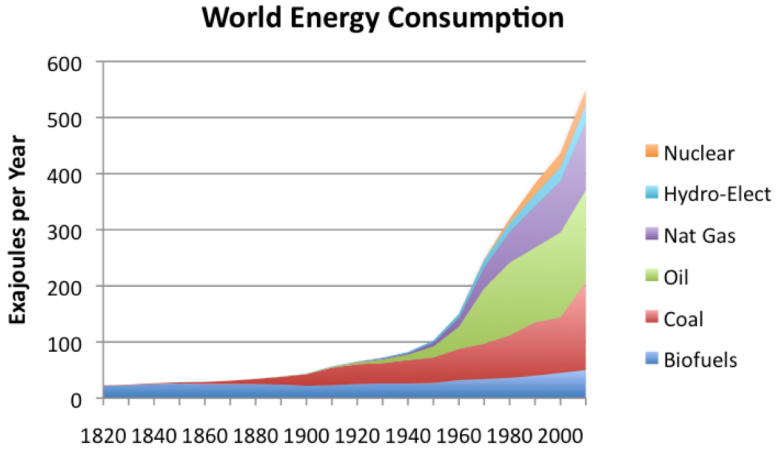
Profitability in a Green Energy Future

Understanding the role of Conventional and
Renewable Energies in the German Power Market

Background

Basis:

- Global power consumption is continually increasing
- European power production has been towards renewable energy (e.g. wind, solar, hydro-electric)
- Off-peak energy storage plays an important role in balancing the load
- The need for fossil-fuel based energy production is decreasing



Problem:

- *For fossil-fuel energy producers, when is it profitable to operate the plant?*
- *Does the weather forecast play a significant role in the energy price?*

