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The very long-term role of gas in the California grid

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Intro

- Calpine has ~6 GW of gas generation in California, so we are interested in the future of gas generation
- Existing studies generally have a near term focus and/or do not represent reliability very carefully
 - IRP
 - UCS
 - CAISO TPP studies
- Calpine enlisted E3 to look carefully at reliability in a 2050 deeply decarbonized grid

Key Findings

- It's economic to retain some emissions in the electricity sector
- Eliminating gas generation entirely is prohibitively expensive
- Even with lots of solar and storage, it is generally economic to retain gas generation to assure reliability through multi-day periods of low solar generation
- Our results with respect to gas generation are robust to a wide range of input assumptions

Approach

This study was completed using three E3 models of the California electricity system

1. California PATHWAYS model develops scenarios for meeting 2050 economy-wide decarbonization goals
 - Electric Sector carbon budgets and electrification loads passed to RESOLVE

PATHWAYS
Economy-wide GHG Scenarios

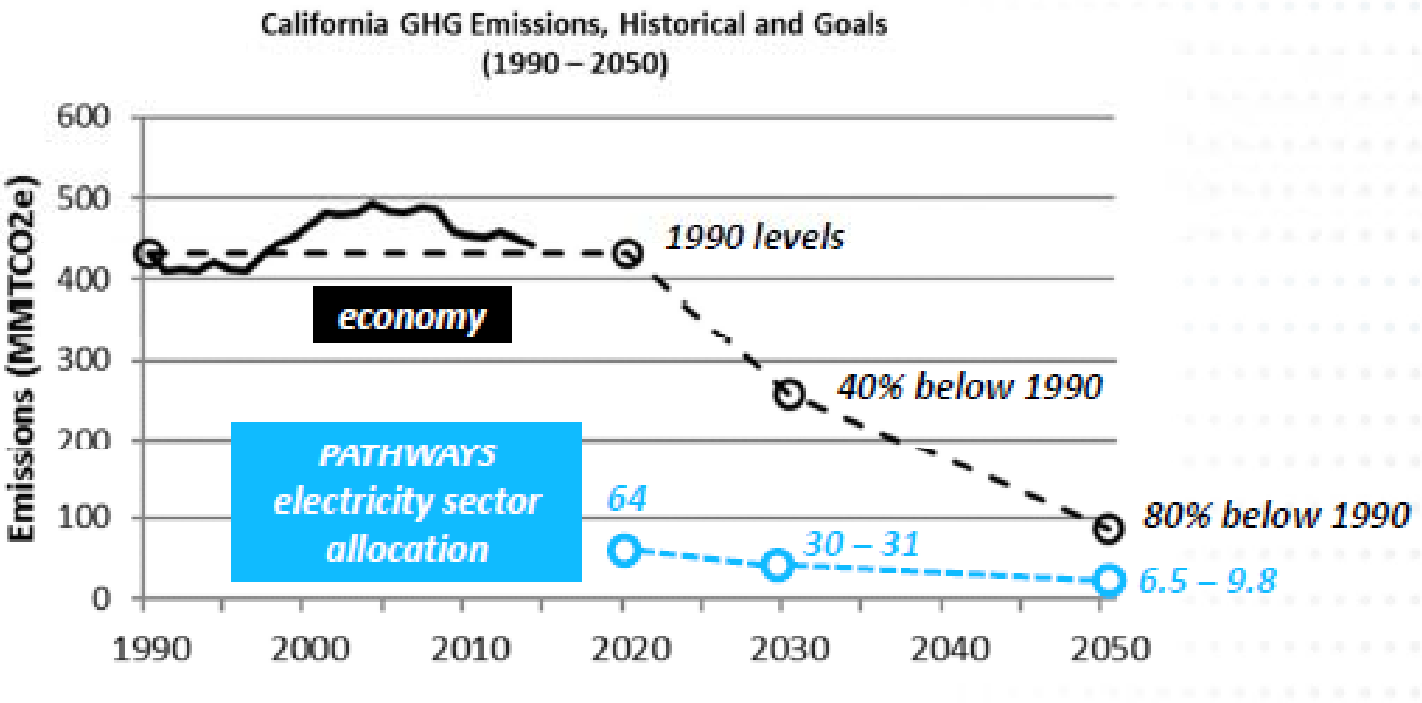
2. **California-wide RESOLVE model developed least-cost resource portfolios to meet GHG targets**
 - Electricity resource portfolio passed to RECAP

