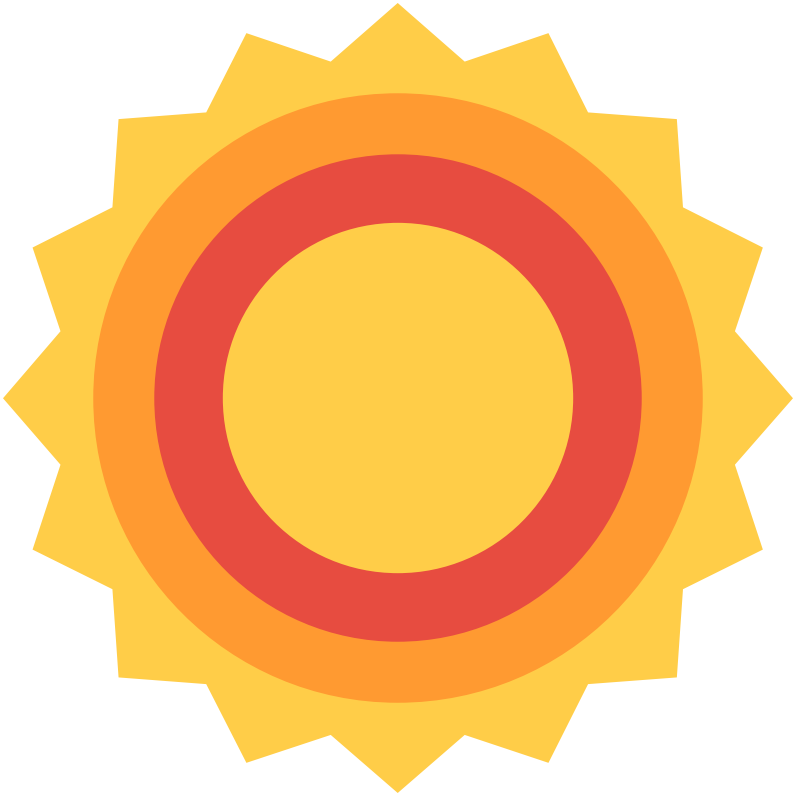
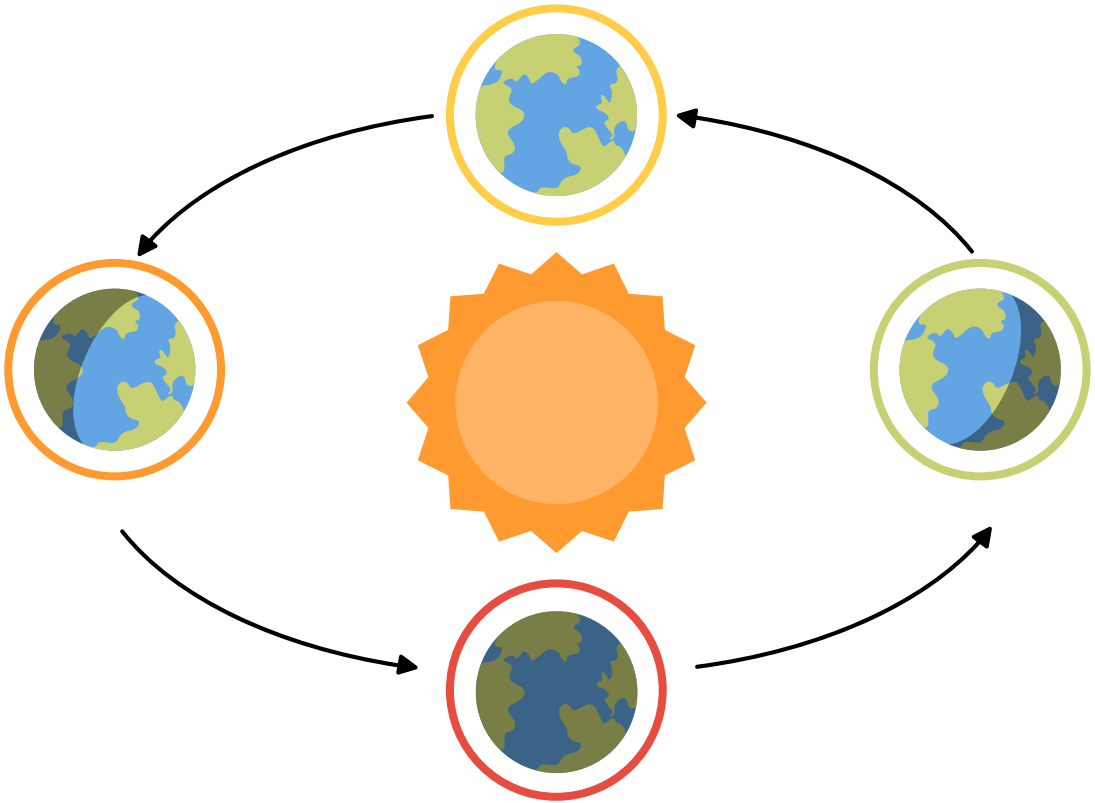
Data analysis for solar radiation and grid simulation



Team 13
Leo Naab
Ying-Jieh Xia
Sharvari Deshmukh
Tsung-Hsiang Ma
Arkid Bera

Solar Irradiance Concepts



DNI

Direct Normal Irradiance
(W/m^2)

DHI

Diffuse Horizontal Irradiance
(W/m^2)

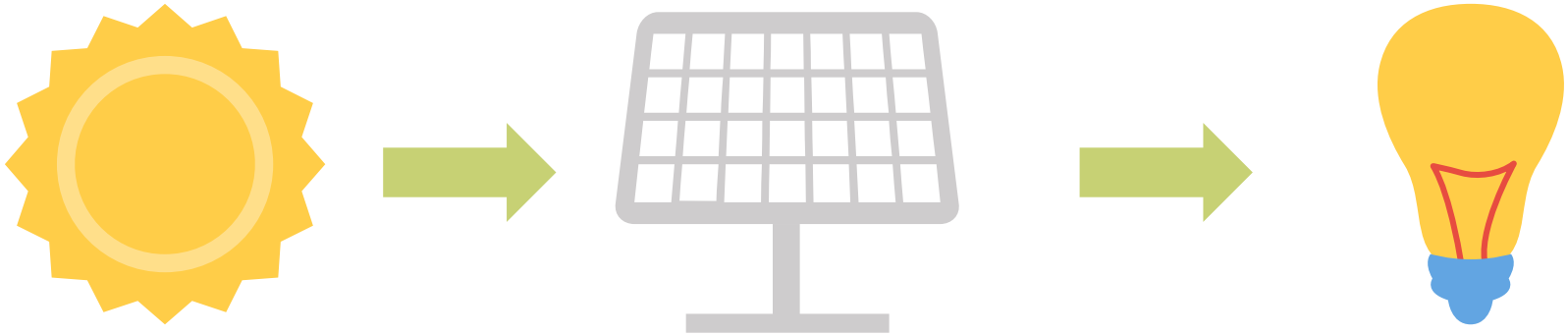
Solar Zenith Angle (Z)

Angle between normal of the Earth and the Sun's rays (Degrees)

GHI

DHI + cos(Z) * DNI
(W/m^2)

How GHI translates to power supply?



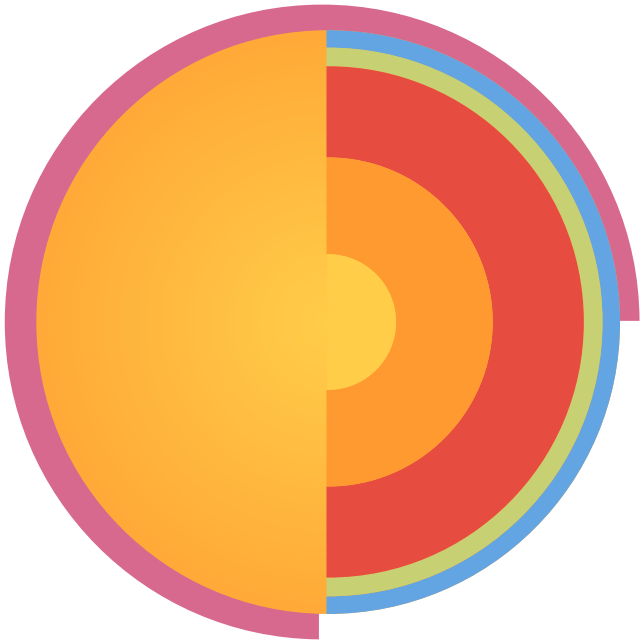
GHI,
Hours of Available Sunlight

Solar Panel
Efficiency

Solar Power
Supply

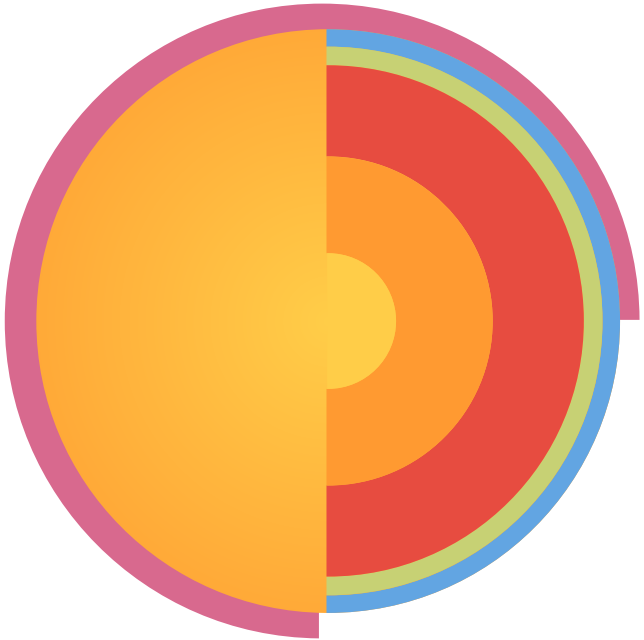
A GHI of 1000 is roughly equivalent to solar energy resources generating at 100%

