CRITERIA POLLUTANTS ANALYSIS (UPDATED 2/20/2020)

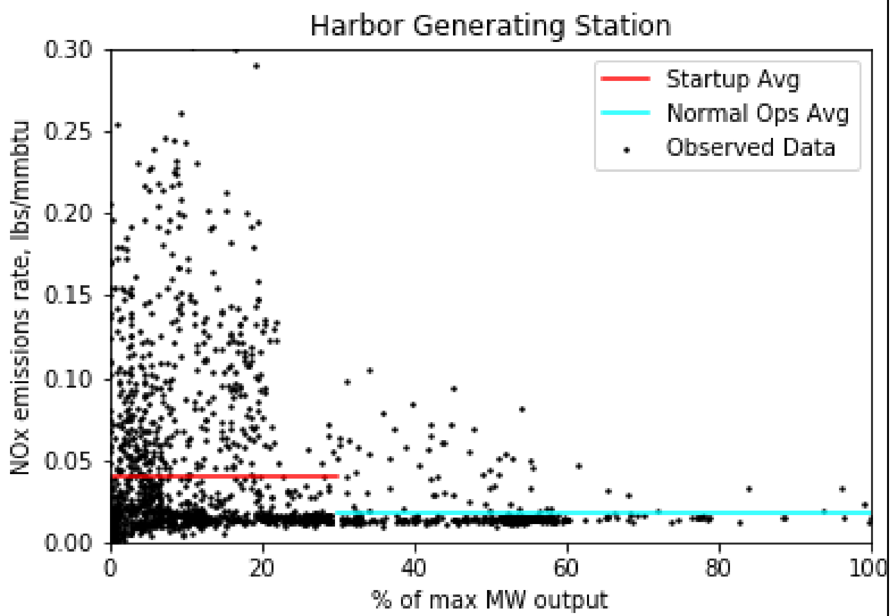
Background: Criteria Pollutants in IRP

- 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).
- **These results correspond to the RSP recommended in the February 2020 Proposed Decision; they supersede the results originally presented November 6th, 2019.**

