

A woman's profile is shown on the left side of the image, looking towards the right. Her hair is blowing in the wind, creating a sense of movement. The background is a soft, light-colored sky. The word "ANEEO" is written in large, bold, black letters across the middle of the image, slightly tilted upwards.

ANEEO

Better Bidding for Aneo's Hydropower Plants

– Our experiences from bidding based on
stochastic programming

About Aneo

Nordic renewable energy company

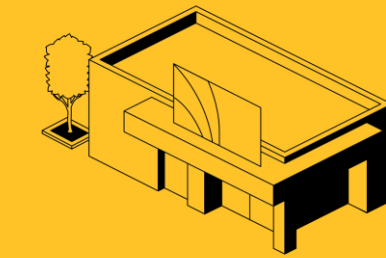


Headquartered in Trondheim, Norway
350+ employees

Energy as a Service



1 Aneo Mobility
EV charging solutions for housing associations and commercial customers



2 Aneo Retail
Delivers and manages sustainable energy infrastructure for retail

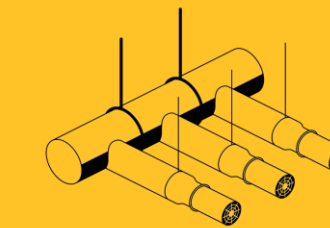
Energy management



7 TWh, 1.5 TWh of which is for third parties

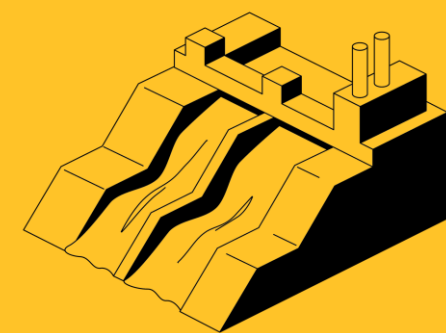


3 Aneo Build
Delivers and manages charging containers for electrification of building and construction



4 Aneo Industry
Energy saving and zero emission solutions for process industry

17 hydropower plants



2.6 TWh

Wind and solar



5 Aneo Real Estate
Solar energy solutions for commercial property

Introduction

- Aim of project: Improve bidding for hydropower in the day-ahead spot market
- Current solution:
 - SHOP with deterministic prices + multiple runs + manual adjustments
 - "Operator-determined bids"
- New solution:
 - SHOP with stochastic prices (i.e. SHARM)
 - Towards more automatic bid generation, which is necessary when markets move to shorter time resolution
 - "Stochastic-based bids"
- Parallel testing of these two alternatives for an extended period of time – we'll show results and discuss our experiences so far

Development

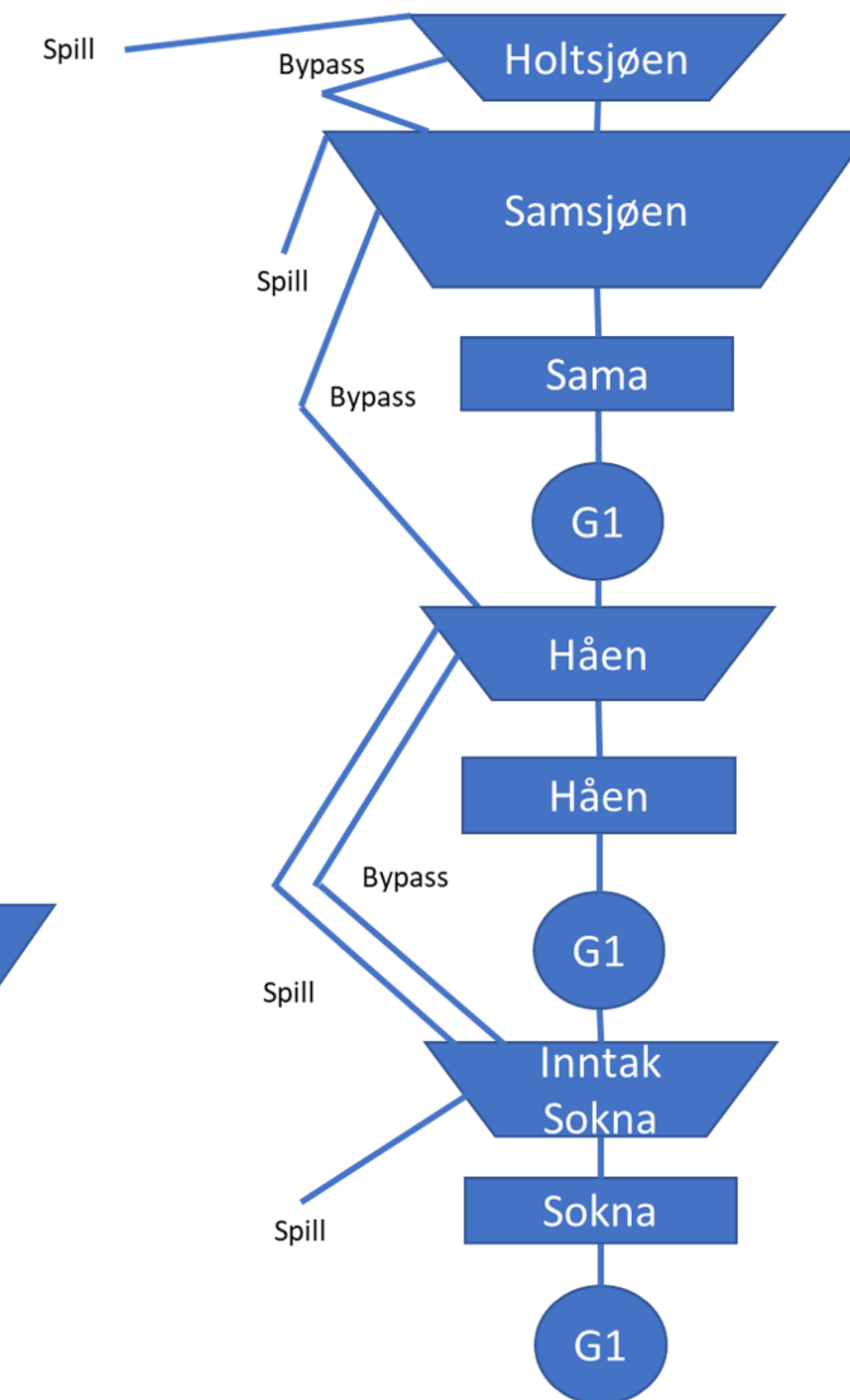
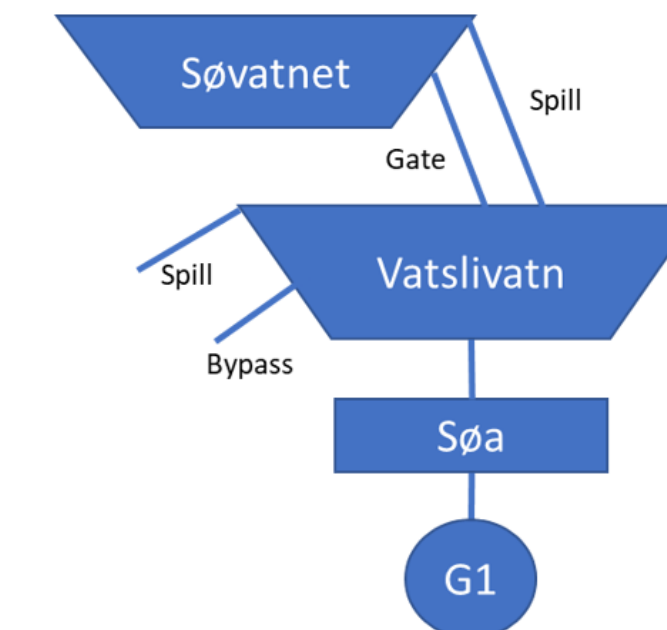
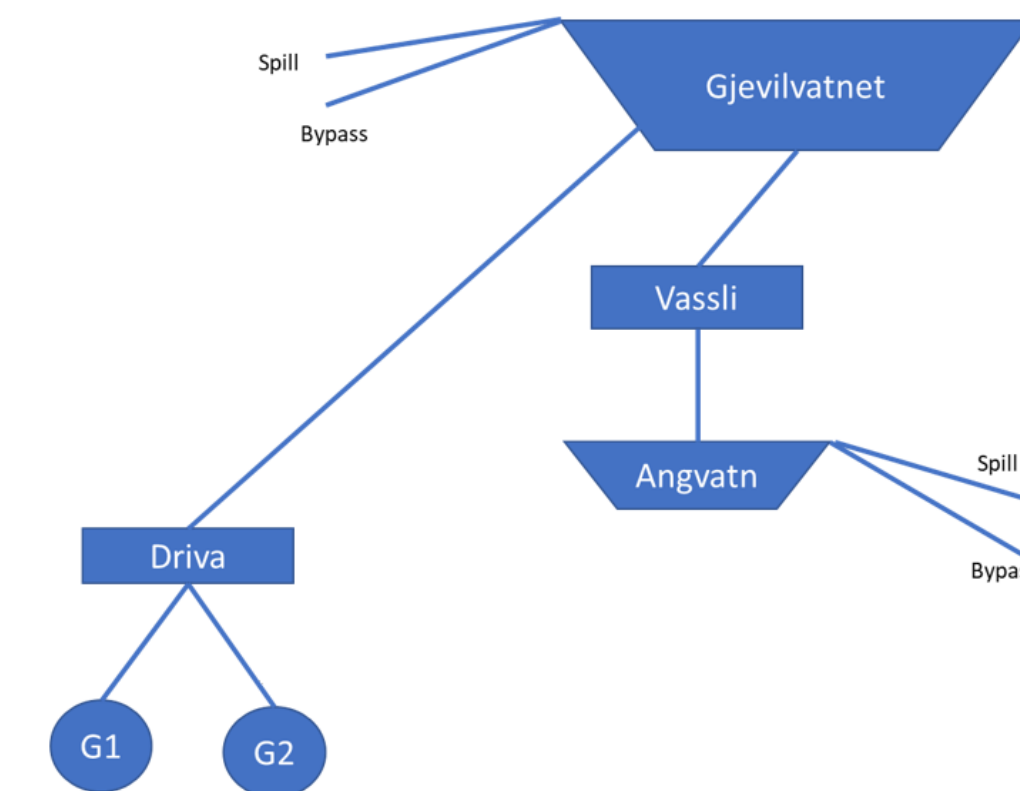
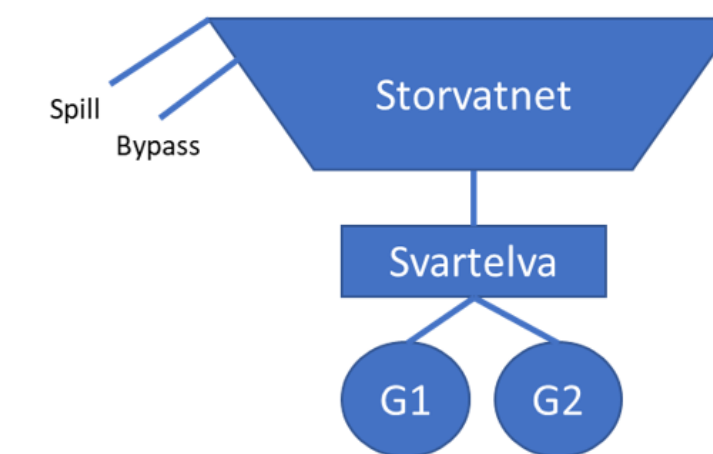
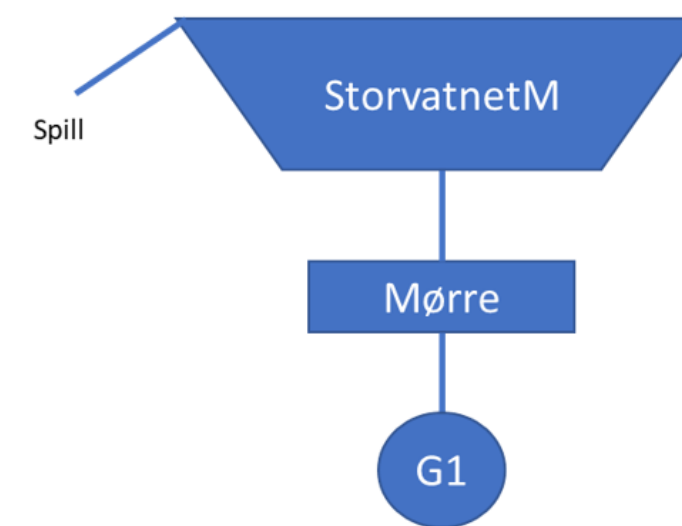
- SHARM has been in development at SINTEF from 2009 and onwards
- SHARM incorporates uncertainty in prices and inflow into the successive linear programming algorithm in SHOP
- SHARM can output bids as a direct result from the optimization
- Main new constraint for bid generation is that production volumes must be non-decreasing for increasing prices
- SHARM also includes a reduction algorithm to reduce the resulting bid matrix into the size allowed by the market operator
- As far as we know, Aneo is the first company in the Nordic to do extensive testing for SHARM towards full implementation...

