

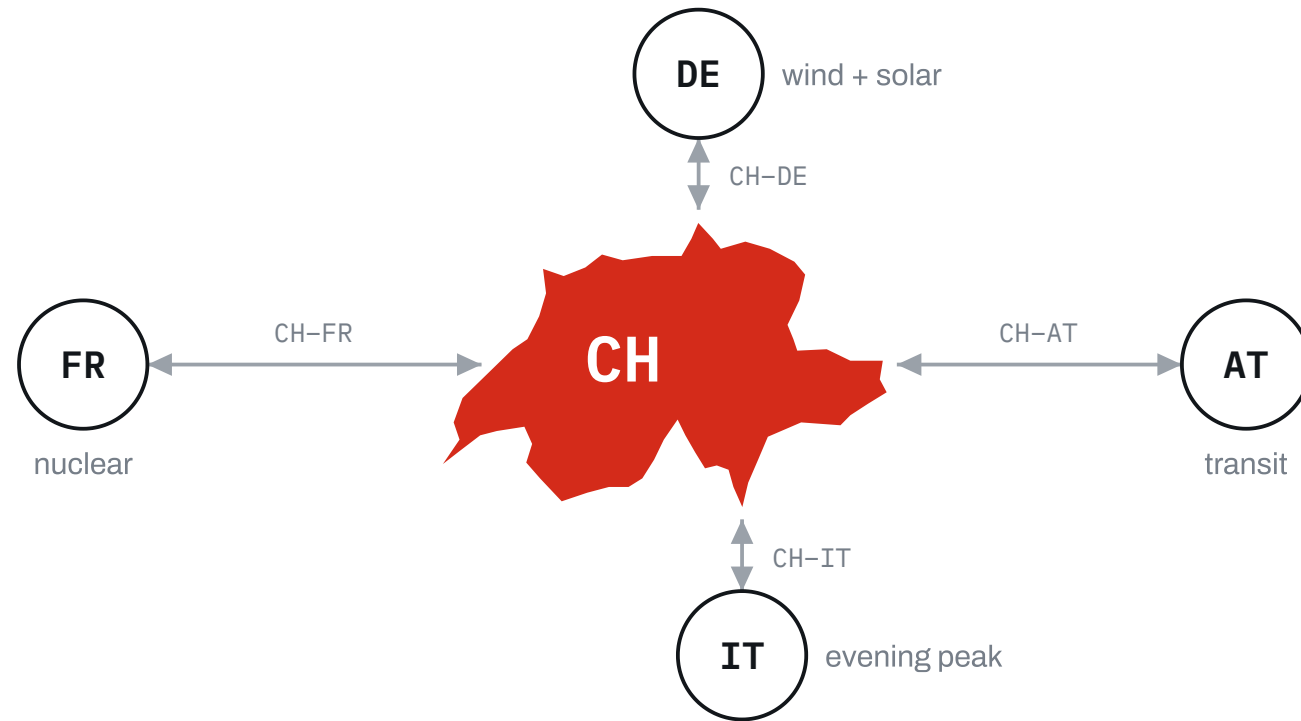
# Swiss Cross-Border Flows

Probabilistic forecasts across four borders, 168 hours ahead.  
Two approaches to the same problem.

