Californias
Advanced Clean Cars
Midterm Review

Appendix M:
California GHG Technology Trends

January 18, 2017

California Environmental Protection Agency
Air Resources Board

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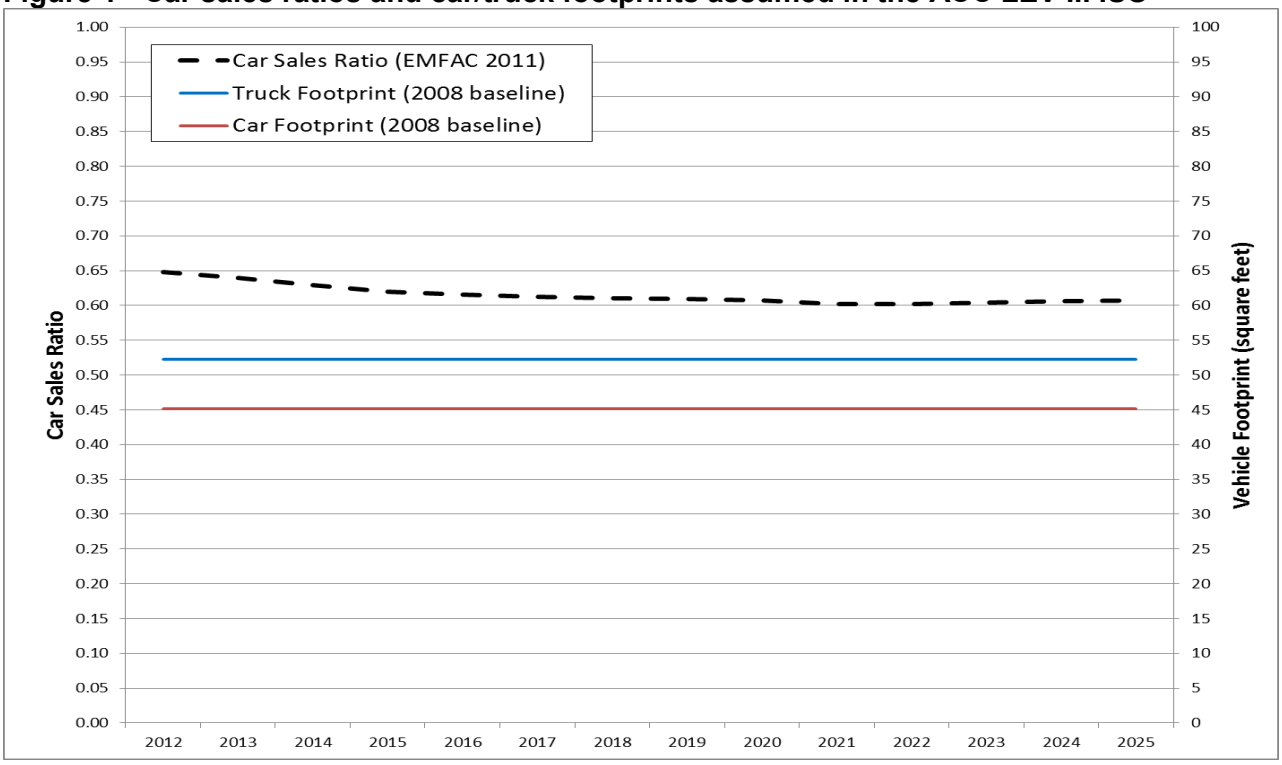
At the 2012 Advanced Clean Cars (ACC) rulemaking, the California Air Resources Board (ARB or the Board) asked staff to examine whether a shift in California's fleet mix to larger vehicles and the reclassification of cars as trucks that deviates from what was projected in the original rule would impact the expected benefits of LEV III GHG regulation (Resolution 12-11). As discussed in the 2016 draft joint-agency Technical Assessment Report (2016 TAR), it is expected that nationwide, the mix of new vehicle sales will shift to more trucks and fewer cars than was originally projected in 2012. In terms of the California fleet, as will be shown below, the trends are similar but the overall impact on GHG emissions is different because of a larger fraction of car sales in California's market. The Board also asked staff to study any changes in the footprint size for cars and trucks to evaluate any impacts on emission benefits. This is also reviewed here.

I. Introduction

The calculation of greenhouse gas (GHG) emission benefits associated with the California Pavley and Low-Emission Vehicle (LEV III) GHG regulations (LEV III GHG) requires assumptions about the future relative fraction of cars and trucks sold in the California fleet as well as the sizes (footprint) of the vehicles sold to determine the actual carbon dioxide (CO_2) emission targets that will apply. The 2011 Initial Statement of Reasons (ISOR) analysis for the ACC LEV III rulemaking projected CO_2 emission targets based on assumptions about future car/truck sales splits and vehicle footprints.[1] Specifically, staff used the EMFAC 2011 model to project future car/truck sales splits in California while new vehicle footprints were kept at the California 2008 fleet baseline value (45.1 and 52.3 square feet for cars and trucks, respectively). The car sales ratios (fraction of new light-duty vehicle sales that meet the passenger car definitions applicable to GHG and Corporate Average Fuel Economy or CAFE standards) and footprint assumptions for the 2012 – 2025 model years used in the ACC ISOR are shown in Figure 1.

[1] ARB, 2011. California Air Resources Board. Initial Statement Of Reasons For Proposed Rulemaking, Public Hearing To Consider The "Lev III" Amendments To The California Greenhouse Gas And Criteria Pollutant Exhaust And Evaporative Emission Standards And Test Procedures And To The On-Board Diagnostic System Requirements For Passenger Cars, Light-Duty Trucks, And Medium-Duty Vehicles, And To The Evaporative Emission Requirements For Heavy-Duty Vehicles. December 7, 2011. https://www.arb.ca.gov/regact/2012/leviiighg2012/leviiighg2012.htm

Figure 1 - Car sales ratios and car/truck footprints assumed in the ACC LEV III ISO



Based on these assumptions, staff calculated the CO_2 emission targets for each model year from 2012 to 2025 and determined the percent annual changes in CO_2 emission targets relative to the 2008 baseline CO_2 target. These percent annual changes were subsequently used to adjust the real world CO_2 emission factors in the EMFAC 2011 LDV inventory model, which could then be used to calculate real world CO_2 emission reductions for new vehicles in California from 2012 to 2025. The projected CO_2 emission targets and relative changes in CO_2 emission target for cars, trucks and the combined fleet are shown in Table 1, which is taken from Table III-A-3-3 of the ACC LEV III ISOR:

Table 1 - Projected targets for light-duty vehicle gCO_2/mile emission rates

	Model year	Car		Truck		Combined light-duty	
		gCO_2/mi	Annual change	gCO_2/mi	Annual change	gCO_2/mi	Annual change
Baseline	2008	291		396		336	
Previous Rule Targets	2009-2011						
	2012	263		340		290	
	2013	256	2.8%	330	2.8%	283	2.6%
	2014	248	3.3%	321	2.8%	275	2.8%
	2015	236	4.5%	306	4.5%	263	4.3%
	2016	226	4.5%	292	4.5%	251	4.4%
Proposed Rulemaking Targets	2017	213	5.5%	290	0.7%	243	3.2%
	2018	203	4.9%	280	3.5%	233	4.2%
	2019	192	5.2%	273	2.8%	224	4.0%
	2020	183	4.9%	264	3.0%	215	3.9%
	2021	173	5.5%	245	7.5%	201	6.3%
	2022	165	4.4%	233	4.9%	192	4.6%
	2023	158	4.5%	221	4.9%	183	4.8%
	2024	151	4.5%	210	5.0%	174	4.8%
	2025	144	4.6%	200	4.9%	166	4.8%
Average change, (2016-2025)			4.9%		4.1%		4.5%
Change, 2008-2016		-23%		-26%		-25%	
Change, 2016-2025		-36%		-32%		-34%	
Change, 2008-2025		-51%		-50%		-51%	

Notes: Car, truck, overall targets shown are based on projected sales of vehicles by footprint, category (ultimate gCO_2/mile levels are determined by end-of-year sales); the original California GHG standards for model years 2009-2011 are based on a different two-category system (PC/LDT1 and LDT2) than the car and truck system of the 2012-2016 federal standards and proposed 2017-2025 standards; Difference of individual columns may not match due to rounding.

Since the 2012 ACC rulemaking, new data concerning car/truck sales splits and vehicle footprints for vehicles sold in California have become available for the 2012 - 2014 model years. Specifically, staff acquired nationwide car/truck sales splits and vehicle footprint data from the annual manufacturer performance reports released by the United States Environmental Protection Agency (U.S. EPA) combined with California-specific sales information provided by the vehicle manufacturers. These annual reports are developed from nationwide sales data submitted by individual auto manufacturers and are required by law to be made available to the public. In order to acquire California-specific data from these reports, staff requested information from individual auto manufacturers in the same format they submitted to the U.S. EPA, but constrained to vehicles sold only in California. The specific manufacturer and model year data acquired are shown in Table 2. The combined sales volumes for the manufacturers who submitted such data to ARB represent approximately 90% of total nationwide vehicle sales in the 2012 – 2014 model year timeframe. Based on this data, staff developed new projections of California car/truck sales splits and vehicle footprints, which were then used to calculate modified CO_2 emission targets for the combined car/truck vehicle fleet.

Table 2 - California car/truck sales and footprint data.
An "X" in the box indicates data were available for the specific manufacturer and model year

Manufacturer	2012	2013	2014
BMW	X	X	X
Fiat Chrysler	X	X	X
Ford	X	X	X
GM	X	X	X
Honda	X	X	X
Hyundai	X	X	X
Mercedes	X	X	X
Mitsubishi	X	X	X
Nissan	X	X	X
Porsche	X	X	
Subaru	X	X	X
Tesla	X	X	X
Toyota	X	X	X
Volvo	X	X	

II. Methodology

The calculation of new California CO_2 emission targets required two steps. The first step involved using the actual California sales/splits and vehicle footprint data from the performance reports to calculate new combined CO_2 emission targets for the 2012 – 2014 model years. The second step involved the forecasting of new car/truck sales splits and vehicle footprints for future model years. A detailed description of the second step is provided below for the car/truck sales splits and footprint projections.

II.A. Car/Truck Sales Split Projections

The car/truck sales split projections were based on two data sources. The first source was the 2012 – 2014 performance report data. These data were used to derive a three-year trend line in the car sales ratio. This trend line showed a decrease in the car sales ratio from 2012 to 2014. The second data source was the 2016 Annual Energy Outlook (AEO) published by the Energy Information Administration.[2] This report projects nationwide car/truck sales splits from 2014 to 2040 based on assumptions about economic growth and future fuel price forecasts. ARB used this data source for the future car/truck sales projections to be consistent with the analyses done for the federal mid-term evaluation.

For this analysis, staff examined car/truck sales splits associated with three AEO scenarios: the reference case, the high oil price case, and the low oil price case. In regards to the low oil price and high oil price cases, AEO incorporates assumptions regarding future global oil demand and investment in the oil sector. Figure 2 below shows the crude oil prices projected in the AEO for each of the cases with crude oil barrel prices varying from just over $50 in 2015 to approximately $40, $90, and $190 in 2025 for the low oil price, reference, and high oil price

[2] EIA, 2016. United States Energy Information Administration. Annual Energy Outlook 2016. August 2016. http://www.eia.gov/forecasts/aeo/

cases, respectively. Figure 3 shows the resultant projected price per gallon for gasoline in each of these three cases starting at $2.52 per gallon in 2015 and following different trajectories to reach approximately $2.00, $3.00, and $4.75 per gallon for the low oil price, reference, and high oil price cases, respectively.

