# California Power

## optimizing a flexible grid

By Samuel Hawkes

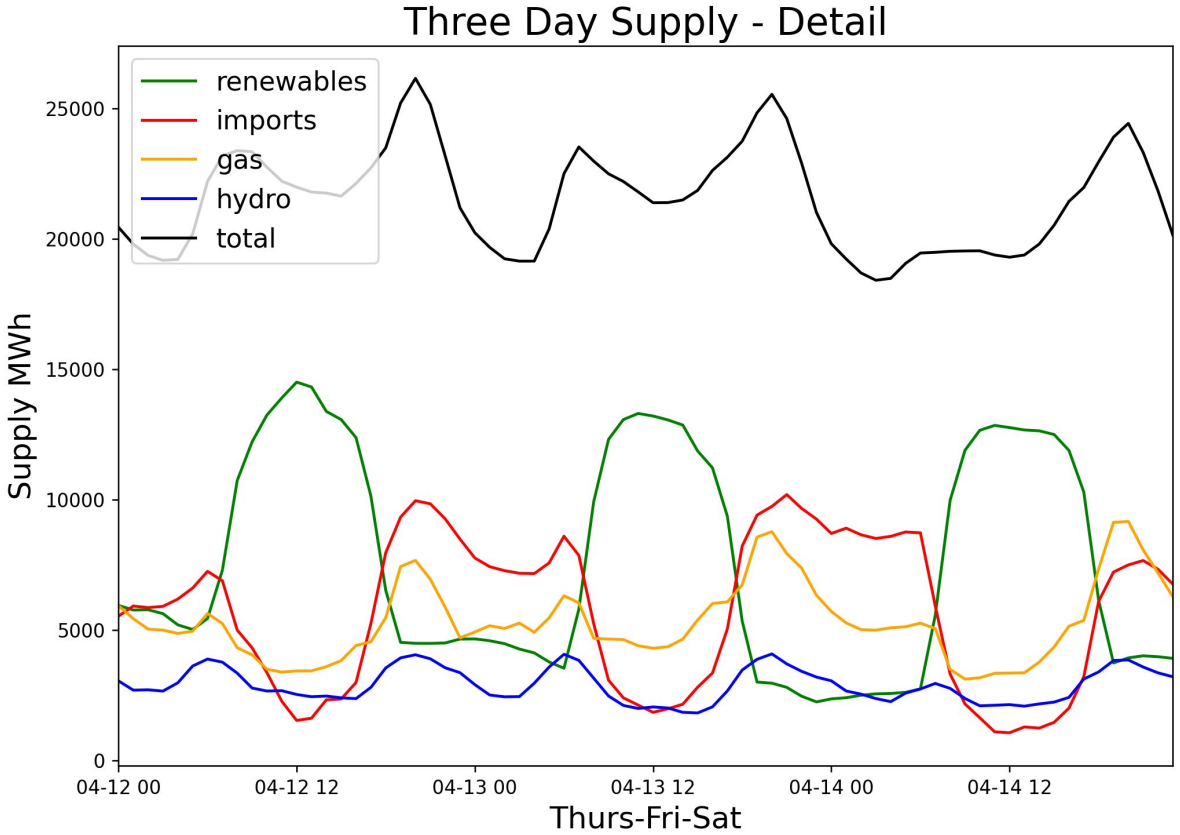
# The renewable energy problem

- A massive effort is underway to transition our society away from dependence on fossil fuels

- Renewable energy sources like wind and solar are ideal candidates to turn to because they are emissions free

- **These resources are time-variable and externally controlled, we cannot tell the sun when to shine or the wind when to blow**

