Analyzing Energy Risk in a Changing Winter Environment

FTR Performance & Climate Risk Assessment

Executive Summary

- Minnesota winters show paradox: Rising average temperatures but more severe cold extremes

- Wind patterns trending toward lower average speeds and more low-wind events

- This combination creates unprecedented price risk during extreme weather

- Traditional risk metrics (CVaR) fail to capture tail risk in evolving climate

- GRE's WAUE→GRE.AZ FTR: ~$3M profit in 2025-2026 vs. projected -$800K loss in Uri scenario

- GRE's FTR strategy is a critical offset for risks of energy costs

- Success requires understanding of local operations and forward-looking scenario modeling, not historical statistics

Project Overview

Four-Stage Analysis:

1. Document Minnesota's changing winter weather patterns

2. Demonstrate extreme weather translation to market outcomes

3. Examine FTR profit/loss under normal vs. extreme conditions

4. Discuss implications for hedging strategy
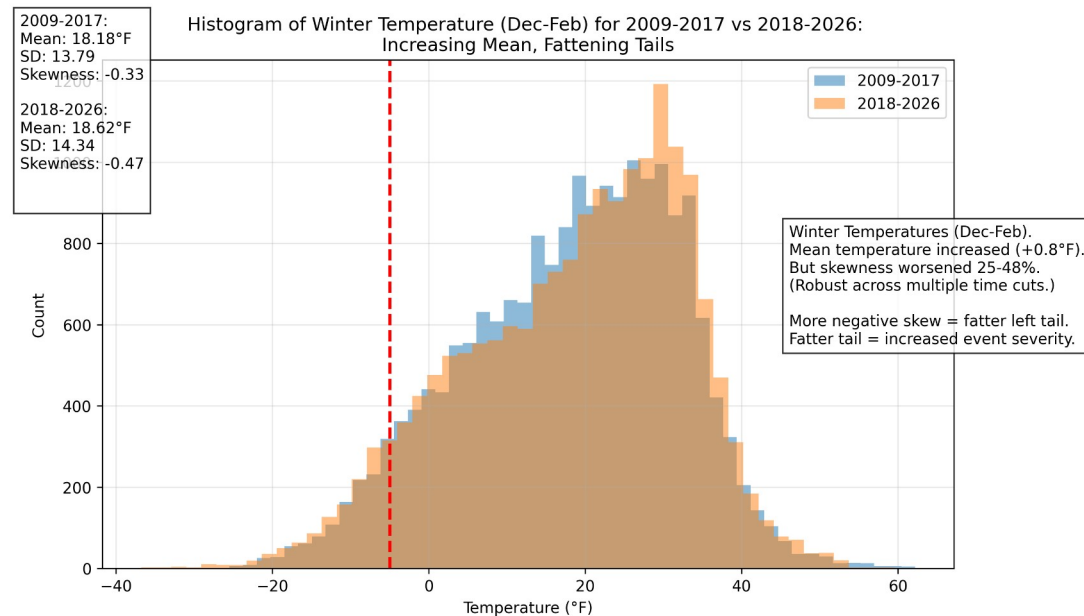
Key Questions:

- How is climate change affecting winter energy risk?

- What drives extreme price events?

- Why do some market participants profit while others face catastrophic losses?

Winter Climate Trend - Temperature

Key Finding: Fattening Left Tail Despite Rising Average

- Average temperature increased 0.44°F (2018-2026 vs 2009-2017)

- BUT skewness worsened 25-48%: -0.33 → -0.47

- More negative skew = fatter left tail = more extreme cold events

- Average warming masks increased severity of cold snaps

Implication: Historical temperature data underestimates future cold risk

Histogram of Winter Temperature (Dec-Feb) for 2009-2017 vs 2018-2026: Increasing Mean, Fattening Tails

2009-2017:
Mean: 18.18°F
SD: 13.79
Skewness: -0.33

2018-2026:
Mean: 18.62°F
SD: 14.34
Skewness: -0.47

Winter Temperatures (Dec-Feb).
Mean temperature increased (+0.8°F).
But skewness worsened 25-48%.
(Robust across multiple time cuts.)

