Resource Adequacy in the Desert Southwest

Public Webinar

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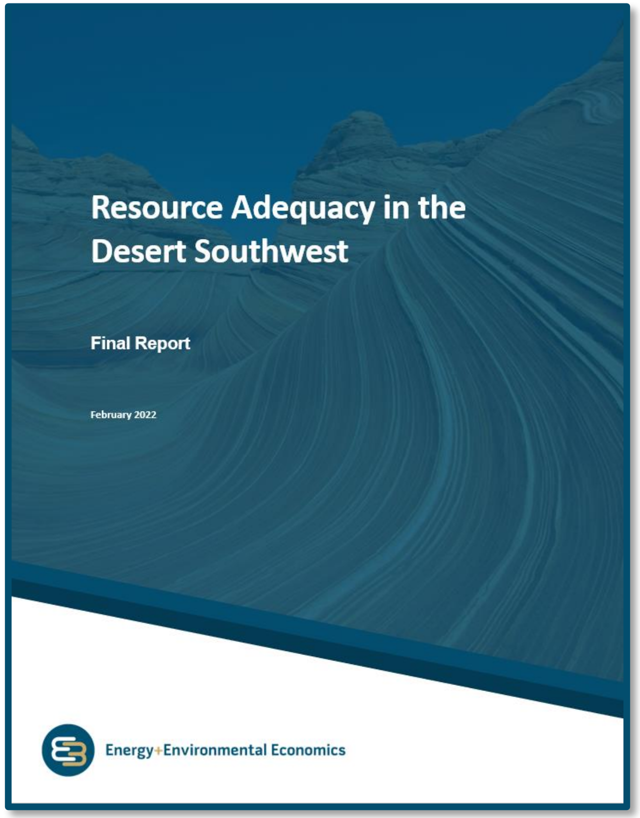
Energy+Environmental Economics

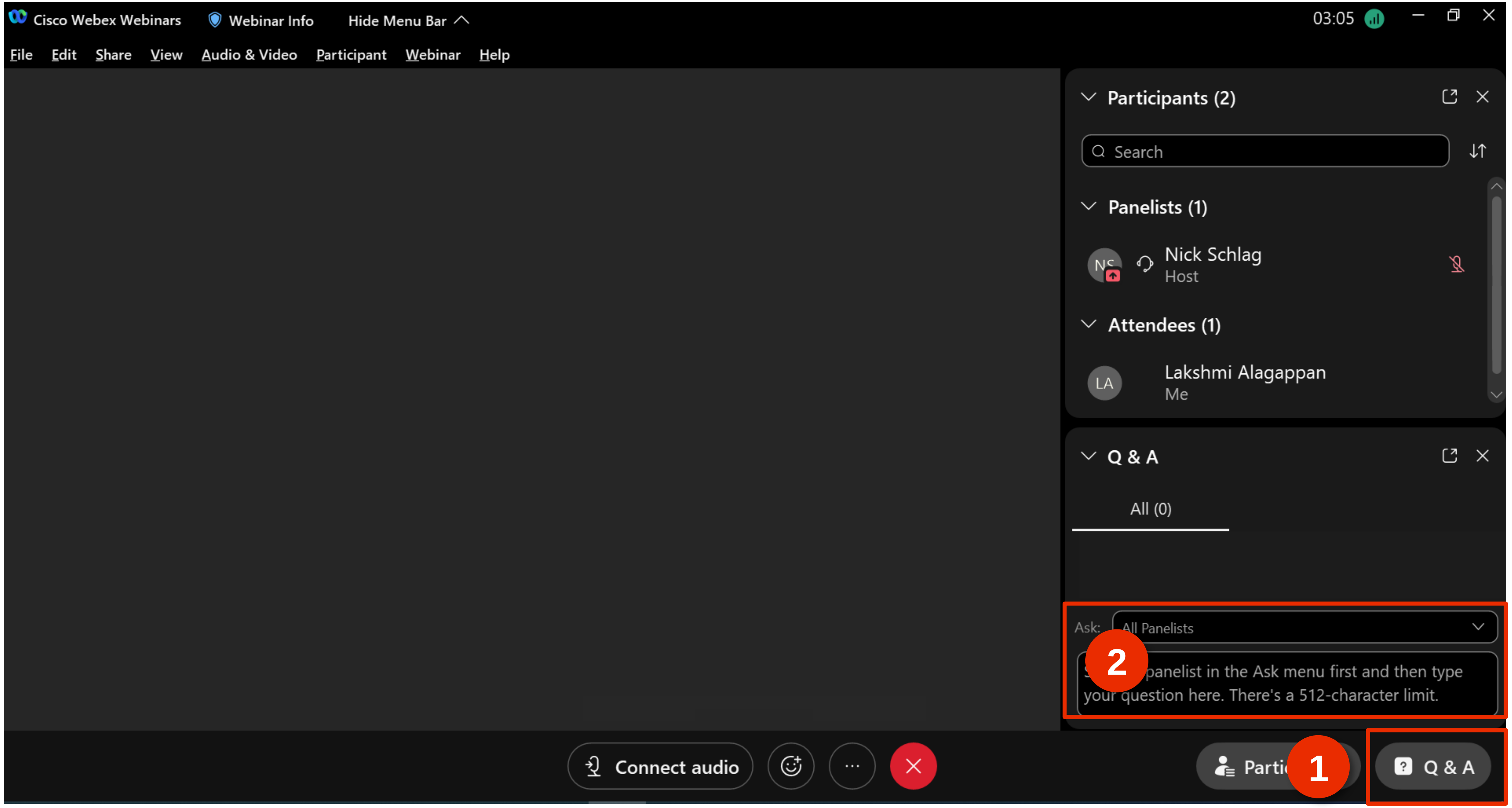
Agenda

+ Introduction & acknowledgements
+ Study motivation & purpose
+ Analytical methods & assumptions
+ Summary of study results
+ Key findings
+ Questions

Final Report & Technical Appendices available on E3's website: www.ethree.com/publication



How to ask questions

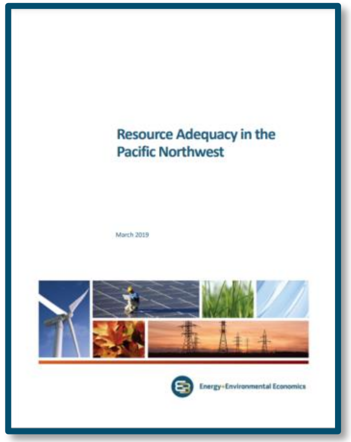


Find **“Q&A”** button (1) in the bottom right corner and type your questions in the box (2)

About E3

- Founded in 1989, E3 is a leading energy consultancy with offices in San Francisco, Boston, New York, and Calgary
- E3 works extensively with utilities, developers, government agencies, and environmental groups to inform strategy and key decisions
- Our experts lead rigorous technical analyses, develop innovative methods to study new problems, and provide critical thought leadership to the industry
- E3 is an industry leader in studying the resource adequacy needs in the transition to a decarbonized grid

[Resource Adequacy in the Pacific Northwest](#) *(sponsored by a coalition of Northwest utilities)*

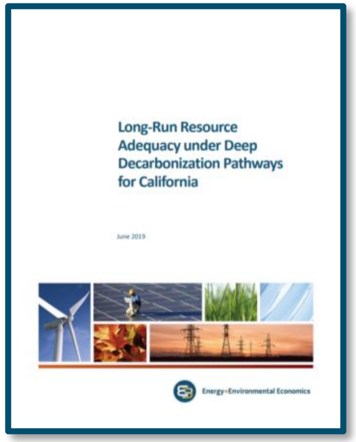


Resource Adequacy in the Pacific Northwest

March 2019

Energy+Environmental Economics

[Long-Run Resource Adequacy under Deep Decarbonization Pathways for California](#) *(sponsored by Calpine)*

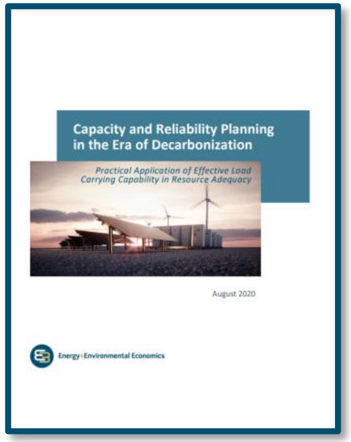


Long-Run Resource Adequacy under Deep Decarbonization Pathways for California

June 2019

Energy+Environmental Economics

[Capacity and Reliability Planning in the Era of Decarbonization](#) *(E3 whitepaper)*



Capacity and Reliability Planning in the Era of Decarbonization

Practical Application of Effective Load Carrying Capability in Resource Adequacy

August 2020

Energy+Environmental Economics

Acknowledgements

Study Sponsors:

Arizona G&T Cooperatives
Touchstone Energy® Cooperatives

aps®

The Electric Company® El Paso Electric

PNM®

SRP®

TEP

The study sponsors retained E3 to provide an independent assessment of the resource adequacy situation in the Desert Southwest region. The sponsors provided technical information and informed the development of study scenarios. E3 utilized data from the study sponsors and other sources to develop a Southwest resource adequacy model. E3 retained full editorial control over the report and is solely responsible for all contents.

Technical Advisory Group:

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+ **Pat O'Connell**
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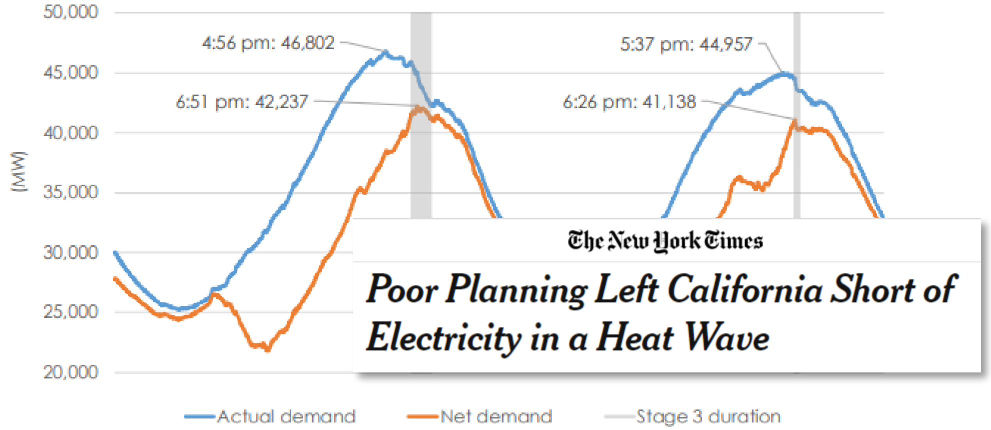
Participation in the Technical Advisory Group does not indicate endorsement of the report's findings

Study Motivation & Purpose

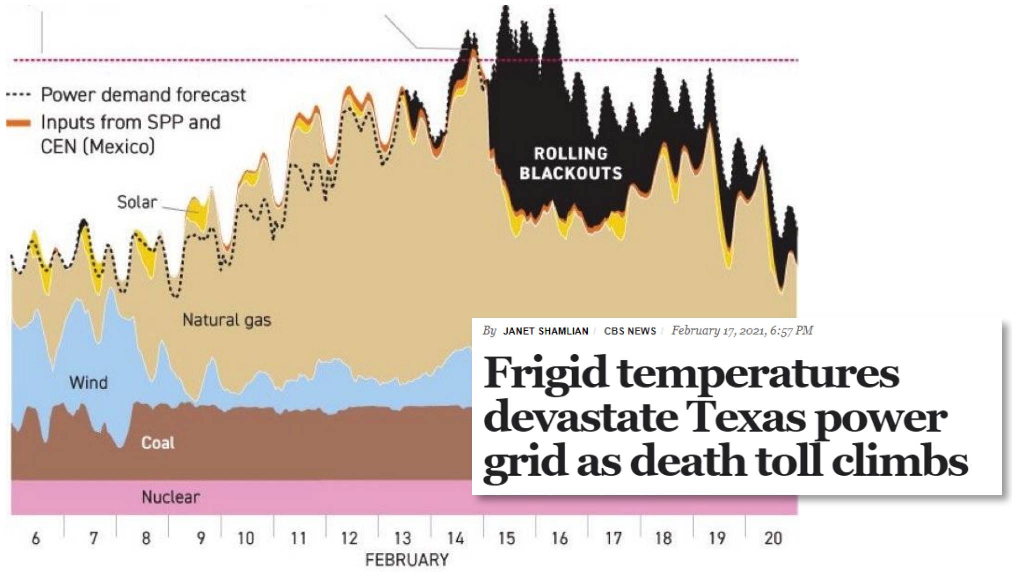
Energy+Environmental Economics

Planning for reliability 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 essential to our day-to-day lives at home and at work – and will become increasingly important**
  - Meeting cooling and heating demands under more frequent extreme weather events is may be 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

