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Filer:	Robert Sarvey
Organization:	Robert Sarvey
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APPENDIX F

California ISO Renewable Integration Study in Support of the California Air Resources Board for Meeting Assembly Bill (AB) 1318

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California ISO
Renewable Integration Study in Support of the California Air Resources Board for Meeting Assembly Bill (AB) 1318

May 7, 2013

California ISO
Shaping a Renewed Future

1. Introduction

In support of the directives of Assembly Bill 1318 (AB 1318, Perez, Chapter 285, Statutes of 2009), the California Independent System Operator Corporation (ISO) conducted production cost simulations to evaluate the performance of resources in the L.A. Basin and to identify incremental system-wide capacity needs to manage variations between load and supply on the ISO's system. The simulation relies on the Plexos production cost simulation model that the ISO uses in its renewable integration study efforts as well as the 2010 Long Term Procurement Plan (LTPP) proceedings before the California Public Utilities Commission. The modeling methodology and assumptions were reviewed by stakeholders participating in these processes. In addition, the ISO had submitted testimony in the Commission's proceedings based on the simulation results of the model.[1]

2. General Modeling Assumptions

1) Production cost simulation methodology

Plexos is production cost simulation software. It finds generation unit commitment and dispatch solutions to meet demand with minimum cost, including variable generation cost as well as start-up and shut-down costs. The simulation runs chronologically through all hours of year 2020 in hourly intervals. The simulation enforces generating unit constraints, including ramp rate, start-up time, minimum run and minimum down time, as well as transmission constraints.

2) Structure of the model

The production cost simulation model for this study has the same structure as the model the ISO used in the 2010 LTPP study. It has zonal configurations for the entire Western Electricity Coordinating Council (WECC) region. There are total 25 zones, eight of them in California. The ISO Balancing Authority Area is divided into four zones, PG&E_BayArea, PG&E-Valley, SCE, and SDG&E.

The model assumes that there is no transmission constraint inside each zone. However, transmission limits between the zones are enforced. The transmission limits between any two zones reflect the maximum simultaneous direct transfer capabilities between the two zones.

Each zone has a load that can be met by generation from resources inside the zone and from generation outside the zone. Imports are subject to the transmission limits into the zone. Besides load, there are also requirements for ancillary services (regulation-up, regulation-down, spinning reserve, and non-spinning reserve) and load following (up and down) capacity for the ISO and for other California Balancing Authority Areas.

[1] Mark Rothleder July 1, 2011 CPUC testimony http://www.cpuc.ca.gov/NR/rdonlyres/1DE789A2-29EB-4E95-9284-9E680C0113E6/0/CAISOTestimony70111_FINAL.pdf

Simulation with the model is in hourly intervals. It commits and dispatches resources to meet hourly average load. The actual real-time dispatch schedules in current ISO markets are in 5-minunte intervals. Load-following is on-line flexible capacity reserved to cover deviations between hourly and 5-minute average loads within each hour in both upward and downward directions. Regulation reserve is dispatched automatically to cover the deviations between 5-minute average and 1-minute actual loads in each 5-minute interval in both upward and downward directions. A tool developed by Pacific Northwest National Laboratory (PNNL) is used to calculate the requirements for regulation and load following up and down based on forecasts and forecast errors of load as well as solar and wind generation.

The requirement for spinning reserve equals 3% of total load. Non-spinning reserve requirement is another 3% of load.

Ancillary service requirements can be met by generation resource capacity that is on-line and can ramp to the required capacity level within 10 minutes. Some resources can also provide non-spinning reserve while they are off-line based on their start-up and ramping capability. Load following requirements can be met by generation resource capacity that is online and can ramp to the required capacity level within 20 minutes. The total contribution to ancillary services and load-following by a generation resource cannot exceed 20 minutes ramping capability of the resource. Inter-hour energy changes can be met by generation capacity that is online and can ramp to the required capacity level within 60 minutes. The sum of contribution to ancillary services, load-following, and inter-hour energy ramping cannot exceed 60 minutes ramping capability of the resource.

3) Base data of the model

The ISO developed the model based on the WECC Transmission Expansion Planning Policy Committee (TEPPC) model version PC0 (for 2020) dated March 21, 2011. Data for California renewable portfolios identified in Table 1 and load scenarios are developed in the CPUC's 2010 LTPP proceeding.[2]

In this study, the ISO uses the 2010 CPUC LTPP Trajectory High-Load scenario for 2020 as basis. Additional assumptions about local capacity and demand response resources are implemented to create the cases for this study.

The Trajectory High-Load scenario reflects a combination of future uncertainties, including increased load growth and lack of performance from demand side management resources. The scenario also has 1,497 MW of additional renewable resources compared to the Trajectory scenario to meet the 33% Renewable Portfolio Standard target. For emission assessment purpose, the Trajectory High-Load scenario also represents the upper bound of expected emissions among the 2010 CPUC LTPP scenarios.

