CALIFORNIA
AIR RESOURCES BOARD

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Sent via Overnight Delivery

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Attention: NHTSA Docket ID No. NHTSA-2018-0067
U.S. EPA Docket ID No. EPA- HO-OAR-2018-0283

Re: Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021-2026 Passenger Cars and Light Trucks

Dear Mr. Lieske and Mr. Tamm:

In reviewing supplemental public comments on the proposed Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021-2026 Passenger Cars and Light Trucks (the Proposal), including those submitted on April 19, 2019, by the Alliance of Automobile Manufacturers,[1] the California Air Resources Board (CARB) identified additional significant errors in the modeling done by the United States Environmental Protection Agency (U.S. EPA) and the National Highway Traffic and Safety Administration (NHTSA) (collectively, the Agencies) of technology costs. As we have previously commented, the Agencies wrongly overstated the costs of electrification

[1] Alliance Supplemental Comment, April 19, 2019, Docket No. NHTSA-2018-0067-12385; EPA-HQ-OAR-2018-0283-7455.

technology for meeting the greenhouse gas emissions and fuel economy standards.[2] Our further review in response to the supplemental comments reveals additional errors that we were unable to identify in the inadequate comment period initially provided. Because this is a matter "of central relevance to the rulemaking,"[3] CARB is submitting this supplemental comment letter.

Introduction

One facet of the CAFE Model used by the Agencies to model and evaluate the costs of compliance with greenhouse gas emission and fuel economy standards is an assessment of needed electrification technology on a given vehicle type. The CAFE Model treats electrification technologies hierarchically, first applying one and assessing if that is sufficient to comply with the standards, and, if not, moving to the next technology. The Model incrementally applies costs as it adds technologies. The Agencies published the electrification technology costs they purport to have used in the Proposal's notice of proposed rulemaking (NPRM) and Preliminary Regulatory Impact Analysis (PRIA); the input files for the CAFE Model also include the costs that were used by the Model.

In this supplemental comment letter, we focus most on the Start-Stop 12-Volt (SS12V) technology costs, as this is where the Agencies' significant mathematical error in cost development and Model application is introduced, producing unreasonably high SS12V costs. Moreover, because the CAFE Model incrementally applies costs as it adds further electrification technologies, the error compounds, substantially inflating high costs throughout all subsequent electrification technologies. The analysis provided in this supplemental comment yields the following conclusions:

- The SS12V and subsequent electrification technology costs within the PRIA (Table 6-30 and Tables 6-32 and 6-33) do not match, when they should (once converted to represent the same level of cost—Table 6-30 represents incremental costs, and Table 6-32 represents absolute costs). The SS12V costs in Tables 6-32 and 6-33 are notably higher than those in Table 6-30.

- The SS12V and subsequent electrification technology costs within the CAFE Model technology input file appear to align with PRIA Tables 6-32 and 6-33, but not PRIA Table 6-30. This is problematic in part because the Model applies electrification technology costs in the incremental manner as listed in Table 6-

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[2] CARB, Analysis in Support of Comments of the California Air Resources Board on the Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021-2026 Passenger Cars and Light Trucks, Docket Id No. EPA-HQ-OAR-2018-0283-5054, pp. 122-87.

[3] 42 U.S.C. § 7607(d)(4)(B)(i); *see also id.* § 7607(d)(7)(A) (providing that such material forms part of the administrative record for judicial review).

30, while PRIA Tables 6-32 and 6-33 purport to represent *absolute* costs which are not directly used by the Model.

- The discrepancies between PRIA Table 6-30 and Tables 6-32 and 6-33 and the Model input file are predominantly from a mathematical error: the Agencies wrongly used a cost for SS12V in the CAFE Model input file that already includes the cost of electric power steering (EPS) and improved accessories (IACC). Thus, the Model applies a SS12V cost that includes EPS and IACC on top of, instead of in lieu of, the EPS and IACC costs that were previously added to a vehicle. The extra EPS and IACC costs from this double-counting are then propagated through the rest of the electrification technologies due to the sequential way the CAFE Model applies electrification technology costs.

- The discrepancies between the cost values in the PRIA and the Model input file also in part stem from differences in the learning rate[4] multipliers. The learning rates actually applied in the Model are notably higher than those published as used by the Agencies in PRIA Table 6-34, resulting in higher modeled costs than those reported as used in the Proposal.

As a result, the Model substantially overestimates the costs of electrification technology used to meet the greenhouse gas emission and fuel economy standards. Indeed, the cost of SS12V for a small car in PRIA Table 6-32 and the NPRM CAFE Model input file is $271.38 higher than reported in PRIA Table 6-30, and approximately $200 to $215 higher than the value used by the Agencies in the 2016 CAFE Model and Draft Technical Assessment Report (TAR). Table 1 below provides the mismatching and high costs for SS12V, including, for reference, the costs used by the Agencies and CARB in the 2016 midterm review Draft TAR, as well as the 2016 CAFE Model and the 2015 National Academy of Sciences (NAS) study:

[4] The learning rate is a series of multiplier values generated by the Agencies to represent the reduction of the cost of a technology over time due to economies of scale and improved manufacturing efficiencies. Higher learning rate multiplier values mean smaller reductions in costs over time.

Table 1: SS12V Total Costs Across Different Tables and Data Sources for CY-2025 in 2016$						
Vehicle Type	Table 6-30 Line Item[5]	Tables 6-32 & 6-33	NPRM CAFE Model Tech Cost Input File	Mid-Term Review Draft TAR[6]	2016 CAFE Model[7]	2015 NAS Study[8]
SmallCar	$237.45	$508.83	$508.83	$292.18	$311.90	$336.77
MedCar	$260.72	$508.83	$508.83	$292.18	$342.40	$336.77
SmallSUV	$280.03	$508.83	$508.83	$331.27	$367.80	$336.77
MedSUV	$286.90	$568.69	$568.69	$331.27	$376.80	$381.60
Pickup	$324.38	$568.69	$568.69	$364.20	$426.00	$418.77

These errors pervade all calendar and model years. We explain these errors in detail below, beginning with the costs provided in the PRIA and then the costs used in the CAFE Model. We also examine the learning rates in both the PRIA and the Model that the Agencies' applied to these costs.

PRIA Costs

To begin, the Agencies summarized their estimated electrification costs in Tables 6-29 through 6-34 of the PRIA. We reprint those tables below to assist in the explanation of the issues, with relevant columns outlined in red. The Tables, as they are printed, are not particularly clear in their function for several reasons. First, the Tables require some explanation and calculation to understand what the Agencies estimated for the incremental and absolute costs of the various electrification technologies. Second, the result of those calculations, based on the information printed in the PRIA, show disparities in the costs of individual technologies among the different summary tables. Additional discrepancies arise when comparing the Tables to the costs within the CAFE Model Documentation, which we discuss further beginning on page 12.

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[5] These values were derived by applying an RPE of 1.5 and the learning rate value from Table 6.34 of the PRIA for SS12V (0.61) to the line item value from Table 6-30 for SS12V.
[6] We converted 2013$ to 2016$ using U.S. Department of Labor's Bureau of Labor Statistics' CPI Inflation Calculator from January of 2013 to January of 2016 as the input dates. This resulted in an inflation value of 2.88%.
[7] This version of the CAFE Model was used for the Agencies' Mid-Term Evaluation Draft TAR, available at ftp://ftp.nhtsa.dot.gov/CAFE/2016-Draft-TAR/Central-Analysis/Central%20Input.7z. We used the same 2013$ to 2016$ inflation value as with the Mid-Term Review Draft TAR.
[8] We converted 2010$ to 2016$ using U.S. Department of Labor's Bureau of Labor Statistics' CPI Inflation Calculator from January of 2010 to January of 2016 as the input dates. This resulted in an inflation value of 9.34%. We assumed NAS' medium car to be equivalent to the Agencies' SmallCar, MedCar, and SmallSUV; NAS' large car to be equivalent to the Agencies' MedSUV; and NAS' pickup to be equivalent to the Agencies' Pickup.

