



INSTITUTE FOR RISK MANAGEMENT AND INSURANCE INNOVATION



THE UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL

Assessing financial risk due to hydro-meteorological variability: A case study using Central Valley Project's power customers

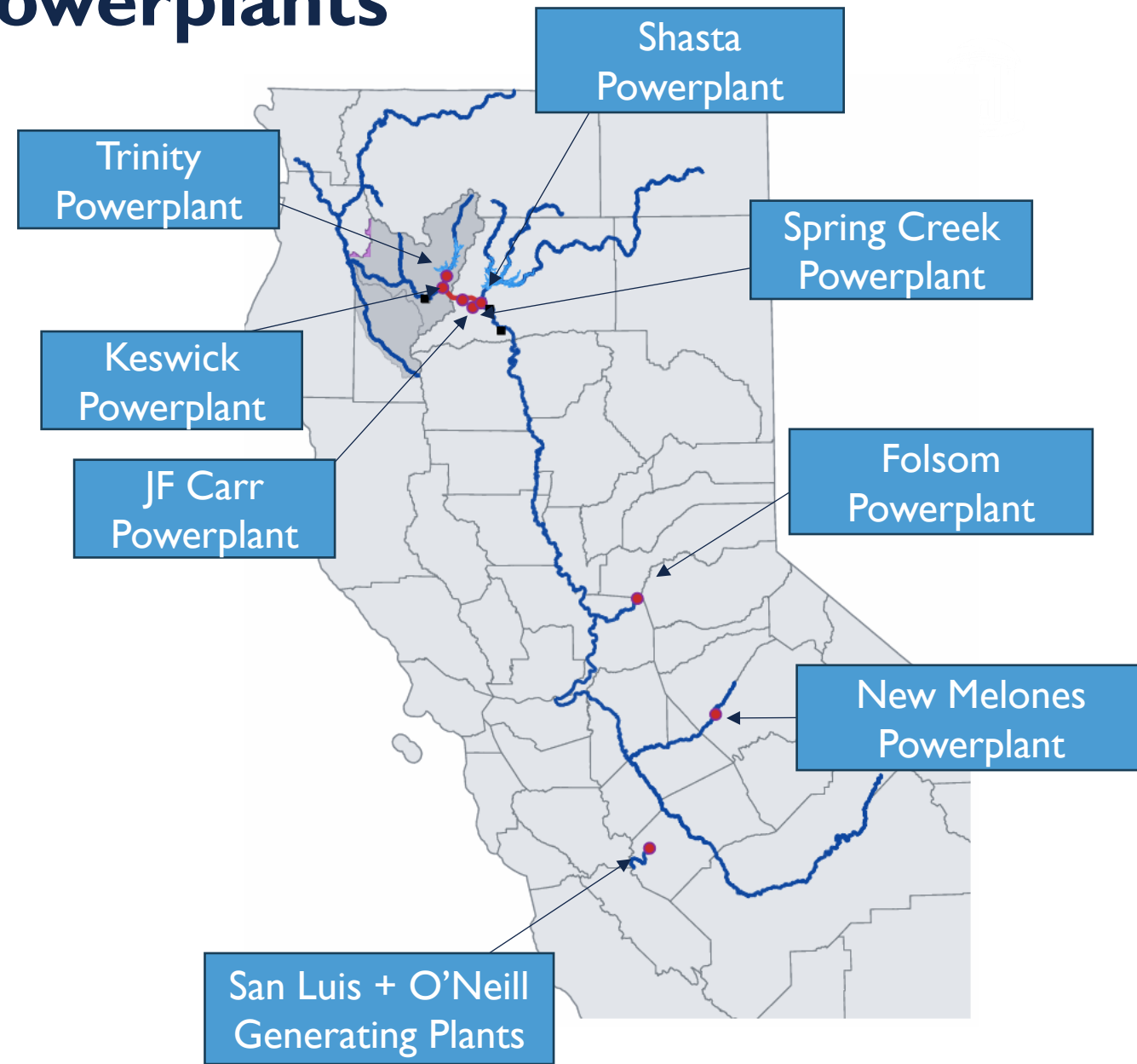
Ahmed M. Hamed, H.B. Zeff, Yash V. Amonkar, Gregory W. Characklis

Institute for Risk Management & Insurance Innovation



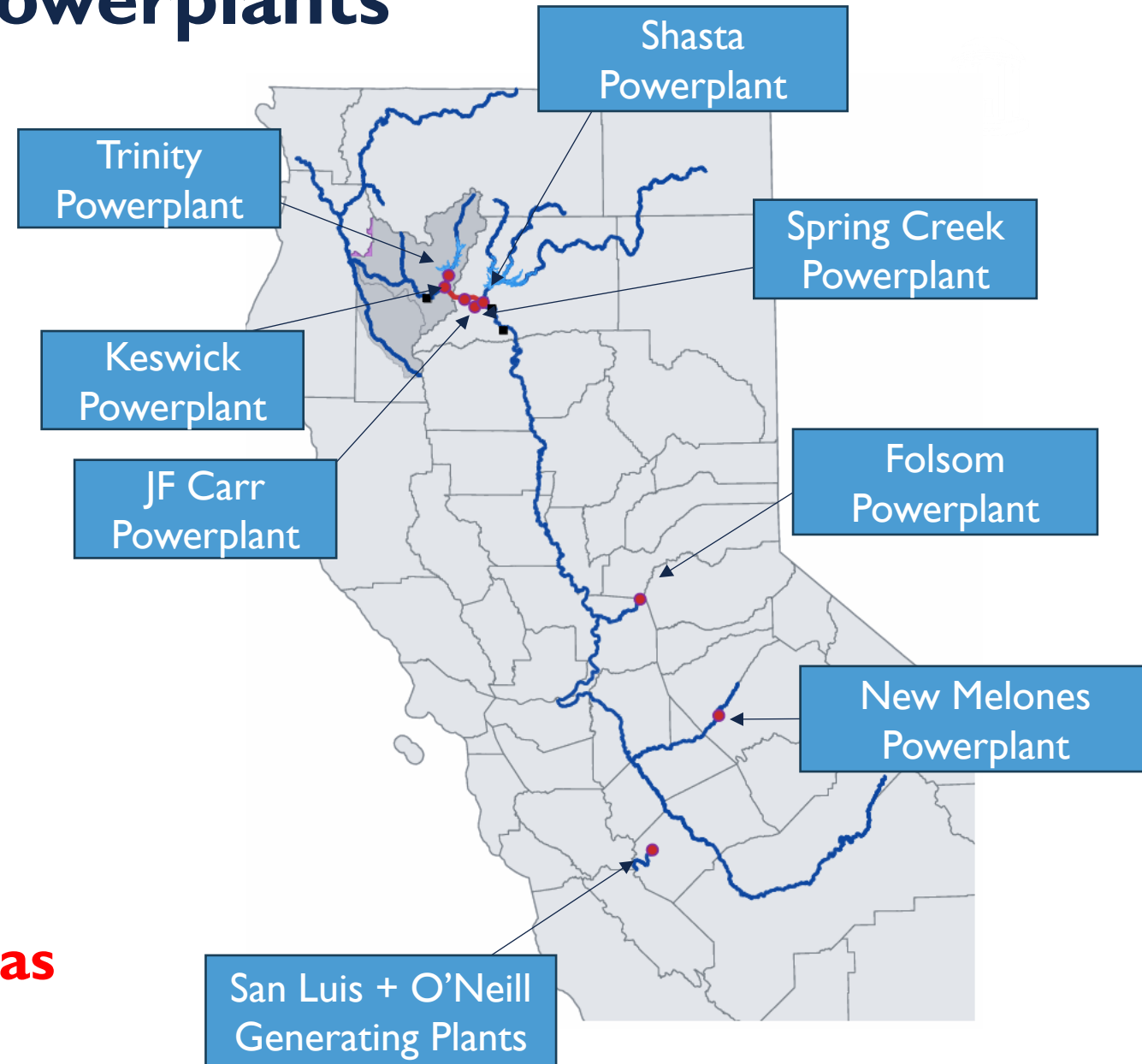
THE UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL

Central Valley Project Powerplants



Central Valley Project Powerplants

- CVP has an installed capacity of 2100 MW.
- CVP operates as “Peaking Plants”:
 - Operate during hours with **high demand (5-9 PM)** and **high prices**
 - Mean Price:
60 vs 35 \$/MWh
 - 99th percentile:
328 vs 96 \$/MWh
 - **Hydropower** ↔ **Natural Gas**



Fuel prices could keep rising for months even if Hormuz reopens, US EIA says

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BUSINESS INSIDER

DOW ▼ -0.61% NASDAQ 0% S&P 500 ▼ -0.16% OIL ▲ +0.43% AAPL ▼ -0.33% NV

ENERGY

Goldman warns of a 'very painful' oil market that could rival the oil crisis

The Washington Post
Democracy Dies in Darkness

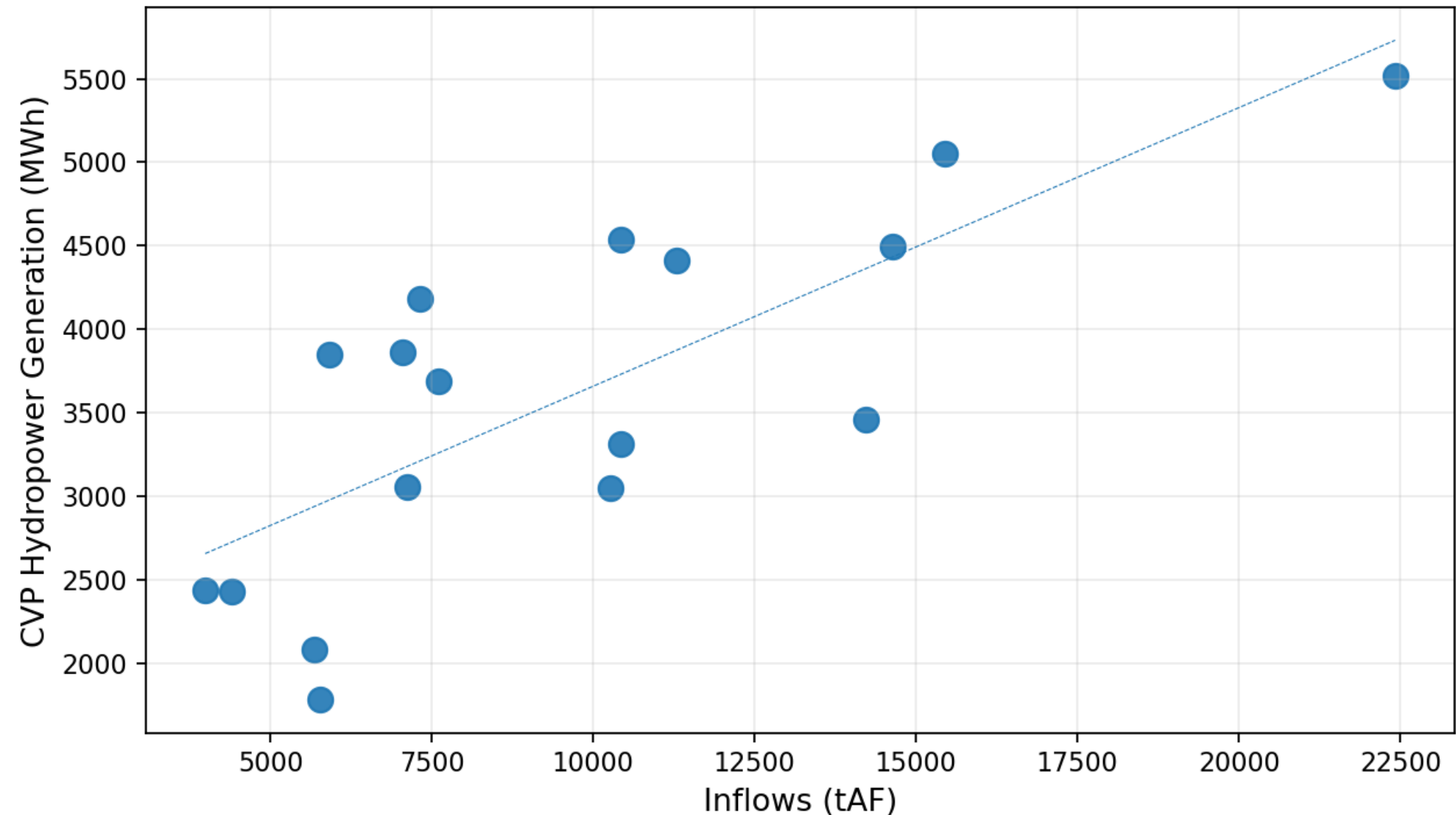
Gas prices eclipse \$4 a gallon in the US, the highest since 2022

U.S. gas prices have jumped past an average of \$4 a gallon for the first time since 2022 as fuel prices continue to soar worldwide amid the Iran war

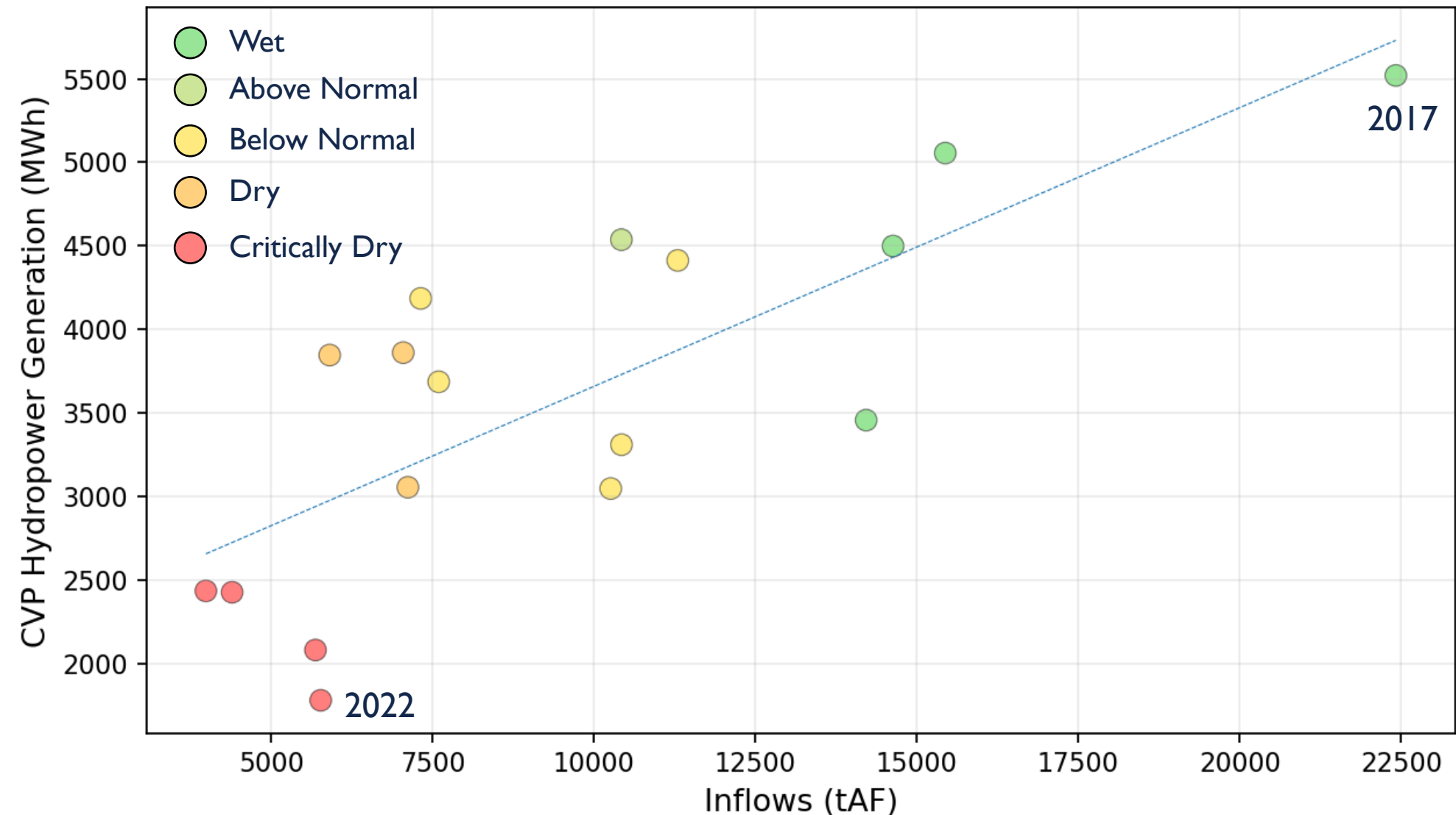
March 31, 2026

Rising gas prices hitting US household finances and more pain is expected, Reuters/Ipsos poll finds

Hydro-meteorological Variability = Hydropower Volatility

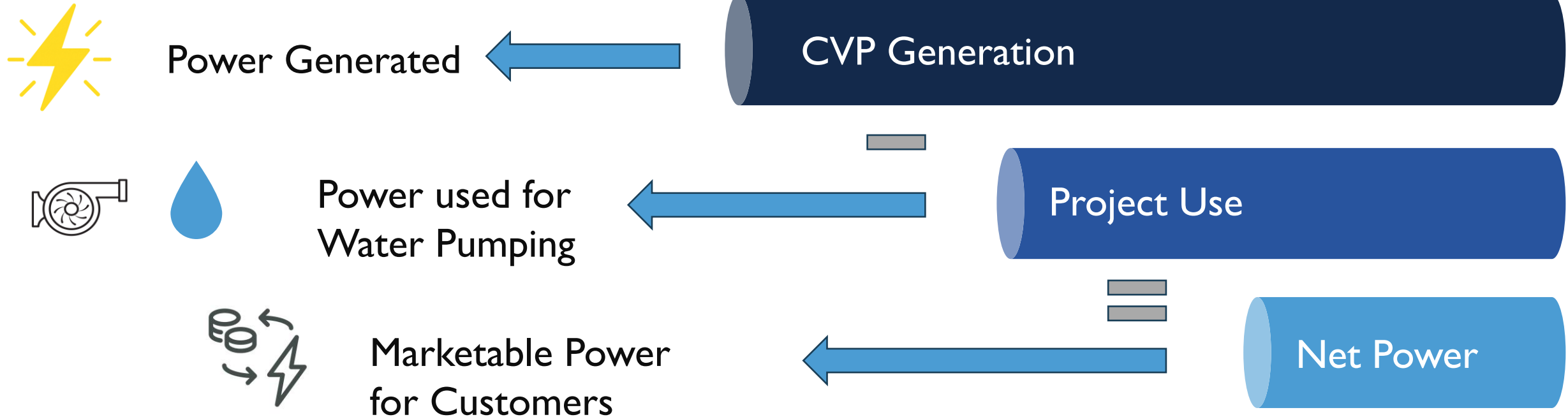


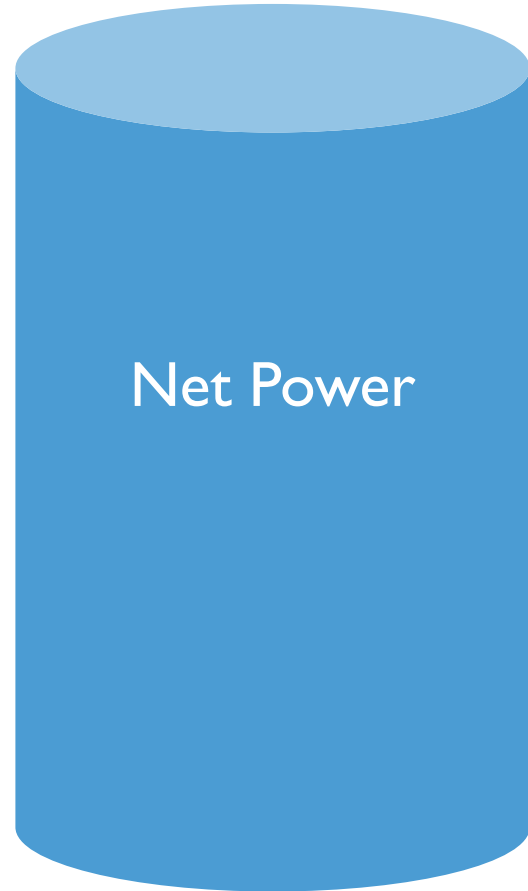
Hydro-meteorological Variability = Hydropower Volatility



Compounded Volatility

$$\text{Net Power} = \text{CVP Generation} - \text{Project Use}$$





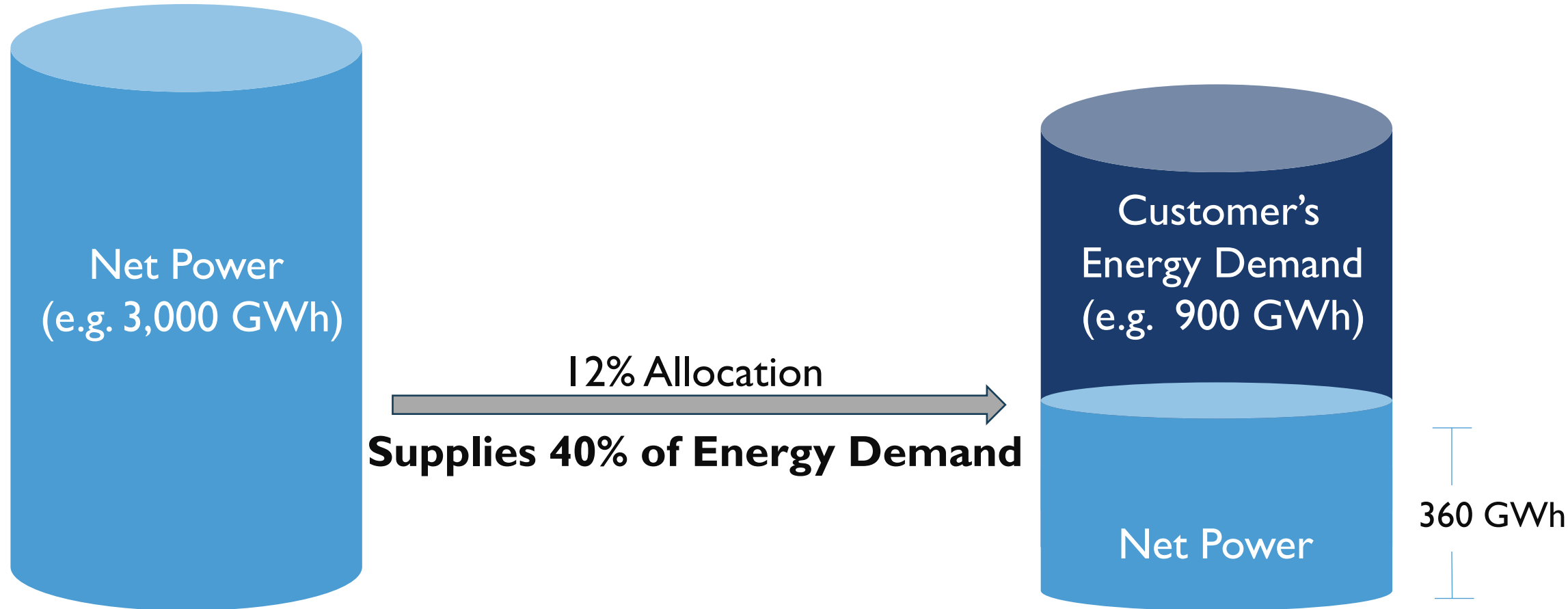
12% of Net Power is Allocated to a Theoretical Customer