[2] See http://www.cpuc.ca.gov/PUC/energy/Procurement/LTPP/LTPP2010/2010+LTPP+Tools+and+Spreadsheets.htm

Table 1. The CPUC 2010 LTPP Renewable Portfolios for 2020

Scenario	Region	Biomass/ biogas	Geothermal	Small Hydro	Solar PV	Distributed Solar	Solar Thermal	Wind	Total
Trajectory	CREZ-North CA	3	0	0	900	0	0	1,205	**2,108**
	CREZ-South CA	30	667	0	2,344	0	3,069	3,830	**9,940**
	Out-of-State	34	154	16	340	0	400	4,149	**5,093**
	Non-CREZ	271	0	0	283	1,052	520	0	**2,126**
	Scenario Total	338	821	16	3,867	1,052	3,989	9,184	**19,266**
Environmentally Constrained	CREZ-North CA	25	0	0	1,700	0	0	375	**2,100**
	CREZ-South CA	158	240	0	565	0	922	4,051	**5,935**
	Out-of-State	222	270	132	340	0	400	1,454	**2,818**
	Non-CREZ	399	0	0	50	9,077	150	0	**9,676**
	Scenario Total	804	510	132	2,655	9,077	1,472	5,880	**20,530**
Cost Constrained	CREZ-North CA	0	22	0	900	0	0	378	**1,300**
	CREZ-South CA	60	776	0	599	0	1,129	4,569	**7,133**
	Out-of-State	202	202	14	340	0	400	5,639	**6,798**
	Non-CREZ	399	0	0	50	1,052	150	611	**2,263**
	Scenario Total	661	1,000	14	1,889	1,052	1,679	11,198	**17,493**
Time Constrained	CREZ-North CA	22	0	0	900	0	0	78	**1,000**
	CREZ-South CA	94	0	0	1,593	0	934	4,206	**6,826**
	Out-of-State	177	158	223	340	0	400	7,276	**8,574**
	Non-CREZ	268	0	0	50	2,322	150	611	**3,402**
	Scenario Total	560	158	223	2,883	2,322	1,484	12,171	**19,802**
High Load	CREZ-North CA	3	0	0	900	0	0	1,205	**2,108**
	CREZ-South CA	30	1,591	0	2,502	0	3,069	4,245	**11,437**
	Out-of-State	34	154	16	340	0	400	4,149	**5,093**
	Non-CREZ	271	0	0	283	1,052	520	0	**2,126**
	Scenario Total	338	1,745	16	4,024	1,052	3,989	9,599	**20,763**

4) New resource characteristics

In the model new CCGT and GT resources are used to meet the local capacity requirement in Southern California. Multiple such new resources are added to meet the requirements as specified in the case assumptions. The new resources are also referred to as Local Capacity Requirement (LCR) resources. Table 2 compares the main operating characteristics of the new CCGT and GT resources with similar existing units.

Table 2. Characteristics of New LCR resources and Selected Existing Units

Resource	Max/Min Capacity (MW)	Full-Load Heat Rate (Btu/kWh)	Ramp Rate (MW/min)	Forced Outage Rate (%)	Maintenance Rate (%)	Start-up Time (hour)	Start-up Cost ($)
NEW CCGT	500/200	7,000	7.5	4.96	10.0	2	44,520
NEW GT	100/40	9,191	12.0	7.24	10.0		1,200
Gateway (CCGT)	530/265	7,000	10.0	10.00	10.0	2	24,411
Sentinel (GT)	106/43	9,191	12.0	10.00	10.0		1,000

Gateway is an air-cooled CCGT unit started operation in 2009. It is chosen to be the reference for comparison since it has the newest technology of CCGT built in California. Its size and generation characteristics are similar to that of the new CCGT added in the

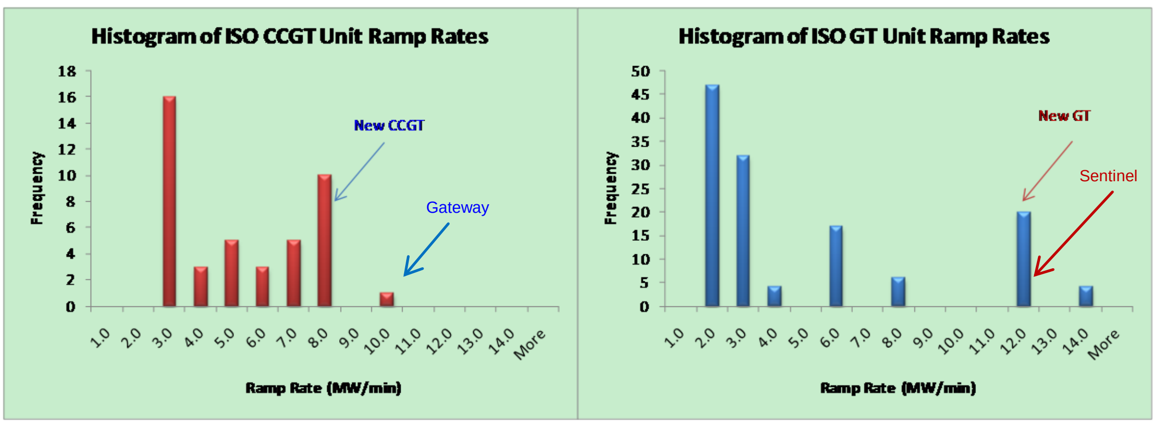
SCE and SDG&E zones. The characteristics of the Gateway unit are from publicly available sources.[3]

The characteristics, except forced outage rates, of the new CCGT and GT resources are inherited from the generic unit assumptions for the 2010 CPUC LTPP proceeding and the ISO renewable integration study. The assumptions were adopted through discussions with stakeholders participating in the study. The forced outage rates of the new CCGT and GT resources are from NERC GADS source.[4]

In simulation forced outage rate and maintenance rate of a resource are used to determine the availability of the resource over the year. For example, the New CCGT unit in Table 2 has 4.96% of the 8,786 hours not available in 2020 due to forced outage. The outage occurs randomly. The unit also has 10% of the 8,786 hours on maintenance. The maintenance is scheduled mostly for spring and winter months. It does not have any maintenance in the summer months.

