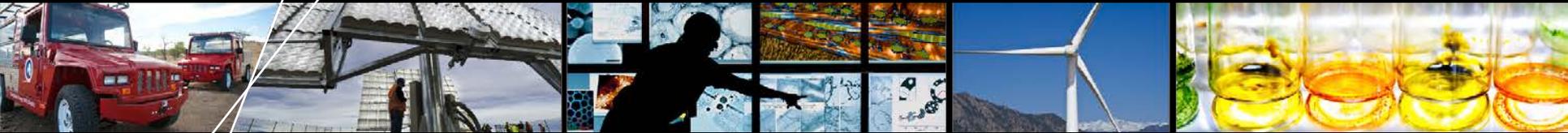


# Missing Money – Will the Current Electricity Market Structure Support High (~50%) Wind/Solar?



**AWEA WindPower Conference**

**May 18, 2015**

**Orlando, Florida**

**Michael Milligan**

# Acknowledgements

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- **NREL**

- Bethany Frew, Kara Clark, Aaron Bloom,  
Aaron Townsend

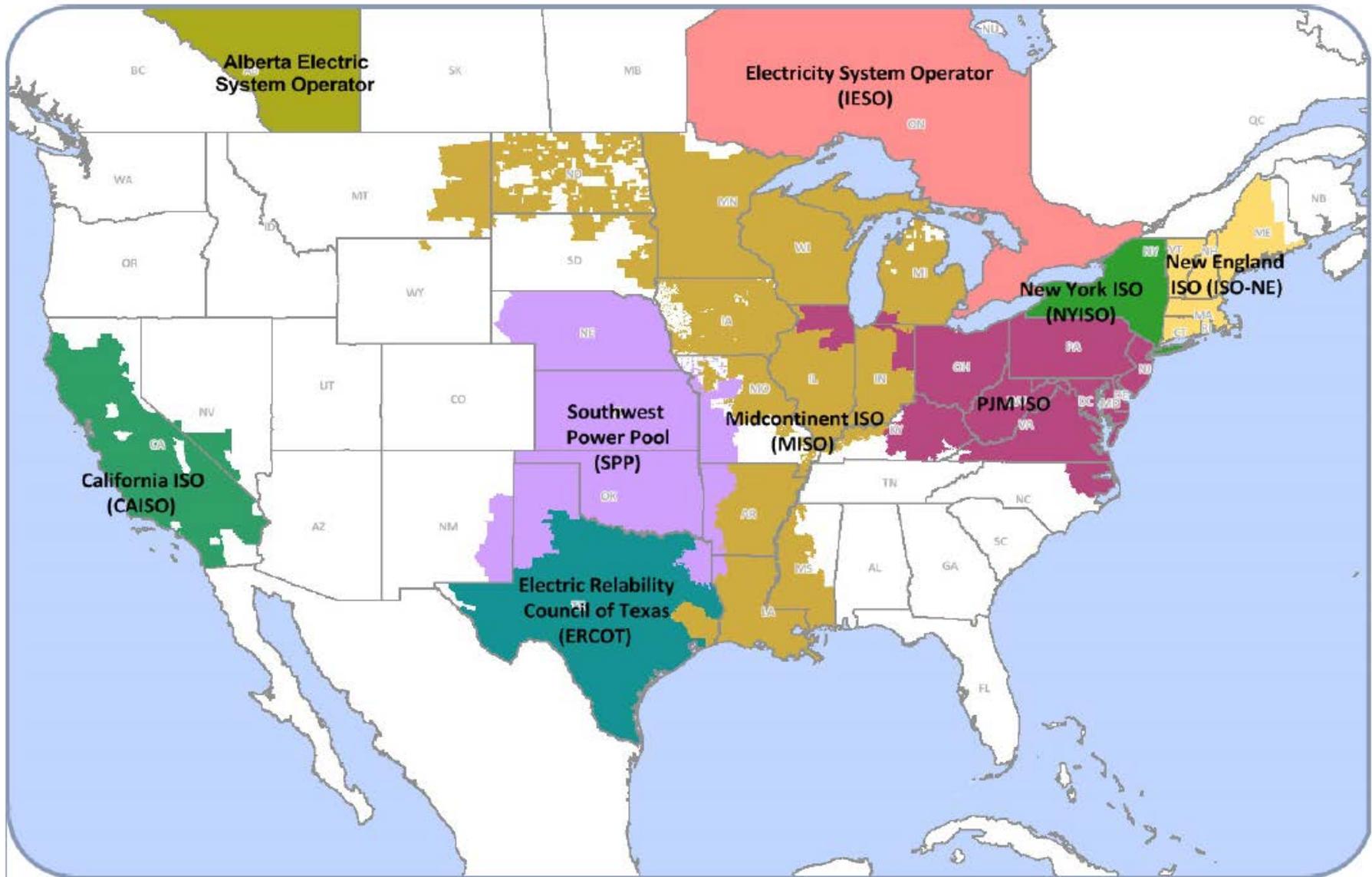
- **EPRI**

- Erik Ela

- **ECCO**

- Alex Papalexopoulos, Dave Perrino, Rodd Frowd,  
Chuck Hanson

## North American Regional Transmission Organizations



# The Fundamental Market Problem

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- **Many technologies have high fixed costs and low marginal costs**
- **With these economies of scale, competitive markets can be shown to fail (i.e., price = marginal cost), where marginal cost = cost of producing the next unit of output**
- **Examples:**
  - What if Microsoft priced at marginal cost?
  - What if wind power sold energy at marginal cost (approximately \$0/MWh)?
- **This is not an electricity-only problem—high fixed cost and low/zero marginal cost is “well understood”**
- **This problem is exacerbated by the constraints on electricity delivery**

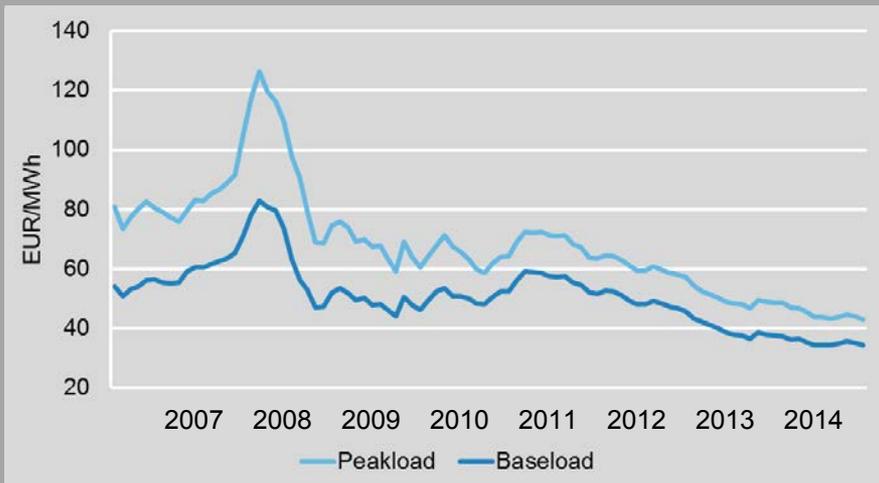
# What Is the Missing Money Problem?

- **“There is growing world-wide concern over depressed energy prices and need for capacity adequacy...”**  
