CALIFORNIA
AIR RESOURCES BOARD

Transport Refrigeration Unit (TRU) Emissions Inventory

May 2025

What is a TRU? Why are They Important?

- TRUs are refrigeration systems that provide temperature control and air flow for goods in trucks, trailers, railcars, and shipping containers.

- A TRU generator set is a generator that provides electricity for a refrigeration system.

- Most TRUs and TRU generator sets run on **diesel**, which create pollutants like diesel **particulate matter** (PM) and **oxides of nitrogen** (NOx). This can have significant health impacts particularly when many TRUs are running at the same location, like food distribution facilities.

What is an Emissions Inventory?

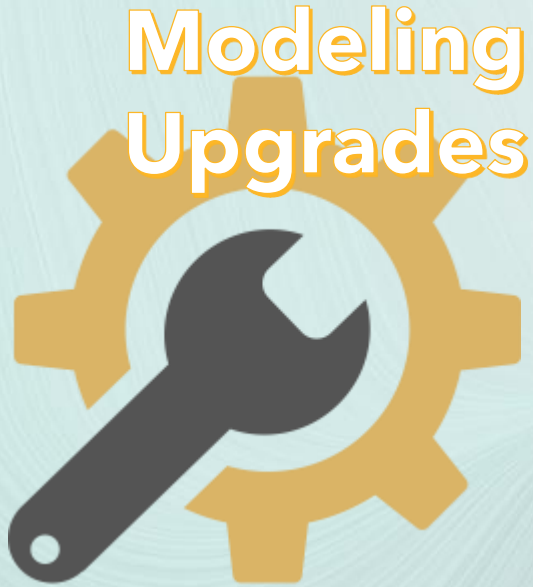
An emissions inventory accounts for:

- ***Population*** or number of TRUs being used
- ***Activity*** or how many hours per year the engine runs
- ***Model year*** or age of the engine
- ***Rated power*** or the size of the engines used
- ***Load factor*** or how hard the equipment is run on average
- ***Emission factor*** or the average emissions per unit work of the engine

These variables can be used to determine the total annual emissions from all equipment for a given region and year.

TRU Inventory Update

- The current TRU emissions inventory was last updated to include the 2022 Amendments (referred to as 2021 Emissions Inventory) to the TRU Air Toxic Control Measure in 2022
- Updates broadly include emissions factors from in-use testing, newer certification data, TRU registration data, updated growth forecasts, and improved fleet level specificity



Categories: Equipment Types

CARB delineates TRUs into five categories:

- **Trailer TRU:** Most common TRU type, attached to trailers generally pulled by semi-trucks.
- **TRU Generator Set:** Provides power to a non-integrated refrigeration unit.
- **Truck TRU:** Used to cool single-body trucks, generally used on shorter routes.
- **Railcar TRU:** Supply refrigeration to refrigerated boxcars pulled by locomotives.
- **Domestic Shipping Container (DSC) TRU**: TRUs that refrigerate a shipping container, often intermodal.

Both Trailers TRUs and TRU Generator Sets are split into:

- **In-State :** Registered to a company based in California.
- **Out-of-State :** Registered to a company based out-of-state (OOS).

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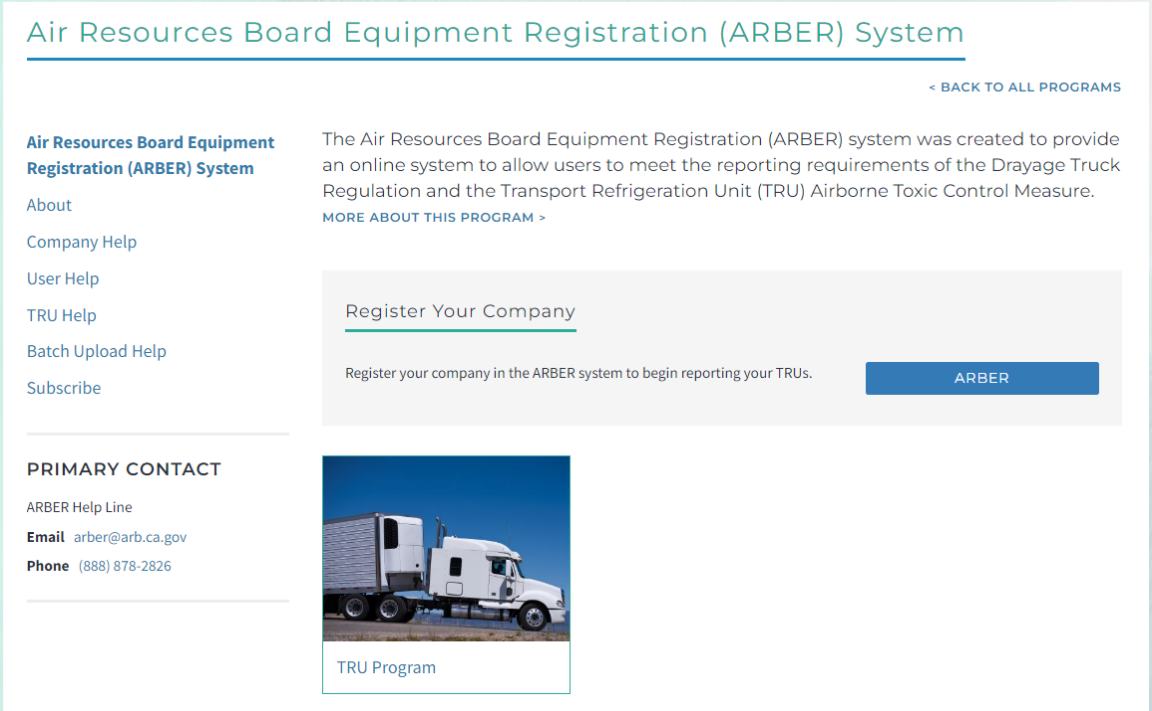
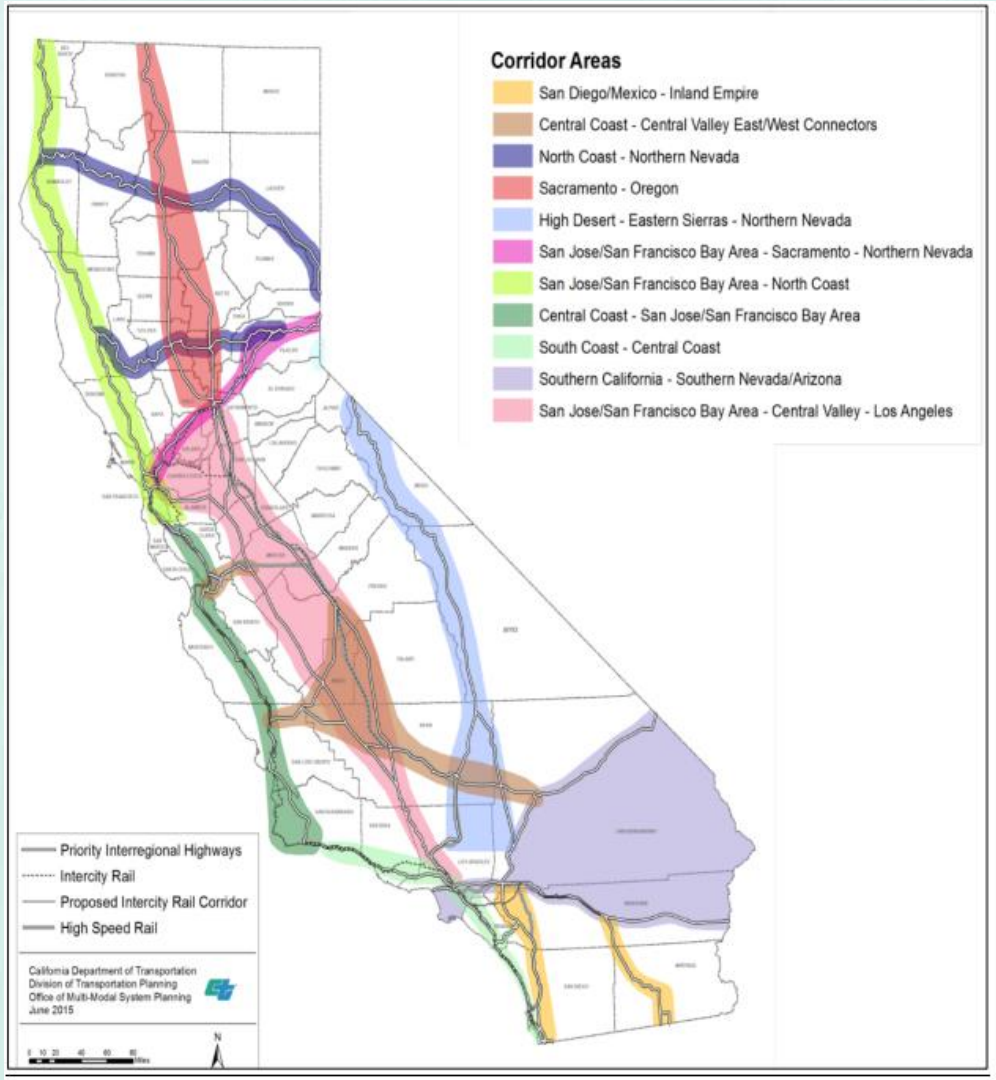
Population

