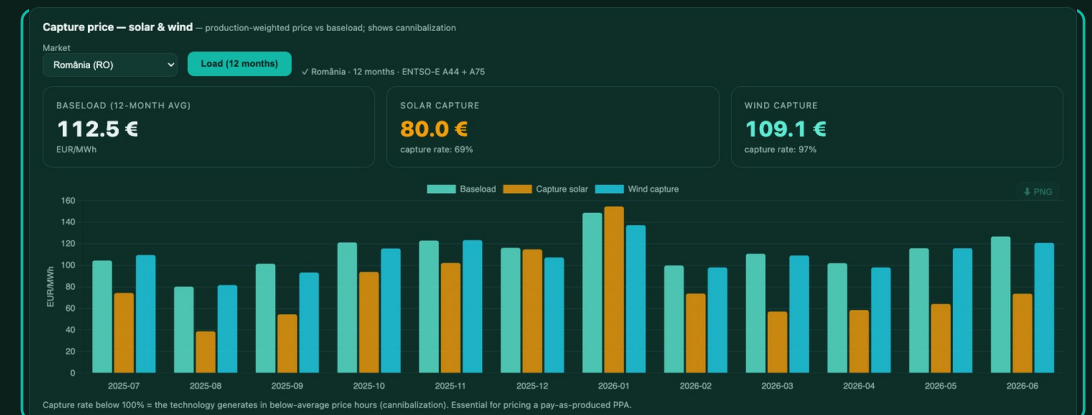




Real-Time European Energy-Market Analytics

Three products on one live data engine: grid observability, trading & PPA analytics, and renewable-asset investment simulation — built end-to-end, single-handedly, on real ENTSO-E market data.

Claudiu Bocse · Energy Analytics & AI · Product case study, July 2026 · Live demo available on request



The energy transition broke the old market playbook

Wind and solar made power cheap — and prices wild. Every supplier, trader and asset owner now needs hour-by-hour analytics that used to be reserved for utility trading desks. These are real numbers the platform measured on the Romanian market in July 2026:

€267

average intraday price spread (daily max – min, 30 days) — the battery-storage opportunity

19 hrs

of negative prices in 30 days — solar oversupply is already here

69%

solar capture rate — solar earns 31% below baseload (cannibalization)

€124

avg. cost per MWh of forecast error (imbalance vs day-ahead)

What this means

- Suppliers bleed money on forecast errors — a 5 GWh/month portfolio with 4% error loses ≈ €28,700 every month on imbalances alone.
- PPA prices signed on baseload assumptions overpay solar by ~30% — capture-rate analytics are now essential to price any renewable contract.
- Volatility is the new asset class: a 1 MW battery arbitraging the daily spread would have earned €13,600/month on day-ahead prices alone.

Three products, one live data engine

the platform

Energy Observability

Free public dashboard: real-time load, generation mix, prices, CO₂ intensity, self-sufficiency, grid map. The audience funnel.

the platform TRADE

Markets • Imbalances • PPA

B2B analytics desk: cross-market spreads, capture prices, PPA simulator, imbalance cost, volatility, cost-to-serve, PDF market reports, REST API.

the platform INVEST

Asset Simulation

Solar/wind park production forecasting (weather-driven), project profitability (IRR, payback, LCOE) and battery-storage arbitrage backtesting.

ONE ENGINE UNDERNEATH

4 data sources

ENTSO-E Transparency, OPCOM (RO power exchange), OpenStreetMap grid data, central-bank FX

25+ API endpoints

prices, load, generation, flows, capture, imbalance, forecasts — with a keyed B2B API v1

15+ EU bidding zones

every analysis runs on any market from one selector — RO, DE, FR, HU, BG, PL...

15-min ingestion

background poller with on-disk history, multi-layer caching, graceful degradation

Live grid observability, for anyone



Real-time market state

Load, generation mix, day-ahead price, cross-border flows — refreshed continuously from ENTSO-E.

CO₂ intensity model

Emissions factor per source, weighted by the live mix — plus a “green & cheap” consumption signal.

CO₂ avoided tracker

Cumulative tonnes displaced by renewables, from the platform's own 15-min history.

Installable PWA

Offline-capable app, kiosk/TV mode for control rooms, bilingual EN/RO, PNG/CSV export.

Self-sufficiency & the residual curve



The metric behind the price

- Residual load = demand - wind - solar: the demand that dispatchable (and expensive) plants must cover. It explains why prices explode at sunset.
- Self-sufficiency tracks how much of national demand is covered domestically vs. imported, hour by hour.
- Computed live and historically for every supported bidding zone, from raw ENTSO-E generation & load series.
- This is exactly the feature set a price-forecasting ML model needs — engineered and validated here first.

