STOCHASTIC NODAL ADEQUACY PRICING (SNAP) PLATFORM

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Traditional Probabilistic Resource Adequacy Assessment vs. SNAP

Traditional RAs

- Performed annually for future year(s)
- Use long-term forecast of weather conditions and load
- Run 1,000s Monte Carlo scenarios combining generation outages with a few dozen weather year scenarios
- Rely on highly stylized models of power systems:
  - *Ignore most operational constraints and contingencies*
  - *Rely on pipes and bubble transmission models that ignore Kirchhoff Voltage Law*
- Translate RA assessments into installed capacity requirements based on outdated metrics that do not have economic justification and not suitable for modern power systems
- Offer no metrics for assessing contribution of transmission to RA and make it virtually impossible to co-optimize generation and transmission investments
- Use the above to justify billions of $$ investments and cost recovery

SNAP

- Performed daily for the next 1 -3 – 5 days
- Relies on modern weather science and technology to generate 100+ probabilistic short-term weather forecasts (PFs) and uses probabilities that can be empirically validated
- Runs 10,000 – 100,000 Monte Carlo scenarios combining PFs with generation *and* <u>*transmission*</u> <u>outages</u>
- Relies on validated models of the MMS level of details that
  - *use SCUC to factor in operational constraints and perform contingency analysis*
  - *Run SCOPF on physical network models*
- Evaluates and monetizes contribution of each generation, demand-side and transmission asset to system adequacy
- Sends nodal economic signal to investors in generation, transmission and demand resources
- Effectively provides spot pricing for adequacy that is consistent with the physics of the system

Probabilistic Weather is a Primary Contingency

Creating a Probabilistic Weather Forecast

1. IBM/ The Weather Company utilizes 87 different numerical weather prediction models (and their ensemble members) as inputs to their forecast system
2. Ensemble members are generated by varying assumptions about initial conditions and model physics. Ensembles in their raw form tend to be biased, and under-dispersive
3. Corrects the raw ensemble member data using Bayesian model averaging to adjust for systematic errors (bias correction), and calibrate the distributions for each output variable individually (spread the dispersion)
4. Rearranges the individual values into the rank order structure of the raw ensemble to create 100 synthetic weather system scenarios through use of Ensemble Copula Coupling–Quantile technique

- The result is a probabilistic forecast wherein each of one hundred scenarios is equally likely
  - The predicted outcomes have been "spread" to deal with under-dispersion in the underlying weather models
  - The variables are internally consistent with each other in space and time (preserved the correlations among variables by preserving the weather system dependence template)
- Probabilistic forecasts are created on demand for hourly time steps out 15 days for any location.
  - Algorithms used to create synthetic probabilistic forecasts for hub height winds and solar from available probabilistically forecast parameters

“Prototype” Weather Scenarios

A probabilistically calibrated ensemble

On-demand set of calibrated, equally-likely ”prototype” forecast scenarios for quantifying risk, uncertainty, or expected value in impact and outcome models.

Multi-model Ensemble Forecasts

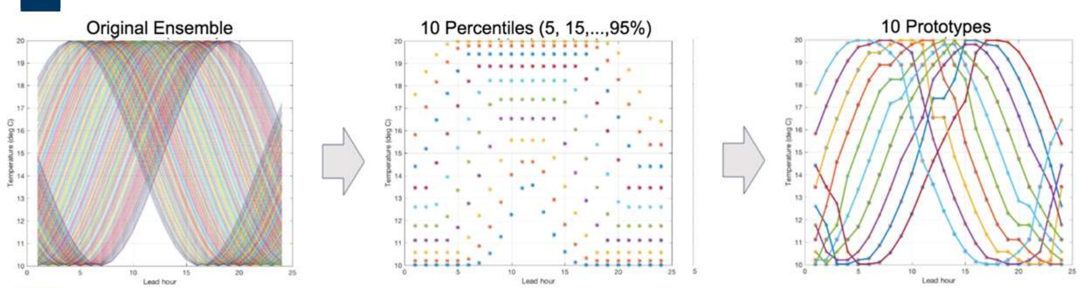
Forecast Error Archive

→ **Remove Systematic Errors**

→ **Calibrate Probability Distributions** for each variable and location using Bayesian Model Averaging