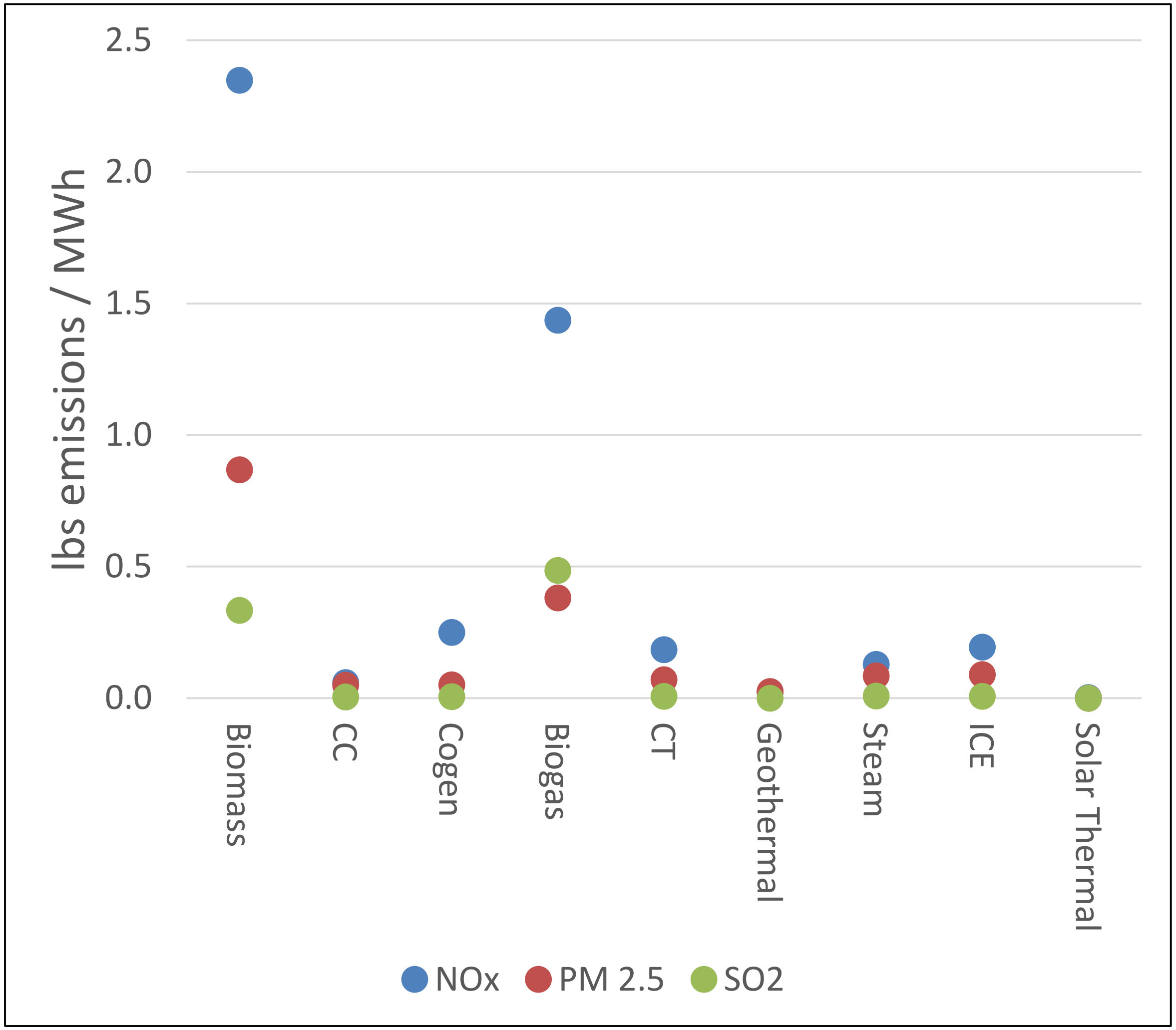
Overview of California-wide capacity, energy, fuel burn, and criteria pollutant emissions, 2030

	Capacity, MW	Annual generation, TWh	Fuel Burn, millions of MMBTU	NOx, MT	PM 2.5, MT	SO2, MT
Biomass	707	4.5	54.7	4,806	1,778	684
CC	20,554	64.7	480.4	1,733	1,436	136
Cogen	2,318	10.6	80.6	1,198	241	26
Biogas	291	1.5	20.7	1,003	266	339
CT	10,807	12.3	131.1	1,026	392	38
Geothermal	2,644	19.9	81.8	215	227	0
Steam	272	0.2	2.5	13	9	1
ICE	305	0.2	1.5	15	7	0
Solar Thermal	1,608	4.2	4.2	5	0	0
Coal	0	0.0	0.0	0	0	0
Total	**39,506**	**118.2**	**857.6**	**10,014**	**4,356**	**1,223**

- 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. For PM 2.5, the top three are Biomass, CC, and CT. For SO2, the top three are Biomass, Biogas, and CC. 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 ~2,900 MT of NOx, ~800 MT of PM2.5, and ~3,200 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

