

# A primer on forecasting for smart energy systems: from buildings to markets

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# KU Leuven





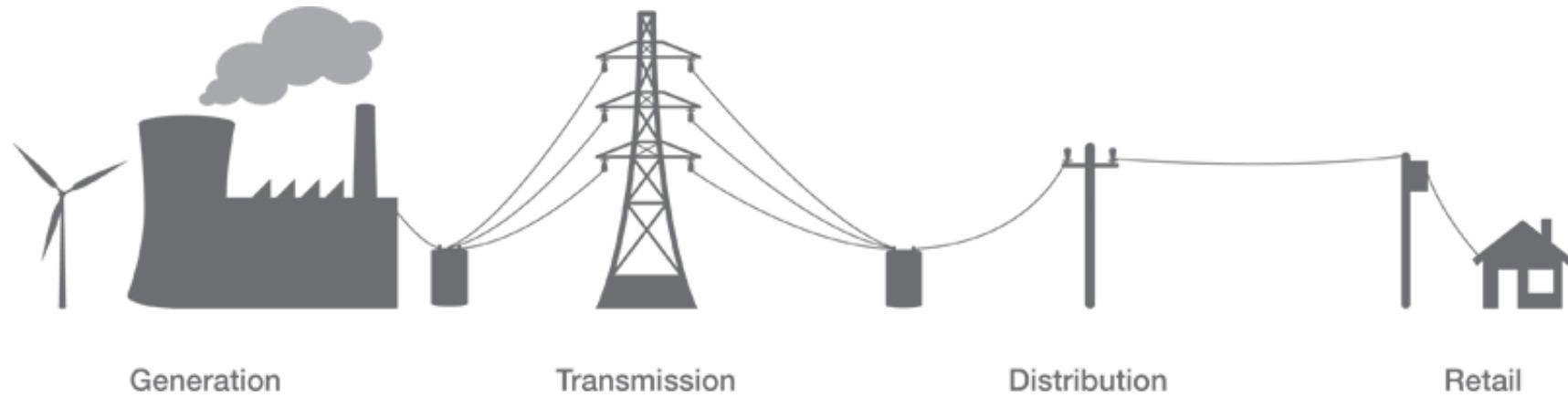
# A bird's eye view

- The electricity system;
- Recent trends in demand and generation;
- Forecasting – use cases and challenges;
- Forecasting, how to.

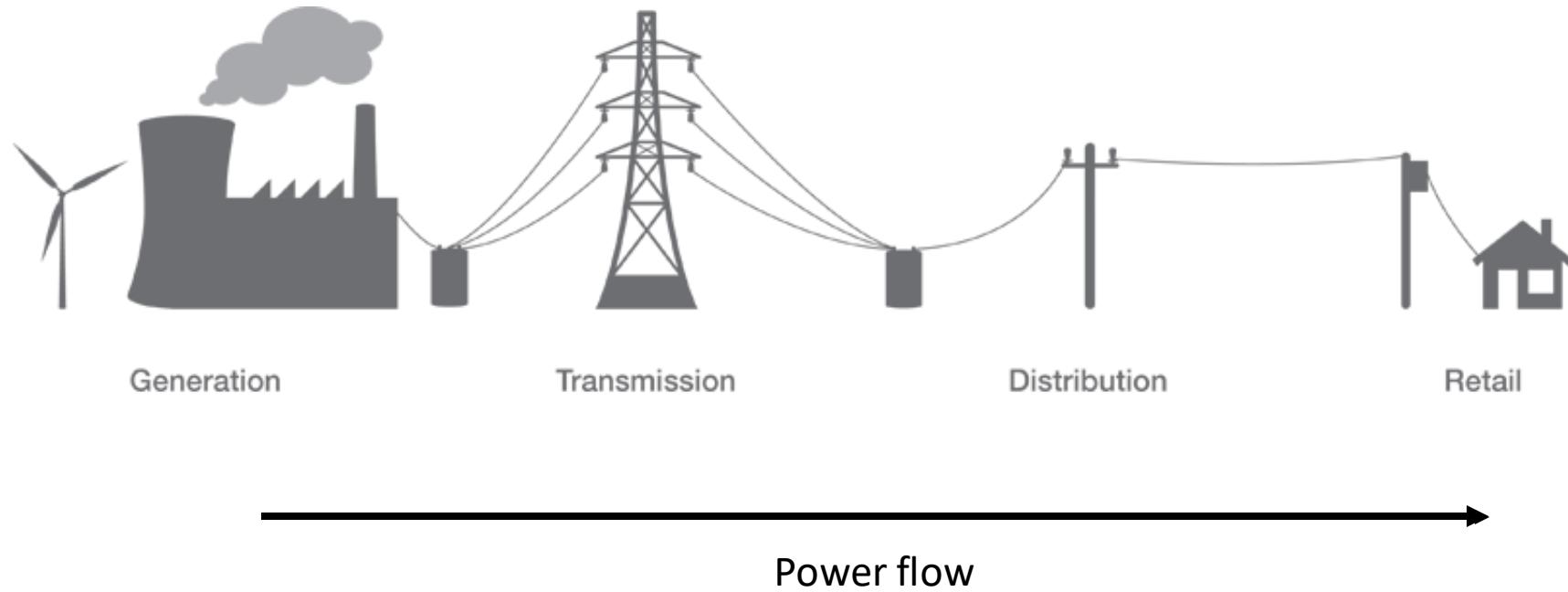
A black and white photograph showing a complex network of electricity pylons and power lines against a backdrop of a cloudy sky and a forested landscape. The pylons are tall, lattice-structured towers that support multiple sets of wires. The power lines crisscross between the towers, creating a dense web of lines against the lighter sky. The foreground is dark, suggesting a field or a body of water.

