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SB100 Draft Results

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Agenda

- Scope of SB 100 analytical work for the 2021 Joint Agency Report
- Changes since the Inputs and Assumptions Workshop
- Scenario Framework
- Draft Results

Resource Planning Modeling and Analytics

Inputs

May include, but not limited to:

Existing System

Demand Forecasts or Scenarios

Resource Costs

Reliability Metrics

Policy Goals

Resource Potential

Land Use Screens

Portfolio Development

Capacity Expansion Modeling

Current SB 100 Report

Portfolio Reliability

Operability/ Full Dispatch:
Production Cost Modeling

Resource Adequacy:
Probabilistic Production Cost Modeling

Local Reliability:
Power Flow Modeling

Portfolio Impacts

May include, but not limited to:

Rate Impacts | Workforce Impacts | Land Use Impacts

Air Pollutants/ Air Quality Impacts

SB 100 Modeling Results are Directional

All portfolios presented today are directional in nature and do not represent a "State Plan" to reach SB 100.

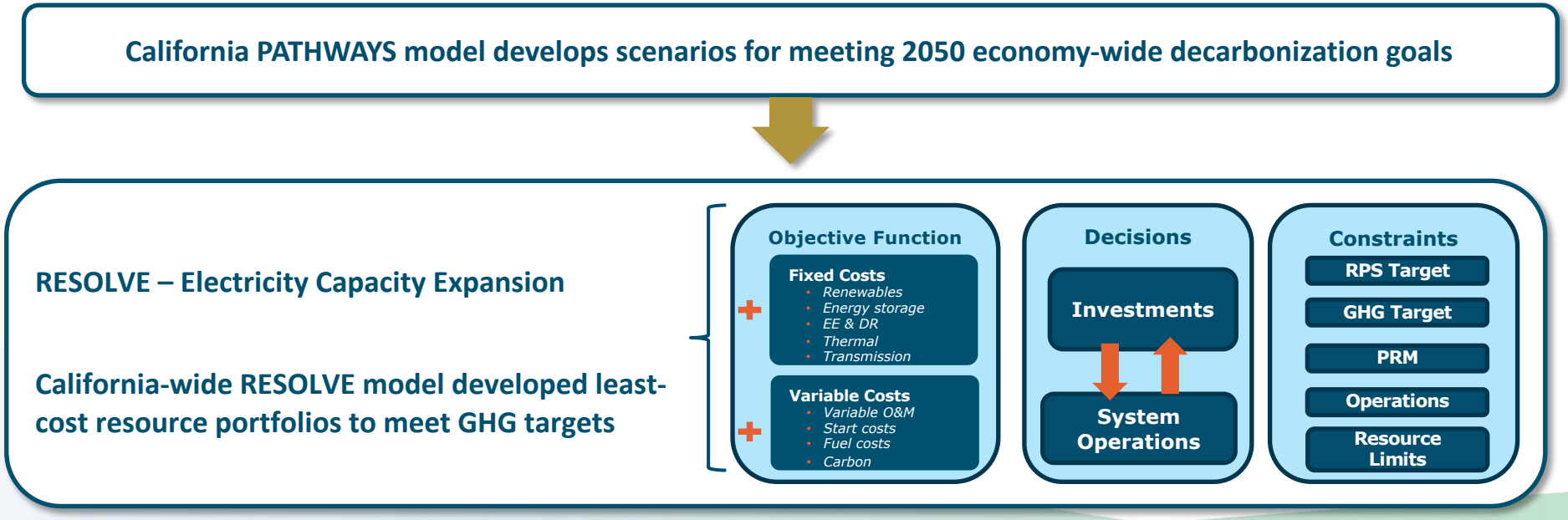
- The SB 100 report will provide insight to State Agencies for further analytical work and implementation considerations to achieve SB 100 and other relevant state policies.
- The SB 100 modeling does not include all zero-carbon resources that could be zero-carbon eligible under SB 100. Future analyses may include additional resources.

Core Scenarios reflect the Joint Agency interpretation of SB 100.

Study Scenarios are outside the Joint Agency interpretation of SB 100 and provide information to further support California energy planning.

California RESOLVE Model

- All modeling was conducted by E3.
- California RESOLVE model:
  - Co-optimizes NPV of investment and operational costs
  - Adapted from 2019 CPUC IRP model to include all of CA



Changes to Modeling Since I&A Workshop

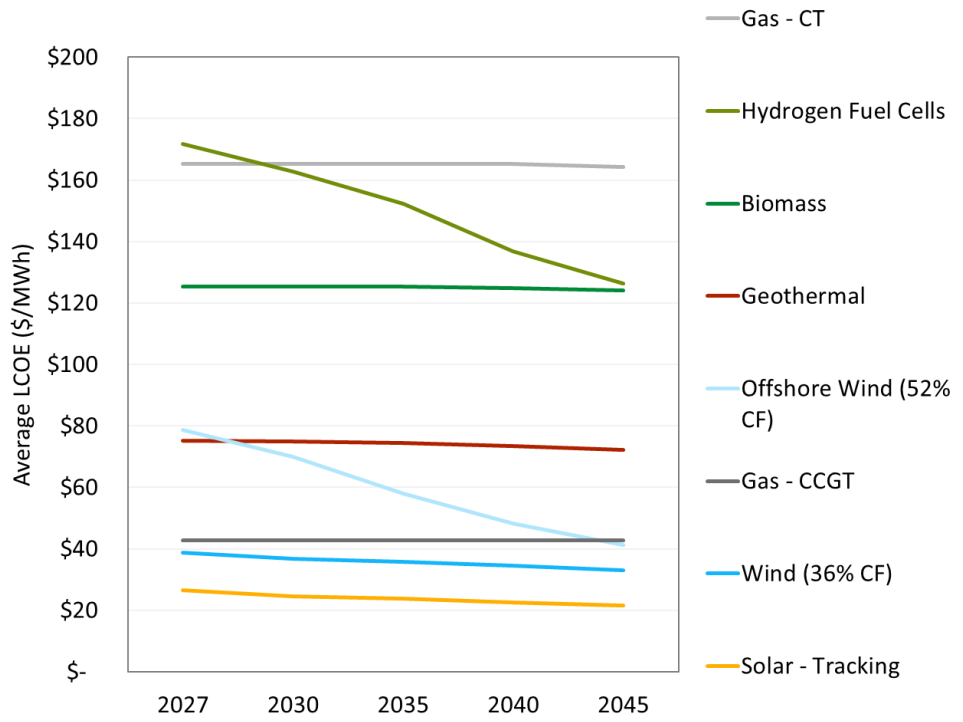
- Candidate Resources
  - Made “all resources” the default for candidate resources
  - Increased out-of-state wind potential to 12 GW
  - Increased offshore wind potential to 10 GW
  - Removed Natural Gas w/ CCS due to insufficient cost data
- Added additional study scenarios

Core Assumptions: Resources

Demand Side Resources (Fixed Input)	**Supply Side Resources (Selected by Model)**
Shed Demand Response • 2 GW Shed DR	Shed Demand Response
Customer Solar • 39 GW in 2045	Customer Solar
Energy Efficiency	Renewable Energy Resources Conventional Resources Incremental and new transmission

Core Assumptions: Resources

Implied LCOE of Average Technologies (2016$/MWh)

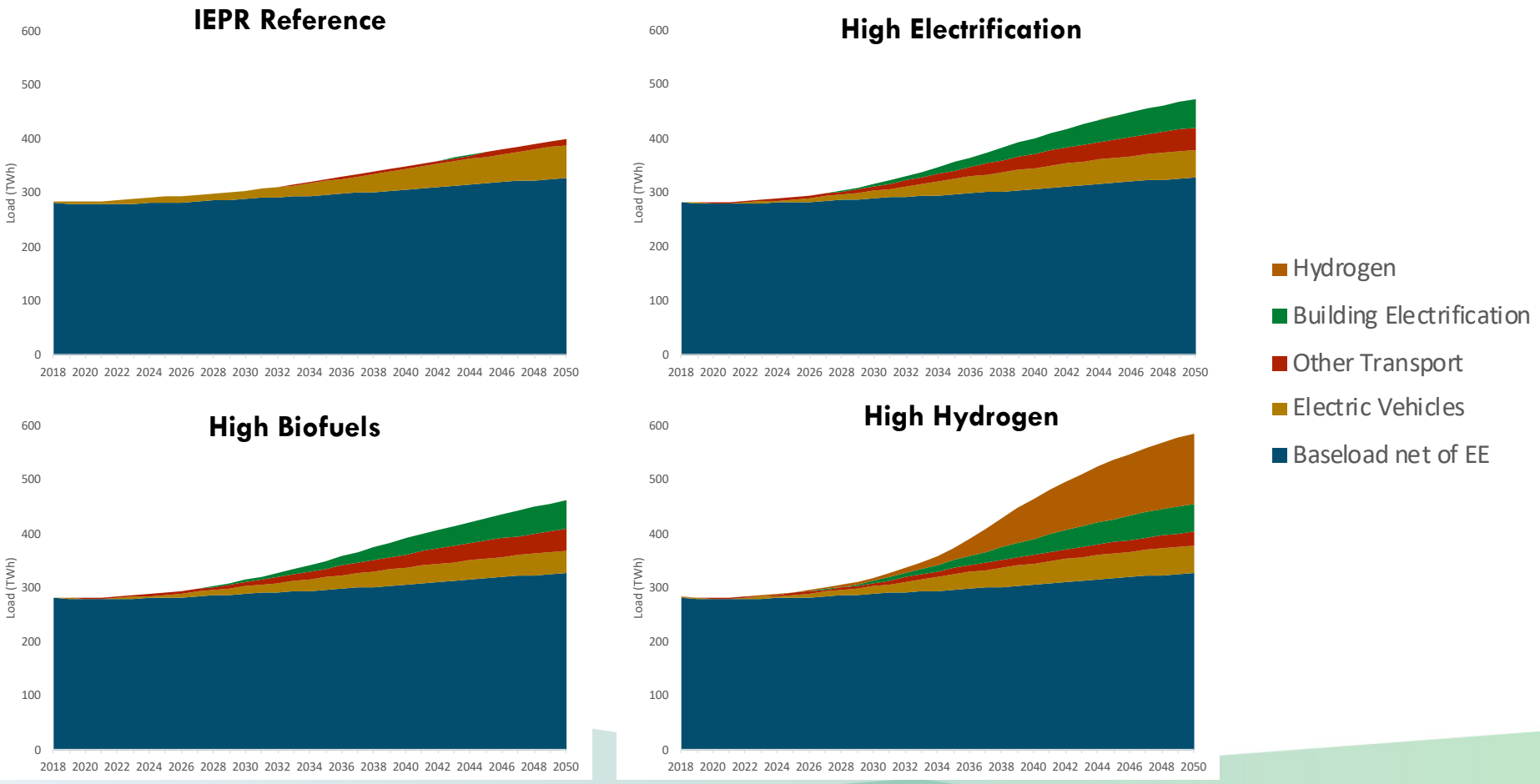


Most costs were derived from the NREL 2019 Annual Technology Baseline. Hydrogen fuel cell costs were derived from the Department of Energy.

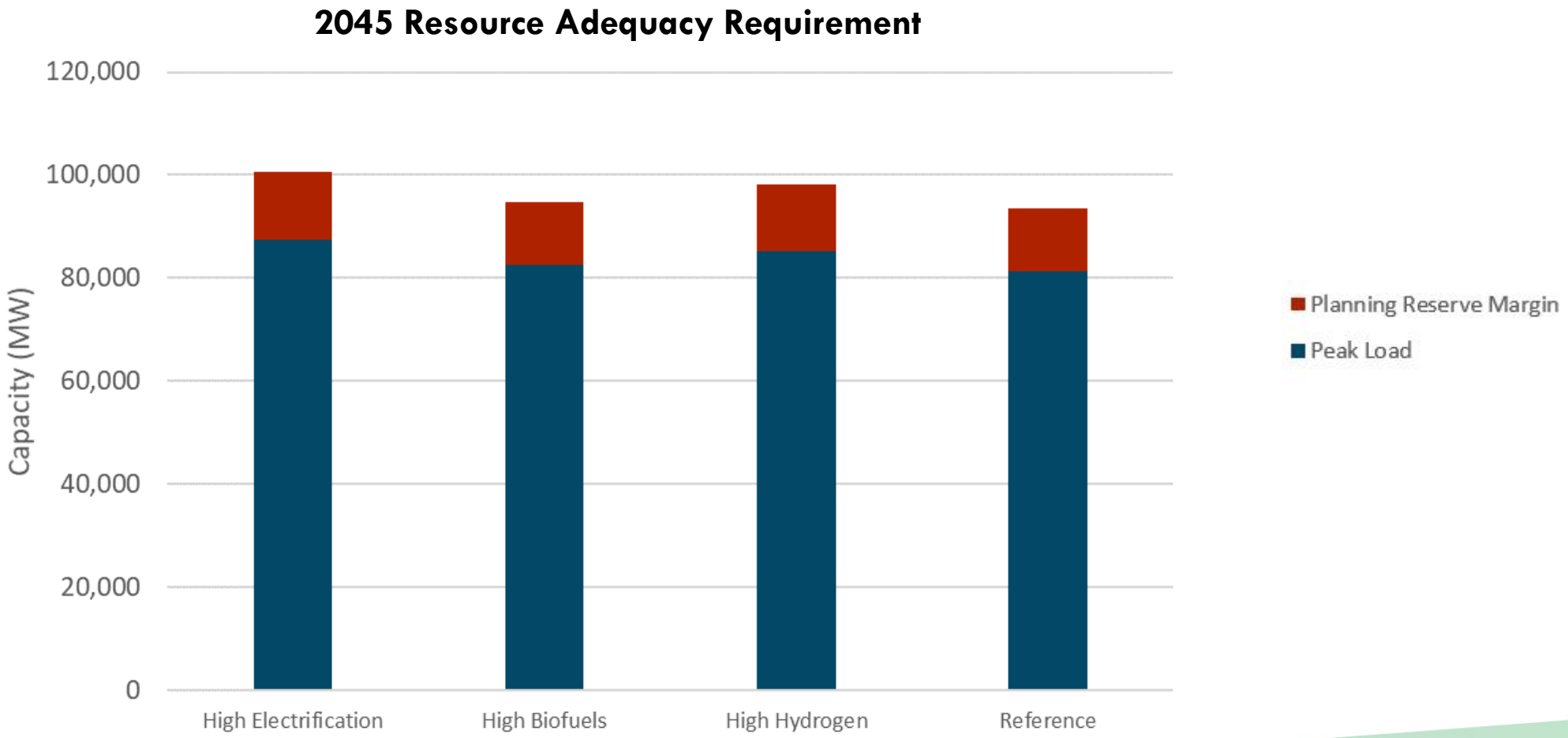
Core Assumptions: Demand Scenarios

PATHWAYS provides RESOLVE:

- Annual loads by category (GWh/yr)
- Some load shape information for load modifiers

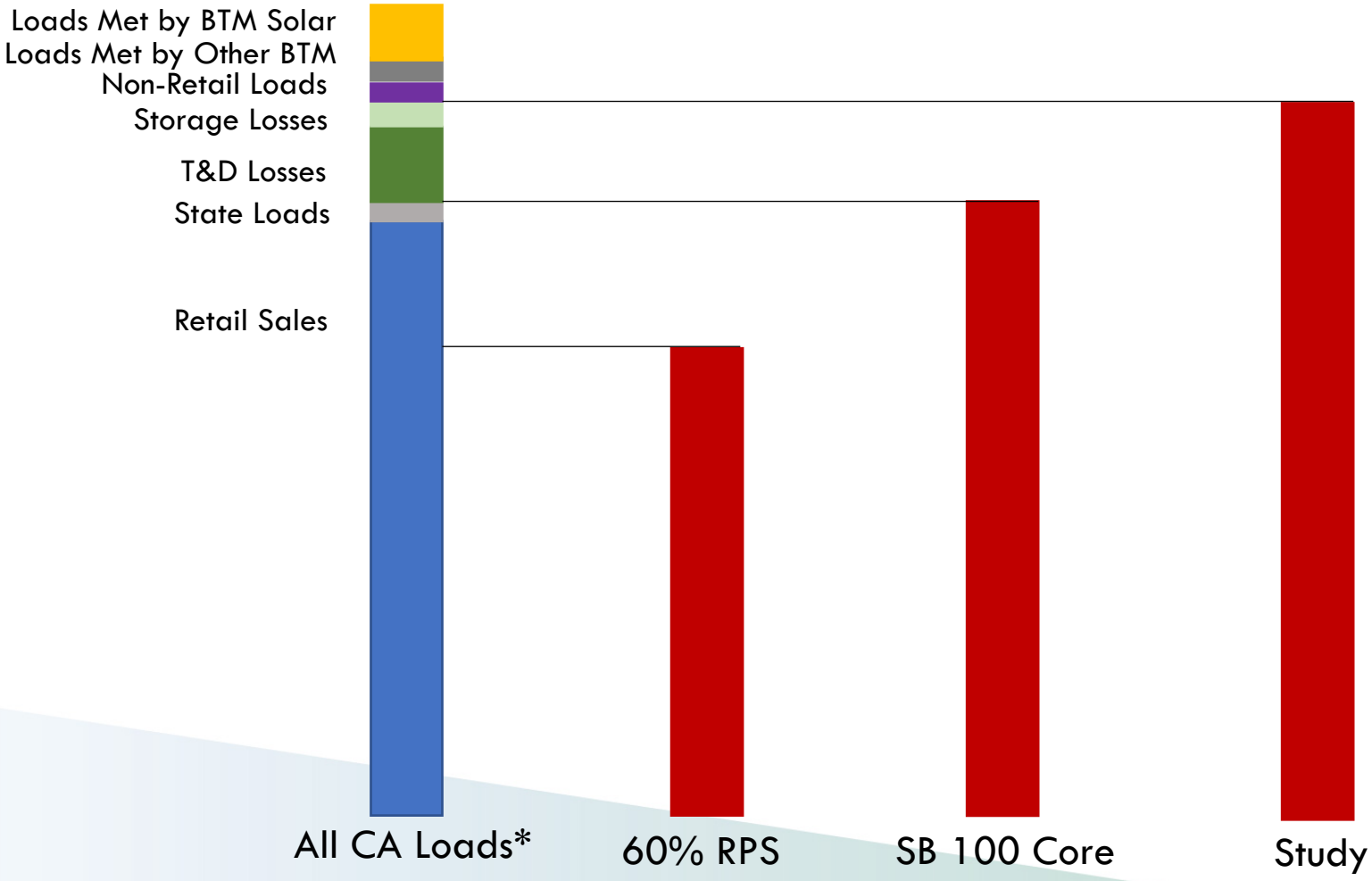


Core Assumptions: Demand Scenarios



For reference, the 2018 August CPUC committed System RA resources totaled 47 GW.

2045 Zero Carbon Load Coverage



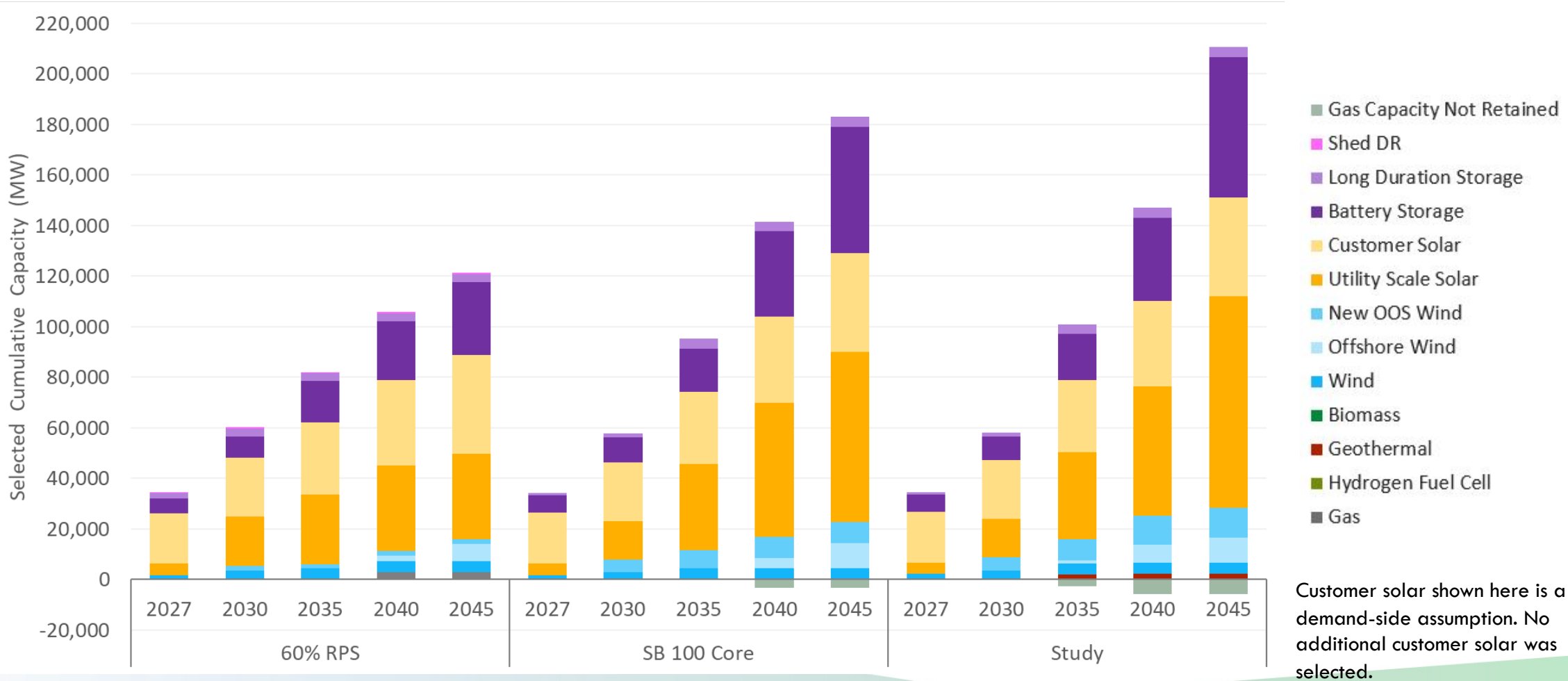
*Not to scale

Scenario List

Scenario Classifications	Scenario Descriptions
60% RPS (Counterfactual)	60% RPS through 2045
SB 100 Core Scenario	Core Load Coverage; High Electrification Demand; All candidate resources available
SB 100 Core, Demand Sensitivities	Change: Demand Scenarios
SB 100 Core, Resource Sensitivities	Change: Candidate Resource Availability
Study: Expanded Load Coverage	Core Load Coverage plus storage and T&D losses; High Electrification Demand; All candidate resources available
Study: Expanded Load Coverage, Demand Sensitivities	Change: Demand Scenarios
Study: Expanded Load Coverage, Resource Sensitivities	Change: Candidate Resource Availability
Study: Zero Carbon Firm Resources	Add generic zero carbon firm resources to candidate resources
Study: Accelerated Timelines	Accelerate 100% target to earlier years
Study: No Combustion	No combustion candidate resources; retire combustion resources

Results

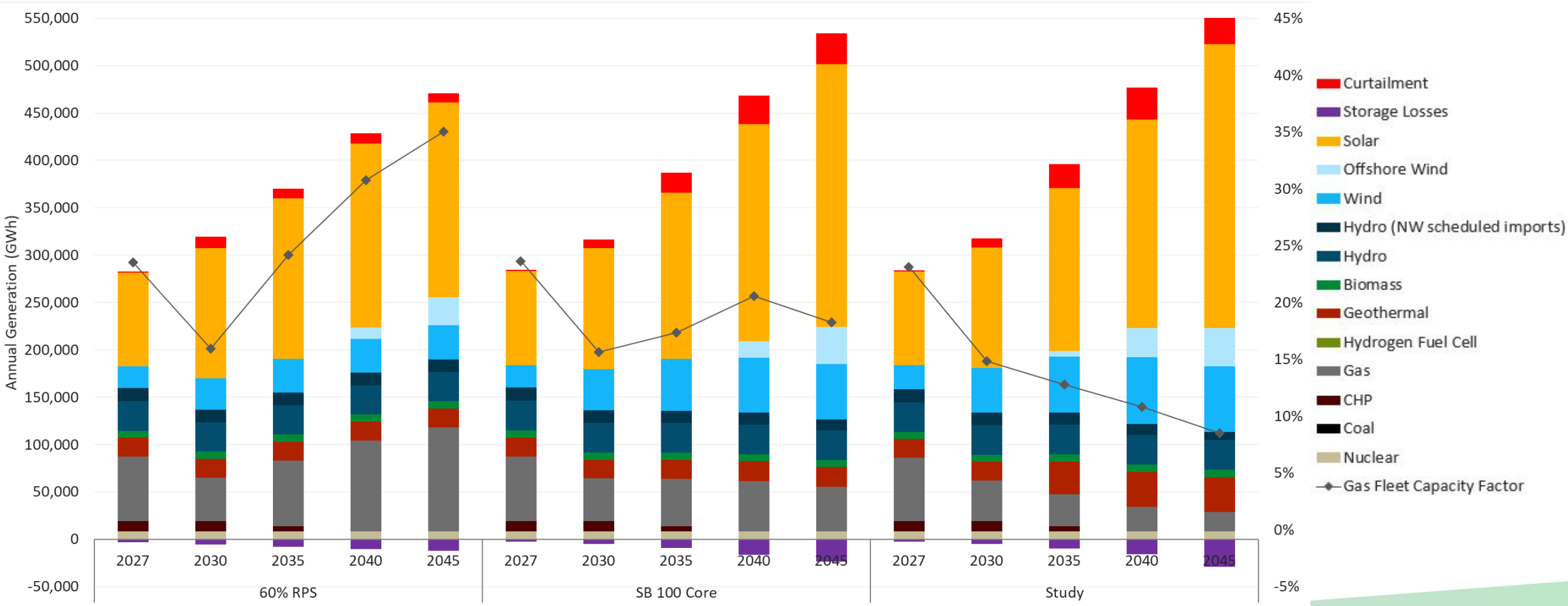
Results: Capacity Additions



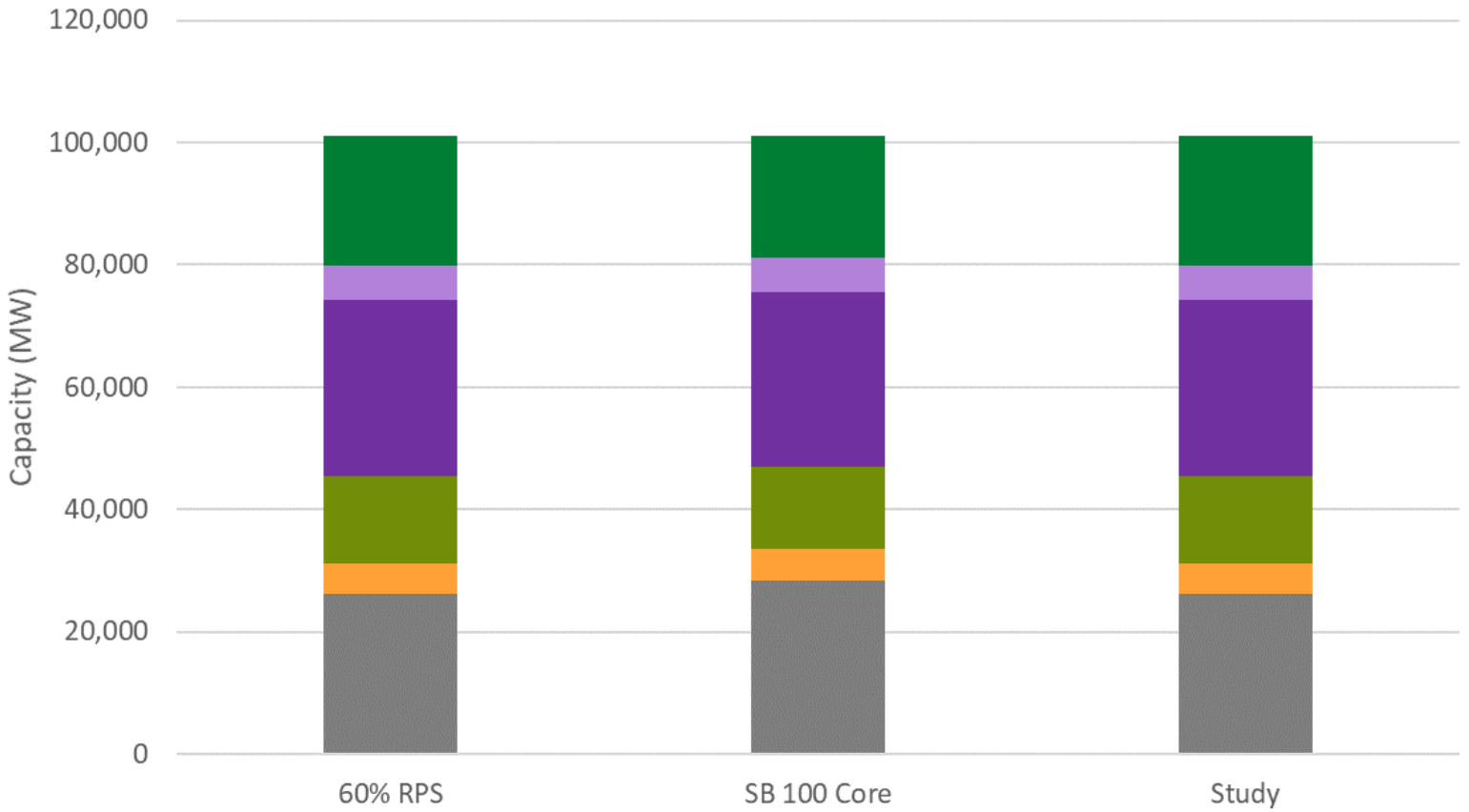
Customer solar shown here is a demand-side assumption. No additional customer solar was selected.

