Resource Planning Advisory Council

January 27, 2026

Agenda

1 Safety Minute/Introductions

2 Modeling License Update

3 PRM & ELCC study

4 Feedback Review & RPAC Portfolios

5 Data Dashboard Demo

6 Wrap-Up

TEP

Safety Minute & Logistics

- In case of emergency, proceed down the stairs, out the doors, and gather on the lawn of the Children's Museum just to the south
- Restrooms
- Cafe

Introductions

- Your name

- Who you represent

Modeling License Update

Aurora Licensing

The anticipated cost of stakeholder licenses for Energy Exemplar's Aurora during the 2026 IRP cycle is $7,000 per license.

- Per the license framework, LSEs will provide the anticipated cost of the modeling license by February 4th

- Stakeholders will provide Notice of Intent to obtain a license no later than March 6th

Agenda

+ **Introduction**

+ **Resource Adequacy Best Practices**

+ **Methods & Assumptions**

+ **PRM and ELCC Results**
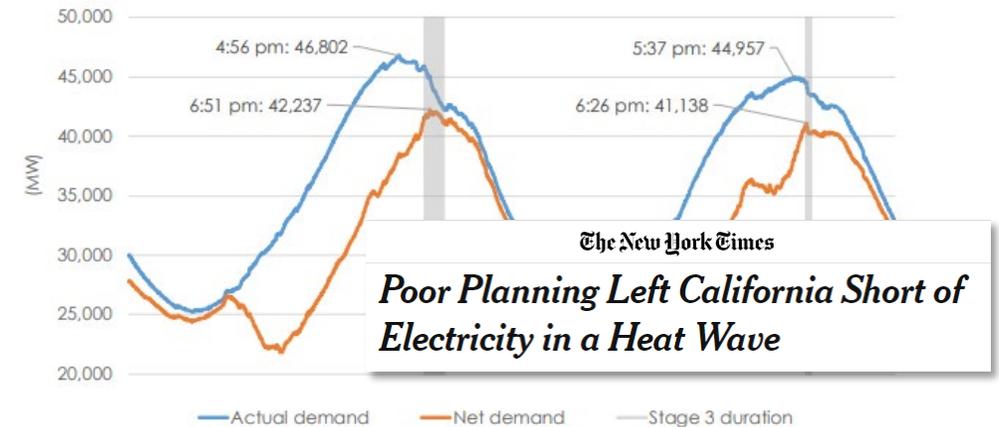
Background

Energy+Environmental Economics

Resource adequacy is increasing in complexity – and importance

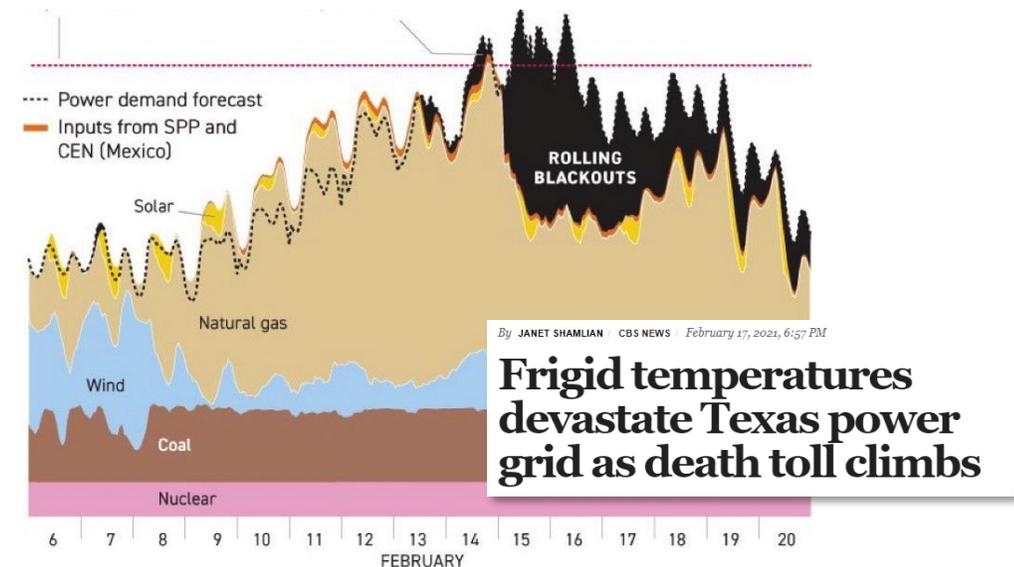+ **Transition towards renewables and storage introduces new sources of complexity in resource adequacy planning**

    • 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

The New York Times

Poor Planning Left California Short of Electricity in a Heat Wave

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

By JANET SHAMLIAN / CBS NEWS / *February 17, 2021, 6:57 PM*

Frigid temperatures devastate Texas power grid as death toll climbs

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

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Study purpose

+ **TEP retained E3 to conduct an RA study to establish PRM requirement and ELCC values for use in the development of TEP and UNSE's upcoming IRPs**

+ **This study was built on E3's previous study for TEP as well as data sets developed as part of an ongoing effort to update E3's study "Resource Adequacy in the Desert southwest"**

+ **Relatively to the last analysis in 2023, the major updates include:**

  1. Updates to TEP and UNSE's load forecasts (including updated outlook for new large customers) and existing resource portfolio (based on recent RFP outcomes)

  2. Additional granularity in quantification of ELCC values to better capture dynamic of saturation effects

  3. Independent technology ELCCs for TEP and UNSE systems separately
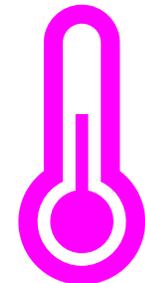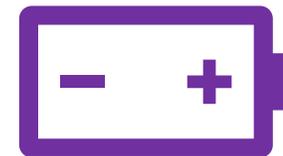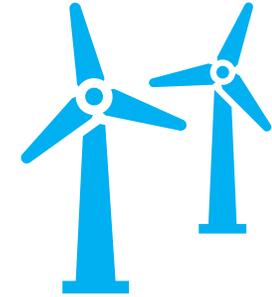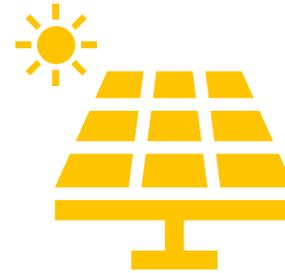
Resource Adequacy Best Practices

Energy+Environmental Economics

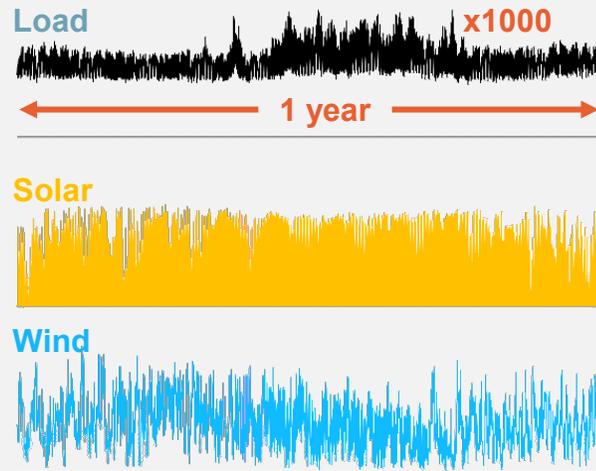# Planners are increasingly using LOLP models to support enhancements to resource adequacy

Part 1: Model + Data Development

Develop a robust dataset of the loads and resources, typically in a loss of load probability (LOLP) model

LOLP modeling evaluates resource adequacy across all hours of the year under a broad range of weather conditions

Robust probabilistic models + datasets are the foundation of any resource adequacy analysis

Part 2: Need Determination

Identify the Total Reliability Need to achieve the desired level of reliability

Factors that impact the amount of effective capacity needed include load & weather variability, operating reserve needs
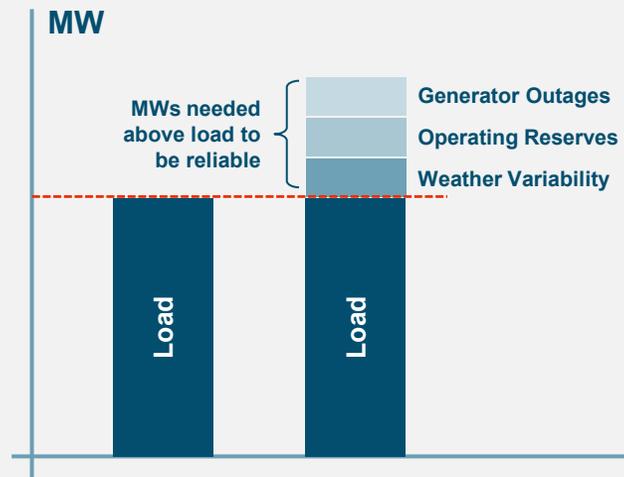
The total reliability need is calculated to meet a target reliability standard (e.g. 0.1 LOLE)