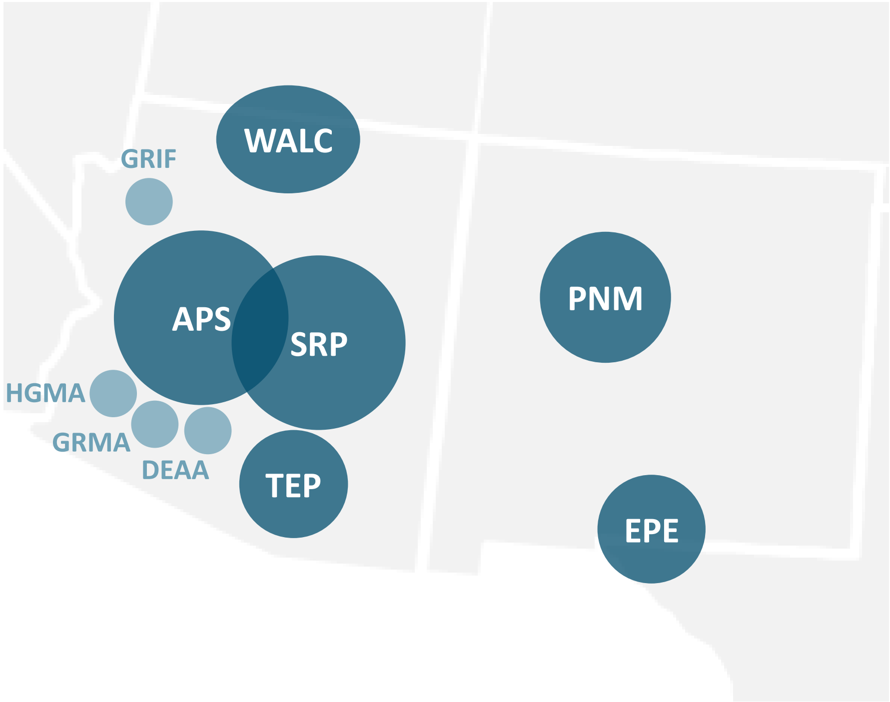
Study purpose

+ **The project's sponsors retained E3 to conduct a study to characterize resource adequacy in the Southwest region over the coming decade**

+ **Purposes of this effort are threefold:**
  1. Examine the current situation in the Desert Southwest in light of recent challenges in neighboring regions and identify any immediate risks to reliability in the region;
  2. Characterize best practices for resource adequacy planning that will provide a durable foundation for utilities' efforts to preserve reliability within the region; and
  3. Demonstrate these techniques to evaluate the region's readiness to meet the resource adequacy challenges it faces in the next decade

Study Geographic Scope

Includes all balancing authorities in Arizona and New Mexico



What is resource adequacy?

- **Resource adequacy is a measure of the ability of a portfolio of generation resources to meet load across a wide range of system conditions, accounting for variability of supply & demand**
- **Typically, electricity systems are planned to a standard where loss of load due to insufficient supply occurs very rarely**
  - The most common standard used throughout North America is a "one-day-in-ten-year" standard

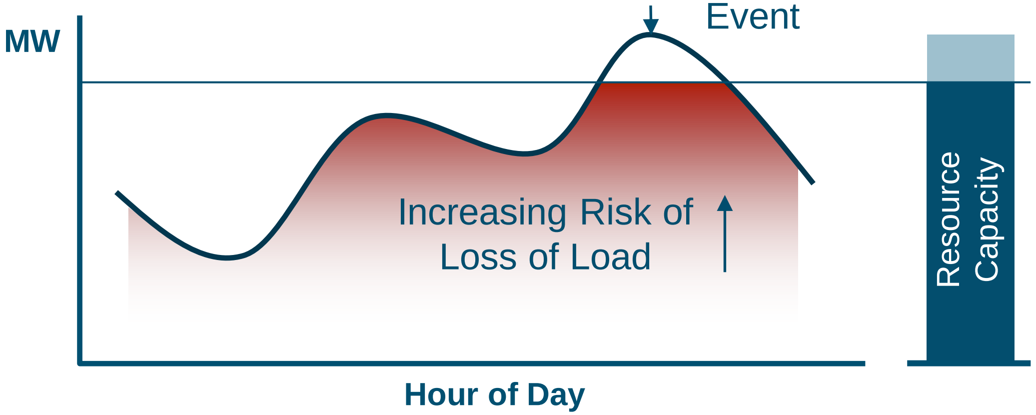
NERC Definition of Resource Adequacy:

"The ability of the electric system to supply the aggregate electrical demand and energy requirements of the end-use customers at all times, taking into account scheduled and reasonably expected unscheduled outages of system elements."

Source: *NERC Glossary of Terms*

Loss of Load Example

Insufficient resource capacity to serve load



Key trends in the Southwest region will reshape resource adequacy

Load growth
Expected 2+% load growth resulting from net migration, electrification, and new large customers

Planned coal & gas retirements
Utilities' planned retirements total 1,400 MW by 2025 and over 5,000 MW by 2033

Rapidly increasing reliance on renewables, storage, and DERs
Carbon-free resource additions driven by policy, customer preferences, voluntary commitments, and economics

Climate change impacts on extreme weather
Increased frequency and intensity of extreme heat events results in more frequent extreme peak demand

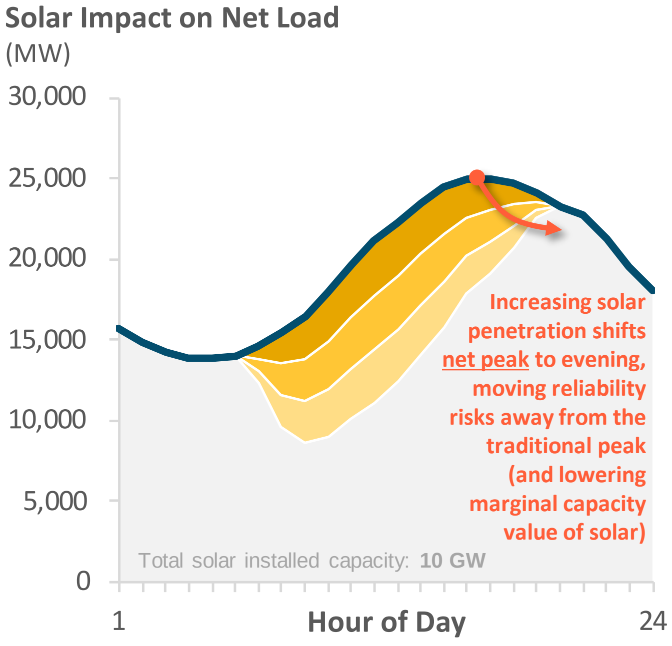
Increasing risk of sustained drought
Hydroelectric generation facilities susceptible to significant impacts under drought

Tightening Western markets
Changes & trends across the broader Western Interconnection reshaping market dynamics

Variable and energy-limited resources contribute to resource adequacy, but also add complexity

1

"Variable" resources shift reliability risks to different times of day



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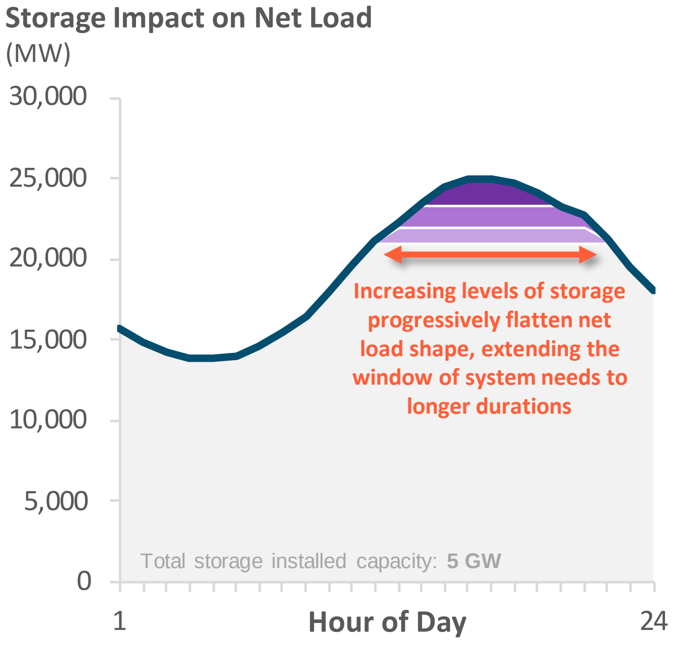
"Energy-limited" resources spread reliability risks across longer periods



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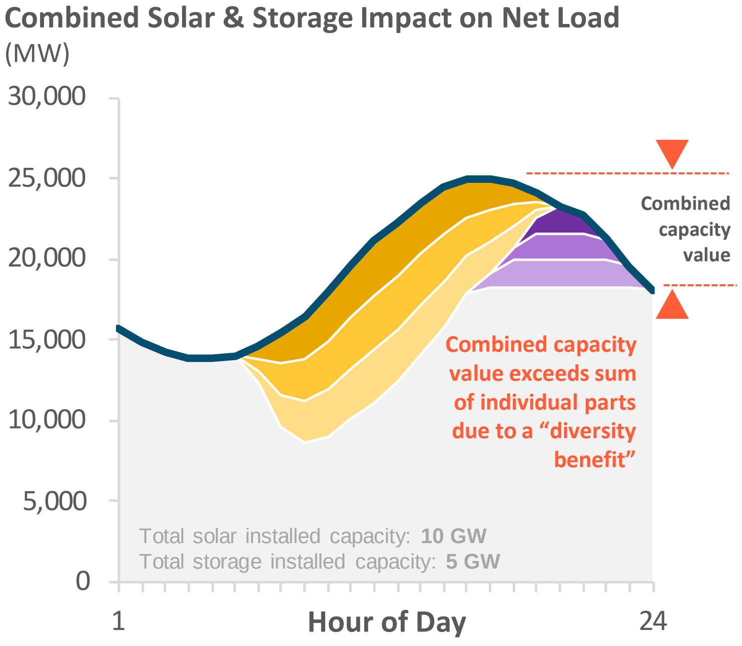
A portfolio of resources exhibits complex interactive effects, where the whole may exceed the sum of its parts



A preview of our key findings

1. Load growth & resource retirements are creating an urgent need for new resources in the Southwest
2. Utilities' current resource plans have identified sufficient capacity additions to maintain reliability
3. A significant share of the region's long-term needs are expected to be met by solar and storage resources
4. Even as solar and storage grow, the region's remaining firm resources – including nuclear and natural gas – will be needed for reliability
5. Substantial reliability risks remain as the region's electricity resource portfolio transitions

