SERVM
Strategic Energy Risk Valuation Model

Astrape Consulting

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Topics

- **Resource Adequacy Overview**
- **SERVM Model Overview**
- **Reserve Margin Study (2013)**
- **Renewable Integration Study (2015)**
  - Effective Load Carrying Capability
  - Flexibility Study
  - Integration Costs

Resource Adequacy Overview

Resource Adequacy

- **Resource Adequacy Definition: The ability of supply-side and demand-side resources to meet the aggregate electrical demand (NERC Definition)**
- **Resource Adequacy Studies**
  - **<u>Reserve Margin Study</u>**
    - Goal: Calculate generating capacity deficiencies and determine the amount of capacity needed to maintain resource adequacy during peak conditions
    - Purpose: Input into expansion planning processes
  - **<u>Effective Load Carrying Capability Study</u>**
    - Goal: Determine the capacity contribution of intermittent resources
    - Purpose: Necessary to calculate the system reserve margin
  - **<u>Flexibility Study</u>**
    - Goal: Determine reliability deficiencies including both firm load shed events and renewable resource curtailment due to system ramping/startup constraints (not capacity deficiencies)
    - Purpose: Provides assistance in setting appropriate parameters for resource additions and to determine system operating reserve requirements
  - **<u>Integration Cost Study</u>**
    - Goal: Determine incremental system costs caused by adding intermittent resources
    - Purpose: Used in capacity procurements and in resource selection processes

Resource Adequacy Metrics

- **Loss of Load Expectation ($LOLE_{CAP}$):** Expected number of firm load shed events in a given year due to capacity shortfalls
- **Loss of Load Expectation ($LOLE_{FLEX}$):** Expected number of firm load shed events in a given year due to not having enough ramping capability

- **Loss of Load Hours ($LOLH_{CAP}$):** Expected number of hours of firm load shed in a given year due to capacity shortfalls
- **Loss of Load Hours ($LOLH_{FLEX}$):** Expected number of hours of firm load shed in a given year due to not having enough ramping capability

- **Expected Unserved Energy (EUE_{CAP}):** Expected amount of firm load shed in MWh for a given year due to capacity shortfalls
- **Expected Unserved Energy (EUE_{FLEX}):** Expected amount of firm load shed in MWh for a given year due to not having enough ramping capability

SERVM Model Overview

Strategic Energy Risk Valuation Model (SERVM)

- **SERVM has over 30 years of use and development**
- **Probabilistic hourly and intra-hour chronological production cost model designed specifically for resource adequacy and system flexibility studies**
- **SERVM calculates both resource adequacy metrics and costs**

SERVM Uses

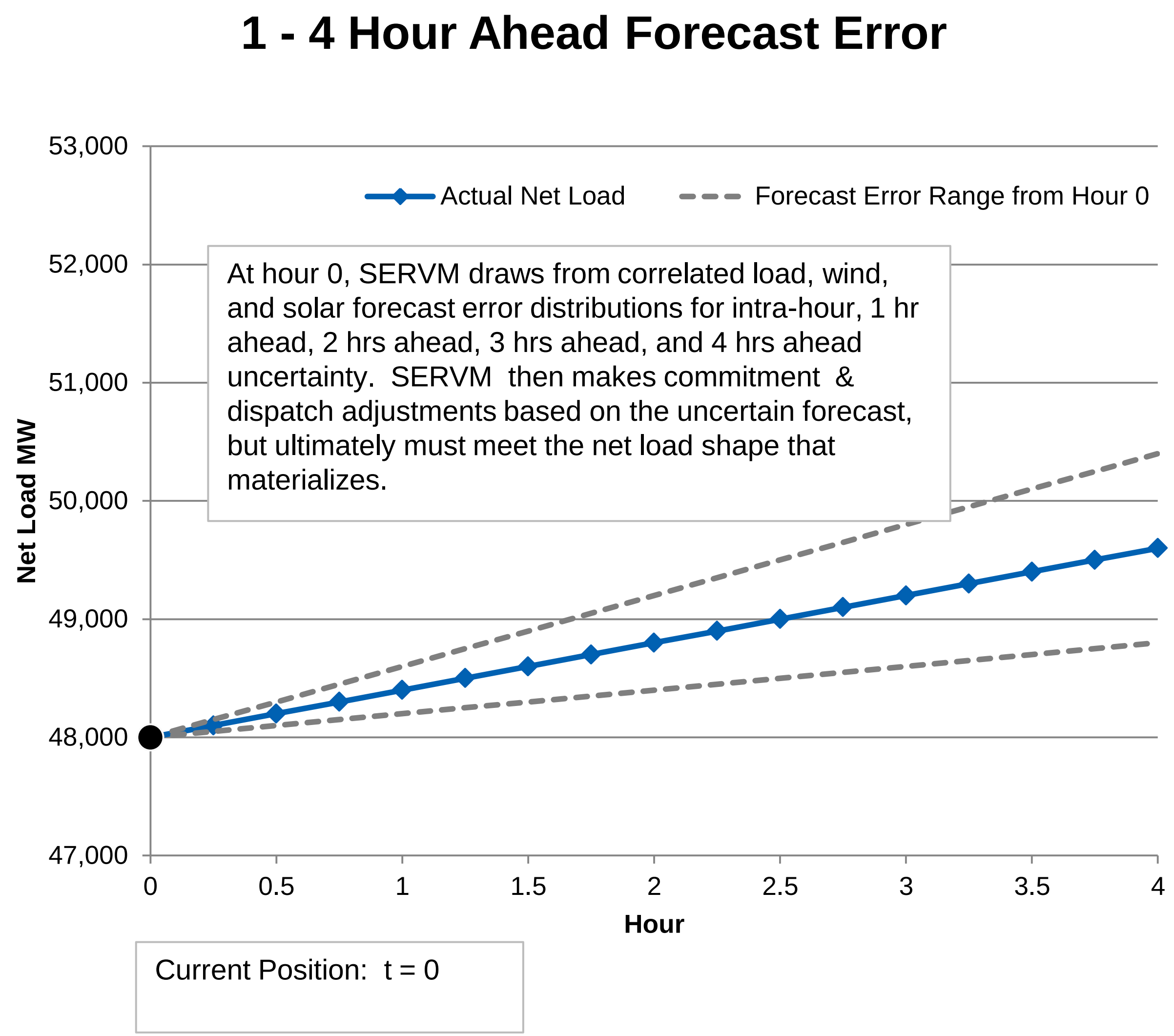
- **Resource Adequacy**
  - Loss of Load Expectation Studies
  - Optimal Reserve Margin
  - Operational Intermittent Integration Studies
    - Penetration Studies
    - System Flexibility Studies
  - Effective Load Carrying Capability of Energy Limited Resources
    - Wind/Solar
    - Demand Response
    - Storage
  - Fuel Reliability Studies
    - Gas/Electric Interdependency Questions
    - Fuel Backup/Fixed Gas Transportation Questions
  - Transmission Interface Studies
- **Resource Planning Studies**
  - Market Price Forecasts
  - Energy Margins for Any Resource
  - System Production Cost Studies
  - Evaluate Environmental/Retirement Decisions
  - Evaluate Expansion Plans

Resource Commitment and Dispatch

- **8760 Hourly Chronological Commitment and Dispatch Model**
- **Simulates 1 year in approximately 1 minute allowing for thousands of scenarios to be simulated which vary weather, load, unit performance, and fuel price**
- **Capability to dispatch to 1 minute interval**
- **Respects all unit constraints**
  - Capacity maximums and minimums
  - Heat rates
  - Startup times and costs
  - Variable O&M
  - Emissions
  - Minimum up times, minimum down times
  - Must run designations
  - Ramp rates
- **Simulations are split across multiple processors linked up to the SQL Server**

