Probabilistic Forecasting of Extreme Market Events

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Extreme Market Events

- Extreme Market Events – a subcategory of High Impact Low Frequency (HILF) events
- What is "High Impact" is in the eye of the stakeholder
- That could be
  - involuntary service interruptions
  - reserve shortages
  - violations of supply contracts
  - extreme price excursions
  - Other?

What analytical tools do we have to predict extreme market events?

- Note: extreme weather event is an input in such analysis, not an output
- What probabilistic modeling tools are available to predict the detailed outcome of extreme market events and answer the following questions:
  - What is likely to happen?
  - Where and when it is likely to happen?
  - What is the probability of this happening?
  - What can/should be done about it given the forecast?
- ????
- Maybe Resource Adequacy tools? They use Monte Carlo modeling

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Can Existing Resource AdequacyTools be Trusted with Prediction of Extreme Events?

Traditional Resource Adequacy Tools

1. Use stylized power system models that do not properly represent the physics of power flow in transmission network
2. Do not properly represent operational limitations of generating units based on SCUC and SCED optimization subject to transmission constraints
3. Do not represent the impact of uncertain information on operational decisions

Such a model cannot represent system operations and/or market outcomes under extreme conditions?

We need a high-fidelity production costing model run in a Monte Carlo fashion

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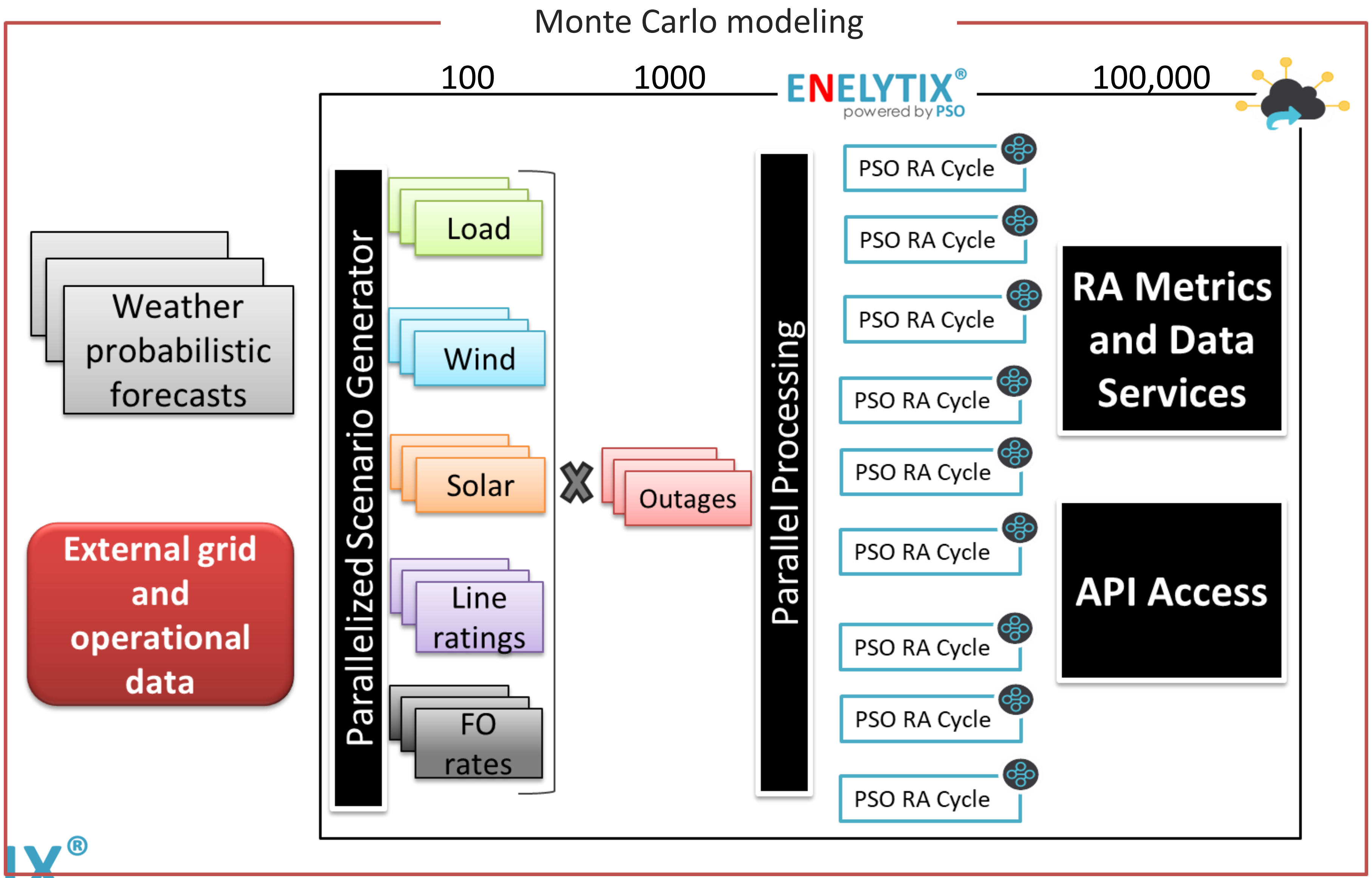
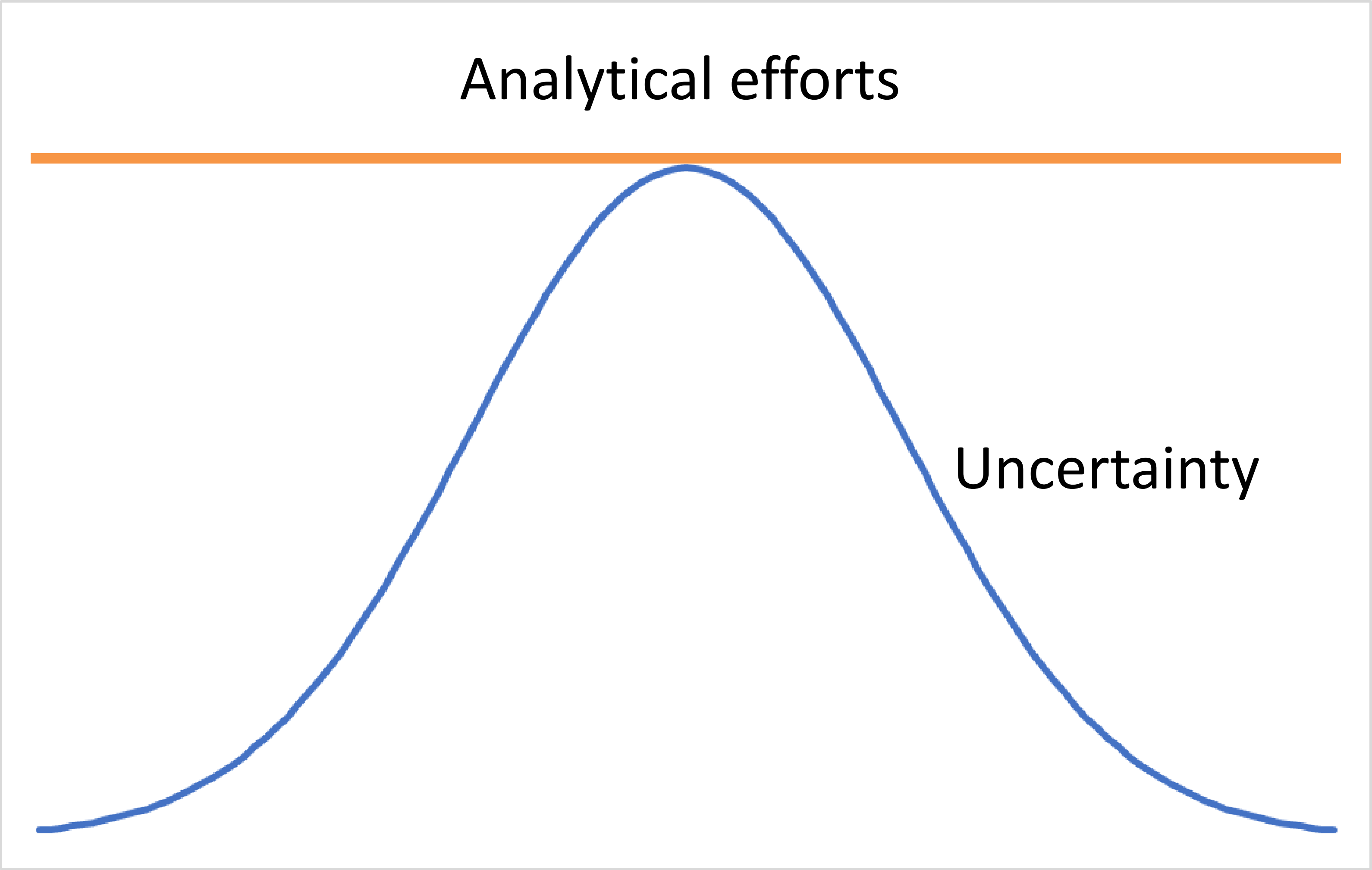
Probabilistic World

