

# **(Im)precision and inaccuracy in price and load forecasts: Resiliency implications of combining forecast data with simulations of n-k contingencies**

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through Improved Software**

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**MITRE**

# Outline

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- Intro to MITRE
- Infrastructure interconnections and cascades
  - Power and communications coupling research
- Exploring the impact of power markets
- Next steps

# MITRE: A Company of FFRDCs

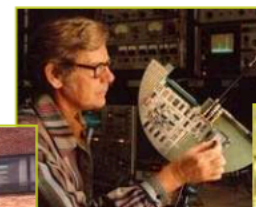
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# Interacting infrastructure modeling

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Brian Tivnan, MITRE

Jason Veneman, MITRE

Paul Hines, UVM

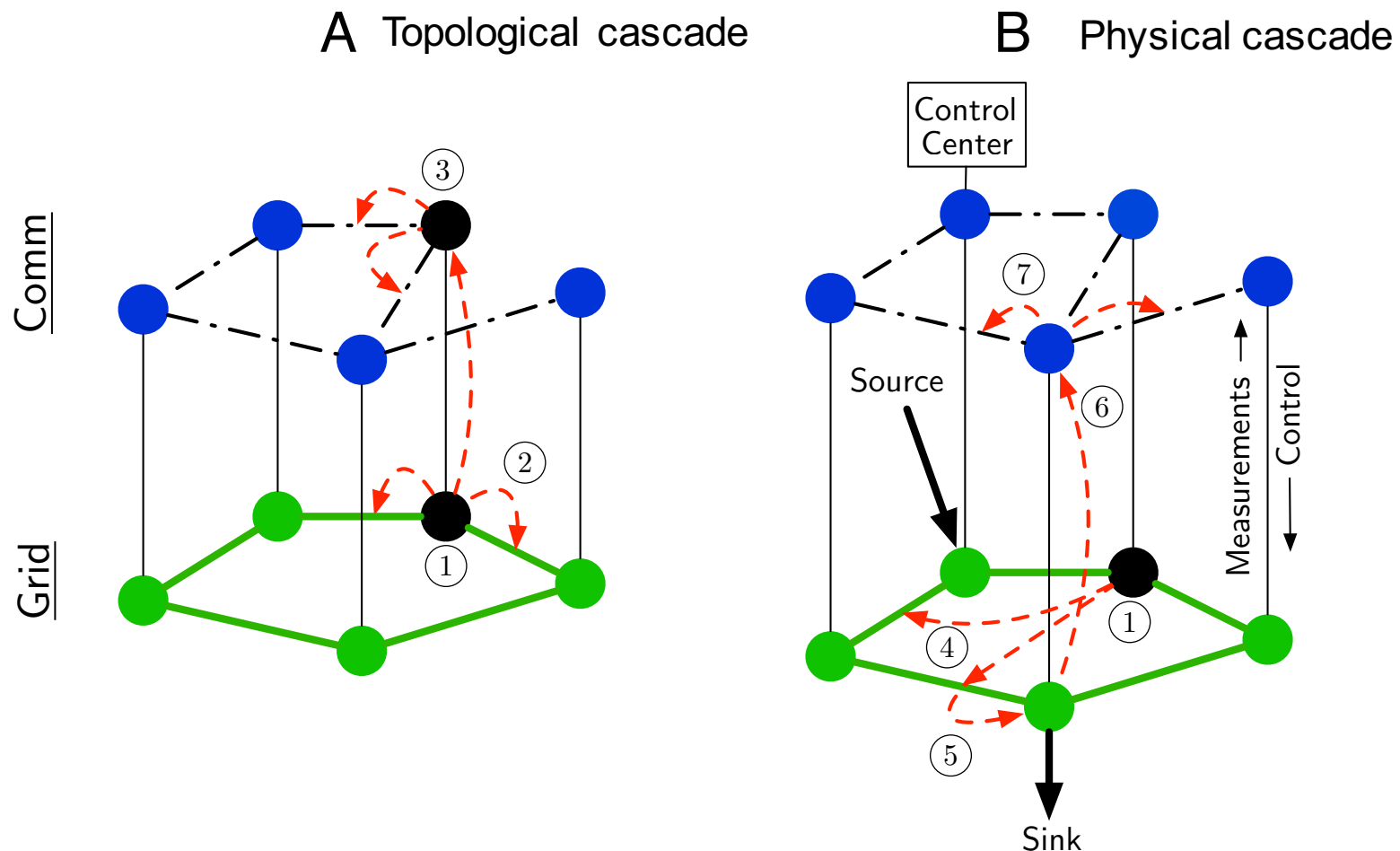
Mert Korkali, UVM/Lawrence Livermore

# Do coupled infrastructures have greater blackout risk?

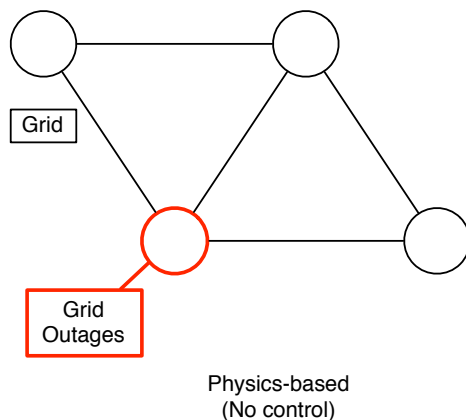


# Improve Coupled Cascading Failure Risk Analysis by Differentiating Cascades

Model the risks and/or benefits of coupling of power and communication networks with a combination of sufficient engineering accuracy and computational tractability

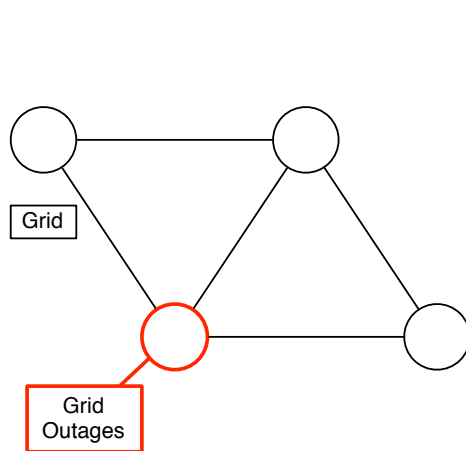


# Modeling Concept – From One to Two Bodies

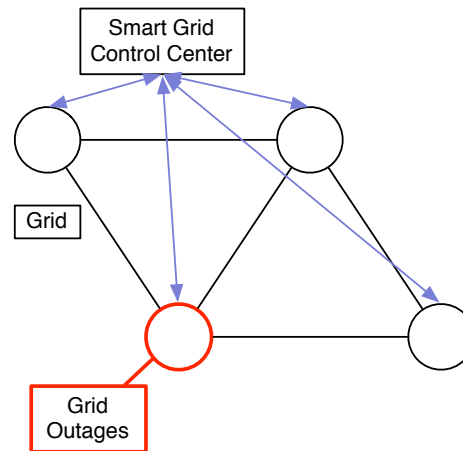


- No Smart Grid
- Physics based, DC power flow cascading failure model

# Modeling Concept – From One to Two Bodies



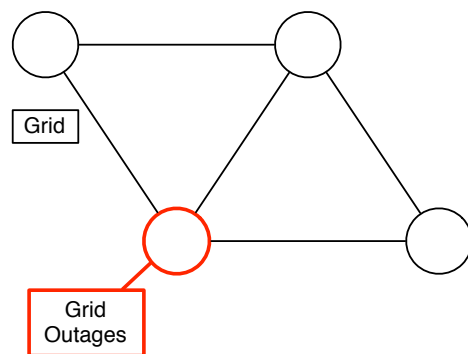
- No Smart Grid



- Robust coupling – Ideal smart grid, no dependencies
- Buses with communication network connections have additional measurement and control capabilities to mitigate cascades