Resource Commitment and Dispatch

- **Commitment Decisions on the Following Time Intervals allowing for recourse**
  - Week Ahead
  - Day Ahead
  - 4 Hour Ahead, 3 Hour Ahead, 2 Hour Ahead, 1 Hour Ahead, and Intra-Hour
- **Load, Wind, and Solar Uncertainties at each time interval (decreasing as the prompt hour approaches)**
- **Benchmarked against other production models such as PROSYM**



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Ancillary Service Modeling

- **Ancillary Services Captured**
  - Regulation Up Reserves
  - Regulation Down Reserves
  - Spinning Reserves
  - Non Spinning Reserves
  - Load Following Reserves
- **Co-Optimization of Energy and Ancillary Services**
  - Each committed resource is designated as serving energy or energy plus one of the ancillary services for each period

SERVM Framework

- **Base Case Study Year**
  - Weather (35 years of weather history)
    - Impact on Load
    - Impact on Intermittent Resources
  - Economic Load Forecast Error (distribution of 5 points)
  - Unit Outage Modeling (thousands of iterations)
    - Multi-State Monte Carlo
    - Frequency and Duration

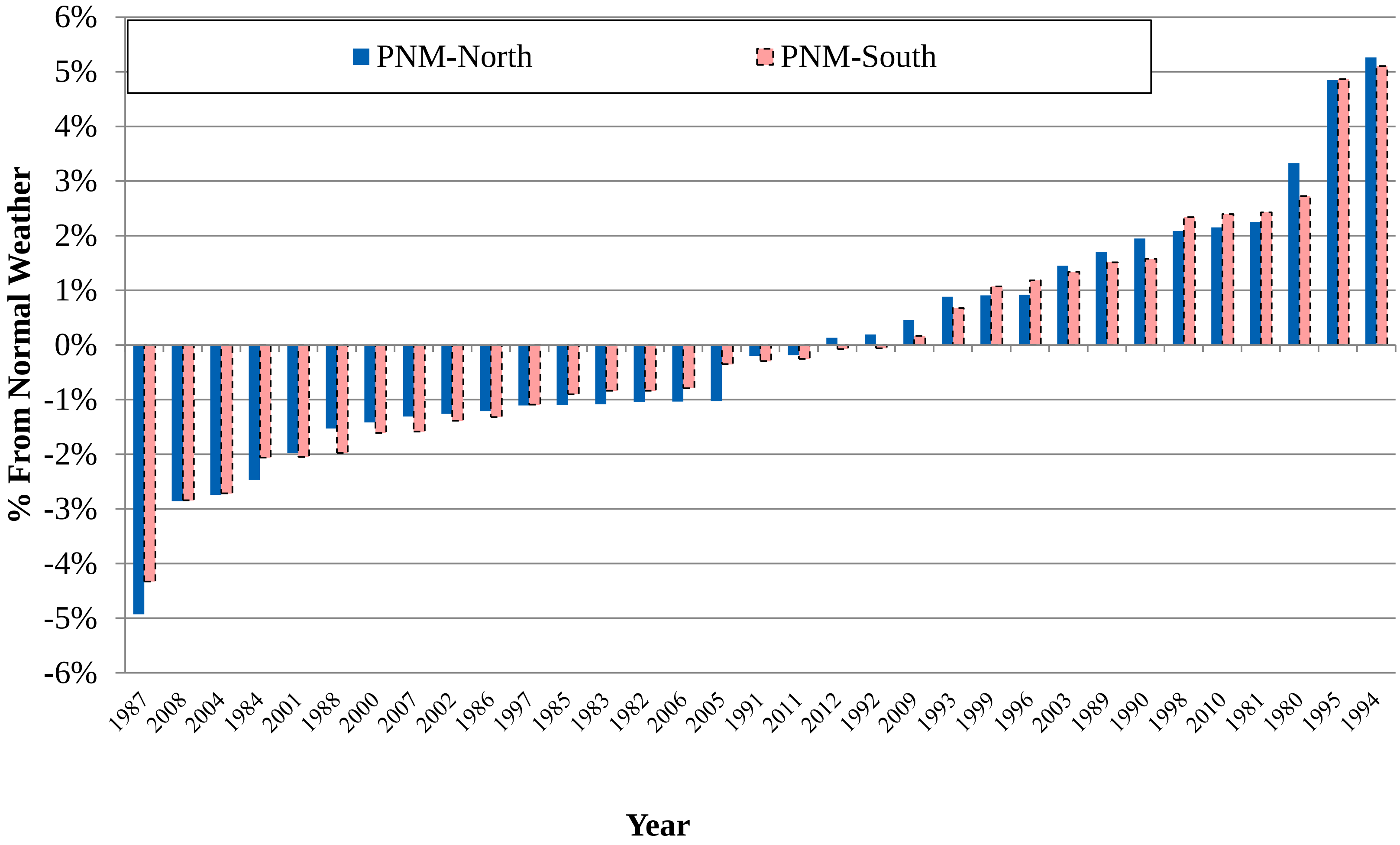
- Base Case Total Scenario Breakdown: 35 weather years x 5 LFE points = 185 scenarios
- Base Case Total Iteration Breakdown: 185 scenarios * 100 unit outage iterations = 18,500 iterations

- Reserve Margin Study/ELCC Study: Hourly Simulations
- Flexibility and Integration Cost Studies: Intra Hour Simulations

Reserve Margin Study (2013)

