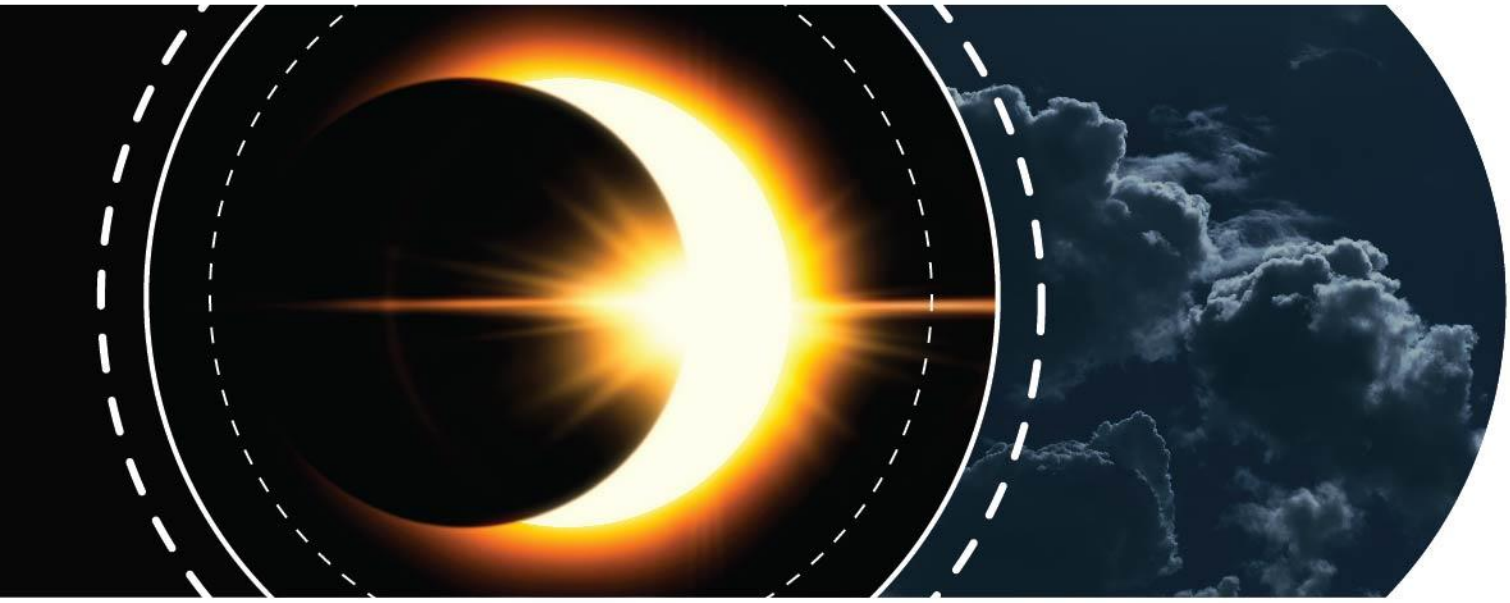
APRIL 8, 2024
SOLAR ECLIPSE TECHNICAL BULLETIN



California ISO

March 6, 2024

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Executive Summary

On Monday, April 8, a total solar eclipse will pass over the southern and eastern United States from Texas to Maine, bringing a partial eclipse across the western U.S.

This bulletin details the expected impact of the solar eclipse and 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), other balancing authority areas (BAAs), and market participants 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 10 a.m. through 1 p.m. Pacific Daylight Time (PDT) on April 8. Each WEIM area will have varying times and magnitudes of impact from the eclipse, with locations beginning between 10:03 a.m. and 10:48 a.m. and ending between 12:16 p.m. and 12:57 p.m. PDT. The range that the sun will be obscured varies from 89% in southeast New Mexico to 16% in northwest Washington.[1] The California BAA will be affected by the eclipse from approximately 10:05 a.m. to 12:30 p.m. PDT, with solar obscuration ranging from 25% in the northwest corner of the state to 59% in the southeast corner. 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 and the WEIM.

The April eclipse will affect the ISO and WEIM differently than the annular solar eclipse that occurred on October 14, 2023. An annular eclipse obscures most of the sun except for a halo of sunlight around the edge of the moon's dark disc. The April eclipse will be total, meaning that the entirety of the sun will be blocked by the moon, but it will travel a different path, much farther to the east.

The October 2023 eclipse's path of annularity passed across eight Western states from Oregon to Texas. In contrast, the April eclipse's path of totality will not pass across the West. Its effects on the WEIM and California will be far less than in October.

In October, the ISO weighed the huge buildout of utility-scale solar between the last eclipse in 2017 and the 2023 eclipse. Since October, there has been some growth in grid-scale solar but nowhere near as much as between the 2017 and 2023 eclipses.

During the October 2023 eclipse, there were more than 16,500 MW of grid-scale solar installed capacity throughout CAISO. There are now more than 18,500 MW. At the same time, behind-the-meter rooftop solar capacity has increased from 14,350 MW in the CAISO BAA to 15,770.

[1] https://www.timeanddate.com/eclipse/map/2024-april-8

Within the WEIM entities[2], grid-scale solar has grown from 10,280 MW in October 2023 to 12,150 MW as of February 2024, and behind-the-meter rooftop solar has increased from 6,458 MW to 6,903 MW.

There are 21 balancing areas that participate in the WEIM, accounting for about 80% of load in the Western Interconnection.[3] In addition, the ISO provides reliability coordination services to most of the balancing areas in the Western Interconnection through RC West.

With the West more interconnected now than ever, entities can utilize these connections and relationships to maintain reliable operations, collaborate and optimize resources throughout the eclipse.

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

The April 2024 eclipse will be less impactful than the 2023 eclipse because of the eclipse's trajectory. Solar obscuration across California and the West will be far less than in October, and the impacts to load and grid-scale renewables will be less significant. This is true even though CAISO grid-scale and rooftop solar have grown by over 2,000 MW and 1,420 MW respectively since October 2023, and WEIM grid-scale and rooftop solar have grown by 1,870 MW and 445 MW since October.

For the CAISO Balancing Authority Area, the eclipse will start to impact grid-scale solar and load at 10:00 a.m. on April 8, reaching maximum impact at 11:15 a.m. before returning to normal conditions at 12:30 p.m. Precise timing and levels of obscuration will depend on geographic location relative to the eclipse path. In comparison, the October eclipse began around 8:00 a.m. in the CAISO BAA, reaching peak conditions at 9:30 a.m. and ending around 11 a.m.

The CAISO BAA has approximately 18,500 MW of installed grid-scale solar capacity and 15,770 MW of rooftop solar capacity. Obscuration from the eclipse will reduce generation from all solar resources.

The change in grid-scale solar generation and gross load is greatest on the eclipse return. Grid-scale solar generation will decrease by 6,349 MW from the start of the eclipse to maximum impact and increase by 6,718 MW on the eclipse return. Gross load will increase by 2,294 MW from the start of the eclipse to maximum impact and drop by 5,159 MW from the eclipse maximum to the eclipse end.

Net load ramp rates on the eclipse return are larger than from the eclipse start to maximum impact. At the eclipse start to the period of maximum impact, the net load ramp rate will increase by an average of +115 MW per minute and decrease by -150 MW per minute on the

[2] The CAISO BAA is excluded from WEIM reported values
[3] Including the CAISO but excluding Avangrid, a generation-only participant.

return. The ramp-up rates are expected to be similar to the October 2023 eclipse ramp rates, which exhibited an average +100 MW per minute net load ramp rate. Ramp down rates are expected to be slightly steeper compared to the October 2023 eclipse, which exhibited -118 MW per minute net load ramp.

