Webinar

Optimal value-stacking with batteries

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KYOS

Agenda

- 15:00 Overview energy storage market
  - Reasons for growing interest in energy storage projects
  - Revenue streams of energy storage projects
- 15:10 Valuation of energy storage
  - Market trading with batteries
  - Value stacking with FCR
  - Value stacking with solar co-sharing
- 15:35 – Q&A and discussion
- 15:45 – End of the webinar

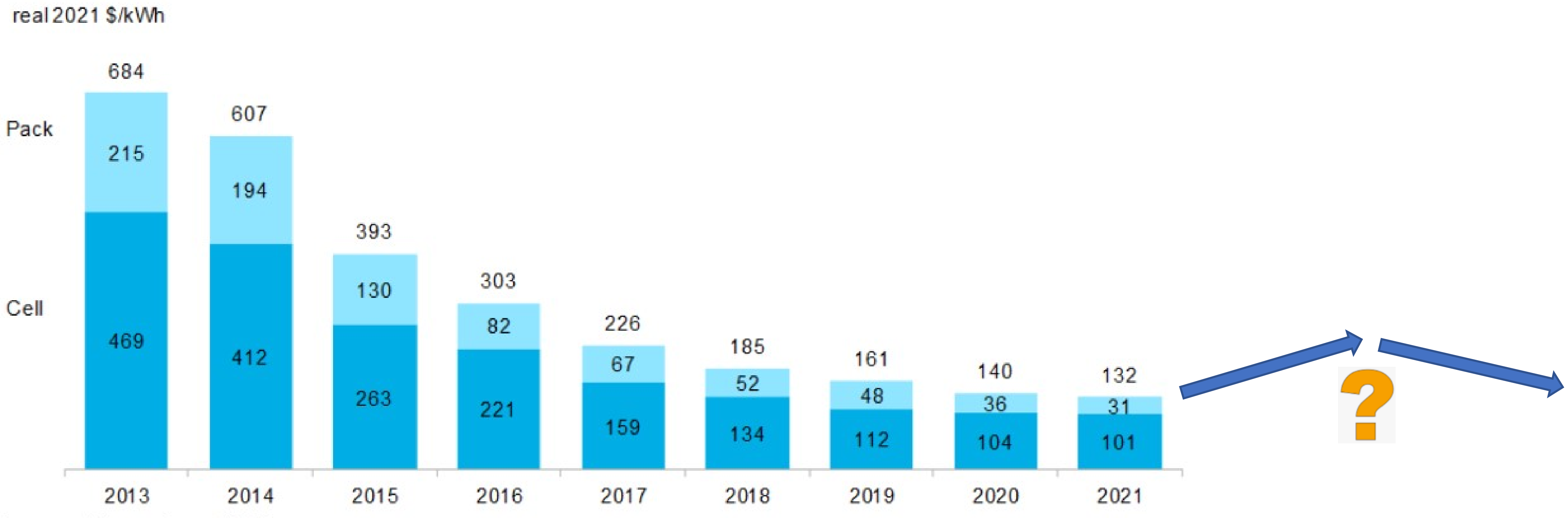
About KYOS Energy Analytics

- Provide analytical support to energy companies
- Software to value and optimize complex energy assets with flexibility
  - Energy storage
  - Renewable PPAs
  - Natural gas storages
  - Gas swing contracts
  - LNG contracts
  - Power plants
- Delivered in **easy to use, on-line system**: the KYOS Analytical Platform