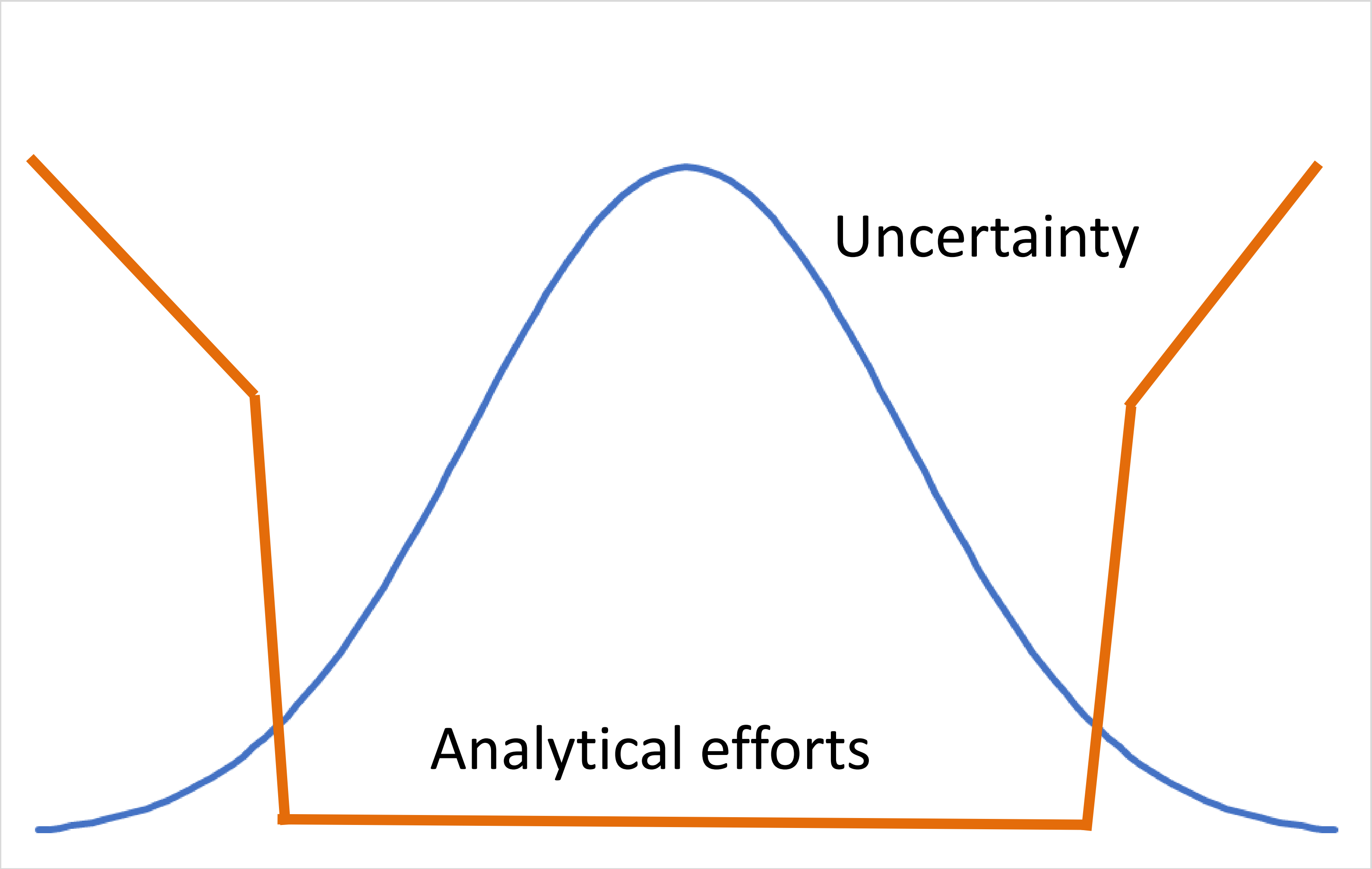


Uncertainty and Allocation of Analytical Efforts



If we are interested in extreme events, there is no point in spending efforts on analyzing the middle portion of the uncertainty curve

Uncertainty and Allocation of Analytical Efforts



If we are interested in extreme events, there is no point in spending efforts on analyzing the middle portion of the uncertainty curve

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General Overview of the Computational Approach

- Monte Carlo based simulations of SCUC/SCED.
- 10,000 – 100,000 scenarios explored
- Set a threshold LMP level and screen scenarios with a moderate fidelity model: an outcome with LMP rising above the threshold level is considered possible extreme scenario
- Skip all scenarios that are not potentially extreme
- Process all potentially extreme scenarios with a high-fidelity model
- Statistical analysis of all results. Reporting and visualization of all identified extreme events

