

# **Appendix F**

## **Emissions Analysis Methodology and Results**

**Medium Heavy-Duty Diesel Trucks, Heavy Heavy-Duty Diesel Trucks,  
and Regulated Bus Categories**



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## List of Acronyms

AEO	Annual Energy Outlook
ARB	Air Resources Board
BOE	Board of Equalization
CY	Calendar Year
DMV	Department of Motor Vehicles
DPF	Diesel Particulate Filter
EIA	Energy Information Administration
GVWR	Gross Vehicle Weight Rating
HDT	Heavy-Duty Truck
HHDDT	Heavy Heavy-Duty Diesel Trucks
IRP	International Registration Plan
MHDDT	Medium Heavy-Duty Diesel Trucks
MY	Model Year
NO <sub>x</sub>	Nitrogen Oxides
PM	Particulate Matter
SIP	State Implementation Plan
TEU	Twenty-foot equivalent unit
VMT	Vehicle Miles Traveled

## **A Introduction**

In an effort to best characterize present-day heavy duty truck emissions in support of the proposed regulatory amendments, four inventory-related updates were made. The effect of these updates were changes to: truck VMT; truck fleet age distributions; the truck populations associated with specific rule compliance scenarios; and the assignment of existing engine model-year emission factors for truck model-year emission calculations. This appendix only provides discussion of these changes and their impact on emissions in the context of the proposed amendments. The technical appendices (ARB, 2008; ARB, 2010a) from prior Truck and Bus regulatory actions can be referred to for a full discussion of the methodologies and assumptions that have not changed.

## **B Heavy-Duty Truck Emissions Inventory Updates**

### **1) Updated VMT Based on New (2013) Fuel Sales and Use Data**

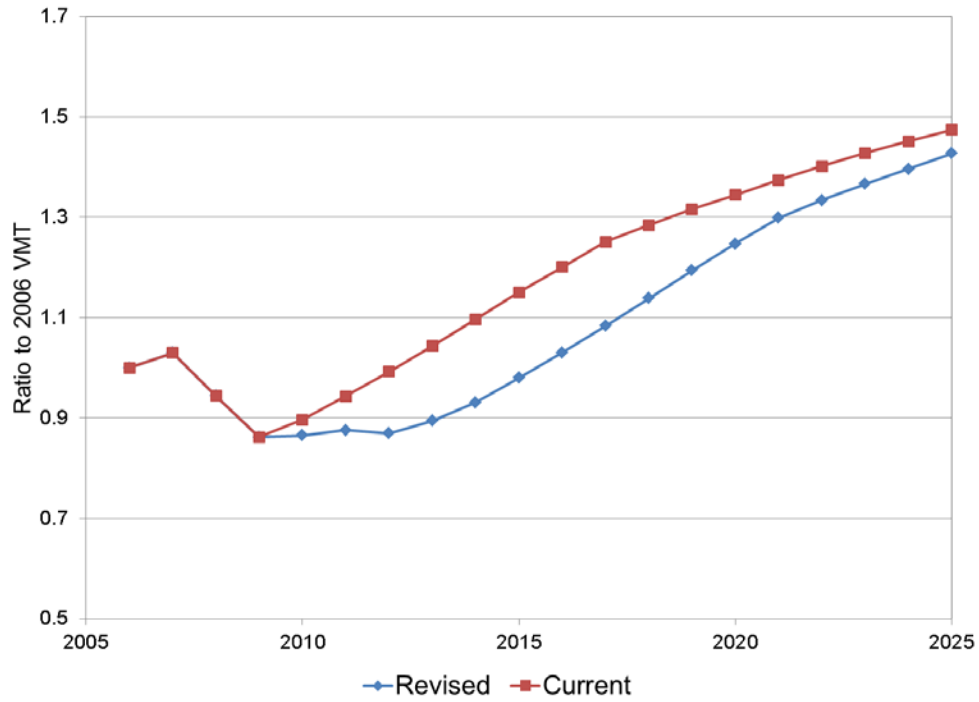
In the 2010 Rule inventory, staff used trends in historical fuel sales and use data published by the Board of Equalization (BOE) as a surrogate for estimating historical VMT for heavy duty diesel truck fleets that do not have vocation-specific growth trends. More specifically, future year VMT trends were estimated assuming the recovery would begin in 2010 and grow at a rate roughly consistent with forecasted transportation and warehousing employment that was published in several economic studies at that time. Since that time, the growth rate in fuel use has been lower than projected. For this update, staff refreshed the BOE historical fuel sales and use data with recent (2013) data. These data show little or no growth in taxable diesel fuel sales since 2009. Staff used the new data up to 2013 to represent historical VMT growth, then, starting in 2014 and beyond, assumed the same future year, economic recovery trend that was previously assumed in the 2010 Rule inventory (ARB, 2010a).

Figure 1 and Figure 2 show the current and revised VMT growth trends for heavy heavy-duty (T7) and medium-heavy-duty (T6) diesel trucks. In general, the revised VMT estimates are lower than previously estimated. However, the differences are smaller after 2020.

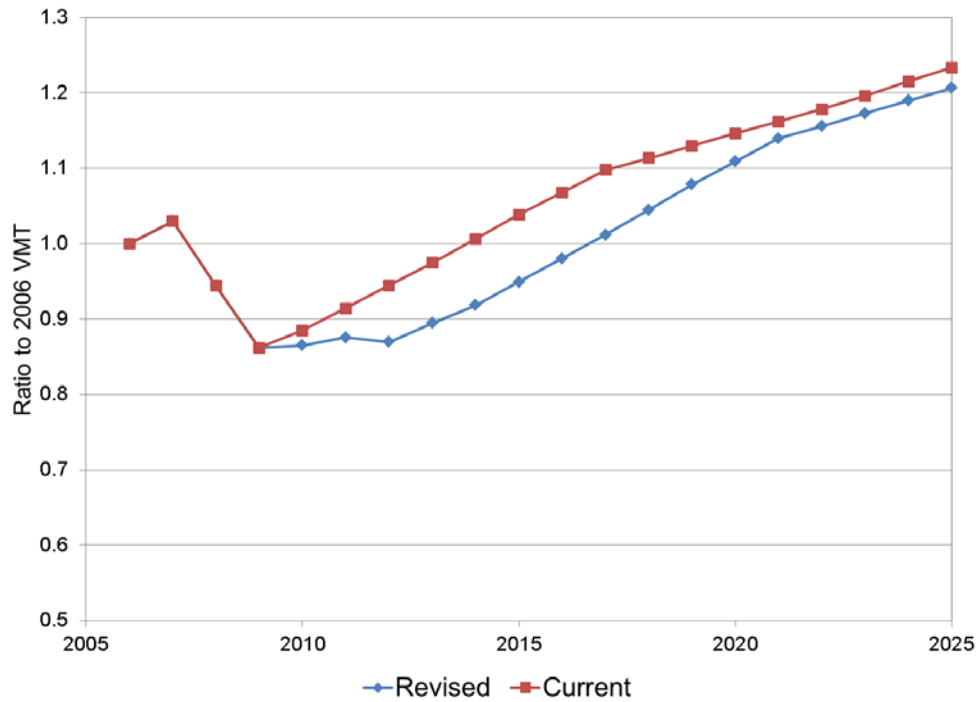
For drayage trucks, the twenty-foot equivalent unit (TEU) statistics from ports (Port of Los Angeles, 2013; Port of Long Beach, 2013; Port of Oakland, 2013) were used as surrogate to update the historical drayage truck VMT growth trends. Figure 3 and Figure 4 show the growth trends for drayage trucks serving ports in South Coast and in San Francisco Bay areas, respectively.

