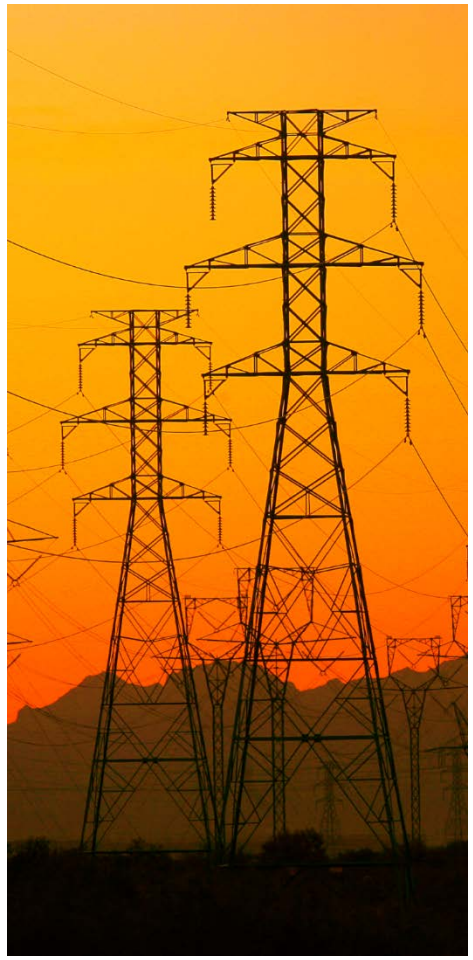
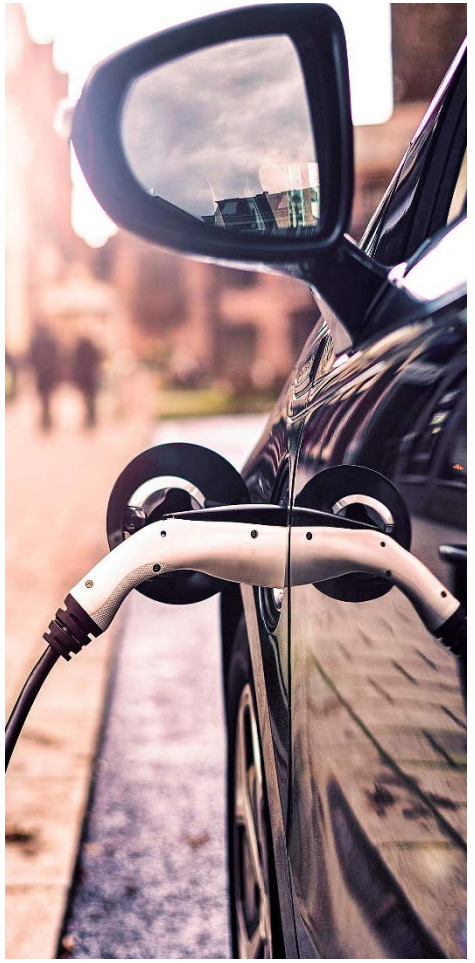


Evaluating Resource Adequacy in the TEP Integrated Resource Plan

Advisory Council Meeting

Lee Alter, Lead Supply Side Planner

August 16, 2019

Tucson Electric Power

Overview

- What is resource adequacy and how is it measured
- TEP's approach to determining resource adequacy in this IRP
- Assumptions and scenarios considered
- Results
- Conclusions
- Next steps

Resource Adequacy

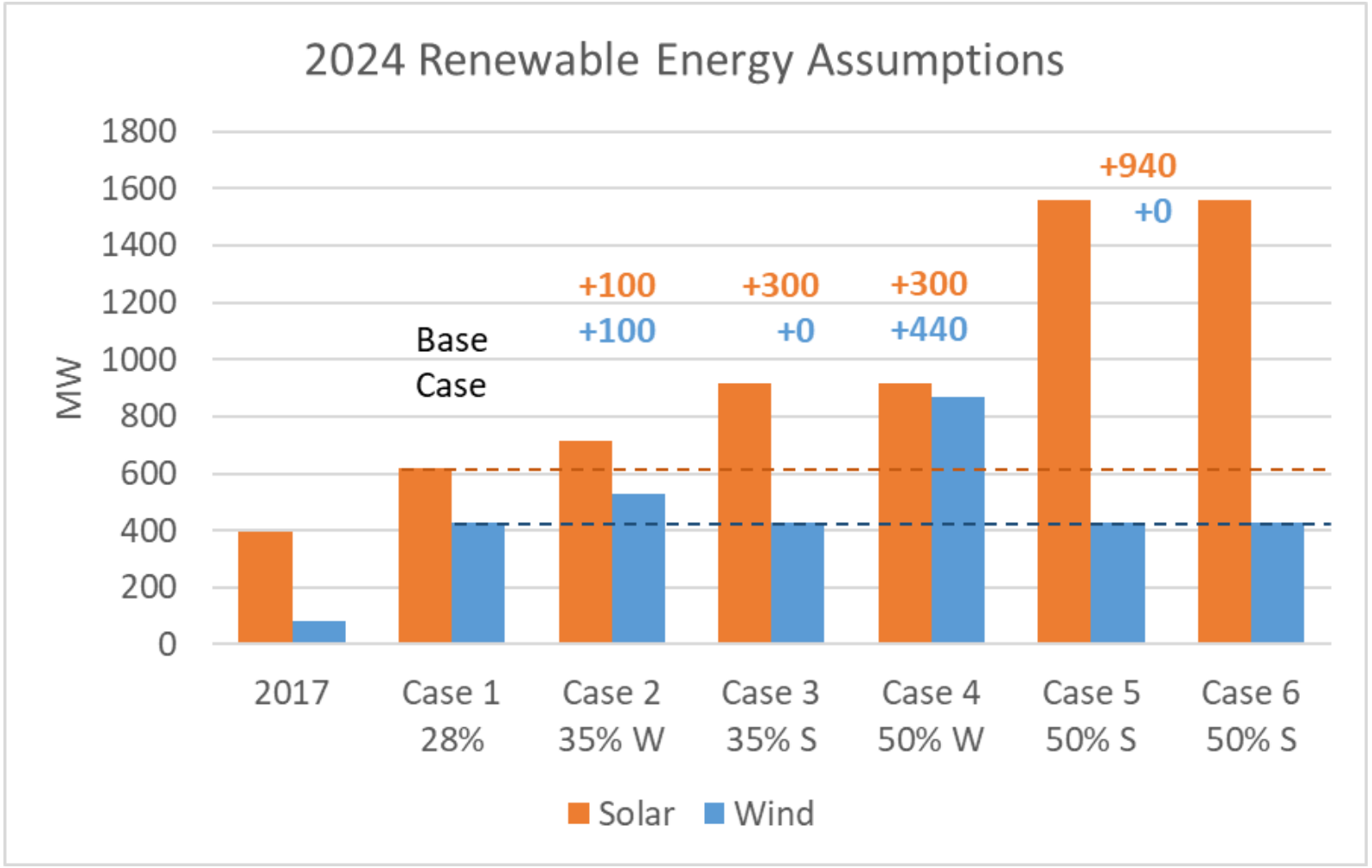
- In the context of resource planning, resource adequacy is the ability to serve demand under all but the most extreme conditions.
- Historically, TEP and other utilities have demonstrated resource adequacy by developing IRPs with a planning reserve margin of at least 15% in each year.
  - Firm capacity = 1.15 * firm peak demand
- Renewable energy introduces new considerations to resource adequacy.
  - How much “firm” capacity can solar and wind provide?
  - Do other resources provide enough “flexible capacity”?
    - Can they adjust their generation quickly enough and deeply enough to balance the variable output of wind and solar (from minutes to hours)?
    - Can they store or use energy during periods of excess generation to help achieve clean energy goals?

