2019-20 IRP: Proposed Reference System Portfolio Validation with SERVM Reliability and Production Cost Modeling

CPUC Energy Division

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Purpose

- Summarize key inputs and highlight most recent revisions to SERVM model inputs
- Present CPUC staff operational and reliability modeling results for the Proposed Reference System Portfolio

Content

1. CONTEXT AND BACKGROUND

IRP Modeling Context

- Staff used the RESOLVE capacity expansion model to design portfolios of new resources expected to meet electric system planning goals at least cost
  - See the main Proposed Reference System Portfolio presentation for details on portfolio development with RESOLVE
- Staff used the SERVM probabilistic reliability and production cost model to validate the reliability, operability, and emissions of resource portfolios generated by RESOLVE
  - This presentation describes results from SERVM informing the choice of and validating the Proposed Reference System Portfolio
- Both models have roles in developing a robust and optimal resource portfolio suitable for guiding policy, procurement, and transmission planning
- For further description of the overall IRP modeling framework, see the 10/8/19 workshop Preliminary Modeling Results and Calibration presentations on the IRP website

SERVM Model Overview

The Strategic Energy Risk Valuation Model (SERVM)* is a probabilistic system-reliability planning and production cost model. SERVM is designed to inform security-constrained planning, meaning the primary objective is to reduce risk of insufficient generation to an acceptable level.

- Configured to assess a given portfolio in a target study year under a range of future weather (20 weather years), economic output (5 weighted levels), and unit performance (30+ random outage draws)
- Hourly economic unit commitment and dispatch
  - Reserve targets to reflect provision of subhourly balancing and ancillary services
  - Multiple day look-ahead informs unit commitment
  - Individual generating units and all 8,760 hours of year are simulated
  - Unit operating costs and constraints
- Zonal representation of transmission system
  - 8 CA regions, 16 rest-of-WECC regions
  - Includes region-to-region flow limits and hurdle rates as well as simultaneous flow limits

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Modeling Activity Background

- Through most of 2019, RESOLVE and SERVM underwent a calibration process involving input development from a common dataset and iteratively running and adjusting both models to align common metrics
- Baseline inputs were shared with stakeholders at the 6/17/19 Modeling Advisory Group webinar
- Calibration results were shared with stakeholders at the 10/8/19 IRP workshop
- Up-to-date inputs used by SERVM are posted to the Unified RA and IRP Modeling Datasets 2019 webpage
- Updated RESOLVE inputs are separately described in detail at the latest RESOLVE model webpage found at the IRP website

2. OVERVIEW OF MODELING INPUTS

Key Updates to SERVM from Version Used in 2017-18 IRP Cycle

Staff performed a full data update at the beginning of the IRP cycle. Updates included:

- Use of the CEC's 2018 Integrated Energy Policy Report (IEPR) Update Demand Forecast
- Updated weather-based hourly profiles to cover weather years 1998-2017: includes scheduled hydro, hourly electric demand, hourly wind and solar generation profiles as described at the 6/17 Modeling Advisory Group webinar and the 10/8 IRP workshop
- Updated operating parameters for individual resources (and aggregated to RESOLVE categories) based on January 2019 CAISO MasterFile information and WECC 2028 Anchor Data Set Phase 2 V1.2
- Added the ability for storage to provide spinning and load following reserves (in addition to already providing regulation and frequency response)
- Updated forced and scheduled outage statistics based on 2013-2017 from NERC's Generating Availability Data System
- Developed scaling factors in SERVM to ensure that annual energy from behind-the-meter (BTM) solar PV installations modeled in SERVM would match with the annual energy from BTM solar projected in CEC's IEPR
- Approximated ambient temperature capacity derate for gas units based on summer Net Qualifying Capacity for these units

Key SERVM Updates Since 10/8/19 Workshop

Up-to-date SERVM inputs are posted to the Unified RA and IRP Modeling Datasets 2019 webpage. Changes since 10/8 include:

- Corrected BPAT to PG&E Valley zone transmission flow limit
- Made small corrections to baseline units accounting for recently online projects
- Implemented Once-Through-Cooling units extension as modeled in RESOLVE
- Added generic solar to BANC and LADWP regions, consistent with RESOLVE and assumed achievement of SB 100 required levels of renewables penetration by 2030
- Implemented additional constraint on CAISO import flows during peak load conditions – details on next page

Implementing an Additional Simultaneous Import Constraint Due to Limits on Firm Import Capacity

- Both RESOLVE and SERVM model a 11,665 MW CAISO simultaneous import limit covering all hours. In any hour, the import flow into CAISO cannot exceed this limit.
- RESOLVE also models a separate Planning Reserve Margin (PRM) constraint where the portfolio must always have enough effective capacity to meet a 15% PRM. As a default, RESOLVE assumes that 5,000 MW of imports can count towards effective capacity to meet Resource Adequacy (RA) requirements.
  - In a future where non-CAISO areas are less willing to provide RA for CAISO entities, RESOLVE assumes only 2,000 MW of firm imports that can count towards RA
- SERVM does not model a PRM constraint like RESOLVE. To reflect a constraint on firm imports that can count towards RA, staff added a second CAISO simultaneous import limit of 5,000 MW that would apply for all hours where gross electric demand is higher than the 95th percentile. This approximates the stressed hours of the year that the RA program is intended to cover.
  - Previously presented SERVM results did not include this second constraint. As will be explained later in this presentation, this is a key constraint that can contribute to loss-of-load events.

