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
- 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:

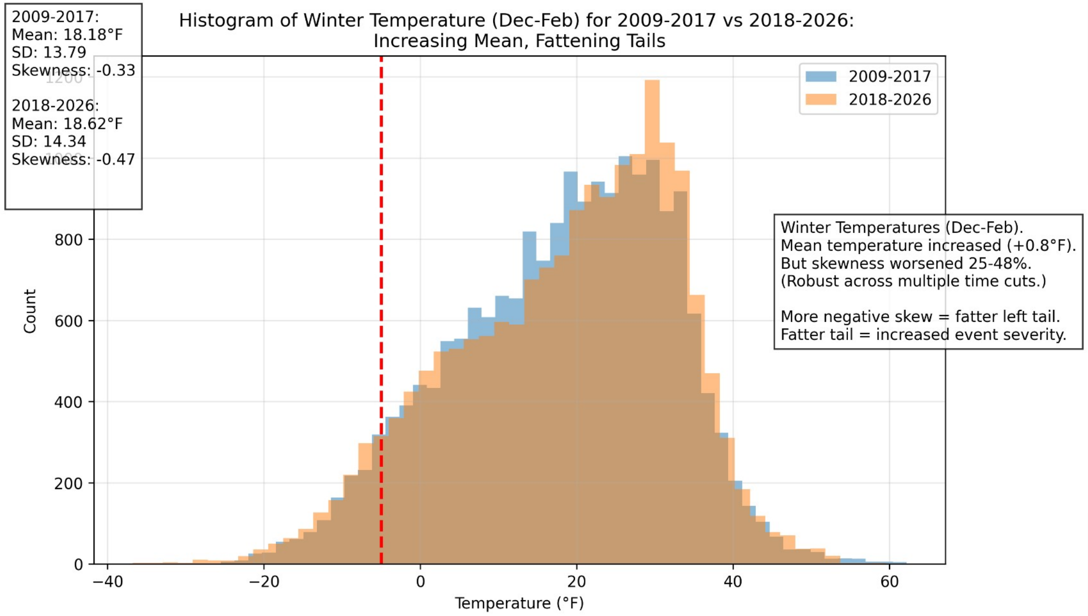
- How is climate change affecting winter energy risk?
- What drives extreme price events?
- Why do some market participants profit while others face catastrophic losses?

