EXHIBIT A

Comments of the National Coalition for Advanced Transportation

Docket Nos. NHTSA-2018-0067, EPA-HQ-OAR-2018-0283, NHTSA-2017-0069

October 26, 2018

From: Charmley, William
Sent: Monday, June 18, 2018 12:51 PM
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Subject: Material for today's Light-duty GHG NPRM discussion.

Dear Chad, Chandana, and Jim –

Attached are materials for our conference call this afternoon. Most of this material you have seen previously, here is what we have sent for our discussion

1) An EPA staff presentation dated today, which builds off of our April 16, 2018 presentation to OIRA. This is what we would like to discuss with OIRA today. The file is 8 pages, and is named "1. EPA Staff Review of CAFE Model for OMB June 18, 2018.pdf"

2) An EPA staff memo dated today, which includes the detailed assessment supporting the information in today's presentation

3) EPA initial observations on the CAFE model from February 9, 2018

4) EPA further observations on the CAFE model and inputs from February 28, 2018

5) EPA Presentation to OMB from April 16, 2018

Thanks
Bill

Summary points from EPA review of CAFE model (NPRM version) – Effect of EPA code revisions

Meeting with Office of Management and Budget/OIRA

6/18/2018

Growth in Fleet Size Due to Scrappage Model

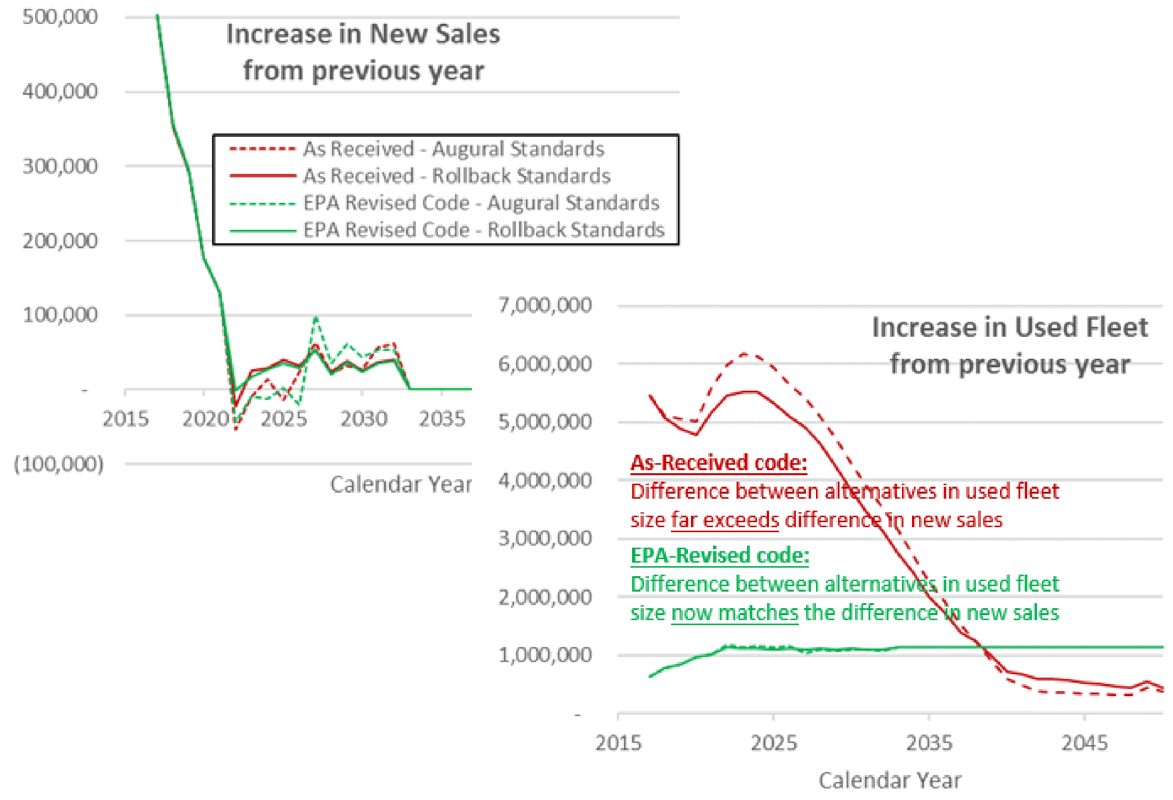
Issues with CAFE model implementation

The new vehicle sales model produces small reductions in projected sales under the Augural standards, while the scrappage model projects an increase in fleet size that far outweighs the sales reductions (by a factor of 60:1.) The combined result is a fleet size that grows much more rapidly than AEO projections.

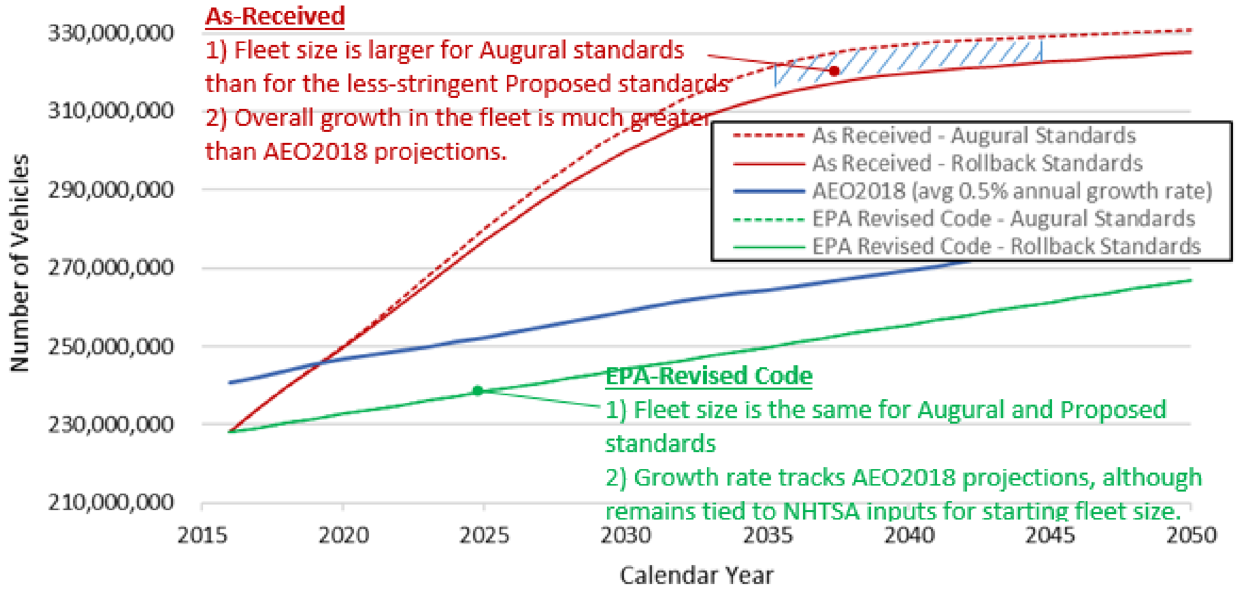
EPA-Revised code issue resolution

Specific the overall fleet growth as an input, and scale the scrappage rate curves (maintain the new sales model as is)

Year-over-year change in new vehicle sales (top) and increase in used fleet size (bottom) (note the difference in y-axis scale)



Total Fleet size

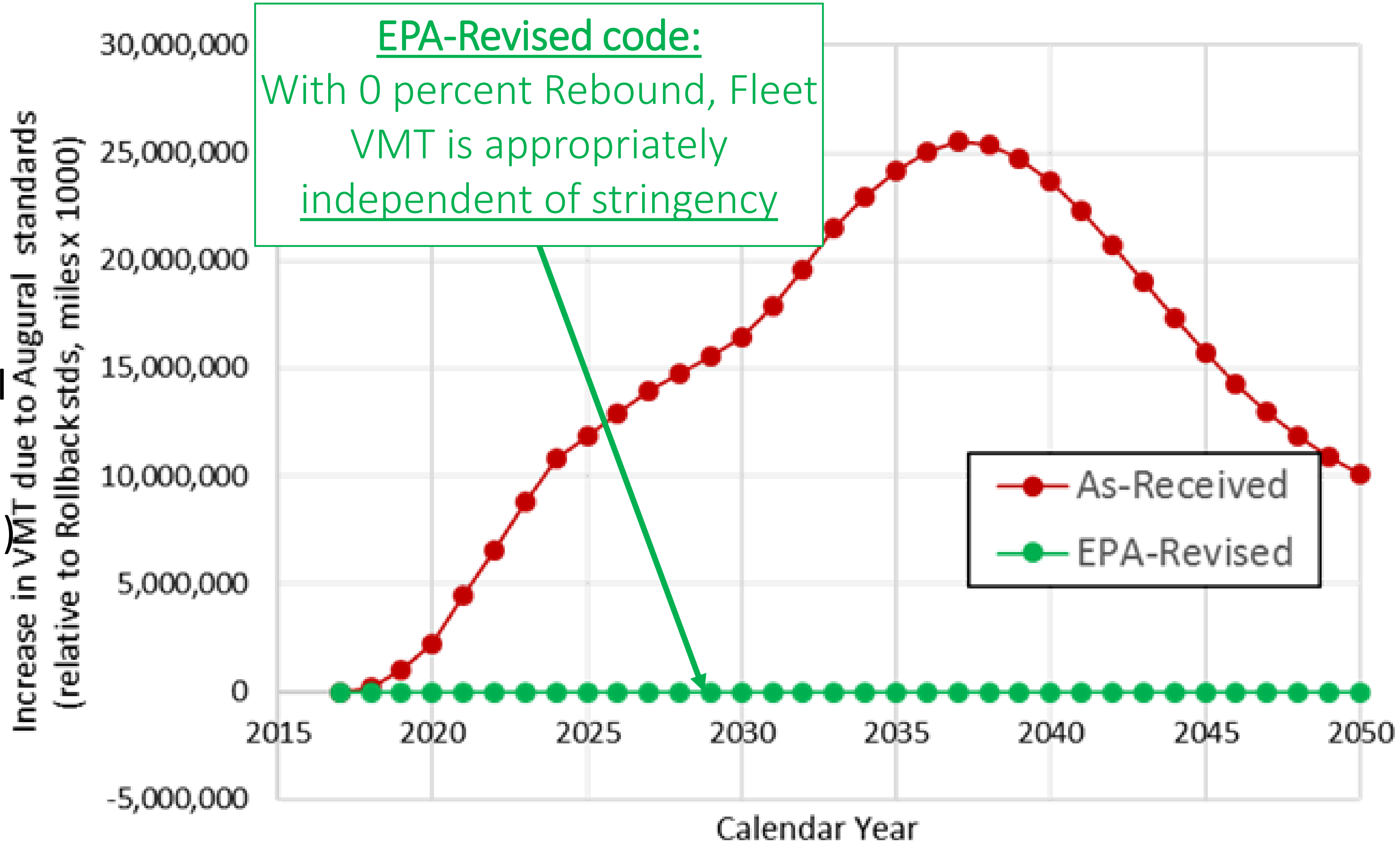


Growth in VMT beyond the intended rebound-related increase

<u>Issues with CAFE model implementation</u>
Per-vehicle VMT schedules are fixed, and not dependent on the scrappage model. As a result, total VMT can vary in an unexpected/unintended ways (e.g., VMT changes with zero rebound, zero rebound growth more expensive new and used vehicles.)

<u>EPA-Revised code issue resolution</u>
Scale per-vehicle VMT schedules so that total VMT is consistent with definition of rebound (i.e. Total VMT remains constant across regulatory alternatives at 0 percent rebound.)

Change in VMT due Augural standards, with 0 percent rebound (relative to Proposed standards)



Anomalous definition of cost-per-mile (CPM) reference in rebound calculations

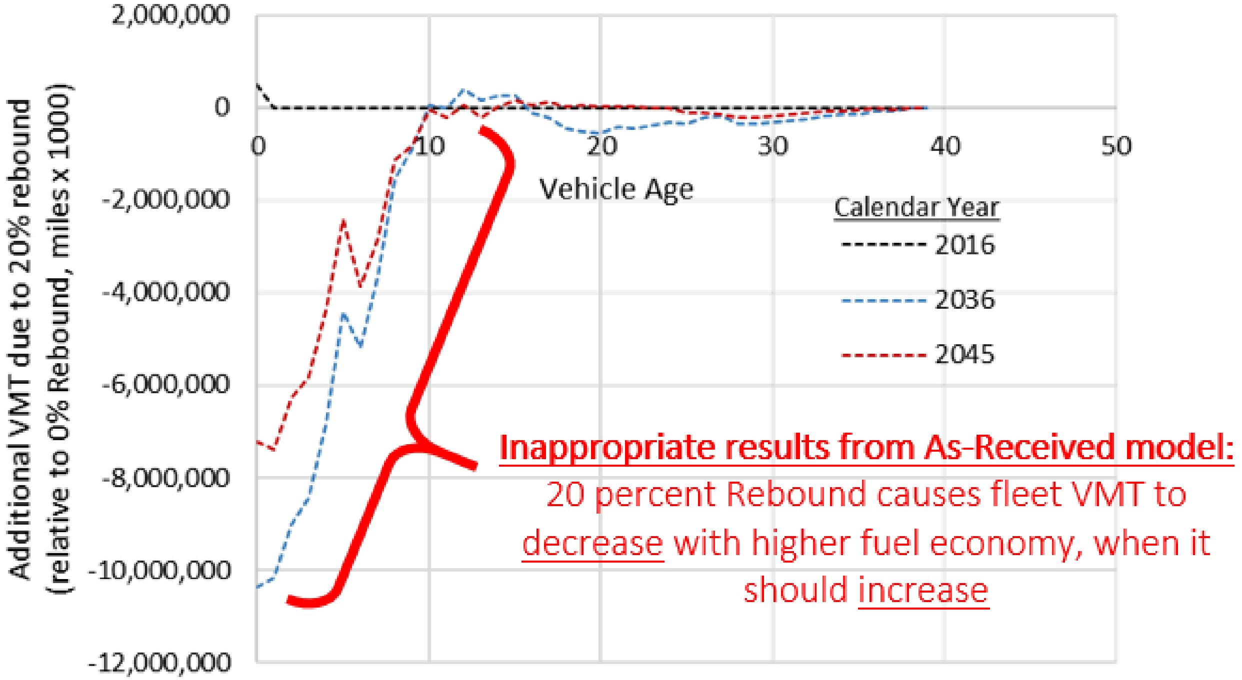
Issues with CAFE model implementation

The CPM 'reference' in calculation of rebound VMT erroneously tracks FE values backward in time. (i.e. Analysis year MY2017 uses a MY2015 FE reference; MY2018 uses a MY2014 FE reference; MY2019 uses a MY2013 FE reference, etc.) The fuel price in the CPM 'reference' remains fixed in CY2016, while fuel price projections in future analysis years generally increase. The combined effect produces an anomalous results with VMT reductions under the Proposed standards, despite increases in FE.

