

Prediction of Renewable Power Loss caused by Feed-In Management

Using Advanced Linear Models and Recurrent Neural Networks for Time Series Predictions


26.November 2020



Tjade Appel

- B.Eng. in Mechanical Engineering
- M.Sc. in Sustainable Energy Systems
- M. Thesis: Modelling Environmental Conditions for the Design of Offshore Wind Turbines
- 1 year internship experience in the energy industry
- If you want to talk sports, I'm your man!

Looking for a challenging position as a Jr. Data Scientist.

 [GitHub.com/tjade27](https://github.com/tjade27)

 [LinkedIn.com/in/Tjade-Appel](https://www.linkedin.com/in/Tjade-Appel)



Jonas Jaenicke

- B.Eng. in Industrial Engineering
- M.Sc. in Computer Science
- M. Thesis: Modelling of Pumped Hydro Power Energy Storage
- 3 years internship experience in energy industry and M&A
- adventures Kitesurfer, wind lover & Rock Climber

Let's explore together! Data, Systems, Cultures, Models.

 [GitHub.com/JonJae](https://github.com/JonJae)

 [LinkedIn.com/in/JonasJaenicke](https://www.linkedin.com/in/JonasJaenicke)

I

BACKGROUND: energy industry

Volatile Renewable Energy, Definition of
Feed-In Management, Demand-Side-Management

II

EDA: Data Overview, Preprocessing

Feed-In-Management Data, GFS Weather
Forecasting Data, Price Data, Consumption Data

III

MODELS: comparison of results

Naive models, FB Prophet, LSTMs,
best model results and use case

IV

FUTURE WORK

Feed-In Management as a Service through
integration of APIs, optimization of LSTMs

A solid yellow vertical bar on the left side of the slide.

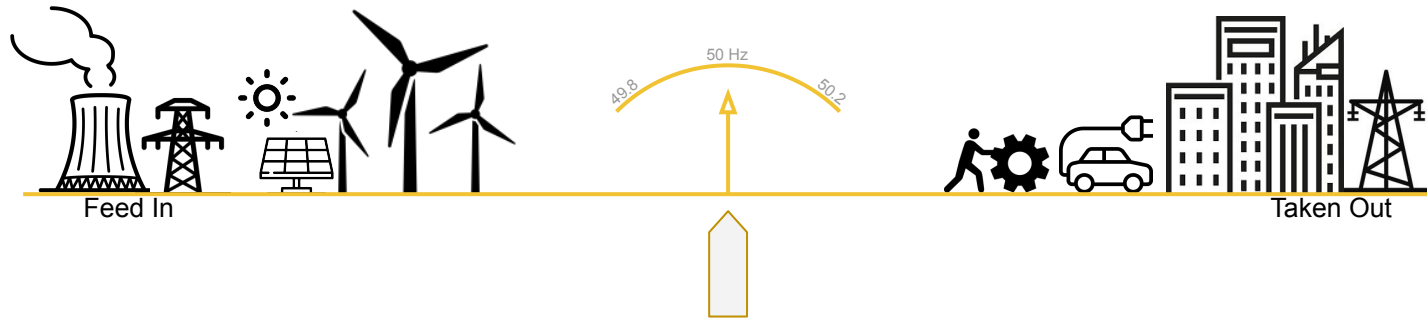
BACKGROUND

DATA ANALYSIS

MODEL RESULTS

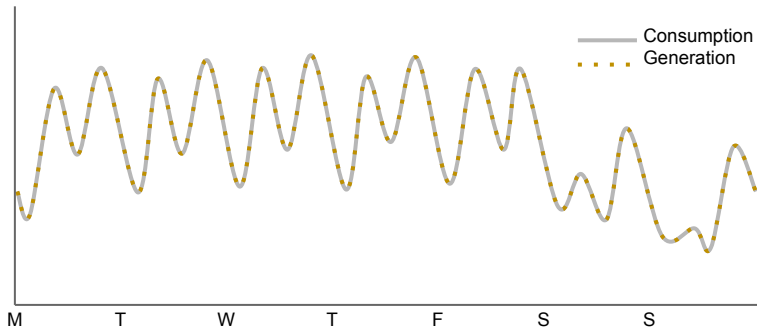
FUTURE WORK

Energy fed into the system needs to equal energy taken out of the system at all times. This was already difficult with conventional electricity generation. It is even more difficult with a combination of volatile renewable energy sources. For example, on a windy and sunny day in June, there is potentially a lot of excess wind energy. Feed-In Management describes the curtailment of energy to protect grid infrastructure of overloads. What if we could instead use the excess energy?

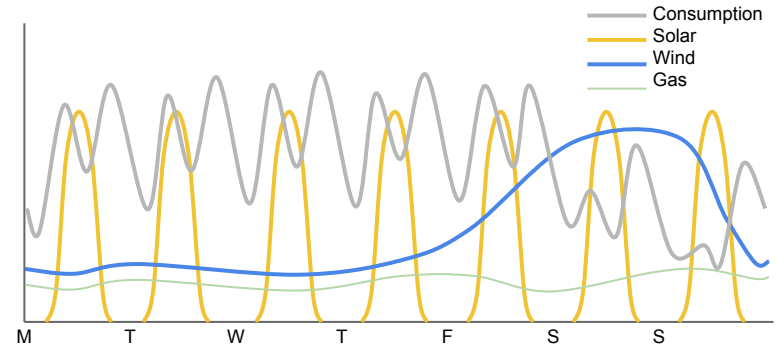


Energy fed into the system needs to equal energy taken out of the system at all times. This was already difficult with conventional electricity generation. It is even more difficult with a combination of volatile renewable energy sources. For example, on a windy and sunny day in June, there is potentially a lot of excess wind energy. Feed-In Management describes the curtailment of energy to protect grid infrastructure of overloads. What if we could instead use the excess energy?

