Tucson Electric Power ELCC Study

Prepared for RPAC presentation

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Energy+Environmental Economics

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Background

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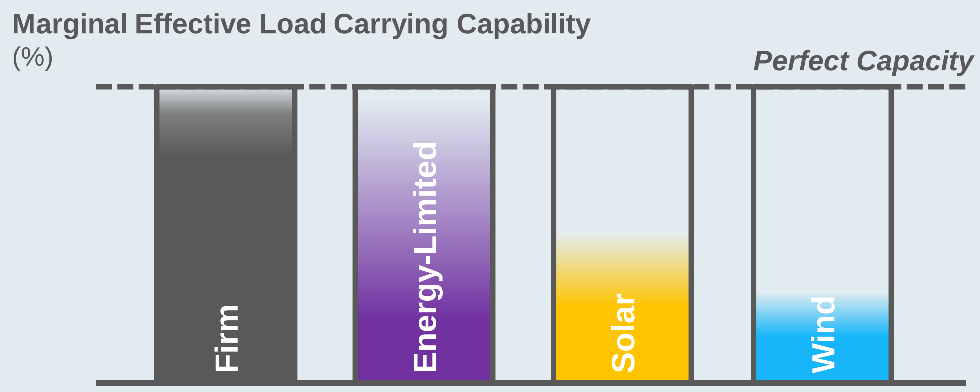
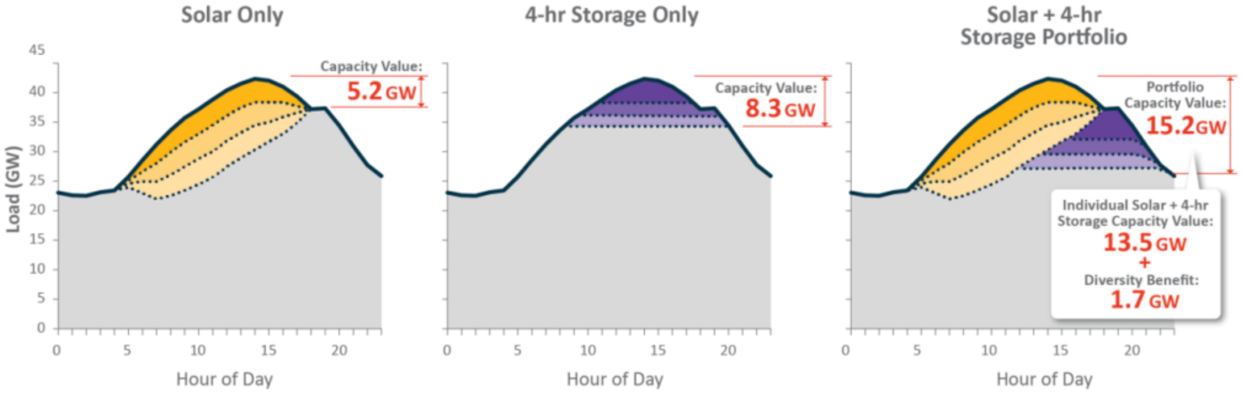
Accurately accounting for resources' reliability contribution is necessary to ensure reliable electric service

- **Renewables and storage penetration will continue to grow, driven by deep-decarbonization goals and economics**
- **Accurately measuring the effective capacity contribution of these resources with an Effective Load Carrying Capability (ELCC) is important to maintain reliability.**
- **ELCC:**
  - Captures capacity contribution across a broad range of system conditions
  - Robustly accounts for saturation effects and interactive effects between resources
  - Allows system to function efficiently and effectively even as it transitions away from reliance on firm resources

ELCC measures a resource's contribution to the system's needs relative to perfect capacity, accounting for its limitations and constraints

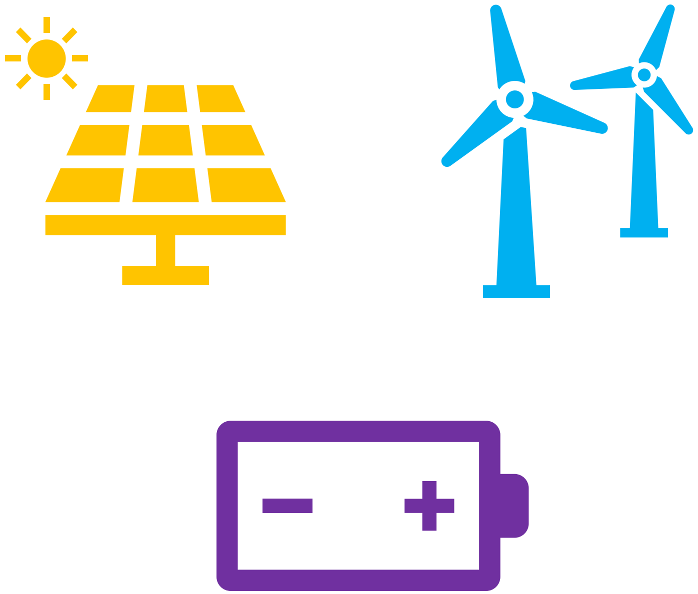


Saturation effect with increasing penetration | **Interactive effect**



Study purpose

+ **TEP retained E3 to calculate the ELCC for variable renewable and energy/duration-limited resources**
  - These include, solar, wind, 4 and 8-hr storage
+ **Study results can be used to:**
  - Accurately account for the value of these resources in future IRPs to build a cost-effective resource portfolio that will also be reliable
  - Inform resource procurement in the near-term for summer preparedness