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



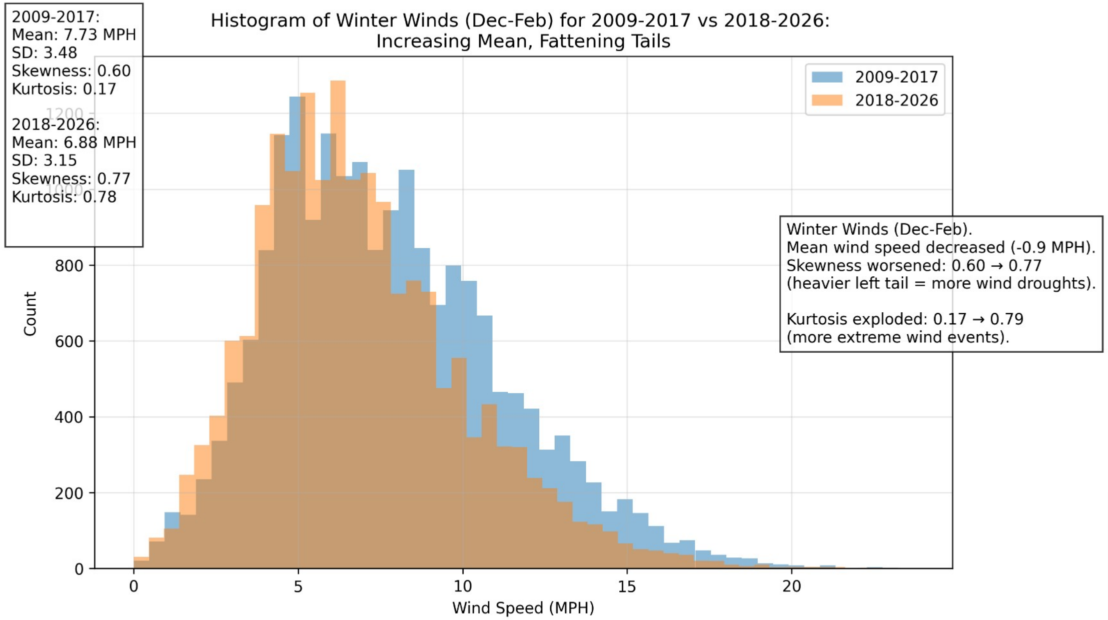
Winter Climate Trend - Wind

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



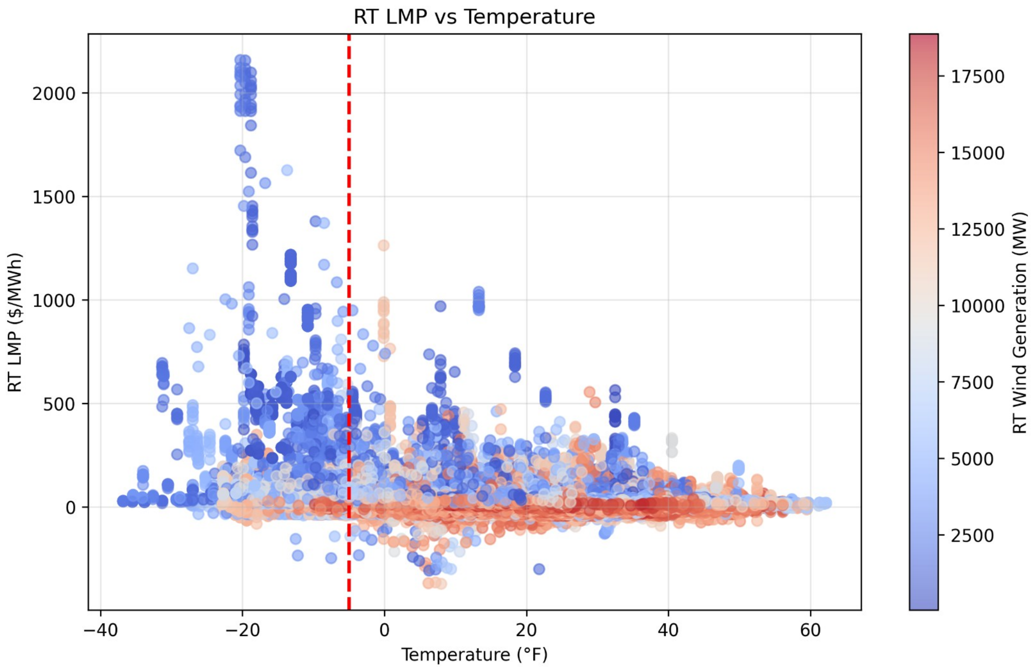
Weather-Price Relationship

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)