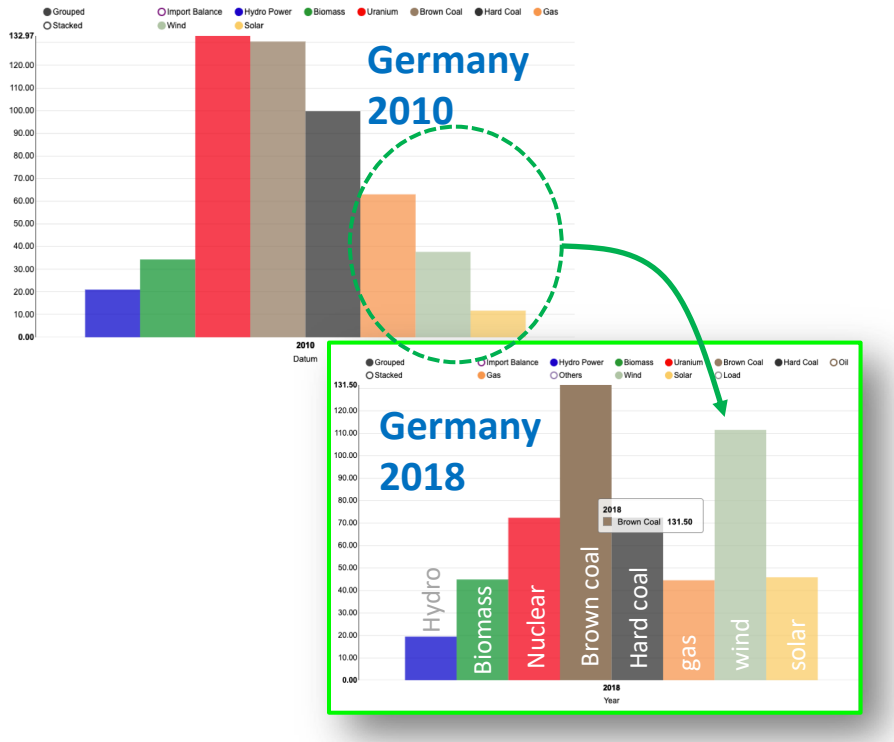
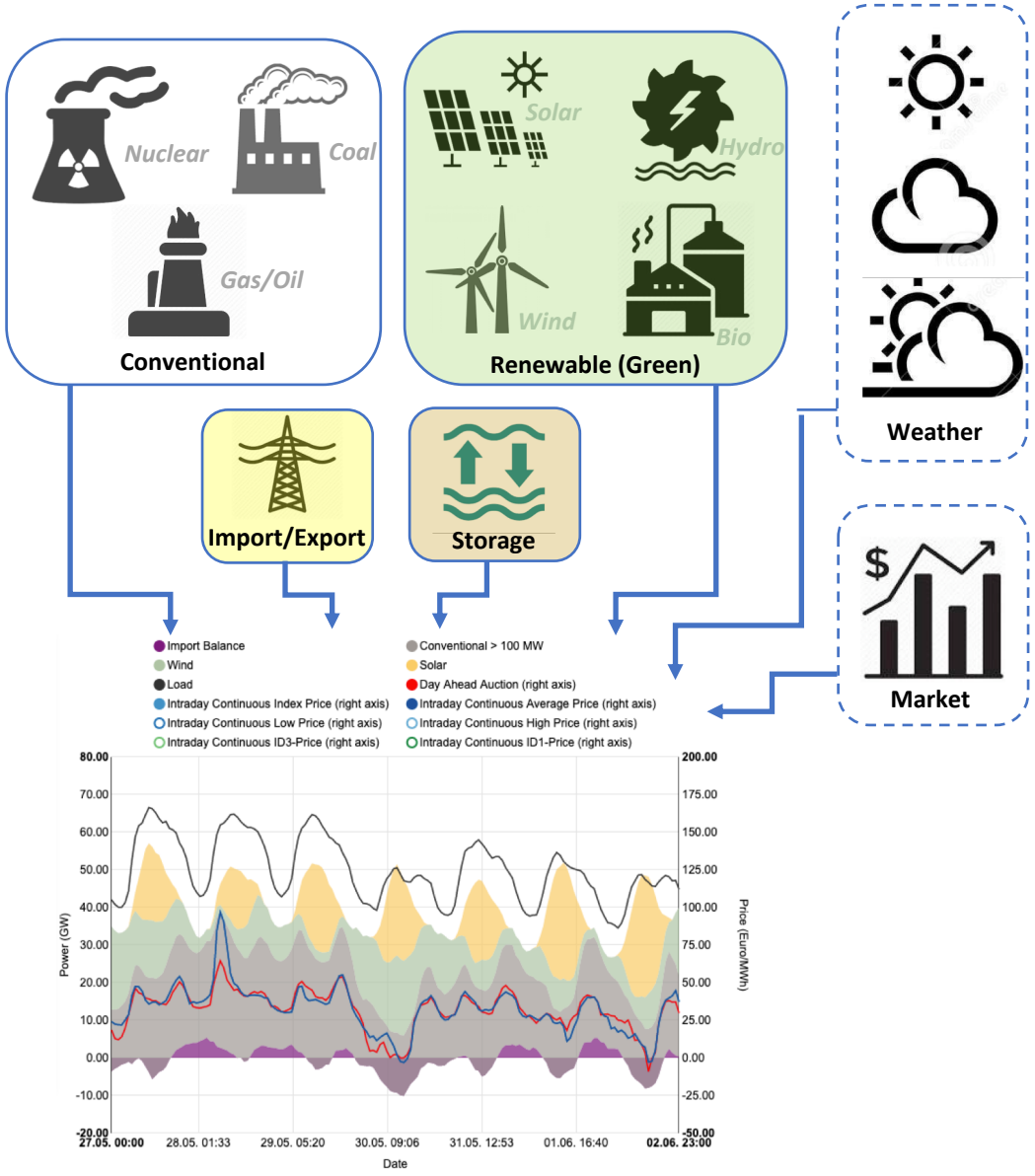


Chart sources:

- https://www.treehugger.com/fossil-fuels/world-energy-use-over-last-200-years-graphs.html
- https://www.energy-charts.de/energy.htm?source=all-sources&period=annual&year=2019

Analysis



Possible Questions:

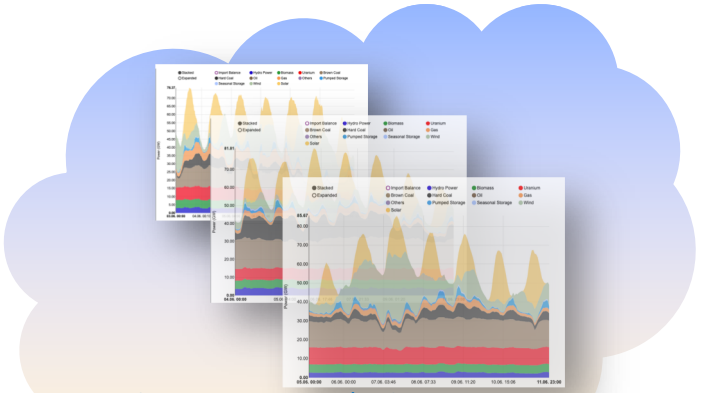
- What portion of the energy production comes from conventional and renewable sources?
- Does the weather forecast influence the energy spot price?
- When is it profitable to operate coal or gas energy production plants?