As of 2019, there is 80 GW of in-state capacity in California.

Results: Annual Generation



Results: System Resource Adequacy

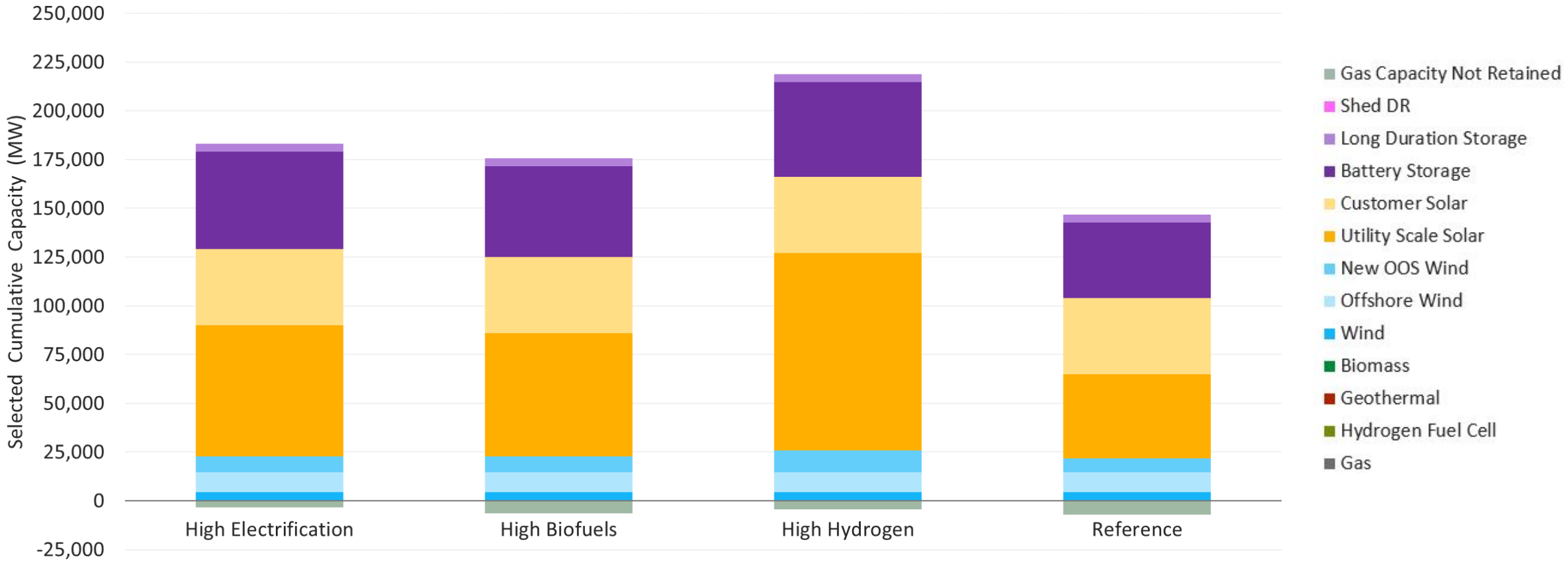


Solar Marginal ELCC: 2%
Wind Marginal ELCC: 19%

"Variable renewable" resources include wind and solar.
"Zero carbon firm" resources include hydro, nuclear, geothermal, hydrogen, biomass.

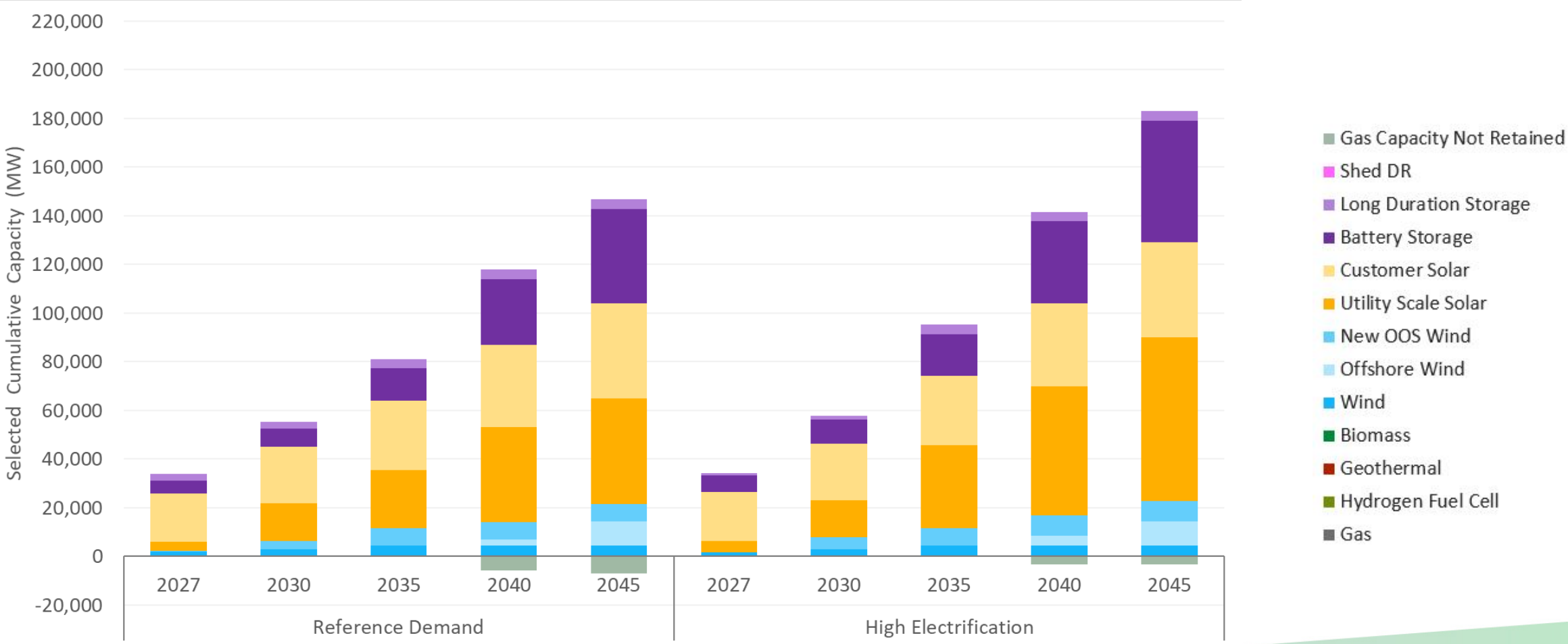
For reference, the 2018 August CPUC committed System RA resources totaled 47 GW.

Demand Sensitivities



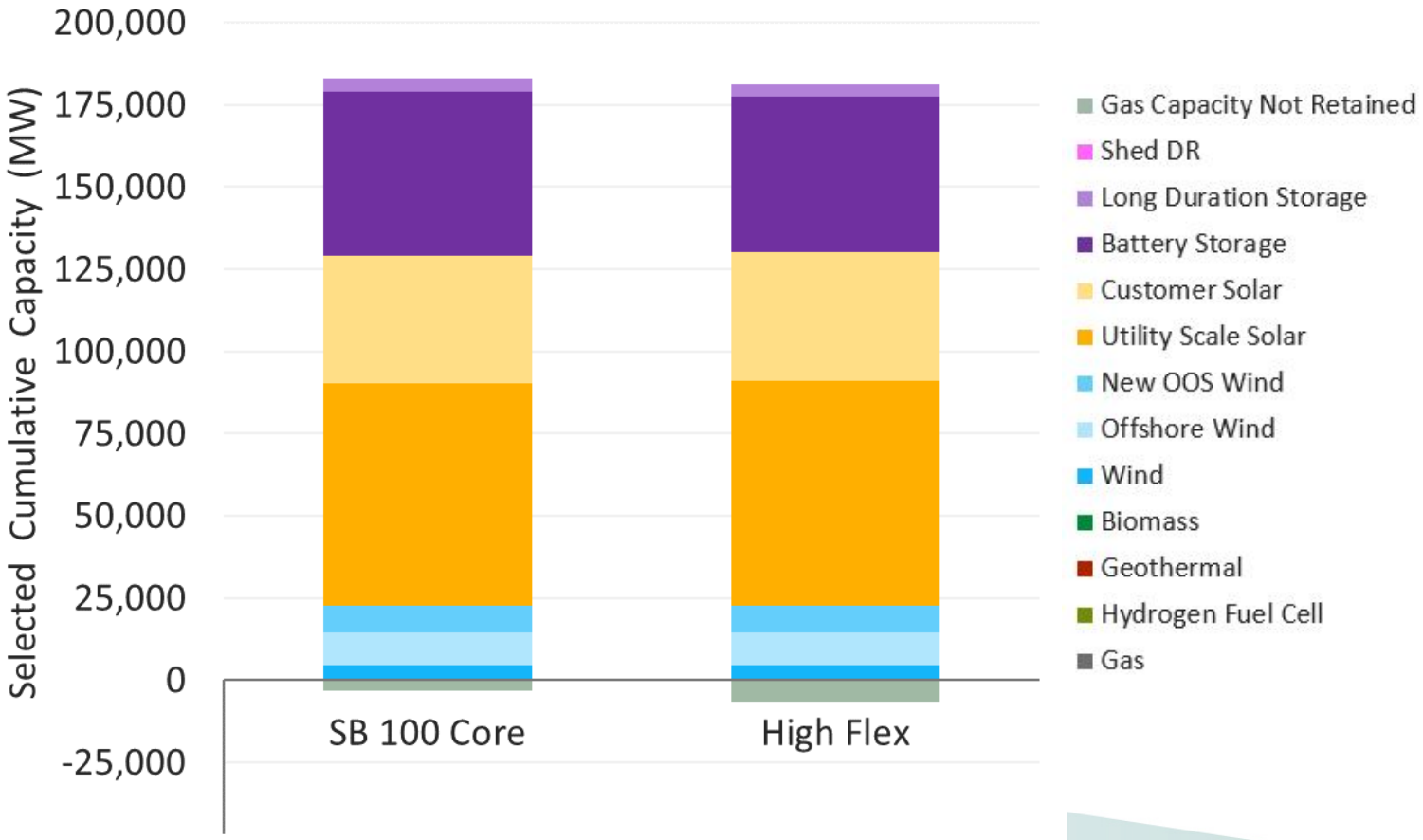
Load Coverage: Core; Resource Options: All; Year: 2045

Demand Sensitivities



Load Coverage: Core; Resource Options: All

High Flexibility Scenario



High Flexibility Scenario

Adjusted hourly load profile for:

- EV managed charging profile
- Building end-use flexibility

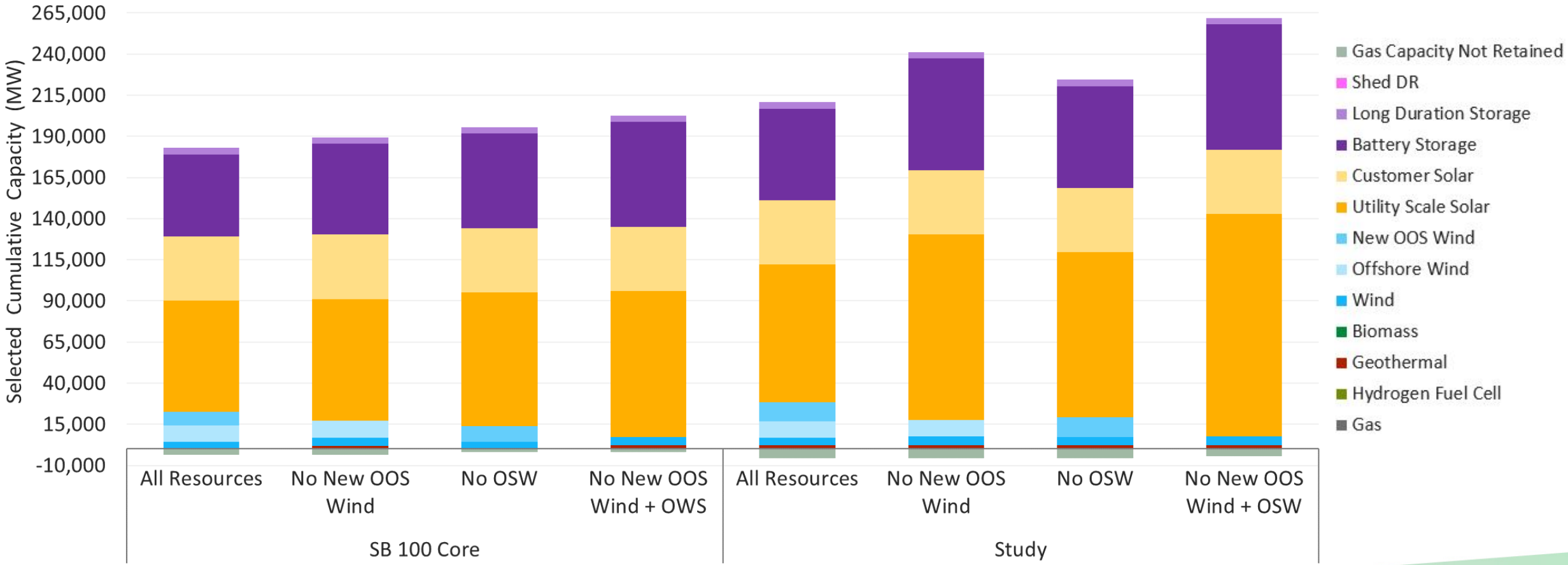
Resource Adequacy Reduction: 6 GW

Notable Change in Resource Build:

- 2.7 GW avoided battery storage
- 3.3 GW increase in economic gas retirements

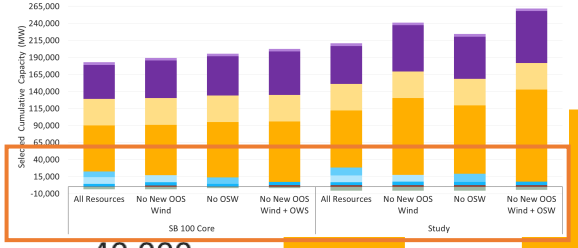
Load Coverage: Core; Demand: High Electrification; Resource Options: All; Year: 2045

Resource Sensitivities



Demand: High Electrification; Year: 2045

Resource Sensitivities

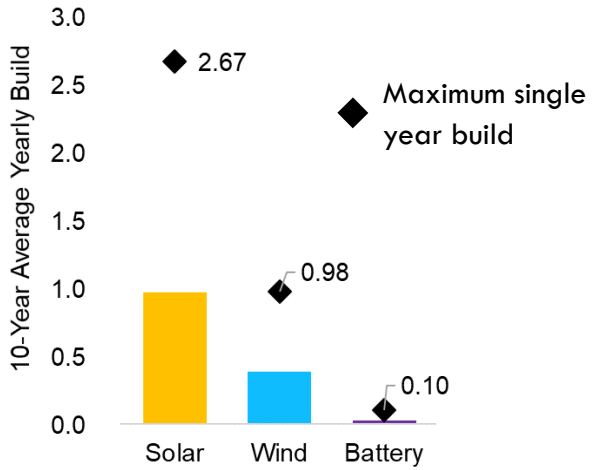


Demand: High Electrification; Year: 2045

Resource Build Rates

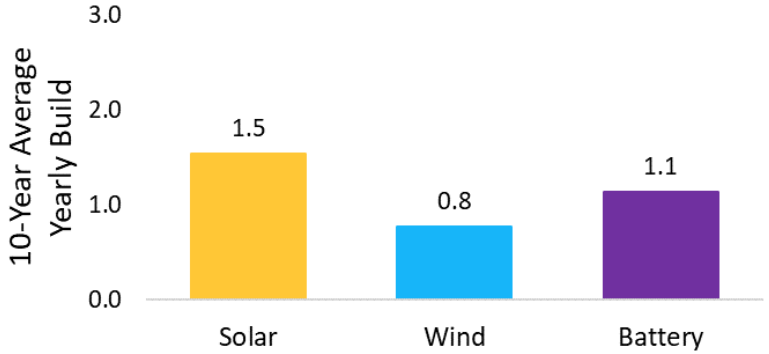
All build rates shown in "GW/year"

Average Build Rate to Date

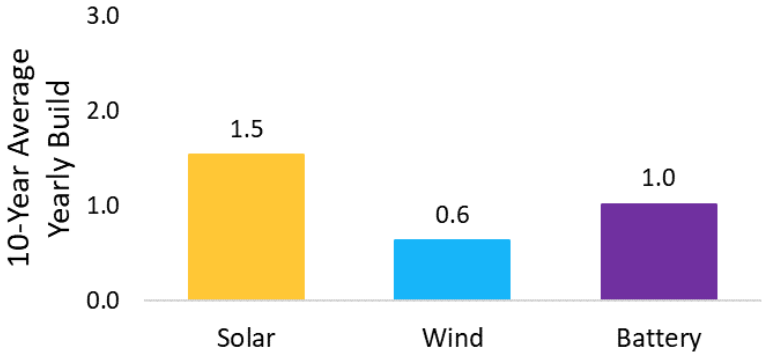


Average Build Rate to 2030

High Electrification Demand

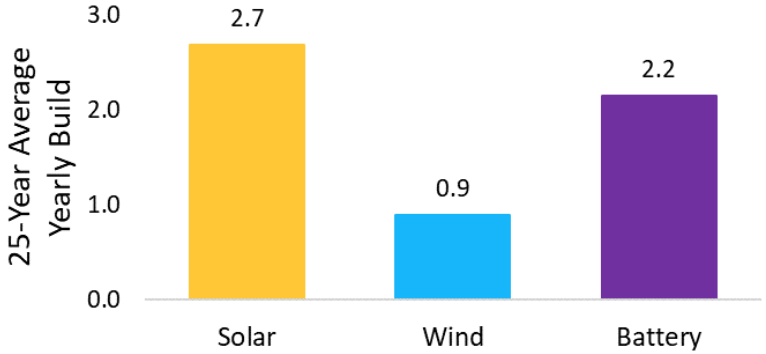


Reference Demand



Average Build Rate to 2045

High Electrification Demand



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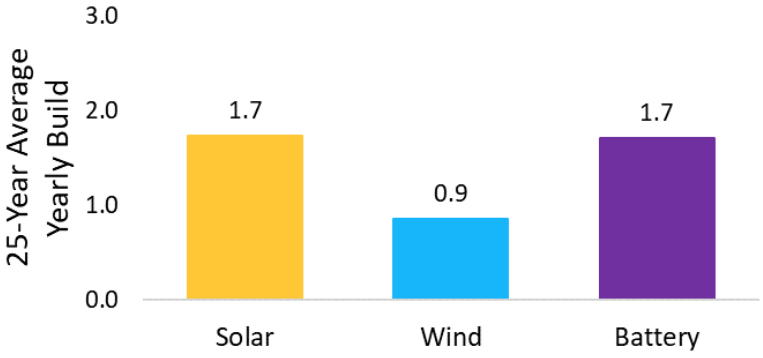
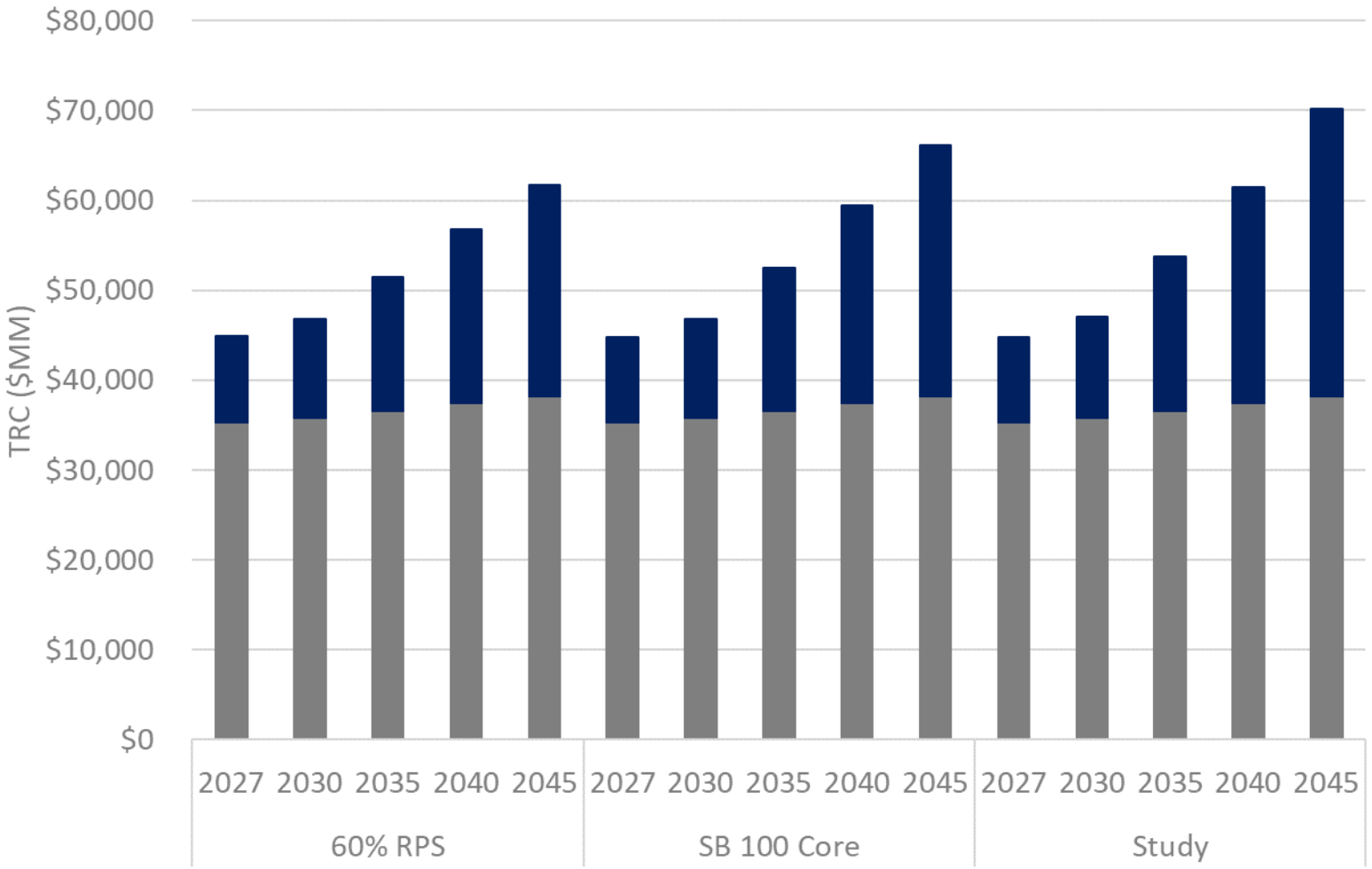


Total Resource Cost



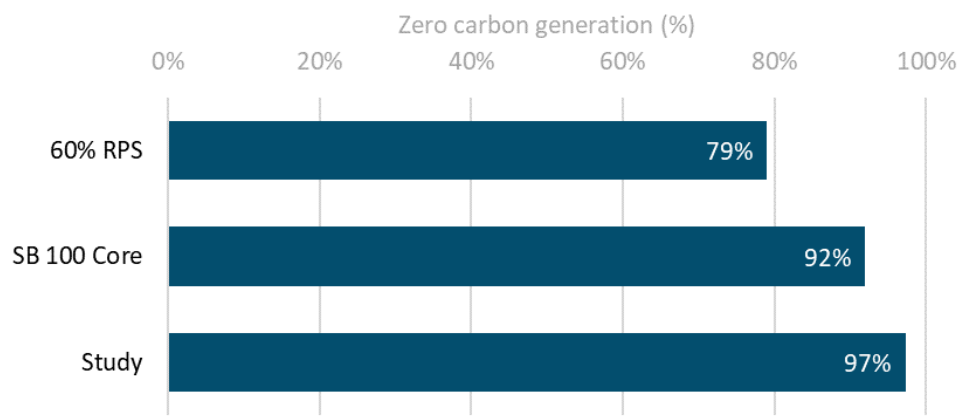
2045 Scenario Costs

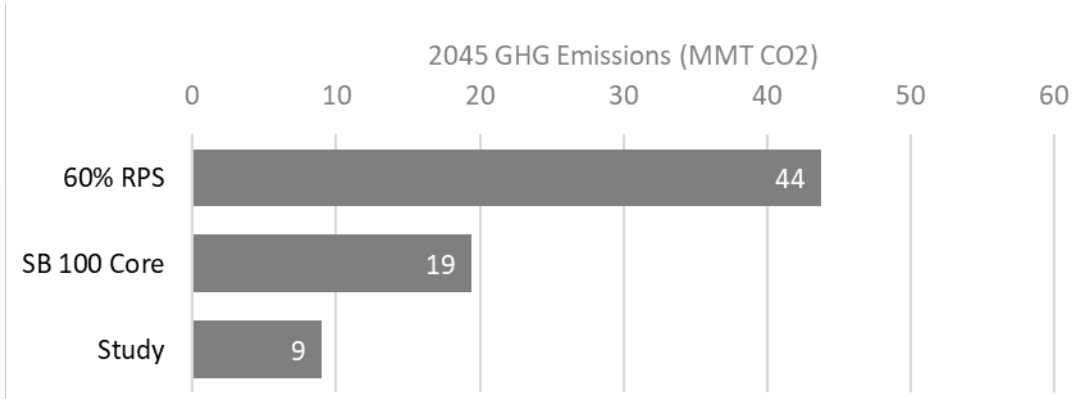
Scenario	Total Resource Cost ($B)	Average Cost (¢/kWh)
60% RPS	$62	14.8
SB 100 Core	$66	16.0
Study	$70	17.1
High Flex	$65	15.7

Total resource cost (TRC) includes existing system costs (baseline costs), capital investments and operation costs.

