Predicting Wind Energy Curtailment in Germany

CAPSTONE PROJECT

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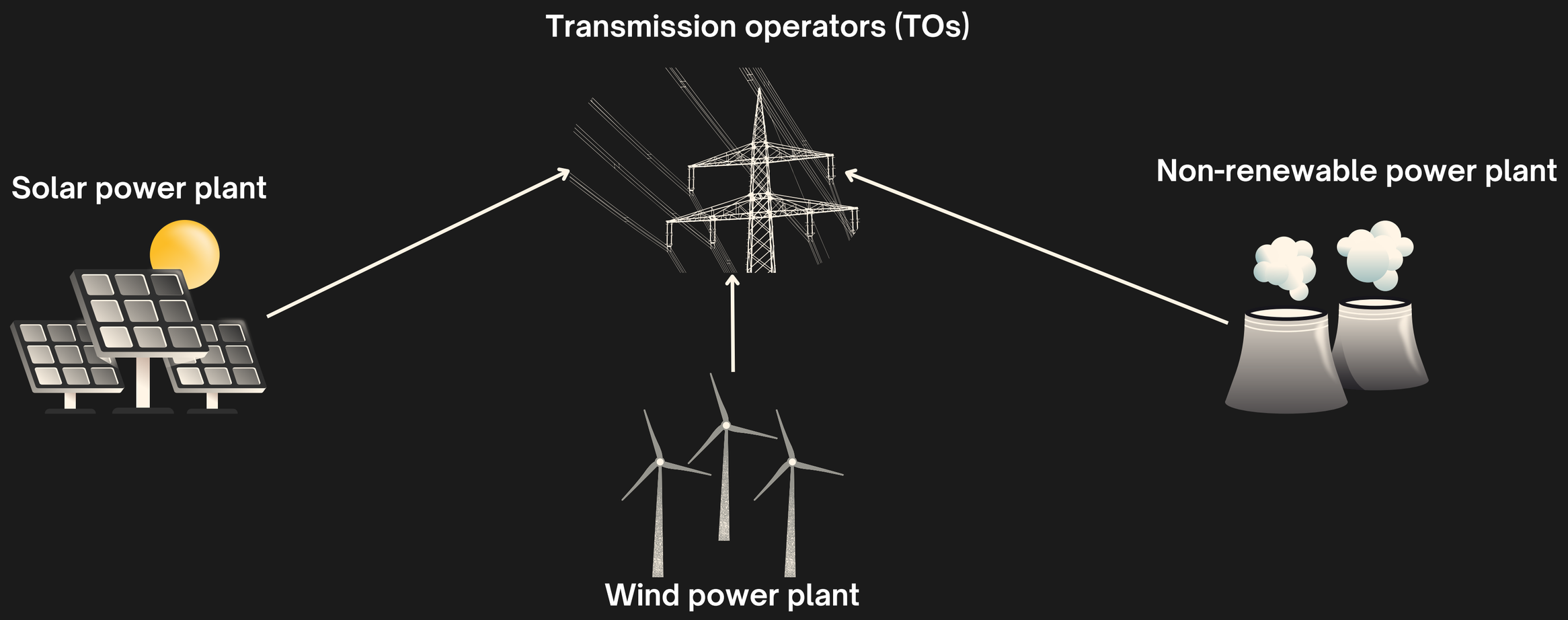
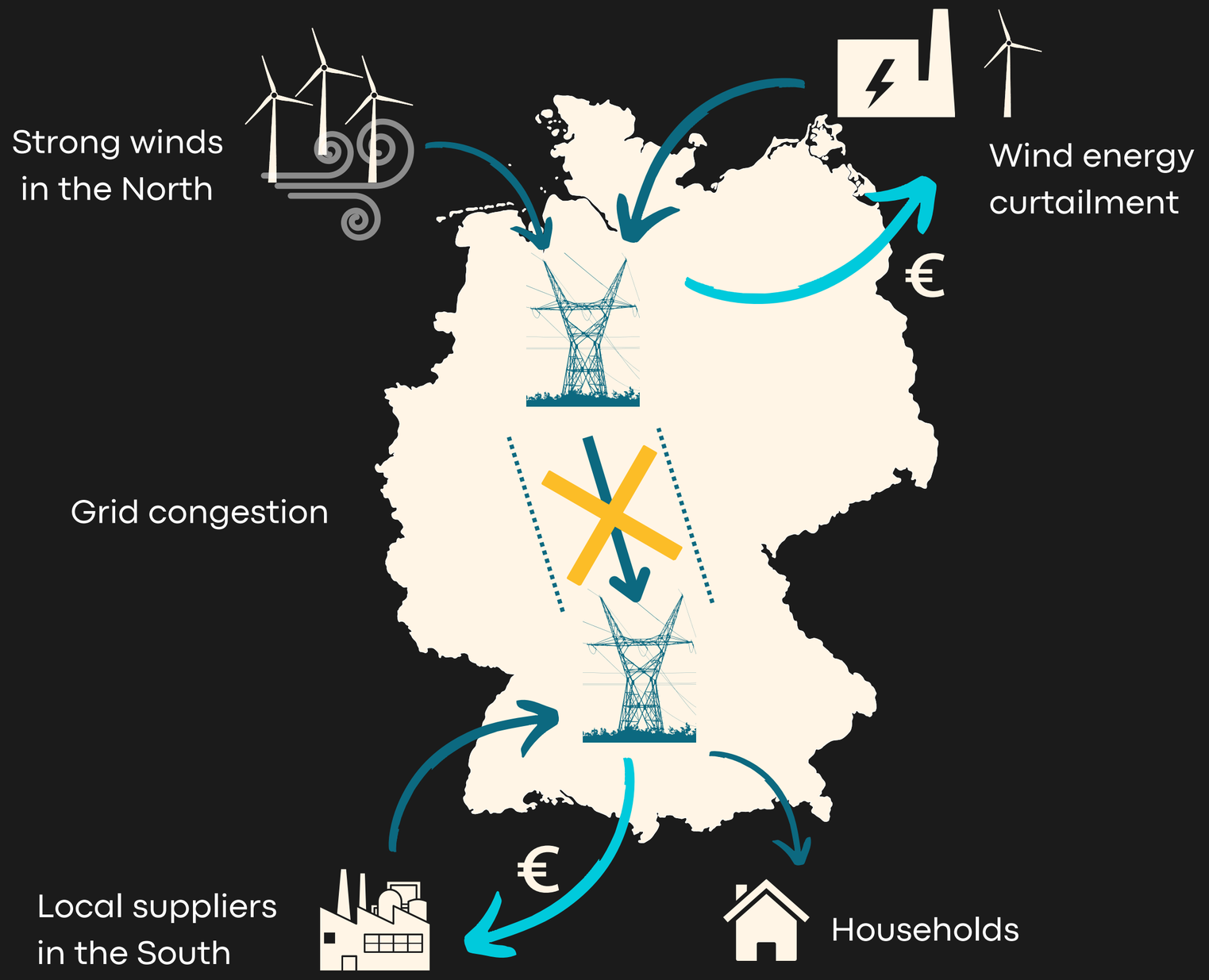
NEXTRACT ENERGY

