Resource Flexibility

The rapid growth in renewable resources in California represents significant progress toward reaching the state's renewable energy and greenhouse gas reduction goals but has also brought new challenges for grid operators. As discussed in the Renewables Tracking Progress page, wind and solar resources have grown tremendously over the last decade. Solar photovoltaics in particular increased from essentially zero megawatts (MW) in 2001 to more than 9,100 MW of utility-scale and 5,900 MW of rooftop in 2016. More than half (3,500 MW) of rooftop solar has been installed since 2014 alone. Maintaining the reliability of the electricity system while integrating larger amounts of variable wind and solar generation requires more flexible resources to balance supply and demand.

With the rapid growth in renewables in recent years, along with efforts to meet the 50 percent Renewables Portfolio Standard (RPS) by 2030, there has been growing recognition that system operators needed additional flexible capabilities to accommodate late afternoon upward ramps in energy demand as renewable resources come off the system. In addition, current system operating data highlight the extent to which overgeneration has become a concern.[1] Furthermore, because of expected changes in the dispatchable natural gas-fired fleet, the California Independent System Operator (California ISO) is concerned that it needs greater operational control over flexible capacity.[2]

The Need for Flexible Resources

The California ISO popularized a graphical depiction of the "net load curve" (the "duck chart") that dispatchable generating resources must satisfy each hour on a "typical" spring day. A net load curve shares many features with a total load curve but subtracts the hour-by-hour contribution of wind and solar generation. **Figure 1** on the next page illustrates the extent to which resources must be available to ramp up or down to satisfy this need. When solar electricity generation peaks at midday, then the net load is low and is described as the "belly of the duck." As solar generation trails off at the end of the day and demand remains high, the steep ramp up is referred to as the "neck of the duck."

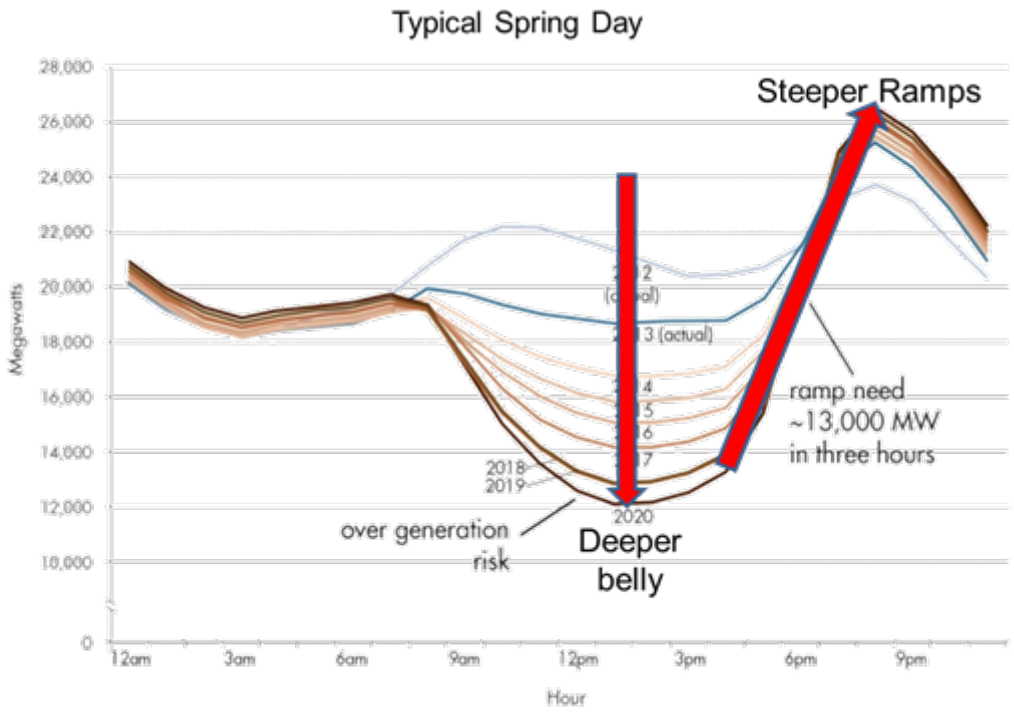
The ramps up in the evening and down in the morning ("the tail of the duck") have become more pronounced and steeper than the California ISO anticipated, largely due to faster-than-anticipated growth in rooftop solar PV and progress toward the 2030 RPS goal. In 2013, the California ISO projected that net load could be as low as 12,000 MW by 2020 and that meeting peak demand may require generators ramping up as much as 13,000 MW in three hours.

