

Hybrid Energy Forecasting and Trading Competition

Abstract

Forecasting production from wind and solar power plants, and making effective decisions under forecast uncertainty, are essential capabilities in low-carbon energy systems. This competition invites participants to develop state-of-the-art forecasting and energy trading techniques to accelerate the global transition to net-zero and to win a share of \$21,000 in prize money. It aims to bridge the gap between academic and industry practice, introduce energy forecasting challenges to new communities, and promote energy analytics and data science education.

The competition is organised by the IEEE Power and Energy Society Working Group on Energy Forecasting and Analytics and is sponsored by Ørsted, one of the world's largest renewable energy companies, and rebase.energy, and tech start-up based in Sweden. Forecasting power production and participating in energy markets is a core part of Ørsted's business, and an area where data and decisions science can bring great value. The competition platform developed by rebase.energy gives participants access to a wide variety of data, including weather forecasts and real electricity market data, to generate their forecasts and trading decisions.

The competition will run from February to May 2024, but the platform will open in advance for participants to begin developing and testing their solutions. This is a genuine forecasting task! It requires daily submissions of forecasts and market bids. Automation is strongly encouraged.

Key Dates

Following an unexpected reduction in the export capacity from Hornsea 1 wind farm, the competition start and proceeding dates have been revised to give participants time to adapt to the new situation. The export limitation at Hornsea 1 is expected to end on 17 February, however, the competition start will not be pushed back any further. Participant should consider any potential reduction capacity in their submissions. Data on capacity reductions is available via REMIT.

Registration will be open from 1 November 2023 to 26 January 2024

1 November 2023: Competition platform opens for development and testing

19 February 2024: First submission of the competition period (forecasts and bids for 20 February 2024)

18 May 2024: Last submission of the competition period (forecasts and bids for 19 May 2024)

24 May 2024: Deadline to respond to participant survey

31 May 2024: Announcement of final leaderboard and prizes

Organisers

This competition is organised by the IEEE Power & Energy Society Working Group on Energy Forecasting and Analytics and sponsored by Ørsted and rebase.energy. The organising committee are:

Jethro Browell (Chair, University of Glasgow), Sebastian Haglund (rebase.energy), Henrik Kälvegren (rebase.energy), Edoardo Simioni (Ørsted), Ricardo Bessa (INESC TEC), Yi Wang (University of Hong Kong)

Competition Tasks

There are two tracks: forecasting and trading. Participants are encouraged to compete in both tracks, and an additional prize is on offer for combined performance across forecasting and trading. Submissions to both tracks must be made by 9:20AM UTC on each day of the competition period.

The forecasting track requires participants to produce probabilistic forecasts of the power production from a hybrid power plant comprising the Hornsea 1 wind farm and the combined solar capacity of East England, totalling approximately 3.6GW. Forecasts in the form of quantiles from 10% to 90% in increments of 10% are required for each half-hour period of the day-ahead. Forecasts will be scored using the Pinball Loss.

The trading track requires participants to trade the energy produced from the hybrid power plant in the day-ahead electricity market. This track is based on Great Britain's wholesale electricity market, which features a day-ahead auction and single-price imbalance settlement.

Scoring and Prizes

Live scoreboards will be maintained on the competition website. This will display team name and their score in each track. The scoreboards will be updated as data become available, which is typically with a lag of seven days.

During the test period, a scoreboard displaying scores for the most recent full week of evaluation data will be displayed. During the competition period, scores will be displayed covering the period from the start of the competition to the most recent evaluation data.

The following cash prizes will be awarded:

Rank	Energy Trading Track	Forecasting Track	Combined Ranking
1	\$3,000	\$3,000	\$3,000
2	\$2,000	\$2,000	\$2,000
3	\$1,000	\$1,000	\$1,000
Best placed student team	\$1,000	\$1,000	\$1,000

A team's score in the "Combined Ranking" category will be the sum of ranks from the Energy Trading and Forecasting tracks. Ties will be broken based on ranking in the Forecasting track. A student team finishing in the top three will receive the main prize and the prize for the placed student team.