Solution:

- *By utilizing Big data analysis, the break-down of the energy source utilization trends will be determined*
- *The link with external sources (e.g. weather forecasts), will allow the determination of the energy price relative to environmental factors*

Project Infrastructure

Chart sources:
- https://www.meteoblue.com/en/weather-maps/
- https://www.energy-charts.de/energy.htm?source=all-sources&period=annual&year=2019

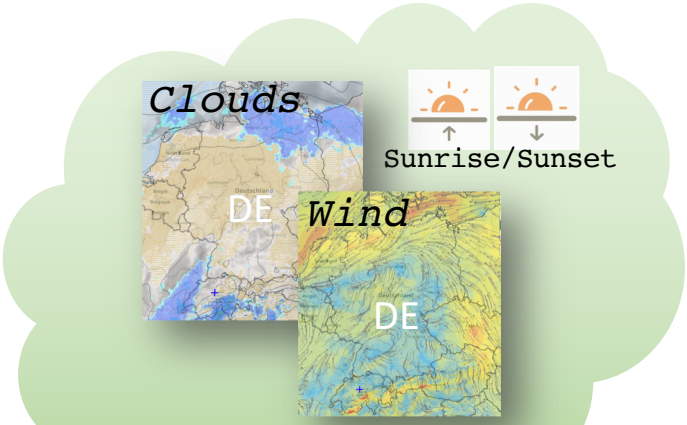


German Energy production:
Type/Source/Location/Demand

Daily

JSON files

Python
JSON loader



German/European 3-day
weather forecast

15-min

REST API JSON

Python

Python

Python

Producers…

…Consumers

Python
Kafka→InfluxDB

kafka
Event hub

Process topic consumers

InfluxQL

InfluxQL

influxdb

jupyter

pandas

matplotlib

Static analysis

Grafana

Project documentation

Chart sources:
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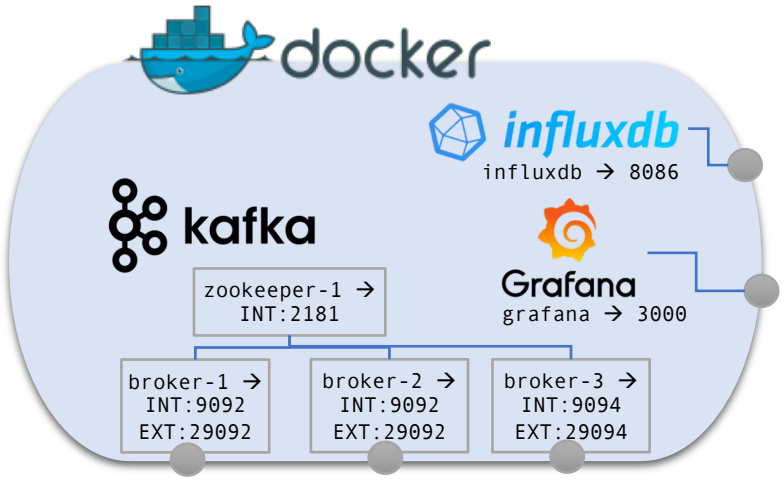
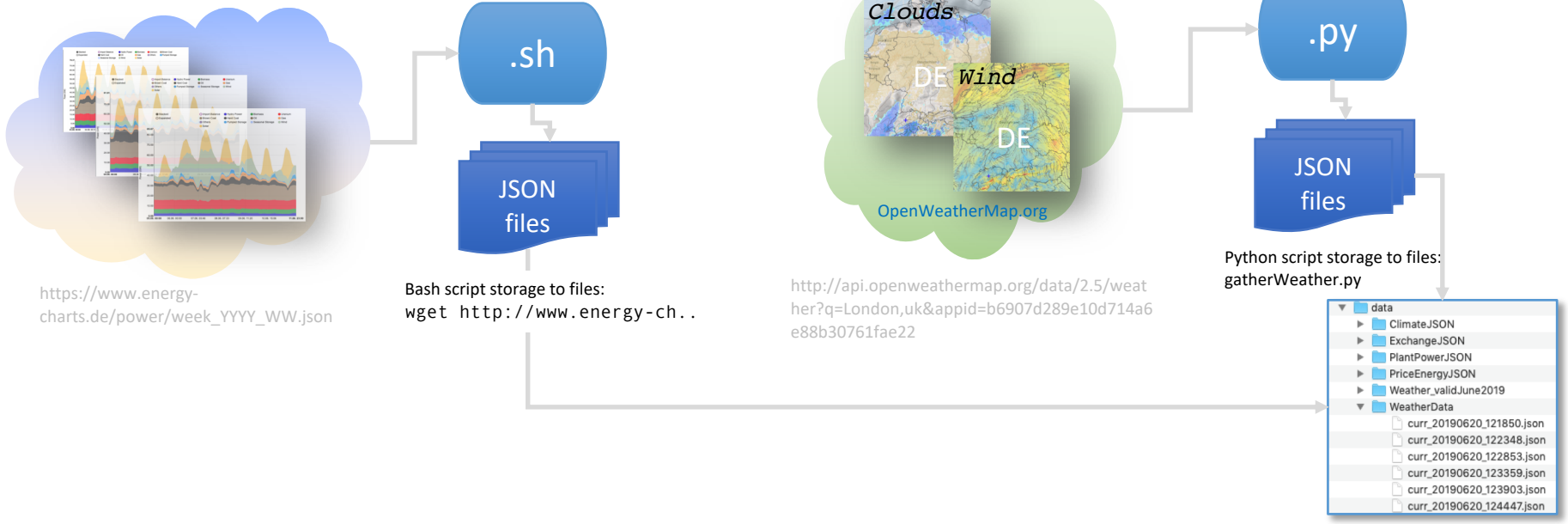
Infrastructure: **Preparation**



