Achieving Near- and Long-term Reliability in the Desert Southwest

Public Webinar

April 28, 2026

Energy+Environmental Economics

Webinar: Resource Adequacy in the Desert Southwest

1 Introductory Remarks

2 Motivation & Key Findings

3 Near-Term Assessment Highlights

4 Long-Term Assessment Highlights

5 Study Implications

Ron Klawitter
Senior Manager, Resource Analysis & Planning, Salt River Project

Section 1: Introductory Remarks

Nick Schlag
Partner, E3

Sections 2 & 5: Motivation & Key Findings; Implications

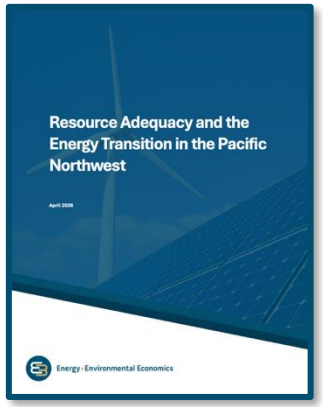
Adrian Au
Associate Director, E3

Sections 3 & 4: Near-Term & Long-Term Assessment Highlights

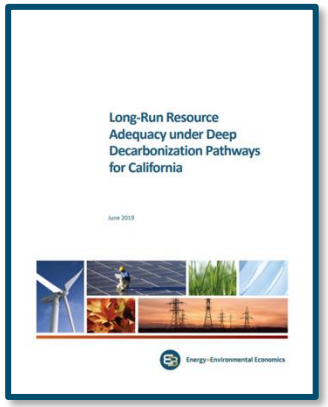
About E3

- Founded in 1989, E3 is a leading energy consultancy with offices in San Francisco, Boston, New York, Denver, 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 for the energy transition

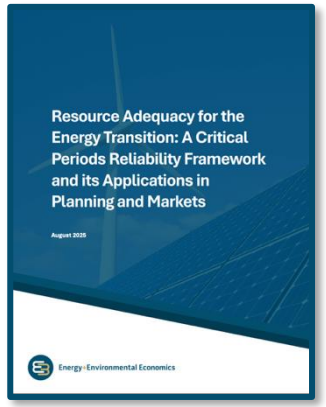
[Resource Adequacy and the Energy Transition in the Pacific Northwest] *(sponsored by a coalition of Northwest utilities)*



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



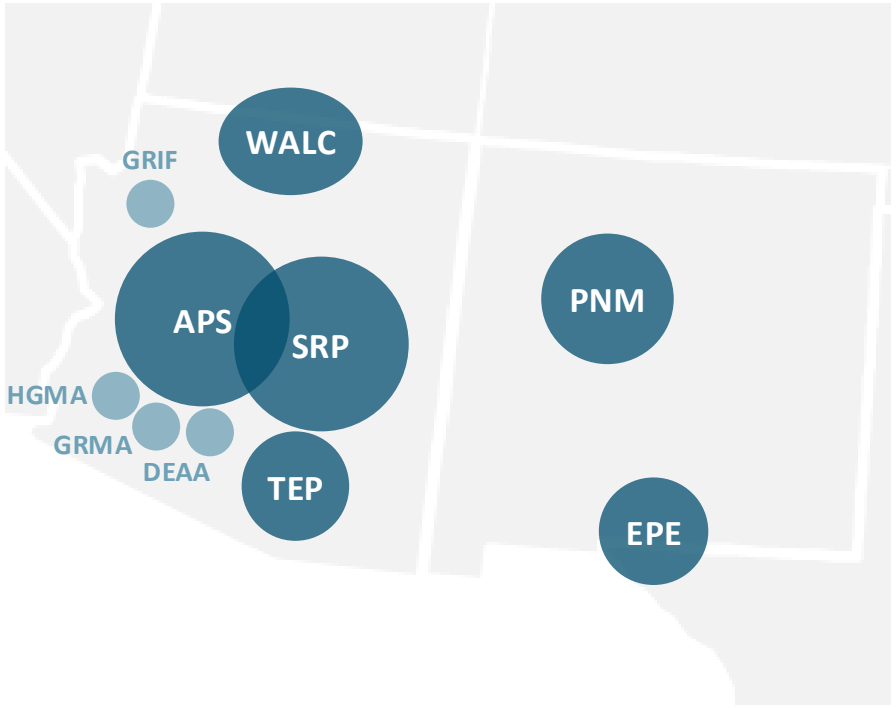
[Resource Adequacy for the Energy Transition: A Critical Periods Reliability Framework] *(E3 whitepaper)*



Acknowledgements

Study Geographic Scope

Includes all balancing authorities in Arizona and New Mexico



Technical Advisory Group:

- **Genevieve de Mijolla**
  Electric Power Research Institute
- **Bethany Frew, Gord Stephen*, Sinnott Murphy**
  National Laboratory of the Rockies
- **Branden Sudduth**
  Western Electricity Coordinating Council
- **Gary Dirks**
  Arizona State University
- **Rebecca Sexton and Ryan Roy**
  Western Power Pool
- **Derek Stenclik**
  Telos Energy

Participation in the Technical Advisory Group does not indicate endorsement of the report's findings

**formerly at NLR, currently at Imperial College London*

Study Sponsors

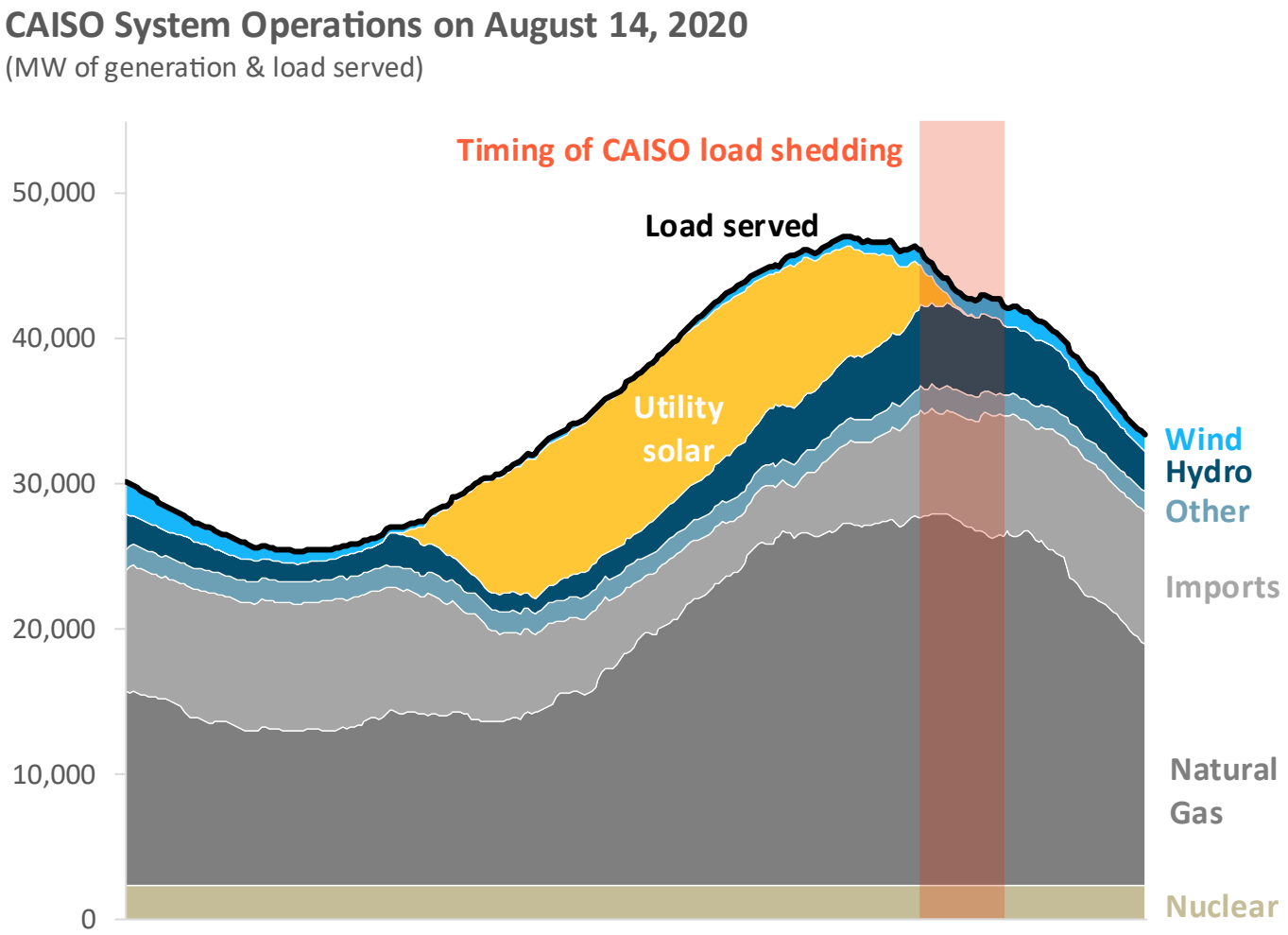
aps · Arizona G&T Cooperatives (Touchstone Energy® Cooperatives) · The Electric Company, El Paso Electric · PNM · SRP · TEP

Motivation & Key Findings

Resource Adequacy is Increasing in Complexity – and Importance

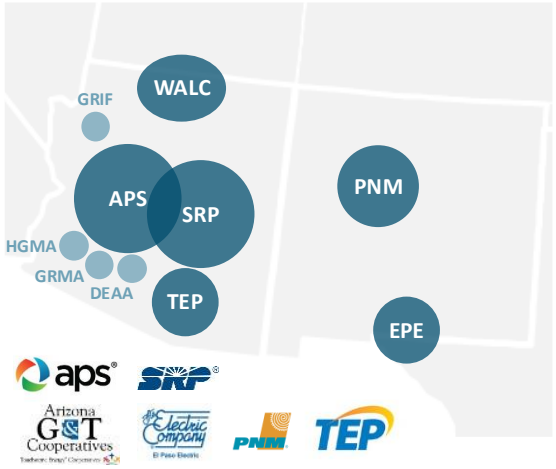
+ **Transition towards renewables and storage introduces new sources of complexity in resource adequacy planning**
  - The concept of planning exclusively for "peak" demand becoming obsolete
  - Risk is shifting to periods outside of the traditional peak (e.g. California's rotating outages during August 2020 "net peak" period)