Part 3: Resource Accreditation

Calculate resource capacity contributions

Measures a resource's contribution to reliability needs relative to target reliability, accounting for performance across all hours
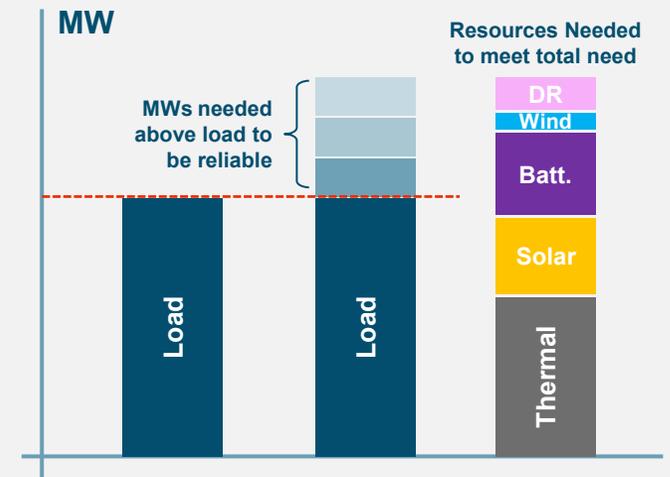
Resource accreditation determines how much each resource counts towards the total reliability need

Using ELCC to accredit resource contribution to system needs

+ Effective Load Carrying Capability (ELCC) represents the equivalent "perfect" capacity that a resource provides in meeting the target reliability metric (e.g., 0.1 day/year LOLE)

+ ELCC is a <u>technology-agnostic</u> metric of capacity value and accounts for all factors that can limit availability:

- Energy availability
- Hourly variability in output
- Duration and/or use limitations
- Temperature-related de-rates and outage rates
- Correlated outage risk...

+ Calculation of ELCC requires iterative use of LOLP modeling:

①
Calculate existing system reliability and tune the system to the target

②
Add desired resource to portfolio

Addition of new source of generation will increase reliability relative to measurement in Step 1

③
Remove perfect capacity until target reliability is restored

Removal of perfect capacity results in decrease in reliability until original target is met

A resource's ELCC is equal to the amount of perfect capacity removed from the system in Step 3

Illustrative ELCC Values Across Technologies

| | 0% | % ELCC Value | 100% |

Wind

Solar

Storage (4 hr)

Storage (8 hr)

Hydro

Demand Response

Natural Gas
Interruptible Service

Natural Gas
Firm Pipeline Service

Natural Gas
On-Site Fuel Storage
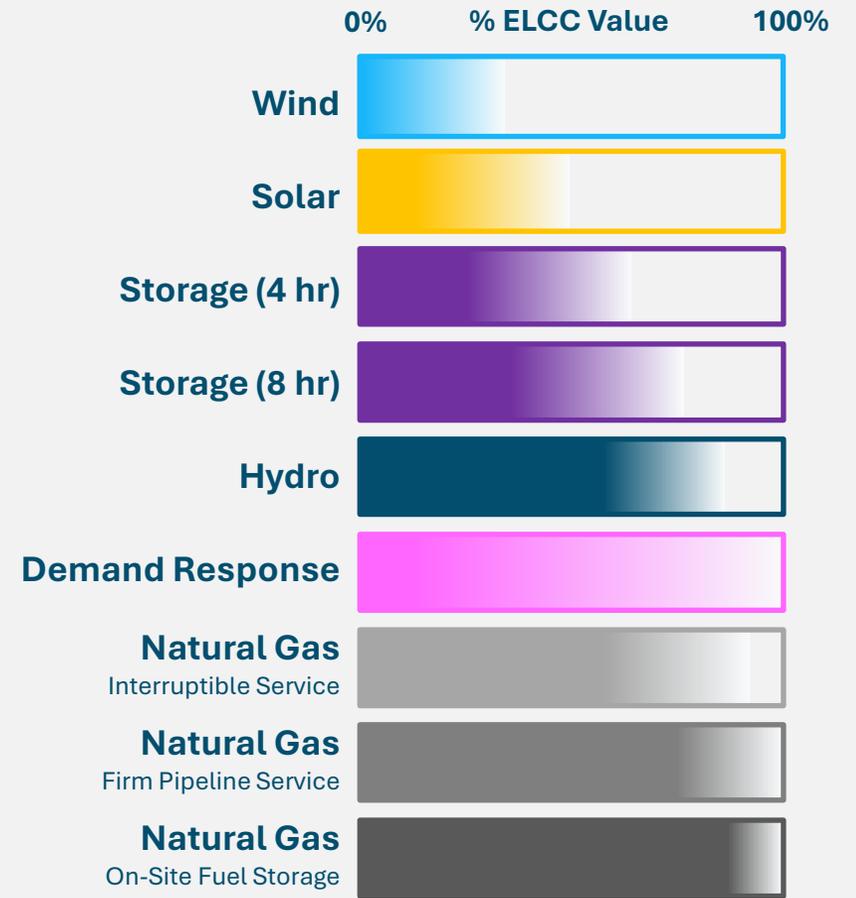
ELCC captures diversity benefits among technologies

+ **Resources with complementary characteristics produce the opposite effect, synergistic interactions (also described as a "diversity benefit")**

+ **As penetrations of intermittent and energy-limited resource grow, the magnitude of these interactive effects will increase and become non-negligible**
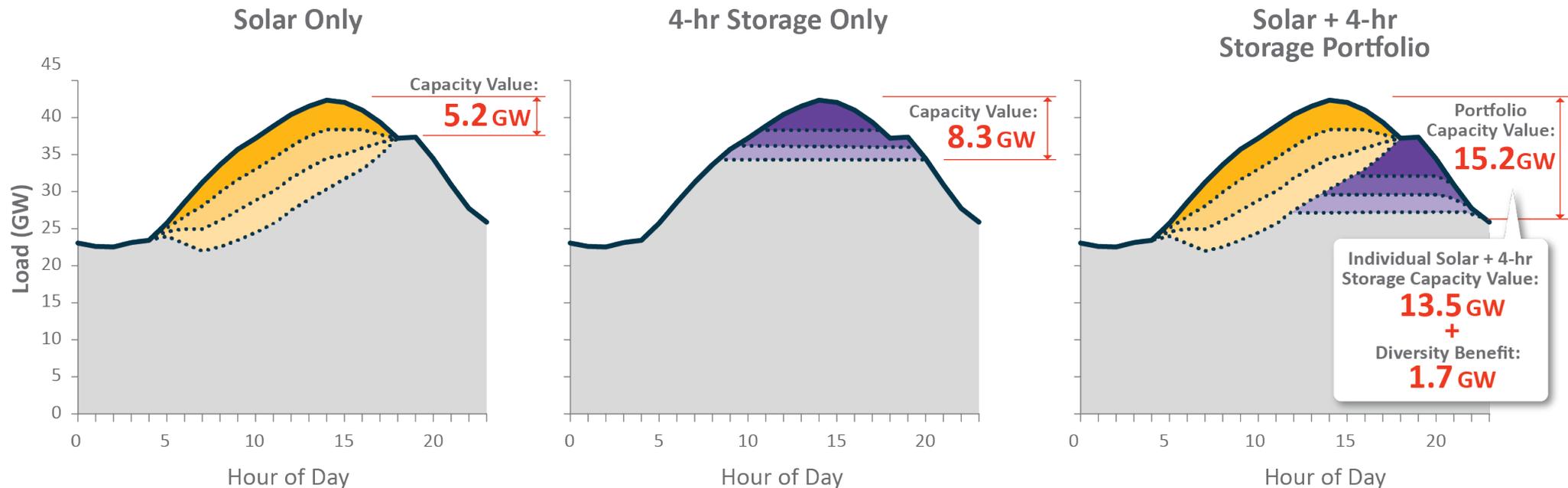
Methodology and Input Assumptions

