Appendix III – Emissions Inventory Analysis and Results

Air Resources Board (ARB) staff estimates that by 2020, heavy-duty trucks and buses exceeding 8,500 pounds gross vehicle rated weight (GVWR), will be responsible for about 30% of the total on-road statewide greenhouse gas (GHG) emissions and 70% of the total on-road statewide NOx emissions (EMFAC2011). ARB has developed and is implementing a comprehensive regulatory program to reduce these emissions. This Appendix provides an overview to calculations of emissions benefits for several regulations and regulatory amendments designed to achieve these emissions reductions. The first two sections in this appendix describe emissions benefits for two regulations designed to reduce GHG emissions from the heavy-duty fleet. The third section discusses the potential impact of proposed optional lower NOx emissions standards on the statewide NOx emissions inventory.

1. Emissions Benefits: ARB Tractor-Trailer GHG Regulation

1.1. Overview of Regulation

In 2008, ARB adopted a regulation designed to accelerate the use of low rolling resistance tires and aerodynamic fairings to reduce GHG emissions in the heavy-duty truck fleet.

1.1.1. Tractor Requirements

The regulation applies to owners of Class 7 and 8 heavy-duty tractors (>26,000 pounds GVWR) operating on California highways. The regulation includes the following requirements for tractors:

- 2011 and newer model year (MY) sleeper-cab tractors that pull affected trailers in California must be SmartWay certified beginning January 1, 2010.
- 2011 and newer MY day-cab tractors that pull affected trailers in California must use SmartWay verified low rolling resistance tires beginning January 1, 2010.
- All 2010 and older MY tractors that pull affected trailers in California must use SmartWay verified low rolling resistance tires beginning January 1, 2013.

This regulation offers special exemptions for local- and short-haul tractors. A registered local-haul tractor is exempt from the aerodynamic requirements of this regulation, but not from the low rolling resistance tire requirements. An affected short-haul tractor is exempt from all the requirements of this regulation when registered with ARB and updated on an annual basis.

1.1.2. Trailer Requirements

The regulation also applies to owners of 53-foot or longer box-type trailers, including both dry-van and refrigerated-van trailers. The regulation includes the following requirements for trailers:

- 2011 and newer MY 53-foot or longer box-type trailers must, beginning January 1, 2010, be either:
  - SmartWay certified or
  - Retrofitted with SmartWay verified technologies, as follows:
    - Low rolling resistance tires, and
    - Aerodynamic devices
- 2010 and older MY 53-foot or longer box-type trailers (with the exception of certain 2003 to 2009 MY refrigerated-van trailers) must meet the same aerodynamic device requirements as 2011 and newer MY trailers either:
  - By January 1, 2013, or
  - According to a compliance schedule based on fleet size which allows them to phase-in their compliance over time.
- 2010 and older MY trailers must use SmartWay verified low rolling resistance tires by January 1, 2017.
- 2003 to 2009 MY refrigerated-van trailers equipped with 2003 or newer MY transport refrigeration units have a compliance phase-in between 2017 and 2019.

This regulation offers special compliance options for pre-2011 model year trailers. While all 2011 and newer model year trailers must comply as of January 1, 2010 with both the aerodynamic device requirements and low-rolling resistance tire requirements, small fleets (less than 20 trailers) and large fleets (21 or more trailers) can choose to phase-in compliance of their 2010 and older model year trailers for the aerodynamic technology requirements of the regulation.

