Appendix D

Non-Cancer Health Risk

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I. Health Impacts Assessment

A substantial number of epidemiologic studies have found a strong association between exposure to ambient $PM_{2.5}$ and a number of adverse health effects (ARB, 2002). For this report, ARB staff quantified seven noncancer health impacts associated with the change in exposures to the diesel PM emissions.

Staff estimates that current exposure to direct and secondary diesel PM emissions from at-berth ocean-going vessel auxiliary engines can be associated with about 61 premature deaths (17 – 100, 95 percent confidence interval (95% CI)) per year. Due to the location of the ocean-going vessels' operations, their emissions were assumed to affect the population only within the county in which the vessels are docked. Other health impacts are listed in Table 1 below. The methodology for estimating these health impacts is outlined below. Details can be found in Appendix A of the Emission Reduction Plan for Ports and Goods Movement in California (ARB, 2006) [1].

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

Table 1: Baseline Health Effects Associated With the Operation of Auxiliary Engines on at-Berth Ocean-Going Vessels for the Year 2006*

Endpoint	Pollutant	# of Cases 95% C.I. (Low)	# of Cases (Mean)	# of Cases 95% C.I. (High)
Premature Mortality	PM	11	39	68
	NOx	6	21	36
	Total	*17*	*61*	*100*
Hospital admissions (Respiratory)	PM	5	8	12
	NOx	3	5	6
	Total	*8*	*13*	*18*
Hospital admissions (Cardiovascular)	PM	10	16	24
	NOx	5	8	13
	Total	*15*	*24*	*37*
Asthma & Lower Respiratory Symptoms	PM	450	1,200	1,900
	NOx	250	620	990
	Total	*700*	*1,800*	*2,800*
Acute Bronchitis	PM	0	97	210
	NOx	0	50	110
	Total	*0*	*150*	*320*
Work Loss Days	PM	5,900	6,900	8,000
	NOx	3,200	3,700	4,300
	Total	*9,000*	*11,000*	*12,000*
Minor Restricted Activity Days	PM	33,000	40,000	47,000
	NOx	17,000	21,000	25,000
	Total	*50,000*	*61,000*	*72,000*

*Health effects from primary and secondary PM are labeled as PM and NOx, respectively. The sum of PM and NOx impacts may not equal the total given due to rounding.

Since diesel PM is a constituent of ambient $PM_{2.5}$, using the epidemiologic study results to quantify diesel PM health effects is reasonable. This analysis shows that the statewide cumulative health impacts of the emissions reduced through this regulation from year 2009 through 2020 are approximately:

- 280 premature deaths (78 – 480, 95% CI)
- 60 hospital admissions due to respiratory causes (38 – 83, 95% CI)
- 110 hospital admissions due to cardiovascular causes (70 – 170, 95% CI)
- 8,200 cases of asthma-related and other lower respiratory symptoms (3,200 – 13,000, 95% CI)
- 680 cases of acute bronchitis (0 – 1,400, 95% CI)
- 49,000 work loss days (42,000 – 57,000, 95% CI)
- 280,000 minor restricted activity days (230,000 – 330,000, 95% CI)

Table 2 below lists the impacts associated with primary and secondary diesel emissions separately. The methodology for estimating these health impacts is described below, and details can be found in Appendix A of the Emission Reduction

Plan for Ports and Goods Movement in California (ARB, 2006)[2]. Due to the location of the ocean-going vessels' operations, their emissions were assumed to affect the population only within the county in which the vessels are docked.

