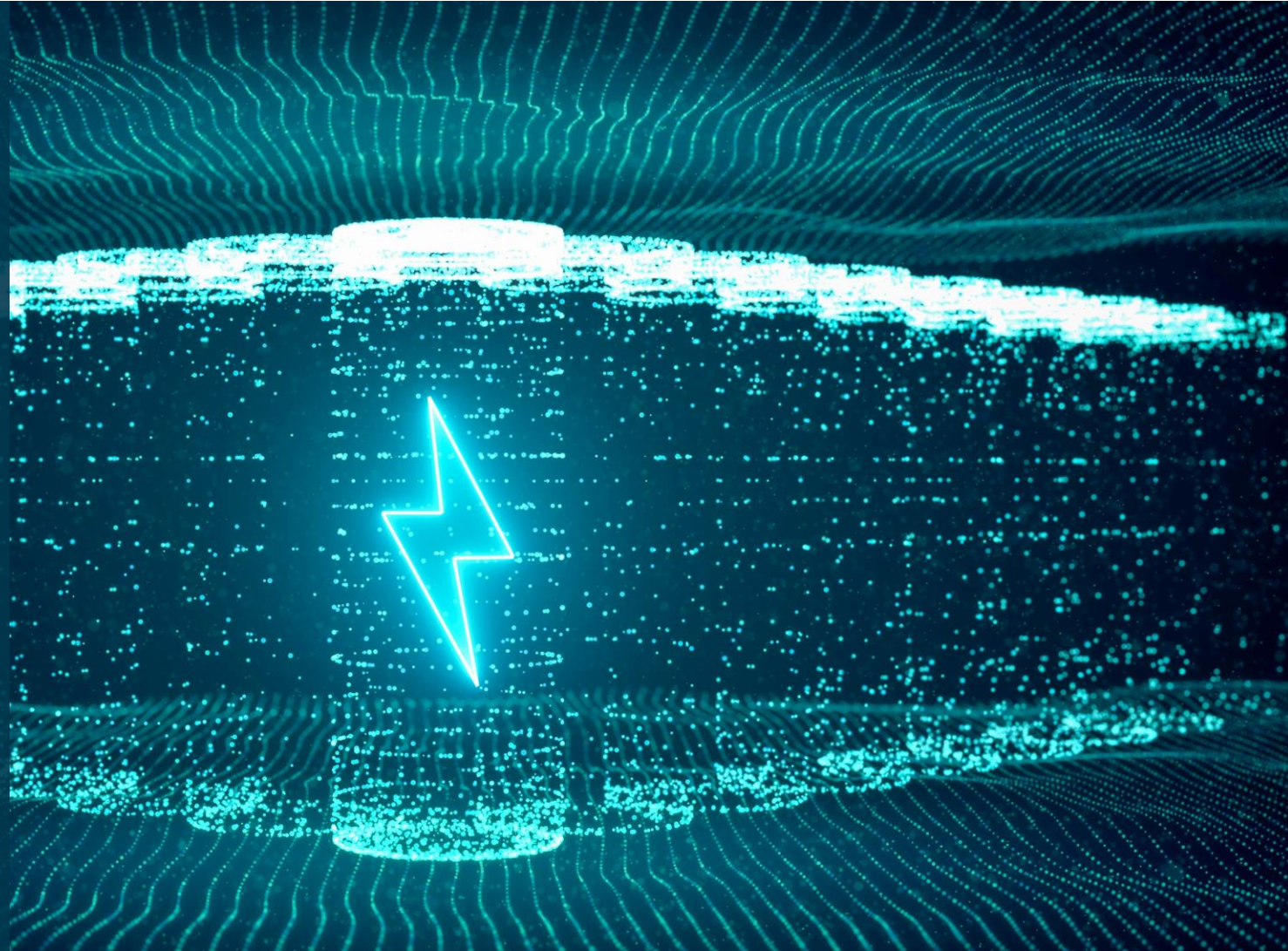


Energy storage report

KYOS benchmark –
assessments of battery
energy storage value

No 6 – September 2024



KYOS Battery Revenues 2025



Revenues 2025 (k€/MW)	Market	Day-Ahead		Day-Ahead + FCR		Intraday		Intraday + imbalance	
		Average	10%	Average	10%	Average	10%	Average	10%
	NL	96.0 ↑	90.6 ↑	163.6 ↑	160.3 ↑	271.2 ↑	258.4 ↑	277.1 ↑	264.2 ↑
BE	86.2 ↑	80.7 ↑	373.5 ↑	372.6 ↑	148.8 ↑	143.3 ↑	160.7 ↑	155.0 ↑	
DE	89.7 ↑	83.6 ↑	154.1 ↑	150.3 ↑	159.4 ↑	150.3 ↑	n/a	n/a	
ES	88.3 ↑	69.3 ↑	n/a	n/a	103.5 ↑	79.7 ↑	n/a	n/a	
GB	80.9 ↑	69.4 ↑	n/a	n/a	104.9 ↑	96.8 ↑	106.2 ↑	98.2 ↑	

Battery revenues in k€/MW in 2025 for a stand-alone located, 0.5C battery with a roundtrip efficiency of 90% and a maximum of 730 cycles per year. For more details, see page 6 in this report.

↑ increase from May report

↓ decrease from May report

Please note that values are in k€/MW (=€/kW). As we use 0.5C batteries, to understand the figures in €/kWh just divide by two.

Our fifth edition of the report used May 13th as a trading date. Since then (September 3rd in this 6th edition), gas prices have increased by more than 10% (e.g., TTF Cal-25 from 34.94 to 39.24 EUR/MWh). This increment in gas prices

resulted in higher electricity prices (e.g., NL Cal-25 from 85.9 to 88.6 EUR/MWh) and higher predicted spreads as a consequence. This effect, together with the summer showing an increase in volatility in the real-time markets across all regions (as shown in pages 7 to 9 in this report), has induced higher (~15%) assessments for all categories of our 2025 battery revenue projections.

The most notable contrast can be found in the higher Day-Ahead + FCR valuations, which is caused by the substantial increase in average FCR prices in the last 3 months (as seen in page 10). This resonates into higher 12-months average FCR prices of 30, 35 and 40% for BE, DE and NL respectively, which then propagates into our DA+FCR valuations (36, 26 and 34% increase respectively).

