2023 Proposed PSP & 2024-2025 TPP

Resolve Modeling Results

October 5, 2023

California Public
Utilities Commission

Background

Contents

Types of Portfolios Considered in IRP

- There are at least three types of portfolios that are analyzed in IRP.
- They each have a distinct purpose but are not mutually exclusive and can be combined to some degree depending on use case.

	1. Least Cost Optimized	2. LSE Plans	3. Resource Limitation
Description	Show the **least cost resource mix** for meeting state goals over the planning horizon	Faithfully **represent how the CPUC-jurisdictional LSEs planned in 2022** to meet their share of state goals over the planning horizon, potentially amending the portfolio as needed when LSEs plans are insufficient	Reflect **the range of resources we may expect to get developed** over the planning horizon as we seek to achieve our GHG and reliability goals
Purpose	Identify the cost-optimal trajectory for meeting state goals and serve as a reference point when evaluating LSE plans and future procurement needs	Illustrate how LSEs would collectively procure to meet state goals, evaluate the effectiveness of LSE planning, and identify those resource types that are of interest to LSEs	Represent the most realistic pathway to meeting state goals based on known real world constraints and reasonable resource growth trajectories
Other Considerations	Resources selected later in the planning horizon may be most relevant to decisionmakers, when constraints and trajectories are less certain and the CPUC has more ability to influence procurement	The extent to which this serves as the basis for a PSP depends in part on how much divergence there is between this portfolio and portfolios developed under use cases #1 and #3	Resource build limits and other modeling restrictions may be most appropriate earlier in the planning horizon when constraints and trajectories are more certain. Sensitivity scenarios can further explore a range of potential futures

Context: Overview of Preferred System Plan (PSP) Analysis Categories

- The table below includes the multiple analyses categories supporting PSP development
- The names are used consistently throughout this deck, as well as the PSP Reliability & Emissions Analysis Slide Deck. More detailed information is available in the corresponding sections referenced in the table.

Analysis Name	Description	Model(s) Used	Use Case(s)	PSP Slide Deck (Section Name)
Baseline-Only	Determine current reliability situation based on A) planned retirements and B) baseline existing and in-development resources coming online between 2024-2028	SERVM	Inform Baseline + Ordered Procurement analysis	2023 PSP Reliability and Emissions Analysis Slides (Reliability Analysis – Baseline-Only)
Baseline + Ordered Procurement	Estimate sufficiency of the MTR order after analyzing MTR incremental capacity in the 2023 PSP baseline	SERVM	Inform 2023 PSP development, determine need for additional procurement action, and comparison to SB 846 and CAISO's 2023 Summer Assessment	2023 PSP Reliability and Emissions Analysis Slides (Reliability Analysis – Baseline + Ordered Procurement)
Baseline + LSE Plans	Examine the reliability and emissions of aggregated LSE plans	SERVM	Reliability and emissions analysis to inform the use of RESOLVE to develop potential PSP portfolios	2023 PSP Reliability and Emissions Analysis Slides (Reliability & Emissions Analysis – Baseline + LSE Plans)
Potential PSP Portfolios	RESOLVE portfolios simulated in SERVM to examine reliability and GHG emissions		Decision-making for 2023 PSP and 2024-25 TPP	2023 PSP Reliability and Emissions Analysis Slides (Reliability & Emissions Analysis – Potential PSP Portfolios)
Core Cases	*Potential PSP cases optimized with 11/1/2022 LSE Plans as minimum build constraint*	*RESOLVE SERVM*	*As above*	*2023 PSP 2024-25 TPP Analysis (25 MMT Core Case; 30 MMT Core Case)*
Least-Cost Cases	*Potential PSP Cases optimized to least-cost without 11/1/2022 LSE Plans*	*RESOLVE SERVM*	*As above*	*2023 PSP 2024-25 TPP Analysis (25 MMT Least-Cost; 30 MMT Least-Cost)*
Sensitivity Cases	*Test changes to portfolio results to least-cost cases, using alternative assumptions for key variables*	*RESOLVE*	*As above*	*2023 PSP 2024-25 TPP Analysis (multiple sections)*

Key RESOLVE Model Updates

Previous IRP Filings and Requirements

- The 2021 Preferred System Plan (PSP) was adopted in D.22-02-004 in February 2022 and informed LSE IRP filings
  - The 2021 PSP used the 2020 IEPR
- The 2021 PSP was updated in July 2022 to reflect the latest IEPR (2021 IEPR)
  - The updated 2021 PSP was used to produce the LSE filing requirement
- LSEs submitted their individual IRPs to satisfy filing requirements in November 2022
- The 2021 PSP was used to inform transmission upgrade needs, which were reflected in the 23-24 Transmission Planning Process (TPP)
  - The 23-24 TPP was transmitted to CAISO in February 2023

Modeling Updates Since 23-24 TPP portfolios

- Since the 23-24 TPP cases were transmitted to CAISO in February 2023, a number of modeling input and assumptions updates have been made
- These updates are summarized in the Inputs and Assumptions (I&A) document available on the IRP's "2022-2023 IRP Cycle Events and Materials" page
- Key updates include:
  - Additional baseline and in-development resources have been added
  - Cost updates to reflect latest 2023 NREL Annual Technology Baseline (ATB) cost estimates
  - Updates to resource potential based on updated techno-economic screen and environmental screen
  - Updates to PRM accounting and resource accreditation
  - Updates to day sampling from 3 weather years to sampling from SERVM's 23-weather years dataset, including updates to load and generation profiles
  - Updates to resource-transmission representation and transmission deliverability upgrades based on summer 2023 CAISO transmission data
  - Updates of the resource builds in the non-CAISO external zones using 2032 WECC ADS and publicly available IRPs to reflect all BAAs meeting their respective policy targets
  - Modeling and data updates for modeling load shifting resources
  - Emerging technologies were added as candidate resources (to be explored in forthcoming sensitivity scenarios)

Resource Cost Updates

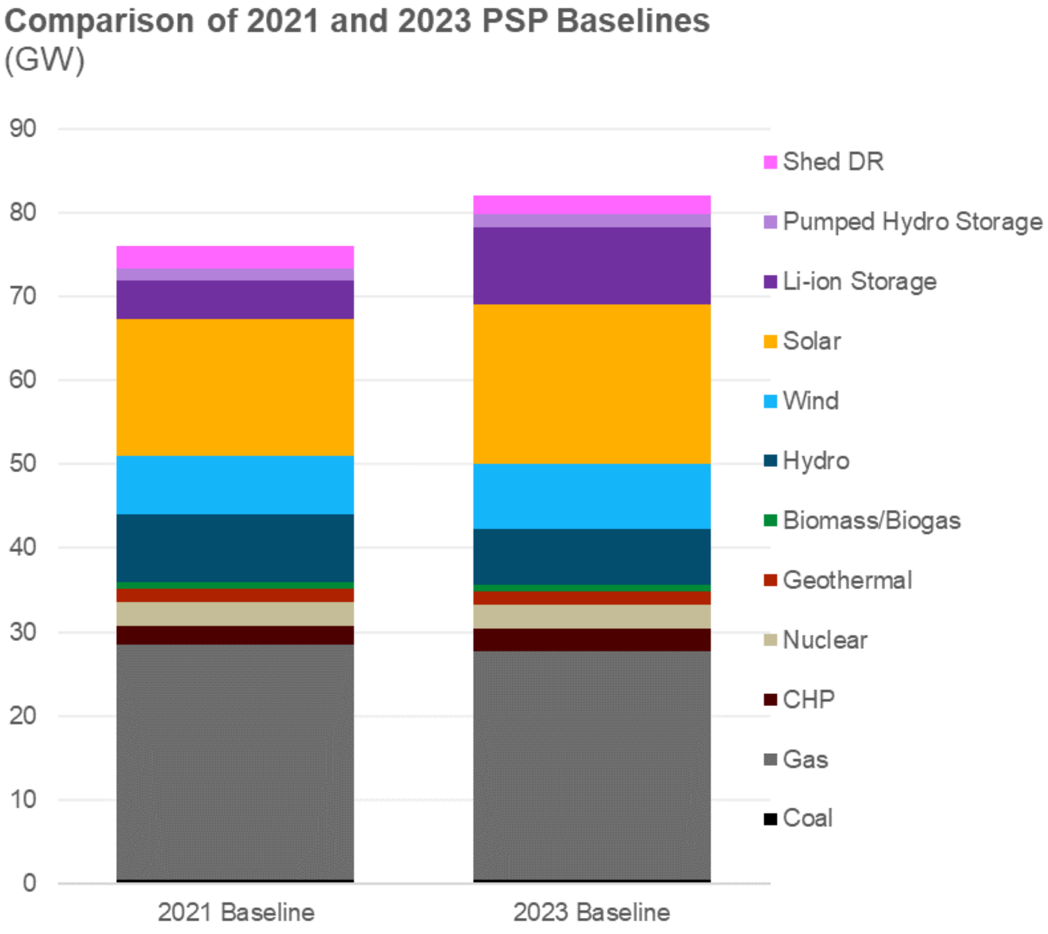
Additional updates following the September 2022 MAG Webinar

- **Updated cost inputs to NREL 2023 Annual Technology Baseline (ATB)**
- **Updated financing costs to reflect current market conditions**
- **Incorporated new/expanded Inflation Reduction Act (IRA) tax credits**
  - Extensions of existing tax incentives to all zero-carbon technologies **through 2048**[1]
  - IRA "Bonus" incentives assumed for all technologies, where applicable
  - Production Tax Credit (PTC) is available to candidate solar resources and assumed to be selected in lieu of the Investment Tax Credit (ITC)
  - ITC is available to all storage technologies (Li-ion Batteries, Pumped Hydro Storage, and emerging technologies)
  - PTC credits available for CCS, direct air capture (DAC), and hydrogen production (CCGT w/ CCS, Synthetic Natural Gas, Hydrogen) for projects beginning construction by 2032
- **Made additional cost modifications for solar PV, onshore wind, and Li-ion batteries**
  - These technologies have been disproportionately affected by commodity price increases, supply chain disruptions, and surging demand
  - Modifications to the overnight capital cost trajectories were made for all three technologies to either **slow or delay** the cost decline over time, to better reflect current market conditions

[1] *Pursuant to IRA guidelines, 100% of the tax credit value can be monetized by eligible projects until the U.S. achieves 75% reduction in GHG emissions, relative to 2022 levels. This is assumed to occur in 2045, which then triggers a 3-year stepdown of incentives.*

Baseline and In-Development Resource Updates

- The resource baseline includes both online and in-development resources, and is an input to both the RESOLVE and SERVM models
  - Online: Resources that are already built and operating, net of expected retirements
  - In-development: Resources with approved contracts, or resources already under construction, which have made sufficient progress towards an expected online date
- Updates to baseline and in-development resources are informed by CAISO Master File and November 2022 LSE Filings
  - For the 2023 PSP, baseline capacity increased from ~76 GW to ~82 GW, primarily reflecting the addition of new wind, solar, and storage resources



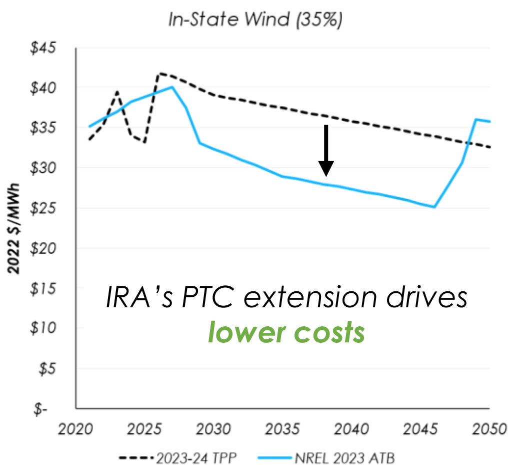
Note: while installed hydro generating capacity has not changed, the counting convention has changed in RESOLVE (to align with SERVM), showing lower GW in this chart.

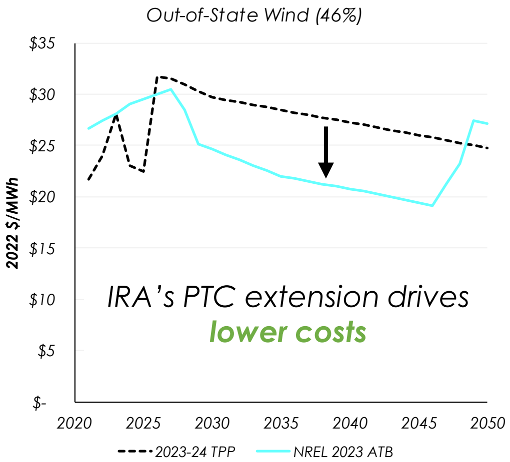
Updates to RESOLVE and SERVM Generating Units

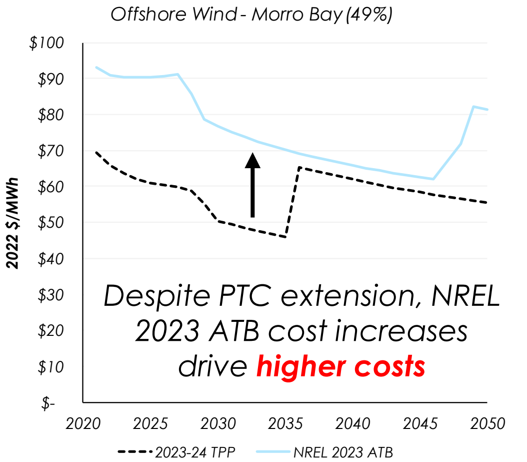
- Staff updated its Baseline resource list, which involved reconciling data from multiple sources (CAISO, WECC, EIA, CPUC, CEC) and developing a common list of units for both SERVM and RESOLVE models.
  - CAISO Master Generating Capability (MGC) List as of 1/2023 (updated online status of in development resources and reconciled with newly online units)
  - 11/1/2022 LSE IRP compliance filings
  - 1/2023 NQC List
  - WECC Anchor Dataset 2032
  - Unit operating data updated from 2018$ to 2022$ from latest CAISO MasterFile
  - Once-Through-Cooling (OTC) steam units assumed to go offline by 2023 and DCPP assumed to go offline in 2024/25, and no further retirements
- Cogen/Biomass/Biogas/Geothermal operating constraints: monthly capmax and capmin were calculated to reflect historical operations and minimum dispatch observed in the CAISO bidding database
  - Average production during peak managed demand used as capmax (equivalent to resource NQC)
  - The Max of Day Ahead Market scheduled and Real Time Market bid level was used to determine capmin
  - Cold and hot startup profiles updated
  - Imposing monthly capmax and capmin for Cogen/Geothermal/Biomass/Biogas units distorted heat rate curves. Corrected by using a single point heat rate curve matching the average heat rate from CAISO Masterfile data.

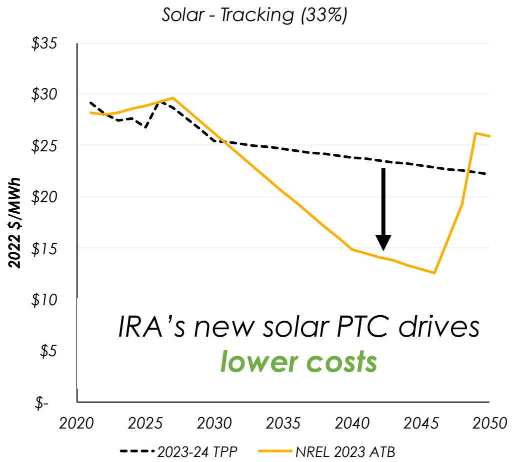
Resource Cost Comparison

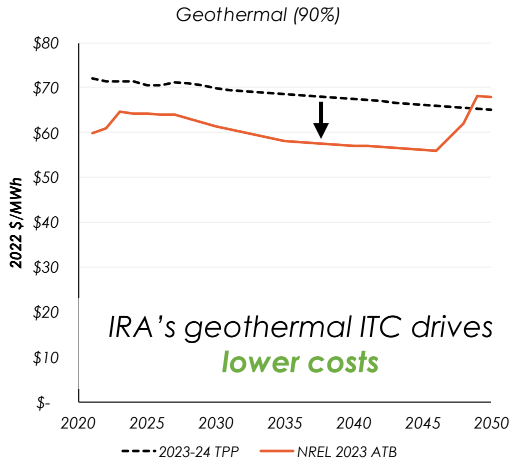
(LCOE or Levelized Fixed Cost), 23-24 TPP cases vs. 2023 PSP/2024-2025 TPP cases

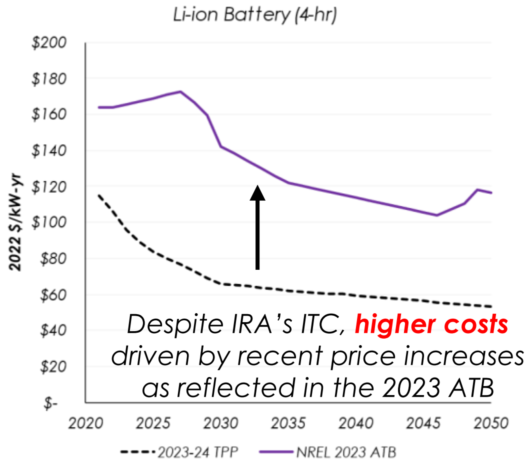








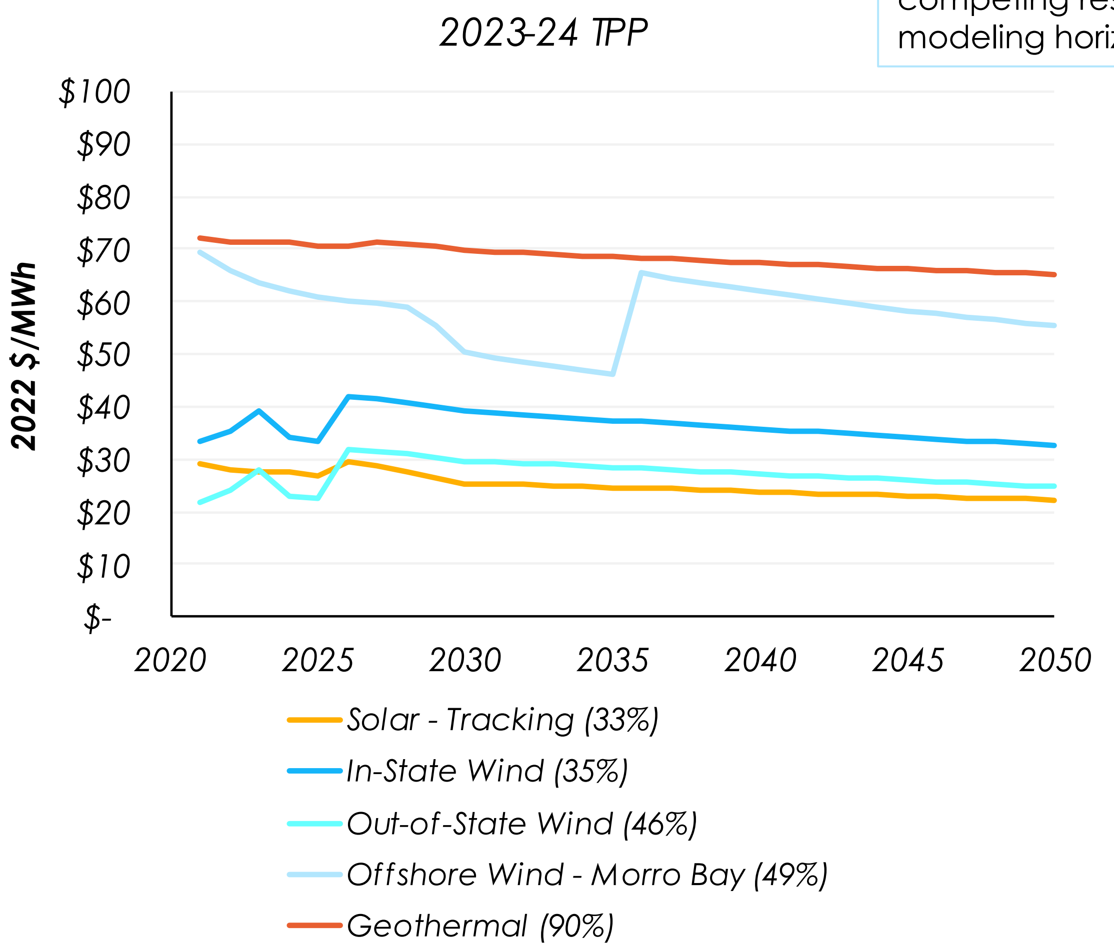


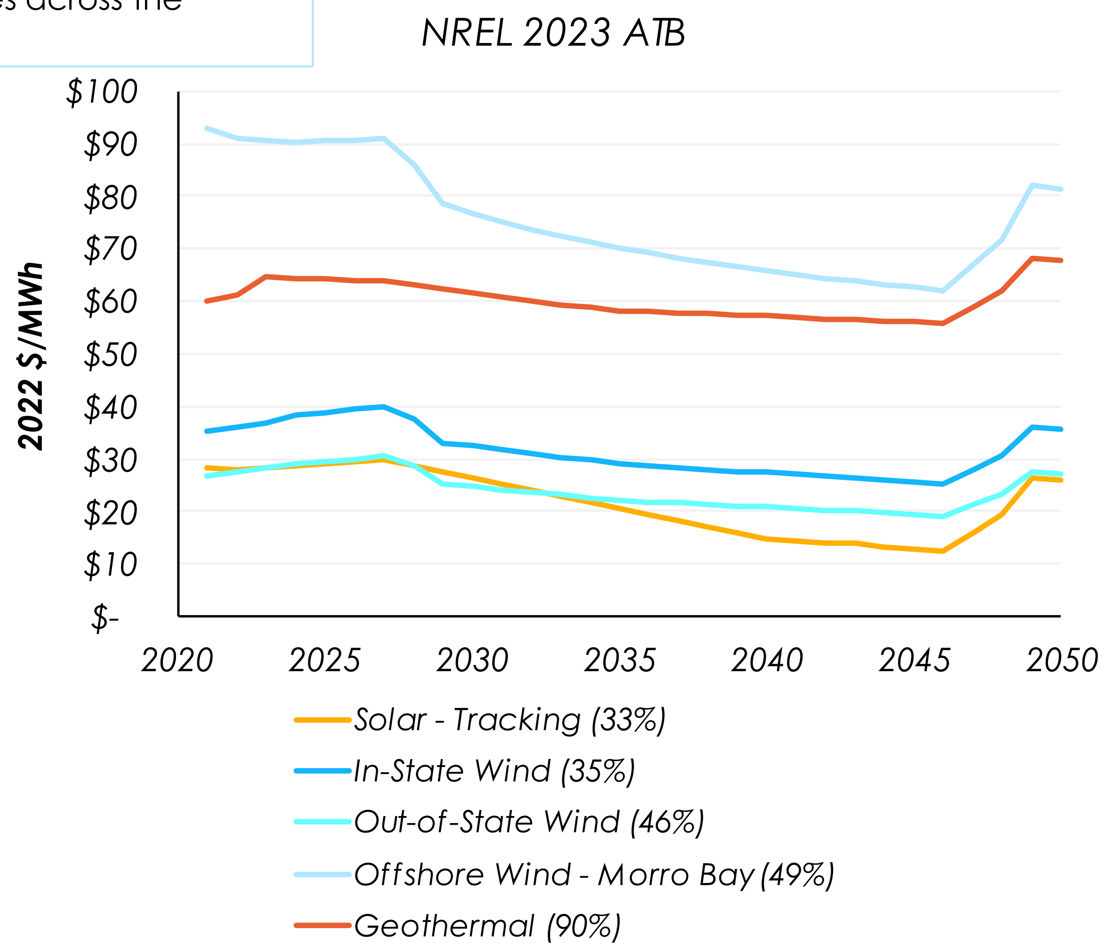


2023-24 TPP vs. NREL 2023 ATB

LCOE Comparison

The costs of offshore wind have gotten significantly higher relative to its competing resources across the modeling horizon





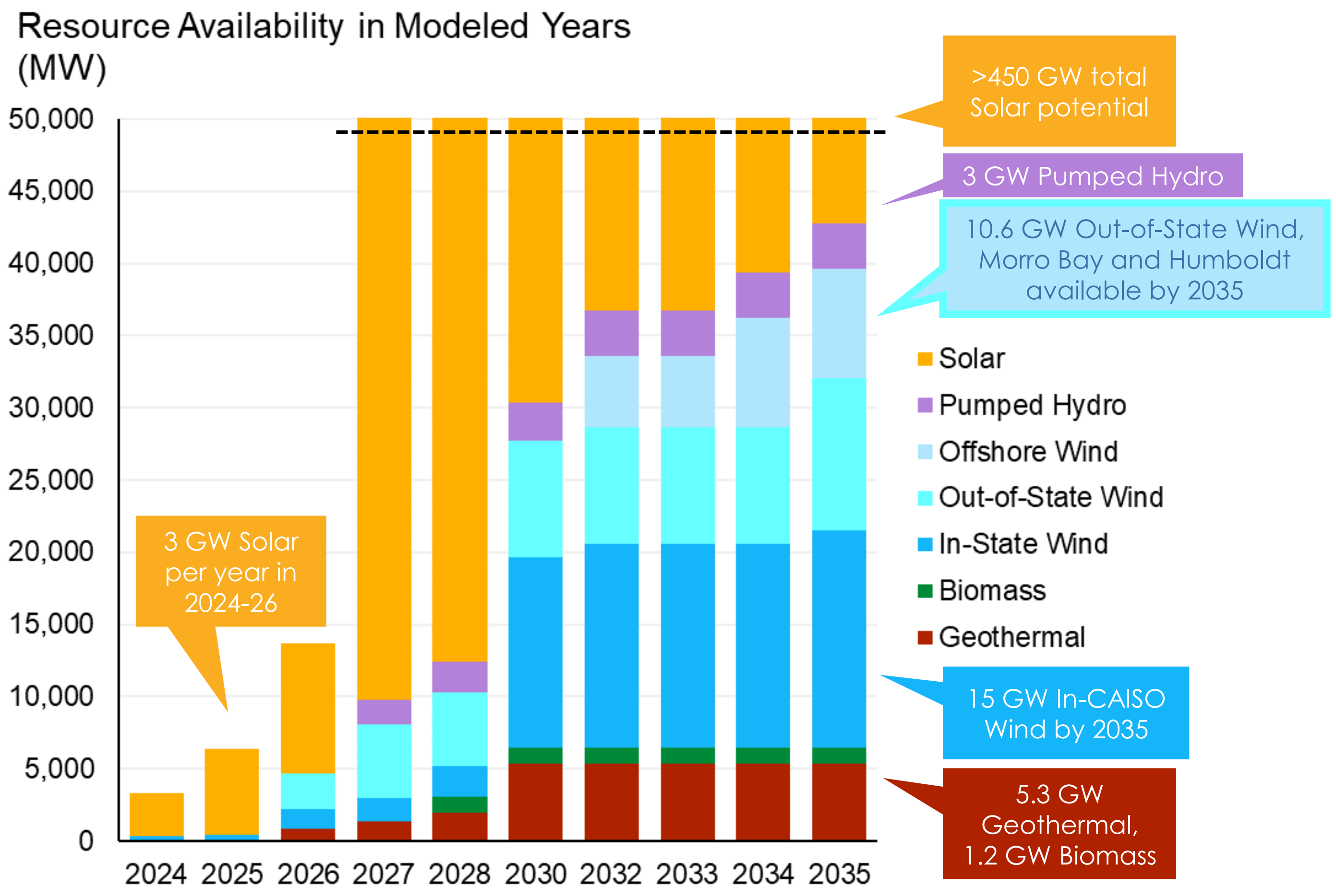
Resource Potential Updates

- Offshore wind resource potential was increased from the "Low" to "High" potential values from the June 2022 AB 525 NREL presentation[1]
- Updated near-term annual build-out limits for solar to constrain the model from building more solar in the near-term than is feasible – update due to IRA
- Updated near-term build limits for land-based instate wind and out-of-state wind
- Techno-economic screen uses updated capacity factor thresholds for commercial viability of candidate wind resources
- Environmental land use cases are based on the current draft CEC "Core" scenario land use screen[2]
- Assumptions on the first available online year for long-lead time resources have been updated to reflect best available information

(1) *CEC Docket 17-MISC-01. https://efiling.energy.ca.gov/GetDocument.aspx?tn=243707&DocumentContentId=77539*
(2) *https://www.energy.ca.gov/event/workshop/2023-03/commissioner-workshop-land-use-screens*

Default Resource Availability

- Resource availability is constrained in the long-run by available land, but is also constrained in the near-term by transmission (either insufficient interconnection queue MW or time delays for major Tx upgrades)
  - **Solar** and small amount of **in-state wind** are available before 2026
  - **Out-of-state wind** and **geothermal** are available starting 2026
  - **Biomass** is available starting 2028
  - **Offshore wind** is available from 2032



Staggered availabilities for Geothermal, In-State Wind, Out-of-State Wind, and Pumped Hydro in late 2020s reflecting commercial interest (via interconnection queues), non-CAISO transmission project lead-times, and LLT resource availability

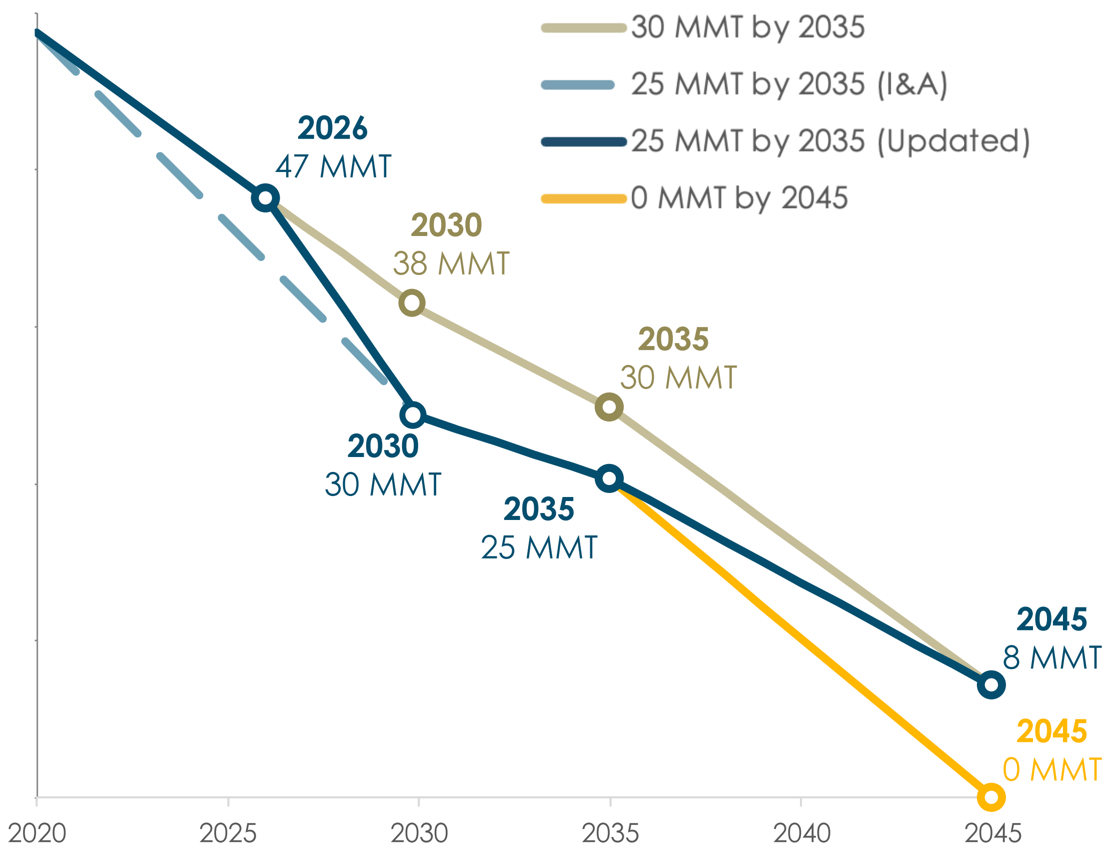
Other Key Model Inputs

- Updated the way transmission constraints are modeled
  - Transmission constraints are informed by CAISO's representation of the transmission system in its TPP modeling and the associated Transmission Deliverability Whitepaper
  - Resource potentials are mapped to substations, which are grouped into transmission clusters with their own unique constraints
- Fuel prices for natural gas, coal, uranium, and biomass have been updated to reflect the latest available forecasts from CEC IEPR, NREL Annual Energy Outlook, and NREL Biomass Technology Report
- Modeling now incorporates SB 1020, which requires LSEs to achieve a higher clean retail sales target of 90% by 2035, 95% by 2040 and 100% by 2045
  - In addition to RPS eligible resources, large hydro and nuclear are also eligible

GHG Planning Target Trajectories

- Changes from previous cycle:
  - GHG targets have been renamed but *remain the same by 2030 & 2035*:
    - "30 MMT by 2030" → "25 MMT by 2035"
    - "38 MMT by 2030" → "30 MMT by 2035"
  - 2045 target updated to 8 MMT to reflect 2022 CARB Scoping Plan[1]
  - Baseline historical electric sector emissions updated to 59.5 MMT for 2020, based on CA GHG Inventory[2]
- GHG trajectory updated *through 2026* from 2023 PSP draft I&A[3] to reflect near-term resource availability constraints

CA-wide GHG Emissions Planning Target [4]
million metric tons



1 https://ww2.arb.ca.gov/sites/default/files/2022-11/2022-sp-PATHWAYS-data-E3.xlsx
2 https://ww2.arb.ca.gov/sites/default/files/classic/cc/inventory/ghg_inventory_by_scopingplan_00-20.xlsx
3 https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/integrated-resource-plan-and-long-term-procurement-plan-irp-ltpp/2023-irp-cycle-events-and-materials/draft_2023_i_and_a.pdf
4 CAISO-wide target is 81% of CA-wide target and includes emissions from BTM CHP equivalent to 4-5 MMT/year

Reliability Need and Resource Contributions

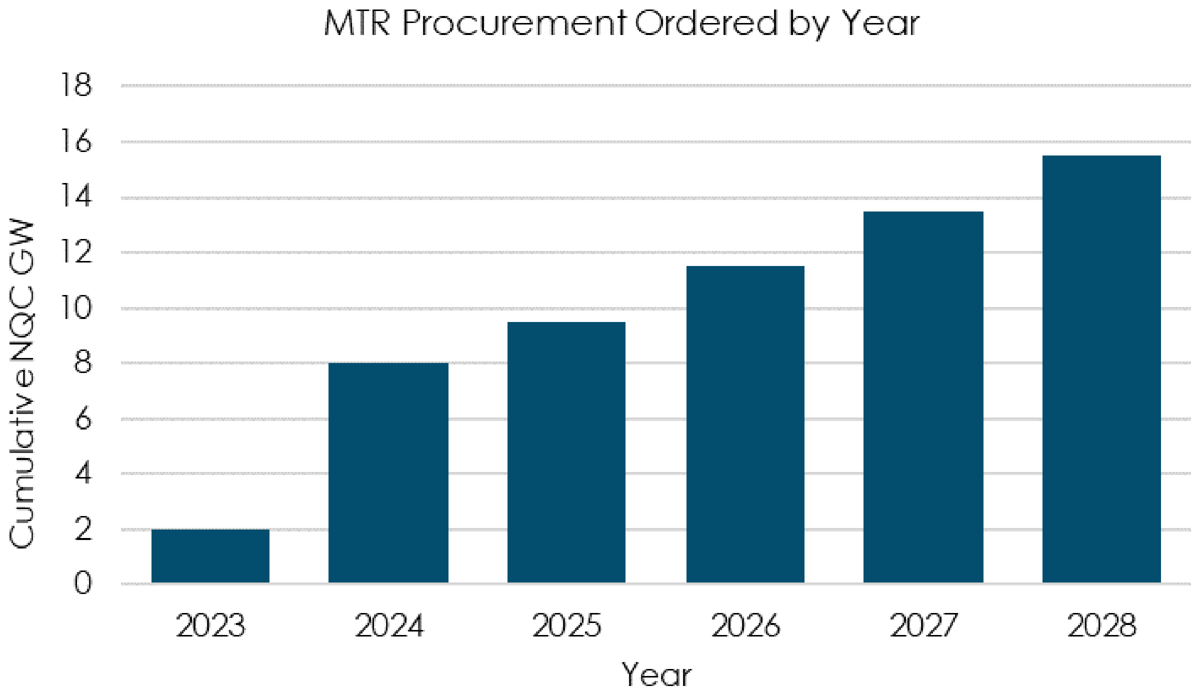
1. **Updating RESOLVE's total reliability need (Planning Reserve Margin, PRM)**
   - Switch from ICAP (Installed capacity) to PCAP (Perfect capacity) PRM
   - Update PRM to meet 0.1 days/year LOLE, based on SERVM analysis
   - Switch basis of PRM percentage from managed peak to gross peak
   - Perform additional calibration of the reliability need based on SERVM testing of portfolios
2. **Updating resource contributions to resource adequacy in RESOLVE**
   - Count all resources at their perfect capacity equivalent (Effective Load Carrying Capability, or ELCC) to be consistent with the PCAP PRM
   - Update resource ELCCs based on SERVM analysis
   - Move to a solar + storage ELCC surface to capture diversity benefits
     - Added new DR and Long-Duration Storage multipliers onto the storage dimension of the surface
   - Create new ELCC curves for in-state, out-of-state, and offshore wind

These updates better align RESOLVE + SERVM
to better ensure RESOLVE develops sufficiently reliable portfolios

Reflecting Mid-Term Reliability (MTR) Procurement Orders

- In June 2021 and February 2023, the CPUC ordered its jurisdictional in-CAISO LSEs to procure 15.5 GW NQC of new zero-emission resources from 2023 through 2028[1]

- MTR procurement ordered in each year is included as a requirement *(for new resource additions)* that RESOLVE must meet in addition to the PRM requirement *(for total resources online)*
  - Includes requirements for 1 GW each of firm generation and long-duration (at least 8-hr) storage
  - Resources are counted toward the NQC requirement using ELCCs derived from the MTR ELCC Studies[2,3], which are converted into de-vintaged values that RESOLVE can utilize

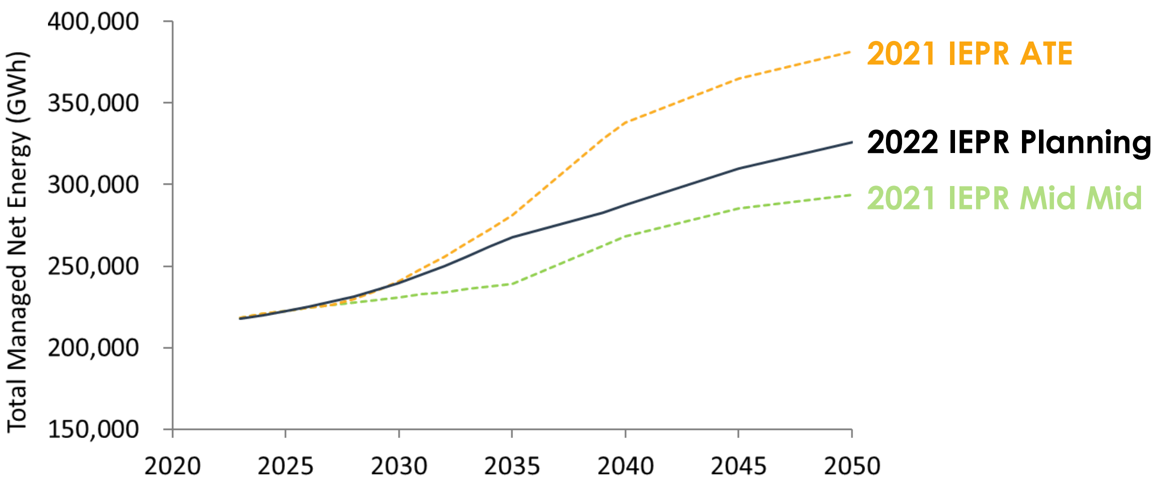


[1] D.21-06-035 and D.23-02-040
[2] Incremental ELCC Study for Mid-Term Reliability Procurement (Updated)
[3] Incremental ELCC Study for Mid-Term Reliability Procurement (January 2023 Update)

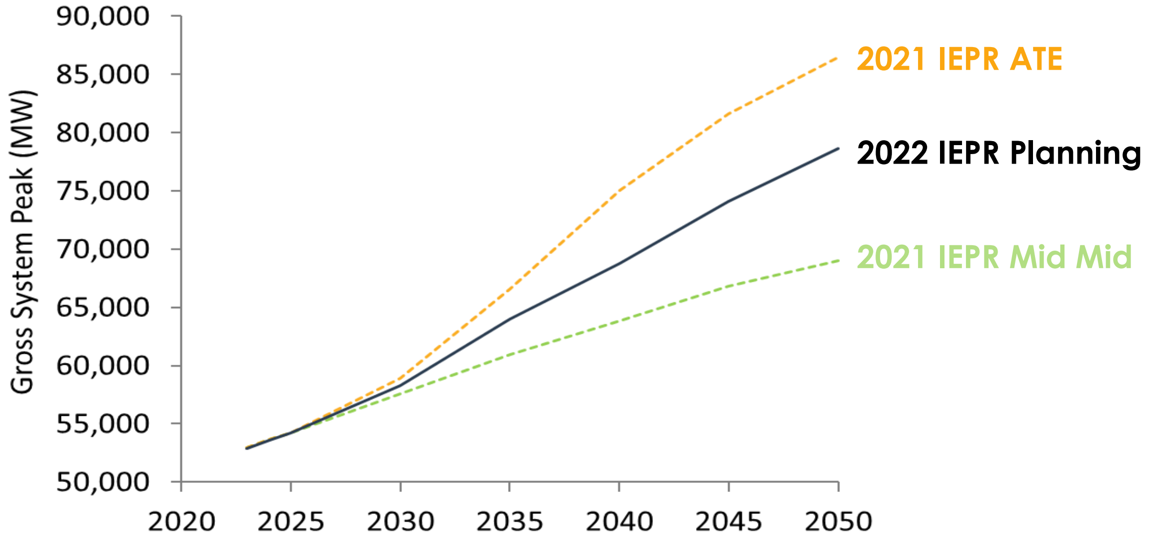
Loads Forecast Updates

- The PSP/TPP analysis in this current IRP cycle will use the CEC's 2022 Integrated Energy Policy Report (IEPR) Planning Scenario[1] for CAISO and non-CAISO California loads
- Relative to the 2021 IEPR Mid Mid, which had been used for 2022 LSE Filings, the 2022 IEPR Planning Scenario has higher retail sales and CAISO gross system peak
- Relative to the 2021ATE, which had been used for the 2023-2024 TPP, the 2022 IEPR Planning Scenario has lower retail sales and significantly lower CAISO gross system peak

CAISO Retail Sales



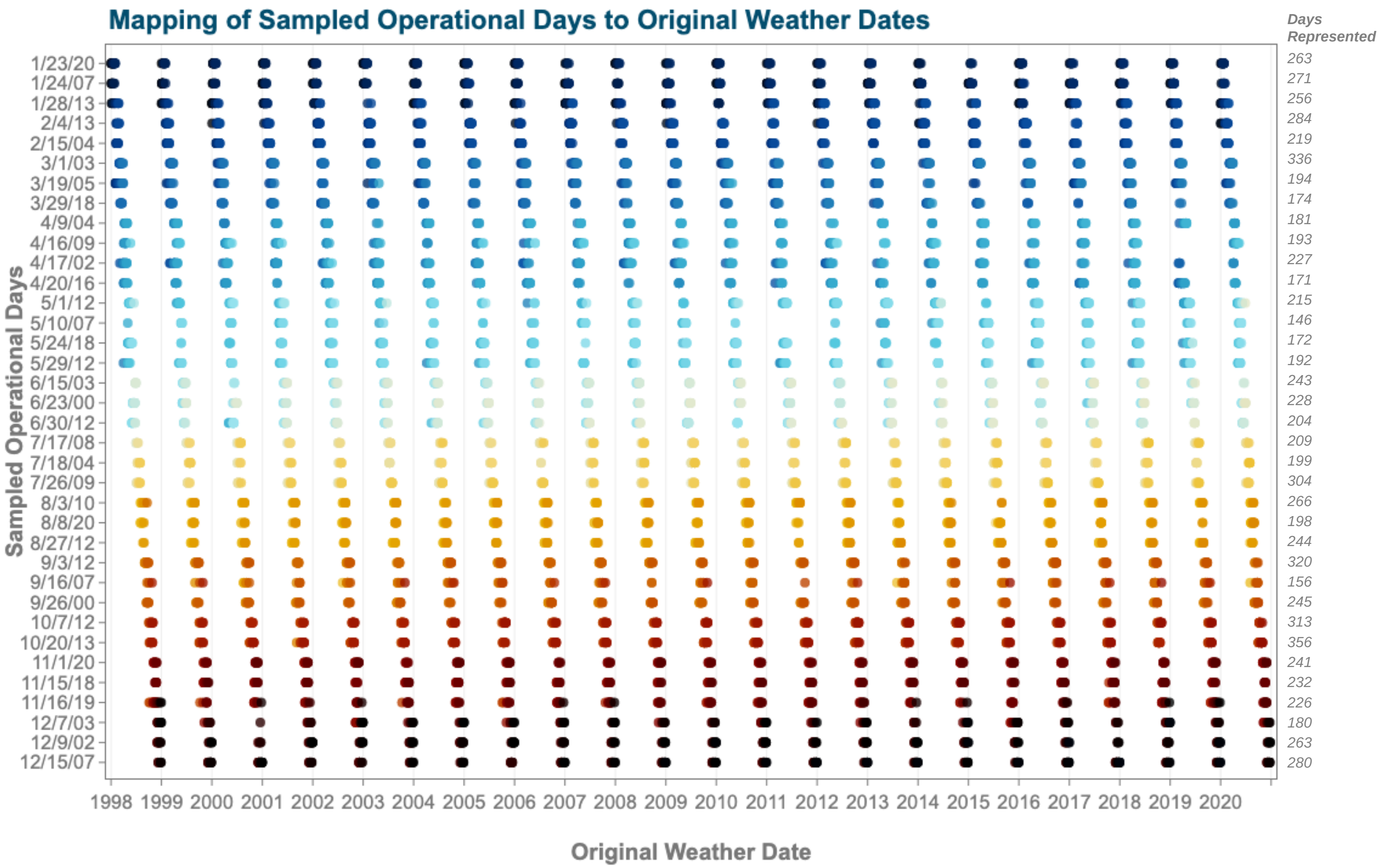
CAISO Gross System Peak



[1] *2022 IEPR Load:* https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report/2022-integrated-energy-policy-report-update-2

RESOLVE Sample Days

- RESOLVE's sampled days are updated from previous cycle, moving to **36** sample days
  - Sampled days sampled from 23 weather years of load, renewables & hydro generation profiles
  - Sampled resource generation profiles re-scaled to match capacity factors over 23 weather years
- To capture multi-day energy needs (e.g., for LDES), updated sampling also preserves chronological information on the **sequence** of sampled days



Demand Response (DR) Resources

Shed (or “conventional”) DR

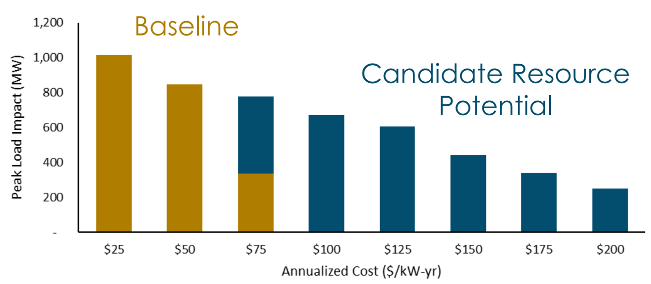
- Shed DR are loads that can be curtailed to provide resource adequacy
- Shed DR is available for selection in all RESOLVE model runs
- Baseline Shed DR available in 2035 has decreased (from 2,195 MW to 1,740 MW)

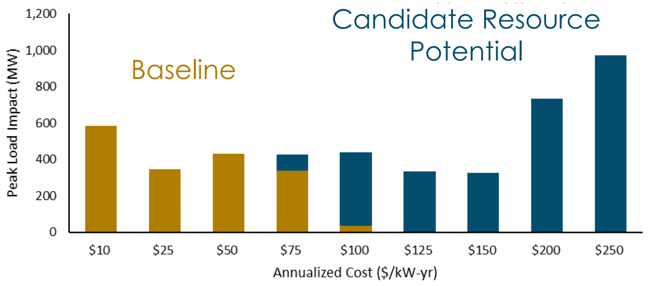
Shift DR

- Shift DR are loads that can be shifted between hours
- Shift DR is only available in sensitivity model runs
- A new Shift DR resource has been added with data inputs for hourly availability based on underlying load profiles
- Supply curve and hourly shift potential vary by technology

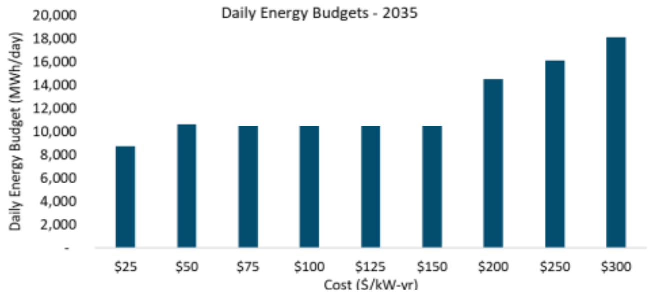
2035 Shed DR Supply Curve

Previous RESOLVE Inputs	Updated





2035 Shift DR Supply Curve



**Daily energy budget is the maximum amount of energy that can be shifted during the day. Shiftable load in a given hour depends on the underlying load profiles and technical constraints for each technology. Chart shows cumulative energy budget across price tranches.*

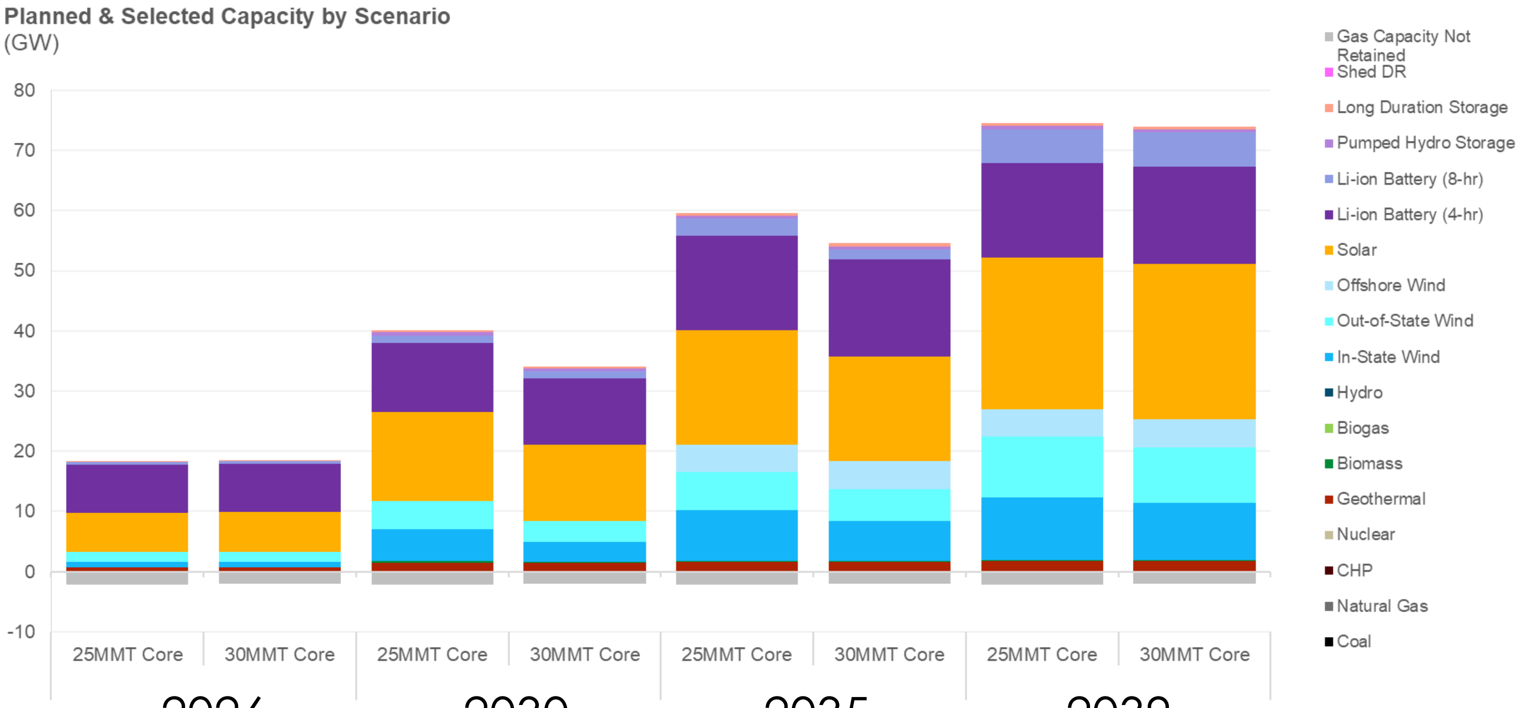
Summary of RESOLVE Results

Definitions of the Scenarios and Sensitivities

Cases	25 MMT by 2035	30 MMT by 2035	Sensitivity Modification
Core Cases: Cases optimized ***with 11/1/2022 LSE Plans*** as minimum build constraint **(Proposed TPP Base Case – 25 MMT by 2035)**	☑	☑	**N/A**
Least-Cost Cases: Cases optimized to least-cost ***without 11/1/2022 LSE Plans***	☑	☑	**N/A**
Least-Cost Sensitivity: Moderate Gas Retirements	☑		*Retires additional 4.1 GW by 2030, 4.5 GW by 2040*
Least-Cost Sensitivity: High Gas Retirements ***(Proposed TPP Sensitivity Case)***	☑		*Retires additional 3.1 GW by 2030, 12.1 GW by 2040*
Least-Cost Sensitivity: High Solar PV & Battery Costs	☑		*12% increase in Solar PV costs, 17% increase in battery costs*
Least-Cost Sensitivity: High Land-Based Wind Costs	☑		*7% increase in-state,12%-14% increase in out of state wind costs*
Least-Cost Sensitivity: High Geothermal & Biomass Costs	☑		*2x Geothermal and Biomass costs*
Least-Cost Sensitivity: Low Offshore Wind Costs	☑		*Uses 2022 vintage costs based on NREL CA-specific offshore wind costs (15% lower)*
Least-Cost Sensitivity: Significantly Reduced Land-Based Clean Resource Availability	☑		*Resource potentials reduced to: 1 GW of in-state wind, 2 GW of out-of-state wind, 1.8 GW Geo, 0.5 GW pumped hydro*
Least-Cost Sensitivity: Reduced Land-Based Clean Resource Availability	☑		*Resource potentials reduced to: 2 GW of in-state wind, 5 GW of out-of-state wind, 1.8 GW Geo, 0.5 GW pumped hydro*
Least-Cost Sensitivity: Low Offshore Wind Costs and Significantly Reduced Land-Based Clean Resource Availability	☑		*2022 vintage offshore wind costs; Resource potentials reduced to 1 GW of in-state wind, 2 GW of out-of-state wind, 1.8 GW Geo, 0.5 GW pumped hydro*
Least-Cost Sensitivity: Low Offshore Wind Costs and Reduced Land-Based Clean Resource Availability	☑		*2022 vintage offshore wind costs; Resource potentials reduced to 2 GW of in-state wind, 5 GW of out-of-state wind, 1.8 GW Geo, 0.5 GW pumped hydro*
Least-Cost Sensitivity: Low BTM PV	☑		*Uses the CEC IEPR 2022 Low BTM PV forecast*

25 MMT Core vs 30 MMT Core

- ***There are minimal cost impacts of reducing the GHG target trajectory*** from 30 MMT in 2035 to 25 MMT in 2035
  - Annual cost impact = ~$5-170M/yr
- The GHG emissions and portfolios in the 25 MMT and 30 MMT Core cases are most different in the 2030-2035 timeframe
  - 25MMT requires more GHG-free resource procurement in this timeframe
- By 2039, the GHG trajectories and resource portfolios converge

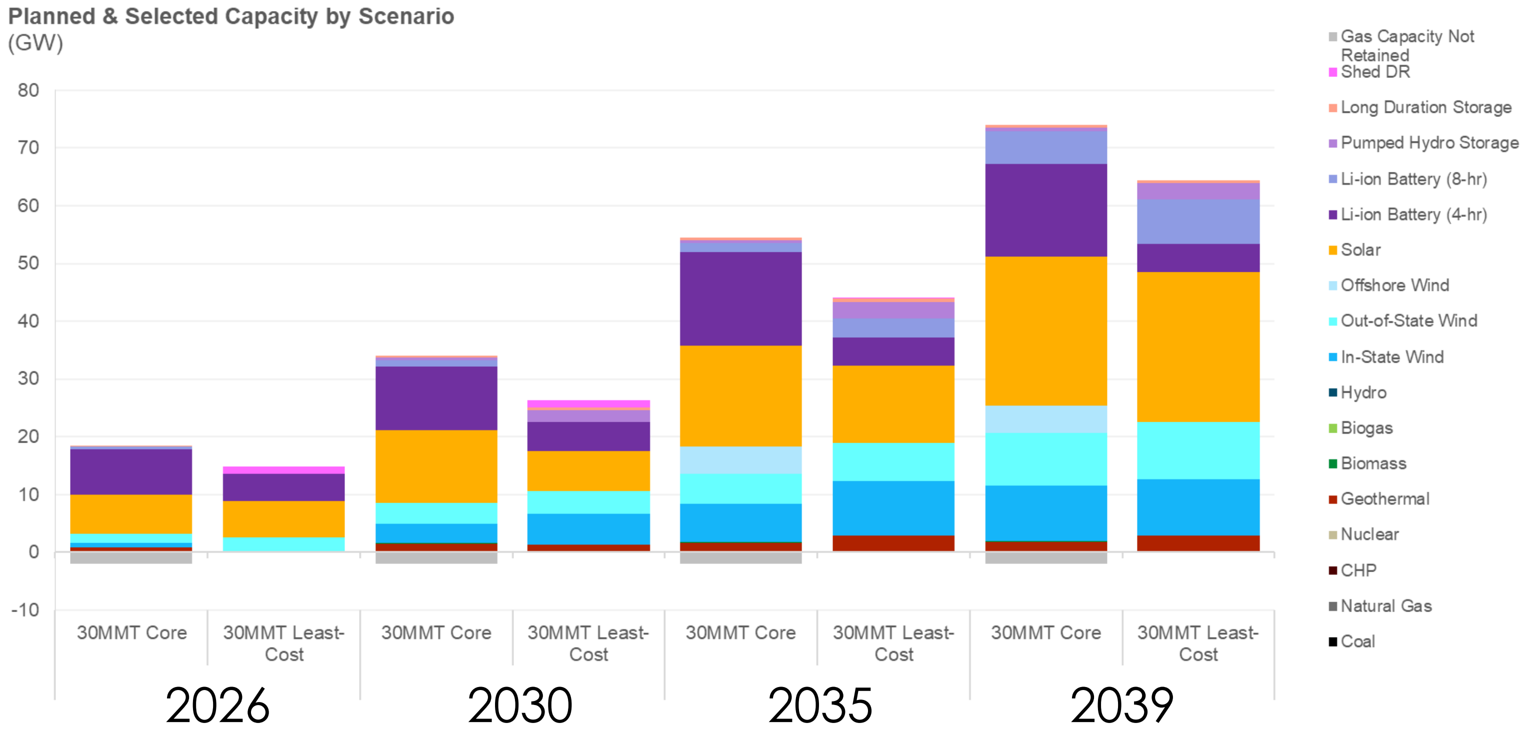


2026		2030		2035		2039	
$49,492	**-$5M**	**$51,986**	**-$56M**	**$56,317**	**-$168M**	**$59,128**	**-$125M**
Annual Costs ($MM/yr)							

NPV of Total Resource Cost ($MM in 2022 Dollar Year, 2024-2065)	
25 MMT Core	$940,541
30 MMT Core	$938,991
	(-$1,550 MM)

30 MMT Core vs 30 MMT Least Cost

- ***30 MMT least-cost scenarios show a significantly lower cost portfolio than the Core portfolio that relies on LSE plans***
  - Annual cost impact = ~$400-$1,600M/yr
- Least-cost cases use 2023-vintage cost inputs that include IRA tax credits, while LSE plans used older cost and resource potential data
- Lower costs in the least-cost scenario driven by:
  - Less offshore wind, battery storage, and thermal retirements
  - More in-state wind and long duration storage