Motivation



- Evaluating spatial and seasonal variations changes in solar supply and energy demands
- Evaluate relationship and gaps in solar supply and energy demand throughout the year
- Measuring efficiency of California grid assuming it is running on only on solar supply and storage

Data Sets



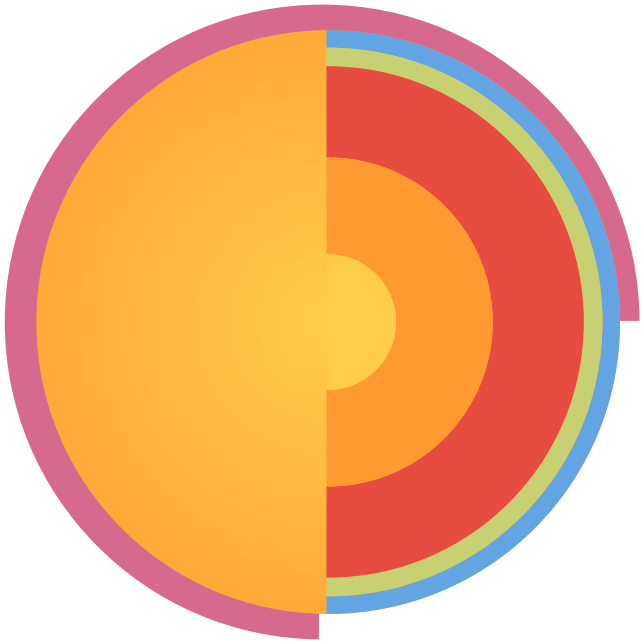
Solar Energy Supply Data

National Renewable Energy Laboratory - National Solar Radiation Database
https://nsrdb.nrel.gov/

Energy Demand Data

California Independent System Operator
https://github.com/grgmiller/CAISO_data

Data Overview



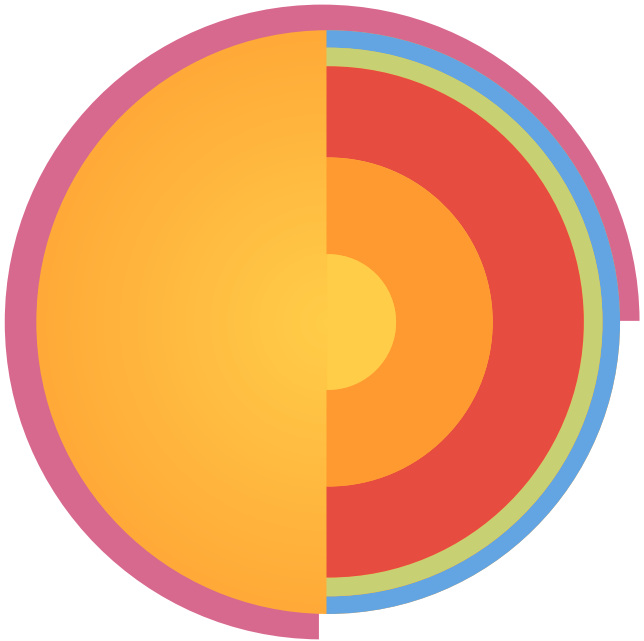
Solar Energy Supply Data

- Temporal resolution - 30 min
- Spatial resolution - 4 km
- California data for 1 year ~70GB!

Energy Demand Data

- Temporal resolution - 60 min
- Spatial resolution - Per State
- California data for 1 year ~13MB

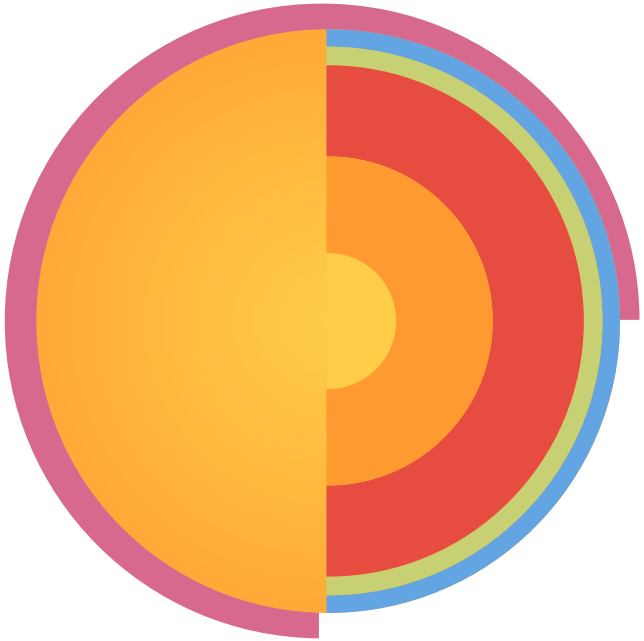
Methodology



Data Pre-processing

- Data Reduction
  - Focused on 3 years
  - Matched supply and demand data
  - Segregated datasets for visualizations and analysis
- Dimensionality Reduction
  - Selected specific attributes
- Data Discretization
  - Temporal: Hourly data instead of every 30 min
  - Spatial: Sampled coordinates

Processed Data



Solar Energy Supply Data

Year	Month	Day	Hour	Minute	GHI	Supply (MW)
2019	1	3	16	30	160	16000

Energy Demand Data

Timestamp	Load (MW)	Zone
1/1/2018 12:00:00 AM	2662.00	CA ISO

Processed Data

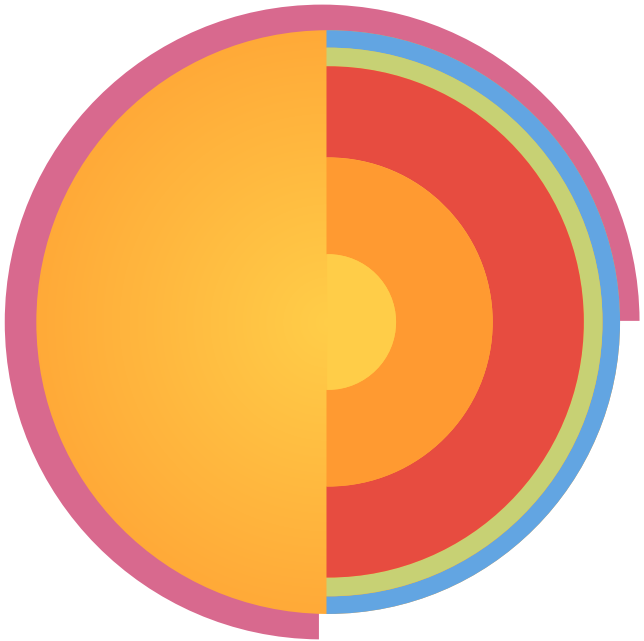
Solar Energy Data Example for Visualization

	latitude	longitude	elevation	timezone	country	state	county	urban	population	landcover
70276	32.529999	-117.099998	55.062500	-8	b'United States'	b'California'	b'San Diego'	b'None'	32326	130
70588	32.570000	-117.099998	7.100000	-8	b'United States'	b'California'	b'San Diego'	b'Tijuana'	27971	190

```
DatetimeIndex(['2019-01-01 00:00:00', '2019-01-01 00:30:00',
               '2019-01-01 01:00:00', '2019-01-01 01:30:00',
               '2019-01-01 02:00:00', '2019-01-01 02:30:00',
               '2019-01-01 03:00:00', '2019-01-01 03:30:00',
               '2019-01-01 04:00:00', '2019-01-01 04:30:00',
               ...
               '2019-12-31 19:00:00', '2019-12-31 19:30:00',
               '2019-12-31 20:00:00', '2019-12-31 20:30:00',
               '2019-12-31 21:00:00', '2019-12-31 21:30:00',
               '2019-12-31 22:00:00', '2019-12-31 22:30:00',
               '2019-12-31 23:00:00', '2019-12-31 23:30:00'],
              dtype='datetime64[ns]', length=17520, freq=None)
```

