



Mitigating Model Bias in Conjunction with Variability-Driven Financial Risks in Solar PV Projects

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Key Results

- Portfolio shortfalls put \$100 million/GW of solar photovoltaic (PV) value at risk. Stakeholders need better approaches to measure, manage, and mitigate such risks.
- The net effect of year-over-year random variability (a.k.a. *aleatoric uncertainty*) diminishes over project life, but model bias (a.k.a. *epistemic uncertainty*) persists.
- Root-sum-of-squares (RSS) uncertainty quantification (UQ) conflates these two uncertainty types, reducing them into one combined metric with limited traceability.
- PowerUQ’s computational methodology quantifies resource, equipment, and grid variability *separately* from model-parameter uncertainty in solar PV projects.
- Distinguishing between these uncertainties enables risk-weighted decision making about the resulting financial risks across the stages of a project’s lifetime.
- Monte-Carlo sampling estimates year-by-year downside, base, and upside generation distributions, as well as joint/marginal credibility distributions of P90 & P50.

Model Inputs with Uncertainty

Module

Make: Trina Solar | Model: TSM-645DEG21C.20

Length [m]: 2.384 | Width [m]: 1.303

Max Power at STC [W]

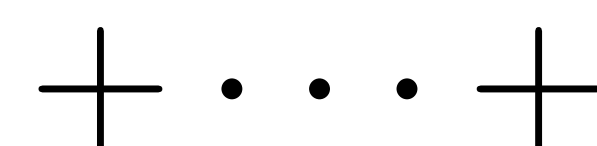
Lower: 630.00 | Nominal: 645.00 | Upper: 650.00

Temperature Coefficient of Max Power at STC [%/°C]

Lower: -0.43 | Nominal: -0.39 | Upper: -0.35

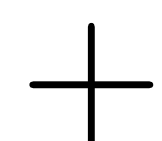
Model Bias in DC Power [%]

Lower: -0.50 | Nominal: 0.00 | Upper: 0.50



Weather Inputs with Uncertainty

25+ Years of Historic Weather



Weather (NSRDB PSM v3.2.2)

Global Horizontal Irradiance (GHI) Relative Uncertainty [%]

Lower: -5.00 | Upper: 5.00

Direct Normal Irradiance (DNI) Relative Uncertainty [%]

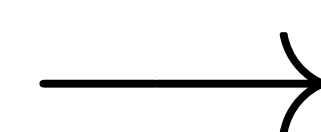
Lower: -10.00 | Upper: 10.00

Albedo Relative Uncertainty [%]

Lower: -10.00 | Upper: 10.00

Spectral Correction Relative Uncertainty [%]

Lower: -2.50 | Upper: 2.50



Yearly-Generation Distribution Scenarios for Out-Years 1, 5, and 20

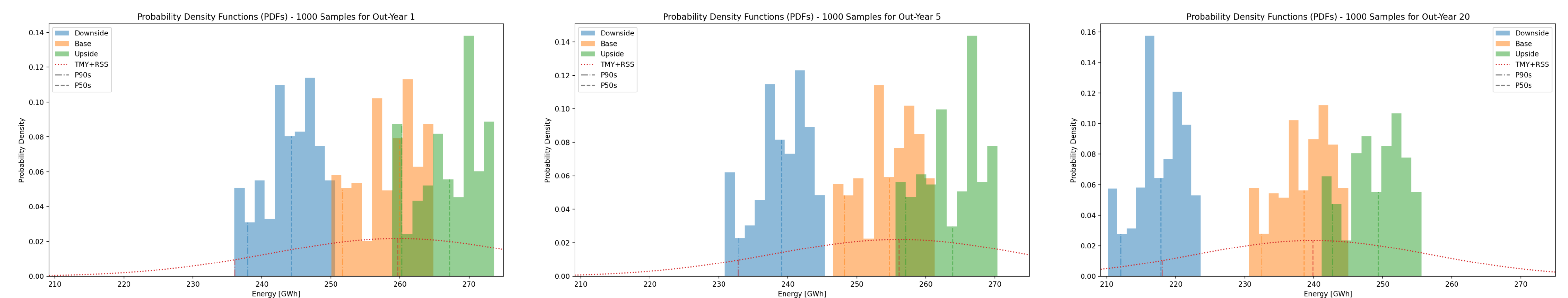


Figure: Empirical probability density functions (PDFs) for Downside, Base, and Upside yearly-generation scenarios, alongside a conventional TMY+RSS result, for project out years one, five, and twenty.

