KYOS Webinar
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KYOS ENERGY CONSULTING

Webinar: Energy storage valuation and optimization

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KYOS Energy Analytics

Agenda

15:00 Overview energy storage market – Ewout Eijkelenboom

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

15:15 Valuation of energy storage – Cyriel de Jong

- Stacking revenue streams
- Passive imbalance trading
- Methodology for energy storage valuation

15:35 – Q&A and discussion

15:45 – End of the webinar

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

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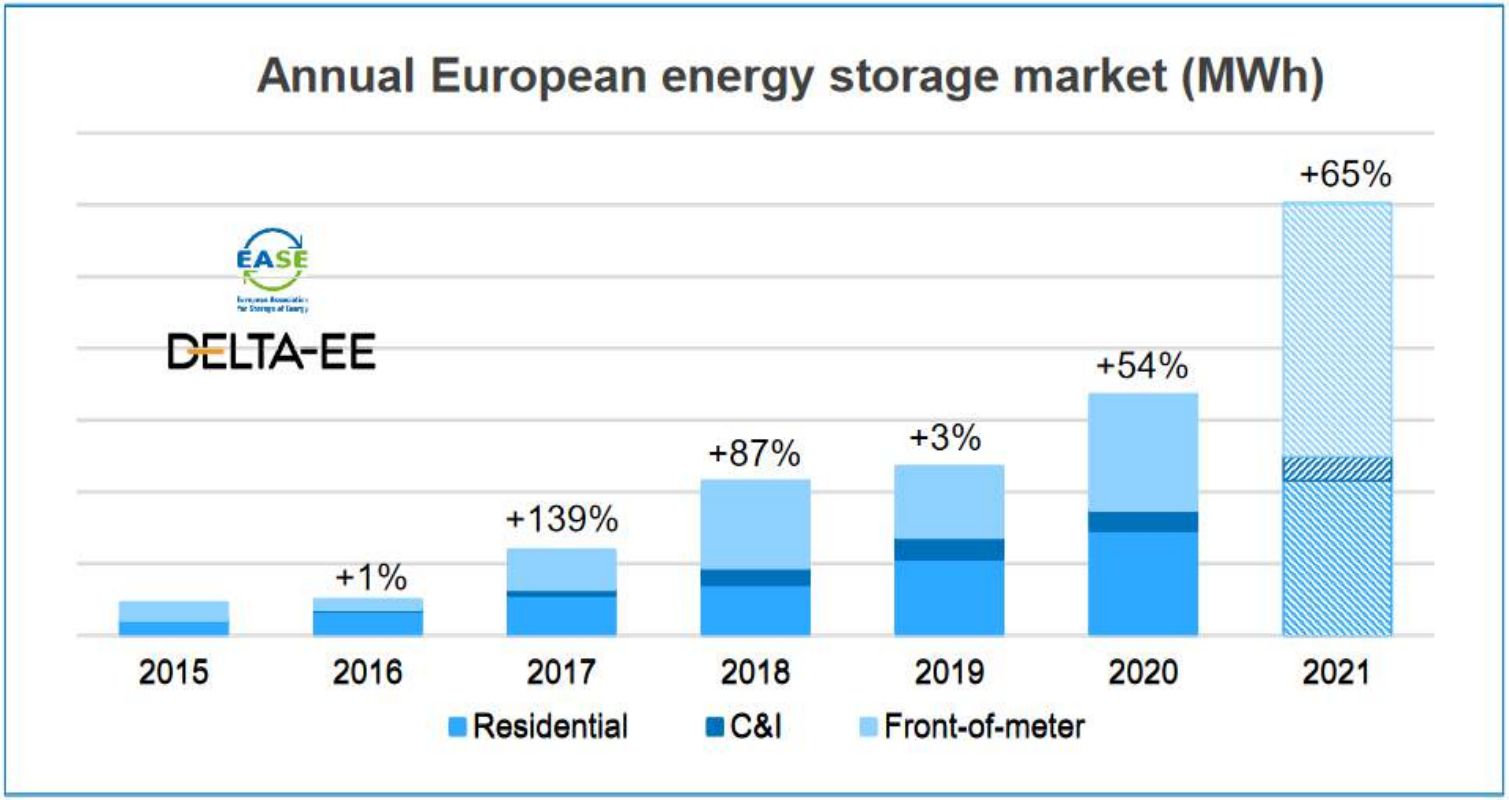
Storage market quickly growing

8.3 GWh
2021

0.6 GWh
2015

Cumulative installed base



European Market Monitor on Energy Storage - European Association for Storage of Energy

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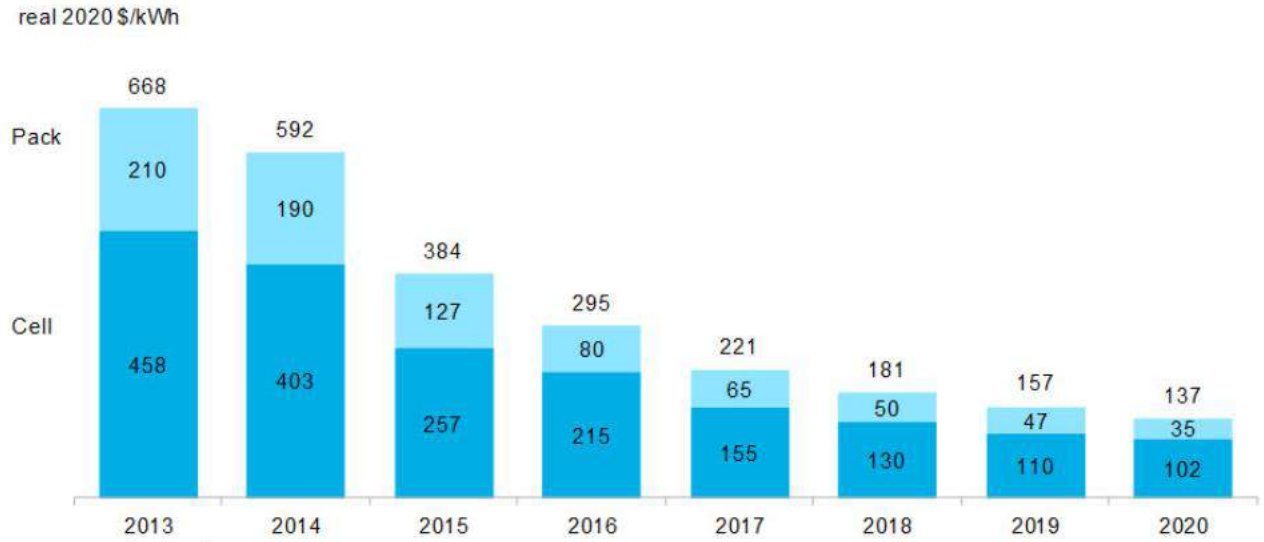
Falling costs of Li-ion battery packages

