ENERGY DELIVERY AND CUSTOMER SOLUTIONS

Trends in Stochastic Modeling for Integrated Resource Planning

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October 2024

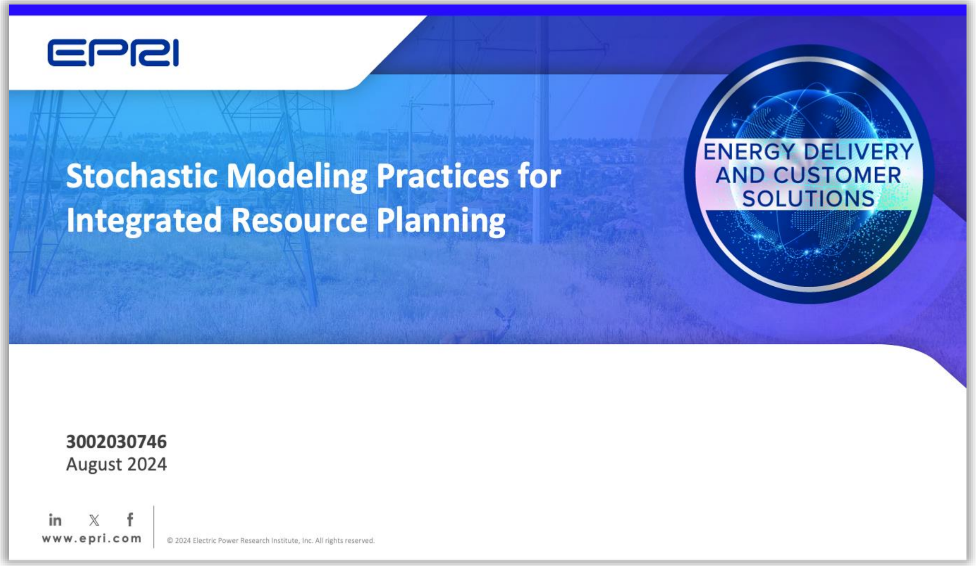
Introduction

Background
Resource plans look decades into the future. Stochastic analysis helps resource planners evaluate the risks posed by the uncertainty inherent in IRP.

Objective
Offer practical insights, guidance and examples for how resource planners can characterize, evaluate, and manage risk using stochastic planning.

Value
This project identifies trends in stochastic planning practices. It also offers practical guidance for using stochastics in IRP. An **Excel workbook with illustrative examples** for developing stochastic parameters from data is provided in an attachment to the project report.

Project in collaboration with DTE Energy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Stochastic Modeling Practices for Integrated Resource Planning

ENERGY DELIVERY AND CUSTOMER SOLUTIONS

3002030746
August 2024

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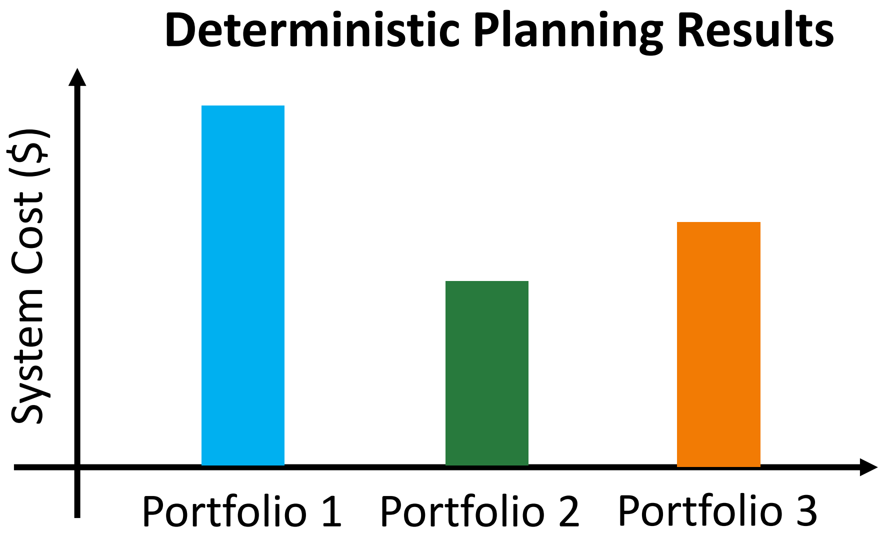
Final report is free and publicly available on EPRI.com