Average-Generation Distribution Scenarios for Thru-Years 1, 5, and 20

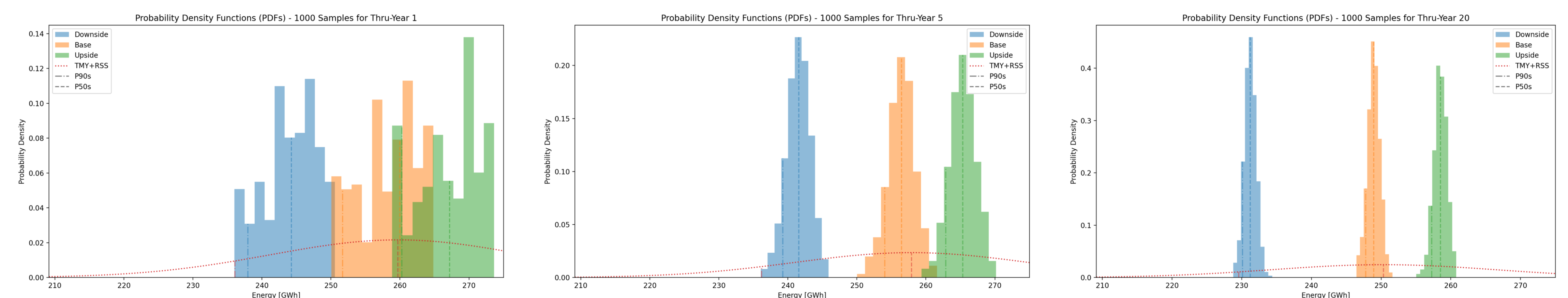


Figure: Empirical probability density functions (PDFs) for Downside, Base, and Upside average-generation scenarios, alongside a conventional TMY+RSS result, for project thru years one, five, and twenty.

P50 vs. P90 Credibility Distributions for Year 10 and Externally Calibrated Results

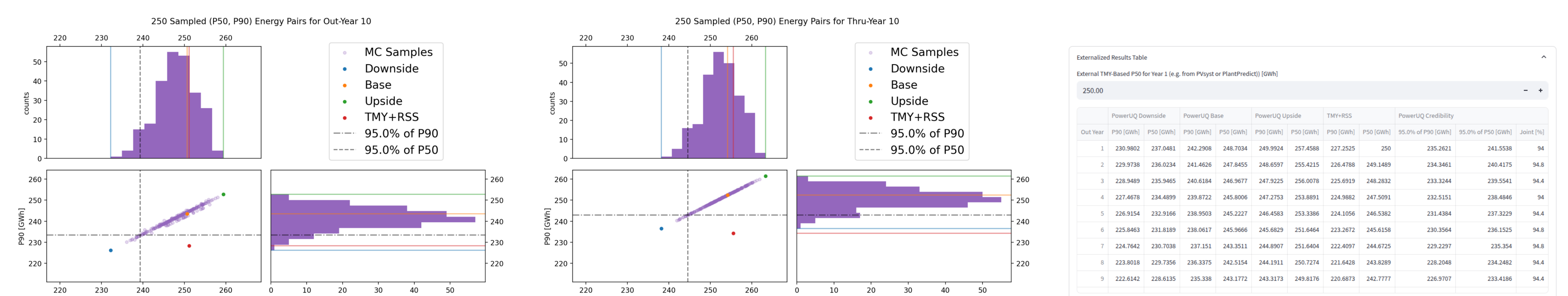


Figure: A comprehensive set of uncertain performance-model inputs. Each input parameter’s credibility is modeled by an appropriate probability distribution, which is derived from manufacturer’s or service provider’s materials, independent testing reports, or operational data.

Figure: Joint and marginal credibility distributions of P50 vs. P90 for the tenth out year and tenth thru-year average, with a multi-year-generation summary-results table calibrated to an externally computed TMY-production value for year one.