Conventional Electricity Grid

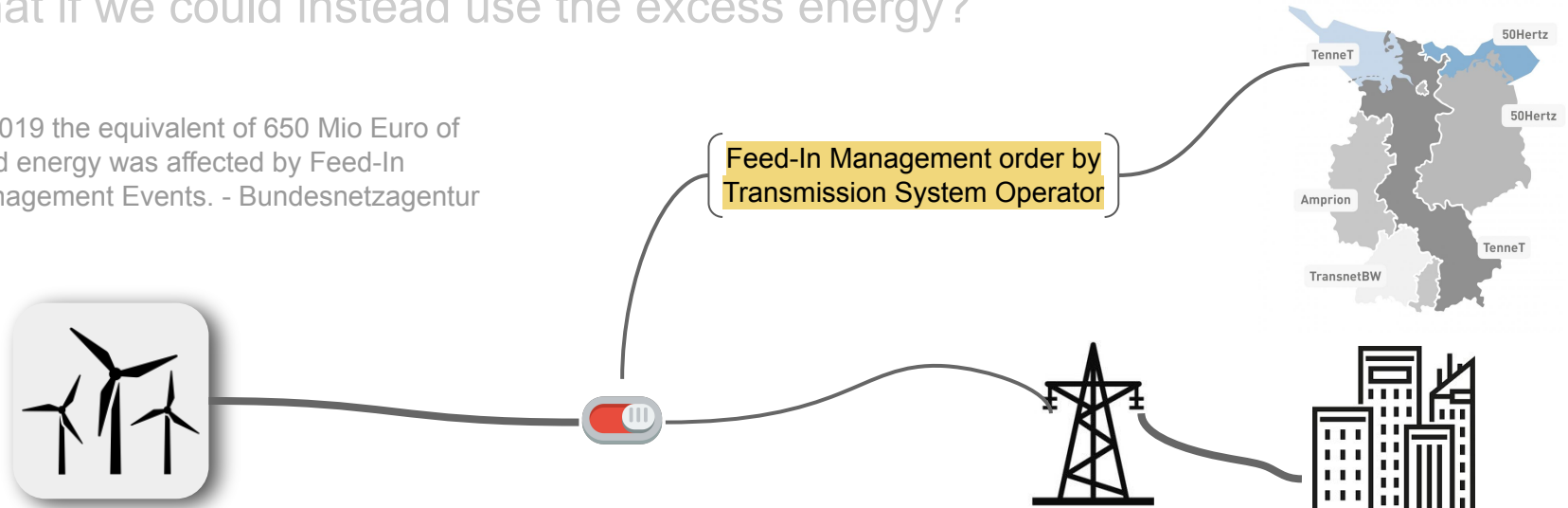


Renewable Electricity Grid



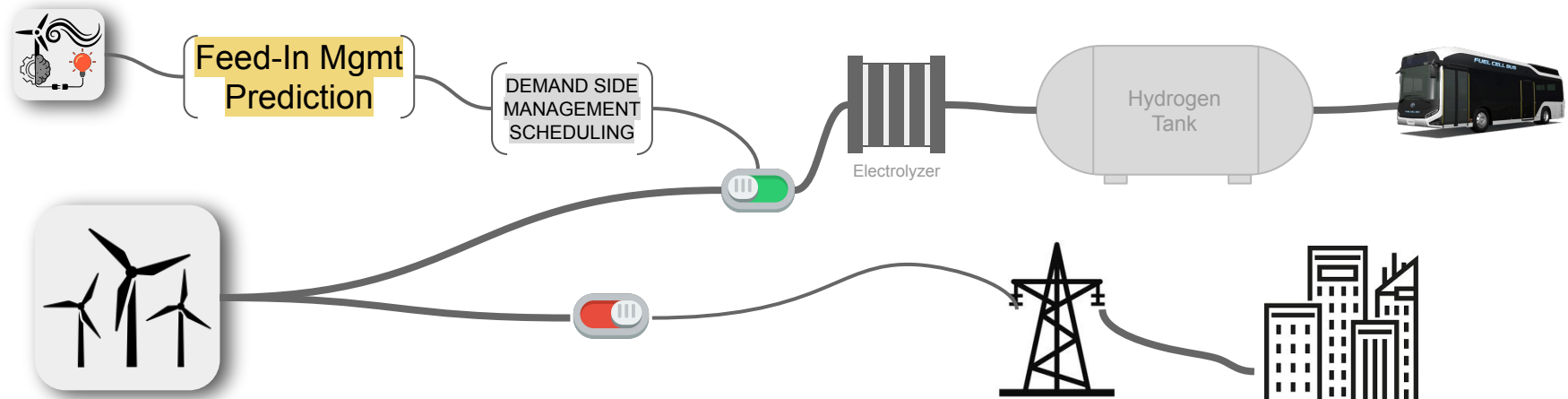
Energy fed into the system needs to equal energy taken out of the system at all times. This was already difficult with conventional electricity generation. It is even more difficult with a combination of volatile renewable energy sources. For example, on a windy and sunny day in June, there is potentially a lot of excess wind energy. **Feed-In Management** describes the curtailment of energy to protect grid infrastructure of overloads. What if we could instead use the excess energy?

In 2019 the equivalent of 650 Mio Euro of wind energy was affected by Feed-In Management Events. - Bundesnetzagentur



Energy fed into the system needs to equal energy taken out of the system at all times. This was already difficult with conventional electricity generation. It is even more difficult with a combination of volatile renewable energy sources. For example, on a windy and sunny day in June, there is potentially a lot of excess wind energy. Feed-In Management describes the curtailment of energy to protect grid infrastructure of overloads.

What if we could instead use the excess energy?



BACKGROUND

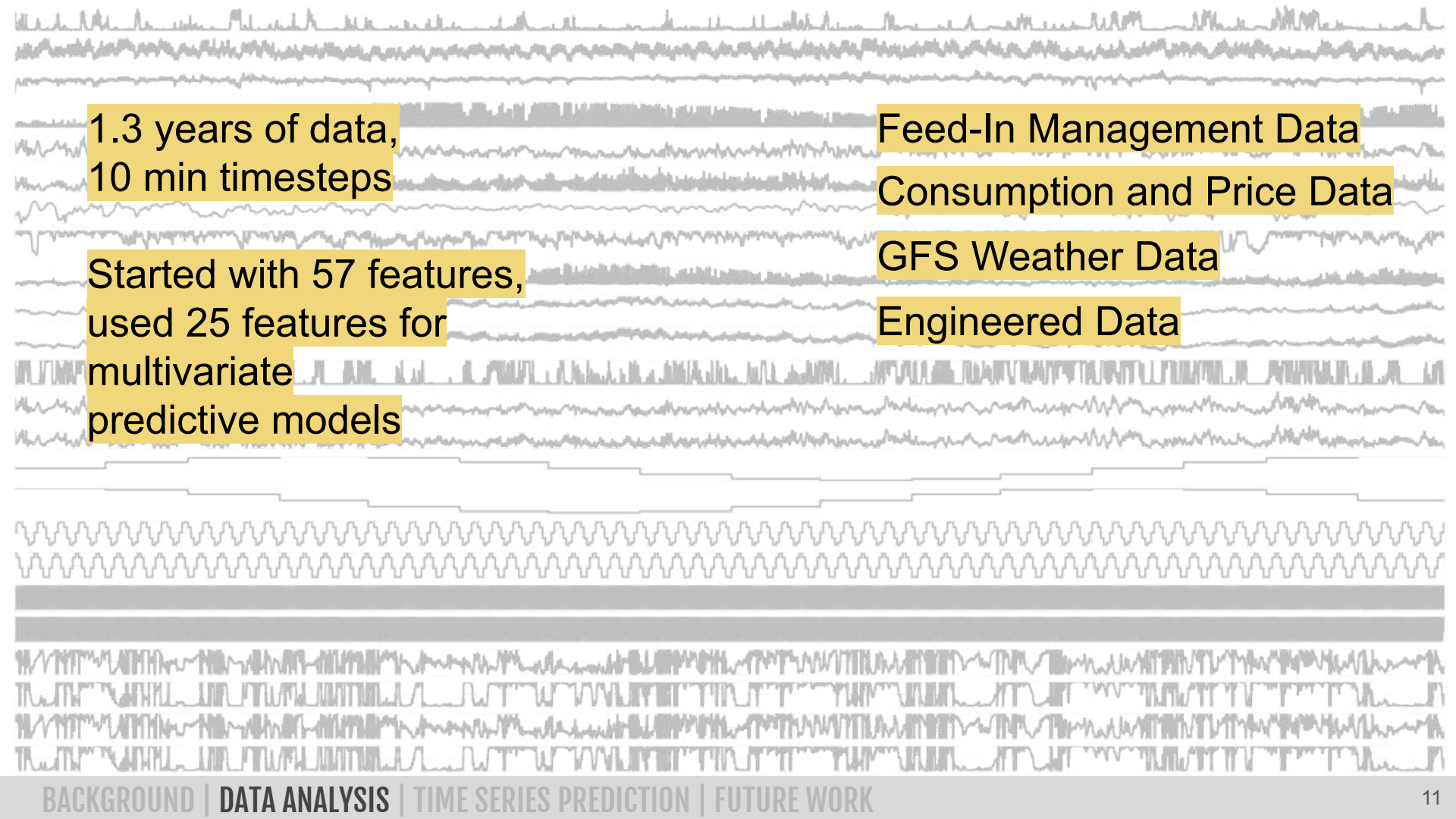
DATA ANALYSIS

MODEL RESULTS

FUTURE WORK

Onshore Wind Farm in
Twistringen, Germany. 6 Enercon
E66 and 6 E70 turbines with
22,8 MW installed capacity





