RESOURCE ADEQUACY

SLICE OF DAY

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ABBREVIATIONS

- **BAA:** Balancing Authority Area
- **CAISO:** California Independent System Operator
- **CIRA:** Customer Interface for Resource Adequacy
- **CPUC:** California Public Utilities Commission
- **FCDS:** Full Capacity Deliverability Status
- **ICDS:** Interim Capacity Deliverability Status
- **LSEs:** Load Serving Entities
- **MW:** Megawatts
- **NQC:** Net Qualifying Capacity
- **PCDS:** Partial Capacity Deliverability Status
- **Pmax:** Maximum Generation Capacity
- **PRM:** Planning Reserve Margin
- **RA:** Resource Adequacy
- **SOD:** Slice of Day

INTRODUCTION

The 2000-2001 California Energy Crisis led the **California Public Utilities Commission (CPUC)** and the **California Independent System Operator (CAISO)** to create the **Resource Adequacy (RA)** Program. The CPUC, a regulatory agency that oversees utility services in California, and CAISO, the entity responsible for managing the state's high-voltage electricity transmission system, developed RAP to ensure that **Load Serving Entities (LSEs)** (utilities or companies that provide electricity to end-use customers) can reliably meet their forecasted customer load demands. The program was designed to guarantee that sufficient energy resources are available to maintain grid reliability, especially during periods of high demand.

Initially, RAP targeted the single peak hour of each month, assuming sufficient supply during peak would cover all other hours. This approach shifted as California transitioned to renewable energy (primarily wind and solar) driven by sustainability goals and incorporated energy storage. This created two reliability challenges: variable supply and the inadequacy of single-hour planning.

First, much of the supply portfolio became reliant on solar irradiance and wind velocity, which are inherently variable, unlike natural gas, which remains consistent except under extreme conditions. As a result, the CAISO's supply portfolio experienced shortages during periods of low wind or solar availability and surpluses during periods of high wind or solar generation.

Second, because the CAISO's supply portfolio output was now highly variable, the premise that reliability could be ensured based on comparing supply availability against customer load in a single hour in a month when customer load was highest was no longer valid.

The unintended consequences of the transition to a supply portfolio dominated by variable energy renewable resources were an oversupply of energy in hours when solar energy was highest and undersupply when solar energy was lowest (which the CAISO termed the "Duck Curve"). The RAP could no longer be based on a single hour.

As a result, the CPUC modified its RAP to what is called **"Slice of Day" (SOD)**, which requires the review of supply sufficiency for not just a single hour in a month but the highest 24 hours of the day in a month. The SOD framework divides the day into different periods, or "slices," reflecting critical moments when the grid is most stressed. LSEs and generator owners must now ensure they have enough resources available during each of these slices rather than just focusing on peak demand periods. This approach addresses the variability of renewable energy, particularly solar and wind, whose generation fluctuates throughout the day.

WHAT ARE THE SOD OBLIGATIONS FOR LSEs?

Beginning in 2025, LSEs must comply with RA requirements under the SOD framework. The obligations are based on the forecasted "worst day," or the day with the most significant expected customer load for each of the 24 hours of the day in each of the 12 months of the year. A **Planning Reserve Margin (PRM)** is also applied to account for unexpected supply outages and other contingencies.

To illustrate this, Tables 1 and 2 below provide examples of an LSE's hourly **Megawatts (MW)** load forecast and the resulting RA obligation based on a 17.5% PRM, while Figure 1 graphically represents the relationship between the hourly load forecast and RA obligation for January.

Table 1 - Example of LSE's Forecast of Highest Customer Load in MW for Each Month of the Year

