PNM 2020-2039
Integrated Resource Plan

September 24, 2019

Integrated Resource Planning Modeling Tools

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Agenda

- Welcome and Introductions
- Safety and Ground Rules
- Online Participation Instructions
- Recap of presentations to date
- Goal of IRP
- Tools to Achieve Goal
  - EnCompass (Norm Richardson)
  - SERVM (Nick Wintermantel)
- Overview of Next Sessions (Data & Forecasts)
- Core assumptions/constraints/sensitivities we will be using
- High level scenarios we are already considering
- Solicit scenarios from audience – flip charts and online chat
- Closing slide

Nick Phillips
Director, Integrated Resource Planning

Mr. Phillips manages the PNM Resource Planning department and is responsible for developing PNM resource plans and the regulatory filings to support those resource plans.

Prior to joining PNM, Mr. Phillips was involved with numerous regulated and competitive electric service issues including resource planning, transmission planning, production cost analysis, electric price forecasting, load forecasting, class cost of service analysis, and rate design.

Mr. Phillips received the Degree of Master of Engineering in Electrical Engineering with a concentration in Electric Power and Energy Systems from Iowa State University of Science and Technology, and the Degree of Master of Science in Computational Finance and Risk Management from the University of Washington Seattle.

Safety and logistics

- In case of an emergency please exit to the LEFT of the stage.
- Another exit is through the main entry of the Museum.
- Restrooms are located behind the Admission desk around the corner down the hall to the left.

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Meeting ground rules

01

- Questions and comments are welcome – One Person Speaks at a Time

02

- Reminder; today's presentation is not PNM's plan or a financial forecast, it is an illustration of the IRP process

03

- Please wait for the microphone to raise your question or make your comment so we can ensure you are clearly heard and recorded. ***Only Q&A are transcribed for our filing package***.
- Questions and comments should be respectful of all participants

04

- These meetings are about the 2020 IRP, questions and comments should relate to this IRP. Any questions or comments related to other regulator proceedings should be directed towards the specific filing

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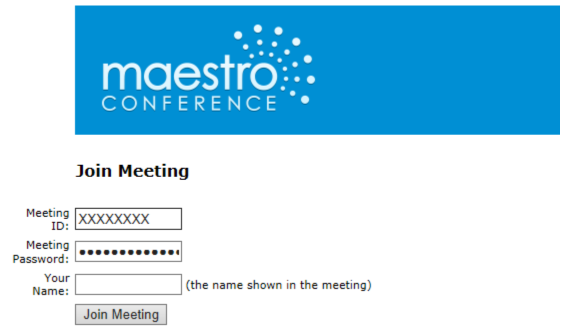
Online Participation

Please follow these steps to join:

1) Call the number emailed to you from Maestro Conference or select the hyperlink if you are using "**your computer**"
2) Enter the Pin # that was sent to you via the notification email
3) To view the presentation:
    a. Select the Screen Sharing hyperlink from the notification email
    b. Enter your name
    c. Select "Join Meeting"



4) **Press 1 on your phone to ask a question or make a comment during the session.**

Disclosure regarding forward looking statements

The information provided in this presentation contains scenario planning assumptions to assist in the Integrated Resource Plan public process and should not be considered statements of the company's actual plans. Any assumptions and projections contained in the presentation are subject to a variety of risks, uncertainties and other factors, most of which are beyond the company's control, and many of which could have a significant impact on the company's ultimate conclusions and plans. For further discussion of these and other important factors, please refer to reports filed with the Securities and Exchange Commission. The reports are available online at www.pnmresources.com.

The information in this presentation is based on the best available information at the time of preparation. The company undertakes no obligation to update any forward-looking statement or statements to reflect events or circumstances that occur after the date on which such statement is made or to reflect the occurrence of unanticipated events, except to the extent the events or circumstances constitute material changes in the Integrated Resource Plan that are required to be reported to the New Mexico Public Regulation Commission (NMPRC) pursuant to Rule 17.7.4 New Mexico Administrative Code (NMAC).

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RPS = 80%, CO_2 = 0% … But How?!

Primer on Resource Planning Optimization

Mixed Integer Linear Programming

- **Resource Planning Models Include Binary and Integer Decisions**
  - 0-1 Decision Variable to Represent a Choice about a Given Resource
  - Commitment Logic
  - Also Allows for logical constraints
  - New Assets cannot be fractional

- **Other Decisions are Linear**
  - Power Output
  - Emissions
  - Transmission Flows
  - Etc.

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Primer on Resource Planning Optimization

Minimize $\mathbf{c}^{\mathrm{T}}\boldsymbol{x} = \sum_{N} \boldsymbol{c} * \boldsymbol{x}$

Subject to: Ax ≤ b

$\mathbf{x}_{\mathbf{1}\,\ldots\,n}\{\mathbf{0}, \mathbf{1}\}$ **(or integer)**

$\mathbf{x}_{\mathbf{n+1}\,\ldots\,N}\{\mathbb{R}, \geq \mathbf{0}\}$

Primer on Resource Planning Optimization

Seems simple right, but…
The problem grows exponentially

n = number of binary variables
Possible combinations = 2^n

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Primer on Resource Planning Optimization

Number of Resource Combinations:

2^{10}**= 1,024**
2^{20}**= 1,048,576**
2^{30}**= 1,073,741,824**
2^{40}**= 1,099,511,627,776**
2^{392}**=**
10,086,913,586,277,000,000,000,000,000,000,0
00,000,000,000,000,000,000,000,000,000,000,0
00,000,000,000,000,000,000,000,000,000,000,0
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Primer on Resource Planning Optimization

Time to Solve (assuming 1 second per combination):

2^{10} ≈ 17 minutes
2^{20} ≈ 9 days
2^{30} ≈ 34 Years
2^{40} ≈ 34,865 Years
2^{392} ≈ 319,853,931,579,053,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000 Years

Primer on Resource Planning Optimization

A common fallacy – LPs solve quickly compared to IPs, so just relax the LP and round…

- **Rounding the LP relaxation may not be feasible**
- **Rounding the LP may be far from optimal**

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Primer on Resource Planning Optimization

Example

Maximize $Z = x_2$

Subject to: $-x_1 + x_2 \le 0.5$

$x_1 + x_2 \le 3.5$

$x_1, x_2 \ge 0$

x_1, x_2 are integers

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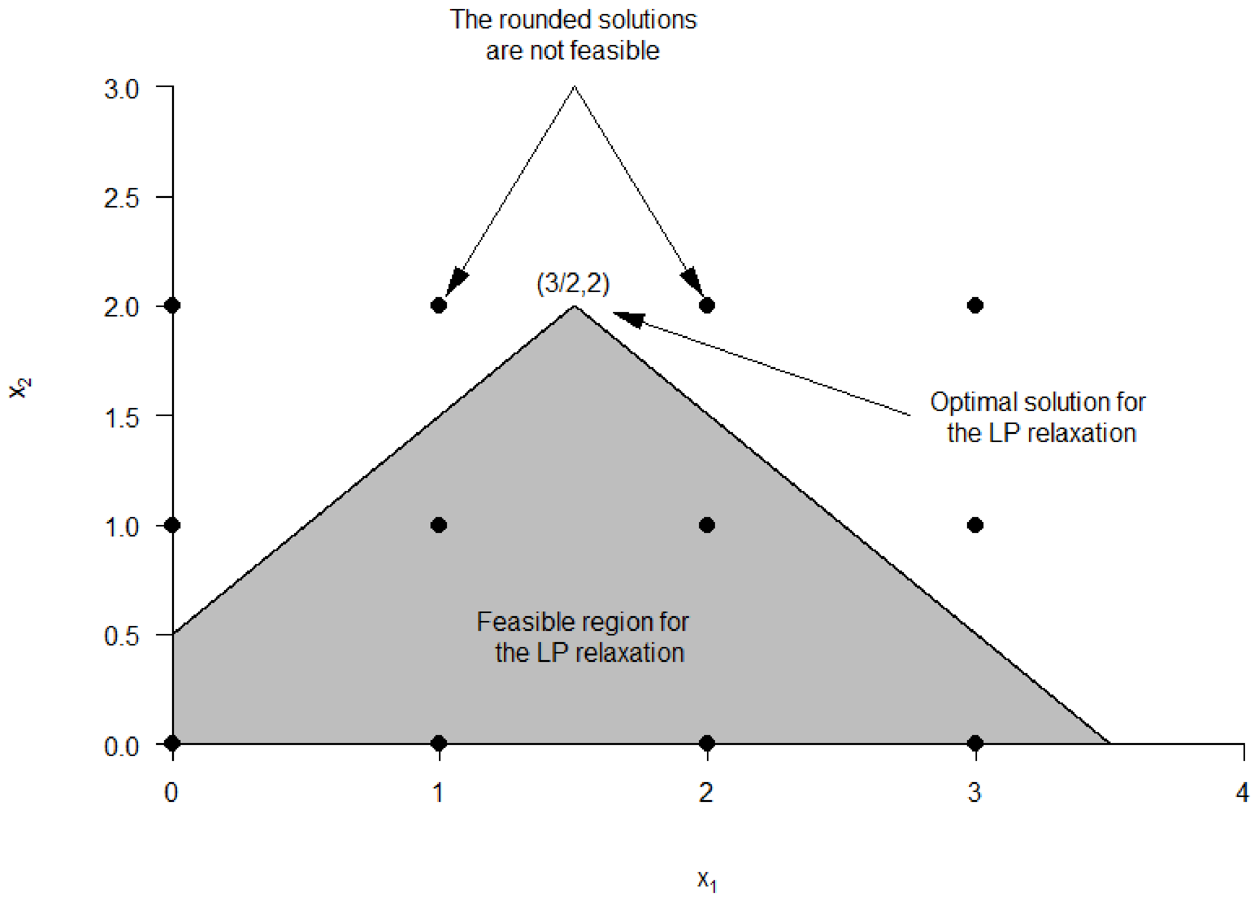

