SAMPLE REPORT

Scoped Diagnostic Windfarm A — 6 × 2.05 MW onshore

Twelve months of 10-minute SCADA, screened for underperformance, availability and curtailment losses, with recoverable energy quantified per turbine and a prioritised action list.

PERIOD
Jan–Dec 2025

DATA
10-min SCADA · 6 turbines · 52,560 records / turbine

PRODUCTION
40,509 MWh

RECOVERABLE ENERGY IDENTIFIED
569 MWh/yr technical, annualised (1.3 % of expected; 433 MWh recorded in the 12-month dataset) + up to 101 MWh/yr conditional

This sample uses a synthetic SCADA dataset built on a 2.05 MW turbine power curve with realistic turbulence, downtime, curtailment and three injected faults. The structure, method and depth are identical to a client deliverable; client data is never shown in samples. Prepared by Spenta Power, Tokyo.

Four findings. Two cost energy, one is a false alarm, one is a permit question.

TECHNICAL OPPORTUNITY (FINDINGS 1–2)

569 MWh/yr

annualised (433 MWh recorded Jan–Dec) · ≈ €37 k/yr at €65/MWh · 1.3 % of expected production · realisation depends on cause confirmation and post-correction performance

CONDITIONAL OPPORTUNITY (FINDING 4)

≤ 101 MWh/yr

noise-curtailment energy; recoverable only to the extent the permit allows a narrower window — not yet verified

#	FINDING	TURBINE	ENERGY	CONFIDENCE	ACTION
1	Partial-load underperformance since 10 April; power curve 8–12 % below fleet in 6–11 m/s	WT03	**282 MWh recorded Apr–Dec ≈ 418 MWh/yr if uncorrected**	High (effect) · Medium (cause)	Pitch / controller hypothesis: request parameter change log and pitch readouts; confirm before action
2	Direction-dependent deficit consistent with ≈ 10° yaw misalignment, present all year	WT02	**151 MWh/yr (2.4 %)**	Medium	Nacelle-direction calibration check; LiDAR or nacelle-mounted verification if OEM disputes
3	Nacelle anemometer transfer function shifted +3 % in August — turbine performance unchanged	WT05	0 MWh (false alarm)	High	Recalibrate / replace anemometer; close OEM "underperformance" ticket
4	Night-time 800 kW cap, Jun–Sep, sector 120–280° — noise curtailment as implemented	WT06	101 MWh/yr (conditional)	High (effect)	Reconcile implemented window against the permit; quantify by sector and hour if a narrower window is allowed

Why this is not visible in the OEM monthly report for this farm

The OEM availability report reviewed for this farm scores each turbine against its own nacelle anemometer, as is common though not universal. A turbine with a misaligned yaw reference or a drifting anemometer then looks healthy, or looks faulty for the wrong reason. This diagnostic checks every nacelle sensor against the other turbines first and then scores performance against a reference curve built from the most stable machines on site (WT01, WT04), so sensor problems and genuine turbine problems separate — Finding 3 is the direct example.

Recommended sequence

- **Week 1:** raise WT03 with the OEM including Figure 1; request pitch-angle readouts and the controller parameter change log for 1–20 April, plus the service record for that window.
- **Week 1:** close the WT05 underperformance ticket; schedule anemometer recalibration at the next service visit.
- **Week 2–4:** WT02 direction-reference check; if a sensor offset is confirmed, correction is a parameter change subject to OEM approval.
- **Within quarter:** reconcile the WT06 curtailment settings against the noise permit; a sector-by-hour energy breakdown is available on request to size the recoverable share.

Energy values are relative to the fleet reference power curve (Section 2), not to the pre-construction P50; components and residual are reconciled in Section 4. Revenue at €65/MWh is a placeholder.

What was analysed and how

Inputs

- 10-minute SCADA, 6 turbines, Jan–Dec 2025: active power, nacelle wind speed and direction, status / alarm codes, ambient temperature and pressure (pressure from the met mast; nacelle pressure where available).
- Layout and turbine specification (hub height, rotor diameter, warranted power curve) for wake-sector definition.
- Curtailment schedule, noise permit, OEM availability reports and service / parameter-change records — used for cross-checking and cause attribution, not as scoring inputs.

