October 14, 2023 Solar Eclipse Technical Bulletin

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Prepared by

Short Term-Forecasting

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Executive Summary

On Saturday, October 14, 2023, an annular solar eclipse will pass over the western United States including California, Oregon, Nevada, Utah, Arizona, Colorado and New Mexico.

This bulletin details the expected impact of the solar eclipse, identifies the risks and possible measures to be taken by the California Independent System Operator (CAISO), the Western Energy Imbalance Market (WEIM), Reliability Coordinator West (RC West) and other balancing authority areas (BAAs) as well as market participants and stakeholders to address the loss of solar generation during the eclipse.

The WEIM, which covers much of the West, will be affected by the eclipse from 8 a.m. through 11 a.m. Pacific Daylight Time (PDT) on October 14. Each WEIM area will have varying times and magnitude of impact from the eclipse, with locations beginning between 8:05 a.m. and 8:15 a.m. and ending between 10:40 a.m. and 11:15 a.m. PDT and sun obscuration ranging from 65-90%. The California BAA will be affected by the eclipse from approximately 8:05 a.m. to 10:57 a.m. PDT. The range that the sun will be obscured varies from 89% in Northern California to 68% along the Southern California coast.[1] The reduction in solar radiation will directly affect the output of photovoltaic (PV) generating facilities, behind-the-meter (BTM) rooftop solar, load, and net load within the CAISO BAA, as well as the WEIM.

On Monday, August 21, 2017, the United States experienced a total solar eclipse that had impacts across the CAISO BAA and the Western Interconnection. At that time, the CAISO had approximately 10,000 megawatts (MW) of installed capacity of commercially operational grid-connected PV solar and approximately 5,800 MW of BTM rooftop solar. Four utilities were participating in the CAISO WEIM services at the time of the 2017 eclipse. With proper planning, the CAISO was able to maintain grid reliability throughout the entire three hours of the eclipse.[2]

Since 2017, grid-scale PV solar has grown to over 16,500 MW of installed capacity, and there is now 14,350 MW of BTM solar within the CAISO BAA. Within the WEIM entities[3], grid-scale PV solar has grown from 866 MW in 2017 to 10,280 MW and BTM solar has increased from 738 MW to 6,458 MW. Since then, the CAISO has also started offering reliability coordination services to the bulk of balancing areas in the Western Interconnection as the RC West, and there are now 21 balancing areas that participate in the WEIM.[4] With the West more interconnected now than ever, the CAISO is evaluating the effects of the 2023 solar eclipse with a broader scope. Impacts will be felt across all of the utilities at various times and magnitudes within the WEIM and RC West, and entities can utilize these connections and relationships to maintain reliable operations, collaborate and optimize resources throughout the eclipse.

[1] https://www.timeanddate.com/eclipse/in/usa?iso=20231014
[2] http://www.caiso.com/Documents/CaliforniaISOSuccessfullyWeatheredSolarOutputDropDuringEclipse.pdf
[3] The CAISO BAA is excluded from WEIM reported values
[4] Including the CAISO but excluding Avangrid, a generation-only participant.

Assuming clear sky conditions, initial estimates show the following impacts and planned mitigations for the CAISO BAA:

The October 2023 eclipse will be more impactful than the 2017 eclipse because of the growth in solar capacity since 2017. CAISO grid-scale and rooftop BTM solar have grown by 6,500 MW and 8,550 MW respectively since 2017. WEIM grid-scale and rooftop BTM solar have grown by 9,414 MW and 5,720 MW since 2017.

For the CAISO Balancing Authority (BA) on October 14, the eclipse will start to impact grid-scale solar and load at 8:05 a.m., reaching maximum impact at 9:30 a.m. before returning to normal conditions at 11:00 a.m. Precise timing and levels of obscuration will depend on geographic location relative to the eclipse path.

The CAISO BA has approximately 16,500 MW of installed grid-scale solar capacity and 14,350 MW of rooftop BTM solar capacity. Obscuration from the eclipse will significantly reduce generation from all solar resources.

The change in grid-scale solar generation and gross load is largest on the eclipse return. Grid-scale solar generation will decrease by 9,374 MW from the start of the eclipse to the maximum impacted time period and increase by 10,801 MW on the eclipse return. Gross load will increase by 2,374 MW from the start of the eclipse to the maximum impacted time period and drop by 6,643 MW from the eclipse maximum to the eclipse end.

Net load ramp rates on the eclipse return are larger than on the eclipse start to maximum impacted time period. At the eclipse start to maximum impacted time period, the net load ramp rate will increase by an average of +122 MW per minute and decrease by -190 MW per minute on the return.

WEIM regions will see varying eclipse impacts on renewables generation and load depending on levels of installed grid-scale and BTM rooftop solar. The Central region has the largest amounts of installed grid-scale solar capacity, while the Desert Southwest region has the largest total installed BTM solar capacity.

The CAISO will coordinate with RC West, Utility Distribution Companies (UDCs), and WEIM entities to ensure stable market operations to support reliable operations on the eclipse day. CAISO and WEIM renewable scheduling coordinators should ensure appropriate eclipse impacts in their forecasts.

Grid-scale solar resources will utilize specialized procedures to manage eclipse ramping requirements. The specialized solar procedures include the potential to limit the solar generation ramp rate during the return of the eclipse, in addition to utilizing an Operating Instruction (OI) for the fleet to ensure solar resources are following their Dispatch Operating Target (DOT) and linearly ramping from Dispatch Operating Point (DOP) to DOP. Much of the success of the 2017 eclipse event was due to the accuracy with which solar generation was forecasted in the day-ahead (DA) timeframe, which limited the need for real-time redispatch.

Due to the expected impact on solar resources, it is critical that solar resources within CAISO and the WEIM footprint account for the eclipse impacts in their market submittals.

The CAISO will ensure coordination with hydro and battery resources to safeguard availability to assist with large ramps expected on the system during the eclipse. Similar to the growth of solar since 2017, CAISO has had significant growth in battery resources to assist with the faster ramping needs on the system, and the CAISO plans to utilize battery and hydro resources during the solar eclipse.

The CAISO will procure additional operating reserve requirements to assist during the eclipse. During the 2017 eclipse, additional reserve procurement helped grid operators handle resource deviation in addition to large ramps on the system. For 2023, the CAISO will procure additional operating reserve requirements to assist with the planned movement in solar generation, in addition to the potential for cloud cover to impact the system.

To get the most benefit while minimizing risk, greater coordination and preparation across utilities is required throughout the RC West and WEIM footprints as well as the CAISO balancing area. While there have been many changes and additions within the CAISO BAA, WEIM and RC West since the 2017 eclipse, the CAISO remains committed to providing details on potential impacts and actions to allow entities to prepare for the eclipse, as well as support to ensure reliable operations throughout the event.

Introduction

The CAISO has evaluated the expected impact of the solar eclipse and possible measures to be taken by the CAISO, market participants, and other balancing authorities in the WEIM footprint. This bulletin details the risks and possible measures that can be taken to mitigate impacts of the grid related to the eclipse.

This bulletin covers the following topics:

- The solar eclipse trajectory related to the CAISO balancing authority
- Eclipse impacts on CAISO grid-scale renewable generation, gross load and net load
- Eclipse impacts on WEIM regional gross loads
- Estimates of grid-scale and rooftop BTM solar capacity in CAISO and WEIM regions
- Operation mitigation measures
- A timeline of key deliverables and stakeholder meetings

Background

Solar Eclipse Trajectory

As stated above, on Saturday, October 14, 2023 an annular solar eclipse will pass over the western United States. An annular eclipse means that the moon will not obscure 100% of the sun as in a total eclipse, rather in this annular event, 90% of the sun will be obscured by the

moon. **Error! Reference source not found.** below shows the difference between a total eclipse, w hich was observed with the previous eclipse that impacted California on August 21, 2017, and an annular eclipse that will occur on October 14, 2023.

