Reliably Reaching California's Clean Electricity Targets

Stress Testing Accelerated 2030 Clean Portfolios

CPUC EPIC Strategic Goals Grid Modernization Workshop

September 7 2023

GridLAB

TELOS ENERGY

ENERGY INNOVATION
POLICY & TECHNOLOGY LLC

Project Team & Roles

ENERGY INNOVATION POLICY & TECHNOLOGY LLC

Public policy report, result dissemination & communications.
Overall management and organization of technical review committee.

GridLAB

Technical project management, modeling report lead.
Scenario development and RESOLVE portfolio development.

TELOS ENERGY

Technical and engineering analysis.
PLEXOS production cost analysis, weather modeling, and results visualizations.

STATE OF CALIFORNIA ENERGY COMMISSION SINCE 1975

Project advisor and member of the Technical Review Committee.
Source of original PLEXOS model and participated in regular updates.

Project context

- In 2018, California signed SB 100, which set targets of 60% renewable energy by 2030 and 100% carbon-free power by 2045.
- In December 2020, the Joint Agencies SB 100 report showed that accelerating this timeline to 100% carbon-free power by 2030 or 2035 could be cost-effective.
    - *Policymakers need further analysis on these accelerated timeline proposals to better understand impacts- especially on reliability*
    - *August 2020 event highlighted the shifting resource adequacy challenges for California and the increasing importance of weather analysis in long-term planning.*
    - *This study aims to help fill that analysis gap, and complement rather than preempt, longer term efforts such as the CEC commissioned long duration energy storage projects and the CEC's own modeling*

Study Objective & Approach

Objectives

- Identify interim targets for California on the path to 100% clean electricity by 2035 (85% clean by 2030)
- Supplement SB100 analysis conducted in RESOLVE

Approach

- Develop accelerated clean portfolios for 2030 (in RESOLVE) and evaluate these using production cost modeling (PLEXOS) for the WECC using multiple weather years
- Test the 2030 portfolios in PLEXOS against **stress conditions** — such as retiring thermal generation, weather variability, electrification, import dependency — to answer various "what if" questions

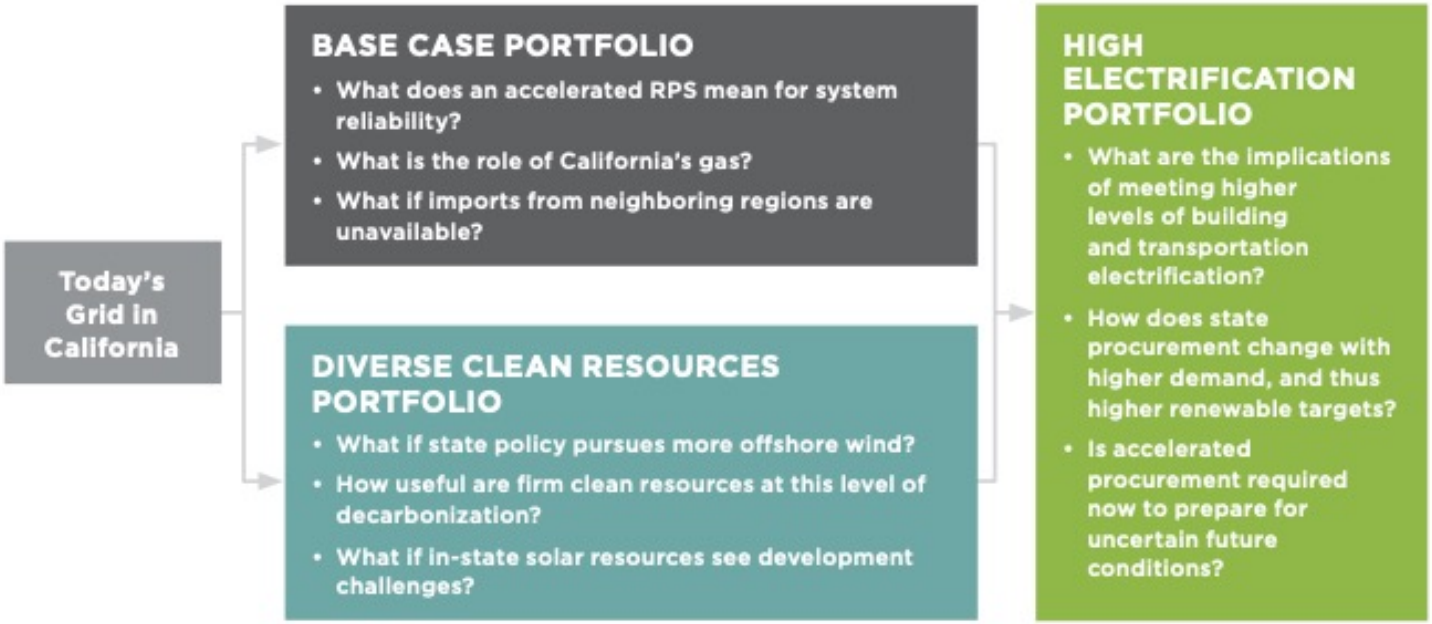
Study aims to identify interim targets (e.g., 80-90% clean electricity by 2030) for California on the path to 100% clean electricity by 2035

Portfolio Development

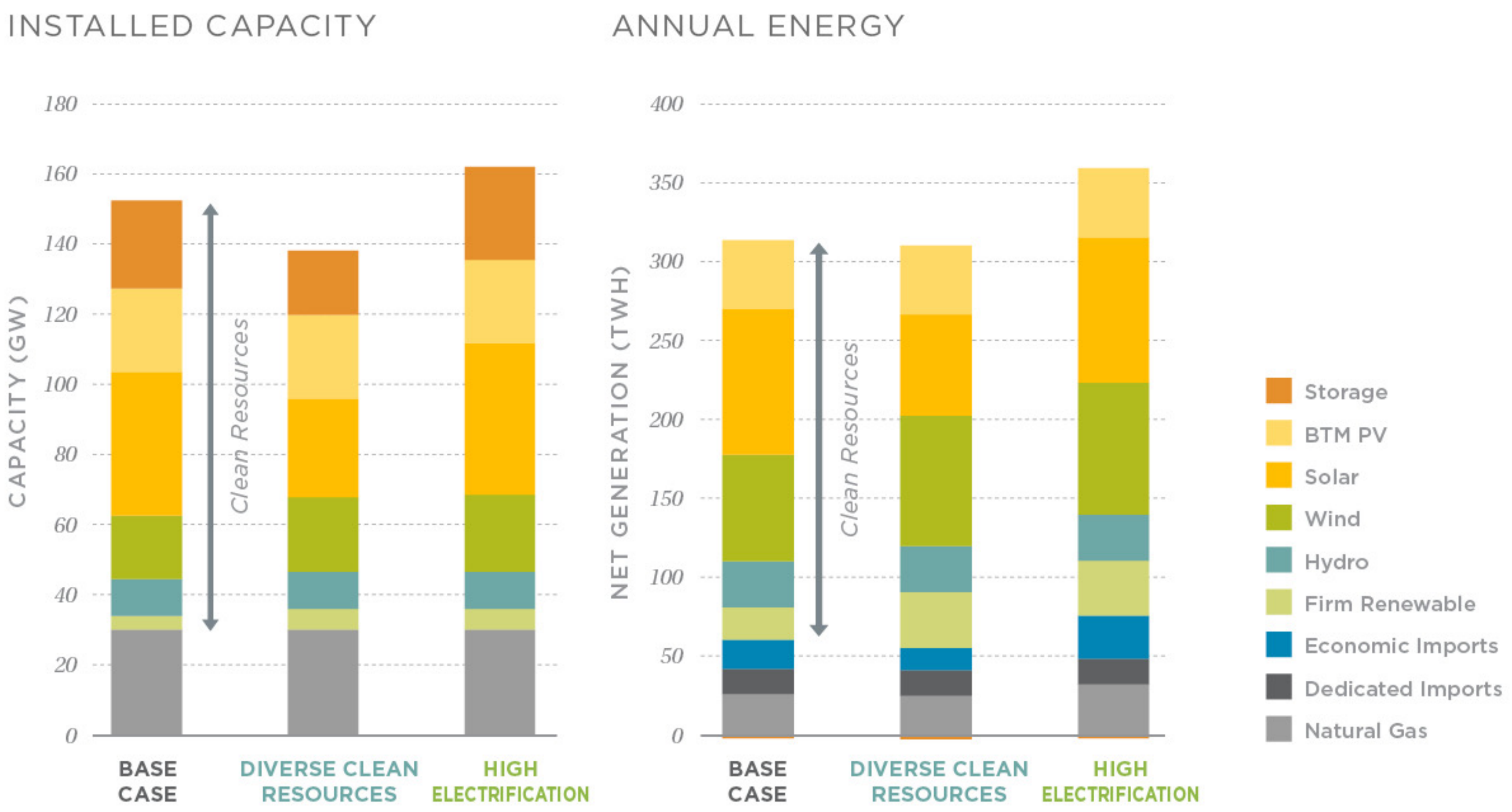
Portfolio analysis: large changes to the resource mix which alters the RPS target or portfolio of clean energy resources

- **Portfolio 1: Base Case, 75% RPS**
- **Portfolio 2: Diverse Clean Resources (OSW*, Geothermal)**
- **Portfolio 3: High Electrification (includes OSW, Geothermal)**

* 800 MW Humboldt Bay, 1200 MW Morro Bay, 2000 MW Diablo Canyon

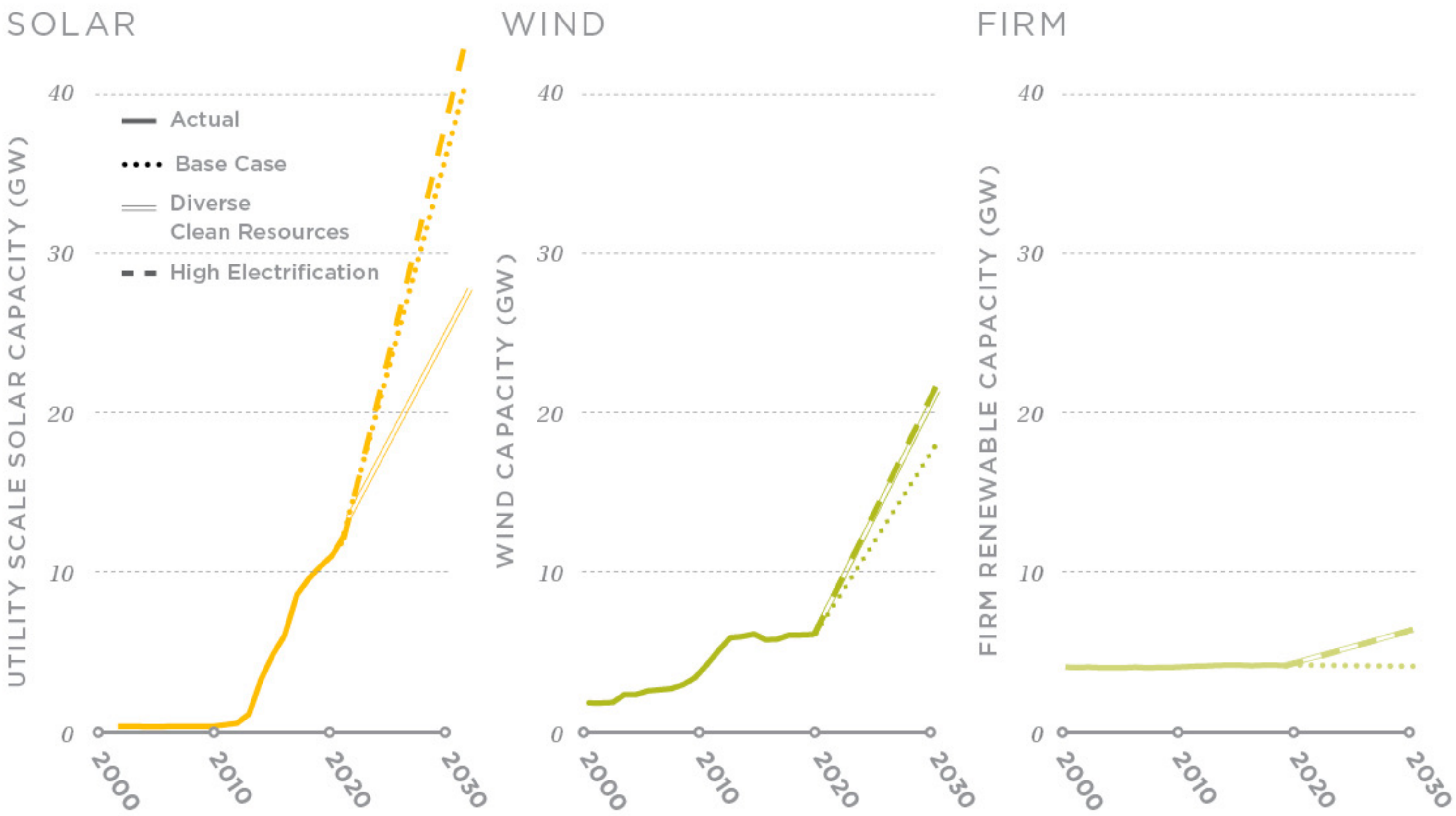


Portfolios evaluated to reach an 85% Clean Electricity Target by 2030



Installed Capacity, GW (left) and Annual Energy, TWh (right) by Resource Type and Portfolio