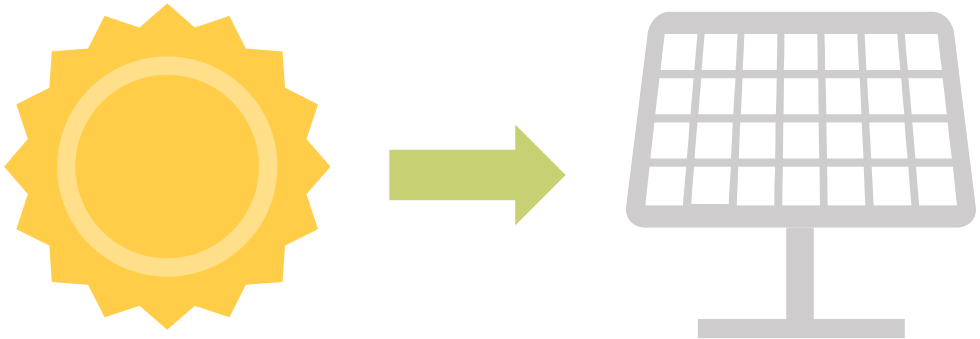
	longitude	latitude	ghi
0	-175.259995	-19.990000	5.0
1	-174.860001	-19.990000	3.0

Methodology

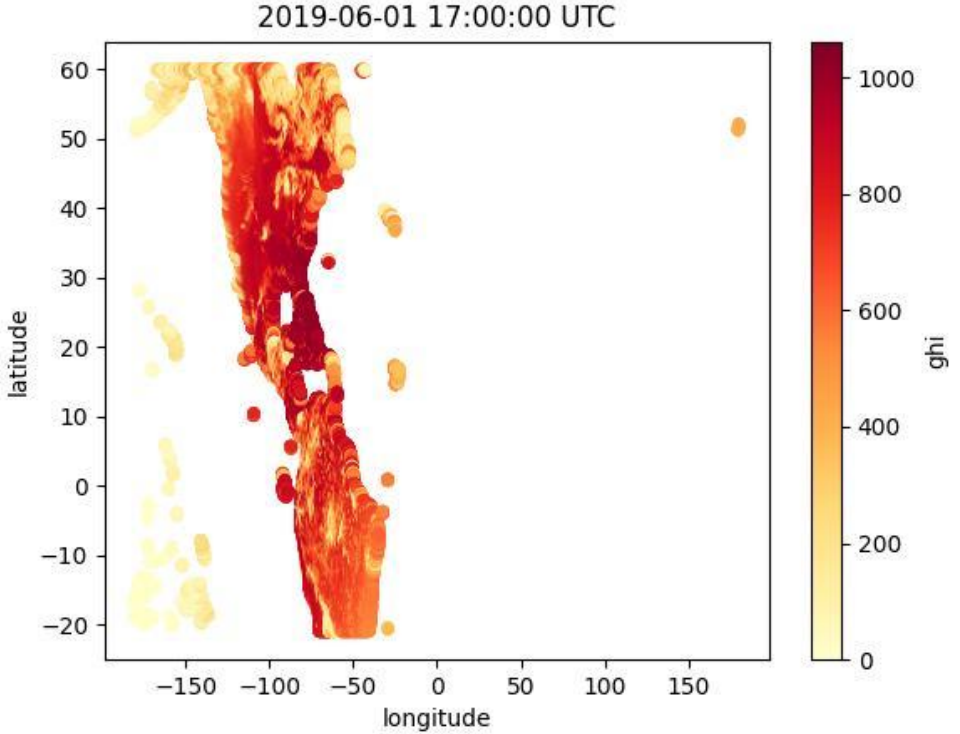


Data Analysis

- Solar supply analysis
  - Spatial
  - Temporal
- Electricity demand analysis
  - Temporal
- Supply demand gap analysis
  - Temporal
  - Grid Simulation with energy storage resources.

