Sandneselva kraftverk (Lavangen)

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

INSTALLED	MAX FLOW	RESERVOIR
5,0 MW	3,3 m³/s	0 h · 0,0 Mm³

WATERCOURSE & COMPONENTS · LAVANGEN

THE HEADLINE · 2025

Co-optimising Sandneselva kraftverk (Lavangen) across **all balancing markets** lifted modelled revenue **+204 %** over day-ahead-only dispatch — almost entirely from reserve capacity, not extra energy.

+204 % REVENUE UPLIFT

€ 108 633 ADDITIONAL / YEAR

PERFORMANCE — ALL MARKETS (HYBRID)

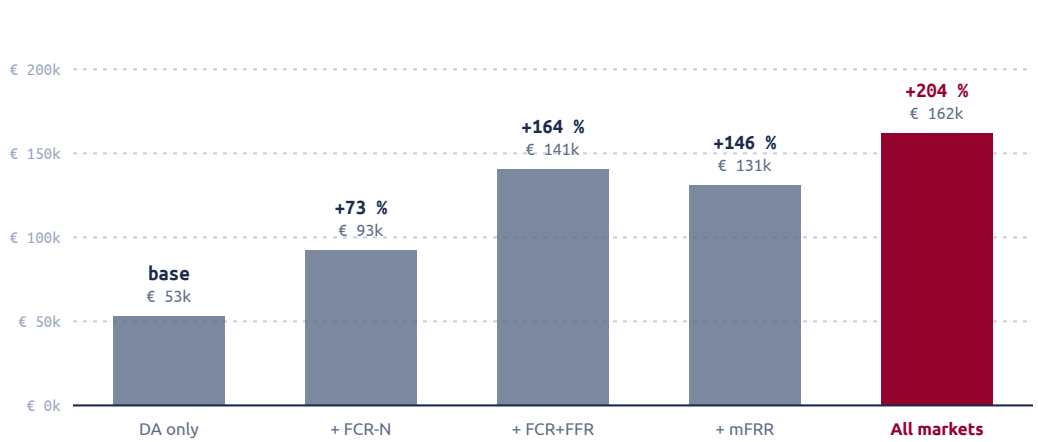
SELECT MARKET STRATEGY ↓

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
€ 161 965	7 443	17,0 %	167 %	n/a	8,6
+203,7 % vs. DA only	MWh to grid	of 5,0 MW	21,8 €/MWh realised (all markets ÷ energy)	full equiv. / yr	Mm³ · 33,2 %

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	–	0,85	5,0	€ 40 869	25%
FCR-N reserve	0,30	0,03	1,9	€ 63 084	39%
FCR-D up	0,04	0,00	2,0	€ 4 396	3%
mFRR up / down	0,49	0,00	5,0	€ 40 096	25%
FFR profile + flex	0,10	0,00	1,0	€ 13 520	8%
Total				**€ 161 965**	

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	€ 53 332		–	10 805	55 %	24,7 %	0 %
DA + FCR-N (standalone)	€ 92 529		+73,5 %	8 436	95 %	19,3 %	6 %
DA + FCR + FFR (hybrid)	€ 140 722		+163,9 %	6 221	145 %	14,2 %	13 %
DA + FCR-N + mFRR (standalone)	€ 130 971		+145,6 %	8 830	135 %	20,2 %	21 %
All markets (hybrid)	€ 161 965		+203,7 %	7 443	167 %	17,0 %	19 %

02 WATER BALANCE & CAPTURE · All markets (hybrid)

TOTAL INFLOW
26,0
Mm³ · Sildre (Øvrevatn) × 0.03 — scaled so capped-turbinable energy matches the NVE concession estimate (11.2 GWh; beta)