**Charlie Smith, UVIG**
- **There is insufficient revenue to cover fixed and operating costs**
  - Revenue is based on marginal cost, but must pay for both fixed and marginal costs
- **This impacts long-term reliability**
  - This results in premature plant retirements and/or a lack of new resources for capacity and/or flexibility
- **This is due to market design failures (not VG!)**
  - Consumers are insulated from actual time-sensitive prices
  - Consumers cannot choose the level of their individual electric reliability

# Impacts of Increasing VG Penetration

- **Amplified missing money problem**
  - Zero marginal cost, which reduces prices and increases occurrence of zero or negatively priced periods
  - Reduces the energy that other suppliers can sell in the energy market
- **Variability**
  - More volatile LMPs from one time period to another
- **Uncertainty**
  - Increased disparity between DAM and RTM LMPs

**The View from Europe**  
(Source: Markus Steigenberger, Agora)



German utilities: Economic prospects are bad. No recovery of wholesale prices expected. Already today, most plants no longer covering their costs.

Utilities: To keep existing plants in the system and incentivize new firm capacity, a capacity reserve market is needed. Otherwise, system reliability would be at risk.

However, most experts see low prices as an effect of general oversupply. In 2014, Germany possessed 184 GW installed capacity (incl. 79 GW RES) while peak load was 80 GW.

