Monte Carlo Simulation-Based Financial Risk Analysis of Hedging Strategies in Bitcoin Mining Operations (ERCOT, May 2025)

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Scope: Evaluating the financial and risk-mitigation performance of 7x24 electricity hedge strategies in Texas based Bitcoin mining operations for January. Monte Carlo simulations using Geometric Brownian Motion model price volatility to assess hedge effectiveness under various entry scenarios.

Executive Summary

**Profit figures exclude other operational costs*
**Bitmain Antminer S21 Pro in Normal Mode set as default miner*
**Figures represent simulated outcomes under 10,000-path Geometric Brownian Motion Monte Carlo modeling*

Hedging Strategies Delivered Strong Returns and Consistent Stability Across the Board:

- LZEW Hedges remained a top performer, offering Sharpe Ratios above 14 and volatility shielding of 73.34%, even when executed at suboptimal timing. The well-informed entry scenario yielded a Sortino Ratio of 24.39 with an average return of $104.48/MW, while cutting downside risk exposure to just -$2.99/MW. All entry scenarios for LZEW hedges maintained 0% probability of loss, underlining strong protective value.

- In contrast, the Unhedged mining strategy still posted a high mean return of $107.80/MW, but with far greater exposure: 26.70% volatility, tail gap of -$11.14/MW, and Value at Risk (95%) of $63.83/MW, proving that even strong returns in isolation carry hidden fragility.

All HB_WEST Hedging strategies slightly outperformed LZEW Hedges in raw returns, but without meaningful risk reduction improvements:

- Average returns under HB_WEST ranged up to $108.73/MW, yet tail gaps remained above -$3.10/MW and hedging efficiency trailed slightly at ~72.3%, indicating marginally lower downside shielding than LZEW hedges. Despite slightly higher top-line profits, the risk-adjusted gains didn't meaningfully separate the strategy.

HB_NORTH Hedges delivered solid profits, but suffered from higher volatility and less precise shielding:

- Though maximum profits reached $108.13/MW, the standard deviation for HB_NORTH Hedge strategies was the highest of all at ~$10.58/MW, and tail gaps exceeded -$4.45/MW, putting them well behind the other strategies in terms of consistency. Hedging efficiency was the lowest of the bunch at 60.4%.

Purpose

This report extends the prior analyses of hedging strategies in ERCOT-based Texas Bitcoin Mining Operations through the utilization of stochastic machine learning modeling methods. Monte Carlo Simulations and Geometric Brownian Motion were employed extensively to evaluate the risk-adjusted performance of 5 hedging strategies under volatile Real-Time Market pricing dynamics.

Monte Carlo simulation method was chosen due to its ability to generate a statistically significant range of outcomes based on the probabilistic characteristics such mean, and volatility of historical data. Given the highly volatile nature of the RTM in ERCOT where the price changes every 5 minutes, deterministic or single-scenario models were simply ineffective and insufficient to capture the full range of possible outcomes. For that reason, 1,000,000 million scenarios using the Monte Carlo simulation were simulated and stress-tested to ensure coverage of the full distribution of potential outcomes.

In addition, Brownian Motion and its exponential form, the Geometric Brownian Motion are commonly employed to simulate forward price paths and cumulative returns. Geometric Brownian Motion was particularly applicable in this study due its widespread and well-known application in financial modeling of assets where the prices changes are proportional to the asset's current value, this behavioral pattern is also observed in energy markets such as ERCOT and relevant for its compounding effects on energy-intensive operations such as Bitcoin Mining operations and Data Centers.

These stochastic models in the scope of this study offer a robust framework for evaluating risk through metrics like Sharpe Ratio, Value-at-Risk, and Conditional-Value-at-Risk) and helping quantifying hedge efficiency, downside protection, tail risks associated with different hedging strategies and entry price points.

Glossary

Metric	Formal Definition
Mean	The arithmetic average of simulated monthly profits, expressed in USD per MWh.
Standard Deviation	The standard deviation of simulated outcomes, representing the volatility or dispersion of results.
Loss Probability	The probability, expressed as a percentage, that the simulation yields a negative return (i.e., a financial loss).
Min/Max	The minimum and maximum profit values observed across the entire simulation, indicating extreme potential outcomes.
Sharpe Ratio	The Sharpe Ratio measures average return per unit of total risk. Higher values indicate better risk-adjusted performance.
Sortino Ratio	The Sortino Ratio measures return per unit of downside risk, focusing solely on negative volatility. Higher is preferable.
Omega Ratio	The Omega Ratio quantifies the ratio of expected gains to expected losses. It reflects the likelihood of achieving favorable outcomes.
VaR 95%	Value at Risk (VaR) at 95% confidence level indicates the worst loss not exceeded with 95% certainty.
CVaR 95%	Conditional Value at Risk (CVaR) represents the average loss assuming that losses have exceeded the 95% VaR threshold.
Tail Gap	Tail Gap is defined as the difference between CVaR and VaR. It represents the expected severity of tail-end losses.
Hedging Efficiency	Hedging Efficiency quantifies the percentage reduction in risk due to the hedge. Values closer to 100% signify higher effectiveness.

