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Impacts of Power Plant Operational Flexibility on Emissions of Nitrogen Oxides

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2023/09/27

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Background

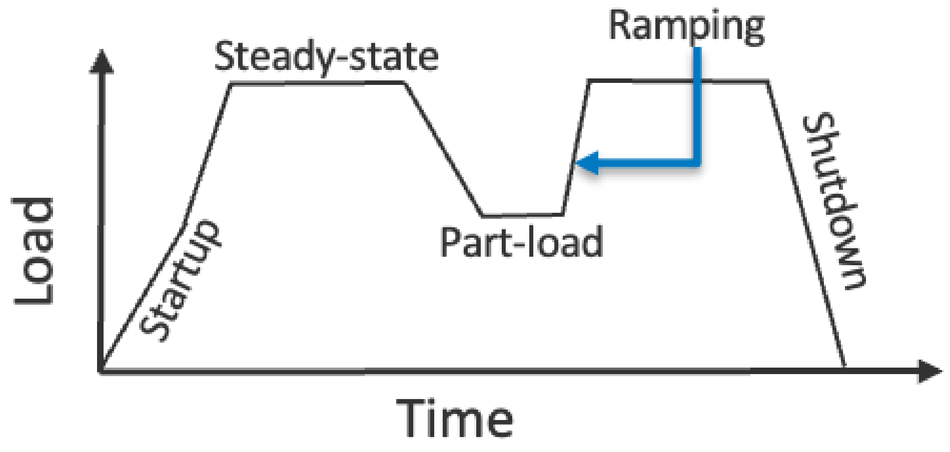
Why is distinguishing steady state and nonsteady state operations important?

Air Quality Impacts of Power Plants

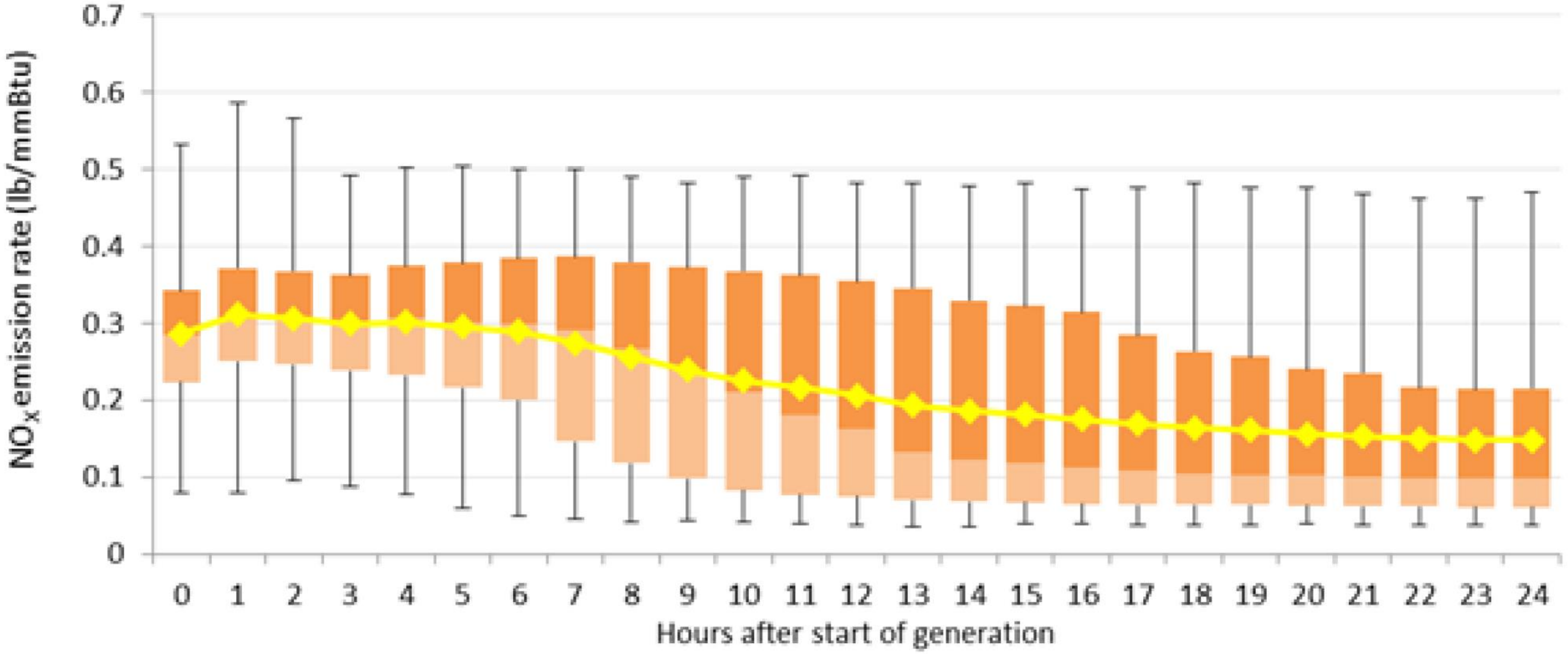
- Generate emissions of primary fine particulate matter ($PM_{2.5}$), nitrogen oxides (NO_x), sulfur dioxide (SO_2), ammonia (NH_3), volatile organic compounds (VOCs)…
- Form ozone (O_3) and secondary $PM_{2.5}$ via chemical reactions
- Cause public health concerns especially in neighboring communities

