Air Resources Regulatory Experts

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TECHNICAL REPORT: ENVIRONMENTAL BENEFITS OF INCREASED TRUCK WEIGHTS FOR NATURAL GAS TRUCKS USED IN THE CALIFORNIA SOLID WASTE INDUSTRY

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Executive Summary

CleanFleets.net is pleased to present this technical report to inform clean transportation stakeholders about the future environmental benefits that derive from aligning alternative fueled truck weights in California with recent federal law.[1] For more than a decade, municipal and contracted solid waste and recycling service providers have made tremendous strides in clean transportation, operating in excess of 4,800 alternative fueled vehicles (AFVs) running on compressed natural gas (CNG) or liquefied natural gas (LNG) with three waste facilities producing renewable natural gas (RNG).

The environmental benefit of the existing AFV fleet is eroded because AFVs are heavier than diesel vehicles and the loss of cargo payload negatively impacts AFV owners currently. Congress and the President acted in a bipartisan manner late last year to rectify this situation by fixing this AFV "weight penalty" by including a provision in the Fixing America's Surface Transportation (FAST) Act that explicitly allows, "A vehicle, if operated by an engine fueled primarily by natural gas, [to] exceed any vehicle weight limit (up to a maximum gross vehicle weight of 82,000 pounds)…" States may now choose to align with the new federal law.

There is a compelling environmental benefit to California should the legislature choose to align with the AFV FAST Act provision noted. The greenhouse gas (GHG) emissions reductions from the existing solid waste AFV fleet alone would be equal to removing over 120,000 passenger cars from California roads over the next ten years. Relating to smog forming chemicals like oxides of nitrogen (N0x), the emissions benefit statewide is 110 tons annually, 82 of which are in southern California. Using annual mileage and fuel consumption estimates from multiple sources, this technical report compares the greenhouse gas (GHG) emissions and criteria pollutant (CP) emissions impact of five scenarios relating to solid waste trucks. The first two scenarios isolate how the AFV weight penalty affects GHG emissions (additional scenarios model transition to AFVs fleets). Scenario 1 represents the status quo (i.e. the existing fleet with no future change) and represents current, or "baseline", emissions. Scenario 2 increases the AFV payload to align with federal law. The summary table for the GHG benefits of this comparison appears below and is described in this report.

GHG Emissions Reduction Over Ten-Year Project Life		
	Scenario 1	**Scenario 2**
Total Emissions (MTCO_2e)	25,487,044	24,914,081
GHG Reduction (MTCO_2e)	0	-572,964
Equivalency in Passenger Cars Removed from CA Roads*	0	-120,624

[1] HR22 (FAST Act) became law on December 4, 2015 (https://www.congress.gov/bill/114th-congress/house-bill/22/text)

By enabling AFVs to carry greater payloads, existing AFVs can perform more collection and transportation, thereby offsetting diesel use.

The bottom line is that there are significant environmental benefits to California when it aligns with federal law relating to AFV truck weights. Those benefits are even more pronounced when more waste vehicles convert to alternative fuel over time but near-term California legislative action is needed to achieve the benefits detailed in this report.

Introduction

California's solid waste and recycling vehicles support the basic public health and resource recovery needs of 39 million Californians. State law mandates that residents and businesses have weekly collection service[2] and approximately 20,000 trucks meet that need statewide.

Beginning in the late 1990's the focus on air quality improvement led to the vehicles used in solid waste and recycling services becoming the focus of regulatory actions to reduce diesel emissions from collection trucks. Both the California Air Resources Board (CARB) and the South Coast Air Quality Management District (AQMD) asked the solid waste and recycling collectors to take a leadership role in cleaning up their collection trucks. The CARB Solid Waste Collection Vehicle Regulation (2003) cited environmental justice as a factor for singling out these vehicles for early action to reduce emissions.[3] Environmental justice and improving air quality in disadvantaged communities remains a priority for solid waste and recycling hauling operations, including public and private fleet operators.

To demonstrate their commitment as an early partner to implement the clean air goals, CARB reported, "[w]aste haulers also went beyond ARB projections with regard to using Level 3 retrofit devices (particulate traps which reduce diesel PM by at least 85%). Back in 2003, staff estimated that 12% of California's waste trucks would use Level 3 retrofit devices in 2004. In reality, the use of Level 3 devices was 22%."[4] Also, within the South Coast AQMD jurisdiction, collectors have successfully deployed over 3,500 CNG and LNG vehicles due to a combination of contract length and public investment in infrastructure to support the cleaner vehicles.[5]

[2] California Code of Regulations, Title 14, Section 17331 states, ""[t]o prevent propagation, harborage, or attraction of flies, rodents or other vectors and the creation of nuisances, refuse, except for inert materials, shall not be allowed to remain on the premises for more than seven days."

[3] "This control measure is in direct response to the environmental justice policy to reduce health risks from toxic air pollutants in all communities, especially low income and minority communities. This control measure, when adopted, will provide immediate air-quality benefits by reducing diesel PM emissions from collection vehicles, which operate in neighborhoods." http://www.arb.ca.gov/regact/dieselswcv/isor.pdf

[4] http://www.arb.ca.gov/msprog/swcv/2004swcvreport.pdf at p. 1

[5] http://www.aqmd.gov/docs/default-source/Agendas/aqmp/white-paper-working-groups/wp-bizcase-final.pdf?sfvrsn=2 , 2016 Air Quality Management Program White Paper, "Lessons Learned" at p. 6

The transition to AFVs has come with significant operational challenges due to the new technology weight. There is a maximum weight limit established for commercial vehicles operating on California roads.[6] Based on an industry survey, at present AFV collection vehicles are limited to carrying 11 tons of waste and recyclable material. Comparable diesel vehicles are capable of carrying a maximum of 12 tons. The reduced payload of the AFV collection vehicles is related to the increased weight of the AFV equipment (primarily the tanks and fueling system). Similarly, AFV transfer vehicles are permitted to carry 23 tons of material, and diesel transfer vehicles may carry up to 24 tons.

The following sections model five discrete scenarios relating to truck weights and AFVs:

	Existing Payload	**Equal Payload***
Current AFV Fleet Inventory	Scenario 1 (Status Quo)	Scenario 2
Complete Diesel Fleet Replacement with CNG	Scenario 3	Scenario 4
Complete Diesel Fleet Replacement with RNG	Scenario 5	

*Achievable if CA adopts federal FAST weight increase for AFVs across all weight classes

Table 1. Scenarios Modeled

Implementation of Environmental Policies

Truck weights have a bearing on the current climate change policy discussion. As Governor Brown and the California Legislature provide additional direction to refine the state's climate change laws, the solid waste and recycling industry is a key stakeholder capable of advancing several climate change programs. A summary of major legislation and regulatory efforts and the connection to AFV truck weights is summarized on the following page.

