Webinar

Optimal value-stacking with batteries

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KYOS

Agenda

15:05 Overview energy storage market

- Reasons for growing interest in energy storage projects
- Revenue streams of energy storage projects

15:15 Valuation of energy storage

- Market trading with batteries
- Value stacking with FCR

15:35 – Q&A and discussion

15:45 – End of the webinar

KYOS Energy Analytics

- International client base across Europe, plus Americas and Japan
- 30+ people, of which 20+ in Haarlem
- More than 100 corporate clients for its software services

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KYOS approach to renewable energy assets

- Apply advanced financial models combined with experience of the energy market to value and optimize renewable assets and PPAs.
  - Models developed by own quant team. All with background in econometrics or similar studies. Combined experience >40 years
  - Many KYOS employees have experience at energy companies and bring real life market knowledge.

- Calculate the market value that an asset can obtain by optimizing it in the market
  - Use realistic scenarios and trading strategies for the valuation of the market value.
  - Use transparent methodologies and scenarios

KYOS renewable energy services

KYOS supports all players in the renewable energy sector

	Project developer	Bank or investor	Utility or Aggregator	Corporate off-taker
Software	• KYOS Analytical Platform - complete software system to price and manage renewable assets and PPAs • Make long-term power price projections and perform what-if analysis • Monitor and manage a complete portfolio of assets, PPAs and hedges • Analyse different hedging strategies before entering in new deals • Obtain detailed risk reports for managers, investors and analysts			
Advisory	• Valuation and risk management support during PPA negotiations and M&A activities • Regular PPA valuations for accounting and trading purposes • Support with evaluating business cases of energy storage projects • Benchmark projects for energy storage projects • Support with arbitration cases, re-financing and re-powering			

Energy storages

Energy storage -> strong growth

- Strong increase in renewable generation
- Phase out of conventional generation

- European Market Monitor on Energy Storage*
  - > 5-8GW/year growth
  - 57GW installed by 2030

- For reference: TenneT expects 10.3GW installed by 2030 in NL only
- Recent study** shows that 34GW of battery projects have requested grid connection in NL!

* European Association for Storage of Energy
** https://www.stratergy.nl/post/34-gw-aan-batterijprojecten-in-beeld-bij-netbeheerders-per-eind-februari-2023

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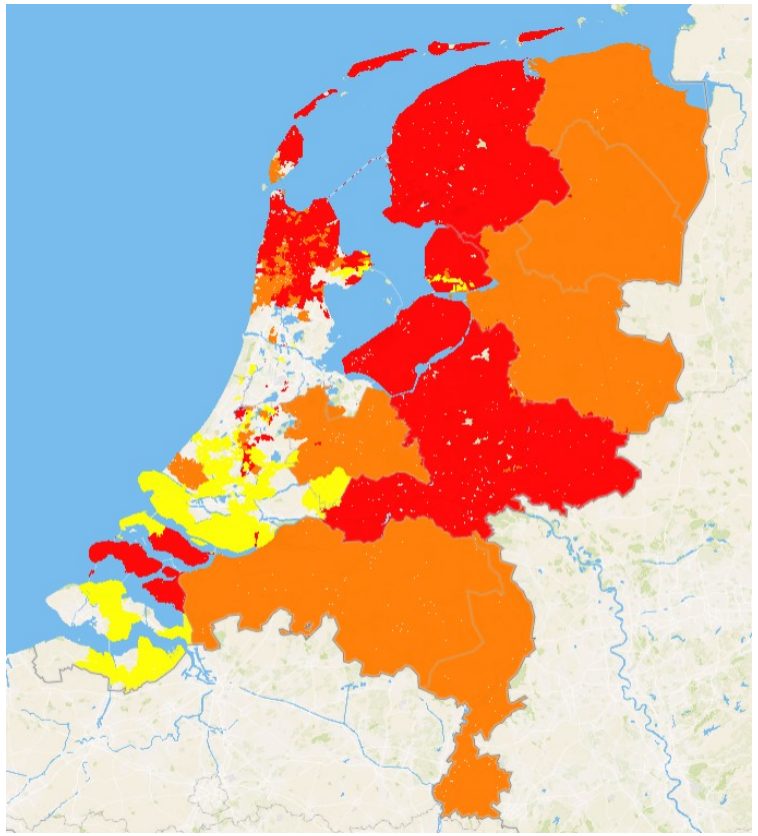
But growth also challenging

- Grid congestion
  - Grid expansion
  - Congestion management
  - Innovative solutions
- Supply chain issues
  - Project delays



https://capaciteitskaart.netbeheernederland.nl/

Energy storage – project valuation

Challenging!