# Traditional Market Designs to Ensure Revenue Sufficiency

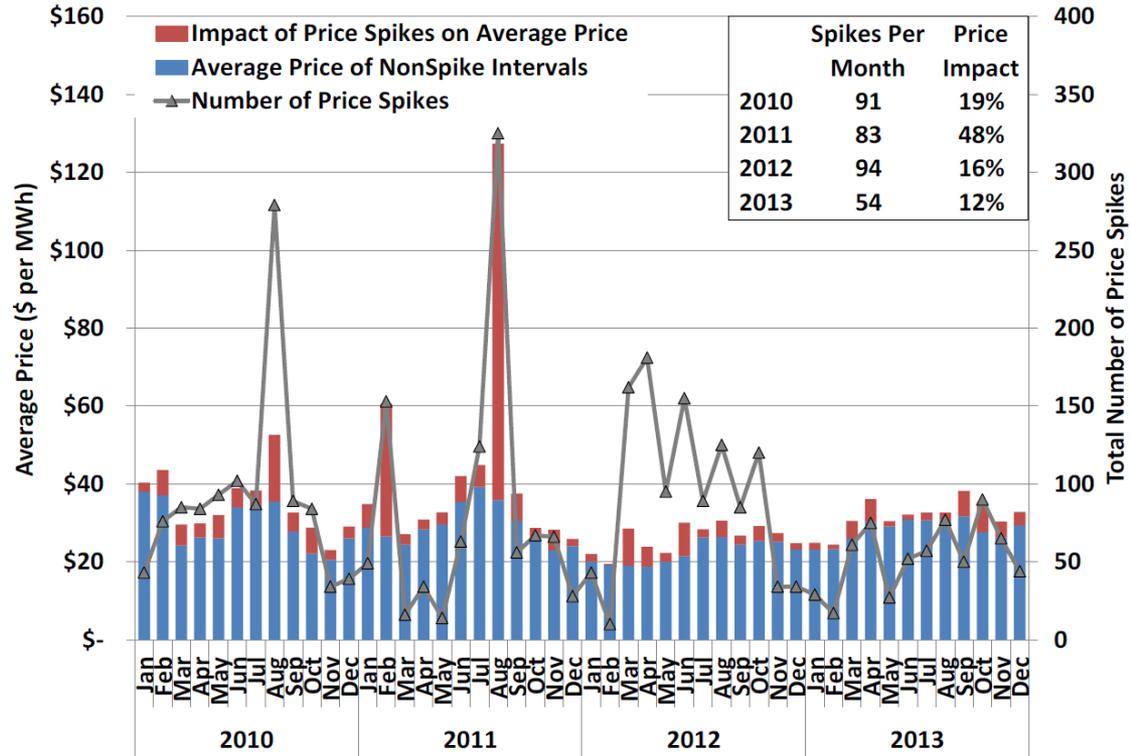
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**1. Scarcity Pricing**

**2. Forward Capacity Markets**

# Scarcity Pricing

- Price spikes in energy market when system is capacity constrained
- Usually originate as administratively set prices in ancillary service market
- Reflects large economic losses of outages
- Uncertain and volatile



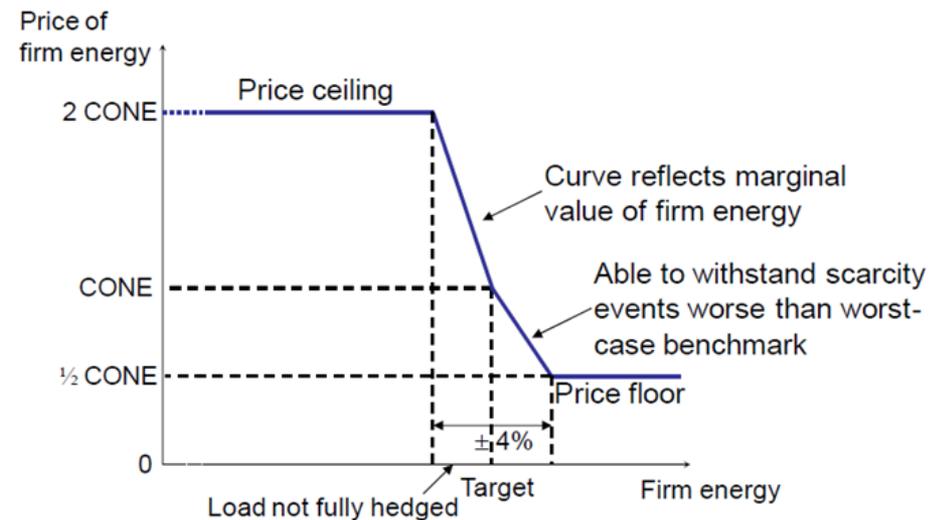
Source: Potomac Economics, LTD. September 2014. *2013 State of the Market Report for the ERCOT Wholesale Electricity Markets*: Independent Market Monitor for the ERCOT Wholesale Market.

# Forward Capacity Markets

- Incentivize new capacity that will be needed at a future date in the locations it is most needed
  - Prices based on demand curve
- Different markets have different forward and commitment periods