→ **Ensemble Copula Coupling-Quantile***

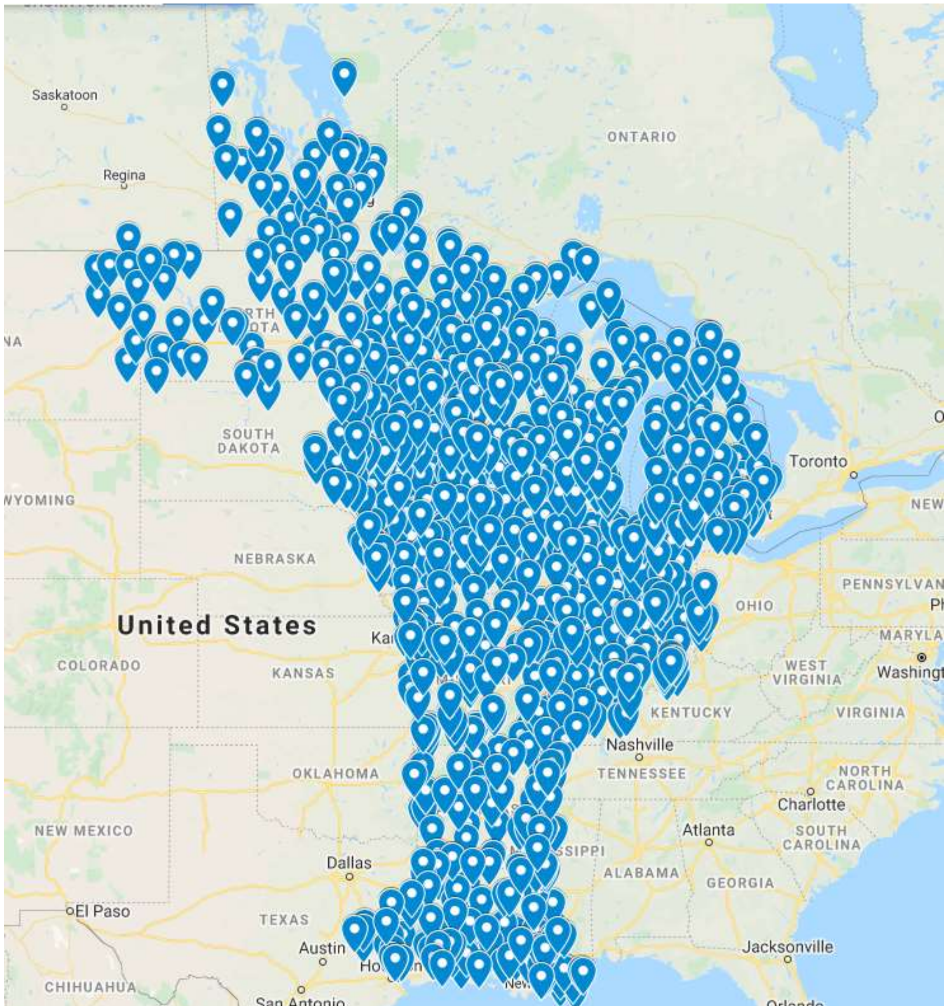
→ **Prototype Weather Scenarios**



* Schefzik et al., *Statistical Science,* 2013
Bouallègue et al., *MWR,* 2016