1.3 years of data,
10 min timesteps

Feed-In Management Data

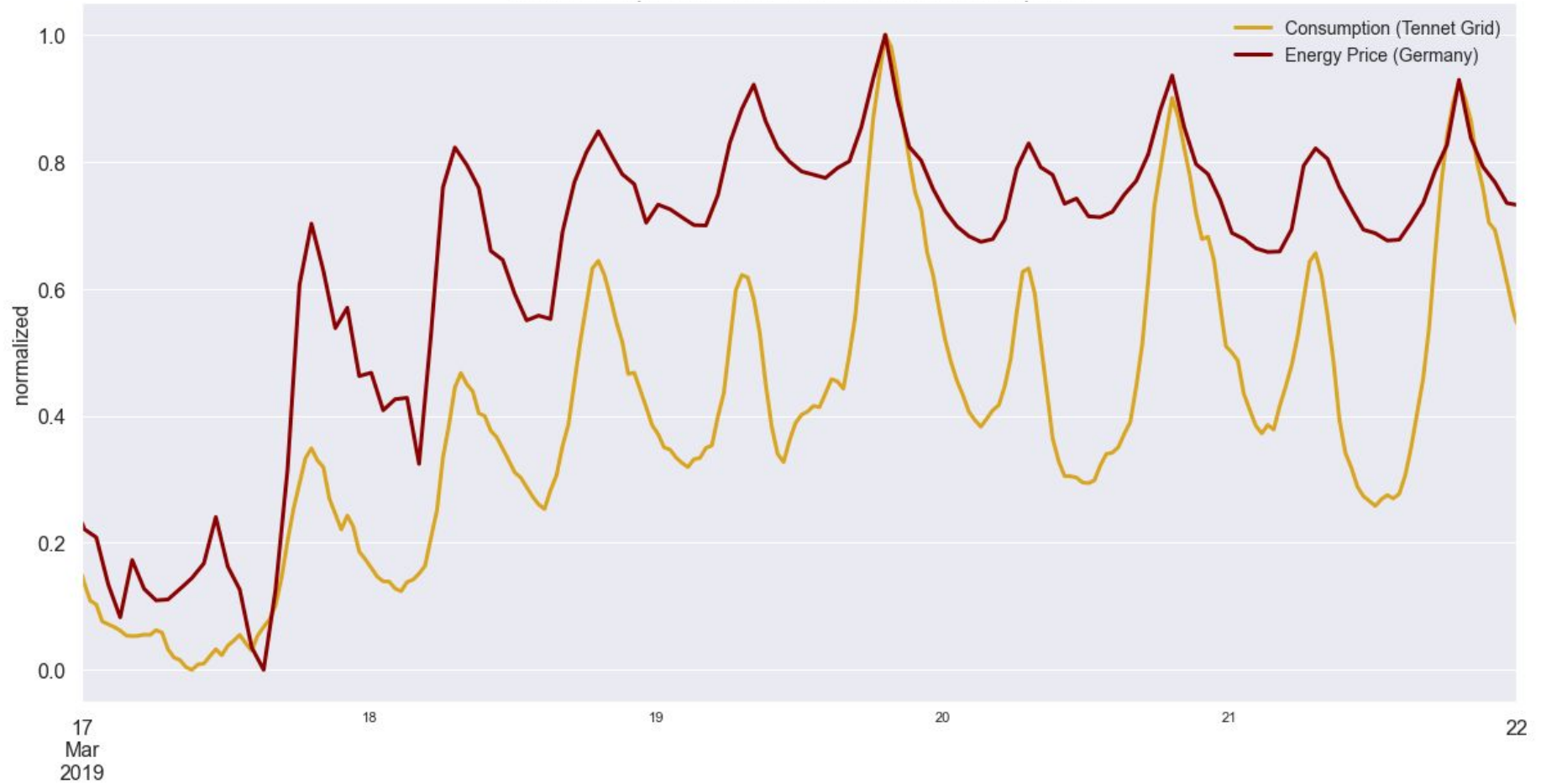
Consumption and Price Data

GFS Weather Data

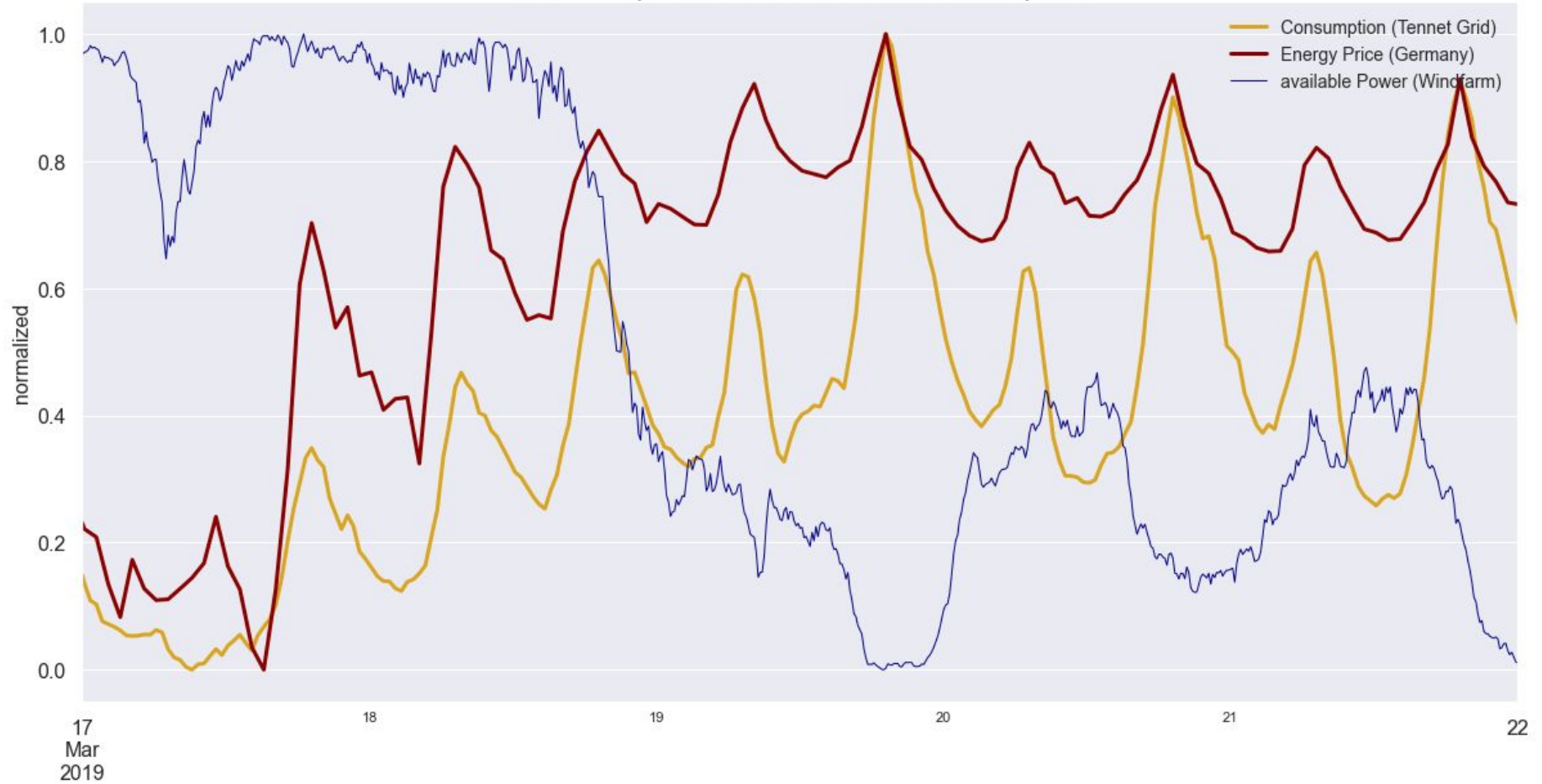
Engineered Data

Started with 57 features,
used 25 features for
multivariate
predictive models