$49,487	-$425M	$51,930	-$794M	$56,149	-$1,567M	$59,003	-$1,511M

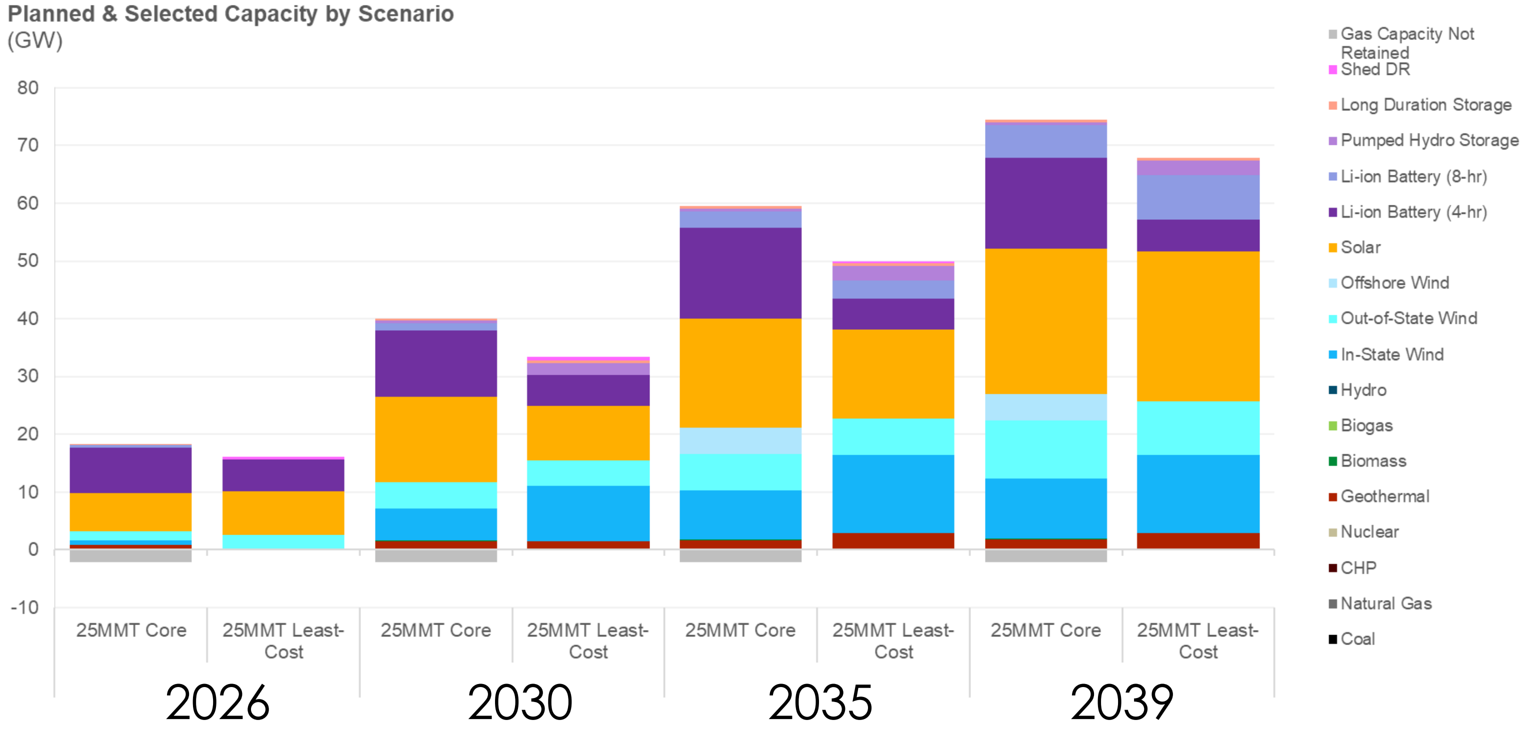
Annual Costs ($MM/yr)

<u>NPV</u> of Total Resource Cost ($MM in 2022 Dollar Year, 2024-2065)	
30 MMT Core	$938,991
30 MMT Least-Cost	$922,596
	(-$16,395 MM)

25 MMT Core vs 25 MMT Least Cost

- ***25 MMT least-cost scenarios show a significantly lower cost portfolio than the Core portfolio that relies on LSE plans***
  - Annual cost impact = ~$500-1,500M/yr
- Least-cost cases use 2023-vintage cost inputs that include IRA tax credits, while LSE plans used older cost and resource potential data
- Lower costs in the least-cost scenario driven by:
  - Less offshore wind, battery storage, and thermal retirements
  - More in-state wind and long duration storage

<u>NPV</u> of Total Resource Cost ($MM in 2022 Dollar Year, 2024-2065)	
25 MMT Core	$940,541
25 MMT Least-Cost	$925,303
	(-$15,238 MM)

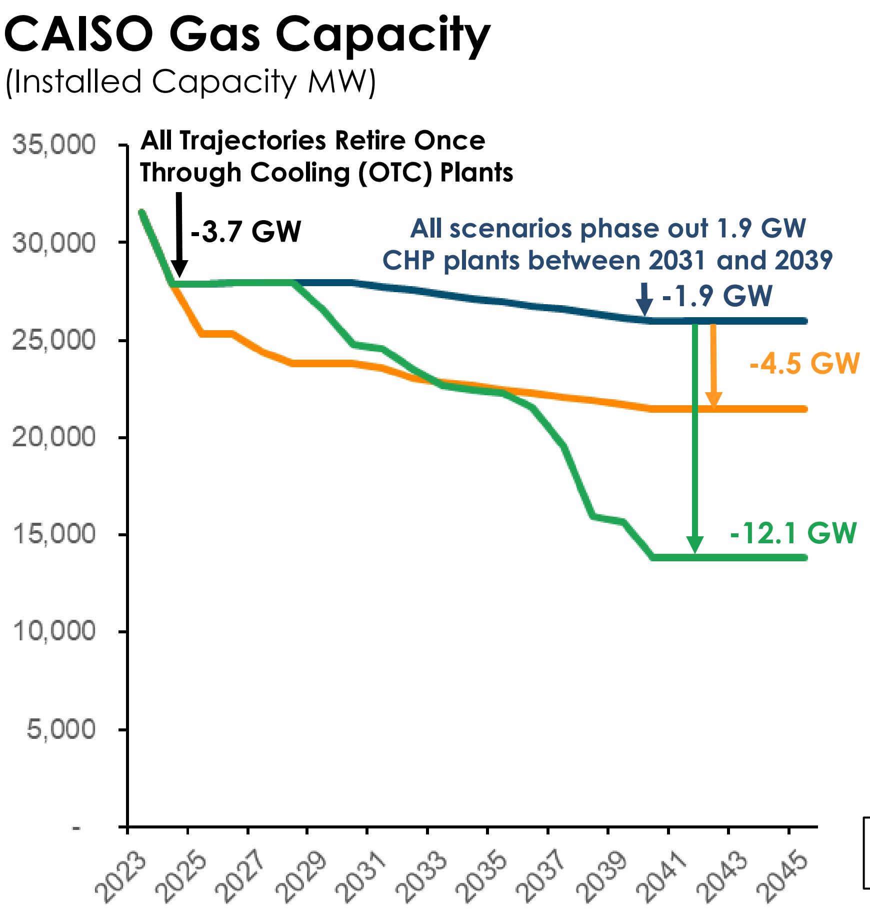


2026 Core	2026 Least-Cost	2030 Core	2030 Least-Cost	2035 Core	2035 Least-Cost	2039 Core	2039 Least-Cost
$49,492	**-$495M**	**$51,986**	**-$622M**	**$56,317**	**-$1,483M**	**$59,128**	**-$1,427M**

Annual Costs ($MM/yr)

Summary of Gas Retirement Sensitivities

Gas Retirement Trajectories



Base: No gas forced to retire after OTC retirements, except for CHP phase out in the 2030s

Moderate Gas Retirement: Trajectory includes LSE plans' un-contracted CC and CT gas plants, shows accelerated retirements in the near-term but available gas capacity is relatively constant beyond 2030

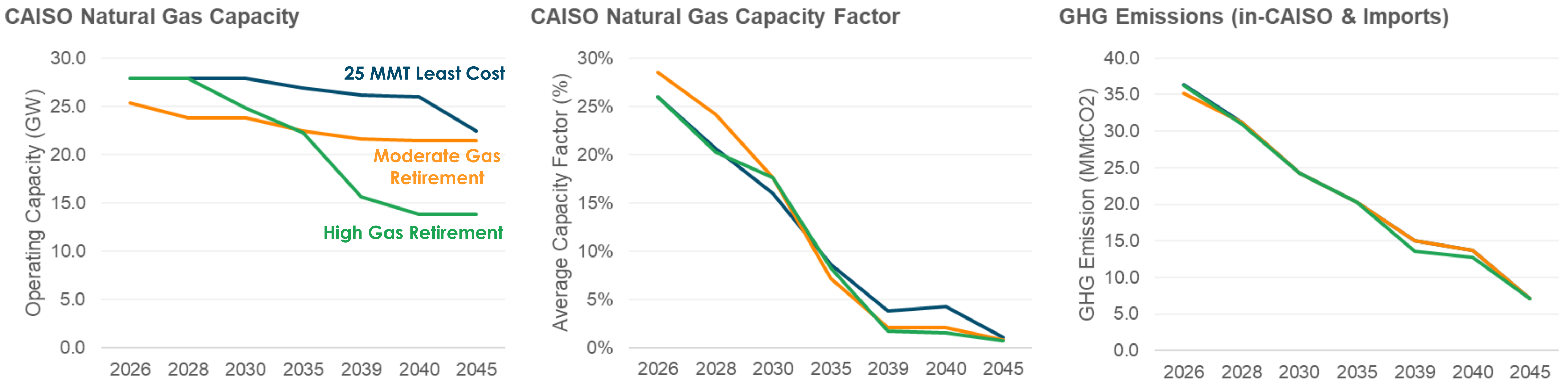
High Gas Retirement: Additional Retirements start in 2029 to meet the amount of LSEs un-contracted CC and CT gas capacity by 2035; continues to reduce gas capacity through 2040 using a 35-year age-based criteria

High Gas Retirement scenario is proposed as the TPP Sensitivity Case

In all scenarios and sensitivities, RESOLVE can choose to not retain additional gas capacity; the plot represents the maximum existing CAISO gas capacity available

Thermal Fleet Utilization in Gas Retirement Sensitivities

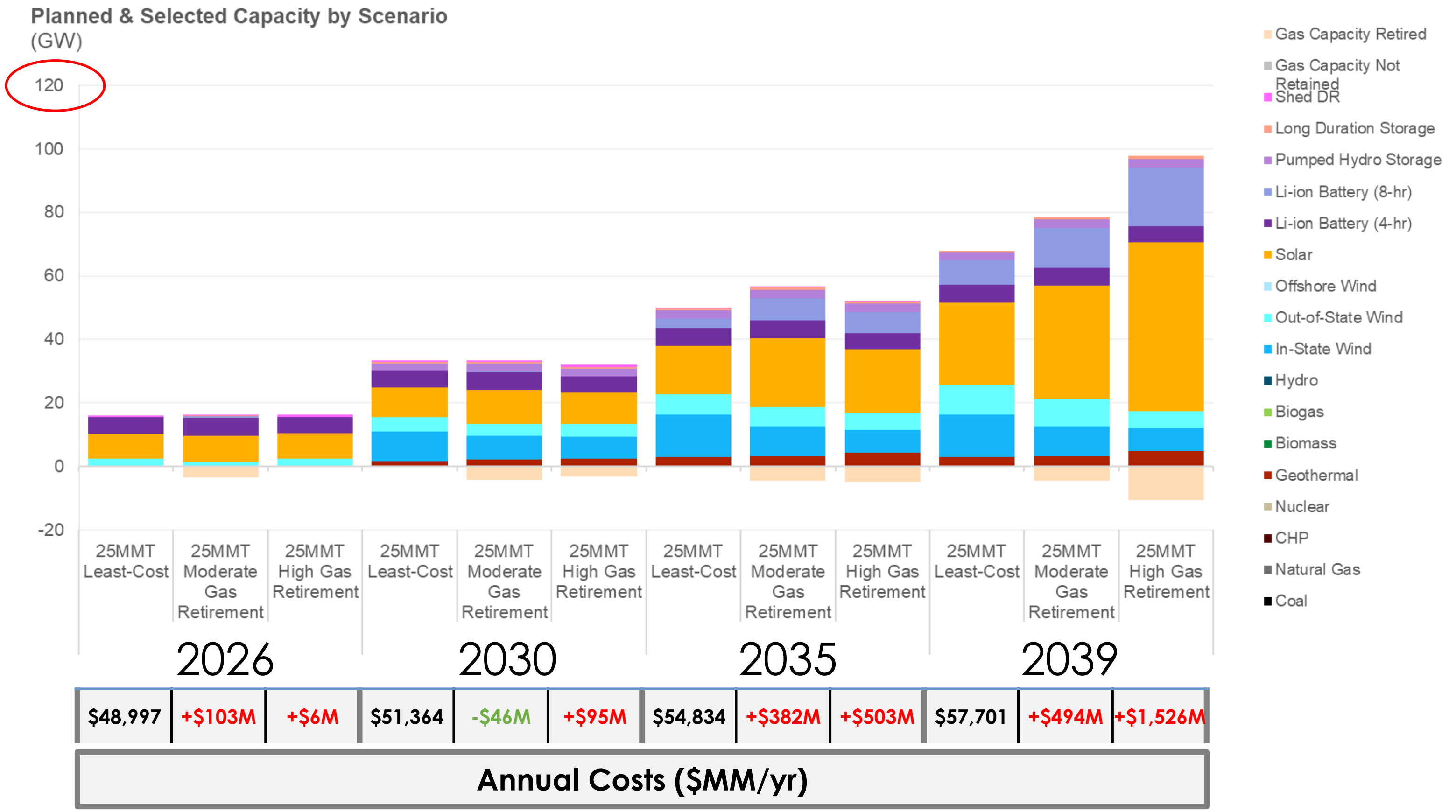
- Reflecting the deployment of clean energy from greenhouse gas emissions limits, natural gas fleet utilization declines to ~5% by 2035 regardless of whether gas plants are retired
- ***Gas retirements provide little to no GHG emissions reductions benefits***
  - While in-state gas generation goes down, it is replaced with imports (frequently gas plants in neighboring regions)
    - In the late 2030s and beyond, the least-cost case does show higher *in-CAISO* gas generation than either gas retirement trajectory, but total GHG emissions are similar across all three cases because of higher levels of unspecified imports.
    - This change in in-CAISO gas generation represents a significant decrease relative to previously adopted IRP portfolios, though this result should be interpreted in the context of the delicate economic balance between in-CAISO and external gas generation. It is possible that RESOLVE's decision to choose mostly imports instead of in-CAISO gas plants could be reversed with different cost projections and other model inputs.



25 MMT Least Cost vs Gas Retirement Sensitivities

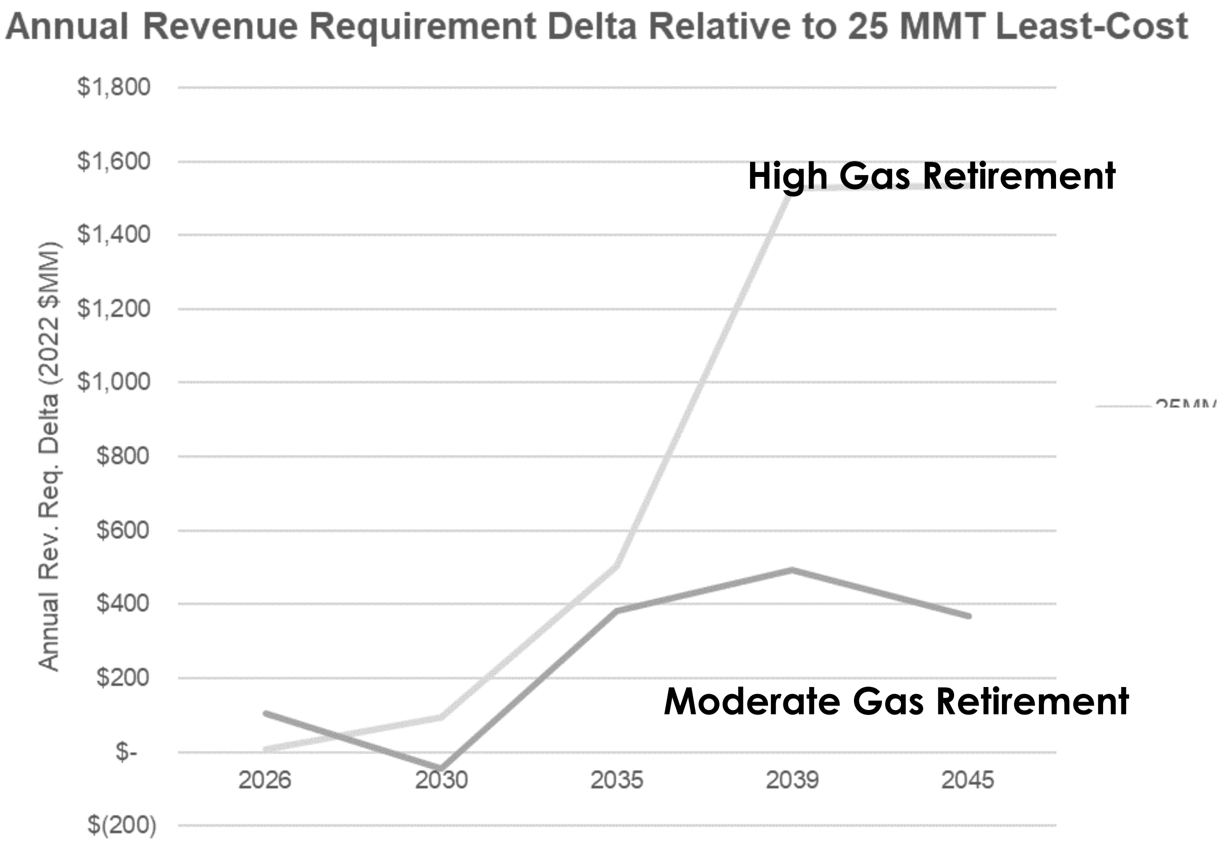
- ***Gas retirement scenarios increase system costs the more gas is forced to retire***
  - Annual cost impact = ~$6-$1,500M/yr
- Gas plants are replaced largely with solar and long-duration storage resources
  - This in turn displaces lower cost and likely more valuable land-based wind resources
  - This does not result in substantive net-new clean generation (or GHG emission reduction) as resource selection is still driven by the GHG emissions trajectory

<u>NPV</u> of Total Resource Cost ($MM in 2022 Dollar Year, 2024-2065)	
25 MMT Least-Cost	$925,303
25 MMT Moderate Gas Retirement	$929,045 (+$3,742MM)
25 MMT High Gas Retirement	$938,342 (+$13,039MM)



Gas Retirement Cost Impacts

- Gas retirements increase costs despite not showing a material reduction in GHG emissions
- Sensitivities were not analyzed to see if they would meet the local reliability requirements in local areas where gas generators are retired
  - Replacing firm capacity in local areas may be a challenge for the high gas retirements scenario
  - Long-duration storage or other resources that can be cited locally may be able to replace some of the retired local capacity, and transmission solutions can reduce also local capacity needs.
    - The cost impact of implementing solutions to address local capacity requirements is not addressed in the gas retirement sensitivities presented here, and thus the costs presented in this slide are likely an underestimate of the full cost of gas retirement.



Cost impacts are limited near- to mid-term as new renewables and storage for GHG-reduction provide new reliability value

However, ***long-term the cost impacts become significant*** (and under higher retirement levels) as renewable and storage capacity value saturates, limiting their ability to offset firm capacity

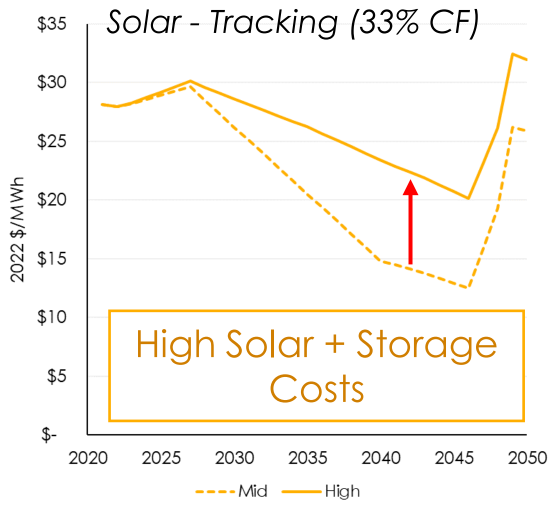
Summary of Cost Sensitivities

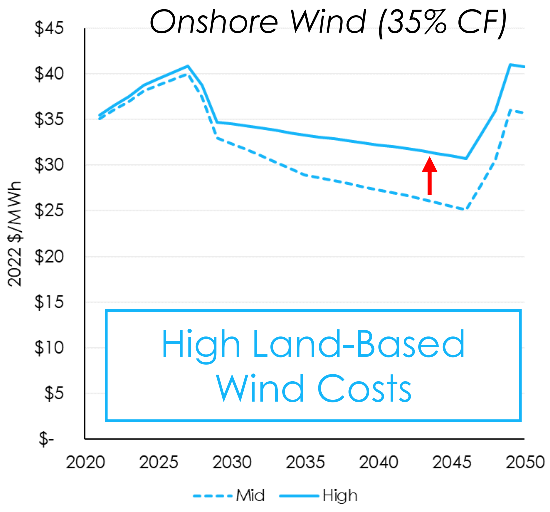
Cost Sensitivities

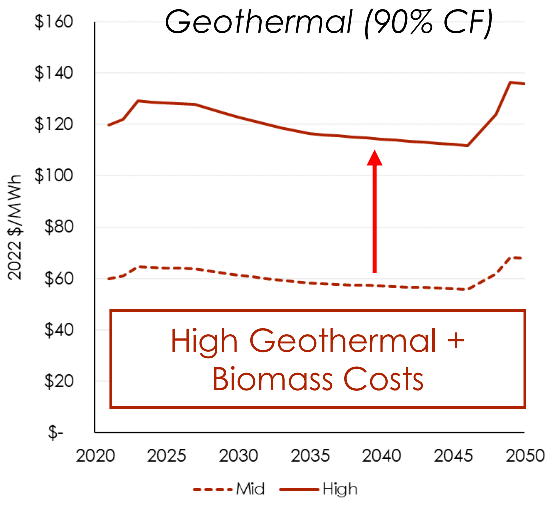
- Cost risk is not explicitly considered in each RESOLVE cost optimization; performing multiple cost sensitivities enables the consideration of cost risks as part of the portfolio development process
- Cost sensitivities explore how changes in resource costs could impact portfolio selection, showing if resource choices are, or are not, robust to differences in resource costs
- Cost sensitivities analyzed include:
  - High Solar & Battery costs
  - High Land-Based Wind costs
  - High Geothermal & Biomass costs
  - Low Offshore Wind costs

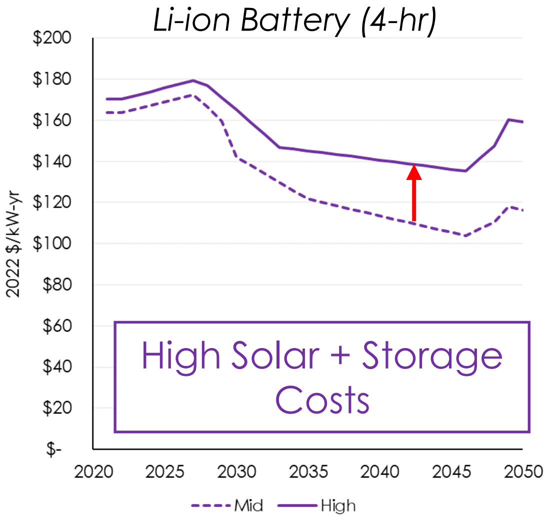
Cost Sensitivities: Resource Cost Comparison

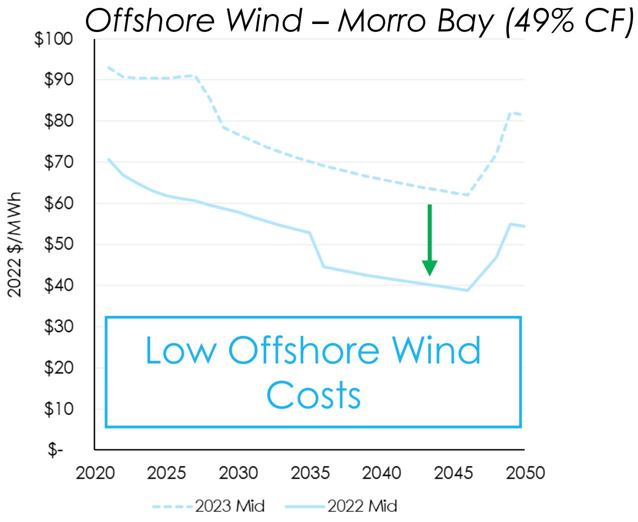
(LCOE or Levelized Fixed Cost)

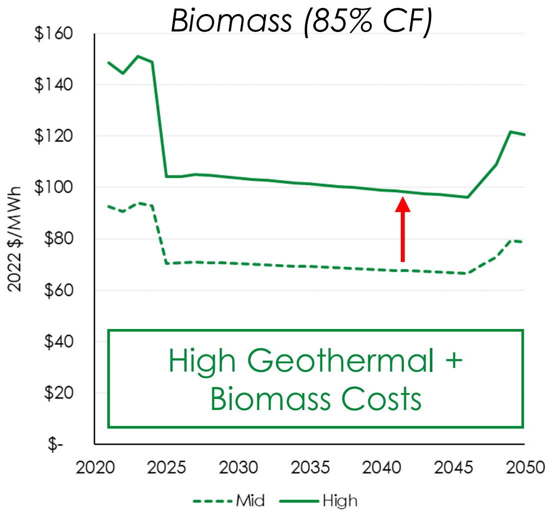








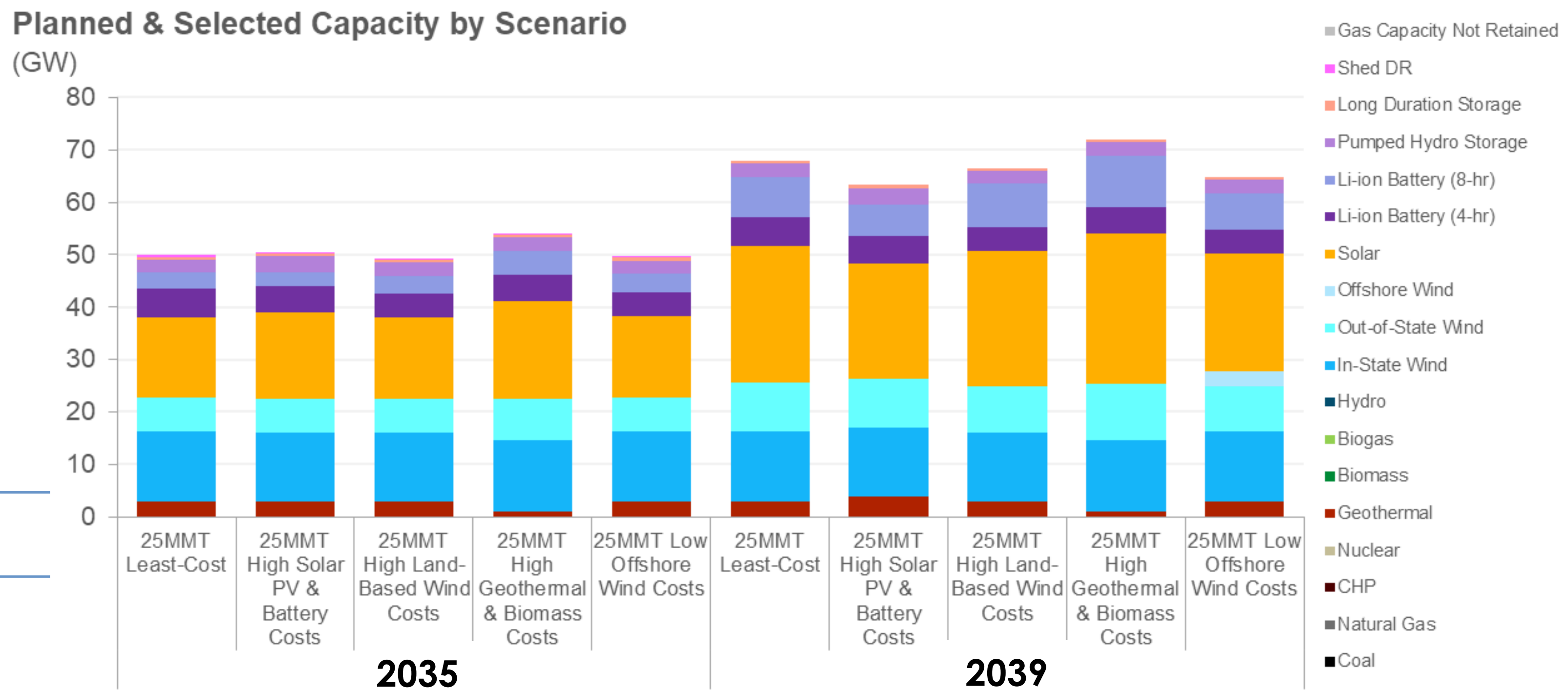




CF = Capacity Factor

25 MMT Least Cost Case vs Cost Sensitivities

- Despite some differences, ***the 2035 and 2039 resource portfolios are relatively similar across a range of cost sensitivities***, except for:
  - Addition of offshore wind in 2039 the Low Offshore Wind Costs sensitivity
  - Reduction in geothermal capacity resulting from higher geothermal costs



2035 Least-Cost	High Solar PV & Battery	High Land-Based Wind	High Geothermal & Biomass	Low Offshore Wind	2039 Least-Cost	High Solar PV & Battery	High Land-Based Wind	High Geothermal & Biomass	Low Offshore Wind
$54,834	+$235M	+$128M	-$1M	+$3M	$57,701	+$743M	+$179M	+$563M	-$27M

Annual Costs ($MM/yr)

<u>NPV</u> of Total Resource Cost
($MM in 2022 Dollar Year, 2024-2065)

25 MMT Least-Cost	$925,303
25 MMT High Solar PV & Battery Costs	$935,886 (+$10,583MM)
25 MMT High Land-Based Wind Costs	$927,136 (+$1,833MM)
25 MMT High Geo & Biomass Costs	$933,038 (+$7,735MM)
25 MMT Low Offshore Wind Costs	$924,506 (-$797MM)

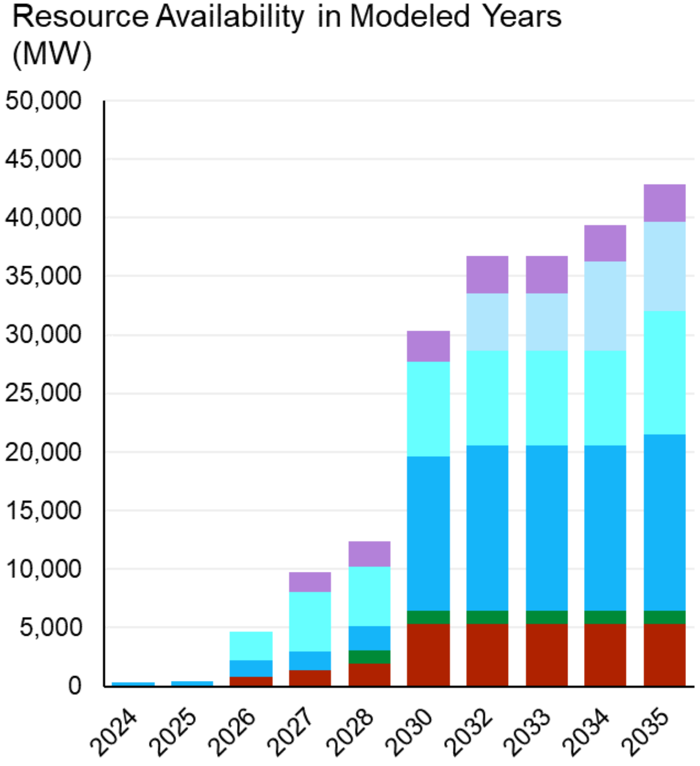
Summary of Reduced Resource Availability Sensitivities

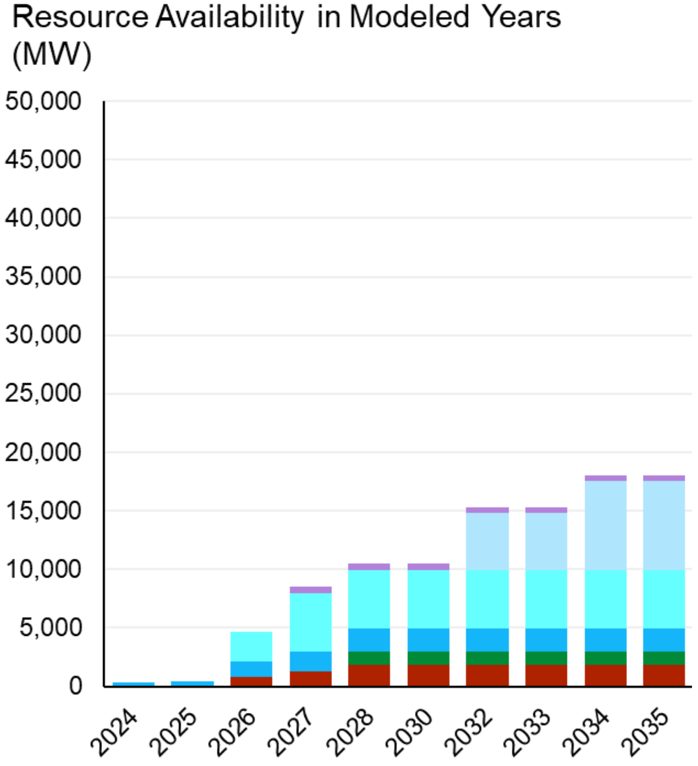
Resource Availability Sensitivities

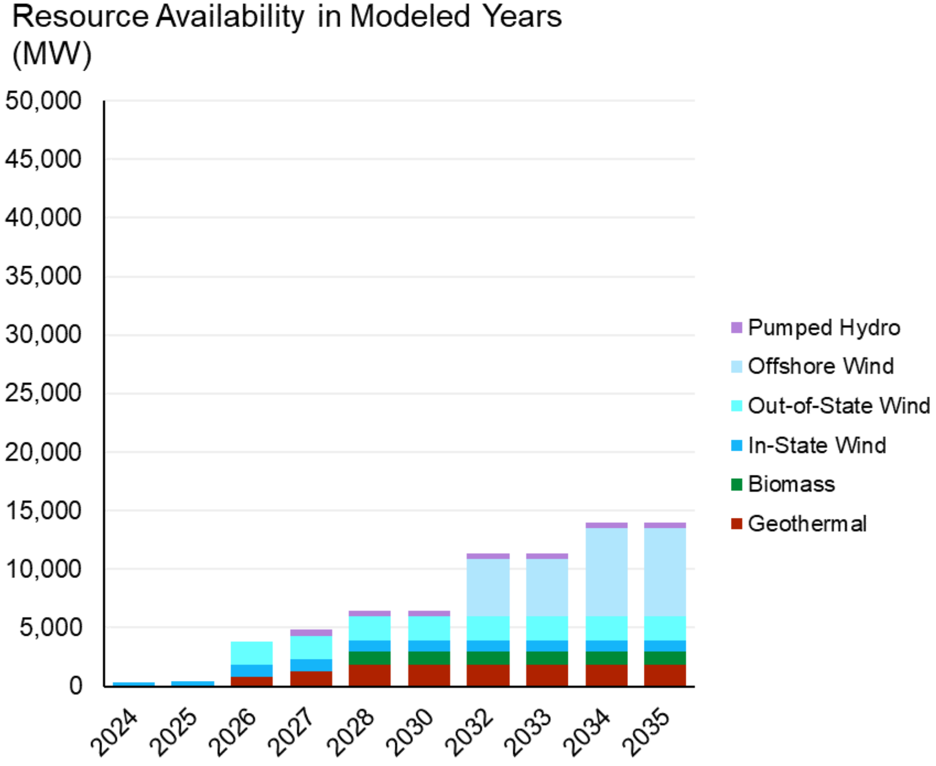
Reduced and Significantly Reduced Resource Availability

To test offshore wind needs in the absence of alternatives, these sensitivities include large reductions to the availability of other competing resources with limited potential (onshore wind, pumped hydro, and geothermal).

Base Availability	Reduced Availability	Significantly Reduced Availability

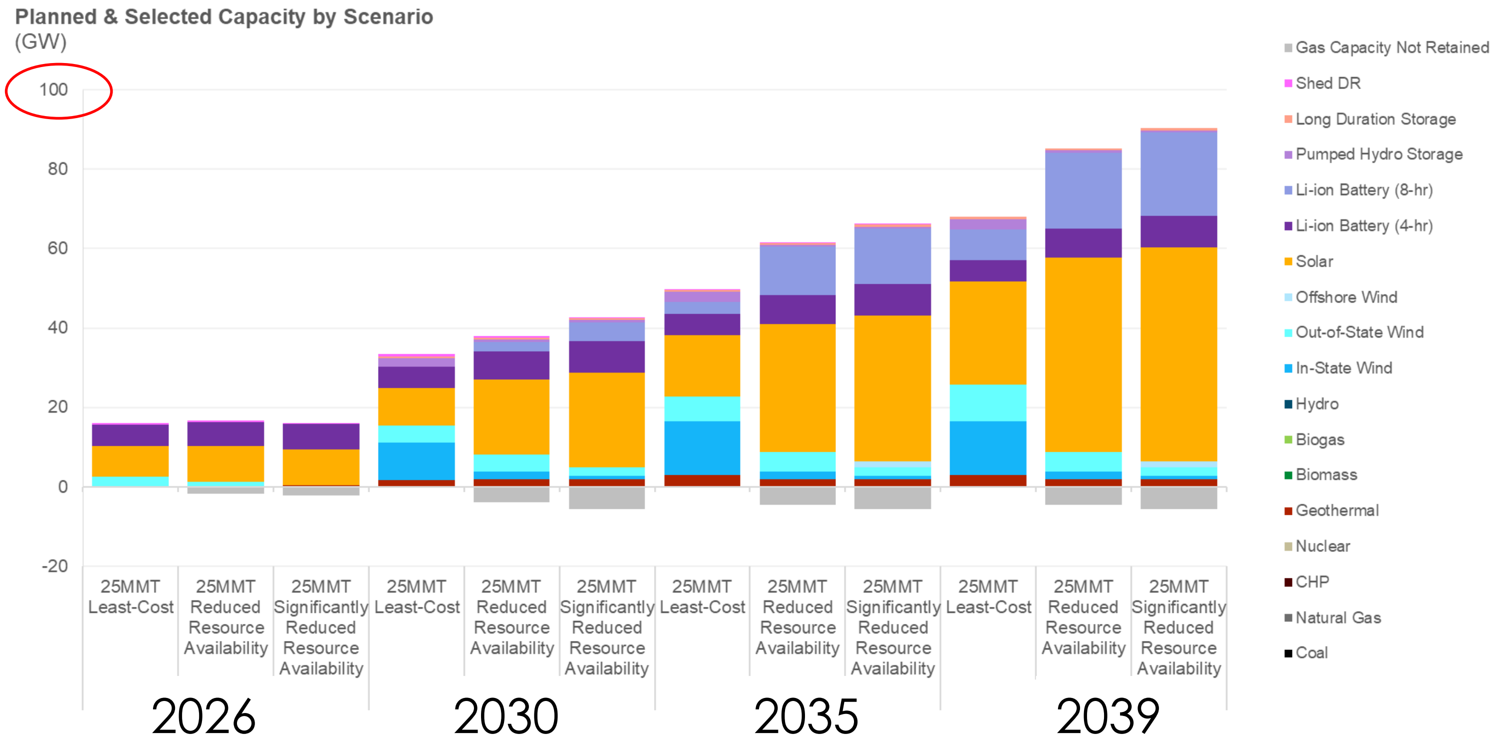






25 MMT Least Cost vs Reduced Resource Availability Sensitivities

- The Reduced Resource Availability sensitivities result in a portfolio that is heavily dependent on solar and batteries
  - Despite this lack of resource diversity, only 1.5 GW of offshore wind is built by 2035
  - Has much higher costs, demonstrating the cost savings of a diverse resource portfolio
    - Annual cost impact = ~$5-$2,400M/yr
  - Has higher battery additions to integrate increased solar growth
    - The additional batteries provide resource adequacy, which allows for 4.5-5.6 GW of gas capacity to not be retained by 2039



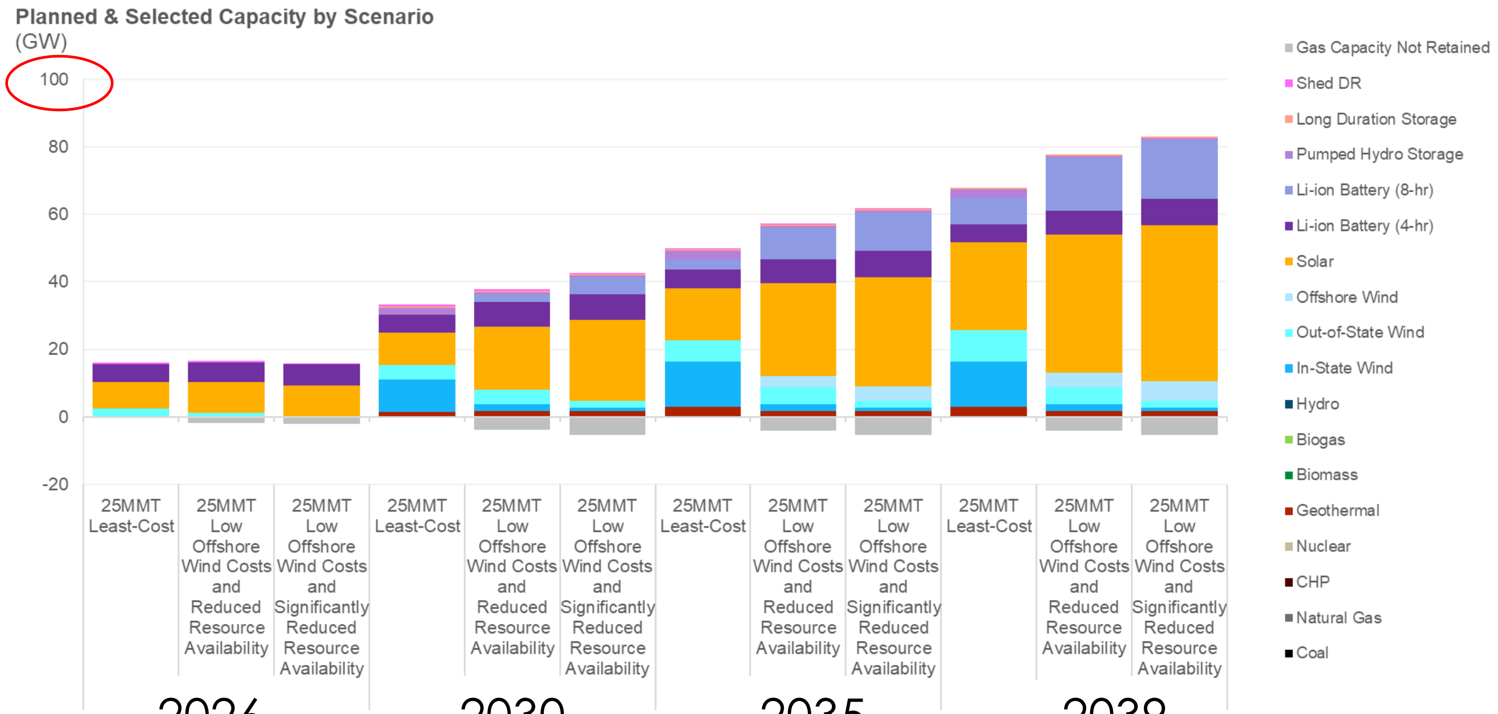
2026			2030			2035			2039		
$48,997	+$5M	+$72M	$51,364	+$1,519M	+$95M	$54,834	+$1,701M	+$2,325M	$57,701	+$1,701M	+$2,397M

Annual Costs ($MM/yr)

NPV of Total Resource Cost ($MM in 2022 Dollar Year, 2024-2065)	
25 MMT Least-Cost	$925,303
25 MMT Reduced Resource Availability	$942,449 (+$17,146MM)
25 MMT Significantly Reduced Resource Availability	$950,149 (+$24,846MM)

25 MMT Least Cost vs Reduced Resource Availability and Low Offshore Wind Cost Sensitivities

- These sensitivities result in a portfolio that is heavily dependent on solar and batteries , even with low offshore wind costs
  - Despite this lack of resource diversity, only ~4 GW of offshore wind is built by 2035
  - Has much higher costs, demonstrating the cost savings of a diverse resource portfolio
    - Annual cost impact = ~$5-$2,200M/yr
  - Has higher battery additions to integrate increased solar growth
    - The additional batteries provide resource adequacy, which allows for 4.2-5.4 GW of gas capacity to not be retained by 2039



2026			2030			2035			2039		
$48,997	+$5M	+$72M	$51,364	+$1,064M	+$1,543M	$54,834	+$1,428M	+$2,081M	$57,701	+$1,571M	+$2,180M

Annual Costs ($MM/yr)

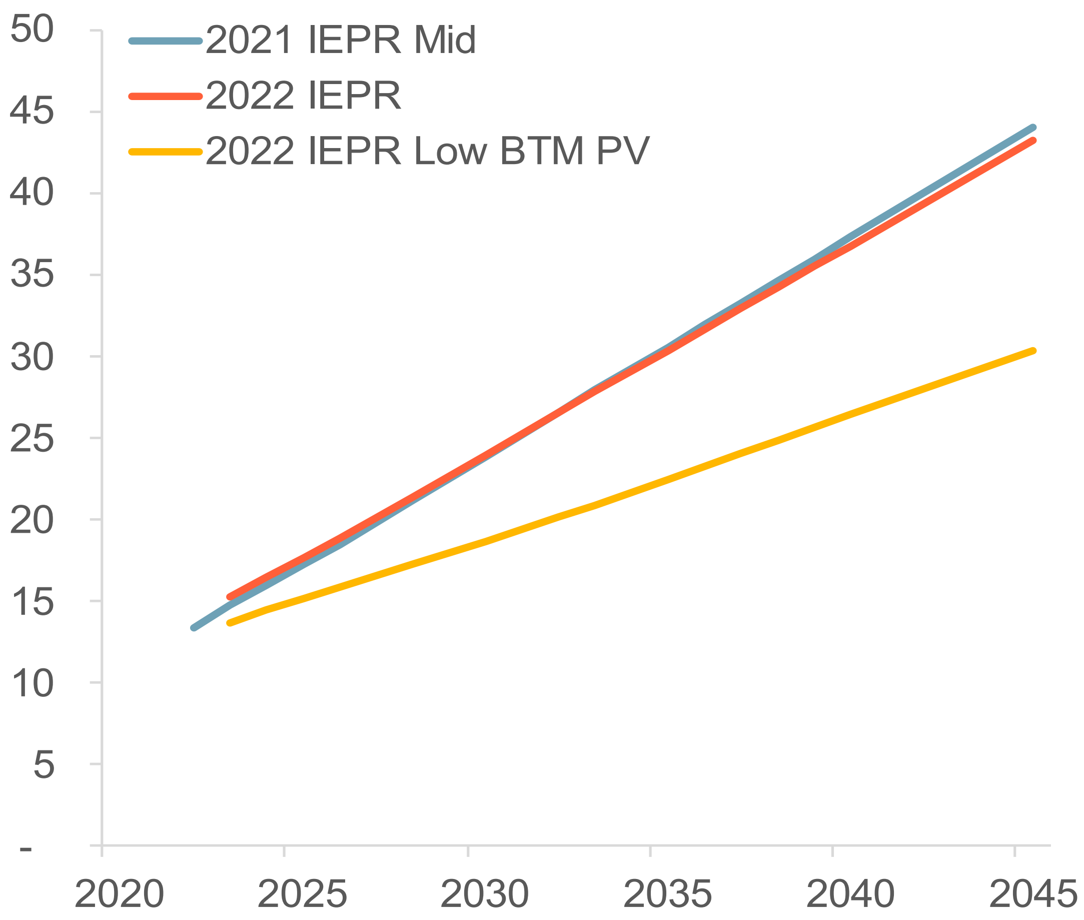
NPV of Total Resource Cost ($MM in 2022 Dollar Year, 2024-2065)	
25 MMT Least-Cost	$925,303
25 MMT Low Offshore Wind Costs & Reduced Resource Availability	$940,067 (+$14,764MM)
25 MMT Low Offshore Wind Costs & Significantly Reduced Resource Availability	$946,943 (+$21,640MM)

Resource Availability Sensitivities

Low BTM PV Growth

- This sensitivity tested what replacement resources are needed if customer-sited, behind-the-meter (BTM) solar growth is lower than expected
  - There is ~30% less capacity by 2045 in the Low BTM PV forecast
- This is the only sensitivity that included changes to non-modeled costs (i.e. costs that are not optimized by RESOLVE), accounting for reduced customer spending on BTM PV systems captured in RESOLVE's total resource cost view

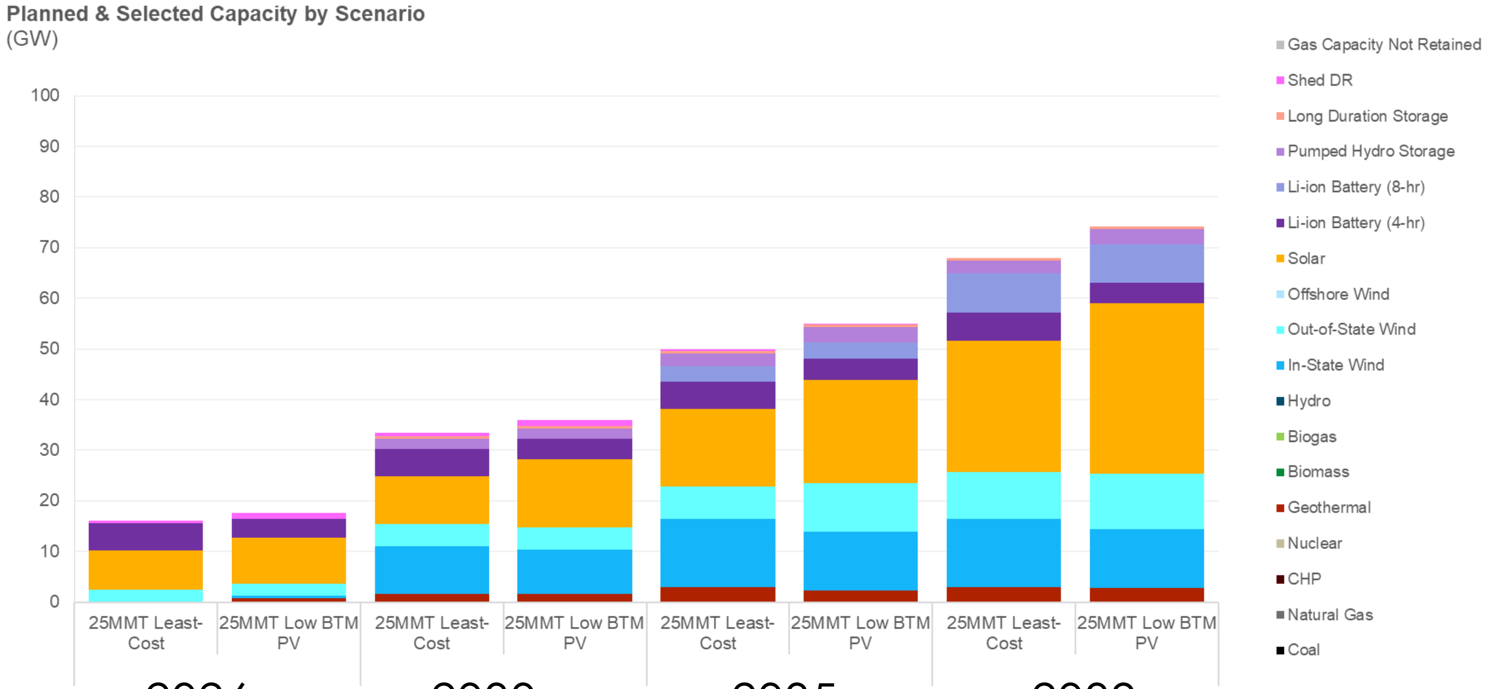
BTM PV Forecast (GW)



25 MMT Least Cost Case vs Low BTM PV

- Lower BTM PV capacity is offset by modest increases in geothermal and Shed DR (near term) and utility-scale solar capacity (across the modelling horizon)
  - Higher supply-side portfolio costs of $180-$590M/yr
  - Demand-side Total Resource Cost (TRC) cost savings of $290-900M/yr
    - Driven by estimated BTM PV installation cost of ~$70-100/MWh, which is significantly higher than utility-scale resource costs
  - Net TRC cost **savings** of $116-$553M/yr

NPV of Total Resource Cost ($MM in 2022 Dollar Year, 2024-2065)	
25 MMT Least-Cost	$925,303
25 MMT Low BTM PV	$920,230
	(-5,073MM)



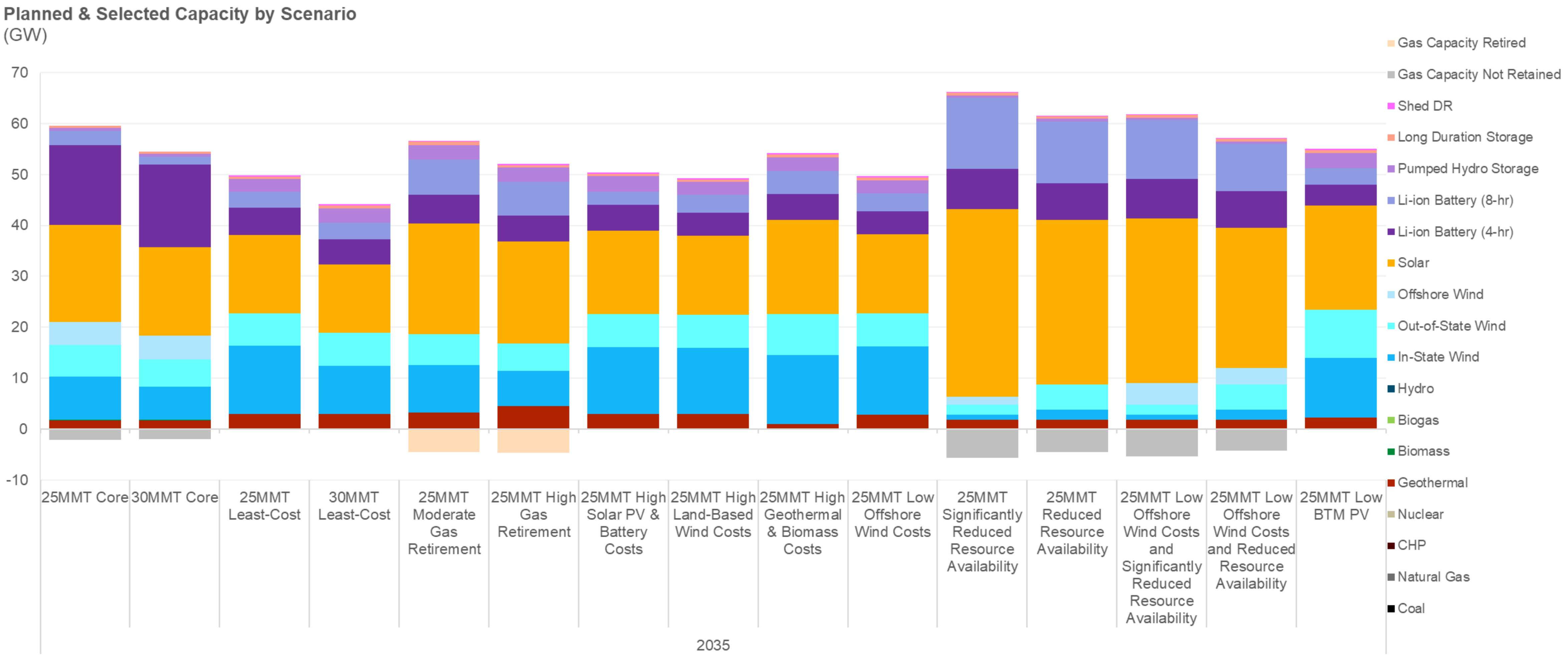
2026		2030		2035		2039	
$48,997	**-$116M**	**$51,364**	**-$344M**	**$54,834**	**-$553M**	**$57,701**	**-$310M**

Annual TRC* Costs ($MM/yr)

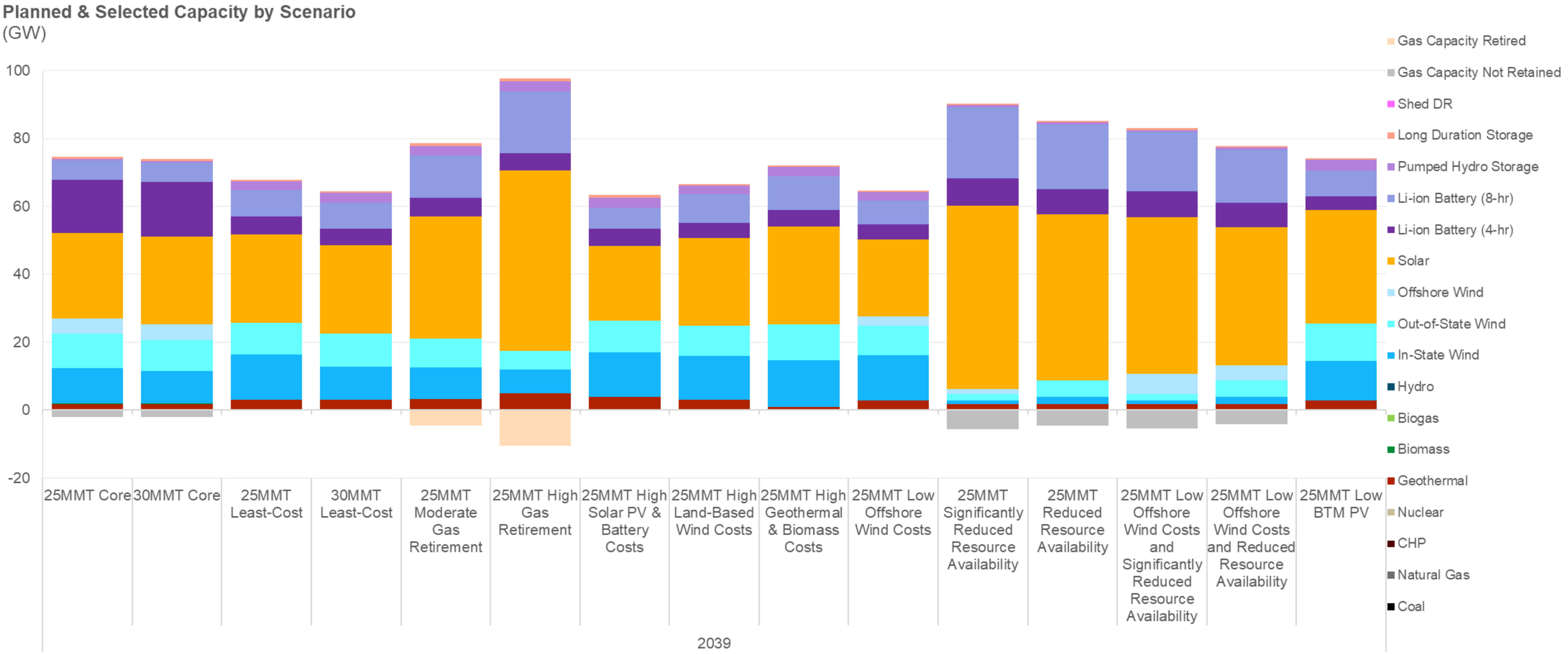
** TRC includes estimated customer costs for BTM PV installation*

Summary Comparison of All Cases

Comparison of 2035 Results For All Cases

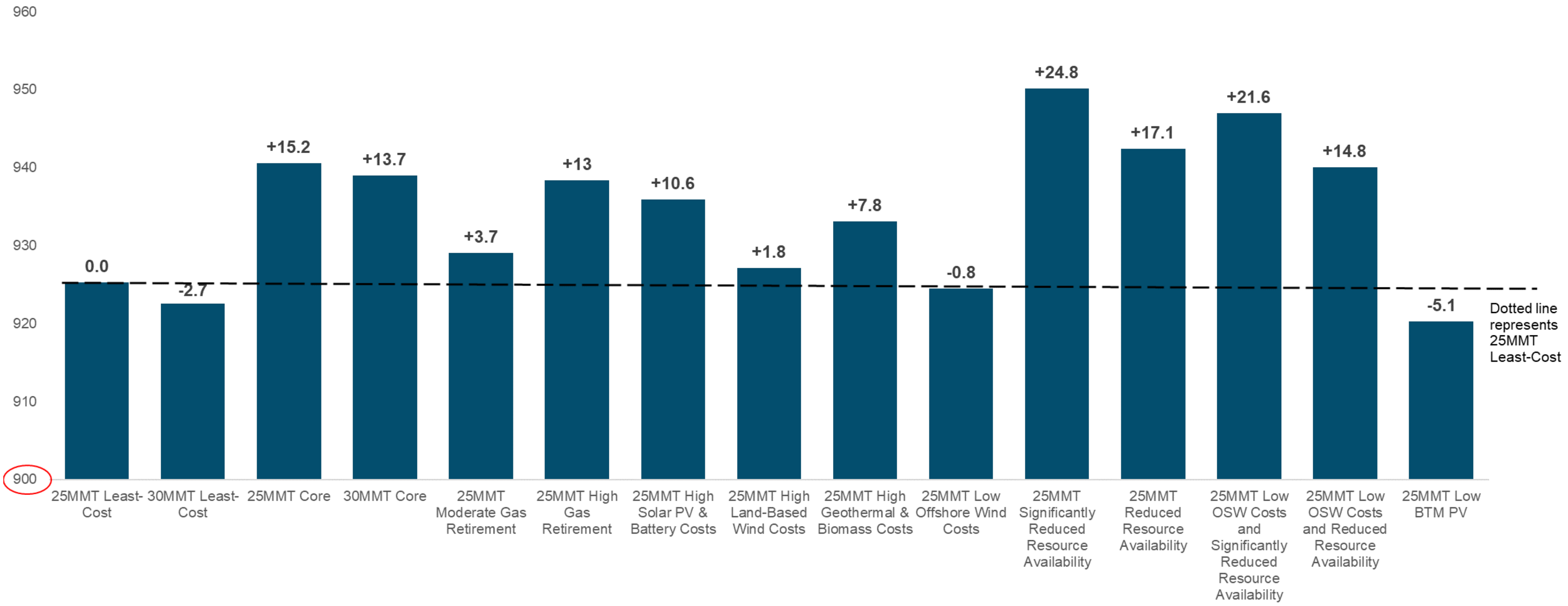


Comparison of 2039 Results For All Cases



Comparison of NPV For All Cases

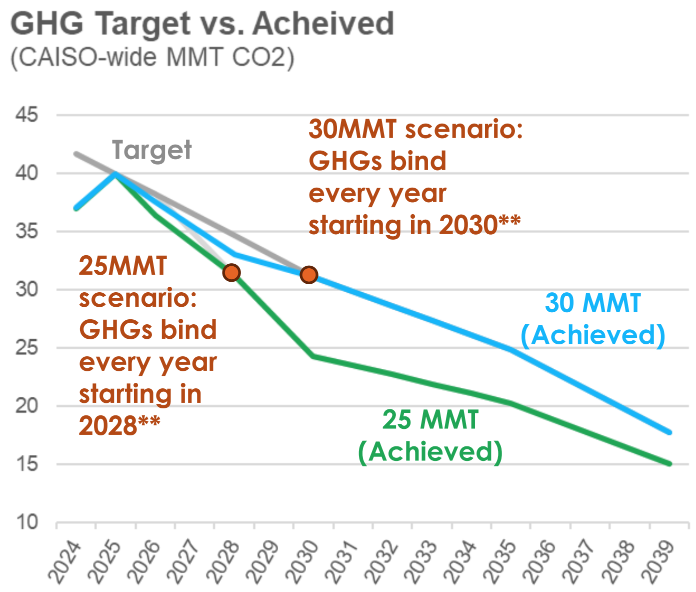
Net Present Value (Billion 2022$) by Scenario
Labels Show Difference from 25MMT Least-Cost

