February 24, 2022

Via cleancars@arb.ca.gov

California Air Resources Board
Sustainable Transportation and Community Division
1001 I Street
Sacramento, CA 95814

Re: EDF Analysis of Impact of Post-2026 GHG Standards on ACCII ICEV Costs

Environmental Defense Fund (EDF) respectfully submits the following comments and cost analysis in support of protective Advanced Clean Cars (ACC) II standards for passenger vehicles in California. In previous comments EDF highlighted the importance of accounting for the cost of future greenhouse gas (GHG) controls on internal combustion engine vehicles (ICEVs).[1] We specifically recommended that the Air Resources Board (ARB) add these additional costs to the ICEV delete costs when calculating the incremental cost of a zero-emission vehicle (ZEV).

We understand that ARB has projected the cost of compliance of GHG emission control requirements only through the 2026 model year (MY), largely based on the Environmental Protection Agency's (EPA) recently finalized light-duty vehicle GHG standards for MY 2023-2026. For MYs beyond 2026, ARB has assumed no further increase in the stringency of GHG standards for ICEVs, and thus no added cost of compliance, even though available technologies can deliver additional reductions from these vehicles.

However, we do not believe this assumption is reasonable in light of the commitments both in California and at the federal level[2] to substantially reduce greenhouse gas pollution from passenger vehicles. And while the precise greenhouse gas standards for post-2026 vehicles have yet to be adopted, for ICEVs to have any role during the transition to all zero-emissions sales in 2035, additional GHG reductions will need to be achieved from ICEVs during the transition and they will need to deploy cost-effective greenhouse gas reducing technologies that are already in the marketplace today.

Accordingly, our new analysis quantifies the additional ICEV delete costs beyond 2026 that would result from applying available GHG control technologies to post-2026 vehicles that are

[1] Comments from Environmental Defense Fund on Advanced Clean Cars (ACC) II at 4, June 11, 2021.
[2] *See e.g.*, Executive Order 14037, Strengthening American Leadership in Clean Cars and Trucks, 86 Fed. Reg. 43583 (President Biden's goal of 50 percent sales of new zero-emitting passenger cars and light trucks by 2030, and eliminating tailpipe pollution from new passenger vehicles by 2035).

not otherwise required by the existing standards through MY 2026. It utilizes the same modeling and analytical framework that EPA relied on in its recent GHG rulemaking. The Attachment provides more details on the study's methodology and results.

Our modeling concludes that when all available ICEV control technology is employed, there is a $3,350 per vehicle incremental compliance cost over ARB's MY 2026 compliance costs for passenger cars and $2,886 incremental cost for light trucks. This is in addition to the $965 GHG compliance cost that ARB modeled for MY 2025[3] vehicles in the SRIA.[4] For context, if ICEVs are required to adopt these additional GHG control technologies by 2030, the added delete cost of $3,350 per vehicle for passenger cars would be more than twice ARB's current estimated incremental cost of $1,366 for BEV300 small cars in 2030.[5] In other words, simply incorporating these additional ICEV costs without addressing any of the other issues we have raised with ARB's ZEV cost assumptions, would result in ZEVs reaching cost parity with ICEVs much earlier in the program and possibly well before 2030.

In order to accurately project the cost of ZEV sales requirements, we strongly urge ARB to include these additional delete costs in its current analysis. If this is not possible, we ask ARB to include in the ISOR a quantification and discussion of the impact of future GHG requirements on its cost assessment of ZEVs.

We appreciate ARB's consideration of this analysis and can likewise provide any additional details related to this analysis or the results of alternative scenarios that would be helpful.

Respectfully submitted,

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[3] In the SRIA, ARB references cost compliance estimates for MY 2026 ("GHG emissions cost estimates in 2026MY from ACC I") and for MY 2025 ("the GHG compliance costs from the Advanced Clean Cars I LEV III GHG are also avoided with ZEV technologies. These costs are determined to be $965 in 2021 dollars for 2025 model year vehicles and beyond and are applied to all ZEV technology combinations from 2025 to 2035."). Because the MY that ARB utilized in its compliance cost estimates is unclear, we have used MY 2026 throughout this letter.
[4] SRIA at 60, Table 25.
[5] SRIA at 157, Table A.1.