Primer on Resource Planning Optimization

Example

Maximize $Z = x_1 + 5x_2$

Subject to: $x_1 + 10x_2 \leq 20$

$x_1 \leq 2$

$x_1, x_2 \geq 0$

x_1, x_2 are integers

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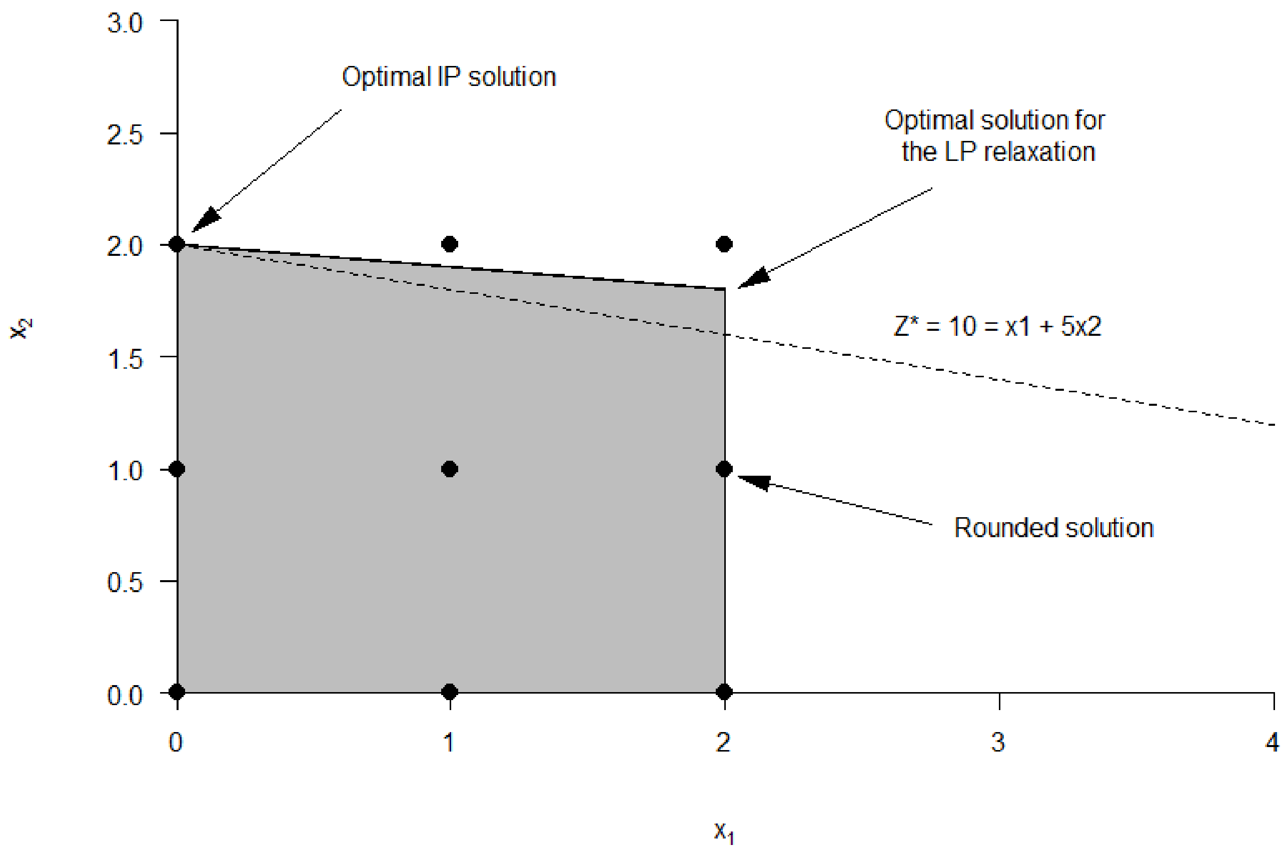


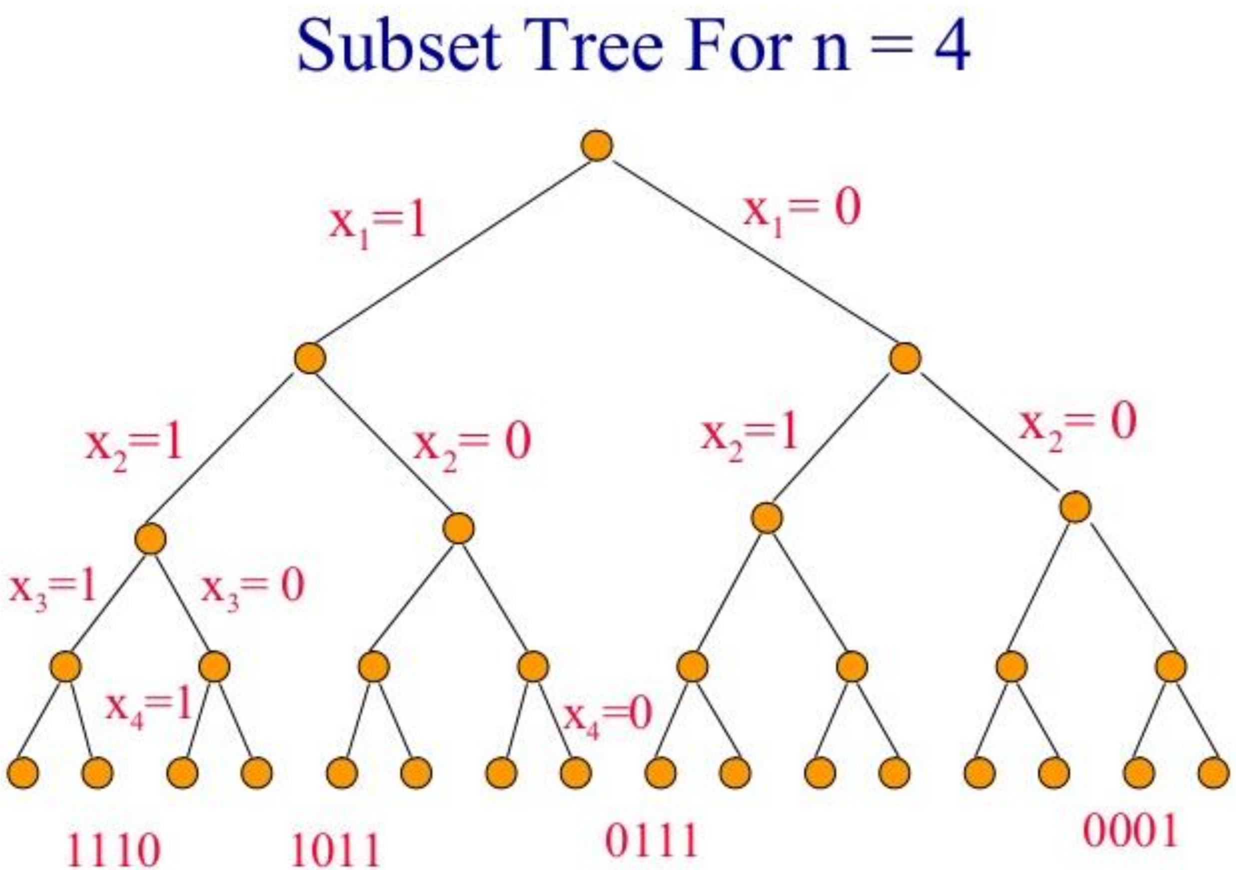
Rounding x_2=9/5 into the feasible region yields x_1=2, x_2=1, Z=7

The optimal solution is x_1=0, x_2=2, Z=10

Primer on Resource Planning Optimization

Luckily there is an intelligent way to eliminate the vast majority of potential solutions without having to evaluate them and still prove optimality… this is known as the Branch and Bound Algorithm.

Primer on Resource Planning Optimization



By organizing the problem in this way and making intelligent use of information, the tree can be “pruned” so that all possible solutions do not have to be evaluated yet optimality can still be proven. This allows the underlying structure of the problems to remain detailed and complex.

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Primer on Resource Planning Optimization

To start off, obtain somehow (e.g. by extortion, creativity, or magic) a feasible solution x^*. At each iteration of the algorithm, we will refer to x^* as the *incumbent solution* and its objective value z^* as the *incumbent objective*. Here, incumbent means "best so far."
Next, mark the root node as active.

While there remain active nodes

Select an active node j and mark it as inactive

Let $x(j)$ and $z_{LP}(j)$ denote the optimal solution and objective of the LP relaxation of Problem(j).

<u>Case 1</u>: **If** $z^* \geq z_{LP}(j)$ **then**

Prune node j

<u>Case 2</u>: **If** $z^* < z_{LP}(j)$ and $x(j)$ is feasible for IP **then**

Replace the incumbent by $x(j)$

Prune node j

<u>Case 3</u>: **If** $z^* < z_{LP}(j)$ and $x(j)$ is not feasible for IP **then**

Mark the direct descendants of node j as active

End While

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Example:

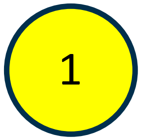
Maximize $15x_1 + 12x_2 + 4x_3 + 2x_4$

Subject to $8x_1 + 5x_2 + 3x_3 + 2x_4 \leq 10$

x_k binary for $k = 1$ to 4

Example from MIT Open CourseWare http://ocw.mit.edu

Primer on Resource Planning Optimization



Step 1 – find a feasible solution and mark as the incumbent

$x^* = (0,0,0,0)$
$z^* = 0$

Step 2 – evaluate the LP relaxation for problem 1

$x_{LP}(1) = (0.625,1,0,0)$
$z_{LP}(1) = 21.375$

Results in Case 3 – branch on the node and mark children as active.

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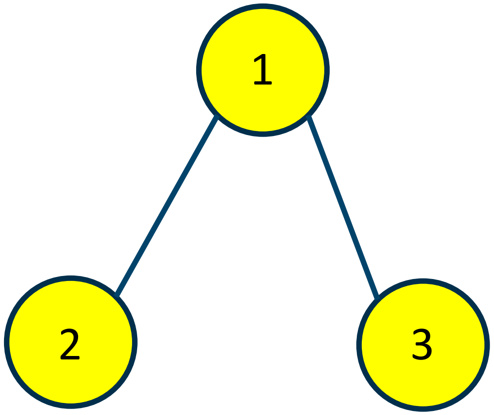

Step 3 – solve LP relaxation of problem 2

$x_{LP}(2) = (0,1,1,1)$
$z_{LP}(2) = 18$

Incumbent
$x^* = (0,0,0,0)$
$z^* = 0$

Notice the LP relaxation results in an integer solution with an objective value better than the current incumbent objective

This is Case 2 – replace the incumbent with this better solution and prune node 2

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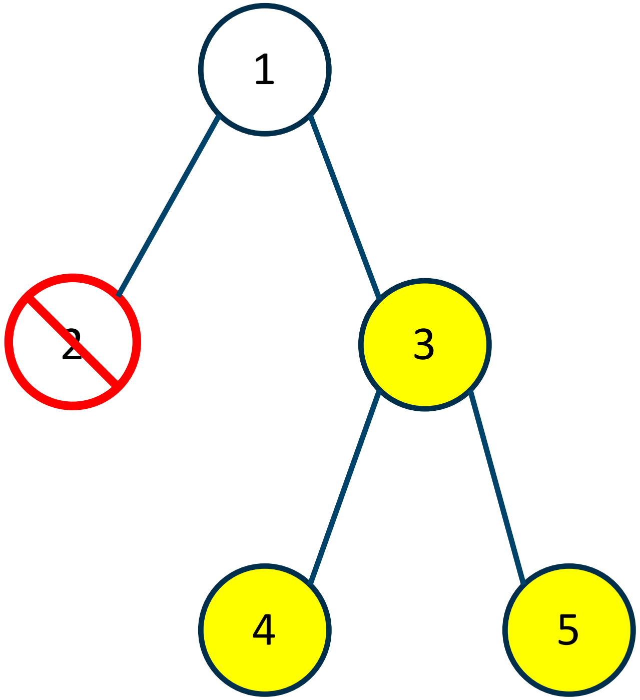

