

Energy Forecasting for Market-led Multi-vector Energy Networks

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Supergen
| Energy Networks



**Engineering and
Physical Sciences
Research Council**

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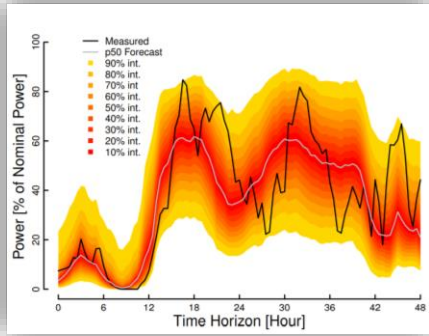
Contents

- EnFORMM Overview
- Intraday markets and balancing
 - Market structures
 - Price formation
- Electricity imbalance volume and price forecasting
 - Available data
 - Forecasting methodologies
 - Preliminary results

Thanks to our partners!



EnFORMM Overview



Predict electricity and gas prices and volumes, and quantify risk

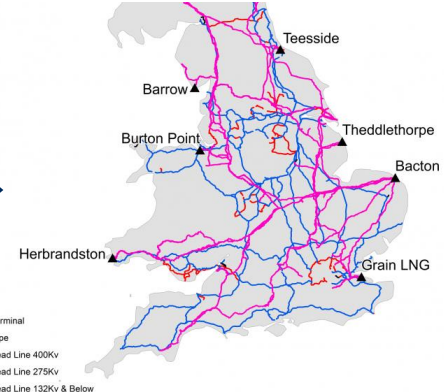
Energy **FOR**ecasting and analytics for **Market-led Multi-vector** networks

> **epexspot**

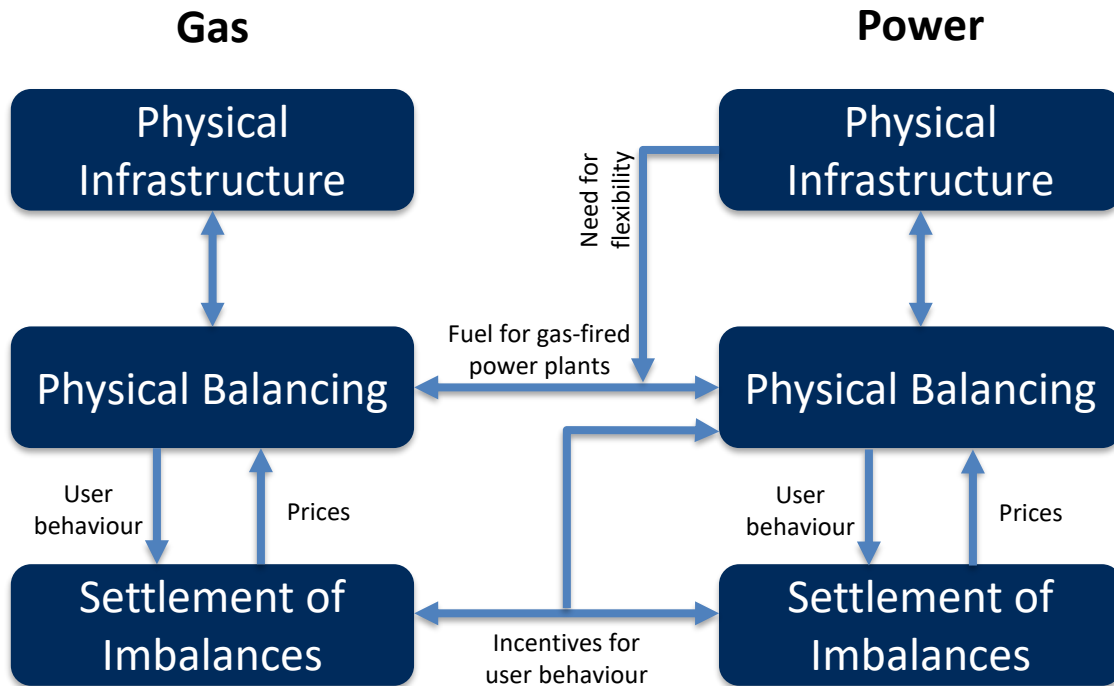
**NORD
POOL**

ICE ENDEX®

Balancing markets at interface of
wholesale supply/demand and
delivery via *multi-vector* networks