More than 100 corporate clients using KYOS software and services




Falling costs of Li-ion battery packages

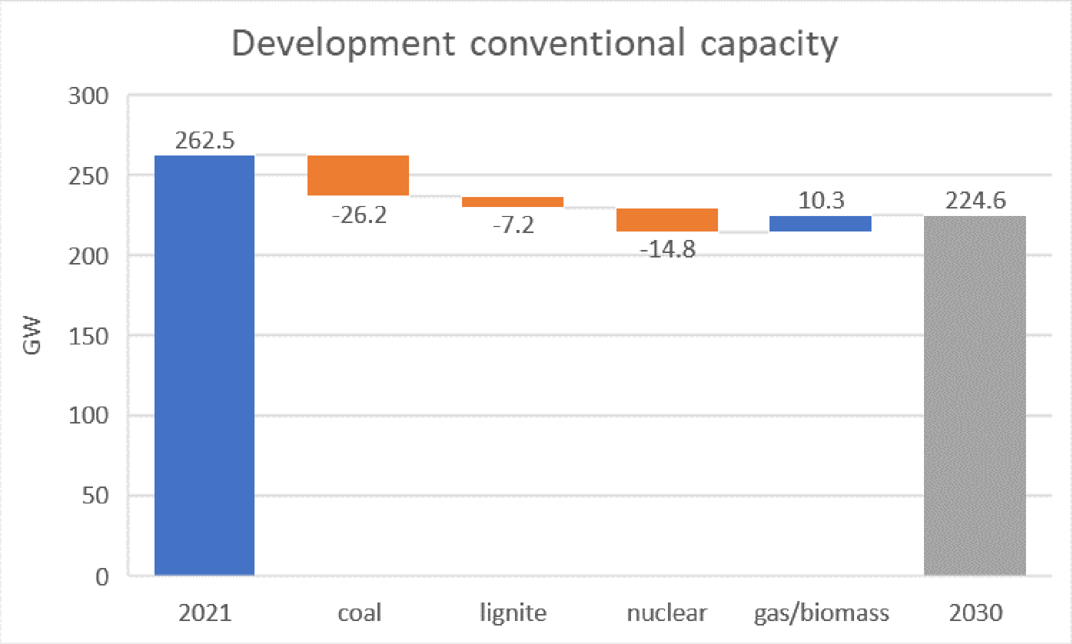


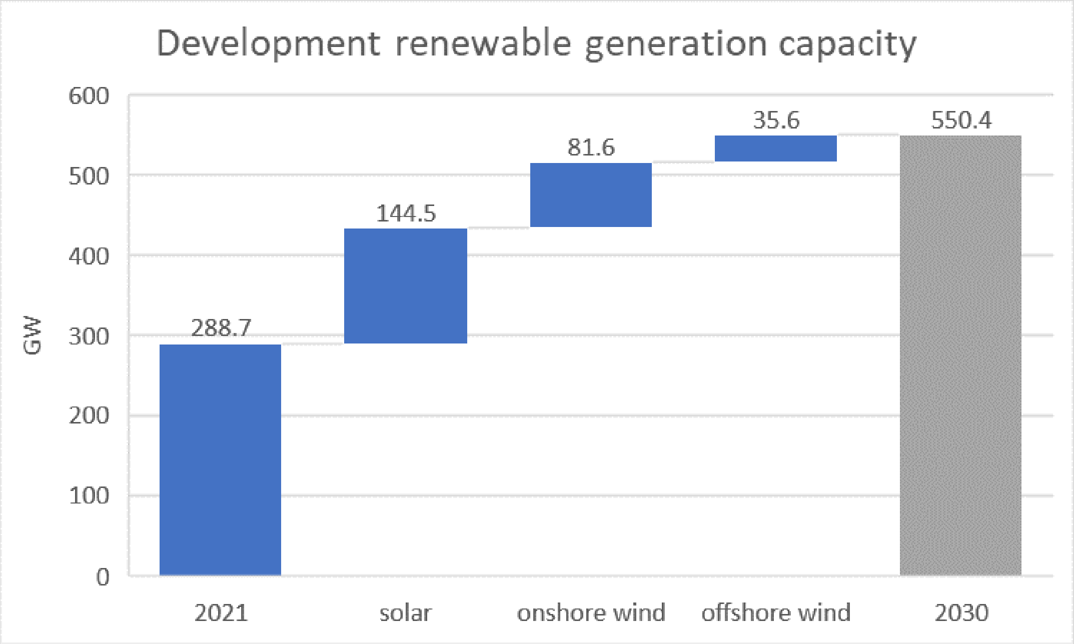
Source: BloombergNEF.

- Cost in 2010: 1,000 USD/kWh
- Costs expected to fall further, but growing uncertainty about raw materials prices
- Innovations to reduce dependence on existing key raw materials (lithium, graphite, cobalt, manganese)

Why interest in energy storage?

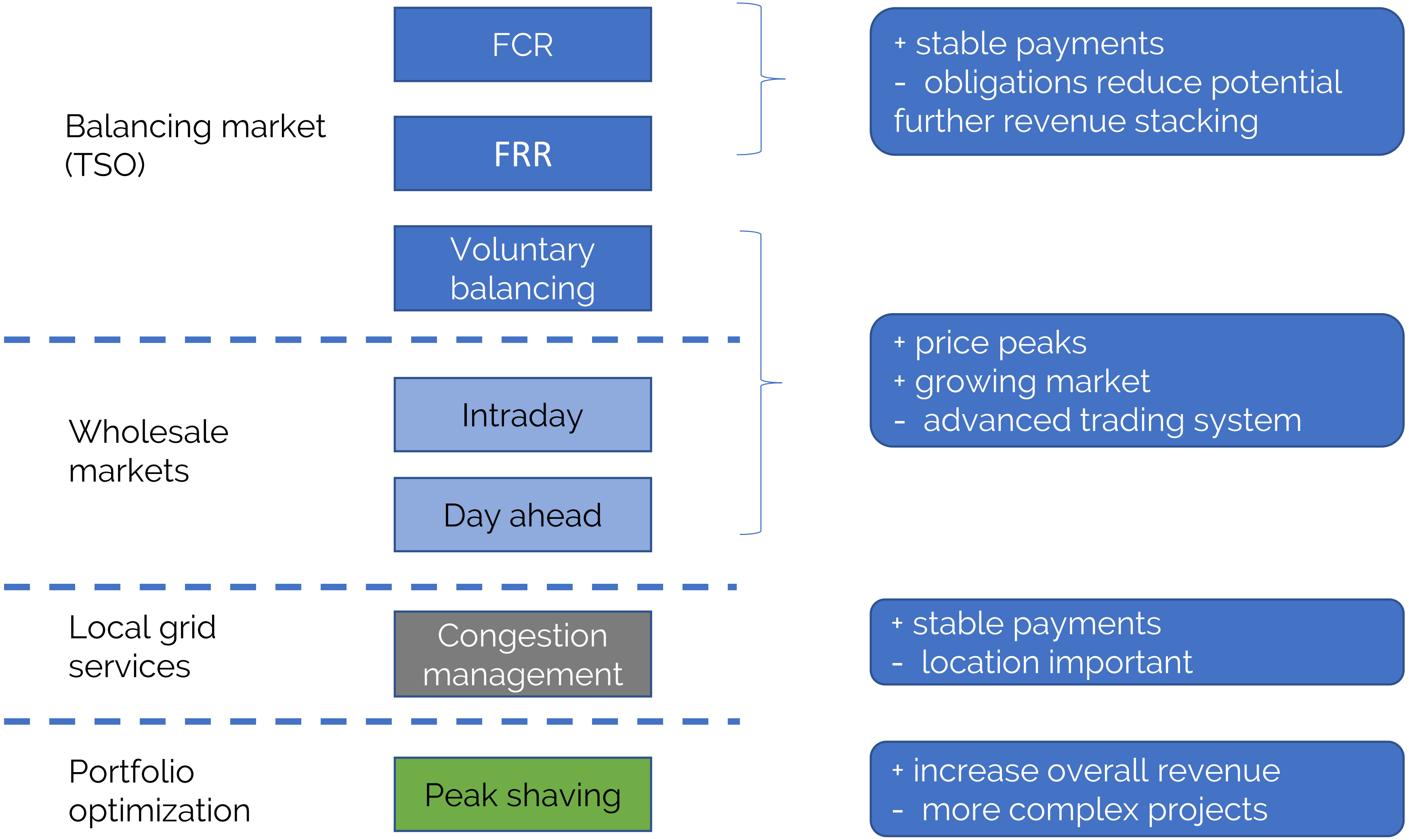
- Decrease in conventional power plants capacity
- Large increase in renewable generation