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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

+ **Model results include:**
  - Loss of load expectation (LOLE) and other reliability statistics
  - PRM requirements
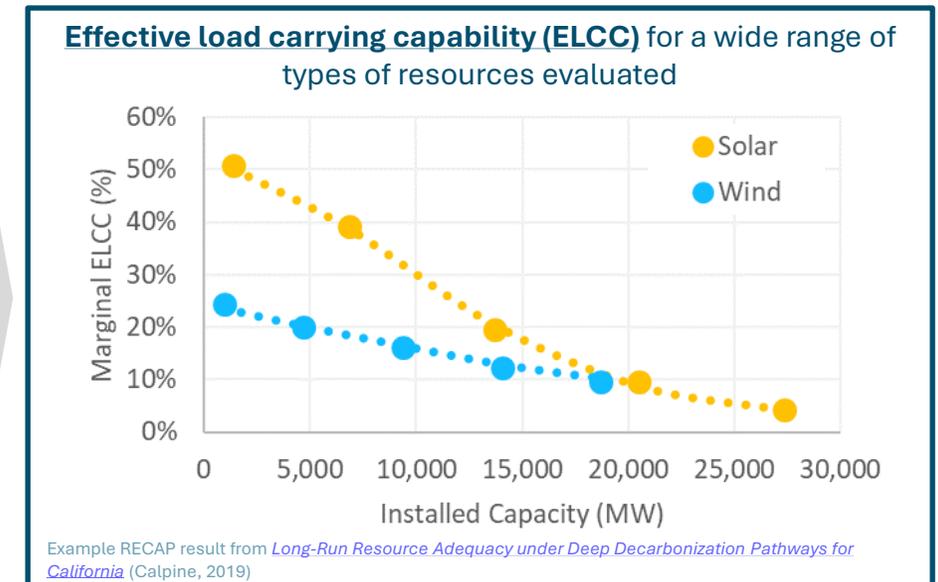 - ELCCs of different resources

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

Load x1000

← 1 year →

Firm Resources *(with outages)*

Solar

Wind

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

The reliability challenge in today's electricity system is ensuring sufficient capacity to meet peak load on hot, late summer afternoons/evenings as the sun is setting

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)

Using RECAP for Need Determination and Resource Accreditation
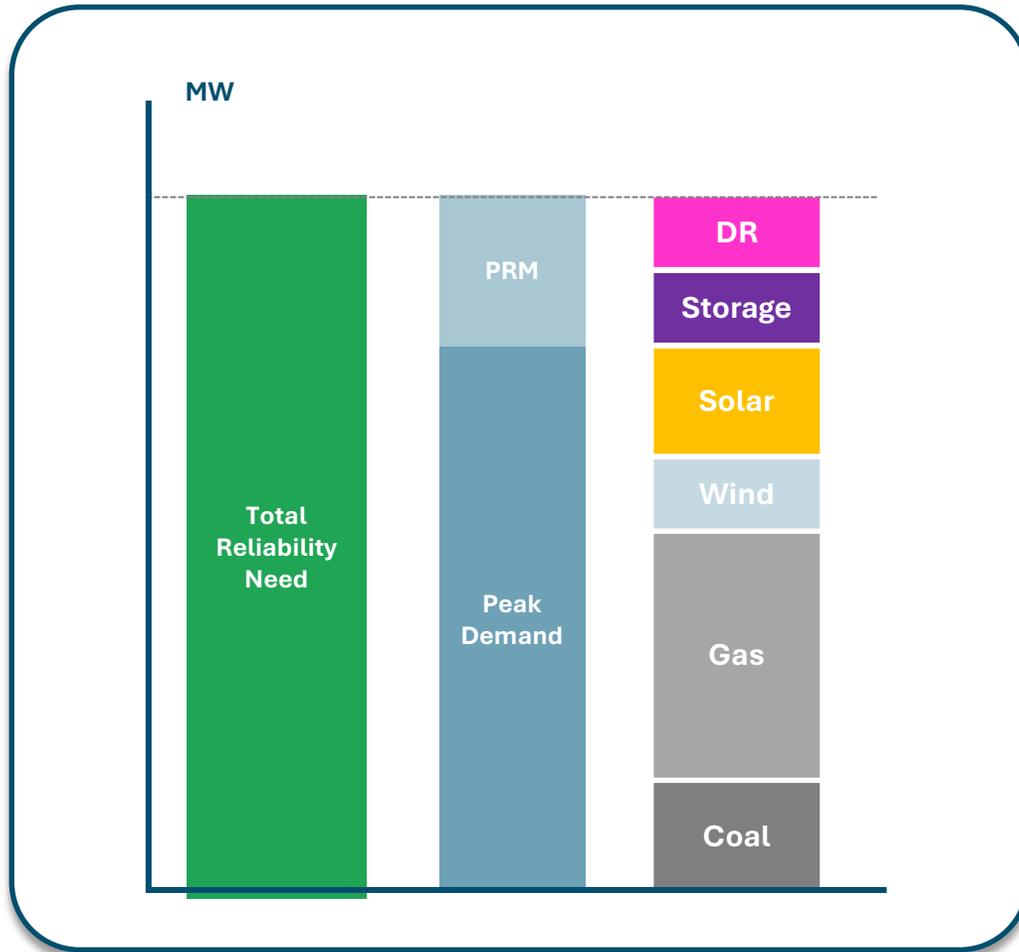
Need Determination Deliverable:

Total Reliability Need measured in ICAP, converted to an **PRM target** for UNSE +TEP system

Resource Accreditation Deliverable:

1. **Static capacity value provided by *existing and committed resources* in the portfolio**
   - Summer net dependable capacity for thermal resources
   - ELCC for existing renewable and storage resources

2. **Dynamic capacity accreditation for *generic resources* evaluated in IRP analyses (changes with penetration)**
   - Incremental wind curves
   - Incremental Solar – Storage surfaces

TEP Loads and Existing Resources

TEP Energy Forecast
GWh

System peak forecast:
3,099 MW
Annual load forecasts:
13,837 GWh

Legend: ■ TEP baseload ■ TEP EVs (Res) ■ TEP EVs (Com) ■ TEP Industrial ■ TEP Datacenters
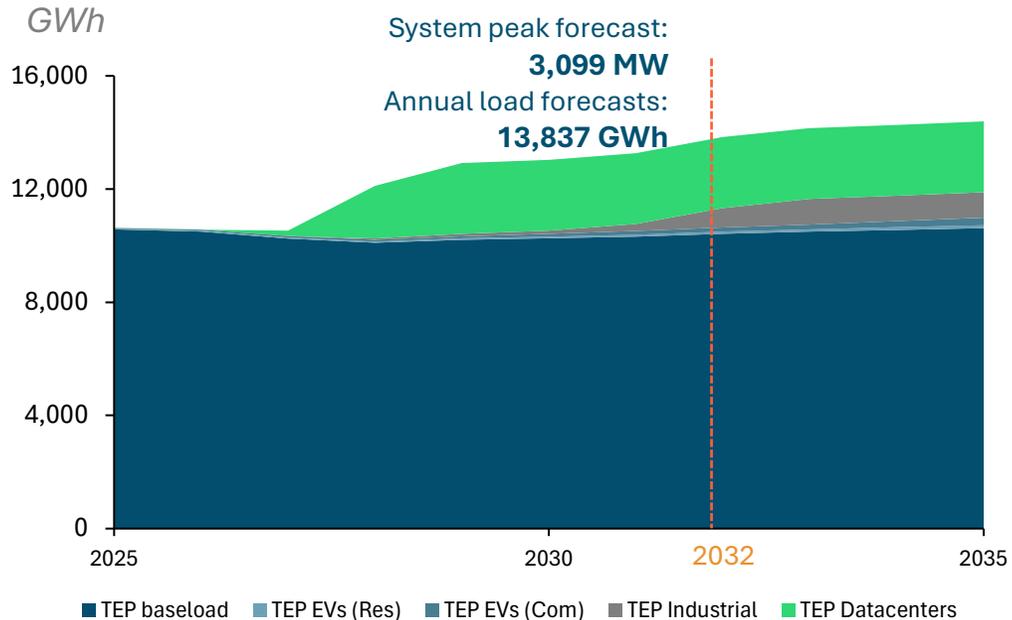
+ Load among existing end uses projected to remain relatively flat (includes impacts of energy efficiency and behind-the-meter solar)

