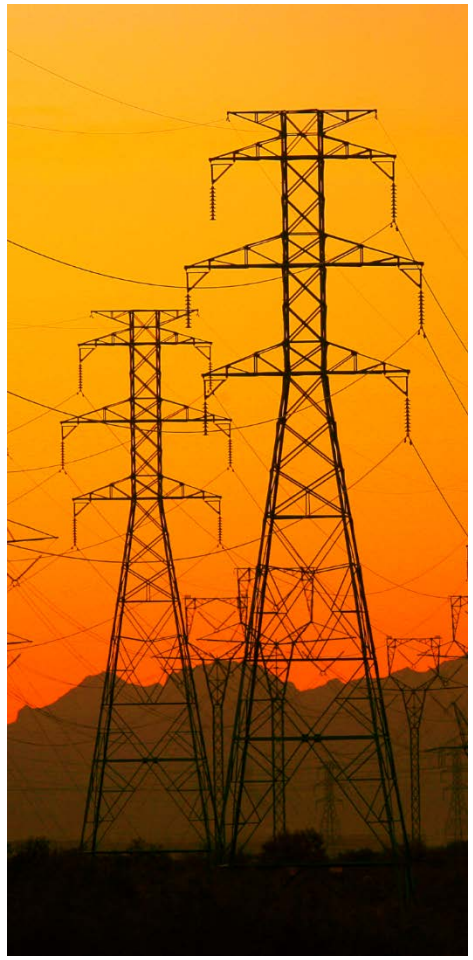
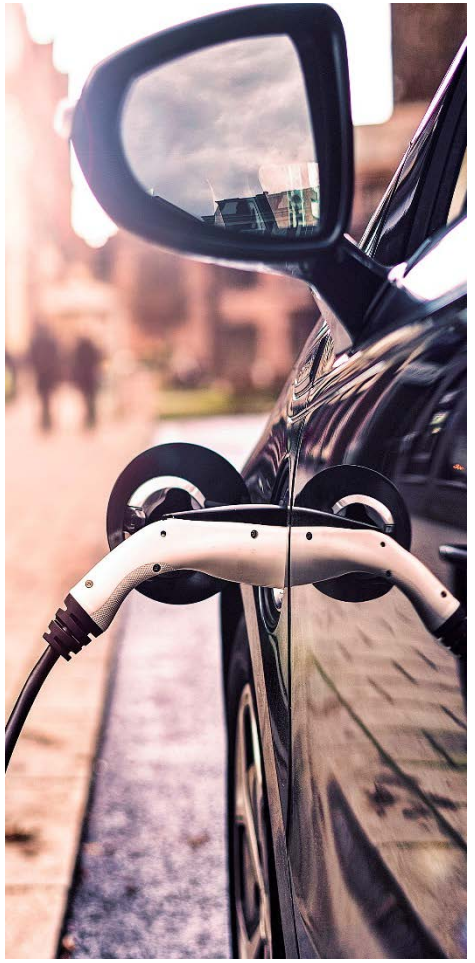