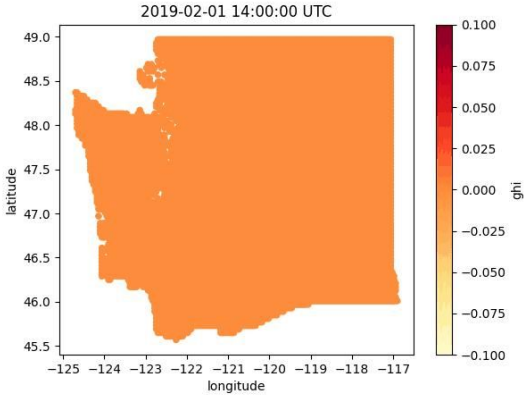


Supply Data Analysis

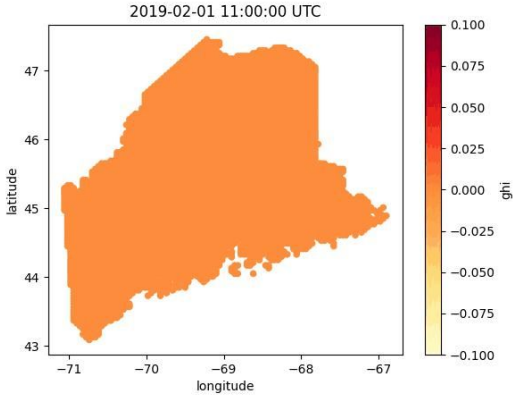


Heatmap of GHI across complete dataset at a particular time

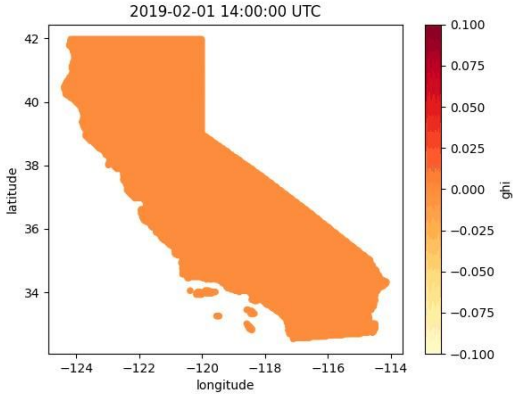
WA



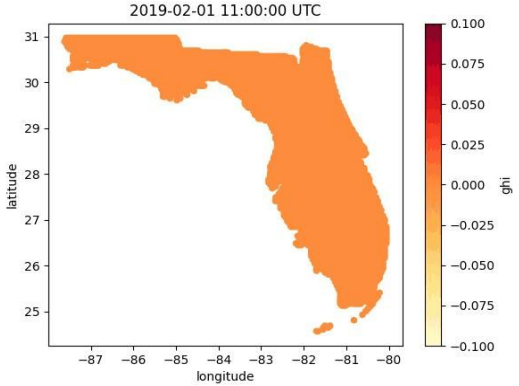
ME



CA

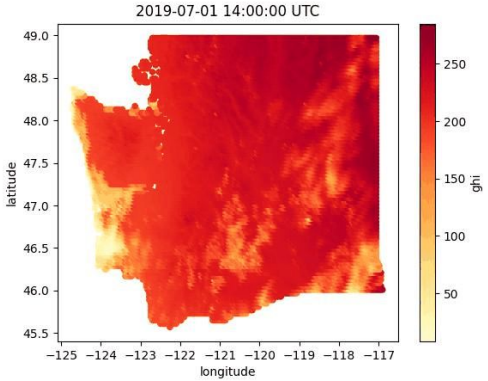


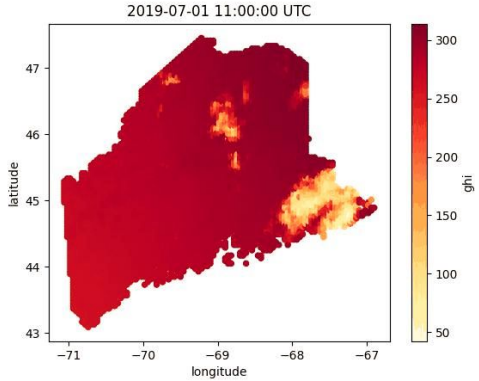
FL



GHI variations in the corner states
over a day in February

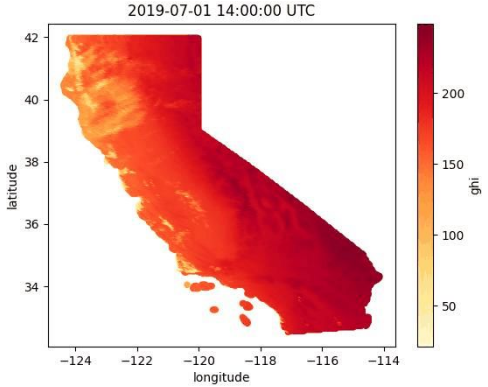
WA

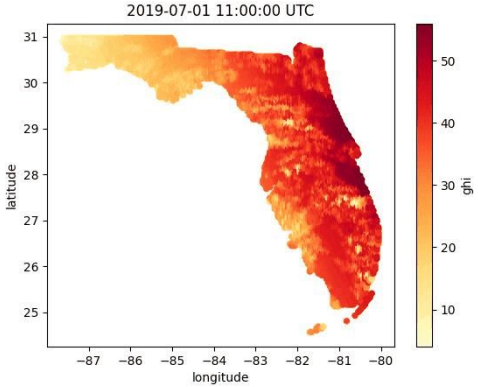




ME

CA

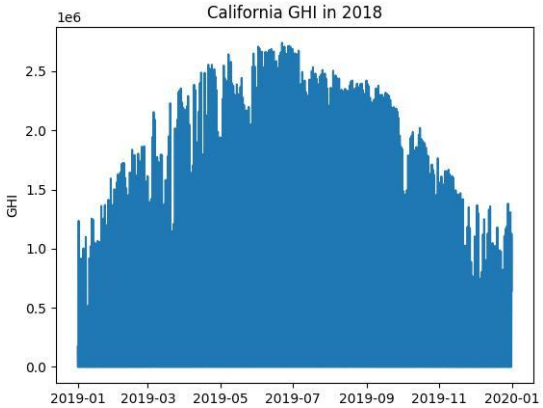




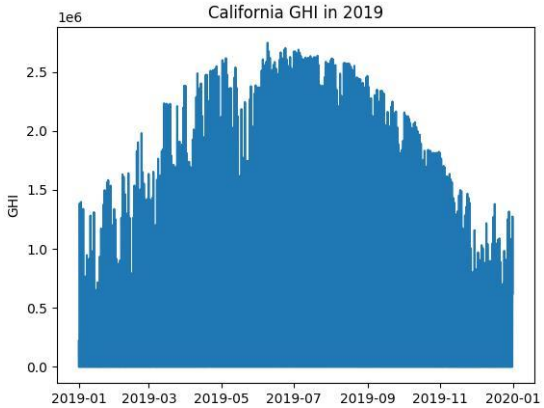
FL

