Dislocations in North American Energy Markets
Implications for Valuation and Portfolio Management

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Outline

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Fragmented Market Landscape

- Some segments of North American power and natural gas markets are deregulated in the sense of:
  - Open access to transmission, transportation and storage.
  - Well-defined spot market clearing.
  - Retail competition.

- The following map shows the U.S. markets by control region.

- The ISOs (independent systems operators) administer market clearing of power and ancillary (reliability) products.

- The most actively traded markets are:
  - PJM
  - Other northeast markets: NY, New England
  - ERCOT (Texas)
  - California/West
Forward Markets

- Term swaps and forwards reference buckets of hours.
  - Trading hourly forwards would be prohibitively cumbersome at long tenors.

- Delivery Buckets:
  - Given the dramatic differences in demand (and price) over the course of a day market convention has evolved to using swaps that reference ratable delivery defined days/hours.
    - These buckets are:
      - Peak (5x16): Business days (usually M-F) 7AM - 11PM.
      - Offpeak: The complement of peak.
      - Offpeak is occasional split into 7x8 and 2x16.
      - Western power markets define Peak as 6x16 (M-Sat).
Forward Markets

- Forwards trade “liquidly” at several hubs and zones—including PJM Western Hub.

- The following figure shows:
  - PJM Western Hub and NYMEX NG forwards;
  - The forward heat rate.
 Locational Marginal Pricing (LMP)

- The first few power markets in the U.S. were “hub based” with socialized congestion and losses.
  - Congestion zones priced at zonal hubs; or,
  - No congestion pricing at all.

- Typically transitioned to LMP structure.
  - Nodal pricing for generation.
  - Zonal pricing for loads.

- The resulting risks are very high-dimensional.
  - Typically hundreds of bus-bar (nodal) price points.
  - Ostensibly hedgable with FTR markets.
Context

Locational Marginal Pricing (LMP)

Figure: PJM Zonal Map
Natural Gas Markets

- Market structure by pipeline.
  - Transportation accessibility and costs by tariff.
  - Locational pricing by delivery point.

- Hedging contracts often reference published indices established by survey.
  - Monthly indices (e.g. IFERC)
  - Daily indices (e.g. Platts Gas Daily)

- U.S. Price Dynamics
  - Winter premia across all curves—highest where it’s cold.
  - Locational price spreads (basis) effected by:
    - Slow variables—changes in production.
    - Fast variables—temperature and mechanical failure.
Natural Gas Markets—Basis

- This figure shows TETCO M3 / Henry Hub GD spot basis.
  - Substantial premia in spot prices that can arise due to high demand and low supply on occasional days in the winter.
  - Recent discount (negative basis) has arisen due to shale gas production.
Generation and Retail

- **Merchant Generation:**
  - Funding the construction of a combined cycle requires large sums.
  - Cost can exceed $1000/kW all in.
  - Often financed by debt.
  - Lenders require that the unit hedged for 5-7 years.
  - The less effective the hedge, the more expensive the terms.

- **Retail Aggregation:**
  - Commercial enterprises which deliver physical power and natural gas to individual end-users.
  - **Customer base:**
    - Residential, commercial and industrials tranched according to utility protocol.
    - Retailers must deliver energy and related reliability products.
  - **Inherent risks:**
    - Commodity price risk at the load zone level.
    - Variable quantity risk.
    - Customer migration risk.
Each of these facets of deregulated marketplace require the ability to hedge risks at or “near” the price exposure point.

- “Near” means with a (plausibly) stationary residuals between hedge location and delivery location.

Sources of non-stationarity:

- Long time-scale changes in supply and demand.
- Shale gas.
- Renewables (notably wind).
- Demand response.

- Infrastructure failure.
- While an on-going affair, power systems are too high-dimensional to support inference given current computational limits.

- Extreme weather events.
- Similarly, while ostensibly an on-going affair, the ability to forecast system response to rare weather events is wanting.

The last two years have witnessed all of these phenomena in play, at a time when reduction in dealer activity has reduced liquidity.
Recent Dislocations—Liquidity

Less liquidity $\implies$ dirtier hedges.

- **Dealer exodus:** Barcap, DB, CS, JPM (physical), MS (partial).
  - “Post Enron” banks provided substantial liquidity in power and gas.
  - This was consistent with the banking tenant of “making the illiquid liquid” in financial assets.
  - Generally good credit supported hedging programs.
  - Related rates and credit desks afforded unconventional (and useful) credit support for hedgers.