Analytical Approach & Key Assumptions

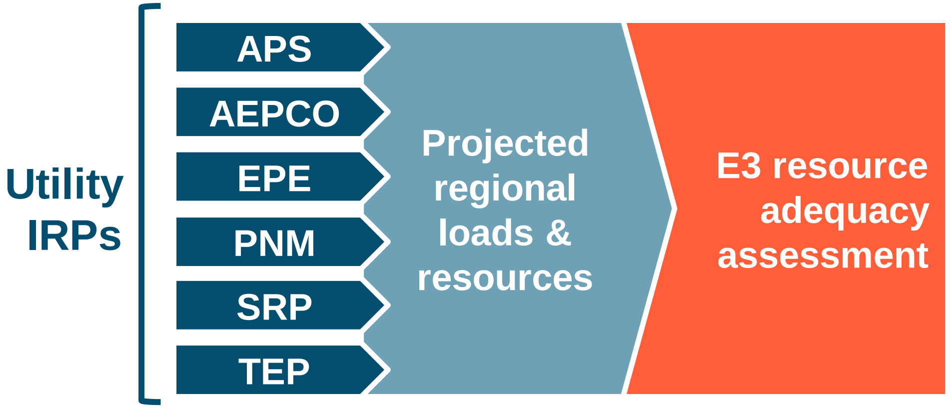
Energy+Environmental Economics

Scope of technical analysis

Three questions addressed in this analysis:

1. **How much capacity is needed to maintain reliability in the Southwest?**
   (measured against a "one day in ten year" standard)
2. **To what extent will utilities' existing & committed resources satisfy this requirement?**
3. **What additional resources are needed to ensure regional reliability?**

+ **This study builds upon the integrated resource plans of the Southwest utilities to address specific questions on how these plans will impact reliability within the region over the next decade**

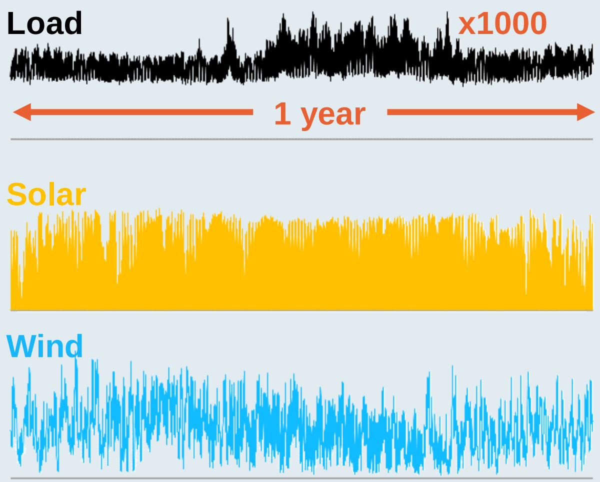


+ **Loss of load probability analysis used to study level of reliability achieved across the Southwest region, including metrics such as:**
  - Loss of load expectation (LOLE), expected unserved energy (EUE) and other statistical methods
  - A planning reserve margin (PRM) and effective load carrying capability (ELCC) values for different resources

Overview of best practices in resource adequacy analysis

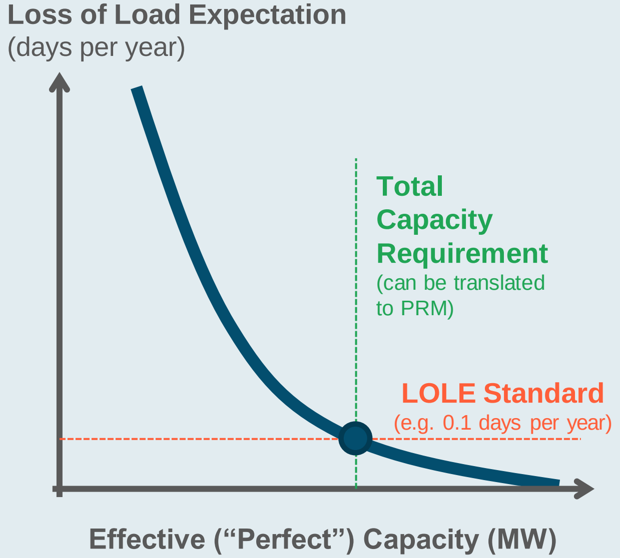
Develop a representation of the loads and resources of an electric system in a loss of load probability model

LOLP modeling allows a utility to evaluate resource adequacy across all hours of the year under a broad range of weather conditions, producing statistical measures of the risk of loss of load



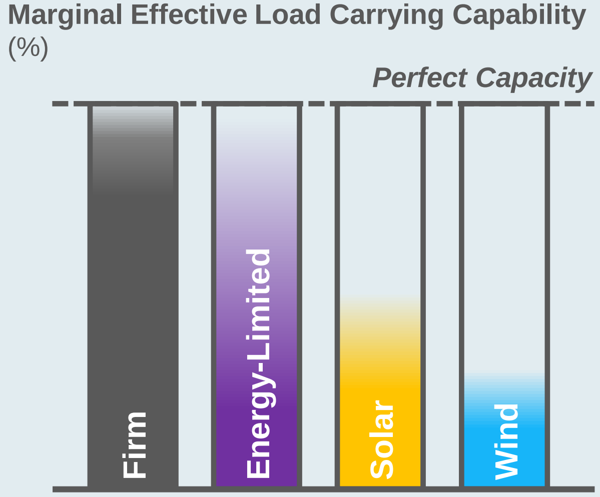
Identify the amount of perfect capacity needed to achieve the desired level of reliability

Factors that impact the amount of perfect capacity needed include load & weather variability, operating reserve needs



Calculate capacity contributions of different resources using effective load carrying capability

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



RECAP: E3's Renewable Energy Capacity Planning model

+ **RECAP uses a time-sequential simulation approach to assess the availability of supply to meet system needs on an hour-to-hour basis**
  - Simulation approach designed to focus on challenges resulting from increasing penetrations of variable & energy-limited resources
+ **Each simulation analyzes conditions across hundreds or thousands of possible years using a Monte Carlo approach to capture year-to-year variations in:**
  - Underlying weather, load, wind & solar profiles
  - Power plant outage patterns
  - Energy-limited resource dispatch
+ **Primary results include an array of indicators of system resource adequacy:**
  - Statistics of loss of load frequency, duration, and magnitude
  - Planning reserve margin requirement and ELCCs of different resources

*Correlations between **load and variable** resources preserved*

System Demand
simulated hourly demand (net of EE) across a range of weather conditions

Variable Resource
simulated with weather-matched hourly profiles (including BTM PV)

Firm Resources
simulated based on rated capacity and outage rates

__Energy-limited resources__ dispatched time-sequentially

Hydroelectric Resources
dispatched based on monthly capacity & energy limits

Storage Resources
dispatched according to limits on duration and round-trip losses

DR Programs
dispatched subject to limits on number of calls & duration

72°

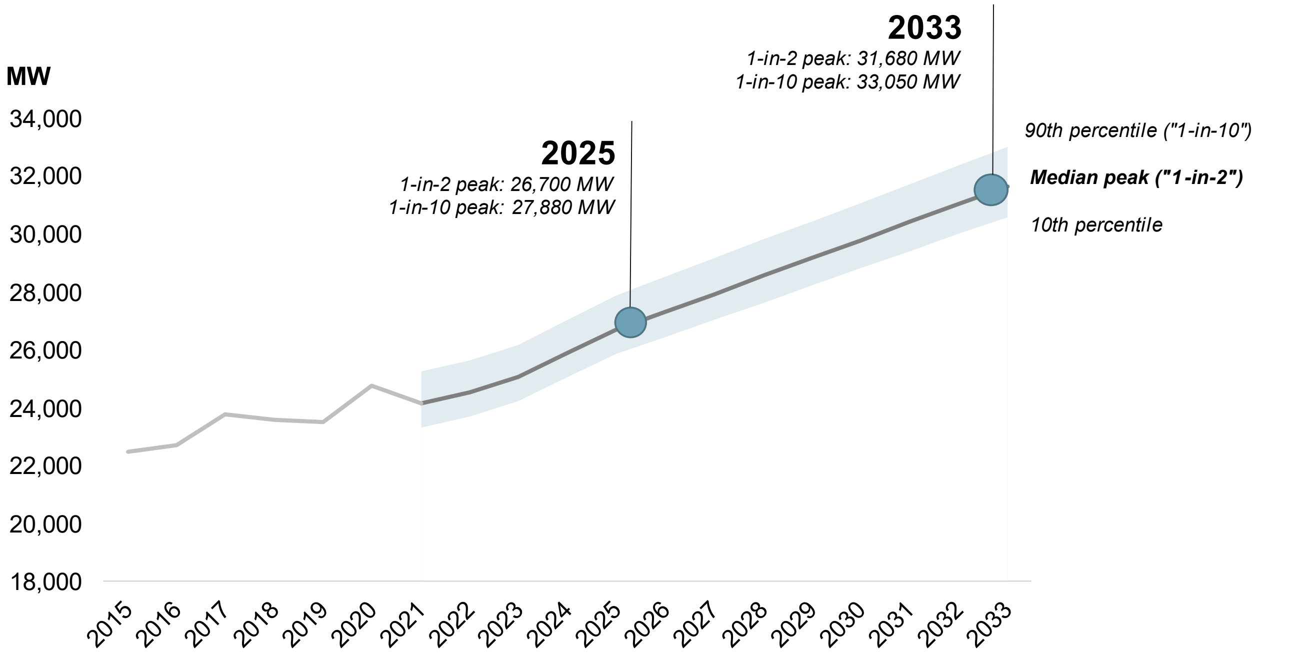
Unserved Energy
identified based on any unmet demand

Peak demand is the primary driver of total capacity needs

+ **Regional load forecast derived from aggregation of individual utilities' forecasts and reflects:**
  - Demographic shifts and net migration to growing urban areas
  - Increasing levels of transportation electrification
  - Addition of new large customers
  - Impacts of future energy efficiency programs
  - Projections of BTM PV adoptions

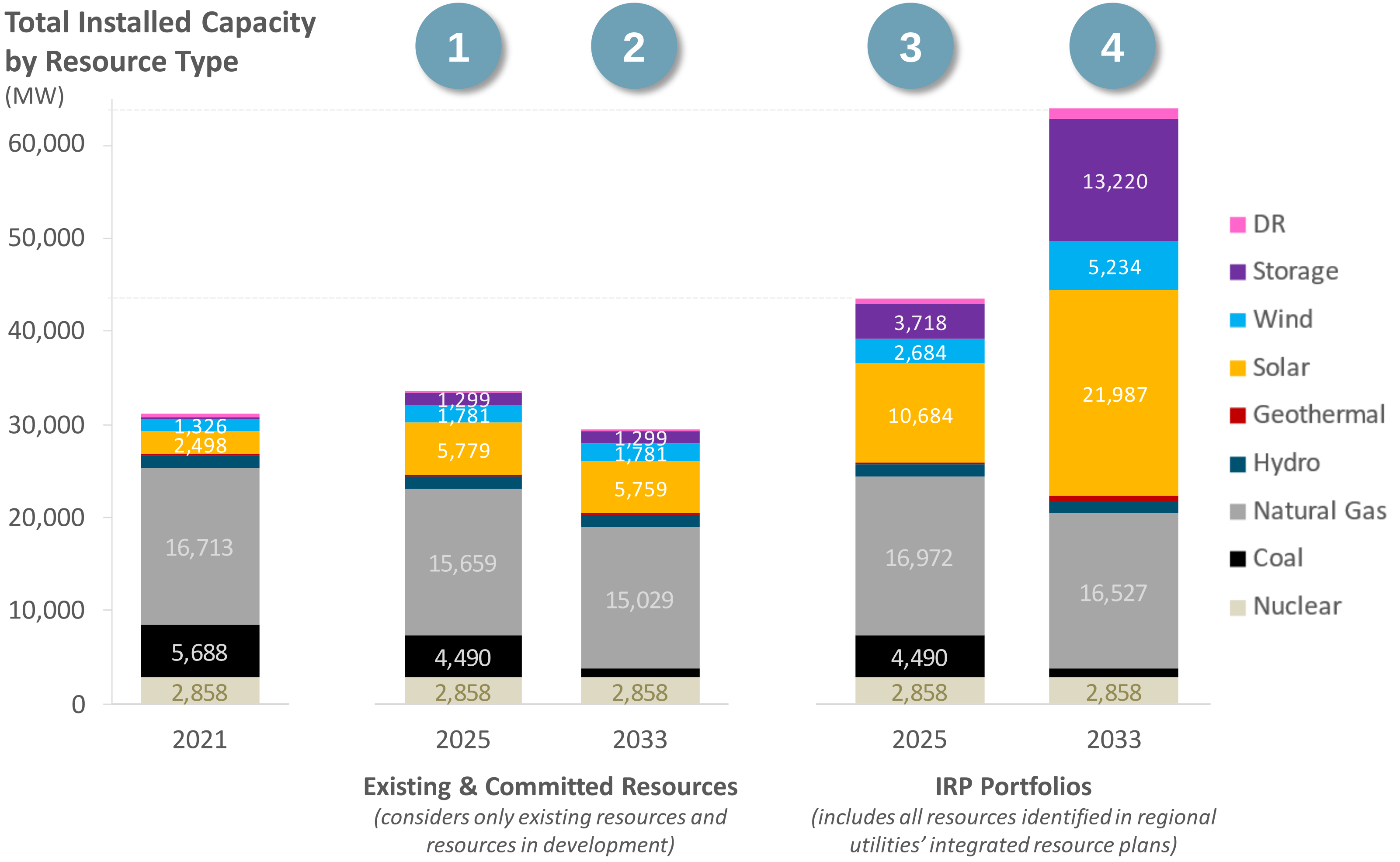
+ **In aggregate, regional peak demand is projected to grow at a rate of 2.5% per year**