+ **Reliable electricity supply is becoming increasingly important to society:**
  - Space heating and air conditioning under extreme weather conditions can be a matter of life or death
  - New electric loads – from data centers to electric vehicles – make electricity even more central to day-to-day life and economic development

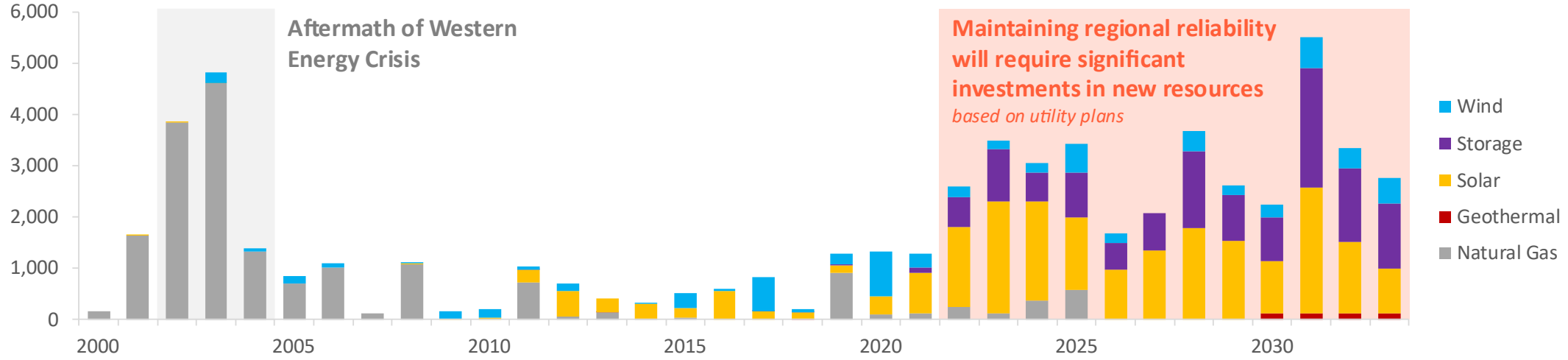


Key Findings from the 2021 Southwest Resource Adequacy Study

1. **Load growth and aging plant retirements are creating a significant need for new capacity (13+ GW of effective capacity across the region by 2033) – but utilities' resource plans have identified resources sufficient to meet those needs**
2. **A large share of the region's needs will be met with solar, storage, and other "non-firm" resources – but firm resources will remain essential for reliability**
3. **The scale of new resource additions needed requires unprecedented levels of development, necessitating immediate and sustained action over the next decade**



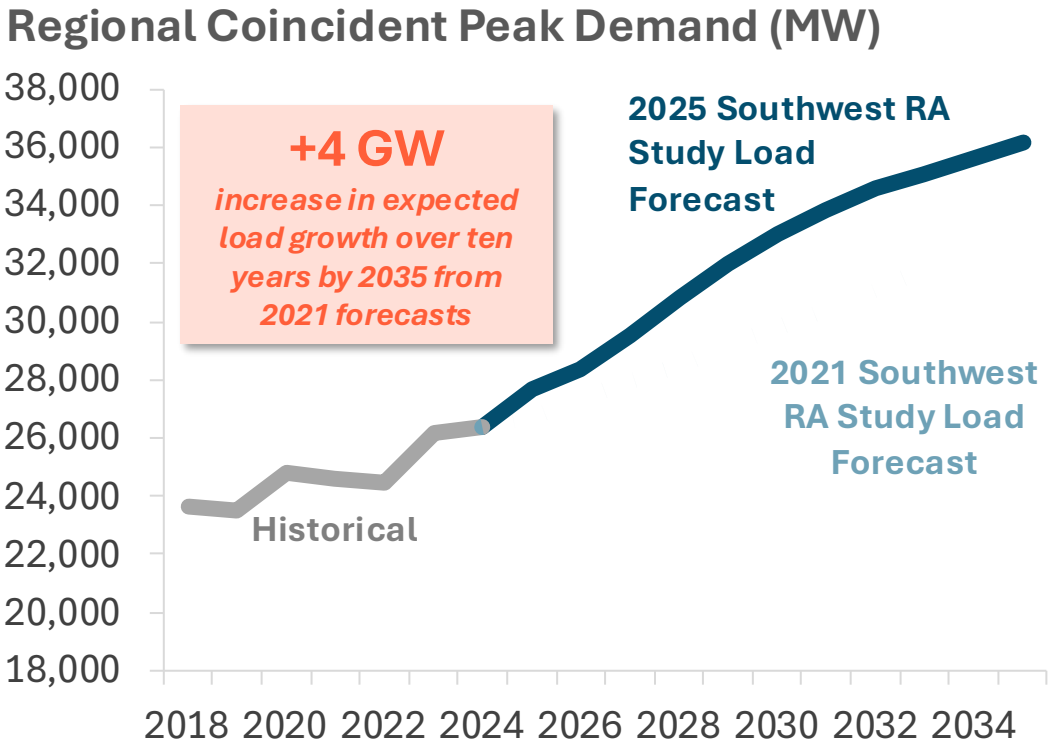
New Installed Capacity Additions by Year (Southwest Region)
(Nameplate MW)



Changes and Uncertainties Drive Focus on Resource Adequacy

Accelerated growth due to large loads

New industrial and data center loads – on top of other sources of load growth – has caused upward revisions to capacity needs



Evolving generation mix

Increasing reliance on renewables and energy storage adds complexity to resource adequacy planning, causing reliability risk to shift toward periods of lower renewable production and storage depletion

Headwinds for resource development

Many sources under development have experienced delays or cancellations due to continuing supply chain dynamics, leading to slower-than-expected additions of new resources

Fuel supply constraints

Existing natural gas pipelines are fully subscribed, with limited expectations of turnback from California

Increasing frequency of extreme weather

Growing frequency and intensity of extreme heat events result in more frequent peak demand conditions

Comparison of Scopes for Near- and Long-Term Assessments

- **Near-term assessment:** a refresh to the analysis conducted in the 2021 study Resource Adequacy in the Desert Southwest, incorporating more recent information on utility loads and resources
- **Long-term assessment:** an extension beyond the 2021 study's scope to explore various portfolios to maintain reliability, providing additional context for how upcoming resource decisions contribute to long-term system needs

Study Element	Near-Term Assessment	Long-Term Assessment
Time Horizon	**Ten years** *(2025-2035)*	**Twenty years** *(through 2045)*
Modeling Tools	**RECAP** *(loss of load probability)*	**PLEXOS LT & RECAP** *(long-term capacity expansion & LOLP)*
Load Forecast	**Single load forecast** *provided as inputs by utilities and aggregated by E3*	**Three load forecasts** *developed by E3 to reflect a range of long-term growth outcomes*
Resource Portfolios	**Single portfolio** *provided as an **input** by utilities*	**Twenty portfolios** *created as **outputs** using LTCE*
Principal Study Question	***Are utilities' resource plans sufficient to meet near-term resource adequacy needs of the region?***	***What are the features and characteristics of portfolios capable of meeting long-term resource adequacy needs?***

Key Findings from Near-Term and Long-Term Assessments

Near-Term Assessment

1 Need for New Resources is Urgent

Large increases in regional demand, coupled with anticipated retirements, continue to drive a pressing need for new resources across the region to maintain reliability

2 Utility Plans Demonstrate Adequacy

Over the next decade, utilities' resource plans include new natural gas, renewables, and storage sufficient to meet a regional resource adequacy standard of 0.1 days per year

3 Reliability Risks are Shifting Rapidly

Reliability risk has already shifted from afternoon peak to the evening "net peak," and will extend deeper into overnight periods as resource mix evolves

Long-Term Assessment

4 Diversity is a Robust Long-Term Strategy

Meeting growth with a combination of new gas, renewables, storage, and demand-side resources is a robust strategy across a wide range of longer-term future conditions

5 Firm Resources are Critical to Reliability

Firm generation resources remain essential to long-term resource adequacy, mitigating risks of large energy deficiencies during periods of low renewable output

6 Natural Gas Remains Primary Option for Firm

Across all portfolios, natural gas fulfills the majority of the region's long-term need for firm resources, even under highest clean energy penetrations studied

Key findings assume that transmission system and gas transportation system are also adequately sized to meet the region's growing needs

Near-Term Resource Adequacy Assessment Highlights

Energy+Environmental Economics

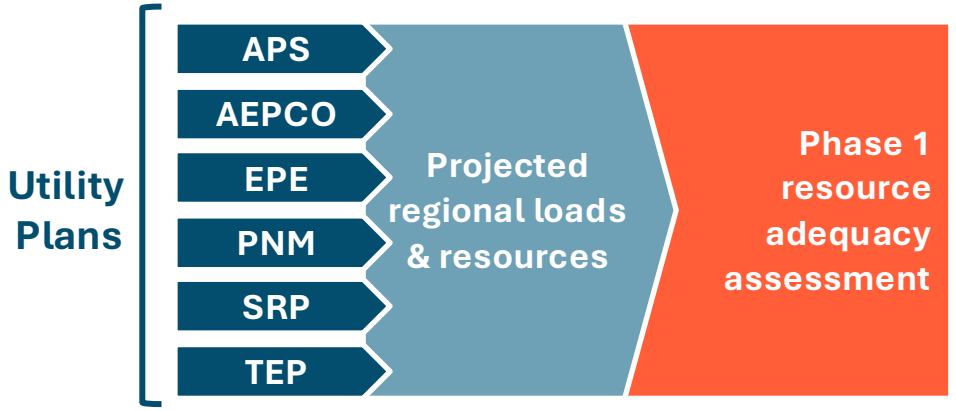
Scope of Near-Term Assessment Technical Analysis