- **Potentially filling the void:**
  - Physical commodities shops and PE firms.
  - Expanding role of majors and utilities.
  - Strategic “self hedging.”
Less liquidity $\Rightarrow$ dirtier hedges.

**Considerations:**
- Credit support is a major concern on both sides of the trade.
- Clearing has inflexible posting requirements.
- Clearing does not make liquidity.

**Massive drop in liquidity in power forward markets.**
- PJM Western Hub:
  - The debate used to be: "Can you trade 8 years out or ten years?"
  - At this moment live prices for 2016 can be the extent of what is observed on screens.
- Masshub in the New England power pool:
  - Formerly the second-most liquid hub in the Northeast.
  - Trading two years out is now challenging.
Recent Dislocations—Shale Gas

Production and Consumption

- North American demand is highly seasonal.
- Observations:
  - High winter peak demand and the relatively mild summer peaks (air conditioning power demand met with CC generation)
  - Non-seasonal production profile.
  - Recent increase in domestic production—shale gas glut.

U.S. Natural Gas Production and Consumption
Recent Dislocations—Shale Gas

Storage: Inventory History

- Roughly 4.2 bcf of storage capacity resolves the production/consumption mismatch.

- Compare historical inventory levels versus ”normal.”
  - ”Normal” is a Fourier fit with the number of modes used determined by an out-of-sample selection method with estimates of working capacity.
  - The figure shows the results through 31 Dec 2012.

U.S. Working Storage

- The figure shows the results through 31 Dec 2012.

```
bcf

500 1000 1500 2000 2500 3000 3500 4000

Actual
Normal
```
Recent Dislocations—Shale Gas

Storage: Inventory History

- Departure of inventory levels from “normal”: $R(t) \equiv S(t) - \bar{S}(t)$

$$\bar{S}(t) = \alpha + \beta t + \sum_{k=1}^{K} [\gamma_k \sin(2\pi kt) + \delta_k \cos(2\pi kt)]$$

- At the end of 2012 the worry was running out of storage capacity.

U.S. Working Storage Residual

![Graph of U.S. Working Storage Residual with data points from 2000 to 2010, showing fluctuations in bcfof storage capacity.](image-url)
Recent Dislocations—Shale Gas

Price Behavior

- Predictably natural gas prices fell meaningfully relative to other energy benchmarks.
  - The figure shows rolling cal strips.
  - The post credit crisis recovery demonstrated by oil and coal was not shared by natural gas.
  - Peak power, being tightly coupled by CC generation, showed the same.
Recent Dislocations—Shale Gas

Locational Basis

- Geographic location of production has dramatically altered basis.
  - The following figure shows the current state of Henry Hub (NYMEX NG) and TETM3 forward curves.
  - Note the meaningful discount of M3 in the summer months.
Natural Gas Inventory Redux

The following two plots show the inventory level and the inventory residual through the present.
Clearly something significant happened, particularly in early 2014.
Recent Dislocations—Polar Vortex

Temperature Views

- Long data sets in temperature facilitate estimation.
  - The following figures show results based on Scoville models.
  - This is LaGuardia in NYC—the same qualitative features pertain to all Northeast and Midwest locations.

![KLGA: Daily Deviation](image)

![KLGA: Cumulative HDDs](image)
Temperature Views

- The geographical extent of “the vortex” was as surprising as the temporal.
  - This is Houston—roughly 2500 km miles away and 1500 km south.
Recent Dislocations—Polar Vortex

Natural Gas Price Levels

- The result was unprecedented natural price spot price behavior.
  - TZ6NY is northeast delivery point notorious for substantial price spikes.
  - Winter 2014 saw price levels multiples greater than seen previously.

Transco Z6 Spot Prices
Recent Dislocations—Polar Vortex

Natural Gas Basis

- “Close” price locations decoupled.
  - These northeast delivery locations commonly underpin pricing for physical generation and hedging structures.
  - The decoupling caused many hedges to decouple from the generators.

Spot Basis: Z6NonNY / Henry Hub
Recent Dislocations—Impact

- **Price Decrease**
  - Inflicted substantial damage to many generators.
    - The value of “fixed strike” generation (nuke, trash, wind) or NG powered (CC’s) are all to leader order linear in natural gas prices.
    - Benefited retailers (more on this momentarily) who compete with utility “price-to-beat” which is often changes.
    - Non-linearities in heat rate behavior effects on “energy” delta became non-trivial.