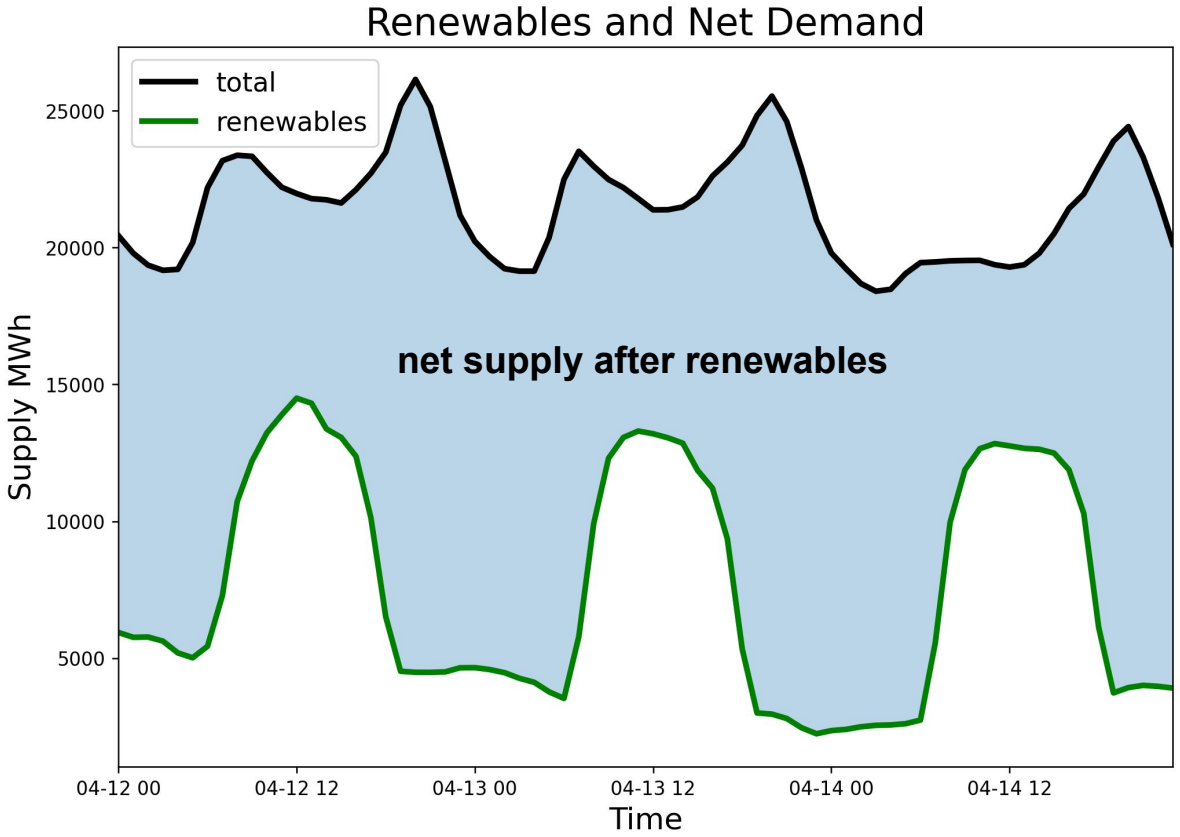
# California Energy Portfolio




While renewables provide the top peak energy supply, they are highly variable and must be offset by contributions from other sources

Net demand is met by mostly by gas and hydro plants that can be flexibly ramped up and down

# California Energy Portfolio

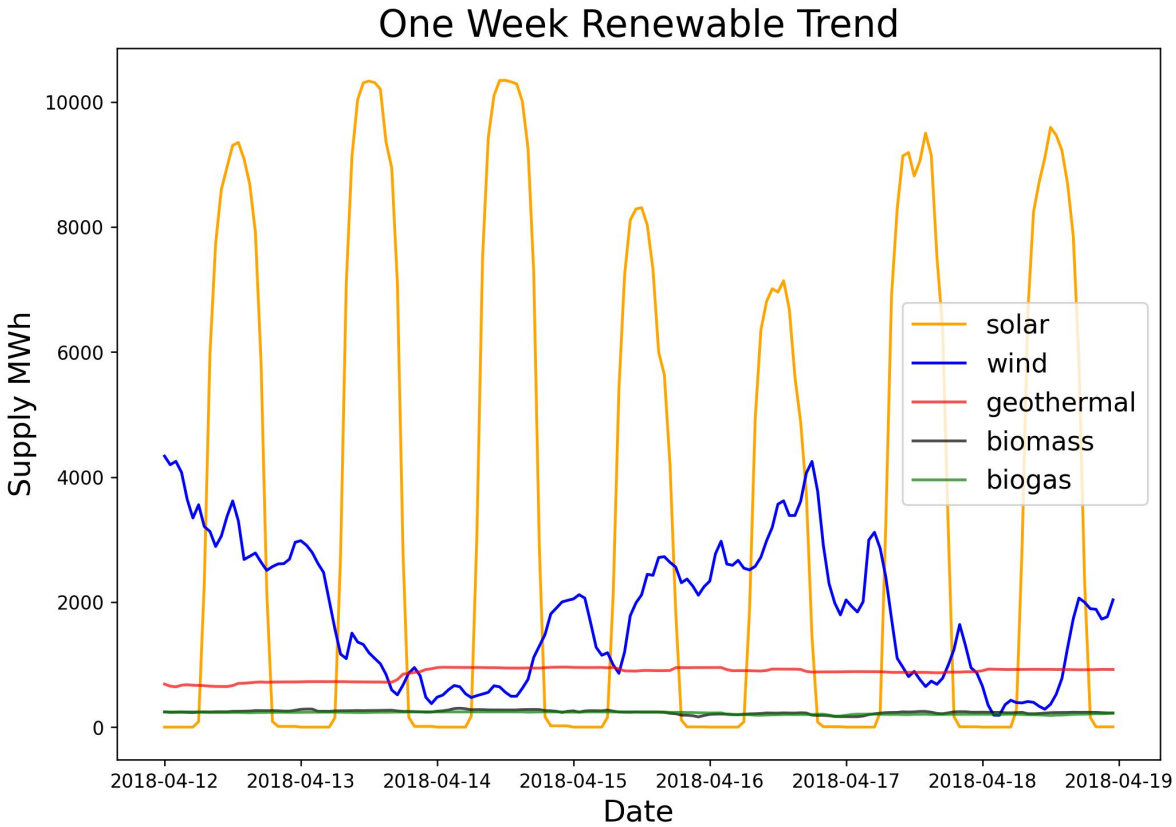



While renewables provide the top peak energy supply, they are highly variable and must be offset by contributions from other sources

Net demand is met by mostly by gas and hydro plants that can be flexibly ramped up and down

For maximum grid efficiency, renewable energy contributions must be accurately predicted so that other fuel types can fill in