Accelerating California's Renewable Builds to Reach 2030 Goals



California's Historical and Future Capacity Additions by Resource Type, by portfolio

Sensitivity Analysis Overview

- **Sensitivity analysis:** Single change to an individual input or assumption to test its impact on each of the 3 portfolios
- All but the demand flexibility sensitivity *stress* system reliability

3 Portfolios
x **8 Sensitivities**
x **8 Weather Years**
= **192+ years of simulation***

**The 20-year multi-year load variability and combined stressor sensitivity were evaluated across 20-years, resulting in over 264 total years of simulation.*

A. **Baseline Assumptions**
B. **California gas retirements:** retired 11.5 GW of mostly CC-gas generation due to decreased utilization
C. **Low Hydro Availability:** used a low hydro year from 2001-2020 based on the 10th percentile of annual hydro availability
D. **WECC Coal Retirements:** retired all coal capacity in WECC, replaced with a portfolio of wind, solar, and storage resources to test import availability for California
E. **California Import Assumptions**: limited California economic imports (non-RPS, non-dedicated) to 13,100 MW during summer peak load hours
F. **Multi-year load variability:** evaluated 20 years of hourly load variability and assessed reliability under August 2020 conditions
G. **Combined-stressor sensitivity:** assessed impact of all the above stressors in combination
H. **Demand flexibility**: included load flexibility for Industrial processes, pumping, HVAC, and EV charging loads

Metrics Tracked Across the Simulations

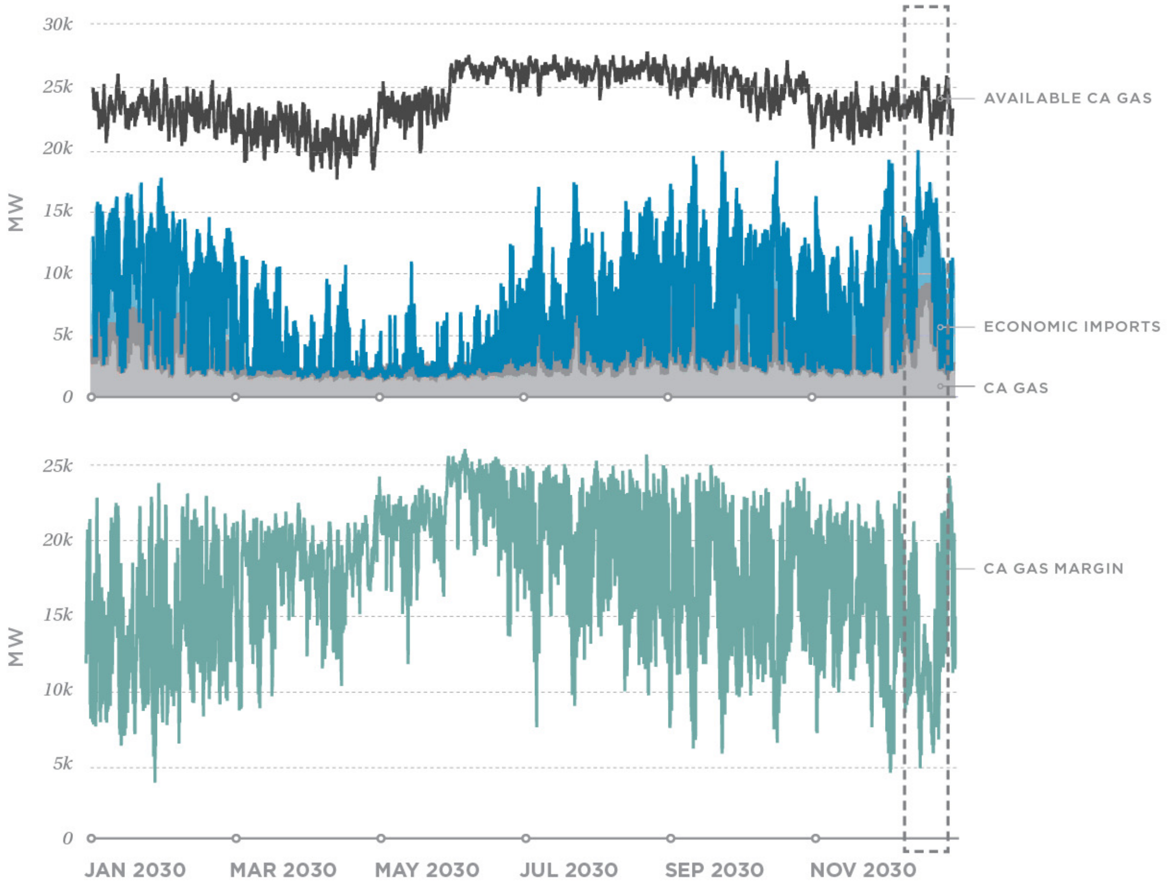
Primary metrics

- RPS and clean electricity attainment
- Natural gas margin
- WECC hourly reserve margin

Also important

- Net generation by resource type
- Net interchange by import/export type
- Inverter based resource fraction
- Multi day low wind and solar events

How would the future grid operate during a multi-day low renewable event?



Dotted box represents a low wind and solar event

Key Findings

Main finding: California can reliably meet an 85% clean standard by 2030 through multiple resource pathways, which rely primarily on wind, solar and storage.

Key findings…

1. California can reliably meet an 85% clean standard by 2030 through multiple resource pathways, which rely primarily on wind, solar and storage.
2. Diverse clean energy resources (e.g., offshore wind, geothermal) help offset the high levels of solar and storage needed to hit clean energy goals, which will be particularly helpful under higher levels of electrification; and reduce dependence on gas and inverter-based resources.
3. California will need to retain much of its existing gas fleet even though it will be used sparingly; however, it can possibly retire the environmental-justice sensitive units and serve load.
4. The California system is reliable even if all the coal across the west is retired and replaced with a clean energy portfolio, but economic imports will remain important.

Key Findings *(continued)*

5. The California system can meet load when assessed against multiple weather years, including multi-day low wind and solar events and heat events which occurred during the August 2020 rolling blackouts.
6. The system can reliably serve load when tested against the multiple stressors simultaneously (i.e., retired EJ sensitive gas, no coal across the west, import constraints, low hydro availability, multiple weather years).
7. Load flexibility/shifting can help offset battery needs and provide a hedge against resource and demand uncertainty, particularly in the winter when newly electrified loads are expected to contribute to winter reliability risk.
8. Modeling tools and planning processes could evolve to better capture the effects of geographically diverse resource data, technology cost uncertainties, and inter-regional coordination.
9. This analysis is not the end-point to understanding reliability impacts of hitting an 85% clean target; assessing clean portfolios against additional sets of weather data, generator outages, and assessing grid stability are next steps.

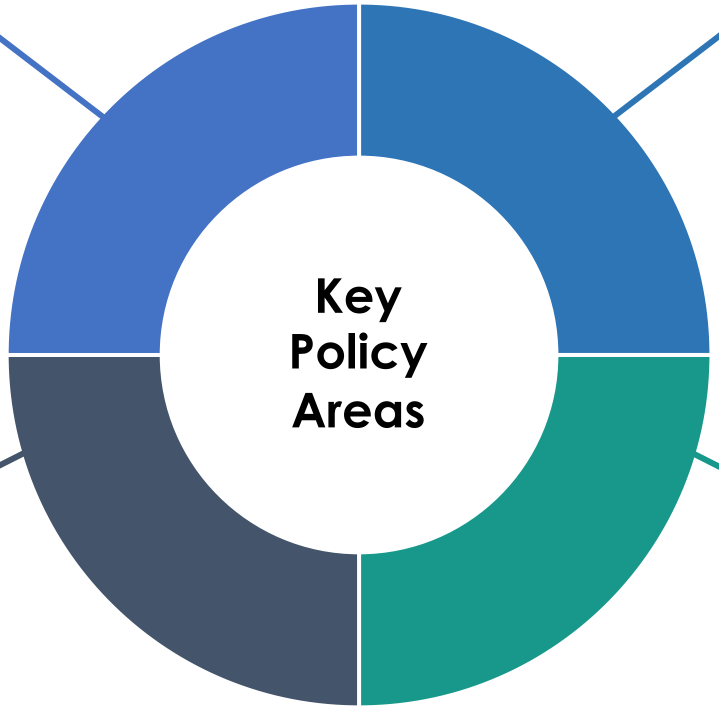
Companion Policy Report by Energy Innovation

Accelerating and Diversifying Clean Energy Deployment

Develop strategies to increase resource diversity and ensure timely deployment.

Reducing Dependence on Natural Gas Capacity

Develop new tools to ensure local reliability and advance environmental justice.



Leveraging Demand-side Resources

Use demand-side resources to mitigate deployment and operational risks.

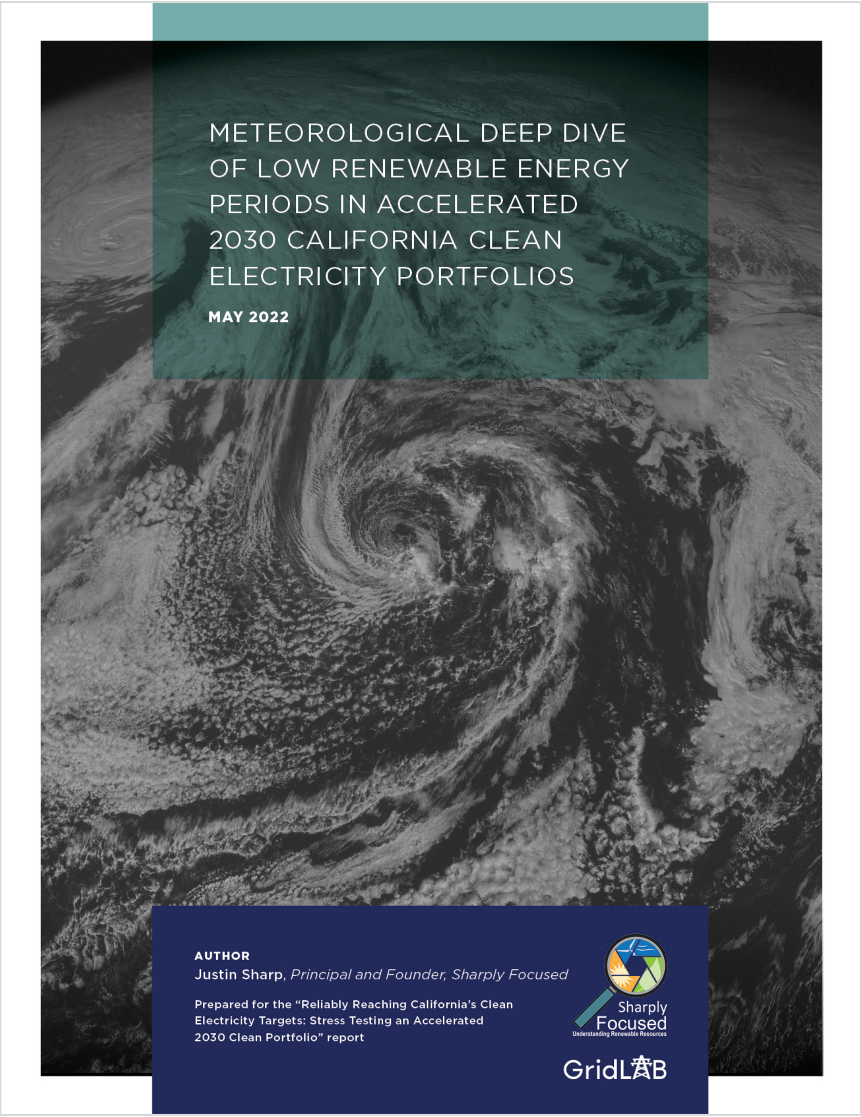
Improving Regional Coordination

Work to ensure imports perform as desired when they are needed.

Based on the companion policy report, Achieving an equitable and reliable 85 percent clean electricity system by 2030 in California, by Energy Innovation provides recommendations to further enhance reliability and equity through the transition from today's challenges to an 85% clean by 2030 future.

Links

- Report documents are at gridlab.org/california-2030-study and energyinnovation.org/publication/85-percent-clean-electricity-by-2030-in-california/
- Report, fact sheet, data visualization are posted
- In addition, a **meteorological deep dive** is posted on the GridLab website
- The meteorological deep dive analyzes the conditions across the WECC driving low renewable output in the wintertime



Appendix I

Methods and summary results

What's In-Scope, What's Out?