Table 2: Total Health Benefits Associated with Reductions in Emissions from the Operation of Auxiliary Engines on At-Berth Ocean-Going Vessels (2009-2020)*

Endpoint	**Pollutant**	**# of Cases 95% C.I. (Low)**	**# of Cases (Mean)**	**# of Cases 95% C.I. (High)**
Premature Death	PM	22	80	140
	NOx	56	200	340
	Total	*78*	*280*	*480*
Hospital admissions (Respiratory)	PM	11	17	24
	NOx	27	43	59
	Total	*38*	*60*	*80*
Hospital admissions (Cardiovascular)	PM	20	31	49
	NOx	50	79	120
	Total	*70*	*110*	*170*
Asthma & Lower Respiratory Symptoms	PM	910	2,400	3,800
	NOx	2,300	5,900	9,300
	Total	*3,200*	*8,200*	*13,000*
Acute Bronchitis	PM	0	200	430
	NOx	0	480	1,000
	Total	*0*	*680*	*1,400*
Work Loss Days	PM	12,000	14,000	16,000
	NOx	30,000	35,000	41,000
	Total	*42,000*	*49,000*	*57,000*
Minor Restricted Activity Days	PM	66,000	81,000	96,000
	NOx	160,000	200,000	240,000
	Total	*230,000*	*280,000*	*330,000*

* Health effects from primary and secondary PM are labeled PM and NOx, respectively. The sum of PM and NOx impacts may not equal the total given due to rounding.

1. Primary Diesel PM

Consistent with U.S. EPA (2004), ARB has been using the PM-premature death relationship from Pope et al. (2002) since the approval of the Ports and Goods Movement Emission Reduction Plan by the Board (ARB, 2006). In 1998, the ARB estimated a statewide population-weighted average diesel $PM_{2.5}$ exposure of 1.8 $\mu g/m^3$ (ARB, 1998). Using this population-weighted exposure estimate and the study by Pope et al. (2002), staff estimated that diesel PM exposure can be

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

associated with a mean estimate of 2,200 premature deaths per year in California, about 10 percent higher than previous estimates (Lloyd and Cackette, 2001). 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 for the year 2000 based on the emission inventory developed for 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 of diesel PM 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 the operation of auxiliary engines on at-berth ocean-going vessels. These basin-specific factors were developed using basin-specific diesel PM concentrations and emissions for the year 2000. The basin-specific factors were applied to the county where each port is located to estimate health benefits. After adjusting for population changes between each future year and 2000, staff estimates that the cumulative total of approximately 1,100 tons of emissions from the operation of auxiliary engines on at-berth ocean-going vessels reduced through the implementation of this regulation in years 2009-2020 are associated with a reduction of approximately 80 deaths (22 – 140, 95% CI). Estimates of other health benefits, such as hospitalizations and asthma symptoms, were calculated using basin-specific factors developed from other health studies. Details on the methodology 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 beyond those associated with 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 of PM and then associated the impacts with the basin-specific NOx emissions to develop basin-specific factors (tons per case of health endpoint). The basin-specific factors were applied to the county where each port is located to estimate health benefits. Using an approach similar to that used for primary diesel PM and adjusting for population changes between each future year and 1998 (the year with the greatest geographic extent of nitrate monitoring), staff estimates that the cumulative reduction of approximately 61,700 tons of emissions from the operation of auxiliary engines on at-berth ocean-going vessels in 2009-2020 are associated with the reduction of an estimated 200 premature deaths (56 – 340, 95% CI). Other health effects were also estimated as outlined above.

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, the exposure assessment, and the baseline incidence rates. These are briefly described below.

- For premature death, calculations were based on the concentration-response function of Pope et al. (2002). ARB staff assumed that the concentration-response function for premature death in California is comparable to that developed by Pope and colleagues. This is supported by other studies (Dominici et al. 2005, Franklin et al. 2007) in California showing an association between $PM_{2.5}$ exposure and premature death similar to that reported by Pope et al. (2002). 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).

- ARB staff assumed the model-predicted diesel PM exposure estimates published in the report titled “Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant” (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.

- Due to the location of the ocean-going vessels’ operations, their emissions were assumed to affect the population only within the county in which the vessels are docked.

- The basin-specific factors relating emissions to health effects were applied to the county where each port is located to estimate health benefits. That is, ARB staff assumed that the basin-specific factors applied to each county within a basin.

- ARB staff assumed the baseline incidence rate for each health endpoint was uniform across each county. 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.

