When RSS Breaks:
Clipping and the Limits of Symmetric Uncertainty

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Introduction

- In recent years, solar project uncertainty has emerged as an increasingly important metric for understanding energy production risk.
- Root sum of squares (RSS) has traditionally been the standard method for combining uncertainty types.
- While Monte Carlo (MC) is widely used in financial modeling, it has not become a standard in our industry.
- Since clipping is a hard physical limit and not a stochastic effect that averages out, applying a symmetric distribution around annual P50 ignores the fact that the system has a ceiling. MC avoids this by clipping at each hourly step within every simulation, then aggregating to annual production.

How does MC and RSS vary across the distribution?

Methods

- Sample: Selected 10 utility-scale projects (50–250MW each) across US climate zones; DC:AC ratios 1.3–1.4.
- Applied uncertainties to both Monte Carlo and RSS methodologies to compare upside versus downside cases for 10-year Pxx values.
- Monte Carlo: 5,000 ten-year iterations using Python to produce the simulated energy production distribution.
- Compared P1, P5, P10, P25, P50, P75, P90, P95, P99 from each method; deviations reported as (MC − RSS) / MC.
- Applied the same uncertainty types for all projects, combined as:

$$\text{Uncertainty Year 10} = \sqrt{\sigma^2_{Model} + \sigma^2_{Solar\ Resource} + \sigma^2_{Deg\ Unc} + \sigma^2_{IAV}}$$

Results

Across all 10 projects, RSS and MC agree closely on the downside (P90–P99), but RSS systematically overstates the upside (P1–P10) for clipped systems.