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. **How much will existing & committed resources contribute to this need?**
3. **To what extent will utilities' resource plans meet regional resource adequacy needs over the next decade?**

The ten-year reliability outlook completed in Phase 1 used load forecasts and resource portfolios provided by utilities in early 2025. Since that time, utilities have continued to adjust load forecasts and resource plans in response to continuously changing conditions. For this reason, these results do not reflect the most current outlook for loads and resources within the region, but nonetheless serve as a useful directional indication of the relative scale of resource needs and provides validation that utility planning processes continue to identify resource portfolios capable of meeting regional reliability needs

+ **This phase of the study relies on utility load forecasts and resource plans as inputs to address specific questions on how these plans will impact reliability within the region over the next decade**

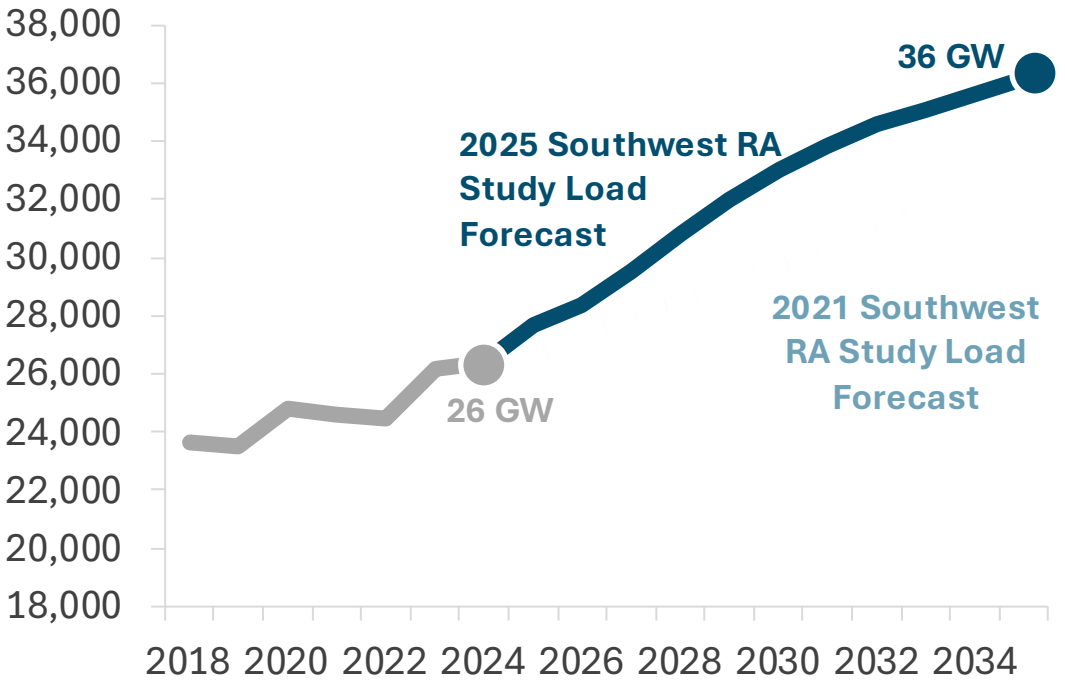


+ **Loss of load probability analysis used to study level of reliability achieved across the Southwest region, including metrics such as:**
  - A planning reserve margin (PRM) and effective load carrying capability (ELCC) values for different resources
  - Loss of load expectation (LOLE), expected unserved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

Phase 1 Highlights: Regional Coincident Peak Demand Forecast and Impacts of Extreme Weather on Peak Demand

1. **Forecast of regional coincident peak demand developed by aggregating load forecasts provided by utilities**
   - Forecast for larger customers with high load factors modeled with flatter shape to capture differences in shape from existing customers
2. **Neural network simulation used to create hourly profiles for 55 historical weather years, capturing interannual variability and extreme events for resource adequacy analysis**
   - Allows for stochastic representation of rare, extreme events in RECAP LOLP modeling

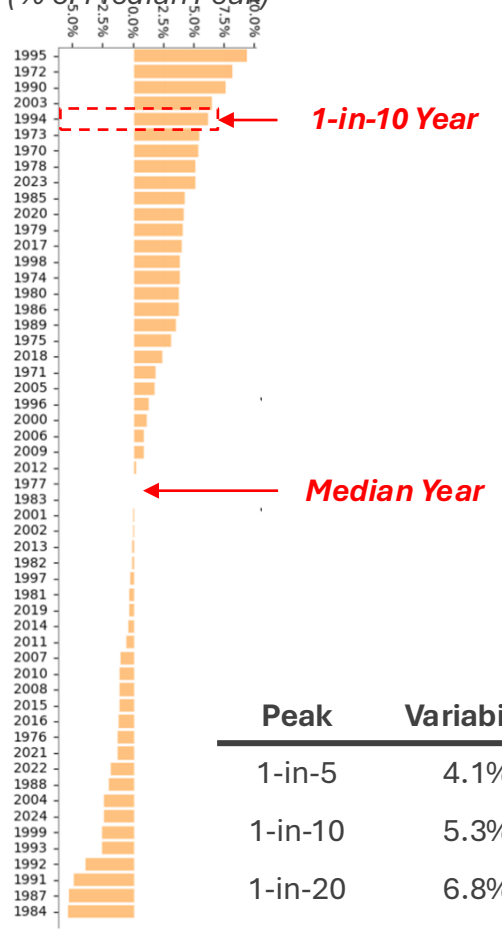
(1) Regional Coincident Peak Demand (MW)



Load forecast assumptions used in Phase 1 analysis are based on projections provided by utilities in 2025 Q1 and may no longer align with most recent utility forecasts. In general, utilities across the region have signaled expectations that updated forecasts will be higher than previous assumptions due to increased large customer growth.

(2) Weather Year Variability

(% of Median Peak)



Peak	Variability
1-in-5	4.1%
1-in-10	5.3%
1-in-20	6.8%

Phase 1 Highlights: Resource Portfolios Over Next Ten Years Based on Utility Plans

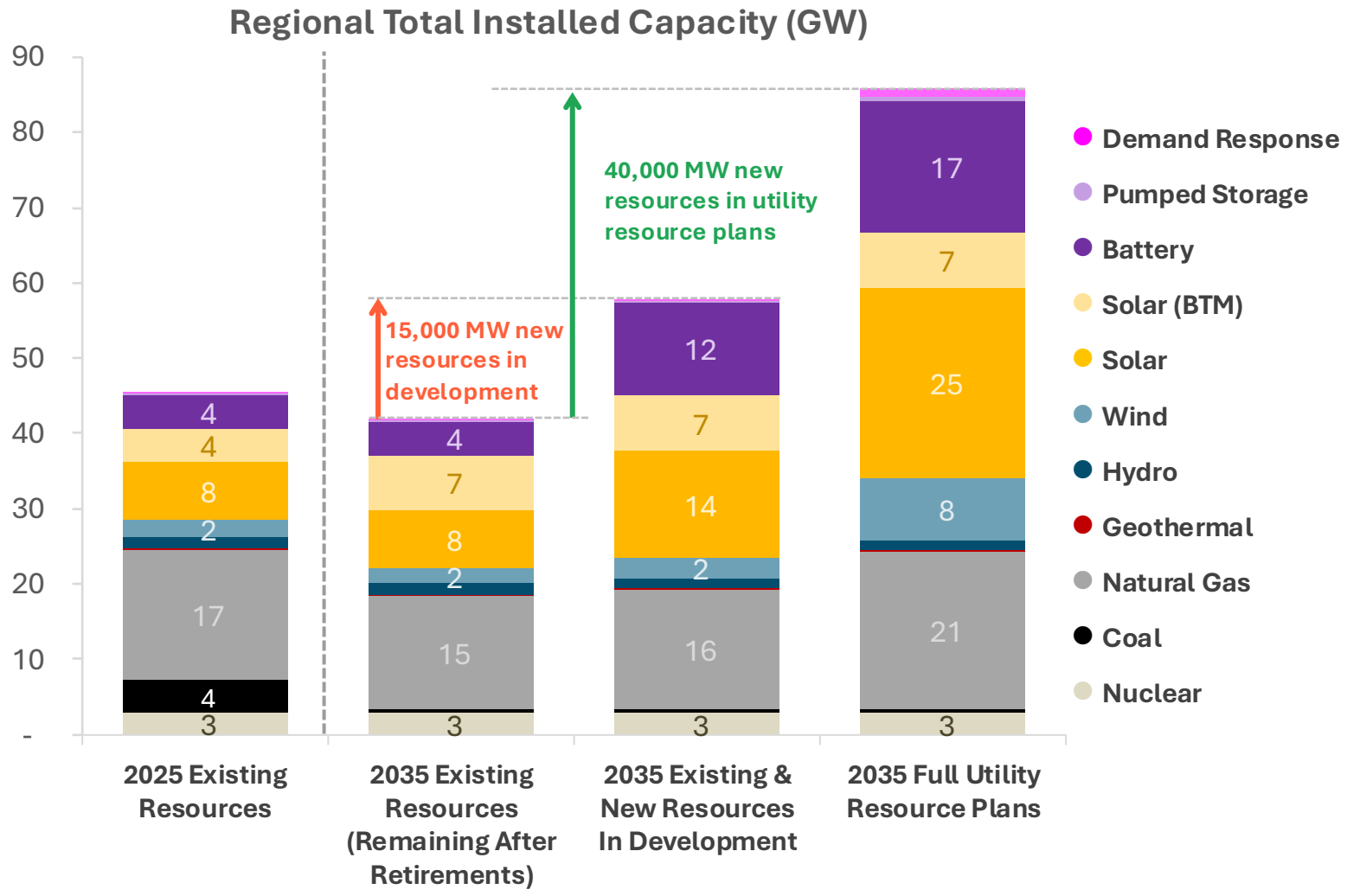
+ **Phase 1 focuses on analysis of three resource sets; each provides a specific useful insight into the region's resource adequacy outlook:**

  A. **Existing resources (remaining after retirements):** how much new capacity is needed within the region to meet needs, accounting for growing loads & retiring resources?