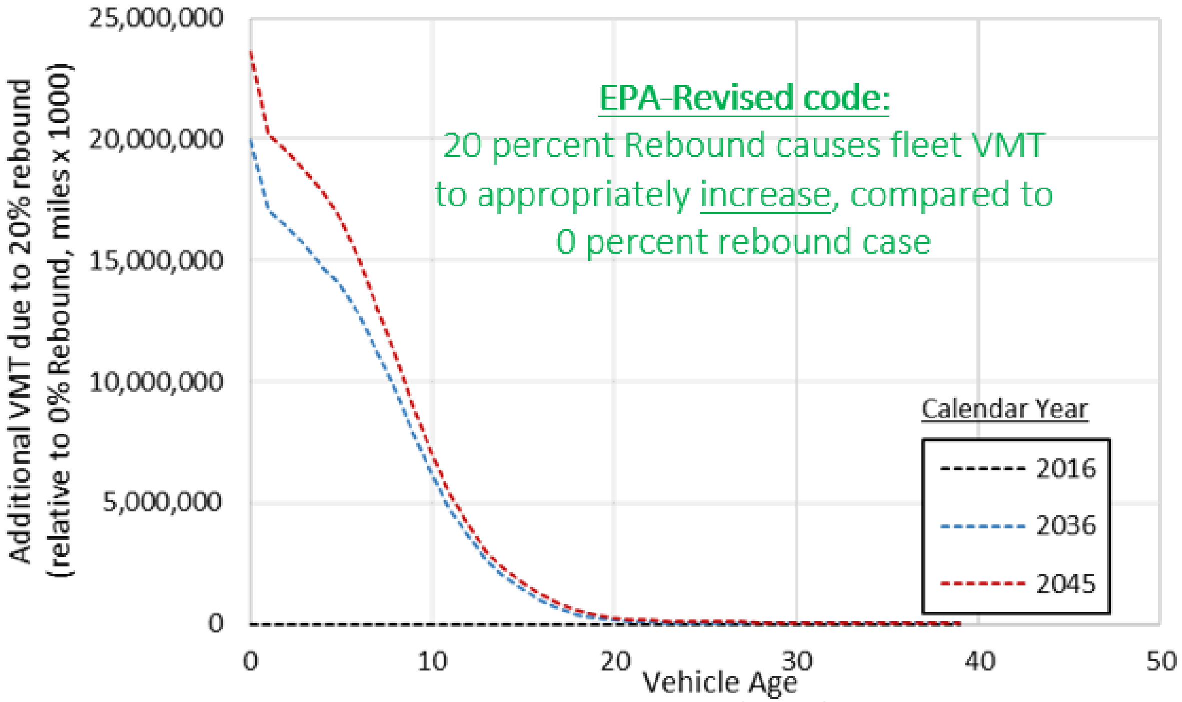
EPA-Revised code issue resolution

CPM 'reference' is defined based on each vehicle's own MY2016 baseline FE, and the current analysis year fuel price.

Change in VMT due to 20 percent rebound, Proposed standards case (relative to 0 percent rebound)



As-Received code



EPA-revised code

Model logic contains an error in ranking factor for manufacturer tech package application decisions

Background of CAFE model logic

Cost-minimizing 'Efficiency' metric is used to select packages. Based on tech cost, fuel savings to consumer (2.5 years), consumer welfare loss from electrified vehicles, and manufacturer valuation of compliance credits

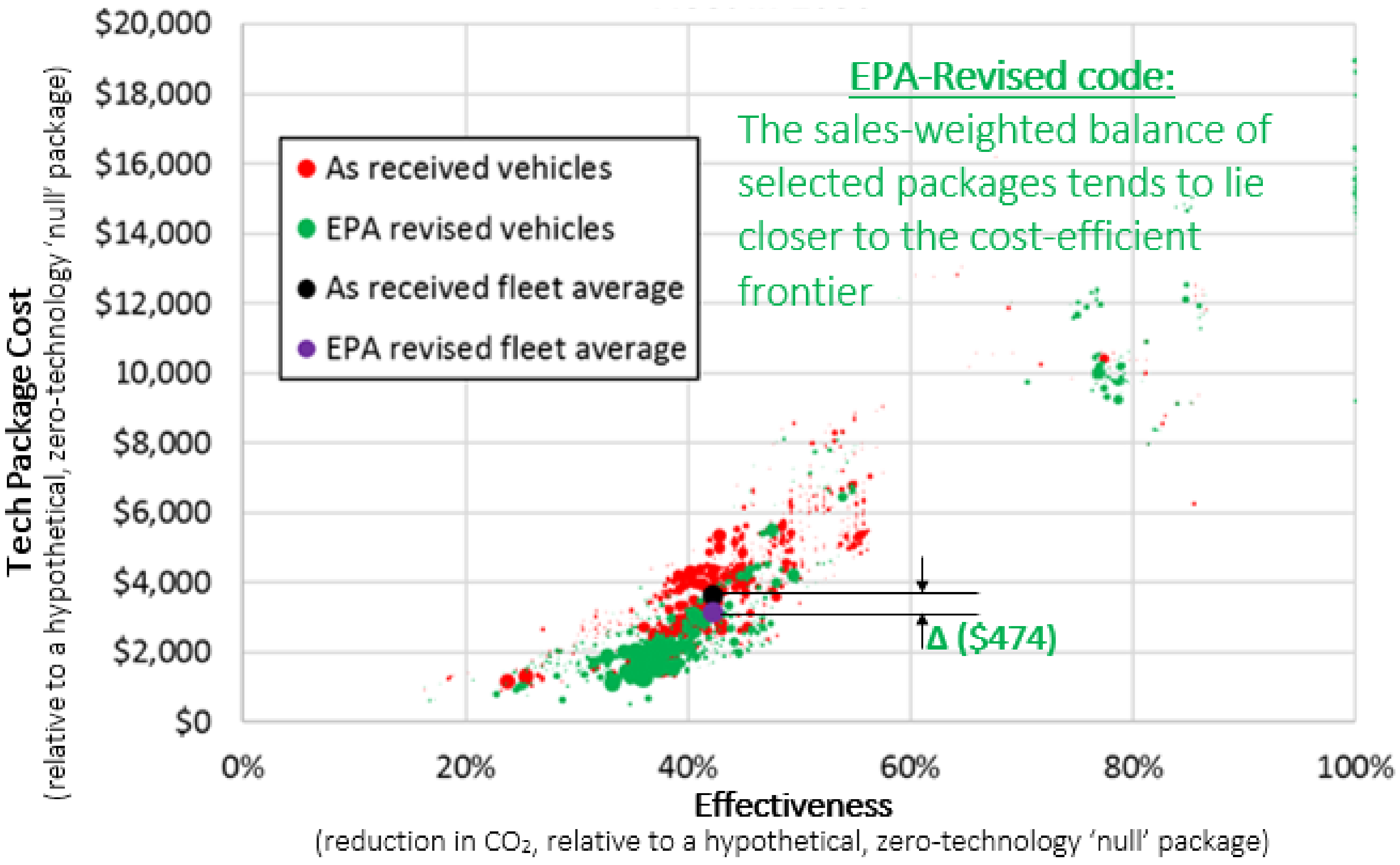
Issues with CAFE model implementation

- In GHG mode, **reducing CO_2 below a vehicle's CO_2 target is erroneously given a manufacturer valuation of zero.**
- Consumer welfare loss for electrified vehicles is taken as the difference between technology cost and observed WTP for electrification from transaction price

EPA-Revised code issue resolution

- 'Efficiency' metric revised so that net cost per gCO_2 credit is minimized, regardless of above or below vehicle target CO_2 value
- Results in significant reduction in tech costs, and more efficient utilization of available technology packages, including electrification

Cost and Effectiveness of MY2030 vehicles relative to a 'null' tech package



Model logic for determining manufacturer compliance status inhibits fleet averaging (car-truck trading)

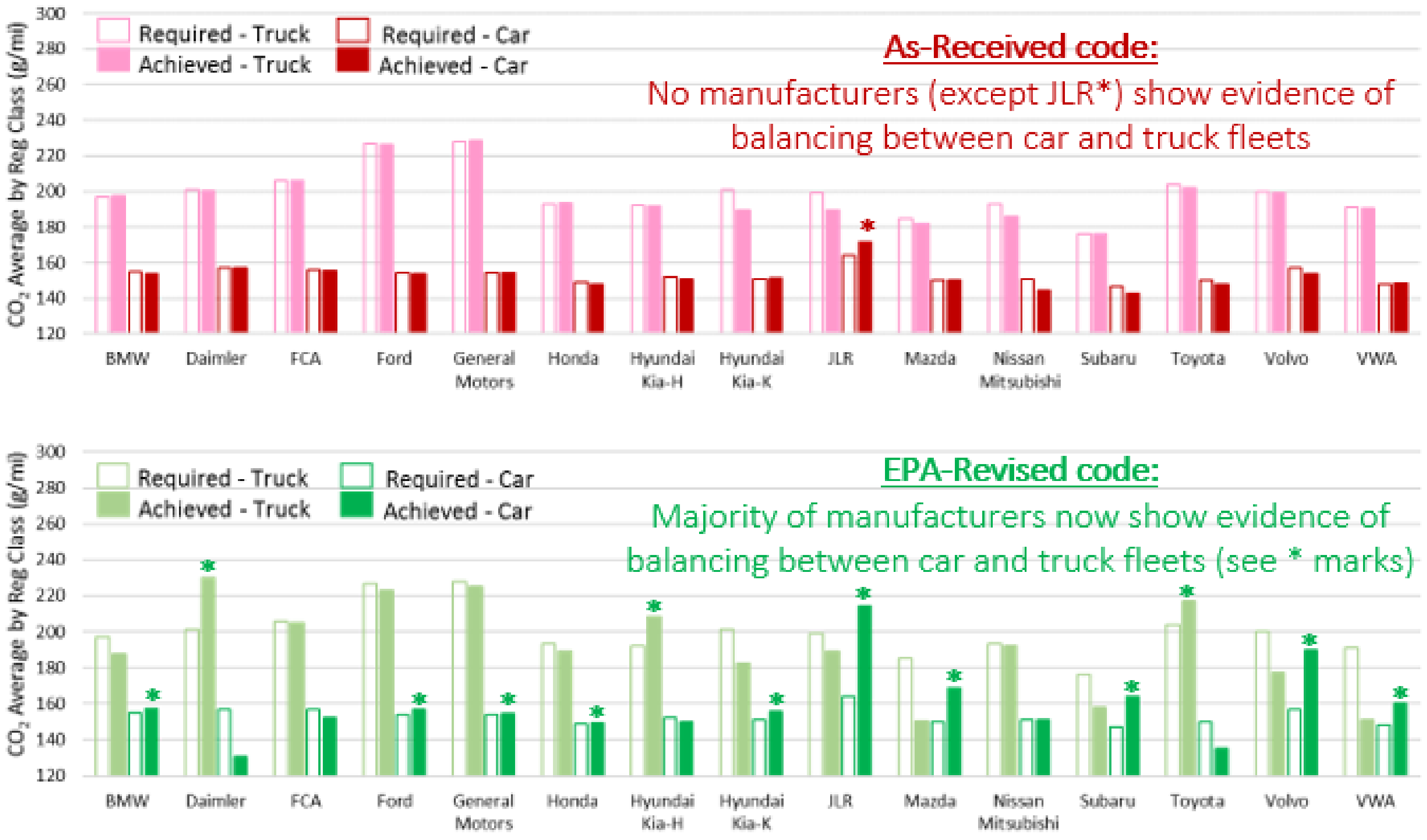
Issues with CAFE model implementation

- Logic for manufacturer compliance status requires that both car and truck fleets have positive credits. As a result, within-year transfer of credits between car and truck fleets is prevented.

EPA-Revised code issue resolution

- Changed the manufacturer compliance status determination so that a positive sum of car and truck fleet credits will be appropriately considered as 'in compliance.' The results show broad transfer of credits between car and truck fleets, as would be expected.

MY2030 Required and Achieved CO2 levels for Each manufacturers regulatory car and truck fleets



Technology Cost and Fuel Savings Results: Comparison of As-Received (Apr17) and EPA-revised code

Table 3 Technology Costs, Fuel Savings, Payback

Source	As Received		EPA Revised Code	
Scenario	Augural	Proposed	Augural	Proposed
MYs	2017-2025	2021-2026	2017-2025	2021-2026
Annual Rate of Stringency Increase	No Action	0%/yr PC 0%/yr LT	No Action	0%/yr PC 0%/yr LT
Total Tech Costs, $/veh, MY2030 relative to MY2016 packages	$2,518	$639	$2,044	$474
Incremental Tech Costs, $/veh, MY2030	Baseline	-$1,879	Baseline	-$1,570
Fuel Savings, $/veh, MY2030 (3% discounting) *	Baseline	-$1,519	Baseline	-$1,734
Payback based on Total Cost of Ownership 20% Rebound (years, 3% discounting)	11.6	4.1	3.5	1.0

*Negative fuel savings indicate an increase on consumer spending on fuel.

Fatality and Net Benefits Results: Comparison of As-Received (Apr17) and EPA-revised code

Table 4 Changes in Fatality Metrics and Net Social Benefits

Source	As Received		EPA Revised Code	
Scenario	Augural	Proposed	Augural	Proposed
MYs	2017-2025	2021-2026	2017-2025	2021-2026
Annual Rate of Stringency Increase	No Action	0%/yr PC 0%/yr LT	No Action	0%/yr PC 0%/yr LT
Change in Average Annual Fatalities, Calendar Years 2036-2045, No Rebound *	Baseline	-150	Baseline	+17
Change in Average Annual Fatalities per Trillion Miles, Calendar Years 2036-2045, No Rebound	Baseline	+4.5	Baseline	+6.9
Average Annual Employment, Lifetimes of MY2016-2032 vehicles	Baseline	-35,020	Baseline	-27,269
Change in Net Social Benefits, 20% Rebound, excluding rebound-related fatality and non-fatal crash costs and 'value-loss' associated with electrified vehicles, ($Billions, 3% discounting) **	Baseline	+$49	Baseline	-$83

*The change in average annual fatalities during CYs 2036-2045 including the additional miles driven voluntarily due to rebound are projected by the model as -863 (As-Received) and -321 (EPA-Revised).
**The change in net social benefits inclusive of rebound-related fatality and non-fatal crash costs and NHTSA's 'value-loss' associated with electrified vehicles would be +$202 billion for the As-Received code and +$103 billion for the EPA-Revised code. Social benefits sum Technology, Maintenance/Repair, Value Loss, Pretax Fuel, Drive and Refuel Value, Fatality, Crashes/Congestion/Noise and all Emission Damage costs changes for the lifetimes of MY2016 through 2032 vehicles; a negative Net Social Benefit represents a net social cost.