Southwest Regional Coincident Peak Forecast (MW)



Scenarios and sensitivities

Four core scenarios examine regional adequacy of different portfolios:



Sensitivity analysis explores additional uncertainties:

- Battery storage performance
- Hydro availability
- Load impacts of more extreme weather
- Natural gas generator performance
- Interregional market dynamics
- Timing of additions
- "Summer stress test"

Developing a rich library of hourly load & renewable profiles

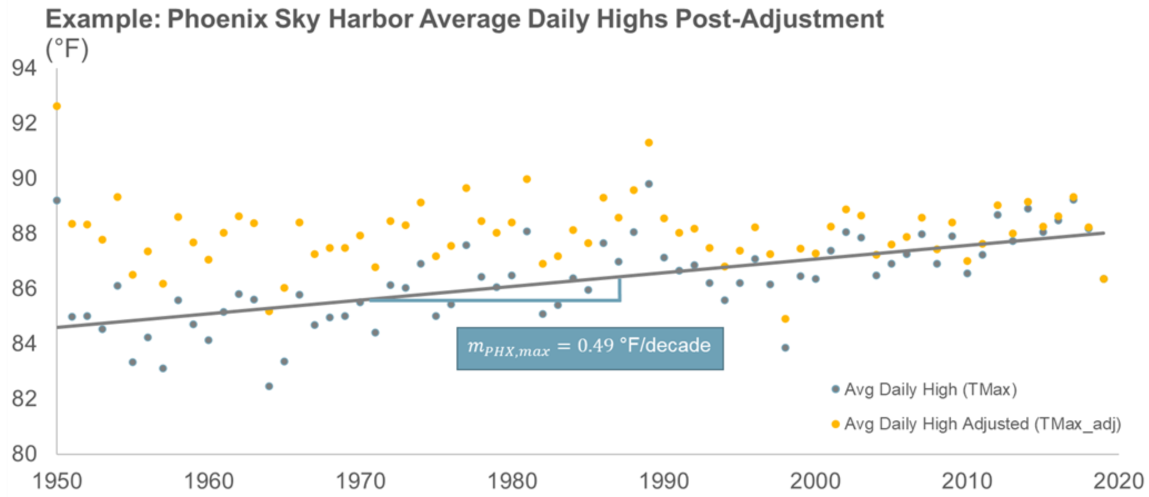
Profile	Primary Source(s)	Weather Conditions Captured	Notes
Loads	**WECC** Data request **NOAA** Historical Weather Data	2010 2019 1950 2019	• Neural network regression used to simulate hourly load patterns under broad range of weather conditions using recent historical load data (2010-2019) and long-term weather data (1950-2019) • 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 **future wind resources** simulated based on generic locations chosen by E3 with input from sponsors
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 **future utility-scale solar resources** simulated based on generic locations and technology characteristics chosen by E3 with input from sponsors • Profiles for **behind-the-meter/distributed solar** simulated for each utility service area

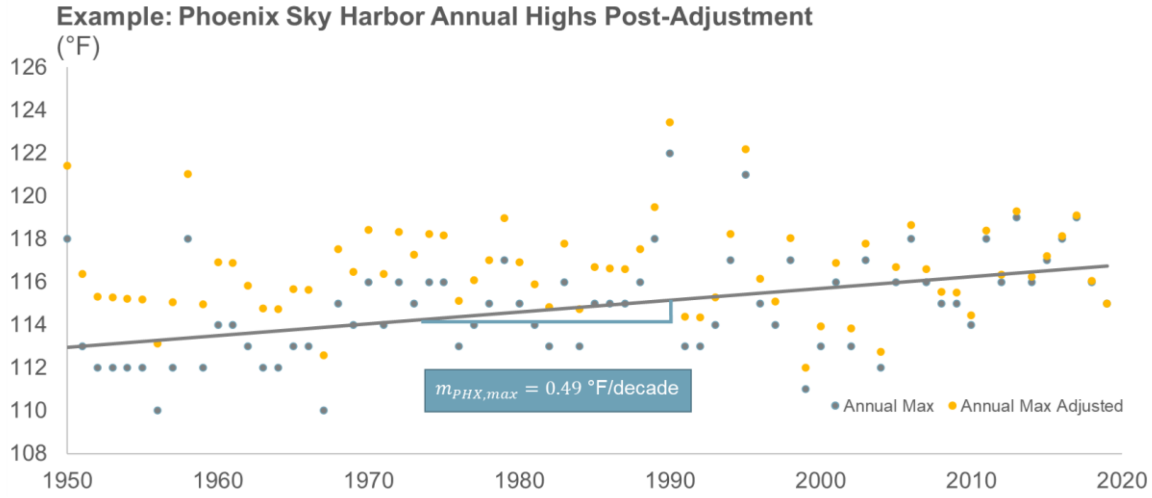
RECAP's endogenous day-matching algorithm extends shorter samples of wind and solar data to cover full historical period while preserving underlying correlations with load

Detrending historical weather data to account for impacts of climate change

- **Historical weather data is frequently used to simulate loads under a broad range of conditions for LOLP models – but the presence of a strong warming trend in historical data means that the past is not a predictor of the future**
  - Warming trend is particularly notable in Phoenix – the largest load center – where average and maximum temperatures have increased by 0.5F per decade since 1950
- **Load shapes for the Southwest region are simulated based on a “detrended” weather record, wherein the distribution of historical conditions is shifted upwards, resulting in:**
  - More extreme peak temperatures
  - More frequent high temperature extremes

Weather Station	Average Temperature Change, 1950-2019 (Δ°F/decade) Annual Maximum Daily High Temp	Annual Average Daily High Temp	Annual Average Daily Low Temp
Albuquerque International Airport	+0.08	+0.08	+0.52
El Paso International Airport	+0.43	+0.31	+0.58
Phoenix Airport	+0.55	+0.49	+1.60
Tucson International Airport	+0.57	+0.52	+0.58





Additional detail on modeling assumptions available in final report

Module	Inputs Needed
System Demand	+ Annual energy demand (including energy efficiency impacts) + Annual 1-in-2 peak demand (including energy efficiency impacts) + Hourly profiles corresponding to a wide range of weather conditions (20+ years) + Minimum operating reserve requirements
Firm Resources *(e.g. nuclear, coal, gas, biomass, geothermal)*	+ Monthly capacity rating by resource + Forced outage rate by resource + Maintenance profile by resource
Variable Resources *(e.g. wind, solar)*	+ Installed capacity by resource + Hourly profiles for multiple years, ideally including multiple years of overlap with hourly load profile data
Hydroelectric Resources	+ Installed capacity by resource + Monthly/daily energy budgets across a range of plausible hydro conditions + Minimum output levels by month/day + Sustained peaking limitations by month/day
Storage Resources *(e.g. batteries, pumped storage)*	+ Installed capacity by resource + Duration by resource + Charging & discharging efficiency by resource + Paired variable resource (for hybrids) + Interconnection configuration & rating (for hybrids)
Demand Response Resources	+ Expected load impact by program + Limits on number of program calls (per year or per month) + Duration of calls

+ **Key data sources:**
  - **Utility IRPs**
  - ABB VelocitySuite
  - WECC historical load data
  - NREL SAM & Wind toolkit
  - EIA Form 860
  - EIA Electric Grid Monitor

Study Results

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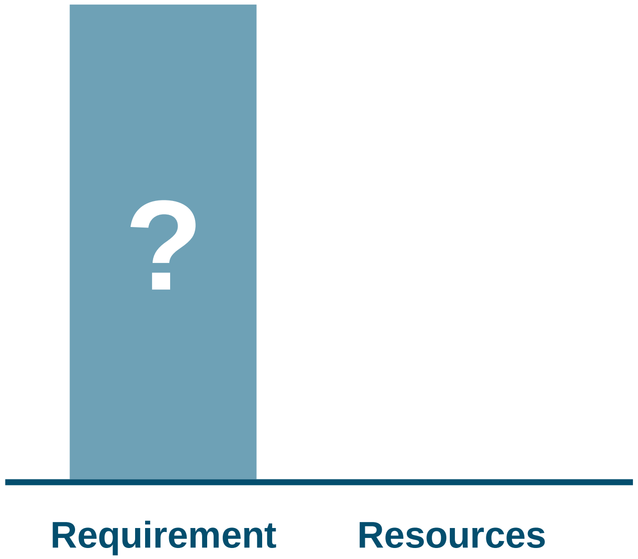
1. **How much capacity is needed to maintain reliability in the Southwest?**