# Renewable Energy Portfolio




Solar production shows expected daily pulses but efficiency can vary up to 30% in depending on weather conditions

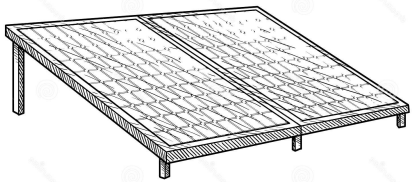
Wind production has the second highest peak output capacity but can drop well below 50% efficiency

Geothermal, biomass, and biogas are stable but collectively make up less than 2,000 MWh

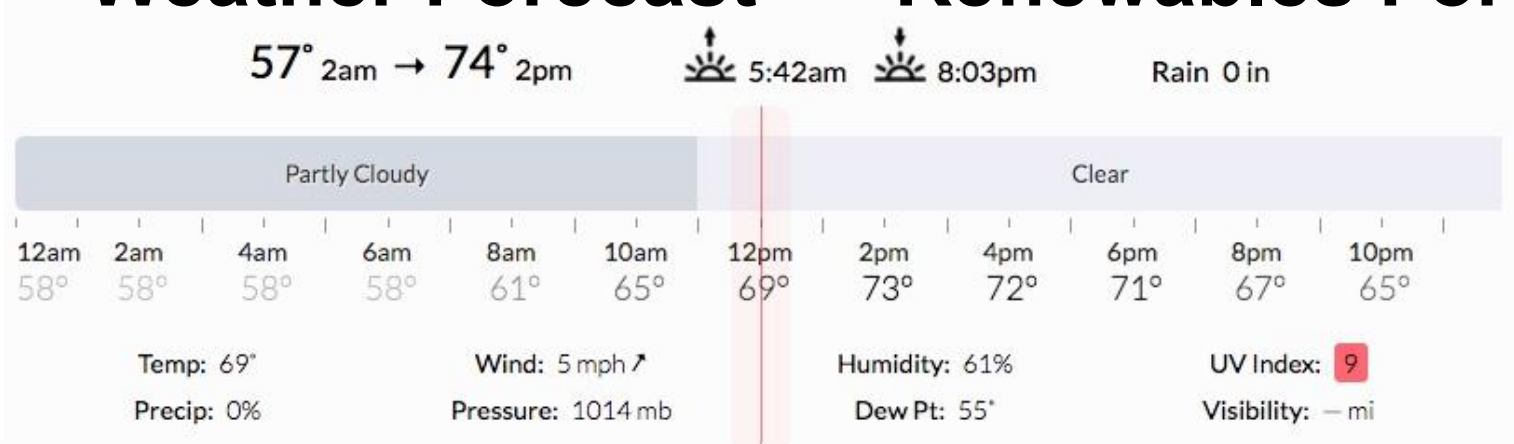
# Weather Forecast => Renewable Forecast

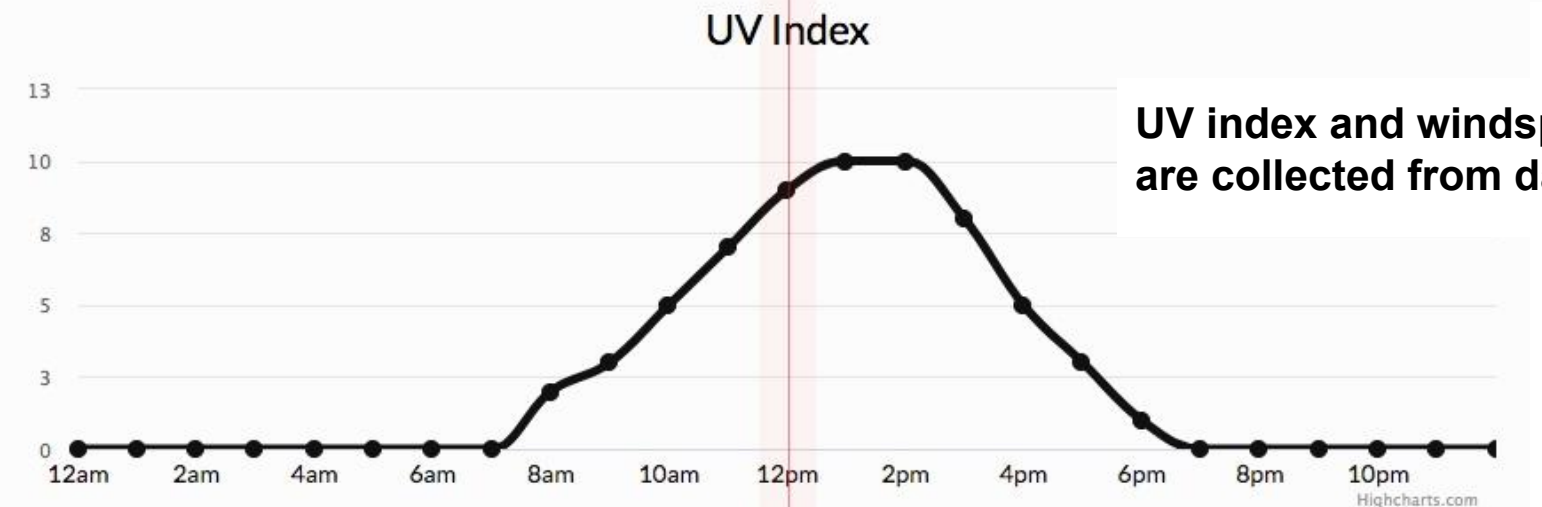
Solar and wind power are strongly affected by fluctuations in sunlight and wind speed

Can we use the weather forecast to predict solar and wind contributions to the grid?