WEIM regions will see varying eclipse impacts on solar generation and load depending on levels of installed grid-scale and behind-the-meter rooftop solar. The Central region has the largest amounts of installed grid-scale solar capacity, while the Desert Southwest region has the greatest total installed BTM solar capacity. The Central and Desert Southwest regional loads are forecast to increase by 4.3% and 19.4% during the upcoming April 2024 eclipse ramp-up period, respectively. During the October 2023 eclipse, these regions saw 5.2% and 12.9% increases during the eclipse ramp-up period.

The ISO 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 use special procedures to manage eclipse ramping requirements. The specialized solar procedures include the potential to limit the solar generation ramp rate during the eclipse return and to utilize an Operating Instruction (OI) for the fleet to ensure solar resources follow their Dispatch Operating Target (DOT) and linearly ramp from Dispatch Operating Point (DOP) to DOP. Much of the success of the 2023 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 re-dispatch. 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 ISO 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 2023, CAISO has seen some growth in battery resources to assist with the faster ramping needs on the system. The ISO plans to use battery and hydro resources during the solar eclipse.

The ISO will procure additional operating reserve requirements to assist in the eclipse. During the 2023 eclipse, additional reserve procurement helped grid operators handle resource deviation in addition to large ramps on the system. For 2024, the ISO will procure additional operating reserves to assist with the expected change in solar generation and to offset potential cloud cover.

To get the most benefit while minimizing risk, greater coordination and preparation across utilities is required throughout the RC West and WEIM footprints and the CAISO balancing area. The ISO remains committed to providing details on potential impacts and actions to allow entities to prepare for the eclipse, as well as support reliable operations throughout the event.

The ISO will utilize lessons learned from the October 2023 eclipse to improve upon some aspects of the eclipse methodologies and mechanisms. Enhancements regarding load forecasting, regulation requirements and automatic generation control (AGC) will be implemented for the April eclipse.

Introduction

The ISO has evaluated the expected impact of the solar eclipse and possible measures to be taken by the ISO, 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 and WEIM.
- 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

On Monday, April 8, 2024, a total solar eclipse will pass over the southern and eastern U.S.

The eclipse's "path of totality" will travel from Texas to Maine across the South, the Midwest and the East, but the West will feel its impacts as well. In the West, New Mexico will see the greatest effect with areas experiencing solar obscuration of 89%.

Throughout the WEIM, areas such as southern Arizona and southern California will see the eclipse begin at 10:04 a.m. PDT, while in northeastern Montana, it will begin as late as 10:48 a.m. PDT. The maximum solar obscuration across the WEIM states varies from 16% to 89% depending on the distance from the path of totality.

The totality will last for four to five minutes across Texas, peaking around 11:30 a.m. to 11:45 a.m. PDT. The eclipse will end at 12:16 a.m. PDT for northwest Washington but last until 12:57 p.m. PDT for far northeast Montana. The solar production areas in California will be affected by a partial eclipse between 10:05 a.m. and 12:31 p.m. Across California, the maximum impact will be 59% of sun obscuration across the southeastern deserts and 25% across the northwestern California coast. This is different from the October 2023 eclipse, when the greatest solar obscuration passed across the West, and northern California felt the effects more than Southern California.

Compared to the October eclipse, the Western U.S. will not be as significantly impacted. During the October eclipse, eight states across the WEIM footprint experienced 90% solar obscuration, with California ranging from 68% to 89% obscuration. During the upcoming April eclipse, no areas in the WEIM will experience 90% or more solar obscuration.

While the impact of the April eclipse is not expected to be as drastic as it was in October, impacts will still be felt across the West to grid-scale and behind-the-the meter rooftop solar generation, and demand for electricity will be affected.

Figure 1 shows the path of the total eclipse across the United States. The northern and southern path limits of totality are denoted in yellow. The map notes percentages of solar obscuration for areas outside the path of totality.

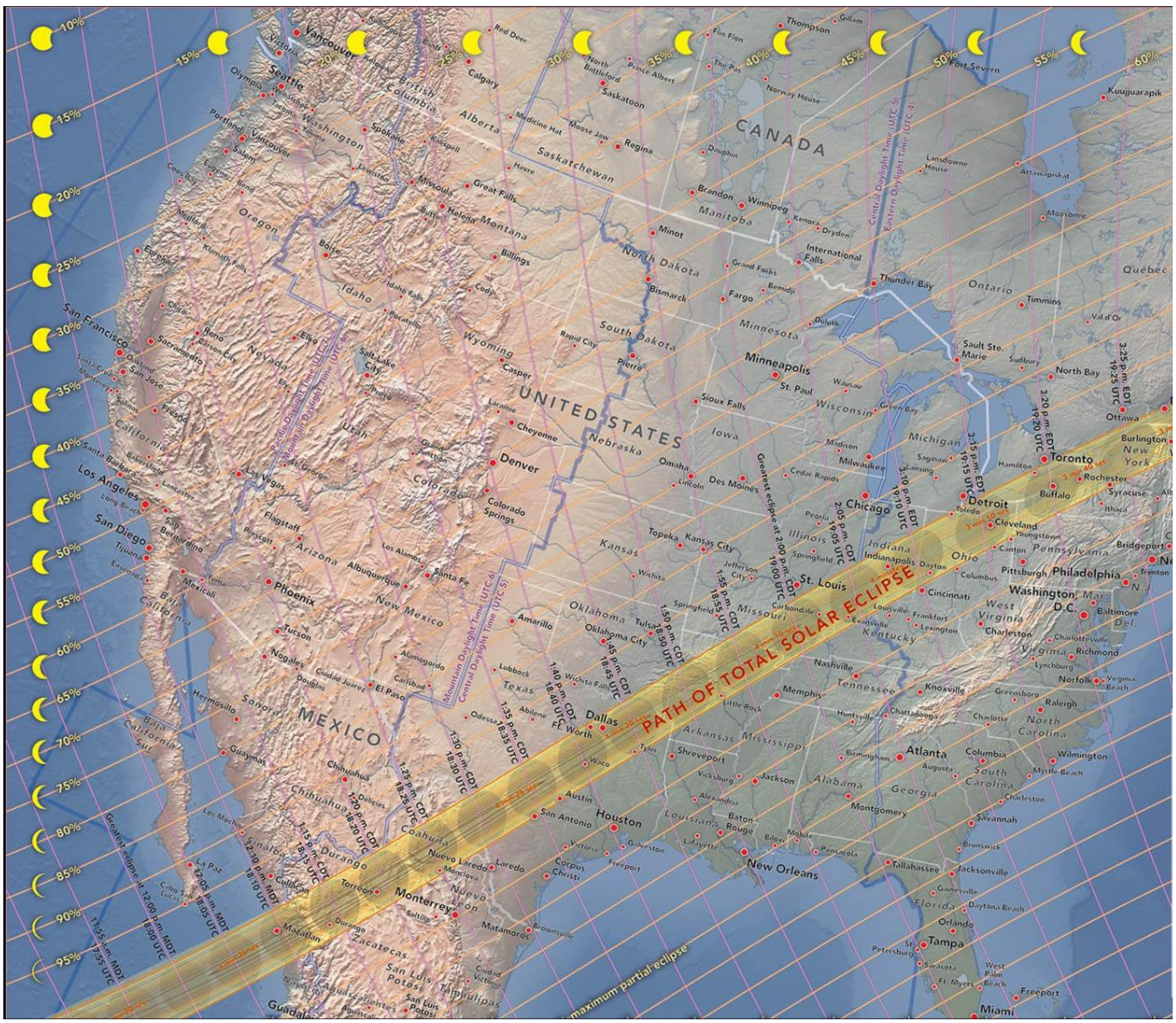

Figure 1: A map of the April 8, 2024 total eclipse path and percent obscuration across the US[4]

[4] https://www.greatamericaneclipse.com/april-8-2024

Lessons Learned from October 2023 Eclipse

During the October 2023 eclipse, the ISO and WEIM did not experience significant problems but learned ways to improve for April. A complete analysis of the renewable, load and market performance during the October 2023 eclipse can be found here.

