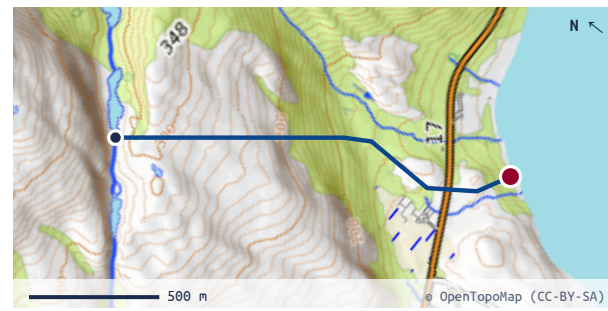
Hundåga kraftverk

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

INSTALLED	MAX FLOW	RESERVOIR
1,9 MW	0,8 m³/s	0 h · 0,0 Mm³

WATERCOURSE & COMPONENTS · LURØY



THE HEADLINE · 2025

Co-optimising Hundåga kraftverk across **all balancing markets** lifted modelled revenue **+138 %** over day-ahead-only dispatch — almost entirely from reserve capacity, not extra energy.

+138 % REVENUE UPLIFT

€ 75 875 ADDITIONAL / YEAR

PERFORMANCE — ALL MARKETS (HYBRID)

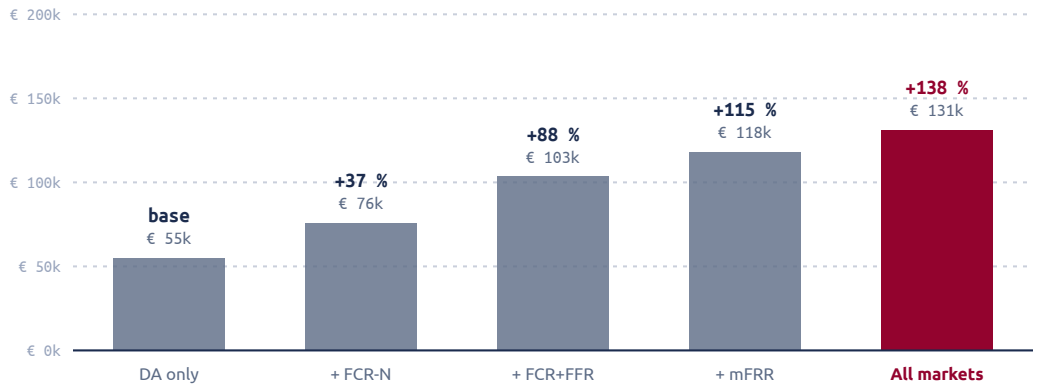
SELECT MARKET STRATEGY ↓

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
€ 130 975	5 648	33,9 %	157 %	n/a	5,9
+137,7 % vs. DA only	MWh to grid	of 1,9 MW	23,2 €/MWh realised (all markets ÷ energy)	full equiv. / yr	Mm³ · 40,9 %

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	–	0,65	1,9	€ 45 857	35%
FCR-N reserve	0,15	0,02	0,7	€ 32 213	25%
FCR-D up	0,02	0,00	0,8	€ 1 802	1%
mFRR up / down	0,52	0,00	1,9	€ 45 966	35%
FFR profile + flex	0,04	0,00	0,4	€ 5 138	4%
Total				**€ 130 975**	

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	€ 55 100		–	7 853	66 %	47,2 %	0 %
DA + FCR-N (standalone)	€ 75 628		+37,3 %	6 497	91 %	39,0 %	8 %
DA + FCR + FFR (hybrid)	€ 103 464		+87,8 %	4 708	124 %	28,3 %	20 %
DA + FCR-N + mFRR (standalone)	€ 118 305		+114,7 %	6 335	142 %	38,1 %	41 %
All markets (hybrid)	€ 130 975		+137,7 %	5 648	157 %	33,9 %	38 %

02 WATER BALANCE & CAPTURE · All markets (hybrid)

TOTAL INFLOW
14,5
Mm³ · Sildre (Vassvatn) × 0.19 — scaled so capped-turbinable energy matches the NVE concession estimate (8.1 GWh; beta)

