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A meta-learning approach

for short-term energy load, generation, and price forecasting

11th International Ruhr Energy Conference (INREC)

Master Thesis, University of Applied Sciences Hamm-Lippstadt
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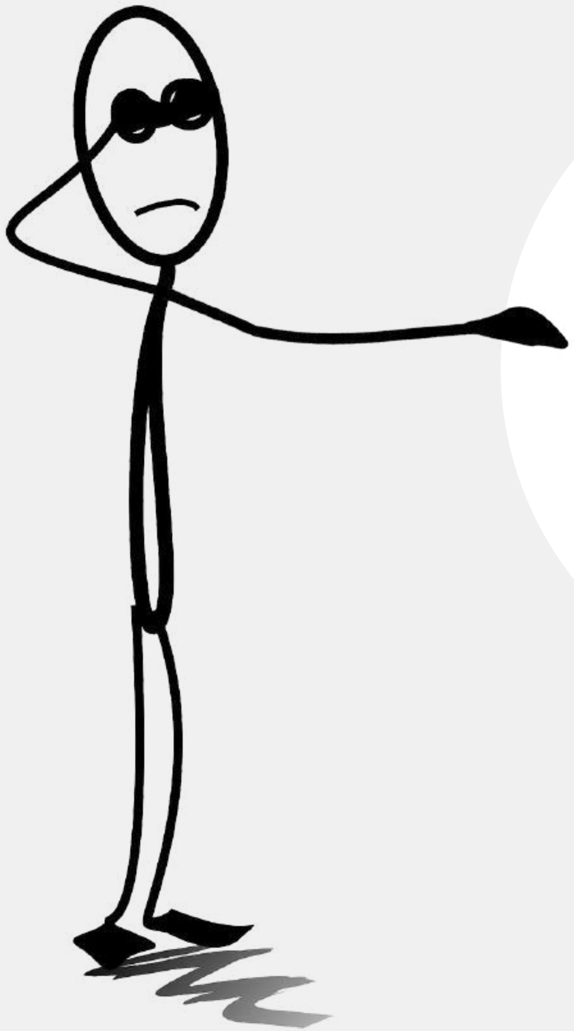
09/22

HOW FORECASTING METHODS ARE SELECTED TODAY...



LSTM

Linear Regression

ARIMA

Reccurent Neural Network

Deep AR

Moving Average

Exponential Smoothing

N-BEATS

SARIMAX

Prophet

Temporal Fusion Transformer

Prophet

Temporal Fusion Transformer

Multiple Linear Regression

Multiple Linear Regression

CNN

Prophet

Reccurent Neural Network

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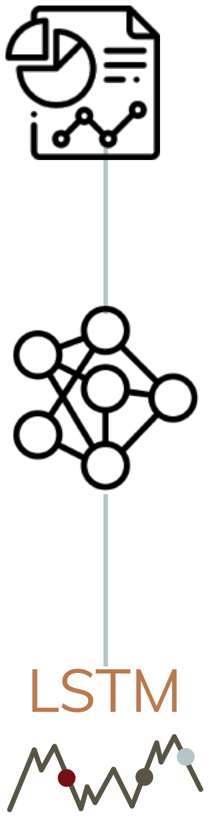
HOW THEY COULD BE SELECTED...



- Analysis of the input time series
- Trained model selects most suitable forecasting model
- Performing the forecast