Filtering

- Records flagged stopped, starting, curtailed or with communication gaps are excluded from power-curve scoring and accounted for separately as downtime / curtailment.
- Suspected icing (temperature < 2 °C with anomalous power) excluded from the reference curve.
- Density correction to 1.225 kg/m³ per IEC 61400-12-1.

Reference power curve and scoring

Two reference turbines (WT01, WT04) are selected for stable nacelle transfer functions, no sustained alarms and unobstructed exposure in the prevailing sectors. Their density-corrected power is binned at 1 m/s against their own nacelle wind speed (≥ 30 records per bin) to form the reference curve.

Each turbine's expected energy is then computed from *its own* nacelle wind speed — after that signal has been checked against the reference turbines in wake-free sectors and corrected where the transfer function has shifted (Finding 3). Wake-affected sectors (layout-derived, ±15° around each upwind neighbour) are excluded from scoring. Scores are reported in 30° direction sectors and aggregated.

- **Power-curve performance:** actual ÷ expected energy over available, uncurtailed, wake-free records; the denominator is the expected energy of those records from the reference curve. Loss figures in MWh are those recorded in the 12-month dataset and are not extrapolated to excluded periods, except where explicitly annualised.
- **Downtime loss:** expected energy during unavailable periods. **Curtailment loss:** expected minus actual during flagged curtailment.
- **Significance:** the four unaffected turbines scatter ±0.1 % around the reference; deviations beyond ±1 % are reported as findings. Bin-wise bootstrap confidence intervals are included in the full deliverable.

TURBINE	PRODUCTION MWH	AVAILABILITY	PC PERFORMANCE VS REFERENCE	DOWNTIME LOSS MWH	CURTAILMENT MWH
WT01	6,630	97.7 %	+0.0 %	165	–
WT02	6,119	97.1 %	-2.4 %	225	–
WT03	6,894	97.5 %	-3.9 %	177	–
WT04	7,051	96.4 %	-0.0 %	254	–
WT05	6,944	95.3 %	-0.1 %	316	–
WT06	6,871	97.5 %	+0.2 %	146	101

Percentages are relative to the mean of the two reference turbines, which is why WT01 and WT04 read 0.0 %. The same values appear in Figure 2.

FINDING 1 · WT03 · EFFECT: HIGH CONFIDENCE · CAUSE: HYPOTHESIS

Partial-load underperformance from 10 April: 282 MWh recorded Apr–Dec (−3.9 %), ≈ 418 MWh/yr if uncorrected

WT03 tracked the fleet reference until early April, then dropped 8–12 % below it between 6 and 11 m/s while reaching rated power normally. The deficit is largest at low wind speed and closes toward rated. This shape is most consistent with a pitch-angle offset or a changed controller parameter; an aerodynamic cause (leading-edge erosion, damaged add-ons) cannot be excluded from SCADA alone and would normally also depress the knee of the curve, which is not seen here. No alarm accompanies the change and the OEM report shows WT03 at 97.5 % availability. The energy figure is the loss recorded over the 266 days from onset to year end; the annualised value assumes the fault persists and scales by the share of annual expected energy falling in that window (67.5 %), not by calendar days.

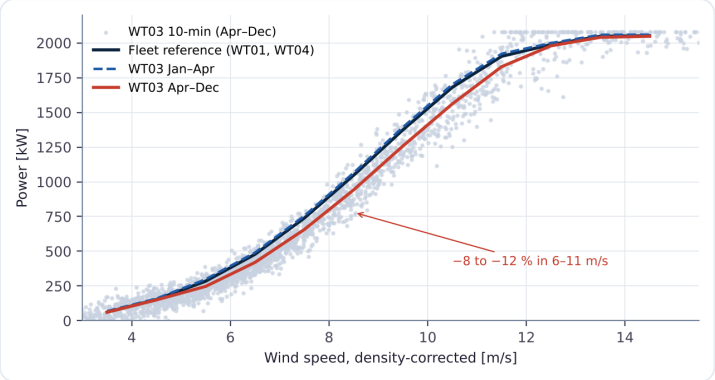


Figure 1 — WT03 binned power curve before and after 10 April against the fleet reference. Grey points: 10-min records Apr–Dec.

Action: request pitch-angle readouts, the controller parameter change log and the service record for 1–20 April. Confirm the cause before scheduling a correction; if a parameter or pitch offset is confirmed, correction normally needs no component replacement.