Study Questions

- Are TEP's currently-planned resources adequate for integrating the renewable energy necessary to achieve it's corporate goal of serving 30% of retail load with renewables?
- If so, how much additional renewable energy can be integrated before additional flex capacity is needed?

Renewable Energy (RE) Assumptions

Case	RE as % of 2024 Sales	Resources Beyond Case 1
1*	28%	----
2	35%	Majority wind
3	35%	Solar
4	50%	Majority wind
5	50%	Solar
6	50%	Solar

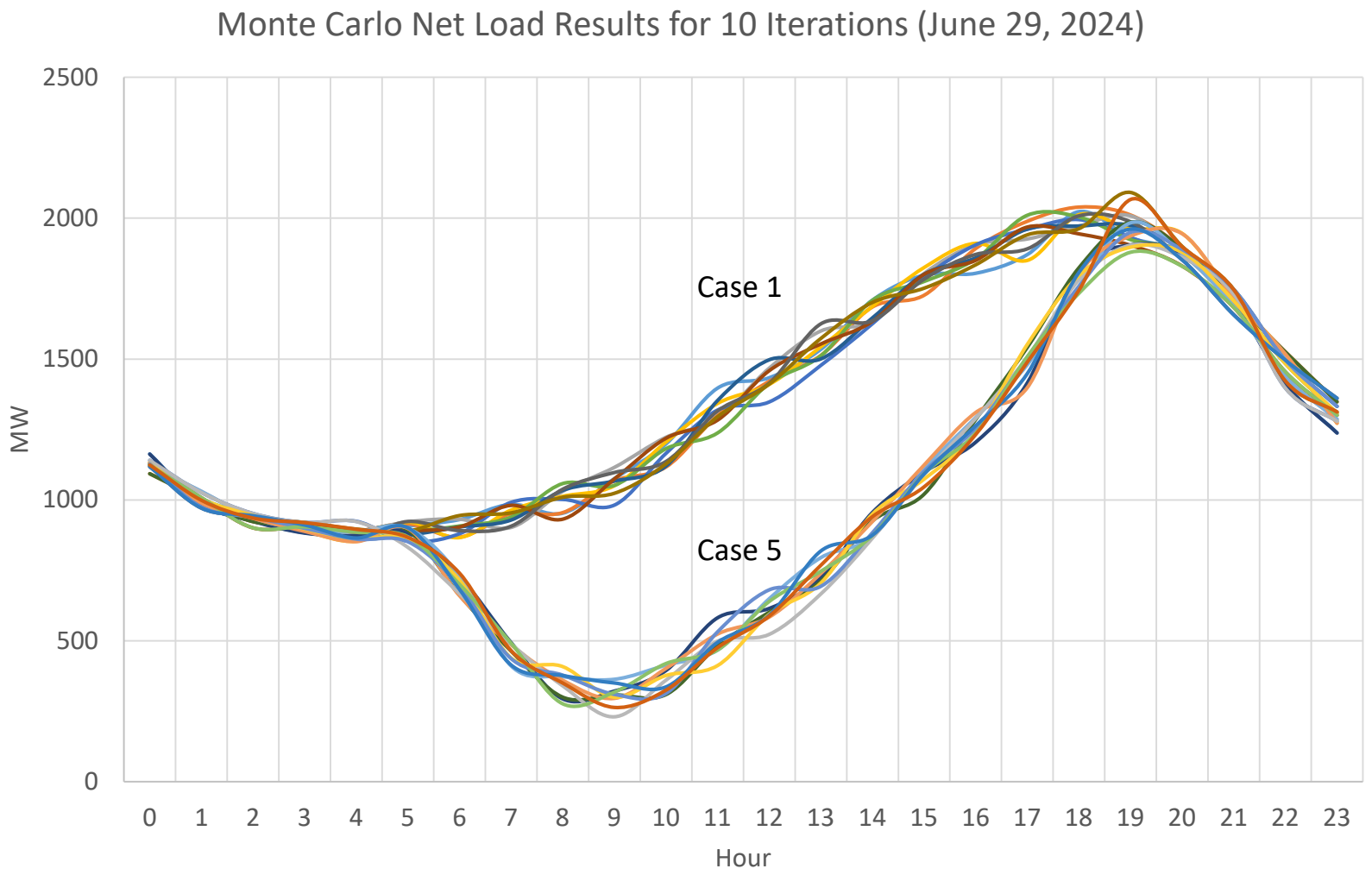


* Case 1 includes the following resources to be added by 2021: 350 MW of wind, 100 MW of solar, and 30 MW of storage.