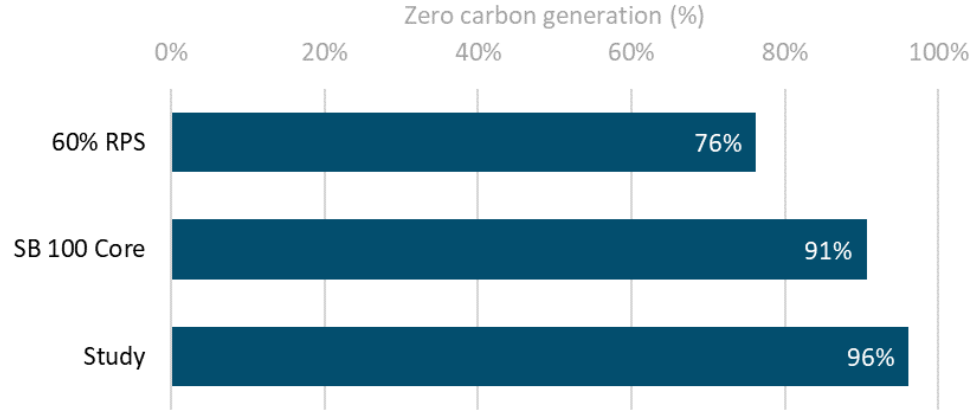
Zero Carbon Generation & GHG Emissions

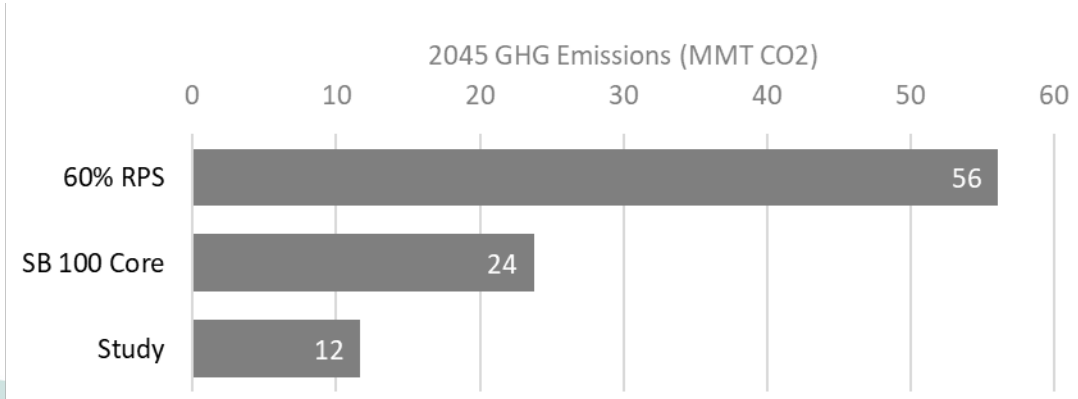
Reference Demand





High Electrification Demand

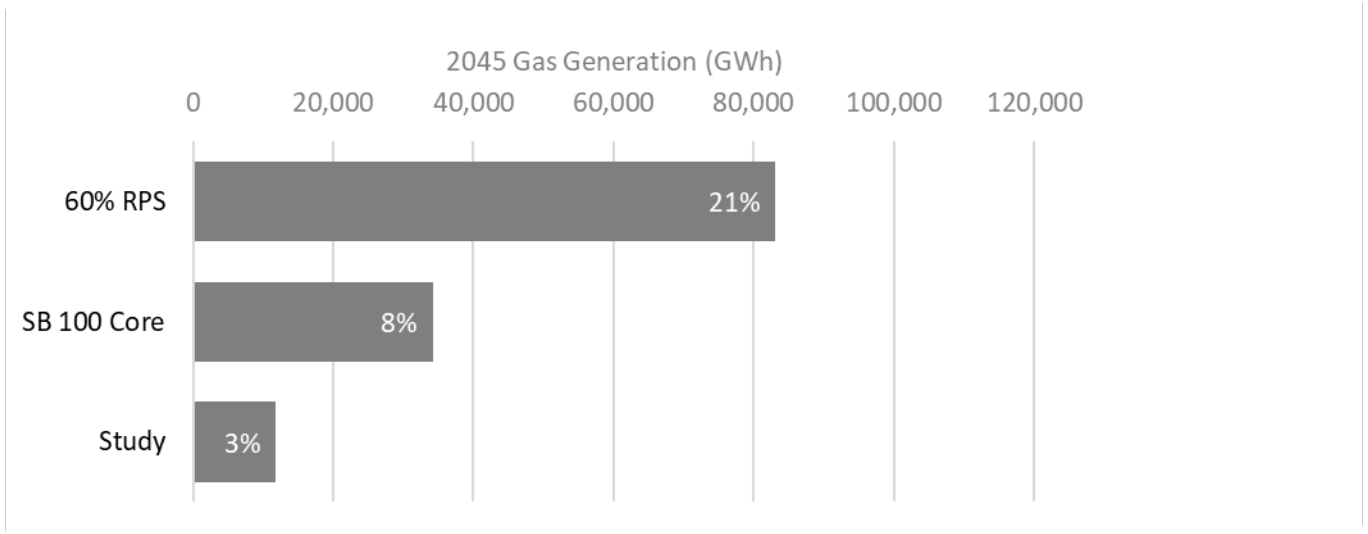


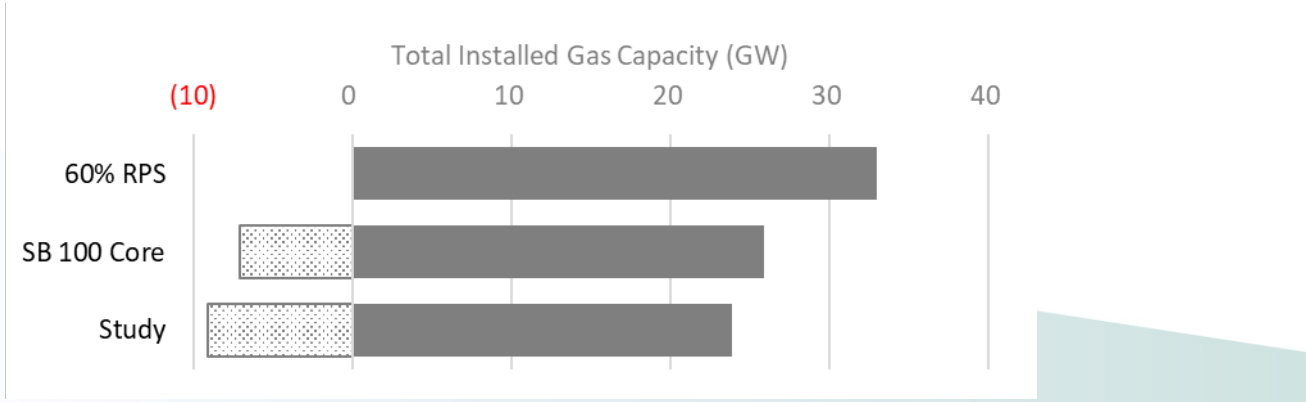


Load Coverage: Core; Resource Options: All; Year: 2045

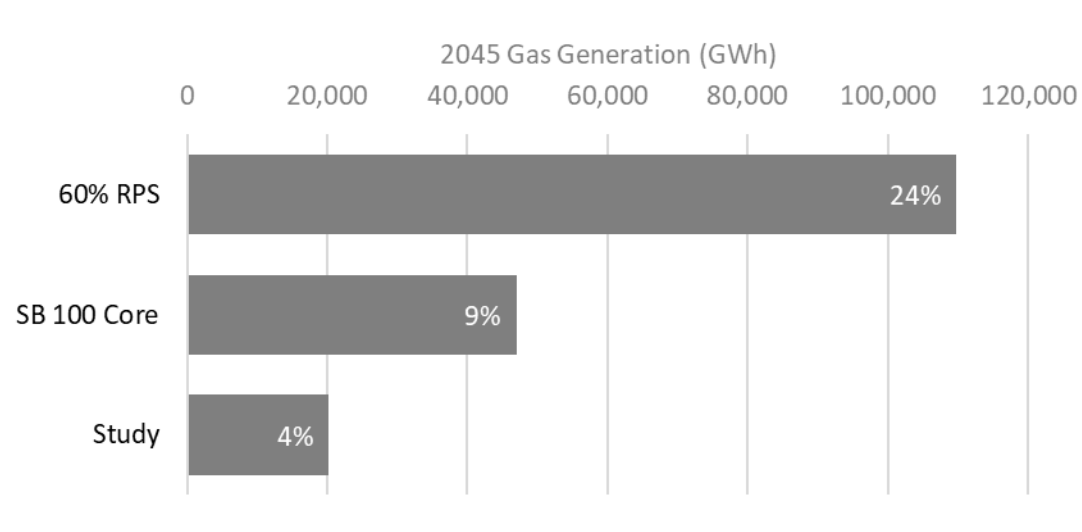
Gas Generation & Capacity

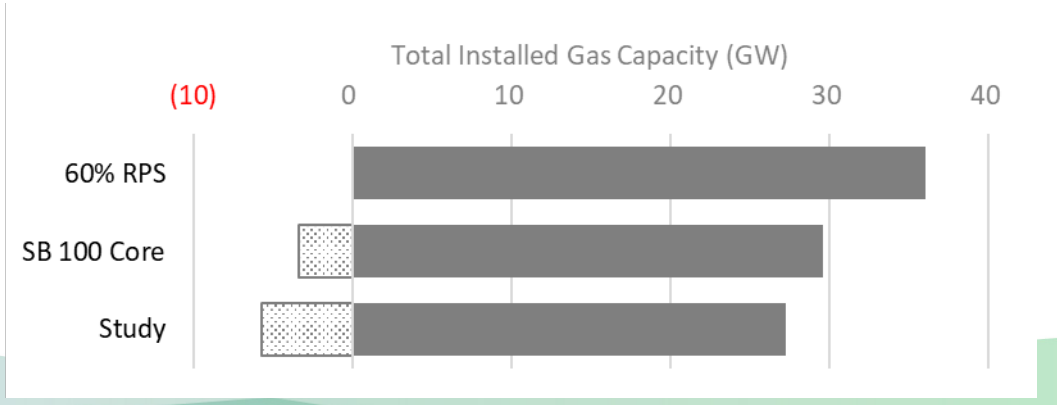
Reference Demand





High Electrification Demand





Load Coverage: Core; Resource Options: All; Year: 2045

Additional Study Scenario

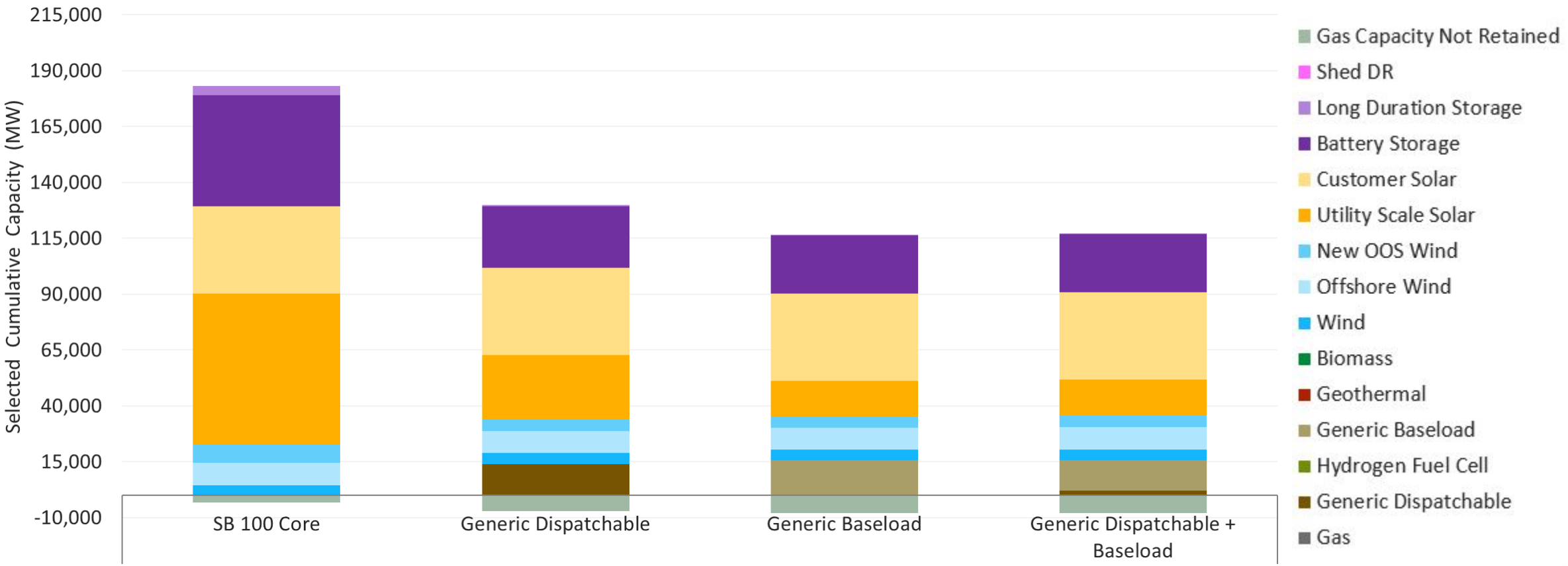
- Zero Carbon Firm Resources
- No Combustion Scenario
- Accelerated Timeline Scenarios

Study: Zero Carbon Firm Resources

- Modeling limitations and lack of established cost data precluded a range of zero carbon firm resources from being included as candidate resources.
- Zero carbon firm candidate resources:
  - Geothermal
  - Hydrogen Fuel Cells
  - Biomass
  - Generic zero carbon firm dispatchable
  - Generic zero carbon firm baseload

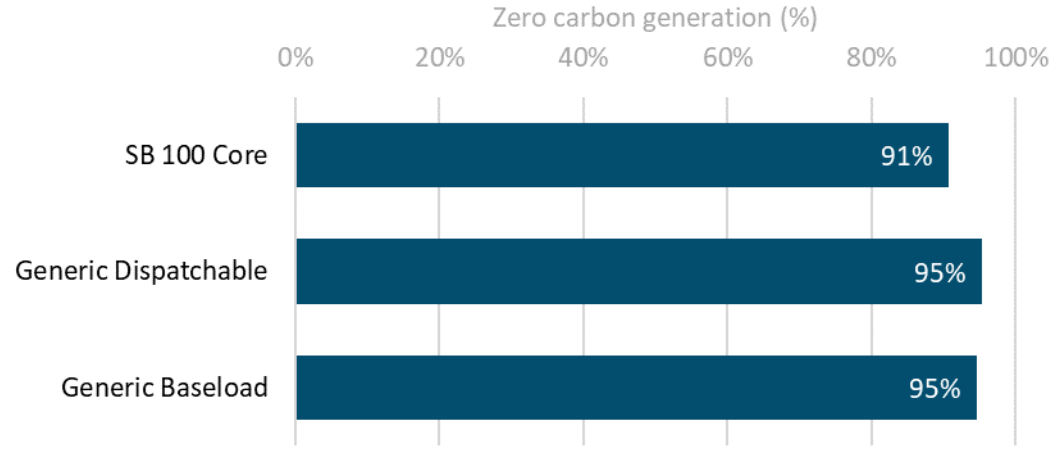
Candidate Resource	Capital Cost	Variable Cost	2045 LCOE ($/MWh)
Hydrogen Fuel Cell	High	High	$126
Biomass	High	High	$124
Geothermal	High	Low	$72
Generic Dispatchable	Medium	Medium	$60
Generic Baseload	High	Very Low	$60