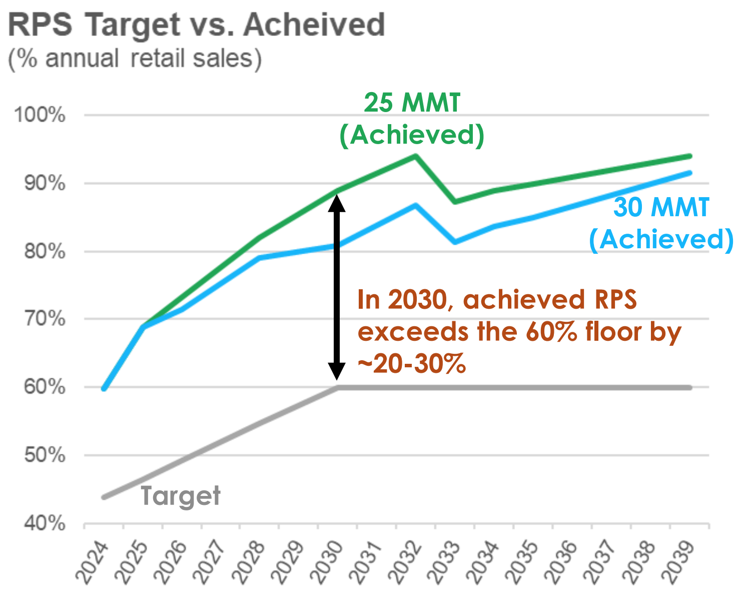


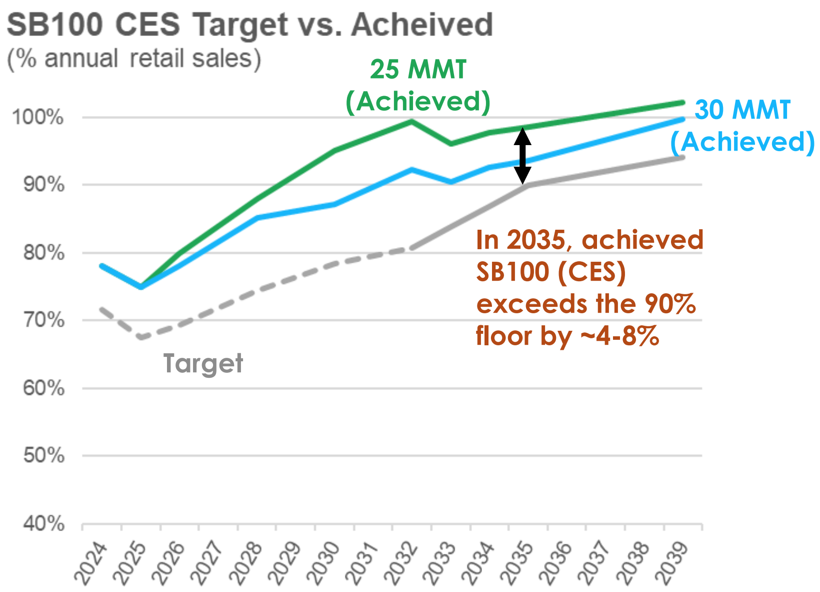
Additional Takeaways from RESOLVE results

Least-Cost 25MMT and 30MMT Scenarios

Clean Energy Dynamics







Electric sector GHG targets are the primary clean energy constraint, driving new resource builds beyond SB100 minimum RPS/CES targets

Minimum RPS requirements (per SB100) are exceeded in every year

Minimum CES/SB100 requirements (per SB100 and SB1020) are also exceeded in every year

* Least-cost cases are shown; however, core cases show very similar achieved GHG, RPS, and CES
** Least-cost cases show 2025 binding after Diablo Canyon retirement; core cases have sufficient planned LSE additions for 2025

Reliability dynamics

Reliability dynamics in RESOLVE are dependent upon whether LSE plans are included or not

Core scenarios w/ LSE plans

- LSE plans build even beyond MTR needs, creating a long capacity position in the 2020's
- RESOLVE builds additional GHG-free capacity above LSE plans in the 2030's, further driving reliability over-supply
- While LSEs did not contract w/ up to ~6 GW of gas by 2035, RESOLVE chooses to not retain only 2.1 GW (starting in 2024)
  - The rest of the fleet is economically retained for 2039-2045 firm capacity needs

Least-cost scenarios w/o LSE Plans

- Without LSE plans, the PRM and MTR constraints bind more frequently, impacting resource selection
- The size of MTR makes it the primary reliability procurement driver in the 2020's
- By 2032, the PRM binds for all remaining years
- RESOLVE retains all gas plants until 2045, when it chooses to economically not retain 3.5 GW

Core 25mmt	2024	2025	2026	2028	2030	2032	2033	2034	2035	2039	2040	2045
PRM		■								■	■	■
MTR	■											

■ Model years where constraint is binding in RESOLVE

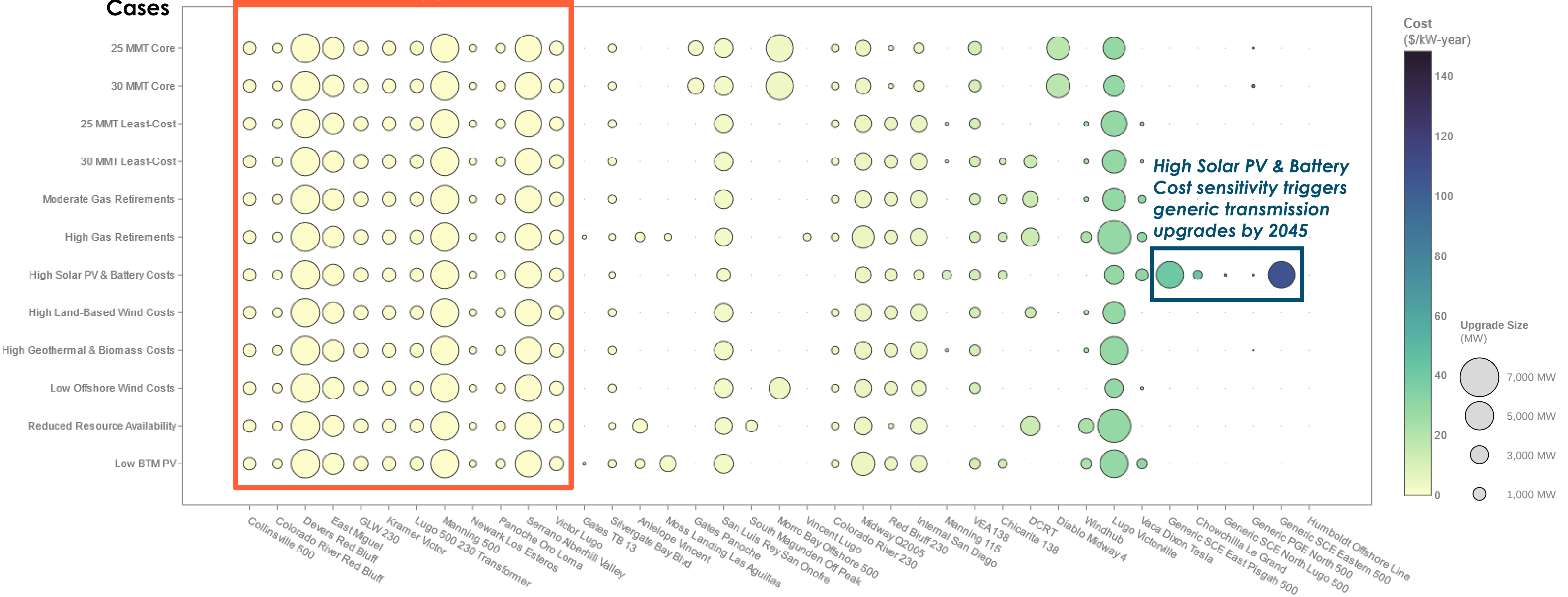
Least-cost 25mmt	2024	2025	2026	2028	2030	2032	2033	2034	2035	2039	2040	2045
PRM						■	■	■	■	■	■	■
MTR	■	■	■	■								

■ Model years where constraint is binding in RESOLVE

2045 Approved & Selected Transmission Upgrades

Boxed area represents 2022-23 TPP approved upgrades that are modeled as zero cost in RESOLVE

Many incremental upgrades are cost-effective after 2035

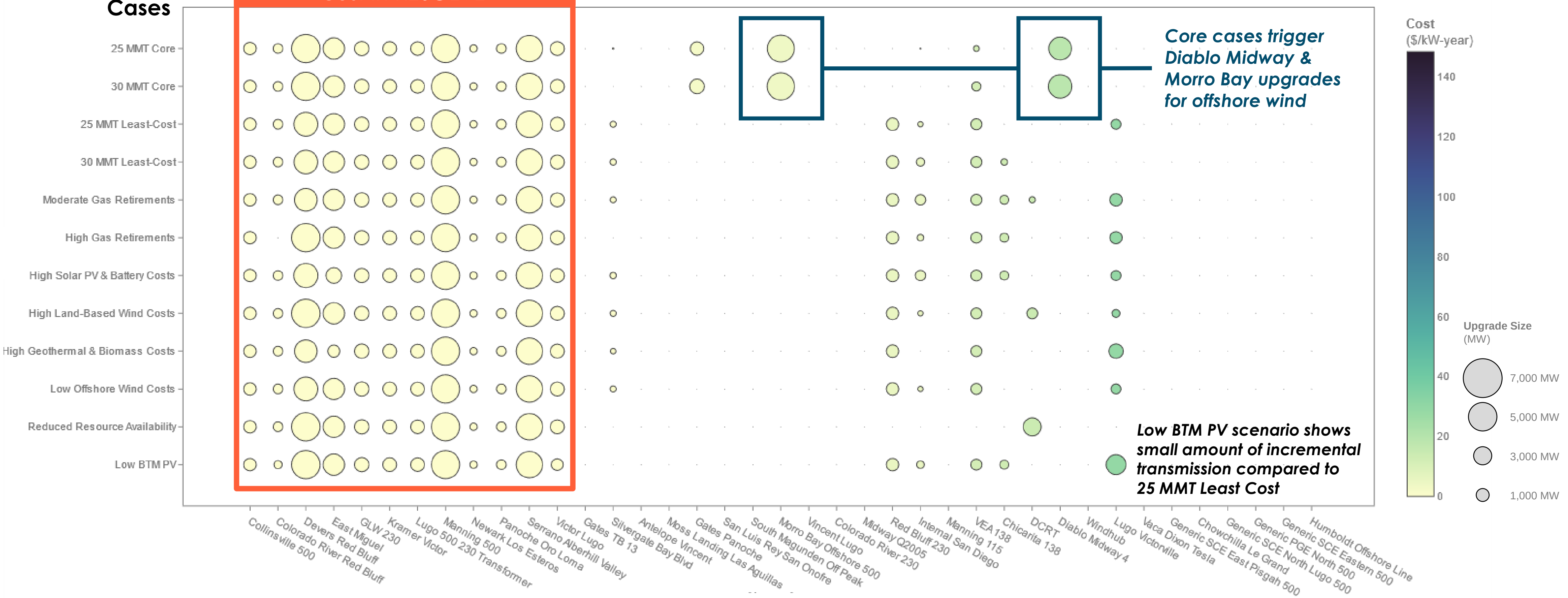


Not all upgrades considered by RESOLVE are depicted as many are not selected in any case

2035 Approved & Selected Transmission Upgrades

Boxed area represents 2022-23 TPP approved upgrades that are modeled as zero cost in RESOLVE

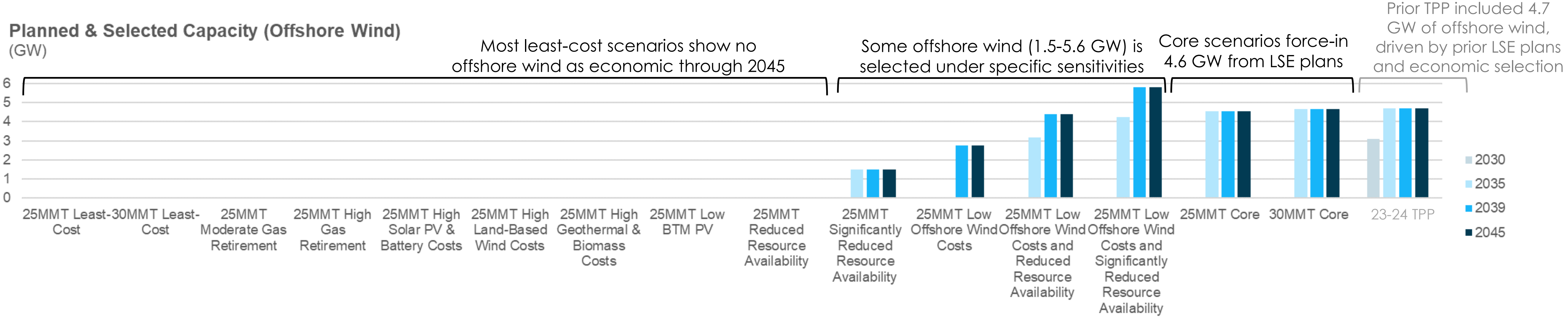
Moderate capacity of upgrades costing up to $30/kW-year selected in most cases by 2035



Not all upgrades considered by RESOLVE are depicted as many are not selected in any case

Offshore Wind Results

- ***Less offshore wind is selected in the 2023 PSP least-cost plans***, compared to past system portfolios (2021 PSP, 23-24 TPP, etc.). This result is driven by:
  - Significant increase in offshore wind costs in latest NREL ATB
  - Moderate decrease in land-based wind (in-state and out-of-state) costs
  - Significant increase in available potential for land-based wind
- ***There is no offshore wind selected in the base least-cost scenarios and most sensitivities***
  - Certain sensitivities show offshore wind being selected by 2035-2039 considering:
    1. Reduced offshore wind capital costs (reduced to the 23-24 TPP vintage assumptions)
    2. Reduced resource availability of alternatives (onshore wind, pumped hydro storage, and geothermal)
       - Note: these reduced resource availability sensitivities that do build offshore wind show significantly higher costs than the base 25MMT least-cost portfolio (by ~$15-24 billion NPV) due to lack of portfolio diversity.
- ***Only Morro Bay offshore wind is selected, not offshore wind in Humboldt (except for the one scenario that combines both reduced capital cost and significantly reduced availability of alternatives)****



* While some LSEs specified a small amount of Humboldt wind in their plans, only the technology-level LSE planned resources are incorporated for offshore wind, not the resource-specific builds. The low offshore cost AND "significantly reduced availability" scenario that causes Humboldt wind to be built in the least-cost sensitivity reduces total capacity available from in-state wind, out of state wind, pumped storage, and geothermal from ~35 GW to ~7 GW.

Detailed RESOLVE Results

Core Portfolios Overview

- **Purpose:** Understand the CAISO system resources needed to meet the GHG target (25 MMT or 30 MMT by 2035), clean energy targets, and reliability needs at least-cost, while accounting for the LSE plans for the 25 MMT or 30MMT goal
- **Key metrics to be discussed:**
  - Selected resources throughout the modeling period
    - Planned new resources from LSE Plans
    - Other resources RESOLVE selects beyond the LSE Plans for reliability, MTR requirements, GHG reduction, or economics
  - Planning reserve margin and MTR highlights
  - RPS and SB 100 policy
  - GHG emissions

Overview of LSE Plan Info for Core Cases

- In the core cases, LSE Plans are forced-in as minimum builds in RESOLVE
  - Natural Gas Retirements implied by the LSE plans are not forced-in, however RESOLVE may choose to economically not retain this capacity

25 MMT LSE Plans (GW of planned capacity)

Resource	2026	2030	2035
Geothermal	0.85	1.35	1.45
Biomass	0.09	0.17	0.17
In-State Wind	1.56	4.34	4.95
Out-of-State Wind	0.94	2.87	3.00
Offshore Wind	0.00	1.58	4.53
Solar	5.54	15.21	19.42
Li-ion Battery (4-hr)	8.00	11.58	15.71
Li-ion Battery (8-hr)	0.53	1.34	3.14
Pumped Hydro Storage	0.47	0.48	0.48
Long Duration Storage	0.00	0.20	0.20
Shed DR	0.03	0.10	0.10

30 MMT LSE Plans (GW of planned capacity)

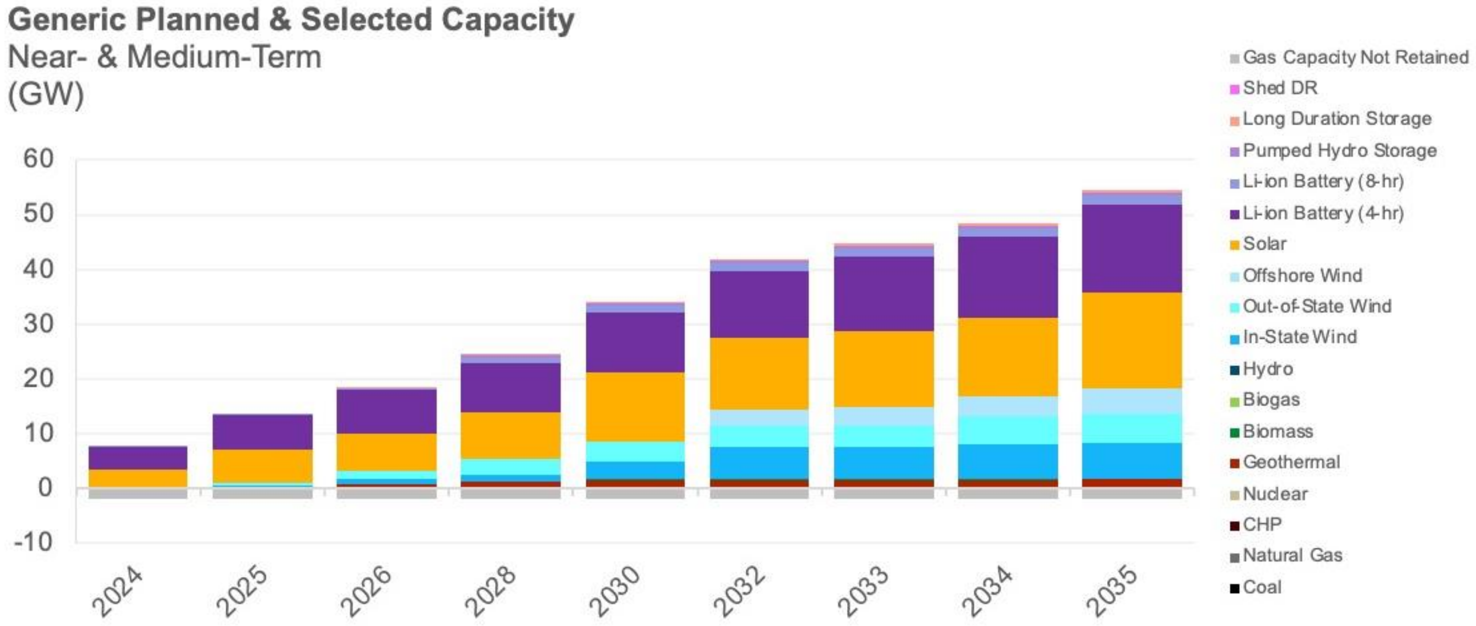
Resource	2026	2030	2035
Geothermal	0.84	1.33	1.43
Biomass	0.09	0.17	0.17
In-State Wind	1.56	4.20	4.85
Out-of-State Wind	0.94	2.88	3.09
Offshore Wind	0.00	1.66	4.65
Solar	5.53	13.19	18.05
Li-ion Battery (4-hr)	8.00	10.98	16.14
Li-ion Battery (8-hr)	0.53	1.31	1.95
Pumped Hydro Storage	0.47	0.48	0.48
Long Duration Storage	0.00	0.20	0.20
Shed DR	0.03	0.10	0.10

25 MMT Core Case

25 MMT Core Case

Planned & Selected Capacity, Near- & Mid-Term (GW)

Solar and battery capacity grow steadily over time
Long duration storage is also added (primarily 8-hr batteries) per LSE plans to meet MTR



All three categories of wind (in-state, out of state, offshore) also show steady growth. RESOLVE does not select offshore wind above the levels in the LSE plans.

A relatively small amount of gas (2 GW) is not retained, starting in 2024, as MTR, LSE plans to build beyond MTR, and RESOLVE selected resources for GHG reduction create a capacity surplus

25 MMT Core Case

Planned & Selected Capacity, Long-Term (GW)

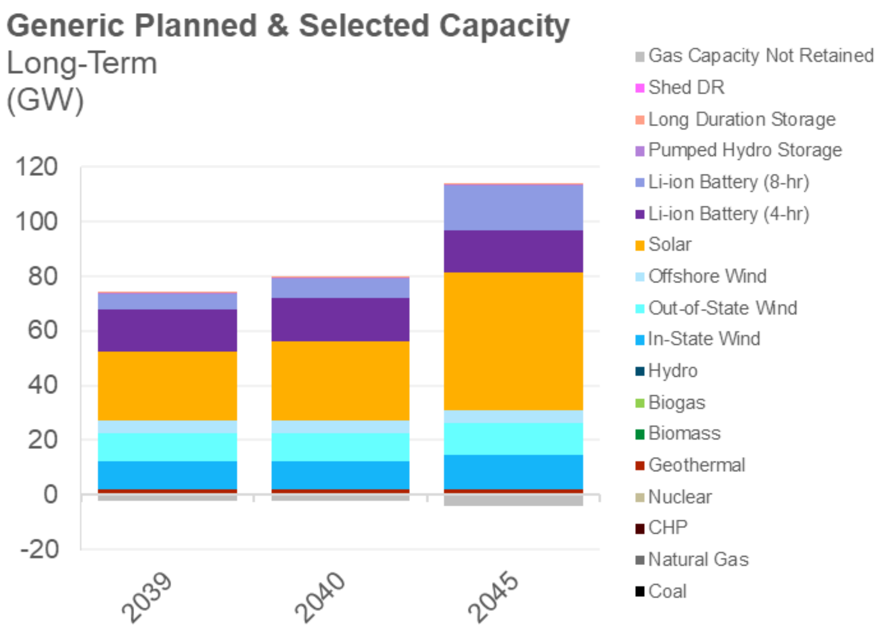
- Along with increasing solar, RESOLVE selected long duration li-ion batteries become a larger part of the portfolio in the late 2030s and beyond

RESOLVE is currently set up to select either 4hr li-ion, 8-hr li-ion, 12-hr pumped storage, or 24-hr A-CAES. RESOLVE sees increased value from longer durations due to:

- Resource adequacy value as additional duration provides additional ELCC
- Greenhouse gas reduction from shifting continuously growing solar power
- Transmission availability, since longer duration batteries are modeled as requiring the same amount of transmission as 4-hour (but provide more resource adequacy per MW of capacity)

By 2035, the average duration of battery resources is 4.7 hours, increasing to 6.4 hours by 2045.

The specific optimal mix of storage durations is subject to the future cost of increased duration relative to the market value of that duration as captured in LSE procurement solicitations.



25 MMT Core Case

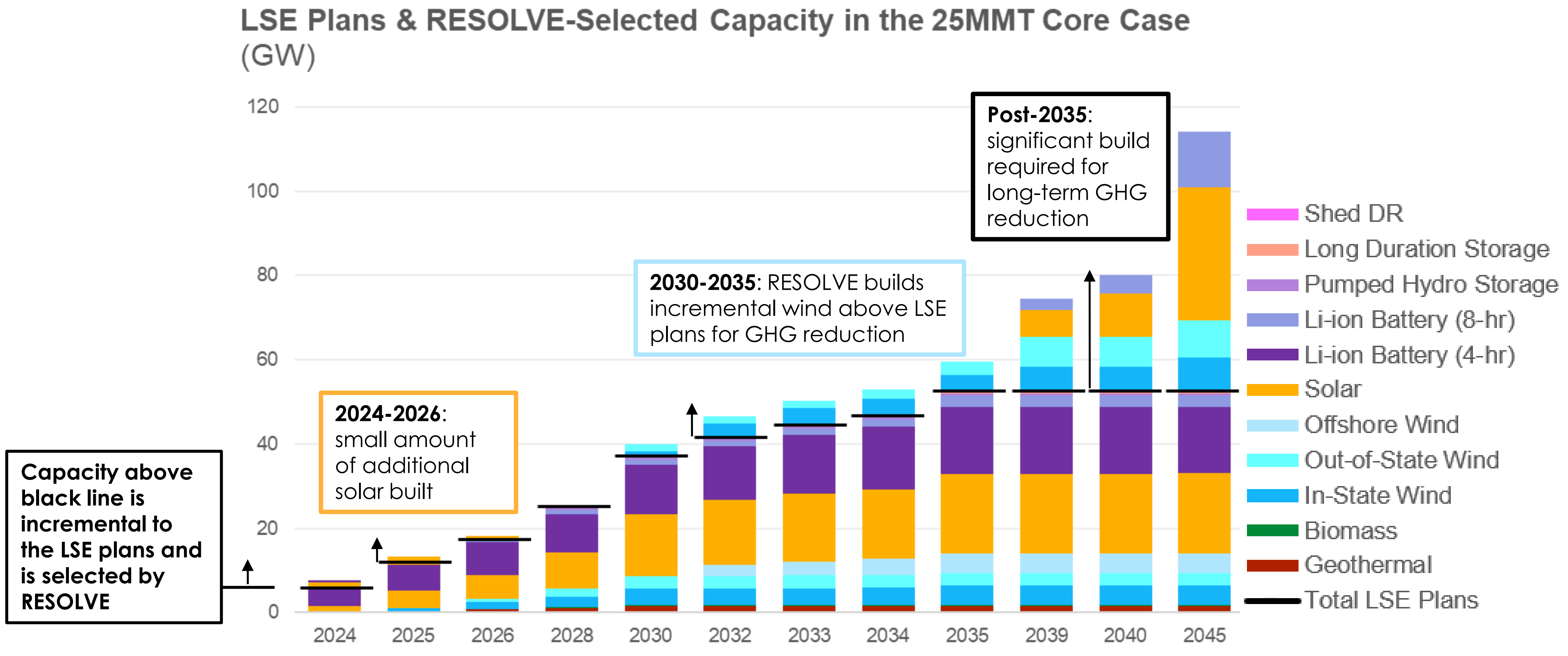
Planned & Selected Capacity (GW)

Resource Category	2024	2025	2026	2028	2030	2032	2033	2034	2035	2039	2040	2045
Geothermal	-	-	0.8	1.1	1.5	1.6	1.6	1.6	1.6	1.7	1.7	1.7
Biomass	-	-	-	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
In-State Wind	0.3	0.4	0.8	1.1	5.4	7.4	8.1	8.1	8.5	10.4	10.4	12.7
Out-of-State Wind	0.0	0.6	1.7	3.4	4.6	4.6	4.6	5.3	6.3	10.2	10.2	11.6
Offshore Wind	-	-	-	-	-	2.7	3.3	3.9	4.5	4.5	4.5	4.5
Solar	3.0	6.0	6.5	8.5	14.8	15.3	16.1	16.4	19.0	25.2	29.1	50.6
Li-ion Battery (4-hr)	4.3	6.3	8.0	9.0	11.6	12.7	14.0	15.0	15.7	15.7	15.7	15.7
Li-ion Battery (8-hr)	0.0	0.0	0.4	1.0	1.2	1.4	1.4	1.7	2.8	5.7	7.3	16.1
Pumped Hydro Storage	-	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Long Duration Storage	-	-	0.1	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.5	0.5
Shed DR	-	-	-	-	-	-	-	-	-	-	-	-
Gas Capacity Not Retained	*(2.1)*	*(2.1)*	*(2.1)*	*(2.1)*	*(2.1)*	*(2.1)*	*(2.1)*	*(2.1)*	*(2.1)*	*(2.1)*	*(2.1)*	*(4.0)*
Total	**5.5**	**11.2**	**16.2**	**23.0**	**37.9**	**44.5**	**48.1**	**50.9**	**57.5**	**72.4**	**78.0**	**110.1**

25 MMT Core Case

Planned Builds vs. RESOLVE-Selected Builds (GW)

LSE Plans are mostly sufficient for reliability & GHG reduction needs until 2035

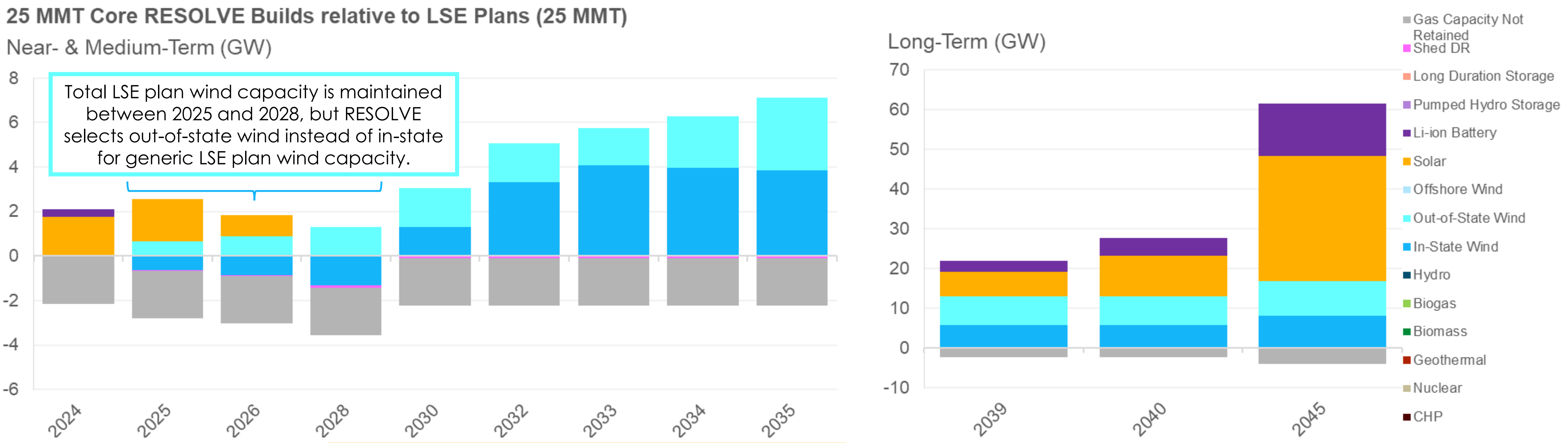


25 MMT Core Case

Planned & Selected Capacity, Compared to LSE Plans (GW)

After 2030, RESOLVE adds in-state and out of state wind on top of LSE Planned resources. This is driven by the need for additional GHG reductions in 2030-2035 since LSE plans used a lower 2021 IEPR load forecast in these years and since POU planned additions are not included in CPUC's LSE plans. Additionally, more in-state wind potential is now available starting in 2030 relative to previous analyses.

Since LSE plans only went through 2035, beyond that period incremental clean energy resources are needed to meet long-term GHG reduction targets and resource adequacy requirements

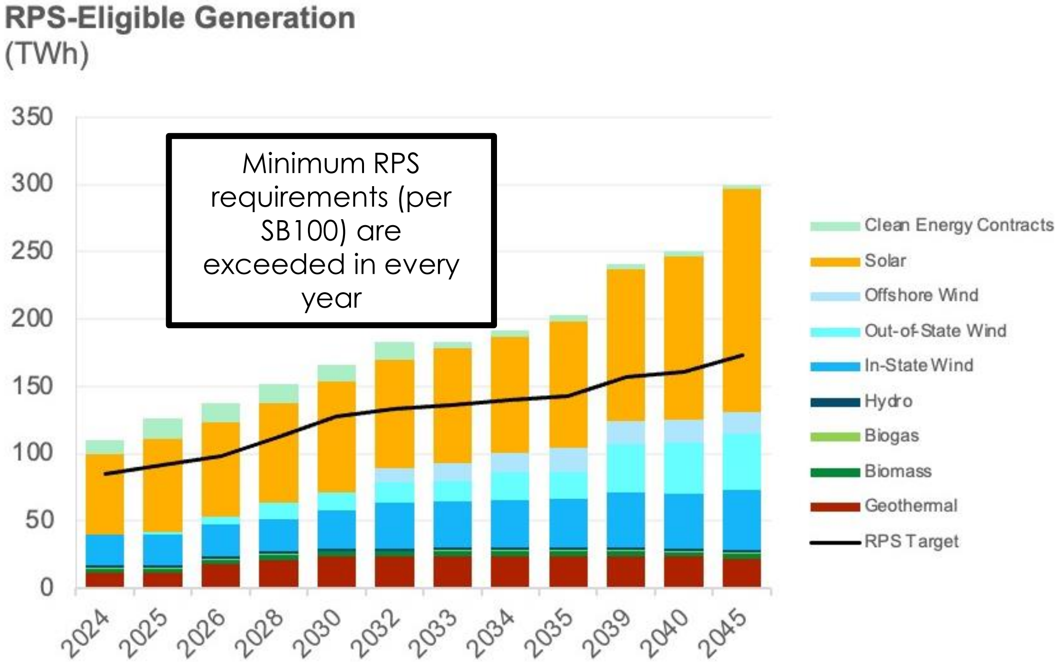


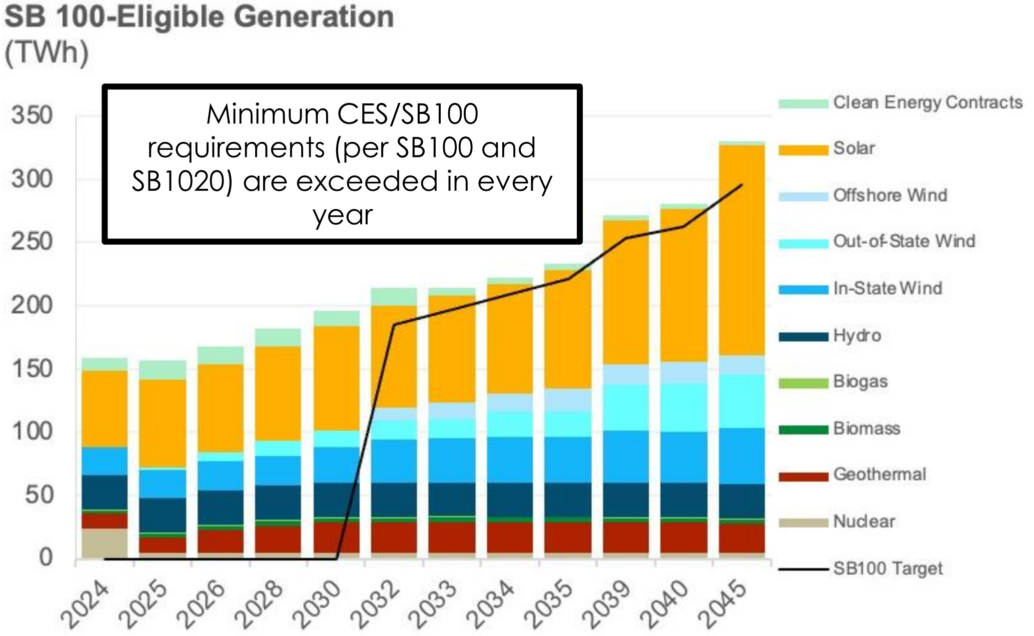
RESOLVE doesn't build solar and battery capacity above the LSE plans between 2028 and 2035

25 MMT Core Case

RPS & SB 100

Clean energy requirements (RPS/CES) are *not* drivers of resource selection. LSE plans (core cases only), GHG targets, and reliability requirements (MTR + PRM) are main drivers of resource selection.





$0/MWh shadow price indicates that there is zero incremental cost to meet RPS requirements

$0/MWh shadow price indicates that there is zero incremental cost to meet CES/SB100 requirements (per SB100 and SB1020)

25 MMT Core Case

PRM Results

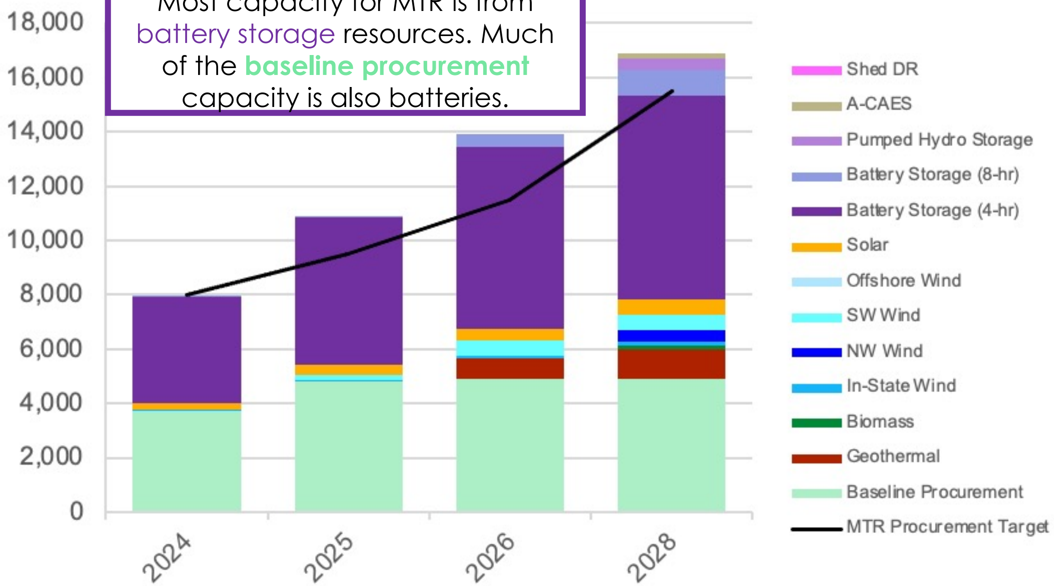
Especially in 2026 and 2028, renewable resources provide incremental MTR capacity

Most incremental capacity needs are met with solar and storage. Geothermal and wind also provide incremental resource adequacy.

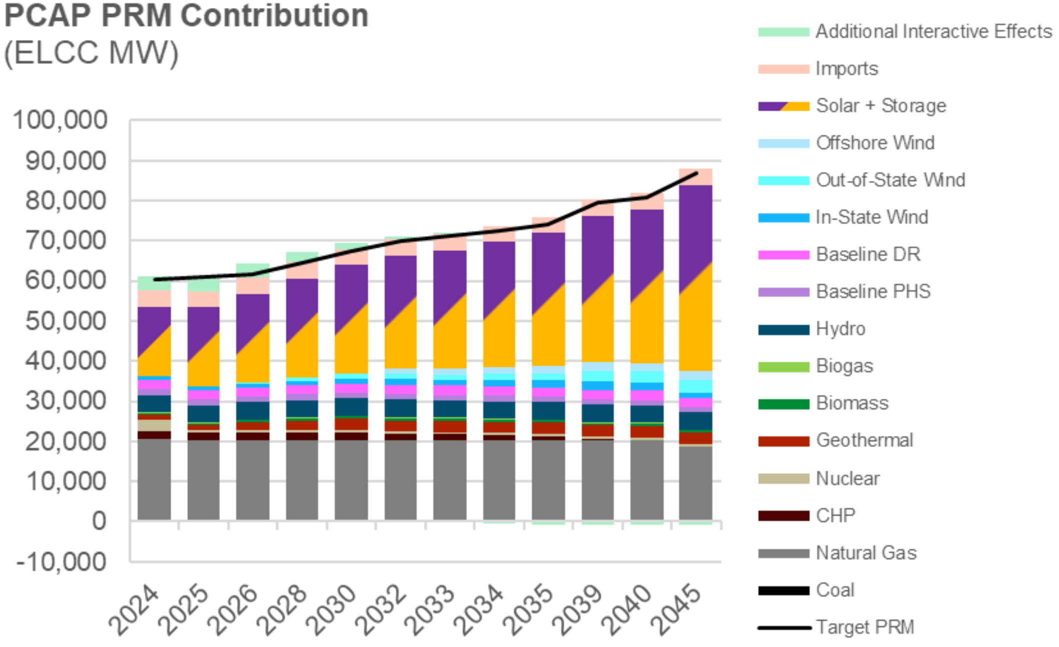
Natural gas resources provide ~20 GW of capacity throughout the study horizon and – though 6 GW by 2035 are uncontracted in LSE plans – are retained by RESOLVE to support long-term reliability needs at least cost

MTR Contribution by Resource Type
(ELCC MW)

Most capacity for MTR is from battery storage resources. Much of the **baseline procurement** capacity is also batteries.



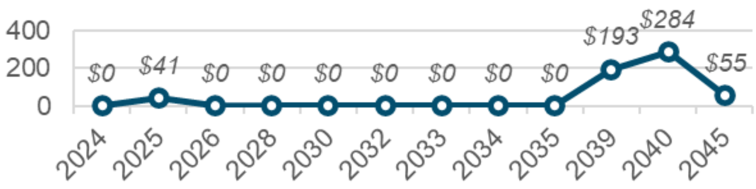
PCAP PRM Contribution
(ELCC MW)



MTR Shadow Prices
($/kW-year)

As shown by $0 shadow price in all MTR years except for 2024, the LSE plans are sufficient to meet MTR requirements… in fact, LSE planned additions exceed MTR requirements in 2025-2028

PRM Shadow Prices
($/kW-year)



Additional resources above those in the LSE plans are only required to meet reliability requirements in the outer years (2039+)

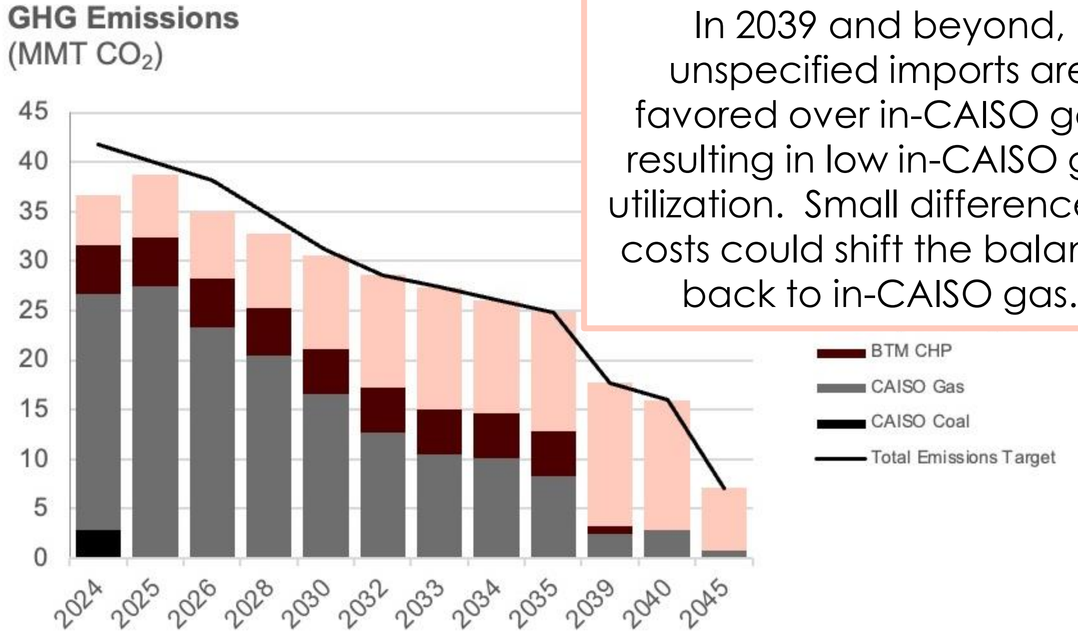
25 MMT Core Case

In-state & Unspecified Import Emissions (MMT)

In-CAISO gas and **unspecified imports** (frequently from gas plants outside of CAISO) are economic substitutes within RESOLVE modeling; a mix of unspecified import and in-CAISO gas emissions are shown in each year.

BTM CHP, and associated GHG emissions, are assumed to phase out between 2035 and 2040.

LSE plan resources, reliability requirements (MTR + PRM), and resource economics are adequate to meet the GHG target at no incremental cost ($0/ton CO_2 shadow price) through 2030.
In the 2030s, the cost to meet the GHG target is relatively small ($2-36/ton CO_2).



In 2039 and beyond, unspecified imports are favored over in-CAISO gas, resulting in low in-CAISO gas utilization. Small differences in costs could shift the balance back to in-CAISO gas.

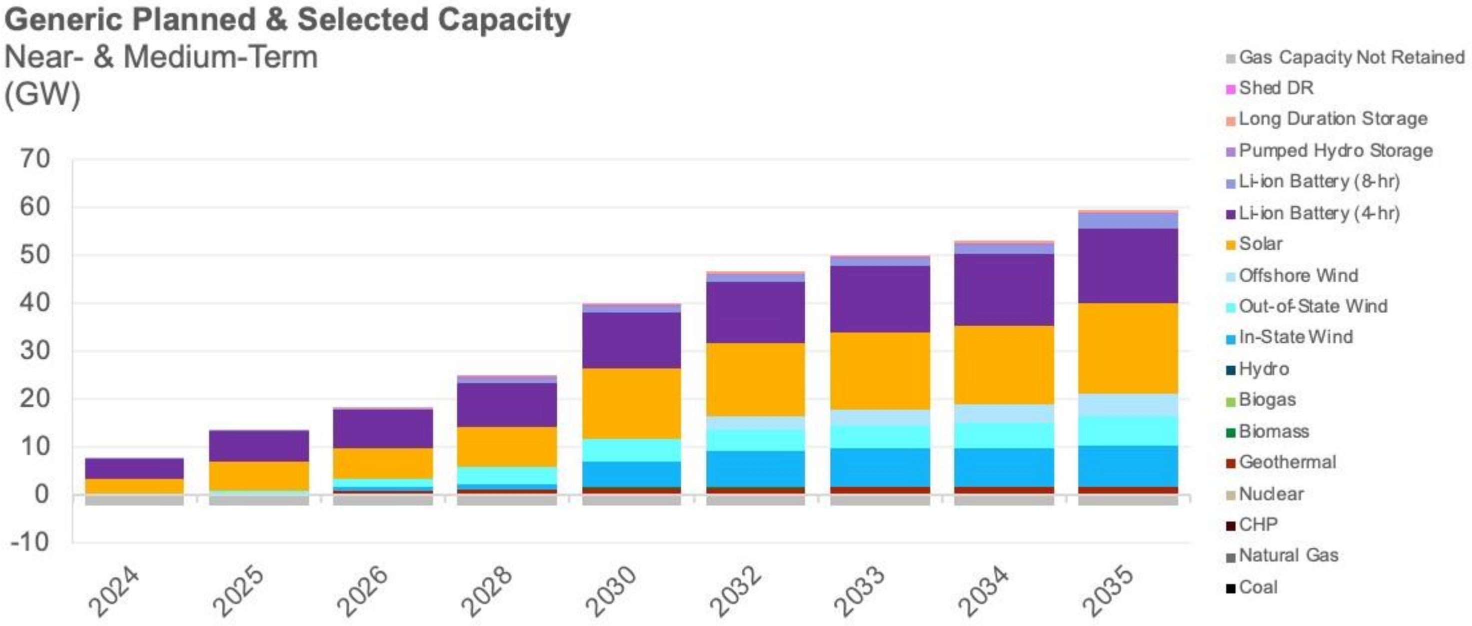
In the terminal year of 2045, the cost rises steeply to meet the stringent 2045 GHG target.

30 MMT Core Case

30 MMT Core Case

Planned & Selected Capacity, Near- & Mid-Term (GW)

Solar and battery capacity grow steadily over time



All three categories of wind (in-state, out of state, offshore) also show steady growth.
RESOLVE does not select offshore wind above the levels in the LSE plans.

A relatively small amount of gas (2 GW) is not retained

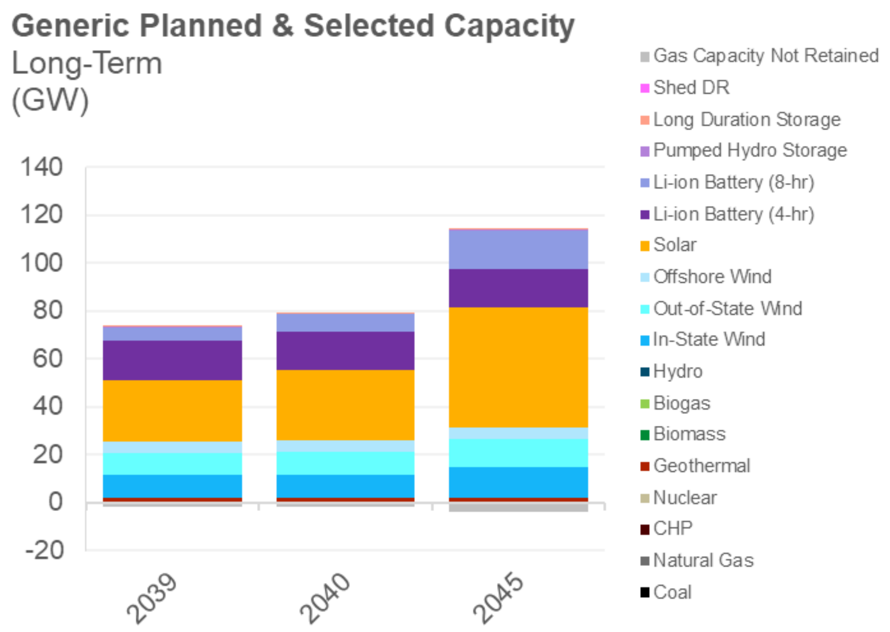
30 MMT Core Case

Planned & Selected Capacity, Long-Term (GW)

Longer duration (8-hr) Li-ion batteries become a larger part of the portfolio in the late 2030s and beyond

Resource adequacy value and greenhouse gas reductions are likely key to the adoption of 8-hour batteries.

Transmission availability may play a role as well – 8-hour batteries are modeled as requiring the same amount of transmission as 4-hour but provide more resource adequacy per MW of capacity



30 MMT Core Case

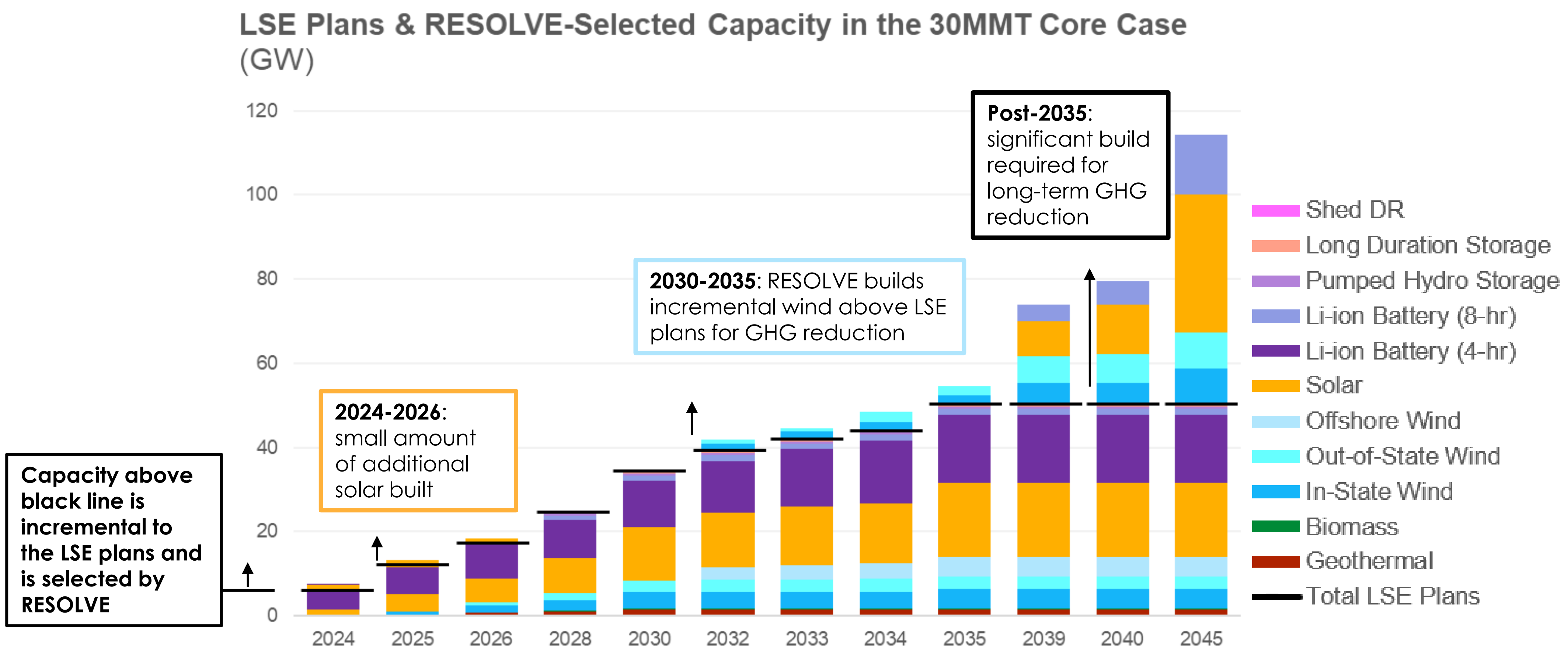
Planned & Selected Capacity (GW)

Resource Category	2024	2025	2026	2028	2030	2032	2033	2034	2035	2039	2040	2045
Geothermal	-	-	0.8	1.1	1.5	1.6	1.6	1.6	1.6	1.7	1.7	1.7
Biomass	-	-	-	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
In-State Wind	0.3	0.4	0.8	1.1	3.3	5.8	5.8	6.2	6.6	9.6	9.6	13.0
Out-of-State Wind	0.0	0.6	1.7	3.0	3.5	4.0	4.0	5.3	5.3	9.2	9.7	11.5
Offshore Wind	-	-	-	-	-	2.8	3.4	3.7	4.6	4.6	4.6	4.6
Solar	3.0	6.0	6.6	8.3	12.6	13.2	13.9	14.2	17.5	25.8	29.4	50.4
Li-ion Battery (4-hr)	4.3	6.3	8.0	9.0	11.0	12.3	13.6	14.9	16.1	16.1	16.1	16.1
Li-ion Battery (8-hr)	0.0	0.0	0.4	1.0	1.2	1.3	1.3	1.3	1.6	5.7	7.2	15.7
Pumped Hydro Storage	-	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Long Duration Storage	-	-	0.1	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.5	0.5
Shed DR	-	-	-	-	-	-	-	-	-	-	-	-
Gas Capacity Not Retained	*(2.0)*	*(2.0)*	*(2.0)*	*(2.0)*	*(2.0)*	*(2.0)*	*(2.0)*	*(2.0)*	*(2.0)*	*(2.0)*	*(2.0)*	*(3.9)*
Total	**5.7**	**11.3**	**16.4**	**22.6**	**32.1**	**39.9**	**42.7**	**46.4**	**52.5**	**72.0**	**77.5**	**110.4**

30 MMT Core Case

Planned Builds vs. RESOLVE-Selected Builds (GW)

LSE Plans are mostly sufficient for reliability & GHG reduction needs until 2035



Planned & Selected Capacity, Compared to LSE Plans (GW)

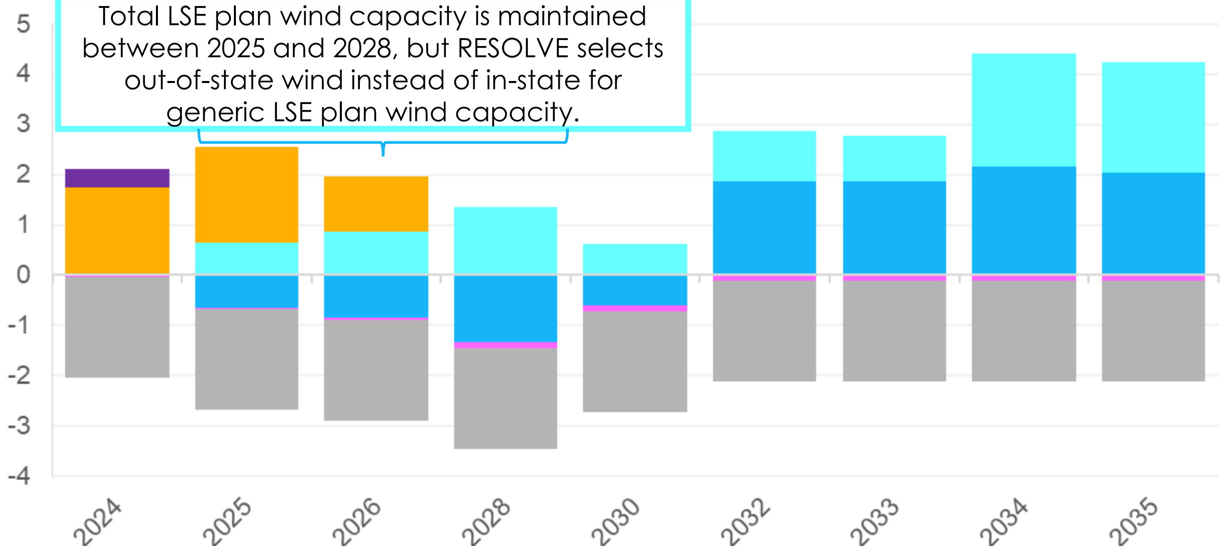
After 2030, RESOLVE adds in-state and out of state wind on top of LSE Plan wind resources. This dynamic is driven by need for GHG reductions in 2030-2035 since LSE plans used a lower 2021 IEPR load forecast in these years and since POU planned additions are not included in CPUC's LSE plans. Additionally, more in-state wind potential is available starting in 2030 relative to the 2022 PSP analysis.

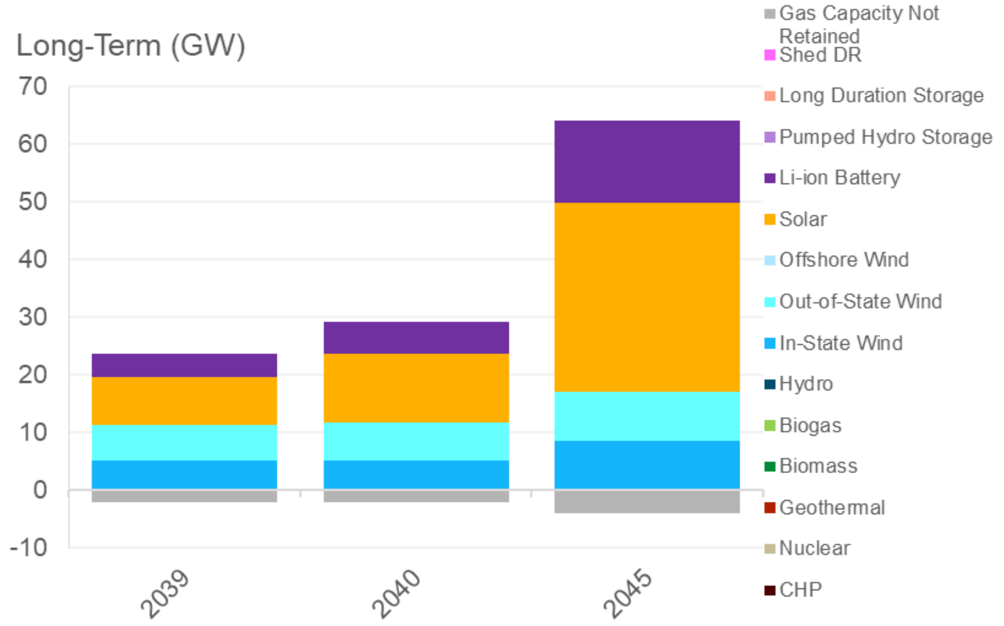
In the late 2030s and beyond, incremental clean energy resources to the LSE plans are needed to meet GHG reduction targets and resource adequacy requirements

30 MMT Core RESOLVE Builds relative to LSE Plans (30 MMT)

Near- & Medium-Term (GW)

Total LSE plan wind capacity is maintained between 2025 and 2028, but RESOLVE selects out-of-state wind instead of in-state for generic LSE plan wind capacity.