Starting with Tables 6-30 and 6-31, which provide direct manufacturing costs (referred to as "DMC" in some tables and equations) for various electrification technologies, the PRIA states:

> The direct manufacturing costs for this NPRM analysis are presented in the tables below. Costs have been updated to reflect 2016 dollars. Table 6-30 through Table 6-31 show the incremental costs that incorporates both the battery costs from BatPac and the individual components costs.[9]

Figure 1.

Table 6-30 - DMC for Electrification Technologies for this NPRM in 2016$

Electrification Technologies - Direct Manufacturing Cost (2016$)						
	SmallCar	**MedCar**	**SmallSUV**	**MedSUV**	**Pickup**	**Incremental to**
EPS	$93.59	$93.59	$93.59	$93.59	$93.59	BaseV
IACC	$49.55	$49.55	$49.55	$49.55	$49.55	EPS
SS12V	$259.51	$284.94	$306.04	$313.55	$354.51	IACC
BISG	$1,055.94	$1,055.94	$1,055.94	$1,212.01	$1,212.01	SS12V
CISG	$2,210.82	$2,797.66	$2,809.77	$3,432.94	$3,432.94	SS12V

Figure 2.

Table 6-31 - Hybrid Electrification Path - Direct Manufacturing (2016$)

	SmallCar	MedCar	SmallSUV	MedSUV	Pickup	Incremental to
SHEVP2	$1,977.82	$2,614.50	$2,128.50	$2,437.05	$2,572.18	CISG
SHEVPS	$1,875.25	$2,478.91	$2,018.12	$2,310.66	$2,438.79	SHEVP2
PHEV30	$3,076.60	$5,573.14	$3,564.29	$5,573.14	$5,573.14	SHEVPS
PHEV50	$3,289.28	$5,958.41	$3,810.69	$5,958.41	$5,958.41	PHEV30
BEV200	$452.85	$2,467.70	$147.29	$2,467.70	$2,467.70	PHEV50
FCV	$15,174.68	$15,174.68	$15,174.68	$15,174.68	$15,174.68	BEV200

Using this description provided by the Agencies, the absolute direct manufacturing cost of a technology can be calculated by sequentially working through each technology, and adding the cost for the technology that is identified in the "Incremental to" column to the cost listed in the line item for the technology in question.

[9] We understand "individual components costs" to mean, essentially, the non-battery costs for each technology—so that the costs provided in Tables 6-30 and 6-31 include both the battery and non-battery technology costs.

For example, to obtain SS12V costs for a "SmallCar" relative to a base vehicle, add the line item for the SS12V incremental cost ($259.51) in the SmallCar column to what it is incremental to, being IACC as shown in Table 6-30 ($49.55), which itself is incremental to the EPS cost ($93.59).[10] We show Table 6-30 again below with these costs identified in the red boxes.

Figure 3.

Table 6-30 - DMC for Electrification Technologies for this NPRM in 2016$

Electrification Technologies - Direct Manufacturing Cost (2016$)						
	SmallCar	**MedCar**	**SmallSUV**	**MedSUV**	**Pickup**	**Incremental to**
EPS	$93.59	$93.59	$93.59	$93.59	$93.59	**BaseV**
IACC	$49.55	$49.55	$49.55	$49.55	$49.55	**EPS**
SS12V	$259.51	$284.94	$306.04	$313.55	$354.51	**IACC**
BISG	$1,055.94	$1,055.94	$1,055.94	$1,212.01	$1,212.01	**SS12V**
CISG	$2,210.82	$2,797.66	$2,809.77	$3,432.94	$3,432.94	**SS12V**

The total of those incremental costs comes to $402.65. That number, based on the direction prescribed in Table 6-30, is the Agencies' estimate of the absolute direct manufacturing cost for SS12V in 2016 dollars relative to a base vehicle (absent any reductions from advancements in deploying the technology).

Table 2 below shows all the electrification technologies by vehicle type as listed in Tables 6-30 and 6-31 with their absolute direct manufacturing costs relative to a base vehicle calculated using the "Incremental to" instruction for Tables 6-30 and 6-31.

[10] Contrary to the logic described in Table 6-30, the CAFE Model does not treat SS12V as an incremental technology to EPS or IACC for cost. See *infra*, pp. 11-17, for more discussion and illustration.

Table 2: Absolute Direct Manufacturing Cost Calculated From Tables 6-30 and 6-31

Tech	SmallCar	MedCar	SmallSUV	MedSUV	Pickup
EPS	$93.59	$93.59	$93.59	$93.59	$93.59
IACC	$143.14	$143.14	$143.14	$143.14	$143.14
SS12V	$402.65	$428.08	$449.18	$456.69	$497.65
BISG	$1,458.59	$1,484.02	$1,505.12	$1,668.70	$1,709.66
CISG	$2,613.47	$3,225.74	$3,258.95	$3,889.63	$3,930.59
SHEVP2	$4,591.29	$5,840.24	$5,387.45	$6,326.68	$6,502.77
SHEVPS	$6,466.54	$8,319.15	$7,405.57	$8,637.34	$8,941.56
PHEV30	$9,543.14	$13,892.29	$10,969.86	$14,210.48	$14,514.70
PHEV50	$12,832.42	$19,850.70	$14,780.55	$20,168.89	$20,473.11
BEV200	$13,285.27	$22,318.40	$14,927.84	$22,636.59	$22,940.81
FCV	$28,459.95	$37,493.08	$30,102.52	$37,811.27	$38,115.49

However, the CAFE Model does not apply only the absolute direct manufacturing cost to a vehicle when the Model applies that technology. The Model works with technology costs in terms of the cost the consumer faces, or the manufacturers' suggested retail price (MSRP) of a vehicle. To convert the direct manufacturing cost of a technology to the additional retail cost added to the MSRP of a vehicle in the CAFE Model, the Agencies apply a Retail Price Equivalent (RPE) multiplier of 1.5[11] and a learning rate multiplier for the model year. In the case of SS12V in model year 2017, for instance, the learning rate is 0.81, sourced from Table 6-34 of the PRIA. Using this example, the Agencies describe the Model as performing the following calculation:

$$\$402.65\ (absolute\ DMC) \times 1.5(RPE\ multiplier) \times 0.81(learning) = \ \$489.22$$

Thus, according to Table 6-30, with RPE and learning rate multipliers applied, $489.22 is the CAFE Model's predicted retail price increase for adding SS12V technology to a base small car in 2016 dollars for the 2017 model year.

PRIA Tables 6-32 and 6-33 (reprinted below) purport to "show the *absolute* electrification cost *without batteries* relative to a baseline internal combustion engine, and *including learning effects and retail price equivalent factor*" (emphasis added).

[11] PRIA at 1174-77.

Figure 4.

Table 6-32 - Summary of Car and Small SUV Absolute Electrification Technology Cost without batteries vs. Baseline Internal Combustion Engine, Including Learning Effects and Retail Price Equivalent[363]

Name	Technology Pathway	CY-2017	CY-2021	CY-2025	CY-2029
EPS	Electric Improvements	$127.78	$119.33	$112.48	$107.39
IACC	Electric Improvements	$188.36	$156.72	$140.67	$131.35
CONV	Electrification	$ -	$ -	$ -	$ -
SS12V[364]	Electrification	$657.92	$568.03	$508.83	$473.05
BISG	Electrification	$1,137.19	$829.75	$714.98	$655.86
CISG	Electrification	$893.28	$781.09	$691.89	$651.54
SHEVP2	Hybrid/Electric	$2,206.07	$1,942.13	$1,732.29	$1,637.38
SHEVPS	Hybrid/Electric	$6,477.91	$5,664.33	$5,017.49	$4,724.85
PHEV30	Advanced Hybrid/Electric	$8,180.35	$6,956.06	$6,008.25	$5,587.55
PHEV50	Advanced Hybrid/Electric	$8,338.69	$7,011.23	$5,994.55	$5,546.75
BEV200[365]	Advanced Hybrid/Electric	$2,976.02	$2,324.66	$1,859.67	$1,664.95
FCV	Advanced Hybrid/Electric	$19,673.32	$17,607.59	$16,485.05	$15,702.81

Figure 5.