GHI variations in the corner states over a day in July

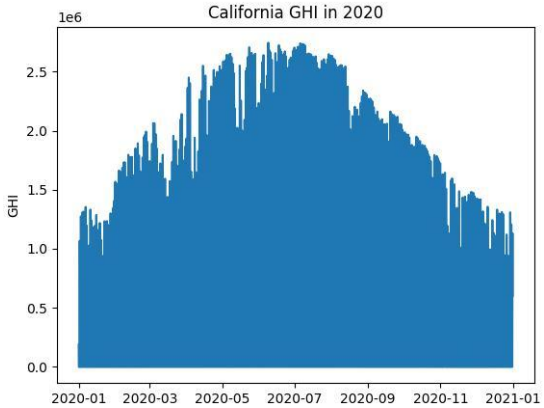
2018



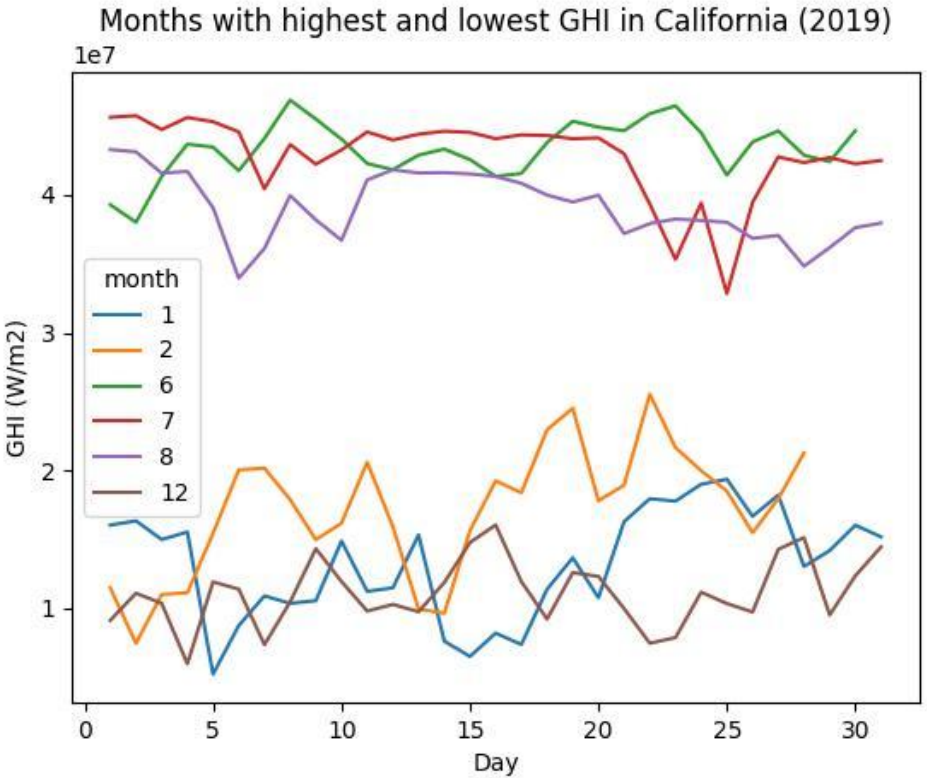
2019



2020



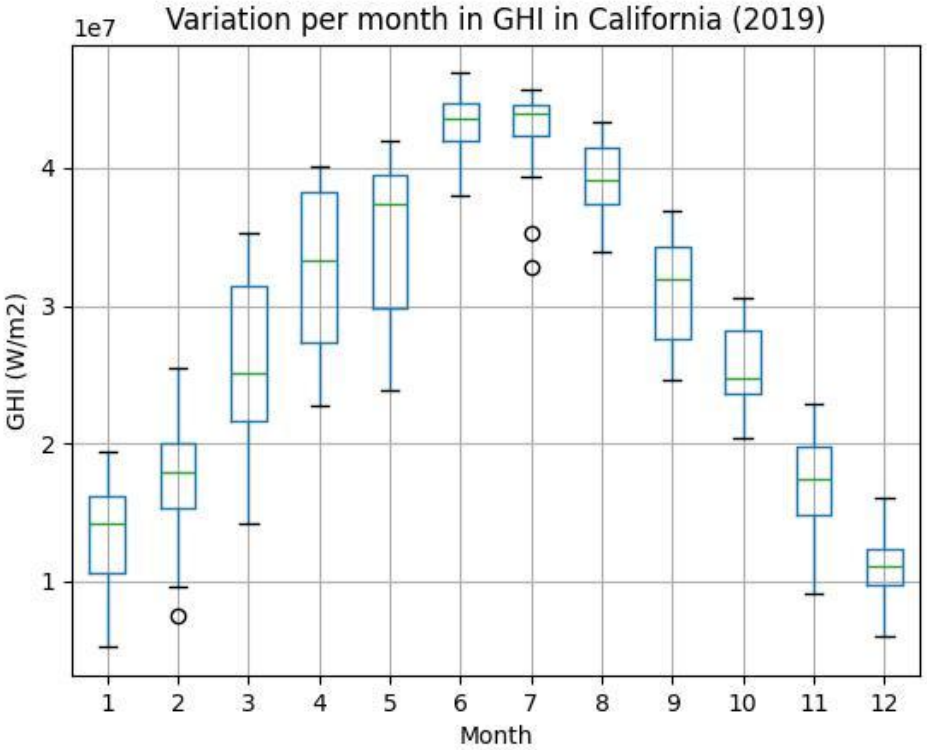
Total GHI across 3 years



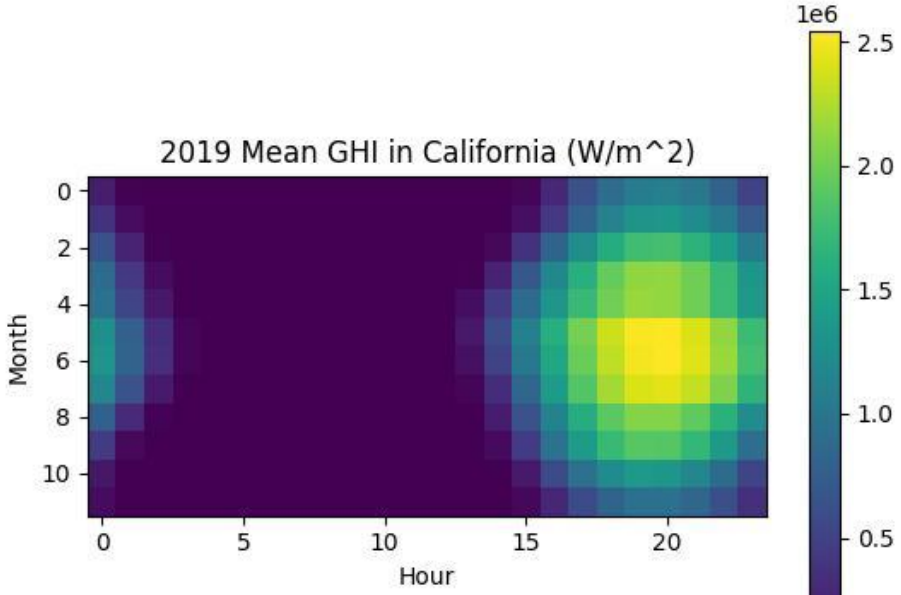
Jun, Jul, Aug

Dec, Jan, Feb

Total GHI across months for the year 2019

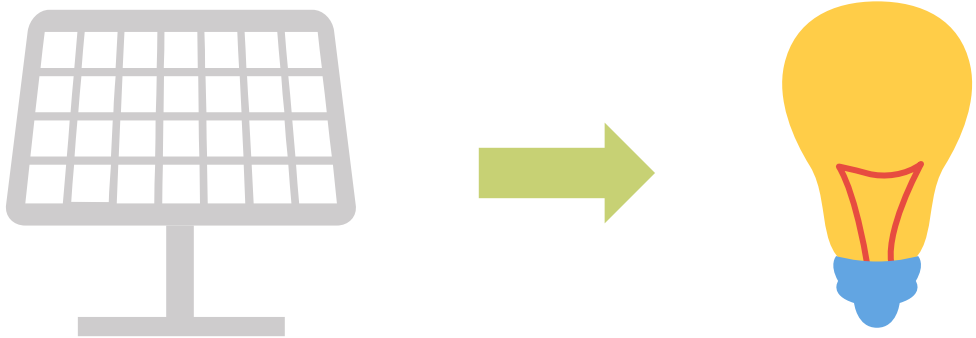


Variation in GHI in per month for the year 2019

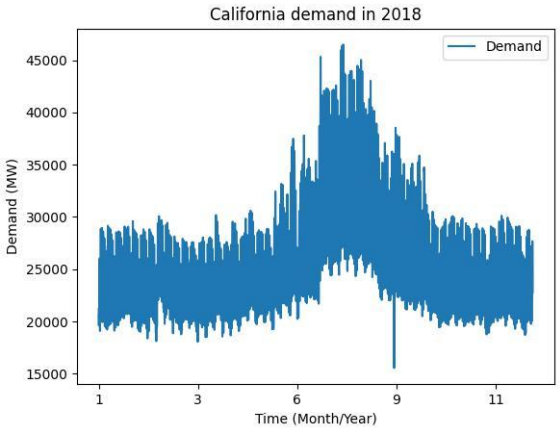


Month vs Hour GHI Heatmap for the year 2019

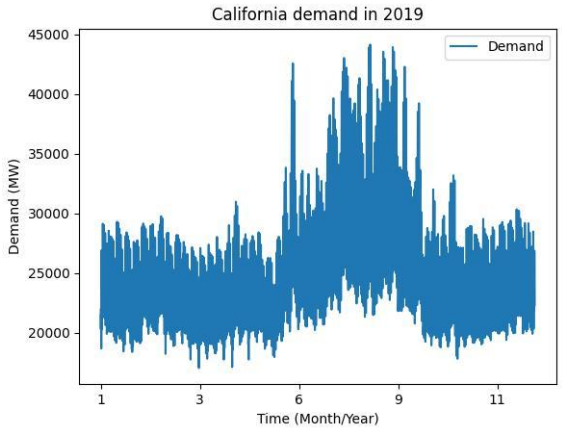
Demand Data Analysis



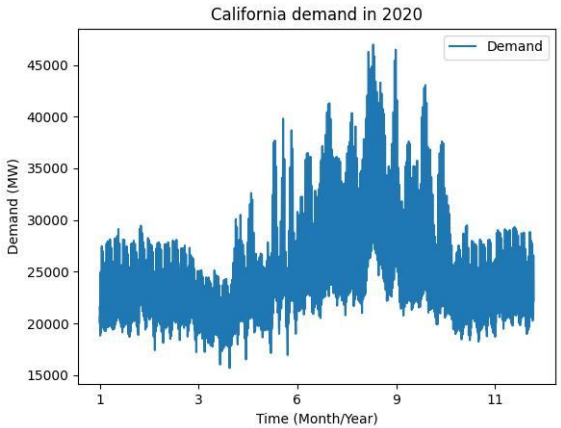
2018