- **Polar Vortex**
  - Generally good for fixed strike generation; problematic for natural gas driven generation.
  - Catastrophic to some short load positions (e.g. retailers).

- **Diminished Liquidity**
  - Much harder (more expensive) to hedge locational exposures.
Origins

- Many utilities by choice or by regulation solicit contracts to serve pools of customers.
  - Such contracts often result from large load auctions / RFPs.
  - Contracts refer to tranches of customers of varying behavior (industrial, commercial, residential).
  - Delivery obligations extend beyond energy to reliability products (ancillary services) and capacity.

- Load obligations are natural hedges for owners of generation.
  - OTC hedging of sizable generation positions can take months and can involve large transaction costs.
  - A load obligation is often a poor match to a generation owners portfolio.
    - Baseload (e.g. nuclear) generation is essentially flat 7x24 power.
    - Actual load varies dramatically.
Origins

- **Retail Aggregators**

  - Regulatory imperatives exist which are intended to facilitate competitive supply to the end-user.
    - This can include explicit credit support and billing support of companies who “own” customers in a utility’s control area.
    - Fixed and transparent utility “price-to-beat.”

  - Aggregators originate customers for whom they procure energy.

  - The customers are typically “tranched” at high level
    - At high level as commercials, industrials, residential.
    - At lower level by meter type (e.g. residential with electric heating vs. without electric heating.)

  - Often the credit support for the trading activity by aggregators is provided by dealers through whom the aggregator sleeves trades and procures power in the ISO markets.
Load Transactions—Intro

Structures

- The typical load position is short (requires delivery of):
  - The energy commodity.
    - At the relevant time-scale (power hourly; natural gas daily).
    - Inclusive of congestion and losses.
  - Reliability products—ancillary services and capacity.

- In return the seller receives the payment related per unit of commodity delivered.

- Pricing mechanics can take many forms:
  - Fixed price: Seller receives $p_f$ per unit commodity delivered.
  - Variable price: Seller can pass the realized procurement costs through to the customer.
  - Hybrids
We will focus on the energy component of these transactions. The payoff for a given month $m$ is:

$$\Pi_m = \sum_{h \in m} \bar{L}_h (p_f - p_h)$$

- $L_h$ is the hourly demand index.
- $p_h$ is the hourly spot price.
- $p_f$ is the fixed contract price.

Equivalently:

$$\Pi_m = \sum_{h \in m} [\bar{L}_h (p_f - p_h) + (L_h - \bar{L}_h) (p_f - p_h)]$$

- The first term is a fixed notional swap on power prices; the second is “quanto-like.”
Common Approach

- Load is not commoditized.
  - Load swaps do not trade on exchange or liquidly OTC.

- Ascribing a value to $\Pi_m$ will involve the physical measure.

- Most shops implicitly acknowledge this and proceed by:
  - Hedging the expected load
    - As forecasted by whatever econometrics are used.
    - Analyzing historical data for “uplift”.

- Hedging expected load will turn out to be not the optimal hedge, though it remains the norm.
Common Approach

- **Historical Analysis**
  
  - Historical uplift is ratio of the fair-value price to the vanilla bucket price.
  
  - Given historical data for a given month $m$ and bucket $B$, the implied (in arrears) fair price $p_f$ solves:

    $$
    \sum_{h \in B(m)} [L_h p_f - L_h p_h] = 0
    $$

  - The historical uplift is the ratio of realized “load-weighted” energy cost to the average realized hourly price:

    $$
    U(m, B) = \frac{\sum_{h \in B(m)} L_h p_h}{\left(\sum_{h \in B(m)} L_h \right) \frac{1}{N_{B(m)}} \left(\sum_{h \in B(m)} p_h \right)}
    $$

    where $N_{B(m)}$ is the number of hours in $B(m)$.

  - If load $L_h$ is constant, the uplift is identically one—any departure from this value is due to correlation between load and price.
Common Approach

- **Historical reference**
  
  - Here is uplift for between PJM Western Hub 5x16 DA prices and PJM Classic Preliminary Load Index.\(^1\)

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\(^1\) Preliminary load estimates are published by PJM within a few days of the delivery day based upon econometric analysis and samples of subsets of consumption. Final load estimates are published a few months later, and are typically very close to to the preliminary estimate, which makes the preliminary load index more suited to swaps with monthly settlements.
Methodology

- We will proceed in valuation by crafting a hedged portfolio.

