Assessment of the CPUC-Selected 38 MMT Integrated Resource Plan Portfolio

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California Independent System Operator

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1. Executive Summary

The California Public Utilities Commission (CPUC) adopted in Decision (D.) 20-03-028 a 2019-20 Reference System Portfolio (RSP) with a 46 MMT CO2 emission target. The CPUC also provided a second portfolio with a 38 MMT CO2 emission target. CPUC-jurisdictional load serving entities (LSEs) were required to file conforming individual integrated resource plans (IRPs) for both the RSP and the 38 MMT portfolio. D.20-03-028 did not provide complete information about the expected level of reliability or CO2 emission expectations for both portfolios based on production cost modeling. The CAISO has conducted an independent assessment of the 38 MMT portfolio with a focus on assessing levels of reliability and CO2 emissions resulting from the portfolio. Specifically, the CAISO assessment was conducted for 2026 to understand if the portfolio provides sufficient resources to replace the retiring Diablo Canyon Power Plant (Diablo Canyon), and for 2030 to test if the portfolio can meet a 0.1 day loss of load expectation (LOLE) and the 38 MMT CO2 emission target.

The CAISO's assessment used both stochastic and deterministic PLEXOS production cost models with assumptions consistent with the CPUC SERVM model. The CAISO's PLEXOS models, however, have methodologies that differ from the CPUC SERVM model.

The CAISO's assessment found that:

- The 38 MMT portfolio did not meet the 0.1 day per year loss of load expectation reliability criterion[1] in 2026 or in 2030. The portfolio is short of effective capacity to meet that target by 3,493 MW in 2026 and 1,383 MW in 2030.[2]
- The 38 MMT portfolio also produced 41.2 MMT CO2 emissions, materially higher than the 38 MMT target.
- The high solar and battery storage concentration provided in the 38 MMT portfolio results in the system being heavily dependent on the existing gas generation resources in the summer and winter months. From these results, the CAISO has concluded that diversifying the resource portfolios is more feasible to maintaining system reliability, especially if the majority of the existing gas generation fleet cannot be retained until 2030 and beyond.

2. About the CAISO Assessment

2.1 Purposes

In the CPUC's decision on March 26, 2020 (D.20-03-028), the CPUC released the 2019-20 46 MMT RSP and a 38 MMT scenario portfolio requiring the LSEs to file two individual IRPs conforming with the 46 MMT RSP and 38 MMT portfolio. D.20-03-028 included production cost modeling results about the reliability—from a supply adequacy perspective—and CO2 emission expectations of the 46 MMT RSP. According to the CPUC SERVM production cost modeling results, the 46 MMT RSP was found to marginally meet the loss of load expectation (LOLE)

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1 For the definition of loss of load expectation criterion, see "Administrative Law Judge Ruling Directing Production Cost Modeling Requirements" and "Unified Resource Adequacy and Integrated Resource Plan Inputs and Assumptions Guidance for Production Cost Modeling and Network Reliability Studies, March 29, 2019" p.12

2 Effective capacity is the energy-backed capacity that is avaiable when it is needed to avoid loss of load events.

reliability criterion of 0.1 day per year. It produced 50.3 MMT of CO2 emissions, which exceeds the 46 MMT target set in the RESOLVE capacity expansion model.[3] However, D.20-03-028 did not include similar production cost modeling results for the 38 MMT portfolio.

The CAISO conducted an independent assessment of the reliability and CO2 emission expectations of the 38 MMT portfolio for the reasons set out below. The CAISO assessment used PLEXOS production cost simulation models, which use an optimization method different from that of the SERVM model that the CPUC uses in its IRP proceeding. The CAISO PLEXOS models also implement some unique mechanisms to address the special needs for modeling the system with high penetration of renewable and storage resources. The CAISO PLEXOS model methodologies are discussed in Section 3 below.

