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Revenue Sufficiency and Reliability in a Zero Marginal Cost Future

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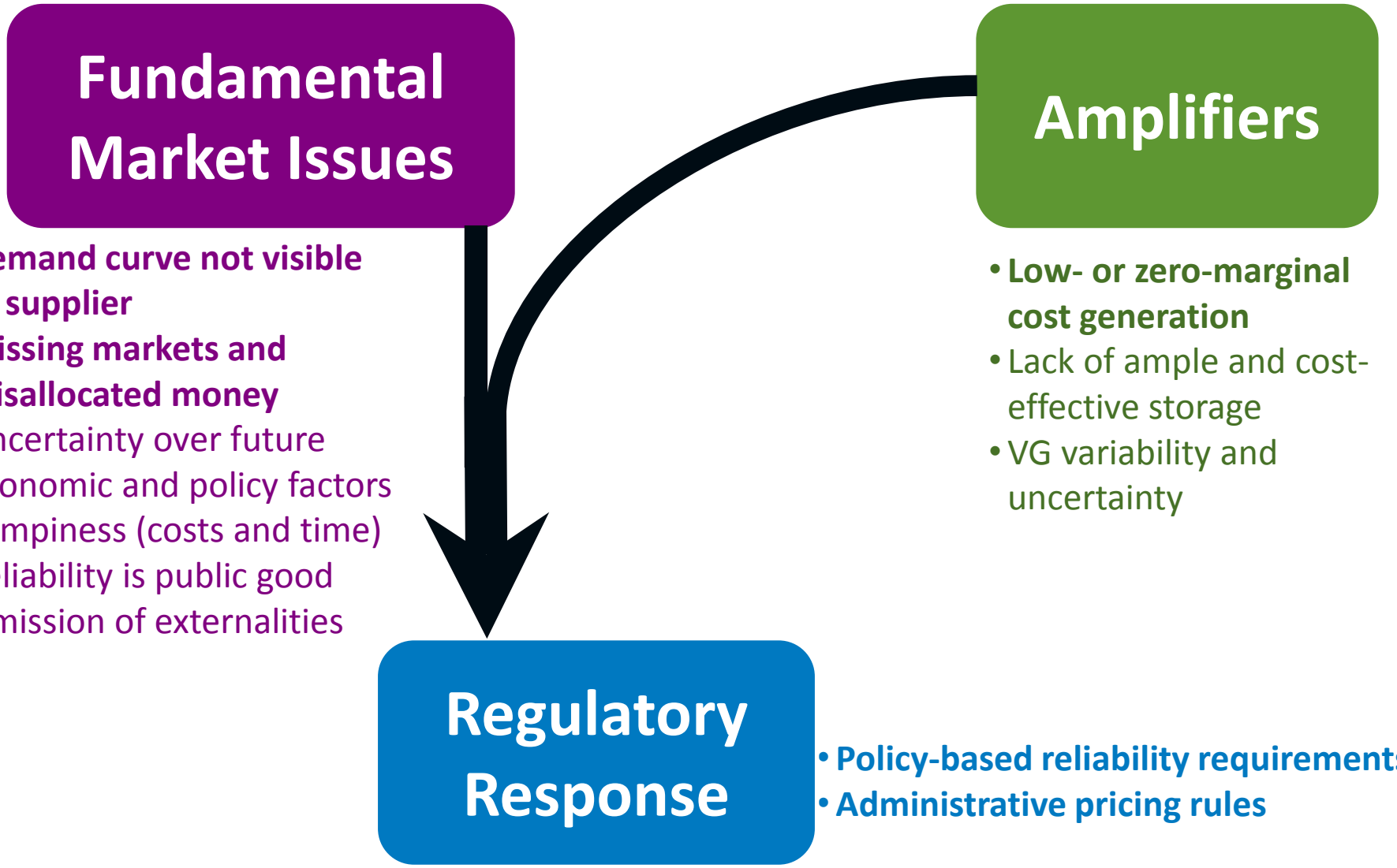
United States observations

- ISO/RTO market monitor reports noting low energy prices, driven by historically low natural gas prices and demand
- Nuclear premature proposed/planned shut downs due to insufficient revenues

Are these symptoms of a deeper problem or an appropriate response to an evolving system?