Demand curve for new capacity with price caps based on CONE

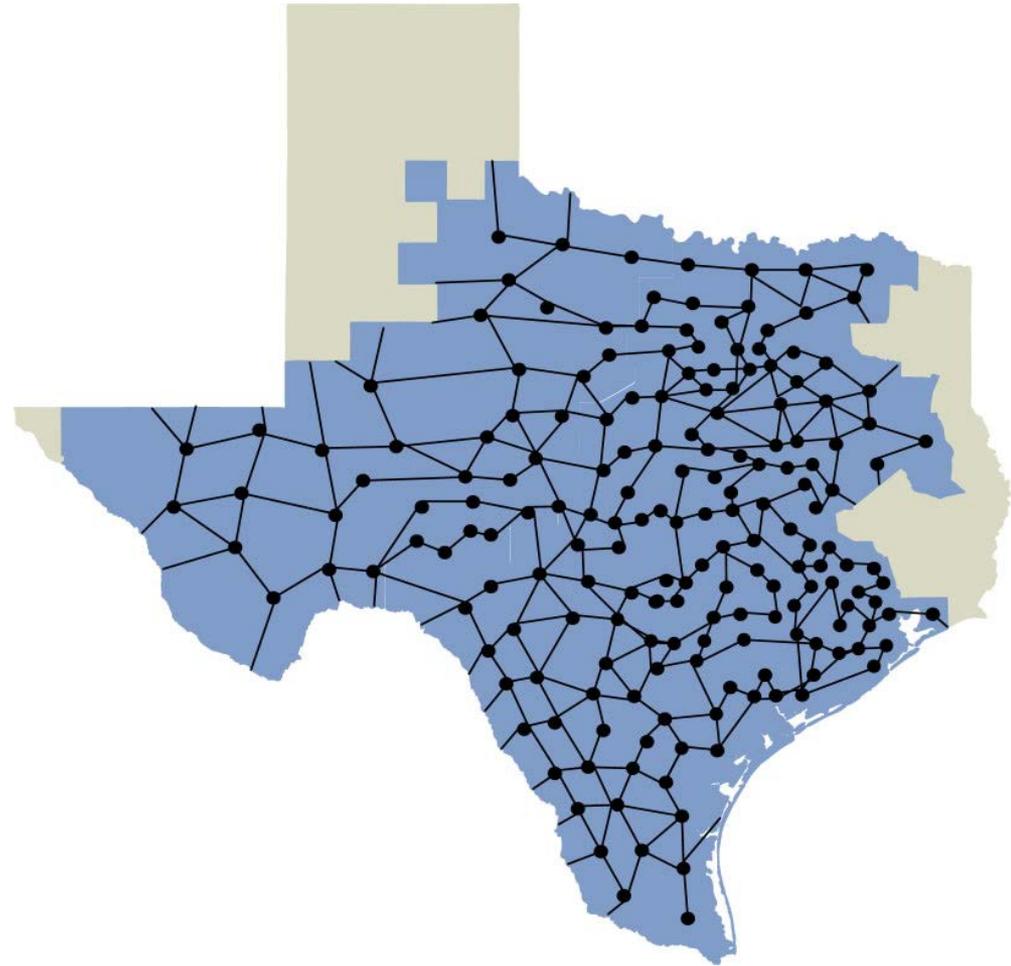
Source: Crampton and Ockenfels 2012



CONE = Cost of New Entry (marginal unit)

# ECCO/NREL Project

- **Focus on ERCOT**
- **Extensive benchmarking on price**
- **Estimate of all-in cost and revenue balance**



