



Appendix A.9 Emissions Inventory Analysis Supporting Information

Emissions Inventory Analysis

Supporting Information

The emission analysis described here was conducted in December 2016 using data available at that time.¹⁰

2010 and 2040 Freight Locomotive Emissions Analysis

Emission rates by certification tier used for freight locomotives are reported in Table A.19, and the locomotive fleet make-up is presented in Table A.20. Weighted emission rates, in terms of grams per gallon of diesel, are shown in Table A.21.

Freight activity was provided in terms of estimated ton-miles in each air basin for 2013, 2040, and “2040-High.” Straight line interpolation was used to extrapolate 2011 ton-miles, and converted to fuel consumption, then scaled to match the most recent California Air Resources Board (CARB) estimated fuel consumption estimate of 210 million gallons of fuel consumed annually¹¹. Estimated ton-miles and scaled fuel consumption were extrapolated for a 2010 baseline year; and scaled fuel economy was estimated for the 2040 and “2040-high” activity estimates (Table A.22). Estimated emissions from freight were estimated by combining these fuel consumption data with the emission rates (Table A.23)¹².

¹⁰ The California Air Resources Board (CARB) has released a locomotive emissions inventory dated October 2017. That update was based on proprietary data that CARB was unable to share in advance due to confidentiality agreements between CARB and the railroads, and that October 2017 information is not reflected in the 2018 CSRP. In general, CARB’s 2017 inventory data show slightly lower fuel use and emissions estimates. In that sense, results presented in the 2018 CSRP are conservative and appropriate for the purpose and intent of the document.

¹¹ Nicole Dolney and M. Malchow, (2014) Locomotive Inventory Update: Line Haul Activity, CARB tech distribution ref. (Presentation), 2014, California Air Resources Board.

¹² The California Air Resources Board (CARB), has released a locomotive emissions inventory dated October 2017. That update was based on proprietary data that CARB was unable to share in advance due to confidentiality agreements between CARB and the railroads, and that October 2017 information is not reflected in the 2018 Rail Plan. In general, CARB’s 2017 inventory data show slightly lower fuel use and emissions estimates. In that sense, results presented in the 2018 Rail Plan are conservative and appropriate for the purpose and intent of the document.

2010 and 2040 Passenger Locomotive Emissions Analysis

Passenger locomotive emissions were estimated, first assuming no electrification based on existing CARB passenger locomotive data,^{13,14} and scaling factors based on estimated passenger miles of travel (PMT) in each air basin (Table A.24, Table A.25, and

Table A.26). This approach implicitly assumes the mix of locomotive technologies assumed by CARB. The 2035 inventory was used directly to represent 2040, assuming there would not be changes to the locomotive fleet and train schedules between 2035 and 2040. Subsequent adjustments are made on these tables to account for electrification. Statewide emissions from the CARB inventory were used as a control total; emissions were allocated to each air basin based on the relative distribution of passenger miles of travel in each air basin.

Table A.27 provides PMT data used to scale the CARB emissions inventory. The 2040 with-demonstration data were broken out into electric and diesel operation by assuming that in the San Joaquin Valley, Mojave Desert, San Francisco Bay Area, South Coast, and San Diego, 100 percent of the increases in PMT sources in 2040 (relative to 2040 no plan, and 50 percent of the 2010 to 2040 growth without the demonstration plan) would be electrified and have zero emissions. Table A.28 then presents the 2040 with-demonstration emissions assuming electrification.

CO₂ emissions from electric power generation were then incorporated into the draft CSRP. Estimates were based on the megawatt-hours required to power locomotives in each air basin; and emission factors for power generation assuming California's Renewable Portfolio Standard. The final draft will present emissions assuming that all of the electricity used to power the system will be generated from renewable resources such as solar and wind.

2010 and 2040 On-Road Vehicle Emissions Analysis

On-road emissions were estimated based on emissions for 2010 and 2040 that were calculated using EMFAC 2014, run for each air basin in California. For passenger vehicles, emission rates were derived from EMFAC and applied to passenger-vehicle miles of travel estimates from the CSRP, by air basin. 2010 and 2040 passenger vehicle miles of travel, without the 2040 rail plan, were scaled to match EMFAC 2014 estimates. Scaling is necessary because the statewide travel demand model network is coarser than the regional model networks that EMFAC default vehicle miles of travel (VMT) is based on. The 2040 scaling factor was then applied to the reduced 2040

¹³ For criteria pollutants: CARB (2016) ARB's Emission Inventory Activities, California Air Resources Board, Accessed 2016).