Setup:

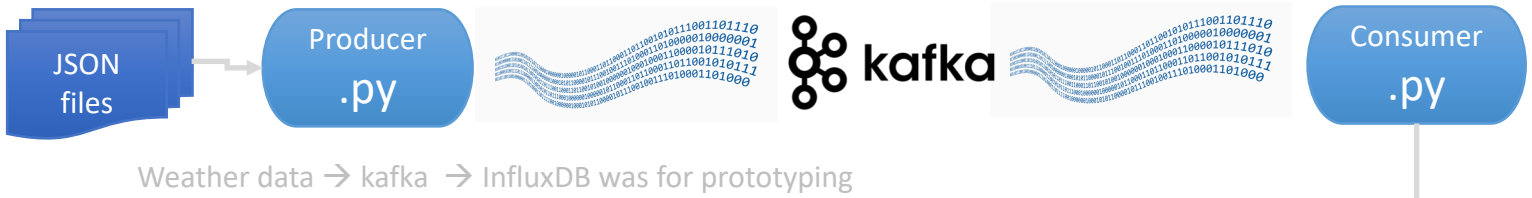
- Hardware:
  - Ubuntu 18 LTS , Xeon 6-core 3GHz, 24GB
- Docker:
  - InfluxDB, Kafka, Grafana
- Data to files:
  - For prototyping, all data was saved in JSON files; later this can be changed to direct API calls