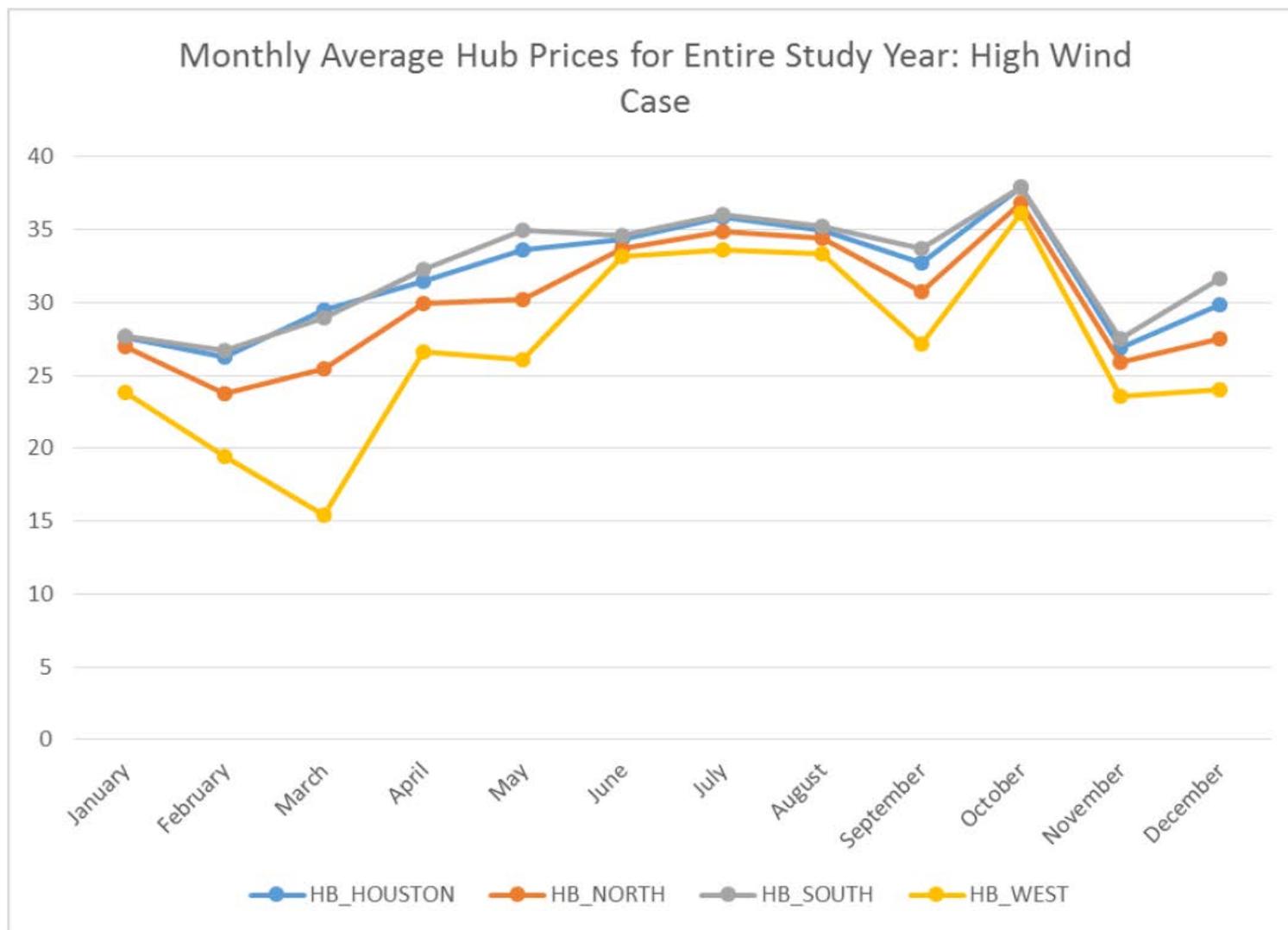
Nodal map of ERCOT from PUC Texas



# Analytical Results – ERCOT

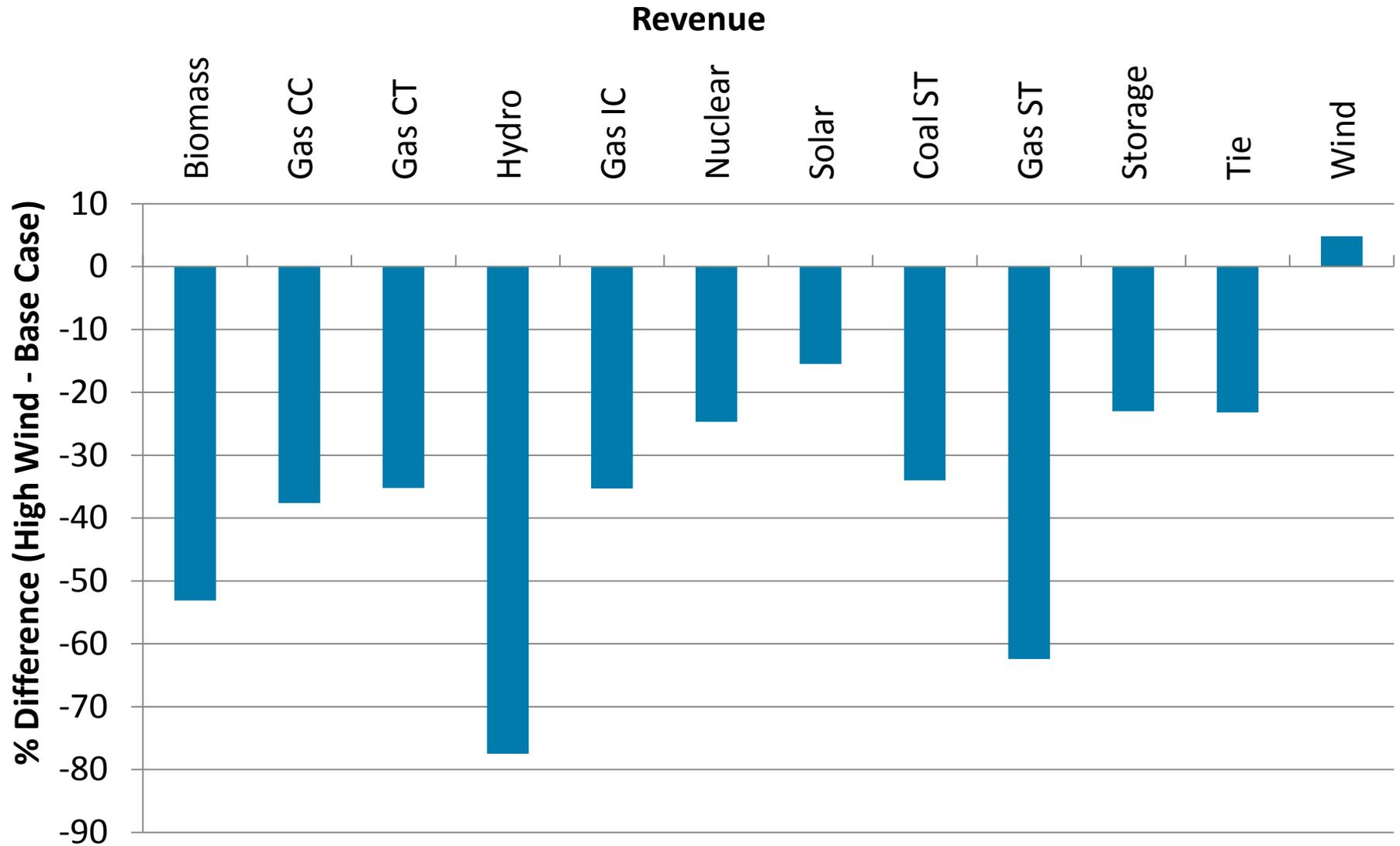
- **Adding more wind to the ERCOT system resulted in:**
  - Lower LMPs, both on an hourly and monthly basis
  - Lower overall profits, due to larger fixed costs and lower revenues
  - Dramatically reduced energy production of conventional units, offset by increased production from wind
  - More spinning reserve provision by conventional generators, which was offset by a nearly 50% reduction in the spinning price