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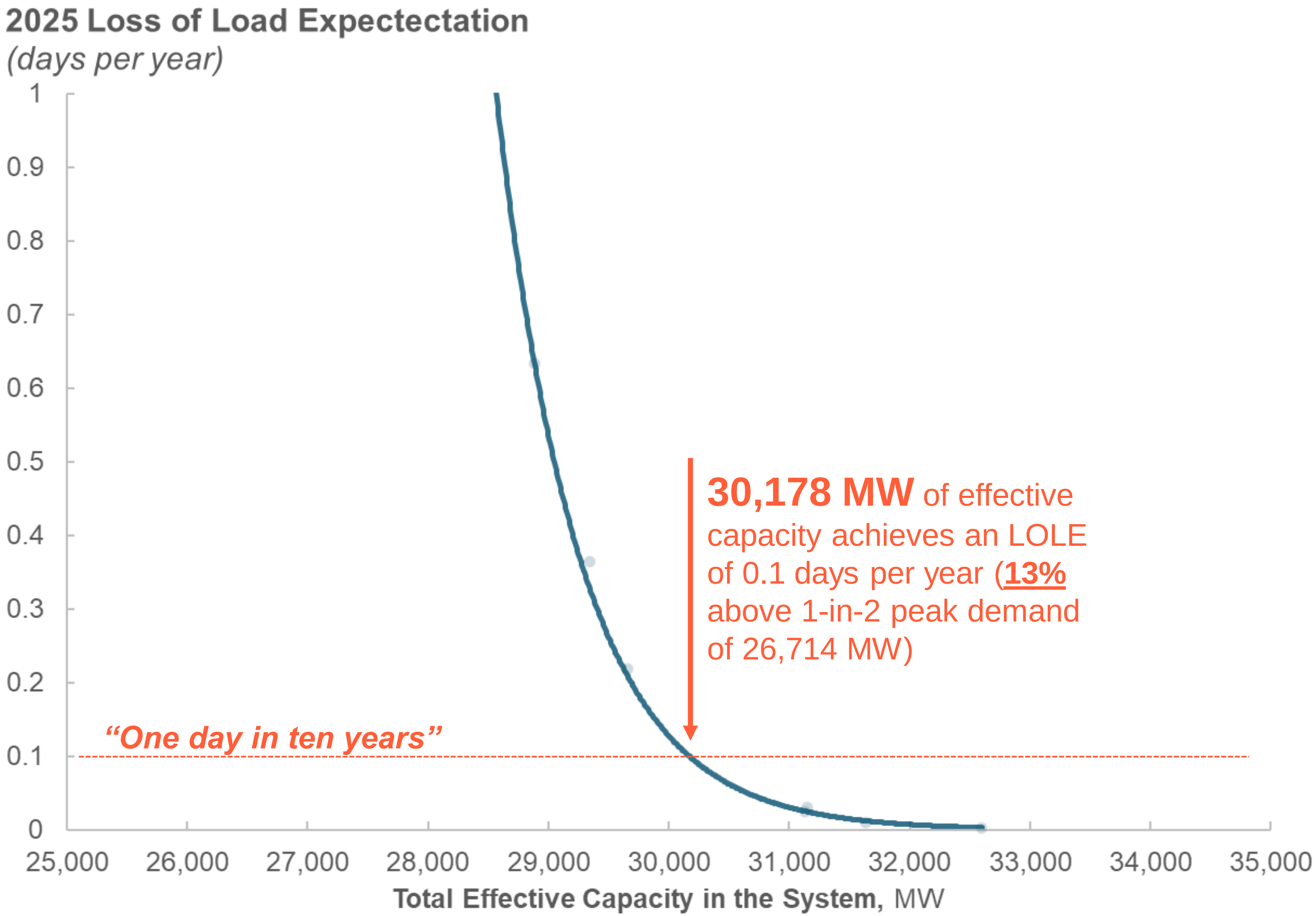
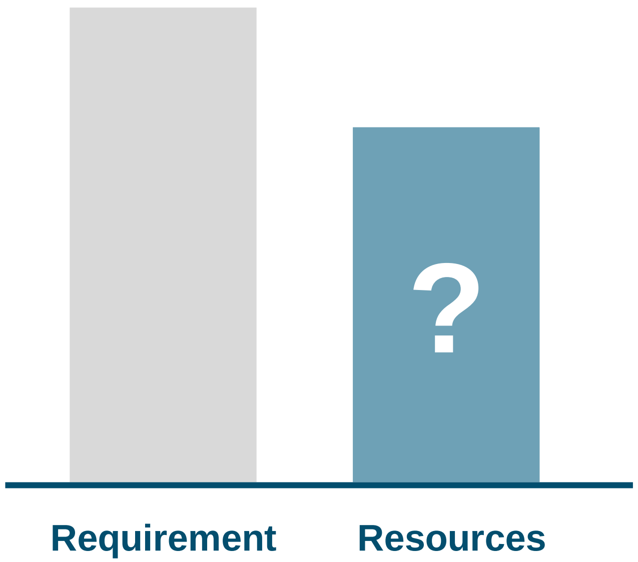
Achieving reliability requires 13% of effective capacity above the median peak

- **In 2025, achieving "one day in ten years" standard for the Southwest region requires 30,200 MW of effective capacity**
  - Increases to 35,800 MW by 2033
  - Reflects a **+13%** reserve margin above the regional coincident peak demand in both years
- **Expected frequency of reliability events grows rapidly below these thresholds**
  - Key implication: a rising capacity shortfall will rapidly lead to untenable frequency of load shedding events
- **Measuring need in terms of *effective capacity* makes this requirement is entirely independent of the characteristics of resources that to meet it**



2. To what extent will utilities' existing & committed resources satisfy this need?



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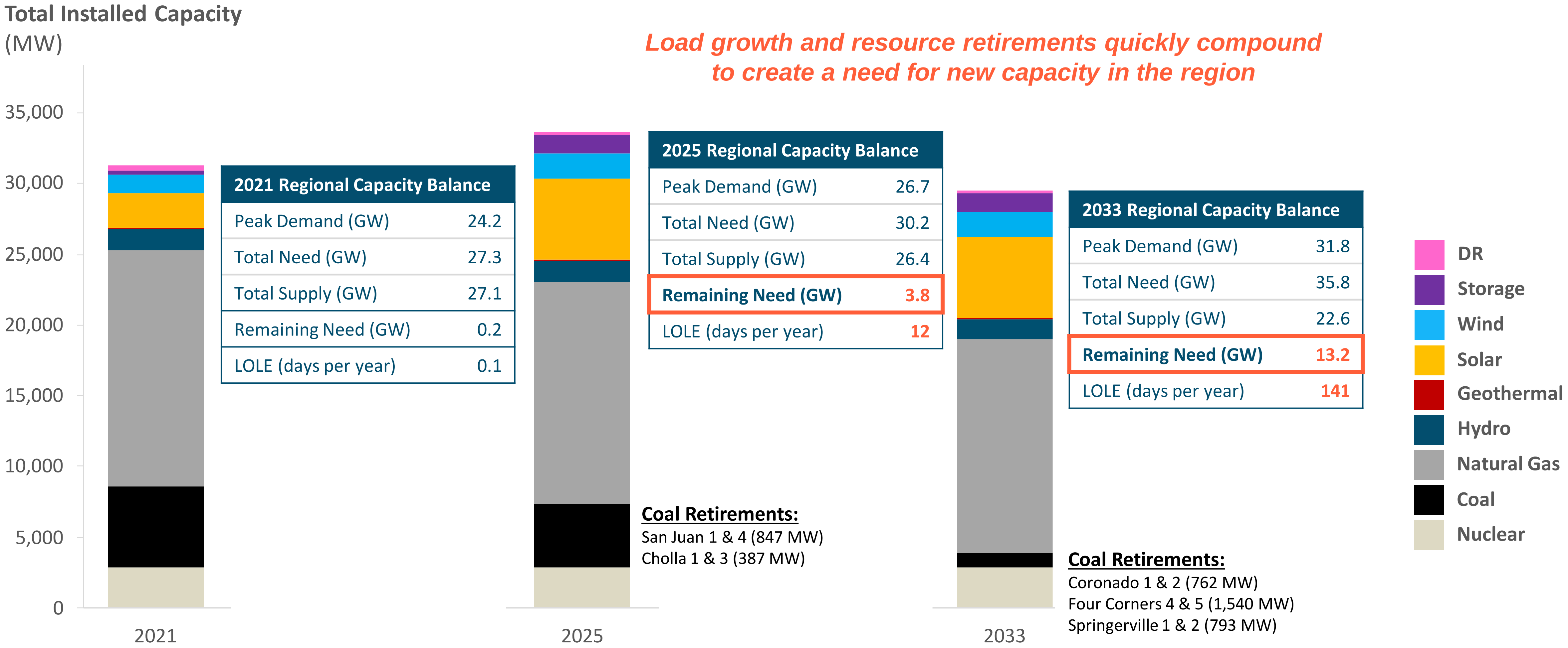
Existing & committed resource scenario summary results

Load growth and resource retirements quickly compound to create a need for new capacity in the region



2021 Regional Capacity Balance	
Peak Demand (GW)	24.2
Total Need (GW)	27.3
Total Supply (GW)	27.1
Remaining Need (GW)	0.2
LOLE (days per year)	0.1

2025 Regional Capacity Balance	
Peak Demand (GW)	26.7
Total Need (GW)	30.2
Total Supply (GW)	26.4
Remaining Need (GW)	**3.8**
LOLE (days per year)	12

Coal Retirements:
San Juan 1 & 4 (847 MW)
Cholla 1 & 3 (387 MW)

2033 Regional Capacity Balance	
Peak Demand (GW)	31.8
Total Need (GW)	35.8
Total Supply (GW)	22.6
Remaining Need (GW)	**13.2**
LOLE (days per year)	141

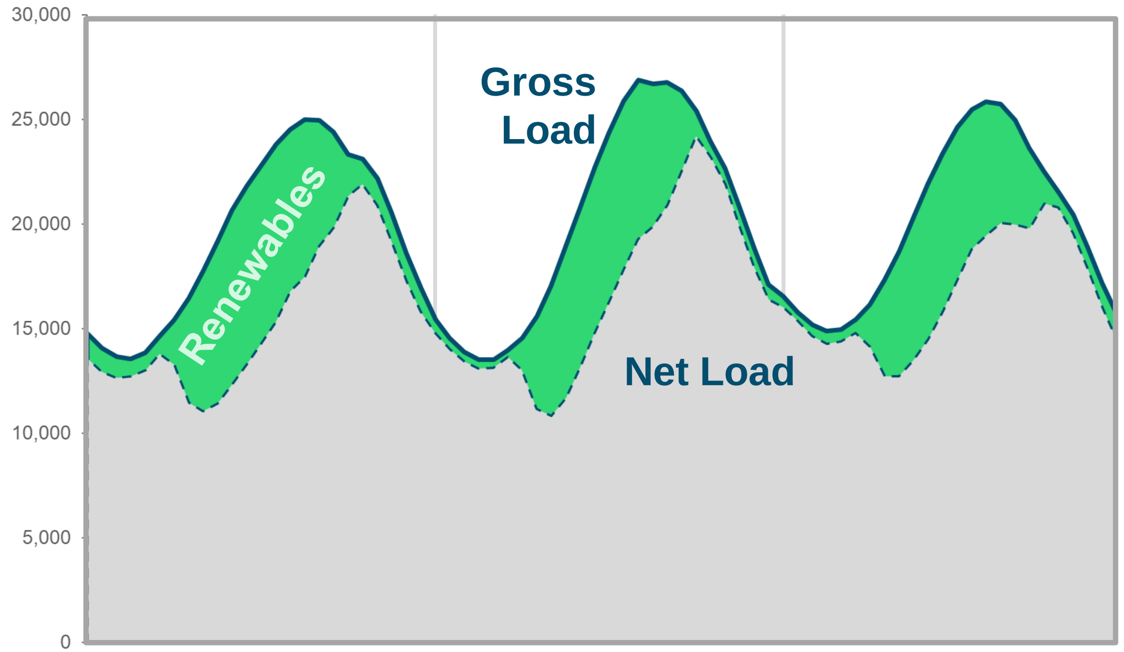
Coal Retirements:
Coronado 1 & 2 (762 MW)
Four Corners 4 & 5 (1,540 MW)
Springerville 1 & 2 (793 MW)

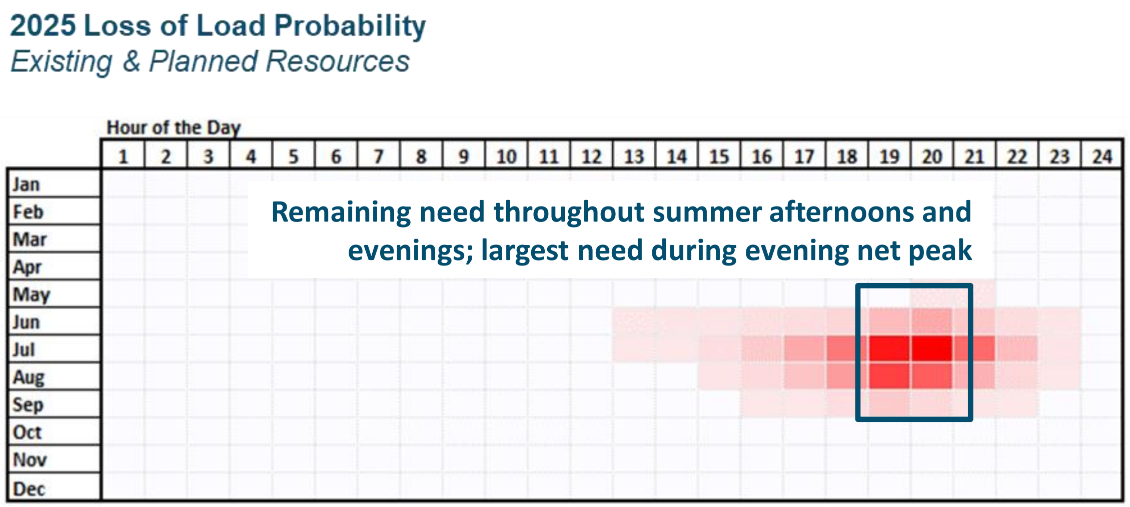
Notes:
"Total Need" and "Total Supply" are both measured in terms of "effective capacity"

By 2025, the principal resource adequacy challenge in the Southwest is the evening “net peak”