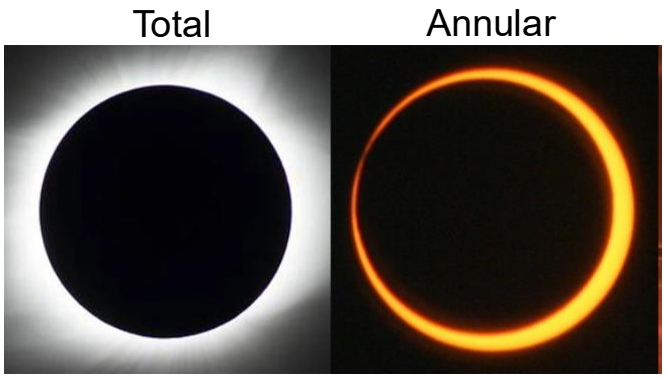

Figure 1: A comparison of a total eclipse, such as what was observed on August 21, 2017, and an annular eclipse that will occur on October 14, 2023.[5]

Oregon, Nevada, Utah and New Mexico will have large areas experiencing the maximum of the annular eclipse, while California and Arizona will have smaller portions experiencing the full annular eclipse, with the rest of the state having a partial eclipse. Across the WEIM, areas further west such as the Oregon coast will see the eclipse begin at 8:04 a.m. PDT while in New Mexico and Montana, it will begin as late as 8:17 a.m. PDT. The maximum solar obscuration across the WEIM varies from 65-90% depending on the distance from the path of annularity. The annularity will last for 4 to 5 minutes, peaking around 9:20 a.m. PDT for Oregon and 9:40 a.m. PDT for New Mexico. The eclipse will end at 10:37 a.m. PDT for northwest Washington, but last until 11:19 a.m. PDT for far southeast New Mexico. The solar production areas in California will be affected by a partial eclipse between 8:05 a.m. and 10:57 a.m. The sun will be obscured from approximately 89% at the higher latitudes of Northern California to approximately 68% in the lower latitudes of Southern California.

Figure 2 shows the path of the annular eclipse across the United States. The northern and southern path limits of areas experiencing annularity are shown between the red lines with yellow shading. Areas outside of the annular line, such as most of California, will experience varying amounts of partial eclipse based on distance from the central path, which is denoted by the percentages throughout the map.

[5] https://solarsystem.nasa.gov/eclipses/about-eclipses/types/#annular

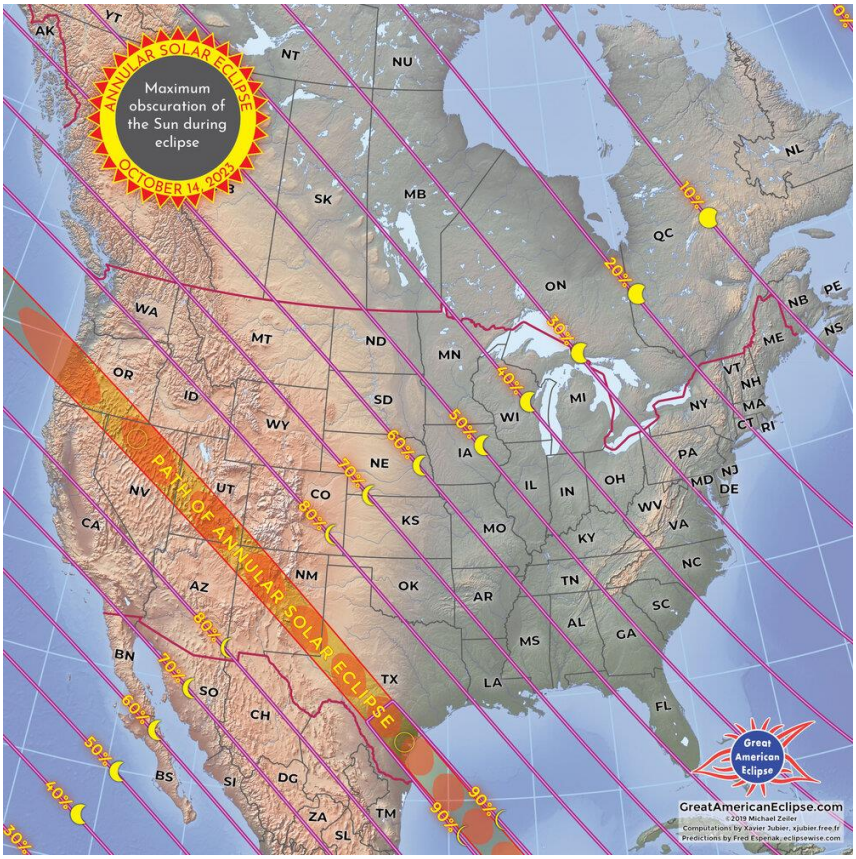

Figure 2: A map of the October 14, 2023 annular eclipse path and percent obscuration across the US[6]

Impacts to the CAISO Load and Renewables

Eclipse modeling assumptions

The weather forecast for October 14 will not be available until about two weeks prior to the eclipse. Forecasts for the grid scale renewables will not be available until seven days prior. For this study, a set of common assumptions are made to facilitate consistent modelling of renewables generation and load-related eclipse impacts.

For grid-scale solar, rooftop BTM and load, the study assumes that there will be clear sky conditions across the entire CAISO BAA and WEIM footprint. As such, results in this study should be viewed as a high-impact scenario since eclipse impacts are modeled under a clear-sky assumption. Normal October temperature assumptions are based on selecting a representative day from October 2022, which is near the 50th percentile. The CAISO contracts with third-party providers to receive both grid-scale solar and rooftop BTM forecasts. The third-party providers have supplied eclipse impacts for both grid-scale and rooftop BTM solar used in this study.

For modeling eclipse impacts on load, only expected changes in rooftop BTM solar are included in this analysis. More nuanced weather effects of the eclipse on load such as changes in

[6] https://www.greatamericaneclipse.com/october-14-2023

temperature or wind speed are not included. The CAISO load forecast also only includes the major TAC areas: SCE, SDG&E and PG&E and does not include metered sub-stations (MSSs), pumps or the Metropolitan Water District (MWD).[7]

Potential Grid-Scale Solar Reduction

Solar obscuration defines the solar irradiance reduction striking the earth at a given location such as a PV solar site. As these locations get further from the central path of the eclipse, the percentage of solar obscuration lessens. PV solar site production will be reduced during the eclipse by the amount of solar obscuration. Figure 3 shows the path of the annular eclipse relative to the general locations of the California PV solar regions within the CAISO BAA.