EPA Further Review of CAFE Model & Inputs, June 18, 2018

Overview

Since first receiving a copy of the CAFE model executable from NHTSA in January, EPA technical staff have been attempting to answer the question of whether or not the model and its inputs are suitable for use in representing the EPA GHG program for the upcoming NPRM. We have adopted a number of approaches, including in-depth analysis of the input and output files, running the executable model with alternate settings which more closely represent the GHG program, and using input files that reflect EPA's technical assessments. Our initial findings stemming from this work were summarized in the briefing we gave to OIRA career staff on April 16th, with additional detail in our March 1st materials.[1] Among these findings were several issues related to the internal logic and calculations within the CAFE model. First, the scrappage model produces vastly unrealistic growth in the overall fleet size, which in turn causes an unrealistic over-inflation of the fatalities estimated for the Augural standards.[2] Second, the technology packages applied by the model tend to be much more costly than necessary for any specified set of inputs and application constraints. Finally, the model tends to produce fleets that over-comply and make sub-optimal use of available credits, resulting in an unrealistic over-estimation of costs.

In this memo, we document our investigation of the underlying computer code for the version of the CAFE Model as received from NHTSA on April 13, 2018. We also document a small number of modifications to the CAFE Model code. The combined effects of our revisions are presented in tables and figures at the end of this memo.

Altogether, the effects of our code revisions on the CAFE model outputs are substantial, and resolve several of the most indefensible aspects of the CAFE model's representation of the GHG program. Compared to the results from the As-Received version, our EPA-Revised version provides technology costs that are nearly $500 lower[3] and safety outcomes that show the Proposed standards are detrimental to safety, rather than beneficial as suggested by the As-Received version. In other words, results with our code revisions indicate that the Proposed standards would result in an increase in the fatality rate of 7 deaths per trillion miles driven, and an average increase of 17 fatalities per year in CYs2036-2045 relative to the Augural standards.[4] Additionally, the EPA-Revised version shows that the Augural standards have a consumer payback period of 3.5 years, instead of the 11.6 year payback period in the As-Received model. Additionally, both As-Received and EPA-Revised code suggest job losses under

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[1] Document titled 'EPA Feb 28, 2018 findings on review of NHTSA Jan-22, 2018 CAFE model runs'

[2] In this memo, we use the term "Augural standards" for ease of discussion since that term is used throughout the As-Received input files provided by NHTSA/Volpe to reference the standards that would align with EPA's existing MY 2022 to 2025 standards.

[3] For the Augural standards, the MY2030 technology cost increase from the baseline vehicle fleet is estimated to be $2,044 per vehicle (EPA-Revised version), compared to $2,518 per vehicle (As-Received version.) The incremental technology cost for the Augural standards relative to the Proposed standards in MY2030 is estimated to be $1,570 (EPA-Revised version), compared to $1,879 (As-Received version.)

[4] The safety outcomes from our EPA-Revised CAFE model version show 17 additional fatalities per year attributable to the Proposed standards, excluding any fatalities that occur from voluntary changes in VMT due to the rebound effect.

the Proposed standards, with 35,000 and 27,000 jobs lost per year, respectively. Finally, the EPA-revised version shows that the Proposed standards would reduce Net Social Benefits by $83B, in stark contrast with the increase of $49B indicated by the As-Received version.[5]

In summary, with the EPA-Revised version of the CAFE model;

- Proposed standards increase fatalities by 17 fatalities per year in CYs 2036-2045
- Proposed standards increase fatality rate by 7 deaths per trillion miles driven in CYs 2036-2045
- Proposed standards result in 35,000 jobs lost per year
- Proposed standards reduce Net Social Benefits by $83B
- Augural standards have a consumer payback period of 3.5 years

Scope of this memo

The significant changes in outcomes with our EPA-Revised version for the CAFE model were achieved solely by correcting some erroneous and otherwise problematic elements of the model's logic and algorithms. We did not make any modifications to the input files, or to the particular elements of the CAFE model that constrain technology applications based on platform sharing and redesign cycle considerations. While the results of the EPA-Revised version of the CAFE model are now directionally closer to our previous work where we used our own tools and models for the 2012 FRM, 2016 DTAR, and 2016 Proposed Determination, we are not endorsing the use of our modified version of the CAFE model for use in policy setting for the GHG program, in part because of the range of issues we have previously identified with the modeling inputs and assumptions—such as unduly high battery costs, production-ready but unconsidered and/or overly constrained technologies and technology application processes, etc.—that are outside of the scope of this memo and are not addressed by the EPA-revised version of the CAFE model.

Note that we did not attempt to evaluate the suitability of the As-Received version for policy use in the CAFE program. While some of the issues that we identify here are unique to the GHG program (e.g. accounting for the compliance value of CO_2 credits), other elements are common to both the GHG program and the CAFE program (e.g. the implementation of the rebound effect calculations, and logic and decision rules for comparing and selecting cost-efficient technology packages.) Given the opportunity, we would therefore recommend that NHTSA consider these issues further before using the As-Received version of the model for setting policy for the CAFE program.

Table 1 CAFE model changes itemized by NHTSA in the draft NPRM text – Scope of this EPA review

NHTSA-identified changes since 2012 FRM	Within scope of this memo?
Expansion of model inputs, procedures, and outputs to accommodate technologies not included in prior analyses	Not addressed in this memo
Updated approach to estimating the combined effect of fuel-saving technologies using large scale simulation modeling	Not addressed in this memo
Modules that dynamically estimate new vehicle sales and existing vehicle scrappage in response to changes to new vehicle prices that result from manufacturers' compliance actions	See Issue #1 in this memo

[5] These net social benefit values exclude the additional fatality and non-fatal crash costs from voluntarily-driven miles associated with rebound, and the 'value loss' that NHTSA adds on top of the tech costs for electrified vehicles.

A safety module that estimates the changes in light-duty traffic fatalities resulting from changes to vehicle exposure, vehicle retirement rates, and reductions in vehicle mass to improve fuel economy	See Issue #1 in this memo
Disaggregation of each manufacturer's fleet into separate "domestic" passenger car and "import" passenger car fleets to better represent the statutory requirements of the CAFE program	Not addressed in this memo
Changes to the algorithm used to apply technologies, enabling more explicit accounting of shared vehicle components (engines, transmissions, platforms) and "inheritance" of major technology within or across powertrains and/or platforms over time	See Issue #3 in this memo
An industry labor quantity module which estimates net changes in the amount of U.S. automobile labor for dealerships, Tier 1 and 2 supplier companies, and original equipment manufacturers (OEMs)	Not addressed in this memo
Cost estimation of batteries for electrification technologies incorporates more direct and internally consistent use of Argonne National Laboratory's BatPAC (battery) model for HEVs, PHEVs and BEVs	Not addressed in this memo
Expanded accounting for CAFE credits carried over from years prior to those included in the analysis (a.k.a. "banked" credits) and application to future CAFE deficits,	See Issue #3 in this memo*
The ability to represent a manufacturer's preference for fine payment (rather than achieving full compliance exclusively through fuel economy improvements) on a year-by-year basis,	See Issue #3 in this memo

* Also discussed in the 'Unresolved Issues' section of this memo.

Table 2 CAFE model revisions specific to GHG program – Scope of this EPA review

NHTSA-identified changes since 2012 FRM	Within scope of this memo?
Calculation of vehicle models' CO2 emission rates before and after application of CO2-reducing technologies	Not addressed in this memo
Calculation of manufacturers' fleet average CO2 emission rates under attribute-based CO2 standards	Not addressed in this memo
Accounting for adjustments to average CO2 emission rates reflecting reduction of air conditioner refrigerant leakage	Not addressed in this memo
Accounting for the treatment of alternative fuel vehicles for CO2 compliance	See Issue #3 in this memo
Accounting for production "multipliers" for compressed natural gas (CNG) vehicles, plug-in hybrid electric vehicles, (PHEVs), battery electric vehicles (BEVs), and fuel cell vehicles (FCVs)	Not addressed in this memo
Accounting for transfer of CO2 credits between regulated fleets	See Issue #3 in this memo
Accounting for carried-forward (aka "banked") CO2 credits, including credits from model years earlier than modeled explicitly	Not addressed in this memo

Issue #1: Unrealistic growth in overall fleet size due to scrappage model

Background on the CAFE model approach for developing a fleet of new and used vehicles in each calendar year

The As-Received version of the CAFE model contains two elements added since the 2012 FRM which are intended to dynamically estimate new vehicle sales and existing vehicle scrappage in response to the various regulatory alternatives under consideration. The first element is a Dynamic Fleet Share model (DFS), which estimates new vehicle sales and car/truck split as a function of vehicle price (as determined by the average MY2016 vehicle price plus the average additional technology costs to future standards in a given year) and the macroeconomic variables of GDP and a consumer confidence index.[6] The second element is a scrappage model which estimates the quantity of used vehicles remaining in each calendar year by vehicle type and age. The Volpe-developed scrappage rate equation was estimated by a regression of historical new vehicle prices, and average fuel costs per mile for the car, van/SUV, and pickup vehicle types.[7] As shown in Figure 1, the total fleet in each calendar year is the combination of the outputs from these two fleet models: a fleet of new vehicles sold in that year, and a fleet of used vehicles of various ages remaining in the fleet that have not been scrapped.

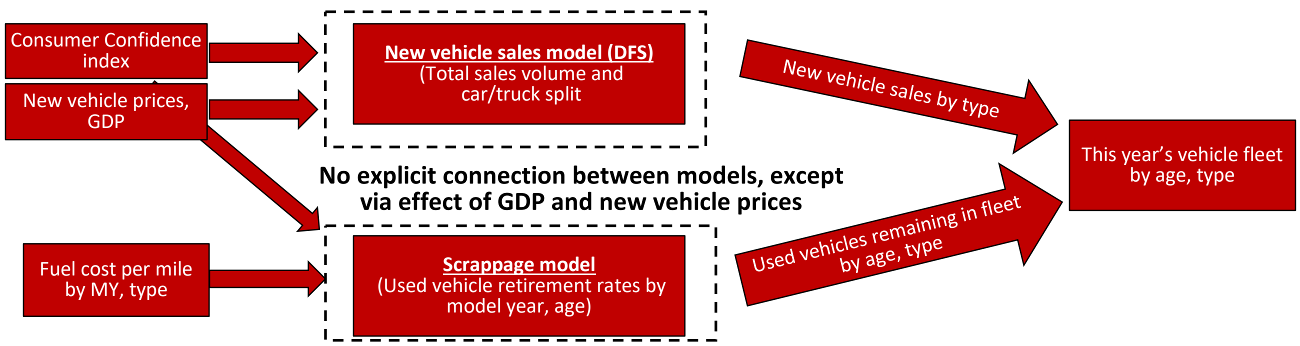


Figure 1 As-Received CAFE model generation of total fleet of registered vehicles by in each calendar year

Directionally, the incorporation of new vehicle price as an independent variable tends to drive the individual outputs of sales and scrappage models in offsetting ways; higher vehicle prices result in lower new vehicle sales and additional retention of existing vehicles, while lower vehicle prices result in greater new vehicles sales and increased scrappage of existing vehicles. However, these models operate completely independently, and there is no mechanism within the CAFE model to reconcile the combined effects of the sales and scrappage models in order to produce a realistic total fleet of registered vehicles.

Identification of the problem with the overall fleet size in the CAFE model

The effect of the disconnect between the new sales and scrappage models in the As-Received version is illustrated in Figure 2. Both the new sales fleet (i.e. vehicles of age 0) and the used fleet (i.e. vehicles of age greater than 0) generally increase year-over-year in the Augural and Proposed cases. For the used fleet, this is an expected trend since new vehicle prices and GDP increase for both the Augural and

[6] In other words, the DFS is a consumer choice model.

[7] The scrappage model represents an added layer of consumer choice modeling in that it attempts to predict whether consumers will purchase new or retain used vehicles and the types of vehicles consumers will continue to drive versus shed in favor of a new purchase. As with the dynamic fleet share model, we do not believe that such a model should be integrated into the primary analysis and should instead be presented as a sensitivity, if at all.

Proposed cases, resulting in the model's prediction of delayed scrappage. The new vehicle sales model has increasing sales for all but a few years, indicating that the positive effects of GDP growth generally outweigh the negative effect of increased vehicle prices.

While directionally those trends are logical, the difference in the magnitude of impact the Augural standards have on the new sales and scrappage models is difficult to justify. The As-Received model estimates that the Augural standards will reduce the year-over-year annual increase sales of new vehicles by approximately 8,000 vehicles on average between CY2021 and CY2032. However, during the same period, the As-Received model estimates that the used fleet will grow by an average of 512,000 vehicles per year, far exceeding the decrease in new vehicle sales. It's hard to imagine any real-world scenario under which over 60 additional used vehicles are retained for each new vehicle that the sales model predicts will be unsold as a result of the higher new vehicle prices.