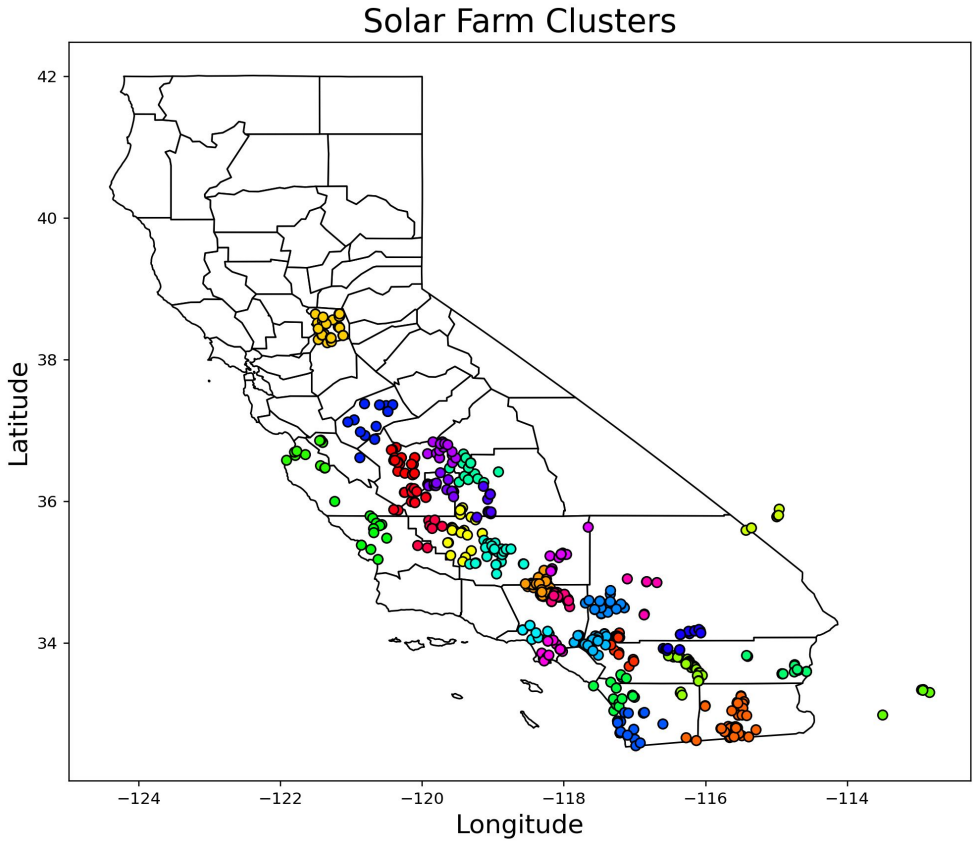
# Weather Forecast => Renewables Forecast




**UV index and windspeed data are collected from darksky.net**

# Weather Forecast => Solar Forecast



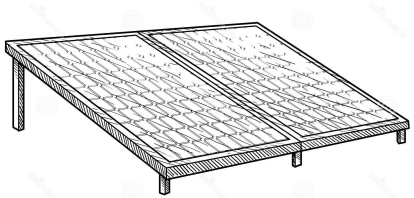

KMeans clustering is applied to 849 solar plant locations, resulting in 30 groups with similar weather forecasts

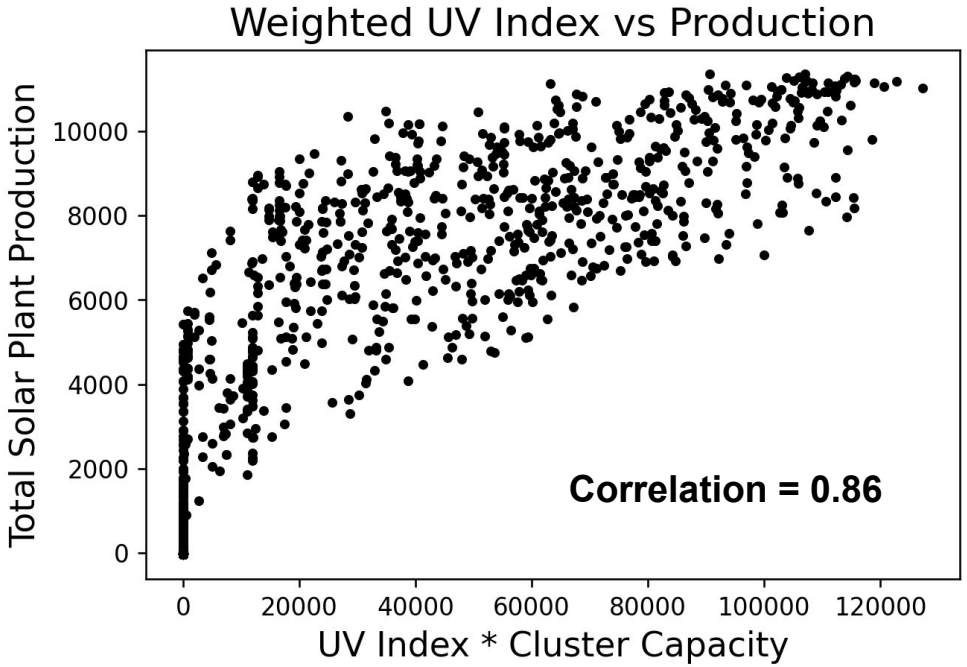
3 months of UV index data is collected for each centroid location and weighted by the total cluster production capacity