Figure 2 - Oil Prices for AEO 2016 Projections

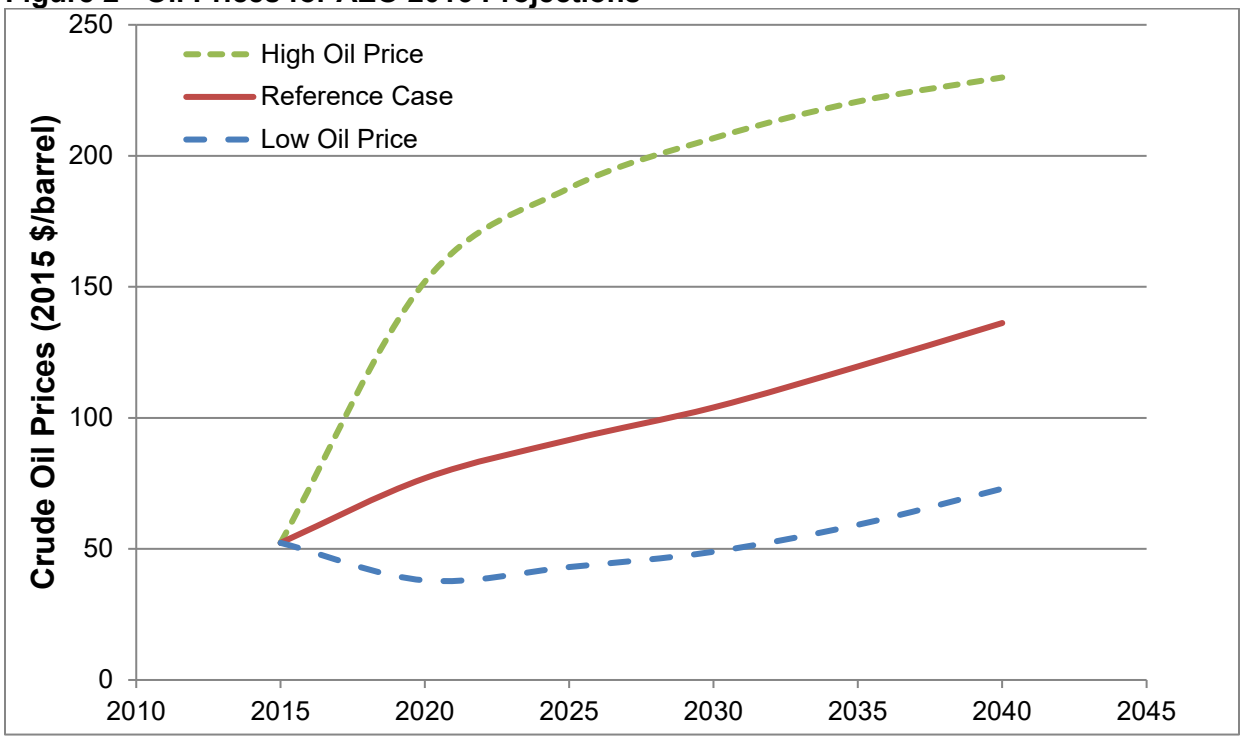
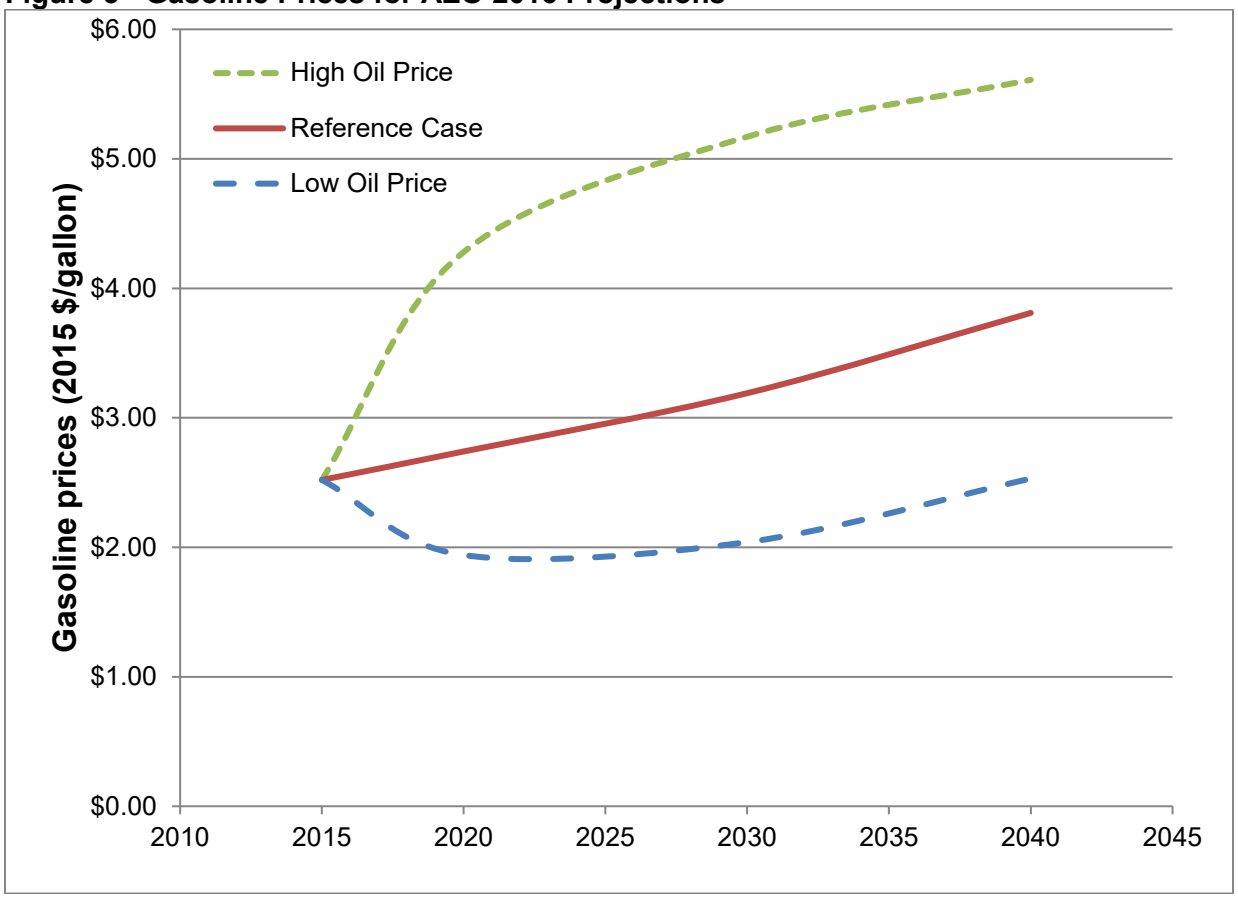


Figure 3 - Gasoline Prices for AEO 2016 Projections



In all three of these scenarios, the AEO projects a continuing decrease in car sales ratios beyond 2014 before bottoming out at a particular future year (dependent on which AEO scenario is being utilized). At that point, the decline ends and car sales ratios begin to increase steadily (or flatten in the low oil price scenario) through 2025. For this analysis, staff used the slope of the three-year trend line in car sales ratio from the actual California fleet 2012 through 2014 model year performance reports to extrapolate the decline out to the "bottom out" year of the AEO projections. The car sales ratios after that year were then projected to rise consistent with the relative annual increase in the AEO trend lines for each scenario. The 2014 to 2025 projected car sales ratios are shown in Figure 4, Figure 5, and Figure 6 for the reference, high fuel price case, and low fuel price case, respectively.