1.2. Emissions Inventory Methods

Staff used EMFAC2011 and the 2008 staff report as the starting point for this analysis. Based on previous staff analysis and the Tractor-Trailer GHG Reporting database (TRUCRS), staff estimated CO_2 emissions rate reductions under different combinations of calendar year, model year, tractor cab type, trailer van type, haul type, and trailer phase-in options. Previous staff analysis indicated tire improvements lead to a 1.5% reduction in GHG emissions. This same analysis also indicated that the aerodynamic improvements lead to 2%, 4%, and 5% reduction in GHG emissions on tractors, refrigerated vans, and dry vans respectively. The detailed documentation for this analysis can be found in Appendix G, of the "Staff Report: *Initial Statement of Reasons* *for Proposed Rulemaking Proposed Regulation for In-Use On-Road Diesel Vehicles" (ARB, 2008b).*

Lacking more detailed data, staff assumed that each tractor pulls the same model year trailer. With this assumption, staff calculated overall CO_2 reductions for each tractor-trailer combination as a function of calendar year, model year, tractor cab type, trailer van type, haul type, and trailer phase-in options. Since emissions data from EMFAC2011 does not provide information on haul type, cab type, van type, and options; staff used a variety of data sources to calculate weighted-average reduction factors as a function of calendar year, model year, and speed.

In order to calculate the population shares among the tractor-trailers that choose short- or local-haul exemptions, staff used the registration data from TRUCRS to aggregate the emission reduction factors over different haul types of long-, local-, and short-hauls. Having the total number of tractors and those that are exempt (either local or short haul), staff calculated the population shares of local or short haul by model year. Staff assumed that these shares will remain the same for 2012 model year and newer.

1.2.1. Day vs. Sleeper Cabs

Data from EMFAC2011-HD were used to calculate the splits between sleepers and non-sleeper tractors. Following EMFAC2011-HD, 42% of the affected heavy-duty truck vehicle miles travelled (VMT) is linked to the non-sleepers tractors, while the rest of the 58% are associated with sleeper tractors.

1.2.2. Trailer Type

The trailer production data from 1997 to 2000 Current Industrial Reports (Census, 2000) indicates that 69% of box type trailers are dry-van trailers and the rest (31%) are refrigerated-van trailers. Since this regulation only applies to 53" or longer box type trailers, staff also estimated the percent of VMT in California driven by 53" or longer box type trailers. According to this analysis, 68% of total Tractor-Trailer combinations are affected by this regulation.

1.2.3. Regulatory Options

According to the registration data from TRUCRS for small/large fleet options, 58% of pre-2011 model year trailers that are eligible for phase-in option will be fully compliant with the aerodynamic technology requirements by 2013, 30%are registered in Option 1 of the large fleet compliance plan and will be fully compliant by January 1, 2016. 11% are registered in Option 2 of the large fleet compliance plan and will also be fully compliant by January 1, 2016, and 1% are registered in the small fleet compliance plan and will be fully compliant by January 1, 2017. Table III-1 and Table III-2 show the compliance phase-in dates and percentages for each compliance plan.

Table III- 1: Large Fleet Option 1 and 2 Compliance Plan Schedules

Option 1 % of Trailers	Option 2 % of Trailers	Compliance Before
5%	--	January 1, 2011
15%	20%	January 1, 2012
30%	40%	January 1, 2013
50%	60%	January 1, 2014
75%	80%	January 1, 2015
100%	100%	January 1, 2016

Table III- 2: Small Fleet Compliance Plan Schedule

Percentage of Trailers	Compliance Before
25%	January 1, 2014
50%	January 1, 2015
75%	January 1, 2016
100%	January 1, 2017

1.2.4. Benefits as a Function of Speed

Staff assumed that the full benefit from aerodynamic technology only occurs at speeds above 50 mph. Staff assumed aerodynamic technologies provide no benefit at speeds below 25 mph. Staff assumed a linear increase in aerodynamic technology effectiveness from 25 mph to 50 mph.[1]