TEP Integrated Resource Plan

Flexible Resource Adequacy Study

Tucson Electric Power

May 20, 2020

Overview

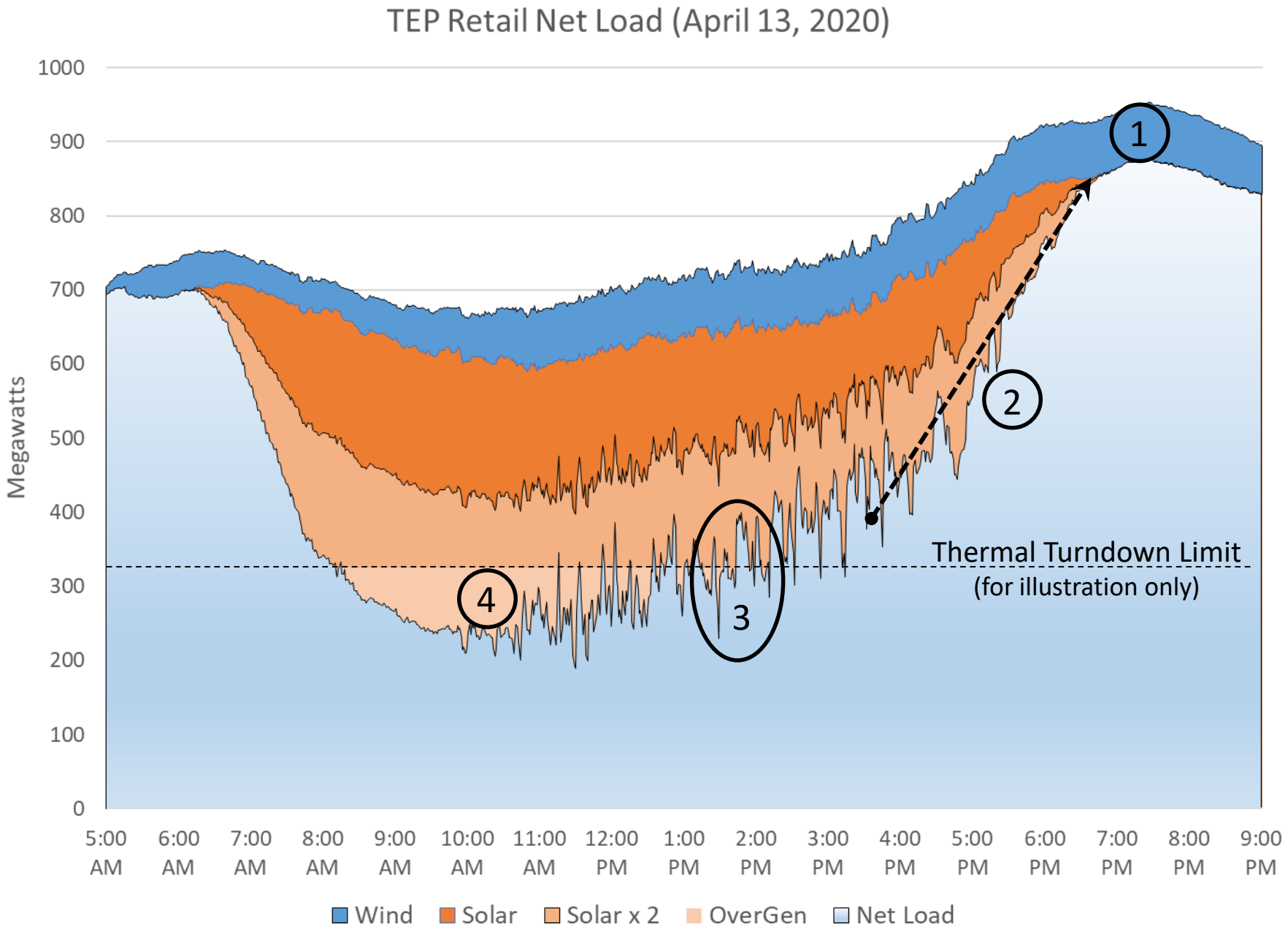
- What is resource adequacy?
- How is TEP evaluating its resource adequacy?
- Assumptions and scenarios considered
- Results
- Conclusions

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 * (forecasted retail peak demand + firm wholesale)
  - This will continue to be an important criteria in the IRP to ensure supply can meet peak demand
- However, renewable energy introduces new considerations to resource adequacy
  - How much “firm” capacity can solar and wind provide at the times of peak demand?
  - Do other resources provide enough “flexible capacity” to accommodate renewable variability?
- This study seeks to answer whether TEP’s current system can integrate the renewable energy (RE) necessary to achieve it’s corporate RE goal of 30%, and if so, how much additional RE can be integrated before additional flex capacity is needed.
- Pace Global (now a Siemens business) was retained to lead the technical work.