¹⁴ For CO₂: Statewide total based on June 2016 California GHG Inventory, less estimated freight CO₂ emissions.

passenger vehicle VMT with the CSRP, and the resulting VMT was used in estimating with CSRP emissions. Commercial vehicle VMT and emissions were taken directly from EMFAC 2014.

Table A.29 shows the resulting vehicle emissions inventory for 2010, 2040, and 2040 with the CSRP.

2020 and 2025 Emissions

Straight line interpolation was used to estimate emissions for intermediate analysis years.

Table A.30 and Table A.31 show estimated grams of carbon dioxide emitted per passenger mile of travel from passenger locomotives and on-road passenger vehicles; these data are derived from the preceding tables.

Table A.19: Freight Locomotive Emission Factors

Certification		Manufacture		g/bhp-hr			
Tier	Year	CO ₂	ROG	NO _x	CO	PM ₁₀	PM _{2.5}
Pre Tier	Pre 1973	491.20	0.48	13.00	1.28	0.32	0.310
Tier 0	1973-2001	491.20	0.48	8.60	1.28	0.32	0.310
Tier 0r	2008+	491.20	0.30	7.20	1.28	0.20	0.194
Tier 1	2002-2004	491.20	0.47	6.70	1.28	0.32	0.310
Tier 1r	2008+	491.20	0.29	6.70	1.28	0.20	0.194
Tier 2	2005	491.20	0.26	4.95	1.28	0.18	0.175
Tier 2r	2008+	491.20	0.13	4.95	1.28	0.08	0.078
Tier 3	2012-2014	491.20	0.13	4.95	1.28	0.08	0.078
Tier 4	2015+	491.20	0.04	1.00	1.28	0.015	0.015

Certification		Manufacture		g/gal @ 20.8 bhp-hr/gal			
Tier	Year	CO ₂	ROG	NO _x	CO	PM ₁₀	PM _{2.5}
Pre Tier	Pre 1973	10217	9.98	270.40	26.62	6.66	6.448
Tier 0	1973-2001	10217	9.98	178.88	26.62	6.66	6.448
Tier 0r	2008+	10217	6.24	149.76	26.62	4.16	4.035
Tier 1	2002-2004	10217	9.78	139.36	26.62	6.66	6.448
Tier 1r	2008+	10217	6.03	139.36	26.62	4.16	4.035
Tier 2	2005	10217	5.41	102.96	26.62	3.74	3.640
Tier 2r	2008+	10217	2.70	102.96	26.62	1.66	1.622
Tier 3	2012-2014	10217	2.70	102.96	26.62	1.66	1.622
Tier 4	2015+	10217	0.83	20.80	26.62	0.312	0.312

Source: EPA *Emission Factors for Locomotives*, (2009), EPA-420-F-09-025.



Table A.20: Freight Locomotive Fleet Certification Mix

Certification Tier	Without SCAB MOU			With SCAB* MOU (Used for SCAB)			Avg. of SCAB & Non-SCAB Fleet (Used outside of SCAB)		
	2010	2013	2040	2010	2013	2040	2010	2013	2040
Pre-Tier									
Tier 0	47.6%	18.8%		20.5%	10.4%		34.05%	14.60%	
Tier 0r	21.4%	40.7%		9.7%	24.4%		15.55%	32.55%	
Tier 1	8.4%	3.5%		3.7%	2.6%		6.05%	3.05%	
Tier 1r	3.8%	9.0%	1.4%	1.9%	4.8%	1.4%	2.85%	6.90%	1.4%
Tier 2	18.8%	18.5%		64.2%	38.6%		41.50%	28.55%	
Tier 2r		2.5%	5.4%		5.4%	5.4%		3.95%	5.4%
Tier 3		7.0%	9.2%		13.8%	9.2%		10.40%	9.2%
Tier 4			84.0%			84.0%			84.0%

* SCAB = South Coast Air Basin

Source: Nicole Dolney and M. Malchow (2014) Locomotive Inventory Update: Line Haul Activity, CARB tech distribution ref. (Presentation), November 7, 2014, California Air Resources Board.