Adaptations to SHOP's bids

- We run SHOP with stochastic prices and the constraints that volumes needs to be increasing for increasing prices...
- ... but we create our own bids from the optimized production schedules.
- Better control – bottom up
- Avoid production at infeasible levels and ensure must-run production and flows
- Keep better track of information potentially lost when reducing the number of prices in the bid matrix
- Explainability

Case study

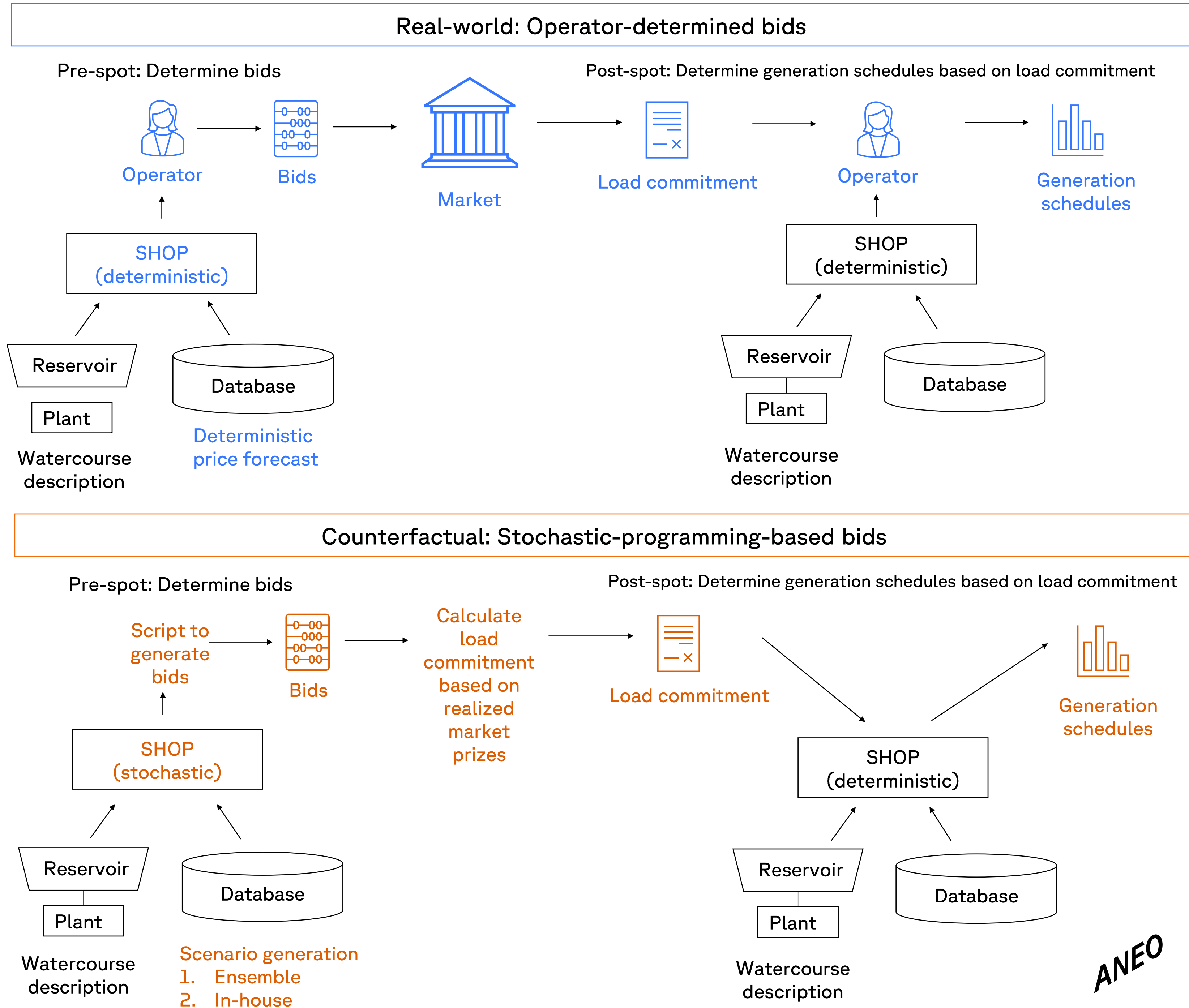
- A portfolio of 5 watercourses
 - Both simple systems and cascades
 - NO3
- Testing period:
 - 7 two-week periods (March-July)
 - Why? Reset water values at the end of each two-week period to not deviate too much from the real world
 - Spring = snow melting



Set-up

- What are we comparing:
 - **Operator-determined bids**
 - **Stochastic-based bids using in-house price scenarios**
 - **Stochastic-based bids using ensemble price scenarios**