# Lower LMPs on Monthly Basis



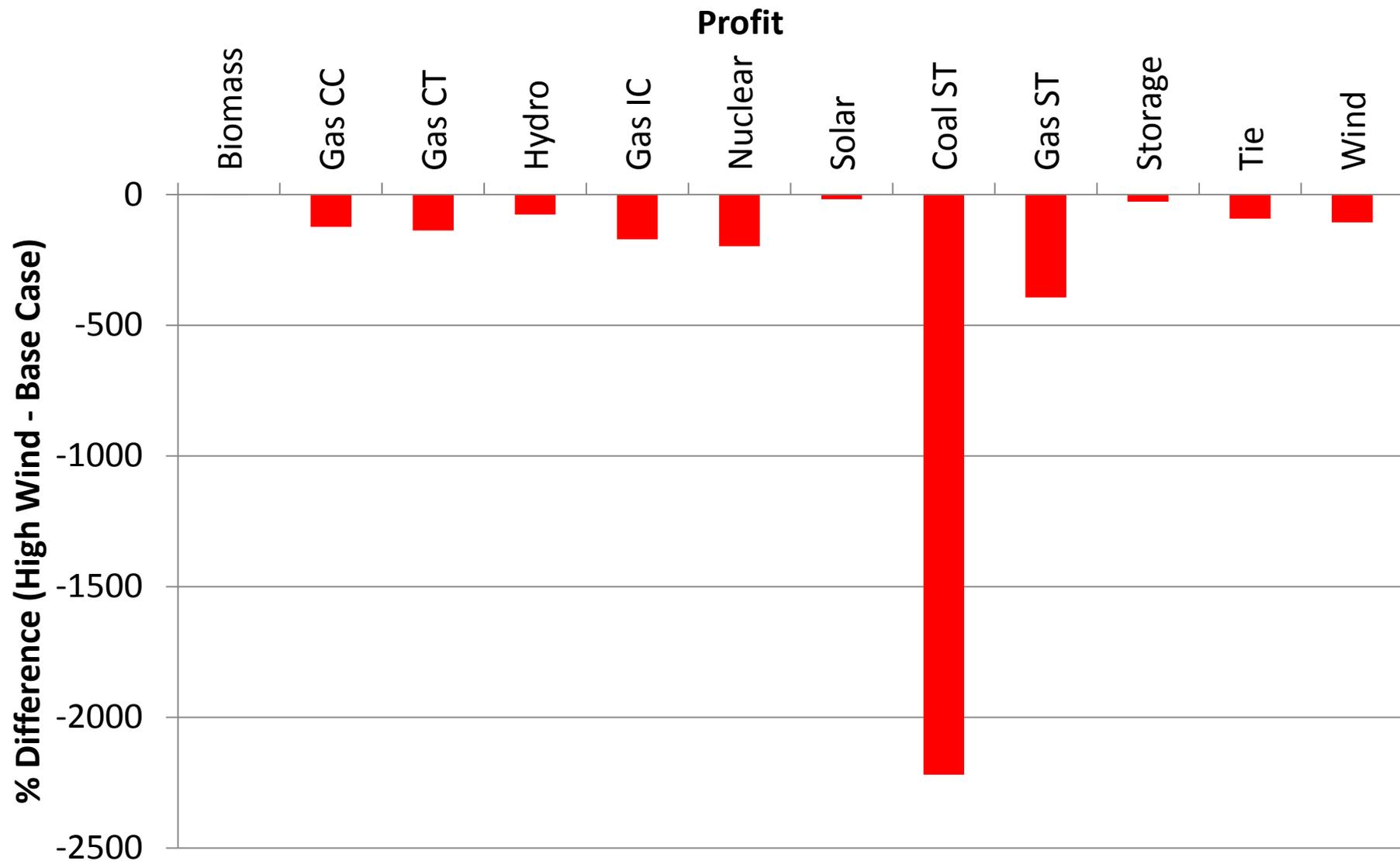


# Lower Overall Revenue and Profit





# Lower Overall Revenue and Profit



# New Market Designs to Ensure Revenue Sufficiency: ERCOT

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- **Energy-only market**
- **Increase scarcity price caps**
- **Implement dynamic operating reserve demand curve (ORDC) in RTM**
  - Price of operating reserves will depend on the hourly probability of lost load, which depends on the amount of operating reserve available
  - Currently uses fixed reserve requirement and scarcity price

# Wrap Up

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- **Revenue sufficiency is a problem, and may compromise long-term reliability**
- **The missing money problem is due to market design flaws, but increased VG penetration is amplifying the problem**
- **Strategies to deal with this problem depend on existing market designs and have not been demonstrated to be successful**