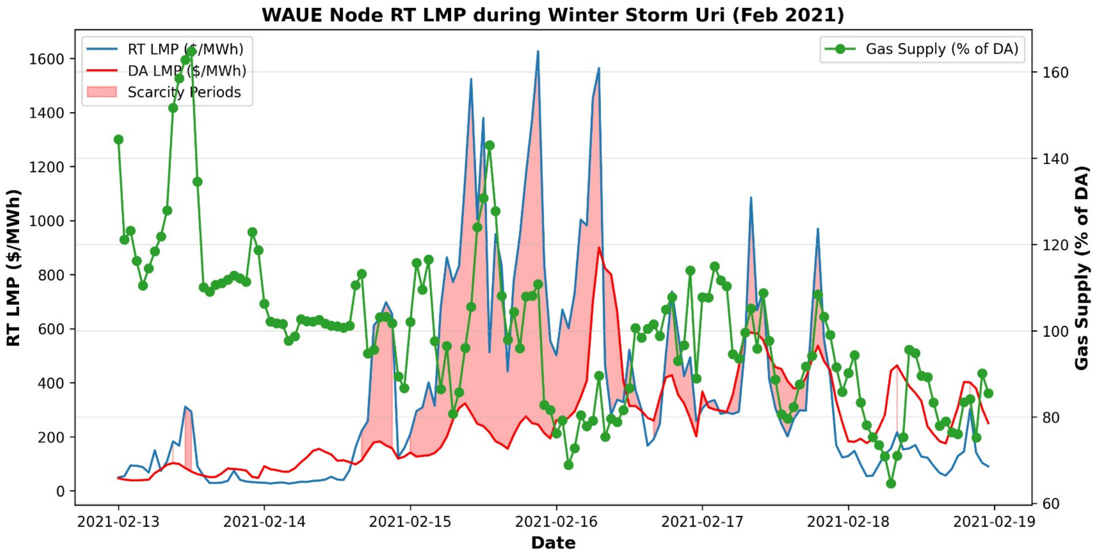
Winter Storm Uri - WAUE Node

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



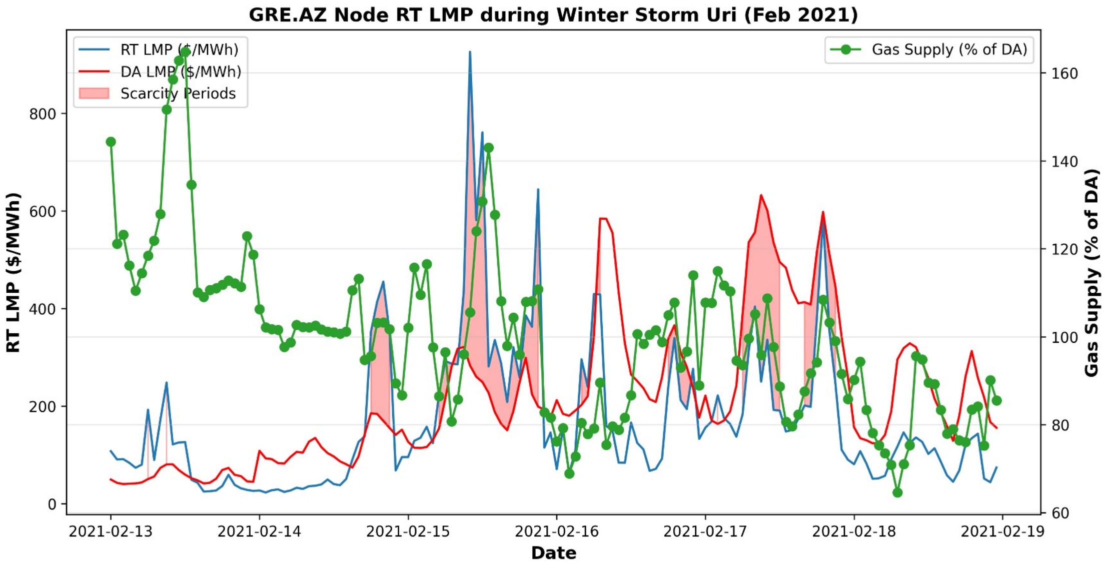
Winter Storm Uri – GRE.AZ Node

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

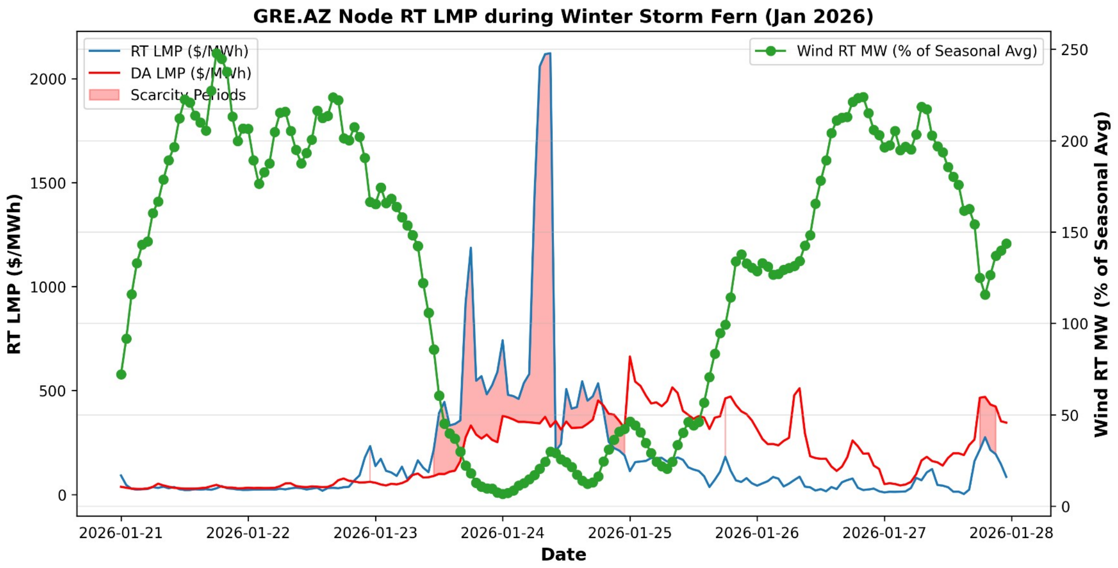