Table A.21: Weighted Emission Rates for Freight Locomotives

Pollutant	Without SCAB MOU			With SCAB ⁺ MOU (Used for SCAB)			Avg. of SCAB & Non-SCAB Fleet (Used outside of SCAB)		
	2010	2013	2040	2010	2013	2040	2010	2013	2040
CO ₂ (g/gal)	10,217	10,217	10,217	10,217	10,217	10,217	10,217	10,217	10,217
ROG (g/gal)	8.15	6.56	1.18	6.60	5.71	1.18	7.38	6.14	1.18
NO _x (g/gal)	153.55	140.83	34.46	125.10	124.97	34.46	139.33	132.90	34.46
CO (g/gal)	26.62	26.62	26.62	26.62	26.62	26.62	26.62	26.62	26.62
PM ₁₀ (g/gal)	5.48	4.40	0.56	4.50	3.84	0.56	4.99	4.12	0.56
PM _{2.5} (g/gal)	5.31	4.27	0.56	4.37	3.73	0.56	4.84	4.00	0.56

Table A.22: Estimated Annual Gallons of Diesel Consumed by Freight Operations (in millions)

Air Basin	2010	2040	2040 High
Mojave Desert	71.0	101.0	104.1
Mountain Counties	14.4	25.2	25.2
North Central Coast	1.4	2.2	2.2
Northeast Plateau	5.3	7.1	7.1
Sacramento Valley	21.9	31.8	31.8
Salton Sea	4.9	7.3	8.8
San Diego County	1.9	3.0	3.0
San Francisco Bay	7.8	14.3	14.3
San Joaquin Valley	45.0	62.7	62.7
South Central Coast	3.3	3.9	3.9
South Coast	30.5	44.6	58.5

Table A.23: Estimated Freight Locomotive Emissions

Pollutant	Bay Area & N Cal	Greater LA and LOSAN South	LOSAN North and Central Coast	Xpress West and Inland Empire	Cantal Valley	Total
2010 Freight Locomotive Emissions (Tons/Day)						
CO ₂	1,525	997	144	2,343	1,390	6,399
ROG	1.10	0.65	0.10	1.69	1.00	4.55
NO _x	20.79	12.29	1.96	31.95	18.95	85.95
CO	3.97	2.60	0.37	6.11	3.62	16.67
PM ₁₀	0.74	0.44	0.07	1.14	0.68	3.08
PM _{2.5}	0.72	0.43	0.07	1.11	0.66	2.99
2040 (Low Activity) Freight Locomotive Emissions (Tons/Day)						
CO ₂	2,420	1,470	189	3,343	1,935	9,356
ROG	1.75	0.96	0.14	2.41	1.40	6.65
NO _x	33.00	18.12	2.57	45.58	26.38	125.67
CO	6.31	3.83	0.49	8.71	5.04	24.38
PM ₁₀	1.18	0.65	0.09	1.63	0.94	4.50
PM _{2.5}	1.15	0.63	0.09	1.58	0.92	4.37
2040 (High Activity) Freight Locomotive Emissions (Tons/Day)						
CO ₂	2,420	1,896	189	3,483	1,935	9,923
ROG	1.75	1.23	0.14	2.52	1.40	7.03
NO _x	33.00	23.35	2.57	47.50	26.38	132.81
CO	6.31	4.94	0.49	9.08	5.04	25.86
PM ₁₀	1.18	0.84	0.09	1.70	0.94	4.76
PM _{2.5}	1.15	0.81	0.09	1.65	0.92	4.62

Table A.24: 2010 Passenger Locomotive Emissions without Plan (based on CARB 2010 statewide inventory) ¹⁵

	Bay Area & N Cal	Greater LA and LOSSAN South	LOSSAN North and Central Coast	Xpress West and Inland Empire	Central Valley	Total
CO2 (Tons/Day)	283.62	109	8	2	138	541
ROG (Tons/Day)	0.30	0.12	0.01	0.00	0.15	0.58
NOx (Tons/Day)	5.28	2.04	0.16	0.04	2.56	10.08
CO (Tons/Day)	0.46	0.18	0.01	0.00	0.22	0.87
PM10 (Tons/Day)	0.11	0.04	0.00	0.00	0.05	0.21
PM2.5 (Tons/Day)	0.10	0.04	0.00	0.00	0.05	0.20
Passenger miles traveled	2,025,908	781,541	59,433	14,881	982,879	3,864,641

Table A.25: 2040 Passenger Locomotives Emissions without Plan (based on CARB 2035 statewide inventory) ¹⁶

	Bay Area & N Cal	Greater LA and LOSSAN South	LOSSAN North and Central Coast	Xpress West and Inland Empire	Central Valley	Total
CO2 (Tons/Day)	572.15	136	11	3	345	1,068
ROG (Tons/Day)	0.44	0.10	0.01	0.00	0.26	0.82
NOx (Tons/Day)	7.69	1.83	0.15	0.05	4.64	14.35
CO (Tons/Day)	0.67	0.16	0.01	0.00	0.40	1.25