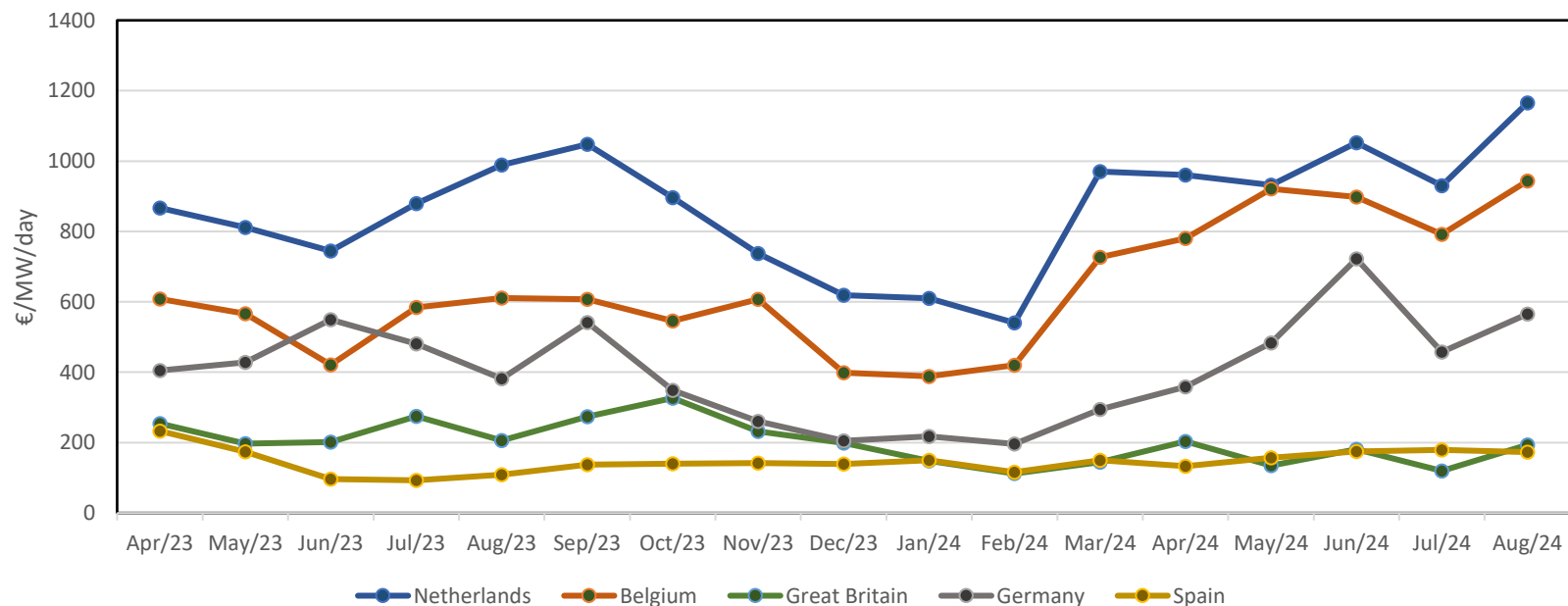
KYOS Battery Index

The **KYOS Battery Index** serves as a benchmark for battery optimizers. It shows the average daily revenue in the past months when trading a 2-hour battery in the intraday market. In GB, NL & BE it includes passive imbalance trading with 30% of the capacity. A description of the methodology can be found on page 6 of this report. This index shows the wholesale cashflow potential for batteries, which cannot be directly translated into

market attractiveness for batteries as grid fees are not included in the calculation of the index.

This update of the KYOS Battery Index shows an increase in the last three months for Netherlands, Belgium and Germany (top 3 respectively), which corresponds to the seasonal pattern shown so far of high summer and low winters. However, this summer has exceeded the values

observed on 2023, which points to a general upward trend driven by more renewables in the system, and a slow adoption of flexibility. Spain and Great Britain, whose systems have relative higher share of flexibility are notoriously far from the values displayed in the CWE markets, remaining relatively stable for 2024, and a very mild increase since our last report in May.



Battery revenues in €/MW/day. The index considers a participation in the ID and IB markets (the latter capped to a maximum of 30% of the capacity) for the NL, BE and GB indexes, and an ID only participation for the DE and ES indexes.

From power.kyos.com

KYOS Battery Index vs Revenues



Equivalent value (€/MW/day)	Market	Index 12-month average (Sep23-Aug24)	Assessment 2025
	NL	872	759
	BE	669	440
	DE	388	437
	ES	149	283
	GB	189	291

In order to compare the **KYOS Battery Index** and the latest **KYOS Battery Revenue Assessment for 2025** we show them in the same unit: €/MW/day.

The GB, NL and BE figures are based on Intraday + Imbalance, while for DE and ES only Intraday.

Our historical analysis (KYOS Battery Index) and our prospective analysis (2025 Assessment) agree on the ranking of wholesale cashflow potentials for the five markets. Both instruments rank the Netherlands far above, and Spain and Great Britain far below.

The most visible contrast between the two metrics, is the magnitude of the difference between Belgium and Germany. This is influenced by the

doubling of intraday volatility in Germany in the last three months, surpassing Belgium in this metric for the first time. Belgium still stay ahead of Germany despite this as passive imbalance trading exposes part of the battery capacity to higher spreads.

Also interesting is the increase in the breach between the 2025 assessment and the KYOS Battery Index in Spain and Great Britain. This

is a consequence of the market anticipating higher spreads for 2025 in both regions compared to the last year, which only gets reflected in our 2025 assessment but not in the KYOS Battery Index. Surprisingly, Great Britain is the only market where the 12-month average of the index did not increase as compared to our last report.