KYOS base case - Countries: GB, BE, DE, NL, FR, ES, IT

Energy storage revenue streams



Balancing market (TSO)

- FCR
- FRR
- Voluntary balancing

Wholesale markets

- Intraday
- Day ahead

Local grid services

- Congestion management

Portfolio optimization

- Peak shaving

FCR, FRR:

\+ stable payments
\- obligations reduce potential further revenue stacking

Voluntary balancing, Intraday, Day ahead:

\+ price peaks
\+ growing market
\- advanced trading system

Congestion management:

\+ stable payments
\- location important

Peak shaving:

\+ increase overall revenue
\- more complex projects

Battery business case typically combination of revenue streams

Market trading with batteries

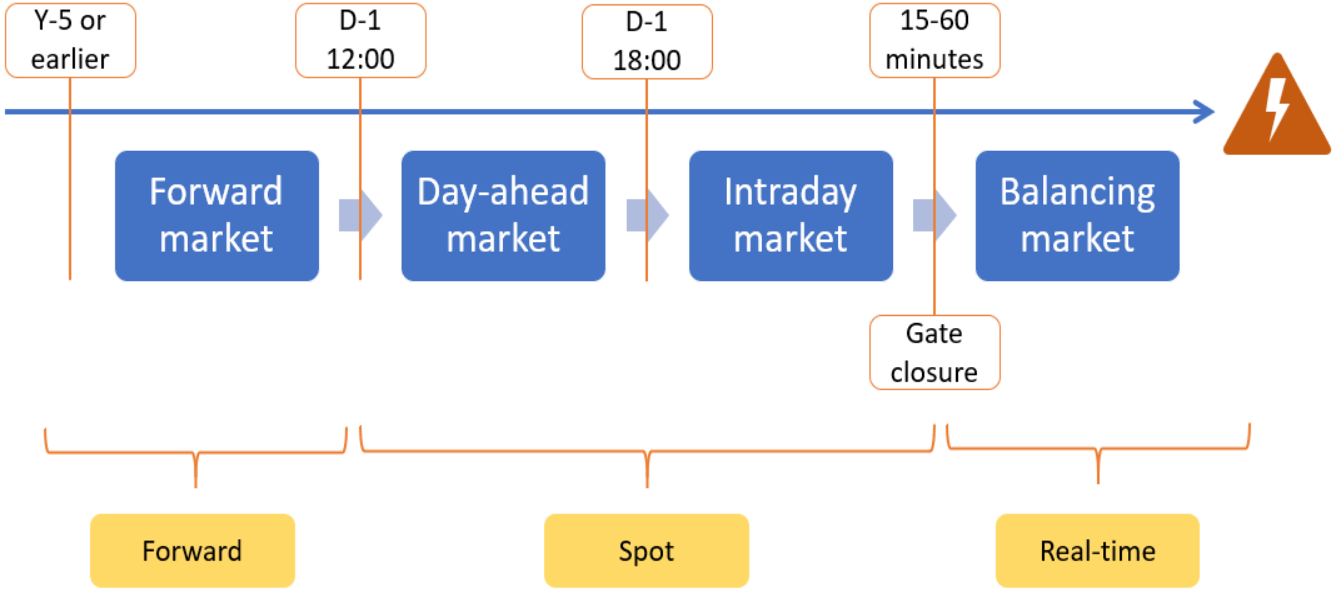
Short-term power markets

Creators of imbalances

- Balancing Responsible Parties (BRP)
- Control generation / consumption
- To match their forecast (e-program)
- If not: create imbalances

Providers of ancillary services

- Provide capacity to the TSO
- Are paid for their services
- Are activated when needed
- Resolve system imbalances