The VMT growth trends for construction fleets were also updated based on the trends in the In-Use Off-Road Equipment emission inventory (ARB, 2010b).

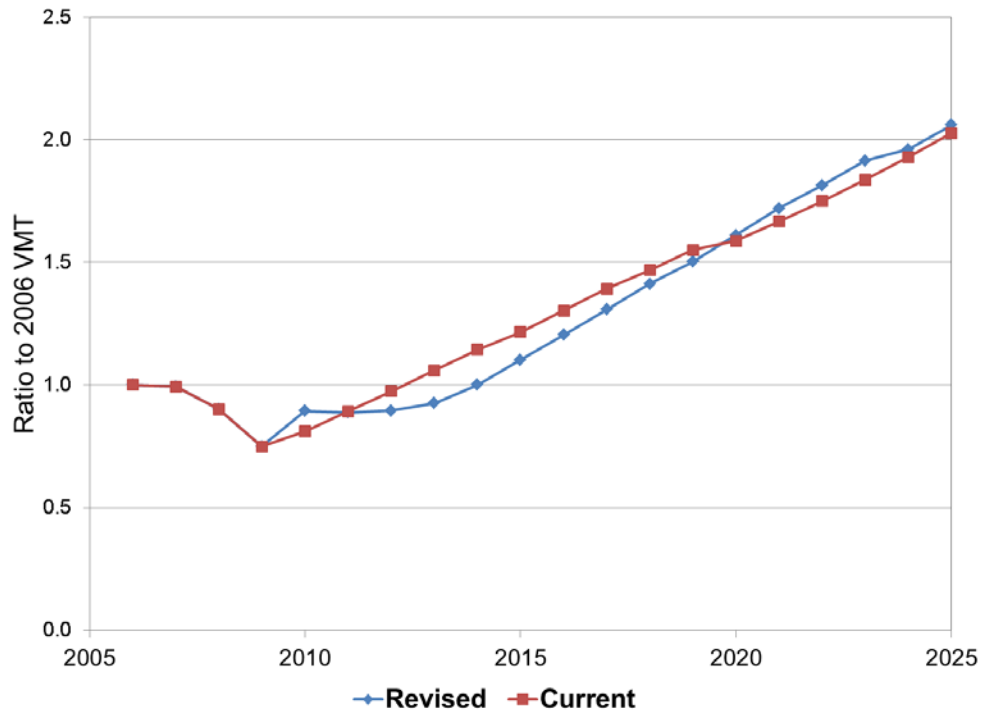
**Figure 1. Heavy-Heavy Duty Diesel Truck VMT Growth Trend Assumption**



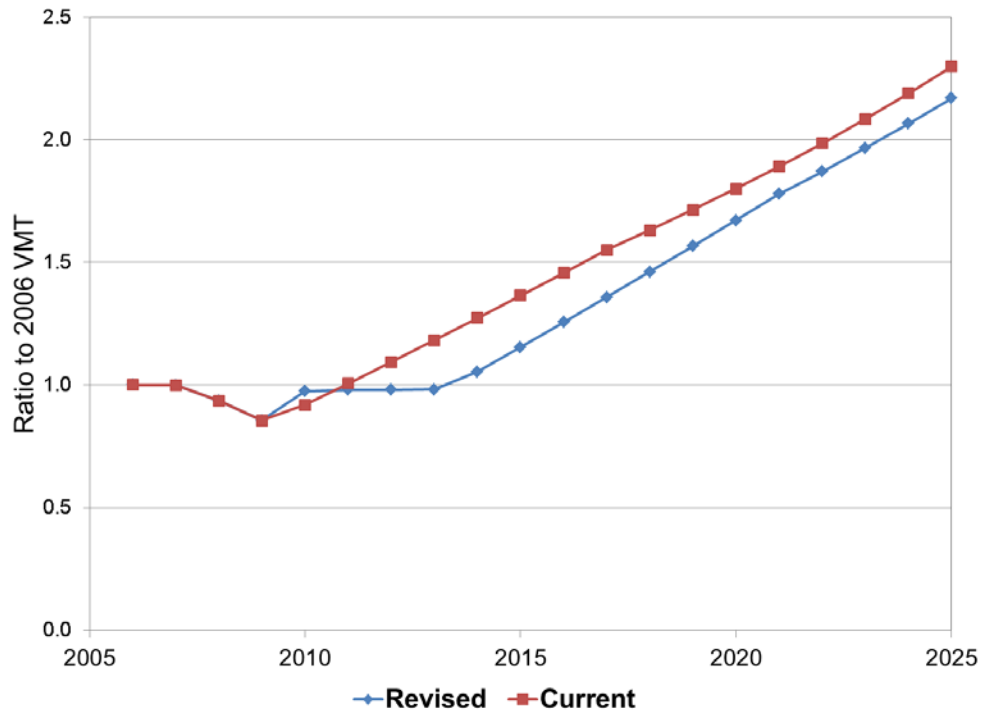
**Figure 2. Medium-Heavy Duty Diesel Truck VMT Growth Trend Assumption**



**Figure 3. VMT Growth Trends of Drayage Trucks Serving South Coast**



**Figure 4. VMT Growth Trends of Drayage Trucks Serving San Francisco Bay**



## 2) Updated Fleet Age Distributions Based on New (2013) Truck Sales Data

New truck sales are used to calculate the fleet and calendar year specific age distributions from an average age distribution as described in previous technical appendices (ARB, 2008; ARB, 2010a). Year-specific adjustments to an average age distribution are calculated as ratios of year-specific vehicle sales to a best-fit regression 'trend' line level of sales (where the trend line functions as a surrogate for average sales conditions).

For this update, staff used the latest Annual Energy Outlook (AEO) projected nationwide truck sales published by the U.S. Energy Information Administration (EIA, 2014). Following the same approach used in the 2010 inventory, staff used scalars based on the revised California VMT (described above) to nationwide VMT as a California-specific adjustment to the nationwide truck sales data. The California-specific sales estimate was then used to develop California specific fleet age distributions.