Resource Adequacy Metrics

1. Peak Net Load
2. 3-Hour Ramp of Net Load
3. 10-Minute Ramp of Net Load
4. Over Generation

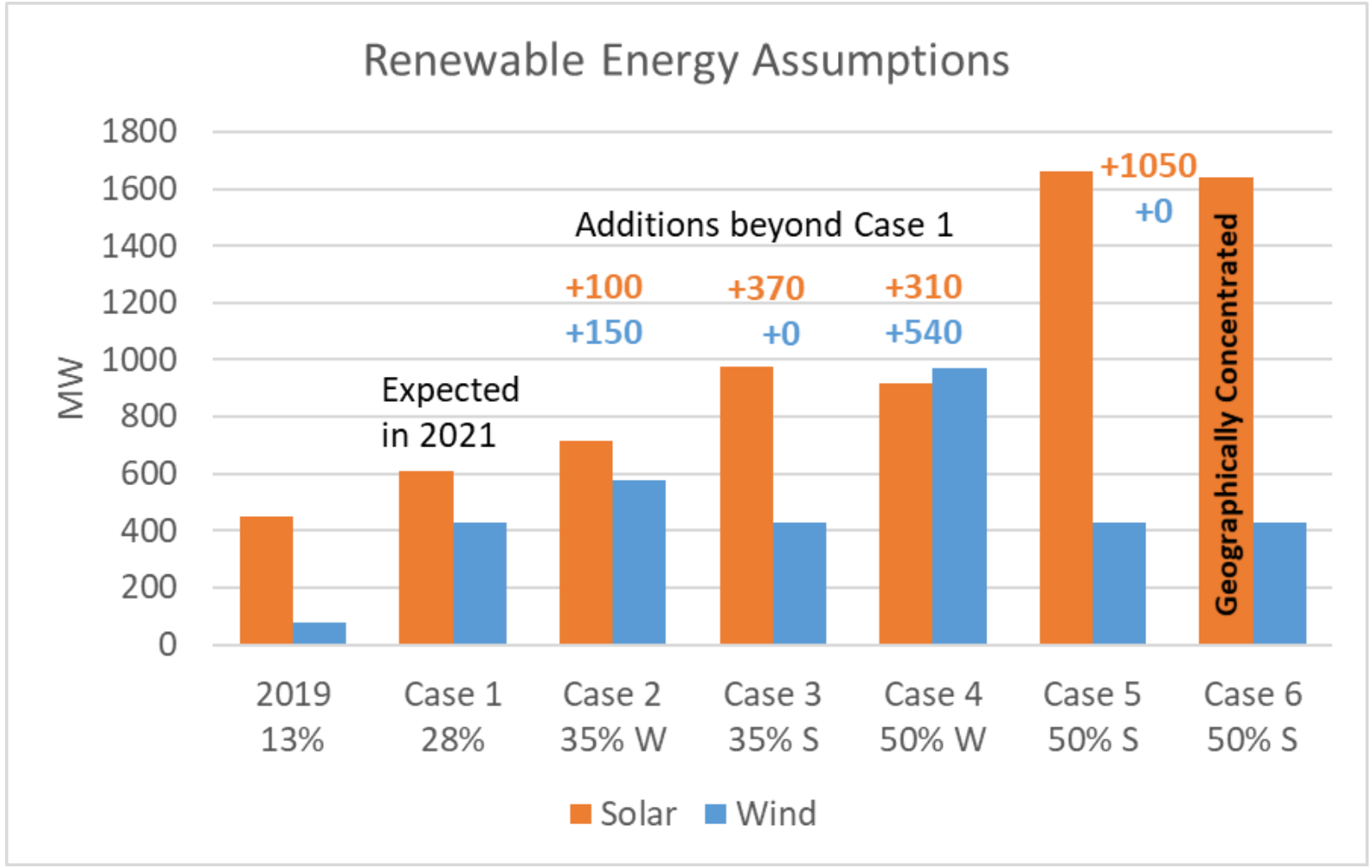


Methodology

- Use loads and resources anticipated in mid 2020s
  - Representative snapshot of the IRP's mid-planning horizon
  - Follows the retirement of 508 MW of coal and 160 MW of gas, and the addition of 450 MW of renewables
- Two-pronged analytical approach
  1. Stochastic analysis of net load
     - Monte Carlo modeling (99th percentile of 250 iterations)
     - Based on two years of coincident TEP load and renewable data
  2. Detailed simulation of TEP generation and transmission system
     - Uses Aurora to independently quantify any resource deficiencies

Renewable Energy Penetration Cases

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



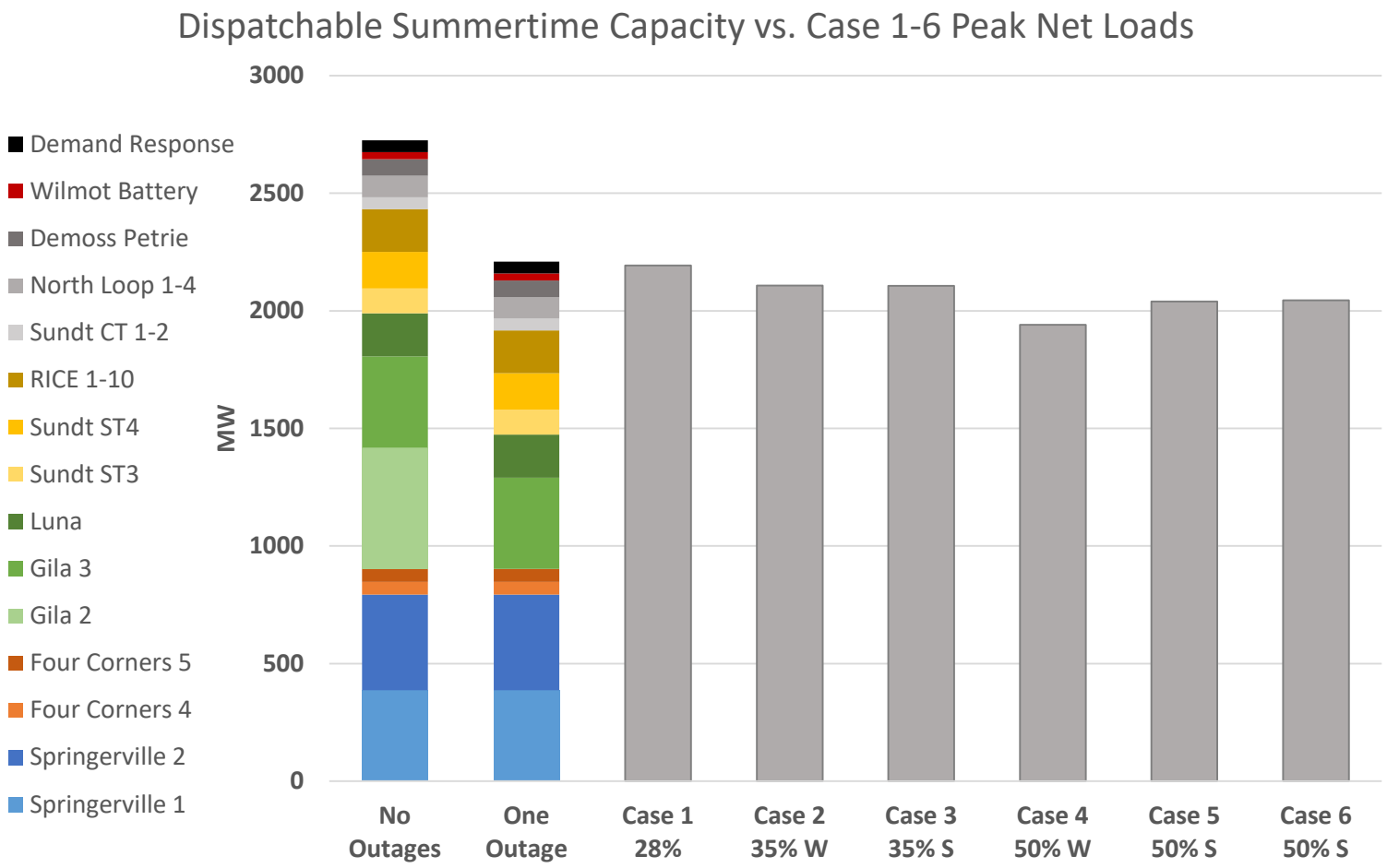
* Case 1 includes the following resources to be added in/by 2021: 350 MW of wind, 100 MW of solar, 100 MW of DG, and 30 MW of storage.