2.2 Focus of the assessment

As stated in the CPUC decision, the 46 MMT RSP actually produced 50.3 MMT of CO2 emissions in 2030 based on the CPUC SERVM production cost modeling results. Extrapolating those results to the 38 MMT portfolio, this suggests that the 38 MMT portfolio would produce CO2 emissions between 38 and 46 MMT, which is a reasonable intermediate target in order to achieve 100% carbon-emission free electricity in 2045. Therefore, the CAISO used the 38 MMT portfolio as the basis of its assessment.

The CAISO conducted its assessment for years 2026 and 2030. 2026 represents an important inflection point for California's electric system because it is the first year that Diablo Canyon will be fully retired. In 2030, the 38 MMT portfolio should have sufficient resources to meet system load and reserve requirements while also achieving the CO2 emission target set in the definition of the portfolio.

2.3 Production Cost Modeling

The CAISO assessment used both stochastic and deterministic PLEXOS production cost modeling. Stochastic production cost simulation is able to determine the reliability of the portfolio, which is measured as a LOLE of the portfolio less than or equal to 0.1 day per year. The deterministic production cost simulation was used to accurately calculate the CO2 emissions produced by the portfolio.

3. Modeling Methodologies

3.1 Basic methodologies

The production cost modeling methodologies of the assessment are described in detail in the CAISO testimonies filed into the CPUC 2014 long-term procurement plan (LTPP) proceeding.[4] The testimonies covered the specifics of modeling approaches, model structures, assumptions and input parameters, as well as creation of random load, solar and wind generation profile samples for the stochastic models.

The fundamentals of production cost modeling is the optimization method used to solve the models. The CAISO PLEXOS models use a mixed integer programming (MIP) optimization

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[3] See D.20-03-028 p.44

[4] See http://www.caiso.com/Documents/Aug13_2014_InitialTestimony_ShuchengLiu_Phase1A_LTPP_R13-12-010.pdf and http://www.caiso.com/Documents/Nov20_2014_Liu_StochasticStudyTestimony_LTPP_R13-12-010.pdf

method, which is the same method used in the CAISO market clearing/scheduling system. It is, however, different from the optimization method of the SERVM model that the CPUC uses in the CPUC's IRP proceeding.

3.2 Changes to the methodologies in the testimonies

Since filing the LTPP testimonies, some aspects of the modeling methodologies have been updated. The changes improved modeling of resources, system topology and commercial arrangements, and addressed the needs of modeling resource portfolios with a higher penetration of renewable and battery storage resources.

The major changes made to the modeling methodologies since the CAISO filed the testimonies in the 2014 LTPP are set out below.

3.2.1 Dedicated import paths

The CAISO PLEXOS models have virtual dedicated transmission paths for imports from out-of-state renewables that are contracted with the CAISO market participants, and for imports from other generation resources that the CAISO market participants have ownership shares, including Hoover and Palo Verde. The dedicated import paths for the two coal plants Navajo and San Juan have been removed after the expiration of the ownership share contracts.

The dedicated import paths are virtual because they do not exist physically, but are carved out from the physical transmission paths. Each virtual dedicated import path has a dynamic rating equal to the flow of the energy the path was created to transmit. The energy flowing through the dedicated import paths is referred to as dedicated imports. Dedicated imports have scheduling priority over economic imports to ensure the energy of these specific resources is delivered to the CAISO, with or without congestions on the physical import paths. With the dedicated import paths incorporated in the model, the model is able to accurately track CO2 emissions by the imported energy.

3.2.2 Frequency response requirement

As described in the CAISO testimonies, there was a 25% local generation requirement for some zones in California. The local generation requirements for CAISO, SCE and SDG&E are now replaced by a CAISO-wide frequency response requirement in the current model. 50% of the 752 MW CAISO's frequency response obligation is provided by hydro generation resources. It is not modeled explicitly. The other 50% can be provided by combined cycle gas turbines (CCGT) and battery storage resources. Battery storage can meet the frequency response requirement 1 MW-for-1 MW, while CCGT can meet the requirement 1/0.08 = 12.5 MW-for-1 MW with its online installed capacity. The CCGT and battery storage resources to provide frequency response need to have sufficient unused online capacity reserved.