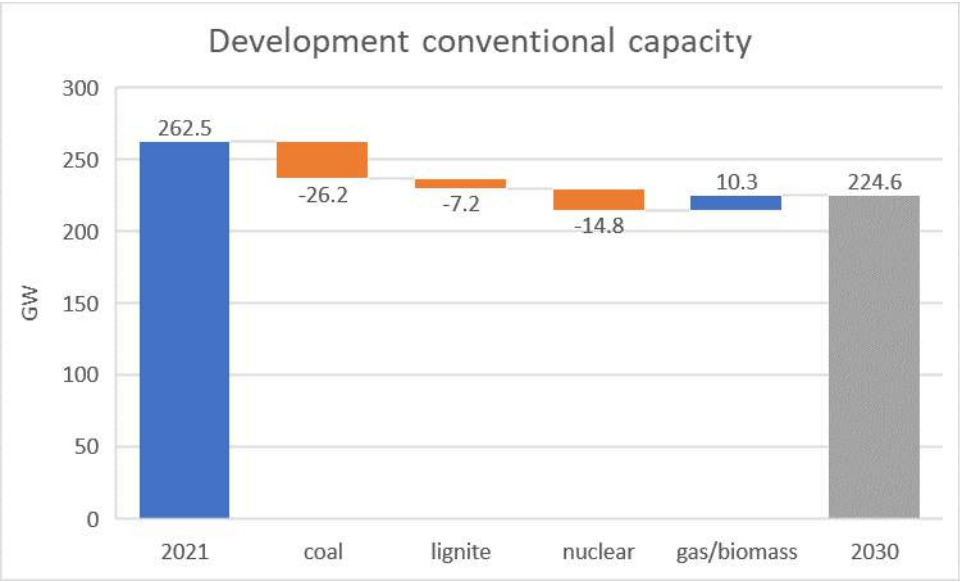
Figure 1: Volume-weighted average pack and cell price split

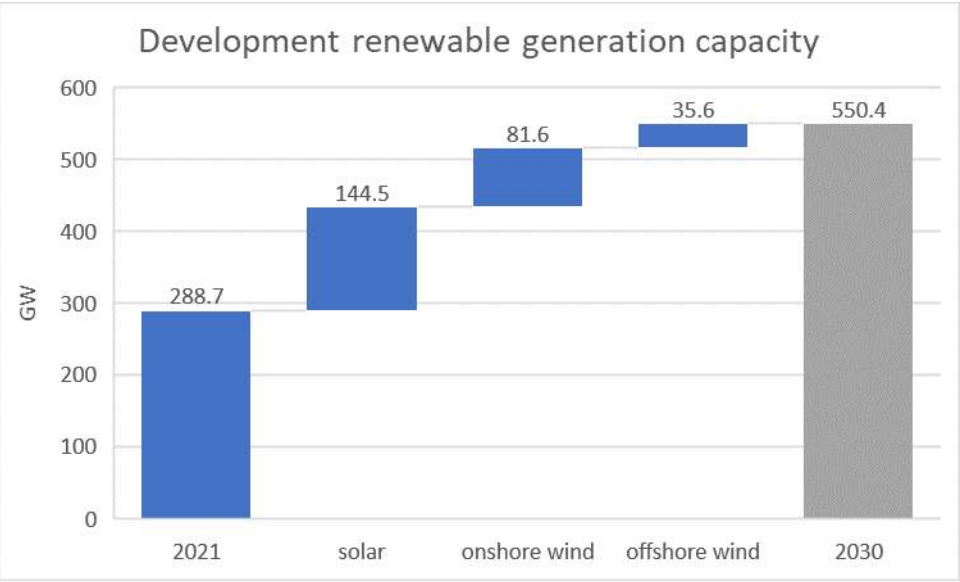


Source: BloombergNEF

Why interest in energy storage?

