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Proposed Preferred System Portfolio for IRP 2017-18: System Analysis and Production Cost Modeling Results

January 11, 2019

California Public Utilities Commission

Contents

Acronyms & Abbreviations

AAEE	Additional Achievable Energy Efficiency
AAPV	Additional Achievable Photovoltaics (BTMPV)
BANC	Balancing Area of Northern California
BTM	Behind-the-Meter
Btu	British thermal unit
CAISO	California Independent System Operator
CARB	California Air Resources Board
CCA	Community Choice Aggregator
CCGT	Combined Cycle Gas Turbine
CEC	California Energy Commission
CHP	Combined Heat and Power
CPUC	California Public Utilities Commission
CREZ	Competitive Renewable Energy Zone
DAC	Disadvantaged Community
DER	Distributed Energy Resources
DR	Demand Response
EE	Energy Efficiency
ELCC	Effective Load Carrying Capability
EO	Energy Only
EV	Electric Vehicle
FCDS	Full Capacity Deliverability Status
GHG	Greenhouse Gas
ICE	Internal Combustion Engine
IEPR	Integrated Energy Policy Report
IOU	Investor Owned Utility
IRP	Integrated Resource Plan (or) Planning
LOLE	Loss-of-load-expectation
LSE	Load Serving Entity

$MM	Millions of Dollars
MMBtu	Millions of British thermal units
MMT	Million Metric Tons
MT	Metric Tons
NOx	Nitrogen Oxide or Dioxide
NQC	Net Qualifying Capacity
OOS	Out-of-state
OTC	Once Through Cooling
PCC	Portfolio Content Category
PCM	Production Cost Model(ing)
PM 2.5	Particulate Matter, 2.5 microns
POU	Publicly-owned utility
PRM	Planning Reserve Margin
PV	Photovoltaics
RA	Resource Adequacy
REC	Renewable Energy Credit
RETI	Renewable Energy Transmission Initiative
RPS	Renewables Portfolio Standard
SERVM	Strategic Energy Risk Valuation Model
ST	Steam Turbine
TOU	Time-of-Use (Rates)
TPP	Transmission Planning Process
TRC	Total Resource Cost
WECC	Western Electricity Coordinating Council
ZEV	Zero Emissions Vehicle
ZNE	Zero Net Energy

EXECUTIVE SUMMARY

Purpose

Purpose of this work product:

- Describe the process for analyzing and aggregating the IRPs filed by individual LSEs, and present:
  - Aggregation of baseline and new units
  - Hydro analysis of aggregated IRPs filed by LSEs
- Present Strategic Energy Risk Valuation Model (SERVM) production cost model (PCM) results for the Hybrid Conforming Portfolio
- Propose an IRP 2018 Preferred System Portfolio
- Solicit feedback from parties on the above items

Overview of Contents

Contents of this work product:

- A "**Hybrid Conforming Portfolio**" representing the aggregation of LSE Conforming Portfolios with adjustments to fit within the resource potential and transmission availability assumed in the RESOLVE model. A description of the process and rationale for the aggregation and adjustments are included.
- Aggregation analysis results for baseline and new resources included in IRPs filed by LSEs.
- Analysis of hydro availability compared to the planned use of hydro implied by the aggregated IRPs filed by LSEs.
- PCM results for the Hybrid Conforming Portfolio using SERVM, including system reliability and operational performance metrics.

Role of the Preferred System Portfolio within the Proposed IRP 2017-18 Process

1. CPUC adopted a Reference System Plan reflecting:
   - A statewide GHG Planning Target of 42 MMT for the electric sector
   - A Reference System Portfolio that achieves the statewide GHG Planning Target
   - Policy actions to ensure that IRP guidance informs other CPUC proceedings and results in adequate resource procurement
2. LSEs filed IRPs with Conforming Portfolios that reflect the Reference System Plan
3. Staff evaluated LSE Plans individually and in aggregate to validate reliability and GHG emissions
4. CPUC will determine whether to authorize procurement based on approved, aggregated LSE portfolios (the Preferred System Portfolio)
5. CPUC will consider how to use IRP results to inform other resource-specific proceeding activities

Key Conclusions and Recommendation Based on Aggregated LSE Plans

Conclusions:

- Many thermal resources in the 2017 Reference System Plan baseline are not reflected in aggregate LSE plans, especially after 2023.
- Uncertainty with regard to the feasibility of LSE Plans is a natural part of the IRP process and should continue to be explored by CPUC staff and parties in future IRP cycles.
- Aggregate LSE plans alone do not include sufficient resources on an energy or capacity basis to conduct a reliability analysis.

Staff recommendations:

- Make adjustments in the aggregated LSE Conforming Portfolios in order to fit within the resource potential and transmission availability assumed in the RESOLVE model, and generate a new “Hybrid Conforming Portfolio”
- In future IRP cycles, simplify the IRP data template, reduce the number of inputs that LSEs must provide, and provide clearer instructions to LSEs.

Key Conclusions and Recommendations Based on Analysis of Hydro Feasibility

Conclusions:

- The aggregation of LSE portfolios appears feasible with respect to LSEs' planned use of PNW hydro based on historical data.
- However, the planned use of in-state hydro may present some risks based on historical data.

Staff Recommendations:

- Revisit RESOLVE's assumption of 8.02 TWh/year of specified hydro from the PNW, which appears too low given historical data.
- Revise the Clean Net Short Calculator to more clearly distinguish between inputs for in-state vs. out-of-state hydro resources.
- Require LSEs to provide a description in their Plans of hedging strategies to address risks of in-state drought
- Develop filing requirements that enable CPUC staff to analyze and monitor the potential risk of resource shuffling

Key Conclusions and Recommendations Based on PCM Study of Hybrid Conforming Portfolio

Conclusions:

- The Hybrid Conforming Portfolio reflects the planning preferences of LSEs, which modeled their plans based off the Commission-adopted 2017 Reference System Portfolio.
- The Hybrid Conforming Portfolio also reflects some adjustments made by CPUC staff, including aligning with the resource potential and transmission availability assumed in the RESOLVE model, and using a 40 year age proxy for some amount of potential fossil retirement in the future.
- Staff conducted production cost modeling to demonstrate that the Hybrid Conforming Portfolio is a reliable and operable portfolio.
- The Hybrid Conforming Portfolio produces higher emissions and a different system energy balance than the Reference System Plan, which may or may not require Commission action in the near term.

Staff Recommendations:

- The Commission should adopt the Hybrid Conforming Portfolio as the 2018 Preferred System Portfolio for this IRP cycle.
- CPUC staff should align inputs to RESOLVE and SERVM and converge outputs at the beginning of the next Reference System Plan development process.

BACKGROUND

Integrated Resource Planning (IRP) in California Today

- Integrated Resource Planning (IRP) has traditionally been the domain of a single vertically integrated utility
- California today presents a more complex landscape:
  - Multiple Load Serving Entities (LSEs) including utilities, community choice aggregators (CCAs) and competitive retail service providers
  - Multiple state agencies (CPUC, Energy Commission, Air Resources Board) and California Independent System Operator (CAISO)
  - Partially deregulated market
- The value proposition of <u>integrated</u> resource planning is to reduce the cost of achieving GHG reductions and other policy goals by looking across individual LSE boundaries and resource types to identify solutions to reliability, cost, or other concerns that might not otherwise be found
- Goal of IRP 2017-18 cycle at CPUC is to ensure that the electric sector is on track to help California reduce economy-wide GHG emissions 40% from 1990 levels by 2030

Statutory Basis of IRP at CPUC

The Commission shall…

PU Code Section 454.51

Identify a diverse and balanced portfolio of resources… that provides optimal integration of renewable energy in a cost-effective manner

PU Code Section 454.52

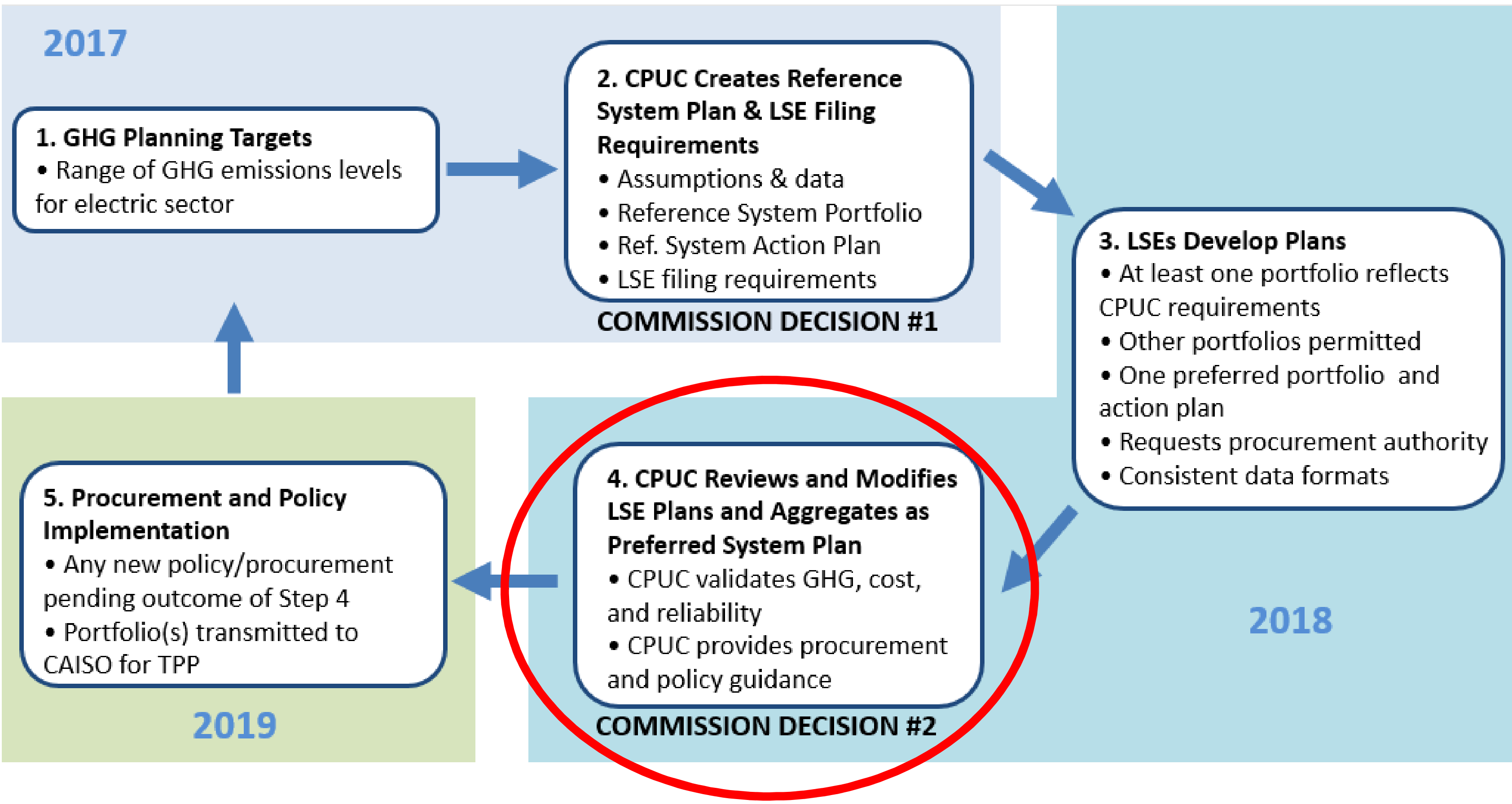
...adopt a process for each load-serving entity…to file an integrated resource plan…to ensure that load-serving entities do the following…

- Meet statewide GHG emission reduction targets
- Comply with state RPS target
- Ensure just and reasonable rates for customers of electrical corporations
- Minimize impacts on ratepayer bills
- Ensure system and local reliability
- Strengthen the diversity, sustainability, and resilience of the bulk transmission and distribution systems, and local communities
- Enhance distribution system and demand-side energy management
- Minimize air pollutants with early priority on disadvantaged communities

Background on the CPUC IRP 2017-18 Cycle

- Commission Decision (D.18-02-018) established IRP as a two-year planning cycle designed to ensure LSEs are on track to achieve GHG reductions and ensure electric grid reliability at least cost while meeting the state's other policy goals.
- In the 2017-18 IRP cycle, Year 1 was spent developing the **Reference System Plan** using the RESOLVE capacity expansion model. In February 2018, the Commission adopted an optimal Reference System Portfolio of resources to meet an electric sector GHG planning target of 42 MMT by 2030.
- LSEs used the guidance provided in the Commission's decision to develop individual IRPs ("LSE Plans"), and they filed their IRPs with the Commission on August 1, 2018.
- CPUC staff conducted production cost modeling (PCM) to evaluate system reliability, emissions, and operational performance of the adopted Reference System Plan calibrated with the California Energy Commission's (CEC's) 2017 Integrated Energy Policy Report (IEPR) demand forecast. The PCM process was formalized by ruling on November 15, 2018.
- CPUC staff aggregated and adjusted the portfolios of each LSE's IRP to create the system Hybrid Conforming portfolio, to be further analyzed with the PCM process.
- The Commission expects to adopt a **Preferred System Plan** in Q1 2019.

Step 4 of the IRP 2017-18 Process



Staff has evaluated the LSE Plans, aggregated the LSE portfolios, and conducted production cost modeling to inform the Preferred System Plan

AGGREGATION OF LSE CONFORMING PORTFOLIOS

Definitions

- **Planned purchases**: proposed energy or capacity purchases that the LSEs submitted in their data templates
  - Note: these planned purchases do not imply RA compliance positions and do not include the assumed short-term market purchases that LSEs will make to serve load.
- LSEs submitted two different data templates: **baseline** and **new**.
  - **Baseline** planned purchases of energy or capacity are from resources that are:
    - Online
    - Not yet online but have secured a contract and therefore highly likely to be built to completion
  - **New** planned purchases of energy or capacity are from resources that do not exist and have no contract. These are comparable to the resources “selected” by RESOLVE in the Reference System Plan (RSP).
- **Integrated Energy Policy Report (IEPR) load:** represents forecasted annual energy sales from CPUC-jurisdictional LSEs within CAISO
- These terms will be used throughout the aggregation analysis

Analytic Approach

- Summarize total planned baseline and new resource energy purchases in aggregated conforming LSE plans
- Compare LSEs’ planned capacity purchases from baseline resources to existing capacity on the CAISO system
- Compare LSEs’ planned new resources to the new resources selected by RESOLVE in the Reference System Plan based on the 2017 IEPR
- Verify new resource purchase proposals do not exceed system potential or transmission capability

Data Preparation and Cleaning

- Aggregate all LSE plans into single dataset
- Standardize resource types and regions to allow for aggregation and ensure that planned purchases of capacity do not exceed physical limits of system
- Data cleaning – identify and correct anomalous values, units called by multiple names, incorrectly entered resource types or regions.
- Contact LSEs to answer clarifying questions and have LSEs correct and re-submit data in formal IRP filings, where necessary
- Make adjustments to LSE proposed new resource locations to fit within assumed resource and transmission potential limits

Use of Conforming Portfolios

- Staff aggregated LSE plans using only conforming portfolios and not preferred portfolios.
- LSEs' conforming and preferred portfolios differed primarily in their assumptions about which policy futures will materialize
  - SCE's and PG&E's preferred plans assumed approval of their PCIA proposal, which did not occur
  - SCE's preferred plan targeted 30 MMT by 2030
- Other differences between conforming and preferred portfolios did not impact system-level resources enough to justify modeling preferred portfolios in aggregate.
- Analysis in subsequent slides reflects characteristics of the aggregate conforming portfolios.