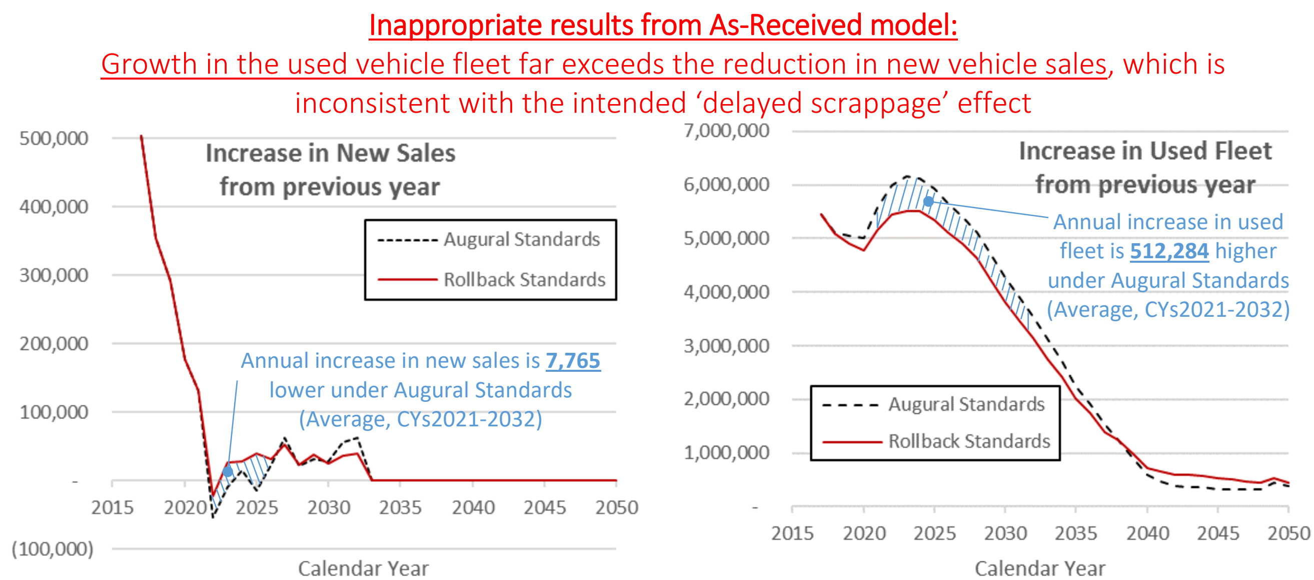


Figure 2 Year-over-year increase in new vehicle sales (left) and increase in used fleet size (right) using As-Received CAFE model (note the difference in y-axis scale)

Figure 3 shows the combined effect of the new vehicle sales model and the scrappage model in the As-Received version of the CAFE model. A change in the overall fleet size due to the Augural standards might not in and of itself be problematic, as long as the VMT schedules are adjusted to account for overall travel activity that is distributed over a larger number of vehicles. However, the As-Received version of the model does not adjust VMT schedules, with the result that the additional unscrapped vehicles inflate total VMT proportionately. During the period over which the summary statistics for fatalities are reported in the draft NPRM (CYs 2036-2045), the difference in the estimated fleet sizes between the Augural and Proposed standards is approximately 7 million vehicles, or over 2% of the roughly 300 million vehicles in the fleet. The effect of this error is to erroneously inflate the total VMT, and thus increase the estimated fatalities due to the Augural standards by many hundreds of lives.[8]

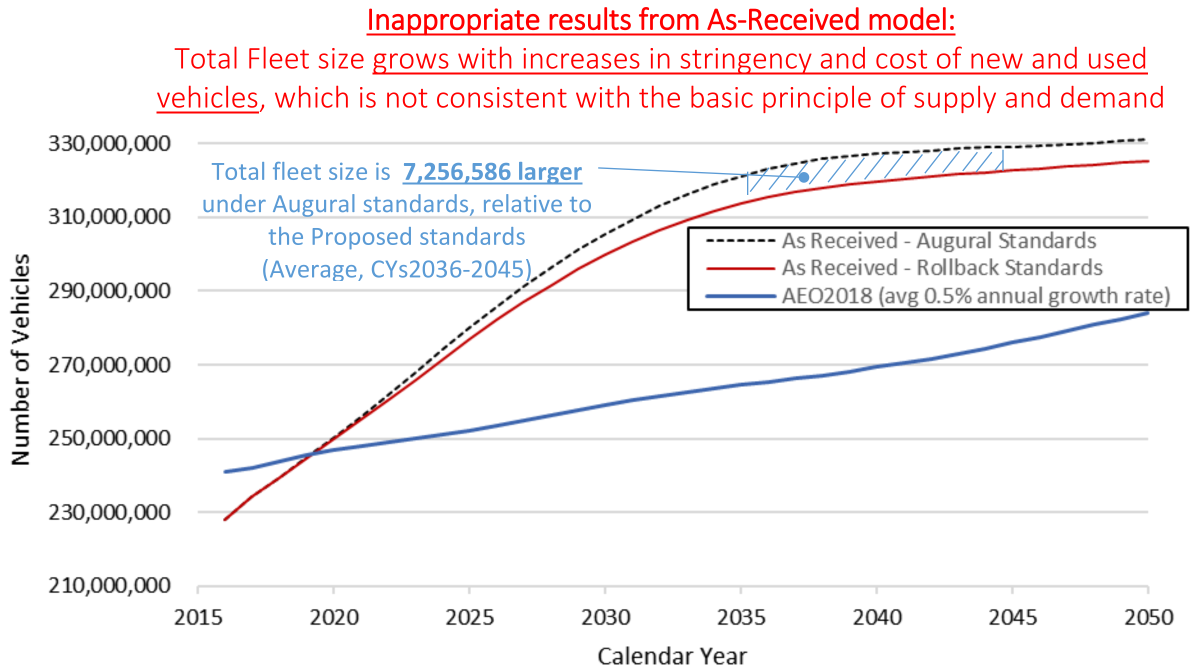


Figure 3 Total fleet size in As-Received CAFE model (AEO 2018 0.5% growth rate shown for reference)

Description of EPA Revision to resolve unrealistic growth in overall fleet size

NHTSA's written description in the draft NPRM indicates that the intent of the As-Received scrappage model was to capture the effect of changes in new vehicle prices and fleet fuel economy on the composition of total fleet (i.e., the balance between new and old vehicles and proportion of the various vehicle types), rather than the effect on the total fleet size. The emphasis on fleet composition is re-iterated in one of NHTSA's conclusions in the scrappage model section of the draft NPRM, that '*differences in the composition of the baseline fleet and the fleet under each alternative are the source of many of the proposed action's benefits and costs.*'

EPA modified the CAFE model to align with the NHTSA's stated intent, so that the scrappage model predicts fleet composition, but does not dictate total fleet size. Our modified code allows the user to select a fleet growth rate (we have used the AEO value of 0.5% growth per year by default, but other rates could be used.) Our code then allows the model to run as usual to determine new vehicle sales and the composition of the used vehicle fleet. These values are then used to scale the size of the used vehicle fleet (maintaining the predicted composition) to achieve the user-provided growth in fleet size. This way the new vehicle sales are identical to the As-Received values, the used vehicle fleet has the identical composition as the As-Received values, but the fleet size grows at much more reasonable rates.

[8] The As-Received CAFE model and inputs apply a fixed safety effect of about 10 fatalities per billion miles in CY2030. Assuming an average vehicle drives 10,000 miles per year, an overestimation of fleet size by 7 million vehicles would result in the model's overestimation of fatalities by approximately 700 lives.

Finally, because the real-world consequence of substituting older vehicles for newer vehicles would cause a departure from the empirically-derived mileage accumulation schedules (which define annual mileage by vehicle age), we developed mileage accumulation scaling factors in a similar manner to the fleet size scaling factors described above to maintain total fleet VMT under a 0 rebound case. Then in a second pass of the effects model, we apply the scaling factors to produce a realistic total VMT in the 20 percent rebound case.

See Appendix B for the details of the code revisions.

Issue #2: Inconsistency between total VMT estimates and specified value of the Rebound Effect

Background on the CAFE model approach for accounting for the rebound effect when estimating VMT

The Proposed standards would produce higher fuel costs per mile than the Augural standards. This higher cost may result in a reduction in miles driven – what NHTSA refers to in the draft NPRM text as a 'reverse rebound effect.' The principle is the same as the rebound effect we normally associate with improvements in fuel economy, but in the opposite direction. The As-Received CAFE model assumes that the magnitude of the effect is the same (20 percent), irrespective of whether cost per mile increases and VMT decreases, or cost per mile decreases and VMT increases. In the CAFE model code, the rebound value is used to estimate the fractional change in VMT (CPMrate) that results from a change in the cost per mile relative to a reference cost per mile according to:

(Equation 1)

CPMrate = (CPMnew / CPMref - 1.0) * reboundEffect; where reboundEffect is equal to -0.2

The fractional change in VMT (CPMrate) is then applied to the mileage accumulation values from the 'parameters' input file which specify the annual miles (MILESPERYEAR) based on the age of the vehicle. Separate mileage accumulation curves are defined for Car, Van/SUV, and Pickup vehicle styles. The total VMT for a vehicle of a given age, i, is defined according to the following equation:

(Equation 2)

$VMT_{(age=i)} = FLEET_{(age=i)} * MILESPERYEAR_{(age=i,vehiclestyle)} * (1.0 + CPMrate)$; where FLEET is the number of vehicles remaining at that age as determined by the scrappage model

Identification of the problem with VMT estimation and the application of the rebound effect in the CAFE model

One of the problems with the implementation of the rebound calculations in the code of the As-Received model is illustrated in Figure 4 for the Proposed standards. In this case, the inclusion of 20 percent rebound causes a <u>reduction</u> in VMT in future calendar years, despite the fact the Proposed standards produce a fleet with higher fuel economy and lower cost per mile than the baseline (MY2016) fleet. This result is clearly inappropriate, since by definition the rebound effect should result in more miles driven as cost per mile decreases.

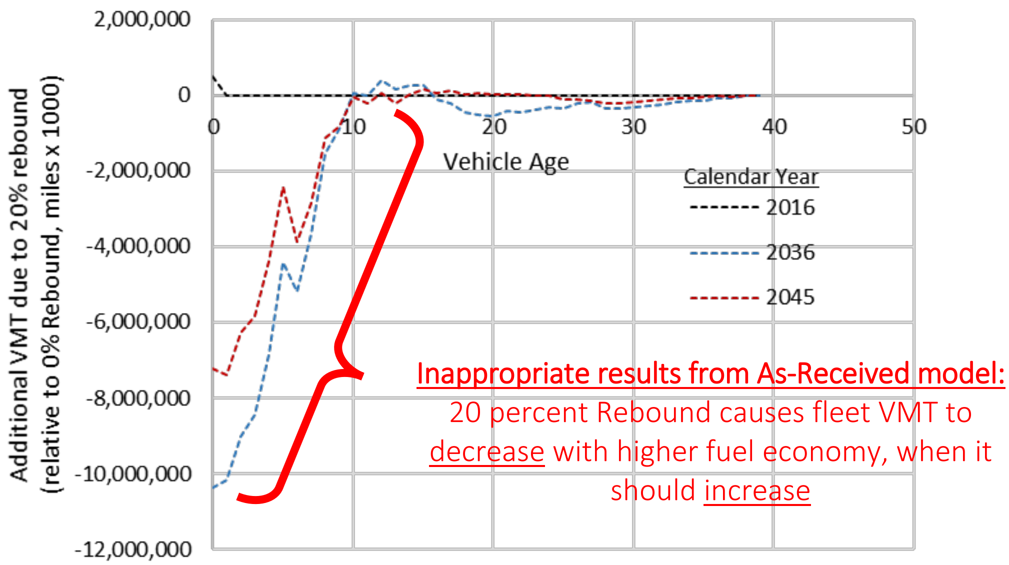


Figure 4 Change in VMT due to 20 percent rebound with As-Received model, Proposed standards case (change shown is relative to 0 percent rebound)

Figure 5 gives a closer view of the CPMrates determined from Equation 1 for three example vehicles, with MY2016 versions which maintain a constant fuel economy at levels equal to, 25 percent above, and 25 percent below an average MY2016 car.[9] These values are maintained until a MY2025 redesign, when the fuel economy is improved by either 10 percent (left panel) or 50 percent (right panel) compared to the MY2016 versions.

One notable observation is how the CPMrates vary by calendar year as the individual vehicles age. This is unexpected, since the CPMrate is applied to the annual mileage values that already account for the progressive decline in the miles driven each year as vehicles age. What the age- or year-related phenomenon this variation in CPMrate would be intended to represent is not clear. Another notable observation is the inconsistency in the direction of change in CPMrate of the new MY2025 vehicle, relative to the 8-year old MY2016 vehicle in CY2024. When the MY2025 vehicle is 50 percent more fuel efficient than MY2016 (right panel of Figure 5), the CPMrate shifts upward, resulting in higher VMT for the vehicle with greater fuel economy as would be expected. However, when the MY2025 vehicle is only 10 percent more fuel efficient than MY2016 (left panel of Figure 5), the CPMrate shifts downward. This tendency to produce VMT reductions for newer vehicles with moderate levels of fuel economy improvement is consistent with the inappropriate VMT results shown in Figure 4 above, indicating that this issue is caused by the calculation of CPMrate within the CAFE model.

[9] The average car fleet fuel economy is 36.9 mpg for a MY2016 car, as defined in the CAFE model's 'parameters' input file.

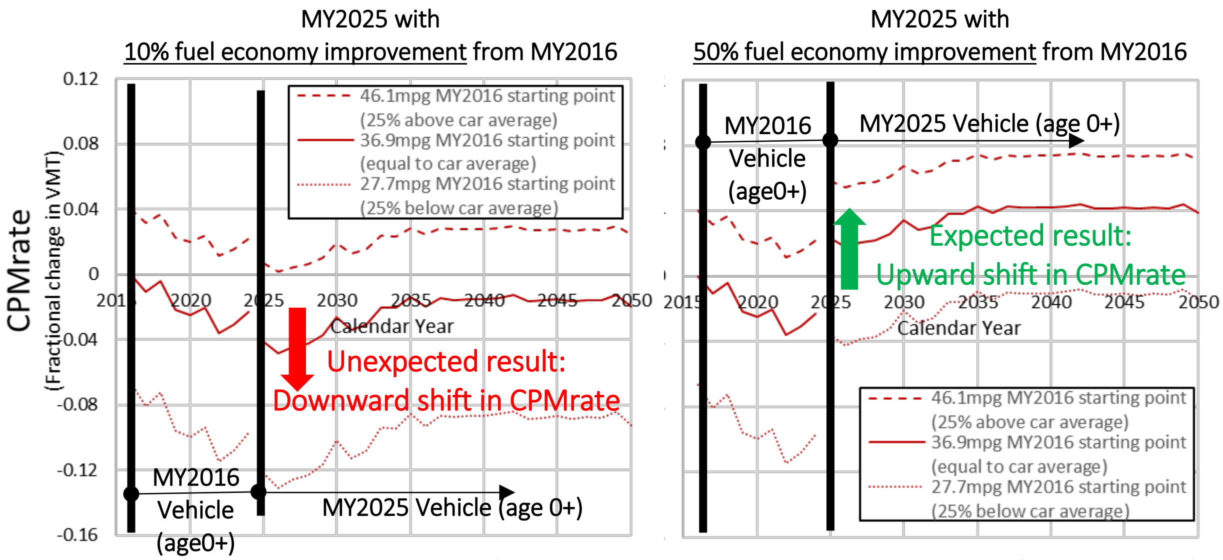


Figure 5 CPMrate variation by vehicle age and fuel economy improvements during redesign of 10 percent (left panel) and 50 percent (right panel)

In addition to the problems described above with the As-Received model's implementation of the rebound effect, an additional inconsistency between VMT estimates generated by the model and the specified rebound value became evident when we looked at the VMT results for alternatives with different stringencies, holding rebound at 0 percent.[10] With no rebound, we would not expect to see any change in total VMT, since by definition rebound is measured as the change in VMT for a given change in fuel cost per mile. However, even with 0 percent rebound, the As-Received model does produce total VMT values that are influenced by stringency level. See Figure 6, below. We believe that this zero-rebound VMT growth is an artifact of the disconnect between the sales model, scrappage model and mileage accumulation schedules described with Issue #1. And while this problem is not directly related to the model's calculation of the rebound effect, it points to the importance of carefully considering how the various elements are integrated when making changes or additions to a model.

[10] We evaluated a range of rebound values as part of our QAQC process and to investigate the sensitivity of the model to changes in the rebound effect. Note that we are not suggesting here that a value of 0 is the most appropriate assumption for the rebound effect.