¹⁵ The CSRP emissions analysis had to be completed before January 2017 using data that was available during the fall of 2016. For the most updated passenger locomotive inventory please visit: <https://www.arb.ca.gov/msei/ordiesel.htm>

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	Bay Area & N Cal	Greater LA and LOSSAN South	LOSSAN North and Central Coast	Xpress West and Inland Empire	Central Valley	Total
PM10 (Tons/Day)	0.16	0.04	0.00	0.00	0.10	0.30
PM2.5 (Tons/Day)	0.15	0.04	0.00	0.00	0.09	0.28
Passenger miles traveled	4,086,958	973,808	80,275	24,320	2,465,647	7,631,007

Table A.26: 2040 Passenger Locomotives Emissions with Plan (based on PMT scaling of 2040 no plan data and no electrification)

	Bay Area & N Cal	Greater LA and LOSSAN South	LOSSAN North and Central Coast	Xpress West and Inland Empire	Central Valley	Total
CO2 (Tons/Day)	2,968	3,777	104	1,575	5,578	19,849
ROG (Tons/Day)	2.28	2.90	0.08	1.21	4.28	14.34
NOx (Tons/Day)	39.87	50.74	1.40	21.15	74.93	266.62
CO (Tons/Day)	3.47	4.42	0.12	1.84	6.53	21.97
PM10 (Tons/Day)	0.83	1.06	0.03	0.44	1.57	4.97
PM2.5 (Tons/Day)	0.78	0.99	0.03	0.41	1.46	4.87
Passenger miles traveled	21,204,118	26,982,374	742,253	11,246,981	39,845,493	100,021,220



Table A.27: 2040 Passenger Miles of Travel by Air Basin

Air Basin	2010 Baseline	2040 No-Build	2040 Demonstration (Total)	2040 Demonstration (Electric)	2040 Demonstration (Diesel)
North Coast			62,368		62,368
Northeast Plateau					
Sacramento Valley	277,149	533,131	4,537,482	4,132,342	405,140
Mountain Counties	1,226	1,838	38,644		38,644
Lake County					
Lake Tahoe					
Great Basin Valleys					
San Joaquin Valley	982,879	2,465,647	39,845,493	38,121,231	1,724,263
North Central Coast	8,422	15,900	520,998		520,998
Mojave Desert	14,375	24,006	10,784,900	10,765,710	19,190
South Central Coast	51,011	64,375	221,255		221,255
Salton Sea	506	313	462,081		462,081
San Francisco Bay	1,747,533	3,551,989	16,565,624	13,915,864	2,649,761
South Coast	721,824	896,862	22,674,116	21,864,773	809,343
San Diego County	59,717	76,946	4,308,258	4,239,927	68,331
<i>Total</i>	<i>3,864,641</i>	<i>7,631,007</i>	<i>100,021,220</i>	<i>93,039,845</i>	<i>6,981,375</i>
Aggregated to Planning Areas					
Bay Area & N Cal	2,025,908	4,086,958	21,204,118	18,048,205	3,155,913



Air Basin	2010 Baseline	2040 No-Build	2040 Demonstration (Total)	2040 Demonstration (Electric)	2040 Demonstration (Diesel)
Greater LA and LOSAN South	781,541	973,808	26,982,374	26,104,700	877,674
LOSAN North and Central Coast	59,433	80,275	742,253		742,253
Xpress West and Inland Empire	14,881	24,320	11,246,981	10,765,710	481,271
Central Valley	982,879	2,465,647	39,845,493	38,121,231	1,724,263

Bay Area and N. Cal = North Coast, Northeast Plateau, Sacramento Valley, Mountain Counties, Lake County, Lake Tahoe, San Francisco Bay Area

Greater LA and LOSAN South = South Coast, San Diego County

LOSAN North and Central Coast = North Central Coast, South Central Coast

Xpress West and Inland Empire = Great Basin Valleys, Mojave Desert, Salton Sea

Central Valley = San Joaquin Valley



Table A.28: 2040 Passenger Locomotives Emissions with Plan (based on PMT scaling of 2040 no plan data, with electrification)