Example project — MC simulation vs. RSS Gaussian

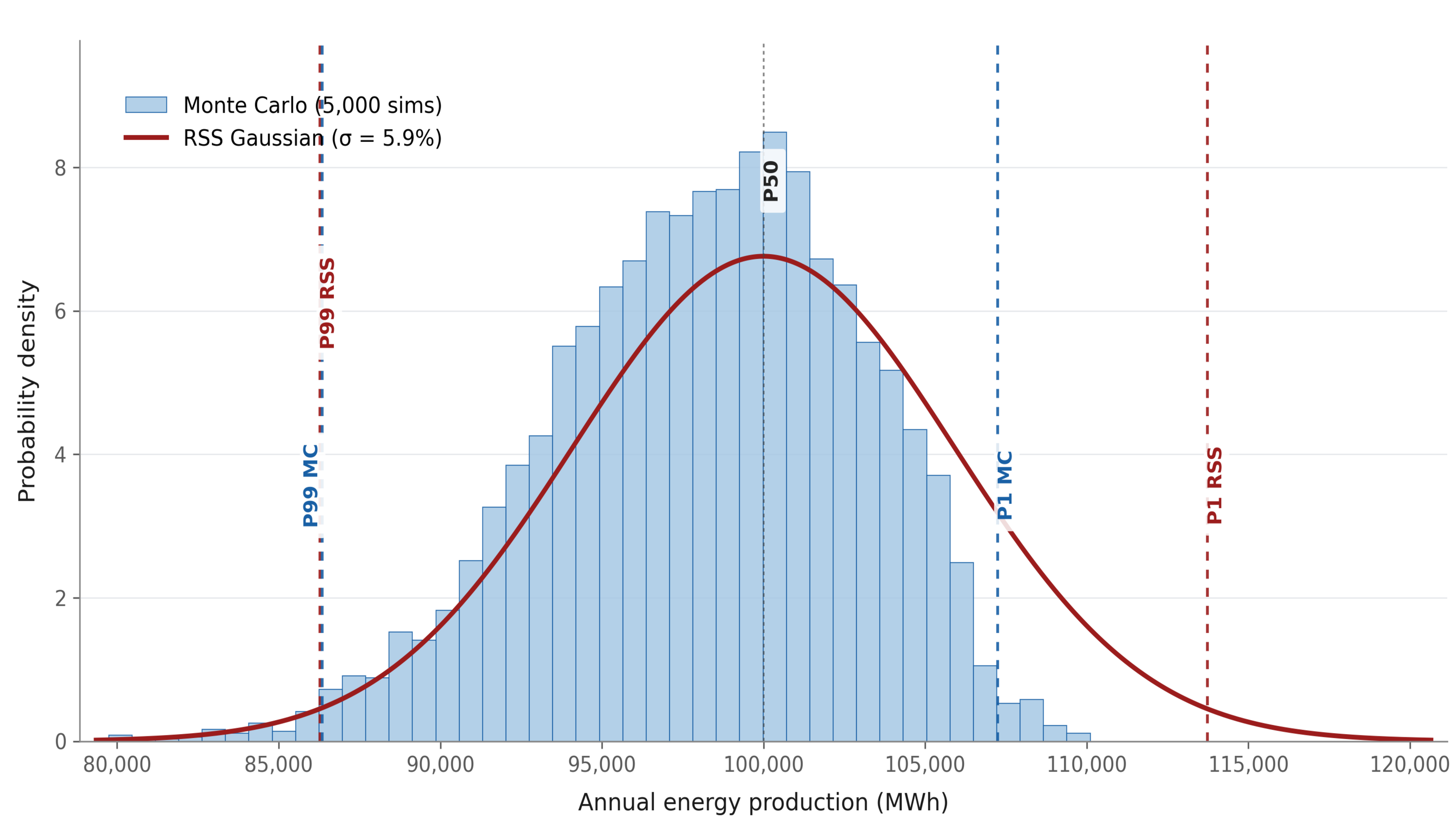

Figure 1 — Illustrative MC distribution vs. RSS Gaussian (10-year, σ = 5.9%) for representative project.

Cross-project deviations: Monte Carlo vs. RSS

(MC − RSS) / MC at each quantile · 10 utility-scale projects

	P99	P95	P90	P75	P50	P25	P10	P5	P1
	DOWNSIDE								UPSIDE
Prj 1	-2.6	-1.1	-0.7	-0.1	0.0	-0.3	-1.0	-1.5	-3.1
Prj 2	-2.6	-0.5	-0.2	+0.1	0.0	-0.4	-0.9	-1.5	-3.1
Prj 3	-2.5	-0.8	-0.4	-0.1	0.0	-0.4	-0.8	-1.2	-2.0
Prj 4	-2.3	-0.9	-0.4	0.0	0.0	-0.1	-0.5	-1.2	-2.8
Prj 5	-2.0	-0.6	-0.1	0.0	0.0	-0.4	-0.7	-1.1	-2.1
Prj 6	-1.8	-0.5	0.0	+0.2	0.0	-0.4	-1.2	-1.8	-3.4
Prj 7	-0.6	-0.3	+0.1	+0.4	0.0	-1.1	-2.4	-3.3	-5.1
Prj 8	+0.1	+0.2	+0.2	+0.3	0.0	-0.9	-2.0	-2.8	-4.6
Prj 9	+0.6	+0.8	+0.6	+0.4	0.0	-0.6	-1.7	-2.4	-4.4
Prj 10	+0.9	+0.6	+0.6	+0.4	0.0	-0.5	-1.5	-2.2	-3.7
Average	**-1.3**	**-0.3**	**0.0**	**+0.2**	**0.0**	**-0.5**	**-1.3**	**-1.9**	**-3.4**

Quantile · (MC − RSS) / MC [%]

Figure 2 — Cross-project deviation (MC − RSS) / MC at each quantile, 10-year simulations. Downside quantiles on the left, upside on the right.

Conclusions

- For debt sizing (downsides: P90–P99): RSS and MC downsides are similar across the 10 projects but appear to result in some variation as they approach the P99 quantile. Note: MC downside is highly sensitive to the degradation uncertainty model and inputs (not shown here).
- For equity analysis (upside: P1–P10): MC is likely more physically realistic because several underlying uncertainty sources are asymmetric (clipping, availability, soiling), violating RSS's symmetric assumption.
- Scope: 10 utility-scale projects, DC:AC ratios 1.3–1.4, US climate zones. Findings may not extend to higher clipping ratios or different system configurations.
- Future work: benchmark against measured performance data to assess accuracy, and test sensitivity to DC:AC ratios.
- This analysis covers technical uncertainty only. Commercial factors (O&M budget/plan, workmanship quality, spare parts, maintenance strategy, equipment selection, etc.) can significantly affect results.