3.2.3 Tiered curtailment prices

In the PLEXOS model, a tiered renewable energy supply curve is implemented. It was developed based on analyses of the CAISO market clearing results. The supply curve is used to decide the curtailment of renewable energy.

Table 1. A Tiered Renewable Energy Supply Curve

	Segment 1	Segment 2	Segment 3	Segment 4
Offer Price ($/MWh)	-15	-25	-50	-150
Segment Capacity (MW)	2,000	5,000	5,000	6,000

3.2.4 Solar and wind providing load-following down

Wind and Solar now can provide load-following down up to 50% of the CAISO total load-following down requirement. Wind and Solar cannot provide any other types of reserves.

3.2.5 Removal of the SCIT constraint

The Southern California Import Transmission (SCIT) constraint has been removed from the model because the CAISO has retired the SCIT nomogram in its market operation.[5] The CAISO simultaneous import limit in the CAISO PLEXOS models is now from the CPUC SERVM model.[6] Specifically, the CAISO simultaneous import limit in the PLEXOS models is 6,500 MW for hour ending (HE)17-22, July through September and 11,665 MW for all other hours.

3.2.6 Look-ahead in simulations

One of the important changes is the introduction of a one day look-ahead feature in the simulations. Specifically, the production cost model simulation optimizes resource commitments and dispatches for two consecutive days each time and keeps the results of the first day only. Then the simulation rolls forward one day, until the end of the year. With one day look-ahead, results of the first day are affected by the load and supply balance situation of the second day. Commitment and dispatch of generation resources with long start-up time and charging and discharging decisions of storage resources are optimized better than without look-ahead.

The look-ahead functionality in simulation is important to accurately modeling battery storage resources. Without it, battery storage resources have no information about the conditions in the upcoming days. As a result, battery storage resources tend to underperform significantly compared to their capabilities. The direct consequence of the underperformance is more renewable energy being curtailed and more CO2 emissions produced.

4. Modeling Assumptions

The CAISO PLEXOS models were set up to be consistent with the assumptions of the CPUC RESOLVE and SERVM models to the extent possible. Differences were mostly due to information availability and confidentiality limitations.

4.1 Assumptions consistent with the CPUC models

Assumptions consistent with the CPUC RESOLVE and SERVM models included:

- Existing generation fleet;
- Hydro conditions;
- CAISO import limits;
- Renewable generation shapes; and
- New renewable and storage resources.

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[5] See http://www.caiso.mobi/Documents/SouthernCaliforniaImportTransmissionNomogramRetirementScheduledJune1_2018.html

[6] D.20-03-028 at p.39

Table 2. New Resources of the 38 MMT Portfolio

CAISO New Resources Capacity (MW)	2026	2030	Changes 2026 to 2030
Solar	8,684	11,995	3,311
Wind (existing transmission)	3,811	5,279	1,468
Out-of-State Wind (new transmission)	0	3,000	3,000
Battery (4-hour)	5,036	9,714[7]	4,678
Demand Response	222	222	0
Pumped Storage (12-hour)	1,605	1,605	0
Thermal Retirement	0	-2,046	-2,046
Sum	**19,358**	**29,769**	**10,411**

New resources were from the 38 MMT portfolio, as shown in Table 2. From 2026 to 2030, there are 10,738 MW of additional new resources, including the 327 MW customer side battery storage, being selected. This does not include customer solar, which was embedded in the California Energy Commission (CEC) load forecast.

In Table 3 is the list of all the generation, storage and demand response resources by type in the 38 MMT portfolio. Customer Solar is also included in the table. From 2026 to 2030, the installed capacity of the whole portfolio increased by 14,647 MW.

[7] This does not include 327 MW customer side battery storage that is included in the total capacity of the 38 MMT portfolio.