2019

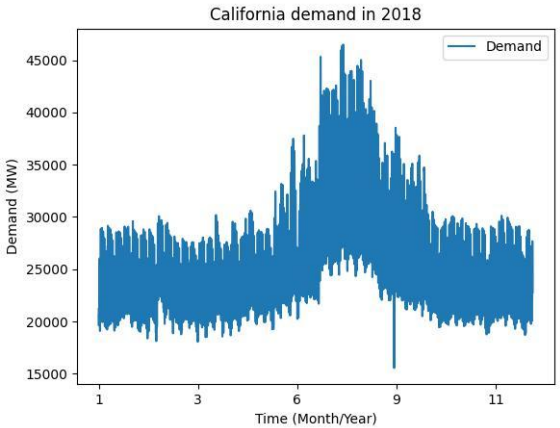


2020

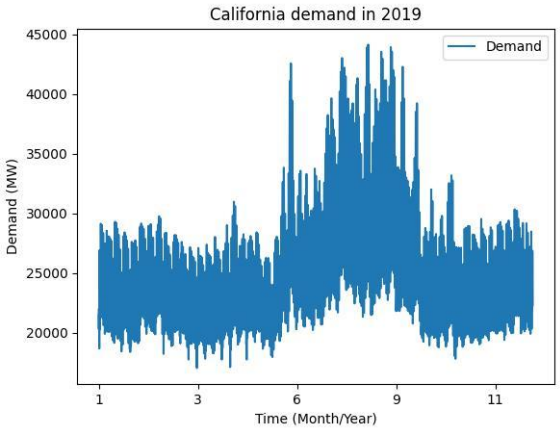


Total power demand for all 3 years

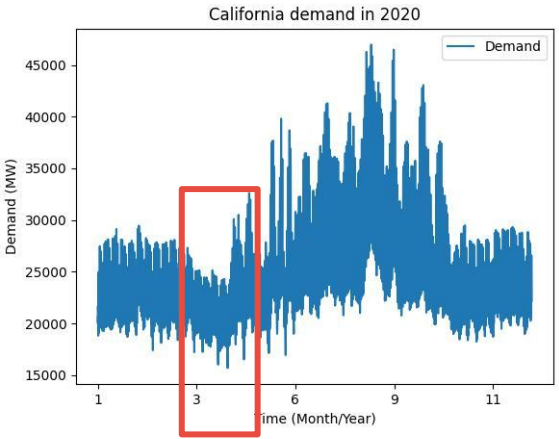
2018



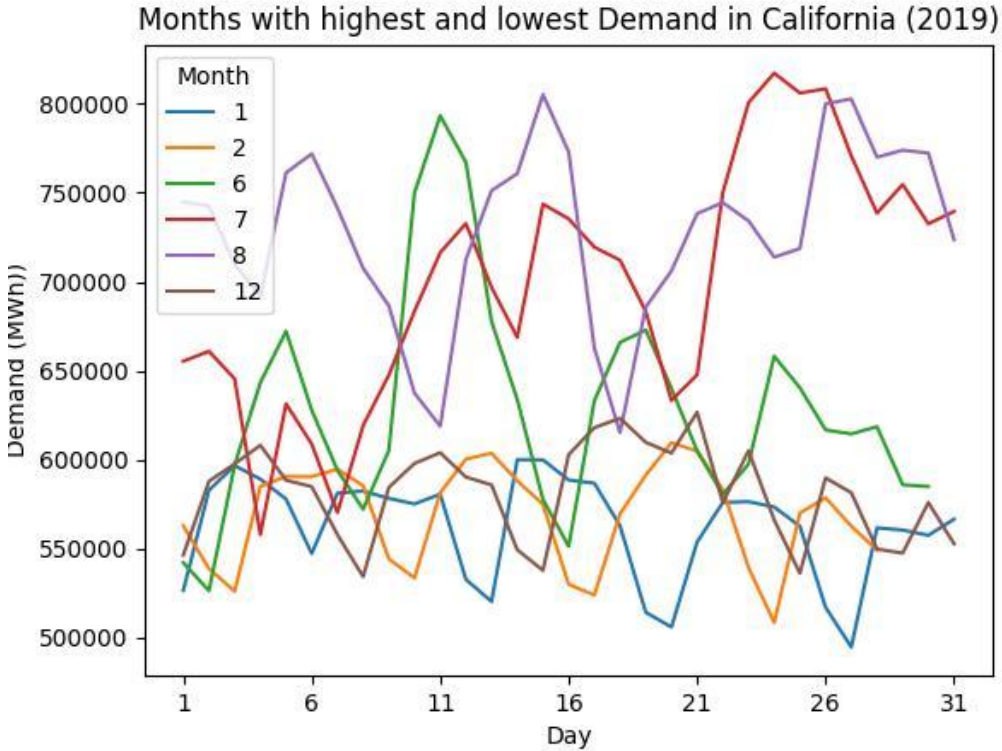
2019



2020



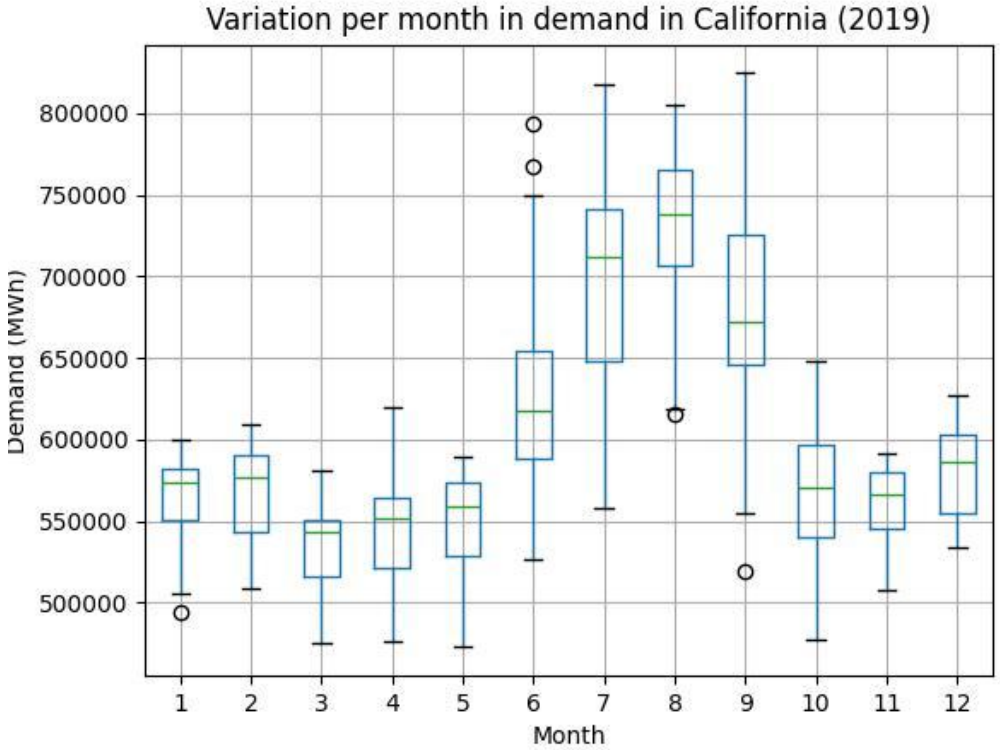
Total power demand across 3 years



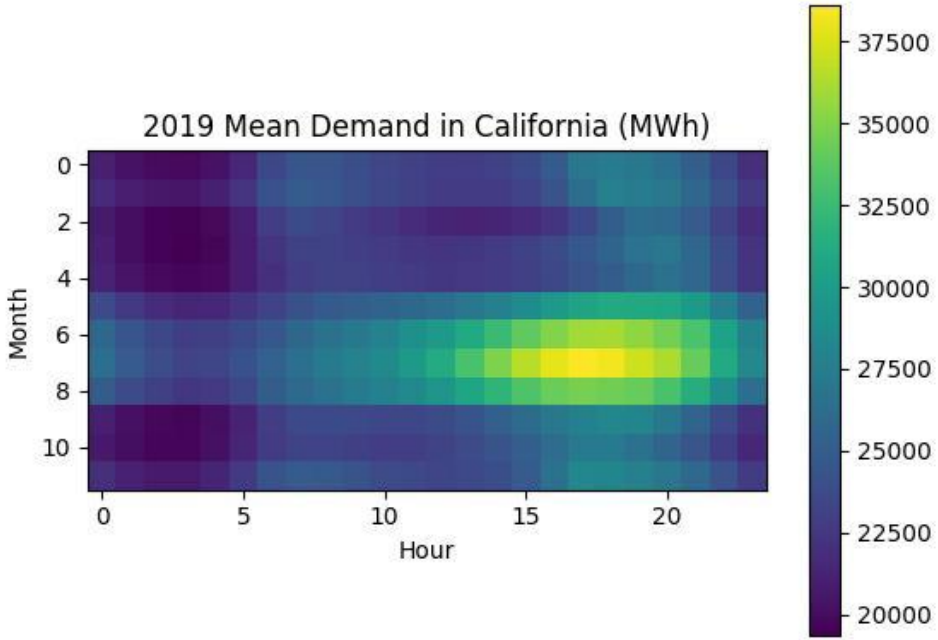
Dec, Jan, Feb

Jun, Jul, Aug

Total Demand across months for the year 2019

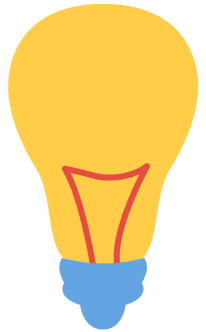


Variation in Demand per month for the year 2019



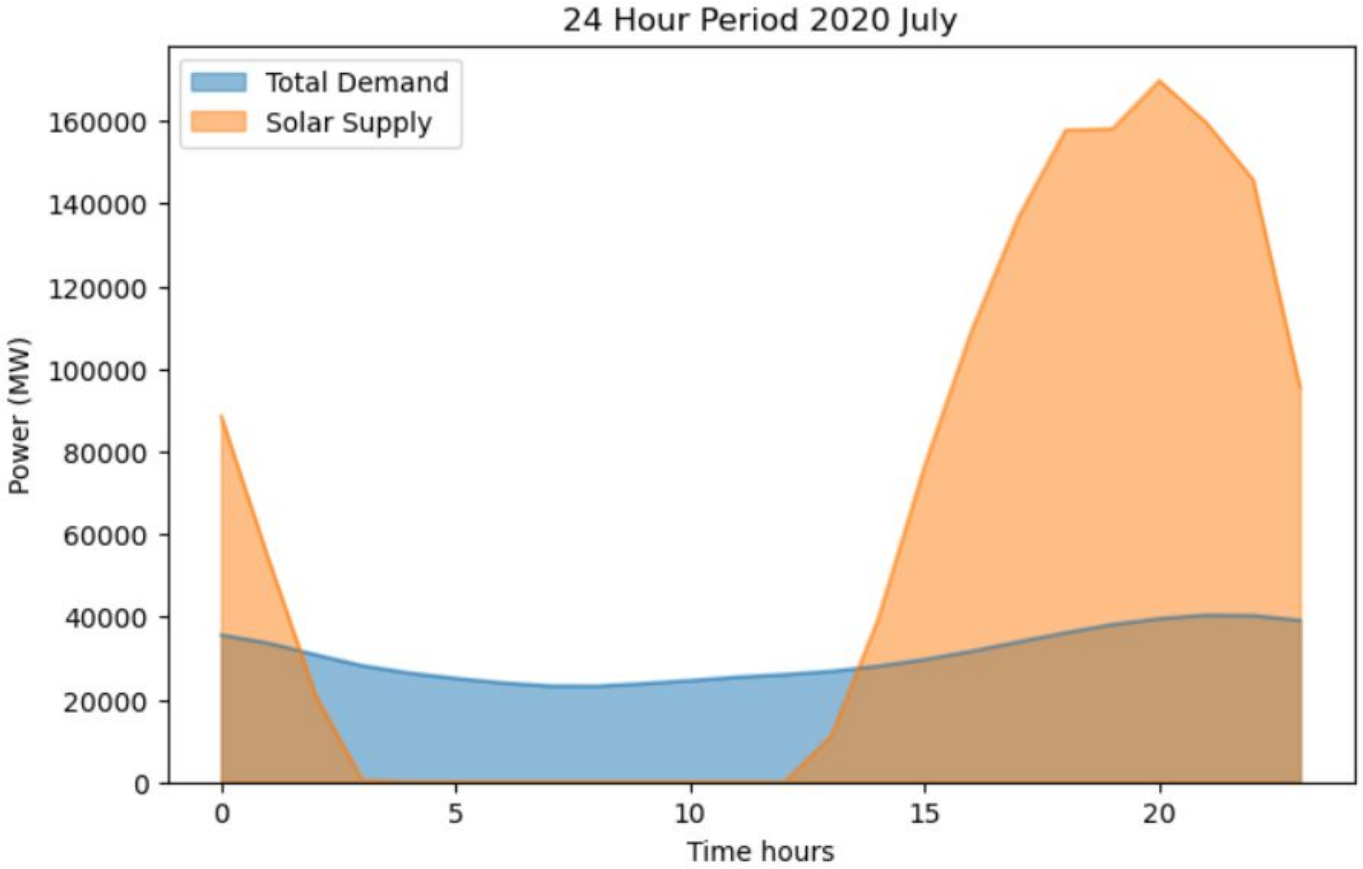
Month vs Hour Demand Heatmap for the year 2019