1. LZEW Hedge

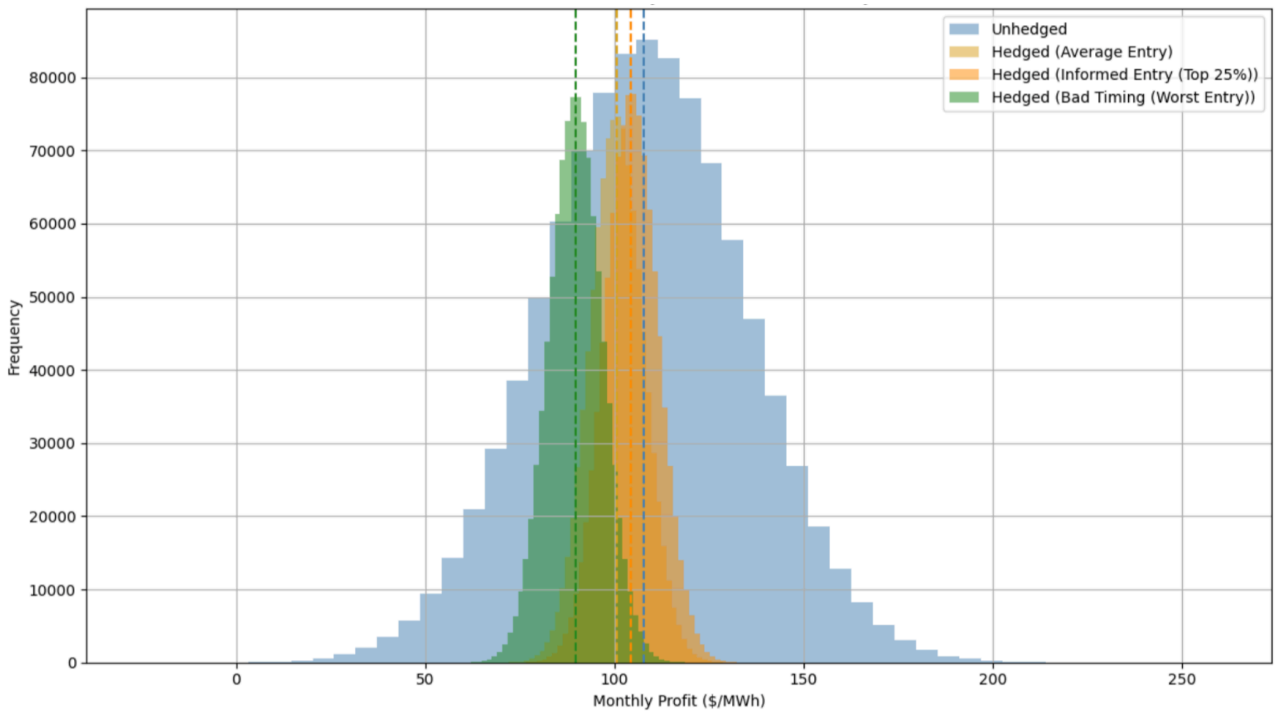

Figure 1.1 - May 2025 LZEW Hedge Risk Distribution

Strategy	Mean	Standard Deviation	Probability Loss	Min	Max
Unhedged	107.80	26.70	0.18%	-25.32	259.47
Hedged (Average Entry)	100.56	7.12	0.00%	69.50	136.58
Hedged (Informed Entry (Top 25%))	104.48	7.11	0.00%	68.28	137.79
Hedged (Bad Timing (Worst Entry))	89.77	7.11	0.00%	55.20	124.29

