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Inputs & Assumptions:
CEC SB100 Joint Agency Report

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1. Introduction

This document describes the key data elements and sources of inputs and assumptions for the California Energy Commission SB100 Joint Agency Report RESOLVE modeling.

The inputs, assumptions, and methodologies are applied to create optimal portfolios for the state of California's electric system that reflect different assumptions regarding load growth, technology costs and potential, fuel costs, and policy constraints.

1.1 Overview of the RESOLVE model

The high-level, long-term identification of new resources that meet California's policy goals is developed using the RESOLVE resource planning model. The RESOLVE model used in this analysis was based off the model used in the 2019/2020 California Public Utility Commission's (CPUC) Integrated Resource Planning (IRP) process. The CPUC uses RESOLVE to develop the Reference System Portfolio, a look into the future that identifies a portfolio of new and existing resources that meets the GHG emissions planning constraint, provides ratepayer value, and responds to reliability needs. The CPUC uses RESOLVE for the development of the Reference System Portfolio because it is a publicly available and vetted tool. The CPUC uses the process of soliciting party feedback on inputs and assumptions to ensure that RESOLVE contains transparent, publicly available data sources and transparent methodologies to examine the long-term planning questions posed within the IRP process.

RESOLVE is formulated as a linear optimization problem. It co-optimizes investment and dispatch for a selected set of days over a multi-year horizon to identify least-cost portfolios for meeting carbon emission reduction targets, renewable portfolio standard goals, reliability during peak demand events, and other system requirements. RESOLVE typically focuses on developing portfolios for one zone, in this case a zone representing the State of California but incorporates a representation of neighboring zones in order to characterize transmission flows into and out of the region of interest. Zone in this context refers to a geographic region that consists of a single balancing authority area (BAA) or a collection of BAAs in which RESOLVE balances the supply and demand of energy. The SB100 - CEC version of RESOLVE includes three zones: one zone capturing California balancing authorities and two zones that represent regional aggregations of out-of-state balancing authorities.[1]

[1] A seventh resource-only zone was added in the 2019-2020 IRP to simulate dedicated imports from Pacific Northwest hydroelectric resources. This zone does not have any load and does not represent a BAA.

RESOLVE can solve for:

- Optimal investments in renewable resources, energy storage technologies, demand response resources, distributed energy resources, and new thermal gas plants, as well as retention of existing thermal resources.

Subject to the following constraints:

- An annual constraint on delivered renewable energy that reflects Renewable Portfolio Standard (RPS) policy;
- An annual constraint on greenhouse gas emissions;
- An annual Planning Reserve Margin (PRM) constraint to maintain capacity adequacy and reliability;
- Operational restrictions on generators and resources;
- Hourly load and reserve requirements; and
- Constraints on the ability to develop specific new resources.

RESOLVE optimizes the buildout of new resources ten or more years into the future, representing the fixed costs of new investments and the costs of operating the CA system within the broader footprint of the Western Electricity Coordinating Council (WECC) electricity system.

1.2 Document Contents

The remainder of this document is organized as follows:

- **Section 2 (Load Forecast)** documents the assumptions and corresponding sources used to derive the forecast of load in California and the WECC, including the impacts of demand-side programs, load modifiers, and the impacts of electrification.
- **Section 3 (Baseline Resources)** summarizes assumptions on baseline resources. Baseline resources are existing or planned resources that are assumed to be operational in the year being modeled.
- **Section 4 (Candidate Resources)** discusses assumptions used to characterize the potential new resources that can be selected for inclusion in the optimized, least-cost portfolio. Candidate resources are incremental to baseline resources.
- **Section 5 (Pro Forma)** describes the financial model used to calculate levelized fixed costs of candidate resources in RESOLVE.
- **Section 6 (Operating Assumptions)** presents the assumptions used to characterize hourly electricity demand and the operations of each of the resources represented in RESOLVE’s internal hourly production simulation model.

- **Section 7 (Resource Adequacy Requirements)** discusses the constraints imposed on the RESOLVE portfolio to ensure system and local reliability needs are met, as well as assumptions regarding the contribution of each resource towards these requirements.
- **Section 8 (Renewable Portfolio Standard and SB100 Policy)** discusses assumptions and accounting used to characterize renewable portfolio standard and SB100 policy targets.

2. Load Forecast

2.1 Statewide forecast

The primary source for load forecast inputs (both peak demand and total energy) is the CEC's 2019 Integrated Energy Policy Report (IEPR) Demand Forecast to 2030. The CEC's 2018 Deep Decarbonization in a High Renewable Future report, as well as the CPUC IRP PATHWAYS modeling, are also used to provide long-term forecasts out to 2045.

Many components of the CEC IEPR demand forecast are broken out so that the distinct hourly profile of each of these factors can be represented explicitly in modeling. The components are referred to in this document as "demand-side modifiers." Hourly profiles for demand-side modifiers are discussed in Section 6.2.1.

Demand-side modifiers include:

- Electric vehicles
- Building electrification
- Other electrification
- Behind-the-meter PV
- Non-PV self-generation (predominantly behind-the-meter combined heat and power)
- Energy efficiency
- Time of use (TOU) rate impacts
- Climate Change

Data sources for demand-side modifier assumptions are discussed in subsequent sections.

Demand forecast inputs are frequently presented as demand at the customer meter. However, the RESOLVE dispatch optimization uses demand at the generator bus-bar. Consequently, demand forecasts at the customer meter are grossed up for transmission & distribution losses based on the average losses across the CAISO zone assumed in the CEC's IEPR Demand Forecast of 7.24%.

2.1.1 Baseline Consumption

Baseline consumption refers to a counterfactual forecast of electricity consumption that captures economic and demographic changes in California but does *not* include the impact of demand-side modifiers. The baseline consumption forecast used is derived from retail sales reported in the CEC's 2019 IEPR Demand Forecast along with accompanying information on the magnitude of embedded demand-side modifiers. Creating a baseline consumption forecast enables different combinations of demand-side modifiers to be used, including combinations that are not explored in the IEPR Demand Forecast. The derivation of baseline consumption from the retail sales forecast is shown in Table 1.

Table 1. Derivation of Baseline Consumption from the CEC IEPR Demand Forecast (GWh)

Component	2020	2025	2027	2030
CEC 2019 IEPR Managed Retail Sales	*250,234*	*250,916*	*252,430*	*255,991*
+ Mid AAEE	2,002	7,129	8,766	10,297
+ Behind-the-Meter PV	19,014	31,624	35,375	40,828
+ Behind-the-Meter CHP	14,064	14,134	14,160	14,198
- TOU rate effects	0	37	39	43
- Electric Vehicles	4,385	10,955	12,597	15,038
= Baseline Consumption	280,929	292,812	298,094	306,233

2.1.2 Electric Vehicles

The CEC SB 100 modeling includes four options for forecasting future electric vehicle demand. The first option is based directly on the IEPR Mid Demand forecast. The remaining three options are based on scenarios from the CEC 2018 Deep Decarbonization report, which extend beyond the 2030 timeframe to reflect different levels of electrification. Post-2030 loads are described in section 2.1.9.

Table 2. Electric vehicle forecast options (GWh)

RESOLVE Scenario Setting	2020	2025	2027	2030
CEC 2019 IEPR - Mid Demand	4,385	10,955	12,597	15,038
CEC 2018 Deep Decarbonization - High Biofuels	1,353	5,521	8,663	13,535
CEC 2018 Deep Decarbonization - High Electrification	1,353	5,521	8,663	13,535
CEC 2018 Deep Decarbonization - High Hydrogen	1,353	5,521	8,663	13,535

2.1.3 Building Electrification

Two options for future building electrification demand are included. The first reflects the IEPR assumption of no incremental building electrification through 2030, and the second is based on the assumptions in the CEC Deep Decarbonization report.

Table 3. Building electrification forecast options (GWh)

RESOLVE Scenario Setting	2020	2025	2027	2030

No Incremental Building Electrification[2]	-	-	-	-
CEC 2018 Deep Decarbonization [3]	-	92	724	3686

2.1.4 Other Transport Electrification

The forecast options for electrification of "other" end uses (e.g. ports, and airport ground equipment) are based on the CEC 2019 IEPR Demand Forecast, and on the CEC Deep Decarbonization Report.

