Market Risk 201 – Risk Measures

A moderate dive into quantitative risk measures commonly used in energy markets

Paul Swoap

Director, Market Risk & Structured Products

Tenaska Power Services

TENASKA® POWER SERVICES CO.


MARKET RISK
ANALYST
WE DO
PRECISION
GUESS WORK
BASED ON UNRELIABLE DATA
PROVIDED BY THOSE OF
QUESTIONABLE
KNOWLEDGE

A brief history of risk management

- **Pre-1900s** – Practically all actuarial risk management
  - Examples date back to 1700s (shipping insurance, life insurance)
- **1900** – Brownian motion is used to analyze financial fluctuations
  - Laid the mathematical groundwork for modern financial theory
- **Mid-1900s** – Focus on risk management starts to grow
  - The first academic risk management books were published in 1963 and 1964, but covered only “pure” risk management, not financial risk
- **1980s** – Financial risk management rises to the fore
  - Black and Scholes publish seminal work on option pricing in 1973, and derivatives trading takes off
- **1990s** – Corporate financial risk management well-established
  - A number of risk management models and tools rise in popularity

What we are covering today:

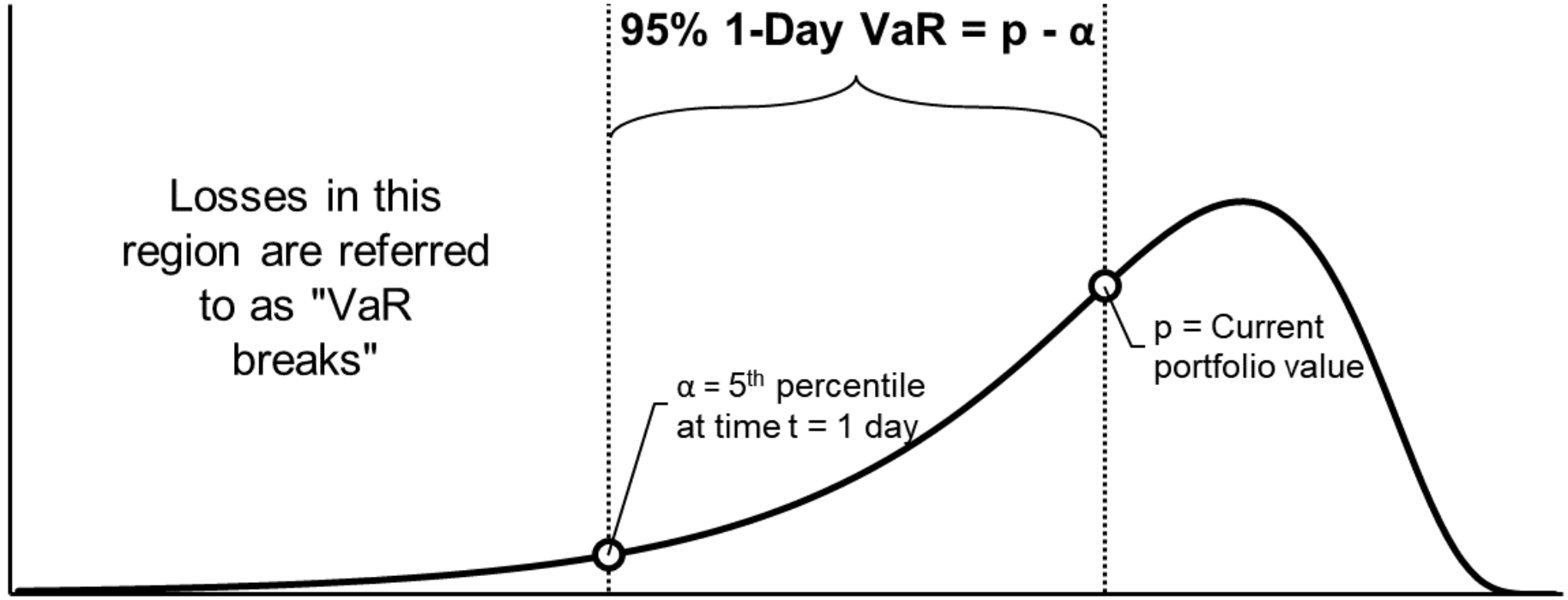
- **Value-at-Risk (VaR)**
  - Parametric (Covariance) VaR
  - Monte Carlo VaR
  - Historical VaR
- **Expected Tail Loss (ETL)**
  - a.k.a. Conditional VaR, Average VaR or Expected Shortfall (ES)
- **Earnings-at-Risk (EaR)**
  - Defines a group of measures that use a similar approach
  - Gross Margin at Risk (GMaR), Cashflow at Risk (CFaR), Profit at Risk (PaR)
- **Stress Testing**

Value-at-Risk (VaR)

Value-at-Risk (VaR)

Goal: Estimate the change in portfolio value that may occur over a specified holding period and at a given level of confidence over.