Top-placed teams will be invited to present their approach at an event in 2024, and to submit an academic paper to the International Journal of Forecasting (which must be fully reproducible). Further details will be provided in due course.

Getting Started & Open Benchmark

The organisers will provide an open-source benchmark which will serve as a reference for performance in the competition and as a quick start tool to aid teams in their participation. See detailed documentation.

For competition networking, team formation and support using the competition API, you are welcome to join the Rebase Community Slack channel through this [link](#).

Competition Rules

Teams: You may participate as an individual or team. There is no limit on the size of teams. Only one registration is required per team.

Student Teams: All members of student teams must be registered full-time students (or part-time but not working in the energy industry) for the duration of the competition period to claim a student prize. The competition organisers will verify student status as part of the registration process.

Data: rebase.energy have provided convenient APIs for all of the data you will need to participate competitively in this competition. However, there is no restriction on the use of additional data. Additional open data sources are suggested in documentation.

Missed submissions: A team may miss up to five submissions during the competition period. Missing entries will be filled by the Open Benchmark and scored accordingly.

Public dissemination of entries: by participating, teams grant the competition organisers the right to publicly disseminate any submitted data (bids and forecasts) after the end of the competition period. This is to enable reproducibility of the results table and further analysis.

Reports: To retain a position in the final leaderboard and to qualify for a prize, participants must respond to a survey that will include providing a high-level description of their methodology and any additional data used by 3 May 2024. A high-level summary of participants' methodologies will be published after the competition.

Competition back-end: Only staff at rebase.energy will have access to the back-end of the competition platform until the end of the competition period. Participants affiliated with rebase.energy or Ørsted are not eligible to claim prizes.

The organisers reserve the right to disqualify teams deemed to have broken rules or undermined the spirit of the competition, and to update the competition rules if necessary.

Change log

Version	Date	Description of changes
1.0	31 October 2023	Initial version.
1.1	1 November 2023	Added invitation link to Rebase Community Slack
2.0	3 November 2023	Update FAQs; update scoring details for trading track to use Intermittent Market Reference Price; IMPR data description; clarification of rules regarding dissemination of submission data.
2.1	9 January 2024	Additional FAQs
2.2	27 January 2024	Additional FAQ
3.0	8 February 2024	Updates to Key Dates following outage at Hornsea wind farm. Details added to FAQs.

Detailed Documentation

The competition has two main tracks, forecasting and trading. Both run in real-time requiring genuine forecasts of production from real-world wind and solar installations, and “shadow trading” in the Great Britain wholesale electricity market. The competition uses multiple sources of real, operational weather forecasts and electricity market data from Great Britain. Both tracks require daily submissions for the day-ahead. This document includes:

1. The tracks are how they are scored
2. The schedule and mechanism for making submissions
3. Data provided by the competition
 - Static training data
 - API access to the latest data
4. Hints and tips
 - Getting started guide
 - Contacting the organisers
 - Additional sources of information

This documentation is accompanied by online API documentation ([energy data](#) and [weather data](#)) and a “Getting Started” guide and example in the [HEFTcom24 GitHub repository](#).

1. Tracks

Hybrid Power Forecasting

The forecasting track requires participants to produce probabilistic forecasts of the energy generation from a hybrid power plant comprising the Hornsea 1 wind farm and the combined solar capacity of East England, with a combined capacity of approximately 3.6GW. Forecasts in the form of quantiles from 10% to 90% in increments of 10% are required for each half-hour period of the day-ahead. Forecasts will be scored using the Pinball Loss.

For a forecast \hat{q}_α of the $\alpha\%$ quantile, and observation y , the Pinball Loss is given by

$$L(y, \hat{q}_\alpha) = \begin{cases} (y - \hat{q}_\alpha)\alpha & \text{if } y \geq \hat{q}_\alpha \\ (\hat{q}_\alpha - y)(1 - \alpha) & \text{if } y < \hat{q}_\alpha \end{cases}$$

which is averaged across quantiles $\alpha = 0.1, 0.2, \dots, 0.9$ and time periods to give a final score.