More negative skew = fatter left tail.
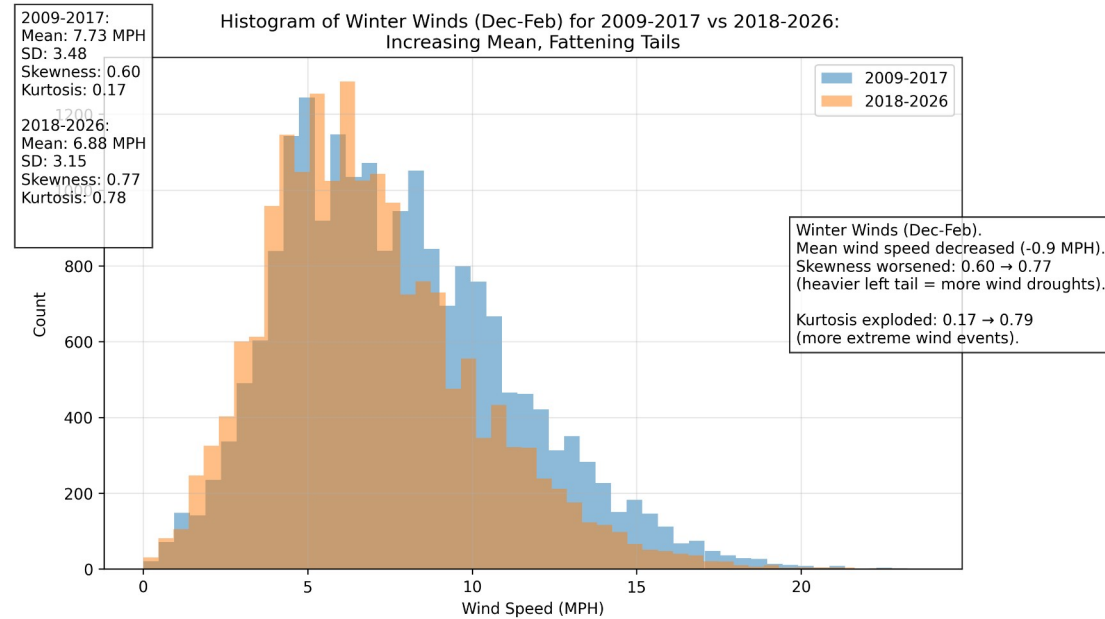Fatter tail = increased event severity.

Winter Climate Trend - Wind

Key Finding: Lower Average, More Low-Wind Hours

- Average wind speed decreased 0.85 MPH (11% reduction)

- Skewness increased: 0.60 → 0.77 (heavier left tail)

- Kurtosis increased: 0.17 → 0.78 (more extreme events)

Implication: More frequent "wind droughts" during winter months

Combined Risk: Extreme cold + low wind = perfect storm for price spikes

Histogram of Winter Winds (Dec-Feb) for 2009-2017 vs 2018-2026: Increasing Mean, Fattening Tails

2009-2017:
Mean: 7.73 MPH
SD: 3.48
Skewness: 0.60
Kurtosis: 0.17

2018-2026:
Mean: 6.88 MPH
SD: 3.15
Skewness: 0.77
Kurtosis: 0.78

Winter Winds (Dec-Feb).
Mean wind speed decreased (-0.9 MPH).
Skewness worsened: 0.60 → 0.77
(heavier left tail = more wind droughts).

Kurtosis exploded: 0.17 → 0.79
(more extreme wind events).

Weather-Price Relationship

Price Spikes Cluster at Intersection of Two Factors:

1. Extreme cold temperatures (below 0°F)

2. Low wind generation (blue dots)

Key Observations:

- Normal conditions: Abundant wind keeps prices low

- Extreme conditions: Cold + low wind = prices exceed $2,000/MWh

- Red dots (high wind) rarely show extreme prices regardless of temperature
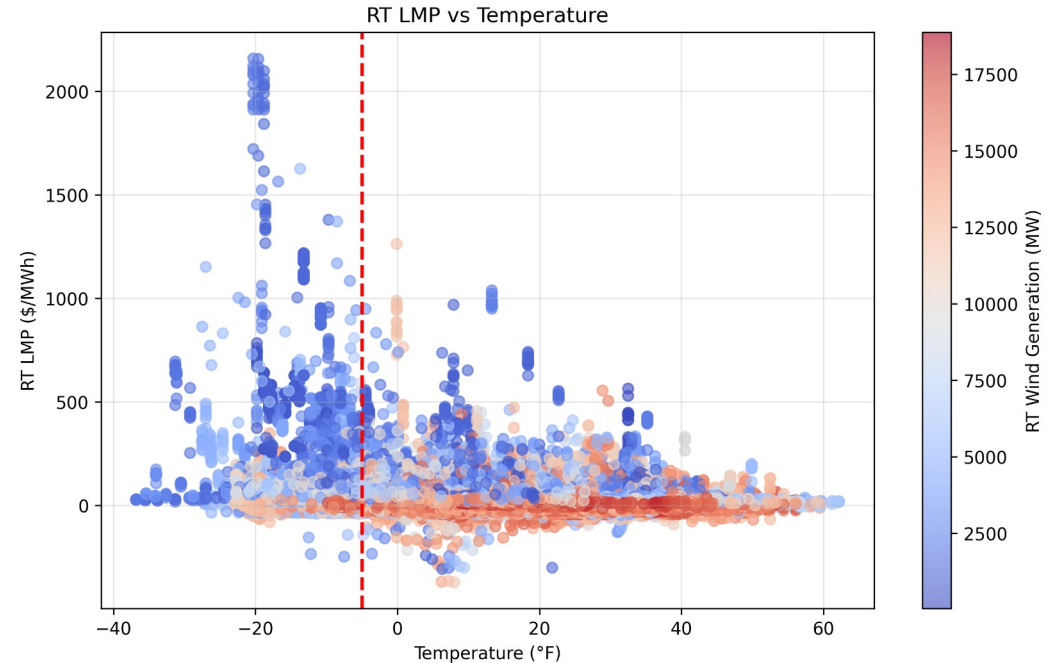
Case Study Overview