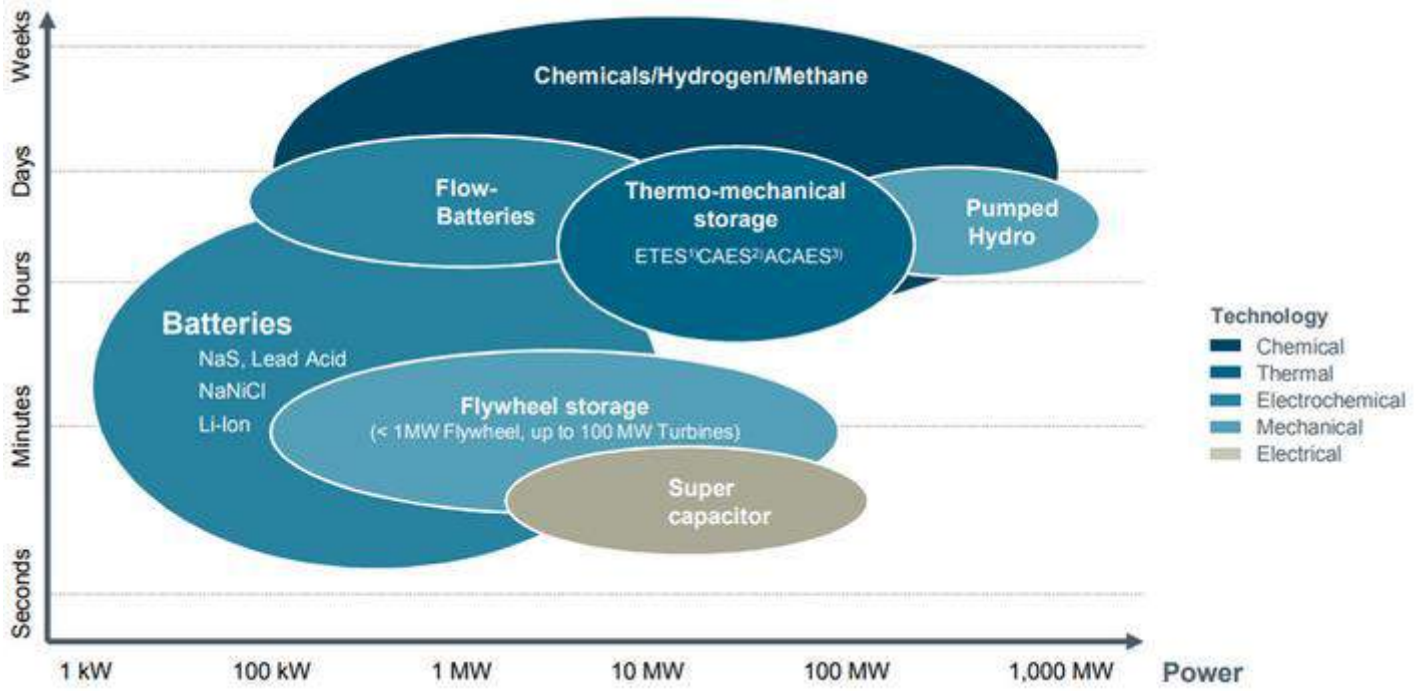
- Decrease in conventional power plants capacity
- Large increase in renewable generation





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

Different types of energy storages



Current status: mainly pumped hydro and batteries
The energy system needs more variation in storage types and especially also longer range storage

Hybrid form of energy storage

Hybrid system in Almelo, the Netherlands (S4 Energy/Leclanché):

- 8.8MW / 7.12MWh of lithium-ion batteries
- 3 MW from 6 flywheels
- Provides primary control power to TenneT
- The flywheels supply instantaneous power for very short periods of time without losing capacity, with 92% efficiency

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Energy storage revenue streams

Different revenue types possible for energy storages

- Upfront/capacity payment
  - Examples: Capacity market, ancillary services
  - Receive fixed payment
  - Energy storage ready to act when required

+ stable payments
- obligations reduce potential further revenue stacking

- Energy payment
  - Price arbitrage
  - Receive variable payment when used

+ price peaks
- Advanced trading system

- Portfolio effects
  - Optimize solar production
  - Optimize network capacity

<u>Battery business case typically combination of revenue streams</u>

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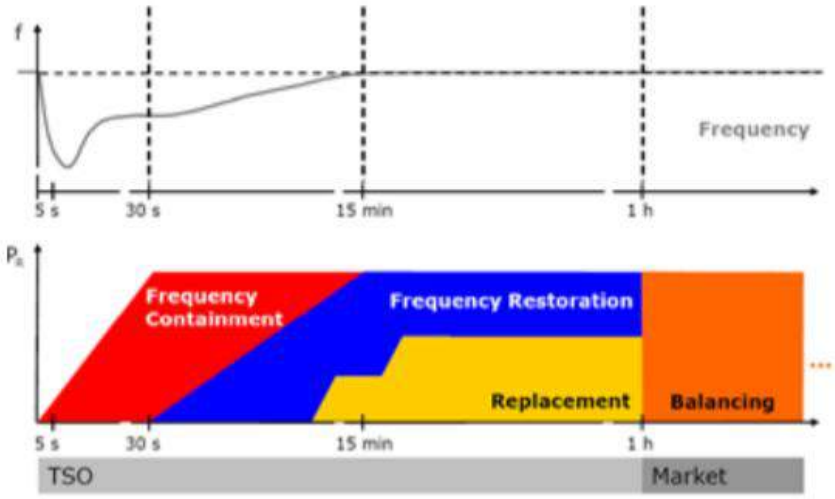
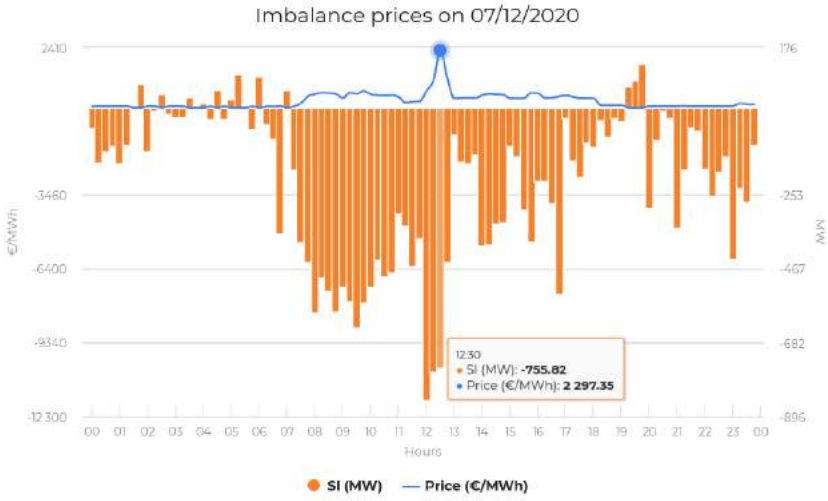
Energy storage revenue streams (cont'd)