In-Scope

- ✓ Multiple scenarios of varying renewables, imports, changing thermal fleet
- ✓ Multi-year weather analysis
- ✓ Site specific wind and solar profiles
- ✓ Evaluation of specific weather events
- ✓ Translation of RESOLVE outputs to PLEXOS
- ✓ EV charging, building electrification, load flexibility

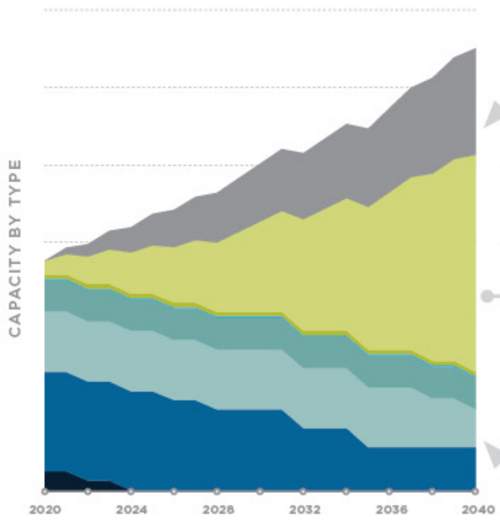
Out of Scope

- X Full resource adequacy simulations across hundreds of samples*
- X Resource adequacy metrics (e.g., LOLE, EUE)*
- X Nodal transmission analysis
- X Stability or weak grid analysis
- X Linking to specific CEC or CAISO scenarios
- X Rate or jobs impacts

** Ongoing CEC and CPUC modeling include these*

Probabilistic Analysis vs. Stress Testing Approaches for Resource Adequacy Analysis

PORTFOLIO SELECTION



IS THE PORTFOLIO RESOURCE ADEQUATE?

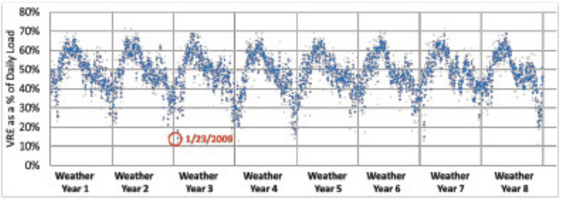
PROBABLISTIC RESOURCE ADEQUACY ANALYSIS

MANY YEARS WEATHER DATA × RANDOM OUTAGE DRAWS = 1000S OF MONTE CARLO SAMPLES

- Probabilistic assessment of weather and random outage draws
- Simplified model for hundreds or thousands of samples
- Aggregated results for probabilities, but limited specific insights

KEY OUTPUTS
Probability & expected value metrics (LOLE, LOLP, EUE)

STRESS TESTING SPECIFIC CONDITIONS



- Detailed stress tests of specific conditions
- Deeper insights into specific weather events
- Additional information in availability of imports and region-wide analysis

KEY OUTPUTS
Unserved energy
Margin (close calls)
Reliance on imports
Key stressors

Approach taken in this study

Probabilistic Analysis vs. Stress Testing Approaches for Resource Adequacy Analysis

Summary of results across portfolios and sensitivities

BASE RESOURCE PORTFOLIO

Metric		Baseline	WECC Coal Retirement	Gas Retirement	Low Hydro	Multiple Load Years	Joint Sensitivity
RPS (% of Sales)	MEDIAN	**76**	76	76	76	76	76
	SPREAD	**2**	2	2	2	2	2
Clean Electricity (% of Sales)	MEDIAN	**87**	86	87	84	87	86
	SPREAD	**2**	2	2	2	2	2
Minimum Gas Margin (GW)	MEDIAN	**7.9**	8.1	(1.4)	7.1	4.5	(6.1)
	LOWEST	**7.5**	7.7	(1.7)	6.3	1.9	(8.5)
Minimum WECC Hourly Reserve Margin (% of Load)	MEDIAN	**25%**	17%	24%	24%	23%	16%
	LOWEST	**23%**	16%	23%	23%	21%	14%
WECC Hourly Reserve Margin during periods of Minimum Gas Margin	MEDIAN	**53%**	38%	48%	62%	62%	47%
	LOWEST	**36%**	29%	30%	58%	62%	56%
"Gas Margin during periods of Minimum WECC Hourly Reserve Margin (GW)"	MEDIAN	**23**	21	8	21	22	9
	LOWEST	**21**	20	12	21	15	3
Number of Low Wind and Solar Events (Consecutive 3-days Below 30% of Load)	MEDIAN	**10**	10	10	10		
	LOWEST	**4**	4	4	4		

DIVERSE RESOURCE PORTFOLIO

Metric		Baseline	WECC Coal Retirement	Gas Retirement	Low Hydro	Multiple Load Years	Joint Sensitivity
RPS (% of Sales)	MEDIAN	**76**	76	76	76	77	76
	SPREAD	**2**	3	2	2	2	2
Clean Electricity (% of Sales)	MEDIAN	**87**	86	87	84	87	86
	SPREAD	**2**	3	2	2	2	2
Minimum Gas Margin (GW)	MEDIAN	**9.2**	9.3	(0.5)	8.1	5.1	(5.3)
	LOWEST	**8.6**	8.8	(0.8)	7.8	3.2	(7.5)
Minimum WECC Hourly Reserve Margin (% of Load)	MEDIAN	**25%**	18%	25%	25%	23%	16%
	LOWEST	**23%**	16%	23%	23%	22%	14%
WECC Hourly Reserve Margin during periods of Minimum Gas Margin	MEDIAN	**49%**	31%	41%	47%	52%	42%
	LOWEST	**56%**	30%	36%	42%	44%	53%
"Gas Margin during periods of Minimum WECC Hourly Reserve Margin (GW)"	MEDIAN	**21**	20	12	22	22	9
	LOWEST	**13**	20	7	17	24	2
Number of Low Wind and Solar Events (Consecutive 3-days Below 30% of Load)	MEDIAN	**13**	0	13	13		
	LOWEST	**7**	0	7	7		

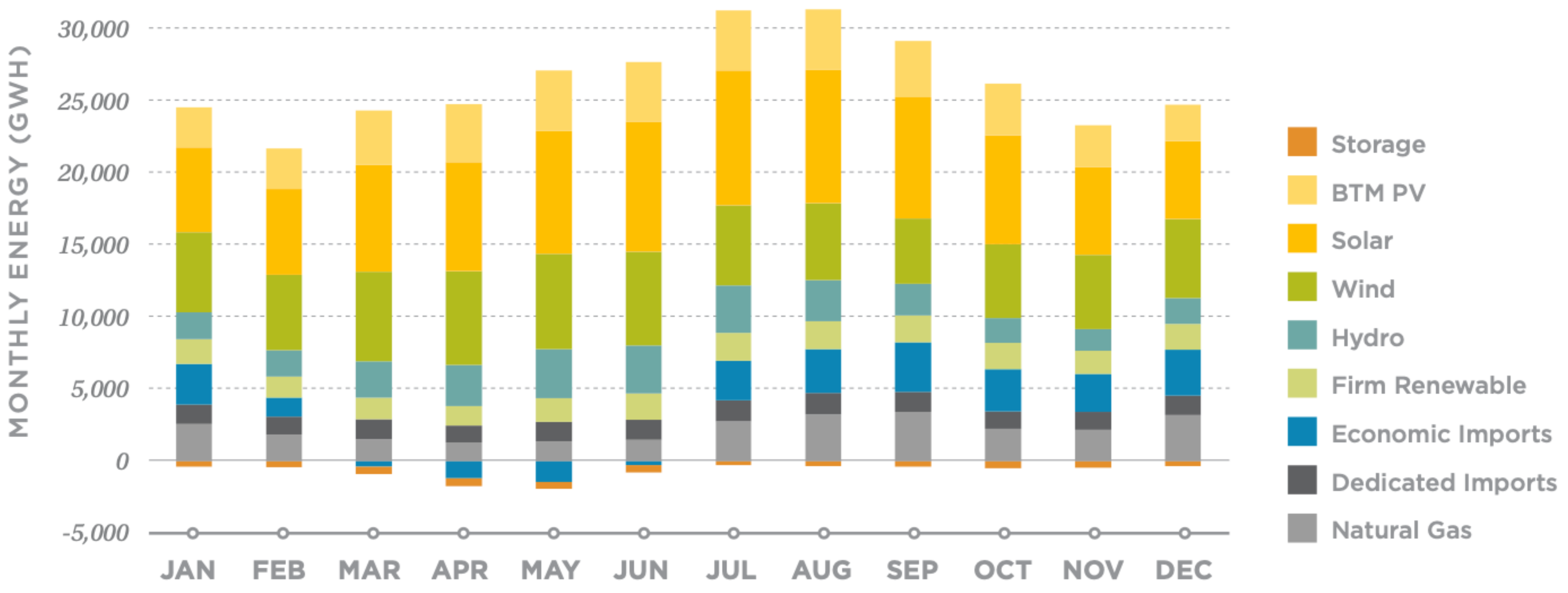
HIGH ELECTRIFICATION PORTFOLIO

Metric		Baseline	WECC Coal Retirement	Gas Retirement	Low Hydro	Multiple Load Years	Joint Sensitivity
RPS (% of Sales)	MEDIAN	**75**	75	75	75	75	75
	SPREAD	**2**	2	2	2	2	2
Clean Electricity (% of Sales)	MEDIAN	**84**	83	84	82	84	83
	SPREAD	**2**	2	2	2	2	2
Minimum Gas Margin (GW)	MEDIAN	**5.0**	4.8	(3.9)	4.0	3.1	(6.7)
	LOWEST	**3.8**	4.0	(4.8)	2.7	0.9	(9.5)
Minimum WECC Hourly Reserve Margin (% of Load)	MEDIAN	**25%**	18%	25%	25%	23%	17%
	LOWEST	**24%**	16%	24%	24%	22%	14%
WECC Hourly Reserve Margin during periods of Minimum Gas Margin	MEDIAN	**50%**	36%	45%	42%	56%	42%
	LOWEST	**37%**	33%	37%	40%	59%	48%
"Gas Margin during periods of Minimum WECC Hourly Reserve Margin (GW)"	MEDIAN	**20**	18	10	19	20	9
	LOWEST	**21**	22	5	18	23	9
Number of Low Wind and Solar Events (Consecutive 3-days Below 30% of Load)	MEDIAN	**16**	16	16	16		
	LOWEST	**5**	5	5	5		