Load Modeling: Summer Peak Weather Variability

2013 Reserve Margin Study



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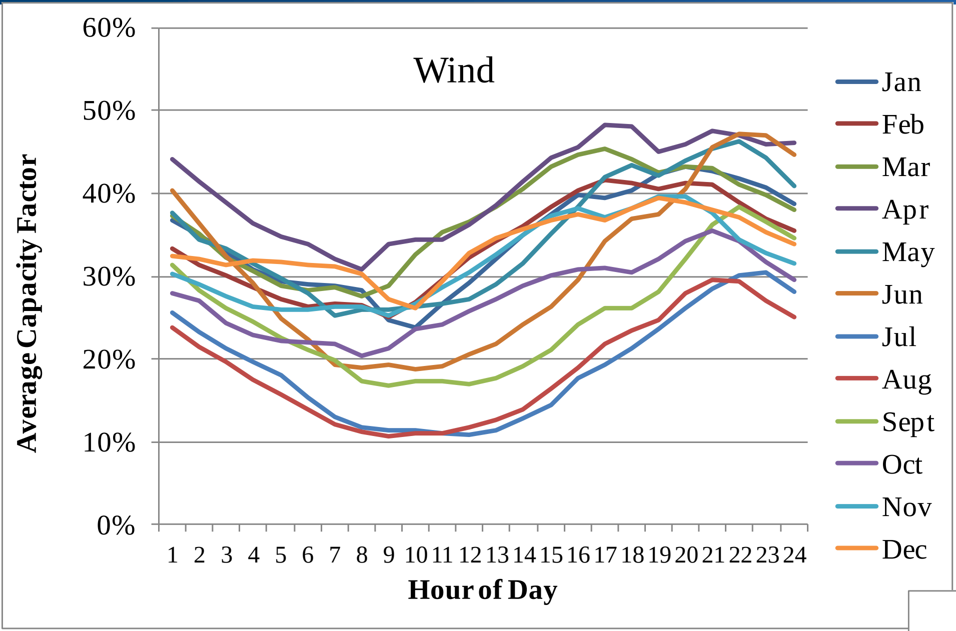
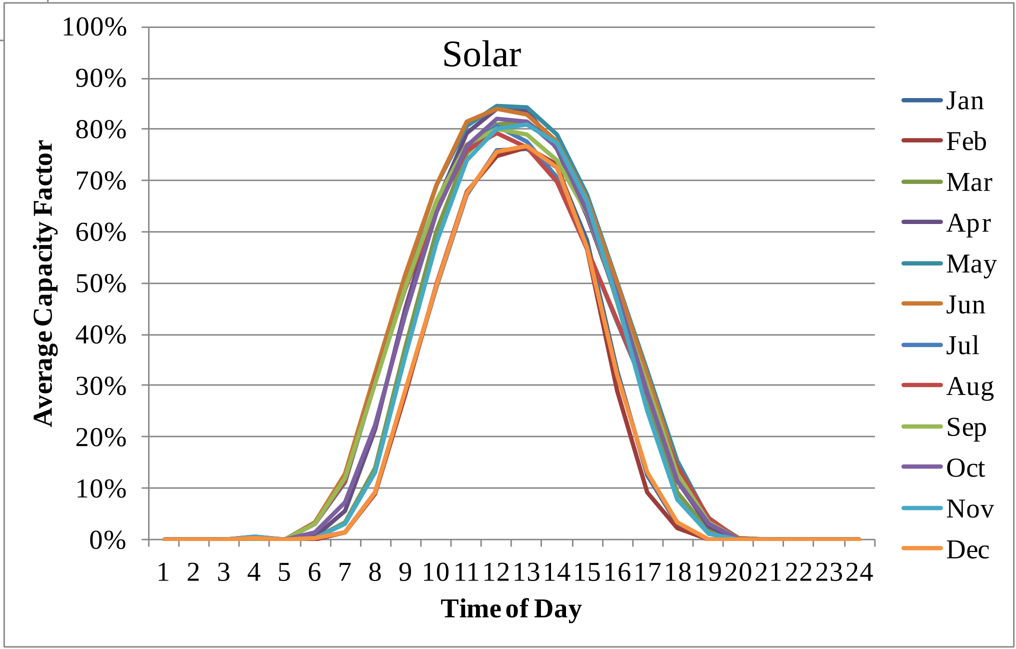
visibility. profitability. execution.

Renewable Shapes: 30 + Years

2013 Reserve Margin Study





Economic Load Forecast Error

2013 Reserve Margin Study

Using CBO GDP approach and assuming 30% multiplier for electric load growth compared to GDP growth

Load Forecast Error Multipliers	Probability %
0.95	2.7%
0.97	14%
0.99	23.8%
1.00	19.1%
1.01	23.8%
1.03	14%
1.05	2.7%

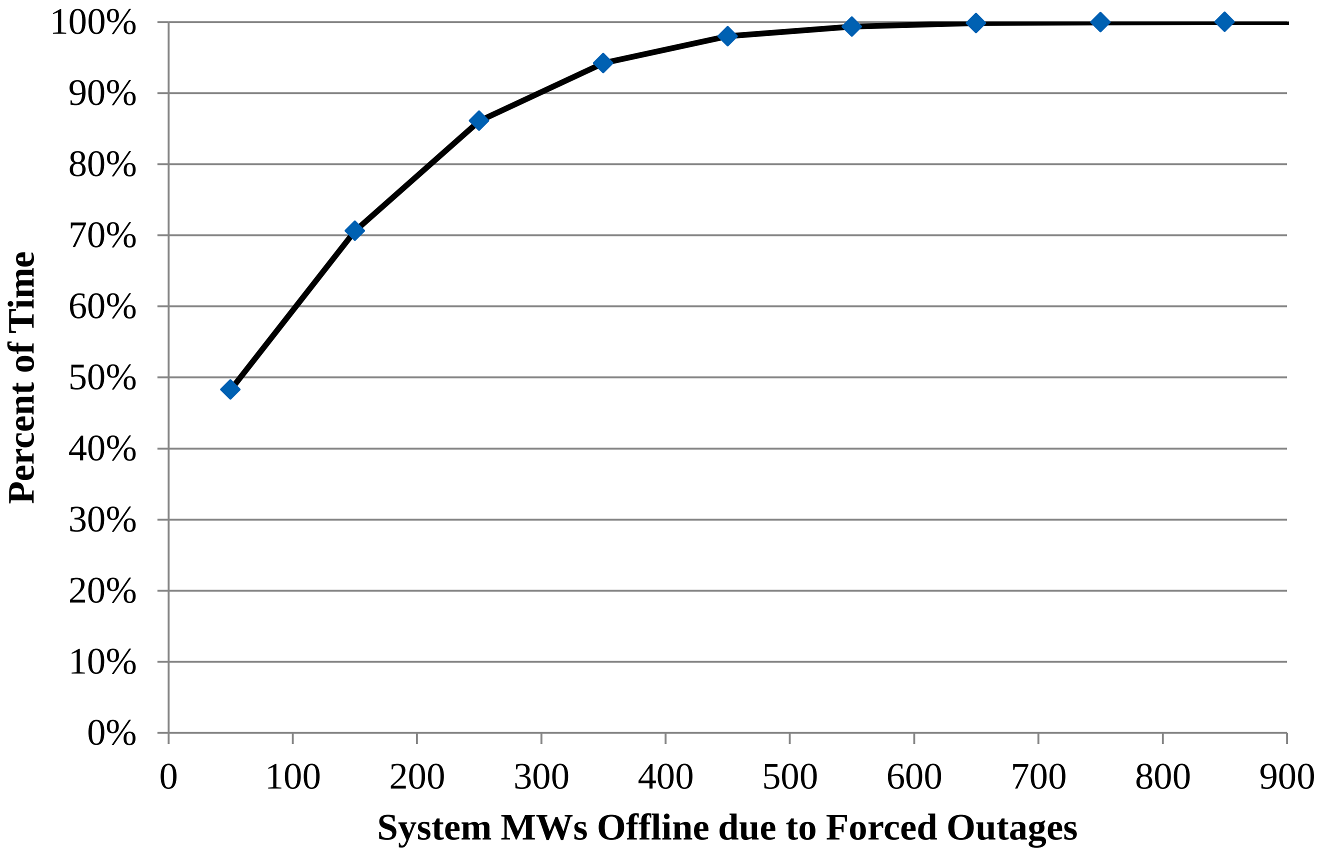
Unit Outage Modeling

- **Full Outages**
  - Time to Repair
  - Time to Failure
- **Partial Outages**
  - Time to Repair
  - Time to Failure
  - Derate Percentage
- **Startup Failures**
- **Maintenance Outages**
- **Planned Outages**
- **Created Based on NERC GADS Data**