Figure 1 shows a comparison of ramp rates of the new CCGT and GT resources with the ramp rates of other existing units of the same type in the ISO area. As shown in the chart, the new CCGT and GT resources generally have higher ramp rates (i.e., more flexible) than other existing units.

Figure 1. Comparison of Ramp Rates by Unit Type



5) Simulations runs

[3] The forced outage rate of the Gateway unit was revised in the 2010 CPUC LTPP proceeding and ISO renewable integration study. The ISO benchmarked the model's total outage (including forced and maintenance outages) with the ISO 2010 actual total outage. Specifically we compared the model's California-wide total outage MW with the ISO-wide 2010 monthly minimum total outage MW (see chart below). Based on the benchmarking, the forced outage rates of most California existing thermal generation units, including Gateway, were increased.

[4] Forced outage rates of the new LCR resources are based on NERC Generating Availability Data System 2006-2010 average EFORd, CCGT for all MW sizes and GT for 50 plus MW. The ISO set the forced outage rate of existing units at 10% to match total MW outage in California in 2020 with the ISO monthly minimum actual MW outage in 2010.

The ISO conducted simulations in two separate model runs.[5]

The first one is called Production Cost Run and the other is called Need Run. The difference between the two runs is in the values of regulation and load following requirements. In the Production Cost Run regulation and load following (up and down) requirements have hourly values as calculated by the PNNL tool. In the Need Run, regulation and load following (up and down) requirements are set to monthly maximum value of each hour. For example, the regulation-up requirements of hour 1 of all 31 days in January are set to the maximum of the hourly requirement calculated by the PNNL tool for hour 1 of the 31 days in January.

The Production Cost Run produces the results of generation output, costs, ancillary service and load following provisions, as well as imports and exports. The Need Run identifies flexibility shortages or flexible capacity need. The purpose of using Need Run is to ensure that the resource fleet has sufficient capability and flexibility to meet a wide range of expected conditions.

The model has two different methods implemented to identify the need for flexible capacity or flexibility shortage, but only one is actually used in a Need Run simulation.

To identify the need for flexible capacity, the model adds a tiered-cost generic resource supply curve on top of the supply curve of the existing supply resources. The generic resources are all GT units. Each has a 100 MW maximum and 50 MW minimum capacity. It can ramp up and down between the minimum and maximum capacity 12 MW per minute. The generic GT units have 0% forced and maintenance outage rates. The units can provide ancillary services and load following when it is committed. The costs of the generic GT units for generating and proving ancillary services and load-following are higher than that of all existing resources, include demand response resources. Therefore the generic GT units will not be committed unless all existing resources have been used up. The upward supply curve prevents unnecessary commitment of the generic GT units. Therefore the number of generic GT units committed in the simulation represents the need for flexible capacity.

The model captures flexibility shortage using a perfectly flexible resource. This resource has 10,000 MW maximum and 0 MW minimum capacity, and a ramp rate of 1,000 MW per minute. It can provide ancillary services and load following, but not energy. Its costs to provide ancillary services and load-following are higher than that of all existing resources. When requirements for ancillary services and load following cannot be met after all existing resources have been exhausted, this perfect resource will provide the needed ancillary services and load following to meet the requirements. The amount of ancillary services and load following this resource provides in a simulation reflects the flexibility shortage.

The flexibility shortage can be met by different combinations of various resources. Using generic GT units to meet the need is just one of them. Due to the 50 MW minimum capacity as well as the 100 MW incremental capacity of the generic GT units, the need

[5] See footnote 1.

for flexible capacity usually does not equal to flexibility shortage.[6] To accurately assess the need for a specific combination of resources to meet the flexibility shortage, a production cost simulation with the combination of resources is needed.

In this report all results, except flexibility shortage and flexible capacity need, are from the Production Cost Run. Flexibility shortage and flexible capacity need are the results of Need Run.

3. A Case of Local Capacity to Replace OTC Resources

In this case, new local capacity resources are added to the resource fleet to replace the retired OTC resources. The simulation is for 2020.

1) Local capacity assumption

This study uses the results of the once through cooling (OTC) studies conducted by the ISO in the 2011-2012 transmission planning process. The OTC studies identify 3,173 MW needs in local capacity areas. This amount reflects the total low end of the range of needed new or repowered local capacity for the Trajectory case in the San Diego (373MW), Los Angeles Basin (2,370MW) and Big Creek Ventura (430MW) areas. Based on the findings of the OTC studies, two 500 MW combined cycle gas turbine (CCGT) units and eighteen 100 MW gas turbine (GT) units are added to SCE zone. One 373 MW CCGT unit is added to SDG&E zone.[7]

Specifically, "SCE NEW CCGT" represents two identical 500 MW CCGT units, "SCE NEW GT" represents eighteen identical 100 MW GT units, and "SDGE NEW CCGT" is a single CCGT unit of 373 MW.

2) Utilization of new LCR resources

Table 3 reflects the monthly and annual capacity factors of the new LCR resources as well as the average capacity factors of all existing CCGT and GT units in the ISO area (excluding the new LCR resources).[8]

[6] Committing one more generic GT unit increases the need for flexible capacity by 100 MW.