Y-5 or earlier

D-1 12:00

D-1 18:00

15-60 minutes

Forward market

Day-ahead market

Intraday market

Balancing market

Gate closure

Forward

Spot

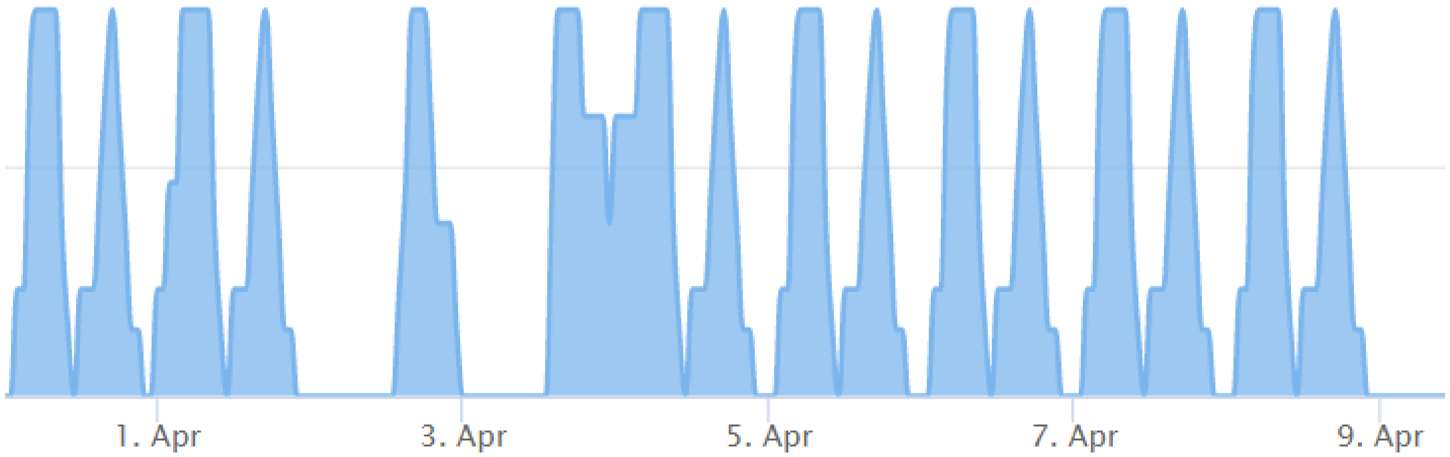
Real-time

Trading in the market

- The battery is used for trading on 1 or more of the following markets:
    - Day ahead market
    - Intraday market
    - Imbalance market (voluntary balancing)
- Joint optimization on multiple markets is possible
- Combination with FCR and/or peak-shaving solar.
- Trading optimization is performed on a large set of simulation paths, without perfect foresight about future prices. Stochastic optimization.

Methodology: least-squares Monte Carlo (LSMC)

- The KyBattery model finds the optimal (though realistic) trading strategy with the battery in the market
- It finds the optimal action/trade:
  - Charge
  - Discharge
  - Do nothing
- The optimal trading strategy is calculated on a large number of possible price developments using Monte Carlo simulations



Example results, Dutch market

- Expected battery value:

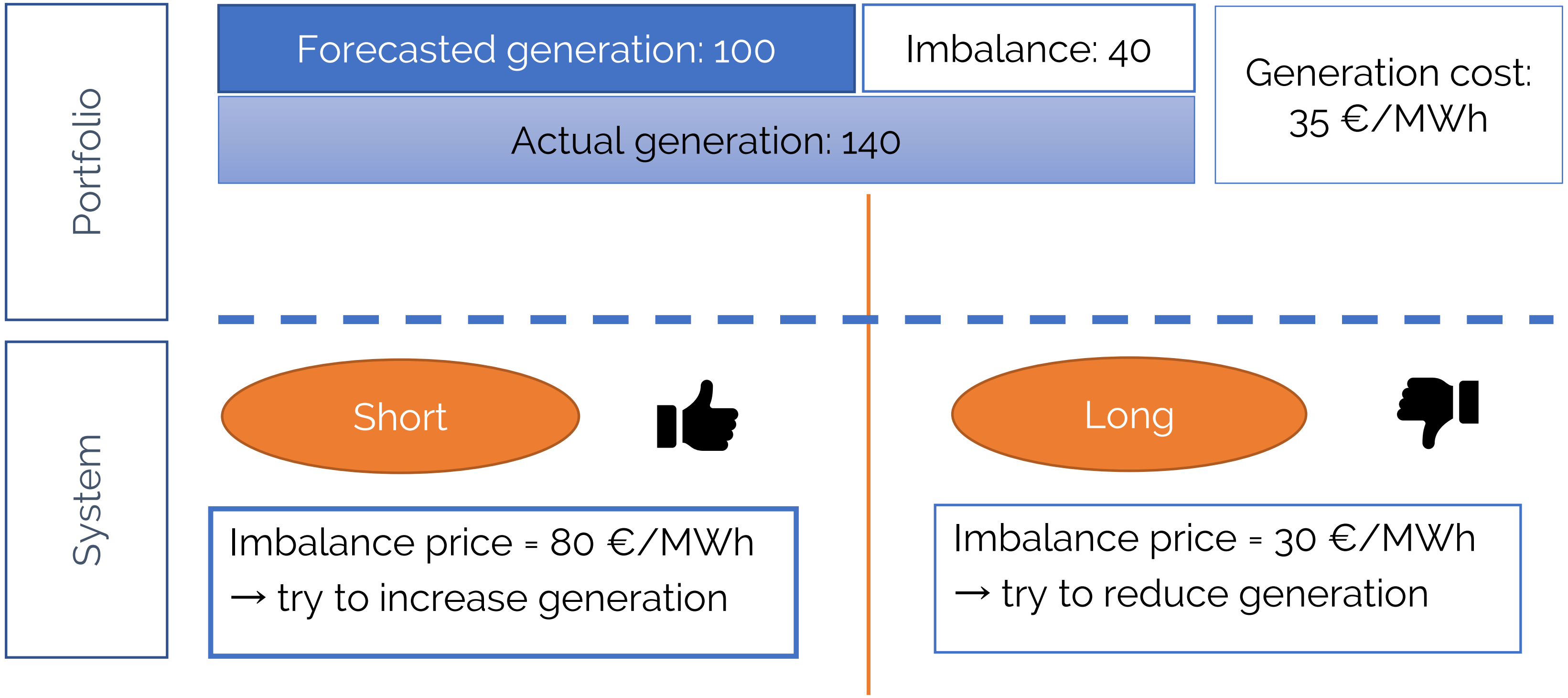
	Low	High
Day-ahead market:	100	100
Imbalance market:	150	300
Intraday market:	250	280
Intraday + Imbalance:	350	450

- Imbalance market: difference between high and low mainly depends on ability to forecast imbalance prices
- Intraday market: difference between high and low mainly depends on liquidity in intraday market
- FCR: can be added to the strategy; FCR payments very different between countries and probably in decline (in NL)

How does passive imbalance trading work?