Table 6-33 - Summary of Truck and Medium SUV Absolute Electrification Technology Cost without batteries vs. Baseline internal combustion engine, including learning effects and retail price equivalent[366]

Name	Technology Pathway	CY-2017	CY-2021	CY-2025	CY-2029
EPS	Electric Improvements	$127.78	$119.33	$112.48	$107.39
IACC	Electric Improvements	$188.36	$156.72	$140.67	$131.35
CONV	Electrification	$ -	$ -	$ -	$ -
SS12V[367]	Electrification	$735.31	$634.85	$568.69	$528.70
BISG	Electrification	$524.86	$382.96	$329.99	$302.70
CISG	Electrification	$1,786.54	$1,562.17	$1,383.78	$1,303.07
SHEVP2	Hybrid/Electric	$1,924.68	$1,696.08	$1,514.34	$1,432.14
SHEVPS	Hybrid/Electric	$8,038.86	$7,029.24	$6,226.53	$5,863.38
PHEV30	Advanced Hybrid/Electric	$10,395.42	$8,839.62	$7,635.17	$7,100.55
PHEV50	Advanced Hybrid/Electric	$10,683.13	$8,982.46	$7,679.93	$7,106.23
BEV200	Advanced Hybrid/Electric	$4,351.27	$3,398.92	$2,719.04	$2,434.34
FCV	Advanced Hybrid/Electric	$25,969.16	$23,242.36	$21,760.59	$20,728.01

Notably, Tables 6-32 and 6-33 are not directly comparable to Tables 6-30 and 6-31 without some additional work. To compare the costs between both sets of tables,

Tables 6-30 and 6-31 need the battery costs specific to each technology removed.[12] The battery direct manufacturing costs are found in Table 6-29 (partially reprinted below as Figure 6). Then, the RPE multiplier (1.5) and the learning rate for the model year must be applied to the battery costs before being removed from the values in Tables 6-30 and 6-31.

Figure 6.

Table 6-29 - BatPac Results for Reference vehicle classes with MR0, Aero0 and Roll0.[362]

Specifications are for the highest demand configurations (MR0, AERO0 and ROLL0). Other demand configurations are sized differently.					
Technology Class	**Vehicle Powertrain**	**Battery Power (Watts)**	**Battery Total Energy (Wh)**	**BatPaC DMC Cost ($)**	**Motor Max Power (W)**
SmallCar	BISG	7692	806	650	10000
	CISG	18132	832	847	15000
	PHEV50	122496	22362	4656	102230
	SHEVP2	29670	1264	1294	26143
	SHEVPS	29670	1264	1294	56121
	PHEV30	50835	14432	3250	60718
	BEV200	132346	65718	10839	92672

However, even when that additional work is done, the costs do not match Tables 6-32 and 6-33. Consider an example of applying belt integrated starter generator technology (BISG, which is also often referred to as a type of 48-Volt mild hybrid technology) to a base vehicle:

$$\begin{aligned}\text{BISG absolute direct manufacturing cost from Table 6-30 for a SmallCar}\\ &= \$93.59\ (EPS\ Incremental) + \$49.55\ (IACC\ Incremental)\\ &+ \$259.51\ (SS12V\ Incremental) + \$1055.94\ (BISG\ Incremental)\\ &= \$1458.59\end{aligned}$$

From Table 6-29, the BISG battery direct manufacturing cost for a SmallCar is $650.[13] To find the BISG non-battery direct manufacturing cost without applying the RPE or

[12] Note that EPS and IACC never have additional battery costs, because their technologies do not require additional battery technology over a base vehicle. Moreover, SS12V is inclusive of battery cost both throughout the PRIA and in the CAFE Model technology input files—meaning battery cost does not need to be removed from SS12V.

[13] As noted by Table 6-29, this cost reflects no road load reductions—i.e., no mass reduction, aerodynamic improvements, or tire rolling-resistance improvements—as compared to a base vehicle. It also does not have the RPE or learning rate multipliers applied.

learning curve, subtract the BISG battery direct manufacturing cost from the BISG absolute direct manufacturing cost calculated from Table 6-30, as follows:

$$\text{BISG Non-battery DMC} = \$1458.59 - \$650 = \$808.59$$

Then, to find the BISG non-battery cost that would be added by the CAFE Model to the MSRP of a vehicle for model year 2017, multiply the BISG non-battery direct manufacturing cost calculated above by the learning effect multiplier for model year 2017 (found in Table 6-34 of the PRIA) and then multiply again by the RPE multiplier (1.5). The calculation is shown below:

$$\begin{aligned}&\text{CY-2017 Small Car BISG Non-Battery RPE}\\ &\quad = \$808.59\ (BISG\ Non\text{-}Battery\ DMC)\\ &\quad \times 0.93(BISG\ MY2017\ Learning\ Effect) \times 1.5\ (RPE) = \$1127.98\end{aligned}$$

Using this methodology, we calculated the non-battery RPE costs for calendar years 2017 and 2025 for the various vehicle classes and listed them in Table 3:

Table 3: Non-battery RPE Costs

Tech	CY-2017 Non-Battery RPE		CY-2025 Non-Battery RPE	
	SmallCar	MedSUV	SmallCar	MedSUV
EPS	$127.75	$127.75	$112.31	$112.31
IACC	$188.36	$188.36	$140.67	$140.67
SS12V	$489.22	$554.88	$368.42	$417.87
BISG	$1,127.98	$1,421.09	$691.34	$870.99
CISG	$2,464.23	$4,244.47	$1,881.29	$3,240.40
SHEVP2	$4,154.59	$6,133.28	$3,165.40	$4,672.97
SHEVPS	$7,215.69	$10,013.78	$5,508.76	$7,644.93
PHEV30	$8,590.14	$14,036.95	$6,230.21	$10,180.65
PHEV50	$11,038.17	$19,299.45	$7,849.36	$13,724.05
BEV200	$3,192.38	$11,694.87	$1,944.78	$7,124.46

These costs, calculated from the values in Tabled 6-30 and 6-31, can now be directly compared to the cost values listed in Tables 6-32 and 6-33. Because these costs now represent the same thing ("the absolute electrification cost without batteries relative to a baseline internal combustion engine, and including learning effects and retail price equivalent factor"), they should be identical; inexplicably, they are not. A comparison of costs in Table 4 for a model year[14] 2017 small car converted from Tables 6-30 and 6-31 to those provided in 6-32 illustrates this:

[14] Though not the same thing, "calendar year" and "model year" are used interchangeably by the Agencies in the PRIA. We use calendar year in the table here to be consistent with the PRIA tables, but use model year to describe the years in which the technology is applied.

Table 4: CY-2017 Small Car Non-Battery DMC			
Tech	**Table 6-32**	**Derived from Tables 6-30 & 6-31**	**Difference (6-32 minus 6-30)**
EPS	$85	$85	$0
IACC	$126	$126	$0
CONV	-	-	-
SS12V	$439	$326	$112
BISG	$1,506	$1,366	$139
CISG	$1,570	$3,224	-$1,655
SHEVP2	$2,959	$3,920	-$961
SHEVPS	$5,807	$5,924	-$117
PHEV30	$9,191	$5,286	$3,905
PHEV50	$10,914	$5,812	$5,101
BEV200	$14,449	$6,291	$8,158

There are notable discrepancies for all the technology costs between the two sets of tables (except EPS and IACC), and these discrepancies pervade throughout vehicle type and model year. Assuming the Agencies are not putting a thumb on the scale against the existing standards, it appears these errors arise from incorrect incremental cost calculations (as well as using different learning rates from what were printed in PRIA Table 6-34—see *infra*, pp. 22-24). Using incorrect costs has significant impacts on the modeled cost of compliance for manufacturers, as it skews the electrification costs projected for the existing/augural standards from which the Proposal's rollback is evaluated. Because the Agencies have not explained how any of the costs in Tables 6-30 through 6-32 were derived or estimated,[15] it is unclear which set of costs were the intended set to be used by the Agencies in their modeling efforts, let alone whether any of the sets of costs were correctly and accurately derived. What is clear is that the Agencies have two different sets of electrification costs with no explanation as to why, how, or which should be used.