Supply-Demand Gap Analysis

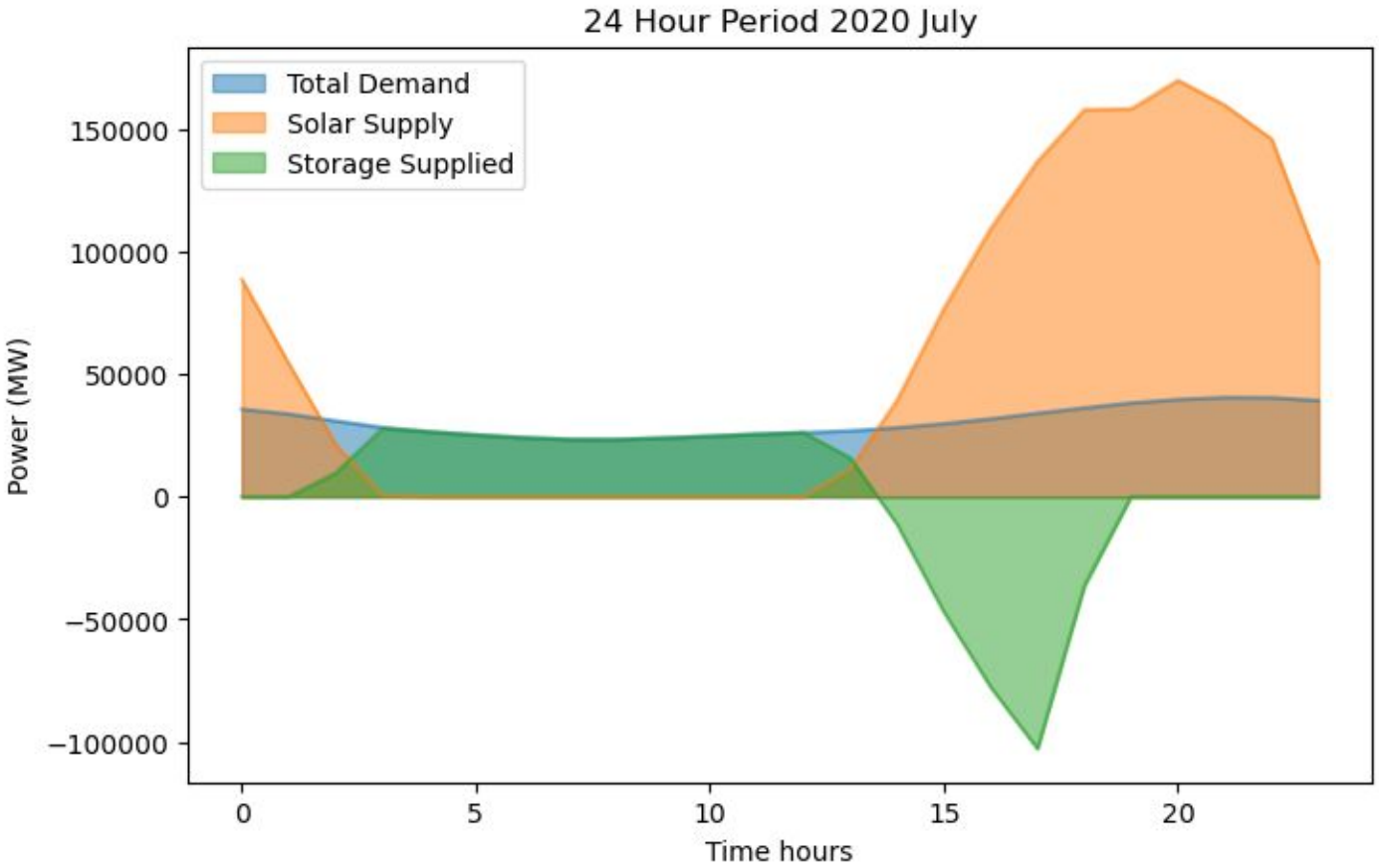


Hypothetical California grid:

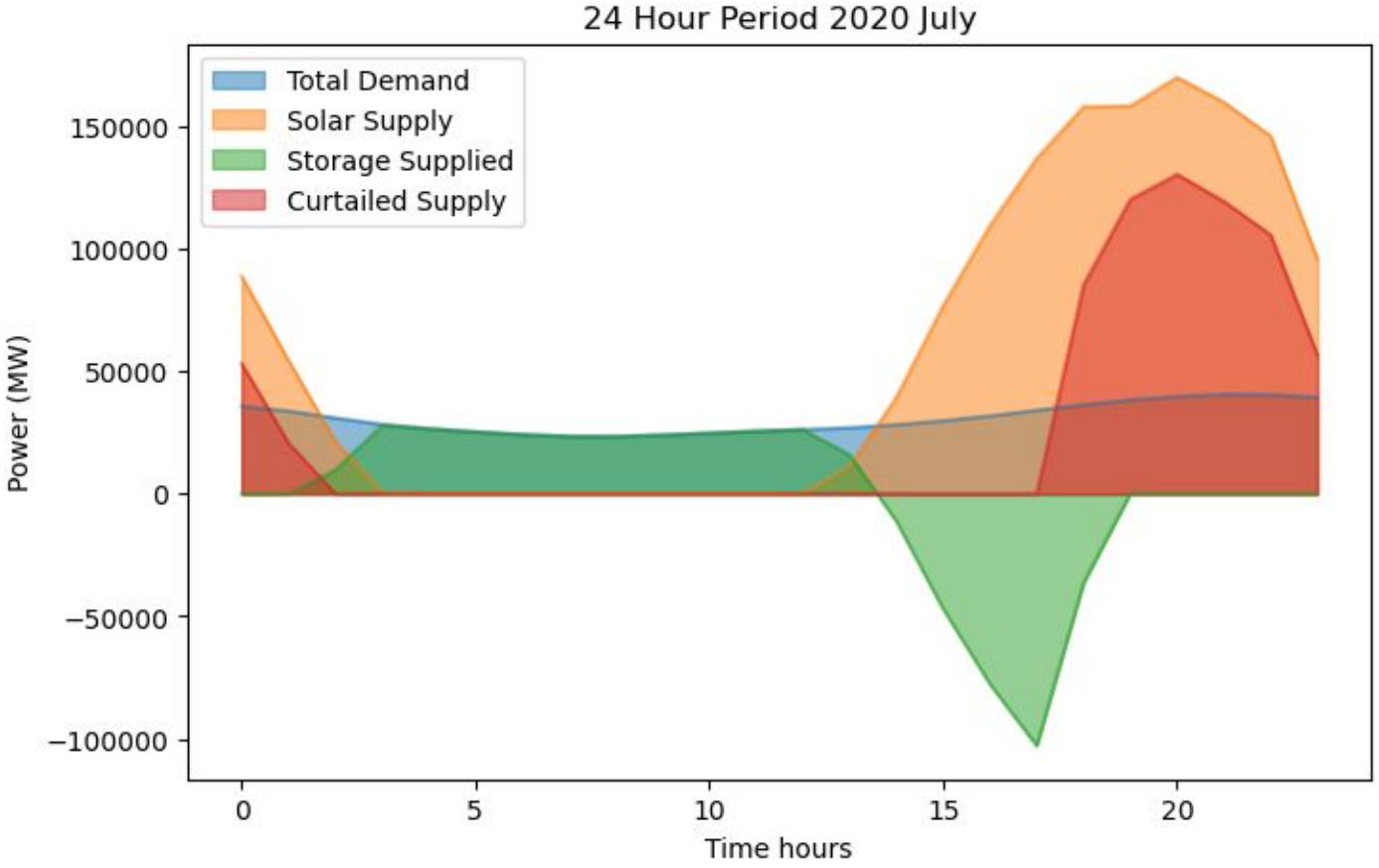
- 1.5X Solar generation capacity, 164 GW capacity
- 24 hours of energy storage, 696 GW•h capacity



Solar Supply and demand rarely match.