Energy & Weather data: Extract JSON files to local directory



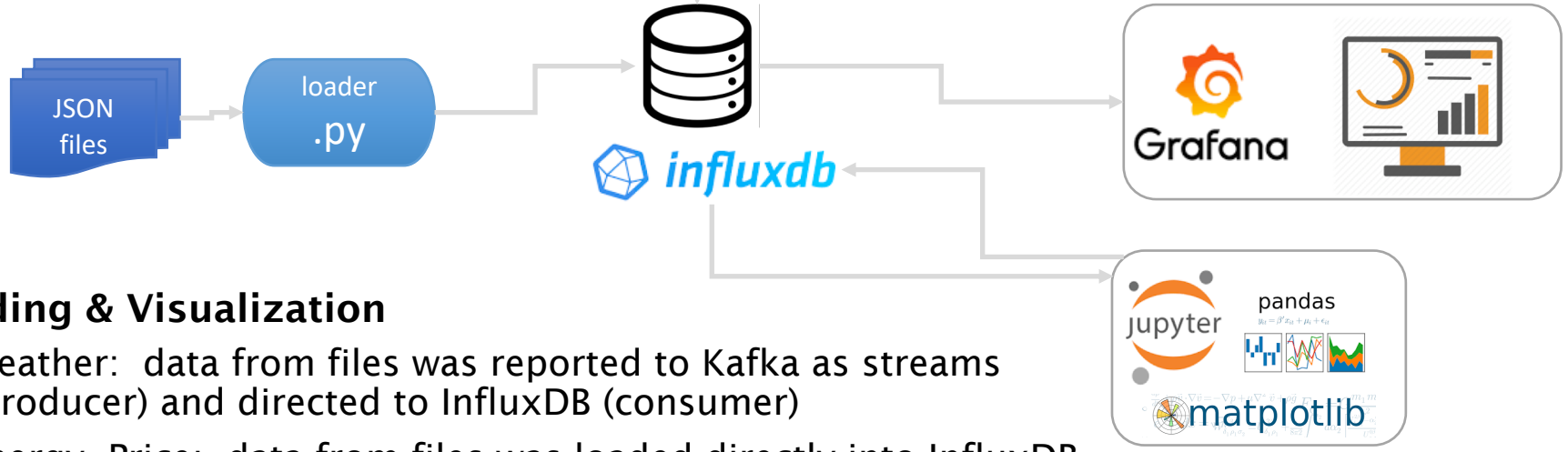
Infrastructure: **Loading & visualization**

Weather data → Kafka



Weather data → kafka → InfluxDB was for prototyping

Energy, Price data → InfluxDB



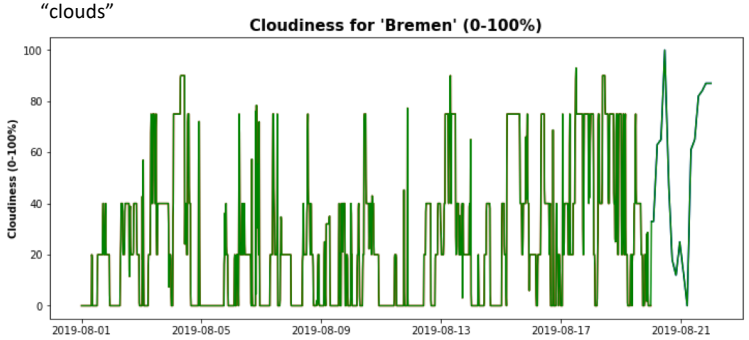
Loading & Visualization

- Weather: data from files was reported to Kafka as streams (producer) and directed to InfluxDB (consumer)
- Energy, Price: data from files was loaded directly into InfluxDB
- Analysis & Visualization: Queries from InfluxDB → Grafana and InfluxDB → Jupyter/Python

Analysis: **Weather → Solar Power**

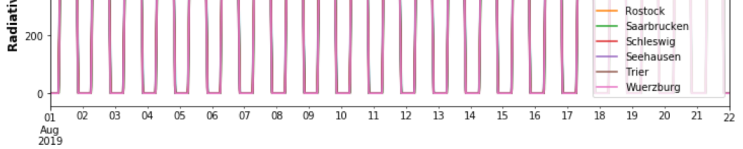
Solar power Prediction

"clouds"



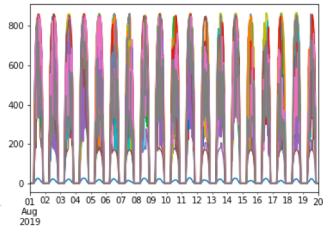
Cloudiness (0 -100%) for selected cities