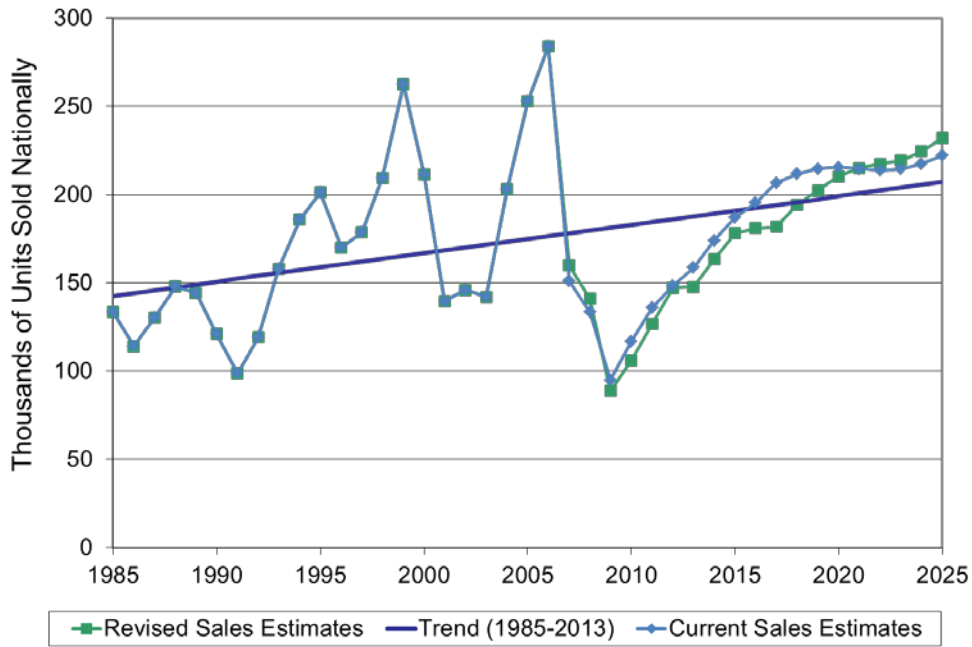
In the 2010 inventory, staff used the heavy duty (GVWR above 26,000lbs) sales in AEO for heavy-heavy duty and medium duty (GVWR 10-26,000lbs) for medium-heavy duty trucks. However, after further review of the data, for this update staff concluded that it would be more appropriate to use the heavy duty sales in AEO for estimating the sales for both medium and heavy-heavy duty diesel trucks.

Figure 5 and Figure 6 show the current and revised truck sales with California-specific adjustments for heavy-heavy and medium-heavy diesel trucks. Similar to VMT growth trends, these sales estimates were used for the majority of the heavy duty diesel truck fleets that do not have vocation-specific growth trends. The sales for trucks in the construction sector are shown in Figure 7 and Figure 8.

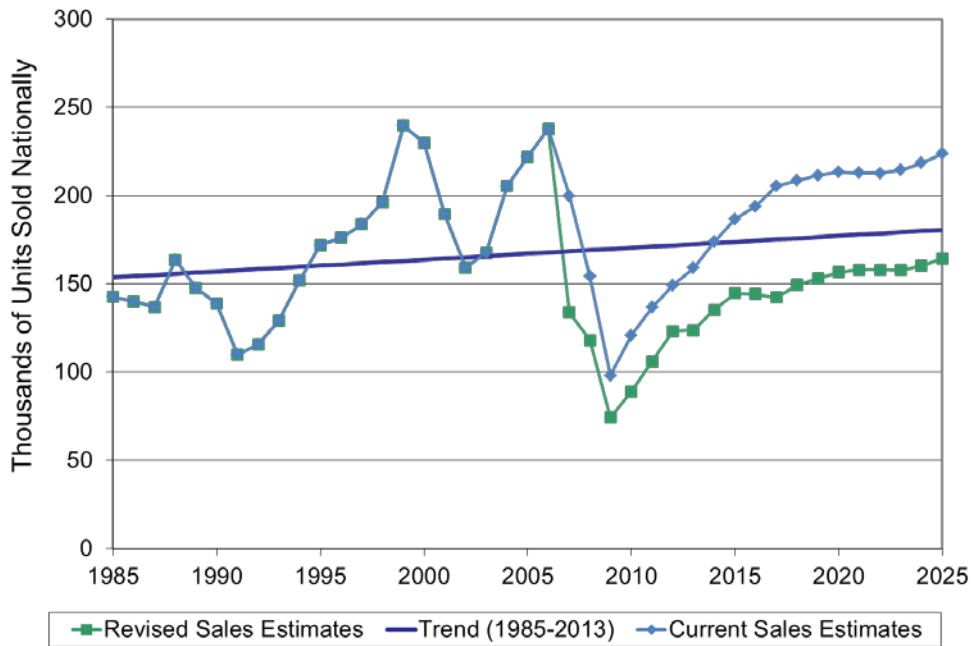
In Figures 5-8, for any specific model year, the ratio between actual/projected sales (green or light blue line) to the regression-based best-fit sales curve (dark blue line) is calculated. This ratio is applied as scalar to the average age distribution fraction for that model year in all calendar years. After applying the scalar, the sum of adjusted age distribution fractions is then renormalized to 1 to generate a new calendar year specific fleet age distribution.



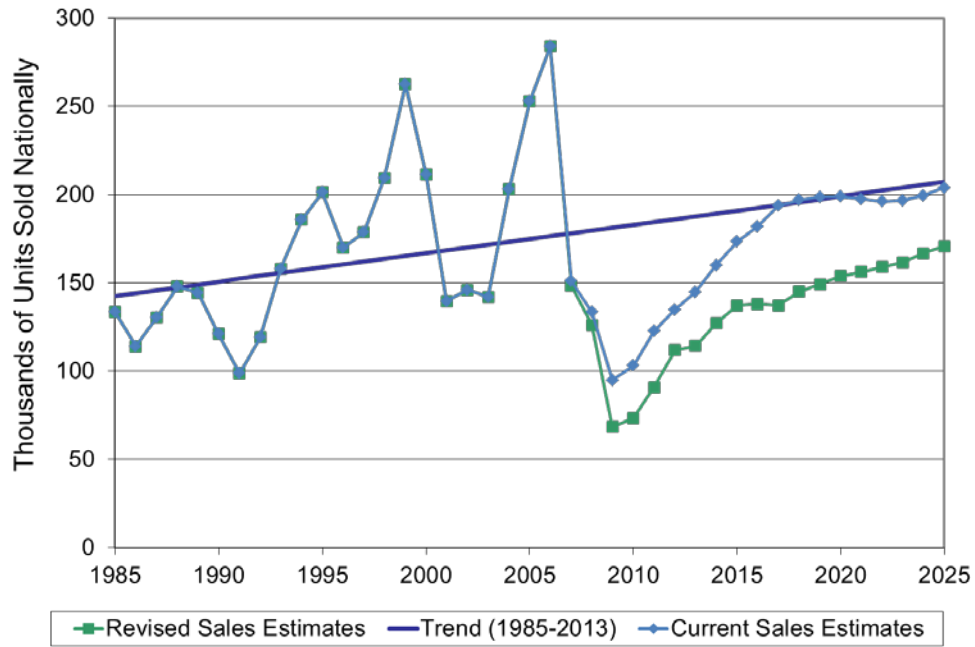
**Figure 5. Sales Forecast for Heavy Heavy-Duty Diesel Trucks**