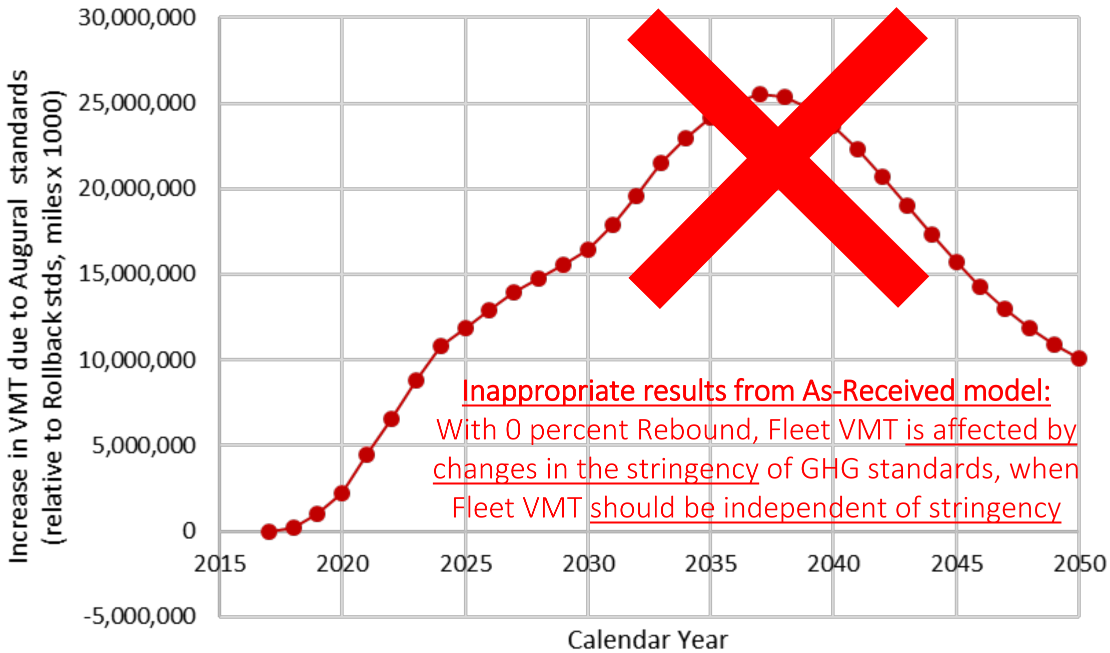


Figure 6 Change in VMT due Augural standards, with 0 percent rebound (relative to Proposed standards)

In total, the As-Received model 1) inappropriately incorporates a vehicle age-related effect due to rebound, 2) exhibits directionally incorrect VMT changes in response to fuel economy improvements, and 3) produces a VMT response to changes in stringency even when the rebound value is set to 0. We conclude that the model's implementation of the rebound effect is inappropriate, and that the model code produces VMT values that are inconsistent with the 20 percent rebound value that is specified in the input files. As with the problems described for the Scrappage Model in Issue #1, resolving the problems with the CAFE model's implementation of the rebound effect is critically important. An inappropriate accounting of the rebound effect will produce unreliable VMT estimates, which in turn will produce unreliable estimates of net fuel savings, emissions costs, fatalities, etc., making it impossible to accurately evaluate and compare the various policy alternatives.

Description of EPA Revision to resolve rebound effect implementation errors and total VMT estimation

After reviewing the CAFE model code, we have determined that the directionally incorrect reduction in total fleet VMT with 20 percent rebound shown in Figure 4 and Figure 5 above is due to the combined effect of two problematic assumptions used for calculating the reference cost per mile (CPMref) in Equation 1. The first assumption is the use of a constant CY2016 fuel price to calculate CPMref, even as CPMnew is calculated using the future year's fuel price. The consequence of using two fuel prices that diverge further with each year (due to future projected increases in fuel prices) is that VMT calculated from Equation 2 becomes lower over time, independent of any changes in fuel economy. Such a result is unjustified since it ignores the economic and income growth that is projected to occur concurrently with fuel price increases.

The second problematic assumption is the selection of fuel economy values used to determine the reference cost per mile. When determining the reference cost per mile, the As-Received code uses a fleet average MPG value that tracks backward in time. In other words, a MY2016 vehicle in CY2019 (i.e., age=3 where CY2016 would be age=0) would not use a baseline MPG value for a MY2016 vehicle, but would instead use a MPG value for a MY2013 vehicle (i.e., age=-3).

A hypothetical example will help to illustrate the importance of making appropriate assumptions when selecting CPMref. Building off the example in Figure 5 with MY2025 improvements to an average MY2016 car with fuel economy of 36.9mpg, Figure 7 shows how the CPMrate (and therefore the VMT) can change dramatically based on assumptions for CPMref. The inappropriate referencing of progressively older fleet average fuel economy values (red and gray curves), causes the CPMrate to be higher than when constant MY2016 reference fuel economy values are used (black and green curves.) The inappropriate referencing of CY2016 fuel prices (red and black curves) causes the CPMrate to be lower than when the current CY fuel prices are used (gray and green curves.) While these two problematic assumptions for CPMref tend to work in opposite directions, the general tendency of the As-Received model to produce a negative CPMrate in the example in Figure 7, despite the improvement in fuel economy, seems to indicate the assumption of maintaining CY2016 fuel prices is dominant.

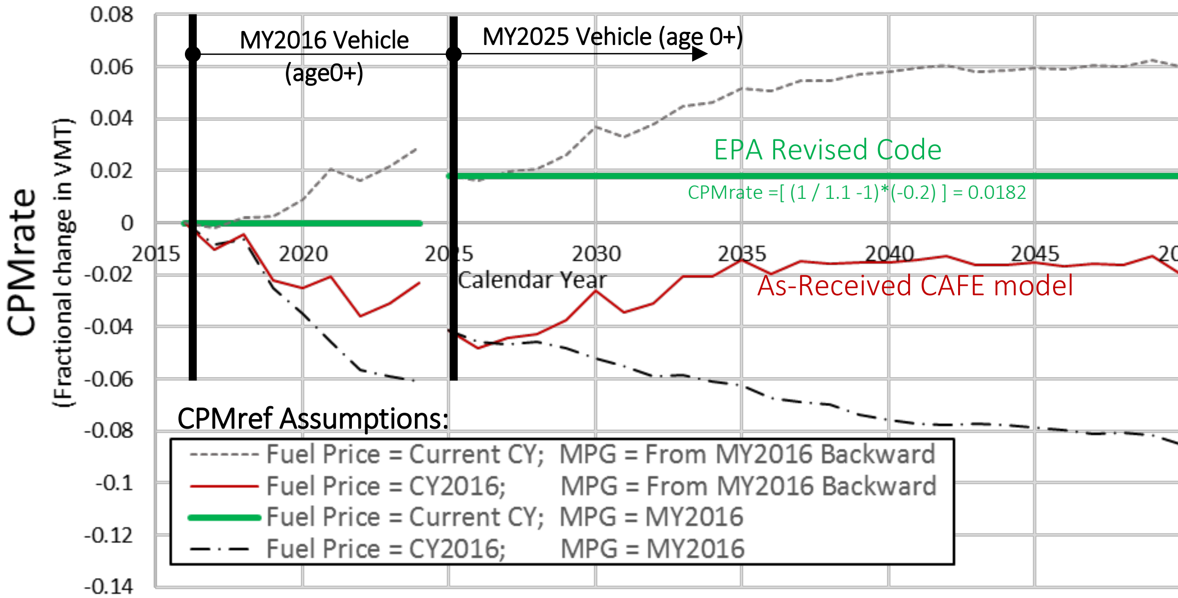


Figure 7 Effect of CPMref assumptions on CPMrate with 20 percent rebound (hypothetical example shown for MY2025 vehicle with 10 percent fuel economy improvement from MY2016 vehicle)

We believe that the most defensible implementation of the rebound effect is one that maintains the same CPMrate over every calendar year in the course of a vehicle lifespan. In the example shown by the green line in Figure 7, the CPMrate for the MY2025 vehicle then becomes simply a function of the ratio of the reference fuel economy to the new fuel economy and the 20 percent rebound effect value, or [(1 / 1.1 -1)* (-0.2)] = 0.0182. To achieve this, we revised the CAFE model code so that:

1) CPMref is calculated using the fuel prices in current calendar year rather than the fixed CY2016 fuel price, and
2) CPMref is calculated using the MY2016 baseline fuel economy of the specific vehicle, rather than a fleet average fuel economy of progressively older MY vehicles.

Please see Appendix B for the details of the code revisions.

Issue #3: Cost-ineffective technology ranking and application decisions

Background on the CAFE model selection of technology packages and ranking decisions

The selection of technology packages by the CAFE model is based on an 'efficiency' measure, which in simple terms prioritizes decisions where the value of CO_2 credits (to the manufacturer) most exceeds the net cost of the technology package.[11] When comparing two packages, given the availability constraints for redesign years, platform sharing, etc., the model will select the one with the most negative efficiency calculated as:

(Equation 3)

efficiency = (netpackagecost - DeltaCO2CreditValue) / totalAffectedSales;

where netpackagecost = techCost + consumer_valueloss - 2.5years_FuelSavings; and

DeltaCO2CreditValue is an assumed monetary value of the difference in compliance credits between the two packages considered.

Identification of the problem with technology package ranking and application in the CAFE model

Figure 8 shows the total technology cost and effectiveness for all technology packages applied by the As-Received CAFE model to the MY2030 fleet, relative to a 'null' package with only basic technologies.[12] While we would not expect manufacturers to consistently apply technology packages that lie exactly on the cost-efficient 'frontier', the frequency with which the As-Received CAFE model applies packages that are several thousand dollars more expensive than other available packages is striking.

[11] The As-Received CAFE model will only consider technology packages where the value of CO_2 credits to the manufacturer exceeds the net package cost, ignoring the potential for any cross-subsidization within a manufacturer's vehicle lineup. This net cost could be thought of as the amount a manufacturer would need to adjust the vehicle price, higher or lower, in order to offset any changes in consumers' willingness to pay for the vehicle due to the added technologies. The model assumes that consumers will be willing to pay for 2.5 years of fuel savings, and that consumers face a loss in value for electrified vehicles between approx. $1,300 (for strong hybrids) and $16,000 (for BEVs.)

[12] I.e. a 5-speed transmission, port fuel injected naturally aspirated engine, no improvements in tires, aerodynamics, or mass reduction.

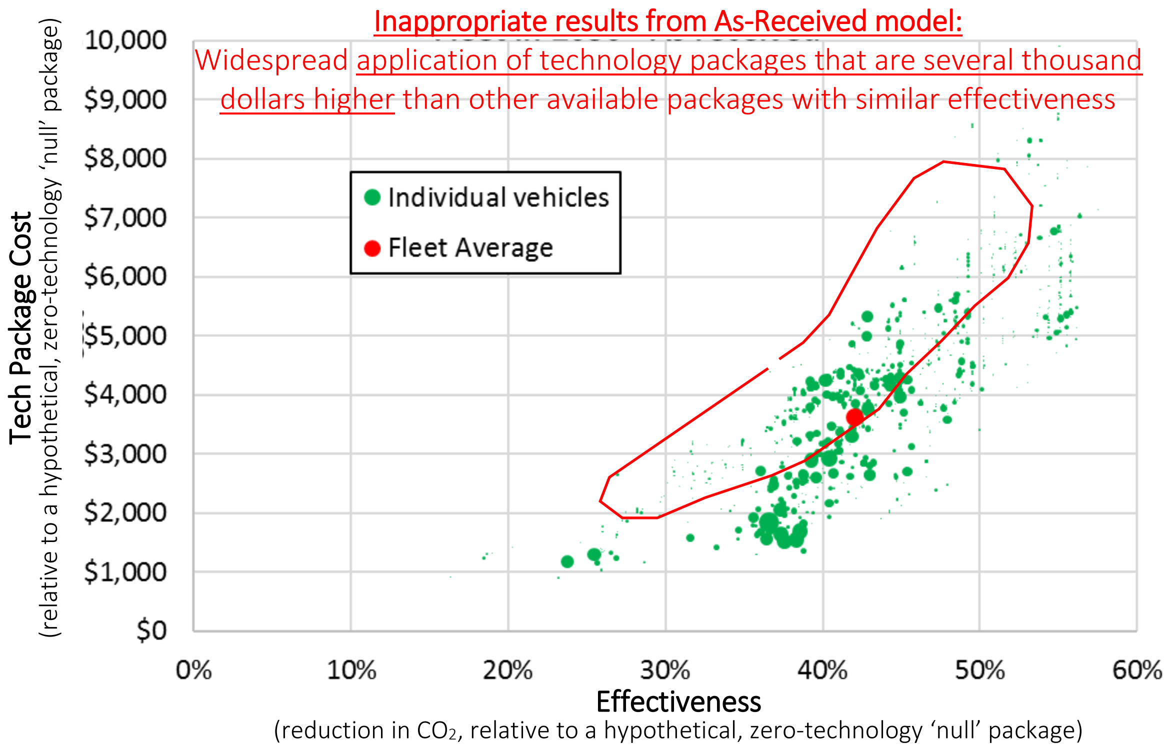


Figure 8 Cost and Effectiveness of MY2030 vehicles relative to a 'null' tech package (PEV's are off chart area, but included in fleet average)

Based on our review of the CAFE model code, we have identified several factors that contribute to the model's widespread application of cost-inefficient packages. The first factor is the problematic approach used by the model for estimating the DeltaCO2CreditValue variable in Equation 3 above. In reality, the value of a CO_2 compliance credit to any manufacturer is a function of complex and inter-related factors, making it difficult to incorporate a realistic estimate into any model. The dollar value of a credit for a particular manufacturer would depend on their compliance status, their fleet composition and applied technologies, the cost of the available technologies for further reducing CO_2 emissions, the availability of banked credits, the level of future stringency increases, and many other factors.

Figure 9 shows the CO_2 Credit Values by Model Year, which are defined in CAFE model input files using a simple scaling of the CAFE fine rates by a constant factor of 6.53. While the application of a uniform credit value is problematic given all the potential variations among manufacturers, it is probably even more problematic that the CO_2 value is assumed to be decreasing over time. Given that the GHG program does not allow manufacturers to pay fines as a compliance strategy, we assume that NHTSA's intent was for the CO_2 credit value to represent a market value for trading credits between manufacturers. Regardless of the intent, as the adoption of the lower-cost technologies leaves only the more expensive alternatives available to meet future year stringency increases, it is implausible that the value of CO_2 credits to a manufacturer will decrease in this way over time.