EnFORMM Overview



EnFORMM Overview

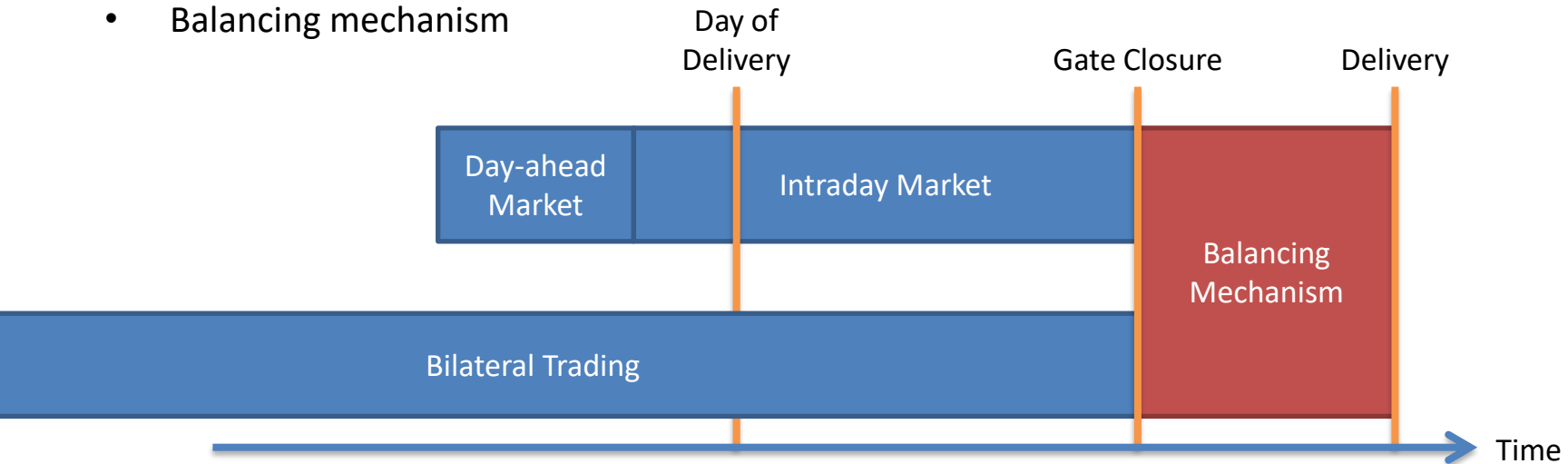
- Availability and flexibility communicated via price signals
- Multi-vector/market forecast required to:
 - Identify and realise cross-vector opportunities
 - Quantify risk for participants and network operators
 - Support and automate trading functions in an increasingly complex environment
- Challenges → objectives:
 - Risk quantification → multivariate probabilistic forecasting
 - Complex fundamentals → encode domain expertise
 - Evolving market rules → adaptive model

INTRADAY MARKETS AND BALANCING

Electricity Marketplaces

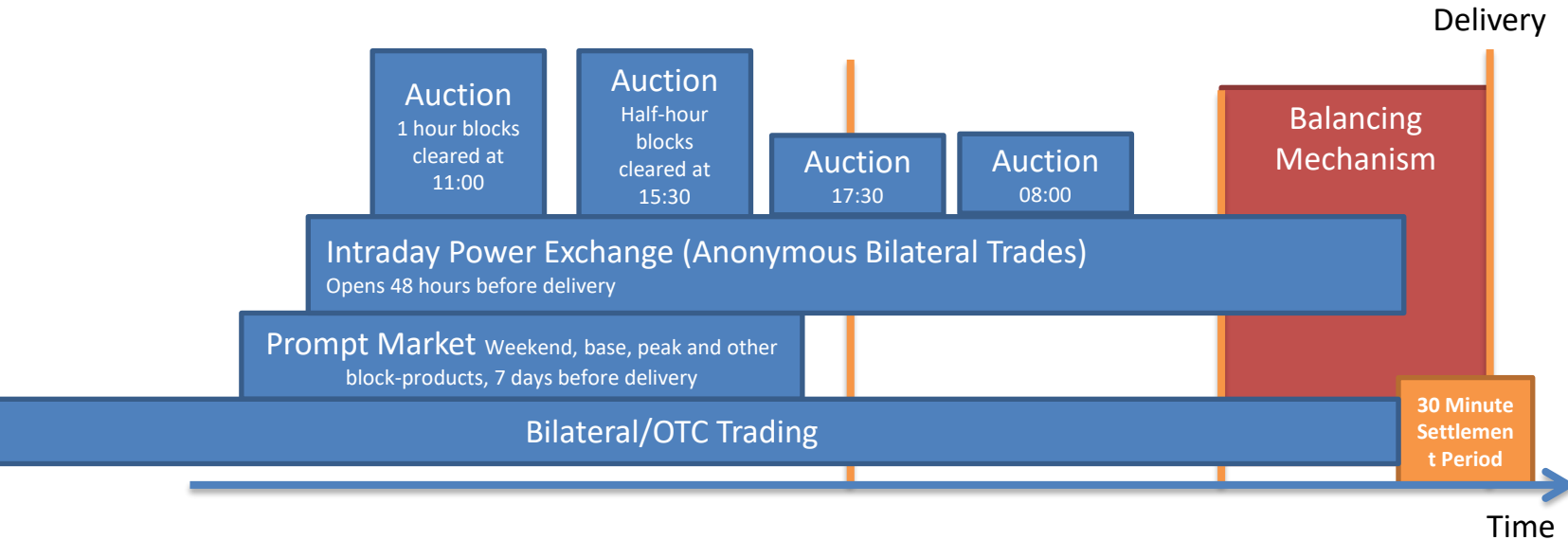
Most electricity markets share some common features:

- Bilateral contracting (“*Over-the-counter*” Trading)
- Day-ahead auction
- Intraday market
- Balancing mechanism



Electricity Marketplaces

- GB:



Since 2 November 2017 trading may continue until start of settlement period – but generator schedule is fixed at BM gate closure. See: [<https://www.elexon.co.uk/mod-proposal/p342/>]

Imbalance Price Formation

Contract and Physical Notifications

- Trading Party contract energy volumes ahead of time
- Balancing Mechanism Units report dispatch schedules, bids and offers

Delivery

- BM Units do their best to stick to dispatch schedules
- NGESO adjusts schedules by accepting bids/offers in order to:
 - Balance supply and demand
 - Relieve physical constraints

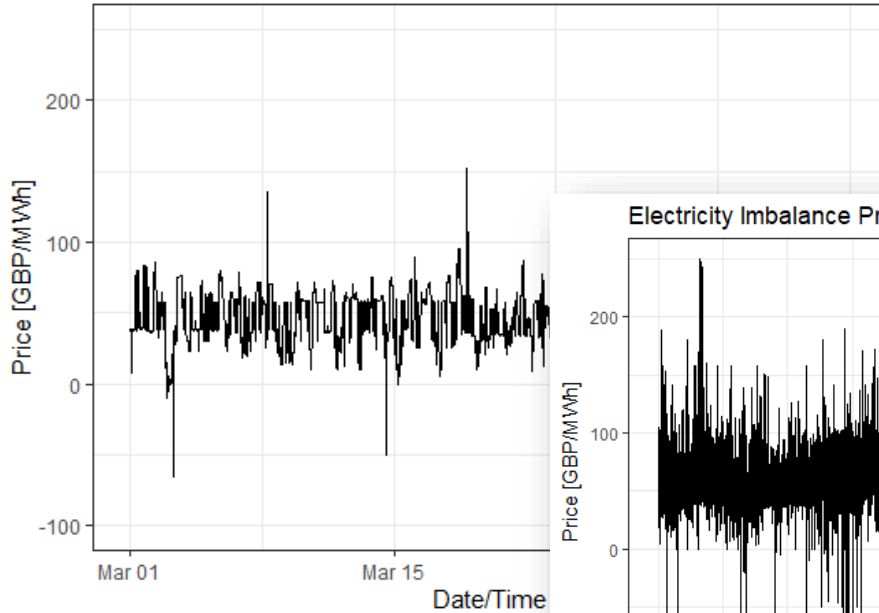
Most expensive 1MWh of energy balancing action set the **Imbalance Price**

Settlement

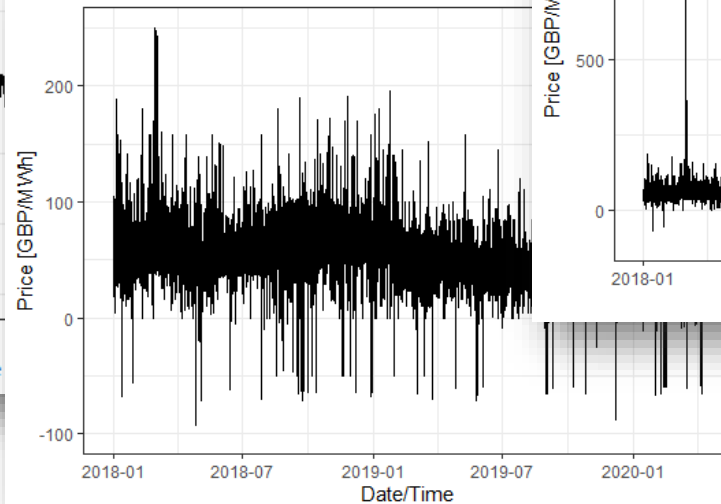
- Each Trading Party's contracted volume compared to delivery
- Difference settled at the **Imbalance Price**