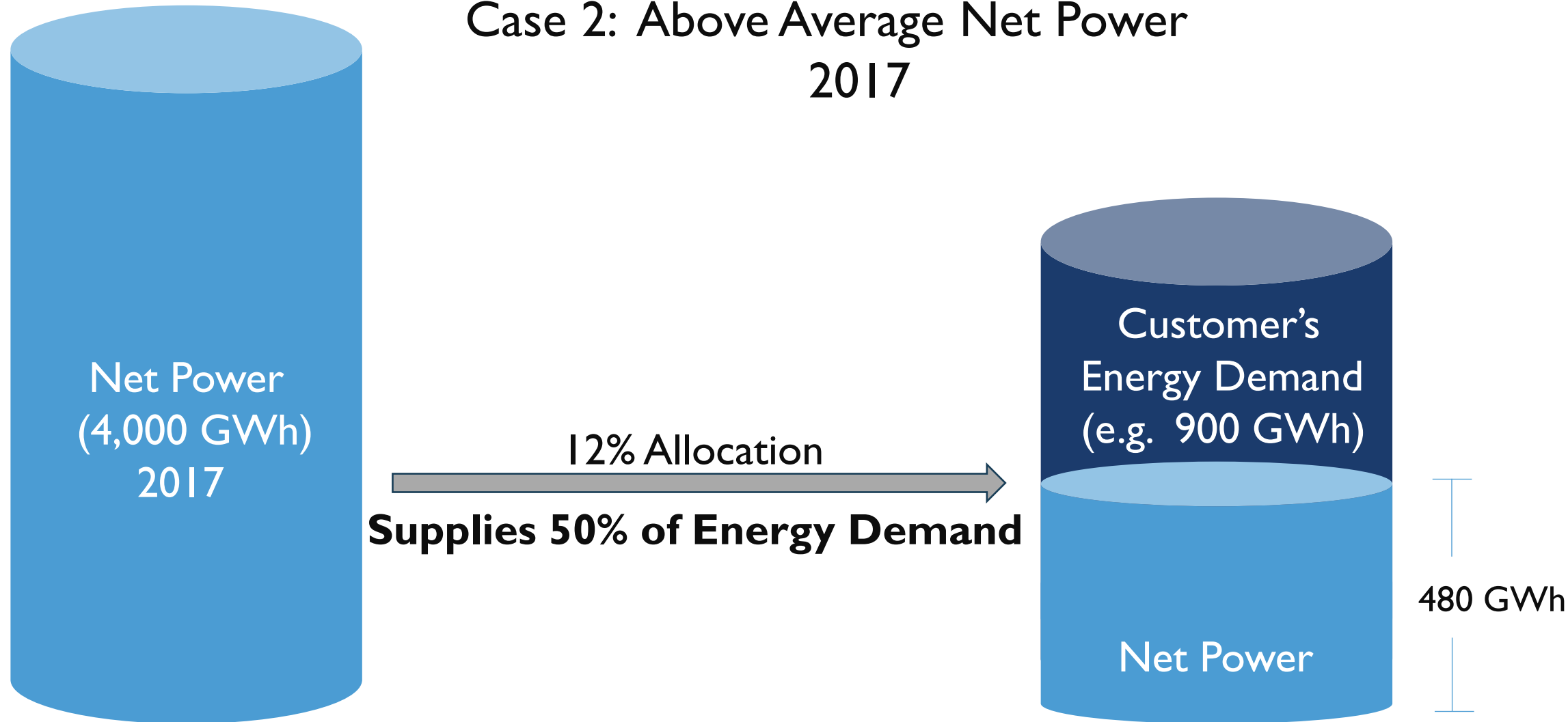
12% Allocation



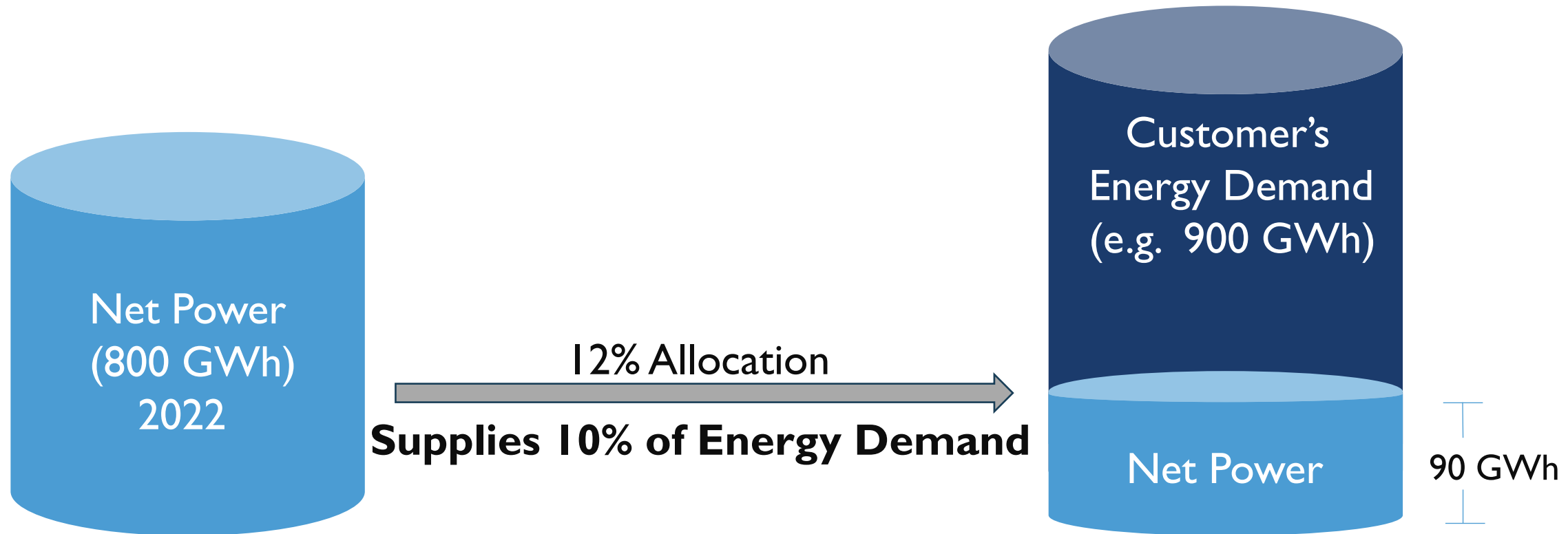
Case I: Average Net Power



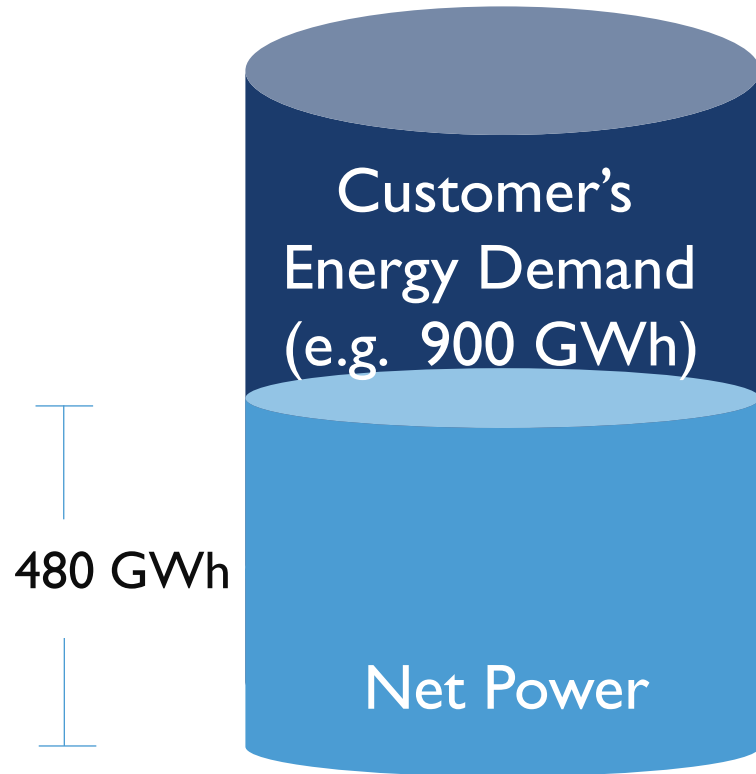
Case 2: Above Average Net Power 2017



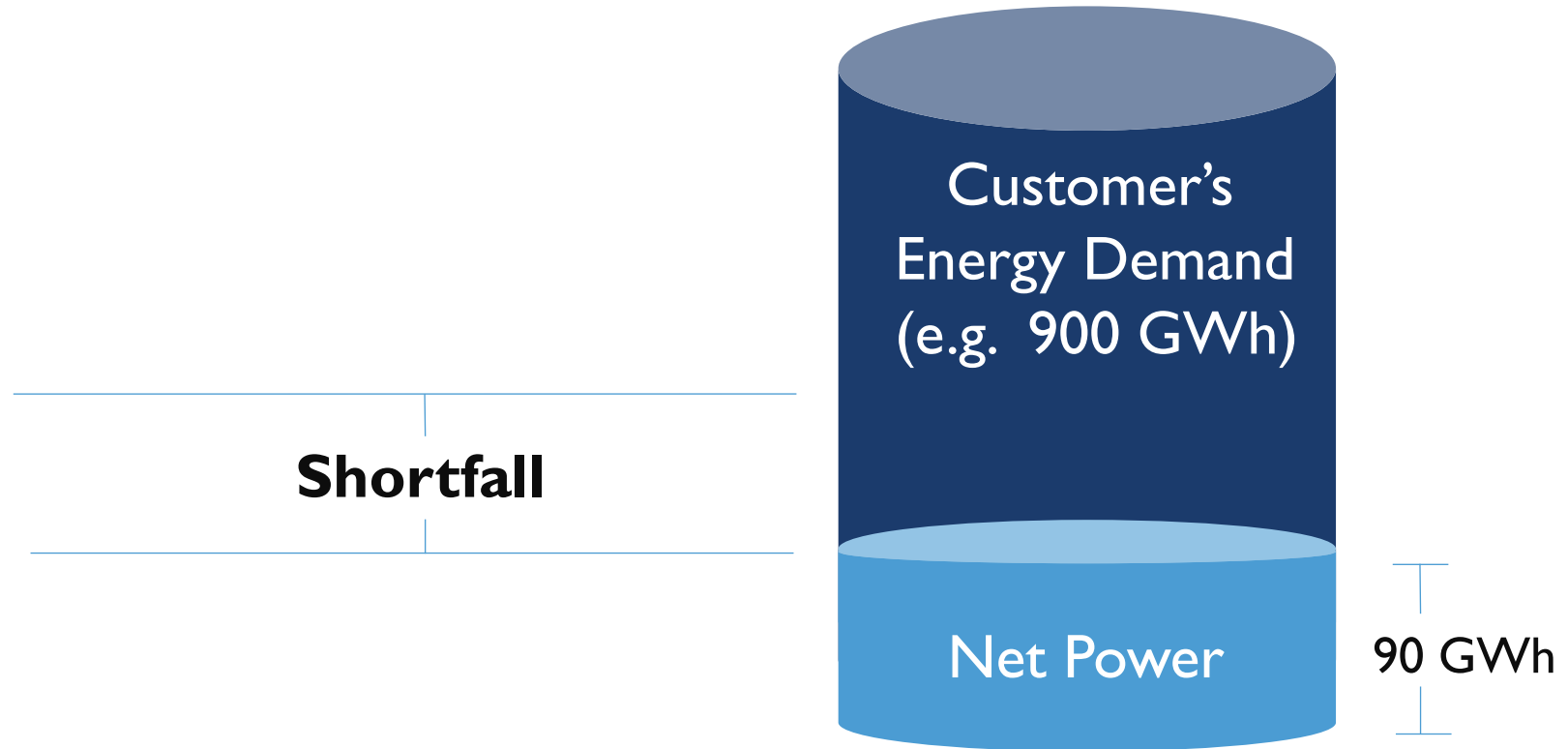
Case 3: Below Average Net Power 2022



Case 2: Above Average Net Power 2017



Case 3: Below Average Net Power 2022



Case 2: Above Average Net Power 2017

Case 3: Below Average Net Power 2022

Shortfall = Less Power



Less Power = Spot Market



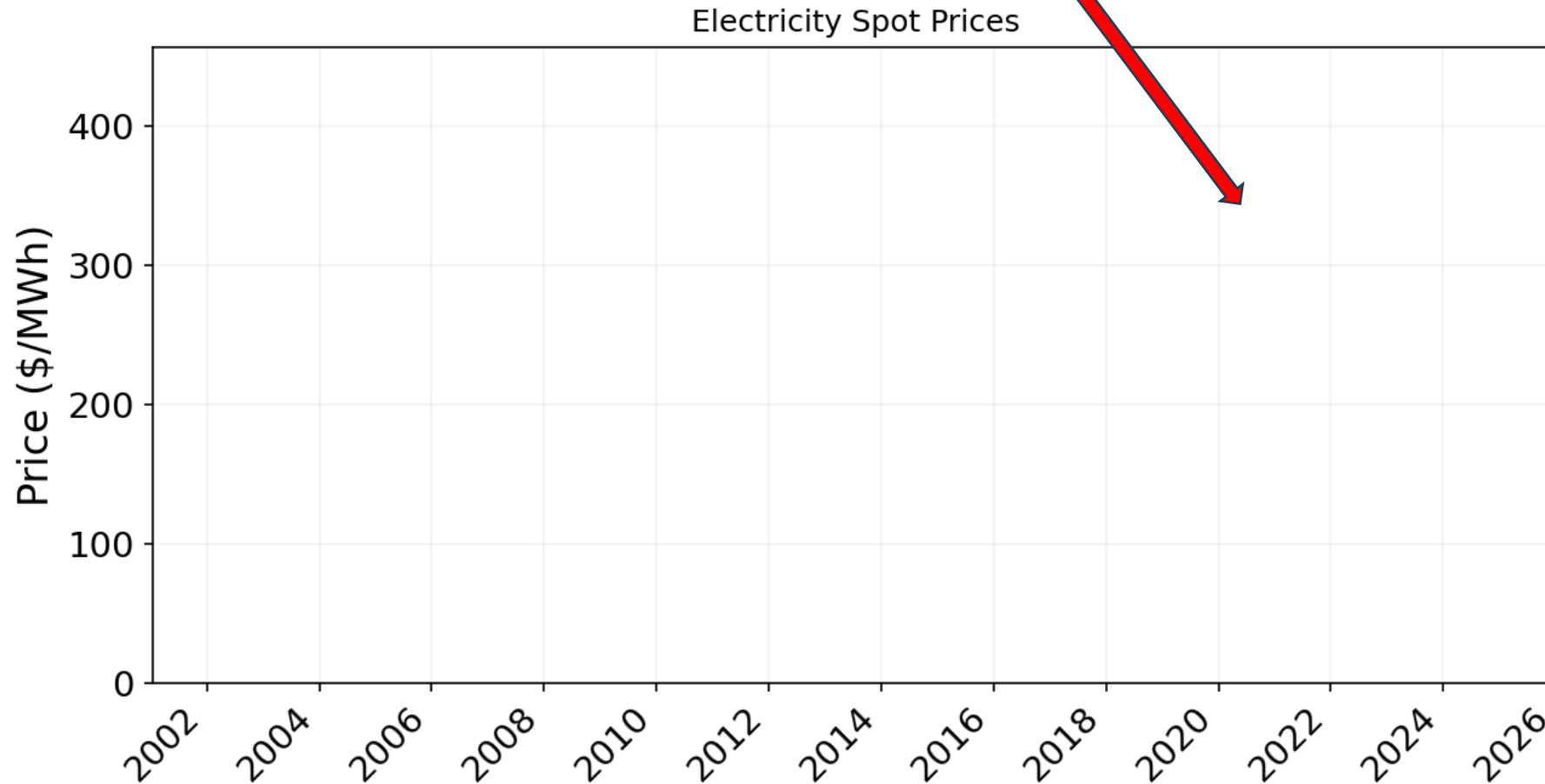
Net Power

Net Power

90 GWh

WHY HEDGE?

Energy spot prices are extremely **volatile**



Forward Contract

- A bilateral agreement to buy/sell a commodity at a **future date (maturity)** for a **predetermined price**
- **Payoff** is the difference between the **spot price at maturity** and the **forward price locked in**

$$\text{Payoff} = \text{Spot Price} - \text{Forward Price}$$

PRICE RISK

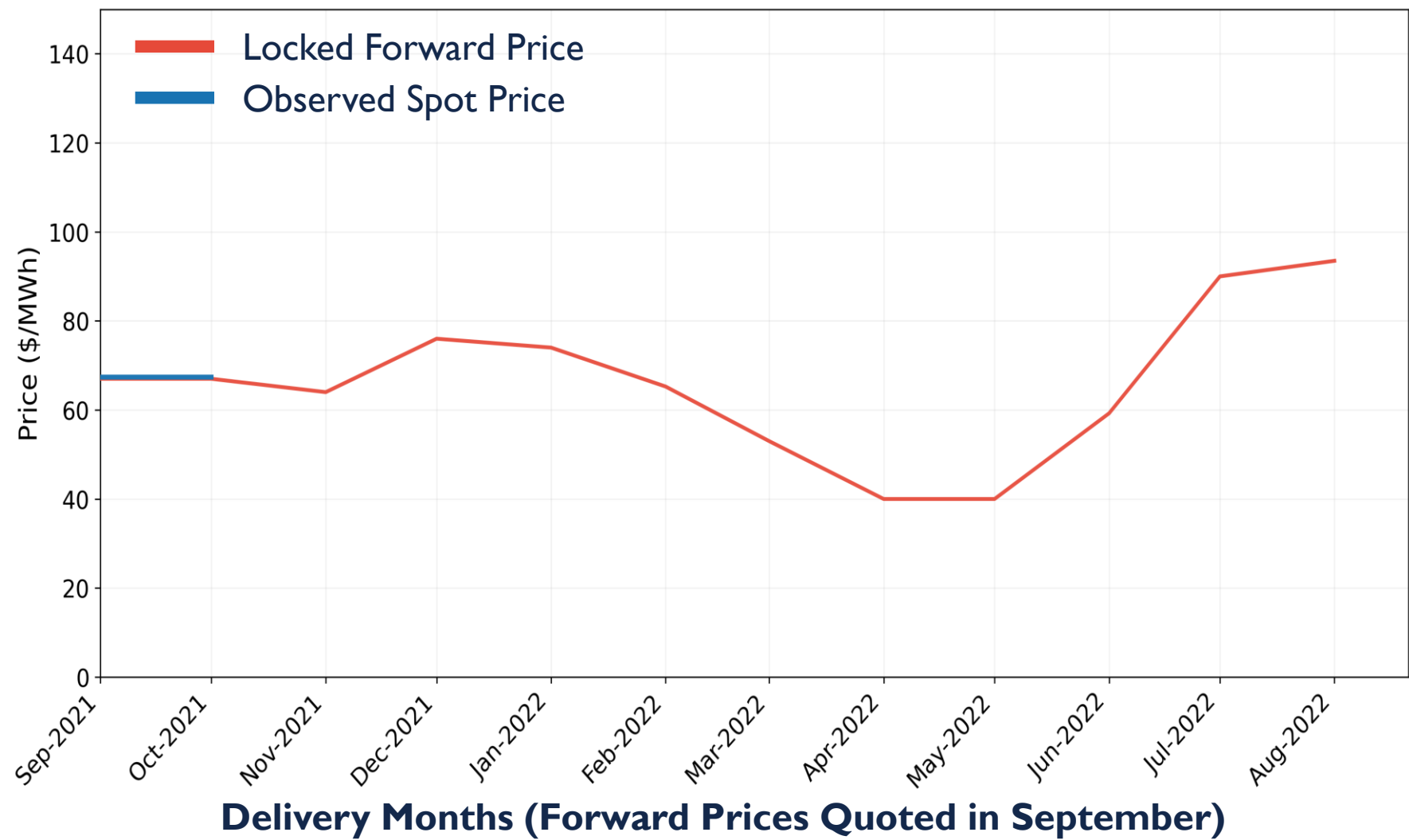
Forward Hedged vs Realized Spot Price



Date	Spot	Forwards
10/1/2021		67
11/1/2021		64
12/1/2021		76
1/1/2022		74
2/1/2022		65
3/1/2022		53
4/1/2022		40
5/1/2022		40
6/1/2022		60
7/1/2022		90
8/1/2022		93

PRICE RISK

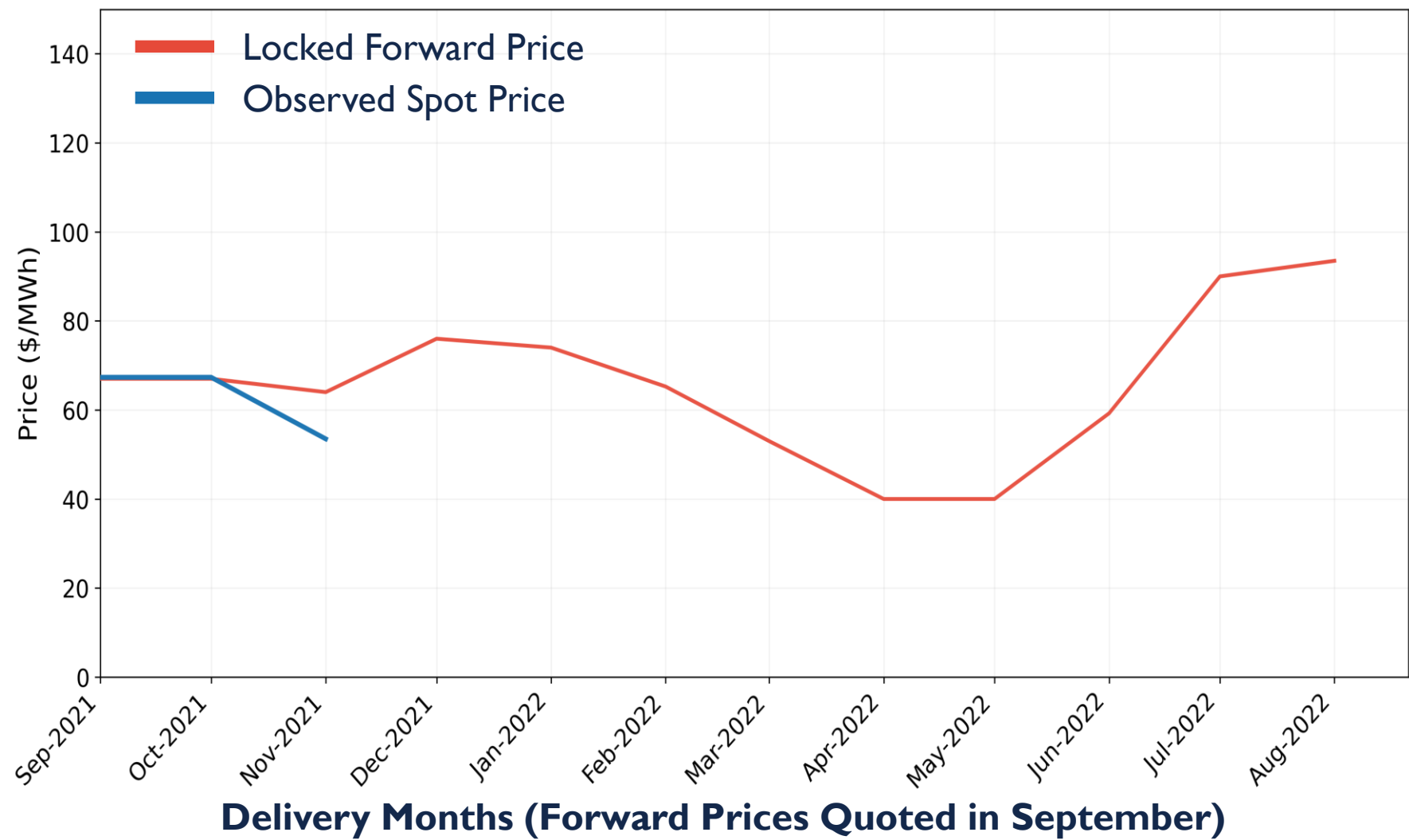
Forward Hedged vs Realized Spot Price



Date	Spot	Forwards
10/1/2021	67	67
11/1/2021		64
12/1/2021		76
1/1/2022		74
2/1/2022		65
3/1/2022		53
4/1/2022		40
5/1/2022		40
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7/1/2022		90
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PRICE RISK