- Air Resources Board Equipment Registration (ARBER) is an online registration program for TRUs used in California.
- New draft TRU emissions inventory uses **January 2024** ARBER data.

- The 2021 Emissions Inventory expanded reporting requirements to newly require reporting of out-of-State TRUs.
- First annual reporting deadline: Dec 31st, 2023
  - Previous inventory estimated **131,200** out-of-State Trailer TRUs, based on trucking patterns.
  - January 2024 ARBER data shows **141,500** out-of-State Trailer TRUs.
  - No longer any adjustment for out-of-State Trailer TRU populations, instead ARBER reporting is used directly with modification.



Population In-State vs. Out-of-State



California Freight Corridors: Caltrans

- TRUs and generator sets are owned by a mix of California-based companies that primarily operate in-State, and out-of-State companies that visit California.
- CARB uses the **ARBER registration company address** to determine in-State vs out-of-State.
- ARBER also provides home state of trailer registration
  - **Analysis**: Less than 2% difference between in-State and out-of-State designations if DMV data is used instead of company address.
- Truck TRUs are modeled as in-State due to shorter routes, and railcar and DSCs modeled as primarily out-of-State due to use on longer freight corridors.

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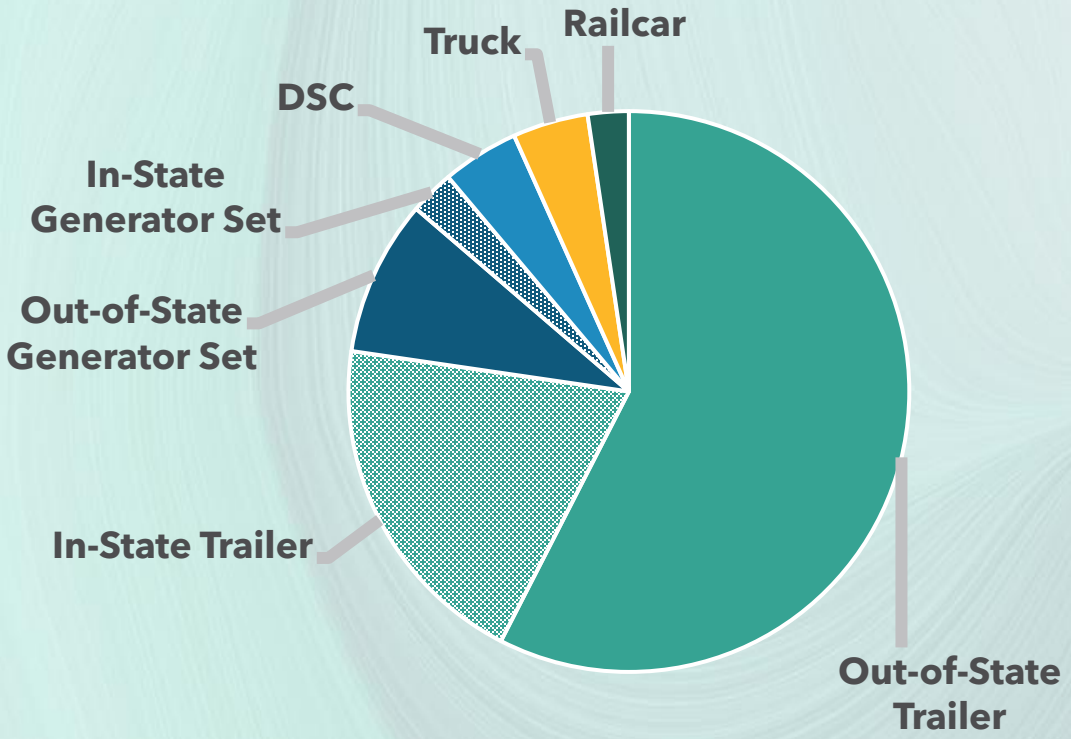
2024 Population by Equipment Type

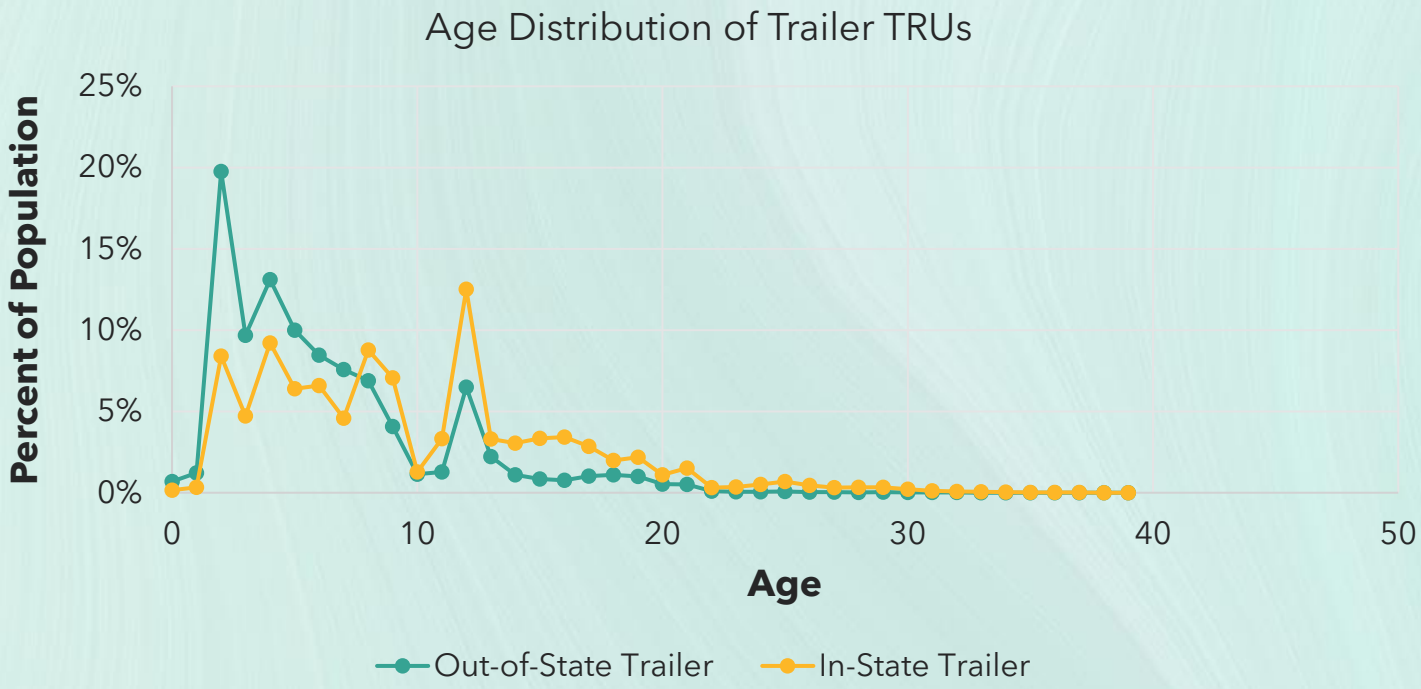
- Majority of population is Trailer TRUs, followed by Generator Sets.