Two Nodes, Two Events, Different Outcomes

Nodes Selected:

- WAUE: MISO-SPP interface, diversified generation (15% wind)

- GRE.AZ: Hub node, wind-heavy region (44% wind/renewables)

Events Analyzed:

- Winter Storm Uri (Feb 2021): Natural gas infrastructure failure

- Winter Storm Fern (Jan 2026): Wind generation collapse

- Why These Matter: Highly relevant GRE FTR path, opposite financial outcomes (discussed in depth later)

Part One of Case Study:

- Price action on DA-RT spreads during extreme events

Part Two of Case Study:

- FTR profit and loss analysis (use DA ex-post for settlement)

Winter Storm Uri - WAUE Node

Natural Gas Constraint Drove Extreme Prices

- Temperatures: -27°F in Minnesota

- Gas supply dropped to 65% of day-ahead forecast

- RT prices spiked above $1,600/MWh during scarcity periods

- DA/RT divergence signals market stress

Root Cause: Pipelines and generators not winterized for extreme cold

**Post-Uri Response:** Infrastructure improvements, winterization mandates

WAUE Node RT LMP during Winter Storm Uri (Feb 2021)
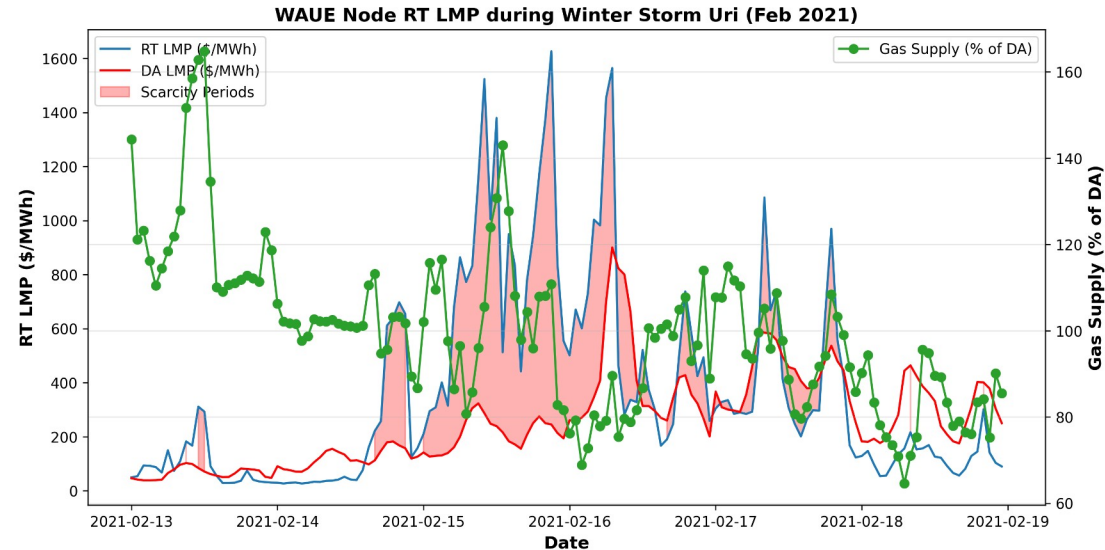
Winter Storm Uri – GRE.AZ Node

Similar Pattern, Lower Peak Prices

- RT prices peaked at $900/MWh (44% lower than WAUE)

- Gas constraints evident but less severe

- Extended periods of elevated prices (>$200/MWh)