Table 4. Other transport electrification forecast options (GWh)

RESOLVE Scenario Setting	2020	2025	2027	2030
CEC 2019 IEPR - Mid Demand	-	-	-	-
CEC 2018 Deep Decarbonization - High Biofuels	1,461	3,643	5,206	8,067
CEC 2018 Deep Decarbonization - High Electrification	1,461	3,643	5,206	8,070
CEC 2018 Deep Decarbonization - High Hydrogen	1,374	3,163	4,328	6,228

2.1.5 Behind-the-Meter PV

The CEC SB 100 scenarios include a forecast for behind-the-meter (BTM) PV adoption, which is based on the CEC's IEPR Demand Forecast.

Table 5. Behind-the-meter PV forecast options (GWh)

RESOLVE Scenario Setting	2020	2025	2027	2030
CEC 2019 IEPR - Mid PV	19,014	31,624	35,375	40,828

2.1.6 Behind-the-meter CHP and Other Non-PV Self Generation

The forecast of non-PV self-generation is based on the CEC 2019 IEPR Demand Forecast. On-site combined heat & power (CHP) that does not export to the grid makes up the majority of this component. The IEPR primarily models on-site CHP using projections based on past on-site CHP

2 This is consistent with the IEPR demand forecast which does not include incremental building electrification, and with the CARB 2016 Scoping Plan "SP" scenario.

3 The High Electrification, High Hydrogen and High Biofuels Scenarios from the CEC's 2018 "Deep Decarbonization in a High Renewables Future" have the same building electrification assumptions.

generation data. CHP units that export energy to the grid are separately discussed in section 3. Forecasts for BTM CHP and the remaining non-PV self-generation are shown in the tables below.

Table 6. Forecast of Behind-the-meter CHP (GWh)

Scenario Setting	2020	2025	2027	2030
CEC 2019 IEPR - Mid Demand	14,064	14,134	14,160	14,198

2.1.7 Energy Efficiency

The CEC SB 100 modeling includes a forecast for energy efficiency achievement among California load-serving entities based on the Mid-AAEE scenario included in the CEC's 2019 IEPR Demand Forecast. "Additional Achievable Energy Efficiency" (AAEE) refers to efficiency savings beyond current committed programs.

Table 7. Energy efficiency forecast options (GWh)

RESOLVE Scenario Setting	2020	2025	2027	2030
CEC 2019 IEPR – Mid-Mid AAEE	2,907	11,817	14,687	17,711

2.1.8 Time-of-Use Rate Impacts

The CEC SB 100 modeling includes two options for representing different impacts of residential time-of-use (TOU) rate implementation on retail load. The first assumes no impact to load shape. The second corresponds to mid residential TOU scenarios from CEC's 2018 IEPR Demand Forecast. As modeled, TOU rates modify the hourly load profile but have little impact on annual load.

Table 8. Residential TOU rate implementation load impacts (GWh)

RESOLVE Scenario Setting	2020	2025	2027	2030
None	—	—	—	—
CEC 2018 IEPR	0	37	39	43

2.1.9 Load extrapolation to 2045

The CEC's 2018 Deep Decarbonization in a High Renewables Future report is used to provide long-term forecasts out to 2045 for the three "mitigation" scenarios (High Electrification, High

Biofuels, and High Hydrogen). The CPUC IRP 2020 PATHWAYS Reference scenario is used to provide long-term forecasts out to 2045 for the Reference scenario modeling. Each scenario follows the PATHWAYS assumptions for load modifiers, including electric vehicles, other transport electrification, building electrification, and hydrogen production. The High Electrification scenario is picked as the default mitigation scenario in the study because it provides a balanced decarbonization pathway between electrification and low-carbon fuels with relatively low costs and commercially available technologies.

All scenarios follow the same assumptions on energy efficiency and baseline consumption. Energy efficiency is held flat after 2030, because energy efficiency is included in the baseline loads from PATHWAYS. PATHWAYS does not report baseline consumption directly, but rather reports baseline consumption net of energy efficiency.

Table 9: Reference Load Forecast (post-2030 values based on CPUC IRP 2020 PATHWAYS Reference)

RESOLVE Scenario Setting	2027	2030	2035	2040	2045
Baseline Consumption	298,094	306,233	313,580	323,128	333,989
Electric Vehicles	12,597	15,038	25,164	37,587	50,185
Other Transport Electrification	-	-	2,328	4,947	7,613
Building Electrification	-	-	268	591	912
Hydrogen Production	-	-	-	-	-
Energy Efficiency	*(14,687)*	*(17,711)*	*(17,711)*	*(17,711)*	*(17,711)*
Total	**296,004**	**303,560**	**323,629**	**348,542**	**374,988**

Table 10. CEC Pathways High Biofuels Load Forecast (GWh)

RESOLVE Scenario Setting	2027	2030	2035	2040	2045
Baseline Consumption	298,094	306,233	313,580	323,128	333,989
Electric Vehicles	8,663	13,535	23,567	31,250	37,176
Other Transport Electrification	5,206	8,067	15,692	24,796	32,746
Building Electrification	724	3,686	14,551	29,193	42,810
Hydrogen Production	-	-	-	-	-
Energy Efficiency	*(14,687)*	*(17,711)*	*(17,711)*	*(17,711)*	*(17,711)*
Total	**298,000**	**313,810**	**349,679**	**390,656**	**429,010**

Table 11. CEC Pathways High Electrification Pathways Load Forecast (GWh)

RESOLVE Scenario Setting	2027	2030	2035	2040	2045
Baseline Consumption	298,094	306,233	313,580	323,128	333,989
Electric Vehicles	8,633	13,954	28,252	39,351	46,863
Other Transport Electrification	5,206	8,070	15,875	25,867	34,401
Building Electrification	724	3,686	14,551	29,193	42,810
Hydrogen Production	-	-	-	-	-
Energy Efficiency	*(14,687)*	*(17,711)*	*(17,711)*	*(17,711)*	*(17,711)*
Total	**297,970**	**314,232**	**354,547**	**399,828**	**440,352**

Table 12. CEC Pathways High Hydrogen Load Forecast (GWh)

RESOLVE Scenario Setting	2027	2030	2035	2040	2045
Baseline Consumption	298,094	306,233	313,580	323,128	333,989
Electric Vehicles	8,633	13,954	28,252	39,351	46,863

Other Transport Electrification	4,328	6,228	11,176	16,109	20,748
Building Electrification	724	3,686	14,551	29,193	42,810
Hydrogen Production	2,272	5,559	23,065	73,892	108,812
Energy Efficiency	*(14,687)*	*(17,711)*	*(17,711)*	*(17,711)*	*(17,711)*
Total	**299,364**	**317,949**	**372,913**	**463,962**	**535,511**

2.2 Peak Demand Forecast

To ensure that the electricity system has adequate resources to reliably operate the system during the hours of highest demand, RESOLVE's planning reserve margin constraint guarantees that all portfolios have at least a 15% margin above the 1-in-2 net peak demand in all modeled years. The peak demand of the system can significantly impact resource portfolio selection by increasing the value of resources that can produce energy during peak periods.

Both the timing and magnitude of peak demand are impacted by changes in demand-side modifiers, including but not limited to behind-the-meter solar and storage, energy efficiency, and new loads from electrification of transportation and other fossil-fueled end uses. Calculation of system net peak demand takes into account the combined impact of all of the demand-side modifiers.

2.2.1 Mid Managed Peak Demand Projection - Through 2030

To be consistent with the use of a Single Forecast Set for electric resource planning activities, the managed net peak through 2030 is calculated using CEC 2018 IEPR "Mid case" assumptions on the annual level of demand and various demand modifiers. An hourly 8760 timeseries of California state-wide electric demand – net of demand modifiers – for the years 2018-2030 is developed by combining peak-load normalized hourly demand shapes from the 2018 IEPR with annual demand projections from the 2019 IEPR. Peak demand impacts for individual demand modifiers are not calculated for the IEPR Mid case because interactive effects between hourly shapes and the timing of peak demand result in demand modifier peak impacts that are interdependent and non-linear. As outlined below, all demand modifiers with an hourly shape are added or subtracted from the hourly consumption forecast, resulting in a peak demand in each year that is referred to as the "Managed Peak" demand.