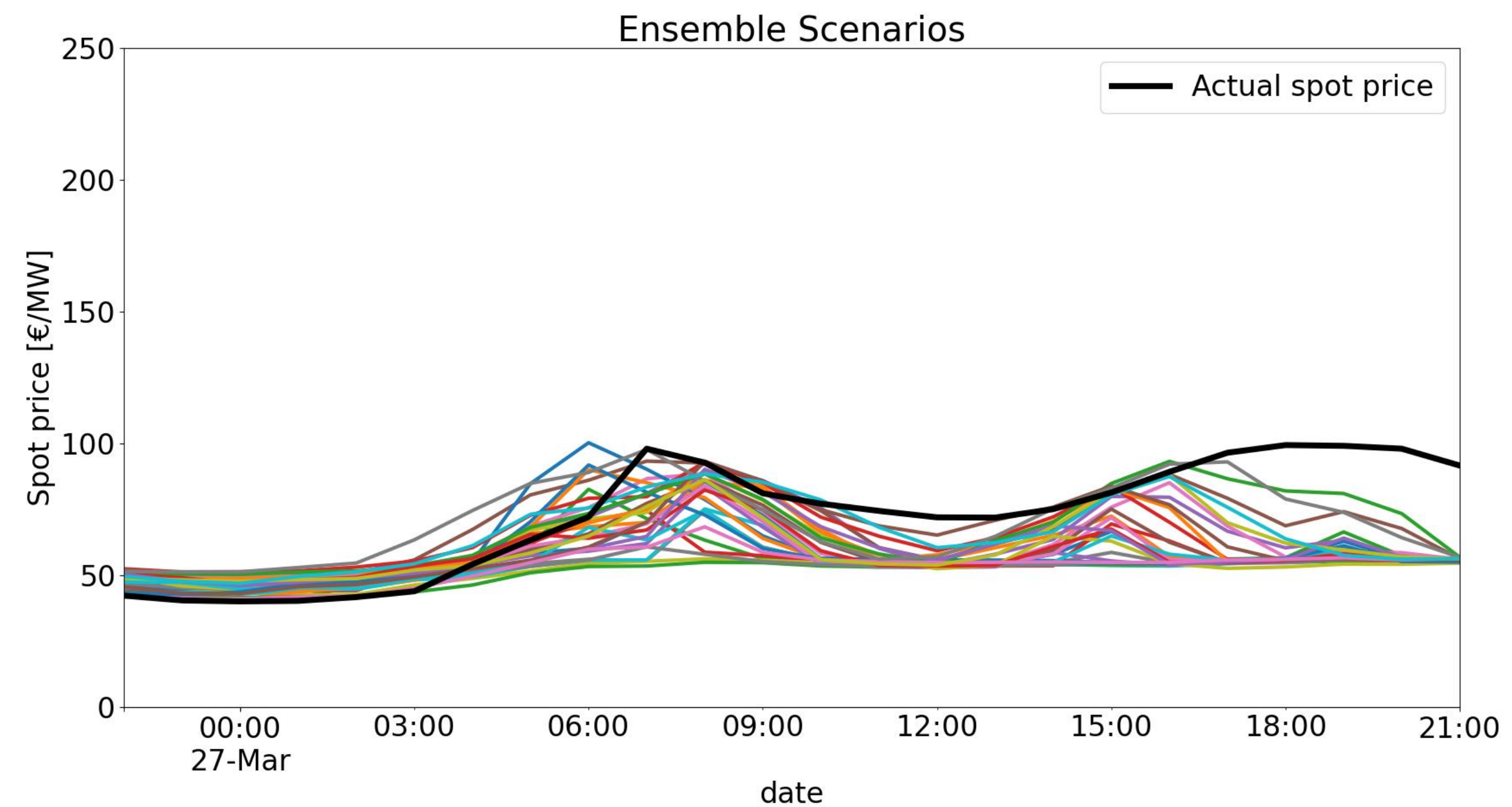
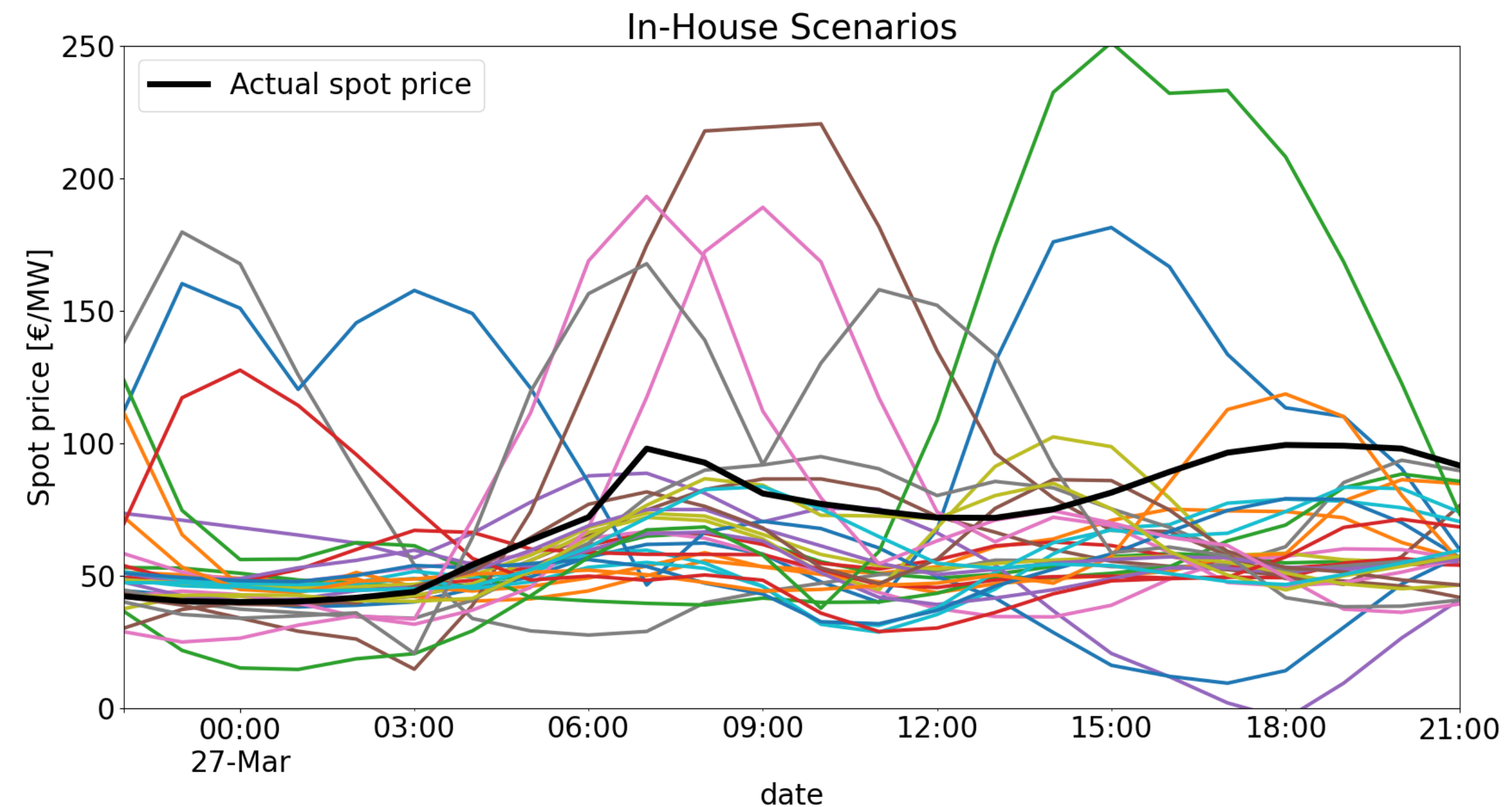
Processes as shown are repeated every day in a rolling horizon framework.



Price input

- Two price scenario alternatives
 - In-house, drawn from a distribution of historical errors
 - Third-party based on ensemble weather forecasts
- Add extreme high and extreme low scenarios
 - By multiplying the main deterministic forecast
 - Low probability
- Scenario fan of 25 scenarios

Note, the plots are of the bidding day only.
The scenarios used in optimization are 14 days long.



Benchmarking

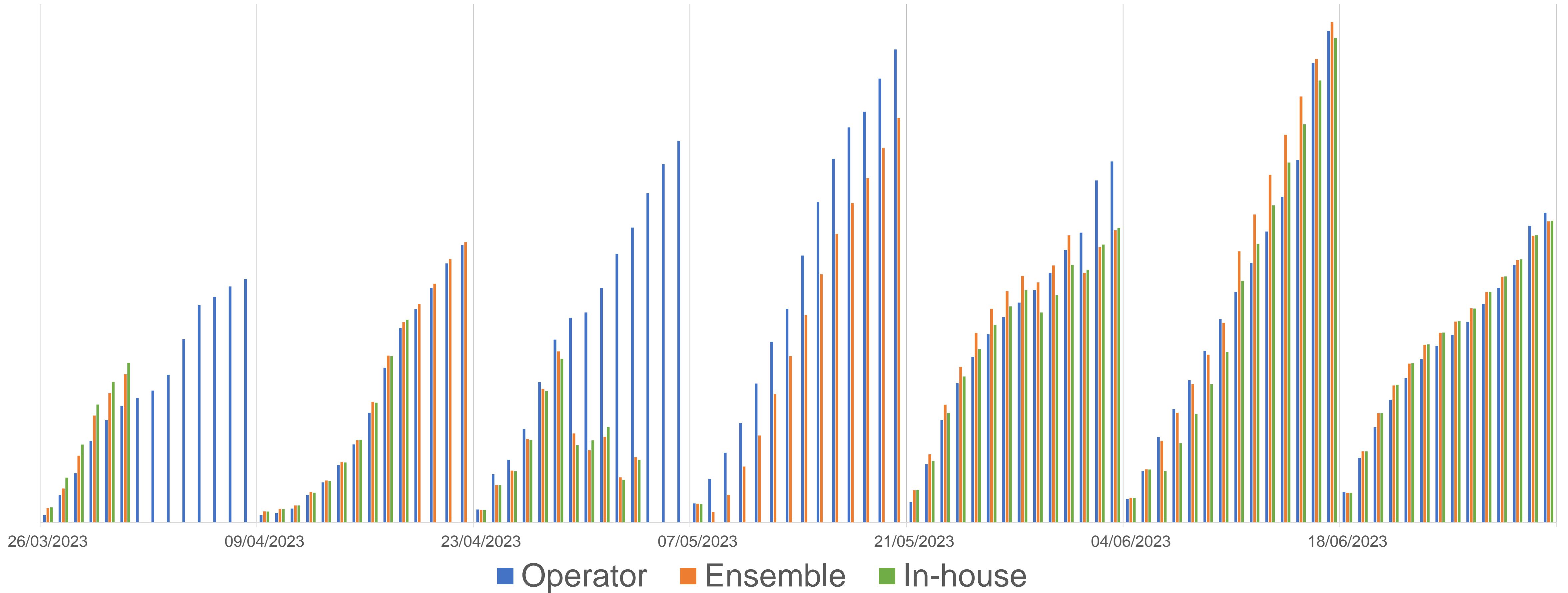
- How are we evaluating?
 - Not the bids directly, but resulting generation schedules after market clearing
 - Every day of the rolling period:

$$\text{Daily grand total} = \text{Revenue from production (market price times produced volume)} - \text{Start-up costs} + \text{Change in the value of water left in storage before and after the bidding day}$$