Hour / Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
January	29.6	28.4	27.8	27.9	29.0	31.3	35.2	37.7	33.2	25.6	19.0	13.9	12.2	13.4	16.2	22.7	31.0	37.3	38.5	38.9	38.2	36.5	33.8	31.2
February	29.2	28.2	27.9	28.1	29.4	32.0	36.0	36.0	27.6	18.3	10.8	5.4	3.8	5.1	8.4	15.3	25.0	33.8	37.2	37.8	37.2	35.8	33.3	30.8
March	28.1	26.8	26.2	26.0	27.1	30.0	33.5	33.2	26.6	18.7	11.6	6.0	2.9	2.0	4.0	8.3	16.0	26.2	33.4	37.0	37.3	35.8	33.1	30.1
April	29.3	27.9	27.0	26.8	27.5	29.8	32.8	31.6	24.3	15.4	9.0	2.3	0.4	0.8	1.7	7.0	13.5	22.0	31.3	37.5	39.2	37.8	34.9	31.6
May	39.2	36.9	35.3	34.6	35.0	36.8	38.1	34.6	27.2	19.7	14.8	10.9	10.2	12.3	15.7	21.6	28.4	37.0	45.7	51.6	53.4	51.9	47.3	42.5
June	50.5	46.7	44.0	42.4	42.4	43.8	44.0	41.1	35.0	29.5	26.6	26.4	28.8	32.9	37.6	43.1	50.9	60.2	68.7	72.3	71.6	69.2	62.8	55.8
July	55.1	50.6	47.3	45.2	44.6	45.2	45.4	42.7	36.9	31.7	29.0	29.8	33.0	37.8	44.6	52.0	61.2	71.3	79.7	83.1	81.0	76.8	68.9	60.9
August	53.4	49.1	46.0	44.1	44.0	45.3	47.2	45.4	40.2	34.8	32.0	33.0	36.9	43.6	51.3	59.3	68.2	78.3	85.5	86.5	82.4	76.4	67.6	59.2
September	44.8	41.5	39.3	37.9	38.2	39.4	42.2	41.8	36.9	31.3	27.0	25.9	27.4	31.1	37.2	43.9	53.5	63.7	68.6	67.8	64.7	60.7	54.9	48.8
October	35.8	33.6	32.5	32.0	32.6	34.6	37.6	38.8	33.4	25.5	18.2	14.0	12.0	14.0	19.2	27.0	37.5	48.3	53.1	52.0	49.5	46.5	42.3	38.2
November	33.2	31.9	31.3	31.4	33.0	35.8	40.3	40.5	33.7	24.2	16.7	11.8	10.2	12.7	17.9	25.8	35.2	41.3	43.0	43.0	42.2	40.8	37.9	35.1
December	35.6	34.0	33.2	32.9	34.3	36.8	40.8	43.2	40.6	35.8	31.4	26.5	24.7	26.2	29.2	35.5	42.3	46.6	47.0	46.8	45.9	44.1	41.0	37.7

Table 2 - Example of LSE's RA Obligation in MW at 17.5% PRM

Hour / Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
January	34.8	33.4	32.7	32.8	34.0	36.8	41.4	44.3	39.0	30.1	22.3	16.4	14.4	15.7	19.0	26.6	36.4	43.8	45.3	45.7	44.9	42.9	39.7	36.7
February	34.3	33.2	32.7	33.0	34.5	37.6	42.3	42.2	32.4	21.5	12.7	6.4	4.5	6.0	9.9	18.0	29.4	39.8	43.8	44.4	43.7	42.1	39.1	36.1
March	33.0	31.5	30.8	30.6	31.8	35.3	39.4	39.0	31.2	22.0	13.6	7.0	3.4	2.3	4.7	9.7	18.8	30.8	39.2	43.5	43.8	42.1	38.9	35.4
April	34.5	32.7	31.7	31.4	32.4	35.0	38.6	37.2	28.6	18.1	10.6	2.7	0.5	0.9	2.0	8.2	15.8	25.8	36.8	44.1	46.0	44.4	41.0	37.1
May	46.0	43.4	41.5	40.7	41.1	43.3	44.8	40.6	31.9	23.1	17.4	12.8	11.9	14.5	18.4	25.4	33.4	43.5	53.7	60.7	62.7	60.9	55.6	50.0
June	59.3	54.8	51.6	49.8	49.8	51.4	51.7	48.3	41.1	34.7	31.2	31.0	33.9	38.7	44.1	50.6	59.8	70.7	80.7	85.0	84.1	81.3	73.8	65.6
July	64.7	59.5	55.5	53.1	52.4	53.1	53.3	50.2	43.4	37.3	34.1	35.0	38.8	44.4	52.5	61.1	71.9	83.8	93.7	97.6	95.2	90.2	81.0	71.6
August	62.8	57.7	54.0	51.8	51.7	53.2	55.4	53.4	47.2	40.9	37.6	38.8	43.4	51.2	60.3	69.6	80.1	92.0	100.4	101.6	96.8	89.7	79.4	69.6
September	52.7	48.7	46.1	44.6	44.9	46.3	49.6	49.1	43.4	36.7	31.7	30.5	32.2	36.6	43.7	51.6	62.9	74.8	80.6	79.6	76.0	71.4	64.5	57.3
October	42.1	39.5	38.2	37.6	38.3	40.6	44.2	45.6	39.3	30.0	21.4	16.4	14.1	16.4	22.5	31.8	44.1	56.7	62.4	61.1	58.2	54.6	49.6	44.8
November	39.0	37.5	36.7	36.9	38.8	42.0	47.4	47.6	39.6	28.4	19.7	13.9	11.9	15.0	21.1	30.4	41.4	48.6	50.5	50.6	49.6	47.9	44.5	41.2
December	41.9	40.0	39.0	38.6	40.3	43.3	47.9	50.8	47.7	42.1	36.9	31.1	29.1	30.8	34.3	41.8	49.7	54.8	55.2	55.0	54.0	51.8	48.2	44.3