Explanation and methodology



Description of the valuations

- The **KYOS Battery Index** reports cashflows in a specific past month for the defined battery and market.
- The index is a single value per market and expressed in EUR/MW/day. A detailed description can be found on the next page.
- The **KYOS Revenue Assessment** simulates and optimizes expected cashflows in 2025 for the defined battery and markets.
- All future (2025) price simulations are arbitrage-free to the forward prices in the market and have been generated with the KySim model. Values are reported in k€/MW.
- All trading strategies have been optimized by the KyBattery model.

Battery definition

- The batteries are of type 0.5C; this means that the battery can be fully charged or discharged in 2 hours
- Passive imbalance trading is limited to a maximum of 30% of the total battery capacity
- No degradation is assumed
- Batteries have a round- trip efficiency of 90%, based on 94.9% charge and discharge efficiency
- The number of cycles per year is limited to 730
- All assets are stand-alone.
- In both valuations, we allow only 30% of the battery capacity in Passive Imbalance Trading (PIT), because of the limited liquidity (due to cannibalization effect).

Analyzed markets

- Day-Ahead (DA): trading in the Day-Ahead market, hourly granularity.
- Day-Ahead and FCR (DA+FCR): offering capacity in the FCR market (4 hours) or trading in the Day-Ahead market, hourly granularity.
- Intraday (ID): trading in the intraday market, 15 min granularity for NL, DE, BE, 30 min for GB, and 60 min for ES.
- Intraday and imbalance (ID+IB): trading in intraday, combined with passively trading imbalance. Only where passive imbalance trading is allowed (NL/BE 15 min, GB 30 min).

Explanation of Index methodology



Battery Index Methodology:

- Data sources: EPEX (ID1) for NL, BE, DE, GB. TenneT, Elia and Elexon for Imbalance in NL, BE and GB. OMIE for ES.
- Intraday trading is done with perfect foresight of the prices, based on dynamic programming optimization. This means the battery charges/discharges in the optimal moments.
- The passive imbalance trading strategy creates a short (or long) position whenever the forecasted IB take (feed) price in the next hour falls (rises) sufficiently below (above) recent IB take (feed) prices. The thresholds are defined independently for each market in a way that it maximizes the revenue. A multi-linear regression based on historical imbalance and intraday prices is used to generate the imbalance price forecasts. The income from passive imbalance trading is calculated on the imbalances times the actual imbalance prices.
- To explain the interaction with the intraday market, pretend there are two independent traders operating in each market:
 - **Intraday Trader:** This trader optimizes battery dispatch based on expected price developments in the intraday market. The primary trader's decisions are made 1 hour ahead of the imbalance trader.
 - **Imbalance Trader:** After the primary trader makes her decision, the imbalance trader reviews the battery's current state and the primary trader's positions. He then decides on trades based on recent imbalance prices and forecasts for the next period.
 - Finally, the imbalance trader must ensure that any trades he makes do not exceed the battery's capacity limits. He updates the primary trader on the new state of charge, which she will consider in her next decision-making cycle.

Day-Ahead daily spreads



The daily Day-Ahead (DA) power price spread is the highest DA price of the day minus the lowest DA price of the day, averaged hourly. The table shows data for the latest N months, up to August 2024 (incl).

Trend: There is an upward trend in the last 12 months for all markets, mainly driven by an aggressive summer volatility in this year.

Observation: The high solar volumes and the rise of gas prices have reflected in higher spreads this summer. This dragged up the 12 months average values used for the 2025 battery assessment simulations.

Regional Comparison: CWE countries spreads are significantly larger than in GB and ES.