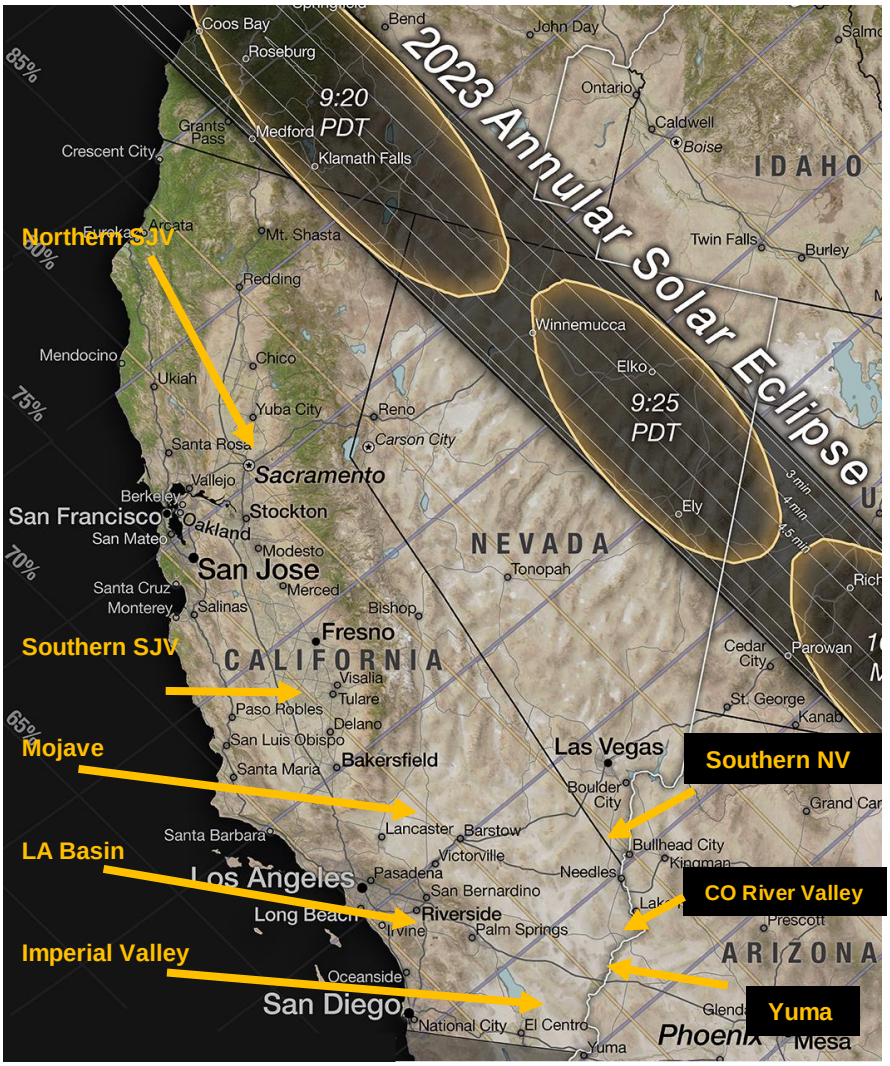

Figure 3: A map of the regional CAISO PV solar locations relative to the path of annularity[8]

[7] The smaller MSS regions do not have rooftop BTM solar forecasts available for the eclipse study. MWD and pumps are non-conforming type loads which are not heavily known at this time.

[8] https://www.nasa.gov/feature/goddard/2023/sun/new-nasa-map-details-2023-and-2024-solar-eclipses-in-the-us

The solar eclipse will begin when the PV solar sites will be ramping up to the maximum amount of daily production and end when the sites are entering their midday peak of daily production. Production will reduce from the time the eclipse starts around 8:05 a.m. for the solar sites in Northern California and around 8:09 a.m. for the sites in Southern California. The time of maximum impact ranges from 9:20 a.m. to 9:29 a.m. for the solar sites further north and south, respectively. As the eclipse wanes, the solar production return will be at a much greater ramp rate than normal production because the sun angle will have continued to increase during the time the sun was obscured. The period after the eclipse maximum to the end of the eclipse, from 9:20 a.m. to approximately 10:57 a.m. is the period of operational interest the CAISO will study to ensure adequate supplies of generation (reserves) are available to mitigate any adverse effects of the anticipated steep up-ramp in solar production.

Forecast Area	Eclipse Start Time (a.m.)	Eclipse Max Time (a.m.)	Eclipse End Time (a.m.)	Eclipse Max Obscuration	Oct. 2023 Regional Capacity	Approx. Area Production at Eclipse Start		Approx. Area Production at Eclipse Max[9]		Approx. Area Production at Eclipse End	
					MW	Cap %	MW	CAP %	MW	Cap %	MW
N. San Joaquin	8:05	9:20	10:43	80%	305	24%	74	12%	38	65%	198
S. San Joaquin	8:06	9:22	10:46	75%	4,355	27%	1,167	16%	693	70%	3,059
Mojave	8:07	9:24	10:50	73%	4,141	38%	1,582	20%	812	78%	3,228
LA Basin	8:08	9:25	10:51	72%	266	38%	102	13%	34	79%	209
Coachella/Imperial Valley	8:09	9:27	10:55	72%	2,635	54%	1,412	23%	608	84%	2,201
S. Nevada	8:08	9:27	10:54	81%	1,407	40%	558	15%	218	87%	1,225
Colorado River Valley	8:09	9:27	10:55	75%	2,241	37%	834	19%	420	82%	1,831
Yuma	8:09	9:29	10:57	78%	1,115	53%	590	18%	202	89%	996
						SUM:	**6,318**		**3,023**		**12,946**

Table 1: The start, maximum, and end times of the eclipse for the different grid-scale PV solar within the CAISO BAA and the approximate reductions in output at those times

Using the data from Table 1, the CAISO calculated[10] approximate amount of solar energy expected to be produced on October 14, 2023 (assuming a full sun day with no clouds) compared to a clear October 2022 day. It is anticipated that PV solar production in MW at the start of the eclipse at 8:05 a.m. will be approximately 6,292 MWs. For the period of 8:05 a.m. through 8:30 a.m., although the eclipse will have begun, solar generation will still continue to

[9] The MW sum for the "area production at the eclipse maximum" (minimum area production) and "area production at eclipse end" are less than the minimum area production and production at the eclipse end time represented on the graph due to the eclipse maximum and times varying by each region.

[10] Based on approximate gen at eclipse maximum time from October 14, 2022, adjusted for capacity updates between 2022-2023 then adjusted for the eclipse max percent obscuration.

increase because the amount of solar irradiance reaching the surface will still be increasing due to the sun angle rising in the sky. Generation during this period will be lower than a non-eclipse day, but will not yet have started the decrease down to the minimum generation. From 8:30 a.m. through 9:30 a.m., solar generation will decrease as the sky darkens across the state. As illustrated in Figure 4, this is a reduction of 5,068 MW over this 90-minute period or a ramp down of - 85 MW per minute, while on a non-eclipse day, the average ramp during this period is +97 MW. per minute. Because this is a partial solar eclipse over the regions of California, Nevada, and Arizona with grid-scale solar, the solar production will never completely stop but will be reduced to a minimum of approximately 3,023 MWs at 9:26 a.m.