Notes on “Alternative LSE Plan” Filers

- Charts presented in this deck represent all the Standard filers, roughly 97% of LSE load.
- The residual 3% of 2030 load is served by Alternative LSE Plan filers (who generally filed S-1 and S-2 forms in lieu of using the data template)
  - LSEs eligible to file an Alternative LSE Plan include those with a projected load of less than 700 GWh/year in each of the first five years of the IRP planning horizon

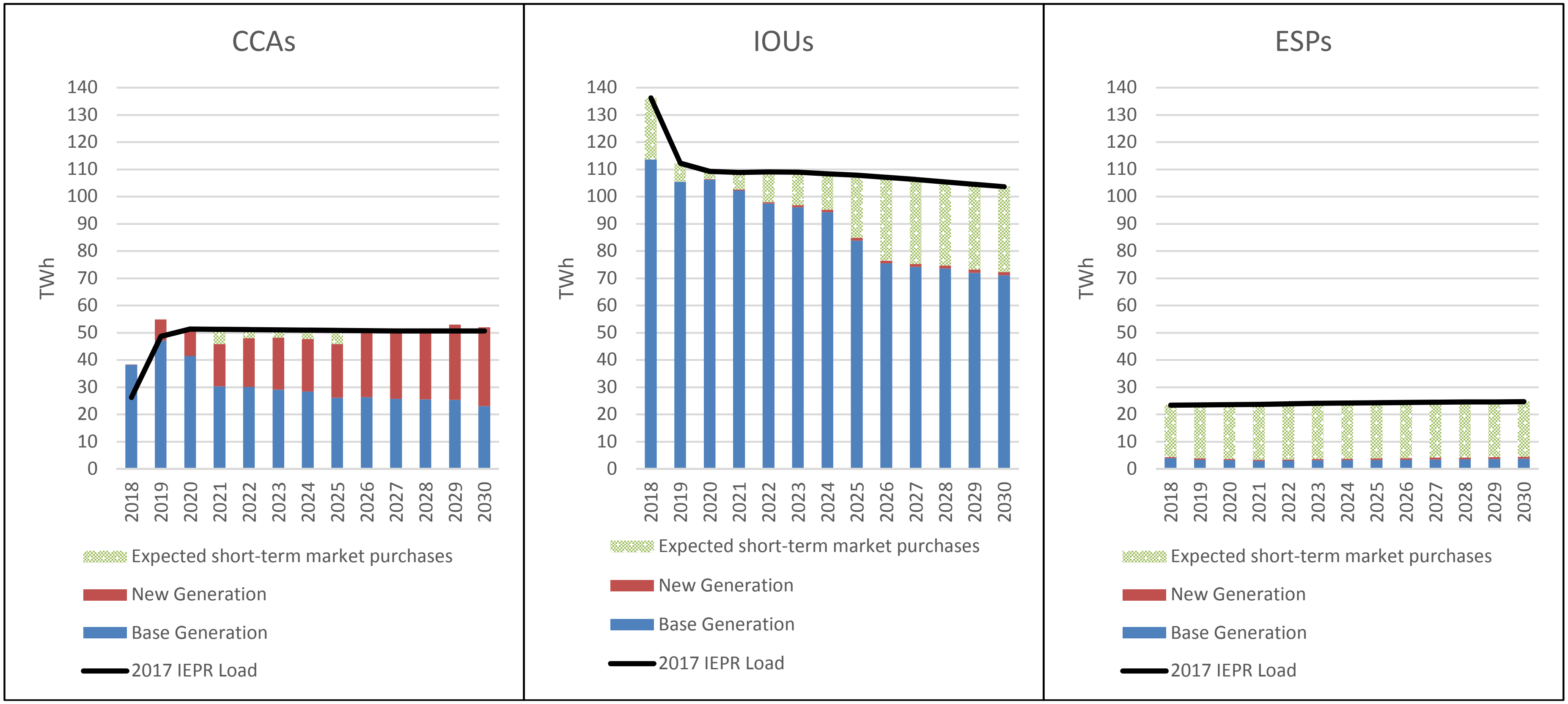
Load estimate from LSEs filing nonstandard plans versus total system load

LSE Type	2030 load subtotal from Alt. LSE Plan filers, 2017 IEPR TWh	2030 load total for all LSEs, 2017 IEPR TWh	Percent of load served by Alt. LSE Plan filers
Co-ops	0.5	N/A	N/A
IOUs	1.6	103.7	2%
ESPs	2.0	24.7	8%
CCAs	0.7	50.7	1%
Total	4.77	179.01	3%

- Data from the Alternative LSE Plan filers is not included in the following results.
- It also does not include data for Direct Energy, as they did not file an IRP plan.

TOTAL BASELINE AND NEW RESOURCE ENERGY ANALYSIS

Total planned baseline and new energy purchases, TWh, by LSE type

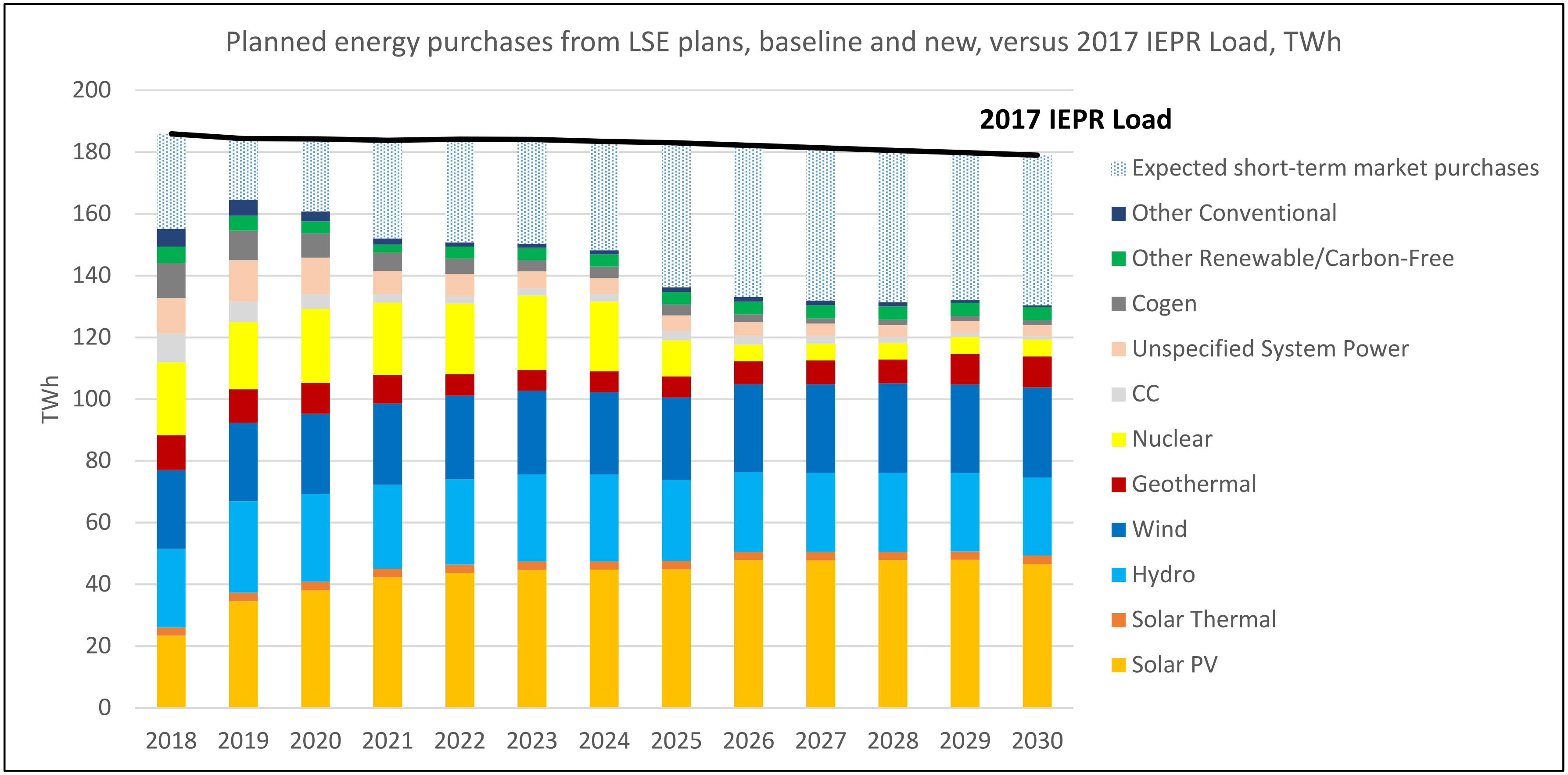


LSEs commit to different levels of energy purchases over time

- IOU procurement intentionally meets a declining portion of total load over time to minimize risk, which may reflect declining load share and hedging practices in the IOUs' bundled procurement plans
- CCAs plan to purchase the majority of new resources and provide portfolios where resources match load through 2030
- ESPs typically purchase resources on a much shorter time frame than the IRP planning horizon

The faded green area indicates the gap between planned energy purchases from LSE plans and IEPR load. The gap is expected to be filled with short-term market purchases and does not imply any procurement or RA deficiencies.

Total planned baseline and new energy purchases, TWh, by resource type



NOTES

- *Wind, Hydro, Geothermal, Nuclear, and Solar form the bulk of planned energy purchases*
- *Nuclear drops off in 2026 due to the retirement of Diablo Canyon*
- *Energy contracts for Cogeneration (Cogen) and Combined Cycles (CC) decrease over time*
- *Many LSEs have indicated purchases of unspecified system power in advance*
- *Other Renewable consists of unspecified RPS-eligible and carbon-free power, biomass and biogas*
- *Other Conventional consists of combustion turbines, internal combustion engines, and unspecified conventional power sources*
- *The faded blue area indicates the gap between planned energy purchases from the LSE plans and IEPR load. The gap is expected to be filled with short-term market purchases and does not imply any procurement or RA deficiencies.*

BASELINE RESOURCE CAPACITY ANALYSIS

Baseline Capacity Analysis Approach

- The baseline capacity analysis considers the capacity LSEs plan to use from the pool of existing resources. The new capacity reported in LSE plans is separately considered in the next section of this presentation, thus the following tables do NOT include the "new resources" indicated in LSE plans.
- Staff aggregated the planned capacity purchases in the LSE baseline plans and compared the result to the existing (baseline) Net Qualifying Capacity (NQC) on the system
- Staff checked that planned capacity purchases do not exceed available NQC by resource class
- Staff checked if the existing resources in the aggregated LSE baseline plans are consistent with existing baseline units in SERVM
- The following slides do not constitute a Resource Adequacy (RA) assessment. Their purpose is to catalog the types and amounts of capacity LSEs are contracting for compared to the types and amounts of NQC available in the existing system.

Changes from previous presentation of capacity data

- In the October 31st workshop, staff presented tables comparing available CAISO system capacity MW with LSE proposed contract MW for the month of August.
- Staff now presents a version of these tables again, with the following changes to the figures implemented:
  - Updated retirement dates for Inland Empire Energy Center Unit 2 and Gates Peaker
  - Renewable remote generators (solar and wind) no longer counted as in-CAISO
  - Clarifying notes about the treatment of OOS Thermal resources such as Intermountain, Arlington, Griffith, Mesquite, and Yuma Cogen

Total existing available system Net Qualifying Capacity (NQC) MW, CAISO area (Table A)

General Type	Resource subcategory	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Thermal	**CC**	17,632	17,511	15,495	15,495	15,495	15,495	15,495	15,495	15,495	15,495	15,495	15,495
	CT	7,492	7,590	7,590	7,590	7,590	7,590	7,590	7,590	7,590	7,590	7,590	7,590
	Cogen	3,135	3,135	3,135	3,135	3,135	3,135	3,135	3,135	3,135	3,135	3,135	3,135
	ICE	211	211	211	211	211	211	211	211	211	211	211	211
	Steam	513	287	61	61	61	61	61	61	61	61	61	61
Nuclear	Nuclear	2,923	2,923	2,923	2,923	2,923	2,923	1,773	623	623	623	623	623
Solar	**Solar PV**	4,970	5,110	5,110	5,110	5,110	5,110	5,110	5,110	5,110	5,110	5,110	5,110
	Solar Thermal	512	512	512	512	512	512	512	512	512	512	512	512
Hydro	Hydro	5,570	5,570	5,570	5,570	5,570	5,570	5,570	5,570	5,570	5,570	5,570	5,570
	Pumped Storage Hydro	1,832	1,832	1,832	1,832	1,832	1,832	1,832	1,832	1,832	1,832	1,832	1,832
Wind	**Wind**	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,840	1,840
Geothermal	Geothermal	1,728	1,728	1,728	1,728	1,728	1,728	1,728	1,728	1,728	1,728	1,728	1,728
Biomass	Biomass	464	464	464	464	464	464	464	464	464	464	464	464
Battery Storage	Battery Storage	391	433	475	1,115	1,115	1,115	1,115	1,327	1,327	1,327	1,327	1,327
Biogas	Biogas	212	212	212	212	212	212	212	212	212	212	212	212
TOTAL	**TOTAL**	49,504	49,437	47,237	47,877	47,877	47,877	46,727	45,789	45,789	45,789	45,710	45,710

Notes:

- This indicates the amount of total capacity that exists or is currently planned to be built (i.e. baseline), but does **NOT** include new resources indicated in the LSE "new resource" plans
- Yellow highlighting indicates a decrease in capacity (retirements) relative to the previous year, green highlighting indicates an increase. White means no change relative to the previous year.
- Capacity data is based on a data extract from SERVM. SERVM data is derived from the August 2017 CAISO Masterfile and TEPPC Common Case, with updates for announced retirements and repowers.
- Includes renewable remote generators assumed to deliver into CAISO such as OOS Wind.
- Does not include OOS Thermal Dynamic units such as Intermountain, Arlington, Griffith, Mesquite, and Yuma Cogen
- Wind and solar are derated by their last adopted August Effective Load Carrying Capacity (ELCC) values to 26.5% and 41% of their nameplate, respectively.
- This table does not include the import capacity that is used in RA capacity counting.

Total planned purchases of Net Qualifying Capacity (NQC) MW (from existing available system NQC) for August, CAISO area, from LSE conforming plans (Table B)

General Type	Resource subcategory	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Thermal	CC	8,410	8,226	6,614	6,321	5,614	4,962	5,003	4,998	4,996	4,956	4,951	4,947
	CT	5,015	4,740	4,588	3,962	1,922	1,801	1,800	1,798	1,754	1,752	1,370	1,368
	Cogen	3,025	2,714	1,794	1,482	843	779	641	622	337	337	337	337
	ICE	163	163	163	163	163	163	163	163	163	163	163	163
	Steam	10	10	10	10	10	10	10	10	0	0	0	0
Nuclear	Nuclear	2,923	2,923	2,923	2,923	2,923	2,923	1,773	623	623	623	623	623
Solar	Solar PV	3,352	3,707	3,923	3,945	3,948	3,950	3,953	3,957	3,973	3,990	3,967	3,777
	Solar Thermal	617	617	617	617	617	617	617	617	617	617	617	617
Hydro	Hydro	3,346	3,120	2,990	2,990	2,990	2,990	2,990	2,990	2,989	2,989	2,989	2,989
	Pumped Storage Hydro	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280
Wind	Wind	1,832	1,843	1,866	1,865	1,863	1,819	1,816	1,773	1,750	1,762	1,735	1,715
Geothermal	Geothermal	1,288	1,205	1,215	941	887	887	887	851	851	851	851	851
Biomass	Biomass	160	125	125	125	125	125	125	124	124	124	124	124
Battery Storage	Battery Storage	353	408	719	808	833	935	934	933	932	931	930	929
Biogas	Biogas	64	58	58	58	58	58	58	58	57	57	55	48
TOTAL	TOTAL	**31,838**	**31,139**	**28,885**	**27,490**	**24,076**	**23,299**	**22,050**	**20,797**	**20,446**	**20,432**	**19,992**	**19,768**

- Data represents planned capacity purchases in the baseline data only. Does not represent capacity from the new resources indicated in the LSE "new resource" plans.
- Caveat: This data includes the Puente Power Project (262 MW) because SCE submitted it in the data template, though its status is uncertain. Puente's CEC permitting process has been suspended, but SCE has put out an RFP to address local capacity needs in Puente's sub-area (Moorpark).
- This table does not present an RA assessment and does not imply capacity surplus or deficit from that perspective.

Total leftover CAISO system August NQC MW: available but NOT included in LSE conforming plans (Table A minus Table B)

General Type	Resource subcategory	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total Available Capacity from Table A, 2030	% planned for purchase, 2030
Thermal	CC	9,222	9,285	8,881	9,174	9,881	10,533	10,492	10,497	10,499	10,539	10,544	10,548	**15,495**	**32%**
	CT	2,477	2,850	3,002	3,628	5,668	5,789	5,790	5,792	5,836	5,838	6,220	6,222	**7,590**	**18%**
	Cogen	110	421	1,341	1,653	2,292	2,356	2,494	2,513	2,798	2,798	2,798	2,798	**3,135**	**11%**
	ICE	48	48	48	48	48	48	48	48	48	48	48	48	**211**	**77%**
	Steam	503	277	51	51	51	51	51	51	61	61	61	61	**61**	**0%**
Nuclear	Nuclear	0	0	0	0	0	0	0	0	0	0	0	0	**623**	**100%**
Solar	Solar PV	1,618	1,403	1,187	1,165	1,162	1,160	1,157	1,153	1,137	1,120	1,143	1,333	**5,110**	**74%**
	Solar Thermal	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	**512**	**121%**
Hydro	Hydro	2,224	2,450	2,580	2,580	2,580	2,580	2,580	2,580	2,581	2,581	2,581	2,581	**5,570**	**54%**
	Pumped Storage Hydro	552	552	552	552	552	552	552	552	552	552	552	552	**1,832**	**70%**
Wind	Wind	87	76	53	54	56	100	103	146	169	157	105	125	**1,840**	**93%**
Geothermal	Geothermal	440	523	513	787	841	841	841	877	877	877	877	877	**1,728**	**49%**
Biomass	Biomass	304	339	339	339	339	339	339	340	340	340	340	340	**464**	**27%**
Battery Storage	Battery Storage	38	25	-244	307	282	180	181	394	395	396	397	398	**1,327**	**70%**
Biogas	Biogas	148	154	154	154	154	154	154	154	155	155	157	164	**212**	**23%**
TOTAL	TOTAL	17,666	18,298	18,352	20,387	23,801	24,578	24,677	24,992	25,343	25,357	25,718	25,942	**45,710**	**43%**

- The data in purple is equal to the available system capacity (Slide 28) minus the planned capacity purchases (e.g. via capacity contracts) (Slide 29). It represents the “leftover” capacity that is available on the system, but not included in planned purchases.
- For comparison purposes, the table shows available capacity in 2030 and the % of that planned for purchase on the right, in blue.
- Negative numbers indicate possible over-reliance on these resources.
- This table does not present an RA assessment and does not imply capacity surplus or deficit from that perspective.