California Hourly Consumption Load: Mid Baseline

+ Other Electrification: Mid (included in hourly consumption load)

- Non-PV Self Generation (predominantly BTM CHP) (included in hourly consumption load)

- Behind-the-Meter (BTM) Storage Peak Impact (included in hourly consumption load)

+ Load from Vernon and SVP data centers

+ Time-Of-Use: Mid (can increase or decrease hourly demand)

+ Climate Change Impacts: Mid (can increase or decrease hourly demand)

+ Light-Duty Electric Vehicles: Mid

- Additional Achievable Energy Efficiency: Mid-Mid

- Committed BTM PV: Mid

California Managed Net Mid Peak, Coincident, through 2030, excluding Load Modifying Demand Response (LMDR)

- LMDR: Mid

California Managed Net Mid Peak, Coincident, through 2030

Notes:

- The peak demand impacts of Other Electrification and non-PV Self Generation (including BTM combined heat and power and BTM storage) are embedded in the CEC IEPR's hourly consumption load shape, and therefore do not have separate hourly profiles.
- The CEC represents the peak discharge capability of BTM storage as the installed BTM storage capacity, reduced by a 1% per year degradation rate (cumulative), and then de-rated to 90% output during peak.
- The peak demand impacts of load modifying demand response are not represented using an hourly load profile and are instead subtracted from the Managed Peak.

2.2.2 Peak Demand Post-2030 Years

RESOLVE simulations require peak demand forecasts for every year that is simulated. The CEC 2019 IEPR forecasts demand through 2030, but the scenarios explored in the CEC SB100 analysis extend past 2030, requiring an extrapolation of the peak demand to years beyond 2030.

To develop peak demand forecasts for years after 2030 for baseline consumption, electric vehicles, energy efficiency, and BTM PV, information from the peak demand sensitivities is used to calculate a normalized peak demand impact. For each of the demand modifiers, the peak demand difference from Mid in the year 2030 is normalized to the increase or decrease in annual demand, resulting in the peak demand increase per unit of demand modifier (Δ MW_{peak} / Δ GWh_{annual}). This factor is used to calculate the increase or decrease in peak demand resulting from a change in annual demand relative to 2030.

2.2.3 Building Electrification and Other Transportation Peak Demand Impact

The peak impact (Δ MW_{peak} / Δ GWh_{annual}) of building and other transportation electrification are calculated using an extrapolated hourly demand projection for the year 2050. The peak demand impact is calculated by adding or removing a small amount of demand and observing the change in peak.

2.2.4 Peak demand adjustment for modeling BTM PV and Storage as supply side

Resource adequacy needs are typically calculated with BTM resources represented on the demand side. In this framework, BTM resources contribute to system peak needs by reducing the 1:2 system peak. RESOLVE represents BTM PV and Storage resources as supply-side resources in both hourly dispatch and resource adequacy retirements. Two adjustments are made to the MW value of RESOLVE's planning reserve margin constraint that align the supply-side treatment of these resources with the typical demand-side resource adequacy representation:

- The peak reduction from each resource is added back to RESOLVE's planning reserve margin MW need. This is necessary to avoid double counting the peak reduction of BTM PV and storage.
    - The peak reduction from BTM PV is calculated by removing Committed hourly production profiles from the "Mid" load profile and recalculating the peak demand in each year.
    - The peak reduction from BTM storage does not vary by hour, so the BTM storage peak reduction is added back to the planning reserve margin target directly.
- Demand-side resources reduce the capacity needed above the peak load because the planning reserve margin (PRM) is calculated as a percentage (typically 15%) above the managed load peak. Consistent with Resource Adequacy accounting, demand-side resources reduce the managed load peak, so the 15% margin above 1-in-2 peak demand is not held for these resources. When modeling demand-side resources on the supply side, the planning reserve margin that is input into RESOLVE is reduced by the PRM percentage multiplied by the MW of peak reduction from BTM resources modeled on the supply-side in RESOLVE.

Figure 2.1. Translation of demand-side resources to the supply-side in RESOLVE. Diagram is conceptual and is not to scale. The heavy black line indicates the PRM MW target.

	PRM Calculation with BTM resources on the demand-side	PRM Calculation without PRM margin reduction for BTM (not used)	PRM Calculation in RESOLVE - with BTM resources on the supply-side
Peak Capacity (MW)		(4) 15% PRM on supply-side BTM resources (15% * (3))	(PRM margin from BTM resources modeled as supply not included)
		(3) Peak Capacity reduction from BTM PV and Storage, added back to supply side	(3) Peak Capacity reduction from BTM PV and Storage, added back to supply side
	(2) 15% PRM on Managed Peak (15% * (1))	(2) 15% PRM on Managed Peak (15% * (1))	(2) 15% PRM on Managed Peak (15% * (1))
	(1) Managed Net Load Peak	(1) Managed Net Load Peak	(1) Managed Net Load Peak

2.3 Other Zones

RESOLVE uses a zonal transmission topology to simulate flows among the various regions in the Western Interconnection. RESOLVE includes three zones: one zone capturing California balancing authorities (Balancing Authority of Northern California (BANC), California Independent System Operator (CAISO), Los Angeles Department of Water and Power (LADWP), and Imperial Irrigation District (IID)) and two zones that represent regional aggregations of out-of-state balancing authorities.[4] The constituent balancing authorities included in each RESOLVE zone are shown in Table 45 (Section 6.5).

Demand forecasts for zones outside California are developed by a process similar to California forecasts. Forecasts for the zones outside of California (the Pacific Northwest and the Southwest), WECC's 2028 Anchor Data Set (ADS) Phase 2 V1.2 is used as the basis for load projections. Sales forecasts net of demand-side modifiers are combined with available

[4] The 2019-2020 IRP includes an additional resource-only zone to simulate dedicated Pacific Northwest Hydro imports. This zone does not have any load and is not included here.

information in the ADS related to demand-side modifier and consumption forecasts. This data is then be aggregated to the RESOLVE zones.

The demand forecasts for each non-California zone are grossed up for transmission and distribution losses. Demand forecasts for zones outside California are shown in the table below.

Table 13. Non-California Net Energy for Load - grossed up for T&D losses (GWh)

RESOLVE Zone	2020	2022	2026	2030	2045
NW	240,828	243,368	248,416	253,973	273,690
SW	142,457	146,338	152,407	158,873	183,496

3. Baseline Resources

Baseline resources are resources that are currently online or are contracted to come online within the planning horizon. Being "contracted" refers to a resource holding signed contract/s with an LSE/s for much of its energy and capacity for a significant portion of its useful life. The contracts refer to those approved by the CPUC and/or the LSE's governing board, as applicable. These criteria indicate the resource is relatively certain to come online.

The capacity of **baseline** resources is an input to capacity expansion modeling, as opposed to **candidate** resources, which are selected by the model and are incremental to the baseline. For some resources, baseline resource capacity is reduced over time to reflect announced retirements. An estimation of baseline resource capital costs is used when calculating total revenue requirements and electricity rates.

Baseline resources include:

- Existing resources: Resources that have already been built and are currently available, net of expected future retirements.
- Resources under development: Resources that have contracts approved by the CPUC or the board of a community choice aggregator (CCA) or energy service provider (ESP) and are far enough along in the development process that it is reasonable to assume that the resource will be completed. To reflect the potential for project failure these resources are discounted by 5 percent, a value based on RPS Procurement Plans and stakeholder feedback.
- Resources not optimized: Future projected resource additions that are expected, but not appropriate for optimization (e.g., achievement of the CPUC storage target).

Baseline resources are assembled from the primary sources listed in Table 14 and are further described below.