- Ancillary services
  - FCR
  - FRR
  - Dynamic Containment
- Timescales matching energy storages
- Procurement via auctions, trend to shorter terms



- Price arbitrage
  - DA
  - WD
  - Imbalance
- Example: imbalance prices in Belgium
  - 7 December 2020
  - Imbalance price peaked to 2,297€/MWh

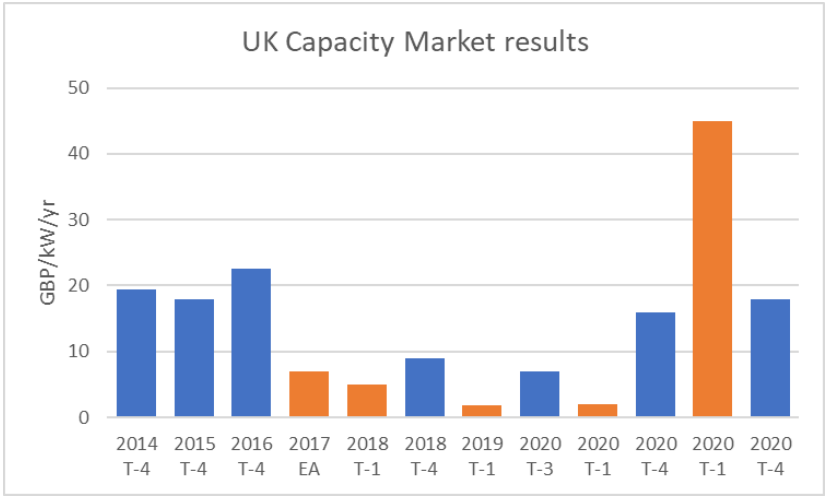


Business models for battery investors

- Sell the capacity to a large creditworthy energy trader
  EdF, Shell/Limejump, RWE, Axpo
  - \+ Receive a high stable cash-flow
  - \- Limited or no participation in the upside
- Sell the capacity to a smaller dedicated battery optimizers
  Habitat, Priogen, Flexitricity
  - \- Receive a low(er) stable cash-flow
  - \+ More participation in the upside
- Optimize the battery yourself
  - \- Full risk
  - \+ Full reward

Attractive start for batteries in the GB market

- GB market vulnerable to capacity shortages
- Capacity market (CM) started in 2014 immediately attracted many batteries
- T-1 and T-4 auctions secures payment for 1-15 years, for being available
- This March, the T-1 auction clearing price was 45 GBP/kW/year
  - Battery: 114MW
- T-4 more stable at around 15-20 GBP/kW/year
  - 2020: 230MW battery
- Capacity market revenues are 1 element in value-stacking for batteries



Battery optimization

Optimization of power generation

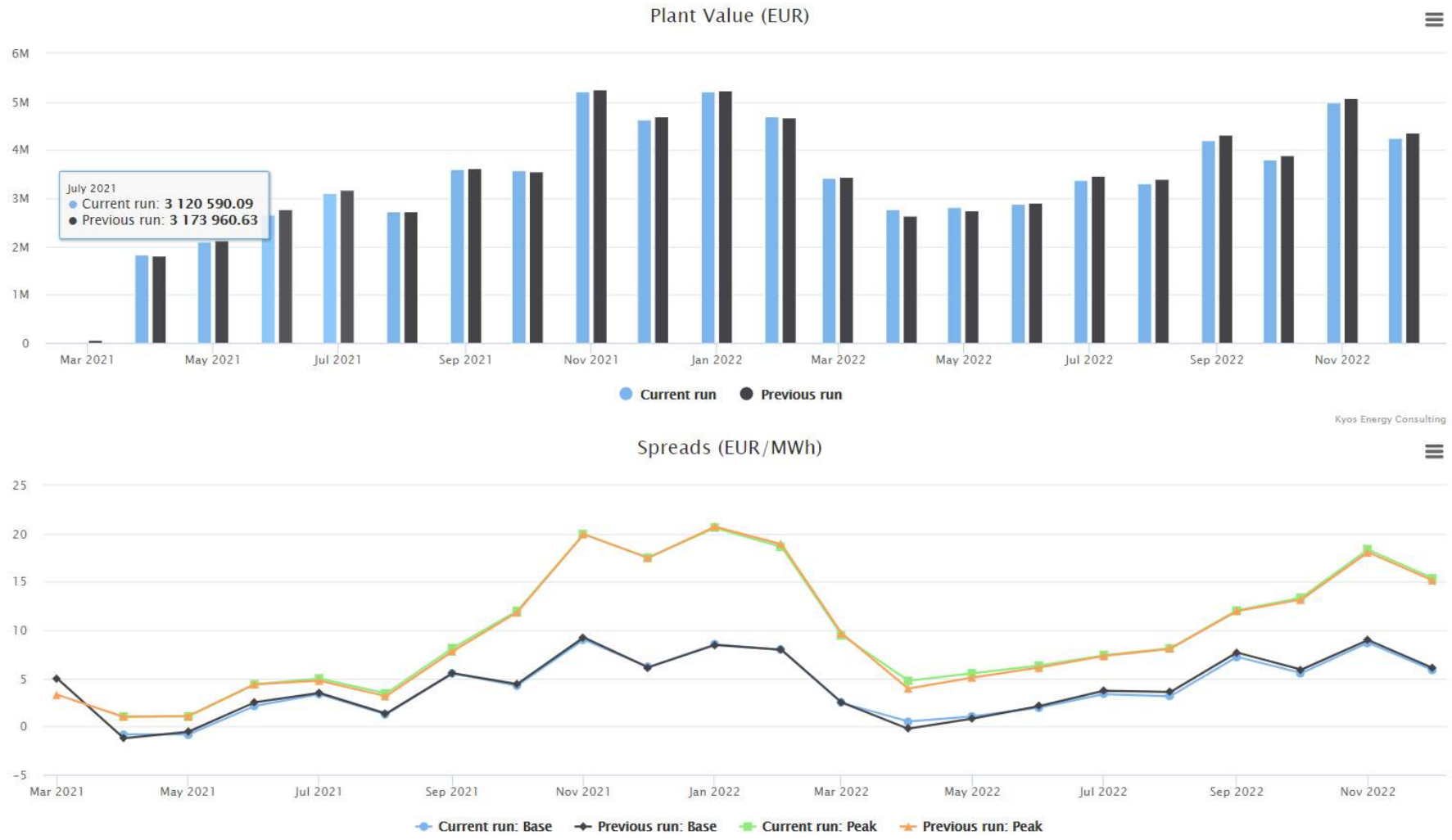
- Most value of conventional generation assets can be derived from optimization in the day-ahead market
- Day-ahead market is most liquid and central price reference; re-optimization possible in intra-day markets
- Other usages can generate extra revenues, but also reduce potential (opportunity costs) in day-ahead markets:
  - Capacity market (e.g. UK)
  - Ancillary services

