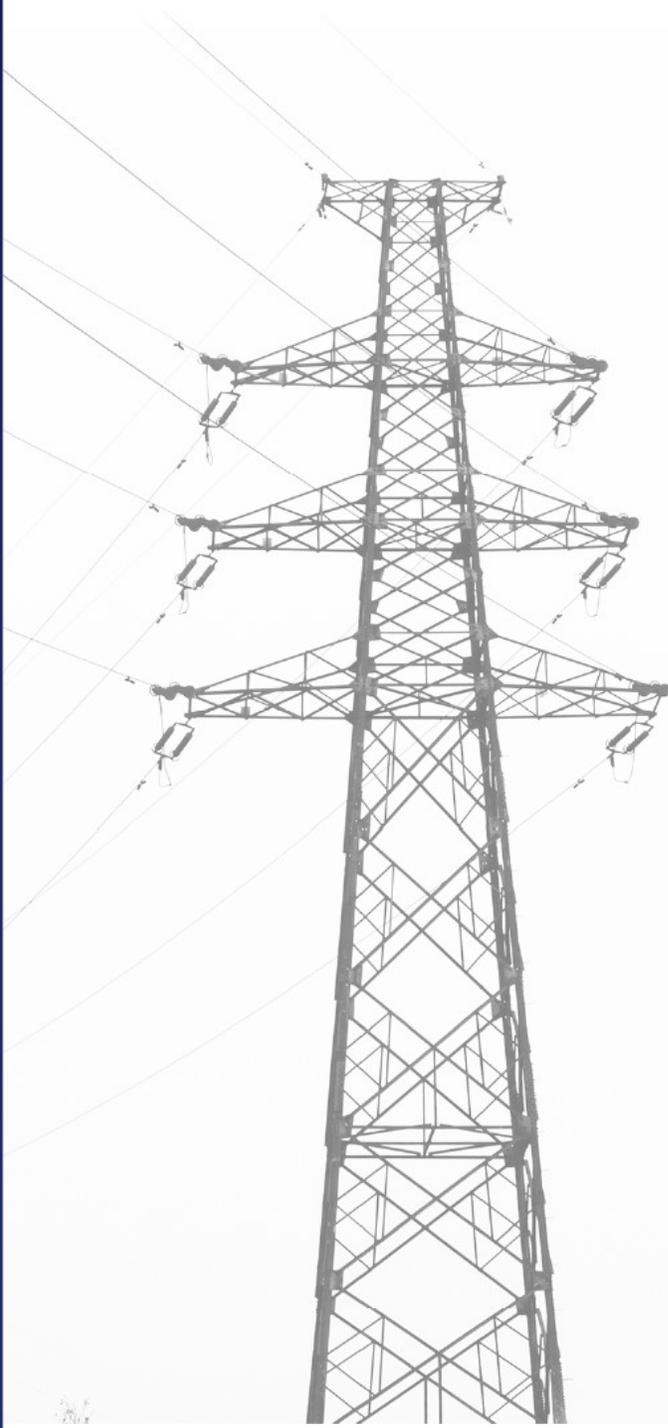




Volatility and Risk Management in Low Carbon Power Markets

A PROJECT OF





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Moderator and Featured Experts



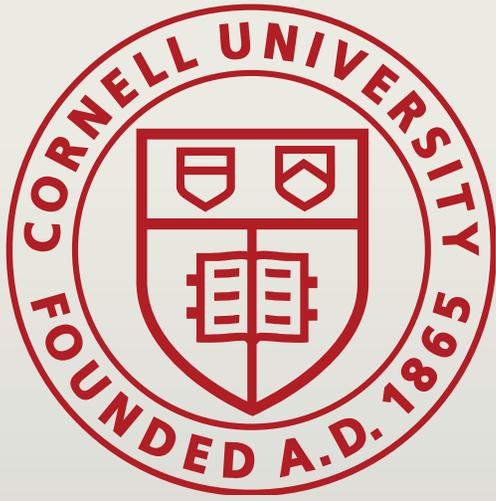
Rob Gramlich
Grid Strategies LLC



Jacob Mays
Cornell University



Harry Singh
Goldman Sachs



Volatility, Risk, and Resource Adequacy in Electricity Markets

Jacob Mays

Future Power Markets Forum

August 3, 2022

Co-authors: Michael Craig, Jesse Jenkins, Lynne Kiesling, Joshua Macey, David Morton, Richard O'Neill, Simon Risanger, Blake Shaffer, Han Shu