System Forced Outages

2013 Reserve Margin Study

- **Multi State Frequency and Duration Modeling vs Convolution**



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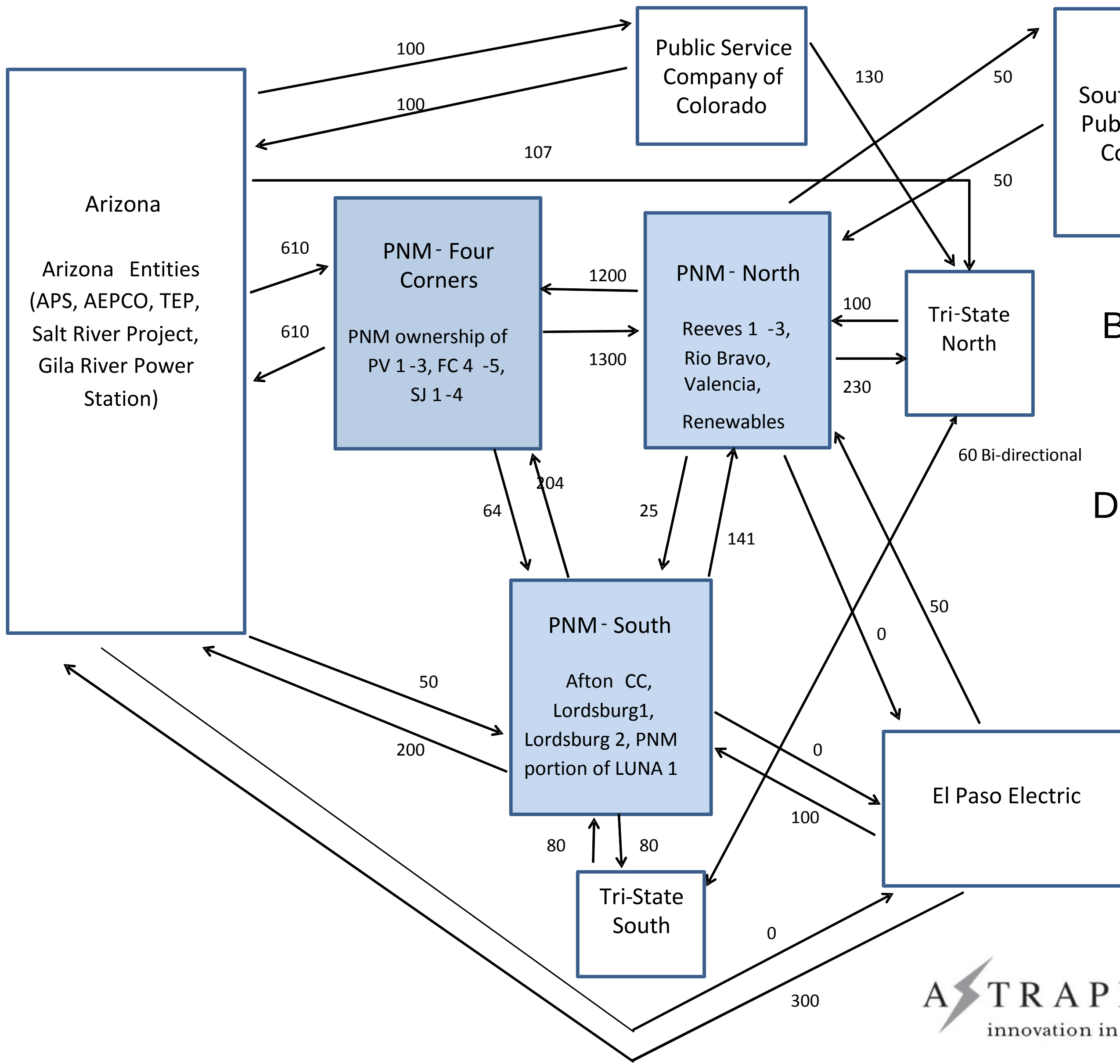
Study Topology and Market Assistance

2013 Reserve Margin Study



BA = PNM + Tri-State Regions

Committed and Dispatched as a single region

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Emergency Operating Procedures

2013 Reserve Margin Study

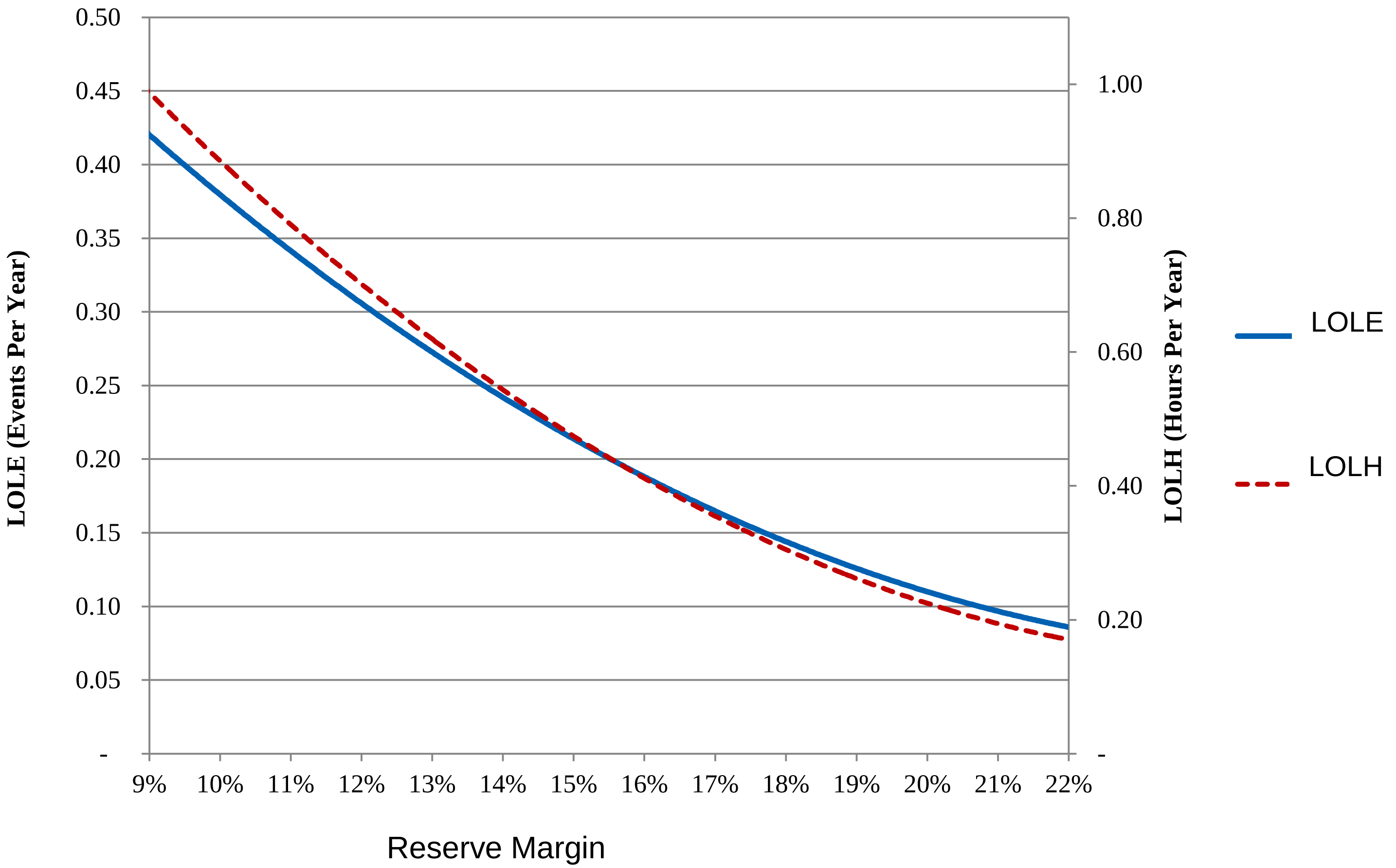
- Demand Response

	Power Saver Program	Peak Saver Program
Capacity (MW)	45	20
Season	June-Sept	June-Sept
Hours Per Year	100	100
Hours Per Day	4	6