3. SERVM RESULTS AND RESOLVE COMPARISON

Review of Model Calibration Process

- Inputs for both models were sourced from common datasets and aligned to the maximum extent possible
- Staff set RESOLVE to the desired GHG target and generated a portfolio of candidate resources
- Staff added the new resource portfolio to SERVM, ran the model, and extracted key metrics (GHG emissions, production costs, LOLE, energy production by resource categories, etc.)
- Both models were adjusted and run iteratively until GHG emissions and resource dispatch were reasonably aligned, and SERVM confirmed the modeled electric system was reliable and operable
- Staff aligned GHG emissions in RESOLVE and SERVM under a range of GHG reduction targets: see details in the Calibration presentation from the 10/8/19 workshop
- Staff used the calibrated RESOLVE to explore additional sensitivities and scenarios as explained in the Proposed Reference System Portfolio presentation
- The reliability of the Proposed Reference System Portfolio was assessed with SERVM for years 2022, 2026, and 2030

Review of SERVM Metrics

- Staff validates the reliability of RESOLVE portfolios through Loss-of-Load Expectation (LOLE) studies with SERVM
  - Output metrics include expected frequency of events (LOLE), expected duration of unserved energy (Loss-of-Load Hours or LOLH), and expected volume of unserved energy (Expected Unserved Energy or EUE)
  - Staff considered the electric system sufficiently reliable if the probability-weighted LOLE was less than or equal to 0.1. This corresponds to about 1 day in 10 years where firm load must be shed to balance the grid.
- Staff also validates operations and emissions through the same studies since SERVM is also a production cost model
  - Annual energy by resource type, imports and exports, curtailment, storage dispatch, and emissions were compared to RESOLVE

SERVM Assessment of Updated RESOLVE Cases

- As discussed in the Proposed Reference System Portfolio presentation, a couple of key updates in RESOLVE cases modeled have occurred since the 10/8/19 workshop that determined which portfolios should be validated for reliability, operability, and emissions using SERVM.
  - RESOLVE implementation of nested transmission constraints and various small updates/corrections to inputs
  - Near-term resource availability studies
- Two updated RESOLVE cases were selected for validation with SERVM, the 46 MMT Default, and the 46 MMT Alternate.
- In addition, staff revised SERVM's modeling of import constraints to approximate a future where firm imports that can be counted upon for resource adequacy are limited, consistent with RESOLVE's PRM constraint.
  - As will be shown on the following pages, this additional constraint materially affects the reliability assessment in SERVM.

Case Definitions

	RESOLVE	SERVM	RESOLVE	SERVM
Name of case in RESOLVE Near-Term Resource Availability Study	**46 MMT**		**46 MMT limited near-term solar and partial OTC extension**	
Name of case in Ruling	**46 MMT Default**		**46 MMT Alternate**	
OTC extension assumption	None	None	2,289 MW [a]	2,241 MW
Near-term solar build limit	None	N/A	Yes	N/A
Imports to count towards RA (the PRM constraint)	5,000 MW	N/A	5,000 MW	N/A
Import limit during peak load conditions	N/A	Both None and 5,000 MW were modeled [b]	N/A	5,000 MW
Import limit for all other hours	11,665 MW	11,665 MW	11,665 MW	11,665 MW

[a] RESOLVE extended half of aggregate OTC capacity to 2023, whereas SERVM extended specific units to 2023, hence the small difference

[b] This case was modeled both with and without the additional import constraint in SERVM

RESOLVE Selected Resources for each Case

		46 MMT Default			**46 MMT Alternate**		
Selected Resource Summary							
	Unit	**2022**	**2026**	**2030**	**2022**	**2026**	**2030**
Biomass	*MW*	-	-	-	-	-	-
Geothermal	*MW*	-	-	-	-	-	-
Solar	*MW*	-	11,807	11,807	4,006	6,006	11,774
Wind	*MW*	1,950	2,372	2,837	1,950	2,550	2,837
Wind OOS New Tx	*MW*	-	-	-	-	-	-
Offshore Wind	*MW*	-	-	-	-	-	-
Battery Storage	*MW*	2,960	5,796	11,376	624	5,193	11,384
Pumped Storage	*MW*	-	-	-	-	-	-
Shed DR	*MW*	222	222	222	222	222	222
Gas Capacity Not Retained	*MW*	-	-	*(3,682)*	-	-	*(3,704)*

Reliability Results for the 46 MMT Default Case

	46 MMT Default w/ no import limit during peak load conditions			46 MMT Default w/ 5,000 MW import limit during peak load conditions		
	2022	*2026*	*2030*	*2022*	*2026*	*2030*
LOLE (expected outage events/year)	**0.000**	**0.000**	**0.005**	**0.220**	**0.108**	**0.166**
LOLH (hours/year)	0.000	0.000	0.007	0.505	0.191	0.268
LOLH/LOLE (hours/event)	0.000	0.000	1.509	2.300	1.758	1.613
EUE (MWh)	0.0	0.0	14.3	456.9	251.1	763.6
annual load (MWh)	247,335,870	253,489,278	256,512,173	249,710,160	253,487,073	256,497,901
normalized EUE (%) *	0.000000%	0.000000%	0.000006%	0.000183%	0.000099%	0.000298%

- 46 MMT Default case was studied in SERVM without the new import constraint. Consistent with earlier studies presented in the 10/8/19 workshop, LOLE was well below 0.1.
- When the 5,000 MW import constraint was added, LOLE increased to above 0.1.
- Given similarity in RESOLVE selected resources between the 46 MMT Default and 46 MMT Alternate cases (see previous page’s comparison), staff expected a SERVM study with the 46 Alternate case as-is from RESOLVE would also result in LOLE > 0.1.

* Normalized EUE = EUE/annual load expressed as a percent

Reliability Results for the 46 MMT Alternate Case

	46 MMT Alternate w/ 5,000 MW import limit during peak load conditions *2022*	 *2026*	 *2030*
LOLE (expected outage events/year)	**0.070**	**0.056**	**0.016**
LOLH (hours/year)	0.097	0.094	0.032
LOLH/LOLE (hours/event)	1.390	1.668	1.955
EUE (MWh)	94.5	114.9	43.9
annual load (MWh)	247,331,018	253,492,922	256,512,296
normalized EUE (%)	0.000038%	0.000045%	0.000017%
Generic effective capacity added only to SERVM	**0**	**2,000 MW**	**2,000 MW**

- Rather than study the 46 MMT Alternate case as-is from RESOLVE, staff added 2,000 MW of generic effective capacity only to SERVM, for the purposes of validating reliability
- Addition of 2,000 MW of generic effective capacity in 2026 and 2030 decreased LOLE to below 0.1 for each year, meeting the threshold for sufficient reliability
- No capacity was added to 2022 since the assumption about partial OTC extension provided sufficient effective capacity in the near-term
- Generic effective capacity was modeled as a perfectly dispatchable peaker with zero-emissions. In reality, the additional capacity could be realized through firm imports, batteries paired with solar, geothermal, more economic retention of existing thermal generation, demand response, or other.