- A note on mechanics:
  - Load swaps are negotiated in terms of the fixed price $p_f$ that an acquirer of a short load position requires for assuming the obligation.
  - This will result in an iterative aspect to valuation.
  - Some products trade with enough liquidity to be potential hedges.
  - Among these we will select a set $\bar{\mathcal{H}}$ that we think are relevant.
  - These current trade at price: $\bar{p}_\mathcal{H}$
  - For a given transaction price $p_f$, the minimum variance hedge $\bar{w}_* (p_f)$ is:

$$
\arg\min_{\bar{w}} \text{var} \left[ \sum_{d \in m} \left( p_f \bar{L}_B (d) - \sum_{h \in B(d)} L_h p_h \right) + \bar{w}^\dagger \left( \bar{\mathcal{H}} - \bar{p}_\mathcal{H} \right) \right]
$$

- The optimal hedge $\bar{w}_* (p_f)$ is a function of $p_f$. 

Methodology

- For general utility preferences one solves for a fixed point.
- In the case of minimum variance the problem is tractable.
  - For a single hedge instrument (e.g. a forward purchase) the solution is:

\[
p_f = -\frac{E[\hat{LP}] - \frac{\text{cov}[\hat{LP}, H]E[H]}{\text{var}[H]}}{E[\hat{L}] - \frac{\text{cov}[L, H]E[H]}{\text{var}[H]}}
\]

and

\[
w_* = \frac{\text{cov}[\hat{LP}, H] - p_f \text{cov}[L, H]}{\text{var}[H]}
\]

- Where:

\[
L \equiv \sum_{d \in m} \tilde{L}_B(d) \quad \hat{LP} \equiv \sum_{h \in B(d)} L_hp_h
\]

- Intuition:
  - The first term in \( w_* \) is what you expect from the cost term.
  - The second term reduces the delta of the trade if \( L \) and \( H \) are positively correlated. If the hedge is just a forward (\( H = p - F \)), then: \( p \uparrow \implies Lp_f \uparrow \).
Methodology

- To value a load transaction we require the joint distribution of $[L, p, \hat{L}P]$. Equivalently:

$$\bar{X}_d \equiv [\bar{L}_B(d), \bar{U}_B(d), p_B(d)]$$

where:

$$\bar{L}_B(d) \equiv \sum_{h \in B(d)} L_h$$
$$\bar{U}_B(d) \equiv \frac{\sum_{h \in B(d)} L_h p_h}{\left(\sum_{h \in B(d)} L_h\right) \left(\sum_{h \in B(d)} p_h\right)}$$

- A characterization of $\bar{X}_d$ is sufficient to value a load transaction.
Working Problem

- **Working Problem**: Calculate the mid-market fixed price $p_f$ for a variable load swap of the form:
  - Pricing Date: 29May2014
  - Delivery: Jul2014
  - Spot price index: PJM Western Hub hourly day-ahead price.
  - Load index: PJM Classic Preliminary Load Index.

In what follows we will sketch an econometric analysis for this problem.

The approach is the point—alternative approaches are easily substituted.
Working Problem

- Market Data:
  - Sample forwards are shown below (slightly different date).
  - Note the substantial peak/offpeak spread in July.
Econometric Analysis

- Power demand (load) is driven by many factors.
  - Time of day.
  - Temperature and other weather variables.
  - Macroeconomic effects.
- The following shows two views of hourly PJM classic load.

![PJM Classic Hourly Demand](image1)

![PJM Classic Hourly Demand (Jul13)](image2)
Econometric Analysis

- Econometric analysis $\implies$ find stationary variables.
- This figure shows load versus the daily average temperature at KPHL.
Econometric Analysis

- Econometric analysis of $L_h$ could be accomplished by:
  - A representation of load in some parametric form.
  - A model of temperature.

- This plot shows historical KPHL average temperature.
Econometric Analysis

- The mean and variance of temperature vary seasonally.
- Mean and variance can exhibit systematic drifts.