pysolar

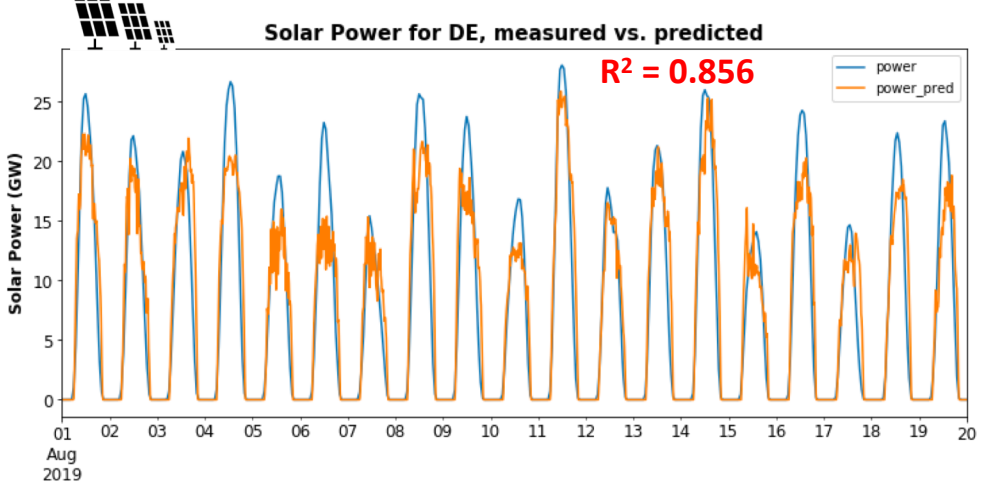


Predicted 'Clear Sky' solar flux

```
radPredict[ct] =
(((100 -cloudsall[ct])
/100)*0.8 + 0.2)*radcalc[ct]
```



```
cols = [*cities,'timestamp']
reg= linear_model.LinearRegression()
reg.fit(X=solarRadPowerTrain[cols],y=solarRadPowerTrain.power)
```



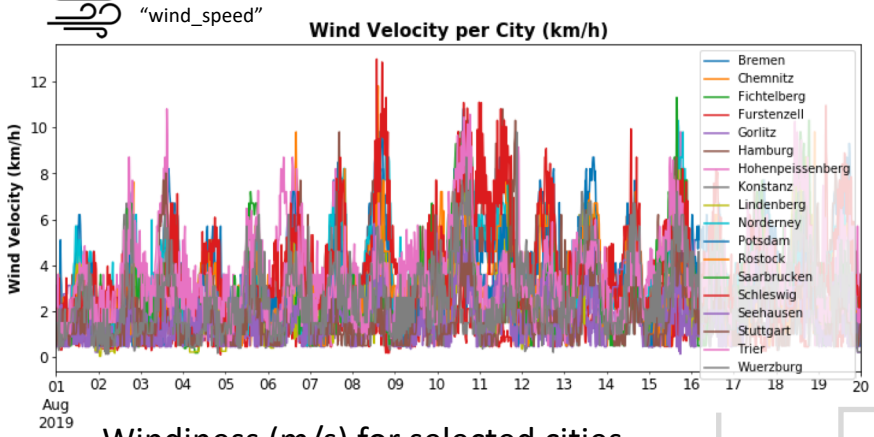
Prediction

- Predicted solar power is a regression fit using the measured solar power and the calculated solar flux of selected cities

Analysis: **Weather → Wind Power**

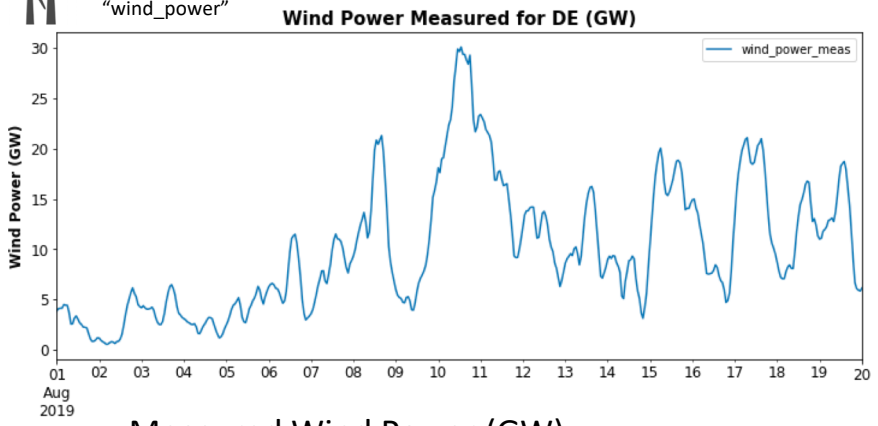
Wind power Prediction

"wind_speed"