# 1. The electricity system

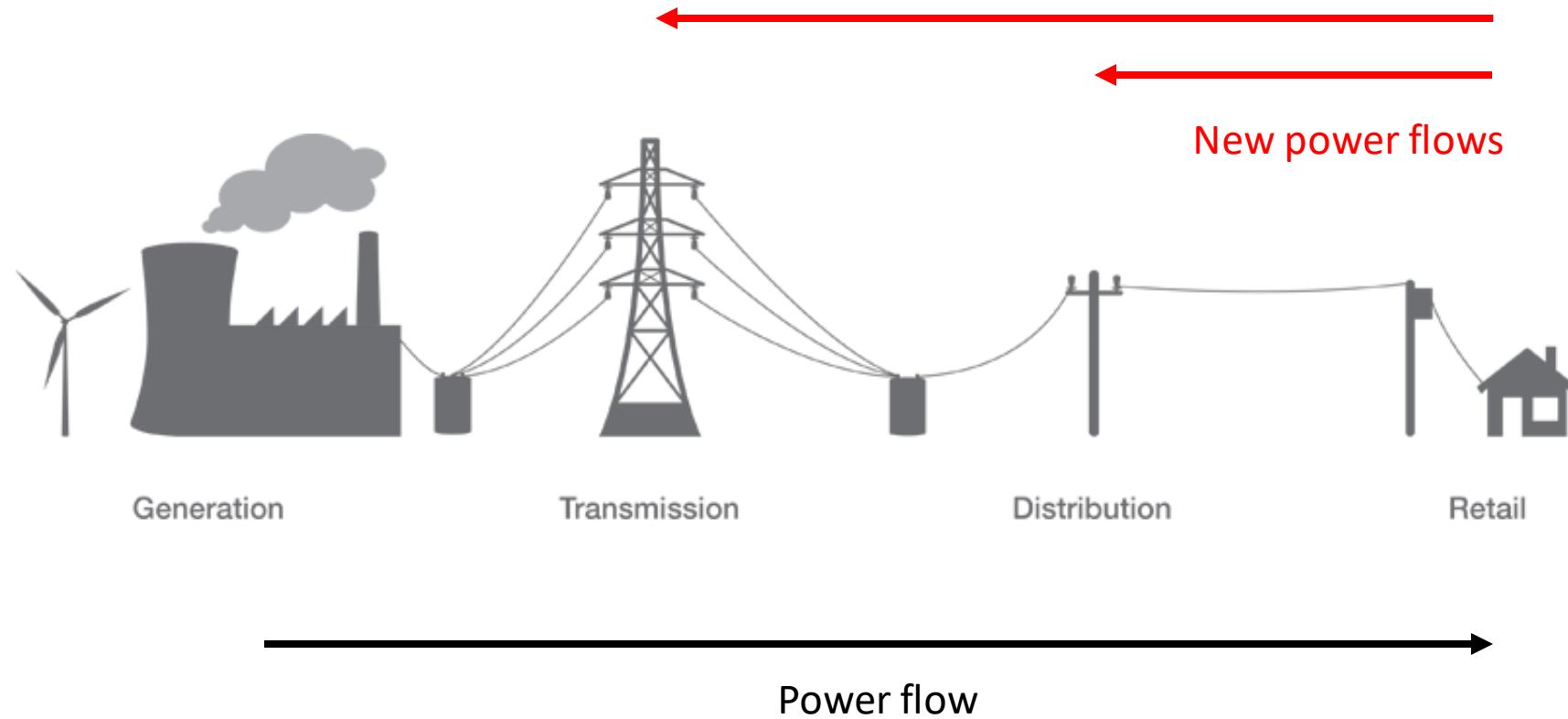
# Classical electricity grid operation



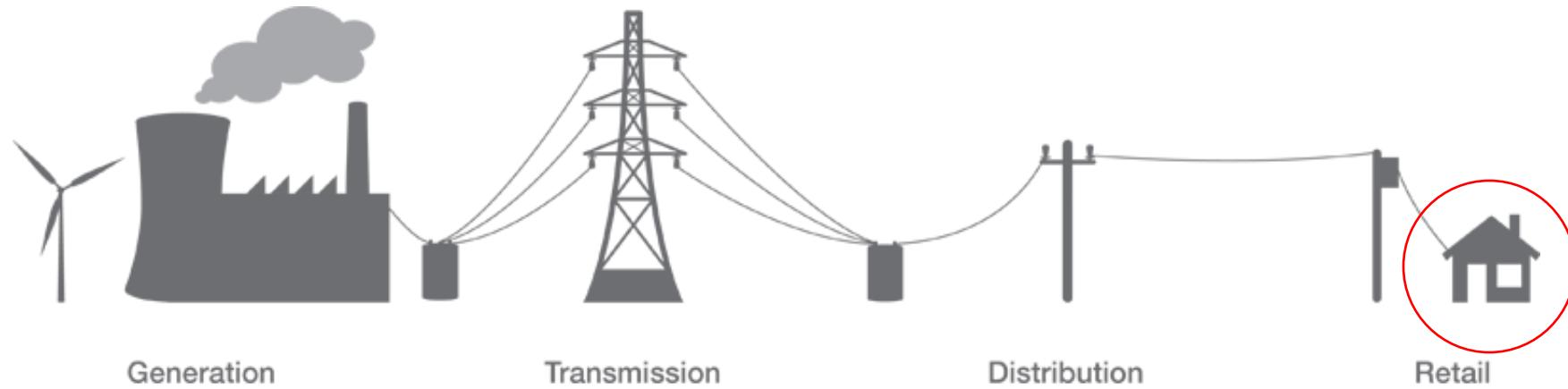
# Classical electricity grid operation



# Modern electricity grid operation

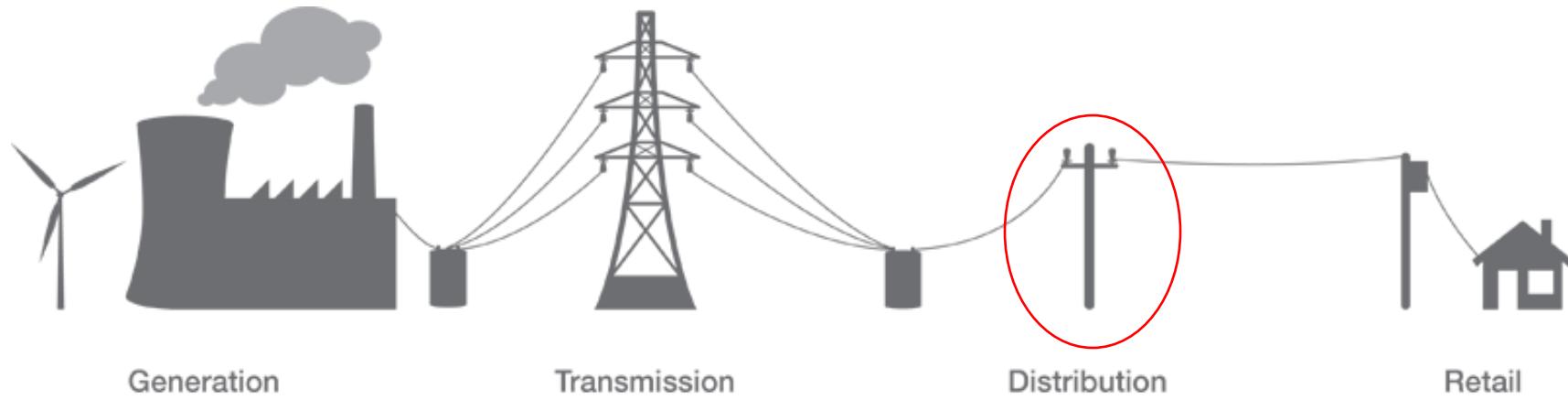


# Changes due to the energy transition (1)



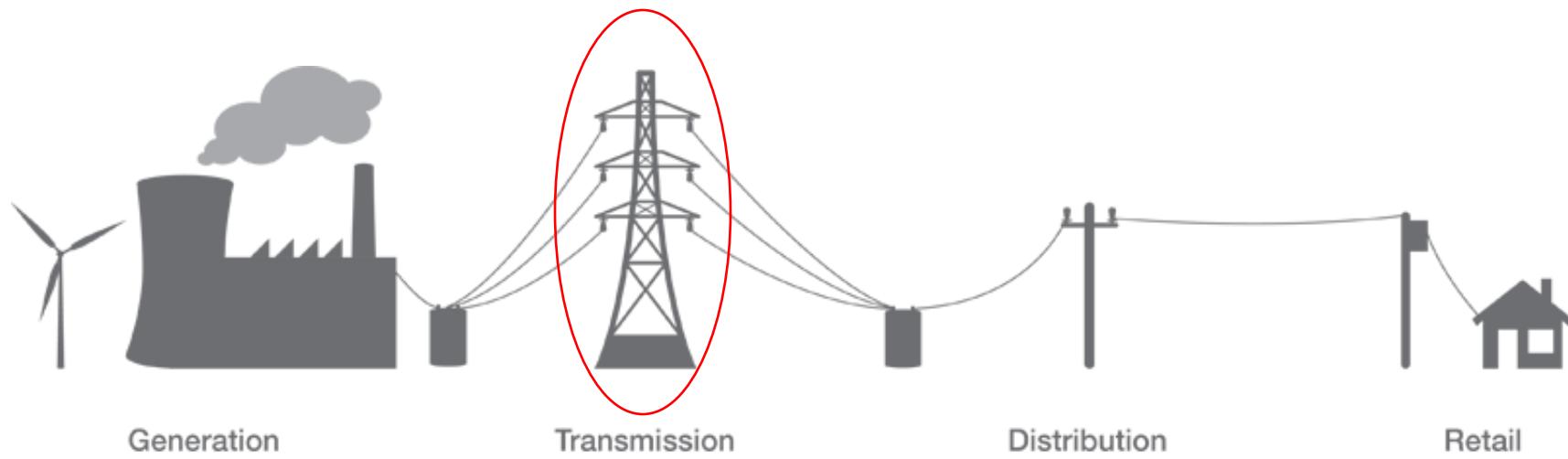
1. Improved energy efficiency (via passive and active measures)
2. Increasing electrification of industry as well as R&C demand with heating / cooling, and transport (Evs)
3. The proliferation of distributed generation with (hybrid) solar PV systems

# Changes due to the energy transition (2)



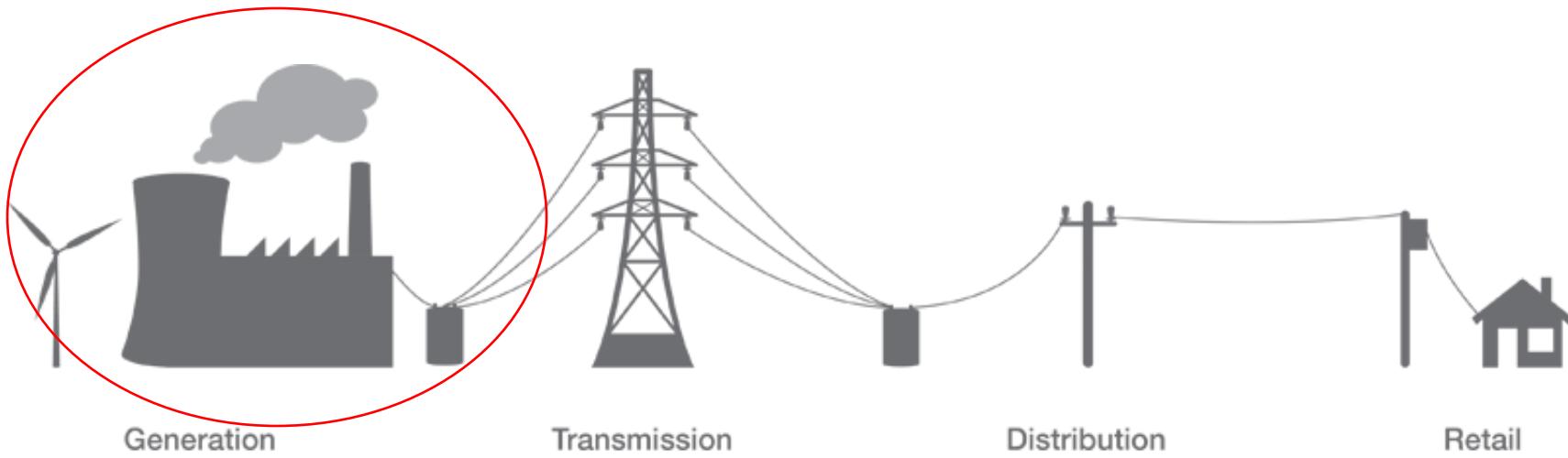
1. Voltage and congestion related issues in the distribution grid in many countries
2. Grid reinforcements vs. active network or demand management

# Changes due to the energy transition (3)



1. Emergence of the infamous duck curve
2. Need for large, fast-reacting reserves to ensure electricity supply and demand remain balanced at all times

# Changes due to the energy transition (4)

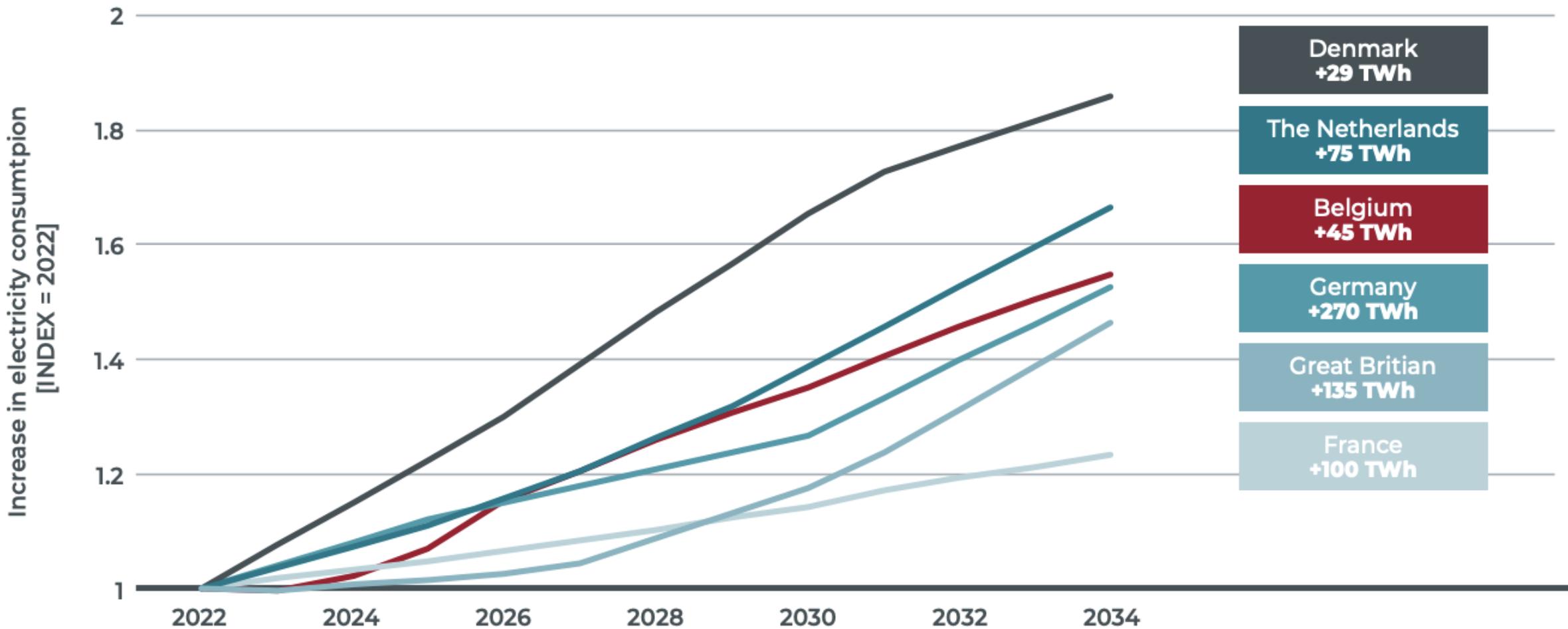


1. Supply system transitioning from fuel-driven to weather-driven
2. Generators need to be more flexible to contend with more uncertainty and volatility in electricity market prices

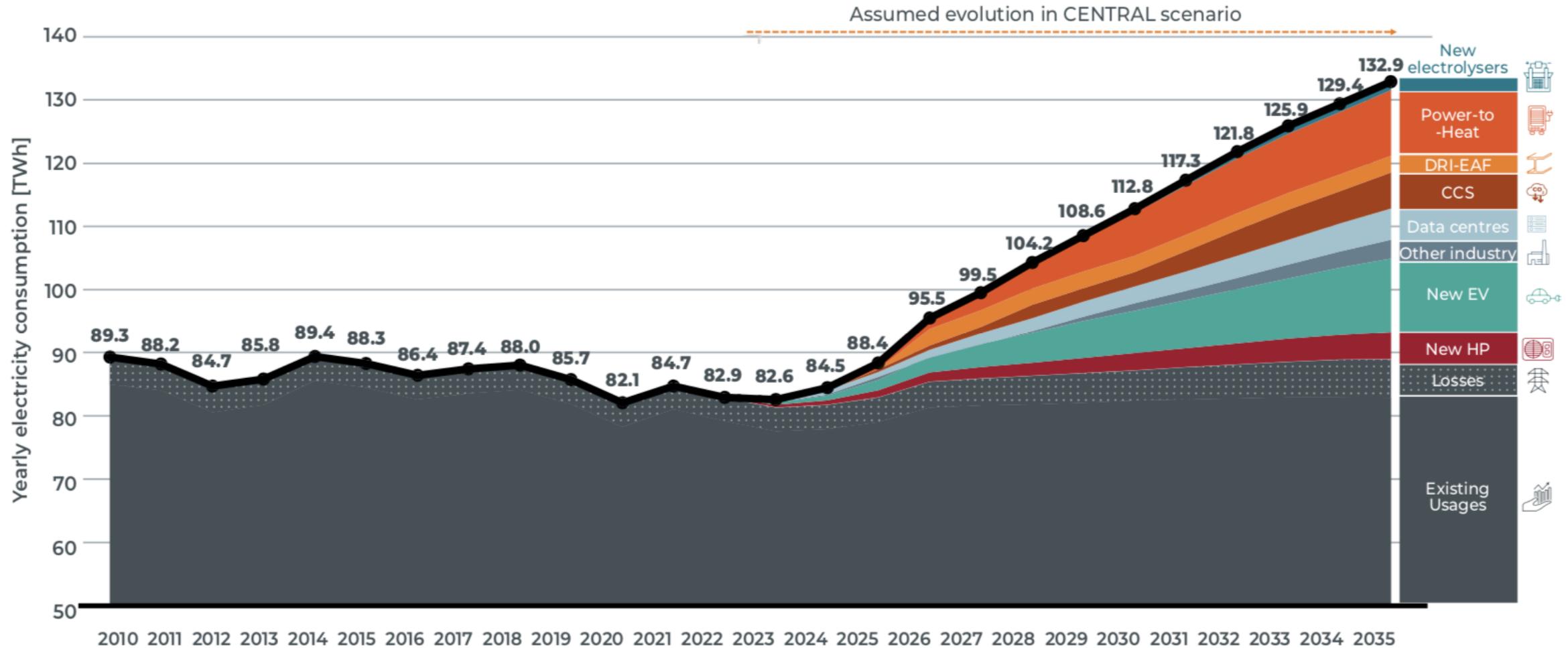
## 2. Recent trends in demand and generation



