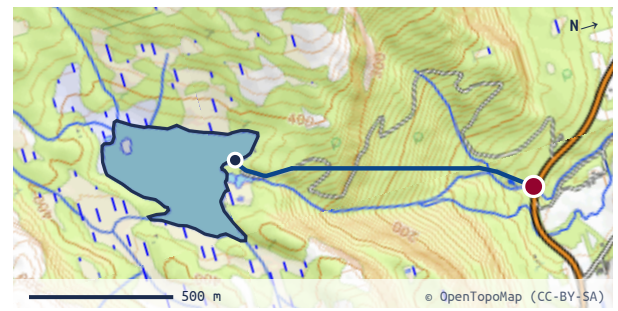
Hilleshamn kraftverk

Run-of-river · · price zone **NO4** — full-year optimised dispatch, 1 Jan – 31 Dec 2025.

INSTALLED	MAX FLOW	RESERVOIR
4,4 MW	1,5 m³/s	10 h · 0,1 Mm³

WATERCOURSE & COMPONENTS · GRATANGEN



THE HEADLINE · 2025

Co-optimising Hilleshamn kraftverk across **all balancing markets** lifted modelled revenue **+249 %** over day-ahead-only dispatch — almost entirely from reserve capacity, not extra energy.

+249 % REVENUE UPLIFT

€ 419 674 ADDITIONAL / YEAR

PERFORMANCE — ALL MARKETS (HYBRID)

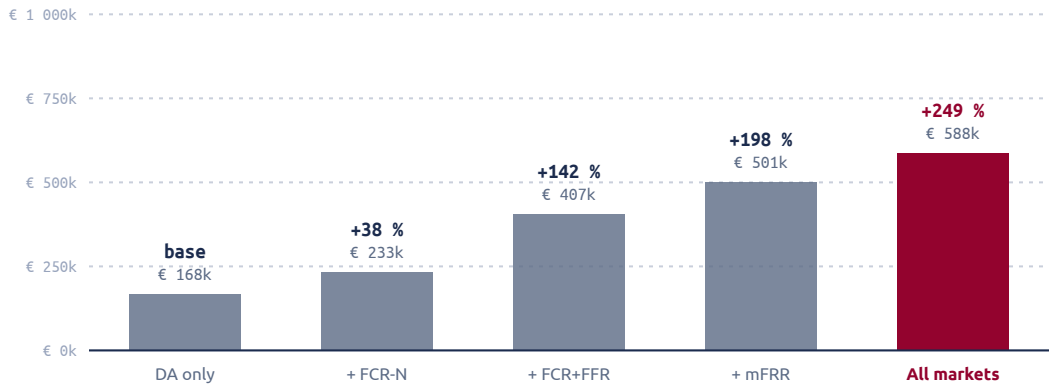
SELECT MARKET STRATEGY ↓

Day-ahead only	DA + FCR-N (standalone)	DA + FCR + FFR (hybrid)	DA + FCR-N + mFRR (standalone)	**All markets (hybrid)**

TOTAL REVENUE	ENERGY	CAPACITY FACTOR	CAPTURE RATE	RESERVOIR CYCLES	SPILL
€ 587 932	11 657	30,2 %	560 %	265,5	0,5
+249,4 % vs. DA only	MWh to grid	of 4,4 MW	50,4 €/MWh realised (all markets ÷ energy)	full equiv. / yr	Mm³ · 3,3 %

REVENUE BY STRATEGY

EUR · Δ vs day-ahead only



REVENUE BY MARKET

All markets (hybrid) · reserved MW · activated MWh/h

MARKET	AVG MW	ACT MWH	PEAK MW	REVENUE	SHARE
Day-ahead energy	–	1,33	4,4	€ 130 046	22%
FCR-N reserve	0,84	0,09	1,8	€ 181 668	31%
FCR-D up	0,24	0,00	1,8	€ 14 128	2%
mFRR up / down	2,38	0,00	4,4	€ 250 192	43%
FFR profile + flex	0,09	0,00	0,9	€ 11 898	2%
Total				**€ 587 932**	

THE MARKET STRATEGIES · what each scenario co-optimises

1 **Day-ahead only**
Spot-price optimised dispatch only — no reserves. The revenue baseline.

2 **DA + FCR-N (standalone)**
Adds FCR-N (symmetric frequency reserve). Autonomous droop setpoint, capped at 10 % of capacity.

3 **DA + FCR + FFR (hybrid)**
FCR-N + FCR-D up + fast frequency response (FFR). Assumes a small ESS hybrid for the sub-second products.

4 **DA + FCR-N + mFRR (standalone)**
FCR-N plus manual restoration reserve (mFRR up/down) — TSO-activated, needs an operations function.