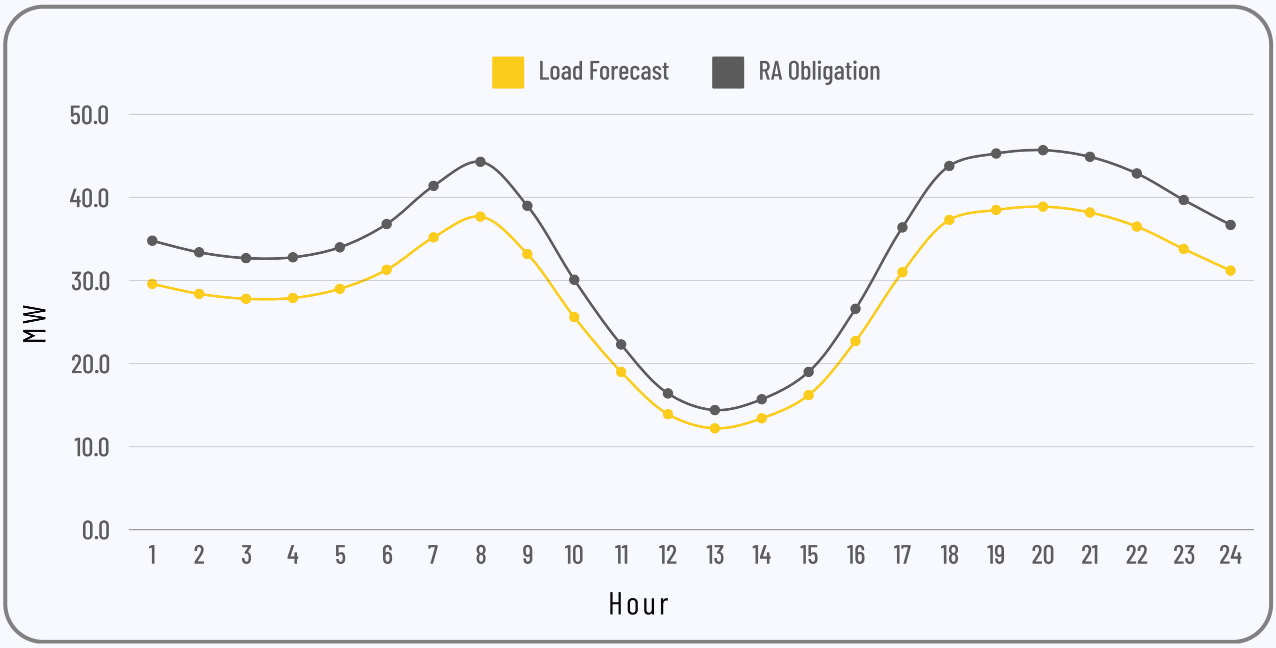

Figure 1 demonstrates how RA obligations (gray line) consistently exceed the load forecast (yellow line) throughout the 24 hours of the day to account for the Planning Reserve Margin (PRM).

The RA obligation requires LSEs to acquire resources that qualify for RA with **Net Qualifying Capacities (NQC)** equal to or greater than the RA obligation in MW for each hour of the day across all months.

This framework introduces a more rigorous approach to RA, requiring careful planning and procurement to ensure reliability across all hours of the day. The key requirements for compliance are as follows:

1. **Worst Day Forecast**
   LSEs must identify the day with the highest expected load for every hour in each month.