Zero marginal cost VG amplify the problem



Electricity markets are fundamentally different than any other market

Current market designs to ensure revenue sufficiency

1) Supplement energy-only market with A/S products and scarcity pricing

2) Forward capacity markets or capacity payments

3) Power purchase agreements or other contracting approaches

Strategies to deal with this problem depend on existing market designs, and it remains unclear if/which of these can provide proper incentives to ensure longer-term reliability

NREL using models to assess evolving grid

Goal: Examine impact of behavior, fleet composition, and operational factors on revenue sufficiency and reliability within a markets framework.

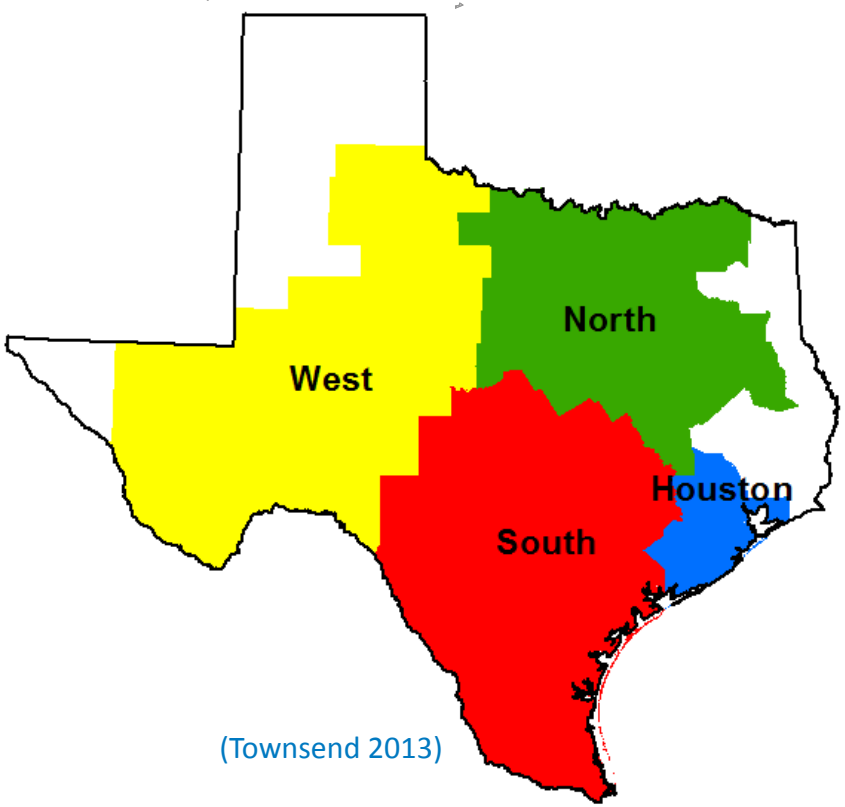
We found (so far):

- Increasing penetration of VG ***amplifies revenue sufficiency challenges***
- New reserve requirement ***marginally abates revenue sufficiency challenges***
- Changing fleet composition ***drives greater concern over resource adequacy***

Getting the prices right

- Market must convey proper economic signals about what is and is not needed for reliability
- Lesson learned: production cost models (PCMs) out-of-box need to be tuned
- Capturing strategic generator **behaviors** is one important factor
  - Generator bid offer markups
  - Imperfect competition models, e.g., Nash-Cournot
- **Outages**, **congestion**, and **contingencies** also key