# Weather Forecast => Solar Forecast

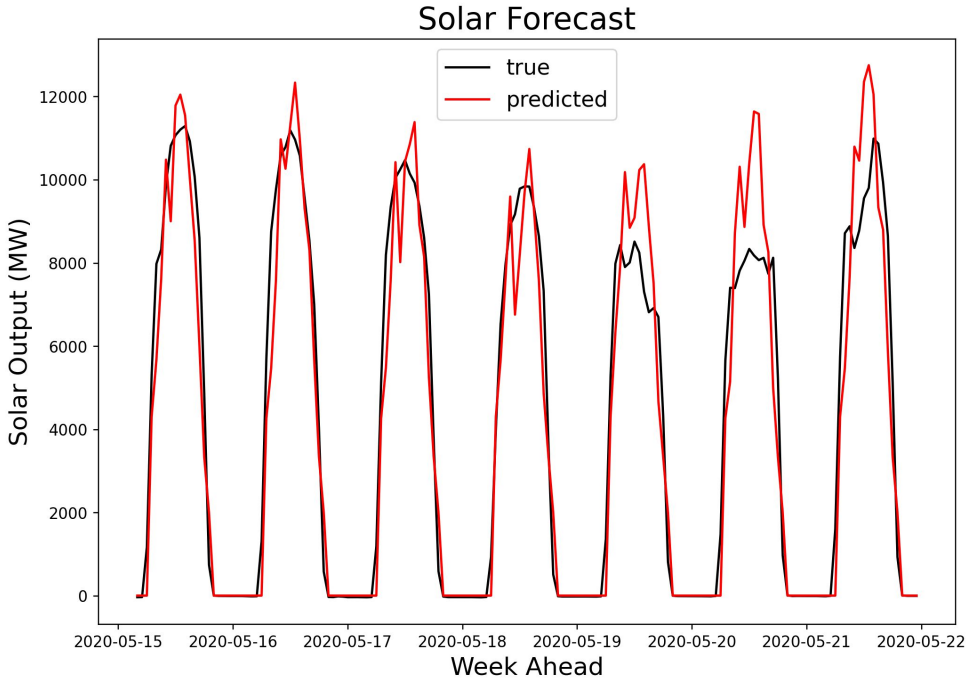
I use linear regression to train cluster capacity weighted hourly UV index records on hourly solar production data

Four dummy terms are also included for morning, midday, afternoon, and evening





# Weather Forecast => Solar Forecast




Linear regression predictions are evaluated with MSE and inspected visually against the true data

Daily fluctuations are well modeled but tend to be over predicted in the middle of the day and underpredicted in the morning and evening

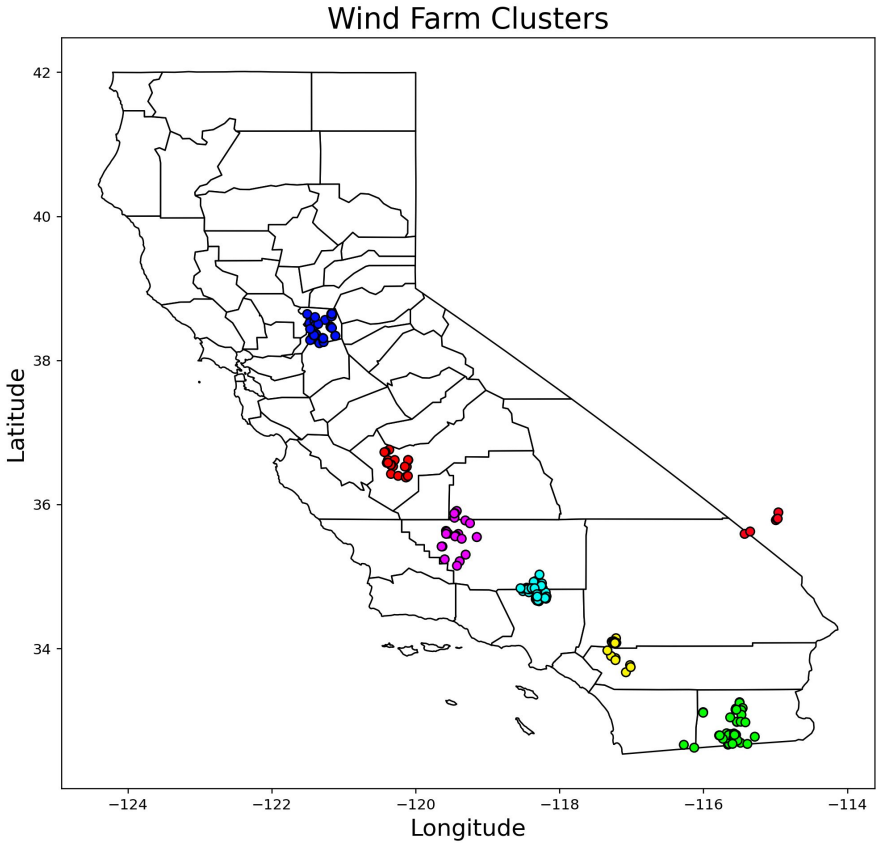
The model reflects peak capacity variation but still overestimates significantly