1Rothleder, Mark. *California ISO Presentation on Renewable Integration*, California Energy Commission Integrated Energy Policy Report Workshop. May 12, 2017. P. 7. http://www.caiso.com/Documents/RenewableIntegrationUnlockingDividends.pdf.

2 The California ISO believes it needs more operational control than is available through California Public Utilities Commission (CPUC) rules or existing California ISO tariffs and this issue is currently being addressed in the California ISO Flexible Resource Adequacy Criteria Must Offer Obligation (FRACMOO 2) Stakeholder Initiative.

However, two events illustrate that the grid is already experiencing unprecedented operational fluctuations that grid operators were bracing for in 2020. On April 23, 2017, the net load reached a minimum of 9,187 MW, and on December 18, 2016, the maximum three-hour ramp was 12,960 MW, with the peak shifting to later hours in the day.

Figure 1: Typical Spring Day



Source: http://www.caiso.com/Documents/RenewableIntegrationUnlockingDividends.pdf

In response to the many challenges of integrating such large quantities of renewable energy, the Energy Commission, California Public Utilities Commission and the California ISO is looking to better manage oversupply and minimize curtailment, accelerate deployment of storage and demand-side programs, improve supply-side forecasting techniques, and take advantage of regional diversity.

Flexibility Requirements

Previously, a standard one-hour time resolution was sufficient to match large amounts of renewable resources with firming resources that can compensate for the intermittency of renewables. However, operational concerns in the California electrical system are increasingly focused on much shorter time scales. For example, there may be plenty of reserve generation capacity but a lack of fast-responding resources that can follow a rapid change in generation and load. Thus, key characteristics of firming resources include not only total capacity, but response times and ramp rates (for example, megawatts per minute).

Analyses to date suggest that flexible capacity has to address variability in load and power production in three time scales: (1) seconds-to-minutes, (2) 5-10 minutes, and (3) multihour. Variations in the seconds-to-minutes time scale can be addressed by expanding the existing regulation service, such as using automatic generation control on existing generators. Storage is increasingly seen as a possible solution to these regulation concerns. The 5-10 minute flexibility requirements address discrepancies between the 5-minute real-time market schedules and actual loads or generation encountered during these intervals. Multihour ramps up and down have been a feature of California's electrical system for decades, but the introduction of large amounts of renewable capacity with strong diurnal cycles exacerbates these traditional patterns, especially in winter and spring months, and is the focus of flexible capacity efforts. Improved forecasting of load and intermittent renewable production is one approach for addressing this issue.

Market changes, as well as flexible resource development, may help the electricity system evolve to include larger shares of renewables in the resource mix. For example, last year the California ISO introduced a formal flexible ramping product into its market system following Federal Energy Regulatory Commission (FERC) approval.[3] Scheduling renewables in smaller time intervals, such as the real-time market, can reduce the amount of reserves required since the opportunity for differences between forecast and actual generation is reduced from an hour to a shorter time interval. Also, expanding the geographic footprint of the market can help in two ways. First, greater diversity of renewable resources can reduce the coincidence of production patterns. Second, loads in larger regions outside the California ISO can help absorb excess production and generating resources in those regions may be able to assist with upward ramping requirements.

Overgeneration

Overgeneration is the condition represented by the "belly" of the duck curve. Overgeneration exists when net load falls below the minimum generation level of other resources that must be on-line. Spring months with high wind and solar production coupled with low loads are the prime time for overgeneration conditions to be encountered.[4] Some options to solve overgeneration include a need for more flexible generating facilities from either a physical or contractual perspective. Overgeneration also can be solved by curtailing renewable generation, retrofitting existing natural gas plants to reduce minimum generation levels, building load through demand response programs when overgeneration conditions are expected, shifting load using system condition-dependent time-of-use (TOU) rates, or by exporting power outside the California ISO balancing authority area.

The development of a regional grid is an important tool to help integrate renewable resources. Initiated in 2014, the Western Energy Imbalance Market (EIM) is a wholesale energy market

3 FERC, Docket No. ER16-2023-000, September 26, 2016. See https://www.ferc.gov/CalendarFiles/20160926164141-ER16-2023-000.pdf.