RESOLVE
Electricity Capacity Expansion

3. **California-wide RECAP model tests the reliability/adequacy of the resource portfolios**
 - Calculates Loss-of-Load Expectation

RECAP
Electricity Resource Adequacy

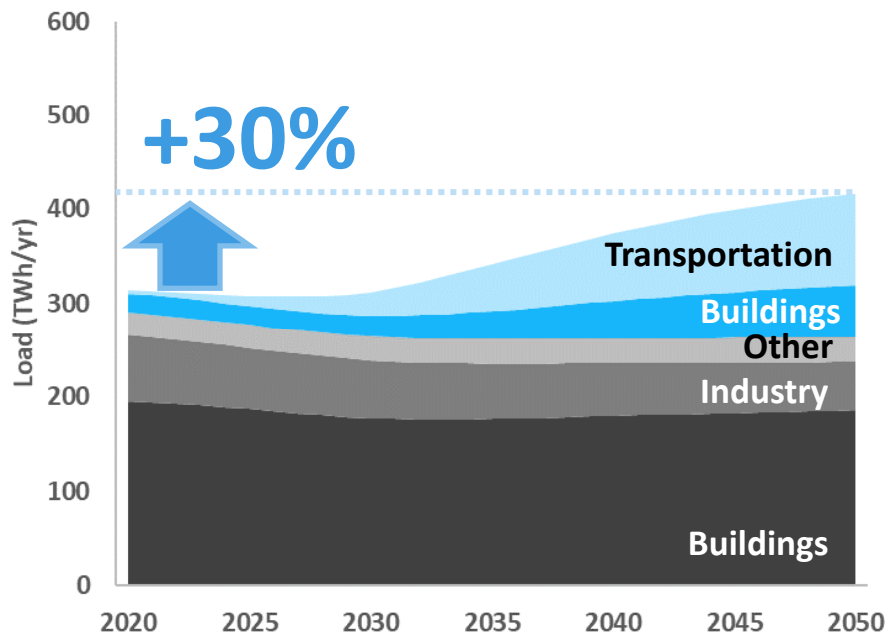
Deep decarbonization



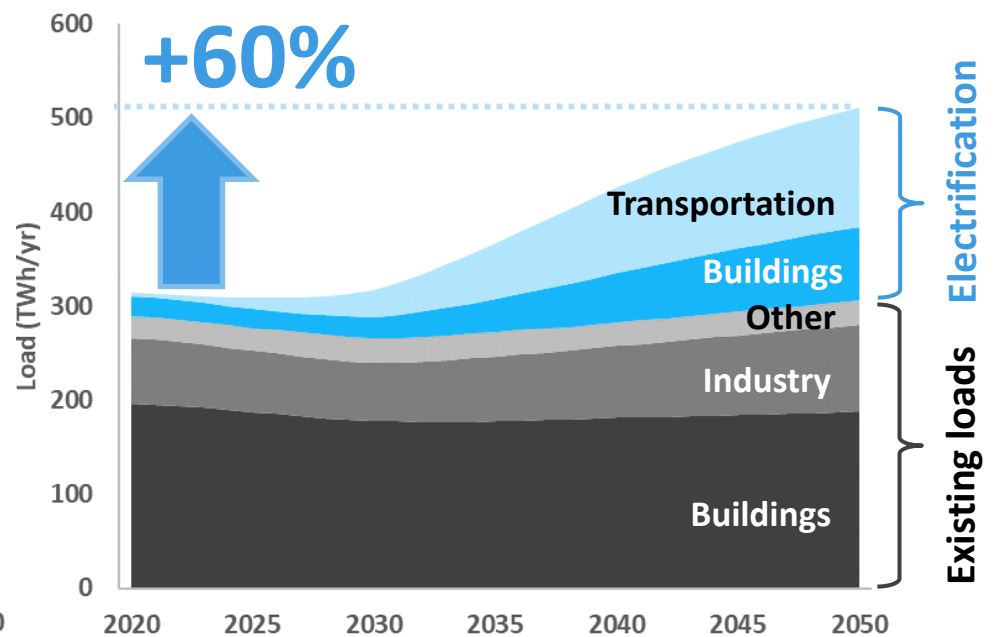
Decarbonization entails electrification

	High Biogas		High Electrification	
	2020	2050	2020	2050
Annual Energy (TWh)	315	417	315	511
Peak Load (GW)	65	78	65	93