RESOLVE doesn't build solar and battery capacity above the LSE plans between 2028 and 2035

30 MMT Core Case

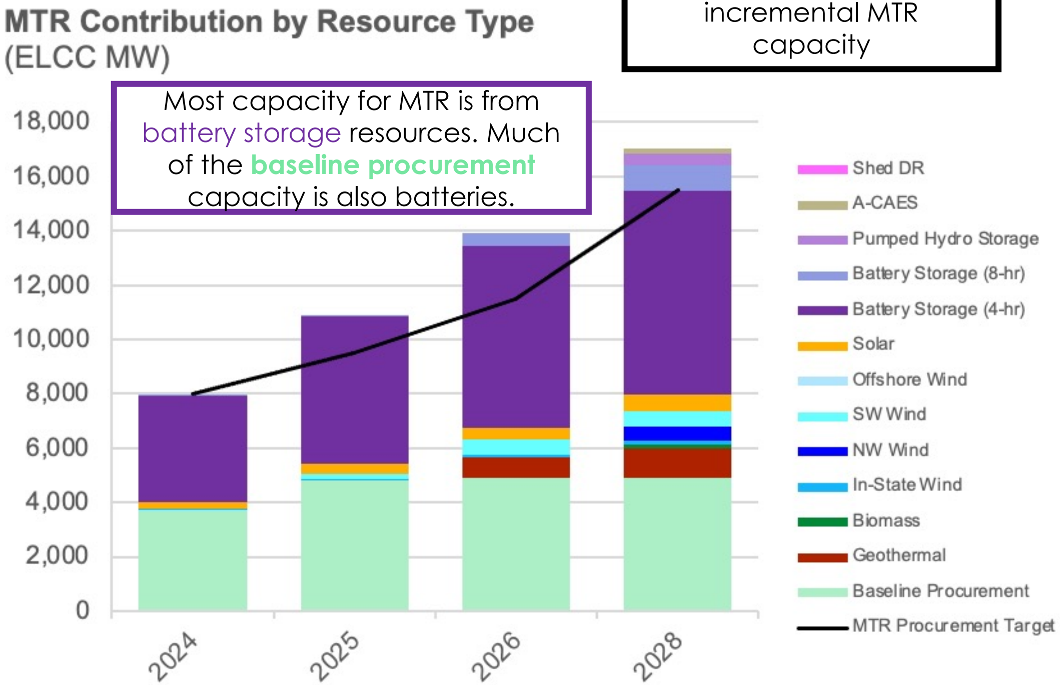
PRM Results

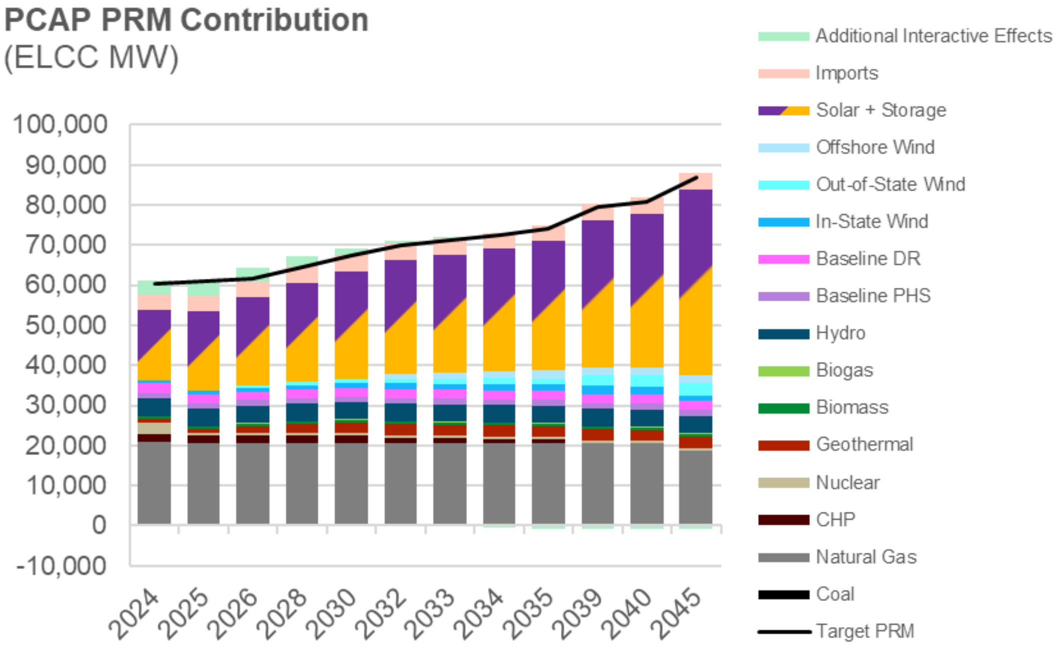
Especially in 2026 and 2028, renewable resources provide incremental MTR capacity

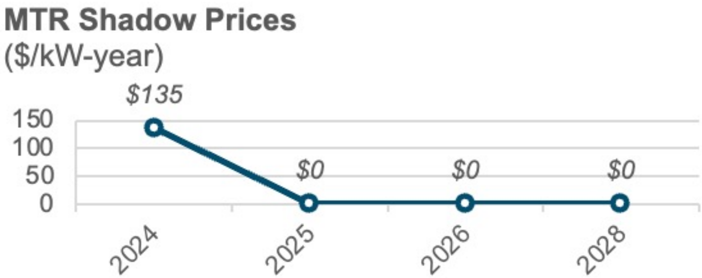
Most incremental capacity needs are met with solar and storage. Geothermal and wind also provide some incremental resource adequacy.

Natural gas resources provide ~20 GW of capacity throughout the study horizon

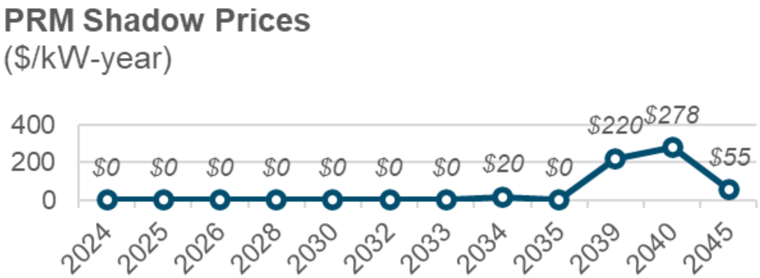
Most capacity for MTR is from battery storage resources. Much of the **baseline procurement** capacity is also batteries.







As shown by $0 shadow price in all MTR years except for 2024, the LSE plans are sufficient to meet MTR requirements



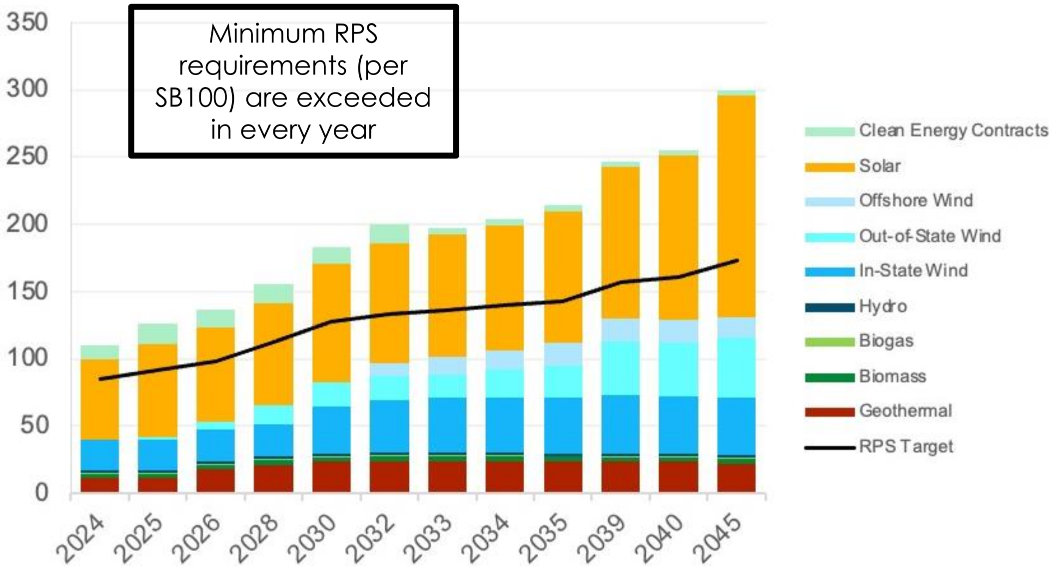
Additional resources above those in the LSE plans are only required to meet reliability requirements in the outer years (2034+), with the main resource need occurring after the LSE plan horizon (2039+)

30 MMT Core Case

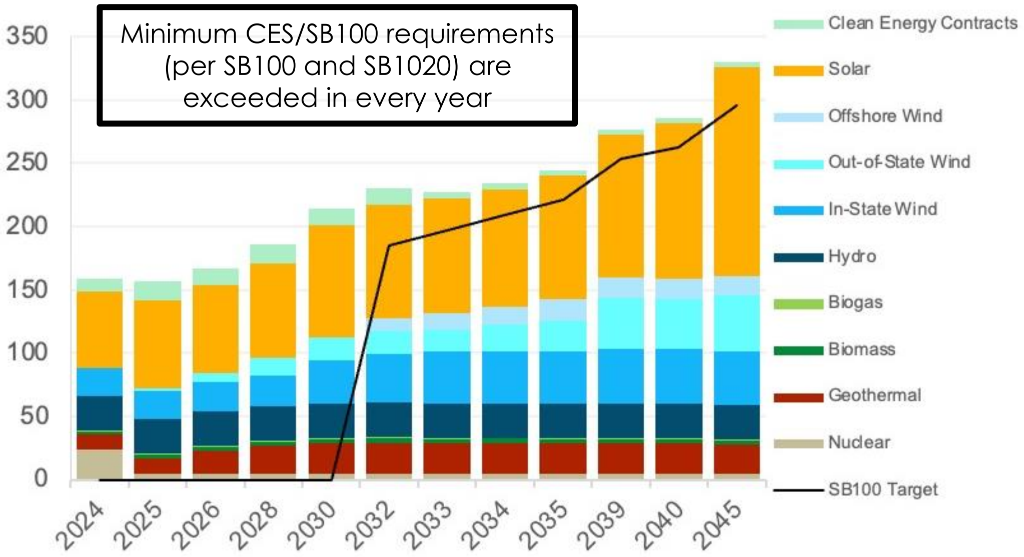
RPS & SB 100

Clean energy requirements (RPS/CES) are *not* drivers of resource selection.
LSE plans (core cases only), GHG targets, and reliability requirements (MTR + PRM) are main drivers of resource selection.

RPS-Eligible Generation
(TWh)



SB 100-Eligible Generation
(TWh)



RPS Shadow Prices
($/MWh)

$0/MWh shadow price indicates that there is zero incremental cost to meet RPS requirements

SB 100 Shadow Prices
($/MWh)

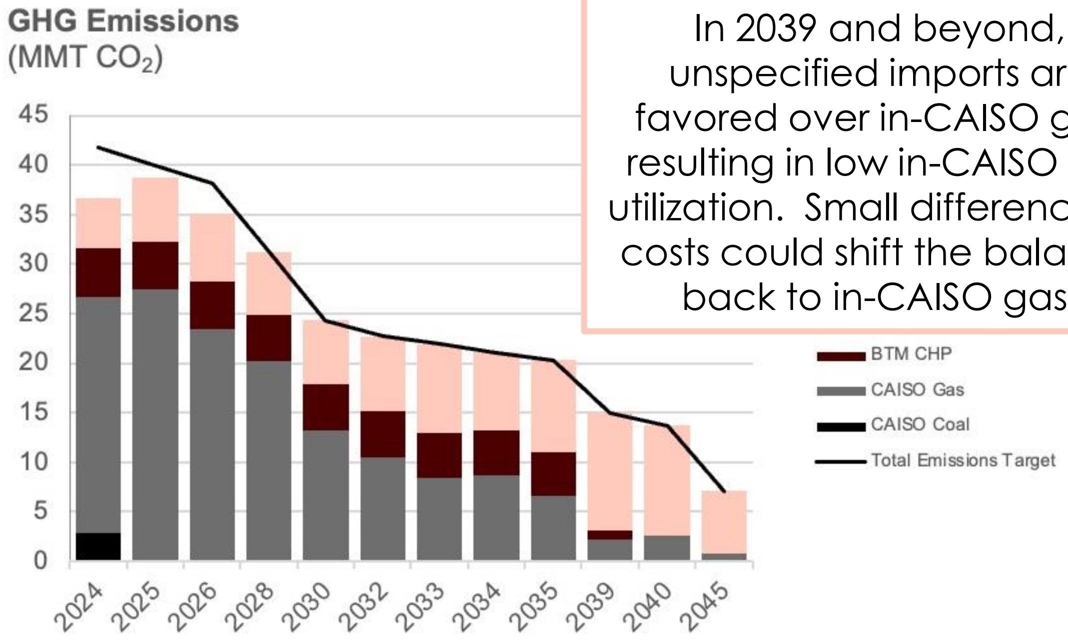
$0/MWh shadow price indicates that there is zero incremental cost to meet CES/SB100 requirements (per SB100 and SB1020)

30 MMT Core Case

In-state & Unspecified Import Emissions (MMT)

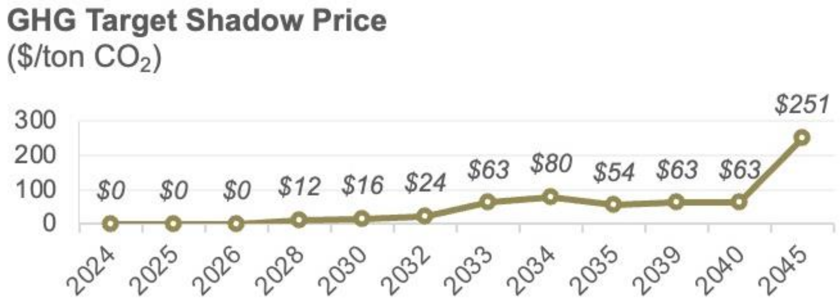
In-CAISO gas and **unspecified imports** (frequently from gas plants outside of CAISO) are on similar economic footing; a mix of unspecified import and in-CAISO gas emissions are shown in each year.

BTM CHP, and associated GHG emissions, assumed to phase out between 2035 and 2040



In 2039 and beyond, unspecified imports are favored over in-CAISO gas, resulting in low in-CAISO gas utilization. Small differences in costs could shift the balance back to in-CAISO gas.

LSE plan resources, reliability requirements (MTR + PRM), and resource economics are adequate to meet the GHG target at no incremental cost ($0/ton CO_2 shadow price) through 2030.
In the 2030s, the cost to meet the GHG target is relatively small ($2-36/ton CO_2).



In the terminal year of 2045, the cost rises steeply to meet the stringent 2045 GHG target.

Least-Cost Portfolios Overview

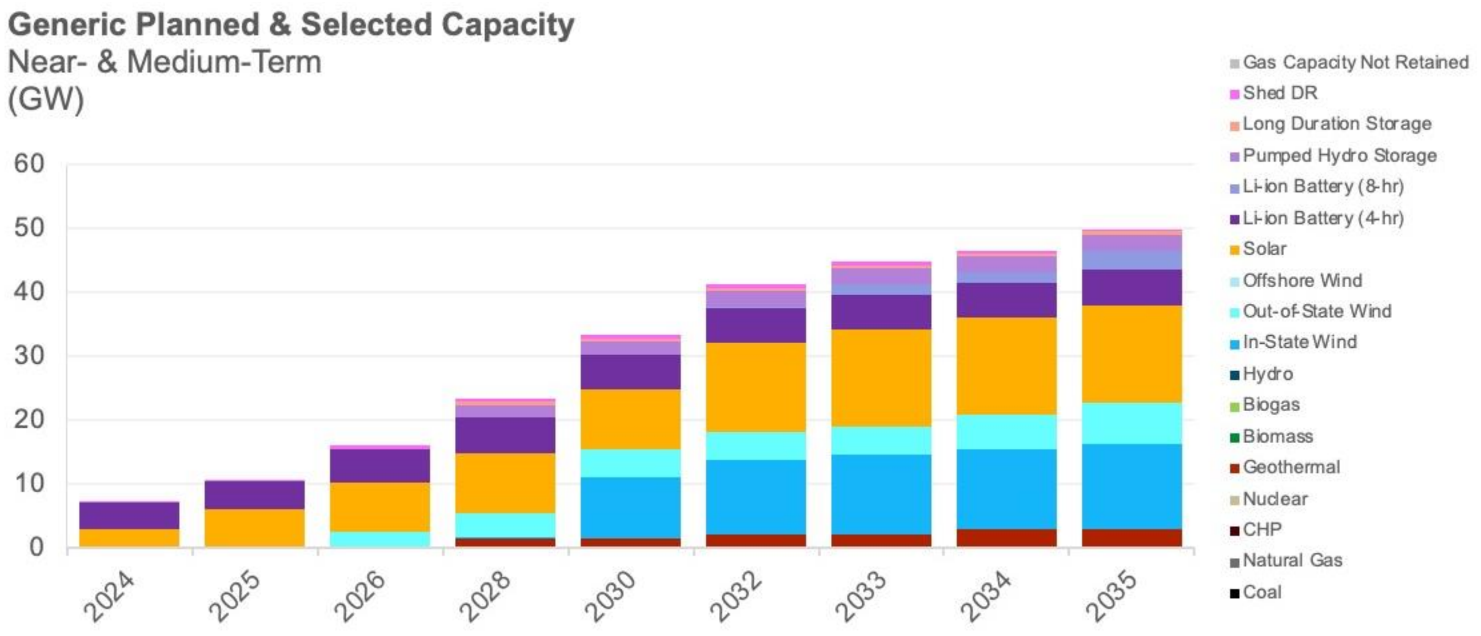
- **Purpose:** Understand the CAISO system resources needed to meet the GHG target (25 MMT or 30 MMT by 2035), clean energy targets, and reliability needs at least-cost, unconstrained by LSE plans
- **Key metrics to be discussed:**
  - Selected resources throughout the modeling period
    - All resources are selected by RESOLVE to optimize the resource mix for reliability, MTR requirements, GHG reduction, or economics
  - Planning reserve margin and MTR highlights
  - RPS and SB 100 policy
  - GHG emissions

25 MMT Least-Cost Case

25 MMT Least-Cost

Planned & Selected Capacity, Near- & Mid-Term (GW)

Solar and battery capacity grow steadily over time



Both categories of onshore wind (in-state, out of state) also show steady growth. RESOLVE does not select offshore wind in the least-cost cases.

All gas is retained until 2045

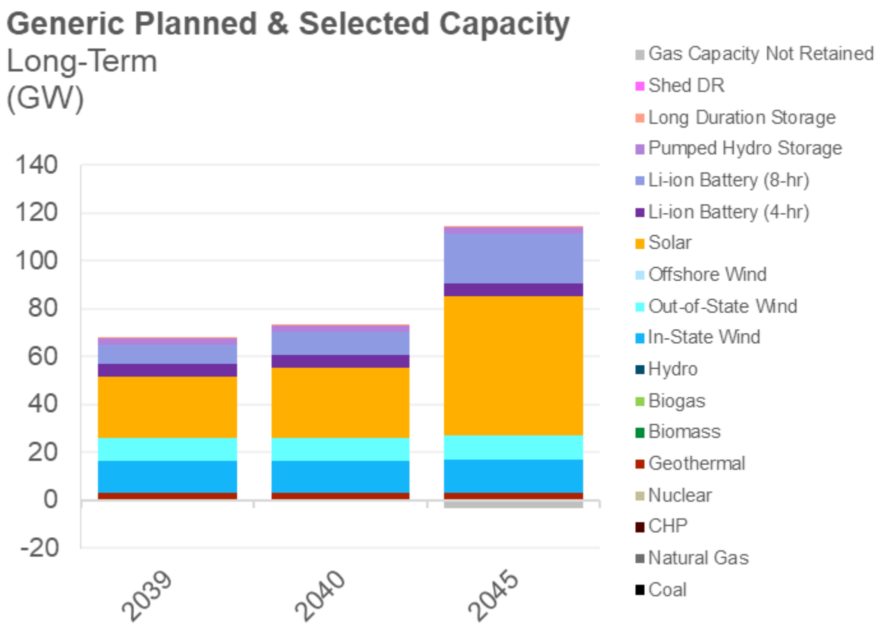
25 MMT Least-Cost

Planned & Selected Capacity, Long-Term (GW)

- Longer duration (8-hr) Li-ion batteries become a larger part of the portfolio in the late 2030s and beyond

Resource adequacy value and greenhouse gas reductions are likely key to the adoption of 8-hour batteries.

Transmission availability may play a role as well – 8-hour batteries are modeled as requiring the same amount of transmission as 4-hour but provide more resource adequacy per MW of capacity



3.6 GW of gas is not retained in 2045

25 MMT Least-Cost

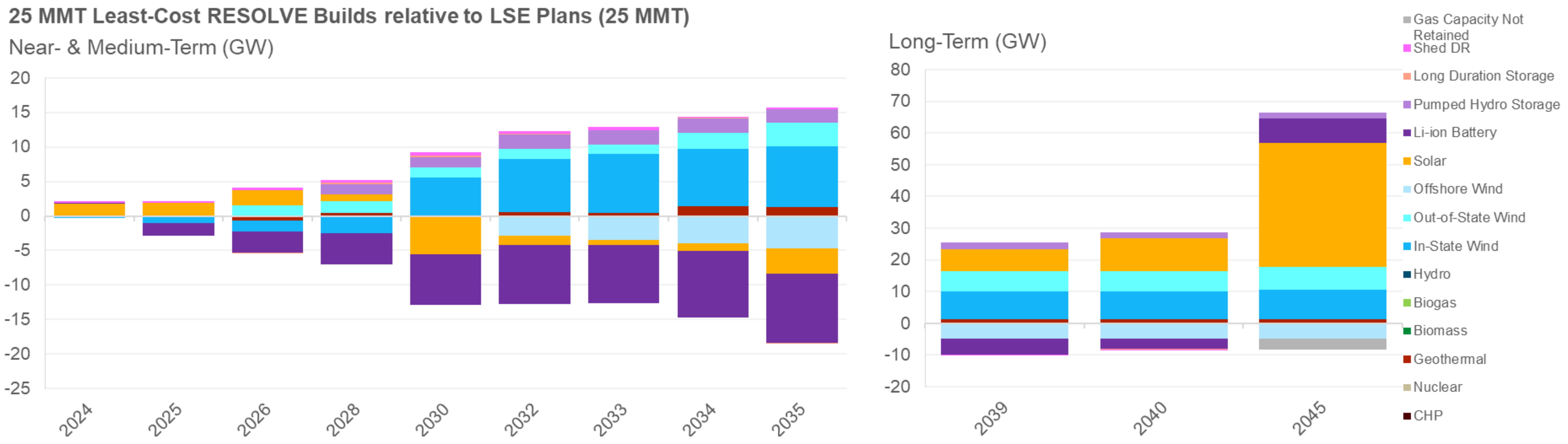
Planned & Selected Capacity (GW)

Resource Category	2024	2025	2026	2028	2030	2032	2033	2034	2035	2039	2040	2045
Geothermal	-	-	0.2	1.6	1.6	2.1	2.1	3.0	3.0	3.0	3.0	3.0
Biomass	-	-	-	-	-	-	-	-	-	-	-	-
In-State Wind	-	-	-	0.1	9.6	11.8	12.5	12.5	13.4	13.4	13.4	13.8
Out-of-State Wind	-	-	2.4	3.9	4.3	4.3	4.3	5.4	6.4	9.3	9.3	10.2
Offshore Wind	-	-	-	-	-	-	-	-	-	-	-	-
Solar	3.0	6.0	7.7	9.4	9.4	14.0	15.3	15.3	15.3	25.9	29.3	58.1
Li-ion Battery (4-hr)	4.1	4.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4
Li-ion Battery (8-hr)	-	-	-	-	-	0.1	1.6	1.6	3.1	7.8	9.6	20.8
Pumped Hydro Storage	-	-	-	2.0	2.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Long Duration Storage	-	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Shed DR	0.3	0.3	0.5	0.6	0.6	0.6	0.6	0.3	0.3	-	-	-
Gas Capacity Not Retained	-	-	-	-	-	-	-	-	-	-	-	*(3.6)*
Total	**7.4**	**10.7**	**16.1**	**23.5**	**33.4**	**41.3**	**44.9**	**46.5**	**49.9**	**67.9**	**73.1**	**110.8**

Planned & Selected Capacity, Compared to LSE Plans (GW)

Least cost has more out of state wind and in-state wind (2030 and beyond) than LSE plans. Least-cost cases use 2023-vintage cost inputs that include IRA tax credits while LSE plans used older cost and resource potential data. Updated resource potential limits for in-state wind show more capacity than was available previously.

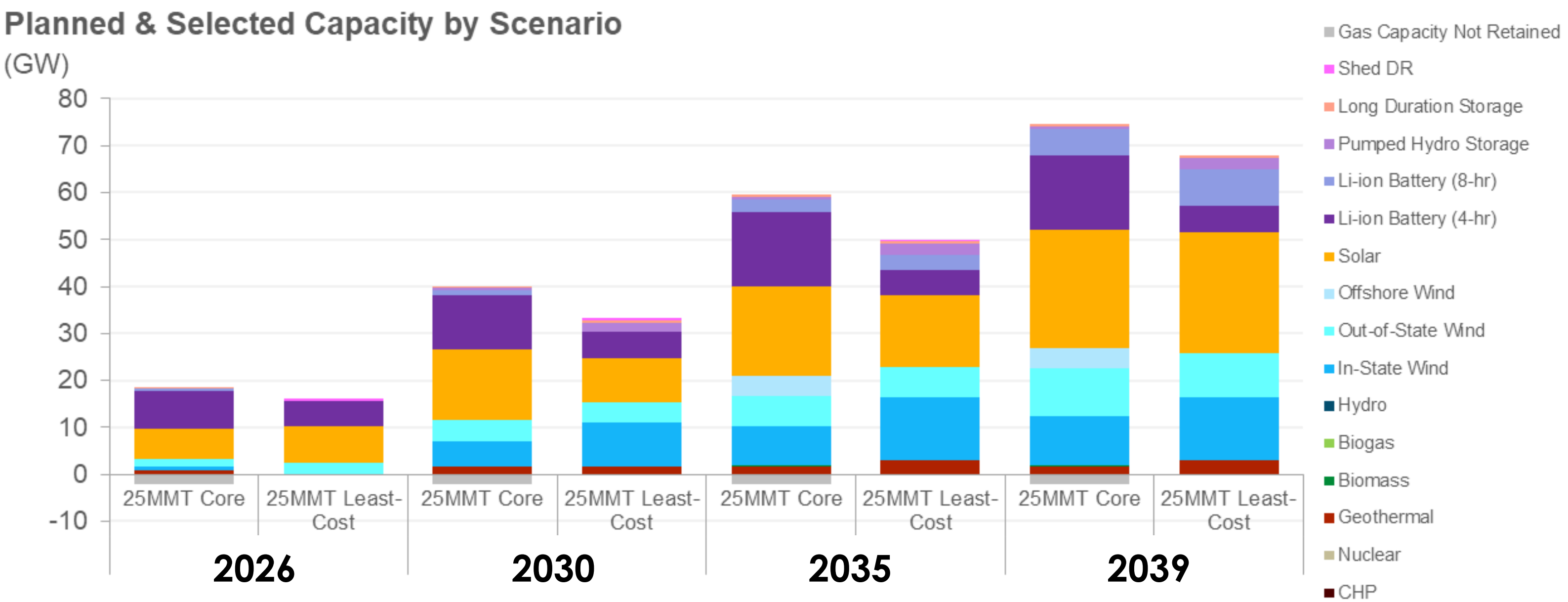
Least cost has less battery storage and more pumped hydro storage than LSE plans, a change that is likely driven by updated resource cost projections, especially higher costs for batteries.



Least cost has no offshore wind, also driven by higher projected costs

25 MMT Core vs 25 MMT Least Cost

- ***25 MMT least-cost scenarios show a lower cost portfolio than the Core portfolio that relies on LSE plans***
  - Annual cost impact = ~$500-1,500M/yr
- Least-cost cases use 2023-vintage cost inputs that include IRA tax credits, while LSE plans used older cost and resource potential data
- Lower costs in the least-cost scenario driven by:
  - Less offshore wind, battery storage, and thermal retirements
  - More in-state wind and long duration storage



2026 Core	2026 Least-Cost	2030 Core	2030 Least-Cost	2035 Core	2035 Least-Cost	2039 Core	2039 Least-Cost
$47,843	-$496M	$50,358	-$621M	$54,936	-$1,483M	$57,393	-$1,428M

Annual Costs ($MM/yr)

<u>NPV</u> of Total Resource Cost ($MM in 2022 Dollar Year, 2024-2065)	
25 MMT Core	$911,538
25 MMT Least-Cost	$896,300
	(-$15,238 MM)

25 MMT Least-Cost

PRM Results

Especially in 2026 and 2028, renewable resources provide incremental MTR capacity

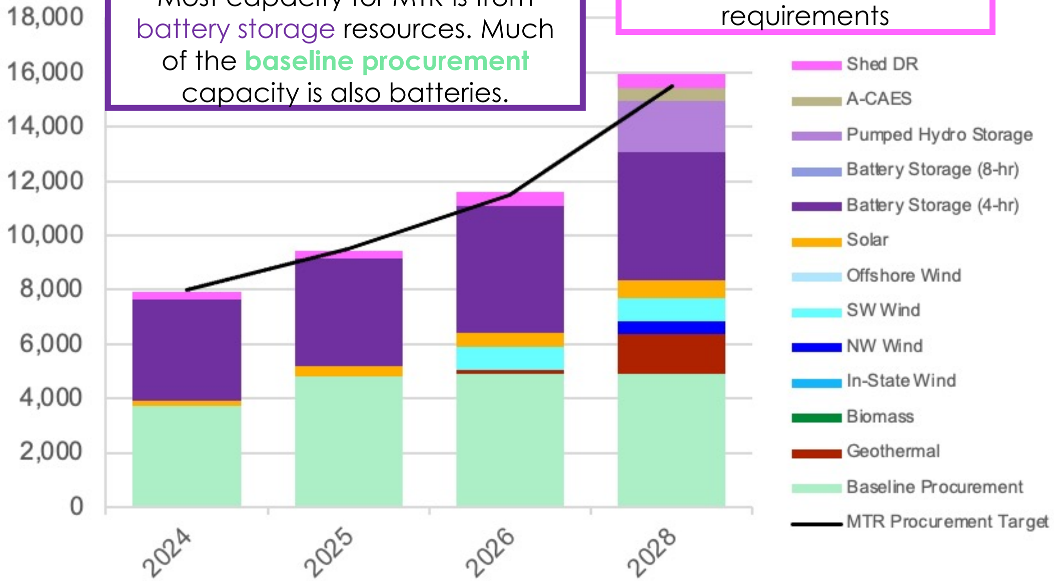
Shed DR capacity added to meet MTR requirements

Most incremental capacity needs are met with solar and storage. Geothermal and wind also provide some incremental resource adequacy.

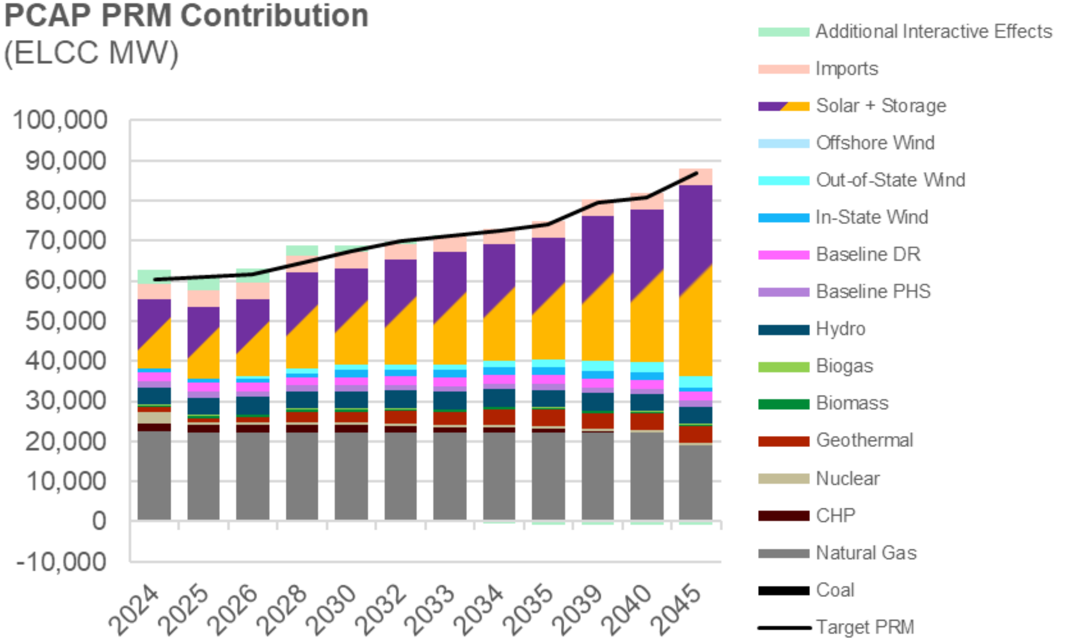
Natural gas resources provide ~20 GW of capacity throughout the study horizon

MTR Contribution by Resource Type
(ELCC MW)

Most capacity for MTR is from battery storage resources. Much of the **baseline procurement** capacity is also batteries.

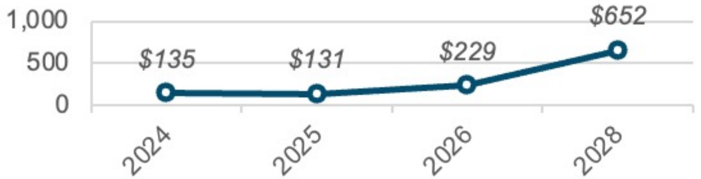


PCAP PRM Contribution
(ELCC MW)



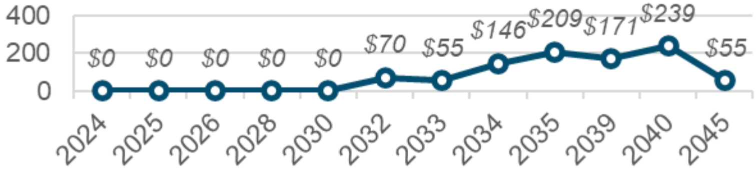
Candidate Shed DR ELCC part of Solar + Storage category

MTR Shadow Prices
($/kW-year)



As indicated by marginal costs (shadow prices)above $100/kW-yr, the MTR constraints are strong drivers of resource selection in the 25 MMT Least Cost scenario.

PRM Shadow Prices
($/kW-year)



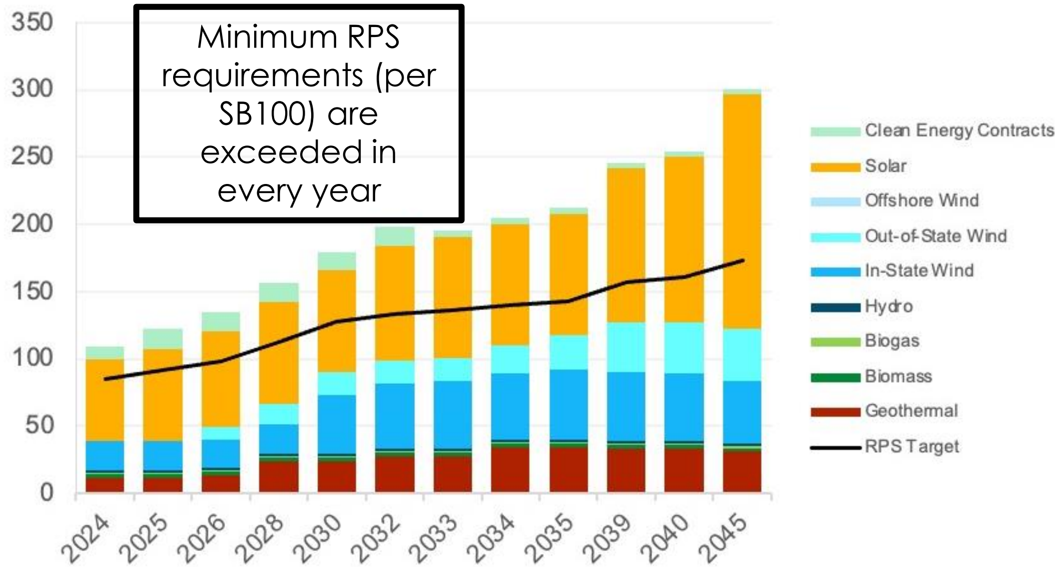
After 2030, the PRM is a strong driver of resource selection

25 MMT Least-Cost

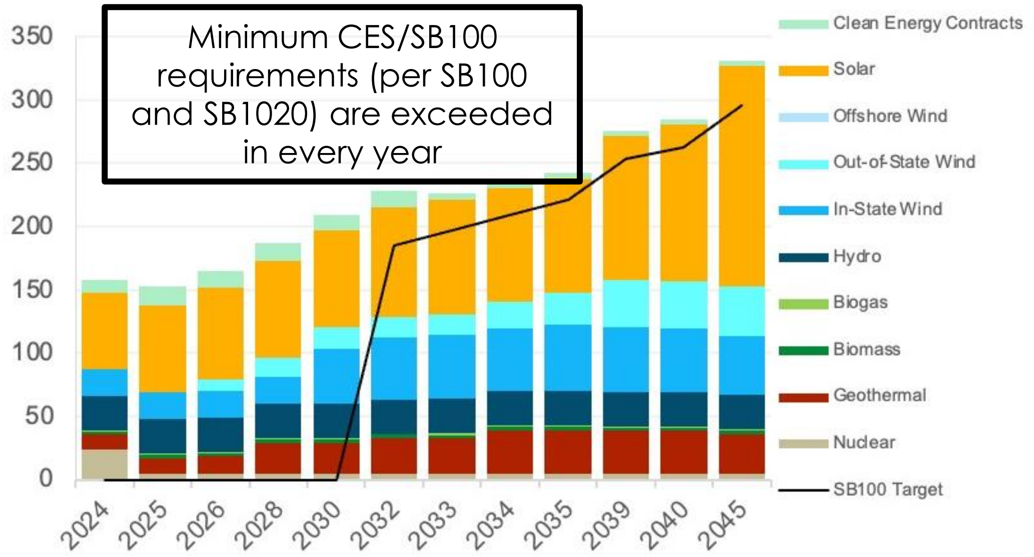
RPS & SB 100

Clean energy requirements (RPS/CES) are *not* drivers of resource selection. LSE plans (core cases only), GHG targets, and reliability requirements (MTR + PRM) are main drivers of resource selection.

RPS-Eligible Generation
(TWh)



SB 100-Eligible Generation
(TWh)



RPS Shadow Prices
($/MWh)

$0/MWh shadow price indicates that there is zero incremental cost to meet RPS requirements

SB 100 Shadow Prices
($/MWh)

$0/MWh shadow price indicates that there is zero incremental cost to meet CES/SB100 requirements (per SB100 and SB1020)

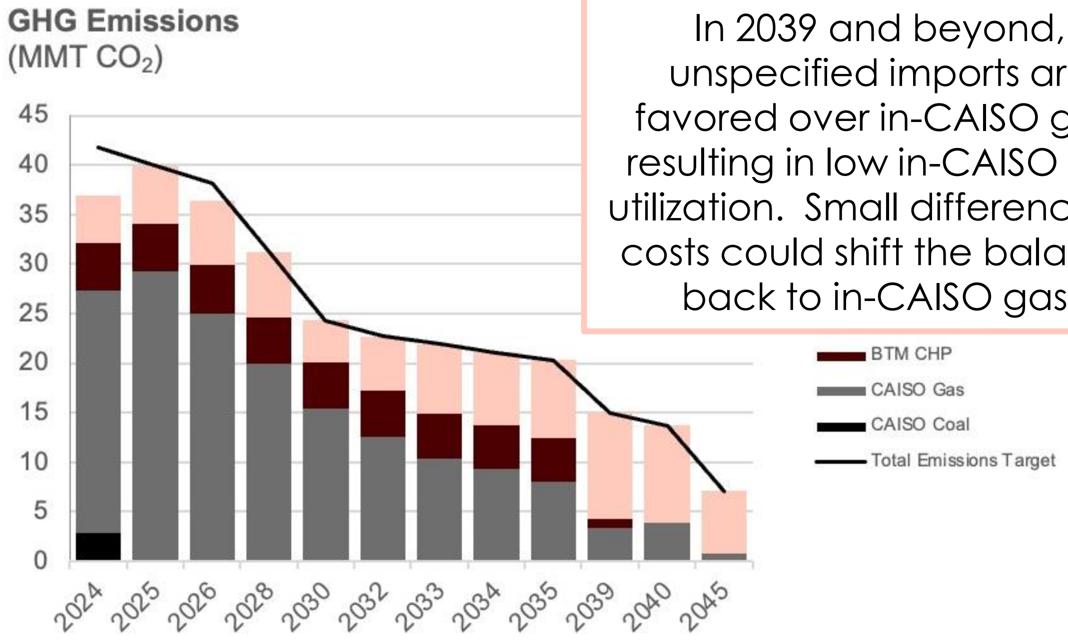
25 MMT Least-Cost

In-state & Unspecified Import Emissions (MMT)

In-CAISO gas and **unspecified imports** (frequently from gas plants outside of CAISO) are on similar economic footing; a mix of unspecified import and in-CAISO gas emissions are shown in each year.

BTM CHP, and associated GHG emissions, assumed to phase out between 2035 and 2040

The relatively high marginal cost of meeting the GHG target (the GHG target shadow price) in 2030 and beyond indicates that GHG reductions are a major driver of resource portfolio selection in and after 2030. Before 2030, economics and other constraints, especially the MTR constraints, drive portfolio selection.



In 2039 and beyond, unspecified imports are favored over in-CAISO gas, resulting in low in-CAISO gas utilization. Small differences in costs could shift the balance back to in-CAISO gas.

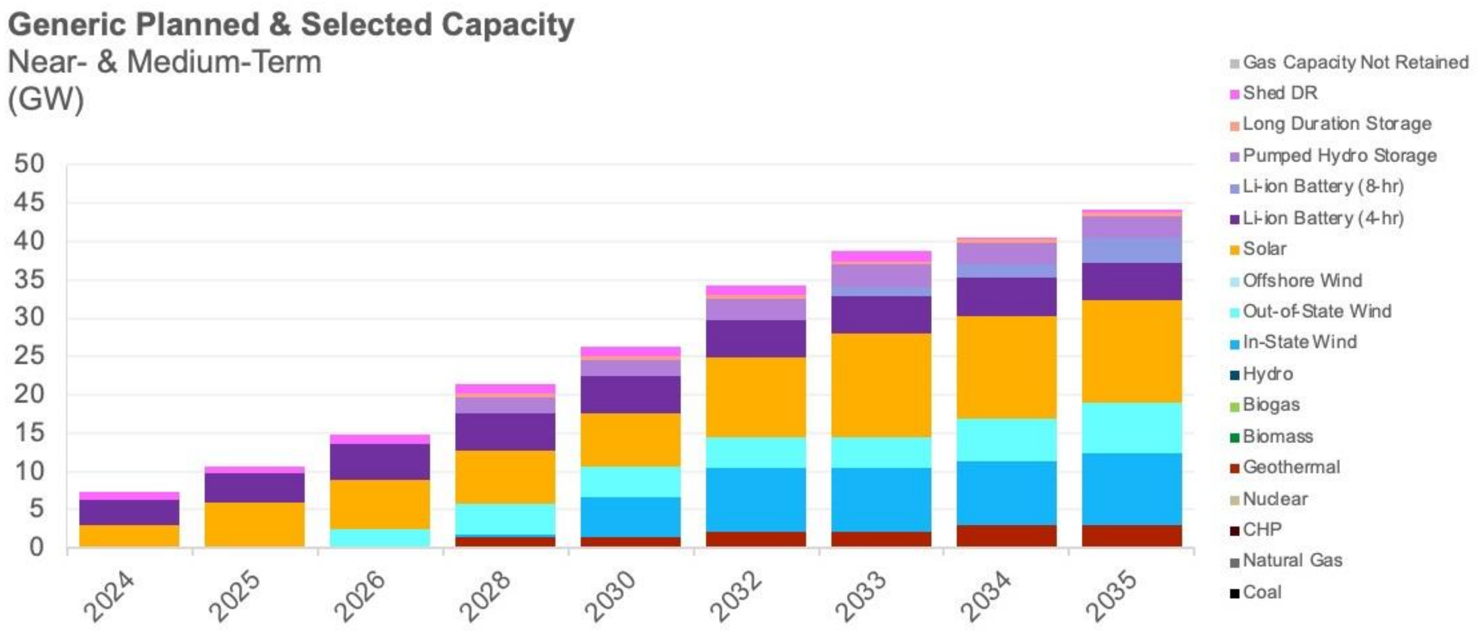
In the terminal year of 2045, the cost rises steeply to meet the stringent 2045 GHG target.

30 MMT Least-Cost Case

30 MMT Least-Cost

Planned & Selected Capacity, Near- & Mid-Term (GW)

Solar and battery capacity grow steadily over time



Both categories of onshore wind (in-state, out of state) also show steady growth. RESOLVE does not select offshore wind in the least-cost cases.

All gas is retained until 2045

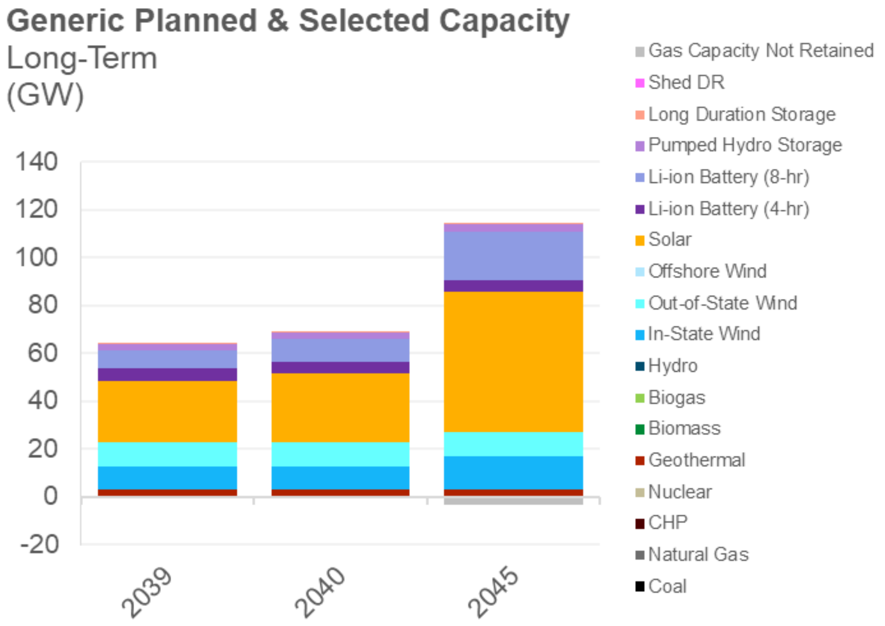
30 MMT Least-Cost

Planned & Selected Capacity, Long-Term (GW)

- Similar to 25 MMT Least-Cost portfolio, longer duration (8-hr) Li-ion batteries become a larger part of the portfolio in the late 2030s and beyond

Resource adequacy value and greenhouse gas reductions are likely key to the adoption of 8-hour batteries.

Transmission availability may play a role as well – 8-hour batteries are modeled as requiring the same amount of transmission as 4-hour but provide more resource adequacy per MW of capacity



30 MMT Least-Cost

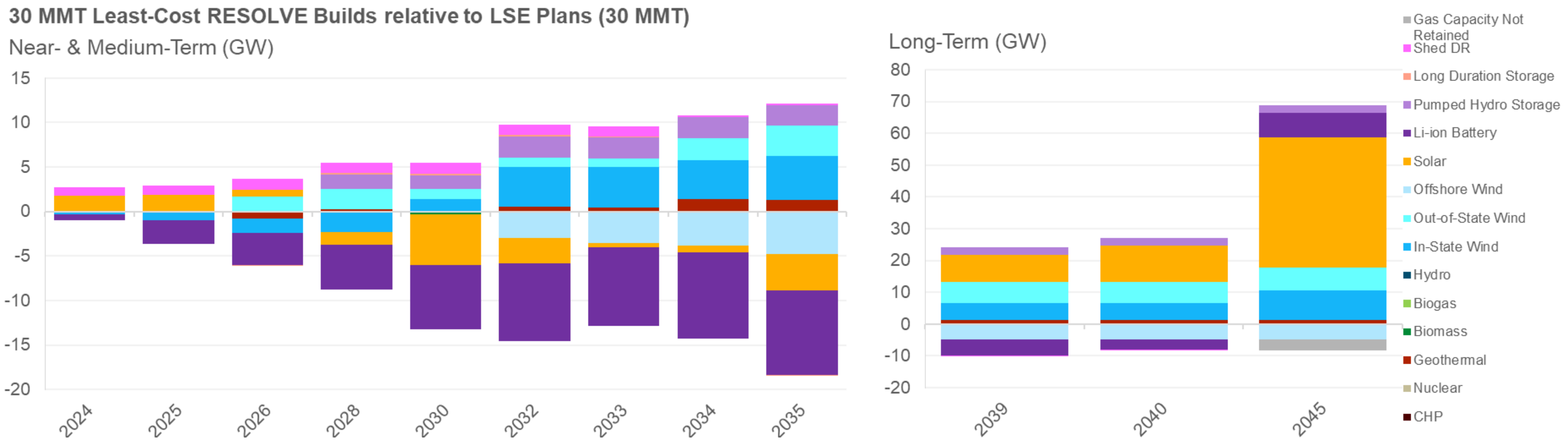
Planned & Selected Capacity (GW)

Resource Category	2024	2025	2026	2028	2030	2032	2033	2034	2035	2039	2040	2045
Geothermal	-	-	0.0	1.4	1.4	2.1	2.1	2.9	2.9	2.9	2.9	2.9
Biomass	-	-	-	-	-	-	-	-	-	-	-	-
In-State Wind	0.0	0.0	0.0	0.3	5.3	8.4	8.4	8.4	9.4	9.7	9.7	13.8
Out-of-State Wind	-	-	2.5	4.0	4.0	4.0	4.0	5.5	6.5	9.9	9.9	10.4
Offshore Wind	-	-	-	-	-	-	-	-	-	-	-	-
Solar	3.0	6.0	6.3	6.9	6.9	10.3	13.5	13.5	13.5	25.9	28.9	58.3
Li-ion Battery (4-hr)	3.3	3.7	4.8	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
Li-ion Battery (8-hr)	-	-	-	-	-	-	1.3	1.7	3.3	7.7	9.6	20.6
Pumped Hydro Storage	-	-	-	2.1	2.1	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Long Duration Storage	-	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Shed DR	1.0	1.0	1.2	1.3	1.3	1.3	1.3	0.3	0.3	-	-	-
Gas Capacity Not Retained	-	-	-	-	-	-	-	-	-	-	-	*(3.5)*
Total	**7.4**	**10.7**	**14.9**	**21.4**	**26.3**	**34.3**	**38.8**	**40.6**	**44.1**	**64.5**	**69.3**	**110.8**

Planned & Selected Capacity, Compared to LSE Plans (GW)

Least cost has more out of state wind and in-state wind (2030 and beyond) than LSE plans. Least-cost cases use 2023-vintage cost inputs that include IRA tax credits while LSE plans used older cost and resource potential data. Updated resource potential limits for in-state wind show more capacity than was available previously.

Least cost has less battery storage and more pumped hydro storage than LSE plans, a change that is likely driven by updated resource cost projections, especially higher costs for batteries.



Least cost has no offshore wind, also driven by higher projected costs

30 MMT Least-Cost

PRM Results

Especially in 2026 and 2028, renewable resources provide incremental MTR capacity

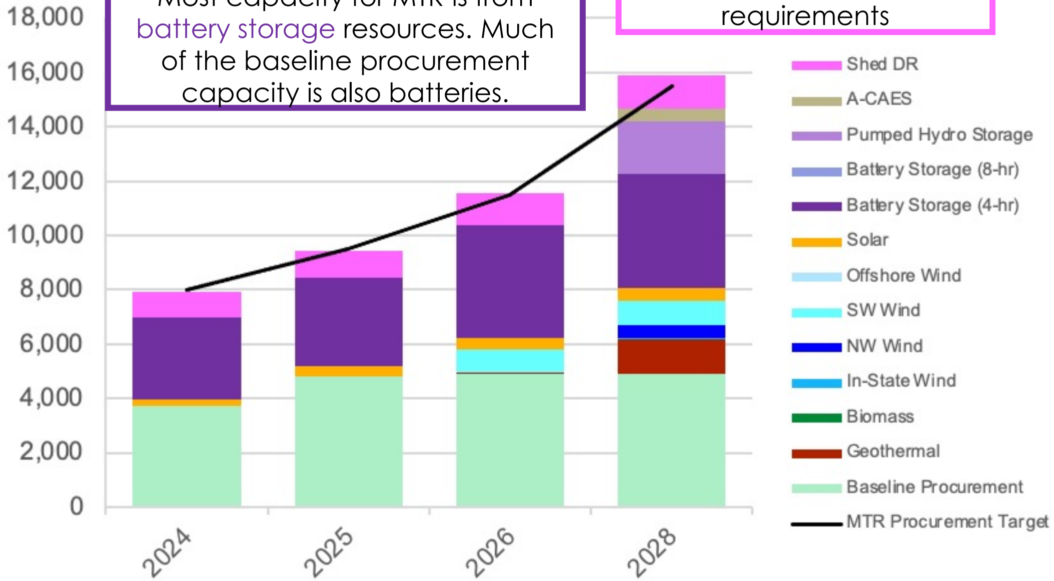
Most incremental capacity needs are met with solar and storage. Geothermal and wind also provide some incremental resource adequacy.

Natural gas resources provide ~20 GW of capacity throughout the study horizon

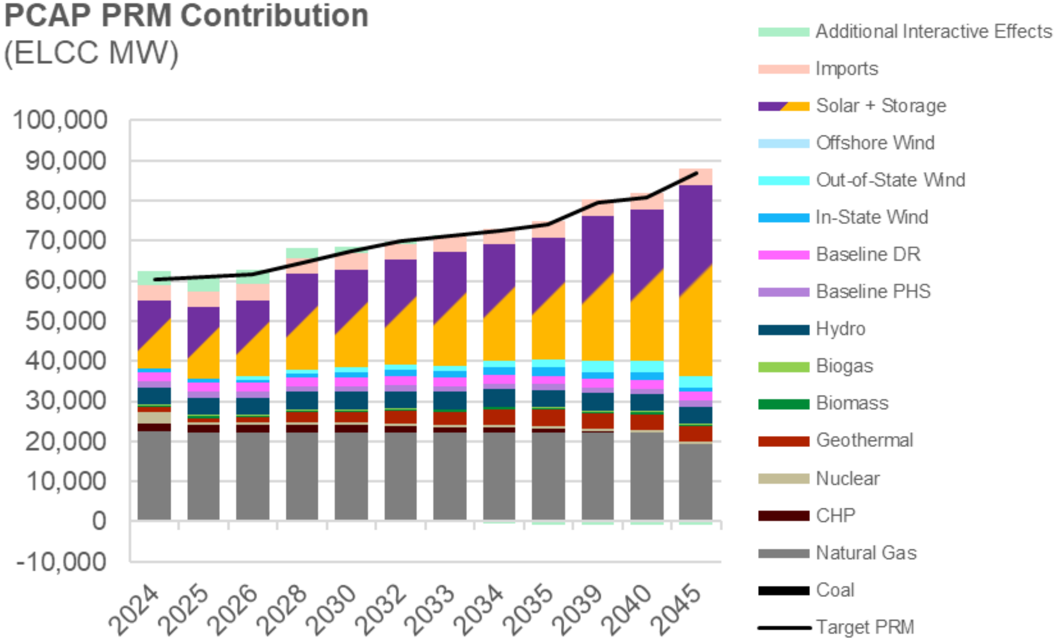
MTR Contribution by Resource Type
(ELCC MW)

Shed DR capacity added to meet MTR requirements

Most capacity for MTR is from battery storage resources. Much of the baseline procurement capacity is also batteries.

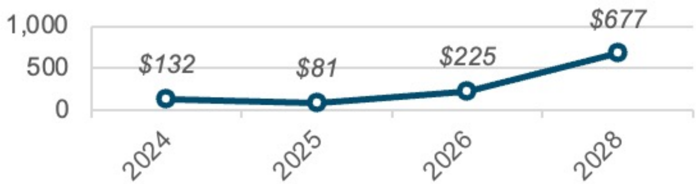


PCAP PRM Contribution
(ELCC MW)



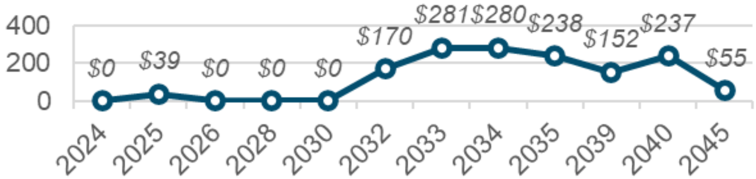
Candidate Shed DR ELCC part of Solar + Storage category

MTR Shadow Prices
($/kW-year)



As indicated by marginal costs (shadow prices)above $100/kW-yr, the MTR constraints are strong drivers of resource selection.

PRM Shadow Prices
($/kW-year)



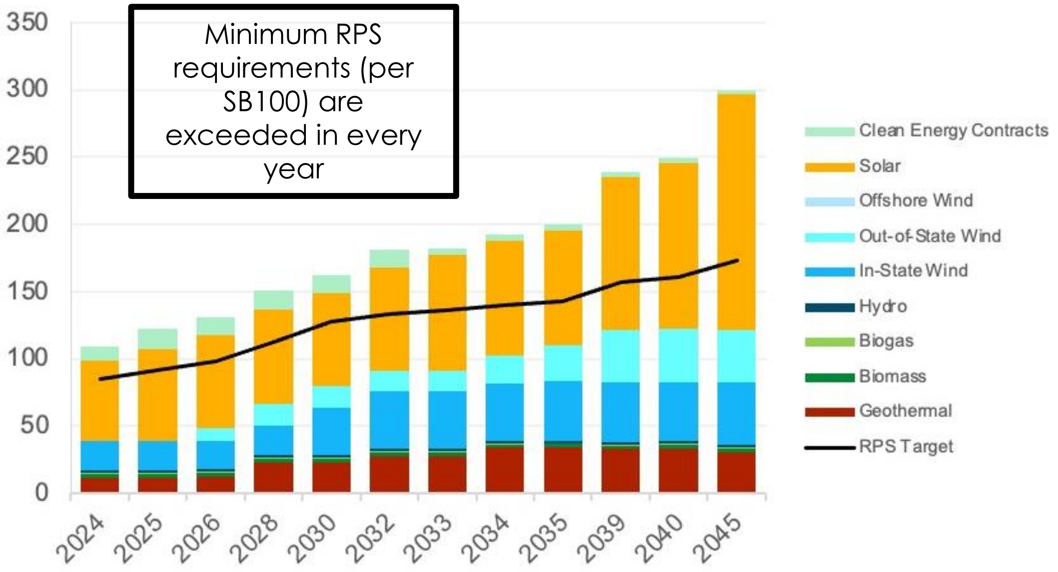
After 2030, the PRM is a strong driver of resource selection

30 MMT Least-Cost

RPS & SB 100

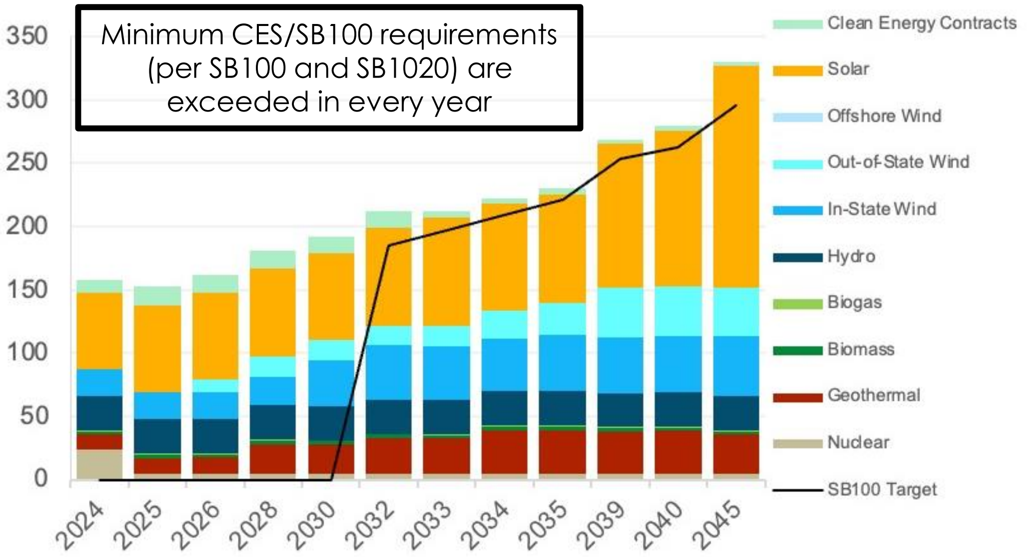
Clean energy requirements (RPS/CES) are *not* drivers of resource selection.
LSE plans (core cases only), GHG targets, and reliability requirements (MTR + PRM) are main drivers of resource selection.