Explanation of Reliability Results

- The PRM constraint in RESOLVE (intended to ensure sufficient effective capacity) and SERVM's reliability assessment appear to be slightly uncalibrated – RESOLVE does not build quite enough effective capacity to ensure no more than 0.1 LOLE. Possible reasons:
  - Effective Load Carrying Capability (ELCC) of wind and solar in RESOLVE (used to count contribution towards meeting PRM constraint) was not based on SERVM analysis
  - Wind ELCC in RESOLVE is somewhat higher than most recent SERVM analysis in the RA proceeding shows
  - The battery storage ELCC curve implemented in RESOLVE may be too generous in quantifying the effective capacity of storage. The RA import constraint implemented in SERVM results in higher capacity need at stressed hours and storage may be less effective at filling that incremental capacity need.
  - Different load, wind, and solar shapes between models
- Although it is challenging to use two different models, uncovering this disconnect demonstrates the utility of two different models each designed for a specific objective of the IRP process
- Both IRP models succeeded at what they were designed to do:
  - RESOLVE selected the least-cost portfolio to satisfy various constraints
  - SERVM tested the reliability of that portfolio

Hours with Expected Unserved Energy (EUE) Occur in the Evening

46 MMT Alternate + 2,000 MW Generic Effective Capacity

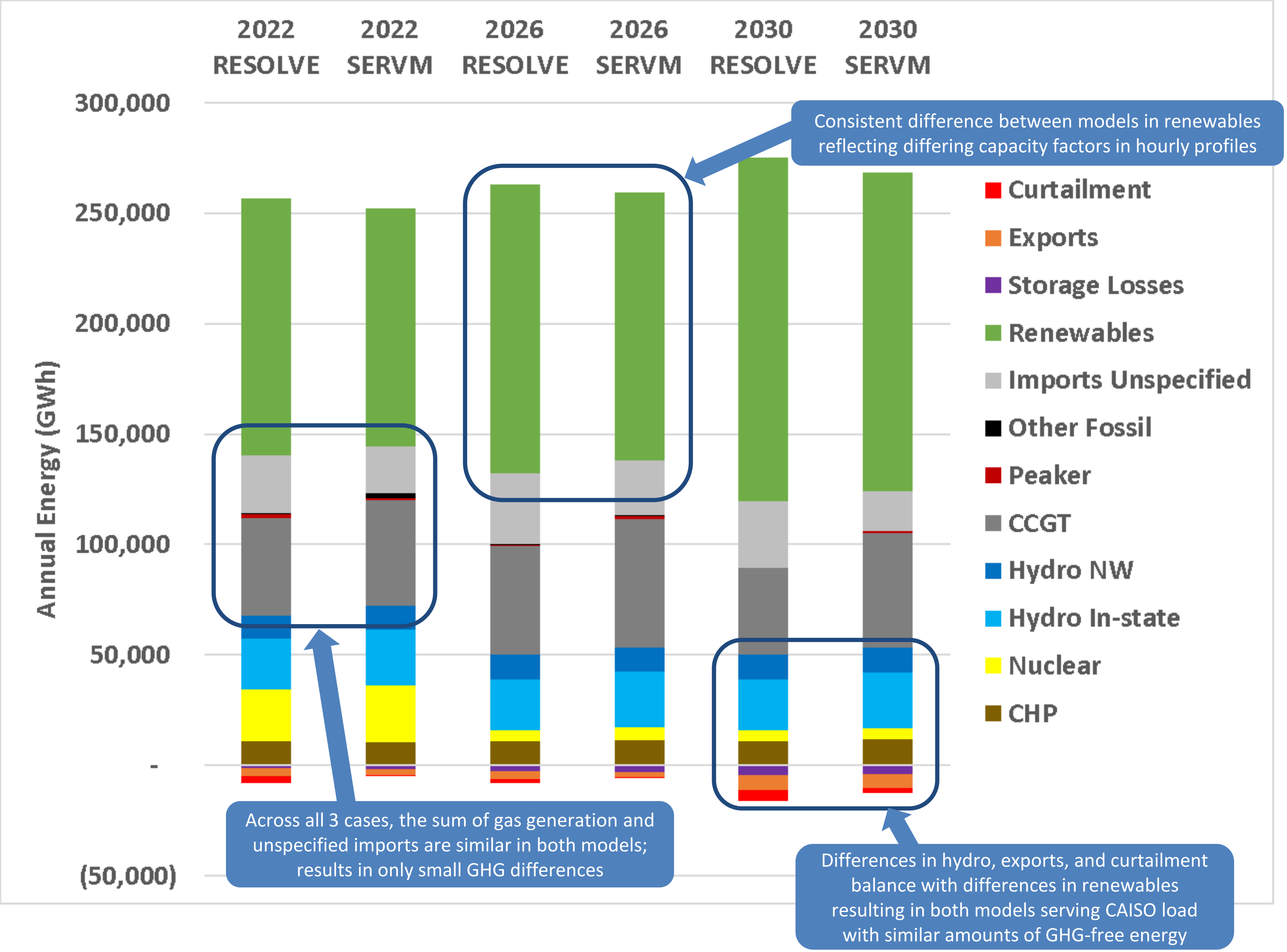
						EUE (MWh), 2022						
Hour Ending	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.48	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	2.07	18.60	2.57	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	17.75	12.00	2.61	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	16.56	7.94	0.81	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	1.33	0.00	0.00	0.00	0.00	0.00

