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Review of CARB On-Road Heavy-Duty Diesel Emissions Inventory

prepared for:

The Ad Hoc Working Group

November 15, 2010

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1. EXECUTIVE SUMMARY

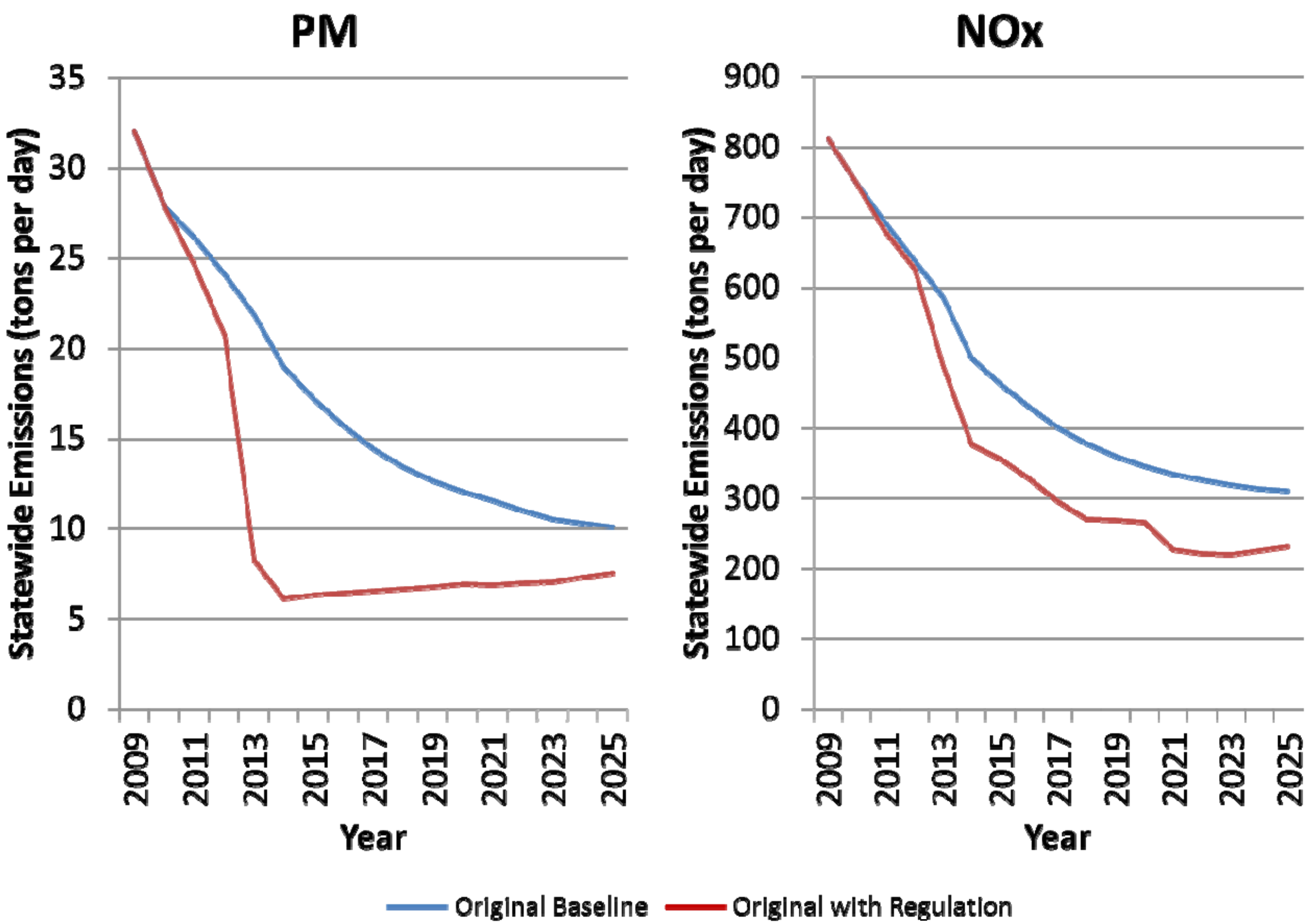
In October 2008, the California Air Resources Board (CARB) published new inventories of oxides of nitrogen (NOx) and particulate matter (PM) for on-road heavy-duty Diesel vehicles as part of the agency's proposed "In-Use On-Road Diesel Regulation." These inventories and the data sources and methodology used in their development differed substantially from then-official inventories based on the EMFAC2007 model. At the same time, CARB used these new inventories to demonstrate the need for the In-Use On-Road Diesel Regulation and to quantify the reductions in NOx and PM emissions the staff believed would result from the implementation of the regulation. The baseline PM and NOx inventories from in-use on-road heavy-duty Diesel vehicles and the estimated impact of the regulations on those inventories are shown in Figures ES-1a and ES-1b, respectively.

As shown in Figures ES-1a and ES-1b, emissions of PM and NOx from on-road heavy-duty Diesel vehicles were forecast to decline dramatically even without the regulation, as the result of new vehicle emission standards and natural attrition. Based on CARB's estimates, the benefit of the regulation—which requires retrofits, repowering, and early vehicle retirement—is to accelerate this already strong downward trend in emissions. Based on the data shown in Figures ES-1a and ES-1b, CARB adopted the In-Use On-Road Diesel Regulation in December 2008.

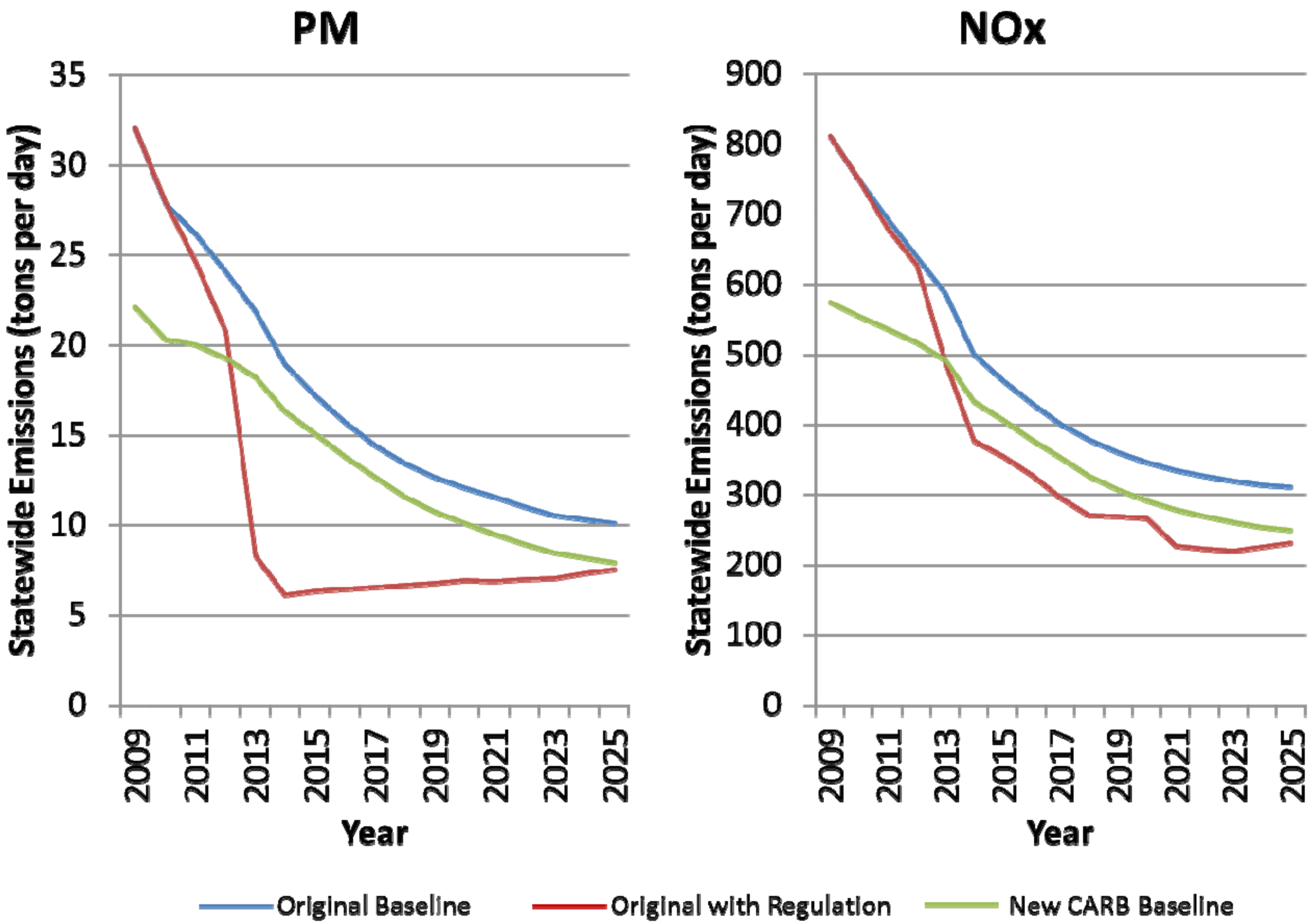
Subsequent to the adoption of the regulation, CARB undertook a review of the 2008 emission inventory in order to assess the impact of the recent economic recession on emissions from in-use on-road heavy-duty Diesel vehicles. This review began late in 2009 with CARB's publication of a limited assessment of the impacts of the recession and was followed by two rounds of more general modifications to the 2008 inventory, which were the subject of CARB workshops conducted in May and August 2010. The most recent baseline emission inventories published by CARB are shown for PM and NOx in Figures ES-2a and ES-2b, respectively, along with the 2008 baseline and "with-regulation inventories."

As shown, the original CARB baseline inventory values for 2009 were about 1.40 times the current CARB baseline inventory values, or, in other words, emissions were overestimated by about 40%. However, the magnitude of that overestimation varies and decreases to about 15–25% in later years. In addition, the current CARB baseline inventories are now substantially closer to CARB's original "with-regulation inventories" that represented the agency's emission control goals at the time the In-Use On-Road Diesel Regulation was adopted.

Figures ES-1a and ES-1b
Original (2008) Baseline and With-Regulation CARB Inventories Used to Support the In-Use On-Road Regulation



Figures ES-2a and ES-2b
Comparison of Current CARB Baseline Inventory to Original (2008) Baseline and With-Regulation Inventories



This is important because it raises issues related to whether there is a need for the regulation in its current form in order to achieve air quality goals, and also raises questions regarding how the regulation might have been different had the current inventory been available at the time the regulation was adopted.

The changes made by CARB to the original baseline inventory are reflected in the current CARB baseline inventory and include the following:

1. An accounting of the assumed impacts of the recession on truck activity and new truck sales using the average of both a "Fast" and a "Slow" recovery scenario;

2. Modifications to vehicle categories and vehicle fleet size categories used in developing the inventory;

3. Revised assumptions regarding travel in California by trucks based out of state;

4. Revisions to the assumed geographic distribution of truck travel in the state; and

5. Capping of the maximum average odometer reading.

At the request of a group of Diesel truck owners and organizations representing a variety of commercial interests known as the Ad Hoc Working Group, Sierra Research attempted to perform an independent review of the current CARB on-road heavy-duty Diesel vehicle inventory. That review was unfortunately restricted by the fact that little documentation is currently available regarding the current CARB inventory and that data from key sources used by CARB are not publicly available. Also not publicly available at the time of this writing is a complete and functioning version of the CARB inventory model. However, it must be acknowledged that although key information related to the current CARB inventory has not been released publicly, CARB did agree to meet with Sierra Research on several occasions to discuss this information in general terms and did provide additional insight into the inventory methodology.