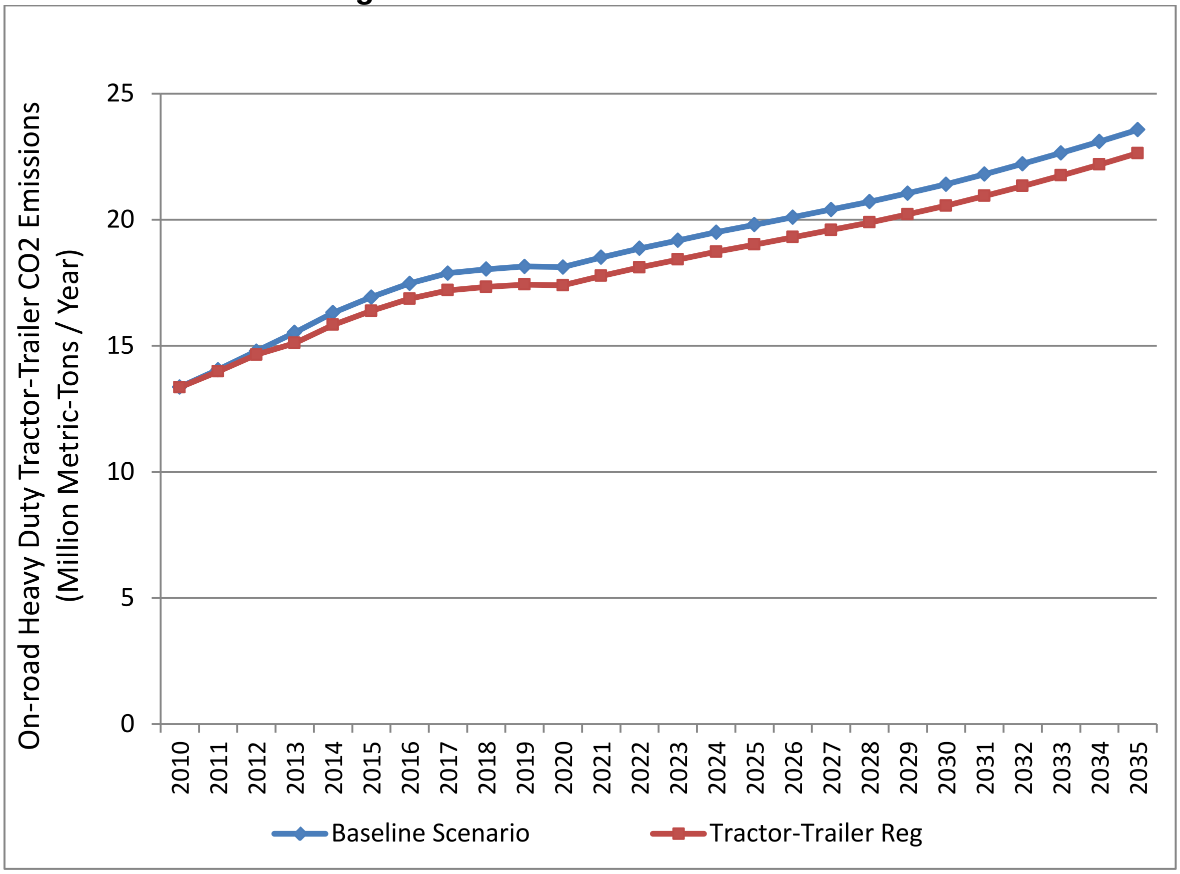
1.3. Emissions Inventory Results

Using the analysis described above, staff calculated a weighted average CO_2 emissions reduction factor at the calendar year, model year, and speed level across all tractor and trailer types, and across short and long haul types. This reduction factor was then combined with CO_2 emissions from EMFAC2011 to calculate the benefits of the regulation as originally adopted, as shown in Figure III- 1. Results suggest a 4% benefit

[1] Staff recognizes that aerodynamic effectiveness would be better approximated as a function of the square of the vehicle speed, resulting in a parabolic increase rather than a linear increase in effectiveness; and will gather the data necessary to further refine this assumption accordingly as part of future emission inventory analysis.