Table 3. Total Resources resulting from the 38 MMT Portfolio

CAISO Total Resources Capacity (MW)	2026	2030	Changes 2026 to 2030
Nuclear	635	635	0
CHP	2,296	2,296	0
Gas	25,113	23,068	-2,046
Coal	0	0	0
Hydro (Large)	7,070	7,070	0
Hydro (NW scheduled imports)	2,852	2,852	0
Biomass	903	901	-2
Geothermal	1,851	1,851	0
Hydro (Small)	974	974	0
Wind (existing transmission)	11,267	12,735	1,468
Out-of-State Wind (new transmission)	0	3,000	3,000
Offshore Wind	0	0	0
Solar	23,571	26,883	3,311
Customer Solar	16,156	20,066	3,911
Battery Storage	7,974	12,978	5,005
Pumped Storage	3,204	3,204	0
Shed DR	2,418	2,418	0
Sum	**106,283**	**120,930**	**14,647**

The 38 MMT portfolio has high concentrations of solar and storage. Solar, including Customer Solar, is 37% and 39% of the installed capacity of the whole portfolio in 2026 and 2030, respectively. Battery and pumped storage together is 11% and 13% in 2026 and 2030, respectively. The share of thermal generation resources dropped from 26% in 2026 to 21% in 2030.

4.2 Assumptions different from the CPUC models

The assumptions that are different from the CPUC models are mostly in the generation resource operation characteristics and the California load forecast.

4.2.1 Operational characteristics

The CPUC SERVM model uses the confidential CAISO Master File data for the operational characteristics of the individual generation resources. The CAISO PLEXOS models do not use confidential data as the CAISO releases its PLEXOS models to the public in the CPUC LTPP and IRP proceedings. The CAISO PLEXOS models rely on publicly availed data. The sources and development of generation resource operation characteristics in the PLEXOS model are discussed in the CAISO testimonies.

4.2.2 Load forecast

The CPUC RESOLVE and SERVM models for developing the 46 MMT RSP and 38 MMT portfolio are based on the CEC 2018 Integrated Energy Policy Report (IEPR) Update load forecast. Since then, the CEC adopted the 2019 IEPR load forecast. The CAISO PLEXOS models are based on the CEC 2019 IEPR load forecast. Table 4compares Managed Load of the 2018 and 2019 IEPR for 2026 and 2030.[8]

The comparison in **Error! Not a valid bookmark self-reference.** 4 shows how much the load forecast has changed from the 2018 IEPR Update to the 2019 IEPR, as well as the differences between the load forecasts for 2026 and 2030.

As stated above, the 46 MMT RSP and 38 MMT portfolio are based on the 2018 IEPR Update load forecast, while the CAISO PLEXOS models use load forecast from the 2019 IEPR. The differences between the 2018 IEPR Update and 2019 IEPR are relatively small. For 2026, the CAISO coincident peak load in the 2019 IEPR is only 401 MW higher than that in 2018 IEPR Update. For 2030, the 2019 IEPR is 1,046 MW higher. This information aids in identifying how much the differences of the IEPR load forecasts contribute to the differences in simulation results of the CPUC RESOLVE and the CAISO PLEXOS models.

Table 4. Comparison of IEPR Load Forecasts for CAISO

CAISO Managed Load (MW)	**2018 IEPR Update**	**2019 IEPR**	**Changes 2018 to 2019 IEPR**
2026 Managed Load			
▪ Coincident Peak Load (MW)	45,610	46,011	**401**
▪ Energy (GWh)	224,426	222,228	**-2,198**
2030 Managed Load			
▪ Coincident Peak Load (MW)	45,970	47,016	**1,046**
▪ Energy (GWh)	220,169	224,222	**4,053**
Changes from 2026 to 2030			
▪ Coincident Peak Load (MW)	**360**	**1,005**	
▪ Energy (GWh)	**-4,257**	**1,994**	

In the 2019 IEPR, the coincident peak load in 2030 is 1,005 MW higher than in 2026, but the 2030 value is only 360 MW higher than the 2026 value in the 2018 IEPR Update. In Table 2, the new resource capacity is 10,738 MW higher in 2030 than in 2026, including 2,959 MW non-renewable capacity.[9] This raised the question of why 10,738 MW of additional resources added between 2026 and 2030 were found to be needed in the 38 MMT portfolio to serve only 360 MW of additional load. This suggests that the resource need is either considerably overstated in 2030, or considerably understated in 2026, which is an issue the CAISO examined in its assessment.