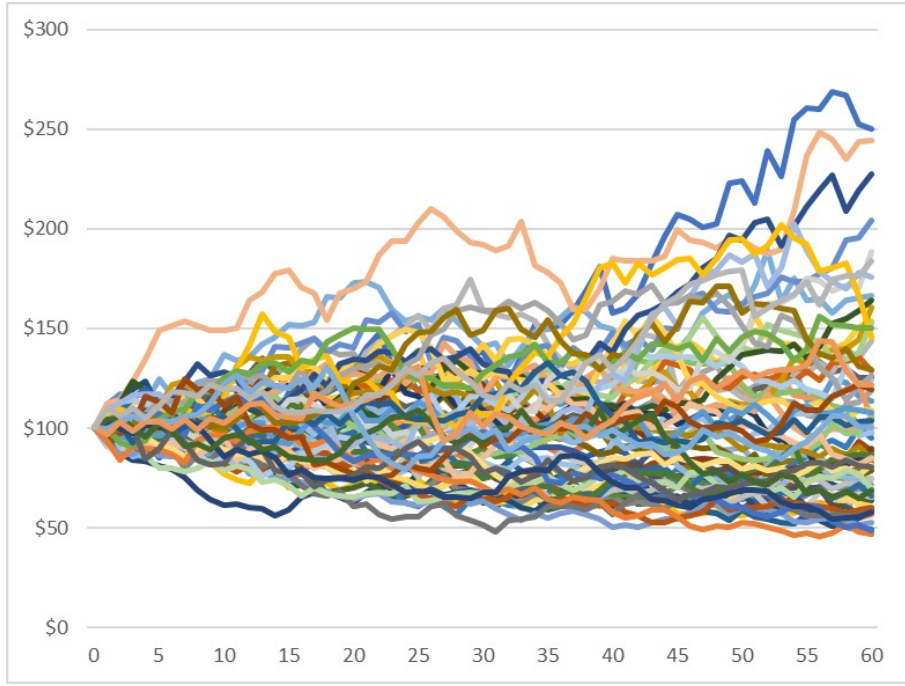
VaR is based on the variation of daily returns (percent changes) for the underlying asset(s). It is primarily a measure of the change in the *mark-to-market value* of a portfolio.



Value-at-Risk (VaR) – Primary Assumptions

1. **Stationarity**
   - Volatility is *constant* over time
2. **Independent Returns**
   - The past does not have any impact on the future
3. **Non-negativity**
   - Asset prices cannot be negative
4. **Time Consistency**
   - Assumptions about changes over one time period apply to changes over any arbitrary number of horizons
5. **Normally Distributed Returns**
   - Daily returns follow assumptions of Brownian motion
6. **Efficient Market**
   - Portfolio can be rebalanced within the defined holding period

VaR assumes all prices behave generally like this:



Value-at-Risk (VaR) – Parametric VaR

- "Closed-form" calculation that can be applied to a portfolio containing many assets
- Multiple asset version uses relatively simple matrix math

$$VaR_{\alpha,t} = (z_\alpha \cdot \sigma) \cdot W \cdot \sqrt{t}$$

Where α is the confidence interval, z_α is the z-score corresponding to the chosen confidence interval, σ is the volatility, W is the current market value (or "weight") of the investment, and t is the holding period, in days.

Example:

Investment (W) = $1,000,000

Volatility (σ) = 5% (SD of daily % returns)

Confidence Interval (α) = 95% ∴ $z_{95\%}$ = 1.96

Holding Period (t) = 5 days

$$VaR_{95\%,\,5\,days} = (1.96 \cdot 0.05) \cdot \$1{,}000{,}000 \cdot \sqrt{5}$$

$$\boldsymbol{VaR_{95\%,\,5\,days} = \$219{,}135}$$

Interpretation: There is a 5% chance (~1 in 20) that the value of this investment will change by $219,135 or more over a 5 day period.

Value-at-Risk (VaR) – Parametric VaR (cont.)

Of the three VaR approaches, Parametric VaR is the most dependent on the underlying assumptions. It's simple and fast to calculate, but can also tend to understate risk.

- **Advantages:**
  - Computationally cheap
  - Parameters can be estimated from a relatively small data set
  - Can be easily applied to a portfolio with any number of assets

- **Disadvantages:**
  - Simplistic assumptions that rarely fit reality
  - Generally underestimates risk the higher the confidence interval gets

Value-at-Risk (VaR) – Historical VaR

Historical VaR

- Uses historical returns directly, so resulting metric will be based on the actual distribution of returns that has been observed over some period
- Generally does a better job than Parametric VaR of capturing tail risk, but assumes past will repeat itself
- Can address the “stationarity” assumption by using seasonally relevant data
- Simple to calculate for a single asset, but can become complex for multiple assets.

Value-at-Risk (VaR) – Historical VaR (cont.)

Historical VaR falls somewhere between Parametric VaR and Monte Carlo VaR on the strength scale. It can be used as a validation tool alongside a primary VaR framework.

- **Advantages:**
  - Accurately represents the known distribution of historical returns
  - Overcomes most of the parametric VaR assumptions
- **Disadvantages:**
  - Doesn't account for events that have not actually been observed, and tail events may not be properly "weighted"
  - Requires a large amount of historical data
  - Difficult to handle options or other non-linear contracts