[7] The 373 MW need in San Diego was based on the ISO updated OTC study results. It assumes that San Diego proposed generation (Pio Pico, Quail Brush and Escondido Energy Center) is included already. However the proposed generation is not included in the analysis since it was not included in the CPUC 2010 LTTP portfolio for the defined scenarios. So the total need in San Diego should be 373 MW plus the following resources.
Pio Pico = 3-LMS100 (100MW) resources total 300MW
Quail Brush = 100MW resources
Escondido Energy Center = 45 MW
The total should be 373 + 300 + 100 + 45 = 818 MW

[8] Capacity factor is the ratio of the actual output of a power plant over a period of time and its potential output if it had operated at full nameplate capacity the entire time

Table 3. Comparison of Monthly Capacity Factors

Resource	1	2	3	4	5	6	7	8	9	10	11	12	Annual
SCE NEW CCGT	53.1	60.0	61.4	64.2	59.4	64.1	73.7	83.4	80.9	66.9	61.1	68.3	66.4
SCE NEW GT	9.5	11.2	10.0	9.8	12.0	16.5	20.3	17.9	7.9	10.0	8.0	10.2	11.9
SDGE NEW CCGT	49.2	62.1	55.9	20.4	72.6	76.5	69.0	87.4	83.7	50.9	37.8	20.3	57.1
Gateway (CCGT)	52.0	45.6	55.3	48.7	45.5	56.1	62.8	55.2	60.1	56.2	60.3	60.7	54.9
Sentinel (GT)	22.1	20.3	17.2	18.3	21.1	19.6	20.4	19.1	11.6	16.2	16.0	12.1	17.8
CCGT Average	48.5	45.9	40.6	39.8	36.1	40.2	62.0	65.4	55.1	51.0	49.6	51.9	49.4
GT Average	10.9	10.7	8.0	10.8	10.9	12.0	11.2	9.5	6.6	8.4	9.3	10.4	9.8

The new LCR resources have higher capacity factors than the average of the same type of units in the ISO area. This outcome is expected because the new LCR resources are more flexible and have lower forced outage rates than most of the existing CCGT and GT units. The new LCR resources' heat rates are also lower than the average of the existing CCGT and GT units.

Compared to Sentinel, the SCE NEW GT has higher start-up cost. As a result, it has a lower capacity factor. For GT units running at low capacity factor, the difference in forced outage rates does not have a significant impact on utilization. The new CCGT resources have higher utilization rates than the Gateway unit. In this case, the higher forced outage rate does make a difference.

Of the two new CCGT resources, SDGE NEW CCGT has a lower capacity factor than the SCE NEW CCGT. This outcome is likely due to the ramp range (the range between minimum and maximum capacity). The SDGE NEW CCGT has 173 MW while the SCE NEW CCGT has 300 MW of range per unit. Since both have the same start-up cost and ramp rate, in certain circumstances the optimization may choose to commit the unit with the larger ramp range over the unit with the smaller range.

3) Contribution to ancillary services and load following

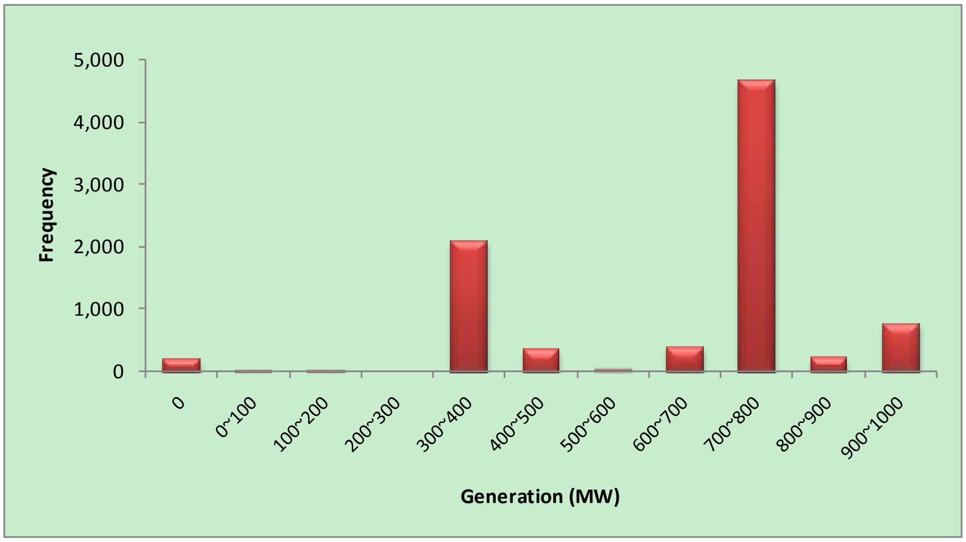
Besides producing energy, the new LCR resources also contribute to meet ancillary service and load following requirements. Table 4 has the annual total contributions to ancillary services and load following by the new LCR resources.