+ Significant increases in load projected as a result of new large customers (primarily data centers)

TEP Total Capacity by Type, 2025 & 2032 (MW)

	2025	2032	Change
Coal *(summer)*	838	0	-838
Natural Gas *(summer)*	1,757	2,487	+730
Wind	428	378	-50
Utility-scale Solar	321	652	+331
Battery Storage	250	630	+380
Demand Response	10	10	-
Total	**3,604**	**4,157**	**+553**

Key portfolio changes

+ Springerville coal-to-gas conversion (734 MW -> 730 MW, 2030)

+ Four Corners exit in 2031 (104 MW)

+ New solar (331 MW UPV), storage (380 MW), and wind contract expiry (-50 MW Macho Springs)
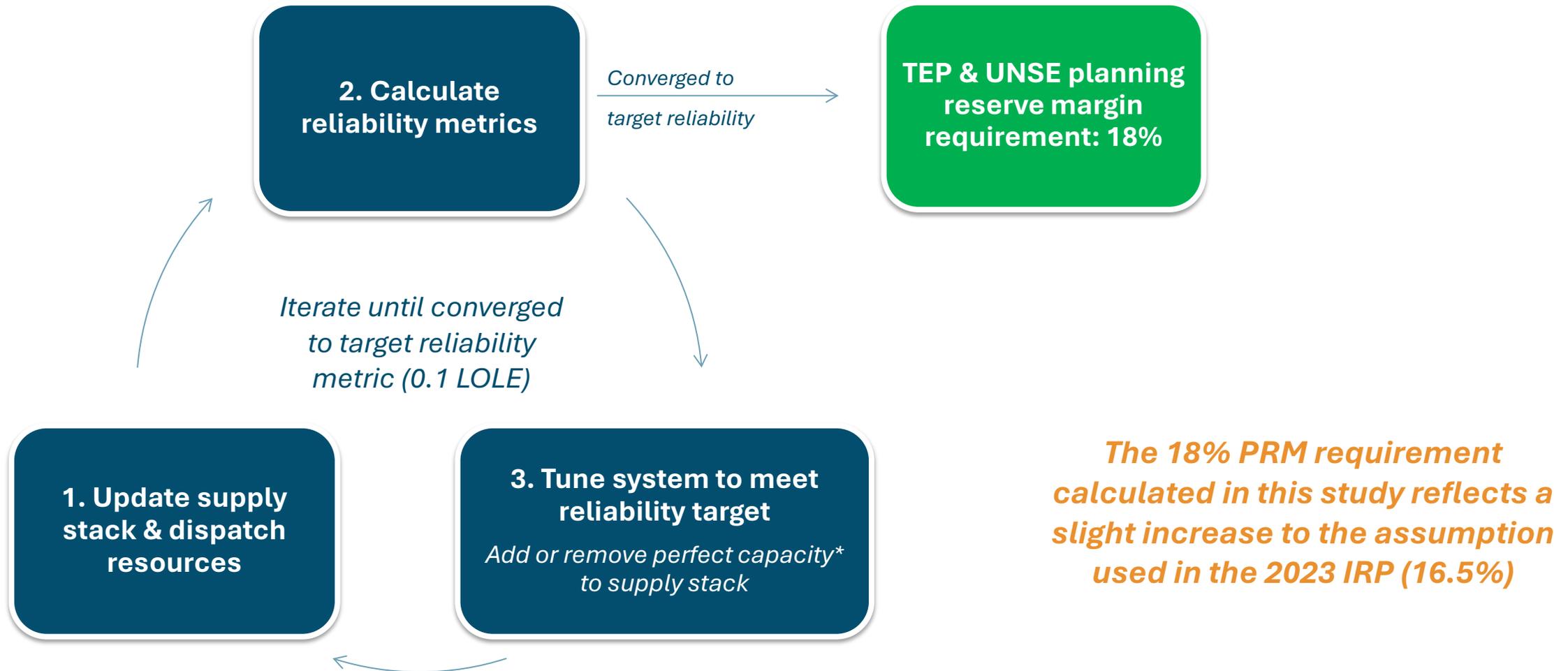
A Rich Temporal Library of Load & Renewable Profiles

Profile	Primary Source(s)	Weather Conditions Captured				Notes
Loads	**TEP** Hourly Historical Load **ERA5 Land** Historical Weather Data	1970		2017	2024	• Neural network regression used to back-cast hourly load patterns under broad range of weather conditions using recent historical load data (2017-2024 for TEP, 2020-2024 for UNSE) and long-term weather data (1970-2024) • 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	2022		• 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

Planning Reserve Margin Requirement

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Calculating Target PRM using LOLP Modeling

2. Calculate reliability metrics

Converged to target reliability →

TEP & UNSE planning reserve margin requirement: 18%

Iterate until converged to target reliability metric (0.1 LOLE)

1. Update supply stack & dispatch resources

3. Tune system to meet reliability target
Add or remove perfect capacity to supply stack*

The 18% PRM requirement calculated in this study reflects a slight increase to the assumption used in the 2023 IRP (16.5%)

Illustrative Example of Tuning to Calculate the PRM Requirement*

Without tuning adjustment (system "as specified")

	Installed Capacity (MW)	Accredited Capacity (MW)**
Coal	0	0
Natural Gas	2,918	2,918
Wind	628	
Solar	1,298	1,287
Storage	1,030	
DR	10	
Tuning Adjustment	0	0
Total Capacity (MW)		**4,205**
Median Peak Demand (MW)**		3,779
Achieved PRM (%)		**13%**
Loss of Load Expectation (days/yr)		**1** ☒

With tuning adjustment (calibrated to 0.1 days/yr)

	Installed Capacity (MW)	Accredited Capacity (MW)**
Coal	0	0
Natural Gas	2,918	2,918
Wind	628	
Solar	1,298	1,287
Storage	1,030	
DR	10	
Tuning Adjustment	+267	+267
Total Capacity (MW)		**4,472**
Median Peak Demand (MW)**		3,779
Achieved PRM (%)		**18%**
Loss of Load Expectation (days/yr)		**0.1** ☑

* Results shown for joint system (TEP & UNSE), capturing benefits of existing load and resource diversity between the two systems; illustrative resource portfolio includes existing & committed resources and generic renewable & storage additions from previous IRP

** Thermal resources are accredited at summer net dependable capacity; renewables, storage, and DR are accredited using ELCC

*** The median peak demand outputs from RECAP differ slightly (<2% difference) from sum of UNSE and TEP forecasts as RECAP captures the coincident peak from all load components in two systems

TEP Current Load Resource Balance in 2032

TEP Load-Resource Balance in 2032
Existing & Committed Resources

	Installed Capacity (MW)	Accredited Capacity (MW)
Median Peak Demand (MW)		3,099
PRM Requirement (%)		18%
PRM Requirement (MW)		**3,657**
Coal	0	0
Natural Gas	2,487	2,487
Wind	378	56
Solar	652	128
Storage	630	572
DR	10	9
Tuning Adjustment	0	0
Total Capacity (MW)		**3,252**
Capacity Shortfall (MW)		**405**

+ **In 2032, TEP's forecasted peak demand is 3,099 MW, resulting in a total requirement for accredited capacity of 3,657 MW at 18% PRM**

+ **TEP's existing portfolio of resources provides 3,252 MW of accredited capacity towards the PRM requirement**
  - Includes existing resources that will remain in TEP's portfolio and resources under development with executed contracts

+ **Maintaining a reliability standard of 0.1 days per year would require procurement of an additional 400 MW of accredited capacity**
  - This serves as the starting point for the ELCC analysis