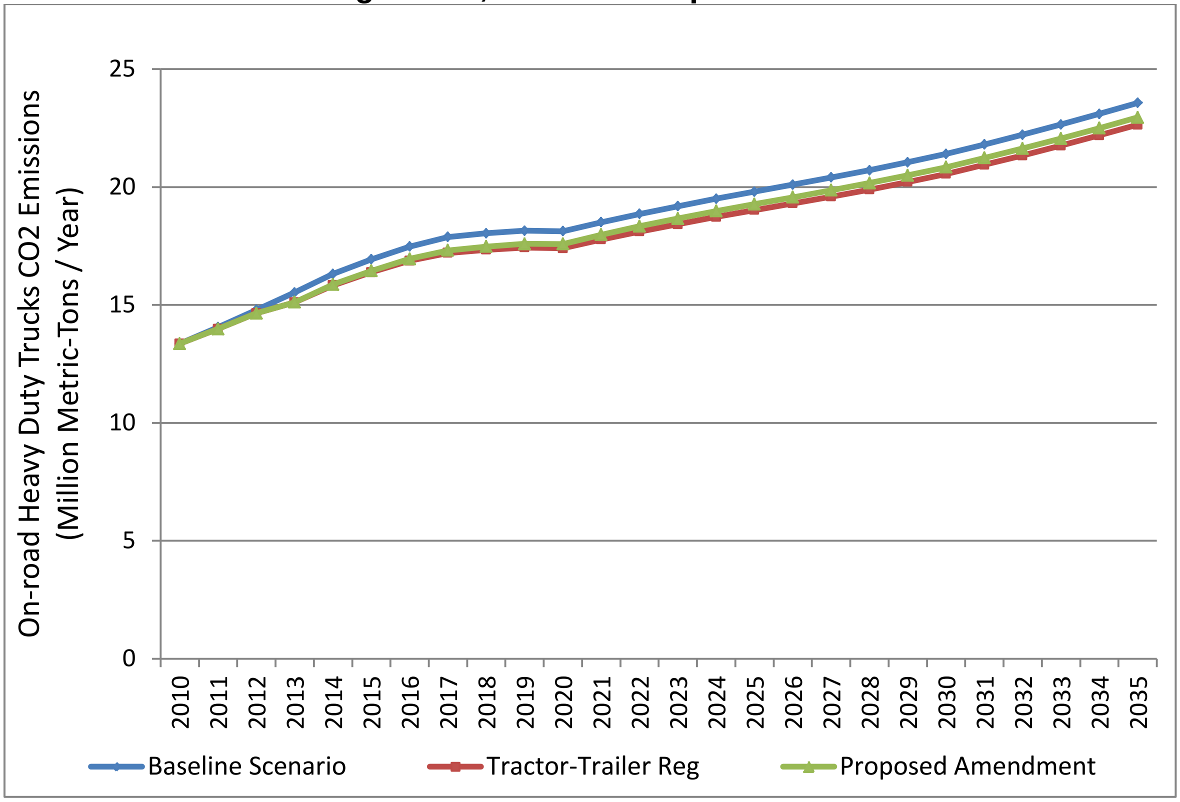
when the regulation is implemented, which a calculated composite from the assumptions is described above.

Figure III- 1: Statewide GHG Emissions without Regulation (Baseline) and with the Tractor-Trailer GHG Regulation



To harmonize the tractor requirements of the Tractor-Trailer GHG regulation with the proposed California Phase 1 GHG standards, the proposed amendments will sunset the requirements of the regulation for 2014 and subsequent model year tractors. Following the proposed amendments, the 2014 and newer tractors will not provide any emission reductions as a result of aerodynamic or tire improvements. The emissions impact of the proposed amendments is shown in Figure III- 2, and is negligible.

Figure III- 2: Statewide GHG Emissions without Regulation (Baseline), with the Tractor-Trailer GHG Regulation, and with Proposed Amendments



2. Emissions Benefits: Alignment with USEPA Phase-I Heavy Duty Truck Standards

In 2011, the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Transportation's National Highway Traffic Safety Administration (NHTSA) jointly adopted GHG emission standards and fuel economy standards for medium- and heavy-duty engines and vehicles, informally known as the "Phase 1" GHG regulations. The proposed California rule will align with federal GHG emission standards and fuel economy standards, and will follow the same structure and stringency levels of the EPA rule, including new engine and vehicle GHG requirements, etc.