Fundamental volatility

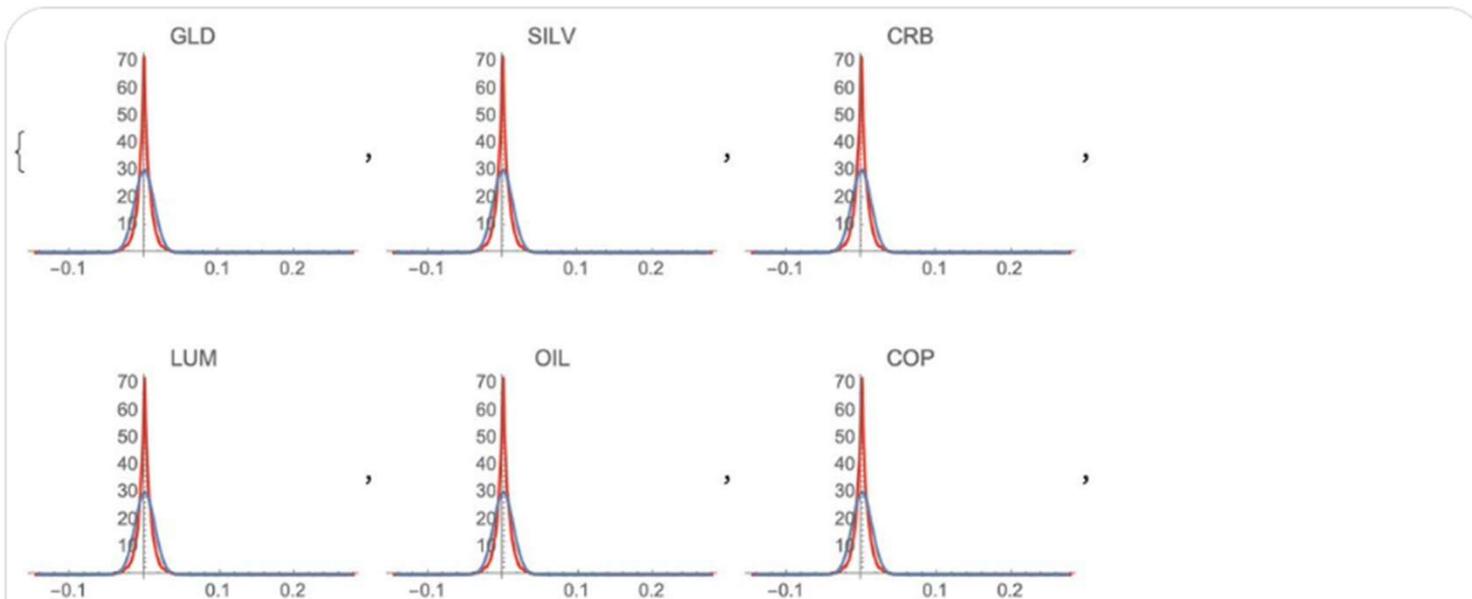


Nassim Nicholas Taleb

@nntaleb

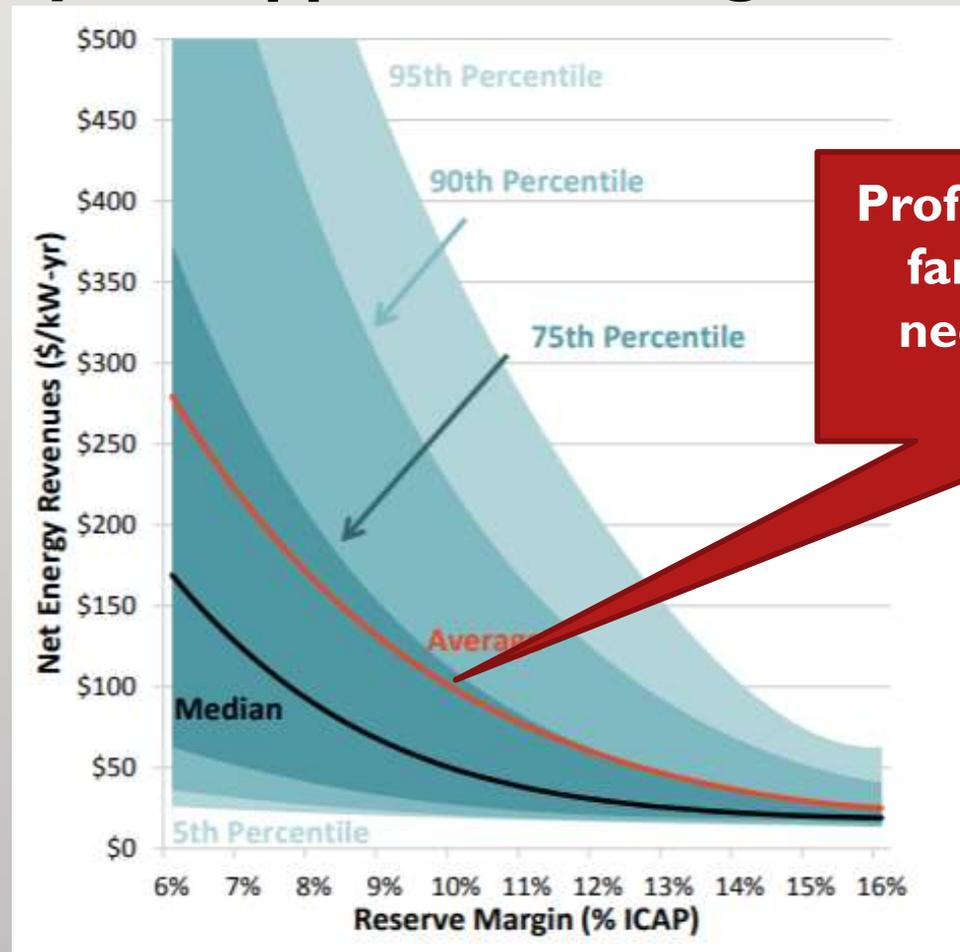


Meanwhile lecturing tomorrow on fat-tailedness in commodities, here are they.
ALL of them are fat tailed. Electricity the most.



Volatility and investment risk

Generation resources need some amount of long-term certainty to support financing



Profit in median year far below what is needed to sustain generators

Source: Estimation of the Market Equilibrium and Economically Optimal Reserve Margins for the ERCOT Region (The Brattle Group)

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Volatility and viability

- 1 Can systems completely rely on voluntary hedging around spot prices?
- 2 Assuming not, what might states and market operators do about it?
- 3 How might this evolve as renewables continue to grow?

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The New York Times

Death Toll From Texas Winter Storm Continues to Rise

Epidemiologists examining causes of deaths reported from Feb. 11 to March 5 have added 59 deaths to the storm's toll, bringing it to 210.



Catastrophic failure in February 2021 poses a serious challenge to energy-only model

Financial viability



**Britain faces 'massacre' of
20 more bust energy
suppliers, Scottish Power
says**



**The market can stay rational longer than
participants can stay solvent**

Bloomberg

Germany's Uniper Seeks Bailout, a Victim of Putin's Gas Feud



Contractual arrangements do not resolve risk, but transfer it to supply side

Financial viability, part 3



AEMO suspends NEM Wholesale Market



Suppressing spot prices can ease liquidity risk, but weakens incentives for performance

BusinessGreenTM

Boris Johnson hints at major reforms to 'frankly ludicrous' energy market



Financial dislocations can be so significant as to threaten social license of market organization

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Preconditioning risk

Two routes for policymakers, regulators, and market operators to manage risk

1 Suppress volatility in spot prices

2 Mandate contracts

▶ My opinion: avoid the former, pursue the latter

Category 1: suppress volatility in spot prices

US wholesale markets suppress volatility in spot prices relative to the theoretical ideal