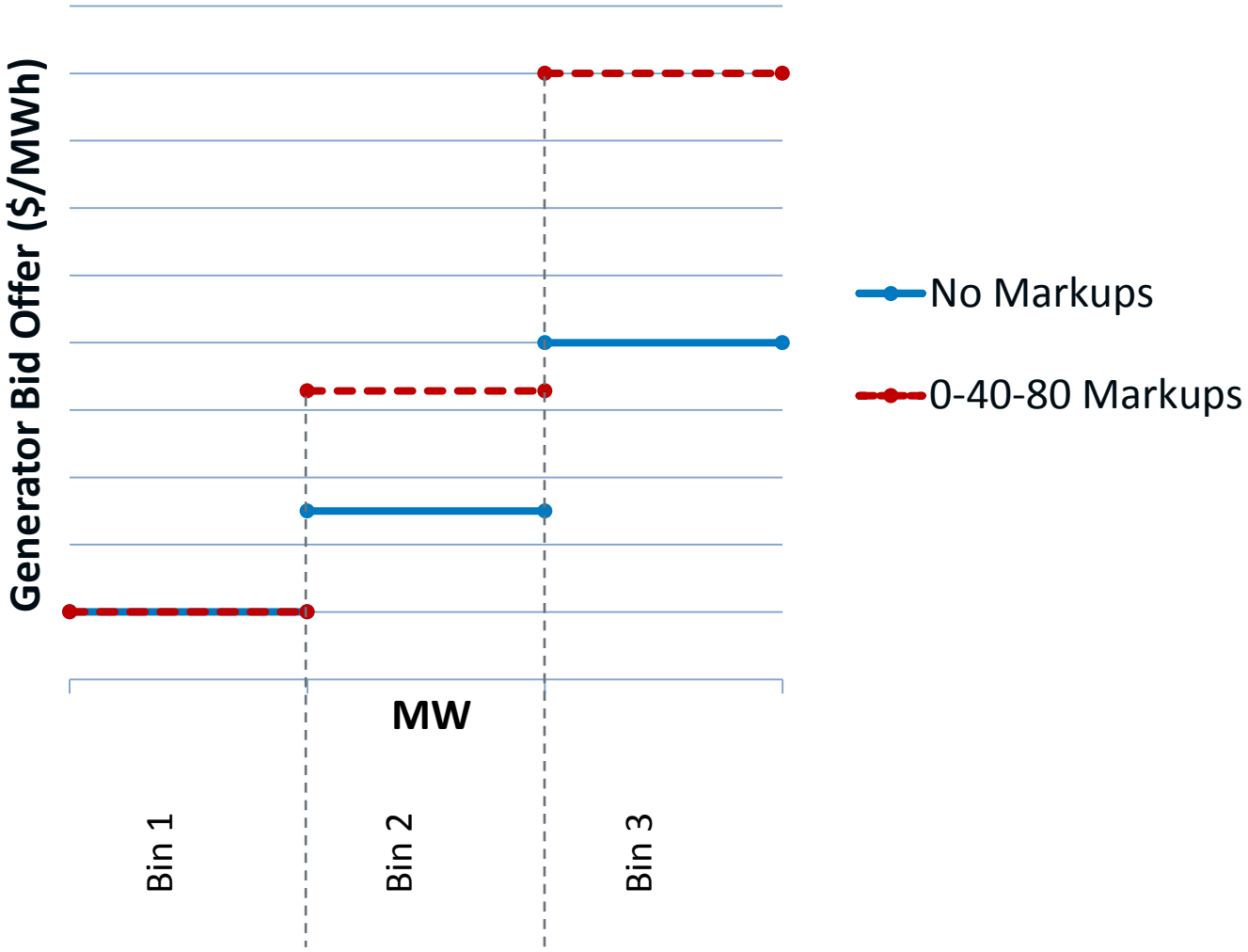
Completed work: ERCOT-like PCM



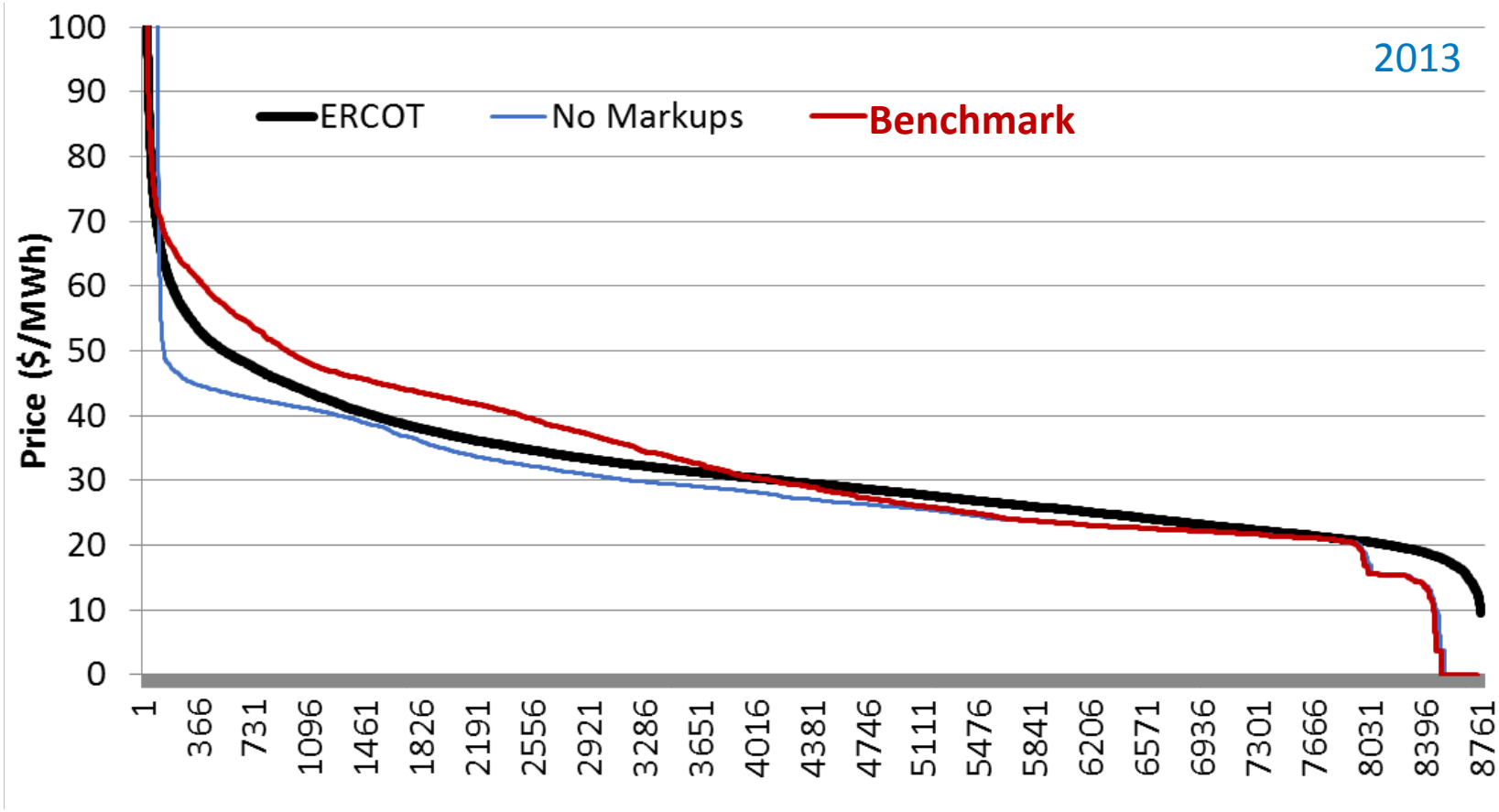
(Townsend 2013)

- ERCOT is energy-only market
- 4 zones, hourly resolution with historic wind and load data, DAM only
- Simulate prices, costs, revenues for 2012-2014, focus on 2013

Bid offer markup scenarios to calibrate model



Validate against historic ERCOT DAM prices



- **Modeling captures mid-section of price duration curve, but misses tails**
- **Using default pricing (*No Markups*) would overestimate the extent of any revenue sufficiency challenges**