Key Difference: Regional generation mix partially insulated from worst impacts

FTR Implication: WAUE prices exceeded GRE.AZ → FTR loses money

GRE.AZ Node RT LMP during Winter Storm Uri (Feb 2021)
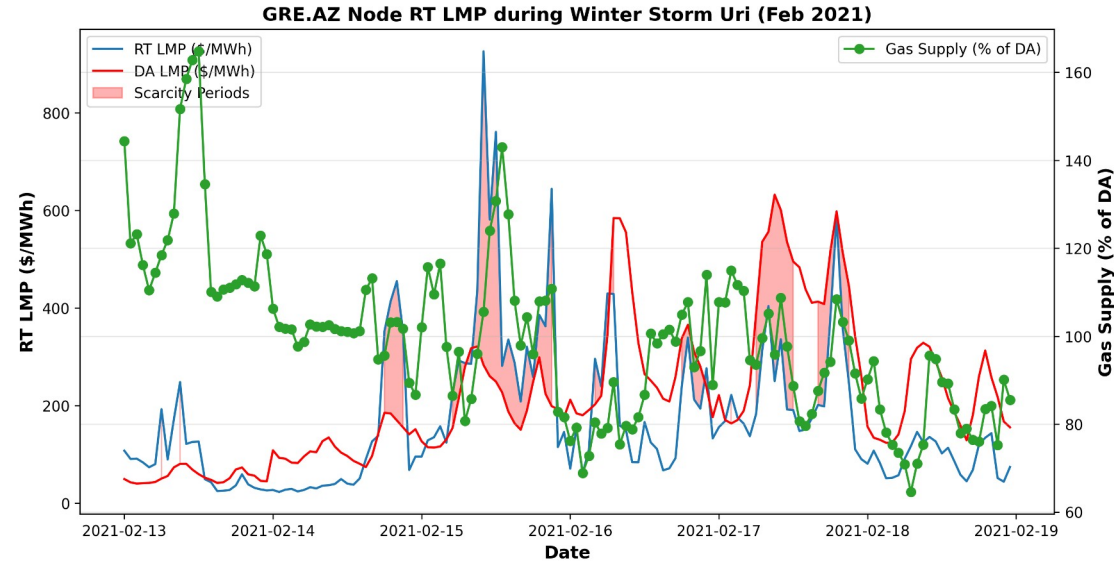
Winter Storm Fern – GRE.AZ Node

Wind Failure Created Unprecedented Spreads

- Temperatures: -22°F

- Wind generation dropped to near zero (5% of seasonal average)

- RT prices exceeded $2,000/MWh

- Sustained prices >$500/MWh for 24+ hours

Critical Factor: GRE's high wind dependence created vulnerability when wind disappeared

GRE.AZ Node RT LMP during Winter Storm Fern (Jan 2026)
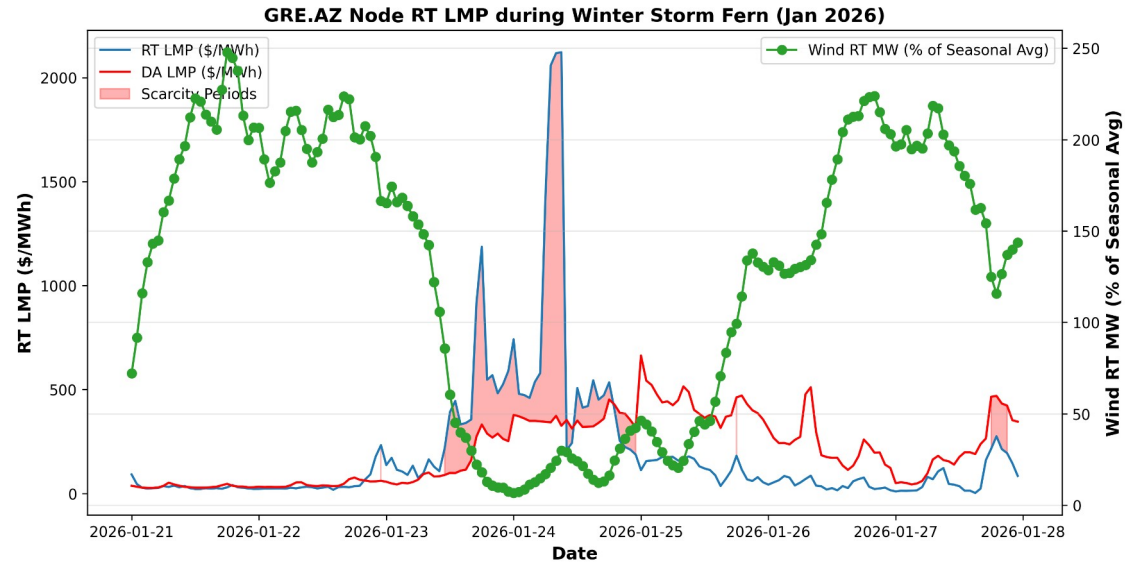
Winter Storm Fern – WAUE Node

Diversified Mix Limited Price Impact

- Peak RT price: $1,750/MWh (13% lower than GRE.AZ)