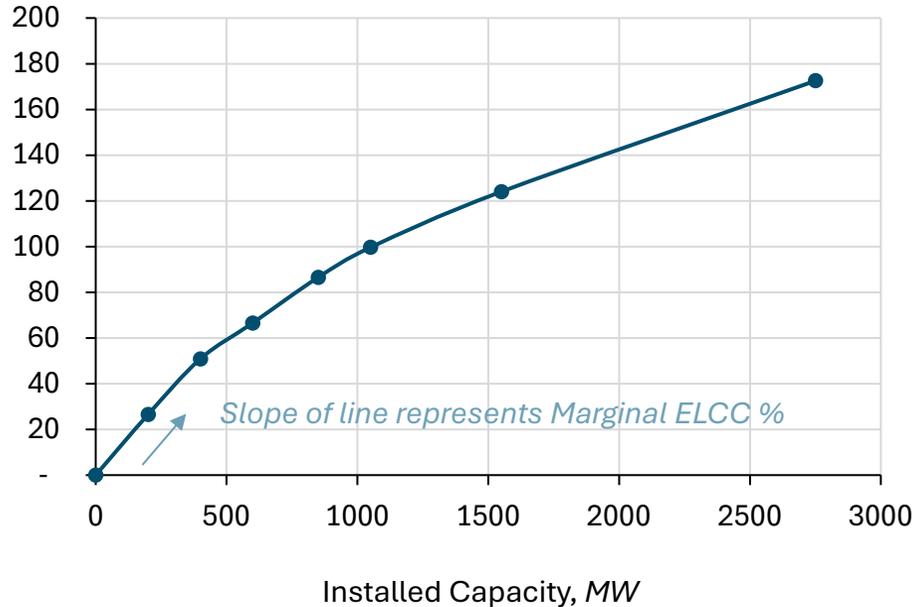# Effective Load Carrying Capability Results

Energy+Environmental Economics

Capacity Value for Generic TEP Wind Additions

Cumulative Wind ELCC

Perfect MW

Installed Capacity, *MW*

Slope of line represents Marginal ELCC %

Cumulative and Marginal Wind ELCC

Wind Capacity MW	Cumulative ELCC (MW)	Average ELCC(%)	Marginal ELCC(%)
-	-	-	-
200	27	13%	13%
400	51	13%	12%
600	68	11%	8%
850	87	10%	8%
1,050	100	9%	7%
1,550	124	8%	5%
2,750	173	6%	4%

Marginal ELCC (%) for wind measures how effective the additional wind can increase the portfolio ELCC

*Adding the initial **200 MW** adds **27 MW** of incremental value, equivalent to a 13% marginal ELCC*

Marginal ELCC decline to single digit after 400 MW penetration – at higher penetrations, loss-of-load risks shift to periods of low wind

Cumulative ELCC (MW) represents total capacity contribution of the incremental resources

Adding more resource capacity brings higher capacity value

Average ELCC (%) represents percentage ELCC of the total capacity contribution of the incremental resource

 Adding more resource capacity brings higher capacity value

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Note: Generic curve wind addition is evaluated beyond existing and committed wind (380 MW)

Cumulative Portfolio Capacity Value provided by Generic Solar and Storage Addition in TEP

Cumulative portfolio ELCC of Incremental Resource Additions

Perfect MW

Increasing Storage Capacity →

		4-hour Battery Storage Capacity (MW)									
		-	100	200	300	550	800	1,050	1,300	1,800	2,300	3,300
Solar Capacity (MW) ↓	-	-	85	165	239	368	452	518	554	615	660	725
	250	34	121	204	283	416	512	582	621	685	735	793
	500	50	143	231	312	459	564	633	683	748	800	862
	750	67	160	247	335	489	604	683	739	808	857	930
	1,000	76	169	257	343	511	631	723	783	863	912	986
	1,500	87	180	270	359	544	666	764	844	945	1,011	1,097
	2,000	97	190	284	367	558	688	791	874	996	1,086	1,192
	3,000	112	206	301	383	576	718	823	906	1,037	1,155	1,290
	4,500	129	222	315	400	598	745	850	929	1,062	1,182	1,332
	6,000	141	232	323	410	614	763	867	948	1,077	1,196	1,340
	7,500	148	240	331	420	625	778	880	957	1,091	1,200	1,347
	9,000	155	247	339	426	630	785	887	965	1,099	1,205	1,351

Increasing Solar Capacity ↓

800 MW 4-hr Storage and 1,500 MW Solar can provide 666 MW perfect capacity toward reliability need

As the penetration of either resource increases, the total capacity contribution of the incremental resources also increases, reflecting their additional reliability contribution to the system

Note: Generic resources are evaluated beyond existing and committed solar (652 MW) and storage (630 MW)

Marginal ELCC for TEP Solar

Marginal ELCC of Incremental Solar Additions
% ELCC of marginal storage additions

Increasing Storage Capacity →

	4-hour Battery Storage Capacity (MW)										
Solar Capacity (MW)	-	100	200	300	550	800	1,050	1,300	1,800	2,300	3,300
-	-	-	-	-		-	-	-	-	-	-
250	14%	15%	16%	18%	19%	24%	26%	27%	28%	30%	28%
500	7%	9%	11%	12%	17%	21%	20%	25%	25%	26%	28%
750	7%	7%	7%	9%	12%	16%	20%	22%	24%	23%	27%
1,000	4%	4%	4%	3%	9%	11%	16%	18%	22%	22%	22%
1,500	2%	2%	3%	3%	7%	7%	8%	12%	16%	20%	22%
2,000	2%	2%	3%	2%	3%	4%	5%	6%	10%	15%	19%
3,000	1%	2%	2%	2%	2%	3%	3%	3%	4%	7%	10%
4,500	1%	1%	1%	1%	1%	2%	2%	2%	2%	2%	3%
6,000	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
7,500	0%	1%	1%	1%	1%	1%	1%	1%	1%	0%	0%
9,000	0%	0%	1%	0%	0%	1%	1%	1%	1%	0%	0%

Increasing Solar Capacity ↓

Diminishing solar ELCCs at higher penetrations →

Marginal solar ELCC is high in the first 250 MW addition but decline to single digit quickly afterwards ("diminishing returns")
As more solar is added to the system, periods of risk move to low-solar generation hours, reducing its ELCC

At higher penetration of storage, marginal ELCC of solar increases ("diversity benefit")
Storage can charge from excess solar in the mid day and discharge in sunset hours / late afternoons when solar output is low, creating a positive interactive benefit

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Note: Generic resources are evaluated beyond existing and committed solar (652 MW) and storage (630 MW)

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Marginal ELCC for TEP Storage

Marginal ELCC of Incremental Storage Additions
% ELCC of marginal storage additions

Increasing Storage Capacity →

Solar Capacity (MW)	4-hour Battery Storage Capacity (MW)										
	-	100	200	300	550	800	1,050	1,300	1,800	2,300	3,300
-	-	85%	80%	74%	52%	34%	26%	14%	12%	9%	6%
250	-	87%	83%	78%	53%	39%	28%	15%	13%	10%	6%
500	-	92%	88%	82%	59%	42%	28%	20%	13%	10%	6%
750	-	93%	87%	87%	62%	46%	32%	22%	14%	10%	7%
1,000	-	93%	88%	86%	67%	48%	37%	24%	16%	10%	7%
1,500	-	93%	91%	88%	74%	49%	39%	32%	20%	13%	9%
2,000	-	93%	93%	83%	76%	52%	41%	33%	25%	18%	11%
3,000	-	95%	95%	82%	77%	57%	42%	33%	26%	23%	14%
4,500	-	93%	93%	85%	79%	59%	42%	32%	27%	24%	15%
6,000	-	91%	91%	87%	81%	60%	41%	33%	26%	24%	14%
7,500	-	92%	91%	89%	82%	61%	41%	31%	27%	22%	15%
9,000	-	92%	92%	87%	82%	62%	41%	31%	27%	21%	15%

Increasing Solar Capacity ↓

Similar diminishing return is observed in storage marginal ELCC (85% to 26% after 1 GW addition)
As more of the same duration (4-hr) storage is added to the system, system increasingly need resources that can sustain output for longer duration

Similarly, at higher penetration of solar, marginal ELCC of storage increases, demonstrating the diversity effect

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Thank You

Nick Schlag, nick@ethree.com

Ruoshui Li, Ruoshui.li@ethree.com

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Feedback

- Some feedback we're incorporating:
  - Renewables Only portfolio is now the Clean Energy Buildout portfolio
  - The Clean Energy Buildout portfolio will include pumped hydro and nuclear as LTCE options
  - Including 8- and 10-hour BESS in LTCE
  - Including geothermal in LTCE (dependent on the availability of pricing)

TEP

Feedback

- Some feedback we're not incorporating:
  - Use the High Load Factor Customer Growth forecast as a sensitivity
  - Extend portfolios to 2045

Planned Portfolio Refresher

Portfolio	Description
Technology Neutral	Least-cost analysis per Order 79589
Natural Gas Expansion	Includes a Natural Gas Combined Cycle plant and facilities to support it per Order 79589
Clean Energy Buildout	Includes only solar, wind, pumped hydro and nuclear as new resources
High Load Factor Customer Growth	Includes a load forecast that contains higher growth than the current forecast

TEP

RPAC Portfolios

- Based on the feedback, TEP suggests the following portfolios as RPAC portfolios:
  - Focus on Technology Type
    - Geothermal – A standalone portfolio, contingent on adequate pricing data
    - Advanced nuclear and solar plus long-duration storage – Based on high interest in both technologies

➢ Our questions/prompts on Sept 30

- What are the key challenges facing local electric utilities?
- Priorities check & Initial prioritization
- Focus on technology-build your tech menu
- Focus on policy- what are you tracking?
- Focus on energy mix- what's a good approach?
- What's the best way to approach unprecedented demand?
- What do we need to know?