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[15] Section 6.3.8.1 of the PRIA indicates that electrification costs "relies primarily on research published" by Argonne National Laboratory (ANL), yet the cited reference has no costs for SS12V systems. Indeed, section 6.3.9.1 of the PRIA confirms the Agencies came up with their own battery costs for SS12V systems: "...this analysis [the Proposal] developed the battery cost estimate and [sic] as ANL did not provide costs for this battery configuration." The Agencies provide no further details as to how costs were derived or what they were based on.

CAFE Model Costs

The costs in the PRIA (one of the cost sets, at least) should also match those used in the CAFE Model. Instead, the discrepancies continue, with the costs used in the Model being a third set of costs. With yet another different set of costs and no explanation of how it was derived or estimated, it is even more difficult to discern which, if any, set of costs is appropriate or accurate. Even so, given how the Agencies' absolute direct manufacturing costs were produced (incremental) and how the Model then applies them, the electrification values the Model produces are significantly overstated regardless of which set of costs are used.

The costs used in the CAFE Model, as published on NHTSA's CAFE Model webpage, can be found in two files: [2018_NPRM_technologies_ref.xlsx] and [2018_NPRM_technologies_with_BEV_and_FCV_ref.xlsx].[16] Those files can be located in the downloadable CAFE Model package under the following folder structure, where "Download Location" is the folder where the package was decompressed (i.e., unzipped to access the constituent files):

//Download Location/2018 CAFE Model/Central Analysis/input/

Both files contain the same costs of components and set of tabs, several of which are named for the 10 different vehicle platform types used in the modeling (e.g., SmallCar, SmallCarPerf, MedCar, MedCarPerf, etc.). Every vehicle platform tab contains several technology cost sections, one of which has incremental non-battery[17] electrification RPE cost data for each technology on model-year-by-model-year basis from 2015 to 2032.

The CAFE Model Documentation provided online[18] contains the rules and logic for how the Model applies electrification costs for any particular technology as it is applied to a vehicle. Section S4.2.3, Vehicle-Level Electrification Pathways, contains the specific logic for how the technologies are applied, while Sections S4.7.1 and S4.7.2 contain the information necessary to understand how the incremental technology costs are applied to each other for the various electrification and battery technologies. The CAFE Model uses the incremental costs listed to apply the absolute cost of a particular technology. For instance, in applying BISG, the Model first adds EPS and IACC (if the vehicle does not already have them), then SS12V, and then the

[16] https://www.nhtsa.gov/corporate-average-fuel-economy/compliance-and-effects-modeling-system
[17] Again, with the exception of SS12V, which always has additional battery cost included.
[18] ftp://ftp.nhtsa.dot.gov/CAFE/2021-2026_CAFE_NPRM/CAFE_Model/CAFE_Model/CAFE_Model_Documentation_NPRM_2018.pdf. The CAFE Model Documentation explains the rules for how specific technology costs are applied and what technology pathways the Model will follow. The CAFE Model generally uses the incremental costs from the input file and applies them incrementally, but there are specific caveats provided in the Documentation (e.g., EPS is included in the BISG incremental cost).

incremental cost for the BISG system (plus its additional battery cost). If the vehicle already had SS12V from a previous year, then the Model just adds the incremental BISG cost (plus battery cost).

To identify which cost the CAFE Model is using and compare that to what the Model is actually applying to a specific vehicle, one must look to the technology cost input file [2018_NPRM_technologies_with_BEV_and_FCV_ref.xlsx]. Figure 7 below is a partial screenshot of the file's tab providing the SmallCar incremental non-battery electrification RPE costs (with emphasis added in the form of red boxes to the most relevant values)[19]:

Figure 7.

	A	B	C	P	Q	R	S	T	U	V
1			SmallCar							
2	Index	Name	Technology Pathway	C-2015	C-2016	C-2017	C-2018	C-2019	C-2020	C-2021
41	38	EPS	Electric Improvements	132.59	130.06	127.78	125.60	123.47	121.36	119.33
42	39	IACC	Electric Improvements	82.10	70.62	60.58	52.98	46.61	41.40	37.39
43	40	CONV	Electrification	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44	41	SS12V	Electrification	727.91	688.89	657.92	630.06	607.73	586.46	568.03
45	42	BISG	Electrification	546.82	520.47	479.27	416.61	341.07	293.39	261.72
46	43	CISG	Electrification	232.89	236.74	235.36	232.96	226.68	220.71	213.06
47	44	SHEVP2	Hybrid/Electric	1,232.42	1,191.02	1,153.03	1,117.51	1,083.93	1,051.95	1,021.35
48	45	SHEVPS	Hybrid/Electric	6,006.73	5,786.89	5,584.63	5,395.46	5,216.61	5,046.28	4,883.24
49	46	PHEV30	Advanced Hybrid/Electric	2,023.19	1,934.09	1,852.73	1,777.19	1,706.27	1,639.20	1,575.44
50	47	PHEV50	Advanced Hybrid/Electric	258.76	246.59	235.51	225.26	215.66	206.60	198.02
51	48	BEV200	Advanced Hybrid/Electric	-5,559.86	-5,191.12	-4,862.08	-4,563.29	-4,288.78	-4,034.58	-3,797.93
52	49	FCV	Advanced Hybrid/Electric	12,974.00	11,942.47	11,334.63	10,988.85	10,796.45	10,663.53	10,596.36

Using the logic described in the CAFE Model Documentation, the absolute RPE costs were calculated for the same model years used in Tables 6-32 and 6-33. For example, to find the SS12V non-battery technology cost with RPE for model year 2017 that the CAFE Model would apply to a base vehicle, sum the incremental costs (which have been outlined by red boxes in Figure 7 for emphasis) for EPS ($127.78), IACC ($60.58), and SS12V ($657.92). This comes to a total of $718.50. Table 5 below shows the calculated absolute RPE costs from the CAFE Model input file for each calendar year highlighted in Tables 6-32 for the SS12V that can be applied to the SmallCar vehicle type:

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[19] We assume "C-" preceding the years in Row 2 of the input file refers to calendar year, even though it is slightly different from the "CY-" used in the PRIA tables. The Agencies provide nothing to the contrary.

Table 5: SmallCar Absolute Non-Battery Cost With RPE				
Tech	**CY 2017**	**CY 2021**	**CY 2025**	**CY 2029**
EPS	$127.78	$119.33	$112.48	$107.39
IACC	$60.58	$37.39	$28.19	$23.96
CONV	-	-	-	-
SS12V	$657.92	$568.03	$508.83	$473.05

To confirm how the Model is using the input file values, we identified several specific vehicle examples in the published NPRM CAFE Model runs to cross-check the costs. There are two places in the CAFE Model outputs for understanding how the Model is applying costs and technology. The first is the vehicle reports file, [vehicles_report.csv], located in the output section of the Model runs. The vehicle reports file contains the state of technology applied to each vehicle in the Model and its resultant price on a year-by-year basis for all scenarios run. It was located here, where "Install Folder" is the location the CAFE Model was run from on a user's computer:

//'Install Folder"/2018 CAFE Model/Central Analysis/output_CO2/CO2/reports-csv

The second place to examine how the Model applies technology costs are the technology trace files, which contain the logs of how the Model has worked through applying various states of technology in a model year to meet a manufacturer's compliance requirement. For the specific vehicle cross-check examples, we used "Scenario 0," representing the existing standards, under the CO_2 runs. That scenario corresponds to the technology trace file [cf_trace_sn0.txt], which is located in the CAFE Model folder structure here:

//'Install Folder"/2018 CAFE Model/Central Analysis/output_CO2/CO2/logs

The specific vehicle examples all have additional electrification technologies added to them by the Model. This allows for a cross-check between the calculated RPE technology costs from the technology input file and what is shown in the vehicle reports file.