  B. **Existing & new resources in development:** to what extent can resources already procured by utilities meet those needs?

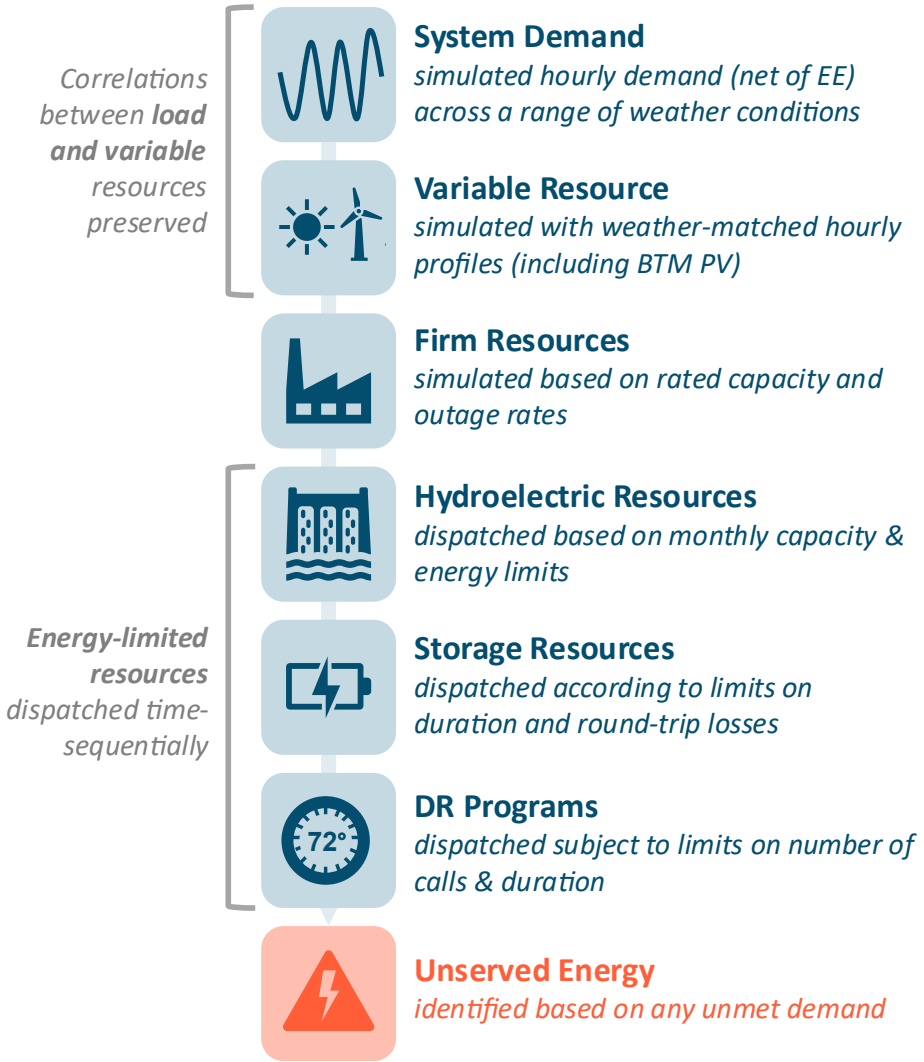
  C. **Full utility resource plans:** to what extent would utilities' current plans meet future resource adequacy needs of the region?

Assumptions for future retirements, resources currently in development, and utility plans in Phase 1 analysis are based on inputs provided by utilities in 2025 Q1 and may no longer align with most recent utility announcements.



RECAP: E3's Renewable Energy Capacity Planning Model

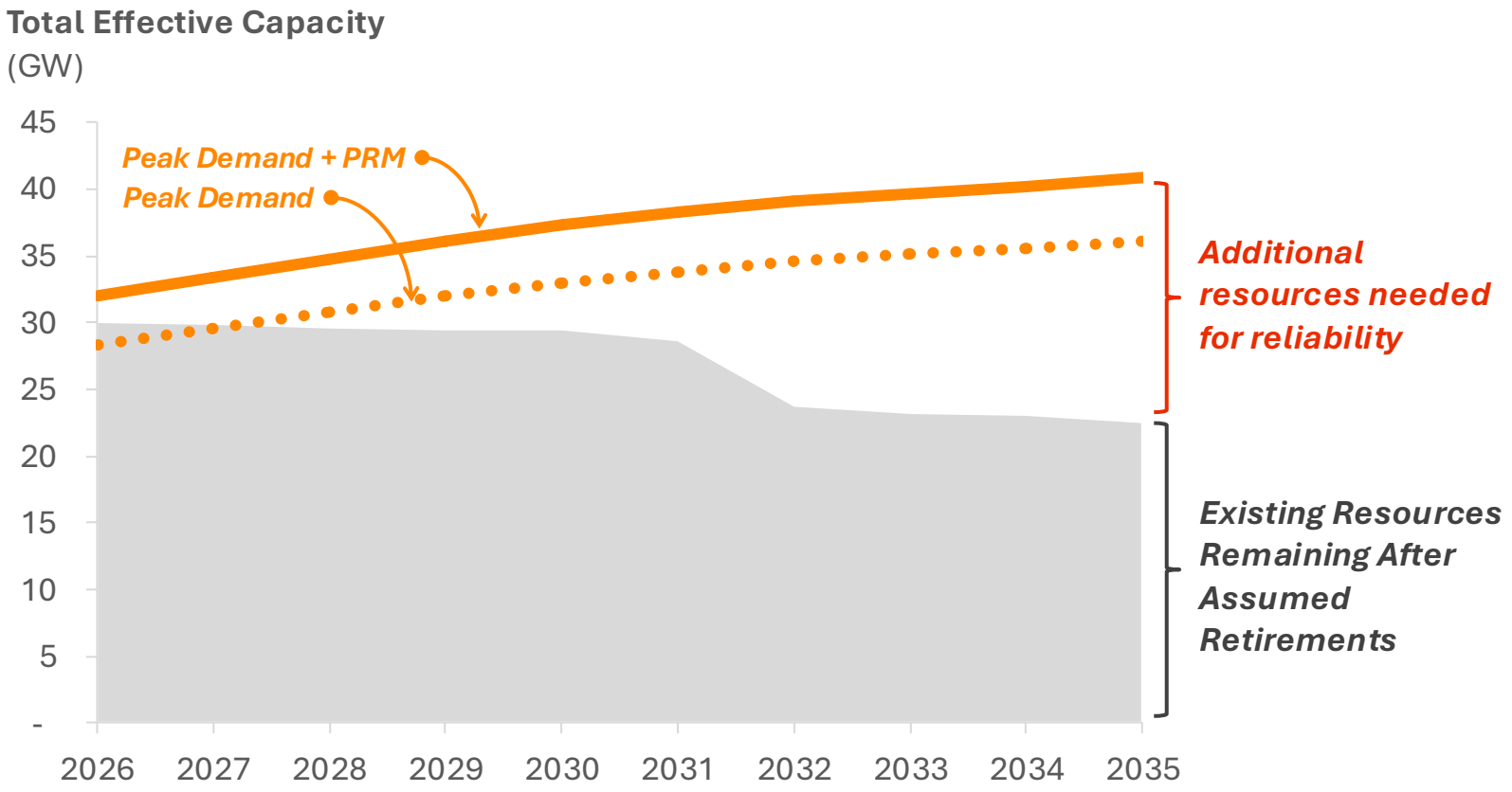
+ **RECAP uses a time-sequential simulation approach to assess the availability of supply to meet system needs on an hour-to-hour basis**
  - Simulation approach designed to focus on challenges resulting from increasing penetrations of variable & energy-limited resources
+ **Each simulation analyzes conditions through hundreds to thousands of possible iterations using a Monte Carlo approach to capture 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



Key Finding #1: Need for New Resources is Urgent

Large increases in regional demand, coupled with anticipated retirements, continue to drive a significant need for new resources across the region to maintain reliability

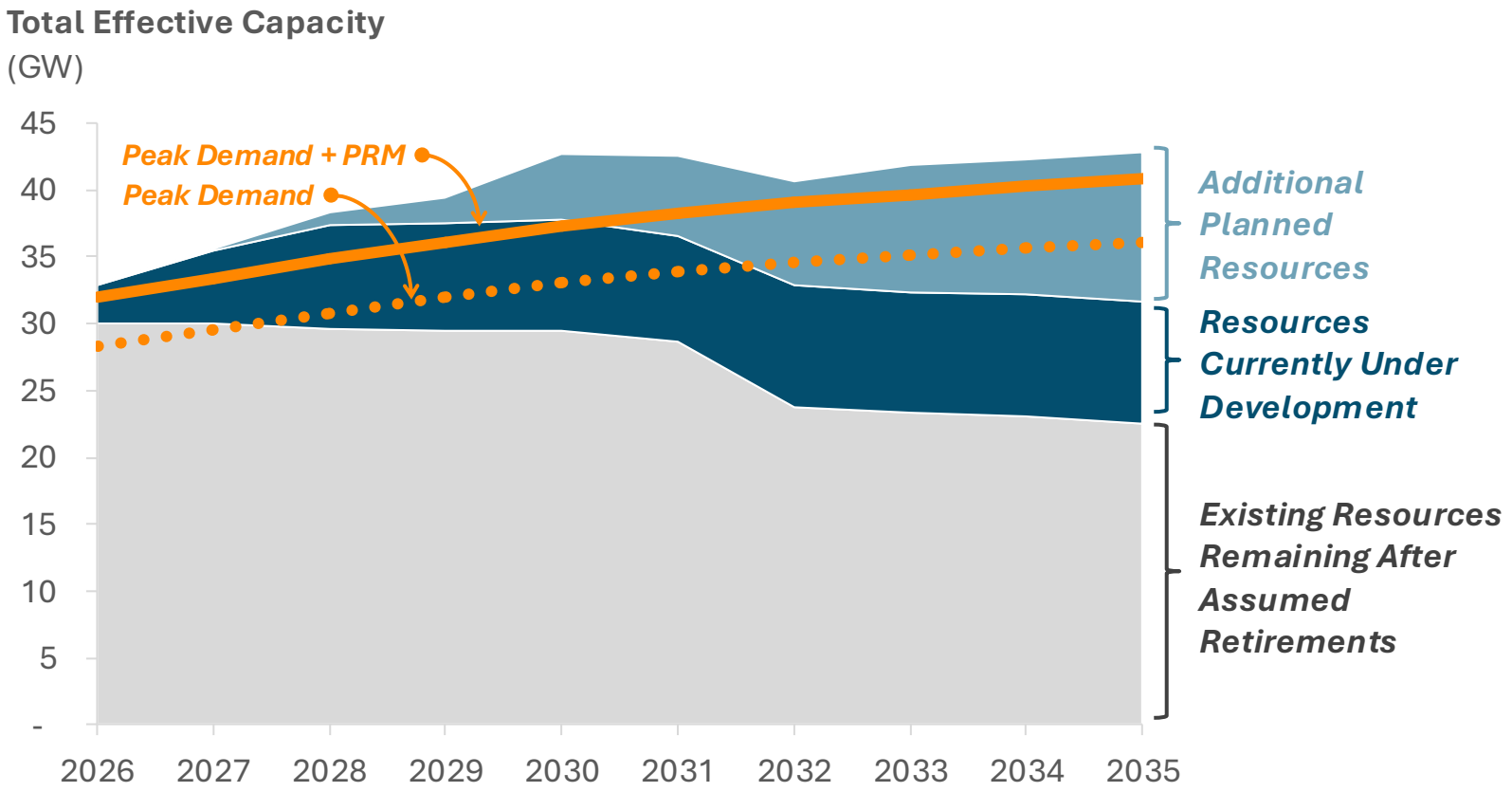
+ **Existing Resources Remaining After Assumed Retirements** in the region will fall short of meet growing needs by **18 GW** in 2035