TEP
Tucson Electric Power

Top Issues Overall

Top 3: Carbon, Storage, Policy

RPAC's Most-Mentioned Issues

Issue	Count
Decarbonization	14
Storage	12
Policy/Uncertainty	11
Growth	9
Markets	8
Affordability	7
Customers	7
Solar	7
Transmission	6
Renewables	6
Water	5
Nuclear	5
Geothermal	5
Grid Modernization	4
Resilience	3
Sustainability	3

TEP
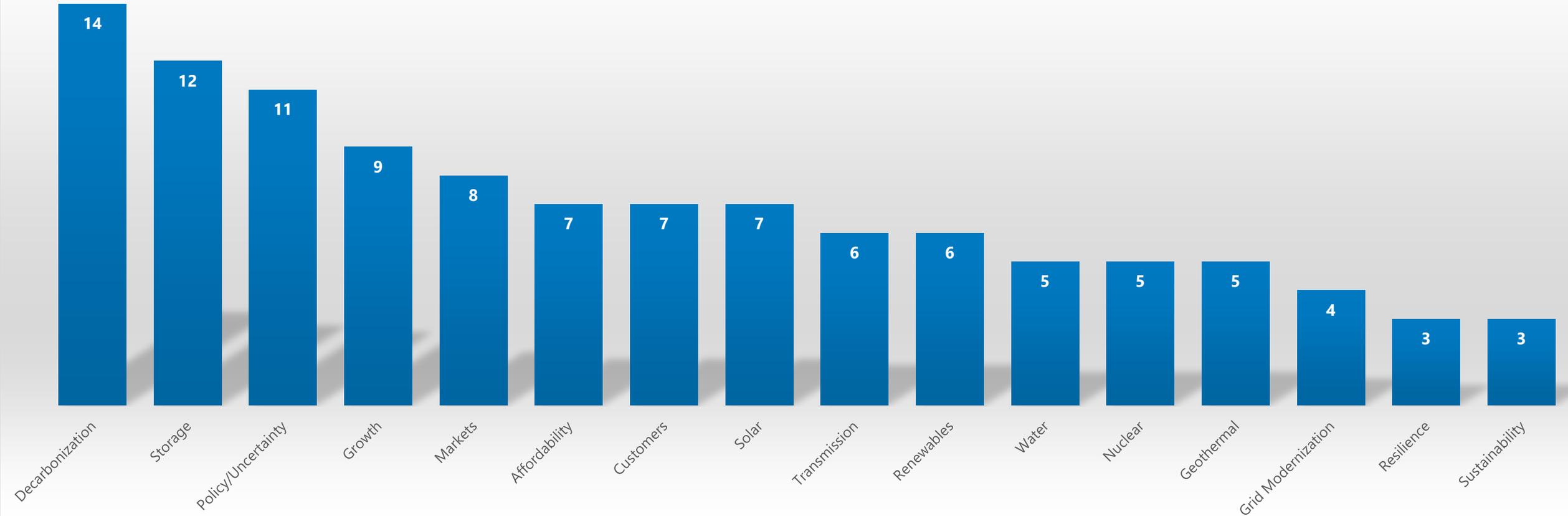
Biggest Utility Challenges

Top 3: Policy Uncertainty, Affordability, Growth

Biggest Utility Challenge
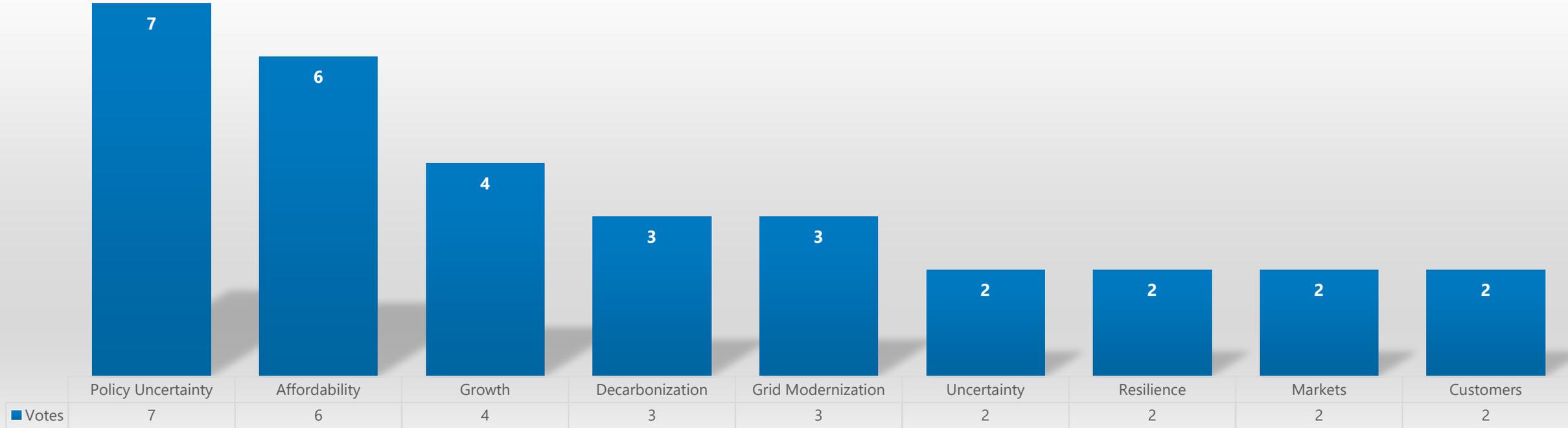
	Policy Uncertainty	Affordability	Growth	Decarbonization	Grid Modernization	Uncertainty	Resilience	Markets	Customers
Votes	7	6	4	3	3	2	2	2	2
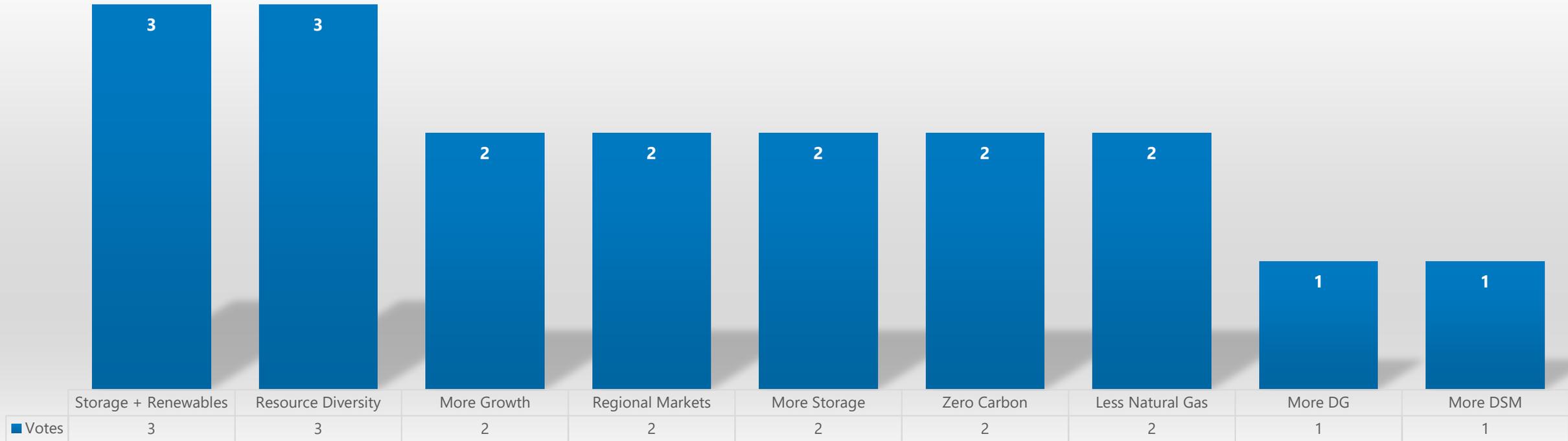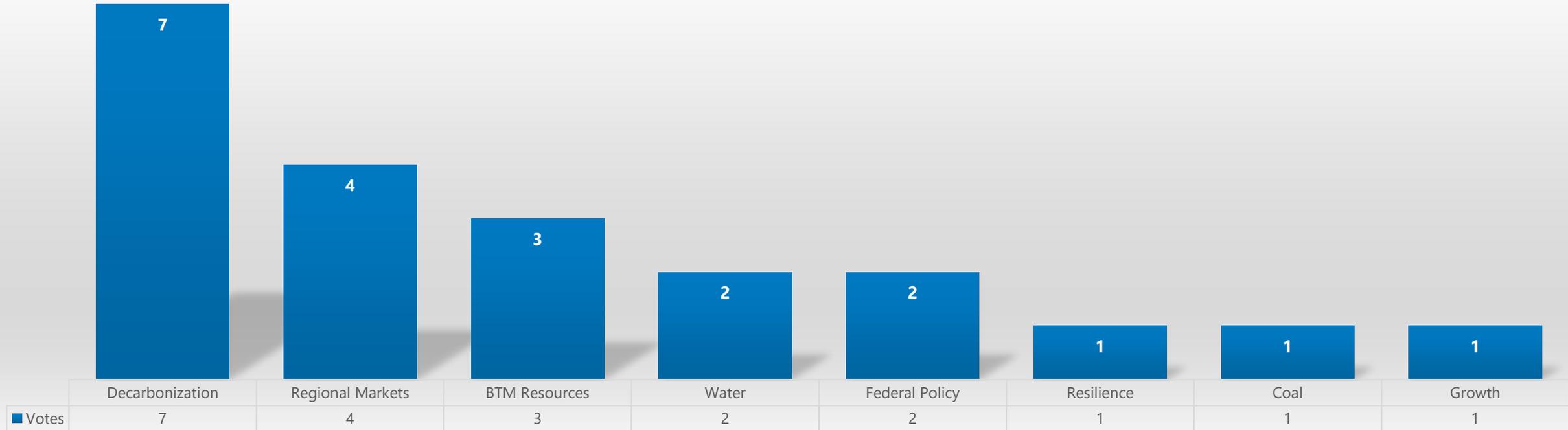
Focus on Technology