<u>Vehicle #110164</u>

Vehicle #110164 is a GMC Terrain that is classified as a SmallSUVPerf with an initial MSRP of $26,250 for the 2015 model year. For the 2018 model year, the vehicle has several fuel consumption-reducing technologies added to it, including SS12V. Figure 8 below is a screenshot of the 2018 model year for vehicle #110164 in the Scenario 0 trace file:

Figure 8.

AO48502 | f_x =SUM(AO2485,AO2515,AO2609,AO2646,AO2634,AO2658,AO2673,AO2686,AO16352,AO16490,AO16766,AO24252,AO23554,AO28700,AO31192)

	A	C	D	E	Y	Z	AA	AB	AC	AD	AE	AO	AZ	BA	BB
1	LN	Scen	Mfr	Applies	Veh	Eng	Trn	Tech-Cl	Eng Tec	Techs	Year	Cost	FC-Adj	New FC	djKey
2485	2485	0	GENERAL I	A	110164	11036	11025	SmallSUVI	6C2B	TURBO1	2018	504.0741	DOHC; VV		TURBO1; AT6; CONV; ROLL20; MR0; AERO0
2515	2515	0	GENERAL I	A	110164	11036	11025	SmallSUVI	6C2B	AT6L2, AT	2018	126.8482	TURBO1; /		TURBO1; AT8; CONV; ROLL20; MR0; AERO0
2609	2609	0	GENERAL I	A	110164	11036	11025	SmallSUVI	6C2B	MR1	2018	24.256	TURBO1; /		TURBO1; AT8; CONV; ROLL20; MR1; AERO0
2634	2634	0	GENERAL I	A	110164	11036	11025	SmallSUVI	6C2B	AERO5	2018	54.8375	TURBO1; /		TURBO1; AT8; CONV; ROLL20; MR1; AERO5
2646	2646	0	GENERAL I	A	110164	11036	11025	SmallSUVI	6C2B	AERO10	2018	57.2747	TURBO1; /		TURBO1; AT8; CONV; ROLL20; MR1; AERO10
2658	2658	0	GENERAL I	A	110164	11036	11025	SmallSUVI	6C2B	AERO15	2018	46.3072	TURBO1; /		TURBO1; AT8; CONV; ROLL20; MR1; AERO15
2673	2673	0	GENERAL I	A	110164	11036	11025	SmallSUVI	6C2B	MR2	2018	25.6343	TURBO1; /		TURBO1; AT8; CONV; ROLL20; MR2; AERO15
2686	2686	0	GENERAL I	A	110164	11036	11025	SmallSUVI	6C2B	MR3	2018	65.7147	TURBO1; /		TURBO1; AT8; CONV; ROLL20; MR3; AERO15
16352	16352	0	GENERAL I	A	110164	11036	11025	SmallSUVI	6C2B	**EPS, IACC**	**2018**	**178.5812**	TURBO1; /		TURBO1; AT8; CONV; ROLL20; MR3; AERO15
16490	16490	0	GENERAL I	A	110164	11036	11025	SmallSUVI	6C2B	LDB	2018	86.6483	TURBO1; /		TURBO1; AT8; CONV; ROLL20; MR3; AERO15
16766	16766	0	GENERAL I	A	110164	11036	11025	SmallSUVI	6C2B	AERO20	2018	121.8611	TURBO1; /		TURBO1; AT8; CONV; ROLL20; MR3; AERO20
23554	23554	0	GENERAL I	A	110164	11036	11025	SmallSUVI	6C2B	MR4	2018	282.441	TURBO1; /		TURBO1; AT8; CONV; ROLL20; MR4; AERO20
24252	24252	0	GENERAL I	A	110164	11036	11025	SmallSUVI	6C2B	TURBO2	2018	593.592	TURBO1; /		TURBO2; AT8; CONV; ROLL20; MR4; AERO20
28700	28700	0	GENERAL I	A	110164	11036	11025	SmallSUVI	6C2B	CEGR1	2018	409.5325	TURBO2; /		CEGR1; AT8; CONV; ROLL20; MR4; AERO20
31192	31192	0	GENERAL I	A	110164	11036	11025	SmallSUVI	6C2B	**SS12V**	**2018**	**630.0572**	CEGR1; AT		CEGR1; AT8; SS12V; ROLL20; MR4; AERO20
48502											**SUM**	**$3,207.66**			

Highlighted for emphasis are the EPS, IACC, and SS12V costs. All of the technology costs applied for the 2018 model year in the trace file for this vehicle were then summed, which came to a total of $3,207.66. This was cross-referenced to the 2018 model year for the same vehicle in the vehicle report file, which is shown below in Figure 9 with the MSRP increase highlighted for emphasis.

Figure 9.

	A	B	C	D	E	F	G	H	BB	BC	BR	CI
1	Scenari	Scenari	Model	Manufa	Veh Inc	Veh Co	Brand	Model	MSRP I	MSRP	Tech Cost	FC TechKey
957	0	Augural C	2016	General M	955	110164	Gmc	Terrain	26250	26250	0	DOHC; VVT; SGDI; AT6; CONV; ROLL20; MR0; AERO0
2606	0	Augural C	2017	General M	955	110164	Gmc	Terrain	26250	26250	0	DOHC; VVT; SGDI; AT6; CONV; ROLL20; MR0; AERO0
4255	0	Augural C	2018	General M	955	110164	Gmc	Terrain	**26250**	**29457.66**	**3207.66**	CEGR1; AT8; SS12V; ROLL20; MR4; AERO20

The MSRP increase ($29,457.66 – $26,250.00 = $3,207.66) matches the value in the Tech Cost column, which also matches the sum of the added technology from Figure 8. A partial screenshot from the technology input file on the SmallSUVPerf vehicle type tab is shown below in Figure 10 with the added 2018 model year technology costs outlined by a red box for emphasis; they exactly match the EPS plus IACC ($178.58) and SS12V ($630.06) costs highlighted in the Scenario 0 trace file (Figure 8). This shows that the individual values for EPS, IACC, and SS12V in the CAFE Model input file are being used directly, without any additional modification.

Figure 10.

	A	B	C	P	Q	R	S
1		SmallSUVPerf					
2	Index	Name	Technology Pathway	C-2015	C-2016	C-2017	C-2018
41	38	EPS	Electric Improvements	132.59	130.06	127.78	125.60
42	39	IACC	Electric Improvements	82.10	70.62	60.58	52.98
43	40	CONV	Electrification	0.00	0.00	0.00	0.00
44	41	SS12V	Electrification	727.91	688.89	657.92	630.06
45	42	BISG	Electrification	546.82	520.47	479.27	416.61
46	43	CISG	Electrification	232.89	236.74	235.36	232.96
47	44	SHEVP2	Hybrid/Electric	1,232.42	1,191.02	1,153.03	1,117.51
48	45	SHEVPS	Hybrid/Electric	6,006.73	5,786.89	5,584.63	5,395.46
49	46	PHEV30	Advanced Hybrid/Electric	2,023.19	1,934.09	1,852.73	1,777.19
50	47	PHEV50	Advanced Hybrid/Electric	258.76	246.59	235.51	225.26
51	48	BEV200	Advanced Hybrid/Electric	-5,559.86	-5,191.12	-4,862.08	-4,563.29
52	49	FCV	Advanced Hybrid/Electric	12,974.00	11,942.47	11,334.63	10,988.85

<u>Vehicle #120060</u>

Another example of SS12V being applied can be seen with vehicle #120060, which is a Dodge Dart and classified as a SmallCarPerf. Shown below in Figure 11 is a partial screenshot from the trace file for the 2017 model year. This vehicle already had EPS applied, so IACC and SS12V were the only additional electrification technologies applied. The sum total cost of all the technologies applied equals $1,448.56.