Methodology

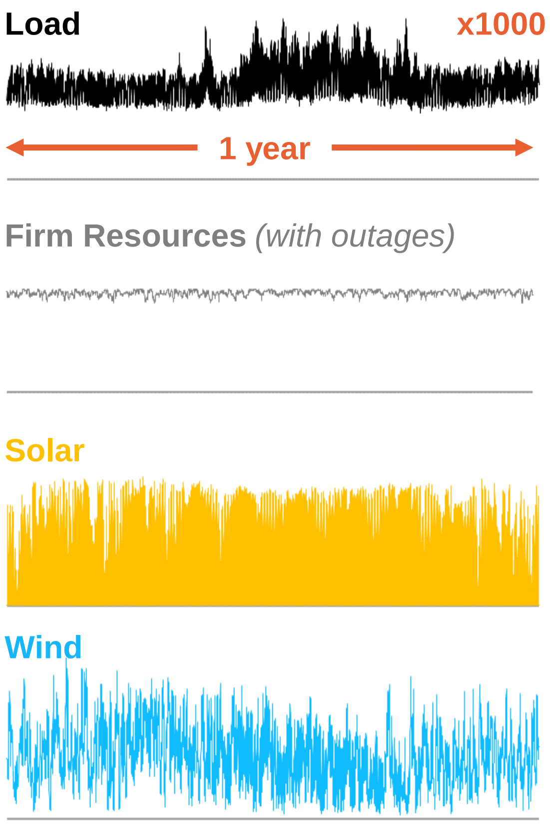
Developing model inputs

Profile	Primary Source(s)	Weather Conditions Captured	Notes
Loads	**EIA** Hourly Electric Grid Monitor **NOAA** Historical Weather Data	1979 – 2020	• Neural network regression used to back-cast hourly load patterns under broad range of weather conditions using recent historical load data (2011-2020) and long-term weather data (1979-2020) • Historical shape scaled to match future forecasts of regional energy demand • Shapes for load modifiers (e.g., transportation electrification) layered on top of neural network results
Wind	**NREL** WIND Toolkit	2007 – 2012	• Profiles for **existing wind resources** simulated based on plant locations, known characteristics (e.g., hub height & power curve) • Profiles for **additional wind resources** simulated based on generic locations chosen by E3 with input from TEP
Solar	**NREL** System Advisor Model	1998 – 2019	• Profiles for **existing utility-scale solar resources** simulated based on plant locations, known characteristics (tracking vs. tilt, inverter loading ratio) • Profiles for **additional utility-scale solar resources** simulated based on generic locations and technology characteristics chosen by E3 with input from TEP • Profiles for **behind-the-meter/distributed solar** simulated for TEP/UNSE service area

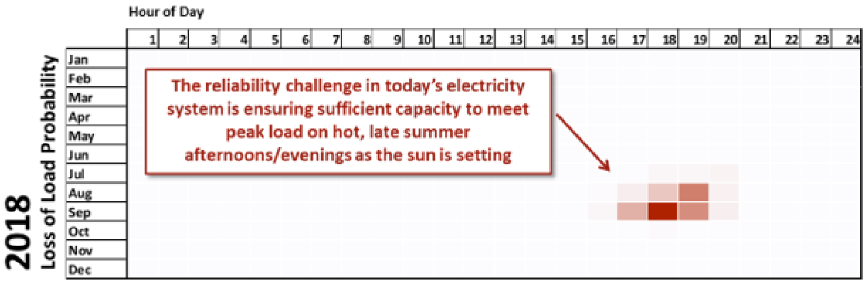
Setting up E3's RECAP model

+ **E3's Renewable Energy Capacity Planning (RECAP) model is a probabilistic method to consider system reliability across a wide range of load and weather conditions**
+ **Monte Carlo simulations consider system operations across a range of conditions**
  - Broad range of loads & renewables
  - Randomly simulated plant outages
  - Dispatch of use-limited resources
+ **Primary results are probability-weighted statistics of loss of load frequency, duration, and magnitude – but can also be used to derive PRM requirements and ELCCs of different resources**

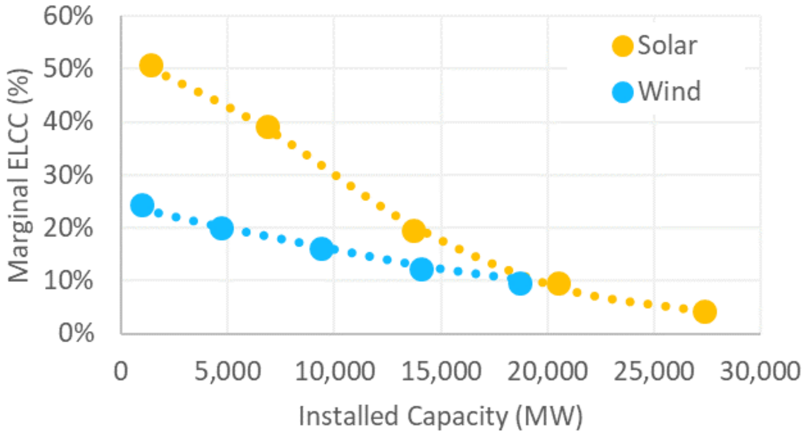
__Monte Carlo simulation__ of loads, renewable profiles, and generator outages used to simulate 1,000 years of plausible system conditions