- Different revenue streams
- Structurally changing markets
  - What works now, will maybe not work tomorrow
- Regulatory changes
  - How will markets look like?
- Explain methodology to bank/investors

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Energy storage – revenue streams

Battery business case typically combination of revenue streams

Balancing market (TSO)

- FCR
- FRR

+ stable payments
- obligations reduce potential further revenue stacking

Wholesale markets

- Voluntary balancing
- Intraday
- Day ahead

+ price peaks
+ growing market
- advanced trading system

Local grid services

- Congestion management

+ stable payments
- location important

Portfolio optimization

- Peak shaving

+ increase overall revenue
- more complex projects

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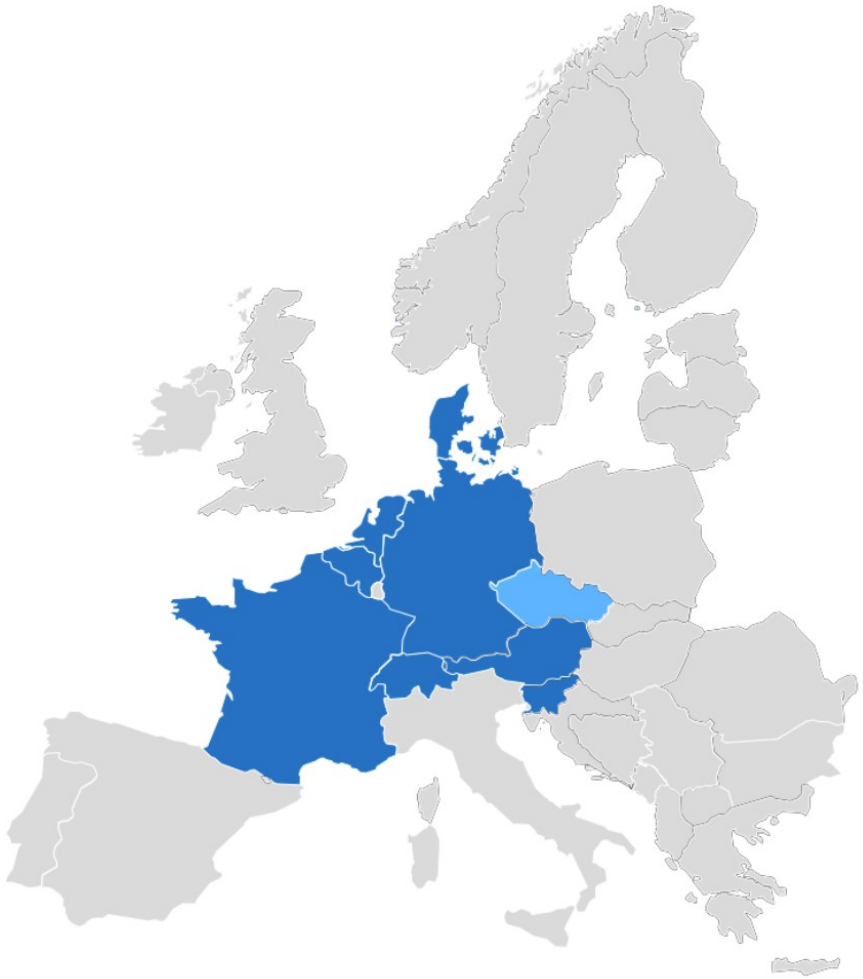
FCR market



- Activation within max 30 sec
- TSOs from 8 countries
  - With internal limits (111 MW NL in 2023)
  - With export limits
- Common prices unless the above limits are violated in a country
- Delivery duration of 4 hours
- 1 MW resolution (& min bid)
  - Maximum indivisible bid of 25 MW
- Netherlands FCR offers
  - 38 MW, 2021 (March)
  - 68 MW, 2022 (March)
  - 76 MW, 2023 (March)

Frequency Containment Reserve (FCR) has been a primary source of revenue for batteries. It requires extremely fast response times, and is therefore quite ideal for flexible storage players.