						EUE (MWh), 2026						
Hour Ending	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.06	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.36	10.59	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	9.71	7.89	0.62	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	32.00	23.54	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	2.95	16.72	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	1.76	5.67	0.00	0.00	0.00	0.00

						EUE (MWh), 2030						
Hour Ending	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.18	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.72	12.50	0.23	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	1.40	21.03	0.68	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.25	0.70	0.00	0.00	0.00

- Heat maps illustrating the month-hour where Expected Unserved Energy (EUE) occurs is an intuitive way of showing when loss-of-load events are likely to occur and quantifying the likely magnitude of those events
- Likely LOLE and EUE hours are consistently in the summer evening hours of 6-9pm and shift later for each study year – an expected outcome as solar PV penetration shifts the peak hour later in the evening

CAISO Energy Balance for 46 MMT Alternate + 2 GW Generic Effective Capacity



Consistent difference between models in renewables reflecting differing capacity factors in hourly profiles

Across all 3 cases, the sum of gas generation and unspecified imports are similar in both models; results in only small GHG differences

Differences in hydro, exports, and curtailment balance with differences in renewables resulting in both models serving CAISO load with similar amounts of GHG-free energy

Energy Balance Table for 46 MMT Alternate + 2 GW Generic Effective Capacity

46 MMT Alternate Case						
CAISO Energy Balance (GWh)	2022	2022	2026	2026	2030	2030
Category	RESOLVE	SERVM	RESOLVE	SERVM	RESOLVE	SERVM
CHP	10,881	10,280	10,881	11,523	10,881	11,638
Nuclear	23,611	25,711	5,108	5,563	5,108	5,136
Hydro In-state	22,996	25,392	22,996	25,391	22,995	25,391
Hydro From NW	10,421	11,000	11,179	11,000	11,298	11,000
CCGT	44,097	47,581	49,092	57,956	38,986	52,139
Peaker	1,641	855	684	1,485	99	798
Reciprocating Engine	127	120	52	152	31	131
Coal	525	1,336	-	-	-	-
Steam	-	1,029	-	-	-	-
BTM PV	23,291	23,225	30,631	30,556	38,046	37,949
Solar	48,913	47,106	54,425	52,847	70,654	68,281
Wind	24,158	18,830	25,980	18,830	26,842	19,491
Geothermal	13,042	13,137	13,042	13,502	13,042	13,567
Biomass	6,778	5,631	6,778	5,611	6,764	5,181
Pumped Storage Roundtrip Losses	(525)	(912)	(576)	(831)	(963)	(797)
Battery Storage Roundtrip Losses	(674)	(731)	(1,966)	(2,026)	(3,573)	(3,231)
Curtailment	(2,886)	(416)	(2,043)	(402)	(5,080)	(2,335)
Imports (unspecified)	26,160	20,970	32,337	24,857	30,228	17,915
Exports	(3,770)	(2,811)	(3,583)	(2,659)	(6,617)	(6,320)
Load	247,401	247,331	253,790	253,493	257,010	256,512

SERVM curtailment lower due to lower wind and solar generation.

Storage utilization is similar between models – improvement from last year's modeling.

GHG Emissions Table for 46 MMT Alternate + 2 GW Generic Effective Capacity

46 MMT Alternate Case						
CAISO GHG Emissions (MMtCO2/Yr)	2022	2022	2026	2026	2030	2030
	RESOLVE	SERVM	RESOLVE	SERVM	RESOLVE	SERVM
CAISO Generator Emissions	22.9	25.3	23.5	28.4	19.5	25.7
Unspecified Import Emissions	11.2	9.0	13.8	10.6	12.9	7.7
CAISO Emissions w/o BTM CHP	34.1	34.3	37.4	39.0	32.4	33.4
CAISO BTM CHP Emissions	5.5	5.5	5.5	5.5	5.5	5.5
CAISO Emissions w/ BTM CHP	39.6	39.8	42.9	44.5	37.9	38.9
Emissions Delta	0.21		1.64		0.96	
CAISO Generation and Imports (GWh)						
Zero-GHG	165,356	165,161	161,971	157,382	178,514	173,311
GHG-emitting	83,431	82,171	93,047	95,972	80,226	82,621

- Zero-GHG generation: Nuclear, Hydro from in-state and NW imports, Renewables net of storage losses, exports, and curtailment

- GHG-emitting generation: CHP, CAISO gas, Unspecified Imports

The sum of CAISO gas and unspecified imports in both models is similar. The relative amounts of CAISO gas and unspecified imports vary between models and across cases, but the differences generally net each other out for each case resulting in similar emissions between models.

The net amounts of zero-GHG energy serving CAISO loads are similar.

Conclusions of SERVM Analysis of Proposed Reference System Portfolio

- SERVM and RESOLVE remain sufficiently calibrated in terms of projecting GHG emissions. The models differ by less than 2 MMT CO2e for each study year.
- The Proposed Reference System Portfolio (the RESOLVE 46 MMT Alternate Case, plus 2,000 MW of generic effective capacity) was found to be a sufficiently reliable and operable portfolio for the CAISO electric system through 2030
- Both IRP models succeeded at what they were designed to do:
  - RESOLVE selected the least-cost portfolio to satisfy various constraints
  - SERVM tested the reliability of that portfolio