2.1. Overview of Regulation

The regulation imposes new requirements for newly manufactured compression and spark ignited engines in Class 2b through Class 8 vehicles. Compliance requirements begin with model year 2014. The regulation is phased-in so that the regulation takes full effect in model year 2019. The Rule organizes truck compliance into three groupings:

- Heavy duty pickups and vans (Class 2b, 3)

- Vocational vehicles (VV) (Class 4 through 8)
- HD Tractor-Trailers (Class 7, 8)

Trucking operations in California differ substantially from the national average. Favorable weather conditions and other factors allow trucks that are operated primarily in California to be retained longer by fleets than the national average. In addition, the California trucking market is segmented, with national, regional and local fleets all competing in different segments of the goods movement economy. This leads to a different vehicle fleet mix, vehicle age, and VMT profiles than the national average. EMFAC2011 reflects these California-specific factors, and is used as the starting point for this analysis. This analysis focuses on the GHG emissions impact of the proposed rule as applied to heavy-duty vehicles operated in California.

2.2. Emissions Inventory Methods

2.2.1. Emission Rates

The EPA Phase-I Regulation sets CO_2 emission standards (gCO_2/ton-mi) for each vehicle category listed below:

- Vocational Vehicles
  - Heavy Heavy (Class 8)
  - Medium Heavy (Class 6 & 7-single-unit and Buses)
  - Light Heavy (Class 4-5)
- Tractors
  - Class 7
  - Class 8
    - Sleeper cab
    - Day cab
- Pickups and Vans
  - Diesel (Class 2b-3)
  - Gasoline (Class 2b-3)
- Buses

Since EMFAC2011 vehicle categories are different than the vehicle categories defined by Phase 1 regulations, staff made necessary adjustments described below to translate the emission reductions in terms of EMFAC2011 vehicle categories. These adjustments were derived from an analysis of VIUS data (Census, 2002) and EMFAC 2011 population/VMT data. ARB calculated the population/VMT shares for:

- T7 trucks (GVWR≥33,001)
  - Vocational (13%)
  - Day cabs tractor-trailer (43.5%)
  - Sleeper cab tractor-trailer (43.5%)
- T6 trucks (14,001≤GVWR≤33000)
  - Vocational class 4 and 5 (41%)
  - Vocational class 6 and 7 (51%)
  - Class 7 tractor-trailer (8%)
- LHDT(8,501≤GVWR≤14,000)[1]
  - Vocational (100%)
  - Tractor-trailer (0%)

Using these population/VMT shares, staff aggregated the emission rates obtained from the vehicle standards to obtain a composite CO_2 emission rate (g/mile) applicable to each EMFAC2011 vehicle category.

Staff applied these reductions to EMFAC2011-HD and LDV CO_2 emissions output. For this analysis, school bus, urban transit bus, motor coaches, motor homes, and all other buses were assigned the same reduction level as medium-heavy duty vocational vehicles. The percentage reductions in CO_2 emission rates with respect to 2010 are shown in Table III- 3.

Table III- 3: Phase 1 CO2 Emission Rate (g/mi) Reduction Percentage

Final Reduction Strategy					
Model Year	LHDT1/LHDT2 Gasoline Reduction	LHDT1/LHDT2 Diesel Reduction	T6 Composite Reduction	T7 Composite Reduction	Buses
2010	100.0%	100.0%	100.0%	100.0%	100.0%
2014	98.5%	97.7%	94.6%	87.3%	94.7%
2015	98.0%	97.0%	94.6%	87.3%	94.7%
2016	96.0%	94.0%	94.6%	87.3%	94.7%
2017	94.0%	91.0%	91.1%	84.8%	91.1%
2018+	90.0%	85.0%	91.1%	84.8%	91.1%

[1] Appendix III uses ARB's EMFAC2011 model definitions of weight classes, e.g., light heavy-duty as 8,501 to 14,000 pounds GVWR.