Winter Storm Fern – GRE.AZ Node

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



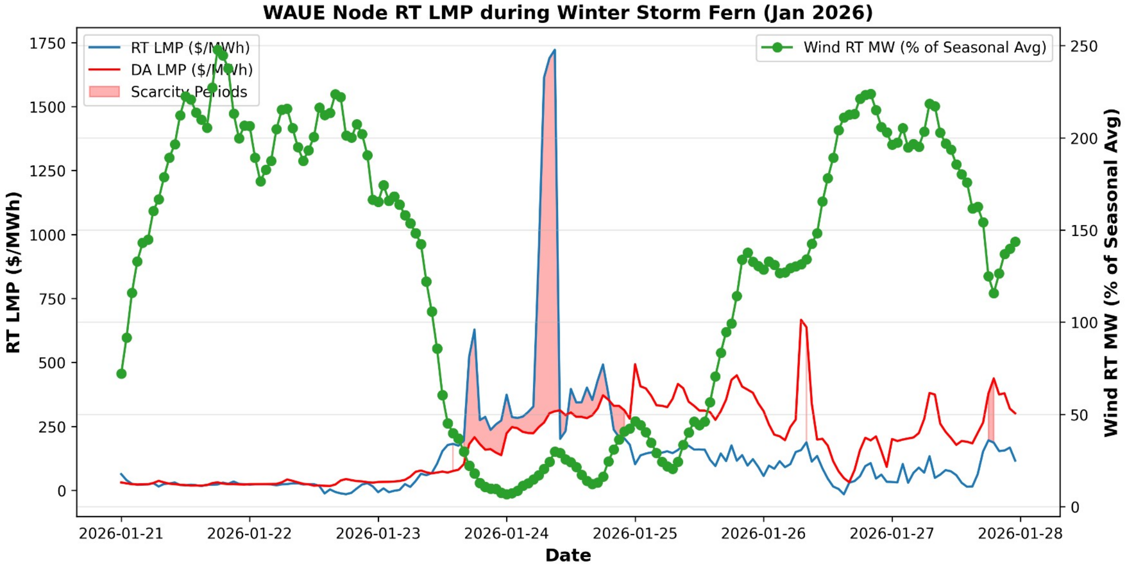
Winter Storm Fern – WAUE Node

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



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