Figure 11.

	A	C	D	E	Y	Z	AA	AB	AC	AD	AE	AO	AZ	BA
1	LN	Scen	Mfr	Applied	Veh	Eng	Trn	Tech-Cl	Eng Tec	Techs	Year	Cost	FC-Adj	New FC djKey
671	671	0	FCA	A	120060	12007	12012	SmallCarP	4C1B	IACC	2017	60.58	SOHC; VV	SOHC; VVT; VVL; AT6; CONV; ROLL20; MR0; AERO0
714	714	0	FCA	A	120060	12007	12012	SmallCarP	4C1B	MR1	2017	34.27	SOHC; VV	SOHC; VVT; VVL; AT6; CONV; ROLL20; MR1; AERO0
756	756	0	FCA	A	120060	12007	12012	SmallCarP	4C1B	MR3	2017	92.77	SOHC; VV	SOHC; VVT; VVL; AT6; CONV; ROLL20; MR3; AERO0
10871	10871	0	FCA	A	120060	12007	12012	SmallCarP	4C1B	AERO5	2017	56.65	SOHC; VV	SOHC; VVT; VVL; AT6; CONV; ROLL20; MR3; AERO5
10988	10988	0	FCA	A	120060	12007	12012	SmallCarP	4C1B	AERO10	2017	59.17	SOHC; VV	SOHC; VVT; VVL; AT6; CONV; ROLL20; MR3; AERO10
10993	10993	0	FCA	A	120060	12007	12012	SmallCarP	4C1B	AERO15	2017	47.84	SOHC; VV	SOHC; VVT; VVL; AT6; CONV; ROLL20; MR3; AERO15
11328	11328	0	FCA	A	120060	12007	12012	SmallCarP	4C1B	LDB	2017	88.32	SOHC; VV	SOHC; VVT; VVL; AT6; CONV; ROLL20; MR3; AERO15
11881	11881	0	FCA	A	120060	12007	12012	SmallCarP	4C1B	AERO20	2017	125.90	SOHC; VV	SOHC; VVT; VVL; AT6; CONV; ROLL20; MR3; AERO20
12224	12224	0	FCA	A	120060	12007	12012	SmallCarP	4C1B	MR4	2017	225.14	SOHC; VV	SOHC; VVT; VVL; AT6; CONV; ROLL20; MR4; AERO20
22000	22000	0	FCA	A	120060	12007	12012	SmallCarP	4C1B	SS12V	2017	657.92	SOHC; VV	SOHC; VVT; VVL; AT6; SS12V; ROLL20; MR4; AERO20
48502											SUM	$1,448.56		

The costs for both IACC and SS12V again match those that are in the technology input file as shown below in Figure 12, a screenshot with the model year 2017 IACC and SS12V costs boxed in red for emphasis.

Figure 12.

	A	B	C	P	Q	R	S	T
1			**SmallCarPerf**					
2	**Index**	**Name**	**Technology Pathway**	**C-2015**	**C-2016**	**C-2017**	**C-2018**	**C-2019**
41	38	EPS	Electric Improvements	132.59	130.06	127.78	125.60	123.47
42	39	IACC	Electric Improvements	82.10	70.62	60.58	52.98	46.61
43	40	CONV	Electrification	0.00	0.00	0.00	0.00	0.00
44	41	SS12V	Electrification	727.91	688.89	657.92	630.06	607.73
45	42	BISG	Electrification	546.82	520.47	479.27	416.61	341.07
46	43	CISG	Electrification	232.89	236.74	235.36	232.96	226.68
47	44	SHEVP2	Hybrid/Electric	1,232.42	1,191.02	1,153.03	1,117.51	1,083.93
48	45	SHEVPS	Hybrid/Electric	6,006.73	5,786.89	5,584.63	5,395.46	5,216.61
49	46	PHEV30	Advanced Hybrid/Electric	2,023.19	1,934.09	1,852.73	1,777.19	1,706.27
50	47	PHEV50	Advanced Hybrid/Electric	258.76	246.59	235.51	225.26	215.66
51	48	BEV200	Advanced Hybrid/Electric	-5,559.86	-5,191.12	-4,862.08	-4,563.29	-4,288.78
52	49	FCV	Advanced Hybrid/Electric	12,974.00	11,942.47	11,334.63	10,988.85	10,796.45

The tech cost and MSRP increase, as shown in the vehicle report file in Figure 13, also match the technologies sum of $1,448.56.

Figure 13.

	A	B	C	D	E	F	G	H	BB	BC	BR	CI
1	Scenari	Scenari	Model	Manufa	Veh Inc	Veh Co	Brand	Model	MSRP I	MSRP	Tech Cost	FC TechKey
271	0	Augural C	2016	FCA	269	120060	Dodge	Dart	24395	24395	0	SOHC; VVT; VVL; AT6; CONV; ROLL20; MR0; AERO0
1920	0	Augural C	2017	FCA	269	120060	Dodge	Dart	**24395**	**25843.56**	**1448.56**	SOHC; VVT; VVL; AT6; SS12V; ROLL20; MR4; AERO20

The above examples show how the Agencies are using the individual costs from the CAFE Model input file within the CAFE Model and how they are applied to a vehicle in the modeling runs. The Model is using the EPS, IACC, and SS12V costs exactly as listed in the technology input file and is applying them incrementally.

Implications

Understanding what costs are used by the Model and how they compare to what the Agencies provided in the PRIA is important to knowing where the disparities between the two may lie. CARB previously commented that the Agencies' modeled costs for electrification were overly inflated and lacked appropriate documentation or explanation of how those costs were developed. One of those electrification technologies, in particular, is SS12V. Table 6 below shows the incremental costs in several calendar years from the CAFE Model technology input file for each vehicle type:

Table 6: SS12V Technology Incremental Costs from CAFE Model Technology Input File				
	Year			
Vehicle Type	CY2017	CY2021	CY2025	CY2029
SmallCar	$657.92	$568.03	$508.83	$473.05
SmallCarPerf	$657.92	$568.03	$508.83	$473.05
MedCar	$657.92	$568.03	$508.83	$473.05
MedCarPerf	$657.92	$568.03	$508.83	$473.05
SmallSUV	$657.92	$568.03	$508.83	$473.05
SmallSUVPerf	$657.92	$568.03	$508.83	$473.05
MedSUV	$735.31	$634.85	$568.69	$528.70
MedSUVPerf	$735.31	$634.85	$568.69	$528.70
Pickup	$735.31	$634.85	$568.69	$528.70
PickupHT	$735.31	$634.85	$568.69	$528.70

As shown by Table 6, the cost of the SS12V technology in the CAFE Model technology input file is segmented into two bins, one for smaller vehicles (SmallCar, MedCar, etc.) and one for larger vehicles (MedSUV, Pickup, etc.). As shown in Table 1 in the introduction and reprinted again below, the SS12V costs from the Model technology input file match those listed in Tables 6-32 and 6-33 when they should not, as the input file is supposed to use incremental costs while Tables 6-32 and 6-33 represent absolute costs. Further, the input file costs are significantly higher when compared to the costs in Table 6-30 (even after RPE and learning have been added) even though they both purport to represent the same incremental costs.