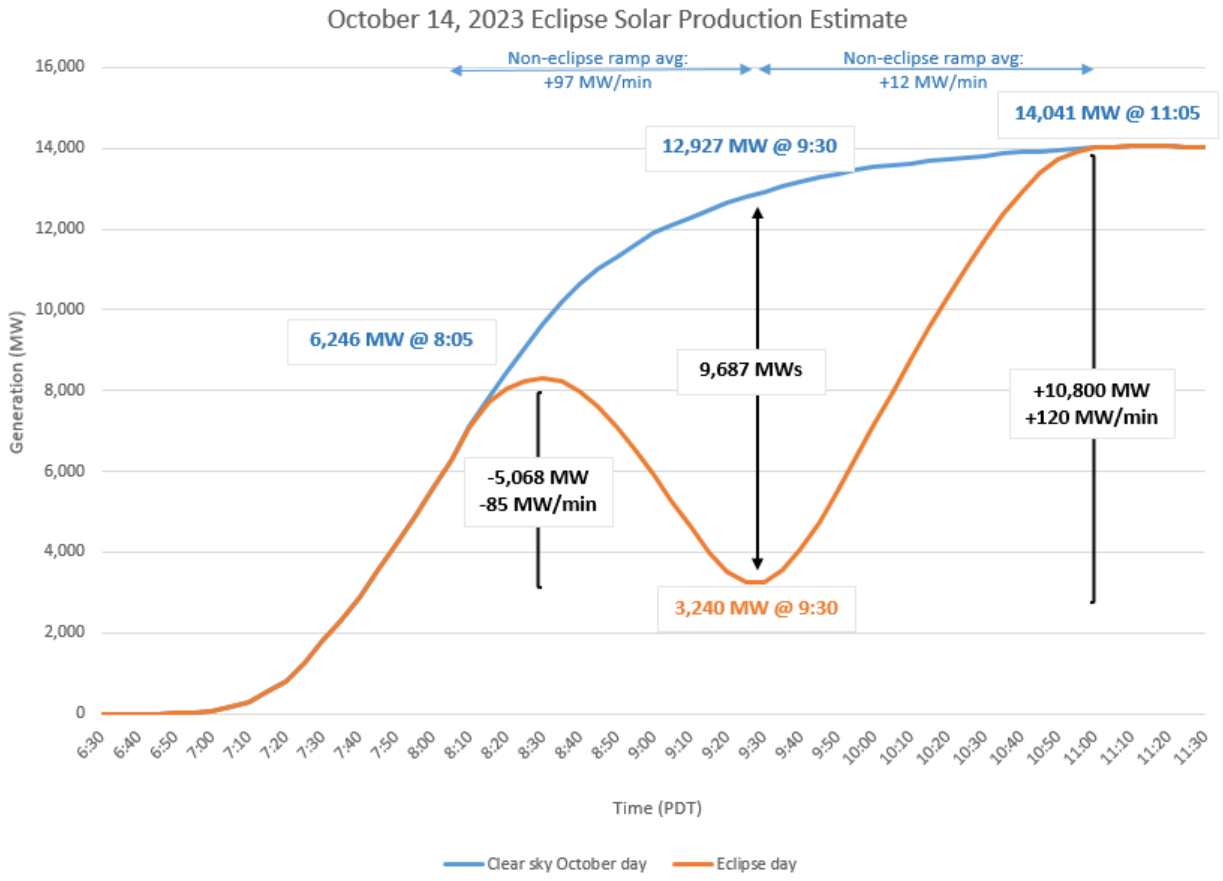

Figure 4: Forecast grid-scale solar production during the October 14, 2023 eclipse. All ramp rates are an average MW per minute over a given period.

As the eclipse wanes, the return to normal production will cause an up-ramp of +120 MW per minute beginning around 9:30 a.m., with generation increasing to 14,041 MW at 11:05 a.m. For reference, the estimated ramp from 9:30 a.m. to 11:00 a.m. on a non-eclipse day is an average of +12 MW per minute with the maximum during this period of +24 MW per minute.

Temperature and Wind Impacts

Other weather-related effects of the eclipse are temperature and grid-scale wind generation. There are many published papers that have investigated the temperature and wind impacts

during the eclipse, but most focus on the area of totality or annularity. There is less data on impacts to areas not within the path of complete obscurity, as much of California on October 14.

An average decrease in temperature of approximately 8°F is observed for areas in the path of totality or annularity, with this minimum temperature being recorded approximately 10-30 minutes after the largest eclipse impact.[11] See Table 2 below for more potential temperature reductions based on obscuration percentages. The same study mentions that eclipses that occur in the morning, such as the October 14 eclipse, the rate of temperature decrease between the start of the eclipse and maximum obscuration was greater than the rate of temperature increase between the maximum obscuration and the end of the eclipse. As a result, the temperature the rest of the day will warm slower compared to the non-eclipse day even after the eclipse is over and could lead to the maximum temperature for the day being reduced as well.

Obscuration level	Potential temperature reduction
60%	~2 degrees
60-80%	2-4 degrees
80-100%	6-8+ degrees

Table 2: Approximate potential temperature impacts during the eclipse based on maximum obscuration

Areas within or very close to complete totality or annularity experience the largest temperature impacts with the effects tapering off the further from the eclipse center. Other factors that can affect how much the temperature is impacted are time of day of the eclipse, season and cloud cover on the eclipse day. The CAISO anticipates approximately a 2-6°F impact to temperatures across the state, depending on how far each location is from the path of annularity and cloud cover.

It is worth noting that as the temperature decreases from the eclipse, relative humidity will increase, but how much so will depend on the temperature at the eclipse time and how much moisture there already is in the air. Areas have seen between a 7-25% increase in relative humidity in previous eclipses, depending on other environmental factors.[12] If there is any cloud cover on the day of eclipse, that would minimize temperature impacts.

Wind speed and direction are also impacted by an eclipse, also with the largest impacts being observed closest to the path of totality. Wind speeds in the past have decreased by

[11] Effect of 21 August 2017 solar eclipse on surface-level irradiance and ambient temperature | International Journal of Energy and Environmental Engineering (springer.com)
[12] The Total Solar Eclipse of 2017: Meteorological Observations from a Statewide Mesonet and Atmospheric Profiling Systems in: Bulletin of the American Meteorological Society Volume 101 Issue 6 (2020) (ametsoc.org)

approximately 2-6 mph during the eclipse near the path of totality and wind directions also tend to rotate counter-clockwise during the time of the eclipse start through the maximum obscuration, and clockwise from the maximum obscuration to the end of the eclipse.[13] During the 2015 eclipse in Great Britain, reports showed a 10% drop in wind generation due to the reduction in wind speeds[14] at approximately 85-95% obscurity;[15] however an impact of this size is not anticipated for the CAISO BAA wind resources during the October 14 eclipse as the locations of the CAISO wind resources are closer to the 70-75% obscurity.

The impacts to temperature and wind will also be taken into account when preparing demand forecasts for the eclipse; however, these are less impactful to grid operations relative to grid-scale or BTM solar generation.

CAISO Load Forecast

There is more than 14,350 MW of BTM rooftop solar capacity in the CAISO footprint. On the eclipse day, partial obscuration of the sun will reduce output of rooftop solar and increase load by 4,843 MW or 29.6% at 9:15 a.m. relative to normal clear sky conditions as shown in Figure 5.

Since the eclipse occurs on a Saturday, load levels are lower than if the eclipse occurred on a weekday. Typically in October, the marine layer can serve to reduce rooftop solar output during the hours of the eclipse, so results from the eclipse clear-sky scenario should be viewed as a high impact scenario.

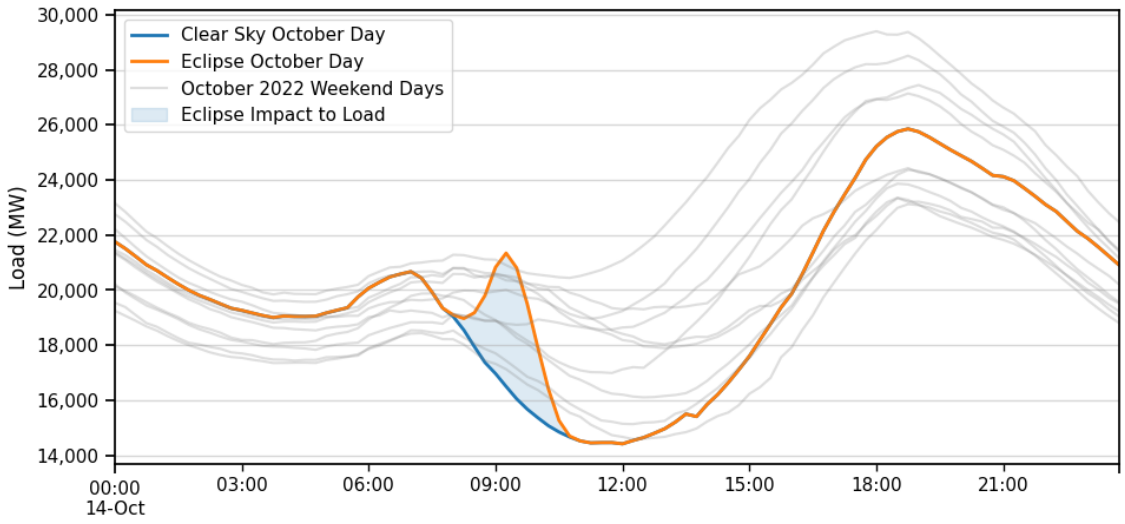

Figure 5: Approximate CAISO load forecast impact from the eclipse

The eclipse will cause a second ramping period from approximately 8:15 a.m. to 10:45 a.m. following the typical morning peaking period. During the ramp-up period, load will increase by

[13] The Total Solar Eclipse of 2017: Meteorological Observations from a Statewide Mesonet and Atmospheric Profiling Systems in: Bulletin of the American Meteorological Society Volume 101 Issue 6 (2020) (ametsoc.org)
[14] entsoe_spe_pp_solar_eclipse_2015_web.pdf
[15] Eclipse Path of Total Solar Eclipse on March 20, 2015 (timeanddate.com)

2,374 MW from 8:15 a.m. to 9:15 a.m. The subsequent ramp-down period shows load dropping by 6,643 from 9:15 a.m. to 10:45 a.m. Figure 6 below shows a zoomed in view of the eclipse ramping periods and Table 3 reports the key load ramping assumptions.