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## 01 – THE STARTING POINT

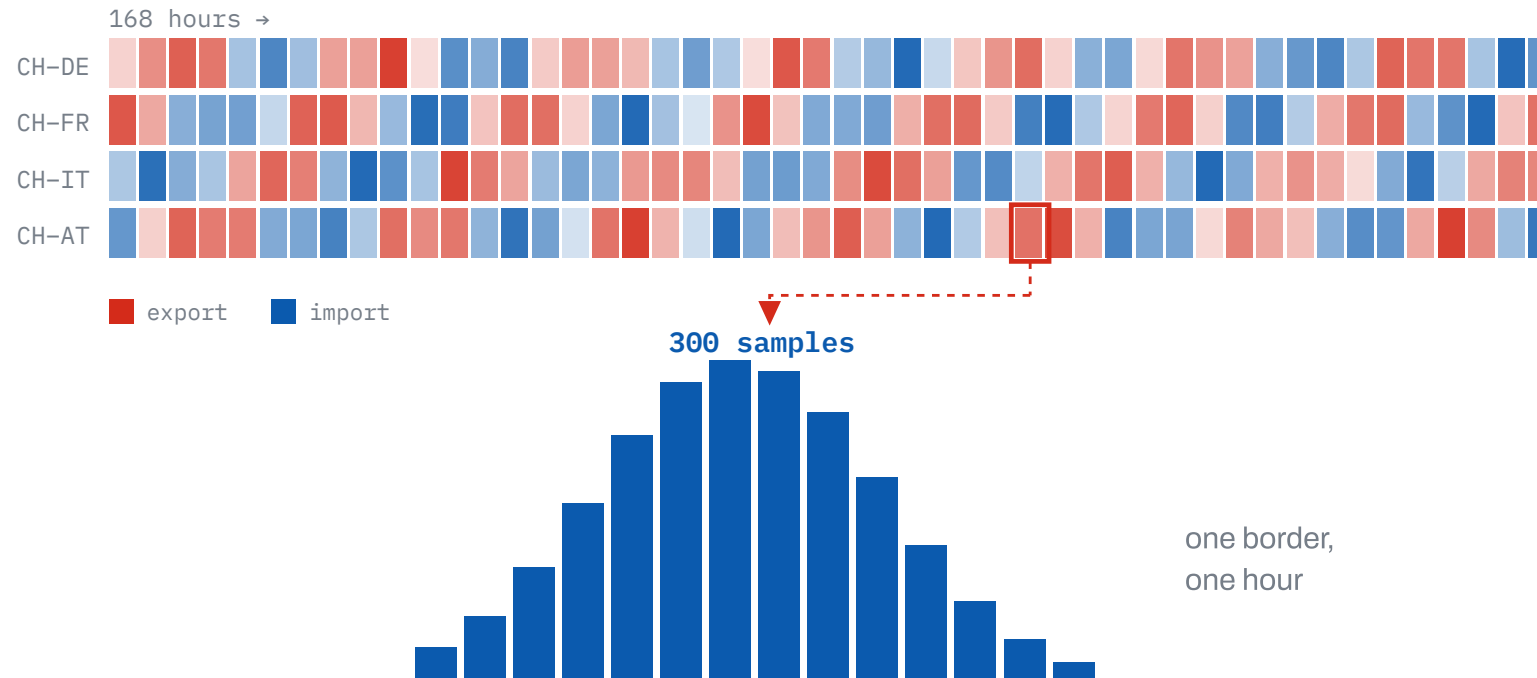
# Power follows price across the border.



Power can't be stored – so **price gaps become physical flows**.

Settled every **15 minutes** since Oct 2025.

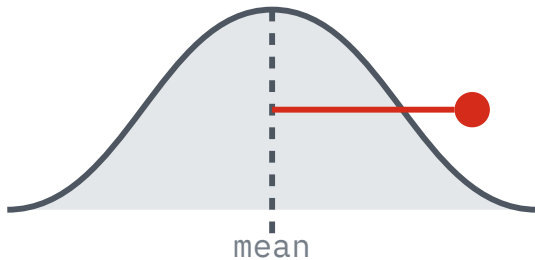
# Every cell is a distribution, not a number.



168 h · 4 borders · 300 samples each = 201,600 numbers

# Three factors — one is a gate.

## 45% Error



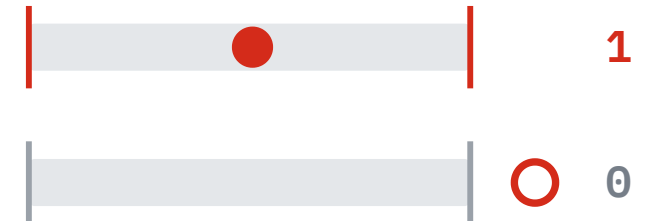
$$1 - |r - \text{mean}| / (3 \cdot \text{std})$$

## 35% Sharpness



$$\text{range} / (\text{range} + 2 \cdot \text{std})$$

## 20% Capture



$$\text{min} \leq r \leq \text{max}$$

Capture is **multiplicative**. Hit 0 and the whole row scores 0 — however good the other two were.

# Approach A

We never forecast a flow. We read the scoring formula, found that it can be maximised without a model at all, and submitted the 300 numbers that do it.