Percent of CAISO system August NQC MW included in LSE conforming plans, by year (Table B / Table A)

General Type	Resource subcategory	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Thermal	CC	48%	47%	43%	41%	36%	32%	32%	32%	32%	32%	32%	32%
	CT	67%	62%	60%	52%	25%	24%	24%	24%	23%	23%	18%	18%
	Cogen	96%	87%	57%	47%	27%	25%	20%	20%	11%	11%	11%	11%
	ICE	77%	77%	77%	77%	77%	77%	77%	77%	77%	77%	77%	77%
	Steam	2%	3%	16%	16%	16%	16%	16%	16%	0%	0%	0%	0%
Nuclear	Nuclear	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Solar	Solar PV	67%	73%	77%	77%	77%	77%	77%	77%	78%	78%	78%	74%
	Solar Thermal	121%	121%	121%	121%	121%	121%	121%	121%	121%	121%	121%	121%
Hydro	Hydro	60%	56%	54%	54%	54%	54%	54%	54%	54%	54%	54%	54%
	Pumped Storage Hydro	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%
Wind	Wind	95%	96%	97%	97%	97%	95%	95%	92%	91%	92%	94%	93%
Geothermal	Geothermal	75%	70%	70%	54%	51%	51%	51%	49%	49%	49%	49%	49%
Biomass	Biomass	34%	27%	27%	27%	27%	27%	27%	27%	27%	27%	27%	27%
Battery Storage	Battery Storage	90%	94%	151%	72%	75%	84%	84%	70%	70%	70%	70%	70%
Biogas	Biogas	30%	27%	27%	27%	27%	27%	27%	27%	27%	27%	26%	23%

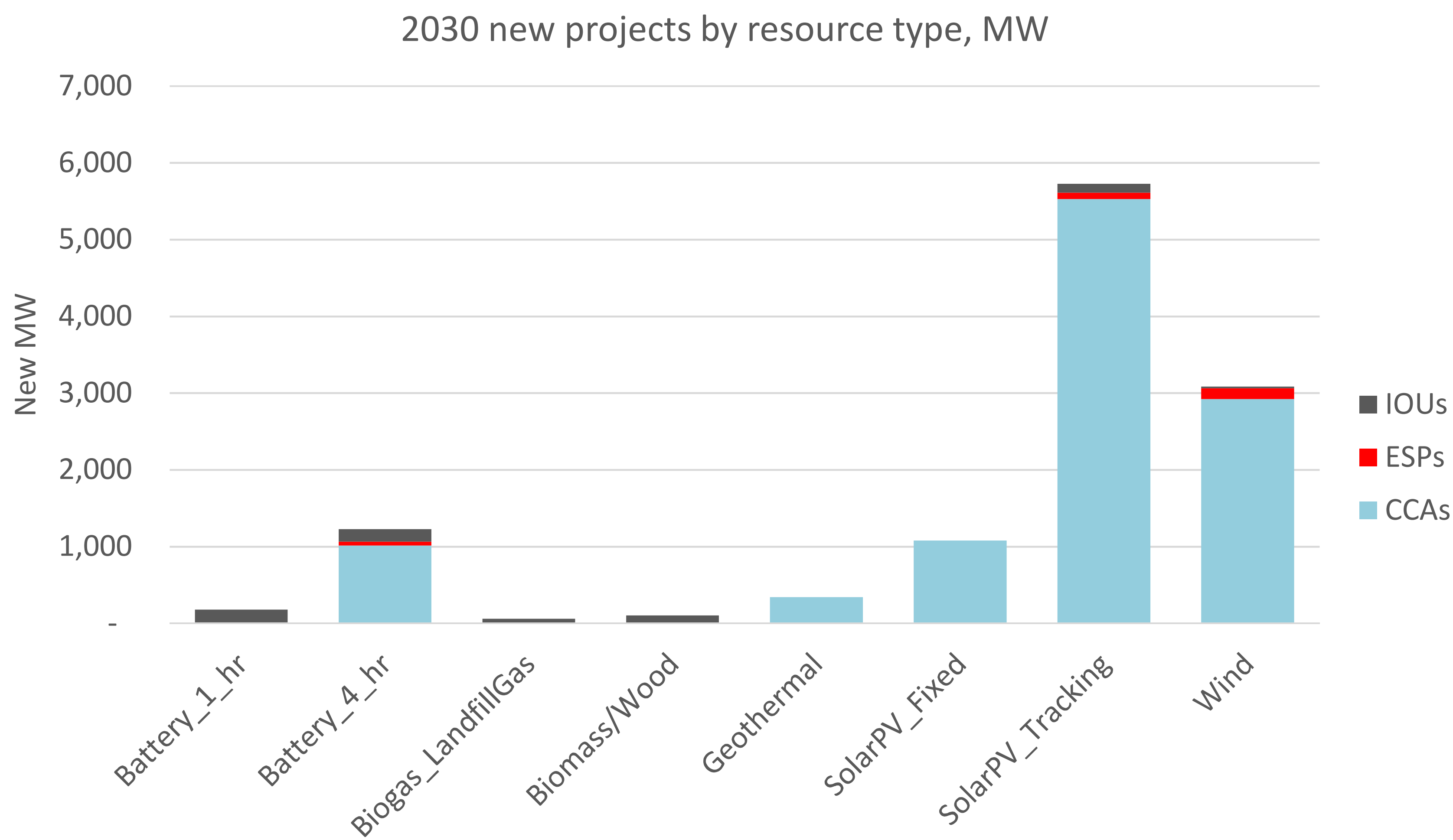
- Does **NOT** include new resources indicated in the LSE "new resource" plans
- Color scale shows the % of available system capacity that is being utilized
- Percentages equal (total LSE conforming plan August NQC MW divided by total CAISO system NQC MW)*100%
  - Numbers less than 100% indicate that there exists uncontracted capacity not included in the LSE conforming plans
    - Green indicates a high amount of uncontracted capacity
    - Yellow and orange indicates less uncontracted capacity
  - Numbers greater than 100% (red) indicate possible over-reliance issues on that resource
- This table does not present an RA assessment and does not imply capacity surplus or deficit from that perspective.

Baseline Capacity Analysis Conclusions

- Over-purchasing of capacity from existing resources is not anticipated to be a problem; there is uncontracted capacity (especially thermal) available to serve load.
  - A small discrepancy in solar thermal could be caused by differing NQC accounting; this issue is minor given that the number of solar thermal MW is small and all units are accounted for with contracts.
  - The 151% over-purchasing of batteries in the previous slide is caused by a proposed purchase of 183 MW of capacity from the Elkhorn/Moss Landing Energy Storage facility which begins in 2021 and goes through 2030, and it is not reflected in the Table A assumptions about available capacity. As overcontracting issues do not appear in any future years, staff believes this to be an accounting discrepancy regarding the year this resource is online.
- A significant quantity of CC, CT, and cogeneration facilities are not included in LSE plans. Possible implications:
  - Many CC and CT plants will lack contracts for output, leading to either merchant status or the potential for retirement. More systematic analysis of this possibility is planned for the 2019 IRP Reference System Plan development process.
  - As a proxy for possible future retirements, the Hybrid Conforming Portfolio being considered as part of the Preferred System Plan includes a 40 year age-based retirement assumption.

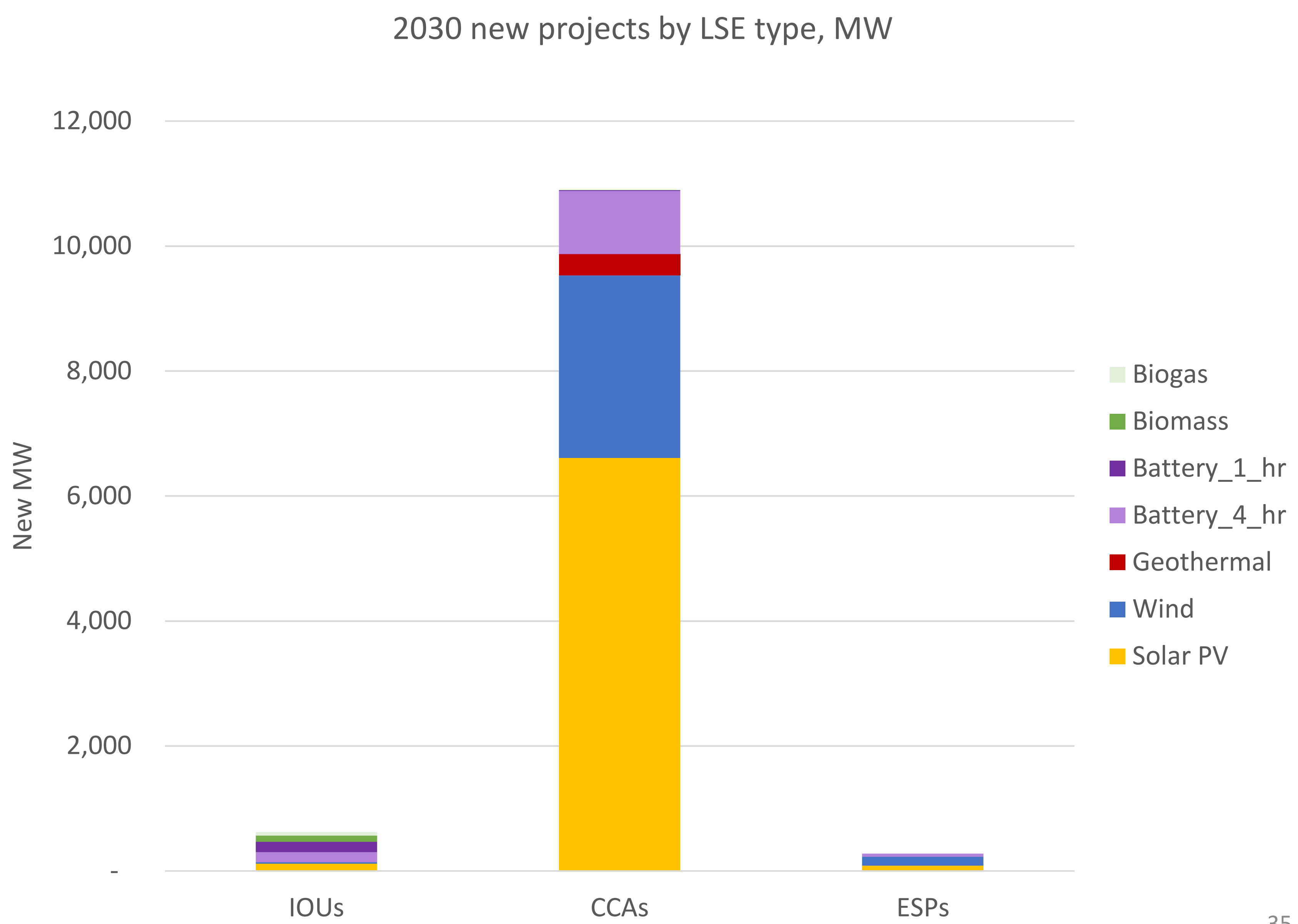
NEW RESOURCE CAPACITY ANALYSIS

The majority of proposed new* capacity is solar, wind, and 4-hour batteries

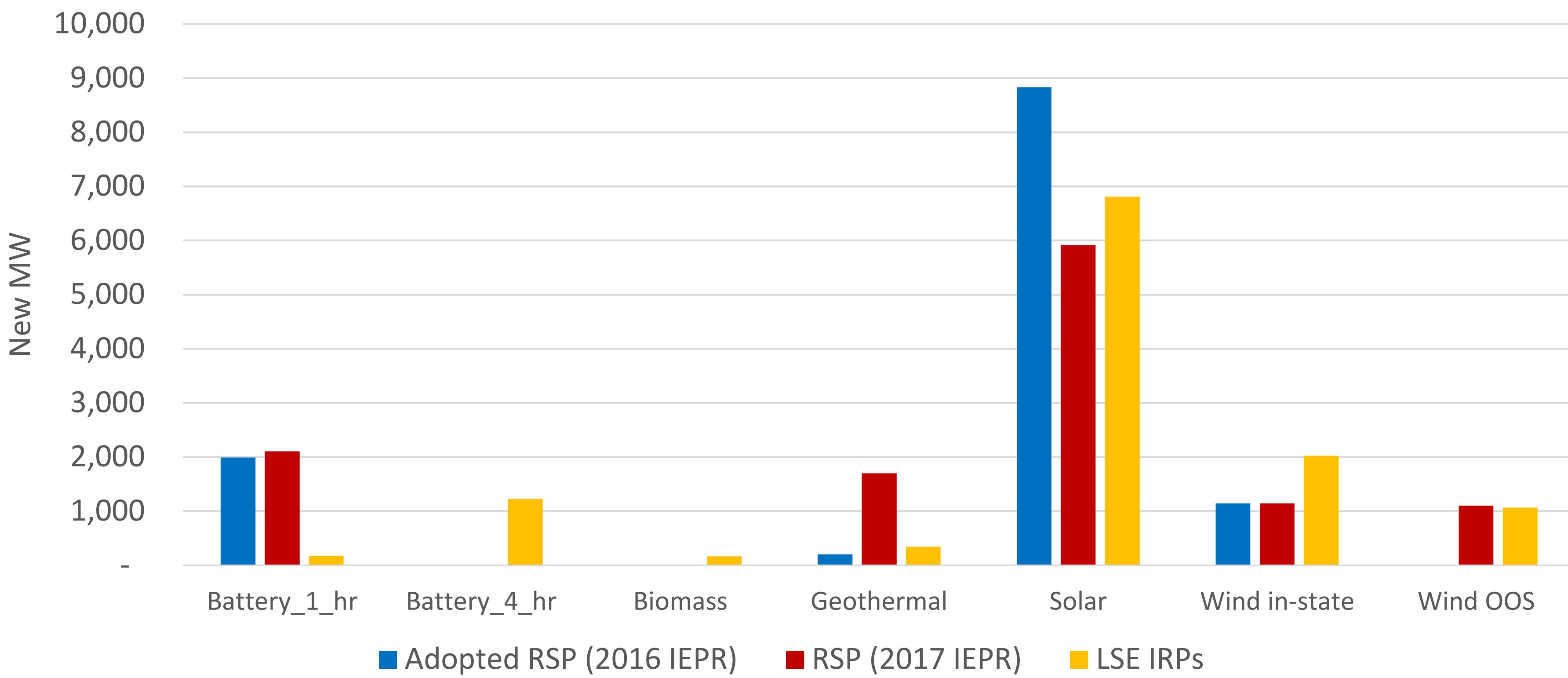


*New resources refers to resources that do not yet exist and are not yet contracted or planned as of 2018, but are included in LSE IRP portfolios and could be built. The CPUC has not formally reviewed or approved the procurement of these resources.

CCAs are proposing the bulk of new resource buildout



New Resources in LSE portfolios compared to 2030 Reference System Plan (RSP)



- Compared to the Reference System Plan (RSP) calibrated with the 2017 IEPR, LSEs plan to purchase:
  - 4-hour batteries generally in lieu of 1-hour batteries
  - About 1,400 MW less geothermal
  - About 900 MW more in-state wind
  - Similar amounts of OOS wind from specific regions like NM and WY

Note: The RSP updated to reflect the 2017 IEPR includes 1,500 MW more geothermal and 2,900 MW less solar PV than the adopted RSP based on the 2016 IEPR, which is provided for comparison purposes. The 2017 IEPR included more BTM PV than the 2016 IEPR, which decreased the value of Utility-Scale PV and increased the value of geothermal and wind in the RSP updated to reflect the 2017 IEPR. See the 3/29/2018 MAG webinar materials located at http://www.cpuc.ca.gov/General.aspx?id=6442451195 for further details.

Reconciliation of Baseline and New Battery Storage

- Staff assumed that all reported IOU battery storage "new build" counts towards the CPUC storage target for IOUs (1,325 MW online by 2024). It is not double counted when combined with assumed generic CPUC battery storage target units already in SERVM.
- A workbook posted to the CPUC IRP website illustrates how the total amount of battery storage in the system is calculated.
  - Existing online battery storage projects in each IOU territory are netted out of the assumed IOU share of the 1,325 MW storage target
  - The remainder is the assumed generic storage build still needed to ensure each IOU meets its share of the storage target
  - New storage proposed in IOU IRPs supersedes this remainder (either replacing a portion or even exceeding the assumed share)
  - Finally, storage proposed by non-IOU LSEs is added on
  - Lake Hodges was assumed to not count towards the CPUC storage target
- The following tables detail the existing online (120 MW) and assumed new batteries (2,360 MW), the sum of which is the total battery storage (2,480 MW) assumed in the CAISO system by 2030
  - PG&E storage procurement recently approved by Commission resolution E-4949 is not comprehensively accounted for in the years before 2024. However, by 2024, the assumed generic storage build in PG&E's planning area that represents achievement of the storage target for IOUs effectively covers the procurement approved in E-4949 (about 568 MW of 4 hour battery storage). This issue is not addressed in the production cost modeling of the Hybrid Conforming Portfolio because only year 2030 is modeled.