KyPlant: valuation, stochastic dispatch optimization, hedging

KyPN: support real-time trading and dispatch optimization in GB and IE markets

KYOS EPEX: find optimal family of bids on day-ahead EPEX market

KyPlant example report



Optimization of gas storage

- Most value of gas storage assets can be derived from optimization in the day-ahead market
- Day-ahead market is most liquid and central price reference; minor re-optimization possible in intra-day markets
- Hedging the exposures in the forward market (capture time spreads) is key to stabilize earnings

Gas Storage and Swing Report

Storage	Market	Product	Period	Cycle Cost	Intrinsic	Rolling Intrinsic Avg	Rolling Intrinsic 10%	Option Avg	Option 10%
	TTF	30/30	SY2021	0.50	1.19 ▼	5.05 ▲	3.21 ▼	6.50 ▲	3.21 ▼
	TTF	60/60	SY2021	0.50	1.19 ▼	3.47 ▼	2.36 ▼	4.25 ▼	3.36 ▲
	TTF	60/120	SY2021	0.50	1.07 ▼	2.71 ▼	1.94 ▼	3.39 ▼	2.67 ▼
	NBP	30/30	SY2021	1.00	9.30 ▼	22.50 ▲	16.63 ▲	24.60 ▲	21.00 ▲
	NBP	60/60	SY2021	1.00	9.30 ▼	16.53 ▲	13.13 ▼	17.72 ▲	15.32 ▲
	NBP	60/120	SY2021	1.00	8.93 ▼	13.97 ▼	11.67 ▼	15.02 ▲	13.02 ▲

KyStore: valuation, stochastic optimization, hedging of gas storage assets

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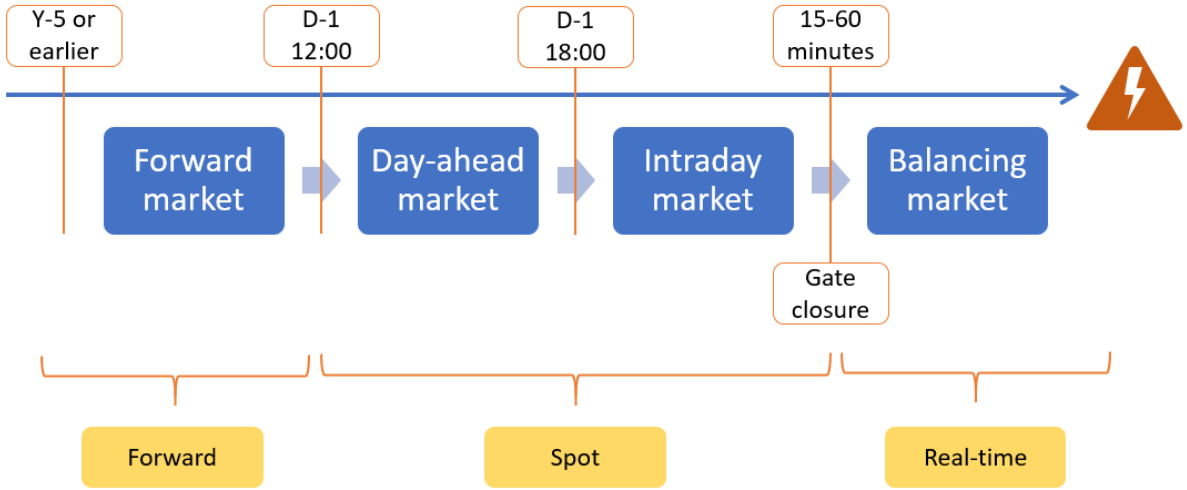
Balancing the system