Top 3: Geothermal, Nuclear, Storage

- **Energy Storage:** 11 responses
  - LDES, S+S, VPP

- **Nuclear:** 6 responses
  - New nuclear, SMRs, Thorium

- **Geothermal:** 5 responses
  - Advanced/deep

- **Demand Management:** 3 responses
  - DSM, VPP

- **Transmission:** 2 responses
  - As capacity resource, new

- **Solar:** 2 responses

Source: RPAC survey responses; TEP analysis

TEP

Focus on Technology

Top 3: Geothermal, Nuclear, Storage

Technologies of Interest

Advanced Geothermal Energy

**Promising Advancements But Many Unknowns**
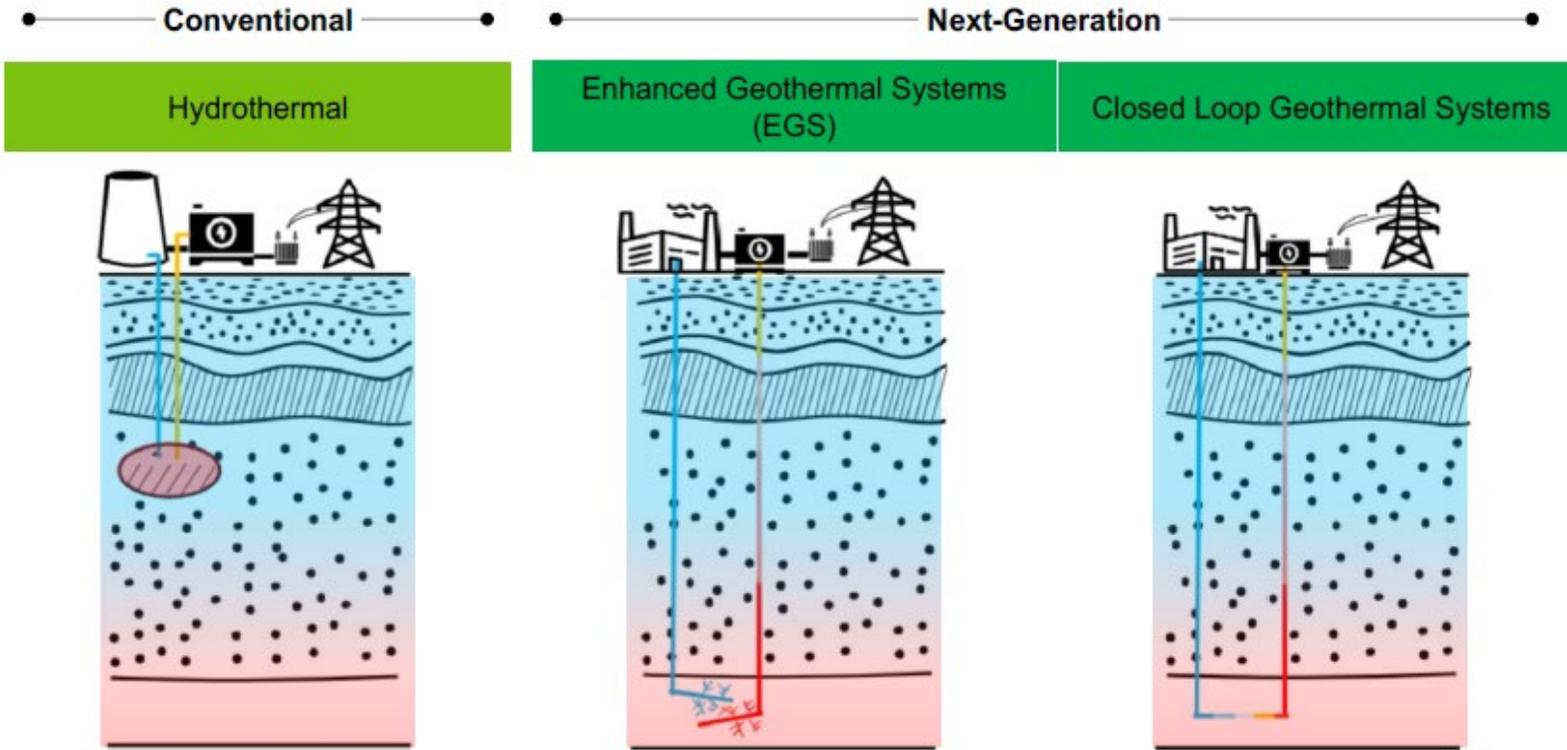
- Geothermal energy systems extract **heat from deep in earth's subsurface** and convert it to electricity by drawing a hot fluid from underground wells and processing it in a power plant.

- Recent advancements in "Enhanced" Geothermal Systems have made geothermal promising in **more areas.**

Advantages
- 24/7, fully dispatchable power
- Zero CO_2 emissions
- Short construction time
  - Uses technology and workforce adopted from oil & gas industry

Adoption Challenges
- High capital cost
- Not demonstrated in all geologies, including AZ
- Financial risk - Resource can degrade unpredictably once operational
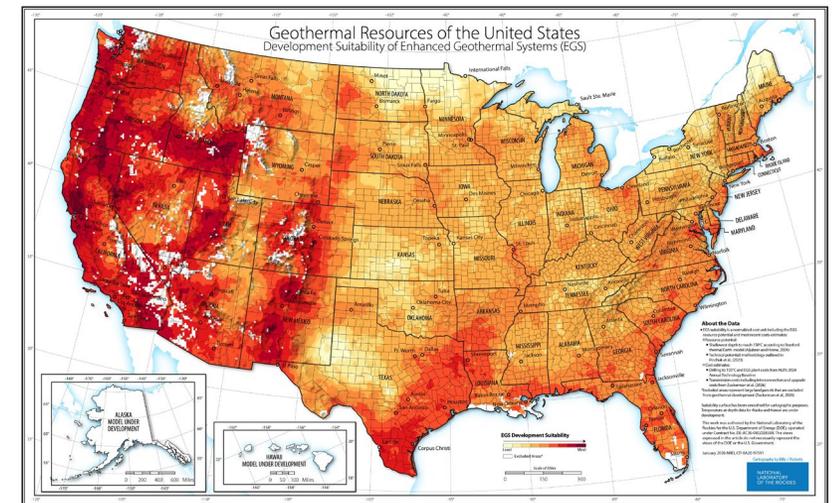
Advanced Nuclear Energy

Decades of Progress in the Lab, Billion-Dollar Overruns in Reality

Advantages
- 24/7 power
- Zero CO_2 emissions
- Excellent safety record + improvements over legacy nuclear reactors

Adoption Challenges
- Long construction times
- High capital cost
- Siting & permitting
- Advanced reactors use a fuel (HALEU) that has no supply chain outside of Russia
- US has lost nuclear know-how
  - Specialized workforce in short supply
  - Cost overruns and project delays

Microreactors
Range: 1 MW to 20 MW
Can fit on a flatbed truck, and are mobile and deployable.