TURBINED
8,6
Mm³ through turbine

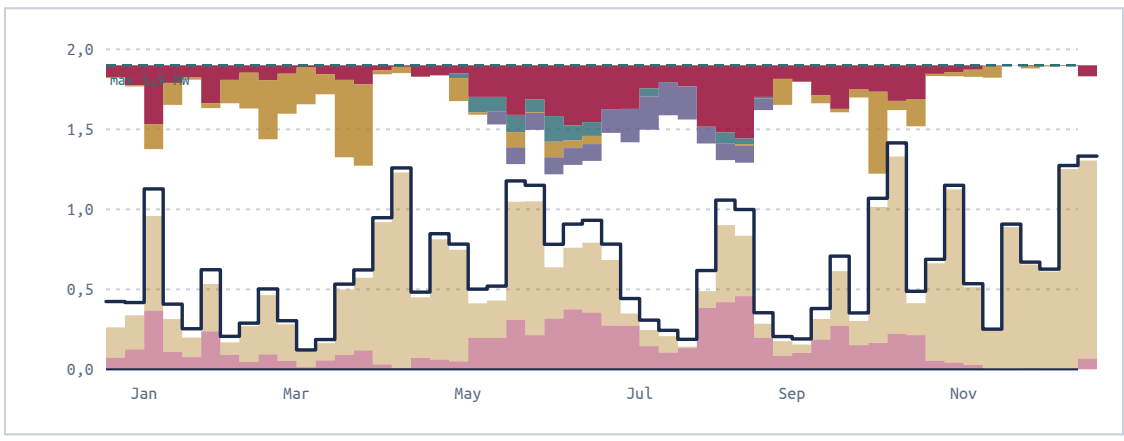
SPILL (LOST)
5,9
Mm³ · 40,9 % of inflow

AVG RESERVOIR
n/a
% of usable volume

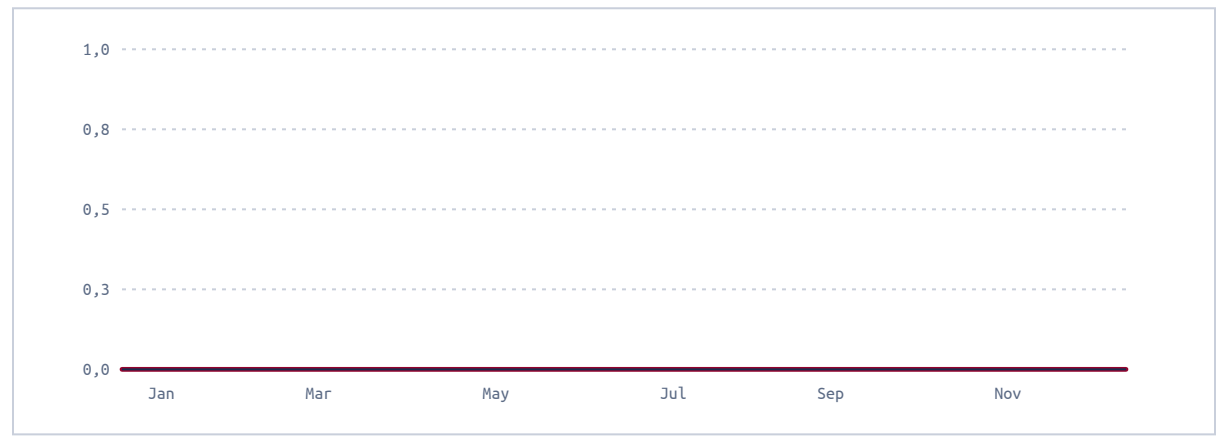
CAPTURE RATE
157 %
revenue ÷ (inflow energy × 8,7 €/MWh)

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

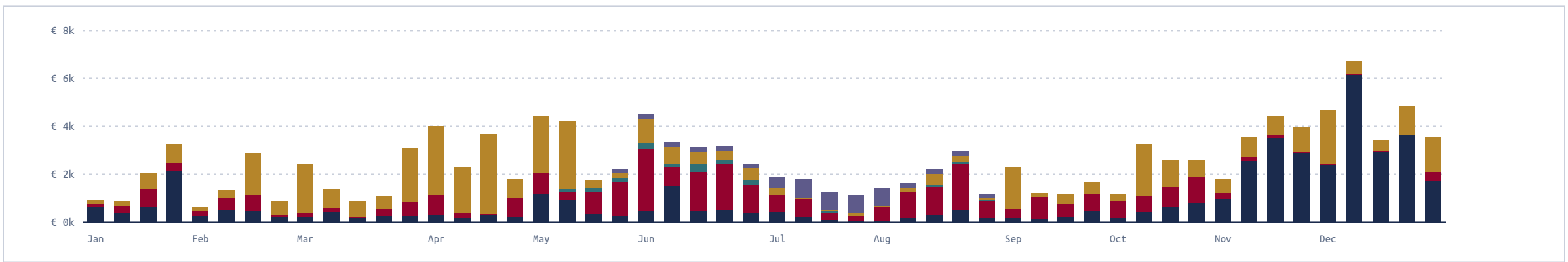
RESERVE CAPACITY HELD
All markets (hybrid) · up from top, down from bottom