Two-Step Analytical Approach

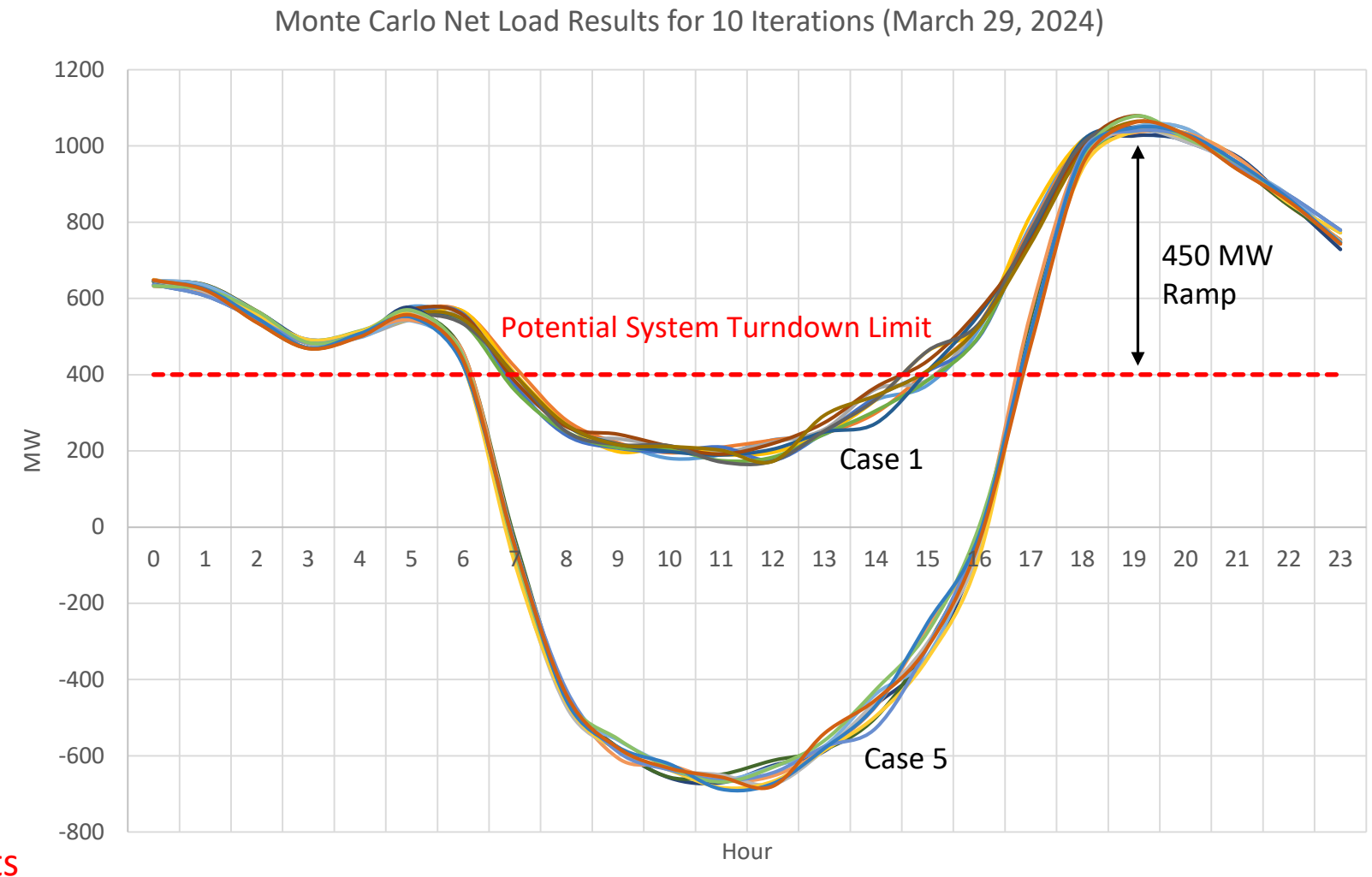
1. Stochastic analysis of net load
   - Net load = retail customer load – renewable energy generation
   - Use Monte Carlo modeling to determine the minimum peak capacity and flexible capacity needed in each case
   - See following slides for examples of metrics and Monte Carlo results
2. Detailed simulation of TEP generation and transmission system
   - Use Aurora to verify adequacy of resources and identify any additional flexibility needed
   - See July 18 presentation for more information on Aurora