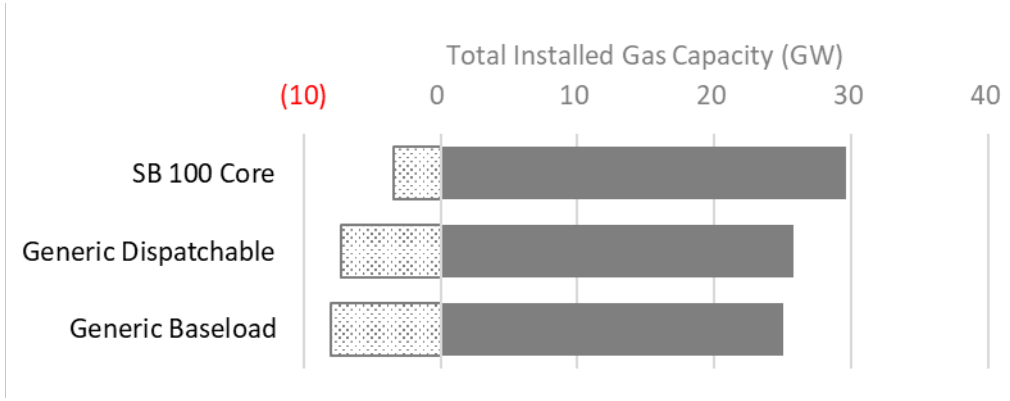
Study: Zero Carbon Firm Resources

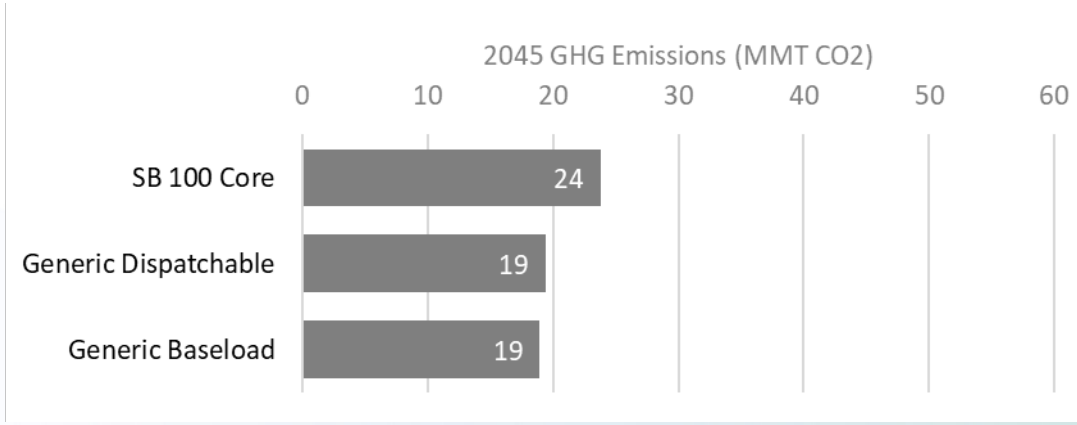


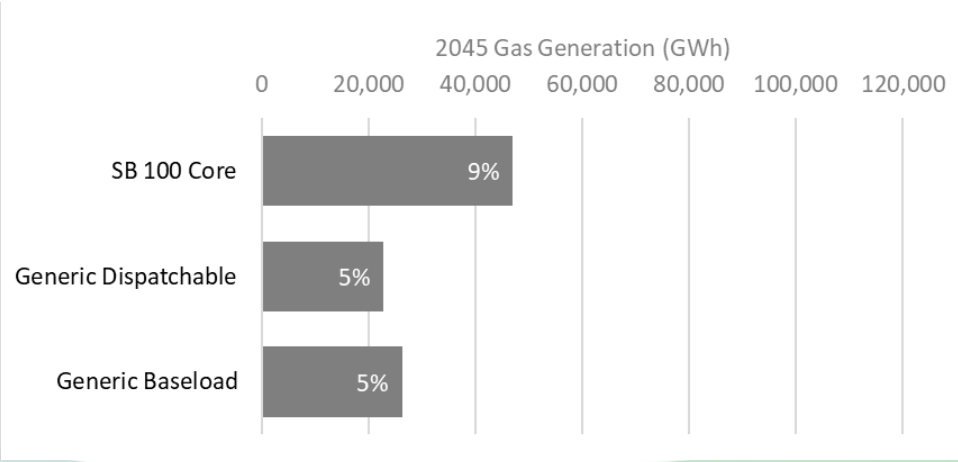
Load Coverage: Core; Demand: High Electrification; Year: 2045

Study: Zero Carbon Firm Resources









Load Coverage: Core; Demand: High Electrification; Year: 2045

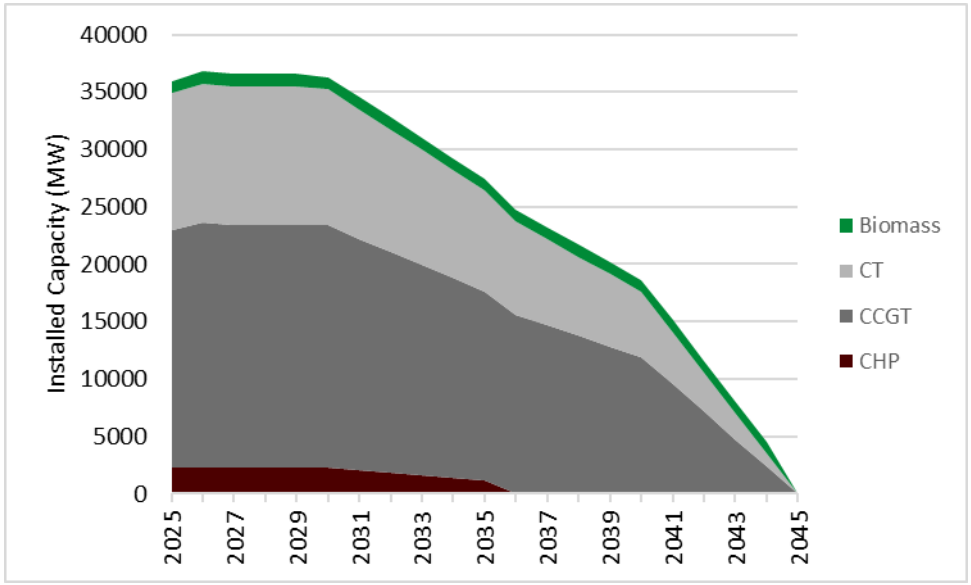
Study: Zero Carbon Firm Resource

- Quantity of Zero Carbon Firm Resource selection is sensitive to the cost point.
  - Geothermal appears to be the marginal resource in Core Scenarios at an LCOE of ~$70/MWh.
  - Reduction in cost of zero carbon firm resources to ~$60/MWh significantly increases resource selection.
- Zero Carbon Firm Resource selection reduces gas capacity economic retention.