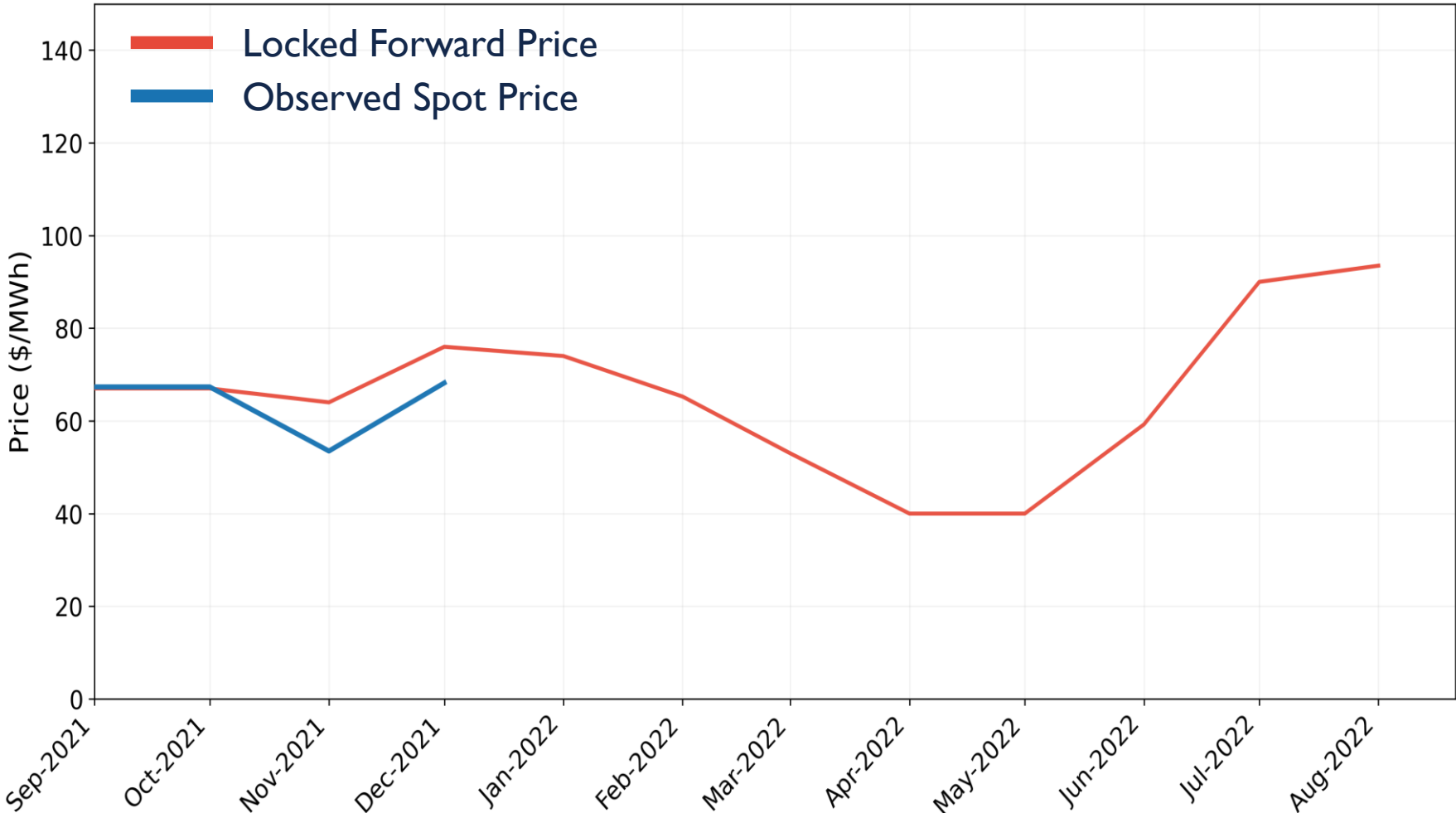
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PRICE RISK

Forward Hedged vs Realized Spot Price



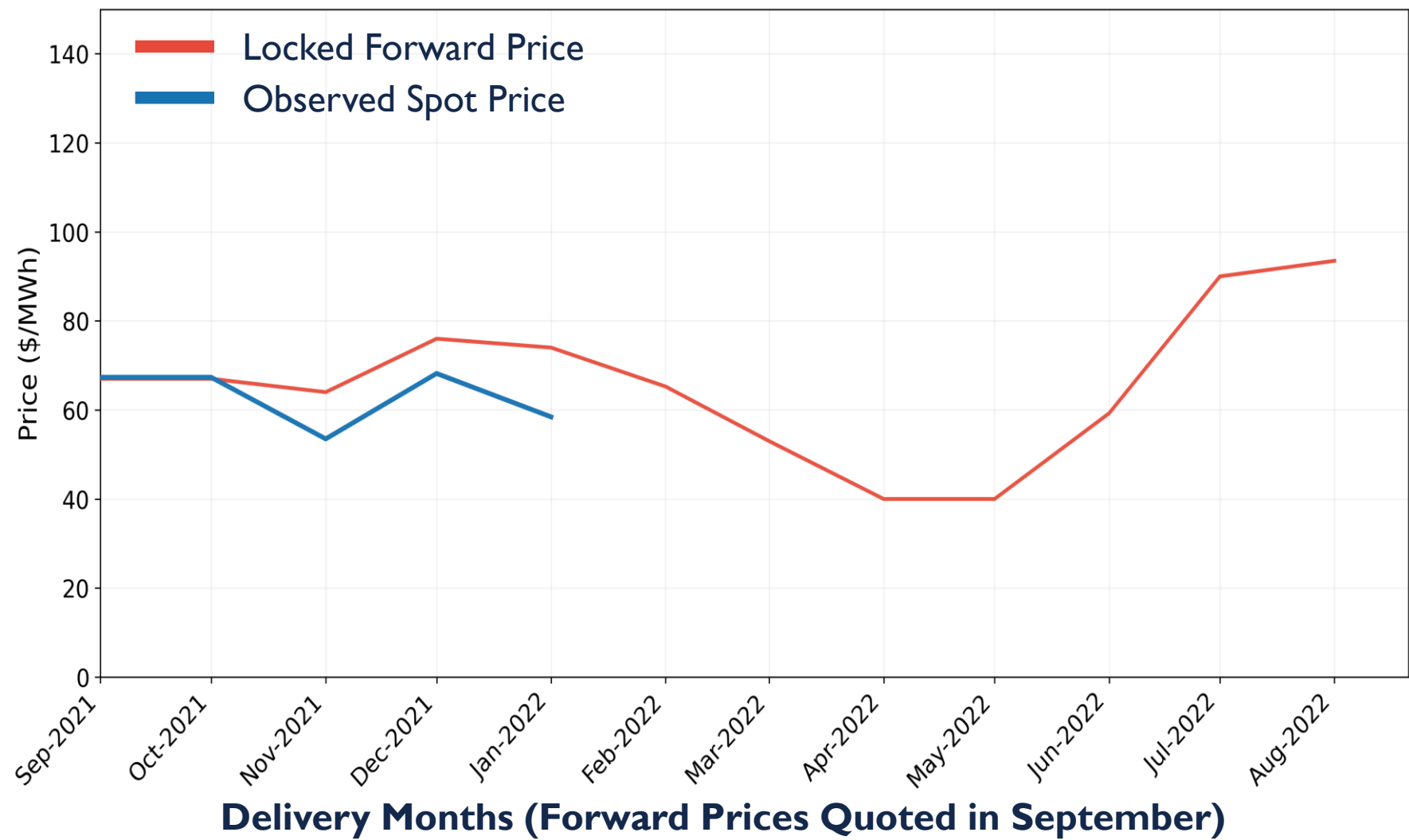
Delivery Months (Forward Prices Quoted in September)

Date	Spot	Forwards
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4/1/2022		40
5/1/2022		40
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PRICE RISK

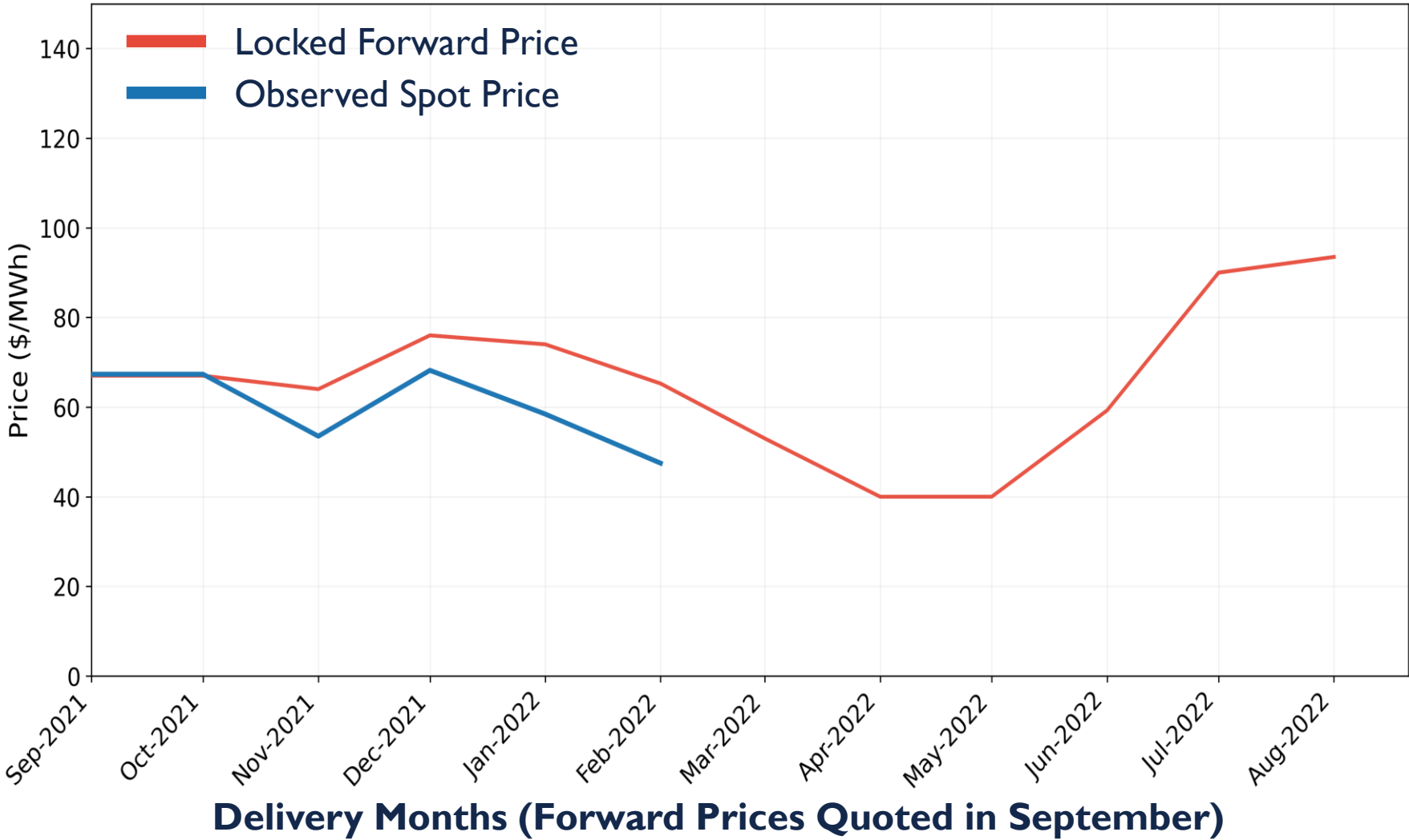
Forward Hedged vs Realized Spot Price



Date	Spot	Forwards
10/1/2021	67	67
11/1/2021	53	64
12/1/2021	68	76
1/1/2022	58	74
2/1/2022		65
3/1/2022		53
4/1/2022		40
5/1/2022		40
6/1/2022		60
7/1/2022		90
8/1/2022		93

PRICE RISK

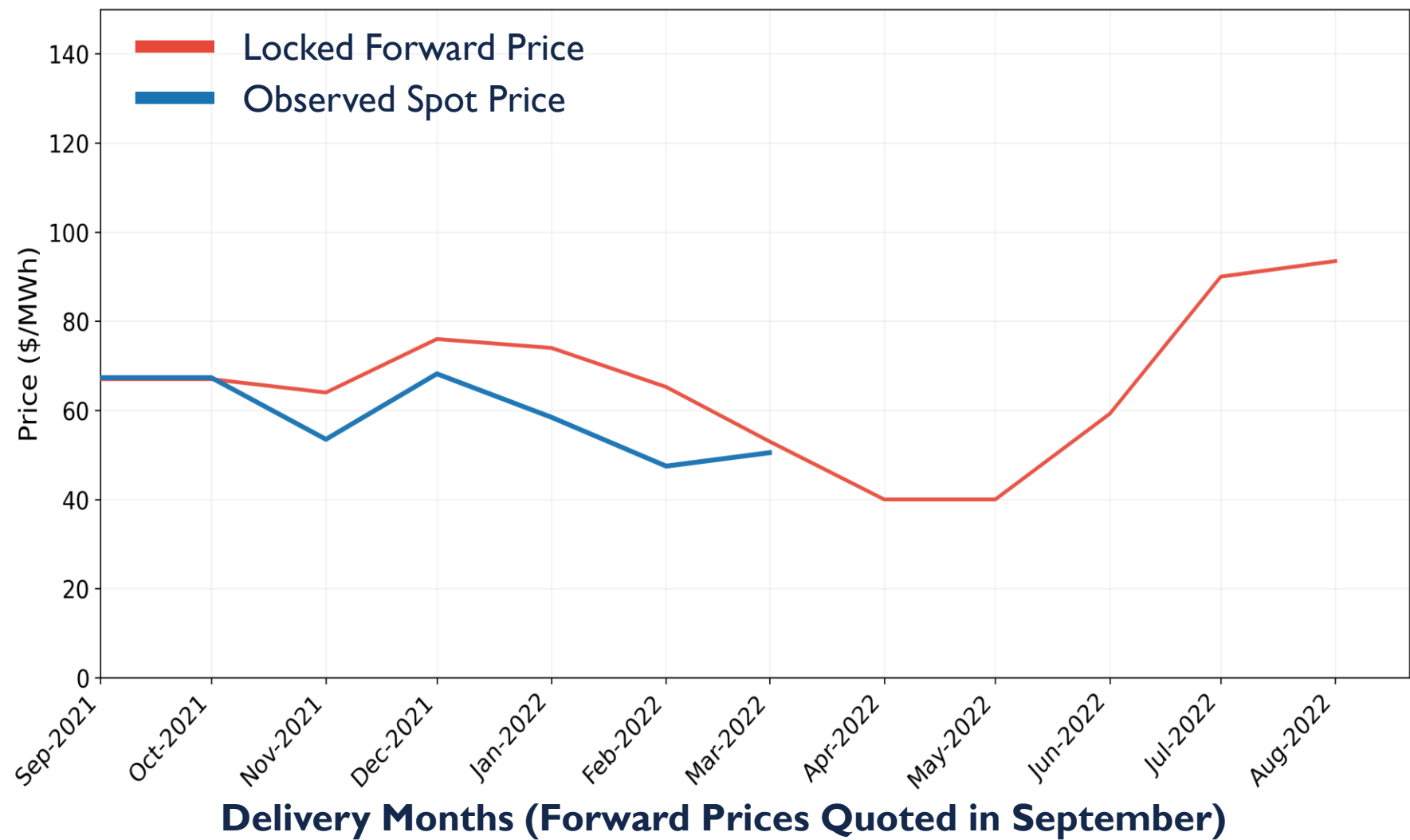
Forward Hedged vs Realized Spot Price



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5/1/2022		40
6/1/2022		60
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8/1/2022		93

PRICE RISK

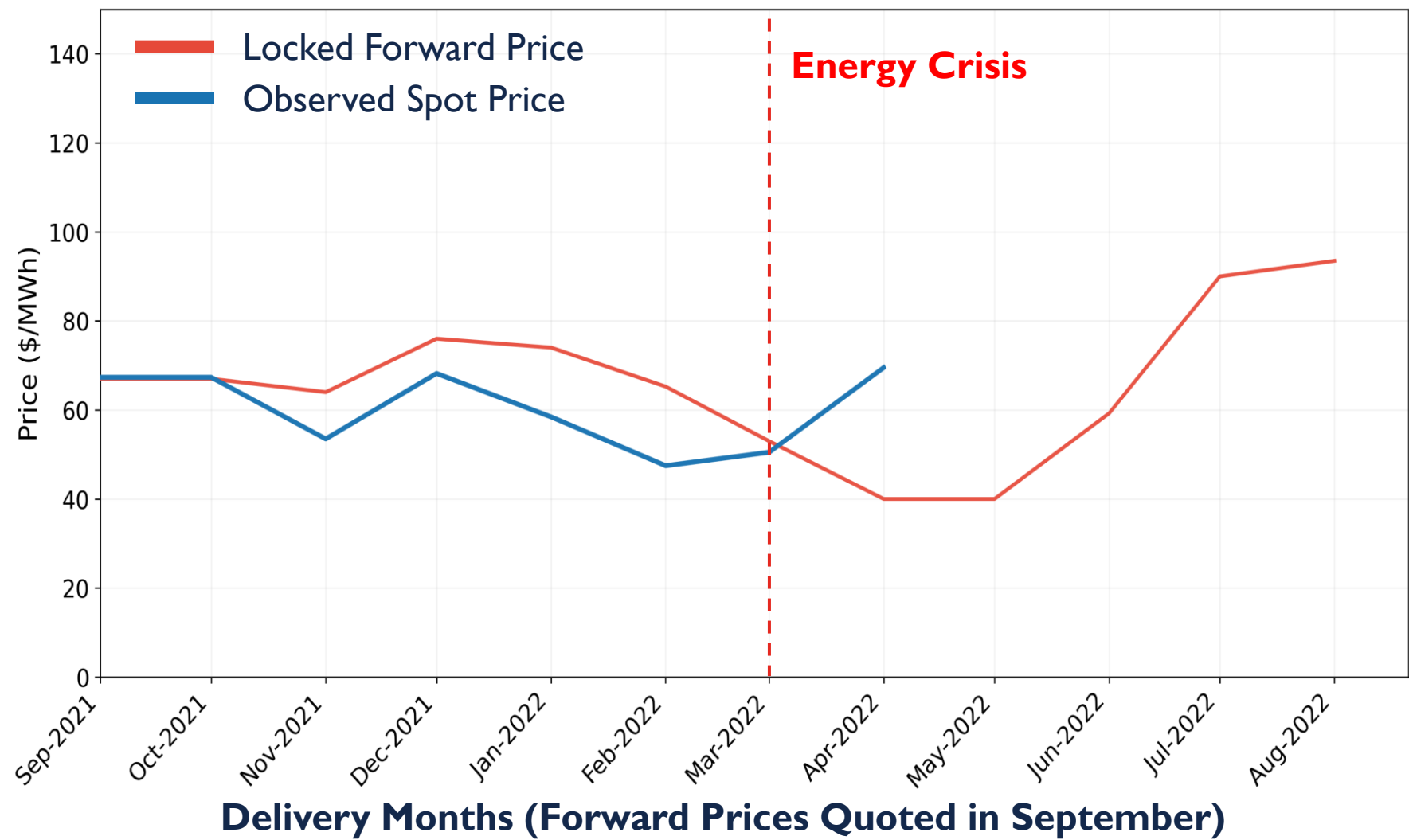
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PRICE RISK

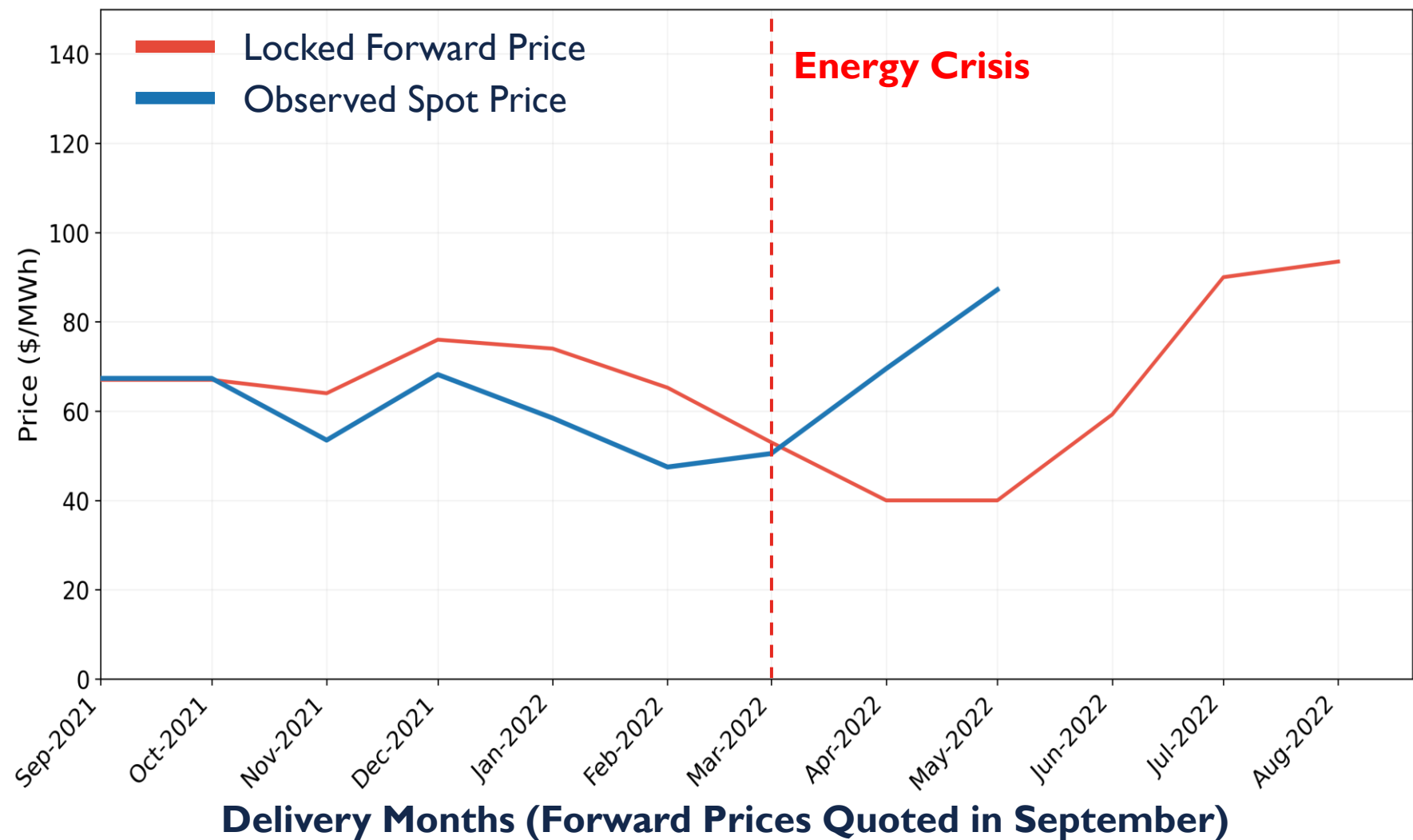
Forward Hedged vs Realized Spot Price



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4/1/2022	69	40
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6/1/2022		60
7/1/2022		90
8/1/2022		93

