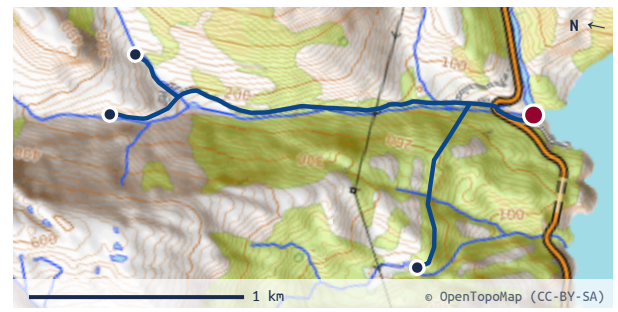
Fossdalen kraftverk

Run-of-river · · price zone **NO5** — full-year optimised dispatch, 1 Jan – 31 Dec 2025.

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

WATERCOURSE & COMPONENTS · MASFJORDEN



THE HEADLINE · 2025

Co-optimising Fossdalen kraftverk across **all balancing markets** lifted modelled revenue **+13 %** over day-ahead-only dispatch — almost entirely from reserve capacity, not extra energy.

+13 % REVENUE UPLIFT

€ 31 430 ADDITIONAL / YEAR

PERFORMANCE — ALL MARKETS (HYBRID)

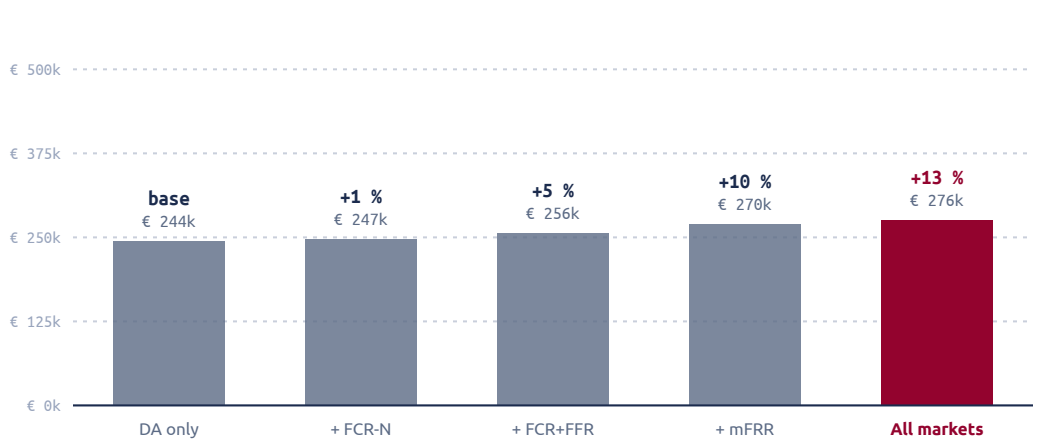
SELECT MARKET STRATEGY ↓

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
€ 275 638	5 435	32,7 %	70 %	n/a	5,0
+12,9 % vs. DA only	MWh to grid	of 1,9 MW	50,7 €/MWh realised (all markets ÷ energy)	full equiv. / yr	Mm³ · 35,8 %

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	–	0,62	1,9	€ 241 187	88%
FCR-N reserve	0,02	0,00	0,7	€ 6 391	2%
FCR-D up	0,00	0,00	0,8	€ 19	0%
mFRR up / down	0,59	0,00	1,9	€ 22 902	8%
FFR profile + flex	0,04	0,00	0,4	€ 5 138	2%
Total				**€ 275 638**	

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	€ 244 208	–	5 669	62 %	34,1 %	0 %
DA + FCR-N (standalone)	€ 247 352	+1,3 %	5 533	62 %	33,2 %	1 %
DA + FCR + FFR (hybrid)	€ 256 139	+4,9 %	5 307	65 %	31,9 %	4 %
DA + FCR-N + mFRR (standalone)	€ 269 746	+10,5 %	5 584	68 %	33,5 %	33 %
All markets (hybrid)	€ 275 638	+12,9 %	5 435	70 %	32,7 %	34 %

02 WATER BALANCE & CAPTURE · All markets (hybrid)

TOTAL INFLOW
14,1
Mm³ · Sildre (Havelandselv) × 0.19 — scaled so capped-turbinable energy matches the NVE concession estimate (5.7 GWh; beta)