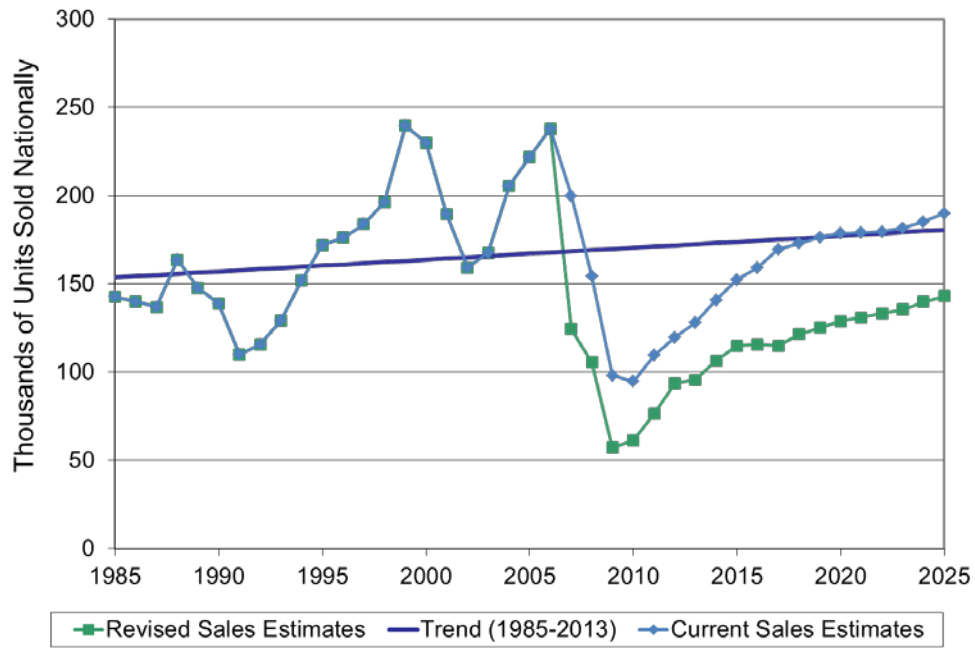
**Figure 6. Sales Forecast for Medium Heavy-Duty Diesel Trucks**



**Figure 7. Sales Forecast for Heavy Heavy-Duty Construction Trucks**



**Figure 8. Sales Forecast for Medium Heavy-Duty Construction Trucks**



### 3) Improved Matching of Existing Engine Emission Factors to Truck Model Years

Truck populations in the emissions inventory are based on California Department of Motor Vehicle (DMV) registration data and International Registration Plan (IRP) submittals. Both data sources provide *vehicle chassis* ('truck') model year. However, data collected to develop emission rates are based on *engine* model year. An earlier survey of about 800 trucks indicated that a miss-match between truck and engine model years could be as high as 20% for some model years. Based on the survey results, staff made minor adjustments to the emission factors used in EMFAC2007 (ARB, 2007).

For this update, the latest data collected through the Drayage Truck Registry (DTR), shown in Table 1 indicates that engine model years are about 1 year older for the majority of late model year trucks. Existing adjustments do not adequately account for these differences, especially for the Diesel Particulate Filter (DPF) and Selective Catalyst Reduction (SCR) equipped trucks, which are the focus of the Truck and Bus regulation. To account for this issue in this update, staff shifted the truck model year by one year (older). This results in the use of more representative emission factors in the calculation of emissions.

**Table 1. Drayage Truck Registry Engine vs. Truck Model Years**

Truck Model Year	Engine Model Year								
	2005	2006	2007	2008	2009	2010	2011	2012	2013
2007	4%	72%	24%						
2008		3%	62%	35%					
2009			5%	62%	33%				
2010					83%	17%			
2011					17%	67%	15%		
2012						15%	68%	17%	
2013						8%	16%	66%	10%

#### 4) Updated Rule Compliance Assumptions

When the Truck and Bus Regulation was amended in 2010, little information was available regarding the actions that truck fleet operators might take in order to comply with the requirements of the regulation. Therefore, staff made the assumption that the operators would choose to comply with the regulation by following the engine model year compliance schedule and that few operators would use credits for downsizing or early diesel PM filter compliance.

The Truck Regulations Upload and Compliance Reporting System (TRUCRS) came on-line in March 2010. Fleet data collected in the past two years through TRUCRS provided more up-to-date information to revise the prior assumptions.

Truck and fleet data collected through TRUCRS shows that as many as 50 percent of trucks in some fleet categories may delay compliance due to credits and flexibility provisions. In addition, some fleet operators preferred to purchase 2007 standard trucks with originally equipped diesel particulate filter than retrofit their existing pre-2007 trucks. Table 2 and Table 3 show the previous assumptions for large fleet tractors in the previous inventory (2010 update) and in the inventory for this proposed update, respectively. The updated assumptions reflected in Table 3 (and subsequent tables) account for the improved matching of engine and truck model year.

**Table 2. Previous Retrofit/Turnover Assumptions (2010 Update) for >26,000 lbs GVWR Tractor Trucks in Large Fleets**

Due Date January 1st of Calendar Year	Truck Model Year Group Affected on Date	Assumed Compliance Action for Affected Truck Model Year Group (DPF or Engine Model Year Required)
2012	1996-1999	DPF
2013	2000-2004	DPF
2014	2005-2006	DPF
2015	Pre-1994	2010
2016	1994-1995	2010
2020	1996-1999	2013
2021	2000-2004	2014
2022	2005-2006	2015
2023	Pre-2010	2015

**IMPORTANT NOTE!** The model years contained in the remainder of this document (Table 3 and beyond) should **not** be referenced to assess compliance with the proposed amendments. The model years listed in the tables are truck model year, where truck model year = engine model year +1. The reason behind this issue is that emission factors are stored in EMFAC2011 based on **truck** model year, not **engine** model year. Because the focus of compliance for the regulation is on **engine** model year, the adjustments to truck model year described in Section 3 (above) are, effectively, 'artificial' adjustments to ensure that the proper emission factors are being used to calculate assumed engine model year compliance scenario emissions for truck model year groups.

**Table 3. Retrofit/Turnover Assumptions for >26,000 lbs GVWR Tractor Trucks in Large Fleets with Adopted Rule in the Revised Inventory Model\***

Due Date January 1st of Calendar Year	Truck Model Year Group Affected on Date	Assumed Compliance Action for Affected Truck Model Year Group (DPF or Engine Model Year* Required)	
		70%	30%
2012	1997-2000	2008	Credit and provisions No action
2013	2001-2005	50%DPF+50%2010	
2014	2006-2007	50%DPF+50%2010	
2015	Pre-1995	2011	Pre-2001 →2008 2001-2007→2012
2016	1995-1996	2012	
2020	1997-2000	2015	
2021	2001-2005	2016	
2022	2006-2007	2017	
2023	Pre-2011	2017	2017

\*See **IMPORTANT NOTE** in the text, above.

### C Proposed Regulatory Scenarios and Compliance Assumptions

The proposed amendments provide additional flexibility to vehicle owners by ensuring a more successful compliance path, thereby better protecting the emission benefits of the regulation through greater levels of compliance. To reflect these amendments, staff has made assumptions about how trucks in each category will respond to proposed regulatory requirements. The assumptions incorporate the updated rule compliance assumption based on information gathered through TRUCRS.

This section provides the assumptions used to calculate the emissions benefits of the proposed amended regulation using EMFAC2011 with updates described in item B (noted as revised inventory model henceforth) for each inventory category for which regulatory requirements changed between the 2010 regulation and the proposed regulation. If the requirements did not change, the assumptions documented in ARB (2010) are still valid.

1) Low Use Vehicles

The proposed amendments expand the existing definition of Low Use Vehicles by including vehicles that travel fewer than 5,000 total miles per compliance year. The 5,000 mile low use exemption sunsets in 2020 and staff assume all pre-2011 low use vehicles would be replaced with model year 2011 vehicles by January 1, 2020.

