Appendix I

Climate Change Impacts of the Off-Road In-Use Regulation

A. Fuel Economy Penalty for PM Retrofits and Accelerated Turnover to Tier 4 Engines

Carbon dioxide emissions from vehicles are directly proportional to fuel consumption, so any changes in fuel economy will have a direct impact on CO_2 emissions. This section provides the calculations and the assumptions that were used in staff's estimate of the impact of the fuel economy penalty of PM retrofits and Tier 4 engines on CO_2 emissions.

1. Annual Fuel Consumption

The data used to determine the amount of diesel fuel consumed annually for the off-road vehicles subject to this regulation is from the Energy Information Administration (EIA, 2005). The fuel sales for year 2005 for the categories of Industrial, Oil Company, Military, Off-Highway Construction, and Off-Highway Non-Construction were summed, and a growth factor applied to round the figure to 300 million gallons of diesel fuel consumed each year for the vehicles in these categories.

2. Inventory

Appendix H describes the methodology for predicting the compliance paths for real individual fleets using the ARB Off-road Compliance Model. Each fleet evaluated varied by horsepower distribution, age, and vehicle type and provided a representation of the variety of fleets present in the state

Table 1 and Table 2 show the fleet data used in this analysis. Several simplifying assumptions had to be made based on the data available.

Assumptions:

1. Fuel consumption is proportional to horsepower (hp)

   This assumes activity is the same for all tier 4 engines, and for all types of equipment)
2. Total fuel consumption (300,000,000 gallons) includes the fuel penalty
3. For every gallon of CARB diesel fuel used, 9. 96 kilograms of carbon dioxide (CO_2) is emitted from the vehicle (CCAR, 2006).

For each year, the number of retrofits due to the regulation was calculated as a percentage of the total fleet for that year.

With assumption #1, this was assumed to represent the percentage of the total fleet consumption used in the vehicles retrofitted to comply with the rule.

A similar calculation was carried out for the Tier 4 turnovers using the horsepower rather than the number of vehicles.

Using assumption #2, the following equation was used to calculate the fuel penalty (or increase in fuel consumption) for a fuel economy penalty of 2 percent

$$\textit{FuelPenalty (gallons)} = \textit{Total fuel consumption} \quad x \quad \frac{1}{1.02} \quad x \quad 0.02$$

The following equation was then used to calculate the increase in CO_2 emissions due to the fuel economy penalty.

CO_2 increase = Fuel Penalty (gallons) x EMF x 0.01

Where: EMF = the emission factor in assumption #3
0.001 = the conversion factor (metric tons/kg)

Table 1: Carbon Dioxide Emissions Increase Due to Fuel Penalty Impact of PM Retrofits

Calendar Year	Retrofits (% of Fleet horsepower)	Fuel Penalty (% of total fuel consumption)	CO2 Emissions Increase (MMT)
2010	18%	0.35%	10,429
2011	30%	0.59%	17,535
2012	44%	0.87%	26,013
2013	45%	0.89%	26,467
2014	50%	0.98%	29,216
2015	51%	1.00%	29,782
2016	50%	0.97%	29,047
2017	45%	0.89%	26,481
2018	41%	0.80%	23,999
2019	36%	0.70%	20,859
2020	38%	0.75%	22,358
2021	42%	0.82%	24,635
2022	39%	0.77%	22,865
2023	35%	0.69%	20,712
2024	34%	0.67%	20,166
2025	34%	0.66%	19,821
2026	33%	0.66%	19,600
2027	33%	0.66%	19,600
2028	32%	0.64%	18,976
2029	32%	0.63%	18,694
2030	31%	0.61%	18,220

Table 2: Carbon Dioxide Emissions Increase Due to Fuel Penalty Impact of Accelerated Turnover to Tier 4 Engines