2.2.2. Rebound Effect

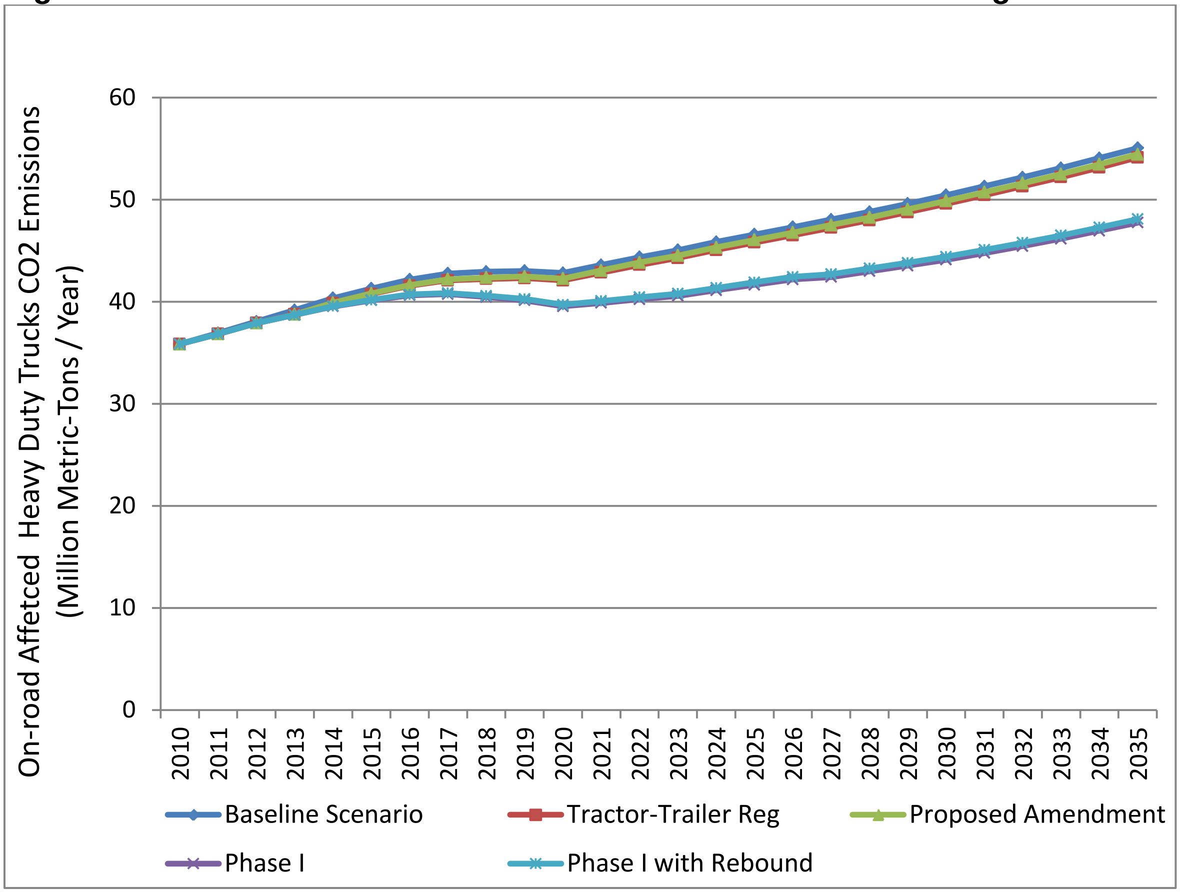
The Rebound Effect is the idea that the demand for driving is a function of the operating costs of the vehicle being driven. When operating costs increase, such as when fuel prices increase, driving becomes more expensive and people drive less. Conversely, if fuel prices decrease people may drive more. In the case of the Phase-I regulation, newly manufactured vehicles obtain better fuel economy and are therefore marginally less expensive to operate. As a result, staff expects there will be a marginal increase in the amount of miles driven per vehicle. Following EPA's Final Regulatory Impact Analysis (RIA) of GHG Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles section 5.3.2.2.2 (U.S. EPA, 2011b), a rebound effect of 1.18% for HD Pickup Vans, 1.33% for vocational vehicles and 0.5% for tractors was assumed.