2) Work/Vocational Truck Phase-in Option

The proposed amendments expand the types of trucks that are eligible for construction extension by expanding the existing Construction Truck definition to include all trucks except for tractor trailer combinations that are not already included in the existing definition. In the revised emission inventory model, staff applied the option to trucks with annual mileage between 5,000 and 20,000 miles including heavy-heavy duty single unit and tractor in construction sector, medium-heavy trucks above 26,000 lbs GVWR in construction sector and heavy-heavy duty single unit. The compliance assumptions are modeled in the revised inventory as illustrated in Table 4.

**Table 4. Retrofit/Turnover Assumptions for Work Truck Phase-In Option in the Revised Inventory Model\***

Due Date January 1st of Calendar Year	Model Year Group Affected on Date	Assumed Compliance Action for Affected Truck Model Year Group (DPF or <b>Engine Model Year*</b> Required)
2014	2006-2007	DPF
2015	Pre-1997	2008
2016	1997-2000	50%DPF + 50% 2008
2017	2001-2003	50%DPF + 50% 2008
2018	2004-2005	50%DPF + 50% 2012
2020	DPF equipped	2013
2023	2008-2010	2013

\*See **IMPORTANT NOTE** in the text, above.

### 3) Limited Mileage Agricultural Truck Extension

The existing agricultural vehicle extension for vehicles with limited mileage is set to expire on January 1, 2017. Staff proposed to lengthen the limited mileage extension out over several years as shown in Table 5.

**Table 5. Retrofit/Turnover Assumptions for Limited Mileage Agricultural Trucks in the Revised Inventory Model**

Due Date January 1st of Calendar Year	Model Year Group Affected on Date	Assumed Compliance Action for Affected Truck Model Year Group (DPF or Engine Model Year* Required)
2017	Pre-1997	2012
2018	1997-2000	2012
2019	2001-2005	2012
2020	2006-2007	2012
2023	2008-2010	2012

\*See **IMPORTANT NOTE** in the text, above.

### 4) Small Fleets Rule Compliance (>26,000 lbs GVWR)

The proposed amendments to the Regulation provide additional flexibility for small fleets by spreading out the compliance schedule for 2 and 3 truck owners so that the second and third truck is upgraded every other year. In addition, staff assumed 10 percent of the intra-state small fleets would be eligible for the special provision that delays compliance for owners that cannot comply. For the 10 percent within small fleets, no action would be needed until 2018. In 2018, all pre-2008 would be replaced with 2012 model year trucks, and in 2023, 2008-2010 would be replaced with 2015 model year trucks. Table 6, Table 7, and Table 8 present the compliance assumptions for the remaining 90% of small fleets.



**Table 6. Retrofit/Turnover Assumptions for >26,000 lbs GVWR Tractor Trucks in Small Fleets in the Revised Inventory Model\***

Due Date January 1st of Calendar Year	Model Year Group	1st truck*	2nd truck*	3rd truck*
2014	1997-2007	1/3DPF, 2/3 2008		
2015	Pre-1995	2012		
2016	Pre-1997	2012	2012	
2016	1997-2007		1/3DPF, 2/3 2008	
2018	Pre-1997			2012
2018	1997-2007			2012
2020	1997-2000	2013	2013	
2021	2001-2005	2014	2014	
2022	2006-2007	2015	2015	
2023	2008-2010	2015	2015	2015

\*See **IMPORTANT NOTE** in the text, above.

**Table 7. Retrofit/Turnover Assumptions for >26,000 lbs GVWR Single-Unit Trucks in Small Fleets**

Due Date January 1st of Calendar Year	Model Year Group	1st truck*	2nd truck*	3rd truck*
2014	1997-2007	2/3DPF, 1/3 2008		
2015	Pre-1995	2012		
2016	Pre-1997	2012	2012	
2016	1997-2007		2/3DPF, 1/3 2008	
2018	Pre-1997			2012
2018	1997-2007			2012
2020	1997-2000	2013	2013	
2021	2001-2005	2014	2014	
2022	2006-2007	2015	2015	
2023	2008-2010	2015	2015	2015

\*See **IMPORTANT NOTE** in the text, above.

**Table 8. Retrofit/Turnover Assumptions for >26,000 lbs GVWR Interstate Trucks in Small Fleets in the Revised Inventory Model\***

Due Date January 1st of Calendar Year	Model Year Group	1st truck*	2nd truck*	3rd truck*
2014	1997-2007	60%2008, 40%2011		
2015	Pre-1995	2012		
2016	Pre-1997	2012	2012	
2016	1997-2007		60%2008, 40%2011	
2018	Pre-1997			2012
2018	1997-2007			2012
2020	1997-2000	2013	2013	
2021	2001-2005	2014	2014	
2022	2006-2007	2015	2015	
2023	2008-2010	2015	2015	2015

\*See **IMPORTANT NOTE** in the text, above.

5) Large Fleet Rule Compliance (>26,000 lbs GVWR)

Although the proposed amendments do not specifically target large fleets, there are credits and provisions that large fleet could utilize for compliance. Staff assumed that half of the large fleet that are currently using credits and provisions would be able to further delay actions by another two years. Table 9, Table 10 and Table 11 show the assumptions for large fleets.

**Table 9. Retrofit/Turnover Assumptions for >26,000 lbs GVWR Tractor Trucks in Large Fleets in the Revised Inventory Model\***

Due Date January 1st of Calendar Year	Model Year Group	Assumed Compliance*		
		70%	15%	15%
2012	1997-2000	2008	Credit and provisions No action	Credit and provisions No action
2013	2001-2005	50%DPF+50%2010		
2014	2006-2007	50%DPF+50%2010		
2015	Pre-1995	2011		
2016	1995-1996	2012	Pre-2001 →2008; 2001- 2007→2012	pre-2008 turnover to 2012
2018				
2020	1997-2000	2015		
2021	2001-2005	2016		
2022	2006-2007	2017		
2023	Pre-2011	2017	2017	

\*See **IMPORTANT NOTE** in the text, above.

**Table 10. Retrofit/Turnover Assumptions for >26,000 lbs GVWR Single-Unit Trucks in Large Fleets in the Revised Inventory Model\***

Due Date January 1st of Calendar Year	Model Year Group	Assumed Compliance*		
		50%	25%	25%
2012	1997-2000	50%DPF+50%2008	Credit and provisions No action	Credit and provisions No action
2013	2001-2005	50%DPF+50%2008		
2014	2006-2007	50%DPF+50%2008		
2015	Pre-1995	2011		
2016	1995-1996	2012	Pre-2001 →2008; 2001- 2007→2012	pre-2008 turnover to 2012
2018				
2020	1997-2000	2013		
2021	2001-2005	2014		
2022	2006-2007	2015		
2023	Pre-2011	2015	2015	

\*See **IMPORTANT NOTE** in the text, above.

