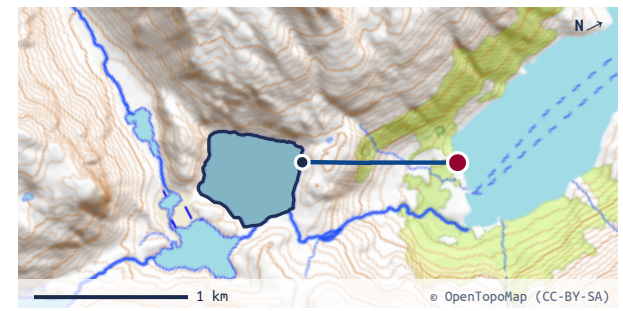
Langfjordhamn kraftverk

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

INSTALLED	MAX FLOW	RESERVOIR
6,2 MW	3,0 m³/s	278 h · 3,0 Mm³

WATERCOURSE & COMPONENTS · LOPPA



THE HEADLINE · 2025

Co-optimising Langfjordhamn kraftverk across **all balancing markets** lifted modelled revenue **+185 %** over day-ahead-only dispatch — almost entirely from reserve capacity, not extra energy.

+185 % REVENUE UPLIFT

€ 539 655 ADDITIONAL / YEAR

PERFORMANCE — ALL MARKETS (HYBRID)

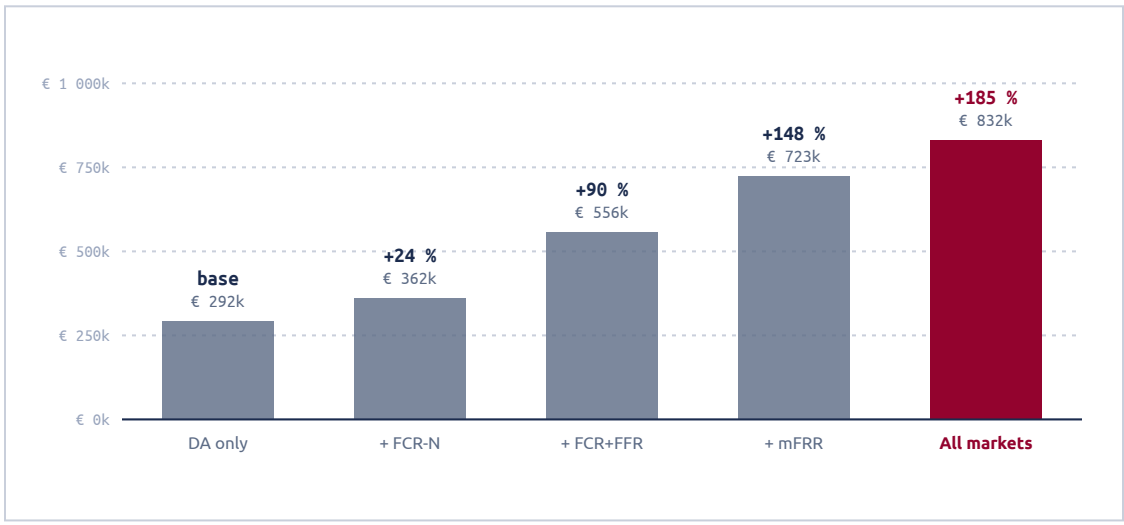
SELECT MARKET STRATEGY ↓

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
€ 831 759	14 415	26,5 %	605 %	8,6	2,4
+184,7 % vs. DA only	MWh to grid	of 6,2 MW	57,7 €/MWh realised (all markets ÷ energy)	full equiv. / yr	Mm³ · 8,7 %

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	–	1,65	6,2	€ 199 673	24%
FCR-N reserve	0,96	0,10	2,5	€ 229 439	28%
FCR-D up	0,19	0,00	2,5	€ 14 341	2%
mFRR up / down	3,93	0,00	6,2	€ 371 541	45%
FFR profile + flex	0,12	0,00	1,2	€ 16 765	2%
Total				**€ 831 759**	

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	€ 292 104		–	16 268	213 %	30,0 %	0 %
DA + FCR-N (standalone)	€ 362 161		+24,0 %	16 478	264 %	30,3 %	7 %
DA + FCR + FFR (hybrid)	€ 556 286		+90,4 %	12 985	405 %	23,9 %	27 %
DA + FCR-N + mFRR (standalone)	€ 723 063		+147,5 %	16 424	526 %	30,2 %	95 %
All markets (hybrid)	€ 831 759		+184,7 %	14 415	605 %	26,5 %	84 %