**MSE = 1254.4**

**$R^2$ = 91.5**

**Features to add:** day of year, hour of day, elevation

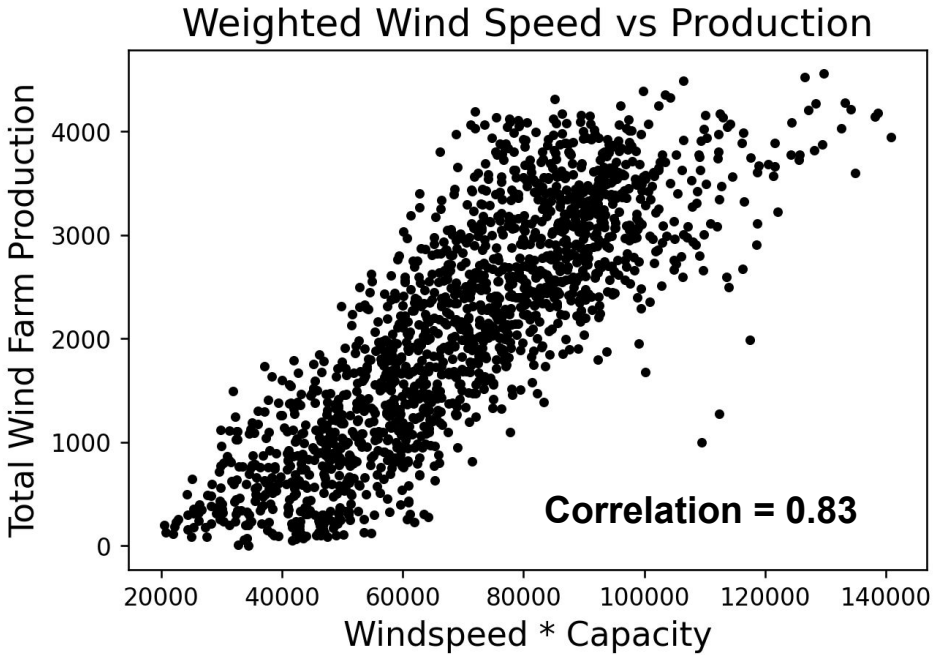
# Weather Forecast => Wind Farm Forecast




KMeans clustering is applied to 137 wind farm locations, resulting in 7 groups with similar weather forecasts

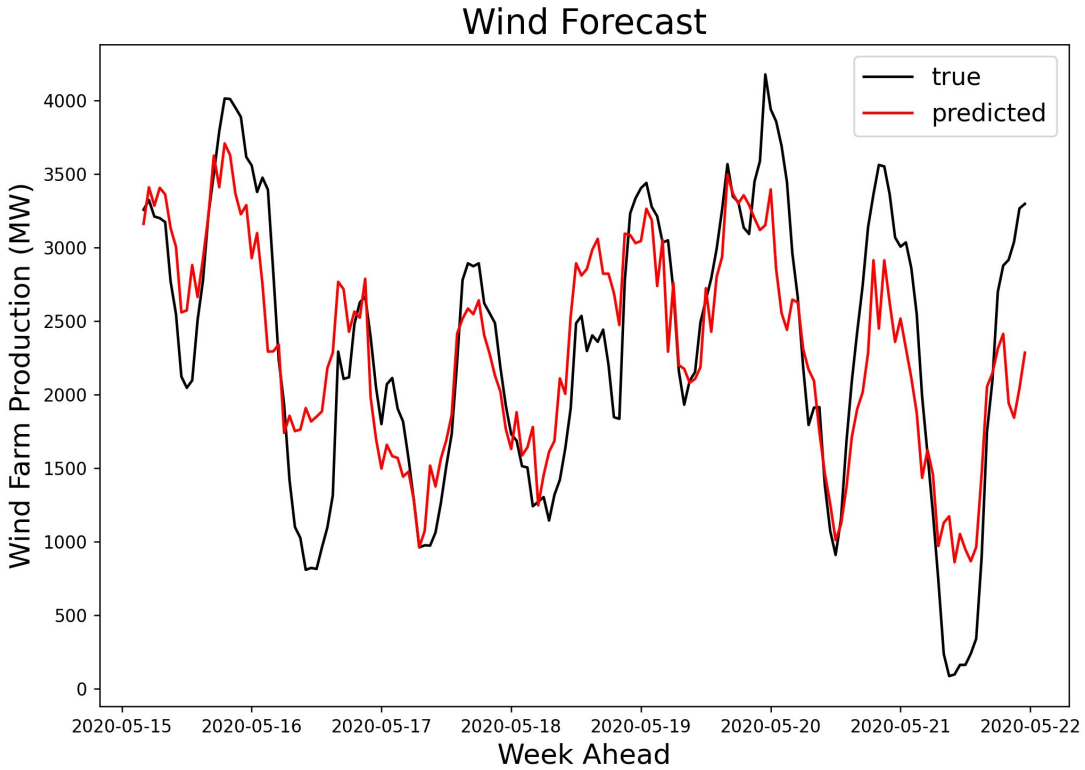
3 months of wind speed data is collected for each centroid location and weighted by the total cluster production capacity