- Wind generation also dropped but regional diversification helped

- Improved infrastructure prevented Uri-style gas failures

Critical Insight: GRE.AZ prices consistently exceeded WAUE during Fern

FTR Implication: GRE.AZ > WAUE = Scenario for massive FTR profits

WAUE Node RT LMP during Winter Storm Fern (Jan 2026)
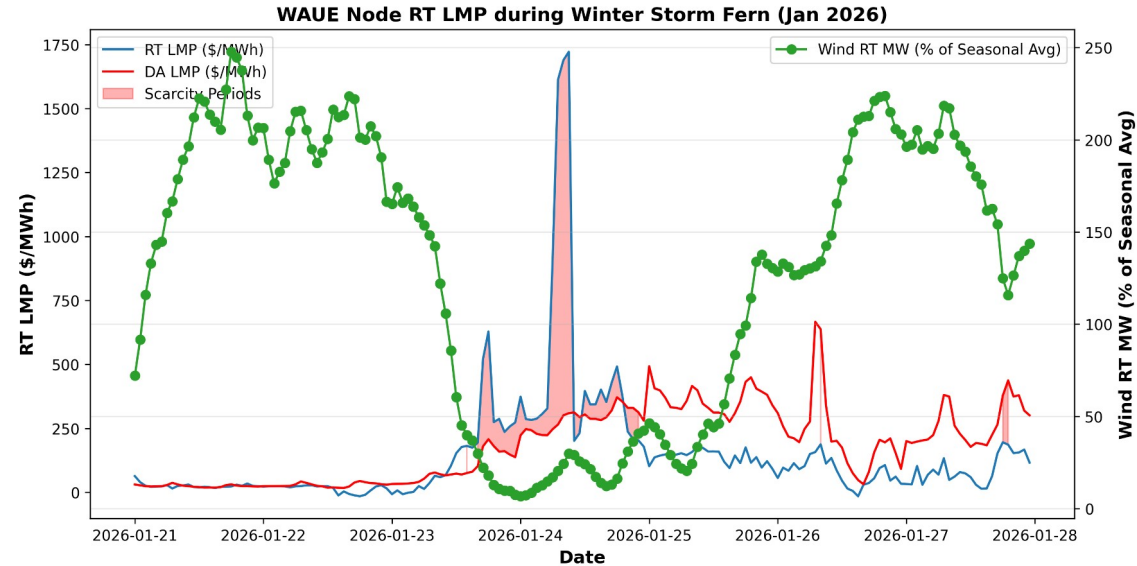
FTR Basics & GRE's WAUE → GRE.AZ Position

How FTRs Work:

- Financial hedge against congestion costs

- Pays: (Sink Price - Source Price) × MW held

- Settled hourly based on day-ahead LMP

GRE's Winter Quarter 2025-2026 Position:

Class	MW	Clearing Price	Total Cost	Break-Even Spread
Peak	77	$3,429	$264,103	$3.40/MWh
Off-peak	55.6	$3,272	$181,977	$2.82/MWh

Total Investment: $446,080

*Based on MISO auction summary data. Clearing price is weighted average cost.

Actual FTR Performance - Winter 2025-2026

Exceptional Returns Driven by Market Knowledge
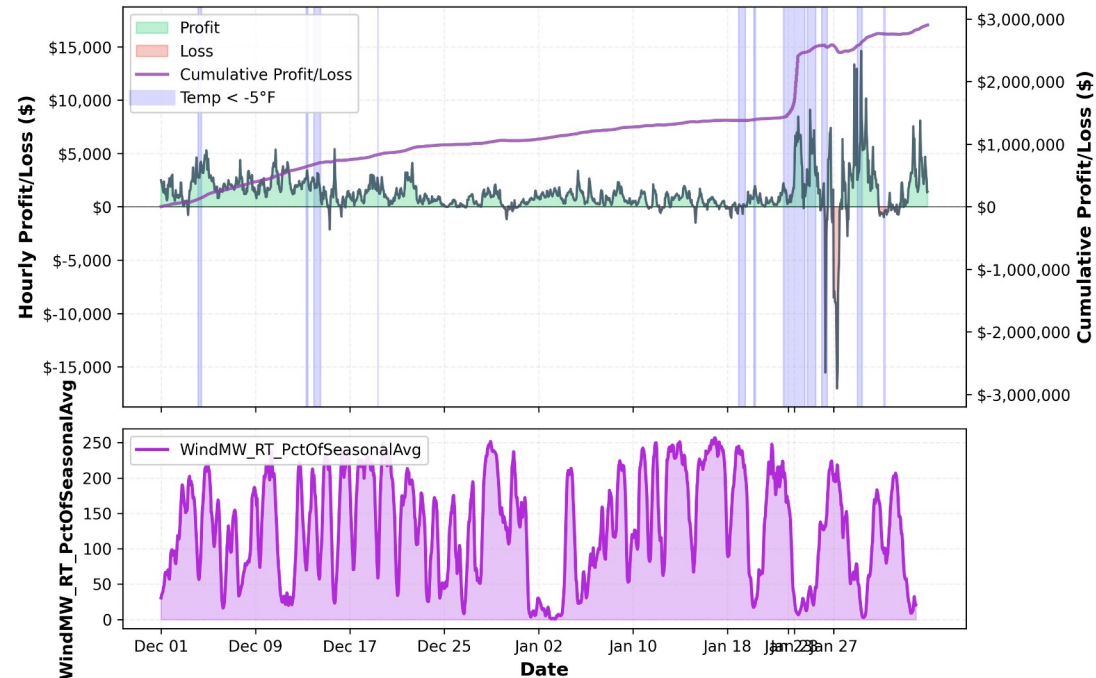
Normal Operations (Dec 1 – Jan 20):