Despite the aforementioned limitations imposed by the lack of publicly available data and the lack of a functioning version of the CARB inventory model, Sierra was able to review two important areas of the CARB inventory related to annual vehicle mileage accrual rates (MAR) and maximum assumed average odometer values. With respect to MARs, Sierra found substantial differences between CARB's assumed values, which are based on a 2002 survey that includes data from approximately 50 California-registered heavy-heavy-duty Diesel trucks, and the values reported as part of a Sierra survey of Ad Hoc Working Group members conducted during the summer of 2010, which included usable data for approximately 950 California-registered heavy-duty Diesel trucks. In particular, Sierra found that the CARB assumptions regarding MARs for older trucks were substantially higher than those observed in the survey data, leading to an overstatement of baseline emissions. Similarly, Sierra's review of available data regarding maximum average odometer values found that CARB's current assumptions overstate the observed values by about 25%, again resulting in an overstatement of baseline emissions.

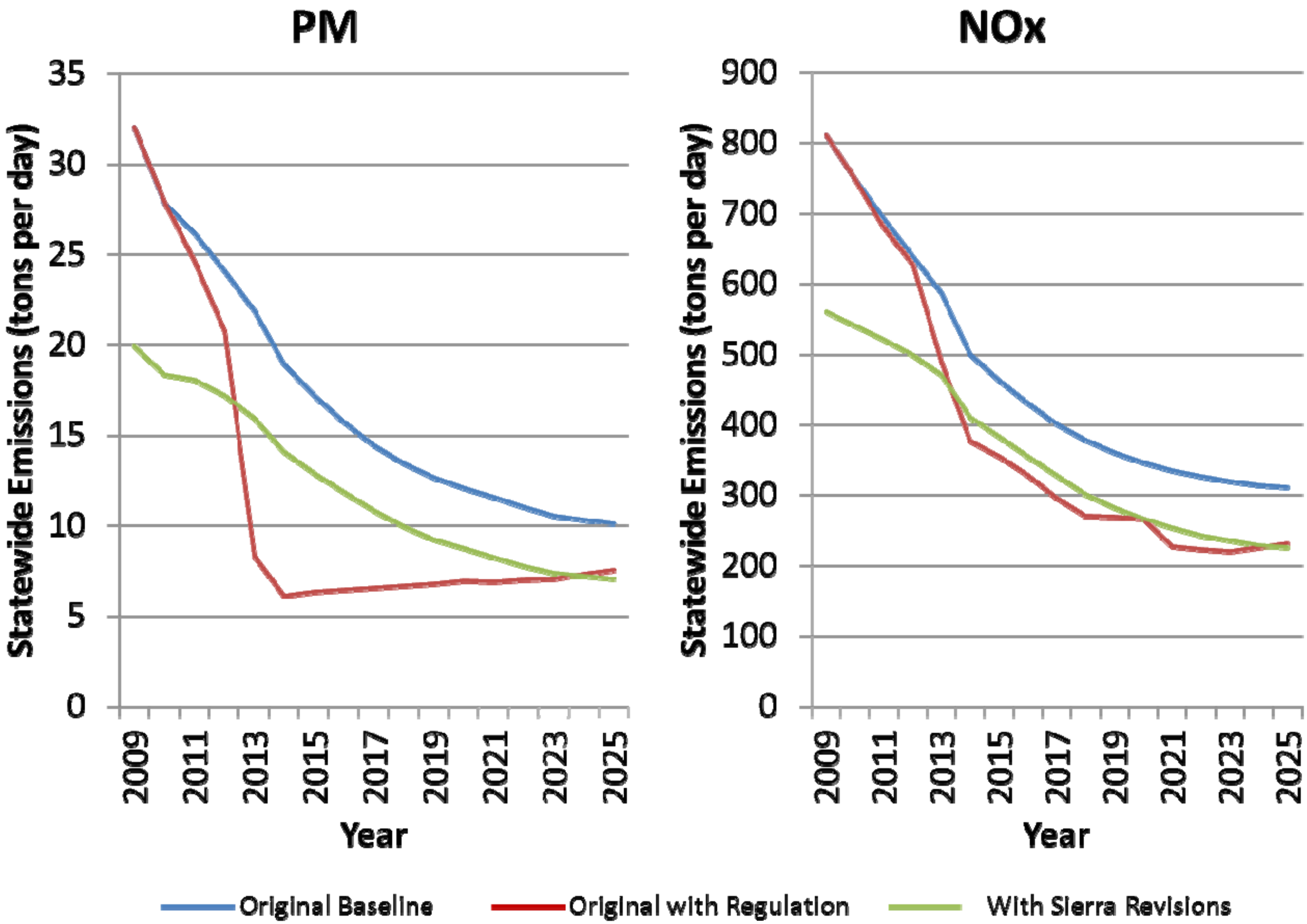
Figures ES-3a and ES-3b present revised baseline inventories for PM and NOx, respectively, that substitute Sierra's revisions to the mileage accrual rates for older trucks and maximum average odometer reading. As shown, these substitutions reduce the baseline inventories even further and result in an estimate that is closer to the original emission targets of the regulation. It must be stressed that the changes in MARs made by Sierra based on the survey data, which are reflected in Figures ES-3a and ES-3b, are conservative in that they apply only to 17-year-old and older vehicles, and CARB's assumed mileage rates for newer vehicles have not been adjusted despite the discrepancies between those rates and the rates observed in the survey data.

Finally, Sierra combined the MAR and maximum odometer assumptions noted above with CARB's Slow economic recovery scenario data, rather than the average of the Fast and Slow scenarios used by CARB, in order to investigate the impacts of the current economy on the baseline inventory. Although Sierra does not perform economic forecasting, there is little evidence available to suggest that a "fast" economic recovery is underway in the California trucking sector and more evidence, including California Diesel fuel sales data and discussions with Ad Hoc Working Group members, indicating that a slow recovery is more likely.

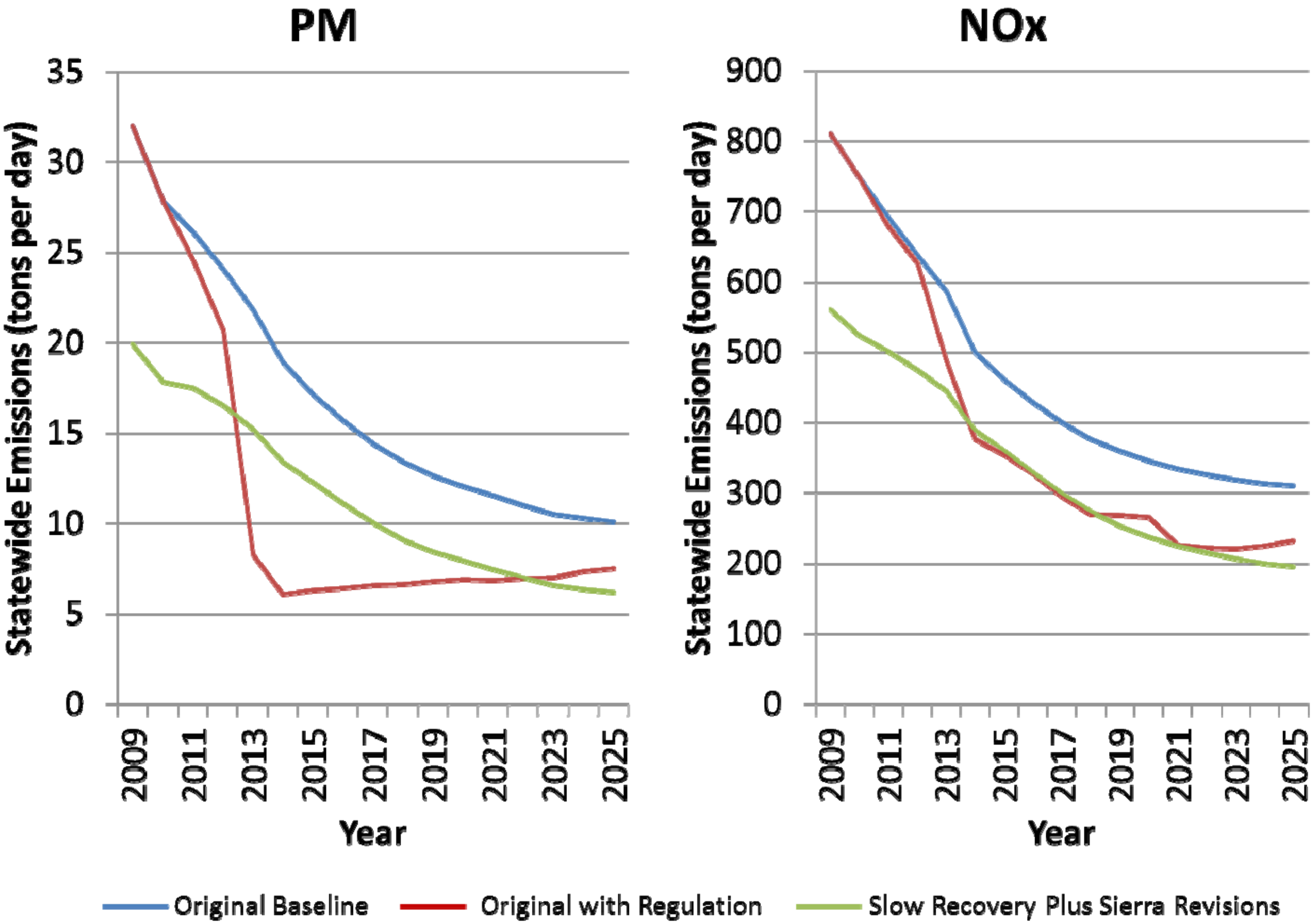
The results of this plausible combination of Sierra's modifications are shown in Figures ES-4a and ES-4b, again for PM and NOx, respectively, along with the original CARB baseline and CARB's original regulatory emission targets. In this case, the original CARB baseline is 1.61 and 1.45 times (or 61% and 45%) higher than the Sierra-estimated baseline in 2009 for PM and NOx emissions, respectively. Further, in 2014, which CARB has indicated to be a key year with respect to the need for the regulation, the original CARB baseline is 1.41 and 1.28 times (or 41% and 28%) greater than the Sierra estimated baseline, again for PM and NOx, respectively.

It is also important to note, as shown in Figures ES-4a and ES-4b, that the combination of the Slow recovery scenario and the other Sierra revisions results in a baseline NOx emission inventory that achieves the original targets of the In-Use On-Road Diesel Regulation and further reduces the difference between the baseline and the original with-regulation inventory for PM emissions. This is an important finding because it brings into question the need for the NOx provisions of the regulation and suggests that the reductions in PM emissions needed to reach CARB's regulatory goals are smaller than those envisioned at the time the regulation was adopted.

Figures ES-3a and ES-3b
Comparison of Current CARB Baseline Inventory Modified Based on Sierra Findings to Original (2008) Baseline and With-Regulation Inventories



Figures ES-4a and ES-4b
Comparison of Current CARB Baseline Inventory Modified Based on Sierra Findings and Slow Recovery to Original (2008) Baseline and With-Regulation Inventories



Overall, Sierra's efforts indicated that the CARB on-road Diesel inventory cannot be reasonably or thoroughly reviewed based on the information currently available and that, where a review is possible, there are substantial issues that need to be addressed. Given this, Sierra strongly recommends that the inventory—as well as all data sources and methodologies—be subjected to an independent "peer" review by an experienced third party or parties before it is used as the basis for regulatory decision making, including the assessment of potential modifications to the In-Use On-Road Diesel Regulation.

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2. INVENTORY OVERVIEW

This section reviews CARB's on-road heavy-duty Diesel emission inventory, the current form of which was originally developed during 2007 and 2008 as a replacement for CARB's official EMFAC2007 model for use in assessing the need for and the benefits of the in-use on-road regulations. Since that time, the on-road heavy-duty Diesel inventory has been further revised by CARB. The overview presented here addresses the basic mathematical calculations that are performed to estimate the inventory and describes some of the assumptions and complexities associated with estimation of the on-road Diesel emission inventory.