Total Existing Online Battery Storage

Existing online battery storage				
CAISO Resource ID	**Technology**	**MW**	**MWh**	**Region**
CHINO_2_APEBT1	Battery Storage	20	80	SCE
ELCAJN_6_EB1BT1	Battery Storage	7.5	32.3	SDGE
ESCNDO_6_EB1BT1	Battery Storage	10	43.2	SDGE
ESCNDO_6_EB2BT2	Battery Storage	10	43.2	SDGE
ESCNDO_6_EB3BT3	Battery Storage	10	43.2	SDGE
KIRKER_1_BATTRY	Battery Storage	2	8	PGE_Valley
MIRLOM_2_MLBBTA	Battery Storage	10	40	SCE
MIRLOM_2_MLBBTB	Battery Storage	10	40	SCE
VSTAES_6_VESBT1	Battery Storage	40	40	SDGE

Total New Battery Storage

Cumulative incremental new battery storage		Nameplate MW			
SERVM unit name	**Type/Duration**	**2022**	**2026**	**2030**	**Region**
hyb_conf_batt_stor_mand_4hr_pge_bay	Battery_4_hr	154	232	232	PGE_Bay
hyb_conf_batt_stor_mand_4hr_pge_valley	Battery_4_hr	230	346	346	PGE_Valley
hyb_conf_batt_stor_mand_4hr_sce	Battery_4_hr	358	540	540	SCE
hyb_conf_batt_stor_mand_4hr_sdge	Battery_4_hr	-	-	-	SDGE
hyb_conf_batt_lse_new_4hr_pge_bay	Battery_4_hr	69	165	186	PGE_Bay
hyb_conf_batt_lse_new_4hr_pge_valley	Battery_4_hr	104	248	280	PGE_Valley
hyb_conf_batt_lse_new_4hr_sce	Battery_4_hr	173	413	466	SCE
hyb_conf_batt_lse_new_4hr_sdge	Battery_4_hr	49	118	133	SDGE
hyb_conf_batt_stor_mand_1hr_sdge	Battery_1_hr	122	166	166	SDGE
hyb_conf_batt_lse_new_1hr_pge_bay	Battery_1_hr	5	11	11	PGE_Bay

Resource potential issues with LSE portfolios

- CPUC staff identified four regions where LSE proposed new wind build may exceed the resource potential assumed in RESOLVE
- RESOLVE resource potential limits are coarse with some uncertainty. Staff chose to firmly adhere to the limits in adjusting the aggregated plans to remove violations.

Region	RESOLVE resource potential (MW)	LSE proposed new wind build (MW)	Amount over potential (MW)
Northern California Wind	0*	438	438
Solano Wind	643	812	169
Southern California Desert Wind	0	120	120
Riverside East Palm Springs Wind	42	100	58

*As described in RESOLVE Inputs and Assumptions documentation, wind potential in Northern CA is assumed to be zero due to the "unproven nature of the resource and expected obstacles in resource permitting." However, the raw source data in RESOLVE does indicate technical potential of about 5.1 GW. Because of this, staff elected to relax this limit when aggregating LSEs' portfolios, as described on a later slide.

Transmission availability issues with LSE portfolios

- CPUC staff identified five regions where LSE proposed new renewable build may exceed the available transmission capacity assumed in RESOLVE
- RESOLVE assumes limits for available Full Capacity Deliverability Status (FCDS) capacity or Energy Only (EO) capacity. The limits are coarse with some uncertainty. Staff chose to firmly adhere to the limits in adjusting the aggregated plans to remove violations.

	RESOLVE available transmission capacity (MW)		LSE proposed new build (MW)		Amount over transmission capacity (MW)	
TX zone	FCDS	EO	FCDS	EO	FCDS	EO
Central Valley North Los Banos	697	0	1,386	19	689	19
Greater Carrizo	0	160	420	0	420	
Southern California Desert	0	0	2,637	34	2,637	34
Northern California	660	4,232	1,568	19	908	
Solano	0	700	967	30	967	

Actions to resolve resource potential and transmission availability issues with LSE portfolios

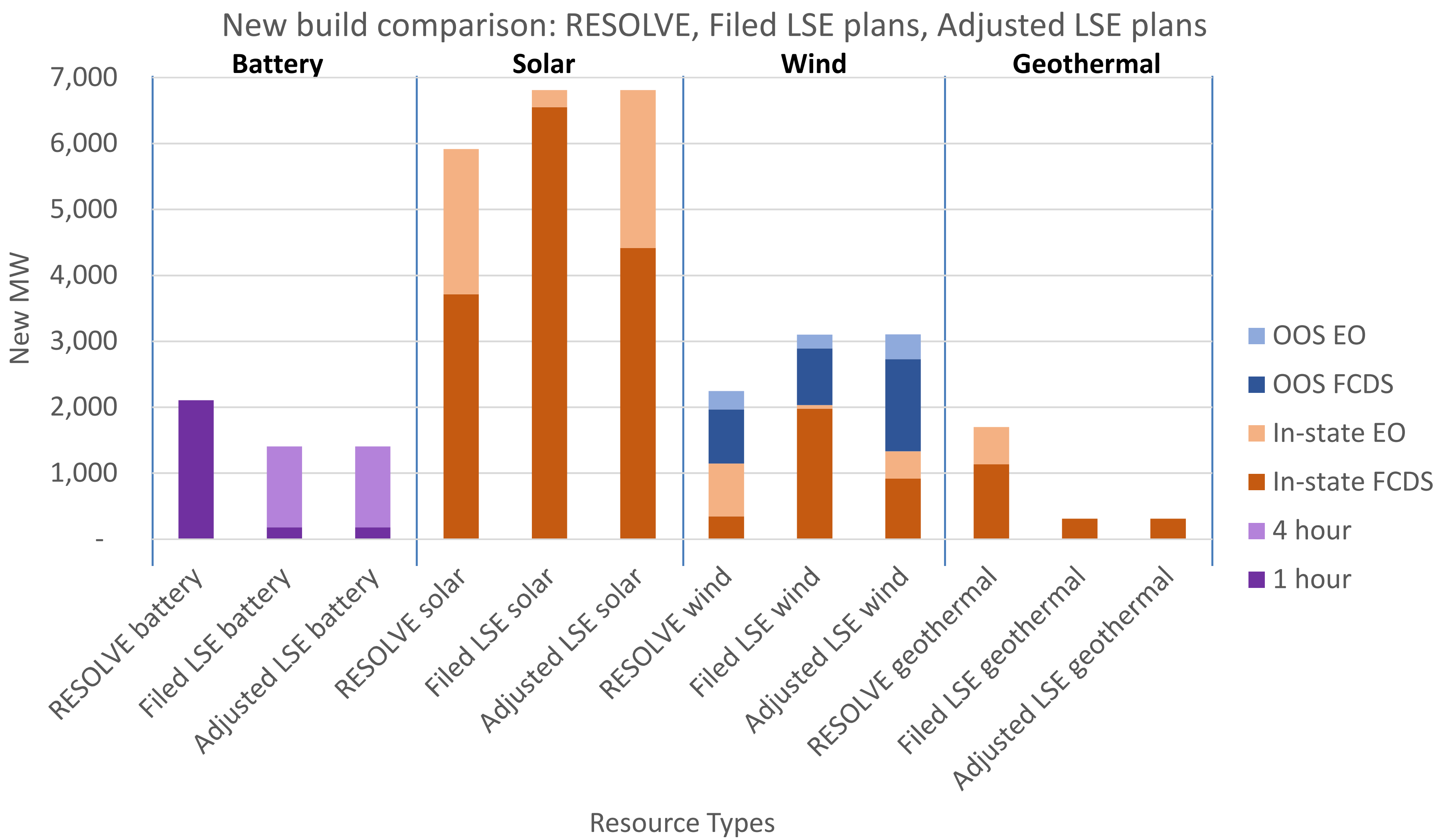
- CPUC staff contacted five LSEs whose portfolios of new resources contained significant resource and transmission oversubscription issues
- Staff confirmed that oversubscriptions indicated in the LSEs' portfolios were not intentional and reflected limitations on information to conduct planning
  - LSEs do not know what specific types and locations they will procure until they conduct solicitations
  - LSEs were asked to provide more precise information than they had available, for example selecting "Tehachapi solar" when selecting "any in-state solar" would be more accurate
- Given the uncertainty in the LSEs' new resource choices that were not backed by signed contracts, it is reasonable to make some adjustments to the resource choices
- Staff made manual adjustments to the location and deliverability status of new resource choices in the aggregate of LSEs' conforming portfolios, such that resource potential and transmission availability issues were resolved
- Staff followed the guidelines described on the next slide

Guidelines for adjusting new build in LSE portfolios

1. Preserved location of resource where possible, either by converting deliverability status to energy-only or moving to an adjacent region
   a. Solar was converted to energy-only more than wind was due to the expected higher capacity value of wind
   b. Use RESOLVE's optimal build as a guide for moving resources to more optimal locations
   c. Where reasonable, move resources with full-deliverability status to regions that had more available transmission capacity
2. Ensure RESOLVE assumed available transmission capacity is not exceeded
3. Ensure RESOLVE assumed resource potential in a region is not exceeded
   a. Exception for Northern California Wind.* RESOLVE screened out 5.1 GW of technical potential to build Northern CA Wind due to uncertainty. However, because of the large technical potential, staff elected to preserve LSEs' proposals to build Northern CA Wind as long as in aggregate they did not exceed the technical potential.
4. LSE choices for OOS wind that may imply transmission upgrades (e.g. Wyoming or New Mexico) were retained. Staff assumed that LSEs intentionally selected this OOS wind as the best option for their needs. Staff contacted individual LSEs to verify the firmness of these choices.
5. The above adjustments were performed only on the new build in 2030. The adjusted 2030 mix of resources was then proportionately applied to amounts of new build in earlier years of the planning horizon.

* As described in RESOLVE Inputs and Assumptions documentation, wind potential in Northern CA is assumed to be zero due to the "unproven nature of the resource and expected obstacles in resource permitting." However, the raw source data in RESOLVE does indicate technical potential of about 5.1 GW.

Adjusted aggregation of 2030 LSE portfolios to match potential limits in RESOLVE



- Total Filed LSE MW by resource type was preserved in the adjustment
- Relative mix of FCDS and EO capacity was adjusted
- OOS wind was increased to preserve LSEs’ preference for wind in certain regions, including AZ, NM, and WY
- No adjustments were made to biomass/biogas so it is not shown to simplify the chart

Summary of adjusted aggregation of 2030 LSE portfolios

- A workbook posted to the CPUC IRP website illustrates the adjusted 2030 LSE new build resource mix and calculations to project that relative mix backwards to the rest of the planning horizon
  - Includes RESOLVE resource names, assignment to SERVM regions, and other details
- The table below summarizes the new build resources by technology type for selected years
  - The battery storage in this table is what was reported in LSE filings and overlaps with some but not all of the remaining generic battery storage assumed to be procured by IOUs to meet the CPUC 1,325 MW storage target by 2024. Refer to the Reconciliation of Baseline and New Battery Storage slide earlier in this section.

Resource Type	**2022 MW**	**2026 MW**	**2030 MW**
Battery_1_hr	127	177	177
Battery_4_hr	414	1,107	1,227
Biogas_LandfillGas	41	61	61
Biomass/Wood	35	86	102
Geothermal	-	-	310
Solar	5,018	6,619	6,807
Wind_In-state	774	1,203	1,329
Wind_OOS	998	1,456	1,773

AGGREGATION OF LSE PLANS: OBSERVATIONS AND CONCLUSIONS

Observations and Conclusions

- **Many thermal resources in the Reference System Plan baseline are not reflected in aggregate LSE plans, especially after 2023**
  - LSEs generally do not have gas/RA contracts in place far into the future, so it is expected that many gas plants do not have contracts post 2023
  - Plants without long-term contracts may or may not choose to retire
- **The feasibility of some LSE Plans is uncertain**
  - Several CCAs (MCE, MBCP, SCP) cautioned against using their 2018 IRP filings for statewide planning activities in this IRP 2017-18 cycle, and instead suggested that the CPUC use their subsequent IRPs, which would be provided at a later date.
  - Aggregate amounts of the LSEs' proposed new resources may not be least-cost or have the lowest impact on the environment and land use, depending on whether those amounts actually exceed transmission constraints or resource potential.
- **Aggregate LSE plans alone do not include sufficient resources on an energy or capacity basis to conduct a reliability analysis**
  - Due to (1) declining planned purchases over time to avoid over-hedging and/or to account for potential load migration; and (2) uncertainty regarding whether or how some baseline thermal resources will participate in the market

Lessons Learned

- Simplify data template and reduce the number of inputs that LSEs must provide
- In aggregating the plans, staff developed metadata tables to help LSEs select from a finite list of pre-defined unit names and types
  - These can be provided in-template for the next cycle of IRP.
  - This has the dual benefit of reducing LSE data development work and minimizing the chance for inconsistencies between filings.
- Provide single identifier for resource from CAISO, TEPPC, or RPS
- Provide more explicit labeling of classes of resources (PCC, CAM, generic RA, etc.)
- Instruct LSEs to clearly distinguish contracted resources from planned purchases that do not have contracts yet
- Instruct LSEs to clearly identify in-state and OOS transmission implications from their selected new resource build
- Staff can build in-template checks and pivot tables to catch errors and display up-front how staff plans to handle data

FEASIBILITY OF HYDROELECTRIC GENERATION USE IN LSE PLANS

Background

- LSEs filed conforming plans showing significant use of in-state and out-of-state hydro, comprising approximately 19% of total planned energy use across the IRP planning horizon
- In their comments filed on LSE Plans…
  - Some parties expressed concern over possible over-reliance on Pacific Northwest (PNW) hydro, with feasibility and emissions impacts needing assessment
  - Other parties stated that planned use of PNW hydro is in-line with historical use
- CPUC staff set out to determine whether the LSEs’ proposed hydro purchases are feasible

Analytic Approach

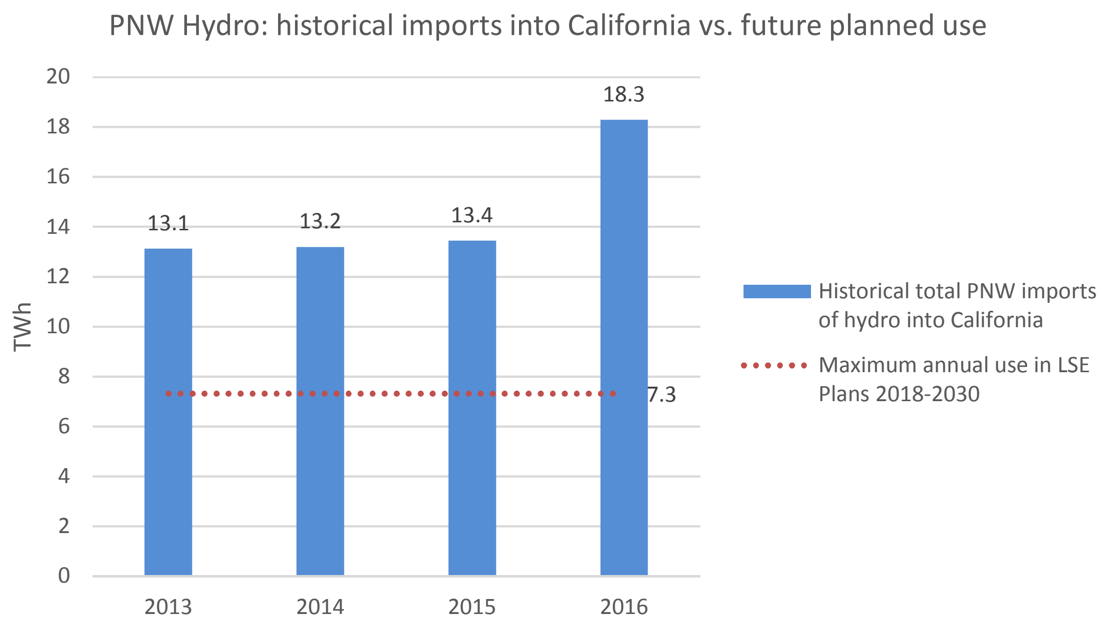
- Key questions analyzed:
  1. Is planned used of PNW feasible (i.e., is resource availability within reasonable expectations)?
  2. Similarly, is planned use of in-state hydro feasible?
- Staff gathered data on:
  - Historical hydro imports
  - Historical in-state hydro production
  - LSEs’ planned use of hydro
- Analysis required addition of publicly-owned utilities’ (POUs) forecast hydro usage to enable like-for-like comparison to statewide hydro production data

Total Statewide Hydro Use

Planned use of hydro energy by Californian entities, by source region and type, TWh

Source Region	Entity Type	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CAISO	LSE	19.28	20.83	20.58	19.47	20.10	19.95	19.88	19.76	19.58	19.30	19.26	19.17	19.11
Non-CAISO CA	LSE	1.62	1.61	1.69	1.49	1.48	1.87	1.86	0.02	0.02	0.03	0.03	0.03	0.00
Non-CAISO CA	POU	4.92	4.86	4.82	4.79	4.71	4.71	4.70	4.51	4.52	4.73	4.73	4.73	4.73
Out-of-State	LSE	4.87	7.50	6.43	6.58	6.31	6.54	6.61	6.69	6.50	6.56	6.50	6.44	6.39
Total	ALL	30.69	34.78	33.53	32.33	32.59	33.08	33.05	30.99	30.62	30.61	30.51	30.37	30.23