Attachment

In our analysis we modeled a single scenario of post-2026 ICEV GHG control which assumed a 3% reduction per year in GHG emissions starting in 2027 and continuing through 2038, when all currently available ICEV GHG control technology ran out. We utilized a relatively modest 3% per year reduction for illustrative purposes (smaller than the reductions achieved on average under the current federal GHG standards for MY 2023-2026) in order to provide GHG control costs across a range of possible ICEV GHG standards and not to suggest a particular pathway for year-over-year improvements. The costs are essentially independent of the rate of control as the effects of learning are very small for these technologies. Thus, the primary measure of each increment of control is the absolute carbon dioxide (CO_2) emission level per mile for cars and light trucks and we present the results in these terms below, as opposed to by model year. This analysis utilizes the same version of the National Highway Traffic Safety Administration's (NHTSA) Corporate Average Fuel Economy (CAFE) model, which the Environmental Protection Agency (EPA) used in evaluating its recent *Revised 2023 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions Standards* (federal GHG standards). 86 Fed. Reg. 74434.

Purpose

EPA recently promulgated federal GHG standards for passenger cars and light trucks for the 2023-2026 model years. These standards replaced the SAFE 2 standards promulgated in 2020, which relaxed the original Phase 2 GHG standards that were established in 2012 and affirmed as part of a midterm review in 2017. ARB is currently developing a second phase to its Advanced Clean Cars program which will ensure all new passenger vehicle sales are zero-emission vehicles (ZEVs) by 2035.

A key factor in projecting the cost of the ZEV sales requirements is the incremental cost of ZEVs. One of the major factors in estimating ZEV costs is the value of the parts of ICEVs which will no longer be needed on a ZEV. These "deleted" parts normally include the internal combustion engine, the transmission, parts related to hybridization, and the emission controls. ARB has estimated the value of these deleted parts (delete costs) through model year 2026 under the federal GHG standards. However, to play any role in compliance with standards after model year 2026, ICEVs will certainly continue to need to meet tighter GHG standards between 2026 and 2035. We offer the results of this study as a conservative estimate of delete costs after model year 2026, which ARB's analysis has failed to consider.

Methodology

This analysis utilizes the same version of NHTSA's CAFE model that EPA used in evaluating its recent federal GHG standards. In projecting the impact of its new federal GHG standards, EPA projected that roughly 17% of car and light truck sales would be ZEVs in model year 2026.[6]

[6] Environmental Protection Agency, *Revised 2023 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions Standards*, 86 Fed. Reg. 74434, 74484.

Compared to ZEV sales in MY 2020, nearly all of the added ZEVs were battery electric vehicles (BEVs) with a range of 300 miles (BEV300s).[7]

As the goal of this analysis is to project the cost of reducing the ICEV emissions beyond the level currently allowed under federal GHG standards in MY 2026, we needed to prevent any increase in ZEV penetration existing in MY 2026 into the future (i.e., preventing the ICEVs in 2026 from being converted into ZEVs). Setting a sales cap at 17% on the Technologies worksheet of the technology input file did not have any effect. Thus, we modified the market input file to "SKIP" over the ZEV technologies for all vehicles that were not ZEV in MY 2026 under the new 2026 EPA GHG standards. This forced the CAFE model to only apply additional technologies applicable to ICEVs to those vehicles which were still ICEVs in MY 2026 under EPA's federal GHG standards.[8]