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[8] CEC 2019 IEPR hourly CAISO load forecast, MID-MID case, available at https://efiling.energy.ca.gov/GetDocument.aspx?tn=231555&DocumentContentId=63372

[9] That is 4,678 MW utility scale battery plus 327 MW customer side battery minus 2,046 MW retirement of thermal generation resources. The 1,468 MW in-state and 3,000 MW out-of-state wind resources should also have some generation during the high net load hours.

5. Simulation and Results

5.1 Simulations

Both stochastic and deterministic PLEXOS production cost models were used in the CAISO assessment. Stochastic model simulations determined the level of system adequacy reliability achieved, and capacity shortfalls of the portfolio in meeting the established LOLE criterion. Deterministic model simulations calculated CO2 emissions that the portfolio would produce. The simulations were performed chronologically in hourly intervals for the whole year.

5.1.1 Monte Carlo simulations

The stochastic model captures the possible variations of load, solar and wind generation, and generation unit forced outages. It is for the purpose of testing the sufficiency of resources to meet load and reserve requirements in various circumstances, especially in challenging situations that will occur with small probabilities.

In the CAISO assessment, a 500-iteration Monte Carlo simulations were conducted. The inputs of the stochastic model included 500 sets of hourly profile of load, solar and wind generation, and generation unit forced outages. The 500 load, 500 solar, 500 wind generation profiles, and 500 forced outage profiles were created randomly based on the methodologies described in the CAISO testimonies. Each profile is unique. The results of the Monte Carlo simulations included the LOLE and the shortfall of effective capacity to meet the 0.1 day per year LOLE criterion. Effective capacity is the energy-backed capacity that is available when needed to avoid a loss of load event. Actual installed capacity may be higher than the effective capacity.

5.1.2 Deterministic simulations

The deterministic model includes the entire WECC footprint. It has detailed modeling of load, reserve and load-following requirements, individual generation and storage resources, and transmission paths between the balancing zones. The results of the deterministic simulation included hourly commitment, dispatch, fuel usage and CO2 emissions of each generation resource, the resources used to meet reserve and load-following requirements, imports from CO2-free and CO2-emitting resources, renewable curtailment, and production costs, including CO2 costs, for the resources, for the CAISO and for the whole WECC system.

5.2 Reliability of the 38 MMT portfolio

Based on the results of the 500-iteration Monte Carlo simulations, the 38 MMT portfolio did not meet the targeted LOLE reliability criterion in 2026 or 2030, having LOLE values greater than 0.1 as shown in Table 5.

Table 5. PLEXOS Model Monte Carlo Simulation Results

Cases	2026	2030
Loss of Load Expectation (LOLE)	0.890	0.268
Shortfall of Effective Capacity (MW)	3,493	1,383

The 38 MMT portfolio has a significant deficit between the selected new resources and the need for capacity to cover load growth and to replace Diablo Canyon in 2026. The simulation results provide the answer to the question posed in section 4.2.2 regarding the increase in capacity of 10,738 MW between 2026 and 2030 while there is only a coincident peak load increase of 360 MW over the same period. The significant increase in capacity in 2030 in part served the increased load, but more importantly closed a portion of the deficit found in 2026.

Diablo Canyon is a resource with very high capacity factor and extremely low forced outage rate. It provides large volume of steady and CO2-free energy supply to the system. Replacing it with renewable and battery storage resources is challenging. It needs to be well planned to ensure the system reliability is maintained and CO2 emission reduction is on target. The 38 MMT portfolio falls short in meeting this need. The significant effective capacity shortfall in the 2026 time frame is particularly critical due to the limited time available to address the shortfall between now and 2026.