Electricity Imbalance Prices

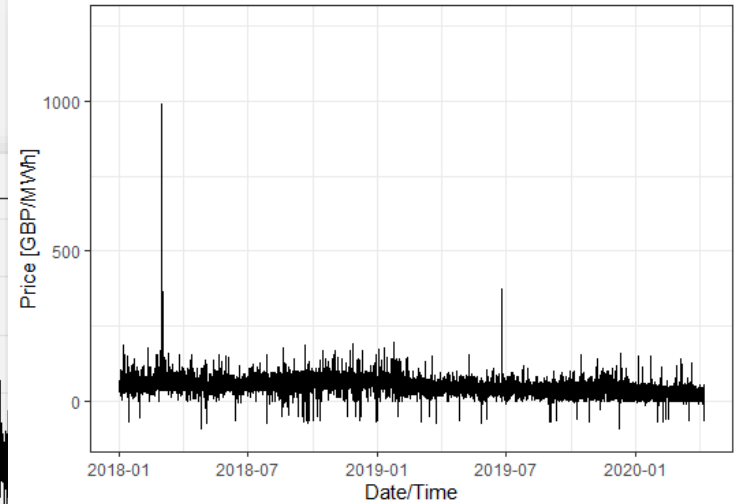
Electricity Imbalance Price 2019



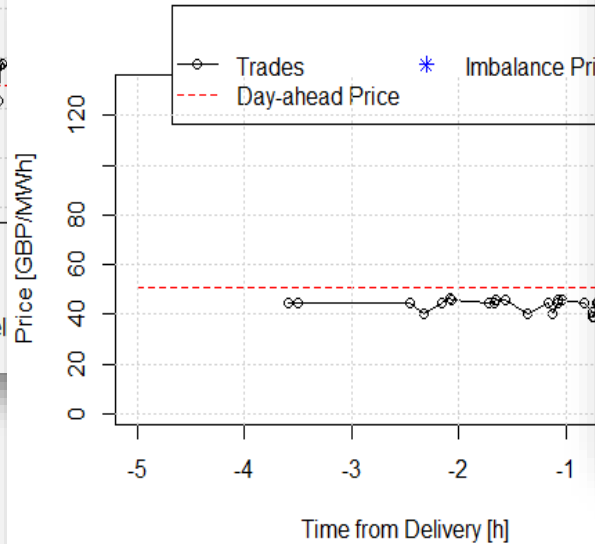
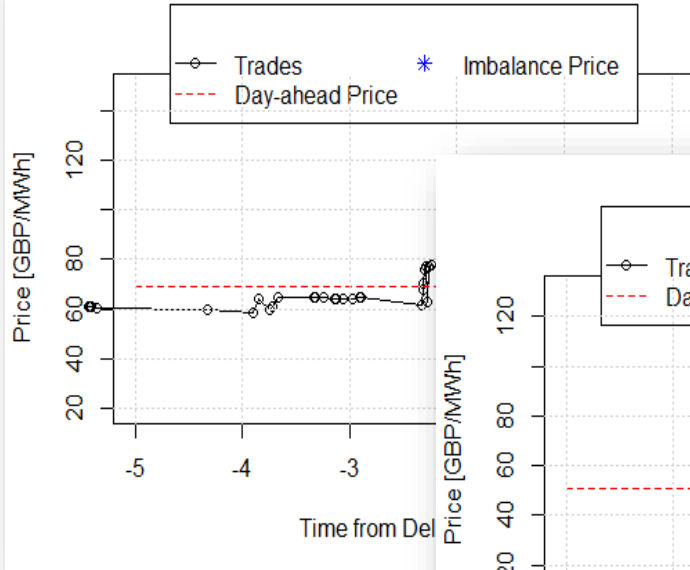
Electricity Imbalance Price