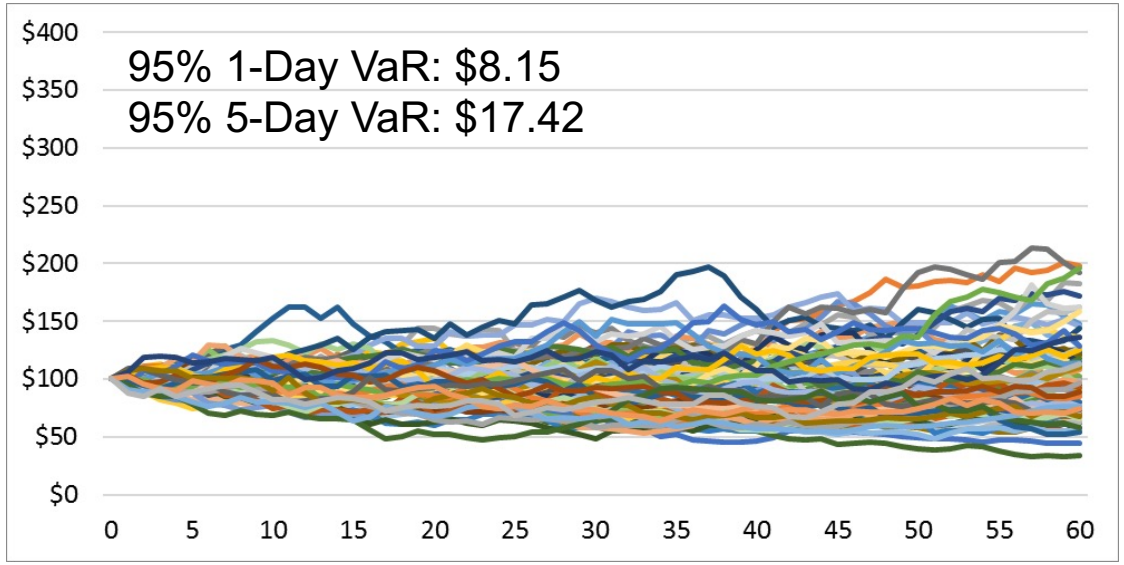
Value-at-Risk (VaR) – Monte Carlo VaR

- Can define arbitrarily complex time series behavior, and then estimate VaR from Monte Carlo simulations of that process
  - Many time series models exist for spot and forward energy prices
- Useful for estimating VaR for processes where the standard parametric assumptions do not hold
- Requires the use of software designed for time series simulation
  - Possible to implement simpler models in Excel
  - Some statistical add-in packages exist for this purpose

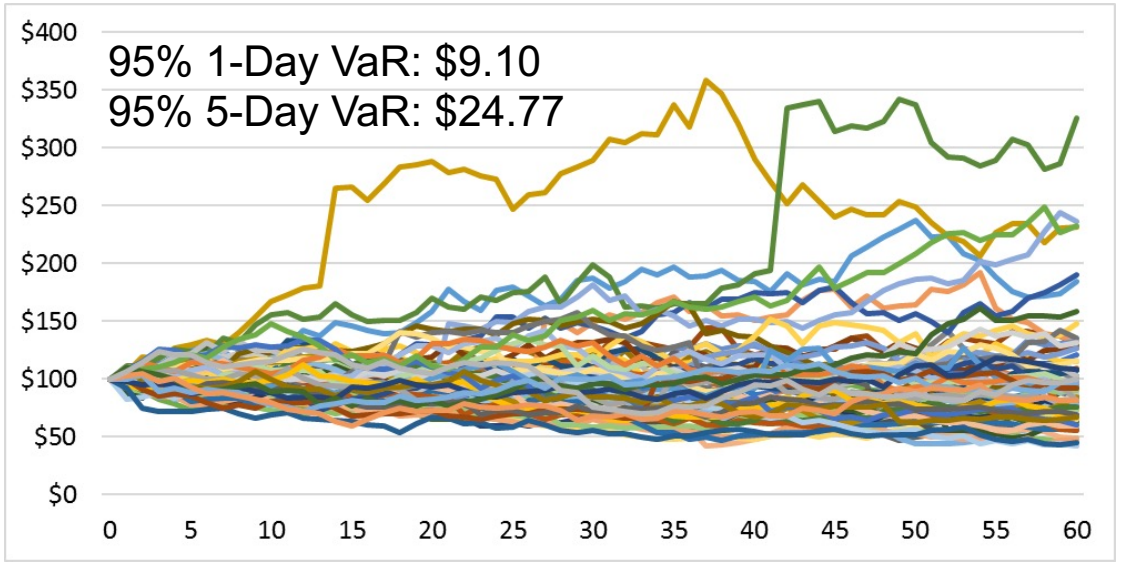
Value-at-Risk (VaR) – Monte Carlo VaR (cont.)

Example: Consider the following two sets of simulated prices

Left: Based on standard VaR assumptions, using a Brownian motion-based approach.



Right: Includes a "jump" component, which has no closed-form solution.



Parametric VaR would understate the risk associated with price dynamics in the example on the right side.

Value-at-Risk (VaR) – Monte Carlo VaR (cont.)

Monte Carlo VaR is generally the strongest VaR approach, but depends heavily on how it is designed. It can be more technically involved, but generally will give the best results.

- **Advantages:**
  - Can overcome many of the assumptions underling Parametric VaR
  - If designed properly, can be a very accurate measure of risk

- **Disadvantages:**
  - High complexity, long setup time
    - Tendency to become a “black box,” can be more difficult to communicate details to management
  - Computationally intensive, especially for a large portfolio
    - May require thousands of simulations to get reasonable convergence at wider confidence levels
  - Calibration is difficult, output sensitive to model parameters

Value-at-Risk (VaR) – Strengths

- **Easy to calculate, communicate, and interpret**
  - Monte Carlo VaR can be more difficult to explain
  - Must also be careful not to develop culture of over-confidence in VaR
- **Works well in conjunction with other measures**
  - For example, Expected Tail Loss (ETL) and stress testing
- **Good measure of short-term liquidity requirements**
  - In power markets this is true for forward market exposures, but *not* true for spot market exposures

