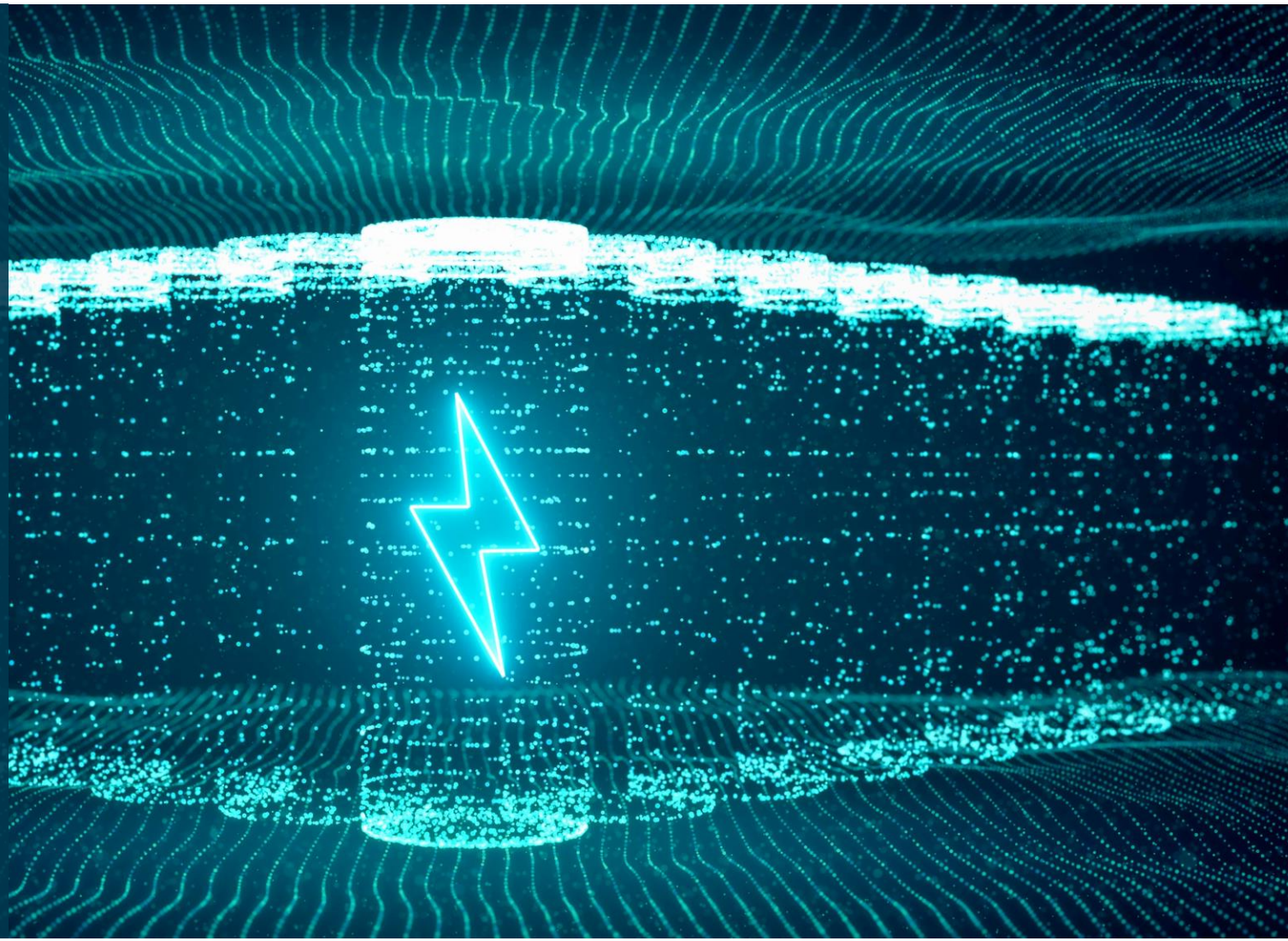
Energy storage report

KYOS benchmark - assessments of battery energy storage value



No 4 – Feb 2024

KYOS

Battery revenue assessments 2025

Revenues 2025 (€/kWh)

Market	Day-Ahead		Day-Ahead + FCR		Intraday		Intraday + imbalance	
	Average	10%	Average	10%	Average	10%	Average	10%
NL	37.0 ↓	33.2 ↓	47.0 ↓	44.4 ↓	120.1 ⇔	111.4 ⇔	223.8 ↑	210.2 ↑
BE	33.7 ↓	30.1 ↓	106.0 ⇔	83.5 ↑	94.3 ↑	89.7 ↑	214.9 ↑	203.1 ↑
DE	34.6 ↓	30.7↓	46.9 ↓	44.2 ↓	81.6 ⇔	77.3 ⇔	n/a	n/a
ES	24.6 ↓	21.0 ↓	n/a	n/a	37,3 ↓	34.4 ↓	n/a	n/a
GB	23.4 ↓	20.5 ↓	n/a	n/a	73.0 ↑	67.7 ↑	124.4 ↑	115.7 ↑

Battery revenues in €/kWh in 2025 for a stand-alone located, 0.5C battery with a roundtrip efficiency of 86% and a maximum of 730 cycles per year. For more details, see next page of this report.