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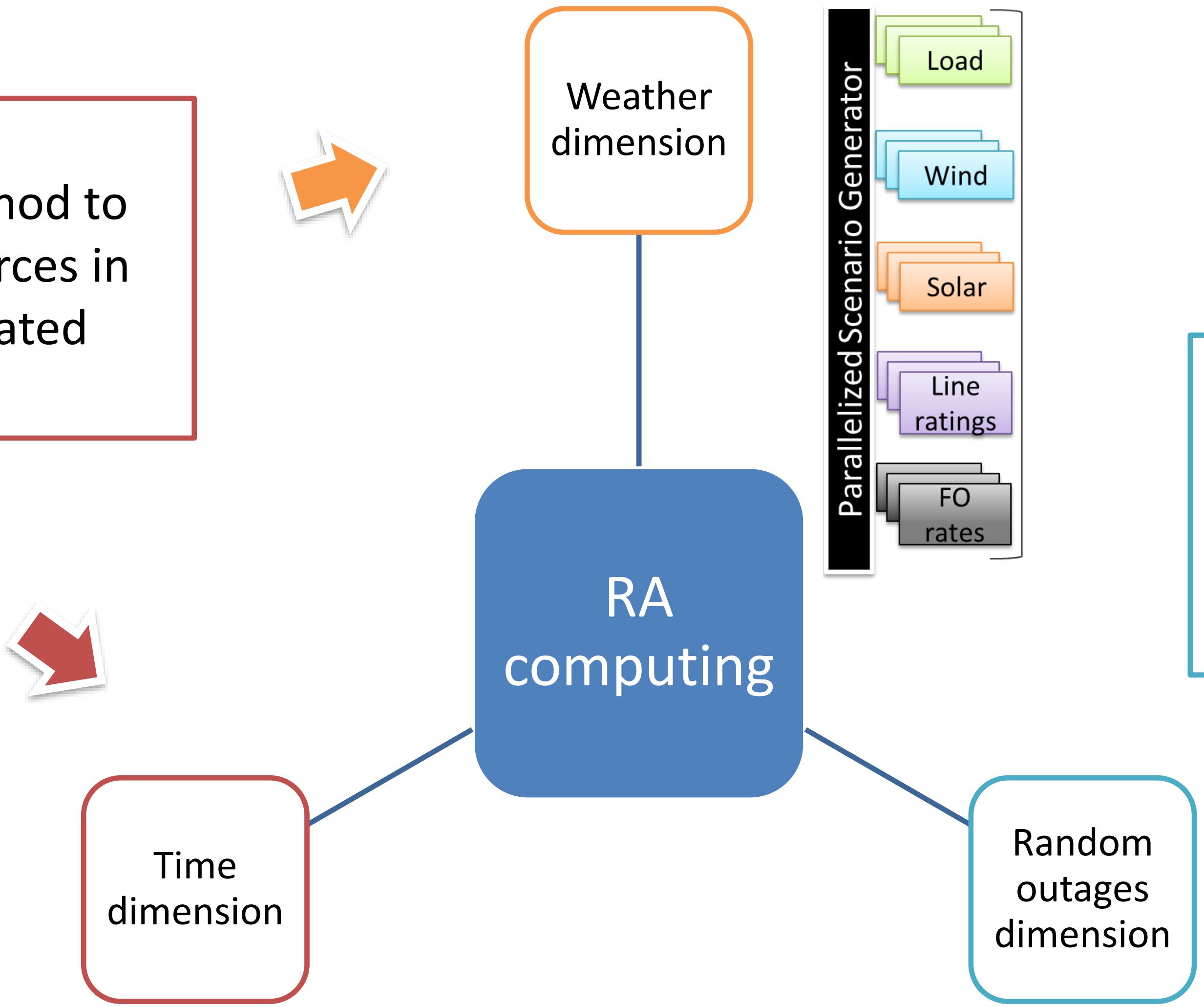
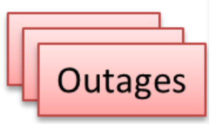
Computational Efficiency

ENELYTIX Level
Stratified sampling method to allocate compute resources in proportion to the estimated case variance

Computational resources should be directed to “eventful” weather scenarios and time periods





PSO Level
Scenario reduction method based on the simplified optimization formulation

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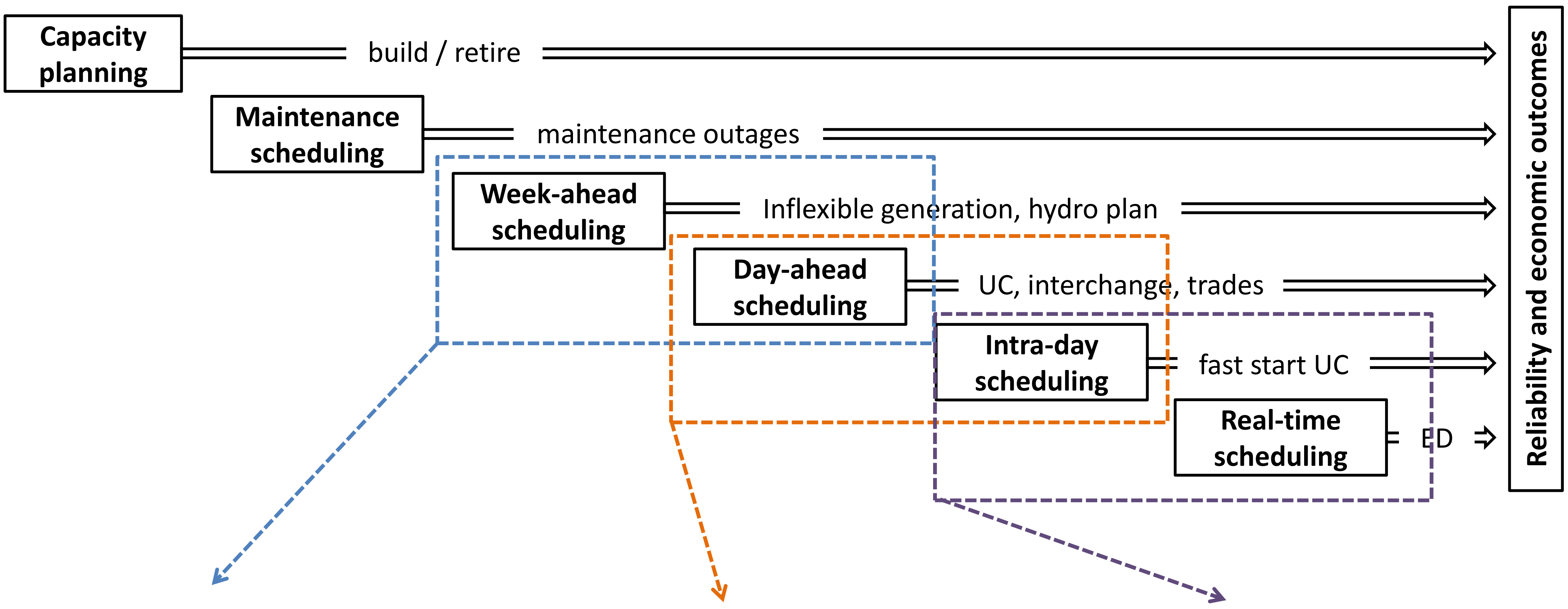
Resource Adequacy Applied to Different Timeframes



Week-ahead & Day-ahead: Assessment of the adequacy of the fleet

Day ahead & Intra-day: Evaluation of impacts of non-recourse decisions (commitment, dispatch of inflexible generation, deployment of demand response, etc.)