Appendix II

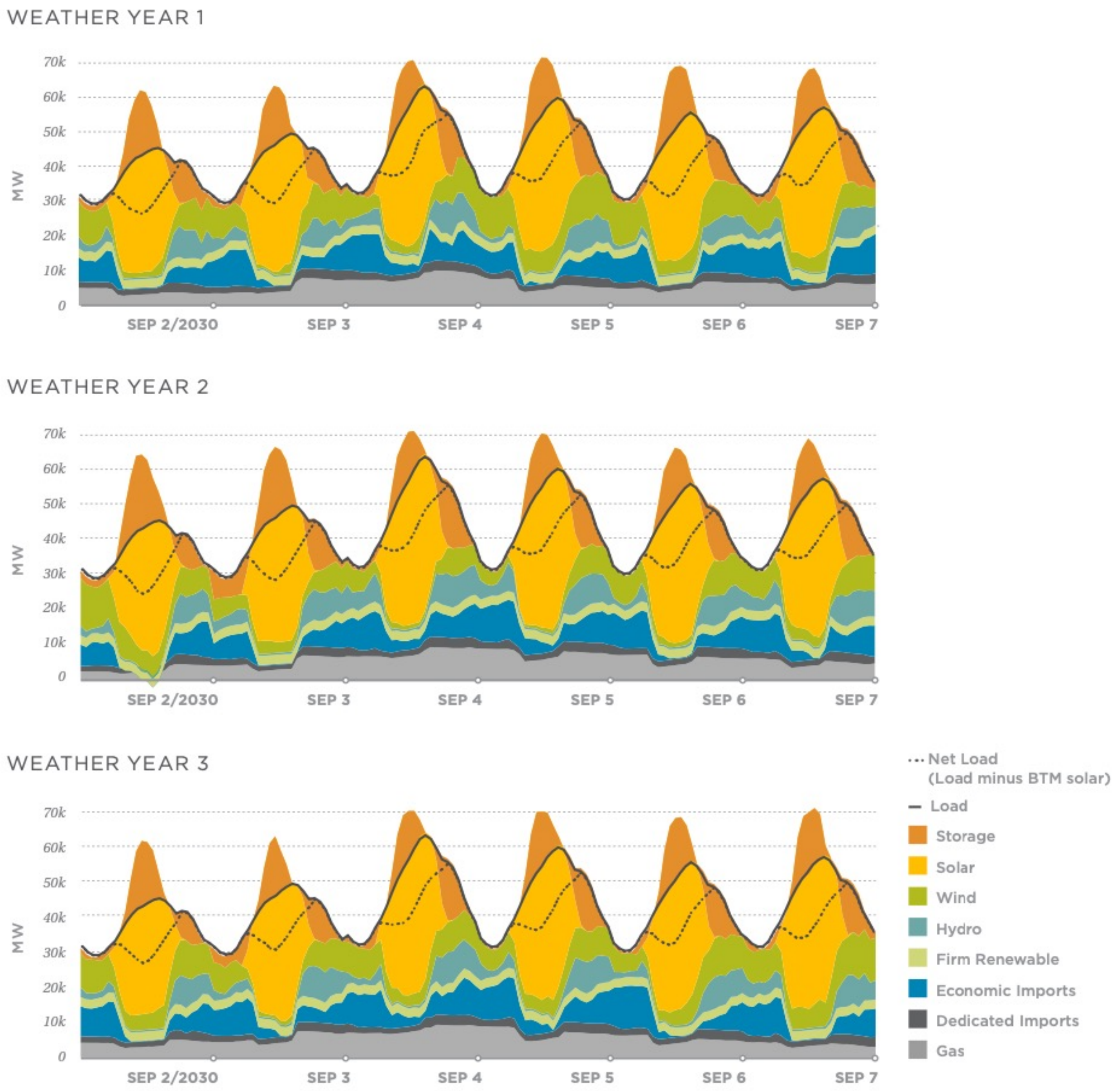
Base Case Portfolio Results

2030 Annual Generation by Resource Type, by Month



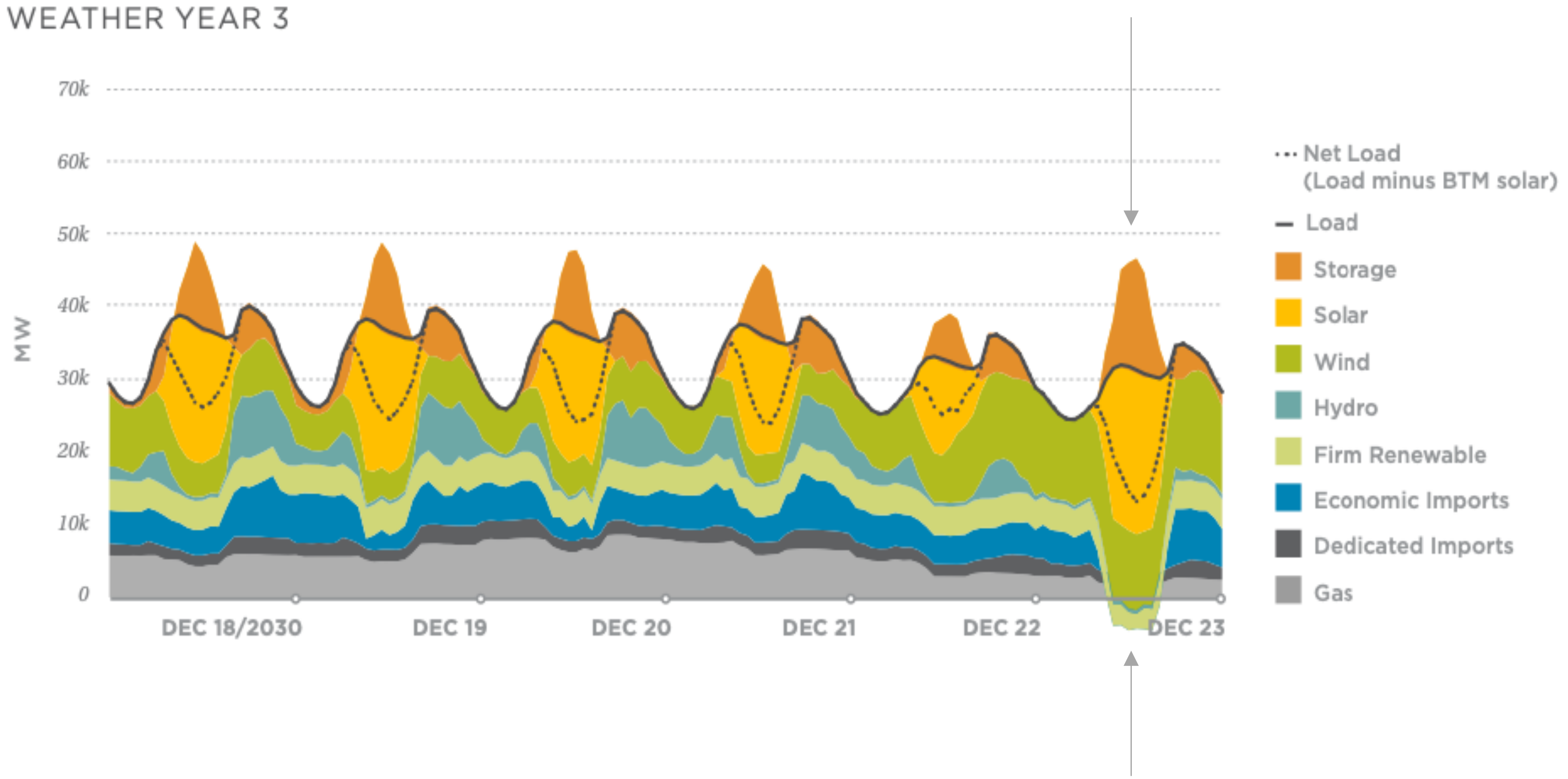
Wind, Solar, and BTM Solar contribute the majority of the system's energy needs

California System Dispatch During Peak Load Week



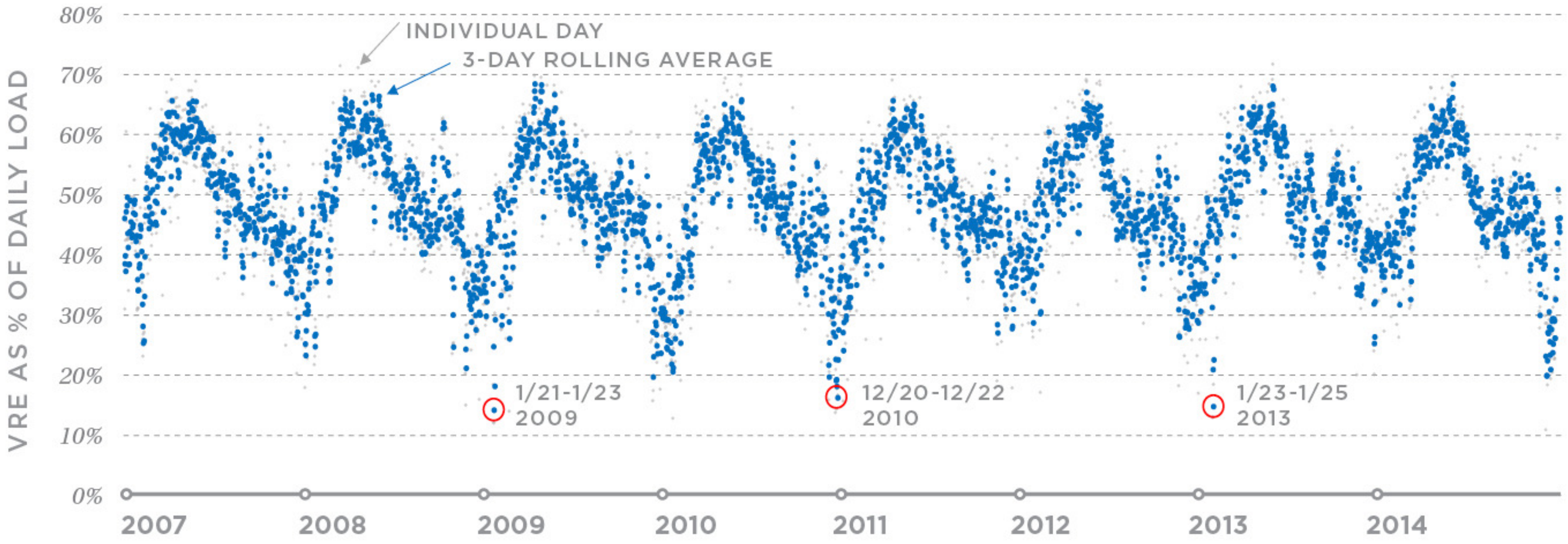
California System Dispatch During Winter Load Days

100% Power Electronic Generation



Net exports (limited to 4000 MW)

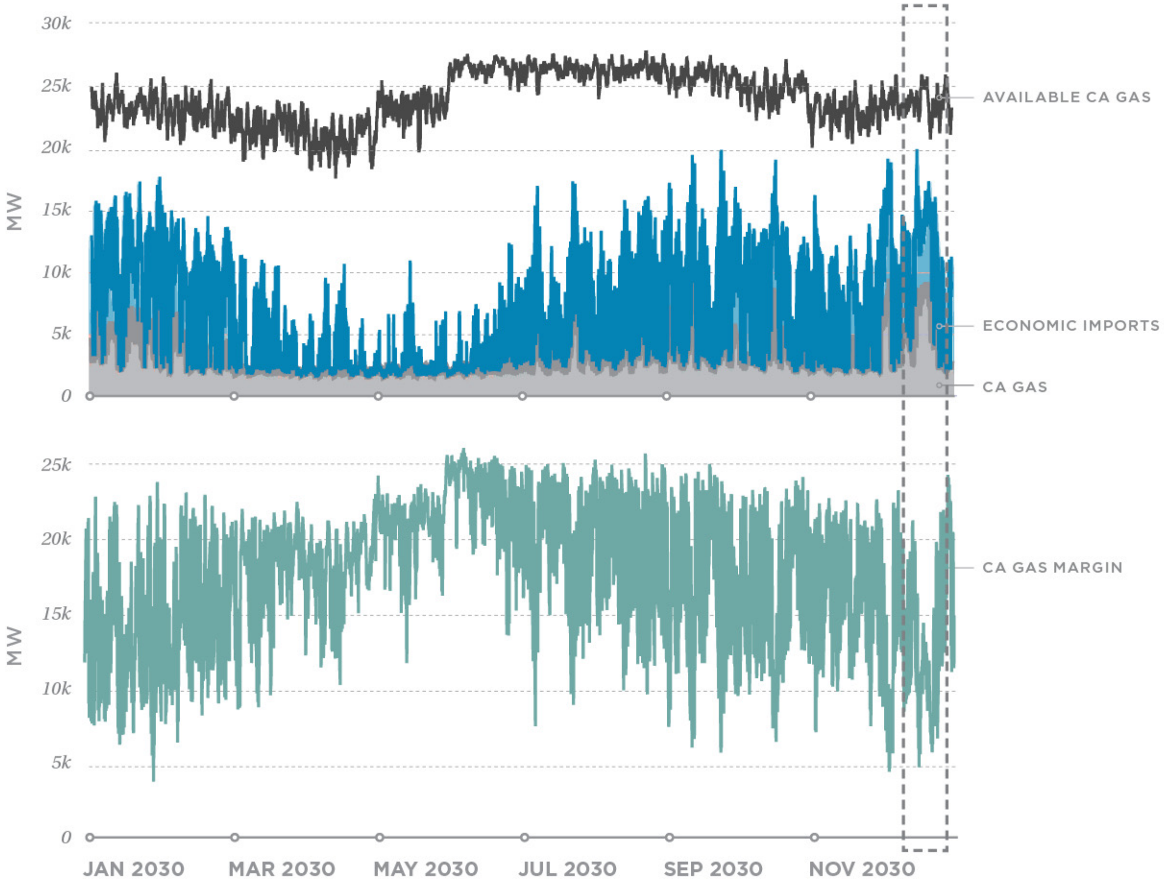
Identifying Multi-Day Low Wind & Solar Events



Multi-day Low Wind and Solar Events in California (based on the Base Case portfolio and baseline operating assumptions); similar trends were observed for the Diverse Clean Resources and High Electrification portfolios.

How would the future grid operate during a multi-day low renewable situation?

While multi-day low renewable events can occur, they tend to be in the winter when load is lower. True even with aggressive electrification.



In-state Gas Dispatch and Economic Imports, Weather Year 2010; dotted box represents a low wind and solar event

Risk Heatmaps: When is California dependent on gas and imports for reliability?