__System reliability__ measured relative to "one day in ten year" standard; periods of high loss of load probability identified



__Effective load carrying capability (ELCC)__ for a wide range of types of resources evaluated

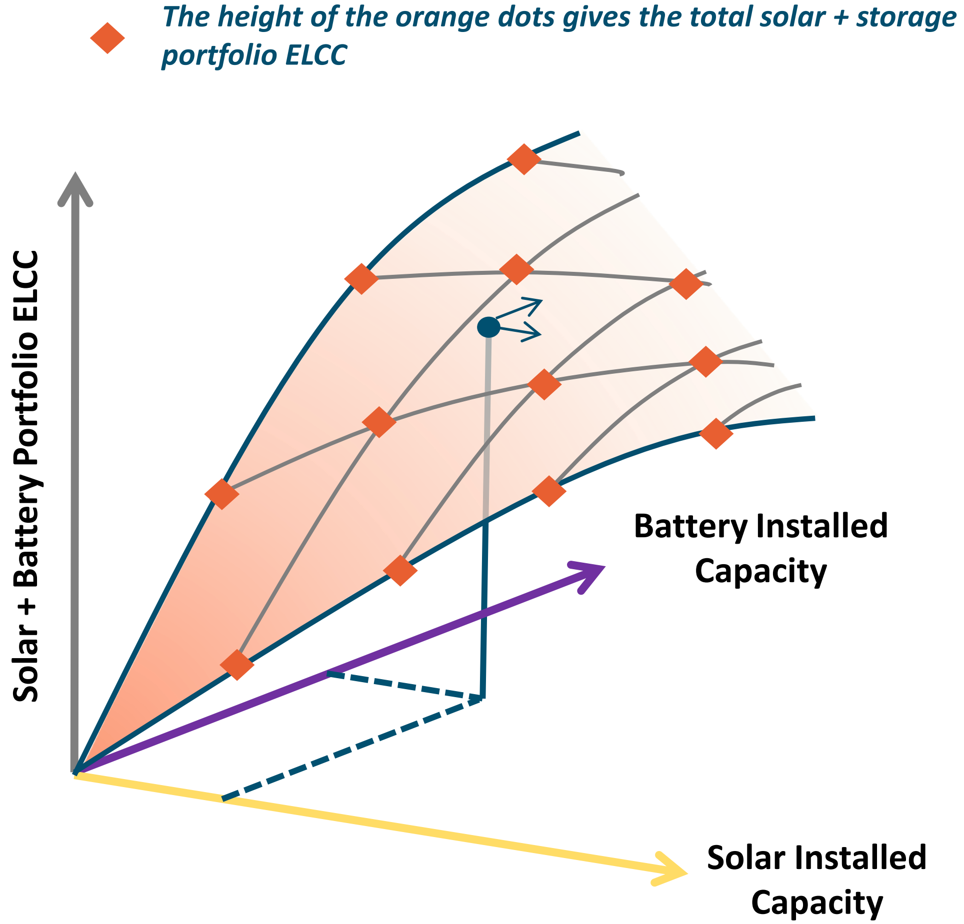


Example RECAP result from *Long-Run Resource Adequacy under Deep Decarbonization Pathways for California* (Calpine, 2019)

Developing ELCC surfaces

+ A multi-dimension ELCC surface can capture interactive effects between multiple resources and show combined capacity contribution
+ Account for both diminishing returns and interactive effects between resources
+ E3 calculated ELCCs for the combined TEP+UNSE system in 2028, chosen by TEP
+ Delivered results included-
  - Wind ELCC curve
  - Solar-4-hr Storage ELCC surface
  - 8-hr Storage ELCC curve