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01 Forecast of Time Series

02 Model Selection

03 Case Study

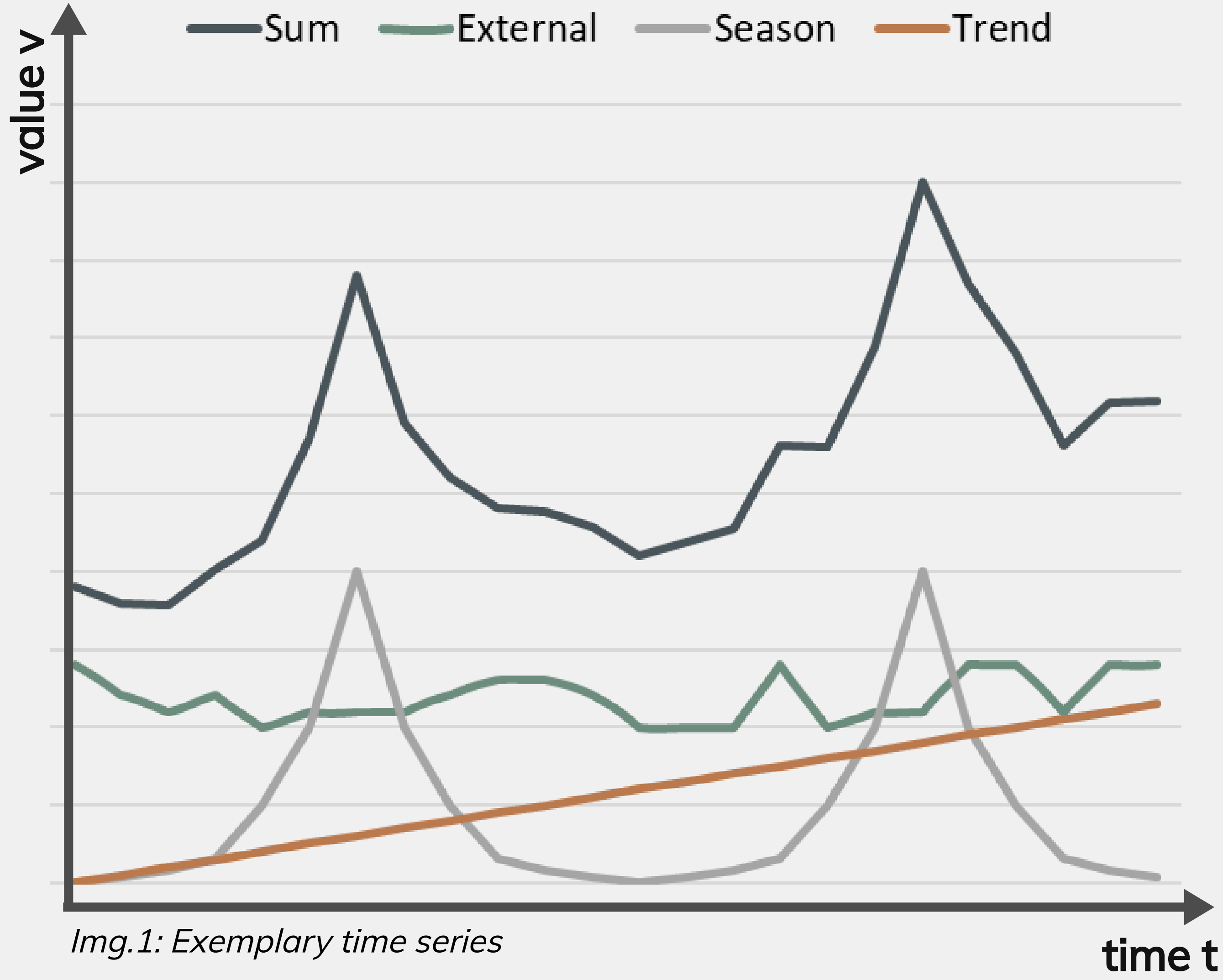
04 Conclusion & Outlook

AGENDA

A meta-learning approach
for short-term energy load, generation, and price forecasting

TIME SERIES COMPONENTS

- Trend
- Seasonality
- Saturating Growth
- Exogenous Dependencies
- White Noise



Img.1: Exemplary time series

SHORT-TERM FORECASTING METHODS

Well-performing benchmark methods (Ensafi 2022, Nguyen 2021)

Complexity

Simple Statistical Methods
- Multiple Linear Regression

Complex Statistical Methods
- Prophet
- SARIMAX (Seasonal Auto-Regressive Integrated Moving Average X)

Advanced Methods
- Feedforward Neural Network
- Recurrent Neural Network (including Memory)
- Long Short-Term Memory (including Forget Function)

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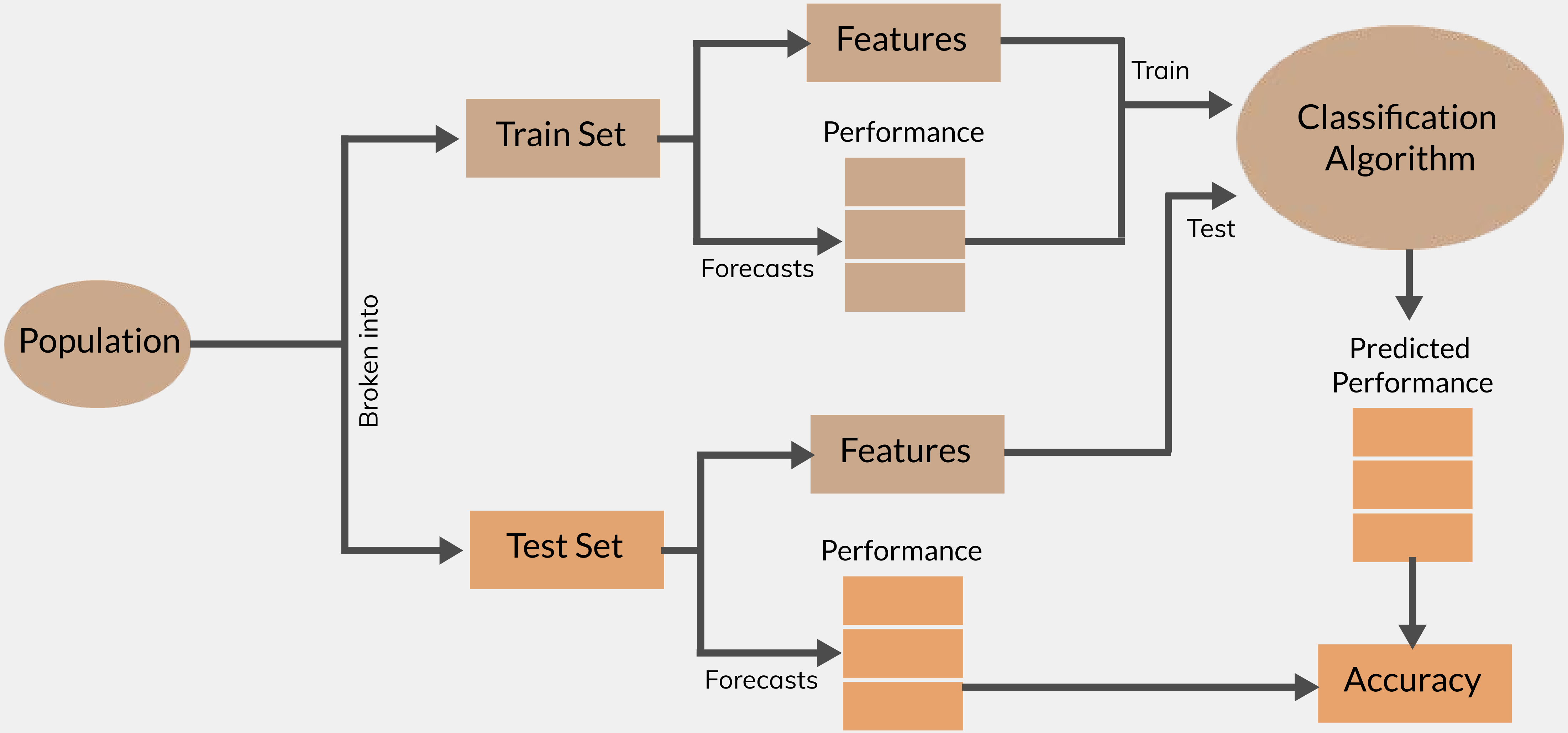
MODEL SELECTION