4 See California ISO report for a summary of overgeneration issues and its study results. http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M152/K411/152411557.PDF.

that allows participants to buy and sell energy in real-time. Its benefits have grown as more entities join and increase access to more generation and transmission. The EIM began with the inclusion of PacifiCorp, but continues to expand with the addition of NV Energy, Arizona Public Service, Puget Sound Energy and Portland General Electric as participants. The list of pending participants includes Idaho Power Company, Powerex, Seattle City Light, Los Angeles Department of Water and Power, Sacramento Municipal Utility District (SMUD), Balancing Area of Northern California, and Salt River Project. The Western EIM is a mechanism to balance deviations in supply and demand and dispatch least-cost resources every five minutes. With the Western EIM, excess energy in the California ISO balancing area can be transferred to other areas in real time Through the third quarter of 2017, the Western EIM has provided gross benefits of $255 million, avoided the curtailment of 500 gigawatt hours of renewable energy, and has reduced greenhouse gas emissions in the west by almost 215,000 tons of carbon dioxide equivalent.[5]

Increasing the regional scale of the system beyond what can be achieved with the Western EIM can provide additional flexibility while reducing costs and GHG emissions. PacifiCorp has shown interest in joining the California ISO as a participating transmission owner rather than continuing to operate as a separate balancing authority. This would reduce scheduling restrictions and facilitate least-cost dispatch. SB 350 establishes a process and criteria for expansion of the California ISO to include other western utilities.[6] The California ISO has completed the economic and environmental impact studies required by SB 350 and has submitted them to the California Legislature.[7]

Ramps

As with its previous studies, California ISO analyses completed in April 2017 show that the problem of rapidly increasing net load ramps is most severe in the winter months of November through March.[8] **Figure 2** provides an estimate of the maximum ramp over 180 minutes by month for four historical years and projected for 2018 based on renewable projects now in the pipeline.[9] **Figure 2** shows that maximum monthly 180-minute ramps were relatively uniform throughout the year up to about 2014 but become much larger for the eight nonsummer months in the following years. The implication is the need for flexible resources to satisfy this increasing ramp for these nonsummer months, the opposite of the traditional capacity planning focus on summer peak months of July to September.

5 https://www.westerneim.com/Documents/ISO-EIMBenefitsReportQ3_2017.pdf.

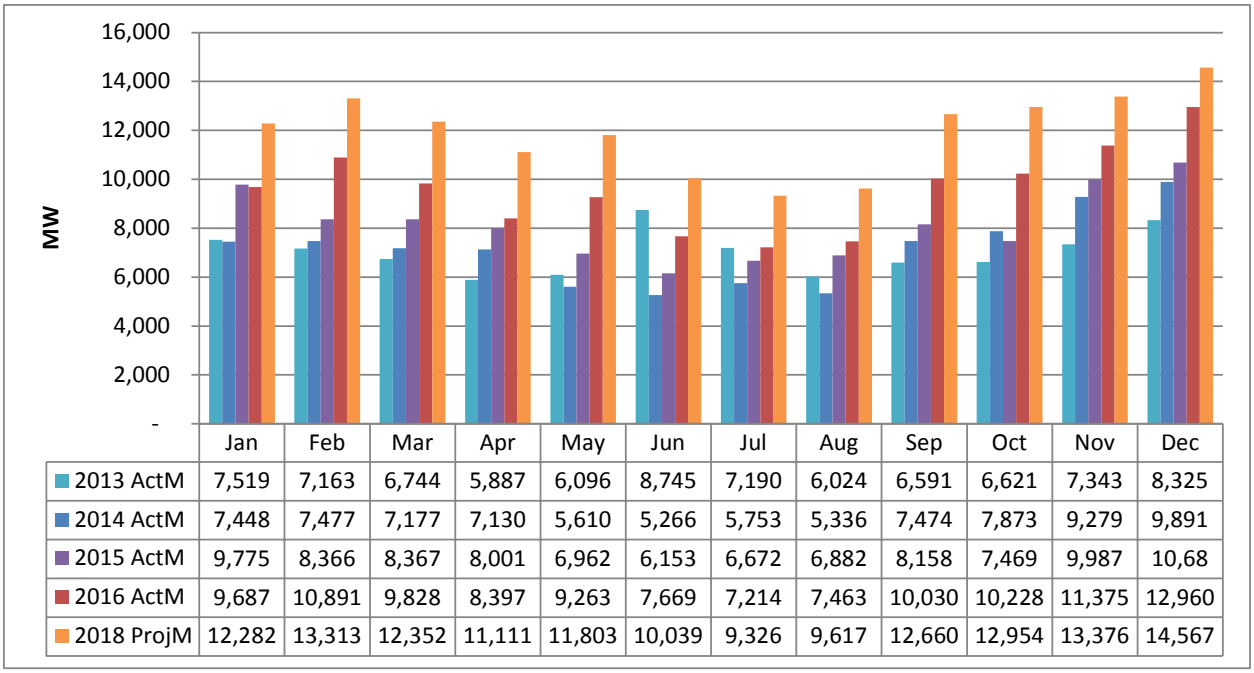
6 Senate Bill 350 (De Leon, Chapter 547, Statutes of 2015).