Definitions: *Deterministic* and *Stochastic* Planning

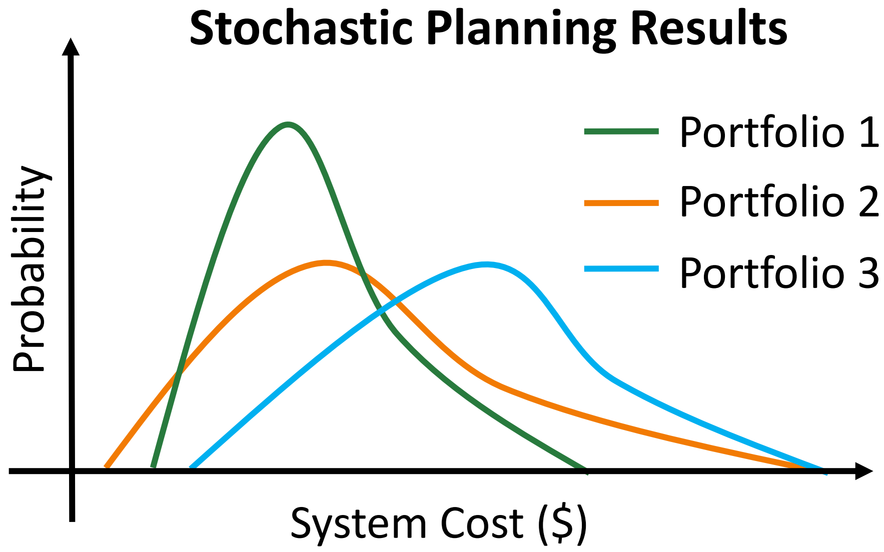
Deterministic Planning: Decision making that assumes all inputs and conditions are known with certainty, producing a **single predictable** outcome.

Deterministic planning provides a snapshot for a single assumed future



Stochastic Planning: Decision making that accounts for uncertainty by considering a **range of possible futures** and their associated **probability** of occurring.

Stochastic planning quantifies economic and other risks posed by a range of possible futures



Uncertainty Modeling in IRP

	Scenario Analysis	Sensitivity Analysis	RA Analysis	Stochastic Planning	Adaptive Planning
Uncertainty Focus	Scenario Uncertainty	Parameter Uncertainty	Reliability	Risk	Robustness
Models Event Occurrence Probability?	✗	✗	✓	✓	✓
Common Methods	Scenario Analysis	Sensitivity Analysis	Monte Carlo Analysis	Monte Carlo Analysis, Probability Trees	Stochastic Optimization
Use Frequency	Common	Common	Common	Fairly Common	Rare

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Resource Adequacy Analysis: Resource portfolios are evaluated (e.g., in an hourly dispatch model) for **how well they meet system needs (e.g., LOLE)** under a wide variety of alternate futures.

Stochastic Planning: Resource portfolios are evaluated (e.g., in an hourly dispatch model) for **how well they perform (e.g., total system costs)** in a wide variety of alternate futures.