Strategy	Sharpe Ratio	Sortino	Omega	VaR 95%	CVaR 95%	Tail gap	Hedging Efficiency %
Unhedged	4.04	6.69	5.95	63.83	52.69	-11.14	
Hedged (Average Entry)	14.13	23.46		88.85	85.89	-2.96	73.34
Hedged (Informed Entry (Top 25%))	14.70	24.39		92.80	89.81	-2.99	73.37
Hedged (Bad Timing (Worst Entry))	12.62	20.92		78.08	75.09	-2.99	73.37

2. Naked HB_WEST Hedge

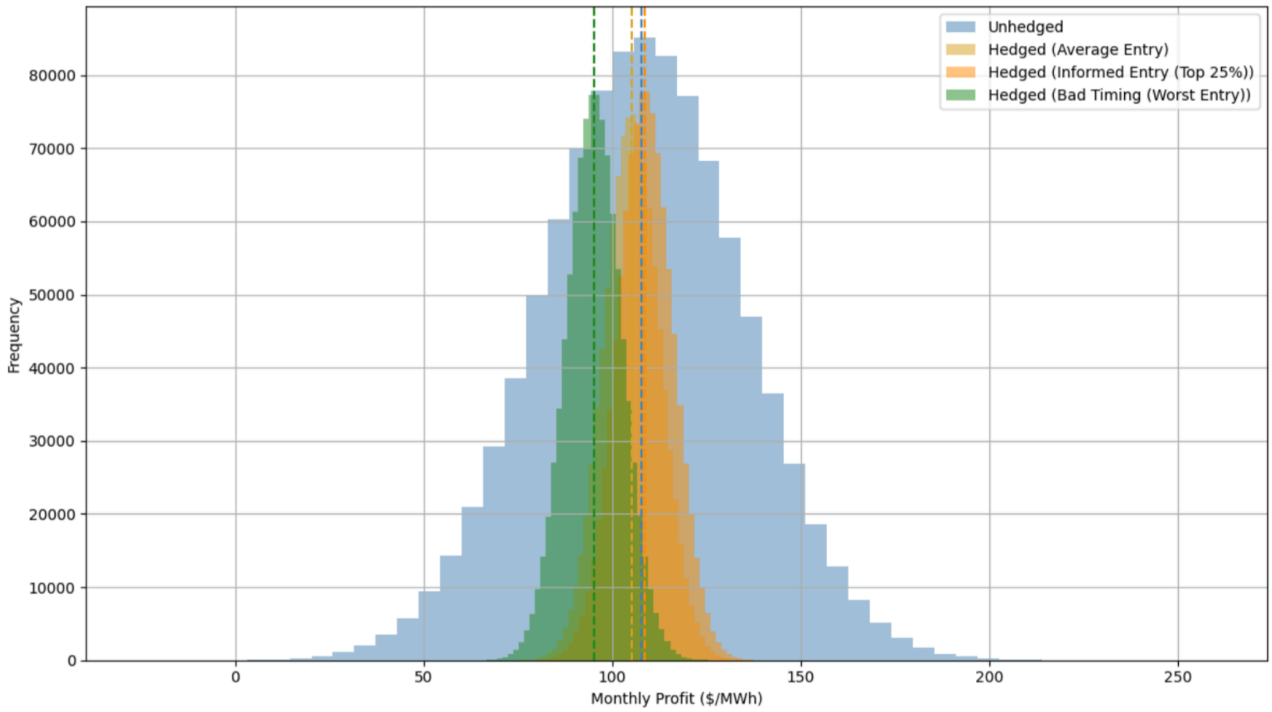

Figure 2.1 - May 2025 Naked HB_WEST Hedge Risk Distribution

Strategy	Mean	Standard Deviation	Probability Loss	Min	Max
Unhedged	107.80	26.70	0.18%	-25.32	259.47
Hedged (Average Entry)	105.21	7.40	0.00%	72.94	142.64
Hedged (Informed Entry (Top 25%))	108.73	7.39	0.00%	71.12	143.34
Hedged (Bad Timing (Worst Entry))	95.27	7.39	0.00%	59.35	131.13

Strategy	Sharpe Ratio	Sortino	Omega	VaR 95%	CVaR 95%	Tail gap	Hedging Efficiency %
Unhedged	4.04	6.69	5.95	63.83	52.69	-11.14	
Hedged (Average Entry)	14.22	23.62		93.04	89.97	-3.08	72.30
Hedged (Informed Entry (Top 25%))	14.72	24.43		96.59	93.49	-3.10	72.34
Hedged (Bad Timing (Worst Entry))	12.89	21.37		83.13	80.02	-3.11	72.33