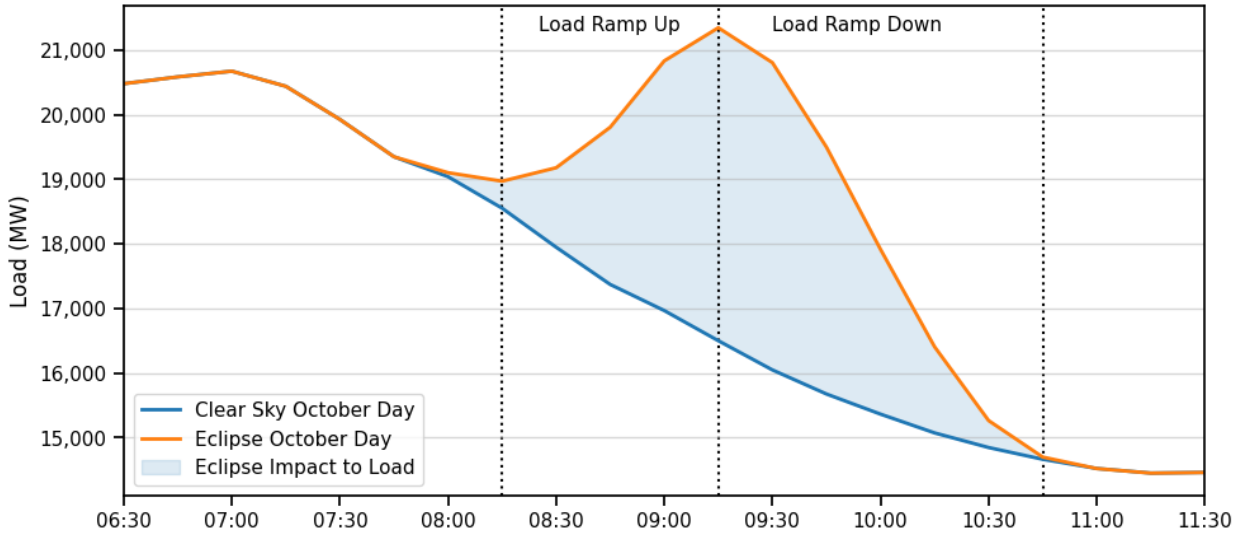

Figure 6: Approximate CAISO load forecast impact from eclipse during ramping period

	Start	End	Load Start	Load End	Total Ramp (MW)	Average Ramp (MW/min)	Max Ramp (MW/min)	Typical Ramp (MW/min)
Ramp Up	8:15	9:15	18,969	21,343	2,374	40	68	-34
Ramp Down	9:15	10:45	21,343	14,701	-6,643	-74	-105	-20

	Start	End	Load Start	Load End	Total Ramp (%)	Average 15 Min Ramp (%)	Max 15 Min Ramp (%)	Typical 15 Min Ramp (%)
Ramp Up	8:15	9:15	18,969	21,343	12.5%	3.0%	5.1%	-2.5%
Ramp Down	9:15	10:45	21,343	14,701	-31.1%	-6.2%	-8.7%	-1.7%

Table 3: CAISO eclipse load forecast ramping data

Net Load

Figure 7 below represents expected net load on October 14, 2023 under clear-sky and eclipse conditions. Wind generation is assumed to follow a normal pattern for October. Net load will follow a typical down-ramp from 7:00 a.m. until 8:00 a.m. At 8:00 a.m., eclipse impacts will start to reduce renewables generation and increase load.

From 8:15 a.m. to 9:15 a.m., net load will increase by 7,293 MW. During the ramp-up period, net load will increase by approximately +122 MW per minute on average, with a max ramp of +194 MW per minute. As the eclipse begins to wane, net load will drop by 17,133 MW from 9:15 a.m. to 10:45 a.m. During the ramp-down period net load will decrease by approximately -190 MW per minute on average with a maximum down-ramp of -267 MW per minute. Figure 7 shows the eclipse impact on net load during the ramping periods and Table 4 reports the key net load ramping assumptions.

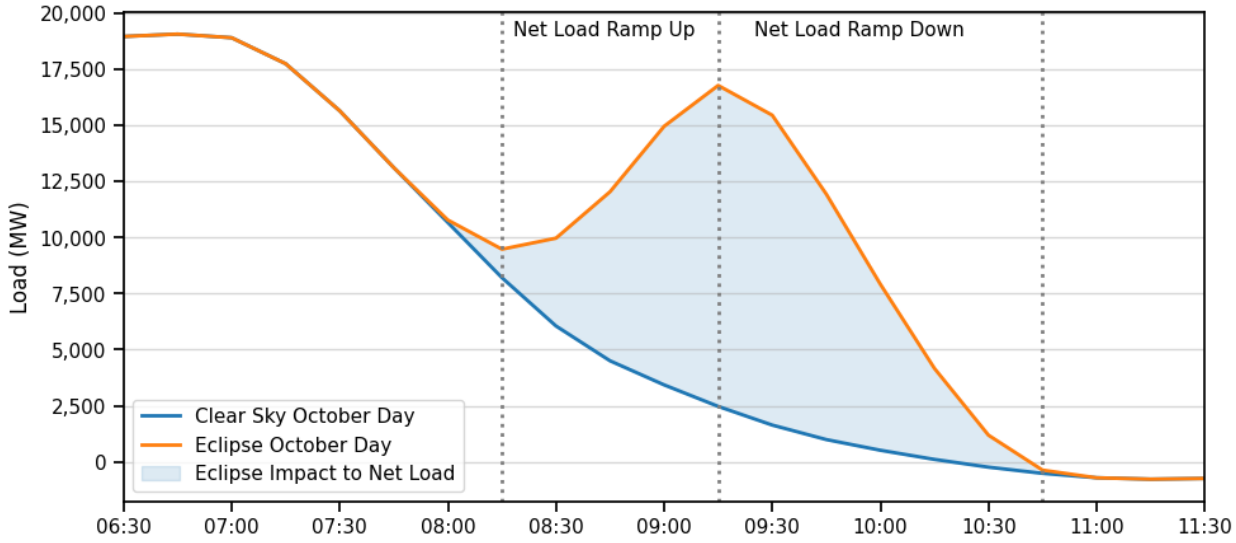

Figure 7: Approximate CAISO net load forecast impact from eclipse during ramping period

	Start	End	Load Start	Load End	Total Ramp (MW)	Average Ramp (MW/min)	Max Ramp (MW/min)	Typical Ramp (MW/min)
Ramp Up	8:15	9:15	9,474	16,767	7,294	122	194	-96
Ramp Down	9:15	10:45	16,767	-366	-17,134	-190	-267	-33

	Start	End	Load Start	Load End	Total Ramp (%)	Average 15 Min Ramp (%)	Max 15 Min Ramp (%)	Typical 15 Min Ramp (%)
Ramp Up	8:15	9:15	9,474	16,767	77.0%	13.9%	22.2%	-11.0%
Ramp Down	9:15	10:45	16,767	-366	-102.2%	-34.8%	-48.8%	-6.0%

Table 4: CAISO eclipse net load forecast ramping data

Figure 8 illustrates the eclipse ramping requirements relative to actual ramping data for 2023[16]. Ramp rates for the eclipse ramp-up period are higher than those typically experienced in the morning but are in line with the steeper ramps experienced during 2023 evening peaks. Ramp rates in the ramp-down period are more noticeably steeper than those experienced to date in 2023. The minimum ramp rate during the down-ramp period of -267 MW per minute exceeds the observed minimum in 2023 by approximately 100 MW per minute.