Table 14. Data Sources for Baseline Resources

Zone	Online Status	Generator type	Dataset used
In California	Existing	Renewable, Storage, and Non-Renewable	CAISO Master Generating Capability List, CAISO Master File and WECC ADS for non-CAISO BAA generators
In California	Under development	Renewable and Storage	RPS Contract Database and data requests
In California	Under development	Non-Renewable	WECC ADS
Out of California	Existing and under development	Renewable, Storage and Non-Renewable	WECC ADS

- The list of generators currently operational inside the CAISO is compiled from the CAISO Master Generating Capability List[5]. These generators serve load inside CAISO and are composed of renewable and non-renewable generation resources, as well as some demand response resources. The CAISO Master Generating Capability List information is supplemented by the CAISO Master File, a confidential data set with unit-specific operational attributes. The CAISO Master File also includes information related to dynamically scheduled generators. These generators are physically located outside of the CAISO but can participate in the CAISO market as if they were internal to CAISO. However, because they have no obligation to sell into CAISO they are modeled as unspecified imports and do not have special priority given to their energy dispatch.
- Future renewable generators that will serve IOU-related CAISO load are compiled from the January 2019 version of the RPS contracts database maintained by CPUC staff and supplemented by data requests from CCAs and ESPs.
- For generators outside of CAISO, including areas within California such as IID, LADWP and SMUD, generator listings and their associated operating information are taken from WECC's 2028 Anchor Data Set (ADS) Phase 2 V1.2.

[5] Available at: http://oasis.caiso.com/mrioasis/logon.do

3.1 Natural Gas, Coal, and Nuclear Generation

3.1.1 Modeling Methodology

Natural gas, coal, and nuclear resources are represented in RESOLVE by a limited set of resource classes by zone, with operational attributes set at the capacity weighted average for each resource class in that zone. The capacity weighted averages are calculated from individual unit attributes available in the CAISO Master File or the WECC ADS. The following resource classes are modeled: Nuclear, Coal, Combined Cycle Gas Turbine (CCGT), Gas Steam, Peaker, Reciprocating Engine, and Combined Heat and Power (CHP).

To more accurately reflect different classes of gas generators associated with the CAISO BAA, CAISO's gas generators are further divided into subcategories, the three other California BAAs do not have this level of disaggregation of resources. The CAISO associated resources are grouped and differentiated into subcategories based on natural breakpoints in operating efficiency observed in the distribution of data within class averages:

- The CCGT generator category is divided into two subcategories based on generator efficiency: higher efficiency units are represented as **"CAISO_CCGT1"** and lower efficiency units are represented as **"CAISO_CCGT2"**.
- The Peaker generator category is the aggregation of natural gas frame and aeroderivative technologies and is divided into two subcategories: higher efficiency units are represented as **"CAISO_Peaker1"** and lower efficiency units are represented as **"CAISO_Peaker2"**.
- The **"CAISO_ST"** generator category represents the existing fleet of steam turbines, all of which are scheduled to retire by default at the end of 2020 to achieve compliance with the State Water Board's Once-Through-Cooling (OTC) regulations. Sensitivity analysis explores alternative retirement assumptions for OTC steam units.
- The **"CAISO_Reciprocating_Engine"** generator category represents existing gas-fired reciprocating engines on the CAISO system.
- The **"CHP"** generator category represents non-dispatchable cogeneration facilities with thermal hosts, which are modeled as firm resources in RESOLVE. "Firm" refers to around-the-clock power production at a constant level.

The capacity of fossil-fueled and nuclear thermal generators that have formally announced retirement are removed from baseline thermal capacity using the announced retirement schedule.

3.1.2 Economic Retention

In the RESOLVE version used in the CPUC 2017 IRP analysis, existing thermal resources were assumed to be available indefinitely unless retirement had already been announced. The version of the RESOLVE model used in this analysis has been updated to determine the optimal level of dispatchable gas resources to retain that minimizes overall California system costs.

Fixed operations and maintenance costs (fixed O&M) of baseline gas-fired resources are considered in RESOLVE's optimization logic such that dispatchable gas generators will only be retained by the model, subject to reliability constraints, if it is cost-effective to do so. Fixed O&M costs are derived from NREL's 2018 Annual Technology Baseline.[6]

- Retention decisions are made for CCGTs, Peakers, and Reciprocating Engines.
- Gas resources located in local capacity regions are retained to maintain local reliability (Section 7.3)
- Combined heat and power (CHP) facilities are all retired in 2035.
- OTC plants (CAISO_ST) are retired on a pre-determined schedule. Retention decisions for these plants are not made by RESOLVE.

Note that RESOLVE's thermal economic retention functionality assesses whether it is economic to retain gas capacity for California ratepayers, but does not assess whether gas capacity should retire. In addition, gas plant operators may choose to keep plants online without a long-term contract.

3.1.3 California Resources Associated with CAISO

Baseline natural gas, coal, and nuclear resources serving California loads within the CAISO BAA are drawn from a combination of the CAISO Master Generating Capability List and the CAISO Master File. Planned new generation for the CAISO area is taken from the WECC 2028 Anchor Data Set. All CAISO OTC capacity is retired by the end of 2023.

[6] https://atb.nrel.gov/electricity/2018/

Table 15. Baseline Conventional Resources in the CAISO balancing area (MW)

Resource Class	2027	2030	2035	2040	2045
CHP	2,296	2,296	1,148	-	-
Nuclear*	635	635	635	635	635
CCGT1	13,333	13,333	13,333	13,333	13,333
CCGT2	2,928	2,928	2,928	2,928	2,928
Coal**	-	-	-	-	-
Peaker1	4,914	4,914	4,914	4,914	4,914
Peaker2	3,683	3,683	3,683	3,683	3,683
Advanced CCGT	-	-	-	-	-
Aero CT	-	-	-	-	-
Reciprocating Engine	255	255	255	255	255
ST (NoOTCExtension Schedule)	-	-	-	-	-
Total	**28,044**	**28,044**	**26,896**	**25,748**	**25,748**

**Diablo Canyon units are assumed to retire in 2024 and 2025. The share of Palo Verde Nuclear Generating Station capacity contracted to CAISO LSEs is included in all years and is modeled within CAISO in RESOLVE. After retirement of Diablo Canyon in 2025, all remaining CAISO nuclear capacity is from Palo Verde.*

*** Dedicated imports from the Intermountain Power Plant, located in Utah.*

3.1.4 Non-CAISO California Zones

For non-CAISO California Zones the baseline gas, coal, and nuclear generation fleet is based on the WECC 2028 ADS. The ADS is used to characterize the existing and anticipated future generation fleet in each non-CAISO associated resource. The ADS uses utility integrated resource plans to inform changes in the generation portfolio, including announced retirements of coal generators and near-term planned additions.

The combination of existing and planned thermal resources from all four California BAAs (CAISO, LADWP, BANC, IID) serve as the baseline thermal resource in this CEC SB100 analysis.

Table 16. Baseline conventional resources in non-CAISO California zones (MW)

Zone	Resource Class	2027	2030	2035	2040	2045
LADWP - Associated	Nuclear*	407	407	407	407	407
	Coal	-	-	-	-	-
	CCGT	2,755	2,755	2,755	2,755	2,755
	Peaker	1,647	1,647	1,647	1,647	1,647
	ST	371	197	197	197	197
	Subtotal, LADWP	**5,180**	**5,006**	**5,006**	**5,006**	**5,006**
IID - Associated	CCGT	255	255	255	255	255
	Peaker	327	327	397	327	327
	Subtotal, IID	**582**	**582**	**652**	**582**	**582**
BANC - Associated	CCGT	1,863	1,798	1,798	1,798	1,798
	Peaker	867	867	867	867	867
	Subtotal, BANC	**2,730**	**2,664**	**2,664**	**2,664**	**2,664**

3.1.5 Non-California, External Zones

For external zones (Northwest and Southwest), the baseline gas, coal, and nuclear generation fleet is based on the WECC 2028 ADS. The ADS is used to characterize the existing and anticipated future generation fleet in each associated resource. The ADS uses utility integrated resource plans to inform changes in the generation portfolio, including announced retirements of coal generators and near-term planned additions.