5.3 CO2 emissions of the 38 MMT portfolio

Deterministic simulations optimize generation, import and export, reserve provision, and renewable curtailment for the whole WECC system, and also calculate CO2 emissions from generation and imports. Some aggregated results of the PLEXOS deterministic simulations and RESOLVE model are provided in Table 6.

The CPUC RESOLVE model was based on the 2018 IEPR Update load forecast and the CAISO PLEXOS model was based on the 2019 IEPR. However, the differences between the two load forecasts are relatively small. Most of the differences in simulation results appear to be because of differences in modeling methodologies and in some data used in the models.

As shown in Table 6 the PLEXOS simulations identified 41.2 MMT state-wide CO2 emission in 2030, while RESOLVE reported 38 MMT. Since RESOLVE is a simplified model for capacity expansion planning purposes, while the CAISO PLEXOS model has detailed modeling of generation resources, transmission paths, import and export, and uses MIP optimization method to solve the model, the CO2 emission result from the PLEXOS model should be more accurate. According to the results, the 38 MMT portfolio did not achieve the 38 MMT CO2 emission target as intended.

Table 6. PLEXOS and RESOLVE Model Deterministic Simulation Results

Simulation Results of the CAISO	2026		2030	
	RESOLVE	PLEXOS	RESOLVE	PLEXOS
CAISO CO2 Emission (MMT)	39.0	38.5	31.1	33.7
CA CO2 Emission (MMT)	47.7	47.0	38.0	41.2
RPS Achieved[10]	65.0%	60.0%	68.2%	71.5%
In-CAISO Generation (GWh)[11]	222,186	192,211	238,699	198,317
Net Import (GWh)	36,484	63,292	25,231	66,066
Renewable Curtailment (GWh)	2,938	821	6,696	1,689
Production Cost ($million)				
▪ CAISO		1,668		1,406
▪ WECC		11,467		11,602

As discussed in section 3.2.6, the one day look-ahead functionality in the simulation allows for better optimization of battery storage performances. With supply and demand information of the next day, PLEXOS simulations are able to make good use of battery storage resources to reduce renewable curtailment. Compared to the results of the RESOLVE model, which simulates 37 discrete days for each year, the renewable curtailment was significantly lower in the PLEXOS simulations. Lower curtailment led to more renewable energy being utilized and lower CO2 emission produced. Even so, the 38 MMT portfolio still produced 3.2 MMT more CO2 emissions than the 38 MMT target in 2030.

The results of the two models also had inconsistent results of the Renewables Portfolio Standard (RPS) achieved. This is because is addition to different renewable curtailments, different values of electricity retail sales were used. The RESOLVE model calculated electricity retail sales using total load, customer solar generation, California Department of Water Resources pump load and transmission/distribution losses. The CAISO PLEXOS model used retails sales values from the CEC 2019 IEPR Form 1.1C.

5.4 Impacts of high concentration of solar and storage in the portfolio

The 38 MMT portfolio has high solar and storage concentrations, as discussed in section 4.1. Solar is heavily favored in the RESOLVE model because it is a low cost renewable resource and is paired with battery storage. This complement works well to achieve the RPS and CO2 emission reduction targets within the model. However, the effectiveness of the pairing starts to diminish when the concentration reaches a certain level.

