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 in particular increased from a little more than 400 megawatts (MW) in 2001 to more than 7,000 MW in 2015. Rooftop solar photovoltaic (PV) has also seen dramatic growth with 4,400 MW installed statewide, nearly 2,000 MW of which was installed in 2014 and 2015. 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.

The continued projected growth of intermittent renewable generation to meet California's 33 percent Renewables Portfolio Standard (RPS) by 2020 spurred several studies to determine the extent to which the system operator needs additional flexible capabilities to accommodate late afternoon upward ramps in energy demand.[1] These studies and current system operating data also highlight the extent to which overgeneration has become a concern.[2] Several advocacy groups have undertaken their own studies. Senate Bill 350 (De León, Chapter 547, Statutes of 2015) established a higher mandate of 50 percent of qualifying retail sales to be supplied by renewable generation by 2030.[3] Intuitively, any challenges in addressing intermittent generation at 33 percent are increased when planning to achieve 50 percent. Furthermore, because of expected changes in the natural gas-fired dispatchable fleet, the California Independent System Operator (California ISO) is concerned that it needs greater operational control over flexible capacity than is available through California Public Utilities Commission (CPUC) rules or existing California ISO tariffs.

Flexibility Requirements

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,

1 http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M064/K141/64141005.PDF.

2 http://www.caiso.com/Documents/Briefing_DuckCurve_CurrentSystemConditions-ISOPresentation-July2015.pdf.

3 SB 350, See Section 20.
http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB350.

key characteristics of firming resources include not only total capacity, but response times and ramp rates (for example, megawatts per minute).[4]

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 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, the California ISO has recently introduced a formal flexible ramping product into its market system following Federal Energy Regulatory Commission (FERC) approval.[5] 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 can help absorb excess production and generating resources may be able to assist with upward ramping requirements.

The Need for Flexible Resources

The California ISO popularized a graphical depiction of the "net load curve"[6] (the "duck chart") that dispatchable generating resources must satisfy each hour. **Figure 1** illustrates the extent to which resources must be available to ramp up or down to satisfy this need. A net load curve shares many features with a total load curve but superimposes the hour-by-hour variability of wind and solar generation. The ramps up and down in the net load curve have become sharper and more exaggerated faster than anticipated given the rapid increase in behind-the-meter solar PV and progress toward the 2020 RPS goal.