PRICE RISK

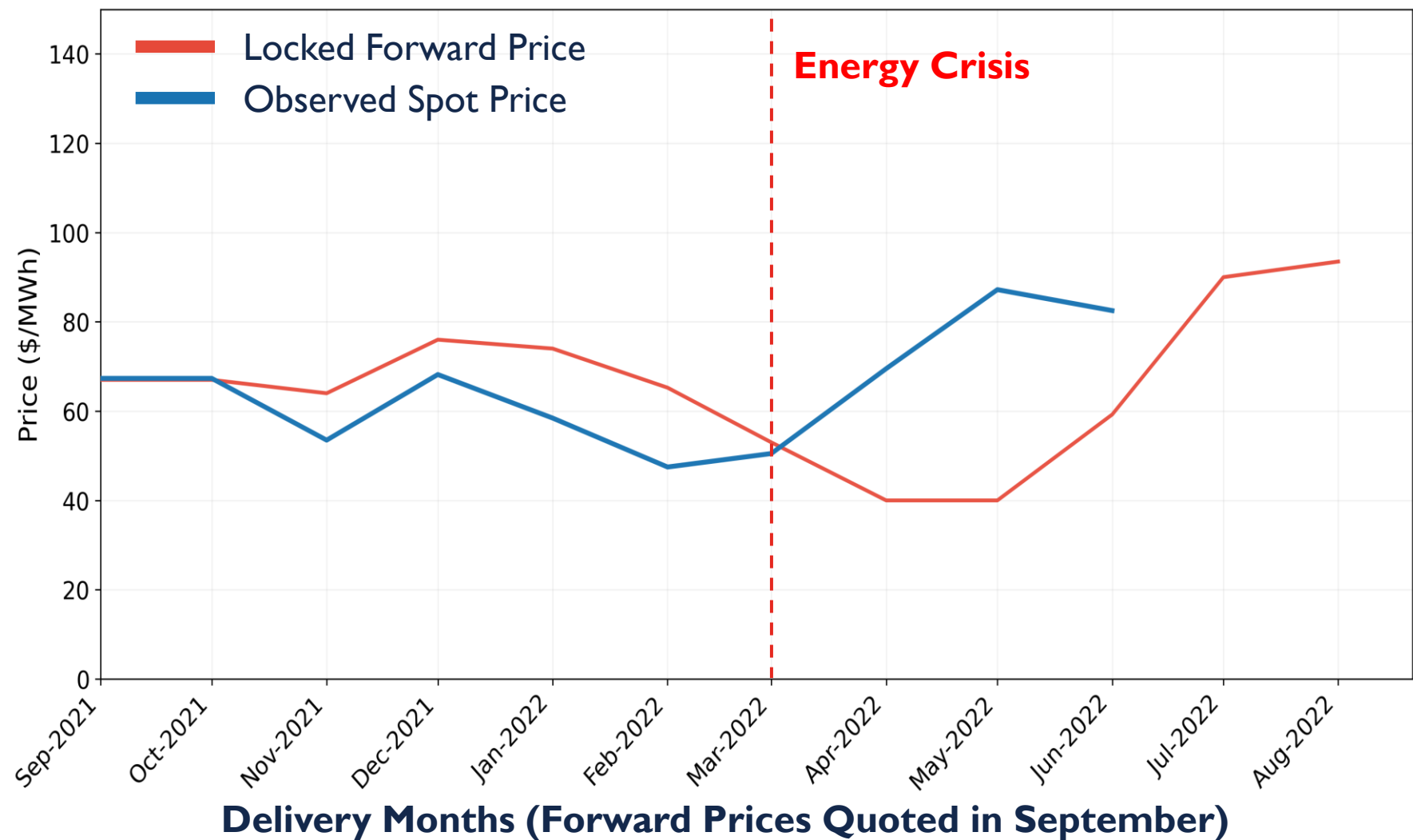
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3/1/2022	50	53
4/1/2022	69	40
5/1/2022	87	40
6/1/2022		60
7/1/2022		90
8/1/2022		93

PRICE RISK

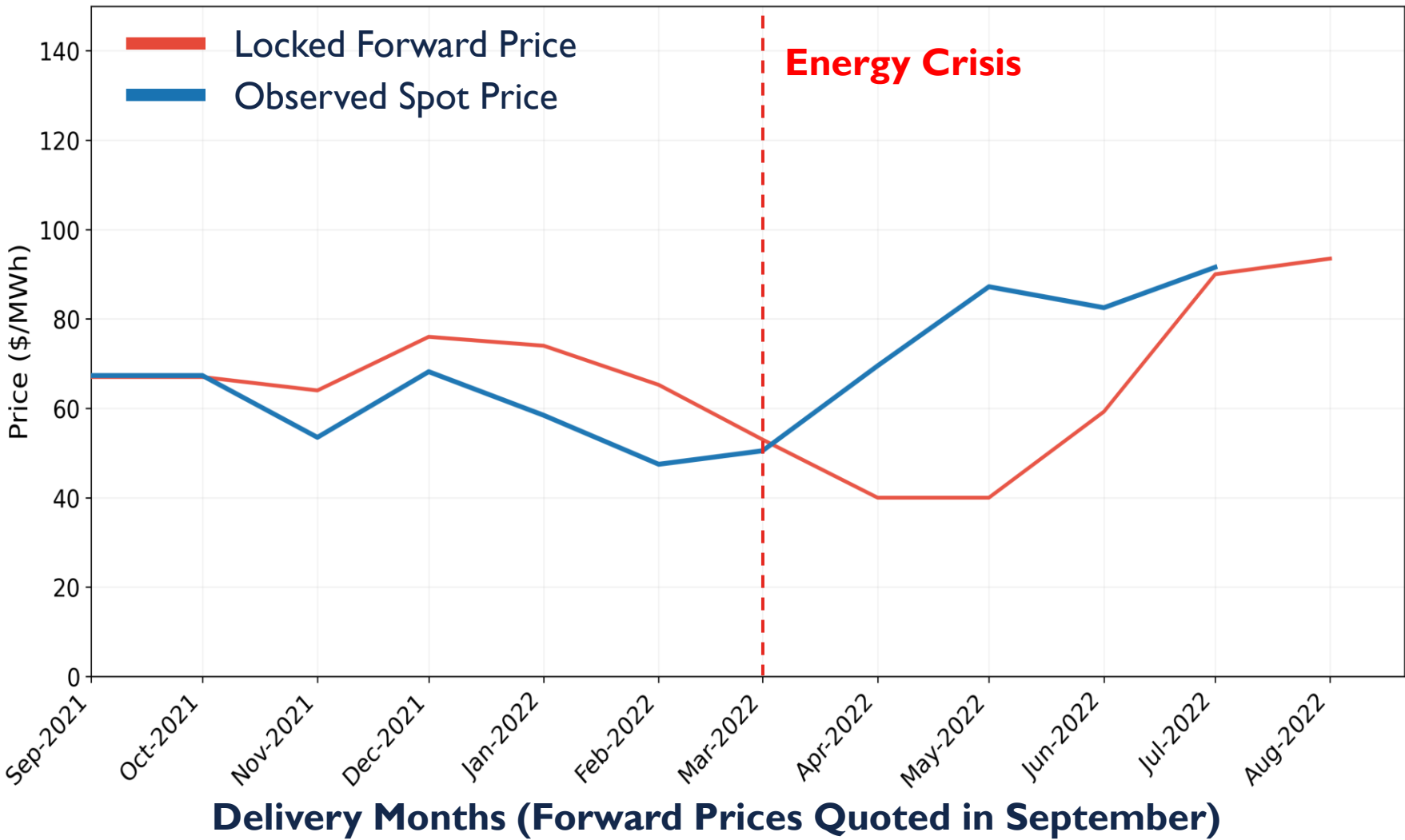
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PRICE RISK

Forward Hedged vs Realized Spot Price

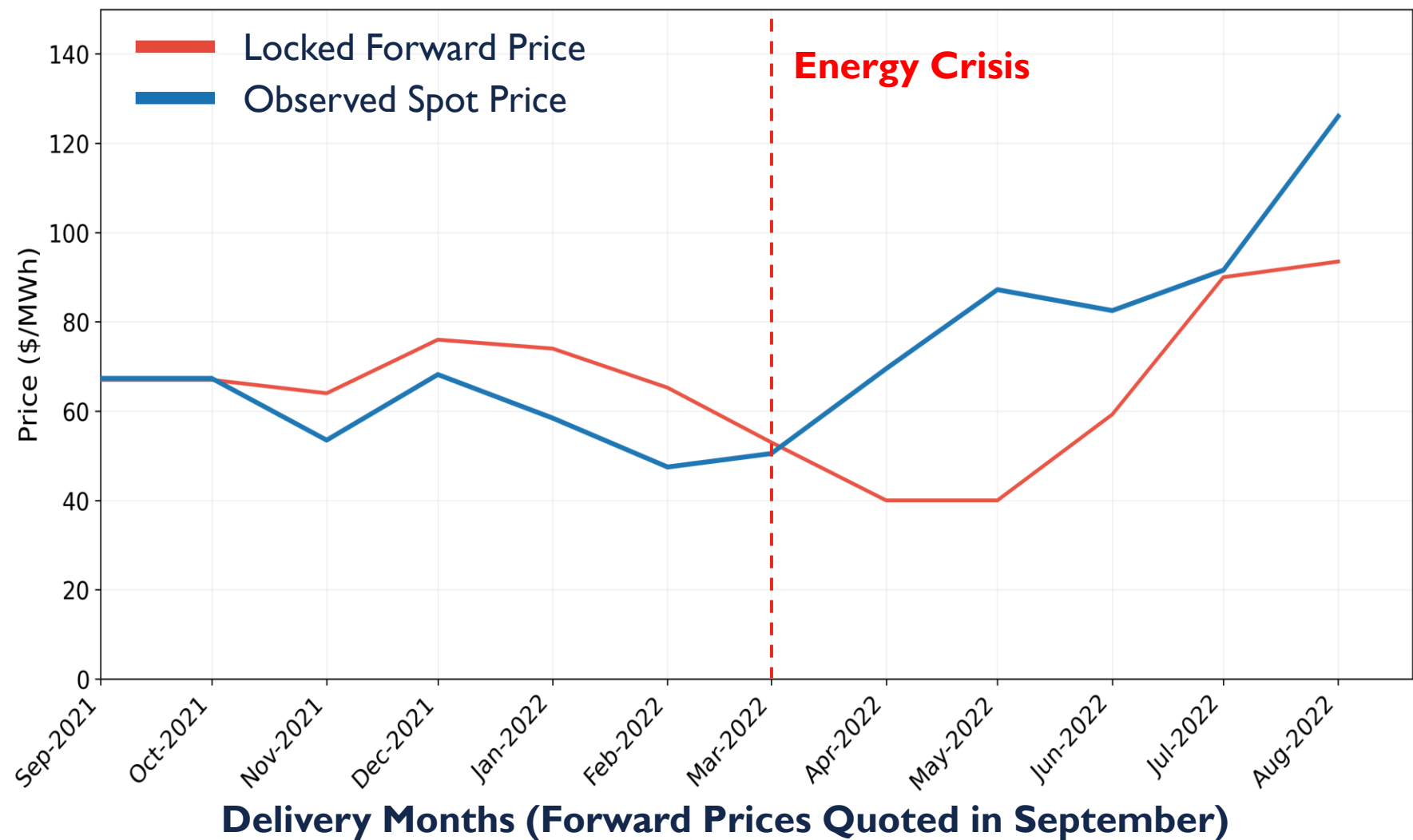


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8/1/2022		93



PRICE RISK

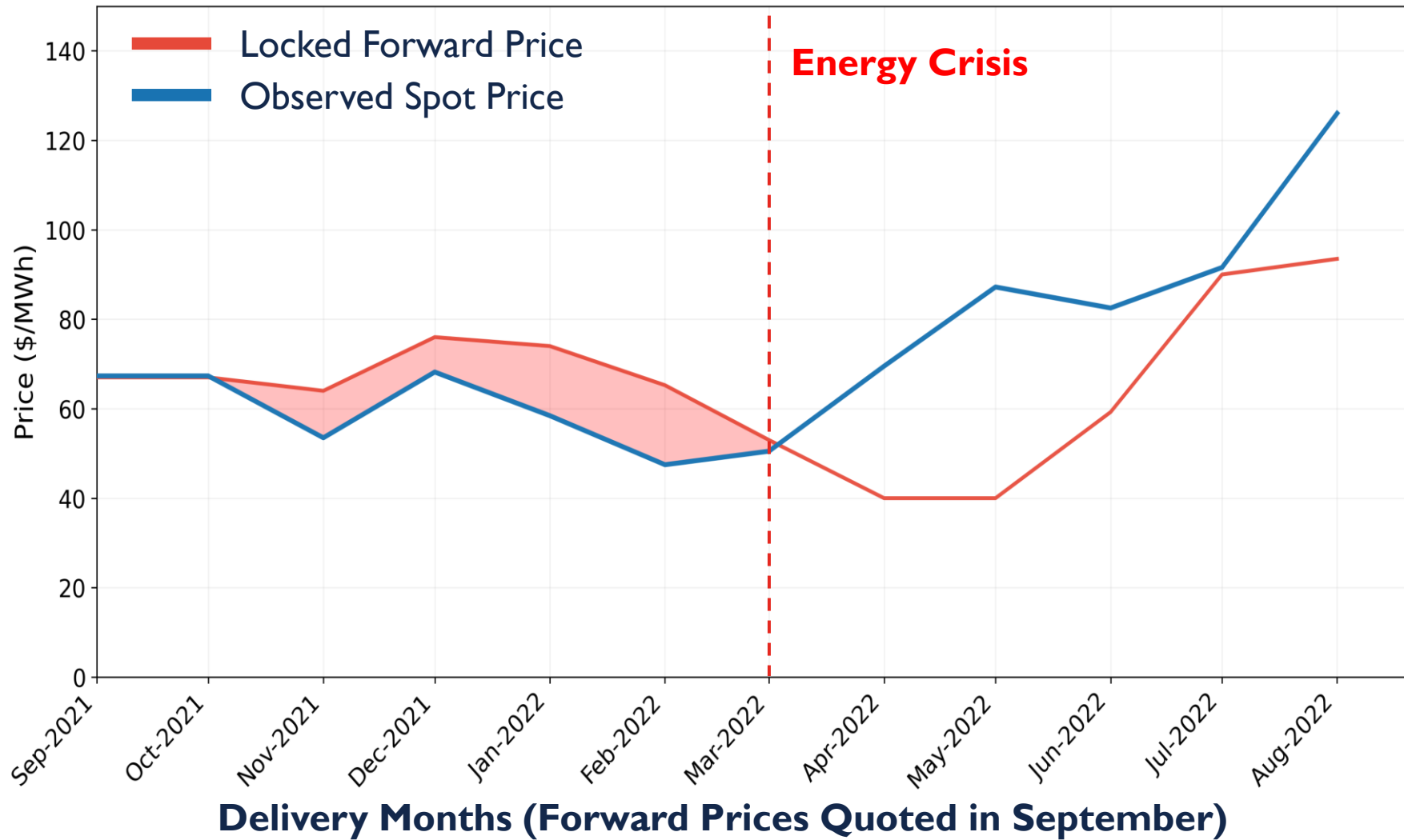
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3/1/2022	50	53
4/1/2022	69	40
5/1/2022	87	40
6/1/2022	82	60
7/1/2022	91	90
8/1/2022	126	93

PRICE RISK

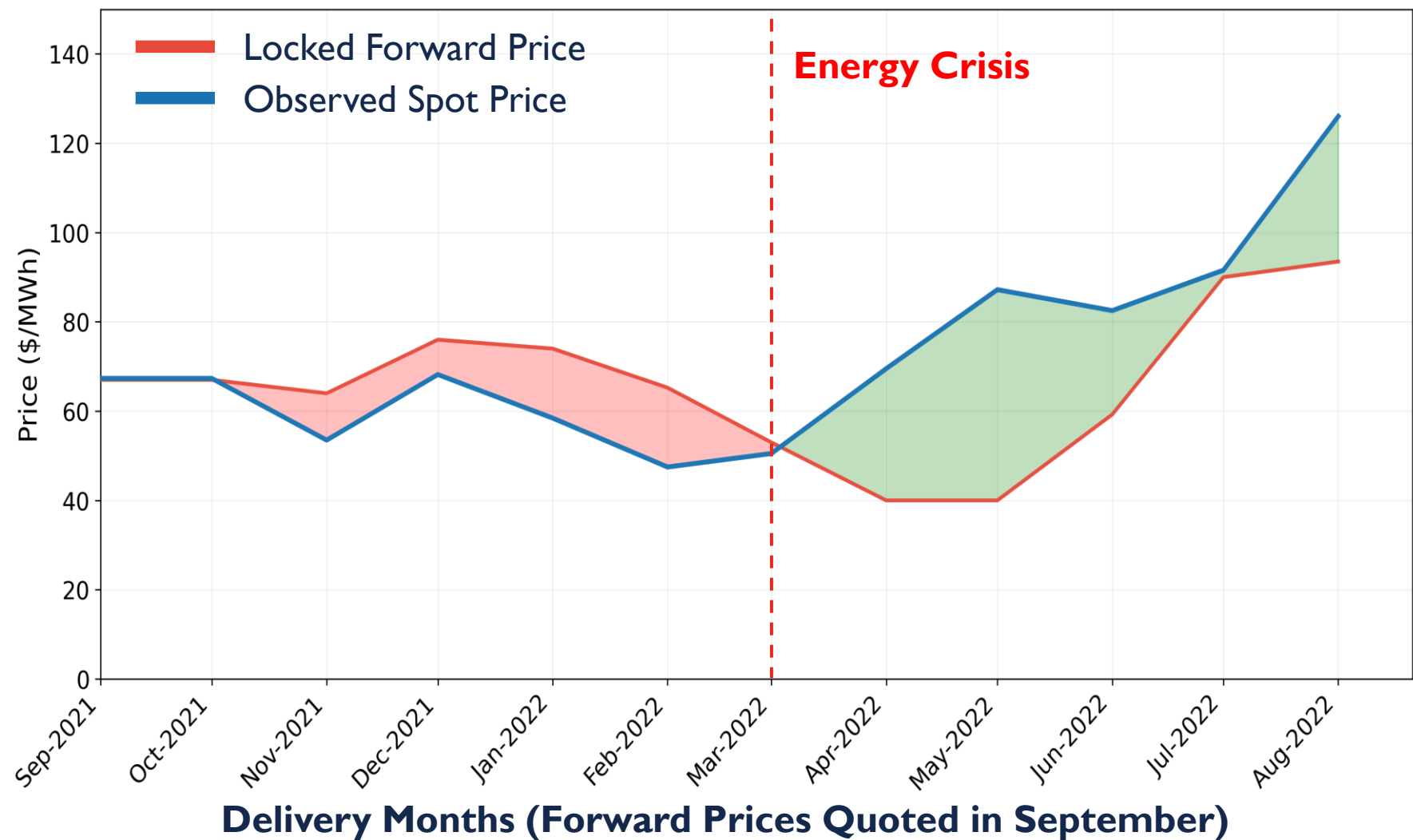
Forward Hedged vs Realized Spot Price



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7/1/2022	91	90
8/1/2022	126	93

PRICE RISK

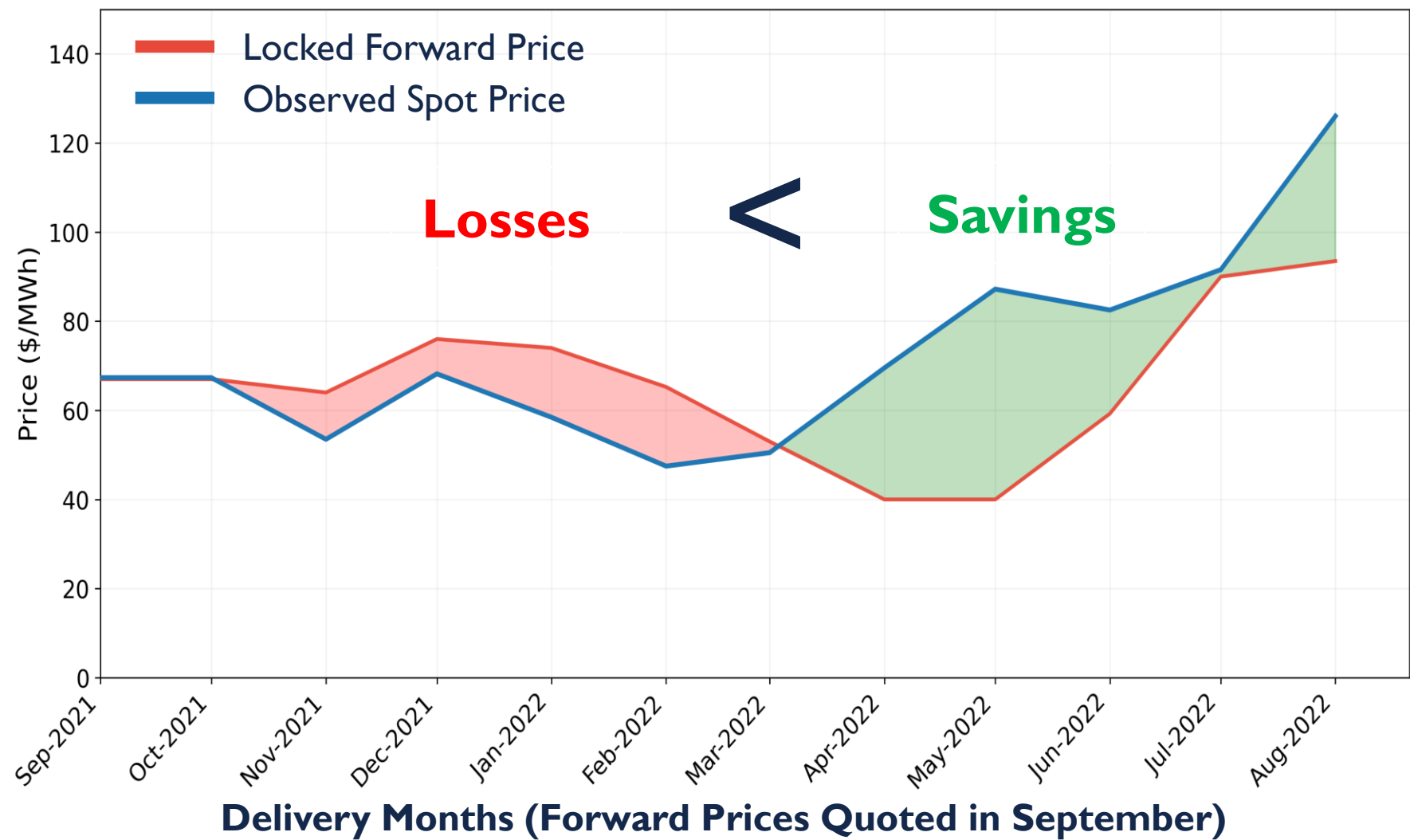
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PRICE RISK