5 **All markets (hybrid)**
Co-optimised across every balancing market (DA, FCR-N/D, mFRR, FFR) as a hybrid.

Day-ahead only	DA + FCR-N (standalone)	DA + FCR + FFR (hybrid)	DA + FCR-N + mFRR (standalone)	**All markets (hybrid)**

01 SCENARIO COMPARISON · uplift vs. day-ahead only

STRATEGY	REVENUE	REVENUE (BAR) · Δ VS DAY-AHEAD		ENERGY (MWH)	CAPTURE RATE	CAP. FACTOR	RESERVE UTIL.
Day-ahead only	€ 168 258		–	12 046	160 %	31,3 %	0 %
DA + FCR-N (standalone)	€ 232 934		+38,4 %	12 092	222 %	31,4 %	9 %
DA + FCR + FFR (hybrid)	€ 406 894		+141,8 %	11 441	388 %	29,7 %	37 %
DA + FCR-N + mFRR (standalone)	€ 500 803		+197,6 %	11 963	477 %	31,0 %	93 %
All markets (hybrid)	€ 587 932		+249,4 %	11 657	560 %	30,2 %	81 %

02 WATER BALANCE & CAPTURE · All markets (hybrid)

TOTAL INFLOW
14,3
Mm³ · Sildre (Strandvatnet, Bogen) × 0.10 — scaled so capped-turbinable energy matches the NVE concession estimate (12.1 GWh; beta)

TURBINED
13,8
Mm³ through turbine

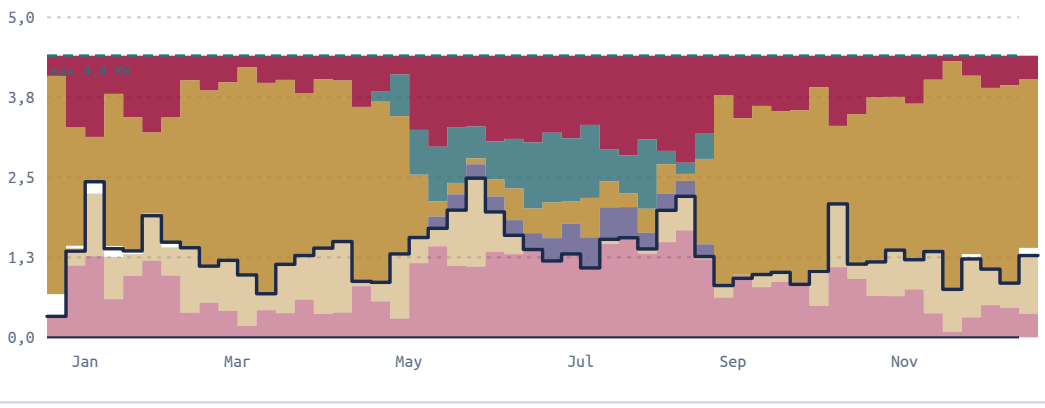
SPILL (LOST)
0,5
Mm³ · 3,3 % of inflow

AVG RESERVOIR
52 %
% of usable volume

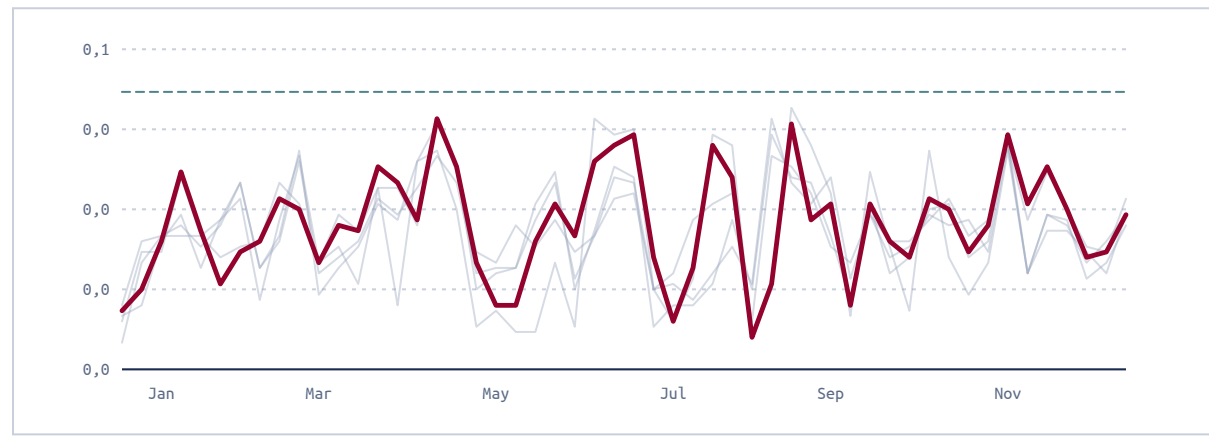
CAPTURE RATE
560 %
revenue ÷ (inflow energy × 8,7 €/MWh)