Average daily spread in the Day-Ahead prices (€/MWh)

Country	Last 36 months	Last 12 months	Last 3 months
NL	146.1	108.2	143.6
BE	132.6	91.1	118.1
DE	137.2	109.0	167.7
ES	80.6	66.4	83.4
GB	124.2	69.5	69.6

Intraday daily spreads



The daily Intraday (ID) power price spread is the highest intraday price of the day minus the lowest intraday price, averaged hourly

Trend: ID spreads in the Netherlands, Belgium, and Germany are on the rise for the last year, but they have risen considerably in the last three months. This is explained by the increase in solar production during summer, and the lower thermal capacity. This results in a situation with growing volumes of

intraday adjustments due to the hard-to-predict renewable generation, and a lower flexibility buffer to counteract them.

Regional Comparison: Every country has seen a sharp increase in ID spreads, except for GB. This is due to Great Britain's larger shares of pumped-hydro and battery storage and the flexibility it provides.

Average daily spread in the Intraday prices (€/MWh)

Country	Last 36 months	Last 12 months	Last 3 months
NL	321.8	375.1	503.4
BE	220.2	237.3	334.1
DE	253.8	266.3	452.6
ES	95.5	77.6	94.4
GB	151.1	85.6	83.3

Imbalance daily spreads



The daily Imbalance (IB) power price spread is the highest imbalance price of the day minus the lowest imbalance price, averaged hourly.

Trend: Imbalance prices in the Benelux are growing in the long, medium and short term. Similarly to the intraday market, the rapid deployment of behind-the-meter solar generation has increased intermittent renewable generation,

reducing the volume of flexible thermal generation available for system balancing.

Regional trend: Great Britain present significantly lower imbalance price spreads than the Netherlands and Belgium, but even there the spreads have increased in the last three months by 14%. This is more than in the Netherlands (9%), but less than in Belgium (23%).

Average daily spread in the Imbalance prices (€/MWh)

Country	Last 36 months	Last 12 months	Last 3 months
NL	806.6	1184.0	1595.6
BE	561.4	690.4	918.4
GB	230.4	141.1	137.3

FCR prices



Netherlands and Germany: FCR prices have increased in the last 3 months, as renewables displacing plants out of merit in the day ahead markets have decreased the available FCR volumes offered (resulting in higher prices). Also note the slight divergence between the FCR prices in these two countries (they have been pegged for the most of the last two and a half years).

Belgium: FCR prices here also increased in the last 3 months and are still considerably higher than its neighbors (more than 75%), sustained by a lack of committed flexible thermal generation capacity.

Spain and Great Britain: These countries are not part of the FCR market. They use their own mechanisms for frequency regulation.

	Average FCR prices* (€/MW/h)		
Country	Last 36 months	Last 12 months	Last 3 months
NL	19.13	16.51	25.15
BE	32.65	42.48	43.87
DE	18.83	15.94	22.89

*Note: The NL 02-11-2023 FCR price of 77.777 €/MW between 16 and 20hrs was removed out of the sample.



Software – KyBattery

- 1) State of the art tool to provide energy storage valuations
- 2) Based on Monte Carlo price simulations and Least-squares Monte Carlo to perform realistically optimal trading strategy
- 3) Supports wide range of battery configurations
- 4) Supports different technologies: Li-ion, pumped hydro, flow batteries, compressed air energy storage
- 5) Supports different set-ups: standalone assets, co-located assets
- 6) Participation in multiple markets: day-ahead, intraday, imbalance, FCR and aFRR (also combined strategies).

Consulting – examples

- 1) Valuation of battery cashflows with different market participation approaches to develop business cases
- 2) Independent assessment of expected revenue streams for third parties
- 3) Comparison between different storage assets and types to identify competitive advantages per market
- 4) Battery sizing for optimal network use in combination with co-located generation assets
- 5) Benchmarks to validate performance of energy storage optimizers

Across all European markets, for all energy storage techniques

Do not hesitate to contact us for more information, or ask for a short demonstration: info@kyos.com



Nieuwe Gracht 49
2011 ND Haarlem
The Netherlands
E-mail: info@kyos.com
Tel: +31 (0)23 551 02 21
www.kyos.com