**Table 11. Retrofit/Turnover Assumptions for >26,000 lbs GVWR Out-of-State Trucks in Large Fleets in the Revised Inventory Model\***

Due Date January 1st of Calendar Year	Model Year Group	Assumed Compliance*
2012	1997-2000	2008F
2013	2001-2005	50%DPF+50%2010DPF
2014	2006-2007	50%DPF+50%2010DPF
2015	Pre-1995	2011
2016	1995-1996	2012
2020	1997-2000	2015
2021	2001-2005	2016
2022	2006-2007	2017
2023	Pre-2010	2017

\*See **IMPORTANT NOTE** in the text, above.

6) Extended NOx Exempt Areas

The proposed amendment extend the regions that could use the NOx exempt provision. The provision can only apply to vehicles that travel exclusively within the NOx exempt areas and staff assumed that 25% of activities in the areas are eligible for the exemption described in Table 12.

**Table 12. Retrofit Assumption for Trucks in the NOx Exempt Areas  
in the Revised Inventory Model\***

Due Date January 1st of Calendar Year	Model Year	Large fleets	Small Fleets		
			One Truck	Two Truck	Three Truck
2015	pre-1995	DPF			DPF
2016	1995-1996	DPF		DPF	
2017	1997-2000	DPF	DPF		DPF
2018	2001-2002	DPF			
2019	2003-2004	DPF		DPF	DPF
2020	2005-2007	DPF			

\*See **IMPORTANT NOTE** in the text, above.

## D Emissions Results

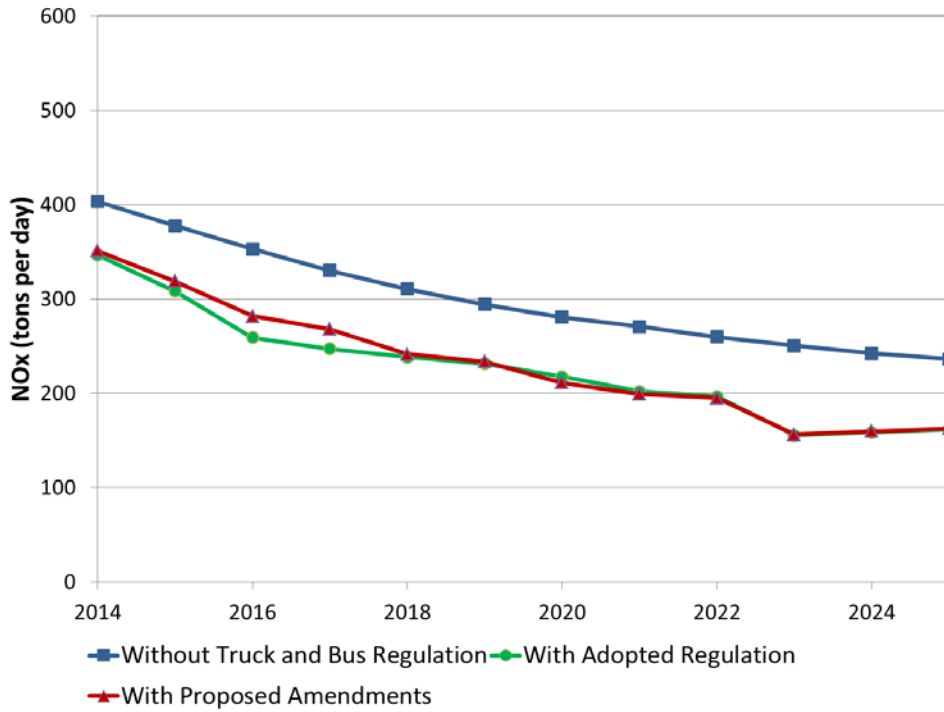
### 1) Estimating Statewide Emissions Benefits of the Regulation

The proposed regulatory amendments are designed to preserve the emissions benefits of the regulation for milestone years while providing additional regulatory flexibility to small fleets, lower mileage fleets, and fleets in certain rural areas. Staff anticipates the proposed amendments to the regulation will reduce diesel PM emissions by 39 percent from a baseline (without the regulation) levels in 2014 and achieve a 37 percent reduction in statewide NOx emissions in 2023.

The emissions results presented in this section all reflect the updates discussed in Item B of this technical appendix and include vehicles subject to either the Truck and Bus or Drayage Truck regulations. Figure 9 and Figure 10 show the NOx and diesel PM2.5 emissions inventories for baseline without Truck and Bus Regulation, with adopted regulation and with proposed amendments. As can be seen, the NOx and PM benefits of the proposed amendments are lower in 2014 and 2017. However, since most of the new provisions still require trucks to have diesel PM filters equipped by 2020 as in the current regulation, the PM benefits become identical in 2020. Since the truck operators are much more likely to meet the PM requirements by purchasing a 2010 standard truck in 2020, the NOx emissions reductions could be slightly higher than anticipated. By 2023 emissions reductions are very similar because the proposed rule requirements in 2023 are unchanged by the proposed amendments. Figure 11 and Figure 12 compare

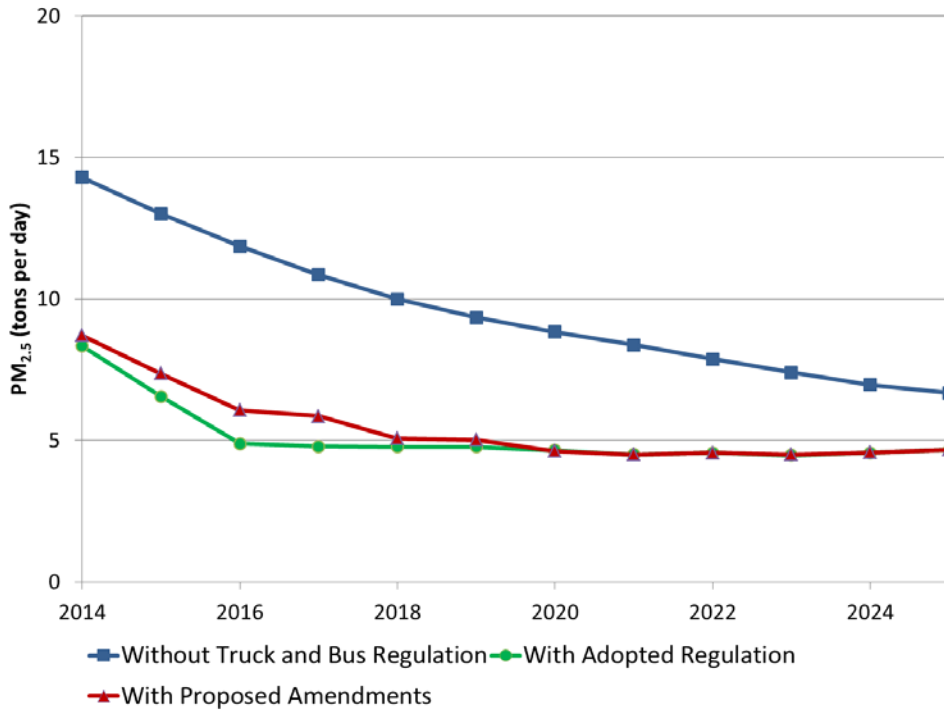
anticipated emissions in the South Coast. Figure 13 and Figure 14 compare the anticipated emissions in the San Joaquin Valley.