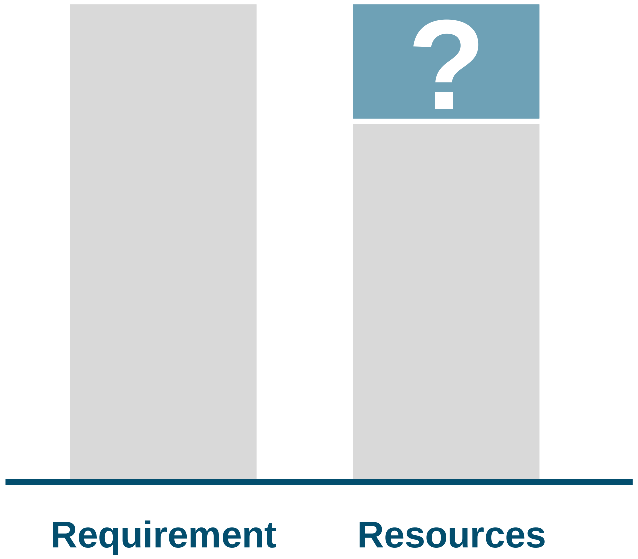
- **With increasing penetration of solar resources, the highest “net peak” period occurs after sundown** *(i.e. the highest loss of load probability occurs when solar is not producing)*
- **This shift has direct implications for the relative capacity value of different types of resources**

2025 load & net load on representative summer peak days
(MW)





3. What additional resources are needed to ensure regional reliability?



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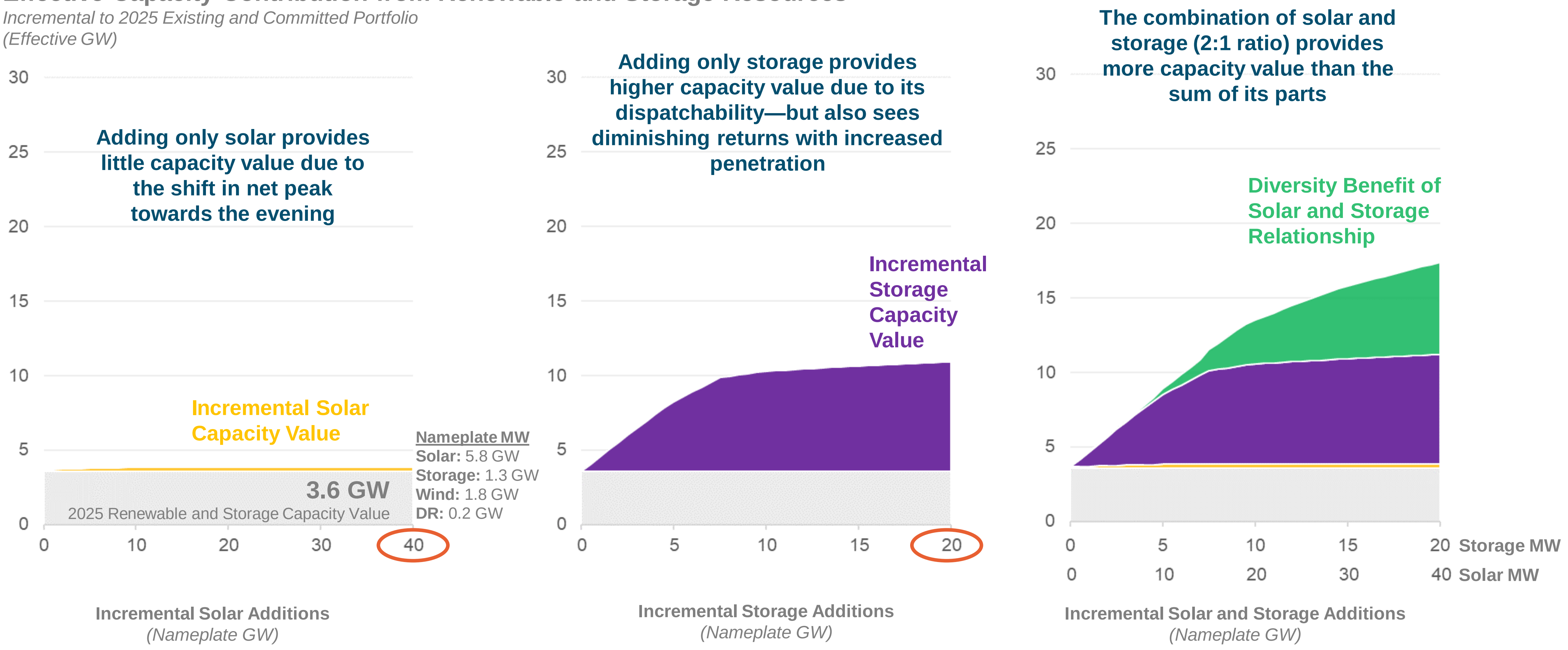
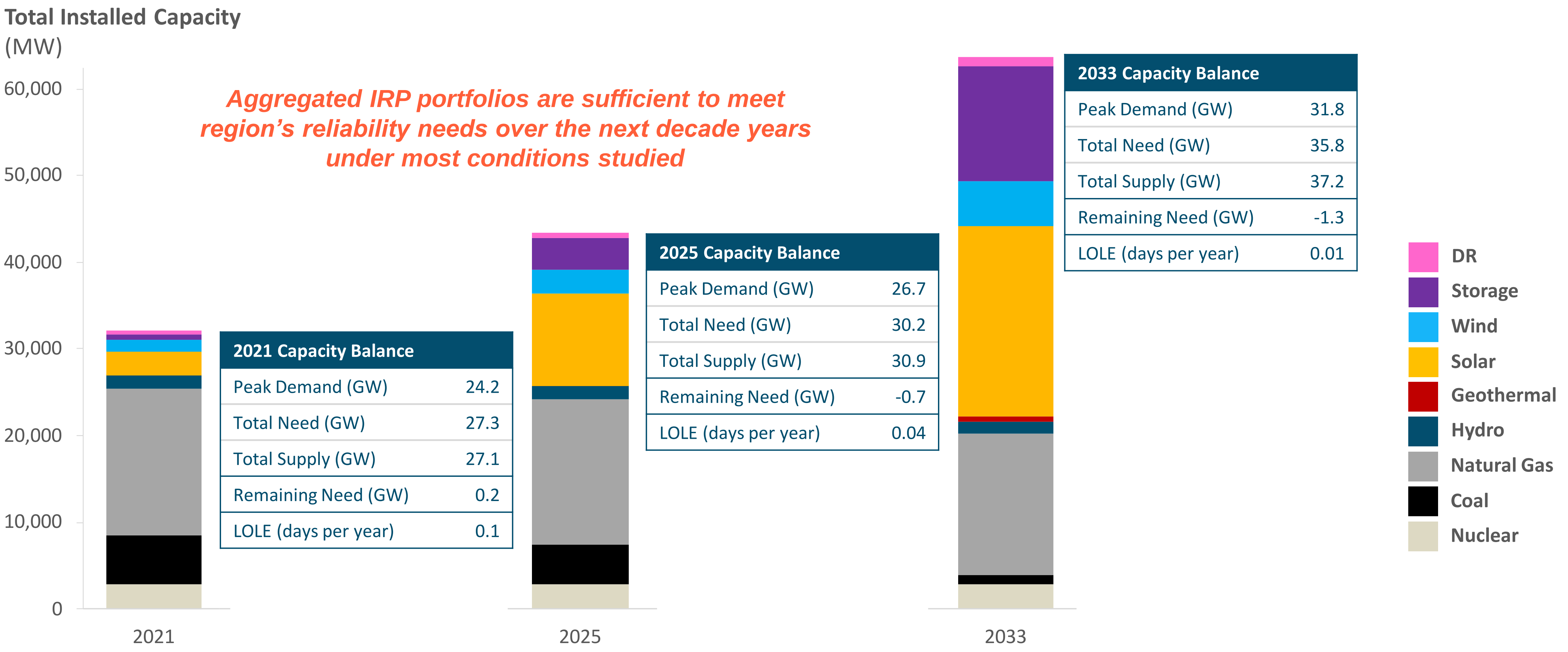
The Southwest will rely on increasing levels of solar and storage to meet future reliability needs

Effective Capacity Contribution from Renewable and Storage Resources

Incremental to 2025 Existing and Committed Portfolio (Effective GW)



IRP portfolio analysis results



2021 Capacity Balance	
Peak Demand (GW)	24.2
Total Need (GW)	27.3
Total Supply (GW)	27.1
Remaining Need (GW)	0.2
LOLE (days per year)	0.1

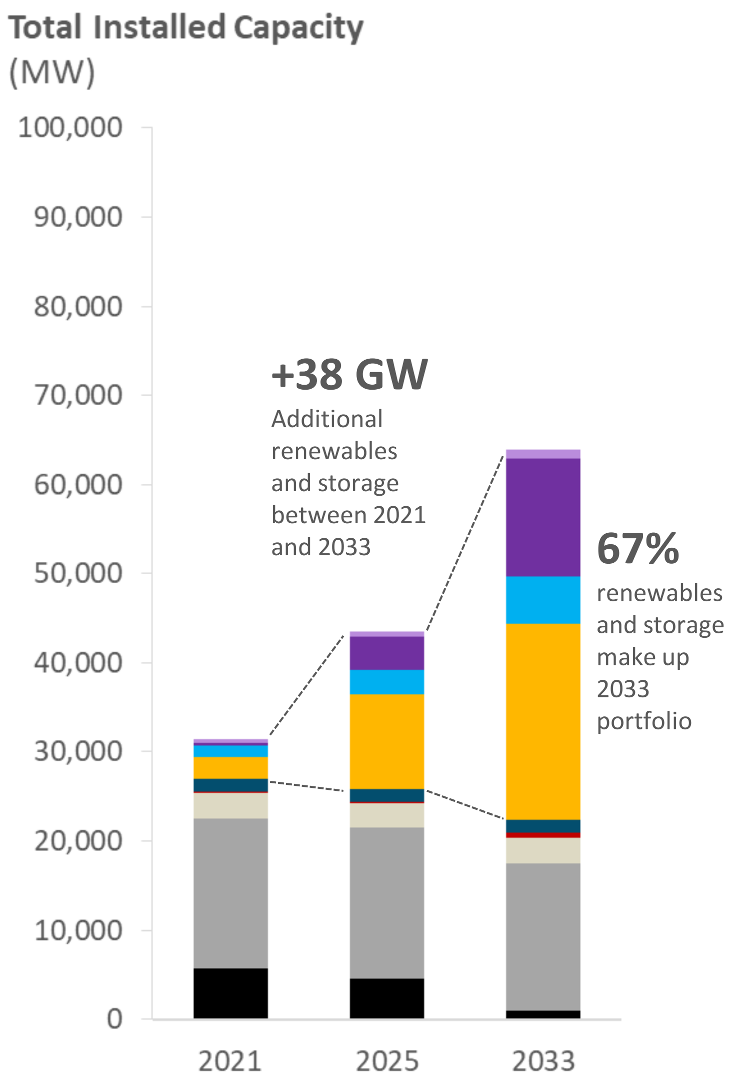
2025 Capacity Balance	
Peak Demand (GW)	26.7
Total Need (GW)	30.2
Total Supply (GW)	30.9
Remaining Need (GW)	-0.7
LOLE (days per year)	0.04

