Appendix C

Health Impacts from Off-Road Diesel Vehicles

Assessment of Health Impacts from Off-Road Diesel Vehicles

A. Methodology

The methodology for estimating these health impacts is outlined below and details can be found in Appendix A of the Emission Reduction Plan for Ports and Goods Movement in California (ARB, 2006) [1].

1. Primary Diesel PM

Lloyd and Cackette (2001) estimated that, based on the study by Krewski and colleagues (2000) of the American Cancer Society (ACS) cohort, a statewide population-weighted average diesel $PM_{2.5}$ exposure in year 2000 of 1.8 $\mu g/m^3$ resulted in a mean estimate of 1,985 premature deaths per year in California (Lloyd/Cackette, 2001). In 2002, Pope and colleagues extended the follow-up period for the same ACS cohort and published new findings based on a longer follow-up time, greater number of deaths, and improved statistical modeling techniques. Consistent with U.S. EPA (2004), ARB has been using the new PM-premature death relationship from Pope et al. (2002) since the approval of the Ports and Goods Movement Emission Reduction Plan (ARB, 2006). Using the study by Pope et al. (2002), a statewide population-weighted average diesel $PM_{2.5}$ exposure of 1.8 $\mu g/m^3$ resulted in a mean estimate of 2,200 premature deaths per year in California, about 10% higher than previous estimates. The diesel $PM_{2.5}$ emissions corresponding to the diesel $PM_{2.5}$ concentration of 1.8 $\mu g/m^3$ is 36,000 tons per year for the year 2000 based on the recently updated emission inventory used the ARB staff in developing this rule. Using this information, we estimate that for every reduction of 17 tons per year of diesel $PM_{2.5}$ emissions, one fewer premature death would result. This factor is derived by dividing 36,000 tons by 2,168 deaths (unrounded number of deaths described above). Although a single statewide factor (tons per death) is discussed in this example, staff actually developed basin-specific factors for the health impacts assessment of emissions from in-use off-road diesel vehicles. These basin-specific factors were developed using basin-specific diesel PM concentrations and emissions in year 2000.

a. *Health Impacts of Diesel PM Baseline Emissions*

After adjusting for population changes between 2005 and 2000, staff estimates that 8,260 tons of emissions from in-use off-road diesel vehicles in year 2005 are associated with approximately 690 annual deaths (190 – 1,200, 95% CI). Estimates of other health impacts, such as hospitalizations and asthma symptoms, were calculated using basin-specific factors developed from other health studies, basin-specific diesel PM concentrations, and emissions in year 2000. Details for these estimates can be found in Appendix A of the Emission Reduction Plan for Ports and Goods Movement in California (ARB, 2006).

[1] http://www.arb.ca.gov/planning/gmerp/march21plan/appendix_a.pdf

b. ***Benefits of Diesel PM Emissions Reductions***

After adjusting for population changes between each future year and 2000, staff estimates that the cumulative total of 35,760 tons of emissions from in-use off-road diesel vehicles reduced through the implementation of this regulation in years 2009-2030 are associated with a reduction of approximately 3,400 deaths (930 – 5,800, 95% CI). Estimates of other health benefits, such as hospitalizations and asthma symptoms, were calculated using basin-specific factors developed from other health studies, basin-specific diesel PM concentrations, emissions in year 2000, and basin-specific populations. Details for the methods used to calculate these estimates can be found in Appendix A of the Emission Reduction Plan for Ports and Goods Movement in California (ARB, 2006).

2. Secondary Diesel PM

In addition to directly emitted PM, diesel exhaust contains NOx, which is a precursor to nitrates, a secondary diesel-related PM formed in the atmosphere. Lloyd and Cackette 2001) estimated that secondary diesel $PM_{2.5}$ exposures from NOx emissions can lead to additional health impacts above those caused by directly emitted diesel $PM_{2.5}$. To quantify such impacts, staff developed population-weighted nitrate concentrations for each air basin using data not only from the statewide routine monitoring network, which was used in Lloyd and Cackette (2001), but also from special monitoring programs such as IMPROVE and Children's Health Study (CHS) in year 1998. The IMPROVE network provided additional information in the rural areas, while the CHS added more data to southern California. Staff calculated the health impacts resulting from exposure to these concentrations, and associated the impacts with the basin-specific NOx emissions to develop basin-specific factors (tons per death).