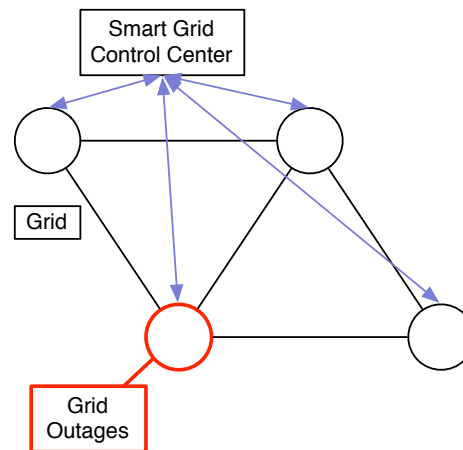


# Modeling Concept – From One to Two Bodies



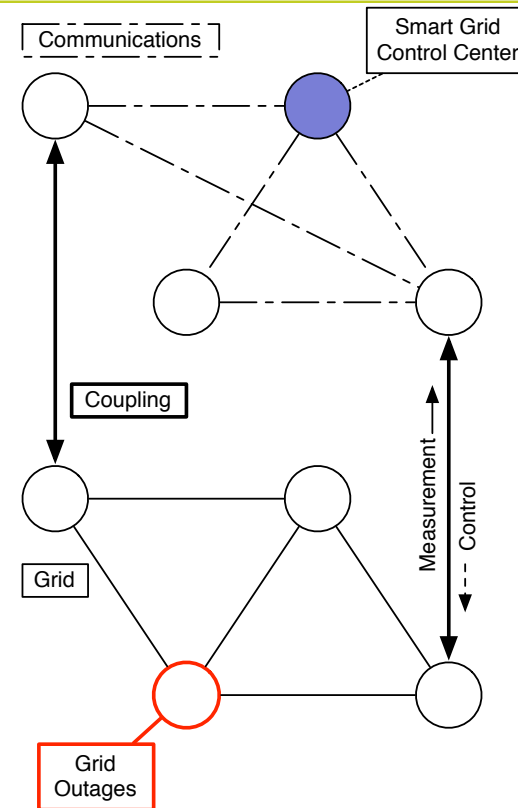
Physics-based  
(No control)

- No Smart Grid



Robust Coupling  
(Full control)

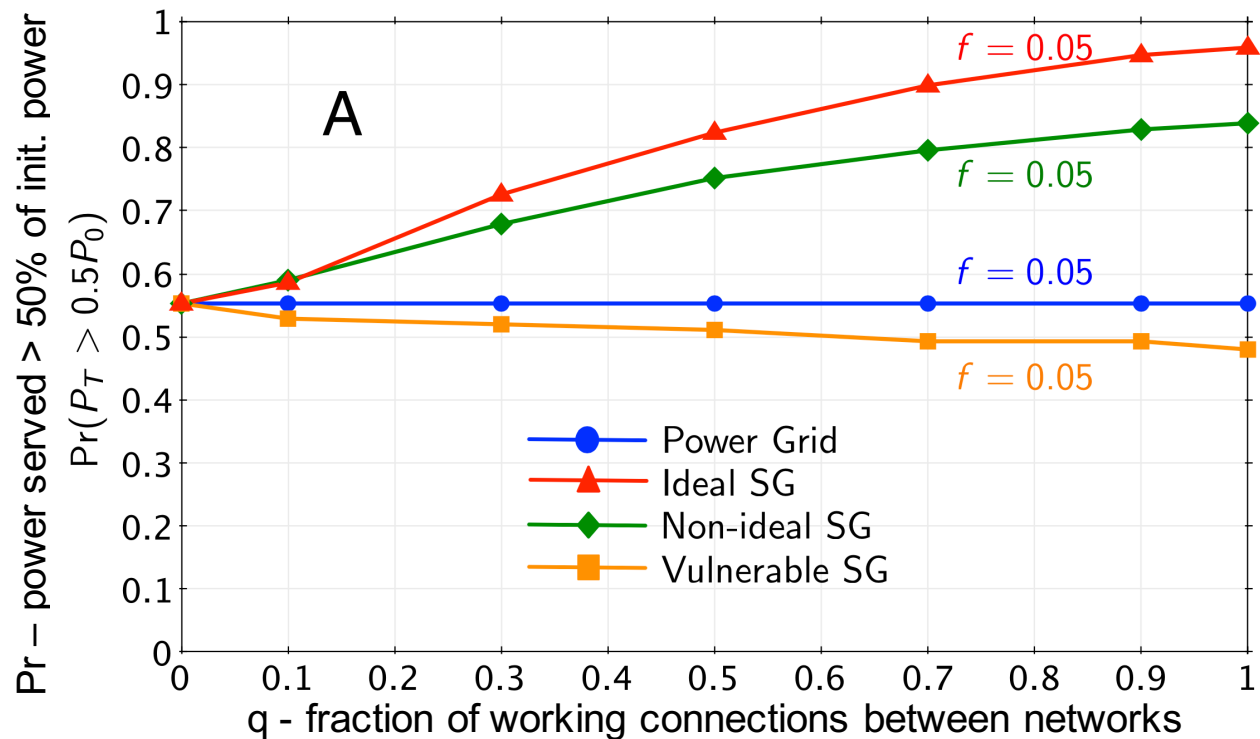
- Robust coupling –  
Ideal smart grid, no  
dependencies



Vulnerable Coupling

- Vulnerable coupling - Two-way dependencies lead to cascading outages across networks in two cases
  - Non-ideal smart grid
  - Extreme vulnerability – generators that lose communications go off-line

# Impact of Coupling



*Results: When implemented well additional automation is helpful (e.g. good backup battery systems that prevent failures from propagating between grid and comms).*

*If implemented poorly, coupling can be harmful.*

See for more details – Korkali et al. 2015 - Reducing Cascading Failure Risk by Increasing Infrastructure Network Interdependency