Calibrated Weather Scenarios → Impact Scenarios

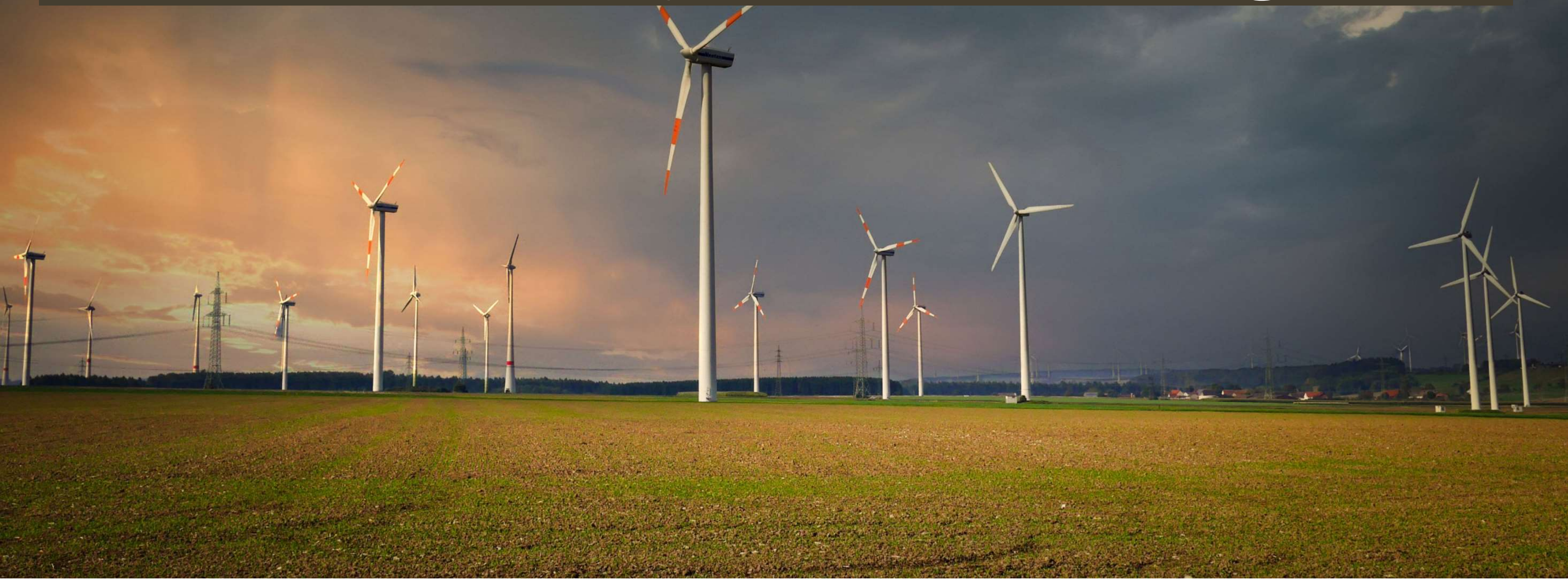
Weather Data Locations



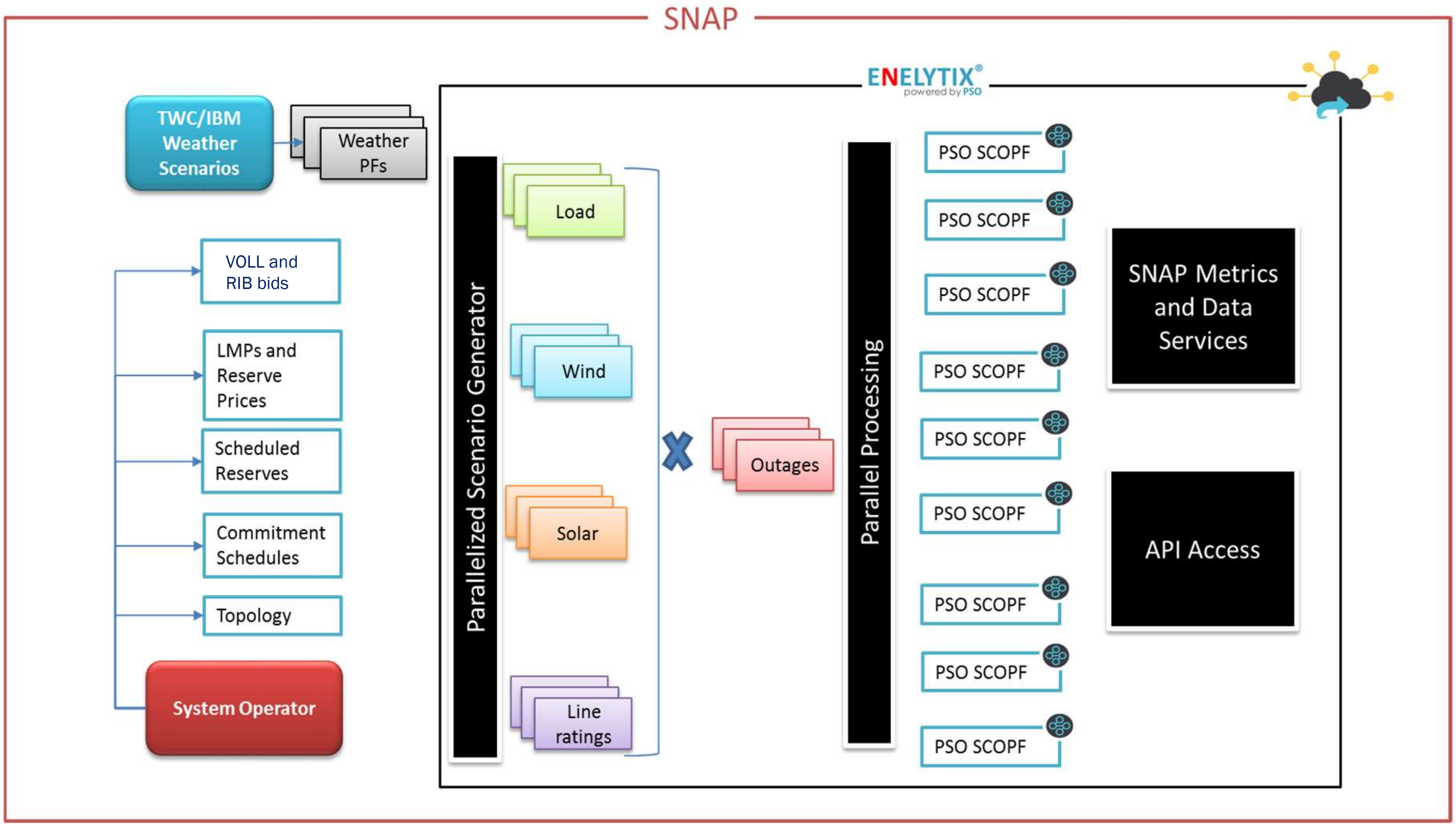
Over 2000 locations within MISO covering