7 http://www.caiso.com/informed/Pages/StakeholderProcesses/PacifiCorpIntegrationStudies.aspx

8 California ISO, http://www.caiso.com/Documents/2018FinalFlexibleCapacityNeedsAssessment.pdf.

9 Energy Commission staff used data directly from the California ISO study for the forecast year, while historical data reflect Energy Commission staff analysis of data from the California ISO.

Figure 2: Comparing Historical and Projected Maximum Three-Hour Ramps by Month



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013 ActM	7,519	7,163	6,744	5,887	6,096	8,745	7,190	6,024	6,591	6,621	7,343	8,325
2014 ActM	7,448	7,477	7,177	7,130	5,610	5,266	5,753	5,336	7,474	7,873	9,279	9,891
2015 ActM	9,775	8,366	8,367	8,001	6,962	6,153	6,672	6,882	8,158	7,469	9,987	10,68
2016 ActM	9,687	10,891	9,828	8,397	9,263	7,669	7,214	7,463	10,030	10,228	11,375	12,960
2018 ProjM	12,282	13,313	12,352	11,111	11,803	10,039	9,326	9,617	12,660	12,954	13,376	14,567

Source: California ISO, *Final 2018 Flexible Capacity Needs Assessment,* Figure 1, page 9, and Energy Commission staff

For the first time, the California ISO study for 2017 flexibility requirements included behind-the-meter PV generation. This increases the three-hour ramps considerably. As noted earlier, the rapid growth in behind-the-meter PV capacity means that the load curve does not remain static, but is lower during the middle hours of the day, creating ramping requirements where none would have existed without the behind-the-meter PV.

Effective Flexible Capacity

Since the California ISO assessments assume that the great majority of renewable resources will continue to be "must take," the California ISO wants to ensure that sufficient flexible capacity will be available to satisfy these growing ramping requirements. The California ISO proposed,[10] and the CPUC accepted,[11] a definition of effective flexible capacity for each generating facility that accounts for its start-up time,[12] ramping ability over three hours, minimum generation level, and net qualifying capacity. **Table 1** assesses the collective amount of effective flexible capacity

10 http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M064/K141/64141005.PDF, slide 18.

11 CPUC, Decision 13-06-024,Rulemaking 11-10-023, Decision Adopting Local Procurement Obligations for 2014, *A Flexible Capacity Framework, and Further Refining the Resource Adequacy Program*, June 27, 2013, http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M070/K423/70423172.PDF.

12 Effective flexible capacity is the number of megawatts eligible to be counted towards meeting a load serving entity's 3-hour net load (load minus wind and solar generation) ramping requirements.

by generating technology and fuel type.[13] Clearly, the total of nearly 35,000 MW of existing flexible capacity expected in 2017 exceeds the largest California ISO estimate of requirements in 2017. There are three concerns suggesting that the balance between requirements and capabilities is tighter than it might appear in comparing **Figure 2** with **Table 1**, as explained below.

Table 1: Effective Flexible Capacity by Generating Technology and Fuel Type (Megawatts)

Generating Technology	Natural Gas	Geo	Coal	Water/ Hydro	Biomass /Biogas	Dist	Sol	Storage	DR	All Fuels
Steam	5,974	478	373	0	77	0	0	0	0	6,902
Combined	11,316	0	0	0	0	0	0	0	0	11,316
Combustion	7,438	0	0	0	0	165	0	0	0	7,603
Reciprocating	100	0	0	0	7	0	0	0	0	106
Hydroelectric	0	0	0	5,226	0	0	0	0	0	5,226
Pumped	0	0	0	1,457	0	0	0	0	0	1,457
Photovoltaic	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	2	0	0	60	0	62
DR Programs	0	0	0	0	0	0	0	0	182	182
All Technologies	24,827	478	373	6,683	85	165	0	60	182	32,853

Source: California Energy Commission staff analysis of California ISO data (Draft 2018 EFC list, 2017)