Nonsteady state vs steady state operations

- Plants operating in steady state at full load have the lowest emissions intensity
  - E.g., emissions control technologies are operating with maximum effectiveness
- There are several non-steady state conditions: startup, shutdown, ramping and part-load
  - They are associated with reduced efficiency (e.g., higher heat rate)



Air pollutant emission during nonsteady state vs steady state operations

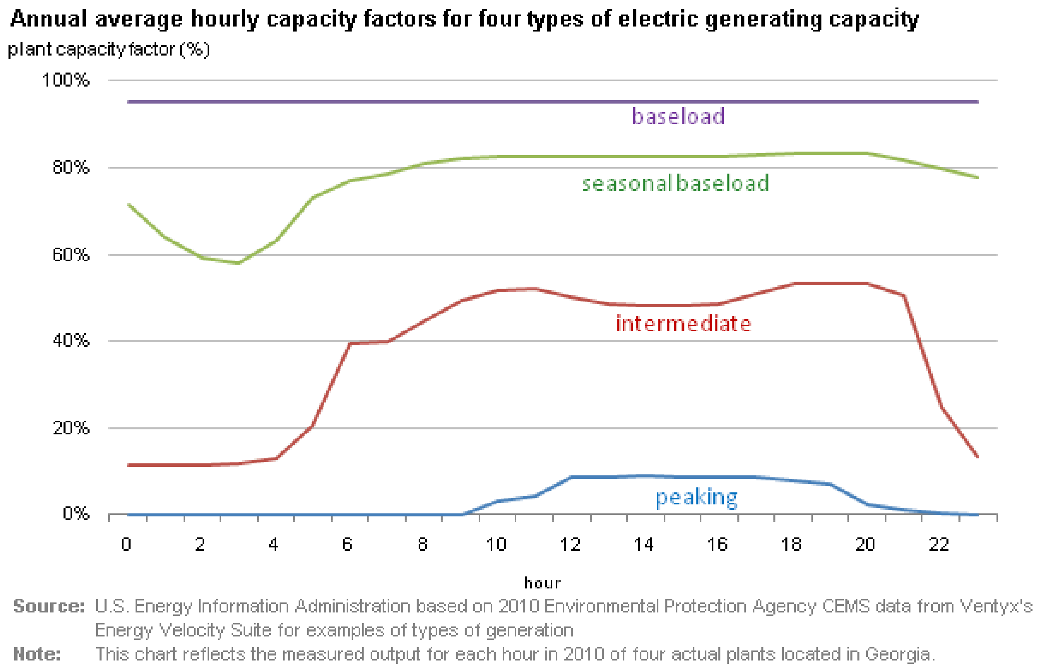


(EPA, 2014)

- Literature shows higher emissions rates during startup and shutdown events
  - Pollution abatement systems are not operating initially (i.e., startup) and then less effective until end of the event (i.e., shutdown)
  - Startup and shutdown emissions rates can be multiple times higher than steady state emissions rates, across a very wide range