Electricity Imbalance Price

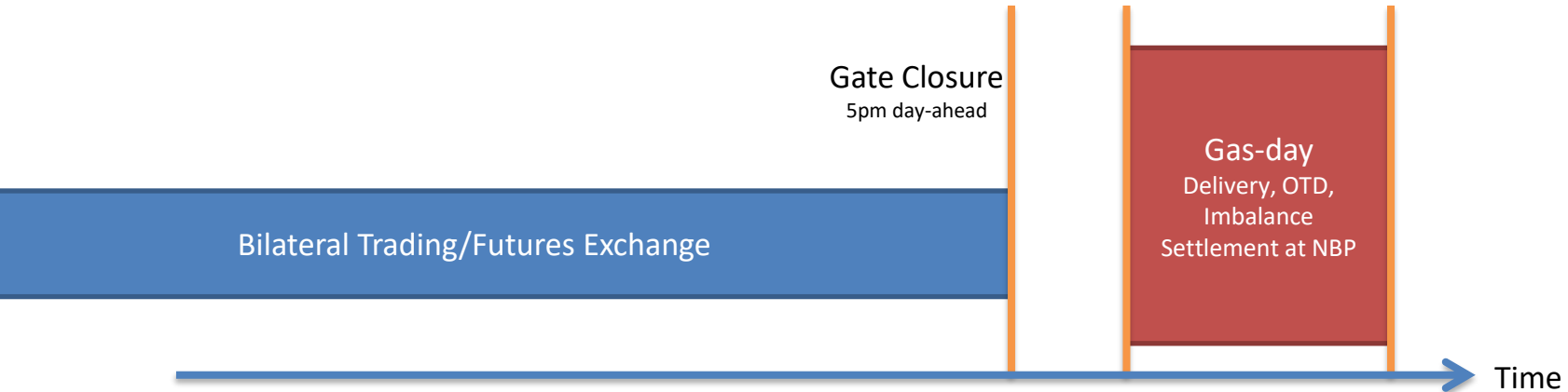


Electricity Intraday Trading

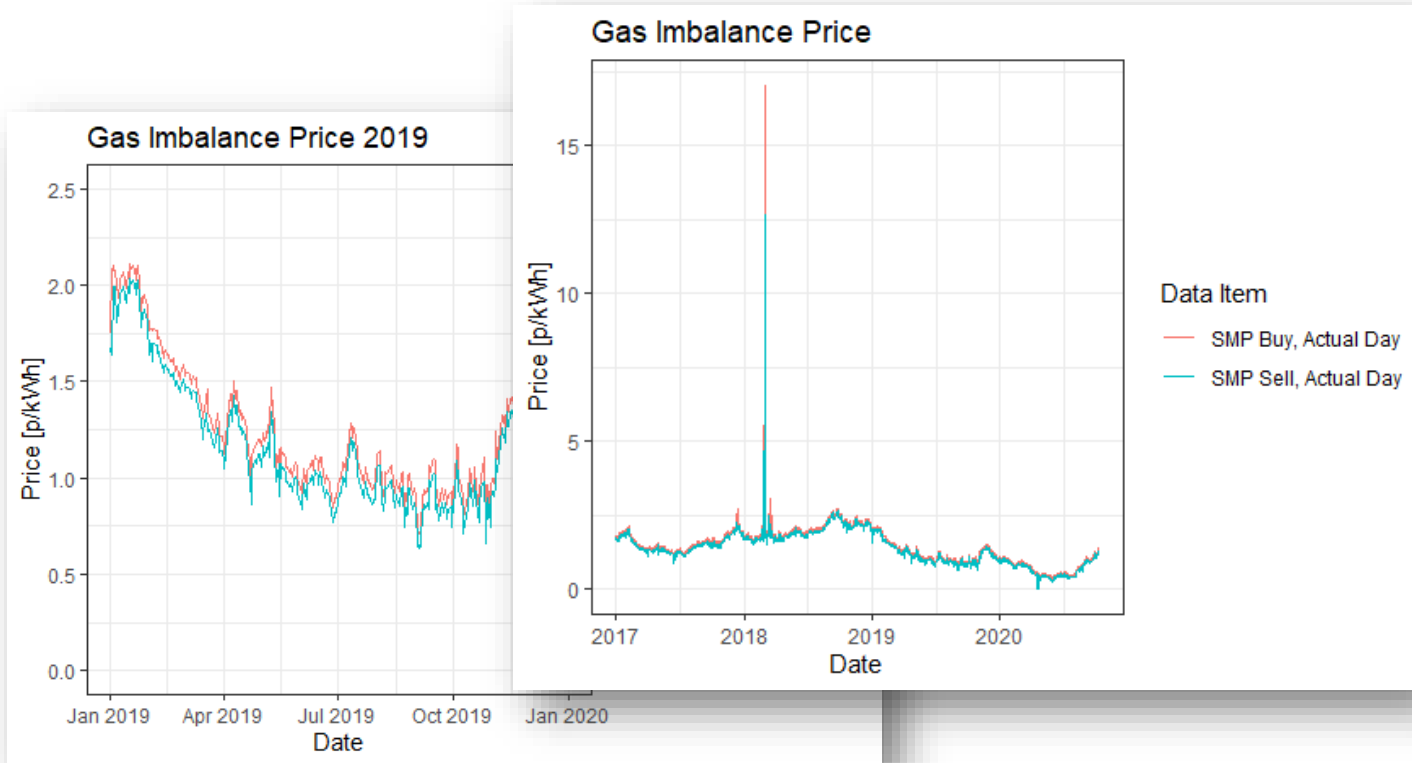


Gas Marketplaces

- Single *National Balancing Point* (NBP)
- Trading until 5pm day-ahead
- Daily imbalance settlement
- Contracts for on-the-day (OTD), range of daily, monthly, quarterly & seasonal futures products traded

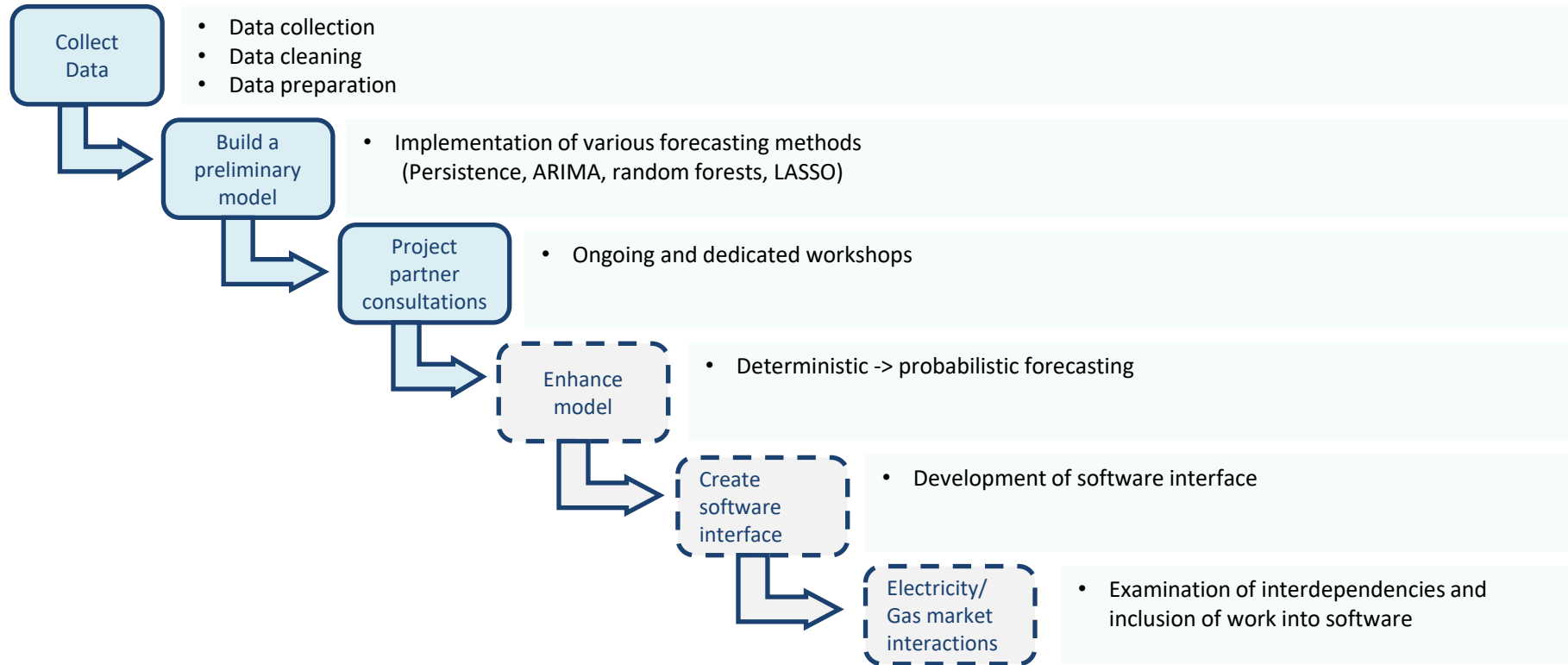


Gas Imbalance Prices



ELECTRICITY IMBALANCE VOLUME AND PRICE FORECASTING

Project Progress



High-Level Data Inputs

GENERATION

Expected power generation (CCGT, Wind, Nuclear etc.)
Outages (REMIT data)

DEMAND

Demand forecast (TSDF, ITDSO, INDO, NDF)
Historic outturn

SYSTEM PROPERTIES

LOLP/ Derated margin
IMBALNGC/MELNGC
Bid/Offers
System Frequency
Interconnector flows
STOR

FORECASTS

Upcoming and historic forecasts (PV, wind, demand etc)
Forecast errors (where have forecast errors got it wrong?)