# Electricity demand increases in EU



# Belgian demand evolution, TWh

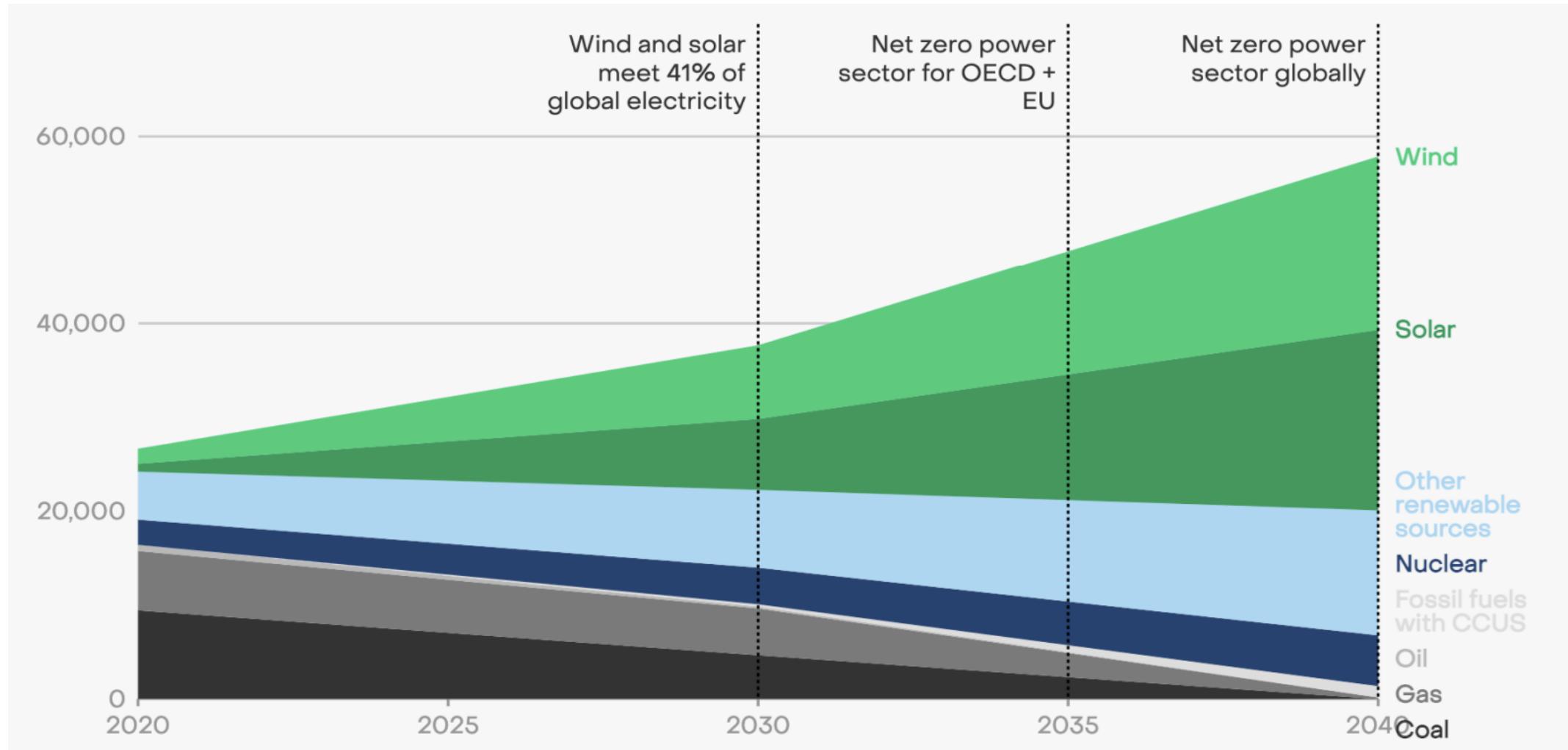




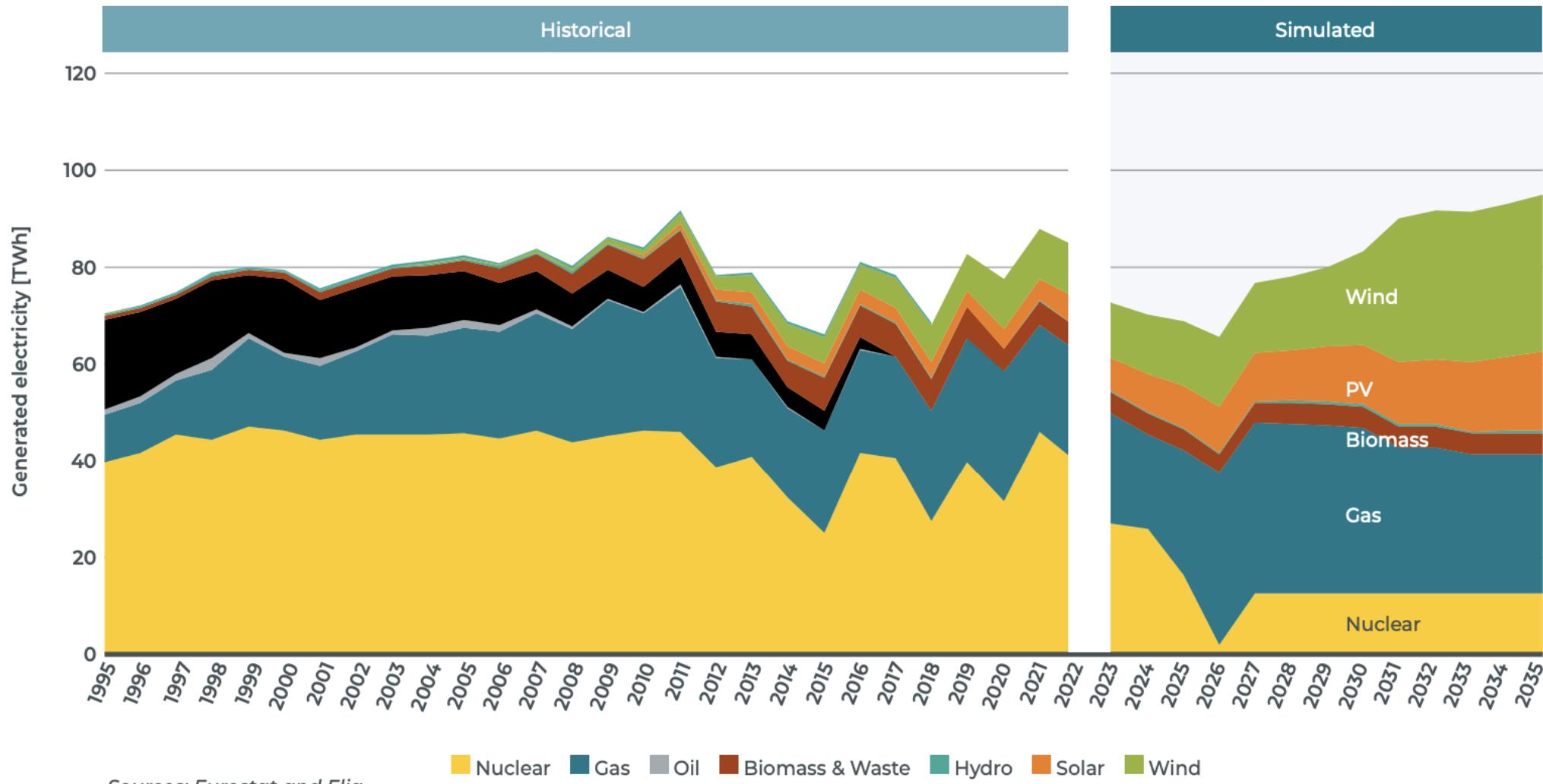
## Belgian demand

- **Projected ban on fossil fuel car sales by 2029** as decided by the Flemish government (also reduction of tax relief and introduction of LEZ's in Brussels);
- **Ban on connecting new buildings to the natural gas infrastructure** from 2025 onwards in Flanders (also phasing out of oil-fired boilers across the whole country);
- **Mandatory reporting of EPC labels.**

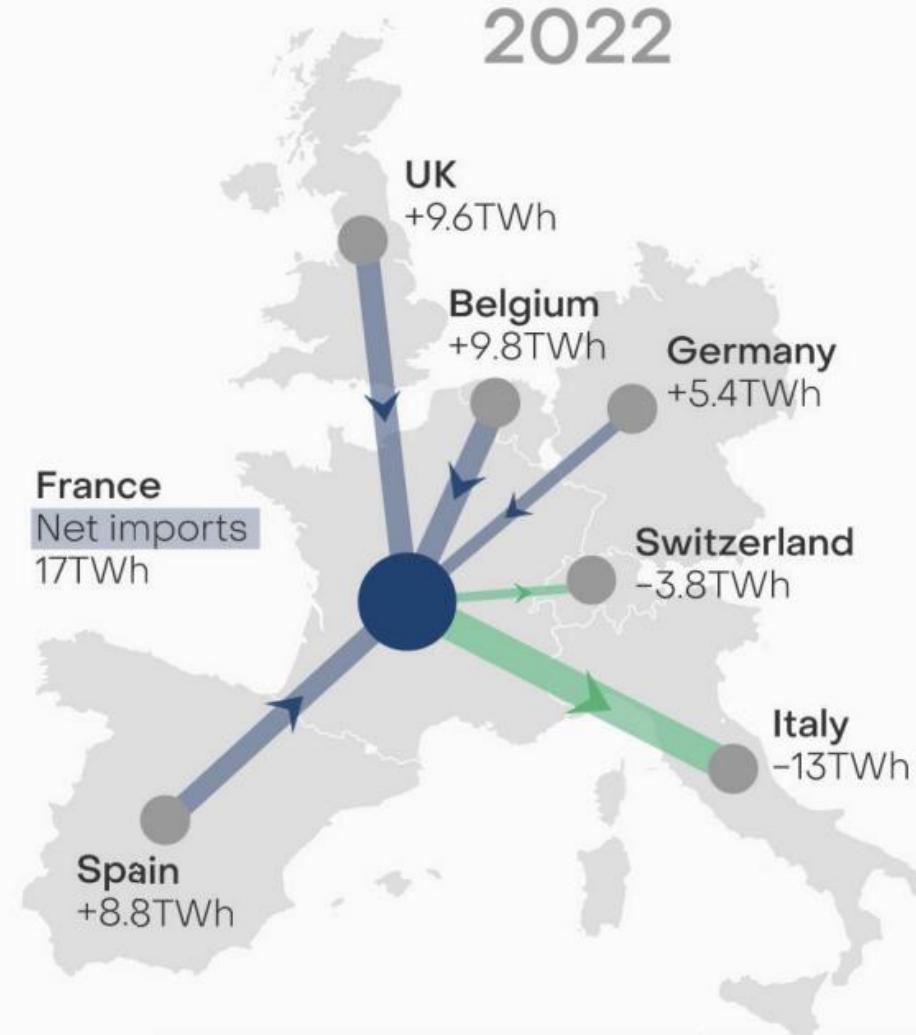
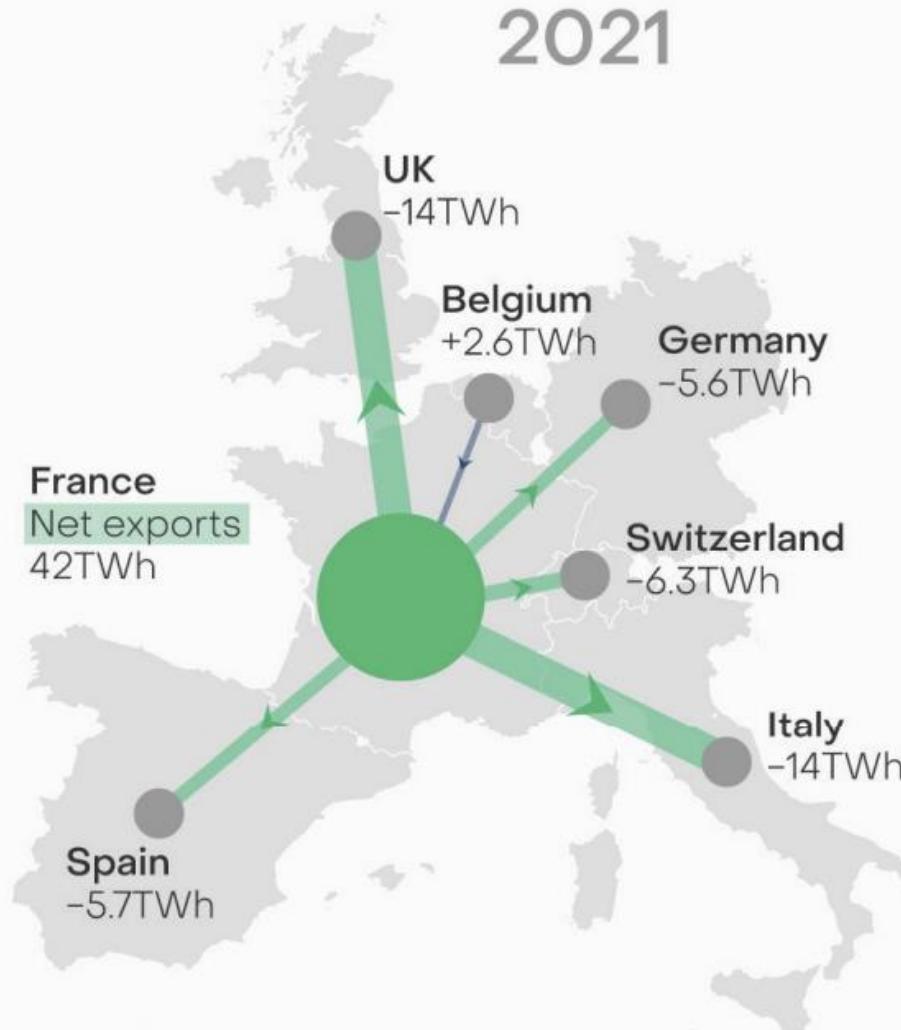
# Global electricity generation mix, TWh