Value-at-Risk (VaR) – Weaknesses

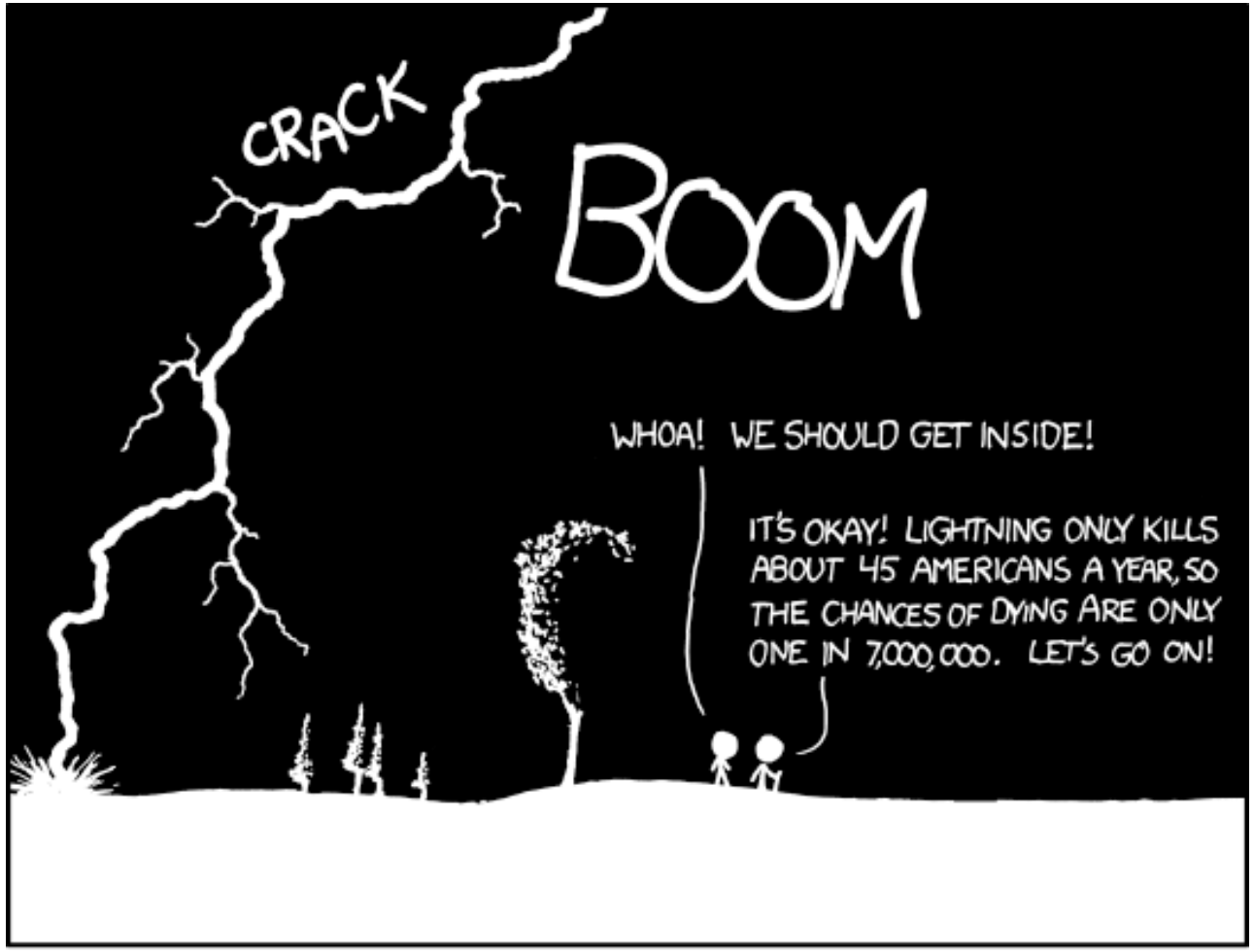
- **Assumptions do not hold in many cases**
  - Especially true in power markets (seasonality, price spikes, etc.)
  - When assumptions fail to hold, it can be difficult to determine to what extent the measure is under- or over-stating actual risk
- **Difficult to handle "nonlinear" exposures**
  - Options, load contracts, power plants modeled as options, etc.
- **May not be a meaningful measure in some cases**
  - Insufficient market information to estimate the volatility can lead to "garbage in, garbage out" scenario
- **Becomes less reliable as confidence interval is increased**
  - A 95% VaR will tend to more accurately represent risk than a 99.9% VaR

Value-at-Risk (VaR) – Summary

- **Do use VaR:**
  - When managing a portfolio of assets whose prices are fairly “well behaved” (e.g., forward power and gas contracts)
  - When you are able to gauge the accuracy of your VaR measure based on the extent to which the underlying assumptions are violated
  - If you have also implemented other measures that address any weaknesses in your VaR framework
- **Do not use VaR:**
  - In the absence of a measure of potential losses beyond the VaR confidence interval
    - VaR tells you nothing how much you can lose if losses *do* exceed the VaR!
    - Simply extending the confidence interval is not adequate and will increase error
  - If you are dealing with very illiquid assets and/or do not have enough info to measure volatility
- **<u>Do not rely solely on VaR as a risk measure!</u>**

Expected Tail Loss (ETL)