COMMODITY PRICES

Gas, Carbon, Oil, Coal

MARKET DATA

APX
N2EX
Day Ahead prices

OTHER



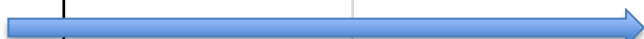
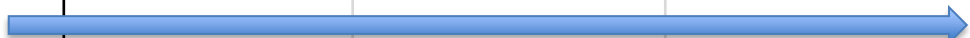
Temperature
Time of the day
Weekday/Weekends/holidays

Persistence model

THEORY

- Assume that the outturn forecast persists during subsequent settlement periods
- Update the forecast with a new forecast every settlement period

EXAMPLE

	Outturn	Forecast			
		01/01/2019 00:30	01/01/2019 01:00	01/01/2019 01:30	01/01/2019 02:00
01/01/2019 00:00	-1058 	-1058	-1058	-1058	-1058
01/01/2019 00:30	-664 		-664	-664	-664
01/01/2019 01:00	-1034 			1034	1034
01/01/2019 01:30	-1319 				-1319

ADVANTAGES

- Simple, easy to implement
- Provides a benchmark

DISADVANTAGES

- Low accuracy
- Doesn't consider trends or influence of external factors

Intermediate methods

ARIMA

THEORY

Forecast future values by:

- Regressing over previous values (AR)
- Differencing to ensure stationarity (I)
- Regressing over previous errors (MA)

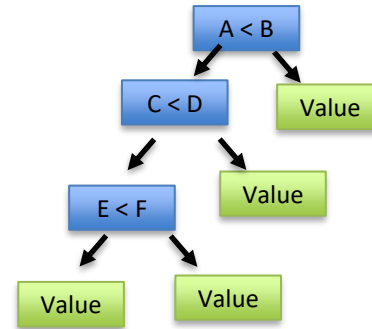
ADVANTAGES

- Simple to implement as based on a single variable
- Provides valuable information on the effect of lagged values on the present value
- Provides a probabilistic forecast

Decision trees/Random Forests

THEORY

Use the historic data to train sets of decision trees. These decide what future values will be based on similar sets of previous values.



ADVANTAGES

- Potential for automatic feature selection – variables which do not improve the model sufficiently can be excluded if desired

LASSO regression

THEORY

- Ordinary Least Squares (OLS) regression with additional penalisation of the coefficients

SOME MATHS

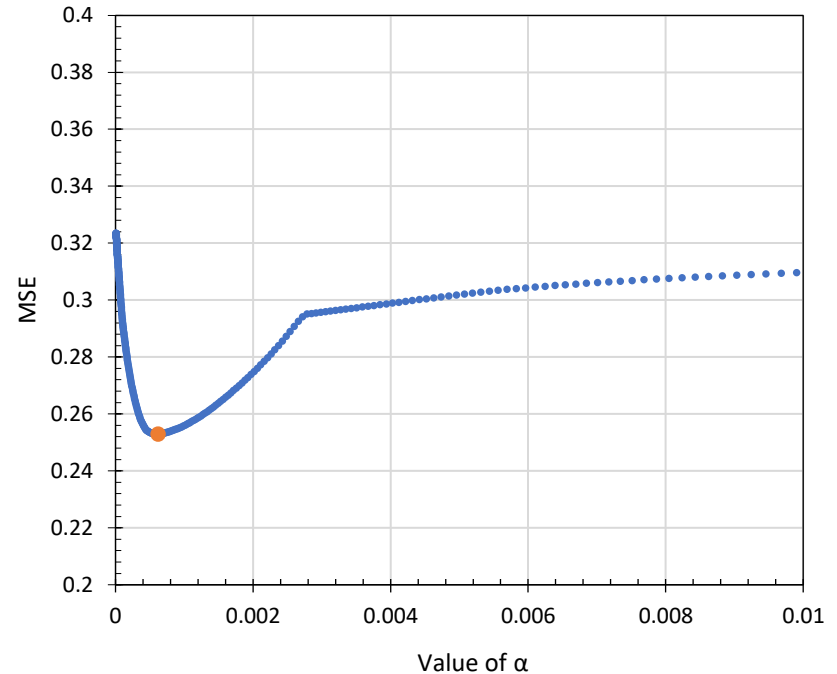
y = actual values

$$\hat{y} = b_1x_1 + b_2x_2 + \dots + b_nx_n$$

$$\min \left(\underbrace{\sum (y - \hat{y})^2}_{OLS} + \underbrace{\alpha \sum |b|}_{LASSO \text{ extension}} \right)$$