One model:

\[ \tau_d = \mu(d) + \sigma(d)X_d \]

where:

- \( d \) denotes day, \( \tau \) temperature.
- The mean is represented as:

\[ \mu(d) = \alpha_0 + \alpha_1(d - d_*) + \sum_{k=1}^{K} [c_k \sin (2\pi k \Phi(d)) + d_k \sin (2\pi k \Phi(d))] \]

where \( d_* \) is a reference date and \( \Phi(d) \) is the fraction of the year corresponding to \( d \): \( \Phi(d) = \frac{d - \text{BOY}(d)}{365} \).

- Similarly for \( \sigma(d) \).
- The residuals \( X_d \) is assumed to be a stationary process.
Econometric Analysis

- Estimation involves:
  - Choosing the number of modes $K$ to keep.
  - Including or rejecting the presence of a systematic drift in the temperature ($\alpha_1 \neq 0$).

- The following figure shows the estimated seasonal mean.
Econometric Analysis

- Being effectively non-storable, is generated from other (storable or renewable) sources.

- The ”stack” is a graphical display of the marginal cost of incremental generation versus generation capacity.
  - Given arrays of capacity \([C_1, \ldots, C_N]\) sorted so that the associated costs of generation in $/MWh are increasing \([p_1, \ldots, p_N]\).
  - The stack is a plot of \(p_n\) vs \(\sum_{1 \leq k \leq n} C_k\).
Econometric Analysis

- The “stack” serves two purposes:
  - The qualitative relationship between load and price.
  - The likely relationship between power prices and input fuels.
    - Broad price distributions at high demand.
    - Substantial dependence on fuel prices in some regimes.
Econometric Analysis

- Note the dramatic variation in price level as well as the increasingly frequent negative prices.
Econometric Analysis

- The “stack-like” nature of the system is manifest also.
  - This plot shows hourly spot prices versus hourly load.

- This will affect your valuation of the load swap.
  - The fact that $L_h$ and $p_h$ are positively correlated makes load swaps more expensive than vanilla hedges.
  - When loads are high (low), you are short (long) relative to your expected load quantity hedge and prices are high (low).
Econometric Analysis

- Our analysis will be at the delivery bucket time-scale; this is what trades in the forward markets.

- Here consider a simple regression of the form:

\[
\log \left[ \frac{p(d)}{p_{NG}(d)} \right] = \alpha + \gamma p_{NG}(d) + \sum_{k=1}^{K} \theta(d)^k + \epsilon_d
\]

where:

- \( p(d) \) is the power spot price; \( p_{NG}(d) \) is the natural gas spot price.

- The modified temperature is: \( \theta(t) = \frac{e^{\lambda(t)}}{1+e^{\lambda(t)}} \) with \( \lambda(t) \equiv \frac{\tau(t) - \tau_{ref}}{w} \).

- Here \( \tau_{ref} \) and \( w \) selected to be characteristic mean and width of temperatures realized over the entire data set.
Econometric Analysis

- The result is shown below. Given:
  - Temperature simulations.
  - Simulations for $p_{NG}$

we have a joint distribution for: $\vec{\pi} \equiv [\tau, p_{NG}, p]$.

- Note: This model is an example only; it can be replaced by better econometric or structural (stack) models.
Econometric Analysis

- Returning to load:
  - Sample regression/simulation form:
    - For load by bucket:
      \[ \bar{L}_B(d) = \alpha + \beta d + \sum_{k=1}^{K_L} \theta^k(d) + \sigma_L(d)\epsilon_L(d) \]
    - For uplift by bucket:
      \[ \bar{U}_B(d) = \sum_{k=1}^{K_U} \theta^k(d) + \sigma_U(d)\epsilon_U(d) \]
  - Where as before:
    - \[ \theta(t) = \frac{e^{\lambda(t)}}{1 + e^{\lambda(t)}} \]
    - \[ \lambda(t) \equiv \frac{\tau(t) - \tau_{\text{ref}}}{w} \text{ with } \tau_{\text{ref}} \]
Econometric Analysis

- Regression results:
  - This shows the results for the $\bar{L}_B(d)$. 

![Load Regression Diagram](image-url)
Mean-Variance Solution

- What hedges should we include in $\mathcal{H}$?
- The plot shows simulated daily 5x16 load deal values versus spot prices.
- We have used a “reasonable” fixed price to make this plot.
- This motivates simply using a single forward as the hedge basket for each delivery bucket (5x16, 2x16, 7x8).
Mean-Variance Solution

The following table shows the results for this valuation based upon:
- Simulations of a form comparable to those discussed above.
- A hedge basket of a single forward (by bucket) and prevailing forward prices.