Regarding load forecasting, the ISO noted that the real-time load models that performed best during the 2023 eclipse were the models that used a reconstituted methodology. Reconstituted models utilize weather data to predict the sum of gross load and rooftop solar. The forecasted rooftop solar value is then subtracted out from the predicted value, leaving a residual gross load forecast. For the April eclipse, the ISO plans to use these methods when possible to assist with real-time demand forecasting.

The ISO also found that the regulation up requirements for the October eclipse were higher than the regulation that was actually needed. The regulation-down usage during the October eclipse was much closer to the regulation down procured. Based on this analysis, the ISO plans to adjust the regulation up recommended for the April eclipse day.

For real-time operations, nearly all of our takeaways from the October eclipse were positive and serve as a template for similar events in the future including the April 8 eclipse. Some minor lessons learned from the October event was with respect to automatic generation control (AGC) bands. We tightened the AGC control bands to be more responsive but that resulted in over-response, so we quickly adjusted back to normal control bands and normal control bands performed to our needs throughout the remainder of the solar eclipse event.

Impacts to CAISO Load and Renewables

Eclipse modeling assumptions

The weather forecast for April 8 will not be available until about two weeks prior to the eclipse. Forecasts for grid-scale renewables will not be available until seven days prior. For this study, a set of common assumptions were made to facilitate consistent modelling of renewables generation and load-related eclipse impacts.

For grid-scale solar, rooftop solar 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 scenarios since eclipse impacts are modeled under a clear-sky assumption. Normal April temperature assumptions are based on selecting a representative day from April 2023 which is near the 50th percentile. The ISO 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 temperature or wind speed are not included. The CAISO load forecast also only includes the

major transmission access charge (TAC) areas: Southern California Edison (SCE), San Diego Gas and Electric (SDG&E) and Pacific Gas and Electric (PG&E) and does not include metered sub-stations (MSSs), pumps or the Metropolitan Water District (MWD) of southern California.[5]

Potential Grid-Scale Solar Reduction

Solar obscuration defines the solar irradiance reduction striking the earth at a given location such as a photovoltaic solar site. Solar obscuration decreases farther from the central path of the eclipse. Grid-scale solar site production will be reduced during the eclipse by the amount of solar obscuration.

Figure 2 shows the solar obscuration relative to the general locations of the California grid-scale solar regions within the CAISO BAA.

Figure 2: A map of the regional CAISO PV solar locations with the percentage of solar obscuration[6]

[5] 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.

[6] https://svs.gsfc.nasa.gov/5123/

The solar eclipse will begin when the grid-scale solar sites will be nearing the end of their morning ramp-up to the maximum amount of daily production, and end when the sites are in their midday peak of daily production. Production will decrease from the time the eclipse starts at around 10:05 a.m. for the solar sites in southeastern California and around 10:16 a.m. for the sites in northern California. The time of maximum impact ranges from 11:13 a.m. to 11:19 a.m. for the solar sites farther north and west, and south and east, respectively.

As the eclipse wanes, the solar production return will be at a similar ramp rate as the decrease going into the eclipse maximum because the entire duration of the eclipse will be during the time when the solar sites are near their midday peak production. This is different from the October eclipse, which started during the daily solar on-ramp and ended during the midday peak, leading to sharper ramp rates on the return than entering the eclipse. The period after the eclipse maximum to the end of the eclipse, from approximately 11:20 a.m. to 12:30 p.m., is the period of operational interest that the ISO will study to ensure adequate supplies of generation (reserves) are available to mitigate any adverse effects of the anticipated steep ramp-up in solar production.

Forecast Area	Eclipse Start Time (a.m.)	Eclipse Max Time (a.m.)	Eclipse End Time (a.m.)	Eclipse Max Obscuration	April 2024 Regional Capacity	Approx. Area Production at Eclipse Start		Approx. Area Production at Eclipse Max[7]		Approx. Area Production at Eclipse End	
					MW	Cap %	MW	CAP %	MW	Cap %	MW
N. San Joaquin	10:16	11:15	12:18	34%	305	74%	227	51%	154	74%	225
S. San Joaquin	10:10	11:14	12:20	41%	4,905	74%	3,647	45%	2,215	74%	3,609
Mojave	10:08	11:14	12:23	48%	4,649	74%	3,455	40%	1,852	76%	3,529
LA Basin	10:06	11:13	12:24	51%	224	74%	167	38%	85	75%	169
Coachella/Imperial Valley	10:05	11:14	12:26	56%	2,635	74%	1,958	34%	897	75%	1,981
S. Nevada	10:11	11:19	12:30	52%	1,533	74%	1,139	37%	566	76%	1,163
Colorado River Valley	10:07	11:16	12:28	56%	2,874	74%	2,136	34%	968	76%	2,182
Yuma	10:08	11:18	12:31	58%	1,115	74%	828	32%	358	76%	846
						SUM:	**13,556**		**7,095**		**13,703**

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

[7] 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 because the eclipse maximum and times vary by each region.

Using the data from Table 1, the ISO calculated[8] the approximate amount of solar energy expected to be produced on April 8, 2024 (assuming a clear-sky with no cloud impacts) compared to a clear non-eclipse April day. We anticipate that grid-scale solar production the start of the eclipse at 10:00 a.m. will be approximately 13,472 MWs. From 10:05 a.m. through 11:20 a.m., solar generation will decrease as the sky darkens across the state. As illustrated in Figure 3, this is a reduction of 6,349 MW from 10 a.m. through 11:20 a.m., or a ramp down of -79 MW per minute, while on a non-eclipse day, the average ramp during this period is +7 MW per minute. During the October 2023 eclipse, solar decreased at a rate of -82 MW per minute from the morning maximum before the eclipse began to the time of the eclipse's peak.