Illustrative ELCC surface



Inputs and Assumptions

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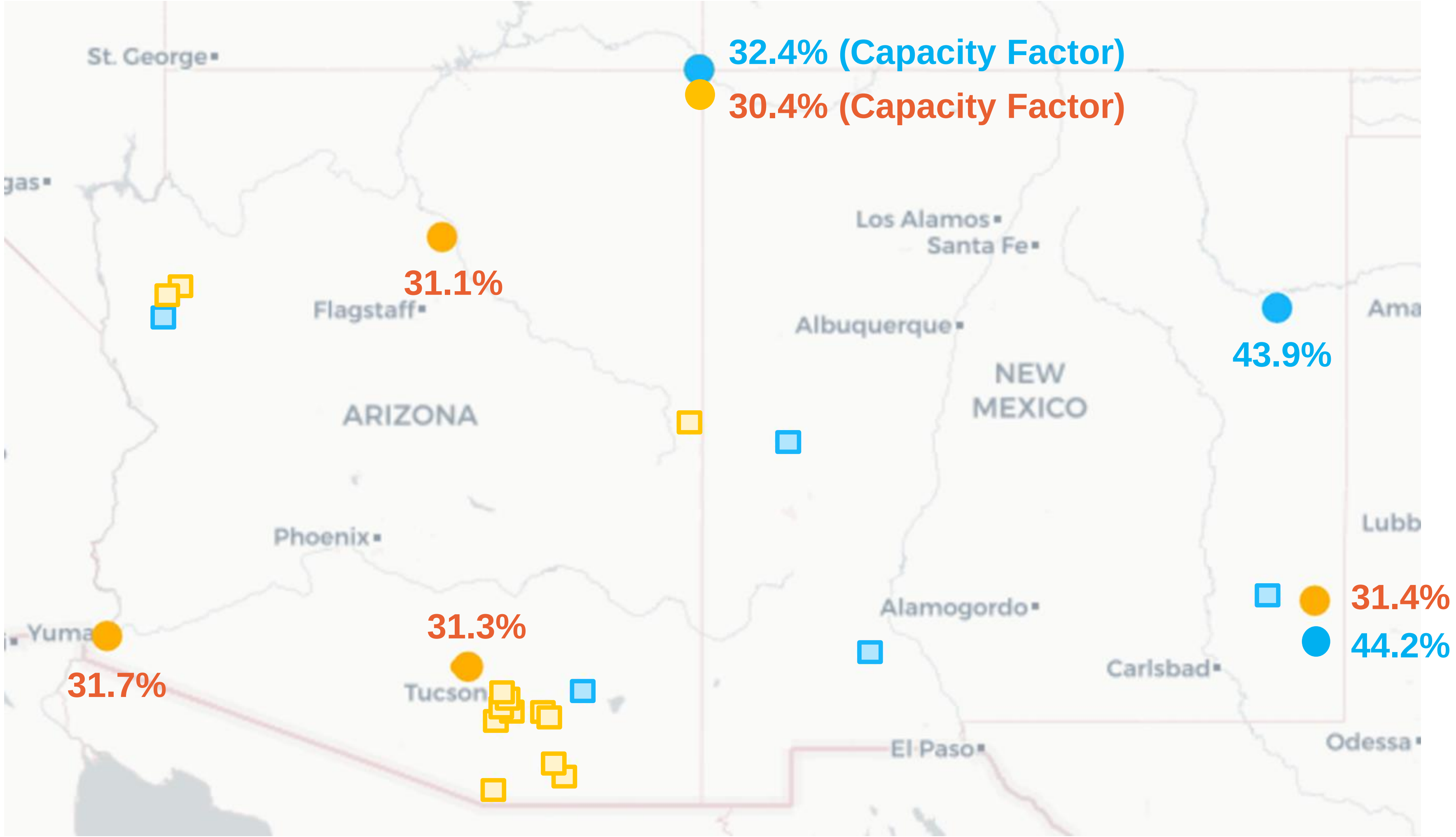
Solar and wind locations



Additional resource profiles considered to capture geographic diversity

- Solar
- Wind

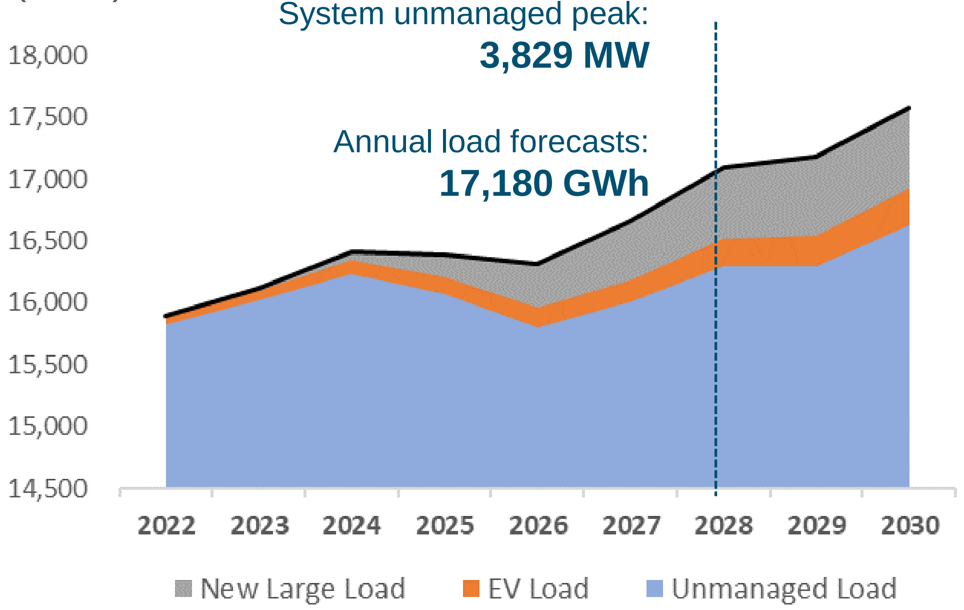
Existing resources

- Solar
- Wind

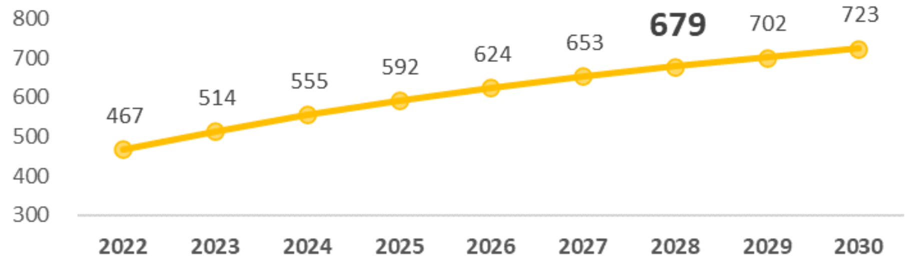
Other inputs and assumptions

+ **Load expected in 2028 was modeled**
  - TEP + UNSE combined peak load is about 3.8 GW
  - Existing and planned resources through 2028 were modeled
  - Higher penetration of solar, wind and storage were also modeled to build a more comprehensive ELCC curve/surface
+ **Behind-the-meter PV installation grows steadily from 2022-2030, with 2028 penetration at 679 MW in TEP + UNSE system**
+ **Storage resources are modeled with 10% forced outage rate (FOR)**

