

255 years ago...

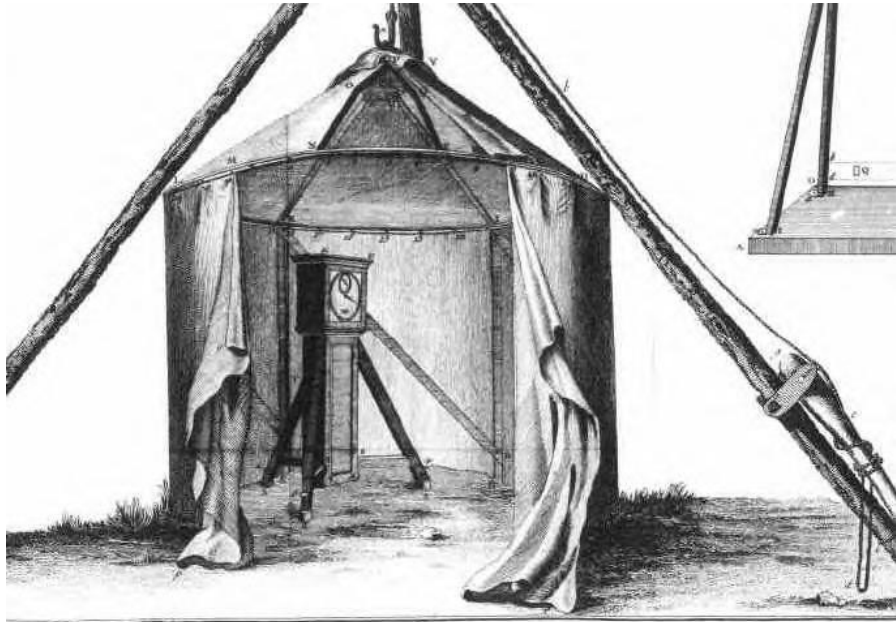
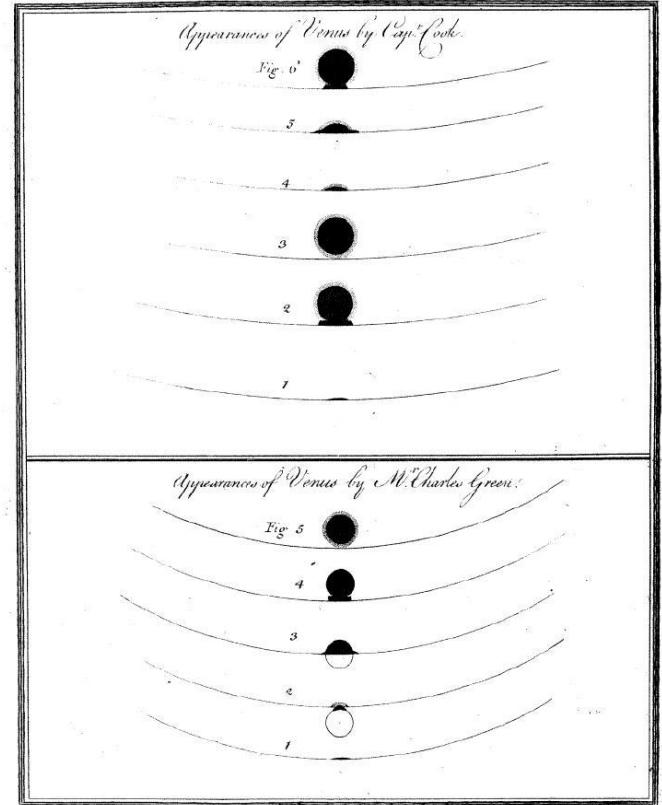


Fig. 1. Observatoire portatif. Fig. 2. Manière d'établir une Horloge Astronomique à terre.

Philos. Trans. Vol. LXXI. Tab. XIV. p. 410.



OE Electricity Advisory Committee Brief: Impact of the 2024 Solar Eclipse on the Interconnections in the United States

**National Renewable Energy Laboratory
North American Electric Reliability Corporation
EPRI
U.S. Department of Energy**

June 5th, 2024

Eclipse Project Team



- Jin Tan (PI)

Temporal and spatial analysis of Solar Eclipse

- Cong Feng
- Afshin Andreas
- Ibrahim Reda
- Travis Williams and his team
- Manajit Sengupta
- Nicholas Gilroy

Real-time Visualization team

- Seong Choi
- Hongfei Sun

Visualization Team

- Kenny Gruchalla

Estimate the impact of the solar eclipse on EI

- Jiazi Zhang
- Micah Webb
- Shuan Dong
- Ningchao Gao
- Randika Bandara Wijekoon

Industry outreach, results dissemination, report and management

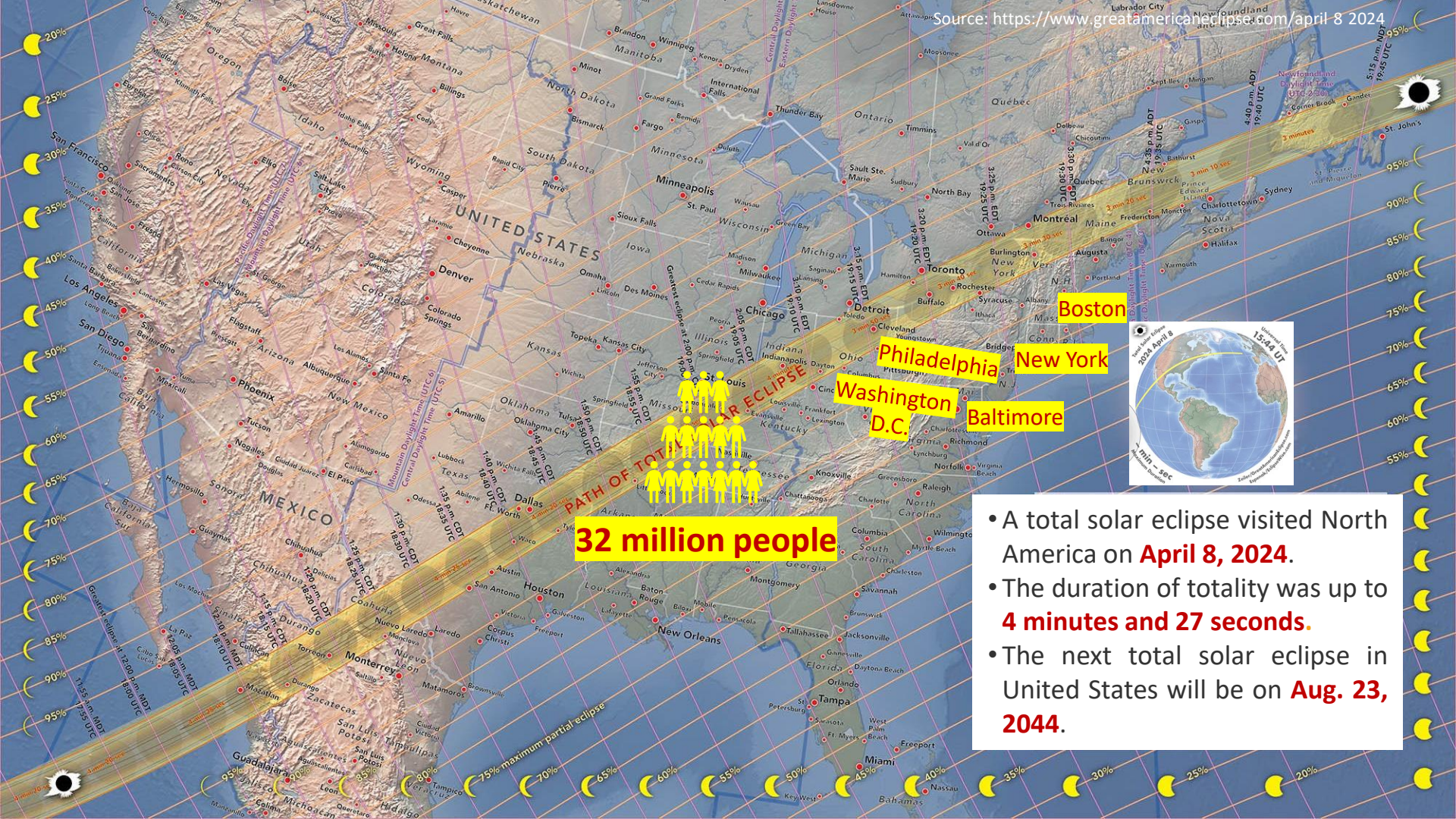
- Barry Mather



- Marilyn Jayachandran
- Mohanmed Osman
- Aung Thant



- Guohui Yuan



32 million people

Boston

New York

Washington D.C.

Baltimore



- A total solar eclipse visited North America on **April 8, 2024**.
- The duration of totality was up to **4 minutes and 27 seconds**.
- The next total solar eclipse in United States will be on **Aug. 23, 2044**.