- METAR weather stations
- Wind sites
- PV sites
- Cities and towns with population of 20,000 or more

SNAP Combines Weather Science with Power Systems Engineering and Economics Enhanced by Cloud Computing



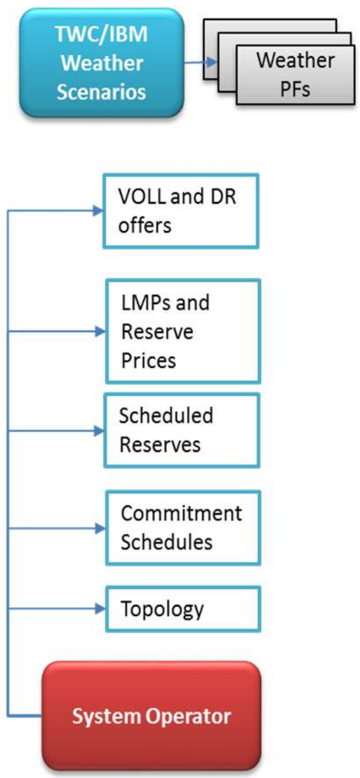
SNAP Schematics



SNAP will be continuously reassessing system adequacy both physically and economically

Calculation of SNAP: The Steps #1

SNAP



Flow of information into SNAP will be regularly updated -- at least daily or more frequently

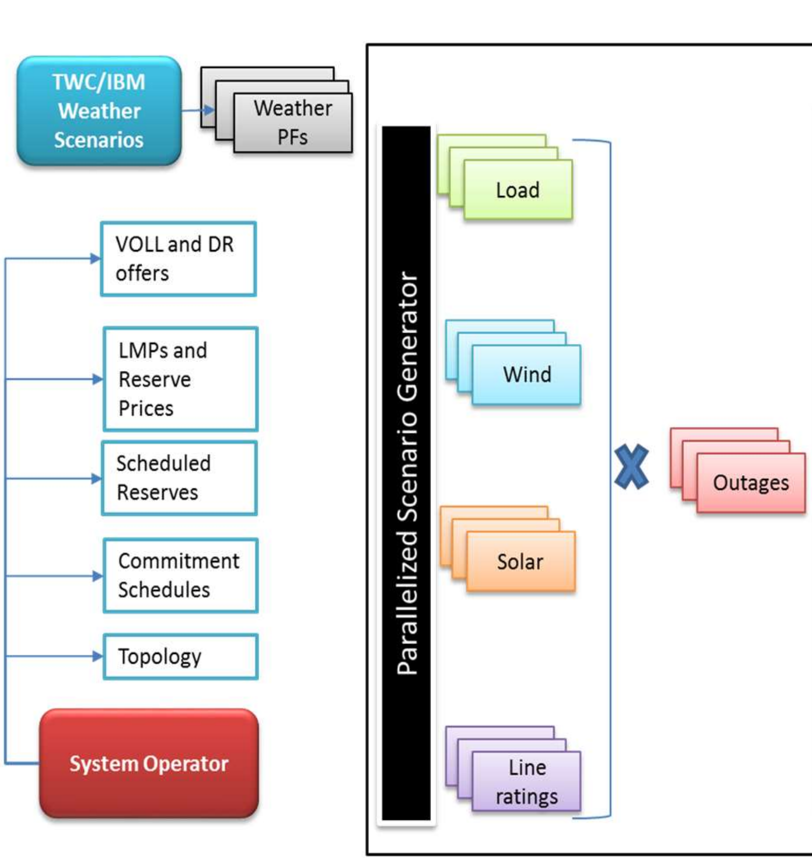
Each Weather PF includes 100 fully *comprehensive* 3D weather scenarios with 1 hour time step and 4 x 4 km spatial granularity