Key Finding #2: Utility Plans Demonstrate Adequacy

Over the next decade, utilities' resource plans include new natural gas, renewables, storage, and demand-side resources sufficient to meet a regional resource adequacy standard of 0.1 days per year

- **Existing Resources Remaining After Assumed Retirements** in the region will fall short of meet growing needs by **18 GW** in 2035
- **Resources Currently Under Development** meet a portion of these needs, providing just over **9 GW** of effective capacity and positioning the region to maintain resource adequacy in the next several years
- **Additional Planned Resources** are sufficient to close the remaining gap, providing some headroom in advance of resource retirements



Key Finding #3: Reliability Risks are Shifting Rapidly

Reliability risk has already shifted from afternoon peak to the evening "net peak," and will extend deeper into overnight periods as resource mix evolves

+ **Changes to the regional generation mix cause the timing of reliability risk to shift into evenings and – eventually – overnight periods**
  - Solar shifts risk from afternoon to evening net peak
  - Storage extends risk deeper into overnight periods
  - Increasing number of hours at which system is at the edge of reliability risk
+ **The changing risk profile has three key implications for future resource valuation:**
  1. Declining capacity value of renewables and shorter-duration energy storage resources
  2. Increasing relative value for additional storage duration – ability to operate for longer periods
  3. High value of firm resources able to operate over sustained periods

Relative Loss-of-Load Risk by Time of Day

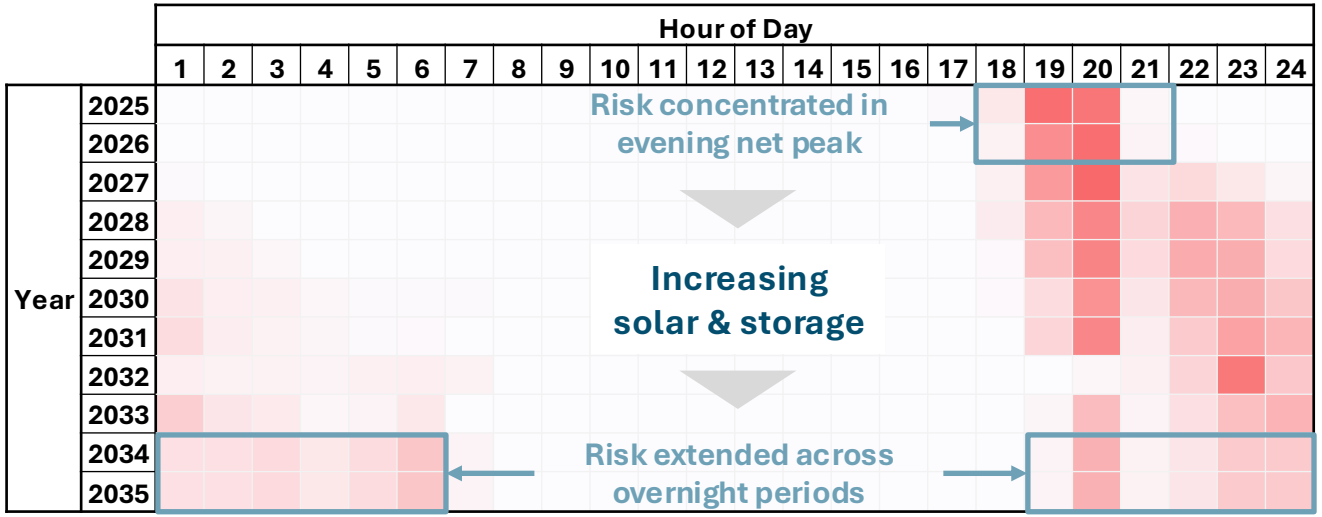


Figure shows relative likelihood of experiencing a supply insufficiency leading to loss of load at different times of day. All risk is observed in summer season (June-Sept).

Phase 1 Highlights: Technology-Specific Marginal ELCCs Change with Evolving Resource Mix

+ **"Effective load carrying capability" (ELCC) measures capacity contribution based on a resource's availability during periods of highest system risk**
  - Most rigorous approach to quantify capacity value
  - Captures declining capacity value with increasing resource penetration ("saturation")
  - Provides a natural feedback to encourage resource diversity
+ **Largest change expected in marginal ELCCs: sharp declines for energy-limited resources due to saturation resulting from battery buildout**
  - Firm resource ELCCs stable and high through horizon as risks shift across an increasingly broad set of hours
  - Variable renewables see small increases as a secondary impact of higher storage penetration

Marginal Effective Load Carrying Capability (ELCC) by Technology

Category	Technology	2025	2035	Change
Firm	Nuclear	94%	92%	-2%
	Coal	82%	-	-
	Natural Gas	91%	93%	+2%
	Geothermal	90%	88%	-2%
Variable	Solar	5%	7%	+2%
	Wind	26%	21%	-5%
Energy Limited	Hydro	73%	73%	-
	Battery	93%	36%	-57%
	DR	87%	38%	-49%

When storage penetration is low, short duration resources are effective in clipping narrow peaks

At high storage penetrations, longer risk periods drive reductions in marginal value

Long-Term Resource Adequacy Assessment Highlights

Energy+Environmental Economics

Scope of Long-Term Assessment Technical Analysis

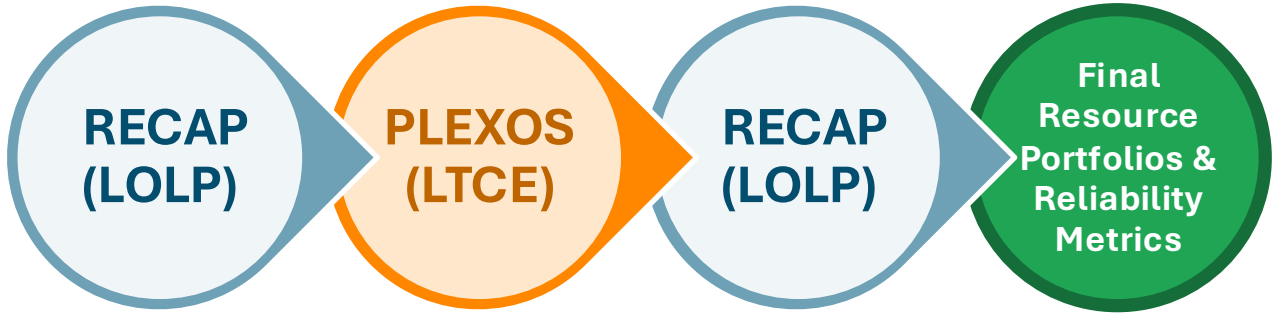
Three questions addressed in this analysis:

1. What are the features and characteristics of resource portfolios capable of meeting long-term (2045) resource adequacy needs?
2. How does the composition of a reliable portfolio change across a range of load forecasts and technology assumptions?
3. Across a broad range of futures, what role does natural gas and other firm resources play in maintaining resource adequacy?