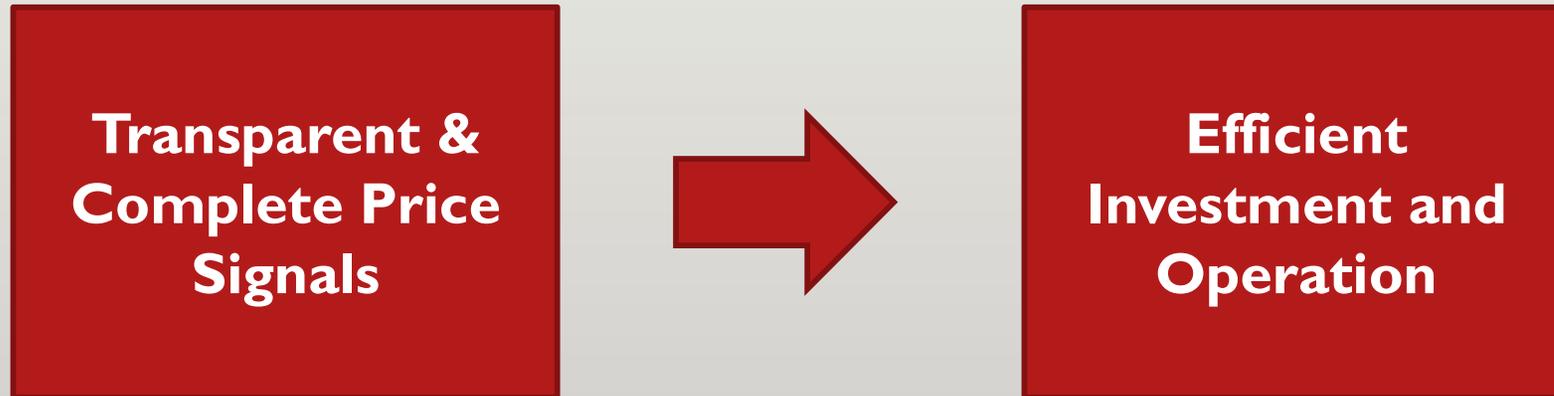
- **Price/offer caps/floors**
- **Mispriced intertemporal constraints**
- **Operator load biasing**
- **Uplift and enhanced pricing**
- **Active power ancillary services**



Difficult to form the “theoretically ideal” prices in real time

Market design philosophy

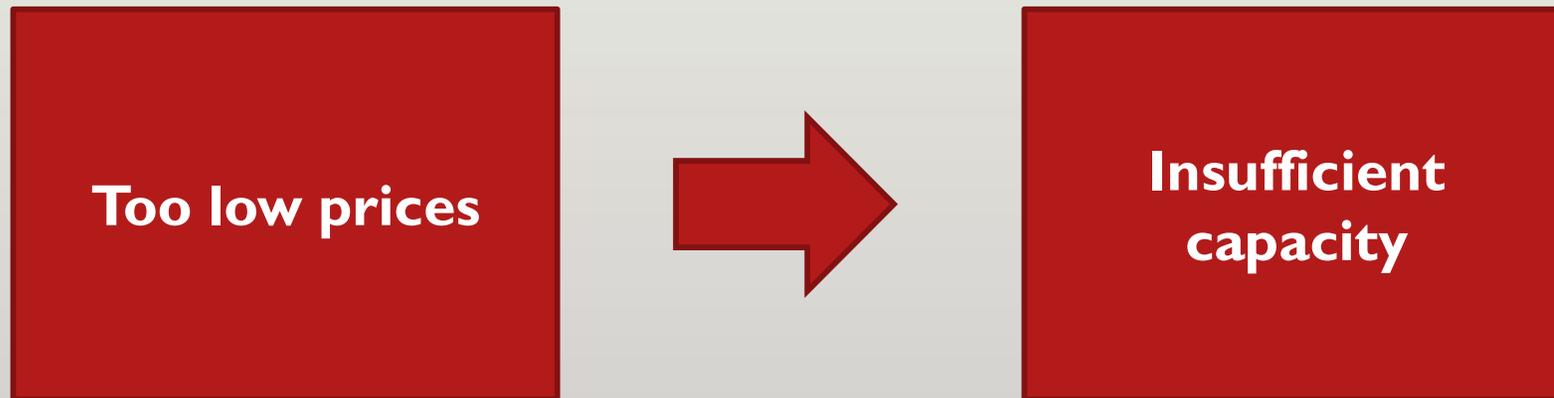
Principle of competitive markets:



- ▶ **Want prices that support efficiency in both short-term operations and long-term investment**