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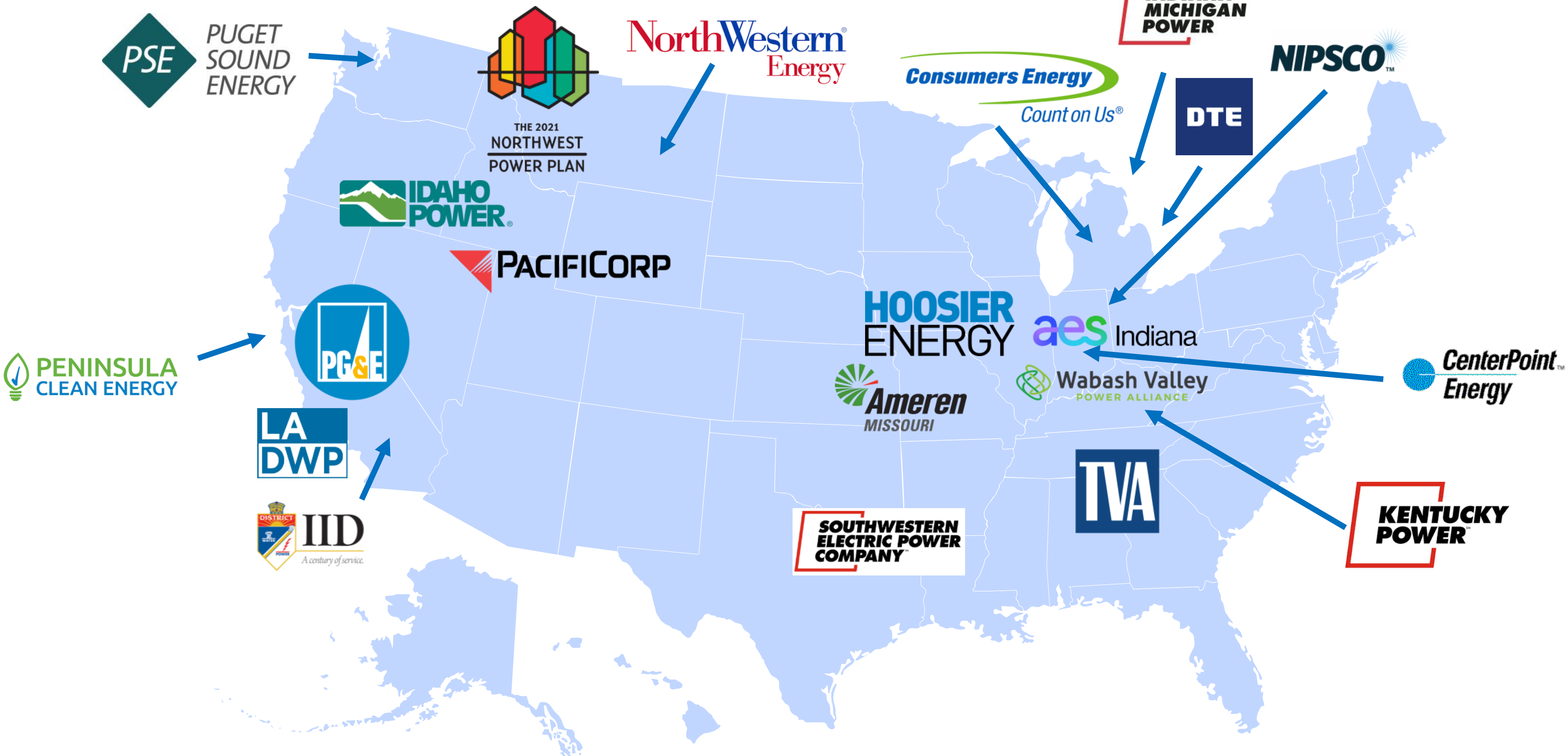
IRPs Selected for Review



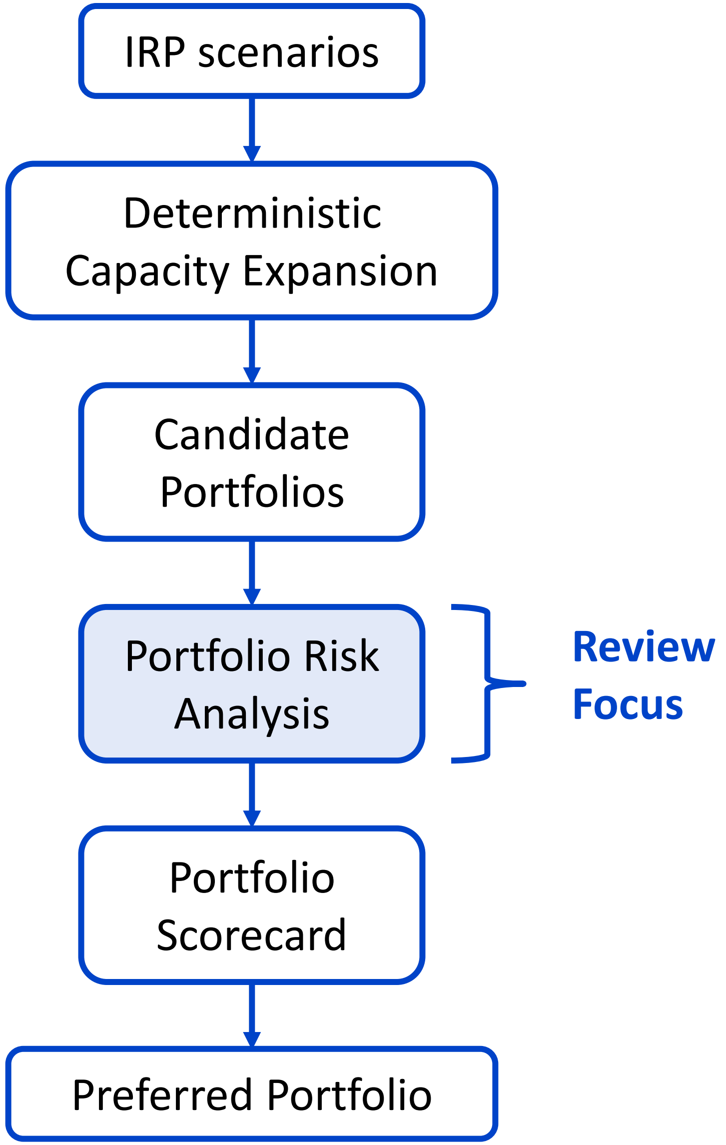
21 IRPs and long-term company plans reviewed for this report