Incumbent
$x^* = (0,1,1,1)$
$z^* = 18$

Step 4 – solve LP relaxation of problem 3

$x_{LP}(3) = (0.675,1,0,0)$
$z_{LP}(3) = 21.375$

Result is Case 3

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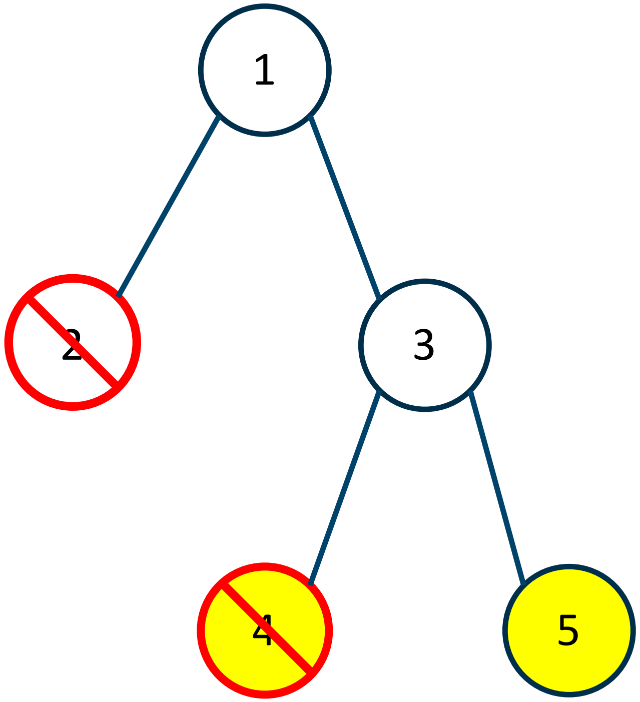


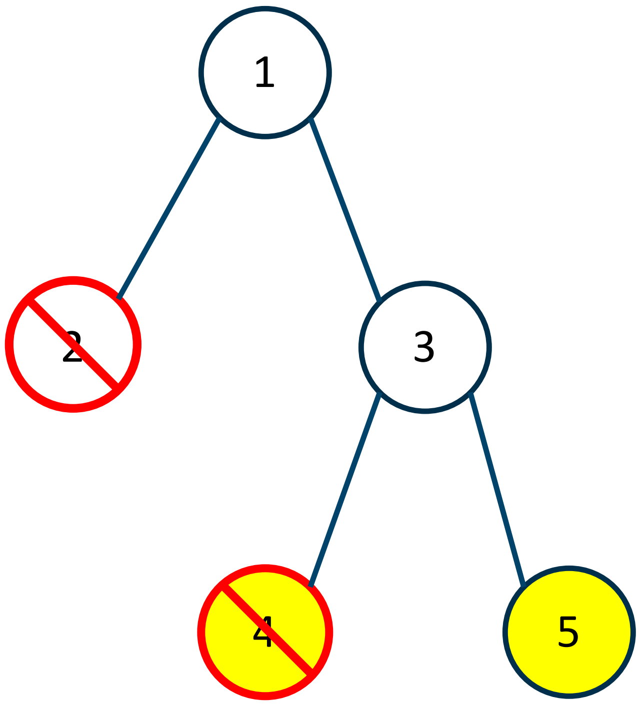
Incumbent
$x^* = (0,1,1,1)$
$z^* = 18$

Step 5 – solve LP relaxation of problem 4

$x_{LP}(4) = (1,0,.667,0)$
$z_{LP}(4) = 17.667$

Result is Case 1 – Prune Node (objective lower than incumbent)

Primer on Resource Planning Optimization



Incumbent
$x^* = (0,1,1,1)$
$z^* = 18$

Step 6 – solve LP relaxation of problem 5

$x_{LP}(5)$ = infeasible
$z_{LP}(5)$ = infeasible

Result is Case 1 – Prune Node (infeasible)

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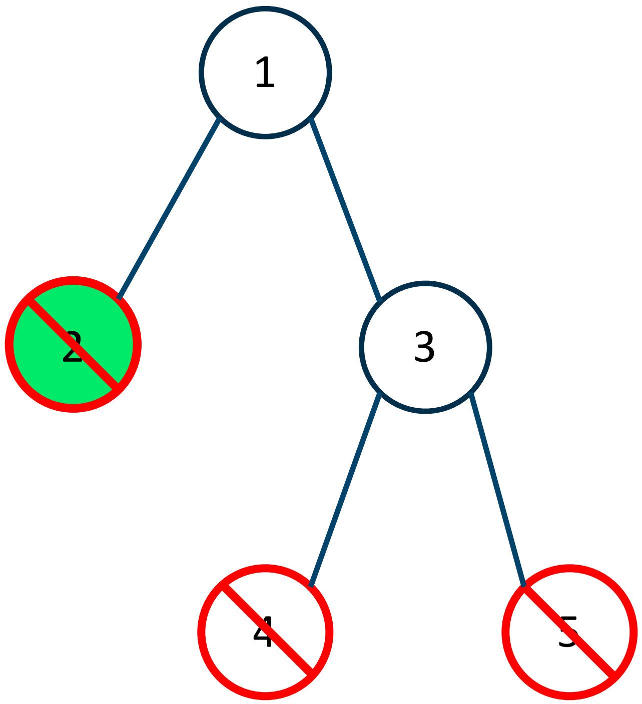
Primer on Resource Planning Optimization



Incumbent
$x^* = (0,1,1,1)$
$z^* = 18$

So we have found our solution – and we never made it to the bottom of the tree, we only evaluated 5 LP relaxations. As the number of combinations grow, the percentage of combinations evaluated relative to the total number tends to decrease

Primer on Resource Planning Optimization

By taking advantage of problem structure and intelligently working our way through the problem, we can maintain sufficient detail and complexity to ensure sufficient analysis. However, no single model does it all

- EnCompass
  - Capacity Expansion/Automated Resource Optimization
  - Production Cost Analysis
  - Near-Perfect Foresight

- SERVM
  - Stochastic, Sub-hourly Production Costs & Reliability Analysis
  - Imperfect Foresight

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Resource Planning with EnCompass

Norm Richardson

- President of Anchor Power Solutions
- 25 years of experience in market price forecasting, integrated resource planning, risk evaluation, and economic transmission analysis
- Experience includes developing software models, collecting and analyzing market data, consulting projects, and expert witness testimony
- Bachelor's of Science in Mathematics from Furman University
- Master's of Science in Electrical Engineering from the Georgia Institute of Technology

ANCHOR POWER SOLUTIONS

EnCompass Software Model

- First released in 2016
- Optimization model used for:
  - Integrated Resource Planning
  - Market Price Forecasting
  - Detailed Production Costs & Risk Analysis

ENCOMPASS
POWER PLANNING SOFTWARE

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Detailed Production Costs

- Unit Commitment
  - Online costs ($/hour)
  - Hot / Warm / Cold Starts and Shutdowns (direct costs and fuel requirements)
- Economic Dispatch
  - Energy / Variable O&M Costs
  - Heat rate curves and emission rates
  - Multiple fuels with blending and delivery costs
  - Market interchange and tariffs

Ancillary Services

- Ramp rates applied to response times
- Operating reserves with spinning requirements
- Regulating reserves, both up and down, with Automatic Generation Control (AGC) ranges
- Co-optimized with commitment and energy dispatch
- Curtailable renewables can be modeled as dispatchable with contributions to ancillary services (mainly Regulation Down)

Storage

- Cycle efficiency
- Minimum and Maximum Storage Levels
- Dependent resource for charging
- Cycle depth penalties
- Ancillary services across the charging / discharging spectrum, subject to available storage

Mixed Integer Linear Programming (MILP)

- Variables:
  - Units Online, Starts, and Shutdowns
  - Generation
  - Limited Fuel Usage
  - Ancillary Services
  - Storage Levels and Charging
  - Transmission Flows
- Constraints:
  - Energy & Ancillary Requirements
  - Operating Constraints
  - Min Up/Down Time
  - Capacity Factor Limits
  - Fuel Limits
  - Ramp & Ancillary Limits
  - Storage & Charging Limits
  - Transmission Limits