Total Solar Eclipse 2024 v.s. 2017



<https://science.nasa.gov/solar-system/skywatching/how-is-the-2024-total-solar-eclipse-different-than-the-2017-eclipse/>

Wider Path

122 Miles v.s. 62 Miles

Longer Time in Totality

4'26" v.s. 2'42"

More Populated

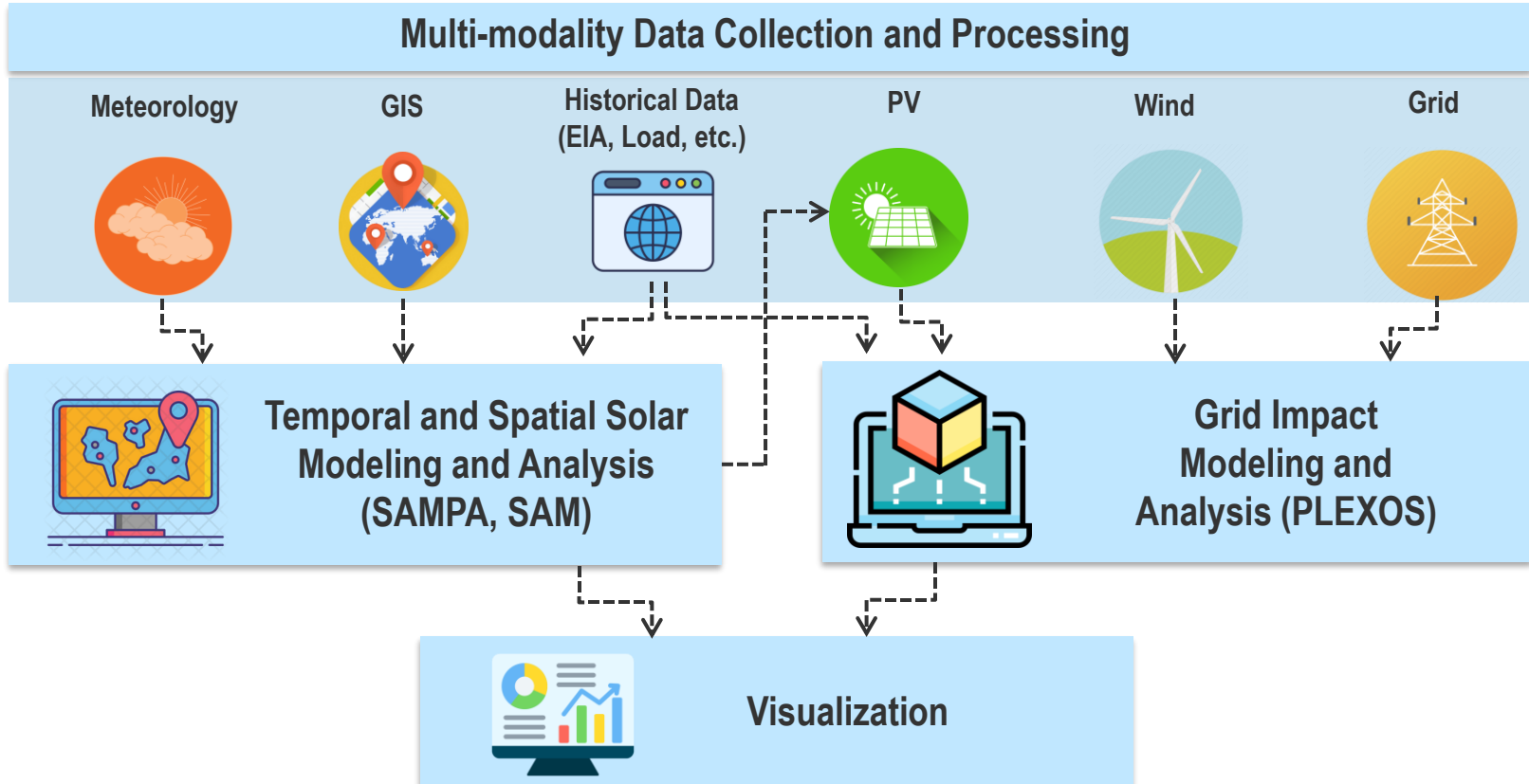
31.6 million v.s. 12 million

Solar Capacity Tripled

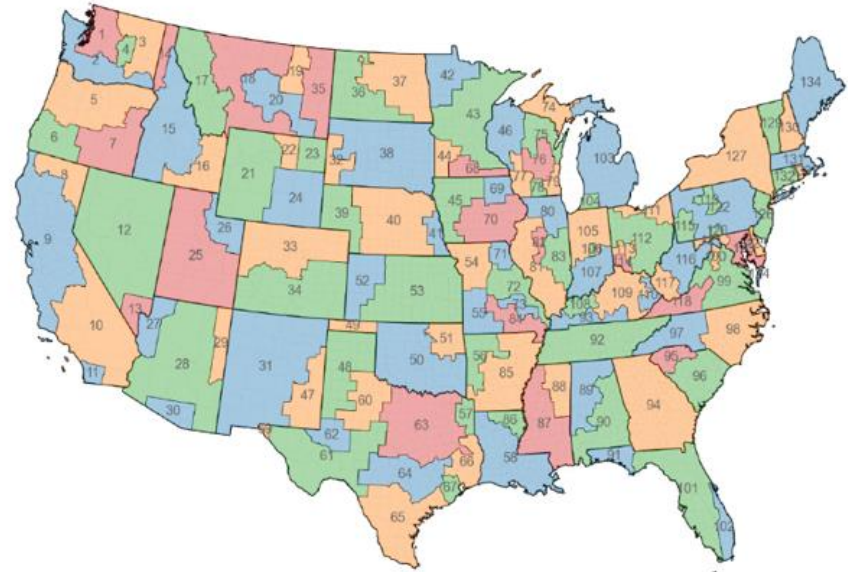
179 GW v.s. 57 GW

Multidisciplinary Modeling Framework

- Multi-physics Modeling
- High Spatio-temporal Resolution

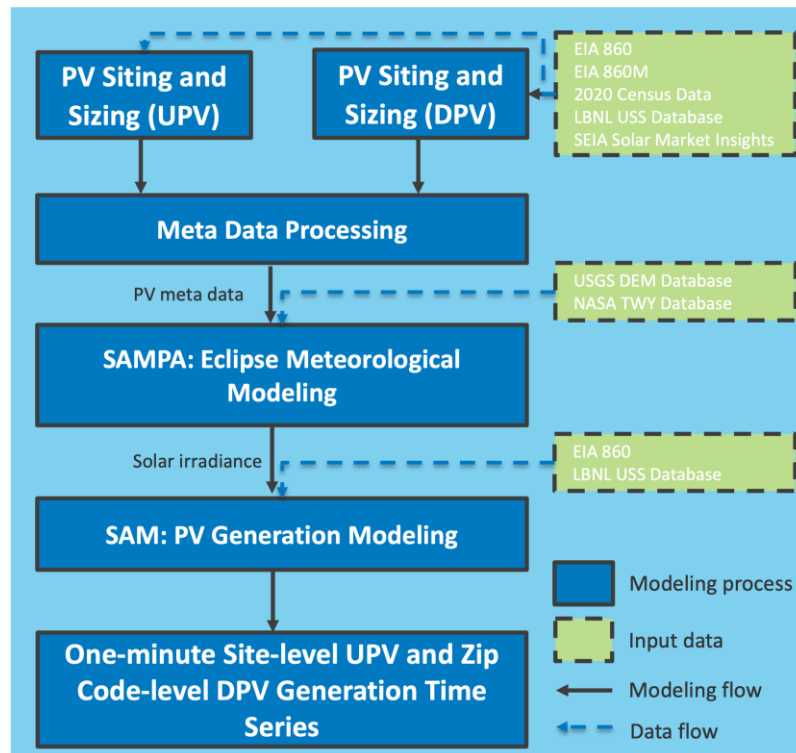
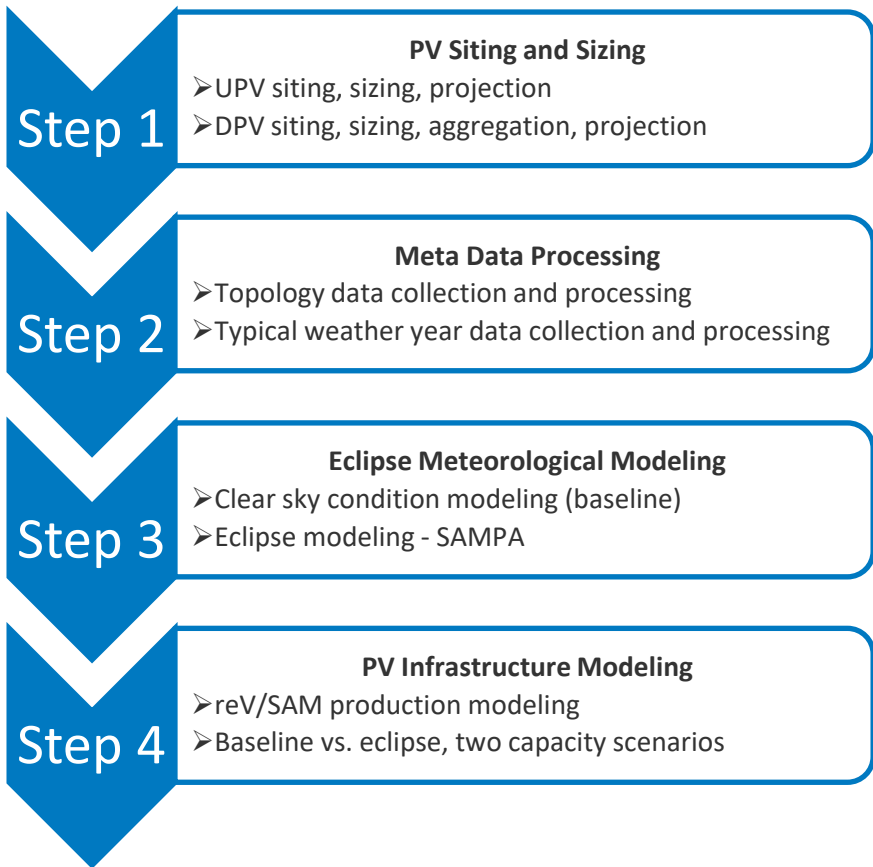