Using a similar approach as that for primary diesel PM and adjusting for population changes between 2005 and 1998 (the year with the greatest geographic extent of nitrate monitoring), staff estimates that 140,963 tons of emissions from in-use off-road diesel vehicles in year 2005 are associated with an estimated 450 annual premature deaths (120 – 770, 95% CI). Other health effects were also estimated as outlined above.

Staff also estimates that the cumulative reduction of 165,700 tons of emissions from in-use off-road diesel vehicles in 2009-2030 are associated with the avoidance of an estimated 610 premature deaths (170 – 1,000, 95% CI). Other health effects were also estimated as outlined above

3. Assumptions and Limitations of Health Impacts Assessment

Several assumptions were used in quantifying the health effects of PM exposure. They include the selection and applicability of the concentration-response functions, exposure assessment, and baseline incidence rates. These are briefly described below.

- Premature death calculations were based on the concentration-response function of Pope et al. (2002). The ARB staff assumed that the concentration-response function for premature death in California is comparable to that in the study by Pope and colleagues. This is supported by other studies in California showing a similar association between $PM_{2.5}$ exposure and premature death. In addition, the Pope et al. (2002) study included subjects in several metropolitan areas of California. The U.S. EPA has been using the Pope et al. (2002) study for its regulatory impact analyses since 2004. For other health endpoints, the selection of the concentration-response functions was based on the most recent and relevant scientific literature. Details are in the Emission Reduction Plan for Ports and Goods Movement in California (ARB, 2006).

- The ARB staff assumed the model-predicted diesel PM exposure estimates published in the diesel ID report (ARB, 1998) could be applied to the entire population within each basin. That is, the entire population within the basin was assumed to be exposed uniformly to modeled concentration, an assumption typical of this type of assessment.

- The ARB staff assumed the baseline incidence rates for each health endpoint were uniform across each county, and in many cases across each basin. This assumption is consistent with methods used by the U.S. EPA for its regulatory impact assessment, and the incidence rates match those used by U.S. EPA.

- Because only a subset of health outcomes is considered here, the estimates should be considered an underestimate of the total public health impact of diesel PM exposure.

B. Health Impacts Associated with Baseline Diesel PM Emissions

Staff estimates that approximately 1,100 premature deaths (310 – 1,900, 95 percent confidence interval (95% CI)) are associated with the baseline uncontrolled emissions from in-use off-road diesel vehicles in year 2005. Other health impacts are listed in the table below. The methodology for estimating these health impacts is outlined above. Details can be found in Appendix A of the Emission Reduction Plan for Ports and Goods Movement in California (ARB, 2006)[2].

[2] http://www.arb.ca.gov/planning/gmerp/march21plan/appendix_a.pdf

Table 1: Baseline Health Effects From In-Use Off-Road Diesel Vehicle Emissions (indirectly from NOx and directly from PM), 2005

Endpoint	Pollutant	# of Cases 95% C.I. (Low)	# of Cases (Mean)	# of Cases 95% C.I. (High)
Premature Death	NOx	120	450	770
	PM	190	690	1,200
	Total	310	1,100	1,900
Hospital admissions (Respiratory)	NOx	60	100	130
	PM	90	150	200
	Total	150	240	330
Hospital admissions (Cardiovascular)	NOx	110	180	270
	PM	170	270	420
	Total	280	440	690
Asthma & Lower Respiratory Symptoms	NOx.	5,000	13,000	20,000
	PM	7,400	19,000	31,000
	Total	12,000	32,000	51,000
Acute Bronchitis	NOx	0	1,100	2,300
	PM	0	1,600	3,500
	Total	0	2,600	5,700
Work Loss Days	NOx	65,000	77,000	89,000
	PM	100,000	120,000	140,000
	Total	170,000	190,000	220,000
Minor Restricted Activity Days	NOx	360,000	440,000	520,000
	PM	550,000	680,000	800,000
	Total	920,000	1,100,000	1,300,000