Table 4. Ancillary Service and Load Following Contribution (GWh)

Resource	LF Down	LF Up	Non-Spin	Reg-D	Reg-U	Spin
SCE NEW CCGT	1,888.00	849.2	0.5	101.8	11.6	577.2
SCE NEW GT	23.9	537.3	1.9	32.1	320	914.8
SDGE NEW CCGT	264.9	217.8	0	202.7	78.6	56.4

Contributing to upward ancillary services and load following requires the generation unit to maintain certain dispatch headroom. The total contribution to upward ancillary services and load following by the unit cannot be greater than the headroom. On the other hand, to contribute to downward regulation and load following the resource must be dispatched above its minimum capacity. The total contribution to downward regulation and load following cannot be greater than the dispatch above the minimum capacity of the unit. The contributions are also subject to the ramping constraints of the unit.[9]

Figure 2. Histogram of SCE NEW CCGT Hourly Generation[10]



As shown in Figure 2, SCE NEW CCGT runs mostly in the range of 700–800 MW out of its 1,000 MW maximum capacity. The headroom allows the resource to provide upward ancillary services and load following between 100 and 150 MW each hour on average (see Figure 3). This new LCR resource also provides 200 to 230 MW of downward ancillary service and load following each hour. This results mainly due to the flexibility of the new LCR resource. These capabilities are important to the reliability of the system, especially during the high load and fast ramping hours in the late afternoon.

It should be pointed out that contributions to ancillary services and load following are not reflected in the capacity factor of the resource even though the contributions hold the capacity from being dispatched to provide energy. Therefore, to correctly measure unitization of a generation unit, its contributions to ancillary services and load following should be counted.

For example, the SCE NEW CCGT resource has a 1,000 (2x500) MW maximum capacity. Over the 8,784 hours of 2020, the total possible generation of the resource is 8,784 GWh. From simulation the resource has an annual capacity factor of 66.4%, which

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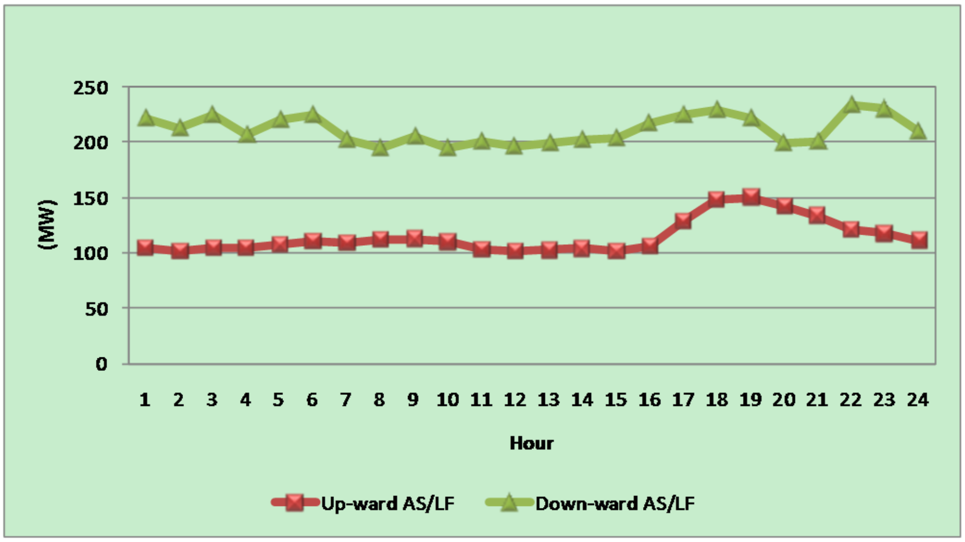
[9] The total contribution of a generation unit to all upward ancillary services cannot exceed 10 minutes time ramp rate of the unit. The total contribution to all upward ancillary services and load following-up cannot exceed 20 minutes time the ramp rate of the unit. That is also true for regulation-down and load following-down.

[10] This chart reflects the total generation of two identical CCGT units under the name SCE NEW CCGT. Each has a 200 MW minimum capacity and 2 hours start time. At the end of first hour in the start-up process a unit will generate 100 MW. Therefore there is generation between 0 and 200 MW in the chart. Zero generation means both units are in outage mode.

represents 5,833 GWh of generation. The total contribution of the resource to upward ancillary services and load following is 1,439 GWh. The sum of generation and ancillary services and load following contribution is 7,271 GWh, which is equivalent to a combined capacity factor of 82.8%. Considering that the resource has a 4.96% forced outage rate and 10% maintenance rate, the SCE NEW CCGT resource is almost fully utilized when it is available.

Figure 3. Average Hourly AS/LF Contribution by SCE NEW CCGT



4) Emission from providing ancillary services and load following

The new LCR resources contribute significant portion of capacity to meet requirements for ancillary services, including regulation, spinning and non-spinning, as well as load following services. All of the services have the energy component. However, the emission associated with the services may be negligible.

Regulation is used to balance the system instantaneously. The values in Table 4 reflect regulation capacity and not necessarily energy. However deploying regulation-up capacity will increase generation. Therefore it should be expected that some of the regulation-up capacity will be converted to energy. On the other hand, deploying regulation-down capacity will reduce generation. The emission impact of the two may offset each other. At least its emission impact should be small.

Spinning and non-spinning reserves cannot be deployed unless there is a contingency, which should be rear. We may consider there is small or no energy component associated with emission.

Load following in the model is designed to cover the variations between hourly average and 5-min average of load. Its utilization in the model is similar to regulation in operation. It also has up and down directions that may offset each other. So we may consider they have no association with emission.