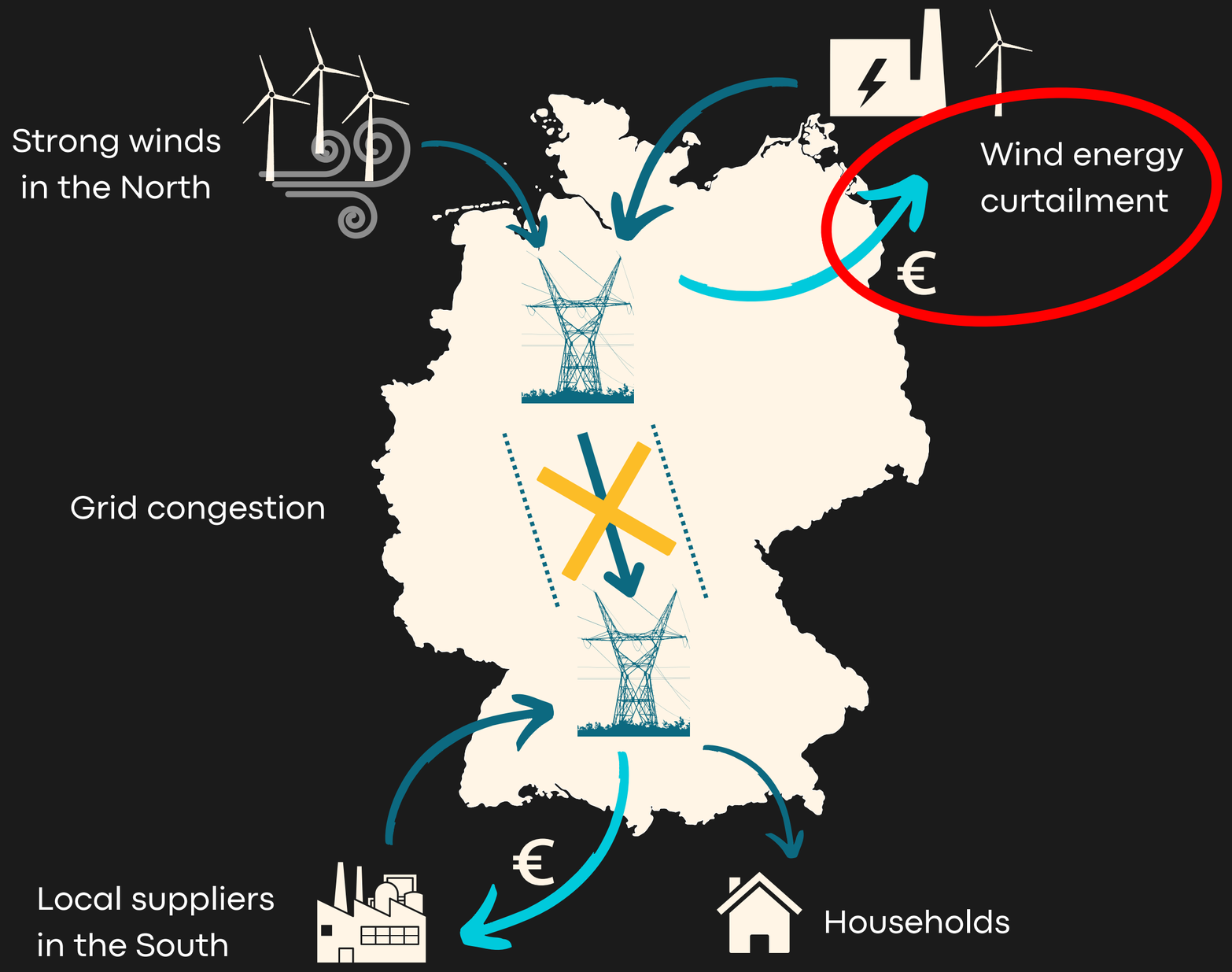
Dispatch & Transmission Operators



Redispatch


Strong winds
in the North
Wind energy
curtailment
€
Grid congestion
€
Local suppliers
in the South
Households