Table 17. Baseline conventional resources in non-California external zones (MW)

Zone	Resource Class	2027	2030	2035	2040	2045
NW	Nuclear	1,757	1,757	1,757	1,757	1,757
	Coal	8,126	7,364	7,364	7,364	7,364
	CCGT	9,573	9,573	9,573	9,573	9,573
	Peaker	2,993	2,993	2,993	2,993	2,993
	Subtotal, NW	**21,862**	**21,687**	**23,896**	**21,862**	**21,687**
SW	Nuclear*	2,998	2,998	2,998	2,998	2,998
	Coal	6,266	6,141	6,141	6,141	6,141
	CCGT	19,421	19,741	19,153	18,498	16,157
	Peaker	6,808	6,302	6,238	5,482	5,482
	ST	1,319	967	825	825	825
	Subtotal, SW	**33,813**	**33,150**	**31,783**	**33,813**	**33,150**

* In RESOLVE, Palo Verde is split between zones according to contractual ownership shares.

3.2 Renewables

Baseline renewable resources include all existing RPS eligible resources (solar, wind, biomass, geothermal, and small hydro) in each zone. Renewable resources with contracts already approved by the CPUC, CCA, or ESP boards, as well as those under development, are included in the baseline, though these resources are discounted by 5 percent to allow for contract or project failure.

Baseline behind-the-meter solar capacity is discussed in Sections 2.1.5 and 2.2 above.

3.2.1 CAISO

CAISO baseline renewable resources include (1) existing resources, whether under contract or not, and (2) resources that have executed contracts with LSEs. As described above, information on existing renewable resources within CAISO is compiled from the CAISO Master Generating Capability List and the CAISO Master File.

Information on resources that are under development with approved contacts is compiled from the CPUC IOU contract database. The CPUC maintains a database of all the IOUs' active and past contracting activities for renewable generation. Utilities submit monthly updates to this database with changes in contracting activities. Renewable contract information obtained from data requests to CCAs and ESPs is used to supplement the CPUC IOU contract database. The baseline renewable resource capacity in CAISO is shown in Table 18.

Table 18. Baseline Renewables in CAISO (MW)

Resource Class	2027	2030	2035	2040	2045
Small Hydro	967	967	967	967	967
Biomass	937	935	935	935	935
Geothermal	1,896	1,896	1,896	1,896	1,896
Solar	14,990	14,990	14,990	14,990	14,990
Wind	8,649	8,649	8,649	8,649	8,649
Total	**27,439**	**27,437**	**27,437**	**27,437**	**27,437**

3.2.2 Non-CAISO California Zones

Similar to the thermal fleet, for non-CAISO entities in California (those in the BAA IID, LADWP or BANC), the renewable resource portfolio is derived from the 2028 WECC ADS. The analysis kept the planned renewable build constant beyond 2020. Baseline renewable capacities for other California entities are shown in Table 19.

Table 19. Baseline Renewables in Other California Entities (MW)

Zone	Resource Class	2027	2030	2035	2040	2045
BANC	Biomass	18	18	18	18	18
	Geothermal	-	-	-	-	-
	Small Hydro	41	41	41	41	41
	Solar	2,078	2,078	2,078	2,078	2,078
	Wind	-	-	-	-	-
	BANC Total	**2,136**	**2,136**	**2,136**	**2,136**	**2,136**
IID	Biomass	77	77	77	77	77
	Geothermal	709	709	709	709	709
	Small Hydro	-	-	-	-	-
	Solar	139	139	139	139	139
	Wind	-	-	-	-	-
	IID Total	**925**	**925**	**925**	**925**	**925**
LADWP	Biomass	-	-	-	-	-
	Geothermal	-	-	-	-	-
	Small Hydro	56	56	56	56	56
	Solar	2,411	2,411	2,411	2,411	2,411
	Wind	418	418	418	418	418
	LADWP Total	**2,885**	**2,885**	**2,885**	**2,885**	**2,885**

3.2.3 Non-California External Zones

The portfolios of renewable resources in the NW and SW are based on WECC's 2028 Anchor Data Set, developed by WECC staff with input from stakeholders. Some of the resources in the ADS that are located outside of California represent resources under long-term contract to California LSEs. Since these resources are captured in the portfolios of CAISO and other California LSEs, they are removed from the baseline resource capacity of the non-California LSEs. Baseline renewable capacities for non-California LSEs are shown in Table 20.

Table 20. Baseline Renewables in non-California LSEs (MW)

Zone	Resource Class	2027	2030	2035	2040	2045
NW	Biomass	584	544	544	544	544
	Geothermal	142	142	132	132	132
	Small Hydro	41	41	41	41	41
	Solar	2,666	2,661	2,660	2,660	2,660
	Wind	11,057	10,956	10,956	10,956	10,956
	NW Total	**14,490**	**14,344**	**14,334**	**14,334**	**14,334**
SW	Biomass	113	108	108	108	108
	Geothermal	702	665	665	665	665
	Small Hydro	-	-	-	-	-
	Solar	1,855	1,831	1,652	1,647	1,637
	Wind	2,277	1,873	1,873	1,873	1,873
	SW Total	**4,947**	**4,477**	**4,297**	**4,292**	**4,282**

Resources that have a contract to supply RECs to a California LSE but are not dynamically scheduled into California are modeled as supplying RECs to California RPS requirements, but energy from these projects is added to the local zone's energy balance. The list of these resources is shown in Table 21.

Table 21.Renewable plants outside of California attributed to California loads

Generator Name	Capacity Contracted to CAISO (MW)
Arlington Wind Power Project-GEN1	103
Big Horn Wind Project-1	105
Big Horn Wind II-1	18
NaturEner Glacier Wind Energy 1-NGW1	107
NaturEner Glacier Wind Energy 2-NGW2	104
Goshen Phase II-1_Jolly Hills	90
Goshen Phase II-2_Jolly Hills	39
Horse Butte Wind I, LLC-1	7
Horseshoe Bend Wind LLC-1 AKA Shepherds Flat - South	145
Juniper Canyon I Wind Project-1	5
Klondike Wind Power-Ph 1	24
Klondike Windpower III-1	90
Luning Solar Energy Project 1	55
Macho Springs Wind Farm GEN	50
Midway Solar Farm	50
Milford Wind Corridor Project 1A	5
Nippon Biomass-ST1	20
North Hurlburt Wind LLC-1 AKA Shepherds Flat	133
Pebble Springs Wind LLC-1	20
NaturEner Rim Rock Energy-RR	189
RooseveltBiogasCC (Total CC Plant)	26
Salton Sea Unit 5 TG51	50
Second Imperial Geothermal Company - Heber II 1-12	33
South Hurlburt Wind LLC-4 AKA Shepherds Flat	145
Tieton Dam Hydro Electric Project-UNIT1	7
Turquoise Solar	10
Vantage Wind Energy LLC-1	96

3.3 Large Hydro

The existing large hydro resources in each zone of RESOLVE are assumed to remain unchanged over the timeline of the analysis. The large hydro resources in RESOLVE are represented as providing energy to their local zone, with the exception of Hoover, which is split among the California and SW zones in proportion to ownership shares.

A fraction of the total Pacific Northwest hydro capacity is made available to California as a directly scheduled import. In this CEC SB100 RESOLVE model, specified imports of hydro power from the Pacific Northwest are included as a baseline hydro resource and are dispatched on an hourly basis (Section 6.5.2). The quantity of specified hydro imported into California is based on historical import data from BPA and Powerex as reported in CARB's GHG emissions inventory.[7] Annual specified imports (in GWh/yr) are converted to an installed capacity (MW) assuming the same capacity factor as historical record of overall NW Hydro (46%) – this is for modeling purposes and is not meant to reflect contractual obligations for capacity.

Table 22. Large Hydro Installed Capacity

Region	Total (MW)
BANC - Associated	2,724
CAISO – Associated	7,070
IID – Associated	84
LADWP – Associated	600
NW	31,478
NW Hydro for CAISO	2,852
SW	2,680

3.4 Energy Storage

3.4.1 Pumped Storage

Existing pumped storage resources in the CAISO BAA are based on the CAISO Master Generating Capability List and shown below.