TRU Type	In-State	Out-of-State	Percent of TRUs
Trailer TRU	48,600	141,500	77%
Generator Set	6,300	22,100	12%
DSC TRU	-	10,900	4%
Truck TRU	10,700	-	4%
Railcar TRU	-	5,800	2%



Population Age Distribution

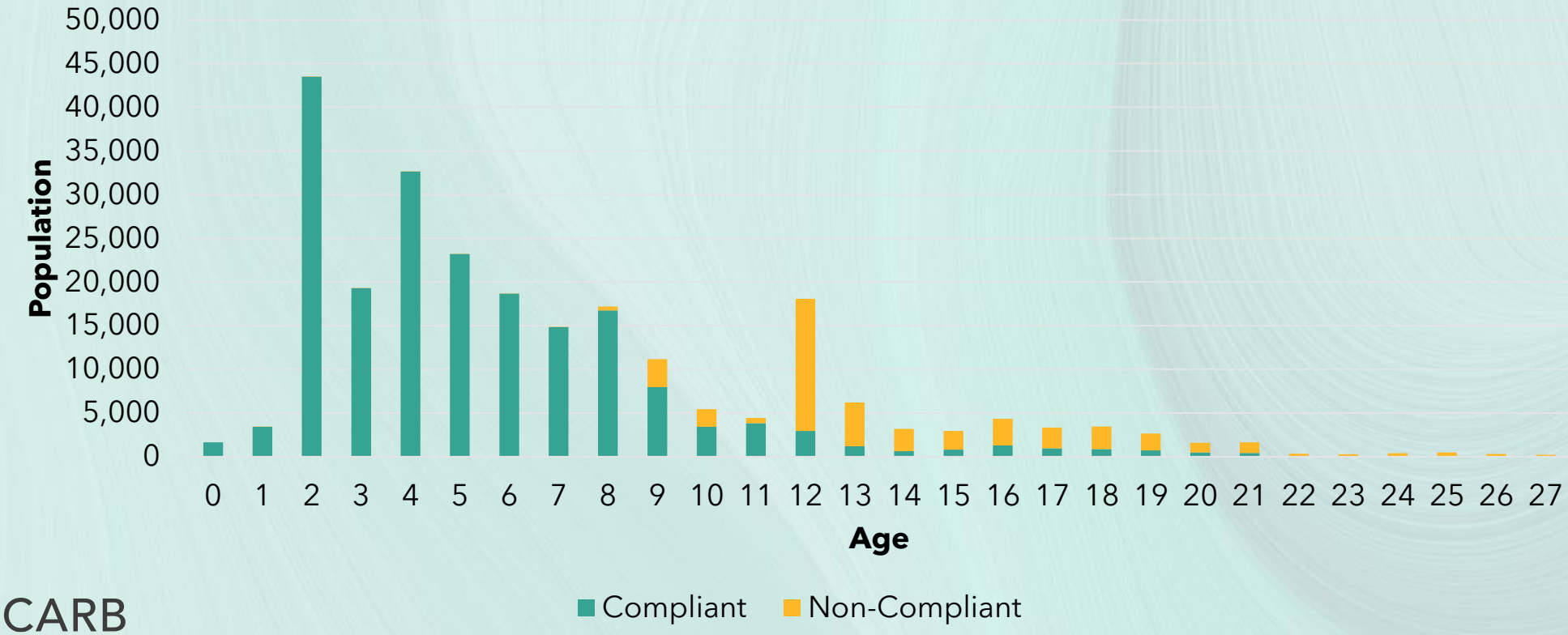
- Each equipment type has a different age distribution, with out-of-State fleets of Trailer TRU and Generator Sets generally younger on average than in-state fleets.



Equipment Type	In-State Average Age	Out-of-State Average Age
Trailer TRU	9.8	6.3
Generator Sets	9.4	6.4
Truck TRU	7.7	7.7
Railcar TRU	4.7	4.7
DSC TRU	2.4	2.4

Population by Age and Compliance Status

- 18 percent of all registered TRUs are not compliant with TRU ATCM.
- Inventory excludes a small number of TRUs from ARBER that were age 28 or older.
  - Data from CARB's enforcement program showed these older TRUs were likely not in service.



Activity

- No planned changes from previous inventory
- Activity data based on surveys of facilities and telematics data
  - **All Trailer TRUs, Generator Sets, Railcar and DSC:** 2018 telematics data and 2011 facility survey data weighted averages
  - **Truck TRUs:** 2011 facility survey data

Data Source	Cumulative TRU Time Represented	TRU Units Represented	Average Annual Hours	Time-weighted Average Hours
Facility Survey - Trailers	1,100,000 Hours (125 years)	5,535 Trailers	1,712	2,201
Telematics Data - Trailers	870,000 hours (99 years)	811 Trailers	2,876	2,201
Facility Survey – Trucks	92,000 hours (11 years)	459 Trucks	1,360	1,360

Activity: In-State Fraction

- Draft inventory carries forward existing methodology that adopts in-State operation fraction to EMFAC data for trucks
- Operation fraction comes from International Registration Plan (IRP) data, which provides information on where trucks drive

Category	Annual Activity Inside and Outside California (hours)	IRP Data – Portion Inside California (%)	Average Annual Activity Inside California (hours)
In-State Trailer TRU and Generator Sets	**2,201**	**78.0%**	**1,719**
Out-of-State Trailer TRUs and Generator Sets*, Railcar* and DSC*	**2,201**	**12.4%**	**272**
Truck TRU	**1,360**	**100%**	**1,360**

*Updated for this inventory, previously modeled with 1,000 annual hours total (including operation inside and outside California)

Engine Rated Power

- The engine rated power is based on each **engine model** reported in ARBER, and the manufacturer's rated horsepower (HP) for each model.