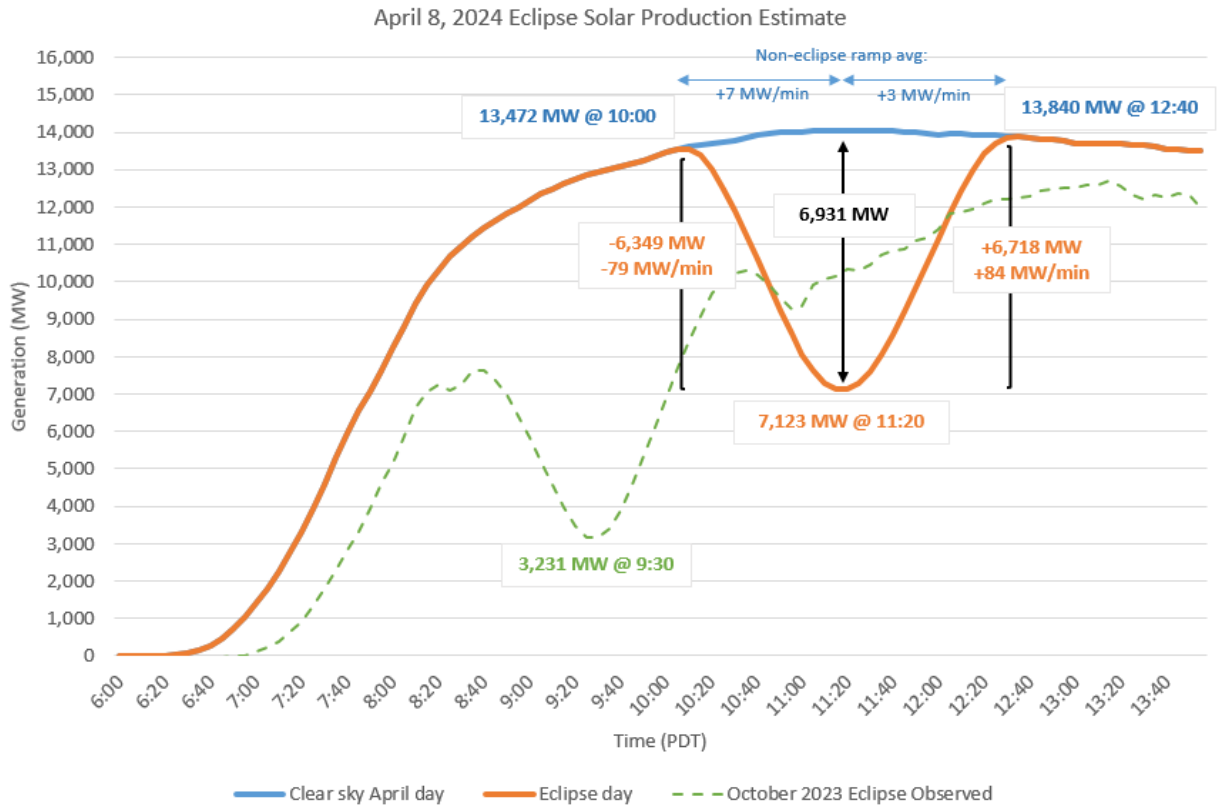

Figure 3: Forecast grid-scale solar production during the April 8, 2024 eclipse. All ramp rates are an average MW per minute over a given period.

Because the sun will not be fully obscured over California, the grid-scale solar production will never completely stop but will be reduced to a minimum of approximately 7,123 MW at 11:20 a.m. This is more than double the amount of the minimum production during the October 2023 eclipse, which hit a low of 3,231 MW at 9:30 a.m.

As the eclipse wanes, the return to normal production will cause an up-ramp of +84 MW per minute beginning around 11:20 a.m., with generation increasing to 13,840 MW at 12:40 p.m.

[8] Based on the approximate generation for a clear-sky April 2023 day, adjusted for capacity updates between 2023-2024 and then adjusted for the eclipse maximum percentage obscuration.

For reference, the estimated ramp from 11:20 a.m. to 12:40 p.m. on a non-eclipse day is an average of +3 MW per minute. Compared to the October 2023 eclipse, the ramp of solar production as the eclipse waned was +131 WM per minute, which is about 1.5 times steeper than the ramp-up expected in April.

Temperature and Wind Impacts

Other potential 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. There is less data on impacts to areas not within the path of complete obscurity, such as California on April 8. However, we can use data from the October 2023 eclipse to determine potential impacts for April.

Table 2 shows the observed temperature impacts across California for the October 2023 eclipse. In April, all of California will see less than a 70% solar obscuration level, so temperature impacts across the state are expected to be 3˚ F or less as a result of the eclipse. Because the maximum obscuration across California will vary between 11:10 and 11:20 a.m., there will likely be some impact to the rate of heating through the rest of the day. This means that the rate of increase into the maximum temperature, as well as the maximum temperature observed for the day could be slightly lower compared to a similar day without an eclipse.

Oct. 2023 obscuration level	Oct. 2023 observed temperature reduction (˚F)
< 70%	3˚
71-80%	5˚
>80%	6˚

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

Areas within or very close to complete totality experience the largest temperature impacts, with the effects tapering off the farther from the eclipse center. For areas such as New Mexico and southeast Arizona that will be closer to the path of totality and experience greater than a 70% obscuration, a +5°F impact to temperature is expected, depending on how far each location is from the path of totality and cloud cover. Other locations within the WEIM, such as the Pacific Northwest, which will experience 30% obscuration or less, so temperature impacts will likely be little to none. 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.

Wind speed and direction can also be impacted by an eclipse, also with the largest impacts closest to the path of totality. During the October 2023 eclipse, little-to-no impacts to wind speed or direction were observed in California. The effects on wind speed and direction are

again expected to be minimal to none in April because the sun will be obscured even less than it was in October.

As discussed above, the potential impacts to temperature will also be taken into account when preparing demand forecasts for the eclipse, but these are less impactful to grid operations relative to grid-scale or rooftop solar generation.

CAISO Load Forecast

There is more than 15,770 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 4,285 MW, or about 40%, at 11:00 a.m. compared to normal clear-sky conditions as shown in Figure 4.

Since the eclipse occurs on a Monday, load levels are expected to exhibit a typical weekday load profile. In April, cloud cover 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.

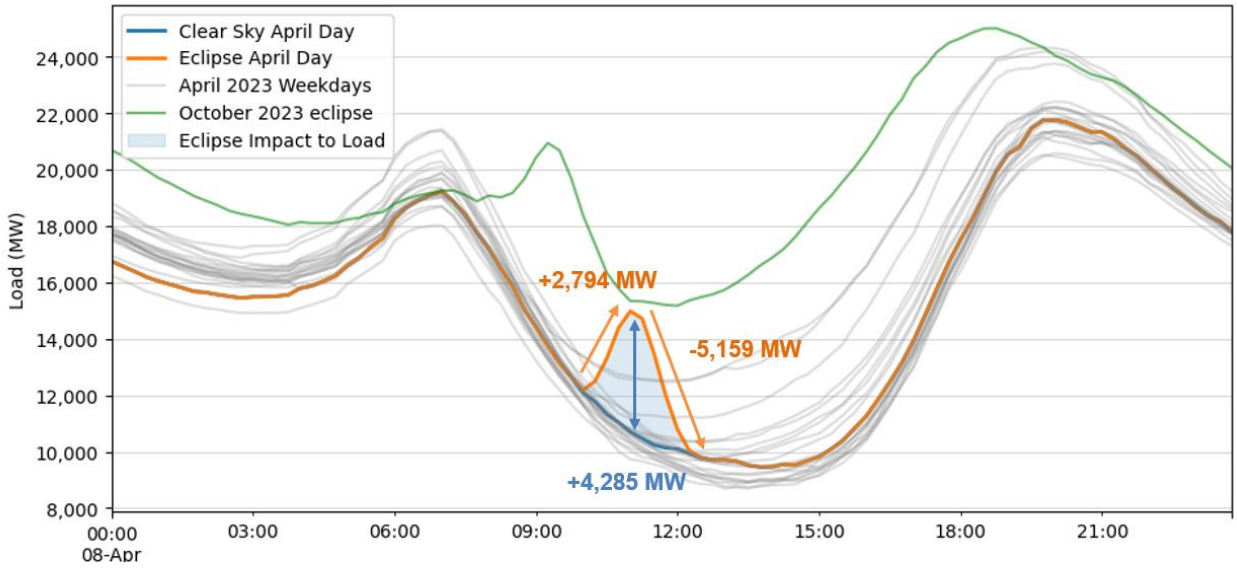

Figure 4: Approximate CAISO load forecast impact from the eclipse

The eclipse will cause a second ramping period from approximately 10:00 a.m. to 11:00 a.m. following the typical morning peaking period. During this ramp-up period, load will increase by 2,794 MW from 10:00 a.m. to 11:00 a.m. The subsequent ramp-down period shows load dropping by 5,159 MW from 11:00 a.m. to 12:30 p.m. During the October 2023 eclipse, load increased by 2,038 MW on the ramp up to the eclipse peak, then decreased by 5,738 MW as the sun returned. These gross load increases and decreases are similar to those forecast for April. Figure 5, below, shows a zoomed in view of the eclipse ramping periods, and Table 3 reports the key load ramping assumptions.