Fossil fuel power plants are expected to undergo more nonsteady state operations in the future

- As variable renewable resources capture growing shares of generation on the power system, conventional fossil fuel power plants will likely operate more to meet peak load
- Peaker plants undergo more startup and shutdown events



(U.S. Energy Information Administration)

Research Questions

- Do the number of startup events change over years 2015—2019?
- How different are the emissions factors during nonsteady state operations (i.e., startup and shutdown) and steady state operations?
  - We are using the data on electric generating units in California for this analysis.

Data and Methodology

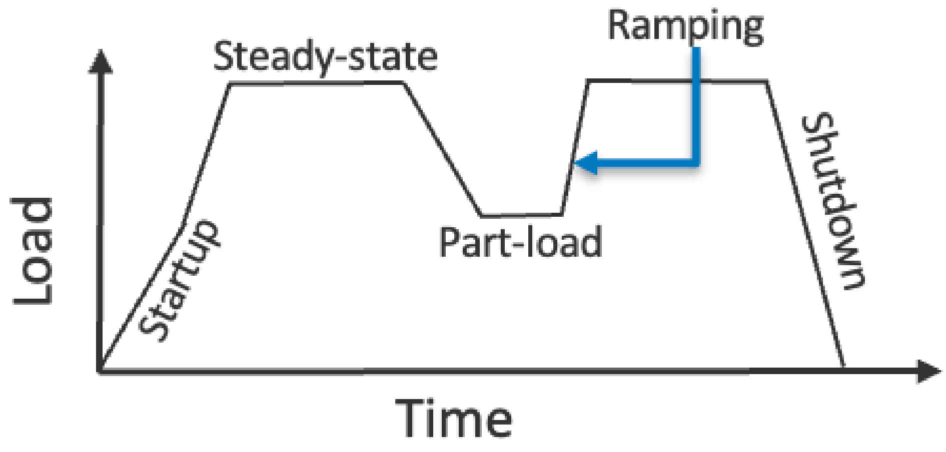
How are steady state and nonsteady state emissions factors obtained and analyzed?

Data Source: CAMPD

- EPA Clean Air Markets Program Data (CAMPD)
  - Hourly information on operations (e.g., load and heat input) and emissions (e.g., NOx and SO_2)
  - Information on power sector facilities/units and their attributes (e.g., unit type, primary fuel type and NOx control technologies)
  - We focus on years 2015—2019

Methodology: Identify nonsteady state operations

- For simplicity, we consider startup and shutdown events as nonsteady state operations
- Startup: From the start of fuel combustion (i.e., non-zero heat input) to when the combustion unit reaches the average steady state emission factor for NOx. Changes in load are considered as a secondary determining factor
- Shutdown: From when the load begins to decrease until reaching zero heat input. Exceeding the average steady state emission factor for NOx is considered as a secondary determining factor