Findings on PNW Hydro

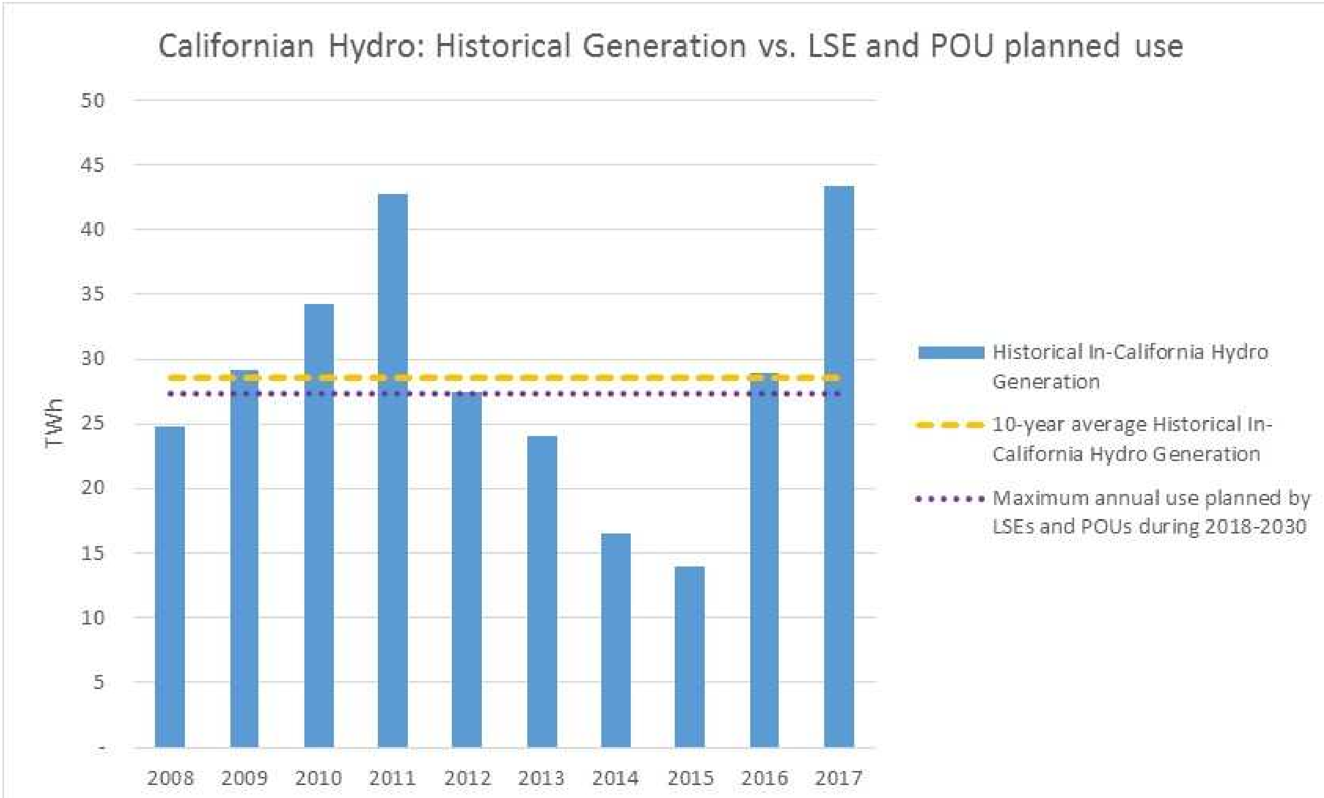


Planned use of PNW hydro is feasible based on historical data

- There appears to be sufficient PNW hydro energy (> 13 TWh/year, even during drought years 2013-2015) to serve the maximum expected LSE need (~7.3 TWh/year)
- Staff have cross-checked this with Northwest Power and Conservation Council's findings from a preliminary study, based on 80 historical water years
- LSEs' planned use of PNW hydro is for energy-only, not capacity

Note: Staff investigated POUs' hydro use and found that POUs do not use significant amounts of hydro from the PNW.

Findings on In-state Hydro



Some risks in planned use of in-state hydro based on historical data

- The maximum planned use of in-state hydro (~27 TWh/year) is only slightly below the average historical generation of years 2008-2017 (~28 TWh/year)
- Historical data indicates high sensitivity to drought conditions, as apparent in years 2013-2015

Conclusions and Next Steps

- The aggregation of LSE portfolios (i.e., Hybrid Conforming Portfolio) is feasible with respect to LSEs' planned use of PNW hydro, based on historical data
- The Hybrid Conforming Portfolio's use of in-state hydro presents some risks based on historical data
- Considerations for the 2019-20 IRP cycle:
  - Revisit RESOLVE's assumption of 8.02 TWh/year of specified hydro from the PNW, which appears too low given historical data
  - Require LSEs to provide a description in their Plans of hedging strategies to address risks of in-state drought
  - Revise the Clean Net Short Calculator to more clearly distinguish between inputs for in-state vs. out-of-state hydro resources
  - Develop filing requirements that enable CPUC staff to analyze and monitor the potential risk of resource shuffling

PCM STUDY OVERVIEW AND INPUT UPDATES

Background

- A September 24, 2018 ruling presented a PCM framework for assessing system reliability and operational performance of the CAISO system
  - Attachment A described guidelines for PCM studies
  - Attachment B presented PCM results with the Reference System Plan with the 2017 IEPR demand forecast
- Parties provided formal comments and replies in October 2018
- Staff held a October 31, 2018 workshop to propose changes to the PCM framework and to present the aggregation of LSE portfolios to be modeled with the revised framework
- A November 15, 2018 ruling formalized revisions to the PCM framework and the aggregation of LSE portfolios to be modeled
  - Attachment A described the revised guidelines for PCM studies
  - The aggregation of LSE portfolios along with various input revisions is defined as the Hybrid Conforming Portfolio – data required for PCM studies is posted to the CPUC IRP website
  - The ruling laid out the schedule for PCM activities to inform the Preferred System Plan

The Hybrid Conforming Portfolio

- The Hybrid Conforming Portfolio represents a combination of the existing baseline resources with the Conforming new resource build-out proposed in the aggregated LSE portfolios, adjusted for assumed physical limitations. It also includes various improvements to PCM input assumptions that were found necessary as a result of comparisons with RESOLVE and party feedback.
- Steps used to build the Hybrid Conforming Portfolio:
  1. Began with the PCM inputs to SERVM for the Reference System Plan with the 2017 IEPR demand forecast that was described in the September 24, 2018 ruling
  2. Replaced the “Selected Resources” (new build) in SERVM to reflect the LSE new build portfolio preferences as submitted in their IRP plans
     - The adjusted aggregation of LSE portfolios merged with the existing SERVM dataset was reposted to the CPUC website. Where necessary, new resources were shifted to different regions than were indicated in LSE portfolios to correct for the transmission potential / resource potential issues described in the October 31 workshop, such that triggering of new transmission build is minimized
  3. Implemented a 40 year age-based retirement assumption for fossil-thermal units
  4. Implemented other model input changes as was described in the November 15, 2018 ruling and in more detail on the following slides.

Overall PCM Framework

- The overall modeling approach was described in detail in the September 24, 2018 ruling Attachment B.
- Probabilistic reliability planning approach (e.g. security-constrained planning) – primary goal is to reduce risk of insufficient generation to an acceptable level
- Uses the Strategic Energy Risk Valuation Model (SERVM),* a probabilistic system-reliability planning and production cost model
  - Configured to assess a given portfolio in a target study year under a range of future weather (35 weather years), economic output (5 weighted levels), and unit performance (outages)
  - Simulate hourly economic unit commitment and dispatch
    - With 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
  - Pipe and bubble representation of transmission system
    - 8 CA regions, 16 rest-of-WECC regions
    - Includes region to region flow limits and simultaneous flow limits

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

Probabilistic Reliability Model Definitions

- Reliability metrics (frequency, duration, and magnitude of reliability events) are reported as expected values (probability weighted averages)
  - To keep run times and file sizes manageable many outputs are aggregated up and/or only reported as an expected value, without reporting the entire distribution.
- Reliability metric definitions – frequency, duration, magnitude:
  - **Loss-of-load event: event** where hourly unit dispatch is unable to serve firm electric demand or necessary reserves (spinning reserves and regulation-up) either by providing capacity or economically curtailing load
  - **Loss-of-Load Expectation (LOLE):** expected **frequency** of loss-of-load events, where multiple events within one day count as one **event** towards the annual total
  - **Loss-of-Load Hours (LOLH):** expected **duration** of unserved electric demand expressed in hours per year, where multiple hours within one day accumulate towards the annual total
  - **Expected Unserved Energy (EUE):** expected **magnitude** of unserved energy, expressed in total MWh of firm electric demand or reserves unserved per year
  - **LOLH/LOLE:** expected average duration of each LOLE event expressed as **hours/event**
  - **Normalized EUE: EUE** normalized by the average annual load level for the target study year
  - **0.1 LOLE per year target:** value for LOLE that corresponds to the "1 day in 10 year" industry standard for probabilistic system reliability, where > 0.1 LOLE indicates a less reliable system and < 0.1 LOLE indicates a more reliable system. There are no commonly accepted standards for the other forms of reliability metrics.

Study Definitions

- Study type definitions:
  - **As-found loss-of-load study:** reliability and production cost study of a given portfolio "as-found" with no changes to the portfolio
  - **Calibrated loss-of-load study:** reliability and production cost study of a given portfolio where additional generation has been added or removed to calibrate the LOLE metric to 0.1 LOLE per year
- Study results presented in the following section compare four types of studies as shown in the table below. All results are for year 2030 unless stated otherwise.

RSP with 2017 IEPR, RESOLVE	RSP with 2017 IEPR, SERVM	Hybrid Conforming, SERVM	Hybrid Conforming, SERVM calibrated LOLE
RESOLVE capacity expansion for the Reference System Plan calibrated to the 2017 IEPR. Results were previously shown in the September 24, 2018 ruling.	SERVM as-found loss-of-load study for the Reference System Plan calibrated to the 2017 IEPR. Results were previously shown in the September 24, 2018 ruling.	SERVM as-found loss-of-load study for the Hybrid Conforming portfolio (which includes a 40 year age-based retirement assumption).	SERVM calibrated loss-of-load study for the Hybrid Conforming portfolio. Additional generation (beyond those retired by the 40 year age-based retirement assumption) has been removed to bring the system to a reliability level of 0.1 LOLE.

Input Updates (1)

- The overall description of inputs was in the Sept. 24, 2018 ruling Attachment B. Inputs have been updated as summarized in the Nov. 15, 2018 ruling.
- The adjusted new build proposed in LSE filings was incorporated.
- Existing units Inland Empire Energy Center Unit 2 (INLDEM_5_UNIT 2, 366 MW) and Gates Peaker (GATES_6_PL1X2, 46 MW) were retired according to the CAISO's recently announced retirement/mothball list.
- BTM PV energy production was scaled down approximately 10% by changing the assumed inverter overloading ratio from 1.1 to 1.0. This more closely matched with the annual energy in the 2017 IEPR demand forecast mid cases.
- Solar PV shapes in SERVM were improved to cap output at AC nameplate. Previously, inverter overloading ratios greater than 1.0 scaled profiles upward without capping output at AC nameplate.

Input Updates (2)

- All fossil-fueled thermal generation units, including cogeneration, were modeled as permanently retired if older than 40 years, unless the unit has a contract that extends its life beyond that point.
- The table below represents the marginal effect of the 40-year assumption in 2030. Note that the previously presented SERVM dataset for the Reference System Plan calibrated to the 2017 IEPR included planned/announced retirements (e.g. once-thru-cooled units). The amounts below represent the ADDITIONAL capacity assumed retired by January 2030 due to the 40-year assumption.

Additional capacity assumed retired by 2030 due to the 40-year assumption, Nameplate MW						
	CCGT	**CT**	**Cogeneration**	**Steam**	**ICE**	**Total**
PGE Bay	0	384	131	0	0	514
PGE Valley	78	25	787	0	0	890
SCE	0	143	1,064	49	0	1,255
SDGE	0	0	109	0	0	109
CAISO	78	552	2,090	49	0	2,768

Input Updates (3)

- Existing out-of-state (OOS) renewables in SERVM were cross-checked with the CPUC's RPS contracts database to determine whether the unit should be modeled as delivering to and balancing within the CAISO, or not. The table below shows the total existing renewables capacity that was changed to deliver to and balance within its home region.
- Certain non-CAISO or OOS gas-fired units are no longer modeled as dynamically scheduled direct imports into the CAISO area. They are now modeled as units economically dispatched primarily into the regions where they are located. This is due to a revised understanding of how dynamically-scheduled resources are used in the CAISO market.

Capacity changed to being economically dispatched in its home region		
Region	**Resource Type or Unit Name**	**Nameplate MW**
IID	Solar PV	75
Various	Wind	2,136
WALC	ARLINT_5_SCEDYN	565
WALC	GRIFFI_2_LSPDYN	570
LADWP	Intermountain_CC_ANAHEIM	159
LADWP	Intermountain_CC_PASADENA	72
LADWP	Intermountain_CC_RIVERSIDE	91
WALC	MSQUIT_5_SERDYN	625
AZPS	YumaCogenCC_Total	63

PCM STUDY SYSTEM RELIABILITY RESULTS

Probabilistic system reliability studies

- Following the steps outlined in the Attachment to the November 15, 2018 ruling, staff used SERVM to conduct probabilistic system reliability and production cost modeling studies for the CAISO area in 2030 with the Hybrid Conforming portfolio
- Staff studied the system “as-found” and found very few loss-of-load events
- Staff then performed a calibrated LOLE study by removing more capacity from the “as-found” system to surface loss-of-load events, up until the point where the LOLE metric reached 0.1 per year
- The following slides present system reliability results and details on the additional capacity that was removed from the “as-found” system to get to the 0.1 LOLE target
- Refer to the preceding PCM Study Overview and Input Updates section for reliability metric and study definitions

Probabilistic system reliability results for the CAISO area, 2030

	RSP w/ 2017 IEPR	Hybrid Conforming	Hybrid Conforming, calibrated LOLE
LOLE frequency (expected outage events/year)	0.00014	0.003	0.142
LOLH duration (hours/year)	0.00014	0.003	0.173
LOLH/LOLE (hours/event)	1.00	1.04	1.22
EUE magnitude (MWh)	0.207	1.21	103.4
annual load (TWh)	254.6	254.6	254.6
normalized EUE (fraction of load)	8.16E-10	4.77E-09	4.06E-07

Findings:

- All loss-of-load metrics (LOLE, LOLH, and EUE) were small for the Hybrid Conforming Portfolio – the system performed more reliably than the 0.1 LOLE standard (i.e. orders of magnitude less than 0.1)
- The process of calibrating to an LOLE target by removing capacity was coarse. The amount of capacity removed resulted in 0.142 LOLE, moderately overshooting the 0.1 LOLE target
- EUE was approximately 100 MWh for the calibrated LOLE study

EUE MWh, by hour and month, for Hybrid Conforming and Hybrid Conforming Calibrated LOLE

	EUE (MWh), Hybrid Conforming											
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	0.00	0.00	0.00	0.00	0.01
19	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.31	0.04	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.09	0.02	0.00	0.00	0.13

	EUE (MWh), Hybrid Conforming Calibrated LOLE											
Hour Ending	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
7	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
9	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.11
19	0.01	0.02	0.00	0.00	0.00	0.00	0.02	4.74	40.53	0.17	0.07	0.59
20	0.04	0.00	0.00	0.00	0.00	0.00	4.66	33.90	10.91	0.03	0.01	0.11
21	0.00	0.05	0.00	0.00	0.00	0.00	0.54	2.24	3.70	0.06	0.09	0.02
22	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.05
23	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
24	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Findings:

- The approximately 100 MWh EUE for the calibrated LOLE system mostly occurred in July-September, Hour Ending 19, 20, and 21 (6 PM – 9 PM).

NOTE: The table only shows hours with nonzero EUE in at least one month. The graded color scale shows the magnitude of the EUE in a given month-hour. Red indicates the largest EUE, followed by orange, yellow, and green.

Methodology for removing capacity in calibrated LOLE study

- Capacity was removed according to the modeling convention described in the November 15, 2018 ALJ ruling attachment:
  - Conventional thermal generators that have announced their retirement will be removed first. If LOLE remains below the target level, additional conventional thermal generation will be removed from CAISO areas in amounts proportional to service area load in each area. The oldest generation in each area will be removed first. No hydro generation or renewable generation will be removed.
- Removed capacity is not indicative of specific excess resources or lack of need for resources in local areas. It is purely an effort to surface system reliability events that do not occur when modeling the Hybrid Conforming Portfolio as found.

Capacity removed from CAISO by 2030, by resource type and region (MW), in order to calibrate to 0.1 LOLE

	CCGT	CT	Cogeneration	Steam	ICE	Total
PGE Bay	102	0	234	0	0	336
PGE Valley	637	192	91	12	49	980
SCE	855	306	82	0	0	1,243
SDGE	0	193	43	0	0	236
CAISO	1,594	691	450	12	49	2,795

NOTE: The capacity removed in the table above is in addition to the capacity assumed permanently retired by 2030 due to the Hybrid Conforming Portfolio 40 year age-based retirement assumption

Interpreting the system reliability results

- The "as-found" system was found to be reliable with measured LOLE much less than the 0.1 LOLE industry standard.
- Additional capacity was removed to surface reliability events. This could be representative of excess system capacity existing above what is sufficient to adequately meet load and reserves. The purpose of doing this and showing these results is to demonstrate how much margin may exist in the system with regards to LOLE specifically.
- Capacity was removed according to a modeling convention and is not meant to predict retirement of units individually or in aggregate. The calibrated LOLE system does not represent a projection of future resource levels or mixes.
- This does not represent a complete reliability assessment, as CPUC staff did not explicitly evaluate sub-hourly flexibility (ramping) needs nor Local Resource Adequacy (RA) needs.
- Hybrid Conforming Portfolio reliability results did record events of shortages of targeted non-spinning reserves. These events occurred somewhat more often than loss-of-load events. However, shortages of targeted non-spinning reserves were not defined as a reliability event and were not analyzed.