FINDING 2 · WT02 · MEDIUM CONFIDENCE

Direction-dependent deficit consistent with ≈ 10° yaw misalignment: 151 MWh/yr (−2.4 %)

WT02 underperforms the reference by a near-constant fraction below rated wind speed and by nothing above it — the pattern a yaw error produces (power scales roughly with $\cos^2$–$\cos^3$ of the misalignment). Its nacelle-direction signal also sits ≈ 10° off the site wind direction derived from the other five turbines, in all sectors and months. A direction-reference calibration error or a local flow effect can produce a similar offset, so the finding is a hypothesis to verify: a nacelle-direction calibration check is a short task for the service team, and LiDAR-based yaw verification is available if the OEM disputes it. If a sensor offset is confirmed, correction is a parameter change, subject to OEM approval.

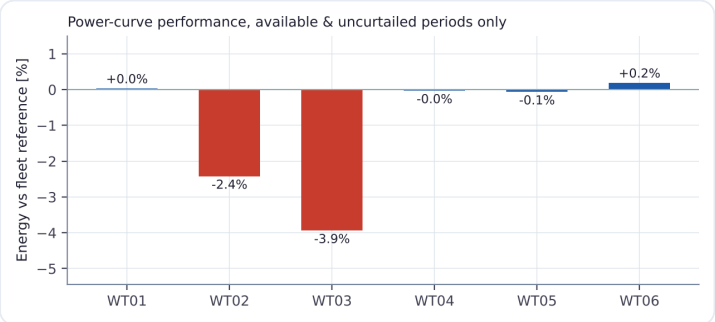


Figure 2 — Power-curve performance per turbine relative to the reference mean (same values as the table in Section 2). Only WT02 and WT03 exceed the ±1 % reporting threshold.

FINDING 3 · WT05 · FALSE ALARM · HIGH CONFIDENCE

Nacelle anemometer transfer function shifted +3 % in August — turbine performance is unchanged

Against its own anemometer, WT05 appears to lose roughly 8–9 % of energy from August: the same indicated wind speed now "produces" less power. Against the reference turbines it performs exactly as before. The transfer function between WT05's nacelle wind speed and the reference changes slope from 1.03 to 1.06 at the start of August (a +2.7 % step; in the near-cubic part of the curve a 3 % speed error is an 8–9 % power error), while power against reference wind speed does not change. The instrument moved, not the turbine. Nacelle transfer functions also vary with turbulence and stability (Clifton et al., NREL 2017), which is why the comparison is made per sector and the step is confirmed in all of them.

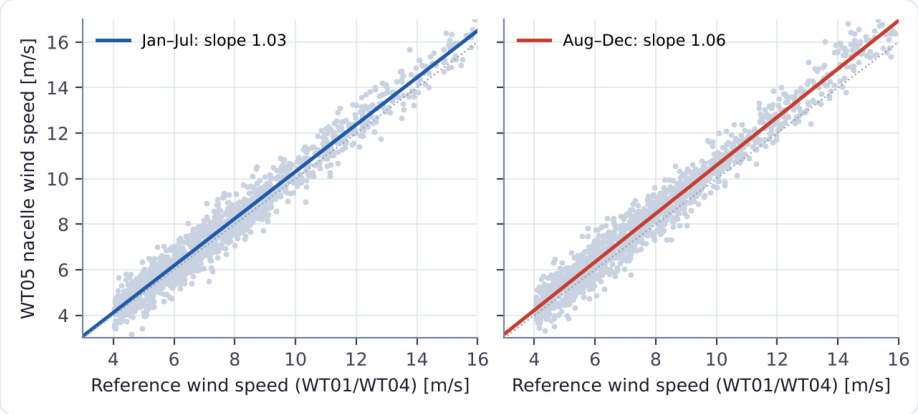


Figure 3 — WT05 nacelle wind speed against the reference turbines, before and after 1 August. The slope step is the anemometer; power versus reference wind speed is unchanged.

Why it matters: a shifted anemometer silently biases power-curve warranty tests, availability-based bonus/malus calculations and the turbine's wind-speed-dependent control. **Action:** recalibrate or replace at the next service visit; close the OEM underperformance ticket opened in September.