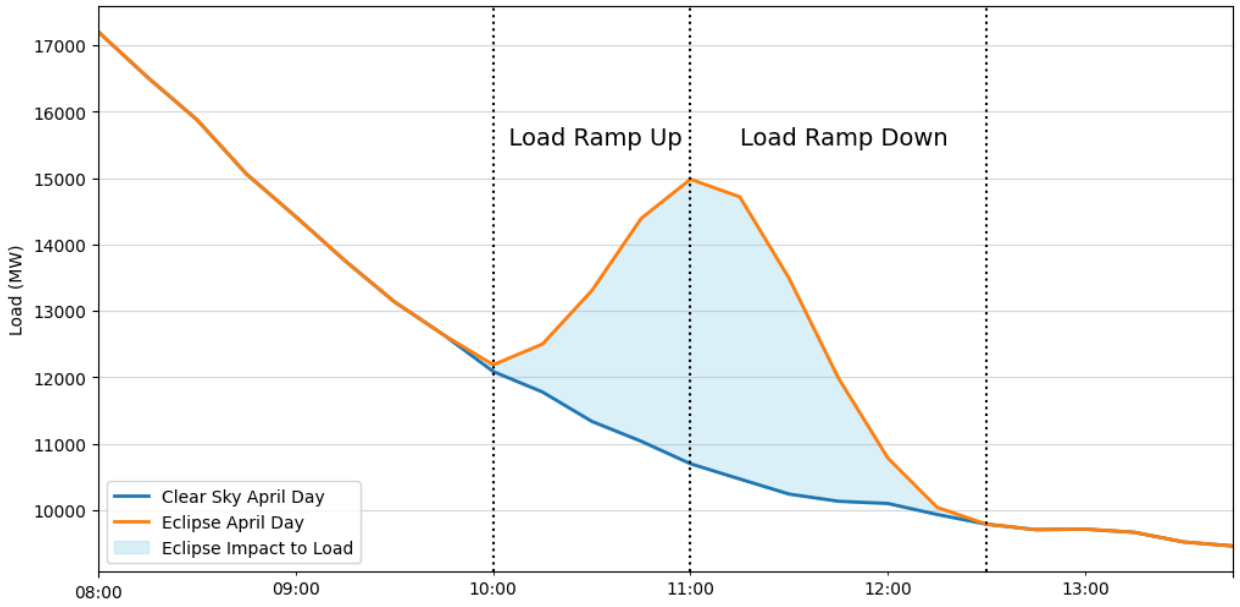

Figure 5: Approximate CAISO load forecast impact from eclipse during ramping period

	Start	End	Load Start	Load End	Total Ramp (MW)	Average Ramp (MW/min)	Max Ramp (MW/min)	Typical Ramp (MW/min)
Ramp Up	10:00	11:00	12,189	14,983	2,794	47	72	-23
Ramp Down	11:00	12:30	14,983	9,788	5,159	-57	-100	-10.1

	Start	End	Load Start	Load End	Total Ramp (%)	Average 15 Min Ramp (%)	Max 15 Min Ramp (%)	Typical 15 Min Ramp (%)
Ramp Up	10:00	11:00	12,189	14,983	22.9%	5.7%	8.7%	-2.9%
Ramp Down	11:00	12:30	14,983	9,788	-34.7%	-5.8%	-10.1%	-1.4%

Table 3: CAISO eclipse load forecast ramping data

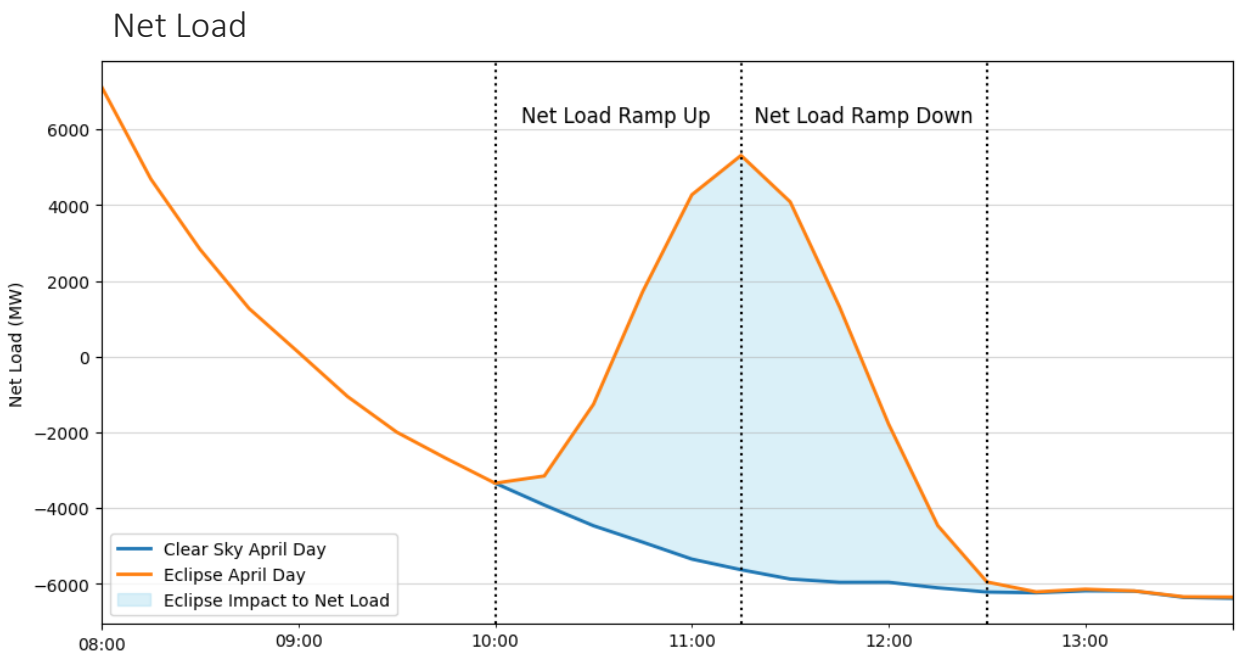

Figure 6, below, represents expected net load on April 8, 2024 under clear-sky versus eclipse

conditions. Wind generation is assumed to follow a normal pattern for April. Net load will follow a typical down-ramp until 10:00 a.m. At 10:00 a.m., eclipse impacts will start to reduce renewables generation and increase load.

From 10:00 a.m. to 11:15 a.m., net load will increase by 8,655 MW. During the ramp-up period, increasing by approximately +115 MW per minute on average, with a maximum ramp of +198 MW per minute. As the eclipse begins to wane, net load will drop by 11,263 MW from 11:15 a.m. to 12:30 a.m. During the ramp-down period net load will decrease by approximately -150 MW per minute on average with a maximum down-ramp of -206 MW per minute. The net load ramp-up period will generally be similar to the 2023 eclipse ramp-up, which exhibited an average ramp increase of +100 MW per minute with a maximum ramp of +180 MW per min. The net load ramp-down period will generally be similar compared to the 2023 eclipse ramp-down, which exhibited an average ramp decrease of -118 MW per minute with a maximum ramp of -267 MW per min.