Incentives for capacity

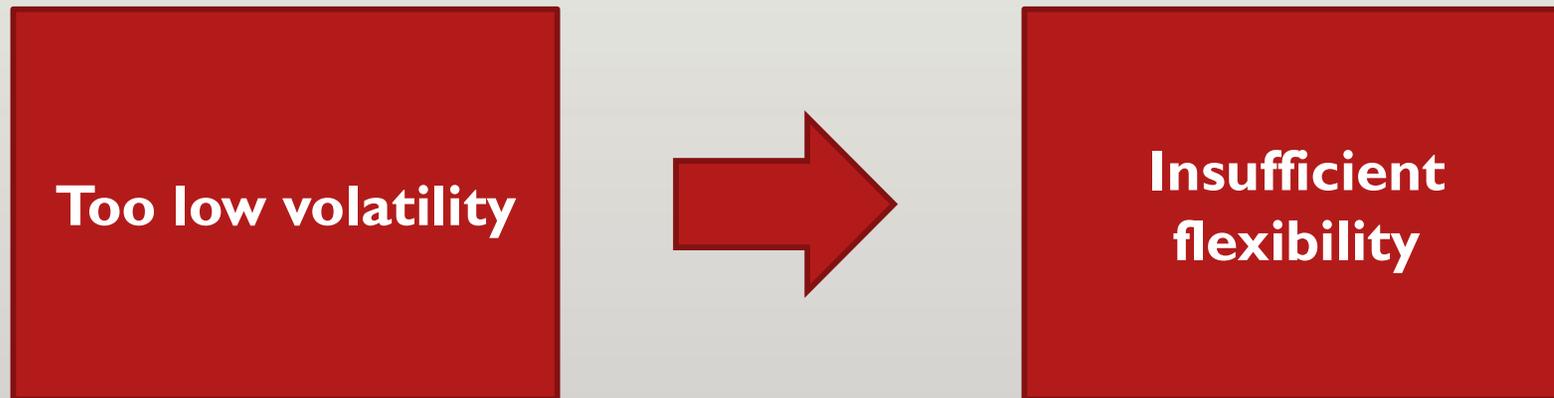
Widely understood that if prices are too low, resources will not be adequate:



▶ Most systems supplement energy revenues with additional payments

Incentives for flexibility and diversity

Less recognized that suppressing volatility could have long-run consequences:



▶ Suppressing volatility weakens incentive for flexibility and assets with uncorrelated failures

Category 2: mandate some form of contracting

Can require that load serving entities contract with suppliers, with several high-level design choices:

- **Full-strength spot prices?**
- **State, ISO, or combination?**
- **Centralized or bilateral?**
- **What contractual form?**
- **Financial or physical?**

 **Ideally, structure contract mandates in such a way that it doesn't crowd out arrangements that could be done more efficiently by participants**

Beyond capacity markets

- **Resource adequacy debates stuck in “energy-only versus capacity”**
 - **Instead, think of capacity markets as one particular form of mandatory contract**
 - **Option-like affect on cash flows**
 - **Analysis made difficult by lack of full-strength spot prices**
 - **No reason to think it is the best single form given the diversity of arrangements that arise in practice**
-  **Want to understand how different contract mandates will affect risk and resource mix**

Contractual form and capacity markets

The missing money replaced by capacity markets aligns with operating profits for higher-cost units

Split of PJM operating profits between energy and capacity

Marginal Cost	% profits from energy market	% profits from capacity market
\$10/MWh	83%	17%
\$100/MWh	10%	90%

 **Facilitates financing of high-marginal cost units relative to low-marginal cost (and low-carbon) ones**

Note: Calculation assumes energy sales in the Day-Ahead Market at the PJM pricing node whenever the LMP is above marginal cost and capacity sales in the Base Residual Auction at the RTO-wide clearing price for delivery years 2014/15–2017/18

Risk transfer: a provocation

State renewable/carbon contracting requirements

- **De-risk investment in certain technologies**
- **Unclear connection to fundamental value of the provided energy**

ISO/RTO capacity requirements

- **De-risk investment in certain technologies**
- **Unclear connection to fundamental value of the provided energy**

 Many market-oriented people are skeptical of former but accepting of latter, but a priori they are playing similar (potentially complementary) roles