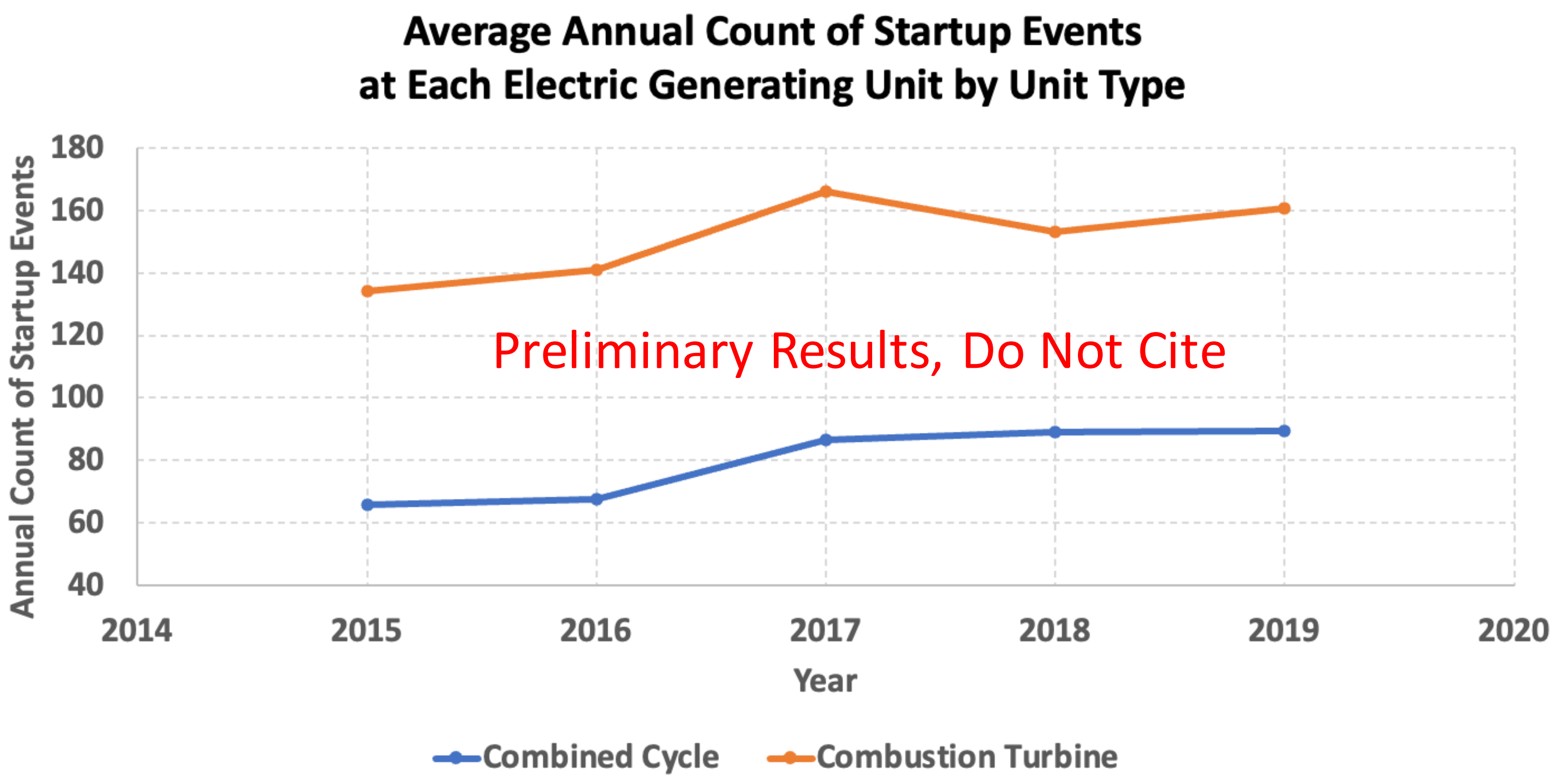
Methodology: Estimate emissions multipliers

- Emission multiplier: the ratio of emissions factors during startup or shutdown events to emissions factors during steady state operation
- Probabilistic assessment method to capture the uncertainty in emissions multipliers: a sample of 10,000 emissions multipliers for startup and shutdown events was drawn from the empirical distribution of the hourly CAMPD data and used to represent the ratio of nonsteady state to steady state emissions levels