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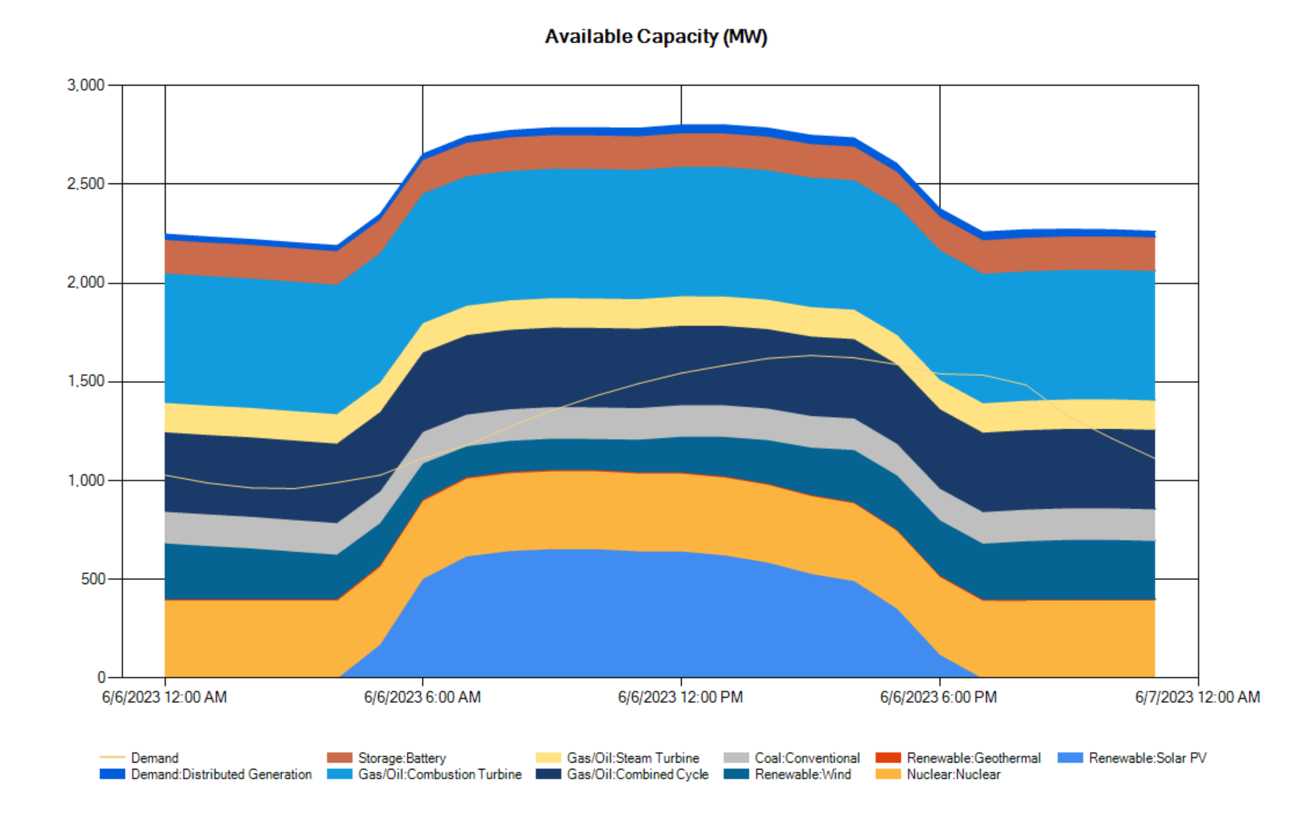
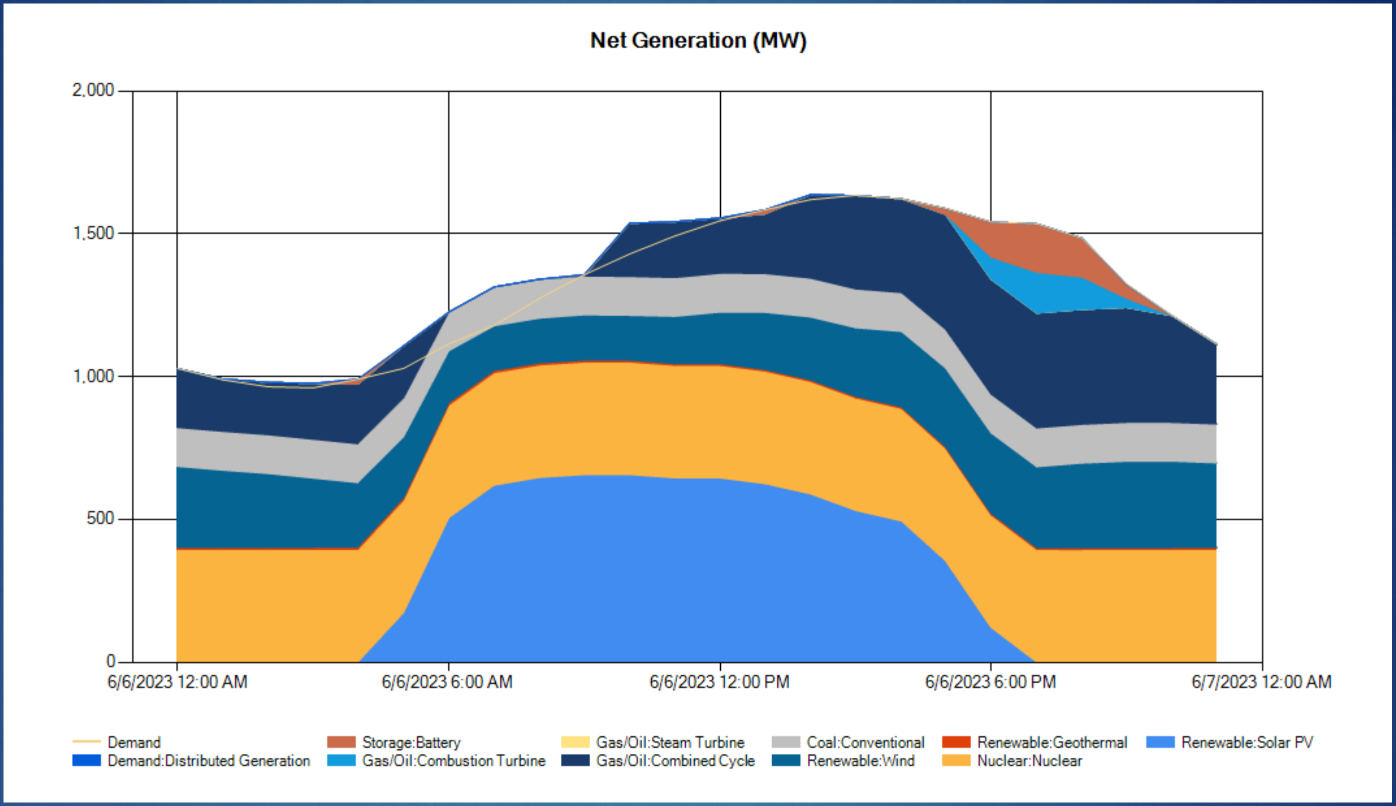
Summer Day Capacity



Simple "stack" models would dispatch resources based solely on variable costs for each hour

Summer Day Generation



With MILP, commitment costs and constraints, ancillary services, and storage are considered over the entire day(s)

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Automatic Capacity Expansion

- Optimizes capacity plan across multiple years, selecting from several different project types
- Includes demand resources, economic retirements, unit conversions, and transmission interface upgrades
- Enforces annual limits for renewable requirements, emissions, fuel, demand response, contracts, etc.

Mixed Integer Linear Programming (MILP)

- Variables:
  - Project Additions & Retirements
  - Environmental Program Bank
  - Capacity Interchange
- Constraints:
  - Reserve Margin Requirements
  - Project Constraints
  - Environmental Limits & Banking Restrictions
  - Annual Capacity Factor Limits
  - Annual Fuel Limits
  - Capacity Interchange Limits

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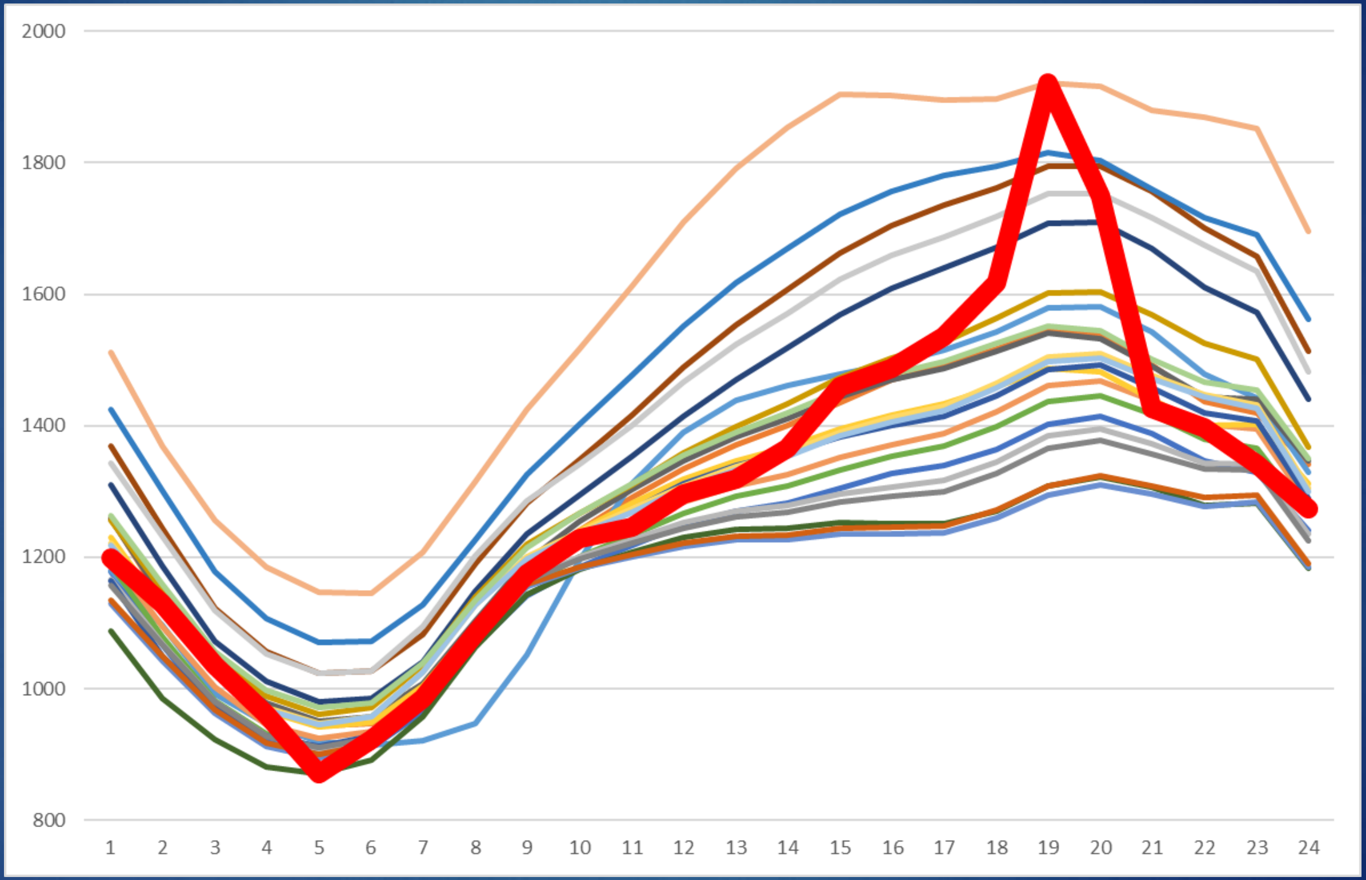
Problem Size

- Nearly all variables and constraints are set for each interval of each day simulated
- A full hourly simulation of 50 resources with commitment constraints over 10 years requires 24 x 365 x 10 x 50 x 8 variables (over 35 million, much too large to solve).
- The larger the problem, the more memory required to solve, and in many instances, longer runtimes.

Typical Day Representation

- Aggregates daily values into a typical day representation
- For demand, adjustments can be made to maintain peak hour, peak load, minimum load, and total energy

Weekday Load Typical Day

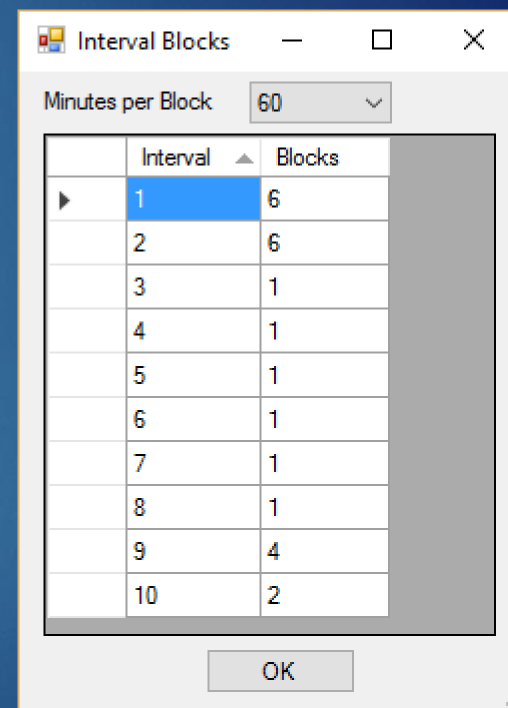


Typical Day Considerations

- Expected available capacity is calculated for each month based on:
  - Scheduled Outages
  - Full Forced Outages
  - Partial Forced Outages
- Chronology is maintained by assuming the end of the typical day/week wraps around to the beginning of the typical day/week

Interval Blocks

- The number of intervals for each day is controlled by setting the number of minutes per block, and how many blocks are in each interval.
- For the case shown on the right:
  - Interval 1 covers midnight - 6 am
  - Interval 2 covers 6 am - noon
  - Hourly intervals from noon – 6 pm
  - Interval 9 covers 6 pm – 10 pm
  - Interval 10 covers 10 pm - midnight

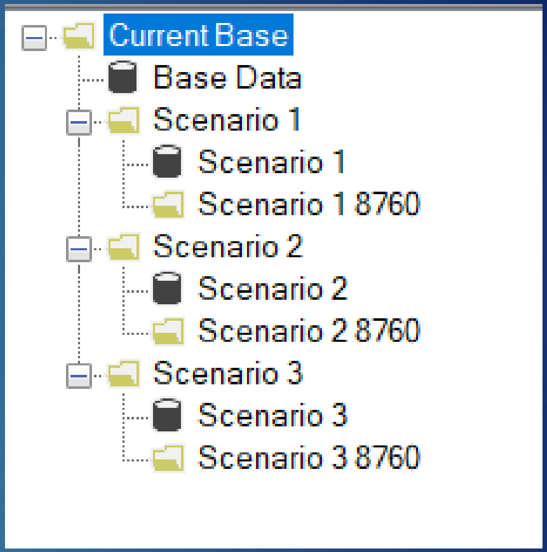


Relaxed Unit Commitment

- Partial Commitment: Fractional tranches
- No Commitment:
  - Ignore minimum capacity, minimum uptime/downtime, start/shutdown constraints
  - Startup/shutdown costs rolled into the cost of energy and “up” ancillary services

Detailed Post-Processing

- Use the simplified modeling only for capacity expansion
- Perform detailed simulations with the expansion locked in place
- The "shadow" prices for environmental constraints (RPS, CO_2 Limits) from the annual run are applied as dispatch costs in the detailed runs as a proxy for the annual limits



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Company Reporting

- Fuel, Environmental, O&M, Contract, and Interchange costs (including fixed)
- Annual revenue requirements for added and existing capital projects
- Reflects any financial contracts for fuel hedges, emission allowance allocations, etc.