Portfolio imbalance versus system imbalance

- Traditionally, BRPs have focused on minimizing the imbalances in their own portfolio; this was even obligatory
- TSOs increasingly accept, or even encourage, BRPs to minimize instead the system imbalance



Portfolio

Forecasted generation: 100

Imbalance: 40

Actual generation: 140

Generation cost: 35 €/MWh

System

Short 👍

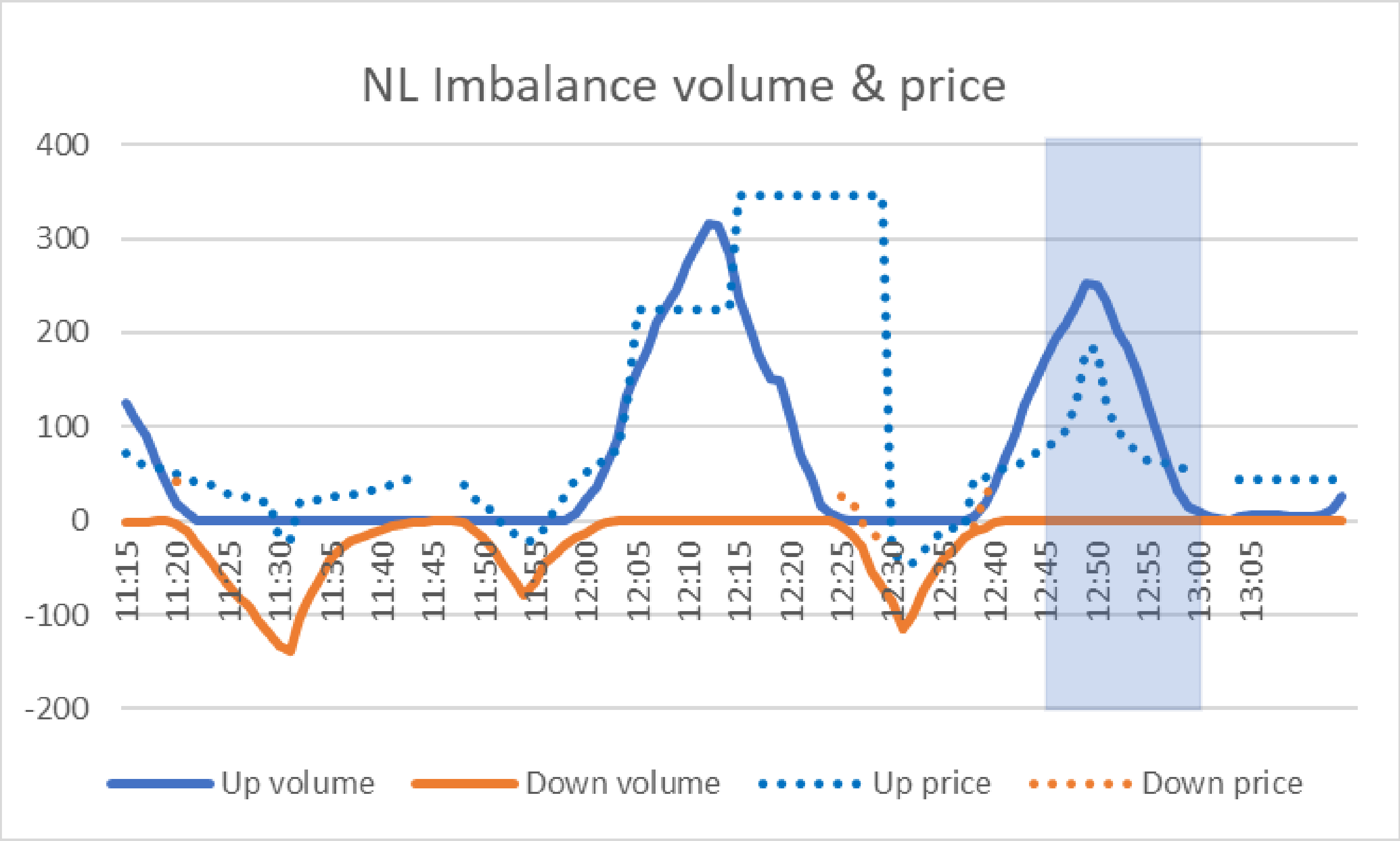
Long 👎

Imbalance price = 80 €/MWh
→ try to increase generation

Imbalance price = 30 €/MWh
→ try to reduce generation

Was this profit opportunity predictable?

- Towards 12:38, the up balancing volumes (shortage) increased
- By 12:45 it was likely that the PTE of 12:45-13:00 would have a shortage, hence it was likely profitable to be long



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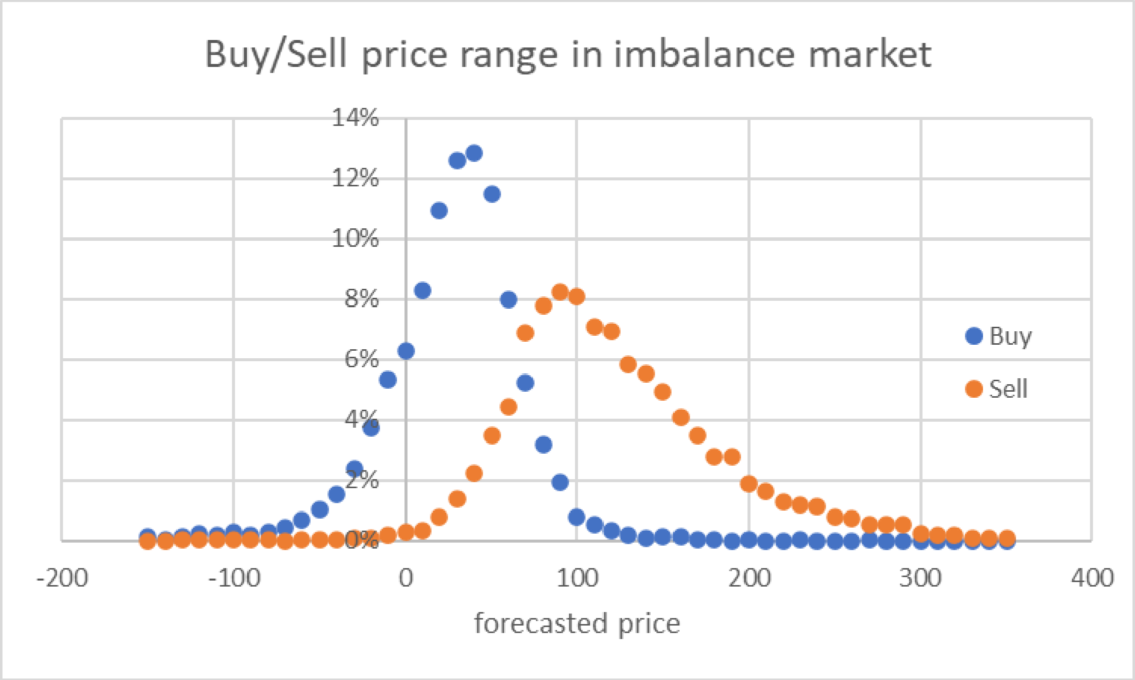
Forecasting imbalance price