Twenty Hypothetical Portfolios Created and Tested for Adequacy

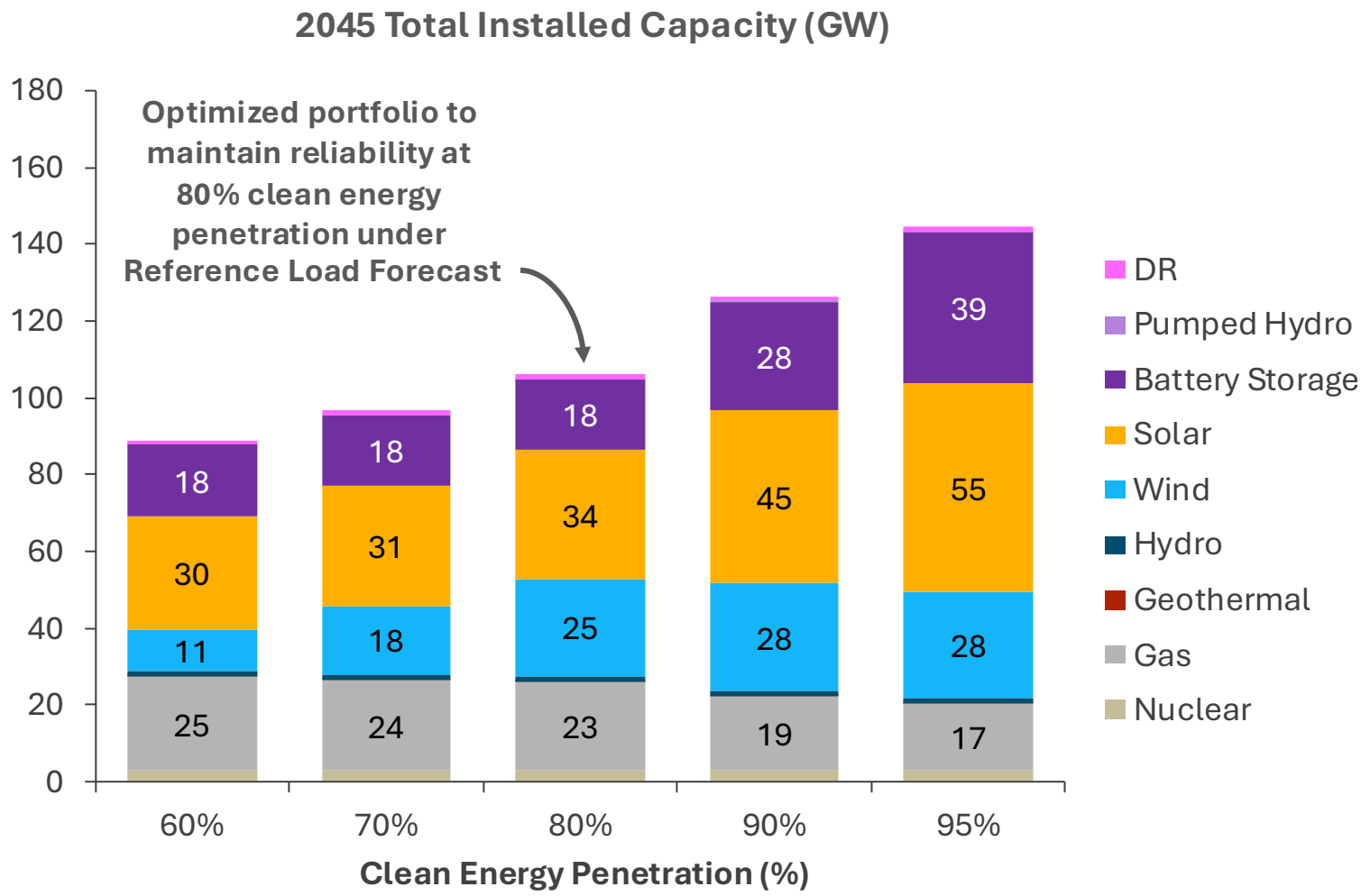
Portfolios span a range of load forecasts, clean energy penetrations, and technology sets

Load Forecast	Technology Set	Clean Energy Penetration (% of Energy)				
		60%	70%	80%	90%	95%
Low	Existing	●	●	●	●	●
Reference	Existing	●	●	●	●	●
High	Existing	●	●	●	●	●
Reference	Existing & Clean Firm	●	●	●	●	●



Phase 2 Highlights: Maintaining Resource Adequacy Over the Next 20 Years Requires a Diverse Portfolio of Renewables, Storage, and Firm Resources

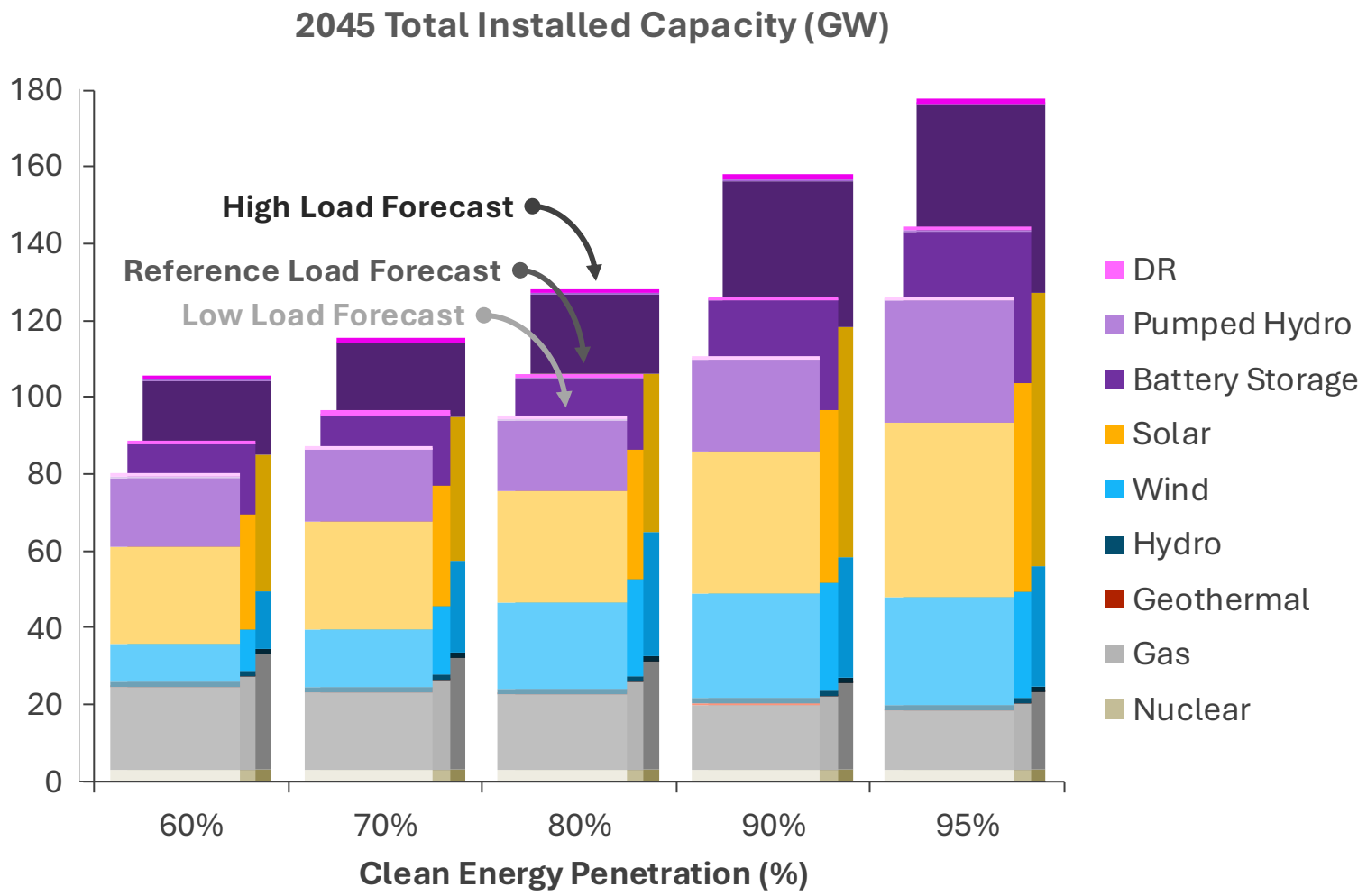
+ **Across all levels of clean energy studied, reliable portfolios in 2045 include a diverse mix of firm, renewable, and storage resources**
  - Wind and solar serve large portions of load when available
  - Storage shifts significant solar surplus from day to night
  - Natural gas and nuclear provide firm capacity around the clock



Phase 2 Highlights: Maintaining Resource Adequacy Over the Next 20 Years Requires a Diverse Portfolio of Renewables, Storage, and Firm Resources

+ **Across all levels of clean energy studied, reliable portfolios in 2045 include a diverse mix of firm, renewable, and storage resources**
  - Wind and solar serve large portions of load when available
  - Storage shifts significant solar surplus from day to night
  - Natural gas and nuclear provide firm capacity around the clock

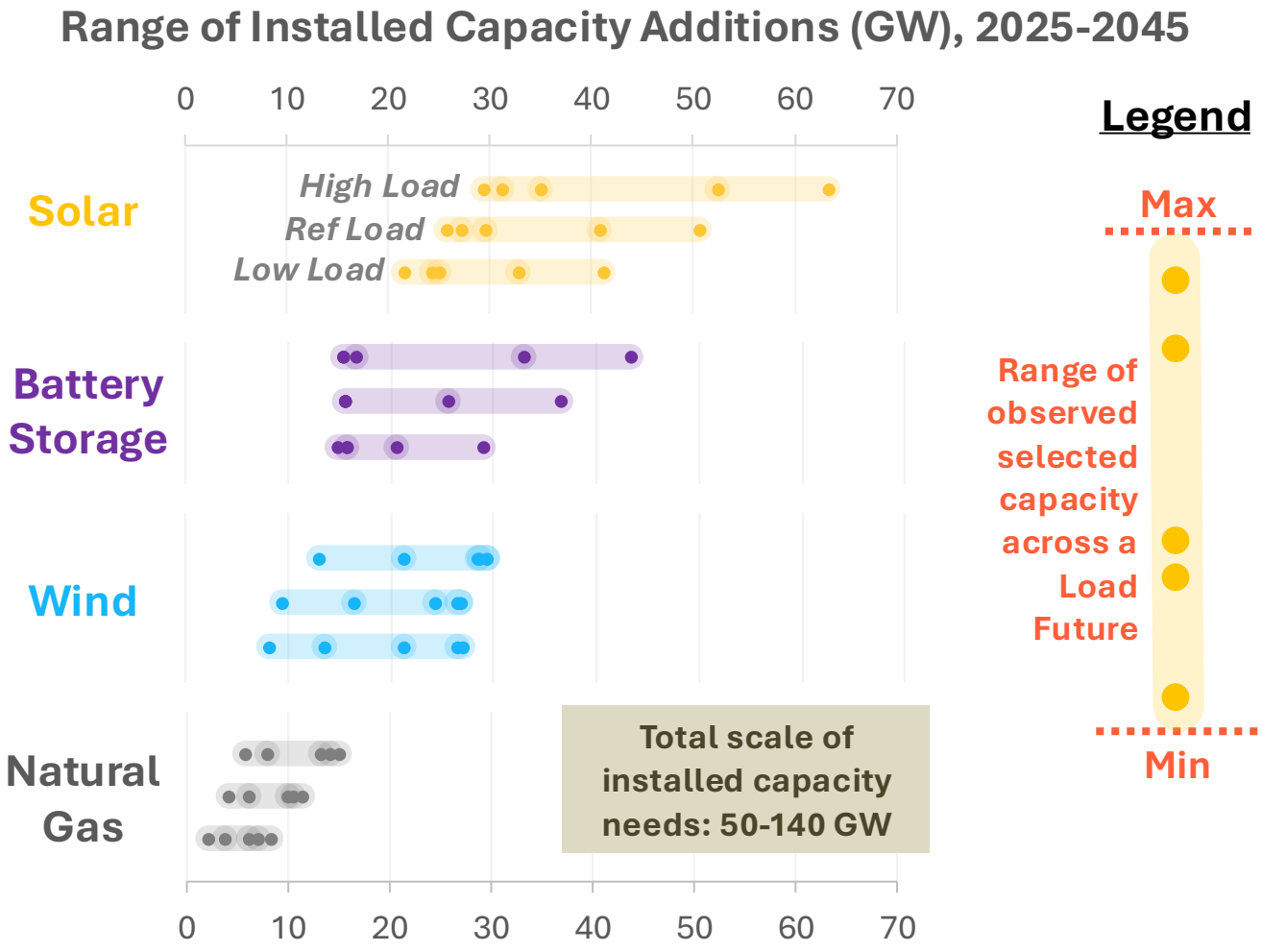
+ **This finding holds true across a range of 2045 load forecasts**
  - Also consistent with a growing body of literature examining the interplay between high clean energy penetration and resource adequacy