BREAK

PNM IRP Meeting

Astrapé Consulting

09/24/2019

Bio - Nick Wintermantel

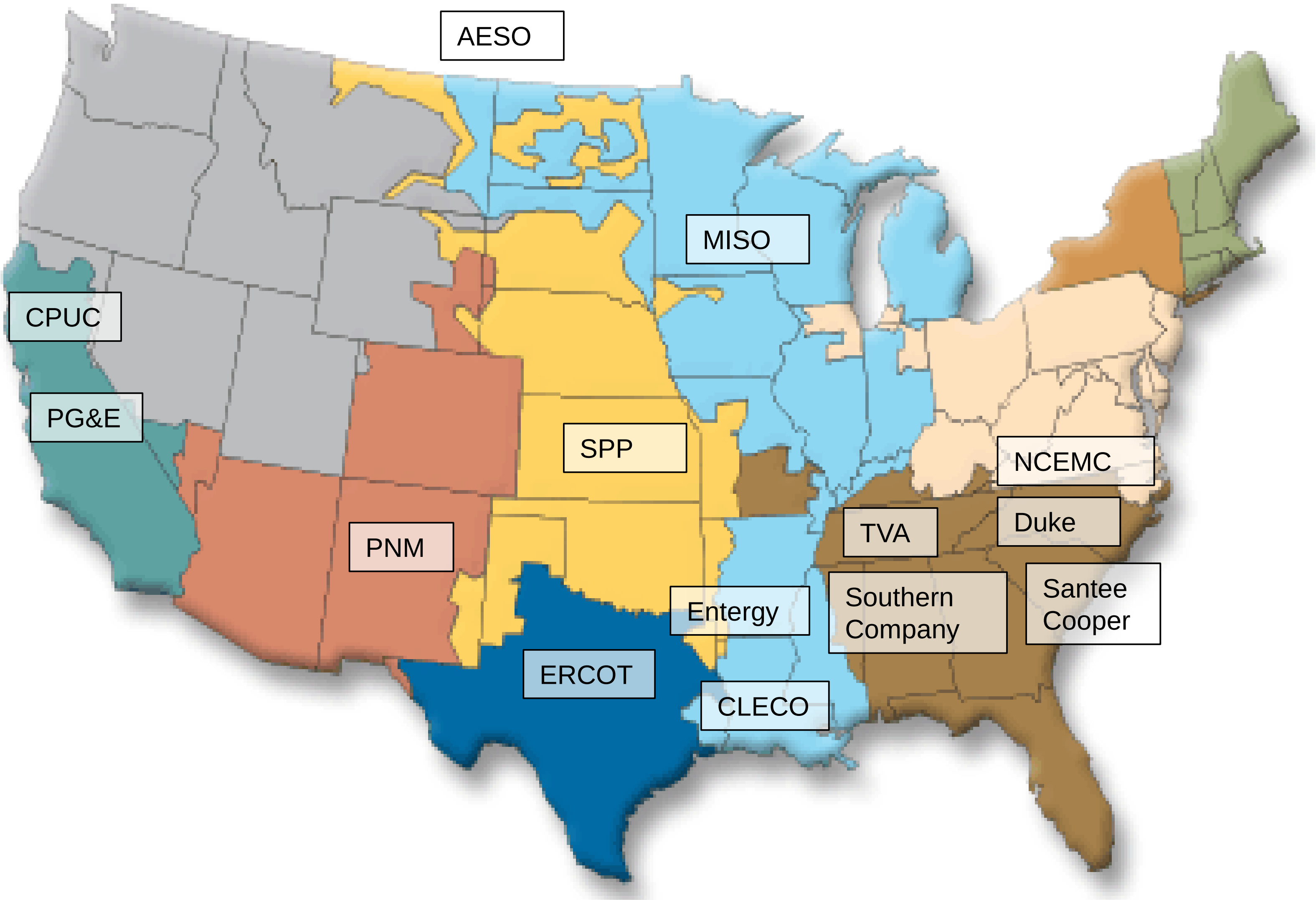
- Nick Wintermantel is a Principal at Astrapé Consulting. An engineer with an MBA, Nick has been active in the energy industry since 2000, holding various positions within the Southern Company before joining Astrapé Consulting. He has broad experience in integrated resource planning, system production cost modeling, reliability modeling, intermittent resource integration, generation development, contract structuring, and risk analysis.
- While at Astrapé Consulting, Nick has performed work for large utilities and organizations across the U.S. including the Southern Company, TVA, Duke Energy, MISO, SPP, Louisville Gas & Electric, ERCOT, FERC, EISPC, PGE, SCE, PNM, and the California Public Utility Commission. Nick's most recent work has focused on system modeling engagements using the Strategic Energy Risk Valuation Model (SERVM) for clients.

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 used in a variety of applications for the following entities:**
  - Southern Company
  - TVA
  - Louisville Gas & Electric
  - Kentucky Utilities
  - Duke Energy
  - Progress Energy
  - FERC
  - NARUC
  - PNM
  - TNB (Malaysia)
  - Sarawak (Malaysia)
  - EPRI
  - Santee Cooper
  - CLECO
  - California Public Utilities Commission
  - Pacific Gas & Electric
  - ERCOT
  - MISO
  - PJM
  - Terna (Italian Transmission Operator)
  - NCEMC
  - Oglethorpe Power

Astrapé Resource Adequacy Clients



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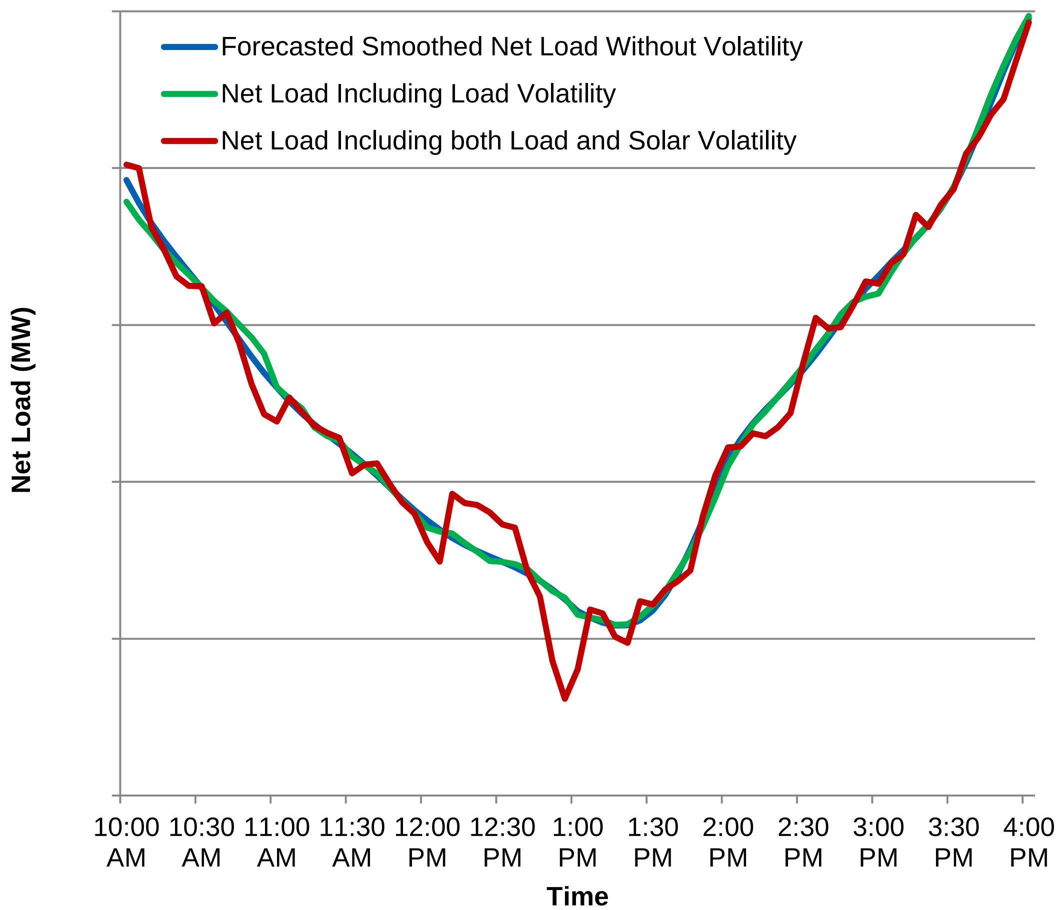
SERVM Uses

- **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

Why Intra Hour Modeling

- **Intermittent Resources with intra hour volatility can impact reliability and new generation decisions**
  - Intra hour modeling ensures reliability is met from not only an installed capacity standpoint but also a flexibility standpoint
  - Intra hour modeling accounts for costs associated with ramping a system to meeting a more volatile net load.
  - Intra hour modeling allows the full value of battery and other flexible resources to be recognized



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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