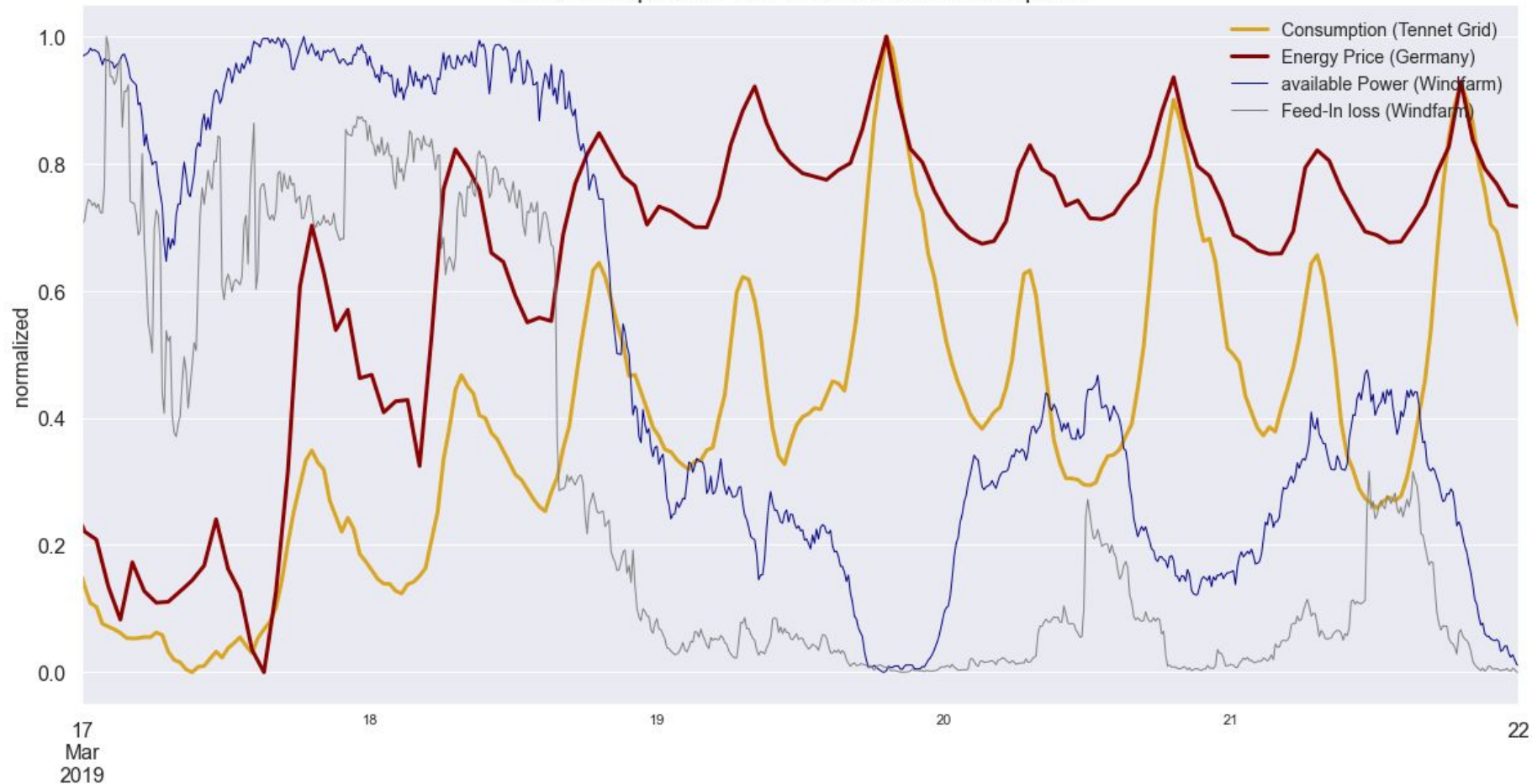
German Energy Price, Tennet Consumption



German Energy Price, Tennet Consumption, and available power

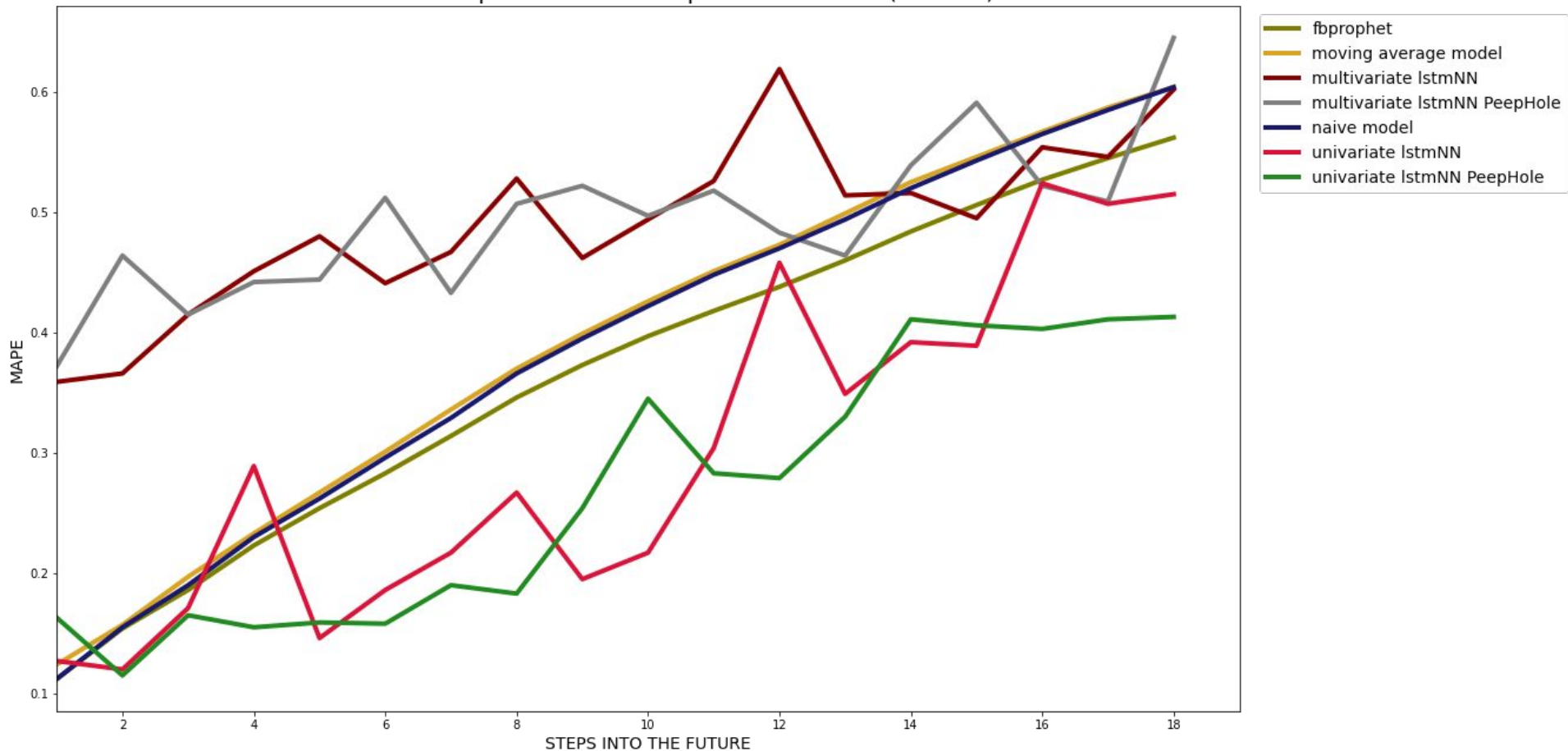


German Energy Price, Tennet Consumption, and
windfarm specific Feed-In loss and available power