Resource Adequacy Metric 1: Peak Net Load



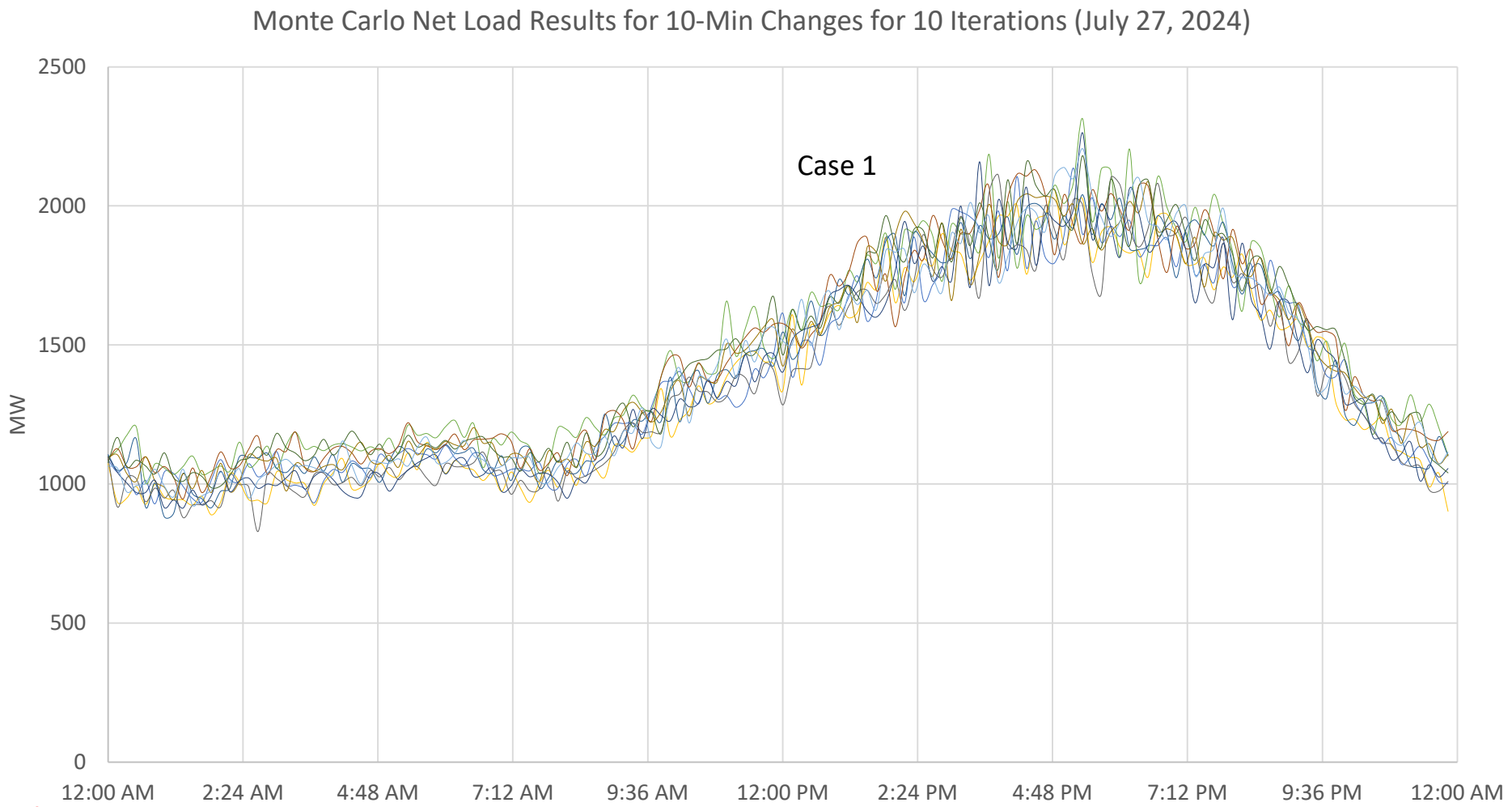
Preliminary results

Resource Adequacy Metrics 2 and 3: Minimum Net Load and 3-Hour Ramping



Preliminary results

Resource Adequacy Metric 4: 10-Minute Regulation

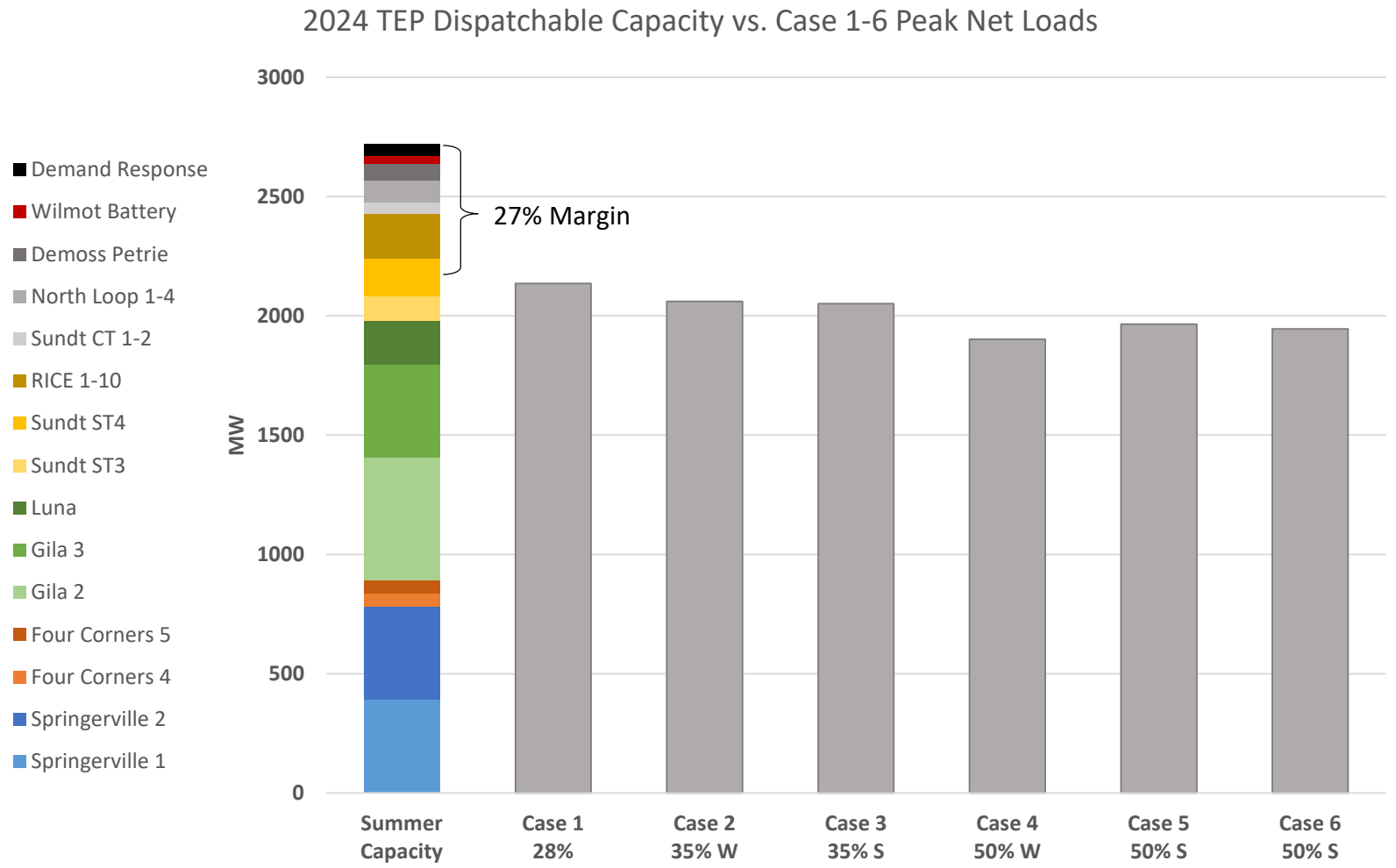


Preliminary results

Peak Net Load

Monte Carlo Results

- TEP's existing and planned dispatchable resources have the capacity to meet peak net load through at least 2024.
- Increasing RE decreases net load and frees up some dispatchable capacity.
- Sharing reserves with neighboring utilities allows for loss of a major unit.
- Aurora analysis confirms no peak capacity issues.