- Immediately profitable, consistent positive spreads

- Accumulated >$1M profit before Fern

- Suggests GRE had superior insight into regional dynamics

Winter Storm Fern (Jan 21-26):

- Single event added >$1M profit

- Price spreads exceeded $400/MWh during peak hours

Total Season Profit: ~$3M (6.7x return on investment)

WAUE → GRE.AZ Peak FTR: Winter Season Profitability Pattern
December 1 2025 - February 2 2026

Hypothetical FTR Performance - Winter 2020-2021

Same FTR, Catastrophic Outcome Under Different Failure Mode

Normal Operations (Dec 1 – Feb 12):

- Consistent losses, -$300K cumulative

- Price spreads inverted: WAUE > GRE.AZ

Winter Storm Uri (Feb 13 – 17):

- Losses accelerated to >-$400K in single event

- Natural gas constraints hit WAUE harder than GRE.AZ

Total Season Loss: ~-$800K (negative ROI)

Key Insight: Infrastructure evolution changed congestion patterns completely

WAUE → GRE.AZ Peak FTR: Winter Season Profitability Pattern (Theoretical)
December 1 2020 - February 28 2021
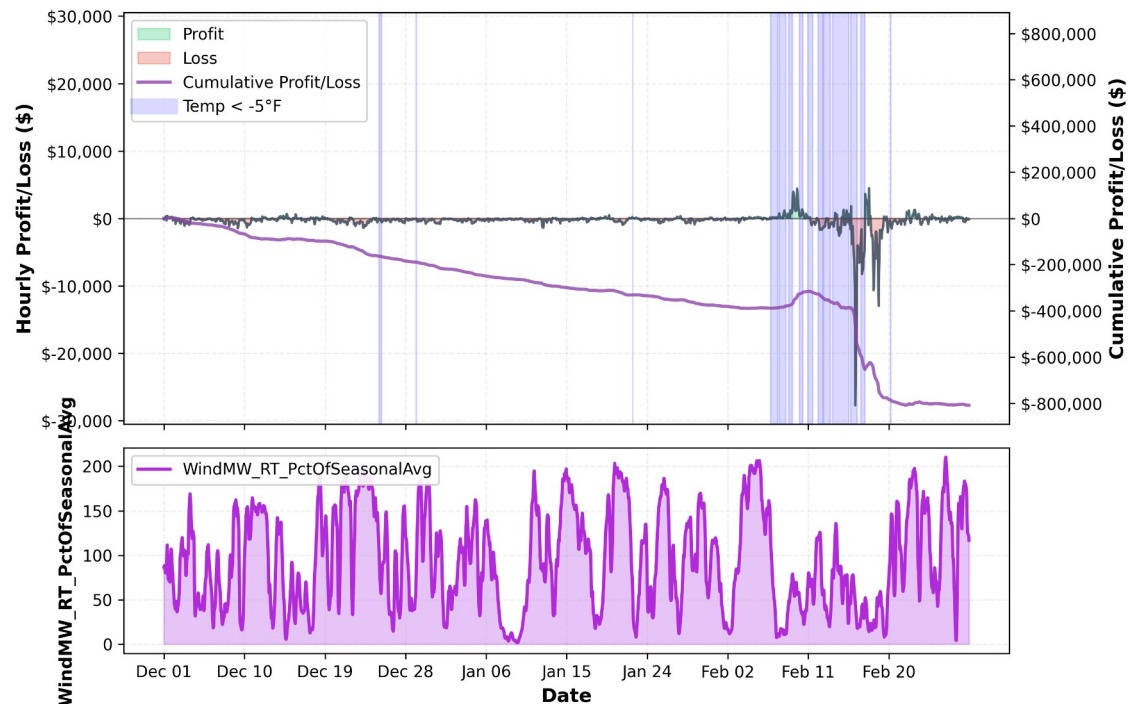
CVaR Analysis - Why Traditional Metrics Fail