3. HB_WEST Hedge with $5/MW Fixed Basis

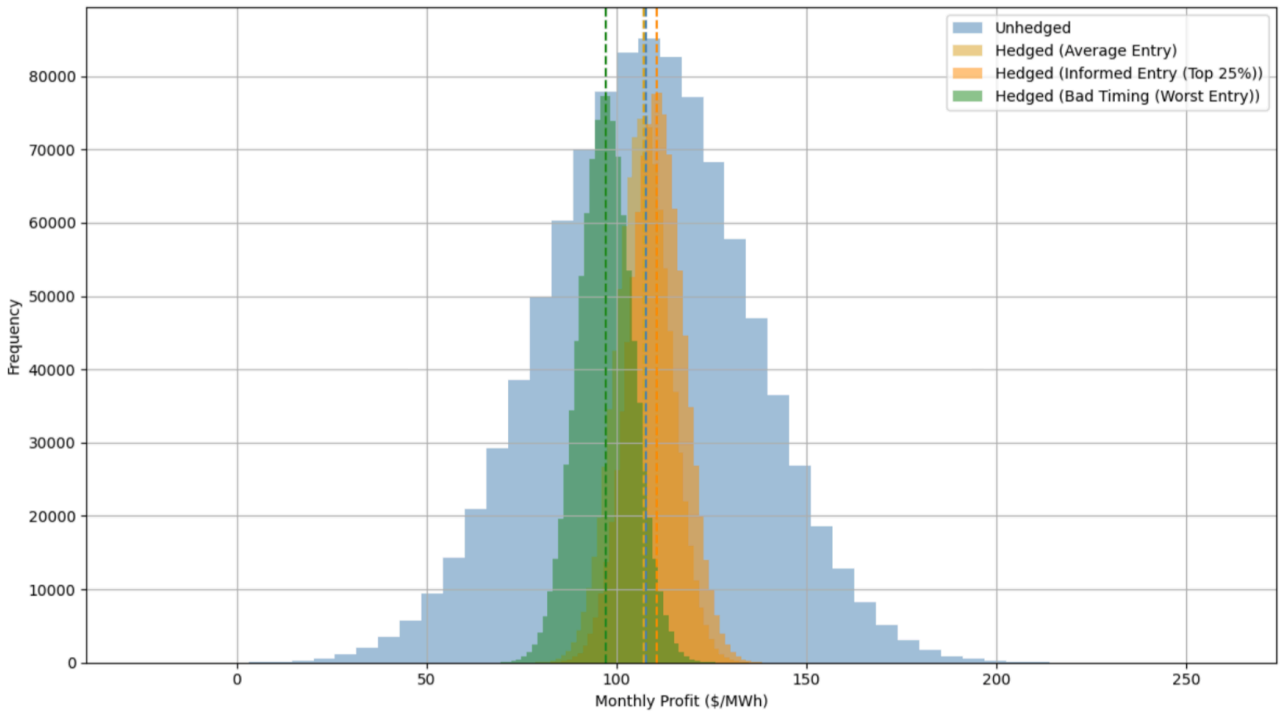

Figure 3.1 - May 2025 HB_WEST Hedge with $5/MW Fixed Basis Risk Distribution

Strategy	Mean	Standard Deviation	Probability Loss	Min	Max
Unhedged	107.80	26.70	0.18%	-25.32	259.47
Hedged (Average Entry)	107.07	7.12	0.00%	76.01	143.09
Hedged (Informed Entry (Top 25%))	110.59	7.11	0.00%	74.39	143.90
Hedged (Bad Timing (Worst Entry))	97.13	7.11	0.00%	62.56	131.65

Strategy	Sharpe Ratio	Sortino	Omega	VaR 95%	CVaR 95%	Tail gap	Hedging Efficiency %
Unhedged	4.04	6.69	5.95	63.83	52.69	-11.14	
Hedged (Average Entry)	15.04	24.98		95.36	92.40	-2.96	73.34
Hedged (Informed Entry (Top 25%))	15.56	25.81		98.91	95.92	-2.99	73.37
Hedged (Bad Timing (Worst Entry))	13.66	22.64		85.44	82.45	-2.99	73.37