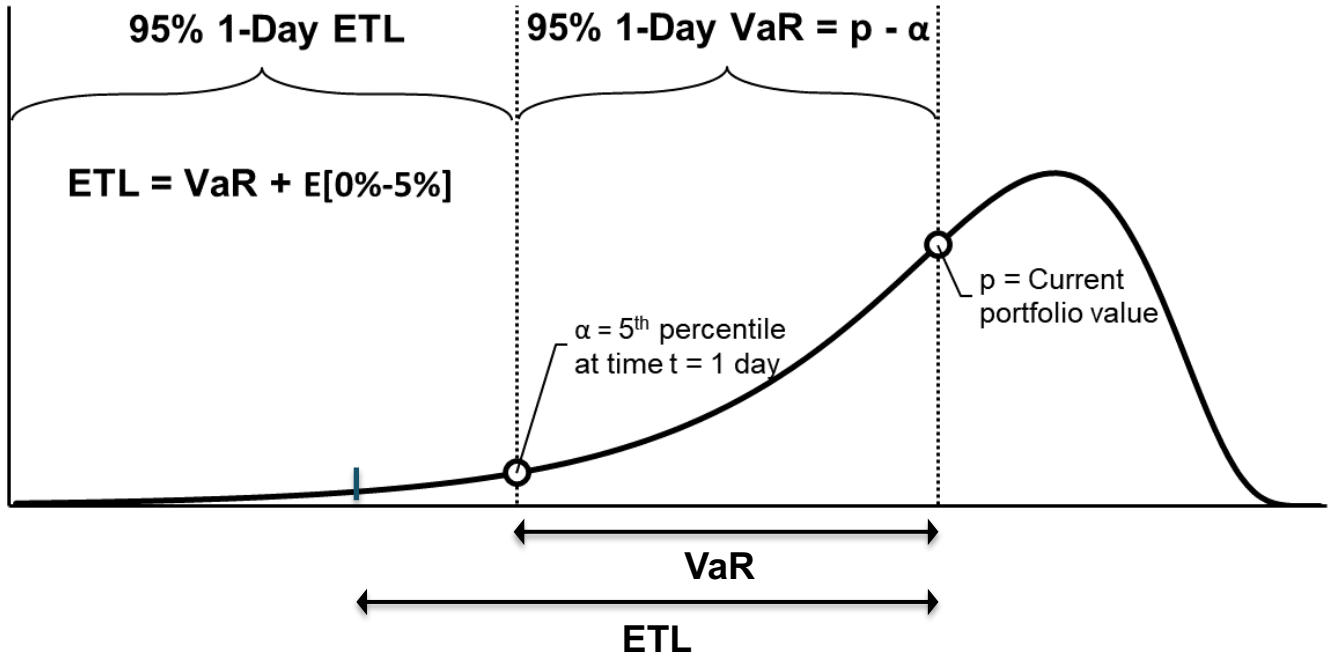
Conditional risk…



Expected Tail Loss (ETL)

Also known as Conditional VaR, Average VaR or Expected Shortfall, this measure attempts to directly quantify tail risk beyond a given confidence interval.

Simple Definition: The average of losses exceeding the VaR confidence level. In the event that a loss exceeds the VaR, what's the average loss that can be expected?



ETL – Assumptions

- ETL assumptions largely mirror the assumptions behind VaR, since these are very closely related
  - By calculating one, you most likely have all of the data needed to calculate the other.

- If using a Monte Carlo approach:
  - ETL will be more sensitive to the underlying model assumptions than VaR
  - Also very sensitive to # of simulations, especially at high confidence levels

- While closed-form calculation of ETL is possible, typically simulation or historical methods will do a better job of capturing tail risk
  - Closed form for ETL is not trivial
  - This approach relies on all of the same assumptions as VaR

ETL – Strengths

- **"Subadditive" measure**
  - Unlike VaR, combining two ETL measures will always result in an overall ETL that is less than or equal to the sum
  - Adding two ETL measures absent any other assumptions will imply a true ceiling on total ETL
- **May be better measure for incentivizing trading behavior**
  - Assuming equivalent returns, a trade that increases VaR by $1M but ETL by $50M is less desirable than a trade that increases VaR by $1M and ETL by $5M.
- **ETL plus solid VaR framework is an effective combination**
  - "What's my maximum loss with x% confidence, and then what could I expect to lose if we actually exceed that level?"

ETL – Weaknesses

- **As with other measures discussed, depends heavily on assumptions**
  - Combination of Historical and Monte Carlo ETL may be needed
- **Moves towards addressing "worst case" scenarios, but doesn't quite get there**
  - Stress testing is required to address this
- **Requires thorough backtesting and a stable model**
  - Because ETL is sensitive to only tail losses, modeling the tail of the distribution is critical
  - Backtesting therefore requires many more observations, since by definition few observations will fall into the tail range
- **Intended for MtM risk measurement, not settlement risk**

ETL – Summary

- **Do use ETL:**
  - As a tool to quantify potential losses beyond the VaR confidence level
  - As a measure to supplement an existing VaR framework
    - VaR to limit “normal” losses, ETL to limit tail losses

- **Do not use ETL:**
  - If you do not have enough data to reliably describe tail behavior, unless it is used in conjunction with a stress testing regime
    - Once again, avoid “garbage in, garbage out” situations

Earnings at Risk (EaR)

Earnings at Risk (EaR)

- VaR and ETL both address short-term risks, but do not describe risk associated with a long holding period
  - VaR applied to long holding periods tends to give nonsensical results

- How do we describe the risk associated with longer-term commitments that cannot be readily unwound? Examples:
  - Merchant power plant exposure
  - A book of congestion instruments purchased in an ISO auction
  - A long-term load obligation

What is the risk of systematic decay in market value?

Earnings at Risk (EaR)

EaR seeks to quantitatively describe the distribution of a set of payoffs over set time horizons (settlement risk / cashflows).