Intra-day & Real-time: Assessment of the adequacy of the reserve procurement policy

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Example RA Use Cases

Assessment of RA for system annual planning

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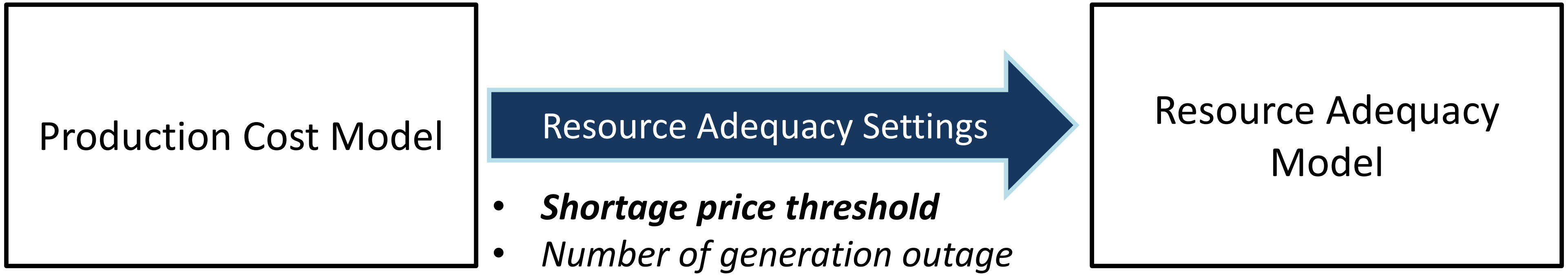
PSO Resource Adequacy Model



- ***Shortage price threshold***
- *Number of generation outage draws*
- *Modeling simplifications to apply at outage draw filtering stage*

In a **decision cycle is designated as RA cycle**, each horizon is evaluated under multiple outage draws with two rounds of evaluation

Round 1 applies simplified optimization formulation to each outage draw

Round 2 applied full optimization formulation to each **shortage** draw revealed in Round 1

Filtering stage

- Evaluate all weather scenarios and time segments for shortage

VM allocation

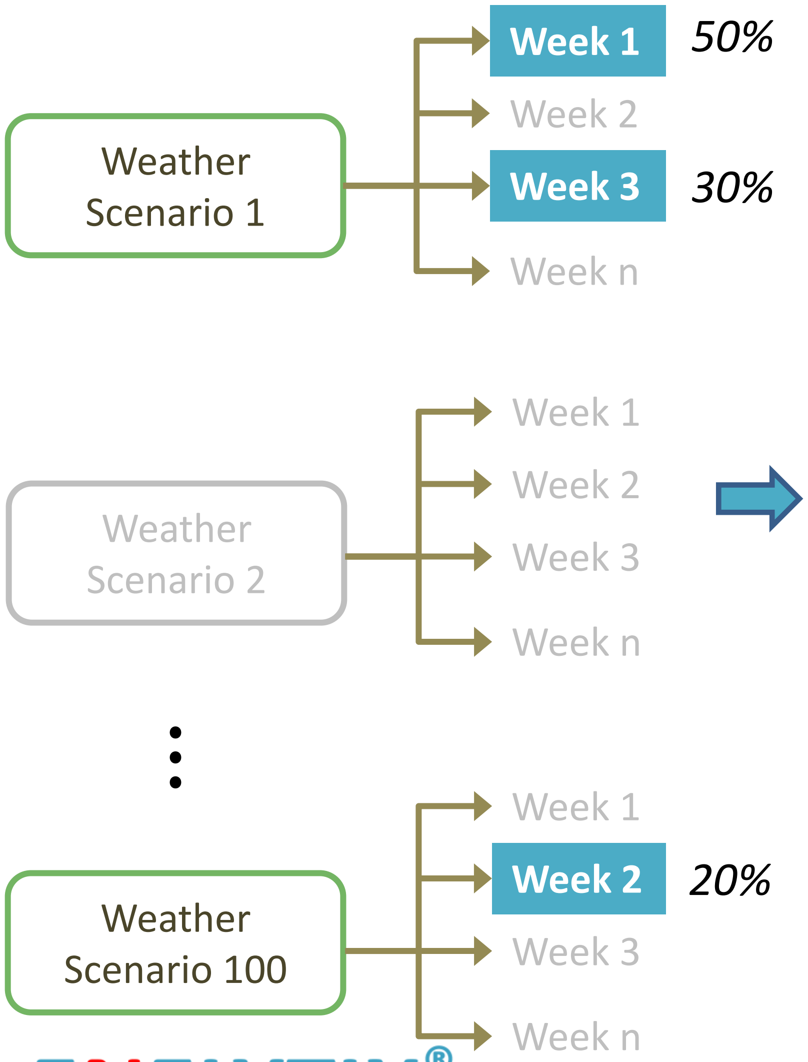
- Allocate VMs to weather scenarios and time segments with detected shortage in proportion to shortage variance

Shortage scenario evaluation

Two Stage Process for Weather and Time Dimension

Stage 1

Variance contribution



Filtering stage evaluation shows shortage in:

- Weeks 1 and 3 of Scenario 1
- Week 2 of Scenario 100

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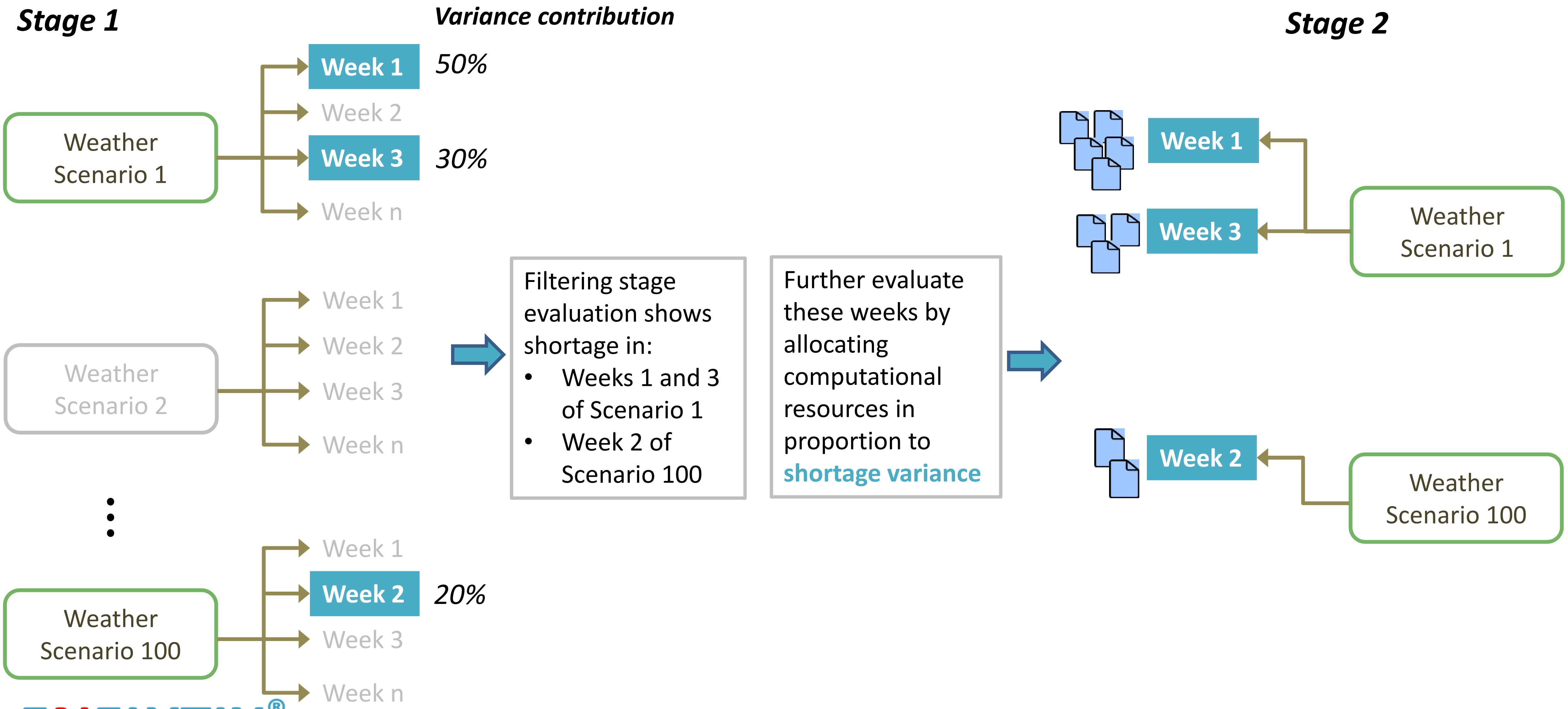
Two Stage Process for Weather and Time Dimension



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Example 1: ERCOT Resource Adequacy Study

- Annual day-ahead simulations for 2024
- Partitioned into weekly segments
- Nodal SCUC/SCED cycle modeled with reserve procurement and ORDC – based price adder
- Goal: Identify weeks and locations with shortage conditions

Summary

Category	Results
Analysis horizon	Annual, partitioned to weekly segments
Transmission	345 kV only
Number of VMs used per week	Filtering Stage: 1 Second Stage: 100
Number of Monte Carlo draws per VM/week	100
Analysis type	Day-ahead (SCUC/SCED over 24-hr horizon)
Variance reduction method used	Stratified Sampling
LOLH	Ranges between 1.06 and 1.68 hrs per year across zones
Average SNAP – ERCOT level	$25.7 per MWh on average over all zones and hours
Turn-around time	~2.3 hrs
Total VM time	~113 hrs
Total VM cost	~$13 spot / ~$57 on demand rate

10,100 DA simulations

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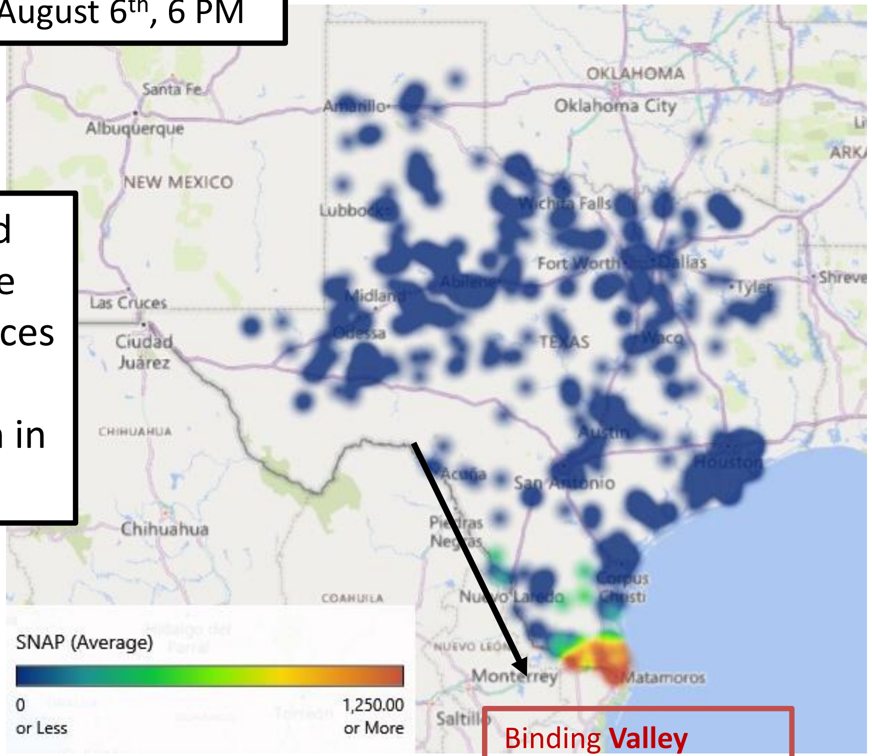
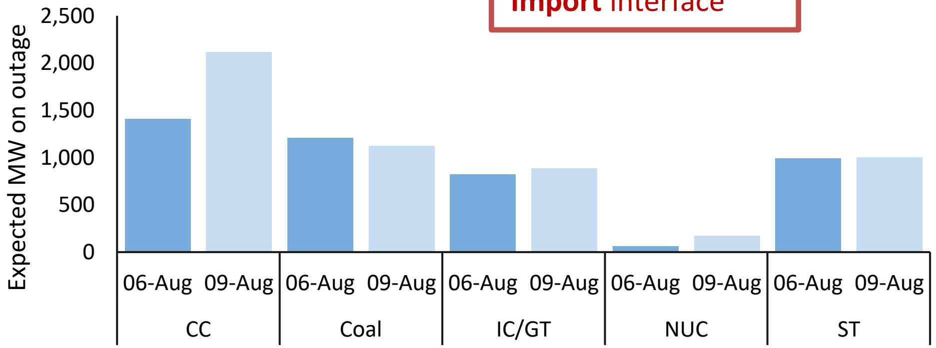
Example ERCOT Geographical results: Two different days in August