Figure 4 - Projected car sales ratios based on AEO reference case trends

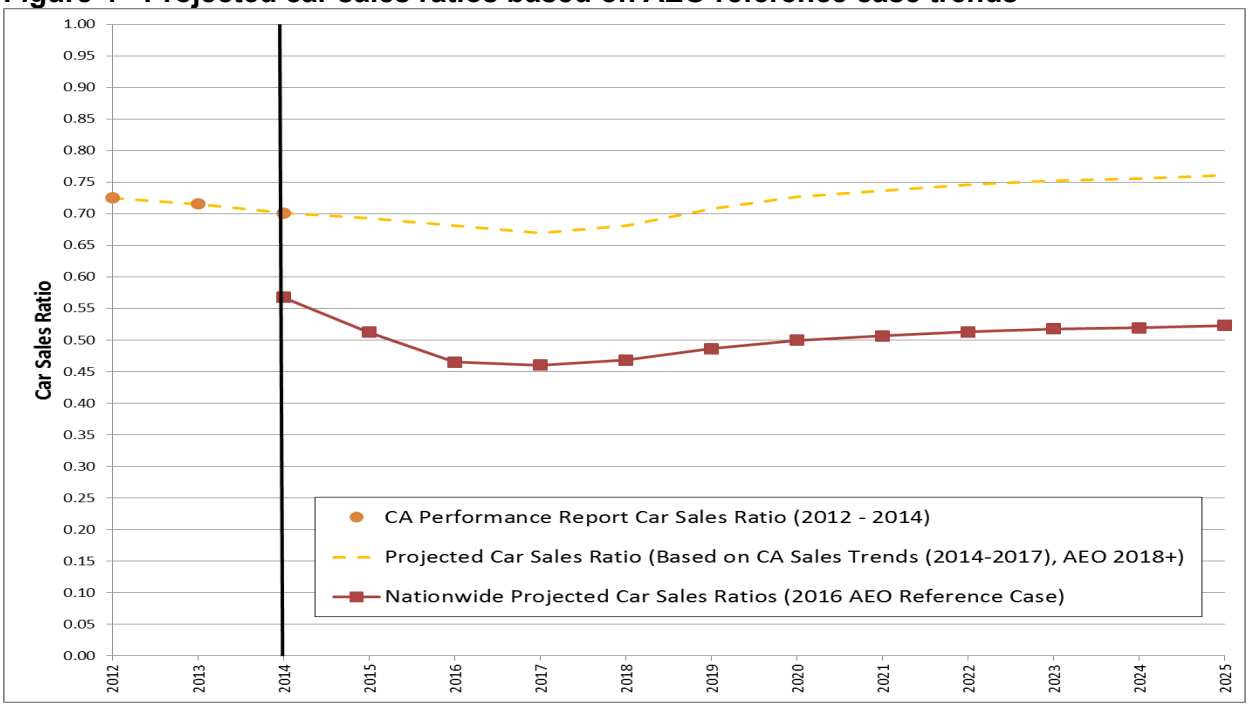


Figure 5 - Projected car sales ratios based on AEO high oil price case trends

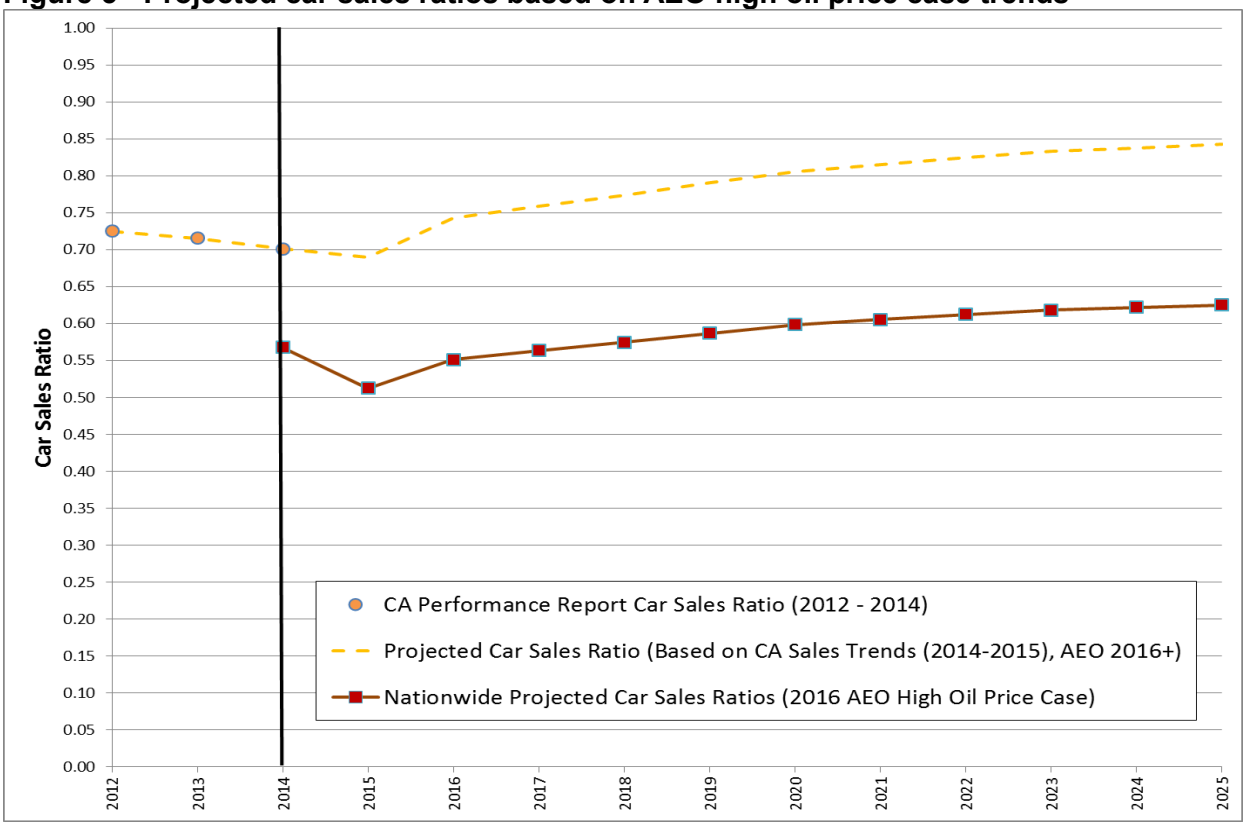


Figure 6 - Projected car sales ratios based on AEO low oil price case trends

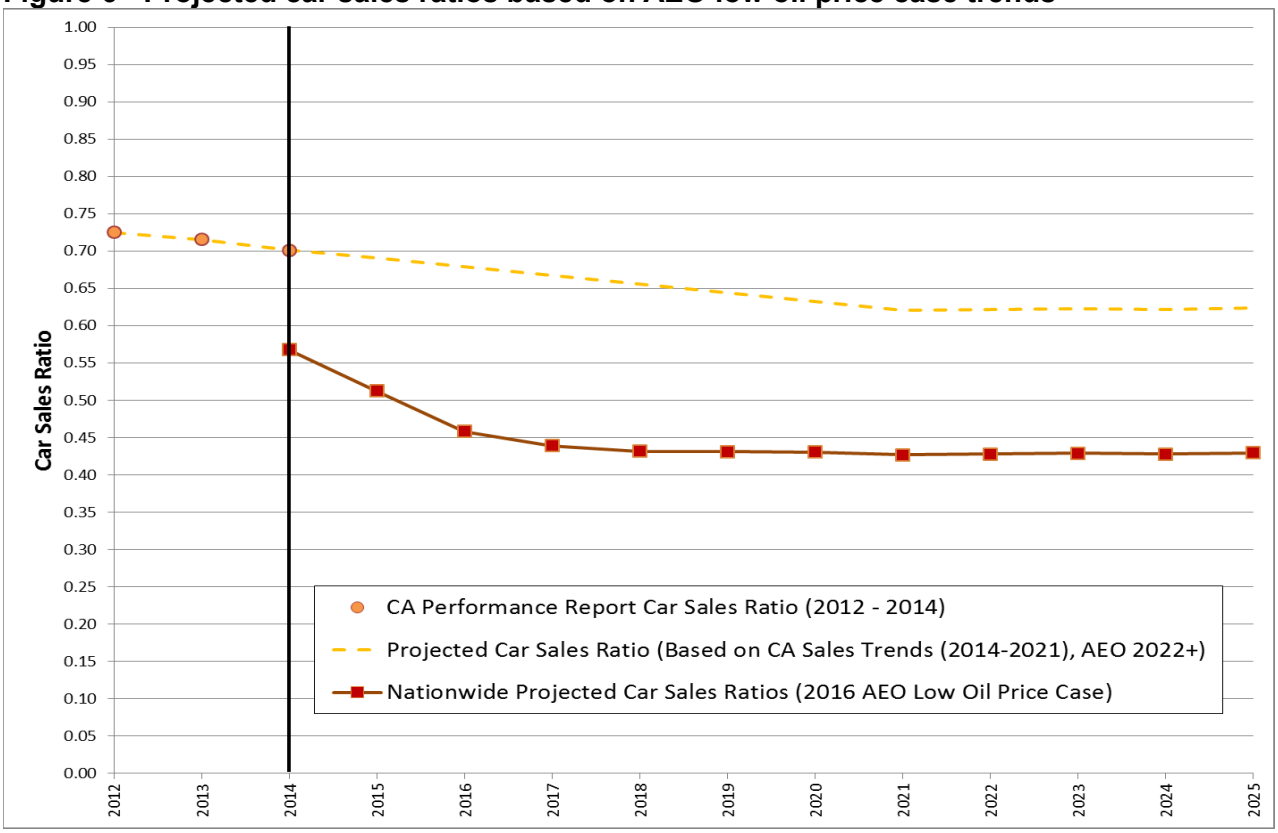


Table 3 summarizes the car sales percentages in tabular form. Note that shaded cells reflect actual data for the California fleet while the unshaded