Modeling, Simulation, and Computational Needs for RTOs: A PJM Perspective

FERC Technical Conference: Increasing Real-Time and Day-Ahead Market Efficiency through Improved Software

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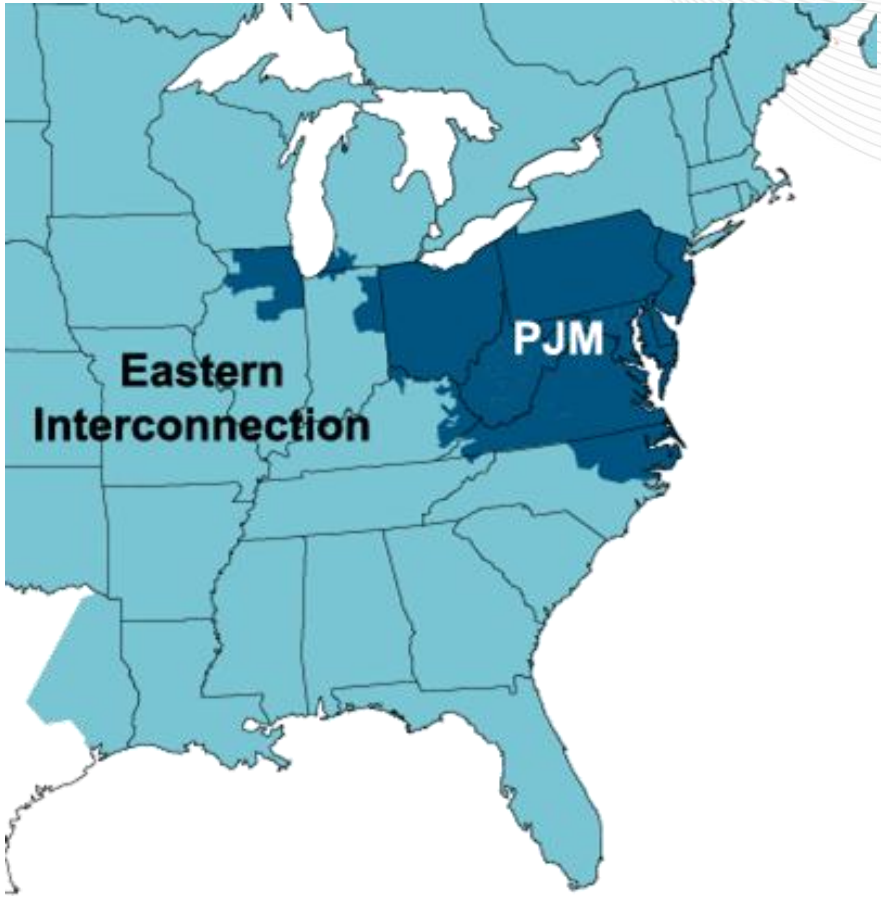
PJM: Who We Are