Heatmap of Average In-State Gas Dispatch and Economic Imports by Month and Hour (Base Case portfolio with Baseline sensitivity assumptions)

Appendix III

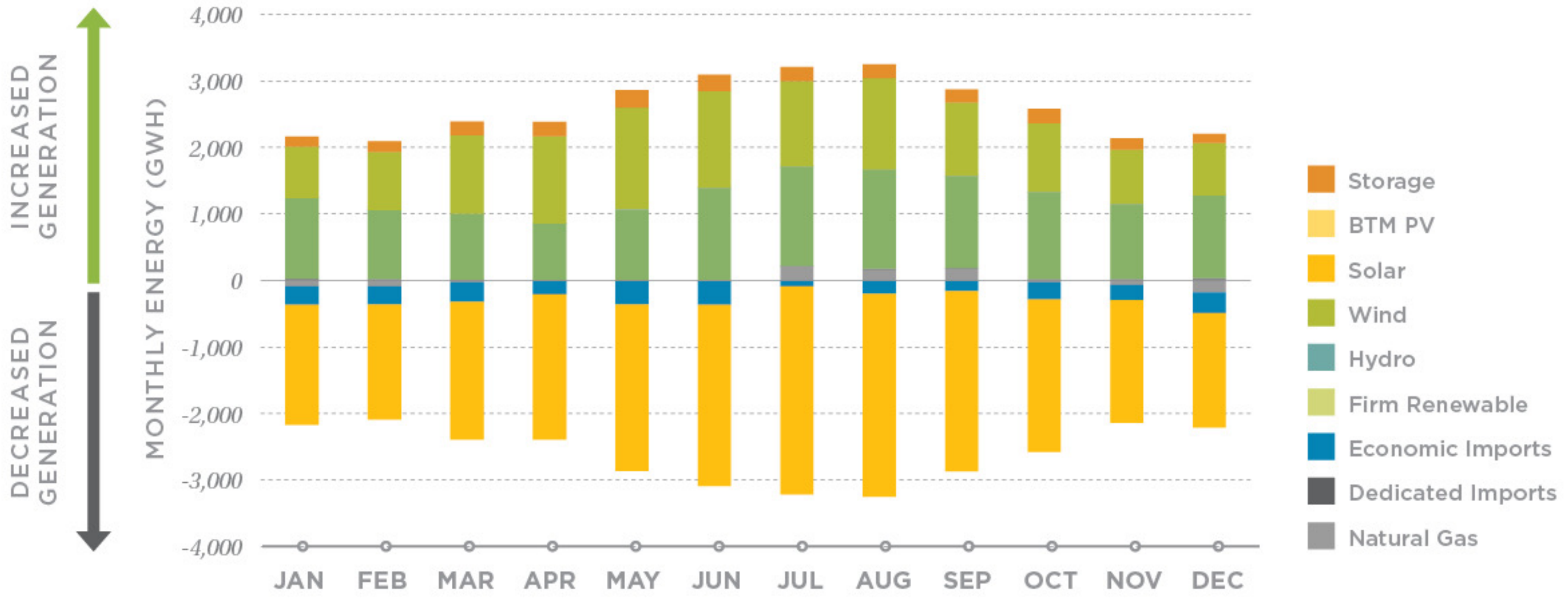
Diverse Clean Resource Portfolio Results

Clean Diverse Resources Portfolio

- **Objective:** Quantify the reliability and operational benefits of a diverse resource mix to evaluate an alternative renewable pathway for California and guide policy discussions on alternative resource types.
- **Method & Assumptions:**
  - 75% RPS target (same as Base Case to allow for direct comparison)
  - Fix build 4,000 MW of OSW* and 2,000 MW of geothermal
  - RESOLVE was run for 75% RPS/4 GW OSW/ 2 GW geothermal
    - RESOLVE mainly reduced solar and storage new build MW
    - We lowered the solar & battery MW slightly to match the PLEXOS resulting RPS

* 800 MW Humboldt Bay, 1200 MW Morro Bay, 2000 MW Diablo Canyon

Comparison of CA Energy by Resource Type

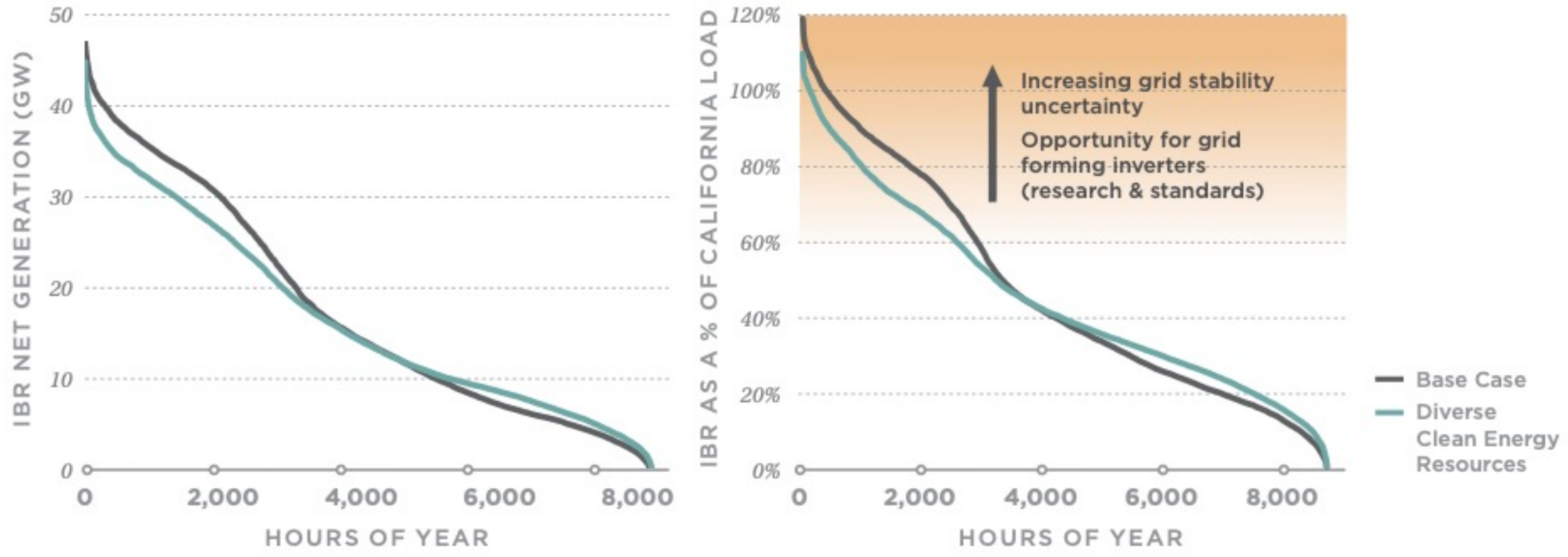


Diverse clean resources leads to a 30% decrease in utility scale solar, but also a 22% decrease in economic imports (proxy for reliability risk) and ~50% decrease in storage round trip losses.

Change in Monthly Generation between the Base Case and Diverse Clean Resources portfolios; storage represents change in round-trip energy losses. Positive values represent fewer losses.

Tracking instantaneous inverter-based generation

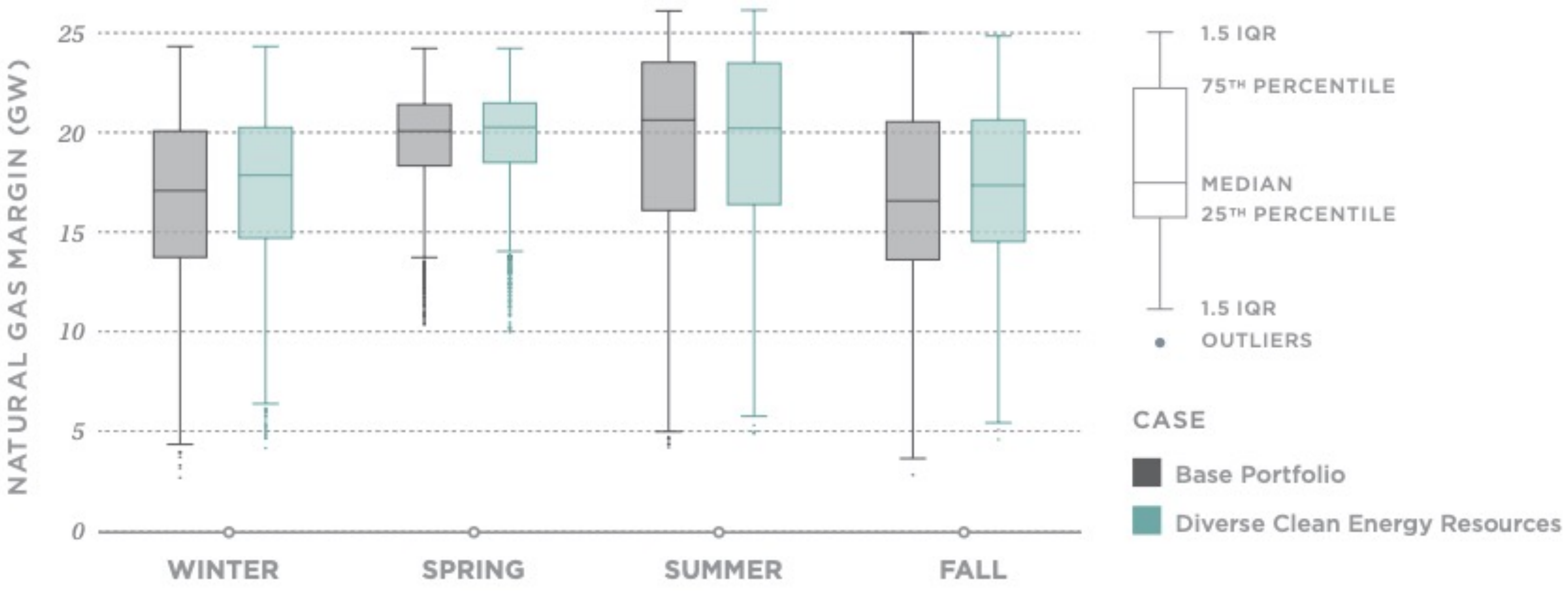
Annual metrics are useful for RPS policy, but instantaneous generation is important for stability & operations



- Instantaneous IBR includes wind, solar, and storage *net* generation for each hour
- Important for monitoring grid stability, grid strength and other transmission security considerations

Comparing Gas Margin between the Base Case and Diverse Clean Resource portfolios

- Peak risk no longer occurs during summer peak load months
- High solar availability shifts peak risk to fall and winter periods
- Offshore wind has favorable availability during these periods
- Somewhat fewer min margins with diverse resource mix



Appendix IV

High Electrification Portfolio Results

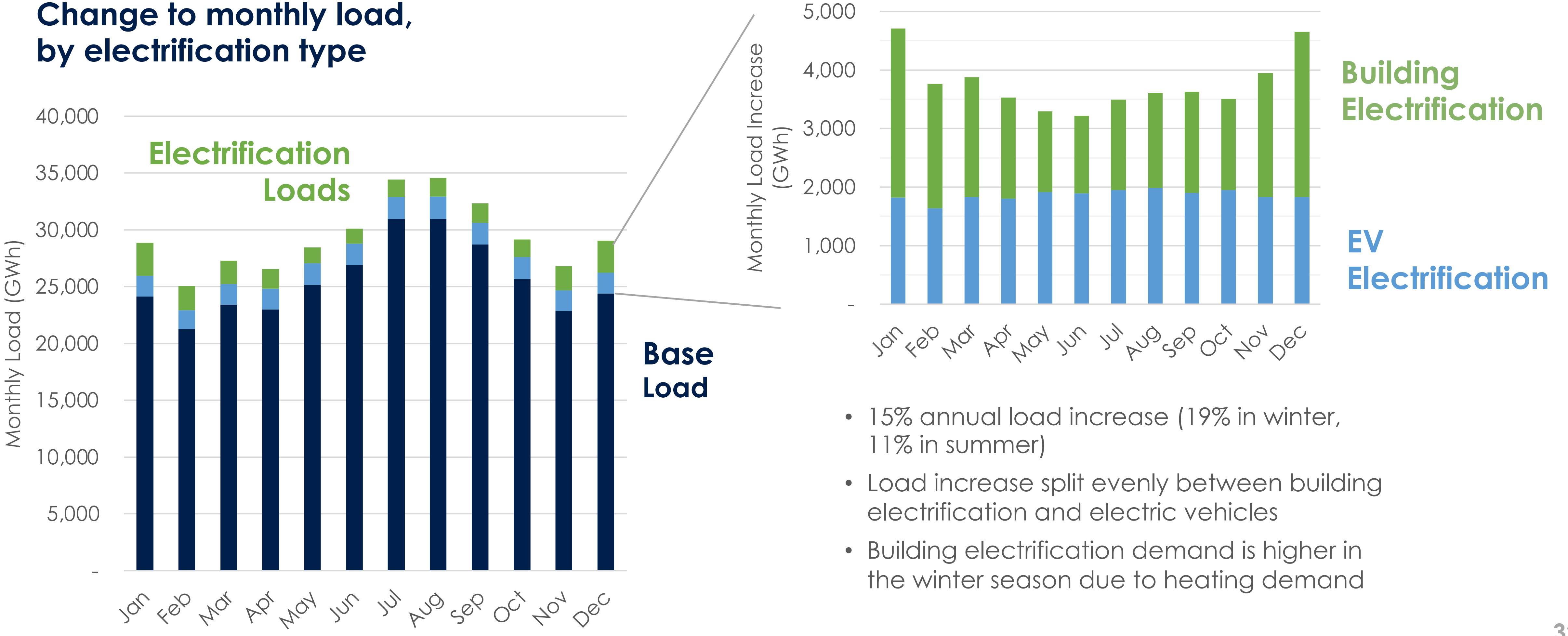
High Electrification Portfolio

- **Objective:** Quantify the new capacity requirements, reliability, and operational considerations for a high electrification scenario with increased building demand and electric vehicle adoption
- **Method & Assumptions:**
  - EV loads based on GridLab 2035 study using the 100% EV sales by 2035 forecast (~70% by 2030)
  - Building electrification load based on AB3232 ("moderate" case*)
  - 75% RPS target (same as Base Case & Resource Diversity to allow for direct comparison)
  - RESOLVE was run with and without the resource diversity fix builds
  - Fix build 4,000 MW of OSW and 2,000 MW of geothermal
  - We selected the resource diversity case for further analysis in PLEXOS **