# Weather Forecast => Wind Farm Forecast




I use linear regression to train cluster capacity weighted hourly wind speed records on hourly wind farm production data

# Weather Forecast => Wind Farm Forecast




Wind speed is able to forecast the overall trend in wind farm production well, but does not capture the low and high end production values well

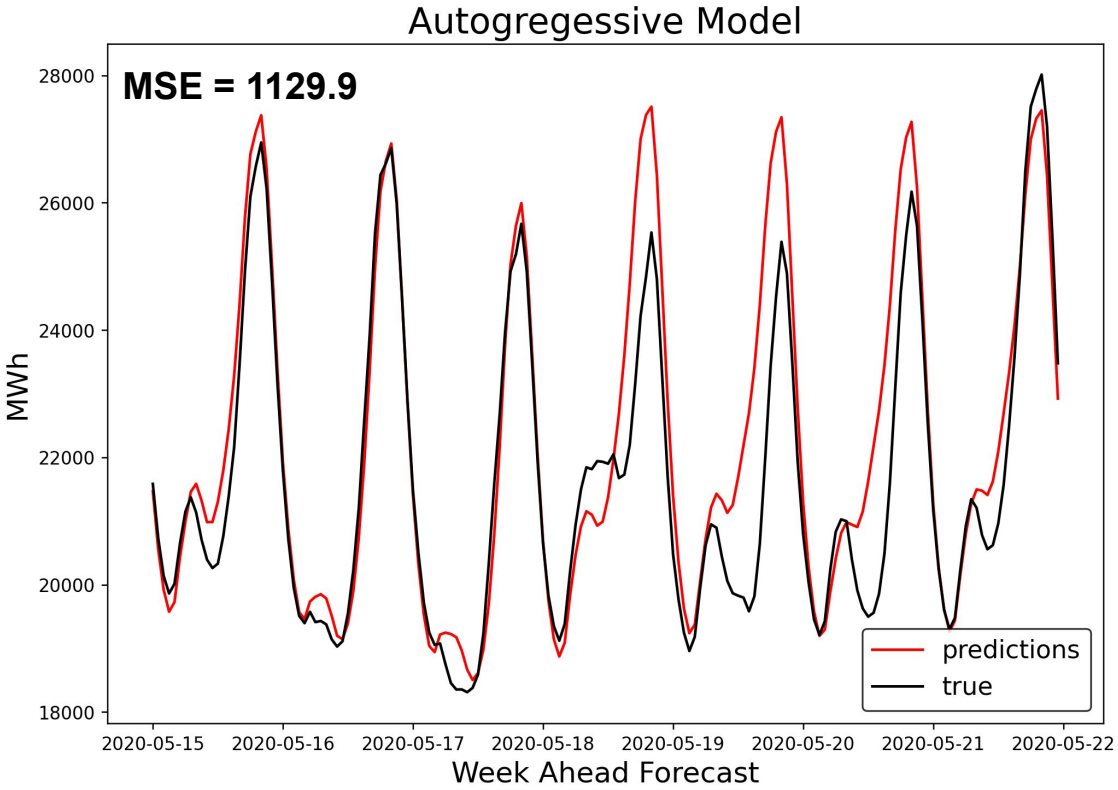
This is a very simple model built only on wind speed