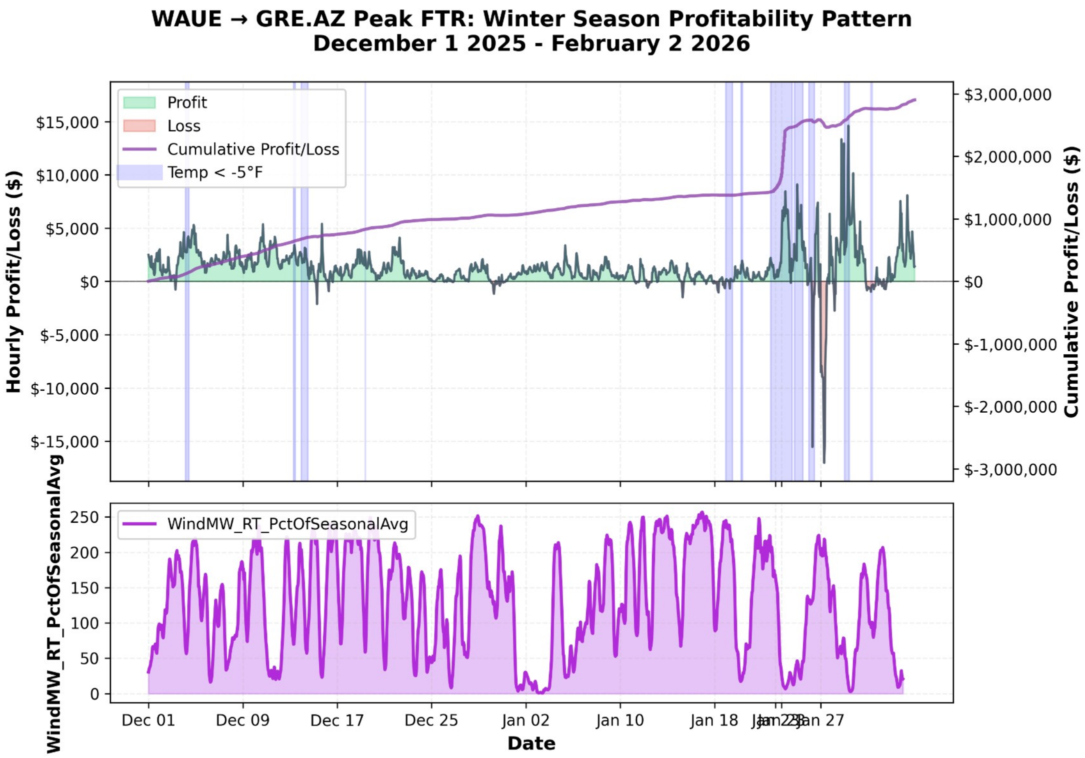
Normal Operations (Dec 1 – Jan 20):

- 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)



Hypothetical FTR Performance - Winter 2020-2021

Same FTR, Catastrophic Outcome Under Different Failure Mode

Normal Operations (Dec 1 – Feb 12):