[7] CARB GHG Current California Emission Inventory Data available at: https://ww2.arb.ca.gov/ghg-inventory-data

Table 23. Existing pumped storage resources in CAISO

Unit	Capacity (MW)
Eastwood	200
Helms	1218
Lake Hodges	40
O'Neil	25.2
Other (WNDGPP)	116
Total	**1599**

The individual existing pumped storage resources shown in the table are aggregated into one resource class. The total storage capability of existing pumped storage in MWh is calculated based on input assumptions in CAISO's 2014 LTPP PLEXOS database. Because of RESOLVE'S 24-hour dispatch window, the energy arbitrage value resulting from the capability to store energy for more than one day is not captured in RESOLVE.

3.4.2 Baseline Battery Storage

Baseline storage resources include all battery storage that is currently installed in the CAISO footprint, as well as further battery storage development that is likely to occur due to state policy mandate. Specifically, 1,285 MW of battery storage is modeled to fulfill the CPUC procurement targets established in response to AB 2514.[8] The remaining 40 MW of the total 1,325 MW of AB 2514 targets is the Lake Hodges Pumped Hydro project, which is included with pumped storage. Mandated battery storage capacity not already installed or contracted is allocated between wholesale (transmission and distribution interconnection domain) and behind-the-meter installations (customer-side) in-line with AB2514.

In addition to the mandated procurement amount, LSE responses to an April 2019 data request identified the following:

- Online dates and capacity, where IOUs have procured storage earlier than required by AB2514. For each IOU and each sub-domain, the greater of actual and mandated procurement is assumed.

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[8] AB 2514 was signed into law on September 29, 2010. https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=200920100AB2514

- Additional behind-the-meter storage installations resulting from the Small Generator Incentive Program (SGIP) not already accounted for under other mandated procurement, including AB2514.
- Non-IOU storage procurement.

Based on the April 2019 data from LSEs, baseline utility scale storage resources are assumed to have an average duration of 4 hours. Baseline behind-the meter storage resources that are LSE-procured are assumed to have an average duration of 4 hours, with the remaining behind-the-meter storage resources assumed to have 2 hours duration.

Table 24. Baseline Battery Storage (MW)

Battery Storage Resource	2027	2030	2035	2040	2045
Utility-scale	1,617	1,617	1,617	1,617	1,617
Behind-the-meter	1,402	1,647	1,647	1,647	1,647

3.5 Demand Response

Shed (or "conventional") demand response reduces demand only during peak demand events. The 2019-2020 IRP treats the IOUs' existing shed demand response programs as baseline resources. Shed demand response procured through the Demand Response Auction Mechanism (DRAM) is included. The assumed peak load impact for each utility's programs is based on the April 1, 2018 Demand Response Load Impact Report.[9] As shown in Table 25, RESOLVE includes two options for baseline shed demand response capacity.

Table 25. Baseline Shed Demand Response (MW)

Scenario Setting	Region	2027	2030	2035	2040	2045
Reliability & Economic	PG&E	541	541	541	541	541
	SCE	1,019	1,019	1,019	1,019	1,019
	SDG&E	56	56	56	56	56

[9] CPUC Decision (D.)16-06-029, *Decision Adopting Bridge Funding for 2017 Demand Response Programs and Activities,* authorized PG&E and SDG&E to eliminate their Demand Bidding Program (DBP) starting in 2017, and SCE to eliminate its DBP program starting in 2018 (at p.43). D.16-06-029 also authorizes decreases in Aggregator Managed Portfolio (AMP) program capacity. The effects of these authorizations should be captured in the April 1, 2018, DR Load Impact Report.

Programs (default)	*Total*	*1,617*	*1,617*	*1,617*	*1,617*	*1,617*
	Total, with avoided losses	**1,752**	**1,752**	**1,752**	**1,752**	**1,752**
Reliability Programs Only	PG&E	330	330	330	330	330
	SCE	696	696	696	696	696
	SDG&E	7	7	7	7	7
	Total	*1,033*	*1,033*	*1,033*	*1,033*	*1,033*
	Total, with avoided losses	**1,119**	**1,119**	**1,119**	**1,119**	**1,119**

An additional 443 MW of interruptible pumping load from the CAISO NQC list is included as baseline shed DR capacity in all years.

4. Candidate Resources

“Candidate” resources represent the menu of new resource options from which RESOLVE can select to create an optimal portfolio. RESOLVE can add many different types of resources, including natural gas generation, renewables, energy storage, and demand response. The optimal mix of candidate resources is a function of the relative costs and characteristics of the entire resource portfolio (both baseline and candidate) and the constraints that the portfolio must meet. Capital costs are included in the RESOLVE optimization for candidate resources, whereas capital costs are excluded for baseline resources.

Generation profiles and operating characteristics are addressed in Section 6.

4.1 Natural Gas

The CEC SB100 model includes three technology options for new natural gas generation: Advanced Combined Cycle (CCGT), Aeroderivative Combustion Turbine (CT), and Reciprocating Engine. Each option has different costs, efficiency, and operational characteristics. Natural gas generator all-in fixed costs trajectories are derived from NREL’s 2019 Annual Technology Baseline[10] and the WECC capital cost study.[11] Natural gas fuel costs are discussed in Section 6.6. Operational assumptions for these plants are summarized in Section 6.3. The first year that new natural gas generation is assumed to be able to come online is 2025.

Table 26. All-in fixed costs for candidate natural gas resources in 2030 (2016$)

Resource Class	Capital Cost ($/kW)	Fixed O&M Cost ($/kW-yr)	All-In Fixed Cost ($/kW-yr)
CA_Advanced_CCGT	$1,205	$11.1	$122
CA_Aero_CT	$1,283	$13.6	$133
CA_Reciprocating_Engine	$1,283	$13.6	$133

4.2 Renewables

RESOLVE can select from the following candidate renewable resources:

[10] https://atb.nrel.gov/electricity/2019/

[11] https://www.wecc.org/Administrative/E3-WECC%20Resource%20Cost%20Update-201905%20RAC%20DS%20Presentation.pdf

- Biomass
- Geothermal
- Small Hydro
- Solar Photovoltaic
- Onshore Wind
- Offshore Wind
- Hydrogen Fuel Cell

Candidate solar photovoltaic resources are represented as either utility-scale or distributed. Utility-scale and distributed solar resources differ in cost (Section 4.2.6.1), transmission (Section 4.2.7), and performance (Section 6.2) assumptions.

4.2.1 Resource Potential and Renewable Transmission Zones

Stakeholder feedback informed updates to the 2017-2018 CPUC IRP assumptions on the potential of candidate renewable resources, which were based on data developed by Black & Veatch for the CPUC's RPS Calculator v.6.3.[12] The Black & Veatch study includes an assessment of potentially viable sites and resource potential within those sites to determine an overall technical potential for each renewable technology.

The Black & Veatch study uses geospatial analysis to identify potential sites for renewable development in California and throughout the Western Interconnection. For input into RESOLVE, the detailed geospatial dataset developed by Black & Veatch is aggregated into "transmission zones." In the 2017-2018 CPUC IRP cycle, the transmission zones were expressed as groupings of Competitive Renewable Energy Zones (CREZs). These groupings have been updated for the 2019-2020 CPUC IRP cycle to incorporate CAISO's most recent transmission capability estimates.[13] Specifically, geospatial information on the extent of transmission constraints is used to assign individual wind, solar, and geothermal resources in the Black & Veatch dataset to a specific transmission zone or subzone. Individual resources within a transmission zone or subzone are aggregated, resulting in a "Base" resource potential for each