- Imbalance price is forecasted for the next PTU
- Actual price will be different from forecast
- Forecasting accuracy can be manipulated in the KyBattery software, ranging from ‘basic’ to ‘perfect’.
- Example actions with imbalance trading:


Buy/Sell price range in imbalance market

How to value revenues from PI / NIV trading?

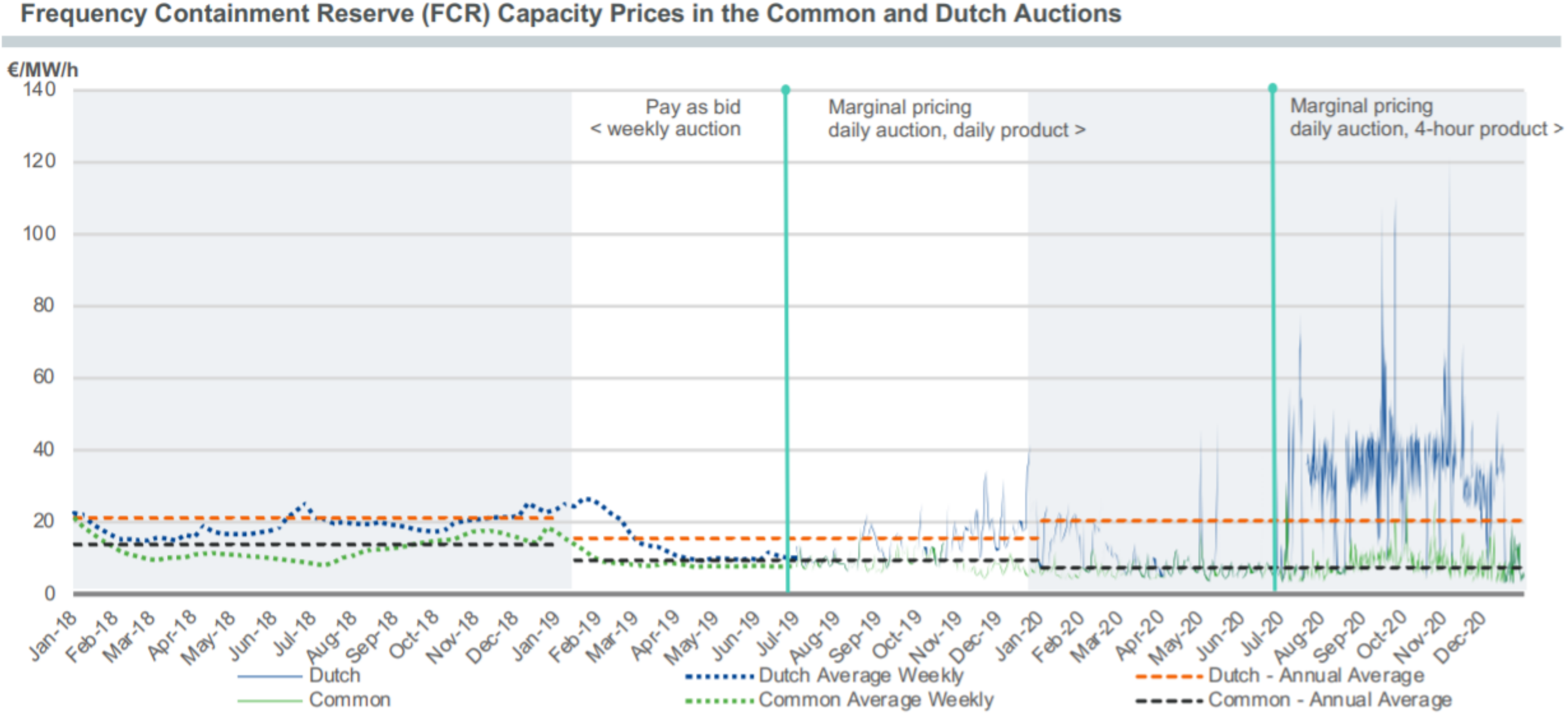
- Requires a short-term forecasting and simulation model for imbalance prices and imbalance volumes, e.g. 15 min basis
- Requires an optimal trading strategy per 15 min.
- Trading strategy should take into account the stochastic (uncertain) nature of the imbalance prices & volumes
- Least-squares Monte Carlo is possible, but also rule-based strategies

Imbalance price forecasting and simulation engine → Optimization engine for trading decisions → Battery revenue streams

Market trading with FCR

General approach

- FCR: each TSO acquires a certain amount of capacity
- FCR in the Netherlands: acquired in 4-hourly blocks
- Service provider should pass tests to ensure almost immediate deliverability, up and down