TURBINED
9,1
Mm³ through turbine

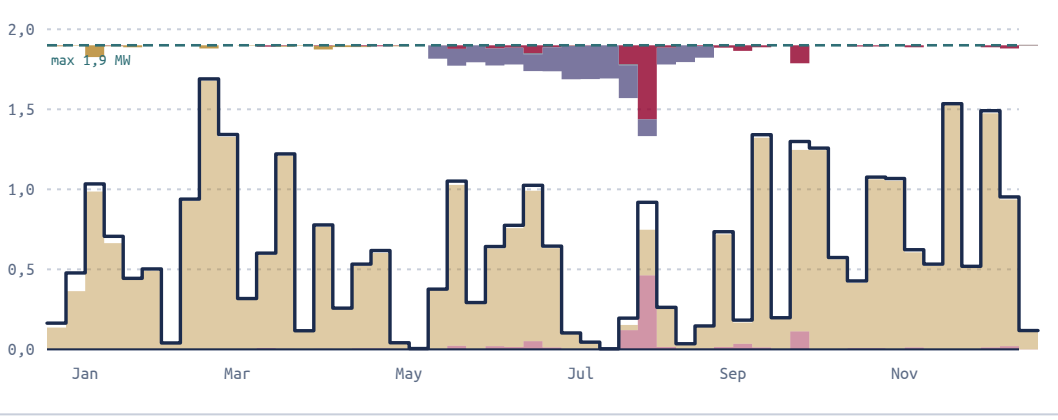
SPILL (LOST)
5,0
Mm³ · 35,8 % of inflow

AVG RESERVOIR
n/a
% of usable volume

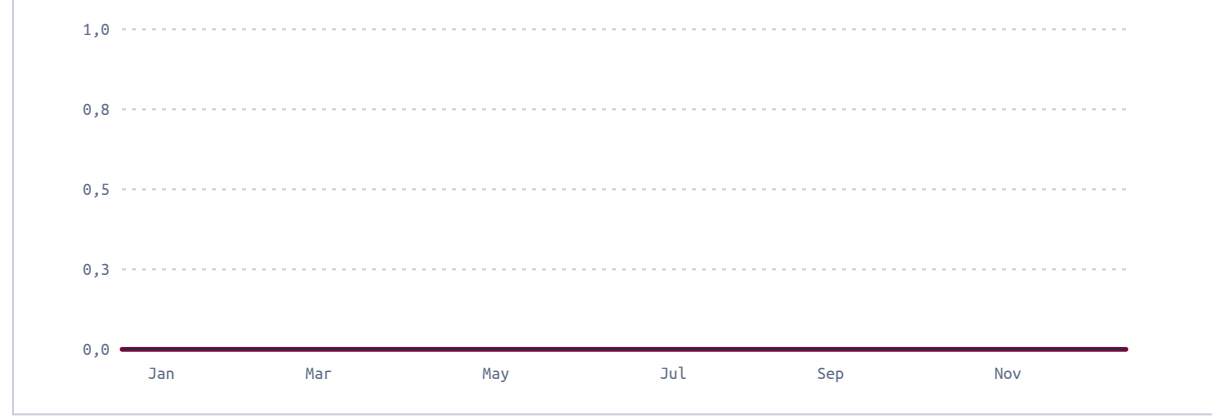
CAPTURE RATE
70 %
revenue ÷ (inflow energy × 46,9 €/MWh)

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

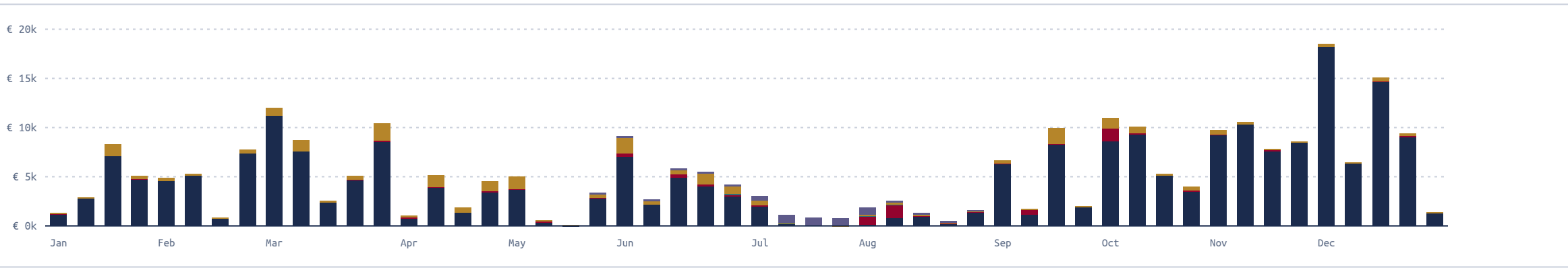
RESERVE CAPACITY HELD
All markets (hybrid) · up from top, down from bottom



RESERVOIR TRAJECTORY
weekly · Mm³ · all strategies, selected highlighted



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

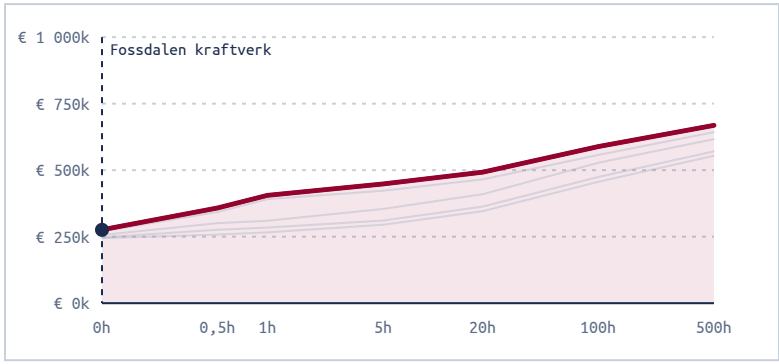


Day-ahead only	DA + FCR-N (standalone)	DA + FCR + FFR (hybrid)	DA + FCR-N + mFRR (standalone)	**All markets (hybrid)**