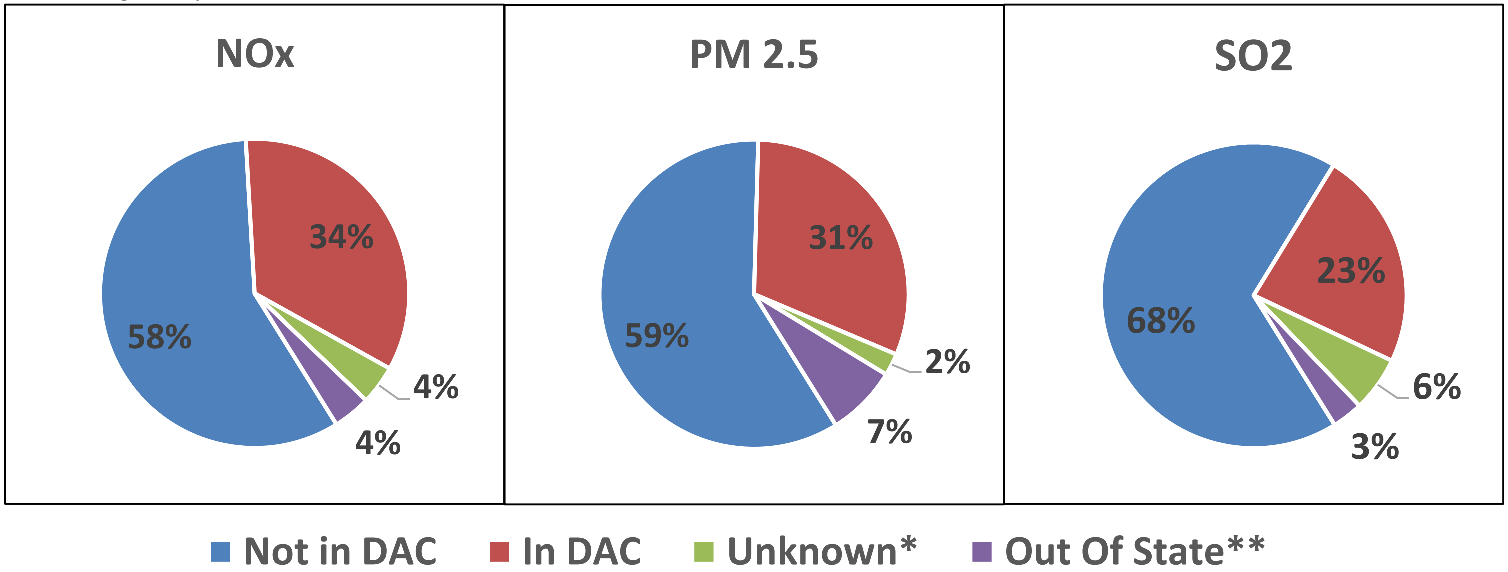
- Biomass and biogas have high total emissions due to their high emissions factors (although their total energy production is relatively small; see previous slide).
- Conversely, CCs have comparatively low emissions factors, but high total emissions due to the large amount of energy produced.
- A table 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	3,405	1,348	285
Not In DAC	5,805	2,584	828
Unknown*	410	101	71
Out Of State**	394	323	40
Total	10,014	4,356	1,224

Emissions percentages by DAC status



- DACs contain 25% of California's population.
- 34% of NOx emissions, 31% 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	106	2,031	798	287
	San Joaquin Valley	80	1,908	889	207
	Sacramento Valley	45	2,026	811	269
	Salton Sea	44	391	189	35
	San Francisco Bay Area	51	762	349	92
	San Diego	28	293	155	30
	Mojave Desert	14	242	139	13
	North Coast	12	731	219	75
	Lake County	8	18	49	0
	South Central Coast	9	74	42	19
	North Central Coast	6	194	94	16
Non-Basin	Out of State	13	394	323	40
	Unknown**	70	410	101	71
Other	Multiple*	8	540	199	69
All	**Total**	**494**	**10,014**	**4,356**	**1,223**

*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	63.3	64.7	2.2%
CT	2.0	10.4	12.3	16.0%
Total	3.4	73.6	77.0	4.4%*

NOx emissions

	In Start (MT)	Normal Operations (MT)	Total (MT)	% in startup
CC	286	1,447	1,733	16.5%
CT	426	601	1,026	41.5%
Total	711**	2,048	2,760	25.8%*

* Startup generation represents approximately 4% of the total generation for CCs and CTs, but 26% of the NOx emissions for these resource categories.
** However, startup emissions represent a relatively small portion of statewide NOx emissions. 711 MT NOx from CC and CT starts / 10,014 MT NOx statewide ≈ 7%.