CRITERIA POLLUTANTS ANALYSIS

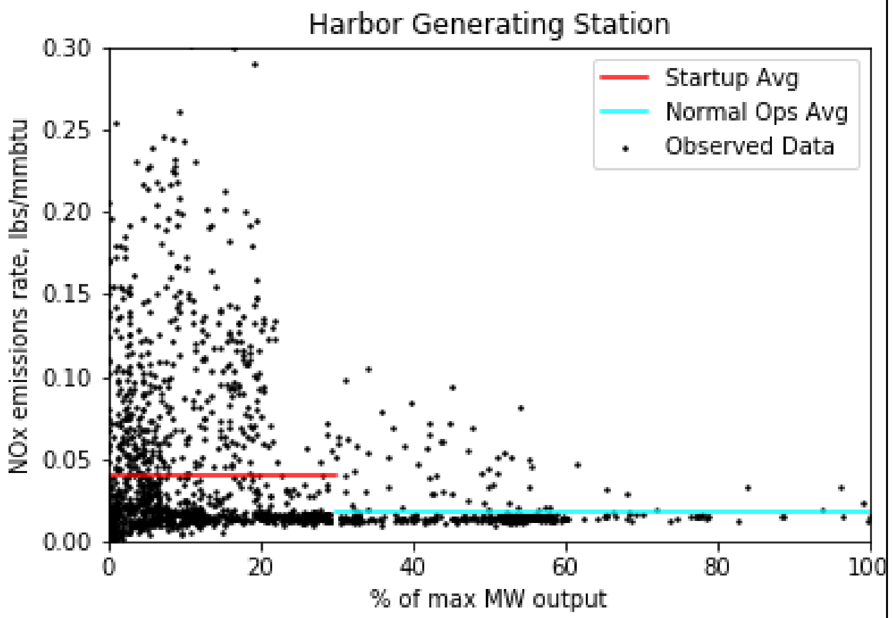
Background: Criteria Pollutants in IRP

- Statute directs the Commission's IRP process to ensure that LSEs "minimize localized air pollutants and other greenhouse gas emissions, with early priority on disadvantaged communities“ (PU Code 454.52 (a)(1)(H)).
- In the 2017-2018 IRP cycle, staff estimated NOX and PM2.5 emissions from power plants by applying a single emissions factor (emissions per mmbtu of fuel burn or per MWh) each for:
  - Hot starts,
  - Warm starts,
  - Cold starts, and
  - Normal operation between Pmin and Pmax.
- Staff then separated the results by disadvantaged community (DAC) and non-DAC areas.
- In workshops and comments in the 2017-2018 IRP cycle, parties expressed a desire to improve the accuracy and locational granularity of these estimates.

Criteria Pollutants Calculation: Improvements in 2019-2020 IRP Cycle

- In response to party comments, Energy Division staff made the following improvements for this cycle of IRP.
  - Count emissions from all emitting generation in California (including natural gas, geothermal, biomass, and biogas plants).
  - Calculate emissions by ARB basin for more locational granularity.
  - Where available, use plant-specific criteria pollutant emissions factors.
  - Include SO2 emissions, as well as NOx and PM2.5.
- Staff proposes to incorporate hourly criteria pollutant data in the Clean System Power calculator tool (formerly Clean Net Short tool) for LSE planning (See Staff Proposal for 2019-2020 Filing Requirements)

Improvements in 2019-2020 IRP Cycle (cont'd): Using generator-level data to estimate NOx from starts versus normal operation



To estimate the emissions effects of gas cycling, staff used generator-level start and normal operations emissions data to the extent it was available.* Data for an example unit is shown to the left. Each point represents an hourly observation of NOx emissions per unit of fuel burn.

By plant, staff calculated an average NOx startup factor and an average factor in normal operations (the red and blue lines, respectively), and then applied those to energy in start and normal operations, as appropriate, to calculate emissions.

*Data from EPA Air Markets Program, available at ftp://newftp.epa.gov/DMDnLoad/emissions/hourly/monthly/2019/

High-level analysis steps

- Staff mapped all emitting generators in California to CARB air basin and disadvantaged community status.
- Staff used SERVM to simulate dispatch of these generators in the Proposed Reference System Portfolio (the 46 MMT Alternate Scenario + 2,000 MW generic effective capacity), in 2022, 2026, and 2030.
- SERVM output generation in MWh and fuel burn in MMBTU for all these generators.
- Staff then calculated criteria pollutant emissions for each generator by multiplying the appropriate NOx, PM 2.5, and SO2 emissions factors by its fuel burn or MWh, as appropriate (depending on data availability, emissions factors were either in terms of emissions per MWh or emissions per MMBtu of fuel burn). These emissions factors were estimated at the generator level to the extent possible—more detail on data sources can be found in the appendix to this section.
- Aggregate and summarize emissions results by resource type, CARB air basin, year, and Disadvantaged Community (DAC) status.
- Results are presented on the following slides. **Note that all figures refer to criteria pollutant emissions from the electric sector only (i.e. they do not include emissions due to transportation).**