Scope of Stochastic Planning Review

21 IRPs / long-term planning documents reviewed for:

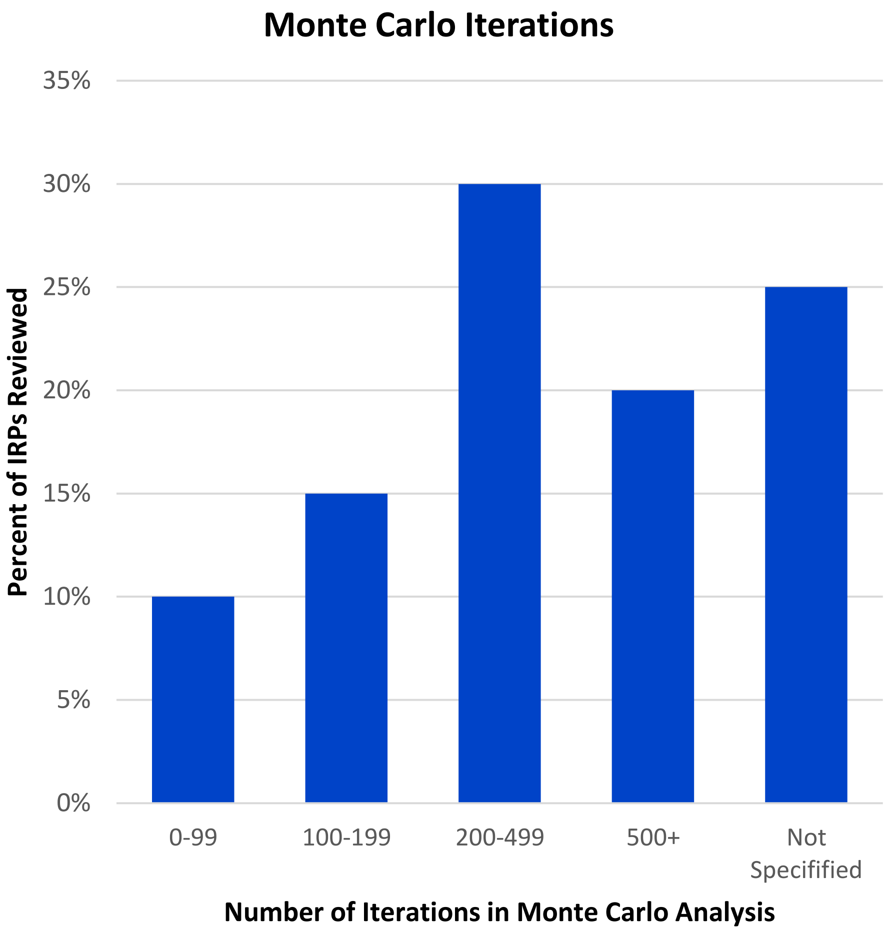
1. Stochastic planning methodology
2. Key drivers of uncertainty
3. Stochastic sample generation methods
4. Interpreting and communicating stochastic results