PATHWAYS High Biogas Scenario



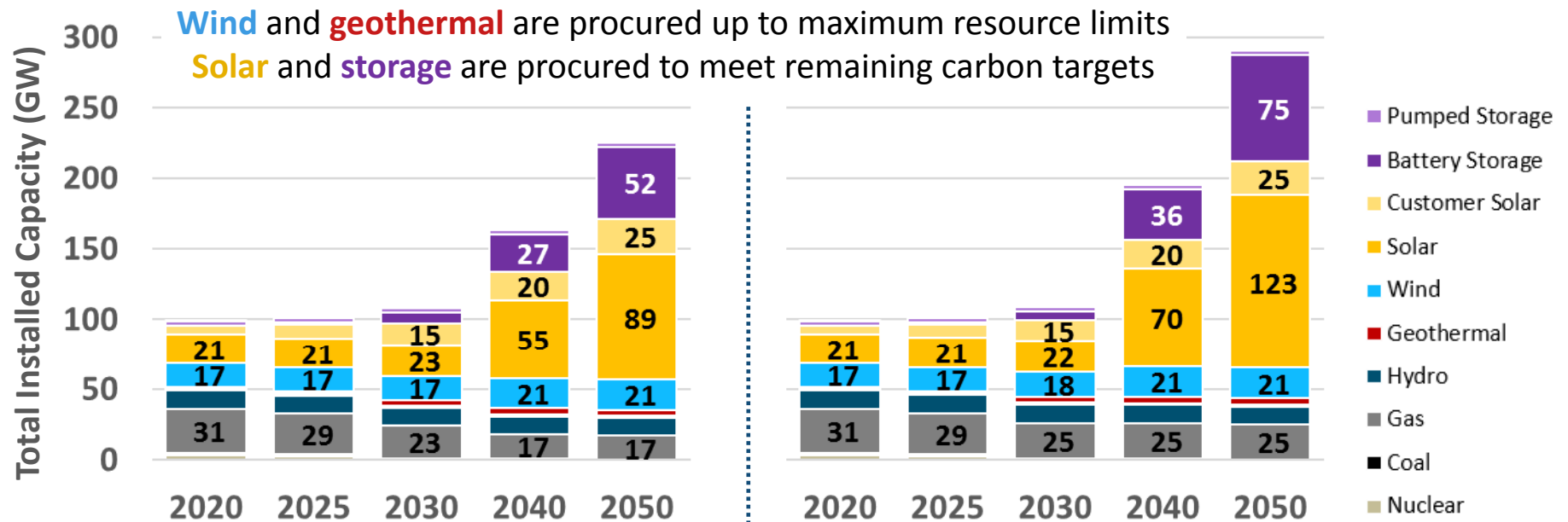
PATHWAYS High Electrification Scenario