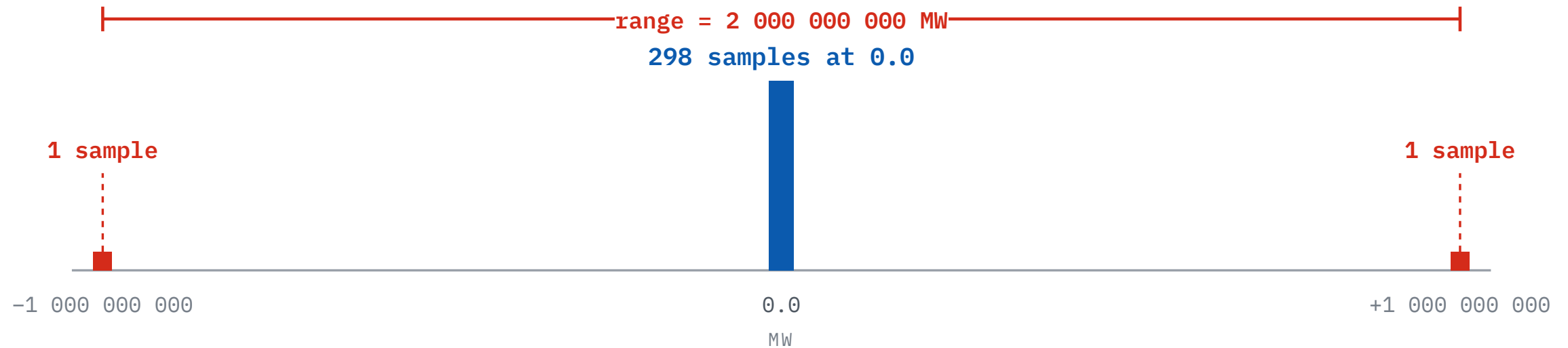
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**NOT** a forecast · no model, no training, no data

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**INSTEAD** the 300 numbers the formula likes best

# No model. Two anchors and 298 zeros.



## capture = 1

No flow on this grid falls outside  $\pm 10^9$  MW. The **multiplicative gate can never fire.**

## sharp = 0.924514

range / (range + 2·std) collapses to  $1 / (1 + \sqrt{(2k/N)})$  — D cancels out entirely.

## error $\approx 1$

3·std is **245 million MW**. Against that denominator a real flow of 2 000 MW is a rounding error.

$$0.2 + 0.45 + 0.35 \times 0.924514 = \mathbf{97.357982 \%} \text{ ceiling} \cdot \text{we scored } \mathbf{97.357746 \%}$$

# Approach B

Approach A never made a forecast — it only shaped 300 numbers so the metric would like them. This one predicts the flow.

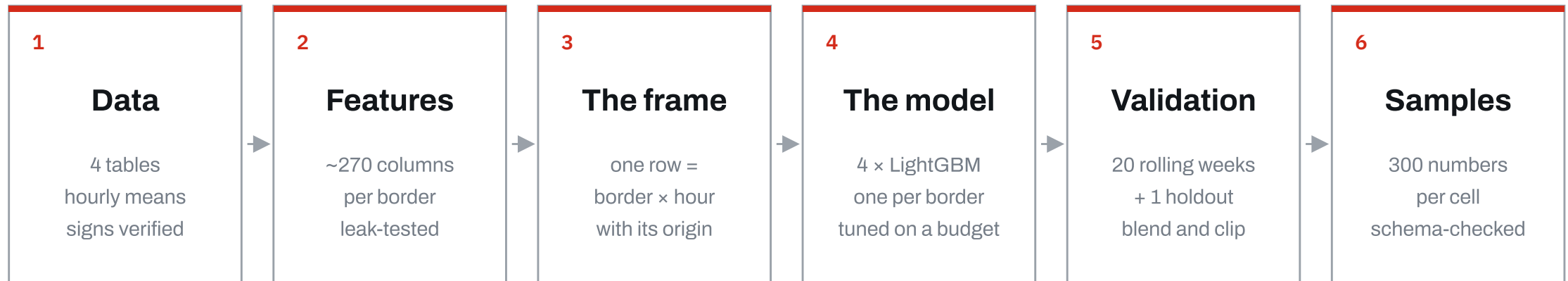
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**DONE** Approach A · two anchors, 298 zeros · no model trained

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**NOW** Approach B · four models, ~270 features, six steps