Analysis Down to Planning Regions and Zones

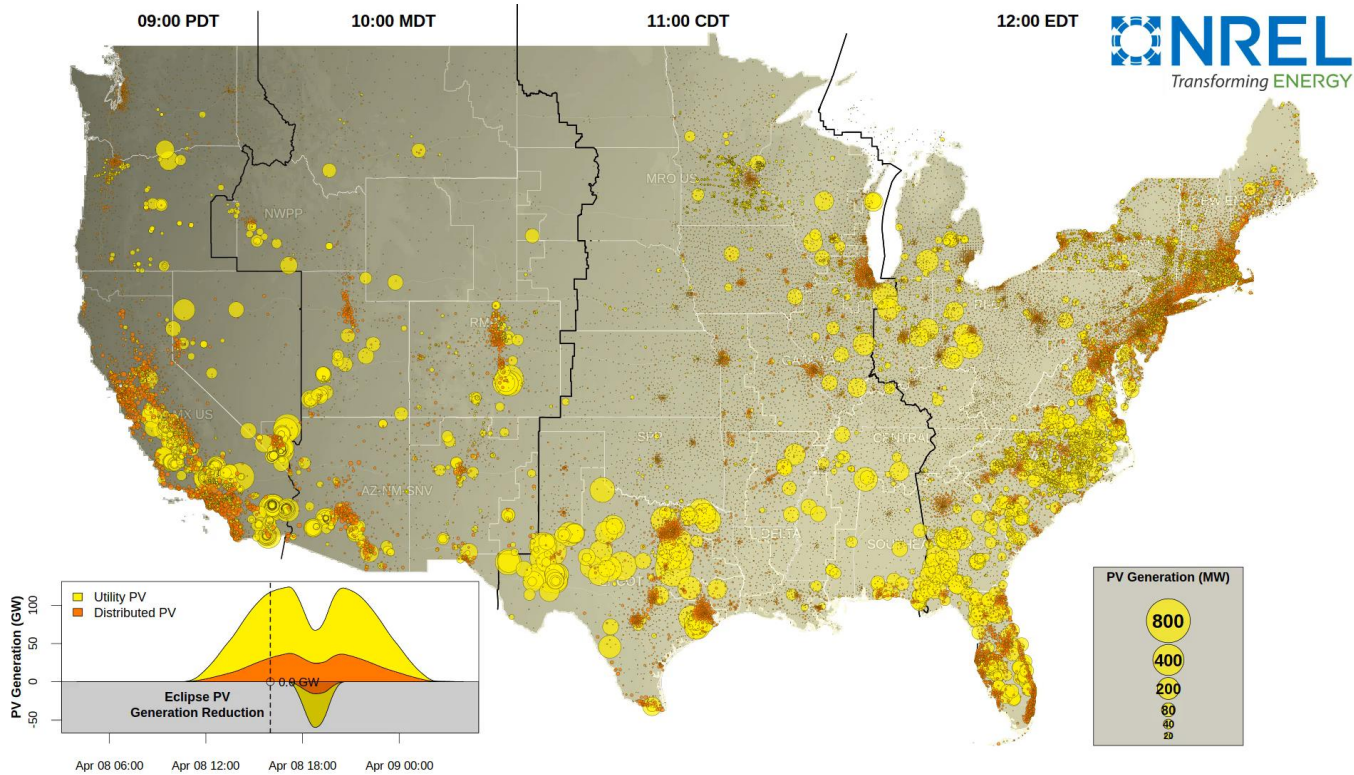


Bottom-up modeling approach enables the synthesis of spatial resolution data, ranging from individual plant-level PV to broader zonal-level, balancing authority (BA) scale, or even ISO and interconnection levels. This approach tailors insights precisely to the users' requirements and interests.

Temporal and Spatial Solar Modeling Approach



Solar Eclipse Impact on Contiguous United States



Solar Eclipse Impact on ERCOT

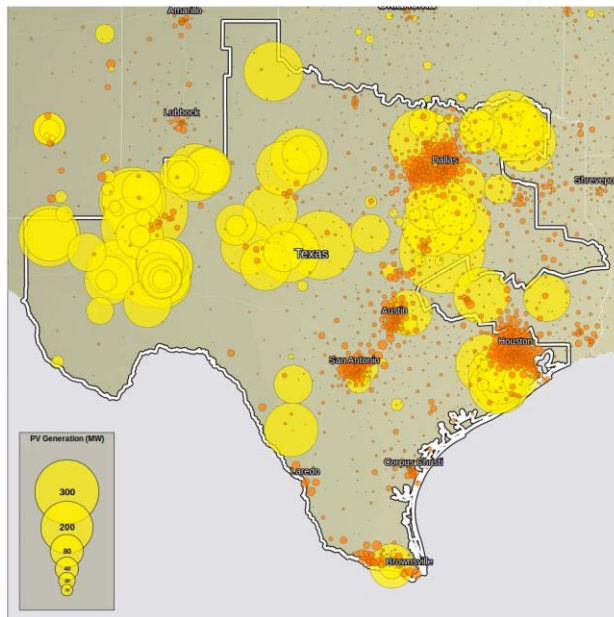
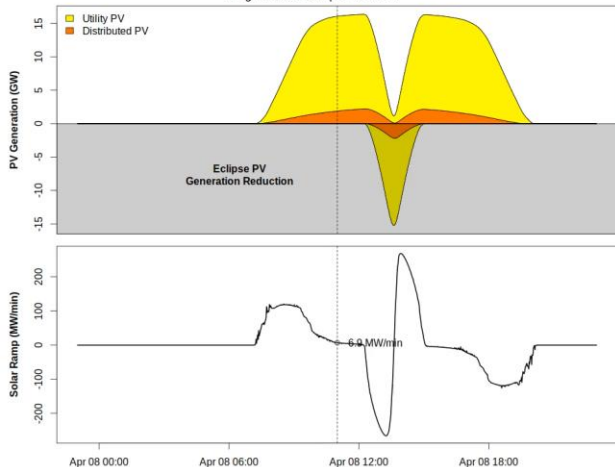
ERCOT

TEXAS RELIABILITY ENTITY (TRE)
Total PV Capacity: 22.8 GW (UPV: 19.4 GW, DPV: 3.3 GW)



Clear-sky eclipse impacts
Impact duration: 2 hours 58 minutes (12:08 to 15:06 CDT)
Total eclipse PV energy reduction: 18.5 GWh
Maximum eclipse PV power reduction: 15.2 GW (93.2%)
Maximum absolute PV generation ramp: 269 MW/min

April 08 11:00:00 CDT
Eclipse PV power reduction: -0.0 GW (-0.0%)
PV generation ramp: 7 MW/min



ERCOT

Peak Load	70~85 GW ¹
	12:08 CDT
End Time	15:06 CDT
	2 hrs 58 mins
	15.2 GW (93.1% ²)
Max. PV Ramp (up)	+268.5 MW/min
Max. PV Ramp (down)	

- 2023 ERCOT Peak Load. <https://www.ercot.com/static-assets/data/news/Content/a-peak-demand/2023/all-time-records.htm#November2023>
- PV generation reduction divided by non-eclipse PV generation

Solar Eclipse Impact on Western Interconnections

WECC

WESTERN ELECTRICITY COORDINATING COUNCIL (WECC)
Total PV Capacity: 76.6 GW (UPV: 46.2 GW, DPV: 30.4 GW)

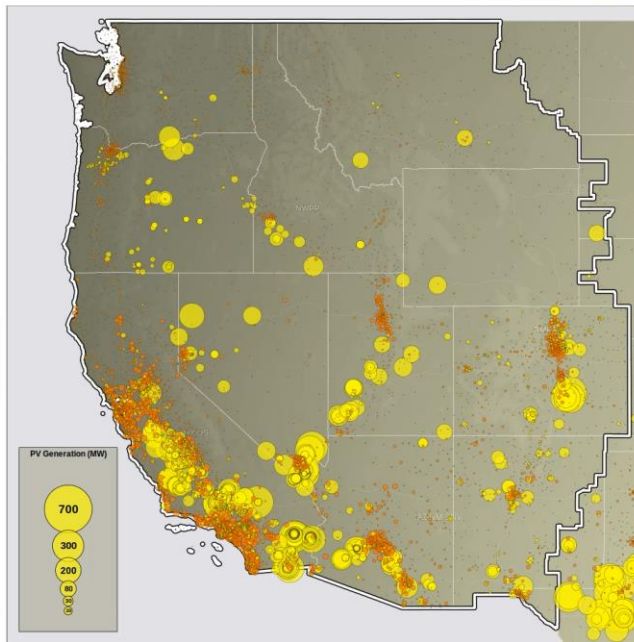
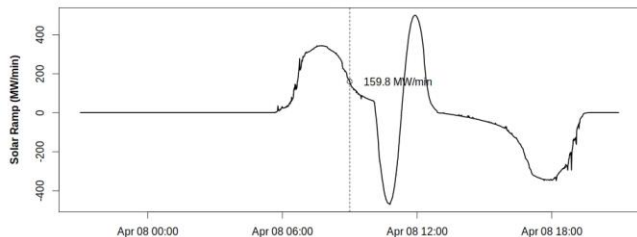
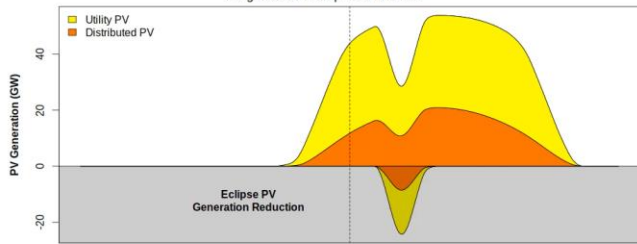


Clear-sky eclipse impacts

Impact duration: 2 hours 55 minutes (10:04 to 12:59 PDT)
Total eclipse PV energy reduction: 29.8 GWh
Maximum eclipse PV power reduction: 24.2 GW (45.1%)
Maximum absolute PV generation ramp: 499 MW/min

April 08 09:00:00 PDT

Eclipse PV power reduction: -0.0 GW (-0.0%)
PV generation ramp: 160 MW/min



WECC	
Peak Load	167~169 GW ¹
	10:04 PDT
End Time	12:59 PDT
	2 hrs 55 mins
	24.2 GW (45.1% ²)
Max. PV Ramp (up)	+499.3 MW/min
Max. PV Ramp (down)	

1. WECC demand: <https://www.wecc.org/ePubs/GenerationResourceAdequacyForecast/Pages/Demand.aspx>
2. PV generation reduction divided by non-eclipse PV generation