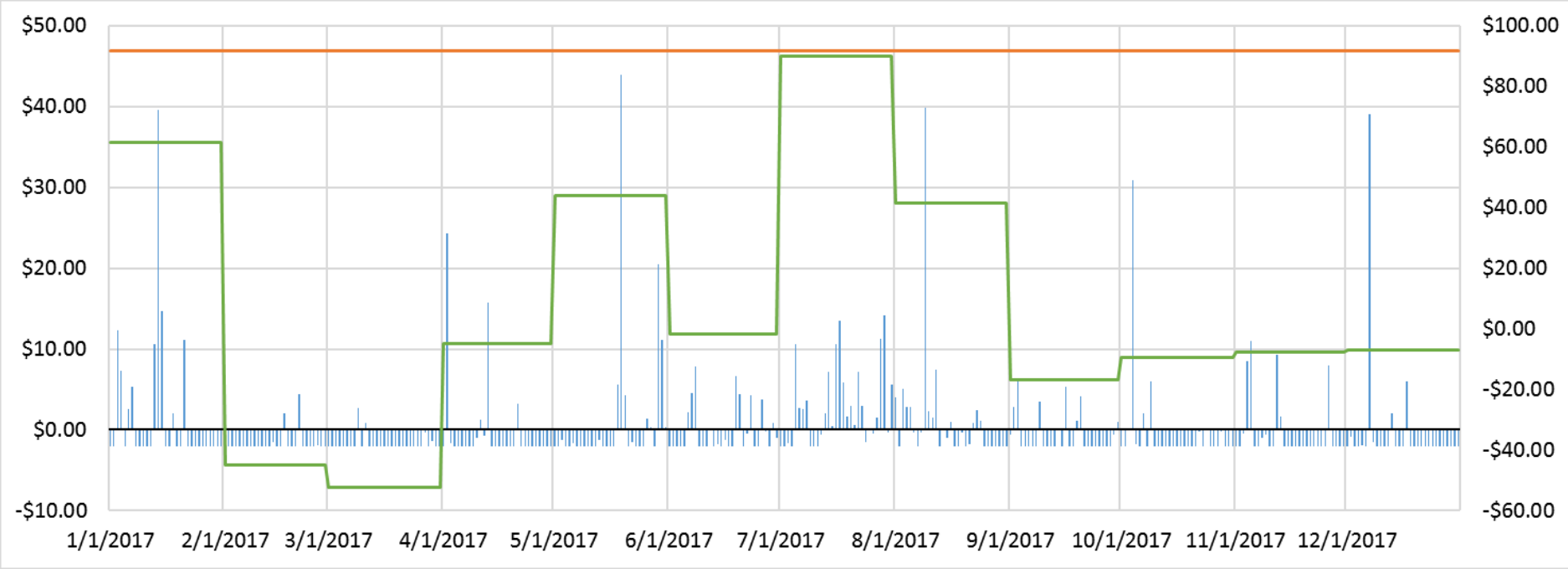
- **VaR/ETL:** Measures risk associated with near-term changes in the mark-to-market value of a portfolio (MtM metric)

- **EaR:** Attempts to quantify the P&L distributions associated with those assets over future time horizons (cashflow metric)

EaR is a label that is attached to a fairly general class of risk frameworks.

Earnings at Risk (EaR) – Conceptual Example

Daily payoffs are in blue (left axis), monthly totals in green and annual in orange (right axis):



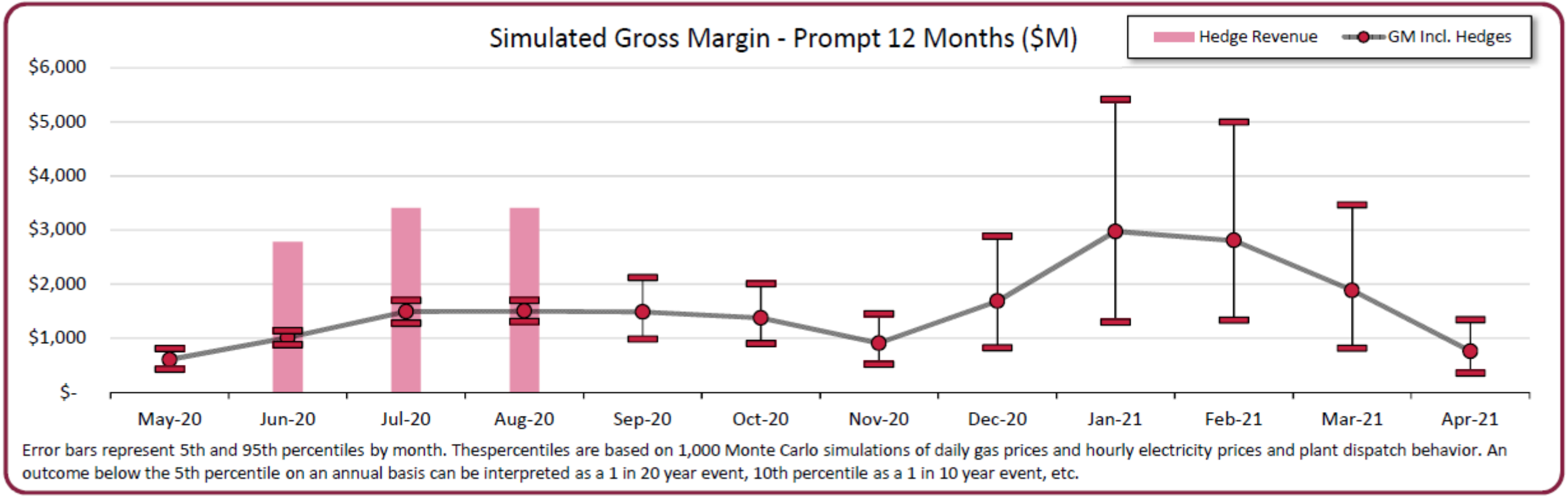
The goal of EaR is to determine the distribution around these monthly and annual aggregations ("buckets"), based on simulations of the more granular payoffs.