- Penalties for the whole SHOP period

Results – daily grand total

Cumulative by period

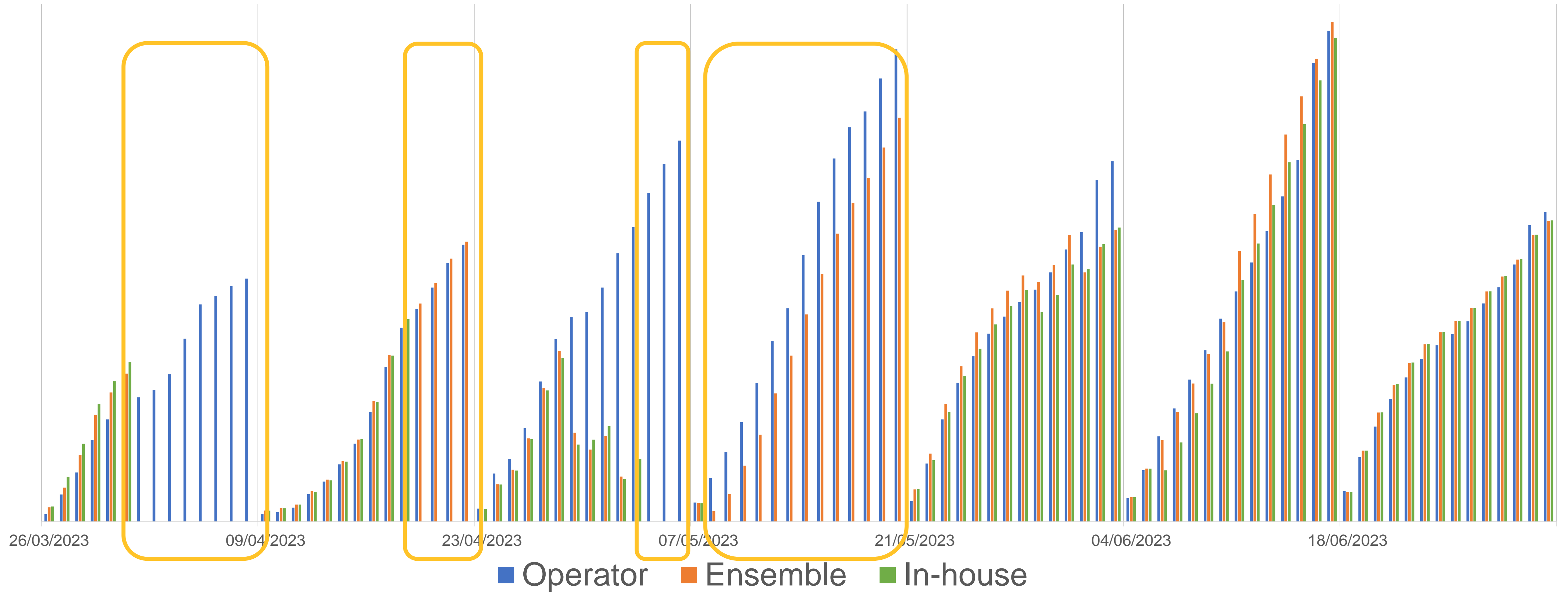


Missing values = we were not able to get reasonable results

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Results – daily grand total

Cumulative by period



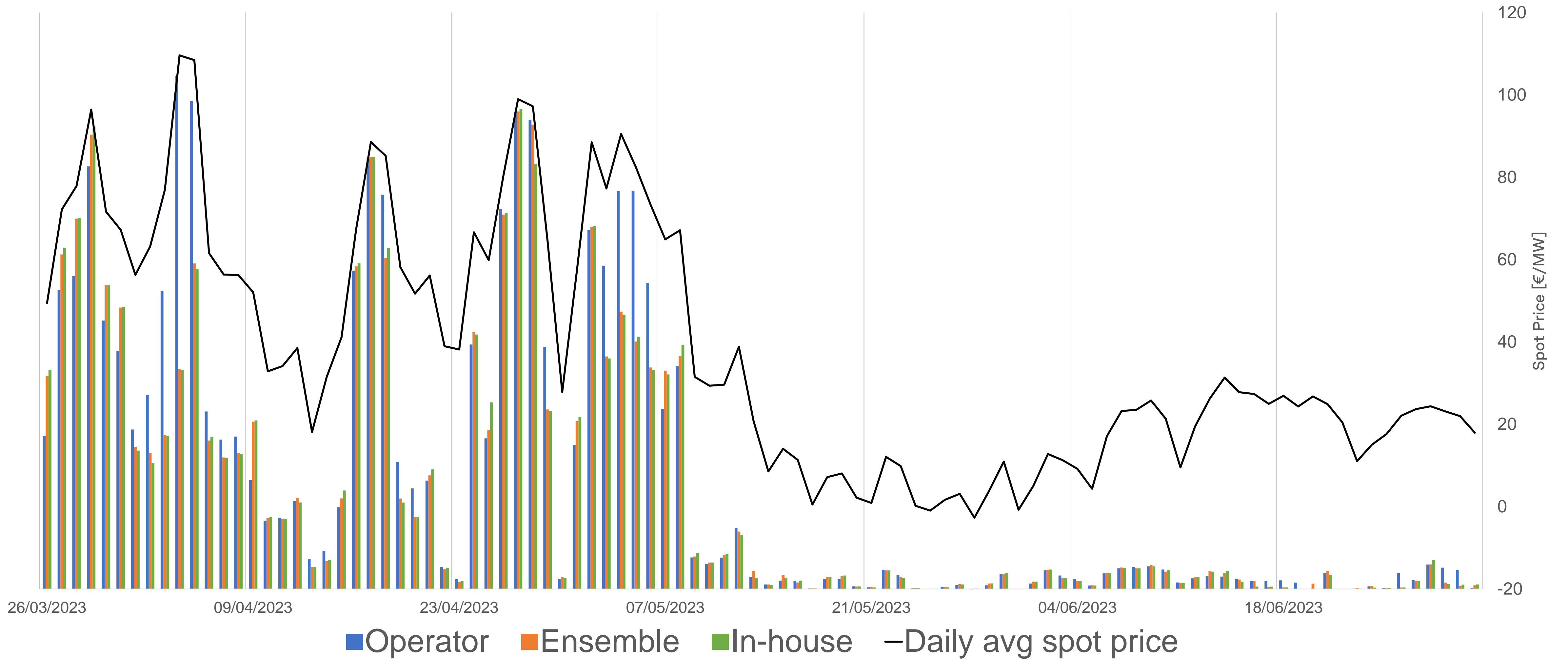
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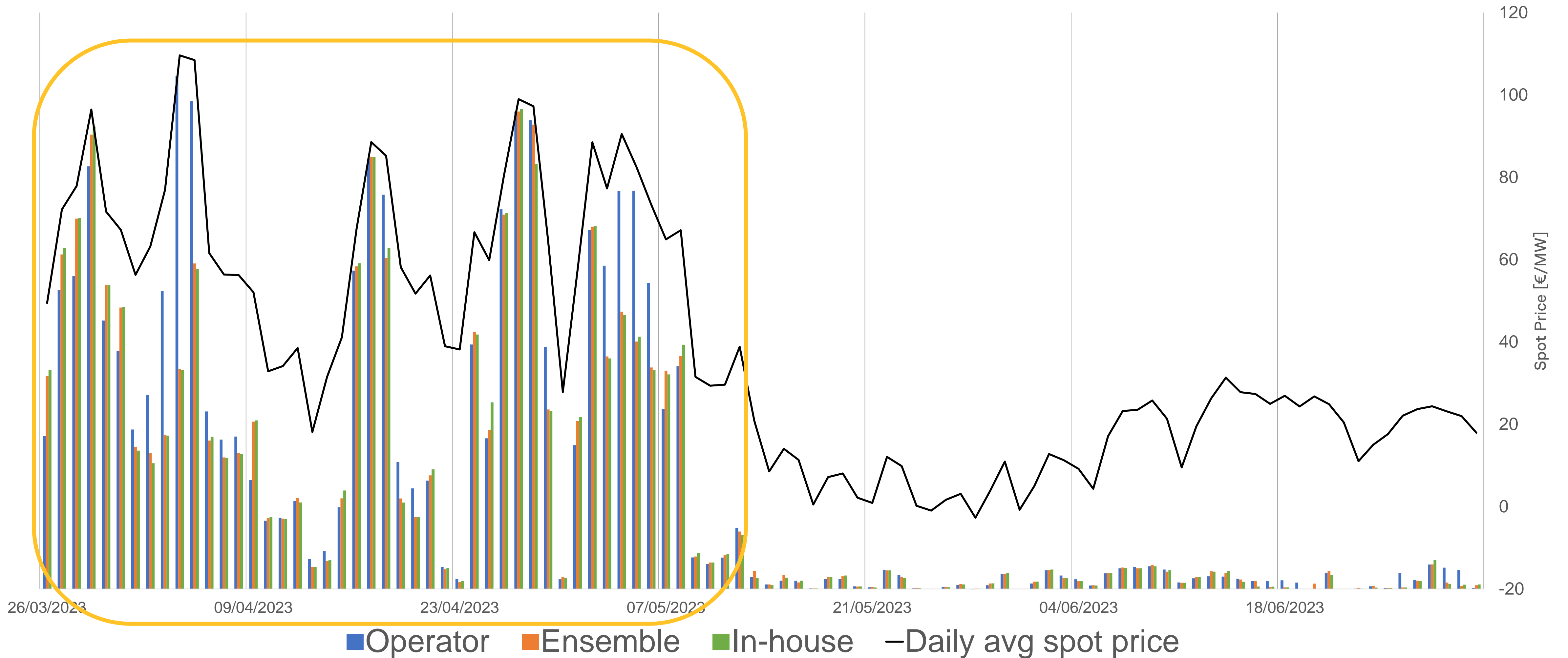
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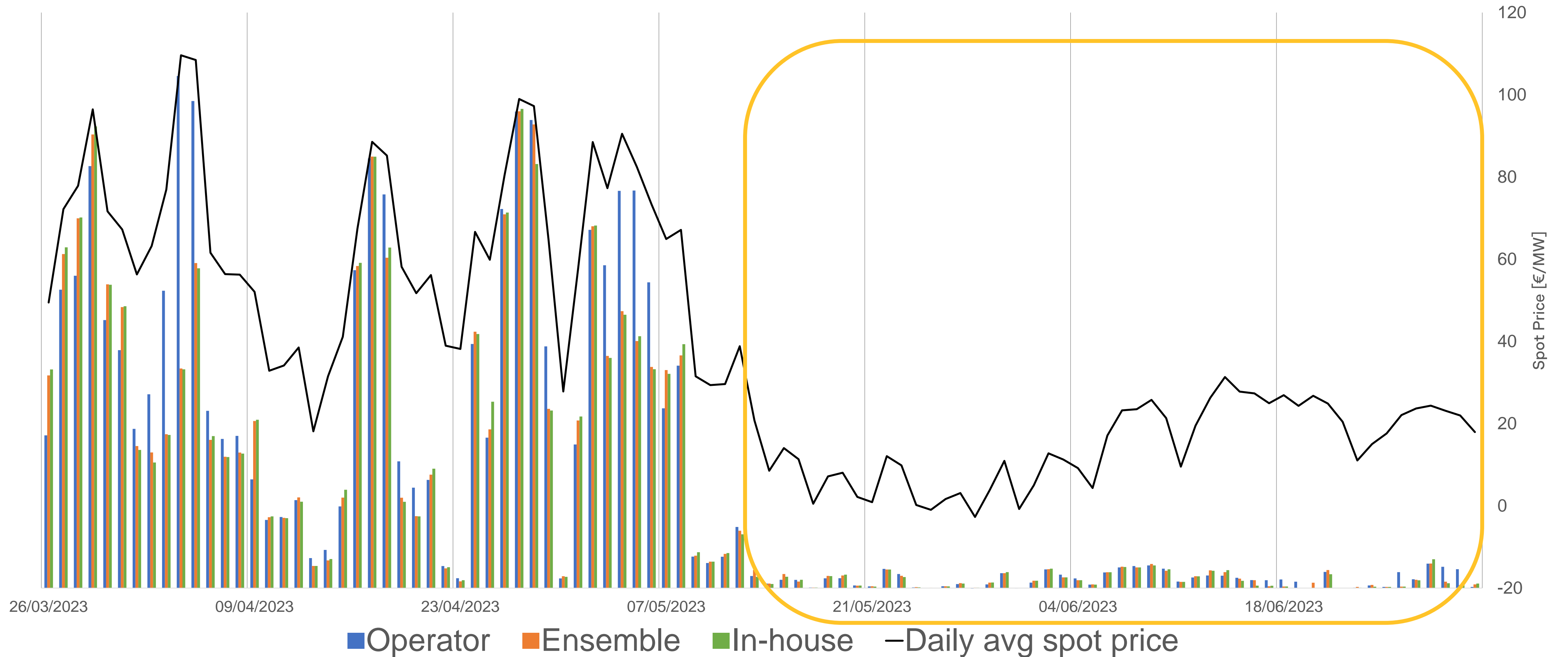
Results – revenues