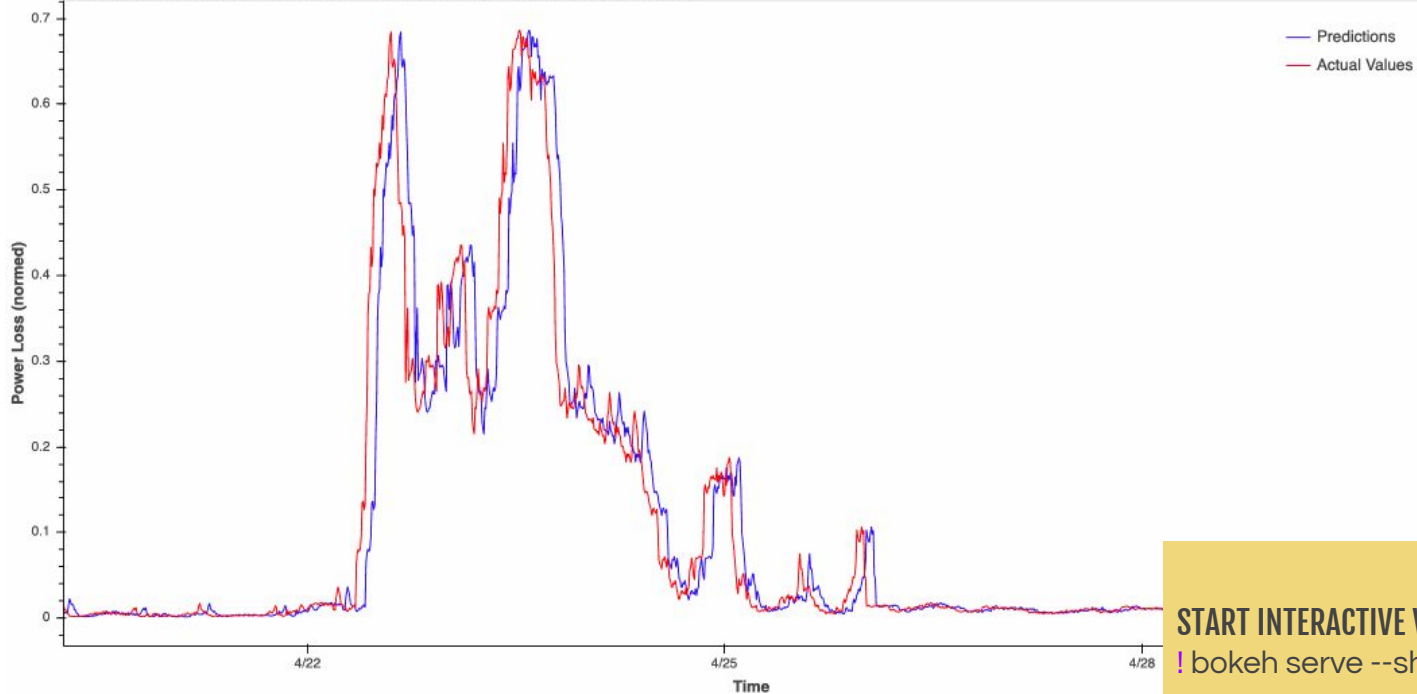


BACKGROUND
DATA ANALYSIS
MODEL RESULTS
FUTURE WORK

MAPE for each predicted timestep into the future (test set)



Predictions vs Actual Values for Test Set on Step 10 calculated by Naive Shift Model