1

Peak Net Load

Monte Carlo Results

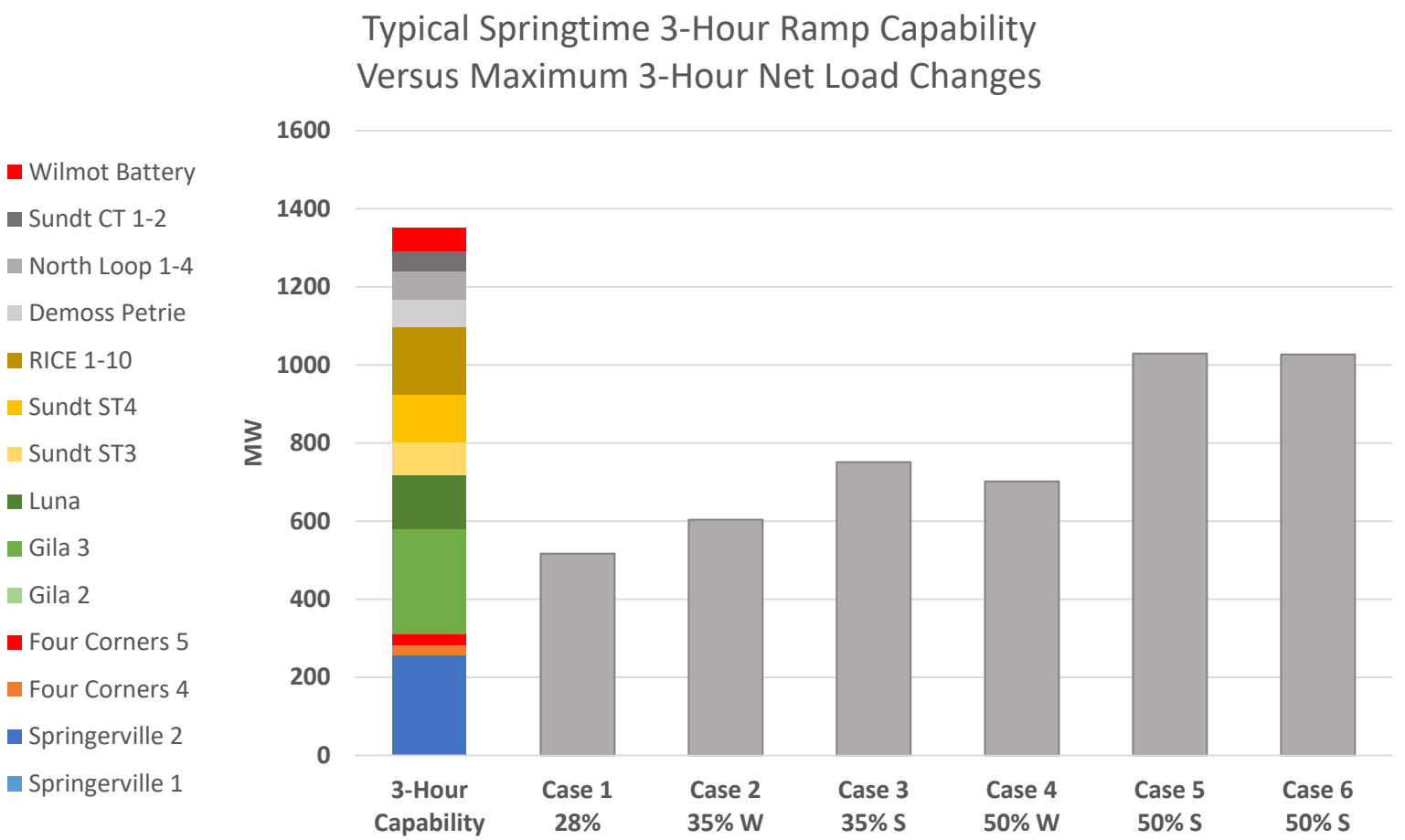
- This analysis indicates TEP will have adequate capacity to meet peak net load in all six cases.
- Assumes the full availability of dispatchable resources and no further retirements beyond San Juan in 2022.
- Aurora analysis confirms peak load can be met.