21% of U.S. GDP produced in PJM

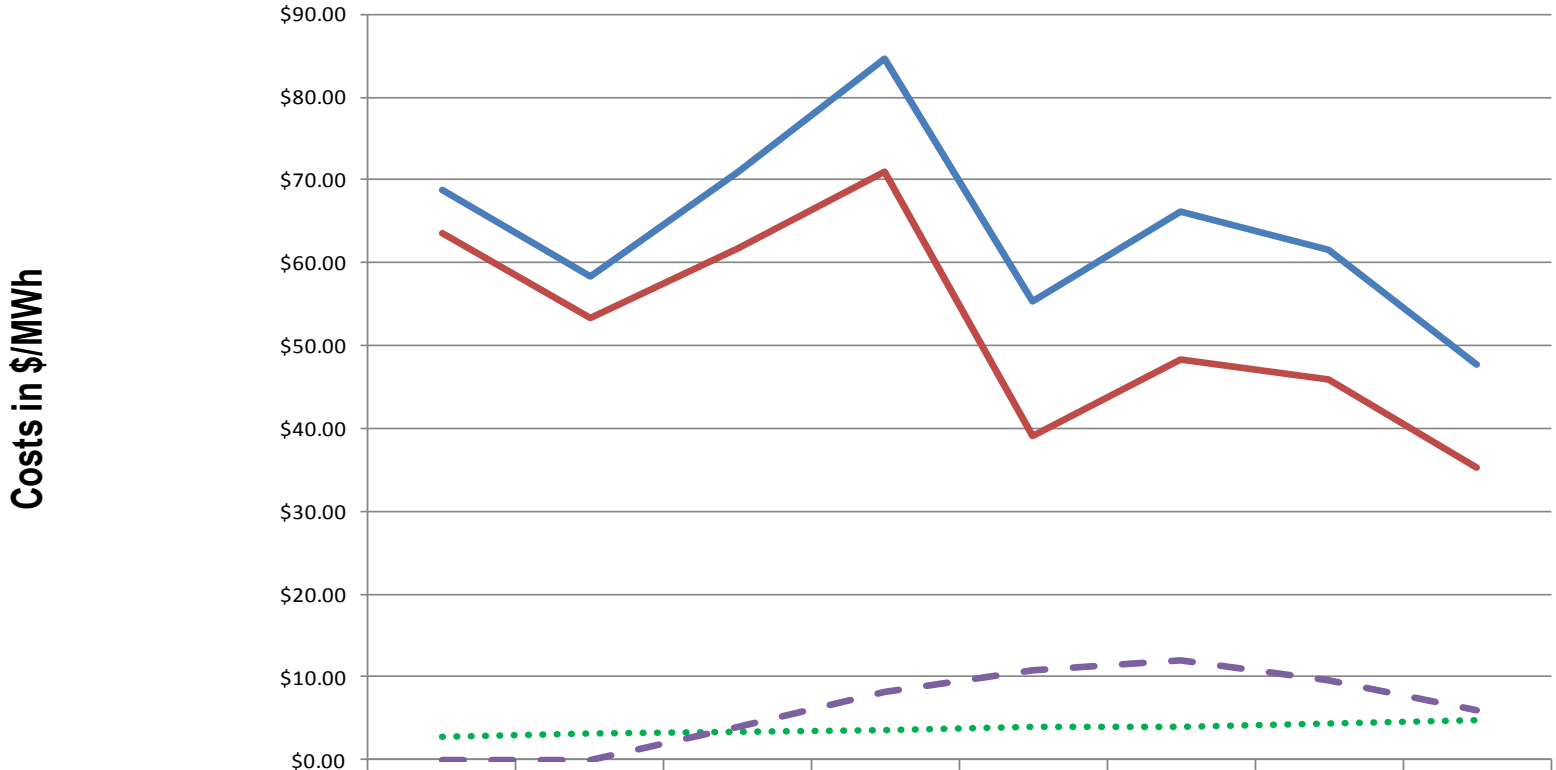
KEY STATISTICS

Member companies	800+
Millions of people served	60
Peak load in megawatts	163,848
MWs of generating capacity	185,600
Miles of transmission lines	59,750
GWh of annual energy	832,331
Generation sources	1,365
Square miles of territory	214,000
States served	13 + DC

As of 7/2012

Components of Wholesale Costs: Prioritizing Computational Effort by Contribution to Costs

PJM Wholesale Power Costs ($/MWh): Total and Major Components 2005 - 2012



	2005	2006	2007	2008	2009	2010	2011	2012
Wholesale Power Cost	$68.78	$58.38	$70.98	$84.66	$55.31	$66.15	$61.65	$47.77
Load-weighted Average LMP	$63.46	$53.35	$61.66	$71.00	$39.05	$48.34	$45.94	$35.23
Transmission Cost	$2.69	$3.16	$3.39	$3.56	$3.94	$3.95	$4.34	$4.71
Capacity Cost	$0.03	$0.03	$3.91	$8.12	$10.79	$11.97	$9.49	$6.02

Market Evolution…Computational Necessities

Evolution of Supply… Happening Now!

