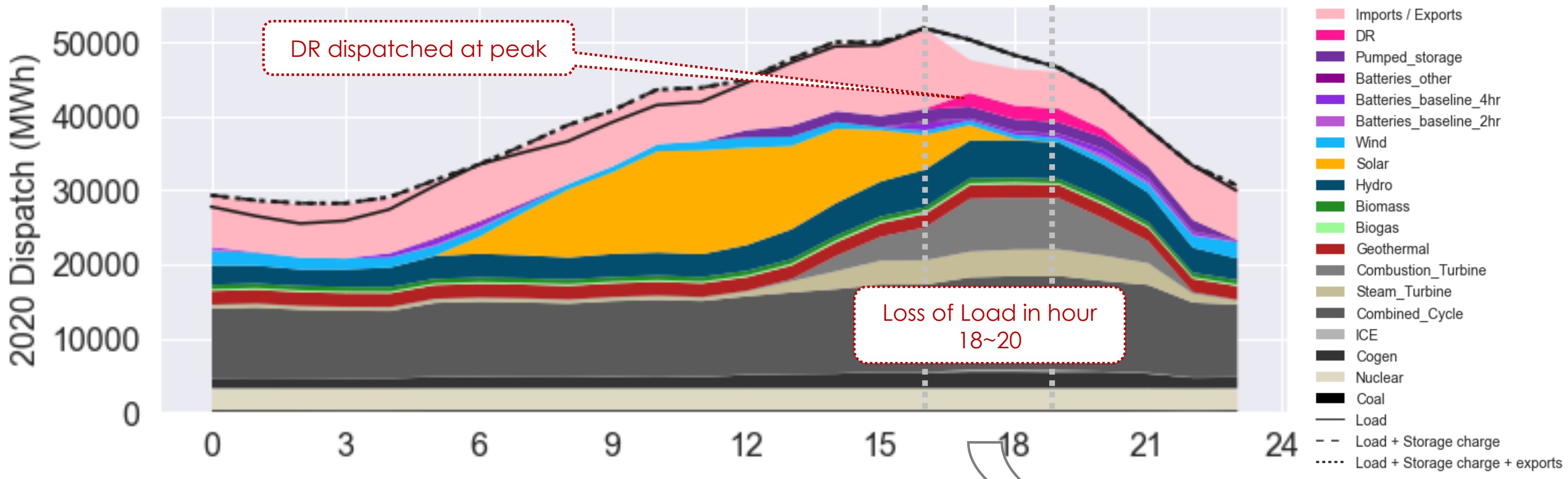
- Mid-day operation:
  - In CAISO's actual operation, some CCGTs remain online during mid-day hours, likely driven by operational constraints and reserve needs
  - SERVM dispatches CCGT down to close to zero; mid-day operation reserves likely provided by hydro and storage
  - Additional solar in SERVM 2020 relative to CAISO 2019 could also explain the lower mid-day gas dispatch
- Evening ramping:
  - CAISO operation uses both CCGT and CT for early evening ramping
  - CCGT / hydro / storage / imports are ramped up for the evening peak in SERVM
- Imports:
  - Note that CAISO imports are not net of exports; SERVM imports are net of exports

SERVM Dispatch During Reliability Events

- **Does SERVM dispatch conform to expectations during loss of load events?**
  - During reliability events, is all available capacity dispatched?
    - **Thermal and storage resources are dispatched to near maximum availability but may retain headroom for reserves**
  - Does SERVM fully utilize the firm import capability during peak hours?
    - **Yes**

Reliability Event: Summer Peak Day Dispatch (2020)

- Thermal:
  - During the loss of load event, all thermal resources are dispatched to near the maximum available level
  - Un-dispatched amounts (~1.4 GW in total spread across 17 units) are within reasonable bounds given operational reserve requirements
- Imports:
  - SERVM fully utilizes the 5 GW firm import capability during the loss of load event
- Demand Response:
  - DR resources are dispatched during peak net load hours