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



Use of batteries to remove imbalances

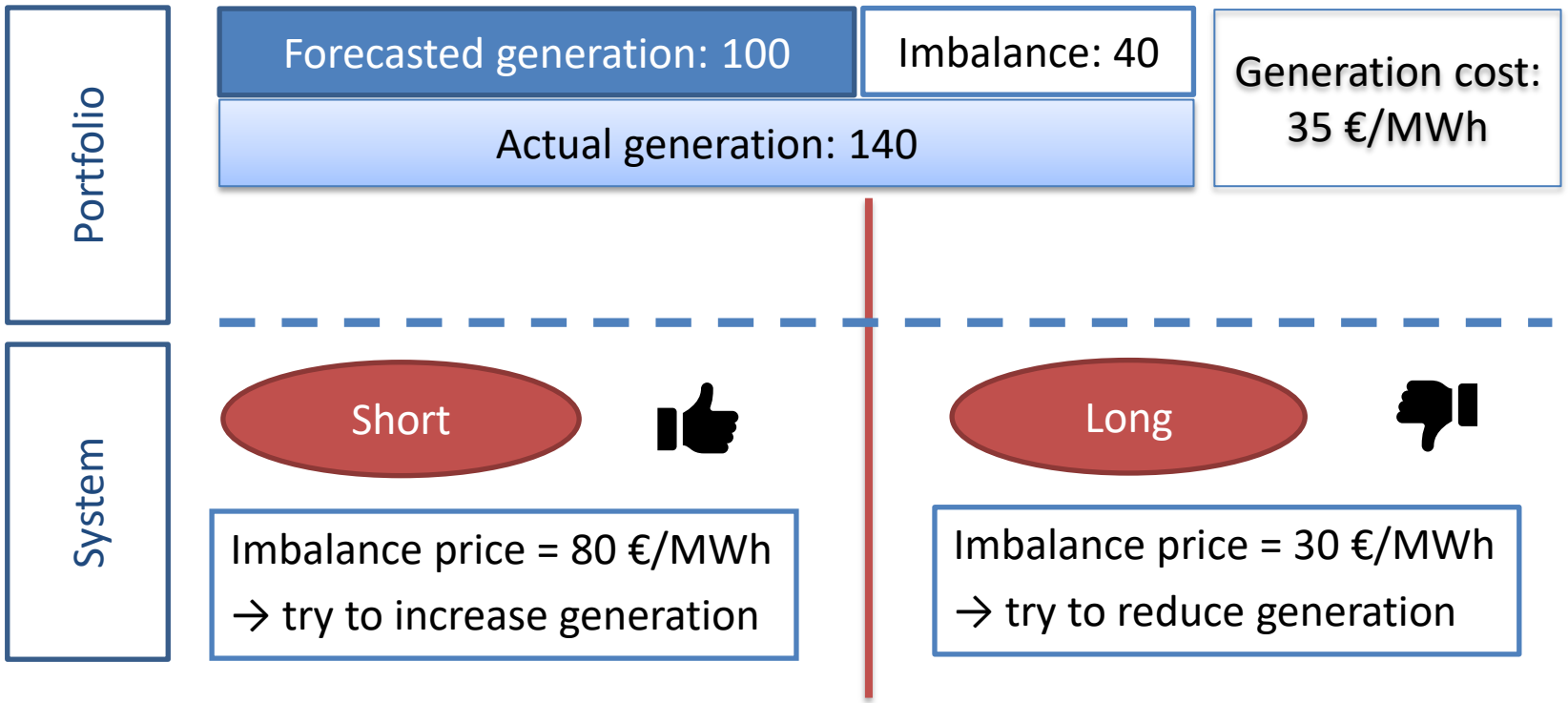
1. In the system, as ancillary service
2. In the own portfolio, e.g. in combination with solar farm:
   - If actual generation > forecasted, store energy in battery
   - (and use battery to shave peaks, and reduce grid fee)

If batteries are only used when the own portfolio is imbalance, then the use is quite suboptimal:

- The direction of your imbalance may be contrary to system
- Being out of balance is not always bad
- Battery usage is limited and not financially optimal

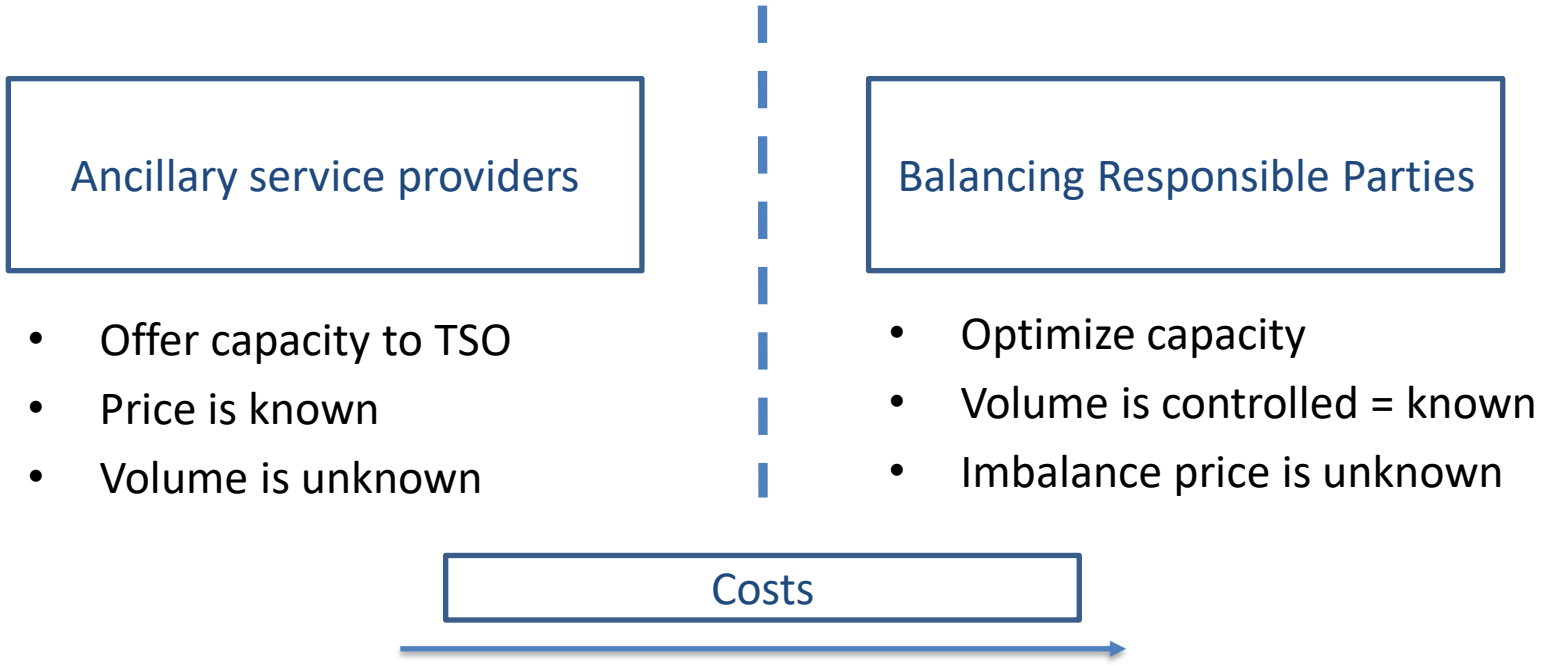
Portfolio imbalance versus system imbalance