Solar Eclipse Impact on Eastern Interconnections

EI

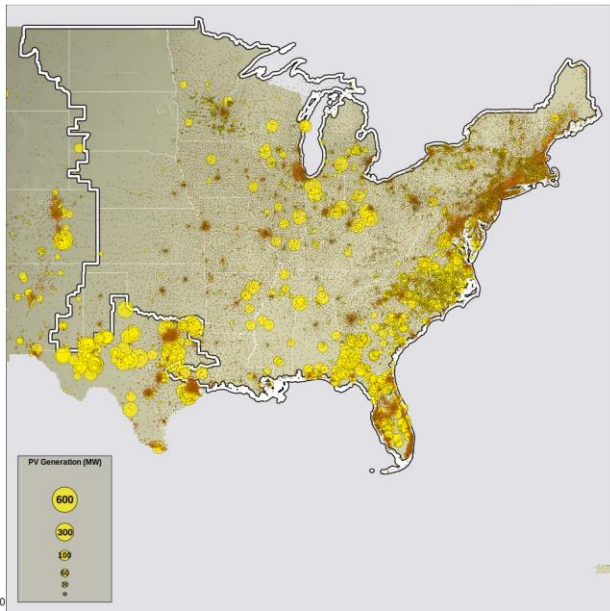
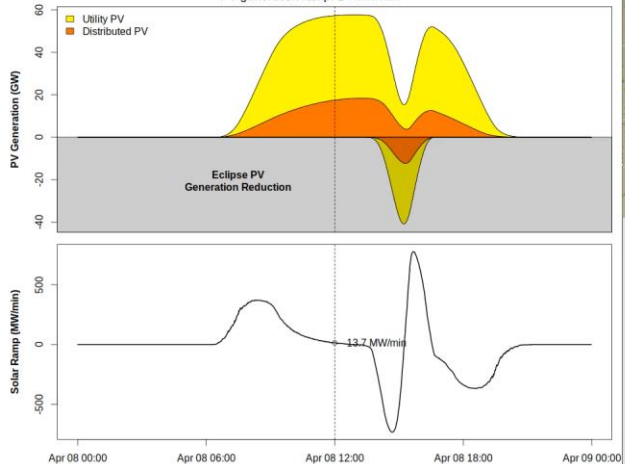
Eastern Interconnection (EI)

Total PV Capacity: 84.7 GW (UPV: 56.7 GW, DPV: 28.0 GW)



Clear-sky eclipse impacts
 Impact duration: 3 hours 29 minutes (13:13 to 16:42 EDT)
 Total eclipse PV energy reduction: 52.5 GWh
 Maximum eclipse PV power reduction: 40.8 GW (70.9%)
 Maximum absolute PV generation ramp: 776 MW/min

April 08 12:00:00 EDT
 Eclipse PV power reduction: -0.0 GW (-0.0%)
 PV generation ramp: 14 MW/min

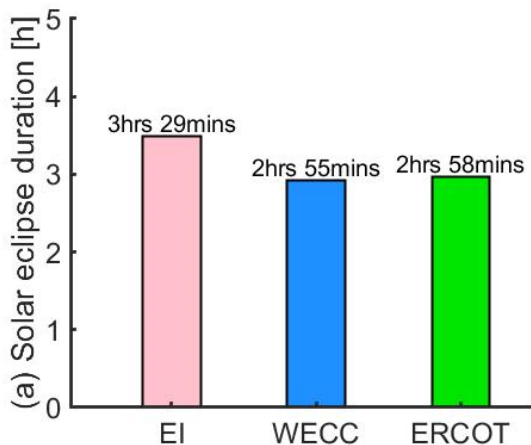


EI	
Peak Load	332 GW ¹
	13:13 EDT
End Time	16:42 PDT
	3 hrs 29 mins
	40.8 GW (70.9% ²)
Max. PV Ramp (up)	+776.0 MW/min
Max. PV Ramp (down)	

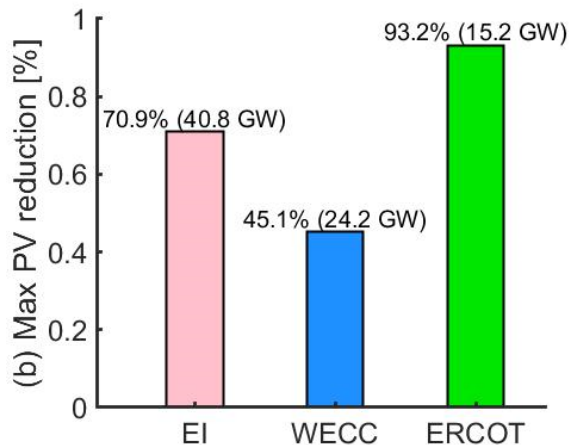
1. EI demand: <https://www.wecc.org/ePubs/GenerationResourceAdequacyForecast/Pages/Demand.aspx>
2. PV generation reduction divided by non-eclipse PV generation

Solar Eclipse Impact on Three Interconnections

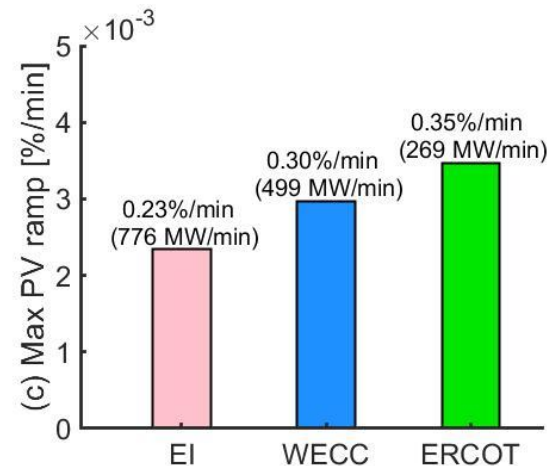
Duration



Max. PV Reduction (Percentage)



Max. PV Ramp



CAISO

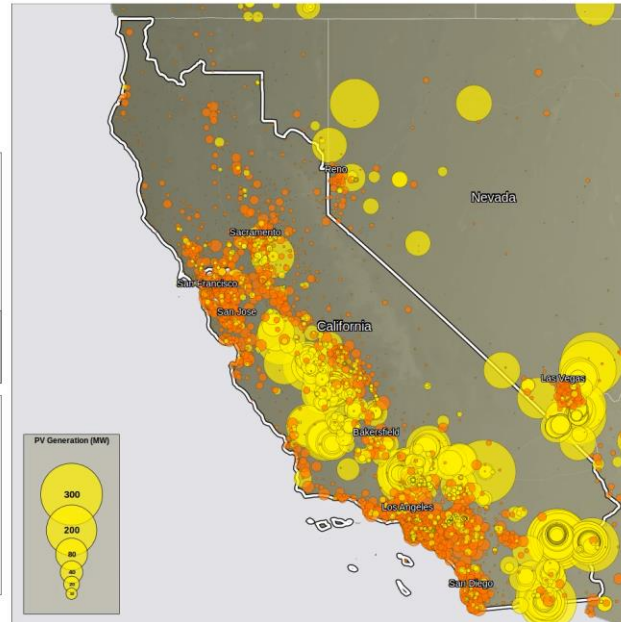
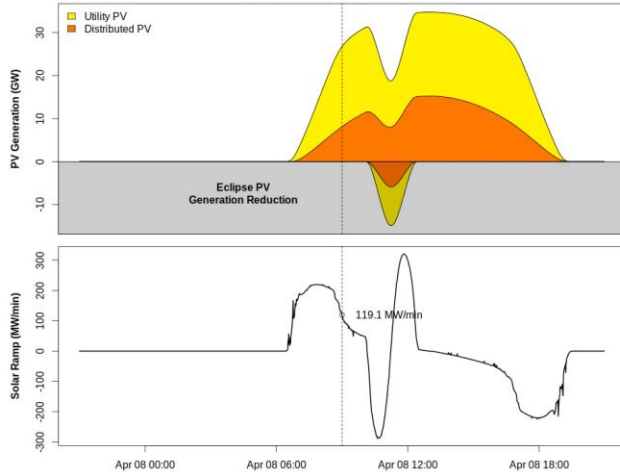
CAISO

WESTERN ELECTRICITY COORDINATING COUNCIL (WECC)
Total PV Capacity: 49.2 GW (UPV: 27.2 GW, DPV: 22.0 GW)



Clear-sky eclipse impacts
Impact duration: 2 hours 27 minutes (10:04 to 12:31 PDT)
Total eclipse PV energy reduction: 17.5 GWh
Maximum eclipse PV power reduction: 14.9 GW (42.8%)
Maximum absolute PV generation ramp: 320 MW/min

April 08 09:00:00 PDT
Eclipse PV power reduction: -0.0 GW (-0.0%)
PV generation ramp: 119 MW/min