cells represent future projections. Also of note is that the actual car share in 2012 through 2014 turned out to be significantly higher than projected for the original rulemaking. Despite the recent decline in car sales and projected continuation of that trend for the next 1 to 7 years in the various AEO scenarios, the updated car sales ratio for 2025 is still higher than the original 2012 ACC projections.

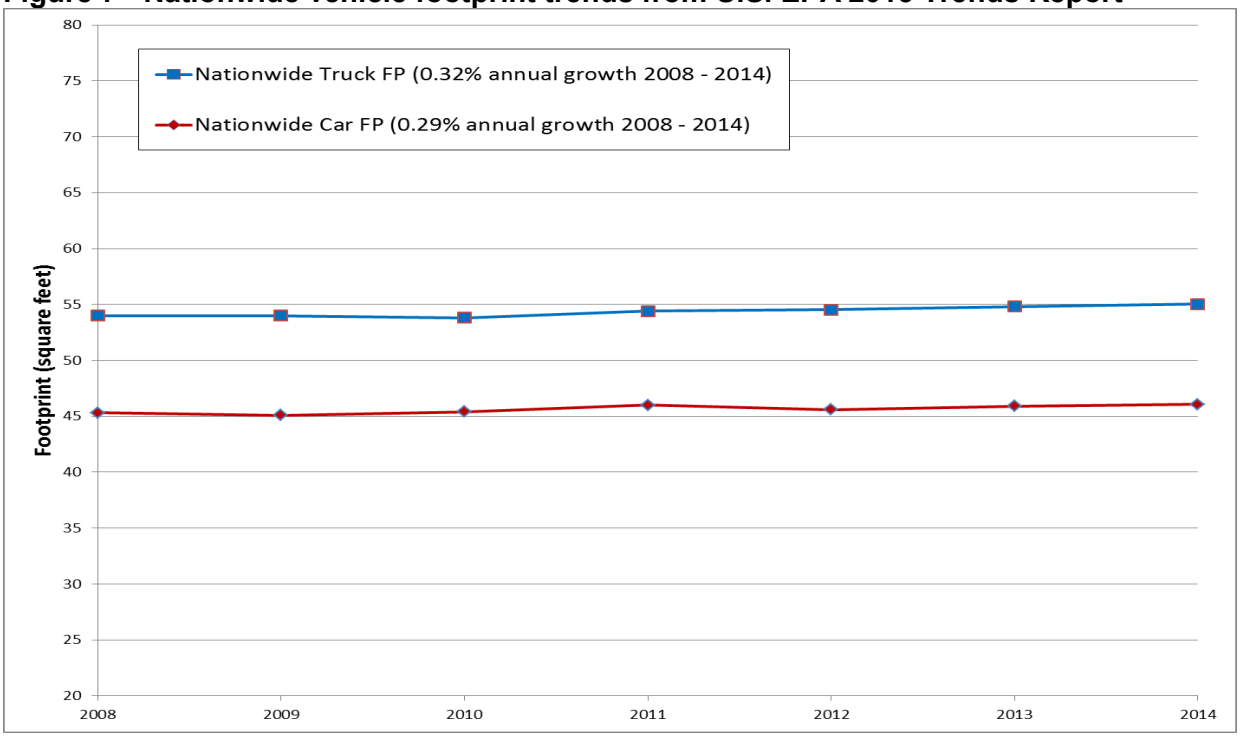
Table 3 - Summary of Projected Car Sales Ratios