ADVANTAGES

- Best-in-class method for similar power market forecasts^[1]
- Inherent feature selection
- Can be extended to probabilistic forecasts (through quantile regression)
- In general leads to lower MAE than persistence, ARIMA or random forest methods
- Returns coefficients of each variable



^[1]F. Ziel, "Forecasting electricity spot prices using lasso: On capturing the autoregressive intraday structure," *IEEE Transactions on Power Systems*, vol. 31, no. 6, pp. 4977-7987, 2016.

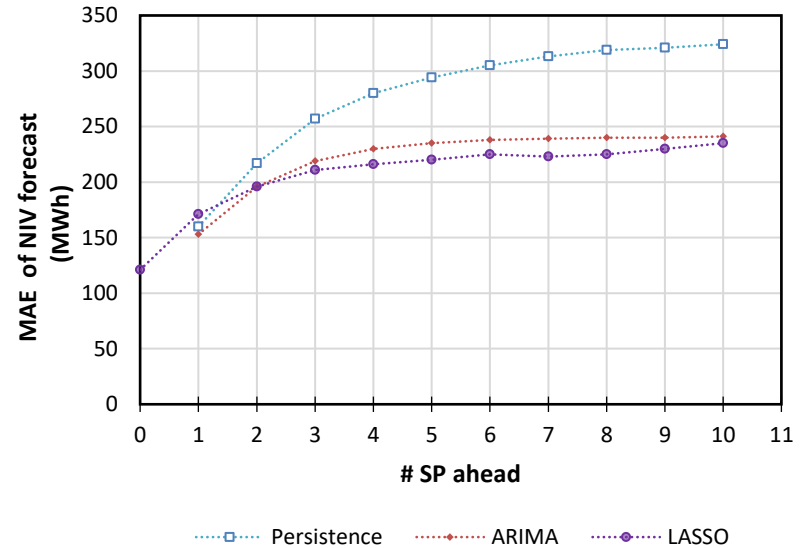
LASSO + logistic regression

- Lasso regression shows a significant improvement in accuracy when trained separately for a long system and a short system.
- Use logistic regression to determine the probability that the system will be long/short.
- Then predict the NIV and cash-out price using the long or short LASSO model.

Results

- Preliminary results (!) - 3 months in...
- Based on historic data from 2019, k -fold cross-validation
- Live data quality may vary...

Preliminary comparison of NIV forecasting methods



Future directions

- Refine the underlying model
- Capture non-linear relationships with spline regression
- Introduce features derived from intraday market data
- Extend to probabilistic forecasting
- User-inspired visualisation for useful decision-support

Summary

- Intraday and balancing markets provide price signals for flexibility providers
- Forecasting prices is an essential activity for all participants, especially flexibility providers
- Leveraging both data and domain knowledge important for successful forecasting
- A range of ML techniques are being evaluated to forecast the Net Imbalance Volume and System Price
- Looking to refine the model further + develop the model to produce probabilistic rather than deterministic forecasts

Thanks! Questions?

Papers and more at jethrobrowell.com

Jethro Browell



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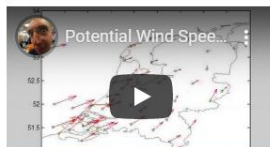
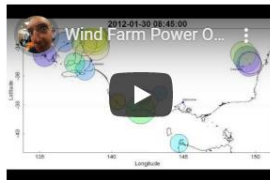


Welcome

Welcome to my website where you can find out about my academic activities and access associated resources.

Thanks for visiting!
Jethro

Contact



Latest News

New Paper! Some thoughts from Calum Edmunds, Sergio Martin Martinez, myself and colleagues on wind participating in response and reserve markets. Just published in Renewable and Sustainable Energy Reviews. Enjoy 50 days free access with [this link](#). [Pre-print](#) also available.

New Paper! Claran Gilbert recently published his work on improving wind farm power forecasts by leveraging data from individual turbines! [Read it here](#).

Editorial Board Appointment: I'm excited and honoured to have been appointed to the editorial board of

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Doug Parr
@doug_parr

Cutting air passenger duty encourages flying and should not be messed with/reduced in order to save a struggling airline

IF this becomes response of govt confronting tricky industrial issue, can be little hope for UK decarbonisation efforts
bbc.co.uk/news/business-...