Category	Average Horsepower: Below 23 HP	Average Horsepower: 23 to 25 HP	Average Horsepower: 25 HP and Over
In-State Trailer TRU	-	24.8	33.8
Out-of-State Trailer TRU	-	24.7	33.7
All Generator Sets	-	24.8	33.2
Railcar and DSC	-	24.7	33.7
Truck TRU	17.2	-	-

Load Factor

- No changes since the 2021 Emissions Inventory
- Based on certification cycle data, which was previously corroborated with telematics data
- Efficiency improvements in trailer TRUs over 25 HP resulted in reduced load factors for MY 2013 and newer

TRU Category	Below 23 HP	Between 23 and 25 HP	Over 25 HP: 2012 and Older	Over 25 HP: 2013 and Newer
All Trailer TRUs	-	0.46	0.46	0.38
All Generator Sets	-	0.33	0.33	0.27
Truck TRUs	0.56			
Railcar TRU	-	0.46	0.46	0.38
DSC TRU	-	0.46	0.46	0.38

Emission Factors

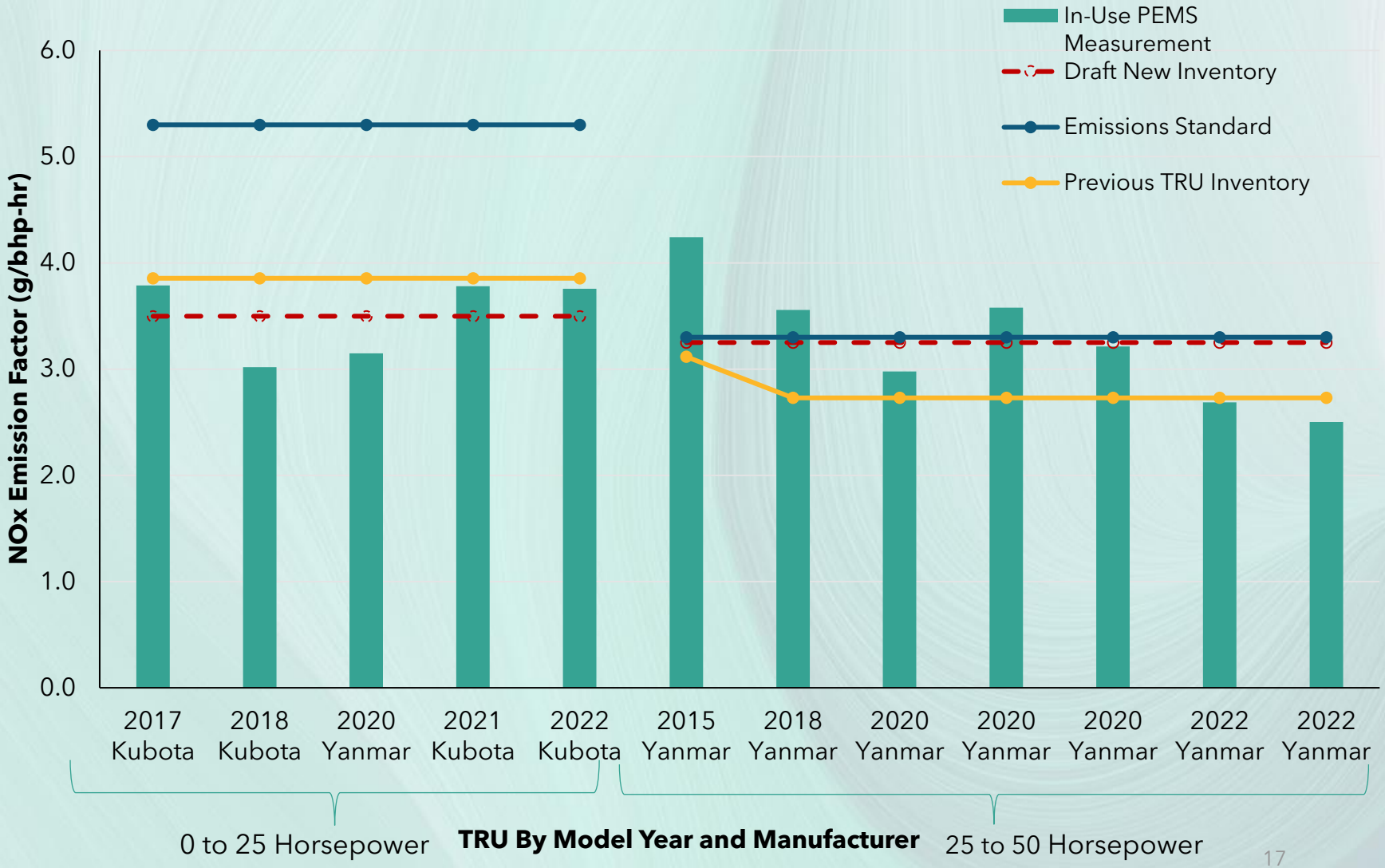
- Emission factors represent the average amount of pollutant per hour for each brake-horsepower
- Previous inventories used engine certification data from manufacturers, measured in laboratory conditions, not during real-world operation
- New draft inventory uses NOx emission factors measured from in-use operation of TRUs
- PM, hydrocarbons (HC), and reactive organic gases (ROG) continue to use certification data as it remains the best available source for those pollutants

In-use Emissions Testing of TRUs using Portable Emissions Measurement Systems (PEMS)

- CARB ran an in-house emissions testing program from 2020-2024 at the Depot Park Facility in Sacramento, California.
- Test modes included cycle-sentry and continuous flow, both with the door open and closed
- Each test was 1 hour, repeated 3 times
- 12 TRUs tested spanning MY 2012 to 2022

TRU NOx Emission Testing Results

- PEMS emissions factors (blue bars) were averaged across units within horsepower bin (0-25 and 25-50) to generate red dashed line
- Relative to previous inventory (orange line), new draft inventory emissions factors are:
  - 0-25 hp: 9% lower
  - 25-50 hp: 19% higher



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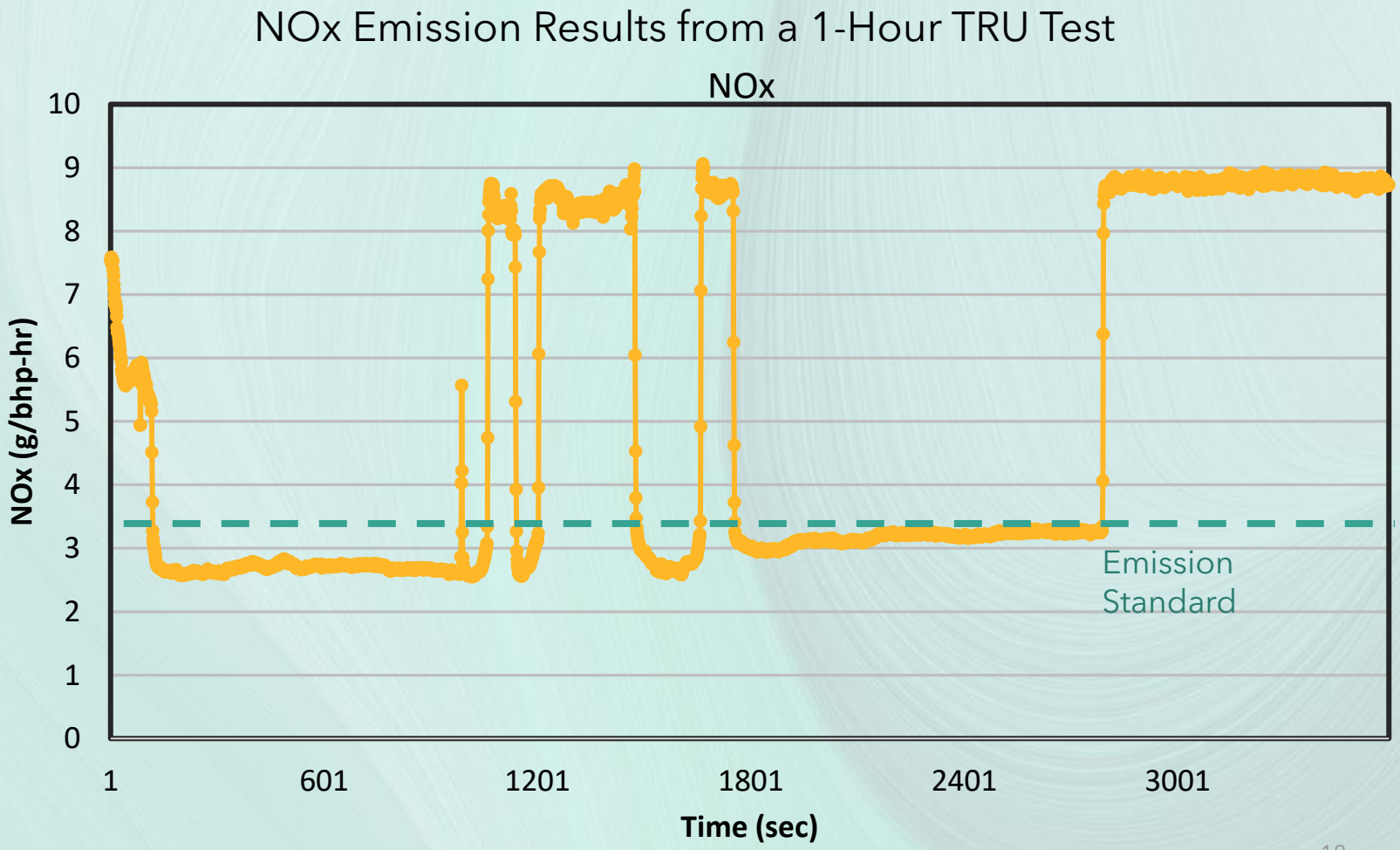
One-Hour TRU Test Showing High-NOx Period