2.1 Basic Inventory Calculation

In the simplest terms, the CARB on-road heavy-duty Diesel emissions inventory is based on the mathematical calculation shown below in Equation (1).

$$\text{Emissions} = \text{POP*MAR*EF} \qquad \text{Eq. 1}$$

The variables in the equation are as follows:

1. "POP" is an estimate of the number of vehicles that constitute a "population" of heavy-duty Diesel trucks of a given vocation, weight rating, and model year that are assumed to be operating in California on a given day or in a given year;

2. "MAR" is an estimate of the "mileage accrual rate" or number of miles vehicles in that population will operate on average in California on that given day or year; and

3. "EF" is an estimate of the average "emission factor" for a given pollutant from the population in units of grams of pollutant emitted per mile of operation.

When using the variables described above in Equation 1, the result is the estimated emissions of a given pollutant for a given population in units of grams of pollutant per day or year. In order to estimate the entire on-road Diesel inventory, the same calculation must be performed for each type of vehicle and each of the 46 model years of vehicles that are assumed by CARB to be in operation in the California fleet during any given calendar year.

2.2 Details of the Emission Inventory Calculation

As noted above, estimating the emissions of a population of on-road heavy-duty Diesel vehicles is based on a relatively simple calculation involving three basic variables. However, as summarized below, the reality of calculating an emission inventory is far more complicated.

Vehicle Populations – At present, CARB uses the following 13 basic vehicle categories in estimating the inventory[1]:

1. Heavy-heavy-duty out-of-state trucks;
2. Heavy-heavy-duty California trucks participating in the International Registration Program (IRP);
3. Heavy-heavy-duty California tractors;
4. Heavy-heavy-duty California single unit trucks;
5. Heavy-heavy-duty California drayage trucks;
6. Heavy-heavy-duty California agricultural trucks;
7. Heavy-heavy-duty California utility trucks;
8. Medium-heavy-duty in-state trucks;
9. Medium-heavy-duty interstate trucks;
10. Medium-heavy-duty California agricultural trucks;
11. Medium-heavy-duty California utility trucks;
12. Buses; and
13. Power-take-off units (PTO).

In addition, there are a variety of subcategories—such as construction trucks and motor coaches, gross vehicle weight ratings, and fleet size[1,2]—that have been considered within some or all of the of the categories above. Further, as previously noted, there are 46 distinct model-year populations within each of the basic vehicle categories listed above. Finally, the population estimates are referenced to a base year of 2006 and then calculated to change for future years based on assumed fleet turnover and new vehicle sales rates, which reflect economic forecasts and transfers of vehicles between the population categories as they age.

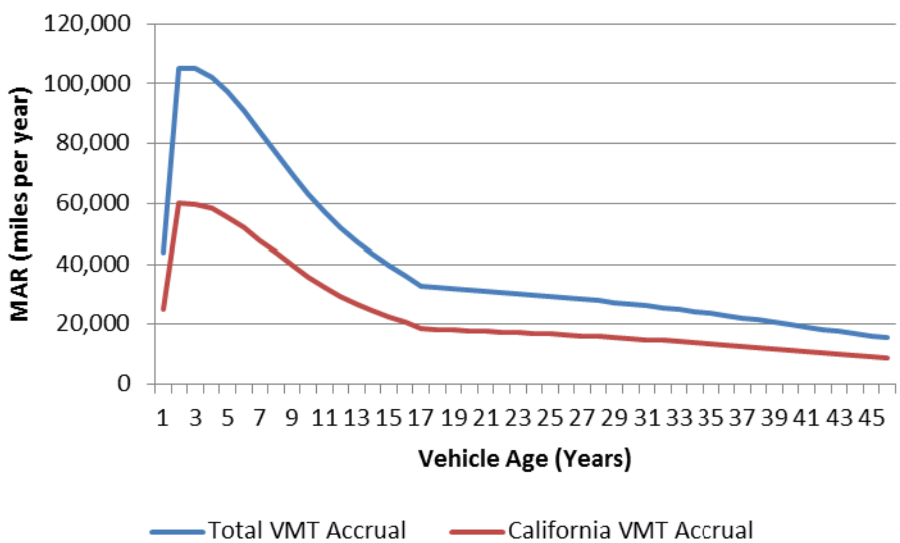
The data used to develop the population estimates are generally derived by CARB from historic registration information obtained from the California Department of Motor Vehicles (DMV). These data are supplemented in some cases with data from a variety of surveys and other sources.[1,2]

Mileage Accumulation Rates – Separate MARs exist for each of the different vehicle population categories and for each model year of vehicle.[1,2] However, the same MAR values are used for certain population categories. In addition, the same MAR value applies to a given model year and population type (e.g., ten-year-old heavy-heavy-duty

California tractors), regardless of calendar year. In general, estimated MAR values tend to be highest for new vehicles and then decline steadily with age.

Figure 2-1 shows the MAR values currently assumed by CARB for heavy-heavy-duty Diesel trucks. The MAR values shown in Figure 2-1 represent total annual mileage accumulation by these vehicles as a function of age (model year) and adjustments made by CARB to account for out-of-state travel by California vehicles registered under the International Registration Plan (IRP). As illustrated in Figure 2-1, CARB assumes that the average new truck will accumulate over 105,000 miles in its first year of operation, and mileage will then decline to about 20,000 miles per year by 34 years of age and ultimately down to 15,500 miles per year at the end of the truck's useful life.

Figure 2-1
CARB-Estimated MARs for Heavy-Heavy-Duty Diesel Trucks
Based on Vehicle Inventory and Use Survey (VIUS)



In order to estimate MARs, CARB indicates that it has used data collected in the Vehicle Inventory and Use Survey (VIUS). VIUS was conducted as a part of the economic census performed every five years by the U.S. Census Bureau; however, that the survey has been discontinued,* and the most recent report dates back to calendar year 2002.[3]

* It is not clear whether the discontinuation of VIUS is temporary or permanent.

Emission Factors – Of the three variables used in Equation 1, the EF or emission factor term is the most complicated. The heart of the EF is the basic emission rate (BER), the grams per mile assumption of emissions, which is estimated according to Equation 2, shown below.

$$BER = ZM+DR*ODO/10,000 \qquad \text{Eq. 2}$$

The variables in the BER for a given pollutant are as follows:

1. "ZM" represents the estimated average emissions of a given pollutant expressed in terms of grams per mile from a vehicle when the vehicle is new, e.g., at the "zero mile level" and free of emissions-related defects and emission control system related tampering;

2. "DR" is the deterioration rate, or the rate of increase in emissions as a function of engine operation, expressed in terms of grams per mile per 10,000 miles of operation resulting from engine wear, defective and/or failed emissions control system components, and/or emission control system tampering; and

3. "ODO" is the average odometer reading of the vehicle or fleet of vehicles, expressed in terms of miles

Current CARB emission factor estimates for heavy-duty Diesel trucks are based upon dynamometer testing of a limited number of randomly selected vehicles operating in California. The most recent emission factor test program was Coordinating Research Council Project E55-59,[4] conducted between September 2001 and June 2005—in this program, emissions testing was performed on fifty-seven 1975 to 2003 model-year heavy-heavy-duty Diesel trucks. The data used by CARB in establishing BERs were all obtained using a loaded vehicle weight of 56,000 pounds and were not adjusted to reflect a distribution of in-use loaded vehicle weights, despite the fact that other data from E55-59 show that vehicle weight does affect emissions. Also, despite the significant changes in the design and use of emission control technologies on newer Diesel vehicles, CARB's current emission estimates for trucks newer than the 2003 model year are not based on any actual emissions test data.

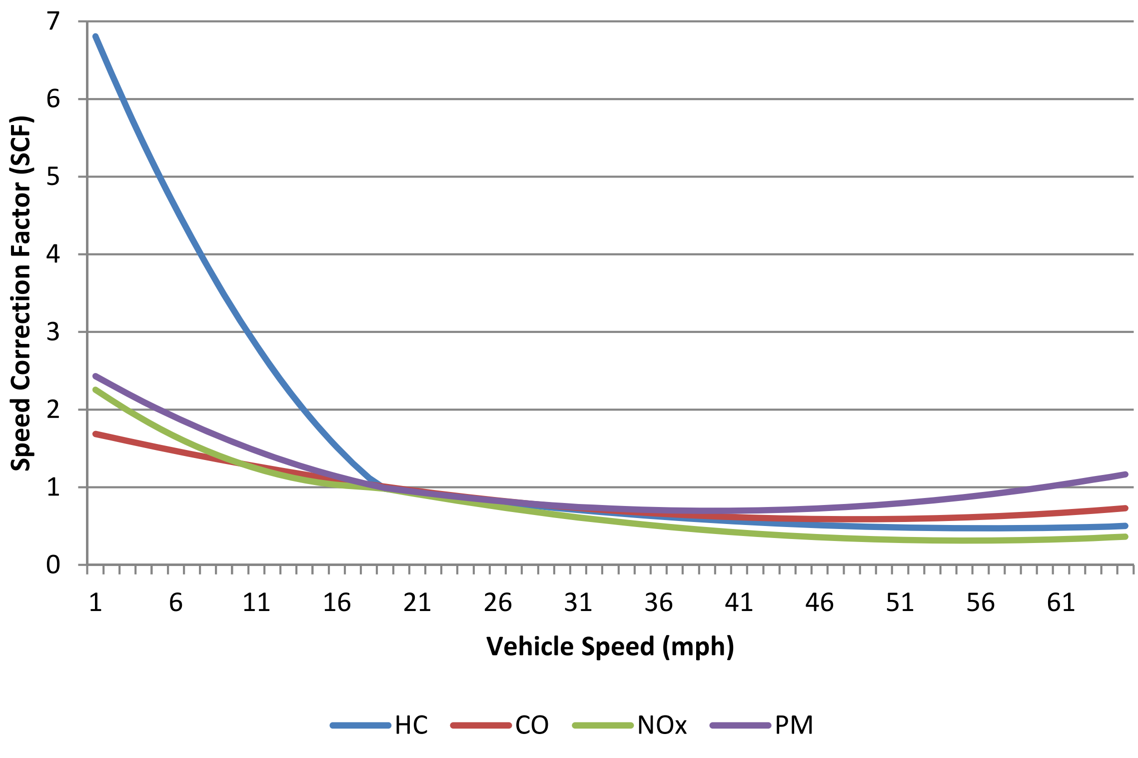
CARB currently assumes for heavy-duty Diesel vehicles that emissions will remain constant over time in the absence of defective, failed, or tampered emission control system components, which is referred to as "tampering and mal-maintenance" (T&M). In order to assess the impacts of T&M on emissions, CARB utilizes a model originally developed by the Radian Corporation in the 1980s that estimates the impact of 19 specific T&M acts within the heavy-heavy-duty Diesel fleet. The incidence or frequency of T&M is estimated by CARB based on a limited number of dated field observations and engineering judgment. Similarly, the emissions impacts of T&M are based on engineering judgment and limited test emissions test data from engines where T&M problems were found or induced.

The process described above by Equation 2 establishes BERs that reflect laboratory emission test conditions. These BERs are adjusted by CARB to account for, among other things, differences in fuel composition using “fuel correction factors” (FCF), and for the effects of vehicle speed using “speed correction factors” (SCF). The final fully adjusted BER is the EF specified in Equation 1.

Diesel FCFs attempt to account for variation in the sulfur and aromatic hydrocarbon content of commercially dispensed fuel compared to the fuels used to perform emissions testing. These factors are different for California fuel and for fuel assumed by CARB to be purchased in other states.

Diesel SCFs were developed by CARB based on data collected during the CRC E55-59 project obtained using four different driving cycles each with a different average speed and one of which was the standard test cycle used for emissions testing. SCFs were developed by CARB for emissions from vehicles of different ages. Pollutant-specific SCFs are illustrated for 2003 and later model-year vehicles in Figure 2-2.

Figure 2-2
Heavy-Heavy-Duty Diesel SCFs (2003 and Later Model Years)



Emission Reductions from the Regulation – CARB estimated the emission reductions due to the regulation by assuming that there would be accelerated turnover of the truck fleet, which increases the number of 2010 and later model-year trucks in the fleet and retrofit of particulate matter (PM) control devices on some older vehicles. In addition, even though CARB assumed, as shown in Figure 2-1, that newer trucks are driven more than older trucks, the agency also assumed that the accelerated turnover of the fleet would not lead to an overall increase in truck travel in the state. Retrofit PM control devices were assumed by CARB to be 85% effective in reducing PM emissions and to be immune from the types of T&M impacts assumed by CARB to occur on trucks equipped with these devices by the manufacturer. The baseline and with-regulation inventories estimated by CARB staff using the methodologies discussed above are shown in Figures 2-3a and 2-3b, respectively, for NOx and PM emissions.