2

3-Hour Ramp
Monte Carlo Results

- This analysis indicates TEP will have adequate flex capacity to accommodate 3-hour ramps in all six cases.
- Assumes the full ramping availability of all but two dispatchable resources, no further retirements beyond San Juan in 2022, and a 300 MW turndown limit.
- Largest 3-hour ramps occur in spring and fall, when maintenance outages are common.
- Aurora analysis confirms 3-hour ramps can be met.

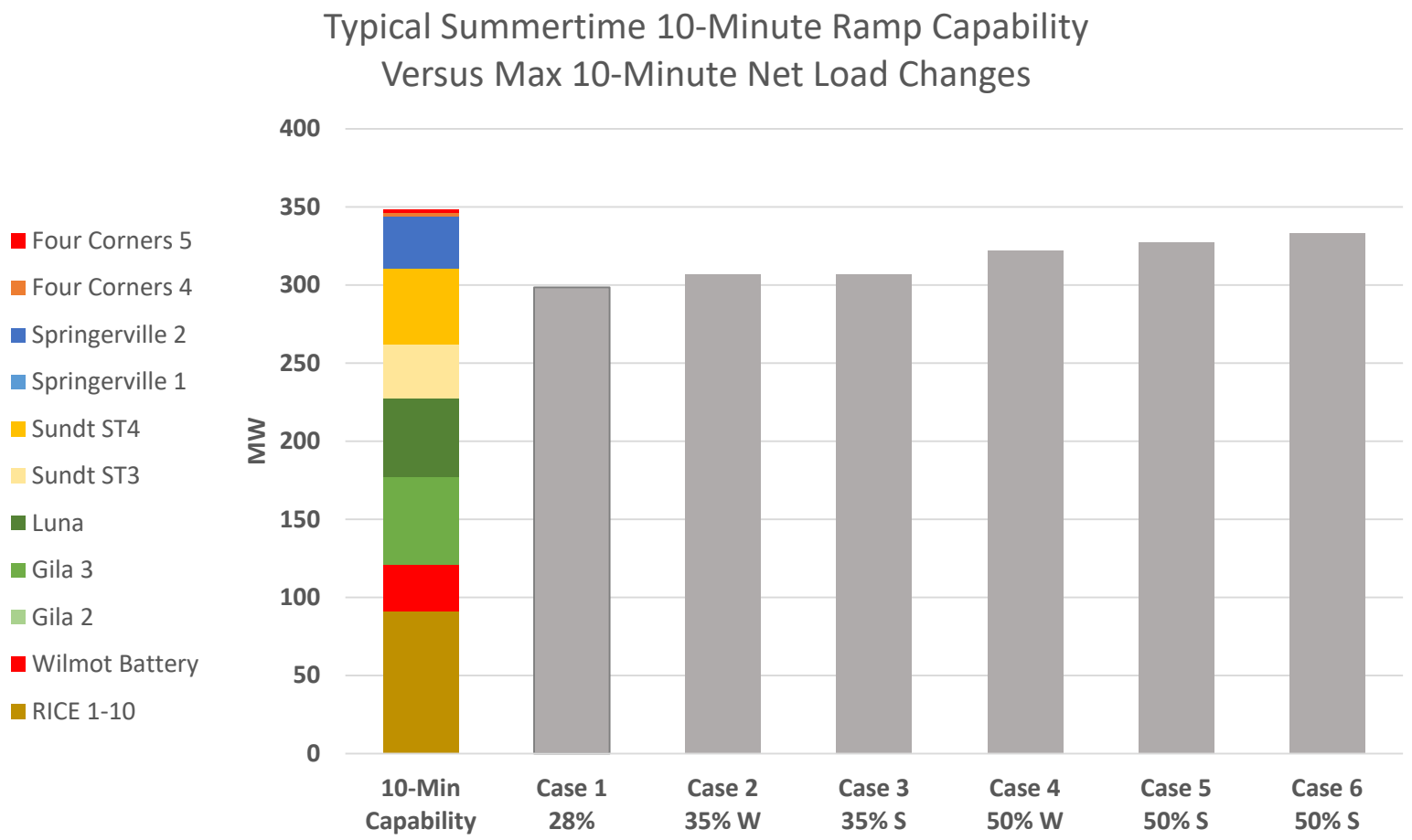


3

10-Minute Ramp

Monte Carlo Results

- This analysis indicates TEP will have adequate flex capacity to accommodate 10-minute ramps in all six cases.
- Assumes the full ramping availability of all but three dispatchable resources and no further retirements beyond San Juan in 2022.
- Largest ramps occur in summer.
- The lack of sensitivity across the six cases (28% to 50% RE) is counterintuitive and suggests that this flexibility requirement should continue to be studied.