- NOx emissions widely fluctuated during tests – CARB staff used average
- Some TRUs had higher NOx emissions toward end of the one-hour test
- Future consideration:
  - Average results could have been higher if testing continued for a longer period

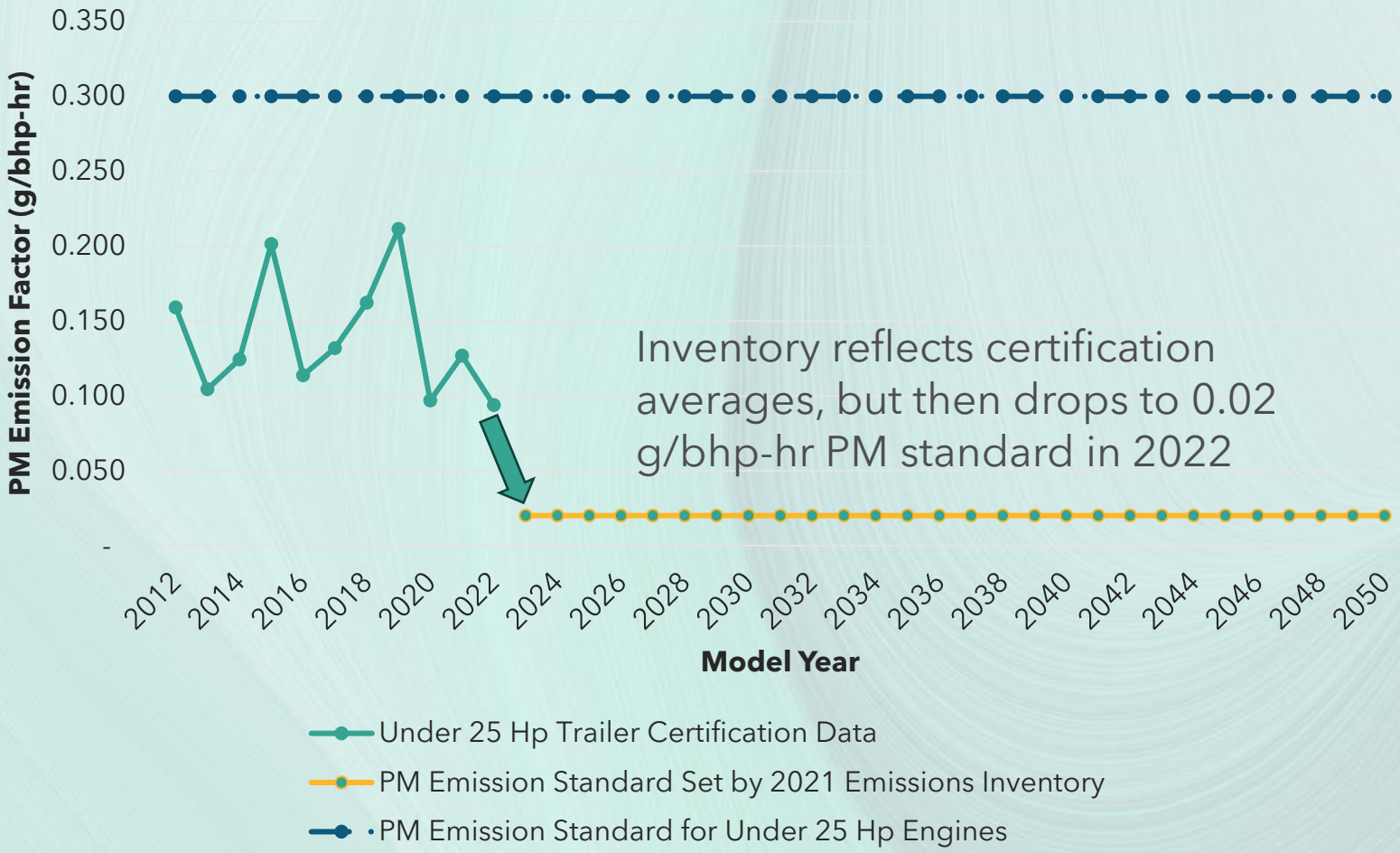


Certification Data

- For PM, HC, and ROG emissions factors, CARB staff continued to use engine certification data
- Each engine manufacturer must test engines following a specific engine cycle and report the results to both the U.S. Environmental Protection Agency and CARB
- CARB staff used ARBER data to determine engine families
- Draft new TRU inventory incorporates additional certification data for MY 2020-2024 engines
- Population of engine families in ARBER was used to weight emission factors