Nearly all of the steam turbine capacity is very old, and most of it uses once-through cooling (OTC) technology. Facility owners must comply with State Water Resources Control Board (SWRCB) OTC policy by retiring or retrofitting the power plants. (For more information, see the Tracking Progress page on Once-Through Cooling.) Responses to SWRCB information requests reveal that nearly all generator owners plan to comply by retiring, although many would prefer to repower if long-term contracts can be secured from load-serving entities (LSEs). Retiring all of the remaining natural gas steam boiler effective flexible capacity (5,974 MW) would reduce the remaining effective flexible capacity of the generating fleet to about 27,000 MW if no additional effective flexible capacity was added. Such retirements are already occurring and impacting the total effective flexible capacity. Since last year's resource flexibility update, about 3,000 MW of gas-fired steam turbines have retired (or are unavailable to meet this effective flexible capacity need). This reduction in capacity has been partially offset by capacity increases of primarily gas-fired combine cycles (about 1,000 MW).[14] Also, all OTC facilities in the California ISO balancing authority area are scheduled for shutdown by the end of

13 Calculated by Energy Commission staff from the draft 2018 Effective Flexible Capacity list posted by the California ISO. http://www.caiso.com/Documents/2017EffectiveFlexibleCapacity-ResourceAdequacyResources.html.

14 EFC capacity is not the same as nameplate or net qualifying capacity. Old, slow-moving steam turbines have much lower EFC ratings than the associated nameplate ratings.

2020, although there may need to be adjustments to the compliance schedule due to construction delay and other litigation issues.

In addition, much of the fossil-fired generating fleet must shut down for annual maintenance, and the optimal time has typically been in the winter months, when loads have been low. The need for much larger amounts of flexible capacity in winter months means that there are now competing motivations for when to schedule maintenance: (1) avoid winter months to make capacity available for flexibility requirements, versus (2) continue maintenance in off-peak months when it is not needed for base capacity.

Also, even if sufficient physical flexible capacity exists, such resources may not be available to the California ISO when flexibility is needed. The California ISO markets have traditionally featured a large amount of self-scheduling. While generation owners can specify the price(s) at which the California ISO can induce changes in the amount of energy or ancillary services they provide, a self-scheduled generation resource does not specify such a price or prices, effectively precluding the California ISO from changing the amount provided. Utilities − load-serving entities that own generation − will frequently self-schedule their own generation to satisfy their load and ancillary service requirements, thereby reducing the amount of capacity that the California ISO can (re)dispatch to meet operational needs. For example, LSEs, through their scheduling coordinator, choose when to generate to serve their load. For capacity that is nominated to satisfy current system and local resource adequacy requirements, the generating capacity must be available to the California ISO if it is not self-scheduled. If it is self-scheduled, then the resource adequacy obligation is satisfied.

However, for flexible capacity that must be responsive to intermittent wind and solar generation, the California ISO wants to have greater control to ensure that it can dispatch capacity up or down to satisfy net loads. LSE/generator contracts with self-scheduling will still be allowed, but such capacity will not count as flexible. An LSE wishing to continue to self-schedule will be required to satisfy its share of the aggregate, or combined, flexible capacity requirements by nominating other capacity that is both physically flexible and can be dispatched up or down by the California ISO.[15] Beginning with calendar year 2015, the flexibility requirements adopted by the CPUC in Decision (D) 13-06-024[16] (parallel requirements were established by the ISO for non-CPUC jurisdictional LSEs within its balancing authority area) were matched by complementary obligations on effective flexible capacity to submit economic bids into California ISO markets and to respond to dispatch instructions.

15 To “nominate” capacity means to submit a proposed schedule and price points to the California ISO scheduling process and to accept the results of the California ISO’s market optimization process.

16 CPUC, Decision 13-06-024, Rulemaking 11-10-023, Decision Adopting Local Procurement Obligations for 2014, *A Flexible Capacity Framework, and Further Refining the Resource Adequacy Program*, June 27, 2013, http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M070/K423/70423172.PDF.

Finally, **Table 1** shows that small amounts of dispatchable storage facilities and demand response are now participating in the California ISO markets. Both are expected to grow in future years.

Balancing Requirements With Expected Capabilities

In D.13-06-024, the CPUC determined that it would implement in 2015 the general approach of imposing an effective flexible capacity requirement proposed by the California ISO.[17] Numerous implementation questions were resolved in D.14-06-050. In June 2015, the CPUC adopted comparable requirements for 2016 using results from a California ISO study for 2016 that largely replicated its analyses for 2015.[18] The CPUC reached a similar conclusion for 2017 in its annual resource adequacy decision, D.16-06-045.[19] And while the CPUC has recognized the need to replace the interim flexible resource adequacy program with a "durable" approach, the interim remains in place for 2018 as written in D.17-06-027.[20]

The evolution of flexibility requirements satisfactory to both the CPUC and California ISO has resulted in mechanisms that assure that an appropriate mix of flexible capacity is available to the California ISO each month. The approved mechanism allows the use of limited resources to satisfy a portion of the flexibility requirements. In D.14-06-050, the CPUC established the following three categories on an interim basis:

- Category 1: Base Flexibility (must offer from 5 a.m. to 10 p.m. daily, year round)
- Category 2: Peak Flexibility (must offer 5 hours per day defined seasonally with at least one start per day)
- Category 3: Super-Peak Flexibility (must offer 5 hours per day defined seasonally, with obligation complete after five starts per month)

The California ISO created obligations on the generators that matched these three categories.