Results – revenues

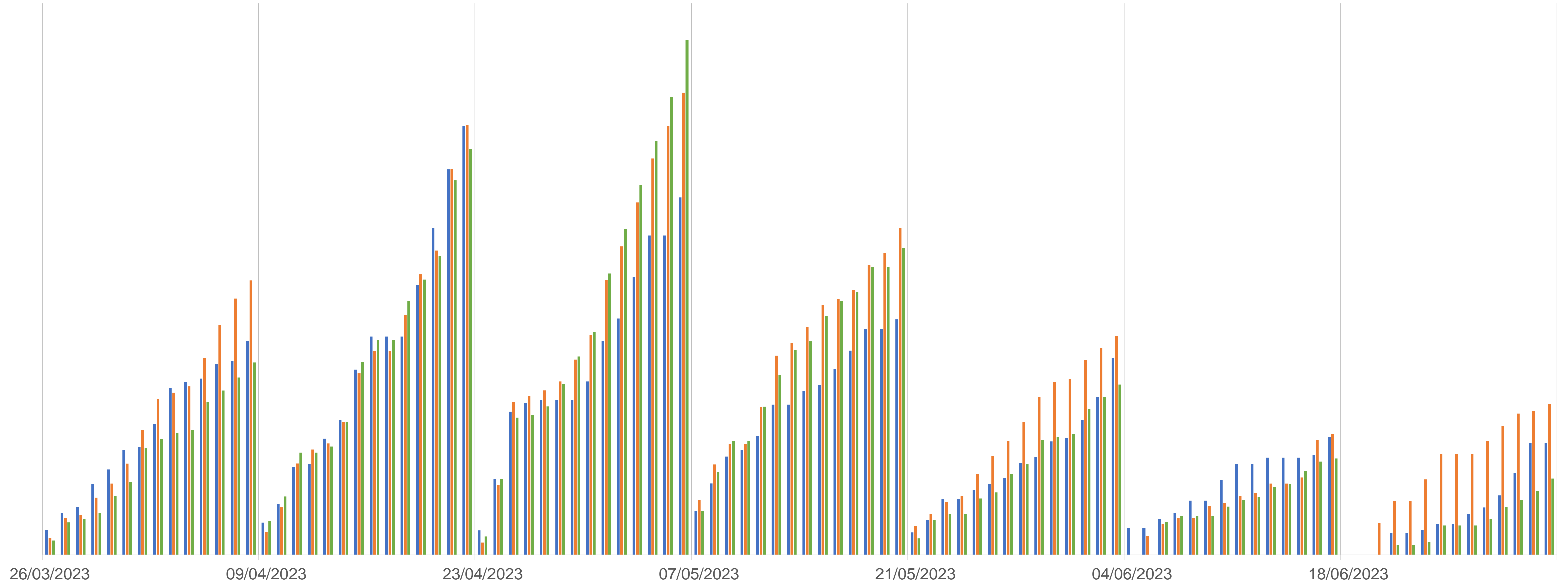


Results – revenues



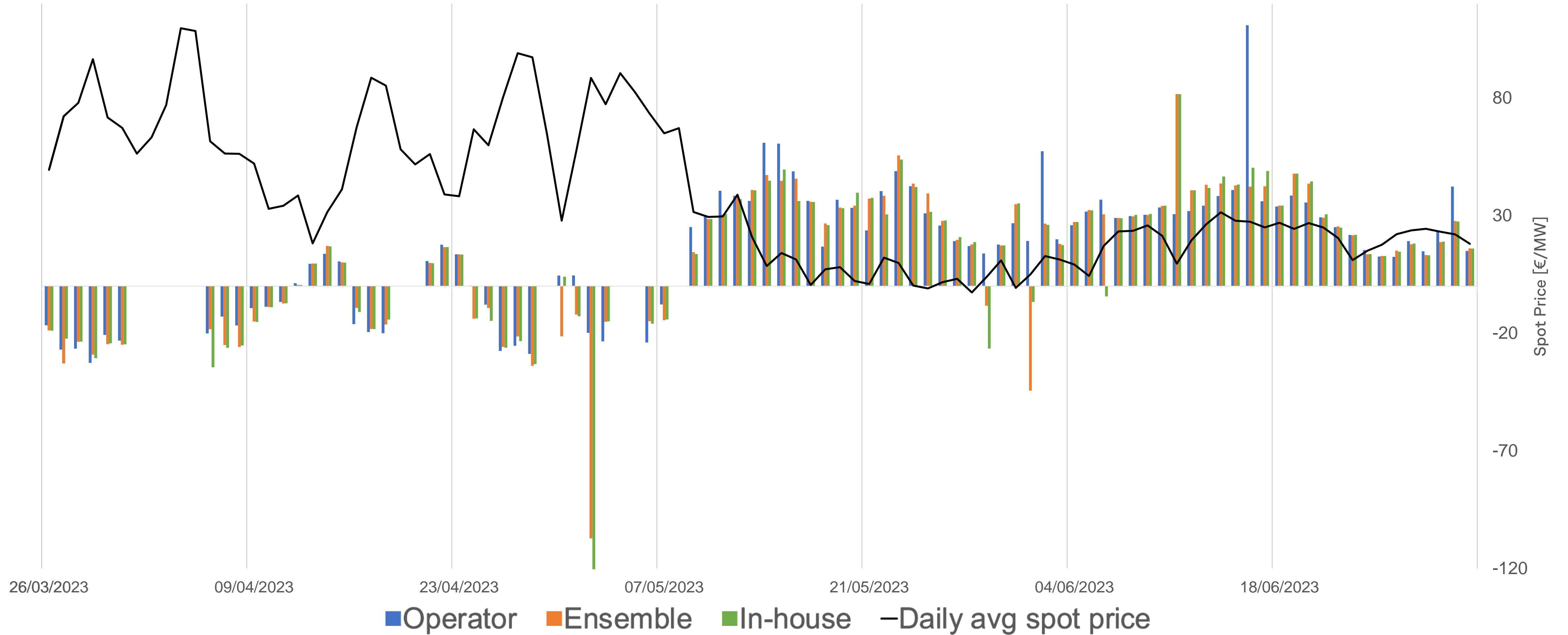
Results – start-up costs

Cumulative by period

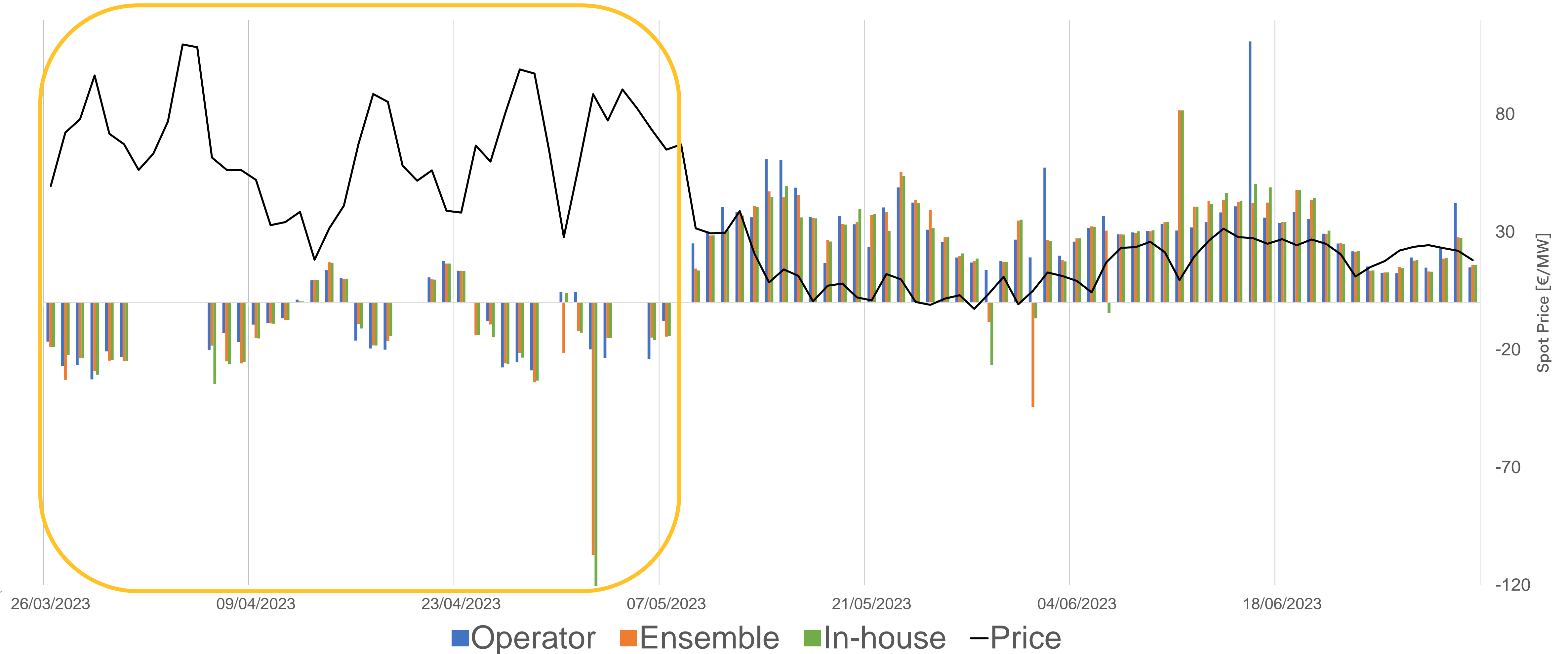


■ Operator ■ Ensemble ■ In-house

Results – change in reservoir value