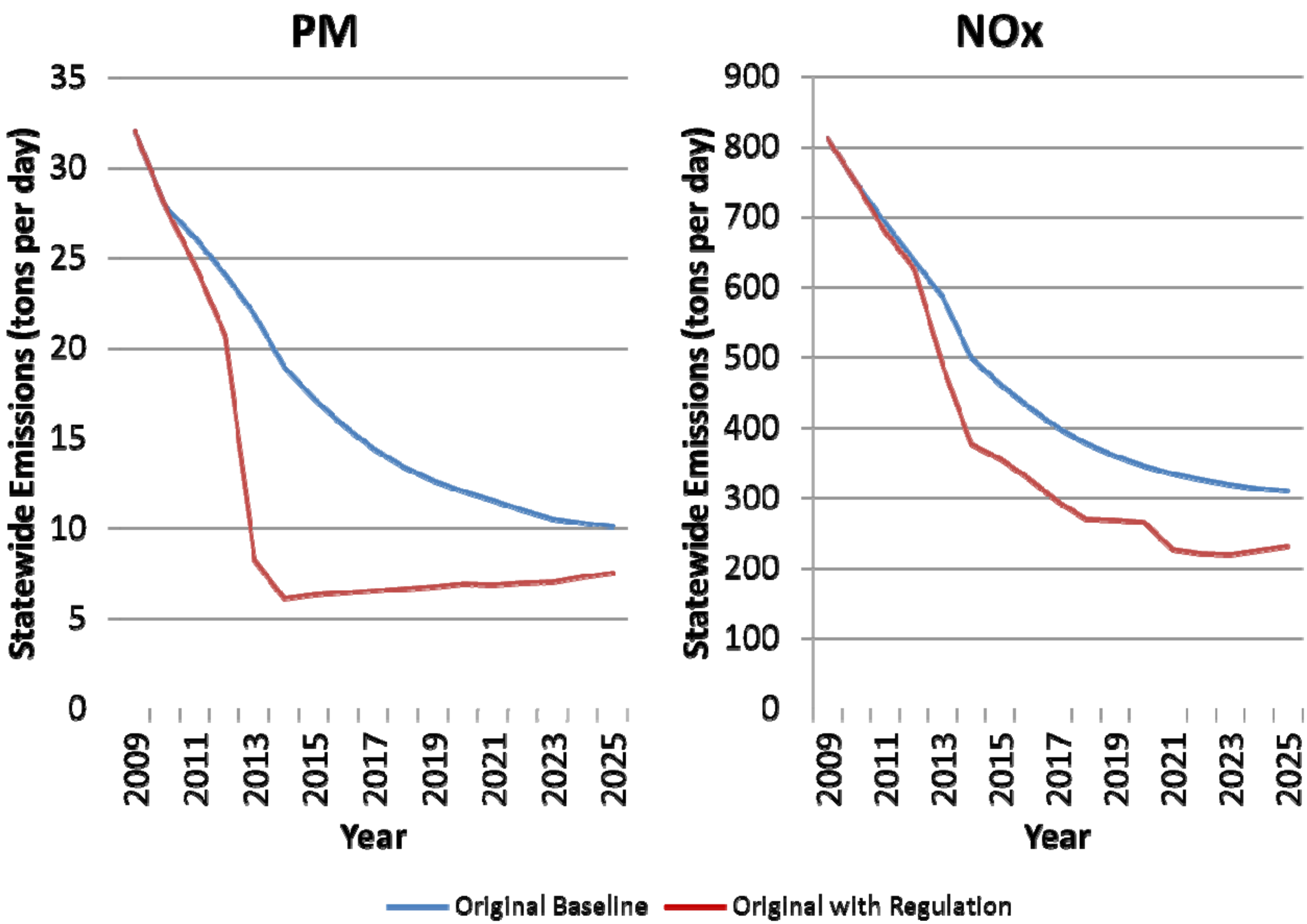
2.3 CARB's Assessment of Recession Impacts

When the Statewide Truck and Bus Rule was adopted in December 2008, CARB indicated that it would analyze the impact of the economic recession on heavy-duty Diesel truck activity and emissions; the results of that analysis were released to the public in December 2009 and January 2010.[5] CARB's analysis adjusts 2009 emissions from on-road heavy-duty vehicles in California to reflect decreased activity (e.g., the number of miles of truck operation, or VMT) using data from a variety of sources. The adjustment made by CARB is based on the assumption that the activity of all trucks in given categories operating in California has decreased by the same amount on a percentage basis. For example, if a 20% decrease in VMT is assumed for International Registration Plan trucks, the VMT levels for both the oldest (highest emitting) and newest (lowest emitting) vehicles in that category are reduced by 20%.

CARB also modified the age distribution of trucks within a given category. In a growing economy, older vehicles tend to leave the fleet as they reach the end of their useful lives and new vehicles are purchased to replace them. The net result is that the average age of the fleet and the fleet's associated emissions tend to decrease as newer, lower-emitting vehicles replace older, higher-emitting ones. The benefits of this natural attrition may be mitigated by growth in fleet size and VMT. In a depressed economy, new vehicle sales decline and it is assumed that older vehicles are retained within the fleet for a longer period of time, resulting in a relative older, higher-emitting fleet. The increase in emissions dictated by delayed fleet turnover may be mitigated by a decrease in fleet size and an overall reduction in VMT.

For 2009, CARB computed a revised inventory using reduced VMT but a higher emission factor that reflected the "older" trucking fleet. Again, the key issue is the validity of CARB's assumption regarding uniform percentage changes in activity for trucks as a function of age. For example, if reduced fleet VMT were occurring but most of the operation was still conducted by newer trucks, fleet emissions as the result of the recession could be far lower than CARB estimates.

Figures 2-3a and 2-3b
Original (2008) CARB Emissions Inventory Estimates With and Without Regulations

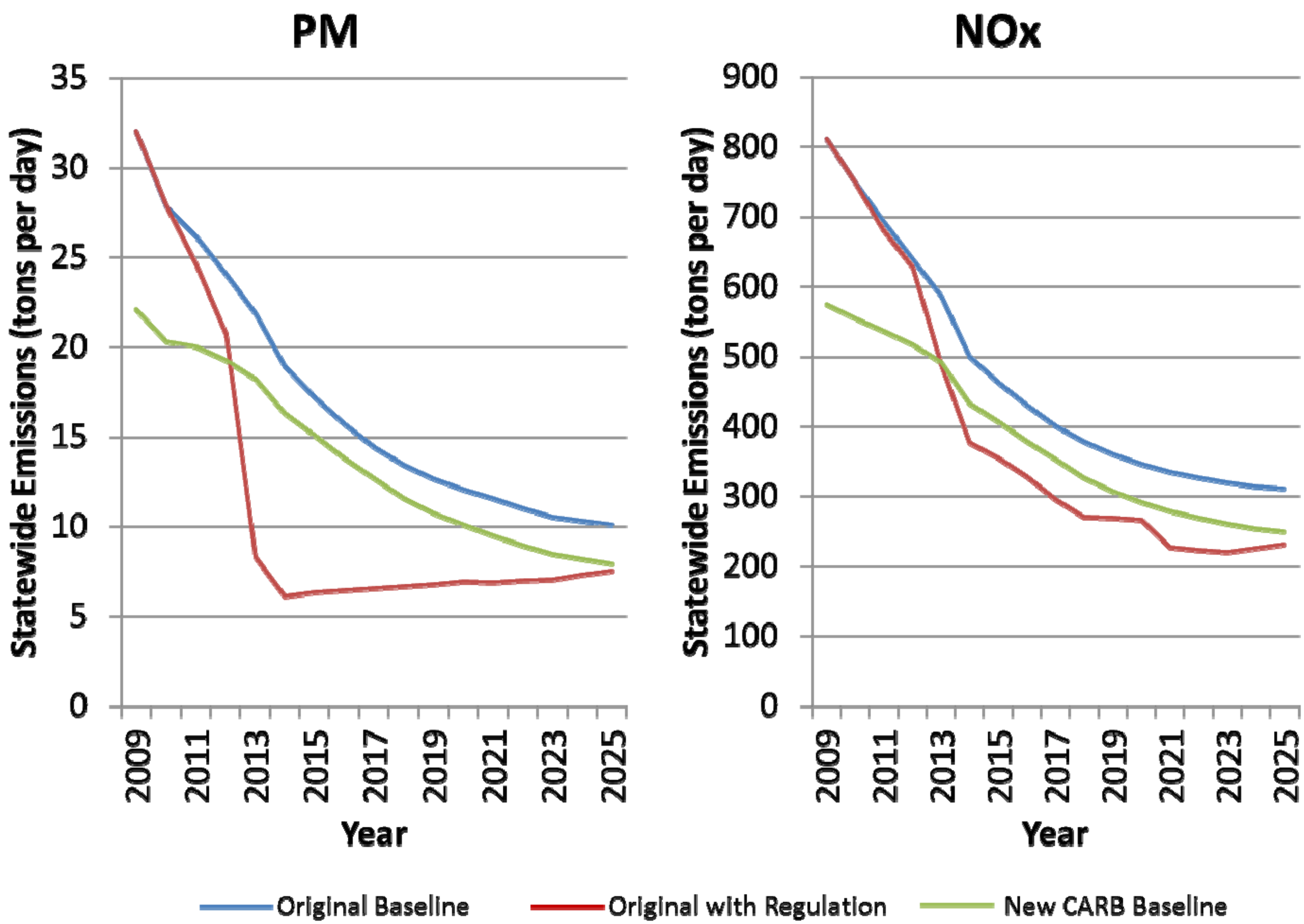


Using the revised 2009 inventory as a baseline, CARB then developed emission forecasts for future years. In doing this, CARB created two alternative fleet growth scenarios, termed “Fast” and “Slow.” Under the Fast growth scenario, new truck sales were assumed to begin increasing in 2010, returning to the long-term trend in eight years. Under the Slow growth scenario, new truck sales were assumed to remain flat from 2009 to 2011 and then begin to grow at average historical rates.

Along with the different age distributions, CARB also used different assumptions regarding truck VMT for the Fast and Slow growth scenarios. For the Fast scenario, the vehicle activity recovery rate was assumed to be linear between 2009 levels and anticipated 2017 levels, which results in a recovery rate of approximately 6.3% per year in heavy-heavy-duty Diesel truck activity. For the Slow scenario, CARB staff assumed that activity in 2010 would be the same as in 2009 and would then grow at annual average growth rates reflected in long-term trends; as published in the Staff Report for the rulemaking, this was 2.6% per year for heavy-heavy-duty Diesel truck activity.

The revised baseline emission inventory that reflects the impacts of the recession is presented in Figures 2-4a and 2-4b, along with the original 2008 baseline and the with-regulation inventories that were also shown in Figures 2-3a and 2-3b. As shown, the revised baseline inventory is considerably lower than the original baseline inventory and reductions from the revised baseline to meet the original regulatory goals are lower.

Figures 2-4a and 2-4b
CARB Original and Revised Emissions Inventory Estimates



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3. REVIEW OF THE CARB ON-ROAD DIESEL EMISSIONS INVENTORY

This section presents the results of Sierra's review of the CARB on-road Diesel inventory with respect to the variables in Equation 1. It should be noted that because resources available for this review were limited and much of the data incorporated into the CARB inventory are not publically available, a comprehensive review was not possible.