Earnings at Risk (EaR) – Applications

- Gross Margin at Risk (GMaR):
  - May be synonymous with “Profit at Risk”, “Revenue at Risk”, etc.
    - Name depends on the target metric
  - “Payoffs” are bucketed generally by month and/or by year

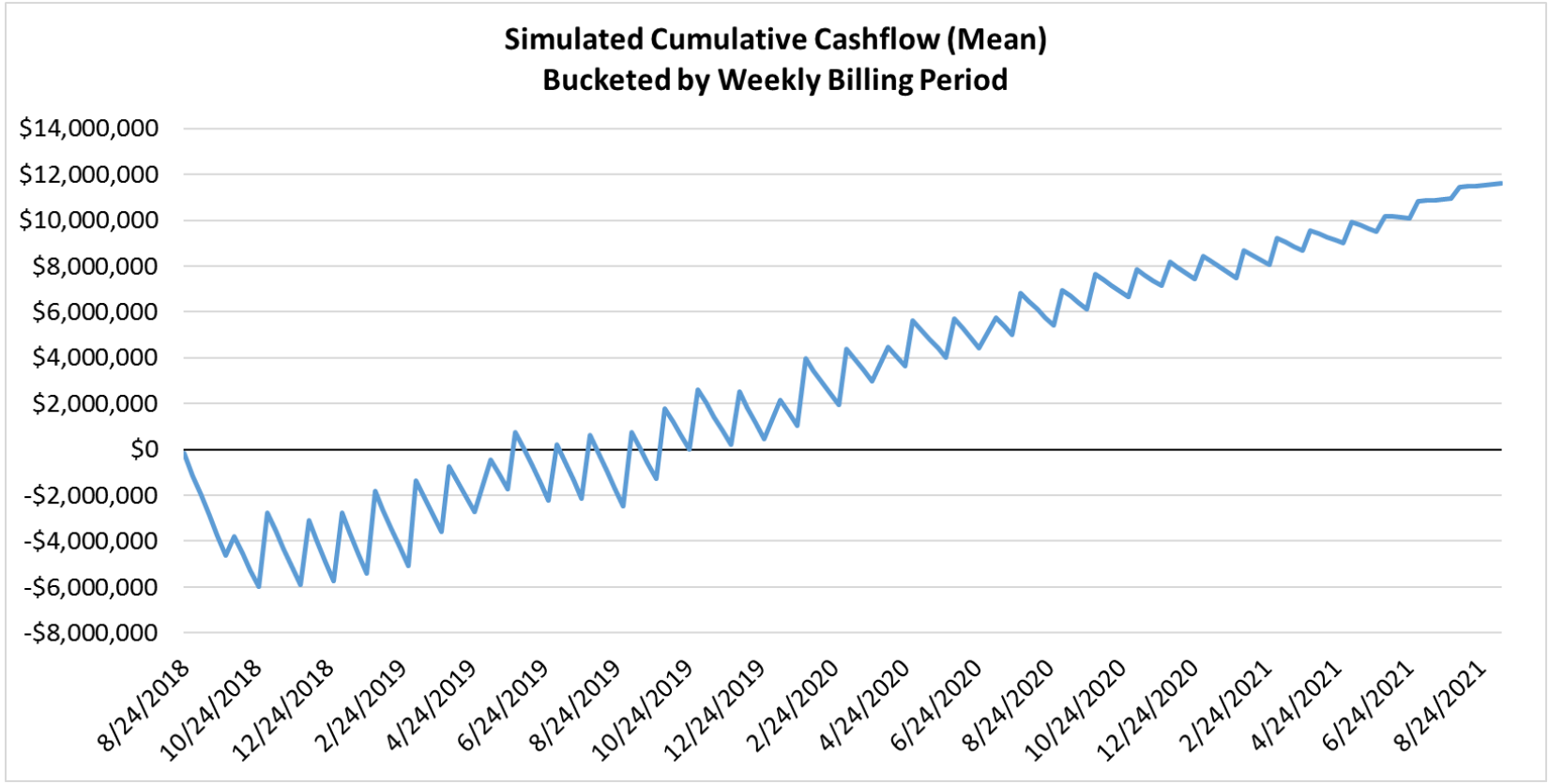
- Cashflow at Risk (CFaR):
  - Separates “payoffs” into payables and receivables
    - Subject to settlement/invoice timelines
    - Generally more granular aggregations are used (weekly or monthly)
  - Goal is to identify potential liquidity requirements resulting from ARAP during “steady state” operations