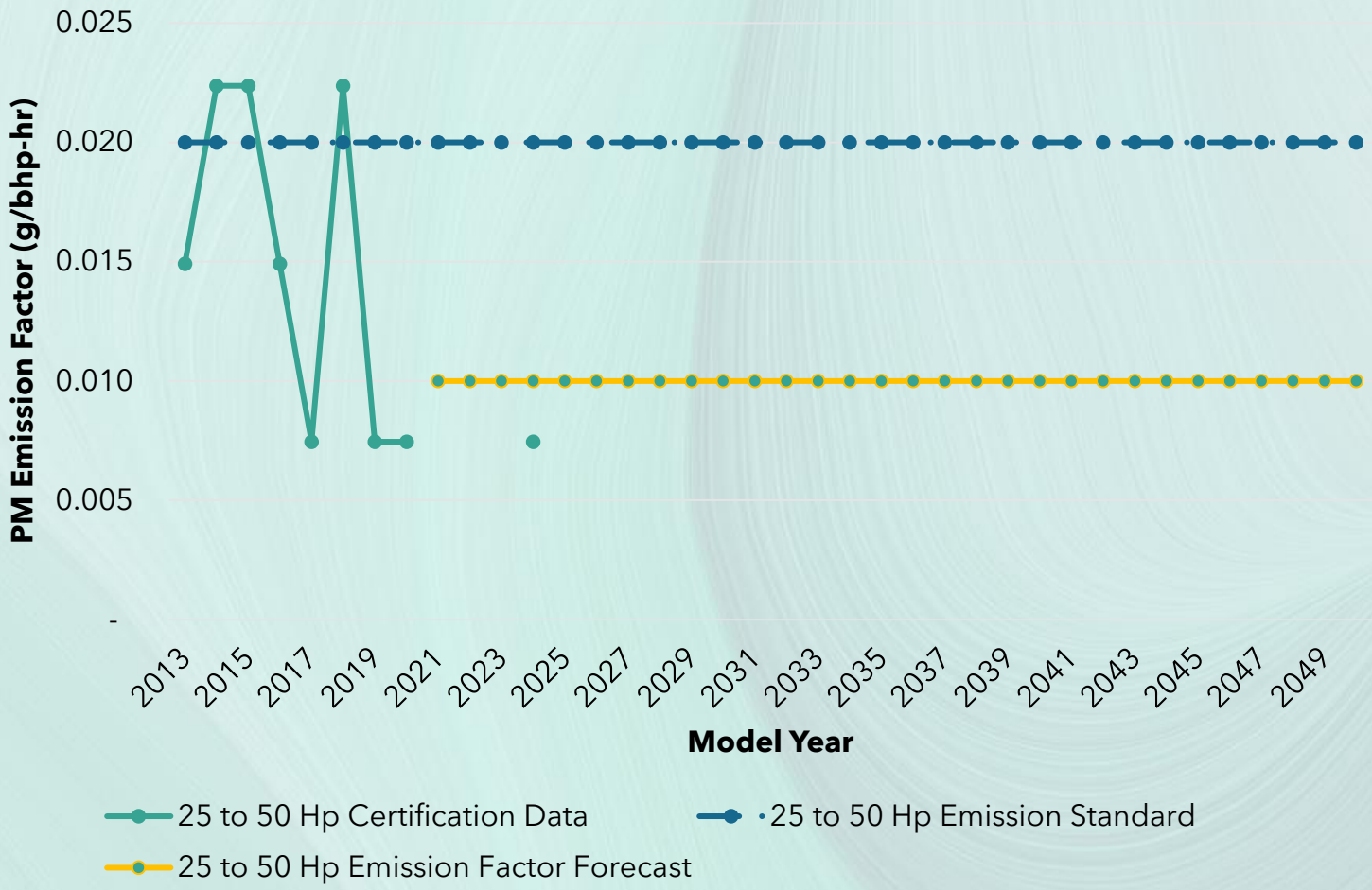
PM Emission Factors for Trailers Under 25 Horsepower

- The 2021 Emissions Inventory set a standard of 0.02 g/bhp-hr, aligning with 25 to 50 horsepower emission standards.
- Inventory is using certification data up to and including model year 2022
- Model year 2023 and later set to 0.02 g/bhp-hr standard



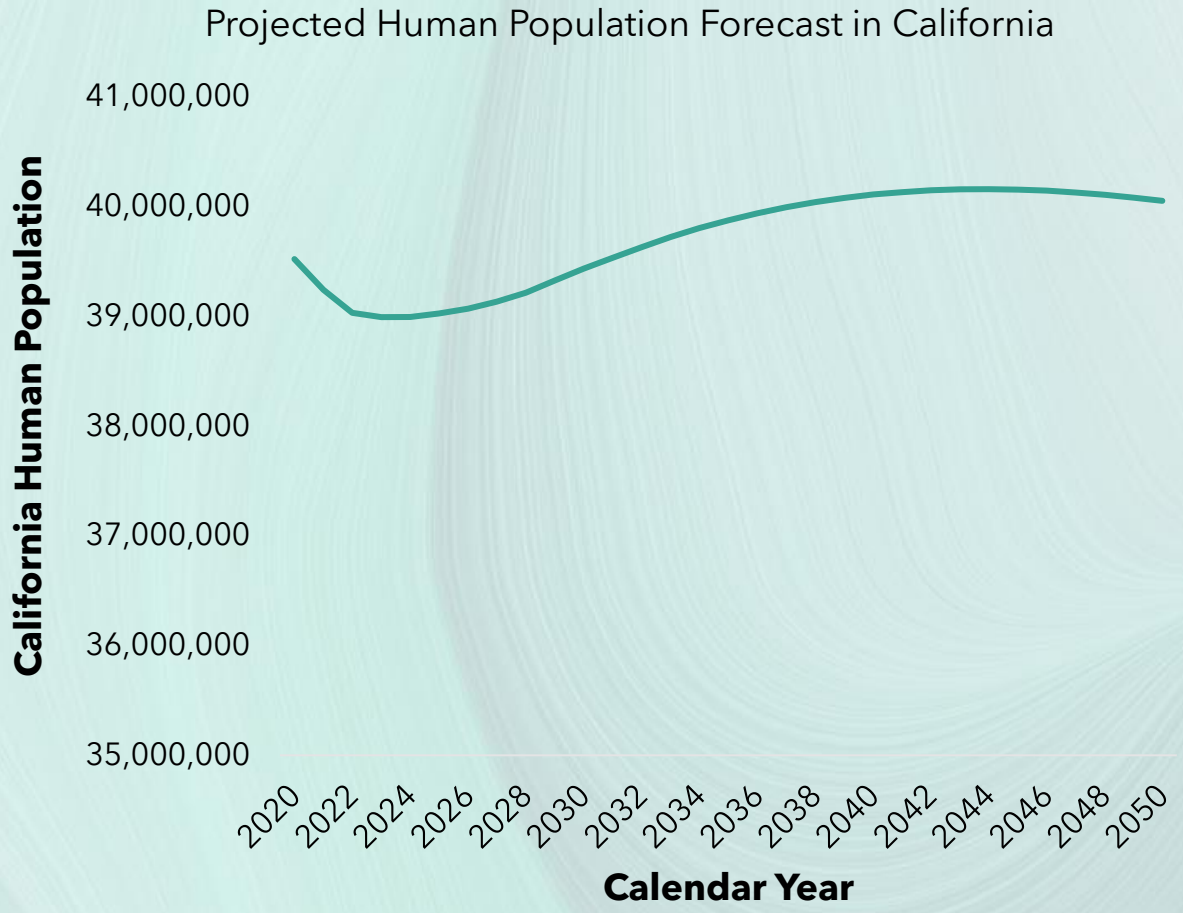
PM Emission Factors 25-50 Horsepower

- Certification data is lower than certification standards for TRUs over 25 horsepower
- Certification data from 2020-2024 showed an average of 0.01 g/bhp-hr compared to the standard of 0.02 g/bhp-hr.



