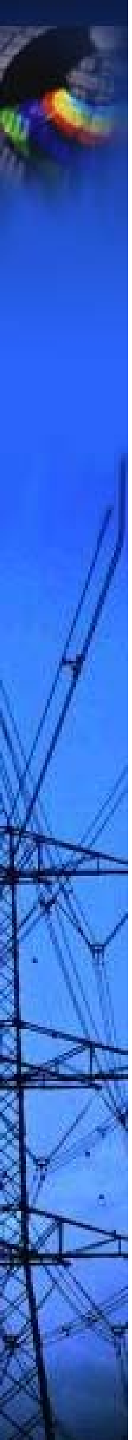

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Evaluating Potential Transmission Projects

Modeling Uncertainty:
Use of stochastic analysis *and* scenarios

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Uncertainty

Uncertainty in outcomes

- A distribution of possible outcomes that will occur around an expected or normal outcome

Identify and Quantify the Sources of Risk

- Electric energy and capacity prices
- Fuel prices
- Hydro energy availability
- Gen unit forced outages
- Emission costs
- Loads, by customer segment

✓ While we can begin to frame the impacts of these effects (through scenario planning and stress testing) ultimately they cannot be predicted with certainty

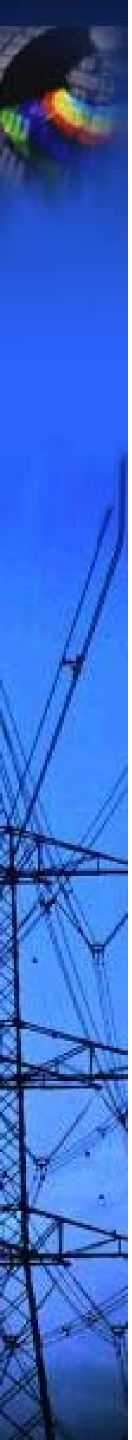
✓ We cannot exactly predict the weather, plant outages or bidding behavior.

✓ Any forecast will thus have some degree of uncertainty associated with it

Assessing Uncertainty – Deterministic Method

- **Single time-series projection of drivers**
  - Base values
  - Median (50th percentile) values
  - Expected (mean) values
- **Multiple discrete cases as alternate scenarios**
  - Two common approaches:
    - 2-5 scenarios (e.g., high, mid, low values)
    - 20-100 “Sculpted” scenarios (e.g., based on historical or assumed fluctuations)
  - Need to weight probabilities of each scenario for decisions

One problem is that scenario development and weighting can be subjective



Assessing Uncertainty – What is stochastic?

Deterministic

- No “random” factors
- Base case or single point forecast
- Snapshot view of the world

Stochastic forecast

- Add random parameters to ‘mean’ estimates
- Incorporate market dynamics (such as correlation among inputs and mean reversion)
- Create large number of possible input streams
- Dispatch system against all inputs
- Average of all iterations (scenarios) is expected value

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Transmission Assessment with Stochastics

- Economic analysis of transmission lines is vastly improved via stochastic analysis, which allows the assessment of risks associated with uncertainty in load, hydro generation, gas prices, unit outages and other key factors – all of which affect power prices
- Many of these input factors are correlated, so changing one factor in isolation (*e.g.* high load) is not appropriate, as load, gas prices, hydro energy, and electric price have statistical correlations.
- These stochastic input streams must then be put through a detailed commitment and dispatch engine
  - Further analysis with a full power flow model should also be performed
  - Develop measures of economic value for the transmission line, including consumer surplus, producer surplus, and congestion revenue

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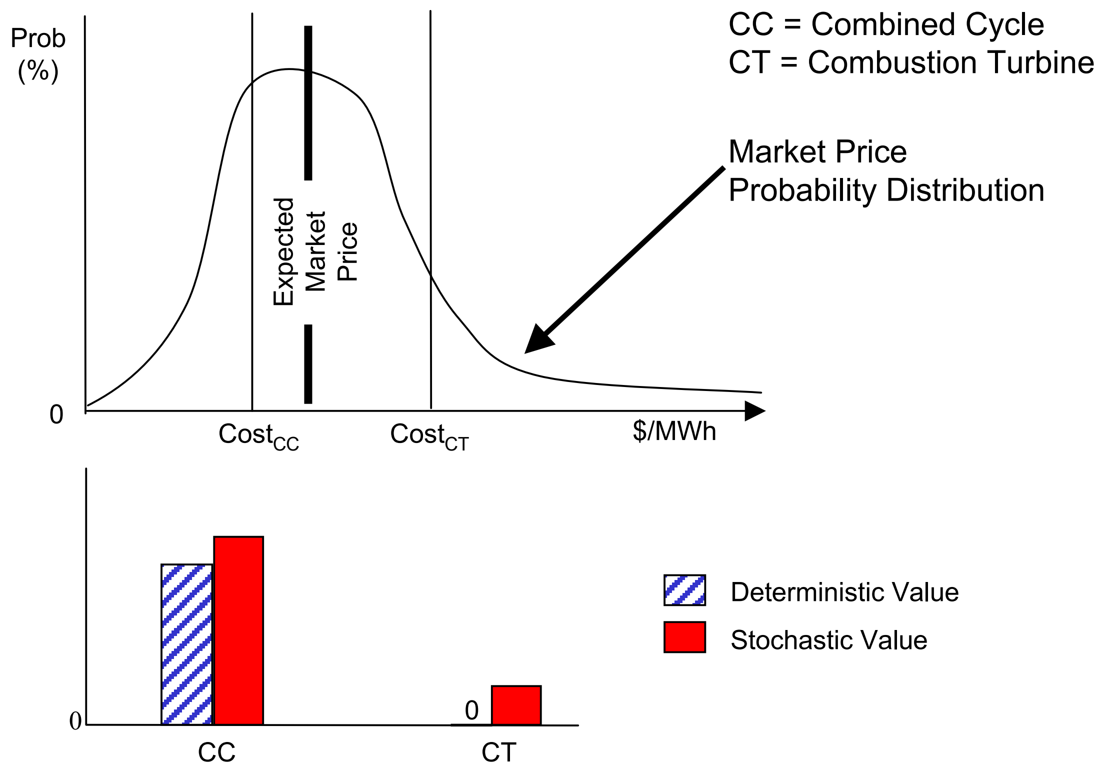
Superiority of Stochastic Over Deterministic Analysis