- Firm load shed to maintain reserves equal to 4% of load

$LOLE_{CAP}$ and $LOLH_{CAP}$ Results

2013 Reserve Margin Study



Events averaged 2 hours

Industry Standard: 1 day in 10 year standard = 0.1 LOLE = 21% reserve margin

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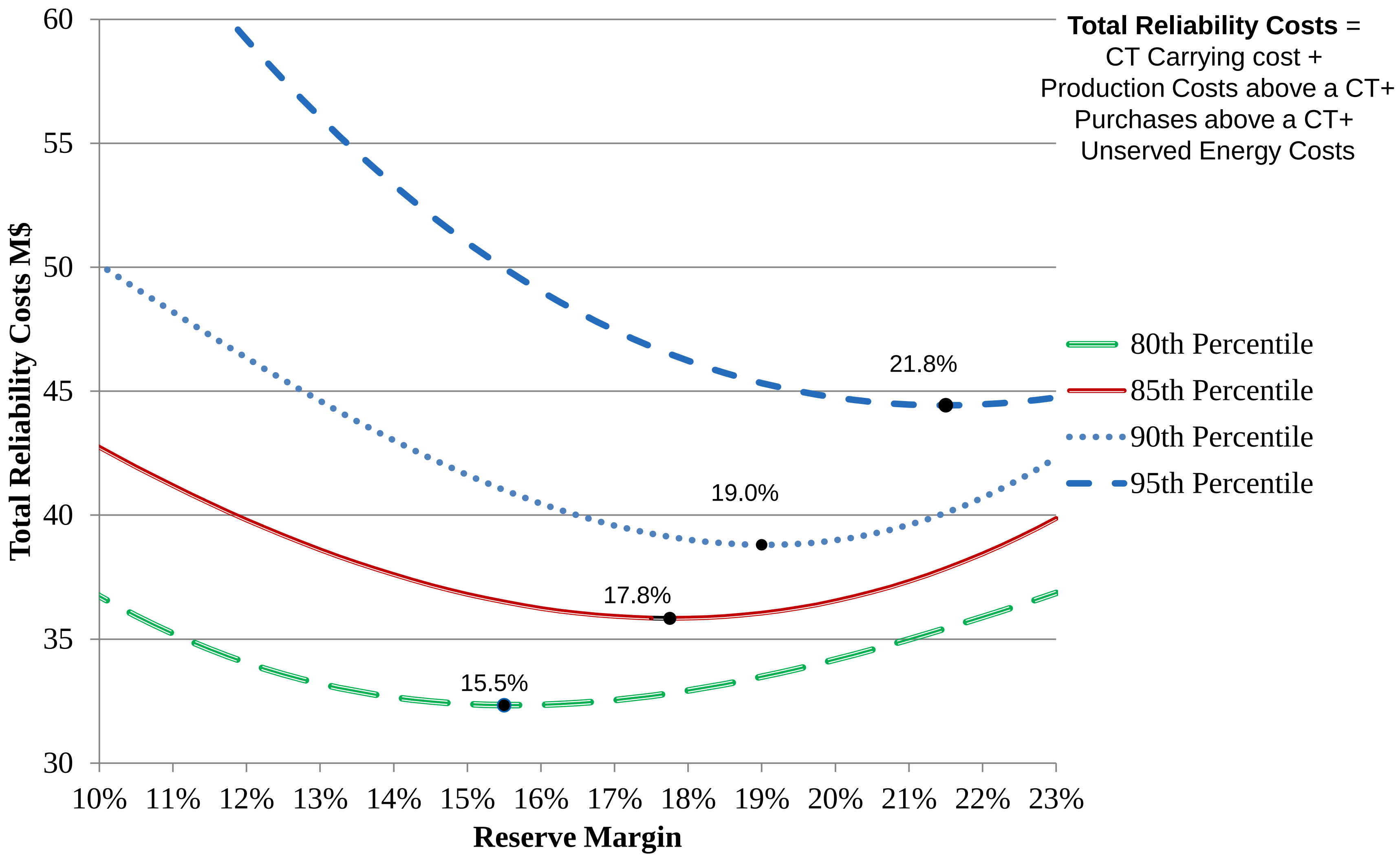
Economic Optimal Reserve Margin

2013 Reserve Margin Study



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Renewable Integration Study: Effective Load Carrying Capability Study

Incremental Effective Load Carrying Capability

Generic Example Only

- **Simulate Base Case:**
  - $LOLE_{CAP}$ = .20
- **Add 50 MW Incremental Wind**
  - $LOLE_{CAP}$ = .19
- **Add 50 MW GT Capacity**
  - $LOLE_{CAP}$ = .15
- **Wind Resource reduced LOLE by 0.01 while GT resource reduced LOLE by .05**
- **ELCC = .01/.05 = 20%**
- **Incremental ELCC can also be approximated by calculating average output during EUE events.**
- **Average ELCC is calculate by removing entire wind portfolio and then adding it back to understand its LOLE reduction compared to GT Resources**

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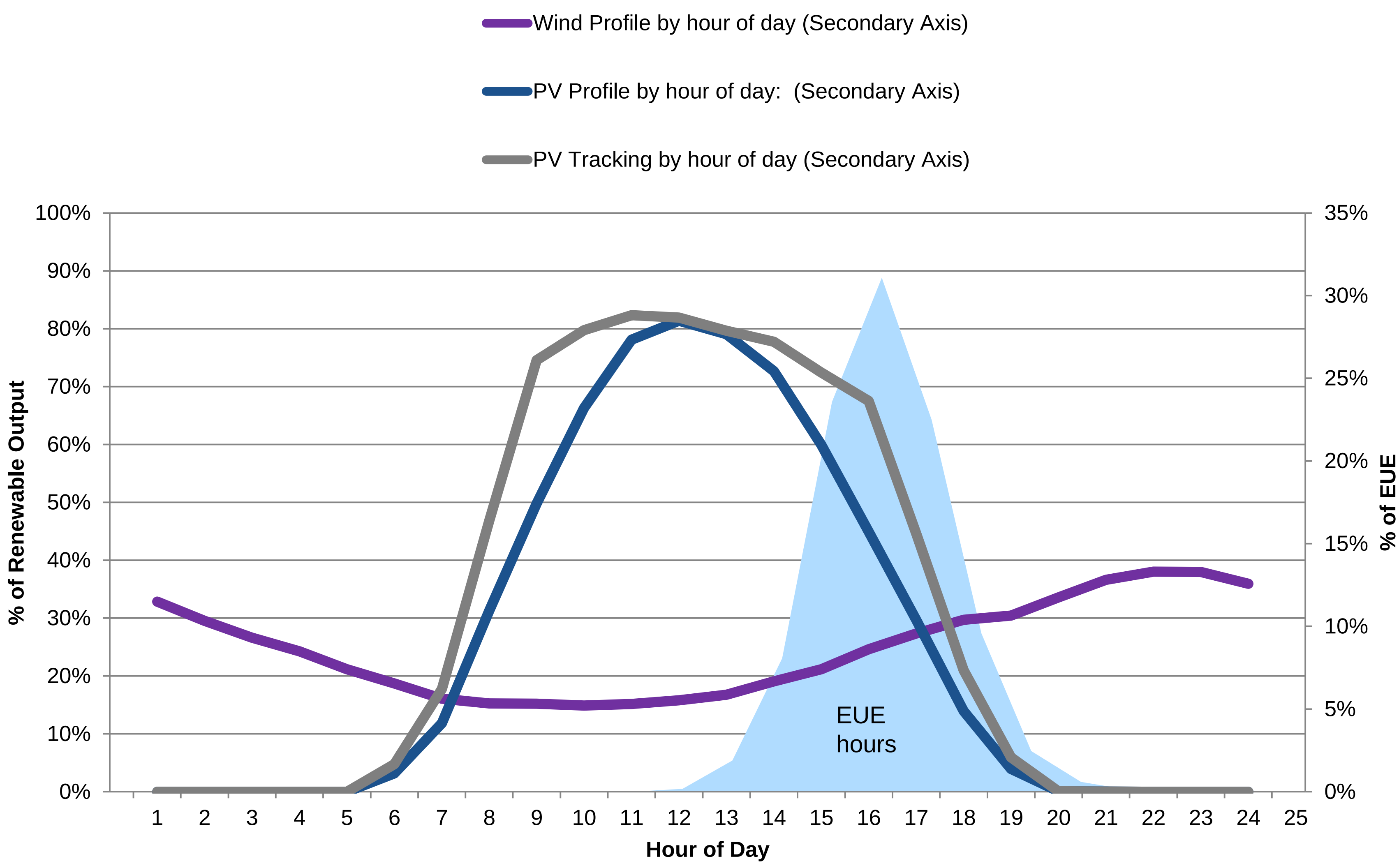
EUE and Renewable Profiles by Hour of Day