3.1 Heavy-Duty Vehicle Populations

As indicated in Equation 1, the assumed population of heavy-duty Diesel vehicles operating in California is directly proportional to the emissions of those vehicles and therefore of critical importance. CARB has indicated[1] that it uses data obtained twice yearly from the California Department of Motor Vehicles as "the primary source for vehicle population and model-year by category." However, these data, which are necessary to confirm CARB's vehicle population and age distributions (e.g., model year by category), are not publicly available because CARB and apparently the Department of Motor Vehicles believe it contains confidential information.

While this may be accurate, the fact that the data are not publicly available makes it impossible to verify in general the accuracy of the vehicle populations and age distributions use by CARB in the on-road Diesel inventory

3.2 MAR Values

As discussed in Section 2, CARB's MAR values are largely based on the VIUS data that date all the way back to calendar year 2002 and include information derived from 136,000 surveys nationwide, of which 3,200 were specific to California.[6] VIUS was a paper-based survey in which owners were asked to provide estimates of usage for a single identified vehicle. It is important to note that the 2002 VIUS included information for both gasoline- and Diesel-powered vehicles ranging from light-duty pick-up trucks to cranes and tankers. The subset of California-registered heavy-heavy-duty Diesel trucks included in the 2002 VIUS was limited to about 50 vehicles that spanned only 17 model years. CARB indicates that the MAR values it used for older vehicles were based on survey data it collected but those data are not documented or publicly available.

3.3 Emission Factors

CARB indicates[1] that the emission factors used in the heavy-duty on-road Diesel inventory were derived from the EMFAC2007 model and the CRC E55-59 project, and that adjustments were made to the penetration rates for advanced technology vehicles (e.g., those meeting 2010 model-year emission standards) used in EMFAC2007.

There are a number of issues associated with the EMFAC2007 emission factors used in the inventory. First, as noted above, the CRC E55-59 emission factors are linked to a specific loaded vehicle weight; no analysis has been performed, however, to determine whether vehicle weight is representative of in-use heavy-duty Diesel trucks operating in California, despite the fact that there appears to be a linkage between vehicle weight and emissions in the CRC E55-59 data.

Next, it should be noted that the EMFAC2007 emission factors for all 2003 and later model-year heavy-duty trucks are based on emissions testing of four 2003 model-year vehicles as part of the E55-59 project. These data were used to create emission factors for 2007 to 2009 model-year vehicles and 2010 and later model-year trucks by applying the ratio of the emission standards to the average emissions of these 2003 model-year trucks (i.e., 2007 emissions = 2007 standard / 2003 standard * 2003 average emissions). This means that the CARB inventory does not reflect any actual emissions test data from vehicles older than the 2003 model year and that the assumed emissions from trucks with advanced emission control systems are directly related to those of older trucks that are not equipped with such systems. More specifically, this means that CARB assumed that emissions from trucks with emission control after-treatment systems like particulate filters and selective catalytic reduction systems are directly related to the emissions from trucks that are not equipped without any such systems.

This assumption, which is questionable at best, warrants careful investigation as the actual emission levels of trucks with advanced emission control technologies are critical to the need for the In-Use On-Road Diesel Regulation. For example, if actual emissions from advanced technology trucks are lower than CARB estimates, normal vehicle attrition will lead to a faster decline in the baseline inventory and could potentially obviate the need for the regulation. In contrast, if the emissions performance of advanced technology vehicles is worse than CARB assumes, the implementation of the regulation—which generally requires that all trucks have 2010 or later model-year engines by 2023—will lead to far lower emission reductions than estimated by CARB.

Another related issue is CARB's assumptions regarding T&M for advanced technology vehicles. As noted previously, CARB uses a dated model developed in the 1980s and later updated to address T&M from all heavy-duty Diesel on-road vehicles. In 2009, CARB initiated a research project to develop an assessment of T&M impacts for advanced technology vehicles.[7] In soliciting proposals to perform the work, CARB stated:

The application of diesel particulate filters (DPFs) and selective catalytic reduction (SCR) as aftertreatment devices starting in the 2007 model year to meet the new truck emission standards is expected to reduce emissions from HDDTs to very low levels. However, because of the reduction potentials of aftertreatment devices, failures of the systems or system components will lead to a dramatic increase in the tailpipe emissions. Therefore, it is critical to understand the failure rates of aftertreatment systems and their key components as well as the T&M frequency of these systems in order to better estimate the emission deterioration rates of HDDTs.

This research project was cancelled, however, and, to the best of Sierra's knowledge, the work was never performed. As a result, the T&M impacts used by CARB in the on-road Diesel inventory for advanced technology vehicles have not been updated to reflect actual data from vehicles equipped with such technologies. This is again important with respect to the emission impacts on the In-Use On-Road Diesel Regulation, for the reasons stated above.

3.4 Assessment of Recession Impacts

As noted previously, CARB has made adjustments to the heavy-duty on-road Diesel inventory to account for the impacts of the recent economic recession. The CARB analysis adjusts current emission estimates to reflect decreased truck operation activity using data from a variety of sources. However, the adjustment made by CARB is based on the assumption that the activity of all trucks in a given population should be decreased by the same percentage. This is a relatively simplistic assumption—it is equally as likely that trucking fleets may park older, less reliable trucks and rely more heavily on newer trucks in order to maximize the economic viability of their operations. Unfortunately, no data are readily available that can be used to examine this assumption.

CARB also assumes that there will be changes due to the economy in the age distribution of trucks within a given population category, resulting in an older, higher-emitting fleet. That is, CARB assumes that the benefits of natural attrition within the fleet will be delayed as older trucks are not being replaced by newer, lower-emitting vehicles. The assumption of a static registration distribution ignores the fact that attrition is not completely voluntary as, in reality, it may become economically infeasible to keep old trucks indefinitely and many vehicles are retired from the fleet due to accidents or other unforeseen events. Again, the key issue is the validity of CARB's assumption regarding uniform percentage changes in population and activity for trucks as a function of age. Alternatively, if the fleet were assumed to be getting older on the basis of population but most of the trucks operating were newer, fleet emissions as the result of the recession could be far lower than CARB's estimates. Given these uncertainties, CARB needs to validate the assumptions used in its analysis.

In addition to addressing the current impacts of the recession, CARB has developed emission forecasts for future years using two economic recovery scenarios, which it refers to as the "Fast" and "Slow" growth scenarios. Under the Fast growth scenario, new truck sales are assumed to begin increasing again in 2010, such that truck operations return in eight years to the level assumed by CARB for its long-term trend. Under the Slow growth scenario, new truck sales are assumed to remain depressed until 2011 and then begin to increase such that truck operations rebound to reflect only the average historic growth rate thereafter.

These scenarios define both revised future year age distributions as well as activity levels for heavy-duty trucks operating in California. Under the Fast growth scenario, fleet average emission rates are lower owing to the greater percentage of new trucks but are offset by higher activity levels. For the Slow growth scenario, fleet average emission rates are higher but are offset somewhat by lower activity levels.

The relative impact of the scenarios is that the fleet-average emission factor is lower for the Fast growth scenario than for the Slow growth scenario. In both scenarios, however, the fleet average emission factors are higher in future years than they were in the baseline used during the rulemaking.

In assessing the impact of the recession on the emissions inventory, CARB uses the average of the Fast and Slow growth scenarios. There is no technical rationale for this choice other than it leads to the use of the middle of the range of potential values, and there has not been any economic analysis that supports the validity of either the Fast and Slow growth scenarios.

3.5 Conclusions

As outlined above, there are several important areas where the assumptions and data associated with CARB's on-road Diesel inventory are either questionable or not publicly available. This is not new issue as the same situation existed in 2008 when the In-Use On-Road Diesel Regulation was adopted. At that time, Sierra urged that CARB conduct a peer-review of the inventory[8]—a request that was ignored by CARB as evidenced by the fact that Sierra's recommendation is not addressed in the Final Statement of Reasons published by CARB.[9] Sierra again urges that CARB conduct a peer review of the inventory to ensure that the need for and the emission benefits of the In-Use On-Road Diesel Regulation are accurately quantified.

Sierra also believes that peer review of the inventory is consistent with California Health and Safety Code Section 39607.3, which requires the following:

> *(a) The state board shall, not later than January 1, 1998, and triennially thereafter, approve, following a public hearing, an update to the emission inventory required by subdivision (b) of Section 39607.*
> *(b) Each inventory update shall include all of the following:*

(1) The state board's and each district's best estimates of emissions from all sources, including, but not limited to, motor vehicles, nonroad mobile sources, stationary sources, areawide sources, and biogenic sources.

(2) A detailed verification of source category emission rate data with available scientific data, including, but not limited to, actual measurements of pollutants in the atmosphere, and an explanation of any discrepancies.

(3) An update to a mobile source emission inventory for any air quality attainment plan required by the federal Clean Air Act (42 U.S.C.A. Sec. 7401 et seq.) or this division, that considers all available information regarding current and projected vehicle miles traveled, vehicle trips, demographics, and other nontechnological factors affecting the mobile source emission inventory, and bases the mobile source emission inventory upon the best information available to achieve compliance.

(c) Any emission inventory update approved on or after January 1, 1997, shall comply with this section.

(d) The Legislature hereby finds and declares that it is in the interests of the state that air quality plans be based on accurate emission inventories. Inaccurate inventories that do not reflect the actual emissions into the air can lead to misdirected air quality control measures, resulting in delayed attainment of standards and unnecessary and significant costs.

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4. ANALYSIS OF ALTERNATIVE ASSUMPTIONS

As noted in the previous section, there are many areas where substantial uncertainties and questions exist with respect to the assumptions and methodologies used in the CARB on-road heavy-duty Diesel inventory. However, given the lack of available data and/or limited resources, an analysis of the potential impacts associated with all of the identified issues was not feasible as part of this study. It was for that reason that a detailed peer review of the CARB inventory was recommended. This section examines the impacts on the inventory of alternative assumptions in three areas: (1) maximum average mileage accumulation, (2) MAR values for older vehicles, and (3) use of only CARB's slow economic recovery scenario.

4.1 Alternative Average Maximum Odometer Values

In earlier versions of CARB's on-road Diesel emissions inventory model "EMFAC," the average odometer for a specific fleet of vehicles was defined as the sum of the age-specific MARs. For example, if it is assumed that the average vehicle travels 15,000 miles in the first year of use and 10,000 in the second, the average two-year-old vehicle would be assumed to have an odometer reading of 25,000 miles.

For gasoline-powered passenger cars and light- and medium-duty trucks, odometer data collected by the California Department of Consumer Affairs' Bureau of Automotive Repair during the periodic inspection and maintenance program (Smog Check) was used by CARB staff to establish age-specific average odometer readings and MARs for these fleets. Because no equivalent program currently exists for heavy-duty vehicles, CARB utilizes information collected in VIUS, formerly known as TIUS, which was conducted every five years by the U.S. Census Bureau and contains estimates of vehicle population by type, average fuel economy, and average annual miles driven. As noted previously, the most recent VIUS report available is for calendar year 2002.*

CARB uses the estimates of average odometer reading to determine the impact of deterioration, increases in emissions attributable to mal-maintenance, and usage-related wear on the engine and/or emissions control system. As discussed in Section 2, DR values are expressed as incremental increases in the base emission rate per every 10,000 miles of driving. Until recently, the fleet average odometer readings in CARB's model ranged from zero to over 1.8 million miles at age 45; however, CARB is now generally

* *http://www.census.gov/prod/ec02/ec02tv-ca.pdf*

assuming average maximum odometer readings of 800,000 miles for heavy-heavy-duty Diesel vehicles and 400,000 miles for medium-heavy-duty Diesel vehicles.[2]

In investigating the accuracy of CARB's assumptions, Sierra Research staff analyzed several datasets in which the odometer readings of heavy-duty trucks were recorded. These datasets were the Coordinating Research Council's (CRC) E55-59 test program, a California Trucking Association (CTA) survey of member activities, and a heavy-duty truck origin/destination survey conducted by CARB. Each is discussed below.