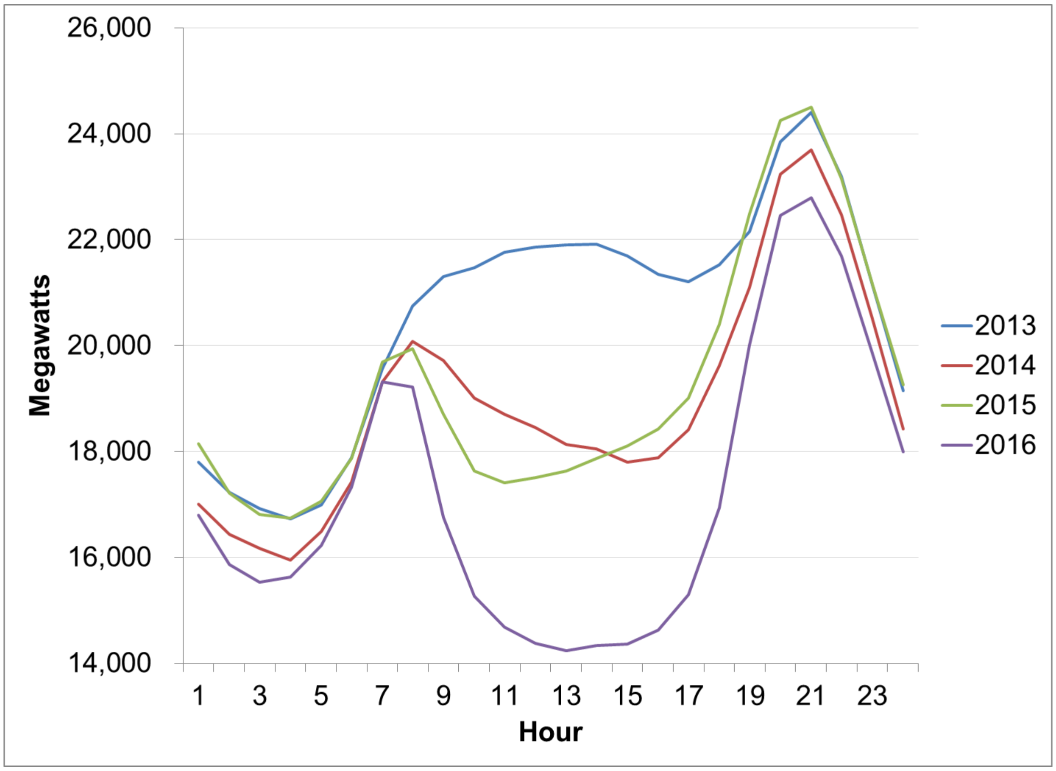
---

4 Alexandra von Meier. California Insititute for Energy and Environment, *Integration of Renewable Generation in California, Coordination Challenges in Time and Space,* 2011, http://uc-ciee.org/electric-grid/4/557/102/nested.

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

6 By definition, a *net load curve* is total load less the production of wind and solar generating facilities. It can be computed with data of any time increment, most commonly hourly or for 1-minute increments.

Figure 1: The Duck Has Landed



Source: Fowlie, Meredith, The Duck has Landed, Energy at Haas, U.C. Berkeley, May 2, 2016. California ISO Hourly Data, March 28-April 3, Years 2013-2016

In 2013, the California ISO projected that net energy demand after subtracting behind-the-meter generation (net load) could be as low as 12,000 MW by 2020 and that meeting peak demand may require ramping up 13,000 MW in three hours. Two days in 2016 illustrate that the grid is already experiencing unprecedented operational fluctuations that grid operators were bracing for in 2020. On May 15, 2016, the net load reached a minimum of 11,663 MW, and on February 1, 2016, the three hour ramp was 10,892 MW, with the peak shifting to later hours in the day.

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. The analyses submitted in the CPUC's 2014 Long-Term Procurement Plan (LTPP) rulemaking identify spring months with high wind and solar production coupled with low loads as the prime time for overgeneration conditions to be encountered.[7] Some options to solve overgeneration suggest a need for more flexible generating facilities from either a physical or

7 At the CPUC's request, the ISO submitted its assessment of additional cases in spring 2015 that supplement its original filings in the 2014 LTPP proceeding from August and November 2014. 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.

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 TOU rates, or by exporting power outside the California ISO balancing authority area, and so forth.[8]

The development of a regional grid is another important tool to help integrate renewable resources beyond what can be achieved with the Energy Imbalance Market (EIM). The EIM started in 2014 with PacifiCorp but continues to expand with NV Energy joining in 2015, and Arizona Public Service and Puget Sound Energy joining on October 1, 2016. The EIM is a mechanism to balance deviations in supply and demand and dispatch least-cost resources every five minutes. With the EIM, excess energy in the California ISO balancing area can be transferred to other areas in real time. If not for energy transfers facilitated by the EIM, the California ISO would have curtailed 272,000 MWh of renewable energy in the first two quarters of 2016, equivalent to 116,000 metric tons of carbon emissions.

PacifiCorp has also 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.[9] The California ISO has completed the economic and environmental impact studies required by SB 350 and has submitted them to the California Legislature.

Ramps

As with its previous studies, California ISO analyses completed in April 2016 show that the problem of rapidly increasing net load ramps is most severe in the winter months of November through March.[10] **Figure 2** provides an estimate of the maximum ramp over 180 minutes by month for three historical years and 2017 based on renewable projects now in the pipeline.[11] **Figure 2** shows that maximum monthly 180-minute ramps were relatively uniform throughout the year historically but become much larger into the future for the eight nonsummer months. 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.