[6] Vehicle Code https://www.chp.ca.gov/ProtectiveServicesDivisionSite/Documents/2015%20Vehicle%20Code.pdf

Figure1. Climate Change Legislation & Governor Brown's Five Pillars

The following four policies are advanced by aligning AFV truck weights in California with federal law:

- Low Carbon Fuel Standard: Better fuel economy from existing AFVs and more incentive to consume low carbon fuels
- Short Lived Climate Pollutants: Black carbon from diesel particulate is eliminated when AFVs are deployed
- Petroleum Demand Reduction: Truck weights aligned saves over 41 million gallons of diesel and replacement of the remaining diesel solid waste saves up to 1.4 billion gallons of diesel over ten years as summarized below.
- Sustainable Freight Action Plan: The May 3, 2016 release of the draft plan emphasizes the need for freight efficiency combined with zero and near-zero

technologies. Scenarios 2 to 5 and truck weights can be critical pieces to implementing the vision of the Plan.[7]

Annual Fuel Reduction-Statewide			
	Scenario 1	Scenario 2	Scenarios 3-5
Diesel Gallons/Year	142,772,229	138,600,042	0
Diesel Gallons Reduced/yr	0	4,172,188	142,772,229
% Eliminated/Year	0%	3%	100%
10 Year Diesel Gallons Eliminated	0	41,721,875	1,427,722,290

Table 2. Diesel Gallons Eliminated

Solid Waste Vehicles

There has been no comprehensive fleet inventory conducted by fuel type for the past decade. Using the sources cited, we estimate that in 2016 there are 12,896 diesel collection vehicles operating within the state. Multiple data sources suggest there are 1,420 diesel transfer vehicles in operation. Support vehicles such as water trucks, flat bed and container delivery trucks are estimated to be 10% of the number of collection vehicles, or 1,298 vehicles. To inform decision makers in Southern California, there is a breakdown of vehicles operating in the South Coast AQMD jurisdiction and San Diego County.

There are three common categories of on-road vehicles that enable solid waste and recycling operations: a) collection vehicles, b) transfer trucks and c) support vehicles. A summary of their use is as follows:

a) Collection vehicle: The state regulation defines this vehicle type as “an on-road heavy-duty vehicle with a manufacturer’s gross vehicle weight rating of greater than 14,000 pounds used for the purpose of collecting residential and commercial solid waste for a fee, including roll off vehicles.” These vehicle types are commonly divided into front loaders, rear loaders, side loaders and roll offs.
b) Transfer truck: A transfer truck is one that moves solid waste between transfer stations and the landfill, or between facilities. Typically, this is a three axle tractor commonly found in goods movement and the trailer is designed to discharge waste and/or recyclables using a hydraulic “walking floor.” These trucks may also hauls sea containers to port facilities for export to reprocessors.
c) Support vehicle: Diesel trucks of various configurations support waste collection and recycling. From flatbed trucks used for container delivery or bulky waste to service/utility trucks used to maintain trucks or containers. Water trucks and street sweepers are commonly used at transfer and recycling facilities to mitigate dust emissions.

[7] http://www.casustainablefreight.org/

In 2005, statewide estimates place the number of diesel collection vehicles in use at 12,975.[8] Given that approximately 475 of these vehicles were AFV, 12,500 diesel collection vehicles were assumed to be in operation that year. California's population, as calculated by the California Department of Finance, increased 3% since then. Given proportional growth, in 2016 there are approximately 12,896 diesel collection vehicles operating within the state. Similar estimates suggest there are 1,420 diesel transfer vehicles in operation. Support vehicles are estimated to be 10% of the number of collection vehicles, or 1,290 vehicles.

Figure 2. Diesel Waste Vehicle Inventory Estimate (2016)

Weight Limits for Solid Waste Vehicles

There is a maximum weight limit established for commercial vehicles operating on California roads. At present, AFV collection vehicles are limited to carrying 11 tons of waste and recyclable material. Comparable diesel vehicles are capable of carrying a maximum of 12 tons. The reduced payload of the AFV collection vehicles is related to

[8] "Data from the ARB survey of fleets in the South Coast combined with additional data from the SCAQMD's survey in 2004 show that there are approximately 5,000 collection vehicles in the South Coast Air District. This is about 39 percent of the estimated 2005 statewide population of 12,975 vehicles."

the increased weight of the AFV equipment (primarily the tanks and fueling system). Similarly, AFV transfer vehicles are permitted to carry 23 tons of material, and diesel transfer vehicles may carry up to 24Tons. These limitations suggest that AFV vehicles may not currently replace diesel vehicles at a 1:1 ratio. Rather, 12 AFV collection vehicles are capable of replacing 11 diesel collection vehicles on average; 24 AFV transfer vehicles may replace 23 diesel transfer vehicles. As part of this analysis, diesel fleets are substitutable only by the equivalent amount of AFV vehicles to carry the equivalent payload, i.e (12/11 AFV to Diesel SWCV and 24/23 AFV to Diesel transfer vehicles). An alternative scenario is also modeled where AFV vehicles are permitted to hold the same payload as diesel vehicles. These two variations are modeled under status quo fleet profiles and complete AFV replacement profiles to examine four discrete scenarios. A fifth scenario examines existing weight limits with all vehicles replaced with renewable natural gas vehicles.

Fuel Types & Carbon Intensity

A summary of the three fuels modeled in this section and their respective CARB-adopted carbon intensity (CI) values is below. The Low Carbon Fuel Standard assigns a CI value to each fuel based on its calculated generation of GHG from exploration/extraction through refining and dispensing to a motor vehicle.

Conventional diesel: CARB required ultra low sulfur to be in place in 2006. The lower sulfur content was required to facilitate the operation of diesel particulate filters, which were required on solid waste collection vehicles as early as 2004. The CI value is 102.

Compressed natural gas (CNG): This fuel is transmitted via utility pipelines and meets specific quality standards to be used as a motor vehicle fuel. The CI value is 78.4.

Renewable natural gas (RNG): The production of renewable natural gas can be a carbon negative fuel. One chemical process is the dry fermentation anaerobic digestion facility with a purification system and vehicle fueling system on a very small footprint within an existing recycling or transfer facility.[9] The CI value is -22.9 which indicates it is the only “carbon negative” transportation fuel in the market today.

The spectrum of carbon intensity (CI) values as adopted by CARB in September 2015 are illustrated in the following figure.