The target variable y is total energy generation from the hybrid power plant in units of MWh for each 30-minute settlement period plus energy curtailed following instructions from the transmission system operator. Data on these instructions, which are called “Bid Offer Acceptances” (BOA) are provided by the organisers.

The Hornsea 1 wind farm is comprised of three [balancing mechanism units](#), T_HOWAO-1, T_HOWAO-2 and T_HOWAO-3, which are metered separately, and receive BOAs individually. The source of generation data is the B1610 data field from Elexon’s [Balancing Mechanism Reporting Service](#) (“Actual Generation Per Generation Unit”), and the source of BOA data is DERBMDATA (“Derived BM Unit Data”), both from Elexon. The competition API aggregates actual generation and BOA data from these three units automatically.

The solar component of the hybrid power plant is the aggregate solar capacity in East England (PES Region 10). The capacity and actual generation is estimated by Sheffield Solar and is not subject to any

BOAs. The source of generation data is the [Sheffield Solar](#) PV_Live API (v4). The competition API aggregates data from all sub-regions of PES Region 10 automatically.

Warning: Take care, wind and solar generation data is average power in units of mega-watts (MW), which must be converted to energy in units of mega-watthours (MWh) for each 30-minute period. BOA data are already in units of MWh, with negative values indicating curtailed energy. A power plant generating at an average power of 2MW for 30-minutes produces 1MWh of energy.

Energy Trading

The trading track requires participants to trade the energy produced from the hybrid power plant in the day-ahead electricity market. This track is based on Great Britain's wholesale electricity market, which features a day-ahead auction and single-price imbalance settlement.

This track is scored according to revenue. Participants' score revenue from the day-ahead market equal to the volume they trade multiplied by the Day-ahead Price (DAP, units £/MWh), however, the difference between the volume of energy traded and actual generation is then settled at the imbalance price (units £/MWh). If actual generation exceeds the traded volume, the excess is sold at the imbalance price; however, if generation is less than the traded volume, the deficit is purchased at the imbalance price.

In practice, a market participant's own imbalance volume, the difference between their actual generation and traded volume) will influence the system's net imbalance volume and therefore the imbalance price. We replicate this effect for the purpose of the competition by calculating an imbalance price for each participant based on the actual Single System Price (SSP) and the participant's imbalance volume. A participant's imbalance price is given by $SSP - 0.07 \times (Actual - Trade)$, where 0.07 is the regression coefficient between the net imbalance volume and imbalance price calculated from recent historic data, and therefore represents the average impact of a change in imbalance volume on the SSP.

For each half-hour period, revenue for a participant is calculated as

$$Revenue = Trade \times DAP + (Actual - Trade) \times (SSP - 0.07 \times (Actual - Trade))$$

and this is summed over the competition period to give a final score.

The volume of energy traded in a single period is limited to the range 0 MWh to 1800 MWh, the maximum generation output of the hybrid power plant. Bids outside of this range will be rejected by the submission API. Actual generation is the same as the target variable in the forecasting track, i.e. the total generation of Hornsea 1 wind farm and the solar capacity in East England, plus bid and offer accepted volumes.

The Day-ahead Price here is the Intermittent Market Reference Price, published by the Low Carbon Contracts Company. It is a weighted average of the prices from Great Britain's two day-ahead auctions, operated by NordPool and EPEX Spot.

The SSP is calculated and distributed by Elexon. This price is subject to revision by Elexon and the most recent available data will be used in competition scoring.

Combined Ranking

A team's score in the "Combined Ranking" category will be the sum of ranks from the Energy Trading and Forecasting tracks. Ties will be broken based on ranking in the forecasting track.

2. Submissions

Submissions must be made before 9:20AM UTC for each half-hour of the day-ahead market. The Great Britain day-ahead market is synchronised with the European market, and therefore runs from 23:00-23:00 UK time. Timestamps will be formatted according to the ISO 8601 standard and correspond to the start of each half-hour settlement period.

For example, the first submission to this competition must be made before 2024-01-31T09:20:00Z and contain market bids and forecasts for each half-hour period from 2024-01-31T23:00:00Z to 2024-02-01T22:30:00Z.