**Figure 9. Statewide Truck and Bus NOx Emissions**

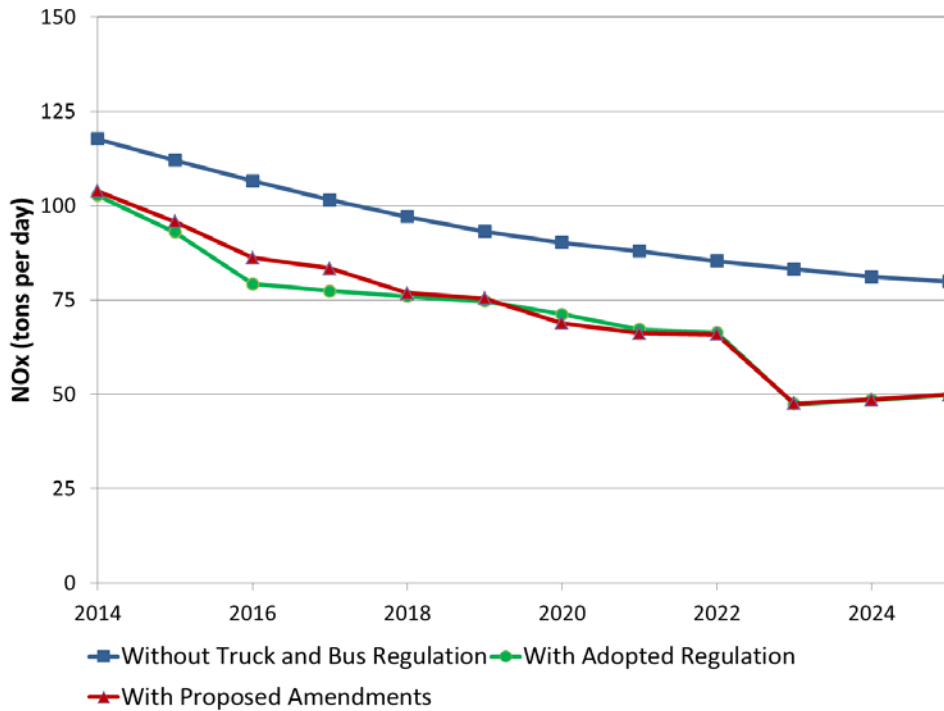




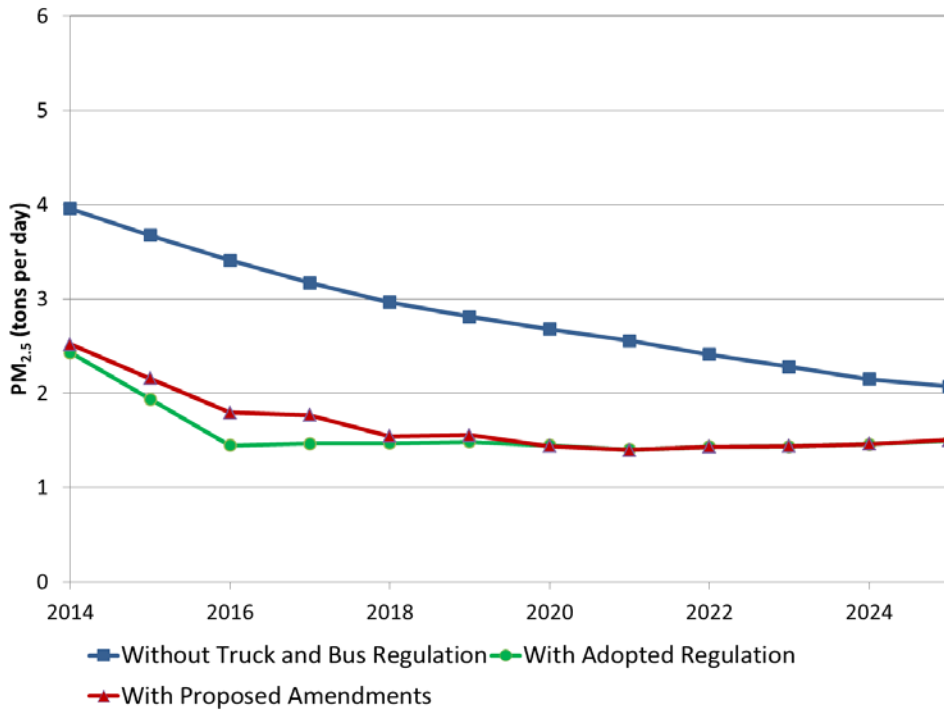
**Figure 10. Statewide Truck and Bus Diesel PM2.5 Emissions**



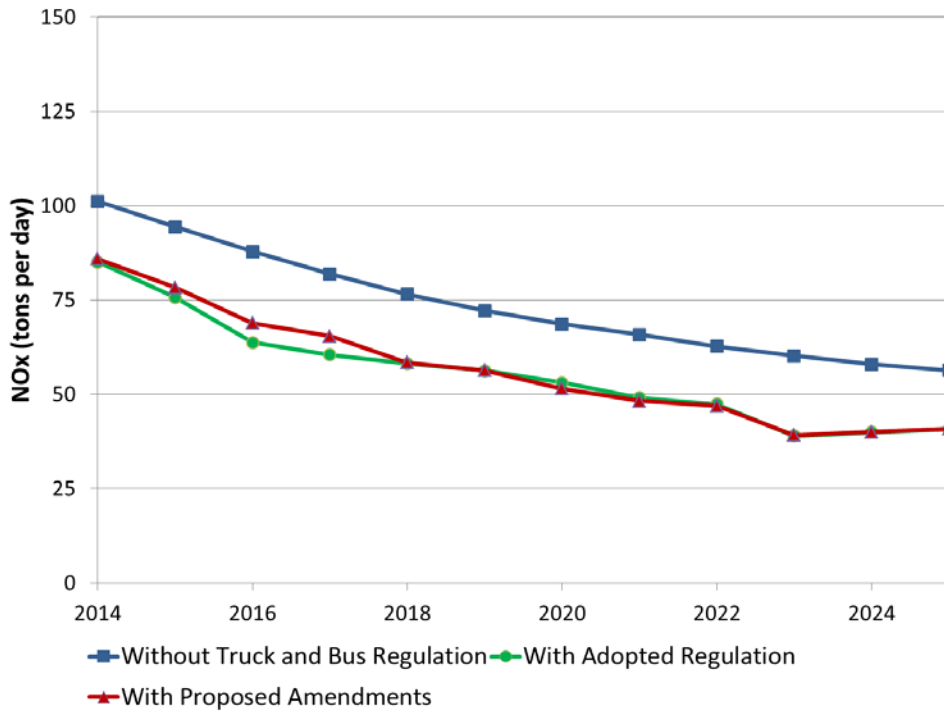
**Figure 11. South Coast Truck and Bus NOx Emissions**