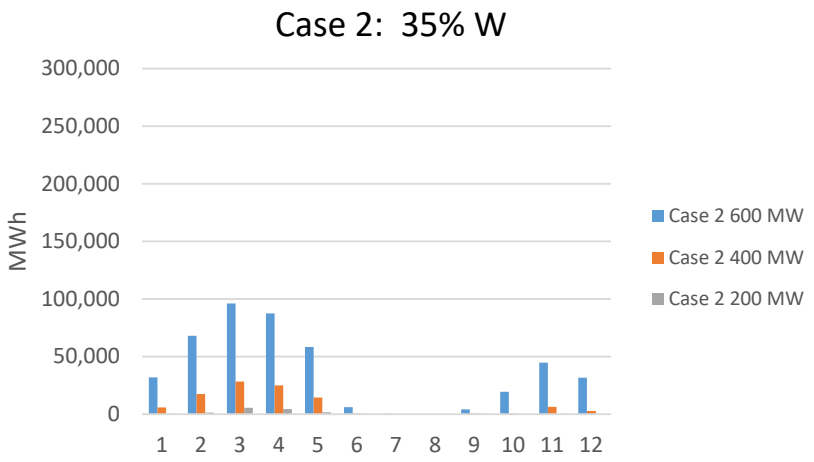


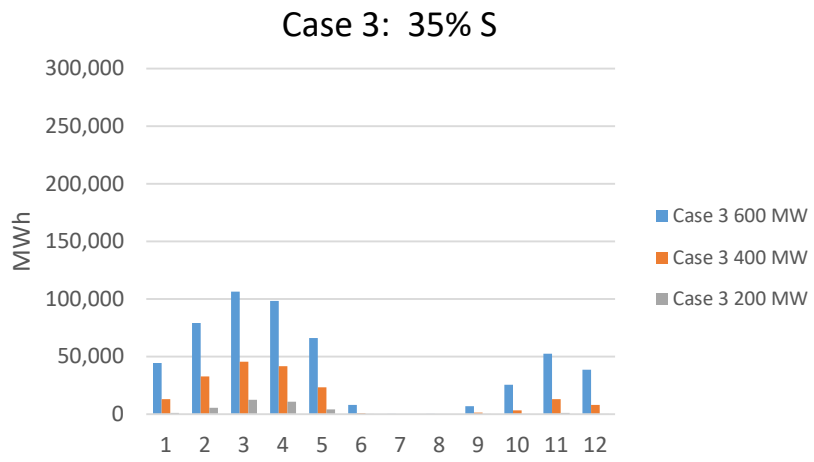
Preliminary results

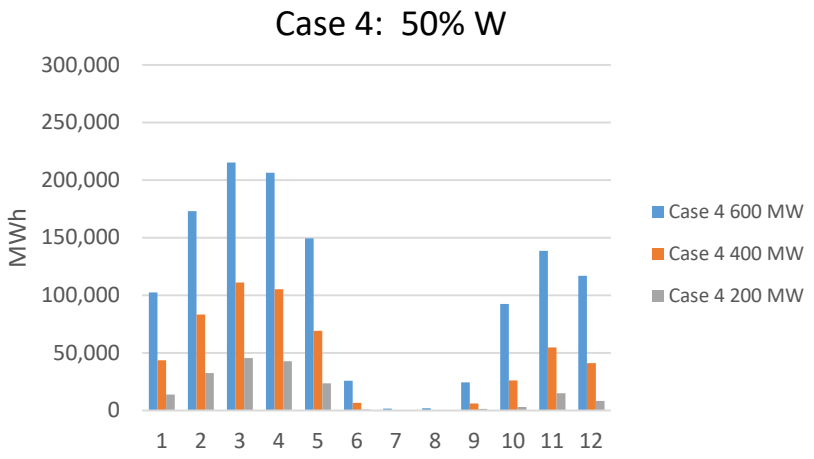
Over Generation
Monte Carlo Results

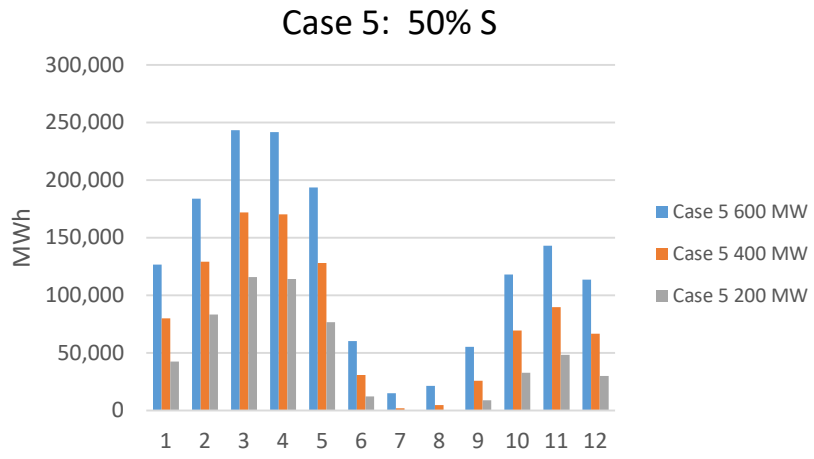
- Over generation occurs mainly in the spring, and to some extent in the winter.
- Over generation depends heavily on which thermal units are on line and their ability to turn down ("turn down limits").