01 WHERE THE MARGINAL VALUE IS

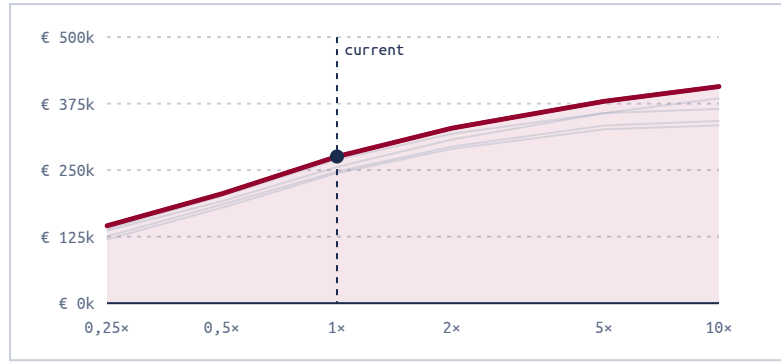
Sensitivity of optimised revenue to the plant's physical envelope, under each market strategy. The **highlighted line is the selected strategy**; the dashed marker is Fossdalen kraftverk's current operating point.

STORAGE DISCHARGE DURATION



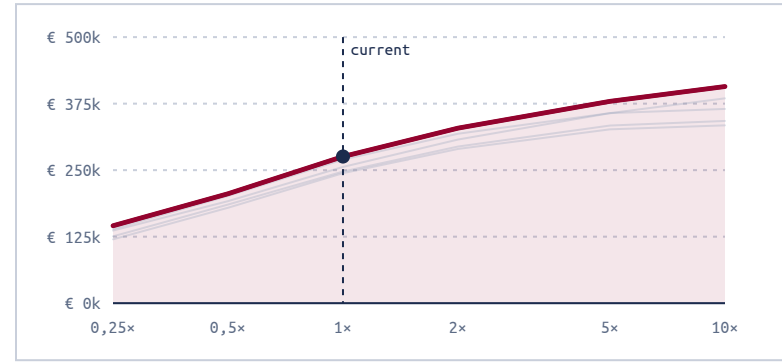
Annual revenue vs. usable storage hours (log). Marker = as-built.

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 · Fossdalen kraftverk as-built

MARGINAL VALUES & BINDING CONSTRAINTS

as-built · All markets (hybrid)

Marginal water value	45,9 €/MWh	Extra revenue from one more MWh of stored water
Turbine capacity (+1 MW)	28 047 €/yr	Extra annual revenue from a turbine uprate at current scale
Storage (+1 MWh)	108 026 €/yr	Extra annual revenue from more usable storage (≈0 when over-provisioned)
Reserve-cap headroom (+1 MW)	3,0 €/MW·h	Extra €/MW·h from relaxing the binding reserve reservation cap
Day-ahead spot (reference)	46,9 €/MWh	Avg. zone NO5 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 **NO5 2025: spot rose to 46,8 €/MWh — the energy thesis got stronger**

Day-ahead alone earned €244 000/yr (up 25 % on 2024) with capture at 95 % of spot; full participation added €31 000 (+13 %). While the NO4 prospects needed reserves to survive 2025, Fossdalen's zone did the opposite — this plant is the portfolio's spot-price diversifier. Perfect-foresight upper bounds.

2 **Reserve entry stays opportunistic**

FCR-N standalone added just €3 100/yr (+1 %) at 2025 NO5 reserve prices; the mFRR route reached €270 000 (mFRR alone €24 000). Nothing here justifies dedicated ops — bundle Fossdalen into whatever portfolio balancing agreement the Nordland plants end up under, or skip reserves entirely.

3 **The €50 000/yr-per-MWh storage signal deserves a look**

With water at a 46 €/MWh shadow value and 36 % of inflow spilling, the sweep prices 0,5 h of buffering at €357 000/yr against the as-built €276 000 and puts the marginal value of the first MWh of storage near €50 000/yr — the highest in the portfolio because every spilled m³ here is dear. If the Masfjorden site can hold any pondage at all, price it; model-preliminary (LER assumptions).

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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 (Havelandselv) × 0.19 — scaled so capped-turbinable energy matches the NVE concession estimate (5.7 GWh; beta)
Station	Havelandselv
Total inflow	14,1 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	NO5
Avg spot	46,9 €/MWh