2015 RIS Study



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2018/2023 Average and Incremental ELCC Values

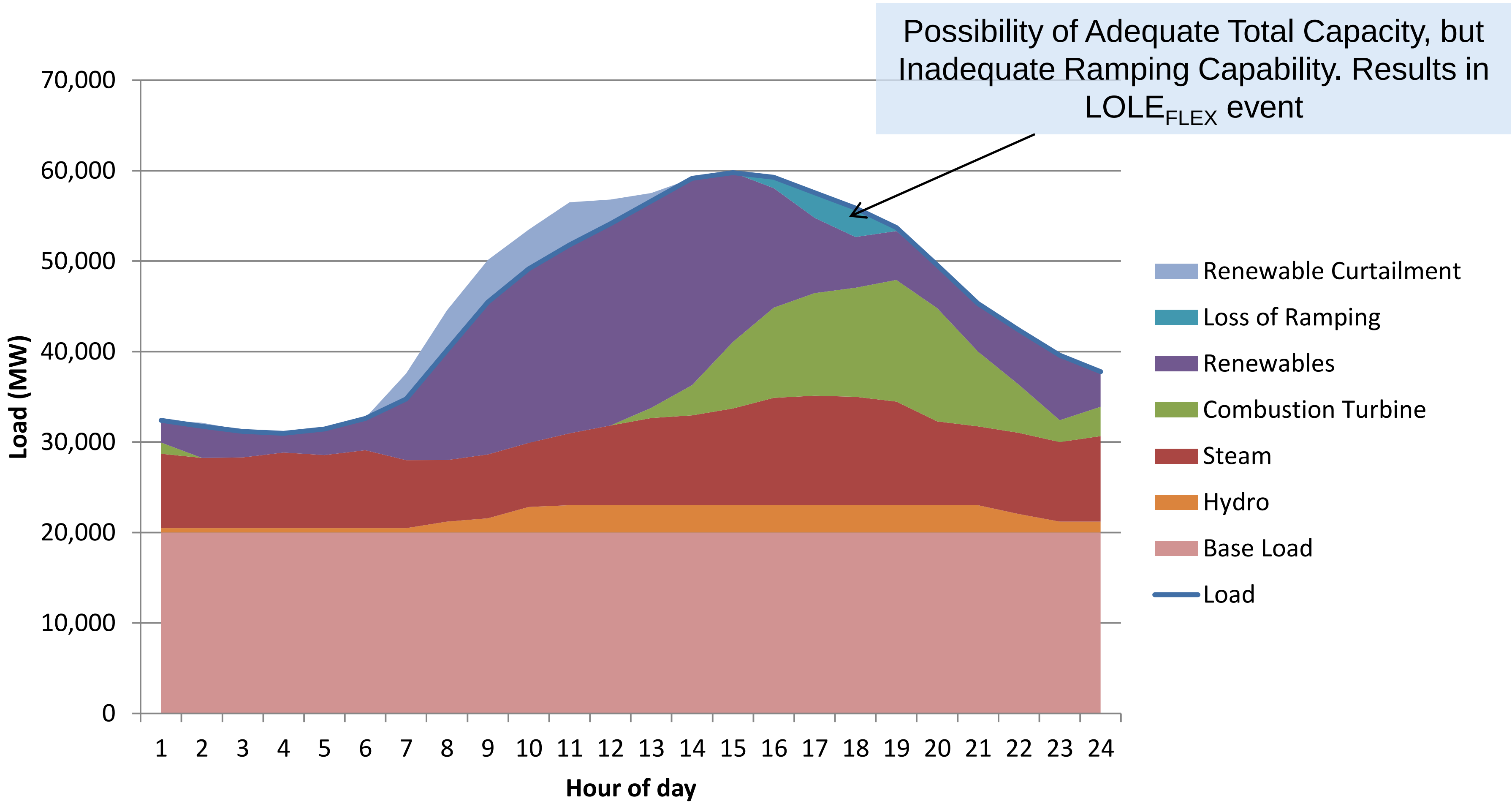
2015 RIS Study

	PV Fixed	PV SAT	Wind
2018 average	47.2%	62.1%	21.9%
2018 incremental	43.0%	57.2%	14.2%
	PV Fixed	PV SAT	Wind
2023 average	46.9%	61.2%	21.7%
2023 incremental	38.9%	52.1%	13.7%

SAT: Single Axis Tracking

Renewable Integration Study: Flexibility Study

What Does the Flexibility Problem Look Like?



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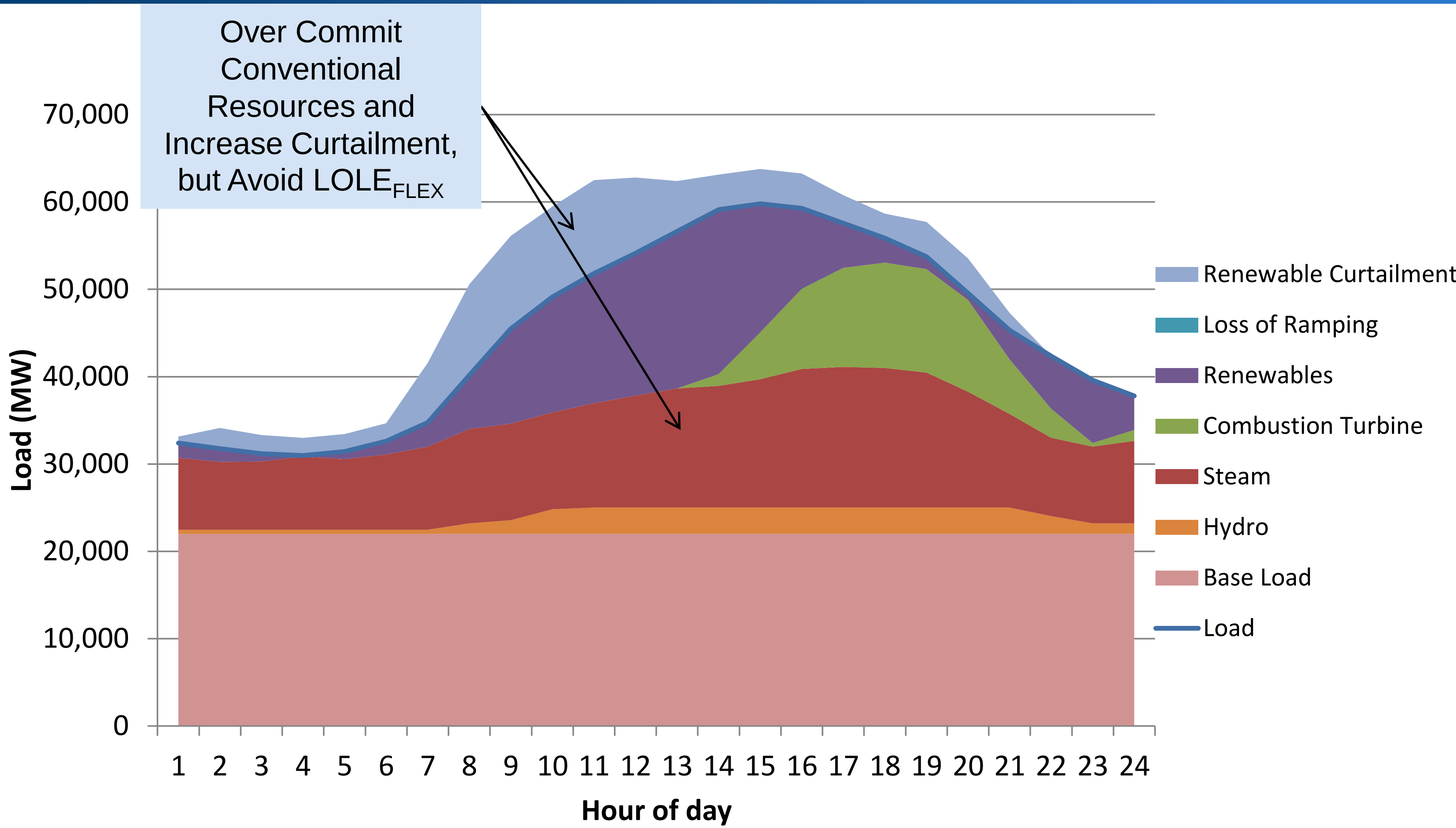
Increase Load Following Reserves to Reduce $LOLE_{FLEX}$ Events