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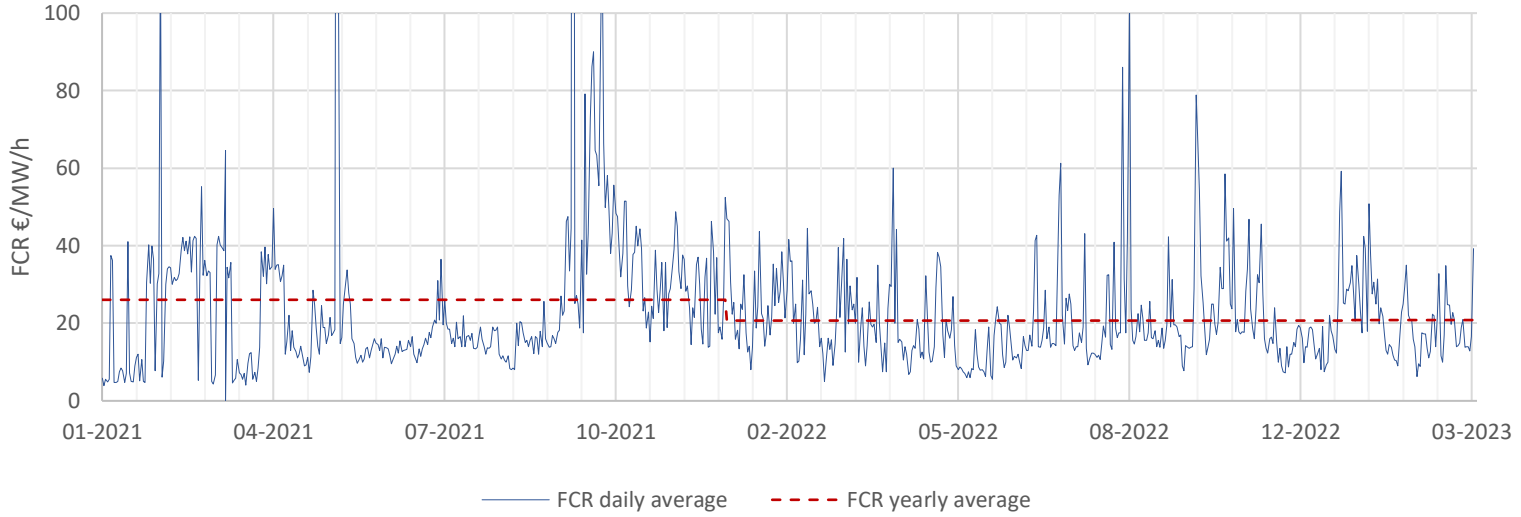
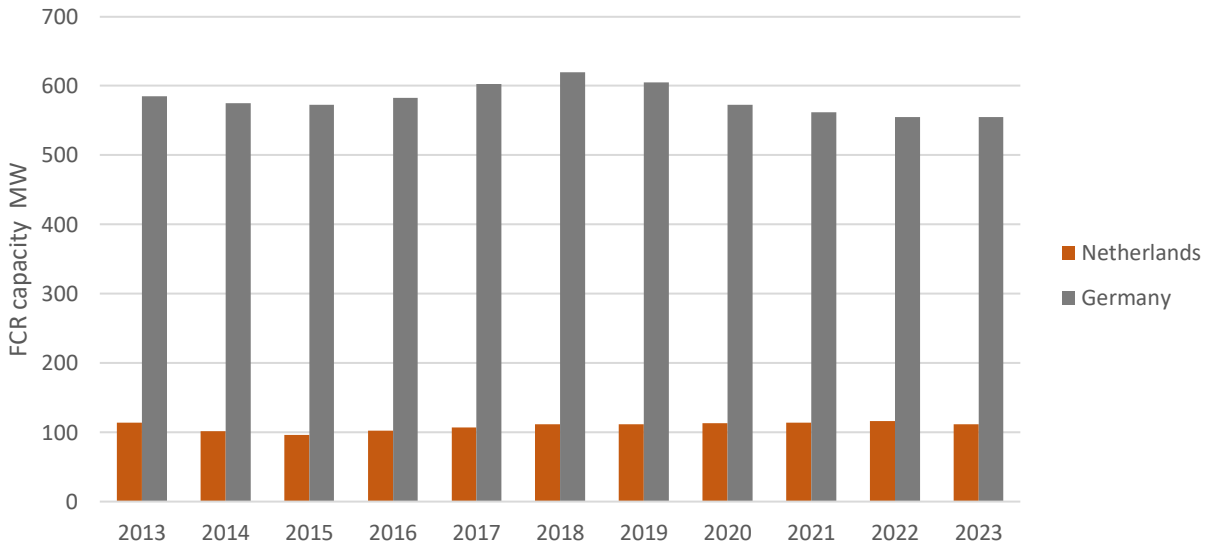
FCR Price evolution