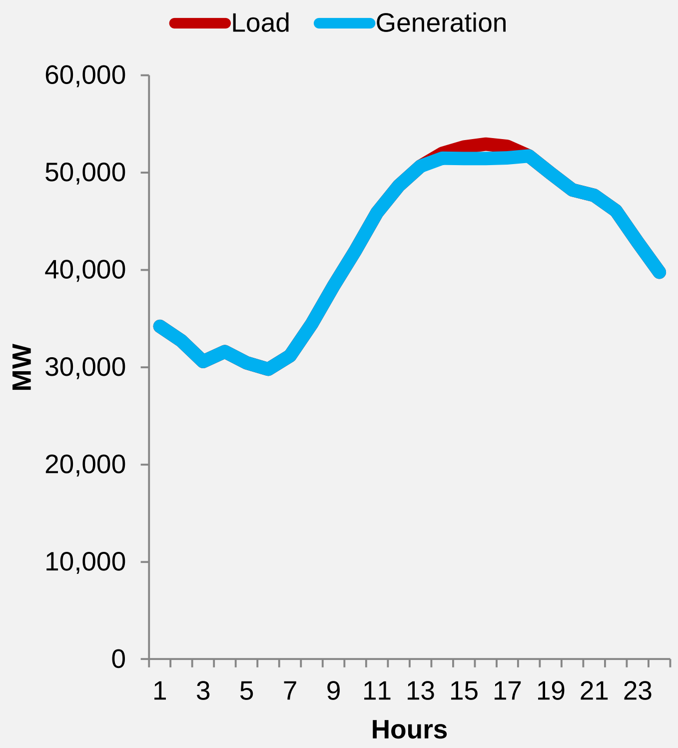
- **Expected Unserved Energy (EUE_{CAP}):** Expected amount of firm load shed in MWh for a given year due to capacity shortfalls
- **Expected Unserved Energy (EUE_{FLEX}):** Expected amount of firm load shed in MWh for a given year due to not having enough ramping capability

Definitions of Existing and New Reliability Metrics

Traditional "Generic Capacity" Metrics

$LOLE_{Cap}$ = 0.2 Target

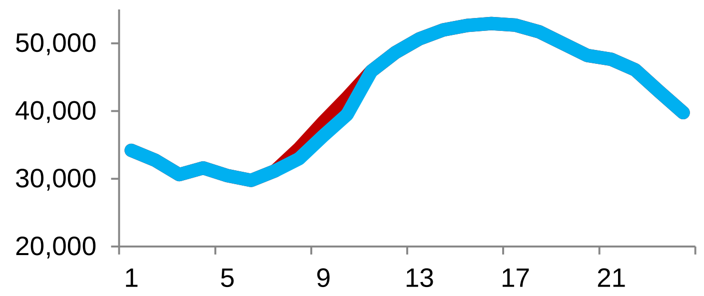
Traditional metric to capture events that occur due to capacity shortfalls in peak conditions



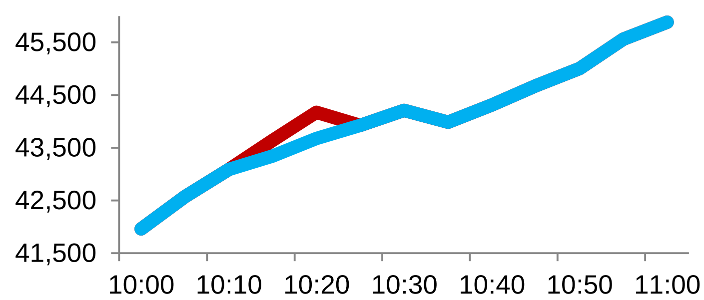
New "Flexible Capacity" Metrics

$LOLE_{FLEX}$ = 0.2 Target

New metric to capture events due to system ramping deficiencies of longer than one hour in duration



New metric to capture events due to system ramping deficiencies inside a single hour



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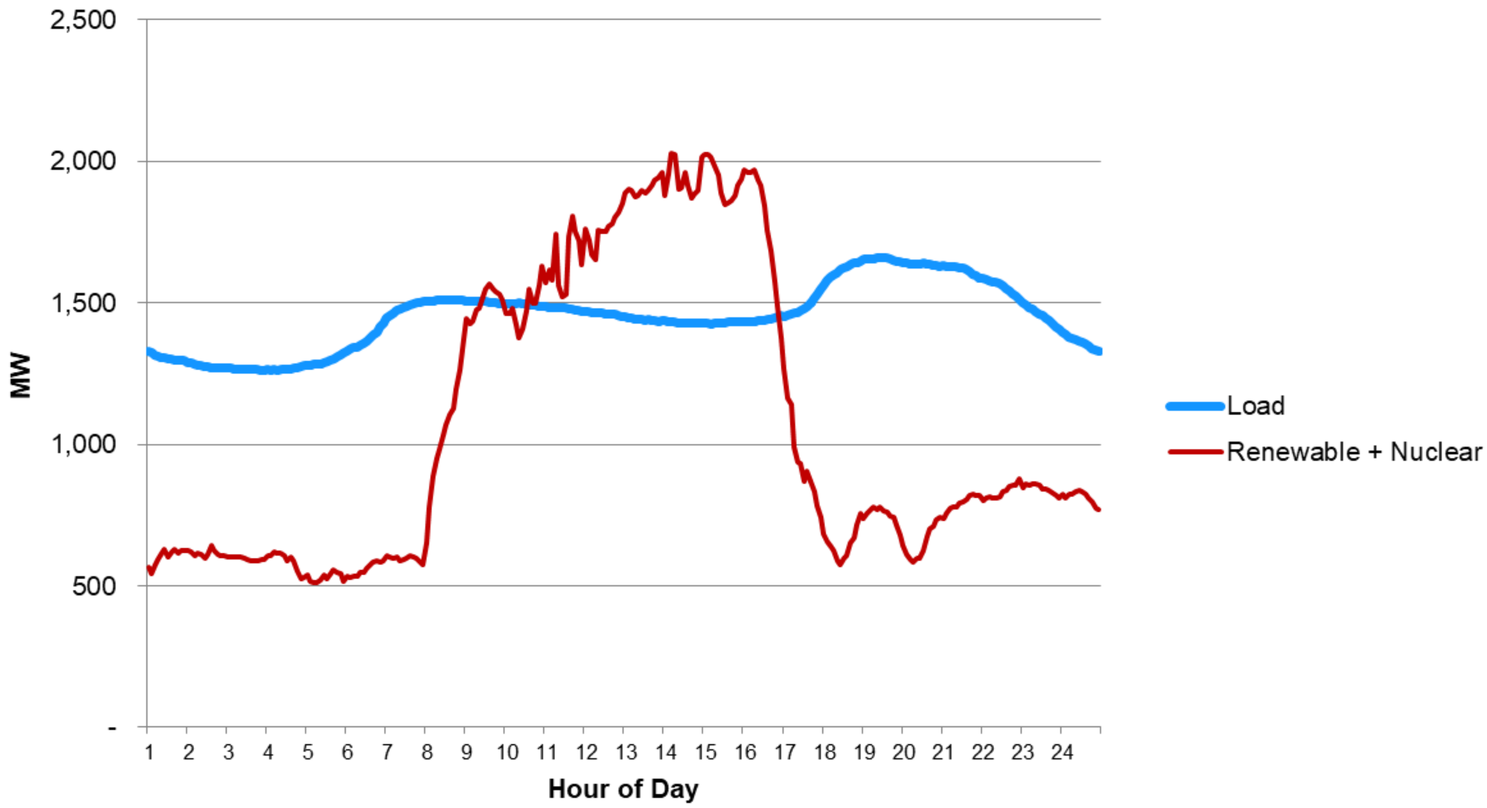
Renewable Curtailment Example



Severe Example Without Any Storage – Storage can assist in alleviating the curtailment

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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)
    - PNM has to maintain minimum operating reserves requirements
  - Add existing capacity with flexible capacity

SERVM Framework

- **Base Case Study Year (TBD)**
  - Weather (36 years of weather history)
    - Impact on Load
    - Impact on Intermittent Resources
  - Economic Load Forecast Error (distribution of 7 points)
  - Unit Outage Modeling (thousands of iterations)
    - Multi-State Monte Carlo
    - Frequency and Duration
- Base Case Total Scenario Breakdown: 36 weather years x 7 LFE points = 252 scenarios
- Base Case Total Iteration Breakdown: 252 scenarios * 5 unit outage iterations = 1,260 iterations
- Intra Hour Simulations at 5-minute Intervals

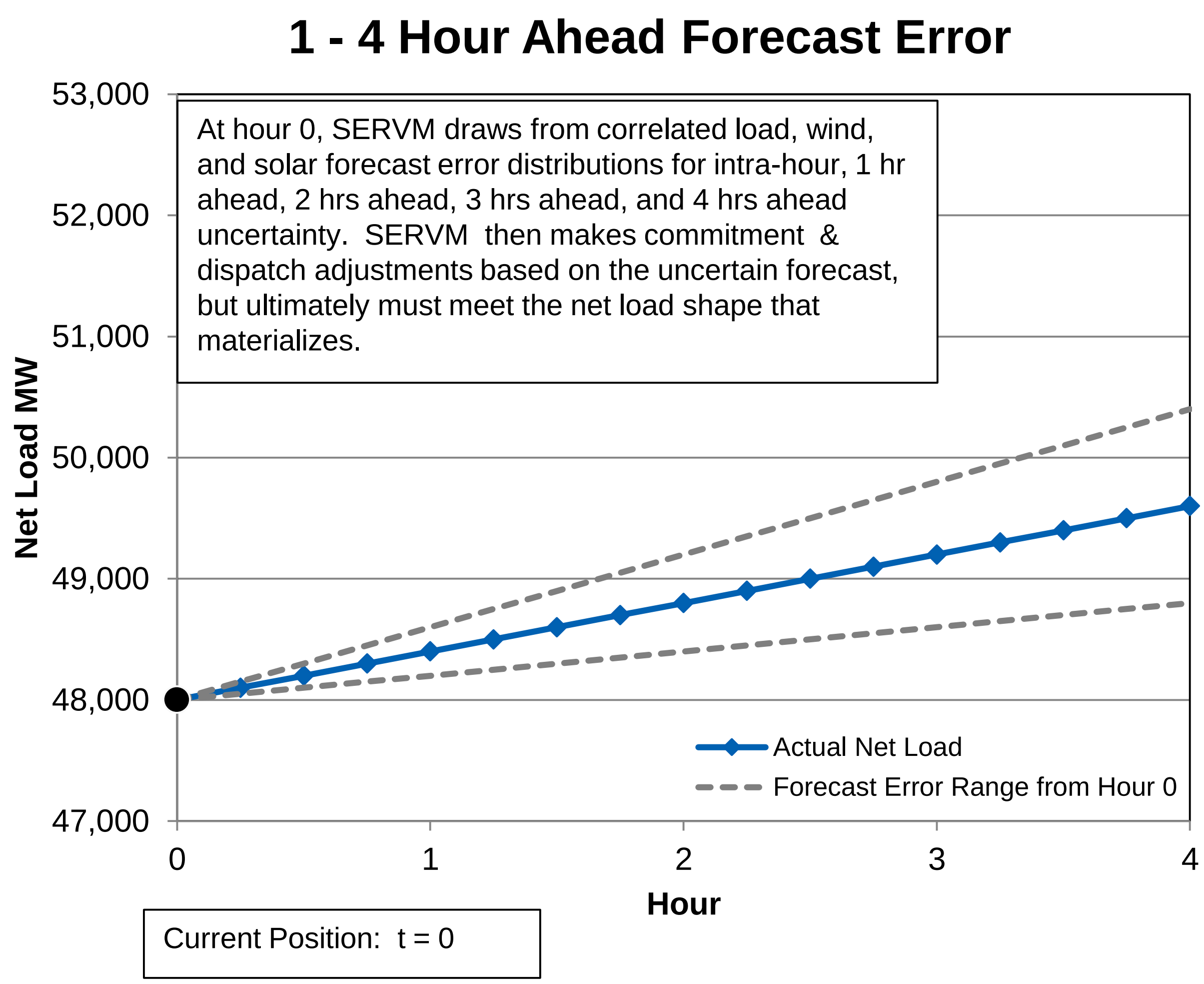
- $LOLE_{CAP}$, $LOLE_{FLEX}$, and production costs are calculated by taking the results of each iteration and multiplying by their probability.
  - Maintaining a 0.1 $LOLE_{CAP}$ would be more expensive than maintaining a 0.2 $LOLE_{CAP}$