  - Energy vs. capacity
  - Methods to account for resource adequacy

# References

- **See also:**

- Ela, E.; Milligan, M.; Bloom, A.; Botterud, A.; Townsend, A.; Levin, T. (2014). Evolution of Wholesale Electricity Market Design with Increasing Levels of Renewable Generation. 139 pp.; NREL Report No. TP-5D00-61765. Available at <http://www.nrel.gov/docs/fy14osti/61765.pdf>.
- Cochran, J.; Miller, M.; Milligan, M.; Ela, E.; Arent, D.; Bloom, A.; Futch, M.; Kiviluoma, J.; Holtinnen, H.; Orths, A.; Gomez-Lazaro, E.; Martin-Martinez, S.; Kukoda, S.; Garcia, G.; Mikkelsen, K. M.; Yongqiang, Z.; Sandholt, K. (2013). Market Evolution: Wholesale Electricity Market Design for 21st Century Power Systems. 57 pp.; NREL Report No. TP-6A20-57477. Available at <http://www.nrel.gov/docs/fy14osti/57477.pdf>.
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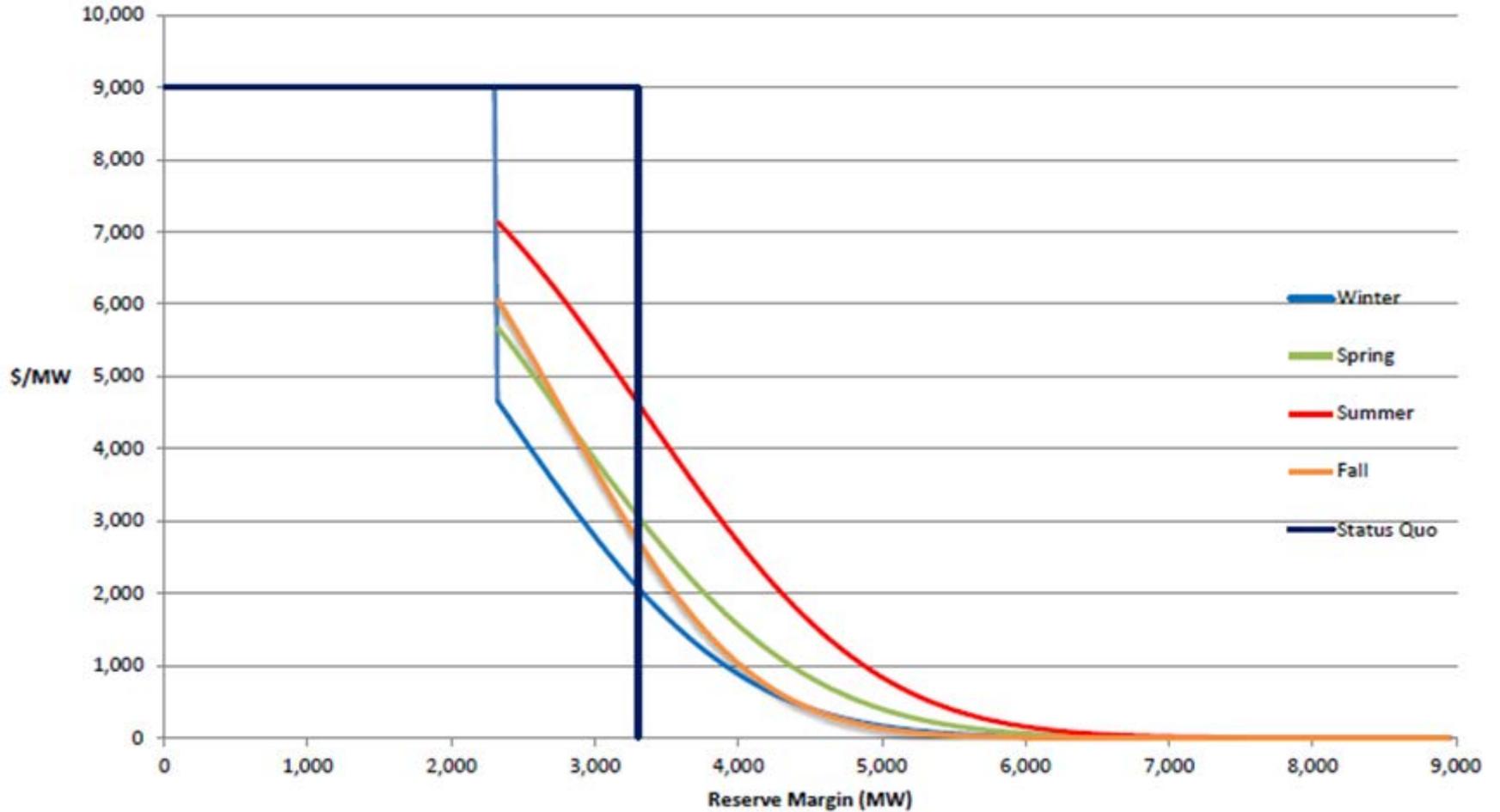
# Extra Slides