Results – change in reservoir value



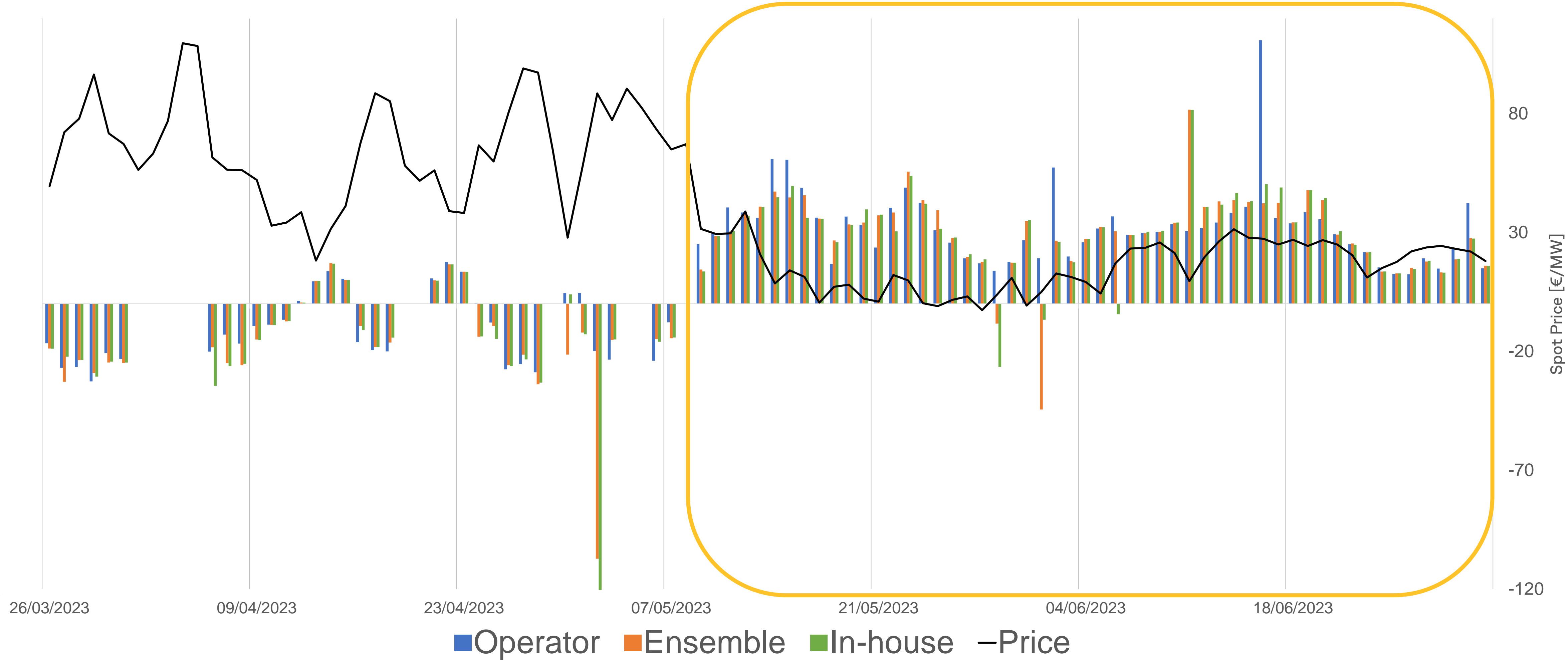
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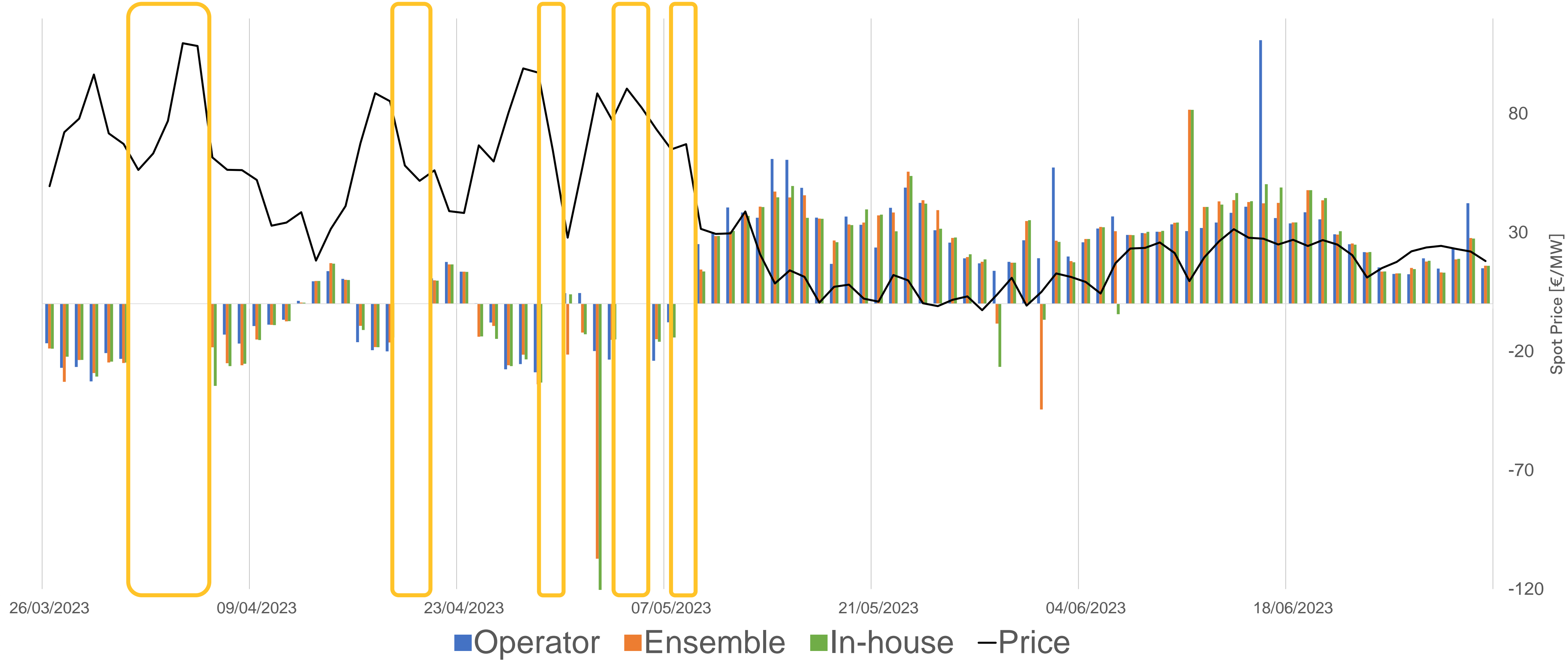
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Results – change in reservoir value