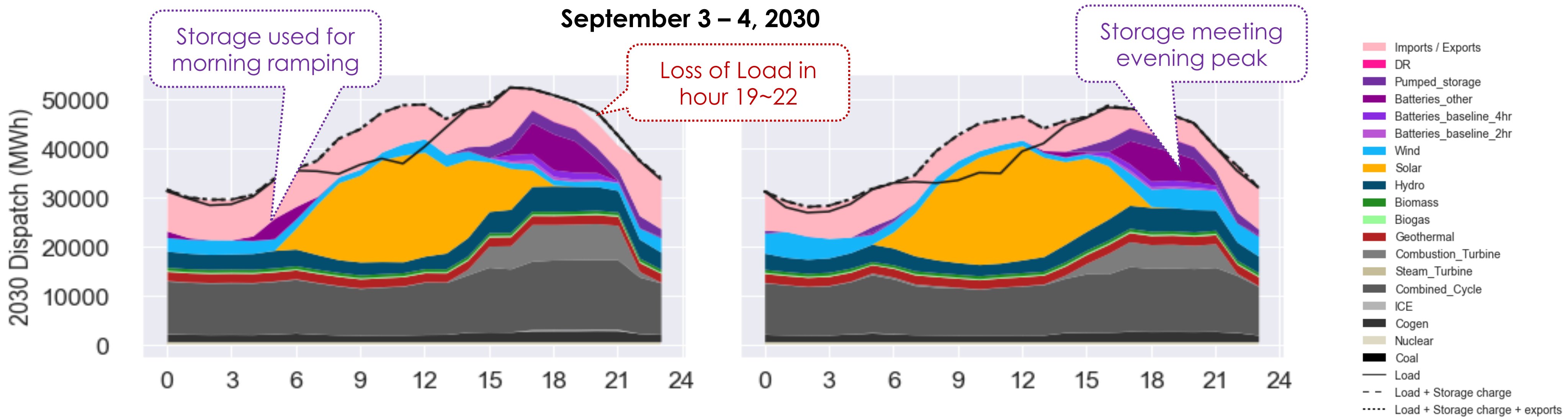
Thermal resources operated below max capacity

Unit	Max Capacity	Hour 5898	Hour 5899	Hour 5900	Undispatched MW
HIDSRT_2_UNITS	830	685	685	685	145
LECEF_1_UNITS	306	110	166	221	140
LEBECS_2_UNITS	765	627	625	628	138
BUCKBL_2_PL1X3	490	382	383	392	104
LMEC_1_PL1X3	575	426	522	518	86
SUNRIS_2_PL1X3	586	502	499	508	83
DELTA_2_PL1X4	813	732	731	731	82
COLUSA_2_PL1X3	610	530	528	534	80
PALOMR_2_PL1X3	566	495	494	492	72
LODIEC_2_PL1X2	303	229	223	246	70
OTMESA_2_PL1X3	604	543	543	540	62
MRCHNT_2_PL1X3	419	359	359	360	60
LAPLMA_2_UNIT_3	256	198	198	198	58
MOSSLD_2_PSP2	510	450	459	457	55
ELSEGN_2_UN1011	263	209	210	210	53
ELKHIL_2_PL1X3	400	349	344	348	53
MOSSLD_2_PSP1	510	459	459	457	52

Note: Behind-the-meter resources have been netted out from the load side.

Reliability Event: Summer Peak Day Dispatch (2030)

- Storage resources are generally dispatched as expected
  - Storage resources charge during mid-day hours and discharge during evening peak hours
- Pumped storage discharge reaches maximum capacity during the loss of load event
- Battery storage discharge peaks in the early evening but cannot sustain output through hour ~20 due to limits on stored energy
  - Battery discharge is spread over a 5-hour period, bringing down hourly output capacity (max battery discharge of 10 GW compared to 12 GW total capacity)
  - Batteries may be providing reserves – not investigated here
- Demand response is not fully utilized in the loss of load event.
  - This may be because DR is dispatched more in early months, causing limited capability in September – not investigated here



Note: Behind-the-meter resources have been netted out from the load side.