CRC E55-59 – As stated earlier, project E55-59 was conducted between September 2001 and June 2005 with the objective of acquiring regulated emissions measurements for the test fleet and non-regulated emissions measurements on a subset of in-use trucks in order to improve the emissions inventory in California.[*]

The various phases of the E55-59 project involved a total of 57 heavy-heavy-duty trucks. Odometer readings of these trucks were recorded at the time of testing and the readings by model year are plotted in Figure 4-1. Also shown are lines representing the previous and current CARB assumptions regarding MAR values as a function of vehicle age as well as a statistical fit of the data.

With respect to the statistical fit of the data, although odometer readings appear to decline after reaching a peak at 600,000 miles, it was assumed—in order to reduce the influence of the sparse sample sizes at advanced vehicle ages—that average odometer readings reached a "cap" and remained at that level. Therefore, an exponential fit of the odometer data was used with the following equation

$$\mathbf{y = y_0 + A_1 e^{(x-x0)/t1}} \qquad \text{Eq. (3)}$$

As can be seen in Figure 4-1, the average odometer readings appear to peak around 600,000 miles and then decline, rather than continuing to increase as CARB assumed previously. The 600,000-mile peak is also considerably below the 800,000-mile peak currently assumed by CARB and is achieved later in the life of the vehicle.

CTA Member Survey – In 2005, in an effort to better quantify the emissions benefits of CARB's clean Diesel fuel, CTA conducted a survey of member trucking companies to obtain mileage accumulation data for heavy-duty Diesel trucks in California. Twenty-seven companies responded, providing odometer readings and model-year information for nearly 1,100 trucks.[10†] As shown in Figure 4-2, the odometer readings again appear to rise to an average of just over 600,000 miles before declining. Also shown again for reference are CARB's current and previous assumptions regarding MAR values. The results of the CTA survey are quite similar to those observed from the CRC E55-59 project.

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[*] *http://www.crcao.com/reports/recentstudies2007/E-55-59/E-55_59_Final_Report_23AUG2007.pdf*

[†] January 6, 2005 memorandum to Michael Jackson, Staci Heaton, and Mark Carlock from Jenny Pont entitled "CTA Survey Odometer Data vs. Emfac2002 Defaults."

Figure 4-1
CRC E55-59 Average Odometer Data

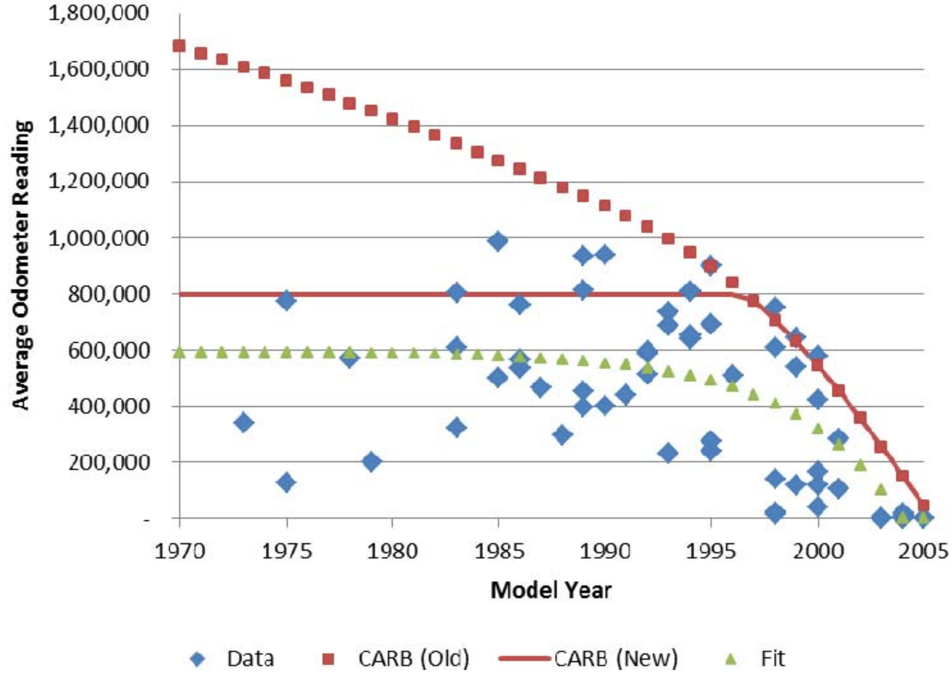
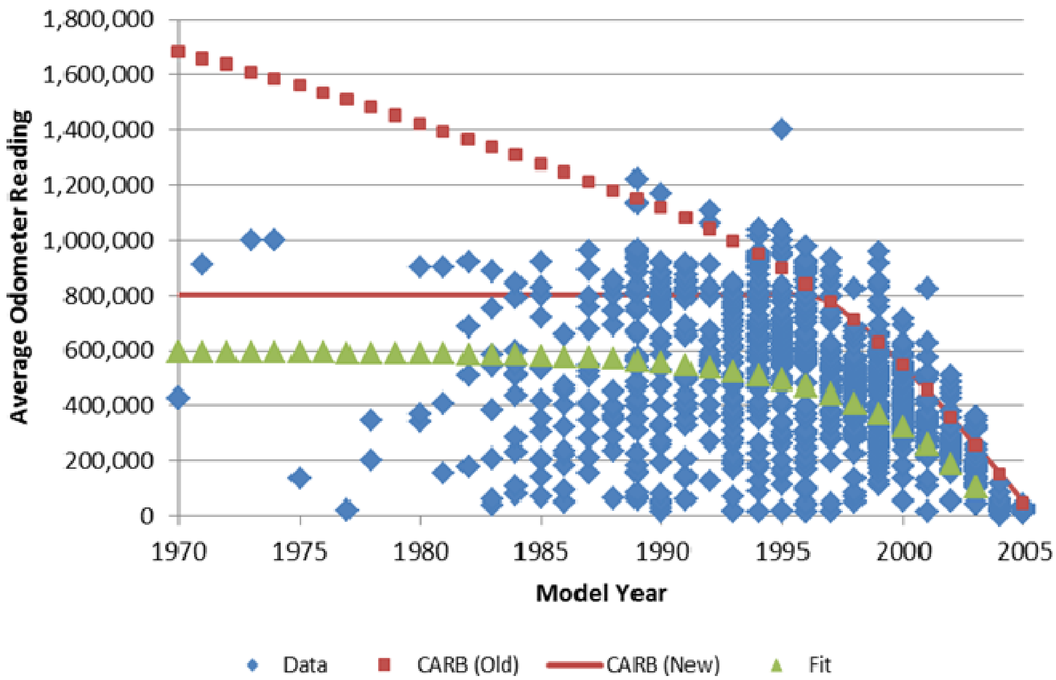


Figure 4-2
CTA Survey Odometer Data



CARB Origin/Destination Study – In an attempt to improve its activity estimates for on-road heavy-duty vehicles, CARB conducted a massive origin/destination (O/D) survey of trucks traveling on state highways and interstates. During this effort, information was collected on over 5,000 vehicles, including their odometer readings and model-year information.

As with most datasets, CARB's O/D survey contained data gaps, entry errors, and other issues that made some records unusable for this analysis and some data screening was required. As a first step, the records of all vehicles with a recorded GVWR of less than 33,001 pounds were eliminated from the analysis, leaving only heavy-heavy-duty vehicles. Next, all records were eliminated that were lacking odometer readings, model-year data, and/or GVWR entries. The remaining records were then analyzed to derive the minimum, maximum, and average odometer readings by model year along with the standard deviation of the data about the mean. Table 4-1 displays the statistics mentioned above (model-year groups with fewer than two vehicles will have no statistics for standard deviation).

Table 4-1
CARB Origin/Destination Survey Odometer Statistics

Model Year	Count	Minimum	Average	Maximum	Std. Dev.
2009	2	9,628	39,905	70,182	42,818
2008	52	1,289	53,099	478,723	73,003
2007	248	1,123	128,623	821,593	122,990
2006	522	4,001	195,082	3,816,193	280,267
2005	501	1,001	260,378	2,295,711	208,219
2004	380	10,073	346,370	4,386,599	361,766
2003	261	3,101	401,246	5,003,124	368,332
2002	257	11,883	737,146	64,100,517	4,000,920
2001	237	4,072	547,539	6,690,417	626,036
2000	367	13,092	607,646	8,107,174	645,286
1999	461	11,147	625,086	10,957,774	737,894
1998	332	568	676,736	10,962,196	770,485
1997	254	7,279	686,326	6,632,255	542,564
1996	243	1,735	635,679	4,658,990	505,876
1995	222	1,754	806,420	37,553,317	2,589,393
1994	181	8,365	741,965	10,998,626	1,223,885
1993	115	48,498	1,047,259	29,160,499	2,806,473
1992	75	8,057	561,573	1,617,995	372,296

Table 4-1
CARB Origin/Destination Survey Odometer Statistics

Model Year	Count	Minimum	Average	Maximum	Std. Dev.
1991	60	46,773	736,192	8,867,164	1,185,226
1990	46	29,849	583,153	1,910,446	395,497
1989	45	17,269	599,266	2,386,807	491,168
1988	38	55,359	844,145	9,000,341	1,409,969
1987	23	13,574	965,337	8,990,380	1,786,665
1986	16	34,767	985,149	9,738,778	2,353,277
1985	28	64,884	608,657	2,408,771	484,437
1984	16	0	1,198,918	10,011,134	2,386,969
1983	10	68,338	539,021	1,400,350	397,339
1982	3	272,004	508,242	870,400	318,451
1981	2	298,960	538,090	777,219	338,180
1980	2	828,646	918,288	1,007,929	126,772
1979	3	176,535	595,131	880,889	370,490
1978	2	100,220	629,611	1,159,001	748,671
1977	2	918,462	1,147,577	1,376,692	324,018
1974	1	168,000	168,000	168,000	
1972	1	386,659	386,659	386,659	
1970	1	4,812	4,812	4,812	
1967	1	749,973	749,973	749,973	
1964	1	230,493	230,493	230,493	
Total	**5,011**				

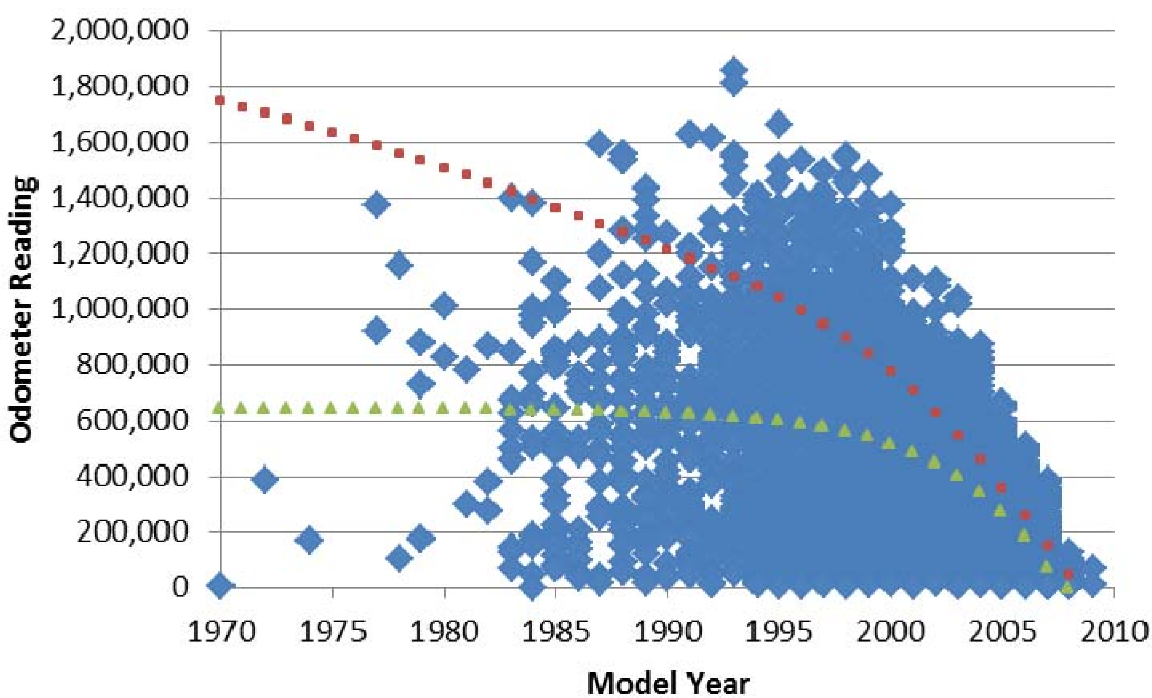
Because of the variability displayed in some of the model-year groups, the data were again screened to remove readings that were found to be beyond three standard deviations in either direction of the mean. The three-sigma, or empirical, rule in statistics states that for a normal distribution, nearly all values (99.7%) lie within three standard deviations of the mean. This process was repeated until no statistical outliers remained. The resulting data are displayed in Table 4-2 and in Figure 4-3.