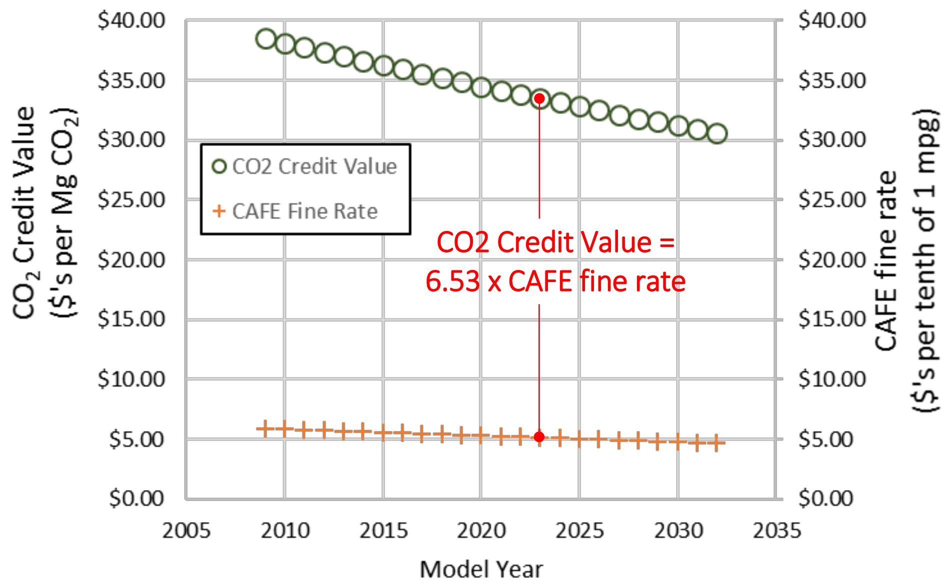


Figure 9 CO_2 Credit Value, by Model Year, as defined in As-Received CAFE model inputs

The second factor that contributes to the CAFE model's application of cost-inefficient packages is in the calculation of the difference in CO_2 credit values between the two packages being considered in Equation 3 above. The newCO2CreditValue and curCO2CreditValue variables in Equation 4 below represent a dollar value of the CO_2 credits or deficits, based on the value of a single credit from Figure 9, and the gap between the given package CO_2 and the CO_2 target for that vehicle. Negative values result from packages above the target (CO_2 deficit), and positive values result from packages below the target (CO_2 credit).

The problem is that in truncating credit values at zero as shown in Equation 4, the CAFE model gives less consideration to technologies that reduce a vehicle's CO_2 below its target, regardless of how cost-effective that technology might be. For example, Package A might reduce CO_2 to well-below the target and be cost-effective in terms of dollars per gram CO_2 reduced, but the CAFE model would give preference to any Package B that meets or exceeds the target by a lesser amount with lower net costs, even if the dollars per gram CO_2 reduced were much higher for Package B than Package A.

(Equation 4)

```
DeltaCO2CreditValue = Min(0.0, newCO2CreditValue)) - Min(0.0, curCO2CreditValue));
```

The consequence of truncating CO_2 credit values at zero in the efficiency calculation may be difficult to understand in the abstract, so to illustrate the concept, we're providing an example here of two vehicles from the same manufacturer which have the same starting CO_2 and sales volume, but different technology pathways and CO_2 targets. Absent other considerations, a manufacturer would choose the most cost-effective packages which, in total, would achieve compliance for the manufacturer's entire fleet, whether those packages were applied to Vehicle A, Vehicle B, or both.

However, because Vehicle A starts out further from its CO_2 target than Vehicle B, the CAFE model will generate efficiency values for Vehicle A that are more negative (and thus preferable) than Vehicle B as shown in Figure 10, since the credit value for reducing Vehicle B below its 280 g/mi target is truncated and not included in the efficiency calculation. The CAFE model will choose to apply technology to Vehicle A to reduce CO_2 to 200 g/mi, even though that technology pathway is less cost effective than one where technology is applied to Vehicle B (point B′ in Figure 10) – with a technology cost of $1,417 for Vehicle A compared to $1,246 for Vehicle B for the same CO_2 reduction.

	Vehicle A	Vehicle B
Initial CO_2 (g/mi)	310	310
CO_2 Target (g/mi)	200	280
Tech pathway cost ($ per incremental % CO_2 reduction)	33 $/ %$CO_2$	29 $/ %$CO_2$
Volume	1000	1000
Total technology cost to reduce CO_2 to 200 g/mi	**$1,417**	**$1,246 (Δ-$171)**

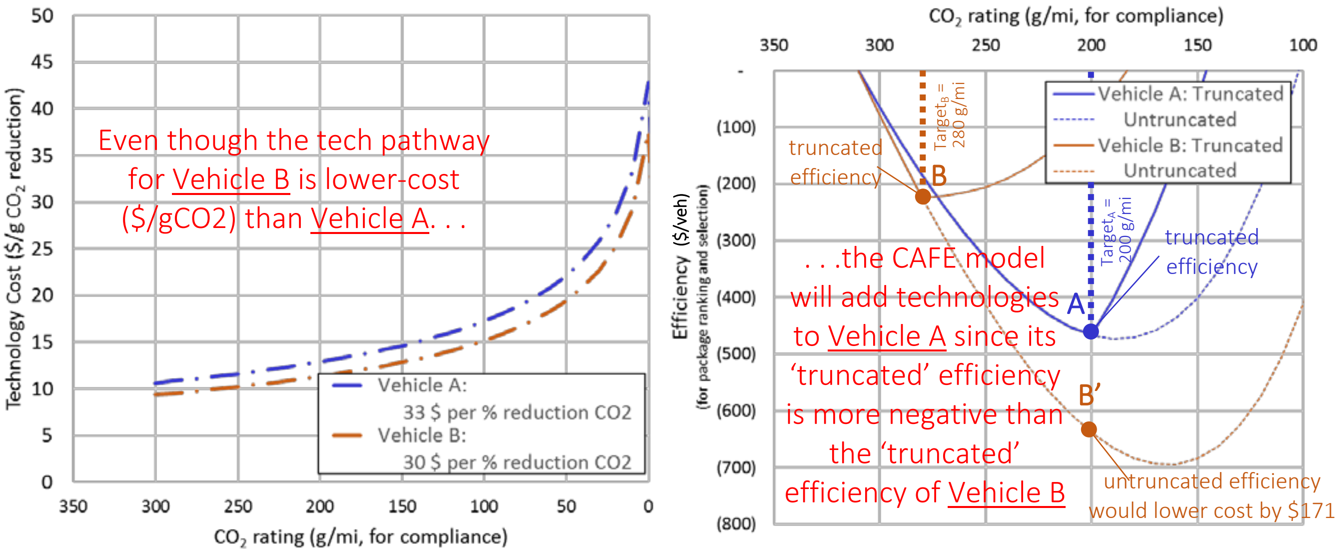


Figure 10 Effect of truncating CO_2 credit value in CAFE model's 'efficiency' calculation for tech package selection
Assuming $3/gal fuel price, $35/MgCO2 credit value, and 30k miles driving in first 2.5 years (for consumer payback)

The third factor that contributes to the CAFE model's application of cost-inefficient packages is the separate treatment of regulatory classes when determining compliance status. Figure 11 below shows that with only one exception,[13] the achieved CO_2 levels for the regulatory car and truck fleets for all manufacturers in MY2030 is below the required CO_2 level. This result is striking, not only in the consistency of overcompliance, but also in the apparent lack of balancing within a manufacturer between car and truck regulatory fleets. A more realistic modelling representation would tend to show some overcompliance in one regulatory fleet, offset by undercompliance in the other fleet as the manufacturer seeks to reduce compliance costs by applying technology to reduce emissions where it is most cost-effective.

[13] JLR's car fleet is the only regulatory fleet for which the achieved CO_2 value is above the target CO_2 value in MY2030.

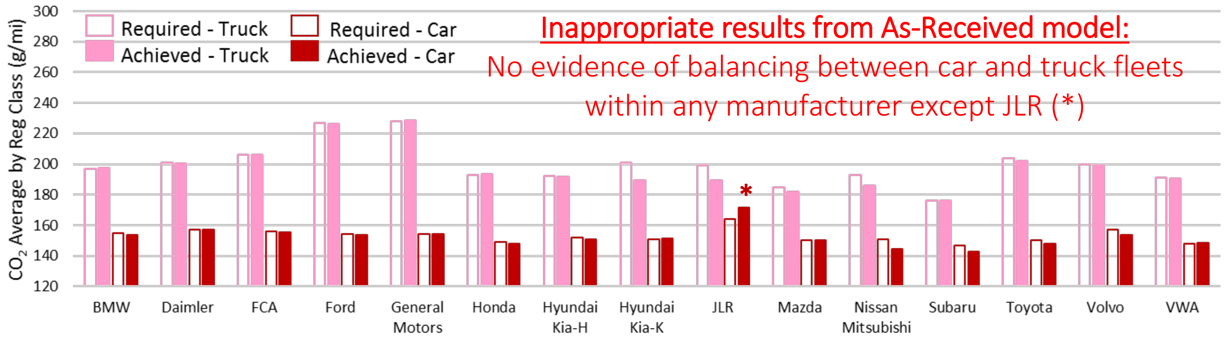


Figure 11 MY2030 Required and Achieved CO2 levels for Each manufacturers regulatory car and truck fleets in As-Received CAFE model output

After our review of the CAFE model code, we have identified an issue that contributes to this lack of within-manufacturer fleet averaging. As shown in Equation 5, the CAFE model does not flag a manufacturer as 'in compliance' unless both the car and the truck fleets have positive credits. While this model requirement may produce the intended results for modeling of the CAFE program, it is not appropriate for representing the GHG program, which has the provision of unlimited transfer of credits between car and truck fleets.

(Equation 5)

$$mfrInCompliance = (GetNetCO2Credits_{cars} >= 0) \text{ AND } (GetNetCO2Credits_{trucks} >= 0)$$

Description of EPA Revision to resolve cost-ineffective technology ranking and application decisions

To resolve the issue of the cost-ineffective technology application decisions, EPA revised two elements of the CAFE model code. First, we revised "efficiency" calculation used for package ranking. Because we don't believe that the value of a CO_2 credit to any manufacturer can be reasonably determined in advance[14], we have removed the monetary valuation of CO_2 credits from the numerator of Equation 3, and instead include the change in quantity of compliance credits (in grams CO_2) as a normalizing factor in the denominator of the efficiency calculation. The modified calculation, shown as Equation 6, can be interpreted as the cost-efficiency of a technology application in terms of the net cost per gram CO_2 credits earned. We think that this decision rule would reasonably represent a manufacturer that is applying technologies in a cost-minimizing manner, subject to all the original constraints on technology availability and redesign cycles specified in the As-Received CAFE model input files. As with the As-Received CAFE model logic, our revised code prioritizes technology packages with more negative efficiency values.

(Equation 6)

$$efficiency = (TechCost – FuelSavings) / (newCO2Credit_{total} – curCO2Credit_{total})$$

The second change in the EPA-Revised code involves the lack of credit transfers between regulatory classes. As shown in Equation 7, we now set each manufacturer's 'in compliance' flag based on the

[14] For the reasons described earlier, the value of a CO_2 credit to any given manufacture will be dependent on their current compliance status, stringency of the standards, available technology and cost, etc.

sum of the credits for car and truck regulatory classes, instead of required positive credits for both classes individually, as in Equation 5.

(Equation 7)

$$\text{mfrInCompliance} = \text{curCO2Credit}_{total} >= 0;$$

Graphical summary of the various effects of EPA code revisions

Effect of EPA-Revisions on Issue #1 (Unrealistic growth in overall fleet size)

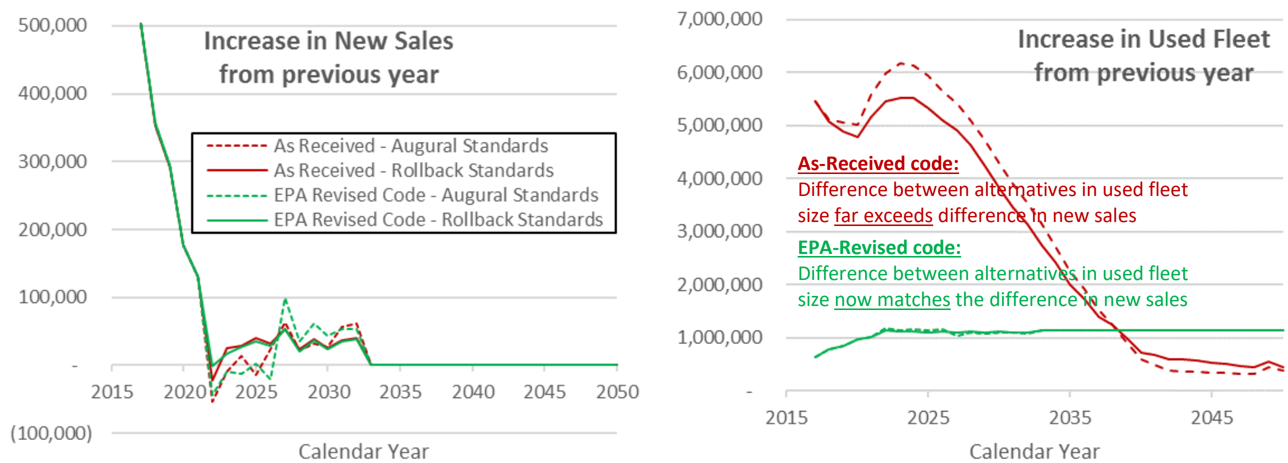


Figure 12 EPA Revised Code Effects, Compare to As-Received CAFE model results in Figure 2: "Year-over-year increase in new vehicle sales (left) and increase in used fleet size (right) using As-Received CAFE model (note the difference in y-axis scale)"

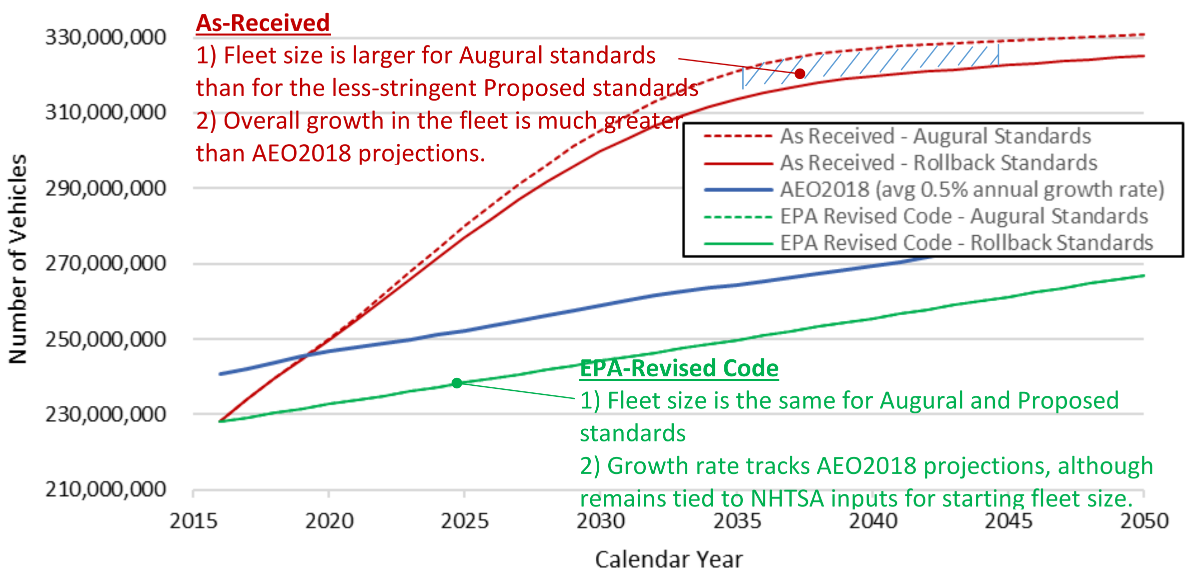


Figure 13 EPA Revised Code Effects, Compare to As-Received CAFE model results in Figure 3: "Total fleet size in As-Received CAFE model"