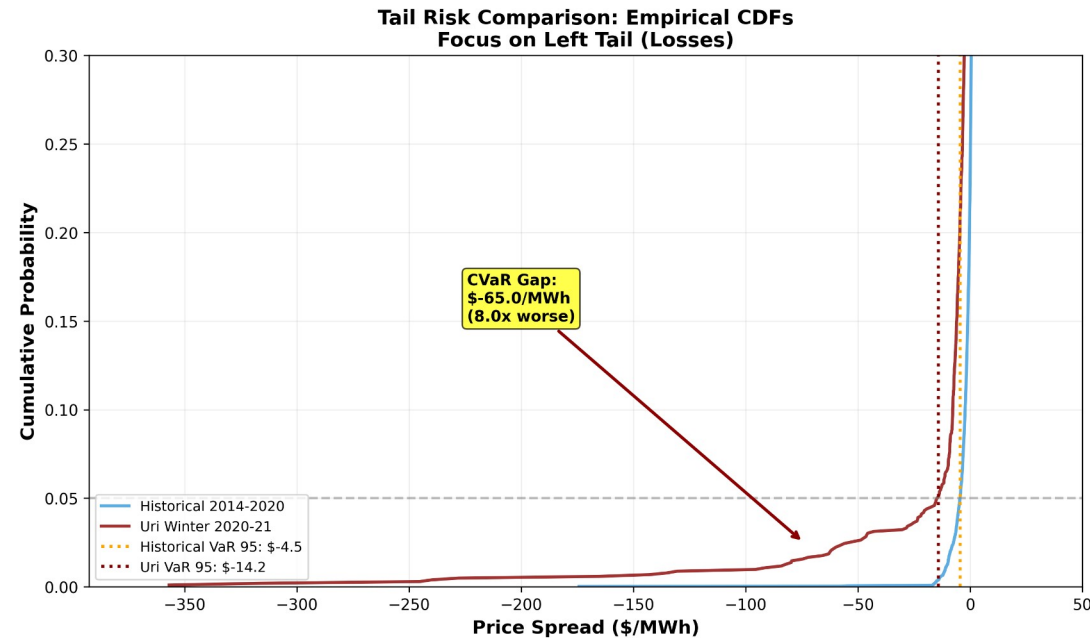**Conditional Value at Risk (CVaR) Assumptions:**

- Tail risk = average of historical worst 5% outcomes

- Historical 2014-2020 CVaR: -$9.27/MWh

Uri Tail Event:

- Actual 5% worst outcomes: -$74.22/MWh (8x worse)

- 7.5% of hours exceeded VaR threshold (not 5%)

Three Critical Failures:

1. Assumes historical data captures worst-case

2. Assumes stable tail distribution

3. Ignores structural grid evolution and climate shifts

Tail Risk Comparison: Empirical CDFs
Focus on Left Tail (Losses)

CVaR Gap:
$-65.0/MWh
(8.0x worse)

Legend:
Historical 2014-2020
Uri Winter 2020-21
Historical VaR 95: $-4.5
Uri VaR 95: $-14.2

CVaR Analysis - Why Traditional Metrics Fail

The historical distribution does not reflect the future distribution in changing environments.