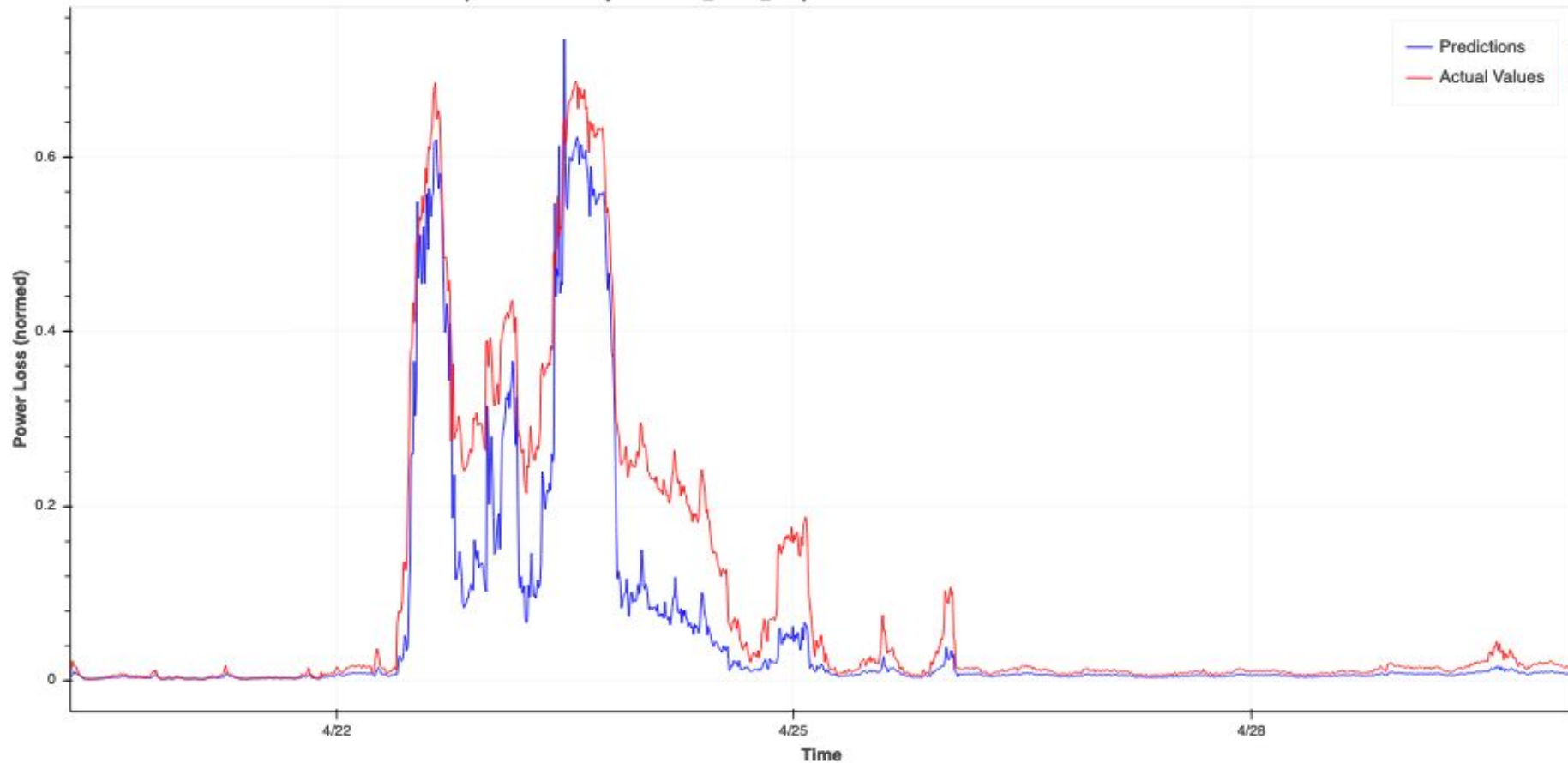
Model
Naive Shift Model

Dataset
Test

Step
Step 10

START INTERACTIVE VISUALISATION
! bokeh serve --show visualization.py

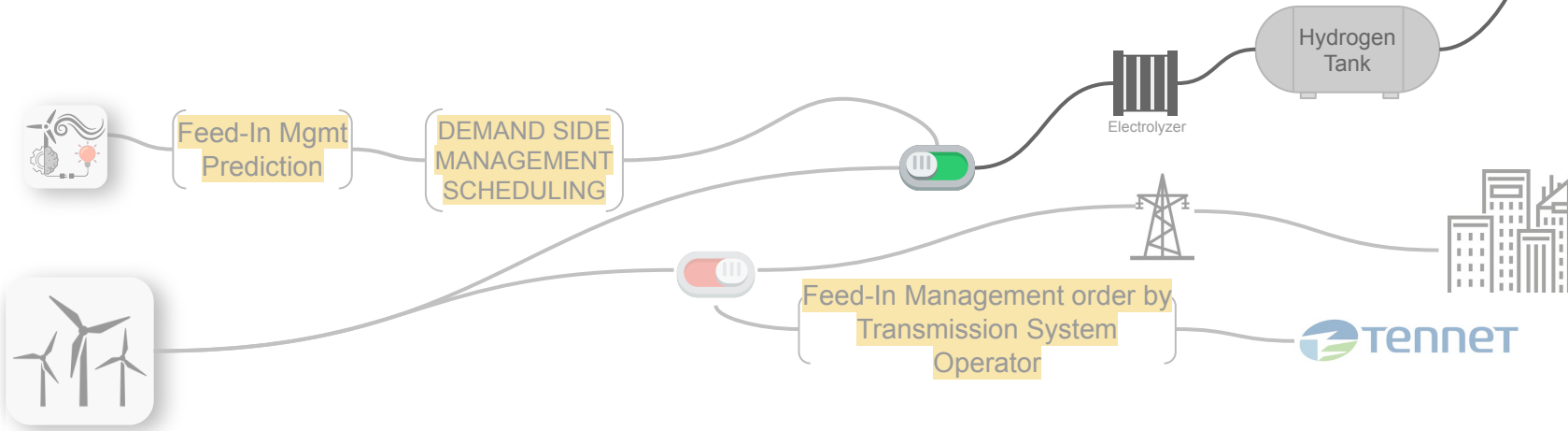
Predictions vs Actual Values for Test Set on Step 18 calculated by Univariate_LSTM_PeepHole



Simplifications:

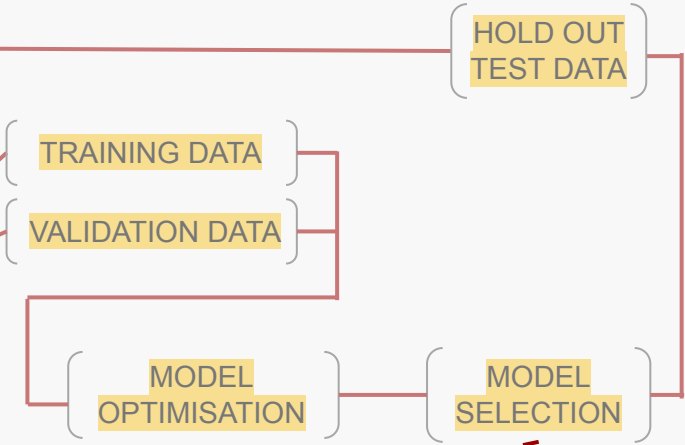
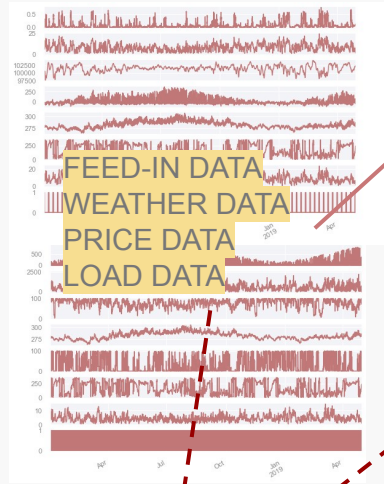
- energy to hydrogen conversion rate: 48 kWh/kg
- fuel cell passenger bus 13.3 kg H₂/ 100 km
- no ramp-up time, no extra logistics

	Lost Power in MWh	Lost Power (forecasted) in MWh	Percentage in %	Potential Mileage of Fuel Cell Bus in km
Prediction 10 minutes ahead	503	495.0	98.4	77343
Prediction 1.5 hours ahead	503	451.9	89.8	70609
Prediction 3 hours ahead	503	322.3	64.1	50359

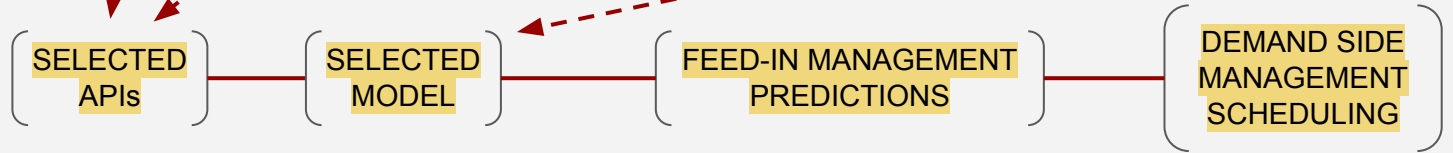


BACKGROUND
DATA ANALYSIS
MODEL RESULTS
FUTURE WORK

[MODEL DESIGN]



[USE CASE]



END. QUESTIONS?

Prediction of Renewable Power Loss caused by Feed-In Management

26.November 2020



Tjade Appel

- B.Eng. in Mechanical Engineering
- M.Sc. in Sustainable Energy Systems
- M. Thesis: Modelling Environmental Conditions for the Design of Offshore Wind Turbines
- 1 year internship experience in the energy industry
- If you want to talk sports, I'm your man!

Looking for a challenging position as a Jr. Data Scientist.



[GitHub.com/tjade27](https://github.com/tjade27)



[LinkedIn.com/in/Tjade-Appel](https://www.linkedin.com/in/Tjade-Appel)



Jonas Jaenicke

- B.Eng. in Industrial Engineering
- M.Sc. in Computer Science
- M. Thesis: Modelling of Pumped Hydro Power Energy Storage
- 3 years internship experience in energy industry and M&A
- adventures Kitesurfer, wind lover & Rock Climber

Let's explore together! Data, Systems, Cultures, Models.