# Belgian generation mix, TWh



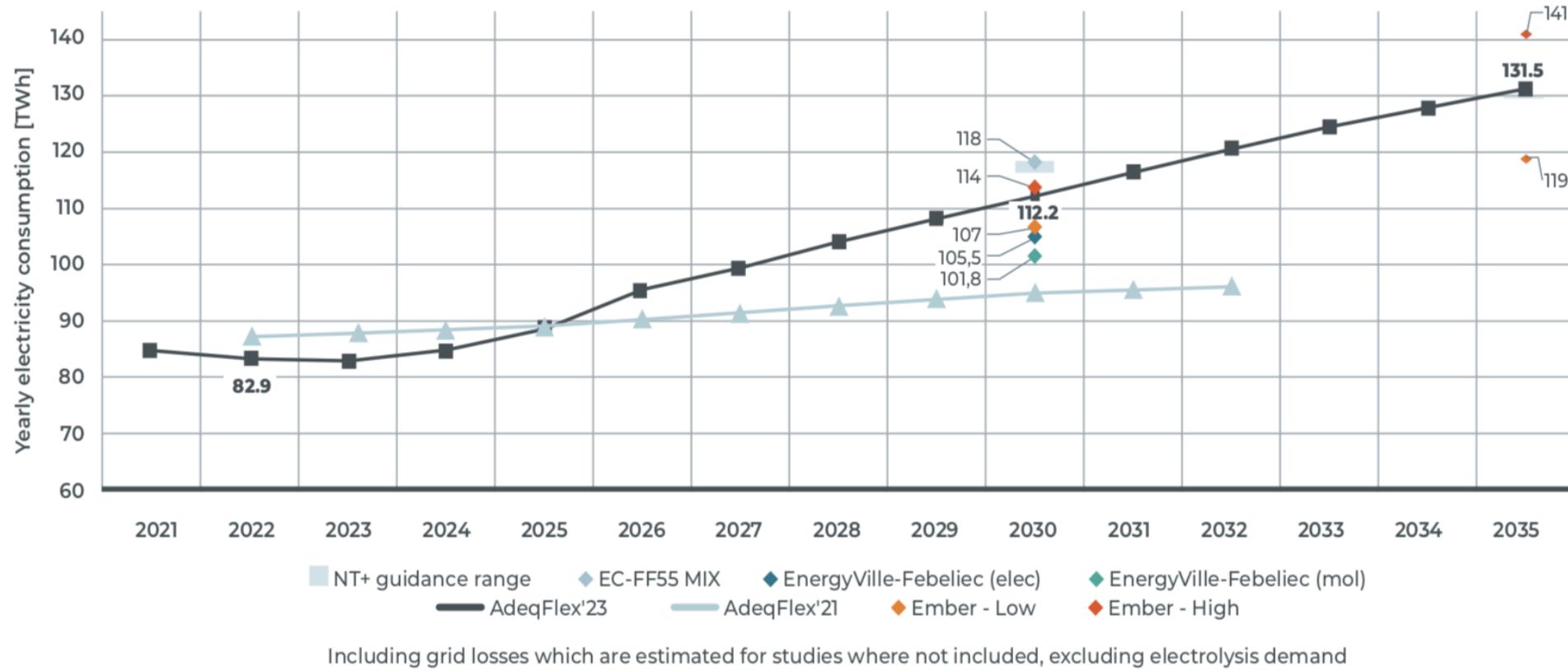
Lines and values represent net imports in electricity between France and each neighbouring country (TWh)



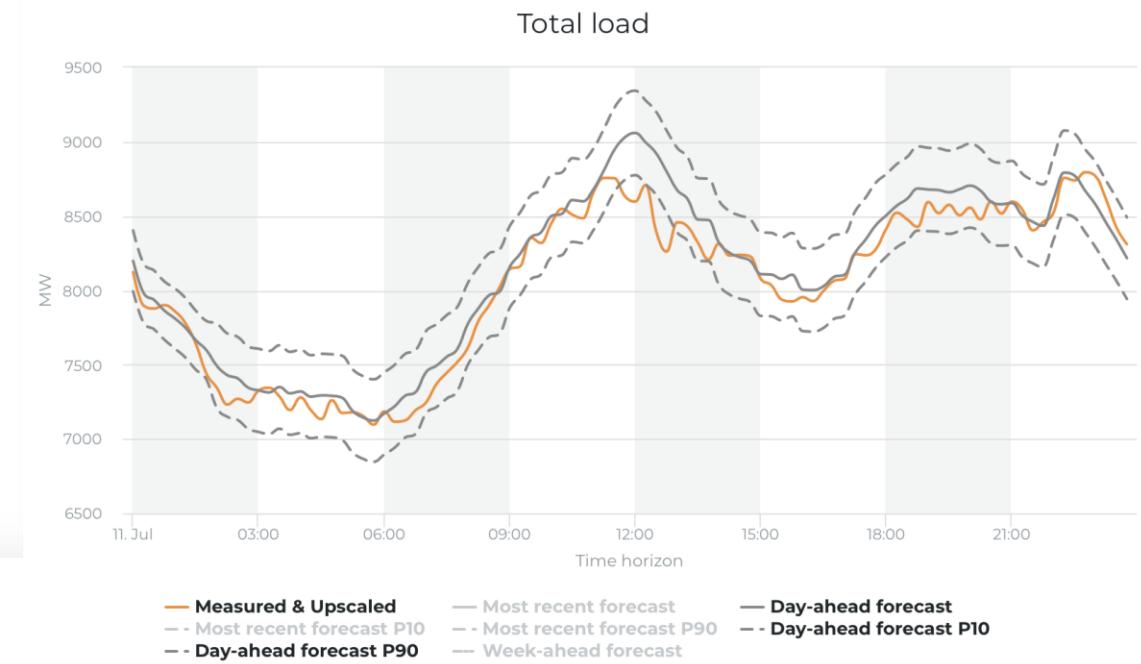
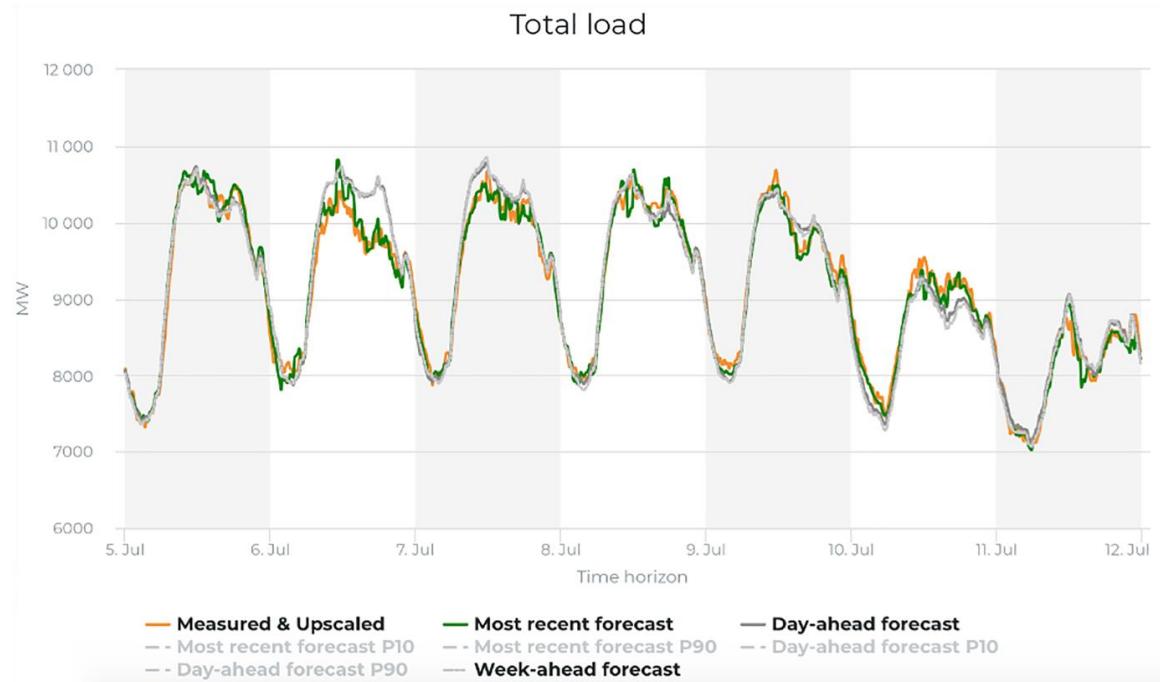
### 3. Forecasting opportunities, challenges