2. **Planning Reserve Margin (PRM)**
   A margin, typically 17.5%, is added to the forecasted load to account for supply risks such as unexpected outages.

3. **Resource Qualification**
   Only resources with NQC, as determined by the CAISO, are eligible to meet RA obligations.

4. **24-Hour Coverage**
   LSEs must ensure sufficient resources are available to meet RA obligations for all 24 hours daily.

The SOD framework ensures that LSEs account for grid reliability during the most critical hours, addressing the challenges posed by the variability of renewable energy sources like solar and wind.

WHAT RESOURCES QUALIFY FOR RA?

Resources that can be counted against a LSE's RA obligation have been reviewed and studied by CAISO, these resources are assigned one of the following deliverability statuses:

- **FCDS** – Full Capacity Deliverability Status
- **ICDS** – Interim Capacity Deliverability Status
- **PCDS** – Partial Capacity Deliverability Status

Each RA resource is assigned a monthly NQC value in MW. The NQC represents the resource's contribution to meeting RA obligations and is determined based on its **Maximum Generation Capacity (Pmax)** and its resource type.

Resources are categorized into three main types:

1. Non-Intermittent Resources

These include natural gas and nuclear generators. Their NQC is equal to their Pmax since they do not rely on intermittent fuel sources.

2. Variable Energy Resources

Resources like solar, wind, hydroelectric, geothermal, and biomass have their NQC adjusted by a technology factor to account for their intermittent generation capabilities.

3. Energy Storage Resources

These resources receive an NQC based on their ability to sustain MW discharge for four continuous hours. This ensures storage systems can reliably support the grid during periods of stress.

By aligning resource deliverability and capacity with their actual reliability contributions, the CAISO ensures the RA framework supports grid stability and meets customer load requirements efficiently.[1]

1 Resources outside the CAISO's **Balancing Authority Area (BAA)** can also be used to count against an LSE's RA obligation when the LSE acquires an RA Import Allocation.

HOW DO LSEs COMPLY WITH THE SOD FRAMEWORK?

Each LSE must demonstrate that it has acquired RA resources with NQCs that in aggregate are greater than or equal to the LSE's 24-hour RA obligation. To comply with the SOD framework, the following steps must be taken:

1 Annual and Monthly RA Plan Submission

Each LSE is required to submit an RA plan to the CPUC on both an annual and monthly basis. These plans must show that the LSE has procured sufficient capacity for each "slice" of the day, including additional capacity to cover the PRM.

2 CAISO Submission

The LSE must also submit its RA plan to CAISO via the Customer Interface for Resource Adequacy (CIRA) portal. This submission must be completed at least 45 days prior to the start of the operational month.

3 Verification & Corrections

CAISO checks the submitted RA plans against the LSEs' RA obligations. If shortages or mismatches are identified, they are flagged and reported to the LSE for correction.

Example of RA Compliance for January:

An example of how an LSE would satisfy its "SOD" RA obligation for January is illustrated if Figure 2 below, the following resources and associated NQCs have been acquired by the LSE.