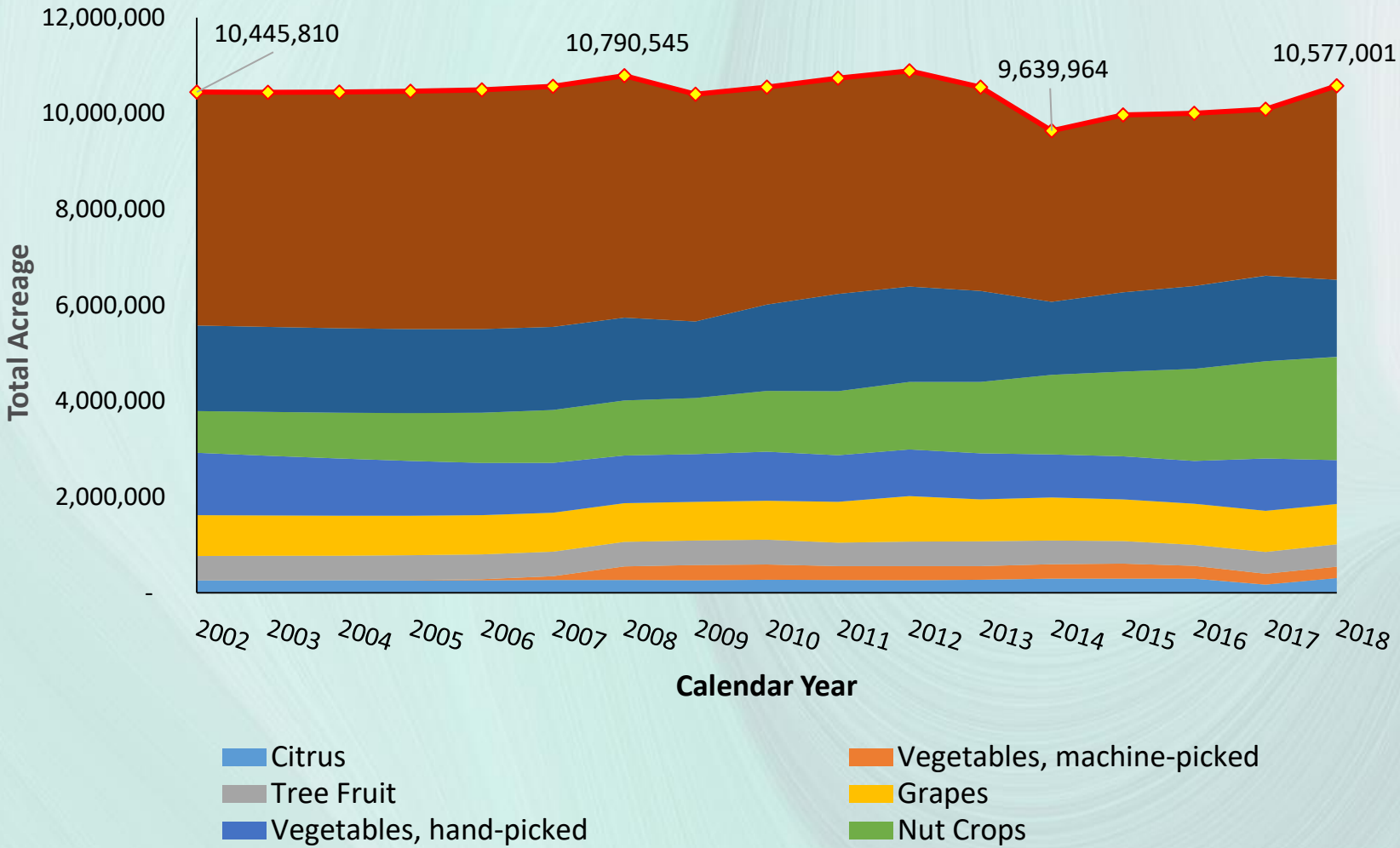
Growth: Population Forecasts

- TRU growth factors based on California population growth (showing an increased demand for frozen goods in California) and agricultural production (showing an increased supply of frozen goods to transport out-of-state).
- Current growth projection comes from California's 2022 population projection from the California Department of Finance.
- The total growth from 2023-2050 is about 1%, or 0.03% annually.



Growth: Agricultural Production

- County Agricultural Commissioners' data reports that the total acreage of California's farms has been relatively flat from 2002 to 2018, suggesting little change in amount of goods exported
- As a result, TRU population and activity forecast projects zero growth
- Staff is still investigating data sources and are open to input



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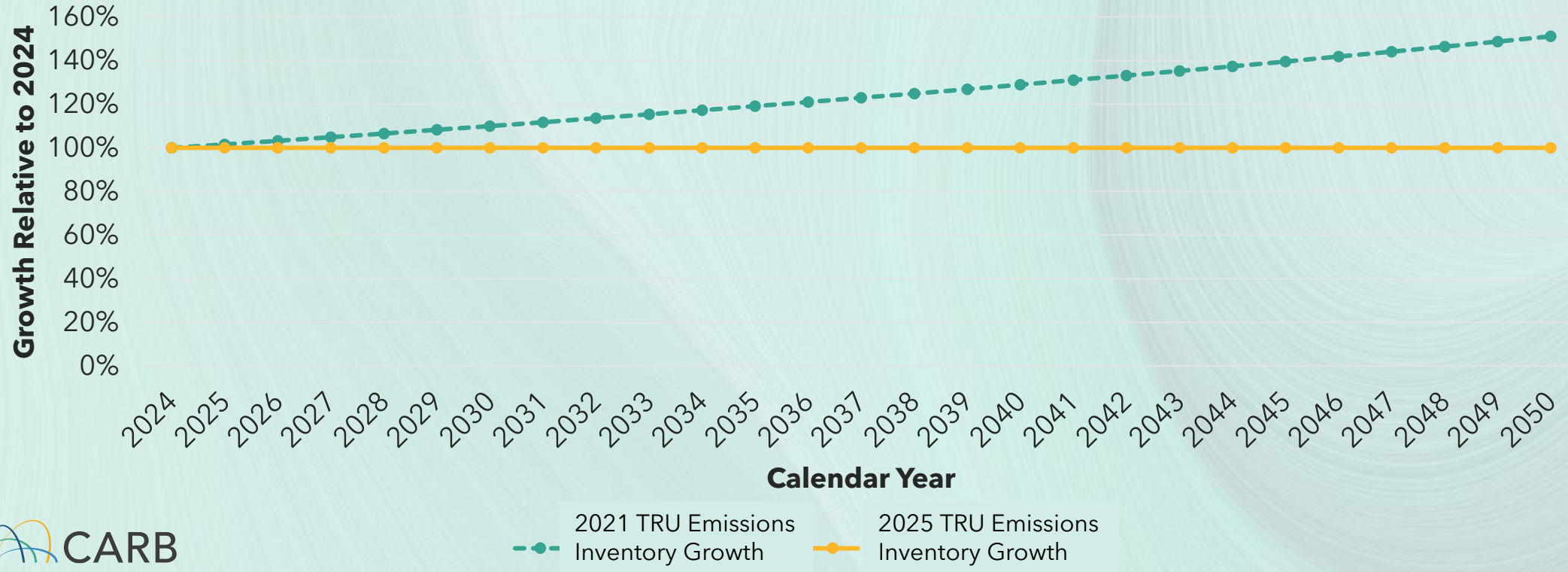
Growth: 2021 Emissions Inventory vs. 2025 Emissions Inventory

- Previous emission inventory showed 1.6 percent annual growth based on economic forecasts of the frozen goods sector.
- Draft new inventory has no growth applied based on the population and production metrics
- Difference between inventories is based on the previous inventory using an economic forecast, which can reflect an increases in prices, vs consumption or volume method which is not showing similar growth



Forecasting Equipment Replacement

- Population turnover is the process of forecasting the age of equipment to better understand future emissions.
- The TRU forecast is from base year 2024 to 2050.
- Future year equipment is projected by fleet age distribution observed in base year 2024.
- Each TRU fleet is modeled individually:
  - Fleets with many newer TRUs turn over quickly, to newer equipment, staying relatively new
  - Fleets with older equipment purchase less often, may purchase used TRUs

Turnover Methodology

1. Identify the average age in each individual fleet.
2. Identify the minimum age within each individual fleet.
3. Turnover occurs when the average age of the fleet is exceeded.
4. The new equipment is based on the minimum age within each fleet.
    - If a fleet buys used equipment, the “new” equipment will turnover to the minimum age within the fleet.