Figure 3 on the next page represents total flexibility requirement allocated by the California ISO to the CPUC, and how the three categories could be used to satisfy the overall requirements for CPUC-jurisdictional LSEs. The numeric limit for Categories 2 and 3 is a maximum, while the limit for Category 1 is a minimum. In effect, peak and superpeak resources are allowed to be chosen up to specified monthly limits, while Category 1 can be used as much as the LSE desires. Each LSE can establish its own preferred combination of specific generating resources,

17 D.13-06-024, http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M070/K423/70423172.PDF.

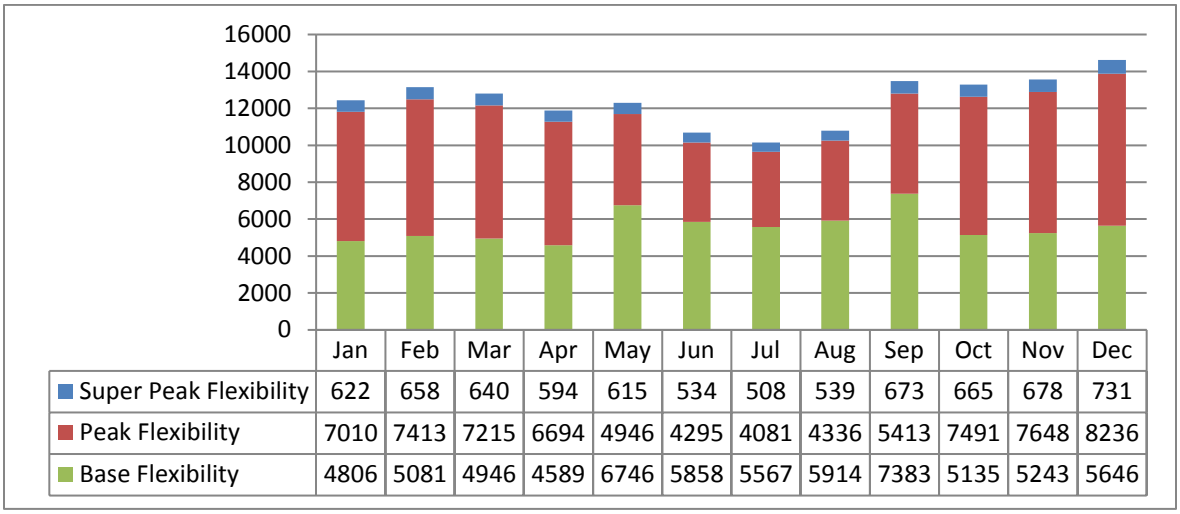
18 CPUC D.15-06-063, http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M152/K977/152977475.PDF.

19 Decision 16-06-045, Rulemaking 14-10-010, *Track 1 Decision Adopting Local and Flexible Capacity Obligations for 2017, and Further Refining the Resource Adequacy Program*, June 23, 2016, http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M164/K214/164214092.PDF.

20 http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M192/K027/192027253.PDF.

or other programs allowed to provide flexible capacity, guided by these aggregate limits. The CPUC adopted these quantities in D.17-06-027.

Figure 3: Monthly Flexible Capacity Limits by Resource Category for CPUC-Jurisdictional Entities



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Super Peak Flexibility	622	658	640	594	615	534	508	539	673	665	678	731
Peak Flexibility	7010	7413	7215	6694	4946	4295	4081	4336	5413	7491	7648	8236
Base Flexibility	4806	5081	4946	4589	6746	5858	5567	5914	7383	5135	5243	5646

Source: *California ISO Final Flexible Capacity Needs Assessment for 2018*, April 28, 2017, page 22.