C. Health Benefits of Reduction in Emissions from In-Use Off-Road Vehicles

A substantial number of epidemiologic studies have found a strong association between exposure to ambient particulate matter (PM) and a number of adverse health effects (CARB, 2002). ARB staff quantified seven noncancer health impacts associated with the change in exposures to the diesel PM emissions. This analysis shows the statewide cumulative impacts of the emissions reduced through this regulation from year 2009 through 2030. The table below lists the impacts associated with emissions from direct and indirect sources of diesel PM separately.

Table 2: Total Health Benefits Associated with Reductions in Emissions from In-Use Off-Road Diesel Vehicle Emissions

(indirectly from NOx and directly from PM), 2009-2030

Endpoint	Pollutant	# of Cases 95% C.I. (Low)	# of Cases (Mean)	# of Cases 95% C.I. (High)
Premature Death	NOx	170	610	1,000
	PM	930	3,400	5,800
	Total	1,100	4,000	6,800
Hospital admissions (Respiratory)	NOx	80	130	180
	PM	460	720	990
	Total	540	840	1,200
Hospital admissions (Cardiovascular)	NOx	150	240	370
	PM	830	1,300	2,000
	Total	980	1,600	2,400
Asthma & Lower Respiratory Symptoms	NOx	6,800	17,000	28,000
	PM	36,000	94,000	150,000
	Total	43,000	110,000	180,000
Acute Bronchitis	NOx	0	1,400	3,000
	PM	0	7,800	17,000
	Total	0	9,200	20,000
Work Loss Days	NOx	88,000	100,000	120,000
	PM	490,000	580,000	670,000
	Total	580,000	680,000	790,000
Minor Restricted Activity Days	NOx	490,000	600,000	710,000
	PM	2,700,000	3,300,000	3,900,000
	Total	3,200,000	3,900,000	4,600,000

D. Economic Valuation of Health Effects

This section describes the methodology for monetizing the value of avoiding adverse health impacts.

The U.S. EPA has established $4.8 million in 1990 dollars at the 1990 income level as the mean value of avoiding one premature death (U.S. EPA, 1999, pages 70-72). This value is the mean estimate from five contingent valuation studies and 21 wage-risk studies. Contingent valuation and wage-risk studies examine the willingness to pay (or accept) for a minor decrease (or increase) in risk of premature death. For example, if 10,000 people are willing to pay $800 apiece for risk reduction of 1/10,000 then collectively the willingness-to-pay for avoiding a premature death, in this example, would be $8 million. This is also known as the “value of a statistical life” or VSL.[3]

As real income increases, people are willing to pay more to prevent premature death. U.S. EPA adjusts the 1990 value of avoiding a premature death by a factor of 1.201[4] to account for real income growth from 1990 through 2020, (U.S. EPA, 2004, page 9-121). Assuming that real income grows at a constant rate from 1990 until 2020, we adjusted VSL for real income growth, increasing it at a rate of approximately 0.6% per year. We also updated the value to 2006 dollars. After these adjustments, the value of avoiding one premature death is $8.2 million in 2006, $8.6 million in 2015 and $9.5 million in 2030, all expressed in 2006 dollars.

The U.S. EPA also uses WTP methodology for some non-fatal health endpoints, including lower respiratory symptoms, acute bronchitis and minor restricted activity days. WTP values for these minor illnesses are also adjusted for anticipated income growth through 2030, although at a lower rate, (1.066 in lieu of 1.201).

For work-loss days, the U.S. EPA uses an estimate of the parent’s lost wages, (U.S. EPA, 2004), which CARB adjusts for projected real income growth.