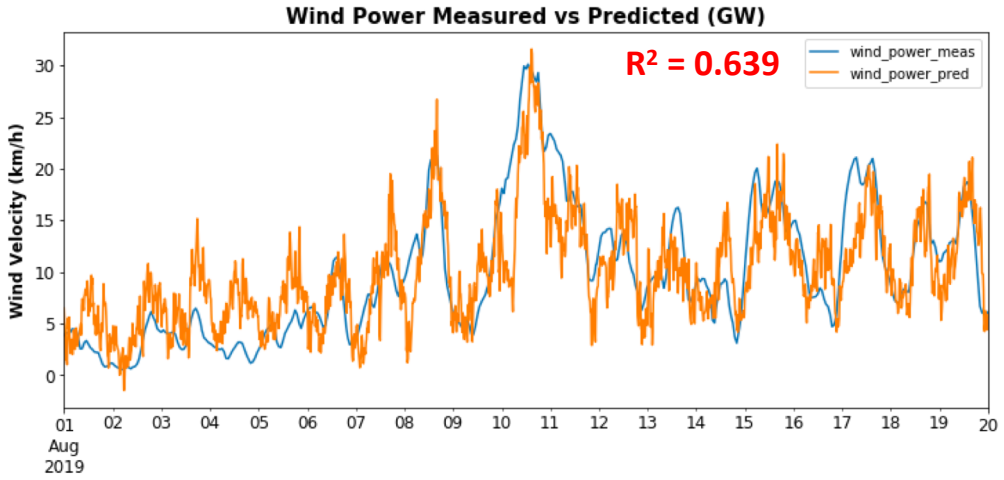
Windiness (m/s) for selected cities

"wind_power"



Measured Wind Power (GW)

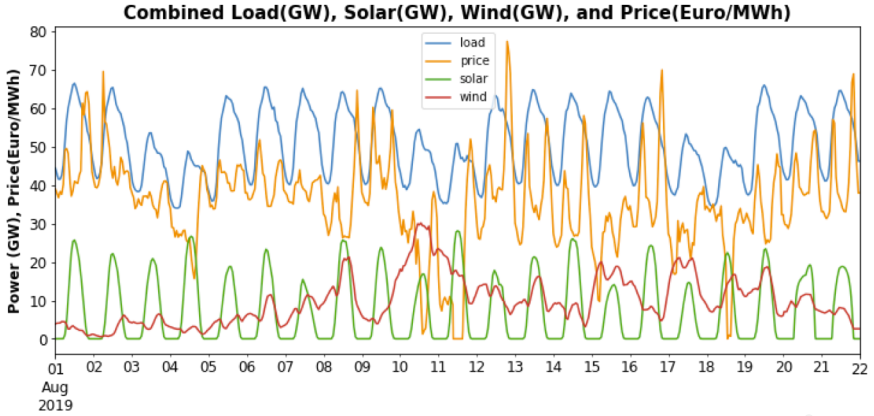
```
windcols = cities
reg = linear_model.LinearRegression()
reg.fit(X=windPowerWeather[windcols],
        y=windPowerWeather.wind_power_meas)
```



Prediction

- Predicted wind power is a regression fit using the measured wind power and the wind velocity for selected cities

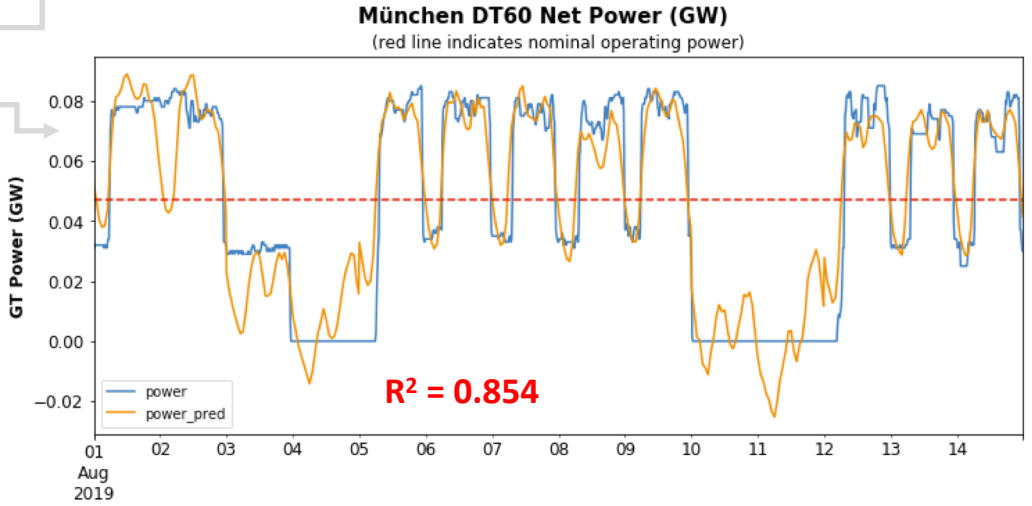
Analysis: **Gas Plant Power Prediction**



Grid conditions (Load, Price, Solar, Wind)