Key Finding #4: Diversity is a Robust Long-Term Strategy

Meeting growth with a combination of new gas, renewables, and storage resources is a robust strategy across a wide range of longer-term future conditions

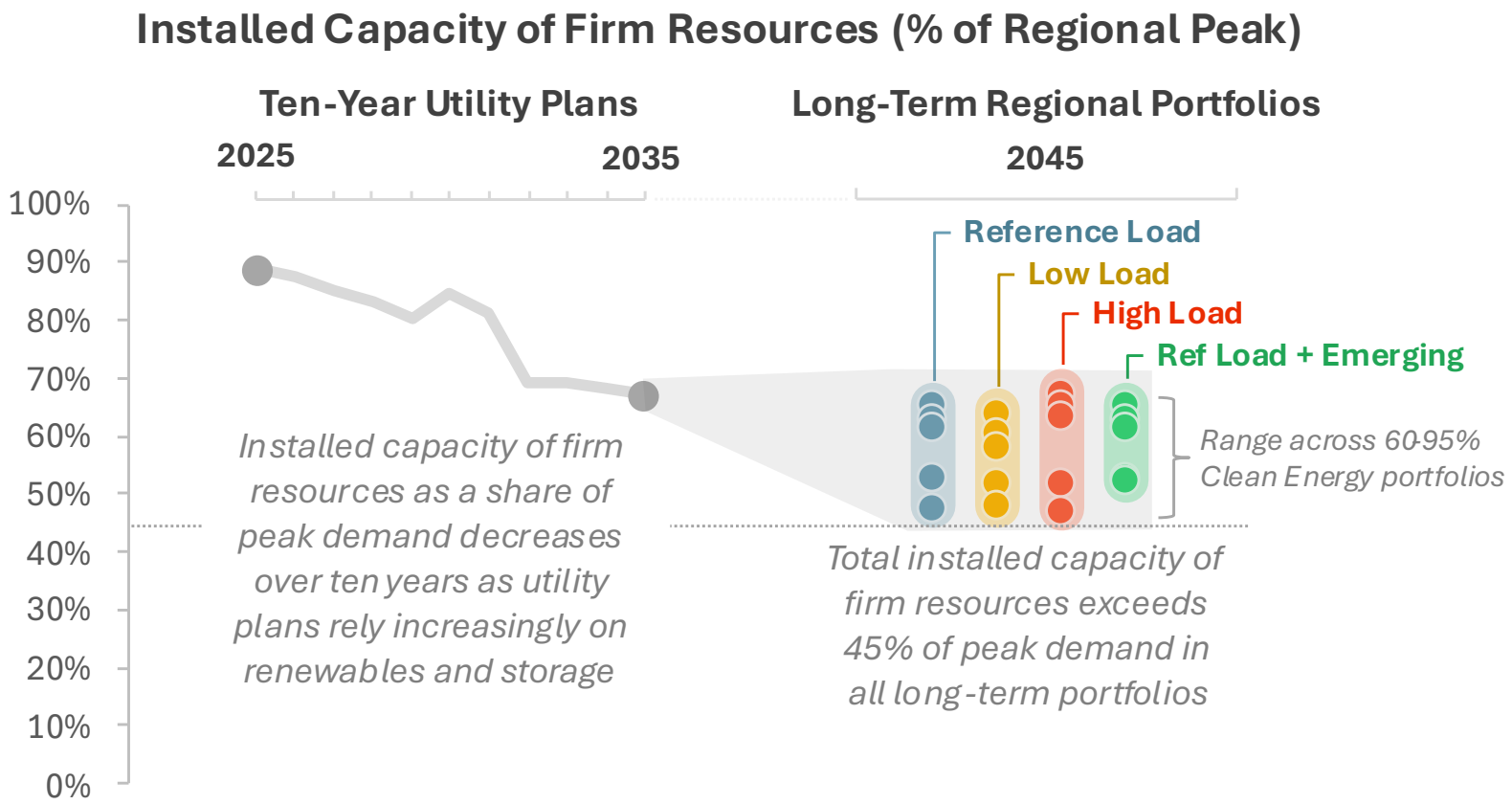
+ **Need for investment in all resource types highlights important role of resource diversity:**
  - **Renewables:** large volumes of energy on an "as available" basis to meet growing energy needs
  - **Storage:** shift energy from periods of surplus to periods of deficit
  - **Natural gas:** dispatch for sustained periods when needed
+ **Additional demand-side resources may reduce scale of utility-scale additions if aligned with grid needs**
  - Behind-the-meter generation, additional energy efficiency and demand response, virtual power plants



Key Finding #5: Firm Resources are Critical to Reliability

Firm generation resources remain essential to ensuring long-term resource adequacy and mitigating risks of large energy deficiencies, particularly during periods when renewable output is low

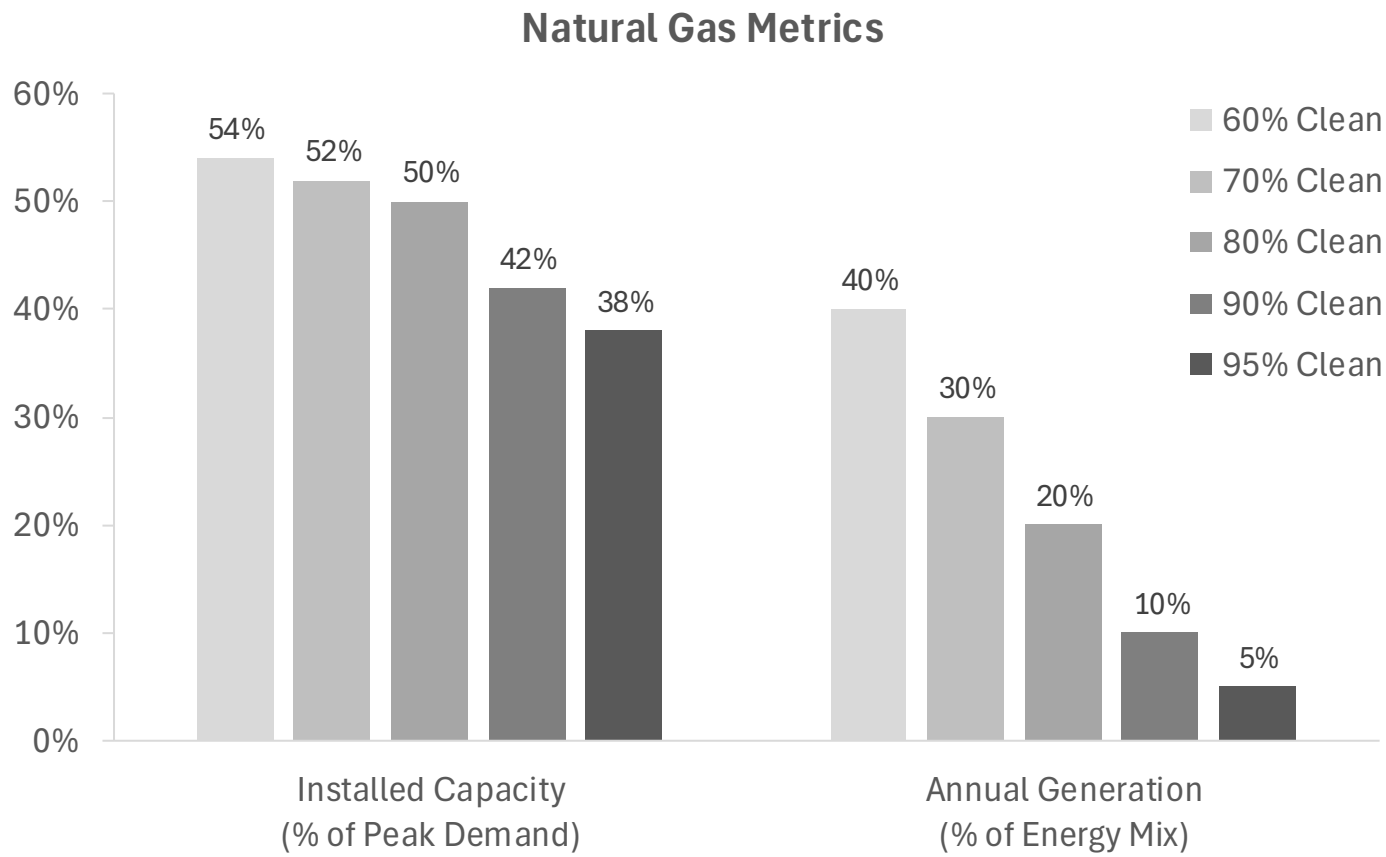
+ **At increasing penetrations, marginal ELCC values for renewables and storage decline substantially due to saturation**
  - Renewables: <10%
  - Four-hour storage & DR: <20%
+ **Across all 2045 portfolios where options for firm resources are not restricted, total capacity of firm resources exceeds 45% of regional peak demand**
  - Includes nuclear and natural gas generation
  - Applies across different load sensitivities