* Moderate case = 100% new construction, 50% replace on burnout, 5% early retirement
** We chose not to analyze the "base-electrification" portfolio from RESOLVE for analysis in PLEXOS due to the amount of solar build, which we deemed to be challenging from a deployment perspective. (~40 GW new build solar; ~60 GW operational)

High Electrification Load Changes

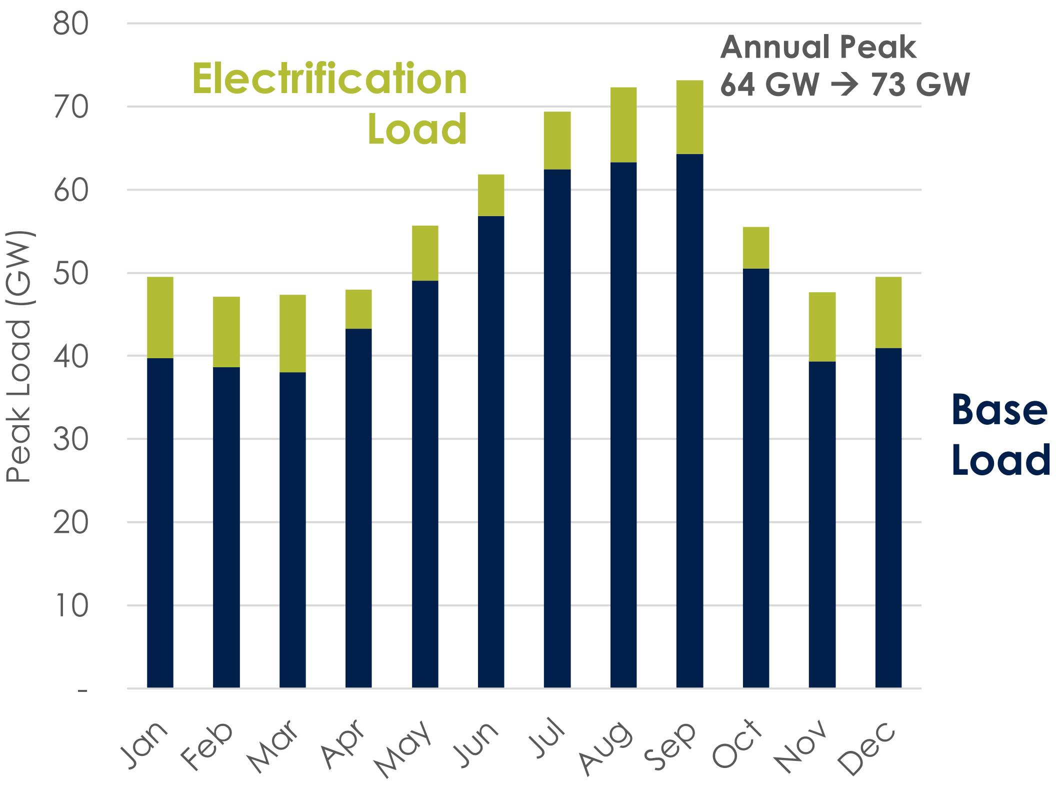
Change to monthly load, by electrification type

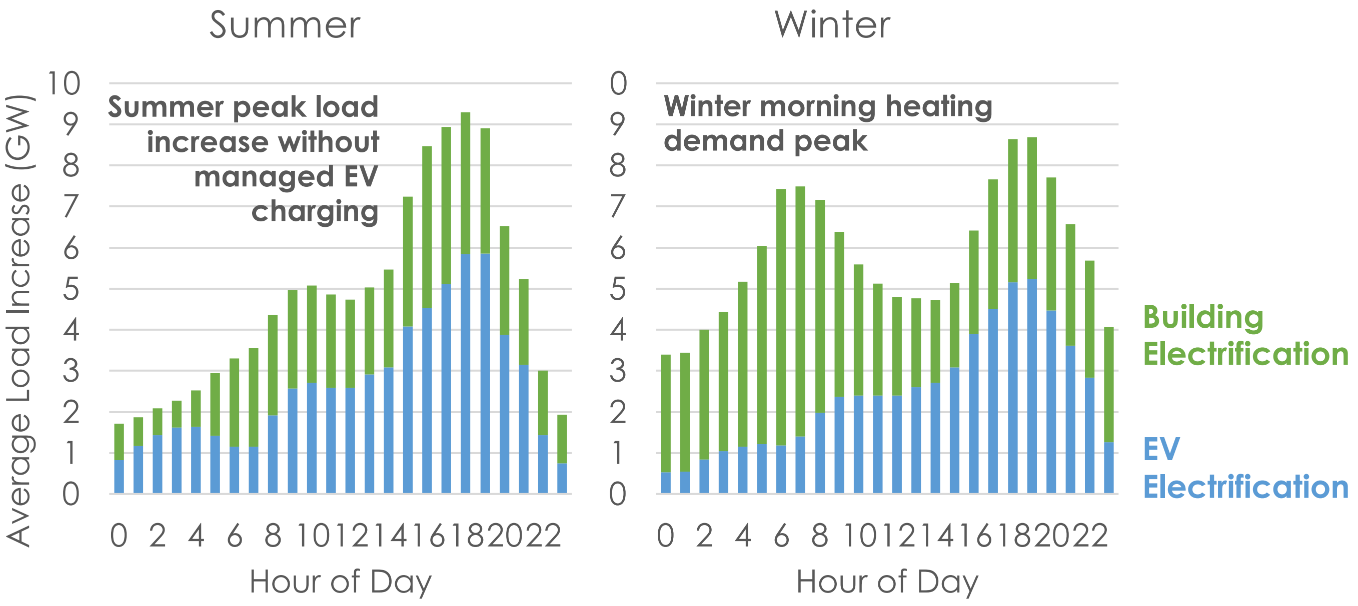


- 15% annual load increase (19% in winter, 11% in summer)
- Load increase split evenly between building electrification and electric vehicles
- Building electrification demand is higher in the winter season due to heating demand

High Electrification Load Changes

Change to monthly load, by electrification type

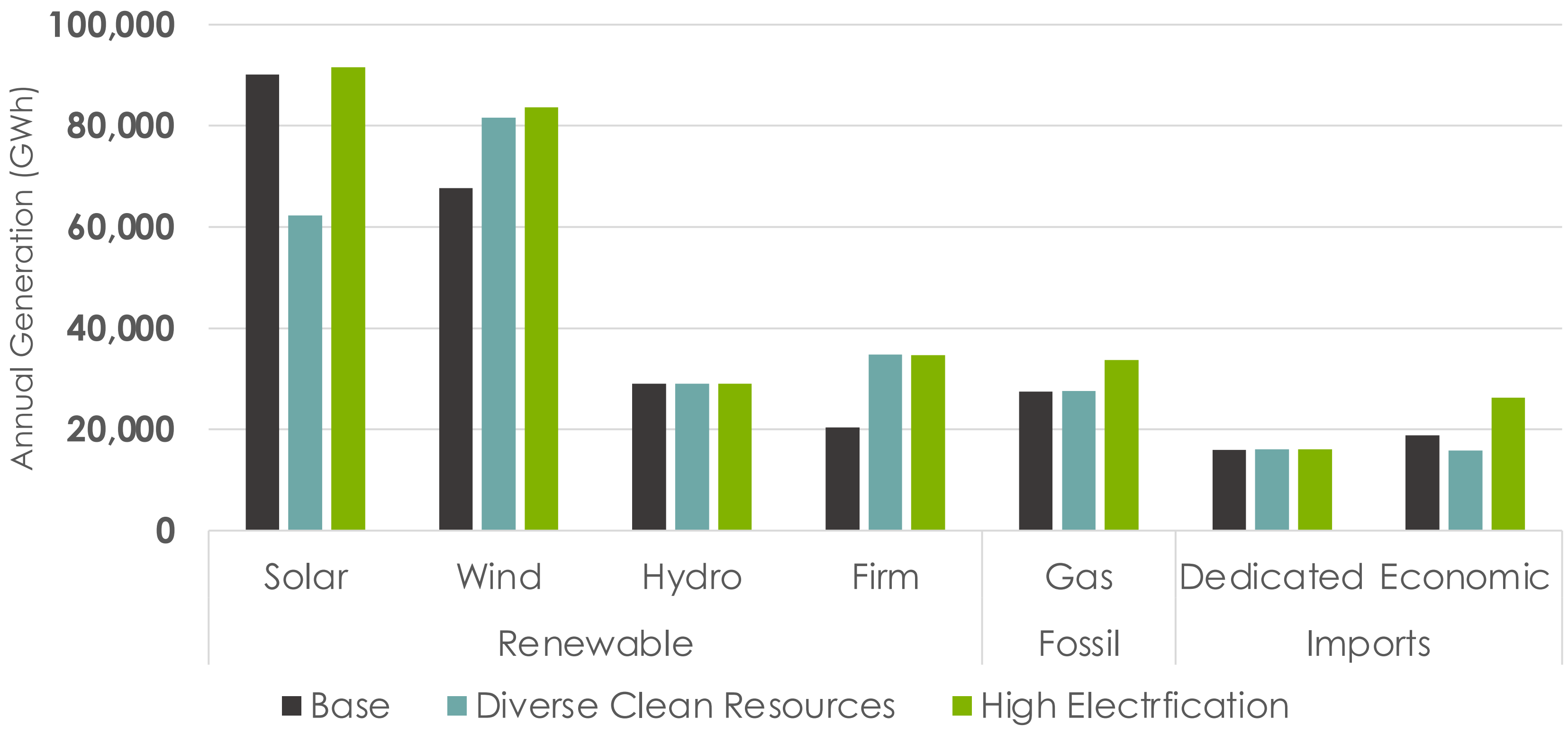




- Annual peak load increase of 9 GW (15%)
  64 GW Peak (base) → **73 GW** with high electrification
- Max EV demand is higher in the summer (~ 5-6 GW)
- Max building electrification demand is higher in the winter (~ 3 – 6.5 GW)

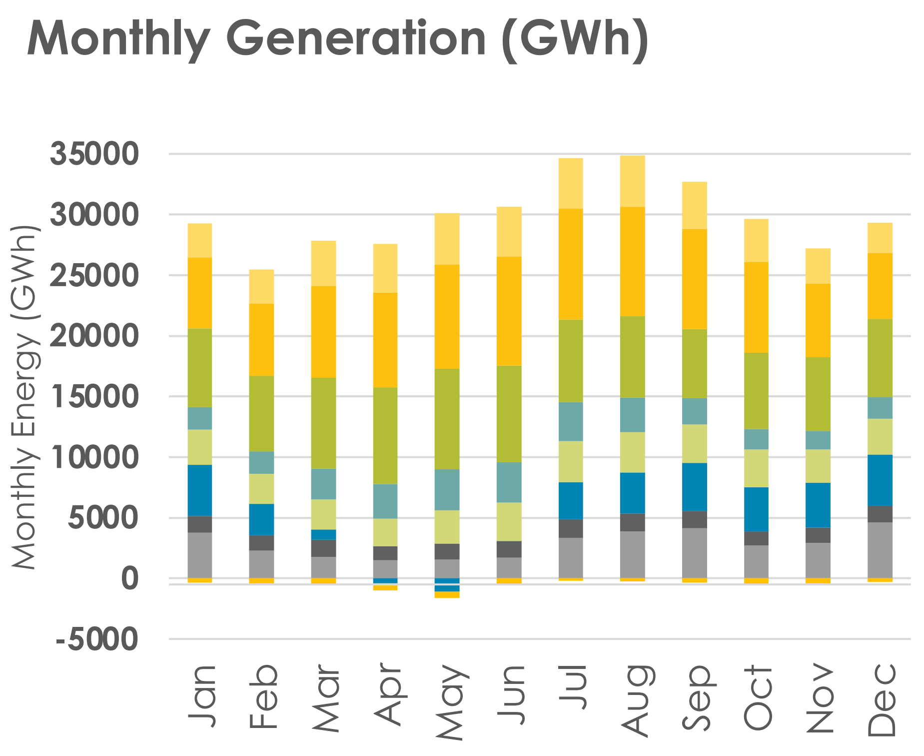
Comparison of CA Energy by Resource Type