Img.2: Generalized procedure of a time series forecasting model selection
(Based on: Talagala 2018, Smith-Miles 2009)

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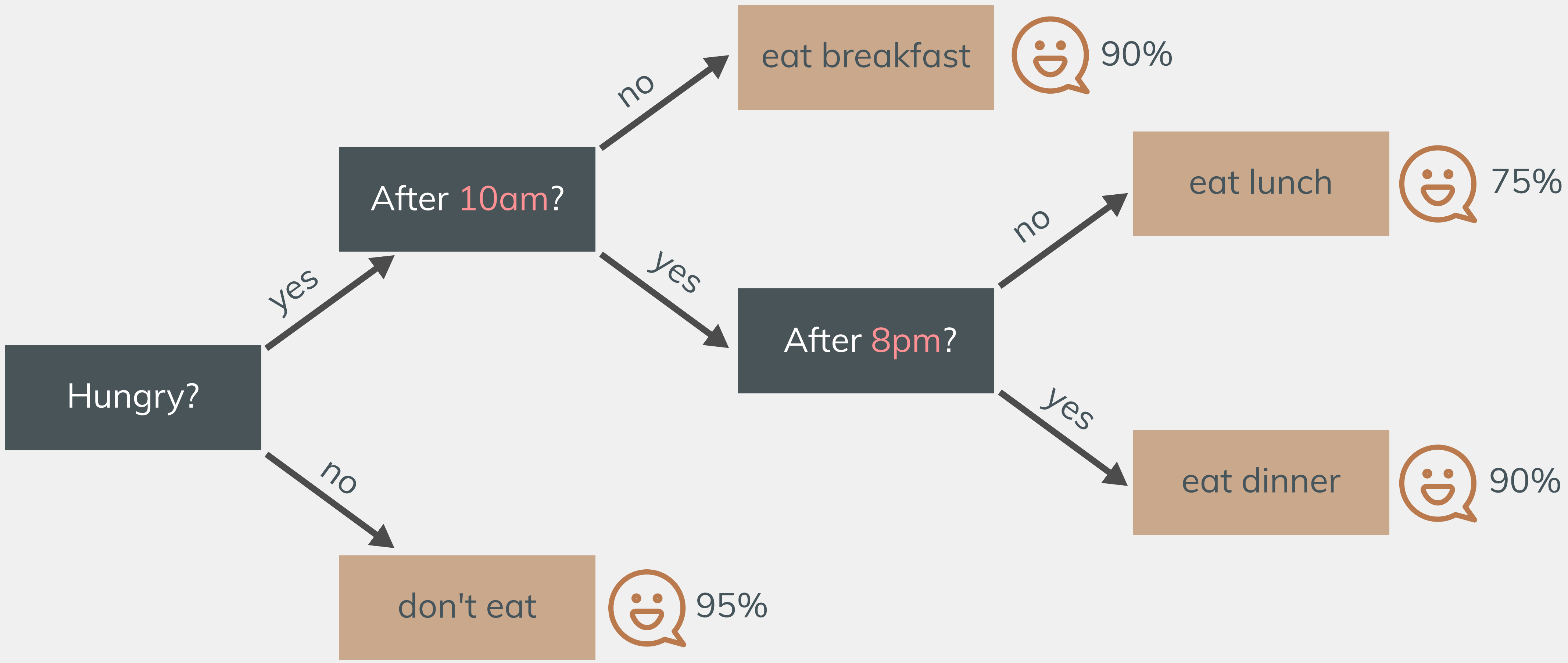
RANDOM FOREST CLASSIFIER