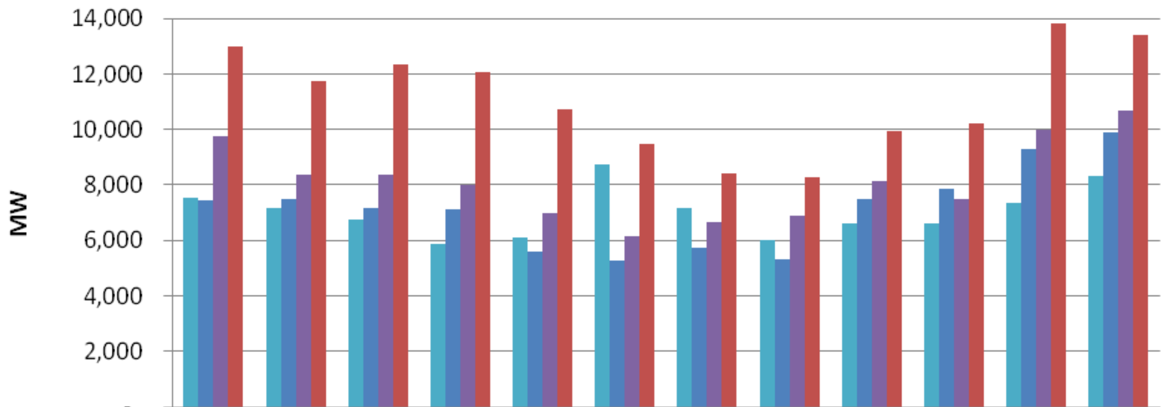
8 For a recent list of potential solutions see the Joint Agency Symposium on the Governor's Greenhouse Gas Reduction Goals, held July 9, 2015, slide 15. http://www.arb.ca.gov/cc/pillars/renewables/slides.pdf.

9 SB 350, Section 12.

10 California ISO, http://www.caiso.com/Documents/FinalFlexibleCapacityNeedsAssessmentFor2017.pdf.

11 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 3-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
2017 ProjM	12,970	11,729	12,364	12,054	10,737	9,464	8,397	8,295	9,918	10,196	13,835	13,399

Source: California ISO, *Final 2017 Flexible Capacity Needs Assessment,* Figure 1, page 10, 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 3-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 itself is lower during the middle hours of the day, creating ramping requirements where none would have existed without the behind-the-meter PV.

Flexible Resources

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,[12] and the CPUC accepted,[13] a definition of effective flexible capacity (EFC)[14] for each generating facility that accounts for its start-up time, ramping ability over three hours, minimum generation level, and net qualifying capacity. **Table 1** on the next page assesses the collective amount of

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

13 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.

14 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.

EFC by generating technology and fuel type.[15] 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, however, suggesting that the balance between requirements and capabilities is tighter than it might appear in comparing **Figure 2** with **Table 1**.

First, nearly all of the steam turbine capacity is very old, and most of it uses once-through cooling (OTC) technology. Facility owners must satisfy 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 EFC (8,931 MW) would reduce the remaining EFC of the generating fleet to about 26,000 MW if nothing more was added. Such retirements are already occurring. Since July 2015, more than 460 MW of steam turbine/natural gas has been retired.[16] Also, all OTC facilities in the California ISO balancing authority area are scheduled for shutdown by the end of 2020, although there may need to be adjustments to the compliance schedule due to construction delay and other litigation issues.

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

Generating Technology	Natural Gas	Geothermal	Water	Biomass /Biogas	Oil	Solar	DR	All Fuels
Steam turbines	8,931	488	0	68	0	0	0	9,486
Combined cycle	10,387	0	0	0	0	0	0	10,387
Combustion turbine	7,176	0	0	2	165	0	0	7,343
Reciprocating engine	262	0	0	10	0	0	0	273
Hydroelectric	0	0	5,858	0	0	0	0	5,858
Pumped storage	0	0	1,457	0	0	0	0	1,457
Photovoltaic	0	0	0	0	0	26	0	26
DR Programs	0	0	0	0	0	0	34	34
All Technologies	26,755	488	7,315	80	165	26	34	34,863

Source: California Energy Commission staff/EAD analysis of California ISO data (Draft 2017 EFC list, 2016).

Second, 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.

---

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

16 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. The difference of 467 MW is the retirement of El Segundo 4 (315 MW) and a rerating of Pittsburg 7 (loss of 152 MW).

Third, 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.[17] 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[18] other capacity that is both physically flexible and can be dispatched up or down by the California ISO. Beginning with calendar year 2015, the flexibility requirements adopted by the CPUC in Decision (D) 13-06-024[19] (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.

Finally, **Table 1** shows that small amounts of dispatchable solar generating 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.[20] 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

17 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. For example, 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.

18 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.

19 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.