Resource Commitment and Dispatch

- **8,760 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**
- **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

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 Volatility**
  - **Captures the flexibility benefit of fast ramping resources and the integration costs of intermittent resources.**



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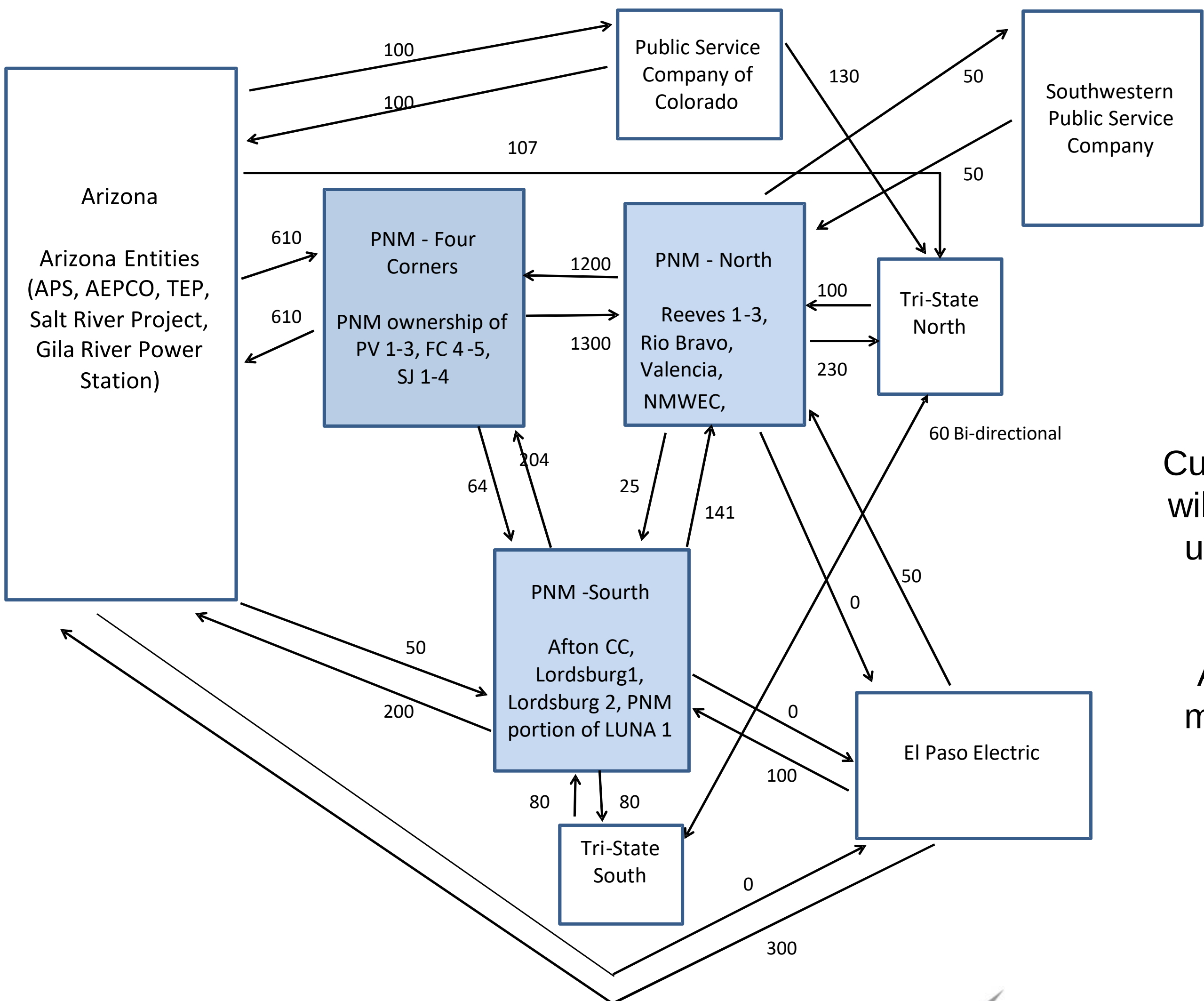
Ancillary Service Modeling

- **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

Study Topology



Current Assumptions will be validated and updated as part of IRP

Allows for hourly market assistance from neighbors.

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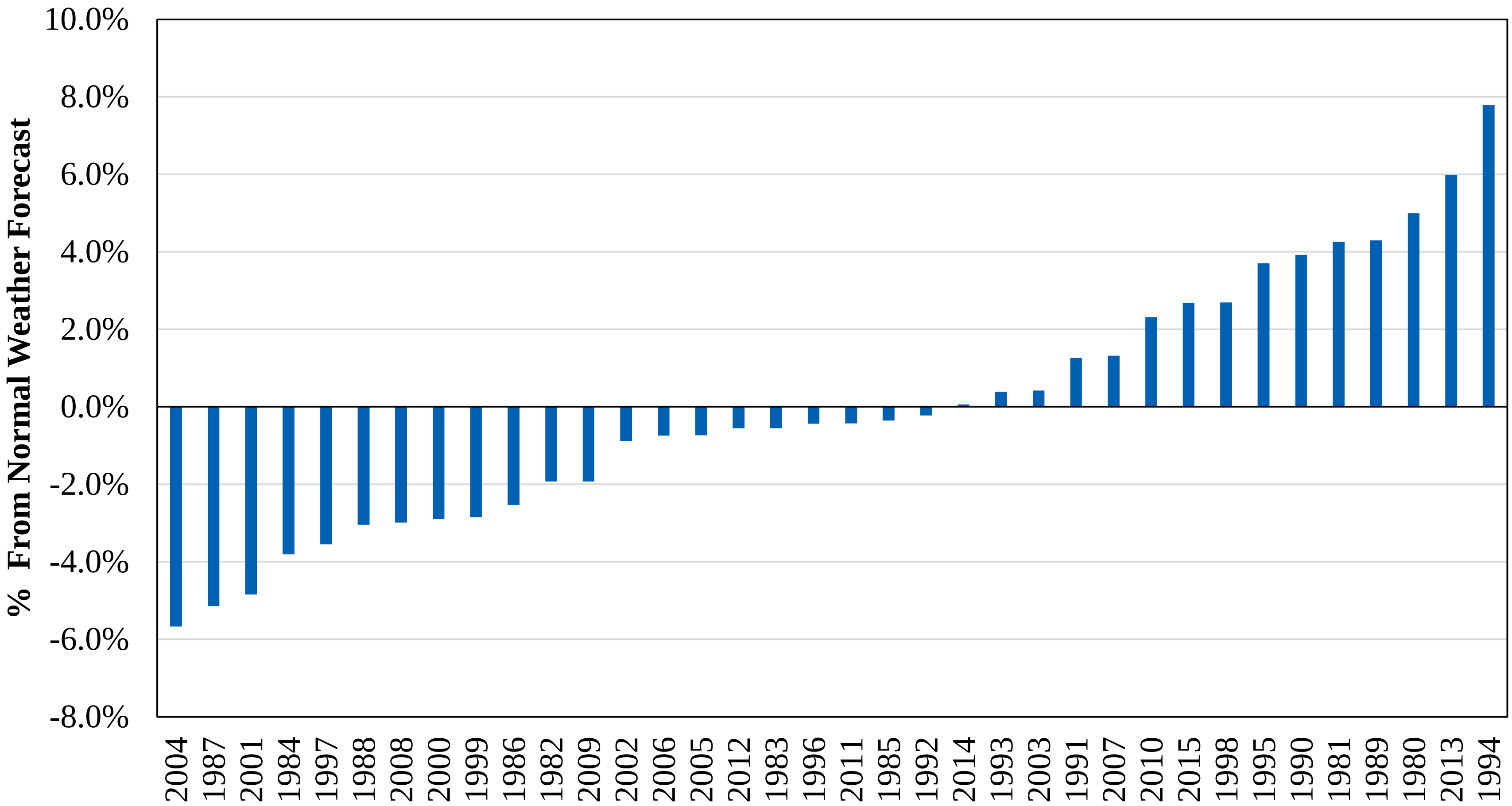
Load Modeling

- **35 weather years**
  - **Peaks below represent severe and mild weather year peaks**



Thermal Resource Modeling

- **Maximum Capacity**
- **Minimum Capacity**
- **Heat Rate Curves**
- **Startup/Shutdown Times**
- **Minimum Up and Minimum Downtimes**
- **Ramp Rates**
- **CO_2 rates**
- **Variable O&M**
- **Startup Costs**
- **Monte Carlo Unit Outage Draws**

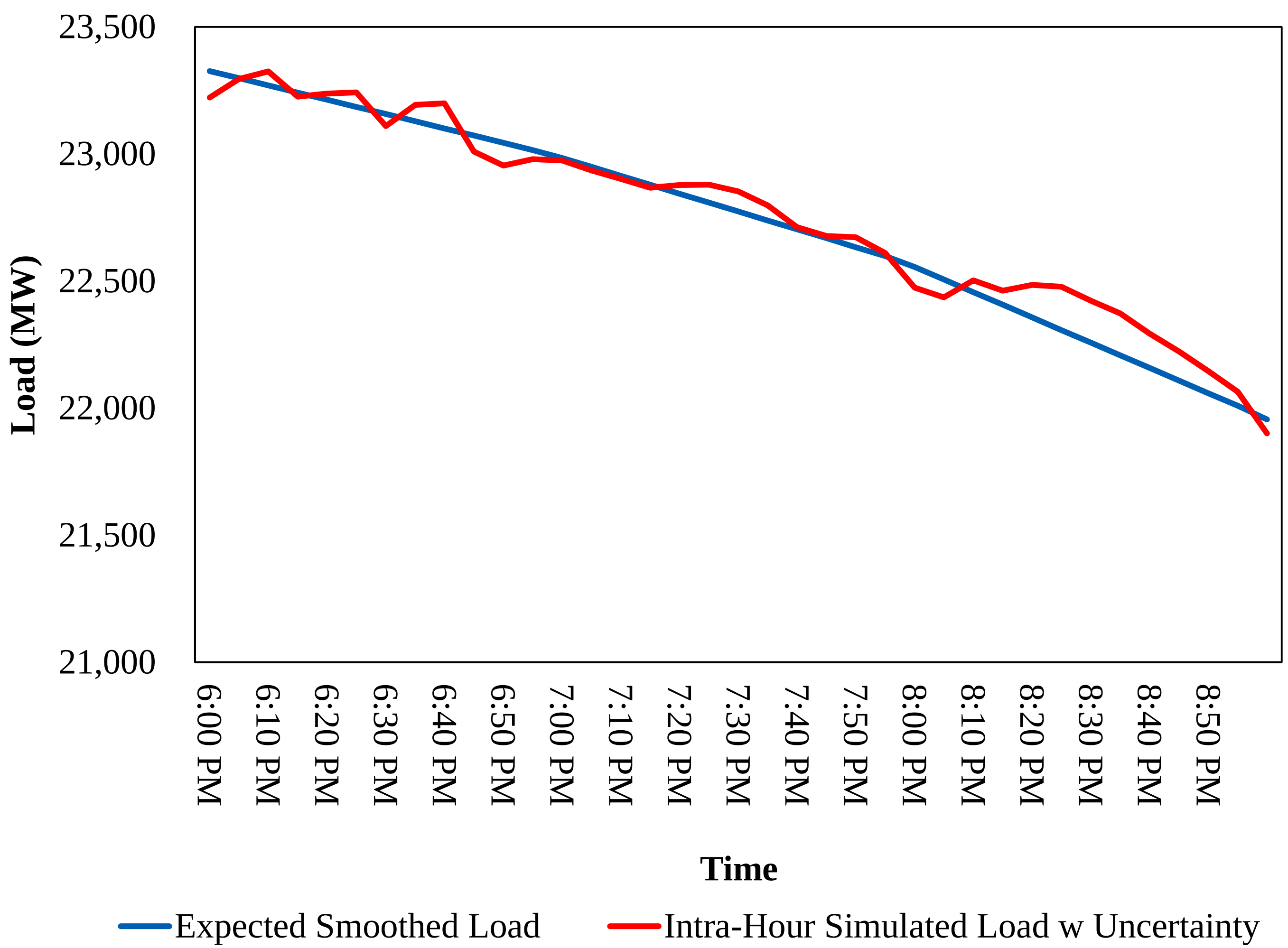
- **Note: SERVM doesn't enforce CO_2 and RPS requirements, it instead only simulates specific future resource plans to determine reliability and costs.**