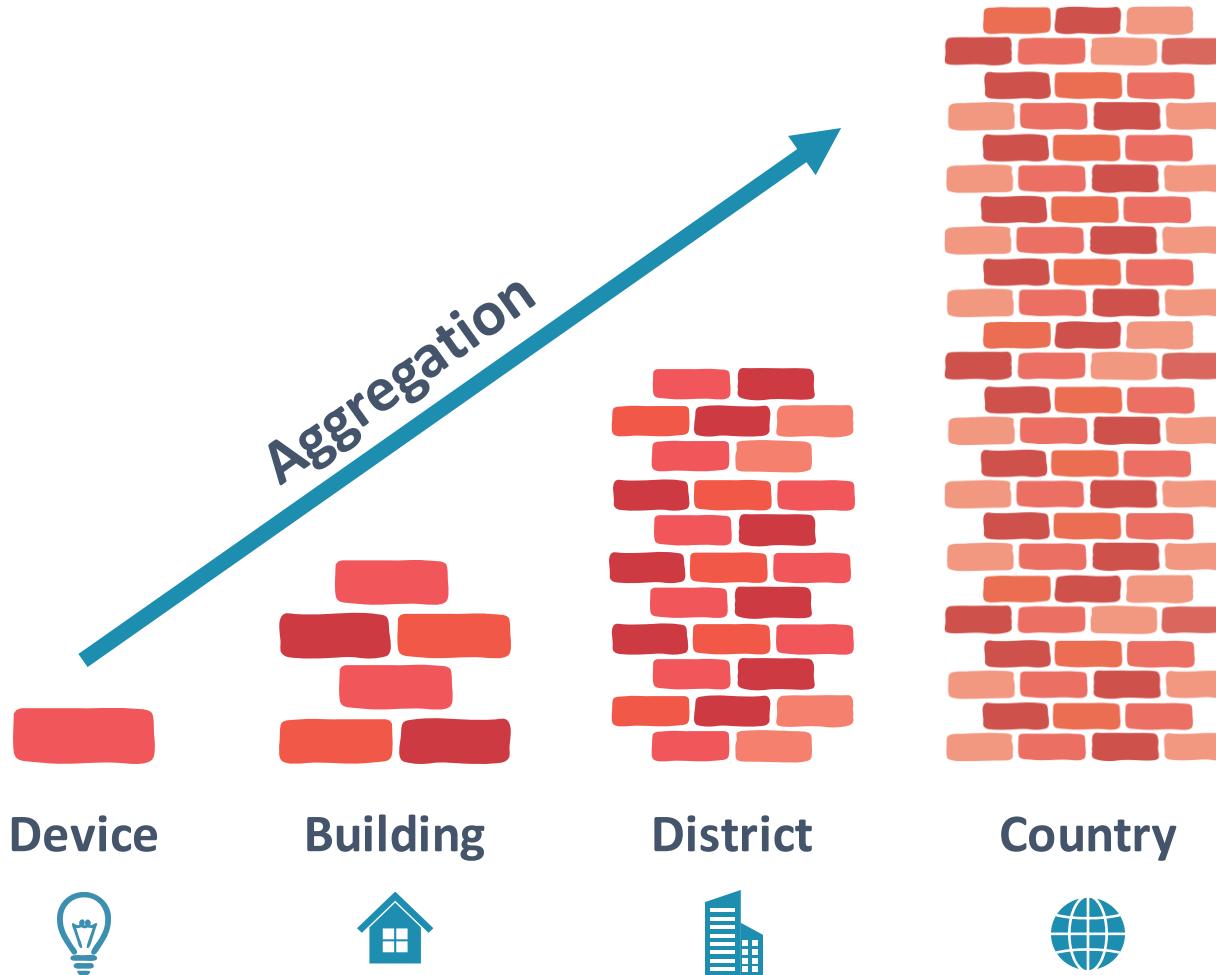
# Long term forecasts - planning



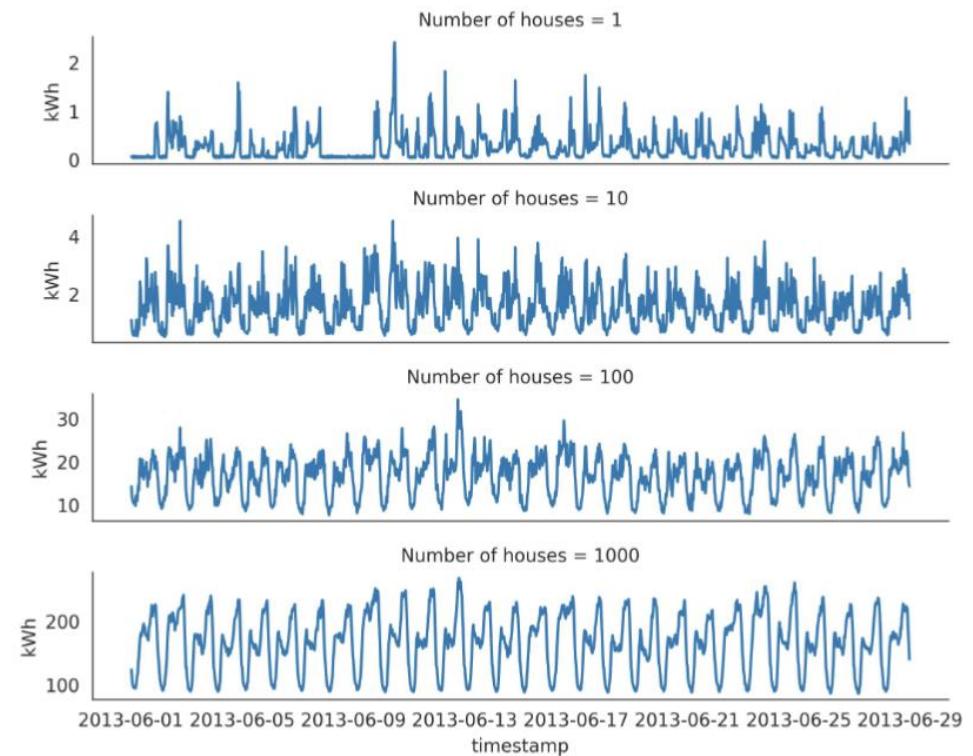
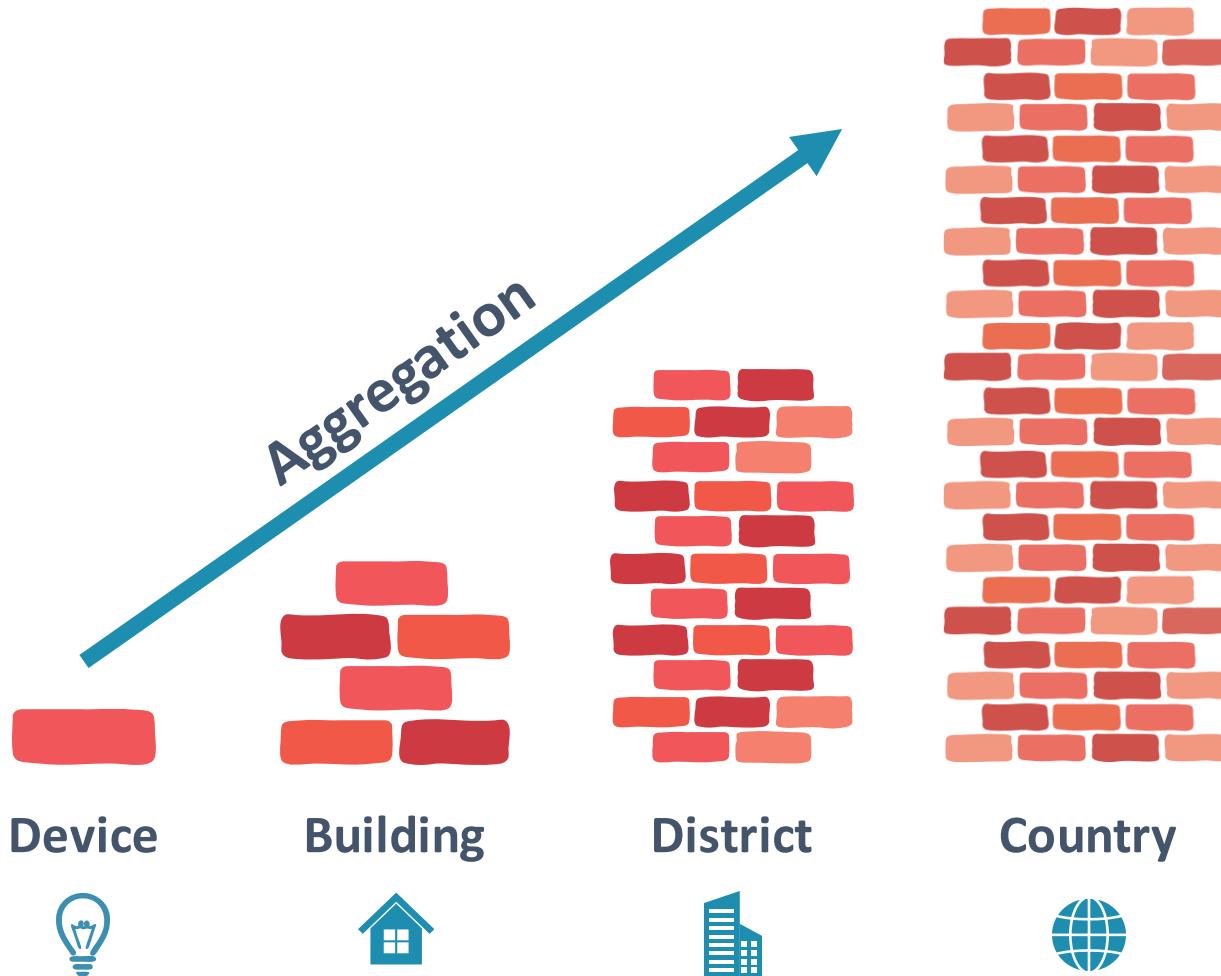
# Short term forecasts - operations



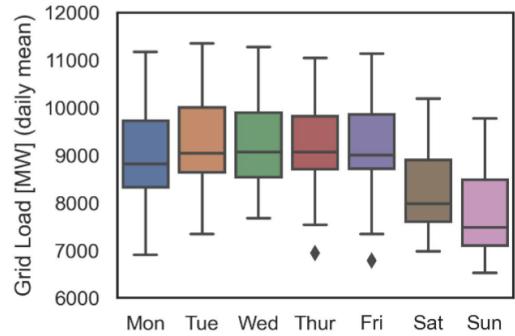
# Short term forecasts - aggregation



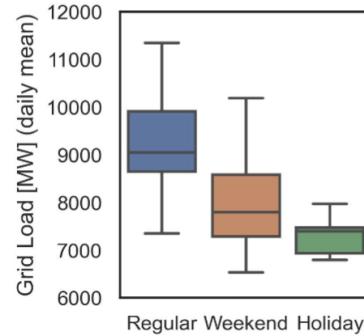
# Short term forecasts - aggregation



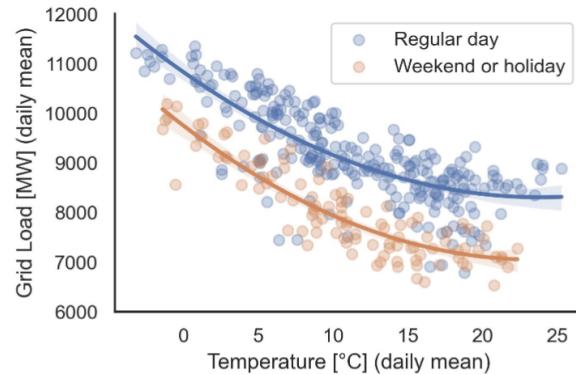
# Short term forecasts - aggregation



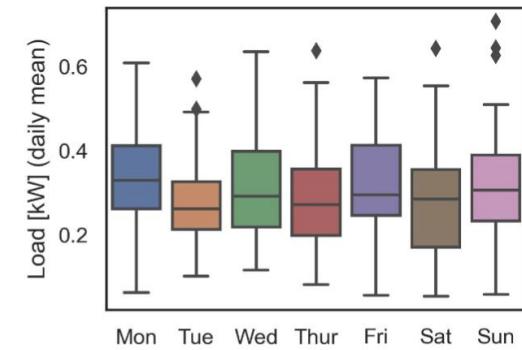
(a) Effect of a weekday.



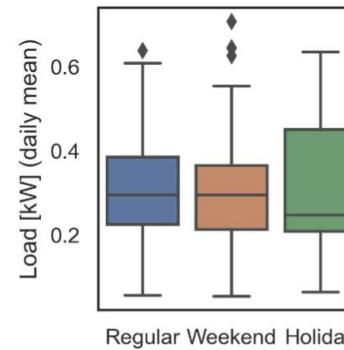
(b) Effect of day type.



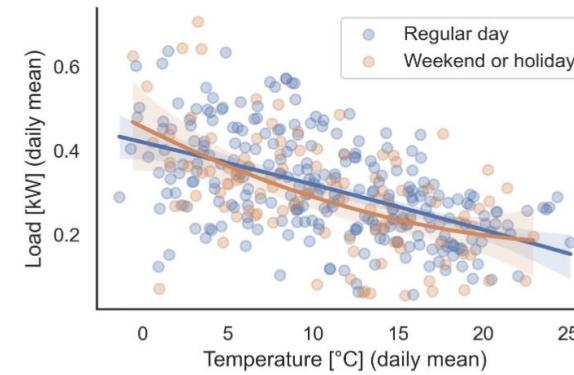
(c) Effect of ambient temperature.