[9] An extensive discussion of RNG appears in “BIOMETHANE TRANSPORTATION FUEL POWERING THE SOLID WASTE INDUSTRY: Community-Scale Distributed Fuel Production Facilities,” Calif Compost Coalition, January 2016 and the the just released “Game Changer: Next Generation Heavy-Duty Natural Gas Engines Fueled by Renewable Natural Gas,” Gladstein Neandross Associates, April 2016

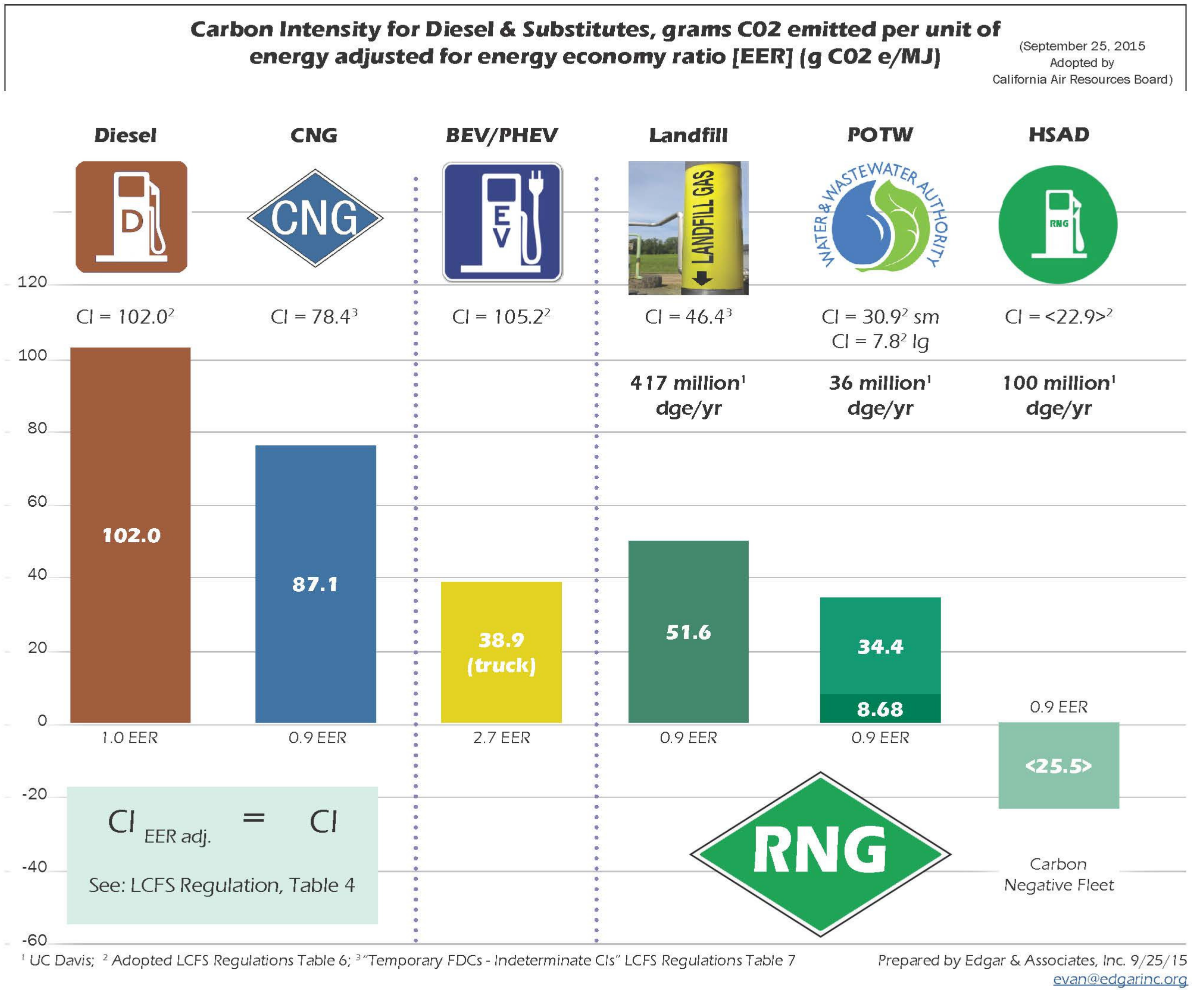


Figure 3. Carbon Intensity for Transportation Fuels (CARB, 2015)

Greenhouse gas emissions and pollutants emissions comparison

The five scenarios model emissions from California's remaining diesel vehicles in terms of greenhouse gases (GHG) and criteria pollutants. Each scenario produces increasingly lower emissions rates for greenhouse gases. Scenario 1 represents the status quo (i.e. the existing fleet with no future change) and represents current, or "baseline", emissions. Scenarios 4 and 5 illustrate the potential future emissions reductions when the waste industry and state and local governments collaborate to make climate change investments in the near term. As part of this collaboration, the adoption of portions of the federal FAST Act to increase in the payload of AFV trucks allows the existing AFV vehicles equal treatment when compared to diesel vehicles. This is modeled as a direct reduction in diesel vehicles whose work is now being performed by the expanded function of the AFV vehicles. In Scenario 3, all diesel vehicles are replaced by AFV vehicles, but the existing legal payload limitations are kept (i.e. CA not adopting federal FAST provisions). In Scenarios 4 and 5, the greatest emissions reductions are achieved by having all AFV vehicles replaced with CNG and RNG produced through high solids anaerobic digestion (HSAD) and the payload increased to treat AFVs on an equal weight as diesel vehicles.

	Existing Payload	Equal Payload*
Current AFV Fleet Inventory	Scenario 1 (Status Quo)	Scenario 2
Complete Diesel Fleet Replacement with CNG	Scenario 3	Scenario 4
Complete Diesel Fleet Replacement with RNG	Scenario 5	

*Achievable if CA adopts federal FAST weight increase for AFVs across all weight classes

Fleet Size-Statewide: Under these five scenarios using the replacement ratios described above, waste industry fleet profiles vary with regard to their AFV/diesel makeup. This in turn affects the greenhouse gas and criteria pollutant annual emissions of this transportation sector. The fleet sizes, as calculated for this study are summarized in the tables below.

Fleet Size-Statewide					
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Diesel Collection Vehicles	12,896	12,496	0	0	0
CNG/RNG Collection Vehicles	4,800	4,800	18,868	17,296	17,296
Diesel Transfer Vehicles	1,420	1,417	0	0	0
CNG/RNG Transfer Vehicles	75	75	1,557	1,492	1,492
Diesel Support Vehicles	1,290	1,290	0	0	0
CNG/RNG Support Vehicles	0	0	1,290	1,290	1,290
TOTAL:	20,481	20,077	21,715	20,077	20,078

Fleet Size- Southern California: For each of the five scenarios this report breaks out the Southern California emissions (counties of Los Angeles, Orange, San Bernardino, Riverside and San Diego).

Fleet Size-Southern California					
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Diesel Collection Vehicles	5,029	4,732	0	0	0
CNG/RNG Collection Vehicles	3,570	3,570	9,057	8,599	9,057
Diesel Transfer Vehicles	620	618	0	0	0
CNG/RNG Transfer Vehicles	50	50	697	670	697
Diesel Support Vehicles	516	516	0	0	0
CNG/RNG Support Vehicles	0	0	516	516	516
TOTAL:	9,785	9,486	10,269	9,785	10,269

Greenhouse Gases-Statewide: Each scenario produces increasingly lower emissions rates for greenhouse gases. The greenhouse gas emissions of each scenario is summarized in the table below.