Historical 2014-2020
CVaR 95: $-9.27/MWh

Uri Winter 2020-21
CVaR 95: $-74.22/MWh
(8.0x worse)
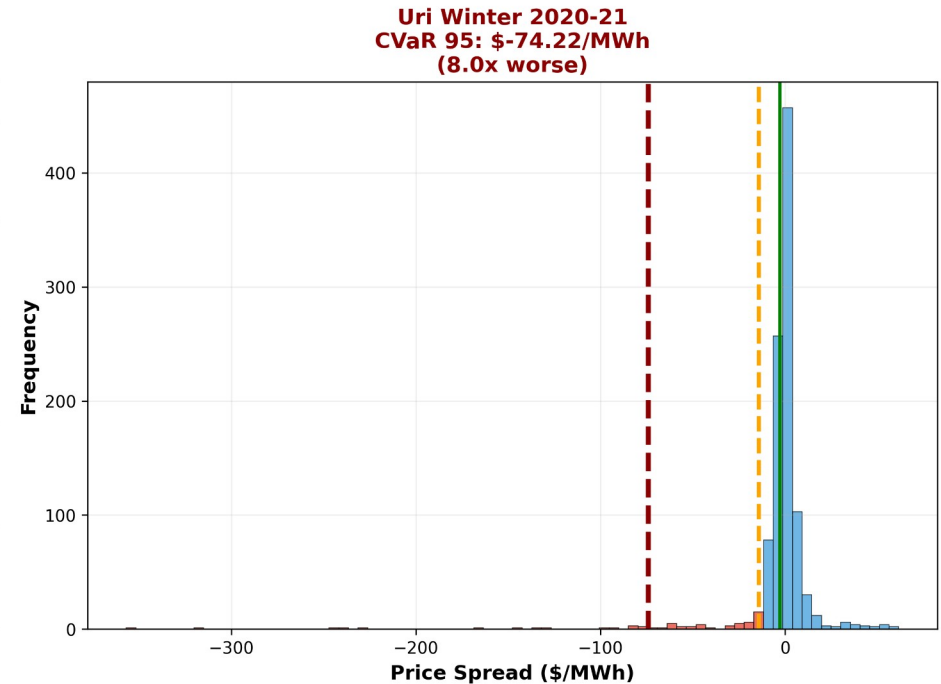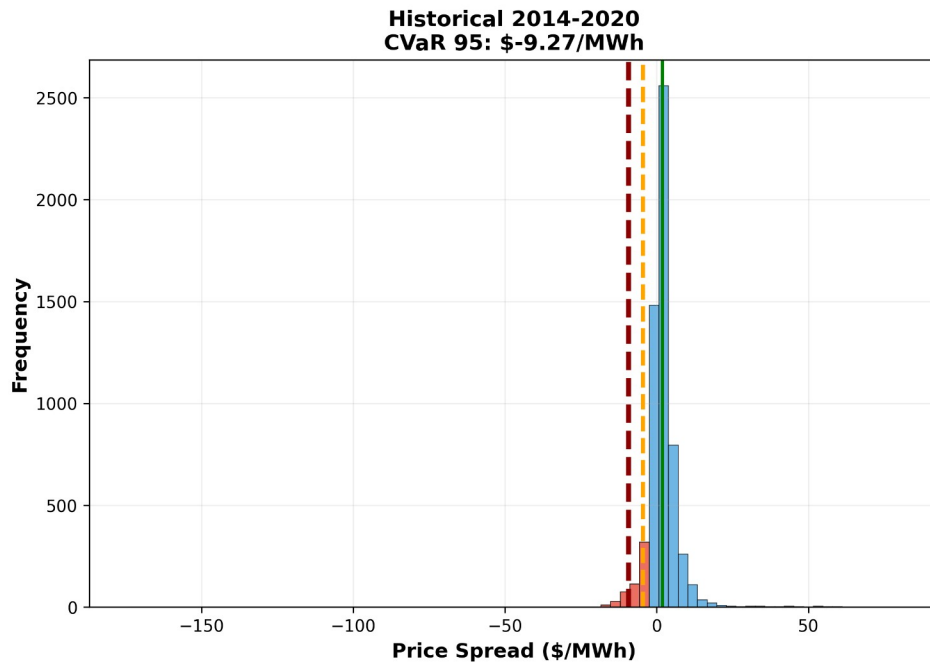
Strategic Success Factors

Inferring as to why GRE succeeded when CVaR failed. GRE likely exhibits some combination of:

Local Operational Knowledge:

- Intimate understanding of GRE.AZ hub physical constraints

- Real-time operational data unavailable to financial participants

- Knowledge of regional generation mix vulnerabilities and operational incentive to hedge

Forward-Looking Scenario Analysis:

- Analyzed compound risk scenarios (extreme cold + wind failure)

- Assessed infrastructure improvements post-Uri

Structural Evolution Recognition:

- 44% wind/renewables creates new vulnerability profile

- Mandating circuit breaker upgrades (-40°C → -50°C) signals risk awareness

- Market illiquidity on WAUE→GRE.AZ path creates opportunity

Key Insights & Implications

Climate Change Amplifies Tail Risk:

- Fattening distribution tails make historical data obsolete

- Compound events (cold + low wind) increasingly probable

Risk Management Evolution Required:

- CVaR insufficient for pricing tail risk

- Physical system modeling essential

- Local knowledge creates competitive advantage in illiquid markets

Infrastructure Matters:

- Uri lesson: Winterize natural gas infrastructure

- Fern lesson: Wind-heavy portfolios vulnerable during calm/cold periods

Success Depends On:

- Understanding regional physical constraints

- Scenario planning for unprecedented events

- Recognizing grid evolution and climate regime shifts

Limitations & Next Steps

Current Analysis Limitations:

- Only 2 extreme events analyzed (small sample)

- Single FTR path examined (not portfolio-level)

- Natural gas constraint data unavailable (used fuel mix as proxy)

- No ARR allocation analysis (confidential data)

- Only Minnesota KMSP weather station data

- Retrospective analysis only

Future Analysis Opportunities:

- Quantitative scenario modeling for future extreme events (work in progress)

- Portfolio-level risk assessment across multiple paths

- Grid modeling with gas constraint data

- Seasonal analysis beyond winter

- Integration with long-term climate projections