- Traditional resources

Less flexible

- Renewable resources

Intermittent

- Less capability to provide power grid services

Evolution of Demand Slow Adoption of Flexibility

- Technology enabled flexibility
- Alternative resource growth
- Enhanced capability to provide grid services

Market Evolution

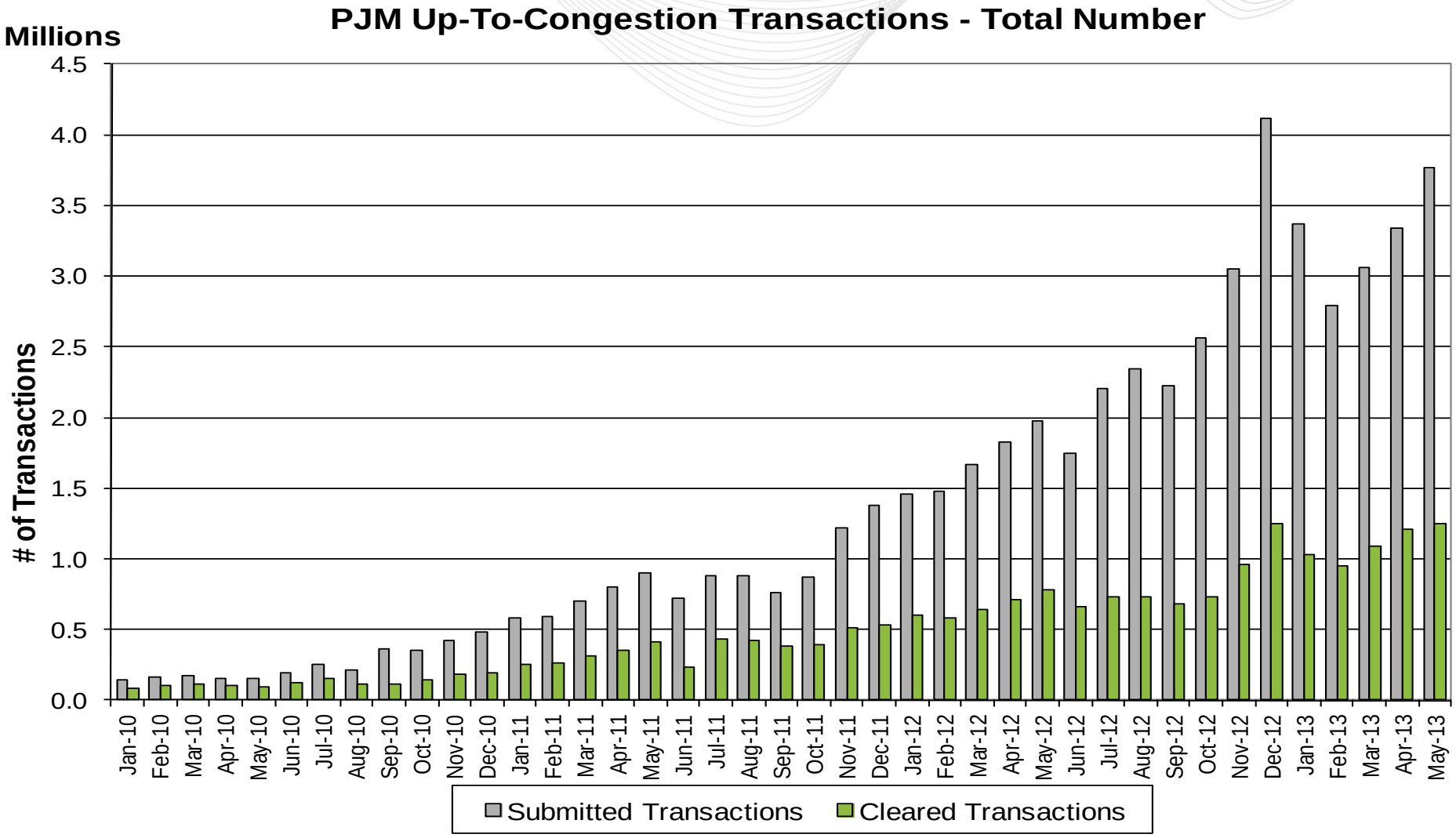
- More "real-time" markets to reward consumer flexibility?
- Development of Forward Demand Response Control Signals
- All this require improvements in optimization and control systems