Dutch FCR prices remained relatively stable over 2022, unlike electricity prices -> energy arbitrage becomes more important for batteries.

The FCR capacity requirement volumes per country are stable in time.

Source: ENTSO-E, TenneT





Approaches to energy storage valuations

	Backtest	**Forward looking**
Requirement	Realistic trading strategy	
Pros	• Actual historical data	• Can take future changes into account • Probabilities
Cons	• How to account for future changes? • Only one reality	• More complex modelling approach

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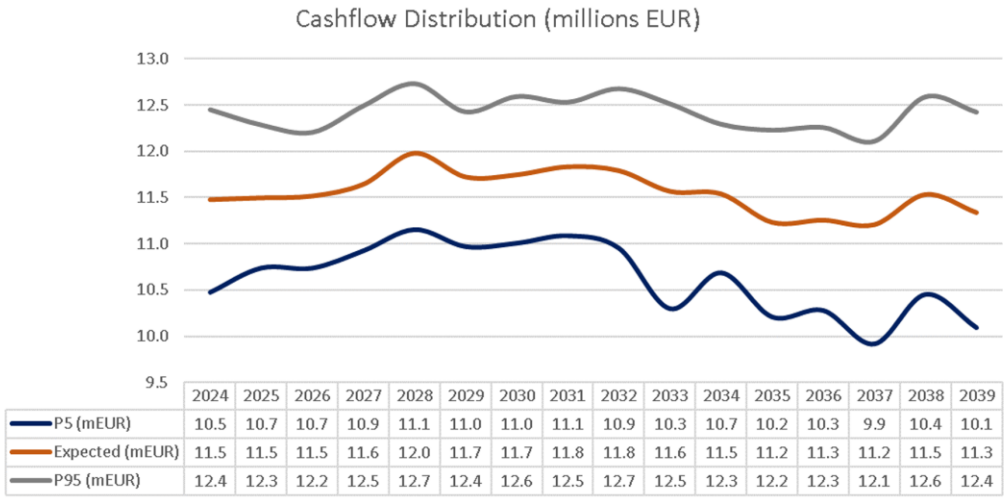
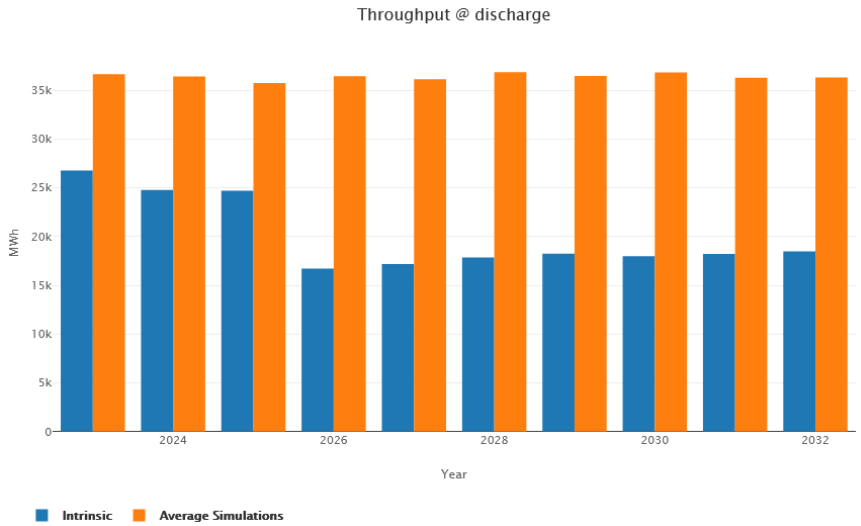
KyBattery – Energy storage valuation