(a) Effect of a weekday.



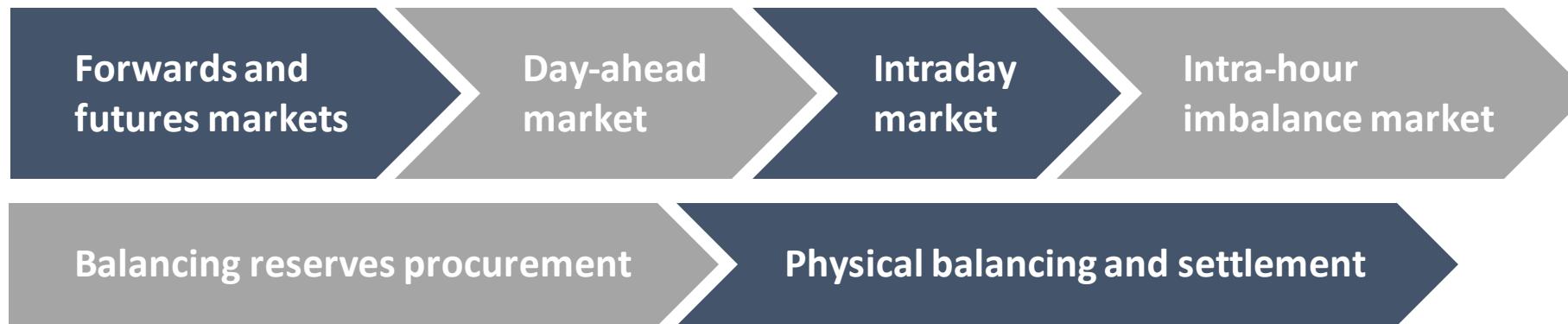
(b) Effect of day type.



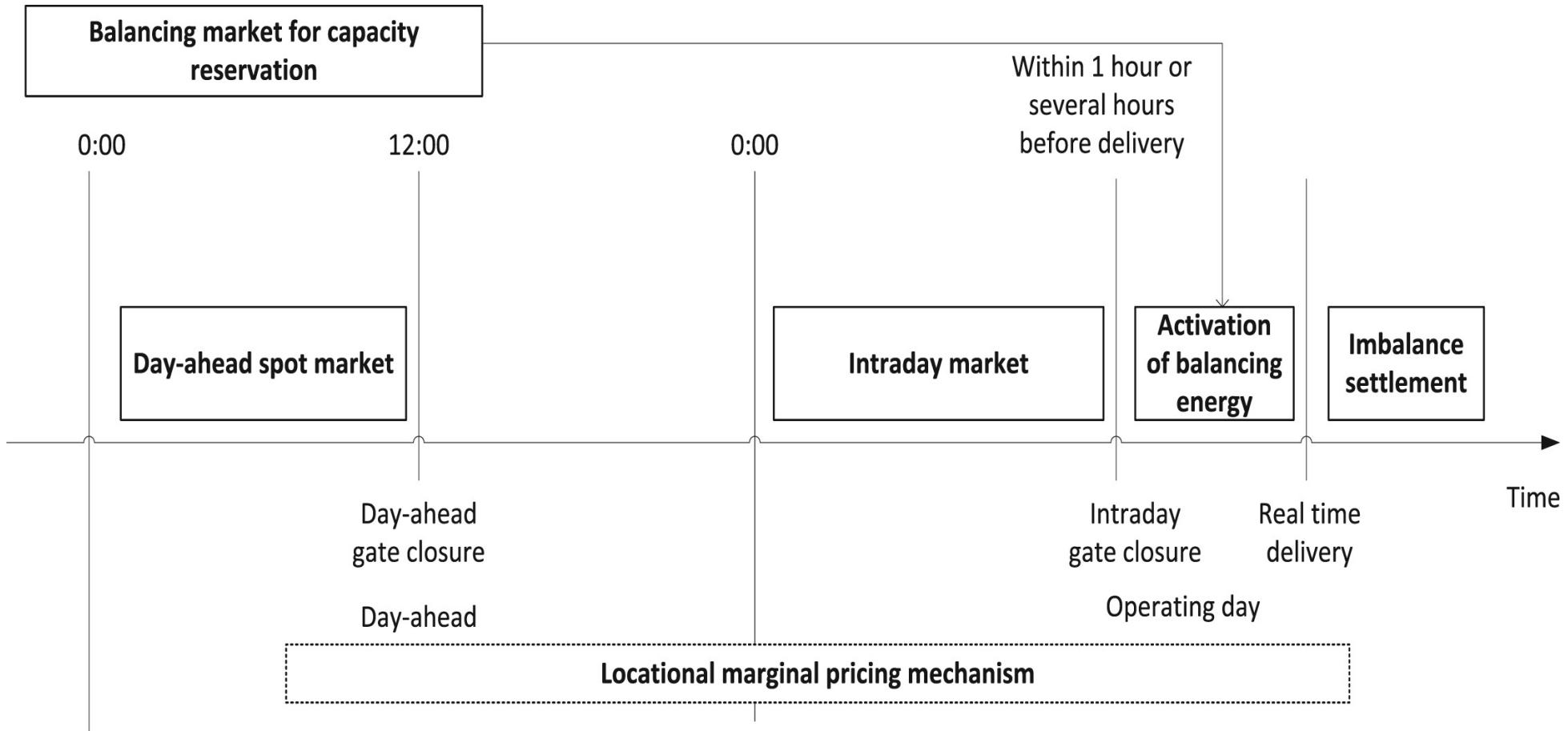
(c) Effect of ambient temperature.