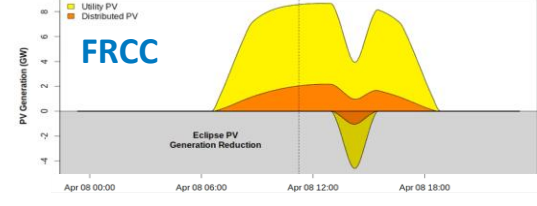
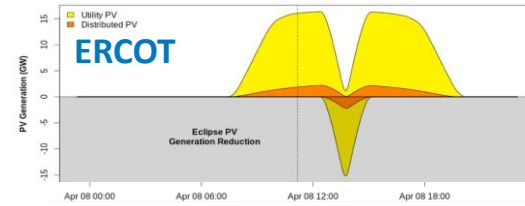
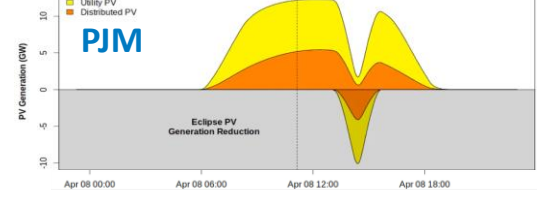
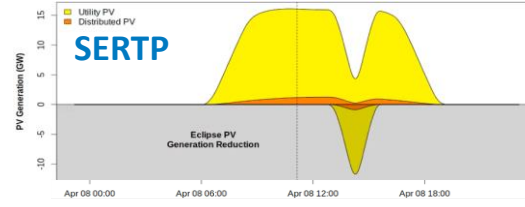
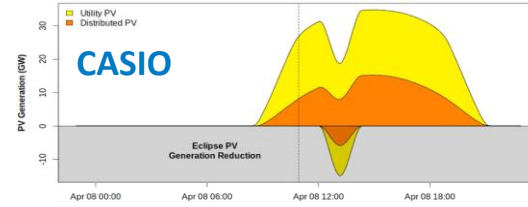
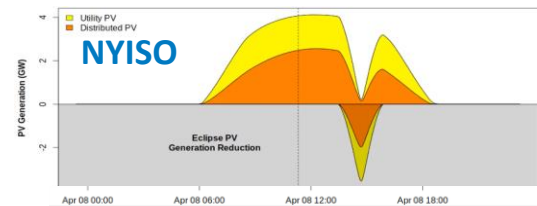
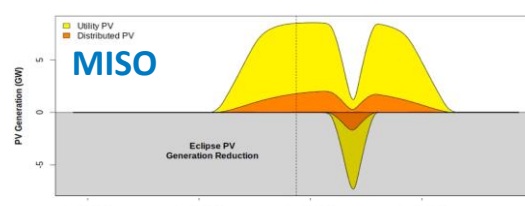
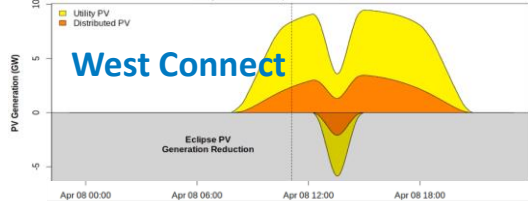
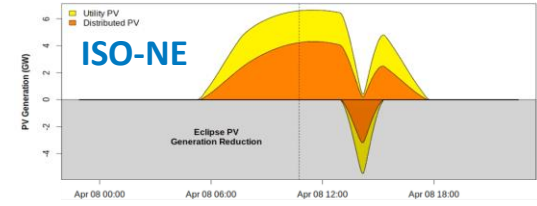
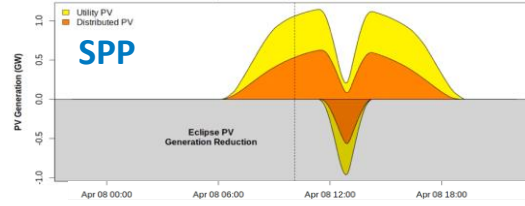
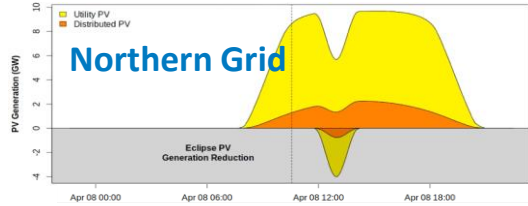


CAISO

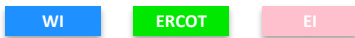
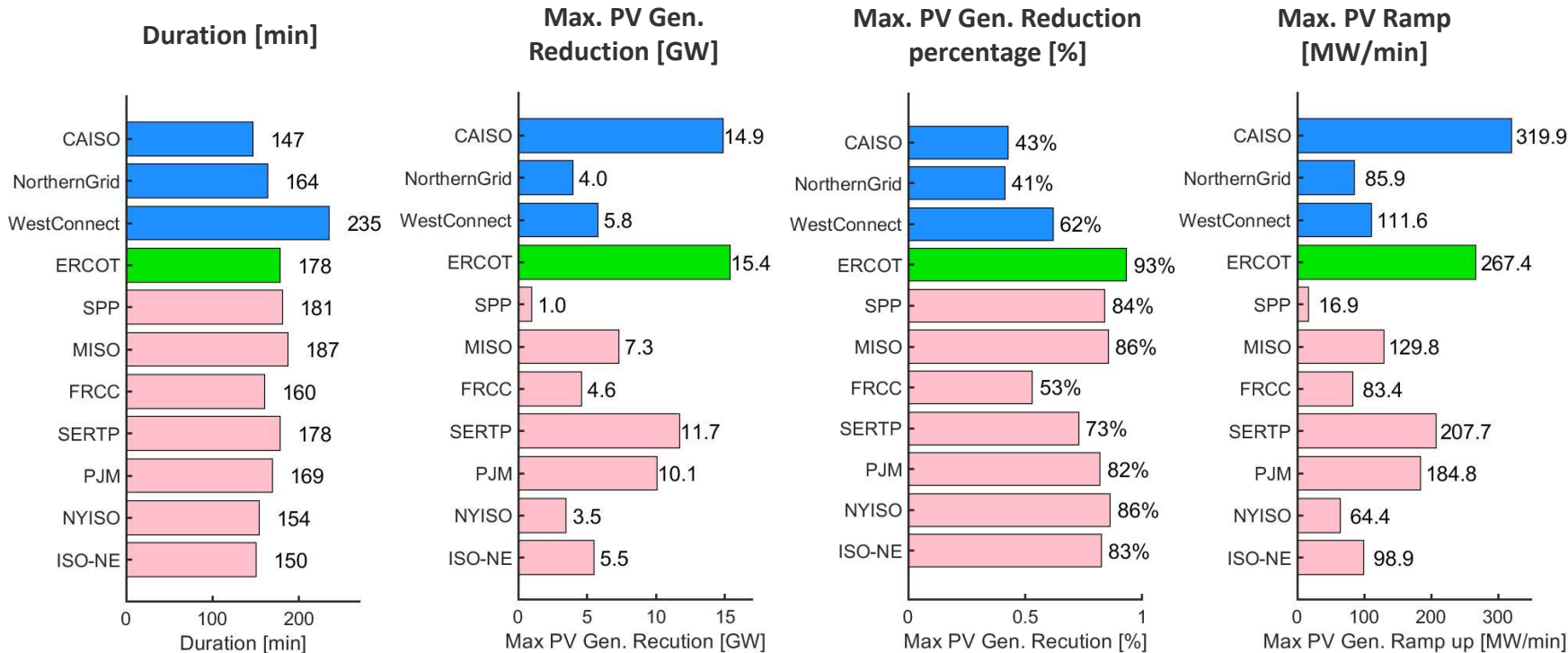
Peak Load	45 GW ¹
Start Time	10:04 PDT
End Time	12:31 PDT
Duration	2 hrs 27 mins
Max. PV Reduction	14.9 GW (42.8% ²)
Max. PV Ramp (up)	+320.1 MW/min
Max. PV Ramp (down)	-287.8 MW/min

- 2023 CAISO Peak Load: <https://www.aiso.com/documents/californiaisopeakloadhistory.pdf>
- PV generation reduction divided by non-eclipse PV generation

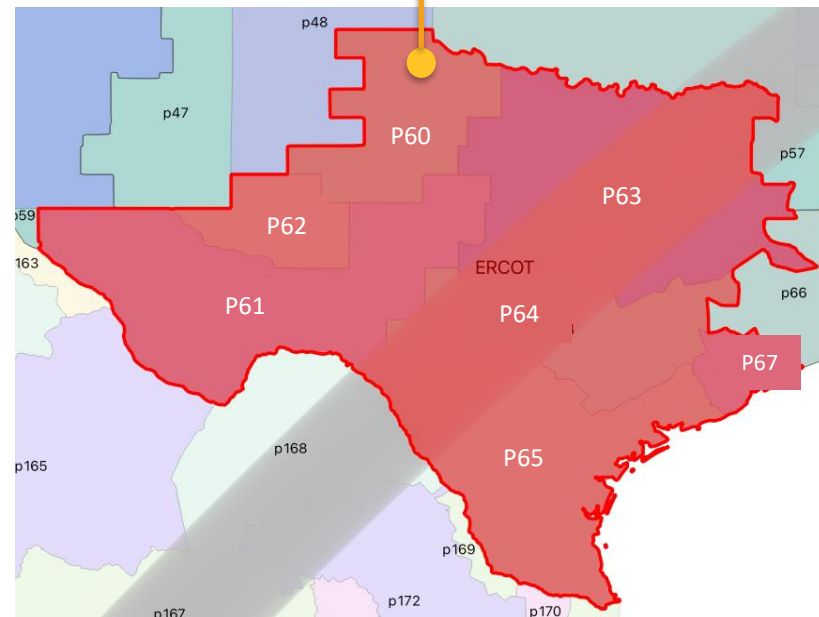
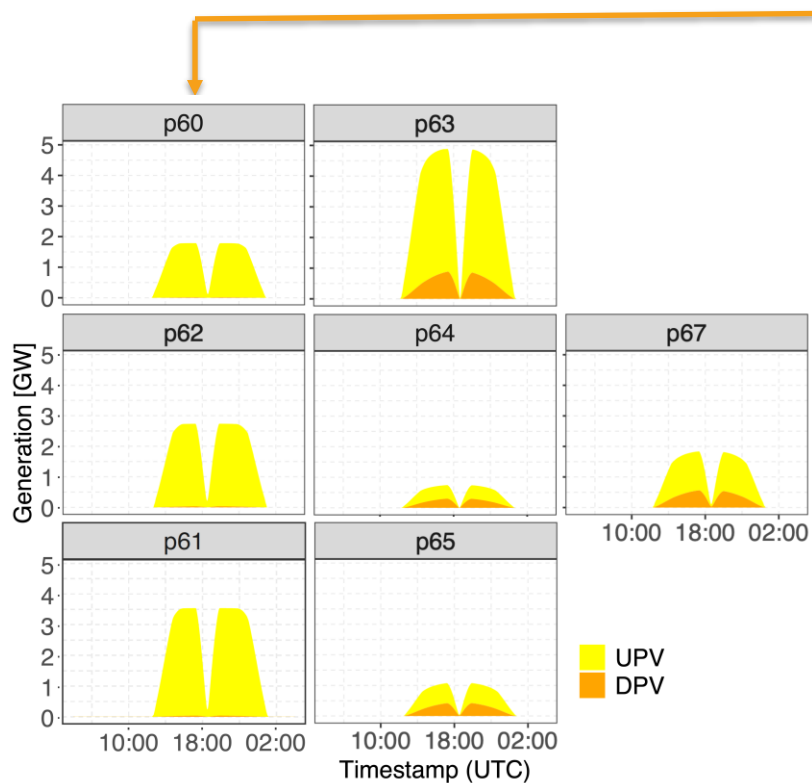
Impact of Solar Eclipse on ISO Solar Outputs