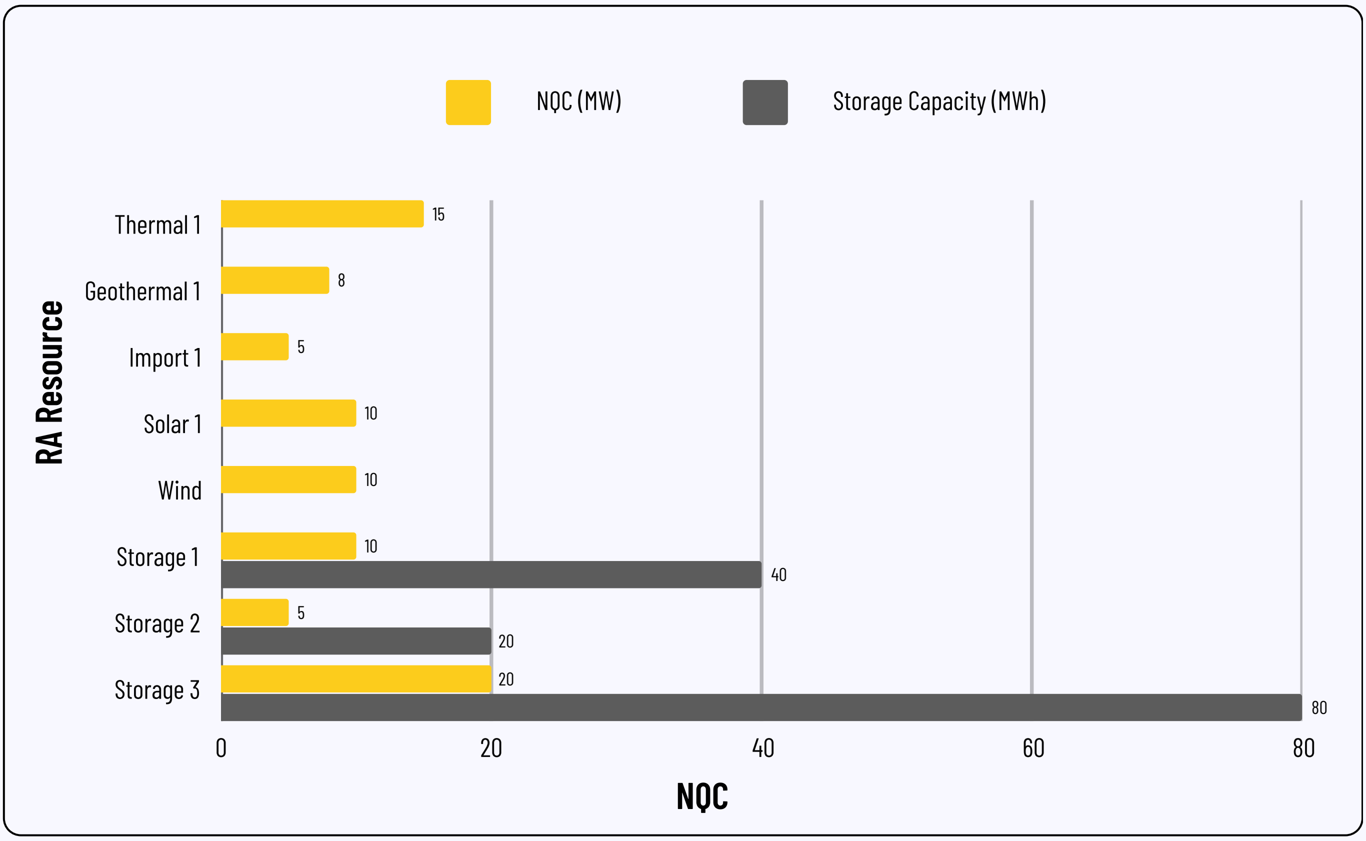

Figure 2

The allocation of these resources to meet the RA obligation is described as follows:

Thermal & Geothermal

These resources provide constant RA MW values for all 24 hours of the day.

Imports

Energy imports are delivered for 16 hours and remain constant during this period.

Solar and Wind

These resources vary throughout the day based on the CPUC's exceedance methodology, which reflects the expected availability of variable energy resources.

Energy Storage

Storage resources address shortfall hours:

- Storage 1 and Storage 2: Their energy volume is distributed over 4 hours at their respective Pmax values.
- Storage 3: Its energy volume is distributed over 12 hours at levels below its Pmax value.

The results are illustrated in Table 3 and Figure 3 below:

Table 3 - Example of LSE's RA Obligation and RA Resources in MW for January

Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
RA Obligation	34.8	33.4	32.7	32.8	34.0	36.8	41.4	44.3	39.0	30.1	22.3	16.4	14.4	15.7	19.0	26.6	36.4	43.8	45.3	45.7	44.9	42.9	39.7	36.7
Thermal 1	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
Geothermal 1	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Import 1	0.0	0.0	0.0	0.0	0.0	0.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	0.0	0.0
Solar 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	5.0	8.0	10.0	10.0	10.0	10.0	8.0	5.0	4.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Wind 1	9.0	9.0	8.0	7.0	6.0	3.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	3.0	4.0	6.0	6.0	7.0	8.0	9.0
Storage 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	10.0	10.0	10.0	0.0	0.0	0.0
Storage 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	5.0	5.0	5.0	0.0	0.0	0.0
Storage 3	3.0	2.0	2.0	3.0	5.0	0.0	12.0	13.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	8.0	9.0	5.0
Net	0.2	0.6	0.2	0.2	0.0	-10.8	0.6	0.7	1.0	7.9	17.7	23.6	25.6	24.3	19.0	8.4	0.6	4.2	1.7	3.3	4.1	0.1	0.3	0.3