RPS-Eligible Generation
(TWh)



Minimum RPS requirements (per SB100) are exceeded in every year

SB 100-Eligible Generation
(TWh)



Minimum CES/SB100 requirements (per SB100 and SB1020) are exceeded in every year

RPS Shadow Prices
($/MWh)

$0/MWh shadow price indicates that there is zero incremental cost to meet RPS requirements

SB 100 Shadow Prices
($/MWh)

$0/MWh shadow price indicates that there is zero incremental cost to meet CES/SB100 requirements (per SB100 and SB1020)

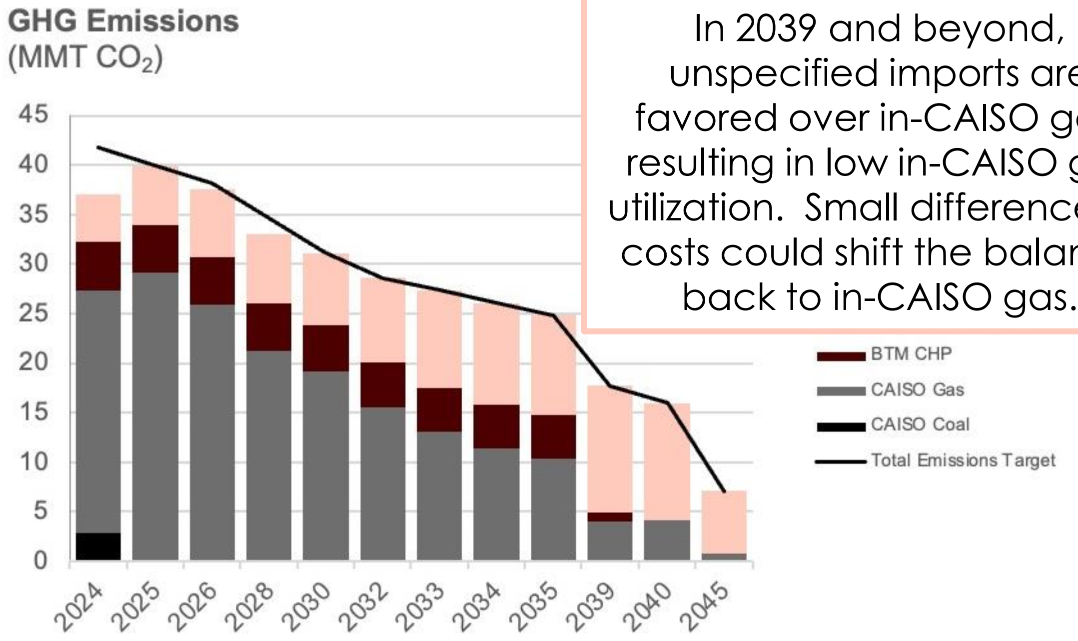
30 MMT Least-Cost

In-state & Unspecified Import Emissions (MMT)

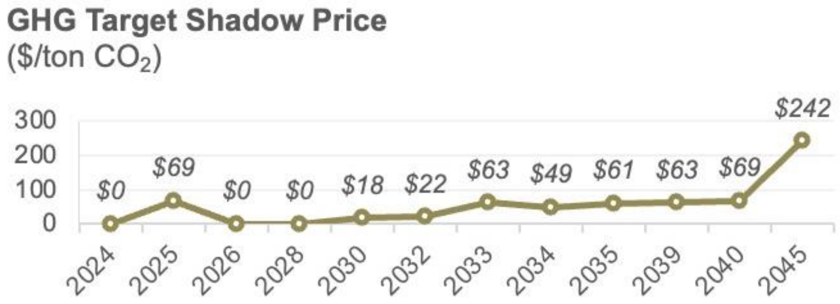
In-CAISO gas and **unspecified imports** (frequently from gas plants outside of CAISO) are on similar economic footing; a mix of unspecified import and in-CAISO gas emissions are shown in each year.

BTM CHP, and associated GHG emissions, assumed to phase out between 2035 and 2040

The relatively high marginal cost of meeting the GHG target (the GHG target shadow price) in 2030 and beyond indicates that GHG reductions are a major driver of resource portfolio selection in and after 2030. Before 2030, economics and other constraints, especially the MTR constraints, drive portfolio selection.



In 2039 and beyond, unspecified imports are favored over in-CAISO gas, resulting in low in-CAISO gas utilization. Small differences in costs could shift the balance back to in-CAISO gas.



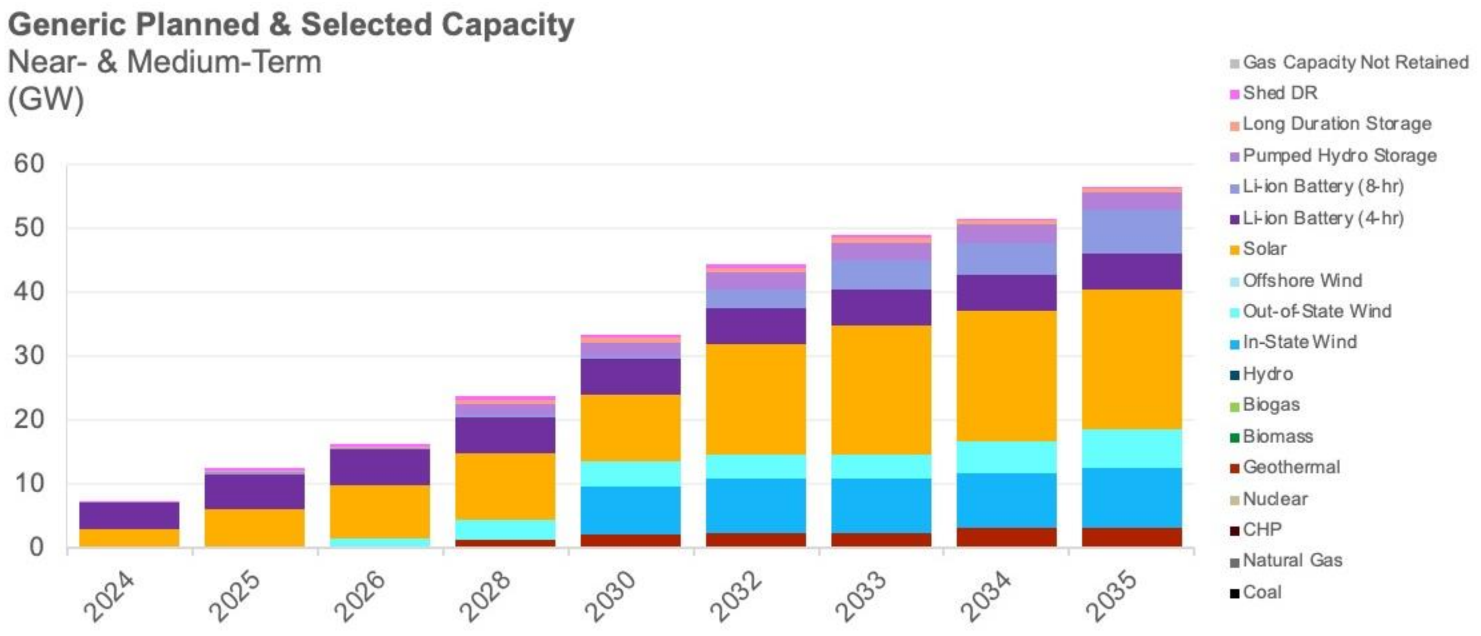
In the terminal year of 2045, the cost rises steeply to meet the stringent 2045 GHG target.

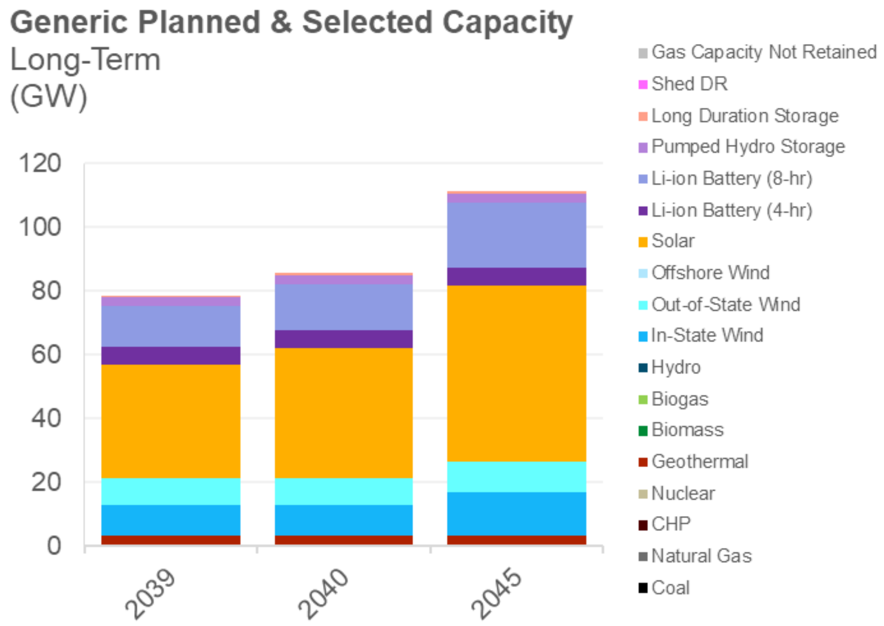
Gas Retirement Sensitivity Cases

25 MMT Sensitivity:
Gas Retirements

Moderate Gas Retirements Sensitivity Case

Planned & Selected Capacity





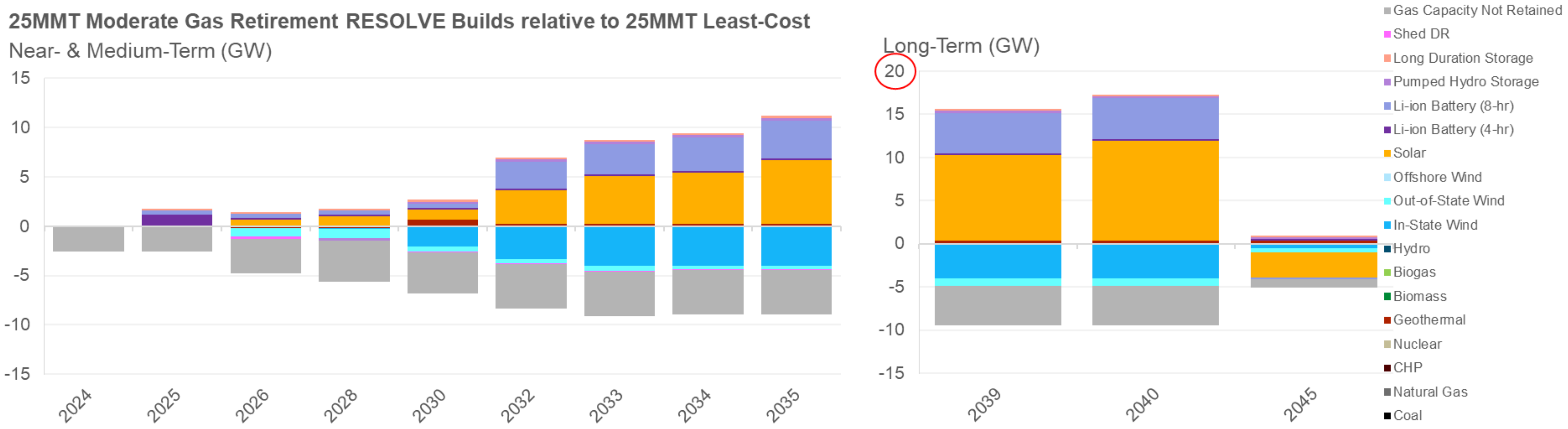
Sensitivity: Moderate Gas Retirements

Planned & Selected Capacity, Compared to Least-Cost (GW)

Gas retirements early in the modeling horizon (2024-26) have a modest impact on the portfolio in the 2020s.

In 2030 and beyond, lower gas capacity drives more solar and 8-hr Battery builds, which displaces some in-state wind build

Longer duration (8-hr) Li-ion batteries are selected earlier, but the total amount built by 2045 is similar to the least-cost case, which chooses not to retain a similar amount of gas by 2045.



Gas retirements shown as negative value on y-axis

Sensitivity: Moderate Gas Retirements

Planned & Selected Capacity (GW)

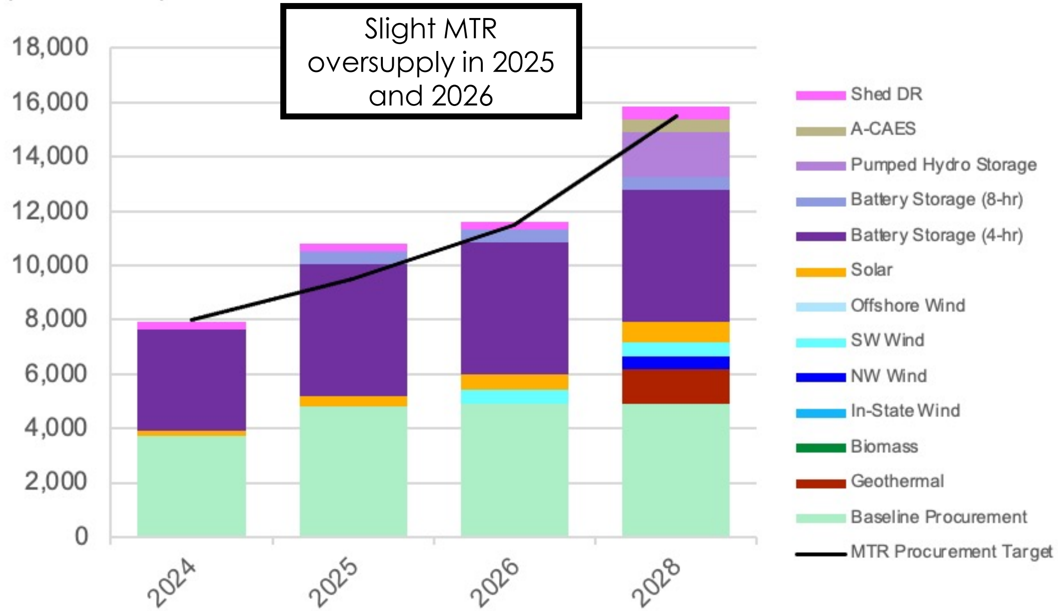
Resource Category	2024	2025	2026	2028	2030	2032	2033	2034	2035	2039	2040	2045
Geothermal	-	-	0.0	1.4	2.2	2.4	2.4	3.2	3.2	3.3	3.3	3.3
Biomass	-	-	-	-	-	-	-	-	-	-	-	-
In-State Wind	-	-	-	-	7.5	8.4	8.4	8.4	9.3	9.3	9.3	13.4
Out-of-State Wind	-	-	1.5	3.0	3.9	3.9	3.9	5.0	6.0	8.5	8.5	9.7
Offshore Wind	-	-	-	-	-	-	-	-	-	-	-	-
Solar	3.0	6.0	8.3	10.4	10.4	17.3	20.2	20.5	21.8	35.8	40.9	55.2
Li-ion Battery (4-hr)	4.1	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6
Li-ion Battery (8-hr)	-	0.4	0.4	0.4	0.4	2.8	4.6	5.0	6.9	12.5	14.4	20.5
Pumped Hydro Storage	-	-	-	1.8	2.3	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Long Duration Storage	-	0.2	0.2	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Shed DR	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.2	0.2	-	-	-
Retired Gas Capacity	*(2.6)*	*(2.6)*	*(3.5)*	*(4.1)*	*(4.2)*	*(4.5)*	*(4.5)*	*(4.5)*	*(4.5)*	*(4.5)*	*(4.5)*	*(4.5)*
Total	**4.8**	**9.9**	**12.8**	**19.7**	**29.2**	**39.9**	**44.5**	**47.0**	**52.1**	**74.1**	**81.0**	**106.7**

Sensitivity: Moderate Gas Retirements

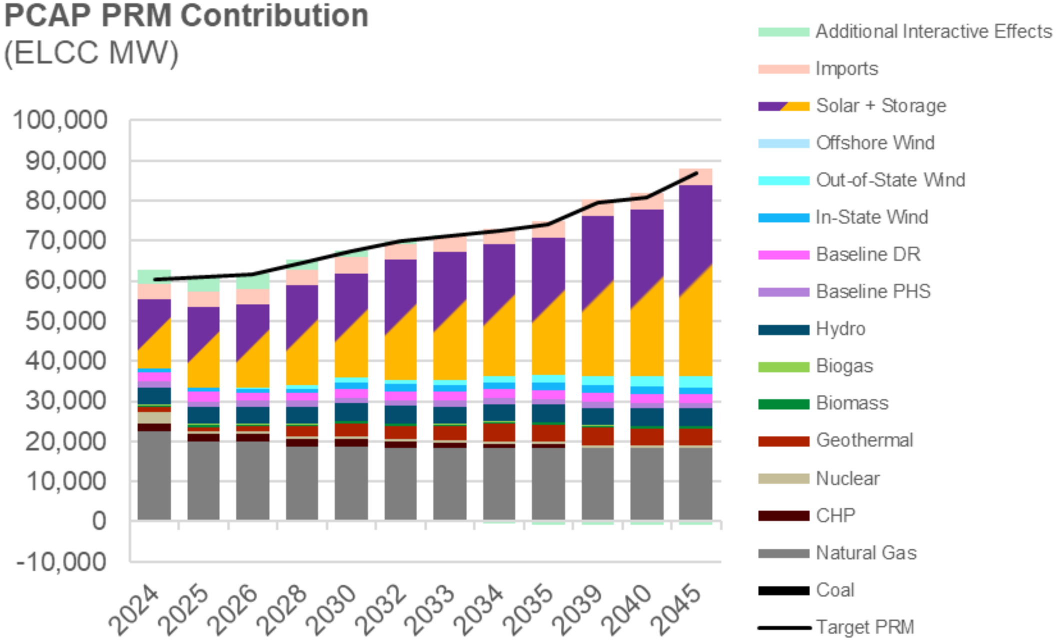
PRM Results

The capacity contribution of natural gas resources declines in the mid 2020s as a result of the Moderate Gas Retirements trajectory

MTR Contribution by Resource Type
(ELCC MW)



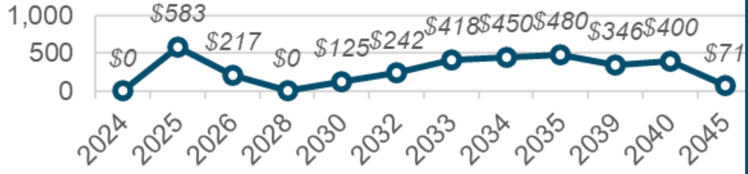
PCAP PRM Contribution
(ELCC MW)



MTR Shadow Prices
($/kW-year)

Due to the retirement of existing gas capacity, which does not qualify for the MTR, the planning reserve margin becomes more binding than the MTR constraint in 2025 and 2026.

PRM Shadow Prices
($/kW-year)



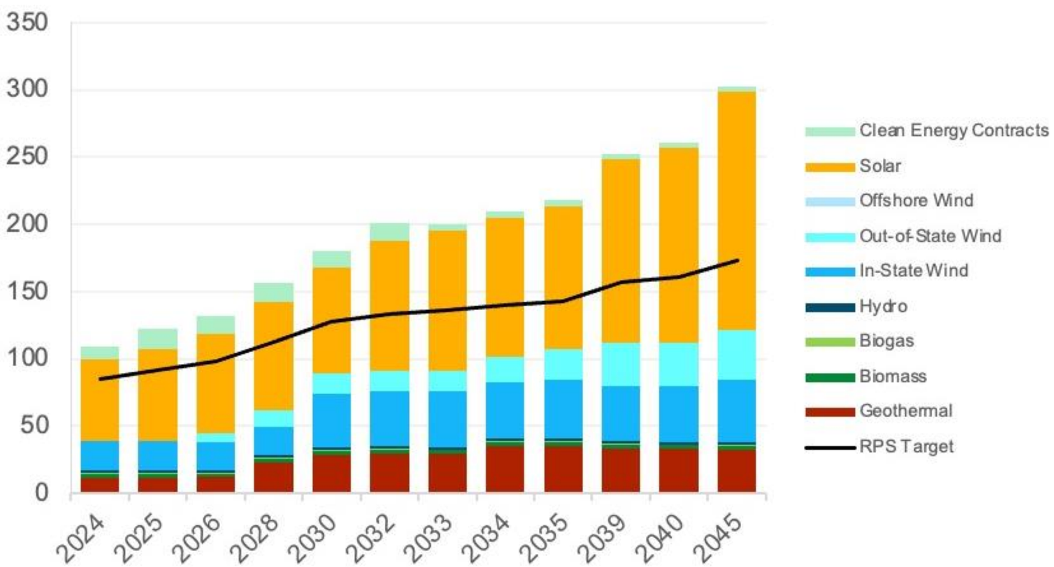
Gas retirements result in expensive (>$100/kW-yr) costs to meet resource adequacy requirements across almost the entire modeling horizon. The high costs to meet resource adequacy reflect the relatively low marginal capacity contribution of energy-limited resources such as solar + storage

Sensitivity: Moderate Gas Retirements

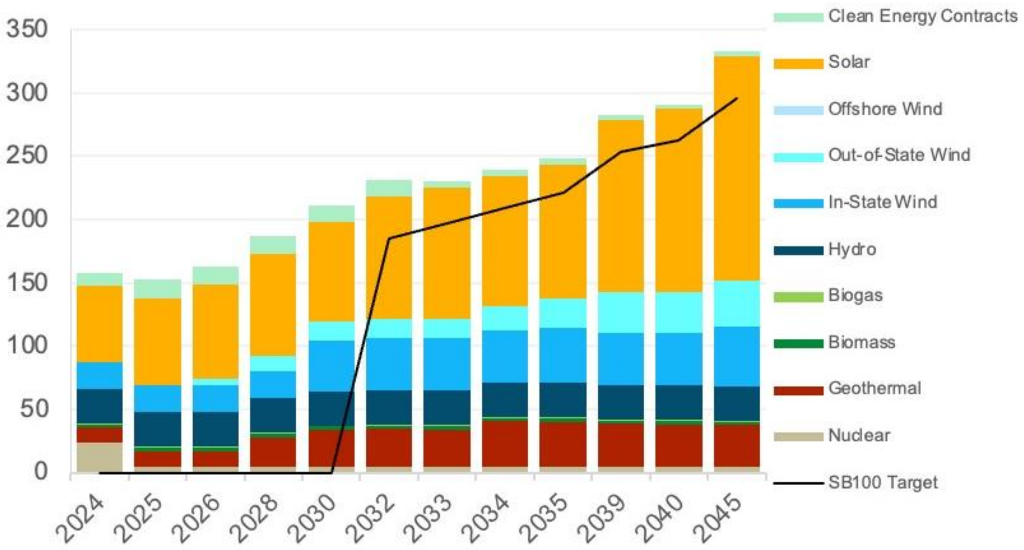
RPS & SB 100

Clean energy requirements (RPS/CES) are *not* drivers of resource selection.
LSE plans (core cases only), GHG targets, and reliability requirements (MTR + PRM) are main drivers of resource selection.

RPS-Eligible Generation
(TWh)



SB 100-Eligible Generation
(TWh)

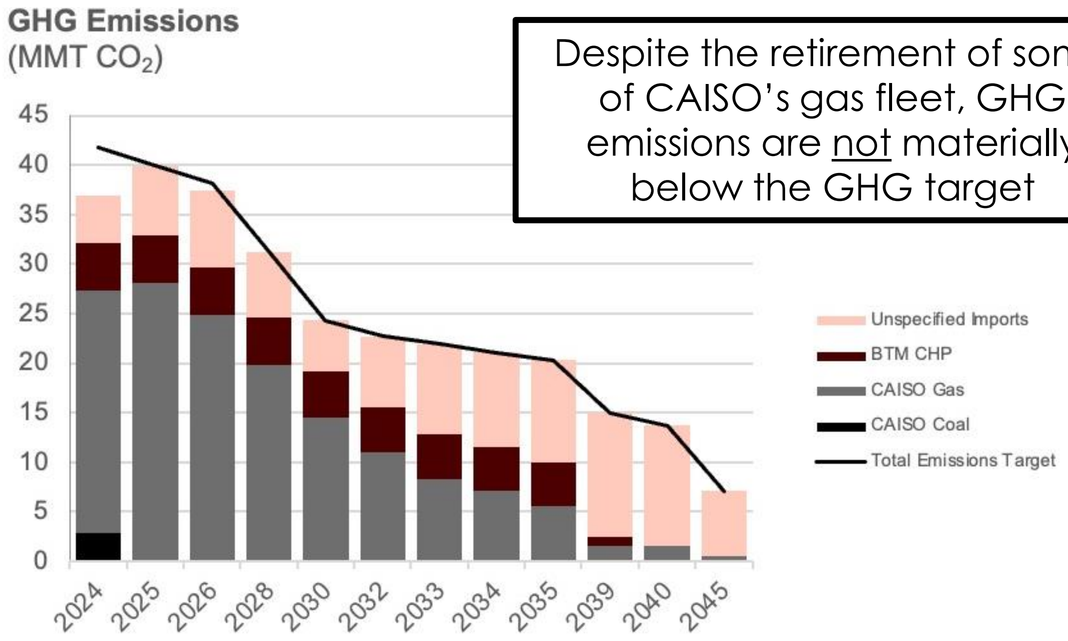


RPS Shadow Prices
($/MWh)

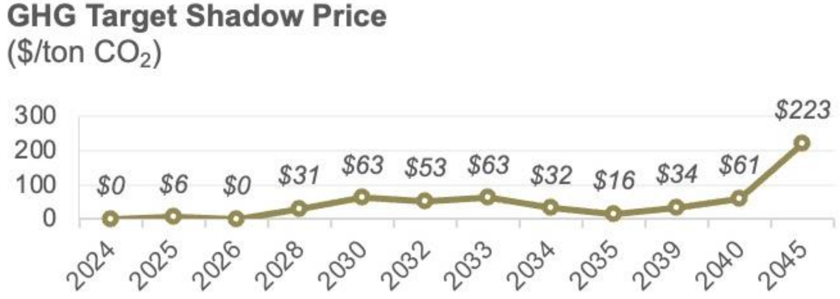
SB 100 Shadow Prices
($/MWh)

Sensitivity: Moderate Gas Retirements

In-state & Unspecified Import Emissions (MMT)



Despite the retirement of some of CAISO's gas fleet, GHG emissions are not materially below the GHG target



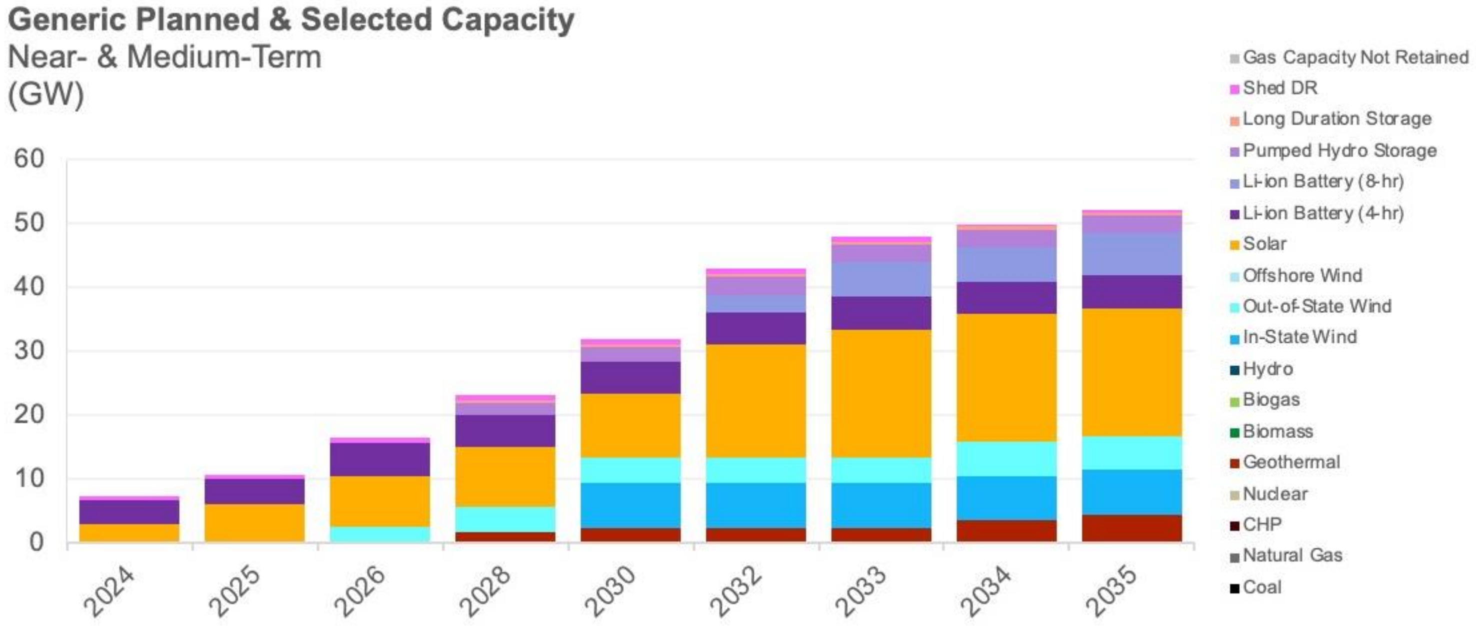
The In the 2030s, the high cost of meeting the planning reserve margin (due to gas retirements) results in lower costs to reduce GHG emissions. The cost rises steeply in 2045, similar to the least-cost case.

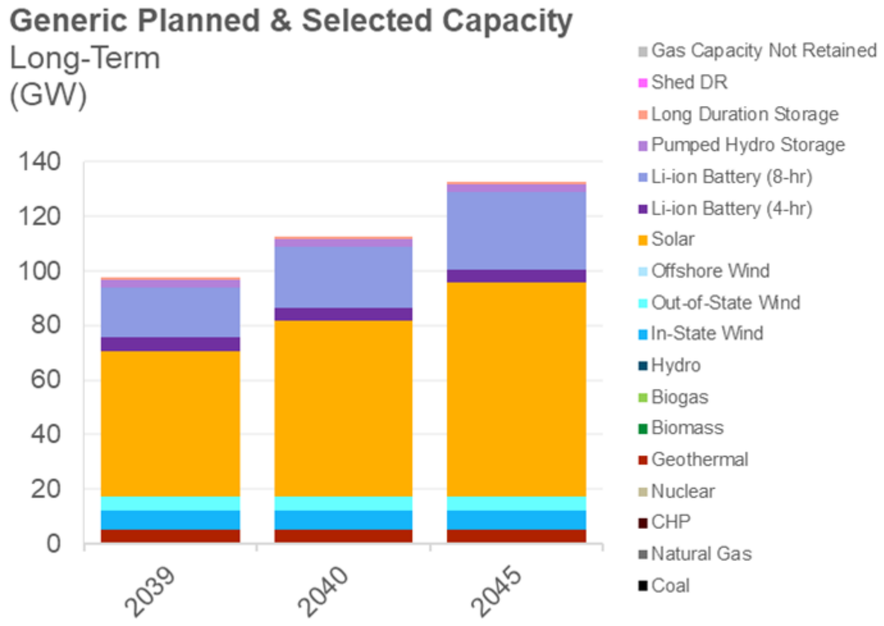
25 MMT Sensitivity: Gas Retirements

High Gas Retirements Sensitivity Case

Sensitivity: High Gas Retirements

Planned & Selected Capacity

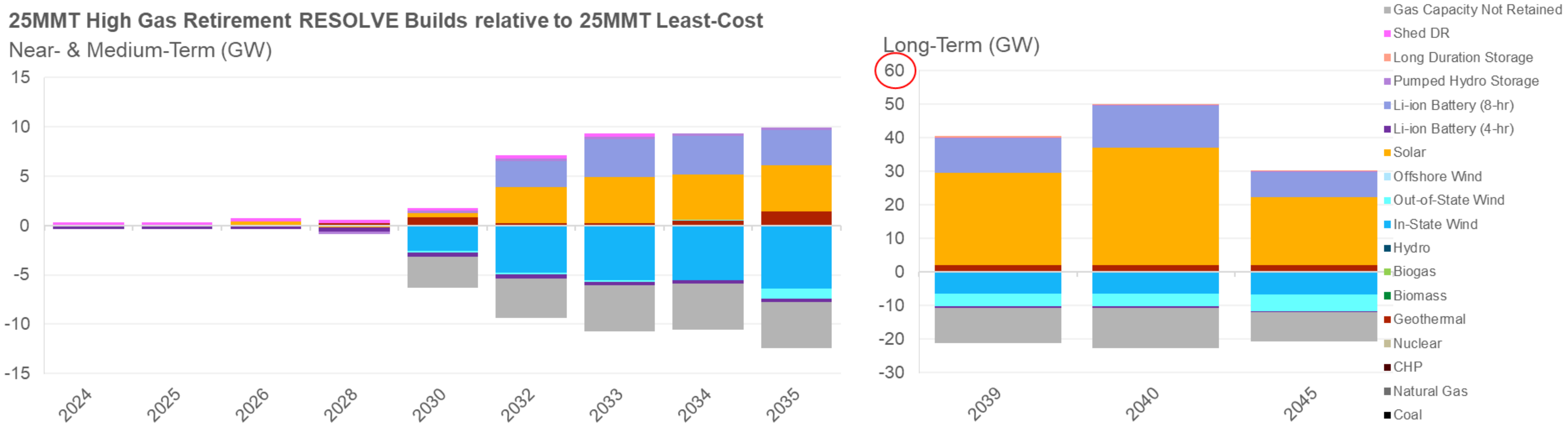




Planned & Selected Capacity, Compared to Least-Cost (GW)

Compared to least-cost case, gas retirements drive significantly more solar and 8-hr Battery builds, which displaces some wind build

Additional geothermal is selected to replace retired gas capacity



Gas retirements shown as negative value on y-axis

Sensitivity: High Gas Retirements

Planned & Selected Capacity (GW)

Resource Category	2024	2025	2026	2028	2030	2032	2033	2034	2035	2039	2040	2045
Geothermal	-	-	0.1	1.8	2.4	2.4	2.4	3.5	4.4	5.0	5.0	5.0
Biomass	-	-	-	-	-	-	-	-	-	-	-	-
In-State Wind	-	-	-	-	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Out-of-State Wind	-	-	2.4	3.9	4.1	4.1	4.1	5.4	5.4	5.4	5.4	5.4
Offshore Wind	-	-	-	-	-	-	-	-	-	-	-	-
Solar	3.0	6.0	8.1	9.3	9.8	17.6	20.0	20.0	20.0	53.3	64.2	78.2
Li-ion Battery (4-hr)	3.8	4.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Li-ion Battery (8-hr)	-	-	-	-	-	2.7	5.4	5.4	6.7	18.3	22.2	28.2
Pumped Hydro Storage	-	-	-	1.8	2.3	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Long Duration Storage	-	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.9	0.9	0.9
Shed DR	0.6	0.6	0.8	0.9	0.9	0.9	0.9	0.3	0.3	-	-	-
Retired Gas Capacity	-	-	-	-	*(3.1)*	*(4.0)*	*(4.7)*	*(4.7)*	*(4.7)*	*(10.5)*	*(12.1)*	*(12.1)*
Total	**7.4**	**10.7**	**16.5**	**23.2**	**28.9**	**39.0**	**43.4**	**45.2**	**47.4**	**87.2**	**100.4**	**120.4**

Sensitivity: High Gas Retirements

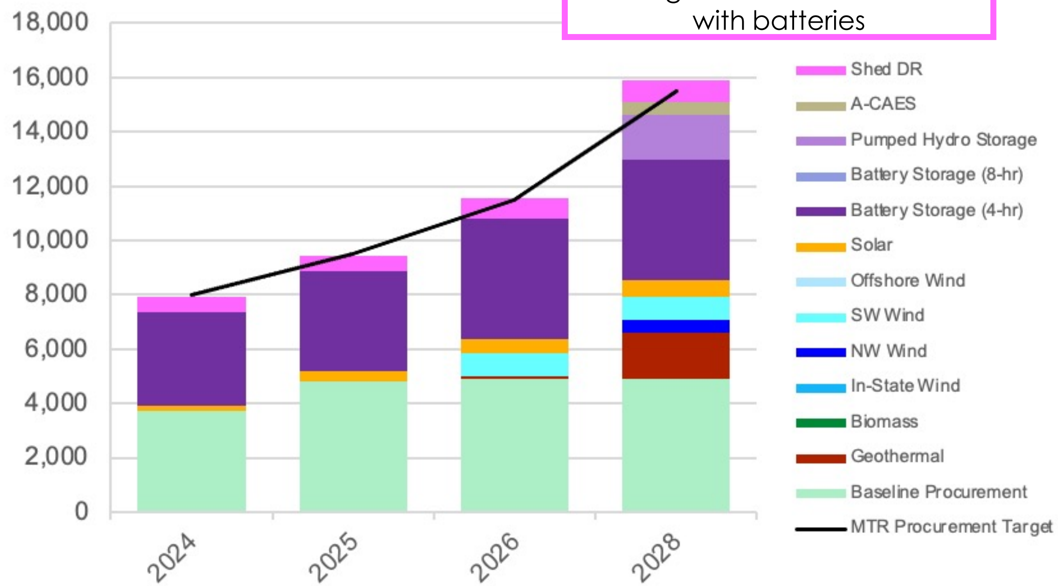
PRM Results

Most incremental capacity needs are met with solar and storage. Geothermal and wind also provide some incremental resource adequacy.

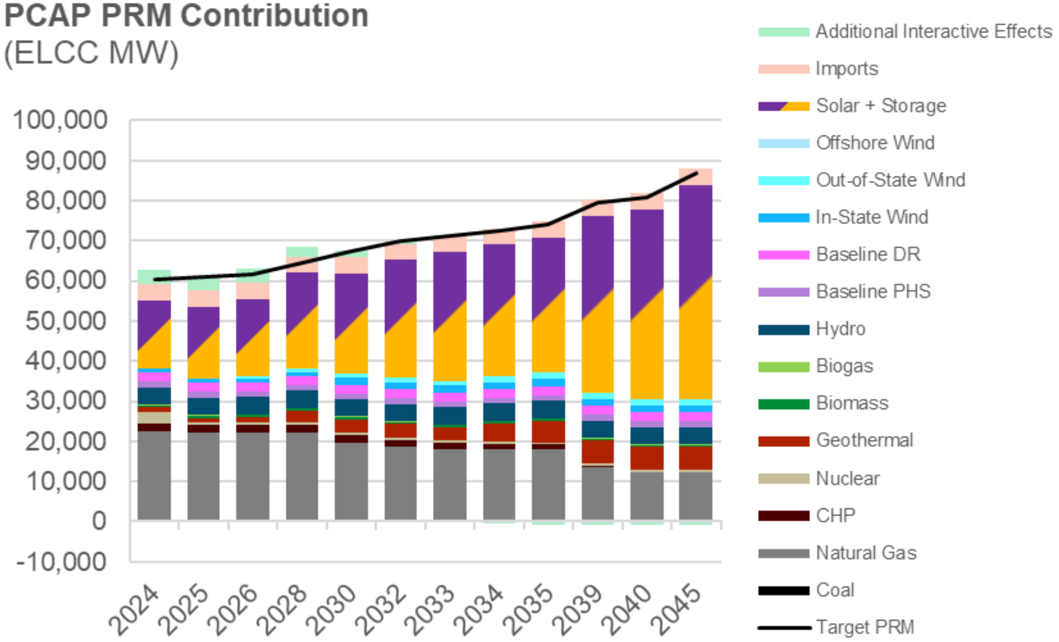
The capacity contribution of natural gas resources declines over time as a result of the High Gas Retirements trajectory of gas plant capacity. New gas builds are not allowed in this sensitivity.

MTR Contribution by Resource Type
(ELCC MW)

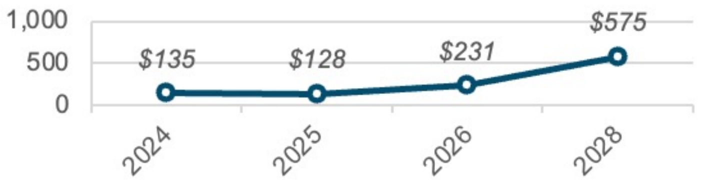
Shed DR capacity added to meet MTR requirements, though most MTR is still met with batteries



PCAP PRM Contribution
(ELCC MW)

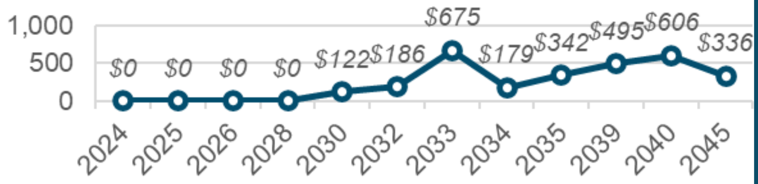


MTR Shadow Prices
($/kW-year)



Cost to meet MTR is similar to the least cost case

PRM Shadow Prices
($/kW-year)



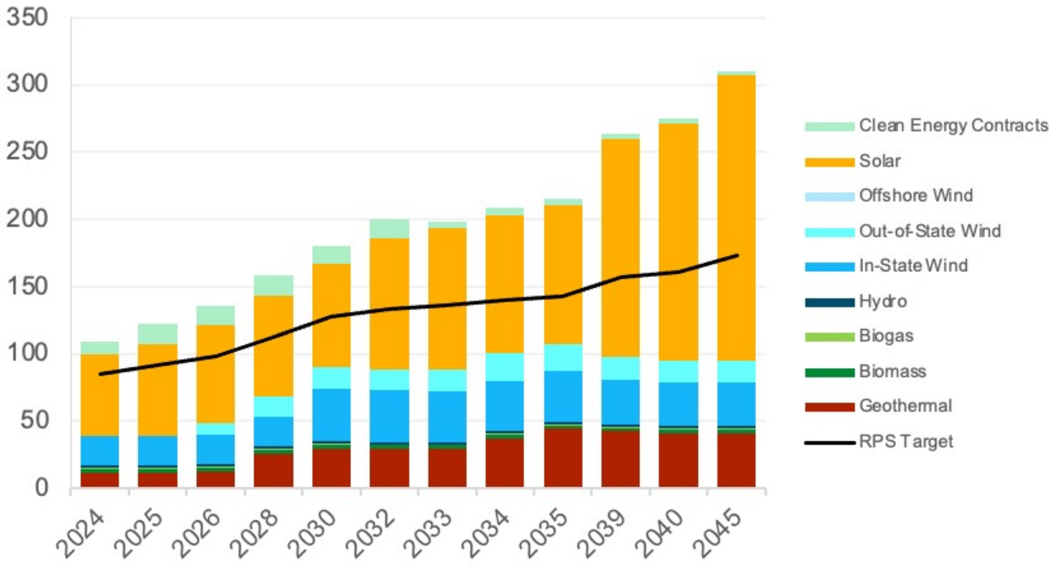
High levels of gas retirements result in expensive (>$100/kW-yr) costs to meet resource adequacy requirements in 2030 and beyond, reflecting the relatively low marginal capacity contribution of energy-limited resources such as solar + storage, as well as the high cost of incremental geothermal

Sensitivity: High Gas Retirements

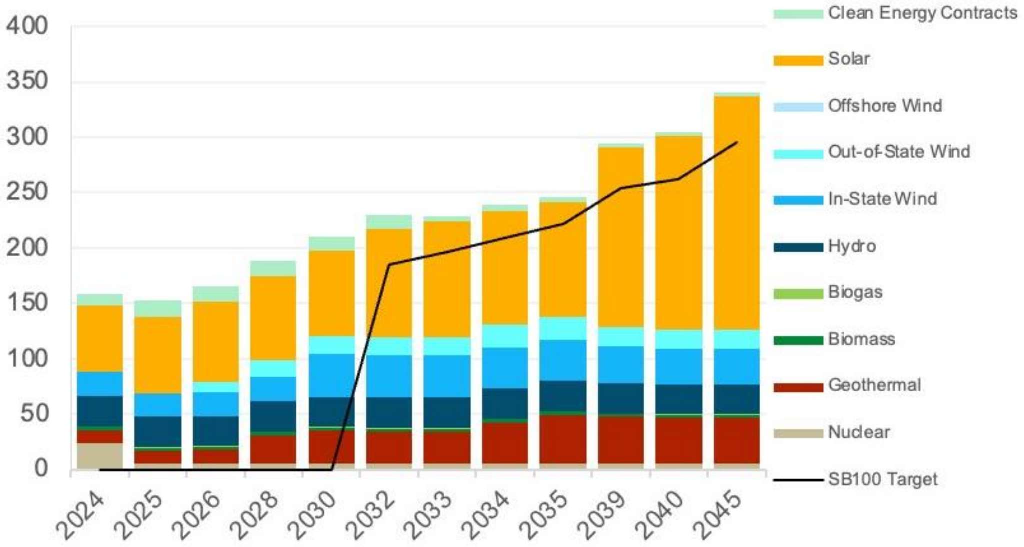
RPS & SB 100

Clean energy requirements (RPS/CES) are *not* drivers of resource selection. LSE plans (core cases only), GHG targets, and reliability requirements (MTR + PRM) are main drivers of resource selection.

RPS-Eligible Generation
(TWh)



SB 100-Eligible Generation
(TWh)

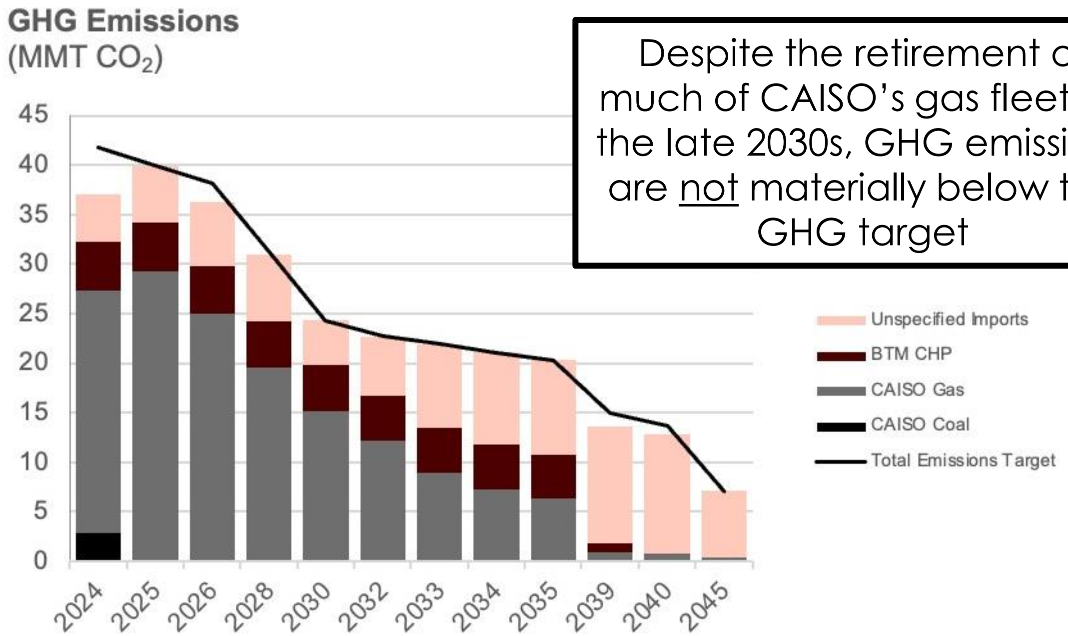


RPS Shadow Prices
($/MWh)

SB 100 Shadow Prices
($/MWh)

Sensitivity: High Gas Retirements

In-state & Unspecified Import Emissions (MMT)



Despite the retirement of much of CAISO's gas fleet by the late 2030s, GHG emissions are not materially below the GHG target

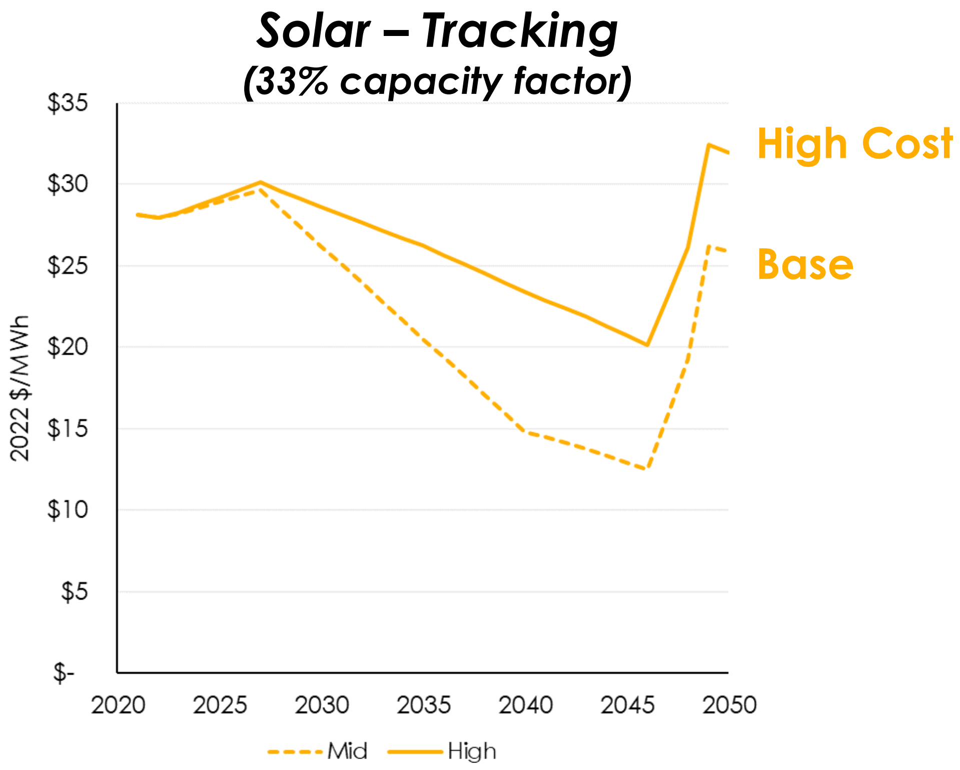
The relatively high marginal cost of meeting the GHG target (the GHG target shadow price) between 2030 and 2035 indicates that GHG reductions are a major driver of resource portfolio selection in and after 2030. After 2035, the high cost of meeting the planning reserve margin (due to gas retirements) results in low costs to reduce GHG emissions

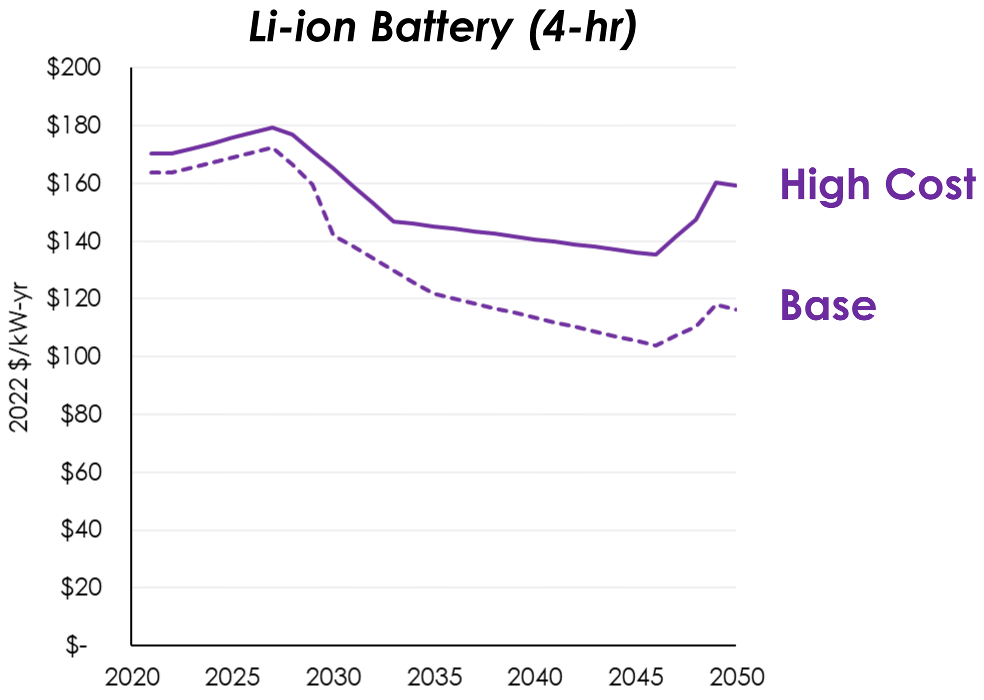
25 MMT Least-Cost Sensitivity

High Solar PV & Battery Costs Sensitivity Case

Sensitivity Cost Trajectories

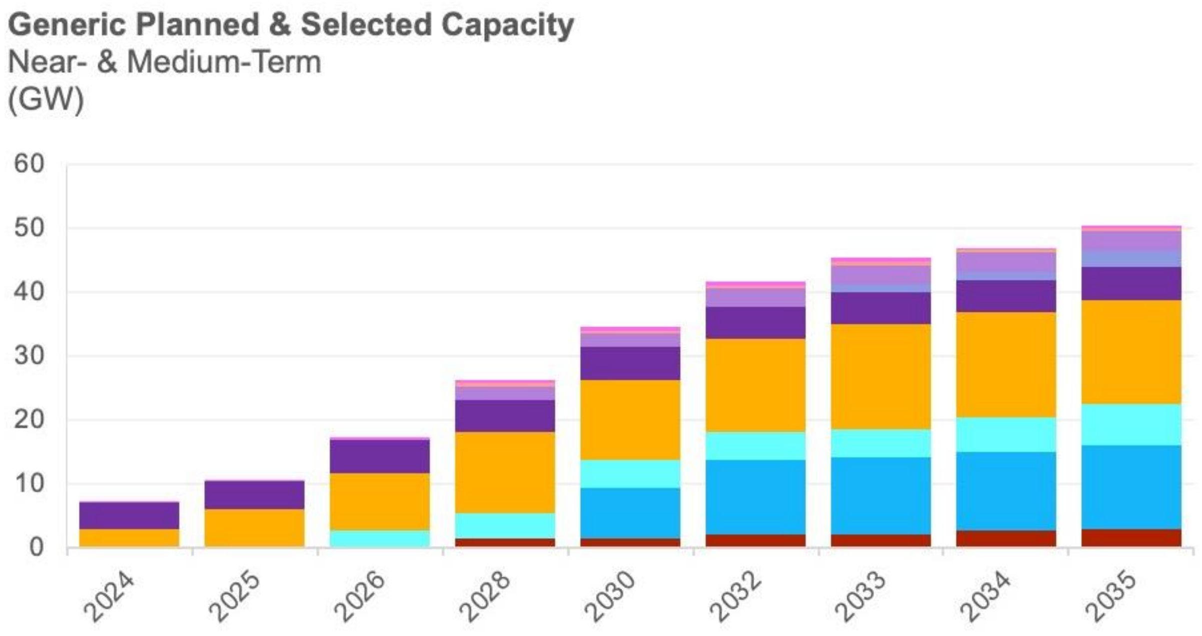
In the High Solar PV & Battery Costs sensitivity, as shown below, the solar and battery cost trajectories are adjusted upwards

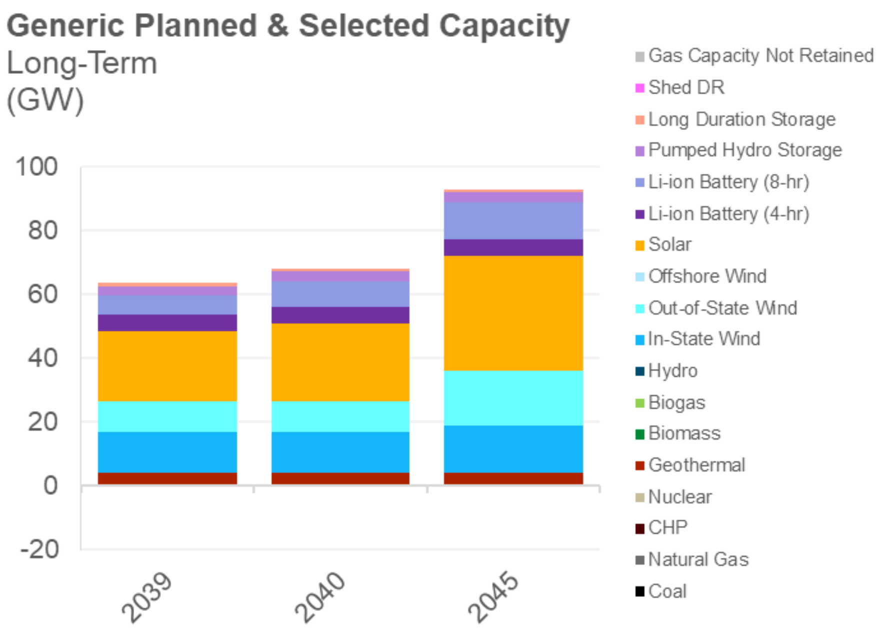




Sensitivity: High Solar PV & Battery Costs

Planned & Selected Capacity





Sensitivity: High Solar PV & Battery Costs

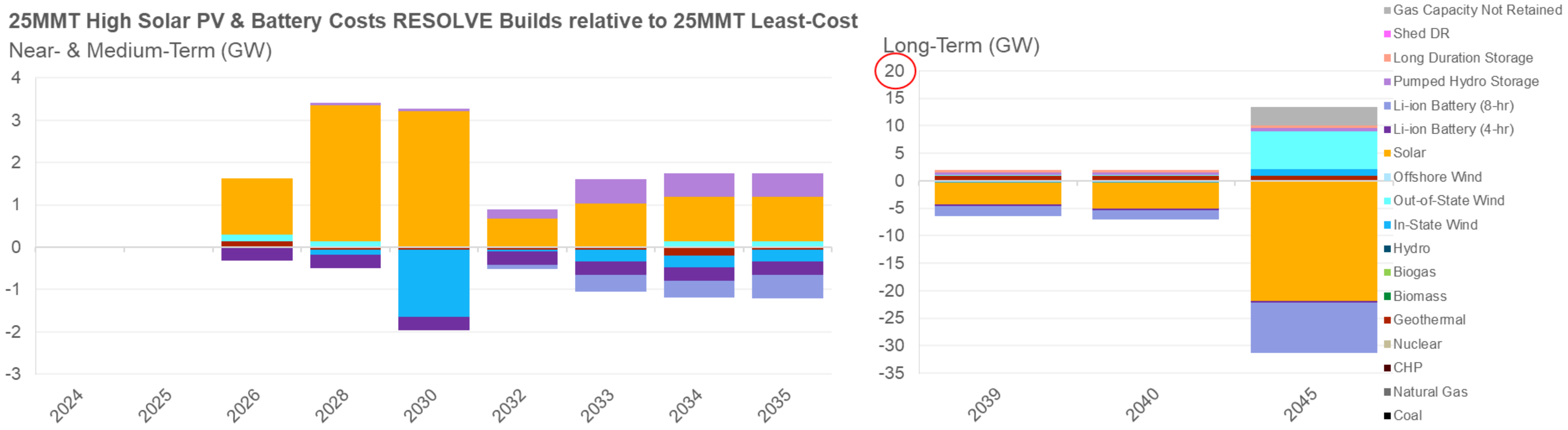
Planned & Selected Capacity, Compared to Least-Cost (GW)

The base and high solar cost trajectories do not diverge until the late 2020s. Earlier solar builds are observed in this timeframe, while it remains fairly cost competitive with other resources.

In the 2030s, pumped hydro replaces some battery capacity, compared to the least-cost case.

By the late 2030s, solar is much less cost competitive, compared to the base cost trajectory. Much less solar and more wind (in 2045) is built than the least-cost case.