Annual gross load forecasts for TEP & UNSE (GWh)



BTM PV forecasts for TEP & UNSE (MW)



Results

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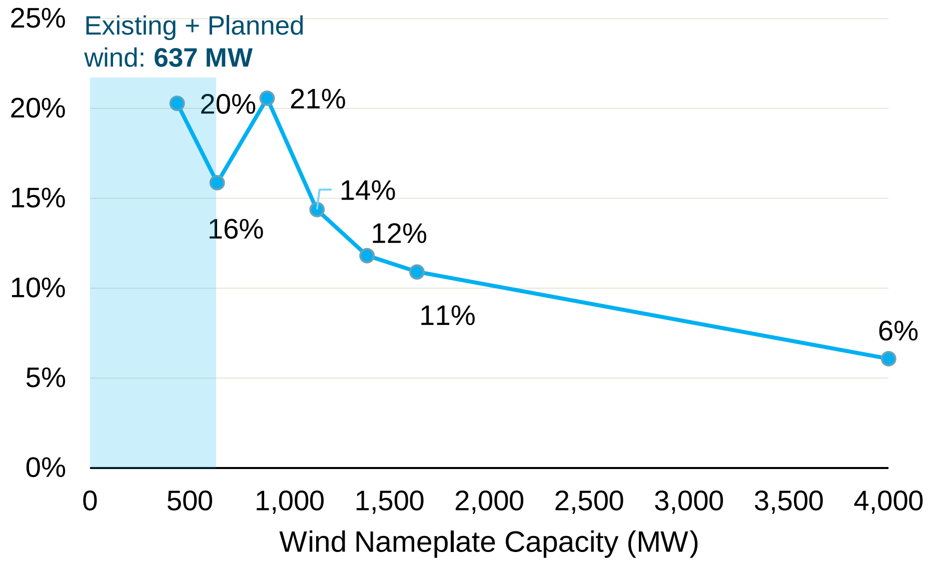
Wind ELCCs

Incremental Wind ELCC (% of capacity added in each tier)

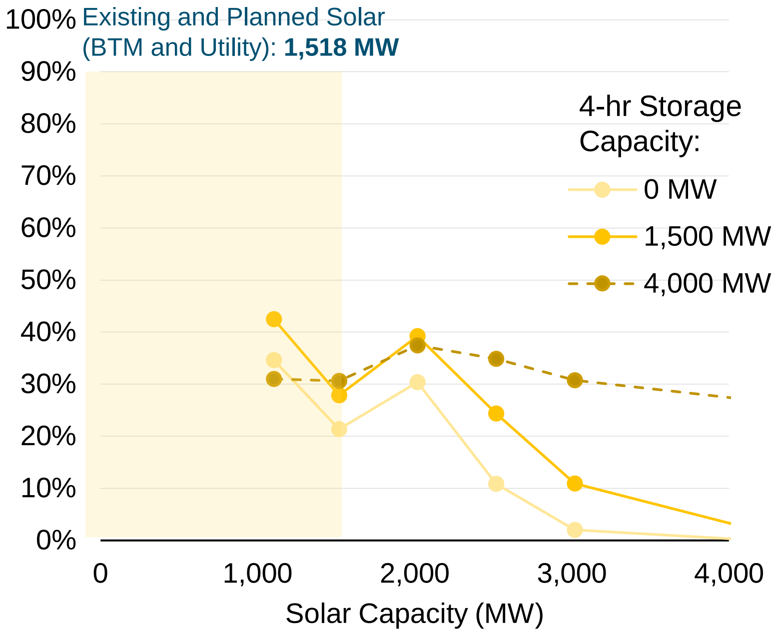


Wind Capacity (MW)	Incremental ELCC (MW)	Average ELCC (MW)	Incremental ELCC (%)	Average ELCC (%)
437	89	89	20%	20%
637	32	120	16%	19%
887	51	172	21%	19%
1,137	36	208	14%	18%
1,387	30	237	12%	17%
1,637	27	265	11%	16%
4,000	144	408	6%	10%