# Adding the third body – electrical power markets

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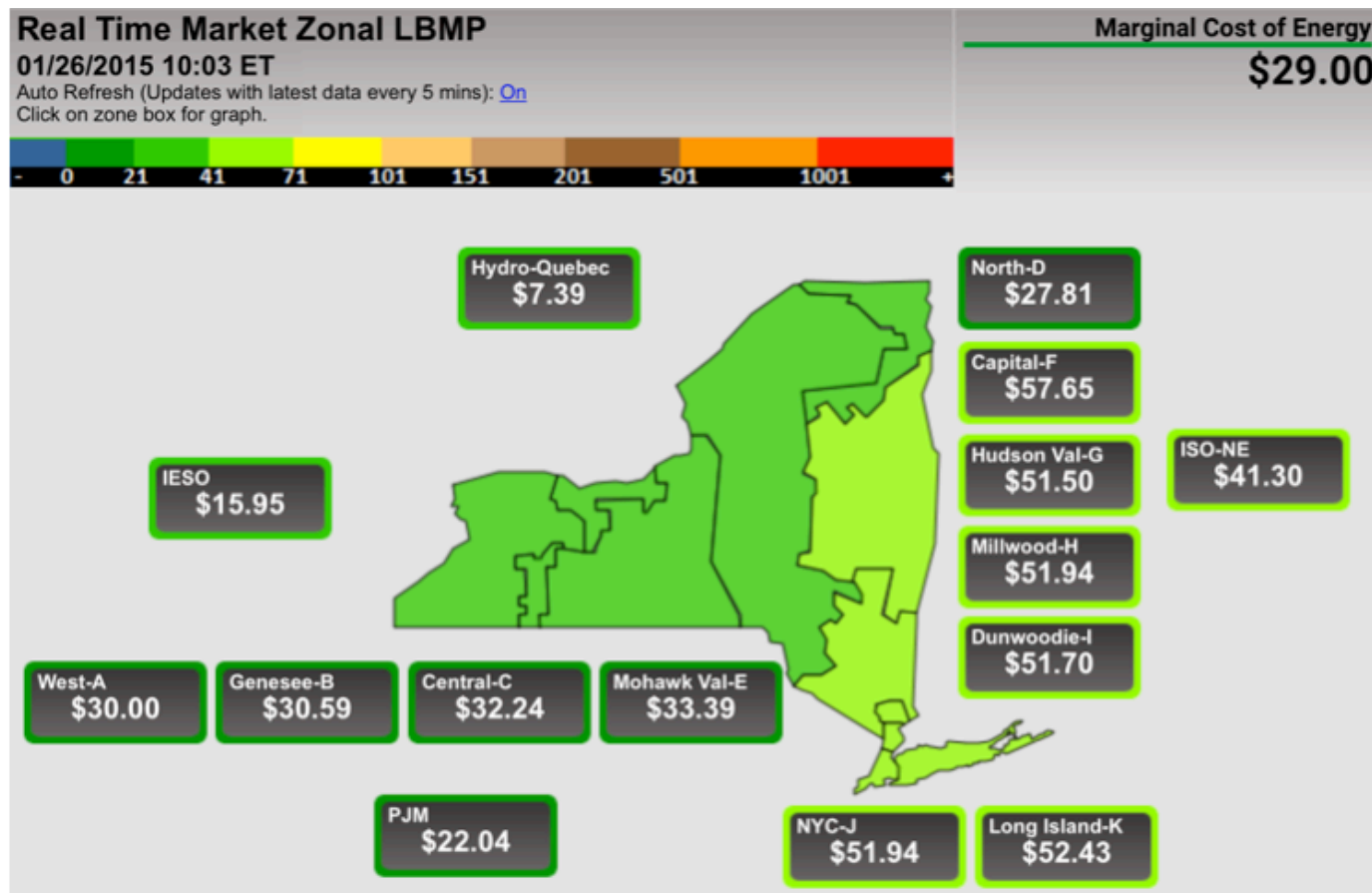
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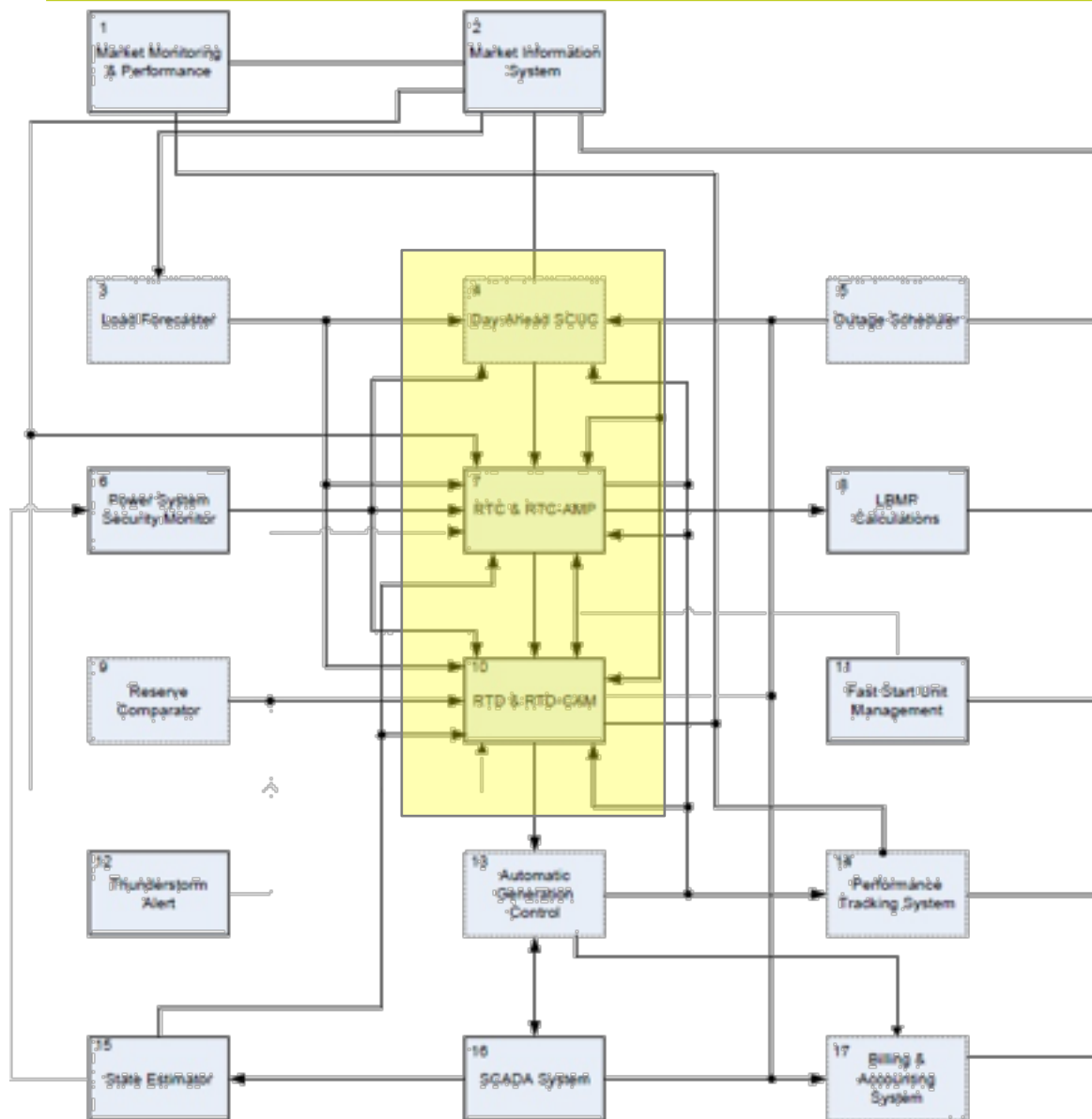
# Extending to the 3-body Problem

What are the effects of coupling the smart-grid to a 3<sup>rd</sup> infrastructure, namely the Electric Power Market?



<sup>1</sup>[http://www.nyiso.com/public/about\\_nyiso/nyisoatagance/index.jsp](http://www.nyiso.com/public/about_nyiso/nyisoatagance/index.jsp)

# NYISO – Energy Market Process



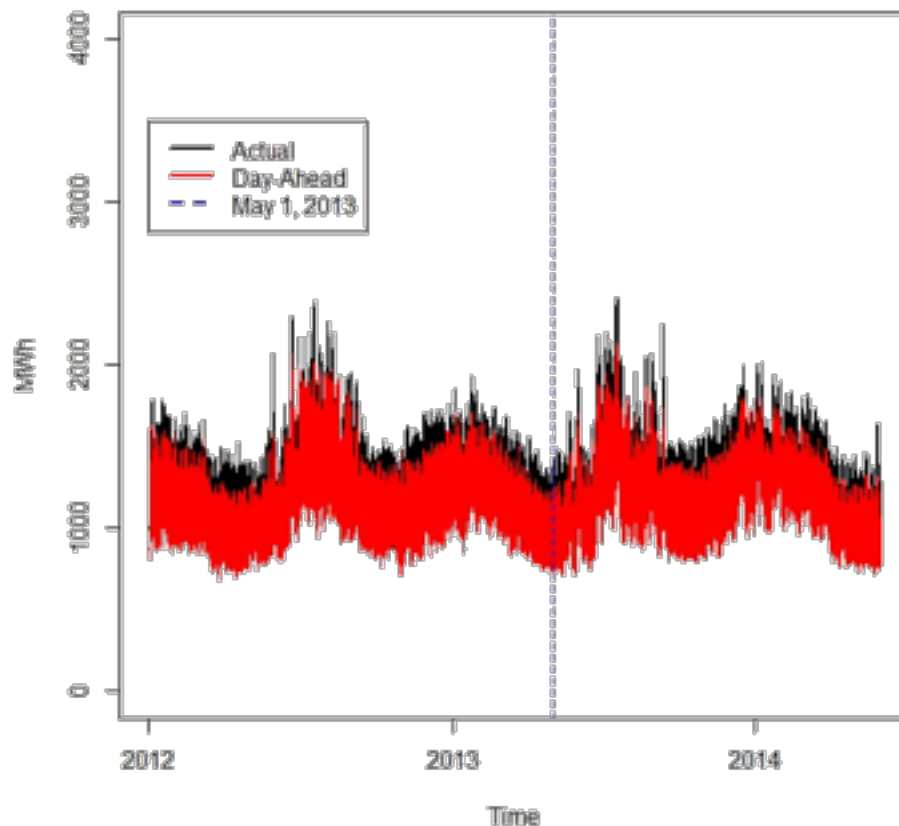
- The Independent Service Operator (ISO) performs 17 different functions
- Outcomes of these functions determine:
  - Congestion contract outcome
  - Power load (demand)
  - Location based marginal price (LBMP)