Small Modular Reactors
Range: 20 MW to 300 MW
Can be scaled up or down by adding more units.

Full-Size Reactors Range:
300 MW to 1,000+MW
Can provide reliable, emissions-free baseload power.

- **Concept** – does not exist yet

- Several companies are developing small reactors, but **none have been deployed**
- Modular reactors **do not exist** yet

- Three reactors built in the US in **25+ years**.
- Two of these (Vogtle 3&4) were **7 years late** and **$17 billion over budget**

**TEP**

Extending Forecast Horizon to 2045

"All models are wrong, but some are useful." - George Box

Modeled future forecasts tend to be more accurate when:

1. The future looks similar to the past; and,
2. The forecasted time horizon is short.

More deviation from historic activity – like adding lots of new energy resources or technologies to the portfolio mix – plus longer time horizons increase uncertainty, making later-year predictions more speculative.

While it's certainly possible to extend a 15-year forecast by 5 years, those additional five years of modeled data deliver little planning value.

**Probabilistic forecasting**
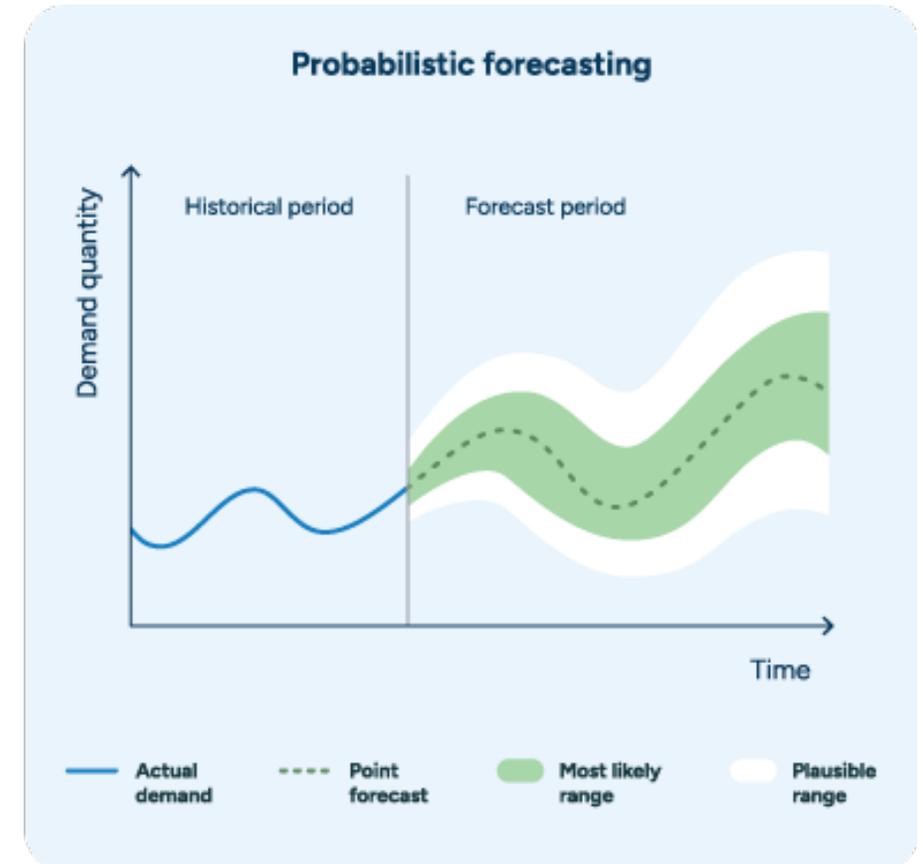
Flexible & Distributed Resources

Building On A Decade of Technology Research & Demonstration

TEP began researching distributed energy resource management systems (DERMS) in 2016 and demonstrating the technology in 2017. Two big learnings from this earlier work were:

1. Integration, interoperability, and connectivity are big challenges; and,

2. It's hard to manage behind-the-meter (BTM) resources cost-effectively.

We then transitioned to partner with DER aggregators to manage devices like thermostats, batteries, and electric vehicle (EV) chargers. We also invested more in utility-scale distributed resources like large batteries.

We continue to investigate technologies, vendors, and applications for DERMS and virtual power plants (VPPs) for customer and system benefit.
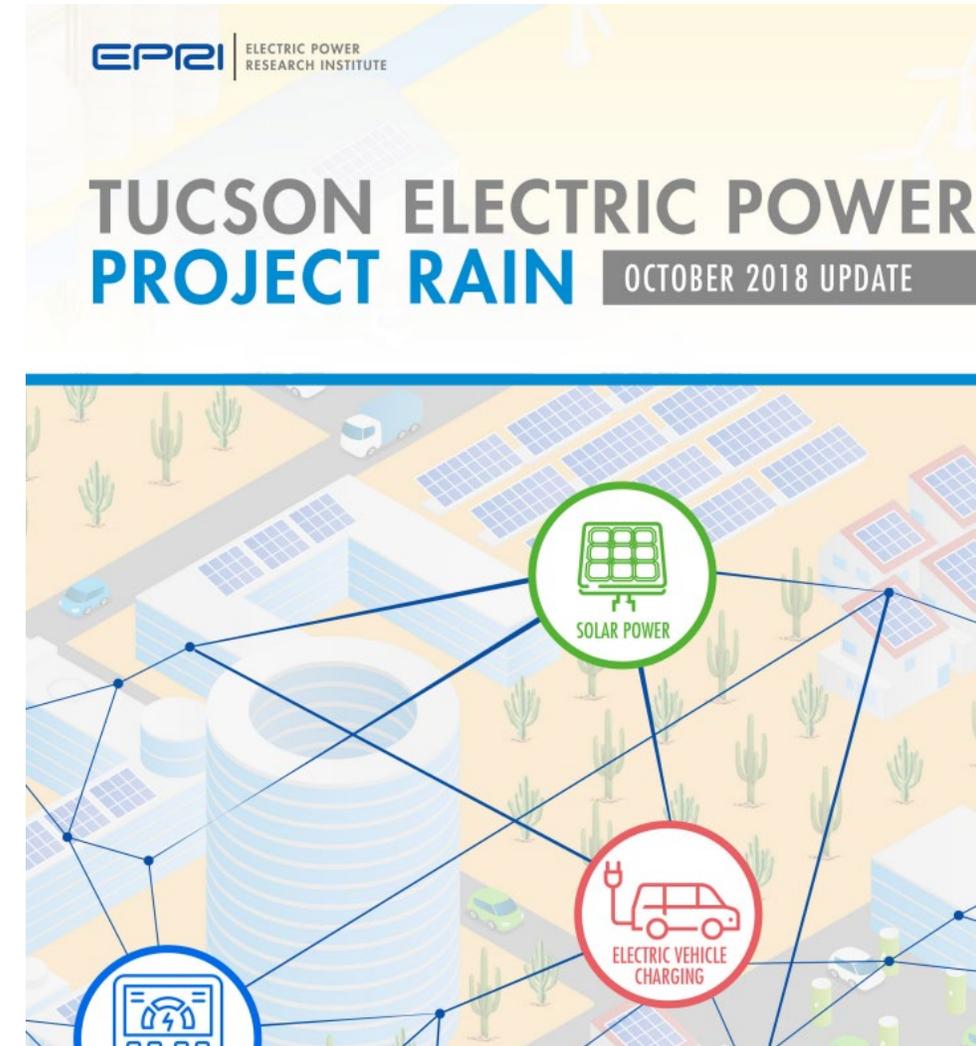
Data Dashboard Demo

Next Meeting:
March 24th
10am – 12pm