PCM STUDY OPERATIONAL RESULTS

System operational results

- The SERVM probabilistic system reliability studies also report production cost modeling metrics and represent the operational performance of a given portfolio and study year, under a range of future weather and economic output
- Staff studied the 2030 Hybrid Conforming portfolio, and the 2030 Hybrid Conforming portfolio calibrated to a 0.1 LOLE target. The following slides report these results and compare them to previously presented results from (1) the RESOLVE RSP with the 2017 IEPR demand forecast, and (2) the SERVM RSP with the 2017 IEPR. Those results were previously presented in the September 24, 2018 ALJ ruling seeking comment.
- Reported on the following slides:
  - System energy balance and generation by resource class
  - Monthly import and export flows
  - Monthly curtailment
  - Hourly dispatch and market price for selected days
  - Annual RPS % for CAISO area
  - Annual production costs for CAISO area

CAISO system balance in 2030

CAISO System balance verification, GWh	RSP with 2017 IEPR, RESOLVE	RSP with 2017 IEPR, SERVM	Hybrid Conforming, SERVM	Hybrid Conforming, SERVM calibrated LOLE
Generation serving CAISO load: includes BTMPV and direct imports; excludes storage discharge and non-PV load modifiers	254,749	269,484	247,300	239,046
Unspecified Imports	12,709	10,985	25,621	32,214
Load after reduction from non-PV load modifiers	255,038	254,601	254,597	254,584
Unspecified Exports	5,686	13,862	9,377	8,424
Battery and Pumped Storage Hydro losses (net of charge and discharge)	3,811	949	1,080	1,129
Curtailment	2,923	11,055	7,866	7,124

- The Hybrid Conforming Portfolios have more imports, less exports, and less curtailment than the RSP with 2017 IEPR, due to decreased in-CAISO generation, including base load resources such as geothermal and cogeneration

NOTES:

- *Green items are "credits" that increase energy in a region, red items are "debits." Total credits minus total debits equals 0*
- *Non-PV load modifiers are the net effect of AAEE, EV, and TOU rates*
- *Generation serving CAISO load amounts are BEFORE curtailment*
- *RESOLVE uses the hourly net of charge and discharge (storage losses) for hourly energy balance (shown in table above). Subhourly charge and discharge is separately tracked in RESOLVE and not included in the RESOLVE value above.*

CAISO generation by resource class in 2030

Generation serving CAISO load by resource type in GWh including in-CAISO generation and direct (specified) imports	RSP with 2017 IEPR, RESOLVE	RSP with 2017 IEPR, SERVM	Hybrid Conforming, SERVM	Hybrid Conforming, SERVM calibrated LOLE
Combined Cycle Gas Turbine (CCGT)	69,371	71,208	74,512	68,271
Combustion Turbine (CT)	26	2,328	2,934	3,450
Steam	0	141	67	0
Coal	0	0	0	0
Biomass	6,792	1,931	2,591	2,630
BTMPV	36,295	42,621	38,746	38,746
Solar PV Fixed + Tracking and Solar Thermal	50,248	52,560	53,587	53,585
Wind	22,579	28,060	24,720	24,720
Scheduled Hydro Plus Run-of-River Hydro	25,317	28,490	28,490	28,491
Geothermal	24,357	23,729	11,293	11,291
Cogeneration	14,759	12,779	5,080	2,696
Nuclear	5,004	5,459	5,459	5,459
Internal Combustion Engine (ICE)	0	179	268	154
Generation subtotal before curtailment	254,748	269,485	247,748	239,493
Curtailment	-2,923	-11,055	-7,866	-7,124
Generation total after curtailment	251,825	258,430	239,882	232,369

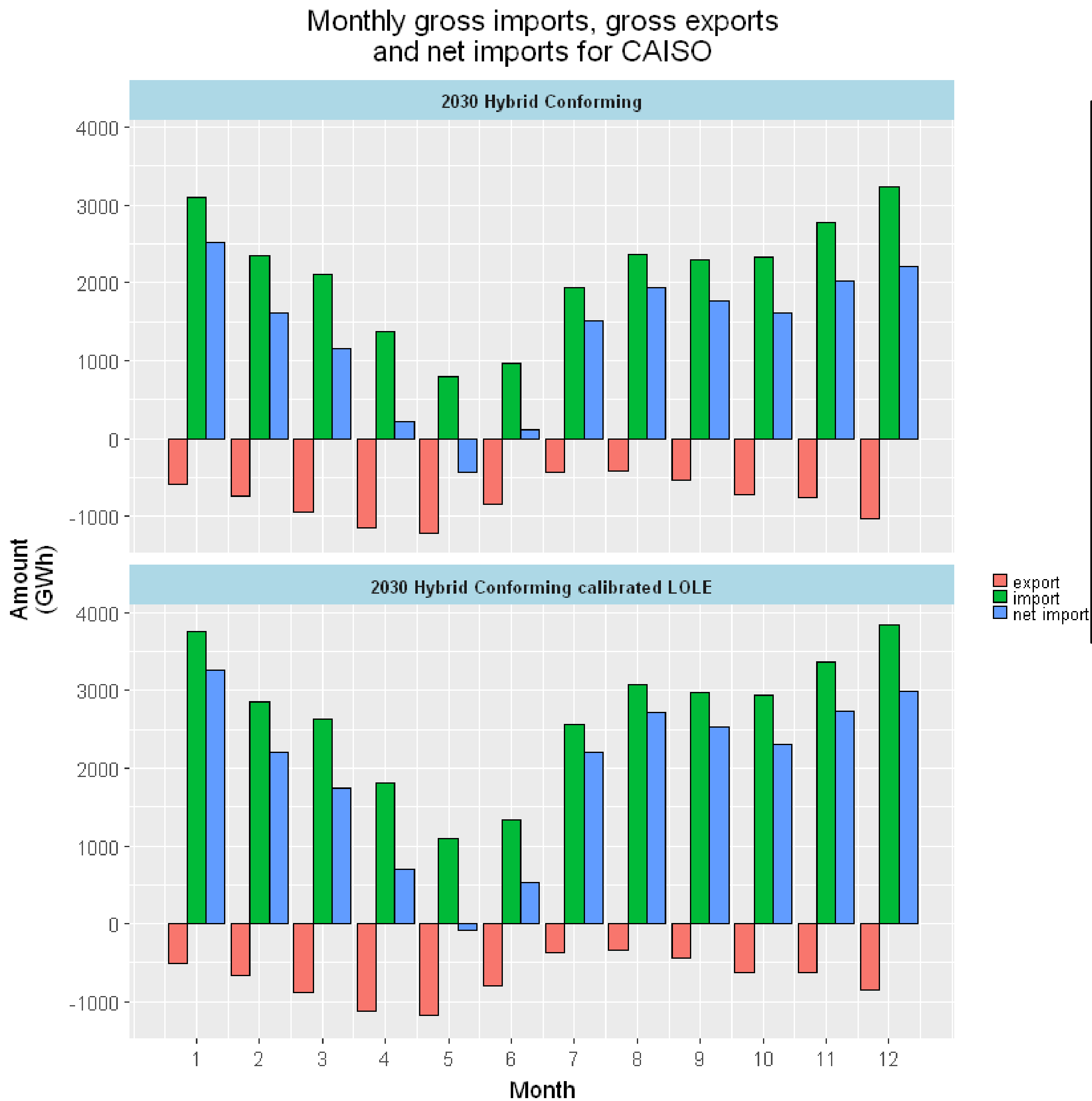
- By default, RESOLVE reports wind and solar generation after curtailment and does not report generation before curtailment. Staff calculated RESOLVE wind and solar generation before curtailment to produce the comparison values in the table above.
- Storage charge/discharge and unspecified imports/exports are not included in this table.

Differences between RESOLVE and SERVM for the RSP with the 2017 IEPR

- Comparisons between RESOLVE and SERVM for the RSP with the 2017 IEPR (first two numerical columns in the preceding table) were previously explained in the September 24, 2018 ruling. In summary:
  - SERVM's dispatchable thermal units were in aggregate less flexible than assumed in RESOLVE, which would contribute to SERVM relying on more peaker use over CCGT use to provide flexibility
  - Some of SERVM's "must-run" units could have a portion of their output economically dispatched whereas RESOLVE's "must-run" units were always running at full output. Thus, SERVM's "must-run" production tended to be less than RESOLVE's.
  - Relative to RESOLVE, SERVM counted more OOS renewables as delivering to CAISO load, and more OOS gas generation as directly importing to the CAISO area, thus contributing to differences in wind and gas generation totals, and import totals.

Differences between SERVM's modeling of the RSP with the 2017 IEPR and the Hybrid Conforming Portfolio

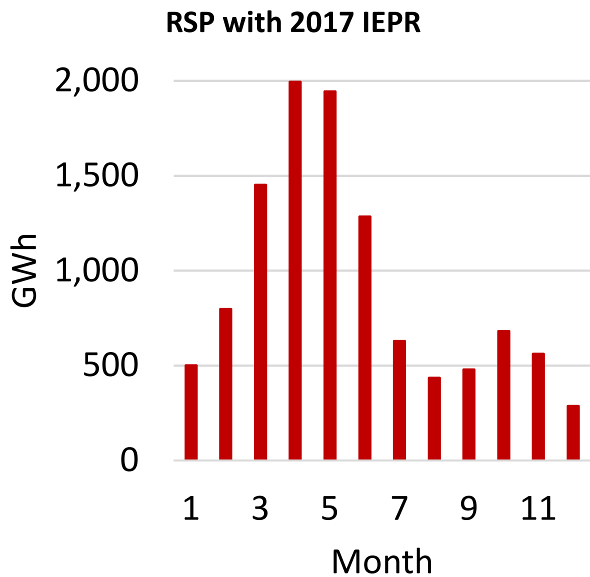
- The Hybrid Conforming Portfolio had less installed capacity from geothermal, wind, and fossil thermal (CCGTs, CTs, and cogeneration), as well as lower assumed BTM PV energy production (reduced capacity factor), each contributing to reductions in annual generation
- The Hybrid Conforming Portfolio had significantly higher unspecified imports to make up for the reduced amounts of in-CAISO generation
- Curtailment in the Hybrid Conforming Portfolio went down because the system had less "must-take" generation
- When additional capacity was removed in the Hybrid Conforming Portfolio calibrated LOLE study, unspecified imports further increased and curtailment further decreased. The additional capacity removed contributed to increased ability to use more renewable output to serve load and increased peaker use to integrate the renewables.
- The changes in the Hybrid Conforming Portfolio from the RSP with the 2017 IEPR also resulted in emissions differences as will be explained later in this presentation.

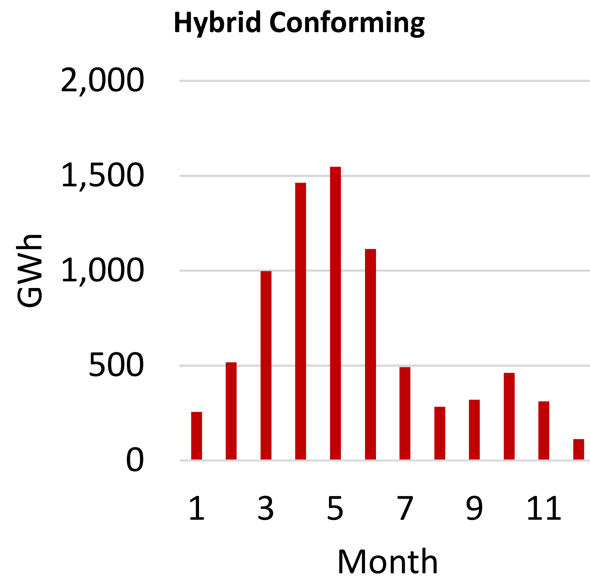


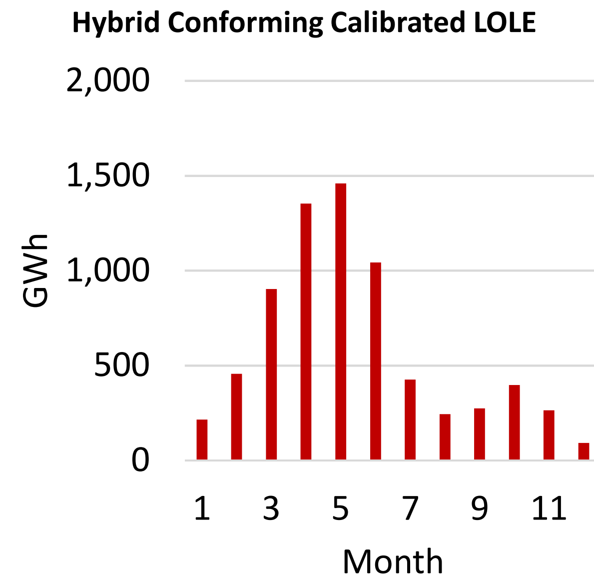
Unspecified imports and exports

CAISO is a net importer for 11 out of 12 months in both the Hybrid Conforming and Calibrated LOLE cases. This is due to decreased reliance on in-CAISO generation due to retiring old plants.

Hybrid Conforming Portfolio CAISO area curtailment decreased moderately relative to RSP with 2017 IEPR SERVM results







Case	2030 Curtailment GWh
RSP with 2017 IEPR	-11,055
Hybrid Conforming	-7,866
Hybrid Conforming Calibrated LOLE	-7,124

- Monthly pattern of curtailment was consistent across all SERVM cases, highest in late spring months.
- Overall level of curtailment dropped between RSP with 2017 IEPR case and the Hybrid Conforming cases – due to input changes including less BTM PV energy, less wind capacity counted as within CAISO, and less baseload geothermal and cogeneration capacity.
- Curtailment dropped a bit more in Hybrid Conforming Calibrated LOLE case – due to even less cogeneration capacity left in the system.

Explanation of how curtailment is modeled in SERVM

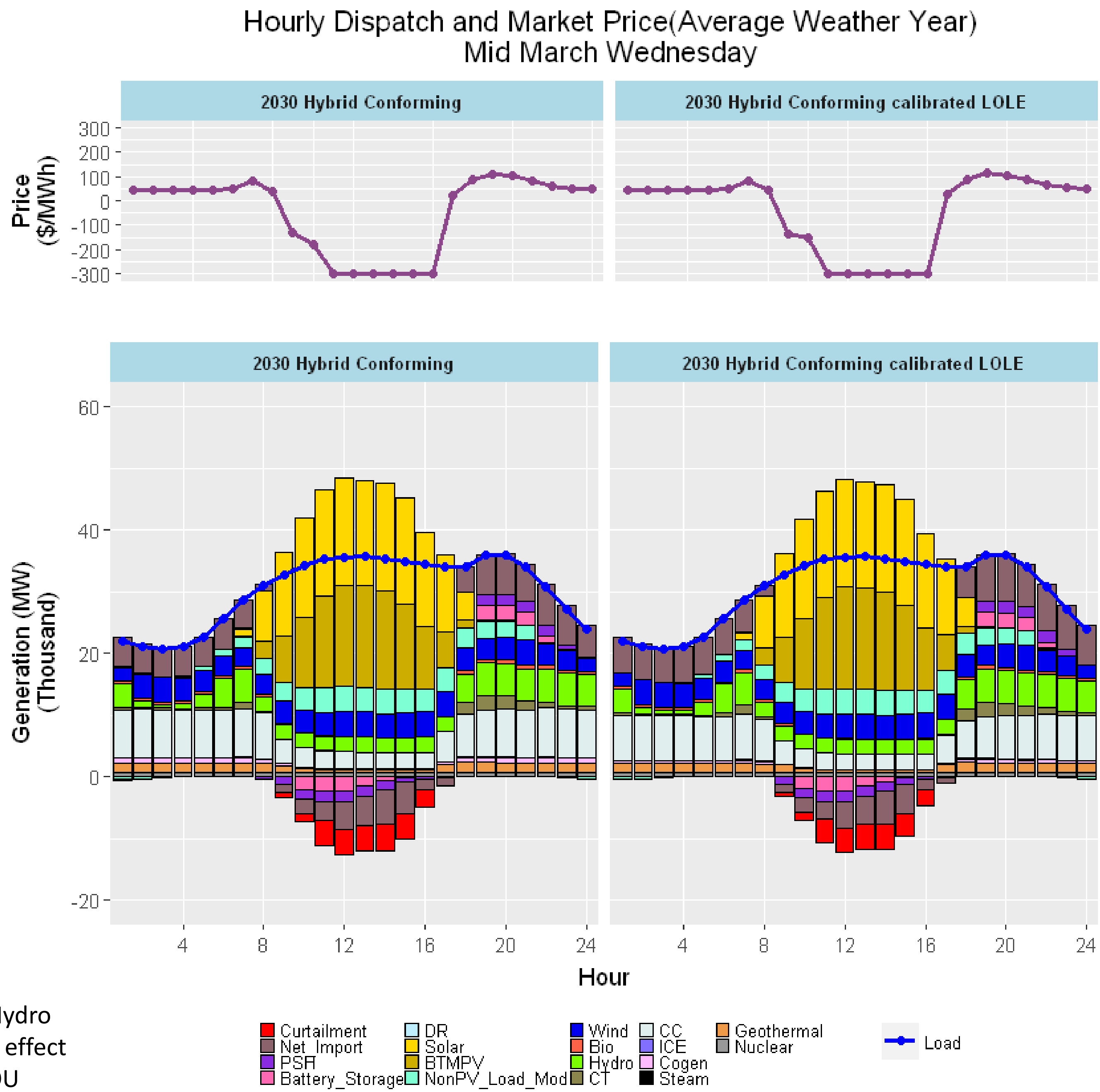
- Energy is dispatched to meet load, but when there is excess energy, some is curtailed.
  - SERVM attempts to sell excess generation over what is needed to meet load.
  - When that ceases to be economical, dispatchable generation is shut down to the extent possible, but sometimes generation cannot be immediately shut down or must be kept at minimum to enable it to serve load later in the day or to provide operational reserves.
  - When generation cannot be economically shut down and energy cannot be sold economically or used to charge storage there is curtailment.
  - In the presence of curtailment, an overgeneration penalty is applied. At low levels of curtailment, the penalty does not overwhelm the other market transactions, but at high levels of curtailment, energy prices have fallen below zero due to the large size of the penalty ($300/MWh) applied in SERVM.
  - Market energy pricing as implemented is a gradient, and negative pricing depends on the quantity of curtailment or if some units have free or low cost curtailment specified.