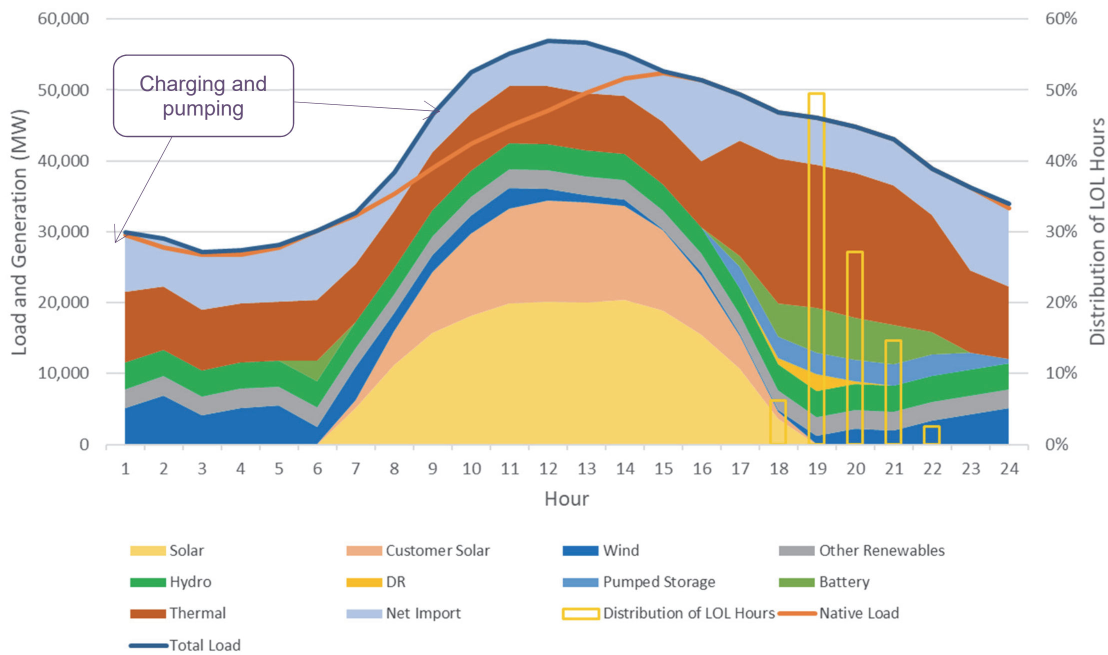
Figure 1 shows the hourly energy balance on a summer high load day in 2026 from the PLEXOS deterministic simulation. On that day, all renewable and hydro energy was fully utilized to serve load. Battery storage resources were charged in the mid-day by thermal generation and imported energy, both of which were assumed to be CO2-emitting resources.

[10] The retail sales values used in the calculation are different. The PLEXOS results use the value from CEC 2019 IEPR Form 1.1C.

[11] Including Customer Solar genreation

In the evening, starting just before sunset, the net load ramped up quickly (see Figure 2). The energy from almost all available resources and imports was needed to serve load and meet reserve requirements. Battery, pumped storage, and demand response resources all responded to the need. Still, the largest portion of energy was from thermal generation resources as imports were limited to 6,500 MW during these hours. All energy discharged from battery and pumped storage resources had CO2 emissions. Further, battery storage resources have round-trip efficiencies between 80% and 85%. It took about 1.2 MWh of thermal generation or imported energy to get 1.0 MWh energy from the storage resources in the evening. While adding more battery storage resources may help recover more renewable energy from curtailment in the spring months, it would actually *increase* thermal generation and CO2 emission in the summer months. This is because on a high demand summer day there is no “excess” or oversupplied renewables to charge the batteries. With the 38 MMT portfolio, retaining most of the existing thermal generation resources until 2030 and beyond becomes the key to integrating the large amount of battery storage resources. The cost of retaining the majority of the thermal fleet until 2030 was not clearly accounted for and explained in the 38 MMT portfolio.

Figure 1. Hourly Energy Balance on a Summer Day in 2026 (version 1)[12]