- 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*



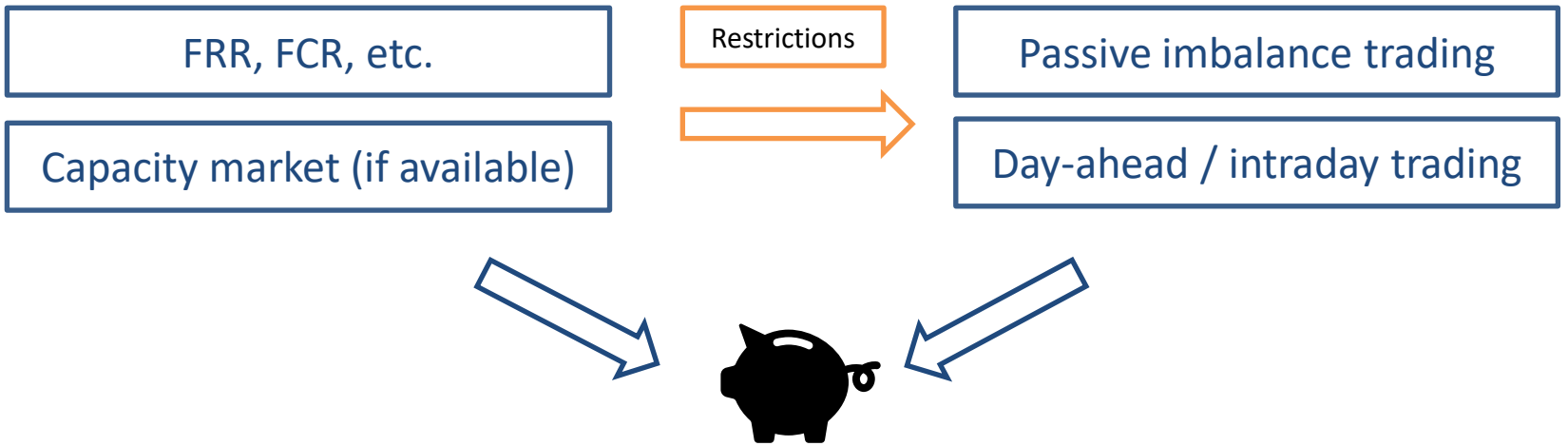
Passive imbalance trading / NIV chasing

- For a battery operator, actual generation/consumption will often differ from the day-ahead plan
- If forecast = 0 net volume, then all actions lead to imbalances (if battery is considered on stand-alone basis)
- Net Imbalance Volume (NIV) chasing = passive imbalance trading



Passive imbalance trading in 15 min periods

- Passive imbalance trading =
  - In next 15 min, forecast system imbalance volume & price
  - Go long or short for 15 min, based on forecast (+ uncertainty)
  - During 15 min, adjust action if needed
- Other revenue streams reduce capacities that can be freely used for passive imbalance trading



Example NL: passive imbalance trading

Number	Seq. nr.	Time	Up	Down	Up	Down	Up	Up	Down
1	789	13:08	6	0	0	0	0	44,52	
2	788	13:07	6	0	0	0	0	44,52	
3	787	13:06	6	0	0	0	0	44,52	
4	786	13:05	6	0	0	0	0	44,52	
5	785	13:04	4	0	0	0	0	44,52	
6	784	13:03	1	0	0	0	0		
7	783	13:02	3	0	0	0	0		
8	782	13:01	5	0	0	0	0		
9	781	13:00	11	0	0	0	0		
10	780	12:59	14	0	0	0	0	53,77	
11	779	12:58	31	0	0	0	0	58,25	
12	778	12:57	58	0	0	0	0	59,68	
13	777	12:56	87	0	0	0	0	64,25	
14	776	12:55	123	0	0	0	0	64,25	
15	775	12:54	156	0	0	0	0	72,03	
16	774	12:53	185	0	0	0	0	84,33	
17	773	12:52	201	0	0	0	0	182,79	
18	772	12:51	233	0	0	0	0	120,92	
19	771	12:50	251	0	0	0	0	182,79	
20	770	12:49	252	0	0	0	0	182,79	
21	769	12:48	230	0	0	0	0	127,80	
22	768	12:47	209	0	0	0	0	95,04	
23	767	12:46	194	0	0	0	0	88,11	
24	766	12:45	170	0	0	0	0	74,09	

Imbalance price = 182.79

- From 12:45 – 13:00 the Dutch system balance was negative and the TSO activated up balancing volumes
- A passive imbalance trader should have tried to be long in this period to earn 182.79 €/MWh for 15 minutes
- Offering upward balancing capacity to the TSO had been an alternative