	Bay Area & N Cal	Greater LA and LOSAN South	LOSAN North and Central Coast	Xpress West and Inland Empire	Central Valley	Total
CO2 (Tons/Day)	441.81	123	104	67	241	977
ROG (Tons/Day)	0.34	0.09	0.08	0.05	0.19	0.75
NOx (Tons/Day)	5.93	1.65	1.40	0.91	3.24	13.13
CO (Tons/Day)	0.52	0.14	0.12	0.08	0.28	1.14
PM10 (Tons/Day)	0.12	0.03	0.03	0.02	0.07	0.27
PM2.5 (Tons/Day)	0.12	0.03	0.03	0.02	0.06	0.26
Diesel Passenger miles traveled	3,155,913	877,674	742,253	481,271	1,724,263	6,981,374

Table A.29: Emissions Based on EMFAC 2014 Emissions Inventory Scaled by Changes in Passenger Vehicle (LDA, LDT1, LDT2, MDV, MC) VMT in Each Air Basin

	Bay Area & N Cal	Greater LA and LOSAN South	LOSAN North and Central Coast	Xpress West and Inland Empire	Central Valley	Total
2010 Baseline (Tons/Day)						
CO2 (Tons/Day)	140,463	238,338	27,627	34,394	62,532	503,353
ROG (Tons/Day)	149.0	207.7	30.8	34.0	59.5	480.98
NOx (Tons/Day)	352.1	469.3	67.6	116.1	225.1	1,230.13
CO (Tons/Day)	1,201.9	1,793.2	256.3	279.1	439.4	3,969.91
PM10 (Tons/Day)	22.5	34.6	4.3	6.5	12.0	79.99
PM2.5 (Tons/Day)	13.3	19.5	2.5	4.4	8.3	47.90
VMT	253,744,662	425,988,835	50,814,352	55,250,354	93,058,417	878,856,620
2040 No Plan (Tons/Day)						
CO2 (Tons/Day)	106,453	185,041	19,051	32,252	62,980	405,777
ROG (Tons/Day)	30.3	50.6	5.7	8.3	12.8	107.73
NOx (Tons/Day)	57.7	87.5	8.9	17.4	44.4	215.93
CO (Tons/Day)	199.2	357.2	38.1	59.9	84.7	739.10
PM10 (Tons/Day)	18.9	32.0	3.6	5.0	9.1	68.52
PM2.5 (Tons/Day)	7.7	13.1	1.5	2.0	3.7	28.06
VMT	327,697,848	554,658,688	62,930,263	81,789,654	149,282,777	1,176,359,230
2040 with Plan (Tons/Day)						
CO2 (Tons/Day)	104,429	179,830	18,259	31,540	59,032	393,090
ROG (Tons/Day)	29	49	5	8	11	102.99
NOx (Tons/Day)	57	87	9	17	44	213.80
CO (Tons/Day)	194	344	36	58	75	707.27
PM10 (Tons/Day)	18	31	3	5	8	65.82
PM2.5 (Tons/Day)	8	13	1	2	3	26.96
VMT	318,824,265	533,299,372	59,560,214	78,670,294	132,319,796	1,122,673,942



	Bay Area & N Cal	Greater LA and LOSAN South	LOSAN North and Central Coast	Xpress West and Inland Empire	Central Valley	Total
Plan Emission Reduction Benefit (Tons/Day)						
CO2 (Tons/Day)	2,024	5,211	792	712	3,948	12,687
ROG (Tons/Day)	0.77	1.93	0.31	0.31	1.42	5
NOx (Tons/Day)	0.34	0.85	0.16	0.16	0.62	2
CO (Tons/Day)	5.08	13.10	2.11	2.14	9.40	32
PM10 (Tons/Day)	0.45	1.07	0.17	0.16	0.85	3
PM2.5 (Tons/Day)	0.18	0.44	0.07	0.06	0.35	1
VMT	8,873,582	21,359,317	3,370,049	3,119,360	16,962,981	53,685,288

Table A.30: Passenger Locomotive Emissions per Passenger Mile Traveled (g/PMT)

	2010 baseline (g/PMT)	2040 no plan (g/PMT)	2040 demonstration (g/PMT)
CO2	127.00	127.00	8.86
ROG	0.14	0.10	0.01
NOx	2.37	1.71	0.12
CO	0.20	0.15	0.01
Exhaust PM10	0.05	0.04	0.00
Exhaust PM2.5	0.05	0.03	0.00

Table A.31: Passenger Vehicle Emissions per Passenger Mile Traveled (g/PMT)

	2010	2040
Trip length	5.50	4.93
CO2	363	179
ROG	0.38	0.07
NOx	0.34	0.03
CO	3.28	0.46
PM10	0.04	0.04
PM2.5	0.02	0.02

Based on assumed vehicle occupancy of 1.2 passengers per vehicle