August 6th, 6 PM



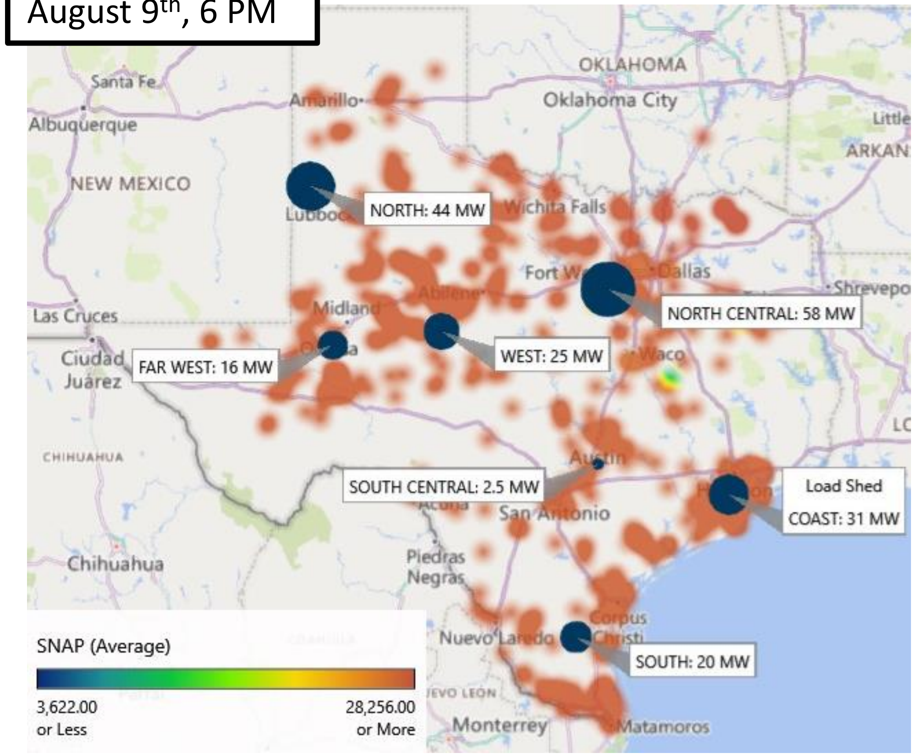
No load shed
Shortage due to excess prices caused by transmission in South

Binding **Valley Import** interface

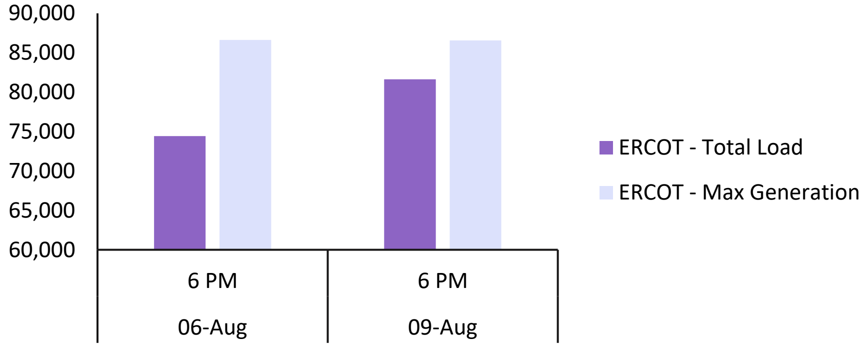


*No maintenance outages in August

August 9th, 6 PM



Load shed in all areas
SNAP high in almost all locations, except for some lower SNAP locations



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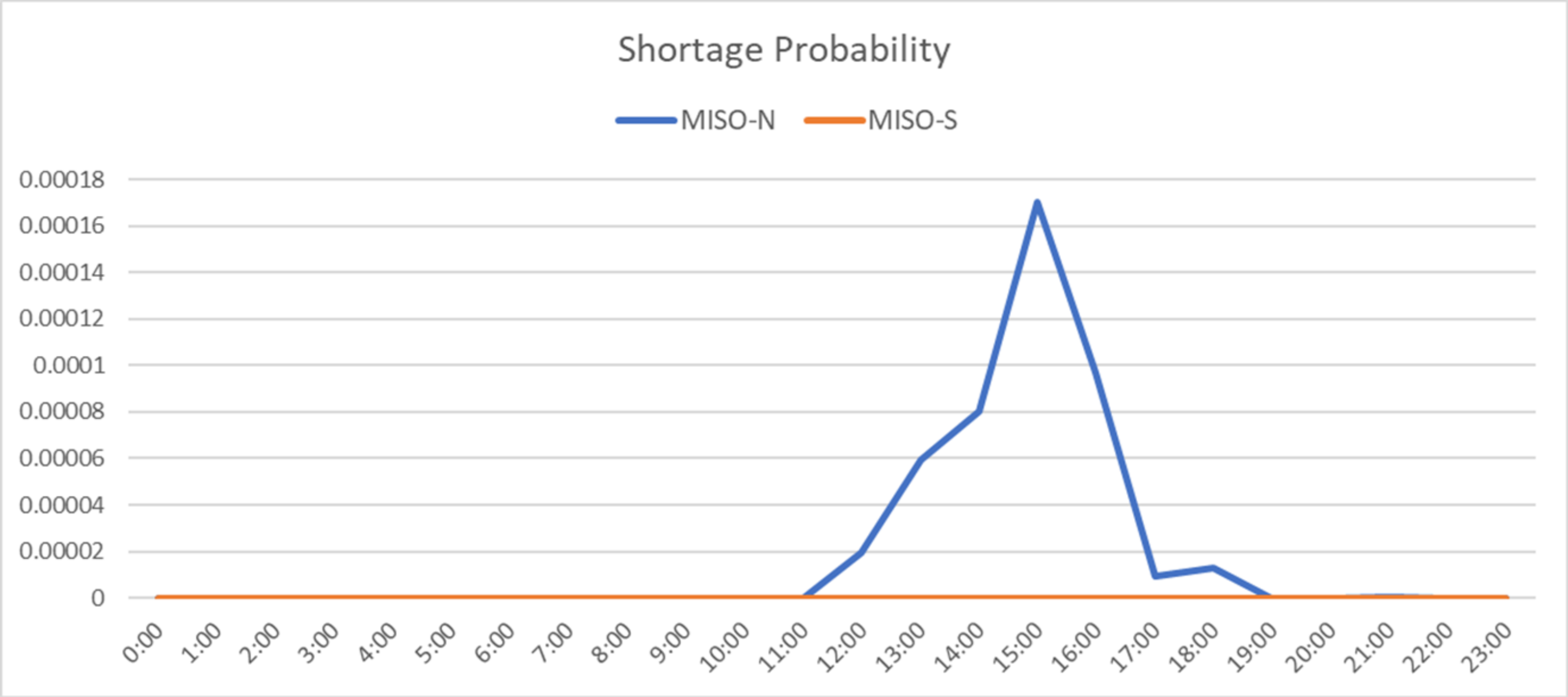
Example 2: Illustrative Retrospect Analysis for MISO. June 10, 2021