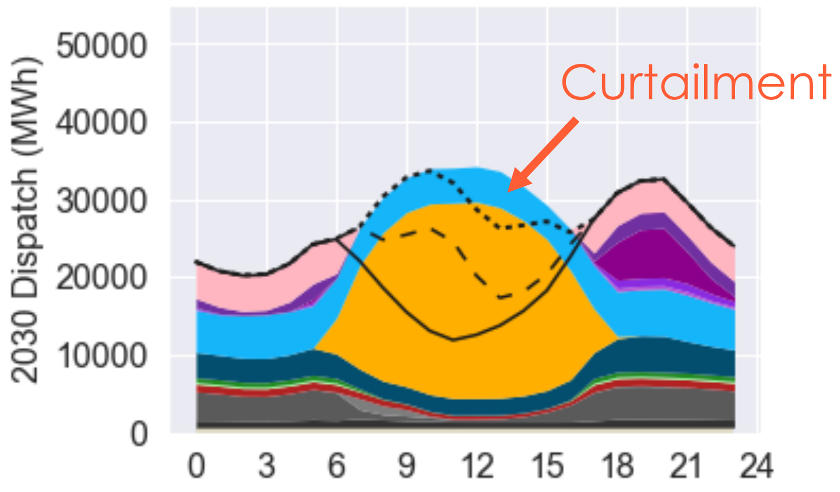
Investigating 2030 SERVM Dispatch

- Does 2030 SERVM dispatch operation appear reasonable (with significant solar surplus and higher levels of battery storage)?
  - **Yes, it does.**

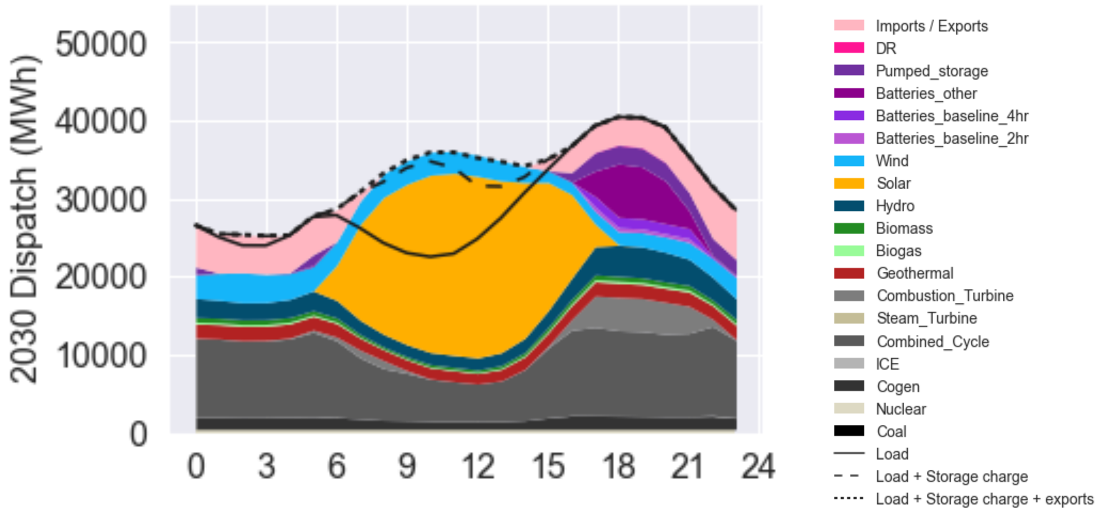
SERVM 2030 Dispatch

- Spring operation:
  - Mid-day thermal generation drops to minimum level in order to absorb renewable generation
  - Exports increase during mid-day hours
  - Significant curtailment seen during mid-day hours
    - Driven by abundance of solar generation
- Summer/Fall operation:
  - Thermal and storage provide afternoon to evening peaks together

SERVM Monthly Average Dispatch: April 2030



SERVM Monthly Average Dispatch: September 2030



Note: Behind-the-meter resources have been netted out from the load side.

Recommendations

- Calibration check on SERVM's utility solar profiles
- Closer investigation on battery storage operation
  - Confirm if the lower-than-maximum discharge during high peak hours is partially driven by batteries providing reserves
- Investigate DR dispatch and ensure it is fully utilized to meet reliability

Questions?