Redispatch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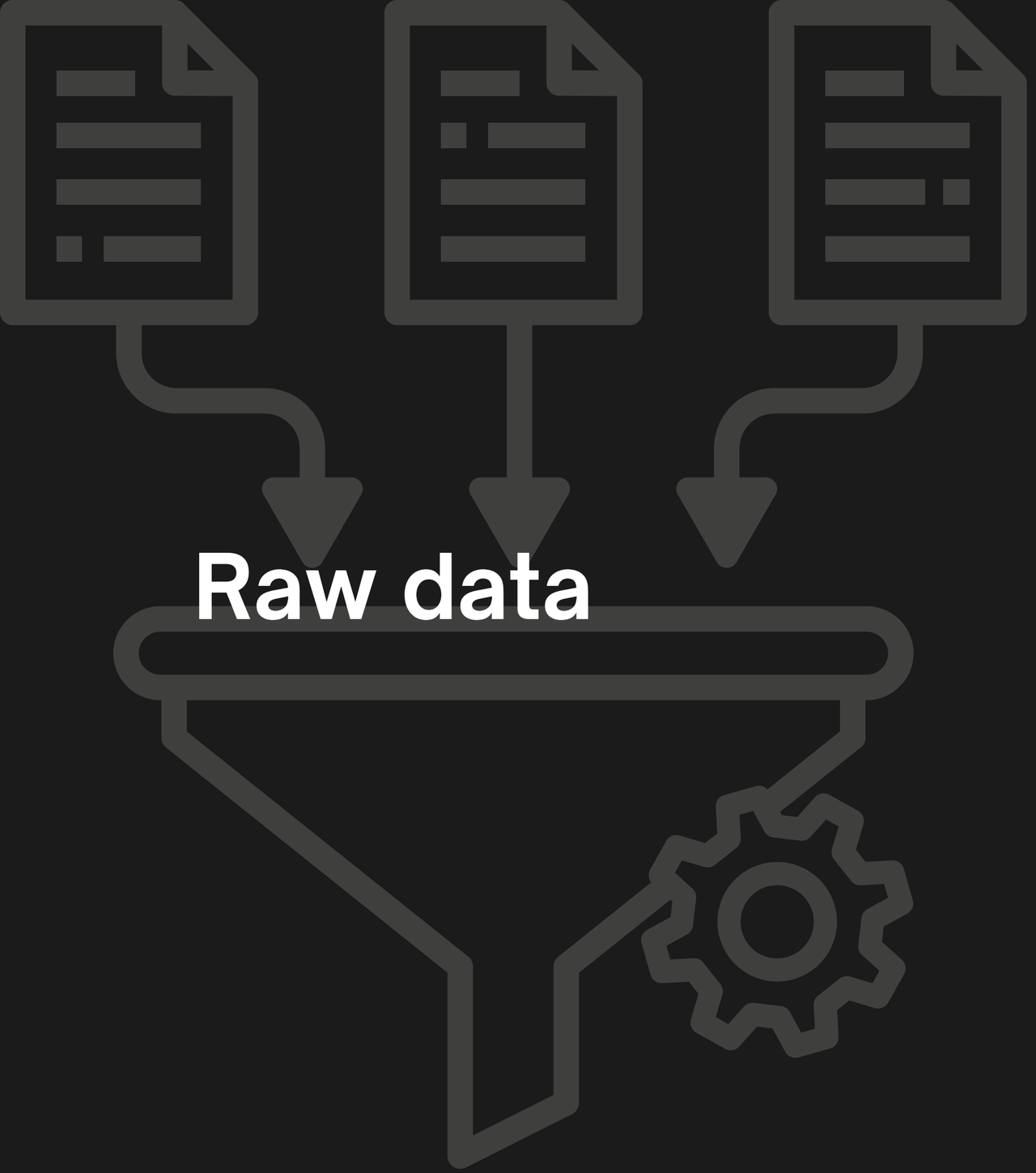
Business case for curtailment prediction

4% RENEWABLE ENERGY CURTAILED IN 2022

TO COMPENSATION

RENEWABLE ENERGY PRODUCERS

MISSED TARGETS



Raw data

CURTAILMENT DATA

WEATHER DATA

ENERGY CONSUMPTION DATA

SOLAR ENERGY DATA

EVALUATION METRIC - PRECISION

Precision

$$\frac{\text{PREDICT curtailment ACTUAL curtailment}}{\text{PREDICT curtailment ACTUAL curtailment} + \text{PREDICT curtailment NO curtailment}}$$

Web app - Streamlit

Baseline model

Input - ‘Wind gust max’