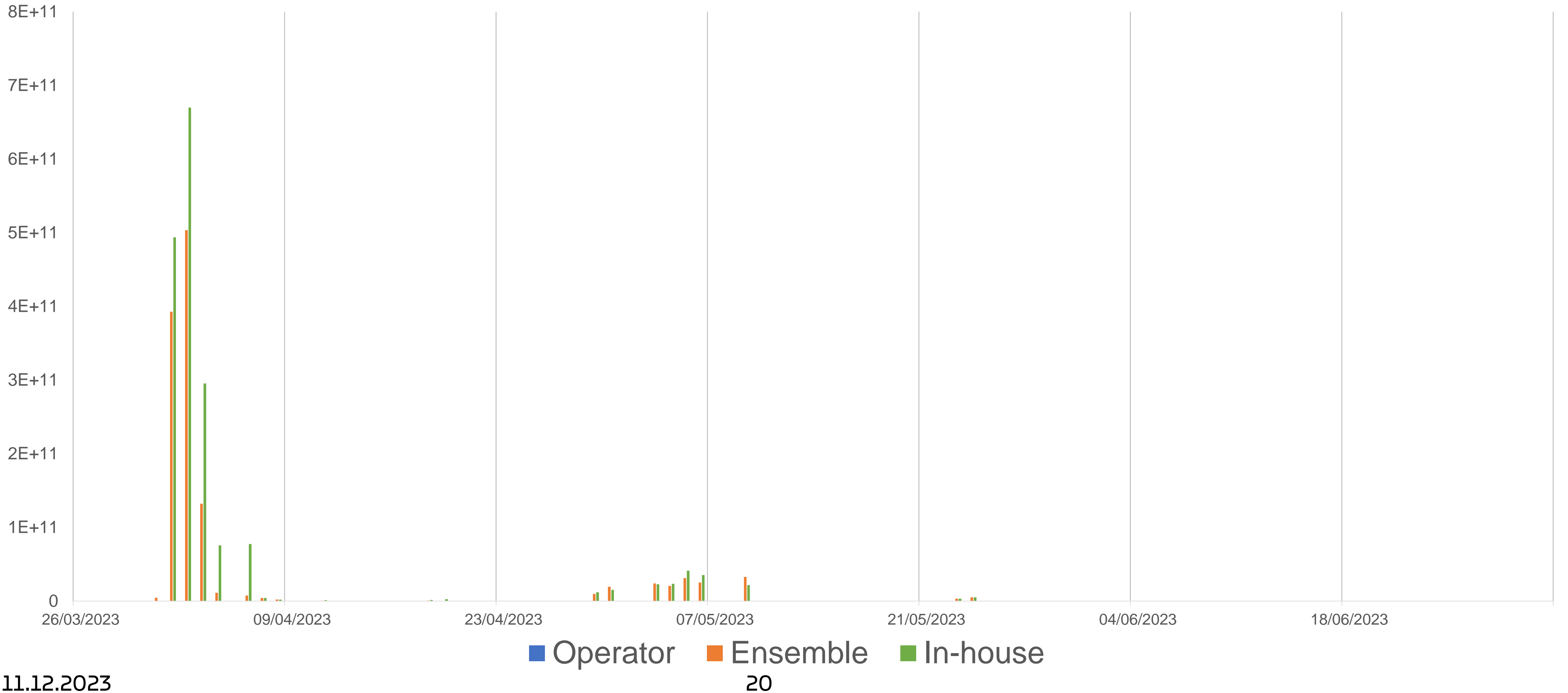
Missing values = we were not able to get reasonable results