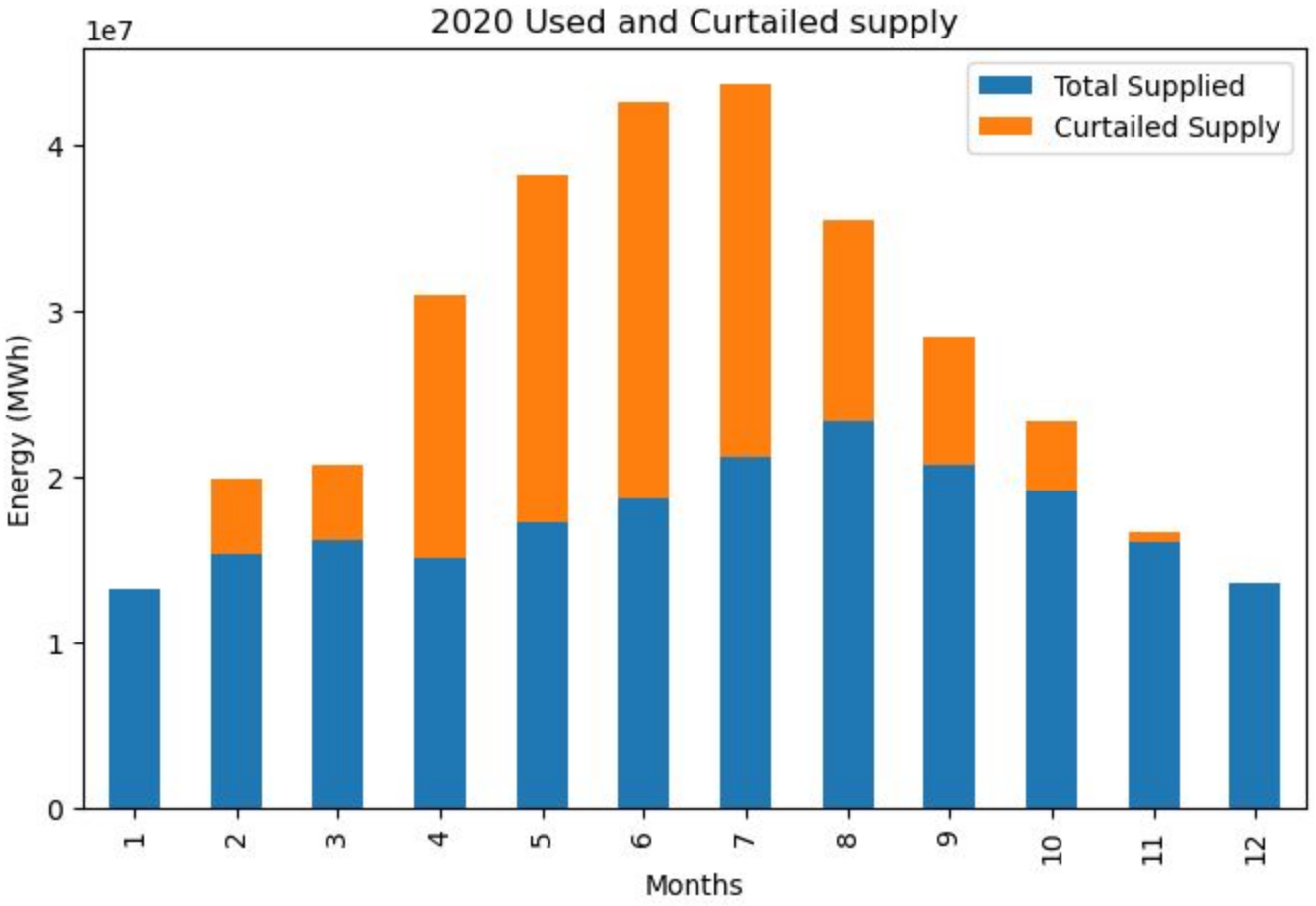


Adding Energy Storage resources allows solar energy to meet 24 hour demand

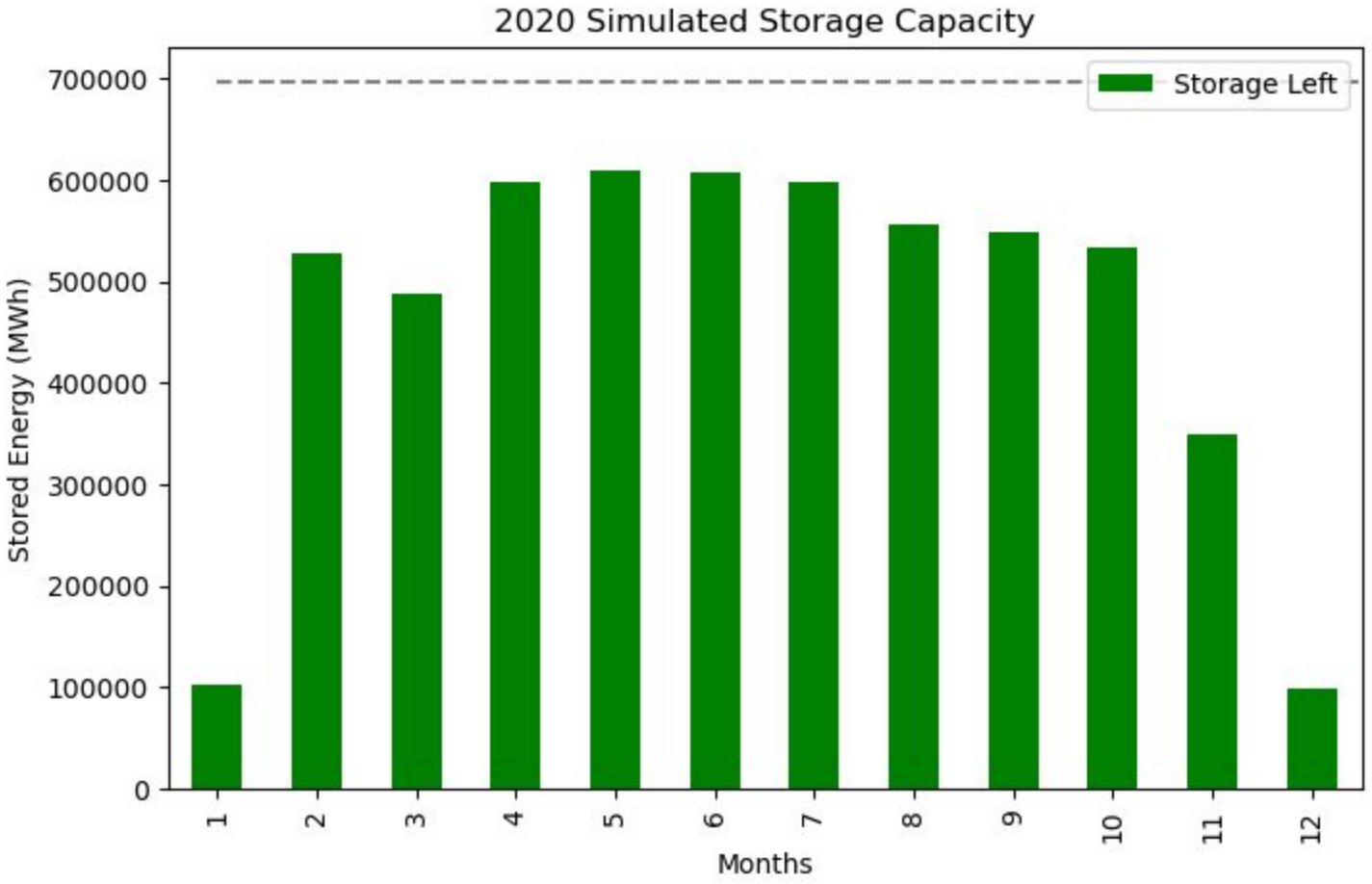


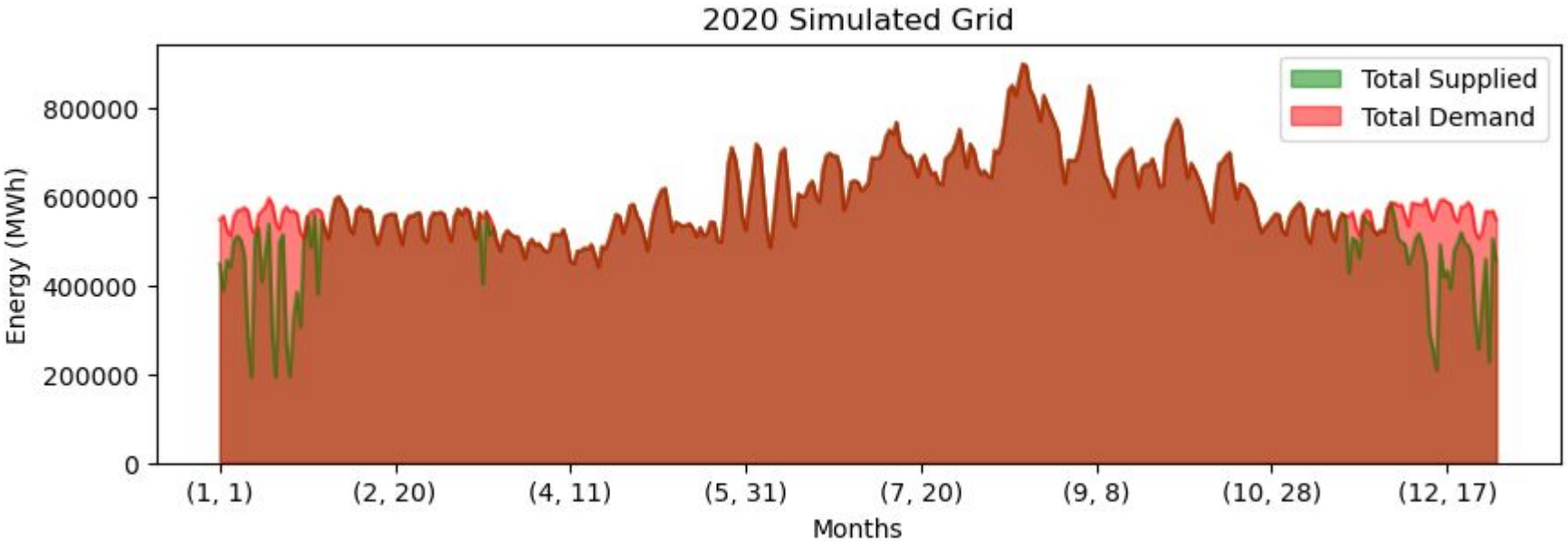
Excess solar energy is wasted

Significant curtailments during the summer months



Unused storage capacity in summer months





Solar + storage meets demand consistently except for winter months

Functionality and Coverage Testing

```
============================= test session starts ==============================
platform linux -- Python 3.9.5, pytest-7.4.2, pluggy-1.3.0 -- /opt/conda/bin/python3
cachedir: .pytest_cache
rootdir: /home/arbera/private/ECE143
configfile: pytest.ini
plugins: cov-4.1.0, anyio-3.2.1
collected 8 items

test_1_supply.py::test_stateNameCheck PASSED                             [ 12%]
test_1_supply.py::test_coordinateCheck PASSED                            [ 25%]
test_1_supply.py::test_plotsCheck PASSED                                 [ 37%]
test_2_demand.py::test_zoneCheck PASSED                                  [ 50%]
test_2_demand.py::test_yearCheck PASSED                                  [ 62%]
test_2_demand.py::test_plotsCheck PASSED                                 [ 75%]
test_3_analysis.py::test_analysisYearCheck PASSED                        [ 87%]
test_3_analysis.py::test_plotsCheck PASSED                               [100%]

----------- coverage: platform linux, python 3.9.5-final-0 -----------
Coverage HTML written to dir htmlcov


============================== 8 passed in 0.89s ===============================
```

Coverage report: 100%

Module	statements	missing	excluded	coverage
__init__.py	0	0	0	100%
test_1_supply.py	17	0	0	100%
test_2_demand.py	10	0	0	100%
test_3_analysis.py	13	0	0	100%
Total	40	0	0	100%

References

- https://nsrdb.nrel.gov/data-sets/how-to-access-data
- https://nsrdb.nrel.gov/data-viewer
- https://www.caiso.com/about/Pages/default.aspx
- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8545301/
- https://www.energy.gov/sites/prod/files/2015/05/f22/CA-Energy%20Sector%20Risk%20Profile.pdf
- https://www.nrel.gov/docs/fy06osti/38603.pdf

Theme & Icons

- https://slidesgo.com/

Thank You!