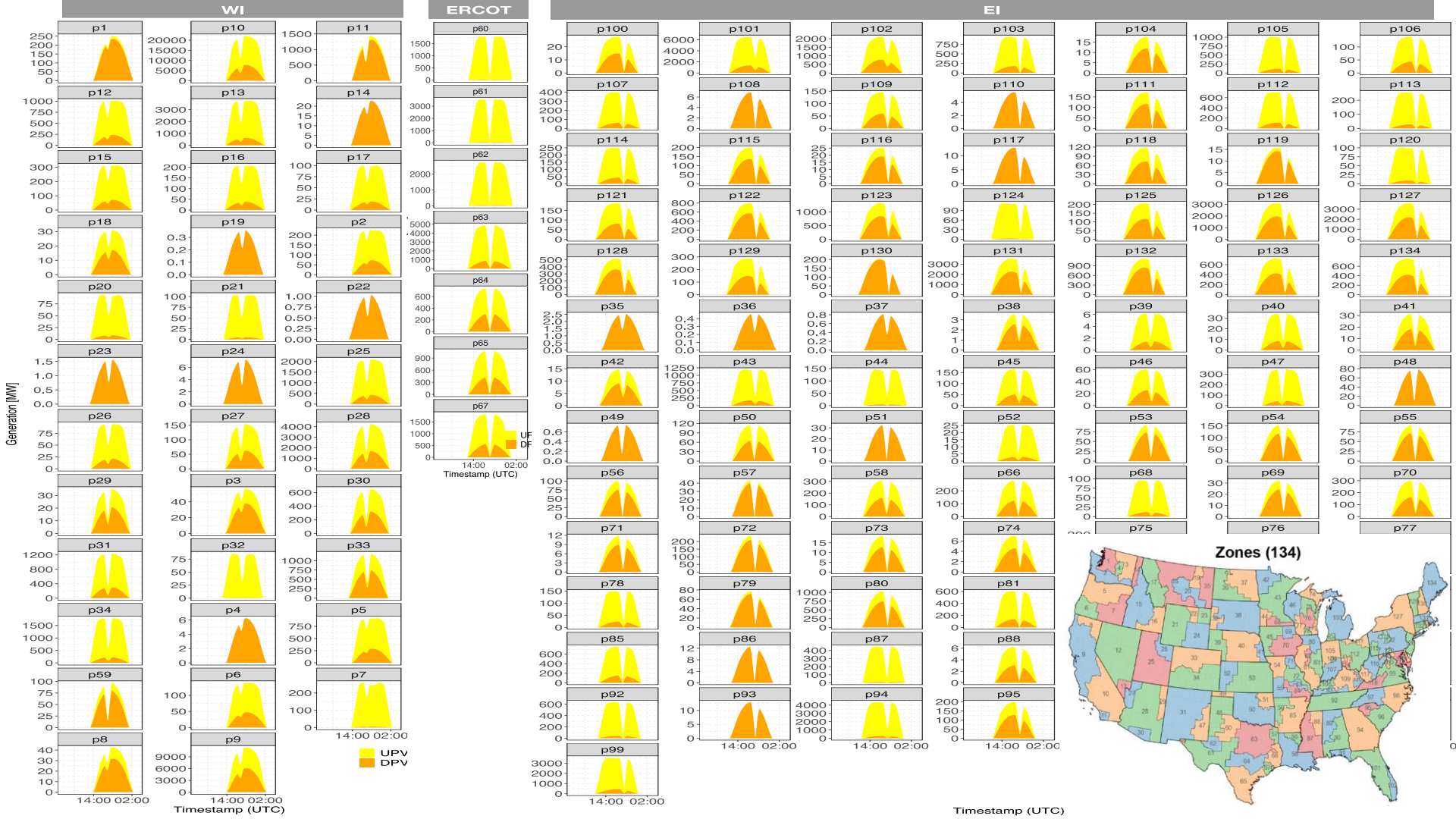


ISOs Comparison: Impact on Solar Gen.



Impact of Solar Eclipse on Zone Level



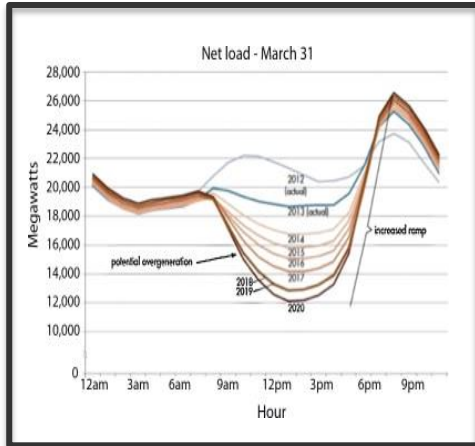


Impact of Solar on Load

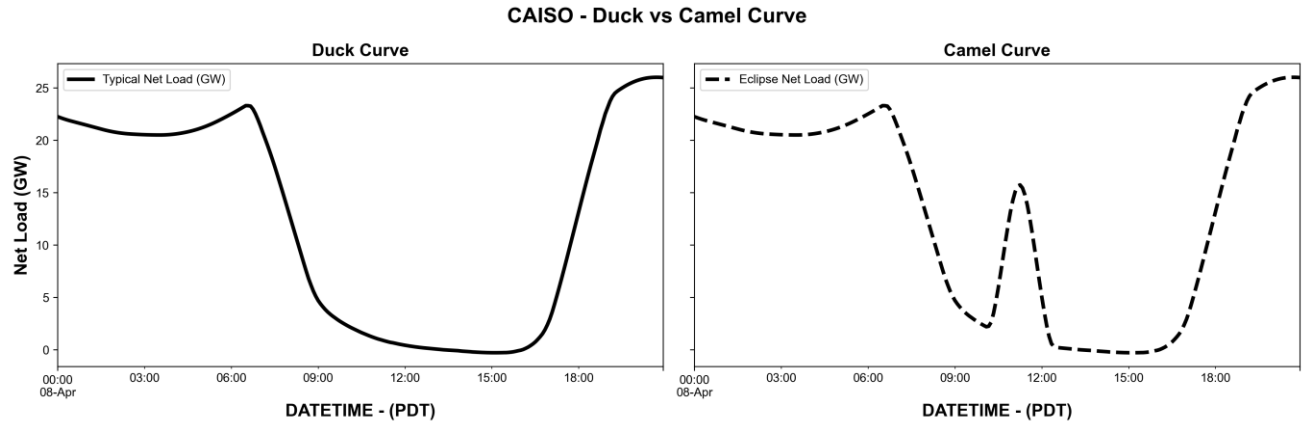
Load profile Assumption:

1. Velocity dataset (2022)
2. No wind consideration in net load.
3. No consideration of human behaviors during the solar eclipse.

DPV = Rooftop PV and Community Solar
Typical Demand = Actual Demand - DPV
Net load = Typical Demand - UPV