Preliminary Results

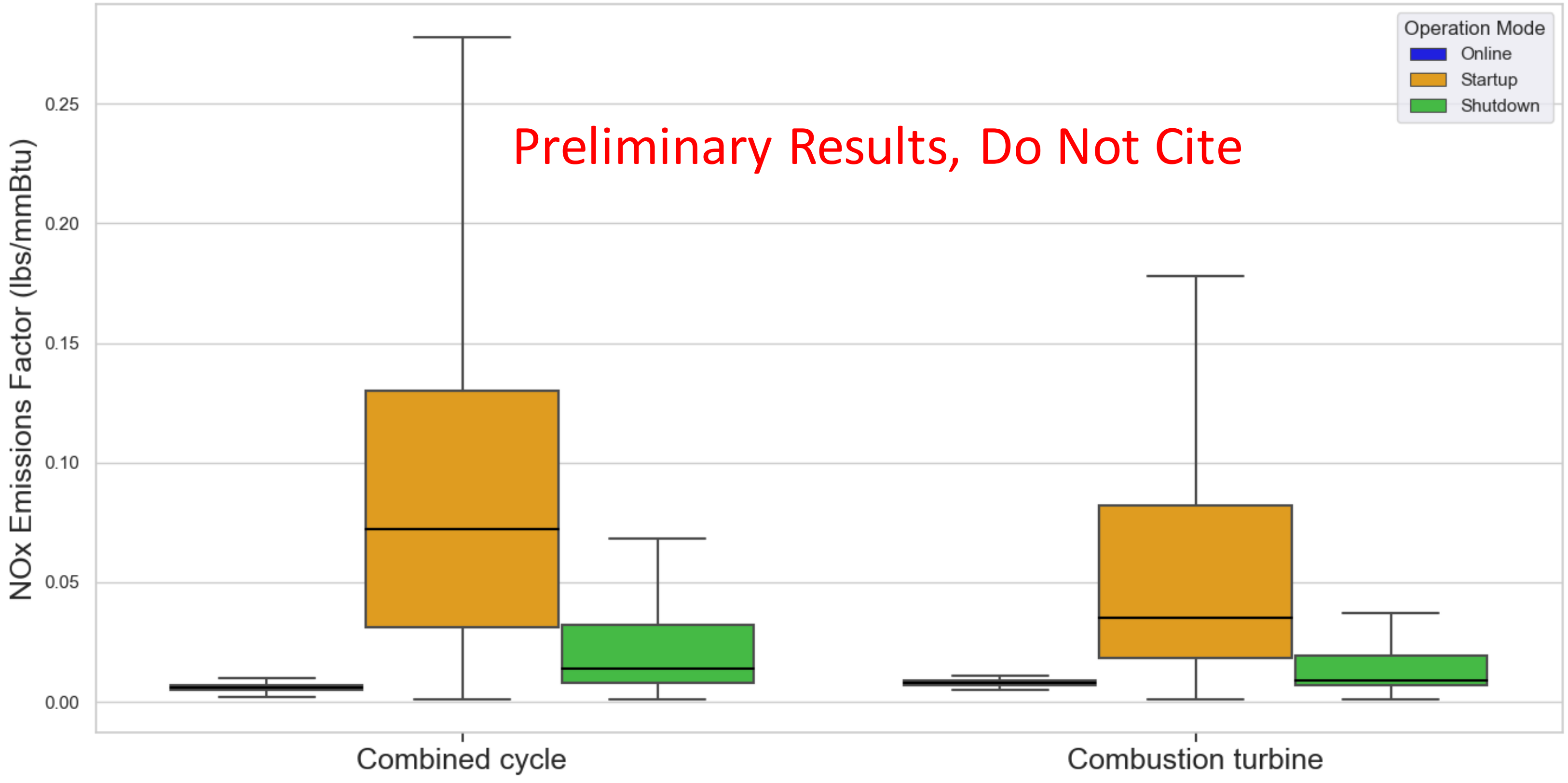
How do nonsteady state emissions factors compare with steady state emissions factors from the CAMPD data?

Annual Trend in Startup Counts



- Annual startup counts at unit level in general follow an increase trend 2015—2019