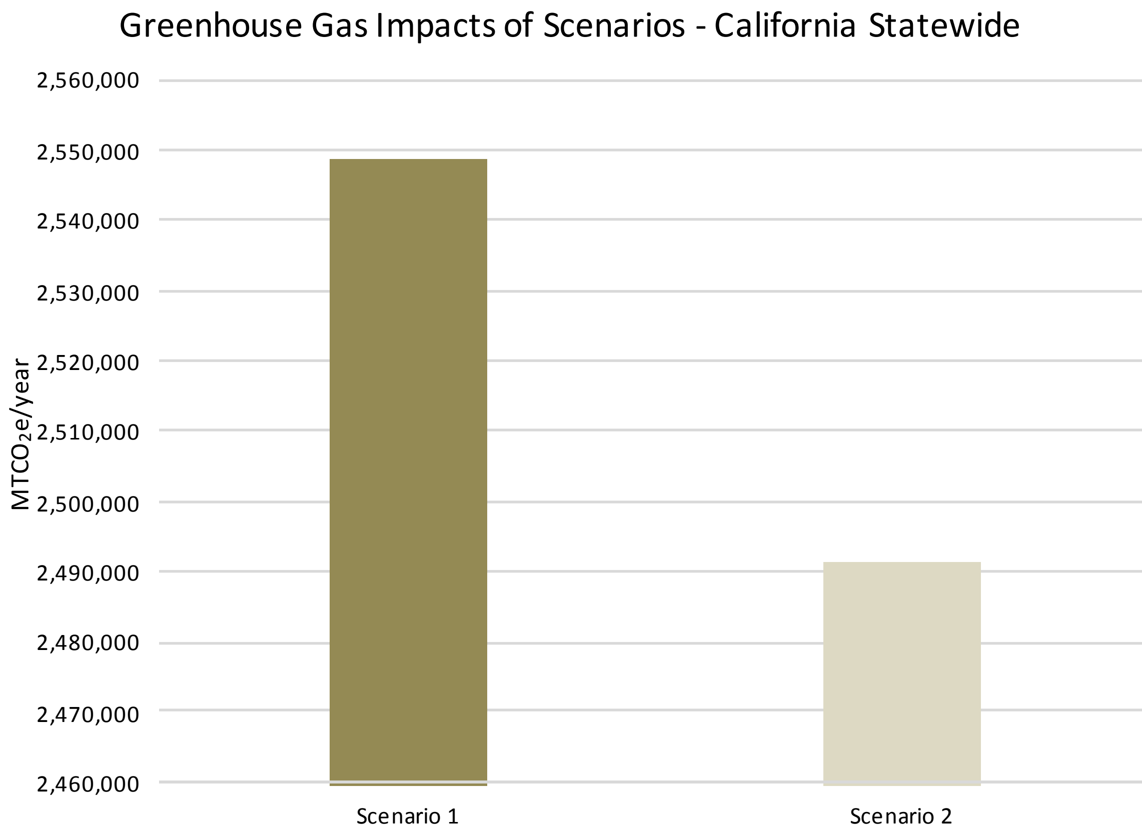
Fleet GHG Emissions-Statewide					
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Diesel Collection	1,841,830	1,784,701	0	0	0
CNG/RNG Collection	584,597	584,597	2,297,990	2,106,491	-672,532
Diesel Transfer Vehicles	76,053	75,886	0	0	0
CNG/RNG Transfer	3,425	3,425	71,099	68,136	-20,808
Diesel Support	42,799	42,799	0	0	0
CNG/RNG Support	0	0	36,497	36,497	-10,681
TOTAL/YR:	2,548,704	2,491,408	2,405,585	2,211,124	-704,021
Comparison to Passenger Car GHG Emissions-Over Ten-Year Project Life					
Total Emissions	25,487,044	24,914,081	24,055,852	22,111,236	-7,040,213
GHG Reduction (MTCO2e)	0	-572,964	-1,431,192	-3,375,808	-32,527,257
Equivalency in Passenger Cars Removed from California Roads*	0	-120,624	-301,304	-710,696	-6,847,844

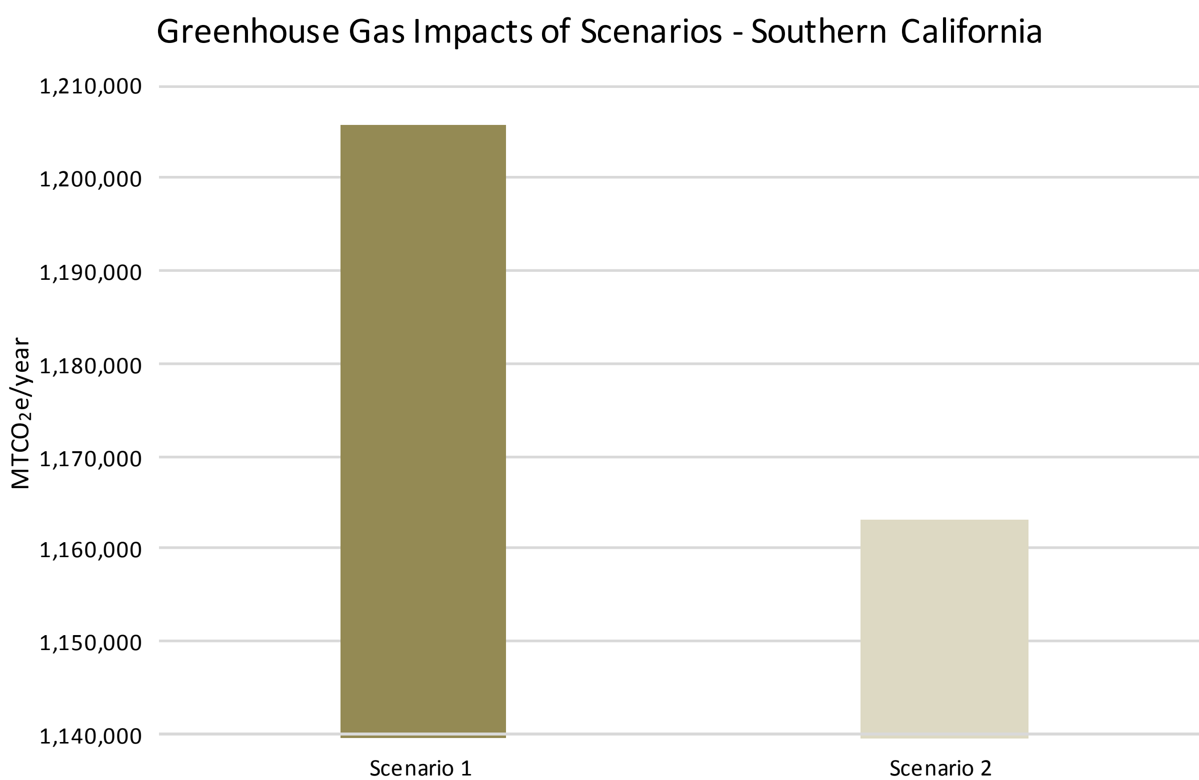
Fleet GHG Emissions-Southern California					
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Diesel Collection Vehicles	718,314	675,824	0	0	0
CNG/RNG Collection Vehicles	434,794	434,794	1,103,017	1,047,332	-322,810
Diesel Transfer Vehicles	33,206	33,095	0	0	0
CNG/RNG Transfer Vehicles	2,284	2,284	31,831	30,600	-9,316
Diesel Support Vehicles	17,120	17,120	0	0	0
CNG/RNG Support Vehicles	0	0	14,599	14,599	-4,272
TOTAL:	1,205,717	1,163,116	1,149,447	1,092,531	-336,398
Over Ten-Year Project Life					
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Total Emissions	12,057,172	11,631,160	11,494,471	10,925,307	-3,363,985
GHG Reduction (MTCO2e)	0	-426,013	-562,702	-1,131,866	-15,421,157
Equivalency in Passenger Cars Removed from SoCal Roads*	0	-89,687	-118,464	-238,288	-3,246,559