4. HB_WEST Hedge with CRRs

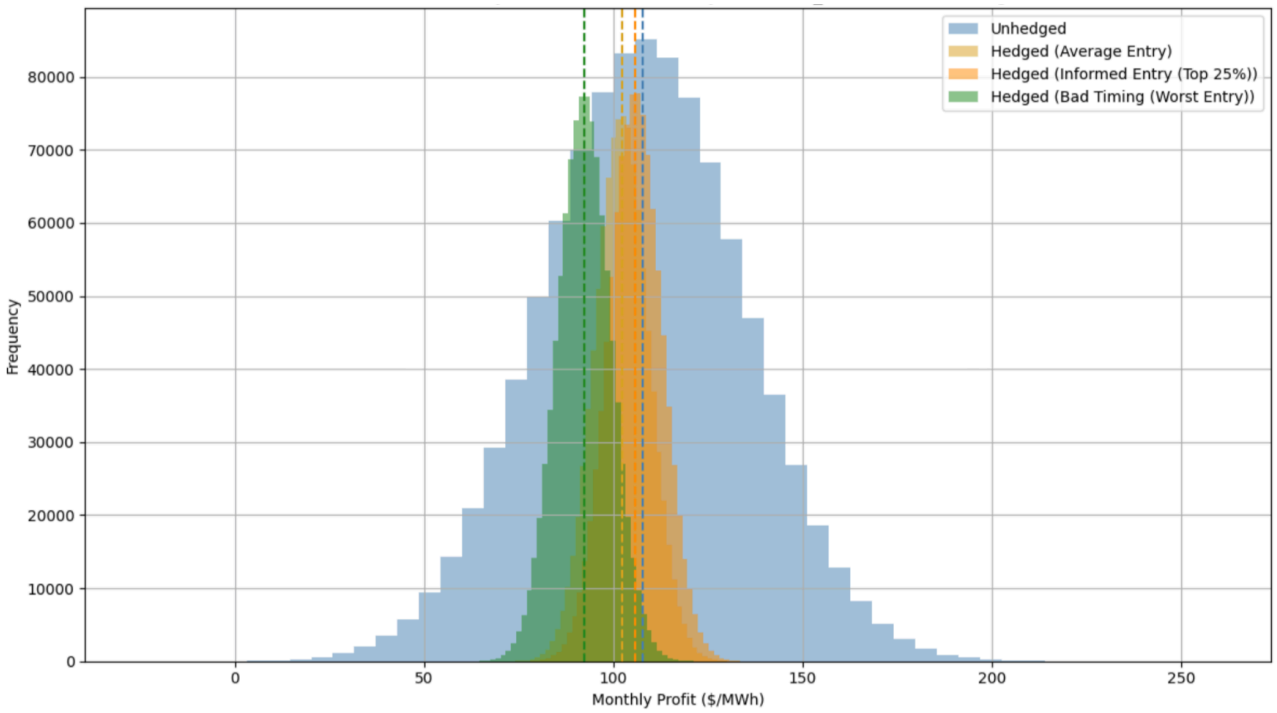

Figure 4.1 - May 2025 HB_WEST Hedge with CRRs Risk Distribution

Strategy	Mean	Standard Deviation	Probability Loss	Min	Max
Unhedged	107.80	26.70	0.18%	-25.32	259.47
Hedged (Average Entry)	102.25	7.10	0.00%	71.27	138.19
Hedged (Informed Entry (Top 25%))	105.78	7.09	0.00%	69.66	139.00
Hedged (Bad Timing (Worst Entry))	92.30	7.09	0.00%	57.82	126.74

Strategy	Sharpe Ratio	Sortino	Omega	VaR 95%	CVaR 95%	Tail gap	Hedging Efficiency %
Unhedged	4.04	6.69	5.95	63.83	52.69	-11.14	
Hedged (Average Entry)	14.40	23.91		90.57	87.61	-2.95	73.40
Hedged (Informed Entry (Top 25%))	14.91	24.75		94.12	91.14	-2.98	73.44
Hedged (Bad Timing (Worst Entry))	13.01	21.56		80.64	77.66	-2.99	73.43