[16] Includes 15-min net load data from Jan 1st 2023 – Aug 17th 2023

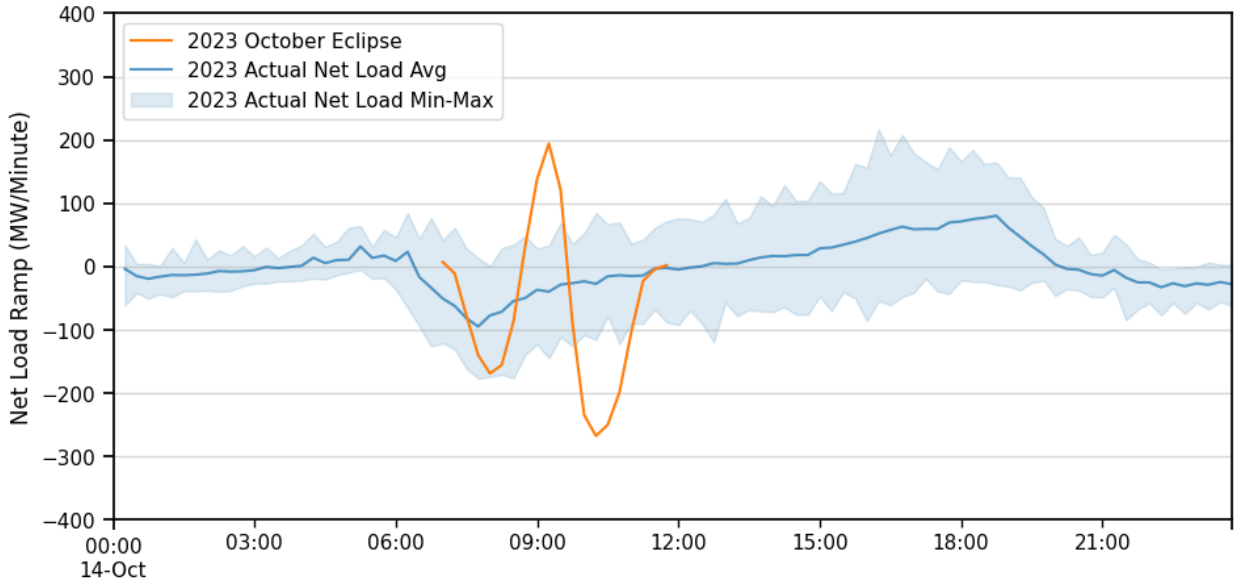

Figure 8: Eclipse ramp rates compared to 2023 actual ramp rates

Impacts to WEIM Load and Renewables

WEIM Grid Connected and Rooftop Solar

The WEIM footprint includes 22 participants and 21 balancing authority areas. Most WEIM participants submit forecasts for their renewables generation through their own Forecast Service Providers (FSPs). The CAISO will coordinate with the WEIM entities to ensure awareness of potential eclipse impacts on renewables generation. It is critical that WEIM entities take these considerations into account. To assist with eclipse preparations, planning, and market simulations; the CAISO requests WEIM entities to provide eclipse impacts on their solar fleet to the Short-Term Forecasting team utilizing the CIDI system, utilizing a subject line "Eclipse Impact to Forecasting". This information will allow the CAISO to provide greater coordination to the WEIM footprint in advance of the eclipse.

The CAISO serves as the real-time (RT) load forecast service provider for most WEIM entities[17]. The CAISO receives estimates of installed rooftop BTM solar for load-serving WEIM entities. WEIM BTM capacity estimates are provided to a third-party vendor which generates a BTM solar forecast that the CAISO can incorporate into its load forecasting process.

Table 5 shows the approximate estimates of grid connected and rooftop BTM solar for each WEIM entity. Also included is a mapping of each WEIM entity to a broader geographic WEIM region. The WEIM regional breakout is used in the WEIM Load Forecast section below to describe more consolidated load impacts of the eclipse.

[17] Avangrid is a generation only WEIM participant.

WEIM Region	Approx. Grid Connected Solar (MW)	Approx. Rooftop BTM Solar (MW)
California	**1,561**	**953**
Balancing Area of Northern CA (BANC)	407	335
Los Angeles Department of Water and Power (LADWP)	1,154	564
Turlock Irrigation District (TID)		55
Central	**4,807**	**1,453**
Idaho Power Company (IPCO)	473	116
Northwestern Energy (NWMT)	178	38
NV Energy (NVEP)	2,471	835
PacifiCorp East (PACE)	1,685	464
Desert Southwest	**2,851**	**3,402**
Arizona Public Service (AZPS)	794	1,761
El Paso Electric Company (EPE)	285	170
Public Service Company of New Mexico (PNM)	841	340
Salt River Project (SRP)	436	497
Tucson Electric Power (TEPC)	428	503
WAPA Desert Southwest Region (WALC)	67	130
Pacifc Northwest	**1,061**	**650**
Avangrid (AVRN)	522	
Avista (AVA)	20	21
Bonneville Power Authority (BPA)	138	88
PacifiCorp West (PACW)	381	173
Portland General Electric (PGE)		161
Puget Sound Energy (PSE)		149
Seattle City Light (SCL)		44
Tacoma Power (TPWR)		15
WEIM Totals	**10,280**	**6,458**

Table 5: WEIM grid connected and rooftop BTM solar capacity

WEIM Load Forecast

Eclipse impacts on WEIM loads will vary with proximity to the eclipse path and levels of installed BTM rooftop solar. Generally, eclipse impacts will be more pronounced in regions with higher levels of BTM capacity relative to native load. The WEIM regional load forecasts on the eclipse day will be heavily influenced by weather conditions and cloud cover. Normal October weather assumptions are based on a representative day for each WEIM region using observed 2022 October weather data.

Eclipse impacts by region are shown in Figure 9[18]. The Desert Southwest shows the strongest eclipse impacts with morning load increasing by up to 17.9% relative to clear-sky conditions.

[18] CAISO loads are not included in this graphic

The California and Central WEIM regions will see load increases up to 9.6% and 5.9% respectively relative to clear-sky conditions. The Pacific Northwest region shows the lowest impact from the eclipse with a load increase of 2.3% relative to clear sky conditions.