Applied classification algorithm



Img.3: Exemplary decision tree (Meltzer, 2021)

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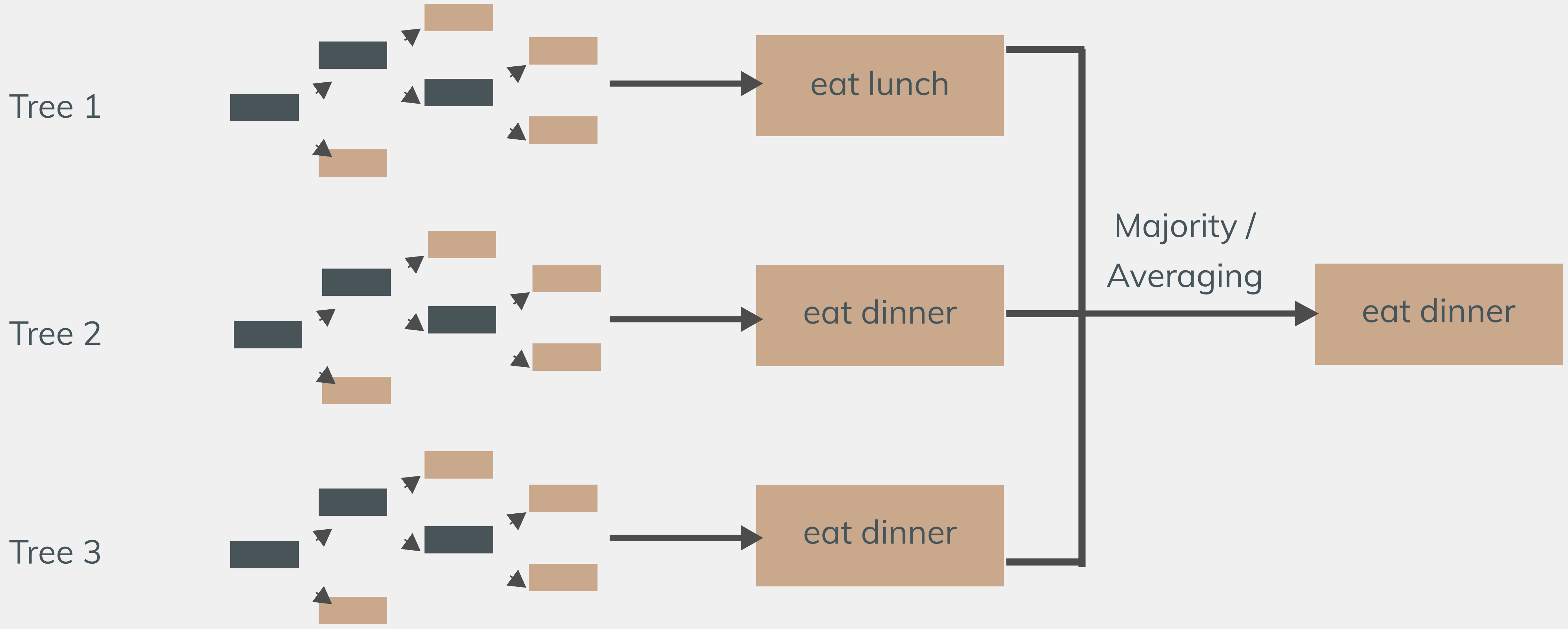
RANDOM FOREST CLASSIFIER II

Applied classification algorithm



Img.4: Generalized process of a random forest classifier (Meltzer, 2021)