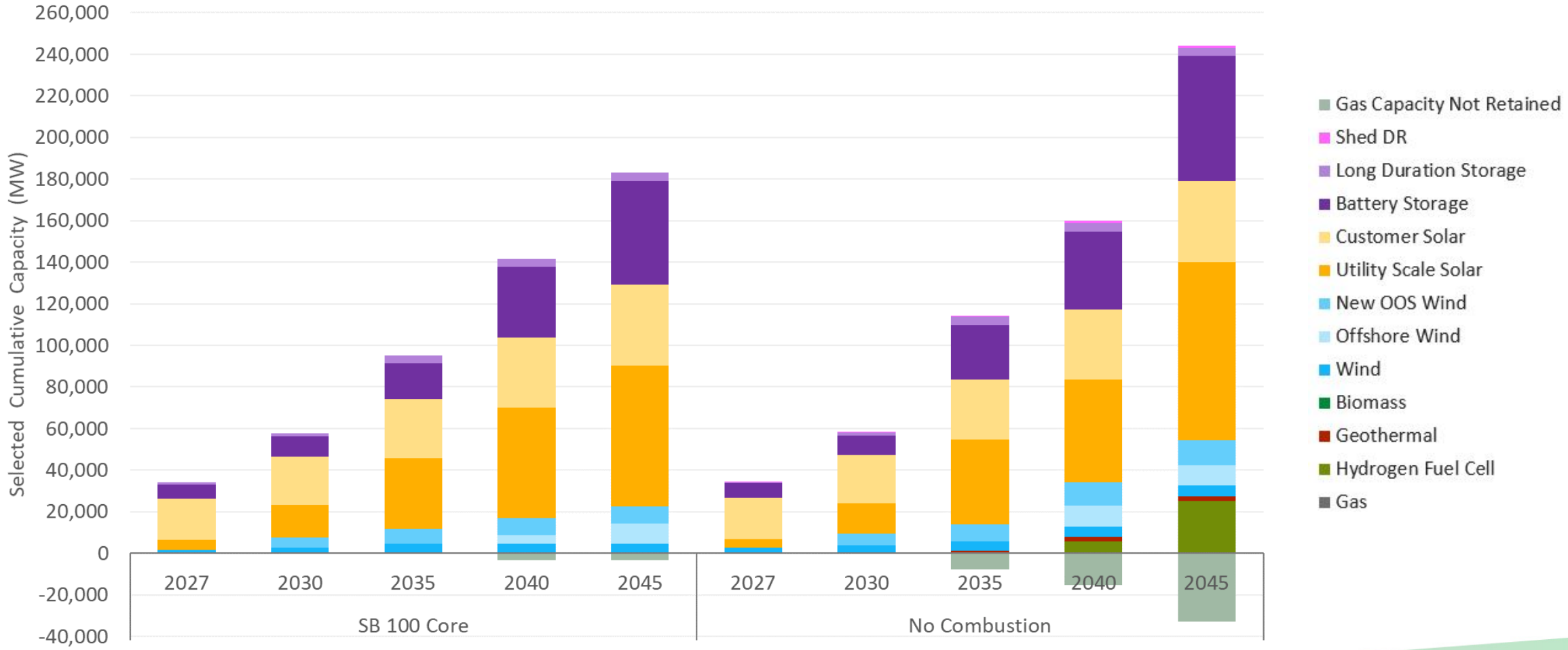
Study: No Combustion Scenario

- All combustion resources retired by 2045
- No combustion candidate resources

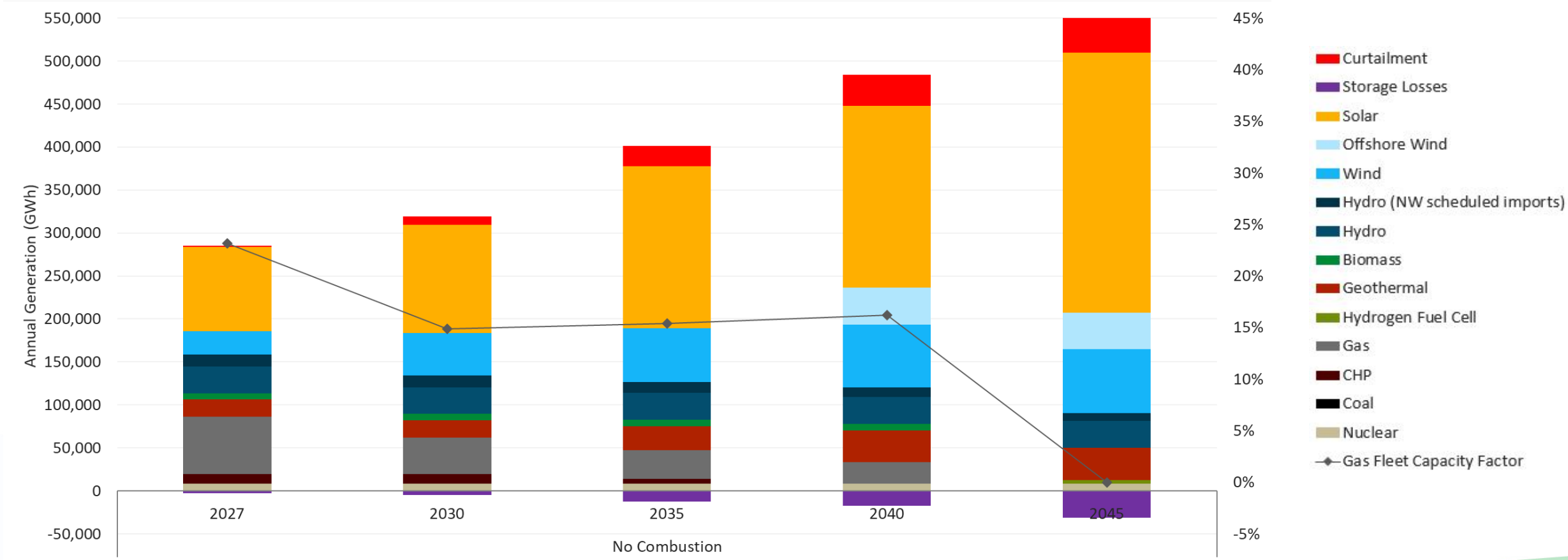
Combustion Resource Retirement Schedule



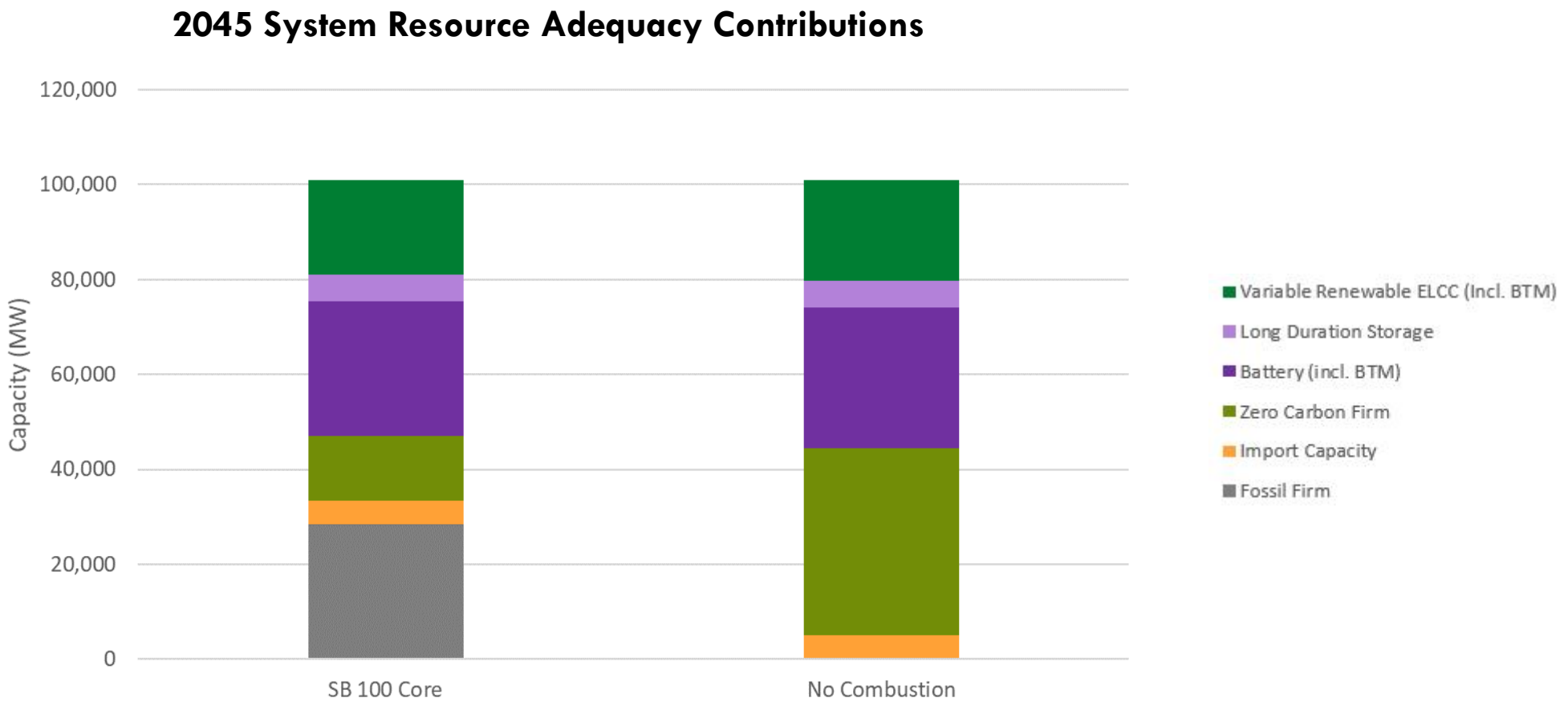
Study: No Combustion Scenario



Study: No Combustion Scenario

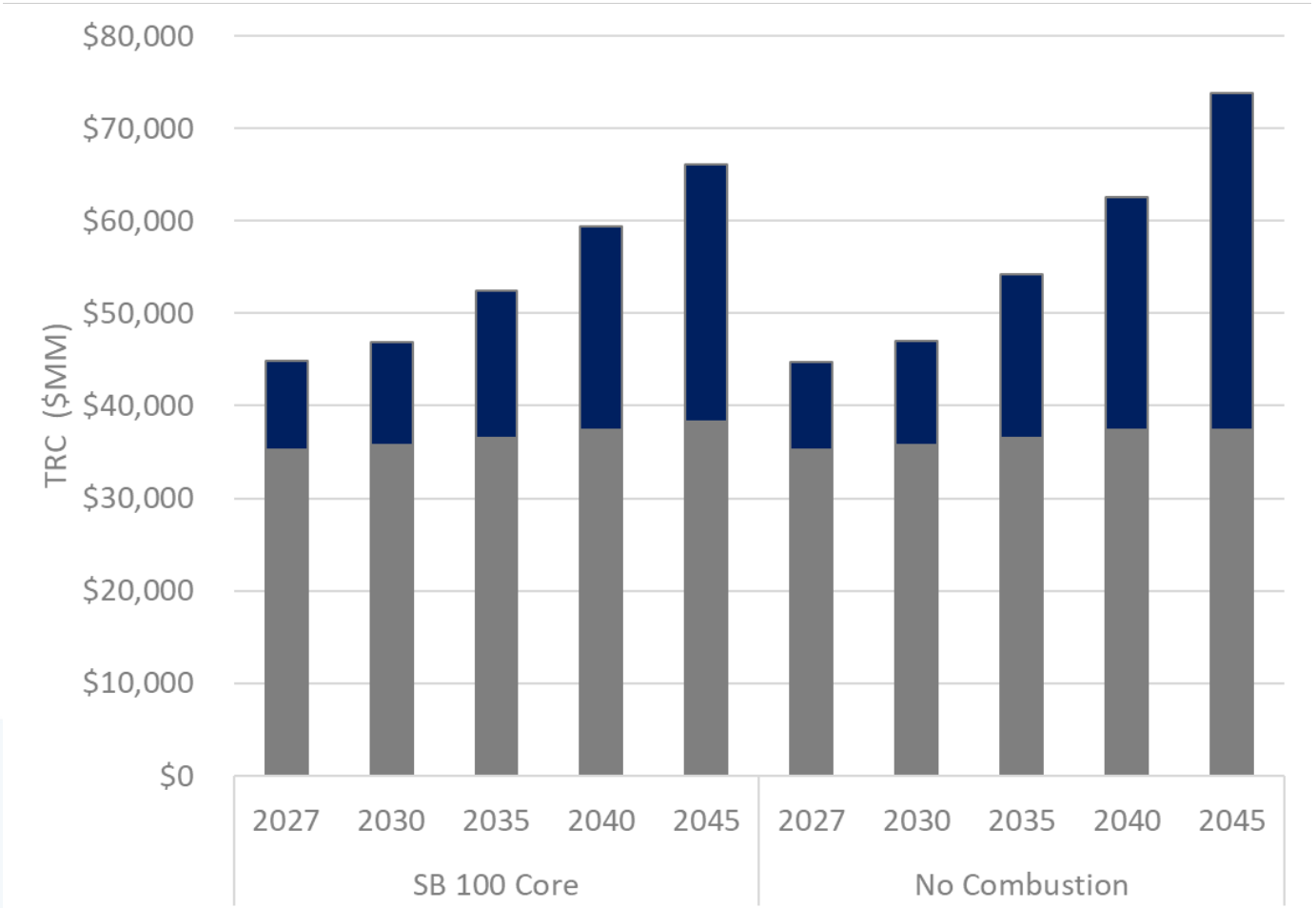


Study: No Combustion Scenario



Demand: High Electrification; Year: 2045

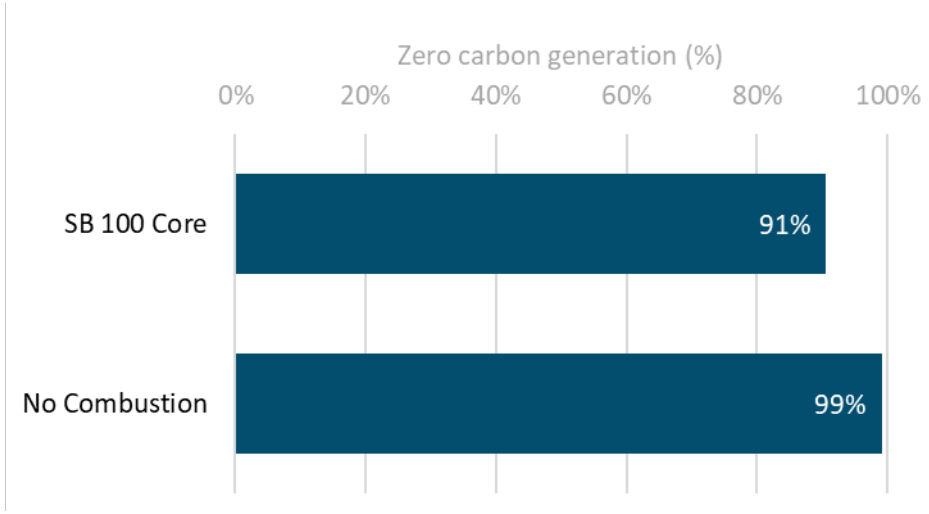
Study: No Combustion Scenario

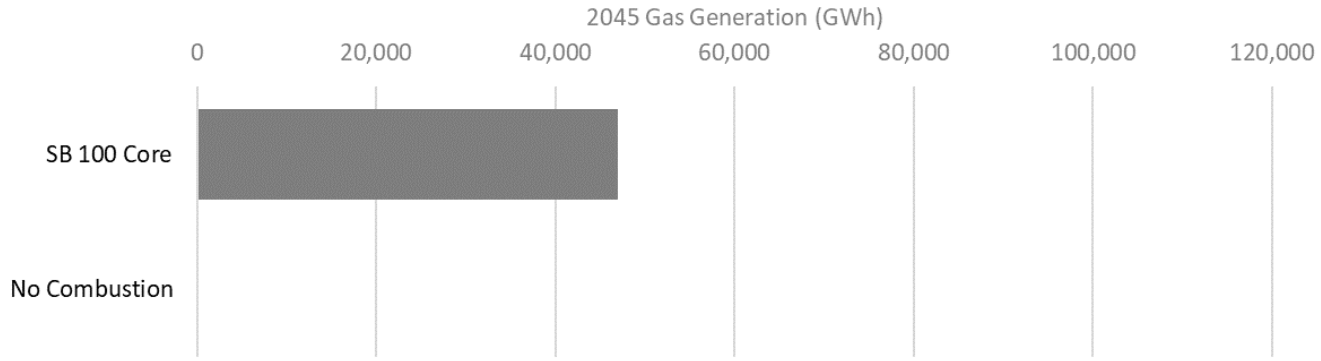


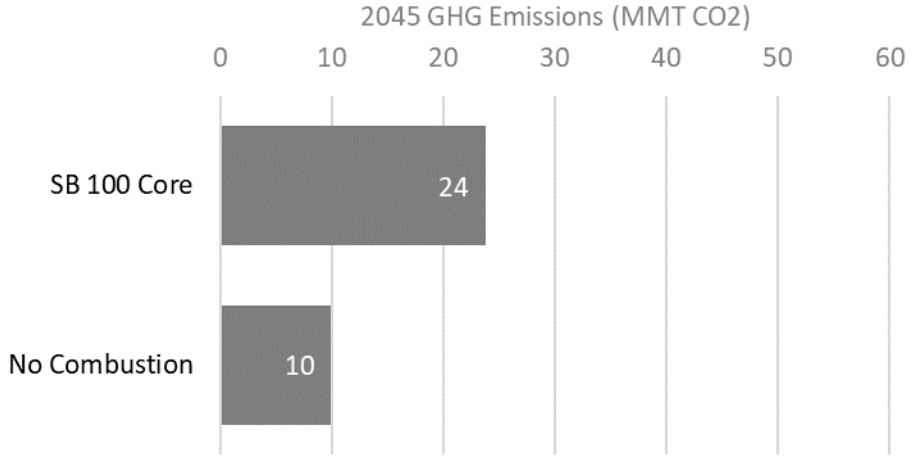
2045 Scenario Costs

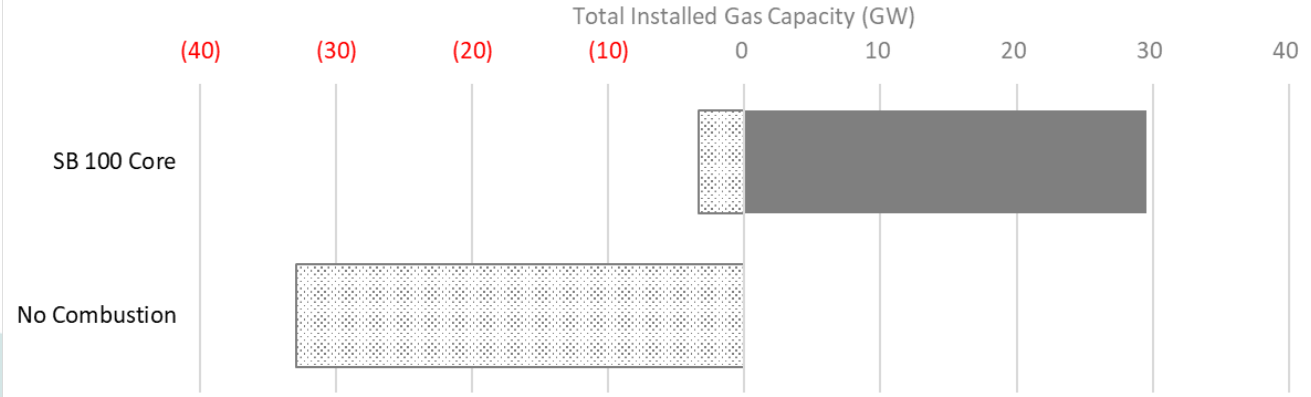
Scenario	Total Resource Cost ($B)	Average Cost (¢/kWh)
No Combustion	$74	18.1
SB 100 Core	$66	16.0