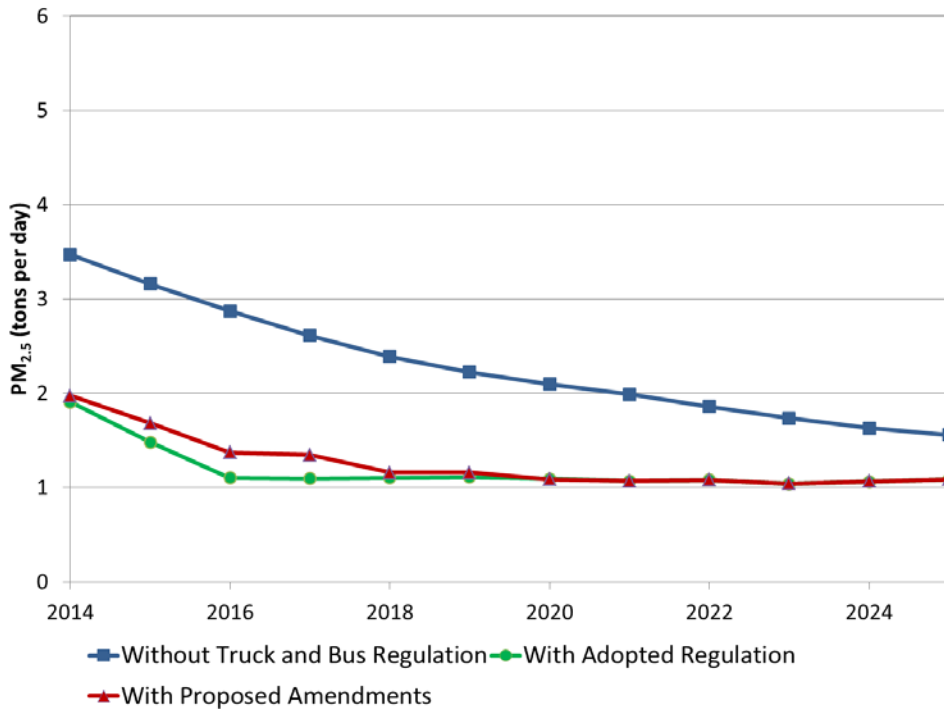
**Figure 12. South Coast Truck and Bus Diesel PM2.5 Emissions**



**Figure 13. San Joaquin Valley Truck and Bus NOx Emissions**



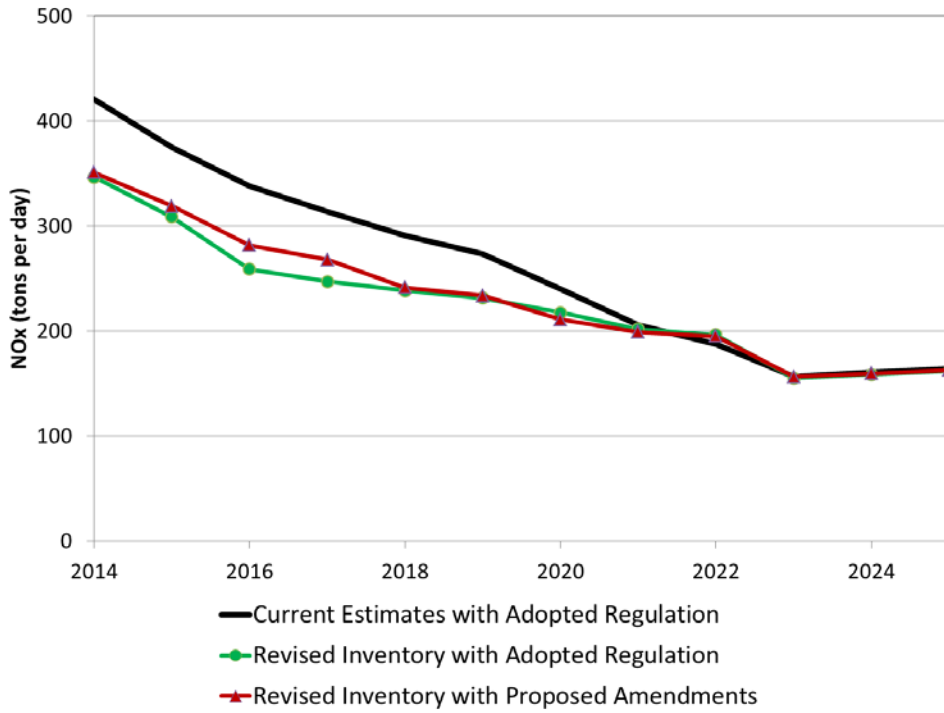
**Figure 14. San Joaquin Valley Truck and Bus Diesel PM2.5 Emissions**



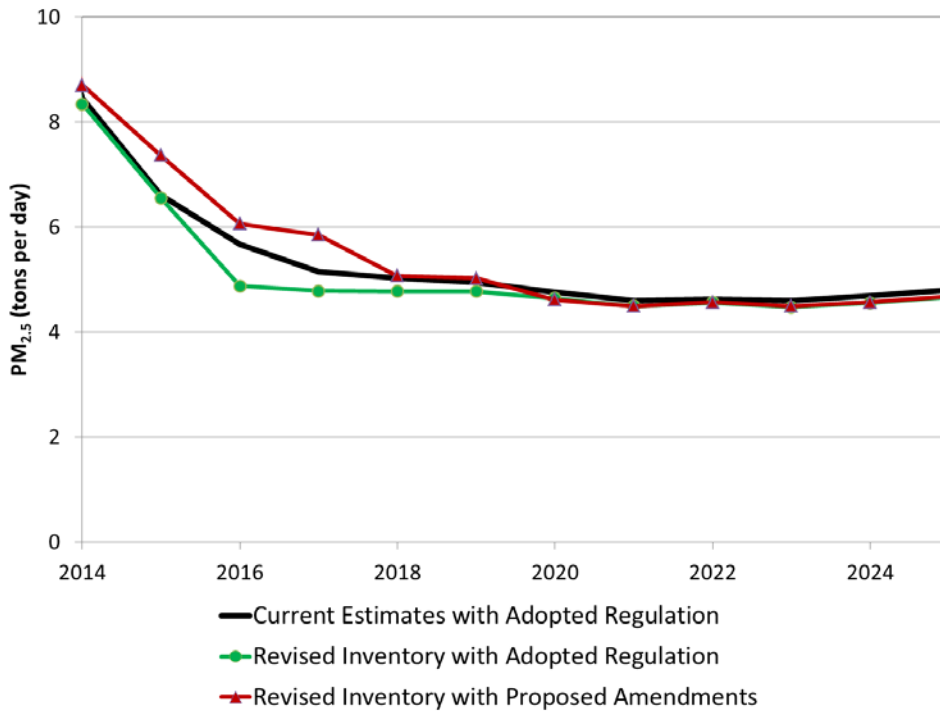
## 2) Comparison to Current Emissions Inventory

The revisions made to truck and bus emission inventories in 2008 and 2010 were incorporated into EMFAC2011, ARB’s current tool for assessing the population, activity, and emissions from on-road mobile sources (ARB, 2011). EMFAC2011 provides the emission estimates with adopted Truck and Bus regulation and staff made updates based on new data. Some of the revisions, such as revised VMT will reduce truck activity and lead to lower emissions. However, the age distribution revision could raise the average age for truck fleets and, therefore, lead to higher emissions. Figure 15 and Figure 16 show the compounding impact of the revisions. EMFAC2011 defaults are noted as “Current Estimates with Adopted Regulation” and revised inventories are the same inventories as in section D-1.

**Figure 15. Revision Comparison of Statewide Truck and Bus NOx Emissions**



**Figure 16. Revision Comparison of Statewide Truck and Bus Diesel PM2.5 Emissions**



## E References

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