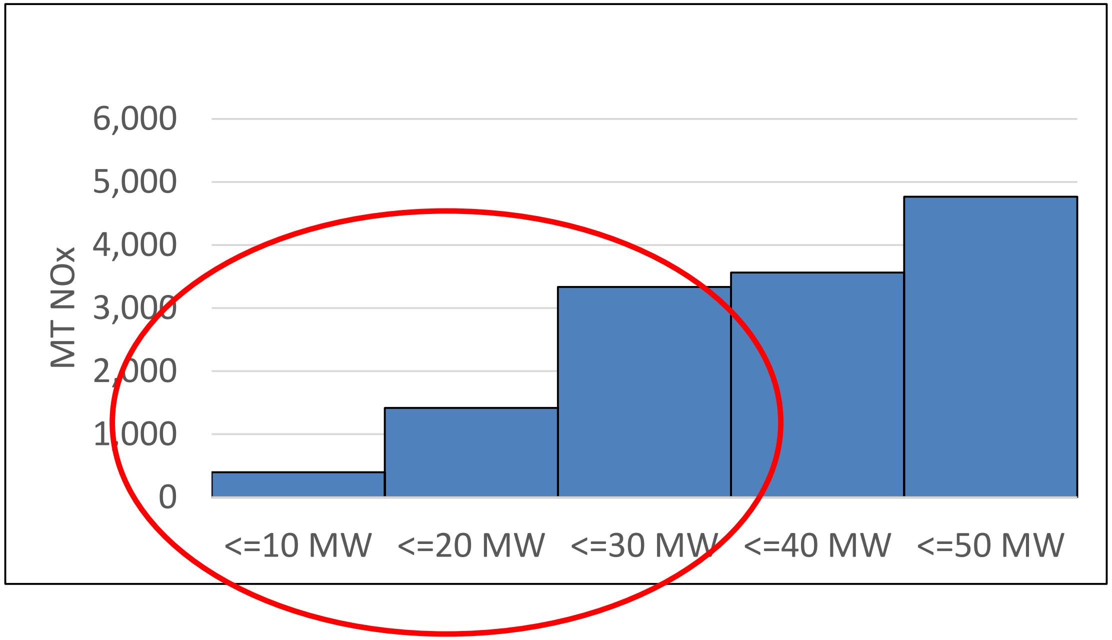
Emissions control technologies and standards

- 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, CC, and cogen are the top three emitters for NOx. For PM 2.5, the top three are Biomass, CC, and CT. For SO2, the top three are Biomass, Biogas, and CC. 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.
  - **CT emissions increased relative to the previous results due to increased capacity (i.e. no retirements) and more stops/starts**
- 34% of 2030 statewide NOx, 31% 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 7% 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 (7% 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	5,091	5,253	4,806	1,885	1,944	1,778	725	748	684
CC	1,428	1,633	1,733	1,172	1,405	1,436	110	133	136
Cogen	1,111	1,155	1,198	223	232	241	24	25	26
Biogas	1,080	1,126	1,003	295	301	266	368	381	339
CT	363	837	1,026	166	317	392	16	31	38
Geothermal	213	217	215	226	231	227	0	0	0
Steam	10	10	13	10	8	9	1	1	1
ICE	10	11	15	4	5	7	0	0	0
Solar Thermal	5	5	5	0	0	0	0	0	0
Coal	2,857	0	0	770	0	0	3,226	0	0
Total	**12,169**	**10,246**	**10,014**	**4,751**	**4,442**	**4,356**	**4,471**	**1,318**	**1,223**
Total (no Coal)	**9,312**	**10,246**	**10,014**	**3,982**	**4,442**	**4,356**	**1,245**	**1,318**	**1,223**

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	1.4367	0.3814	0.4854
Biomass	2.3482	0.8684	0.3340
CC	0.0590	0.0489	0.0046
CT	0.1835	0.0701	0.0068
Cogen	0.2497	0.0503	0.0053
Geothermal	0.0238	0.0252	0.0000
ICE	0.1938	0.0893	0.0063
Solar Thermal	0.0024	0.0000	0.0000
Steam	0.1277	0.0843	0.0084

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/