- 100 weather scenarios produced by the Weather Company/IBM x 1,000 outage draws
- Using ENELYTIX commercial MISO model and historical data assembled from public sources. Historical load data provided by MISO
- Full SCUC/SCED high-fidelity model

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Computational Performance Results: June 10, 2021

Category	Results
Number of VMs used	500
Number of Monte Carlo draws per VM	200
Analysis type	Day-ahead (SCUC/SCED over 24-hr horizon)
Variance reduction method used	Stratified Sampling
LOLH: MISO-North	0.0034 hrs per day. (Compare to 0.5 hrs per year/ 0.0014 hrs per day standard).
LOLH: MISO-South	0
Capacity payment to generators in MISO-N vs MISO-S	\$688/MW-Day vs. \$0/MW-day
Precision of the estimate	3%
Turn-around time	~45 min
Total VM time	~300 hours
Total VM cost	~\$200 On-demand / ~\$120 Spot

100.000 Stochastic Scenarios of SCUC/SCED for Entire **MISO**
500 Virtual Machines deliver solution in 45 minutes at a cost of \$200 on demand or \$120 on spot

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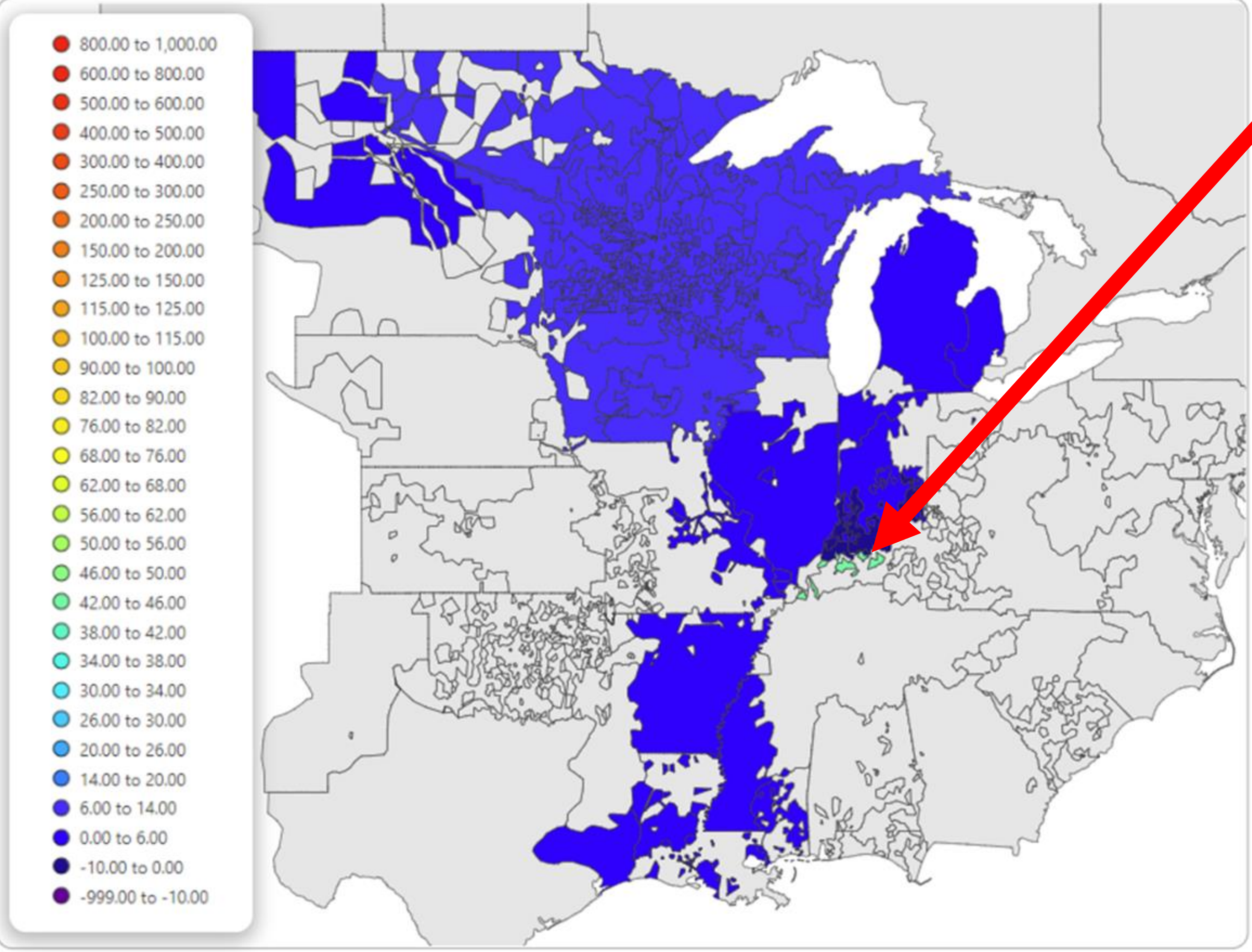
MISO Stochastic Nodal Adequacy Pricing

6/9/2021

Data Refresh Date

Datetime

Thursday, June 10, 2021 (Date) + 3:00:00 PM (Time)



Area	SNAP ($/MWh)	Shortage Probability
BREC	$45.36	0.00163
HMPL	$14.78	0.00020
GRE	$13.43	0.00011
MEC	$13.41	0.00011
NSP	$13.20	0.00011
OTP	$13.13	0.00011
SMP	$12.04	0.00010
MIUP	$12.01	9.43000E-5
UPPC	$11.96	9.43000E-5
MP	$11.90	0.00010
DPC	$11.77	9.57000E-5
WPS	$10.54	9.20000E-5
ALTW	$10.34	9.34000E-5
ALTE	$9.07	9.17000E-5
MGE	$8.48	8.94000E-5
MPW	$8.32	8.94000E-5
WEC	$7.81	8.70000E-5
CON	$5.96	7.82000E-5
MECS	$5.91	7.82000E-5
DECO	$5.87	7.82000E-5
NIPS	$5.66	7.82000E-5
CWLP	$5.40	7.82000E-5
AMIL	$4.67	7.82000E-5
IPL	$4.49	7.44000E-5
DEI	$4.27	7.54000E-5
AMMO	$3.37	4.88000E-5
SIPC	$3.16	3.49000E-5
SME	$2.75	4.83000E-5