Table 4-2
CARB Origin/Destination Survey Statistics (Cleaned)

Model Year	Count	Minimum	Average	Maximum	Std. Dev.
2009	2	9,628	39,905	70,182	42,818
2008	49	1,289	38,848	127,524	29,889
2007	237	1,123	113,991	384,794	93,031
2006	498	4,001	165,319	507,265	114,409
2005	488	1,001	244,401	660,105	150,159
2004	361	10,073	316,454	875,311	191,728
2003	249	3,101	391,465	1,039,282	232,751
2002	249	11,883	446,823	1,101,563	231,267
2001	230	4,072	478,838	1,107,828	281,274
2000	361	13,092	559,826	1,371,382	301,421
1999	456	11,147	571,971	1,482,852	329,394
1998	327	568	609,109	1,553,134	371,615
1997	252	7,279	652,113	1,490,952	355,202
1996	238	1,735	596,428	1,534,151	370,346
1995	217	1,754	594,121	1,663,932	371,338
1994	172	8,365	540,457	1,409,871	357,904
1993	110	48,498	675,660	1,853,838	408,970
1992	73	8,057	569,697	1,617,995	373,682
1991	53	46,773	536,927	1,625,885	362,411
1990	41	29,849	518,741	1,060,326	280,714
1989	42	17,269	574,792	1,434,021	416,222
1988	36	55,359	620,610	1,557,007	386,274
1987	22	13,574	600,563	1,591,870	371,555
1986	15	34,767	401,574	875,432	308,712
1985	27	64,884	541,986	1,104,452	338,317
1984	15	0	611,437	1,377,562	433,601
1983	10	68,338	539,021	1,400,350	397,339
1982	3	272,004	508,242	870,400	318,451
1981	1	298,960	298,960	298,960	
1980	2	828,646	918,288	1,007,929	126,772
1979	3	176,535	595,131	880,889	370,490
1978	2	100,220	629,611	1,159,001	748,671
1977	2	918,462	1,147,577	1,376,692	324,018

Table 4-2 CARB Origin/Destination Survey Statistics (Cleaned)					
Model Year	Count	Minimum	Average	Maximum	Std. Dev.
1974	1	168,000	168,000	168,000	
1972	1	386,659	386,659	386,659	
1970	1	4,812	4,812	4,812	
1967	1	749,973	749,973	749,973	
1964	1	230,493	230,493	230,493	
Total	4,848				

Figure 4-3
CARB O/D Study Average Odometer Data



As with the other two data sets, the fit of the data suggests a maximum average odometer value of 600,000 miles as opposed to the 800,000 assumed by CARB, and demonstrates that the previous CARB methodology greatly overstated maximum average odometer values. Based on the data presented here, Sierra believes that the 600,000-mile value for heavy-heavy-duty Diesel vehicles is more appropriate than CARB's assumed 800,000-mile value, as CARB has presented only a qualitative analysis[2] to support its assumed value. Given that Sierra did not examine maximum odometer data for medium-heavy duty Diesel vehicles, CARB's assumed value of 400,000 miles is not questioned here.

4.2 Alternative Mileage Accrual Rates

As discussed above, CARB has abandoned its previous practice of linking maximum odometer values to its assumed MAR values. However, despite the logical existence of a linkage between average maximum odometer and MAR values, CARB has not reexamined in anyway its assumed MAR values. As noted in the previous section, such a reexamination is warranted based on the age of the VIUS data as well as the fact that the data used to estimate MAR values for older vehicles are not, to the best of Sierra's knowledge, publicly available.

Given the limitations and age of the VIUS information, Sierra Research, in combination with the Ad Hoc Working Group, conducted a survey of heavy-duty-vehicle fleet owners to collect data that could be used to assess CARB's assumed MAR values. This survey was conducted during the summer of 2010. It involved asking fleet operators to provide information on the operation of their vehicles, including historic and current odometer readings and estimates of fuel consumption. Some 20 fleets responded, providing operating data for close to 1,200 vehicles covering calendar years 2005 through 2010.

The initial dataset was screened to remove from the analysis those vehicles that were reported as weighing less than 33,001 pounds gross vehicle weight and/or those records missing the information necessary to determine MAR values. Sierra computed MARs by subtracting the reported odometer reading for one year from the odometer reading recorded for the same vehicle in the prior year. In some instances, odometer readings in a subsequent year were lower than the previous, yielding a negative estimate of mileage accrual. Reasons for these occurrences include mis-entry of the information, odometer rollover, and/or odometer replacement. Rather than speculate on the cause or implement some erroneous adjustment, these negative values were also eliminated from the analysis.

The resulting dataset included some 950 trucks with a model-year range from 1974 to 2010. Because vehicles were either introduced or retired from the fleet from one calendar year to the next, and as a result of the data screening described above, the fleet sizes used to determine the age-specific MARs ranged from 343 to 587 trucks. Table 4-3 summarizes the vehicle count and average MAR for each calendar and vehicle age and provides the VIUS and CARB survey information that CARB assumes to be accurate. It is important to note that 2010 data were not included in this analysis because they represented activity for only a partial year.

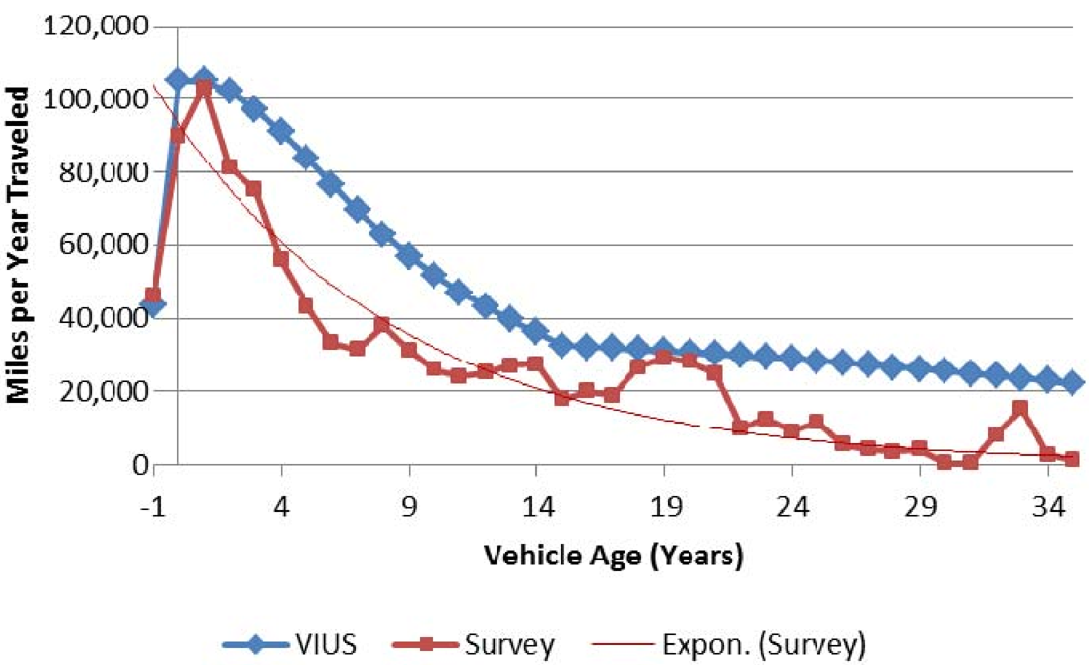
Figure 4-4 compares the results of the analysis of the 2010 survey data to the MARs assumed by CARB to be applicable to California vehicles. The figure includes an exponential fit of the survey data. As can be seen, the MAR values used by CARB are generally higher than those from the 2010 survey, particularly for older vehicles.

Table 4-3
Survey MARs by Vehicle Age and Calendar Year

Age	2005 to 2006		2006 to 2007		2007 to 2008		2008 to 2009		Weighted Average	VIUS
	Count	Average	Count	Average	Count	Average	Count	Average		
-1	0	-	12	58,167	19	38,356	0	-	46,025	43,847
0	10	106,543	8	34,401	17	89,056	27	100,183	89,670	105,234
1	16	79,158	61	126,530	33	82,402	31	91,676	103,164	105,141
2	36	48,764	47	65,648	78	103,579	37	86,850	81,483	102,228
3	42	50,246	71	92,801	48	55,512	82	84,424	75,253	97,292
4	35	30,686	71	65,836	73	64,426	49	47,183	55,980	91,028
5	37	43,540	47	37,665	61	40,776	56	50,416	43,243	84,030
6	38	42,514	42	35,881	40	24,574	55	31,537	33,371	76,791
7	17	49,438	40	31,339	41	24,992	32	31,085	31,641	69,707
8	18	30,013	15	63,494	41	41,119	36	27,464	37,884	63,069
9	38	21,396	16	53,219	14	46,204	43	27,264	31,385	57,069
10	6	23,515	34	17,221	19	38,725	14	31,380	26,050	51,799
11	12	19,847	6	23,126	17	19,676	14	33,627	24,126	47,251
12	8	17,848	12	33,796	5	28,629	6	15,044	25,218	43,315
13	9	43,940	8	14,282	12	32,078	6	8,828	27,075	39,780
14	7	20,507	5	25,406	7	21,317	7	42,102	27,481	36,336
15	12	15,588	3	13,856	9	22,722	5	16,696	17,814	32,572
16	25	19,465	9	12,240	4	35,913	4	25,956	20,101	32,241
17	20	24,336	19	17,373	4	12,507	4	4,722	18,845	31,891
18	11	23,717	10	37,214	11	23,295	2	6,319	26,527	31,521
19	6	22,199	6	28,680	6	36,689	9	29,166	29,182	31,131
20	2	12,504	6	18,144	10	28,191	7	40,836	28,065	30,722
21	2	10,515	3	16,190	6	14,451	8	39,579	24,892	30,292
22	1	5,973	2	7,907	3	10,232	6	11,095	9,921	29,843
23	1	15,000	1	12,880	2	8,962	3	13,723	12,424	29,374
24	0	-	1	11,000	1	12,865	2	6,012	8,972	28,885
25	1	5,690	0	-	1	8,000	1	21,073	11,588	28,377
26	2	4,288	1	7,089	0	-	1	6,000	5,416	27,848
27	0	-	2	2,099	1	8,575	0	-	4,258	27,300
28	0	-	0	-	2	3,459	0	-	3,459	26,732
29	0	-	0	-	0	-	2	4,168	4,168	26,144
30	1	380	0	-	0	-	0	-	380	25,537
31	0	-	1	233	0	-	0	-	233	24,909

Table 4-3 Survey MARs by Vehicle Age and Calendar Year										
	2005 to 2006		2006 to 2007		2007 to 2008		2008 to 2009		Weighted	
Age	Count	Average	Count	Average	Count	Average	Count	Average	Average	VIUS
32	1	16,315	0	-	1	185	0	-	8,250	24,262
33			1	30,208	0	-	1	227	15,218	23,595
34					1	2,640	0	-	2,640	22,899
35							1	1,149	1,149	22,202
Total	414		560		587		551			

Figure 4-4
Comparison of Survey Results and CARB MARs



Because CARB uses different MAR values for different vehicle categories and the survey data were not sufficiently detailed to resolve those vehicle categories, a direct comparison of the survey and CARB MAR values for newer vehicles is not appropriate. It is appropriate, however, for vehicles 17 years old and older where CARB uses the same MAR values for a number of different vehicle categories. This issue is of importance because older vehicles in the fleet are assumed to be the highest emitting.