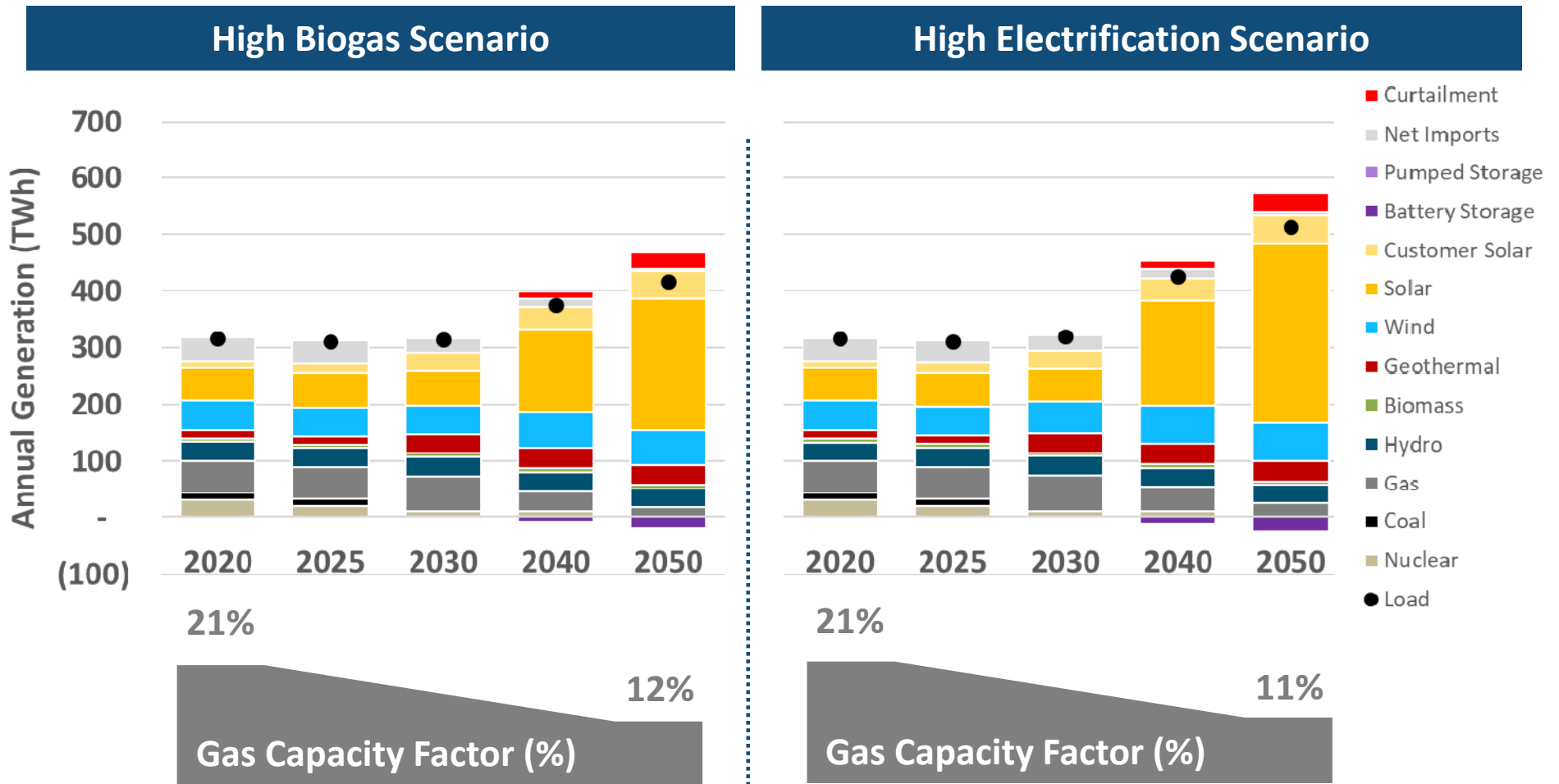
Decarbonized resource portfolios (capacity)