Improving Analytic Methods

The focus of this Tracking Progress page reflects the short-run perspective of the resource adequacy program. Like other aspects of resource adequacy, the main goal is to identify resources that can and will assure reliability by responding to California ISO dispatch instructions. The flexibility requirements established in 2015 and continuing through 2018 have been labeled an "interim approach." It is widely recognized that both short-term and long-term resource adequacy methods need improvement. The CPUC included a more substantive review of short-term methods in a September 2016 scoping memo and ruling.[21] Among other topics, the scoping memo for the rulemaking includes consideration of a more permanent method for assessing flexible capacity requirements and multi-year resource adequacy requirements. More recently, the CPUC opened a new rulemaking, R.17-09-020, (successor to R.14-10-010) for the 2019 and 2020 compliance years and to address changes and refinements for resource adequacy.[22]

Assessing long-term future capabilities versus requirements is necessary to determine whether there is a need for additional flexible capacity and/or solutions to overgeneration projections. This assessment needs to take into account generating resource development in the pipeline, expected generating resource retirements due to age or regulatory mandates like the OTC

21 CPUC, Rulemaking 14-10-010, Assigned Commissioner and Administrative Law Judge's Phase 3 Scoping Memo and Ruling, 9/13/2016. See http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M166/K987/166987422.PDF.

22 http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M196/K747/196747674.PDF.

policy, changes in electricity demand and hourly use, and the potential for renewable curtailment. The CPUC has attempted to develop a long-term assessment by working with the California ISO in the 2010, 2012, and 2014 LTPP rulemakings and more recently in the integrated resource plan (IRP) proceedings. California ISO studies have developed a wide range of 10-year forward estimates of need for upward ramping capacity, depending upon the iteration of the model and input assumptions.[23] In each proceeding, the CPUC has concluded the results of these studies are too uncertain to justify procurement.[24] Generally, the issues involve both methodology as well as input assumptions

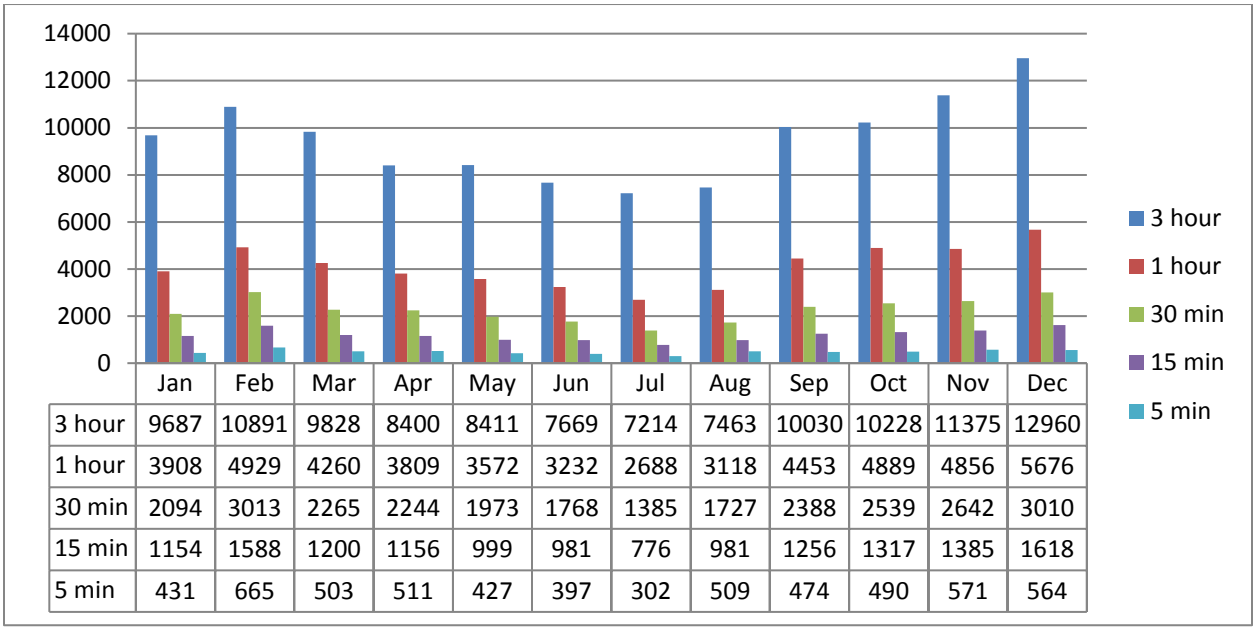
Through the FRACMOO 2 stakeholder initiative, the California ISO is attempting to develop a comprehensive framework to the flexible resource adequacy issue that uses market signals to ensure generation retention and retirement, allows intertie resources to help meet flexible requirements, and provides LSEs and local reliability areas more choices in meeting requirements based on their policies and business objectives.[25] Also, the need for meeting future hourly and sub-hourly ramps is being studied, as historical data are showing a growth in this resource need as well, similar to what is occurring with three-hour ramping needs. Figure 4 below compares these ramping requirements for 2016.