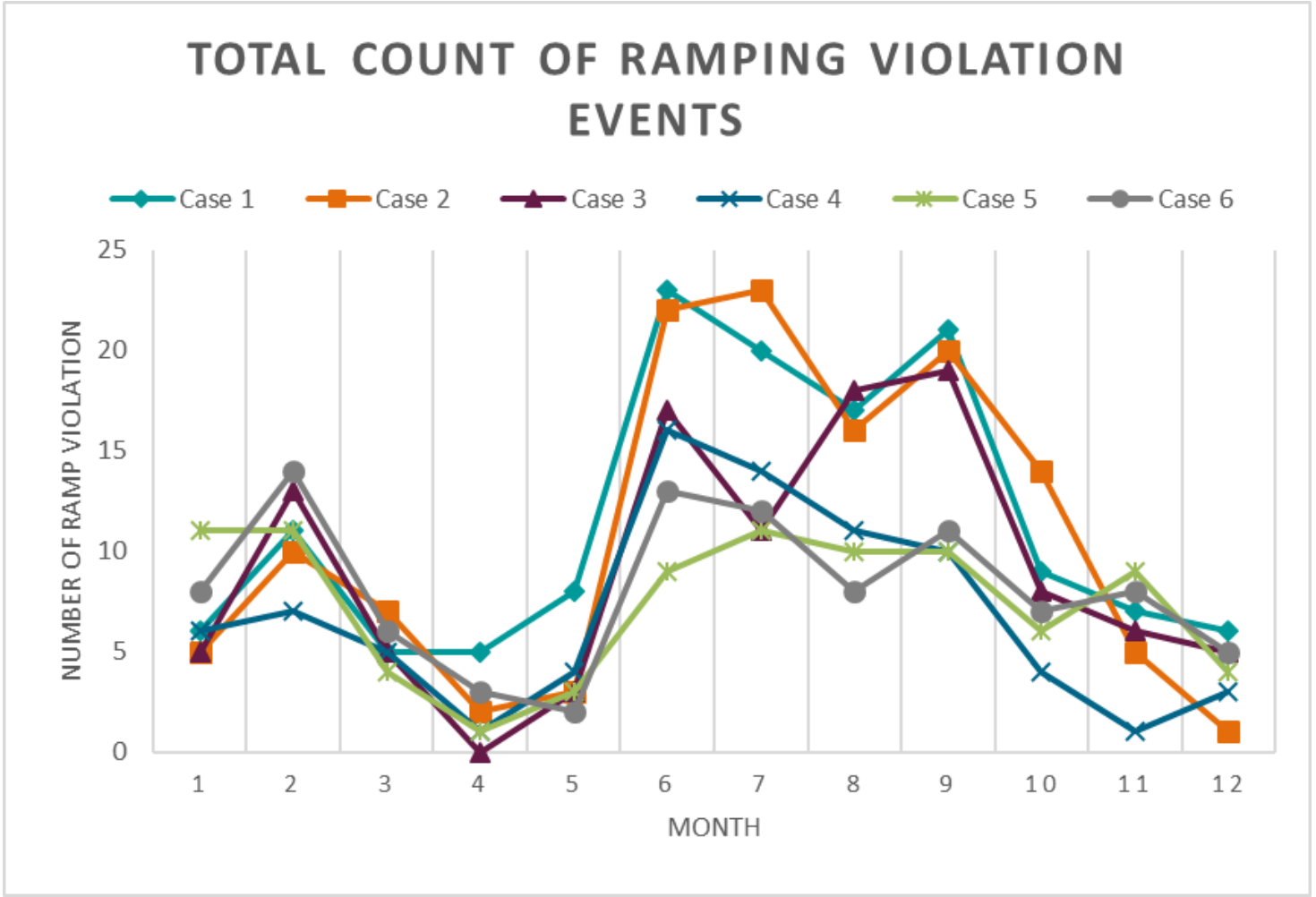


3

10-Minute Ramp

Aurora Results

- Modeling with Aurora identifies a small number of 10-minute intervals in which the net load ramp cannot be met (fewer than 25 out of 4,300 per month).
- Moreover, the relevant grid reliability standard is based on a 30-minute average, and there were only a few hours per year that had more than one 10-minute interval with a ramp that could not be met.
- Nonetheless, the presence of some ramping deficiencies suggests that this flexibility requirement should continue to be studied.