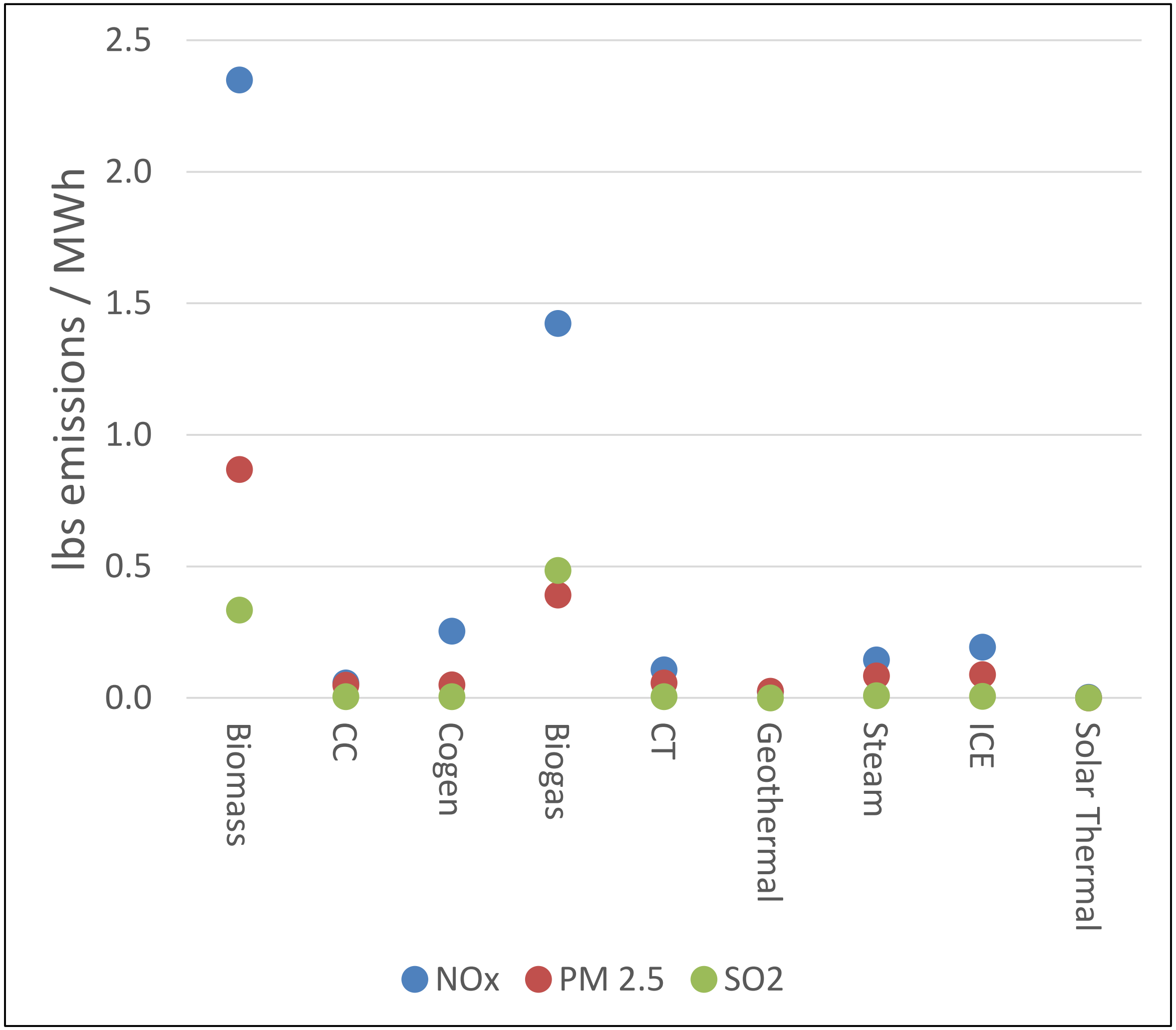
Overview of California-wide capacity, energy, fuel burn, and criteria pollutant emissions, 2030

	Capacity, MW	Annual generation, TWh	Fuel Burn, millions of MMBTU	NOx, MT	PM 2.5, MT	SO2, MT
Biomass	707	4.5	54.2	4,766	1,762	678
CC	20,554	69.3	512.7	1,815	1,533	145
Cogen	2,318	11.6	88.5	1,343	265	28
Biogas	291	1.4	19.0	913	251	311
CT	7,292	4.3	37.8	209	113	11
Geothermal	2,644	19.8	81.5	214	227	0
Steam	272	0.3	3.0	17	10	1
ICE	305	0.2	1.6	16	7	1
Solar Thermal	1,608	4.2	4.2	5	0	0
Coal	0	0.0	0.0	0	0	0
Total	**35,991**	**115.7**	**802.6**	**9,298**	**4,168**	**1,175**

- Colors represent rankings, with darker colors indicating larger quantities, and lighter ones representing smaller ones.
- Biomass, CC, and cogen are the top three emitters for NOx and PM 2.5. For SO2, biogas replaces cogen in the top three.
- Staff also modeled 2022 and 2026, and found that results were similar for those years except for emissions from Intermountain coal imports into CA in 2022, which contributed an additional ~2,600 MT of NOx, ~700 MT of PM2.5, and ~2,900 MT of SO2 in 2022. A complete table of all three years can be found in the appendix.
    - Note: LADWP and various municipal utilities in Southern California are the importers of Intermountain Coal (which is not considered a CAISO resource), and are not CPUC-jurisdictional.

Modeled emissions factors, lbs / MWh, by resource type

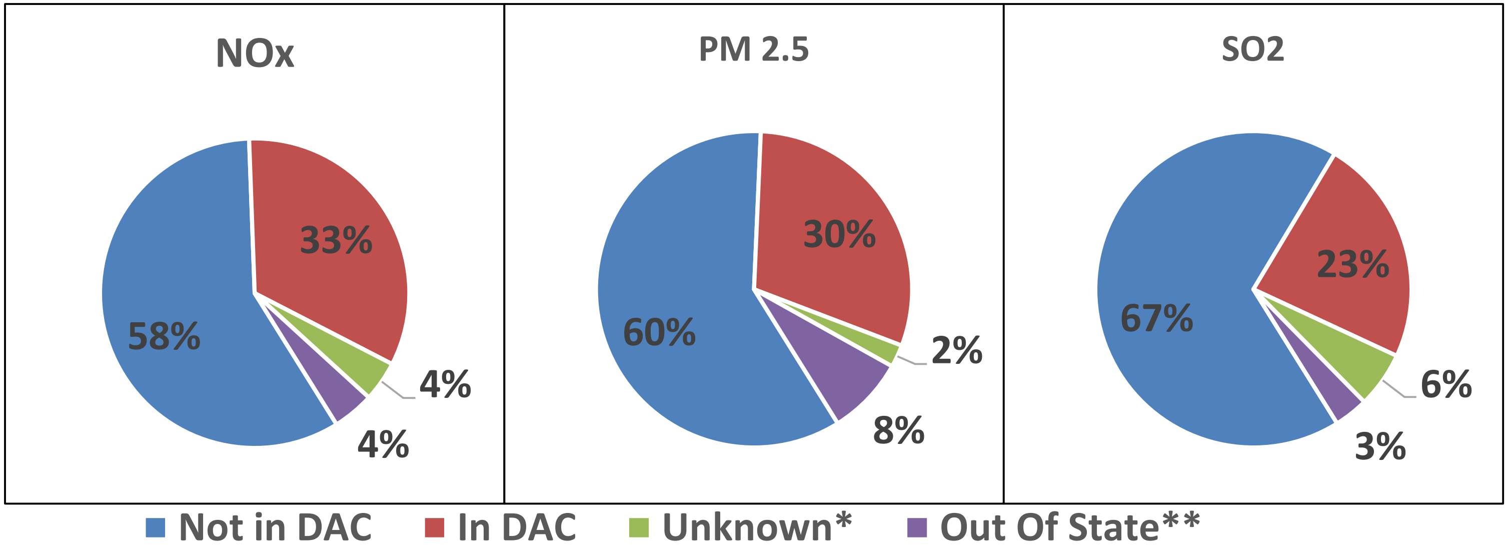
- Biomass and biogas have high total emissions due to their high emissions factors (although their total energy production is relatively small; see previous slide).
- Conversely, CCs have comparatively low emissions factors, but high total emissions due to the large amount of energy produced.
- A table of the emissions factor values in this scatterplot can be found in the appendix.