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CASE STUDY

A meta-learning approach

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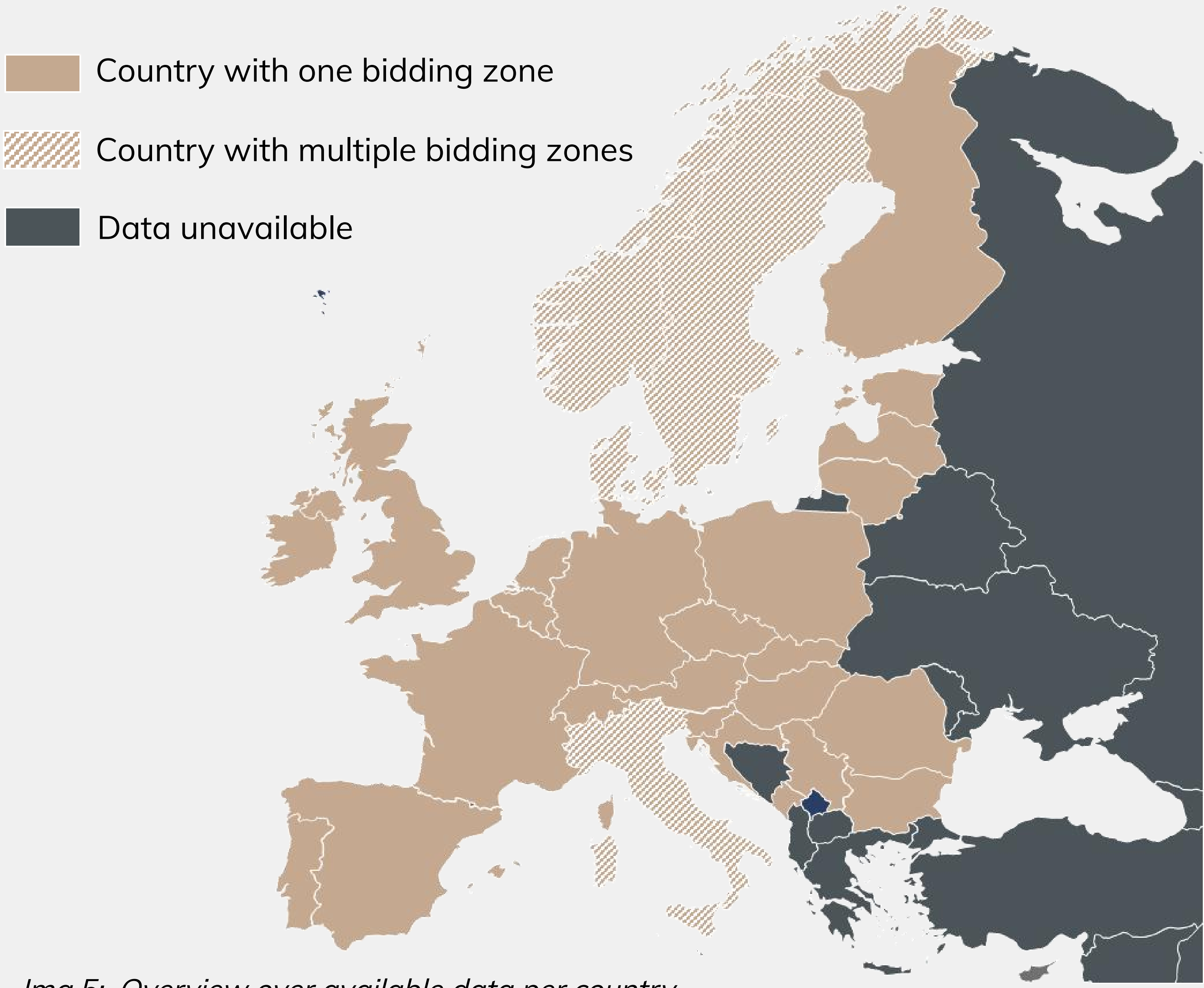
INPUT DATA

37 bidding zones of 28 European countries

Energy Time Series (ENTSO-E, 2022)
- Day-Ahead Price
- Generation (Solar and Wind)
- Load

Weather Time Series (Copernicus, 2022)
- Wind speed
- Solar irradiance
- Air temperature



Img.5: Overview over available data per country

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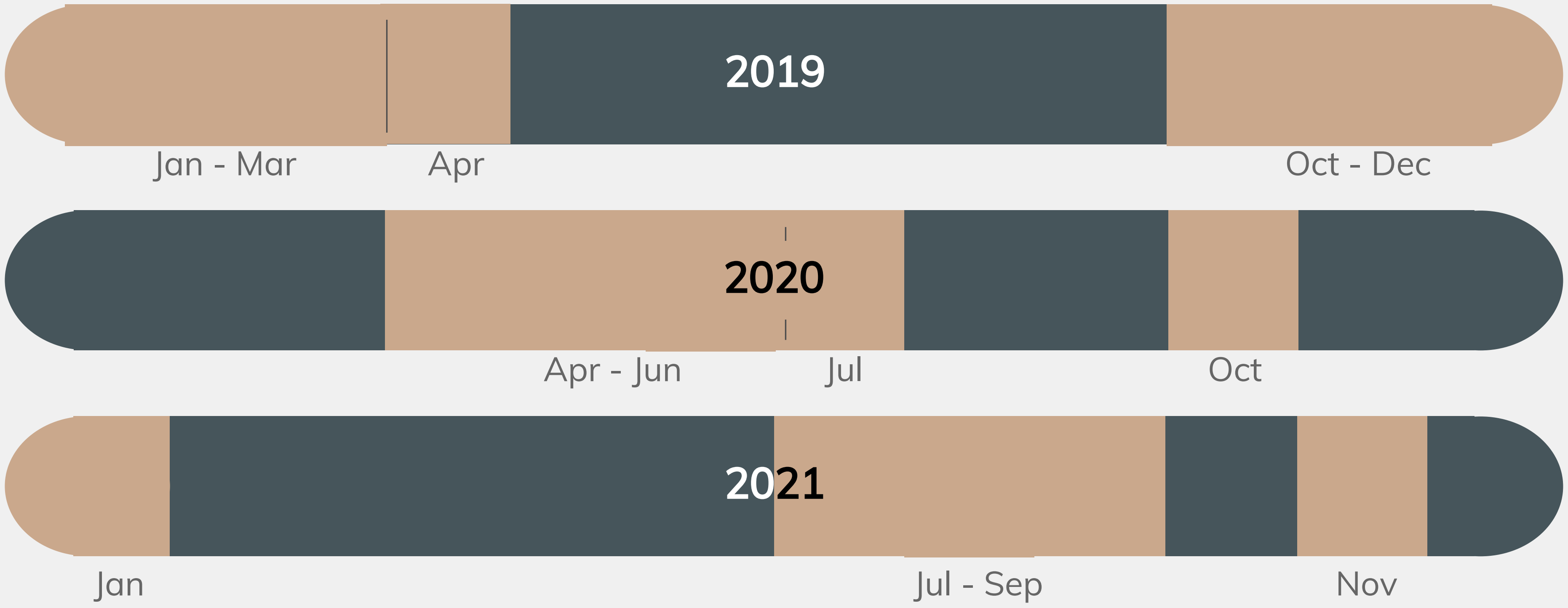
INPUT DATA II