Renewable Resource Modeling

- **Solar Hourly Profiles**
  - **Uses NREL solar irradiance database**
  - **Developed fixed and tracking for various sites across the state**
  - **Scale source profiles to match IRP capacity factor assumptions**

- **Wind Hourly Profiles**
  - **Based on existing PNM projects**
  - **Scale to match IRP capacity factor assumptions**
  - **Random daily profiled pulled by month for RFP offers**

Intra Hour Volatility



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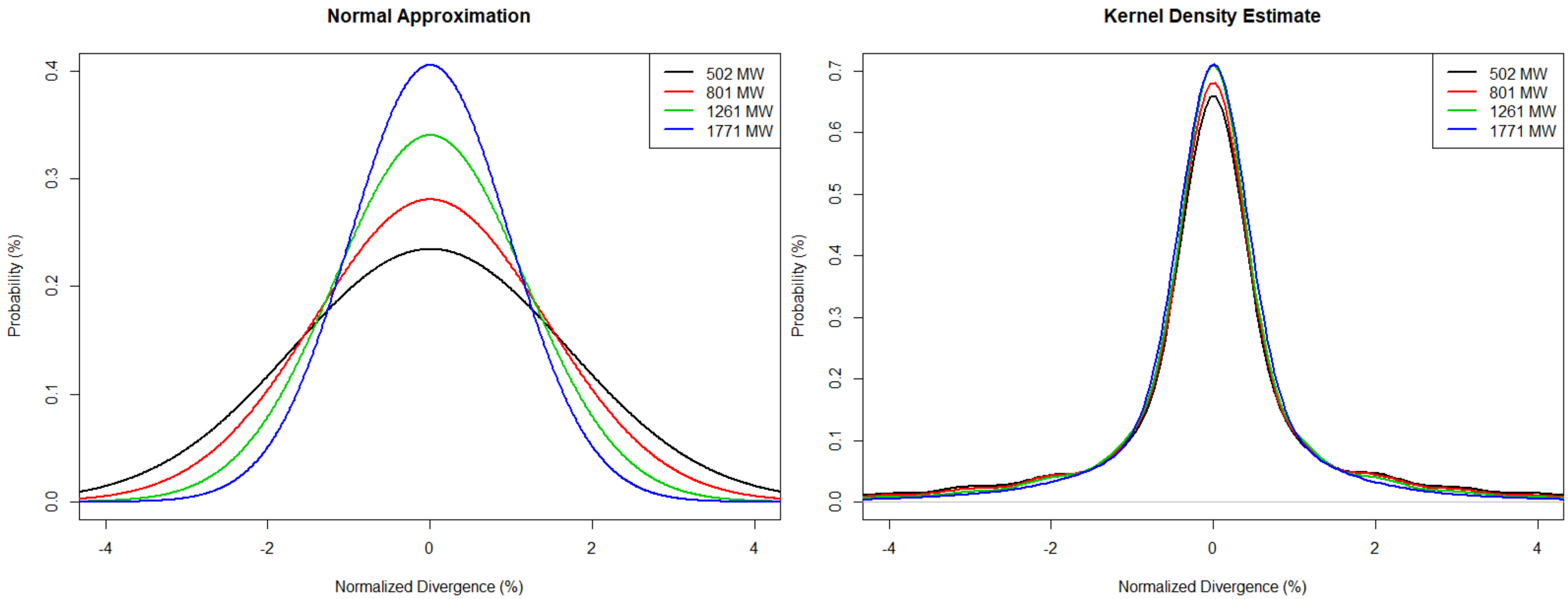
Solar Intra Hour Volatility – 5 Minute Unexpected Movement

Normalized Divergence (%)	Probability (%)						
	502 MW	801 MW	1,061 MW	1,261 MW	1,471 MW	1,771 MW	2,071 MW
-12.8	0.02	0.00	0.00	0.00	0.00	0.00	0.00
-11.4	0.03	0.01	0.00	0.00	0.00	0.00	0.00
-10.0	0.15	0.07	0.03	0.01	0.01	0.00	0.00
-8.6	0.16	0.08	0.05	0.04	0.02	0.01	0.01
-7.2	0.72	0.43	0.30	0.23	0.16	0.07	0.04
-5.8	0.75	0.54	0.41	0.32	0.27	0.27	0.21
-4.4	1.23	1.01	0.83	0.73	0.63	0.95	0.80
-3.0	6.31	5.81	5.40	5.09	4.75	3.41	3.11
-1.6	7.44	7.90	8.09	8.24	8.33	14.04	14.21
-0.2	73.69	76.11	77.85	78.94	80.04	74.34	75.37
1.2	4.25	4.06	3.79	3.59	3.37	5.09	4.73
2.6	2.20	1.90	1.65	1.51	1.34	1.28	1.14
4.0	2.00	1.46	1.22	1.05	0.88	0.39	0.28
5.4	0.43	0.30	0.21	0.14	0.11	0.10	0.08
6.8	0.43	0.22	0.13	0.10	0.08	0.03	0.01
8.2	0.09	0.04	0.03	0.02	0.00	0.00	0.00
9.6	0.05	0.02	0.01	0.00	0.00	0.00	0.00
11.0	0.05	0.02	0.00	0.01	0.00	0.00	0.00
12.4	0.01	0.00	0.00	0.00	0.00	0.00	0.00
13.8	0.01	0.00	0.00	0.00	0.00	0.00	0.00
15.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Solar Intra Hour Volatility – 5 Minute Unexpected Movement



*Disclaimer – PNM Made these plots to help visualize the data but it is an approximation.

Wind Intra Hour Volatility – 5 Minute Unexpected Movement

Normalized Divergence (%)	Probability (%) 467 MW	627 MW	827 MW	1,027 MW	1,127 MW	1,427 MW
-20	0.0	0.0	0.0	0.0	0.0	0.0
-17	0.1	0.1	0.0	0.0	0.0	0.0
-14	0.3	0.2	0.1	0.0	0.0	0.0
-11	0.8	0.5	0.3	0.2	0.2	0.1
-8	2.8	2.0	1.3	0.8	0.9	0.6
-5	12.7	11.2	9.5	7.0	7.4	5.8
-2	54.5	60.0	65.3	72.6	71.7	76.5
1	22.5	21.6	20.3	17.6	17.9	15.8
4	4.5	3.5	2.5	1.5	1.6	1.0
7	1.1	0.7	0.4	0.2	0.2	0.1
10	0.3	0.2	0.1	0.0	0.1	0.0
13	0.1	0.1	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0

Energy Storage (Battery) Modeling

- **Batteries are modeled with the following:**
  - **Discharge and charging maximum capacity**
  - **Storage duration**
  - **Round trip efficiency**
  - **Energy price, if any**
  - **Batteries are allowed to provide its full range of ramping capability in less than 5 minutes**
- **SERVM dispatches the storage resource for energy arbitrage but the resource also provides ancillary services**
- **Combined solar and battery projects are constrained by only allowing the solar to charge the battery for the first five years**
- **Energy Storage vs. Quick Start Gas**
  - **Quick start gas resources, while they have significant ramping capability, are slightly more constrained due to startup times of 5 minutes or more**
  - **The 5 minute modeling allows for these differences in the battery and other flexible resources to be captured**

Demand Response Modeling

	Power Saver Program	Peak Saver Program
Capacity (MW)	38.25	15.75
Season	June-Sept	June-Sept
Hours Per Year	100	100
Hours Per Day	4	6

Demand Response is treated as a resource in the modeling.

Questions

Core Assumptions/Constraints/Sensitivities

- ETA Compliance
  - RPS = 80% by 2040
  - Carbon Emission Free by 2040

- San Juan Coal Plant Shuts Down in June 2022
  - San Juan Replacement Plan Approved

High Level Scenarios

- Four Corners Exit in 2024, 2028 & 2031
- Palo Verde Lease Buybacks in 2023 & 2024
- Load Forecast – Base, Low & High
- Gas Price Forecast – Base, Low High
- CO_2 Price Forecast – Base, Low, High
- EE/DSM Forecast – Base, Low, High
- Technologies & Tech Prices (incl. Tax Credits)
- Others?

PNM Resources

Audience Scenario Ideas

- Online Participants – please press 1 on your phone to share your scenario suggestions.
- In-Person Participants – please utilize the flipcharts that are available to write up your scenario suggestions and discuss when called upon

Tentative Meeting Schedule Through May 2020

July 31:	Kickoff, Overview and Timeline
August 20:	The Energy Transition Act & Utilities 101
August 29:	Resource Planning Overview: Models, Inputs & Assumptions
September 6:	Transmission & Reliability (Real World Operations)
September 24:	Resource Planning "2.0"
October 22:	Demand Side/EE/Time of Use
November 5:	Load & CO2 Forecast
December 10:	Initial Scenarios
January 14:	Technology Review / Finalize scenarios*
March 10, 2020:	Process Update
April 14, 2020:	Process Update/Public Draft
May 12, 2020:	Advisory Group Comments

*NOTE:

Registration for Upcoming Sessions

Please register for each upcoming session separately. You will receive a reminders two days in advance and the day of the event.

To access documentation presented so far and to obtain registration links for upcoming sessions, go to:

www.pnm.com/irp

Other contact information:

irp@pnm.com for e-mails

PNM Resources

THANK YOU