- Valuation of energy storage assets based on price simulations
- Calculates market value of the asset in different energy market:
  - Day-ahead, intraday, imbalance or a combination of these markets
  - Combine with optimizing in FCR market
- Uses advanced trading strategies to calculate value of the asset, avoiding perfect foresight
- Expected value and probability distribution
- Model can also value of energy storage that share grid connection point with renewable generation asset.
- Typical technical/contractual battery constraints can be used

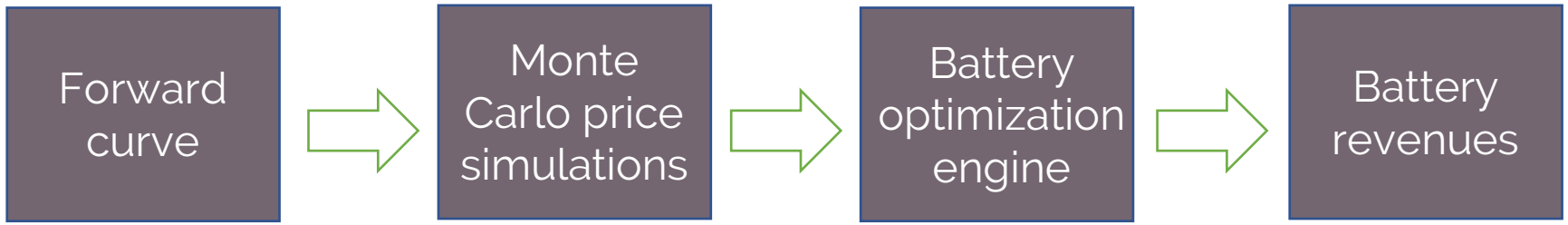


	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
P5 (mEUR)	10.5	10.7	10.7	10.9	11.1	11.0	11.0	11.1	10.9	10.3	10.7	10.2	10.3	9.9	10.4	10.1
Expected (mEUR)	11.5	11.5	11.5	11.6	12.0	11.7	11.7	11.8	11.8	11.6	11.5	11.2	11.3	11.2	11.5	11.3
P95 (mEUR)	12.4	12.3	12.2	12.5	12.7	12.4	12.6	12.5	12.7	12.5	12.3	12.2	12.3	12.1	12.6	12.4



KyBattery – methodology

- The trading strategy should take into account the stochastic (uncertain) nature of the short-term market prices
- Central input is a price forward curve (e.g. hourly/half-hourly)
- KySim generates the Monte Carlo price simulations (e.g. for day-ahead, intraday)
- KyBattery uses Least-squares Monte Carlo to perform a realistically optimal trading strategy:
  - Uncertainty in prices (Monte Carlo)
  - Least-squares regressions to decide about optimal trading
- The result is a complete distribution of revenues streams



KyBattery – with FCR

- KyBattery finds the optimal dispatch and corresponding cash-flows for a battery on a large number of simulations (or on historical prices)
- Until now, the supported strategies are:
  - DA trading
  - ID trading
  - Passive imbalance (IB) trading
  - ID trading + IB trading
- We now allow for FCR bidding, per 4-hourly block
- Example results for a 2-hour battery and 1 MWh capacity

	value	of which FCR	hours	value intr	hours intr
no FCR	167,188	-	-	74,422	-
FCR 25	172,635	20,498	1,645	114,508	7,448
FCR 45	220,968	137,834	6,127	197,625	8,720

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Questions and Answers

- Time for questions!

Contact Details

We look forward to supporting you with the right tools and advice in the rapidly changing energy sector!

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