TURBINED
17,4
Mm³ through turbine

SPILL (LOST)
8,6
Mm³ · 33,2 % of inflow

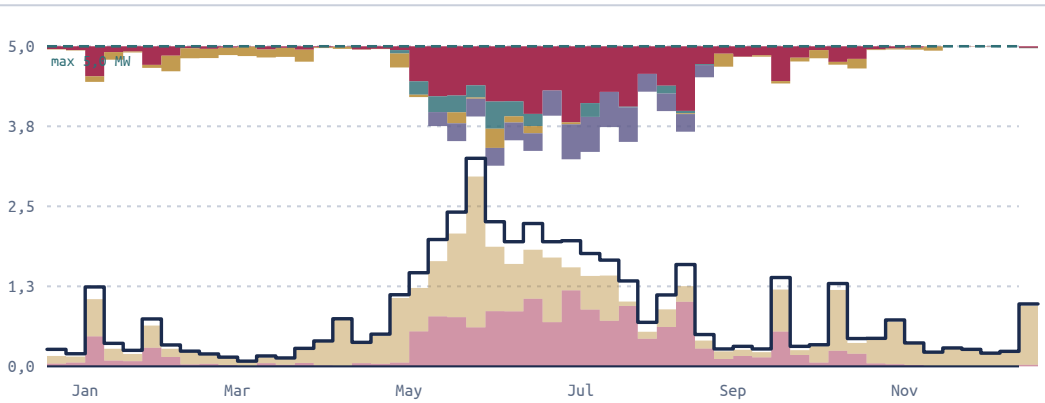
AVG RESERVOIR
n/a
% of usable volume

CAPTURE RATE
167 %
revenue ÷ (inflow energy × 8,7 €/MWh)

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

RESERVE CAPACITY HELD

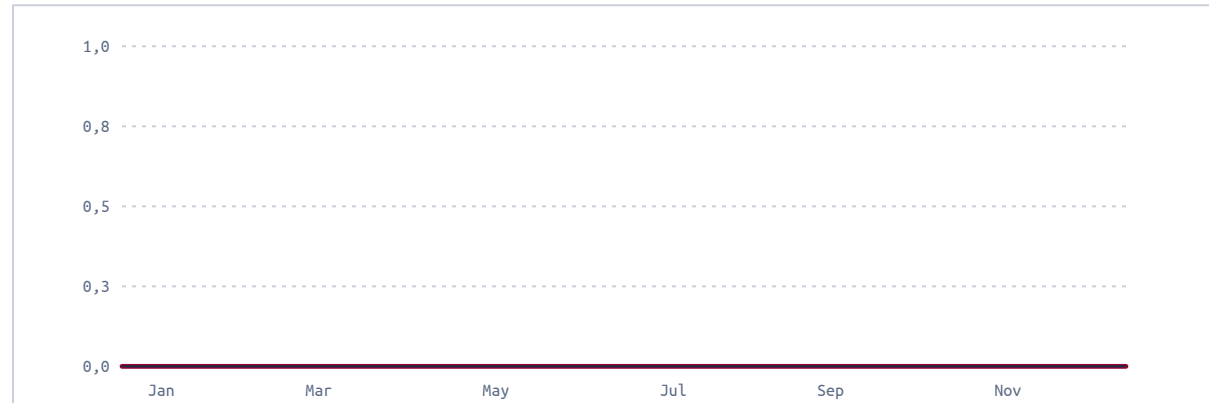
All markets (hybrid) · up from top, down from bottom



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

RESERVOIR TRAJECTORY

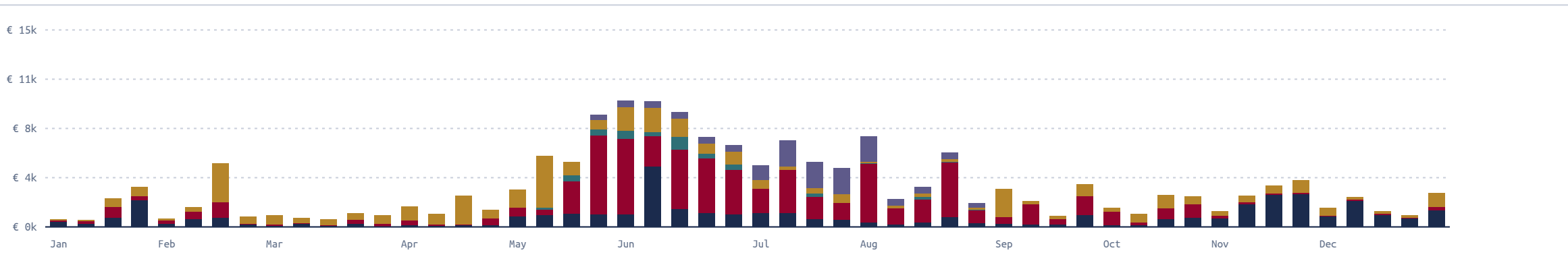
weekly · Mm³ · all strategies, selected highlighted