5) Number of starts of the new LCR resources

With the increase in intermittent renewable resources interconnecting to the ISO, the system needs to deploy more flexible conventional resources to respond to the variations of renewable generation. That may cause some resources to cycle more. Cycling of generation resources depends on many factors such as start time, ramp rate, minimum run and down time, and start-up cost. More flexible ones may cycle more. Resources with lower start-up costs may see a higher number of starts than resources with higher start-up costs.

Tables 5 shows the number of starts of the new LCR resources, similar existing units, and the average of all existing CCGT and GT units in the ISO area (excluding new LCR resources).

The results show much higher number of starts for GT units than the CCGT units. SCE NEW GT resources have higher start-up costs than Sentinel unit, which may have resulted in a lower number of starts for the SCE NEW GT resources.

Table 5. Comparison of Monthly Average Number of Starts[11]

Resource	1	2	3	4	5	6	7	8	9	10	11	12	Annual
SCE NEW GT	26.2	20.3	21.8	20.9	18.7	16.8	25.4	27.4	20.8	24.8	24.1	25.3	272.6
SCE NEW CCGT	3.0	3.0	3.0	2.5	1.0	2.0	1.5	0.0	0.0	2.5	2.5	2.0	23.0
SDGE NEW CCGT	2.0	3.0	3.0	2.0	1.0	1.0	1.0	0.0	0.0	2.0	1.0	3.0	19.0
Gateway (CCGT)	6.0	8.0	6.0	8.0	5.0	4.0	5.0	5.0	4.0	6.0	3.0	3.0	63.0
Sentinel (GT)	54.0	44.0	40.0	42.0	46.0	39.0	32.0	28.0	22.0	35.0	29.0	34.0	445.0
GT Average	8.0	7.9	8.7	7.4	6.9	5.6	12.8	10.8	6.0	6.7	6.9	7.8	95.5
CCGT Average	3.7	3.7	4.3	3.8	3.4	3.6	5.0	4.8	3.0	4.7	3.7	3.8	47.4

The new CCGT resources have lower number of starts than the Gateway unit. As shown in Table 2, the Gateway unit has a higher ramp rate than the new CCGT resources. It is easier to cycle than the new CCGT resources. More importantly, the higher start-up cost makes the new CCGT resources uneconomic to cycle compared to the Gateway unit.

6) System-wide flexibility shortage

With the 3,173 MW new LCR resources added, the Need Run still finds 8 hours in July 2020 with shortages in the 20-minute load following up requirement. The maximum shortage is 1,251 MW.[12]

The ISO has previously identified a need for 4,600 MW of flexible capacity in the 2010 LTPP Trajectory High-Load scenario.[13] Since then modeling of demand response resources has improved. In the Trajectory High-Load scenario some of the high cost demand response resources have a 4-hour minimum run time together with limited

[11] This is the monthly average number of start of the units under each new LCR resource name.

[12] The 8 hours of shortage are identified in Need-Run of the simulation. The Need-Run is performed only for July 2020, which is the month with peak load and highest possible ramping capacity shortage. The load following-up requirement at the hour with 1,251 MW shortage is 2,552 MW.

[13] See section 2. 5) for the definitions of flexibility shortage and need for flexible capacity.

energy usage. These limitations prevent the demand response resources being fully utilized. At some peak load hours, the demand response resources cannot be deployed as the remaining energy is insufficient to run for 4 hours. In this study the ISO has removed the 4-hour minimum run time limit, thereby reducing the ramping capacity shortage during the peak load hours.

From the 4,600 MW need for flexible capacity identified in the Trajectory High-Load scenario to 3,173 MW of new local capacity plus 1,251 MW flexibility shortage in this case, the 176 MW difference could largely be attributed to the improvement in demand response modeling. The results in this case are consistent with that of the previous scenario.

7) Location for additional flexible capacity

The results of this case indicate that additional flexible capacity is necessary to meet the load following up requirement. As the Plexos model has a zonal configuration, it does not determine where the additional capacity should be added. From a flexibility perspective the ISO does not believe the additional capacity needs to be in the LA Basin. Based on historical patterns, however, it may be a better fit if some of the residual need were located south of path 26 especially if the additional flexible capacity is able to provide inertia. This is still true given that large number of renewable resources will come online in the south. Basically solar PV and wind generation provides little or no inertia and frequency response. Inertia and frequency response needs to be provided by thermal units. This case also does not consider the possibility of operating without the generating units at the San Onofre (SONGS) nuclear plant.

4. A Reduced Demand Response Sensitivity Case

In the model each demand response resource has a minimum capacity equal to its maximum capacity. There is no ramp rate constraint so once triggered, the demand response resources will be deployed to their maximum capacity instantaneously.[14] The demand response resources do not have forced or maintenance outage either. The triggering prices of demand response resources are high enough so that demand response resources will not be deployed frequently. Some of the demand response resources have energy usage limits that decide how many hourly each day or each month the demand response resources can be deployed.

At the recommendation of the State Air Resources Board, the California Energy Commission, California Public Utilities Commission, and the State Water Resources Control Board, the ISO study a sensitivity case with reduced demand response resources. It is intended to examine the effectiveness of demand response resources to reduce flexibility shortage.

8) Assumptions

[14] In real world different types of demand response program may have different limitations, such as delay in response to deployment instruction, etc. These limitations are not reflected in the model.

The case has the same assumptions as the case of Local Capacity to Replace OTC Resources except the amount of event-based demand response resources. Table 6 shows the specific changes to demand response resource capacity. The energy usage limits of the demand response resources are not changed. As the results, the demand response resources with energy usage limits may be deployed for more hours.