Model Year	ACC ISOR	AEO Reference	AEO High Fuel	AEO Low Fuel
2012	0.65	0.73	0.73	0.73
2013	0.64	0.72	0.72	0.72
2014	0.63	0.70	0.70	0.70
2015	0.62	0.69	0.69	0.69
2016	0.62	0.68	0.74	0.68
2017	0.61	0.67	0.76	0.67
2018	0.61	0.68	0.77	0.66
2019	0.61	0.71	0.79	0.64
2020	0.61	0.73	0.81	0.63
2021	0.60	0.74	0.82	0.62
2022	0.60	0.75	0.83	0.62
2023	0.60	0.75	0.83	0.62
2024	0.61	0.76	0.84	0.62
2025	0.61	0.76	0.84	0.62

II.B. Vehicle Footprint (FP) Projections

In order to assess the impact of larger footprints on CO_2 emission targets in California, staff used the California-specific 2012 – 2014 performance report data in conjunction with the 2015 U.S. EPA Trends Report to calculate future footprints. Specifically, a seven-year nationwide footprint trend line was derived from the Trends Report for 2008 to 2014 and used to calculate an average annual growth rate for both cars and trucks (Figure 7).

Figure 7 - Nationwide vehicle footprint trends from U.S. EPA 2015 Trends Report



The average annual growth rates were then used to project future California footprints using the 2014 performance report footprint data as a starting point. Once this was completed, new CO_2 emission targets were calculated using the footprint curves for the adopted national GHG standards through 2025. The projected footprints and the associated CO_2 emission targets are provided in Figure 8 and Table 4, respectively.

Figure 8 - Projected California Vehicle Footprints based on Nationwide Trends Data

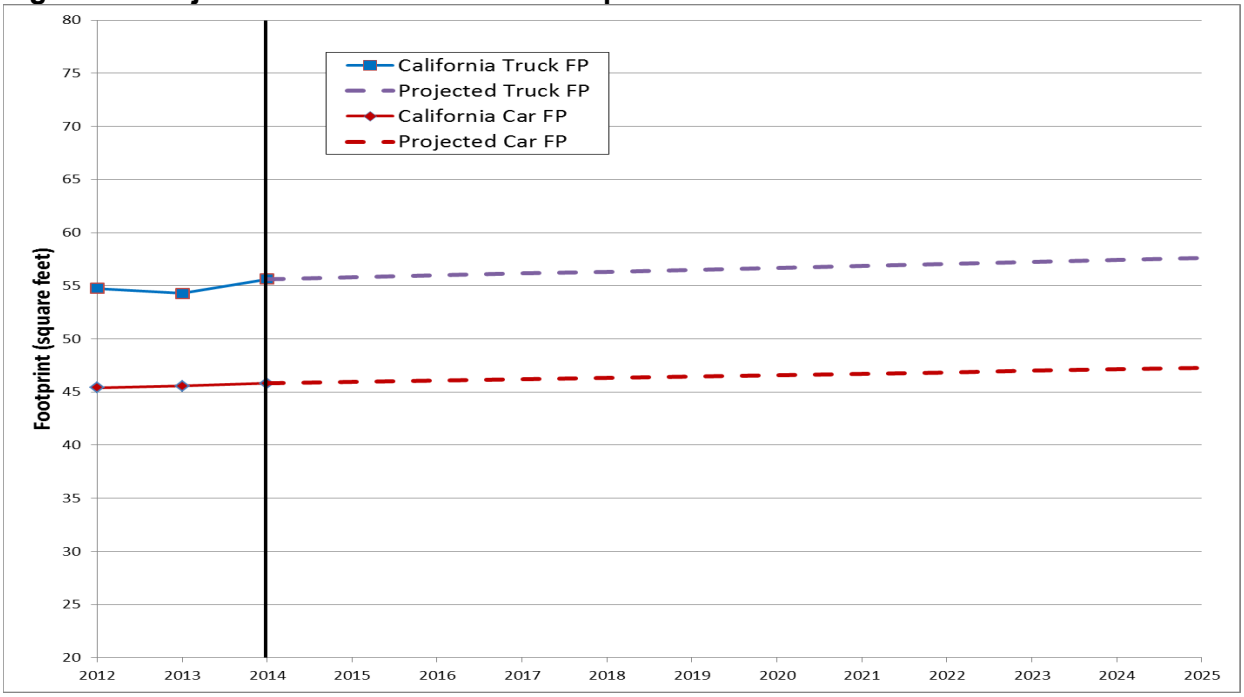


Table 4 - Projected California Vehicle Footprints and Corresponding CO_2 Emission Targets

MY	Car FP (sq. ft.)	Car Target (gCO2/mile)	Truck FP (sq. ft.)	Truck Target (gCO2/mile)
2012	45.4	266	54.7	349
2013	45.6	259	54.3	336
2014	45.8	251	55.6	332
2015	45.9	240	55.8	320
2016	46.1	230	56.0	307
2017	46.2	218	56.1	307
2018	46.3	208	56.3	300
2019	46.5	198	56.5	292
2020	46.6	189	56.7	284
2021	46.7	179	56.9	263
2022	46.9	172	57.0	251
2023	47.0	165	57.2	240
2024	47.1	158	57.4	229
2025	47.3	151	57.6	219

After the new CO_2 targets were generated for cars and trucks, staff combined the results with the previously calculated car sales ratio projections to calculate new combined CO_2 emission targets under the various scenarios.