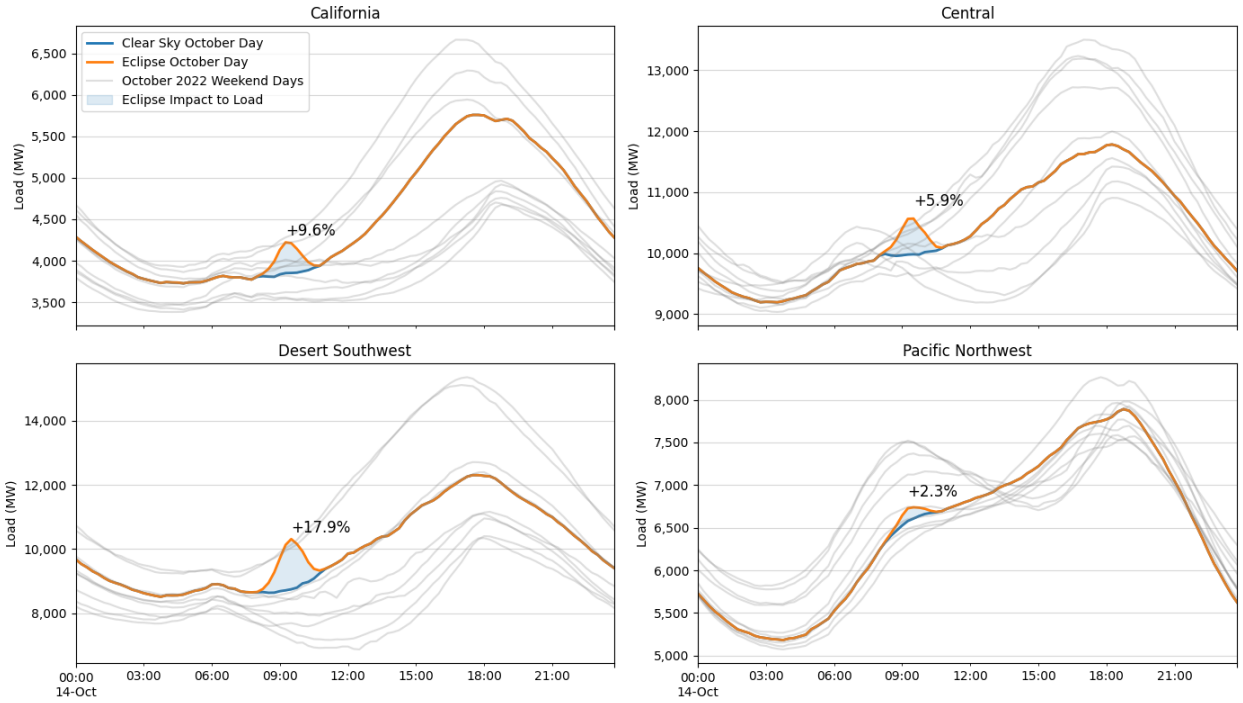

Figure 9: WEIM regional load impacts of eclipse

Grid Protection

Given the expected load, renewable, and weather conditions described above, the CAISO must take certain measures to maintain grid reliability during significantly larger system ramps.

Below is a summary of the mitigation measures that the CAISO expects to deploy in preparation and throughout the day of the event, October 14, 2023:

Grid protection options ahead of and during the eclipse	
Internal market simulation	WECC/RC West coordination
IOU coordination	Adjacent BA coordination
Scheduling Coordinator (SC) interaction	Gas supply coordination
Outage coordination	Assistance Energy Transfer (AET) opt-in
Consider declaring restricted maintenance operations (RMO)	Execution of 48-hour Reliability Unit Commitments (RUC)
Day +2 conference bridge	Importance of DA solar forecasting
Reserves procurement	RUC net short
Resource Optimization of renewable, battery and hydro generation	Minimum state-of-charge

Post-DA Conference bridge	Potential use of Flex Alert or Demand Response
Tighten Automated Generation Control (AGC) bands	Exceptional Dispatch
Use of WEIM transfer capability	Flexible Ramp product usage

Table 6: Grid protection options

Each of these grid protection mechanisms are critical to ensuring reliable operations during the Solar Eclipse. *As we walk through the different grid protection mechanisms let's start with the* ***forward planning horizons****. Items identified within 1.1 through 1.11 will be done prior to October 13, 2023. This will ensure that upon the DA Market horizon coordination across RC West, the CASIO BAA, and the WEIM is prepared for the DA timeframe.*

1.1 Internal Market Simulation

Prior to the eclipse event, several departments in the CAISO will perform an internal, table-top market simulation. One major focus of this will be to ensure the Day Ahead market final Reliability Unit Commitments (RUC) are providing the necessary ramping capacity based upon the latest forecasts, system conditions and forced outages. This simulation will also ensure that the CAISO teams are coordinated and prepared to perform the extras tasks outlined for this Eclipse event.

1.2 WECC/RC West Coordination

RC West will hold an Eclipse prep webinar with adjacent reliability coordinators and separately with member Transmission Operators (TOP)/BA, where individual TOP/BAs will share their prep items and concerns.

On October 13, a day prior to the eclipse, RC West will hold a webinar with Real-Time Working Group (RTWG) members to verify system posture plans by individual TOP/BA members.

Day of (October 14) will hold early morning conference call with real-time TOP/BA Operators and Adjacent RC confirming readiness.

The CAISO will continue to coordinate with RC West and generation community to talk through the operating plan for that day.

1.3 IOU Coordination

The CAISO Real Time Operations will coordinate a meeting with the IOU's (September 13) to review eclipse impact, forecasted grid conditions and operational plan for October 14.

1.4 Adjacent BA Coordination

The CAISO Real Time Operations will coordinate a meeting with the IOU's (September 14) to review eclipse impact, forecasted grid conditions and operational plan for October 14.

1.5 Scheduling Coordinator Interaction

It is critical that Scheduling Coordinators in the CAISO DA market use their solar FSPs' latest forecasts in the DA market. With the latest forecast information submitted, the DA market will be in the best position to account for the reduction in solar output and redispatch other available resources. As stated earlier, much of the success of the prior eclipse event was due to the accuracy with which solar generation was forecasted in the DA because the DA market had already committed resources that accounted for the ramp-down periods, so there was very limited need for real-time re-dispatch.

1.6 Gas Supply Coordination

The CAISO will work with both interstate and intrastate gas suppliers to ensure the availability of sufficient gas supplies during the solar eclipse, and will coordinate with thermal generators to ensure they have procured enough gas to handle generation deviations during the day of the Solar Eclipse.

1.7 Outage Coordination

The CAISO will be analyzing the impacts of generator and transmission outages prior to approving outages for October 14 to ensure needed resources are available to replace the loss of solar capacity.

1.8 Assistance Energy Transfer Opt-in

As part of the Resource Sufficiency Enhancement effort effective in July, WEIM entities including the CAISO may opt-into Assistance Energy Transfer (AET). If opted-in, should an entity fail the Resource Sufficiency Evaluation tests, its ETSR net limits will not be limited to the RTPD Scheduled flow during the interval prior to the failure (the existing failure treatment). The AET functionality may serve as an additional tool to manage the dynamic system conditions expected during the eclipse. For more information on AET and the AET Opt-in process, please refer to the WEIM BPM under Section Resource Sufficiency Evaluation.

1.9 Consider Declaring Restricted Maintenance Operations

The CAISO could declare a Restricted Maintenance Operations (RMO) designed to help prevent the possibility of an inadvertent issue arising from a routine or standard maintenance event.

1.10 Execution of 48-Hour RUC

The 48-Hour RUC is a process that increases grid reliability by reducing the amount of uneconomic cycling of long start and extremely long start resources toward the end of a trade-date or beginning of the next trade date. The 48-Hour RUC considers the net load forecast in the 48-hour timeframe to better position these resources in the DA timeframe. With our forecast service providers submitting the forecast, taking into consideration the obscuration to the solar facilities during the eclipse, we do not expect an increase in forecast error during this event. The RUC recommendation will utilize the updated forecasts based on past historical

uncertainty with similar forecasted conditions. This will allow the current mechanisms being utilized for the RUC recommendation to be optimized.

1.11 Day +2 Conference Bridge

The CAISO Operations will host a conference bridge [details forthcoming] two days in advance of the eclipse to ensure that the upfront planning and coordination remains on track. The objective will be to ensure any changes to the planned actions, or system conditions that may affect the planned actions, are discussed, reevaluated and coordinated with any new adjustments or changes agreed upon, if necessary.

*All the above pre-planning activities are designed to ensure coordination within the DA and RT timeframe to assist the market optimization in seeing and solving for the eclipse impacts. The next few areas will be the items that are focused on **the day prior** to the Eclipse on October 13, 2023. These items span from 1.12 The Importance of DA Solar Forecasting to the Potential Use of Flex Alerts in 1.18.*

1.12 Importance of DA Solar Forecasting

The CAISO obtains BTM solar forecasts as well as large scale solar generation forecasts from two FSPs The FSPs will account for the solar eclipse that will automatically feed through the CAISO's daily processes. Having the most accurate forecast possible for market optimization will allow for optimal use of the CAISO markets to deal with the impacts of the solar eclipse. The aggregate forecast for large scale solar will be available to the market participants, as well as the public, through OASIS applications.

1.13 Reserves procurement

The CAISO anticipates committing an increased amount regulation up and regulation down to assist with the increased ramping needs during the eclipse period. Table 7 shows the values the CAISO may utilize, these values will be updated following market simulations and as new weather information for the day becomes available.