Typical IRP Process

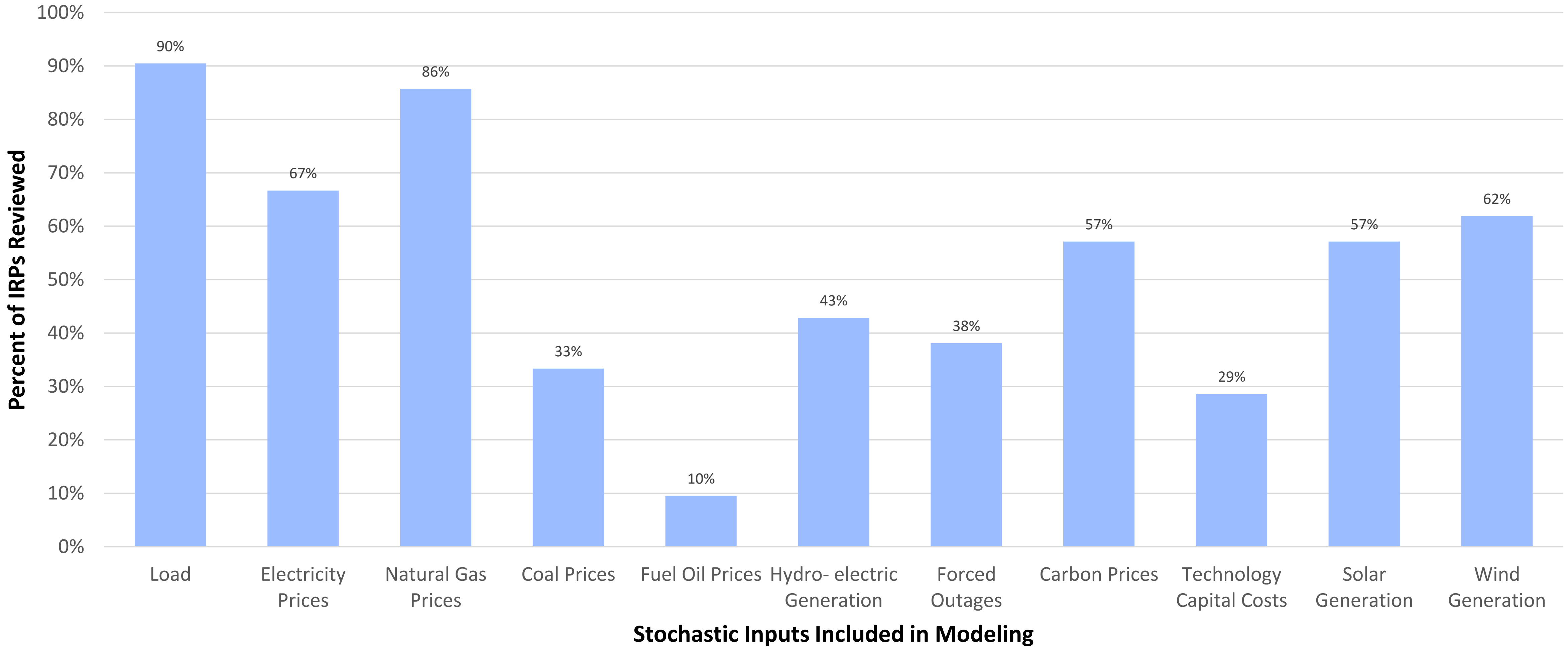


1. Stochastic Planning Methodology

- Almost all companies employ a **Monte Carlo analysis** for their stochastic risk analysis
  - Exceptions: NWPCC, AES Indiana (2019), Ameren Missouri
- Most (>50%) IRPs use **100-500 iterations** in their Monte Carlo analysis
- A variety of commercial tools are used for stochastic modeling including Aurora, PLEXOS, MIDAS, Crystal Ball, EnCompass, and PowerSIMM