5. Naked HB_NORTH Hedge

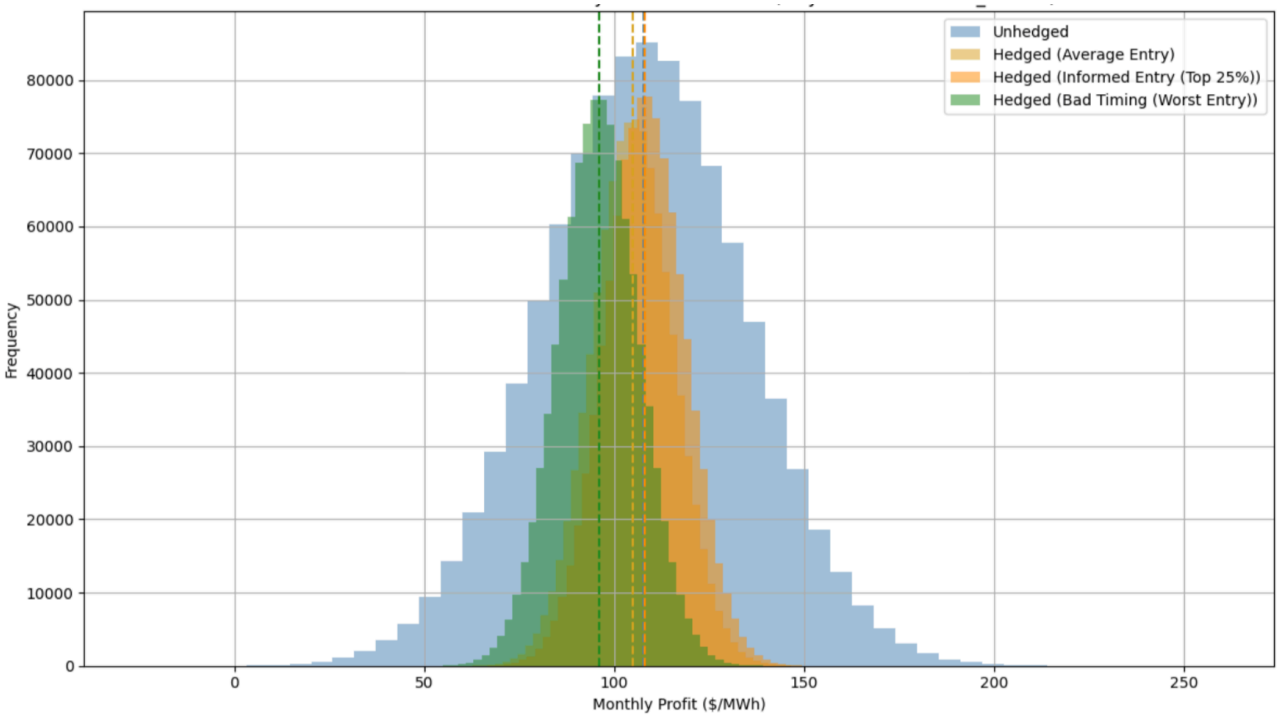

Figure 5.1 - May 2025 Naked HB_NORTH Hedge Risk Distribution

Strategy	Mean	Standard Deviation	Probability Loss	Min	Max
Unhedged	107.80	26.70	0.18%	-25.32	259.47
Hedged (Average Entry)	104.96	10.59	0.00%	58.76	158.55
Hedged (Informed Entry (Top 25%))	108.13	10.58	0.00%	54.27	157.67
Hedged (Bad Timing (Worst Entry))	95.95	10.58	0.00%	44.53	147.30

Strategy	Sharpe Ratio	Sortino	Omega	VaR 95%	CVaR 95%	Tail gap	Hedging Efficiency %
Unhedged	4.04	6.69	5.95	63.83	52.69	-11.14	
Hedged (Average Entry)	9.91	16.46		87.54	83.14	-4.41	60.34
Hedged (Informed Entry (Top 25%))	10.22	16.97		90.75	86.30	-4.44	60.39
Hedged (Bad Timing (Worst Entry))	9.07	15.03		78.57	74.11	-4.45	60.38

Sources

Data Sources:

- ERCOT Historical Load Zone Settlement prices: Yearly Settlement Point Price Data for the Western Texas Load Zone and Western Hub, including 15-minute interval records
- HashRateIndex Hash price Data: Historical Bitcoin Hash Price Data
- Intercontinental Exchange ERCOT West Load Zone options: ICE traded ERCOT HB_WEST options data
- ERCOT Monthly CRR Auction Results: Finalized Monthly Auction Results for OBL and OPT HB_WEST -> LZ_WEST Routed CRRs
- ERCOT Annual CRR Auction Results: Finalized Annual Auction Results for OBL and OPT HB_WEST -> LZ_WEST Routed CRRs

Tools and Technologies:

- Numpy: Official Webpage
- Matplotlib: Official Webpage
- Pandas: Official Webpage
- SpiPy.stats: Official Webpage
- Python (Version 3.13.1): Official Webpage
- Tableau Desktop (Version 2024.3.1 Professional Edition): Official Webpage
- Google Sheets: Google Workspace Official Webpage
- Microsoft Excel (Version 16.94): Official Webpage