FINDING 4 · WT06 · PERMIT QUESTION

Night-time noise curtailment, Jun–Sep, 22:00–06:00, sector 120–280°: 101 MWh/yr as implemented

Power is capped at 800 kW under exactly these conditions and nowhere else — a scheduled curtailment, not a fault. Whether any of it is recoverable depends on the permit: if the permitted window (hours, sectors, wind-speed or season conditions) is narrower than what is implemented, the difference can be released by a settings change after the operator's and, where required, the authority's confirmation. The sector-by-hour energy distribution needed to size that share is part of the full deliverable; no recoverable fraction is claimed here.

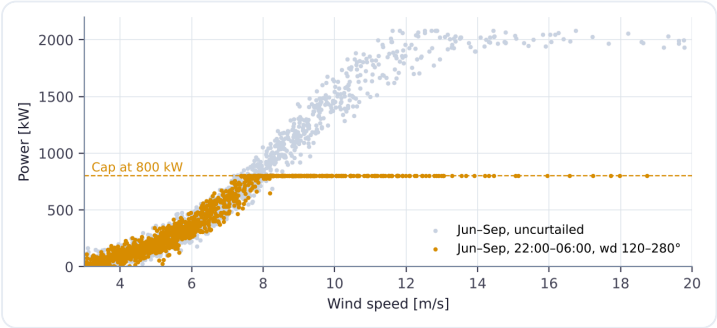


Figure 4 — WT06 summer records; amber points are the curtailed condition. The cap is clean and reproducible.

Where the energy went

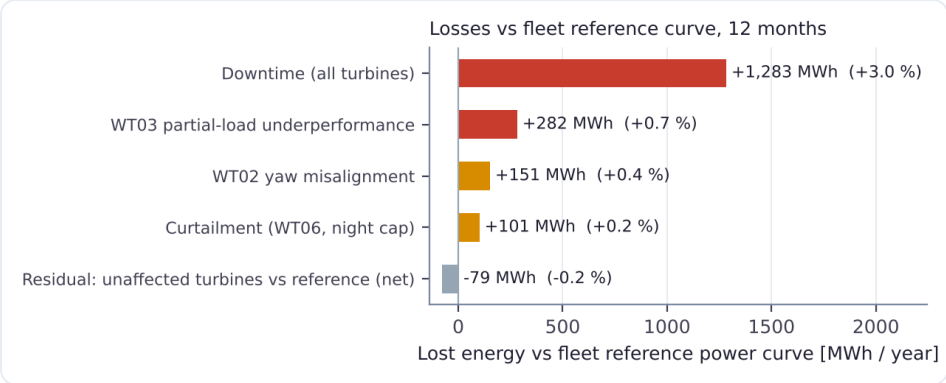


Figure 5 — Twelve-month reconciliation against the fleet reference power curve: 42,247 expected − 1,283 downtime − 282 WT03 − 151 WT02 − 101 curtailment + 79 residual = 40,509 MWh actual. The residual (+0.19 % of expected) is the net difference between the reference-curve expectation and the sum of the quantified components across all six turbines; it is of the same order as the per-turbine scatter of the unaffected machines (σ = 0.1 %, max 0.2 %) and is not attributed to any turbine-specific cause.

Availability

Fleet time-based availability 96.9 %; energy-based 97.0 %. WT05's nine-day main-bearing replacement accounts for roughly a quarter of all downtime energy. No turbine shows the repeated short stops that indicate a developing fault.

What was not found

- No within-year power-curve trend on WT01, WT04, WT05, WT06 (quarterly scores within ±0.5 % of each other). A year-on-year comparison requires the previous year's data.
- No icing losses beyond the expected January–February level.
- No wake-sector anomalies beyond the layout-predicted pattern.

Scoped Diagnostic — what a client receives

- This report on the client's own data, within four to six weeks of receiving a complete data set.
- Per-turbine evidence package (figures, binned curves with confidence intervals, event lists, sector tables) ready to forward to the OEM.
- One review call to walk through findings and the OEM response strategy.
- Optional monthly monitoring on the same method, so that the next WT03 is caught in week two, not month eight.

Data needed to start

10-minute SCADA for ≥ 12 months (power, nacelle wind speed and direction, status codes, temperature, pressure); layout and turbine specification; curtailment settings and the noise permit if any; service and parameter-change records (for cause attribution); OEM monthly reports (for reconciliation).

Spenta Power is an independent wind resource and performance analytics practice. We hold no service, supply or ownership interest in any turbine, OEM or project — which is the point of an independent review. info@spentapower.com · spentapower.com