Sensitivity scenarios to assess revenue sufficiency

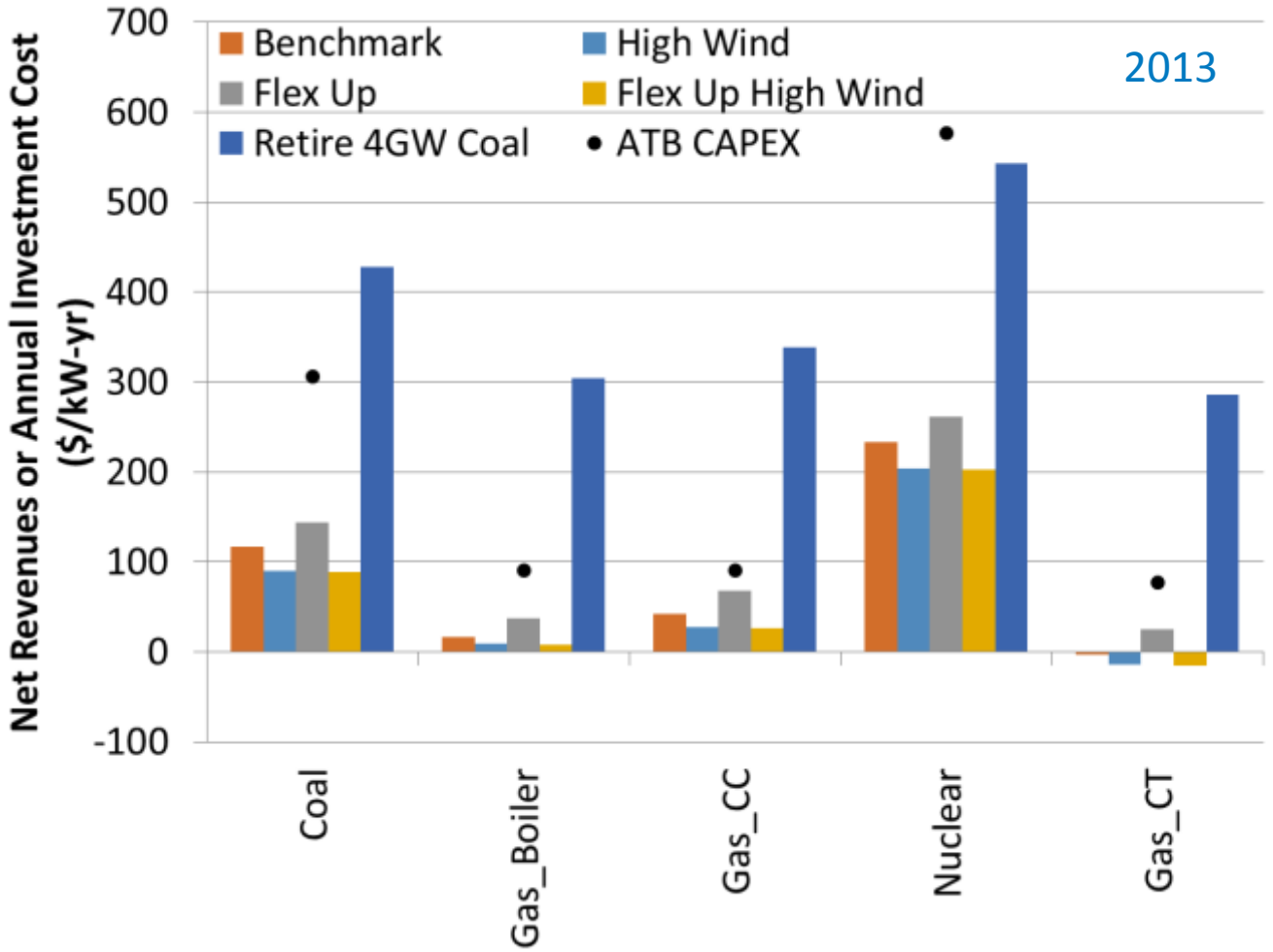
Sensitivity Scenario	Wind Capacity	Flexible Reserve	Coal Retirement
High Wind	High Wind	Benchmark	Benchmark
Flex Up	Benchmark	Flex Up Reserve Requirement	Benchmark
Flex Up High Wind	High Wind	Flex Up Reserve Requirement	Benchmark
Retire 4GW Coal	Benchmark	Benchmark	Retire 4GW coal from North and South zones