SNAP plays out 100 weather scenarios capturing all temporal and spatial correlations of weather and renewable resource

Concurrently, SNAP accumulates information about the state of the electrical grid and key planning/scheduling decisions for the next 24 - 144 hours

Calculation of SNAP: The Steps #2

SNAP



SNAP translates weather scenarios into

- granular load scenarios
- unit-specific wind and solar output scenarios
- transmission line rating scenarios

Each weather scenario is paired against

- Generation outage scenarios
- Transmission outage scenarios

produced using traditional Monte Carlo methods

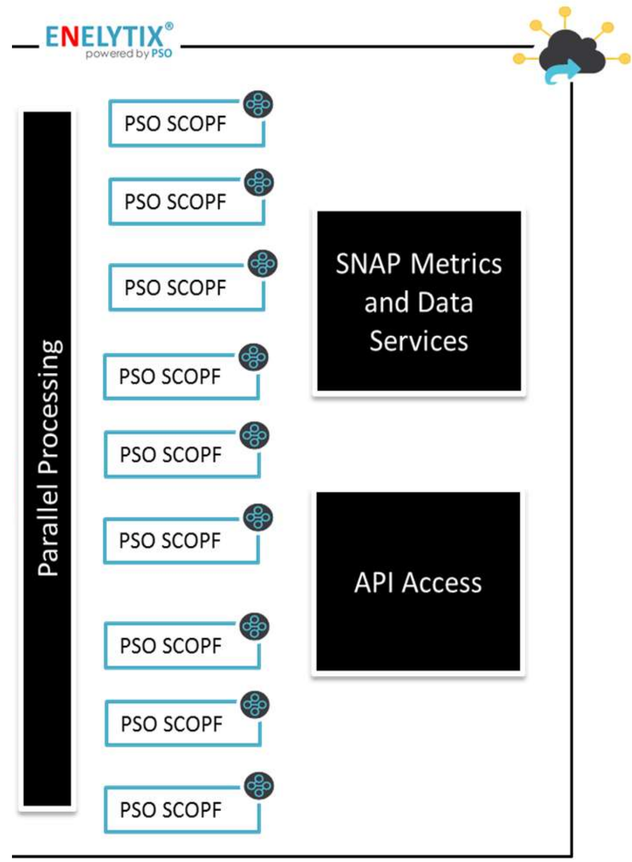
Calculation of SNAP: The Steps #3

SNAP

Scenario inputs focusing on the next 24 – 144 hours of system operation will perform specific SCUC and SCOPF calculations to

- assess system adequacy at the nodal level and
- Compute hourly payments
    - by loads
    - to resources