Effect of EPA-Revisions on Issue #2 (Inconsistency between total VMT estimates and specified value of the Rebound Effect)

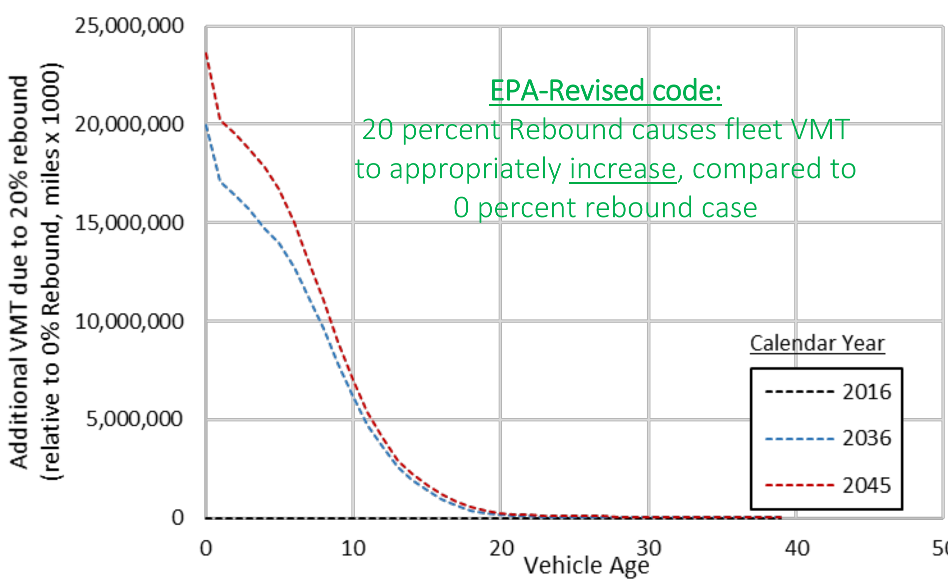


Figure 14 EPA Revised Code Effects, Compare to As-Received CAFE model results in Figure 4: "Change in VMT due to 20 percent rebound, Proposed standards case (relative to 0 percent rebound)"

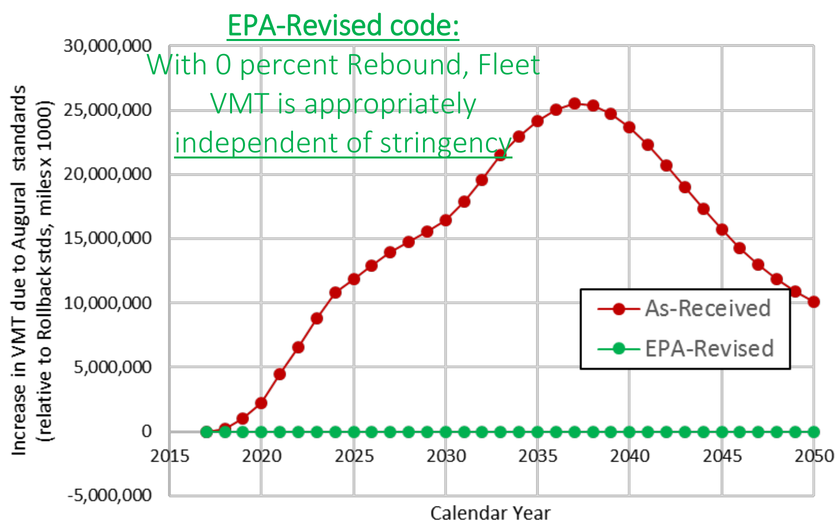


Figure 15 EPA Revised Code Effects, Compare to As-Received CAFE model results in Figure 6: "Change in VMT due Augural standards, with 0 percent rebound (relative to Proposed standards)"

Effect of EPA-Revisions on Issues #3 and #4 (Cost-inefficient application of technology packages)

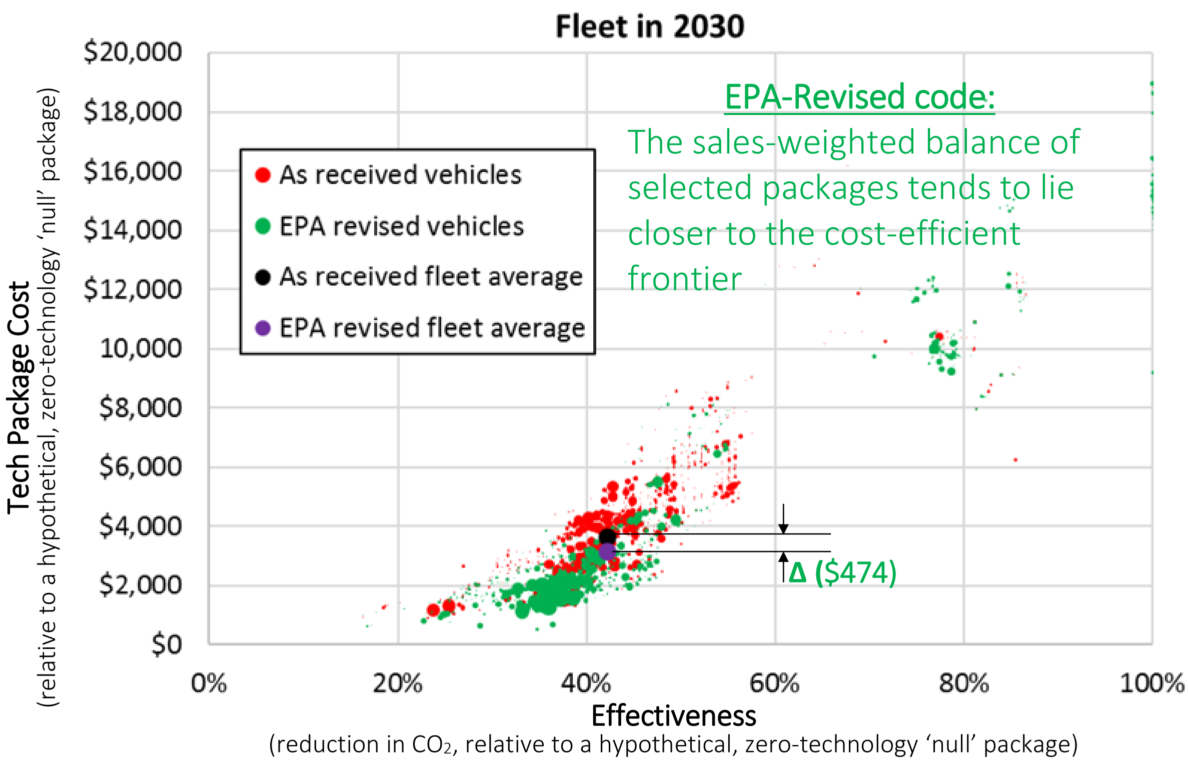


Figure 16 EPA Revised Code Effects, Compare to As-Received CAFE model results in Figure 8 "Cost and Effectiveness of MY2030 vehicles relative to a 'null' tech package"

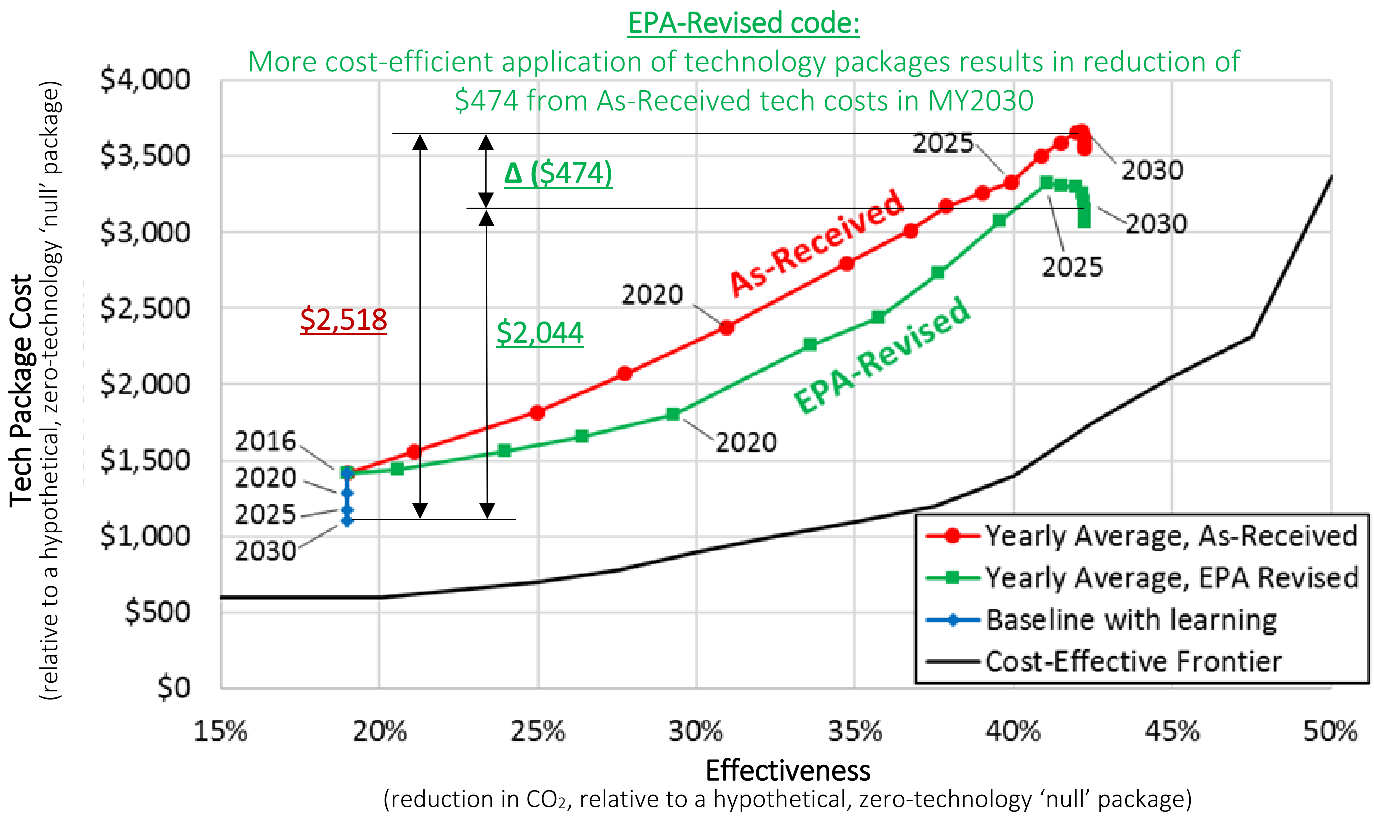


Figure 17 EPA Revised Code Effects:
Cost and Effectiveness of each MY relative to the MY2016 baseline tech package

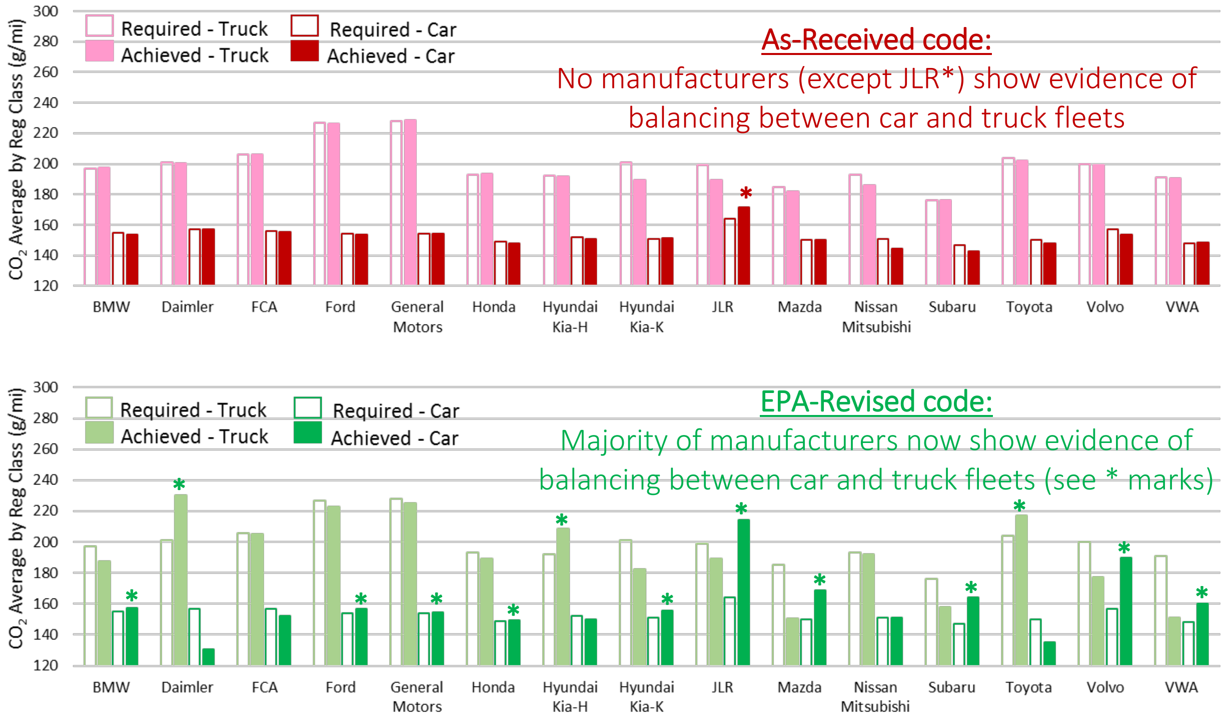


Figure 18 EPA Revised Code Effects, Compare to As-Received CAFE model results in Figure 11 "MY2030 Required and Achieved CO_2 levels for Each manufacturers regulatory car and truck fleets"

Tabular summary of the combined effect of EPA code revisions

Table 3 Technology Costs, Fuel Savings, Payback

Source	As Received		EPA Revised Code	
Scenario	Augural	Proposed	Augural	Proposed
MYs	2017-2025	2021-2026	2017-2025	2021-2026
Annual Rate of Stringency Increase	No Action	0%/yr PC 0%/yr LT	No Action	0%/yr PC 0%/yr LT
Total Tech Costs, $/veh, MY2030 relative to MY2016 packages	$2,518	$639	$2,044	$474
Incremental Tech Costs, $/veh, MY2030	Baseline	-$1,879	Baseline	-$1,570
Fuel Savings, $/veh, MY2030 (3% discounting) *	Baseline	-$1,519	Baseline	-$1,734
Payback based on Total Cost of Ownership 20% Rebound (years, 3% discounting)	11.6	4.1	3.5	1.0

*Negative fuel savings indicate an increase on consumer spending on fuel.