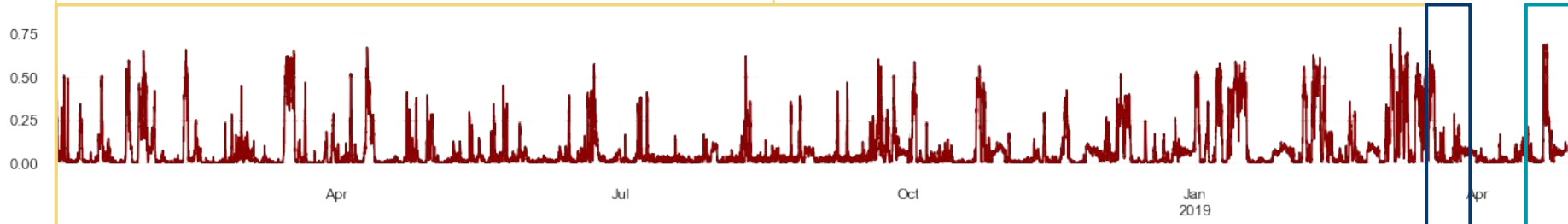
[GitHub.com/JonJae](https://github.com/JonJae)



[LinkedIn.com/in/JonasJaenicke](https://www.linkedin.com/in/JonasJaenicke)

DISCUSSION BACK-UP

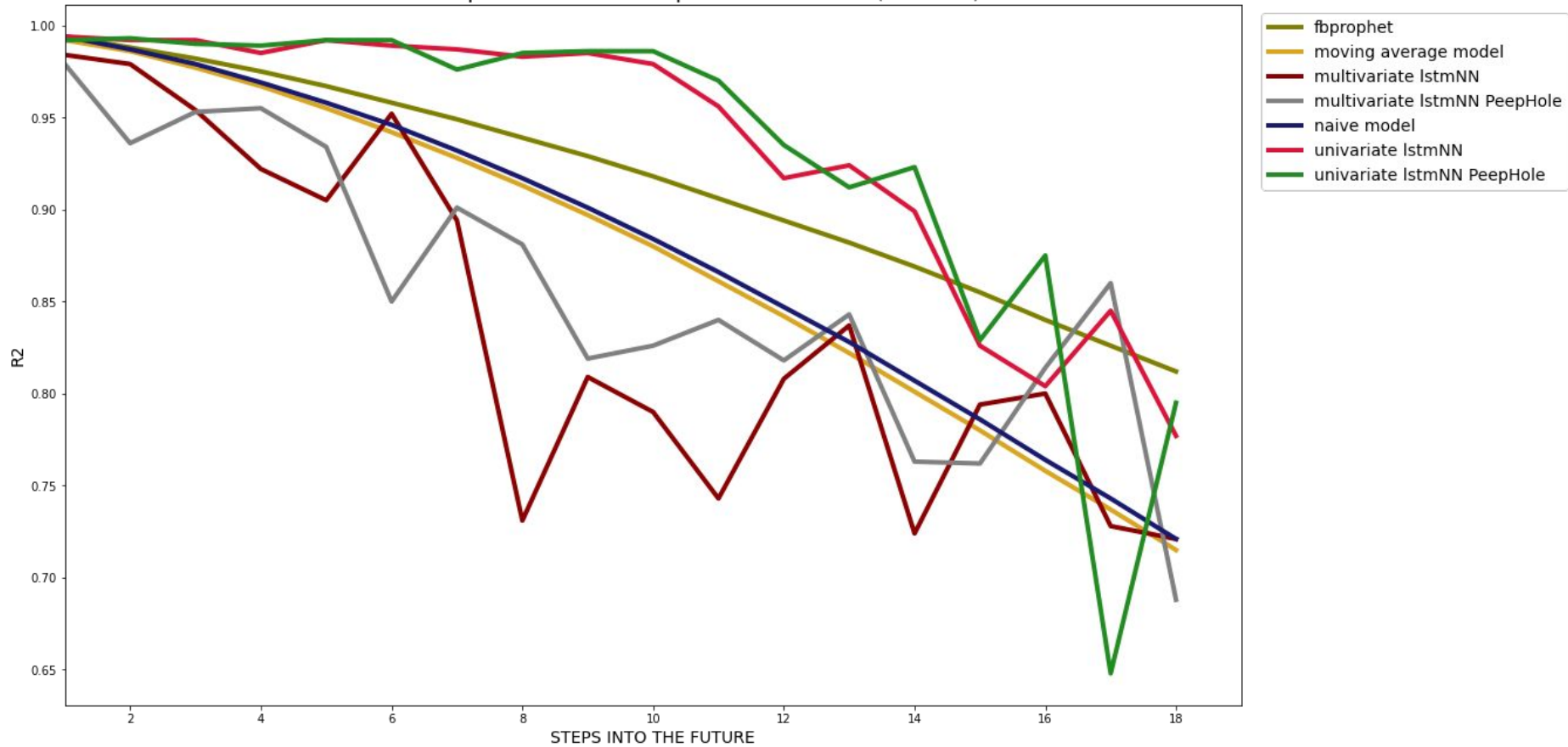
Training 440 Days (63.360 timesteps)
'01.01.2018 06:00:00' to '17.03.2019 05:50:00'



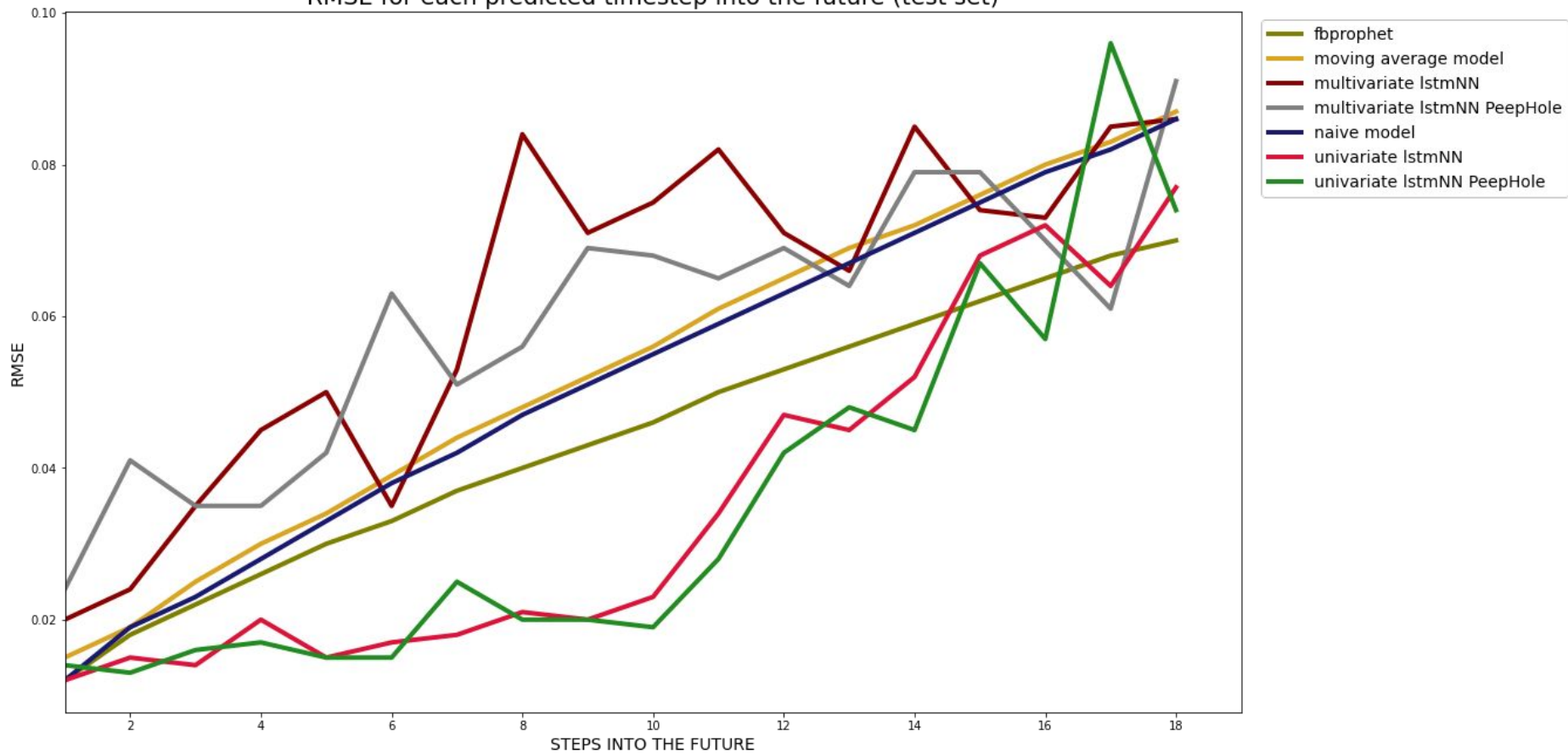
Validation 10 Days (1440 timesteps)
'17.03.2019 06:00:00' to '27.03.2019 06:00:00'