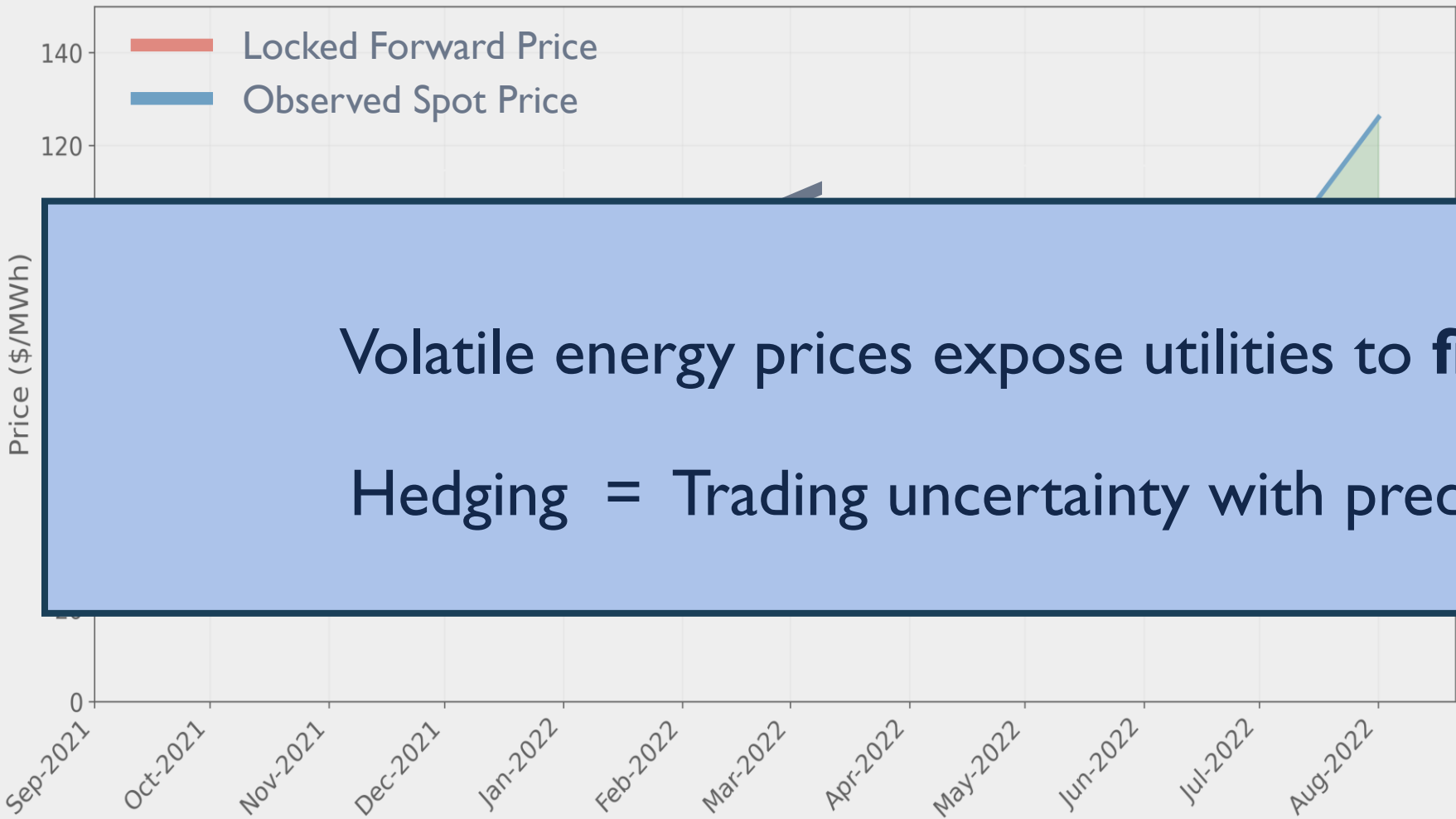
Forward Hedged vs Realized Spot Price



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11/1/2021	53	64
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4/1/2022	69	40
5/1/2022	87	40
6/1/2022	82	60
7/1/2022	91	90
8/1/2022	126	93
Average Savings		7

PRICE RISK

Forward Hedged vs Realized Spot Price



Volatile energy prices expose utilities to **financial risk**

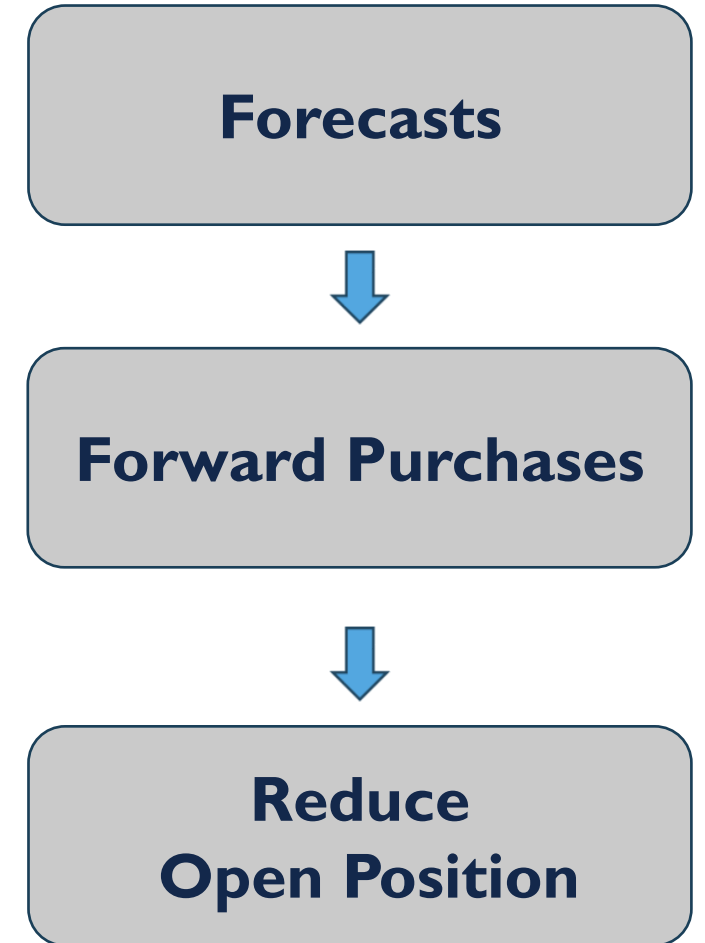
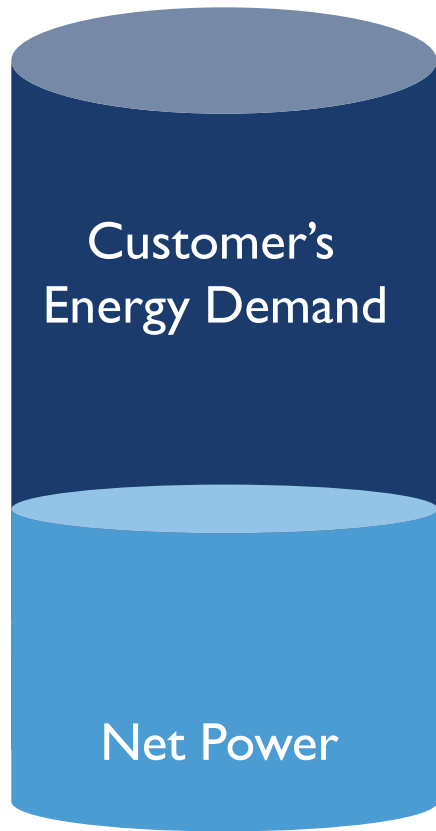
Hedging = Trading uncertainty with predictability

Delivery Months (Forward Prices Quoted in September)

Date	Spot	Forwards
10/1/2021	67	67
6/1/2022	82	60
7/1/2022	91	90
8/1/2022	126	93
Average Savings		7

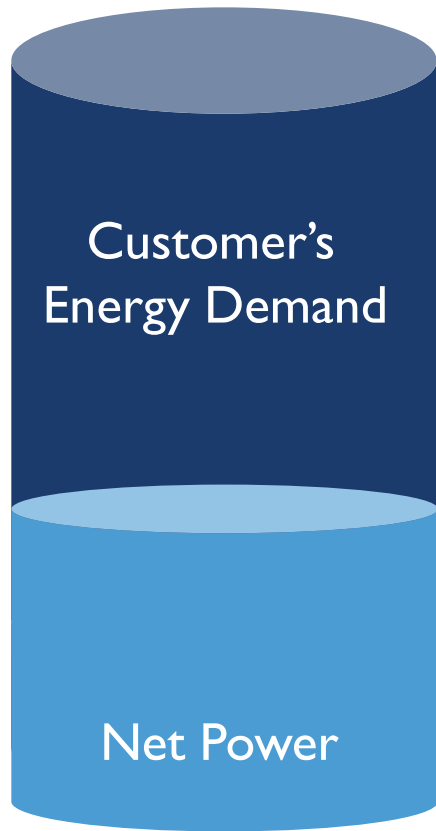
VOLUMETRIC RISK

Forecasted Net Power

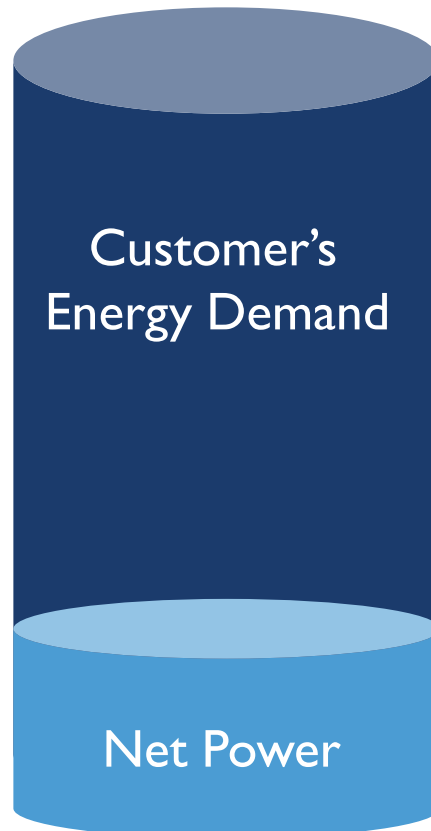


VOLUMETRIC RISK

Forecasted Net Power



Actual Net Power



Mismatch

**Inaccuracy in
Forecasts**



**Forward Hedge
Mismatch**



Additional Costs

VOLUMETRIC RISK



Forecasted Net Power

Actual Net Power

Inaccuracy in

Using CALFEWS to make hedging decisions

Mismatch

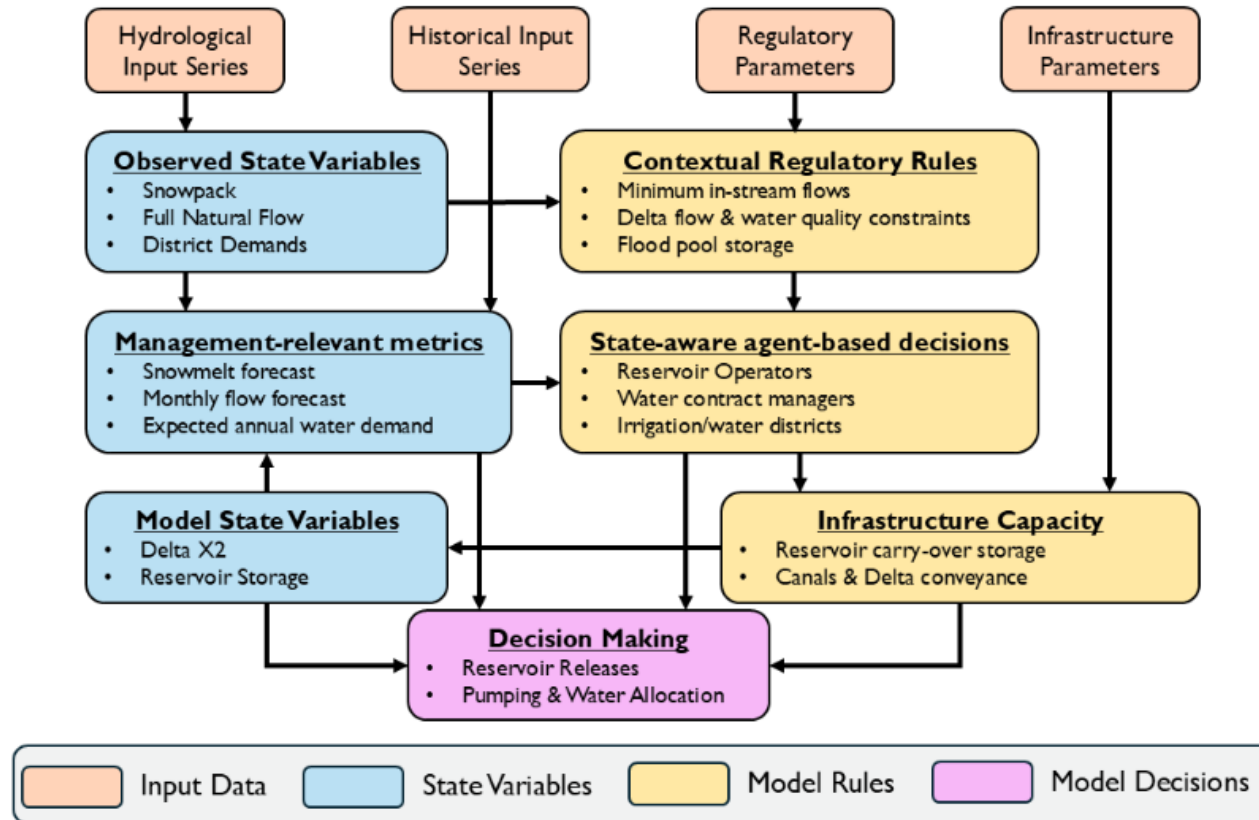
Net Power

Net Power

Additional Costs

CALFEWS

- The California Food-Energy-Water System (CALFEWS) is a **rules based** open-source **simulation model**.
- It incorporates consideration of
 - Flood risk and flood pools
 - Environmental releases
 - Downstream demands
- It is also the only **daily timestep** model.



Inputs

Full Natural
Flows



Models

CALFEWS

Outputs

Reservoir
Storage

Reservoir
Releases

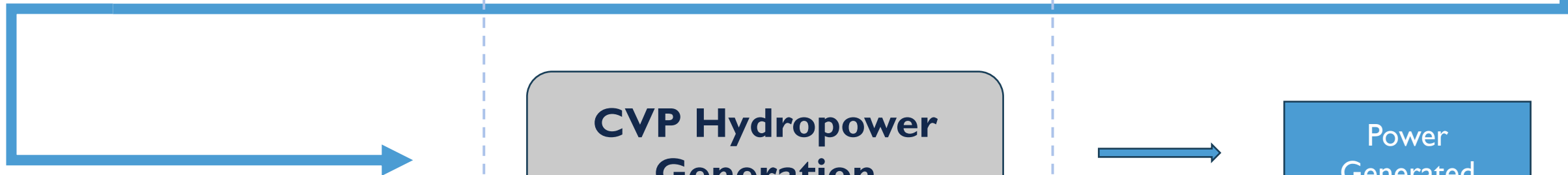
Pumping



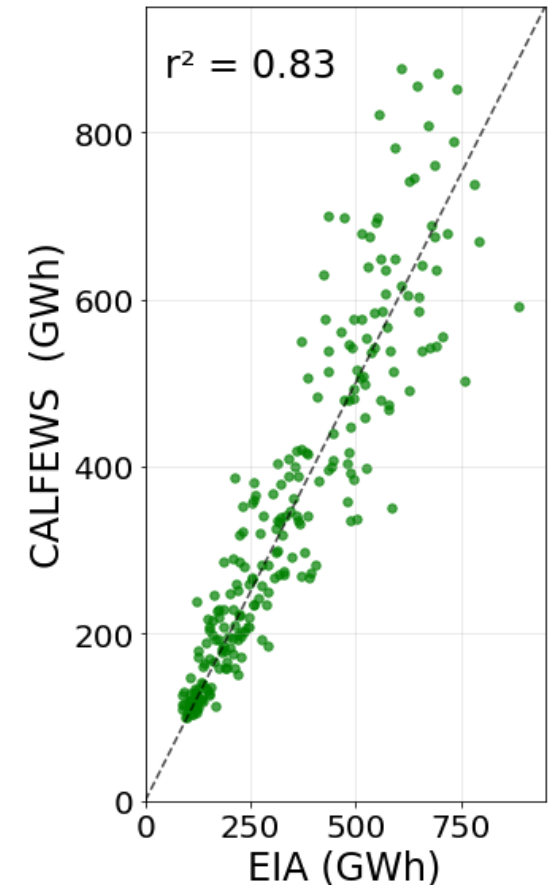
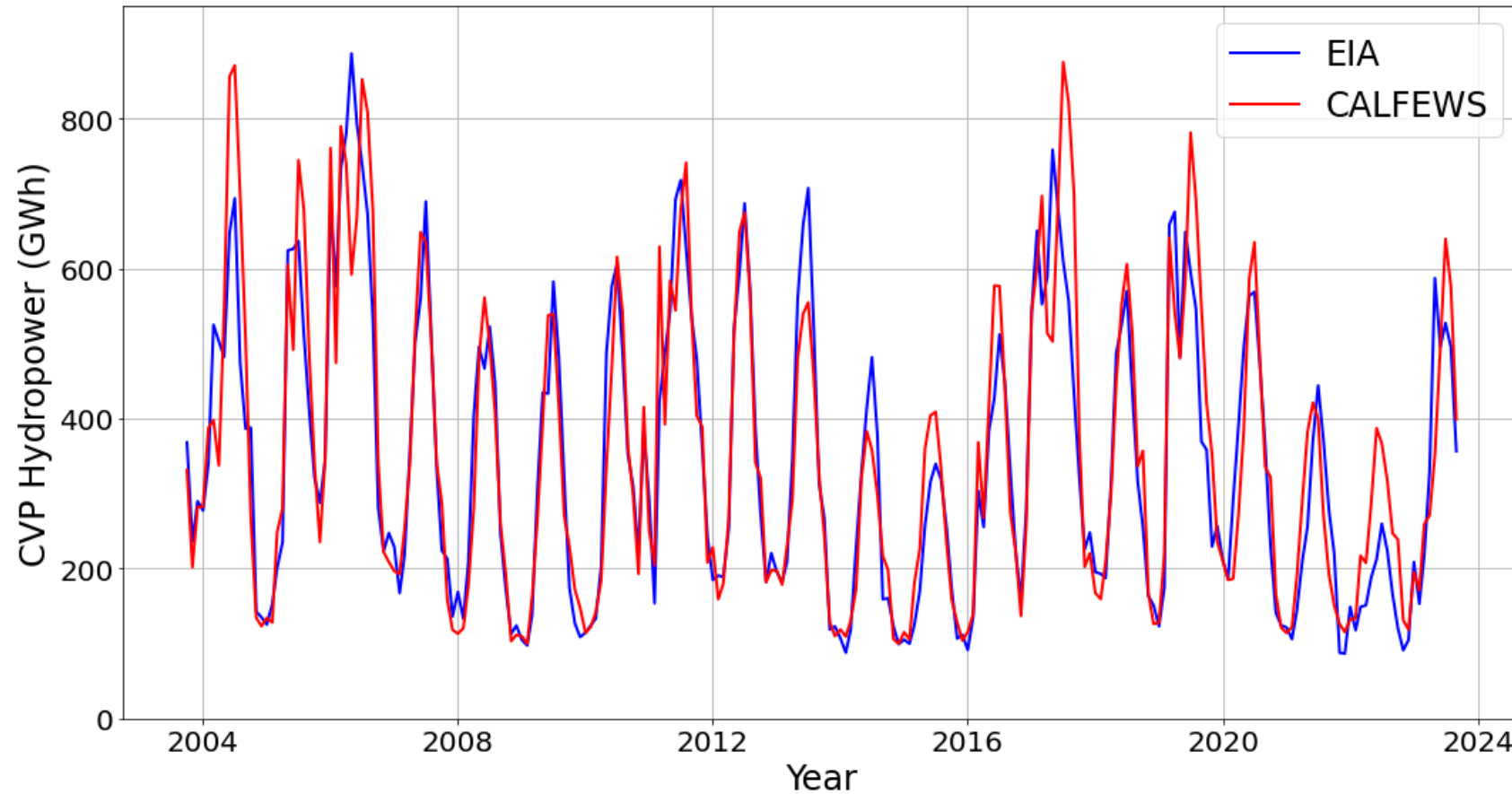
**CVP Hydropower
Generation**



Power
Generated



CVP Hydropower Generation Model Validation

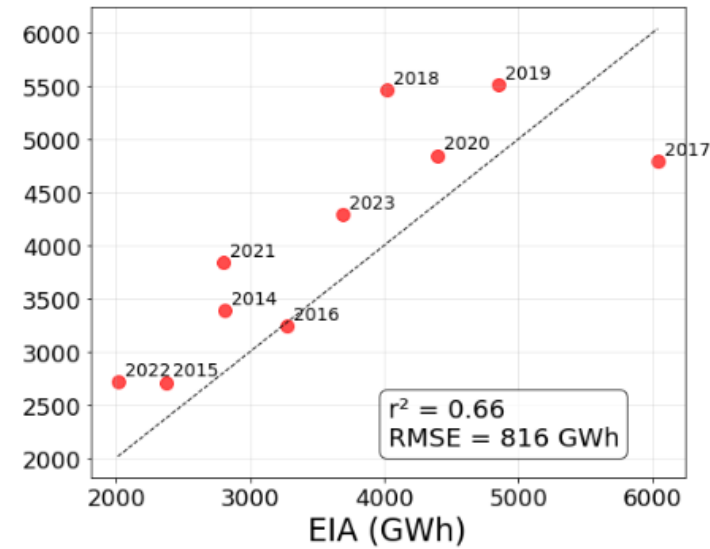
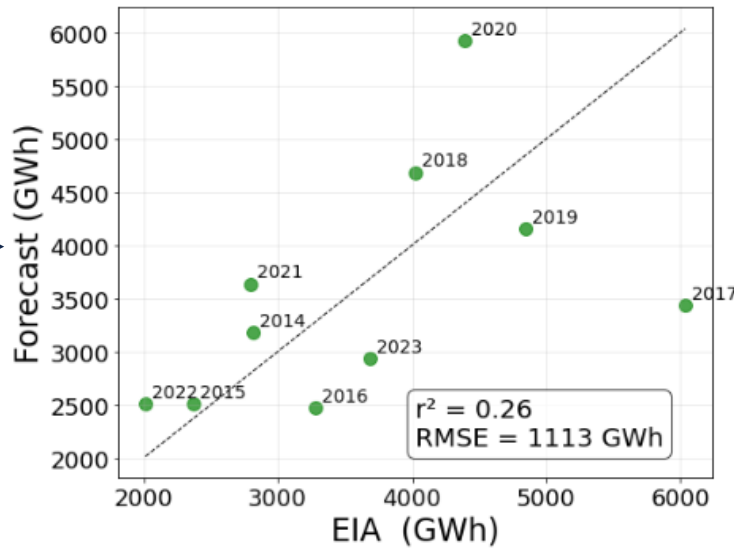