Model - Predict based on value of wind gust

Threshold - 9m/s

Precision ~ 16%

Advanced model

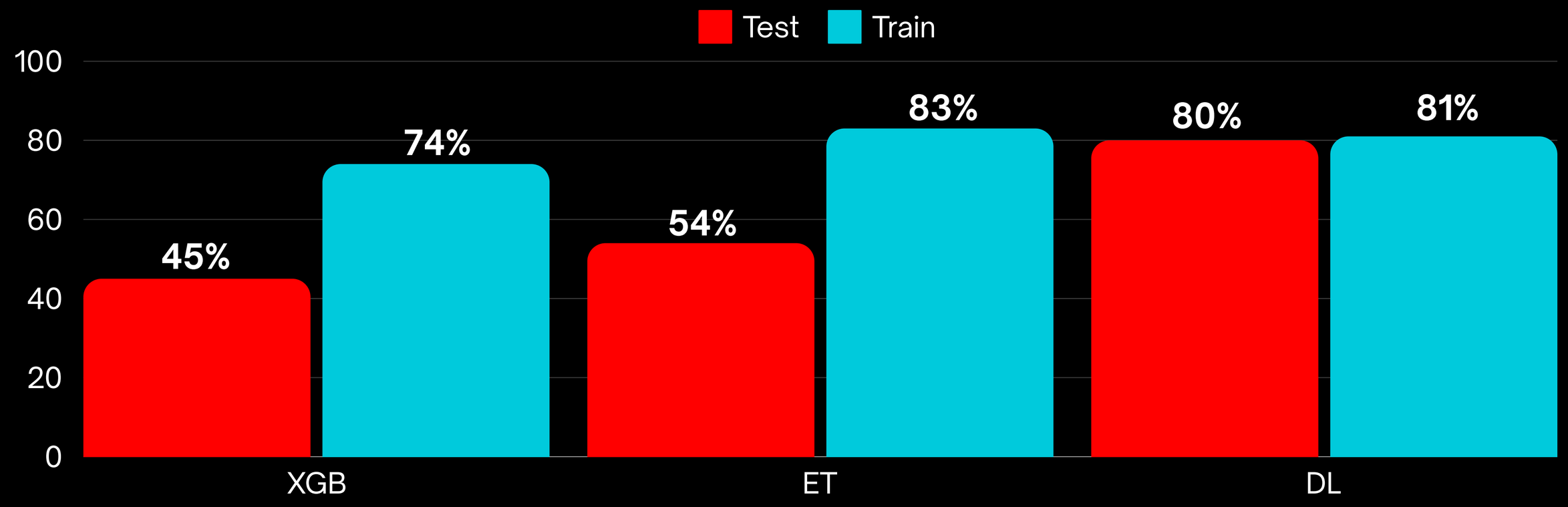
Joint database of all sources

Timeseries elements

Methods - XGBoost Classifier, Extra Trees Classifier, Deep Learning model

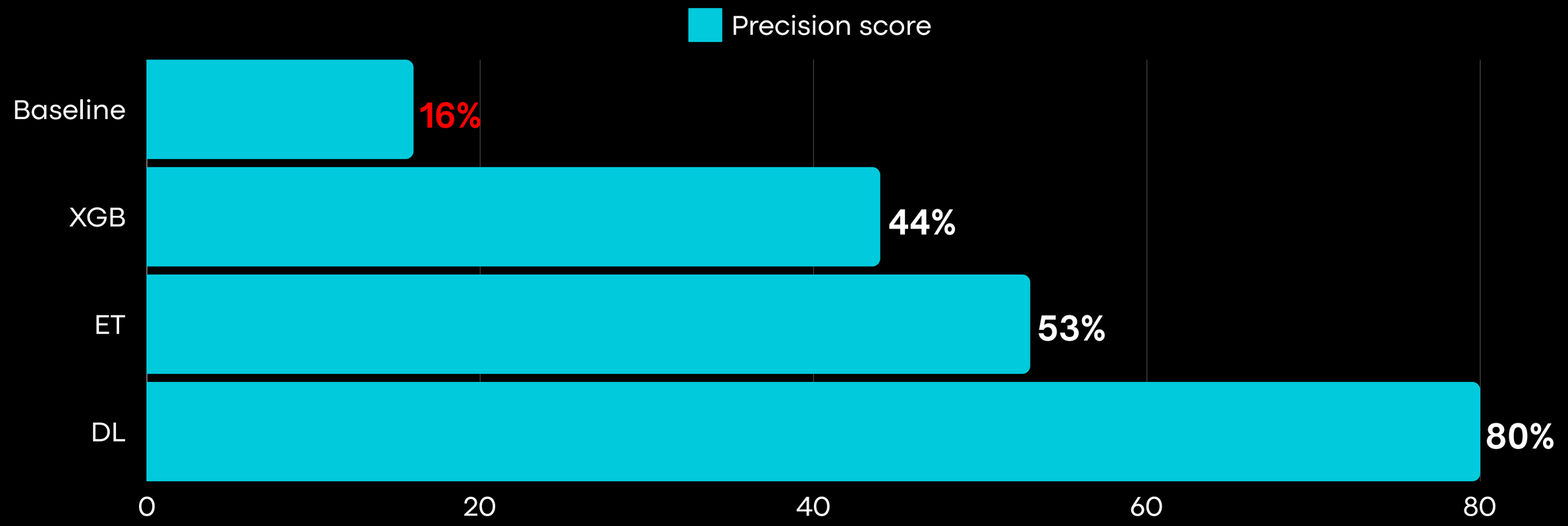
Model results

Performance of XGBoost vs Extra Trees vs Deep Learning

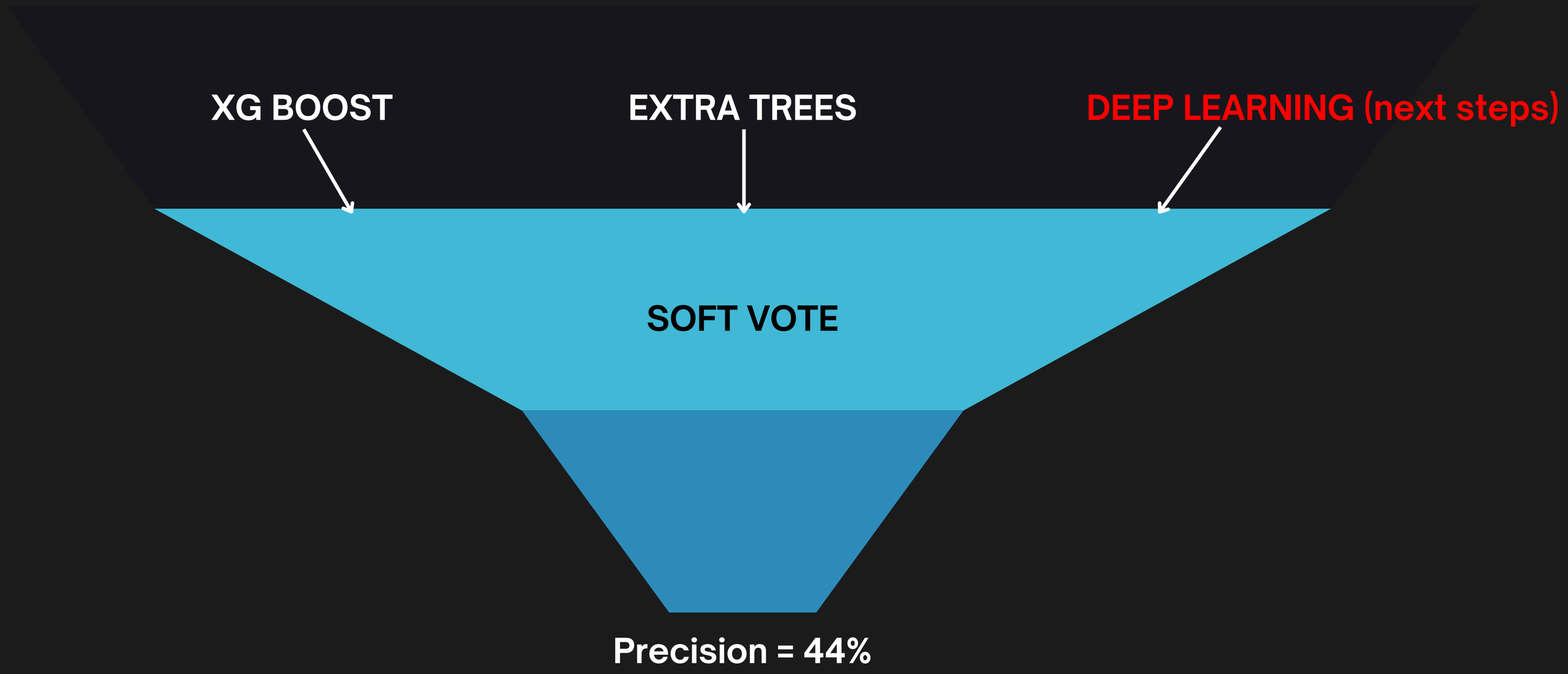


Comparison with baseline model

Performance of XGBoost, Extra Trees, Deep Learning vs baseline model



Voting classifier



Tech stack used

- Python
- Pandas
- Scikit Learn
- Seaborn & Plotly
- Tensorflow and Keras
- Streamlit

Limitations and future scope

- Limited factors
- Historical data
- Only wind curtailment
- Binary classification

- Include pricing, grid capacity, etc
- Forecast model
- Predict solar curtailment
- Regression

Thank you!

(please clap)

BACK-UP

Confusion Matrix

Predicted / True	**Negative**	**Positive**
Negative	TN	FP
Positive	FN	TP

Models

XGBoost Classifier:

- Tree-based ensemble method
- Sequentially adding weak learners with focusing on correcting the errors made by existing ones
- Uses gradient descent optimization technique to minimize a predefined loss function

Extra Trees Classifier:

- Tree-based ensemble method
- Trains several decision trees with entire dataset
- Randomly selects values at which to split feature, creating child notes
- Aggregates results from group of decision trees to output a prediction

Voting Classifier:

- Trained on the collection of the two models
- Prediction based on the largest majority of votes,
- Soft voting: average probabilities of results of each classifier