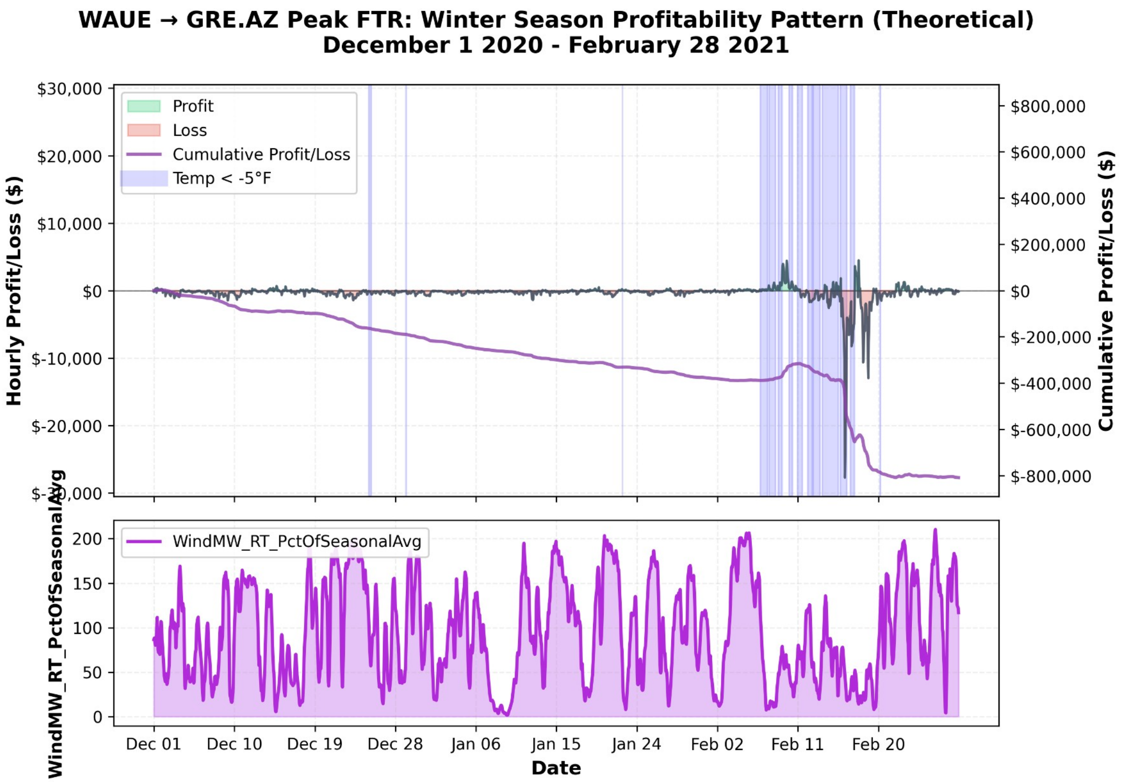
- Consistent losses, -$300K cumulative
- Price spreads inverted: WAUE > GRE.AZ

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



CVaR Analysis - Why Traditional Metrics Fail

Conditional Value at Risk (CVaR) Assumptions:

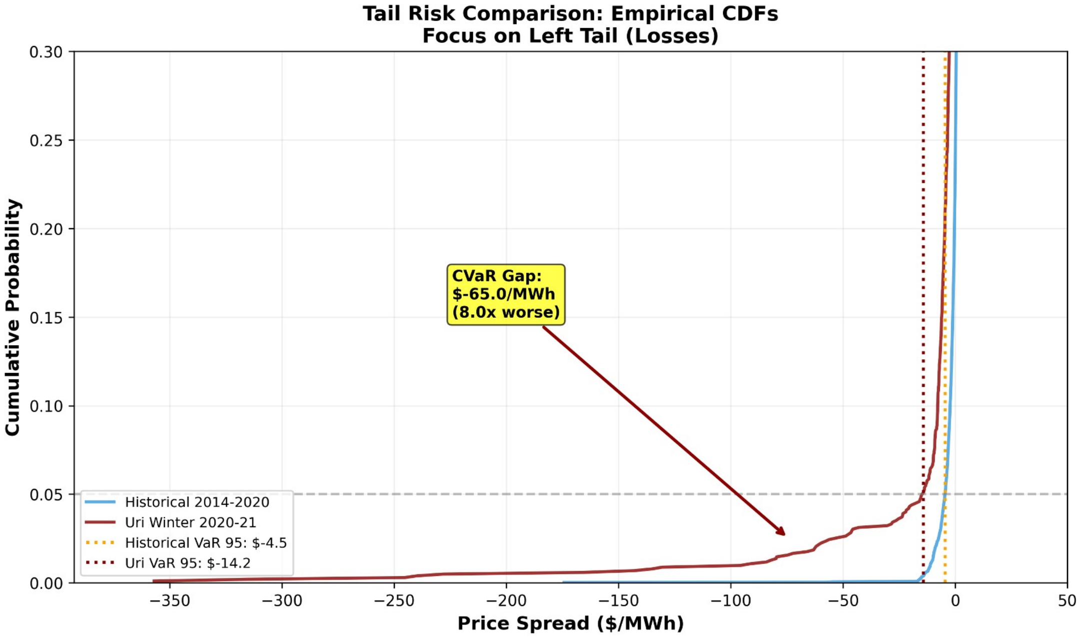
- Tail risk = average of historical worst 5% outcomes
- Historical 2014-2020 CVaR: -$9.27/MWh