In its work supporting the new federal GHG standards, EPA performed a sensitivity analysis of the technology and cost impacts of the standards assuming "perfect" GHG credit trading. Perfect GHG credit trading means that manufacturers are assumed to purchase GHG credits whenever another manufacturer can over-comply with the GHG standard for a lower cost and vice versa. This is typically accomplished by having each vehicle model in the market input file being produced by the same manufacturer (e.g., "industry"). In EPA's case, two composite manufacturers were involved, because EPA modeled the Framework and non-Framework manufacturers separately. There has been considerable trading of GHG credits over the past several years, so it is reasonable to project a significant degree of trading in the future.[9] The greater the volume of GHG credit trading, the lower the fleetwide compliance cost, as manufacturers facing higher than average costs can purchase credits from manufacturers facing lower than average costs for less than the cost of compliance. We believe that the use of post-2026 ICEV GHG costs assuming perfect trading provides a lower limit of the potential cost of additional ICEV GHG controls (and therefore represents a conservative estimate for the delete costs used in estimating incremental ZEV costs).

The precise degree and pace ICEV GHG emission control likely to occur after 2026 is unknown, though, in light of commitments by both California and the federal government, ICEVs will almost certainly need to deploy additional GHG reduction technologies. Therefore, we have evaluated moderately increasing levels of such control, running the CAFE model in a manner similar to that done by EPA. The CAFE model adjusts its technology costs over time to reflect a phenomenon known as "learning". Learning assumes that the cost of a manufacturing process generally decreases over time as experience is gained in its conduct. Therefore, the cost of a

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[7] Environmental Protection Agency, *Revised 2023 and Later Model Year Light Duty Vehicle GHG Emissions Standards: Regulatory Impact Analysis* 4-29, Table 4-31.
[8] In fact, there was a slight increase in ZEV sales after 2026 due to the fact that we combined the two vehicle fleets (automakers participating in Framework Agreements and those not participating) into one single fleet in our modeling, while EPA utilized two separate fleets. We determined that one single fleet is more appropriate in the post-2026 timeframe as the Framework distinction will have concluded by that time. We excluded any impact of this slight increase in ZEV sales by calculating the sales, CO_2 levels and technology costs for ICEVs separately.
[9] Environmental Protection Agency, The 2021 EPA Automotive Trends Report, U.S. EPA, EPA-420-S-21-002 November 2021.

particular level of ICEV GHG emission control generally decreases over time. The effect of learning is very pronounced for ZEV technology due to its relative infancy in development. However, the effect of learning is generally small for ICEV technology.[10] Thus, the level of GHG control assumed has a much greater impact on compliance cost than the timing of the standard. Thus, in order to limit the computing time necessary to conduct this work, we modeled a single scenario of post-2026 ICEV GHG control which assumed a 3% reduction per year in GHG emissions starting in 2027 and continuing through 2038, when all currently available ICEV GHG control technology ran out. As described above, we took this approach to provide a more granular understanding of the impact of modestly increasing levels of additional GHG controls and it was not done to suggest or recommend a particular pace of improvement for ICEVs post 2026.

This overall GHG reduction of 3% per year was sufficient to exhaust ICEV control technology by 2038, providing an upper limit on the level and cost of GHG emissions reductions achievable with ICEV technology under the assumptions made by EPA. This result implies an upper limit on the degree of post-2026 ICEV control of just under 18%.

EPA evaluated the cost of its new GHG standards both with and without the use of phase 2 high compression ratio engines (HCR2). We conducted this analysis assuming that HCR2 engines were both available and not available in this post-2026 timeframe. As described further below, HCR2 was selected by the CAFE model for some vehicles for a few model years, but eventually was replaced by strong hybrids without HCR2 engines. Thus, the inclusion of HCR2 technology had little impact on the results. Thus, we only present ICEV GHG control costs without the availability of HCR2 engines, as EPA did in their primary analysis.

Finally, we ran the CAFE model without dynamic economic modeling. We did so to simplify running the model, as this obviates the need to perform multiple iterations which may or may not converge on a final solution. This also avoids projected changes in the share of passenger car and light truck sales which we believe are based on poorly established relationships between relative car-truck fuel economy and sales. In order to minimize the effect of this decision, we report our modeling results below for passenger cars and light trucks separately. Different breakdowns of the sales of the two vehicle classes can be applied to develop fleetwide average costs.