Almost all gas is retained to avoid building additional, high-cost 8-hr batteries



Sensitivity: High Solar PV & Battery Costs

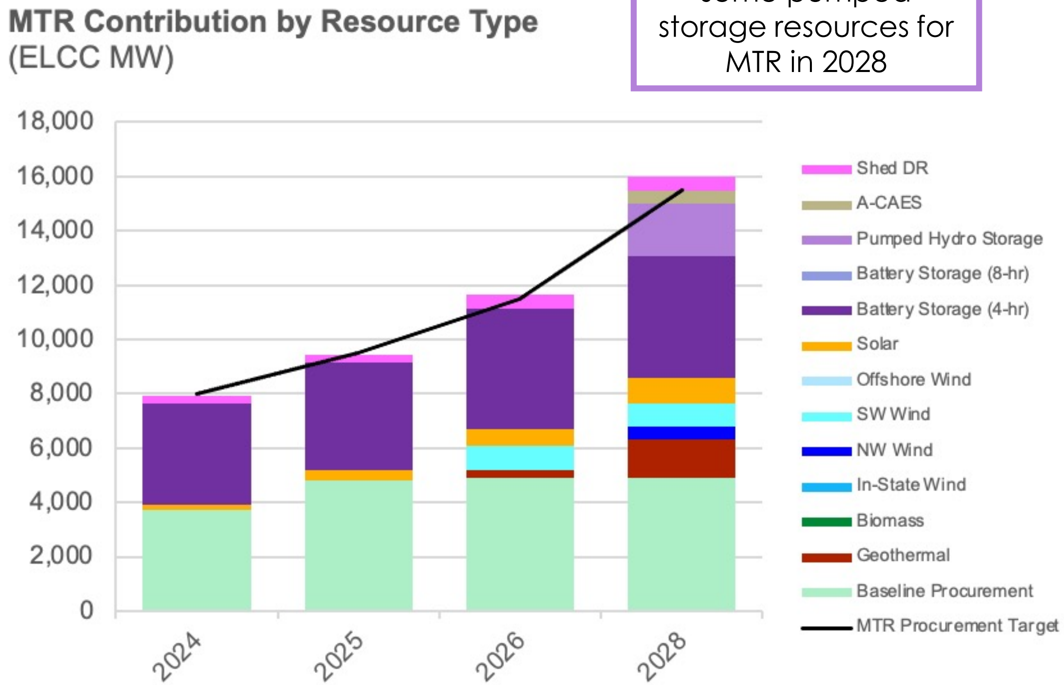
Planned & Selected Capacity (GW)

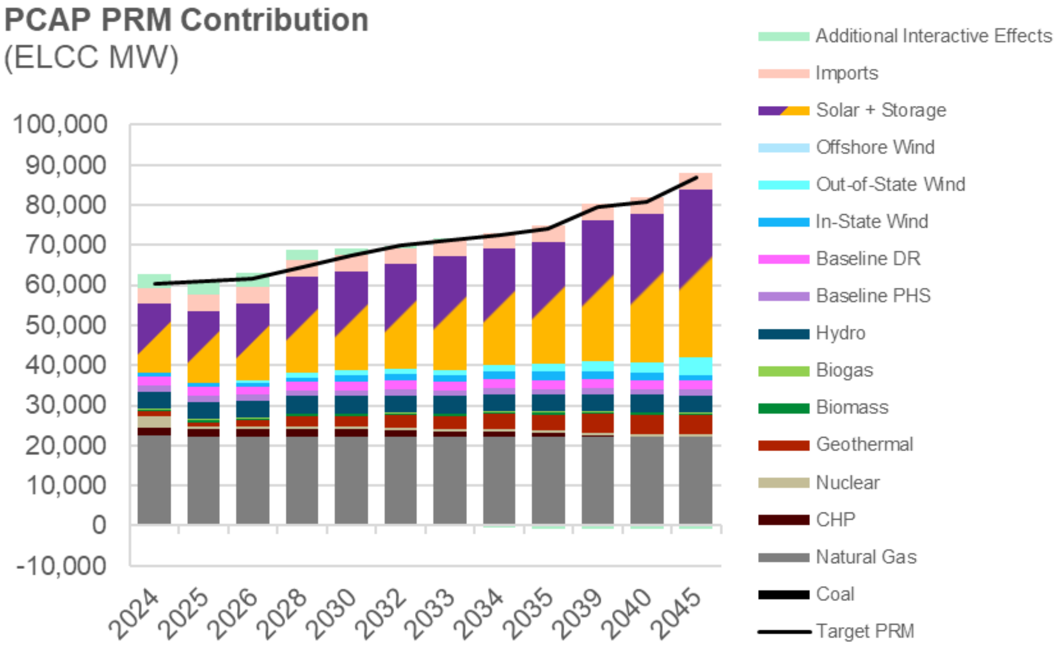
Resource Category	2024	2025	2026	2028	2030	2032	2033	2034	2035	2039	2040	2045
Geothermal	-	-	0.3	1.5	1.5	2.0	2.0	2.8	2.9	3.9	3.9	3.9
Biomass	-	-	-	-	-	-	-	-	-	-	-	-
In-State Wind	-	-	-	-	8.0	11.7	12.2	12.2	13.1	13.1	13.1	15.0
Out-of-State Wind	-	-	2.5	4.0	4.3	4.3	4.3	5.5	6.5	9.4	9.4	17.2
Offshore Wind	-	-	-	-	-	-	-	-	-	-	-	-
Solar	3.0	6.0	9.0	12.6	12.6	14.6	16.4	16.4	16.4	21.9	24.6	36.1
Li-ion Battery (4-hr)	4.1	4.4	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Li-ion Battery (8-hr)	-	-	-	-	-	-	1.2	1.2	2.5	6.0	7.9	11.7
Pumped Hydro Storage	-	-	-	2.1	2.1	2.7	3.1	3.1	3.1	3.1	3.1	3.1
Long Duration Storage	-	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.9	0.9	0.9
Shed DR	0.3	0.3	0.5	0.6	0.6	0.6	0.6	0.3	0.3	-	-	-
Gas Capacity Not Retained	-	-	-	-	-	-	-	-	-	-	-	*(0.2)*
Total	**7.4**	**10.7**	**17.4**	**26.4**	**34.7**	**41.7**	**45.4**	**47.0**	**50.4**	**63.5**	**68.0**	**92.8**

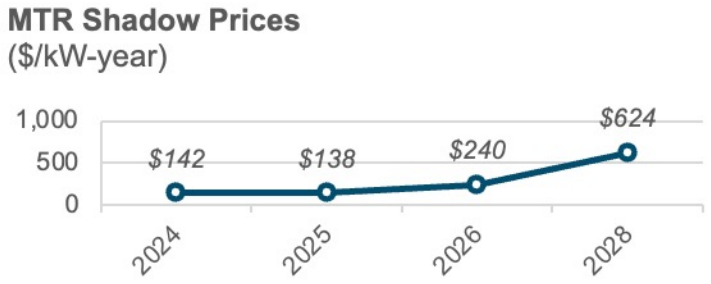
Sensitivity: High Solar PV & Battery Costs

PRM Results

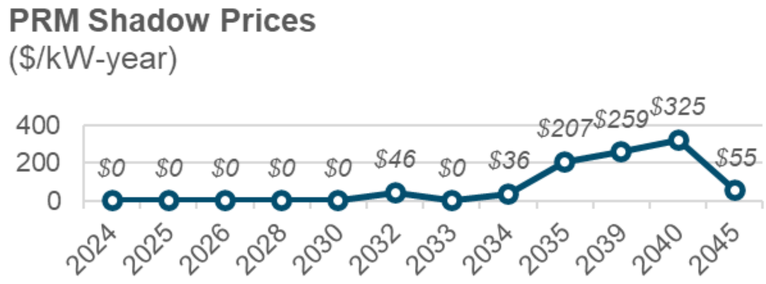
Higher battery costs result in selection of some pumped storage resources for MTR in 2028







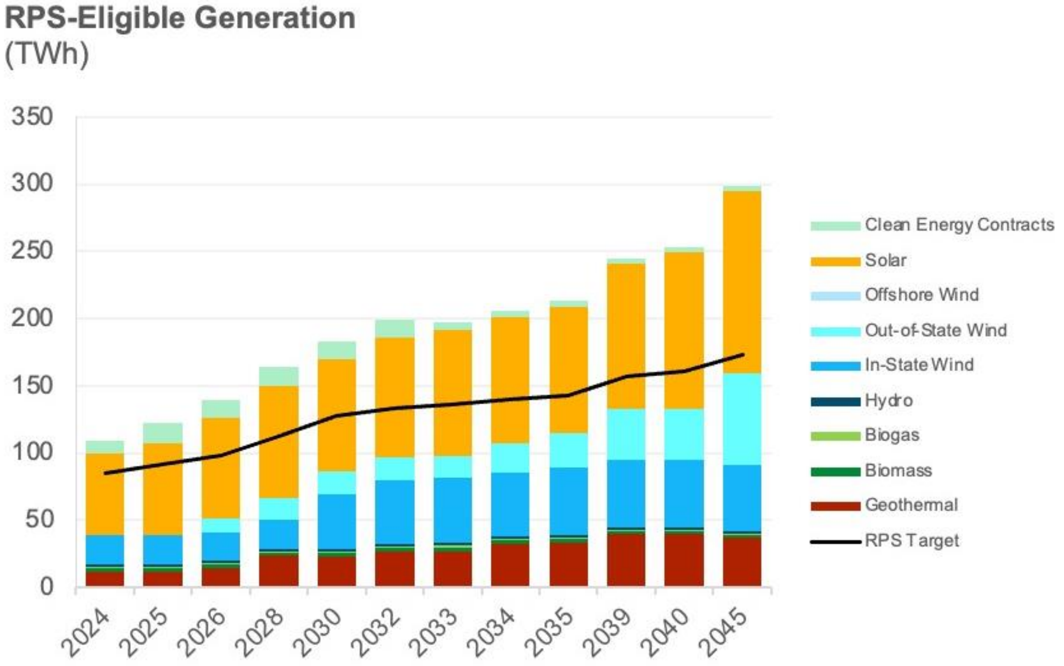
Reflecting increased battery costs, the marginal cost (shadow prices)to meet the MTR and PRM constraints are moderately higher in the High Solar PV & Battery Cost sensitivity than the Least Cost Scenario, especially in the late 2030s and beyond

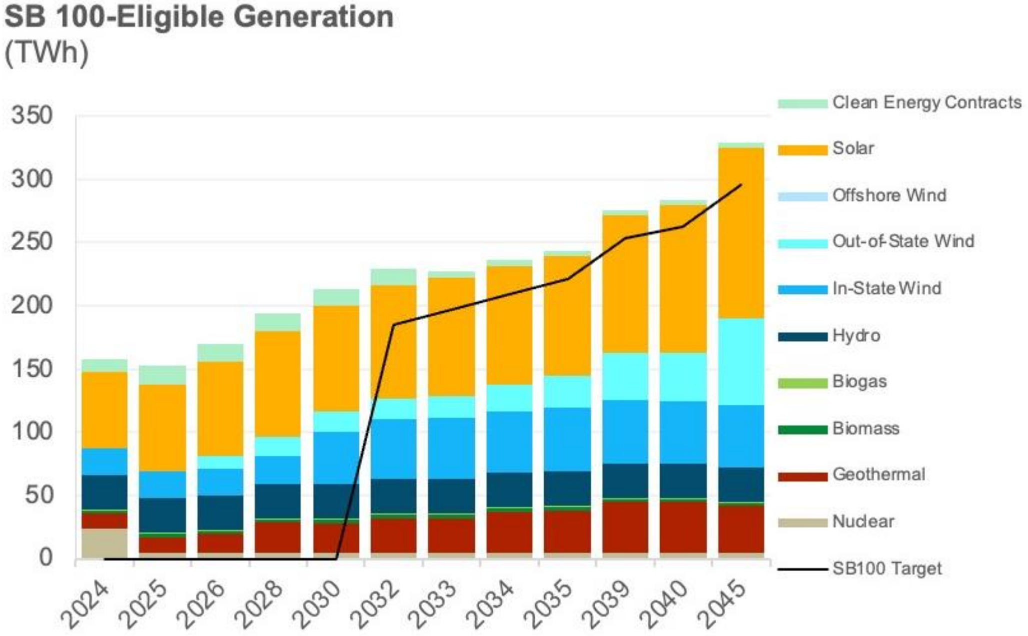


Sensitivity: High Solar PV & Battery Costs

RPS & SB 100

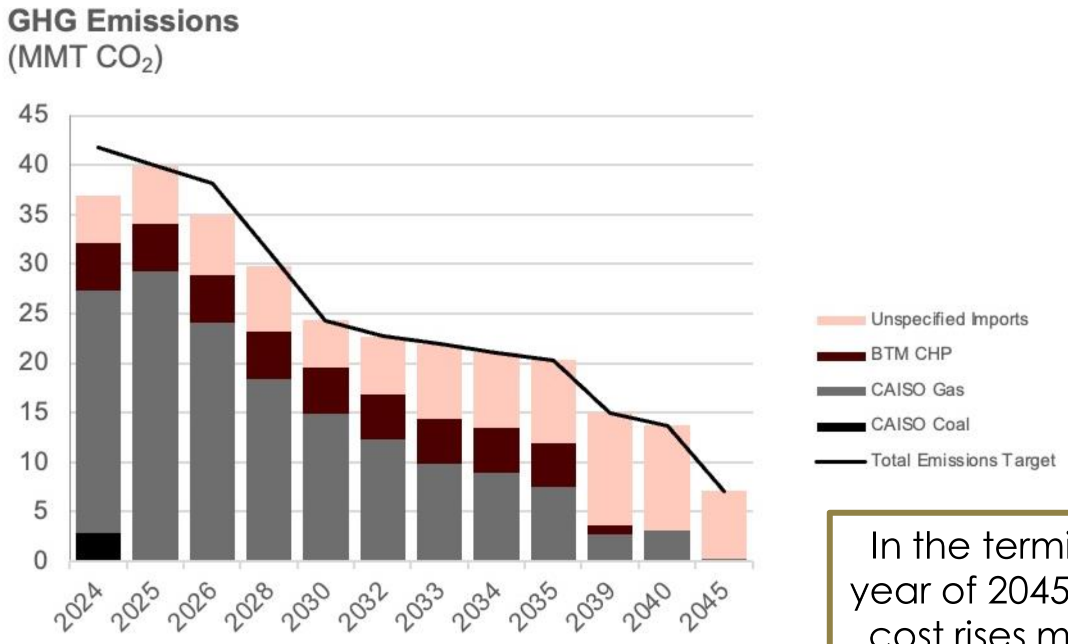
Clean energy requirements (RPS/CES) are *not* drivers of resource selection.
LSE plans (core cases only), GHG targets, and reliability requirements (MTR + PRM) are main drivers of resource selection.





Sensitivity: High Solar PV & Battery Costs

In-state & Unspecified Import Emissions (MMT)



In the terminal year of 2045, the cost rises more steeply when there is more wind and less 8-hr battery and solar built than the least-cost case.

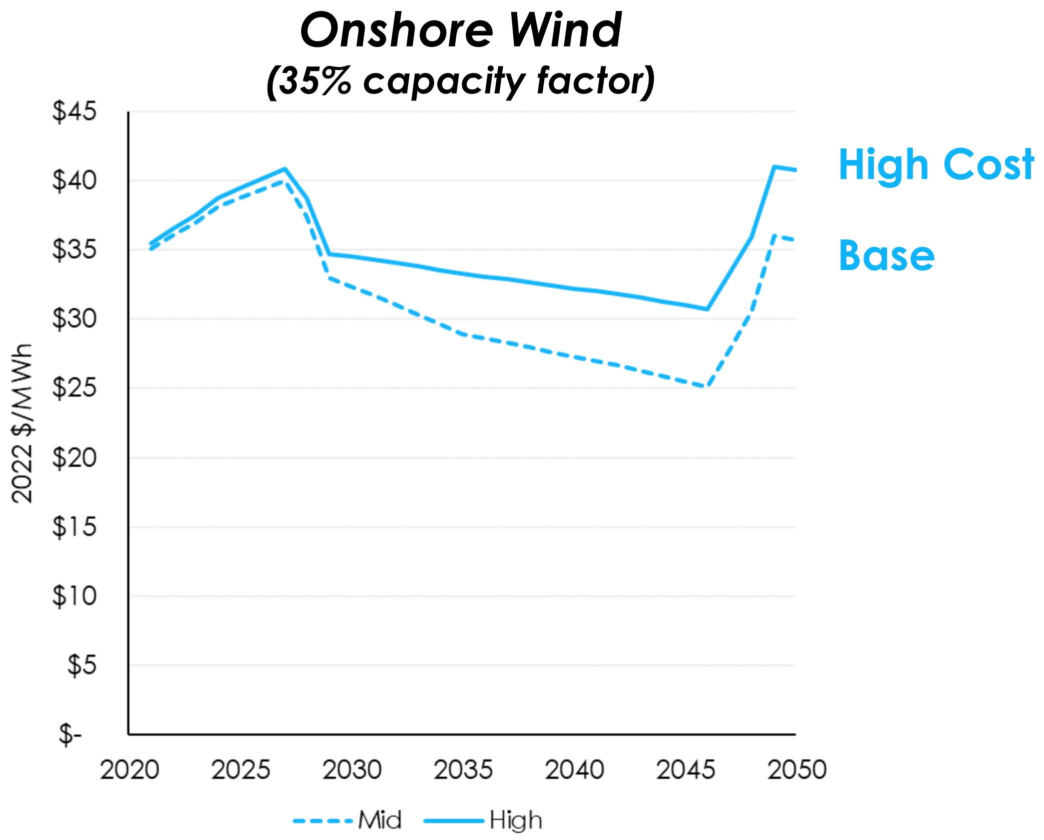
The marginal cost of meeting the GHG target is similar to the Least-Cost case for most years.

25 MMT Least-Cost Sensitivity

High Land-Based Wind Costs Sensitivity Case

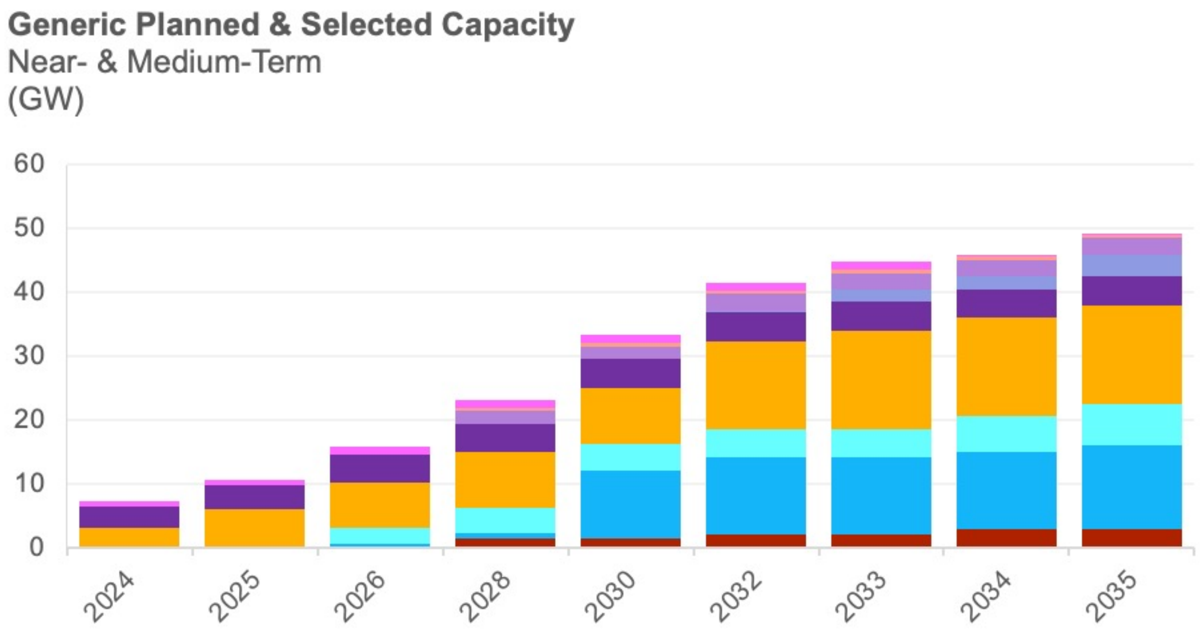
Sensitivity Cost Trajectory

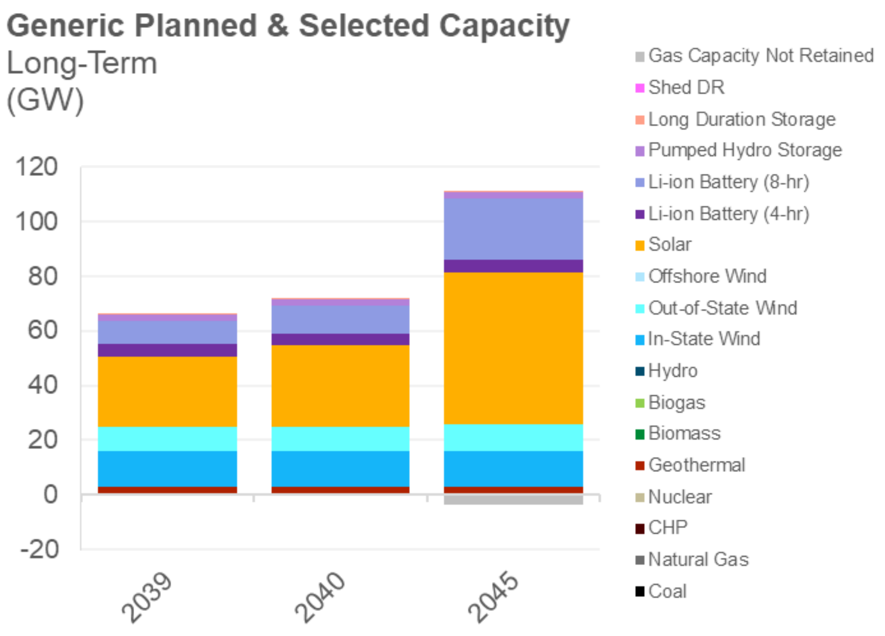
In the High Land-Based Wind Costs sensitivity, as shown below, the land-based wind cost trajectory is adjusted upwards



Sensitivity: High Land-Based Wind Costs

Planned & Selected Capacity





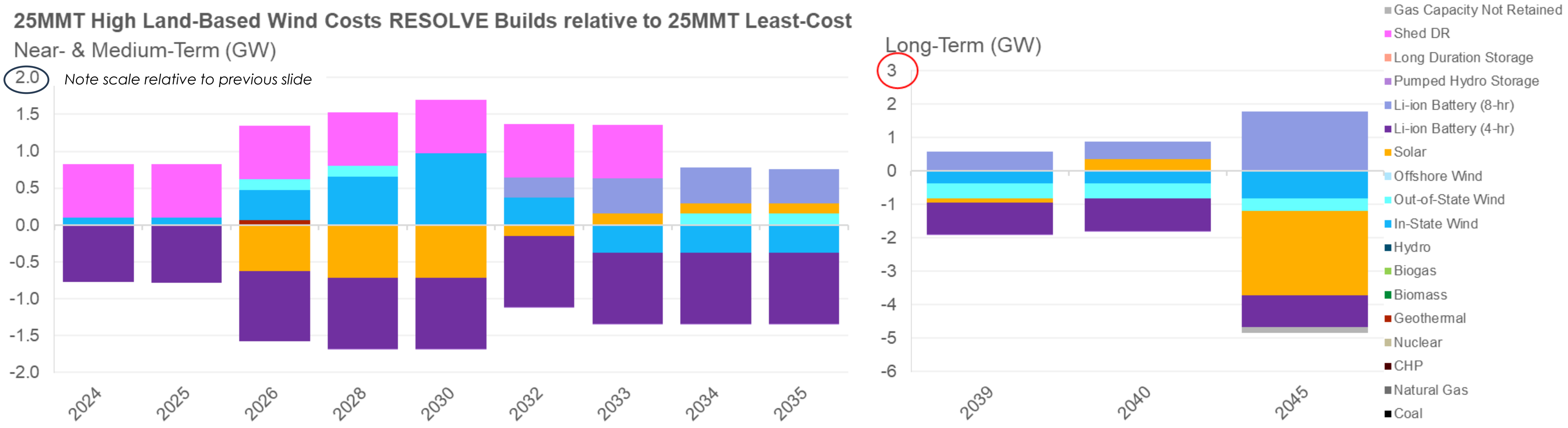
Planned & Selected Capacity, Compared to Least-Cost (GW)

The portfolio impacts of higher wind costs are, in general, modest

The base and high wind cost trajectories do not diverge until the late 2020s. Earlier wind builds are observed in this timeframe, while it remains fairly cost competitive with other resources.

Likely as a result of earlier wind builds offsetting solar in the 2020s, and 8-hr batteries replacing some 4-hr in the 2030s, 10-year DR programs are selected in lieu of some 4-hr batteries in 2024.

Starting in the 2030s, compared to the least-cost case, battery builds shift toward 8-hr instead of 4-hr, likely to replace wind energy during the night.



Sensitivity: High Land-Based Wind Costs

Planned & Selected Capacity (GW)

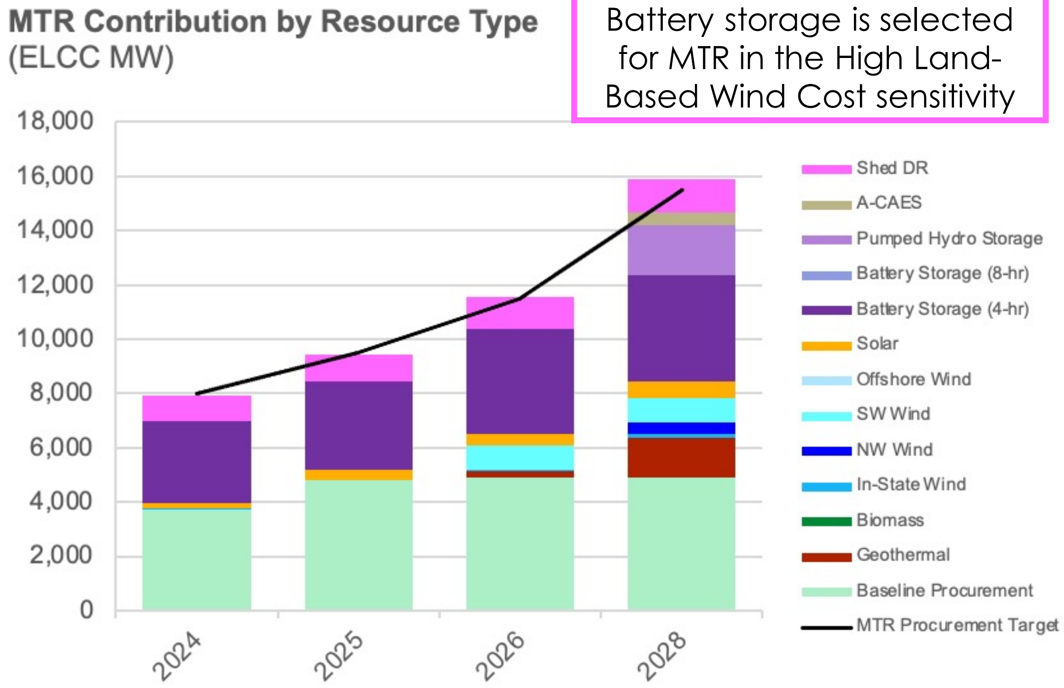
Resource Category	2024	2025	2026	2028	2030	2032	2033	2034	2035	2039	2040	2045
Geothermal	-	-	0.2	1.6	1.6	2.1	2.1	3.0	3.0	3.0	3.0	3.0
Biomass	-	-	-	-	-	-	-	-	-	-	-	-
In-State Wind	0.1	0.1	0.4	0.8	10.5	12.1	12.1	12.1	13.0	13.0	13.0	13.0
Out-of-State Wind	-	-	2.5	4.0	4.3	4.3	4.3	5.5	6.5	8.9	8.9	9.9
Offshore Wind	-	-	-	-	-	-	-	-	-	-	-	-
Solar	3.0	6.0	7.0	8.7	8.7	13.8	15.5	15.5	15.5	25.8	29.6	55.5
Li-ion Battery (4-hr)	3.3	3.7	4.4	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Li-ion Battery (8-hr)	-	-	-	-	-	0.4	2.0	2.1	3.5	8.4	10.2	22.5
Pumped Hydro Storage	-	-	-	2.0	2.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Long Duration Storage	-	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Shed DR	1.0	1.0	1.2	1.3	1.3	1.3	1.3	0.3	0.3	-	-	-
Gas Capacity Not Retained	-	-	-	-	-	-	-	-	-	-	-	*(3.7)*
Total	**7.4**	**10.8**	**15.8**	**23.3**	**33.4**	**41.5**	**44.9**	**45.9**	**49.3**	**66.6**	**72.2**	**107.7**

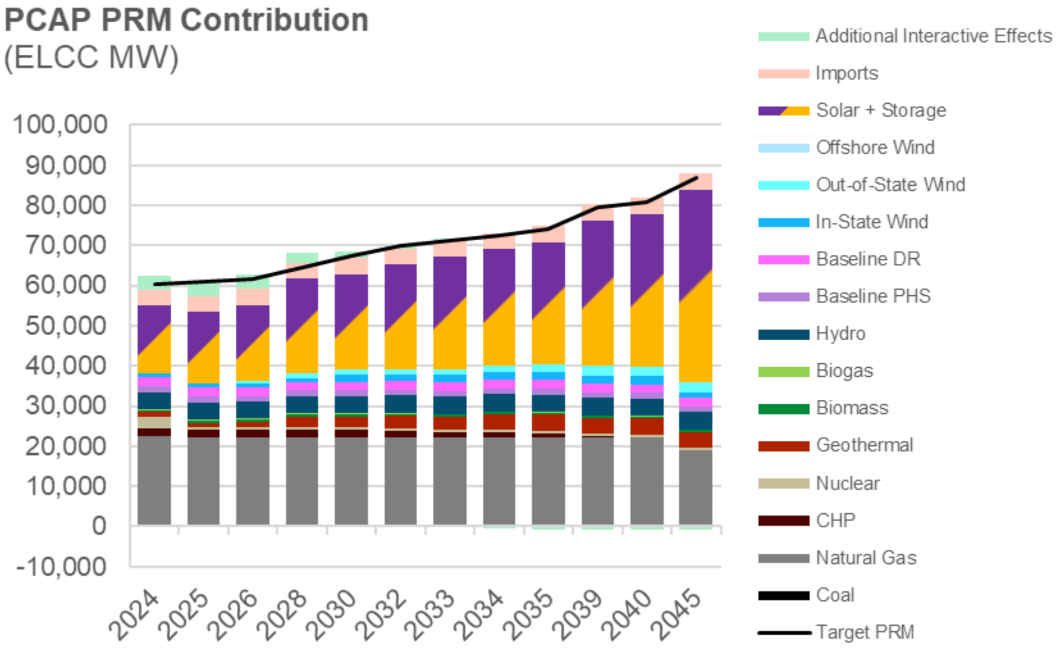
Sensitivity: High Land-Based Wind Costs

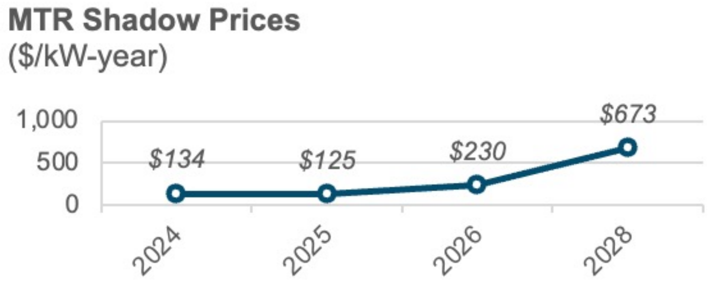
PRM Results

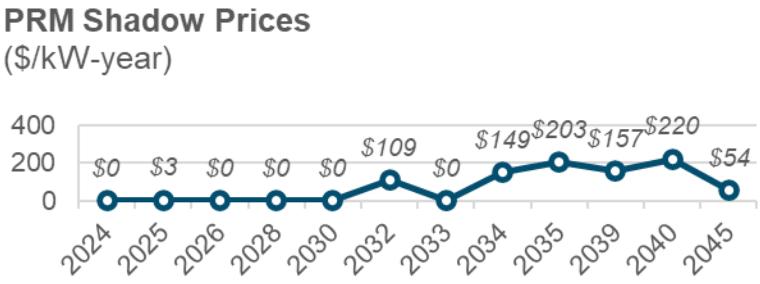
More Shed DR and Less Battery storage is selected for MTR in the High Land-Based Wind Cost sensitivity

PRM results are broadly similar to the Least Cost case







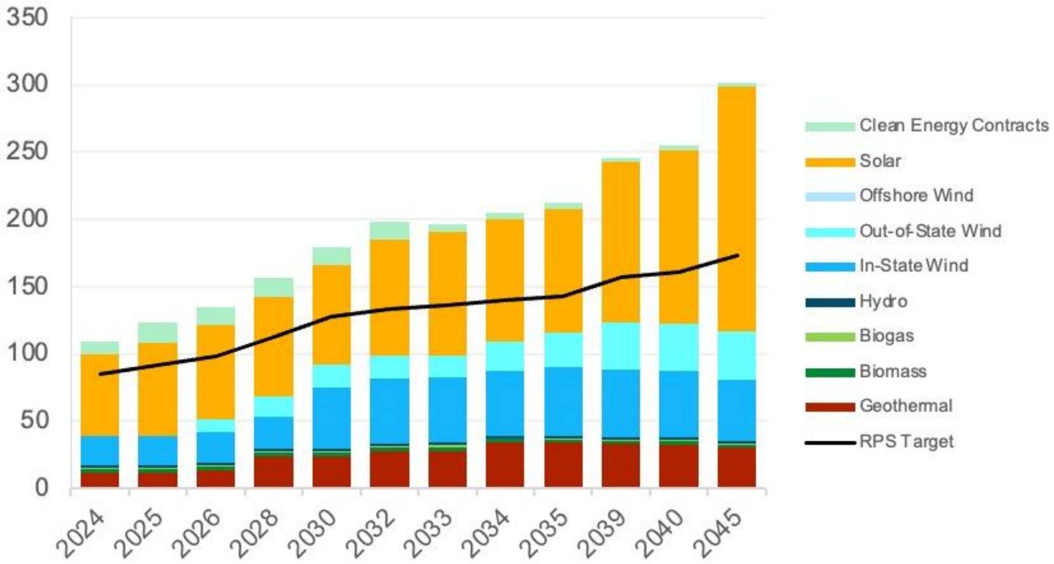


Sensitivity: High Land-Based Wind Costs

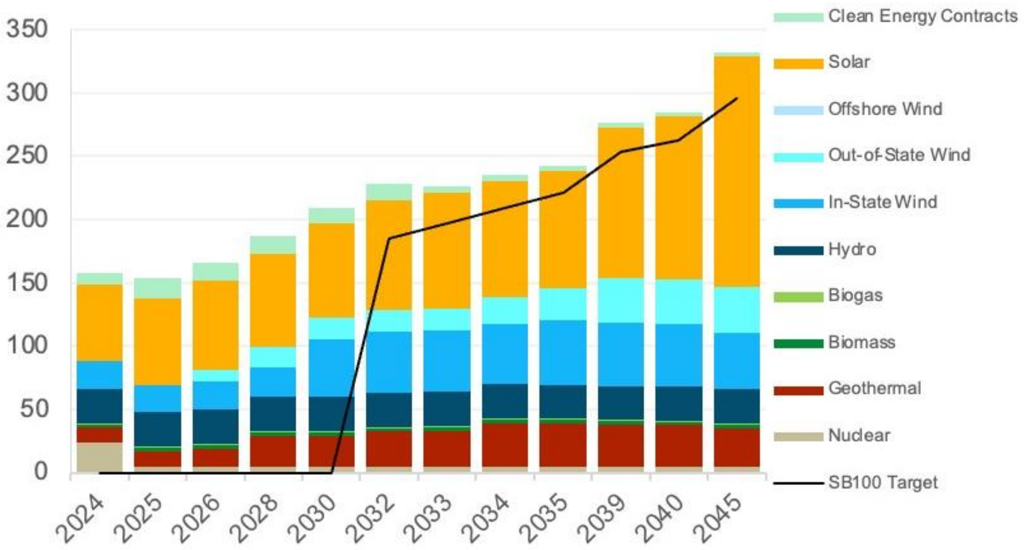
RPS & SB 100

Clean energy requirements (RPS/CES) are *not* drivers of resource selection.
LSE plans (core cases only), GHG targets, and reliability requirements (MTR + PRM) are main drivers of resource selection.

RPS-Eligible Generation
(TWh)



SB 100-Eligible Generation
(TWh)

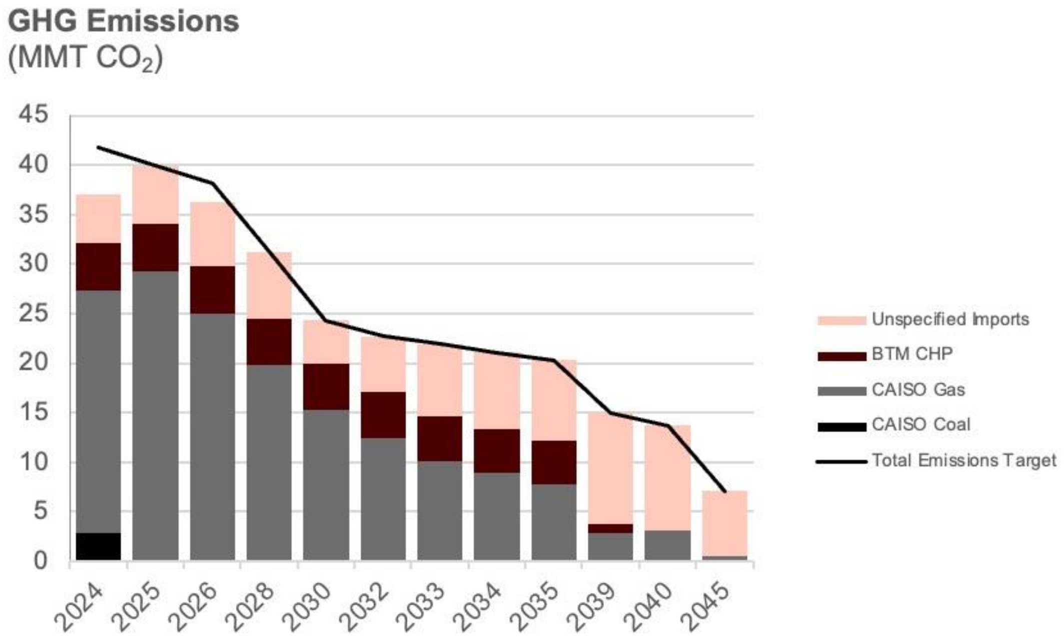


RPS Shadow Prices
($/MWh)

SB 100 Shadow Prices
($/MWh)

Sensitivity: High Land-Based Wind Costs

In-state & Unspecified Import Emissions (MMT)



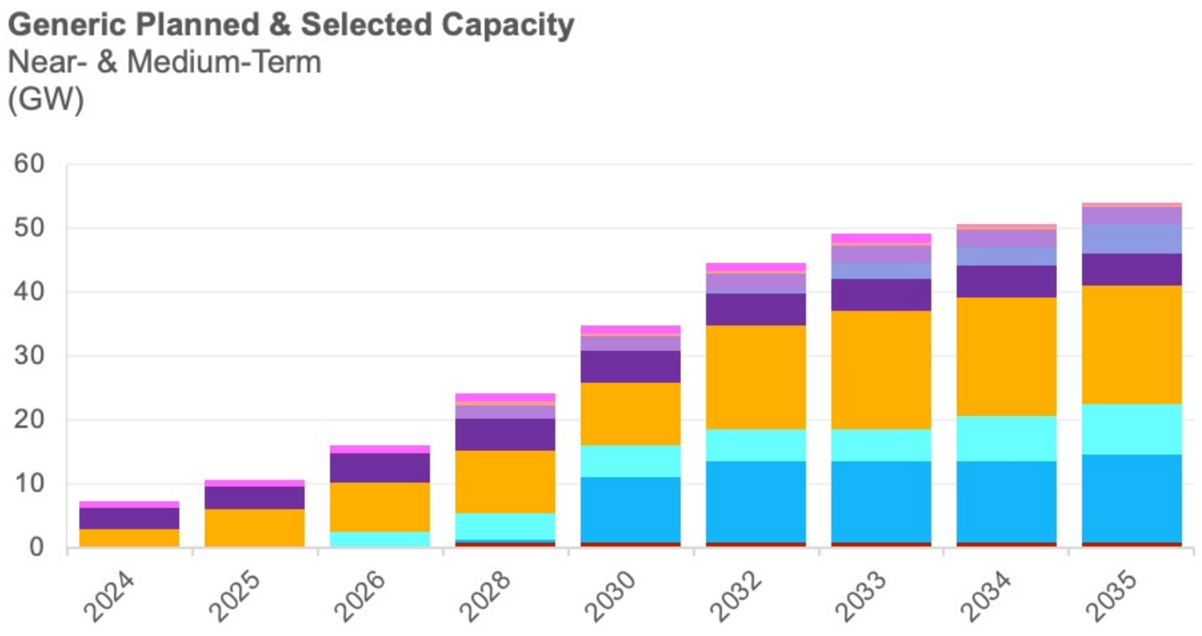
The marginal cost of meeting the GHG target is similar to the Least-Cost case.

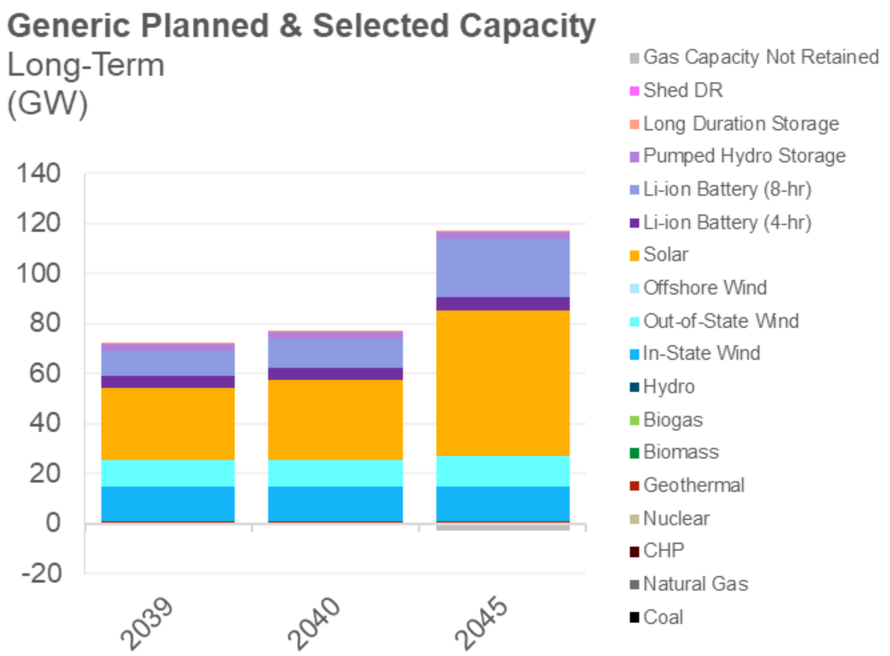
25 MMT Least-Cost Sensitivity

High Geothermal & Biomass Costs Sensitivity Case

Sensitivity: High Geothermal & Biomass Costs

Planned & Selected Capacity





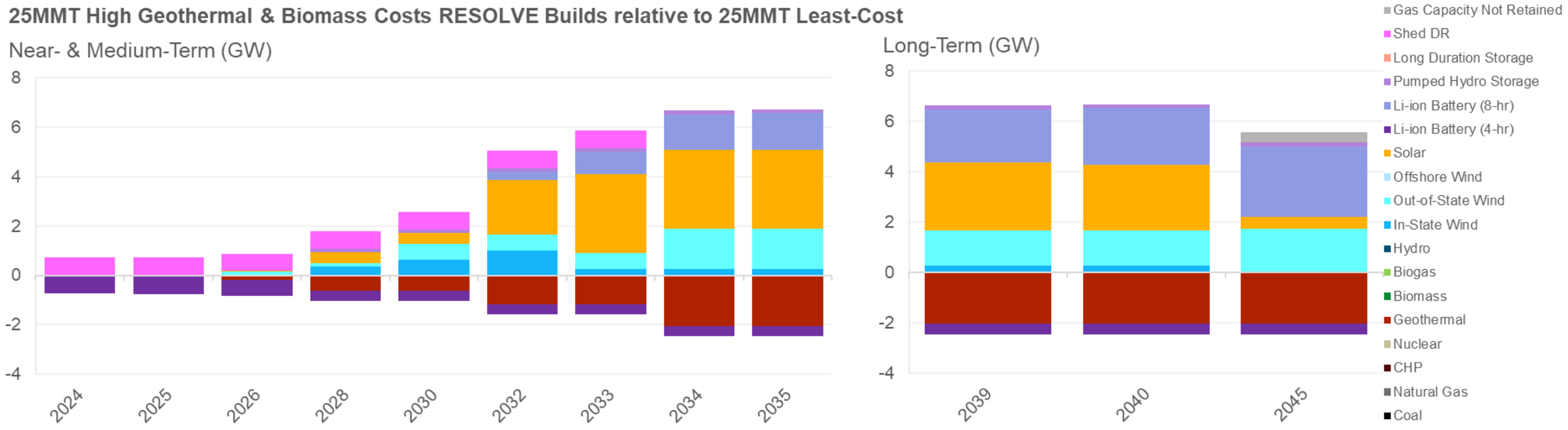
Sensitivity: High Geothermal & Biomass Costs

Planned & Selected Capacity, Compared to Least-Cost (GW)

With higher costs, geothermal build is lowered by 2 GW (2034 and beyond)

Starting in the 2030s, compared to the least-cost case, 8-hr batteries replace some geothermal for firm capacity, and likely provide energy through the night that geothermal would also deliver. Additional solar and wind builds are necessary to charge the batteries and deliver energy.

Likely anticipating 8-hr batteries replacing some 4-hr in the 2030s, 10-year DR programs are selected in lieu of some 4-hr batteries in 2024.



Sensitivity: High Geothermal & Biomass Costs

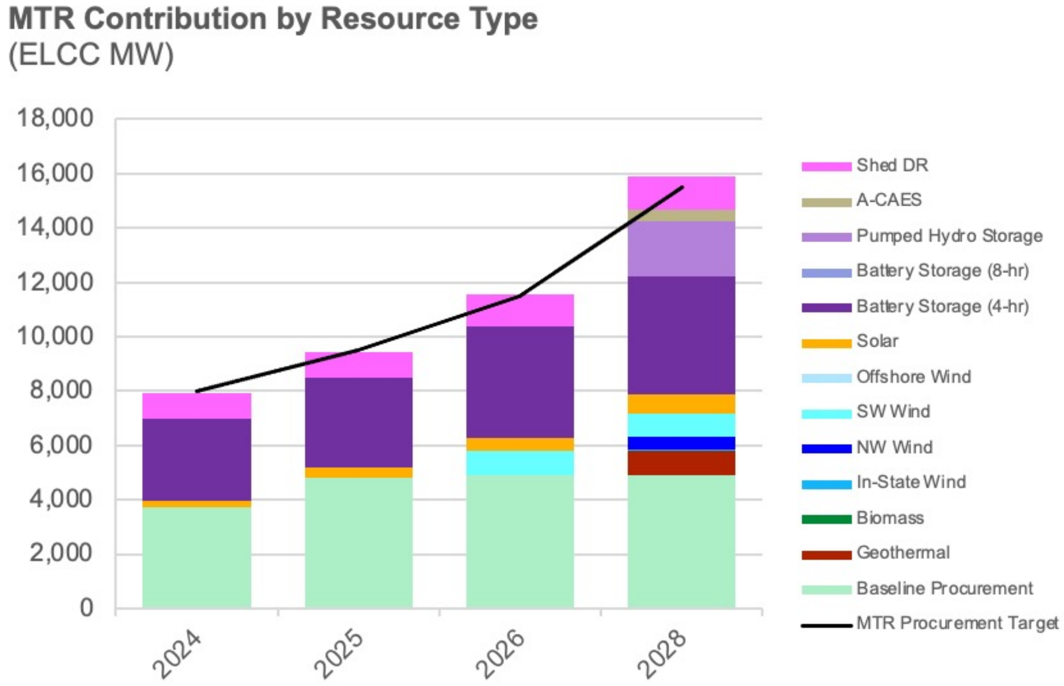
Planned & Selected Capacity (GW)

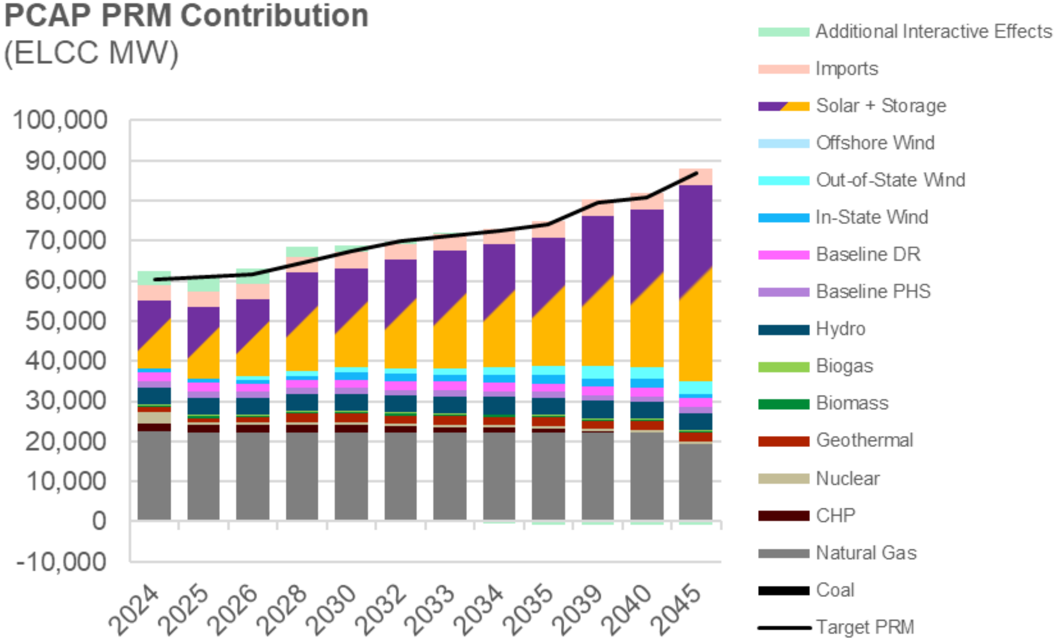
Resource Category	2024	2025	2026	2028	2030	2032	2033	2034	2035	2039	2040	2045
Geothermal	-	-	-	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Biomass	-	-	-	-	-	-	-	-	-	-	-	-
In-State Wind	0.0	0.0	0.0	0.5	10.2	12.8	12.8	12.8	13.7	13.7	13.7	13.8
Out-of-State Wind	-	-	2.5	4.0	5.0	5.0	5.0	7.0	8.0	10.7	10.7	12.0
Offshore Wind	-	-	-	-	-	-	-	-	-	-	-	-
Solar	3.0	6.0	7.7	9.8	9.8	16.2	18.5	18.5	18.5	28.7	31.9	58.5
Li-ion Battery (4-hr)	3.4	3.7	4.7	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Li-ion Battery (8-hr)	-	-	-	-	-	0.4	2.5	3.0	4.6	9.9	11.9	23.6
Pumped Hydro Storage	-	-	-	2.2	2.2	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Long Duration Storage	-	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Shed DR	1.0	1.0	1.2	1.3	1.3	1.3	1.3	0.3	0.3	-	-	-
Gas Capacity Not Retained	-	-	-	-	-	-	-	-	-	-	-	*(3.2)*
Total	**7.4**	**10.7**	**16.1**	**24.2**	**34.9**	**44.8**	**49.1**	**50.7**	**54.1**	**72.1**	**77.3**	**113.9**

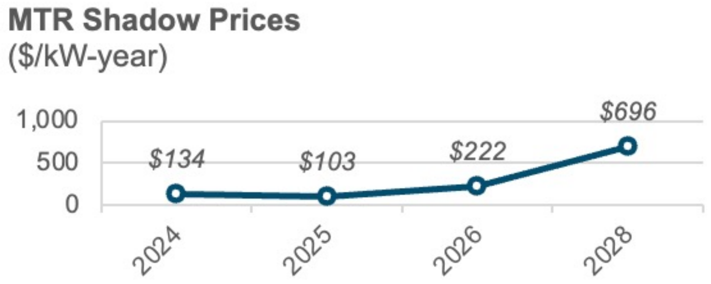
Sensitivity: High Geothermal & Biomass Costs

PRM Results

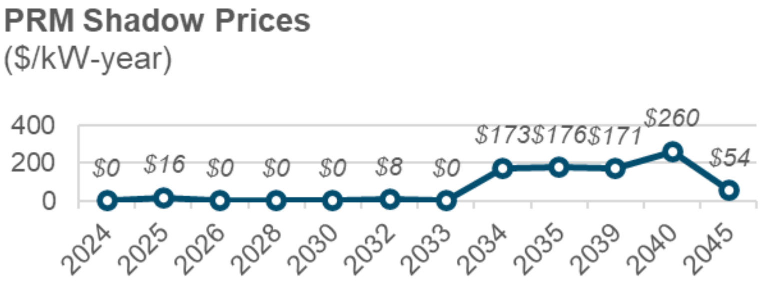
8-hr batteries replace some geothermal for firm capacity needs.







The marginal cost to meet the MTR and PRM constraints follow a similar trajectory as the Least Cost Scenario.

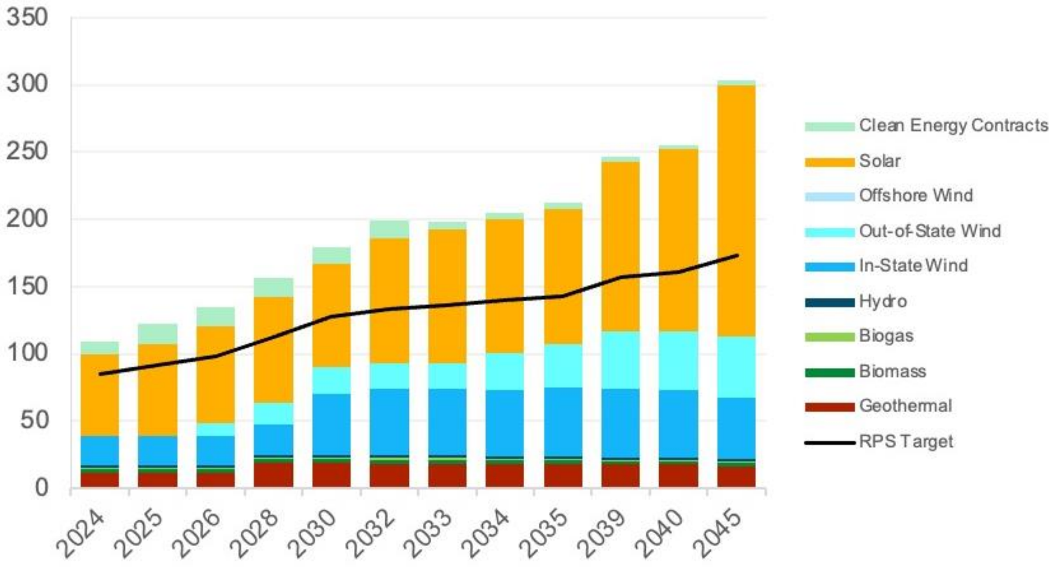


Sensitivity: High Geothermal & Biomass Costs

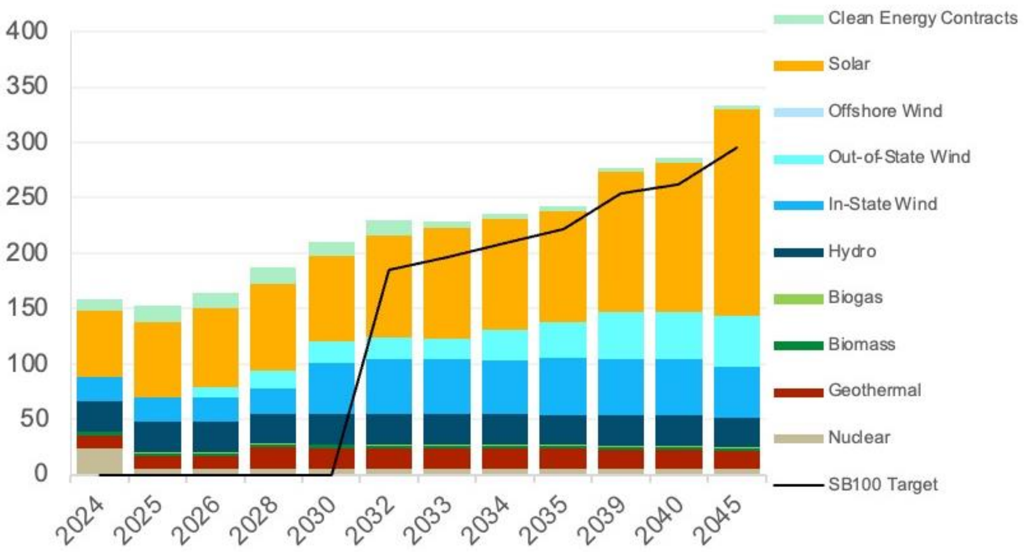
RPS & SB 100

Clean energy requirements (RPS/CES) are *not* drivers of resource selection.
LSE plans (core cases only), GHG targets, and reliability requirements (MTR + PRM) are main drivers of resource selection.

RPS-Eligible Generation
(TWh)



SB 100-Eligible Generation
(TWh)



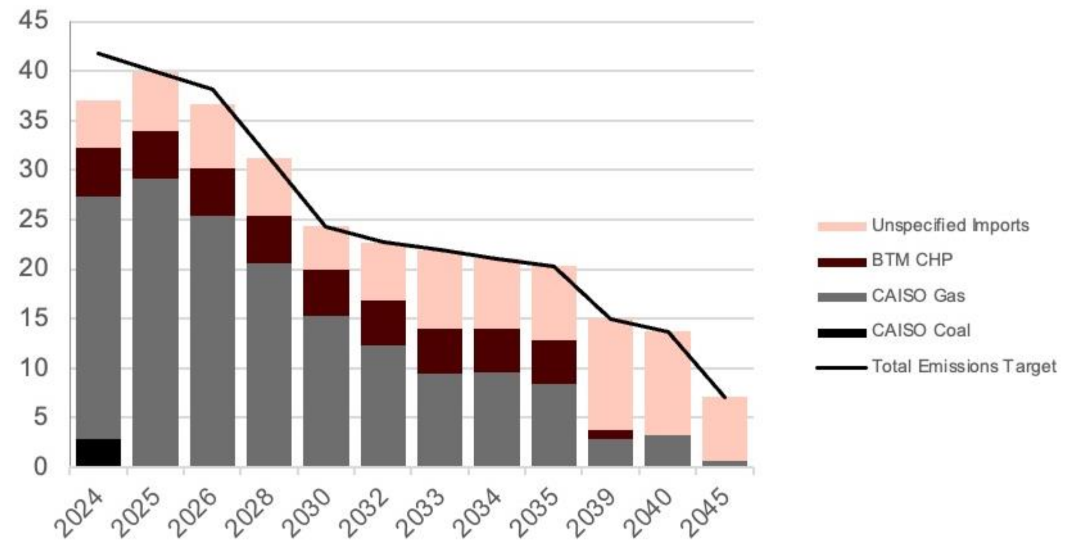
RPS Shadow Prices
($/MWh)

SB 100 Shadow Prices
($/MWh)

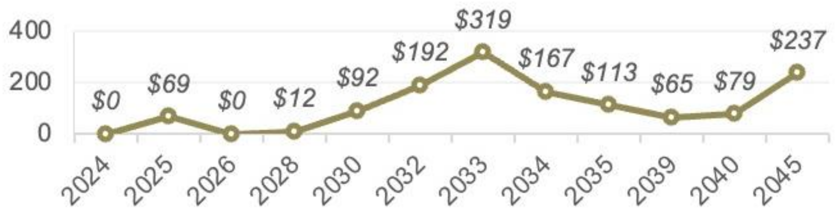
Sensitivity: High Geothermal & Biomass Costs

In-state & Unspecified Import Emissions (MMT)

GHG Emissions
($MMT\ CO_2$)



GHG Target Shadow Price
($\$/ton\ CO_2$)



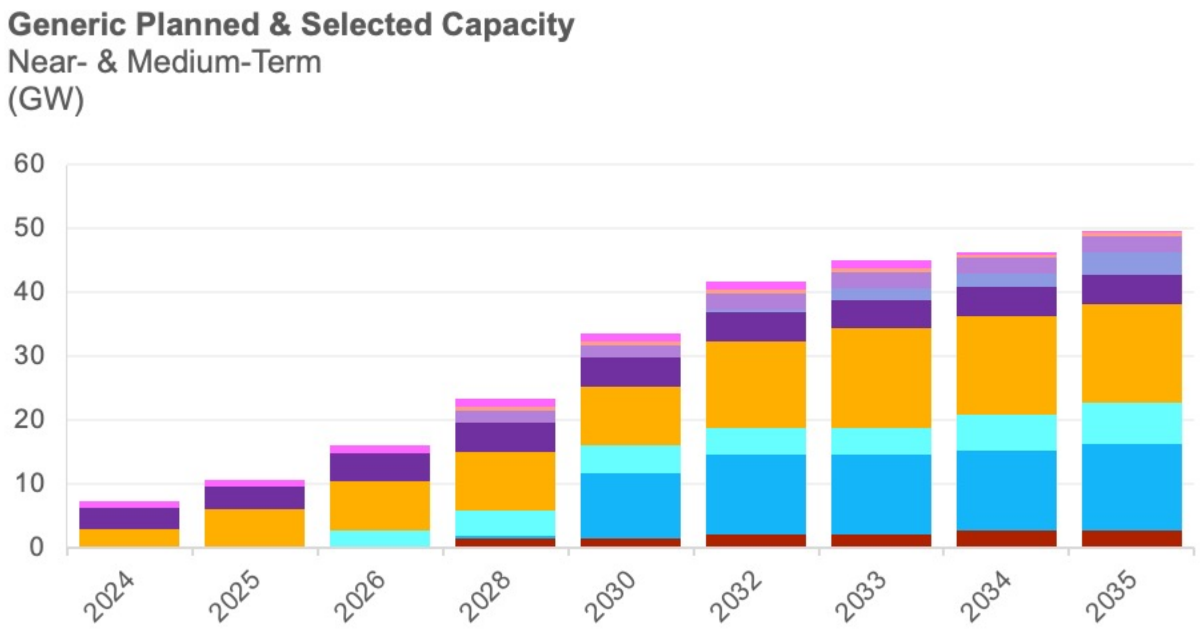
The marginal cost of meeting the GHG target follows a similar trajectory as the Least-Cost case, but is higher in most years. This reflects the replacement of some high-cost geothermal by variable resources and energy-limited batteries.