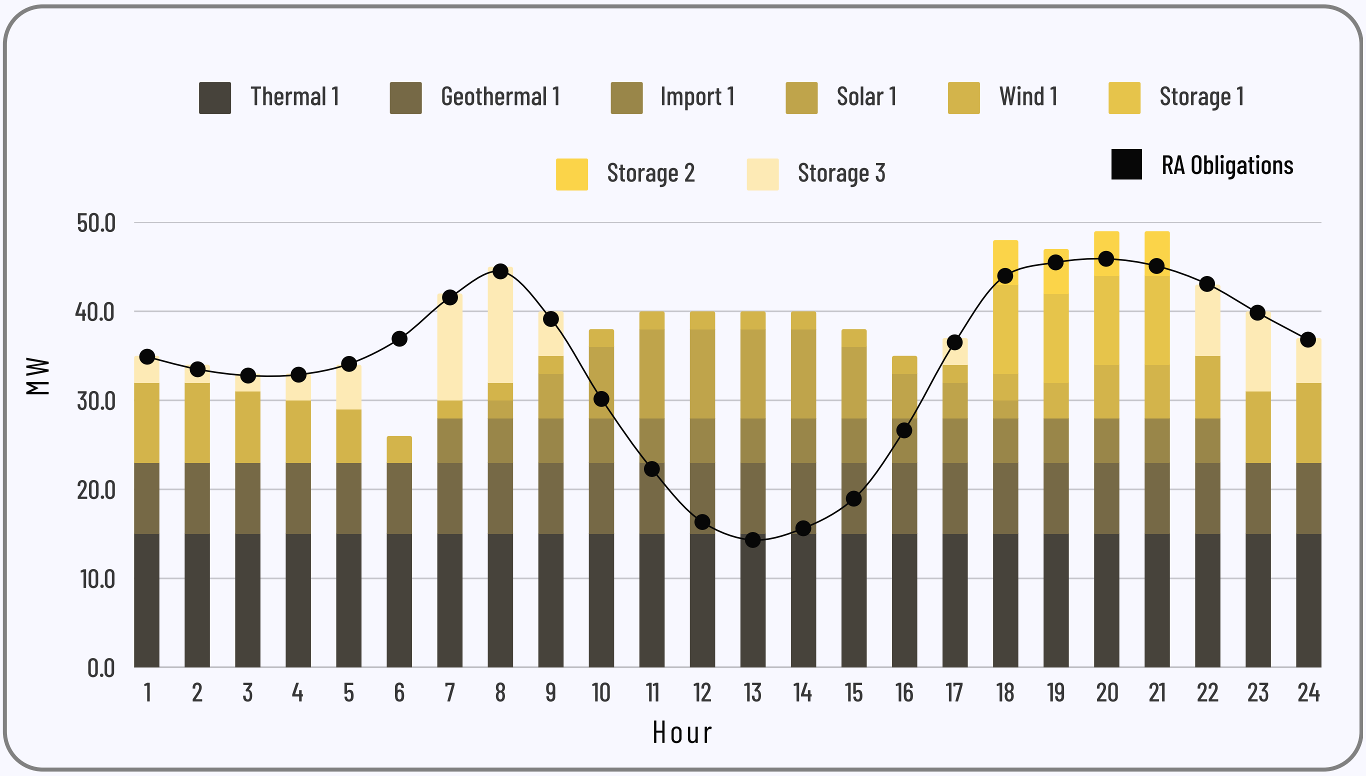

Figure 3 visually illustrates the allocation of RA resources to meet the RA obligation over the 24 hours of a January day. Thermal and geothermal resources provide consistent capacity, while variable energy resources and storage address shortfalls.

By combining different resource types and leveraging energy storage strategically, LSEs can ensure compliance with the "SOD" RA obligations, balancing supply and demand effectively across all slices of the day.

ADAPTING TO THE **SOD** FRAMEWORK: IMPACTS ON **GENERATORS & LSEs**

The SOD framework represents both a challenge and an opportunity for generator owners and LSEs. For generator owners, the shift towards flexible resources may reduce the role of traditional generation, such as conventional natural gas and other inflexible resources, in the RA market. However, those who can adapt to the new requirements stand to benefit from the evolving market dynamics. By investing in hybrid generation and storage solutions, such as combining renewable generation with energy storage systems, generator owners can position themselves to meet the growing demand for flexible and reliable energy resources.