Example Turnover

A fleet with 5 TRUs, with 12 years old average age, and 7 years old minimum age in base year

Calendar Year	TRU 1	TRU 2	TRU 3	TRU 4	TRU 5	Avg Age Before Turnover	Avg Age After Turnover
2023	Age 7	Age 9	Age 12	Age 16	Age 16	12	-
2024	Age 8	Age 10	Age 13	Age 17	Age ~~17~~ **7**	13	11
2025	Age 9	Age 11	Age 14	Age 18	Age 8	12	-
2026	Age 10	Age 12	Age 15	Age ~~19~~ **7**	Age 9	13	10.6
2027	Age 11	Age 13	Age 16	Age 8	Age 10	11.6	-
2028	Age 12	Age 14	Age ~~17~~ **7**	Age 9	Age 11	12.6	10.6

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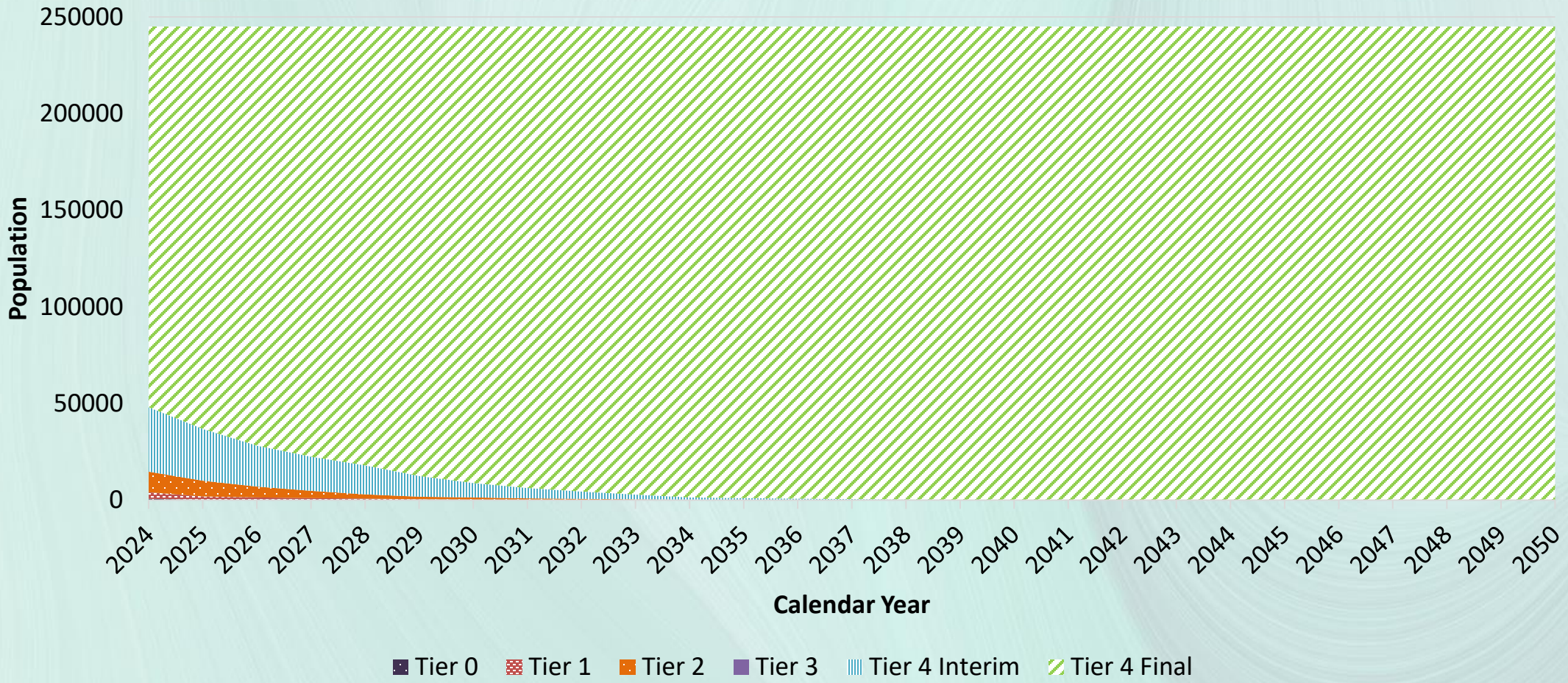
Results: Population



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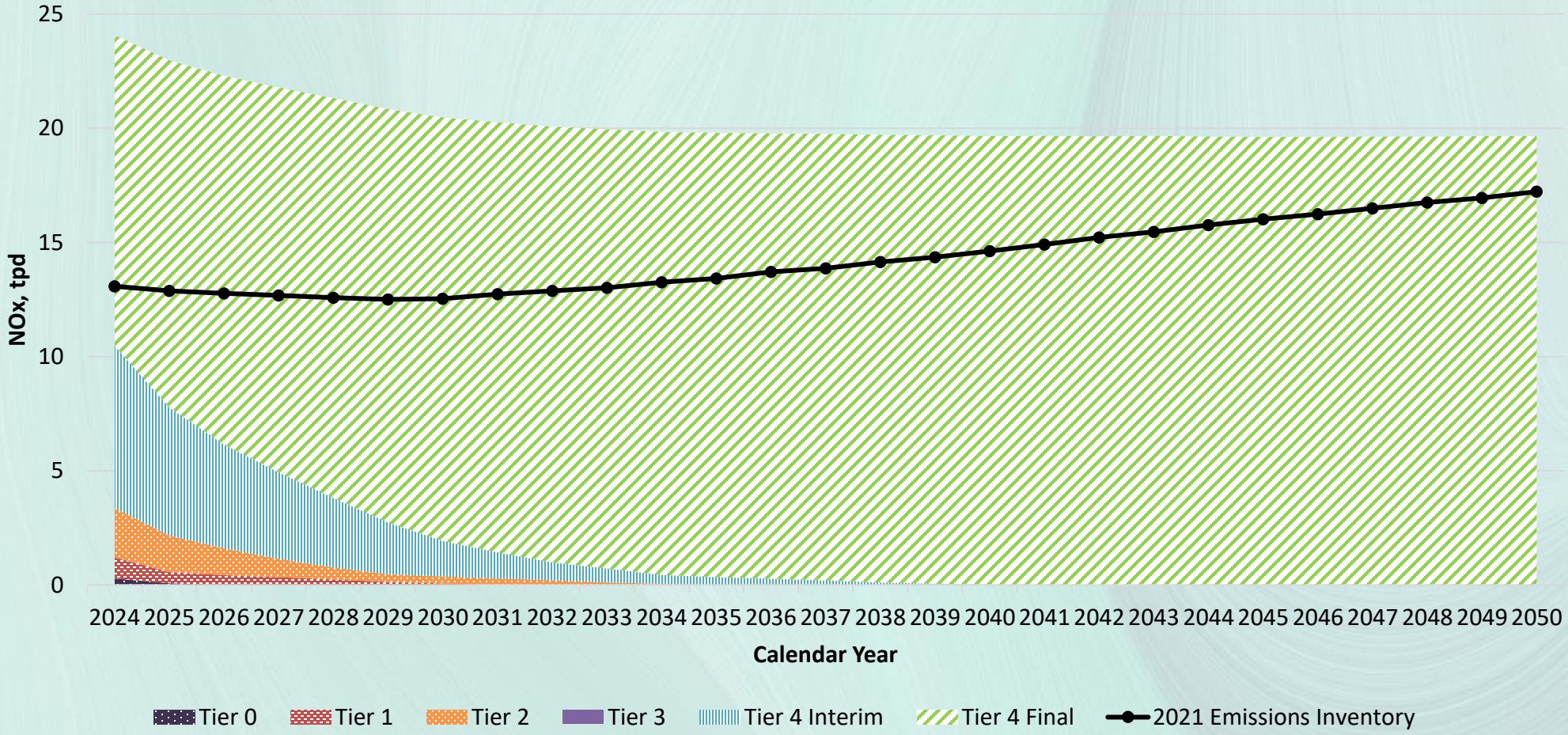
Results: NOx


25
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NOx, tpd
2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050
Calendar Year
Tier 0
Tier 1
Tier 2
Tier 3
Tier 4 Interim
Tier 4 Final
2021 Emissions Inventory

Results: PM2.5