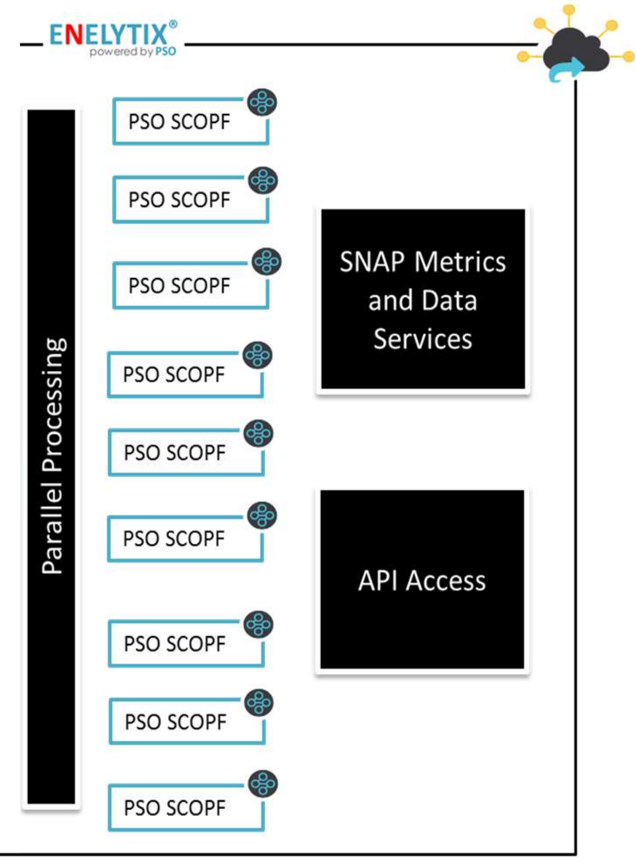
Resources eligible for payments include
-- generators and demand side resources which submitted offers to supply energy or reduce demand to the DA market
-- transmission facilities
-- advanced technology solutions supporting system adequacy (e.g. smart devices, topology control)



Calculation of SNAP: The Steps #4

SNAP

SCOPF calculations:
Objective Function: minimize production (bid/offer) cost of unserved load at VOLL
Generators offers as submitted Day-ahead
Reliability Interruption Bids (RIBs) at offer levels as submitted into DA market (presumably below VOLL)
SCOPF: 100,000+ Monte Carlo scenarios played out for each hour
-- **If no inadequacy events occurs,** scenario is noted. Scenario Nodal Adequacy Price (SNAP) is effectively zero at all locations
-- **if an inadequacy event occurs,** the event sets SNAP value at VOLL or RIB at inadequacy location. SNAP for all other locations is set using standard shadow price mathematics



Calculation of SNAP: The Steps # 5

SNAP

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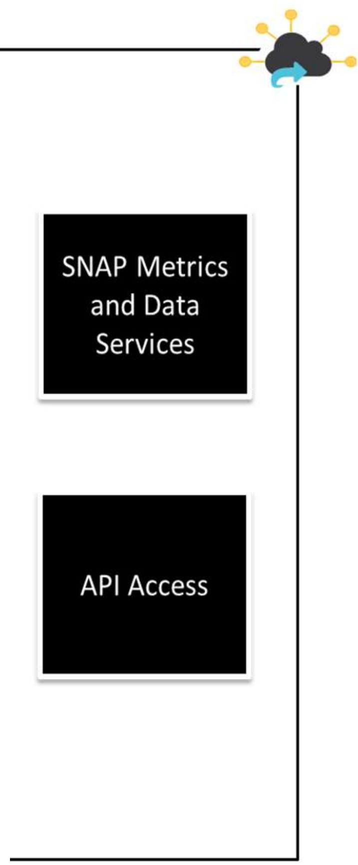

Summary Metrics:

Area level: EUE, LOLH, LOLE, Marginal Unserved Energy

Nodal Level:

Adequacy Price (AP) – expected value of SNAP at each location

Resource Adequacy Payment (RAP) expected adequacy revenues (SNAP x MW delivered) accrued to the resource

Load Adequacy Payment (LAP) – expected cost of serving load (SNAP x served MW)

Transmission Adequacy Payment (TAP) – expected value of adequacy flows (delta SNAP x MW flow) of a transmission facility

Adequacy Rent – the non-negative difference between the sum of all load payments and the sum of all resource receipts

Adequacy Rent equals the sum of all TAPs

Other nodal adequacy metrics specific for variable resources, storage, advanced transmission technologies (topology control, dynamic line rating) and demand resources

Anticipated Benefits of SNAP

- **Long-term benefits:** saving in investments costs in generation and transmission
- **Short-term benefits:** reduced cost in scheduling operating reserves temporarily and locationally

For more information about SNAP

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  - *Contact Russ Philbrick*