Table 1: SS12V Total Costs Across Different Tables and Data Sources for CY-2025 in 2016$						
Vehicle Type	**Table 6-30 Line Item[20]**	**Tables 6-32 & 6-33**	**NPRM CAFE Model Tech Cost Input File**	**Mid-Term Review Draft TAR[21]**	**2016 CAFE Model[22]**	**2015 NAS Study[23]**
SmallCar	$237.45	$508.83	$508.83	$292.18	$311.90	$336.77
MedCar	$260.72	$508.83	$508.83	$292.18	$342.40	$336.77
SmallSUV	$280.03	$508.83	$508.83	$331.27	$367.80	$336.77
MedSUV	$286.90	$568.69	$568.69	$331.27	$376.80	$381.60
Pickup	$324.38	$568.69	$568.69	$364.20	$426.00	$418.77

We recalculated the absolute SS12V costs from Table 6-30 in two different ways in order to attempt to reconcile them with Tables 6-32 and 6-33 and the Model technology input file. One method follows the 'Incremental to' logic from Table 6-30 (which we illustrated earlier on pages 5-6) which combines the costs for EPS, IACC and SS12V to reach the absolute cost per the incremental directions in the PRIA. The second method, however, uses the SS12V line item from Table 6-30 as the stand-alone absolute cost per the direction of the CAFE Model Documentation that indicates SS12V is a stand-alone technology evaluated independently of EPS and IACC. The recalculated values are shown in the tables below:

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[20] These values were derived by applying an RPE of 1.5 and the learning rate value from Table 6.34 of the PRIA for SS12V (0.61) to the line item value from Table 6-30 for SS12V.

[21] We converted 2013$ to 2016$ using U.S. Department of Labor's Bureau of Labor Statistics' CPI Inflation Calculator from January of 2013 to January of 2016 as the input dates. This resulted in an inflation value of 2.88%.

[22] This version of the CAFE Model was used for the Agencies' Mid-Term Evaluation Draft TAR, available at ftp://ftp.nhtsa.dot.gov/CAFE/2016-Draft-TAR/Central-Analysis/Central%20Input.7z. We used the same 2013$ to 2016$ inflation value as with the Mid-Term Review Draft TAR.

[23] We converted 2010$ to 2016$ using U.S. Department of Labor's Bureau of Labor Statistics' CPI Inflation Calculator from January of 2010 to January of 2016 as the input dates. This resulted in an inflation value of 9.34%. We assumed NAS' medium car to be equivalent to the Agencies' SmallCar, MedCar, and SmallSUV; NAS' large car to be equivalent to the Agencies' MedSUV; and NAS' pickup to be equivalent to the Agencies' Pickup.

Table 7: SS12V Technology RPE Cost Recalculated from 6-30 with Incremental Logic				
	Year			
Vehicle Type	C-2017	C-2021	C-2025	C-2029
SmallCar	$488.86	$416.43	$368.15	$337.97
MedCar	$520.12	$443.06	$391.69	$359.59
SmallSUV	$545.75	$464.90	$411.00	$377.31
MedSUV	$554.88	$472.67	$417.87	$383.62
Pickup	$604.64	$515.07	$455.35	$418.03

Table 8: SS12V Technology Line Item RPE Cost from Table 6-30				
	Year			
Vehicle Type	C-2017	C-2021	C-2025	C-2029
SmallCar	$314.94	$268.28	$237.45	$217.74
MedCar	$346.20	$294.91	$260.72	$239.35
SmallSUV	$371.84	$316.75	$280.03	$257.07
MedSUV	$380.96	$324.52	$286.90	$263.38
Pickup	$430.73	$366.92	$324.38	$297.79

These recalculated tables point to two things. First, regardless the method, there are differences in cost for SS12V technology among each of the vehicle types. This is not what is represented in the PRIA Tables 6-32 and 6-33, nor in the CAFE Model technology input files, which purport to only have two sets of costs—one for smaller vehicles and one for larger vehicles. Second, Table 7 has cumulative costs of EPS, IACC, and SS12V that closely align with what the CAFE Model technology input file uses for stand-alone costs of just the SS12V system. Third, Table 8 above has absolute costs for the stand-alone SS12V system that are more consistent with what was published by the Agencies and CARB in the Draft TAR during the midterm evaluation in 2016. Table 9 below includes the cost values from the Draft TAR for SS12V technology for various vehicle types:

Table 9: SS12V Technology Total Cost from Draft TAR[24]				
	Year			
Vehicle Type	CY2017	CY2021	CY2025	CY2029
SmallCar	$377.00	$299.00	$284.00	-
MedCar	$377.00	$299.00	$284.00	-
SmallSUV	$427.00	$339.00	$322.00	-
MedSUV	$427.00	$339.00	$322.00	-
Pickup	$469.00	$372.00	$354.00	-

The difference between the values calculated from the single line item (Table 8) and the values used in the CAFE Model runs appears to come largely from the erroneous inclusion of additional EPS and IACC costs that should not have been part of the cost for SS12V used in the CAFE Model. Discovery of this error was further confounded by additional mistakes made in the PRIA.

When looking at the values from Table 6-32 and 6-33 in 2017, EPS and IACC are shown as having absolute costs of $127.78 and $188.36, respectively. In the CAFE Model technology input file, EPS and IACC are listed as having costs of $127.78 and $60.58, respectively. However, IACC technology is not actually incremental or overlapping with EPS as explained by the CAFE Model Documentation. While IACC is applied sequentially to EPS, its absolute costs are not the sum of EPS and IACC. Thus, the IACC absolute costs in Tables 6-32 and 6-33 mistakenly have EPS included in them when they should not (the sum of EPS ($127.78) and IACC ($60.58) costs from the CAFE Model Technology input file is equal to the single IACC line item cost ($188.36) in Tables 6-32 and 6-33). However, as illustrated with the example of Vehicle #110164 shown above (pages 14-16), the Model applies each individual technology cost from the technology cost input file separately—meaning the costs for IACC ($188.36) in Tables 6-32 and 6-33 are misstated and not representative of what is actually used in the Model ($60.58). In this particular instance, the mistake appears to be limited to only a wrong value listed in Tables 6-32 and 6-33. This, however, is not the case when scrutinizing the SS12V costs.

To understand the possible sources of disparity among the SS12V costs stated in Tables 6-32 and 6-33, Table 6-30, the CAFE Model technology input file, and the Agencies previous Draft TAR, we calculated corrected values for Tables 6-32 and 6-33 by removing EPS and IACC costs from the SS12V costs to represent the incremental costs of the SS12V system as intended to be used by the model. An example

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[24] Sourced from: Table 5.84, page 5-301 of Draft TAR. We assumed Small Car = SmallCar, Standard car = MedCar, Small MPV = Small SUV, Large MPV = MedSUV, and Truck = Pickup.

calculation is provided below for clarity, along with the table (Table 10) of the generated values:

$$\begin{aligned}&Recalculated\ SS12V\ Cost\\&\quad = SS12V\ Cost\ (Tables\ 6\text{-}32\ and\ 6\text{-}33) - EPS\ Cost\ (Tables\ 6\text{-}32\ and\ 6\text{-}33)\\&\quad - IACC\ Cost\ (corrected\ Tables\ 6\text{-}32\ and\ 6\text{-}33)\end{aligned}$$

$$\begin{aligned}&Recalculated\ Small\ Car\ SS12V\ Cost\ for\ CY\text{-}2017\ model\ year\\&\quad = \$657.92 - \$127.78 - \$60.58 = \$469.56\end{aligned}$$

Table 10: Recalculated SS12V Costs from Tables 6-32 and 6-33 without EPS and IACC

Vehicle Type	Year			
	C-2017	C-2021	C-2025	C-2029
SmallCar	$469.56	$411.31	$368.16	$341.70
SmallCarPerf	$469.56	$411.31	$368.16	$341.70
MedCar	$469.56	$411.31	$368.16	$341.70
MedCarPerf	$469.56	$411.31	$368.16	$341.70
SmallSUV	$469.56	$411.31	$368.16	$341.70
SmallSUVPerf	$469.56	$411.31	$368.16	$341.70
MedSUV	$546.95	$478.13	$428.02	$397.35
MedSUVPerf	$546.95	$478.13	$428.02	$397.35
Pickup	$546.95	$478.13	$428.02	$397.35
PickupHT	$546.95	$478.13	$428.02	$397.35

The recalculated cost values shown in Table 10 above (derived from Tables 6-32 and 6-33) are much more in line with those from Table 7 (derived from Tables 6-30), differing by less than five percent on average. Finally achieving a match between the costs in Table 6-30 and Tables 6-32 and 6-33 and without any further information, the SS12V costs used in the Model apparently contain two erroneous incremental cost additions: one for EPS and one for IACC. In other words, the SS12V line item for cost mistakenly contains an EPS cost and an IACC cost in addition to the SS12V cost. Accordingly, any base vehicle that gets SS12V applied would first get the cost of EPS and IACC applied and then additionally get the cost of SS12V applied, which erroneously also includes the cost of EPS and IACC technologies. This arithmetic error has the effect of significantly inflating the costs of electrification technology of the existing standards and thus exaggerating the benefits of the Proposal's rollback.