Img.6: Selected time frames



9 Time Frames x 37 Bidding Zones x 4 Energy Series Types - Missing Series

= 1026 Sample Time Series

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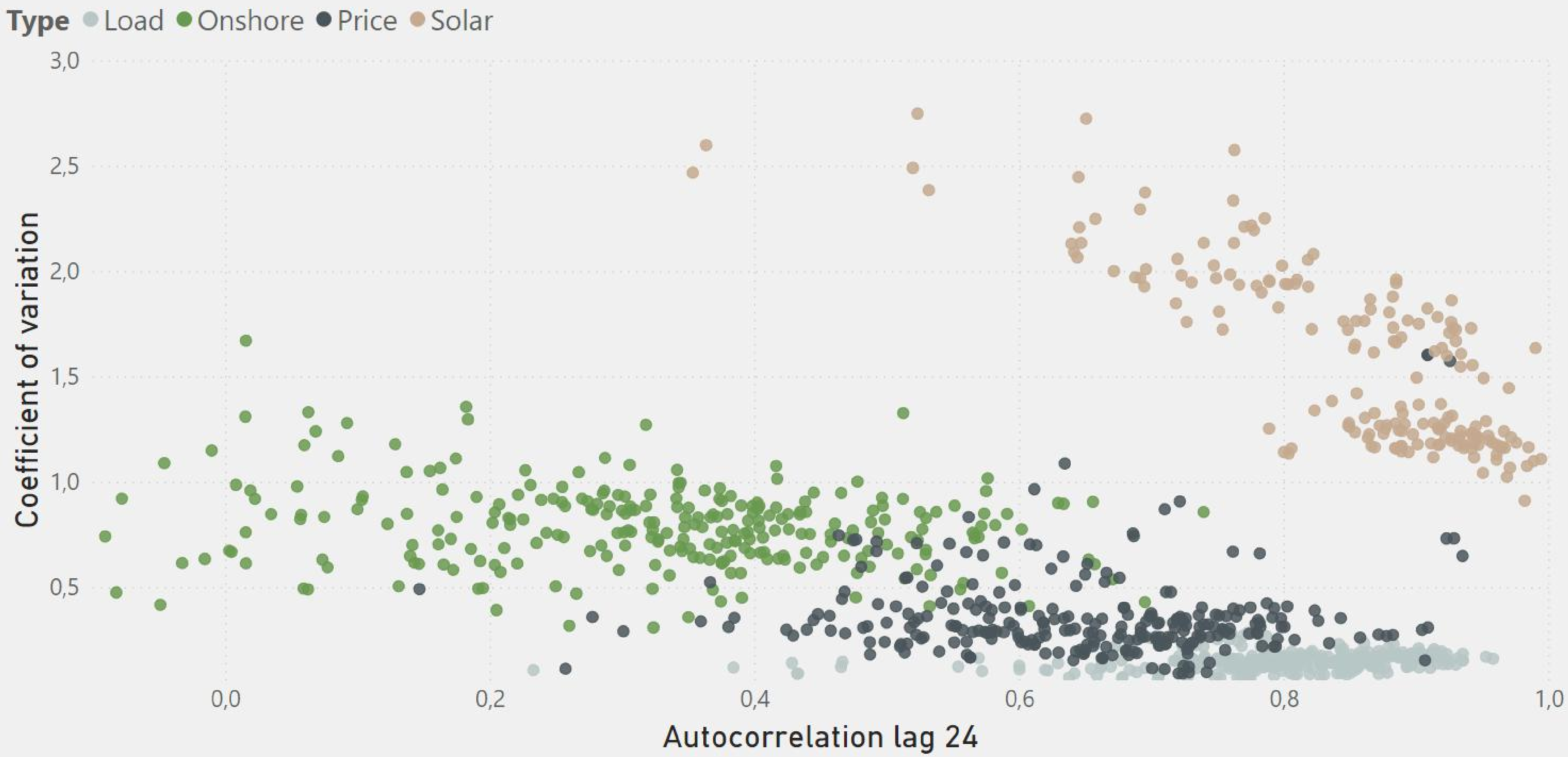
INPUT DATA III



Img.7: Comparison of the sample time series

METHODOLOGY - FEATURES

According to the methodology on slide 9.