The California and national fleets are showing a very slight increase in the sales weighted footprint of the combined fleet but it is not yet clear if the constructs of the GHG standards are influencing this trend. In its 2015 Trends Report,[3] U.S. EPA looked at the sales-weighted average footprint for new cars and trucks sold nationwide for the 2008 through 2014 model years and projected for the 2015 model year. In the analysis done by ARB based on these data, the average footprint of a new car has increased by 0.8 square feet (approximately 1.8 percent) and the average footprint of a new truck has increased by 1.5 square feet (approximately 2.8 percent) within this time period. When combined with the increasing share of the market from truck sales, the combined car/truck fleet-wide average footprint has increased relative to what was originally projected.

The biggest influence appears to be a higher share of truck sales that generally have a larger footprint than cars rather than a significant increase in the average footprint within the car or truck segment itself. However, given the substantial lead time necessary to redesign base vehicle platforms including parameters that determine the footprint, it is probably too early to determine the impact of standards adopted only four years ago.

Of note, however, is that U.S. EPA's more recent 2016 Trends Report,[4] which was released subsequent to this analysis by ARB, shows that the actual 2015 model year resulted in a smaller sales-weighted average footprint for trucks than the 2014 model year while the footprint for cars remained virtually unchanged. Accordingly, ARB's analysis likely over-estimates the growth in truck footprint and, therefore, represents a conservative estimate of GHG reductions in this scenario.

III. Calculation of Future CO_2 Emission Targets

Staff developed four scenarios to gain a better understanding of the potential impacts of changes in future car/truck sales splits and increased footprints on CO_2 emission targets. These four scenarios are described below.

Scenario 1: Assume future car sales ratios follow the AEO reference scenario.

Scenario 2: Assume future car sales ratios follow the AEO high oil price scenario.

Scenario 3: Assume future car sales ratios follow the AEO low oil price scenario.

Scenario 4: Assume future car sales ratios follow the AEO reference scenario *and* that car and truck footprints increase according to the projections described in the previous section.

[3] EPA, 2015. United States Environmental Protection Agency. *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2015 Trends Report*. EPA-420-R-15-016. December 2015. https://www3.epa.gov/fueleconomy/fetrends/1975-2015/420r15016.pdf

[4] EPA, 2016. United States Environmental Protection Agency. *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2016 Trends Report*. EPA-420-R-16-010. November 2016. https://www.epa.gov/sites/production/files/2016-11/documents/420r16010.pdf

For each of these scenarios, staff calculated a combined (car plus truck) CO_2 emission target for each of the model years from 2012 to 2025.

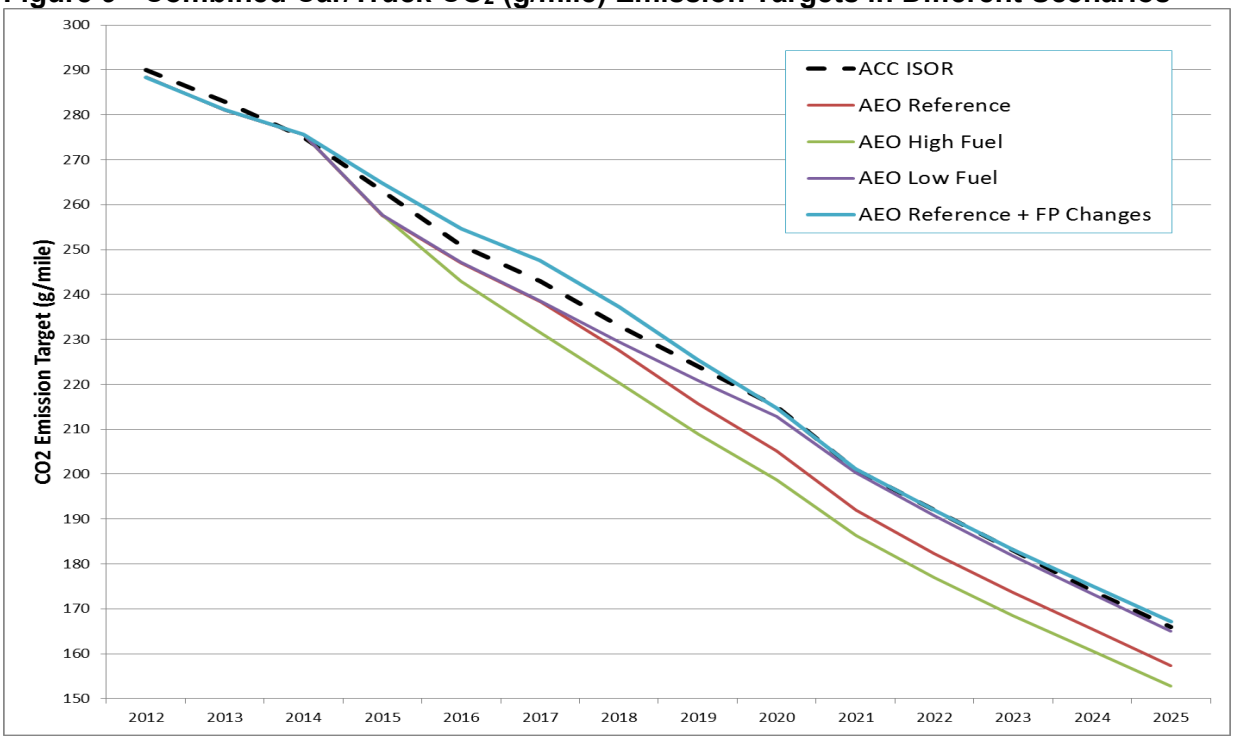
IV. Results

The results from each of the four scenarios are summarized in Table 5 below. The original CO_2 emission targets from the ACC ISOR are provided for comparison purposes. The results are shown graphically in Figure 9. In the first three scenarios, the initial CO_2 emission targets in 2012 are below the ACC ISOR value and continue to remain below the ISOR values out to 2025. In the fourth scenario, the initial CO_2 emission target is also below the ACC ISOR value but begins to exceed the ISOR values in 2014 and continues to stay at or above the ISOR values out to 2025. The lower CO_2 emission targets in the first three scenarios for all model years are expected given the higher car sales ratios in those model years. In the fourth scenario, the larger footprints beginning in 2015 begin to offset the benefits of the higher car sales ratios.