“The Economic Value of Respiratory and Cardiovascular Hospitalizations,” (ARB, 2003), calculated the cost of both respiratory and cardiovascular hospital admissions in California as the cost of illness plus associated costs such as loss of time for work, recreation and household production. CARB adjusts these COI values by the amount that annual medical care price increases for hospitalization exceed “all-item” price increases (CPI).

Table 2 lists the valuation of avoiding various health effects, compiled from CARB and U.S. EPA publications, updated to 2006 dollars. The valuations based on WTP, as well as those based on wages, are adjusted for anticipated growth in real income.

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[3] U.S. EPA’s most recent regulatory impact analyses, (U.S. EPA 2004, 2005), apply a different VSL estimate ($5.5 million in 1999 dollars, with a 95 percent confidence interval between $1 million and $10 million). This revised value is based on more recent meta-analytical literature, and has not been endorsed by the Environmental Economics Advisory Committee (EEAC) of U.S. EPA’s Science Advisory Board (SAB). Until U.S. EPA’s SAB endorses a revised estimate, CARB staff continues to use the last VSL estimate endorsed by the SAB, i.e., $4.8 million in 1990 dollars.

[4] U.S. EPA’s real income growth adjustment factor for premature death incorporates an elasticity estimate of 0.4.

Table 3: Undiscounted Unit Values for Health Effects (at various income levels in 2006 dollars) [1]

Health Endpoint	2006	2015	2030	References
Mortality				
Premature death ($ million)	8.2	8.6	9.5	U.S. EPA (1999), (2000), (2004)
Hospital Admissions				
Cardiovascular ($ thousands)	43	48	57	CARB (2003), p.63
Respiratory ($ thousands)	35	39	47	CARB (2003), p.63
Minor Illnesses				
Acute Bronchitis	451	459	474	U.S. EPA (2004), 9-158
Lower Respiratory Symptoms	20	20	21	U.S. EPA (2004), 9-158
Work loss day	189	217	273	2002 California wage data, U.S. Department of Labor
Minor restricted activity day (MRAD)	64	65	67	U.S. EPA (2004), 9-159

[1] The value for premature death is adjusted for projected real income growth, net of 0.4 elasticity. Wage-based values (Work Loss Days) are adjusted for projected real income growth, as are WTP-derived values (Lower Respiratory Symptoms, Acute Bronchitis, and MRADs). Health endpoint values based on cost-of-illness (Cardiovascular and Respiratory Hospitalizations) are adjusted for the amount by which projected CPI for Medical Care (hospitalization) exceeds all-item CPI.

Benefits from the proposed In-Use Off-Road Diesel Rule are substantial. CARB staff estimates the benefits to be $26 billion using a 3% discount rate or $18 billion using a 7% discount rate. (CARB follows U.S. EPA practice in reporting results using both 3% and 7% discount rates.) Nearly all of the monetized benefits result from avoiding premature death. The estimated benefits from avoided morbidity are less than $400 million with a 3% discount rate and less than $300 million with a 7% discount rate. Most of the benefits, approximately 85 percent, are associated with reduced DPM, and the remaining 15 percent with reduced NOx.

E. Conclusion

The health benefits of implementing the proposed regulation are substantial. Staff estimates that the cumulative emissions reductions over the lifetime of the rule will result in approximately 4,000 fewer premature deaths, 840 fewer hospital admissions due to respiratory causes, 1,600 fewer hospital admissions due to cardiovascular causes, 110,000 fewer cases of asthma-related and other lower respiratory symptoms, 9,200 fewer cases of acute bronchitis, 680,000 fewer work loss days, and 3,900,000 fewer minor restricted activity days. The uncertainty range behind each estimated benefit is on order of +/- 50%. The estimated statewide benefits over 2009 to 2030 from these reductions in adverse health effects is about $18 billion using a seven percent discount rate or $26 billion using a three percent discount rate.

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