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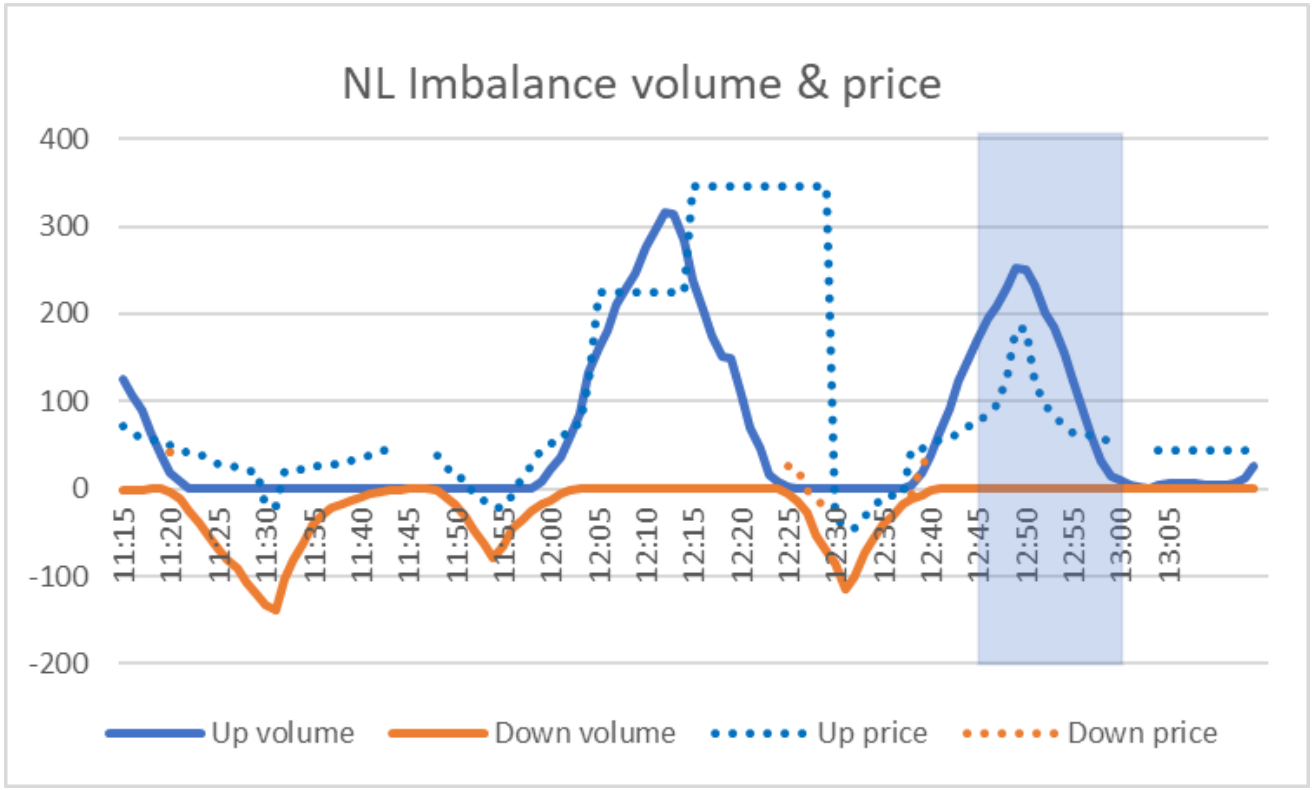
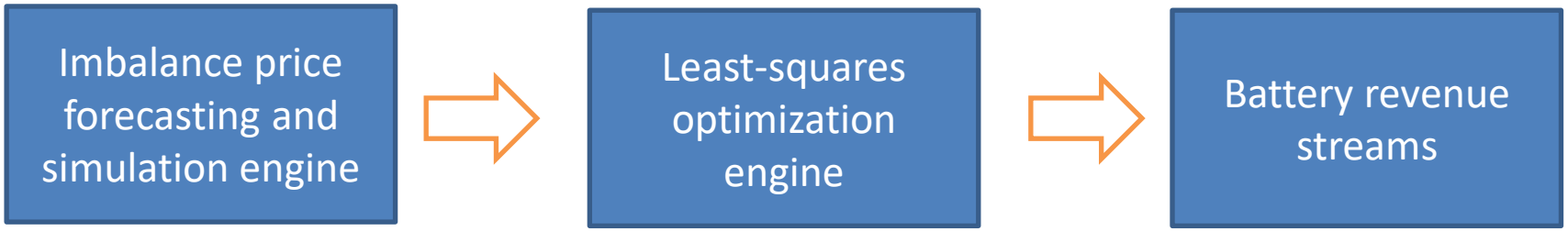
Was this profit opportunity predictable?

- 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



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 ideally suited to perform this task:
  - Uncertainty in prices (Monte Carlo)
  - Least-squares regressions to assess uncertainty in values
- Implementation very similar to gas storage, power plants, pump- hydro power plants, etc.



Parameters to consider in optimization

- Charge/discharge rates, capacity, efficiency
- Battery degradation:
  - Charge/discharge speeds
  - Reaching limits of battery capacity
  - Long charge/discharge periods (heating)
- Capacities reserved for other revenue streams, such as ancillary services

⇨ Can all be incorporated in LSMC methodology

Conclusion

- Passive imbalance trading is generally applicable to all sorts of very flexible assets, such as batteries
- Plays similar role as spot trading for other assets with less flexibility (power) or daily trading market (gas)
- Least-squares Monte Carlo method can perform this stochastic optimization
- In practice, revenues combined with other revenue streams

Thank you

Time for Q&A

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

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