# Short term forecasts - operations

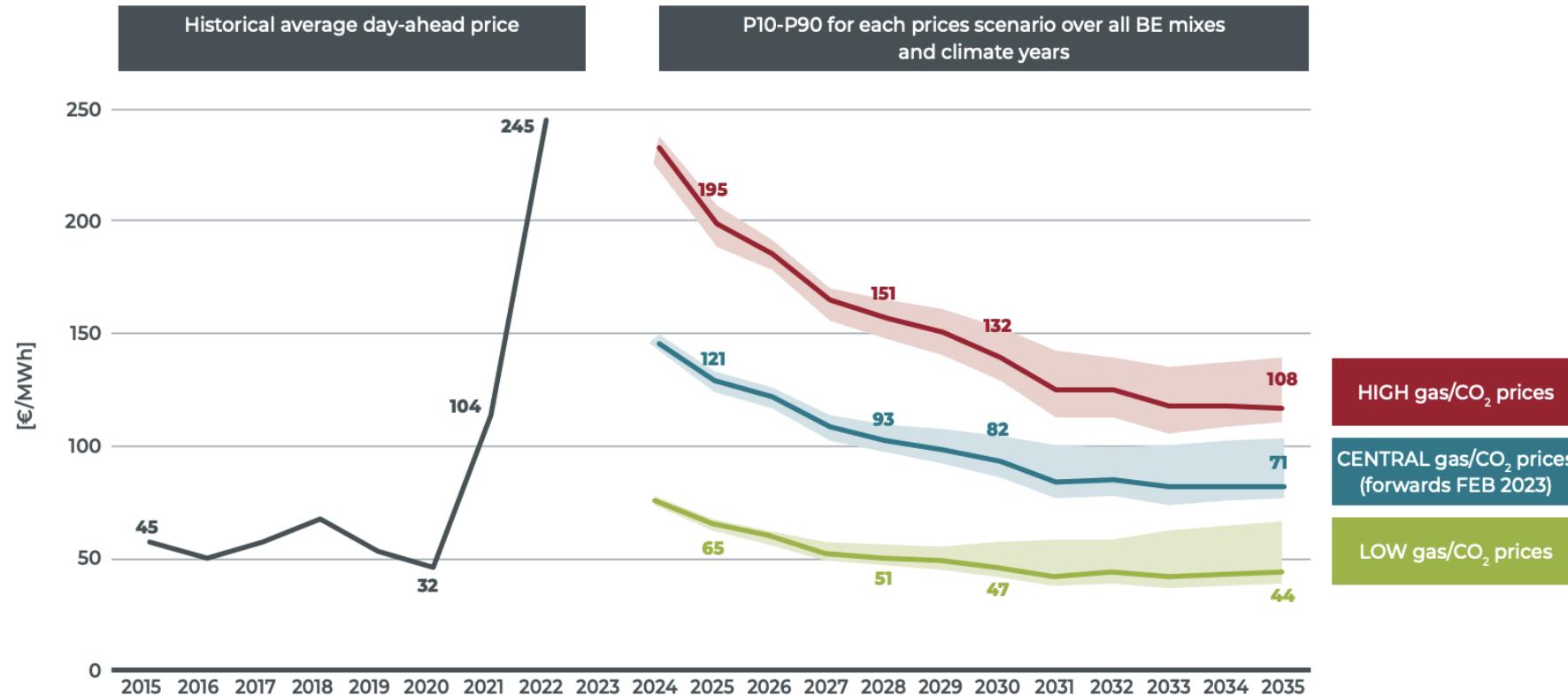
on the market side

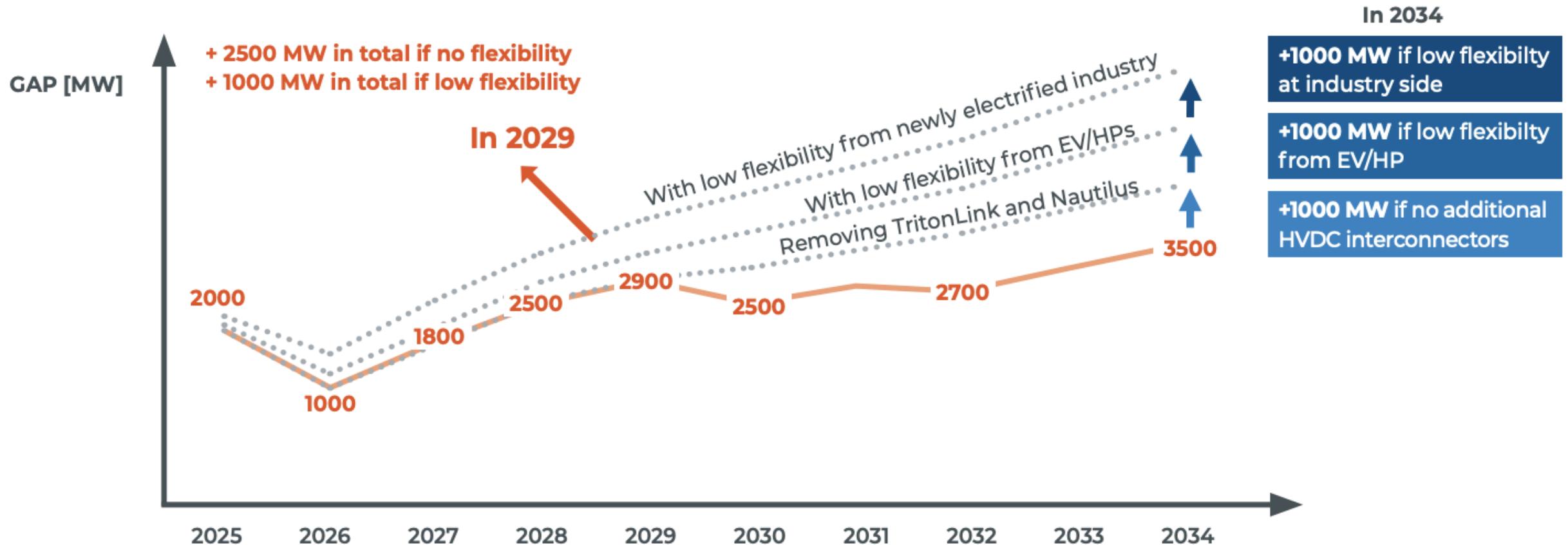


# Short term forecasts - operations



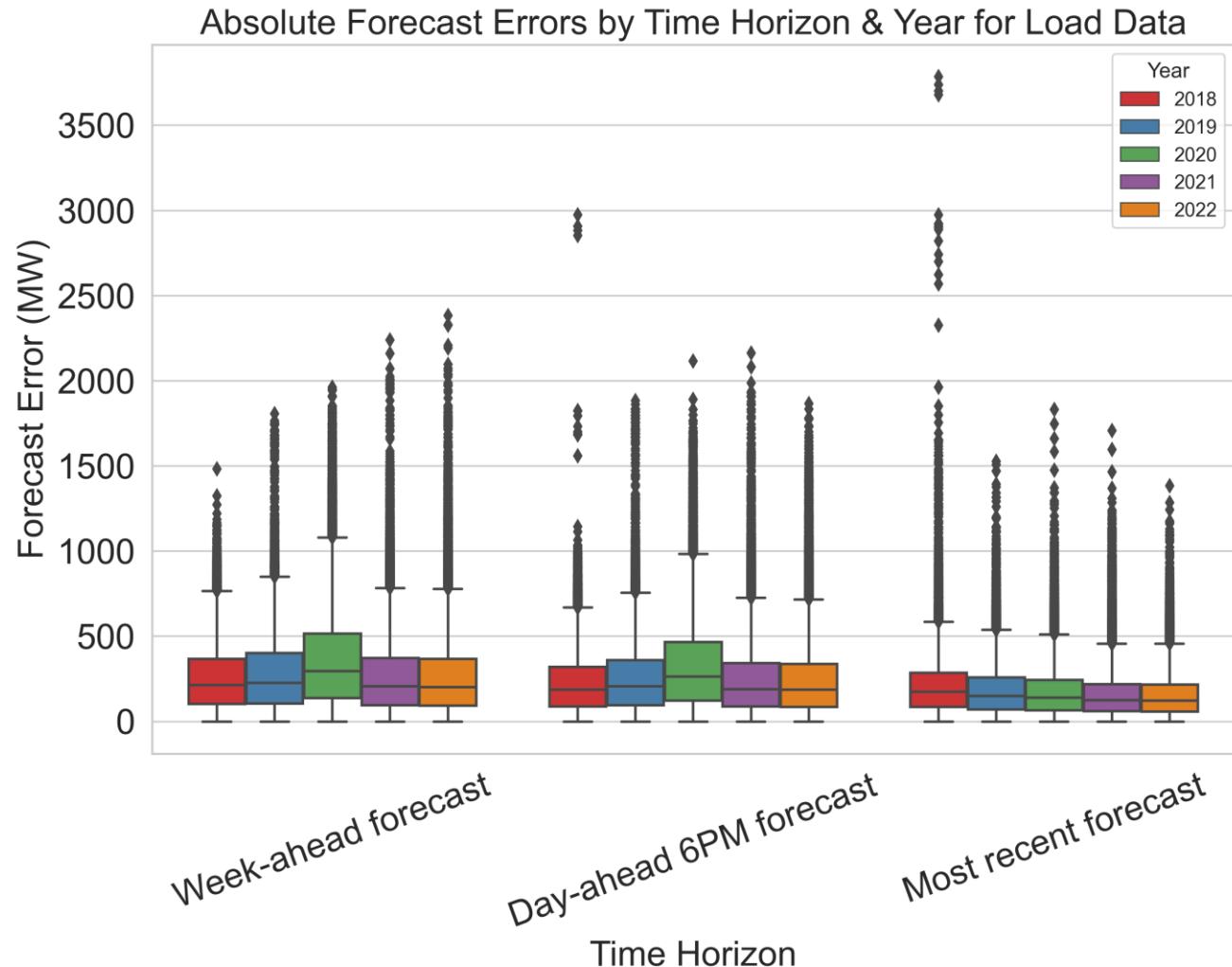
# Short term forecasts - markets



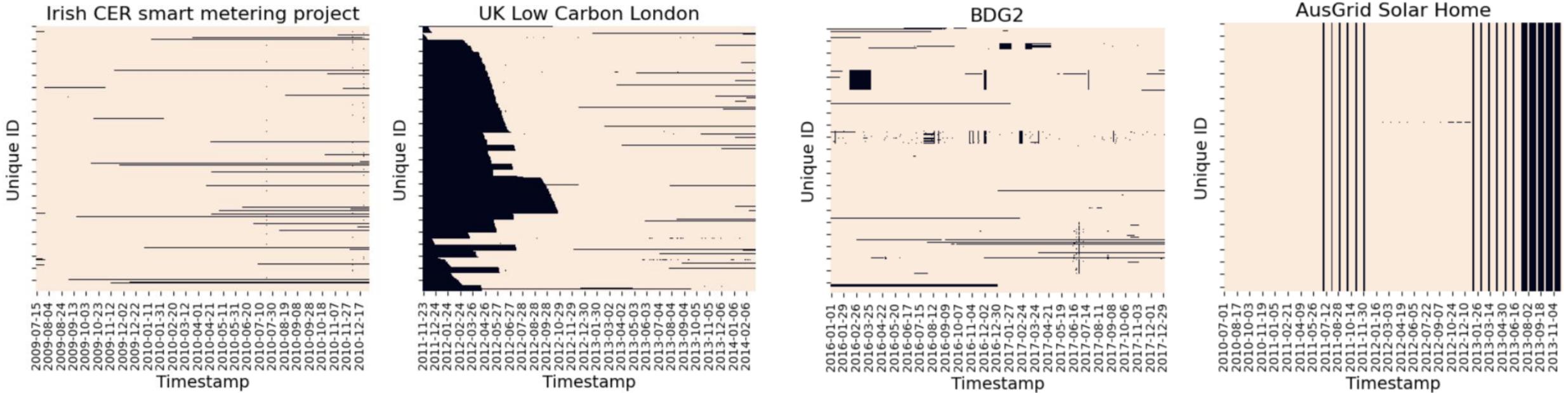


70% of the newly electrified industrial demand is assumed to be flexible by 2030. At the residential level, two thirds of EVs, one third of HPs and more than half of home batteries are assumed to be 'smart' in some way.