Hourly Generation Mix and Energy Price

- The purpose of showing hourly dispatch plots is to validate that the model shows realistic dispatch and market price patterns, and to compare with similar results from other production cost models
- The following slides show samples of hourly generation mix and energy price for the Hybrid Conforming portfolio and the Hybrid Conforming calibrated to 0.1 LOLE, under the following conditions:
  - Wednesday mid March, typical weather
  - Wednesday mid March, hot weather
  - Wednesday mid August, typical weather
  - Wednesday mid August, hot weather
- Significant amounts of spring midday excess energy were exported and curtailed, or used to charge storage for use later in the day, consistent with observations shown on earlier slides
- Dispatch patterns were similar between the Hybrid Conforming portfolio and the Hybrid Conforming calibrated to 0.1 LOLE SERVM cases, despite the latter having about 2,800 MW less fossil thermal. The exception was somewhat higher net imports in the latter case, consistent with results shown earlier.

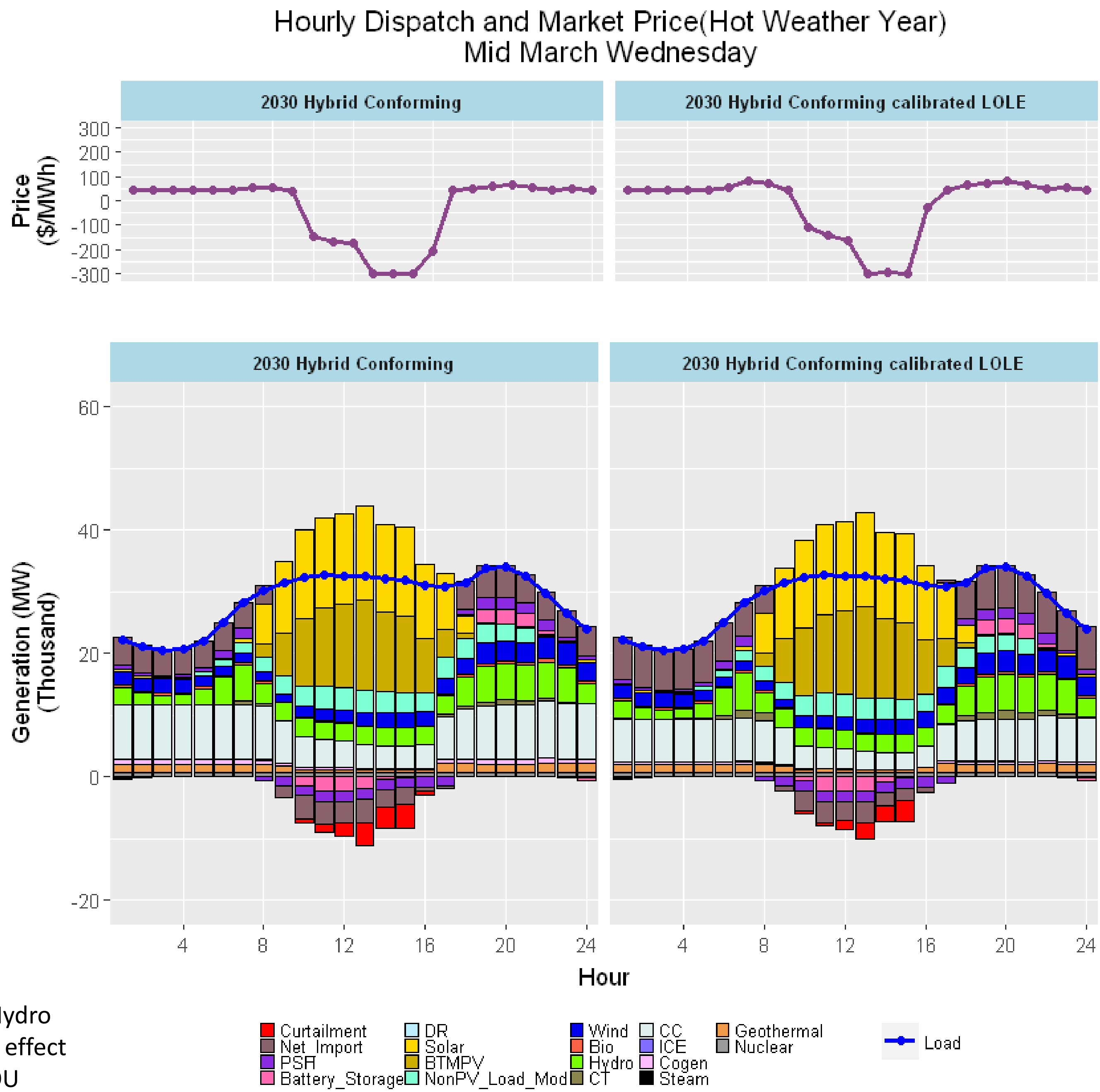
50th percentile March weather (1989, case 43 of 175)

A spring day with median temperatures, negative midday price, and curtailment. System is a net importer when solar is unavailable.



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

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

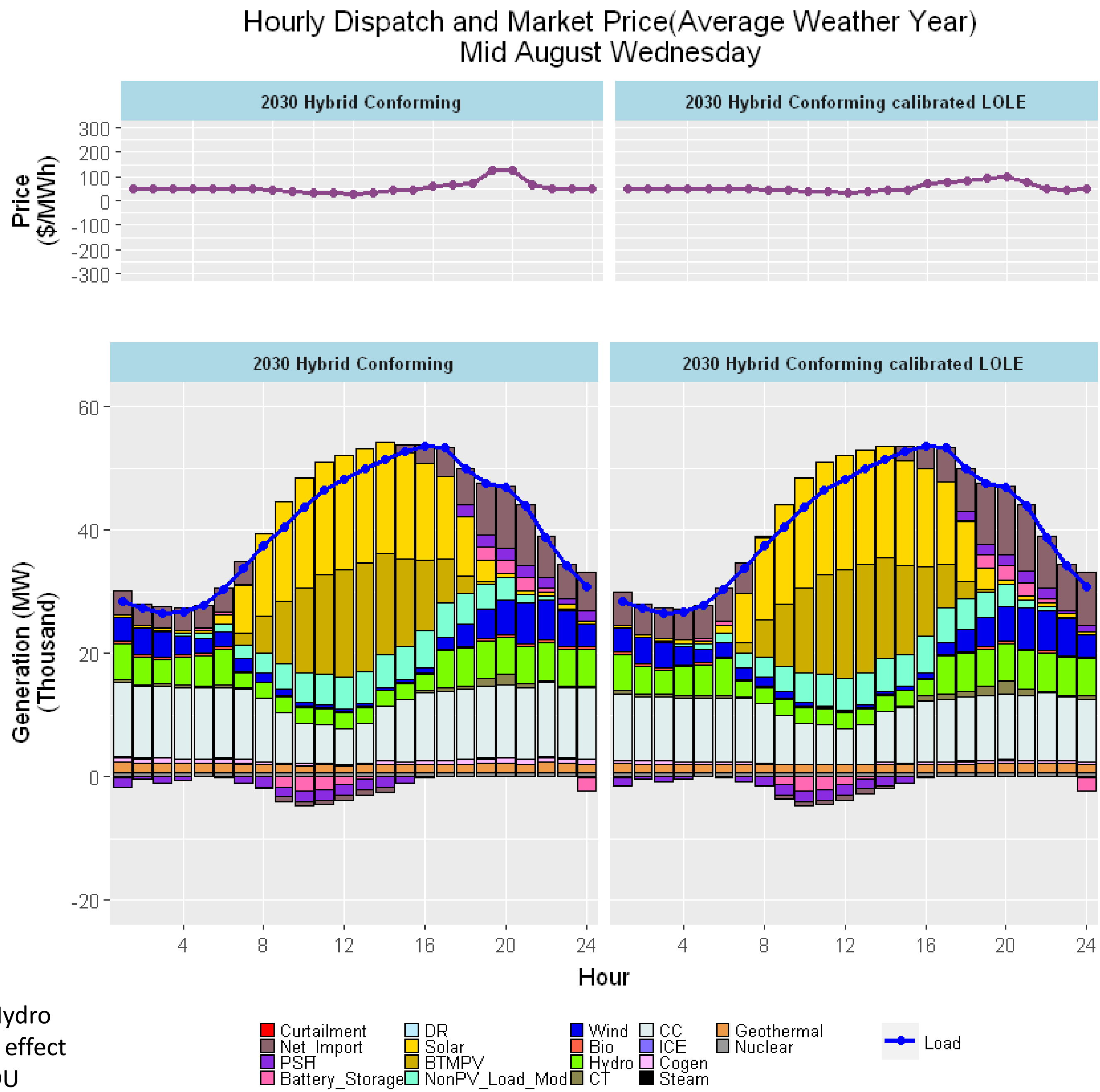


A spring day with hot temperatures, negative midday price, and curtailment. System is a net importer when solar is unavailable.

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

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

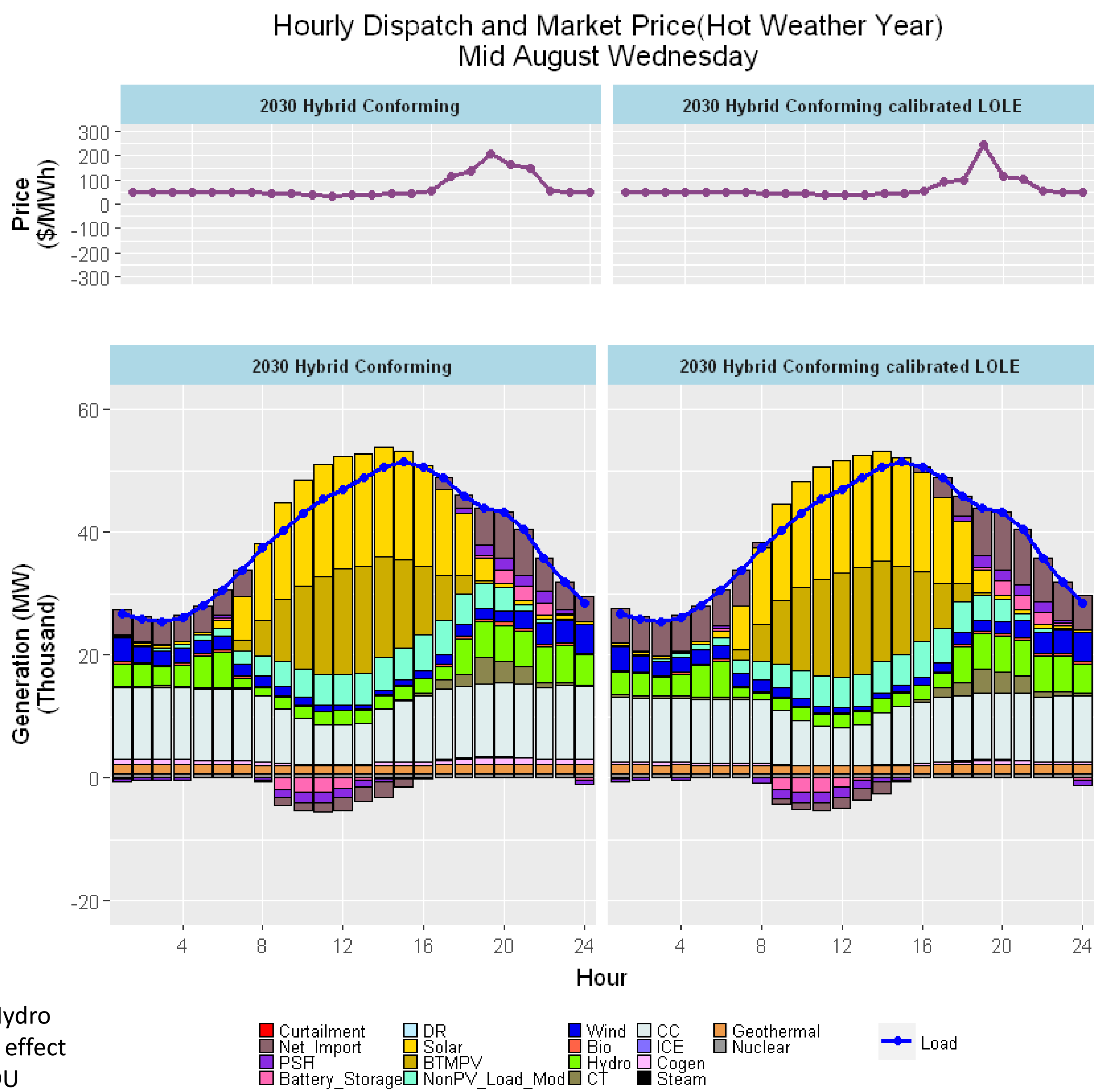
A summer day with median temperatures. There is a price spike for the Hybrid Conforming system around 7-8 PM, possibly due to start up costs of CTs to meet the evening ramp. CTs start up more gradually in the LOLE case, thus the price spike is gradual and spread over a few hours. Curtailment is not significant since load is generally high enough when supply is plentiful.



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 summer day with hot temperatures and higher prices in the 6-9pm hours. Again this is seemingly due to startup of CTs in a group to meet evening ramp.



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

Hybrid Conforming Portfolio achieves at least 50% RPS in 2030

CAISO area RPS% calculation comparison		RESOLVE	SERVM	Hybrid Conforming	Hybrid Conforming Calibrated LOLE
Metric	***Unit***	**2030**	2030	2030	2030
T&D Losses	*%*	7%	7%	7%	7%
Pumping Loads - not grossed up for losses	*GWh*	8,781	8,781	8,781	8,781
Customer_PV (btmpv)	*GWh*	36,295	42,621	38,746	38,746
System Load after non-btmpv load-modifiers & before btmpv reductions	*GWh*	255,038	254,601	254,597	254,584
Metric	***Unit***	**2030**	2030	2030	2030
Delivered RPS Renewables after Scheduled Curtailment	*GWh*	109,136	101,949	91,051	91,826
Non-Modeled RPS Renewables (AESO wind mainly)	*GWh*	2,655			
RPS Spent Bank	*GWh*	8,441	8,441	8,441	8,441
Storage Losses Subtracted from RPS	*GWh*	1,961	949	1,080	1,129
Scheduled Curtailment	*GWh*	2,923	11,055	7,866	7,124
Subhourly Curtailment	*GWh*	1,936			
RPS-bound Retail Sales	*GWh*	193,929	187,661	191,248	191,236
Curtailment (scheduled and subhourly)	*% of RPS Renew.*	4.2%	9.8%	8.0%	7.2%
Curtailment and Storage Losses	*% of RPS Renew.*	5.9%	10.6%	9.0%	8.3%
Delivered Effective RPS Percentage - Excl. Spent Bank	*% of Retail Sales*	55.6%	53.8%	47.0%	47.4%
Spent Bank	*% of Retail Sales*	4.4%	4.5%	4.4%	4.4%
Delivered Effective RPS Percentage - Incl. Spent Bank	*% of Retail Sales*	60.0%	58.3%	51.5%	51.8%

- **Hybrid Conforming had less geothermal, moderately less existing OOS wind counted as in-CAISO, and moderately higher retail sales from less BTM PV energy – leading to a lower calculated CAISO RPS percent**
- Delivered renewables energy including banked RECs must be a certain percentage of "RPS-bound Retail Sales"
- RPS-bound Retail Sales = [System Consumption Load – (Load Modifiers + Btm Pv)] * [1 – T&D Losses] – Pumping Load
- In this context, "PumpingLoad" refers to agricultural/CDWR water pumping load, not pumped hydro storage charging
- Delivered renewables energy = RPS-eligible production – Total Curtailment – Net Losses from storage charging and discharging

2030 CAISO operating costs, $MM

CAISO area operating cost comparison	RSP with 2017 IEPR, RESOLVE	RSP with 2017 IEPR, SERVM	Hybrid Conforming, SERVM	Hybrid Conforming Calibrated LOLE, SERVM
Emissions (from fuel)	859	Operating costs were not calculated for this case due to a small error in fuel prices which would have distorted costs. This error did not materially affect dispatch, so the previously presented dispatch results for this case remain valid.	945	845
Fuel	2,728 (does not include start fuel)		3,266 (includes start fuel)	3,001 (includes start fuel)
Starts	404		30	29
VOM	525		334	313
Direct Imports (cost)	Counted as in-CAISO generation		132	132
Unspecified Imports (cost, including CO2 adder)	555		1,234	1,844
Direct Exports (revenue)	N/A		(1)	(1)
Unspecified Exports (revenue)	(195)		(310)	(282)
Energy credit for OOS renewables contracted to CAISO	(271)		Not calculated	
Total Operating Costs	**4,605**	**N/A**	**5,631**	**5,880**

- **Hybrid Conforming Portfolios relied more heavily on imports, thus the import cost category was higher, consistent with results shown earlier. SERVM also dispatched CTs more often and generally assumed higher heat rates. These factors contributed to overall higher operating costs.**
- Positive numbers represent costs from in-region generation and imports, negative numbers represent revenues (from sales of power to neighboring regions)
- Some of the cost categories in RESOLVE do not match well with the cost categories in SERVM, adding to the comparison challenge. More RESOLVE and SERVM model alignment work is planned for the 2019 IRP Reference System Plan development process.
- “Energy credit for OOS renewables contracted to CAISO” represents revenue from energy sales to non-CAISO areas from renewables contracted to CAISO LSEs. This credit was not calculated for the Hybrid Conforming Portfolios.