For this battery report update we observe a contrasting trend in battery valuations between day-ahead and real-time markets.
On the one hand we see that battery valuations from arbitrage in the day-ahead market only decreased as compared with our previous edition. This is influenced by lower power forward curves at the beginning of 2024, among others a consequence of lower gas and EUA prices.
On the other hand, intraday and imbalance valuations generally increased or kept stable. The spread levels in the intraday and imbalance markets have stayed high, and this has influenced higher volatility estimations.
Spain (ES) remains the zone with the least potential for arbitrage, with lower gas prices and higher flex depressing both DA and ID spreads. The steep development of residential solar in the Netherlands is noticeable in the high intraday and imbalance prices, consequence of the displacement of spinning reserve out of the merit order. Similarly, the low flexibility in the Belgian market is maintaining FCR prices at high levels.

Explanation and methodology

Battery definition

- The batteries are of type 0.5C; this means that the battery can be fully charged or discharged in 2 hours
- No degradation is assumed over the valuation period (2025)
- Batteries have a round trip efficiency of 86%, based on 92.7% charge and discharge efficiency
- The number of cycles per year is limited to 730
- All assets are stand-alone.
- Variable grid costs of 1€/MWh are taken into account

Valuation methodologies

- All valuations have been performed with KYOS software and models: KyBattery and KySim. The values are expressed in €/kWh.
- The trading date for all values is February 1st, 2024.
- The model uses Monte Carlo simulation and Least Square Monte Carlo optimization, combined with a smart trading rule for the imbalance market.
- 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).
- A multi-linear regression on historical imbalance and intraday prices is used to generate imbalance forecasts for the trading strategy.
- ID and imbalance prices are simulated according to the historical market volatility between 2021-01-31 and 2024-02-01.
- The FCR prices of the last 12 months are taken into account.

Day-Ahead daily spreads

The daily Day-Ahead (DA) power price spread is the highest DA price on the day, minus the lowest price on the day per hour (grouped in hourly average blocks for sub-hourly prices).

The spreads declined over the last 12 months from the extreme spreads in 2022, and have kept decreasing in the last three months. A less tight power market, and lower gas and EUA prices have calmed the power market down, which is showing a less volatile behavior.
In the last year and quarter, the Netherlands shows the highest daily DA spreads, while Spain (characterized by lower DA prices) presents the lowest ones, noticeably stable for the last 3 years.

	Average daily spread in the Day-Ahead prices (€/MWh)		
Country	**Last 36 months**	**Last 12 months**	**Last 3 months**
NL	135.1	102.8	74.6
BE	125.9	86.0	65.7
DE	124.6	94.6	67.2
ES	74.0	70.6	60.6
GB	136.5	72.5	72.3

Intraday daily spreads

The daily Intraday (ID) power price spread is the highest intraday price on the day, minus the lowest price per hour (grouped in hourly average blocks for sub-hourly prices).
After the rise starting towards the end of 2021, the Netherlands and Belgium have maintained high values until the beginning of 2024. In the coming months and years, we will see if this is the new normality in these ID markets.
The strong decrease of ID spreads as compared to 36 months ago is mainly driven by the flexibility in the GB electricity market with 5 GW of storage installed capacity (battery & pump-hydro). In the shorter term ID spreads continue to slip, albeit at a slower pace.
The difference between countries is significant, where the Netherlands is at almost three times higher intraday spreads than its interconnected neighbor Great Britain (259 vs 86.1 €/MWh).

	Average daily spread in the Intraday prices (€/MWh)		
Country	**Last 36 months**	**Last 12 months**	**Last 3 months**
NL	251.1	261.7	259.0
BE	178.3	143.2	134.2
DE	205.9	188.1	116.0
ES	86.8	82.1	73.1
GB	159.7	96.2	86.1

Imbalance daily spreads

The daily Imbalance (IB) power price spread is the highest imbalance price on the day minus the lowest price per hour (grouped in hourly average blocks for sub-hourly prices).
Behind the meter solar generation in the Benelux area, saw a twofold increase in capacity, displacing flexible generation "out-of-merit" in the middle of the day even in winter months. This duck shape inversion flipped thermal generation to night-times, reducing the imbalance offered volumes at daytime. Due to this effect, imbalance prices are on the rise, with average daily spreads reaching 915 and 475 EUR/MWh in the NL and BE respectively.
Contrastingly, with more flexibility on its grid, GB spreads continue to drop in 2024 (similarly to Intraday), reaching to 148.9 EUR/MWh. Regardless of operational differences among these markets, the GB situation sets a precedence of what could occur with higher competition in the real-time markets, particularly interesting for those wondering about batteries cannibalization.

	Average daily spread in the Imbalance prices (€/MWh)		
Country	**Last 36 months**	**Last 12 months**	**Last 3 months**
NL	582.1	686.7	915.4
BE	461.2	440.9	475.4
GB	243.2	162.6	148.9

FCR prices

Frequency Containment Reserve (FCR) prices have remained almost completely equal in the Netherlands and Germany in 2023 and 2024. The possibility for the NL to resource a big part of their FCR requirements in Germany has prevented a rise in prices similar to what is occurring in their real-time energy markets.
Belgium high FCR prices (3x as high as their neighbors) are sustained in the last three months, due to the same reason why their intraday and imbalance price spreads have remained high (less committed flexible thermal generation capacity).
Both Spain and Great Britain are not under the geographical coverage of the FCR market, as they have their own capacity retribution mechanisms in place for frequency regulation.

	Average FCR prices* (€/MW/h)		
Country	**Last 36 months**	**Last 12 months**	**Last 3 months**
NL	19.77	12.36	13.44
BE	31.49	26.81	39.49
DE	17.85	12.31	13.44

*Note: The NL 2023-11-02 FCR price of 77,777 EUR/MW between 16 and 20hrs was removed out of the sample.

KYOS - Energy Storage Services

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, and FCR (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

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