8 Time series features were used for the model selection:

- Count of timestamps
- Coefficient of variation of the endogenous variables
- Coefficient of variation of the hour and day-type averages
- Autocorrelation of the endogenous variables for the lags 1 and 24.
- Pearson Correlation between the endogenous and it's exogenous variables (First and second highest)

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METHODOLOGY - FORECASTING METHODS

According to the methodology on slide 9.

10 Methods for day-ahead forecasts were used:

- 3 variants of Multiple Linear Regression (different availability of information)
- 3 variants of SARIMAX (different model parameters)
- 2 variants of Prophet (different availability of information)
- 2 variants of LSTM (high amount of cells vs. high amount of iterations)

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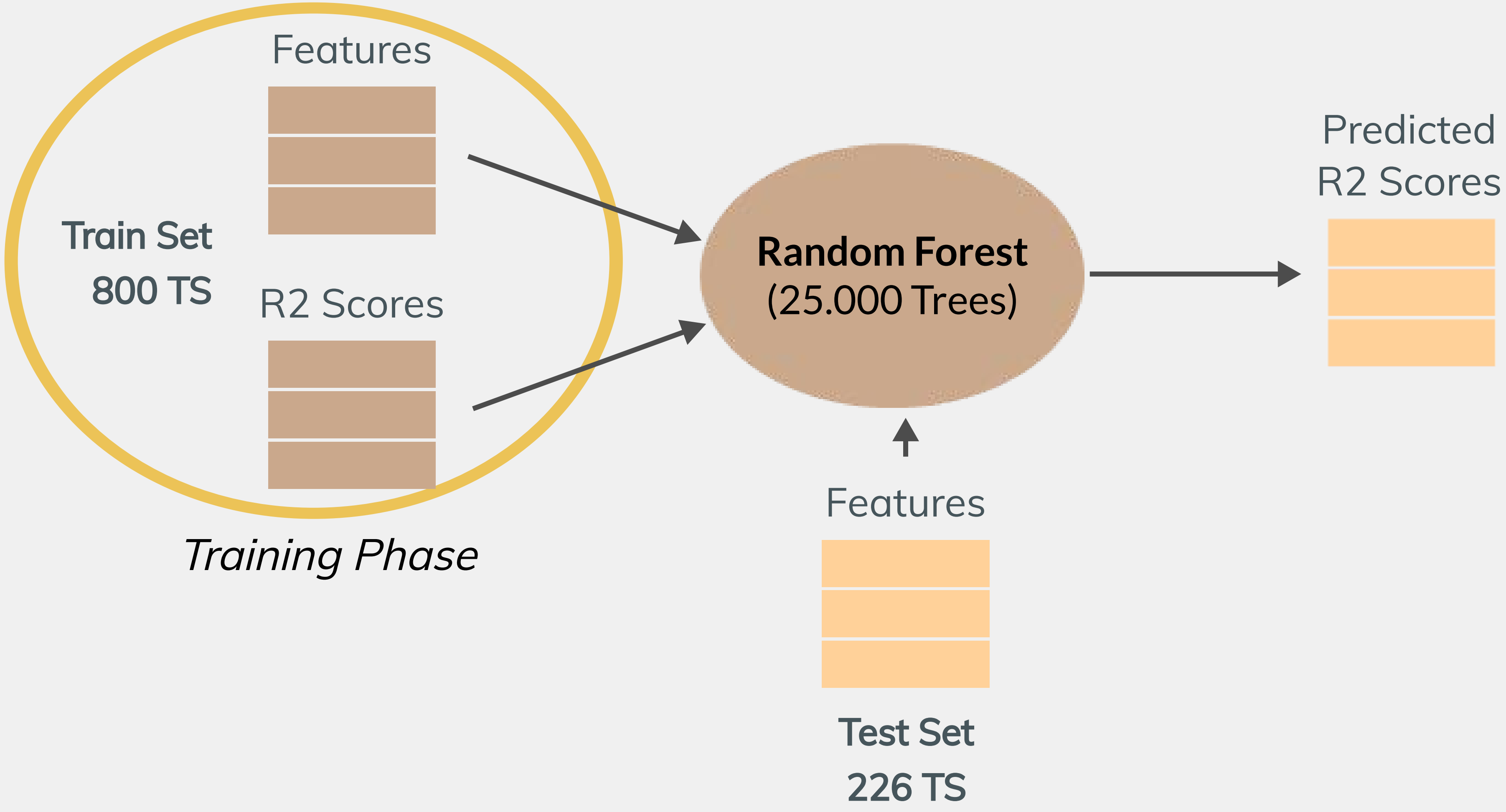
METHODOLOGY - RANDOM FOREST