<sup>1</sup>[http://www.nyiso.com/public/about\\_nyiso/nyisoataglanence/index.jsp](http://www.nyiso.com/public/about_nyiso/nyisoataglanence/index.jsp)

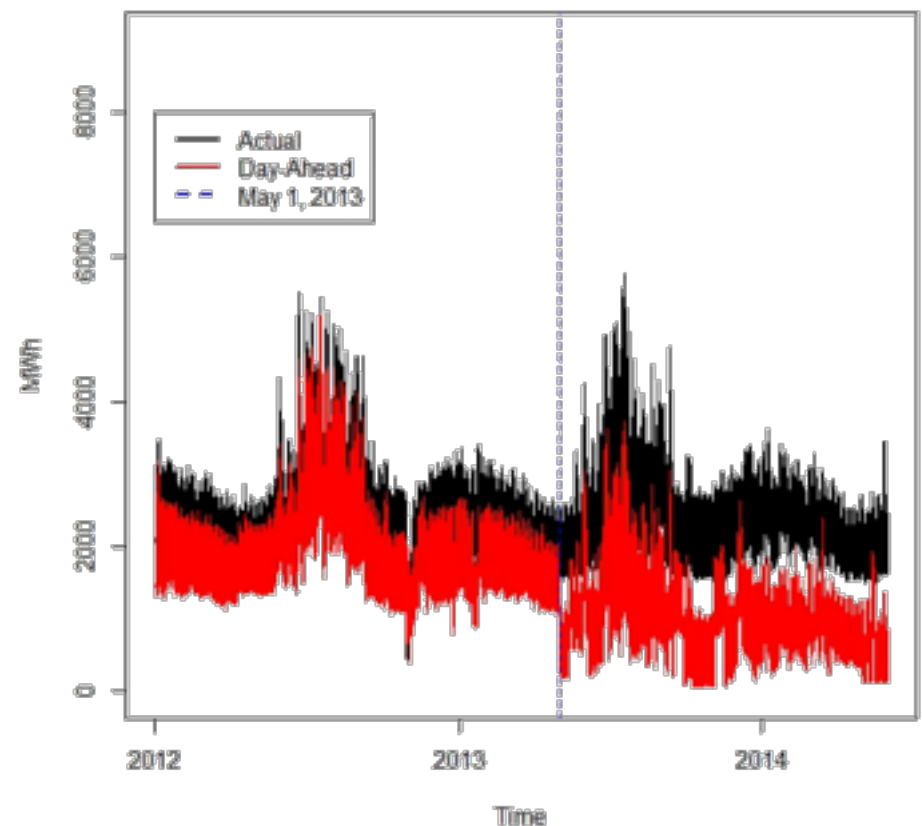
# Load Data Analysis – Zonal Day-Ahead vs. Actual

Initial investigation of the actual load vs. the day-ahead load (hourly) indicates that day-ahead values follow the trends of actual load. However, there appears to be a deliberate bias (downward shift) in the day-ahead time series.

Load Actual vs. Day-Ahead: Capital Zone



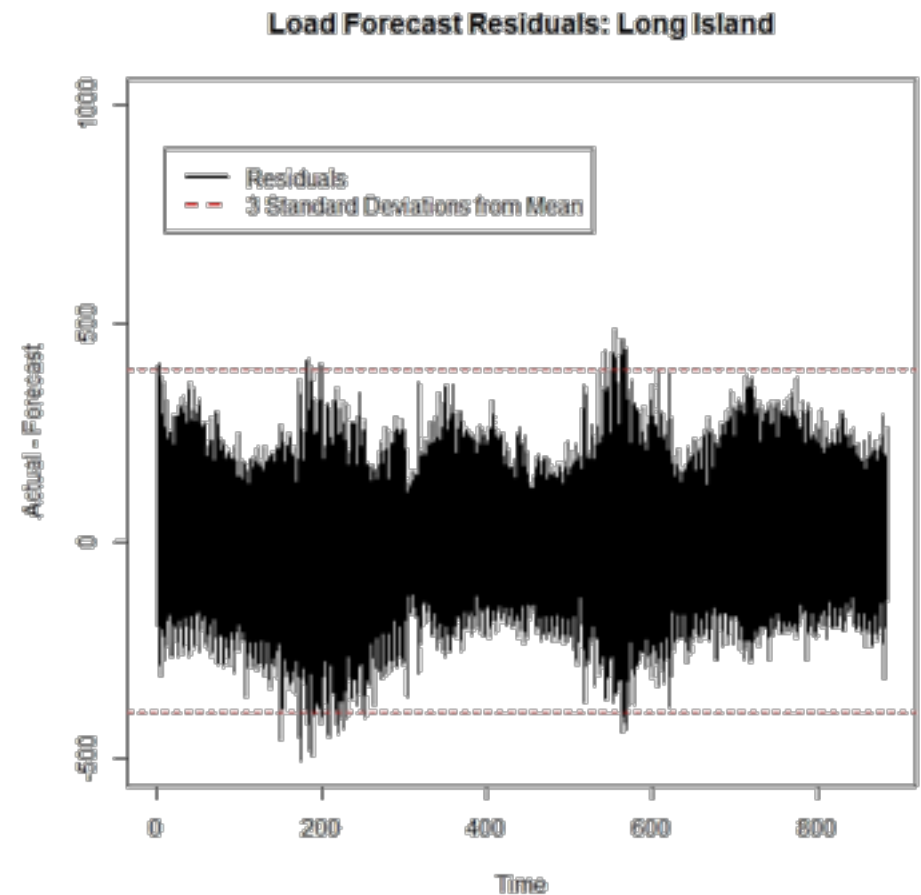
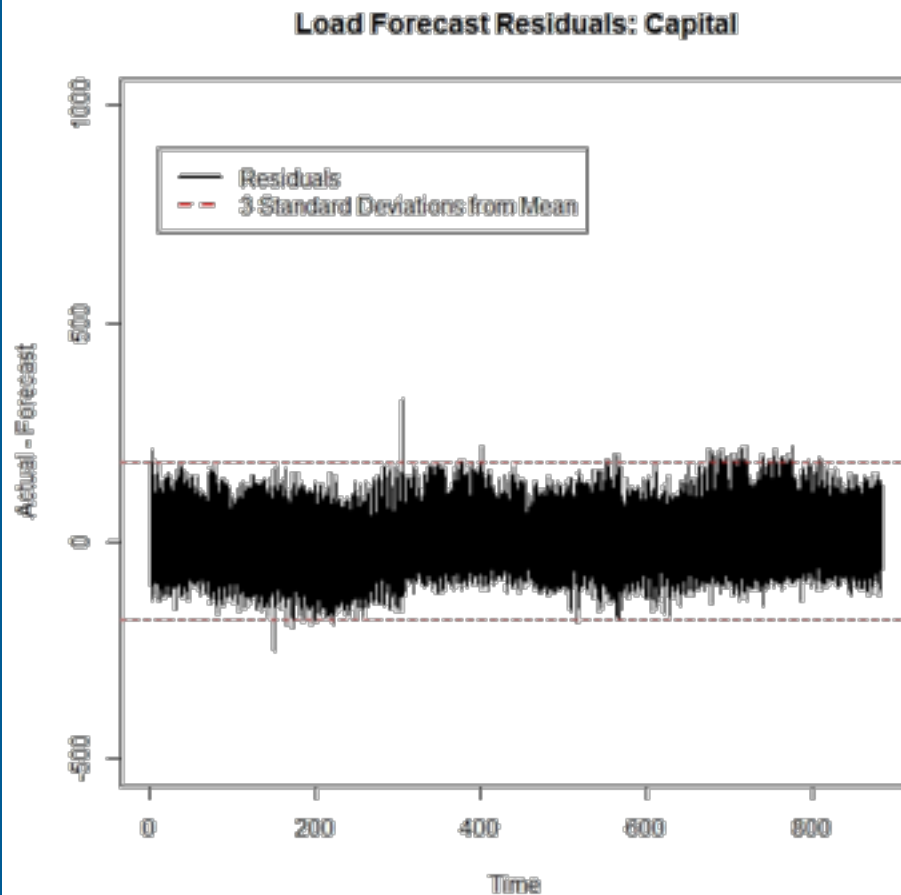
Load Actual vs. Day-Ahead: Long Island Zone