Table 6. Assumptions of Event-Based Demand Response Capacity

Region	Original DR Capacity (MW)	Reduced DR Capacity (MW)	Reduction (MW)
PG&E	1,687	732	955
SCE	2,827	1,977	850
SDGE	302	146	156
TOTAL	4,816	2,855	1,961

9) System-wide flexibility shortage

With 1,961 MW (40.7%) reduction in demand response resource capacity, the utilization of the new CCGT and GT resources has little change. However, the number of hours with flexibility shortage in July 2020 increases from 8 to 12. The maximum shortage increases from 1,251 MW to 3,212 MW, an increase of 1,961 MW. The shortage occurs in both 20-minute load following-up and 10-minute non-spinning requirements. That is a 1-to-1 ratio with the reduction of demand response capacity.

As indicated by the results demand response resources are effective in reducing ramping capacity shortage. It is one of the desirable types of resource in integrating renewable generations.

5. A Case of SONGS Outage

The State Air Resources Board, the California Energy Commission, California Public Utilities Commission, and the State Water Resources Control Board recommended studying a case with both OTC retirement and SONGS nuclear plant on long-term outage. This case is constructed based the 2010 CPUC LTPP Trajectory High-Load scenario, which is also the basis of the Local Capacity to Replace OTC Resources case.

10) Assumptions

The new assumptions of this case are recommended by the above California state agencies. The assumptions include changes in new LCR and demand response resources, and availability of SONGS nuclear plant. Table 7 shows the assumptions.

To model the new LCR resources, eight 500 MW CCGT units and six 102.5 MW GT units are added to SCE zone and one 520 MW CCGT and four 100 MW GT units are added to SDG&E zone. In the model “SCE NEW CCGT” represents the eight CCGT units and “SCE NEW GT” represents the six 102.5 MW GT units in SCE zone; “SDGE NEW CCGT” represents the 615 MW CCGT and “SDGE NEW GT” represents the four GT units in SDG&E zone.

Table 7. Assumptions of the SONGS Outage Case

Region	New LCR CCGT (MW)	New LCR GT (MW)	Demand Response (MW)	SONGS (MW)
PG&E			453	
SCE	4,000	615	348	0
SDGE	520	400	25	
TOTAL	4,520	1,015	826	0

In the 2010 LTPP Trajectory High-Load scenario there are 4,816 MW demand response resources and 2,264 MW SONGS nuclear generation capacity. The SONGS Outage case adds 5,535 MW new LCR resources, but loses 2,264 MW nuclear capacity and 3,990 MW demand response. The net change of supply capacity is -719 MW.

11) Additional system-wide flexible capacity need

For the SONGS Outage case the Need Run simulation for July 2020 finds a need for 5,300 MW flexible capacity.[15]

The ISO has previously identified a need for 4,600 MW of flexible capacity in the 2010 LTPP Trajectory High-Load scenario. From that scenario to the new SONGS Outage case, there is a 719 MW net reduction of supply capacity. However, the resource reduction includes 2,264 MW baseload nuclear capacity and 3,990 MW demand response resources. Most of the demand response resources are subject to usage constraints, such as the maximum number of hours to be used each day or month. They are rarely used. The baseload and demand response resources usually do not provide ancillary services and load-following. The new LCR resources added are all flexible CCGT or GT units. These flexible resources are used differently than the baseload and demand response resources. The flexible resources not only generate energy but also provide ancillary services and load-following. Therefore the increase in need (700 MW) is less than the reduced capacity (719 MW).[16] It indicates that the flexible resources are more effective in both generating energy and providing flexibility.

12) Utilization of the new LCR resources

In Table 8 are the capacity factors of the new LCR resources as well as the average capacity factors of all existing CCGT and GT units in the ISO area (excluding the new LCR resources).

[15] The 5,300 MW need is the total capacity of 53 generic GT units committed in the Need Run. See discussion in section 2. 5).

[16] The demand response resources with minimum run time are not included in this SONGS Outage case. The impact discussed in section 3. 6) does not apply to this case.

Table 8. Comparison of Monthly Capacity Factors

Resource	1	2	3	4	5	6	7	8	9	10	11	12	Annual
SCE NEW CCGT	70.2	71.5	71.6	71.7	68.8	72.2	76.7	80.1	78.4	73.8	72.2	74.6	73.5
SCE NEW GT	4.6	2.9	2.2	2.2	1.8	8.3	13.2	12.1	4.2	4.0	4.6	4.6	5.4
SDGE NEW CCGT	57.2	58.5	54.7	39.2	70.8	69.3	66.4	80.3	79.1	61.0	58.8	53.1	62.4
SDGE NEW GT	8.3	15.4	13.6	14.3	6.5	9.0	19.7	18.7	5.8	9.3	5.8	8.1	11.2
Gateway (CCGT)	51.5	43.9	54.3	47.8	44.9	53.1	64.1	57.3	62.9	57.5	61.2	60.7	54.9
Sentinel (GT)	17.6	17.7	13.5	16.2	17.6	13.1	18.7	16.2	5.7	11.5	10.5	9.0	13.9
CCGT Average	44.7	40.1	36.8	34.3	33.1	39.1	61.5	65.4	54.2	48.7	46.5	47.3	46.7
GT Average	9.4	10.1	6.4	8.7	10.1	8.8	10.5	7.9	5.2	6.3	7.5	7.6	8.2

As shown in the table the new LCR resources in SDGE zone have capacity factors higher than the average of same type of resources in the ISO area. In SCE zone, the SCE New CCGT has a capacity factor much higher than the average of CCGT resources as well as the Gateway unit. However, the capacity factor of SCE New GT is even lower than the average of GT resources. That can be explained as follows:

Both SCE and SDGE zones are subject to the Southern California Import Transmission (SCIT) limit. It limits the total simultaneous import into Southern California. Besides that, SCE has to serve 40% of its load using resources inside SCE zone. Similarly SDGE needs to meet 25% of its load with local resources. Without the baseload SONGS, the new LCR resources need to generate energy almost equivalent to that SONGS used to generate.