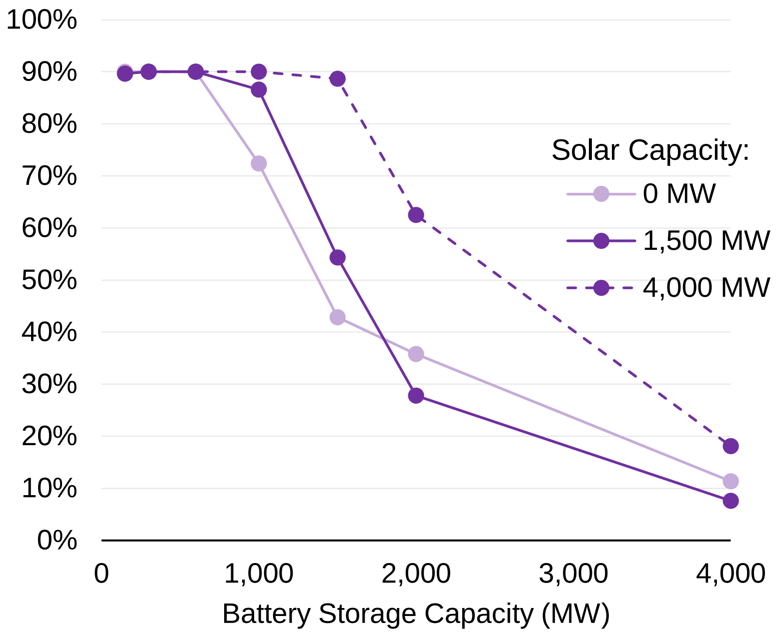
- **Existing wind gets 20% ELCC. 200 MW of additional wind at Oso Grande receives 16% ELCC**
- **Third tranche onward, additional wind is assumed to be a mix of wind from 3 different locations – Eastern NM, Oso Grande and Four corners**
  - Diversity in location and generation helps boost wind ELCC from tranche 2 to 3
- **Diminishing returns are observed as expected with every additional tranche**

Solar and 4-hr storage ELCCs

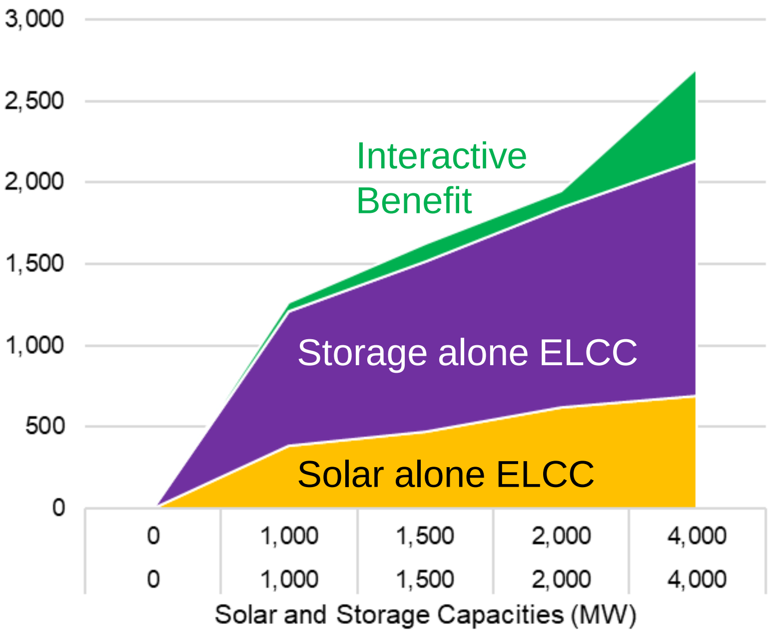
Incremental Solar ELCC (% of capacity added in each tier)



Incremental Storage ELCC (% of capacity added in each tier)



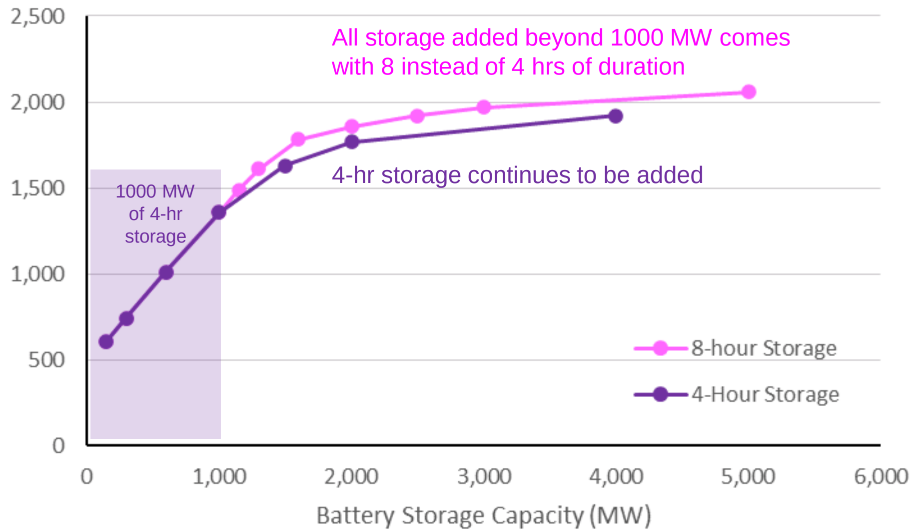
Total Solar and 4-hr Storage ELCC (MW)



- **First 1500 MW of solar is a mix of existing and expected BTM and utility-scale solar expected by 2028**
- **Third tranche onward only utility-scale solar (mix of 5 different locations) is introduced, leading to temporary boost in ELCC**
- **Diminishing returns are observed as expected as net peak shifts into the evening**
- **Storage is modeled with a 10% FOR, that impacts ELCC by approx. 10%**
- **4-hr Storage ELCC is reasonably high until 1.5 GW is added. Sharp drop in ELCC beyond that unless solar penetration is high**
- **Given existing and planned demand response programs offer 4-5 hrs of duration, 4-hr storage ELCC would be a reasonable proxy in the near term. Additional derates may be applied if # of calls offered is very small**