California-Wide Electric Sector Criteria Pollutant Emissions by Disadvantaged Community (DAC) status, 2030 Metric Tons

	NOx	PM 2.5	SO2
In DAC	3,082	1,255	274
Not In DAC	5,422	2,483	793
Unknown*	391	96	67
Out Of State**	403	334	41
Total	9,298	4,168	1,175

Emissions percentages by DAC status



- DACs contain 25% of California’s population.
- 33% of NOx emissions, 30% of PM2.5, and 23% of SO2 emissions occur in DACs.

* Staff was able to map almost all of the resources to DACs, but was unable to find the location of some of the smaller resources.
** This category includes specified imports of emitting generation, such as the natural gas-fired Intermountain Combined Cycle in Utah, and the La Rosita and Termoelectrica de Mexicali power plants in Mexico.

Electric Sector Criteria Pollutants Emissions by CARB air basin, 2030 MT

Region Type	Region Name	Number of emitting generators in region	NOx, MT	PM 2.5, MT	SO2, MT
Basin	South Coast	81	1,768	722	261
	San Joaquin Valley	69	1,734	833	202
	Sacramento Valley	44	1,918	802	268
	Salton Sea	41	369	181	34
	San Francisco Bay Area	39	659	316	83
	San Diego	21	218	123	26
	Mojave Desert	14	269	146	13
	North Coast	12	728	218	75
	Lake County	8	18	49	0
	South Central Coast	8	77	42	18
	North Central Coast	6	207	107	18
Non-Basin	Out of State	13	403	334	41
	Unknown**	70	391	96	67
Other	Multiple*	8	540	198	69
All	**Total**	**434**	**9,298**	**4,168**	**1,175**

*This category includes the Mountain Counties, Great Basin Valleys, and Northeast Plateau basins. Because these basins all contained less than 5 individual generators each, staff aggregated their results into one category to preserve confidentiality of individual generator data.
** Staff could not find regions for all generators, especially smaller ones.

Total modeled California-wide generation and NOx emissions for CCs and CTs, by start / normal operations, 2030

Generation

	In Start (TWh)	Normal Operations (TWh)	Total (TWh)	% in startup
CC	1.4	67.9	69.3	2.1%
CT	0.2	4.1	4.3	5.7%
Total	1.7	72.0	73.7	2.3%*

NOx emissions

	In Start (MT)	Normal Operations (MT)	Total (MT)	% in startup
CC	279	1,537	1,815	15.3%
CT	34	175	209	16.1%
Total	312**	1,712	2,024	15.4%*

* Startup generation represents approximately 2% of the total generation for CCs and CTs, but 15% of the NOx emissions for these resource categories.

** However, startup emissions represent a relatively small portion of statewide NOx emissions. 312 MT NOx from CC and CT starts / 9,298 MT NOx statewide ≈ 3%.

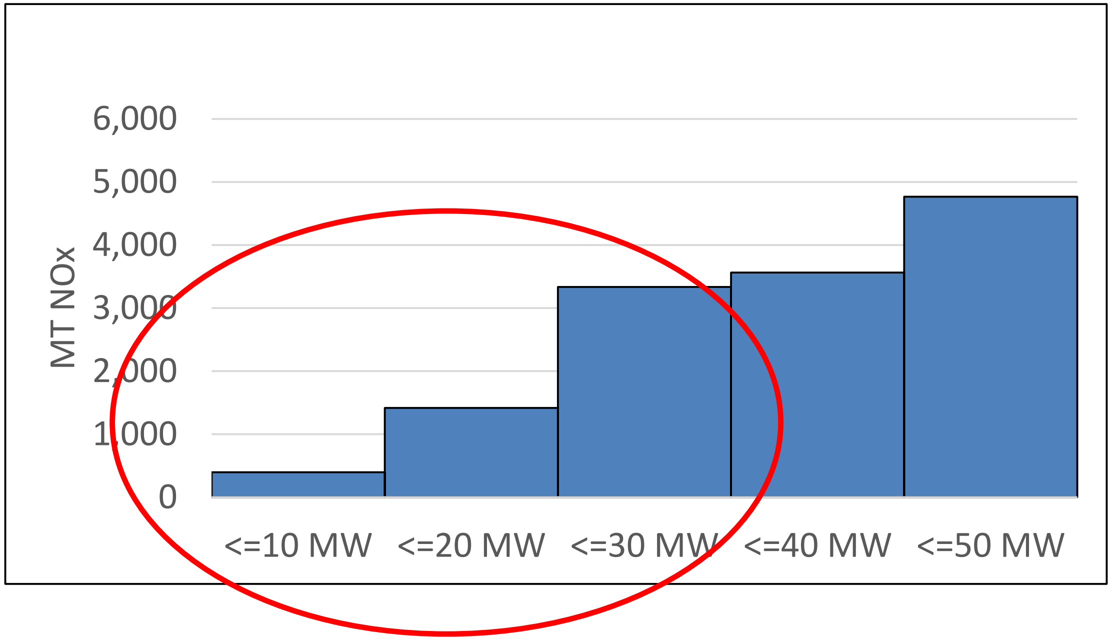
Emissions control technologies and standards

- To better understand emissions results, staff examined EIA generator data on emissions control technologies and interviewed CARB staff.
- Criteria pollutant emissions depend heavily on the type of control technologies installed at a given plant. Control technologies such as Selective Catalytic Reduction (SCR) can drastically reduce output of criteria pollutants such as NOx.
- Large gas-fired generation facilities in California generally already have CARB Best Available Control Technology (BACT) or best available retrofit control technology (BARCT) standards in place. These standards, which apply for plants above a certain MW size, mandate the installation of emissions control technologies. This partially explains the low emissions factors for CC’s and CT’s shown on the previous slide.
- However, biomass plants may not trigger this standard, as they tend to be smaller. Thus it is unclear if they are using best available control technologies. Standards for these plants vary widely, as many of them are set at the local level. The table below, derived from EIA plant data, shows this.