Measured power for specific plant “München DT60”, (GW)

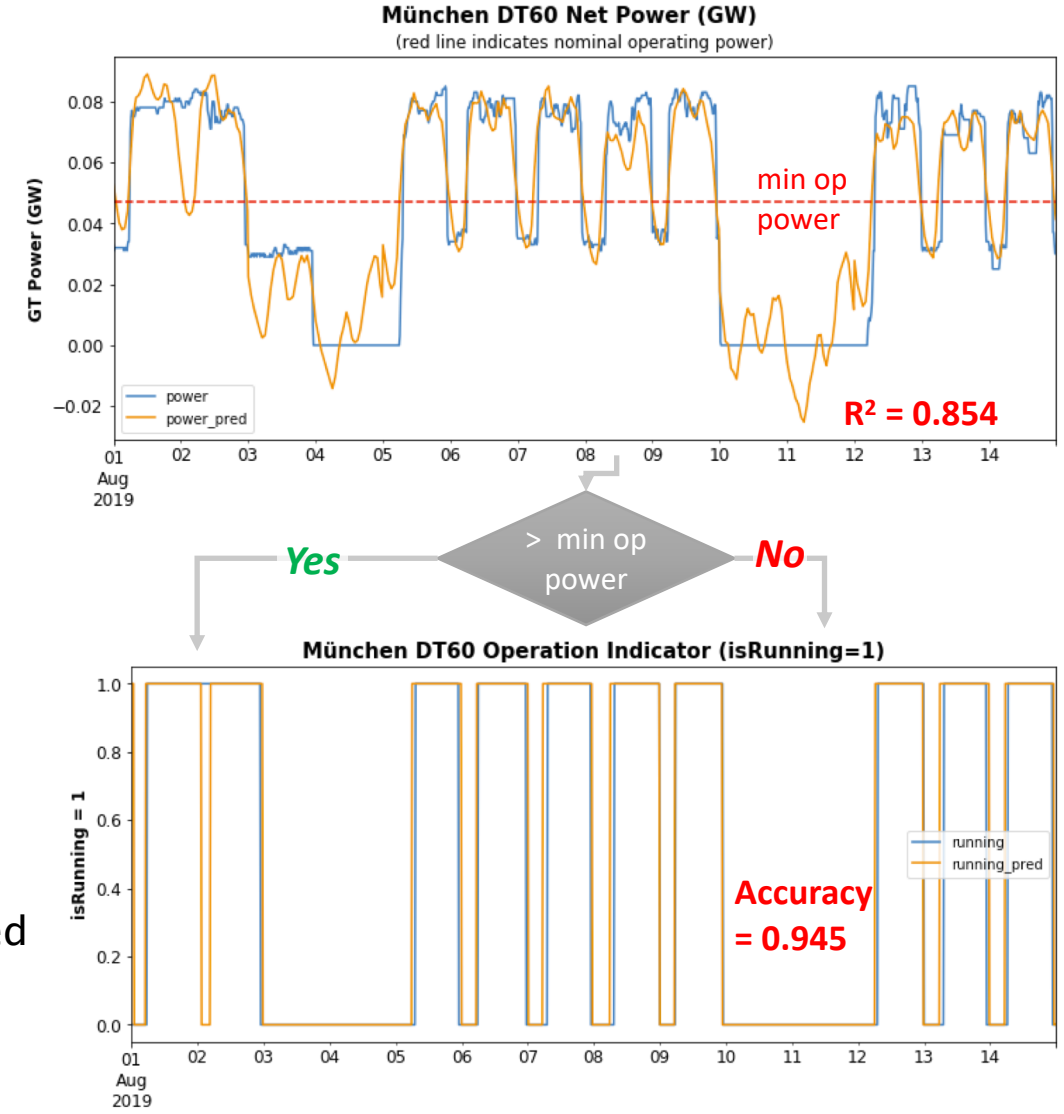
```
regressorCol = 'power'
regressCols = ['load','price','solar','wind','day','isWeekend']
reg = linear_model.LinearRegression()

X = dfRun[regressCols].loc[indices]
y = dfRun[regressorCol].loc[indices]
reg.fit(X=X,y=y)
```



Prediction

- Predicted plant power is a regression fit using the balance of grid requirements and solar and wind sources

Analysis: **End Result → Should the plant operate?**



Result:

- The decision to operate the plant depends on the predicted power need and revenue
- This can be simplified to a binary predictor for ***On/Off***