Financial viability revisited

Bloomberg

Germany's Uniper Seeks Bailout, a Victim of Putin's Gas Feud



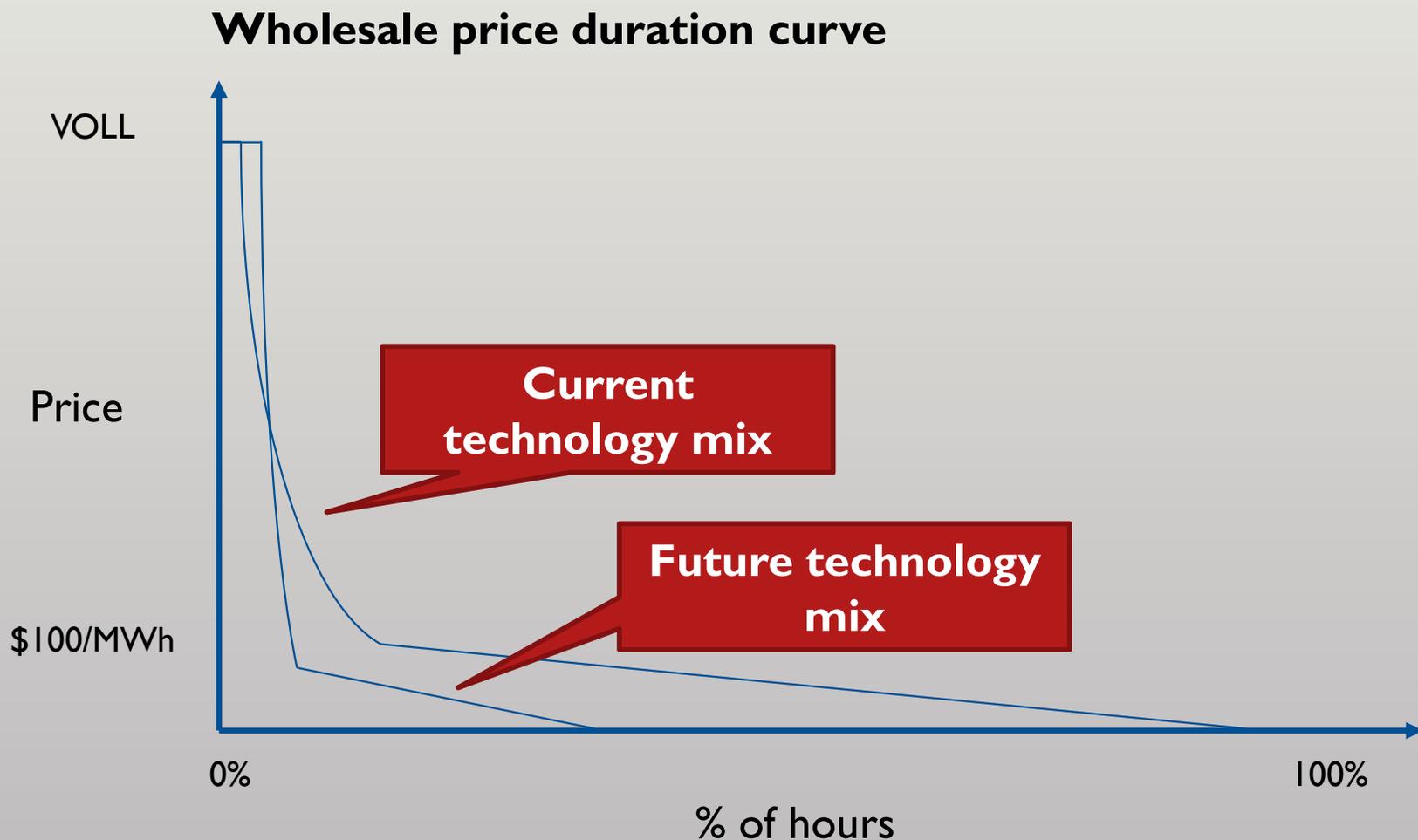
Financial contracts alone do not suffice; need measures to reduce non-performance risk