Expected stochastic output generally not equal to deterministic output due to nonlinear transformations



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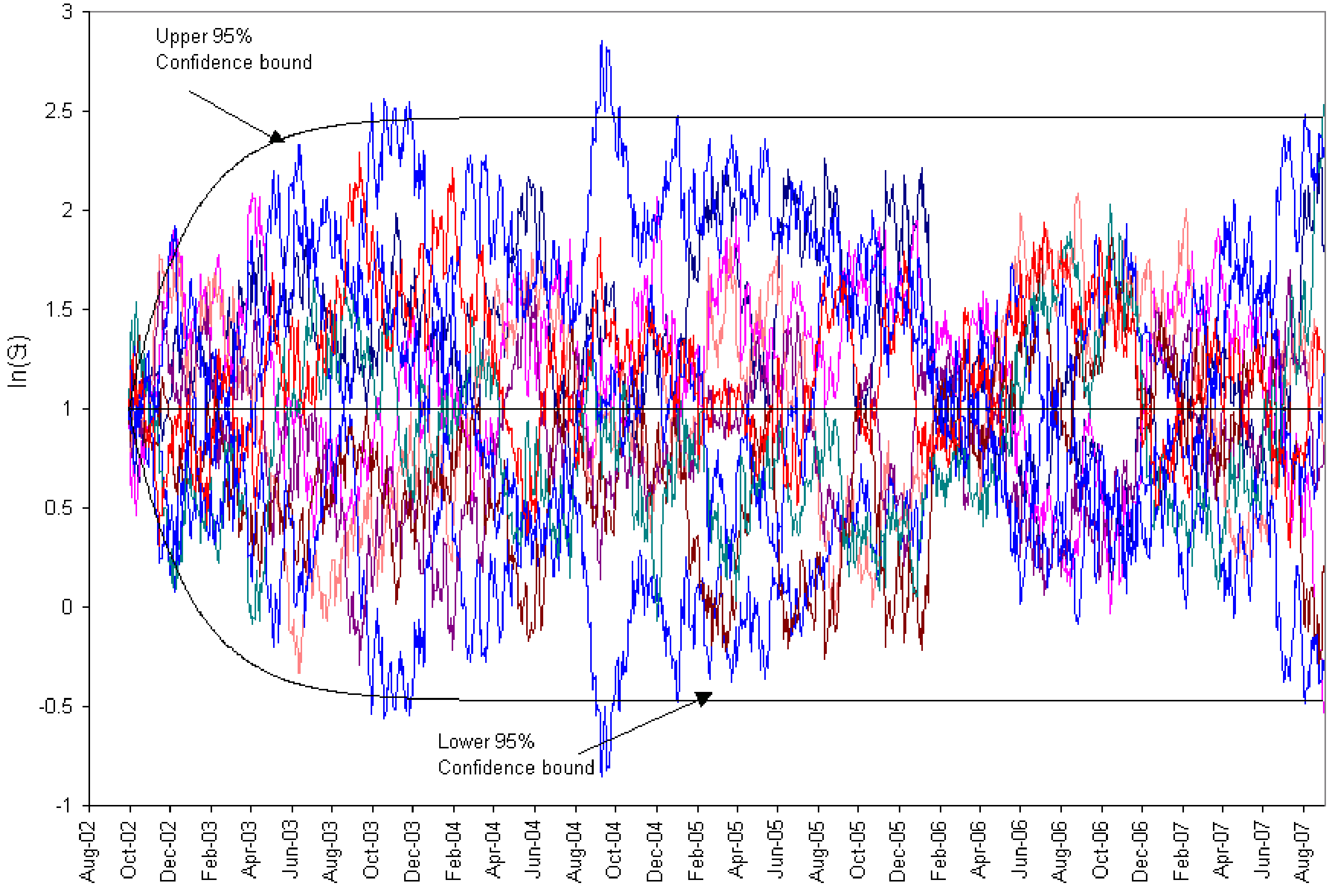
Monte Carlo Simulation of Key Risk Drivers