CVP Hydropower Generation Forecasting



CVP Hydropower Generation Forecasting

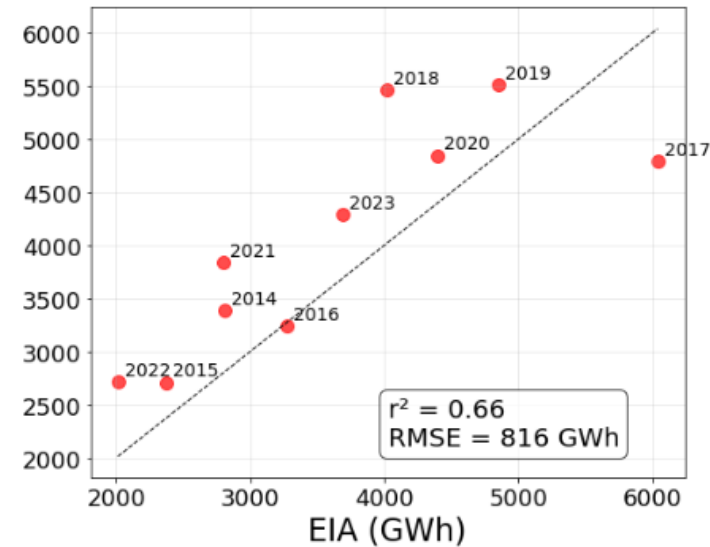
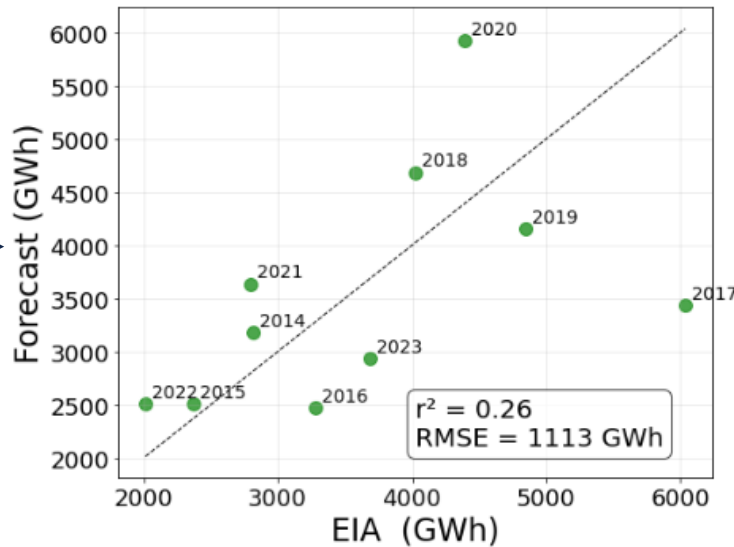
Using a statistical forecasting method



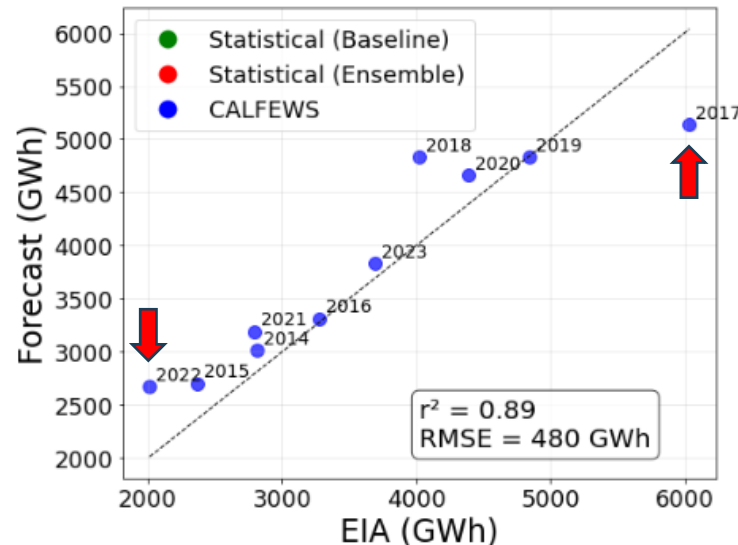
Using a prediction based statistical forecasting method

CVP Hydropower Generation Forecasting

Using a statistical forecasting method

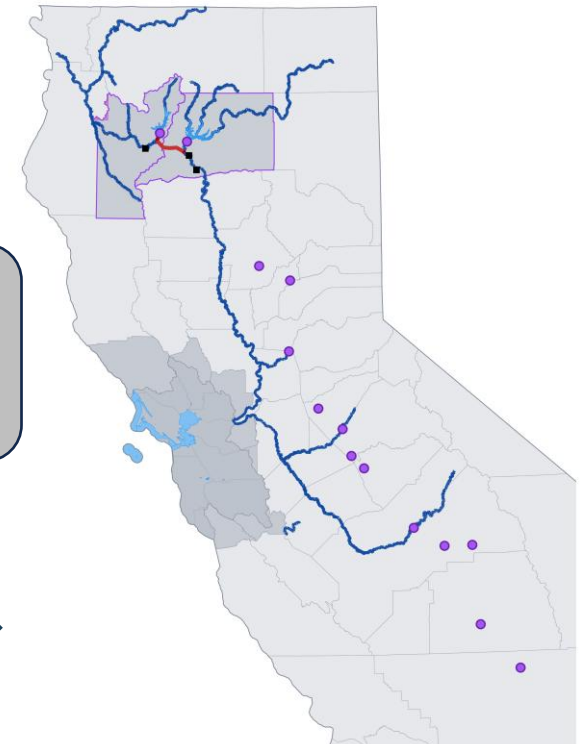
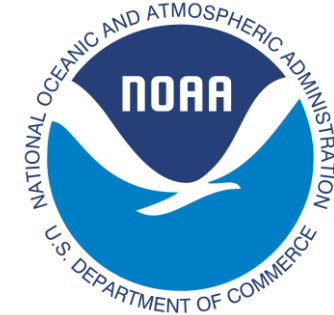