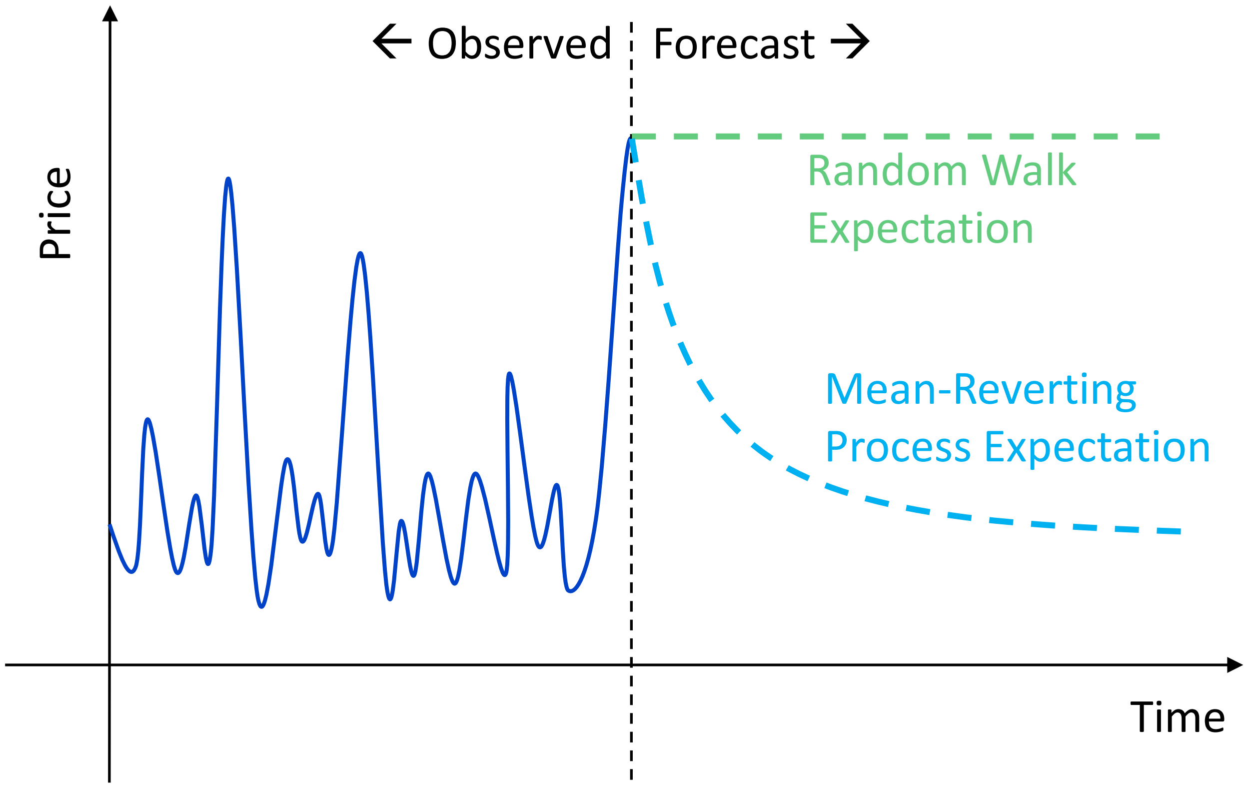
2. Key Drivers of Uncertainty



Geographic region matters when selecting drivers of uncertainty

3. Stochastic Sample Generation Methods

Mean Reversion and Autocorrelation



Adapted from Figure H.1: Stochastic Process, PacifiCorp 2023 IRP, Volume II, Appendix H, Pg 167

Mean-Reversion: after a shock, a process that tends to return to its average value over time.

Autocorrelation: the correlation of a time series with a lagged version of itself. This captures the degree of similarity between consecutive observations of a random variable.

These behaviors can be captured using an **Auto-Regressive Model:** a model that predicts the value of a future variable as a linear function of that variable's past values.