Roughly double the ERCOT-wide wind penetration from Benchmark

Additional reserve requirement to capture uncertainty burden from wind

Retire about 23% of base coal fleet

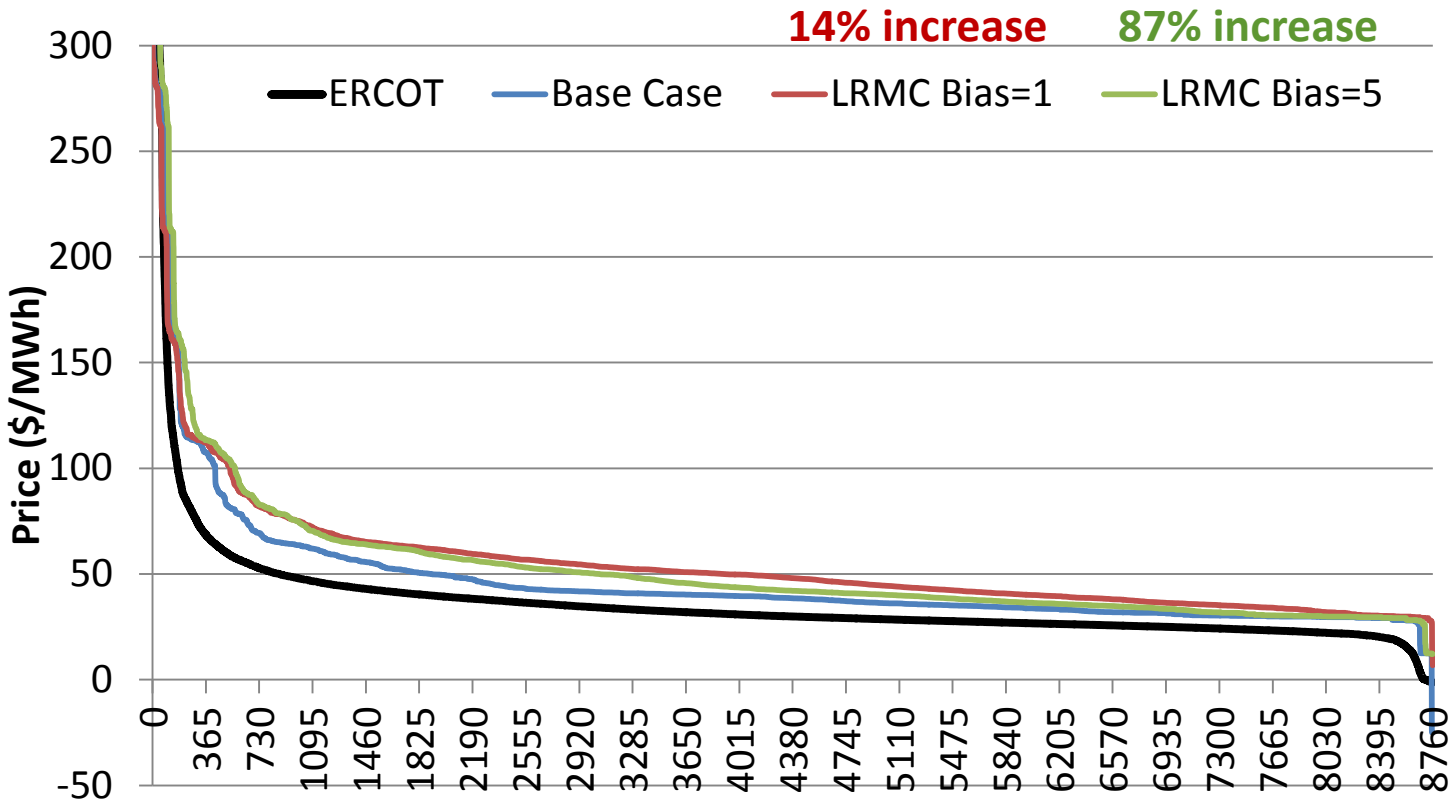
Revenue sufficiency challenges are implied



Revenue sufficiency challenges are implied if annual investment cost for new unit (dot) is greater than observed net revenues (bar)

Preliminary work: How high do prices need to go?

- Cost recovery option: **dynamic markups** to cover long-run marginal cost (LRMC)
- Use improved ERCOT-like PCM: nodal, DA/RT, hourly resolution



Key Conclusions

- Getting the prices right is critical for estimating revenue sufficiency challenges, and out-of-box PCMs may need "tuned" to accurately replicate electricity market prices

- Completed work:
  - Revenue sufficiency challenges are implied in base case, when increase wind, and when add new reserve product; resource adequacy becomes greater concern when retire large amounts of coal → overcapacity is likely key driver of price effects
  - **Full report available: http://www.nrel.gov/docs/fy16osti/66076.pdf**

- Preliminary work:
  - To recover long-run costs, energy-only prices require non-trivial markups of ≥ 10% if assume no sunk costs

Next steps: develop and use market test bed

- Use more comprehensive and accurate model
- Better capture reliability linkage
- Improve representation of bidding strategies and/or operational factors that have greatest impact on prices
- Remove impact of overcapacity
- Include various market mechanisms: uplift payments, congestion charges, redispatch, and A/S components (e.g., ORDC)

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