# Six steps from four raw tables to 201 600 numbers.



each step reads only what the one before it produced – nothing is recomputed implicitly

# Forecasts come free. Realizations cost a week.

## FORECASTS — EXIST BEFORE THE WEEK HAPPENS

18 × generation\_forecast\_\*  
day-ahead solar, wind and total, per country

scheduled\_consumption  
planned load per country

ntc\_month  
transfer capacity per border, a monthly value

→ used at face value, no lag needed

## REALIZATIONS — EXIST ONLY AFTERWARDS

cross\_border\_exchanges  
the four flows — this is also the target

net\_positions  
net export per country

→ only as a lag of 168 h or more

Everything arrives in quarter hours and is averaged to hourly values — **the mean, never the sum**: these are powers in MW, not amounts of energy.

A flipped sign is **invisible** in local validation — forecast and realization flip together and the score never moves. So the four flows are summed and checked against Switzerland's net position; below 0.95 correlation the run aborts.

# Seven families, about 270 columns per border.

## calendar

Season as a circle, so 31 December sits next to 1 January. Holidays for all five countries — **a holiday next door but not in CH is exactly when flows turn.**

## exogenous

Residual load, wind, solar and load — mostly **as a difference to Switzerland**, plus their ramps. The gap drives the flow, not the level.

## NTC + scarcity

Capacity per direction, and the flow as a share of it. **800 MW on a 1 000 MW line is a different world** from 800 on 4 000.

## lags $\geq 168$ h

The same flow one, two, three and four weeks ago. Cross-border flows are **strongly weekly** — this is the workhorse.

## same-hour stats

What a typical Tuesday 14:00 looks like on this border, as a median over 4, 28 and 84 days.

## deviations

The lag against its own typical week. Answers one question: **was last week normal**, or was there an outage?

## origin level

The state of the system at the moment we hit send. Not one hour — **the context all 168 forecasts sit in.**

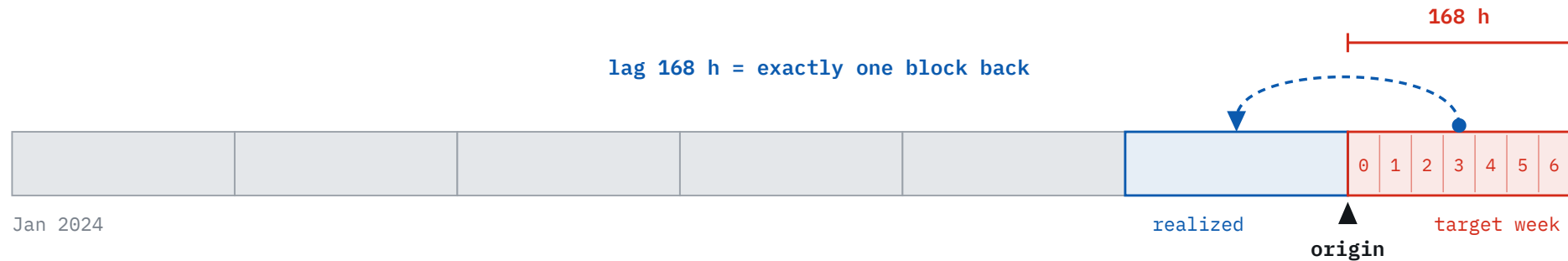
## what gets dropped

Anything missing in more than **20 % of the target week** is removed before training. The dropped list is printed on every run — that is where a failed data source shows up.

■ known before the week starts ■ derived from the border's own realized past — hence every lag  $\geq 168$  h

■ a rule we impose on ourselves

# Every training row is dressed like a real forecast row.



the same 168-hour grid runs back through the whole history — the target week splits into its 7 lead days

## the pseudo origin

A row from March 2024 is treated exactly like one from the target week: it knows **how far it sits from its own forecast moment**. `lead_day` becomes a feature, so day 6 may behave differently from day 0.