Calendar Year	Total Fleet Horsepower (hp)		Difference due to the rule			CO_2 Emissions Increase (MMT)
	With Rule	Without Rule	(hp)	(% of total hp)	(% of total fuel consumption)	
2010	1,962	1,683	279	0.04%	0.001%	24
2011	13,427	13,213	214	0.03%	0.001%	19
2012	15,179	14,590	589	0.09%	0.002%	51
2013	44,616	31,871	12,745	1.9%	0.04%	1,114
2014	86,930	48,505	38,425	5.7%	0.11%	3,360
2015	129,910	73,122	56,788	8.5%	0.17%	4,965
2016	177,331	99,402	77,929	12%	0.23%	6,814
2017	220,508	129,050	91,458	14%	0.27%	7,996
2018	265,376	160,072	105,304	16%	0.31%	9,207
2019	311,945	189,722	122,223	18%	0.36%	10,686
2020	360,799	218,493	142,306	21%	0.42%	12,442
2021	388,611	247,054	141,557	21%	0.41%	12,377
2022	410,927	275,515	135,412	20%	0.40%	11,840
2023	435,223	306,154	129,069	19%	0.38%	11,285
2024	448,309	334,399	113,910	17%	0.33%	9,960
2025	461,350	362,697	98,653	15%	0.29%	8,626
2026	468,615	384,001	84,614	13%	0.25%	7,398
2027	468,615	399,375	69,240	10%	0.20%	6,054
2028	469,580	414,949	54,631	8.2%	0.16%	4,777
2029	470,600	430,364	40,236	6.0%	0.12%	3,518
2030	472,005	445,919	26,086	3.9%	0.08%	2,281

B. Idling Limits

The proposed regulation would limit idling of off-road diesel vehicles to five minutes or less unless such idling is necessary for the proper or safe operation of the vehicle. Limiting unnecessary idling would reduce fuel consumption, and emissions of carbon dioxide – a greenhouse gas and contributor to global warming. The objective of the following exercise was to obtain an estimate of the effect of the proposed idling limit on CO_2 emissions from the in-use off-road diesel vehicles covered by the proposed regulation.

1. Calculation of Idling Activity and CO_2 Emissions

Data and Assumptions

(A) The vehicle population in 2000 is 164,250

(B) Total operation in 2000 is 468,660 hours per day

(C) Unnecessary idling is 1.8% of total activity for public fleets

(D) Unnecessary idling is 7.5% of total activity for private fleets

These estimates of idling activity were obtained from fleet owners with decades of experience managing public and private off-road fleets.

(E) Total public horsepower is 4.80% of the total fleet; the rest is private.

(F) For every gallon of CARB diesel fuel used, 9. 96 kilograms of carbon dioxide (CO_2) is emitted from the vehicle (CCAR, 2006).

(G) Idling fuel consumption rate is 0.5 gallons/hour

(H) Average annual fuel consumption is 300,000,000 gallons of CARB diesel

The following equations were used to calculate the values shown in Table 3:

(1) *Total hours of operation for the year = (B) x 365*

(2) *Average activity = (B) ÷ (C)*

(3) *Nonessential Idling activity (hrs/day/vehicle) = ((C) x (E) +(D) x (1 – (E)) x (B)÷(A)*

(4) Nonessential Idling activity (as % of total activity) = (C) x (E) +(D) x (1 – (E)

(5) Average annual hours of nonessential idling = (4) x (1)

(6) Total idling fuel consumption = (G) x (5)

(7) Fuel consumption reduction = (6) ÷H

(8) Idling CO_2 Emissions = (6 x (G) x 0.001

(9) Statewide CO_2 emissions = (H) x (F) x 0.001

(10) CO_2 emissions reductions as a % of total Statewide emissions = (8) ÷ (9)

Using Equation (4), the overall average idling activity was estimated to be 7.23% of total activity or 0.21 hours/day/vehicle. This value of 7.23% was then multiplied by the total hours of operation (Equation 5) to get the total hours of nonessential idling. The fuel consumed during nonessential idling could then be calculated using Equation (6) The CO_2 emissions is the product of the emission factor (9.96 kg CO_2/gallon of fuel) and the volume of fuel consumed during nonessential idling (Equation 8).

Table 3: Summary of Data and Results of Calculations for Idling Impacts

Total hours of operation =	468,660	hours/day in 2000
Total number of vehicles =	164,250	vehicles in 2000
Average annual hours of operation =	171,060,860	hours/year
Average activity =	2.85	hrs/day/vehicle
Idling activity =	7.23%	of total fleet activity
Idling activity =	0.21	hrs/day/vehicle
Average annual hours of idling =	12,361,542	hours/year
Idling fuel consumption rate =	0.5	gallon/hour
Total idling fuel consumption =	6,180,771	gallons/year
Average annual fuel consumption =	300,000,000	gallons/year
Fuel consumption Reduction =	2%	of total statewide fuel consumption
Emission factor =	9.96	kg CO_2/gallon
Idling CO_2 emissions =	61,560	MMT in 2000
Statewide CO_2 emissions =	2,988,000	MMT in 2000
CO_2 emissions reduction =	2%	of total Statewide CO_2 emissions

2. Conclusion

Implementation of the idling limit requirement of the proposed regulation would provide fuel savings and CO_2 emissions reductions of approximately 2 percent.

3. References

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