03 HOW THE PLANT WAS DISPATCHED · optimised dispatch for the selected strategy

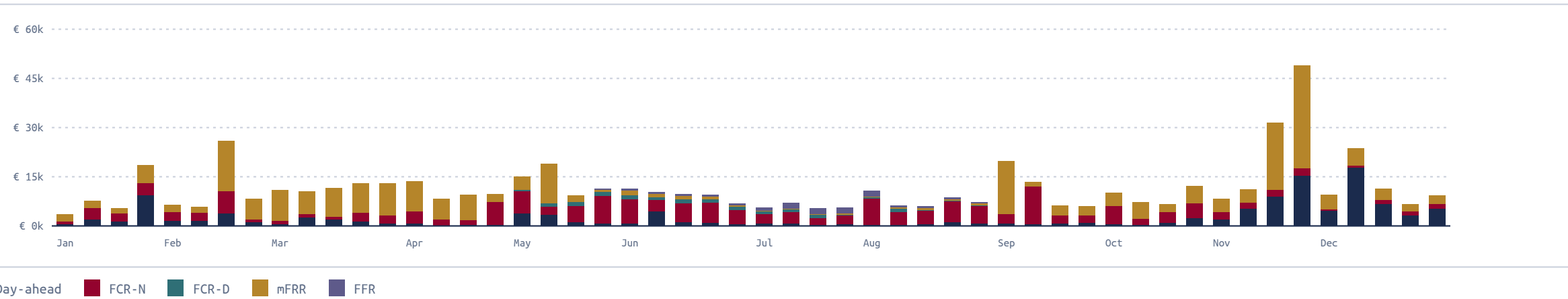
RESERVE CAPACITY HELD
All markets (hybrid) · up from top, down from bottom



RESERVOIR TRAJECTORY
weekly · Mm³ · all strategies, selected highlighted



WEEKLY REVENUE BY MARKET
All markets (hybrid) · 52 equal periods

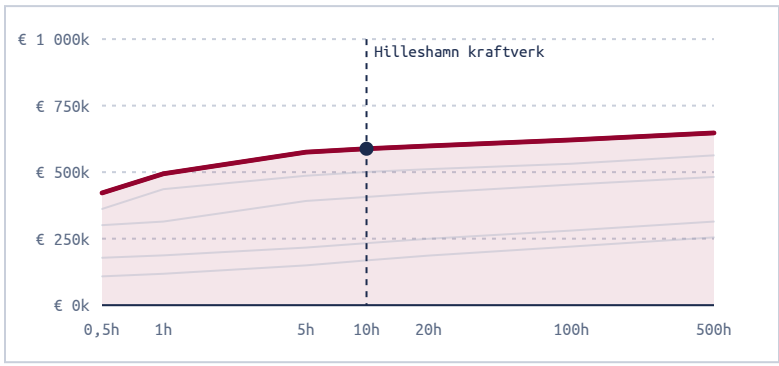


Day-ahead only	DA + FCR-N (standalone)	DA + FCR + FFR (hybrid)	DA + FCR-N + mFRR (standalone)	**All markets (hybrid)**

01 WHERE THE MARGINAL VALUE IS

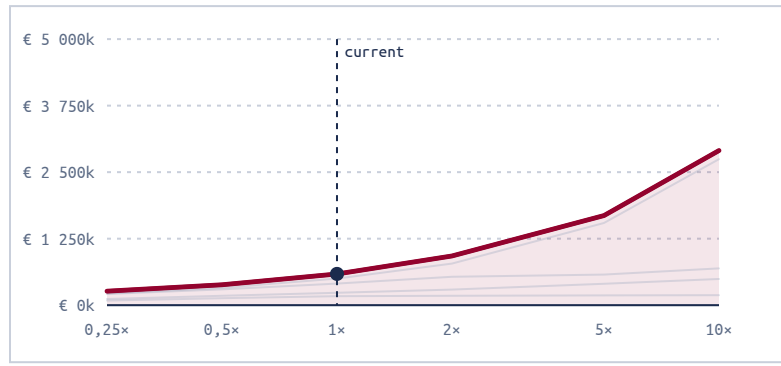
Sensitivity of optimised revenue to the plant's physical envelope, under each market strategy. The **highlighted line is the selected strategy**; the dashed marker is Hilleshamn kraftverk's current operating point.