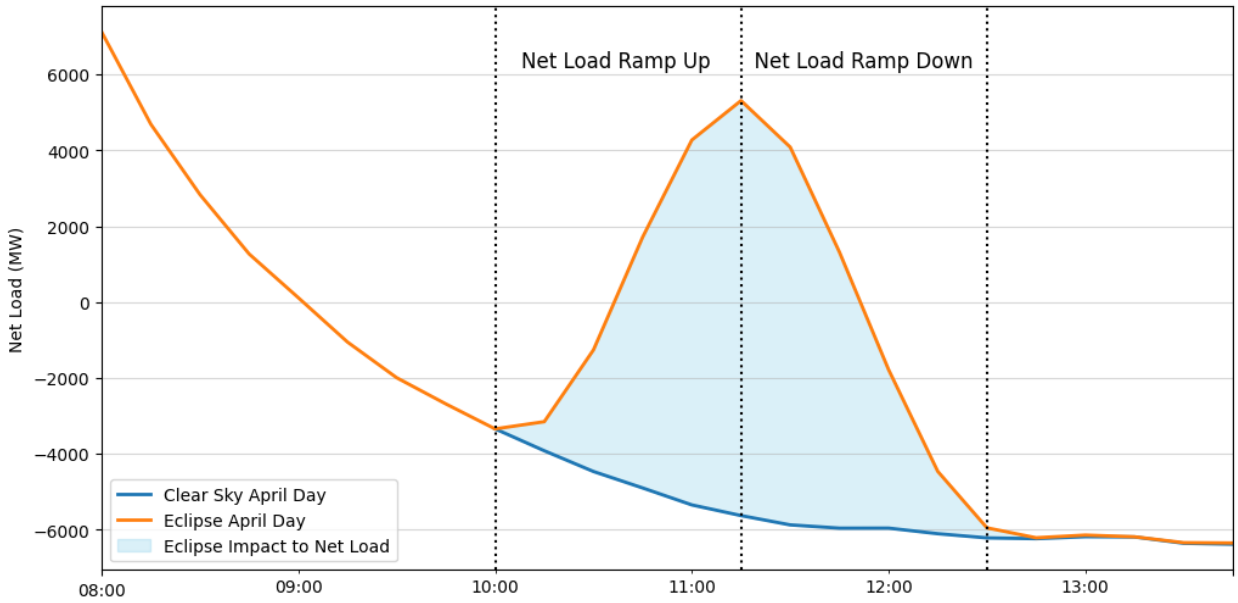

Figure 6 shows the eclipse impact on net load during the ramping periods, and Table 4 reports the key net load ramping assumptions.

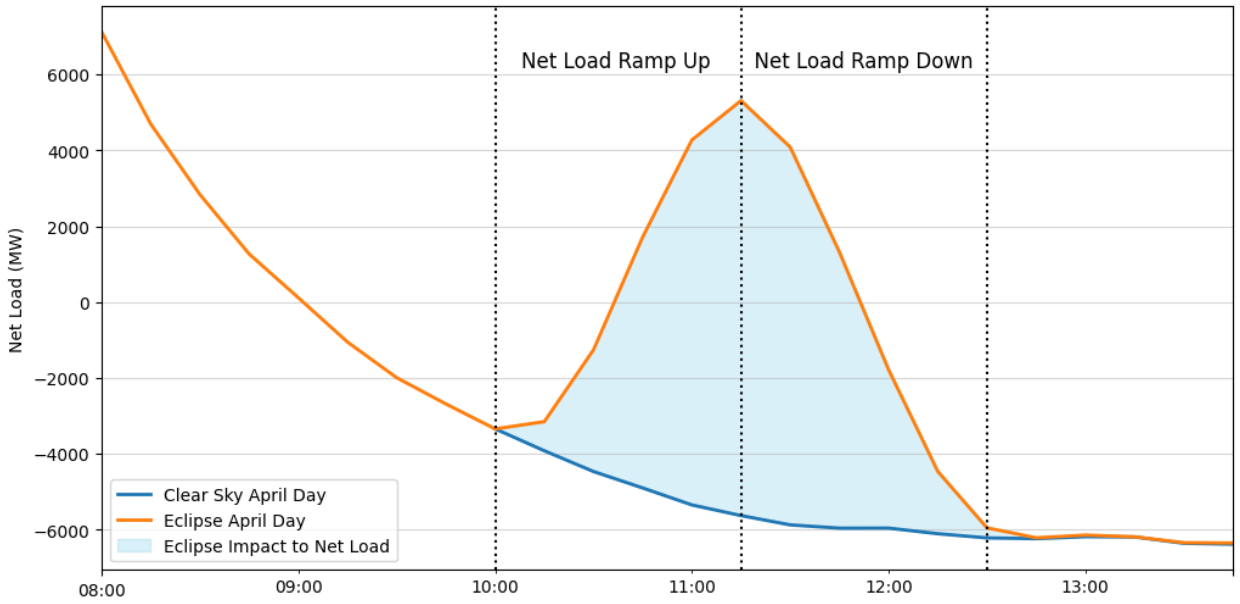

Figure 6: Approximate CAISO net load forecast impact from eclipse during ramping period

	Start	End	Load Start	Load End	Total Ramp (MW)	Average Ramp (MW/min)	Max Ramp (MW/min)	Typical Ramp (MW/min)
Ramp Up	10:00	11:15	-3,344	5,311	8,655	115	198	-30
Ramp Down	11:15	12:30	5,311	-5,952	-11,263	-150	-207	-7.8

	Start	End	Load Start	Load End	Total Ramp (%)	Average 15 Min Ramp (%)	Max 15 Min Ramp (%)	Typical 15 Min Ramp (%)
Ramp Up	10:00	11:15	-3,344	5,311	258.8%	51.8%	89.2%	-13.7%
Ramp Down	11:15	12:30	5,311	-5,952	-212.1%	-42.4%	-58.2%	-2.1%

Table 4: CAISO eclipse net load forecast ramping data

Figure 7 illustrates the eclipse ramping requirements relative to actual ramping data for 2023[9]. Ramp rates for the eclipse ramp-up period are higher than those typically experienced in the late morning but are in line with the steeper ramps experienced during 2023 evening peaks. Similarly, ramp rates in the ramp-down period are lower than those experienced in the late morning peak, but are in line with steeper ramps experienced in 2023 morning time periods. The simulated maximum and minimum net load ramp rates (MW per minute) for the eclipse period are +198 and -207 at 10:45 a.m. and 12:00 p.m., respectively.

[9] Includes 15-min net load data from Feb 12th 2023 – Feb 11th 2024. October 2023 eclipse ramp rates excluded.