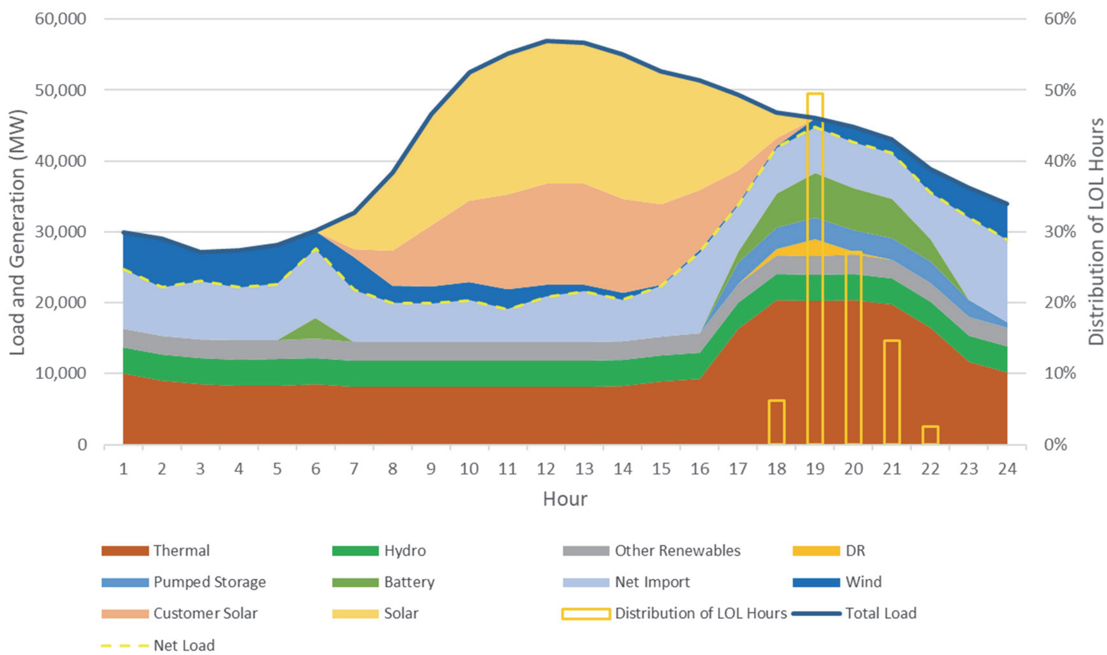
The next part of this analysis looks at the impacts of adding more solar resources to the portfolio. Even though the LOLE definition adopted in the IRP proceeding does not count capacity shortfalls to meet non-spinning reserve and load-following flexibility requirements, it is very important to CAISO system operations to have sufficient flexible capacity to meet non-spinning and load-following requirements all the time.

Figure 2 presents the hourly energy balance of the same day as in Figure 2 but in a different order of stacking up the supply resources. In the chart, the evening net load (total load minus solar, customer solar, and wind generation) experiences a steep upward ramp in late afternoon

[12] “Distribution of LOL Hours” on the right axis of the chart is the frequency distribution of all individual hours with loss of load in the 500-iteration Monte Carlo simulations.

and early evening due to high solar penetration. Securing sufficient flexible capacity to meet energy and reserves requirements during and after the evening ramp is challenging. All of the loss of load events in the Monte Carlo simulations were in the early evening hours and about 50% of them were at HE19 right after sunset. Adding more solar will further depress thermal generation in the mid-day and make the net load ramping situation even more challenging.

Figure 2. Hourly Energy Balance on a Summer Day in 2026 (version 2)



Another challenge is how to maintain system reliability during consecutive cloudy days, especially in the winter months, with a portfolio of high solar and battery concentration. This challenge was not considered in the development of the 38 MMT portfolio as the RESOLVE model simulated 37 discrete days for each year with typical solar and wind generation profiles. The 38 MMT portfolio was also not verified by production cost modeling in the process.

Diversifying the IRP resource portfolios is one option to avoid high solar and battery concentration. Geothermal, out-of-state and offshore wind that have different generation profiles from the California onshore wind, hydrogen for fuel cell batteries, for fuel mix to power existing natural gas generation resources, and for synthetic methane, which could be available in the longer future, should all be considered. These resources may be more expensive than solar and battery, based on the input cost figures in the RESOLVE model. However, RESOLVE is a simplified model. It is not designed to capture all the costs and benefits of different resource portfolios. There should be alternative ways to explore the different portfolios, besides that straight from the RESOLVE model.