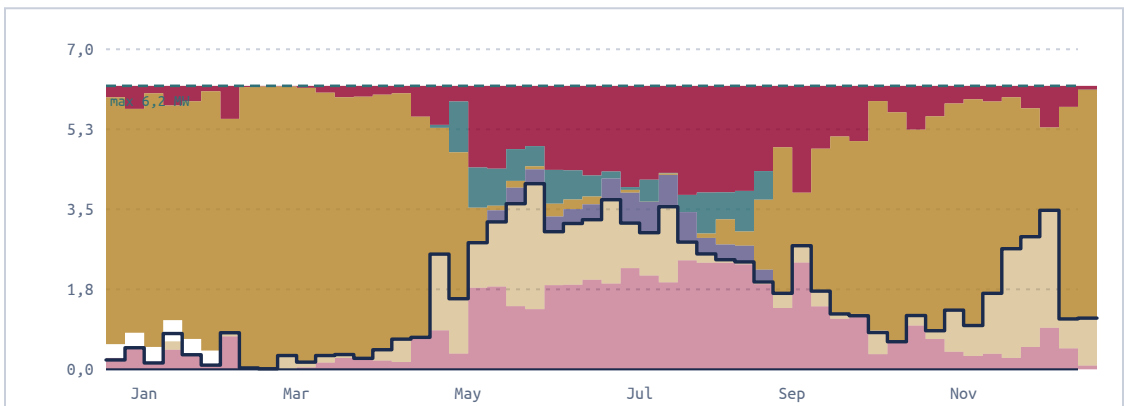
02 WATER BALANCE & CAPTURE · All markets (hybrid)

TOTAL INFLOW	TURBINED	SPILL (LOST)	AVG RESERVOIR	CAPTURE RATE
28,1	25,7	2,4	47 %	605 %
Mm³ · Sildre	Mm³ through turbine	Mm³ · 8,7 % of inflow	% of usable volume	revenue ÷ (inflow energy × 8,7 €/MWh)

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

RESERVE CAPACITY HELD

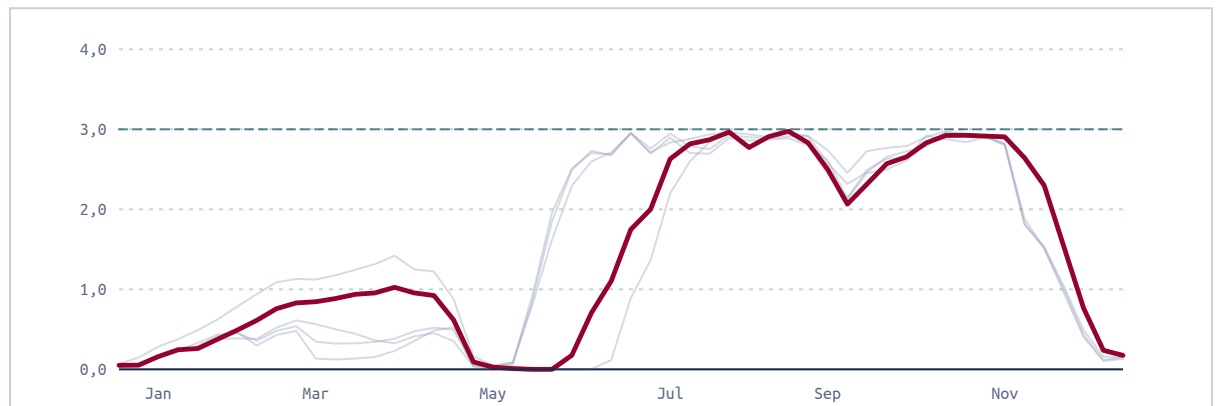
All markets (hybrid) · up from top, down from bottom



FCR-N · FCR-D · mFRR · FFR · Plant output · Max capacity

RESERVOIR TRAJECTORY

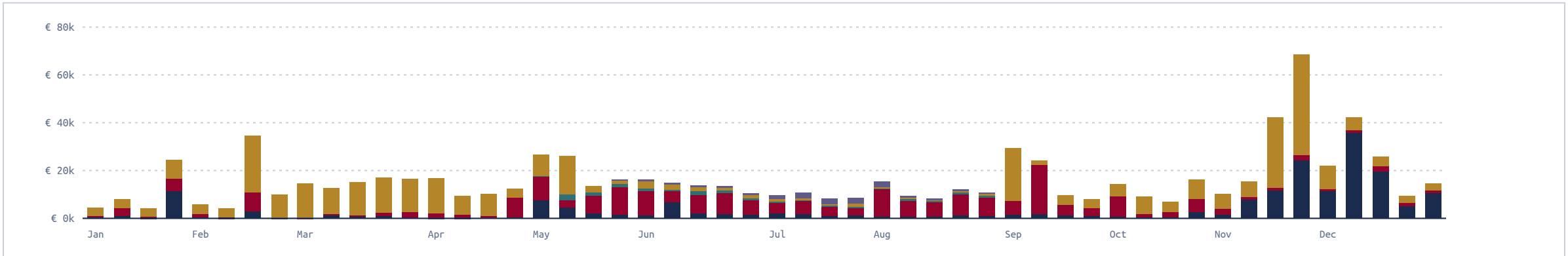
weekly · Mm³ · all strategies, selected highlighted