Monthly Over Generation in 2024 Given Alternative Turndown Limits







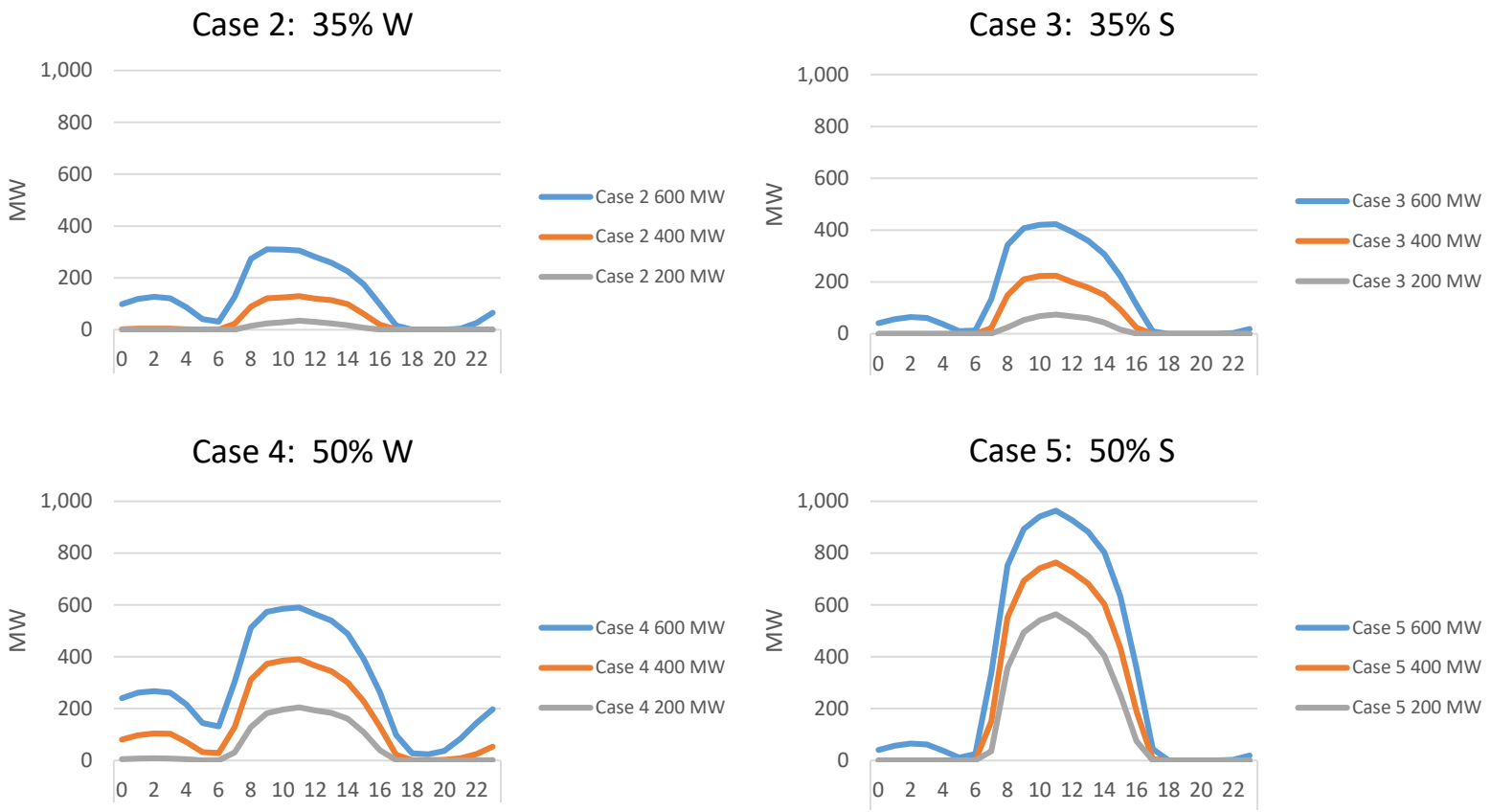


Preliminary results

Over Generation
Monte Carlo Results

- Over generation occurs mostly during the day but can be significant at night in high wind cases.