Cross-market spreads & volatility intelligence

Cross-market spread — day-ahead, arbitrage opportunities between zones

Market A: România (RO) Market B: Ungaria (HU) Range: Last 7 days Calculate ✓ 213 common hours · ENTSO-E A44

AVERAGE SPREAD (A - B)

-4.49 €

RO - HU · EUR/MWh

MAX SPREAD

-86.3 €

Jul 13, 09 AM

HOURS WITH A PRICIER

25 %

of common hours

ARBITRAGE VALUE 1 MW

1,276 €

$\Sigma [\text{spread}] \times 1 \text{ MWh}$ over 213 hours



Any two markets

Day-ahead spread between any EU zones: average, extremes, % of hours in the money, arbitrage value per MW.

-€4.5 avg · -€86 peak

RO-HU spread over 7 days: Romania trades cheaper — and the border flips 25% of hours. Real, current numbers.

Volatility & price context — last 30 days, for timing

Market: România (RO) Analyze ✓ România · 32 days · ENTSO-E A44

TODAY'S PRICE PERCENTILE

85 %

vs last 30 days

AVERAGE INTRADAY SPREAD

267.3 €

daily max - min (battery arbitrage)

NEGATIVE-PRICE HOURS

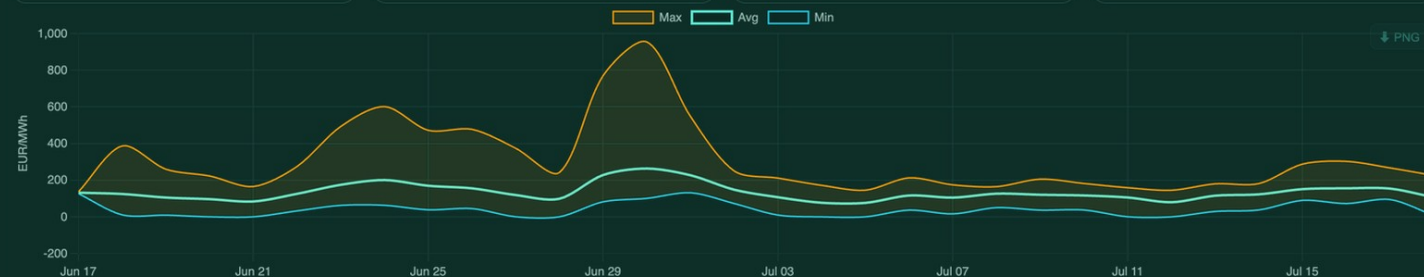
19

of 738 hours

STANDARD DEVIATION

103.8 €

on hourly prices



Price percentile & σ

Today at the 95th percentile of the last 30 days, $\sigma = €104$ — instant context for “buy now or wait”.

For whom

Traders timing cross-border positions, suppliers timing purchases, storage developers sizing the opportunity.

Capture price: quantifying solar cannibalization

Capture price — solar & wind — production-weighted price vs baseload; shows cannibalization

Market

România (RO)

Load (12 months)

✓ România · 12 months · ENTSO-E A44 + A75

BASELOAD (12-MONTH AVG)

112.5 €

EUR/MWh

SOLAR CAPTURE

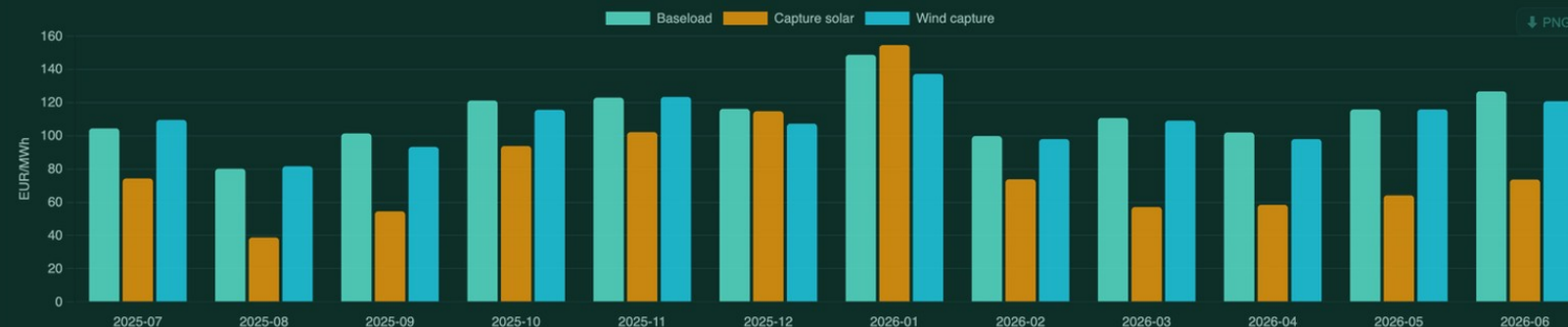
80.0 €

capture rate: 69%

WIND CAPTURE

109.1 €

capture rate: 97%



Capture rate below 100% = the technology generates in below-average price hours (cannibalization). Essential for pricing a pay-as-produced PPA.