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

WEEKLY REVENUE BY MARKET

All markets (hybrid) · 52 equal periods



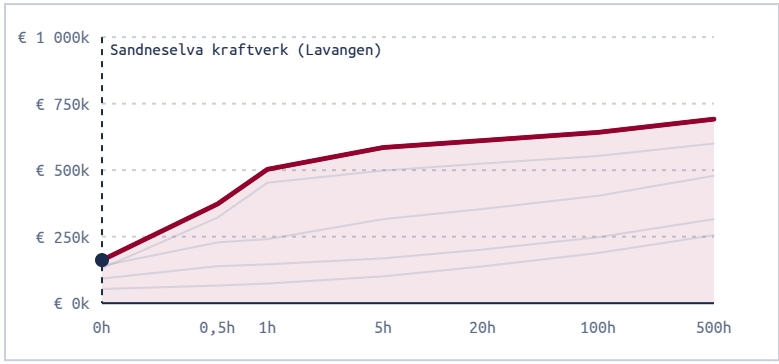
Day-ahead · FCR-N · FCR-D · mFRR · FFR

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

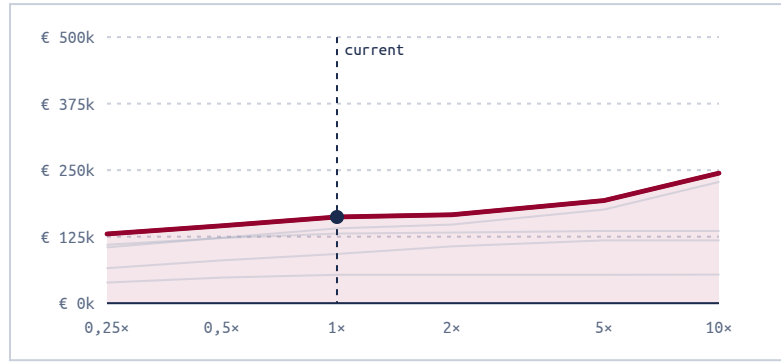
Sensitivity of optimised revenue to the plant's physical envelope, under each market strategy. The **highlighted line is the selected strategy**; the dashed marker is Sandneselva kraftverk (Lavangen)'s current operating point.

STORAGE DISCHARGE DURATION



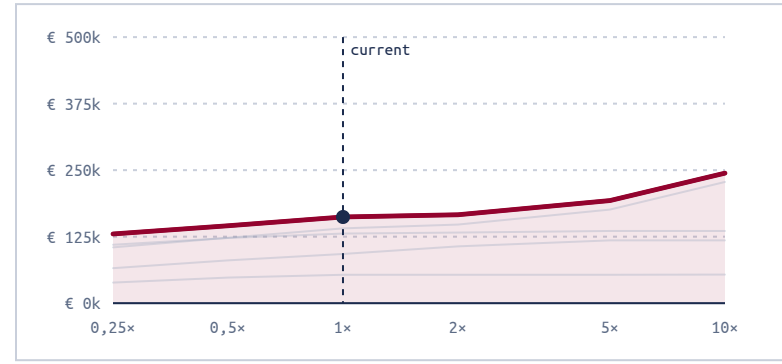
Annual revenue vs. usable storage hours (log). Marker = as-built.

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 · Sandneselva kraftverk (Lavangen) as-built

MARGINAL VALUES & BINDING CONSTRAINTS

as-built · All markets (hybrid)

Marginal water value	17,7 €/MWh	Extra revenue from one more MWh of stored water
Turbine capacity (+1 MW)	814 €/yr	Extra annual revenue from a turbine uprate at current scale
Storage (+1 MWh)	105 452 €/yr	Extra annual revenue from more usable storage (≈0 when over-provisioned)
Reserve-cap headroom (+1 MW)	2,9 €/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: spot collapsed, reserves became the business

NO4 spot averaged 8,6 €/MWh; day-ahead alone earned €53 000 while full participation reached €162 000/yr (+203 %). FCR-N standalone alone added €39 000 (+73 %) — at these prices the droop setpoint out-earns better spot timing many times over. Prequalify FCR-N with Plasselva as one package; the figures are perfect-foresight upper bounds and 2025's price mix need not repeat.

2 Both full routes work; hybrid edged mFRR in 2025

The ESS-hybrid reached €141 000/yr versus €131 000 for the mFRR route (mFRR alone €54 000). The ordering flips between years (mFRR led 2024 marginally), so decide on capex-versus-opex grounds, not on either single year. Spill at full reserves is 33 % of inflow — the structural cost of holding capacity with no buffer.

3 Half an hour of pondage more than doubles the 2025 result

The sweep prices 0,5 h of buffering at €372 000/yr against the as-built €162 000 — the zero-storage constraint binds every hour, and in a reserve-priced year that constraint is what caps revenue. Combined with the same finding at 2024 prices, a small intake pond is the single most valuable design change available; verify against prequalification/LER rules before committing (model-preliminary figure).

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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 (Øvrevatn) × 0.03 — scaled so capped-turbinable energy matches the NVE concession estimate (11.2 GWh; beta)
Station	Øvrevatn
Total inflow	26,0 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