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Flexibility Study Approach

- **Identify $LOLE_{FLEX}$ events and renewable curtailment (overgen) events**
- **Solve the deficiencies using the following approaches and calculate costs:**
  - Change operating procedures (i.e. raise load following requirement)
  - Swap or add existing capacity with flexible capacity (multiple technologies)

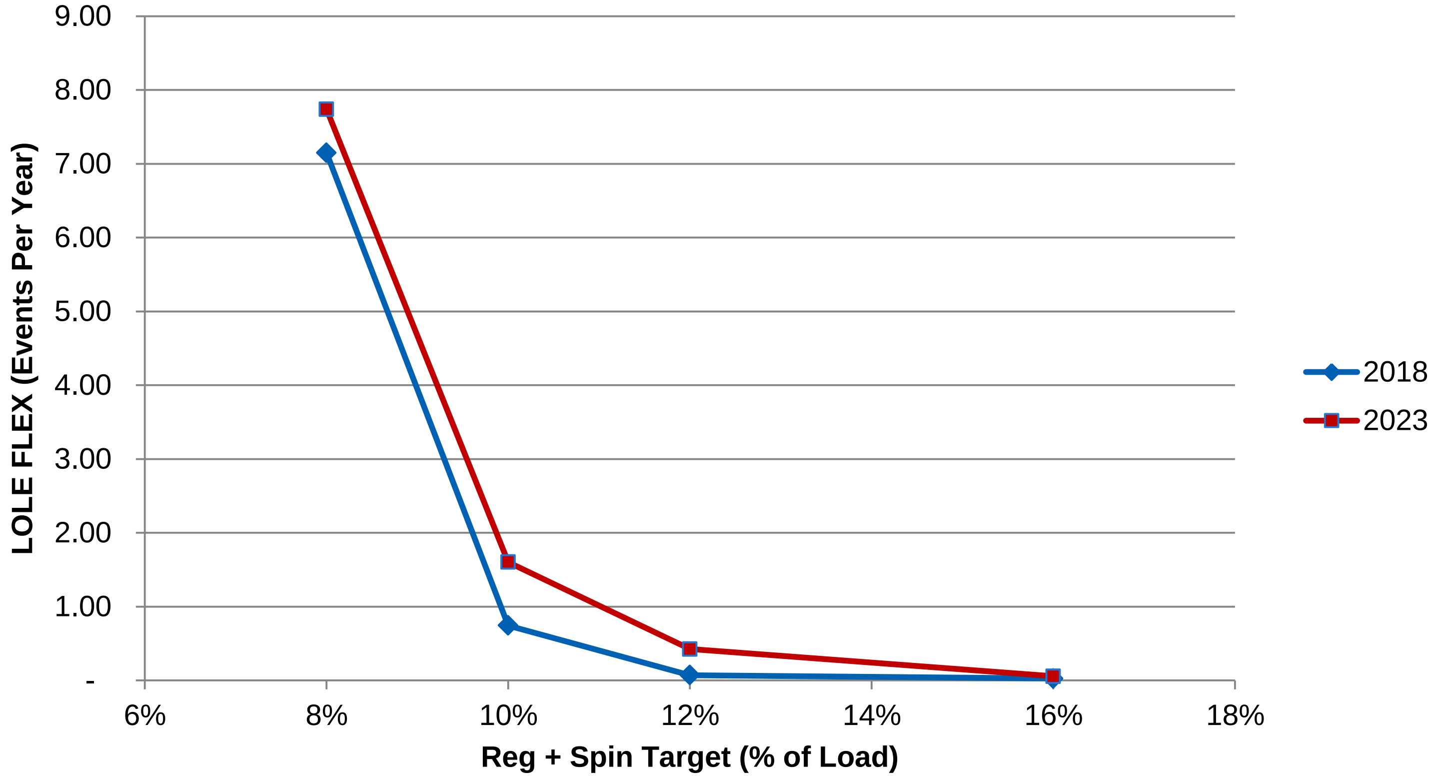
Base Case Physical Reliability Results
Varying Operating Reserve Levels
2015 RIS Study

- **2018: 16% Reserve Margin**
- **Spin + Reg Requirement = Varied from 8% to 16% of Load**
- **$LOLE_{CAP}$ is near previous LOLE study which did not take into account flexibility problems**
- **$LOLE_{FLEX}$ adds more events but are extremely low in magnitude and in duration (<10 min)**
- **10%- reg + spin target is likely reasonable given the size and duration of the $LOLE_{FLEX}$**

2018 Study Year				
Reg + Spin Target	8% of Load	10% of Load	12% of Load	16% of Load
2018 $LOLE_{CAP}$	0.21	0.21	0.21	0.21
2018 $LOLE_{FLEX}$	7.15	0.74	0.07	0.03
2018 Curtailment MWh	21,246	23,708	32,178	118,189
System Production Cost M$	289.04	294.09	301.02	322.35

LOLE$_{FLEX}$ Across Different Operating Reserve Requirements

2015 RIS Study



Note: Largest decrease in LOLE$_{FLEX}$ moving from 8% of Load to 10% Reg + Spin target. Slight benefit thereafter