Data from: [http://www.nyiso.com/public/markets\\_operations/market\\_data/load\\_data/index.jsp](http://www.nyiso.com/public/markets_operations/market_data/load_data/index.jsp)

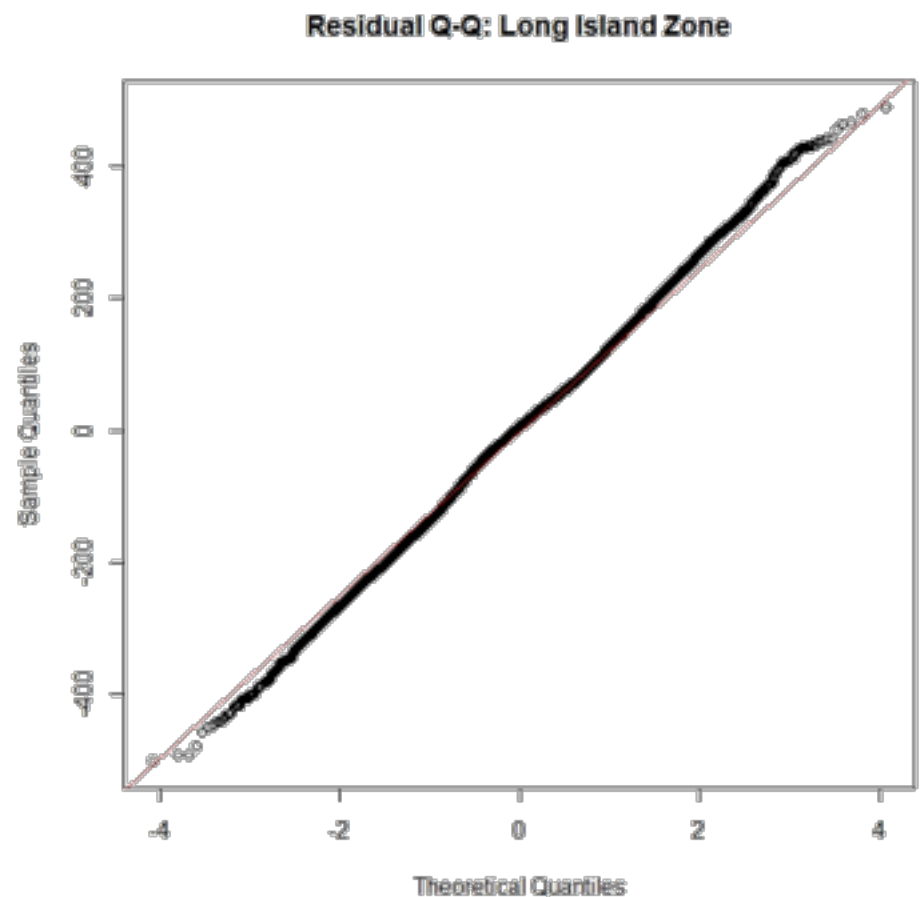
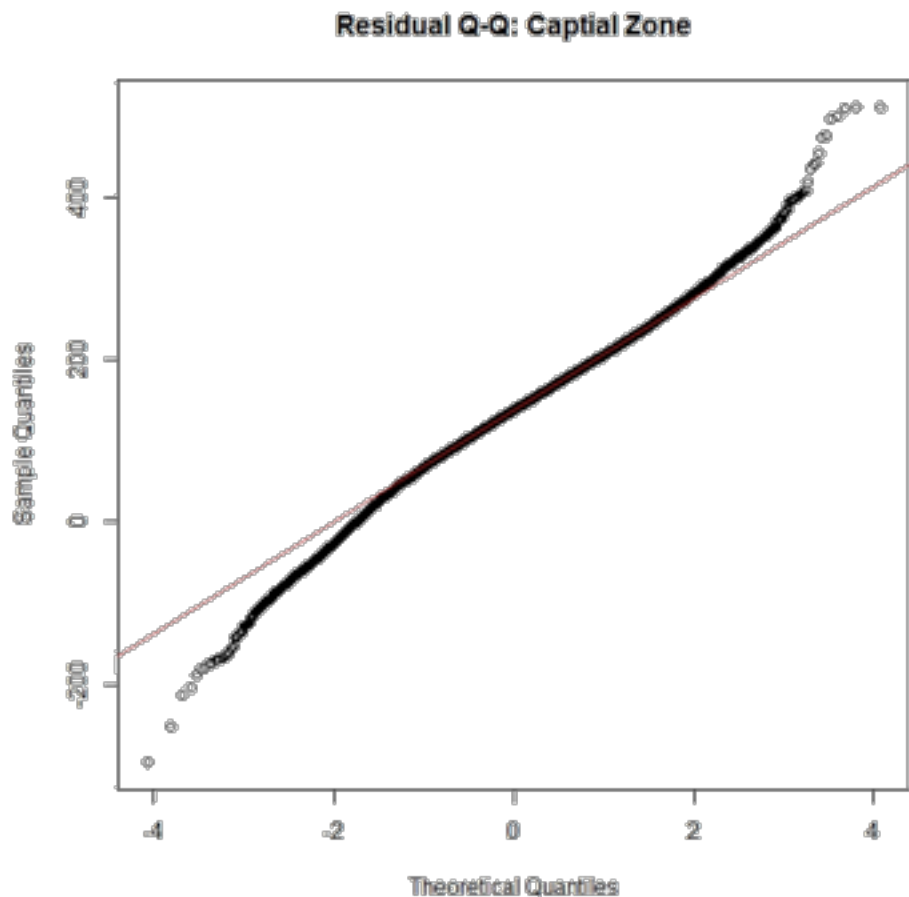
# Load Data Analysis – Behavior of Residuals

Examining the real-time load more closely, we are able to transform the data to an almost stationary data set that is ideal for forecasting.



# Load Data Analysis – Behavior of Residuals

The residuals remaining after detrending the real-time load fit the theoretical quantiles of a normal distribution (along the red line) relatively well.