Results

The results of our modeling of ICEV control after 2026 are summarized in Table 1. As described above, while we modeled the various levels of GHG control in specific model years, the costs shown apply essentially in any model year given sufficient lead time. Thus, we show the levels of GHG control applied versus the specific model years used in the CAFE model.

[10] The results of EPA's modeling of the final federal GHG standards with perfect GHG credit trading indicates very little change in the cost of ICEV control over time between 2027 and 2040. ICEV control costs increased between 2026 and 2027 in these model runs as EPA assumed that upstream electricity emissions would be included in ZEV certification in 2027, increasing the effective stringency of the 2026 GHG standards.

Table 1: Tailpipe CO_2 and Incremental Compliance Costs for ICEVs After 2026				
GHG Reduction from MY 2026	Tailpipe CO_2 (g/mi)		Incremental Compliance Costs Over MY 2026 ($ per vehicle)	
	Passenger Car	Light Truck	Passenger Car	Light Truck
---	191.1	249.0	--	--
3%	188.7	241.5	$58	$183
6%	184.1	234.1	$175	$388
9%	179.6	227.5	$338	$585
12%	178.4	220.7	$366	$797
15%	171.8	215.3	$656	$1,006
18%	167.6	209.3	$828	$1,266
21%	166.2	202.2	$903	$1,603
24%	151.6	194.3	$1,851	$2,024
27%	144.9	191.7	$2,451	$2,194
30%	139.7	187.0	$2,776	$2,450
33%	132.4	184.6	$3,268	$2,693
34%	131.9	182.7	$3,350	$2,886

The incremental vehicle costs shown in Table 1 indicate lower costs for light trucks than passenger cars. This is likely due to the fact that vehicle electrification (i.e., BEVs) was concentrated in the light truck class, 23% versus 10% for passenger cars, in EPA's modeling of the 2026 standards assuming perfect trading.[11]

The post-2026 reduction in ICEV emissions is accomplished via a relatively short list of technologies. The use of HCR2 engines increases as the required GHG reduction approaches 12%, but then wanes to zero use. The application of advanced cylinder deactivation to turbocharged engines (TURBOAD), strong hybrid technology, phase 4 aerodynamic improvements (20%, AERO20) and phase 4 and 6 mass reductions (MR4 and MR6) all gradually increase throughout the entire period shown in Table 1.[12] Thus, the inclusion of HCR2 engines in the modeling likely reduced costs somewhat in the first few GHG control increments, but had no impact later. As EPA did not include the availability of HCR2 engines in its primary analysis, we show our modeling results for the case where HCR2 engine technology was not available below. Table 2 shows the sales penetrations of these technologies for each level of GHG control.

[11] The BEV percentages of passenger cars and light trucks were almost the same in the primary CAFE model runs performed by EPA which did not allow the trading of GHG credits.
[12] Phase 4 weight reductions predominate at 88% at the final level of GHG control , versus 6% for Phase 6.

Table 2: Fleetwide Sales Penetrations of Key Post-2026 Technologies					
Reduction from MY 2026 GHG	TURBOAD	Strong Hybrid	AERO20	MR4	MR6
0%	0.0%	7.6%	28.1%	11.1%	0.0%
3%	0.0%	9.8%	32.9%	11.1%	0.0%
6%	0.0%	13.0%	36.2%	14.5%	0.0%
9%	0.0%	17.3%	42.0%	15.5%	0.0%
12%	0.0%	20.2%	44.2%	19.7%	0.1%
15%	0.0%	26.8%	50.2%	24.8%	0.1%
18%	0.0%	34.9%	56.2%	31.0%	0.4%
21%	2.4%	41.9%	59.6%	36.8%	0.7%
24%	6.3%	60.0%	72.2%	57.7%	1.2%
27%	6.5%	67.3%	76.5%	62.6%	2.9%
30%	7.0%	75.7%	79.5%	72.7%	3.4%
33%	10.0%	82.1%	83.5%	82.6%	4.7%
34%	12.8%	83.6%	83.8%	88.1%	6.2%