For LSEs, the SOD framework introduces greater complexity in the RA process. Unlike traditional approaches that focus solely on peak hours, LSEs must now ensure that they have adequate capacity for all 24 hours of the day. This requires a more detailed and nuanced approach to resource planning and procurement. To comply with the framework, LSEs may need to revise their strategies by relying more heavily on energy storage systems to address shortfall hours, incorporating demand response programs to manage load effectively, and integrating other flexible resources to address variability throughout the day.

By adapting to these new requirements, both generator owners and LSEs can navigate the challenges posed by renewable energy's intermittent nature while supporting grid reliability and meeting their RA obligations in an increasingly dynamic energy market.

PROs & CONs OF THE SOD FRAMEWORK

The SOD framework presents both significant benefits and notable challenges for grid reliability, LSEs, and generator owners.

Pros of the SOD Framework

Improved grid reliability

The SOD framework addresses the challenges posed by the growing reliance on renewable energy, particularly the need to maintain grid stability during periods when renewable generation fluctuates. By requiring LSEs and generators to plan for different slices of the day, the CPUC aims to reduce the risk of blackouts and improve overall reliability.

Better alignment with renewable energy integration

Designed to accommodate the intermittent nature of renewable energy sources like solar and wind, the framework focuses on different times of the day. This approach encourages the development of flexible resources, such as battery storage and demand response, which are crucial for balancing supply and demand in a renewable-heavy grid.

Incentivizes investment in flexible resources

The need for resources that can operate across various slices of the day is likely to drive investment in technologies that offer greater flexibility. This includes energy storage systems, fast-ramping natural gas plants, and advanced grid management tools, all of which are essential for managing a modern energy system.

Cons of the SOD Framework

Increased complexity for LSEs and generator owners

The SOD framework significantly complicates resource planning and procurement. LSEs and generator owners must now account for resource availability across 24 different slices, rather than focusing solely on peak periods. This increases the administrative burden and requires more sophisticated forecasting and planning tools.

Higher costs for consumers

The increased complexity and the need to secure flexible resources could lead to higher costs, which may ultimately be passed on to consumers. Resources that can operate during critical slices are likely to be in high demand, potentially driving up prices in the RA market.

Challenges for conventional generators

Traditional power plants, which are less flexible than newer technologies like batteries, may struggle to compete in a market that prioritizes flexibility. This could lead to reduced profitability for these generators and potentially decrease the overall investment in conventional generation capacity, which still plays an important role in ensuring grid reliability.

The CPUC's SOD framework represents a major evolution in California's approach to RA, reflecting the growing importance of flexibility and the challenges of integrating large amounts of renewable energy into the grid. While the framework is designed to improve grid reliability and better accommodate renewable energy, it also introduces new complexities and potential costs for LSEs and generator owners. The success of this framework will depend on how well these entities adapt to the new requirements and the CPUC's ability to balance the need for reliability with the goals of affordability and sustainability.

CONCLUSION

The SOD framework marks a transformative step in California's approach to RA. Designed to address the growing integration of renewable energy sources like solar and wind, it ensures grid reliability across all 24 hours of the day by encouraging LSEs and generator owners to adopt flexible and diverse energy solutions. The framework moves beyond traditional RA planning, which focused solely on peak-hour demands, to a more comprehensive model that accounts for the variability of renewable energy generation and the increasing reliance on storage and demand response systems.

This study has highlighted the critical elements of the SOD framework, including its obligations, the qualification criteria for RA resources, and the compliance process for LSEs. It also explored the framework's advantages, such as improved grid stability, alignment with renewable energy integration, and incentives for investment in advanced energy technologies. However, the study also addressed the challenges, including increased complexity in planning, higher costs, and difficulties for conventional generators to adapt to a more flexible market.

The success of the SOD framework depends on the ability of LSEs, generator owners, and policymakers to embrace this new paradigm. Effective implementation will require innovative resource planning, investments in energy storage and grid management tools, and a collaborative effort to balance reliability, sustainability, and affordability. As California continues to lead in renewable energy adoption, the lessons learned from the SOD framework may serve as a blueprint for other regions transitioning to cleaner and more resilient energy systems.