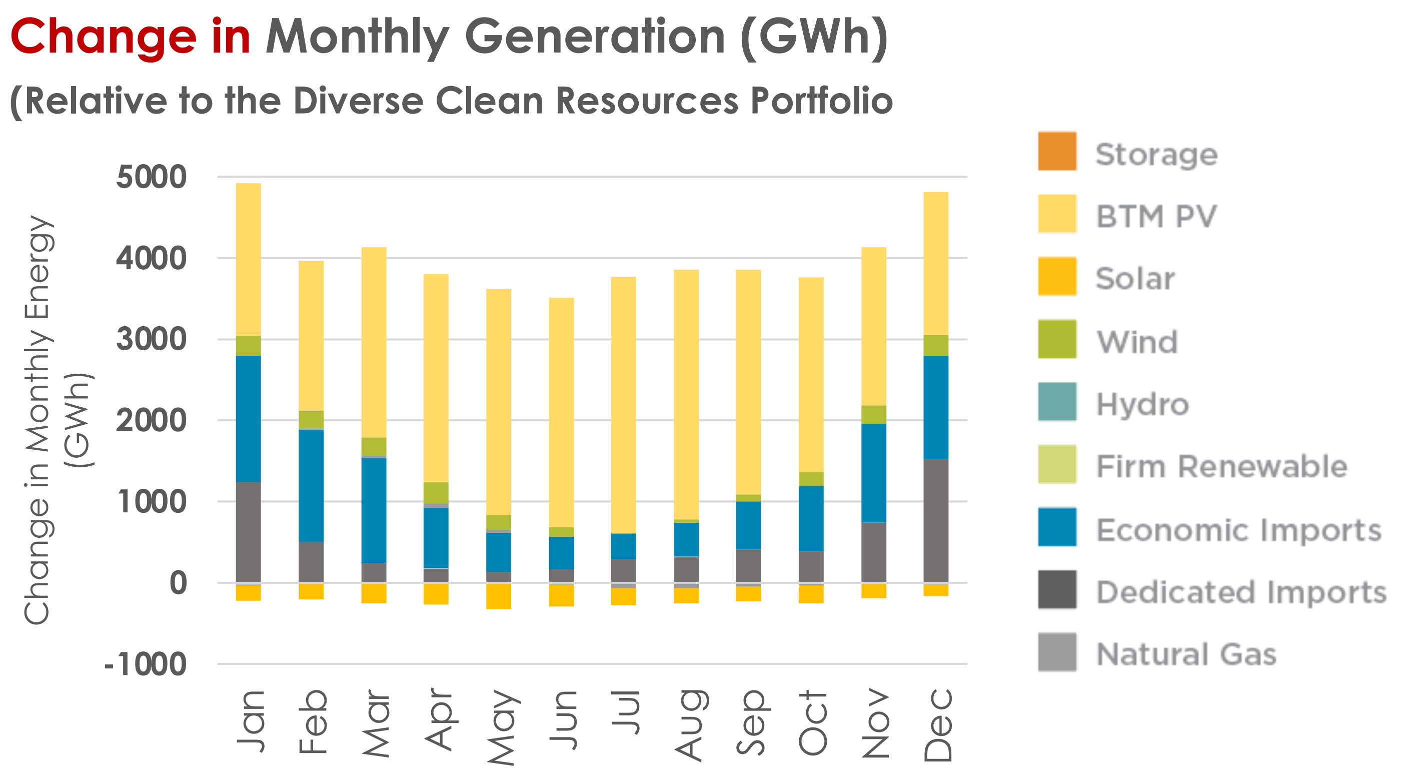
All three portfolios ~75-76% RPS, ~86% Clean



NOTE: Excludes 43 TWh of BTM solar (same value across portfolios) and storage resources (net negative generation)

Monthly energy mix by resource type





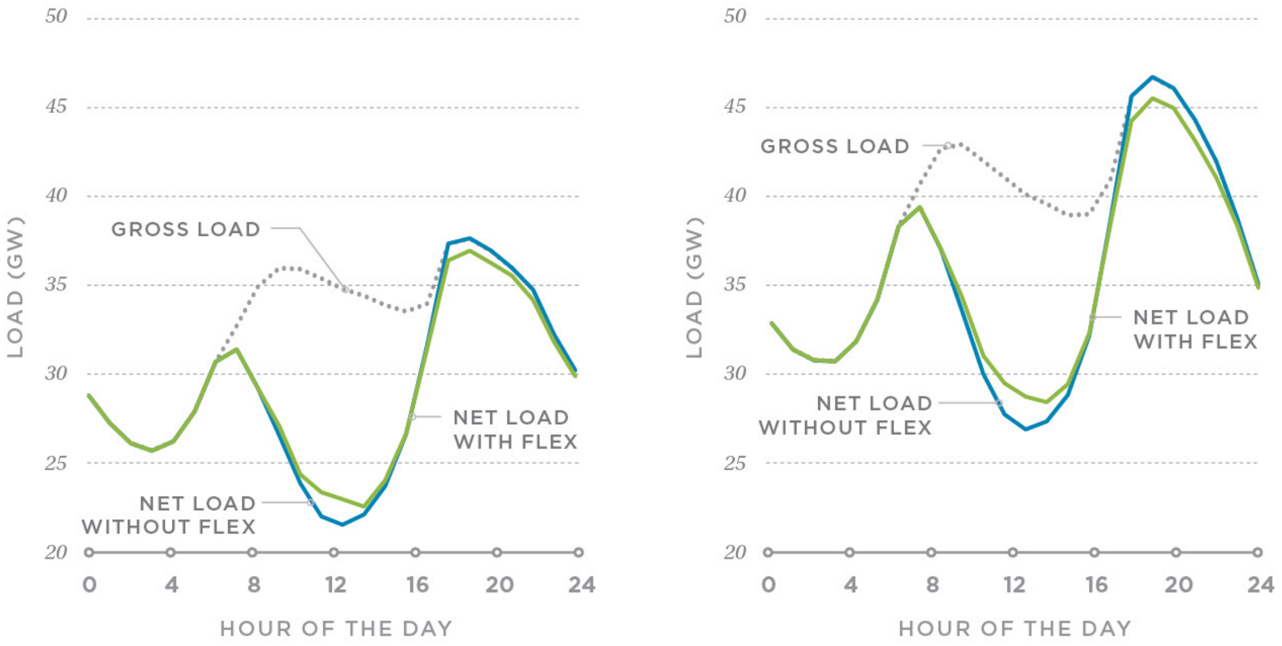
How does demand flexibility mitigate winter load increases due to electrification?

Average Flexible Load Parameters in High Electrification portfolio

RESOURCE TYPE	DAILY PEAK SHIFT MW	DAILY ENERGY MWH
EV Charging	6,250	12,500
HVAC	7,500	15,000
Industrial Processes	1,388	2,775
Pumping Load	465	930
Total	**15,603**	**31,205**

The demand sensitivity assumed up to 20% of newly electrified loads are flexible; other flexible loads informed by the LBNL demand response study phase 3 report.

The load shifting dampens the average hourly load increases due to electrification.

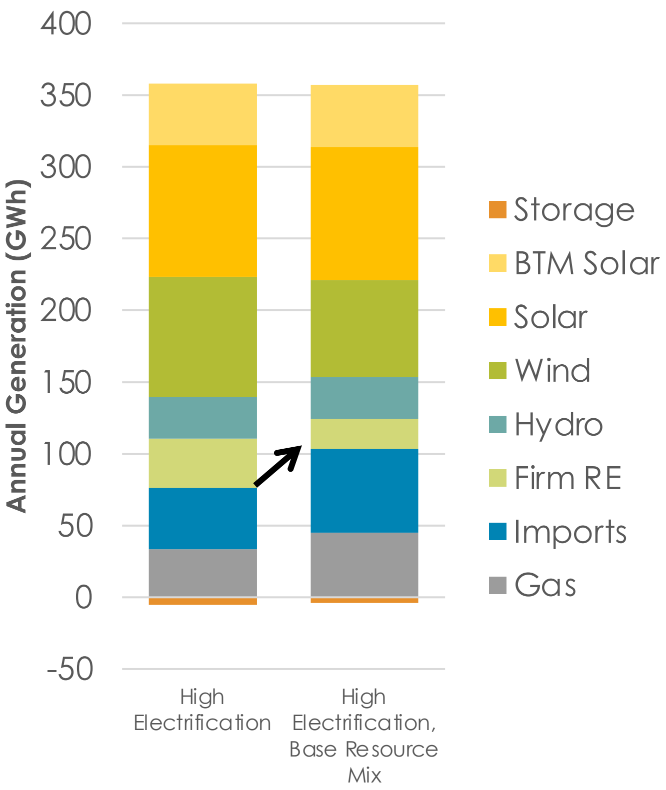


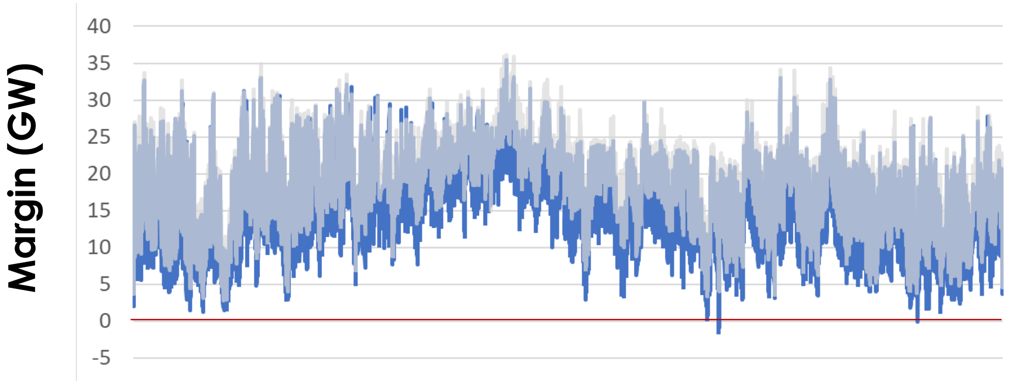
Average Load by Hour in December for Base Case (left frame) and High Electrification Load (right frame) with and without demand flexibility (net load is gross load minus BTM solar)

What if increased electrification occurs, but it is not planned for?

Base Case resource mix under a high electrification load

- No unserved energy in California when the Base Case resource mix is stressed under high electrification assumptions
- Decreased renewable share:
  78% → 71% Clean
  75% → 65% RPS
- Increased reliance on imports and in-state gas (+36% annually)
- 18% reduction in average margin, 3 hours below 0 (reliance on economic imports)





	High Elect. Portfolio	High Elect. Base Portfolio
Max Gas + Econ Imports (MW)	18,175	21,466
Avg Margin	18,127	14,952
Minimum Margin	2,813	-1,467
Hours with negative margin	3	0
Hours < 1000 MW margin	9	0

single weather year results

Appendix V

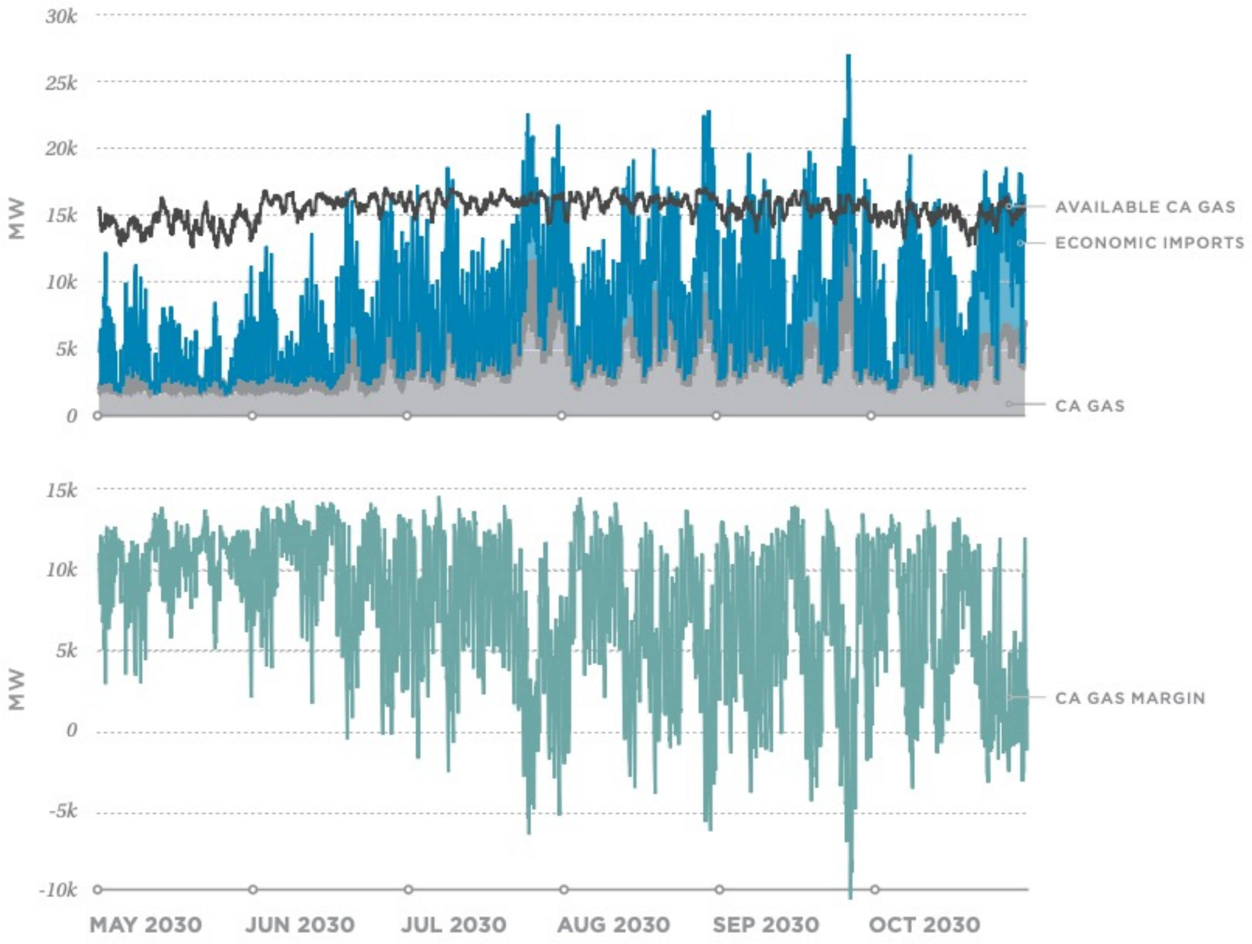
Combined Stressor Sensitivity Results

Combined stressor sensitivity

- In-state natural gas retirements
- Limited imports of 13 GW
- Hydro consistent with drought conditions (10th percentile of monthly available energy)
- Coal retirements across the WECC
- Summer load consistent with 20 different weather years