California Public Utilities Commission

Further information

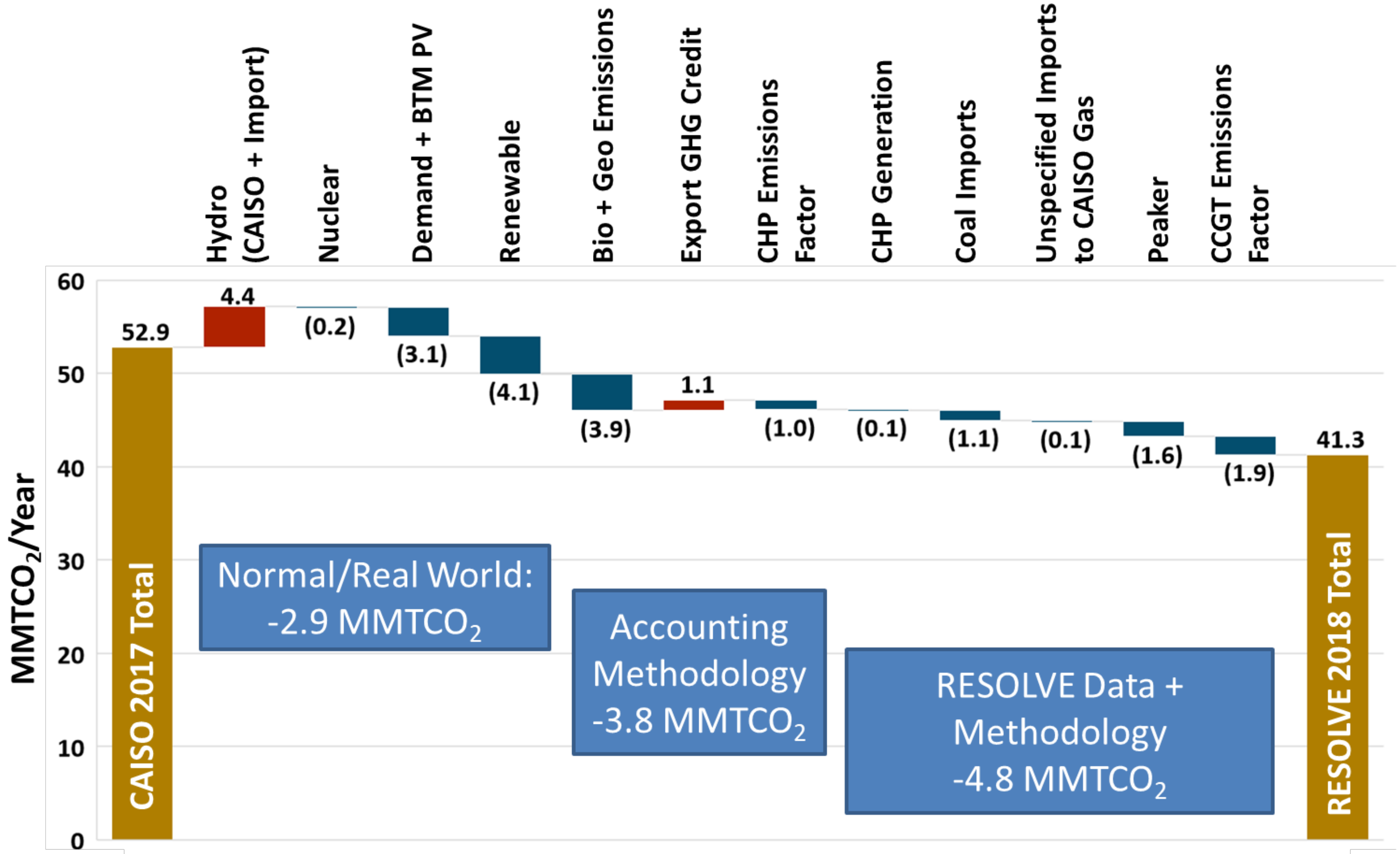
- Thank you for your participation. If you have any questions following the webinar please contact:
  -Ali Eshraghi: (415) 703-1521alireza.eshraghi@cpuc.ca.gov

- Important links: IRP Events and Materials

Appendix

Appendix: CAISO 2017 <> RESOLVE 2018 Waterfall

Available at:
https://www.cpuc.ca.gov/uploadedFiles/CPUCWebsite/Content/UtilitiesIndustries/Energy/EnergyPrograms/ElectPowerProcurementGeneration/irp/2018/IRP_MAG_webinar_2018-08-10_GHG_Accounting_CAISO_RESOLVE.pdf



Note: Methodology used to quantify emissions differences is directional but not precise.