High Biogas Scenario

High Electrification Scenario



Decarbonized resource portfolios (energy)

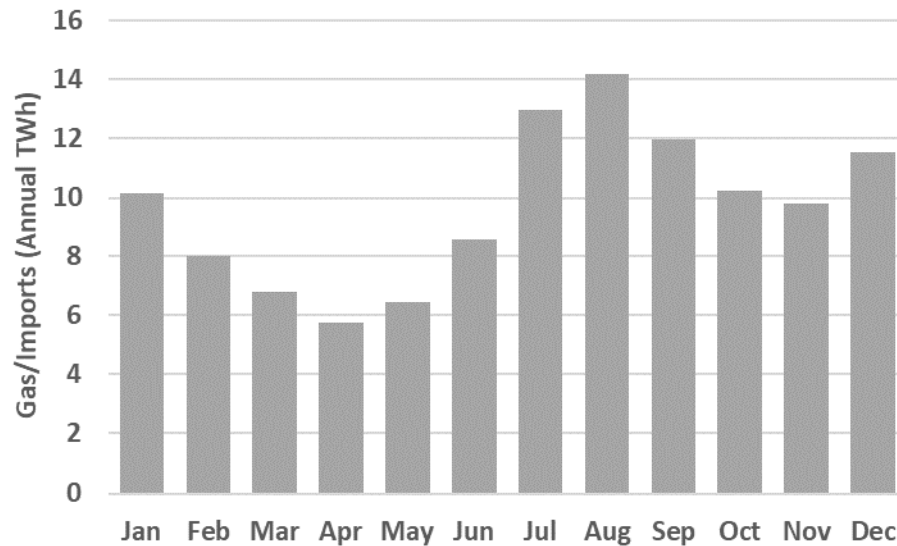


Gas Generation / Imports

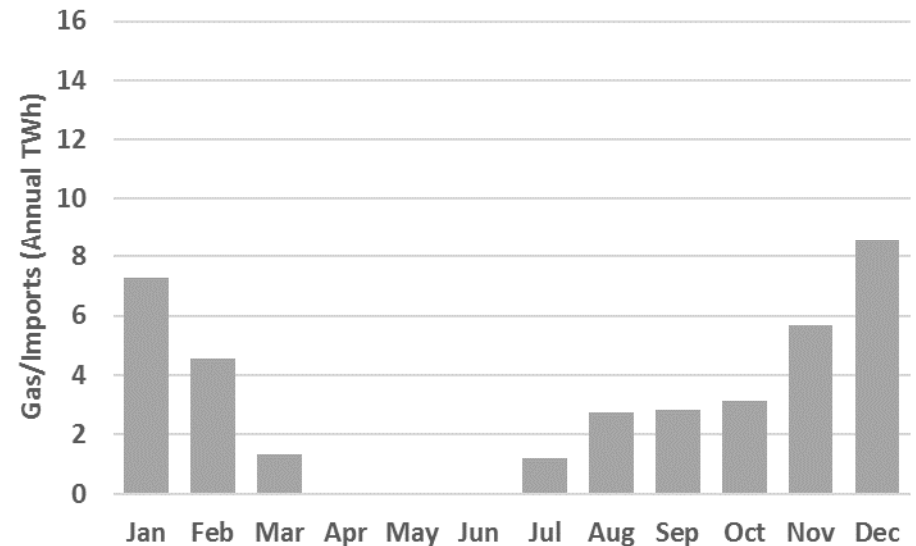
High Electrification Scenario

- In 2020, gas generation and imports are highest in the summer when loads are high
- In High Electrification Scenario in 2050, gas generation and imports decrease in all months
 - Spring/summer renewable generation reduces gas generation substantially
 - Low renewable production in winter requires gas generation for reliability