66% of companies modeled autocorrelations in their stochastic inputs

3. Stochastic Sample Generation Methods

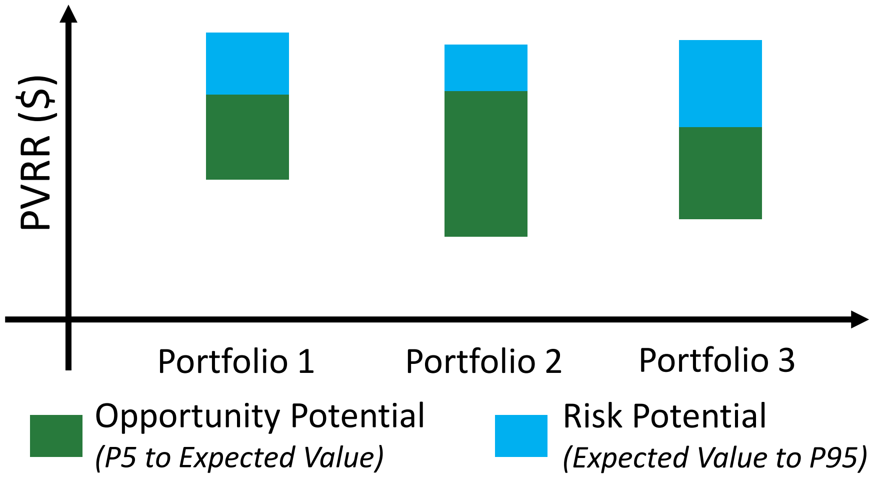
Overview

Stochastic Input	Auto-Regressive Model	Correlated with Other Inputs	Typical Distributions	Uncertainty	
				Intra-Annual	Inter-Annual
Load	√	√	Normal or Lognormal	√	√
Electricity Prices	√	√	Lognormal	√	√
Natural Gas Prices	√	√	Lognormal	√	√
Coal Prices	√	√	Lognormal	√	√
Fuel Oil Prices	√	√	Lognormal	√	√
Hydro-electric Generation	√	√	Uniform, Lognormal, or Non-parametric	√	
Forced Outages			Bernoulli	√	
Carbon Prices			Discrete		√
Technology Capital Costs			Discrete		√
Solar Generation		√	Non-parametric	√	
Wind Generation		√	Non-parametric	√	

4. Interpreting Stochastic Results

Visualization

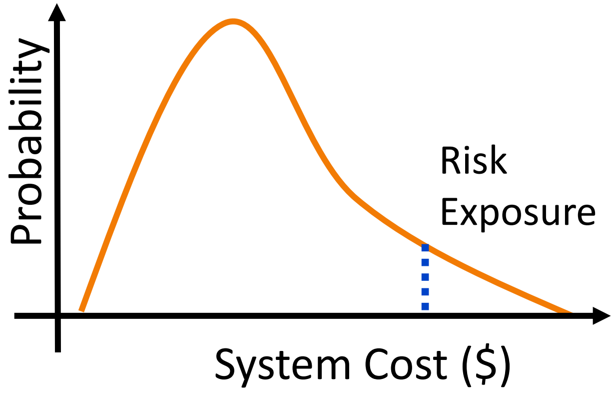
Boxplots visualize the range of stochastic outcomes for each portfolio and provide visual insight into their relative risks.

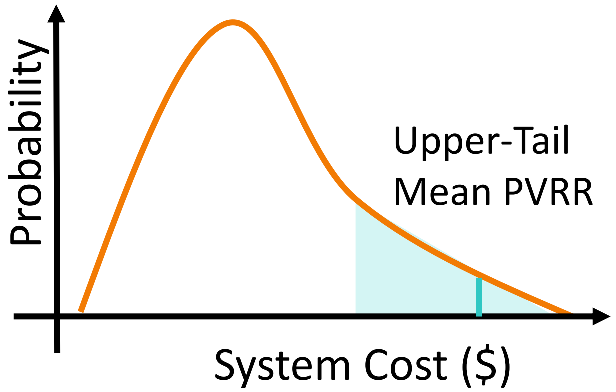


Adapted from Figure 9-72, AES Indiana 2022 IRP, Volume I, Pg 248

Risk Metrics

Risk Metric	Description
Risk Exposure	The 95th percentile of cost or PVRR.
Upper-Tail Mean	Mean of the top 20% highest cost iterations.





Risk metrics can be used in the portfolio scorecard

The Stochastic Planning Process

The following outlines the process for using stochastic planning in portfolio risk evaluation via Monte Carlo methods.

1. Variable Selection

Identify the key stochastic inputs impacting your system.

2. Data Collection

Gather historical observations or simulations of stochastic inputs.

3. Parameter Fitting

Determine the best distribution to describe each stochastic input and fit the parameters of each of the stochastic processes.

4. Portfolio Risk Evaluation

Generate Monte Carlo samples and run the Production Cost Model for each of the samples.

5. Result Interpretation

Analyze the results of the stochastic modeling using the risk metrics and visualizations. Use this analysis to guide the selection of a preferred portfolio.

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Uncertainty Modeling in IRP

As systems evolve with new technologies, policies, and market dynamics, how can planners account for deep uncertainties in integrated resource planning today for a robust portfolio?

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