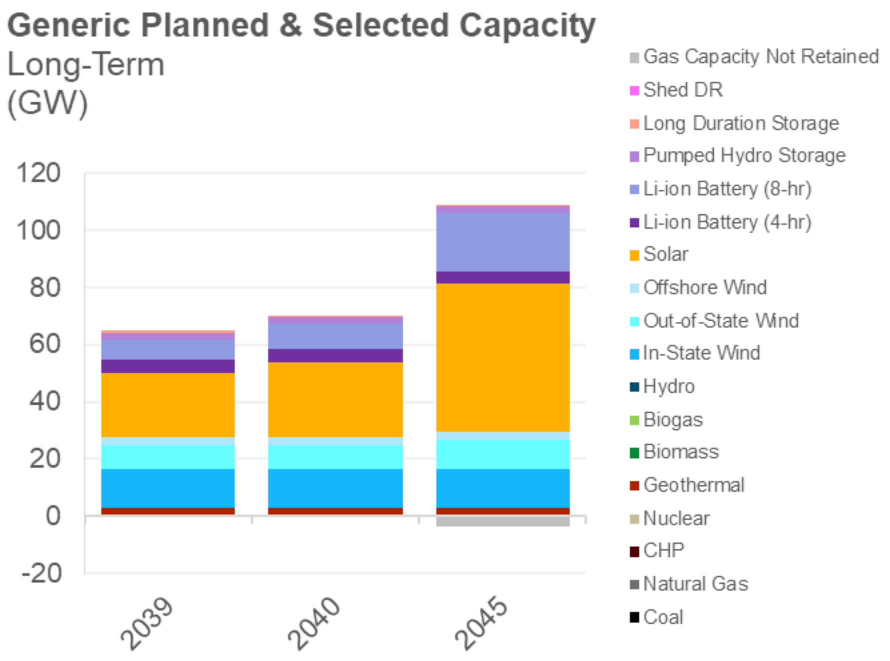
25 MMT Sensitivity: Long Lead-Time Resources

Low Offshore Wind Costs Sensitivity Case

Sensitivity: Low Offshore Wind Costs

Planned & Selected Capacity



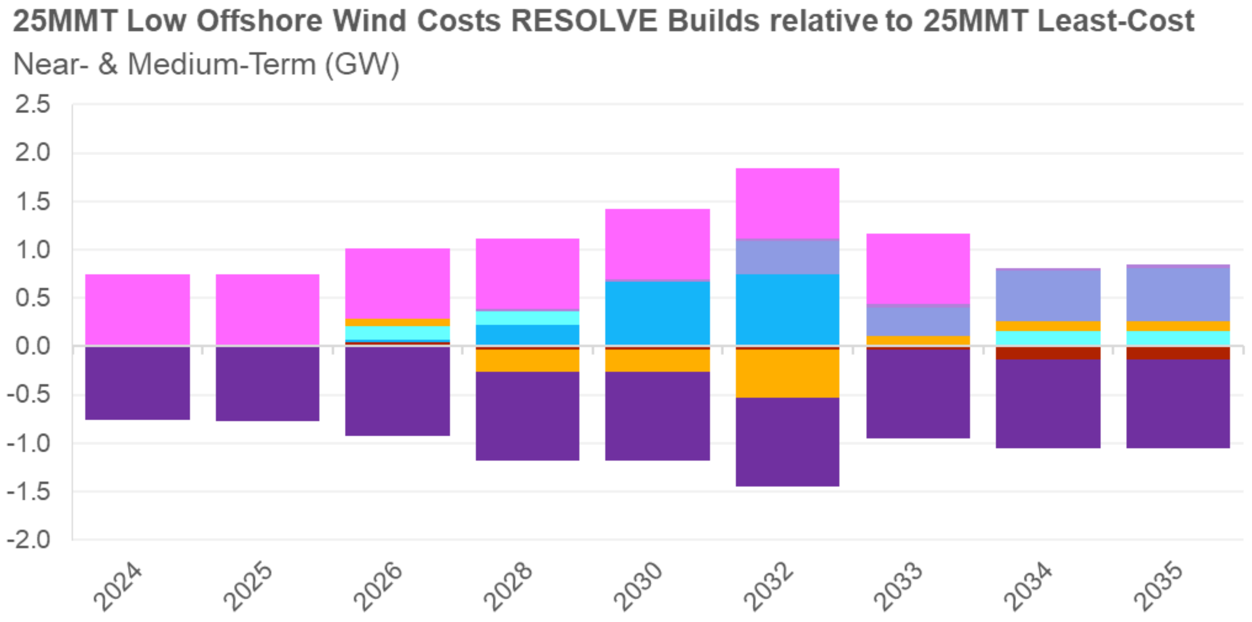


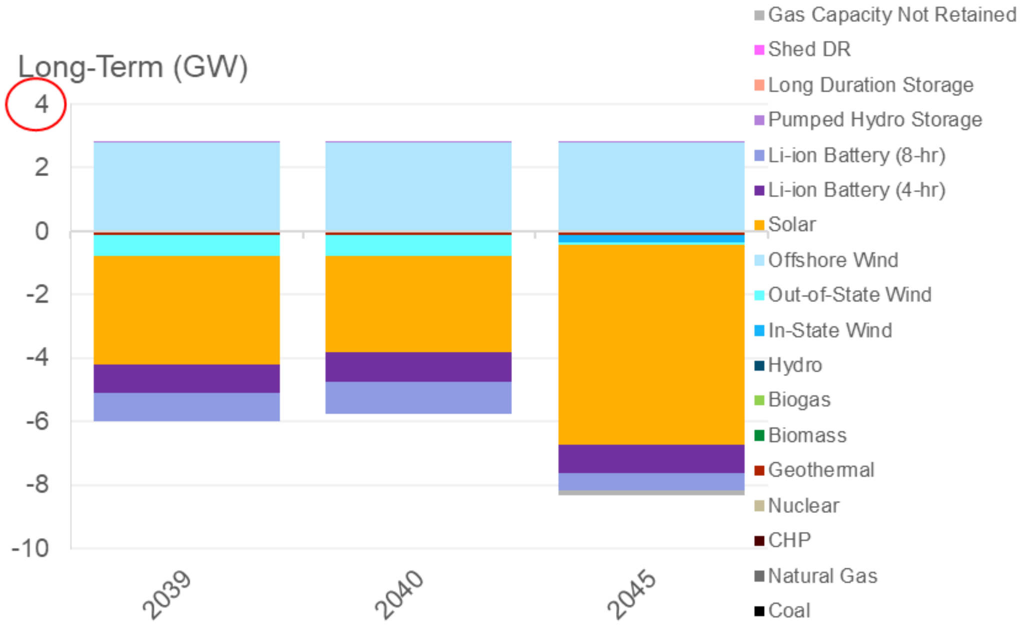
Sensitivity: Low Offshore Wind Costs

Planned & Selected Capacity, Compared to Least-Cost (GW)

As offshore wind is not yet selected before 2039, portfolio changes are modest in this timeframe

Offshore Wind at Morro Bay is selected in 2039. No offshore wind was selected in the least-cost case. Less expensive offshore wind primarily replaces solar.





Sensitivity: Low Offshore Wind Costs

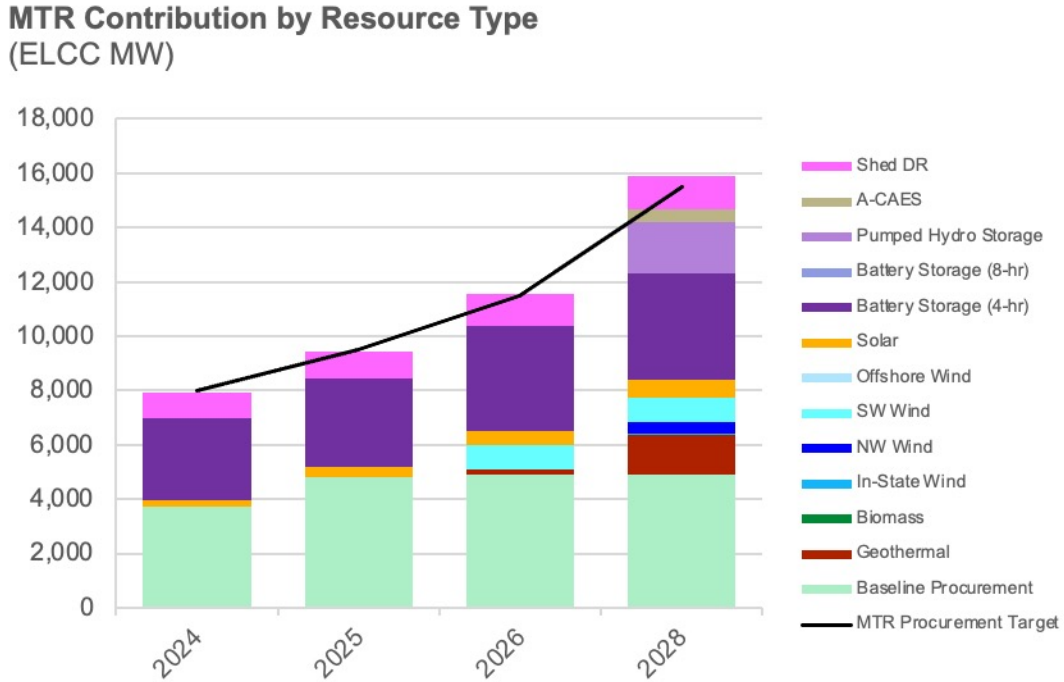
Planned & Selected Capacity (GW)

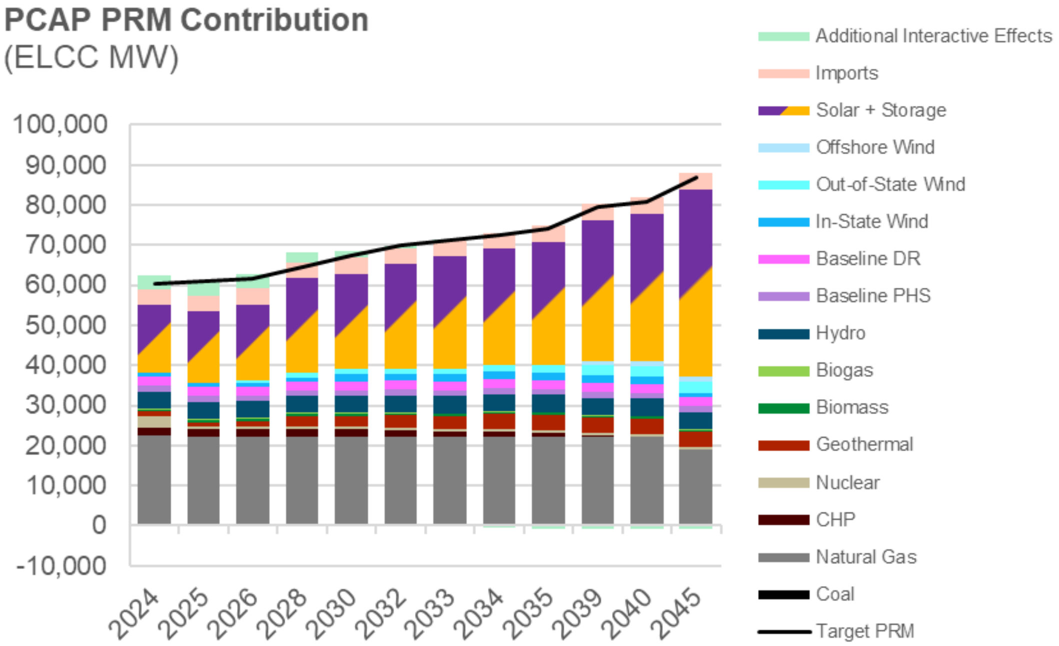
Resource Category	2024	2025	2026	2028	2030	2032	2033	2034	2035	2039	2040	2045
Geothermal	-	-	0.2	1.5	1.5	2.1	2.1	2.8	2.8	2.8	2.8	2.8
Biomass	-	-	-	-	-	-	-	-	-	-	-	-
In-State Wind	0.0	0.0	0.0	0.3	10.2	12.5	12.5	12.5	13.4	13.4	13.4	13.6
Out-of-State Wind	-	-	2.5	4.0	4.3	4.3	4.3	5.5	6.5	8.7	8.7	10.2
Offshore Wind	-	-	-	-	-	-	-	-	-	2.8	2.8	2.8
Solar	3.0	6.0	7.7	9.2	9.2	13.5	15.4	15.4	15.4	22.5	26.3	51.8
Li-ion Battery (4-hr)	3.3	3.7	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Li-ion Battery (8-hr)	-	-	-	-	-	0.4	1.9	2.1	3.6	6.9	8.6	20.2
Pumped Hydro Storage	-	-	-	2.1	2.1	2.6	2.6	2.6	2.6	2.6	2.6	2.6
Long Duration Storage	-	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Shed DR	1.0	1.0	1.2	1.3	1.3	1.3	1.3	0.3	0.3	-	-	-
Gas Capacity Not Retained	-	-	-	-	-	-	-	-	-	-	-	*(3.7)*
Total	**7.4**	**10.7**	**16.2**	**23.4**	**33.6**	**41.7**	**45.1**	**46.2**	**49.7**	**64.8**	**70.2**	**105.2**

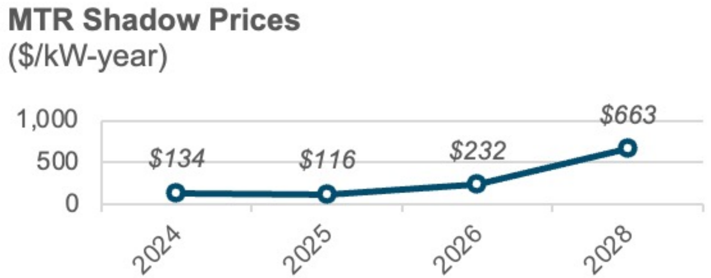
Sensitivity: Low Offshore Wind Costs

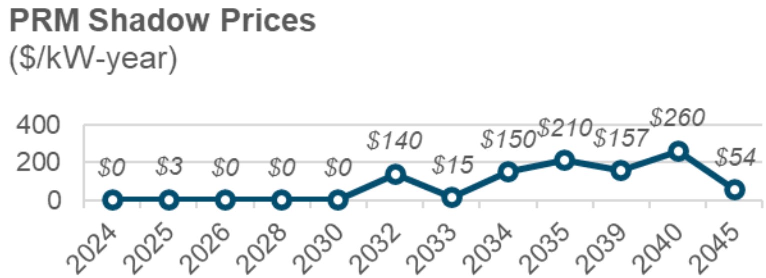
PRM Results

PRM results are broadly similar to the Least Cost case







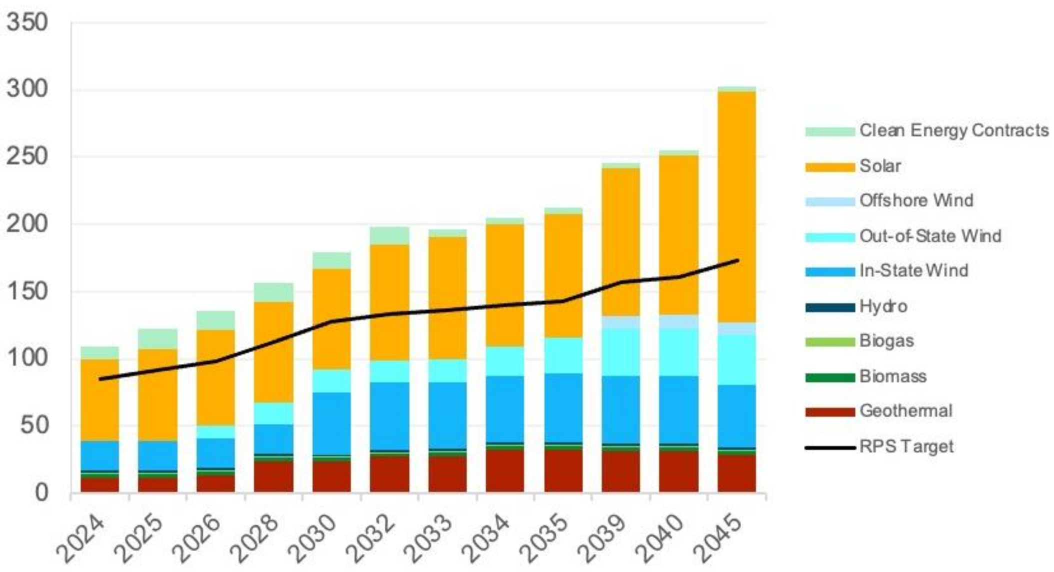


Sensitivity: Low Offshore Wind Costs

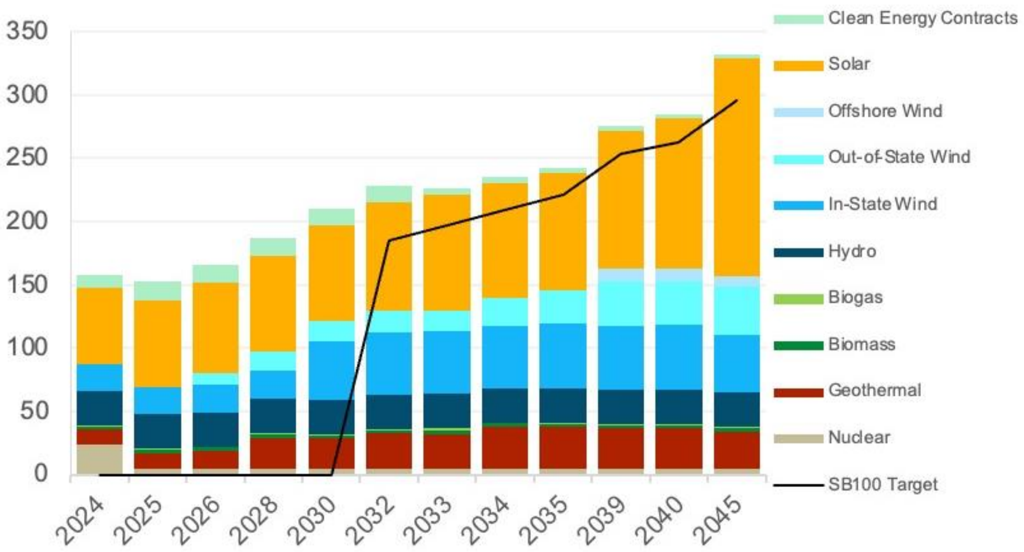
RPS & SB 100

Clean energy requirements (RPS/CES) are *not* drivers of resource selection.
LSE plans (core cases only), GHG targets, and reliability requirements (MTR + PRM) are main drivers of resource selection.

RPS-Eligible Generation
(TWh)



SB 100-Eligible Generation
(TWh)

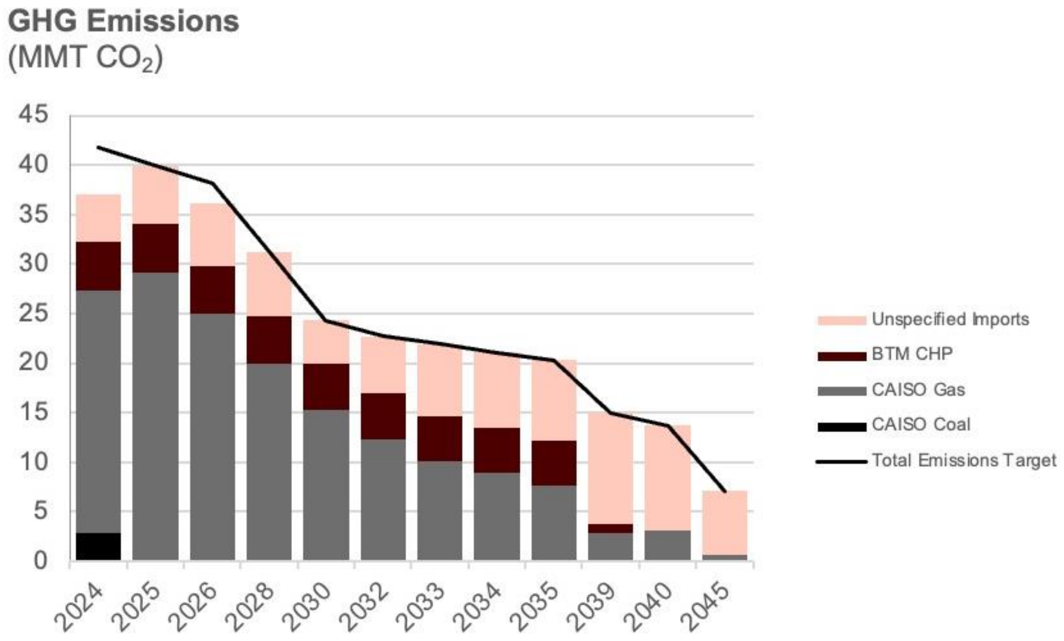


RPS Shadow Prices
($/MWh)

SB 100 Shadow Prices
($/MWh)

Sensitivity: Low Offshore Wind Costs

In-state & Unspecified Import Emissions (MMT)



The marginal cost of meeting the GHG target is similar to the Least-Cost case.

25 MMT Sensitivity: Long Lead-Time Resources

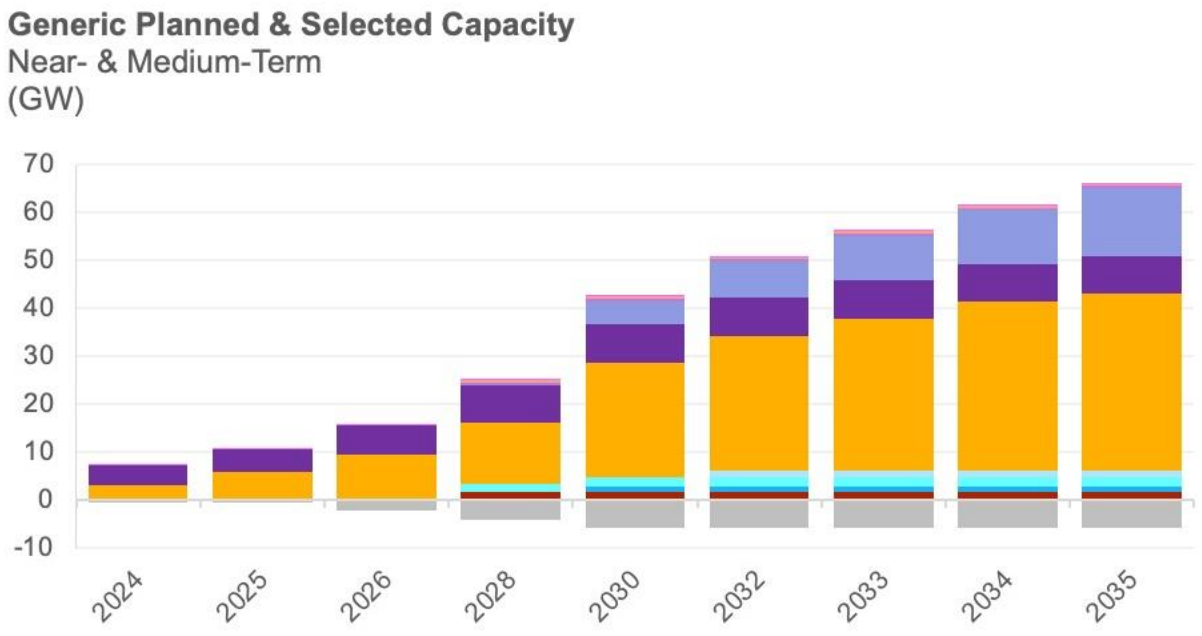
Significantly Reduced Land-Based Clean Resource Availability Sensitivity Case

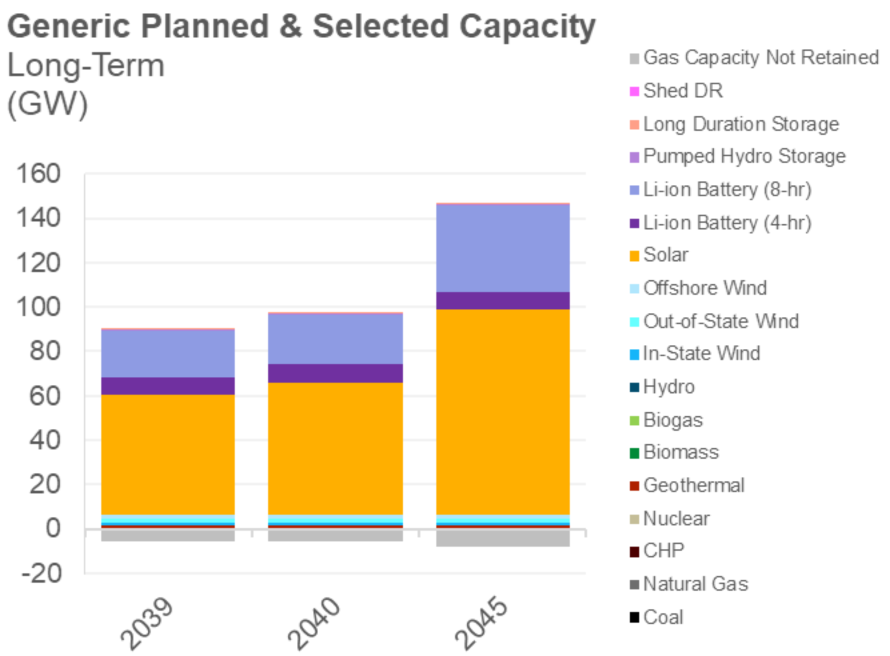
Sensitivity: Significantly Reduced Land-Based Clean Resource Availability

Planned & Selected Capacity

- Constraints on resource builds produce a less diverse portfolio of clean resources

Portfolio additions show significantly more solar and batteries



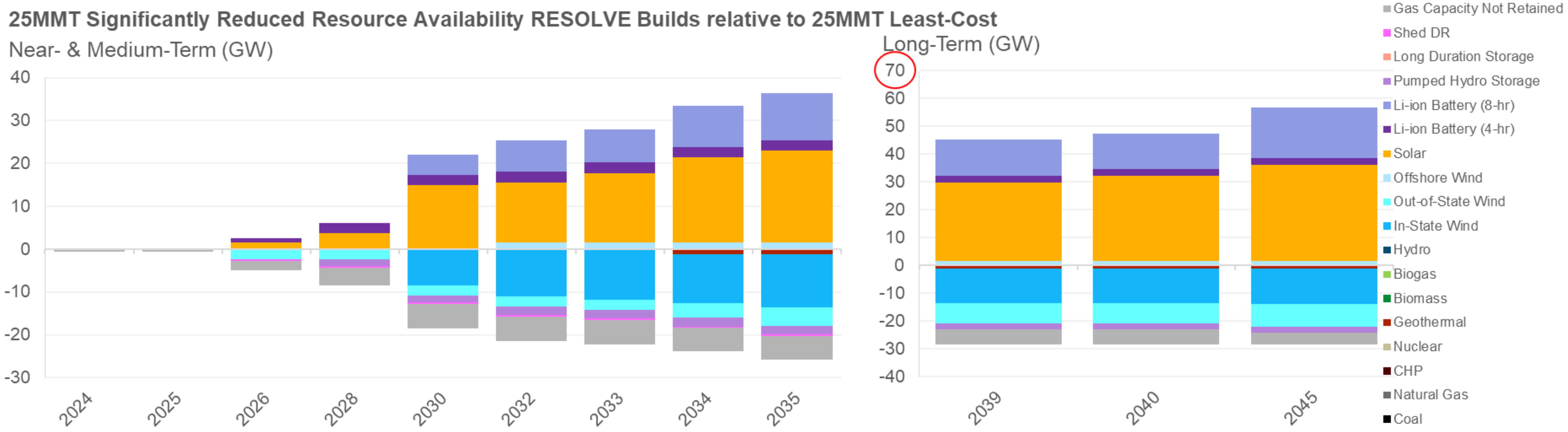


Sensitivity: Significantly Reduced Land-Based Clean Resource Availability

Planned & Selected Capacity, Compared to Least-Cost (GW)

In-state wind, out-of-state wind, geothermal, and pumped storage all have lower resource potentials in this sensitivity and thus lower amounts are selected.

Additional gas is not retained in this sensitivity because the need to reduce GHG emissions, combined with a relative lack of diverse zero-GHG resources, results in the installation of much additional solar and storage capacity. This capacity provides resource adequacy, enabling the model to save costs by not retaining all of gas capacity



Sensitivity: Significantly Reduced Land-Based Clean Resource Availability

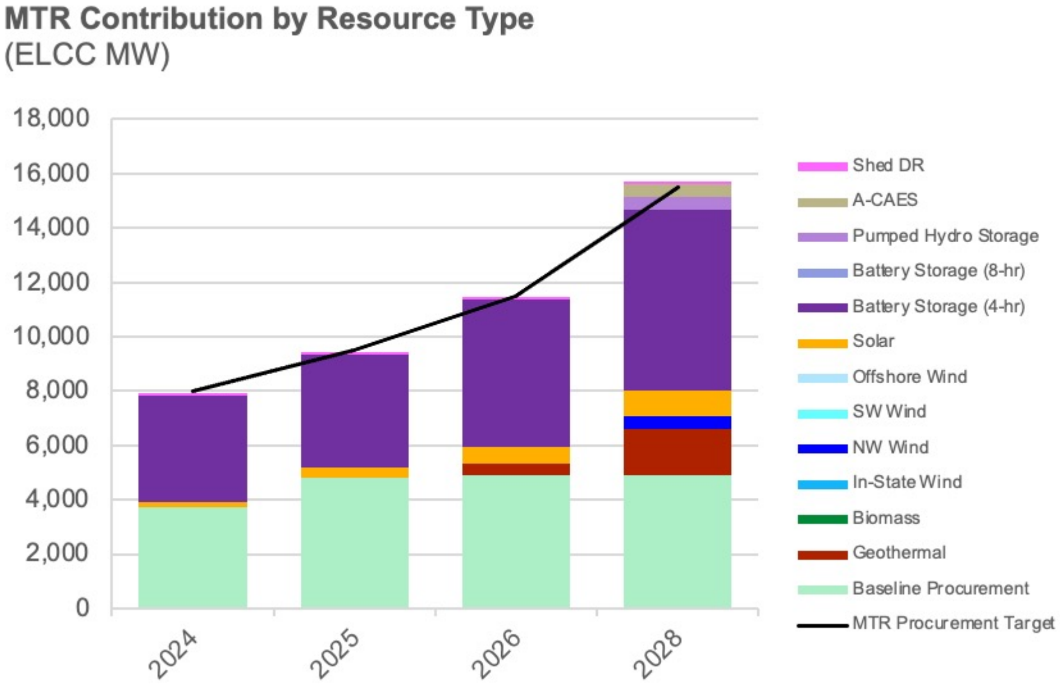
Planned & Selected Capacity (GW)

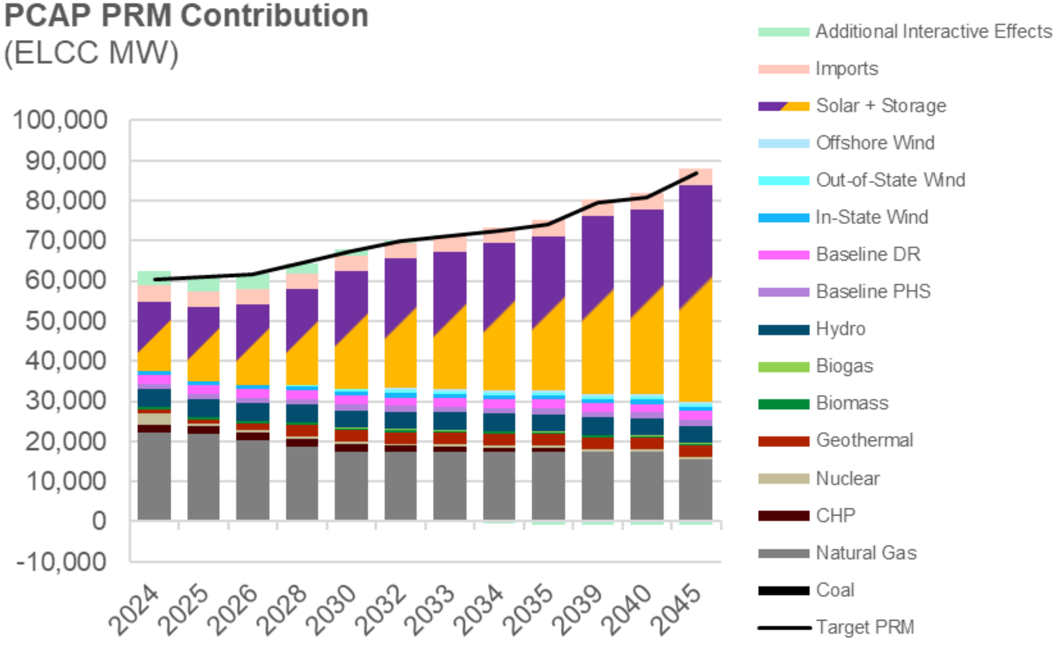
Resource Category	2024	2025	2026	2028	2030	2032	2033	2034	2035	2039	2040	2045
Geothermal	-	-	0.4	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Biomass	-	-	-	-	-	-	-	-	-	-	-	-
In-State Wind	-	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Out-of-State Wind	-	-	-	1.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Offshore Wind	-	-	-	-	-	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Solar	3.0	6.0	9.0	12.8	24.0	28.1	31.6	35.2	36.8	54.0	59.8	92.7
Li-ion Battery (4-hr)	4.3	4.6	6.3	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9
Li-ion Battery (8-hr)	-	-	-	-	4.7	7.5	9.3	11.1	14.0	21.1	22.5	38.8
Pumped Hydro Storage	-	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Long Duration Storage	-	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Shed DR	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	-	-	-
Gas Capacity Not Retained	*(0.5)*	*(0.5)*	*(2.1)*	*(4.0)*	*(5.6)*	*(5.6)*	*(5.6)*	*(5.6)*	*(5.6)*	*(5.6)*	*(5.6)*	*(7.7)*
Total	**6.9**	**10.2**	**13.7**	**21.2**	**37.0**	**45.3**	**50.7**	**55.9**	**60.4**	**84.7**	**92.0**	**139.0**

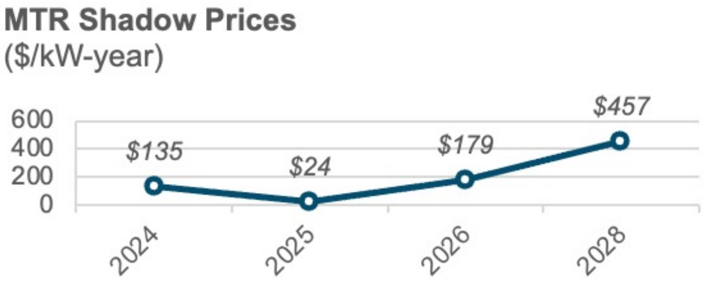
Sensitivity: Significantly Reduced Land-Based Clean Resource Availability

PRM Results

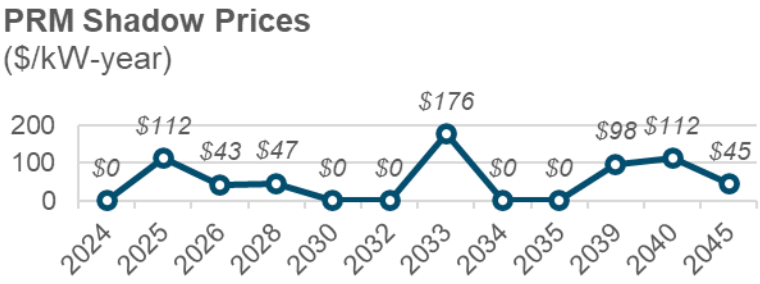
The removal of most resource potential from diverse renewable resources shifts the resource adequacy portfolio further towards solar and batteries.







In the 2020s, PRM costs are higher than the least-cost case, reflecting the shift toward solar and batteries from a more diverse portfolio.



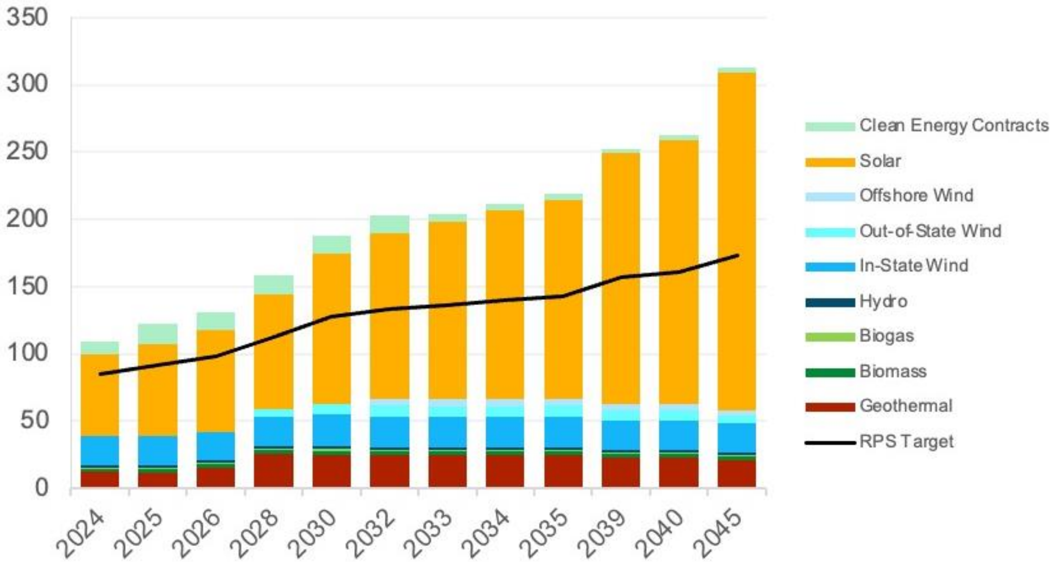
From 2030 onward, The acute need for GHG-free resources results in lower PRM costs because resources are installed primarily for GHG reductions

Sensitivity: Significantly Reduced Land-Based Clean Resource Availability

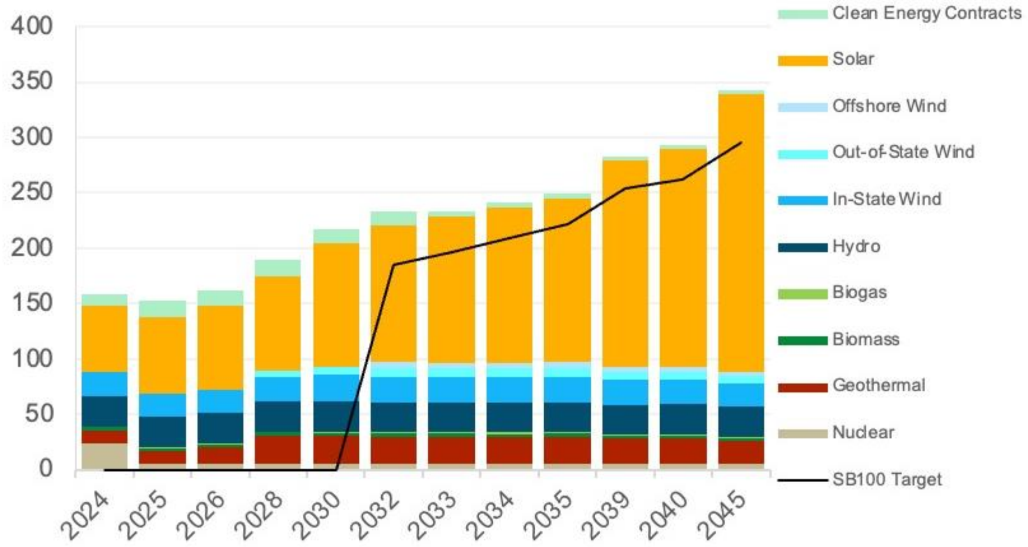
RPS & SB 100

Clean energy requirements (RPS/CES) are *not* drivers of resource selection.
LSE plans (core cases only), GHG targets, and reliability requirements (MTR + PRM) are main drivers of resource selection.

RPS-Eligible Generation
(TWh)



SB 100-Eligible Generation
(TWh)

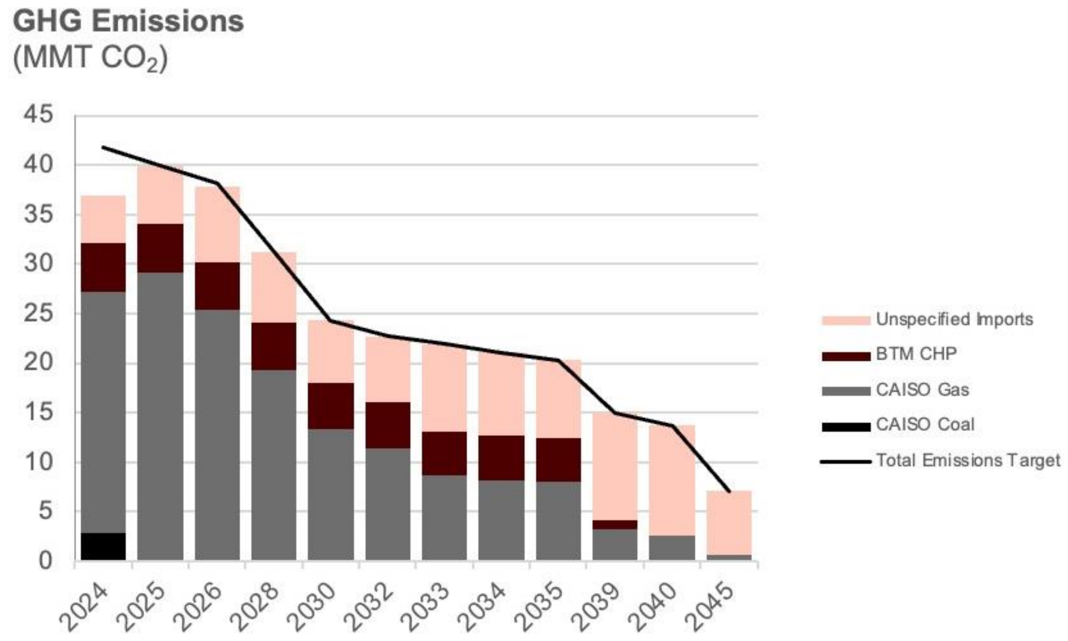


RPS Shadow Prices
($/MWh)

SB 100 Shadow Prices
($/MWh)

Sensitivity: Significantly Reduced Land-Based Clean Resource Availability

In-state & Unspecified Import Emissions (MMT)



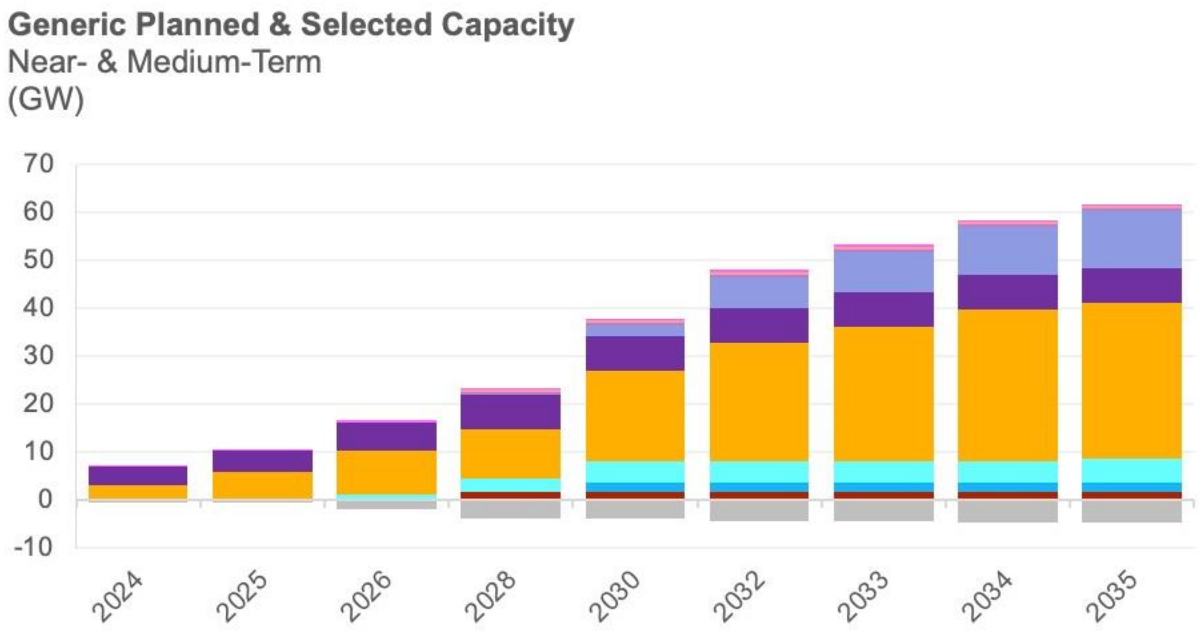
Compared to the least-cost case, the marginal cost of meeting the GHG target from 2030 onward is extremely high due to the lack of diverse zero-GHG resource potential.
Before 2030, economics and other constraints, especially the MTR constraints, drive portfolio selection.

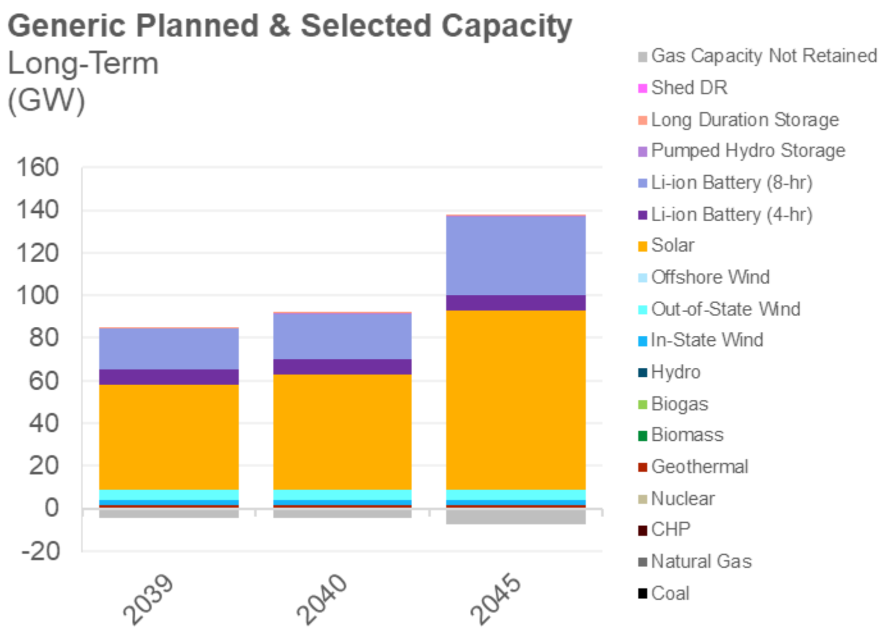
25 MMT Sensitivity: Long Lead-Time Resources

Reduced Land-Based Clean Resource Availability Sensitivity Case

Sensitivity: Reduced Land-Based Clean Resource Availability

Planned & Selected Capacity





Sensitivity: Reduced Land-Based Clean Resource Availability

Planned & Selected Capacity, Compared to Least-Cost (GW)

Despite the relative lack of other diverse zero-GHG resource options, offshore wind is not selected in this case

Additional gas is not retained in this sensitivity because the need to reduce GHG emissions, combined with a relative lack of diverse zero-GHG resources, results in the installation of much additional solar and storage capacity. This capacity provides resource adequacy, enabling the model to save costs by not retaining all of gas capacity

In-state wind, **out-of-state wind**, **geothermal**, and **pumped storage** all have lower resource potentials in this sensitivity and thus lower amounts are selected.

Sensitivity: Reduced Land-Based Clean Resource Availability

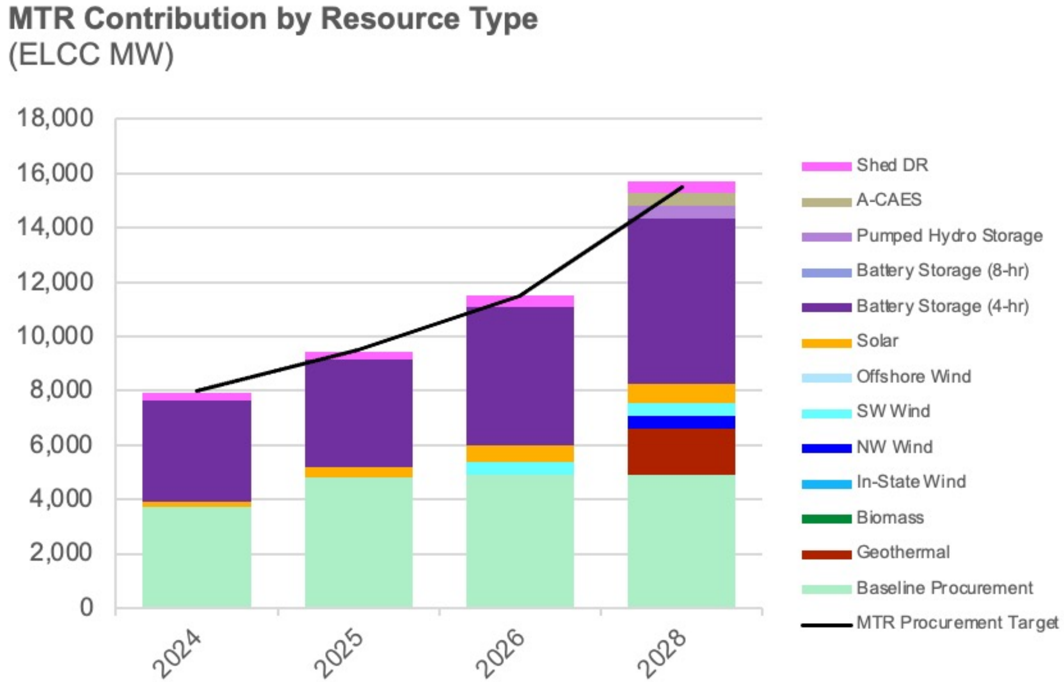
Planned & Selected Capacity (GW)

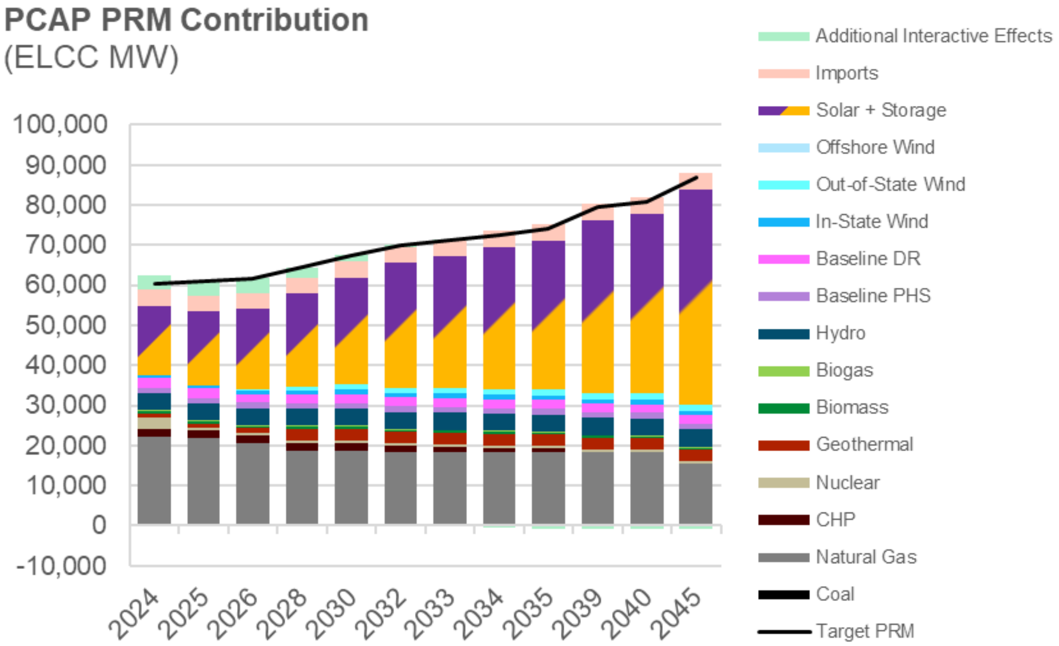
Resource Category	2024	2025	2026	2028	2030	2032	2033	2034	2035	2039	2040	2045
Geothermal	-	-	-	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Biomass	-	-	-	-	-	-	-	-	-	-	-	-
In-State Wind	-	-	-	-	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Out-of-State Wind	-	-	1.3	2.8	4.3	4.3	4.3	4.3	5.0	5.0	5.0	5.0
Offshore Wind	-	-	-	-	-	-	-	-	-	-	-	-
Solar	3.0	6.0	9.0	10.2	18.8	24.7	28.2	31.7	32.3	49.0	54.3	84.3
Li-ion Battery (4-hr)	4.1	4.4	5.9	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2
Li-ion Battery (8-hr)	-	-	-	-	2.4	6.5	8.4	10.1	12.1	19.2	20.7	36.5
Pumped Hydro Storage	-	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Long Duration Storage	-	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Shed DR	0.3	0.3	0.5	0.5	0.5	0.5	0.5	0.2	0.2	-	-	-
Gas Capacity Not Retained	*(0.4)*	*(0.4)*	*(1.8)*	*(3.9)*	*(3.9)*	*(4.4)*	*(4.4)*	*(4.5)*	*(4.5)*	*(4.5)*	*(4.5)*	*(7.6)*
Total	**7.0**	**10.3**	**14.9**	**19.6**	**34.1**	**43.6**	**48.9**	**53.8**	**57.1**	**80.7**	**87.5**	**130.1**

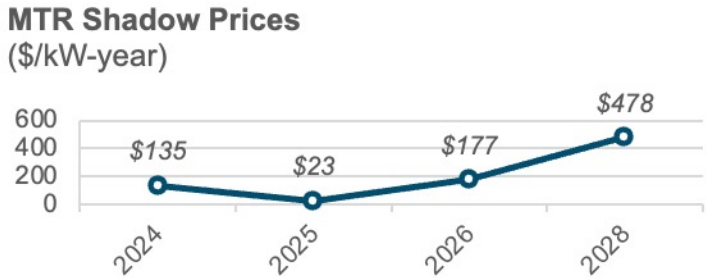
Sensitivity: Reduced Land-Based Clean Resource Availability

PRM Results

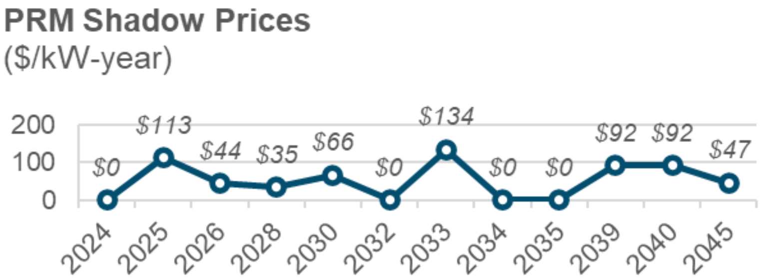
The removal of most resource potential from diverse renewable resources shifts the resource adequacy portfolio further towards solar and batteries.







In the 2020s, PRM costs are higher than the least-cost case, reflecting the shift toward solar and batteries from a more diverse portfolio.



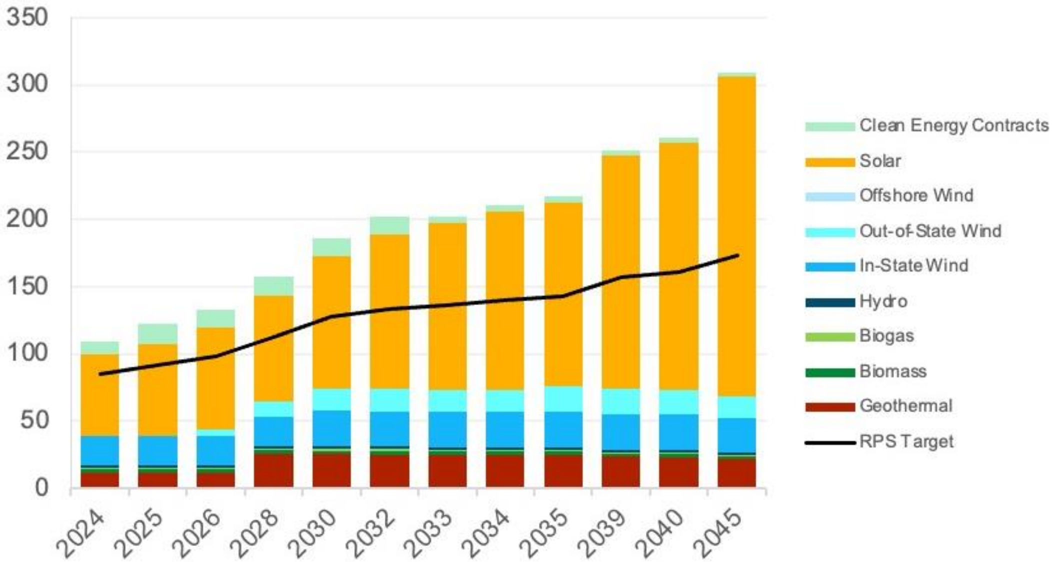
From 2030 onward, The acute need for GHG-free resources results in lower PRM costs because resources are installed primarily for GHG reductions.

Sensitivity: Reduced Land-Based Clean Resource Availability

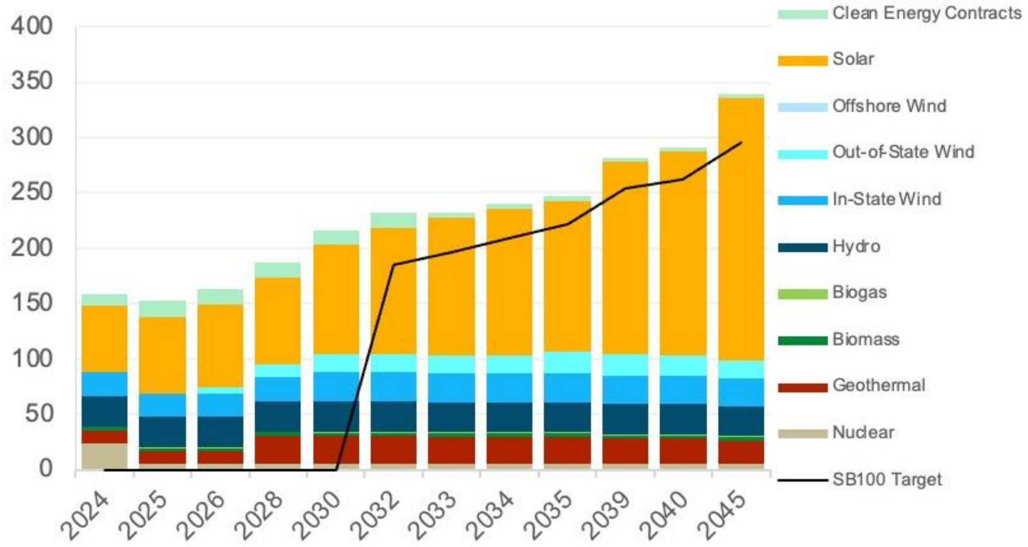
RPS & SB 100

Clean energy requirements (RPS/CES) are *not* drivers of resource selection. LSE plans (core cases only), GHG targets, and reliability requirements (MTR + PRM) are main drivers of resource selection.

RPS-Eligible Generation
(TWh)



SB 100-Eligible Generation
(TWh)

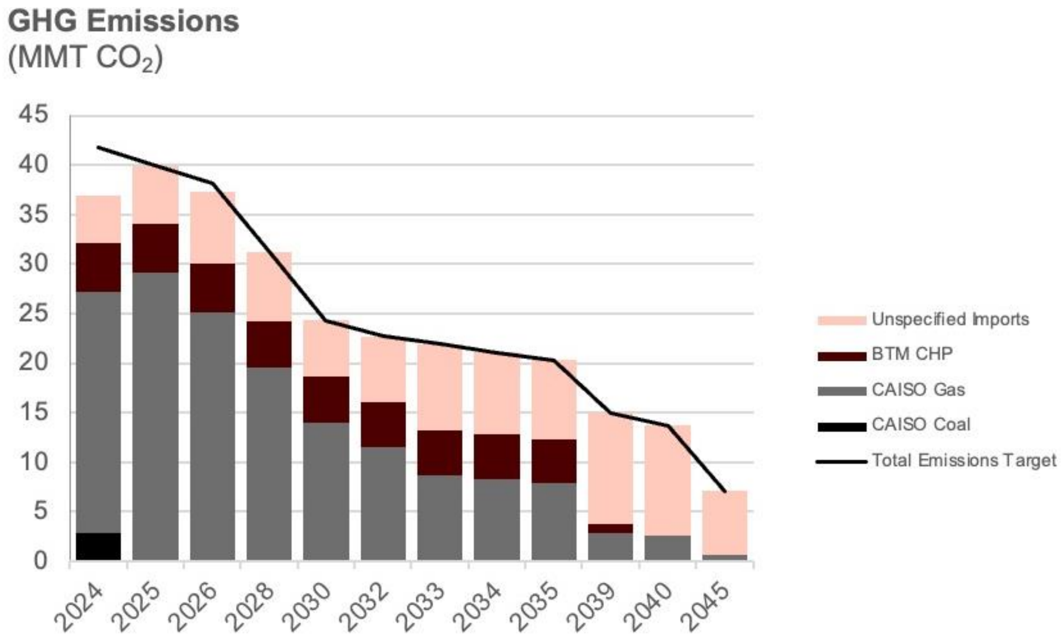


RPS Shadow Prices
($/MWh)

SB 100 Shadow Prices
($/MWh)

Sensitivity: Reduced Land-Based Clean Resource Availability

In-state & Unspecified Import Emissions (MMT)



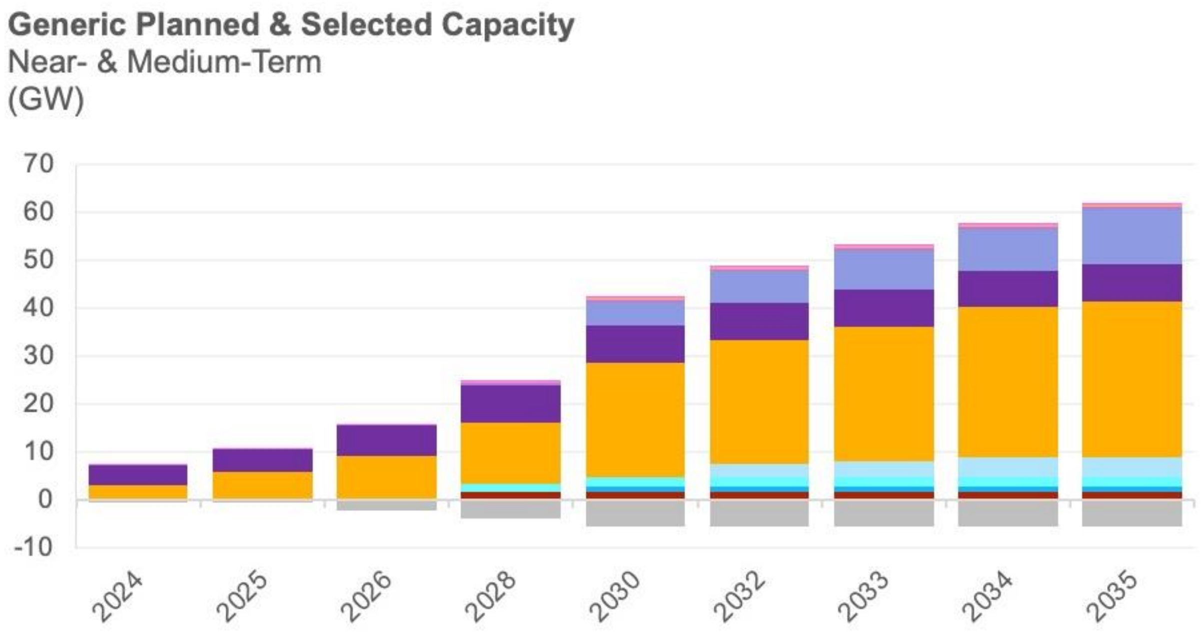
Compared to the least-cost case, the marginal cost of meeting the GHG target from 2030 onward is extremely high due to the lack of diverse zero-GHG resource potential.
Before 2030, economics and other constraints, especially the MTR constraints, drive portfolio selection.