Using CALFEWS for forecasting



Using a prediction based statistical forecasting method

California Nevada River Forecast Center



CNRFC Forecasts



CALFEWS

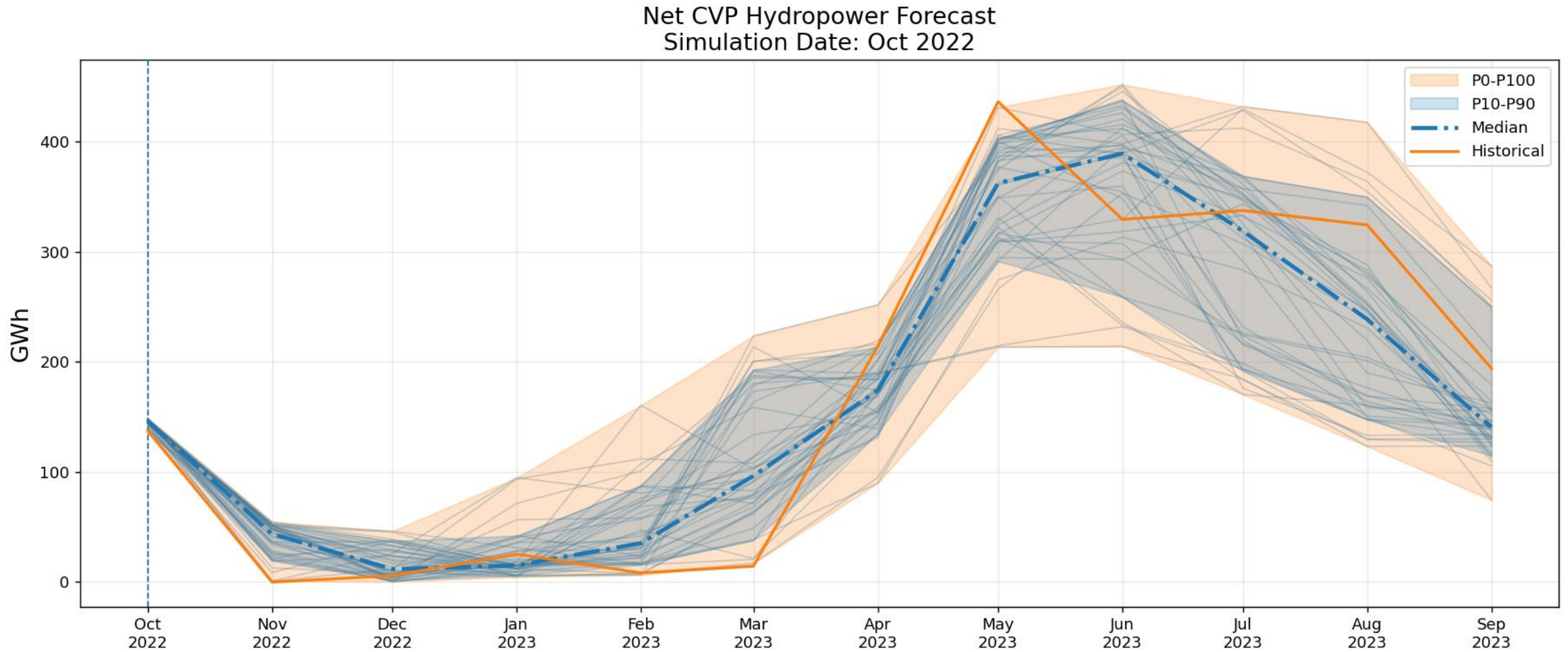


Power Forecasts

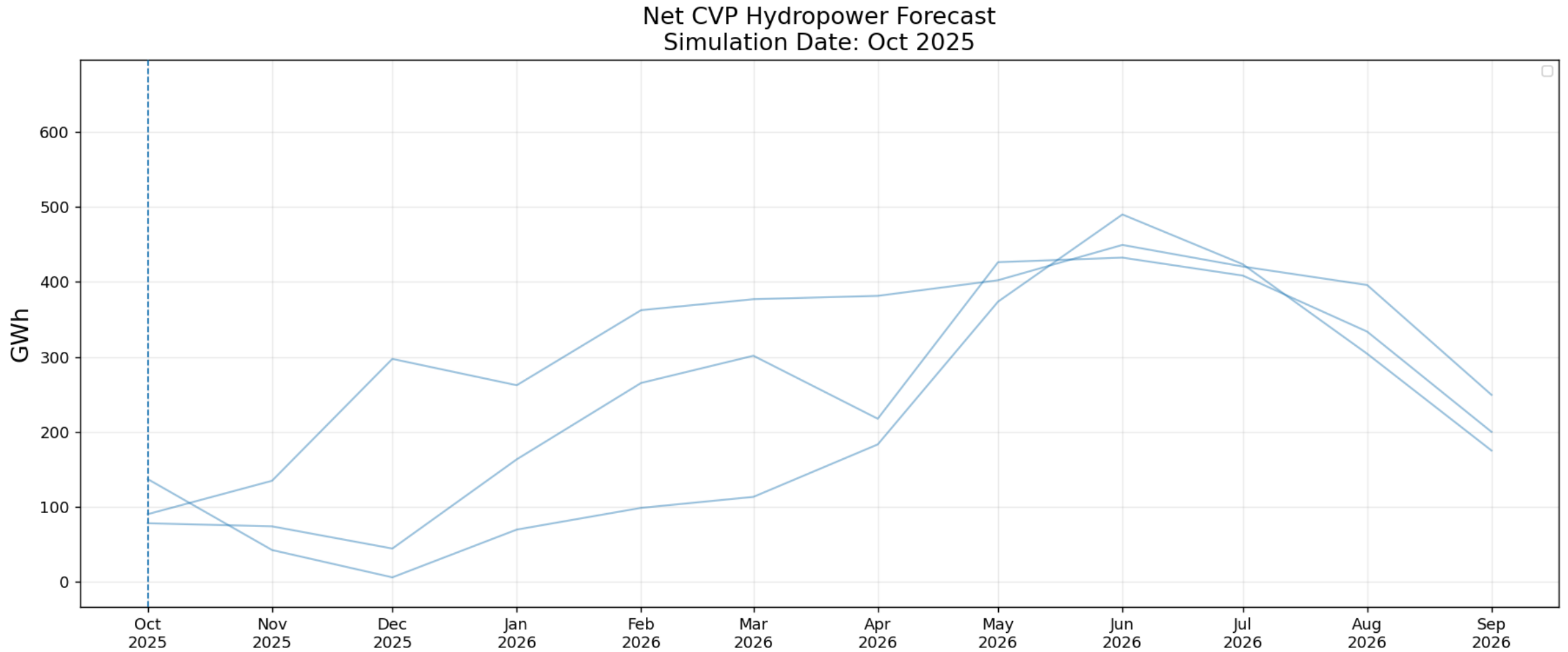
← 12 Months →

← 12 Months →

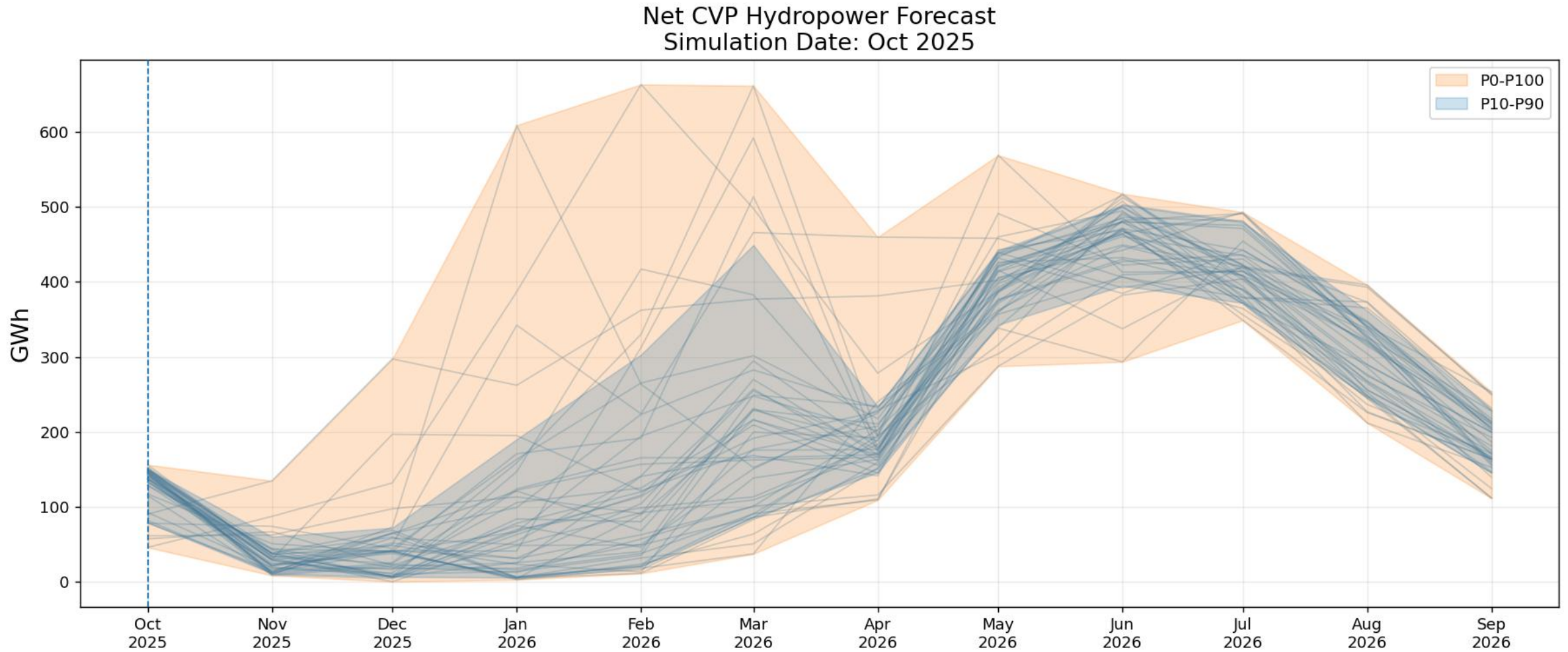
Using CNRFC Forecasts in CALFEWS



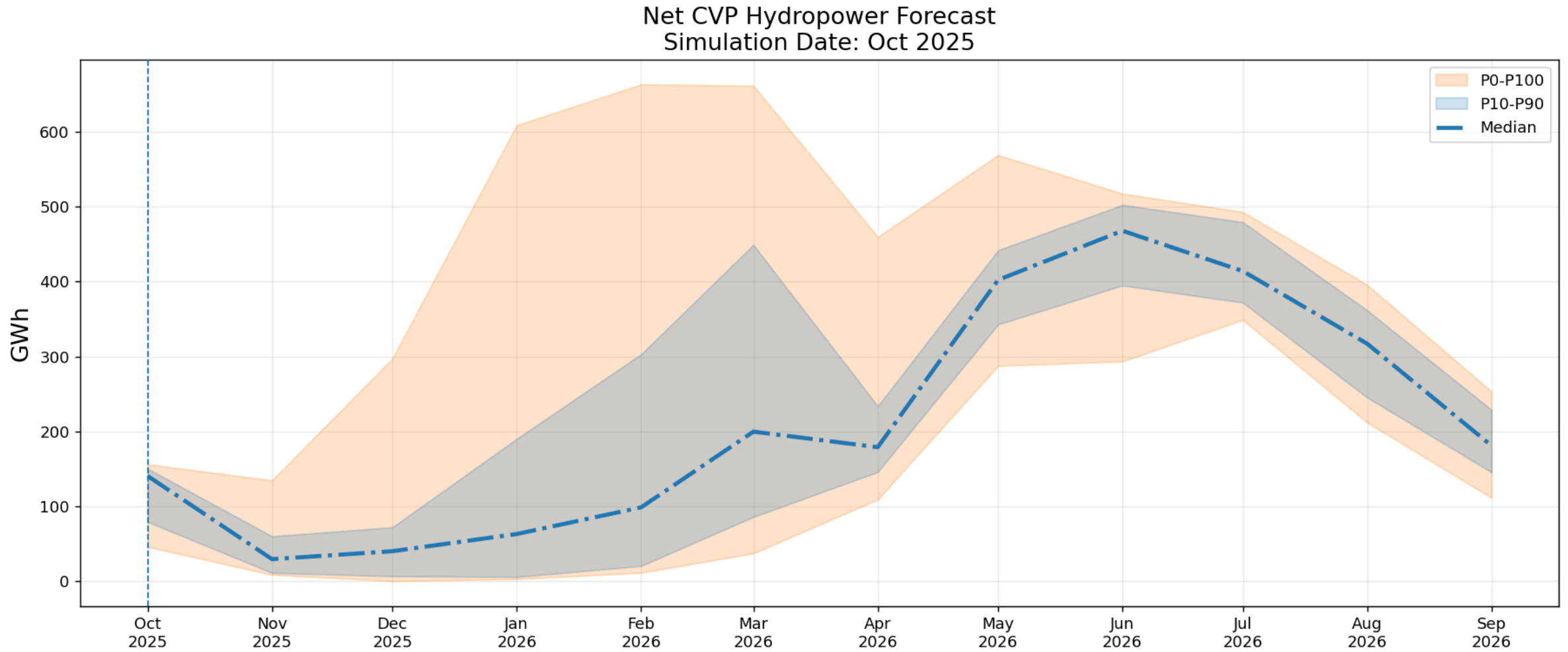
Using CNRFC Forecasts in CALFEWS



Using CNRFC Forecasts in CALFEWS



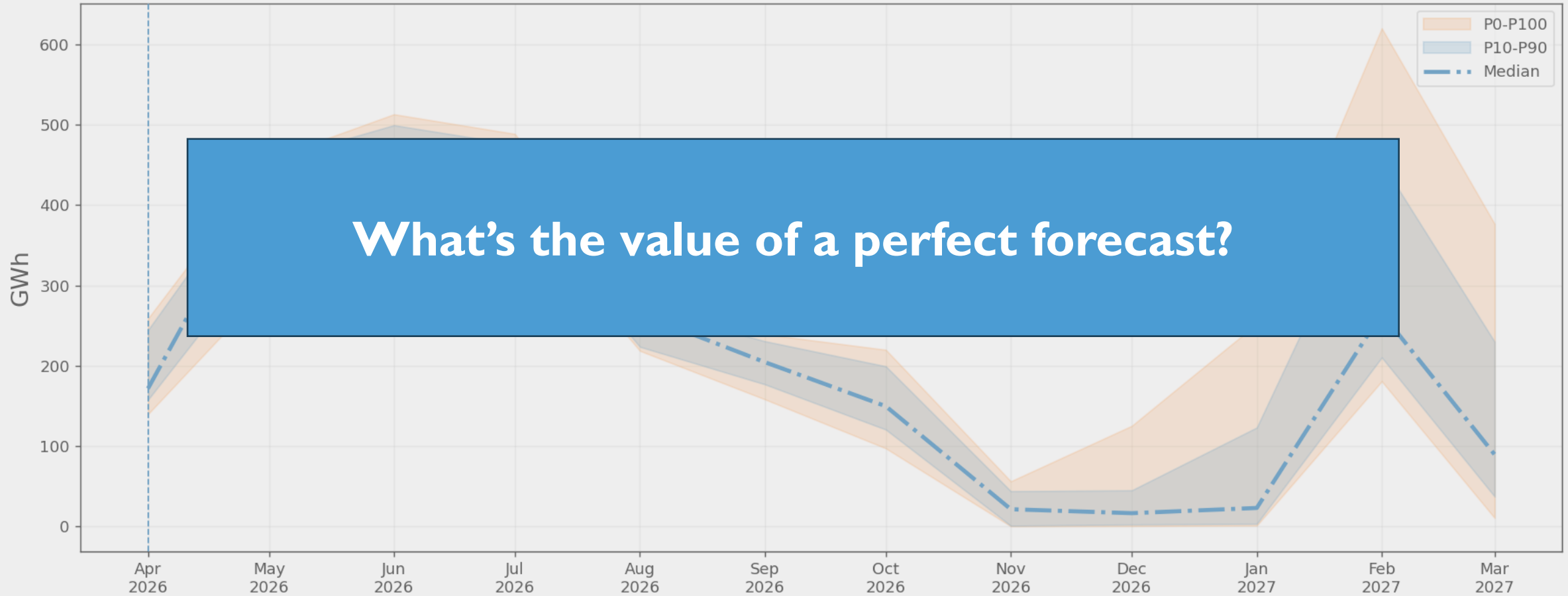
Using CNRFC Forecasts in CALFEWS

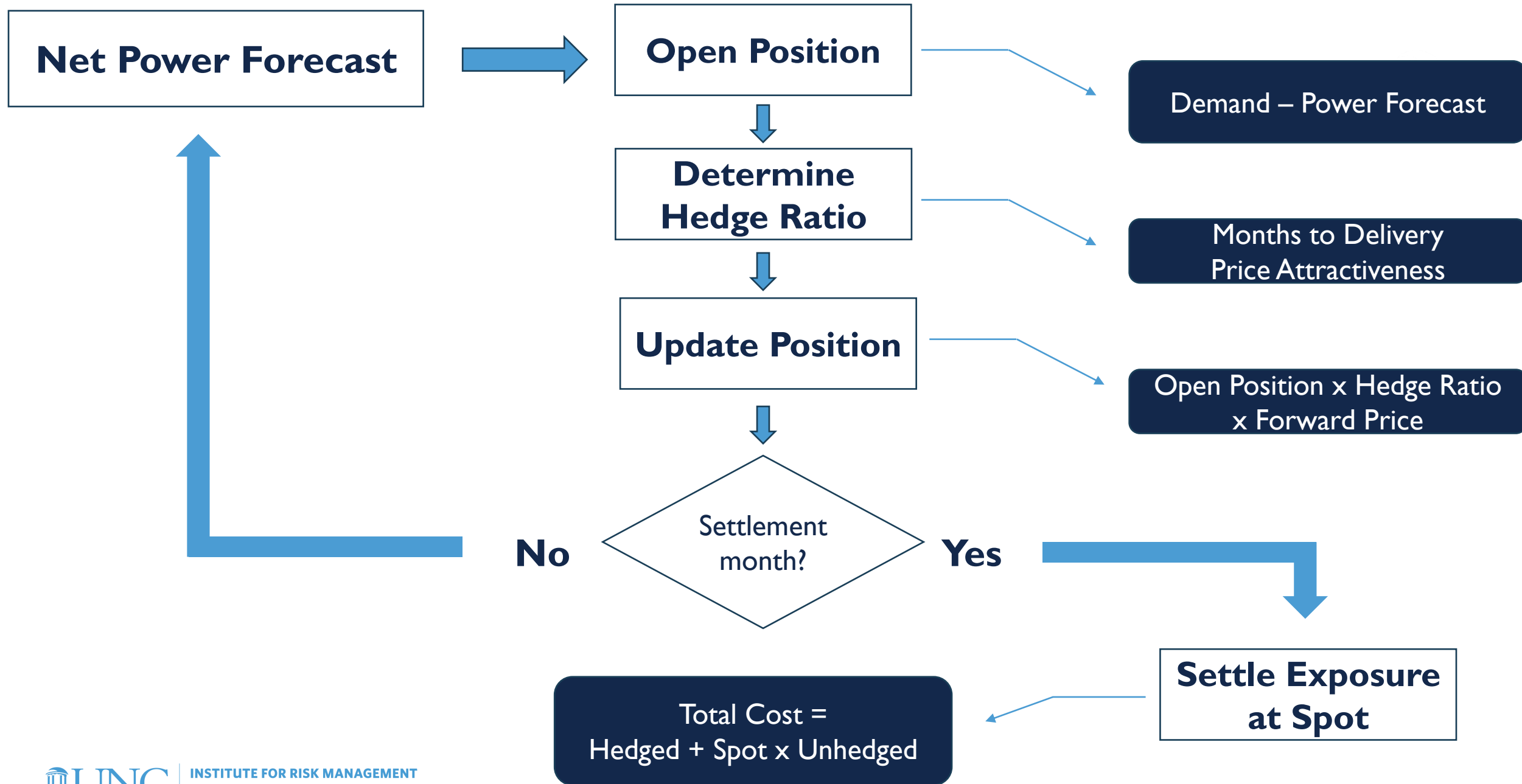


Using CNRFC Forecasts in CALFEWS



Net CVP Hydropower Forecast
Simulation Date: Apr 2026





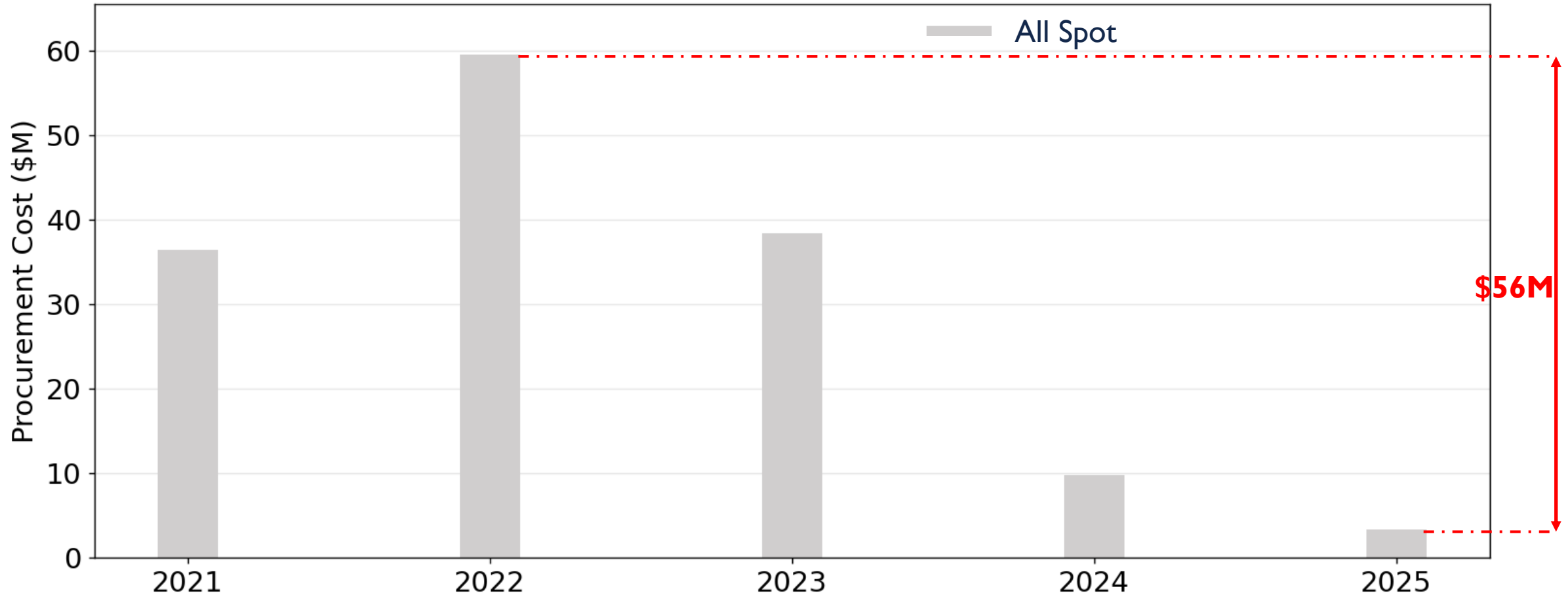
Scenarios

Input Hydrologic Forecasts

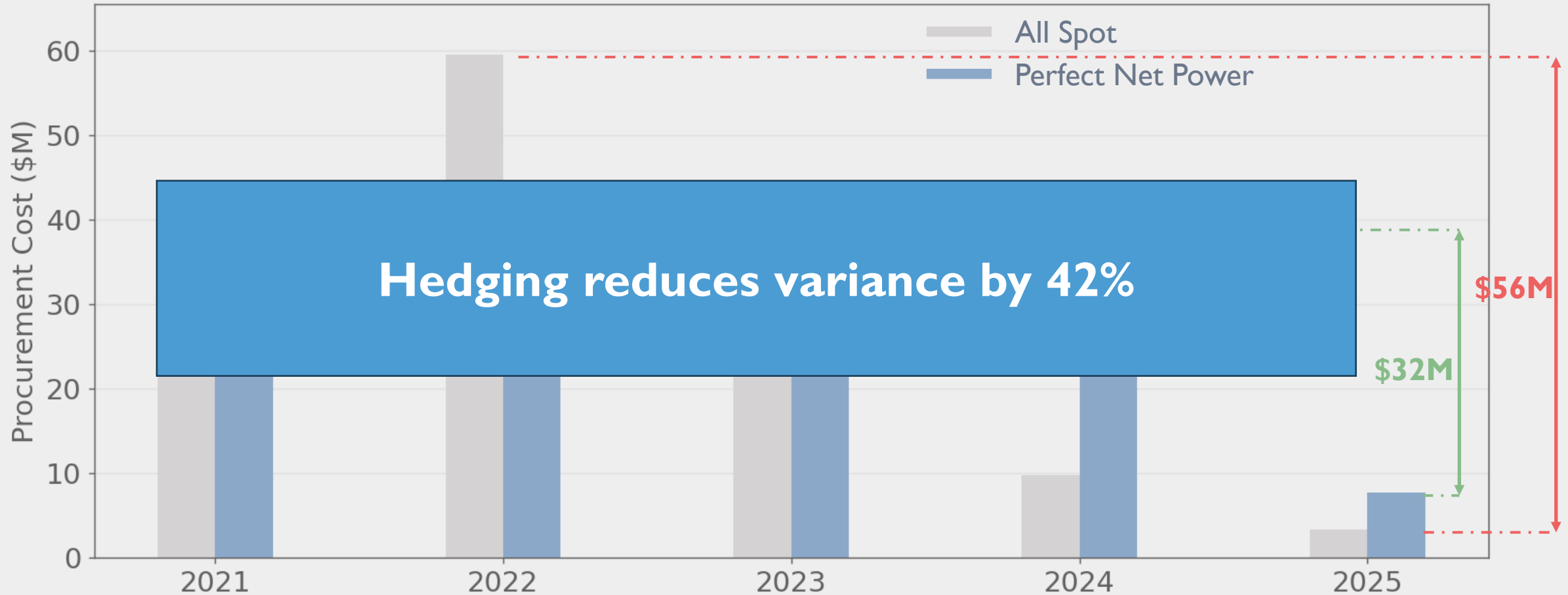
Power Purchase

Scenarios	Input Hydrologic Forecasts	Power Purchase
Scenario 1	All Spot	
Scenario 2	Perfect Net Power	
Scenario 3	Historical Median Inflows	Hedging + Spot
Scenario 4	Historical Observed Inflows	Hedging + Spot

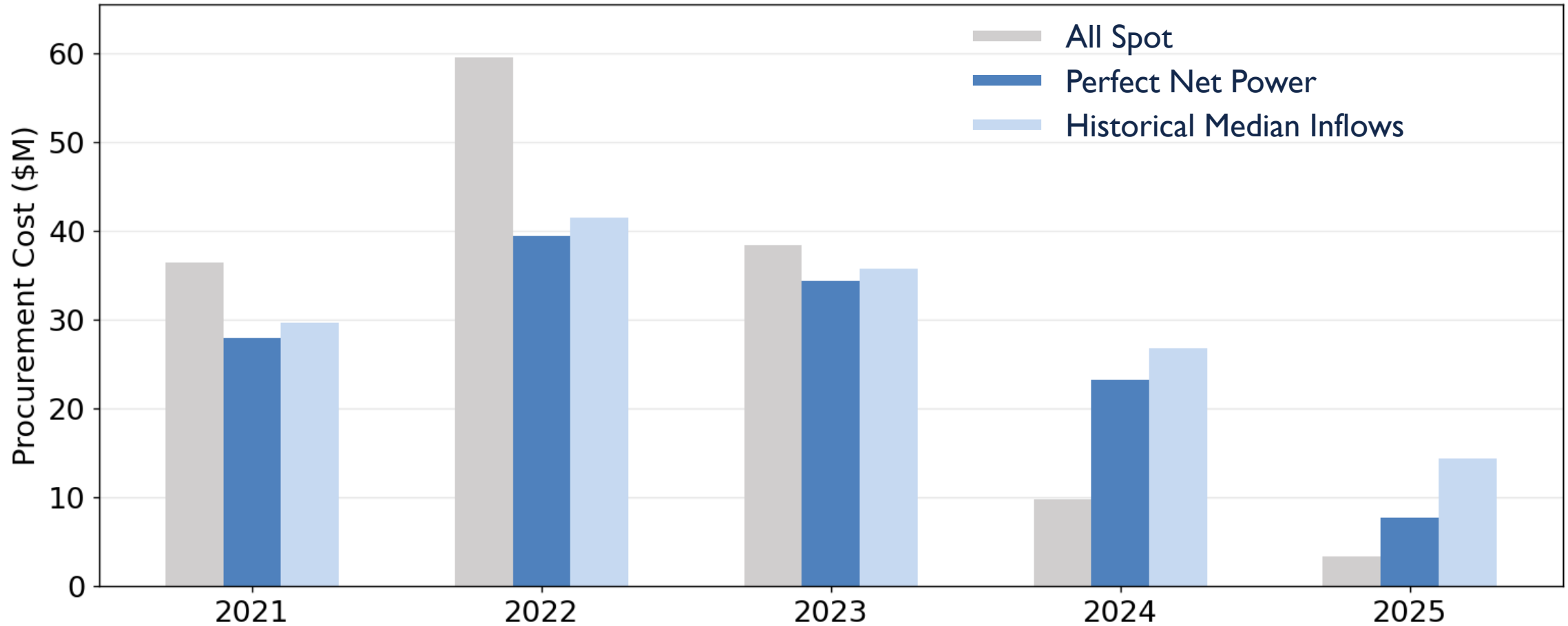
Procurement Costs



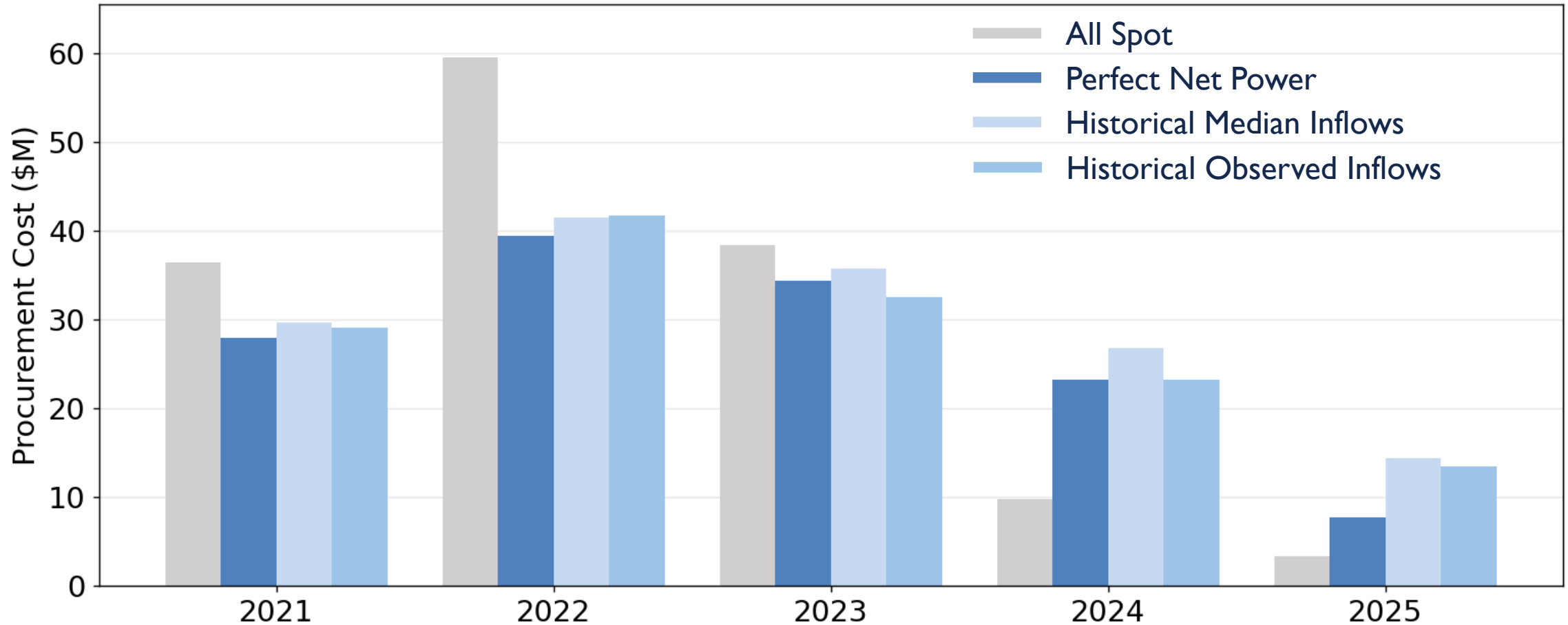
Procurement Costs



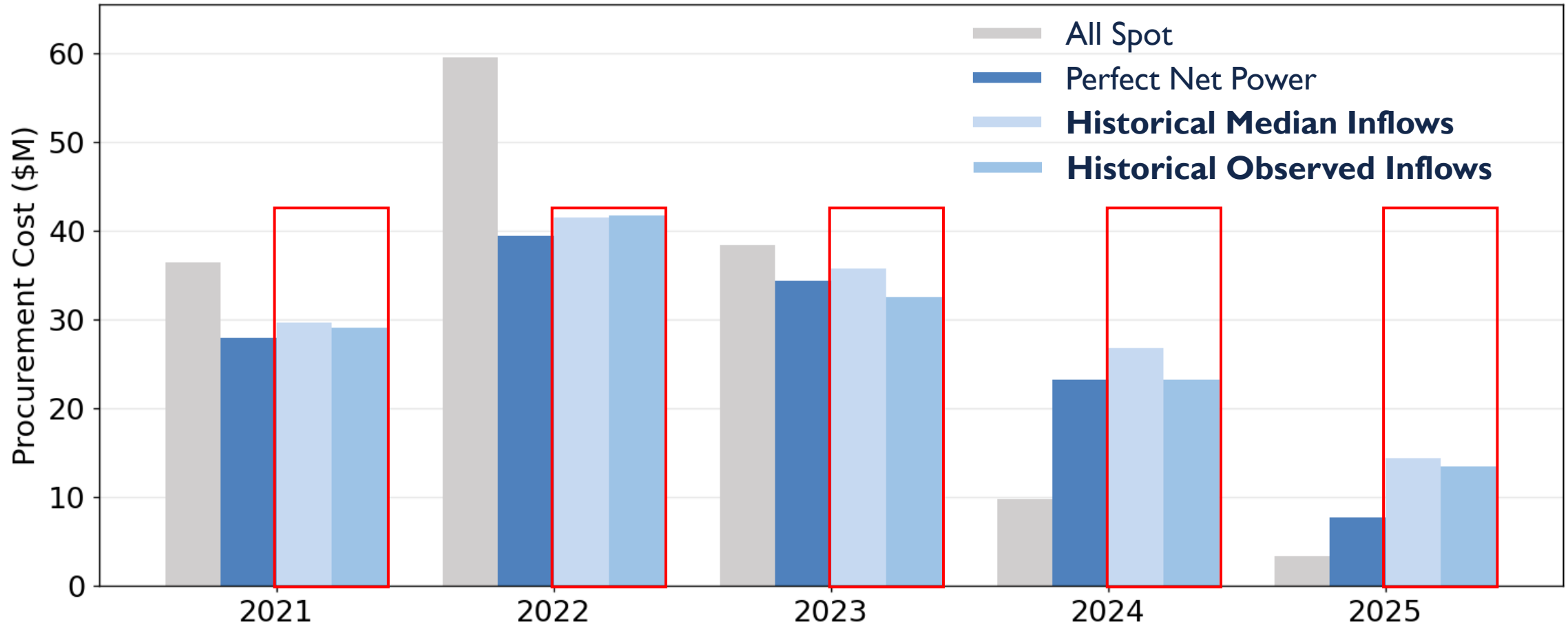
Procurement Costs



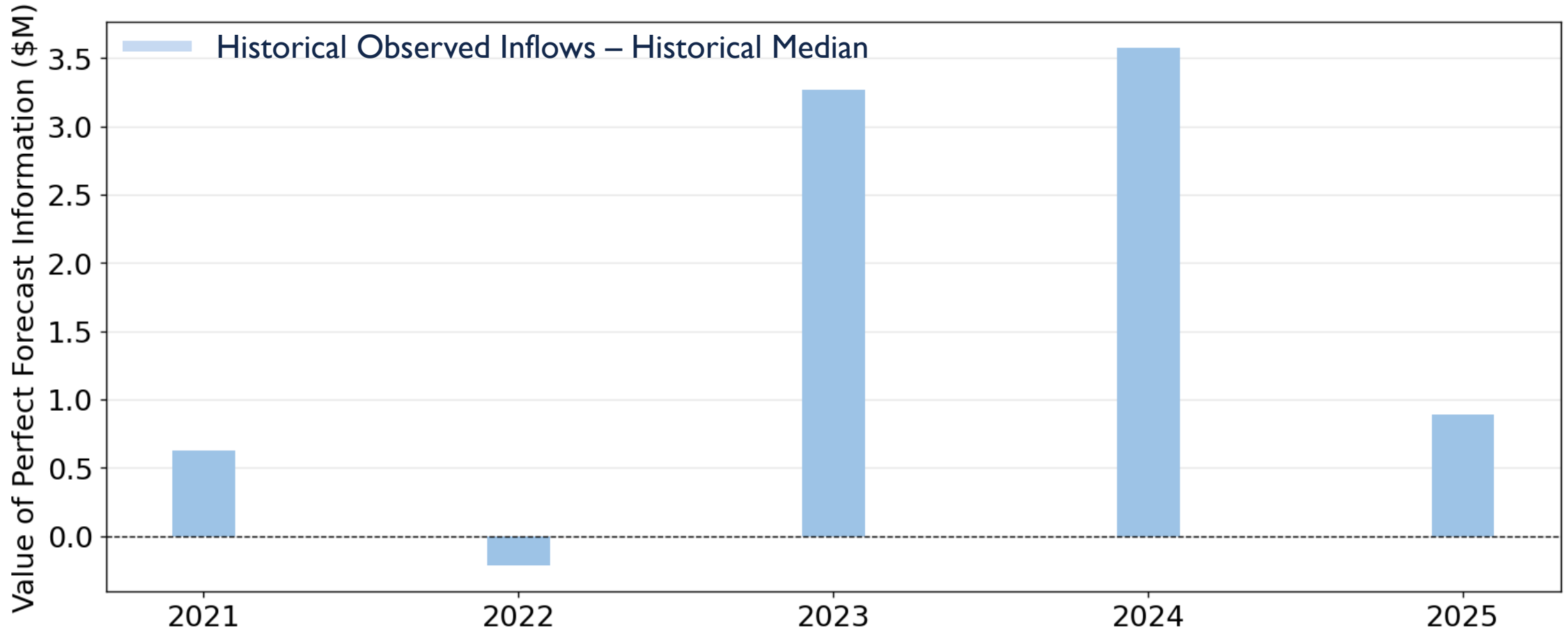
Procurement Costs



Procurement Costs



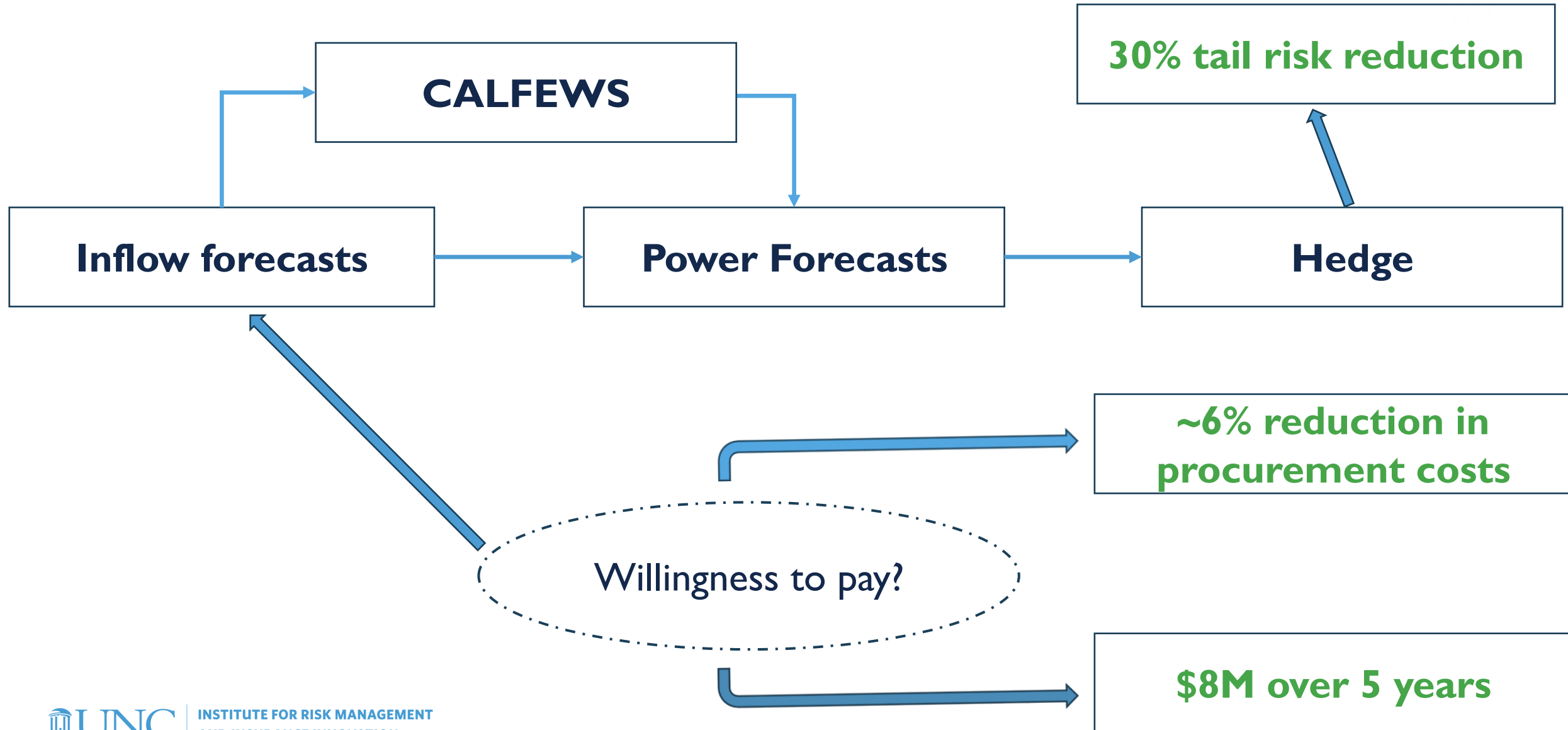
Value of Perfect Hydrologic Forecast Information



Key Takeaways



Key Takeaways



Thank You!