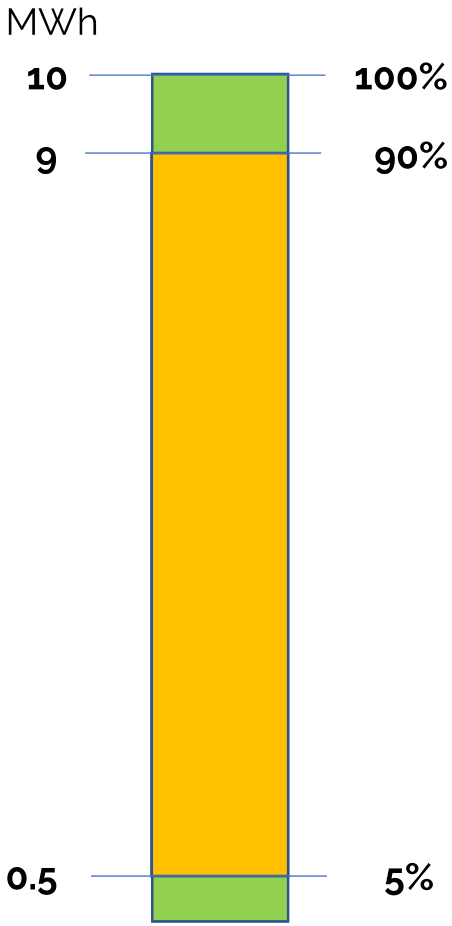

Frequency Containment Reserve (FCR) Capacity Prices in the Common and Dutch Auctions

Example battery parameters and FCR

- Total energy capacity: 10.0 MWh
- Usable capacity: 8.5 MWh
- Charge/discharge rate: 9.0 MW
- Charge/discharge efficiency: 94%
- Time window: 2022 – 2029 8 years
- Maximum # cycles: 7500 full

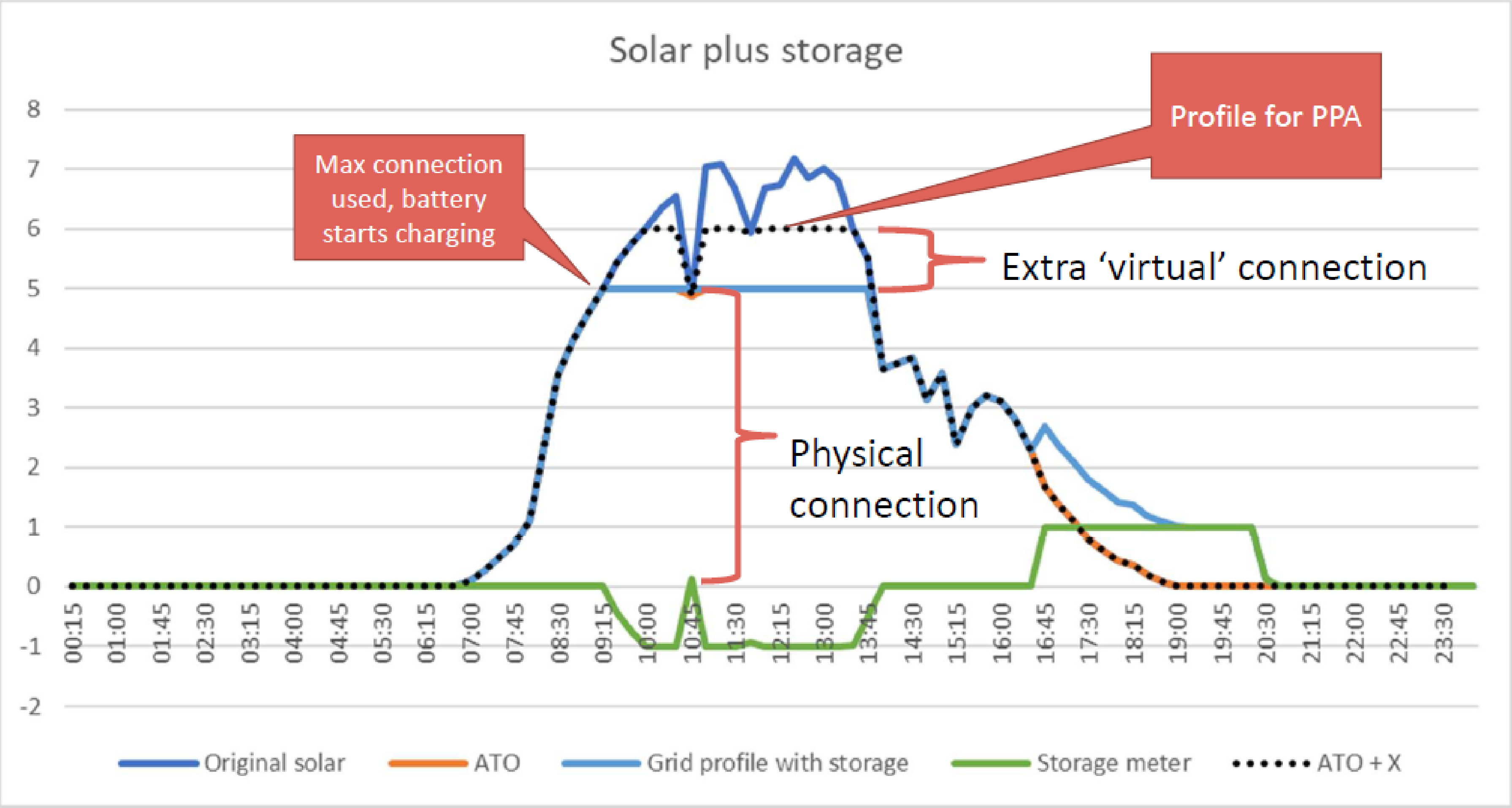
  The model uses 'virtual costs' to arrive at appr. 7500 cycles

- When offering 6 MW FCR, we keep for trading:
  - Around 6 MWh usable energy storage
  - Around 3 MW charge/discharge rate
  - 6000 cycles per year (1500 less)