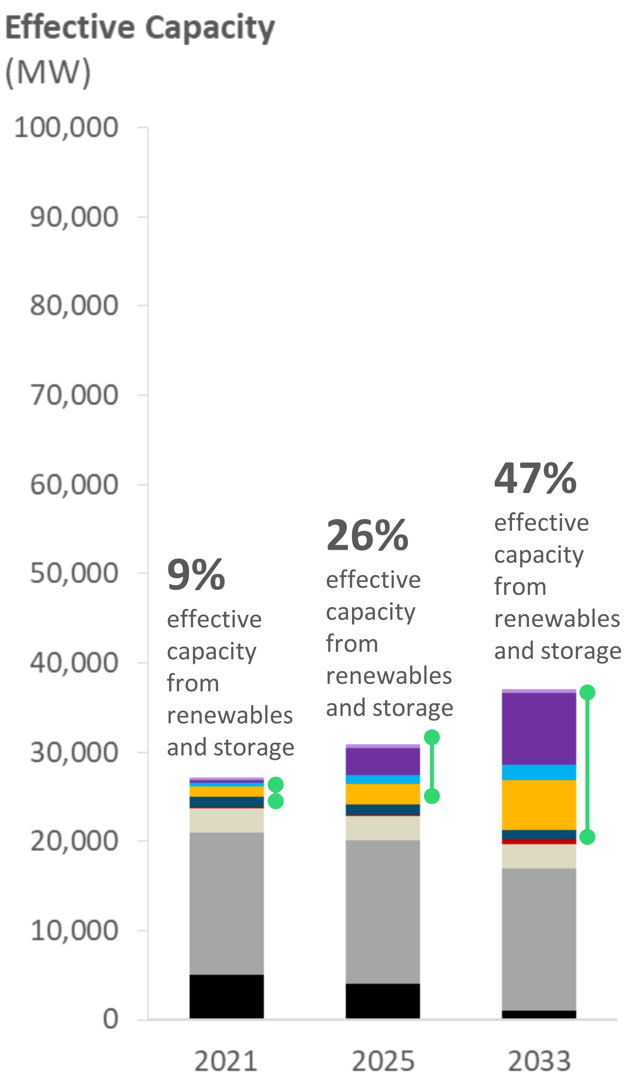
2033 Capacity Balance	
Peak Demand (GW)	31.8
Total Need (GW)	35.8
Total Supply (GW)	37.2
Remaining Need (GW)	-1.3
LOLE (days per year)	0.01

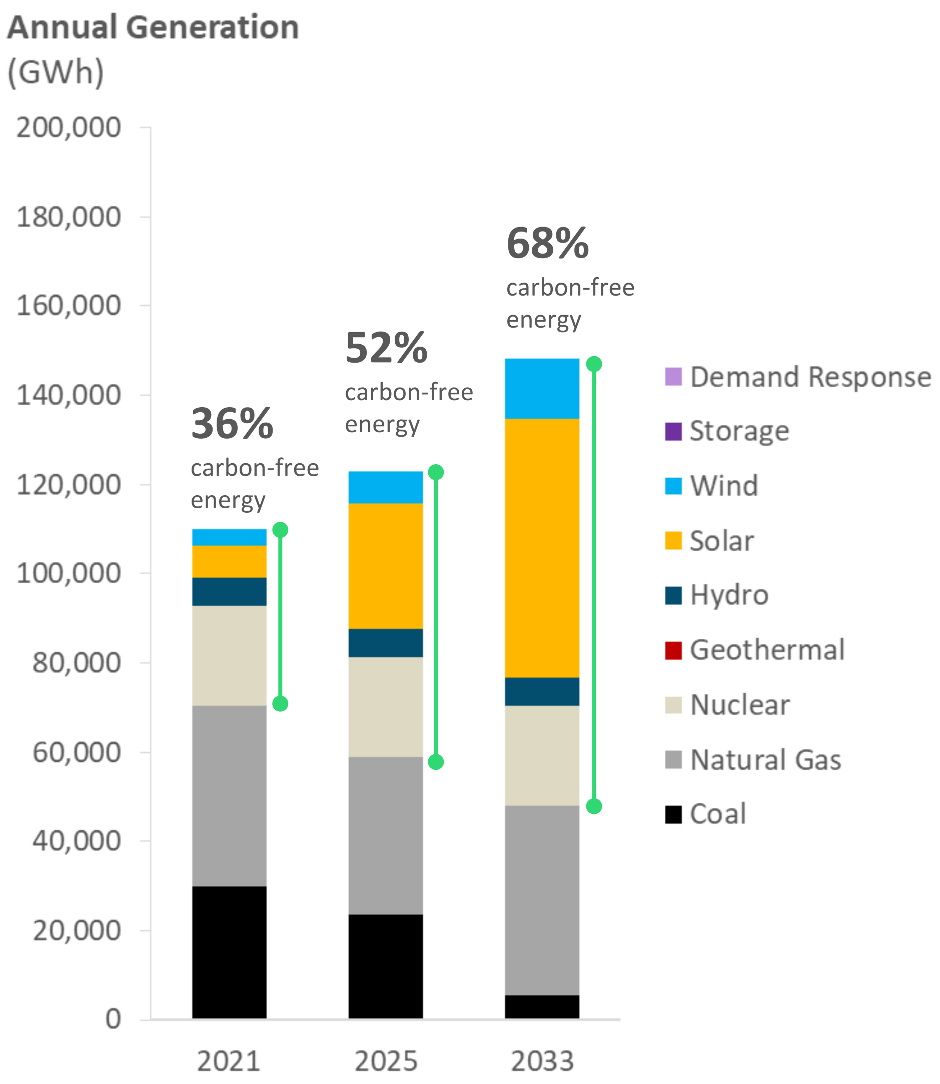
Notes:

"Total Need" and "Total Supply" are both measured in terms of "effective capacity"

Renewables and storage provide valuable energy and capacity, but existing conventional resources provide remaining reliability







Key Findings

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Key Finding #1: Load growth & resource retirements are creating an urgent need for new resources in the Southwest

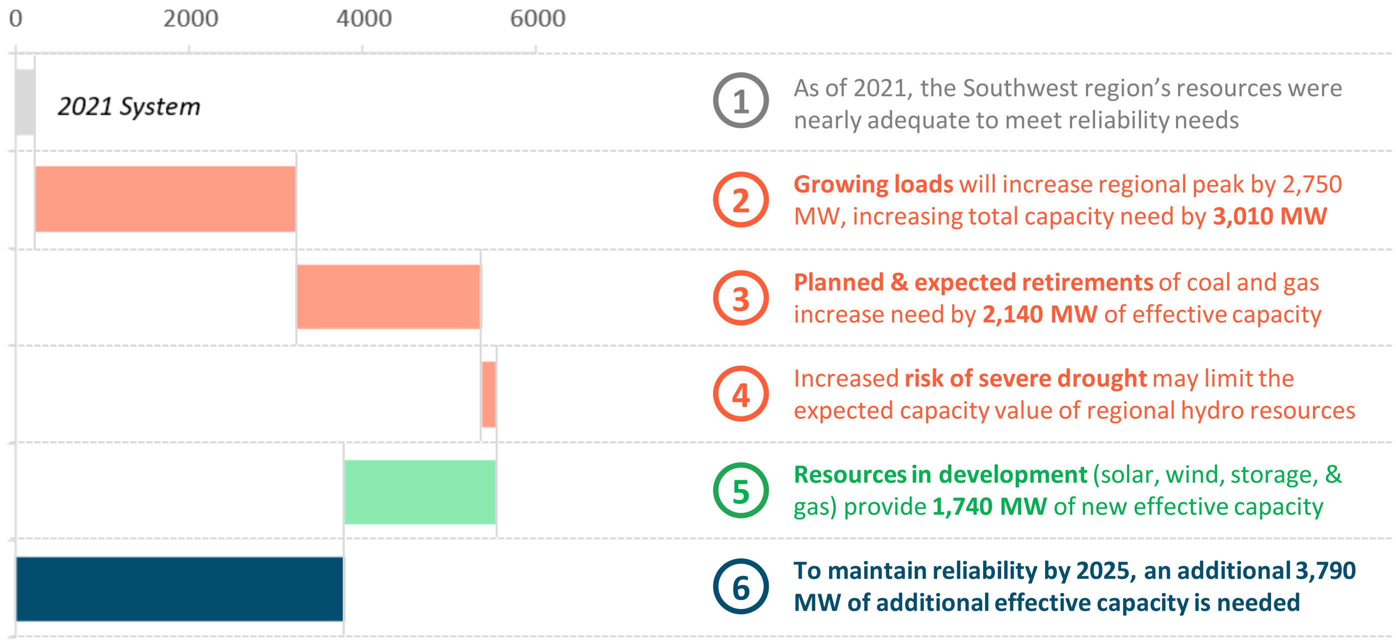
+ **Existing & committed resources will be insufficient to meet the region's rapidly growing resource adequacy needs**

+ **By 2025, approximately 4,000 MW of *effective capacity* will be needed beyond resources already in development**
  - Load growth anticipated by utilities will increase regional peak by roughly 700 MW each year, resulting in a 2,700 MW increase by 2025
  - Retirements of existing coal and gas resources are expected to total 2,500 MW of nameplate capacity by 2025

+ **By 2033, the continuation of these trends will require a total of 13,200 MW of *effective capacity* to maintain reliability**

Changes in Southwest Regional Load-Resource Balance, 2021-2025

(Effective MW)

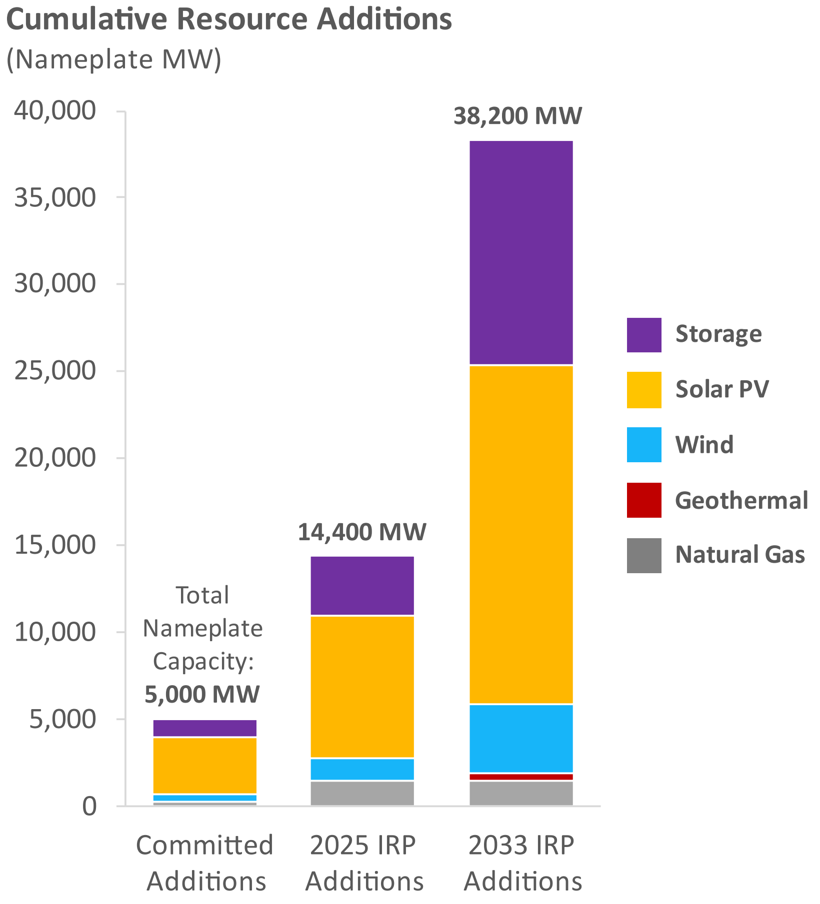


Notes
1. "Effective capacity" measures a resource's contribution to resource adequacy relative and is typically less than its nameplate capacity; the amount of new nameplate capacity needed to ensure resource adequacy will exceed – likely by a multiple of three to four times – the amount of new effective capacity needed
2. Resources in development within the region include solar (3,281 MW), storage (1,040 MW), wind (455 MW), and gas (228 MW)

Key Finding #2: Utilities' current resource plans have identified sufficient capacity additions to maintain reliability

+ **Utilities' IRPs have identified total additions of roughly 14,000 MW of nameplate capacity by 2025 and 38,000 MW by 2033**