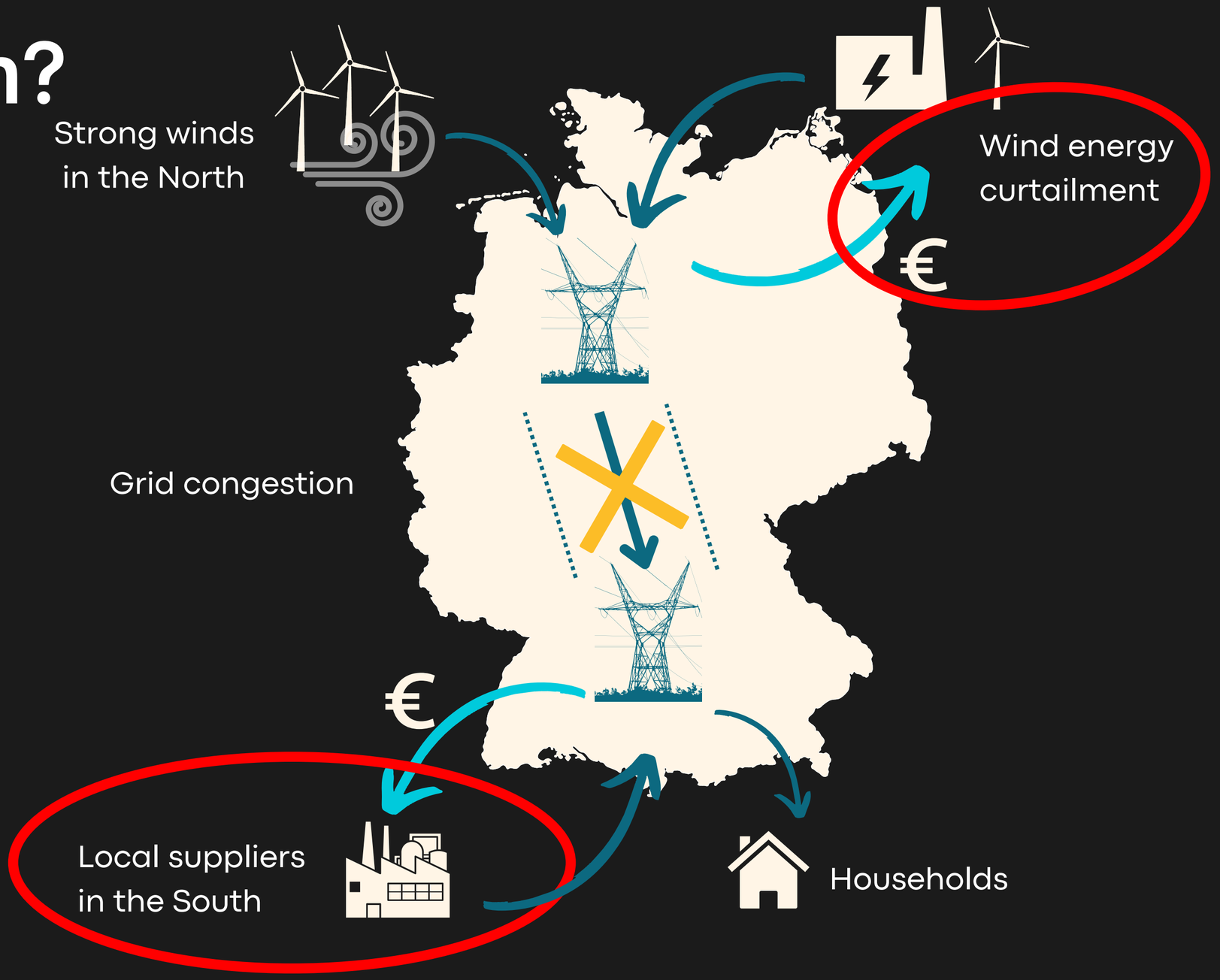
Dispatch, redispatch and curtailment to manage grid integration (congestion mgmt)

Dispatch: Planned schedule of power generation of power plants to know which power plant will feed how much power into the grid and when. Power plant operators give transmission system operators binding notification of their capacity plans for the following day.

Redispatch: Modifications to the initial dispatch schedule. If the analysis of the dispatch shows that bottlenecks are imminent, or if overloads actually occur in the short term, transmission system operators demand power plant operators to adjust their schedules, i.e. redispatch.

Curtailment: Reduction or complete shutdown of power plant output. This can occur on the instructions of the TSO or DSO due to the power plant's inability to meet performance standards, internal issues, or local overloads in parts of the electricity grid. Additionally, a decrease in energy demand can result in a reduction of energy generated by the plant. Regulation can prevent plant overload and shutdown.

Why precision?



Economics

Different EU Member States use various methods to compensate for activated internal or cross-zonal redispatching.

1. Pay-as-bid Pricing (price-related mechanism): Compensating based on bids for providing upward or downward regulation. I.e. power plants are paid based on the prices they bid for their services in the market.
2. Regulated Pricing based on Market Prices (price-related mechanism): Compensating based on market prices, such as day-ahead prices. Power plants receive payment according to the prevailing market prices at the time of redispatching.
3. Cost-based Pricing (cost-related mechanism): Compensated based on the actual costs they incur for adjusting their operating schedules, including fuel costs, CO2 emissions, opportunity costs, and startup costs.
4. Cost-based Plus Pricing (cost-related and price-related mechanism): Power plants are compensated for their costs as in the cost-based approach, but with an additional margin added on top to ensure sufficient compensation for their services.