Note: The UK clock change from GMT to BST will happen on Sunday 31 March 2024! For that market day there will only be 46 half-hour periods. The market periods will be from 23:00 on Saturday 30 March GMT (2024-03-30T23:00:00Z) to 22:30 on Sunday 31 March BST (2024-03-31T21:30:00Z).

Forecasts and bids are submitted via API in JSON format. See the [online API documentation](#) for details. Some useful Python utilities are provided in the [HEFTcom24 GitHub repository](#).

3. Data provided by the competition

Weather forecasts from two different weather centres are provided by the organisers. Similarly, all electricity market data required to score both competition tracks is also provided, along with some additional electricity market data that might be useful for forecasting and bidding strategies. Participants are welcome to supplement this with additional data sources, see hint and tips for relevant suggestions.

Name	Type	Description
dwd_icon_eu_hornsea_1*.nc	Weather forecasts from DWD's ICON-EU model in netCDF format.	Gridded weather forecast data surrounding the Hornsea 1 wind farm.
dwd_icon_eu_pes10*.nc		Multiple weather forecast points spanning PES region 10 (East England).
dwd_icon_eu_demand*.nc		Multiple weather forecast points spanning major population centres in GB (relevant for demand and price forecasting).
ncep_gfs_hornsea_1*.nc	Weather forecasts from NCEP's GFS model in netCDF format.	Gridded weather forecast data surrounding the Hornsea 1 wind farm.
ncep_gfs_pes10*.nc		Multiple weather forecast points spanning PES region 10 (East England).
ncep_gfs_demand*.nc		Multiple weather forecasts points spanning major population centres in GB (relevant for demand and price forecasting).
Energy_Data*.csv	Energy market data in CSV format.	dtm: UTC timestamp corresponding to the beginning of each half-hour period MIP ¹ : Market Index Price, a volume weighted average of intraday trades, £/MWh DA_Price ³ : Day-ahead auction price, specifically the "Intermittent Market Reference Price", £/MWh SS_Price ¹ : Single System Price, £/MWh Solar_MW ² : Solar generation in units of MW Solar_capacity_mwp ² : Estimate of total installed PV capacity in PES region 10 including

		<p>estimated performance degradation (MW-peak)</p> <p>Solar_installedcapacity_mwp²: Estimate of total installed PV capacity in PES region 10 (MW-peak)</p> <p>Wind_MW¹: Power production at Hornsea 1 wind farm in units of MW.</p> <p>boa_MWh¹: Net-volume of bid and offer acceptance volumes at Hornsea 1 in units of MWh</p>
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The rebase.energy API provides endpoints to access these fields as they become available. Endpoints are also provided for forecasts of GB National Wind and Solar production, GB National Demand, and Margin (the difference between demand and available generation capacity), which may be useful for price forecasting. Please see the online API documentation ([energy data](#) and [weather data](#)) and the [Elexon BMRS](#) for further details.

Notices:

¹Data from Elexon via the Balancing Mechanism Reporting Service, licensed under the [BSC Open Data Licence](#); ²Data from Sheffield Solar PV Live ([Terms](#)); ³Data from the Low Carbon Contracts Company, licensed under the [Open Government Licence](#).

4. Hints and tips

Getting started

A static dataset is provided on the IEEE DataPort to allow participants to get started immediately and without having to build a historic dataset via repeated API calls. This static dataset will be updated periodically. It will be necessary to use the APIs provided by rebase.energy to access up-to-date data and to make submissions to the competition. This functionality will be made available for testing on or before 14th November 2023.

A python-based example is [provided on GitHub](#) to demonstrate how to load and manipulate some of the competition data, competition scoring, and use of the rebase.energy API. This should still be useful for non-python users and we encourage all participants to read thought it.

Contacting the organisers

We will use this [Slack channel](#) (use [this invitation link the first time](#)) where competitors can interact with each other and the organisers to ask questions and flag any issues. The Frequently Asked Questions section at the end of this document will be updated periodically to share information with all participants.