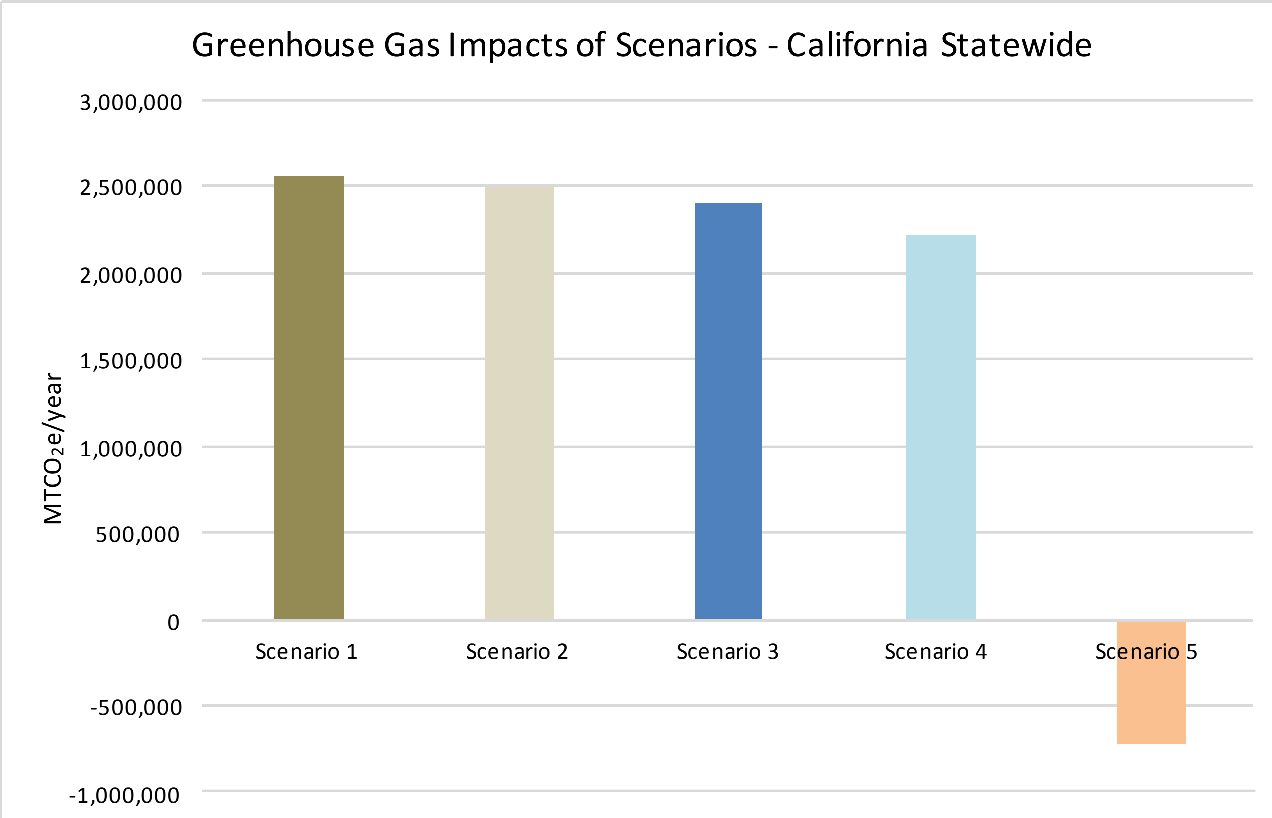
*https://www.epa.gov/energy/ghg-equivalencies-calculator-calculations-and-references#vehicles

The benefit of near-term action to fix the AFV weight penalty (i.e. Scenario 1 to Scenario 2) is equivalent to removing 120,624 passenger cars from state roads of which 89,687 are in southern California.

Views of all scenarios are presented below.







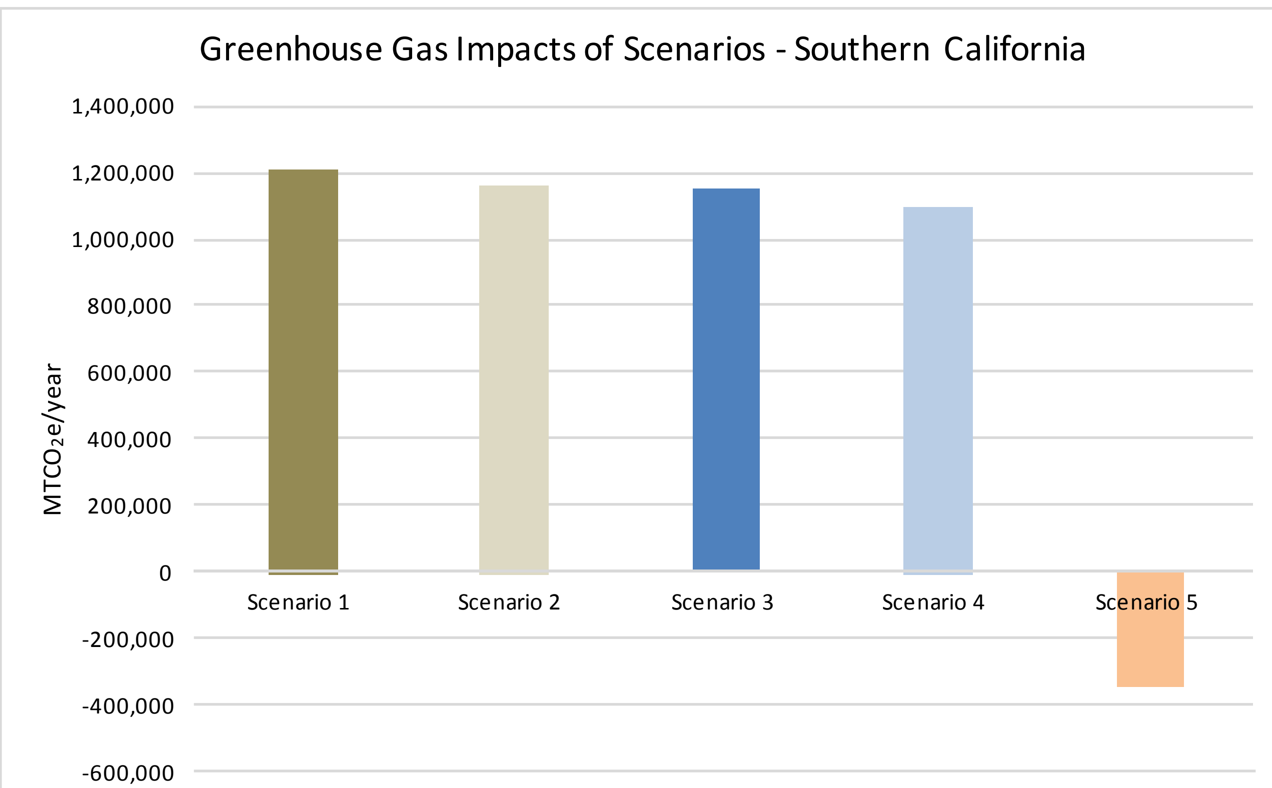


Figure 4. GHG Emissions Summary – All Scenarios

Criteria Pollutants Including Oxides of Nitrogen (N0x)-Statewide: Each scenario produces increasingly lower emissions rates for oxides of nitrogen, which is a major smog forming pollutant. The N0x emissions of each scenario is summarized in the tables below.