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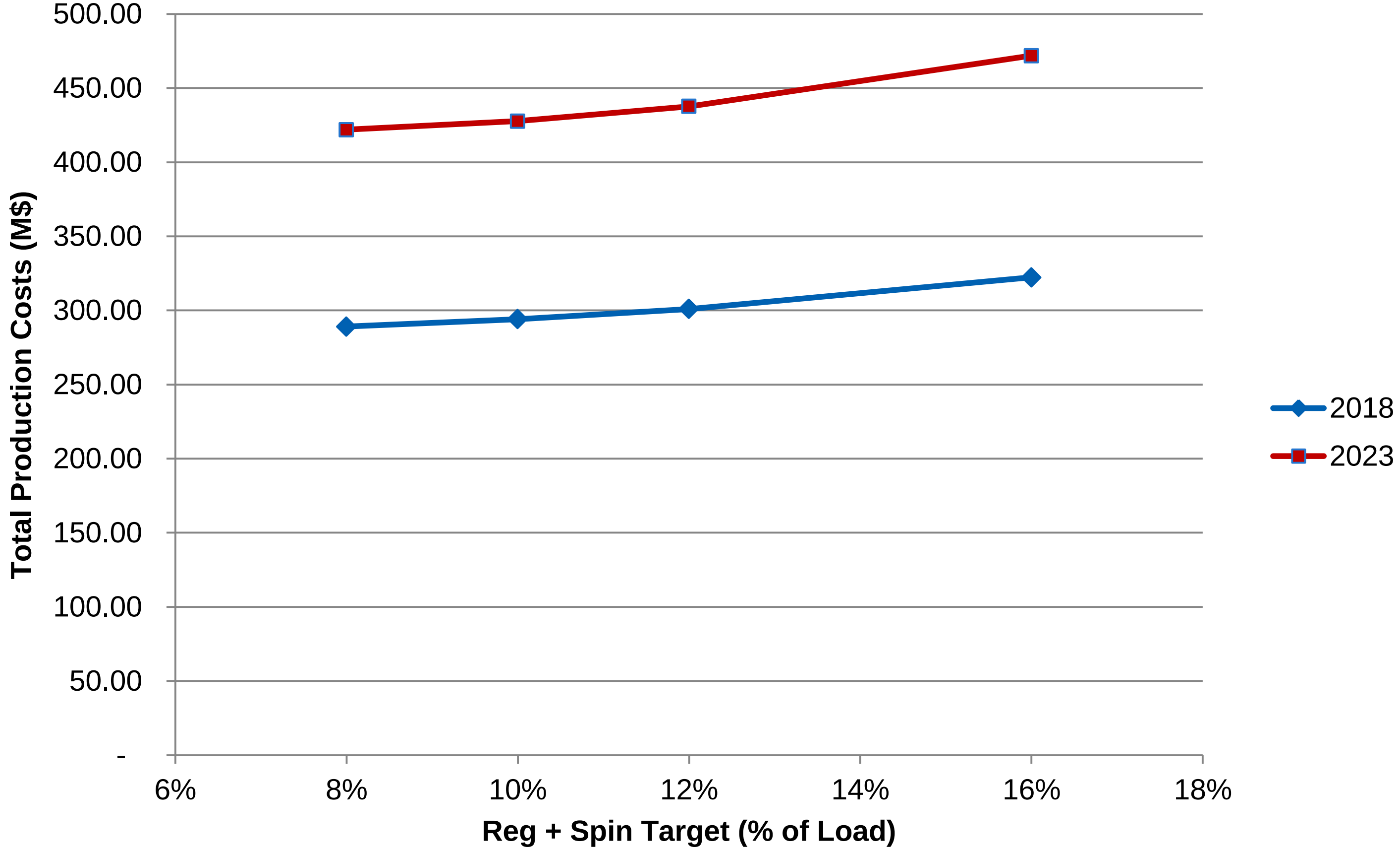
Production Costs Across Different Operating Reserve Requirements

2015 RIS Study



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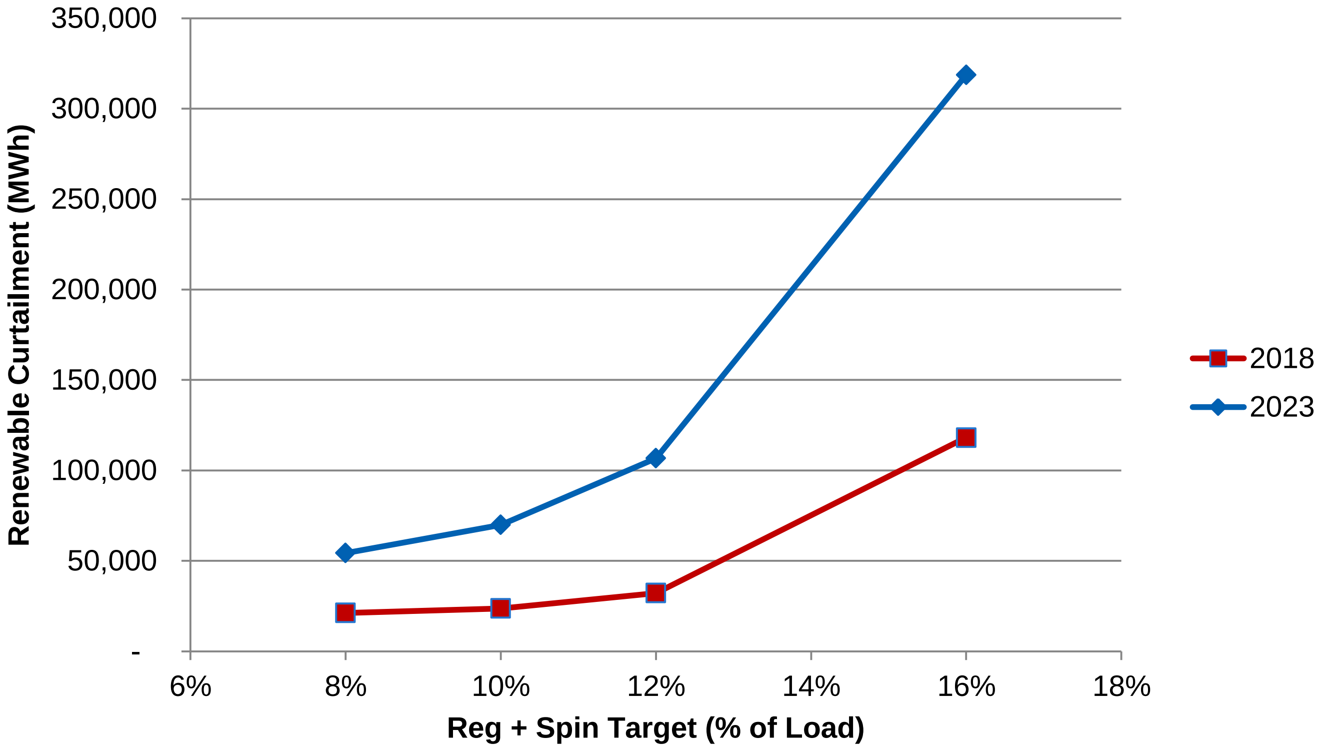
Renewable Curtailment Across Different Operating Reserve Requirements

2015 RIS Study



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Base Case (Monthly Basis)

2015 RIS Study

Month	$LOLE_{CAP}$	$LOLE_{FLEX}$
Jan	-	0.02
Feb	-	0.05
Mar	-	0.21
Apr	-	0.17
May	-	0.07
Jun	0.06	0.02
Jul	0.10	0.01
Aug	0.05	0.01
Sep	0.00	0.03
Oct	-	0.08
Nov	-	0.04
Dec	-	0.02
Total	0.21	0.74

Integration Cost Study

2018 Wind Integration Cost Adder Calculation

- **Simulate Base Case:**
  - $LOLE_{CAP}$ = .21; $LOLE_{FLEX}$ = .07
- **Add 50 MW Incremental Wind/Remove 6.5 MW CT (.13 ELCC * 50 MW):**
  - $LOLE_{CAP}$ = .21; $LOLE_{FLEX}$ = .20
- **Add Reserve MW until $LOLE_{FLEX}$ = .07**
  - Additional Reserves = 4 MW
- **Calculate System Cost Impact of Additional 4 MW Reserves**
  - System Cost = +$794,161
- **Divide by Renewable Energy**
  - Integration Cost Adder = $794,160 / 133,152 MWh = $5.96/MWh

2018 Integration Cost Results

Technology	Incremental Gen (MWh)	Required Spin Increase to Maintain Base Case Reliability	Cost Increase	$/MWh
WIND	133,152	4 MW	794,161	5.96
PV	108,011	15% of Incremental Solar Output	489,772	4.53
PV SAT	126,144	15% of Incremental Solar Output	489,772	3.88