Loss of Load Hours by Month and Hour of Day

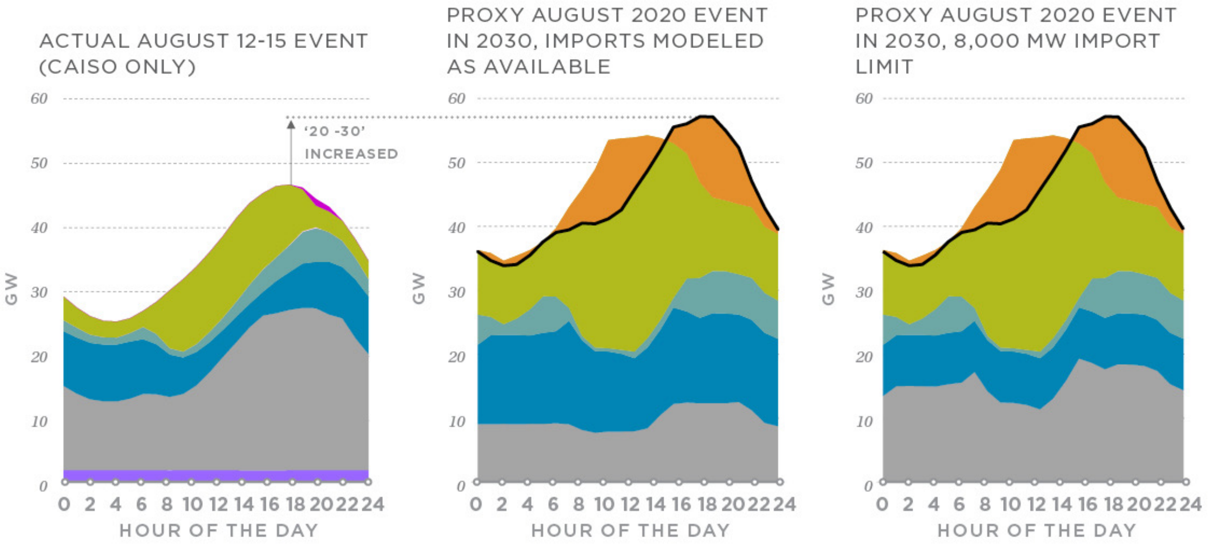
	HOUR OF DAY																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	TOTAL
MAY																									0
JUNE																									0
JULY																		1	1	1					3
AUGUST																1	1	1	1	1	1				6
SEPTEMBER												1			1	1	2	3	3	2	2				15
OCTOBER																									0
TOTAL												1			1	2	3	5	5	4	3				24

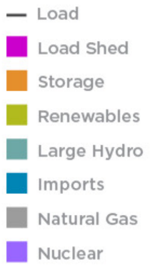


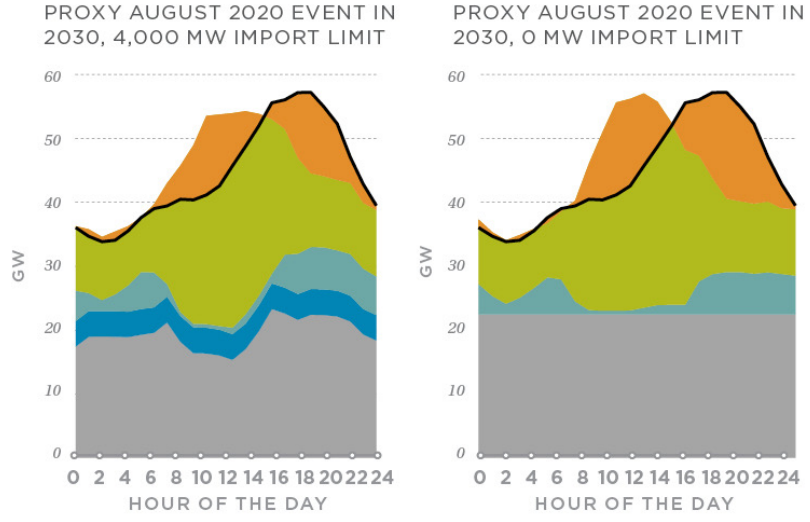
← **Extreme peak (worst day across 20-weather years) see next slide**

Proxy August 2020 Event

- Due to data limitations, did not perform a direct production cost simulation analysis of the 2030 power system against the August 2020 weather data.
- 2017-weather year load to be a sufficient proxy for understanding the impacts of August 2020 conditions on a future power system.
- Evaluated a 2030 event with a CAISO peak evening net-demand of 57,163 MW, which is 22% higher than the actual August 2020
- Tested three different import levels: with a 8,000 MW, 4,000 MW, and 0 MW import limit.







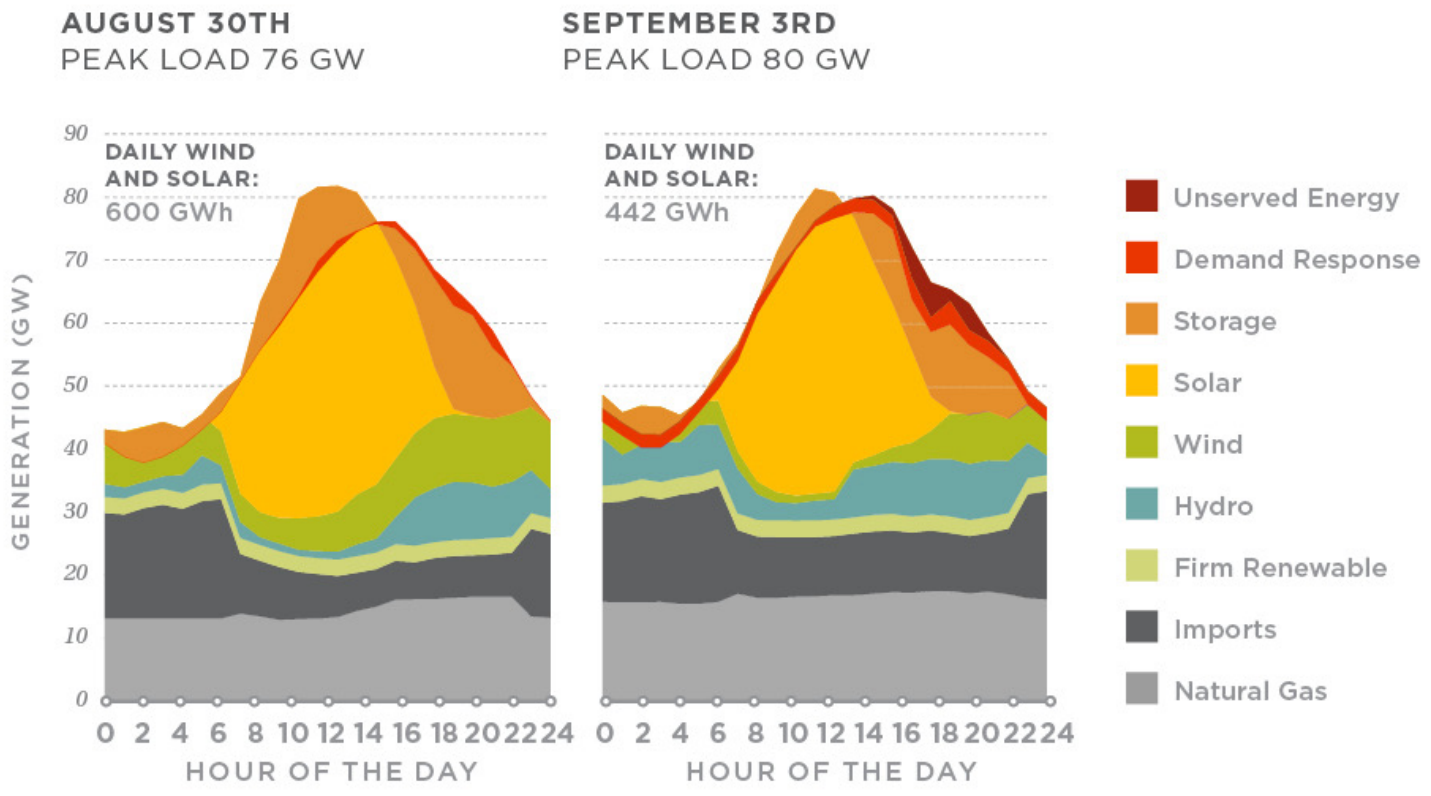
Actual August 2020 Load Event (left frame) versus Proxy August 2020 Event for 2030 (central and right frames)

Extreme Peak Day

- Weather Year 9/3/2017
- 25% higher than average peak loads occurring in September.
- Unserved energy with relatively low renewable availability, natural gas retirements, and an import limit.

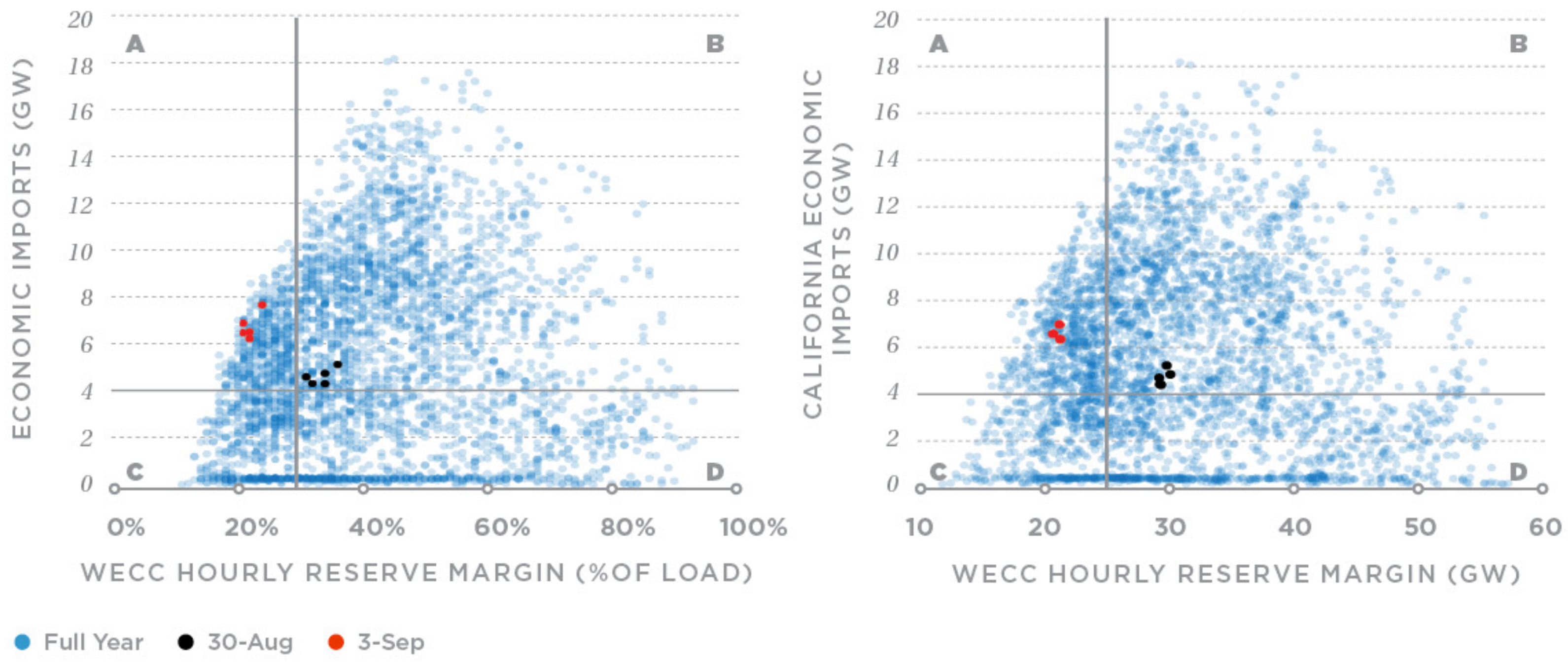
But…

- Battery storage systems are energy limited due to relatively low solar production
- If import restriction was removed mid-day, enough surplus energy in the West to charge batteries in anticipation of peak load



Sampled Extreme Peak Day with Multiple System Stressors and Unserved Energy

Extreme peak days do align with relatively low WECC reserve margin, but surplus capacity is still available



Hourly California Imports versus WECC Hourly Reserve Margin in the Base Case Portfolio, Multiple Stressors Sensitivity