Note the substantial differences between optimal hedge (delta) and expected load.

<table>
<thead>
<tr>
<th>Bucket</th>
<th>5x16</th>
<th>2x16</th>
<th>7x8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected Load (MWh)</td>
<td>1534</td>
<td>567</td>
<td>764</td>
</tr>
<tr>
<td>Delta (MWh)</td>
<td>-1724</td>
<td>-619</td>
<td>-554</td>
</tr>
<tr>
<td>Delta Uplift</td>
<td>1.124</td>
<td>1.093</td>
<td>0.726</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>7x24 Forward Price</th>
<th>$/MWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Price (Mid)</td>
<td>56.44</td>
</tr>
<tr>
<td></td>
<td>62.47</td>
</tr>
</tbody>
</table>
Mean-Variance Solution

- Was setting $\mathcal{H}$ to a single forward adequate?
  - The following figure shows the hedge residuals versus power price.
  - Structure is ambiguous; however, the methodology extends.
  - At the daily level (not shown) there can be more structure.
  - Some practitioners consider options on power or temperature.
Load Transactions—Dislocations

Polar Vortex

- Load Delta Versus Expected Load
  - Realized temperatures were far below norm.
  - Realized loads were far above expectation (as were spot prices).
  - This figure shows the risk profile when hedged at expected load.
  - This resulted in a substantially structurally short position in Jan/Feb 2014 (and much pain).

![Diagram showing load deal + hedge versus spot price (5x16)](image-url)
Stationarity Concerns—Shale Gas and Vortex

Spot Price Dynamics

- This figures show TETM3/Henry Hub spot prices versus KPHL (Philadelphia).
- Note the dichotomy between the two date ranges:
  - Lower basis at moderate temperatures.
  - Arguably different behavior at low temperatures.

![Price Ratio Versus Temp (2008–Now)](image-url)
Stationarity Concerns—Renewables and Demand Response

- Parts of PJM have witnessed a dramatic increase in deployment of solar energy panels.

- PJM is also utilizing much more demand response.

- There is a general belief that:
  - Peak load is no longer growing.
  - Uplift for load risk is dropping.

- Peak load growth:
  - The load calibrations used above (2011-present) selected as statistically significant a decay rate of -.5% for the peak bucket; no drift was deemed significant for offpeak.
  - This is noteworthy—over the past decades growth rates in the 1-3% range were the norm.
The results for uplift are inconclusive.

- This figure shows standardized residuals for the uplift regression used above (which did not have a drift term) and a 30 day moving average.

- No obvious trend—no detected drift using out-of-sample selection methods.
Liquidity

- The risk profile of a typical load aggregator has:
  - Dozens of zonal positions (recall the PJM map alone).
  - Non-uniform volumetric rates in delivery buckets.
    - The bucket risk—2×16 and 7×8 as separate forwards are viewed as non-standard.

- The drop in liquidity forces courser hedging strategies and increases basis risk.
LMP Markets

- The quest for the “ultimately” efficient power markets has led to zonal and nodal price risk for the key natural market participants—generators and load serving entities.

- In theory it sounds good:
  
  - Why should a generator at a node that “should have” a lower shadow price receive a higher zonal or hub price?
  
  - Nodal pricing encourages generators to build where they are needed.

- In practice hedging generation and load at pricing hubs is already laden with estimation and modeling risks.
What is missing?

- Sound economic decision making requires at least one of the following:
  - The ability to hedge a risk over time horizons required by ones funding or investor expectations.
  - The ability to reliably forecast the spread between the risk and where a hedge can be effected.
  - The diminishing of liquidity in zonal forwards means a greater reliance on forecasting.\(^2\)

- Forecasting is hard — the last slide shows the results of a nodal price basis when “something happened” in PJM.

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\(^2\) Some would argue that FTR auctions fill the void, but these do not provide the liquidity required for day-to-day hedging and long tenor pricing.
Perhaps:

- Nodal price exposure is inconsistent with current levels of liquidity.

- A roll-back to hub or zonal pricing would result in a competitive landscape at the length scales that matter and more efficient hedging and financing.

Spot Basis: Camden / PSEG