Addition sources of information

Wholesale electricity markets are complicated, and their documentation includes a lot of industry jargon. These two guides provide a good introduction to the GB electricity market for interested participants:

- CGI's [GB Electricity Industry for Dummies](#)
- Elexon's [The Electricity Trading Arrangements A Beginner's Guide](#)

The competition organisers are providing a wide range of data that should be sufficient for competitive performance in this competition. However, participants are welcome to supplement this with other data. Some potentially useful sources of data might be:

- Elexon's [Balancing Mechanism Reporting Service](#) (and API)
- [National Grid ESO Data Portal](#)
- [ECMWF Open Data](#) and [Python package](#)
- [UK Met Office](#)

Frequently Asked Questions

Responses to FAQs will be updated periodically here. Please use this [Slack channel](#) (use [this invitation link the first time](#)) to post questions to the organisers.

Who owns and Intellectual Property (IP) participants generate?

Are participants required to submit or share code/algorithms?

The competition organisers make no claim to any IP participants generate in terms of their methods/code/knowhow. There is no obligation to submit or otherwise share code. However, the organisers reserve the right to share anonymised submissions data (associated with Team Name only) to enable the leaderboard to be reproduced and analysed for research purposes. Furthermore, to retain a place on the final leaderboard, we require teams to respond to a survey giving a high-level summary of the approach taken, again to report in a research paper for the benefit of all. We will invite all prize winners to give a presentation and submit a fully reproducible academic article describing their methods in detail, but this is optional.

How do I know my submission has been received?

When you successfully make a submission via the competition API, you will receive a “200” response confirming successful submission. Some validation checks are in place which if failed will result in a “422” response and a description of the check that failed. You can also retrieve your past submissions via [this API endpoint](#). See example [here](#).

I can only retrieve the most recent weather forecasts using the competition API. Can I access historic weather forecast data?

Historic weather forecasts are not available via API. Historic weather forecasts are provided on the competition [DataPort site](#) from 2020-09-20 to 2023-10-27 (since competition launch), and from 2023-10-27 to 2024-01-08 (uploaded on 2024-01-09). One further update will be provided on 29 January. After this date, no further updates of historic weather forecast data will be provided until the competition has ended. Historic energy data can be retrieved via API.

The historic energy data from the competition API is not always the same as from the original source. What’s going on there?

Several quantities are subject to revision by data providers. Elexon may update metered production data from Hornsea wind farm and the Single System Price (the Balancing Mechanism imbalance price) as part of the electricity market settlement process. Solar generation data may also be updated as additional metering data is collected by Sheffield Solar’s PV Live system. Solar capacity data may also be updated retrospectively as new data on registrations of solar installations becomes available. The data served by the competition API scores are refreshed daily. Final scores for the competition will be based on data available on Wednesday 29 May.

What is going on at Hornsea 1 wind farm from 23 January into February?

Due to a fault on the export cable, the production capacity at Hornsea 1 has been reduced during this period. Participants may follow developments via REMIT. At the time of writing, the most recent REMIT messages indicate that exports will be limited to 300MW until 6pm on 17 February.

REMIT (regulation on wholesale energy markets integrity and transparency) data is the 'inside information' in respect of businesses or facilities that market participants own or control (or are operationally responsible for) which they are obliged to publish before they can trade on it.

<https://bmrs.elexon.co.uk/remit>

Hornsea 1 wind farm is the combination of three "Balancing Mechanism Units": T_HOWAO-1, T_HOWAO-2, and T_HOWAO-3. To see REMIT messages for Hornsea 1 search for e.g. Asset ID = "T_HOWAO-1", last 30 days.

The cable issue at Hornsea was not anticipated in the competition design, and the organisers did not provide participants with information about outage data source until 1 February. Therefore, on 8 February the competition start date and end date have been pushed back by 20 days, the new start date is 19 February. This should allow all participants time to react to this development and compete on a level playing field.

Outages are a reality of energy forecasting and trading, and the motivation for running a live competition was to make things as realistic as possible. If the Hornsea 1 cable fault persists beyond the expected end date of 17 February, or there are any other similar events, the competition will not be delayed any further. Participants should therefore monitor REMIT for future updates.

The cap for trades will remain unchanged at 1800MWh.