Hour-ending	Normal Regulation Up (MW)	Normal Regulation Down (MW)	Normal Eclipse Regulation Up (MW)	Normal Eclipse Regulation Down (MW)	
8	300	-1020	450	-1530	
9	360	-1250	540	-1875	Eclipse
10	300	-1150	450	-1725	Eclipse
11	300	-1130	450	-1695	Eclipse
12	300	-1030	450	-1545	

Table 7a: Recommended Regulation during solar eclipse compared to normal

Hour-ending	Cloudy Regulation Up (MW)	Cloudy Regulation Down (MW)	Cloudy Eclipse Regulation Up (MW)	Cloudy Eclipse Regulation Down (MW)	
8	380	-1140	570	-1710	
9	540	-1450	810	-2175	Eclipse
10	490	-1280	735	-1920	Eclipse
11	370	-1260	555	-1890	Eclipse
12	360	-1160	540	-1740	

Table 8b: Recommended Regulation during solar eclipse compared to cloudy

1.14 RUC Net Short

The CAISO operator may manually adjust the CAISO forecast of CAISO demand, which is the basis of RUC procurement, under certain circumstances in the event the operations has determined that additional RUC capacity is needed to meet anticipated real-time system conditions. RUC Net Short amounts are published on OASIS after RUC Final Schedules are published.

1.15 Resource Optimization

Renewable and Battery Resources:

The CAISO will issue Market Notification System (MNS) messages and Operating Instructions (OI) to market participants informing them that all renewable and battery resources must follow their Dispatch Operating Target (DOT) to assist in controlling reliability of the grid. Resources should comply with linear ramping procedures[19]. In addition, there is also the potential that operators will instruct a limit of the solar generation ramp rate during the return of the eclipse given the steep ramp-up of solar during this time.

Hydro Generation

Due to the above average California hydro year we are in, August water levels in California are expected to still be available for hydro resources to carry regulation and/or energy during the eclipse. The CAISO will be working with the hydro community and inform participants of the additional need for flexibility on October 14 to assist with that flexibility being available to the market optimization.

1.16 Minimum State-of-Charge

There is a possibility that the Minimum State-of-Charge (MSOC) could be utilized during the Eclipse timeframe. The MSOC was developed as a temporary tool for storage management to ensure that in the RT market, storage resources are charged to a level that will allow them to deliver their DA discharge schedules. However, this tool can only be triggered on days when the

[19] Section 7.2.3.6 of the Market Operations BPM: https://bpmcm.caiso.com/Pages/BPMDetails.aspx?BPM=Market%20Operations

RUC process results in an under-generation infeasibility at any trading hour, which is unlikely on the eclipse trade date. If triggered, the MSOC hours would be enforced during the critical hours that include the Eclipse timeframe. For more information on the MSOC process, see the MSOC section in the Market Operations BPM.

1.17 Post-DA Conference Bridge

The CAISO Operations will host a conference bridge [details forthcoming] one day in advance and following the DA publish [around 14:30 on October 13] to share the DA results for the eclipse. The objective will be to ensure any changes to the planned actions, or system conditions that may affect the planned actions, are discussed, reevaluated and coordinated with any new adjustments or changes agreed upon, if necessary.

1.18 Potential Use of Flex Alert or Demand Response

Although not anticipated due to the eclipse occurring on a weekend when loads are typically lower, the CAISO could utilize a Flex Alert or enact demand response programs within or outside of the market during the eclipse. Within demand response, the use of long- and short-start strategic reliability reserve resources will be engaged in accordance with operating procedure 4420, if necessary.

*Last but not least, are the tools that are within the **real-time horizon**. These tools such as the use of the WEIM transfer capacity are a valuable resource for the West to account for the solar eclipse moving through many of the BAA regions within the WEIM.*

1.19 Tighten Automated Generation Control Bands

The automated generation control (AGC) bands will be tightened during the eclipse hours. This will allow the energy management system (EMS) AGC system to control the area control error (ACE) tighter than required by the reliability based control (RBC) guidelines.

1.20 Exceptional Dispatch

If necessary, the CAISO operators may be required to perform manual re-dispatch via Exceptional Dispatch instructions for additional energy or flexible ramp capacity. It may also be necessary that individual storage resources be Exceptionally Dispatched to charge and then hold the charge to be used during ramping time periods of the eclipse. Exceptional Dispatches are used during a System Emergency, to prevent an imminent System Emergency, or a situation that threatens system reliability. The CAISO operators communicate Exceptional Dispatches directly to Scheduling Coordinators.

1.21 Use of WEIM Transfer Capability

The real-time WEIM design provides a daily mechanism to share and diversify resources to assist in more enhanced management of renewables across the Western United States through

market-based Energy Transfer System Resources (ETSRs). It is recommended that WEIM entities keep ETSRs unlocked with typical transfer limits.

As the RT market solves simultaneously for all WEIM areas including the CAISO , forecasts for BTM solar and large scale renewable resources in each individual WEIM BA can affect the RT market optimization and ETSR dispatches. As stated earlier, it is also critical that all WEIM participants account for the solar eclipse effects in their solar renewable resource forecasts in their base schedules that are being submitted by their forecast service providers to avoid the potential of significant market re-dispatch during the eclipse or the potential of significant ETSR movement during the eclipse ramp down and re-ramp up time-periods.

1.22 Flexible Ramp Product Usage

The Flexible Ramping Product (FRP) is used to account for forecast errors and uncertainty between real-time pre-dispatch (RTPD) and real-time dispatch (RTD) markets, as well as, between RTD advisory and binding intervals. With our Forecast Service Providers submitting the forecast, taking into consideration the obscuration to the solar facilities during the eclipse, we will not expect there to be an increase in forecast error during this event. The FRP will utilize the updated forecasts based on past historical uncertainty with similar forecasted conditions. This will allow the current mechanisms being utilized for the FRP to be optimized.

Conclusion

This bulletin provides an assessment of the potential impacts of the October 14, 2023 annular eclipse on the CAISO BAA and WEIM. Assuming mostly clear-sky conditions, the eclipse is expected to significantly reduce the amount of grid-scale and BTM solar generation. Reductions in BTM solar generation will, in turn, increase gross load to varying degrees based on levels of installed capacity. The results presented in this bulletin should be viewed as a high impact scenario as weather conditions on the eclipse day, notably increased cloud cover, could mitigate impacts to solar generation.

In preparation for the eclipse, the CAISO will employ additional grid protection measures to manage the steeper ramping requirements and to ensure grid reliability. Many of these measures were used during the August 21, 2017 total solar eclipse which the market generally handled with success.

Coordination across the WEIM is crucial so that the market can optimally dispatch during the eclipse conditions. The CAISO will hold a series of outreach events with the WEIM entities to facilitate this coordination and ensure that external submittals use appropriate forecast methodologies that account for eclipse impacts on grid-scale solar and loads as well as any operational constraints.

Following the eclipse the CAISO will produce a report that provides a post analysis of market operations on and leading up to the eclipse day. This report will include any lessons learned or recommendations for future process enhancements based on market performance.

Timeline

An estimated timeline has been developed to allow time to address any issues arising from the eclipse. Following the event, the CAISO will review solar eclipse data and impacts to identify lessons learned. In early 2024 the CAISO will start preparing for the total solar eclipse that will occur on April 8, 2024 that will impact the western United States.[20]

Item	Date
WEIM Bi-weekly Ops Meeting	September 13
IOU coordination discussions	September 13
Adjacent BA Discussion	September 14
RC West, adjacent RC coordination discussion	September 18
RC West Real-Time Working Group (RTWG) - Review of BA/TOP plans	September 19
Follow-Up eclipse stakeholder call	October 2
RC West webinar with RTWG members to verify system posture plans	October 13
TOP/BA – RC West and RC-RC Coordination day-of early morning conference calls confirming readiness	October 14 (03:00 PNW, 04:00 PSW, 06:00 RC/RC)

[20] https://solarsystem.nasa.gov/eclipses/2024/apr-8-total/where-when/