Level of jurisdiction for strictest NOx emissions standard for California biomass plants, % of total biomass MW, from EIA plant data

Jurisdiction	% of MW
Local	59%
Federal	24%
State	6%
Unknown	11%
Total	**100%**

Cumulative MT of NOx emissions from biomass plants in 2030, by MW size tranche



Smaller biomass units contribute a substantial amount of NOx emissions, most likely due to lack of emissions controls.

Conclusions

- Biomass, combined cycle, and cogeneration power plants are the top three emitters of criteria pollutants in California (except for SO2, in which biogas replaces cogeneration in the top three). The reasons for this are as follows:
  - Many emissions controls rules (e.g. BACT) do not apply for biomass because these facilities tend to be smaller and thus are not subject to CARB rules, which are stricter for larger generators.
  - Combined cycles produce by far the most energy and burn the most fuel.
  - Cogen plants tend to be older and less efficient, so they tend to have higher emissions factors.
- 33% of 2030 statewide NOx, 30% of statewide PM 2.5, and 23% of statewide SO2 occur in DACs, which contain 25% of California's population.
- The South Coast, San Joaquin Valley, and Sacramento Valley Basins have the highest criteria pollutant emissions.
- CC and CT startups are responsible for approximately 3% of the state's total criteria pollutant emissions.

Policy Recommendations (1 of 2)

- **Overall:** The most efficient way to reduce criteria pollutants is likely by installing emissions control technologies on biogas and biomass resources. The CPUC should prioritize reducing emissions from these resources, especially in DACs.

- **Modeling:** Due to their differing generation and emissions factors, future RESOLVE modeling in future IRP cycles should separately model biomass and biogas. CAISO settlement data should be used to analyze how these resources are run in the actual market, and determine if they are must-run or economically dispatched.

Policy Recommendations (2 of 2)

- **Operations:** Limiting startups of gas-fired units is not an effective method for reducing criteria pollutants, for the following reasons:
  - Startups are a small portion of emissions (3% of statewide NOx).
  - Large plants already have pollution controls in place (such as Selective Catalytic Reduction) per CARB regulation, and thus it is difficult to achieve marginal emissions reductions for these plants.
  - It is difficult to avoid cycling plants from an operational perspective.
- **Interagency collaboration:** CPUC should work with CARB on a review of local/federal/state emissions standards, especially for small biomass facilities less than 30 MW. The CPUC/CARB should:
  - Study and identify gaps in criteria pollutant emissions standards.
  - Review best available control technology rules to determine the appropriate technologies for different plants.

Appendix: Criteria Pollutants Results by year for 2022, 2026, and 2030

	NOx			PM2.5			SO2		
	2022	2026	2030	2022	2026	2030	2022	2026	2030
Biomass	5,037	5,064	4,766	1,865	1,872	1,762	717	720	678
CC	1,616	1,879	1,815	1,325	1,658	1,533	125	157	145
Cogen	1,183	1,339	1,343	234	262	265	25	28	28
Biogas	1,035	1,012	913	287	277	251	355	345	311
CT	166	205	209	88	106	113	9	10	11
Geothermal	210	214	214	223	226	227	0	0	0
Steam	56	11	17	53	9	10	5	1	1
ICE	14	17	16	7	8	7	0	1	1
Solar Thermal	5	5	5	0	0	0	0	0	0
Coal	2,569	0	0	689	0	0	2,888	0	0
Total	**11,891**	**9,746**	**9,298**	**4,770**	**4,418**	**4,168**	**4,124**	**1,261**	**1,175**
Total (no Coal)	**9,321**	**9,746**	**9,298**	**4,081**	**4,418**	**4,168**	**1,236**	**1,261**	**1,175**

Non-coal results are similar year over year. Intermountain is assumed to be converted to a combined-cycle in 2025, which eliminates coal emissions and slightly increases CC emissions in 2026 and onward.

Appendix: Modeled emissions factors in 2030

Unit Category	Average NOx factor, lbs/MWh	Average PM 2.5 factor, lbs/MWh	Average SO2 factor, lbs/MWh
Biogas	1.4237	0.3914	0.4853
Biomass	2.3491	0.8684	0.3340
CC	0.0577	0.0487	0.0046
CT	0.1068	0.0578	0.0057
Cogen	0.2544	0.0501	0.0053
Geothermal	0.0238	0.0252	0.0000
ICE	0.1939	0.0894	0.0063
Solar Thermal	0.0024	0.0000	0.0000
Steam	0.1448	0.0846	0.0087

Appendix: Data Sources

- Generator-specific curves mapping emissions to fuel burn at different power plant levels of operation from EPA, where available, from ftp://newftp.epa.gov/DMDnLoad/emissions/hourly/monthly/2019/
  - EPA data is mostly steam plants, combustion turbines, and combined cycles. The dataset has no information regarding geothermal, biomass, and biogas, and only approximately 150 MW of cogeneration plant data.
  - Many combined cycles do not have data for the steam unit, though they do have data for the combustion turbines.
- 2017 historical emissions by generating facility, from CARB pollution mapping tool from https://ww3.arb.ca.gov/ei/tools/pollution_map/
- 2017 historical generation by resource, from confidential CAISO settlement data
- EIA Form 860 for information about the generators and their subunits. https://www.eia.gov/electricity/data/eia860/