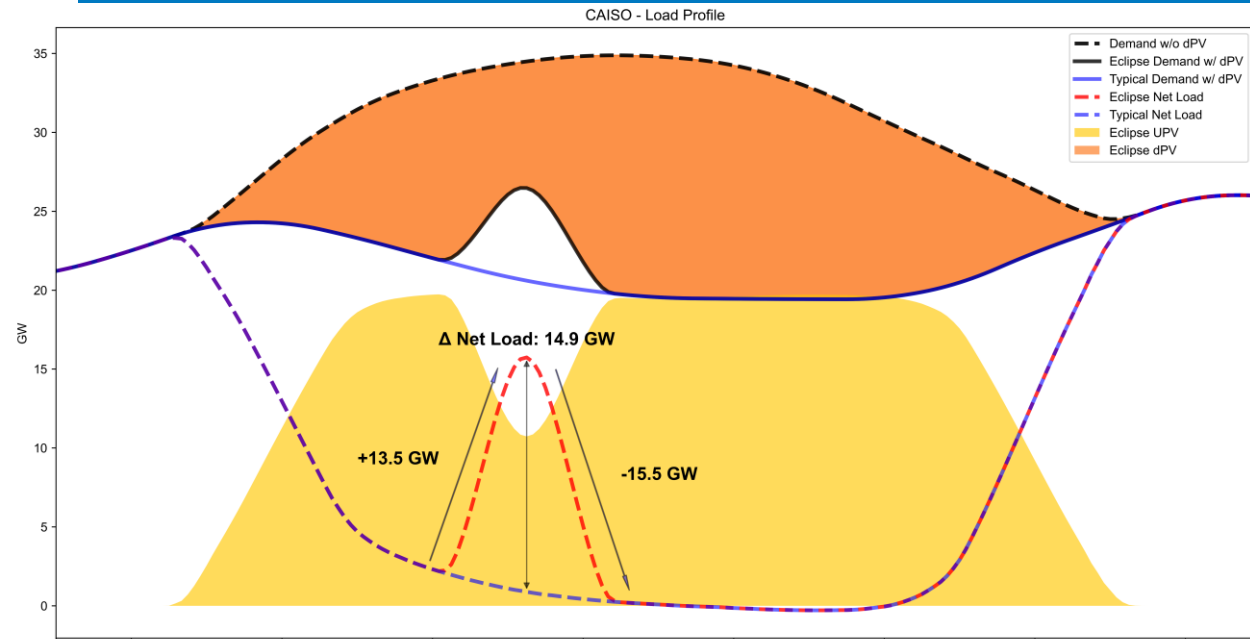
Duck curve



Canyon curve

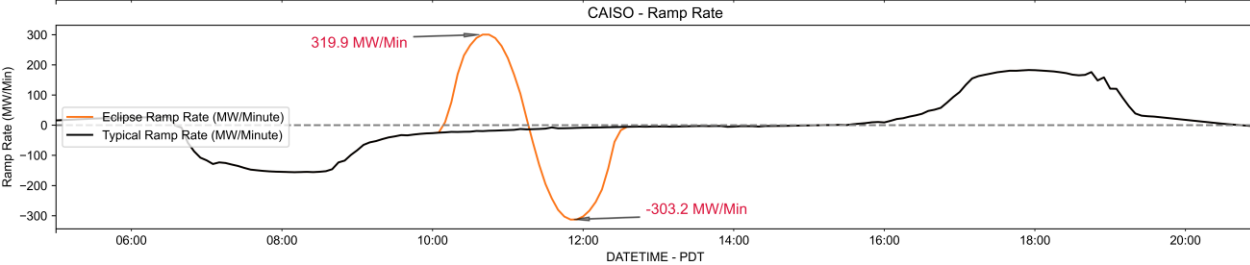
Camel curve

Impact of Solar Eclipse on Load Profile: CAISO



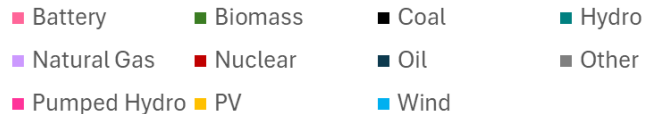
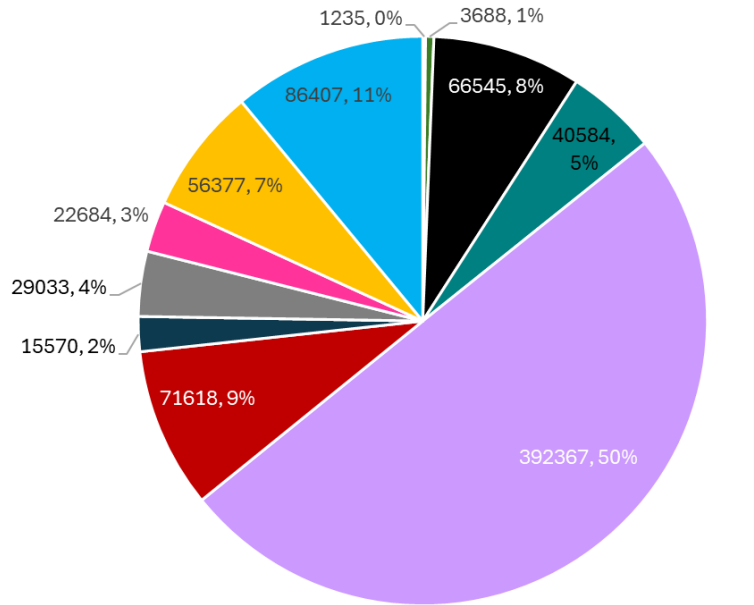
- DPV = Rooftop PV and Community Solar
- Typical Demand = Actual Demand - DPV
- Net load = Typical Demand - UPV

Ramp up (GW)	+13.5
Ramp down (GW)	-15.5
Net load change (GW)	14.9
Percentage of Net load change (%)	74.5%
Max up-ramp rate (MW/min)	319.9
Min down-ramp rate (MW/min)	-303.2

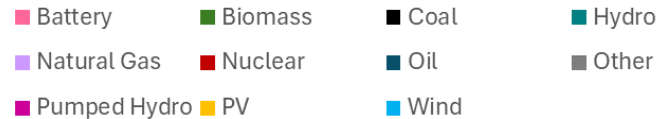
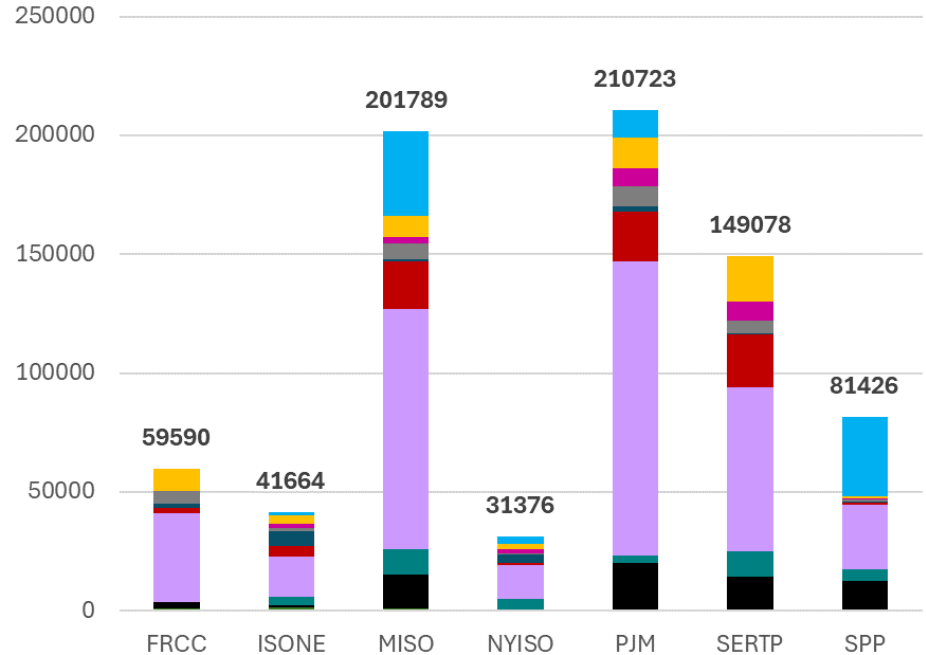


2031 Case: EI Capacity Overview

El Generation Capacity (MW)

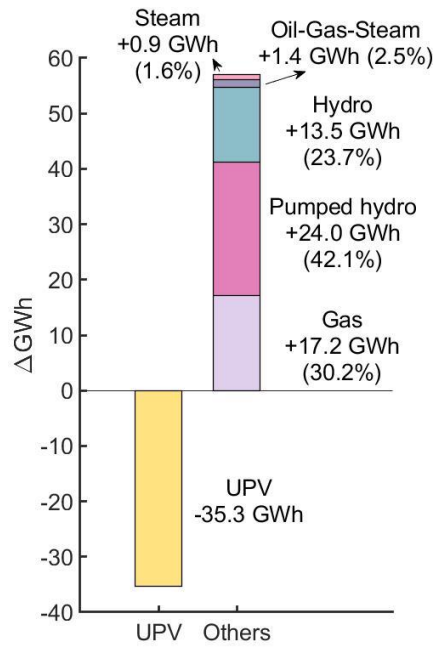
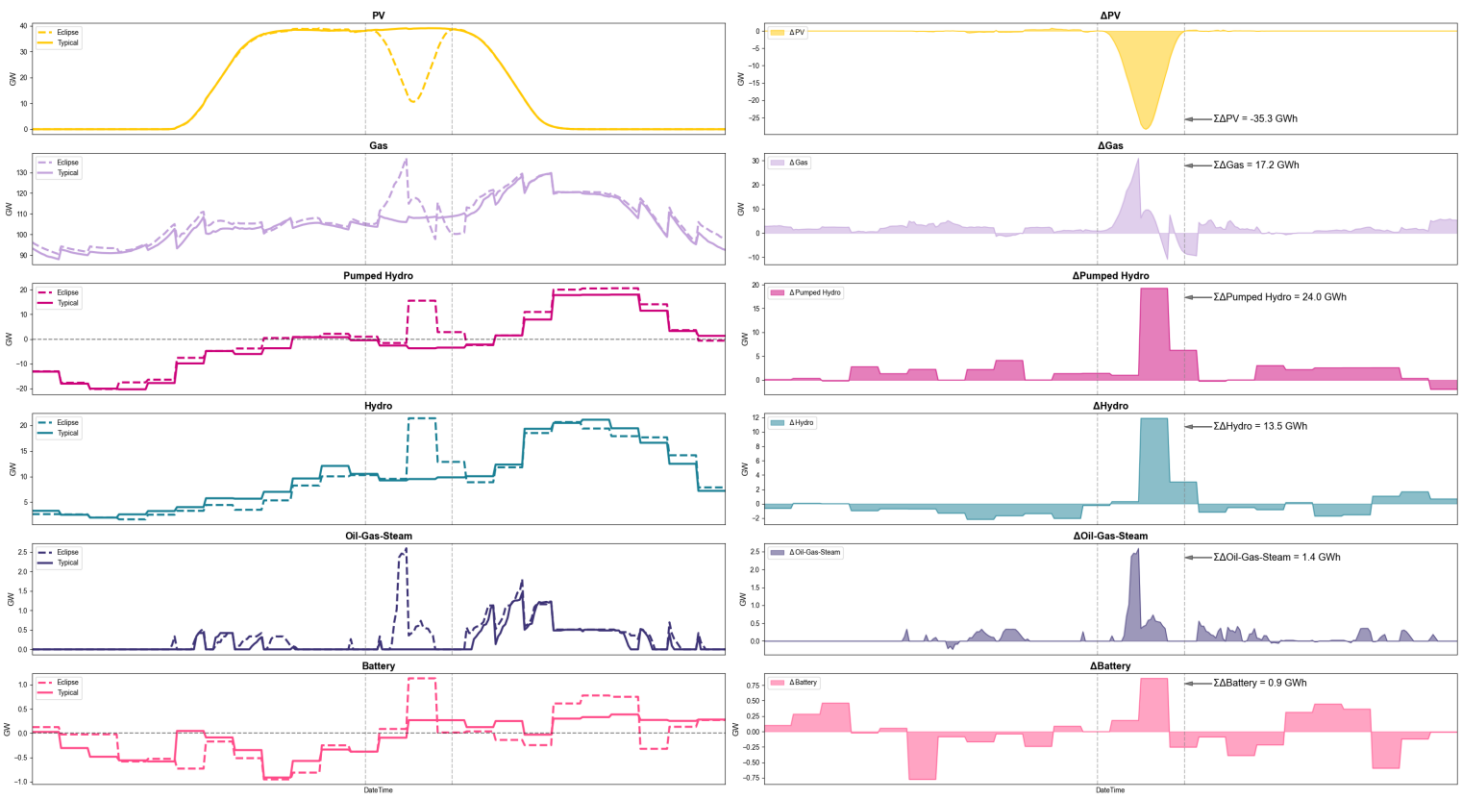


El Generation Capacity (MW)



Who is Helping to Mitigate Solar Eclipse Impact in EI?