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

largely replicated its analyses for 2015.[21] The CPUC reached a similar conclusion for 2017 in its annual resource adequacy decision, D.16-06-045.[22]

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 of the year. 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)

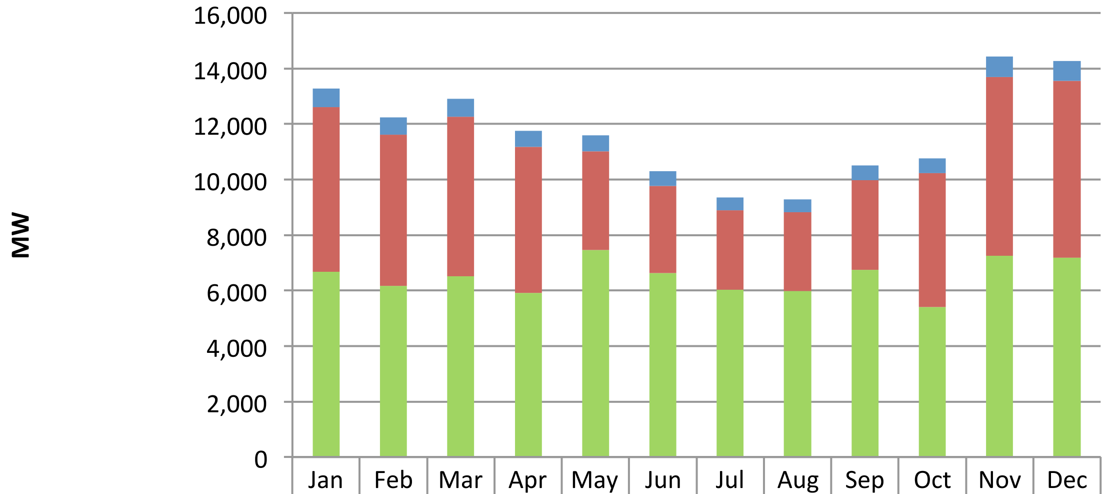
The California ISO created obligations on the generators that matched these three categories.

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 super-peak 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, or other programs allowed to provide flexible capacity, guided by these aggregate limits. The CPUC adopted these quantities in D.16-06-045.

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

22 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.

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	664	612	646	588	580	515	468	465	525	538	721	714
Peak Flexibility	5,930	5,464	5,768	5,253	3,558	3,156	2,873	2,850	3,221	4,805	6,441	6,374
Base Flexibility	6,687	6,162	6,504	5,923	7,462	6,619	6,025	5,977	6,755	5,418	7,263	7,188

Source: *California ISO Final Flexible Capacity Needs Assessment for 2017*, April 29, 2016, 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 2017 have been labeled an "interim approach." Both short-term and long-term methods need improvement.

The CPUC has included a more substantive review of short-term methods in the new phase of its resource adequacy rulemaking.[23] 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.

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 policy, changes in electricity demand and hourly use and potential 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. California ISO studies have developed a wide

---

23 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.

range of 10-year forward estimates of need for upward ramping capacity, depending upon the iteration of the model and input assumptions.[24] In each proceeding, the CPUC has concluded the results of these studies are too uncertain to justify procurement.[25] Generally, the issues involve both methodology as well as input assumptions. For the 2014 LTPP analyses, both the California ISO and Southern California Edison submitted results using stochastic models (simplified production simulations tools iterating hundreds of times using combinations of inputs drawn from probabilistic descriptions of key inputs), which attempt to provide a range of outputs by assessing a wide range of possible input assumptions combinations. All parties sponsoring studies urged the CPUC to refrain from ordering procurement based on these studies.

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 undertaking 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. Also, 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. Given the timeline of these major efforts, the CPUC resource adequacy rulemaking may be the vehicle in which initial changes to flexibility assessments take place. It appears likely that near-term flexibility issues will be tackled in this cycle of the resource adequacy proceeding.

Parties to the LTPP proceeding 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* provides direction to parties that use these types of models in their integrated resource plan 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 integrated resource planning process, this framework may lead to

---

24 http://www.energy.ca.gov/2013_energypolicy/documents/2013-07-15_workshop/background/Summary_of_Studies_of_Sourthern_California_Infrastructure.pdf, Table 2.

25 http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M076/K995/76995686.PDF.

26 CPUC, Rulemaking 16-02-007, *Administrative Law Judge Ruling Directing Production Cost Modeling Requirements*, September 23, 2016.

an analysis of the requirements needed to model flexible resource needs for achieving the 50 percent RPS requirement.

Additional References:

Energy Commission, *Challenges to the Integration of Renewable Resources at High System Penetration*, CEC-500-2014-042, May 2014.

Lazar, Jim**,** *Teaching the "Duck" to Fly***,** Regulatory Assistance Project, January 2014.

Contact:

Richard Jensen, richard.jensen@energy.ca.gov

Next Update:

November 2017 with updates provided annually