Results – change in reservoir value

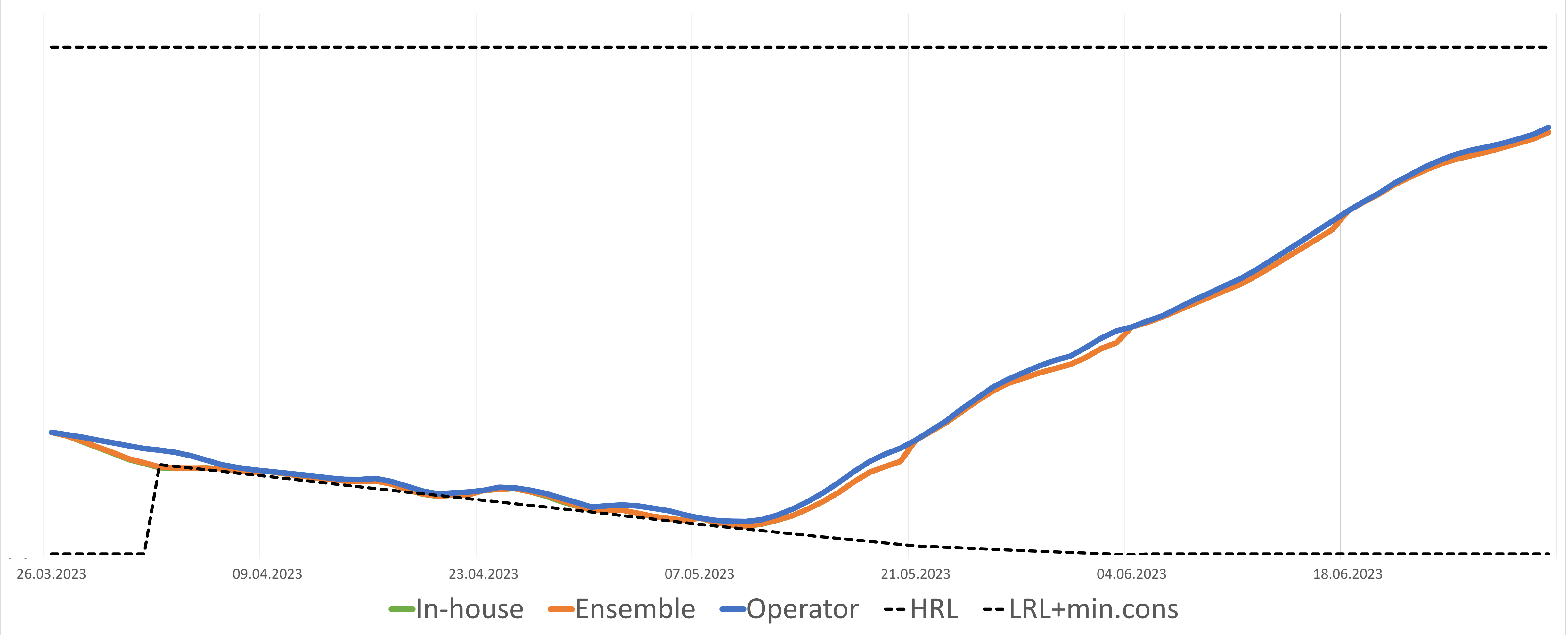


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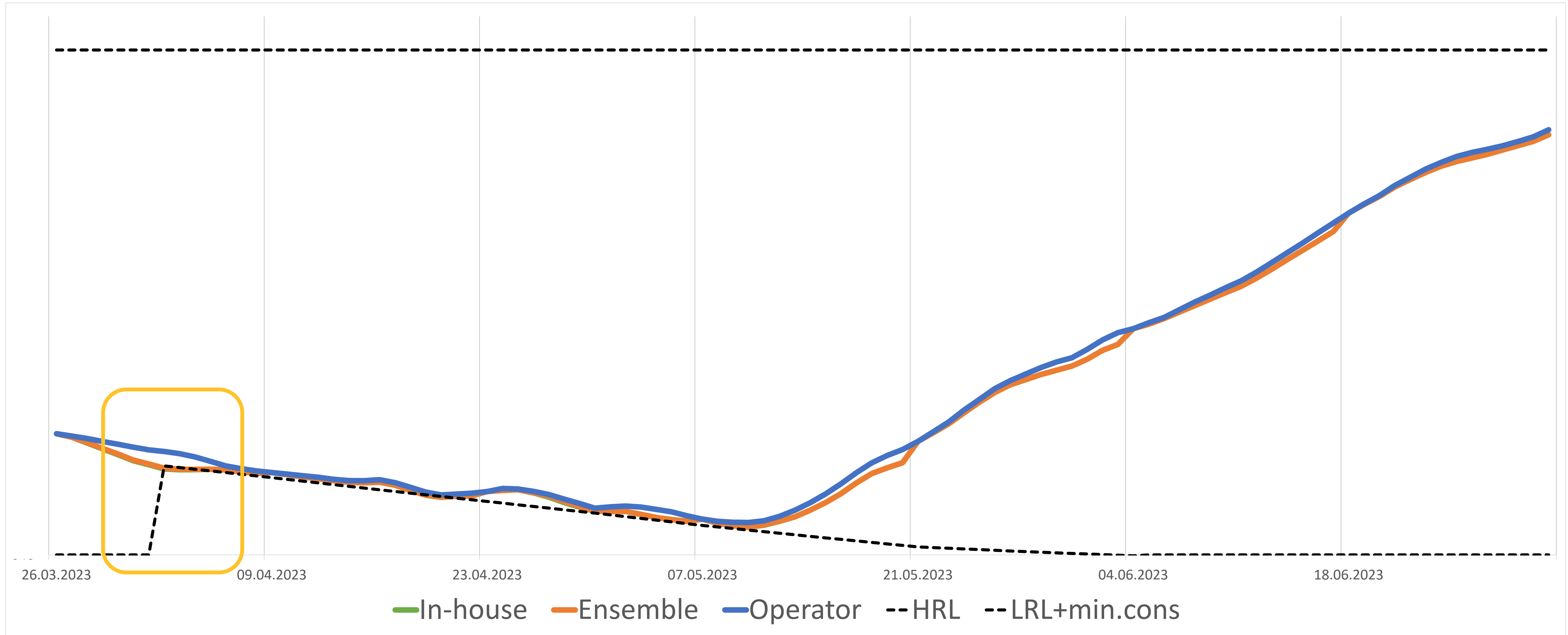
Results – Penalties



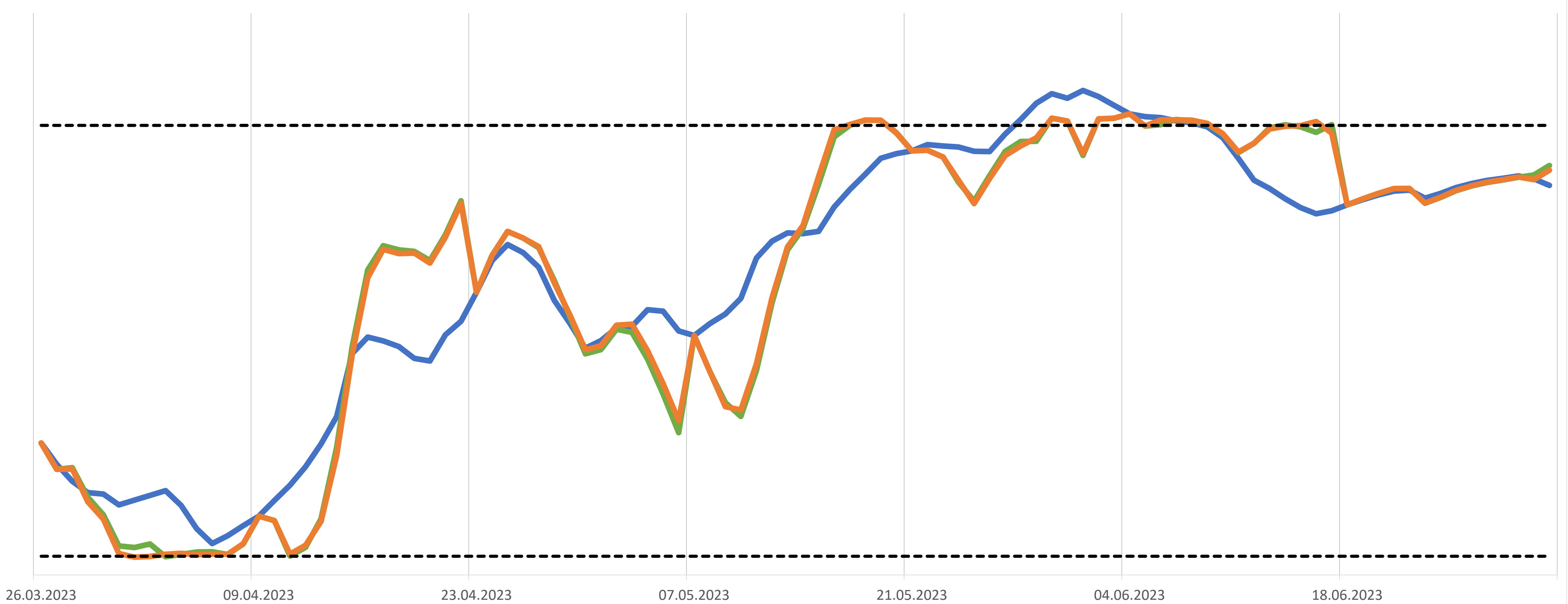
Results – Reservoir storage 1



Results – Reservoir storage 1

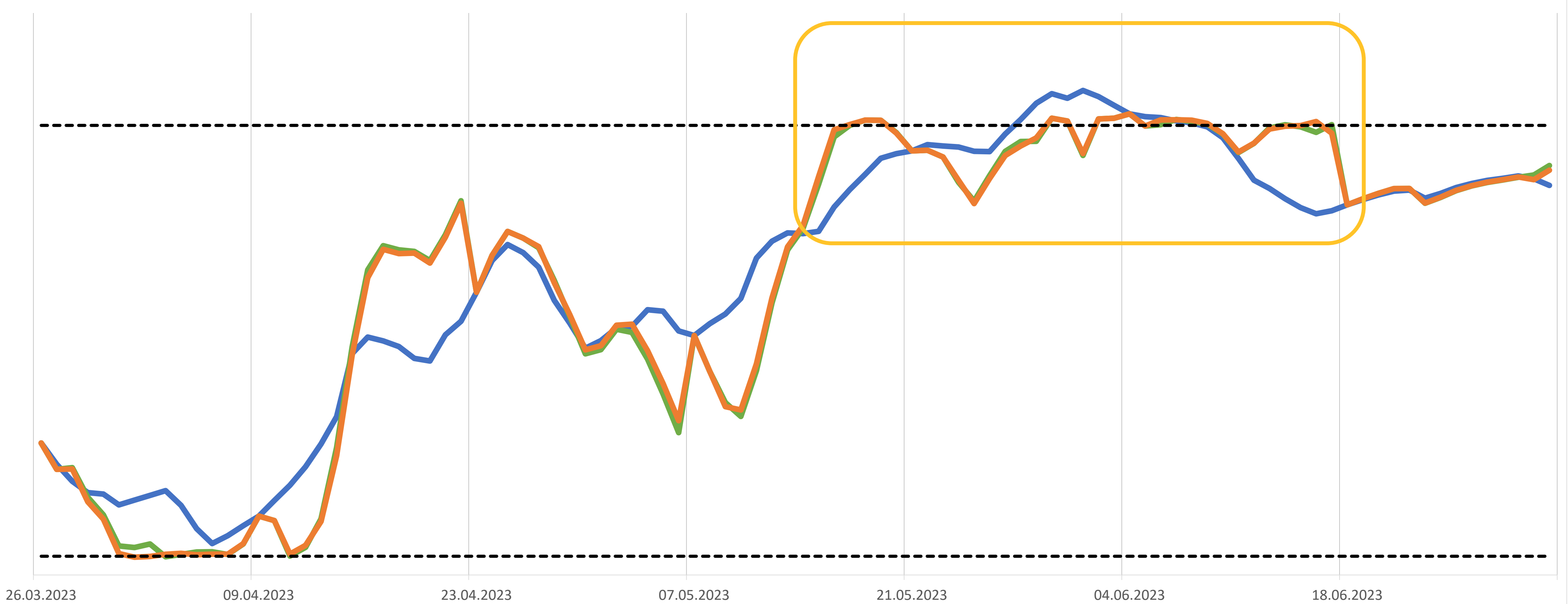


Results – Reservoir storage 2



— Operator — In-house — Ensamble -- LRL -- HRL

Results – Reservoir storage 2



— Operator — In-house — Ensamble -- LRL -- HRL

Conclusions so far

- Operator-determined bids performed best
 - Exemplified by handling of the minimum constraint for Reservoir 1
- Penalties – what they represent and the value of the cost – are more important in stochastic programming so extra care must be taken
- Inflow uncertainty is perhaps more important than price uncertainty? Depends on time of year and how constrained the watercourse is
- Underlying watercourse models needs to be more physically accurate (new SHOP objects such as river, tunnel, creek intake...) and data input needs higher quality (distributed inflow, penalty costs...)
- Our operators are highly experienced, and we are working on a new solution to let them interact more with the new bidding method ...
- Our “experiences with stochastic programming” will continue!