Future versions of this forecast will include humidity, temperature and pressure

**MSE = 523.4**

**$R^2$ = 70.4**

# Demand Forecast

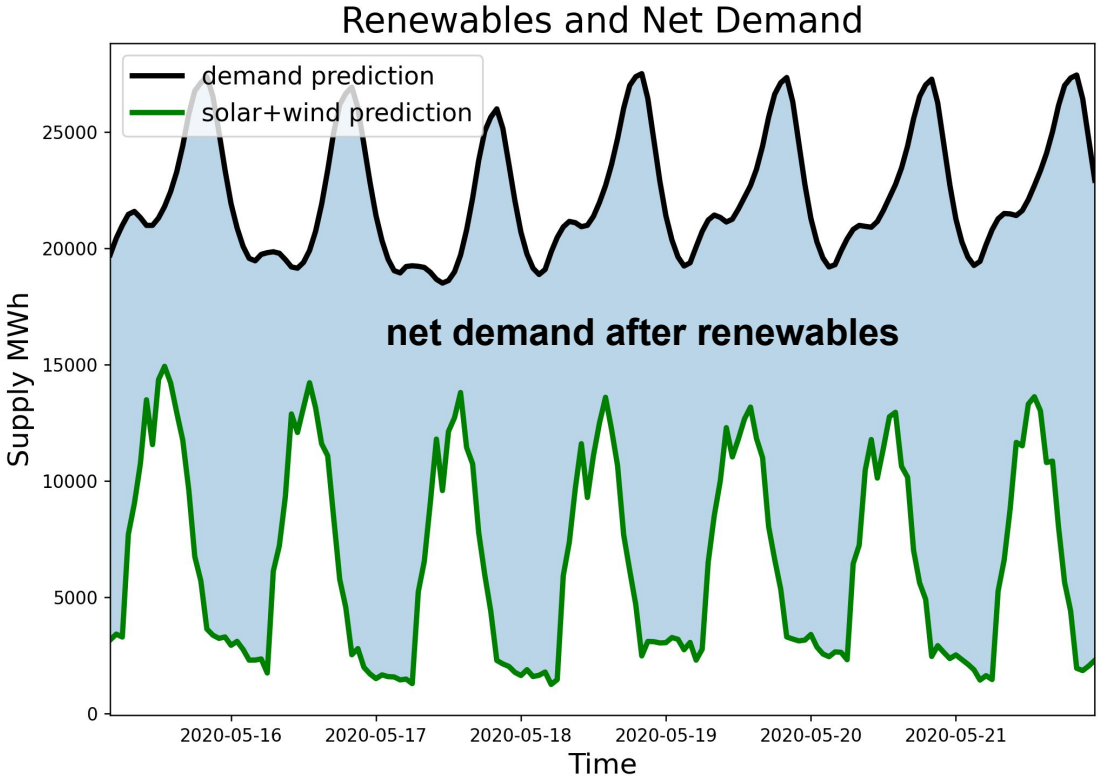



I trained an autoregression model on two years of hourly demand data to generate a week ahead demand forecast

The forecast captures the weekend low on the 16th and 17th but overpredicts Mon-Wed evening

May try VAR model in the future and include day of year, hour of day, and temperature data

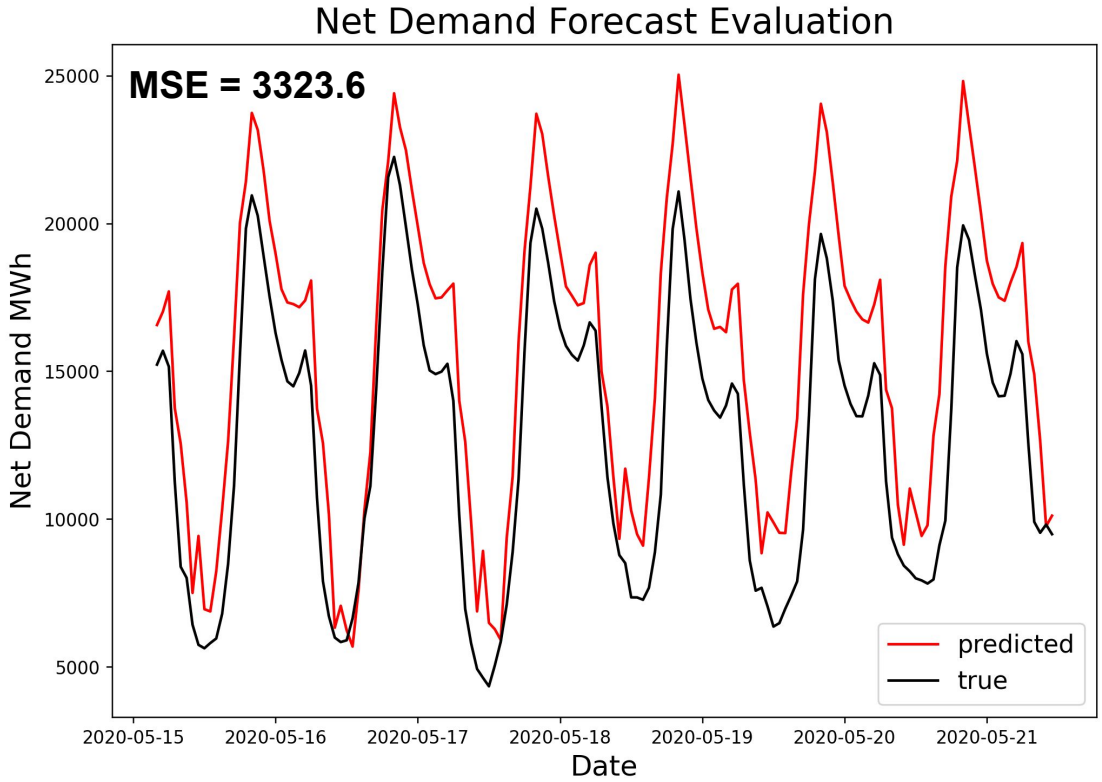
# Renewables Forecast => Net Demand Forecast




From the demand forecast and renewables forecast I am able to generate a net demand forecast as follows:

**Net Demand = Demand - (Solar + Wind)**

# Net Demand Forecast Evaluated




The red net demand forecast is generated using the data on the previous slide

The black true demand curve is generated by adding together gas, hydro, imports, geothermal, biomass, and biogass data

The net demand forecast captures daily fluctuations but consistently overpredicts

# Conclusions

1. Electrical demand in California can be reasonably well forecasted from historical time series demand data
   - *This model could be improved with day of year and day of week features*
   - *May try RNN on daily demand curves to generate 1 day forecast*

2. Wind speed and UV index weather reports can be useful in forecasting wind farm and solar plant production
   - *Wind forecast can be improved with humidity, temperature, pressure data*
   - *Solar forecast can be improved with day of year and hour of day*