- Although the analysis illustrates that reduction in diesel PM exposure would confer health benefits to people living in California, we did not provide estimates for all endpoints for which there are C-R functions available. Health effects such as myocardial infarction (heart attack), chronic bronchitis, and onset of asthma were unquantified due to the potential overlap with the quantified effects such as lower respiratory symptoms and hospitalizations. In addition, estimates of the effects of PM on low birth weight and reduced lung function growth in children are not presented. While these endpoints are significant in an assessment of the public health impacts of diesel exhaust emissions, there are currently few published investigations on these topics, and the results of the available studies are not entirely consistent (ARB, 2006). In summary, because only a subset of the total number of health outcomes is considered here, the estimates should be considered an underestimate of the total public health impact of diesel PM exposure.

II. 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). This value is the mean estimate from five contingent valuation studies and 17 wage-risk studies. Contingent valuation and wage-risk studies examine the willingness to pay (or accept payment) for a minor decrease (or increase) in the risk of premature death. For example, if individuals are willing to pay $800 to reduce their risk of mortality by 1/10,000, then collectively they are willing to pay $8 million to avoid one death. 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). 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 percent 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 2007, $8.3 million in 2009 and $8.9 million in 2020, all expressed in 2006 dollars.

The U.S. EPA also uses the willingness-to-pay (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 2020, although at a lower rate (about 0.2 percent per year in lieu of 0.6 percent per year).

For work-loss days, the U.S. EPA uses an estimate of an individual's lost wages, (U.S. EPA, 2004), which CARB adjusts for projected real income growth, at a rate of approximately 1.5 percent per year.

"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 (COI) plus associated costs such as loss of time for

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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.

work, recreation and household production. When adjusting these COI values for inflation, CARB uses the Consumer Price Index (CPI) for medical care rather than the CPI for all items.

Table 3 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.

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

Health Endpoint	2007	2009	2020	References
Mortality				
Premature death ($ million)	8.2	8.3	8.9	U.S. EPA (1999, p. 70-72, 2000, 2004, p. 9-121)
Hospital Admissions				
Cardiovascular ($ thousands)	44	45	51	CARB (2003), p. 63
Respiratory ($ thousands)	36	36	42	CARB (2003), p. 63
Minor Illnesses				
Acute Bronchitis	452	454	464	U.S. EPA (2004), 9-158
Lower Respiratory Symptoms	20	20	20	U.S. EPA (2004), 9-158
Work loss day	192	198	234	2002 California wage data, U.S. Department of Labor
Minor restricted activity day (MRAD)	64	64	66	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 rule on the operation of auxiliary engines on at-berth ocean-going vessels are substantial. ARB staff estimates cumulative benefits over the period from 2009 to 2020 to be nearly $1.9 billion using a 3 percent discount rate or
$1.3 billion using a 7 percent discount rate[5]. A large proportion of the monetized benefits results from avoiding premature death. The estimated benefits from avoided morbidity are approximately $28 million with a 3 percent discount rate and nearly $20 million with a 7 percent discount rate. Approximately 72 percent of the benefits are associated with reduced PM from NOx emissions, and the remaining 28 percent from direct PM emissions.

[5] CARB follows U.S. EPA practice in reporting results using both 3 percent and 7 percent discount rates.

III. Conclusion

The health benefits of implementing the proposed regulation are substantial. Staff estimates that the cumulative emissions reductions over the lifetime of the rule can be associated with approximately 280 fewer premature deaths, 60 fewer hospital admissions due to respiratory causes, 110 fewer hospital admissions due to cardiovascular causes, 8,200 fewer cases of asthma-related and other lower respiratory symptoms, 680 fewer cases of acute bronchitis, 49,000 fewer work loss days, and 280,000 fewer minor restricted activity days. The uncertainty behind each estimated benefit ranges from about 15 percent to 75 percent for most endpoints. The estimated statewide benefits over 2009 to 2020 from these reductions in adverse health effects is nearly $1.3 billion using a 7 percent discount rate or about $1.9 billion using a three percent discount rate.

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