## the data cut

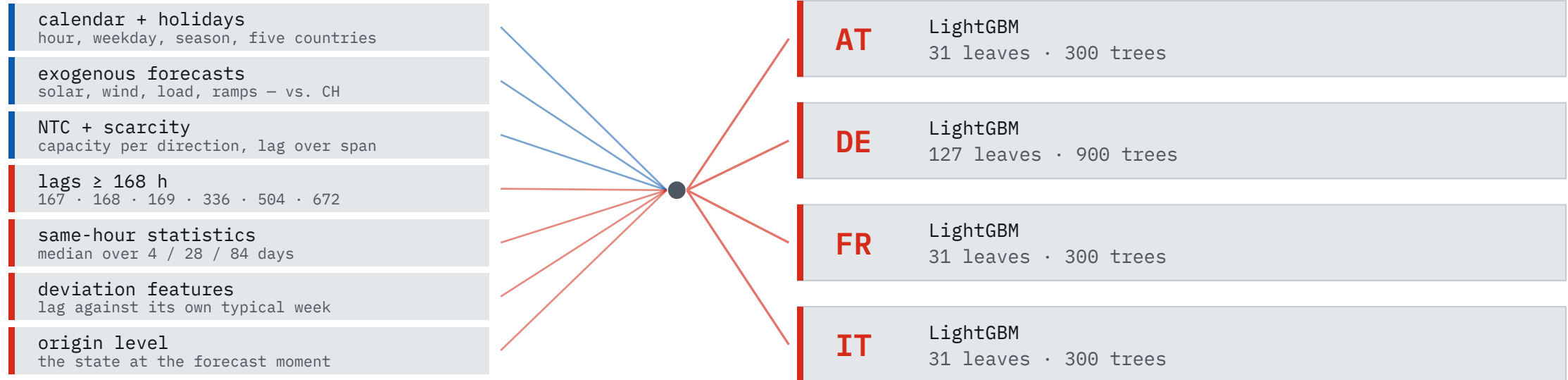
Nothing is computed up to the origin, only up to **origin minus the real gap**. The backtest therefore gets exactly as little information as the live submission — no flattering hindsight.

## four identical frames

All four borders carry **the same column names**, so there is one feature list and one training path. Nothing can quietly drift apart between AT and IT.

The leak test is a proof, not a promise: in the target week **y is completely empty while every lag is complete**. If that holds, none of those values can have come from the week we are predicting.

# Seven feature families, one model per border.



## one tree

A cascade of yes/no questions — weekend? after 18:00? was the flow above 500 MW a week ago? Each end point is a **leaf**. num\_leaves is how finely the tree may cut the world: 31 here, **127 for DE**.

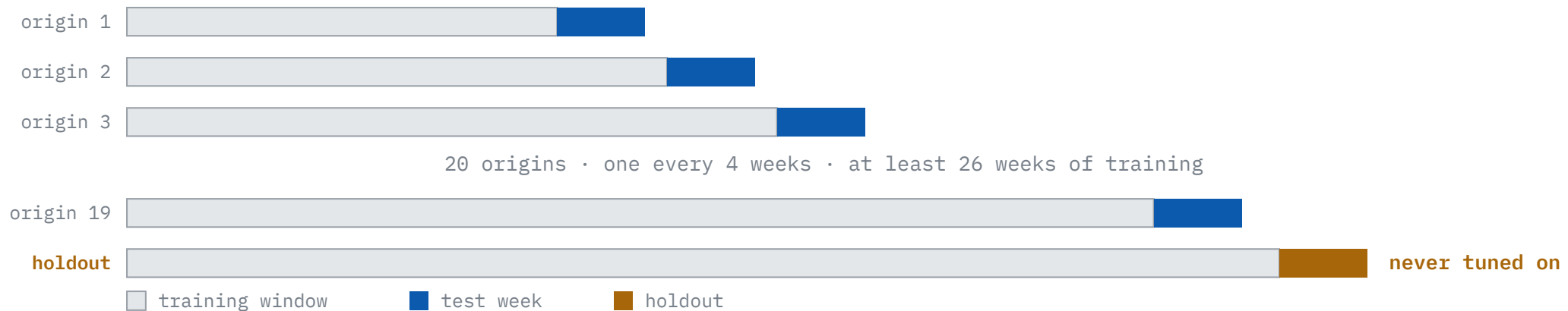
## boosting

Tree two does not learn the flow. It learns **the error tree one left behind**, and so on for three hundred rounds. The learning rate, 0.03 to 0.06, decides how much of each correction is kept.

## l1 or l2

l1 counts the error plainly and lands on the **median** — robust against outliers. l2 squares it and lands on the **mean**, which is exactly what RMSE rewards.