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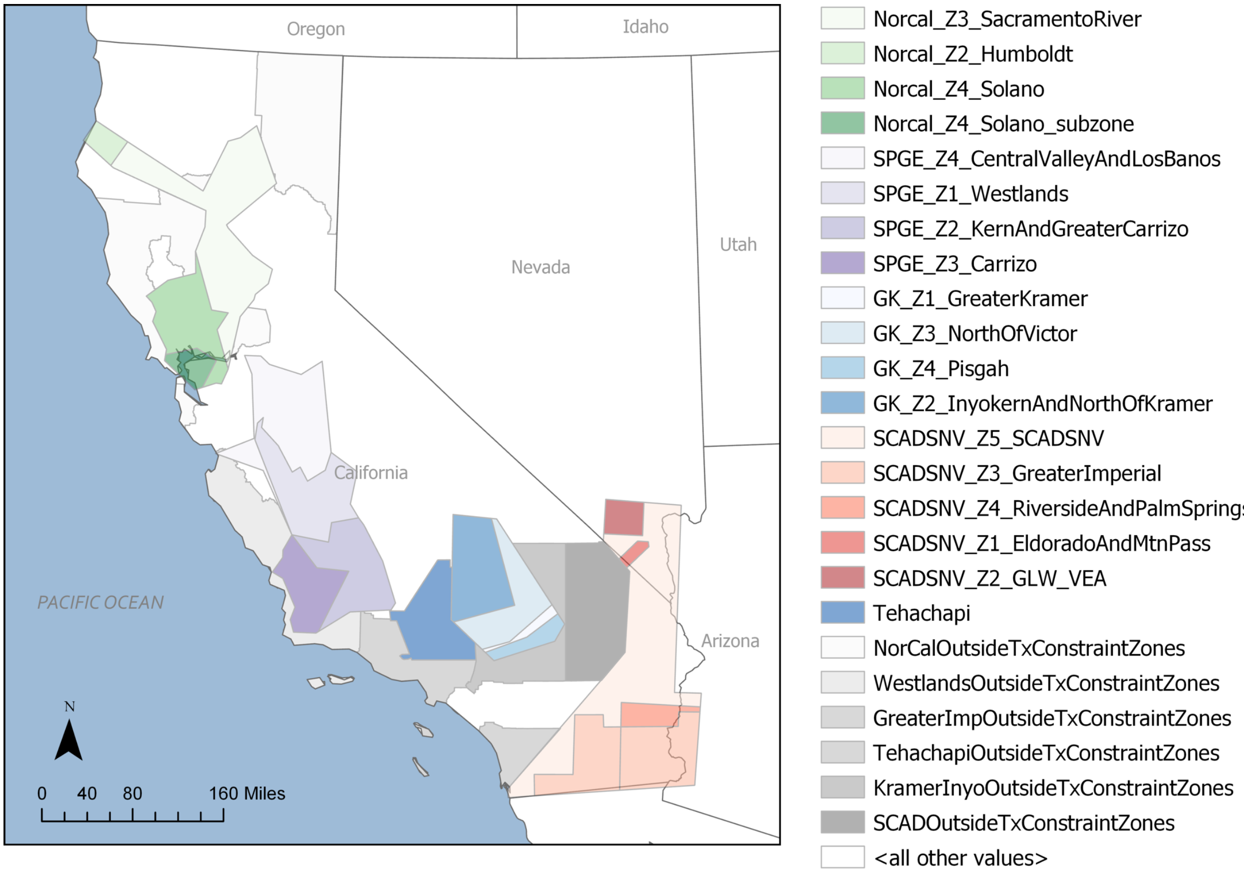
[12] Black & Veatch, *RPS Calculator V6.3 Data Updates*. Available at: http://www.cpuc.ca.gov/uploadedFiles/CPUC_Website/Content/Utilities_and_Industries/Energy/Energy_Programs/Electric_Power_Procurement_and_Generation/LTPP/RPSCalc_CostPotentialUpdate_2016.pdf. Note that although the data was developed with the intention of incorporating it into a new version of the RPS Calculator, no version 6.3 was been developed. This is because the IRP system plan development process replaced the function previously served by the RPS Calculator.

[13] Transmission Capability Estimates for Inputs to the CPUC Integrated Resource Plan Portfolio Development. http://www.caiso.com/Documents/TransmissionCapabilityEstimates-Inputs-CPUCIntegratedResourcePlanPortfolioDevelopment-Call052819.html

zone-technology combination. This is maintained in this CEC SB100 model. The transmission zones are shown in Figure 4.1 below and described in Section 4.2.7.

Figure 4.1. In-state transmission zones in RESOLVE



Candidate biomass and distributed solar resources are not assigned a transmission zone because they are assumed to serve local load.

4.2.2 Environmental Screens

The raw technical potential estimates developed by Black & Veatch are filtered through a set of environmental screens to produce the potential available to RESOLVE (Table 27). The RESOLVE Scenario Tool includes several options for environmental screens, which were originally developed for the RPS Calculator:

- **Base:** includes RETI Category 1 exclusions only
- **Environmental Baseline (EnvBase):** includes RETI Category 1 and 2 exclusions
- **NGO1:** first screen developed by environmental NGOs
- **NGO1&2:** second screen developed by environmental NGOs

- **DRECP/SJV:** includes RETI Categories 1 and 2 plus preferred development areas only in the DRECP (Desert Renewable Energy Conservation Plan)[14] and San Joaquin Valley (SJV).
- **Conservative:** the potential when all the above screens are applied simultaneously

A more detailed explanation of each environmental screen is available in the Black & Veatch, RPS Calculator V6.3 Data Updates.[15]

In the 2017-2018 CPUC IRP, candidate solar capacity as calculated from Black and Veatch geospatial analysis was discounted by 95% to reflect land use constraints and preference for geographic diversity. This value has been updated to 80% in the 2019-2020 IRP because geographic diversity is largely enforced by transmission limits. As a result, the solar potential reflected in Table 27 is four times the 2017-2018 IRP values for most solar resources.

Adjustments are made to the supply curve potentials for certain resources under all environmental screens. In addition, planned resources with an online date after December 31, 2018 that are included in the baseline are subtracted from the available potential in the supply curve. Finally, reflecting commercial interest and recent CAISO interconnection queue capacity, 866 MW of Northern California wind resources are assumed available under all screens.

For this SB100 analysis the DRECP/SJV resource screen was used.

Table 27. California renewable potential under various environmental screens (MW)

Resource Type	Resource	Base	Env Base	NGO1	NGO1&2	DRECP/ SJV	Conservative
Biomass	InState_Biomass	1,147	1,147	1,147	1,147	1,147	1,147
Geothermal	Greater_Imperial	1,352	1,352	1,352	1,352	1,352	1,352
	Inyokern_North_Kramer	24	24	24	24	24	24
	Northern_California_Ex	469	469	469	469	469	469
	Riverside_Palm_Springs	32	32	32	32	32	32
	Solano	135	135	135	135	135	135
	Geothermal, subtotal	**2,012**	**2,012**	**2,012**	**2,012**	**2,012**	**2,012**
Solar	Carrizo	12,021	9,842	11,939	5,867	9,907	5,867
	Central_Valley_North_Los_Banos	28,170	19,759	27,707	16,651	12,873	11,801
	Distributed	36,605	36,605	36,605	36,605	36,605	36,605
	Mountain_Pass_El_Dorado	1,152	60	1,152	41	248	41

[14] https://www.drecp.org/

[15] http://www.cpuc.ca.gov/uploadedFiles/CPUC_Website/Content/Utilities_and_Industries/Energy/Energy_Programs/Electric_Power_Procurement_and_Generation/LTPP/RPSCalc_CostPotentialUpdate_2016.pdf