RESERVOIR TRAJECTORY
weekly · Mm³ · all strategies, selected highlighted



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

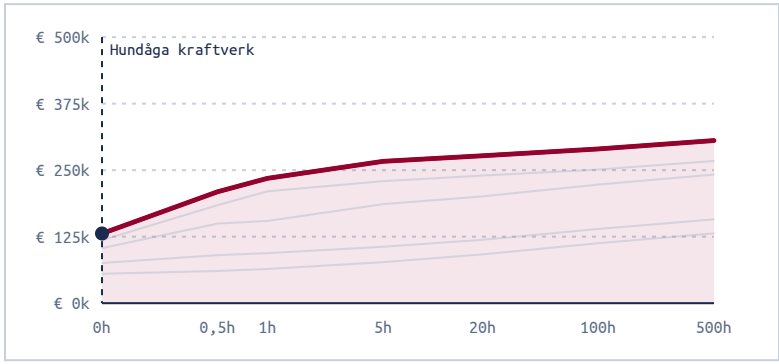


Day-ahead only	DA + FCR-N (standalone)	DA + FCR + FFR (hybrid)	DA + FCR-N + mFRR (standalone)	**All markets (hybrid)**

01 WHERE THE MARGINAL VALUE IS

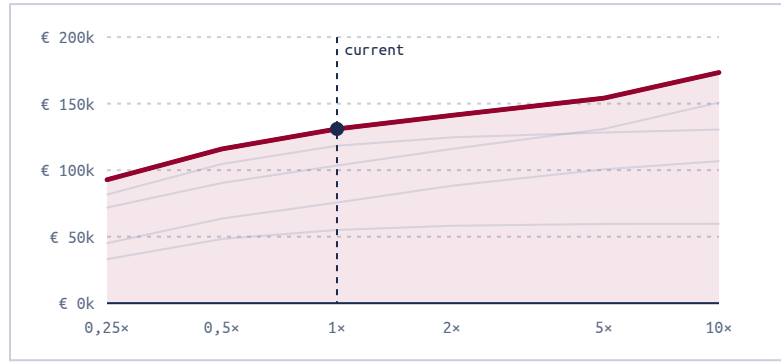
Sensitivity of optimised revenue to the plant's physical envelope, under each market strategy. The **highlighted line is the selected strategy**; the dashed marker is Hundåga kraftverk's current operating point.

STORAGE DISCHARGE DURATION



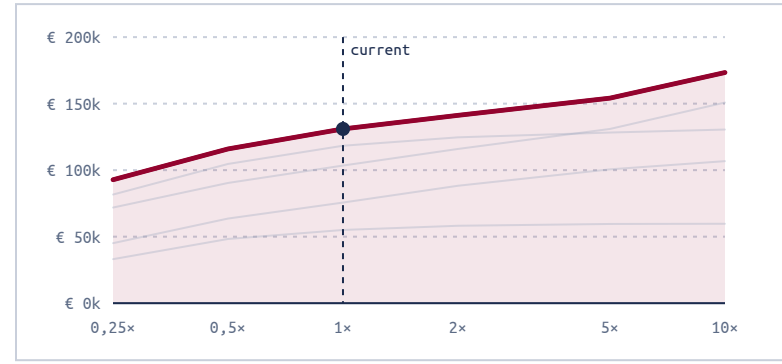
Annual revenue vs. usable storage hours (log). Marker = as-built.

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 · Hundåga kraftverk as-built

MARGINAL VALUES & BINDING CONSTRAINTS

as-built · All markets (hybrid)

Marginal water value	16,3 €/MWh	Extra revenue from one more MWh of stored water
Turbine capacity (+1 MW)	5 384 €/yr	Extra annual revenue from a turbine uprate at current scale
Storage (+1 MWh)	103 034 €/yr	Extra annual revenue from more usable storage (≈0 when over-provisioned)
Reserve-cap headroom (+1 MW)	2,8 €/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 100 %	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: reserves turned +138 % on a collapsed spot**

At NO4's 8,6 €/MWh average, day-ahead alone earned €55 000; full participation €131 000/yr. FCR-N standalone added €21 000 (+37 %) autonomously. For a 1,9 MW plant the lesson is stark: without reserve capability, 2025 barely covers operations; with it, the project stays viable through low-price years. Perfect-foresight upper bounds.

2 **mFRR route led 2025 (€118 000 vs €103 000 hybrid)**

mFRR alone was worth €54 000/yr — double its 2024 value — because balancing prices held while spot fell. At this scale mFRR only works inside an aggregated portfolio agreement; the two-year evidence justifies negotiating one across the ETKKT prospects rather than per plant.

3 **The pond finding repeats: 0,5 h ≈ 1,6× revenue**

€209 000/yr at 0,5 h of buffering versus €131 000 as-built, rising to €266 000 at 5 h. Together with the 2024 result this is a consistent, price-year-independent design signal for the un-buffered Nordland prospects: some pondage pays better than any market choice. Model-preliminary (LER assumptions); verify in prequalification.

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 (Vassvatn) × 0.19 — scaled so capped-turbinable energy matches the NVE concession estimate (8.1 GWh; beta)
Station	Vassvatn
Total inflow	14,5 Mm³
Usable res.	0,0 Mm³ · 0 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