Major Computational Need: Better, Faster MIP Algorithms and Software

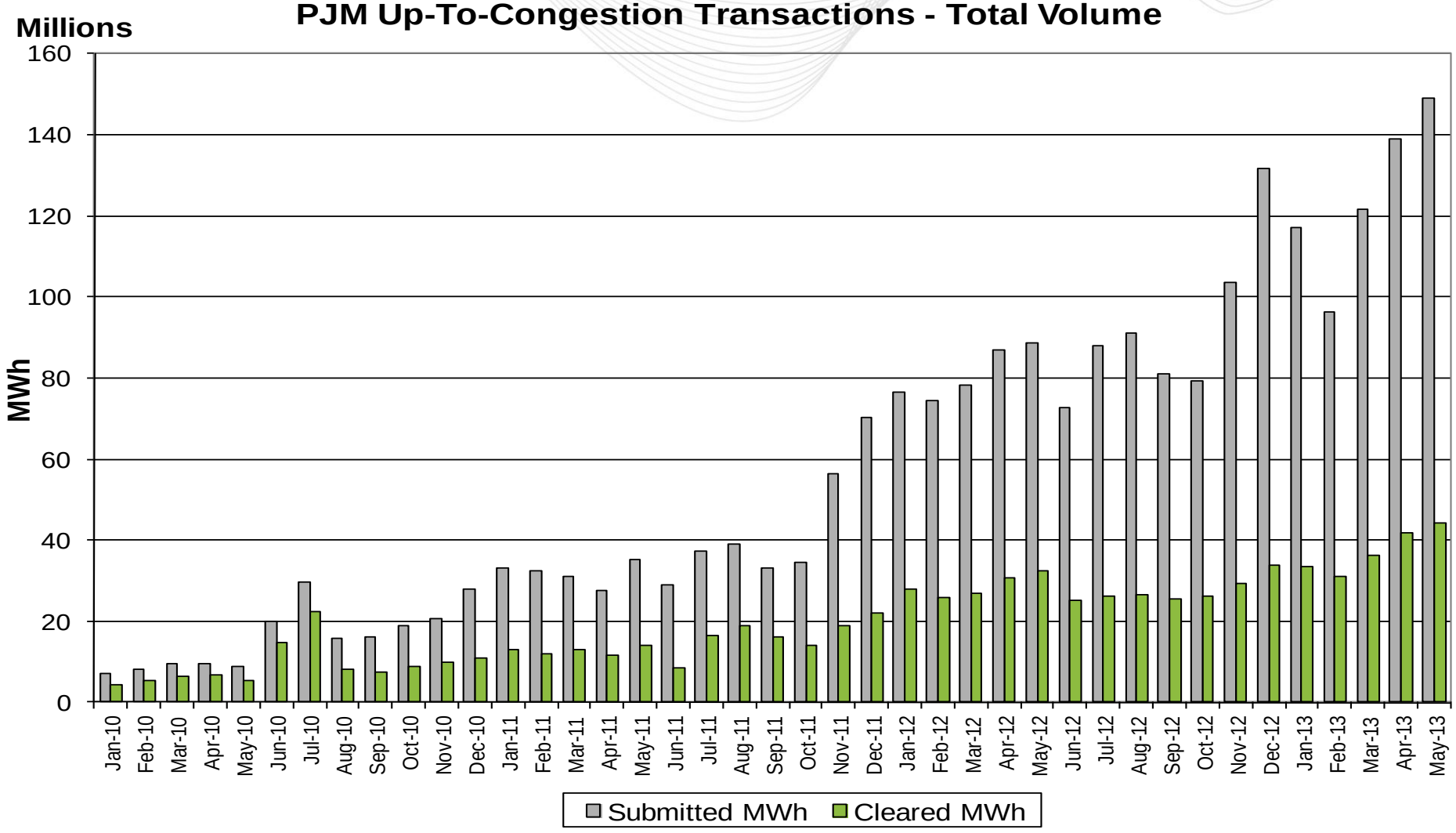
- Day-ahead model with increasing non-convexities
- Co-optimization of energy and ancillary services in real-time operation
- Faster run times on FTR auctions, RPM capacity market auctions
- Allow for policy modeling with combined energy and capacity market dynamic interactions on issues affecting RTOs
- May allow for alternative ways to view the transmission planning process
- Find ways of capturing shadow prices on integer constraints to improve pricing