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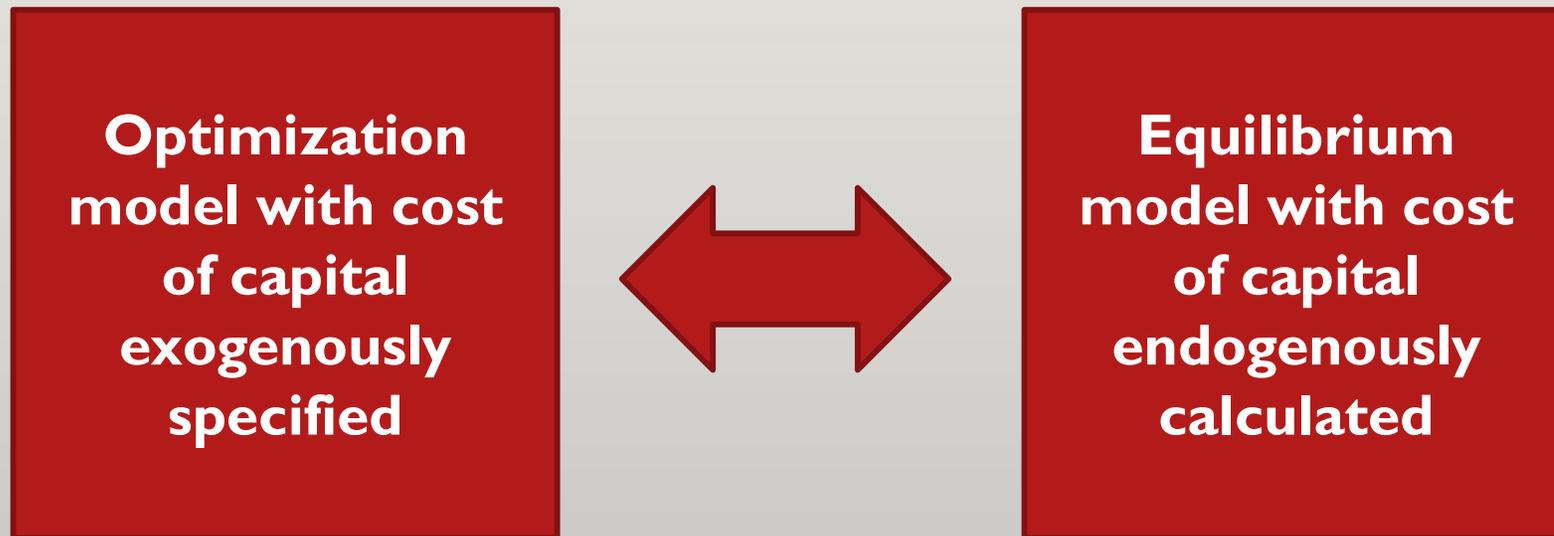
Investment risk

Fundamental value may be even more extremely skewed in deep decarbonization scenarios



Modeling the effect of risk trading

Need to understand how volatility and risk trades affect revenue certainty and therefore cost of capital



▶ Calibrate both models to approximate current resource mix in Texas

Exploratory test: hypothetical futures

- **Construct two hypothetical future mixes with much higher share of variable renewables**
 - **Decreased investment cost for wind/solar/storage**
 - **Increased operating cost for thermal**
 - **Hold risk measures and level of risk trading constant**
 - **Compare results with exogenously specified cost of capital against those with endogenously calculated cost of capital**
-  **Want to see how the cost of capital changes in future systems with high wind and solar**

Equilibrium mixes

Equilibrium capacity mix in constructed futures:

Resource	Current (GW)	High VRE (GW)	Extreme VRE (GW)
Baseload	51	20	0
Peaker	20	6	0
Backup/DR	5	9	25
Solar	3	53	70
Interior Wind	10	50	67
Coastal Wind	3	50	73
Storage	12	43	90
% VRE	19%	96%	100%

Distribution of price spikes

Future systems see high prices with about the same frequency, but concentrated in fewer years

	Current	High VRE	Extreme VRE
Number of high-priced (>\$900/MWh) hours	216	214	230
Number of years with any high-priced hours	47%	42%	31%
Max number of hours with high prices in one year	27	41	58

Cost of capital

Modeled cost of capital increases for thermal resources but falls for wind, solar, and storage

Resource	Current	High VRE	Extreme VRE
Baseload	7.8%	8.1%	—
Peaker	9.2%	9.4%	—
Backup/DR	10.3%	11.7%	13.7%
Solar	6.7%	5.4%	6.6%
Interior Wind	6.1%	5.0%	5.6%
Coastal Wind	6.4%	5.3%	6.2%
Storage	6.4%	6.6%	6.8%

Thermal resources dependent on rare scarcity events see increased cost of capital

Cost of capital

Modeled cost of capital increases for thermal resources but falls for wind, solar, and storage

Resource	Current	High VRE	Extreme VRE
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Interior Wind	6.1%	5.0%	5.6%
Coastal Wind	6.4%	5.3%	6.2%
Storage	11.0%	6.6%	6.8%

Variable renewables have lower risk due to reduced exposure to fuel price

Cost of capital

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Coastal Wind	6.4%	5.3%	6.2%
Storage	11.0%	6.6%	6.8%

Storage sees more regular revenues instead of relying on rare scarcity events

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 **Wind, solar, and storage receive most investment, so consumers payer lower risk premia overall**