Hourly Average Over Generation in March 2024 Given Alternative Turndown Limits

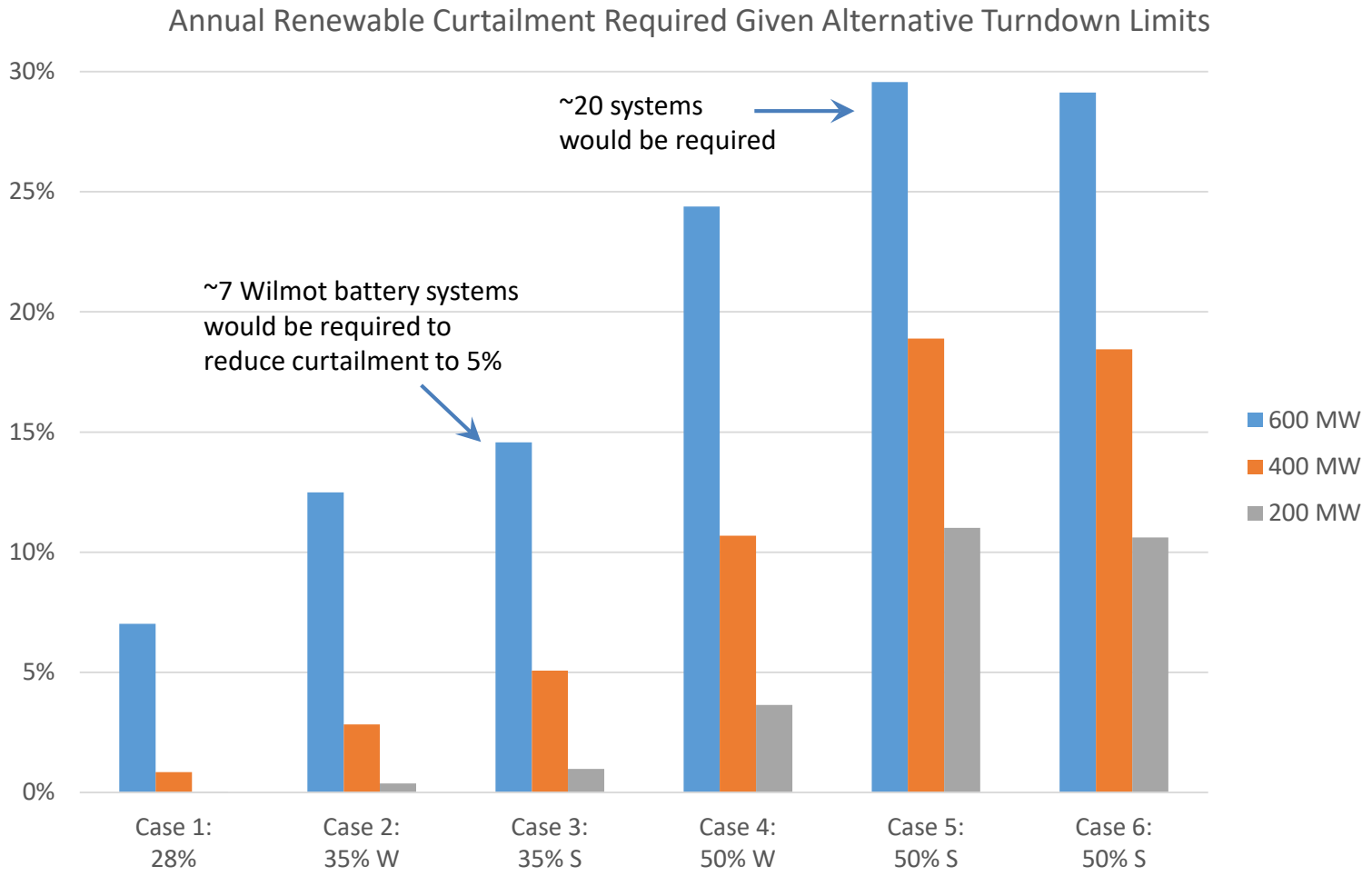


Preliminary results

Over Generation
Monte Carlo Results

- Without additional flexibility, curtailment would become necessary, making it more difficult/expensive to achieve a specific RE goal.
  - Not all RE is curtailable
- Turndown limits are a major factor in the ability to reduce curtailment.
- Alternatively, large amounts of energy storage or other forms of flexible capacity could be used to reduce curtailment.

Preliminary results



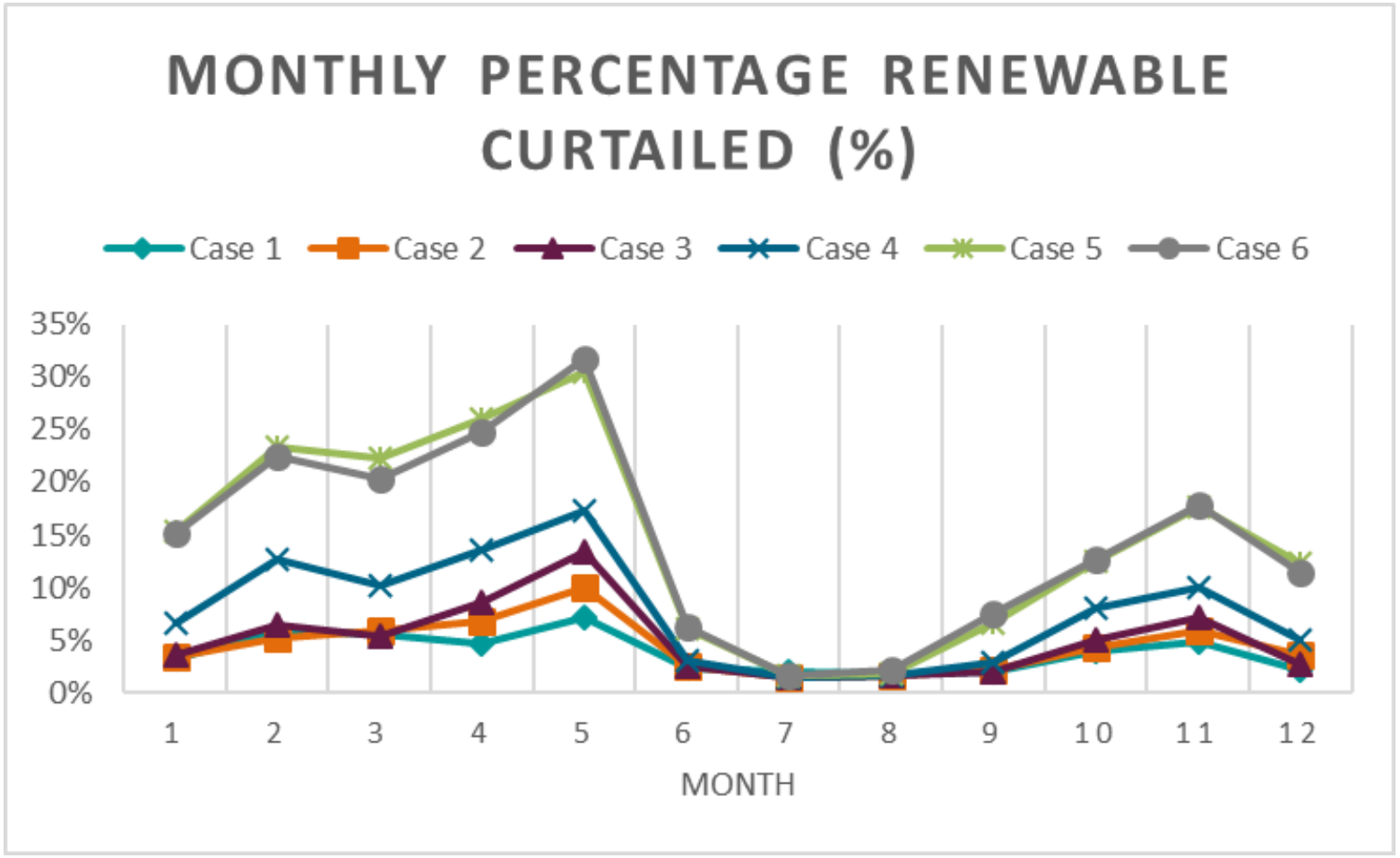
Hornsdale Battery System, Australia
100 MW / 129 MWh

The Wilmot battery system will be approximately this size (120 MWh)

Over Generation

Aurora Results

- Aurora results confirm that over generation can be an issue.
- Consistent with Monte Carlo results assuming a 400 MW turndown.