€113.7

baseload (12-month average price)

€80.5 · 69%

solar capture price & rate — solar earns 31% below the market

€110.1 · 97%

wind capture — wind is barely cannibalized

Why this is the money chart

Every pay-as-produced PPA, every solar park business case and every merchant-revenue forecast depends on the capture price — not the average price. the platform computes it monthly from raw hourly generation × price data, for any EU zone, and benchmarks zones side by side (RO solar 65% vs HU 69% capture in the multi-country comparison). The built-in PPA simulator then prices fixed-strike vs merchant on this real history.

Imbalance analytics: the cost of being wrong



€124 /MWh

average cost of forecast error (|imbalance – day-ahead|)

€873

single worst hour in 7 days — tail risk is enormous

€28.7k /mo

simulated loss: 5 GWh/month portfolio at 4% forecast error

Engineering note

Imbalance prices arrive from ENTSO-E as zipped XML, priced in local currency (RON). The pipeline detects and unpacks the archive with a dependency-free ZIP reader, merges multi-day documents, converts at the central-bank rate, aligns to day-ahead hours, and derives the error-cost metric — all validated by offline self-tests. The portfolio simulator turns it into a number a CFO understands.

Storage arbitrage, backtested on real prices



€14,063

revenue in 30 days — 2 MWh / 1 MW battery, 88% round-trip

€13.6k /MW·mo

one conservative cycle per day, day-ahead only

€227

average spread captured per cycle (net of efficiency)

Honest by design

The strategy is deliberately simple — charge the cheapest hours, discharge the most expensive, one cycle/day — so the result is a floor, not a promise. A real operator adds intraday and balancing revenue on top. the Invest module pairs this with weather-driven production forecasting (solar irradiance + wind power curves), PVGIS yield estimation and full project economics: IRR, payback, LCOE, battery arbitrage — per location, per market.

Engineering: resilient by construction

Data pipeline

Custom parsers for 6 ENTSO-E document types (XML + zipped XML), an HTML scraper fallback for the RO power exchange, FX from the central bank — every source wrapped in timeouts, TTL caches and per-source health status.

Graceful degradation

Promise-level isolation per source: if one feed fails the rest keep serving; the UI labels simulated fallbacks honestly. Offline self-test suite validates every parser and derived metric without network.

Productized

Three branded fronts on one engine (route-based), keyed REST API v1 with rate limiting, PDF report generator, installable PWA with a versioned service worker, kiosk mode, i18n — plus Docker/Render deploy config.

Stack: Node.js/Express · vanilla JS · Chart.js · Leaflet · PWA/Service Worker · jsPDF · Docker — ~5,500 lines, zero heavy frameworks, built and shipped solo with AI-assisted development

The platform is the feature store an ML layer needs

Every model below consumes features the platform already engineers, validates and stores today:

1 Price forecasting (24–48h)

Residual load, wind/solar forecasts (ENTSO-E A69), price history and cross-border spreads are already aligned hourly — the exact feature set for short-term price models.

2 Imbalance risk prediction

Historical imbalance vs day-ahead deltas per hour enable models that warn suppliers when forecast errors will be most expensive — turning the €124/MWh average into an avoidable cost.

3 Battery dispatch optimization

The backtester is the evaluation harness: any RL/optimization dispatch policy can be scored against the greedy baseline on real prices before touching hardware.

4 Renewable yield nowcasting

Weather-driven production models (irradiance, wind power curves) already run in the Invest module — the step to ML-corrected forecasts per asset is incremental.

Same physics, US markets

Every metric in this deck maps one-to-one onto US ISO/RTO markets. The data sources change - the analytics, simulators and reports do not.

Day-ahead & imbalance

EU: ENTSO-E day-ahead (A44) & imbalance (A85). US: ERCOT / CAISO / PJM day-ahead & real-time LMPs - imbalance economics = the DA vs RT settlement spread.

Capture rate & cannibalization

The same production-weighted metric drives solar economics in ERCOT West and the CAISO duck curve - US solar shows the same 60-70% capture pattern measured here.

Residual load = net load

The EU residual curve is exactly CAISO "net load" (the duck curve). The engineered feature set for price forecasting is identical across markets.

Storage arbitrage

DA/RT spread arbitrage plus ancillary services (ERCOT). The backtesting harness ports directly - only the price feed changes.

Porting is an adapter task, not a rebuild

Swapping ENTSO-E for US ISO feeds (gridstatus, EIA, ISO APIs) touches only the ingestion layer: every downstream metric, PPA simulator, storage backtest and PDF report runs unchanged. The same is true for NYISO, MISO or SPP.

What this project demonstrates

Energy-market depth

Capture rates, imbalance mechanics, merit order, PPA structures, storage economics — applied, not academic.

Full-stack delivery

From raw TSO data feeds to three shipped products with API, PWA and reporting — designed, built and tested solo.

AI-ready thinking

Feature engineering, backtesting harnesses and honest evaluation baselines — the groundwork ML teams need.

Claudiu Bocse

Energy analytics & AI · creator of the platform (product case study)

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Live demo available on request — the platform runs on real market data, every number in this deck is reproducible.