CALIFORNIA STATEWIDE

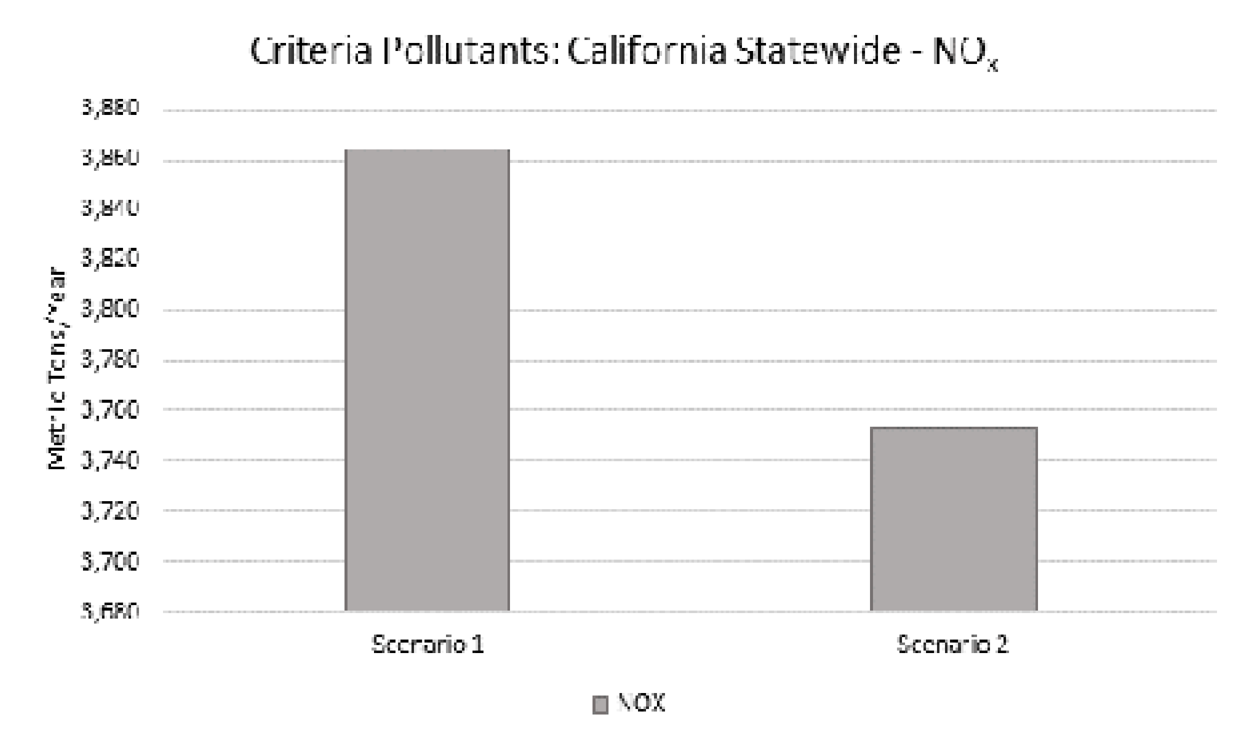
Scenario 1: Status Quo

	Vehicles	GHG	ROG	C_O	NO_X	PM_{10}	PM_{25}
Diesel SWCV	12,896	1,841,830	63	1,720	3,557	4	4
CNG SWCV	4,800	584,597	0	1.7	0.022464	0	
Diesel Transfer	1,420	76,053	0.33	212.66	226.83	2.346	0.445734
CNG Transfer	75	3,425	0.0101749	0.0395261	0.0013163	0.000043875	
Diesel Support	1,290	42,799	4.1925801	14.457254	80.681731	2.642896	2.528566
CNG Support	0	0	0	0	0	0	
TOTAL	20,481	2,548,704	67	1,949	3,864	9	7

Scenario 2: Equal Payload for AFVs

	Vehicles	GHG	ROG	C_o	NO_x	PM_{10}	PM_{25}
Diesel SWCV	12,496	1,784,701	60.885477	1,667	3,446	4	4
CNG SWCV	4,800	584,597	0	1.7	0.022464	0	
Diesel Transfer	1,417	75,886	0.33	212.19	226.33	2.340	0.444753
CNG Transfer	75	3,425	0.0101749	0.0395261	0.0013163	0.000043875	
Diesel Support	1,290	42,799	4.1925801	14.457254	80.681731	2.642896	2.528566
CNG Support	0	0	0	0	0	0	
TOTAL	20,077	2,491,408	65	1,895	3,753	9	7

The N0x emissions benefit of Scenario 2 statewide is 110 tons annually, 82 of which are in southern California. A second view of that appears in the figure below.



Criteria Pollutants Including Oxides of Nitrogen (N0x)-Southern California: Each scenario produces increasingly lower emissions rates for oxides of nitrogen, which is a major smog forming pollutant. For the South Coast Air Quality Management District portion of Southern California, the current 2016 Air Quality Management Program process paints a bleak picture for compliance with federal Clean Air Act requirements:

> *"Preliminary 2016 AQMP analysis indicates that this air basin will require approximately a 65 percent further reduction in nitrogen oxide (NOx) emissions – above and beyond all currently adopted measures – to meet the 8-hour ozone standards."*[10]

The South Coast AQMD also observes,

> *"The majority of NOx emission reductions must come from mobile sources, which are generally divided into two main categories: on-road mobile sources, which typically include automobiles, trucks, buses, and other vehicles that operate on public roadways; and off-road mobile sources which include aircraft, ships, trains, and construction equipment that operate off public roadways."*[11]

The N0x emissions of each scenario is summarized in the tables below.