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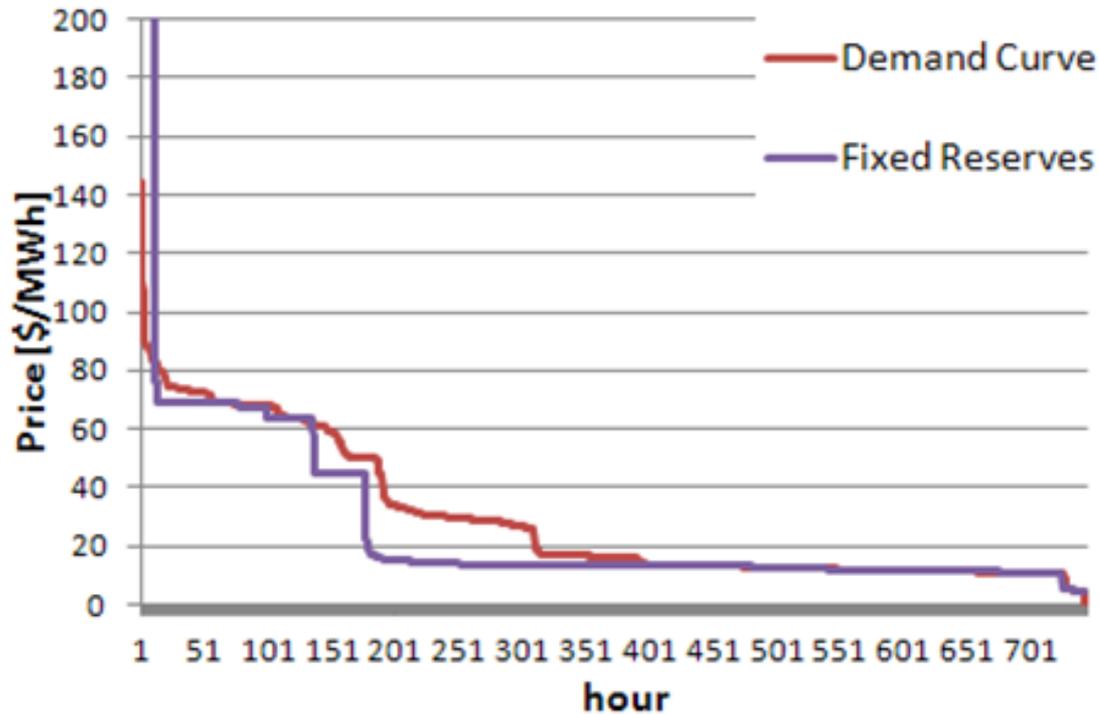


# ORDC

3a.m. - 6a.m.  
(ERCOT Seasonal Data for 2011)



# ORDC Yields Higher Overall Energy Prices



Simulated price duration curves in a day-ahead market for energy with an ORDC and a fixed reserve requirement for one month for an Illinois case study

**Source:** Zhou and Botterud 2013

- Hogan (2013) estimates average price increase in ERCOT if ORDC had been in place:
  - \$7/MWh to \$26/MWh in 2011 (extreme weather events)
  - \$1/MWh to \$4.5/MWh in 2012