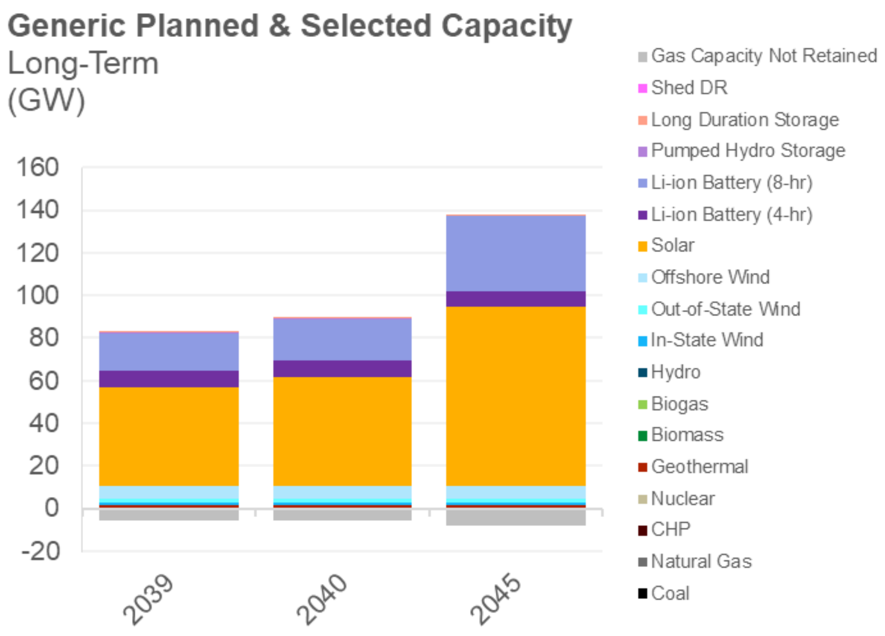
25 MMT Sensitivity: Long Lead-Time Resources

Low Offshore Wind Costs & Significantly Reduced Land-Based Clean Resource Availability Sensitivity Case

Sensitivity: Low Offshore Wind Costs & Significantly Reduced Land-Based Clean Resource Availability

Planned & Selected Capacity, Near- & Mid-Term (GW)



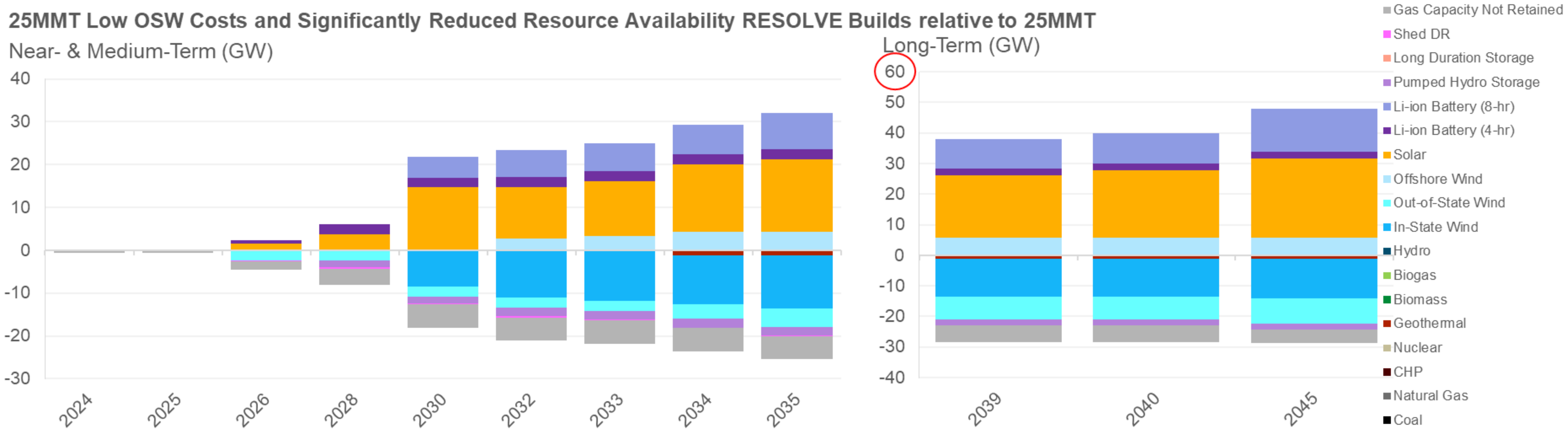


Sensitivity: Low Offshore Wind Costs & Significantly Reduced Land-Based Clean Resource Availability

Planned & Selected Capacity, Compared to Least-Cost (GW)

2.8 Offshore wind selected in 2032, growing to 5.8 GW by 2039.

Additional gas is not retained in this sensitivity because the need to reduce GHG emissions, combined with a relative lack of diverse zero-GHG resources, results in the installation of much additional solar and storage capacity. This capacity provides resource adequacy, enabling the model to save costs by not retaining all of gas capacity



In-state wind, out-of-state wind, geothermal, and pumped storage all have lower resource potentials in this sensitivity and thus lower amounts are selected.

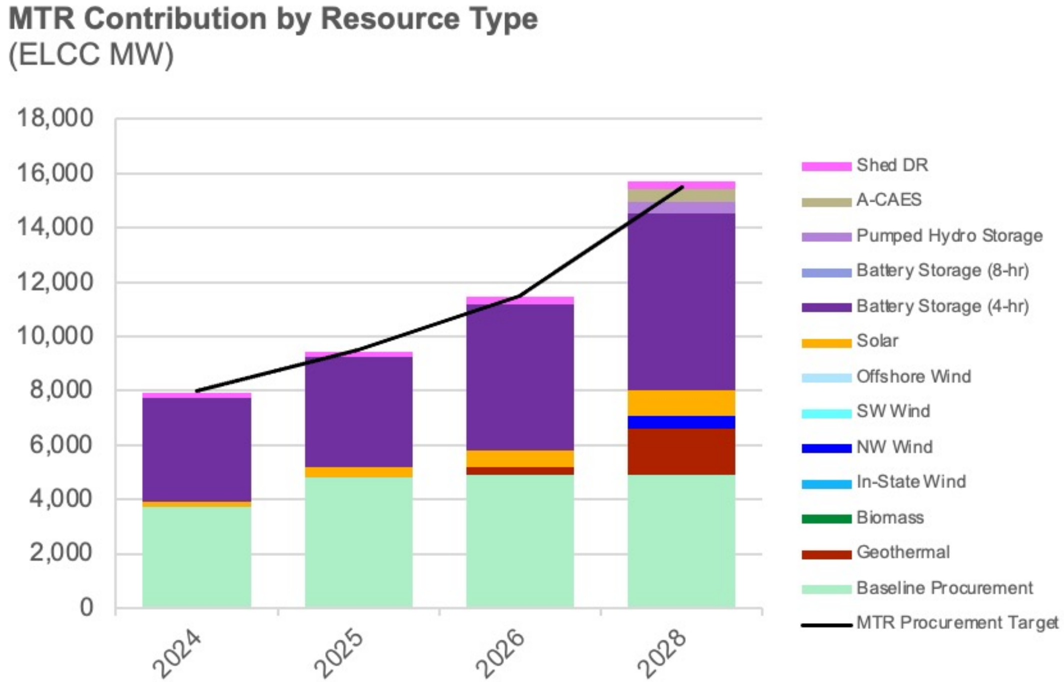
Sensitivity: Low Offshore Wind Costs & Significantly Reduced Land-Based Clean Resource Availability

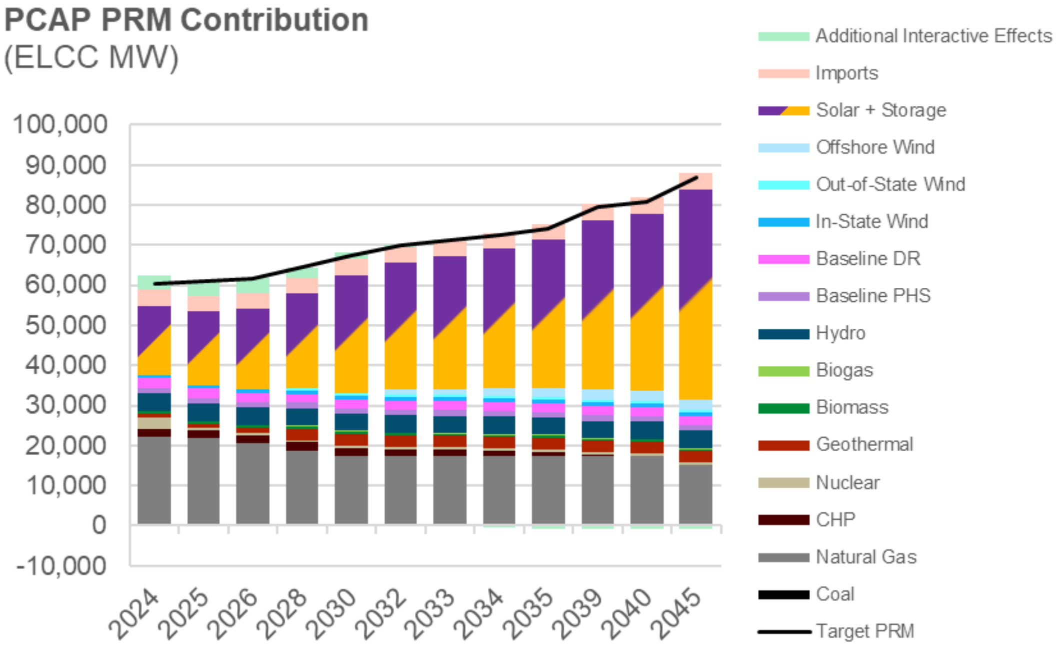
Planned & Selected Capacity (GW)

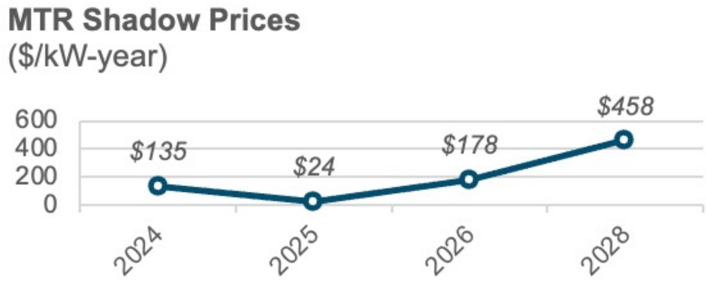
Resource Category	2024	2025	2026	2028	2030	2032	2033	2034	2035	2039	2040	2045
Geothermal	-	-	0.3	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Biomass	-	-	-	-	-	-	-	-	-	-	-	-
In-State Wind	-	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Out-of-State Wind	-	-	-	1.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Offshore Wind	-	-	-	-	-	2.8	3.3	4.3	4.3	5.8	5.8	5.8
Solar	3.0	6.0	9.0	12.9	23.9	26.0	28.2	31.2	32.4	46.2	51.3	83.8
Li-ion Battery (4-hr)	4.2	4.5	6.2	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7
Li-ion Battery (8-hr)	-	-	-	-	4.8	6.5	8.1	8.5	11.5	17.4	19.3	34.9
Pumped Hydro Storage	-	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Long Duration Storage	-	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Shed DR	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.1	0.1	-	-	-
Gas Capacity Not Retained	*(0.5)*	*(0.5)*	*(2.0)*	*(3.9)*	*(5.4)*	*(5.4)*	*(5.4)*	*(5.4)*	*(5.4)*	*(5.4)*	*(5.4)*	*(8.0)*
Total	**6.9**	**10.3**	**13.8**	**21.3**	**37.2**	**43.7**	**48.0**	**52.2**	**56.4**	**77.6**	**84.6**	**130.1**

PRM Results

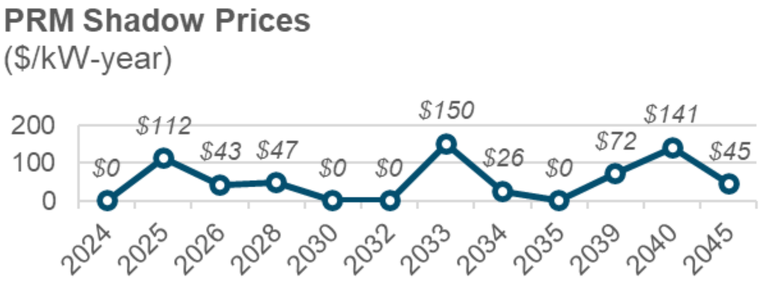
The removal of most resource potential from diverse renewable resources shifts the resource adequacy portfolio further towards solar and batteries.







In the 2020s, PRM costs are higher than the least-cost case, reflecting the shift toward solar and batteries from a more diverse portfolio.

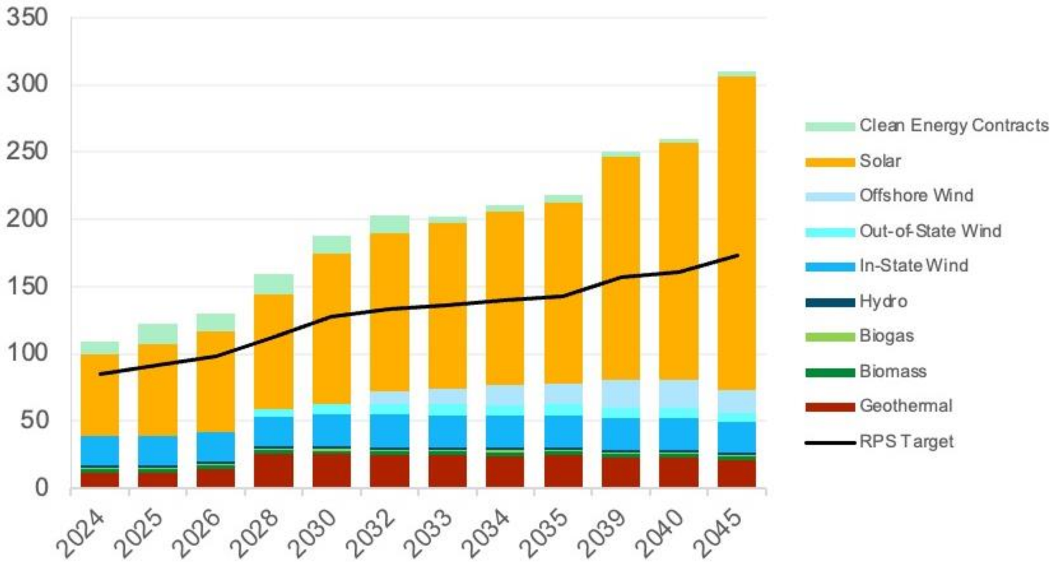


From 2030 onward, The acute need for GHG-free resources results in lower PRM costs because resources are installed primarily for GHG reductions.

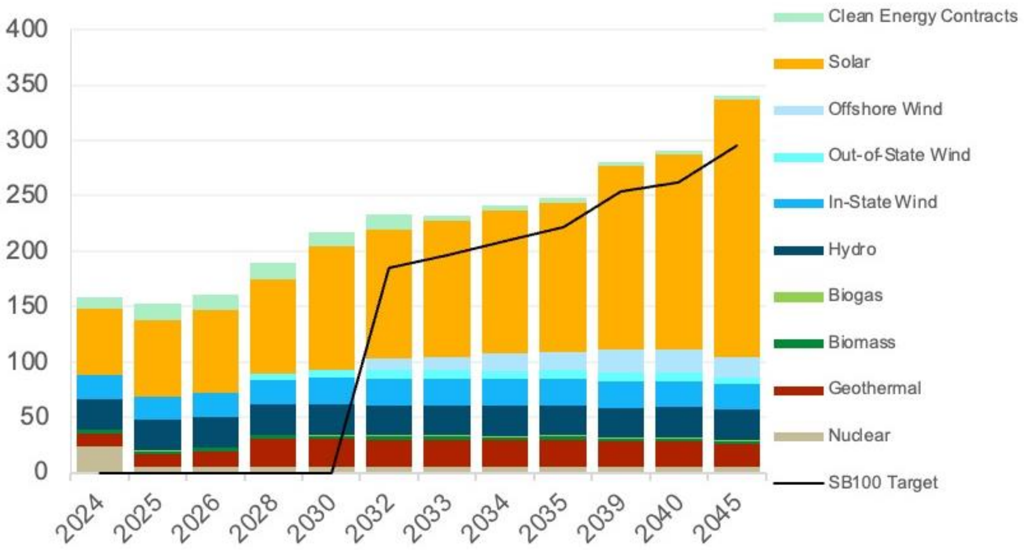
RPS & SB 100

Clean energy requirements (RPS/CES) are *not* drivers of resource selection.
LSE plans (core cases only), GHG targets, and reliability requirements (MTR + PRM) are main drivers of resource selection.

RPS-Eligible Generation
(TWh)



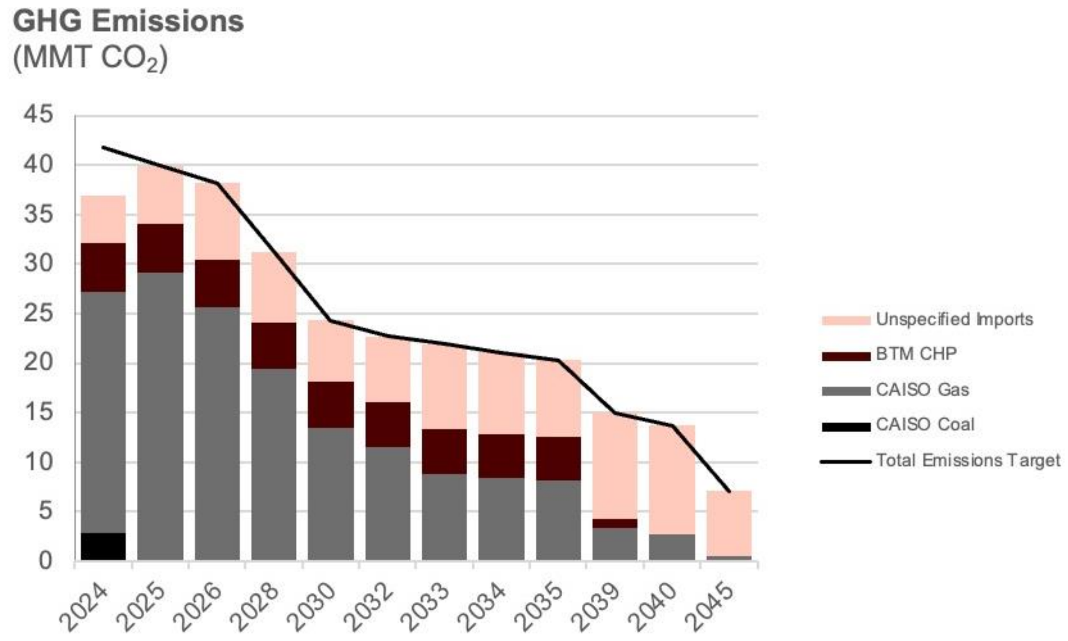
SB 100-Eligible Generation
(TWh)



RPS Shadow Prices
($/MWh)

SB 100 Shadow Prices
($/MWh)

In-state & Unspecified Import Emissions (MMT)



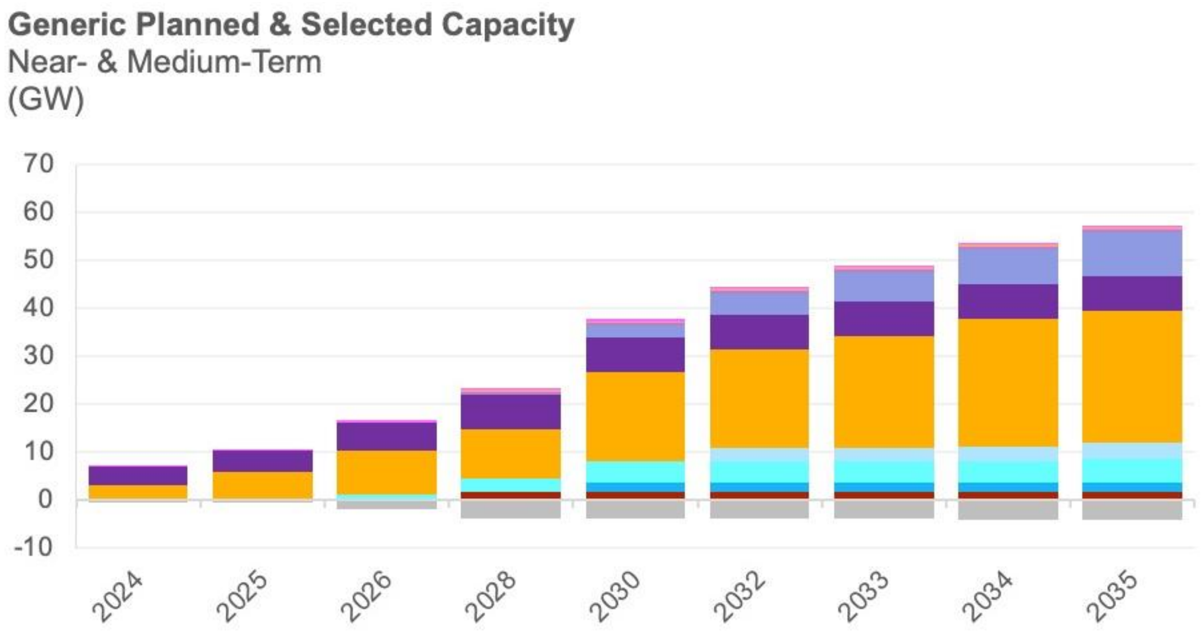
Compared to the least-cost case, the marginal cost of meeting the GHG target from 2030 onward is extremely high due to the lack of diverse zero-GHG resource potential.
Before 2030, economics and other constraints, especially the MTR constraints, drive portfolio selection.

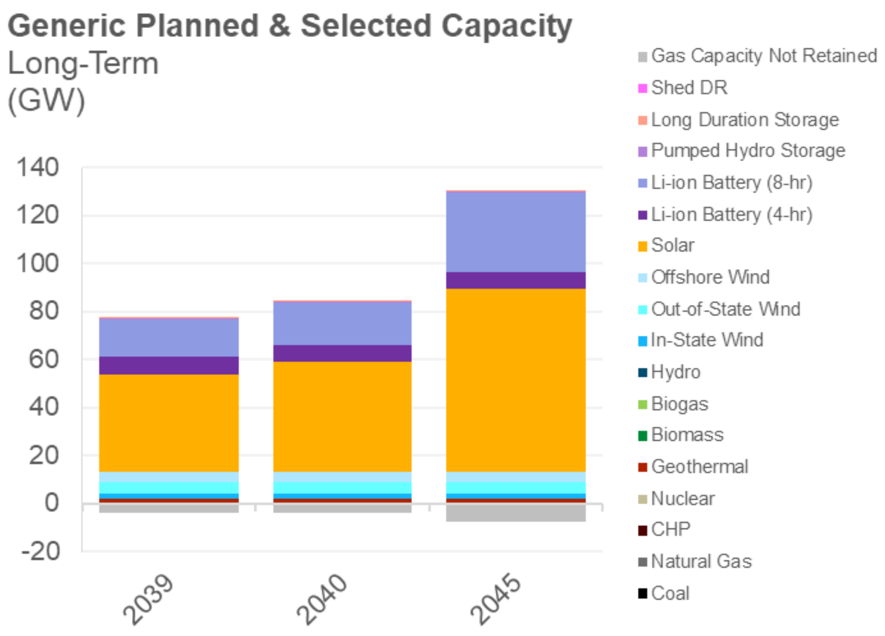
25 MMT Sensitivity: Long Lead-Time Resources

Low Offshore Wind Costs & Reduced Land-Based Clean Resource Availability Sensitivity Case

Sensitivity: Low Offshore Wind Costs & Reduced Land-Based Clean Resource Availability

Planned & Selected Capacity



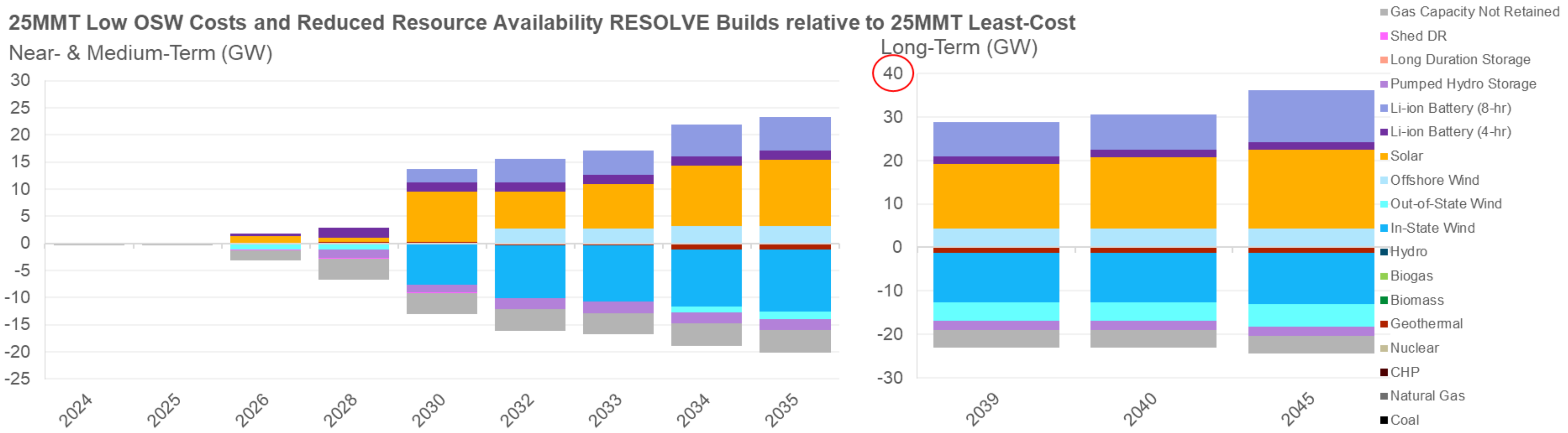


Sensitivity: Low Offshore Wind Costs & Reduced Land-Based Clean Resource Availability

Planned & Selected Capacity, Compared to Least-Cost (GW)

2.8 Offshore wind selected in 2032, growing to 4.4 GW by 2039.

Additional gas is not retained in this sensitivity because the need to reduce GHG emissions, combined with a relative lack of diverse zero-GHG resources, results in the installation of much additional solar and storage capacity. This capacity provides resource adequacy, enabling the model to save costs by not retaining all of gas capacity



In-state wind, **out-of-state wind**, **geothermal**, and **pumped storage** all have lower resource potentials in this sensitivity and thus lower amounts are selected.

Sensitivity: Low Offshore Wind Costs & Reduced Land-Based Clean Resource Availability

Planned & Selected Capacity (GW)

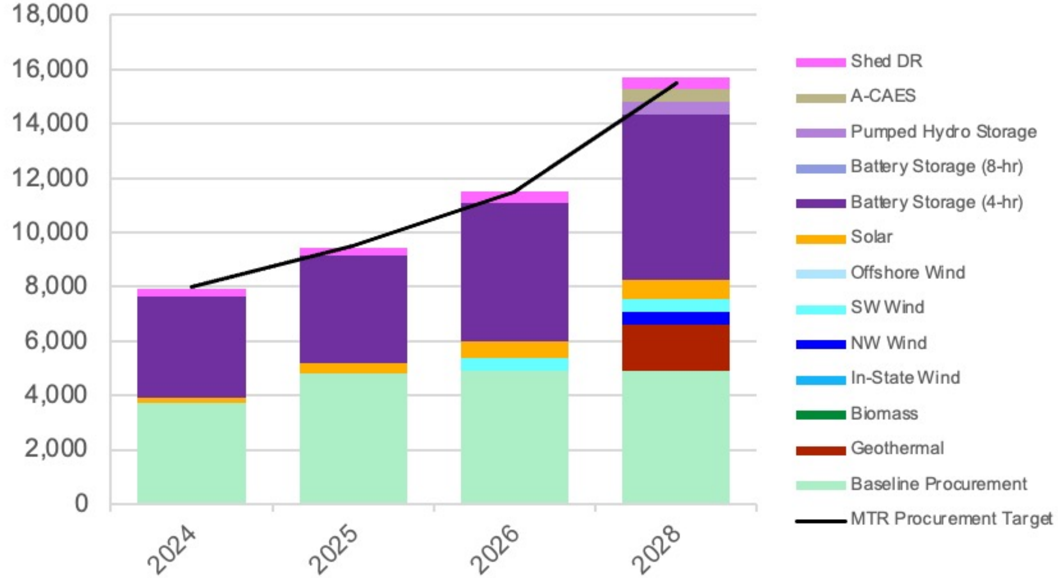
Resource Category	2024	2025	2026	2028	2030	2032	2033	2034	2035	2039	2040	2045
Geothermal	-	-	-	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Biomass	-	-	-	-	-	-	-	-	-	-	-	-
In-State Wind	-	-	-	-	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Out-of-State Wind	-	-	1.3	2.8	4.3	4.3	4.3	4.3	5.0	5.0	5.0	5.0
Offshore Wind	-	-	-	-	-	2.8	2.8	3.2	3.2	4.4	4.4	4.4
Solar	3.0	6.0	9.0	10.2	18.6	20.7	23.4	26.4	27.5	40.7	45.7	76.1
Li-ion Battery (4-hr)	4.1	4.4	5.9	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2
Li-ion Battery (8-hr)	-	-	-	-	2.4	4.4	6.1	7.4	9.3	15.7	17.6	32.8
Pumped Hydro Storage	-	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Long Duration Storage	-	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Shed DR	0.3	0.3	0.5	0.5	0.5	0.5	0.5	0.2	0.2	-	-	-
Gas Capacity Not Retained	*(0.4)*	*(0.4)*	*(1.8)*	*(3.9)*	*(3.9)*	*(3.9)*	*(3.9)*	*(4.2)*	*(4.2)*	*(4.2)*	*(4.2)*	*(7.6)*
Total	**7.0**	**10.3**	**14.9**	**19.6**	**34.0**	**40.7**	**45.2**	**49.3**	**53.0**	**73.6**	**80.5**	**122.6**

Sensitivity: Low Offshore Wind Costs & Reduced Land-Based Clean Resource Availability

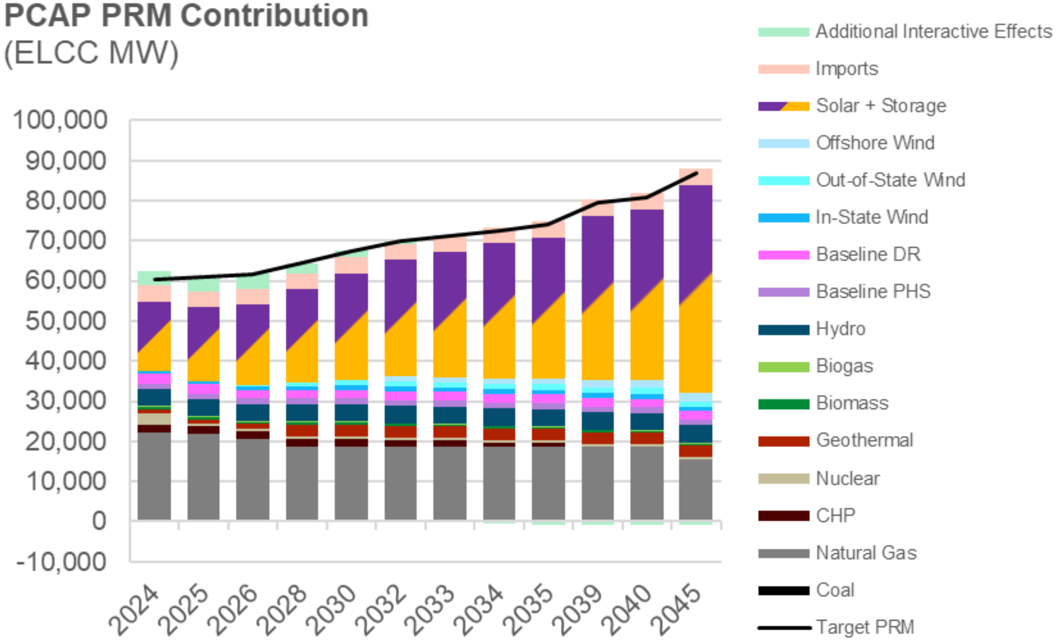
PRM Results

The removal of most resource potential from diverse renewable resources shifts the resource adequacy portfolio further towards solar and batteries.

MTR Contribution by Resource Type
(ELCC MW)



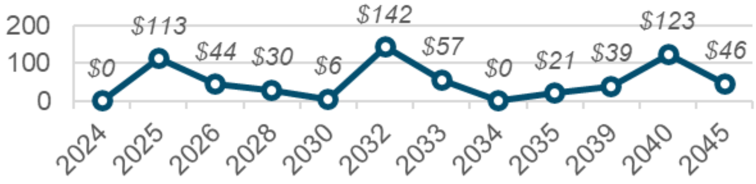
PCAP PRM Contribution
(ELCC MW)



MTR Shadow Prices
($/kW-year)

In the 2020s, PRM costs are higher than the least-cost case, reflecting the shift toward solar and batteries from a more diverse portfolio.

PRM Shadow Prices
($/kW-year)

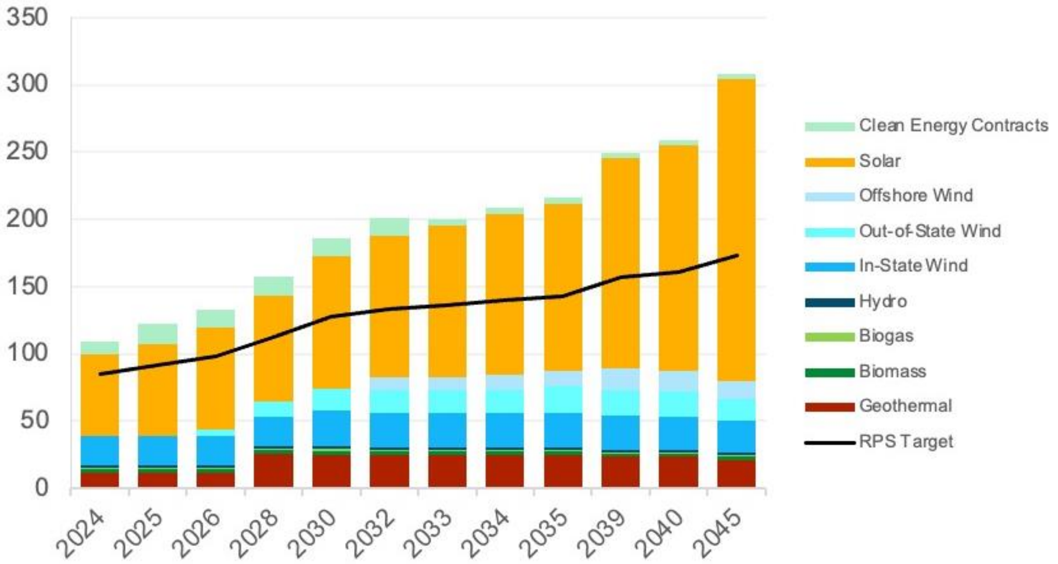


From 2030 onward, The acute need for GHG-free resources results in lower PRM costs because resources are installed primarily for GHG reductions.

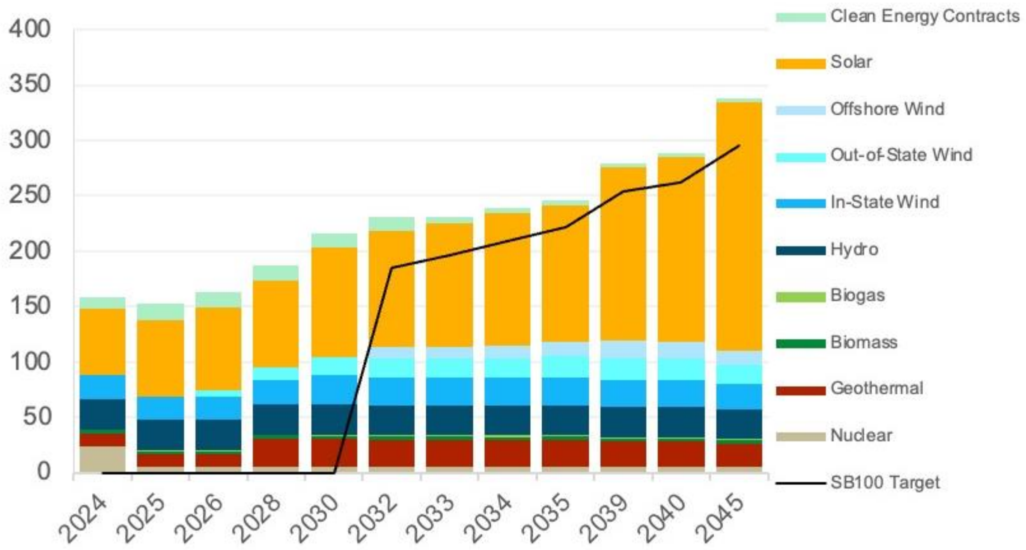
RPS & SB 100

Clean energy requirements (RPS/CES) are *not* drivers of resource selection.
LSE plans (core cases only), GHG targets, and reliability requirements (MTR + PRM) are main drivers of resource selection.

RPS-Eligible Generation
(TWh)



SB 100-Eligible Generation
(TWh)

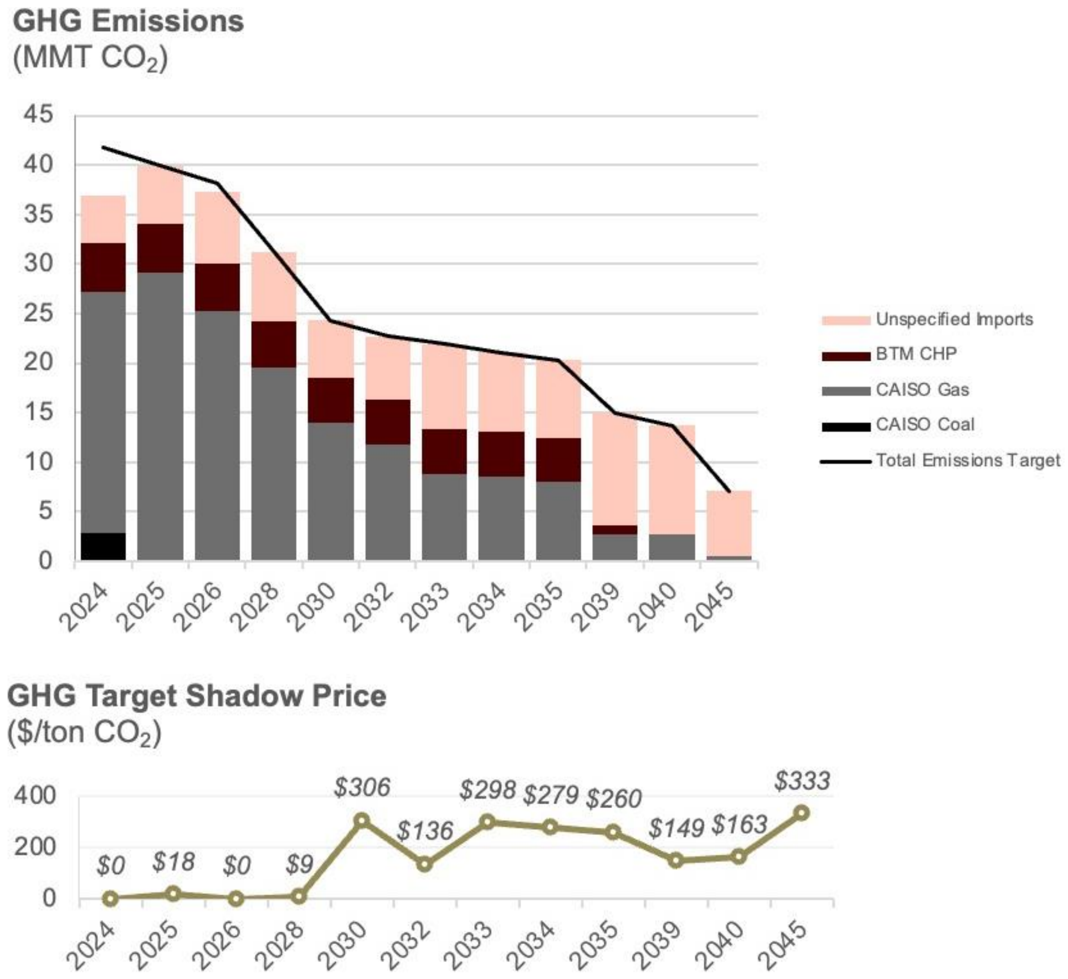


RPS Shadow Prices
($/MWh)

SB 100 Shadow Prices
($/MWh)

Sensitivity: Low Offshore Wind Costs & Reduced Land-Based Clean Resource Availability

In-state & Unspecified Import Emissions (MMT)



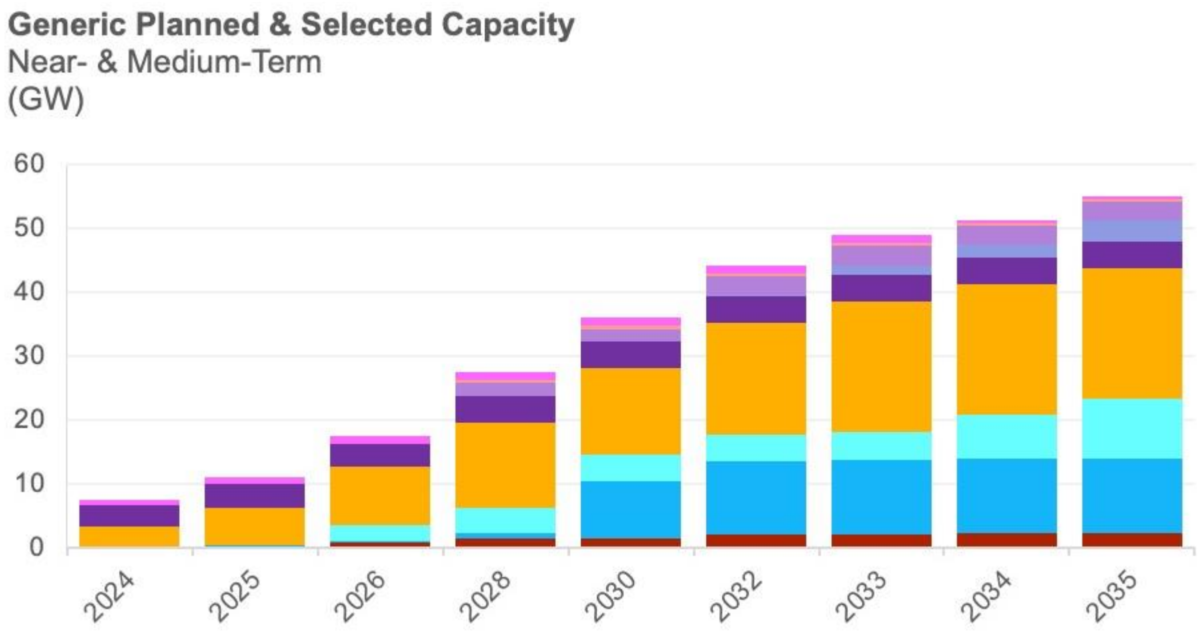
Compared to the least-cost case, the marginal cost of meeting the GHG target from 2030 onward is extremely high due to the lack of diverse zero-GHG resource potential.
Before 2030, economics and other constraints, especially the MTR constraints, drive portfolio selection.

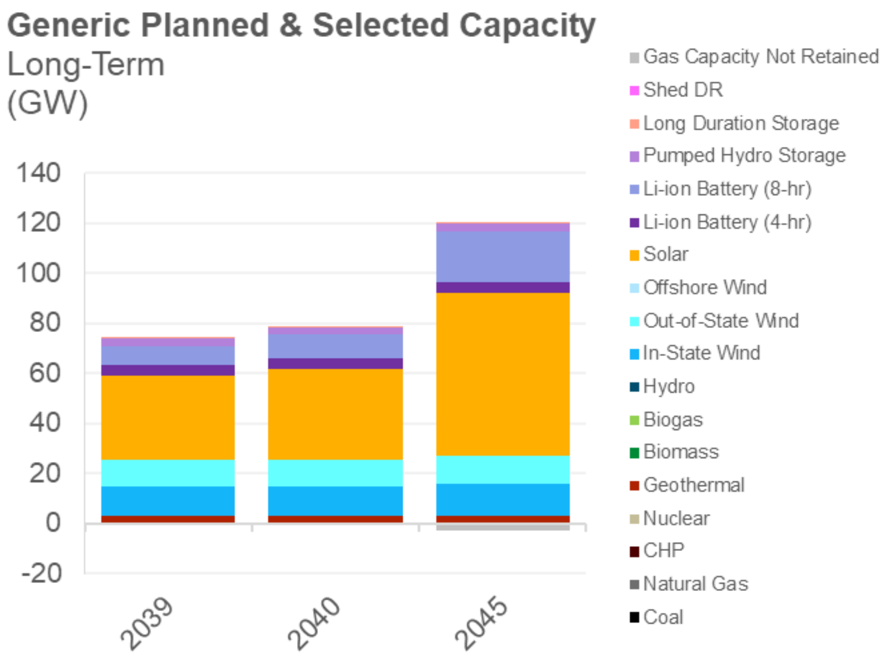
25 MMT Least-Cost Sensitivity

Low BTM PV Sensitivity Case

Sensitivity: Low BTM PV

Planned & Selected Capacity

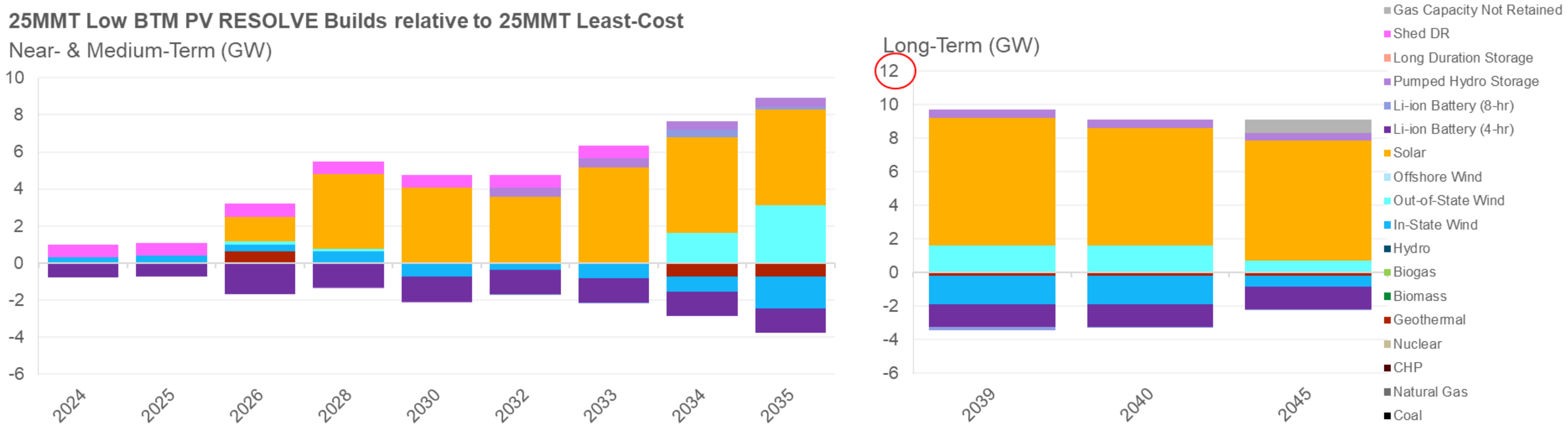




Sensitivity: Low BTM PV

Planned & Selected Capacity, Compared to Least-Cost (GW)

BTM PV is primarily replaced by utility scale solar. **Note:** reduction in BTM PV capacity not shown on the charts below.



Sensitivity: Low BTM PV

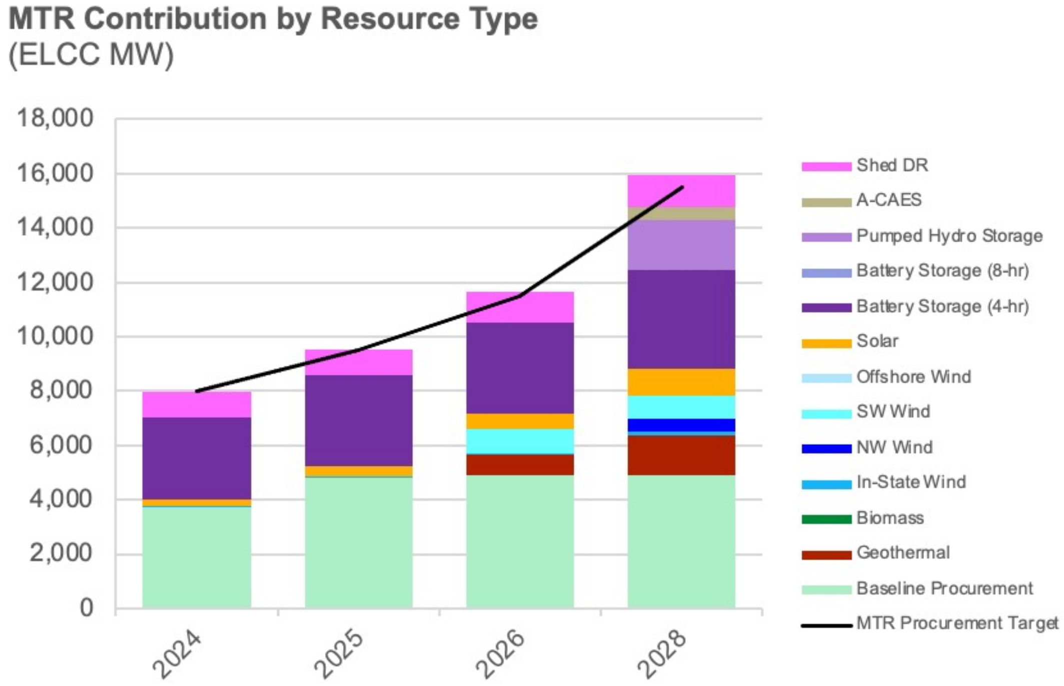
Planned & Selected Capacity (GW)

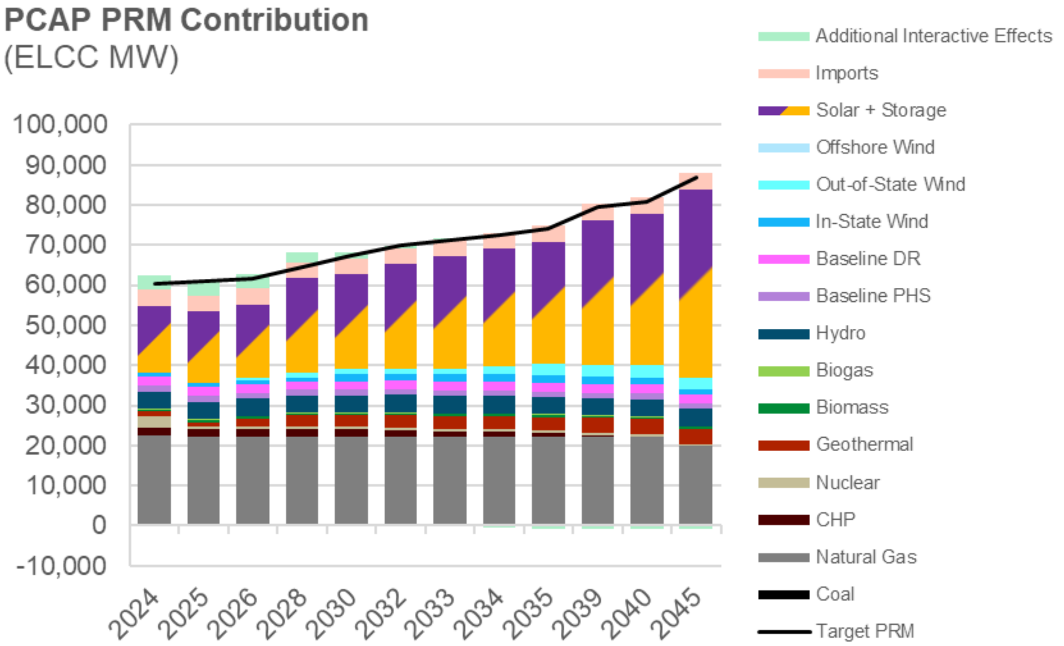
Resource Category	2024	2025	2026	2028	2030	2032	2033	2034	2035	2039	2040	2045
Geothermal	-	-	0.8	1.6	1.6	2.1	2.1	2.2	2.2	2.8	2.8	2.8
Biomass	-	-	-	-	-	-	-	-	-	-	-	-
In-State Wind	0.3	0.4	0.4	0.7	8.8	11.4	11.7	11.7	11.7	11.7	11.7	13.2
Out-of-State Wind	-	-	2.5	4.0	4.3	4.3	4.3	7.0	9.5	10.9	10.9	10.9
Offshore Wind	-	-	-	-	-	-	-	-	-	-	-	-
Solar	3.0	6.0	9.0	13.4	13.4	17.5	20.5	20.5	20.5	33.5	36.3	65.2
Li-ion Battery (4-hr)	3.3	3.7	3.7	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
Li-ion Battery (8-hr)	-	-	-	-	-	0.1	1.5	2.0	3.2	7.6	9.6	20.7
Pumped Hydro Storage	-	-	-	2.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Long Duration Storage	-	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Shed DR	1.0	1.0	1.2	1.2	1.2	1.2	1.2	0.3	0.3	-	-	-
Gas Capacity Not Retained	-	-	-	-	-	-	-	-	-	-	-	*(2.8)*
Total	**7.6**	**11.1**	**17.6**	**27.6**	**36.0**	**44.3**	**49.0**	**51.3**	**55.0**	**74.2**	**78.9**	**117.6**

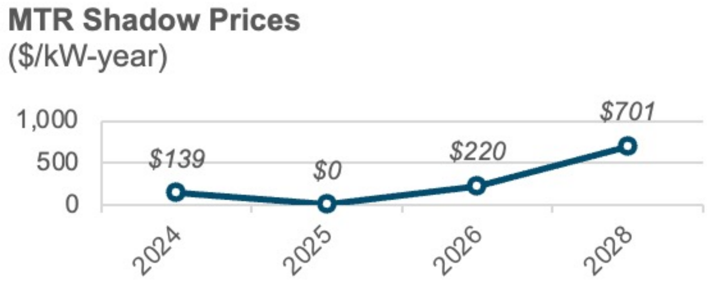
Sensitivity: Low BTM PV

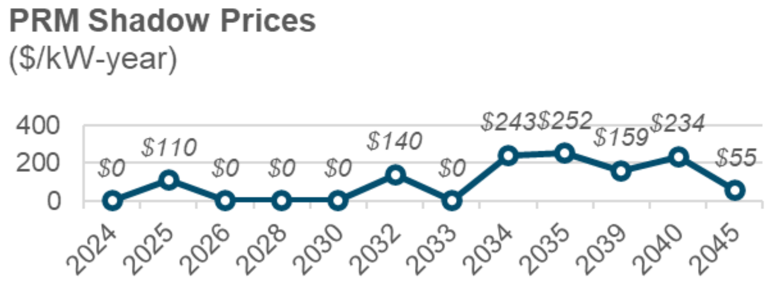
PRM Results

PRM results are broadly similar to the Least Cost case









Sensitivity: Low BTM PV

RPS & SB 100

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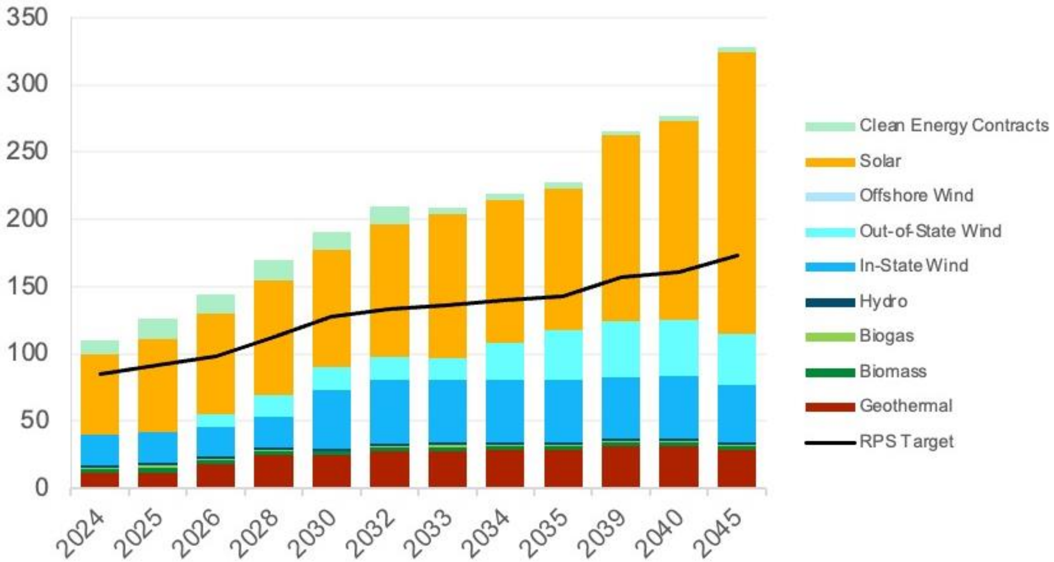
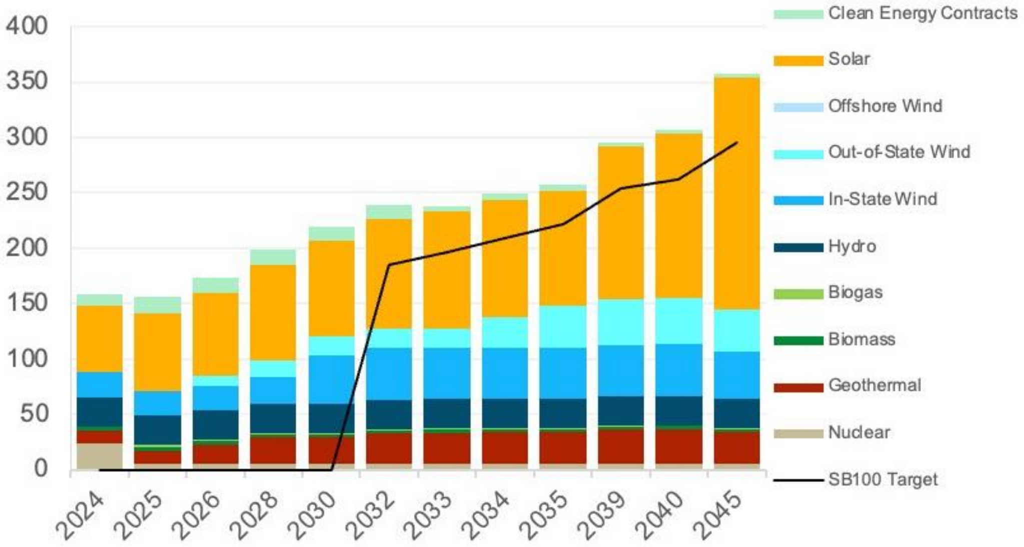
RPS-Eligible Generation
(TWh)



SB 100-Eligible Generation
(TWh)

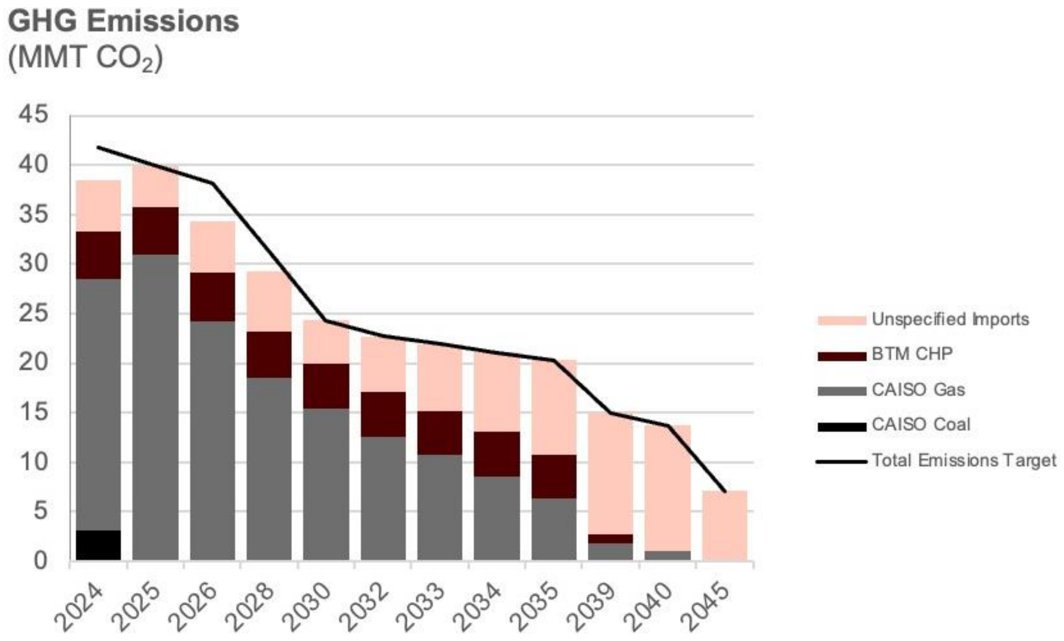


RPS Shadow Prices
($/MWh)

SB 100 Shadow Prices
($/MWh)

Sensitivity: Low BTM PV

In-state & Unspecified Import Emissions (MMT)



The relatively high marginal cost of meeting the GHG target in 2025 reflects the difficulty of replacing Diablo Canyon with reduced energy from BTM PV, since the near-term solar build rate is already at its limit in the least-cost case.