Uri Tail Event:

- Actual 5% worst outcomes: -$74.22/MWh (8x worse)
- 7.5% of hours exceeded VaR threshold (not 5%)

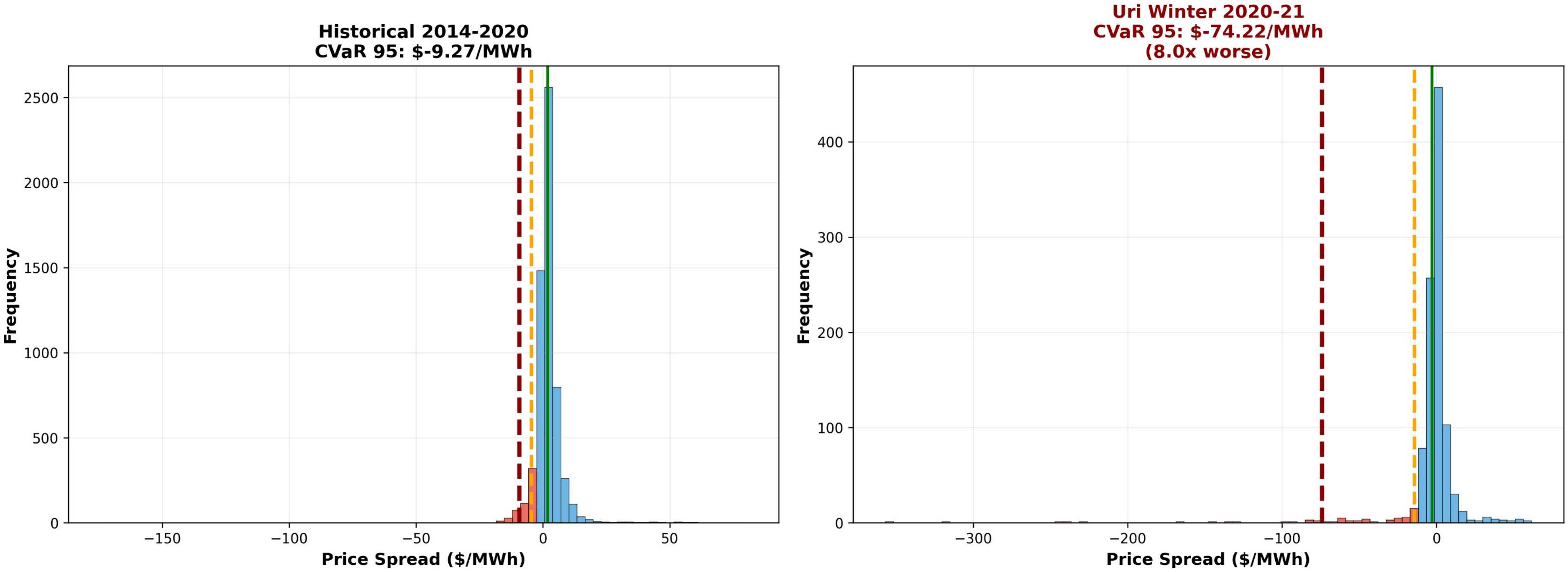
Three Critical Failures:

1. Assumes historical data captures worst-case
2. Assumes stable tail distribution
3. Ignores structural grid evolution and climate shifts



CVaR Analysis - Why Traditional Metrics Fail

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



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

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