Preliminary results

3-Hour Ramp & 10-Minute Regulation

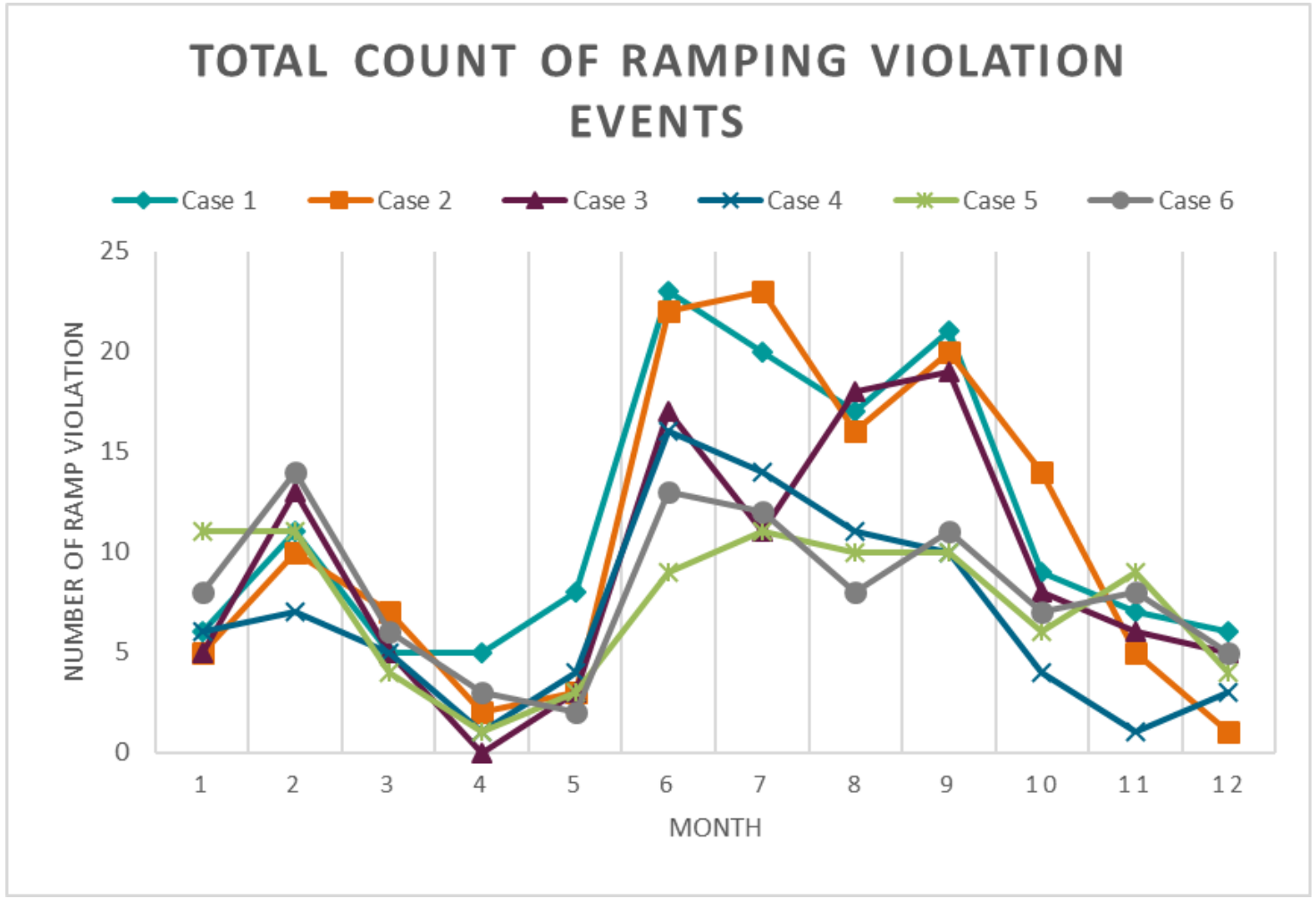
Monte Carlo Results

- Monte Carlo results indicate that TEP has the resources, under ideal operating conditions, to meet the minimum 3-hour ramp and 10-minute regulation requirements for all six cases analyzed
  - The largest 3-hour ramps (~900 MW) occur in Cases 5-6 in the summer months, but can occur throughout the year if low turndown limits are achieved (200 MW)
  - The largest 10-minute ramps (~275 MW) occur in Cases 4-6 in the summer months

10-Minute Regulation

Aurora Results

- The more detailed and comprehensive modeling done by Aurora does identify periods when a 10-minute ramp cannot be met, but the number of periods is very small relative to the total number of periods per month.
- More research should be done on this topic, especially for Cases 4-6.



Preliminary results

Preliminary Findings

- TEP's planned resources should provide adequate peak and flex capacity for meeting its corporate renewable energy goal of 30% renewables through the 2020s. Minor exceptions include:
  - Over generation: Some additional flex capacity might be needed to avoid renewable curtailment and achieve 30% if the system turndown limit cannot be lowered to about 400 MW during the day-time hours of the shoulder months. (Alternatively, some additional renewable capacity could be added to compensate for curtailed energy.)
  - 10-minute regulation: A relatively small number of 10-minute ramps might not be met in the afternoon of summer months. This is a conservative measure and would not necessarily affect reliability since the relevant balancing standard is based on a 30-minute average and provides some tolerances.

Preliminary Findings

- Adding renewable capacity to achieve penetration beyond 30% will have the following effects on resource adequacy:
  - Peak net load: Ability to meet the peak should not be affected since increasing renewables would slightly decrease the net peak.
    - Relying on solar power to increase penetration beyond 35% would shift the time of peak net load from 4-5 pm to 7 pm, significantly reducing the ability of future solar to provide capacity value.
  - Over generation: Ability to minimize over generation depends heavily on system turndown limits. Can become a significant factor at 35%, especially if trying to achieve a renewable energy generation goal rather than a CO_2 emissions goal.
  - 3-hour ramping: Ability to meet ramping requirements should not be affected, although achieving 50% strictly through solar could be testing the ability of the system.
  - 10-minute regulation: Ability to meet 10-minute changes should not be affected, although more research is warranted to confirm this ability at penetrations beyond 35%

Next Steps

- Update analysis to include UNS Electric and to evaluate adequacy of resources across TEP's entire balancing area
- Refine Monte Carlo analysis to include time series and spatial correlations
- Review results further within TEP and with other stakeholders