Additional differences in the SS12V cost values come from further discrepancies between the learning rates that are printed in the PRIA and the learning rates that are actually used in the CAFE Model technology cost input file. The PRIA learning rates are in Table 6-34 (reprinted below):

Figure 14.

Table 6-34 - Learning rate for electrification technologies from MY 2016 to MY 2032

Technology	Model Year																
	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
CONV	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
SS12V	0.86	0.81	0.77	0.74	0.71	0.69	0.67	0.65	0.63	0.61	0.6	0.59	0.57	0.56	0.56	0.55	0.54
BISG	0.98	0.93	0.87	0.81	0.73	0.68	0.64	0.61	0.59	0.57	0.55	0.54	0.52	0.51	0.5	0.5	0.49
CISG. SHEVPS	0.96	0.93	0.89	0.86	0.83	0.81	0.78	0.76	0.73	0.71	0.69	0.68	0.67	0.66	0.65	0.64	0.64
SHEVP2	0.87	0.84	0.81	0.78	0.76	0.73	0.71	0.69	0.66	0.64	0.63	0.62	0.61	0.6	0.59	0.58	0.58
PHEV30	0.95	0.91	0.87	0.84	0.8	0.77	0.74	0.71	0.69	0.66	0.64	0.63	0.61	0.6	0.6	0.59	0.58
PHEV50	0.95	0.9	0.86	0.83	0.79	0.76	0.73	0.7	0.67	0.64	0.62	0.61	0.59	0.58	0.57	0.57	0.56
BEV200	0.93	0.87	0.81	0.76	0.72	0.67	0.63	0.6	0.56	0.53	0.51	0.49	0.48	0.46	0.45	0.45	0.44

The costs in the CAFE Model's technology input file already include the learning rate multipliers, so we back-calculated the learning rate multipliers the Model was actually applying for all vehicle types. The calculation of that learning rate appears to use calendar year 2015 costs as the reference value (1.00) with subsequent years being calculated as a percentage relative to that reference year cost.[25] The following equation describes the calculation:

$$Technology\ learning\ for\ a\ specific\ year = \frac{Technology\ cost\ in\ that\ specific\ year}{Technology\ cost\ in\ reference\ year\ (2015)}$$

An example calculation for the Model's learning rate for SS12V technology in model year 2017 on a small car is provided below:

$$\begin{aligned} &SS12V\ learning\ multiplier\ (2017) \\ &\qquad = (SS12V\ incremental\ cost\ in\ 2017)/(SS12V\ incremental\ cost\ in\ 2015) \\ &\qquad = \$657.92/\$727.91 = 0.90 \end{aligned}$$

We calculated the learning rates in the CAFE Model of the incremental costs for SS12V electrification technology and for BISG technology for small cars across all calendar years. The results of those calculations are shown in Table 11 below, with the differences from the Table 6-34 values calculated as well:

[25] The reference year appears to be 2015, as costs in the input file extend back to 2015. However, the Agencies do not actually state a reference year any of the electrification technologies, so it is unclear if 2015 is universally the reference year; for purposes of this letter, we assumed it was.

Table 11: SS12V and Small Car BISG Technology Learning Rates from CAFE Model Technology Input File and PRIA Table 6-29 with Calculated Difference						
Year	SS12V			BISG		
	Model (Calculated)	PRIA Table 6-34	Difference	Model (Calculated)	PRIA Table 6-34	Difference
CY-2015	1.00	-	-	1.00	-	-
CY-2016	0.95	0.86	0.09	0.95	0.98	-0.03
CY-2017	0.90	0.81	0.09	0.89	0.93	-0.04
CY-2018	0.87	0.77	0.10	0.82	0.87	-0.05
CY-2019	0.83	0.74	0.09	0.74	0.81	-0.07
CY-2020	0.81	0.71	0.10	0.69	0.73	-0.04
CY-2021	0.78	0.69	0.09	0.65	0.68	-0.03
CY-2022	0.76	0.67	0.09	0.62	0.64	-0.02
CY-2023	0.74	0.65	0.09	0.60	0.61	-0.01
CY-2024	0.72	0.63	0.09	0.58	0.59	-0.01
CY-2025	0.70	0.61	0.09	0.56	0.57	-0.01
CY-2026	0.68	0.60	0.08	0.55	0.55	0.00
CY-2027	0.67	0.59	0.08	0.53	0.54	-0.01
CY-2028	0.66	0.57	0.09	0.52	0.52	0.00
CY-2029	0.65	0.56	0.09	0.51	0.51	0.00
CY-2030	0.64	0.56	0.08	0.51	0.5	0.01
CY-2031	0.63	0.55	0.08	0.50	0.5	0.00
CY-2032	0.63	0.54	0.09	0.50	0.49	0.01

The difference between the PRIA and what is used in the Model is quite significant, between eight and ten percentage points. Particularly with the SS12V technology, the higher learning rates used in the Model serve to keep technology costs higher, as the Model assumes economies of scale and efficiency improvements do not permeate as quickly as the rates printed in PRIA Table 6-34. Several other electrification technologies have similar differences between what is printed in Table 6-34 and what is actually used in the CAFE Model by the Agencies.

Conclusion

Further examination of the PRIA, the CAFE Model, and the Model's inputs with respect to electrification technology has shown several substantial inconsistencies and disparities between what was used in the Model and what the Agencies' documented in the PRIA. Those disparities appear to originate with the SS12V costs, which are unrealistically and erroneously high. It is unclear how or why, but the SS12V costs in the Model's input file mistakenly include the costs of EPS and IACC such that, when used by the Model, the SS12V, EPS, and IACC costs are added on top of EPS and

IACC costs that have already been applied to the vehicle. The double-counting of EPS and IACC costs is then propagated through the rest of the electrification technologies due to the sequential way the CAFE Model applies those electrification technology costs. That is, subsequent costs added for more advanced electrification technologies like BISG, SHEVPS/P2, etc. also contain these same extra costs. Because the CAFE Model has most vehicles adopting SS12V technology at a minimum, this math error is far reaching. Moreover, the Model consistently uses SS12V learning rate multipliers that are significantly higher than those stated in the PRIA, which further overestimates system costs and drives up electrification costs produced by the Model.

When the inconsistency of the cost values is coupled with the extreme lack of documentation of how these costs are derived, it leaves the public without the ability to understand why the costs are what they are and what should be applied. Indeed, that the public cannot even rely on the PRIA to accurately summarize what the Agencies actually did – because of both inconsistencies within the PRIA and between the PRIA and the Model – is unacceptable. Yet, at minimum, the result of these inconsistencies and disparities is an exaggeration of electrification costs under the existing standards and an inflation of the Proposal's benefits. The Agencies' reliance on these inaccurate electrification costs to justify the Proposal's rollback would be arbitrary and capricious, and thus the Agencies must abandon the proposed rollback.

Sincerely,

Mike McCarthy
Chief Technology Officer
Executive Office

cc: Richard W. Corey
CARB Executive Officer