10 http://www.aqmd.gov/docs/default-source/Agendas/aqmp/white-paper-working-groups/wp-blueprint-final.pdf?sfvrsn=2

11 Ibid

Scenario 1: Status Quo							
	Vehicles	GHG	ROG	C_O	NO_X	PM_{10}	PM_{25}
Diesel SWCV	5,029	718,314	0	671	1,387	2	2
CNG SWCV	3,570	434,794	0	1.3	0.016708	0	
Diesel Transfer	620	33,206	0.15	92.85	99.04	1.024	0.194616
CNG Transfer	50	2,284	0.006783	0.026351	0.000878	0.00002925	
Diesel Support	516	17,120	1.677032	5.782902	32.27269	1.057158	1.011426
CNG Support	0	0	0	0	0	0	
TOTAL	9,785	1,205,717	2	771	1,518	4	3

Scenario 2: Equal Payload for AFVs							
	Vehicles	GHG	ROG	C_o	NO_x	PM_{10}	PM_{25}
Diesel SWCV	4,732	675,824	23.05589	631	1,305	2	1
CNG SWCV	3,570	434,794	0	1.3	0.016708	0	
Diesel Transfer	618	33,095	0.14	92.54	98.71	1.021	0.193962
CNG Transfer	50	2,284	0.006783	0.026351	0.000878	0.00002925	
Diesel Support	516	17,120	1.677032	5.782902	32.27269	1.057158	1.011426
CNG Support	0	0	0	0	0	0	
TOTAL	9,486	1,163,116	25	731	1,436	4	3

The N0x emissions benefit of Scenario 2 statewide is 82 tons annually in southern Califomia. A second view of that appears in the figure below.

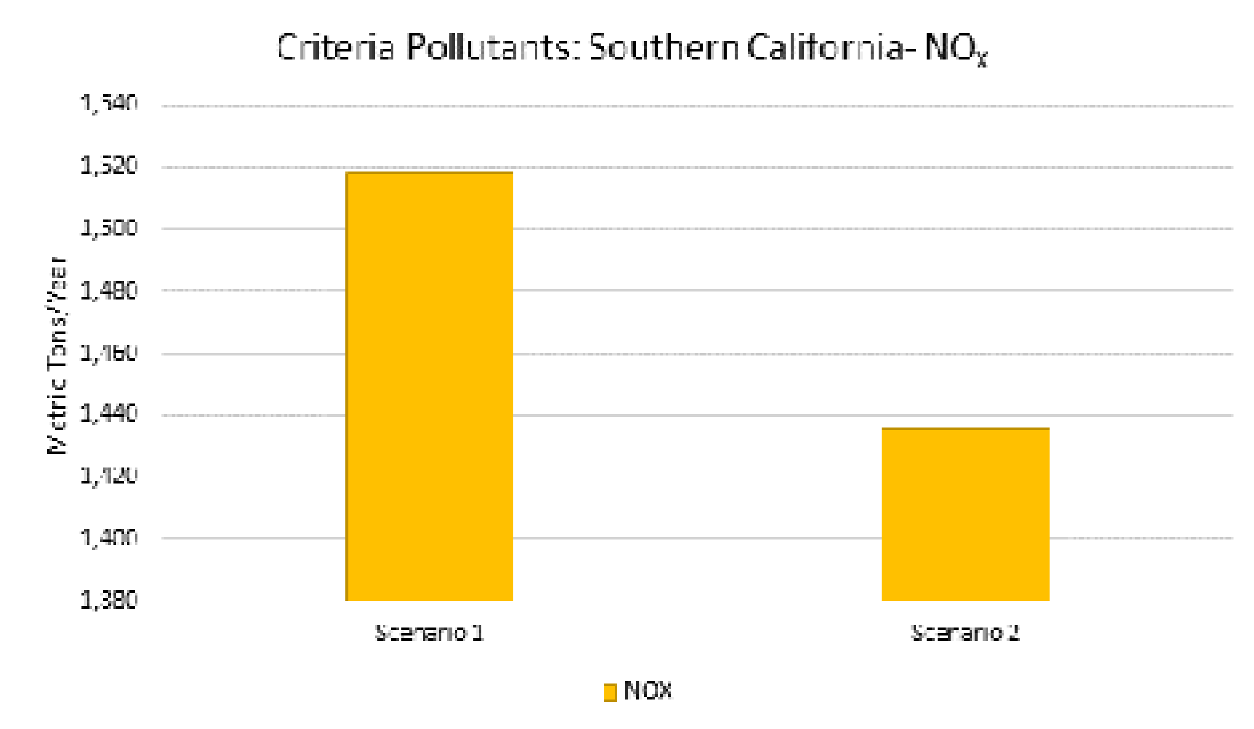


Figure 5. N0x Emissions Summary – Southern California

Emissions Calculations Methodology

Average mileage travelled annually multiplied by the number of each type of vehicles produces a vehicle miles travelled (VMT) estimate for each vehicle group. This estimate is then used to calculate fuel usage, in gallons, and ultimately GHG emissions in metric tons of carbon dioxide equivalent (MTCO2e). The estimates rely on conversion factors provided by the California Air Resources Board (CARB). CARB also provides an emissions factors model (EMFAC) which converts this mileage information into an approximation of criteria pollutant (CP) emissions, given parameters such as speed. As EMFAC has not yet been expanded to include CNG, the CARB executive order for new on-road heavy duty engines is used.

In summary, calculations of both types of emissions are:

Diesel Emissions Estimation

 # Vehicles x Avg Annual Fuel Consumption x Emissions Factor = GHG Emissions

 # Vehicles x Avg Annual Mileage x Emissions Factors$_{\text{(type, speed, model year, etc.)}}$ = CP Emissions

CNG/RNG Emissions Estimation

 # Vehicles x Avg Annual Fuel Consumption x Emissions Factor = GHG Emissions

Vehicles x Avg Annual Hours of Use x Emissions Factor = CP Emissions

Through these calculations, the annual GHG and VOC savings that would be realized from transitioning these vehicles to lower emissions fuels is displayed below.

Fuel Usage: Collection vehicle fuel use was estimated by the South Coast Air Quality Management District to be 10,400 gallons per year in 2001. Data for the transfer and support vehicles is inferred from the most recent census survey of annual mileage of trash, garbage, or recycling vehicles. During the 2002 census period, the US Census Bureau estimates that these vehicles travel 23,400 miles on average. We estimate that California's refuse fleet uses 142,772,229 gallons of diesel fuel annually.

Annual Diesel Fuel Use & Reduction-Statewide			
	Scenario 1	Scenario 2	Scenarios 3-5
Diesel Gallons/Year	142,772,229	138,600,042	0
Diesel Gallons Reduced/yr	0	4,172,188	142,772,229
% Eliminated/Year	0%	3%	100%
10 Year Diesel Gallons Eliminated	0	41,721,875	1,427,722,290

Table 3: Estimated Annual Fuel Use & Reduction

Greenhouse Gas Emissions: CARB's Low Carbon Fuel Standard (LCFS) has established carbon intensities for various fuel types to quantify their GHG impacts on a unit basis. The lifecycle GHG impacts of the fuels modeled here are measured in grams of carbon dioxide equivalent per mega joule of energy (g/MJ). Diesel fuel, as of 2015, has an estimated carbon intensity of 102.01 g/MJ, whereas CNG and RNG are 78.4 g/MJ and -22.93 g/MJ respectively. The negativity of HSAD RNG is due to the mitigation of deleterious emissions from diverting methane producing organic material from landfills.

To evaluate the GHG savings from transitioning from diesel fuel to an alternative fuel, an equivalent amount of the alternative fuel must be estimated. Due to differences in engine efficiency, 1 DGE of CNG fuel is modeled as equivalent to displacing .9 diesel gallons.