# Twenty origins, four borders, one week nobody touched.



## the baseline

A forecast is never good on its own, only better than something dumb. Ours is “**this week will look like last week.**” Every number in the grid search is measured relative to it.

## the holdout

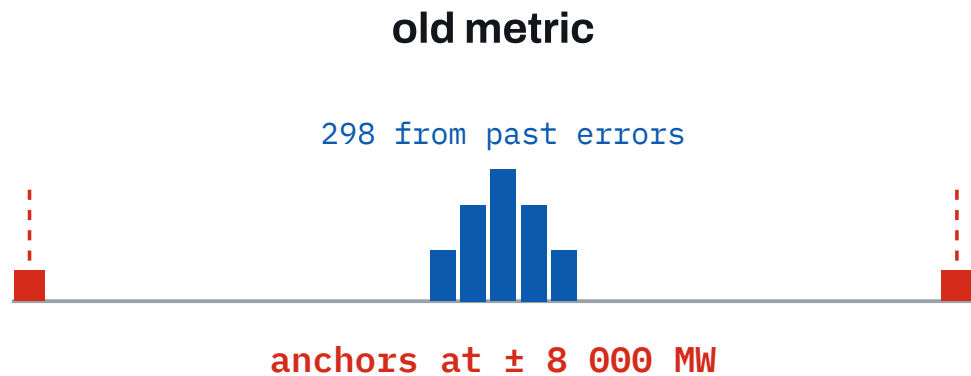
The last of the twenty weeks is never looked at. While tuning you inevitably start fitting the test weeks — that is **overfitting**. The holdout is the one honest number left over.

## blend and clip

What ships is  $w \times \text{model} + (1-w) \times \text{the naive week}$ ,  $w$  chosen leave-one-week-out. Then clipped to the NTC, because a flow above capacity is simply impossible.

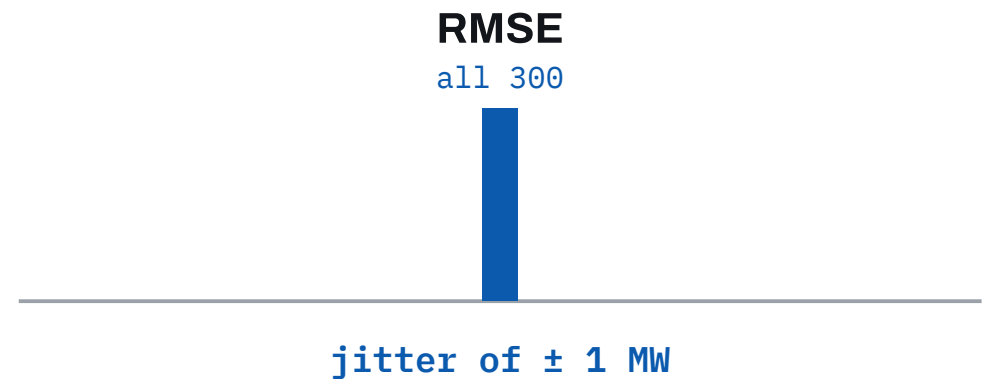
Rows weighted by recency, **half-life 365 days** · grid search: 8 settings × 6 tree counts × 3 weeks × 4 borders, ranked on **0.65 × mean + 0.35 × worst week.**

# One forecast, 300 numbers, two ways to package it.



## where the uncertainty comes from

From the **residuals** — the model's own past errors, collected separately for each hour of the day. If it typically missed by 180 MW at 14:00, that is the honest width for 14:00. A lead-time factor widens day 7 against day 1.



## and where it stops mattering

Under RMSE only the mean of the 300 counts, so the shape is irrelevant. All 300 sit on the rounded forecast; the  $\pm 1$  MW jitter exists purely so the standard deviation is not **zero** and the schema check passes.

The anchor distance D is a deliberate team decision, not a search result. **The old metric rewards a larger D monotonically** — without a ceiling the design keeps widening and optimises the metric instead of the forecast.

# Two tracks, two metrics.

## OLD SCORING

**97.357746 %**

**Approach A · far anchors**

capture · error · sharpness

ceiling is 97.357982 % — no model trained

## RMSE SCORING

**27.615 %**

**Approach B · LightGBM**

4 models, one per border

L1 objective, trained from 2024