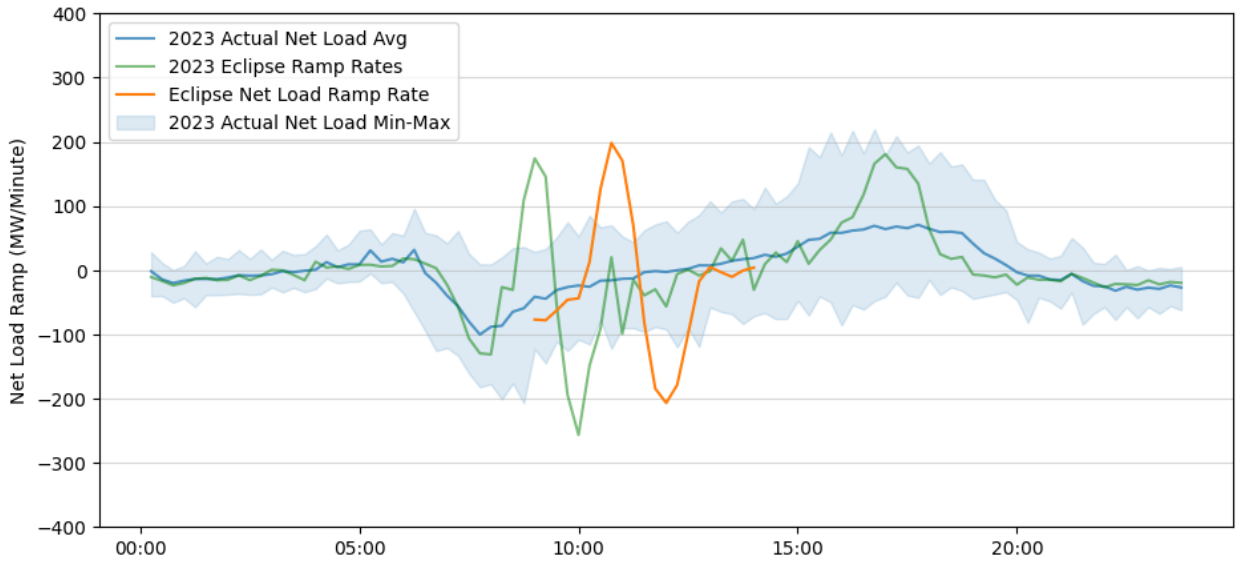

Figure 7: Eclipse ramp rates compared to Feb. 2023 – Feb. 2024 actual ramp rates

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 ISO 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 ISO requests that WEIM entities provide forecasted eclipse impacts on their solar fleet to the Short-Term Forecasting team using the CIDI system with the subject line "Eclipse Impact to Forecasting." This information will allow the ISO to provide greater coordination to the WEIM footprint in advance of the eclipse.

The ISO serves as the real-time (RT) load forecast service provider for most WEIM entities[10]. The ISO receives estimates of installed rooftop behind-the-meter 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 ISO 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.

[10] Avangrid is a generation only WEIM participant.

WEIM Region	Approx. Grid Connected Solar (MW)	Approx. Rooftop BTM Solar (MW)
California	**1,561**	**1,016**
Balancing Area of Northern CA (BANC)	407	347
Los Angeles Department of Water and Power (LADWP)	1,154	597
Turlock Irrigation District (TID)		72
Central	**6,204**	**1,548**
Idaho Power Company (IPCO)	473	126
Northwestern Energy (NWMT)	179	50
NV Energy (NVEP)	3,311	884
PacifiCorp East (PACE)	2,240	488
Desert Southwest	**3,265**	**3,621**
Arizona Public Service (AZPS)	1,109	1,886
El Paso Electric Company (EPE)	285	181
Public Service Company of New Mexico (PNM)	1,040	340
Salt River Project (SRP)	436	534
Tucson Electric Power (TEPC)	428	550
WAPA Desert Southwest Region (WALC)	67	130
Pacific Northwest	**1,117**	**700**
Avangrid (AVRN)	522	
Avista (AVA)	20	21
Bonneville Power Authority (BPA)	139	88
PacifiCorp West (PACW)	436	188
Portland General Electric (PGE)		179
Puget Sound Energy (PSE)		165
Seattle City Light (SCL)		60
Tacoma Power (TPWR)		17
WEIM Totals	**12,150**	**6,903**

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 April weather assumptions are based on a representative day for each WEIM region using observed 2023 April weather data.

Eclipse impacts by region are shown in Figure 8[11]. The Desert Southwest shows the strongest eclipse impacts with morning load increasing by up to 19.3% relative to clear-sky conditions.

[11] CAISO loads are not included in this graphic

The California and Central WEIM regions will see load increases up to 5.7% and 4.3% respectively relative to clear-sky conditions. The Pacific Northwest region shows the lowest impact from the eclipse with a load increase of 0.8% relative to clear-sky conditions.

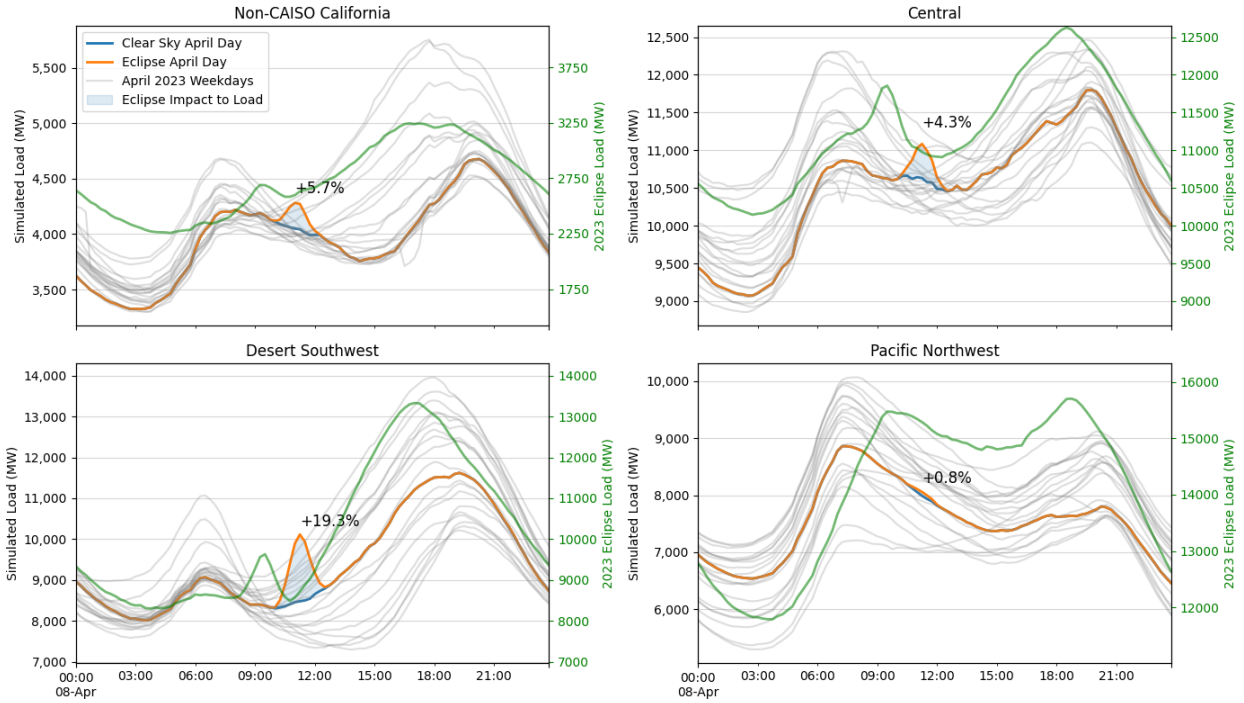

Figure 8: WEIM regional load impacts of eclipse

Regions will experience the effects of the April 2024 eclipse differently than the October 2023 eclipse. The Desert Southwest is expected to see a larger load increase compared to the October 2023 eclipse, as the region previously experienced only a 12.9% increase in October 2023. Non-CAISO California is expected to see a smaller load increase compared to the October 2023 eclipse, having previously seen a 9.0% load increase in October 2023. The Central and Pacific Northwest regions will experience similar effects compared to the October 2023 eclipse. Central entities saw an load increase of 5.2%, and Pacific Northwest entities saw negligible increases during the previous eclipse.

Grid Protection

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

Below is a summary of the mitigation measures that the ISO expects to deploy in preparation and throughout the day of the event, Monday April 8, 2024:

Grid protection options ahead of and during the eclipse	
Internal market simulation (DA)	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 72-hour Reliability Unit Commitments (RUC)
Day +3 Internal Review	Importance of DA solar forecasting
Reserves procurement	RUC net short
Resource Optimization of renewable, battery and hydro generation	Minimum/hold state-of-charge EDs
Post-DA Review	Potential use of Flex Alert or Demand Response
Automated Generation Control (AGC) band adjustments	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 April 7, 2024. This will ensure that upon the day-ahead market horizon coordination across RC West, the CASIO BAA and the WEIM is prepared for the day-ahead timeframe.*

1.1 Internal Market Simulation

Prior to the eclipse, several departments in the ISO will perform an internal, table-top market simulation. One major focus 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 ISO 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 preparation webinar with adjacent reliability coordinators and separately with member transmission operators (TOP)/BA, where individual TOP/BAs will share their preparation items and concerns.