Criteria Pollutants (CP): Criteria pollutants modeled in this study include: Carbon Monoxide (CO), Nitrogen Oxides (NOx), and Particulate Matter (PM). Compressed natural gas vehicles tend to emit lower levels of these criteria pollutants than their diesel counterparts. Furthermore, with the advent of near-zero (NZ) CNG engines this difference becomes ever more pronounced.[12] Using CARBs EMFAC model and CARB Executive Orders for engines used in collection vehicles, a comparison between the CP emissions of these two vehicle types can be established. The first table below illustrates the calculation of CP from CNG vehicles based off of braking horsepower

[12] The benefits of the "Near-Zero" engine technology are eloquently described in the just released "Game Changer: Next Generation Heavy-Duty Natural Gas Engines Fueled by Renewable Natural Gas," Gladstein Neandross Associates, April 2016

hours (bhp-hr). RNG is modeled as being similar to CNG with regard to CP. The second table summarizes the assumptions for CP emissions from diesel based on the EMFAC model.

CNG/RNG Criteria Pollutants Assumptions					
Vehicle Type	Executive Order #	Operating Hours	CO/bhp-hr	NOx/bhp-hr	PM/bhp-hr
Collection	A-021-0630	1,170	0.3	0.004	0.000
Transfer	A-021-0633	585	6.4	0.03	0.001
Support	A-021-0634	363	6.4	0.03	0.001
		TOTAL (MT)/yr	13.1	0.1	0.001

Table 4: CNG/RNG Criteria Pollutants Assumptions

The California Air Resources Board (CARB) EMFAC model provides emissions factors for criteria pollutants for a variety of vehicles on a per-mile basis. These emissions factors, as summarized in the table below are used to evaluate the regional criteria pollutant impacts of the diesel vehicles modeled in this report.

	Diesel Factors (g/mi)		
	Collection	Transfer	Support
Reactive Organic Gases	0.2	0.2	0.2
Total Organic Gases	2.6	0.3	0.3
Carbon Monoxide	5.7	0.9	0.8
Nitrogen Oxides	11.8	6.8	4.3
Carbon Dioxide	4,493.3	1,664.4	1,151.0
Particulate Matter 10	0.014	0.071	0.141
Particulate Matter 25	0.013	0.068	0.135

Table 5: Diesel Criteria Pollutants Charts

EMFAC does not yet model AFV or RNG fuels with regard to criteria pollutants. As such, an alternative set of measurement must be made. For these alternative fuel vehicles, CARB's Executive Orders are used to estimate criteria pollutants. Executive Orders are certified engine-specific emissions standards for vehicles with Gross Vehicle Weight Ratings above 14,000 pounds. To demonstrate the best-case scenario for AFV vehicles, the Cummins Inc. Near-Zero AFV engine is modeled under (EO A-021-0630) for Collection Vehicles (8.9 liter). Cummins' closest transfer vehicle analog, (EO A-21-0633) is used to model transfer vehicles (11.9 liter) as well as support vehicles.

Unlike the EMFAC model, these emissions are based on brake horsepower hours instead of vehicle miles travelled. To normalize these comparisons, average speeds of 20 MPH for collection vehicles and 40 MPH for transfer and support vehicles are used. These assumptions are provided in the table below.

Vehicle Assumptions			
	Collection	Transfer	Support
VMT/per	23,400	23,400	14,500
Annual Run-Time (hours)	1,170	585	363
Average Speed (MPH)	20	40	40

The criteria pollutants from the Executive Orders for the two AFV engines modeled in this report are provided in the figures below.

Cummins 8.9 Liter Executive Order A-021-0630: Collection Truck Engine

in g/bhp-hr	NMHC		NOx		NMHC+NOx		CO		PM		HCHO	
	FTP	SET	FTP	SET	FTP	SET	FTP	SET	FTP	SET	FTP	SET
STD	0.14	0.14	0.02	0.02	*	*	15.5	15.5	0.01	0.01	*	*
CERT	0.01	0.000	0.01	0.004	*	*	1.5	0.3	0.001	0.000	*	*
NTE	0.21		0.03		*		19.4		0.02		*	

Cummins 11.9 Liter Executive Order A-021-0633: Transfer Truck Engine

in g/bhp-hr	NMHC		NOx		CO		PM		HCHO	
	FTP	SET	FTP	SET	FTP	SET	FTP	SET	FTP	SET
STD	0.14	0.14	0.20	0.20	15.5	15.5	0.01	0.01	*	*
CERT	0.03	0.01	0.15	0.03	8.7	6.4	0.003	0.001	*	*
NTE	0.21		0.30		19.4		0.02		*	

Conclusions

There are future environmental benefits that derive from aligning alternative fueled truck weights in California with recent federal law. The existing fleet of 4,800 alternative fueled vehicles (AFVs) running on compressed natural gas (CNG) or liquefied natural gas (LNG) are at a disadvantage when compared to the higher polluting diesel vehicles.

Congress and the President validated this when they acted in a bipartisan manner late last year to rectify this situation by fixing this AFV “weight penalty” in the Fixing America's Surface Transportation (FAST) Act. California may now choose to align with the new federal law.

There is a compelling environmental benefit to California should the legislature choose to align with the AFV FAST Act provision noted. The greenhouse gas (GHG) emissions reductions from the existing solid waste AFV fleet alone would be equal to removing over 120,000 passenger cars from California roads over the next ten years, of which 89,687 are in southern California where the need to reduce air emissions is of extreme importance. Relating to smog forming chemicals like oxides of nitrogen (N0x), the emissions benefit statewide is 110 tons annually, 82 tons of which are in southern California.

There are even greater environmental benefits of expanding the AFV fleet by replacing approximately 16,000 waste vehicles statewide with CNG or RNG vehicles over time. As the total replacement with renewable natural gas is completed, this would eliminate over 1.4 billion gallons of diesel over ten years. Also, over 38,000 metric tons of oxides of nitrogen and other Criteria Pollutants can be reduced over that same period. Finally, the greenhouse gas benefit would be equal to removing over 6.8 million passenger cars from California roads over the next ten years, of which 3.2 million are in southern California

There are near-term benefits from California legislative action to fix the weight penalty and this Technical Report can assist decision makers in quantifying the environmental advantages of doing so.

References

Annual Truck Mileage
United States Census Bureau "Trucks, Truck Miles, and Average Annual Miles for All Trucks: 2002 and 1997. https://www.census.gov/prod/ec02/ec02tv-us.pdf

California Air Resources Board, *Low Carbon Fuel Standard (LCFS) Pathway for the Production of Biomethane from High Solids Anaerobic Digestion (HSAD) of Organic (Food and Green) Wastes,* (updated December, 2014).

California Air Resources Board: SWCV Regulation archives (2003); South Coast AQMD SWCV Hearings archives (2005); *Method For Estimating Greenhouse Gas Emission Reductions From Compost From Commercial Organic Waste* (CARB, November 2011)

South Coast Air Quality Management District, Rule 1193 archives, 2016 Air Quality Management Program White Papers, 2012 Clean Fuels Report.