All markets (selected) · Other strategies · Min / max bounds

WEEKLY REVENUE BY MARKET

All markets (hybrid) · 52 equal periods



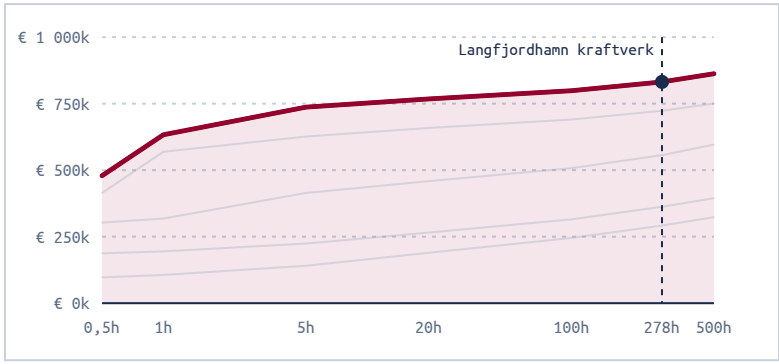
Day-ahead · FCR-N · FCR-D · mFRR · FFR

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

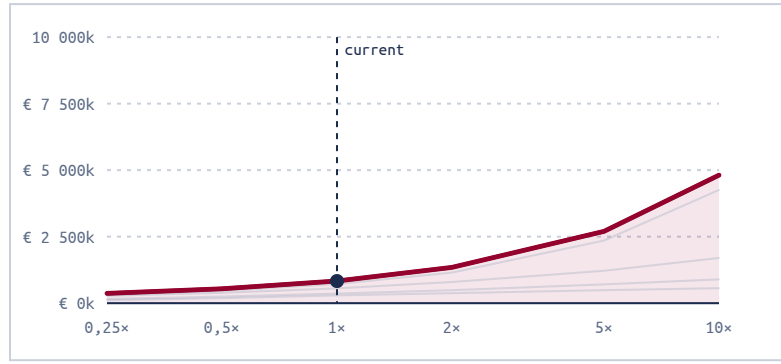
Sensitivity of optimised revenue to the plant's physical envelope, under each market strategy. The **highlighted line is the selected strategy**; the dashed marker is Langfjordhamn kraftverk's current operating point.

STORAGE DISCHARGE DURATION



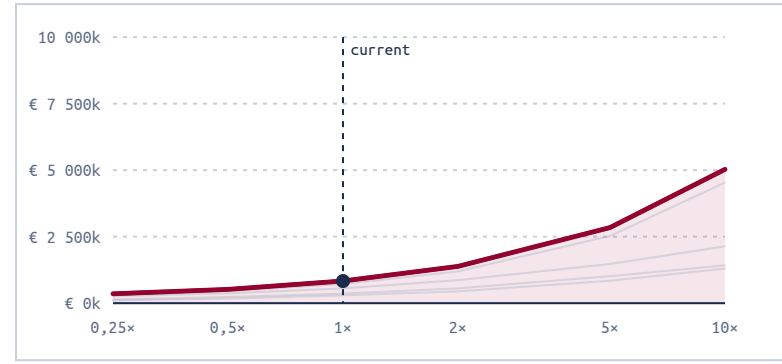
Annual revenue vs. usable storage hours (log). Marker = as-built.

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 — Langfjordhamn kraftverk as-built

MARGINAL VALUES & BINDING CONSTRAINTS

as-built · All markets (hybrid)

Marginal water value	13,9 €/MWh	Extra revenue from one more MWh of stored water
Turbine capacity (+1 MW)	82 761 €/yr	Extra annual revenue from a turbine uprate at current scale
Storage (+1 MWh)	22 €/yr	Extra annual revenue from more usable storage (≈0 when over-provisioned)
Reserve-cap headroom (+1 MW)	8,4 €/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 0 %	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 2025 is the proof of the hedge — reserves carried the plant

NO4 spot collapsed to 8,6 €/MWh in 2025 (from 23,4 in 2024) and day-ahead-only revenue fell to €292 000. Full market participation still earned €832 000 (+185 %) — essentially level with the 2024 total — because mFRR (€372 000) and FCR-N (€229 000) income does not follow spot down. Reserve capability is not an add-on here; it is the revenue floor under low-price years.

2 mFRR led 2025 decisively — revisit the capex/opex fork with that weight

The mFRR route reached €723 000/yr versus €556 000 for the ESS-hybrid — a 30 % gap in 2025 (they were tied in 2024). If low NO4 spot years persist, the opex route (outsourced 24/7 balancing) is the stronger second step after FCR-N standalone (+€70 000, +24 %). Perfect-foresight modelled figures — an upper bound, and 2025's reserve prices need not repeat.

3 At these prices the plant runs as a reserve machine

In the all-markets strategy 84 % of capacity hours carry reserve obligations, capture price reaches 156 % of spot, and spill stays modest at 8,7 % of inflow — the reservoir absorbs what reserve-holding displaces. An extra MW of turbine prices at €82 000/yr in this regime, strengthening the unit-sizing case from the 2024 report.

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.

MARKETS & PRICES

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

HORIZON

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

HYDROLOGY

Inflow source	Sildre
Station	Oksfjordvatn
Total inflow	28,1 Mm³
Usable res.	3,0 Mm³ · 278 h

CAPS

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