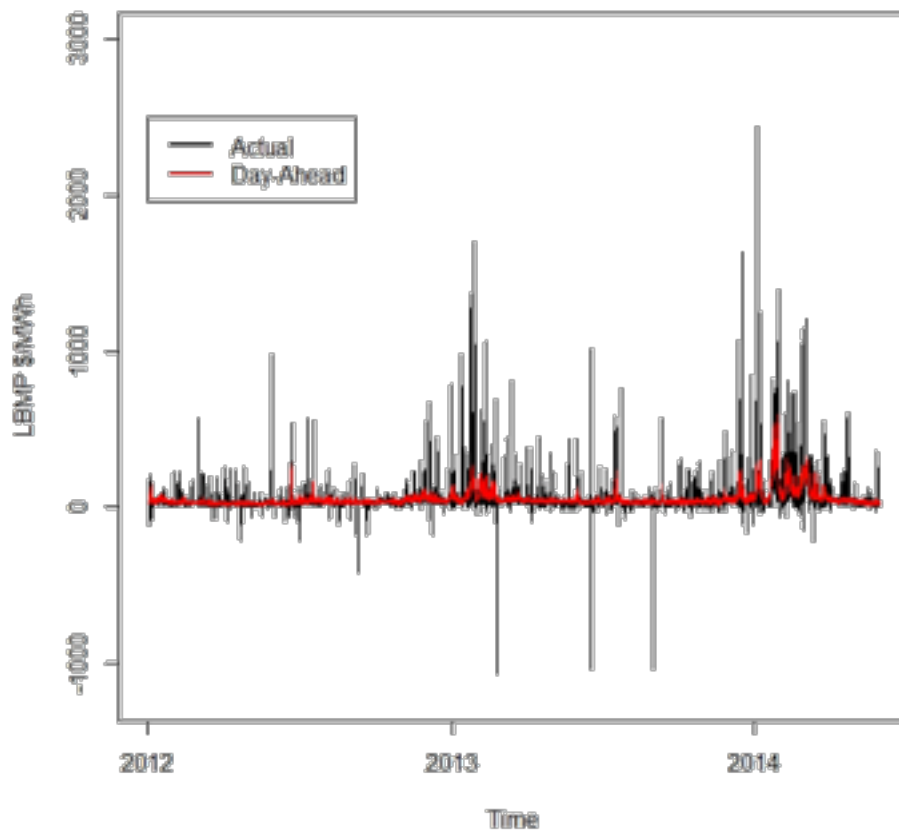




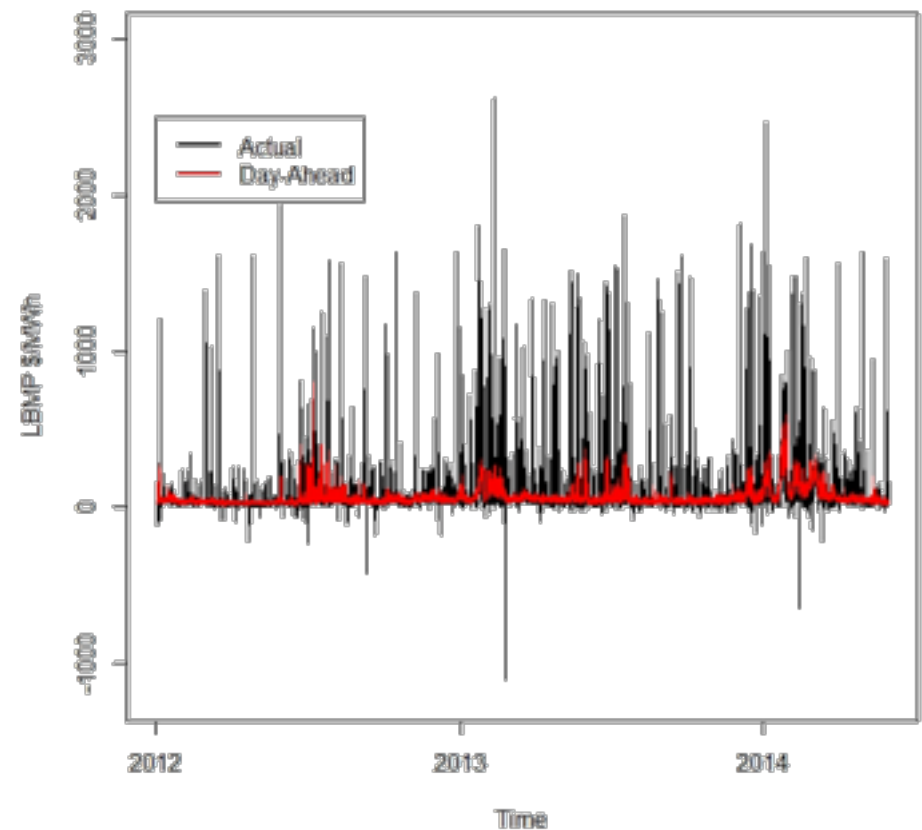
# Price Analysis – Zonal Day-Ahead vs. Actual

Performing the same analysis for the Location Based Marginal Price (hourly) tells a very different story. The data sets are considerably more erratic and the difference between zones is more pronounced.