23 *Summary of Studies of Southern California Infrastructure*, California Energy Commission, 2013. http://www.energy.ca.gov/2013_energypolicy/documents/2013-07-15_workshop/background/Summary_of_Studies_of_Sourthern_California_Infrastructure.pdf, Table 2.

24 Assigned Commission and Administrative Law Judge's Ruling Regarding Track 2 and Track 4 Schedules in Rulemaking 12-03-014. September 2013. http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M076/K995/76995686.PDF.

25 California ISO Presentation, *Flexible Resource Adequacy Criteria and Must Offer Obligation Working Group Meeting*, September, 26. 2017. http://www.caiso.com/Documents/Presentation-FlexibleResourceAdequacyCriteria_MustOfferObligationSep26_2017.pdf.

Figure 4: Maximum Upward Ramps for Various Time Frames Inside Same Three-Hour Window



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3 hour	9687	10891	9828	8400	8411	7669	7214	7463	10030	10228	11375	12960
1 hour	3908	4929	4260	3809	3572	3232	2688	3118	4453	4889	4856	5676
30 min	2094	3013	2265	2244	1973	1768	1385	1727	2388	2539	2642	3010
15 min	1154	1588	1200	1156	999	981	776	981	1256	1317	1385	1618
5 min	431	665	503	511	427	397	302	509	474	490	571	564

Source: California ISO Flexible Resource Adequacy Criteria and Must Offer Obligation Working Group Meeting, September 26, 2017 presentation, page 13

To determine when new resource additions, if any, will be required, a transition needs to be developed between the short-term mechanism for meeting flexibility needs (as adopted in the resource adequacy program by D.14-06-050, D.15-06-063, and D.16-06-045) and the long-term approach that has been considered in the past LTPP rulemakings. With the passage of SB 350, the relative priority of these considerations has shifted. The California ISO is now focused on increased regionalization, which offers the opportunity of a large and more diverse market. Such a market would alter projections of flexibility requirements by changing the location and technology of renewable development, and would offer a more diverse range of market solutions to address flexibility requirements. The CPUC is continuing integrated resource planning, which may increase its focus on the extent to which preferred resources and storage can be used to reduce flexibility requirements and to satisfy a larger portion of any needs than in the past. Moreover, Assembly Bill 33 (Quirk, Chapter 680, Statutes of 2016) requires the CPUC to analyze the potential for long-duration bulk energy storage to help integrate renewable resources.

Parties to the LTPP/IRP proceedings have used production cost models to help evaluate the need for flexible capacity for varied resource portfolios. The September 23, 2016, *Administrative Law Judge Ruling Directing Production Cost Model Requirements* provided direction to parties that use these types of models in their IRP analyses. Parties were directed to use consistent definitions and reliability metrics for modeling (both deterministic and stochastic), produce consistent model output results, and use consistent modeling methodologies. The ruling

directed parties to use, at a minimum, Scenario 2: the Default Scenario with the midlevel additional achievable energy efficiency sensitivity to ensure comparability of modeling results.[26]

While these modeling requirements are being used to develop a framework for resource optimization modeling in the IRP process, this framework may be useful in modeling flexible resource needs for achieving the 50 percent RPS requirement. The CPUC has completed its capacity expansion modeling for the SB 350 /IRP proceeding and more granular, hourly production-cost modeling will be conducted using the new resource portfolios as a key input assumption. The new portfolios will include significant increases in solar generation capacity to meet state mandates for renewable generation and greenhouse gas reductions. The addition of this solar capacity may result in an increase in the need for flexible capacity resources to meet upward and downward ramping requirements. This IRP modeling and analysis were discussed at a November 2, 2017, workshop at the CPUC.[27]

Additional References:

National Renewable Energy Laboratory Grid Integration Webinars: https://www.nrel.gov/esif/grid-integration-webinars.html#video2.

National Renewable Energy Laboratory, *Modernizing Our Grid and Energy System,* NREL/BK-5C00-68026, March 2017. https://www.nrel.gov/docs/fy17osti/68026.pdf.

California Independent System Operator: Fast Facts, *What the duck curve tells us about managing a green grid,* 2016 http://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf

National Renewable Energy7 Laboratory, *North American Renewable Integration Study*. https://www.nrel.gov/analysis/naris.html.

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Next Update:

November 2018 with updates provided annually

26 CPUC, Rulemaking 16-02-007, Administrative Law Judge Ruling Directing Production Cost Modeling Requirements, September 23, 2016. http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M167/K501/167501732.PDF.

27 http://www.cpuc.ca.gov/General.aspx?id=6442451195.