PCM STUDY EMISSIONS RESULTS

Refresher: IRP GHG planning targets and previously presented emissions results

- The February 2018 IRP decision, 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 statewide 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 do. Results compiled from SERVM attempt to follow the same counting convention as RESOLVE, excluding any emissions from BTM CHP (generally the non-PV self-generation component of the IEPR demand forecast).
- Previously presented SERVM modeling of the RSP with the 2017 IEPR reported higher emissions (38 MMT in 2030) than RESOLVE (34 MMT in 2030). This was due to a number of differences between the two models that remain to be reconciled. Much better agreement between the two models is anticipated in the next (2019) IRP RSP development process.
- The Hybrid Conforming Portfolio is significantly different from the current RSP with the 2017 IEPR and will have different emissions. Results for CO_2 emissions as well as criteria pollutants (NO_x, $PM_{2.5}$) are presented in the following slides.

2030 CO2, NOx, PM2.5 emissions, by region

CAISO	Units	RSP with 2017 IEPR, SERVM	Hybrid Conforming, SERVM	Hybrid Conforming, SERVM calibrated LOLE
CO2	MMT	38.2	42.7	41.9
NOx Total	Metric Ton	4,019	3,491	3,173
NOx Steady-state	Metric Ton	3,650	3,190	2,877
NOx Starts	Metric Ton	370	301	296
PM2.5	Metric Ton	2,056	1,943	1,736
California	**Units**	RSP with 2017 IEPR, SERVM	Hybrid Conforming, SERVM	Hybrid Conforming, SERVM calibrated LOLE
CO2	MMT	48.1	49.6	49.2
NOx Total	Metric Ton	5,116	4,659	4,404
NOx Steady-state	Metric Ton	4,586	4,198	3,932
NOx Starts	Metric Ton	530	461	471
PM2.5	Metric Ton	2,594	2,525	2,342
WECC	**Units**	RSP with 2017 IEPR, SERVM	Hybrid Conforming, SERVM	Hybrid Conforming, SERVM calibrated LOLE
CO2	MMT	266.45	270.42	270.07

NOTES:
For CAISO and California:
- *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.*

For the entire WECC region:
- *CO2 emissions are equal to the sum of CO2 emissions from all generators in the WECC.*

CAISO CO2 Emissions in 2030: Detailed breakdown

Thermal generation serving CAISO load and CO2 emissions	RSP with 2017 IEPR, RESOLVE	RSP with 2017 IEPR, SERVM	Hybrid Conforming, SERVM	Hybrid Conforming, SERVM calibrated LOLE
In-CAISO and gross direct imports thermal generation in GWh	84,156	86,635	82,861	74,571
In-CAISO and gross direct imports CO2 emissions in MMT	31.38	36.29	34.53	30.86
In-CAISO and gross direct imports average emissions factor in MT/MWh	0.373	0.419	0.417	0.414
Gross unspecified imports in GWh	12,709	10,985	25,621	32,214
Gross unspecified imports CO2 emissions in MMT	5.44	4.70	10.97	13.79
Gross unspecified imports average emissions factor in MT/MWh	0.428	0.428	0.428	0.428
NW Hydro Credit in MMT	-2.8	-2.8	-2.8	-2.8
Total CO2 emissions in MMT	**34.0**	**38.2**	**42.7**	**41.9**

NOTES:

- *These emissions totals only include fossil resources. They do not include emissions from biomass, biogas, or geothermal.*
- *The NW Hydro Credit is an adjustment inherited from RESOLVE to account for assumed amounts of specified hydro imports coming from the Pacific Northwest into California.*
- *The unspecified imports in all cases likely include some amount of GHG free resources that are under energy and REC contracts with CAISO LSEs. This implies that the CO2 emissions contribution from unspecified imports are likely a high bookend estimate.*

Conclusions on CO2 Emissions

- Although CAISO thermal generation is lower in the Hybrid Conforming than in the RSP (partially due to moving OOS Combined Cycles to their "home" region), emissions are higher in the Hybrid Conforming plans due to:
  - An increased reliance on unspecified imports (to replace generation removed with the 40 year retirement assumption for thermal resources)
  - Less geothermal and existing OOS wind serving CAISO load, and lower BTM PV energy production.
  - LSEs in their IRP plans are partially responsible for the increased emissions, as they recommended greater reliance on solar and wind and less on geothermal, which resulted in less baseload renewable generation, less RPS eligible energy, and greater reliance on imported energy.
- The Hybrid Conforming calibrated LOLE results show that removing even more fossil thermal may reduce some curtailment of renewables, and thereby lower emissions modestly. However, this increases the likelihood of loss-of-load.

Conclusions on CO_2 Emissions (cont'd)

- Comparing the Hybrid Conforming study to the Hybrid Conforming Calibrated LOLE study, WECC-wide CO_2 emissions decreased only slightly (by 0.35 MMT CO_2) due to the retirement of in-CAISO fossil resources. This is because these generators were replaced by increased use of out-of-state thermal resources, especially coal and CC plants.
- Overall emissions declined however due to removal of some generation that was likely to contribute to curtailment (like cogeneration).
- This is shown in the table below. Green numbers represent reductions in carbon emissions, red numbers represent increases.

Change in MMT of CO_2 emissions by region and unit type, Hybrid Conforming Study minus Hybrid Conforming Calibrated LOLE study

	CAISO	Non-CAISO CA	OOS	**Total**
CC	-2.72	0.30	1.11	**-1.32**
Coal	0.00	0.00	1.34	**1.34**
CT	0.33	0.12	0.40	**0.84**
Cogen	-1.15	0.00	0.00	**-1.15**
ICE	-0.06	0.00	0.00	**-0.06**
Steam	-0.05	0.00	0.05	**0.00**
Total	**-3.66**	**0.42**	**2.90**	**-0.35**

Methods and assumptions for estimating criteria pollutant emissions

- CPUC staff estimated total NOx and PM 2.5 emissions as the sum of emissions from steady-state operations and hot, warm, and cold starts
  - Staff used fuel burn, number of hot/warm/cold starts, and MWh generation output from SERVM, applying appropriate emissions factors
  - For NOx, staff used higher emissions factors for hot, warm, and cold starts compared to steady-state
  - Where information on generator subtype was available (e.g. CCGTs can be divided into Aero CC, Single Shaft CC, Industrial CC, etc.), staff used that subtype to determine emissions factor, as emissions can vary substantially across subtype
  - No factors for "warm" starts were available, so staff used a simple average of hot and cold factors as an estimate
  - Data sources were itemized in the September 24, 2018 ruling
- Criteria pollutant emissions were counted from in-CAISO thermal generation only. Unspecified import criteria pollutants are not counted.
- Staff calculated emissions for all of CA, and grouped by whether the plant was located in a Disadvantage Community (DAC) area or not. Staff used this list to determine the location of plants with respect to DACs: RESOLVE Post-Processing Air Pollution and DAC Analysis 2017-09-19

Corrections to previous criteria pollutant results

- The results presented in the September 24, 2018 ruling contained a minor error in calculating start emissions from NOx. Warm start and cold start emissions factors were mistakenly transposed and mislabeled. Warm start factors were erroneously applied to cold starts, and vice versa. Staff appreciates parties finding this error and has corrected it.
- Staff investigated the impact of this error on the SERVM results for the RSP with the 2017 IEPR and found that California NOx emissions were overstated by about 100 metric tons in 2030. The old result is 5,245 metric tons NOx (statewide), and the new corrected result is 5,116 metric tons (statewide).
- Staff has posted the updated emissions factors table at the URL below: ftp://ftp.cpuc.ca.gov/resources/electric/irp2019/Table1_Clarifications.PNG
- This table also contains a correction for a data entry error in the hot start values, but this was a copy-paste error that was introduced when posting the table, after the calculations were performed. Staff confirmed that the correct hot start value was used in the calculation.

Details: Hybrid Conforming 2030 California NOx, PM2.5 emissions

NOx emissions in metric tons, by operation state and resource type							
	CC	CT	Coal	Cogen	ICE	Steam	TOTAL
steady state	3,314	391	0	429	60	5	4,198
hot start	87	40	0	3	2	0	132
warm start	21	209	0	2	11	0	244
cold start	32	48	0	2	3	0	86
total	3,455	688	0	436	76	5	4,659

PM 2.5 emissions in metric tons, by resource type							
	CC	CT	Coal	Cogen	ICE	Steam	TOTAL
steady state	2,187	155	0	168	12	3	2,525

NOTES:

- *NOx and PM2.5 emissions are from in-state generation. CC = Combined Cycle, CT = Combustion Turbine, ICE = Internal Combustion Engine.*
- *The Sept. 2017 Proposed Reference System Plan analysis estimated NOx from CCs in steady state as roughly 2,700 metric tons in 2030, statewide. This SERVM analysis estimates 3,314 metric tons in 2030, statewide. SERVM's higher number is due to multiple factors: some of SERVM's CCs were assigned higher NOx emissions factors based on technology, and CCs run more in SERVM than in RESOLVE.*

Details: 2030 Hybrid Conforming NOx and PM2.5 emissions (Metric Tons) for all California, grouped by plants located inside/outside Disadvantaged Communities areas

		Inside DAC Emissions							Outside DAC Emissions						
		CC	CT	Coal	Cogen	ICE	Steam	TOTAL	CC	CT	Coal	Cogen	ICE	Steam	TOTAL
NOx emissions, by operation state and resource type	steady state	761	146	0	55	0	0	962	2,553	244	0	374	60	5	3,236
	hot start	29	16	0	1	0	0	46	58	25	0	1	2	0	86
	warm start	1	52	0	0	0	0	53	21	158	0	2	11	0	191
	cold start	1	10	0	0	0	0	11	31	38	0	1	3	0	74
	total	792	223	0	57	0	0	1,072	2,663	465	0	379	76	5	3,587
PM 2.5 emissions	total	543	55	0	23	0	0	621	1,644	100	0	145	12	3	1,904
Capacity in region, MW		5,466	3,106	0	299	0	0	8,871	16,678	7,274	0	957	211	12	25,132

NOTE: This table estimates emissions from plants and groups them by location inside and outside DAC areas. This DOES NOT estimate how these emissions impact air quality inside or outside of DAC areas. Air quality is influenced by multiple factors including accounting for wind patterns and other emissions sources, and requires analysis beyond what was done here.

Data sources for criteria pollutant emissions estimation (1)

Generator Type	Item	Units	Quantity	Organization	Source Name	Page and table number	Hyperlink
Coal	Heat Content	MMBTU/US ton coal	19.78	EIA	EIA FAQ: What is the heat content of US Coal?	N/A	https://www.eia.gov/tools/faqs/faq.php?id=72&t=2
Coal	Ash Percentage	%	6.44%	US Geological Survey	Quality of Economically Extractable Coal Beds in the Gillette Coal Field as Compared With Other Tertiary Coal Beds in the Powder River Basin, Wyoming and Montana	p. 11 Table 3, Mean ash content from Powder River Basin	https://pubs.usgs.gov/of/2002/ofr-02-0174/ofr-02-0174po.pdf
Coal	PM 2.5 Emissions Factor	lbs/US ton of coal burn	0.4011592	Argonne National Labs	Updated Greenhouse Gas and Criteria Air Pollutant Emission Factors and Their Probability Distribution Functions for Electric Generating Units	p. 15 Table 5. Assumed scrubber, subtuminous coal, boilers, pulverized, dry bottom, flue gas desulfurization .	https://greet.es.anl.gov/publication-updated-elec-emissions
Coal	Steady-state NOx Emissions Factor	lbs/mmbtu	0.075	DOE National Energy Technology Laboratory	Cost and Performance Baseline for Fossil Energy Plants	p. 15, Exhibit ES-2, Colum B11B Nox Emissions (lb/MMBtu)	https://www.netl.doe.gov/File%20Library/Research/Energy%20Analysis/Publications/Rev3Vol1aPC_NGCC_final.pdf

Data sources for criteria pollutant emissions estimation (2)

Generator Type	Item	Units	Quantity	Organization	Source Name	Page and table number	Hyperlink
All Non-Coal Thermal	PM 2.5 Emissions Factors	lbs/mmbtu	range depending on subtype: 0.0066 to .01	CAISO	Senate Bill 350 Study Volume IX: Environmental Study	p.98 Table 4.4-2	http://www.caiso.com/Documents/SB350Study-Volume9EnvironmentalStudy.pdf
All Non-Coal Thermal	Steady State NOx Emissions Factors	lbs/MWh	range depending on subtype: 0.07 to 0.5	CAISO	Senate Bill 350 Study Volume IX: Environmental Study	p.98 Table 4.4-2	http://www.caiso.com/Documents/SB350Study-Volume9EnvironmentalStudy.pdf
All Thermal	Hot Start NOx Emissions Factors	kg/MW nameplate/ start	range depending on subtype: 0.05 to 1.12	Renewable and Sustainable Energy Reviews	Review of the operational flexibility and emissions of gas- and coal-fired power plants in a future with growing renewables	p. 1507 Table 14	https://www.sciencedirect.com/science/article/pii/S1364032117309206
All Thermal	Cold Start NOx Emissions Factors	kg/MW nameplate/ start	range depending on subtype: 0.07 to 1.57	Renewable and Sustainable Energy Reviews	Review of the operational flexibility and emissions of gas- and coal-fired power plants in a future with growing renewables	p. 1507 Table 14	https://www.sciencedirect.com/science/article/pii/S1364032117309206
All Thermal	Warm Start NOx emissions factors	kg/MW nameplate/ start	range depending on subtype: 0.07 to 1.35	Renewable and Sustainable Energy Reviews	Review of the operational flexibility and emissions of gas- and coal-fired power plants in a future with growing renewables	Simple Average of Hot and Cold	https://www.sciencedirect.com/science/article/pii/S1364032117309206

Corrected NOx emissions table (Table 1 in Attachment B of 11/29/18 Ruling Seeking Comment on Inputs and Assumptions)

Table 1 Proposed NOx (tons/MWh for steady state, tons/MW for starts) emissions factors for 2019 RSP

Type	Steady-state	Hot	Warm	Cold
Combined Cycle (Industrial)	3.45E-05	5.0E-05	2.25E-04	4.0E-04
Combined Cycle (Aero)	3.18E-05	7.0E-05	7.0E-05	7.0E-05
Combined Cycle (Single Shaft)	3.18E-05	5.0E-05	2.25E-04	4.0E-04
Combustion Turbine (Aero)	4.49E-05	7.0E-05	7.0E-05	7.0E-05
Combustion Turbine (Industrial)	1.27E-04	7.0E-05	3.35E-04	6.0E-04
Internal Combustion Engine	2.27E-04	7.0E-05	3.35E-04	6.0E-04
Steam Turbine, Boiler	6.8E-05	7.0E-05	3.35E-04	6.0E-04
Steam Turbine, Boiler with Combined Cycle Single Shaft	4.99E-05	5.0E-05	2.25E-04	4.00E-04

PCM STUDY CONCLUSIONS AND RECOMMENDATIONS

High Level Conclusions

- Significant progress has been made developing the SERVM model dataset and exercising Energy Division staff's production cost modeling process both modeling the Reference System Portfolio and the Hybrid Conforming Portfolio
- Staff modeled the Hybrid Conforming Portfolio and found:
  - Minimal LOLE orders of magnitude less than the 0.1 LOLE industry standard and minimal EUE when implementing the 40 year retirement assumption.
  - When surfacing LOLE by removing about 2,800 MW of fossil capacity from the system, staff observed LOLE mostly in the summer months.
  - Curtailment decreased from retirement of some baseload generation, less geothermal, less BTM PV energy production, and less existing OOS wind counted as in-CAISO
  - Loss of in-CAISO generation was replaced by increased use of unspecified imports, which contributed to higher production cost and total emissions

High Level Recommendations

- The Commission should adopt the Hybrid Conforming Portfolio as the 2018 Preferred System Portfolio for this IRP 2017-18 cycle.
- The Hybrid Conforming Portfolio reflects LSE planning preferences and is a reliable and operable portfolio that can be studied further in the CAISO's TPP to assess transmission implications.
- Aligning inputs to RESOLVE and SERVM and converging outputs at the beginning of the next Reference System Plan development process is a major goal.
- After sufficient alignment between RESOLVE and SERVM, the GHG target can be recalibrated to ensure policy goals can be met