8-hr Storage ELCCs

ELCC (MW) of 1500 MW Solar + Battery Storage



8-hr Battery Storage Capacity (MW)	Incremental ELCC (MW)	Average ELCC (MW)	Incremental ELCC (%)	Average ELCC (%)
150	129	129	86%	86%
300	126	256	84%	85%
600	169	425	56%	71%
1,000	76	501	19%	50%
1,500	62	562	12%	37%
2,000	50	612	10%	31%
4,000	90	702	4%	18%

- **8-hr storage curve assumes 1,000 MW of 4-hr storage is in the base portfolio**
  - **1,518 MW solar and 1,637 MW wind are also in the base portfolio**
- **10% FOR is modeled akin to 4-hr storage**
- **With these assumptions, 8-hr storage provides slightly higher ELCC relative to 4-hr storage**
- **Adding duration alone doesn't help much at relatively low renewable penetrations. There is value in adding more storage (both capacity and duration) in conjunction with more renewables to see big interactive benefits, as shown on previously**

Thank You

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Appendix

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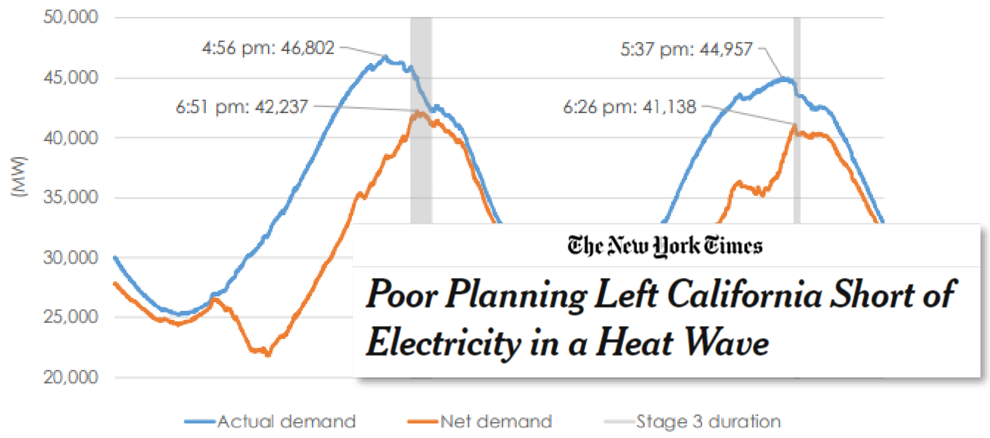
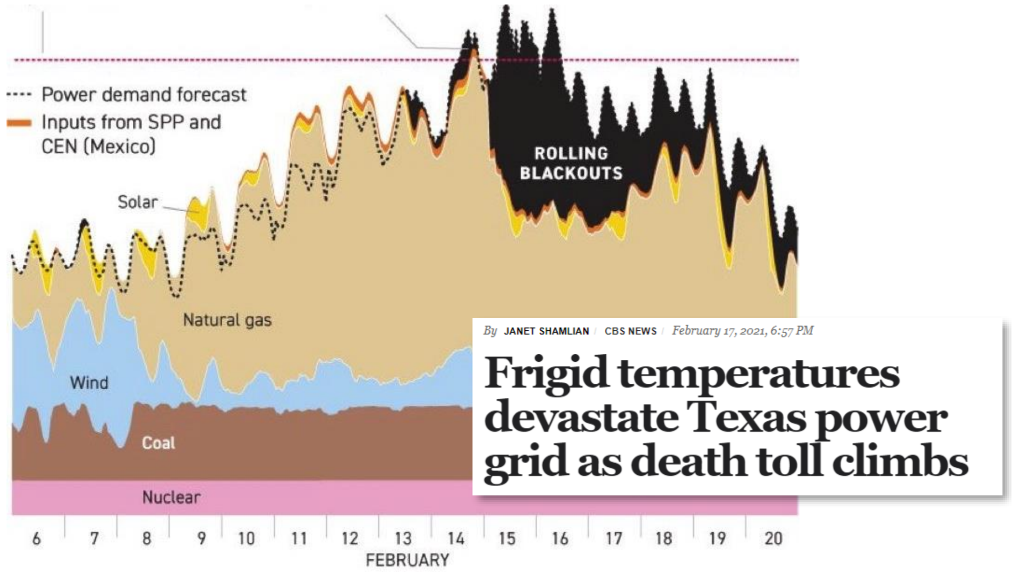
Resource adequacy is increasing in complexity – and importance

- **Transition towards renewables and storage introduces new sources of complexity in resource adequacy planning**
  - The concept of planning exclusively for "peak" demand is quickly becoming obsolete
  - Frameworks for resource adequacy must be modernized to consider conditions across all hours of the year – as underscored by California's rotating outages during August 2020 "net peak" period
- **Reliable electricity supply is becoming increasingly important to society:**
  - Ability to supply cooling and heating electric demands in more frequent extreme weather events is increasingly a matter of life or death
  - Economy-wide decarbonization goals will drive electrification of transportation and buildings, making the electric industry the keystone of future energy economy