Test 10 Days (1440 timesteps)
'20.04.2019 06:00:00' to '30.04.2019 06:00:00'

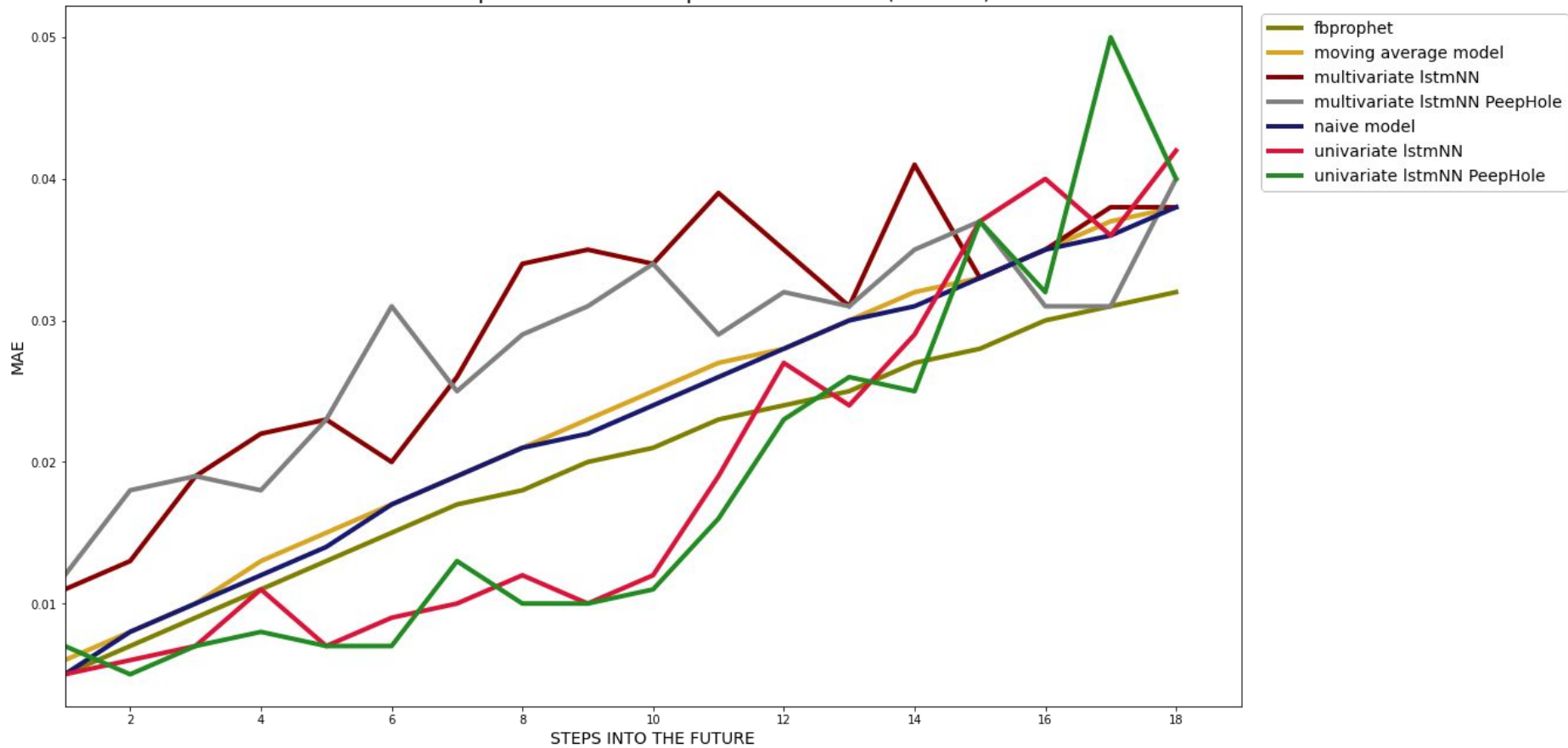
R2 for each predicted timestep into the future (test set)



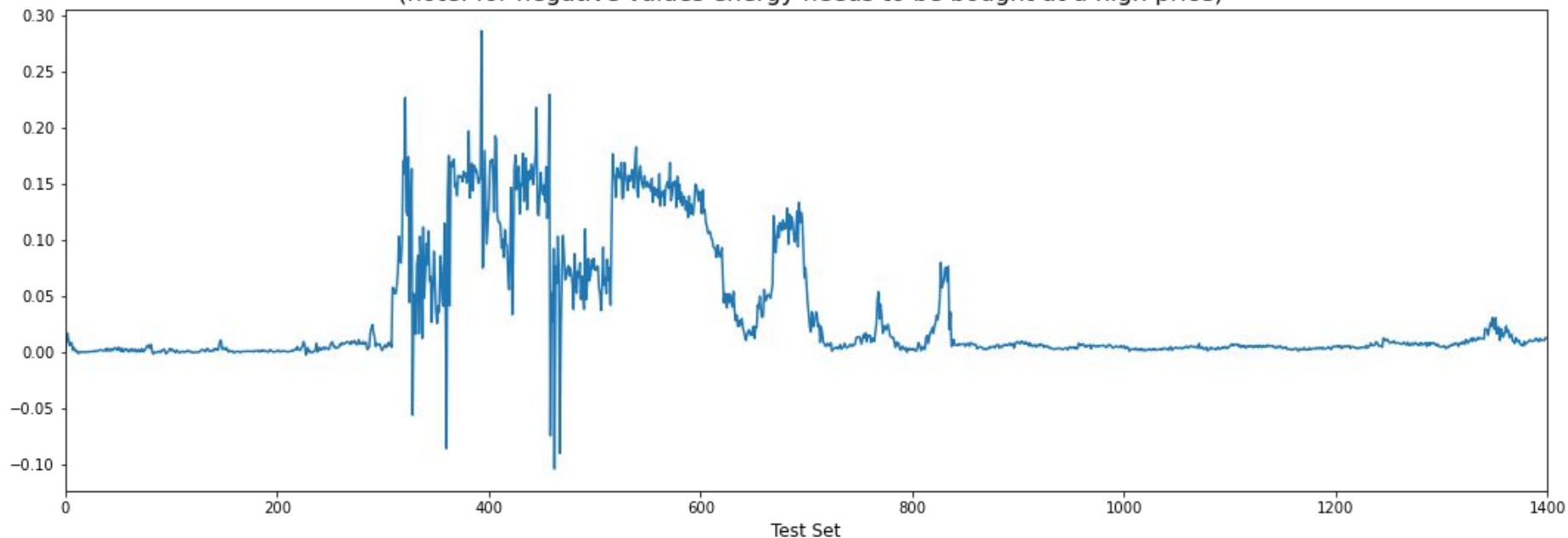
RMSE for each predicted timestep into the future (test set)



MAE for each predicted timestep into the future (test set)



Difference between predicted and
ordered energy loss at 0 Percent regulation
(note: for negative values energy needs to be bought at a high price)



Standard Week: 10 min Median German Price, Tennet Consumption, and
windfarm specific Feed-In loss and available power