	Greater_Imperial	27,759	18,632	27,366	17,714	35,216	14,455
	Inyokern_North_Kramer	7,697	4,804	7,695	4,751	23,653	4,009
	Kern_Greater_Carrizo	20,041	18,280	18,732	12,847	8,329	8,329
	Kramer_Inyokern_Ex*	8,484	6,138	8,409	6,134	4,508	4,508
	North_Victor	6,992	5,886	6,949	5,779	4,608	4,256
	Northern_California_Ex	68,912	41,306	67,698	33,367	41,532	33,367
	Riverside_Palm_Springs	11,777	5,711	11,757	5,396	57,071	5,396
	Sacramento_River	28,684	23,260	27,346	19,784	23,484	19,784
	SCADSNV	10,224	3,121	10,122	3,076	5,608	2,162
	Solano	16,588	11,937	15,521	9,724	12,025	9,724
	Solano_subzone	-	4	-	4	-	-
	Southern_California_Desert_Ex	6,290	3,067	6,230	2,944	43,713	566
	Tehachapi_Ex*	2,202	1,487	2,168	1,481	1,488	1,481
	Tehachapi**	17,650	13,480	17,363	13,294	3,801	3,801
	Westlands_Ex_Solar	5,358	4,394	5,304	4,269	4,404	4,269
	Westlands_Solar	26,671	24,705	26,305	22,599	56,151	22,599
	Solar, subtotal	343,277	254,184	338,214	223,991	385,224	193,020
Wind	Carrizo	288	288	288	244	287	244
	Central_Valley_North_Los_Banos	398	173	352	91	173	91
	Distributed	-	-	-	-	-	-
	Greater_Imperial	785	-	782	-	-	-
	Greater_Kramer	445	80	389	80	-	-
	Humboldt	34	34	34	34	34	34
	Kern_Greater_Carrizo	69	60	69	60	60	60
	Kramer_Inyokern_Ex*	81	-	77	-	-	-
	Northern_California_Ex	866	866	866	866	866	866
	SCADSNV	100	-	96	-	-	-
	Solano_subzone	50	18	46	1	18	1
	Solano	576	550	524	453	542	445
	Southern_California_Desert_Ex	48	48	48	48	-	-
	Tehachapi	802	583	791	572	275	273
	Westlands_Ex	-	-	-	-	-	-
	Wind, subtotal	**4,542**	**2,700**	**4,361**	**2,448**	**2,255**	**2,013**

**Reflecting commercial interest, resource potential was removed via transmission limits*

*** Displayed Tehachapi solar potential reflects a 1 GW increase to pure land use screening due to more availability on transmission network*

4.2.3 Out of State Resource Potential

The available potential for out-of-state resources relies primarily on Black & Veatch's assessment of renewable resource potential that identifies "high-quality" resources in Western Renewable Energy Zones (WREZs). WREZ resource potential is aggregated into regional bundles to create candidate out-of-state renewable resources for RESOLVE. Some of these resources are assumed to require investments in new transmission to deliver to California loads. These estimates of resource potential are supplemented with assumptions regarding the availability of lower capacity factor renewables that may be interconnected on the existing transmission system.

To explore different levels of out-of-state resource availability, the CEC SB100 model includes two "screens" for out-of-state resources[16]:

- **None:** no candidate out-of-state resources are included except for Baja California wind, Southern Nevada wind and solar, and Arizona solar resources that directly connect to the CAISO transmission system.
- **Existing & NM/WY wind:** New Mexico and Wyoming out-of-state wind resources requiring major investments in new transmission, are included as candidate resources.

The amount of renewable potential included under each screen is summarized in Table 28. All estimates of potential shown in this table—with the exception of resources assumed to interconnect to the existing transmission system—are based on Black & Veatch's potential assessment. The Existing & NM/WY wind screen is the default screen for the CEC SB100 analysis, however the default potential of out-of-state wind is limited to 12,000 MW (6,000 MW of Wyoming and 6,000 MW of New Mexico wind resources) to reflect the likelihood that two double-circuit large high-voltage transmission lines (~3,000 MW each) to each of these wind resources could be built.

Reflecting commercial interest and recent CAISO interconnection queue capacity, 600 MW of Baja California wind resources, and all of the Arizona solar potential, are available for selection in all model runs.

[16] Information regarding individual land use screens is available in the Renewable Energy Transmission Initiative 2.0 Plenary Report. https://www.energy.ca.gov/reti/reti2/documents/index.html

Table 28. Out-of-state renewable potential under various scenario settings

Type	Resource	Renewable Potential (MW)	
		None	Existing & NM/WY wind
Geothermal	Southern Nevada	320	320
	Subtotal, Geothermal	**320**	**320**
Solar	Arizona	77,080	77,080
	New Mexico	—	—
	Southern Nevada	148,600	148,600
	Utah	—	—
	Subtotal, Solar	**225,680**	**225,680**
Wind	Arizona	—	—
	Baja California	600	600
	Idaho	—	—
	New Mexico (Existing Tx)	—	500
	New Mexico	—	6,000 (Limited)
	Pacific Northwest (Existing Tx)	—	1,500
	Pacific Northwest	—	—
	Southern Nevada	442	442
	Utah	—	—
	Wyoming	—	6,000 (Limited)
	Subtotal, Wind	**1,042**	**15,042 (Full)**

4.2.4 Offshore Wind Resource Potential

Data for offshore wind potential is sourced from the UC Berkeley study California Offshore Wind: Workforce Impacts and Grid Integration.[17] The report identifies offshore wind resource zones based on existing BOEM call areas for California, as well as potential future development sites identified in studies by BOEM and NREL. In this study, offshore wind availability is limited to 10 GW over four resource zones: Morro Bay, Diablo Canyon, Humboldt Bay, and Cape Mendocino. The offshore wind resource potential assumptions are shown below.

Table 29. Offshore Wind Resource Potential

Offshore Wind Resource Zone	Resource Potential Area (Sq. km)	Resource Potential (MW)
Cape Mendocino	2,072	6,216 (Full) 1,649 (Limited)
Diablo Canyon	1,441	4,324
Morro Bay	806	2,419
Humboldt Bay	536	1,607
Total	**4,855**	**14,566 (Full)** **10,000 (Limited)**

Note that the offshore resource potential shown in Table 29 represents that amount that could be developed offshore.

4.2.5 First Available Year and Annual Deployment Limits

Assumptions for the first available year of candidate renewables resource types reflect feasible timelines for bringing resources online based on the current interconnection queue and typical development timelines. The first available year in RESOLVE is applied on a resource-by-resource basis; accordingly, a range of years applies when summarizing by resource type in Table 30.

Table 30. First available year by candidate renewable resource type

Resource Type	First Available Year
Solar PV	2020

[17] Available at: http://laborcenter.berkeley.edu/offshore-wind-workforce-grid/

Wind (CA onshore)	2022-2023
Wind (OOS onshore)	2026
Wind (offshore)	2030
Geothermal	2024-2026
Biomass	2020
Pumped Storage	2026
Battery Storage	2020

In addition to limiting the deployment of resources based on the first available year, RESOLVE can also enforce annual deployment limits over a group of resources.

4.2.6 Resource Cost

NREL's 2019 Annual Technology Baseline is used as the primary basis for renewable generation cost updates.[18] Hydrogen fuel cell cost estimates are based on the US Department of Energy 2020 technical targets for fuel cell systems[19] and cost trajectories in the E3 study "The Challenge of Retail Gas in California's Low-Carbon Future" for the CEC.[20] The assumptions for RESOLVE renewable resources are shown in the tables below for in-state, out-of-state, and offshore wind resources, respectively. The input to RESOLVE is an assumed levelized fixed cost ($/kW-yr) for each resource; this is translated into the levelized cost of energy ($/MWh) for comparability with typical Power Purchase Agreements (PPA) entered into between LSEs and third-party developers.

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[18] Biomass capital costs were revised from Annual Technology Baseline assumptions based on stakeholder input

[19] US Department of Energy Fuel Cell Technologies Office. 2017. *Multi-Year Research, Development, and Demonstration Plan. 3.4 Fuel Cells.* https://www.energy.gov/sites/prod/files/2017/05/f34/fcto_myrdd_fuel_cells.pdf. Table 3.4.14.

[20] Assuming off-grid California wind or solar to power the electrolyzer, with electrolyzer costs and trajectories developed by the University of California at Irvine (UCI) for the E3 study "The Challenge of Retail Gas in California's Low-Carbon Future" for the California Energy Commission:
Aas, Dan, Amber Mahone, Zack Subin, Michael Mac Kinnon, Blake Lane, and Snuller Price. 2020. *The Challenge of Retail Gas in California's Low-Carbon Future: Technology Options, Customer Costs and Public Health Benefits of Reducing Natural Gas Use. Appendix C.* California Energy Commission. Publication Number: CEC-500-2019-055-AP-G. https://ww2.energy.ca.gov/2019publications/CEC-500-2019-055/CEC-500-2019-055-AP-G.pdf.