2.3. Emissions Inventory Results

Figure III- 3 shows the impact of the Phase 1 regulation on GHG emissions from affected vehicles[1]. Results show a >10% reduction in GHG emissions by 2035.

[1] The affected EMFAC vehicle categories by Phase 1 regulation are heavy-duty trucks and buses exceeding 8,500 pounds GVWR.

Figure III- 3: Statewide On-Road GHG Emissions from Phase-I Regulated Vehicles*



*Without Regulation (Baseline), with the Tractor-Trailer GHG Regulation, with the Proposed Amendment to Tractor-Trailer GHG Regulation, with the Phase 1 Regulations, and with the Phase 1 Regulations Affected by Rebound.

3. Emissions Benefits: Optional Low NOx Standards

ARB's proposal for optional NO_x standards is an effort to encourage engine manufacturers to introduce new lower-emitting technologies than vehicles certified to today's 2010 emissions standard of 0.2 g/bhp-hr. Certification data demonstrates that although the NO_x standard for heavy-duty diesel engine is set at 0.2 g/bhp-hr, 25% of engine families are certified to levels lower than currently required, in the range of 0.03 - 0.14 g/bhp-hr.

3.1. Overview of Regulation

The proposed regulation provides engine manufacturers the option to certify new engines to a 0.1, 0.05, or 0.02 g/bhp-hr NO_x standard. The proposed optional low NO_x standards would encourage engine manufacturers to showcase new technologies and could be used to prioritize funding in incentive programs such as the Carl Moyer Memorial Air Quality Standards Attainment Program.

3.2. Emissions Inventory Methods

Because the proposed low NO_x engine emissions standards are optional, ARB staff has conducted a bounding exercise to estimate the percent of new engines that manufacturers will choose to certify to the proposed new standards. Staff developed two different scenarios, one with a high adoption rate and another with a low adoption rate. These scenarios estimate the percent of a manufacturer's engine product line that might potentially be certified to lower NO_x levels. Table III- 4 shows the proposed optional NO_x standards and the annual compliance percentage assumed under each adoption scenario from 2015 through 2035 model years.

Table III- 4: Assumed Percentage of Heavy Duty Engines Projected to Meet the Optional Low NOx Engine Emission Standards

High Adoption Scenario	**2015**	**2020**	**2025**	**2030**	**2035**
0.1 (50% below std.)	8.0	10.2	13.0	16.6	21.2
0.05 (75% below std.)	0.0	1.2	1.5	1.9	2.4
0.02 (90% below std.)	0.0	1.0	1.3	1.6	2.1
Low Adoption Scenario	**2015**	**2020**	**2025**	**2030**	**2035**
0.1 (50% below std.)	4.0	5.1	6.5	8.3	10.6
0.05 (75% below std.)	0.0	1.0	1.3	1.6	2.1
0.02 (90% below std.)	0.0	0.0	0.0	0.0	0.0

Staff used the assumed percent engine sales from these two adoption scenarios to estimate the overall NO_x emission rate reduction with respect the 2010 engine standard (0.2 g/bhp-hr). The analysis showed that by 2035, NO_x emission rates will decrease by 7% and 14% under low- and high-adoption scenarios.

In California, a sizeable fraction of trucks are purchased used on the national market. Staff assumed that used out-of-state heavy duty engines sold in California would not be certified to the optional low NO_x standards.

3.3. Emissions Inventory Results

Using these model year specific percent reductions in NO_x emission rates, staff assessed the emissions impact of the optional NO_x regulation under both high- and low-adoption scenarios. The result from this analysis is shown in Figure III- 4. The inventory analysis shows a NO_x benefit of 2.7 (low adoption) and 5.6 (high adoption) tons/day by 2032.

Figure III- 4: Statewide NOx Emissions without Regulation (Baseline), with Low Adoption Optional Low NOx Regulation, and with High Adoption Optional Low NOx Regulation.