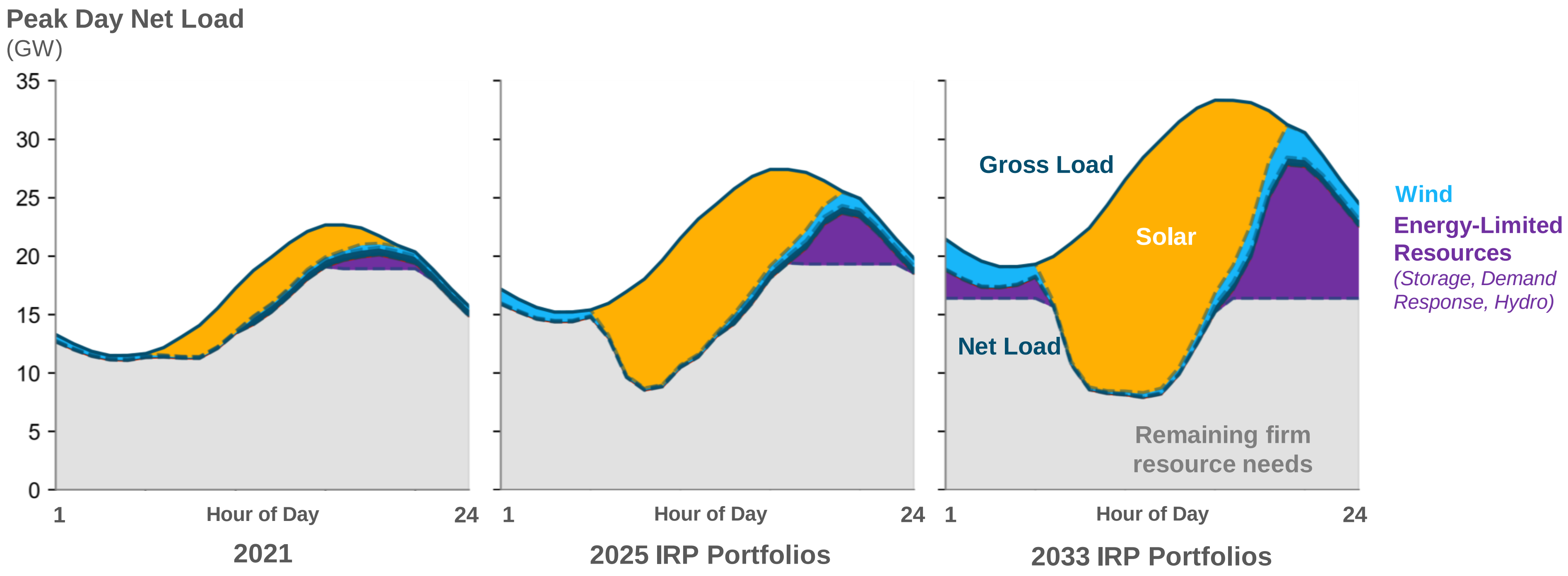
+ **The quantities and types of new resource additions included in utility plans are sufficient to maintain regional reliability under most scenarios**
  - If all resources included in utility IRPs come online during the timeframes identified, the region will maintain a small surplus of effective capacity over the next decade horizon under Base Case assumption
  - The amount of *nameplate* capacity needed to ensure reliability is much larger than the amount of *effective* capacity needed due to inherent limits on the capacity value of variable and energy-limited resources



Key Finding #3: A large share of the region's long-term needs will be met with solar, storage, and other "non-firm" resources

+ **A portfolio of variable renewables, storage, and other energy-limited resources can provide a significant contribution to regional resource adequacy needs**
  - Capabilities of solar and storage are particularly well-suited to matching high summer peak demands

+ **Non-firm resources will account for an increasing share of regional resource adequacy needs:**
  - Roughly 25% of regional needs by 2025
  - Roughly 50% of regional needs by 2033

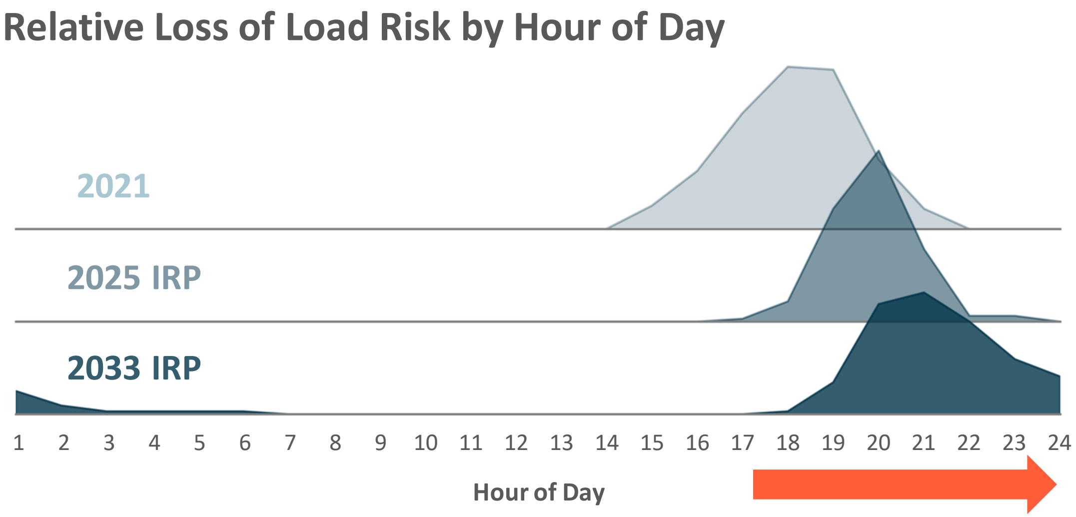


Key Finding #4: Even as solar and storage grow, the region's remaining firm resources will be needed for reliability

+ **By 2025, the evening "net peak" hours will become more constraining than the historical late afternoon peaks due to saturation of daylight hours with solar energy**
  - Additional solar added after this time will provide limited capacity value (<10%)

+ **As penetration of storage increases, risks to reliability extend deeper into the evening and nighttime, indicating a need for resources that can deliver energy to the system for extended periods overnight**
  - As length of risk increases, the marginal capacity value of four-hour energy storage by 2033 will decrease to approximately 50%

+ **Because of their ability to produce energy on demand for sustained periods, existing firm resources – including nuclear and natural gas – will continue to play a key role in meeting regional needs**



The changing composition of the portfolio impacts the timing of reliability risks:

- High levels of solar shift risk to the evening net peak
- Storage "flattens" the net peak, extending risk into nighttime

Key Finding #5: Substantial reliability risks remain as the region's electricity resource portfolio transitions

Climate Impacts

The possibility of significant changes to regional load patterns, e.g., due to climate warming, may increases the need for capacity to meet load during heat waves

Battery Performance

Battery storage has not yet been widely deployed at grid scale, and if it does not perform as idealized in this study, could be less effective as a capacity resource

Recent examples of extended plant outages at existing battery storage projects due to heat or fire provide warnings

Renewable Variability

As the region's supply becomes increasingly reliant on variable resources, weather variability introduces operating risks, including possible sudden, large drops in renewable energy output or extended renewable droughts

Fuel Supply

Reliance on just-in-time delivery of natural gas creates fuel security risks

The interstate natural gas pipeline system does not operate to the same reliability standards as the electricity system, and fuel deliveries have been interrupted during extreme cold weather events

Timing

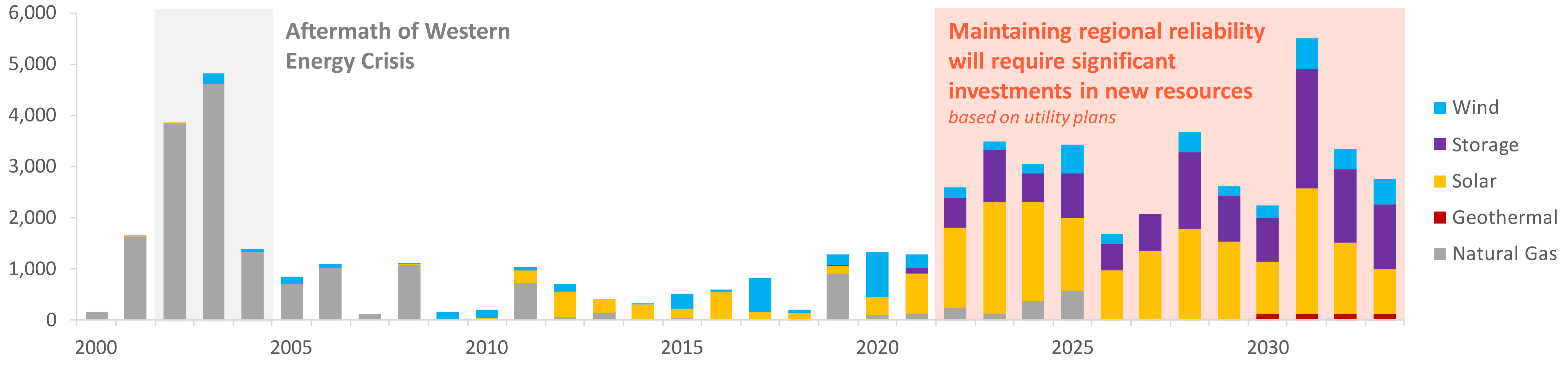
Processes for new resource development typically span multiple years

Project delays or cancellations could result in temporary resource shortfalls

Maintaining reliability will require immediate and sustained action over the next decade

- **The rate of new resource additions required in the next ten years is nearly unprecedented in the history of the Southwest**
- **With project development timelines measured in years and near-term supply chain risks looming, advance planning and prompt action by utilities are needed to avoid falling behind in the transition**
- **Utilities, regulators, developers and stakeholders will share responsibility for working cooperatively to ensure new resources are in place as needed**
  - Plans for new resource additions should account for reasonable risks of project delays and cancellations
  - Failure to develop new resources in a timely manner will either result in (1) a degradation of reliability or (2) the need to retain existing plants with scheduled retirements

New Installed Capacity Additions by Year (Southwest Region) (Nameplate MW)



Thank You

Questions?

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Energy+Environmental Economics

Appendix

Energy+Environmental Economics

Desert Southwest loads & resources, 2025

	Existing & Planned Resources			IRP Portfolios		
	Installed Capacity (MW)	Effective Capacity (MW)	Effective Capacity (%)	Installed Capacity (MW)	Effective Capacity (MW)	Effective Capacity (%)
Nuclear	2,858	2,783	97%	2,858	2,783	97%
Coal	4,490	4,026	90%	4,490	4,026	90%
Natural Gas	15,659	14,711	94%	16,972	16,064	95%
Other	84	83	98%	84	83	98%
Geothermal	77	72	93%	77	72	93%
Hydro	1,437	1,137	79%	1,437	1,124	78%
Solar	5,778	1,531	27%	10,683	2,327	22%
Wind	1,781	696	39%	2,684	996	37%
Storage	1,299	1,167	90%	3,718	2,996	81%
DR	238	184	77%	618	468	76%
Total Supply	**33,701**	**26,388**		**43,621**	**30,938**	
Median Peak Demand		**26,741**			**26,741**	
Total Effective Capacity Need (+13% PRM)		30,178			30,178	
Net Capacity Surplus (Shortfall)		**(3,789)**			**+760**	

Desert Southwest loads & resources, 2033

	Existing & Planned Resources			IRP Portfolios		
	Installed Capacity (MW)	Effective Capacity (MW)	Effective Capacity (%)	Installed Capacity (MW)	Effective Capacity (MW)	Effective Capacity (%)
Nuclear	2,858	2,783	97%	2,858	2,783	97%
Coal	1,022	966	95%	1,022	966	95%
Natural Gas	15,029	14,281	95%	16,527	15,920	96%
Other	84	83	98%	84	83	98%
Geothermal	77	72	93%	577	537	93%
Hydro	1,437	1,101	77%	1,437	1,050	73%
Solar	5,758	1,416	25%	21,986	5,601	25%
Wind	1,781	594	33%	5,234	1,693	32%
Storage	1,299	1,174	90%	13,220	8,082	61%
DR	163	128	79%	1,047	465	44%
Total Supply	**29,508**	**22,597**		**63,992**	**37,180**	
Median Peak Demand		31,787			31,787	
Total Effective Capacity Need (+13% PRM)		**35,824**			**35,824**	
Net Capacity Surplus (Shortfall)		**(13,227)**			**+1,356**	