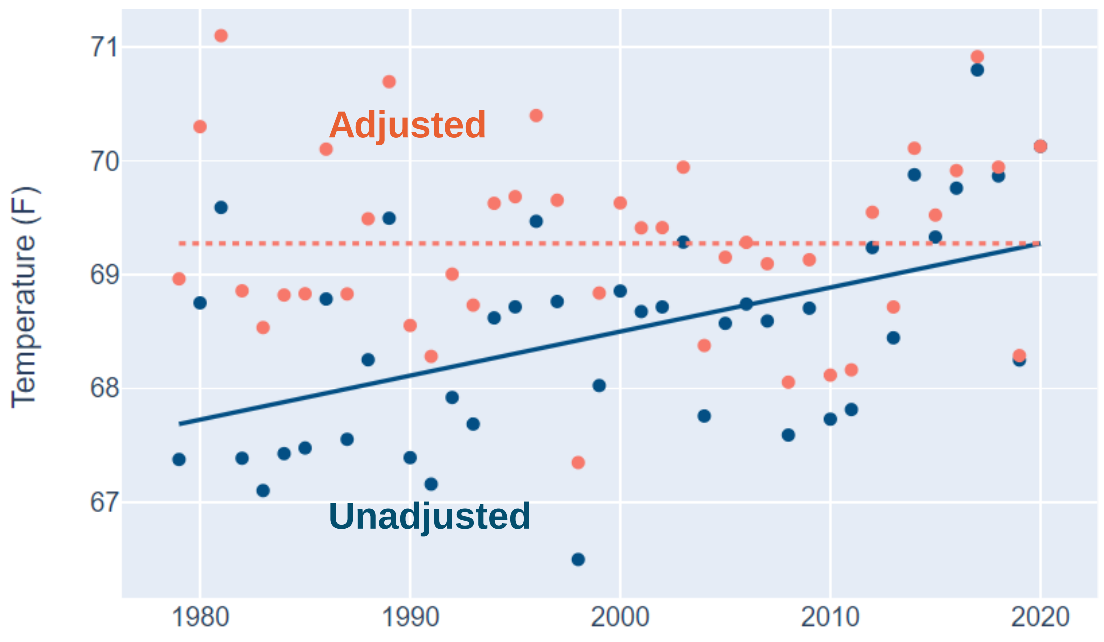
Graph source: http://www.caiso.com/Documents/Final-Root-Cause-Analysis-Mid-August-2020-Extreme-Heat-Wave.pdf



Graph source: https://twitter.com/bcshaffer/status/1364635609214586882

Temperature detrending

Average Annual Temperature, 1979-2020



+ Like in the SWRA study, load shapes were developed using temperature data from 40 years

+ Temperature from 1979-2020 was adjusted to account for warming observed in that period

+ This allows stress-testing the system under different *weather* conditions adjusted for 2020 *climate*

Renewable profile simulation methodology

- **Historical generation record for renewable resources are typically limited. To capture the variability over several weather years, RECAP relies upon simulated solar and wind profiles from NREL's WIND Toolkit and NREL's System Advisor Model (SAM)**
- **For TEP existing resources, plant-level generation profile is simulated based on location, panel characteristics, hub heights, etc. identified**
- **For additional resource profiles considered in this ELCC study, profiles are simulated at locations chosen in collaboration with TEP**
- **Weather conditions captured:**
  - Solar: 1998 – 2019
  - Wind: 2007 - 2012

Resource tiers modeled

Wind

Tier Size (MW)	Cumulative Nameplate Capacity (MW)	Assumptions
437	437	Represents existing wind projects
200	637	Represents existing and 200 MW new wind at Oso Grande.
250	887	Avg of wind profiles from Four corners, East NM and Oso Grande locations
250	1,137	
250	1,387	
250	1,637	
2,363	4,000	

Solar

Tier Size (MW)	Cumulative Nameplate Capacity (MW)	Assumptions
1,103	1,103	Represents existing solar (588 MW utility solar and 514 MW BTM solar)
415	1,518	Represents existing solar and new solar projects (250 MW new utility solar and 165 MW new BTM solar)
500	2,018	Avg of utility-scale solar profiles from Flagstaff, Four Corners, Oso Grande, Tucson, and Yuma
500	2,518	
500	3,018	
1,000	4,018	

4-hr Storage

Tier Size (MW)	Cumulative Nameplate Capacity (MW)	Assumptions
150	150	30 MW existing, 120 MW new. Not location-specific 10% FOR
150	300	Not location-specific 10% FOR
300	600	
400	1,000	
500	1,500	
500	2,000	
2,000	4,000	

- Wind ELCC curve was calculated without any solar or storage in the base system
- Solar-4-hr storage ELCC surface was built for a base portfolio containing 1637 MW of wind
- Each combination of solar and storage penetration in these tables was modeled to construct the full solar-storage ELCC surface

Solar and 4-hr storage ELCCs

4-hr Storage Nameplate Capacity (MW)

Total ELCC for a given combination of solar and storage (MW)

Solar Capacity (MW)	0	150	300	600	1,000	1,500	2,000	4,000
0	0	135	270	540	830	1,044	1,223	1,449
1,103	382	517	652	920	1,261	1,512	1,640	1,791
1,518	471	605	740	1,010	1,356	1,628	1,767	1,919
2,018	623	757	892	1,162	1,512	1,824	1,946	2,106
2,518	677	811	946	1,216	1,574	1,946	2,110	2,280
3,018	687	821	956	1,226	1,584	2,001	2,237	2,434
4,018	690	824	959	1,229	1,589	2,033	2,345	2,707