# Short term forecasts - errors

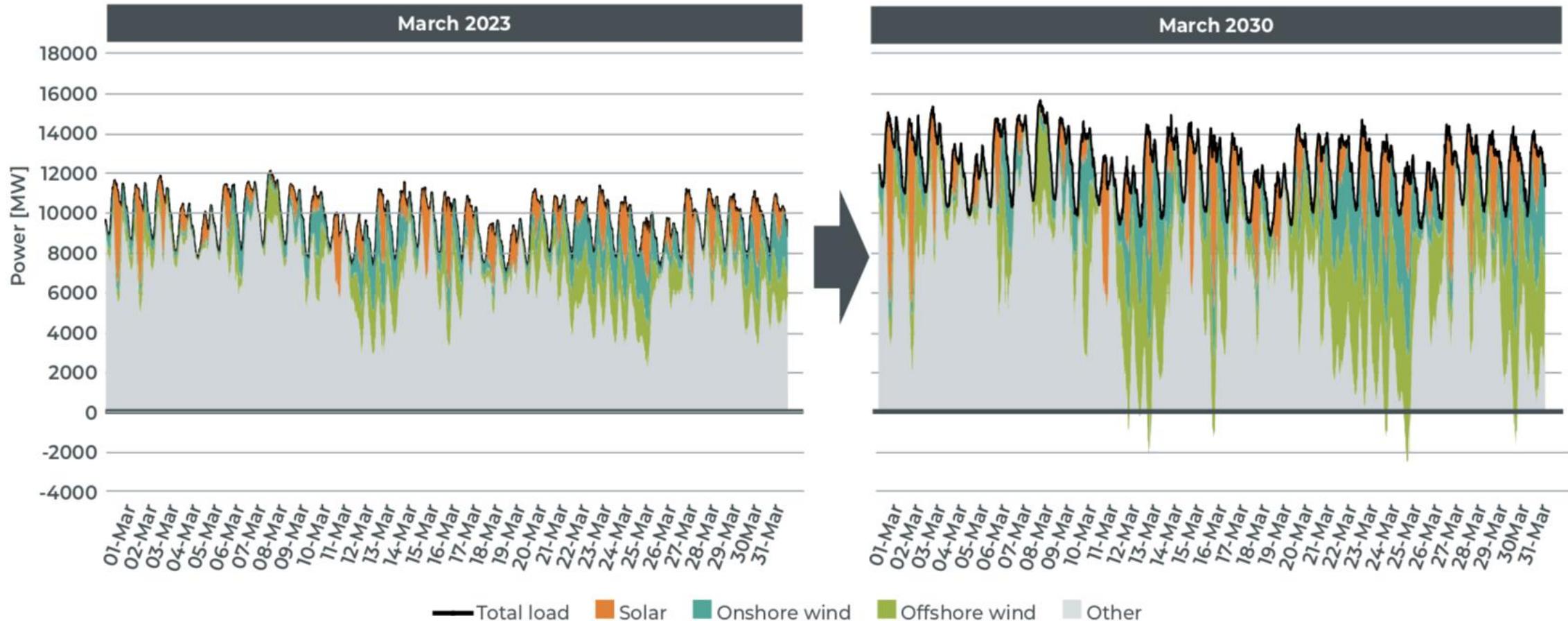


# Short term forecasts - observability



Black spots – or streaks are missing data values

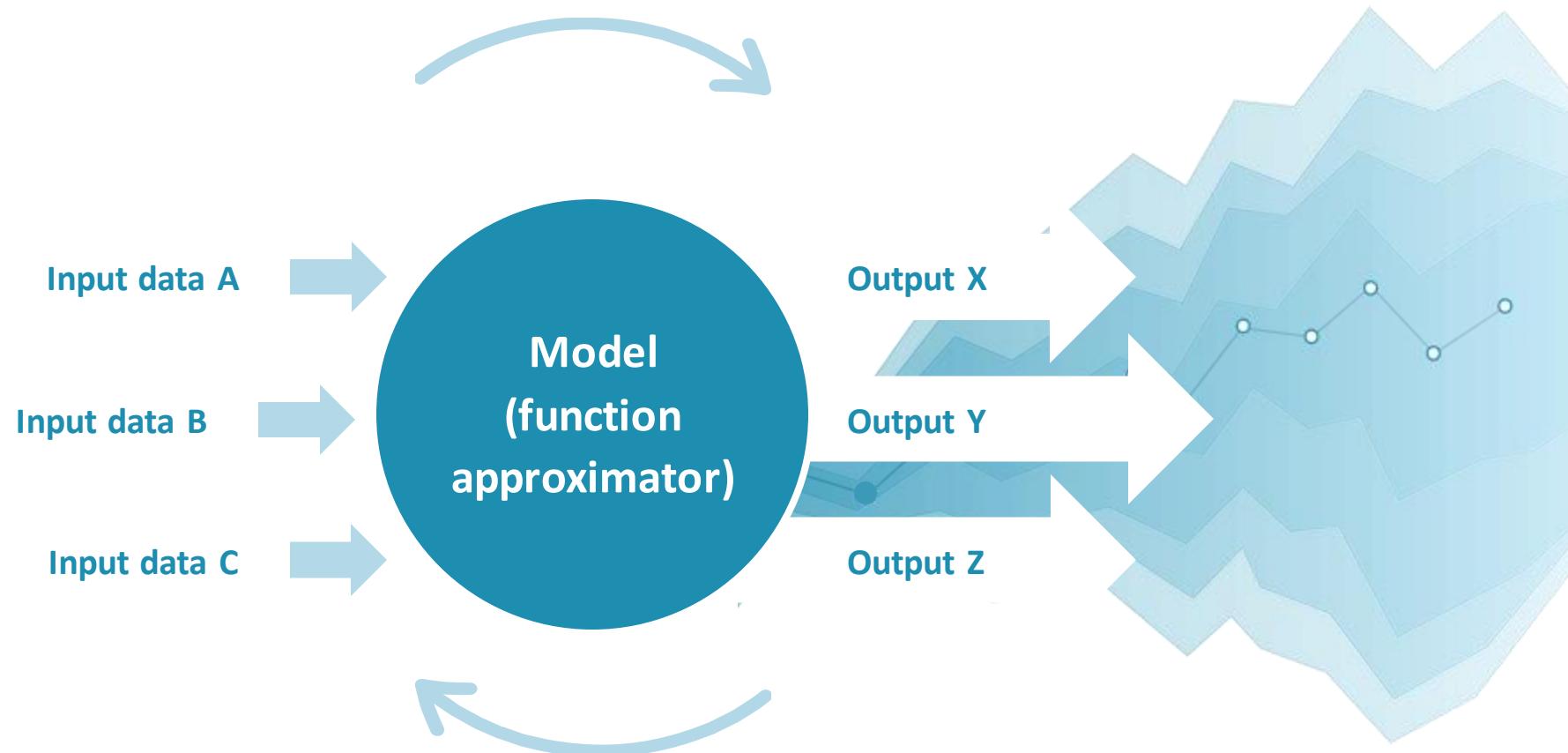
# Short term forecasts - variability



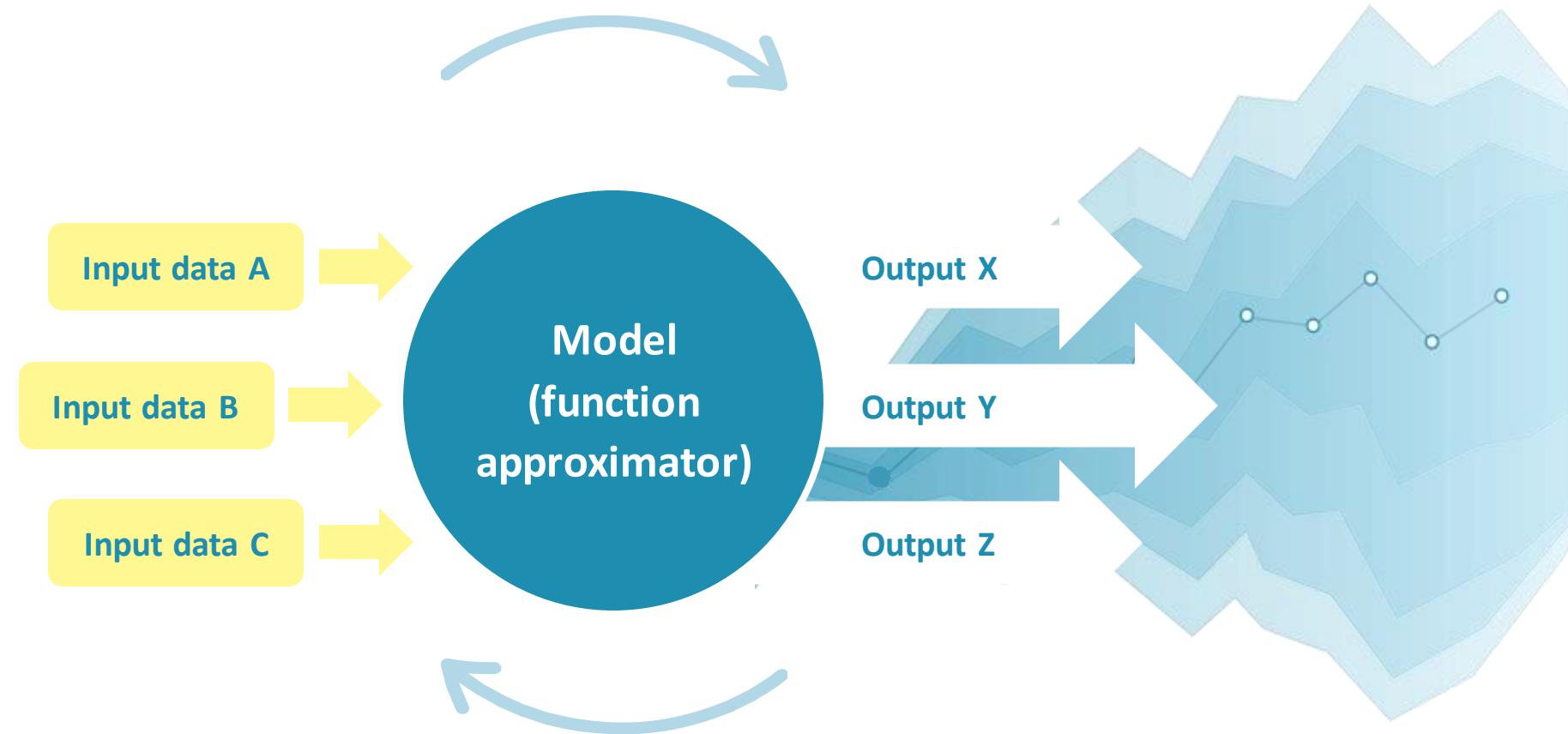
# 4. Forecasting, how to



# How to build a forecaster

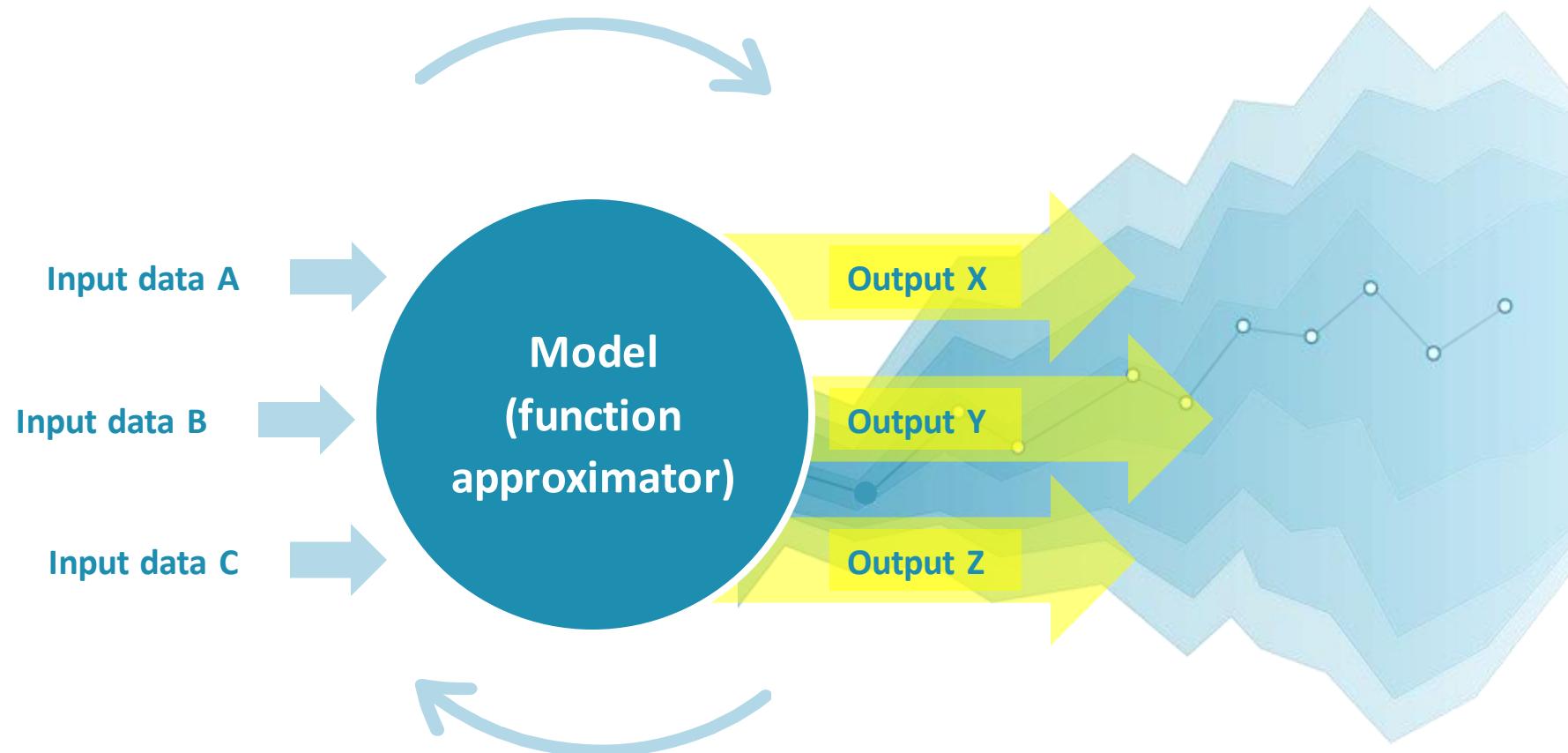


# Feature selection



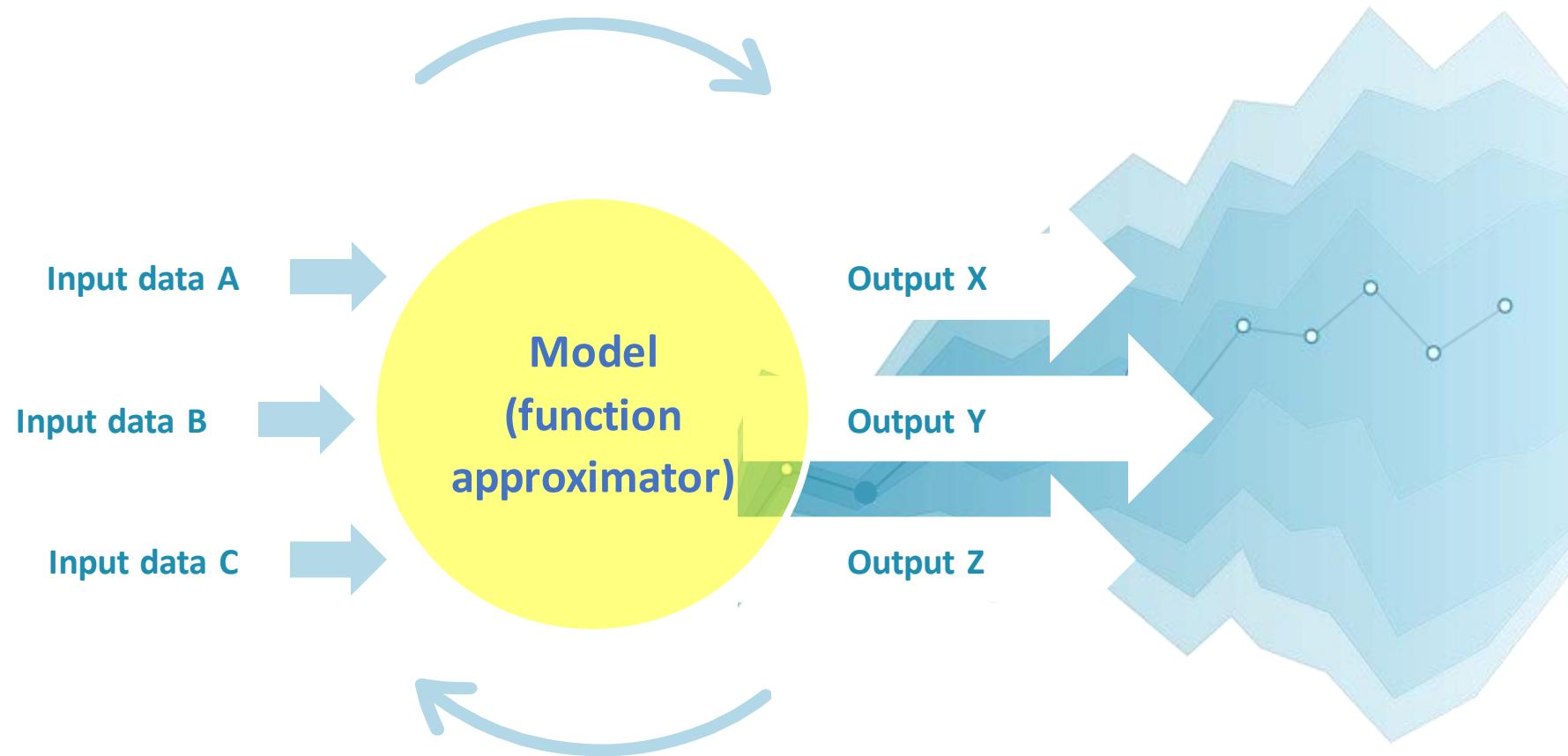
Choice of features, historical extents, feature transformations and normalizations, etc.

# How to build a forecaster



Choice of output, recursive vs. direct models, point vs. interval forecasts etc.

# How to build a forecaster



Choice of function approximator, linear vs. non-linear, optimizer, learning rate etc.

# What makes a good forecaster?

- Error metrics (MAE, RMSE,  $R^2$ , rMAE, MAPE, ...) and distributions
- Generalization, especially in out of distribution and worst-case outcomes
- Scalability and computational complexity (training and inference time)
- Interpretability and uncertainty calibration
- ...

# Sources

- Midjourney, openAI DALLE
- Ember Energy
- ENTSO-E
- Elia
- IEA