Key Finding #6: Natural Gas Remains the Primary Option for Firm

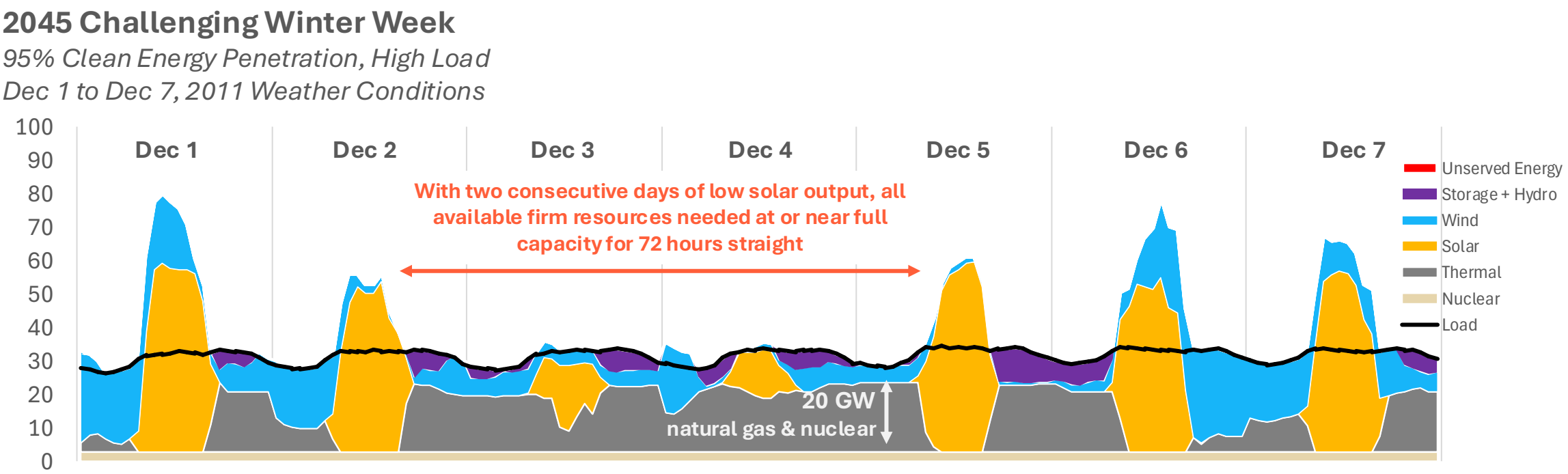
Across all portfolios, natural gas fulfills the majority of the region's long-term need for firm resources, even under highest clean energy penetrations studied

+ **Across all portfolios, installed capacity of natural gas resources falls within a relatively narrow range of 38-54% of peak demand**
  - Even under highest clean energy penetrations studied (95% carbon free), need for natural gas resources is nearly 40% of peak demand, and new natural gas resources are needed to ensure reliability
+ **Share of annual energy needs met by natural gas resources varies considerably more (5-40%), as frequency of natural gas operations is dictated by the needs of the grid**
  - At lower clean energy penetrations (60%), gas represents a higher share of the energy mix
  - At higher clean energy penetrations (95%), renewables and storage meet a much larger proportion of loads throughout the year, while gas resources operates as a backstop for reliability



Firm Resources Essential to Reliability during Periods of Low Renewable Output

- Even at higher penetrations of renewables and storage, there are extended periods during which they are not available
- During these extended periods – which may last days or week – firm resources that can operate at full capacity without limits on duration are essential to maintaining reliability



Implications

Energy+Environmental Economics

Key Findings from Near-Term and Long-Term Assessments

Near-Term Assessment

1 Need for New Resources is Urgent

Large increases in regional demand, coupled with anticipated retirements, continue to drive a pressing need for new resources across the region to maintain reliability

2 Utility Plans Demonstrate Adequacy

Over the next decade, utilities' resource plans include new natural gas, renewables, and storage sufficient to meet a regional resource adequacy standard of 0.1 days per year

3 Reliability Risks are Shifting Rapidly

Reliability risk has already shifted from afternoon peak to the evening "net peak," and will extend deeper into overnight periods as resource mix evolves

Long-Term Assessment

4 Diversity is a Robust Long-Term Strategy

Meeting growth with a combination of new gas, renewables, storage and demand-side resources is a robust strategy across a wide range of longer-term future conditions

5 Firm Resources are Critical to Reliability

Firm generation resources remain essential to long-term resource adequacy, mitigating risks of large energy deficiencies during periods of low renewable output

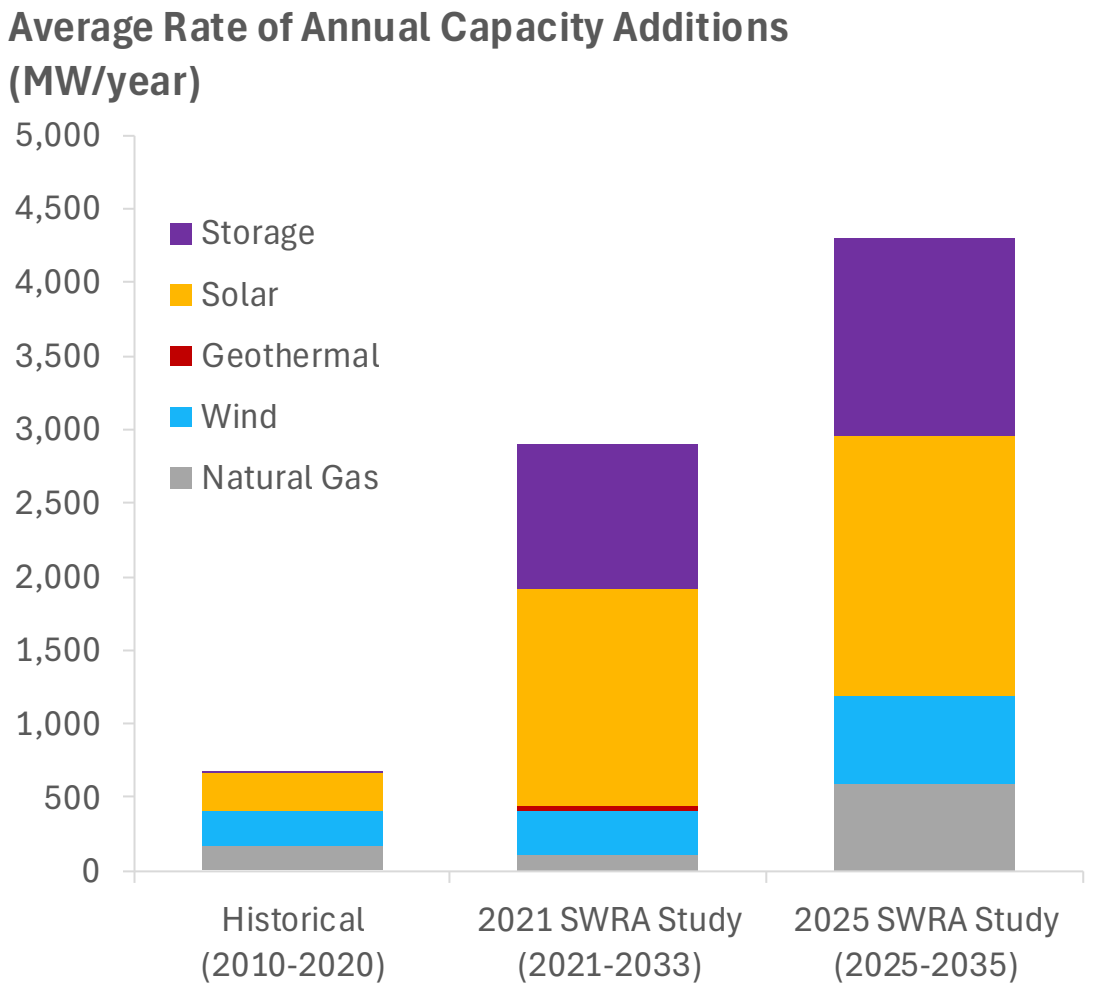
6 Natural Gas Remains Primary Option for Firm

Across all portfolios, natural gas fulfills the majority of the region's long-term need for firm resources, even under highest clean energy penetrations studied

Key findings assume that transmission system and gas transportation system are also adequately sized to meet the region's growing needs

Challenges Lie Ahead in Implementation

- Results indicate that the tools, methods, and processes used by utilities are capable of producing plans that ensure resource adequacy
- Utilities' current plans require additions of new resources at a rate far above historical levels and greater than previous studies have identified
- The primary challenges for resource adequacy over the next decade lie in the implementation of these plans, where a wide range of factors could pose obstacles to successful execution



Implementation Challenges to Ensure Resource Adequacy

Procurement & Supply Chain Risk

Longer project lead times, risks of delay and cancellation

Transmission Deliverability

Transmission system expansion needed to deliver new resources

Fuel Supply Adequacy

Constrained gas pipeline system, new infrastructure in development

Operations & Market Integration

Increasingly complex dispatch of resources to orchestrate

Permitting & Approvals

Multijurisdictional processes to enable development

Load Forecast Uncertainty

Reliability planning as a moving target

Delays or unexpected obstacles caused by any one of these factors could jeopardize regional resource adequacy

Thank You

Nick Schlag, nick@ethree.com

Adrian Au, adrian.au@ethree.com

Energy+Environmental Economics

In case you missed it: Resource Adequacy and the Energy Transition in the Pacific Northwest

E3 similarly conducted a resource adequacy study across the Pacific Northwest. More information can be found on our website.

For the report and the webinar recording:
https://www.ethree.com/ra-pnw/