- **Monte Carlo simulation of hundreds of chronological, correlated trajectories of:**
  - Electric spot market prices
  - Fuel prices
  - Loads
  - Hydro energy availability
  - Emission costs
  - Outages
- **Each type of uncertainty modeled with appropriate seasonally-varying probability distribution**

Short-term Mean Reversion Volatility



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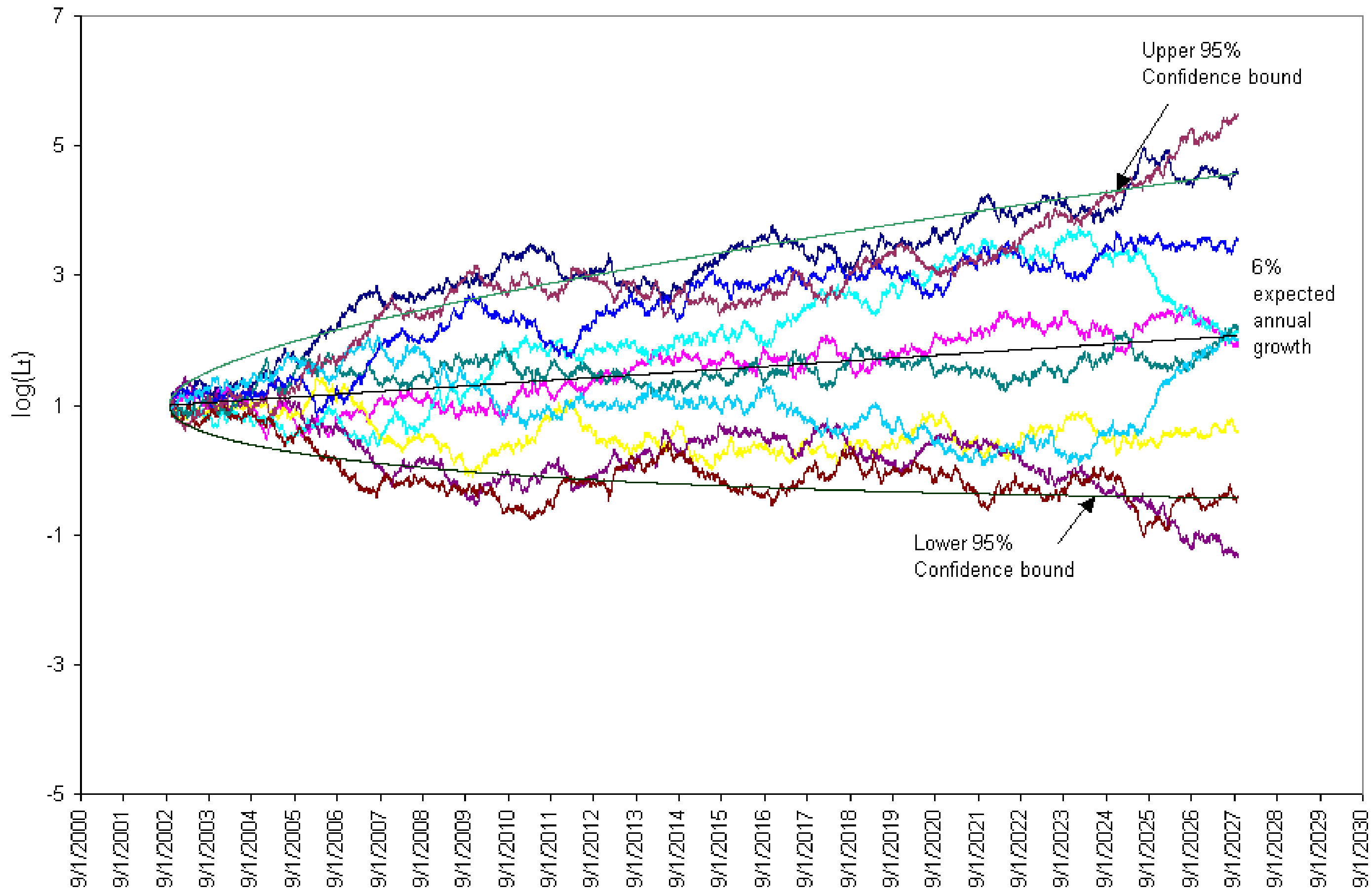
Long-term Random Walk with Drift



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Risk Identification: Key Risk Drivers for Utilities

Risk	Feature	Analytic Approach	Example (s)
Stochastic	Statistically quantifiable	Explicitly represent in the analysis as an uncertain variable	Retail electric load, fuel prices, wholesale electricity prices
Scenario	Measurable but not statistically quantifiable	Represent as “sensitivity cases” and contrast to a Base Case Analysis	Future environmental regulations
Paradigm	Describable but difficult to represent numerically	Address qualitatively outside the modeling process	Electric industry regulation

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