Peak shaving / Co-sharing with solar

Extra virtual capacity for solar



Max connection used, battery starts charging

Profile for PPA

Extra 'virtual' connection

Physical connection

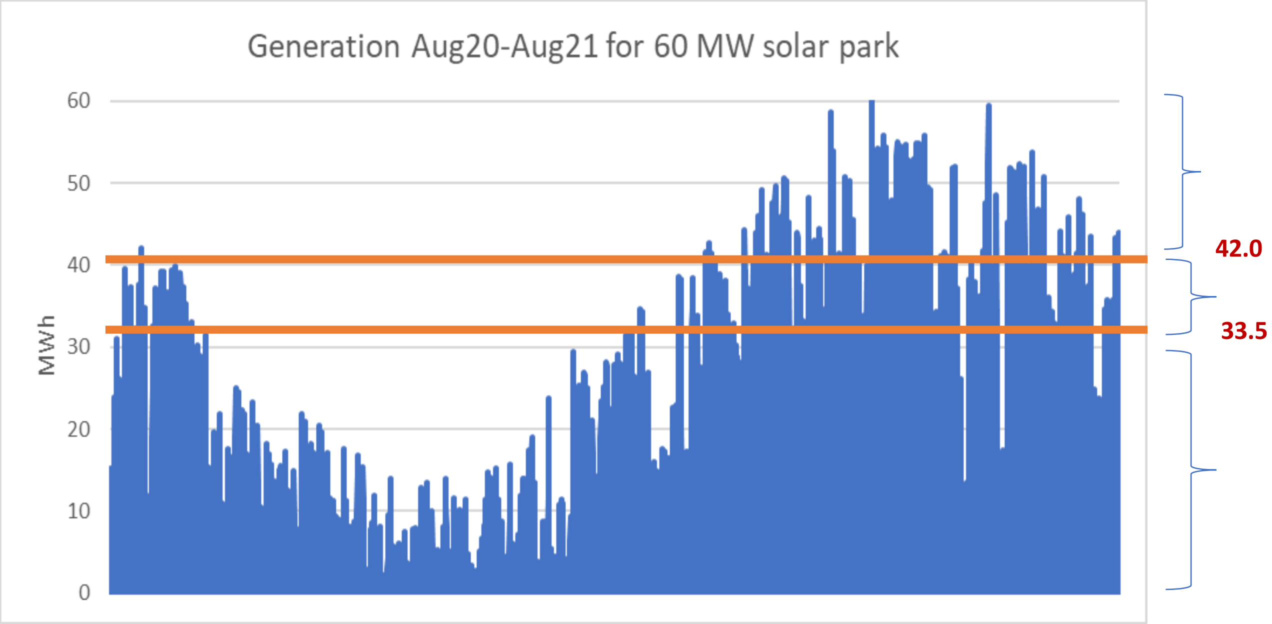
Source: InvestNL / Krachtwerk

Solar generation pattern: 1 year history

Historical analysis:

- 60 MW peak capacity, 42 MW grid connection
- 1 year: Aug 2020 – Aug 2021
- Location in the Netherlands
- Total generation 62.9 GWh, 12% load factor
- 1.26 GWh (2%) cannot be delivered to the grid

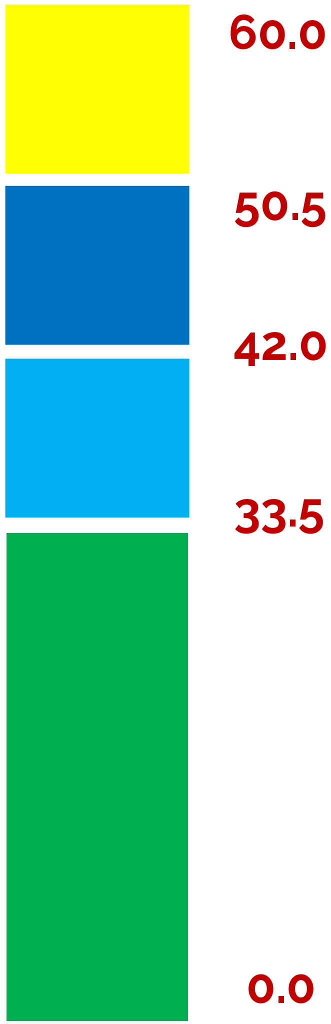
Excess generation, above 42 MW:			
	April	126	
	May	223	
	June	636	
	July	243	
	August	32	
	Year total	1260	MWh
	% of gen	2.0%	



% of MWh	% of time
2.0%	2.4%
4.6%	3.4%
93.4%	94.2%

Overview battery with solar

Solar generation (MW)



Solar generation capped to 50.4 MW

Solar generation capped to 42-50.5 MW
Battery stores up to 8.5 MW
Battery cannot offer FCR

Battery cannot discharge (fully), but market prices are typically low
Battery cannot offer FCR

Full solar generation
Flexible use of battery, including FCR

Valuing battery with solar

- Savings on grid connection costs (shared or sunk)
- Increased revenues for solar at times of high output
- Requires adequate contract between BESS operator and solar:
  - In specific time windows, solar may nominate charge/discharge, settled against DA prices
  - Nominations must comply with storage parameters
  - Battery pays penalty if nomination cannot be absorbed
  - Battery can still be optimized around the nominations

→ constrained optimization in KyBattery

Example results battery with solar

Grid connection savings:	100
Increased solar revenues:	20
Loss in trading revenues:	- 40
Loss in FCR revenues:	- 50
Net gain of combination:	30

Additional advantage: a larger part of the revenue stream is rather predictable

Conclusion

- Batteries earn money with different mechanisms
- FCR has formed an important revenue stream in many markets, but revenues are likely to decrease
- For a sound business case, batteries are optimized across:
- Intraday and imbalance trading markets
- Sharing connections, especially with solar
- Offering ancillary services

Question & Answers

Thank you

Time for Q & A

Contact Details

We look forward to supporting you in the rapidly changing energy sector!

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