MISO-N

$8.12

SNAP ($/MWh)

0.00017

Shortage Probability

MISO-S

$1.41

SNAP ($/MWh)

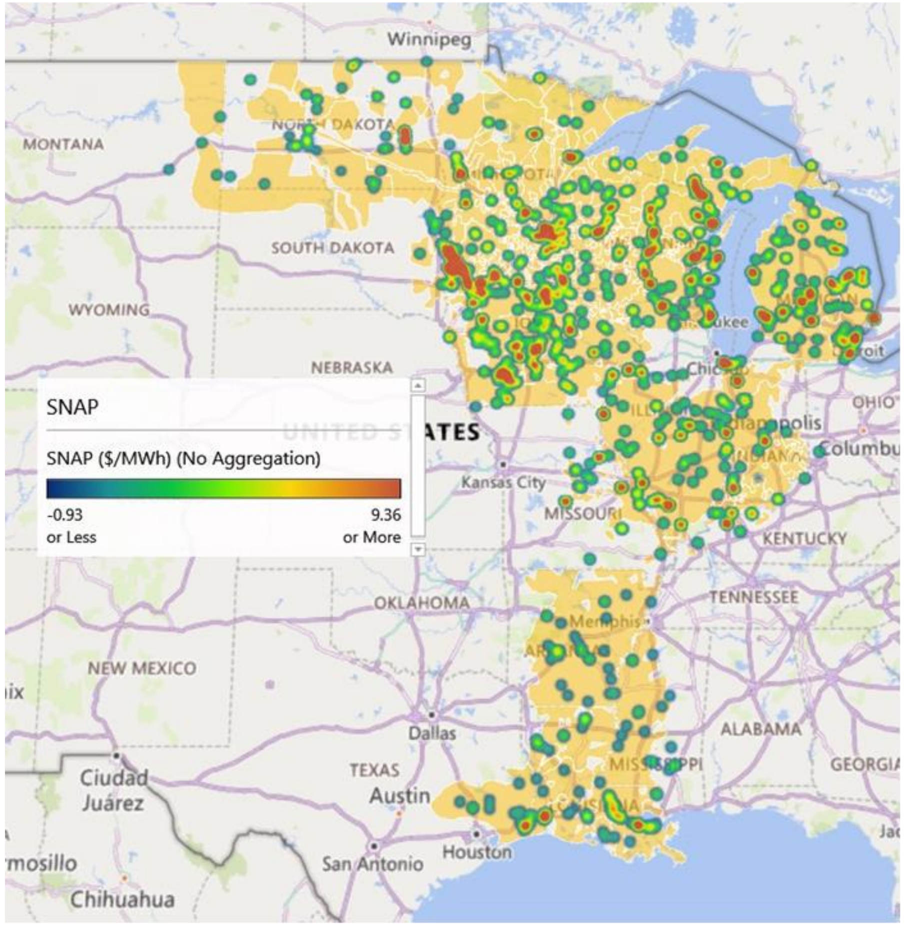
0.00000

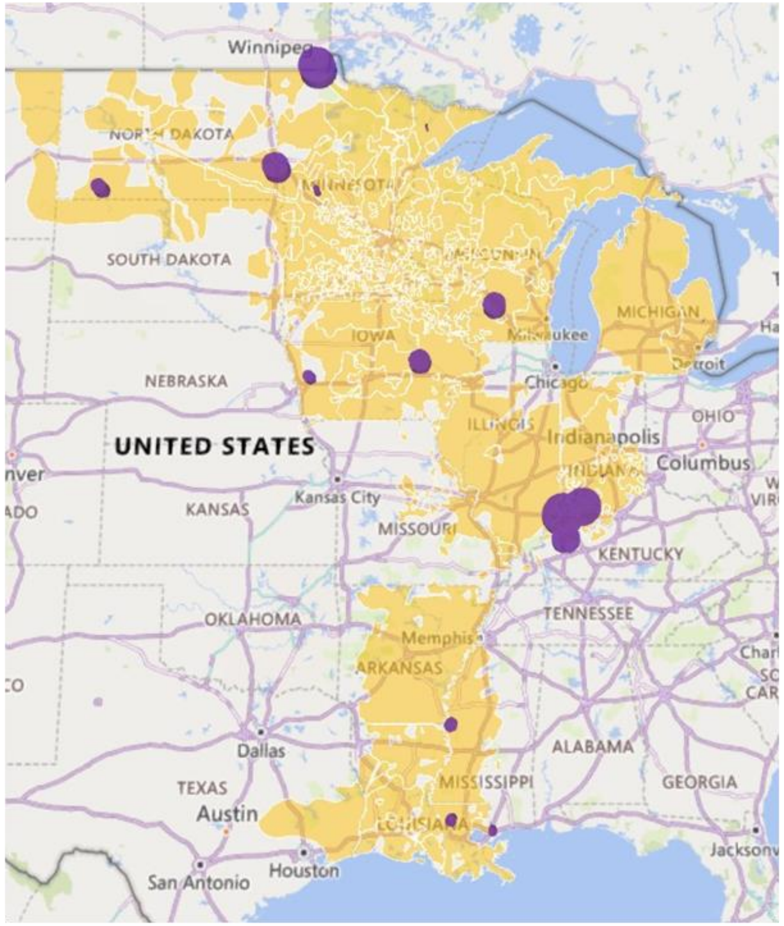
Shortage Probability

Hours with Non-Zero Shortage Probability

6/10/2021 3:00:00 PM
6/10/2021 2:00:00 PM
6/10/2021 4:00:00 PM
6/10/2021 1:00:00 PM
6/10/2021 12:00:00 PM
6/10/2021 6:00:00 PM
6/10/2021 5:00:00 PM
6/10/2021 11:00:00 AM

Daily Average SNAP June 10, 2021 with most contributing constraints





Purple bubbles show transmission congestion (bubble size is magnitude of the shadow prices)

- MISO-North shortages are much greater than MISO-South
  - *Highest SNAP values in BREC, OTP, NSP*
- Some locations have negative SNAP
- Spatial difference in SNAP levels in MISO-North due to transmission constraints
  - *Significant congestion in BREC which is the only area where load shed occurs*
  - *Binding constraints around the high SNAP NSP-OTP area*

Summary

- Resource Adequacy can be analyzed at a nodal level using high-fidelity fundamental – based models and accommodating comprehensive weather scenarios
- Could be used both for planning and operational studies
- Leveraging shared data models between production cost models, capacity expansion, and resource adequacy models
- Flexible level of detail for the underlying physical model
- The same methodology is applicable to differently defined extreme market events

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