Earnings at Risk (EaR) – GMaR Example



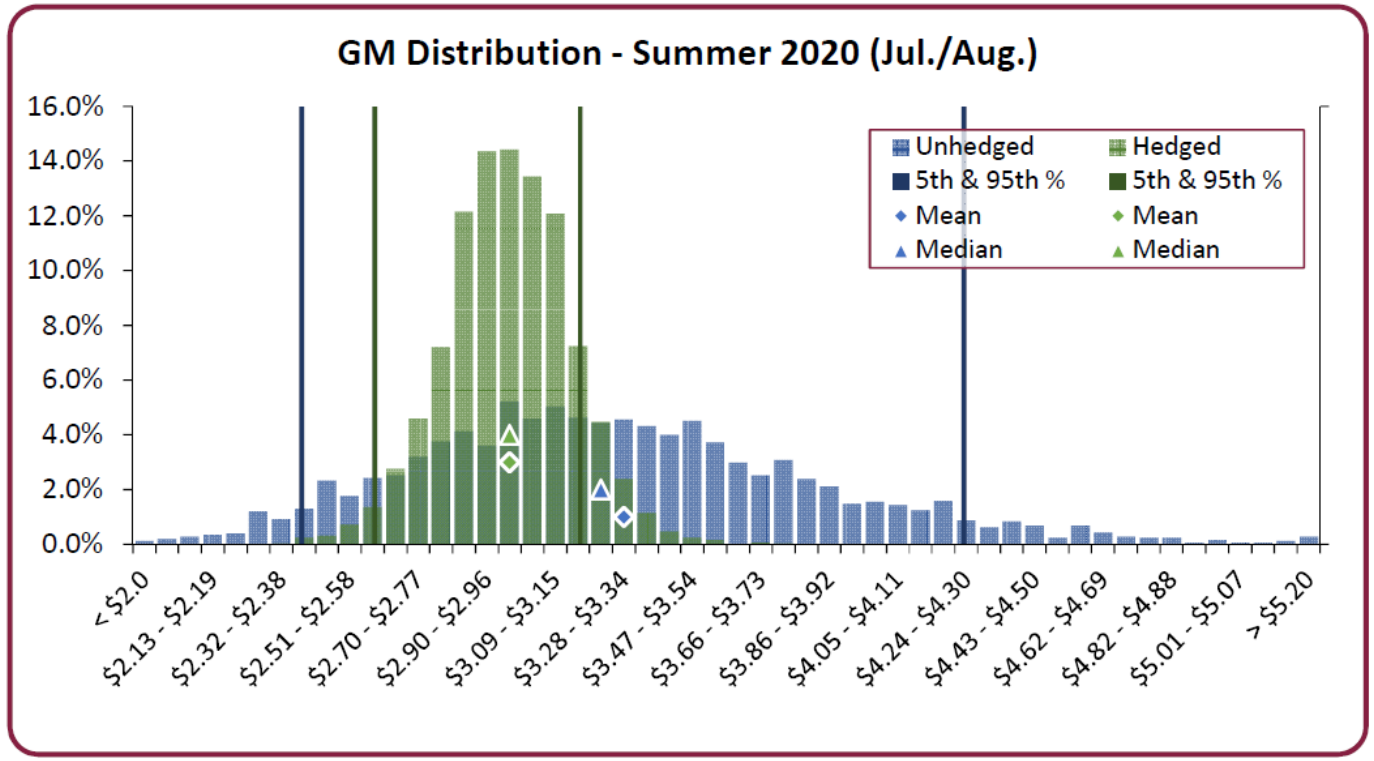
Error bars represent 5th and 95th percentiles by month. Thespercentiles are based on 1,000 Monte Carlo simulations of daily gas prices and hourly electricity prices and plant dispatch behavior. An outcome below the 5th percentile on an annual basis can be interpreted as a 1 in 20 year event, 10th percentile as a 1 in 10 year event, etc.

Earnings at Risk (EaR) – CFaR Example



Earnings at Risk (EaR) – Applications (Cont.)

- Hedge Effectiveness Analysis:
  - Can be demonstrated by running a GMaR analysis without hedges, and then another with hedge contracts layered in



Earnings at Risk (EaR) – Strengths

- Excels at measuring risk associated with assets or obligations that will be part of the portfolio in the long term
- Allows for deeper analysis of hedging strategies (simple or complex)
- Relatively easy to communicate model concepts and results
- Depending on implementation, may be able to extract more than payoff information about an asset (e.g., plant operational data)

Earnings at Risk (EaR) – Weaknesses

- High level of complexity
  - Requires Monte Carlo simulation
  - Models may be very involved
  - Can be very difficult to troubleshoot issues
- Likely requires third party solution
  - More expensive than other risk management options
  - Implementation can be a large, time-consuming project
- Requires ongoing maintenance and calibration
  - True for all Monte Carlo models, but especially true for EaR models

EaR – Summary

- **Do use EaR:**
  - To quantify long-term earnings risk related to assets such as generators and retail contracts
  - To analyze hedge strategies
  - To evaluate steady-state cashflow needs
- **Do not use EaR:**
  - As a complete replacement for a VaR/ETL framework where VaR/ETL can be applied

Stress Testing

Stress Testing

Stress testing allows us to identify cracks in our frameworks and fill them in. It can also help identify longer-term risks and guide strategic decision-making.

- Stress testing is much less rigidly defined than other measures, but very important
- The only “disadvantage” of stress testing is that it can be difficult to design an effective regime
- This section will instead focus on the goals of stress testing, and how to approach setting up a stress testing framework

Stress Testing – Goals

- Identify risks that are not captured by other risk measures
  - May be long-term or short-term risks
- Guide mitigation strategies
- Critical consideration of risk and uncertainty matrix:

		Knowledge of Risk	
		Known	**Unknown**
Awareness of Risk	**Known**	Aware of the risk and understand it	Aware of the risk, but do not understand it
	Unknown	Unaware of the risk, but understand it	Unaware of the risk, and do not understand it

Stress Testing – Art vs. Science

Designing a stress test framework can be a subjective exercise. A general approach could be:

- Identify material risk factors and sensitivities
  - Cast a wide net - consider strategic risks in addition to market-based risks
  - Volatility, macroeconomic effects, trends in the industry, bad actors, etc.
- Design extreme scenarios for identified risks
  - E.g., residential solar penetration of 50% over the next 3 years, 30% increase in natural gas prices over the next year, etc. Consider correlation effects between risk factors!
- Quantify the impact of these scenarios on earnings
  - This may not always be possible, but even a qualitative analysis can be informative

Takeaways

"Essentially, all models are wrong, but some are useful."

- George Box, Statistician

- Risk managers must constantly question their models and the underlying assumptions to ensure adequacy
- A combination of approaches should be used to ensure adequate coverage of risks
  - Risk management must be both proactive and "defensive"
- **Must not become over-reliant on quantitative methods**
  - Subjective, qualitative analysis can also be informative

Questions?