Generation Summary - EI



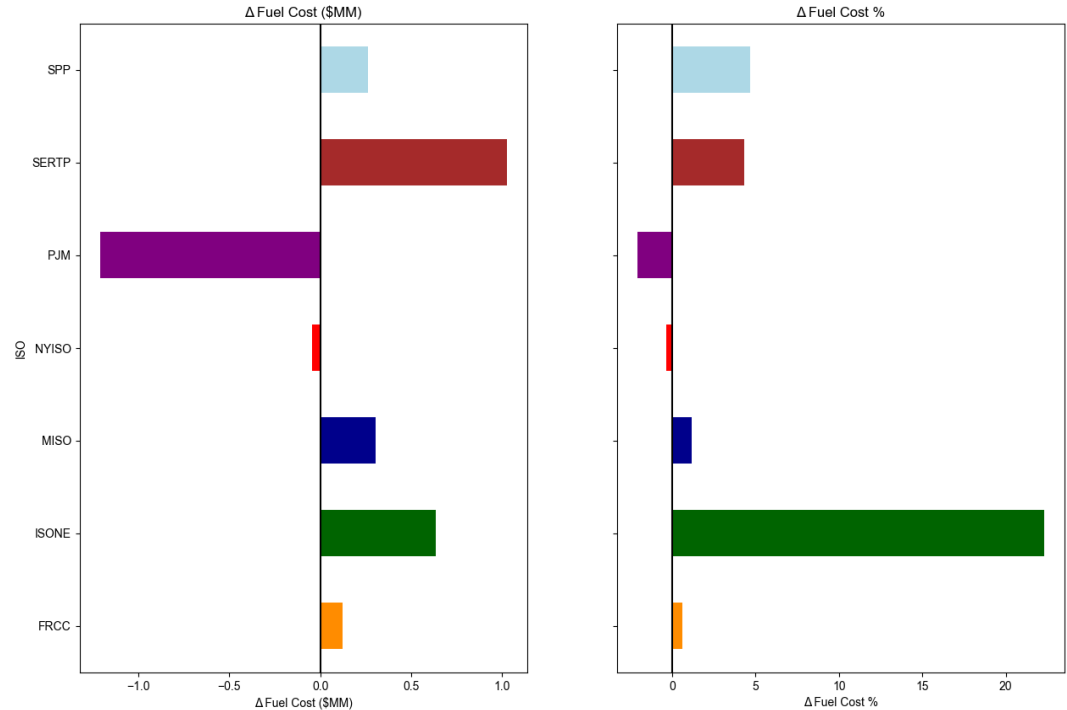
Pumped Hydro > Gas > Hydro > Oil gas steam > Battery

Impact on Production Cost of EI

ISO	Δ Fuel Cost (\$MM)	Δ Fuel Cost (%)
SPP	+0.26	+4.6
SERTP	+1.03	+4.3
PJM	-1.21	-2.1
NYISO	-0.04	-0.3
MISO	+0.30	+1.2
ISO-NE	+0.63	+22.3
FRCC	+0.12	+0.6

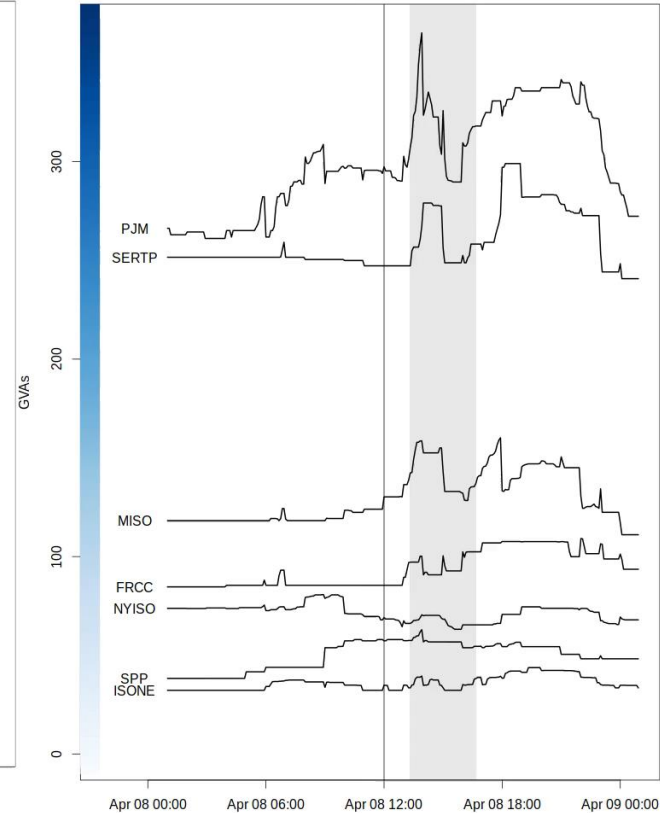
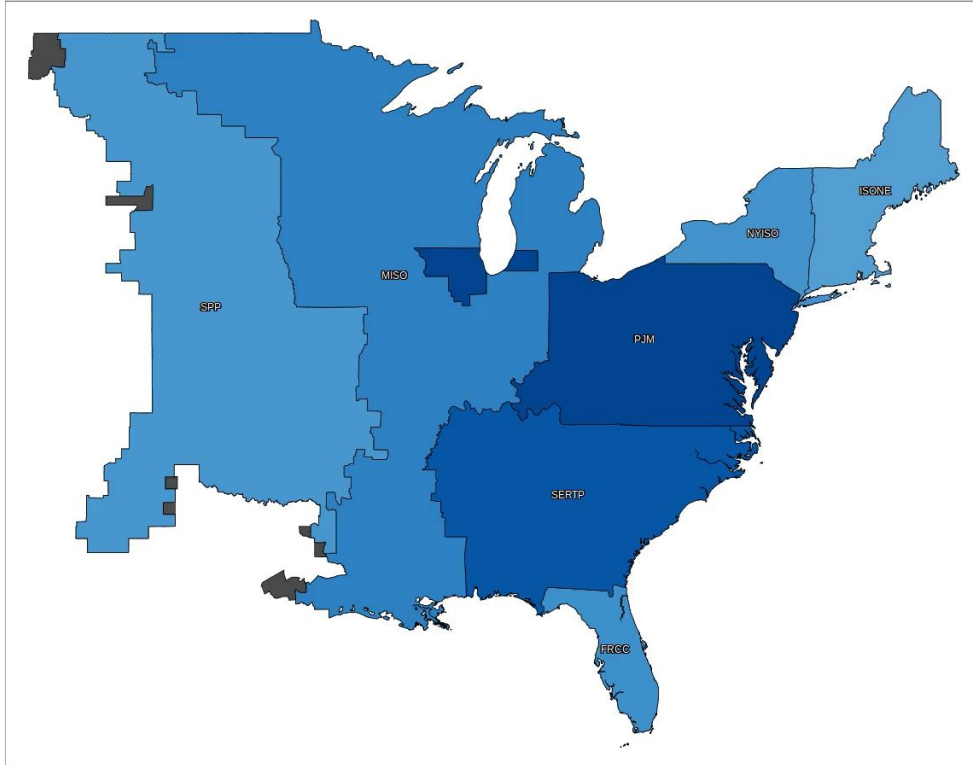
Large reduction in Fuel Cost for PJM from large reductions in Coal.

Change In Fuel Cost: Eclipse vs. Typical



Solar Eclipse Impact on Inertia of EI

El Eclipse Inertia
2024-04-08 12:00:00



Observing Grid Performance During the Eclipse



Industry Engagement and Media



- Tucson Electric
- National Grid
- Avista
- The Electric Company
- Duke Energy Progress
- Nisource
- Prim
- ...



- 500+ for pre-eclipse webinar
- 150+ for livestream
- E&E News (Politico)
- CNN Underscored
- Dallas Morning News
- ...

Next Step



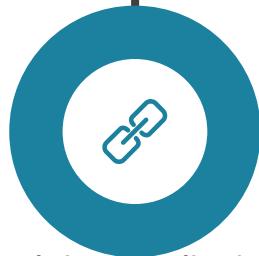
Estimating the impact of the eclipse on PV output for three interconnections.

- UPV and DPV
- By zip code or coordinates

Impact of eclipse on EI

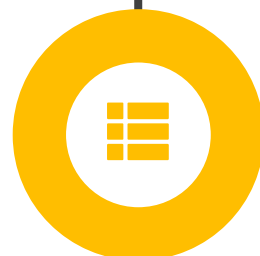
- Ramp rate
- Generation mix
- Power flow

Visualizations



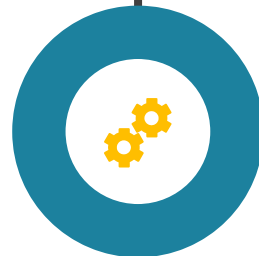
Real-time visualization

- Display the solar eclipse's impact on California in real-time.
- Develop an interactive Q and A app for solar eclipse study (optional)



Post-event analysis

- Quantify the impact of solar eclipse on grid frequency reliability
- Real-world data collection and countermeasure interview
- A systematic study of countermeasures



- Impact of Solar Eclipse on future scenarios

Q&A

Contact: Barry.Mather@nrel.gov

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