Actual & Day-Ahead LBMP: Capital Zone



Actual & Day-Ahead LBMP: Long Island Zone

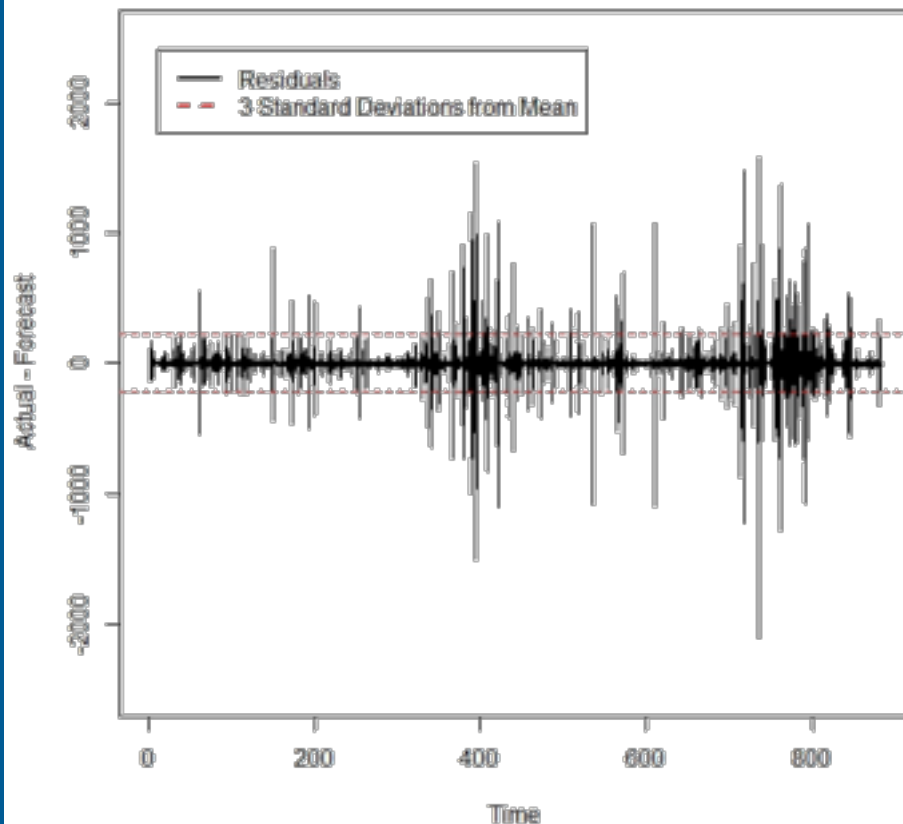


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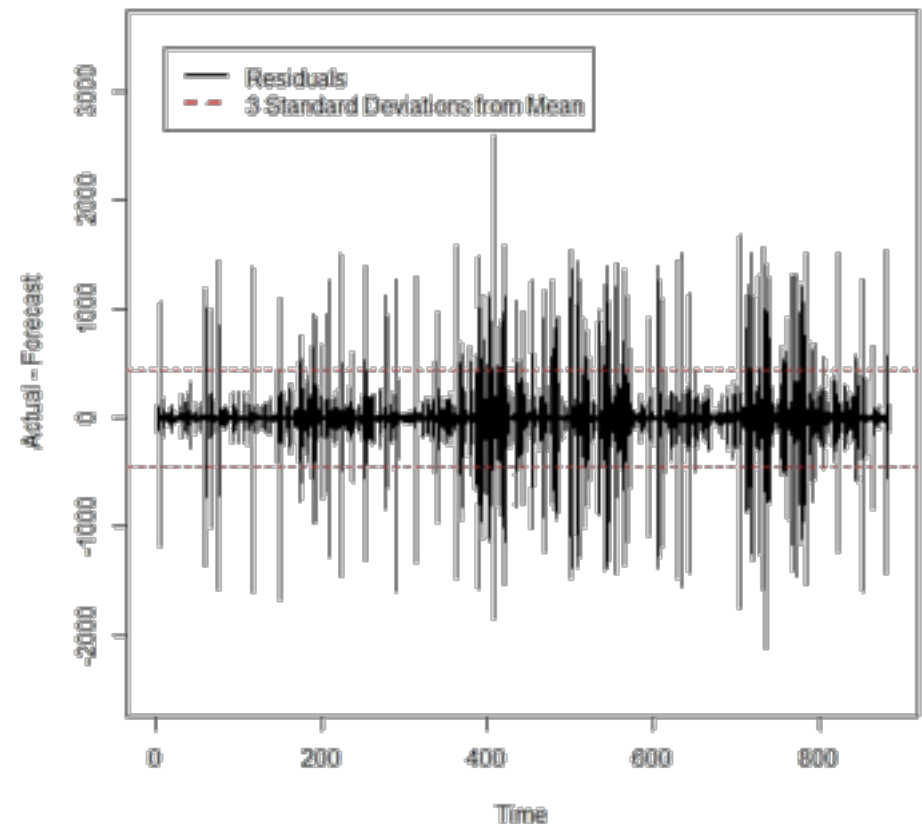
# Price Analysis – Seeking Stationarity

The price data sets exhibit many of the so-called *stylized facts* observed in stock prices and exchange rates. These stylized facts include heavy-tailed marginals and long memory (i.e. slowly decaying auto-correlation functions) in absolute returns.

LBMP Forecast Residuals: Capital

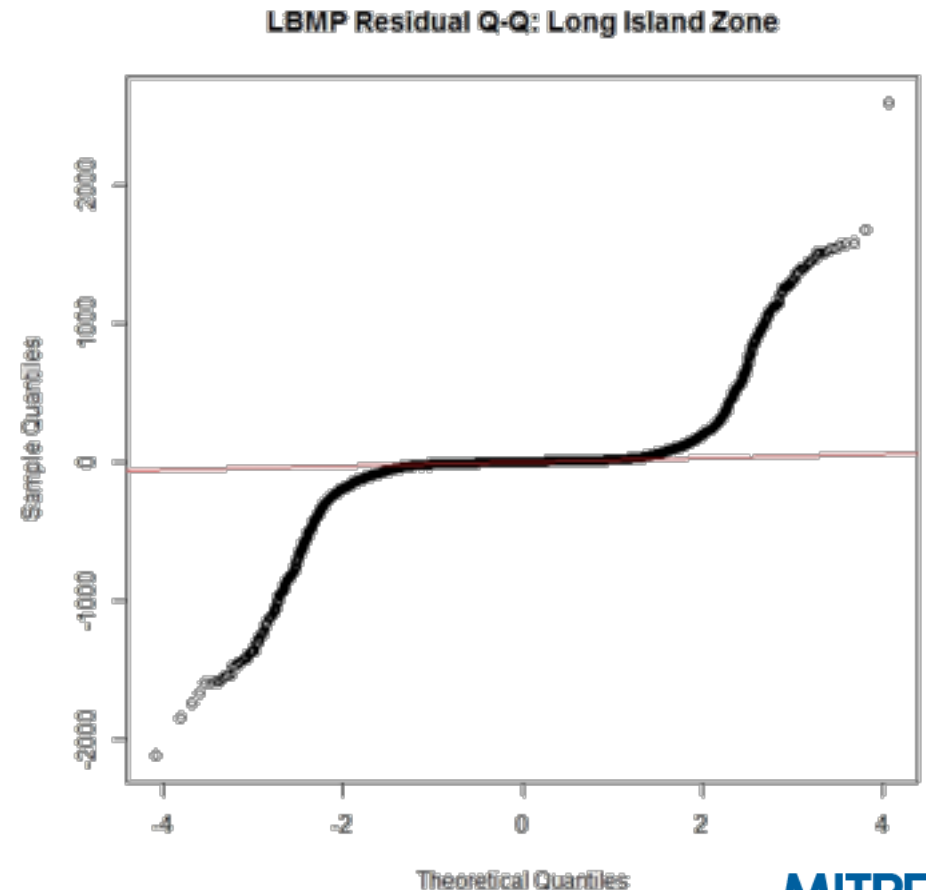
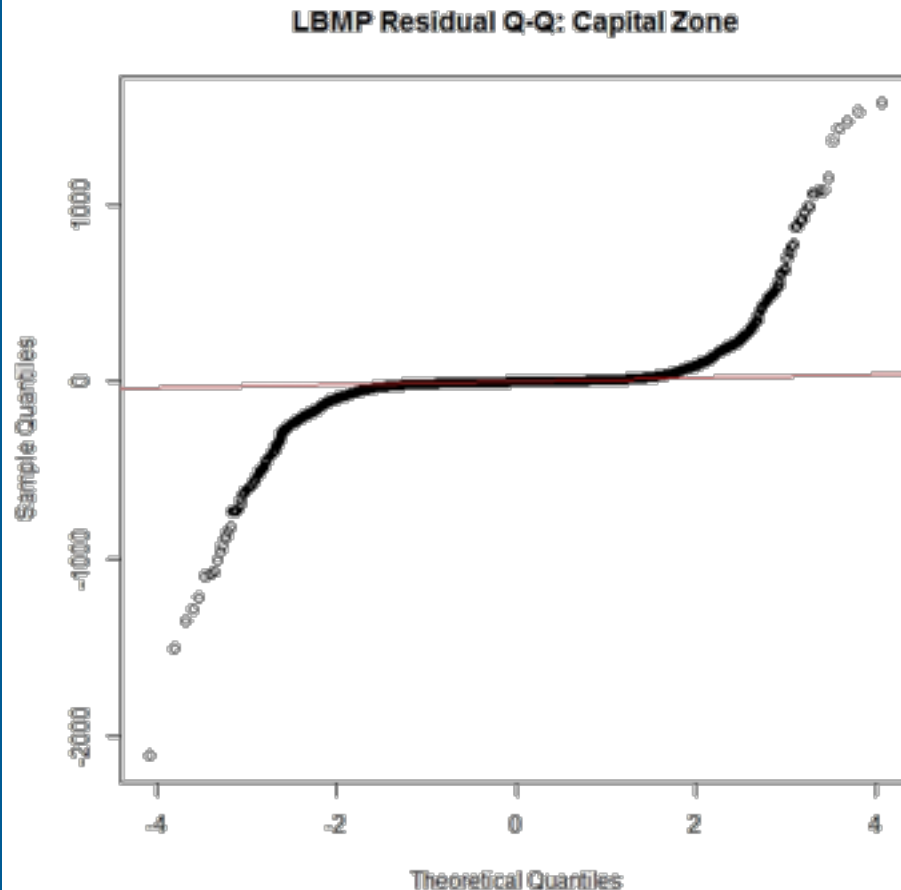