Of the two types of new LCR resources, CCGT resources are more economic than GT resources and will be used more than the GT resources. That is why the SCE New CCGT has a capacity factor of 73.5%. The resources also contribute to ancillary services and load following because of its flexibility. Adding its contribution to upward ancillary services and load following, the total capacity factor of SCE New CCGT is 83.7%, which is close to full utilization rate.[17]

Table 9. Ancillary Service and Load Following Contribution (GWh)

Resource	LF Down	LF Up	Non-Spin	Reg-D	Reg-U	Spin
SCE NEW CCGT	3,852.4	1,865.1	1.6	508.2	52.2	1,664.1
SCE NEW GT	2.8	173.2	0.8	2.6	41.5	79.0
SDGE NEW CCGT	566.6	618.1	0.1	97.0	1.8	125.0
SDGE NEW GT	2.7	220.8	0.4	4.3	60.7	92.9

In SCE zone, the SCE New CCGT is more flexible than the baseload SONGS. The SCE New CCGT not only generates energy to make up for the loss of SONGS, it also provides flexibility (including inter-hour energy ramping, ancillary service and load following) that SONGS does not provide. In such case the utilization of the SCE New GT is reduced. Therefore the SCE New GT has a capacity factor lower than the average.

[17] The New CCGT has a 4.96% forced outage rate and a 10% maintenance outage rate. The maximum possible utilization rate is 85.04%.

6. Summary of the Cases

In this study, three cases were simulated, including Local Capacity to Replace OTC Resources, Reduced Demand Response Resources sensitivity, and the SONG Outage cases. All the three cases are based on the 2010 CPUC LTPP Trajectory High-Load scenario. Table 10 compares input assumptions and results of the three cases with the original Trajectory High-Load scenario.

Table 10. Comparison of Input Assumptions and Results of the Cases

Assumptions & Results	Trajectory High-Load	LCR to Replace OTC Resources	LCR to Replace OTC & Reduced DR	SONGS Outage
LCR Resources (MW)				
SCE CCGT	0	1,000	1,000	4,000
SCE GT	0	1,800	1,800	615
SDGE CCGT	0	373	373	520
SDGE GT	0	0	0	400
Total	0	3,173	3,173	5,535
Demand Response (MW)				
PGE	1,687	1,687	732	453
SCE	2,827	2,827	1,977	348
SDGE	302	302	146	25
Total	4,816	4,816	2,855	826
SONGS Capacity (MW)				
SCE	2,264	2,264	2,264	0
Need for System-Wide Flexible Capacity (MW)	4,600			5,300
System-Wide Flexibility Shortage (MW)		1,251	3,212	

In Table 10, Need for System-Wide Flexible Capacity and System-Wide Flexibility Shortage are identified in Need Runs. Since only one of the two methods to identify need for flexible capacity and flexibility shortage is used in a Need Run simulation, the 2010 LTPP Trajectory High-Load scenario and the SUNGS Outage case have needs for flexible capacity identified, while the Local Capacity to Replace OTC Resources and the Reduced Demand Response Resources sensitivity cases have flexibility shortages identified. As discussed in section 2. 5), need for flexible capacity usually is not directly comparable to flexibility shortage. The results should be used with that understanding in mind.

7. Conclusions

According to the production simulation results, flexibility of the new LCR resources is very important to reducing the shortage in flexible capacity. The simulations identified flexibility shortage or need for flexible capacity in all three cases of this study. Alternatives to meet the observed shortages including adding flexible resources at locations that are deliverable to the system load should be considered. Due to historical patterns of Path 26's north to south flow constraint as well as the SCIT limit and local generation requirements it may be desirable to locate at least a portion of the residual need for flexible resources south of Path 26. The residual capacity may be critical in providing inertia and frequency response with large number of renewable resources coming online in the south.

8. Other relevant studies

This study did not evaluate the frequency response and inertial benefits of the new LCR resources or needs for frequency response and inertia in the ISO system generally. The ISO has conducted a study to analyze the system wide frequency response requirement under higher renewable scenarios. A study report can be found on the ISO website at http://www.caiso.com/Documents/Report-FrequencyResponseStudy.pdf.

Also, as part of the reliability studies performed for AB 1318 and the need for repowering or replacement of once-through cooled generation, the ISO, in its 2011/2012 transmission planning process, evaluated the transient stability of the system for the trajectory, as well as environmentally constrained 33% renewable portfolio standard (RPS) cases and found that the results met applicable WECC transient stability criteria for critical contingencies in the WECC system. The ISO will update its transient stability studies in the future as new proposed repowering options for these once-through cooled generation are made available.