- IRMII
- Collaborators
- Industry Partners

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Forwards vs Futures

Forwards

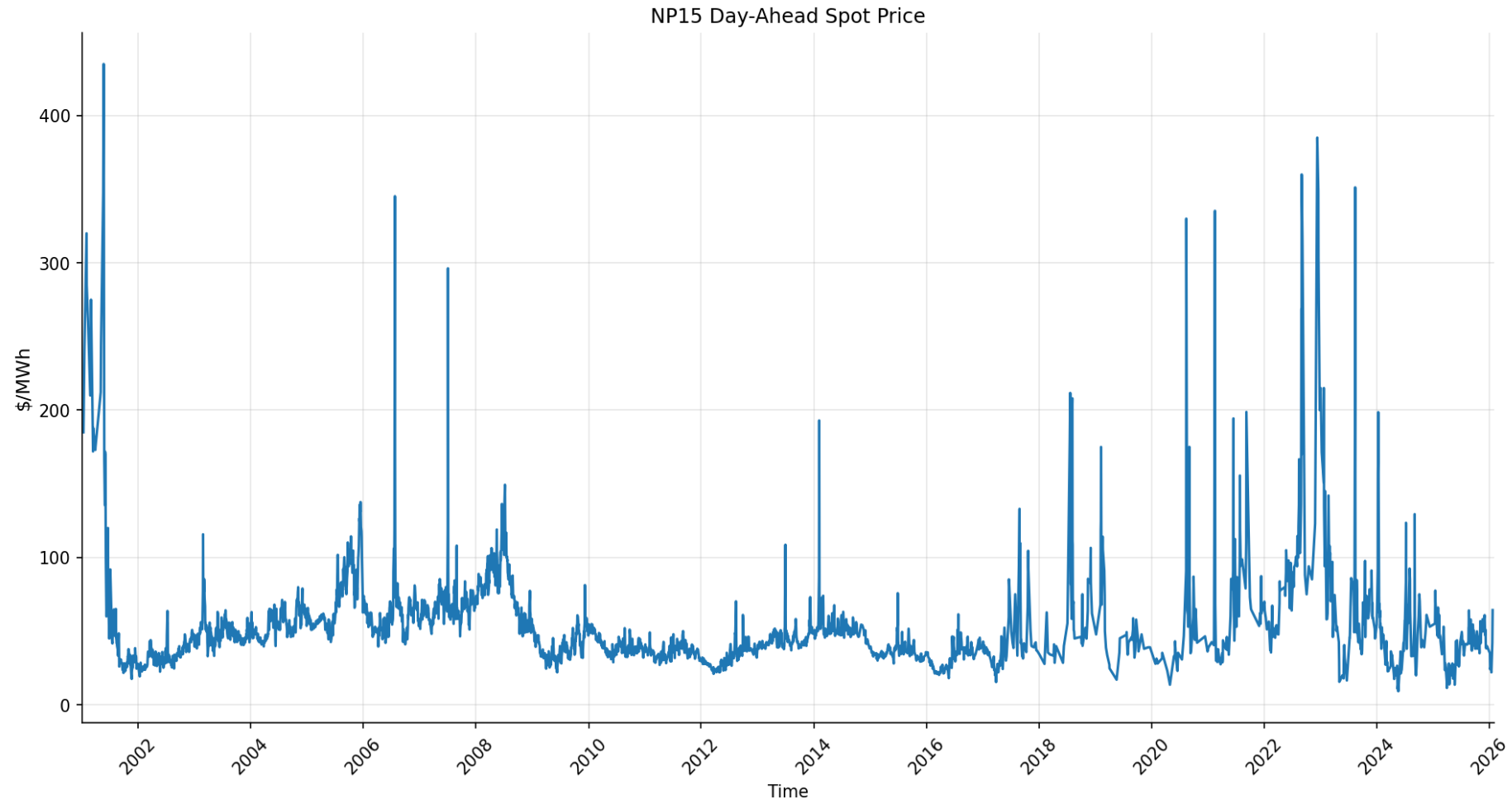
- **Customized contracts**
- **Trade over the counter**
 - **Settled at maturity**
- **Physical settlement**

Futures

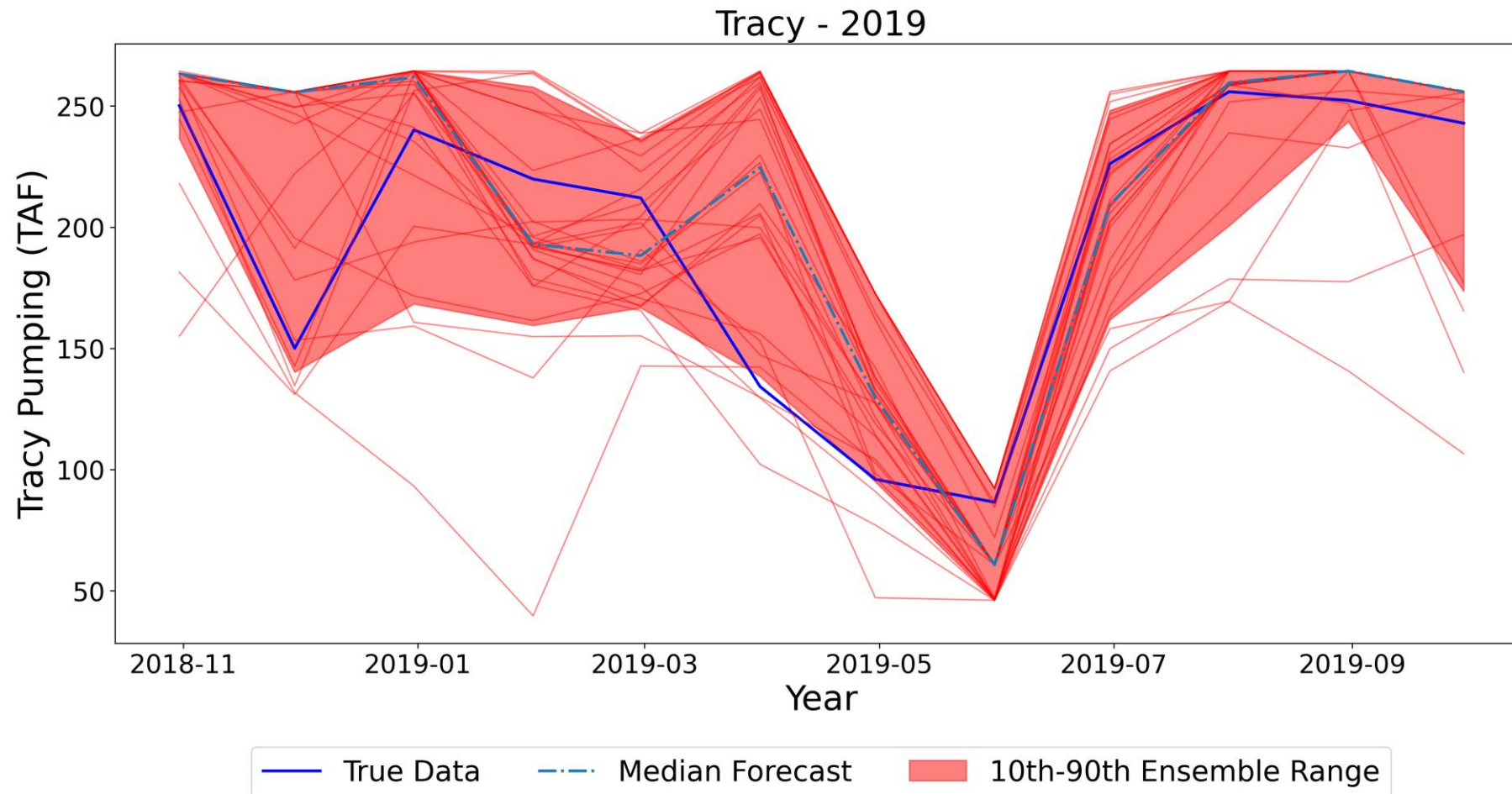
- **Standardized contracts**
- **Trade on exchanges**
- **Marked-to-market**
- **Cash settlement**

WHY HEDGE?

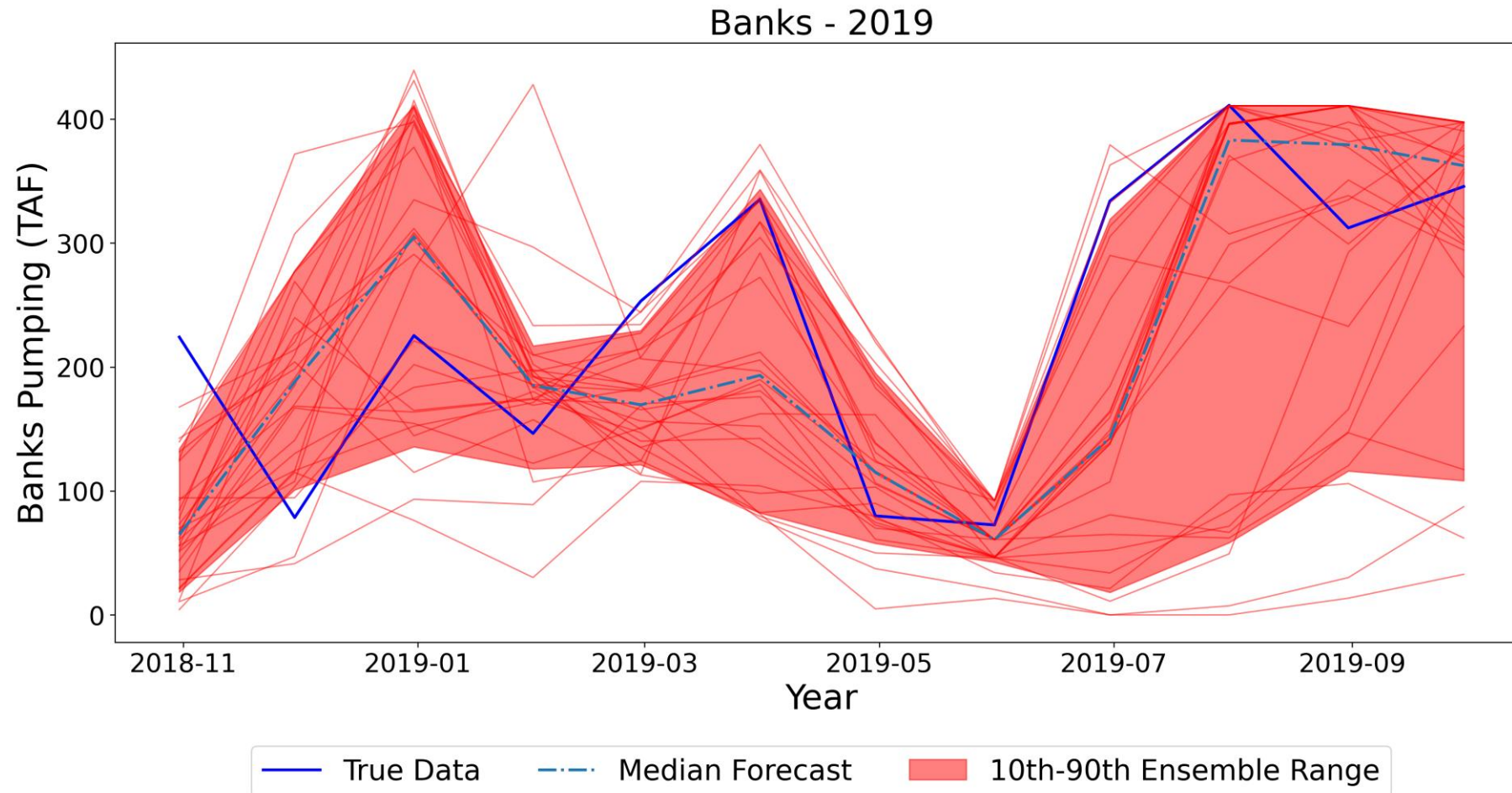
- Energy spot prices are extremely volatile



Simulation model – South-of-delta storage validation



Simulation model – South-of-delta storage validation



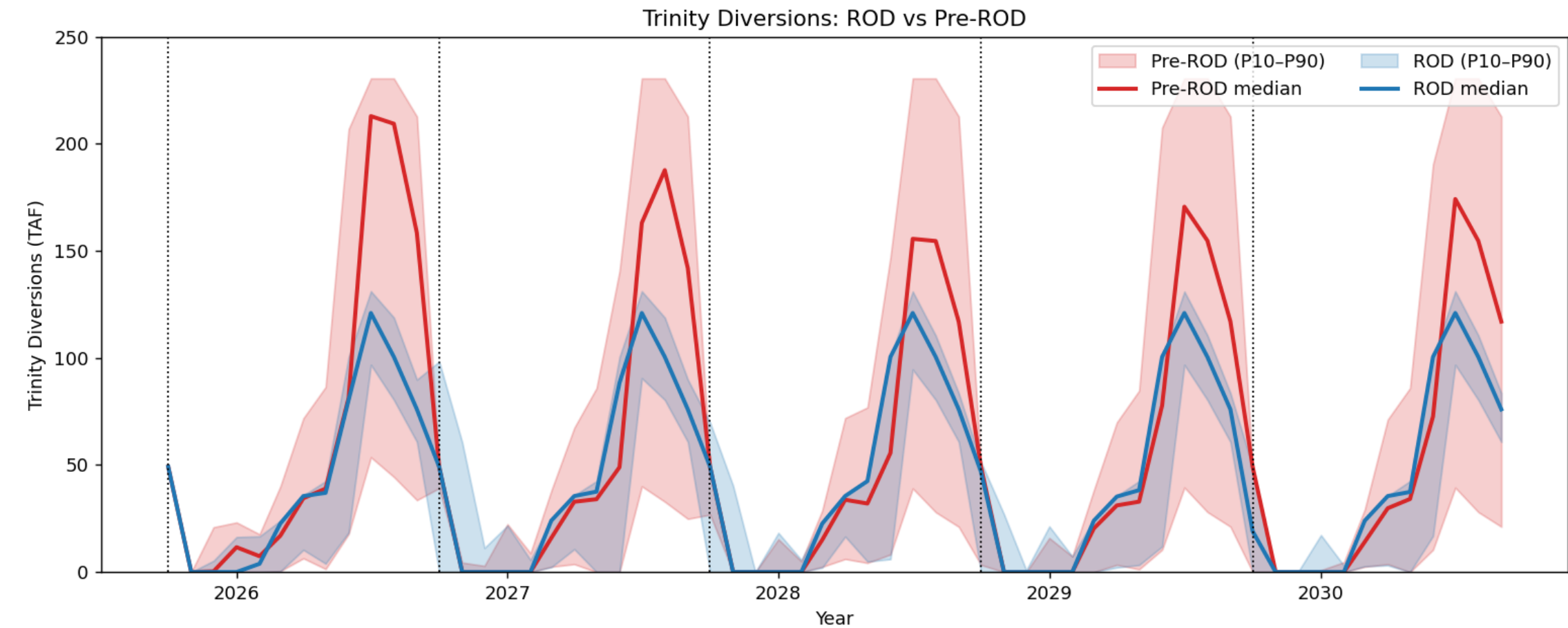
Western Area Power Administration

- WAPA is a power marketing agency that markets power generated from federal dams
- WAPA power customers pay a **near fixed cost** for a **variable power** supply
- This hydropower is attractive due to
 - Cost-based model
 - Low marginal cost of hydropower
- However, allocations are percentage based, rather than MWh based
 - They are not guaranteed supply, just a portion of the excess if it exists



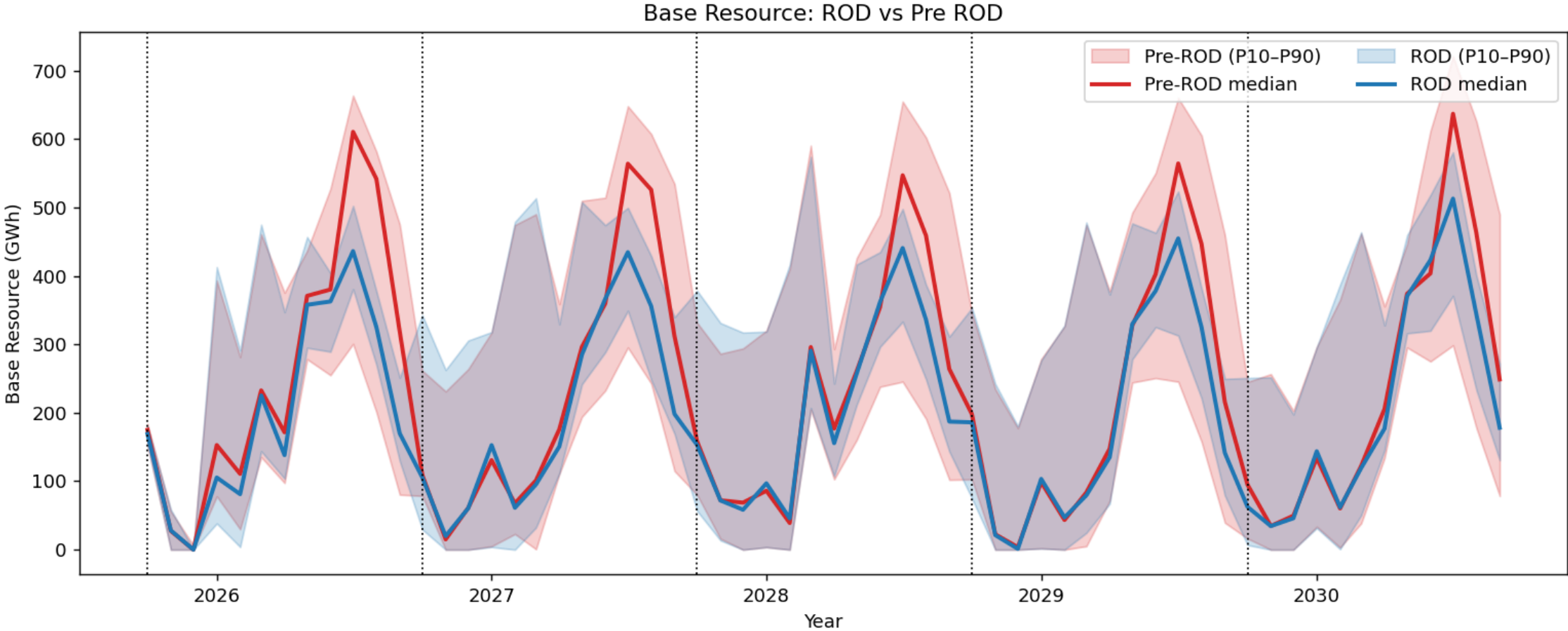
OPERATIONAL/REGULATORY CHANGES

Trinity River Diversions



OPERATIONAL/REGULATORY CHANGES

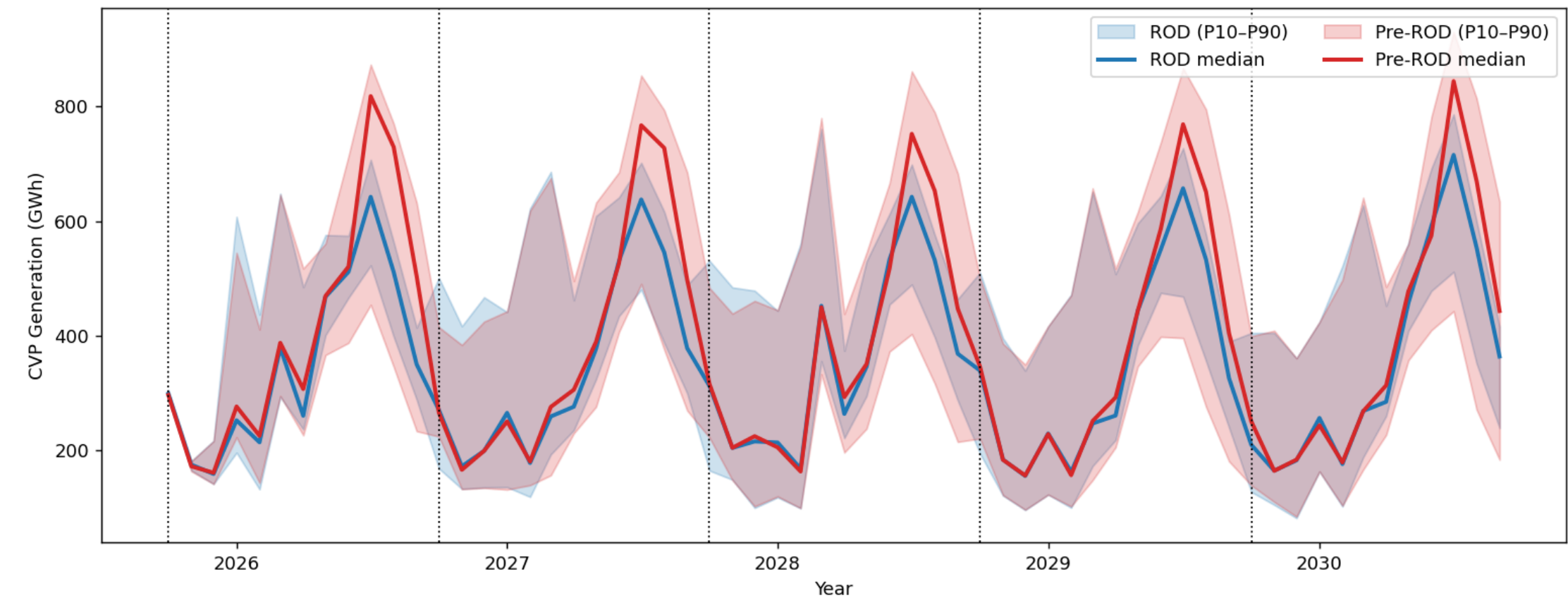
Base Resource



OPERATIONAL/REGULATORY CHANGES

CVP Generation

CVP Generation: ROD vs Pre ROD



Rate Mechanism

- Power Revenue Requirement
 - Revenue required to recover annual expenses, including:
 - Operation & Maintenance (O&M)
 - Capital repayment
 - Administrative fees
 - Power purchased for Project Use
- Customers pay based on PRR, not based on power delivered
- Cost is near fixed, but \$/MWh delivered increases with volatility