STORAGE DISCHARGE DURATION



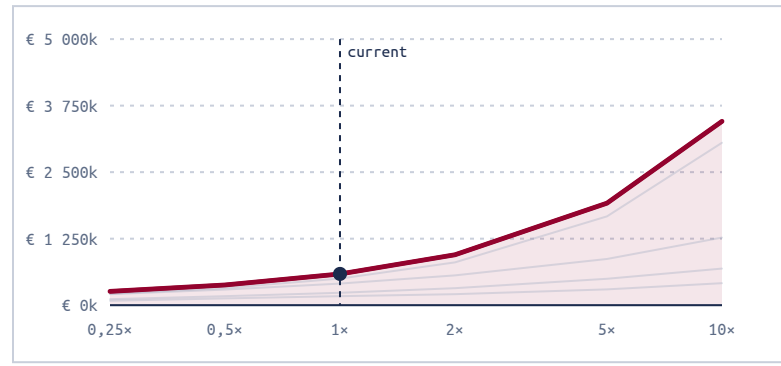
Annual revenue vs. usable storage hours (log). Marker = as-built.

TURBINE CAPACITY



Annual revenue vs. turbine flow capacity (× as-built, log). Marker = as-built.

PLANT SCALE



Revenue vs. scaling turbine + reservoir together (× as-built, fixed inflow). Saturates when the plant outgrows its water.

All markets (selected) · Other strategies · Hilleshamn kraftverk as-built

MARGINAL VALUES & BINDING CONSTRAINTS

as-built · All markets (hybrid)

Marginal water value	11,2 €/MWh	Extra revenue from one more MWh of stored water
Turbine capacity (+1 MW)	76 205 €/yr	Extra annual revenue from a turbine uprate at current scale
Storage (+1 MWh)	236 €/yr	Extra annual revenue from more usable storage (≈0 when over-provisioned)
Reserve-cap headroom (+1 MW)	8,3 €/MW·h	Extra €/MW·h from relaxing the binding reserve reservation cap
Day-ahead spot (reference)	8,7 €/MWh	Avg. zone NO4 day-ahead price
Reservoir upper bound	binds 1 %	Share of hours at the cap — spill risk in the melt

READING MARGINAL (SHADOW) PRICES

A marginal (shadow) price is the extra revenue the optimiser would earn from **one more unit** of a scarce resource — an MWh of stored water, +1 MW of turbine, +1 MWh of storage, or +1 MW of reserve-cap headroom — holding everything else fixed.

A value near **zero** means that limit isn't binding: loosening it wouldn't help, so don't invest there. A **large** value flags the binding bottleneck — where a relaxed limit or an upgrade would pay back, and roughly how much it is worth per year. They answer: *what is holding this plant back, and what is it worth to change it?* (Values are for the selected strategy at the as-built size.)

RECOMMENDATIONS

1 **+249 % — at 2025 prices this plant is a balancing asset with energy on the side**

NO4 spot averaged 8,6 €/MWh in 2025; day-ahead alone earned €168 000 while full participation reached €588 000/yr. mFRR (€250 000) and FCR-N (€182 000) together out-earn the energy market two and a half times over, and 80 % of capacity hours carry reserve obligations. Reserve capability is what makes this project robust to low-price years — the strongest argument yet for the concession application.

2 **FCR-N standalone alone lifts 2025 revenue +38 %**

€65 000/yr on top of day-ahead for a droop setpoint and prequalification — no ESS, no operations function. The pond makes Hilleshamn unusually good at this: spill under full reserve commitment is only 3,3 % of inflow (the 0 h plants in this portfolio pay 30-40 %). Sequence: FCR-N at commissioning, then the mFRR route (€501 000/yr in 2025, ahead of the ESS-hybrid's €407 000).

3 **The pond thesis holds at collapsed prices too**

The storage curve is already flat past the design point (10 h → €588 000, 20 h → €596 000), so the planned magasin captures the value even in a reserve-dominated year; deeper storage remains civil-works economics. An extra MW of turbine prices at €76 000/yr in 2025's regime versus €47 000 at 2024 prices — worth carrying into the detail-design phase. All figures perfect-foresight upper bounds.

Generated with AI assistance · subject to expert review before use.

SIMULATION SETUP & ASSUMPTIONS

MODEL

Method	MILP co-opt.
Solver	CBC
Segments	5
Boundary	cycling res.

HORIZON

Period	2025 full-year
Resolution	60 min MTU
Hours	8 760
Storage bounds	concession

HYDROLOGY

Inflow source	Sildre (Strandvatnet, Bogen) × 0.10 — scaled so capped-turbinable energy matches the NVE concession estimate (12.1 GWh; beta)
Station	Strandvatnet, Bogen
Total inflow	14,3 Mm³
Usable res.	0,1 Mm³ · 10 h

CAPS

FCR-N	10% / 40% hyb.
FCR-D	40%
FFR	10%
mFRR	100%

MARKETS & PRICES

Strategies	DA · FCR-N/D mFRR · FFR
Price zone	NO4
Avg spot	8,7 €/MWh