2020 Gas / Imports

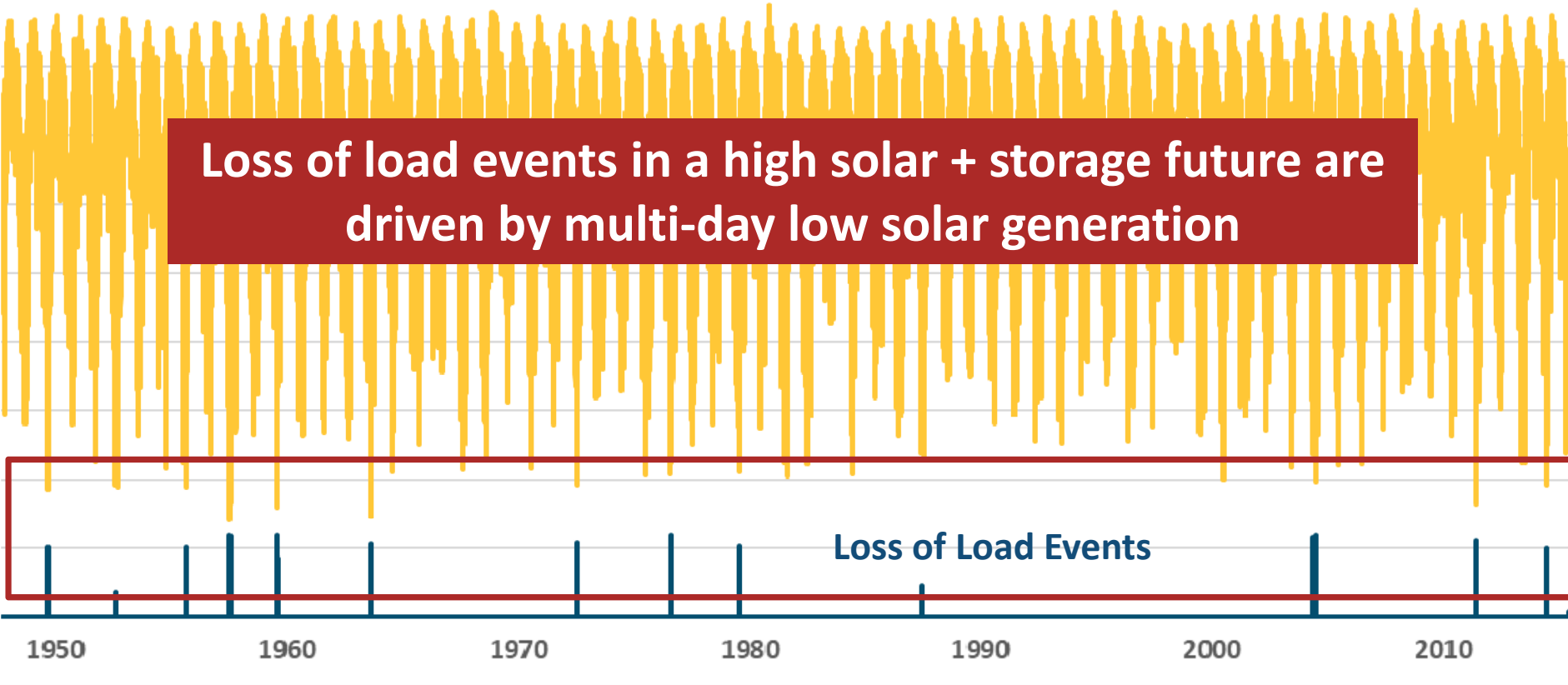


2050 Gas / Imports



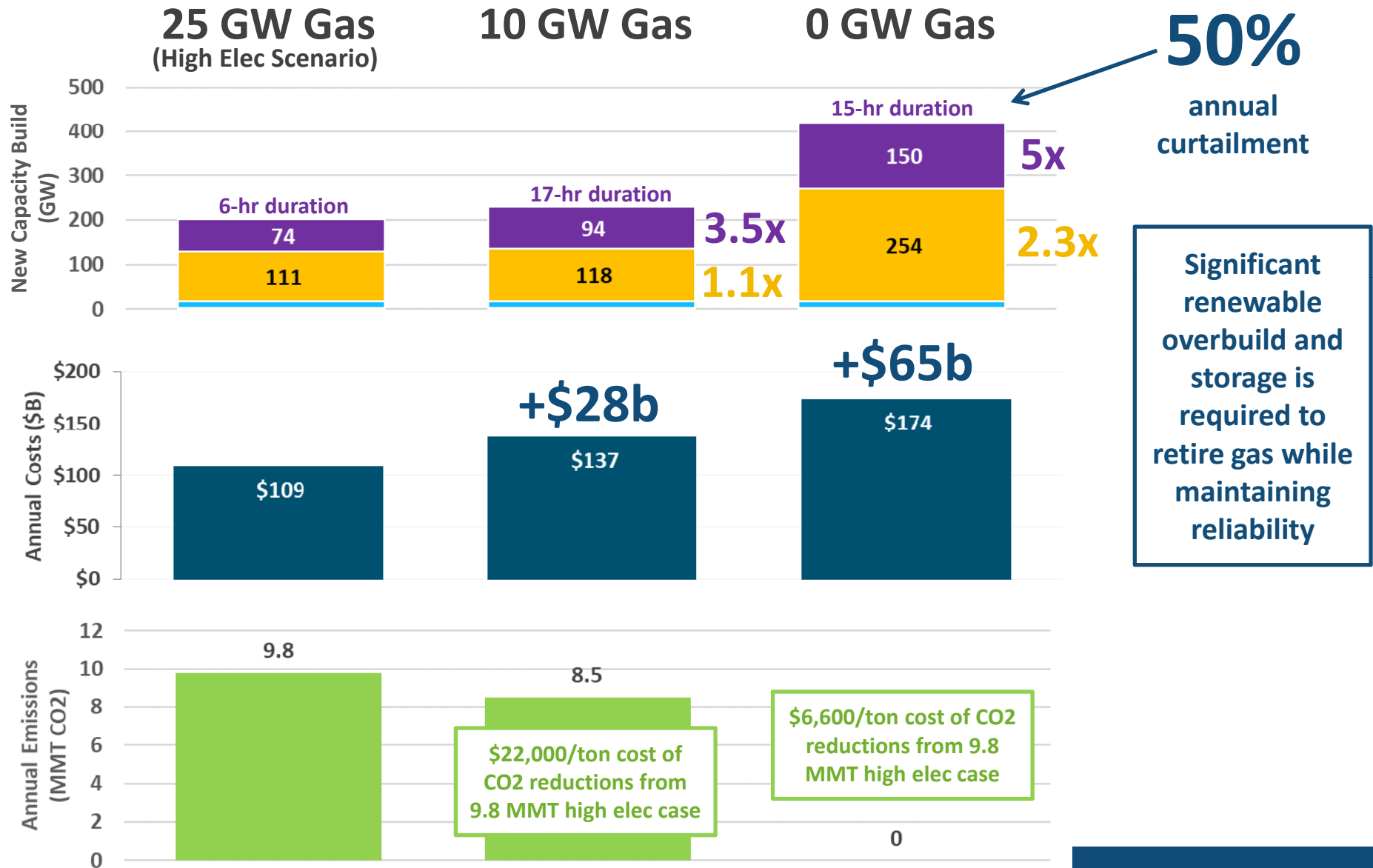
Sustained low solar production events drive resource adequacy needs

3-day simulated running average solar generation



2050 Forced Gas Retirement Cases

Relative to High Electrification Scenario



Sensitivity Analysis Results

Relative to High Electrification Scenario

Retained gas capacity is relatively insensitive to most key drivers