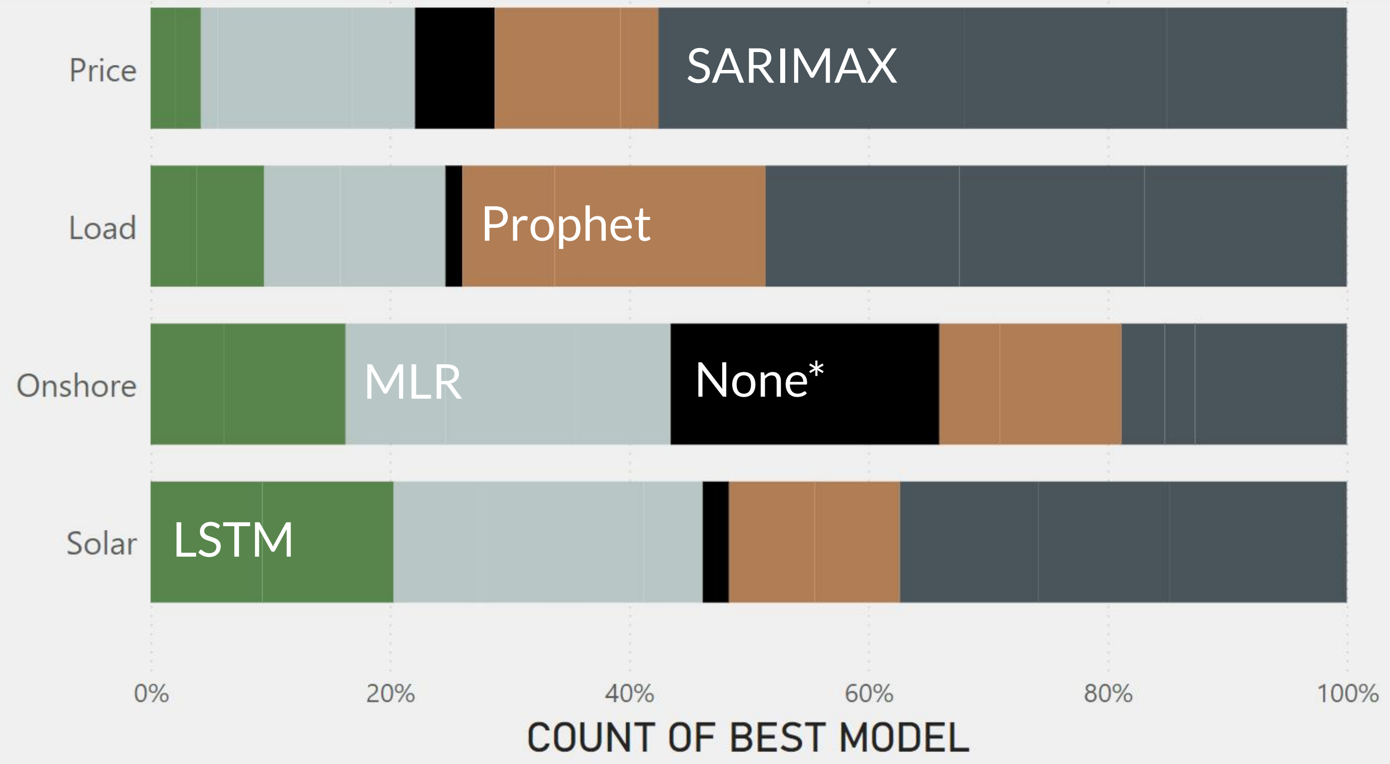


Img.8: Representation of the applied train and test procedure

RESULTS - FORECASTING PERFORMANCE

Median R2 Scores:

1, **SARIMAX** (0,1,2|1,0,1|24)	0.583
2. **Prophet** ExoTime	0.577
3. **SARIMAX** (1,1,1|1,0,1|24)	0.572
[...]	
8. **MLR** ExoTime	0.467
9. **SARIMAX** (2,0,1|2,0,0|24)	0.374
10. **MLR** Exo	0.089



Img.9: Distribution of the best forecasting methods per time series type

**Cases where no forecasting method had sufficient accuracy (R2 Score <= 0)..*

RESULTS - MODEL SELECTION

Result performance indicators as relative share of the test population.

62% — Suggested model and best model match

89% — Model with close-to-best accuracy suggested ($\Delta R2 < 0.05$)

3% — Model with far-from-best accuracy suggested ($\Delta R2 > 0.2$)

CONCLUSION & OUTLOOK

- the choice of the right forecasting method has a high impact on the quality of the forecast.
- time series consist of many components that are essential when choosing a forecasting model.
- with the help of the feature-based forecast model selection framework, the ideal model for energy time series can be predicted with a promising accuracy.
- thinking in terms of higher scales, a universally applicable and highly accurate model selection framework could be created.

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