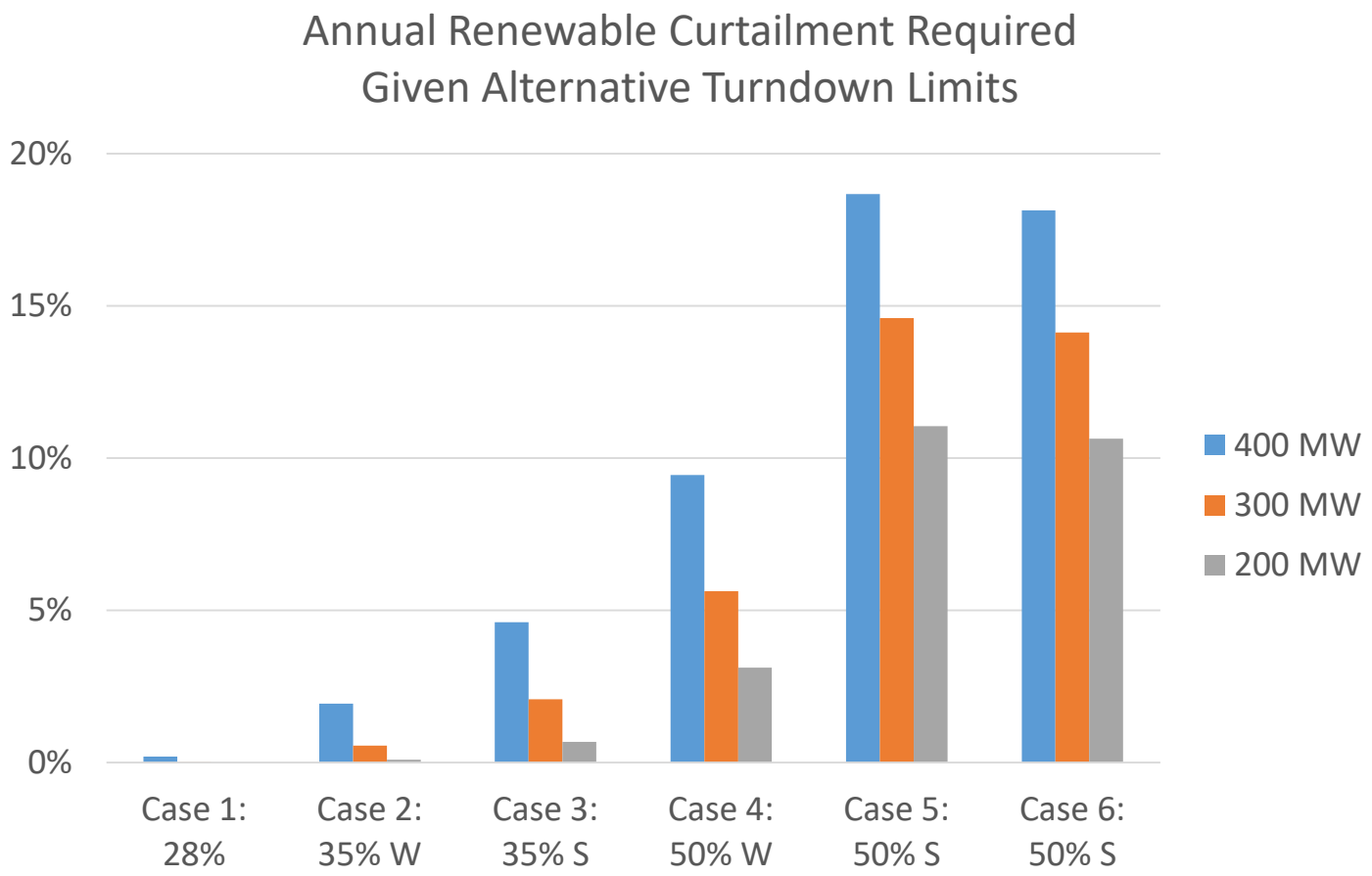


4

Over Generation

Monte Carlo Results

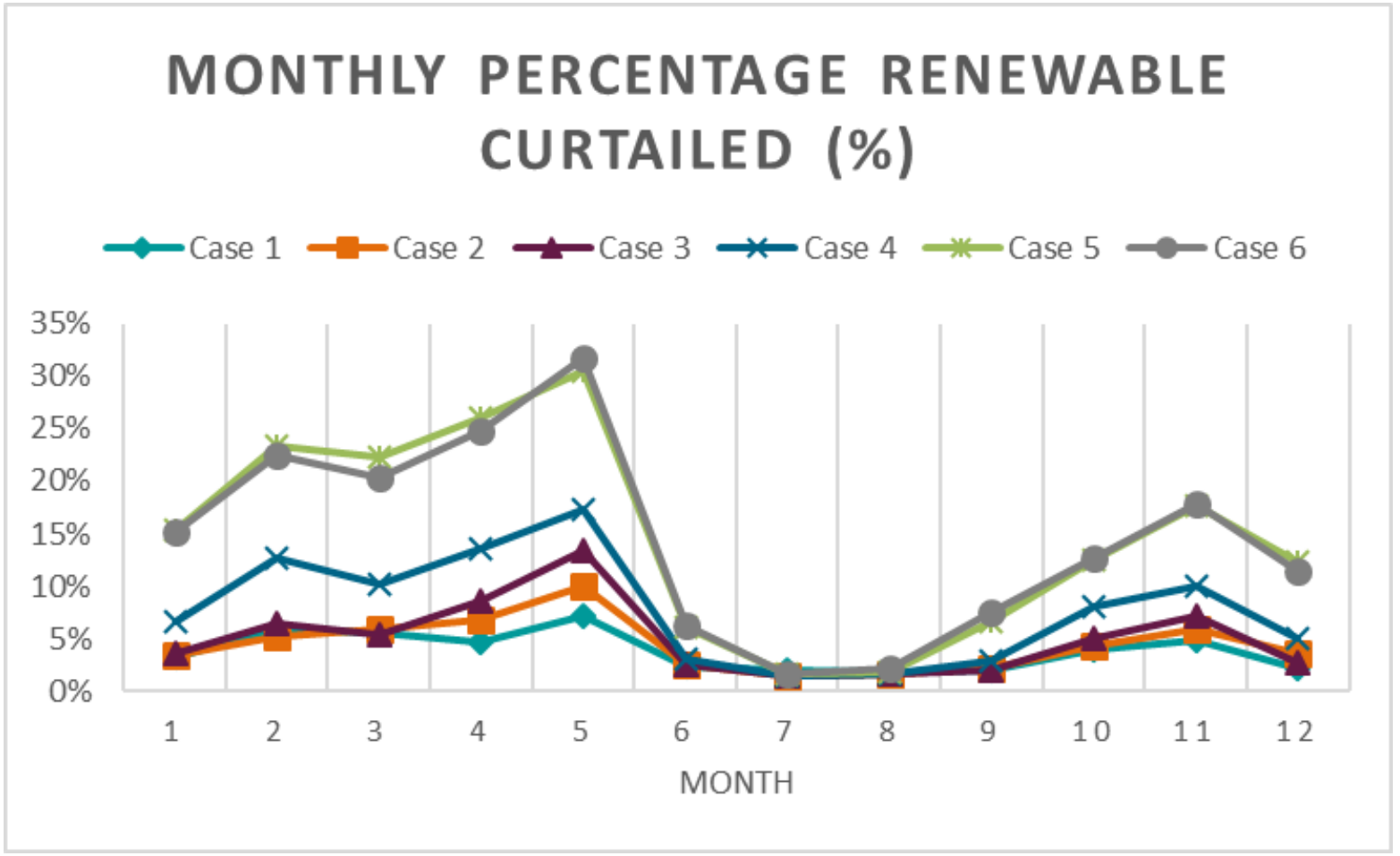
- With a few thermal units on line for reliability purposes, the system turndown limit can reasonably be expected to be about 300 MW.
- At that limit, over generation begins to occur in Cases 2 and 3 and is significant in Cases 4-6.
- Without energy storage or other flexibility measures, the over generated RE would need to be curtailed and would not contribute to meeting a RE target.



4 Over Generation

Aurora Results

- Aurora results confirm that over generation can be an issue.
- The amount of over generation estimated by Aurora is consistent with Monte Carlo results assuming a 300 MW turndown limit.



Conclusions

- TEP's resources should provide adequate peak and flexible capacity for meeting its corporate renewable energy goal of 30% renewables through the 2020s. Caveats include:
  - Over generation: Some additional flex capacity might be needed if the system turndown limit cannot be kept below 400 MW during the day-time hours of the non-summer months. Alternatives include various forms of energy storage, market sales, dispatchable load, and additional renewable capacity to compensate for curtailed energy.

Conclusions

- Adding renewable resources to achieve penetration up to 50% will have the following effects on resource adequacy:
  1. Peak net load: Ability to meet peak demand should not be affected since increasing renewables tends to decrease the peak net load. If major retirements are planned, the ability to meet peak demand should be reevaluated, as additional resources might be required.
  2. 3-hour ramps: Ability to meet 3-hour ramps should not be affected, although achieving 50% strictly through solar could be testing the ability of the system if/when major units are off line in the non-summer months.
  3. 10-minute ramps: Ability to meet 10-minute ramps should not be affected, although more research is warranted to confirm this ability at penetrations beyond 35%.
  4. Over generation: Over generation is likely to be significant at penetrations beyond 35%, making it more difficult or expensive to achieve a RE goal, as opposed to a CO_2 emissions goal.

Comments & Questions