To analyze the inventory impact of substituting the MAR values for 17 year old and older vehicles from the 2010 survey for the MAR values assumed by CARB, a "hybrid" approach was used that melded CARB's assumptions for newer trucks (less than 17 years old) with the results of the 2010 survey for vehicles 17 years old and older. In addition, Sierra used the 600,000-mile maximum average odometer value discussed above in this assessment. The results are shown in Figures 4-5a and 4-5b, along with the original 2008 CARB baseline and the with-regulation inventories.

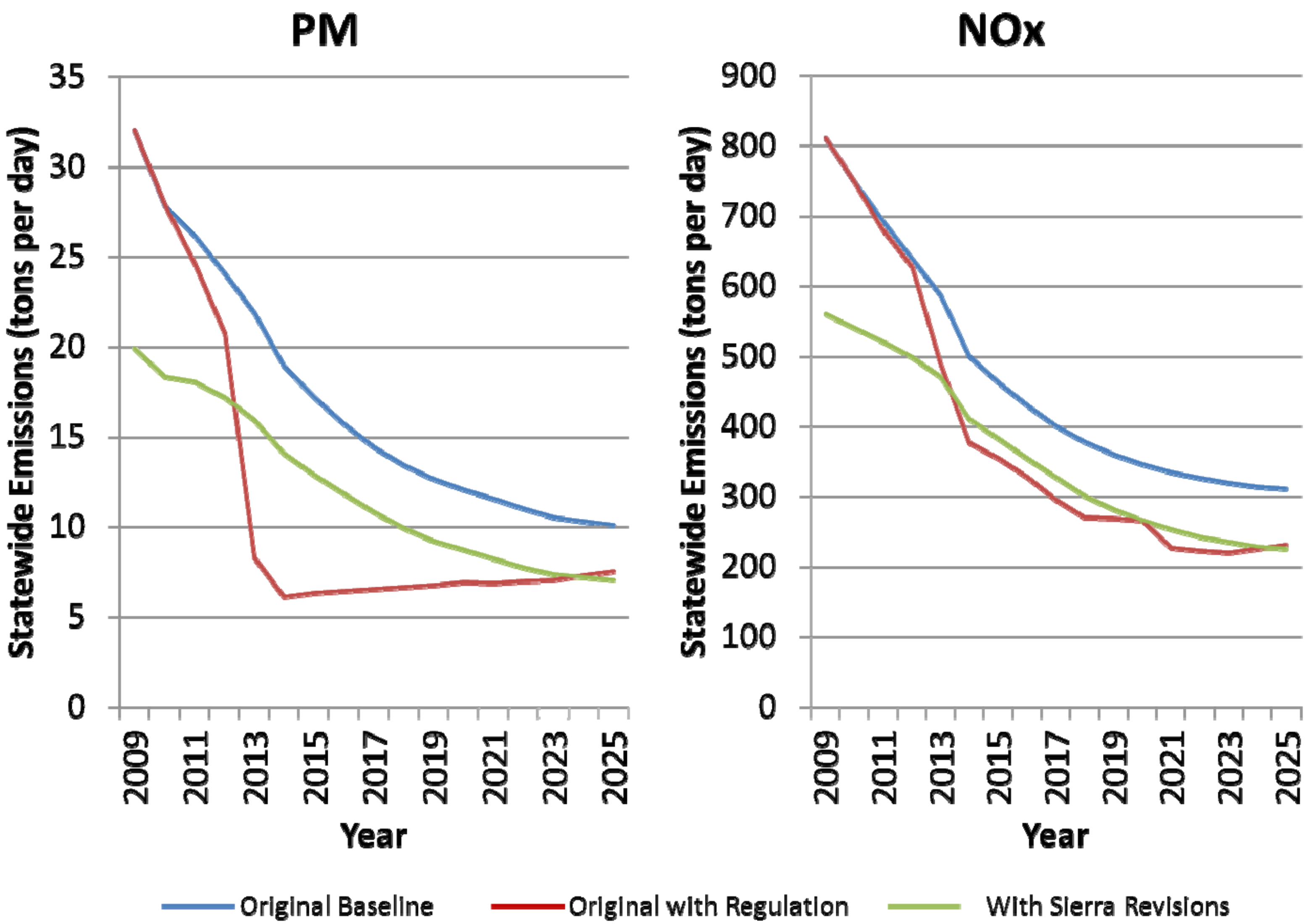
As shown, these substitutions reduce the baseline inventories even further and result in an estimate that is closer to the original emission targets of the regulation. It must be stressed that the changes in MARs made by Sierra based on the survey data, which are reflected in Figures ES-3a and ES-3b, are conservative in that they apply only to 17-year-old and older vehicles, and CARB's assumed mileage rates for newer vehicles have not been adjusted despite the discrepancies between those rates and the rates observed in the 2010 survey data.

Finally, Sierra combined the MAR and maximum odometer assumptions noted above with CARB Slow economic recovery scenario data, rather than the average of the Fast and Slow scenarios used by CARB, in order to investigate the impacts of the current economy on the baseline inventory. Although Sierra does not perform economic forecasting, there is little evidence available to suggest that a "fast" economic recovery is underway in the California trucking sector and more evidence, including California Diesel fuel sales data and discussions with Ad Hoc Working Group members, indicating that a slow recovery is more likely.

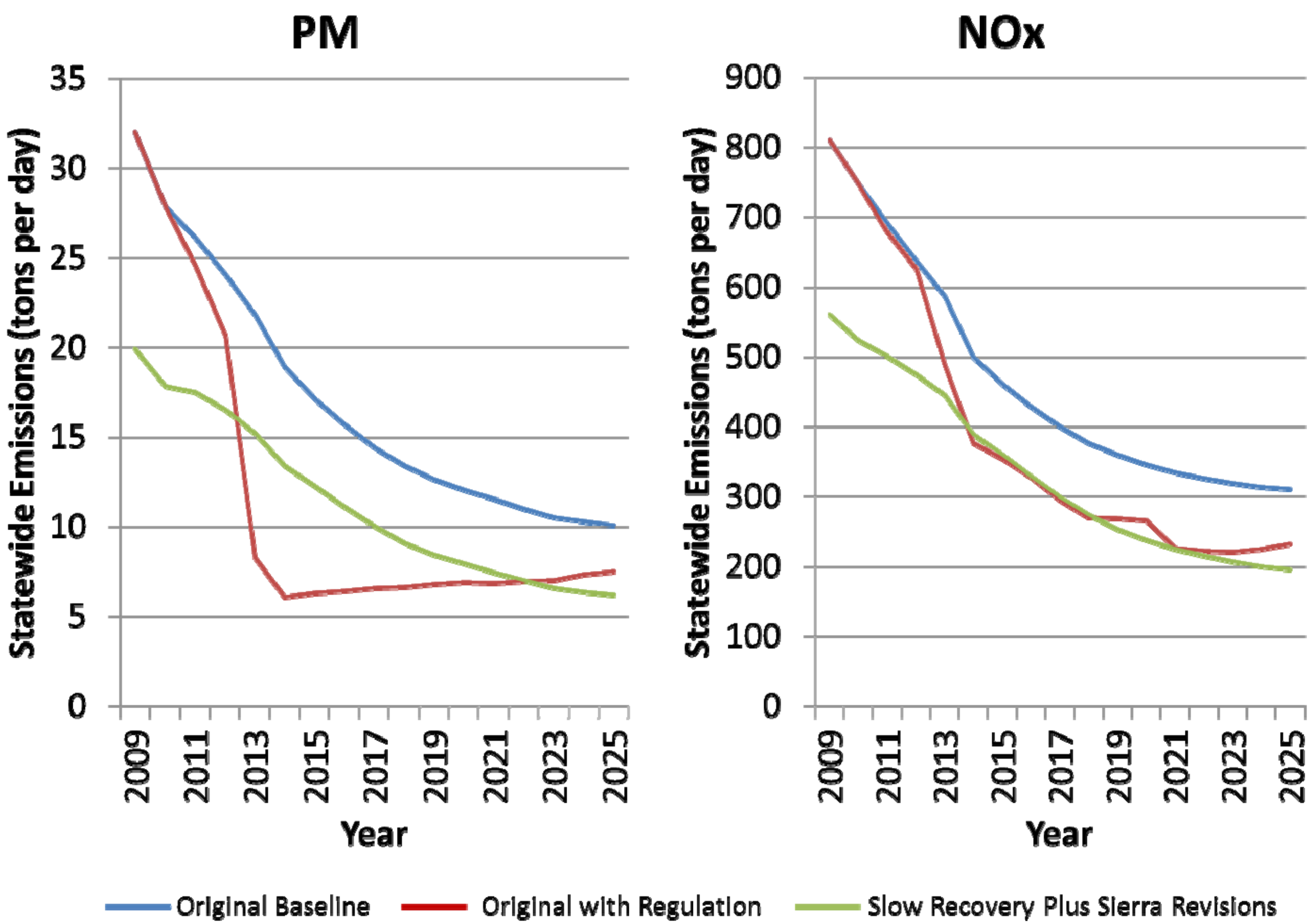
The results of this plausible combination of Sierra's modifications are shown in Figures 4-6a and 4-6b, again for PM and NOx, respectively, along with the original CARB baseline and CARB's original regulatory emission targets. In this case, the original CARB baseline is 1.61 and 1.45 times higher than the Sierra-estimated baseline in 2009 for PM and NOx emissions, respectively. Further, in 2014, which CARB has indicated to be a key year with respect to the need for the regulation, the original CARB baseline is 1.41 and 1.28 times greater for PM and NOx, respectively, than the Sierra estimated baseline.

It is also important to note, as shown in Figures 4-6a and 4-6b, that the combination of the slow recovery scenario and the other Sierra revisions results in a baseline NOx emission inventory that achieves the original targets of the In-Use On-Road Diesel Regulation and further reduces the difference between the baseline and the original with-regulation inventory for PM emissions. This is an important finding because it brings into question the need for the NOx provisions of the regulation and suggests that the reductions in PM emissions needed to reach CARB's regulatory goals are smaller than those envisioned at the time the regulation was adopted.

Figures 4-5a and 4-5b
Comparison of Current CARB Baseline Inventory Modified Based on Sierra Findings to Original (2008) Baseline and With-Regulation Inventories



Figures 4-6a and 4-6b
Comparison of Current CARB Baseline Inventory Modified Based on Sierra Findings and Slow Recovery to Original (2008) Baseline and With-Regulation Inventories



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5. REFERENCES

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2. Initial Statement of Reasons for Proposed Amendments to the Truck and Bus Regulation, the Drayage Truck Regulation and the Tractor-Trailer Greenhouse Gas Regulation, California Air Resources Board, Mobile Source Control Division, Heavy-Duty Diesel Implementation Branch, Appendix G, October 2010.

3. See *http://www.census.gov/svsd/www/vius/2002.html*

4. "Heavy-Duty Vehicle Chassis Dynamometer Testing for Emissions Inventory, Air Quality Modeling, Source Apportionment and Air Toxics Emissions Inventory," CRC Report No. E55/59, August 2007.

5. See *http://www.arb.ca.gov/msprog/onrdiesel/documents/ truck_economic_documentation_v015.pdf*

6. See *http://www.census.gov/svsd/www/vius/2002.html*

7. CARB Request for Proposal (RFP) No. 08-764, "Study of Performance of Emission Control Systems on 2007 and Later Model Year Heavy-Duty Diesel Trucks." April 30, 2009.

8. See *http://www.arb.ca.gov/lists/truckbus08/875-sierra_research_comments.pdf*

9. See *http://www.arb.ca.gov/regact/2008/truckbus08/pt2revfsor.pdf*

10. January 6, 2005 memorandum to Michael Jackson, Staci Heaton, and Mark Carlock from Jenny Pont entitled "CTA Survey Odometer Data vs. Emfac2002 Defaults."