Table 5 - Combined Car/Truck CO_2 (g/mile) Emission Targets in Different Scenarios

		Scenarios			
Model Year	**ACC ISOR**	**AEO Reference**	**AEO High Fuel**	**AEO Low Fuel**	**AEO Reference + FP Changes**
2012	290	288	288	288	288
2013	283	281	281	281	281
2014	275	276	276	276	276
2015	263	258	258	258	265
2016	251	247	243	247	255
2017	243	238	232	239	248
2018	233	228	220	230	237
2019	224	216	209	221	225
2020	215	205	199	213	215
2021	201	192	186	200	201
2022	192	182	177	191	192
2023	183	174	169	182	183
2024	174	165	161	173	175
2025	166	157	153	165	167

Figure 9 - Combined Car/Truck CO_2 (g/mile) Emission Targets in Different Scenarios



V. Additional Analyses

In the draft 2016 TAR, U.S. EPA revised their forecast for the 2025 average car, truck, and combined CO_2 emission targets based on updated projections of car/truck sales splits and vehicle footprints. The updated compliance scenario shows the nationwide combined fleet average is projected to be 175 gCO_2/mile in 2025 model year instead of 163 gCO_2/mile as originally projected in 2012. The primary cause for the higher carbon emissions is a shift in the nationwide car/truck fleet mix to a larger share of trucks than was projected in 2012. Some stakeholders have expressed concern with the fleet mix change resulting in a higher GHG emissions nationwide in 2025 than anticipated and have asked what would be required to get the 2025 fleet back to the original projections of 163 gCO_2/mile. The following analysis considers only changes in stringency, costs, and technology mix. First, the stringency of the standard would have to increase by approximately 5.7% per year from 2021 to 2025 to achieve the original CO_2 fleet average target. The U.S. EPA OMEGA model was used to calculate the incremental costs and incremental technology penetration rates needed to achieve the original 163 gCO_2/mile target in the nationwide fleet. For the analysis, all of the input files and baseline fleet assumptions were those used for the draft 2016 TAR and are described in detail in the TAR. Subsequent updates to the input files and baseline fleet done by U.S. EPA for the Proposed Determination are not reflected in this analysis.

The incremental costs associated with achieving the 163 gCO_2/mile target in 2025 are shown in Table 6 below. These results indicate manufacturers would incur approximately $500 in additional per vehicle incremental costs to achieve the original CO_2 target, above and beyond

the costs ($894) estimated by U.S. EPA for the fleet in the draft 2016 TAR to reach 175 gCO_2/mile. In regards to technology penetration rates compared to the draft 2016 TAR findings, the modeling results show manufacturers would need to utilize higher amounts of several technologies including mild 48 Volt hybrids (33% vs. 18%), Atkinson engines (58% vs. 44%), cooled EGR (70% vs. 53%), and more efficient transmission systems (61% vs 39%).

Table 6 - Incremental costs* needed to achieve 163 gCO_2/mile targets in 2025

Manufacturer	Car	Truck	Combined
BMW	$612	$416	$565
FCA	$700	$717	$712
FORD	$495	$554	$529
GM	$642	$400	$521
HONDA	$93	$686	$369
HYUNDAI/KIA	$397	$829	$449
JLR	$1,530	$1,403	$1,429
MAZDA	$222	$286	$241
MERCEDES-BENZ	$869	$257	$636
MITSUBISHI	$304	$433	$350
NISSAN	$216	$741	$424
SUBARU	$0	$333	$258
TESLA	$0	$0	$0
TOYOTA	$155	$650	$379
VOLKSWAGEN	$1,083	$162	$735
VOLVO	$652	$609	$630
Fleet	$435	$572	$500

* Above and beyond the costs estimated by U.S. EPA for the compliance fleet in the draft 2016 TAR for 175 gCO_2/mile.

VI. Summary and Conclusions

When considered in total, the newer and more accurate information regarding footprint and car/truck share in the California fleet does result in a different projection of GHG benefits than originally estimated for the 2012 ACC rulemaking. With the data available today, staff now know that the actual car share was much higher than the approximate 63 percent assumed in the 2012 rulemaking and, despite a recent shift to trucks, California car sales are still higher than 63 percent today. Even when applying the trends from the recent AEO 2016 projections to the California fleet mix starting point, the 2025 projections for California result in a higher car share than the original assumption.

When combined with the increasing share of the market from truck sales, the combined car/truck fleet average footprint has increased relative to what was originally projected. The biggest influence appears to be a higher share of truck sales that generally have a larger footprint than cars rather than a significant increase in the average footprint within the car or truck segment itself. However, a slight increase in the sales-weighted average footprint has been observed within both the car and truck segment.

Accordingly, the combined new car/truck fleet average in California for the 2025 model year is now projected to be 158 gCO_2/mile when using the AEO Reference case and in the range of 153 to 167 gCO_2/mile in the various scenarios explored. Only in the sensitivity case using the AEO Reference, coupled with an increase in footprint, does the combined new car/truck fleet average exceed what was estimated in the original 2012 ARB rulemaking. This revised projection is independent of the national fleet analysis in the 2016 TAR given the different car/truck market trends in California.

At the national level, modeling of compliance scenarios has projected that the fleet will now be at 175 gCO_2/mile in 2025 and not reach the 163 gCO_2/mile target as originally projected in the 2012 federal rulemaking due to the increased fraction of projected truck sales in the national fleet. Additional analyses of the nationwide fleet using the U.S. EPA's OMEGA model found it would require an additional $500 per vehicle, above and beyond the $894 projected in the draft 2016 TAR to meet the current standards, to meet more stringent 2022 through 2025 model year standards sufficient to bring the national fleet to the original projected fleet-wide average of 163 gCO_2/mile in 2025. As expected, the modeling also showed higher levels of advanced technologies would need to be deployed on vehicles, primarily in advanced gasoline engines, transmissions, and mild hybrid systems while projected levels of advanced electrification such as plug-in hybrids and battery electric vehicles remain at levels below 5%, collectively.

VII. References

ARB, 2012. Air Resources Board. LEV III Regulations ISOR. January 26, 2012. https://www.arb.ca.gov/regact/2012/leviiighg2012/leviiighg2012.htm

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