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.

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

1.3 IOU Coordination

CAISO Real-Time Operations will coordinate a meeting with the investor-owned utilities (IOUs) on March 12 to review eclipse impacts, forecasted grid conditions and operational plans for April 8.

1.4 Adjacent BA Coordination

CAISO Real-Time Operations will coordinate a meeting with the IOU's to review eclipse impacts, forecasted grid conditions and operational plans for April 8.

1.5 Scheduling Coordinator Interaction

It is critical that Scheduling Coordinators in the CAISO day-ahead market use their solar providers latest forecasts in the day-ahead market which include eclipse impacts. With the latest forecast information submitted, the day-ahead market will be in the best position to account for the reduction in solar output and re-dispatch of 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 day-ahead timeframe because the day-ahead 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 ISO 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 ISO will analyze the impacts of generator and transmission outages prior to approving outages for April 8 to ensure that 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 2023, WEIM entities including the ISO may opt-into assistance energy transfer (AET). If opted-in, should an entity fail the resource sufficiency evaluation tests, its Energy Transfer System Resources (ETSR) net limits will not be limited to the real-time pre-dispatch (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 Business Practice Manual (BPM) under the resource sufficiency evaluation section.

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 72-Hour RUC

The 72-hour residual unit commitment (RUC) process increases grid reliability by reducing the amount of uneconomic cycling of long-start and extremely long-start resources. The 72-hour

RUC uses the net load forecast, which includes the load, wind and solar forecasts, in the 72-hour horizon to better position these resources in the day-ahead. With our forecast service providers taking into consideration the obscuration to the solar facilities during the eclipse, and our load models also including the eclipse impact in the forecast, we do not expect an increase in forecast error during this event. The 72-hour RUC recommendation will utilize these forecasts, as well as past historical uncertainty with similar conditions to determine additional resource commitment .

1.11 Importance of DA Solar Forecasting

Having the most accurate forecast possible for market optimization will allow for optimal use of the ISO markets to deal with the impacts of the solar eclipse. The ISO obtains behind-the-meter solar forecasts from a forecast service provider and largescale solar generation forecasts from two forecast service providers. All of the forecast service providers will account for the solar eclipse which will automatically feed through the ISO's daily processes. The aggregate forecast for large scale solar will be available to the market participants, as well as the public, through OASIS applications.

1.12 Reserves procurement

As with the October eclipse, the ISO anticipates committing an increased amount of regulation up and regulation down to assist with the increased ramping needs during the eclipse period For the October 2023 eclipse, additional biases were added to both the regulation up and regulation down requirements between the draft report and date of eclipse. These adjustments can be seen in Figure 19 in the October eclipse performance report.

Table 7 and Table 8 show the normal versus cloudy regulation values that the ISO may use during the eclipse period and adjacent hours. These values will be updated following market simulations and as new weather information for the day becomes available. The final determination in using the normal versus cloudy regulation values will be made in the day-ahead based on the weather forecast for the eclipse day.

Because of the differences in eclipse timing and impact, as well as some lessons learned from the 2023 eclipse, the ISO anticipates adjustments made to regulation values will be smaller in relative magnitude than the adjustments made for the October eclipse, especially for the regulation up recommendation. For the October 2023 eclipse, the magnitude of the recommendation regulation up and down were similar, but as seen in Tables 7 andTable 8 below, the magnitude of the regulation up recommendation is half the magnitude of the regulation down recommendation for most hours.

Hour-ending	Normal Regulation Up (MW)	Normal Regulation Down (MW)	**Normal Eclipse Regulation Up (MW)**	**Normal Eclipse Regulation Down (MW)**
10	360	-1460	**540**	**-2190**

11	410	-1440	**615**	**-2160**	Eclipse
12	510	-1090	**765**	**-1635**	Eclipse
13	540	-1190	**810**	**-1785**	Eclipse
14	700	-1200	**1050**	**-1800**	

Table 7: Recommended regulation during solar eclipse compared to normal system conditions

Hour-ending	Cloudy Regulation Up (MW)	Cloudy Regulation Down (MW)	**Cloudy Eclipse Regulation Up (MW)**	**Cloudy Eclipse Regulation Down (MW)**	
10	450	-1550	**675**	**-2325**	
11	480	-1620	**720**	**-2430**	Eclipse
12	710	-1230	**1065**	**-1845**	Eclipse
13	650	-1370	**975**	**-2055**	Eclipse
14	940	-1310	**1410**	**-1965**	

Table 8: Recommended regulation during solar eclipse compared to uncertain weather conditions

1.13 RUC Net Short

Residual unit commitment (RUC) capacity is procured in the day-ahead market. The ISO operators may manually adjust the CAISO forecast of CAISO demand, which is the basis of RUC procurement. This can be done under certain circumstances in the event the operations team 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.

For the October eclipse, significant bias was added in the hour-ending (HE) 9 to 11 period with highest bias in HE10, the period of maximum obscuration. It was reasoned that reserves procured during HE10 could be extended to cover uncertainty in HE11. Ultimately, the maximum realized uncertainty was observed in HE11. Similar adjustments and reasoning is expected for the April eclipse.

1.14 Resource Optimization

Renewable and Battery Resources:

The ISO 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[12]. 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.

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

Hydro Generation

Due to the spring snow melt and recent winter rainfall, water levels in California are expected still to be available for hydro resources to carry regulation and/or energy during the eclipse. The ISO will be working with the hydro community and inform participants of the additional need for flexibility on April 8 to assist with that flexibility being available to the market optimization.

1.15 Potential Use of Flex Alert or Demand Response

Although not anticipated, the ISO 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.*

1.16 Automated Generation Control Bands

The automated generation control (AGC) bands will be adjusted 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.

1.17 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.

1.18 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 ETSRs. It is recommended that WEIM entities keep ETSRs unlocked with typical transfer limits.

As the real-time 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 real-time 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 resource forecasts within their base schedules that are being submitted by their forecast service providers. This is 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.

1.19 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. As with the October eclipse, forecast service providers providing the grid-scale solar forecast will take into consideration the obscuration to solar facilities during the eclipse. We do not expect there to be an increase in forecast error during this event. Without intervention, FRP showed high coverage in flex ramp up (FRU) but below target coverage in flex ramp down (FRD) during the October eclipse. FRP performance is intended for normal conditions so while its FRD coverage fell below target, its performance overall was sufficient for this exceptional event. No changes are expected in preparation for the April eclipse and similar performance in coverage and requirement is expected.

Conclusion

This bulletin provides an assessment of the potential impacts of the April 8, 2024 total eclipse on the CAISO BAA and WEIM. Assuming 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 ISO 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 October 14, 2023 annular 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 ISO will hold a series of outreach events with WEIM entities to facilitate 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 ISO 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 opportunity to address any issues arising from the eclipse. Following the event, the ISO will review solar eclipse data and impacts to identify lessons learned.

Item	Date
Stakeholder call	March 11
IOU coordination discussions	March 12
WEIM Bi-weekly Ops Meeting	March 13
RC West Real-Time Working Group (RTWG) - Review of BA/TOP plans	March 19 bi-monthly RTWG meeting
RC West, adjacent RC coordination discussion	April 1
RC West webinar with RTWG members to verify system posture plans	April 5
TOP/BA – RC West and RC-RC Coordination day-of early morning conference calls confirming readiness	April 8 (03:00 PNW, 04:00 PSW, 06:00 RC/RC)