Study: No Combustion Scenario







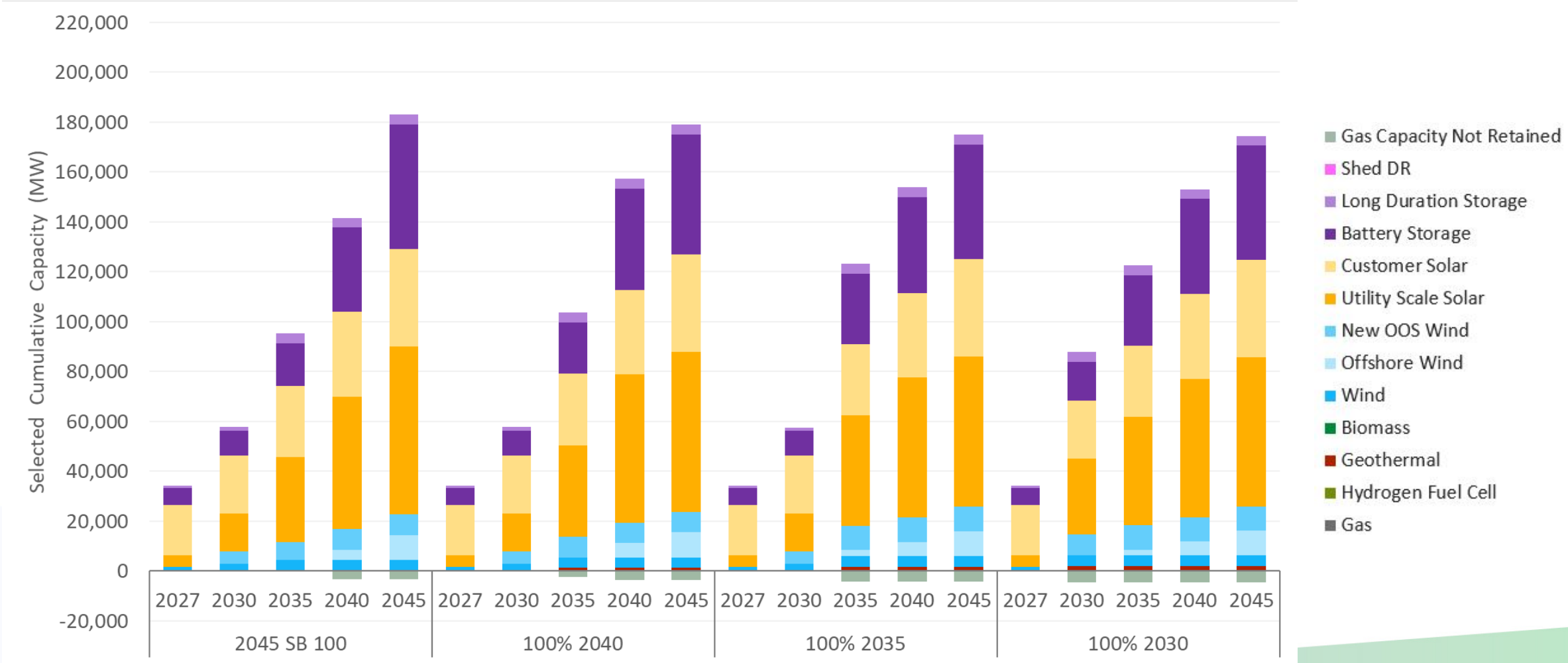


Demand: High Electrification; Year: 2045

Study: Accelerated Timelines

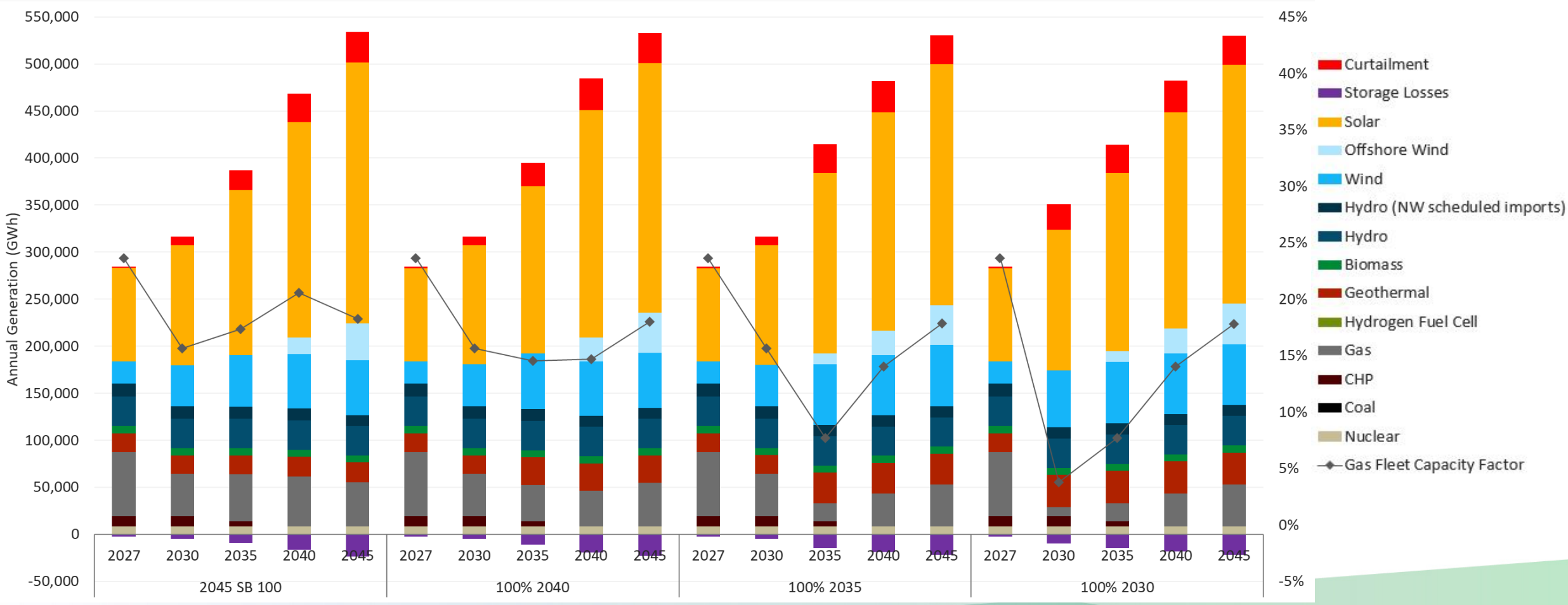
- SB 100 100% Core target accelerated to:
  - 2040
  - 2035
  - 2030

Study: Accelerated Timelines



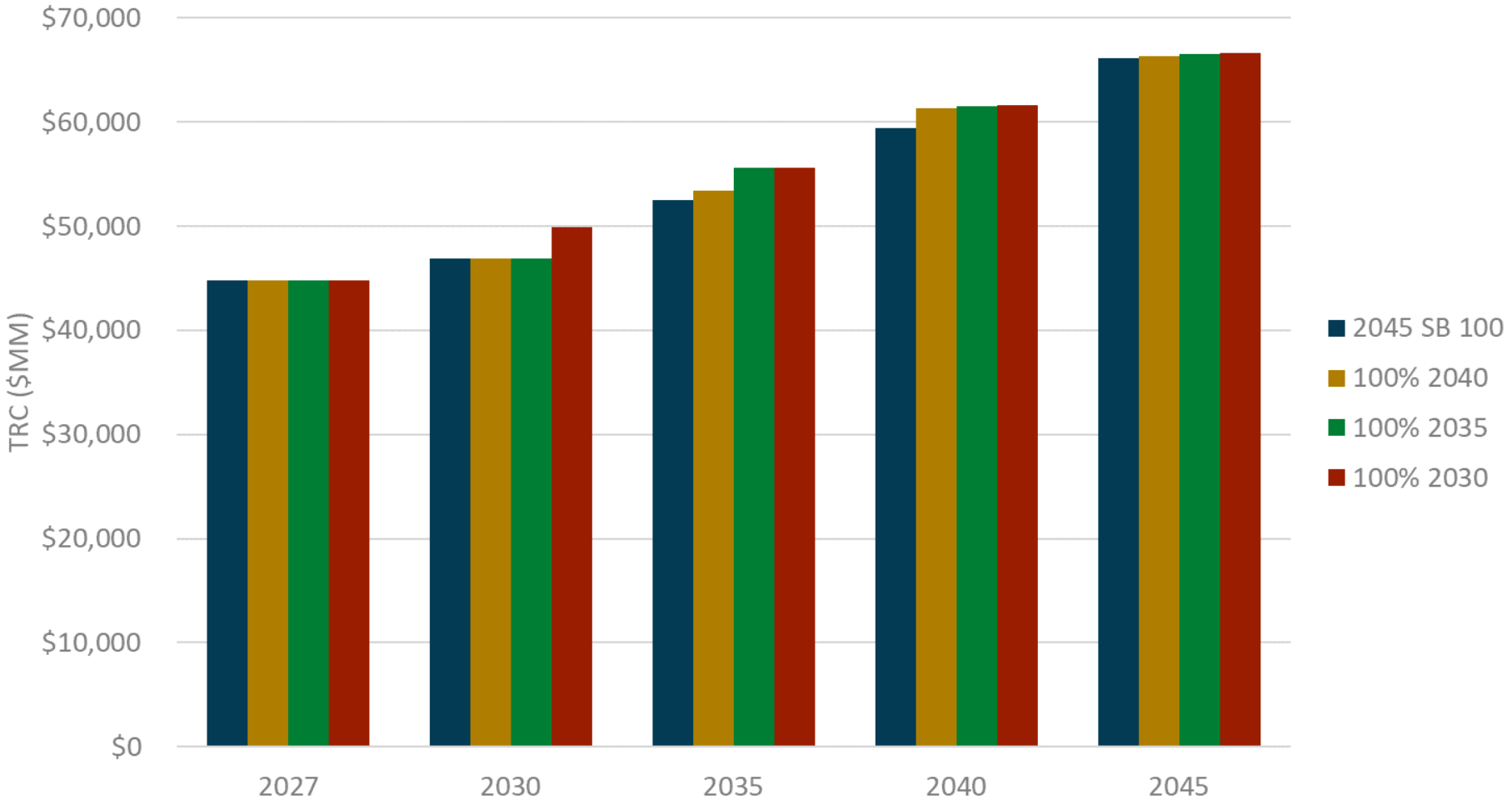
Load Coverage: Core; Demand: High Electrification; Resource Options: All

Study: Accelerated Timelines



Load Coverage: Core; Demand: High Electrification; Resource Options: All

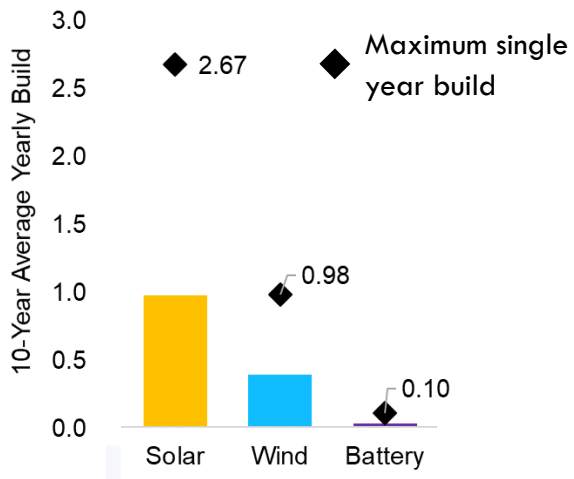
Study: Accelerated Timelines



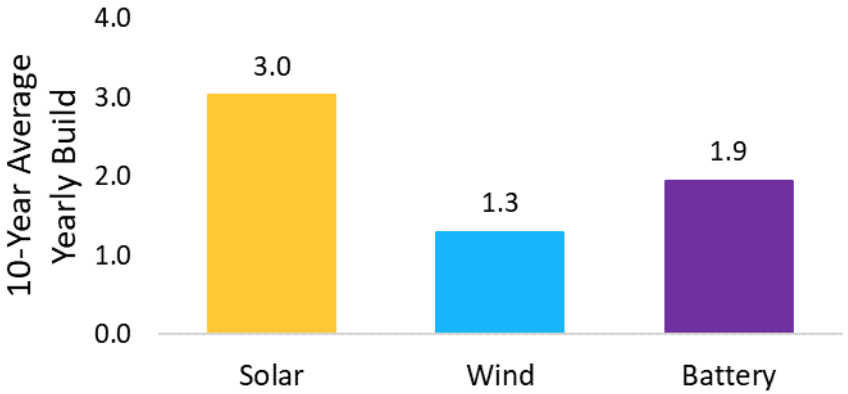
Load Coverage: Core; Demand: High Electrification; Resource Options: All

Study: Resource Build Rates

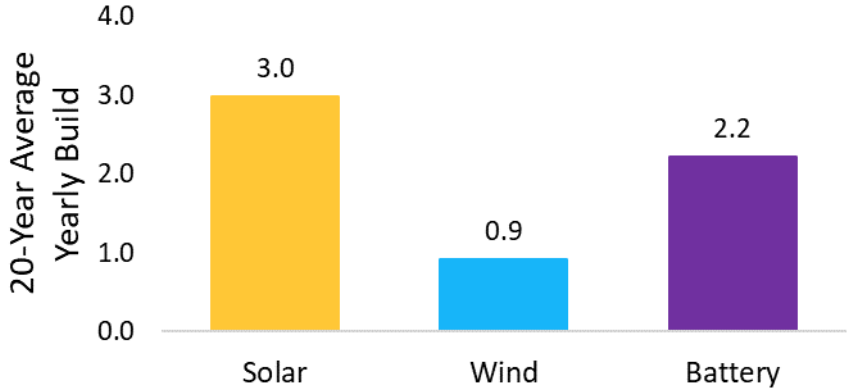
Average Build Rate to Date



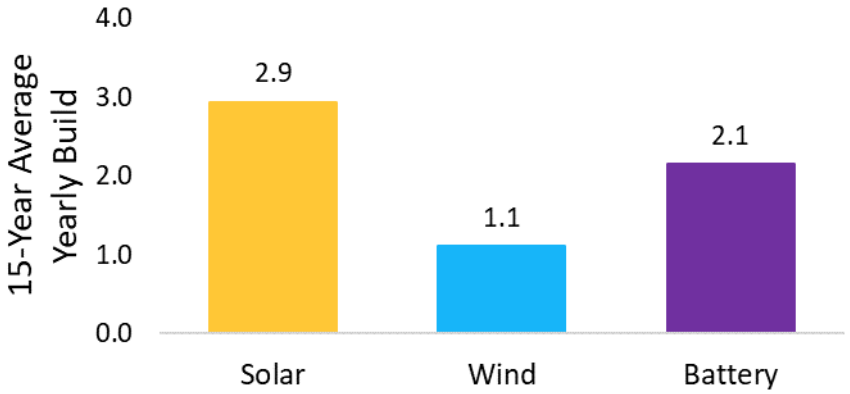
Build Rate to **2030 100%** Target



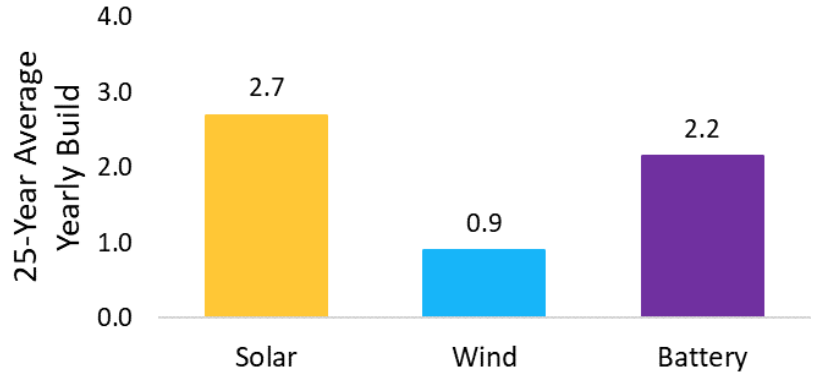
Build Rate to **2040 100%** Target



Build Rate to **2035 100%** Target



Build Rate to **2045 SB 100** Target



Key Takeaways

- SB 100 is achievable with existing technologies.
  - Cost reductions and innovation in zero carbon technologies, as well as demand flexibility and energy storage development can further reduce implementation costs.
- Portfolio diversity is generally valued by the model.
- Sustained record setting resource build rates will be required to meet SB 100.
- Natural gas capacity is largely retained, but fleet-wide utilization decreases by 50% compared to a 60% RPS future.
  - Cost reductions and innovation in zero carbon firm resources and storage resources may reduce economic gas fleet retention.

Thank You

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