Markets and reliability

- **Market logic implies a tradeoff between cost and reliability**
- **Models predict that high-VRE markets will have lost load more frequently than currently accepted**

Mix	Expected unserved energy (MWh/yr)
Current	4,661
High VRE	8,273
Extreme VRE	17,080

- **We can operate a system reliably with a high level of renewables**
- **Current market parameterizations may not deliver a high level of reliability**

Reliability and skewness

Efforts to increase reliability in a market-oriented way can further exacerbate financing challenge

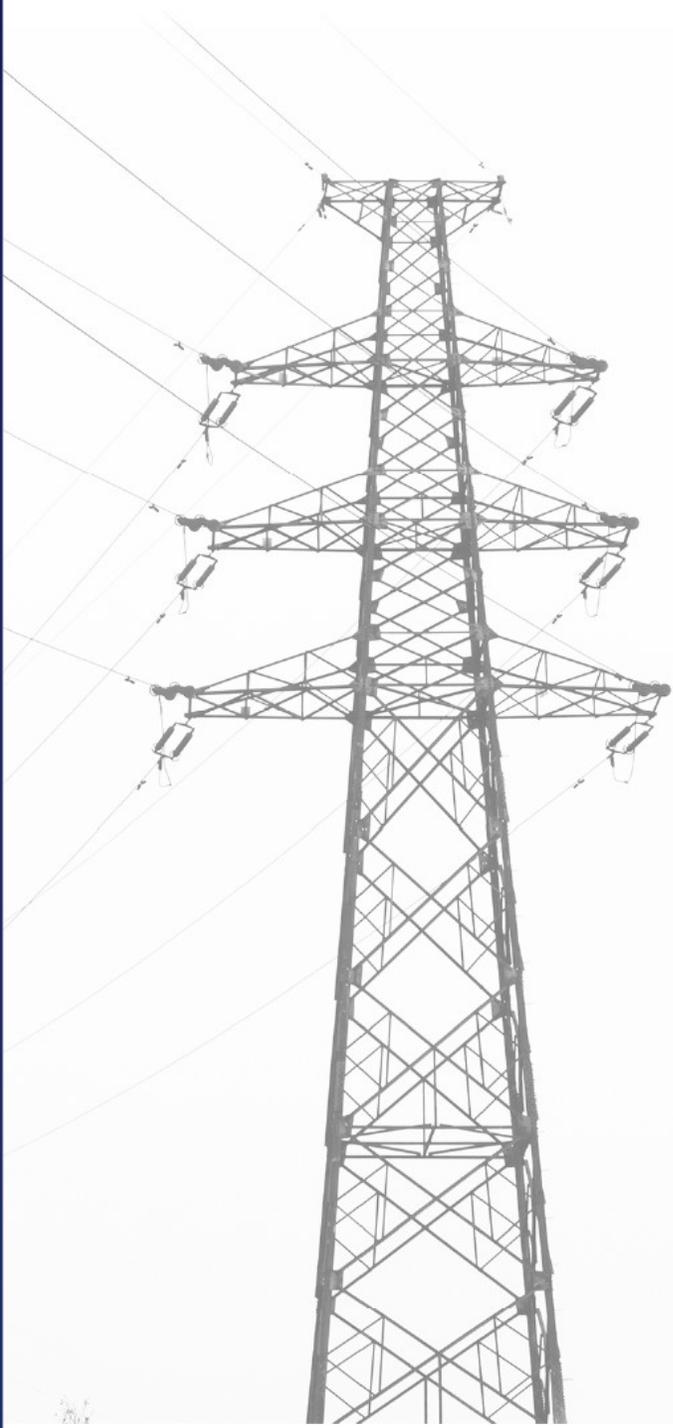
Resource	VOLL=\$9,000/MWh	VOLL=\$20,000/MWh
Baseload	8.1%	8.9%
Peaker	9.4%	10.8%
Backup/DR	11.7%	15.2%
Solar	5.4%	5.1%
Interior Wind	5.0%	4.8%
Coastal Wind	5.3%	5.0%
Storage	6.6%	6.4%

Note: assumes cost parameters from hi

Higher cost of capital for resources dependent on rare scarcity prices

Volatility and viability

- 1** Can systems completely rely on voluntary hedging around spot prices?
 - No
- 2** Assuming not, what might states and market operators do about it?
 - Mandatory contracts around full-strength spot prices
- 3** How might this evolve as renewables continue to grow?
 - To be determined



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