LBMP Forecast Residuals: Long Island



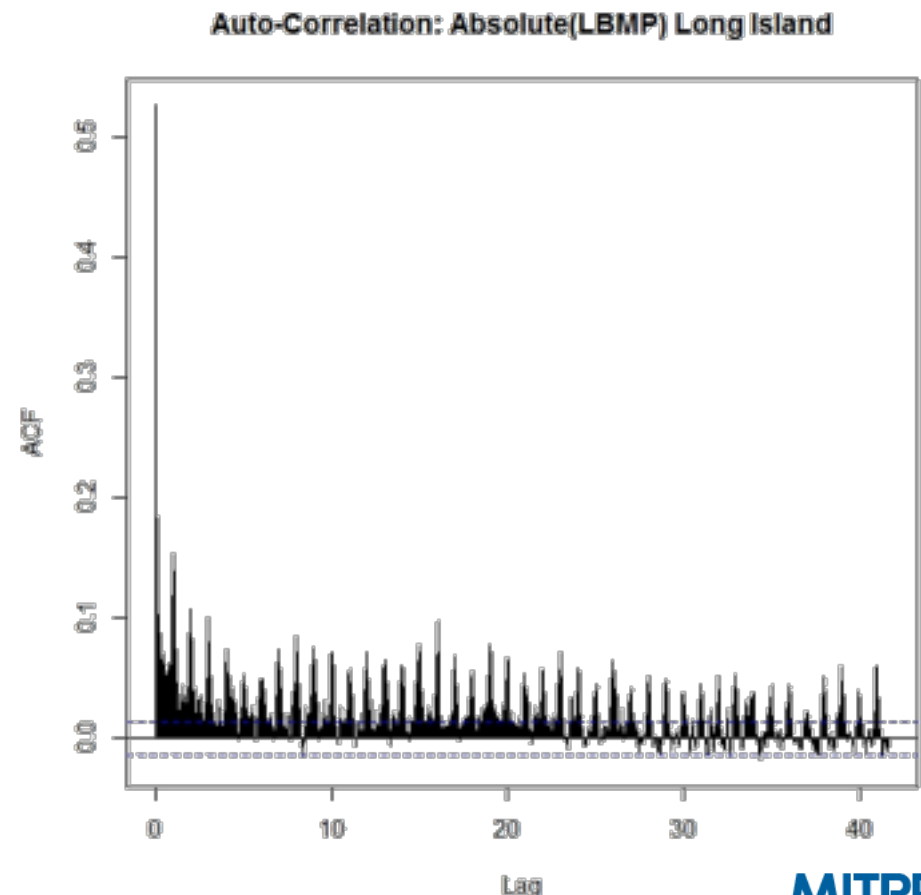
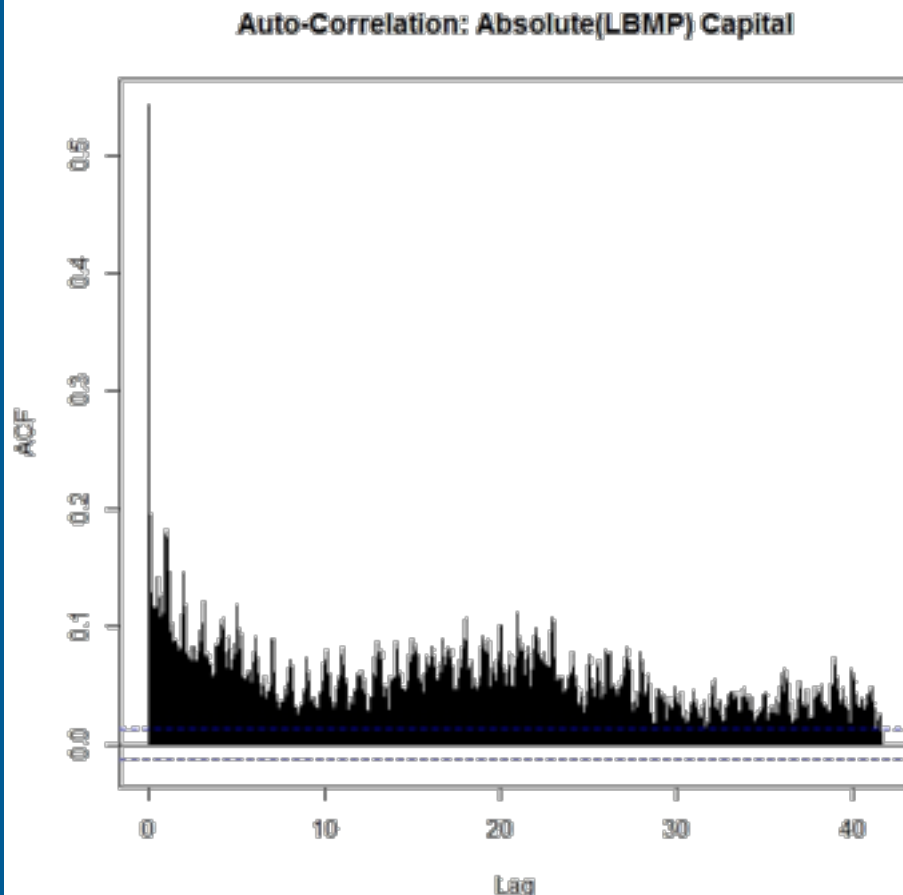
# Price Analysis – Heavy-tails

The quantiles of the detrended residuals now fail to satisfy the tests for normality due mostly to the tails departing from theoretical quantiles. It should be noted that risk-analysis and mitigation depends on being able to predict these now unpredictable tail-probabilities.



# Price Analysis – Long Memory

Plots of the auto-correlation function of the absolute residuals reveal the stylized fact of long memory. The data also exhibit non-linear power-law relationships in the form of statistical self-similarity, a trait also noted in other financial datasets.



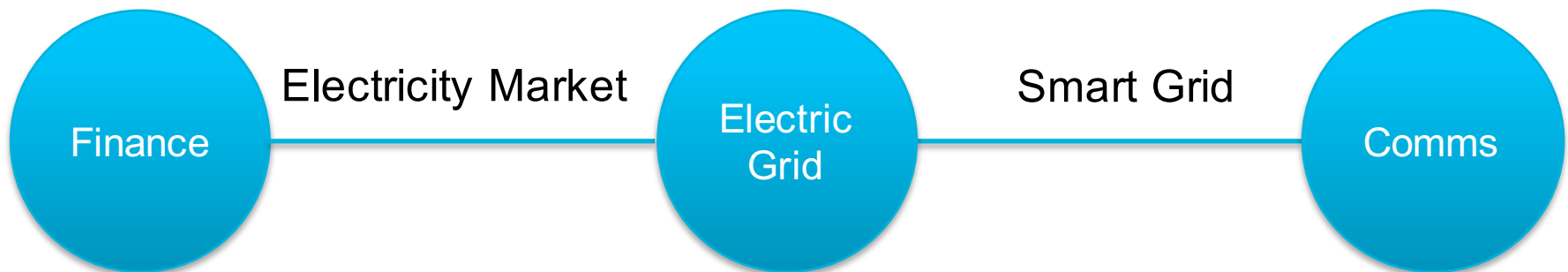
# Initial Conclusions

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- Although the hourly load can potentially be forecasted with a high degree of accuracy using standard statistical analyses, the resulting price driven by demand cannot be forecasted with the same tools due to the presence of the stylized facts.
- Coupling the 3<sup>rd</sup> infrastructure of Electrical Power Markets has introduced a higher degree of complexity into the process as measured by the output of Location Based Marginal Prices.
- Although we cannot say if this more complex process exposes the system to greater risk, we can say that measuring that potential risk has become intractable using standard tools and econometrics due to the stylized facts.

# Next Steps

- Analyze interactions between electricity market participants as well as speculative traders
- Explore couplings and cascades within and possibly between the electric grid, communication networks, and electricity markets



# Questions

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## Thank You!

We welcome your questions, feedback, and other ideas on this preliminary research