- Day-ahead model
  - SCUC with resource non-convexities (e.g. start-up, min run levels, min run times, min down times, etc)
  - Financial bids in the for of Incs (supply), Decs (demand), and up-to congestion
  - Increasing use of non-convex up-to product (approximately 100,000 transactions per day)
  - Only a 4 hour window in which to solve the problem
- Computational Need: Even faster dynamic MIP algorithms that permit increasing non-convexities to be handled without resorting to short-cuts
  - E.g. proposals to limit up to transactions to ease computational burden

PJM Up-To Transactions



PJM Up-To Transactions



Order 719: Shortage Pricing and Co-optimization in RT

- Co-optimization of Energy and Ancillary Services
  - Implemented October 1, 2012 in response to Order 719
  - Concurrent implementation of performance based Regulation and Frequency Response
  - Look-ahead (IT SCED) also implemented looking out up to 2 hours to commit CTs
- Computational Need: Even faster dynamic MIP algorithms that tie together 5 min co-optimization and IT SCED
  - Allows for smoother transitions over time especially with implementation of operating reserve demand curve

- FTRs
  - Define a source and sink pair and number of MW
  - Require simultaneous feasibility
  - Millions of offers per auction (monthly, quarterly, and planning year
- Recent advances in MIP algorithms have reduced solution times, but more can be done
  - Monthly cases solve in 8 hours
  - Quarterly in 24 hours, was 48 hours not long ago
  - Planning Year…days to solve

- Optimization with nested parent/child locations
  - Coupled offers from Demand Resources for three types of services (Annual, Extended Summer, Limited)
  - Credit limited offers
  - “Fill-or-kill” block bids
  - “Fill-or-kill” offers based on new entry pricing treatment
- Computational Need: Even faster dynamic MIP algorithms that can solve this problem
  - Also there is a need for individual rationality checks/constraints that fall out of the algorithm.
  - Getting faster with each BRA, but need to keep up with ever increasing demands for flexibility that are non-convex.

- What are the longer terms effects of various policy and market shifts?
  - Would be great to have models that endogenously determine resource mix, and simulate energy market…
  - …and acknowledge the inherent non-convex decisions on entry, exit, retrofits, operations, account for locations, etc.
- An integrated model of energy and capacity markets that is inter-temporal or dynamic?
  - At its core a large, dynamic MIP
  - Drive for more accurate results/forecasts of the future for policies that are being implemented (e.g. MATS) that linearized, convex models
  - Major database challenge as well

- Planning for public policy and controversy surround cost allocation
  - Today we plan for reliability…have recently accounted for policy impacts on reliability
  - RPS, EPA, major shifts in commodity fuel markets
- New objective: maximize market surplus?...Nice to possibly have, but is it essential?
  - Subject to constraints on reliability, public policy goals and mandates (e.g. RPS, MATS)
  - Choosing discrete transmission projects
  - Could become combinatorially intensive
  - In theory could identify beneficiaries using a monetary metric

Do We Need "Better" Stochastic Unit Commitment Models?

- What do stochastic unit commitment models provide that we do not have today?
  - Facilitate renewable resource integration?
  - Can they be solved in sufficiently short times with realistic distribution of outcomes?
  - What is the improvement in accuracy and efficiency of commitments?
  - We handle uncertainty in demand already
  - At the end of the day we still have one set of commitments that are likely "not optimal" in any case that we will need to manage in RT
  - We have a hard time solving deterministic SCUC models in the time allotted, why do we want to increase the degree of difficulty?

We Already Have Tools to Manage Uncertainty

- Day-ahead and Real-time market construct today
  - Two-settlement system with allocation of uplift charges provides incentives to schedule accurately
  - Use wind forecasting with updates as we do with load
  - Can commit CTs in real-time
  - Price Responsive Demand (PRD) with known bids can offset intermittent resource uncertainty in theory
  - Can deploy reserves in extreme cases
  - We have shortage/scarcity pricing and negative prices in most RTOs to handle both extremes that may happen with wind

Concluding Thoughts Going Forward

- Concentrate on the areas that have the greatest impact on cost
  - Energy market and operations is the greatest contributor
  - But there is room for work in other areas…especially capacity as we are seeing in other RTOs
  - New and evolving market offerings
- Work on MIP
  - Great strides have been made in the last 15 years…still work to do in speeding up computations and getting prices out of non-convex decision variables.
- Focus attention on more market and policy related matters
  - Look at costs and benefits that can come from some computing and modeling advances.