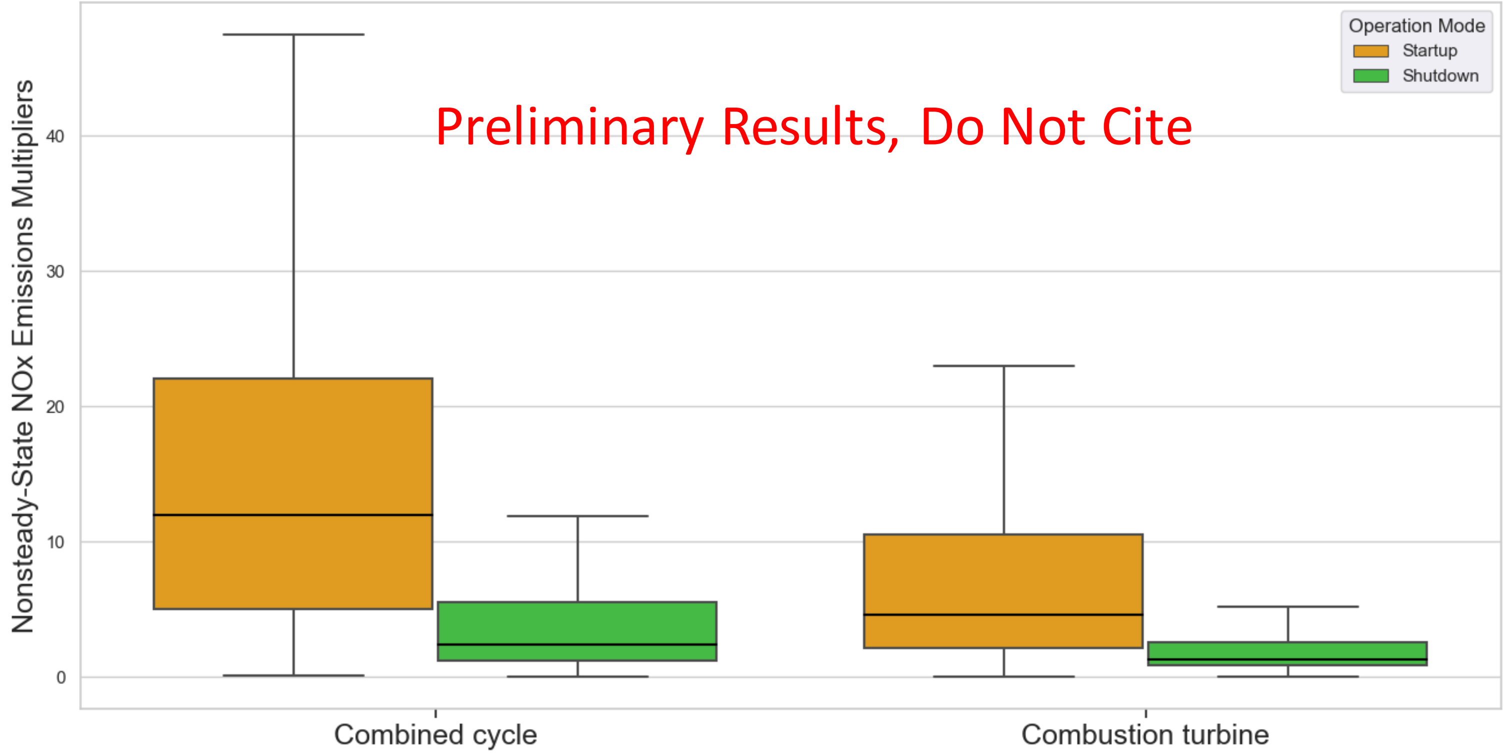
Startup and Shutdown Emission Factor by Unit Type



Average Emission Factor During Online (i.e., Steady State) Operation	
0.0067 lbs/mmBtu	0.027 lbs/mmBtu

- Combined cycle units have lower steady state emissions factors than combustion turbine units
- The ratio between nonsteady state and steady state emissions factors are larger and more uncertain for combined cycle units than combustion turbine units

Startup and Shutdown Emissions Multipliers by Unit Type



- The ratio between nonsteady state and steady state emissions factors (i.e., emissions multipliers) are larger and more uncertain for combined cycle units than combustion turbine units
- For each unit type, startup events have higher emissions multipliers and greater variability in emissions multipliers than shutdown events

Mean Emissions Multipliers

Unit Type	Startup	Shutdown
Combined Cycle	17.7	6.4
Combustion Turbine	10.0	4.7

Conclusion and Next Steps

Conclusions and Next Steps

- Conclusions
  - Nonsteady state operations such as startup and shutdown events have higher emissions factors than steady state operations.
  - Combined cycle units have lower steady state emissions factors but a higher ratio between nonsteady state and steady state emissions factors than combustion turbine units.
- Next Steps
  - Expand the study domain to include comparison among different EPA Emissions & Generation Resource Integrated Database (eGRID) regions
  - Include the comparison among different primary fuel types and NOx control technologies

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