Table 4 Changes in Fatality Metrics and Net Social Benefits

Source	As Received		EPA Revised Code	
Scenario	Augural	Proposed	Augural	Proposed
MYs	2017-2025	2021-2026	2017-2025	2021-2026
Annual Rate of Stringency Increase	No Action	0%/yr PC 0%/yr LT	No Action	0%/yr PC 0%/yr LT
Change in Average Annual Fatalities, Calendar Years 2036-2045, No Rebound *	Baseline	-150	Baseline	+17
Change in Average Annual Fatalities per Trillion Miles, Calendar Years 2036-2045, No Rebound	Baseline	+4.5	Baseline	+6.9
Average Annual Employment, Lifetimes of MY2016-2032 vehicles	Baseline	-35,020	Baseline	-27,269
Change in Net Social Benefits, 20% Rebound, excluding rebound-related fatality and non-fatal crash costs and 'value-loss' associated with electrified vehicles, ($Billions, 3% discounting) **	Baseline	+$49	Baseline	-$83

*The change in average annual fatalities during CYs 2036-2045 including the additional miles driven voluntarily due to rebound are projected by the model as -863 (As-Received) and -321 (EPA-Revised).

**The change in net social benefits inclusive of rebound-related fatality and non-fatal crash costs and NHTSA's 'value-loss' associated with electrified vehicles would be +$202 billion for the As-Received code and +$103 billion for the EPA-Revised code. Social benefits sum Technology, Maintenance/Repair, Value Loss, Pretax Fuel, Drive and Refuel Value, Fatality, Crashes/Congestion/Noise and all Emission Damage costs changes for the lifetimes of MY2016 through 2032 vehicles; a negative Net Social Benefit represents a net social cost.

Table 5 Technology Penetration Rates

Source	As Received			EPA Revised Code[15]		
Scenario	**Augural**	**Proposed**	**Delta**	**Augural**	**Proposed**	**Delta**
MYs	**2017-2025**	**2021-2026**		**2017-2025**	**2021-2026**	
Annual Rate of Stringency Increase	**No Action**	**0%/yr PC 0%/yr LT**		**No Action**	**0%/yr PC 0%/yr LT**	
Tech Costs, $/veh, MY2030	$2,518	$639	-$1,879	$2.044	$474	-$1,570
Technology penetrations						
Weight Reduction (not including powertrain)	19%	12%	-7%	14%	11%	-3%
High Compression Ratio (aka ATK2)	26%	12%	-14%	26%	12%	-13%
Turbo-downsized	62%	46%	-16%	57%	42%	-16%
Dynamic Deac	7%	0%	-7%	0%	0%	0%
Diesel	1%	1%	0%	1%	1%	0%
Advanced transmissions (non-hybrid)	82%	88%	+6%	77%	86%	+9%
Stop-Start (12V)	10%	13%	+3%	9%	12%	+3%
Mild HEV (48V)	41%	2%	-39%	3%	0%	-3%
Strong HEV	14%	2%	-11%	10%	2%	-8%
Sum of Mild and Strong HEV	55%	5%	-50%	13%	2%	-11%
Plug-in HEV	1%	0%	0%	7%	0%	-6%
Battery Electric (BEV)	0%	1%	0%	2%	1%	-2%
Sum of PEVs	1%	1%	0%	9%	1%	-8%

Note that the three tables presented above, comparing the As-Received and EPA-Revised results, maintain NHTSA's costs and effectiveness values from Autonomie large-scale full-vehicle simulation, platform sharing, redesign cycles and technology application constraints. In other words, the input files applied in this analysis are identical to the as-received files from NHTSA.

Unresolved Issues

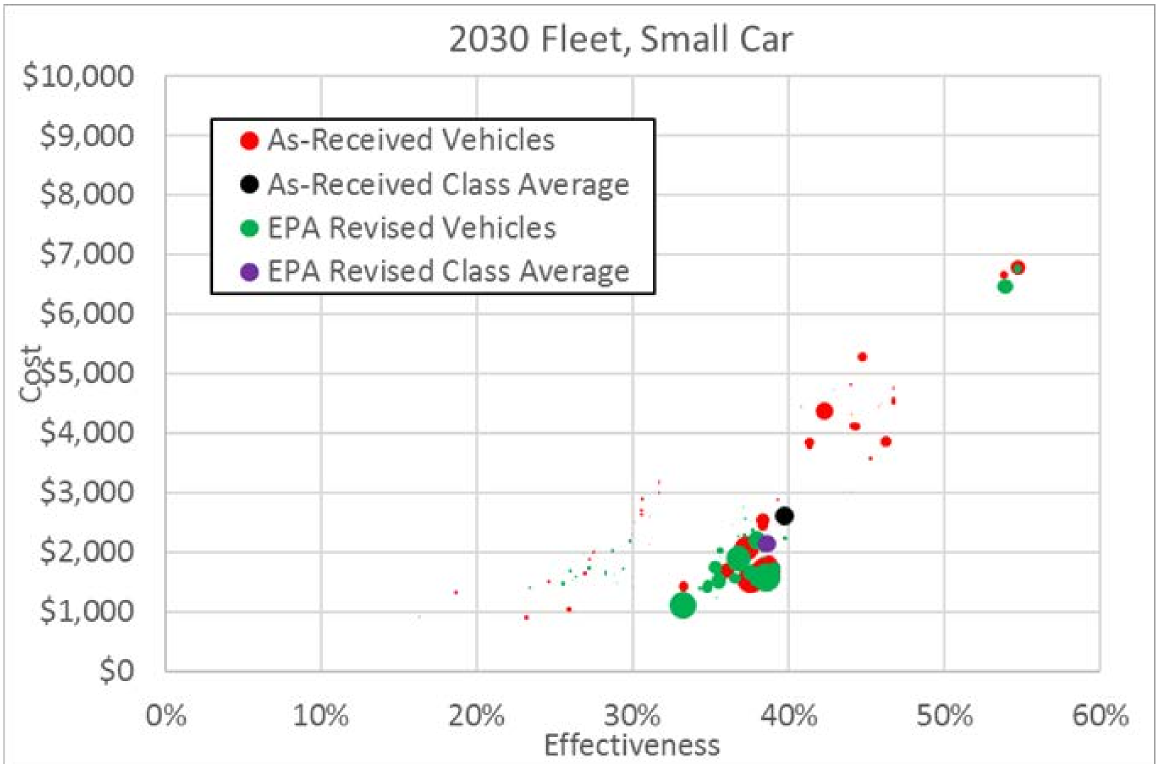
The effects of our minor code revisions on the CAFE model outputs are clearly substantial, and resolve some of the most significant issues with the CAFE model's representation of the GHG program. However, although the "EPA Revised" version of the CAFE model has corrected some issues, there are still outstanding issues with this model. Thus we cannot endorse the use of our modified version of the CAFE model for use in policy setting for the GHG program.

In part, this is because of the range of issues we have previously identified with the modeling inputs and assumptions—such as unduly high battery costs, production-ready but unconsidered and/or overly constrained technologies and technology application processes, etc.—that are outside of the scope of this memo and are not addressed by the EPA-revised version of the CAFE model.

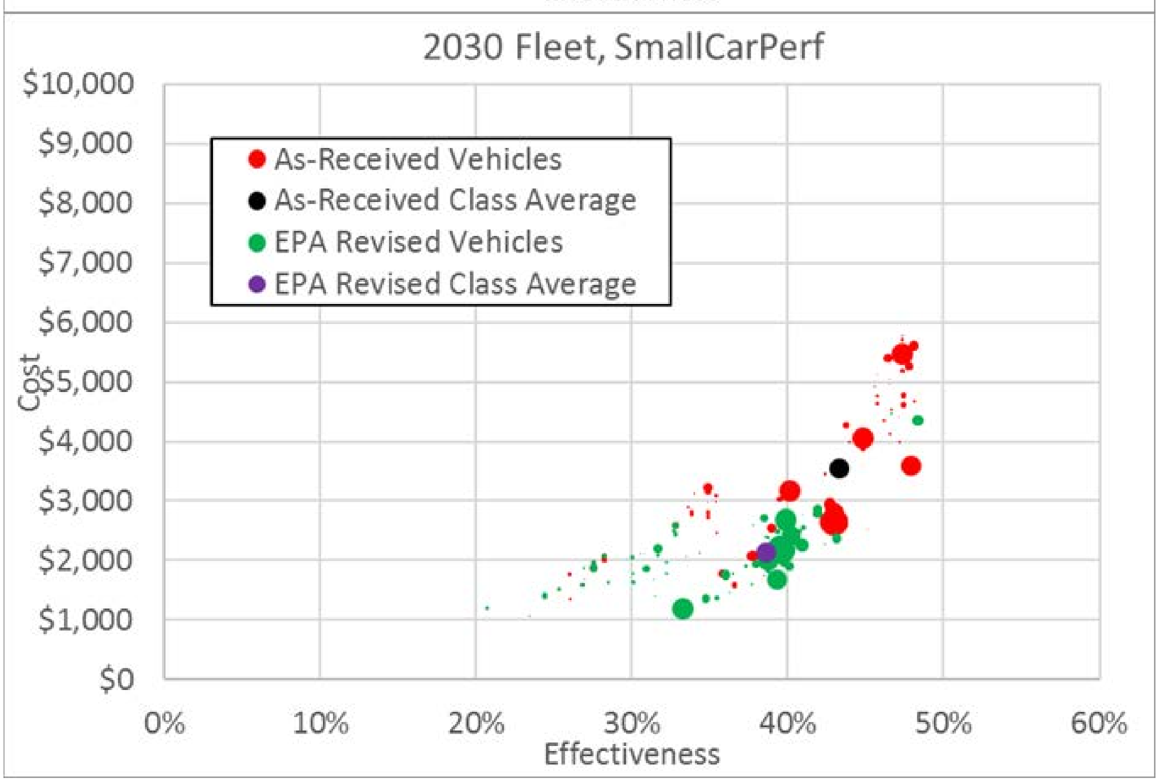
[15] This analysis maintains NHTSA's costs, effectiveness values from Autonomie large-scale full-vehicle simulation, platform sharing, redesign cycles and technology application constraints. In other words, the input files applied in this analysis are identical to the as-received files from NHTSA. Had we applied EPA inputs we would expect a significant change in technology penetration projections.

There are also additional issues with the CAFE model that have been uncovered during the current investigation, but we have not had the time and resources to fully evaluate and/or correct. For example, the model appears to favor credit generation for possible future use over transfer of credits across a given manufacturer's car and truck fleets (a major cost savings element of the GHG program); further, the model does not appear to use credits efficiently once generated; the model uses fuel share in many places but does not maintain a careful accounting of that fuel share to ensure a total of 100% each year; the model continues to make use of what we consider to be strange mileage accumulation rate schedules (as we discussed with NTHSA/Volpe during development of the DTAR); the model still has a general tendency towards overcompliance across the range of years analyzed; and potentially other issues.

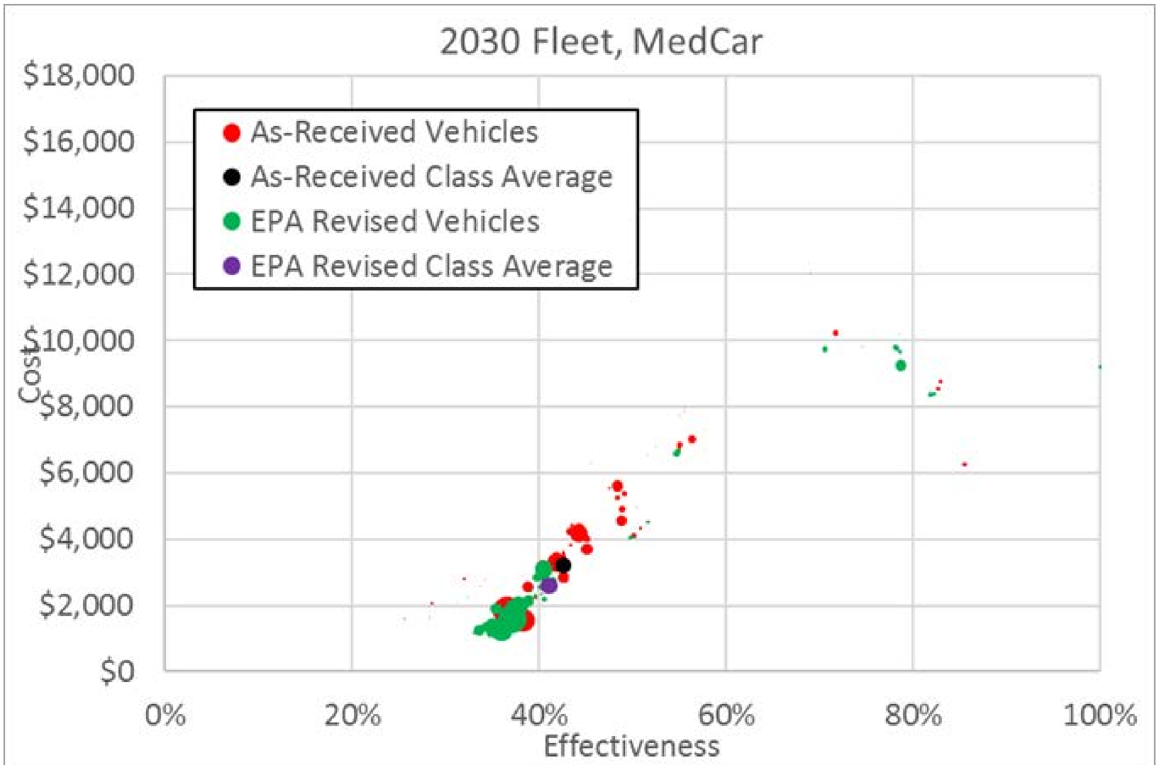
Appendix A: Comparison of the cost-effectiveness of applied technology packages in As-Received and EPA-Revised versions, by Vehicle Type

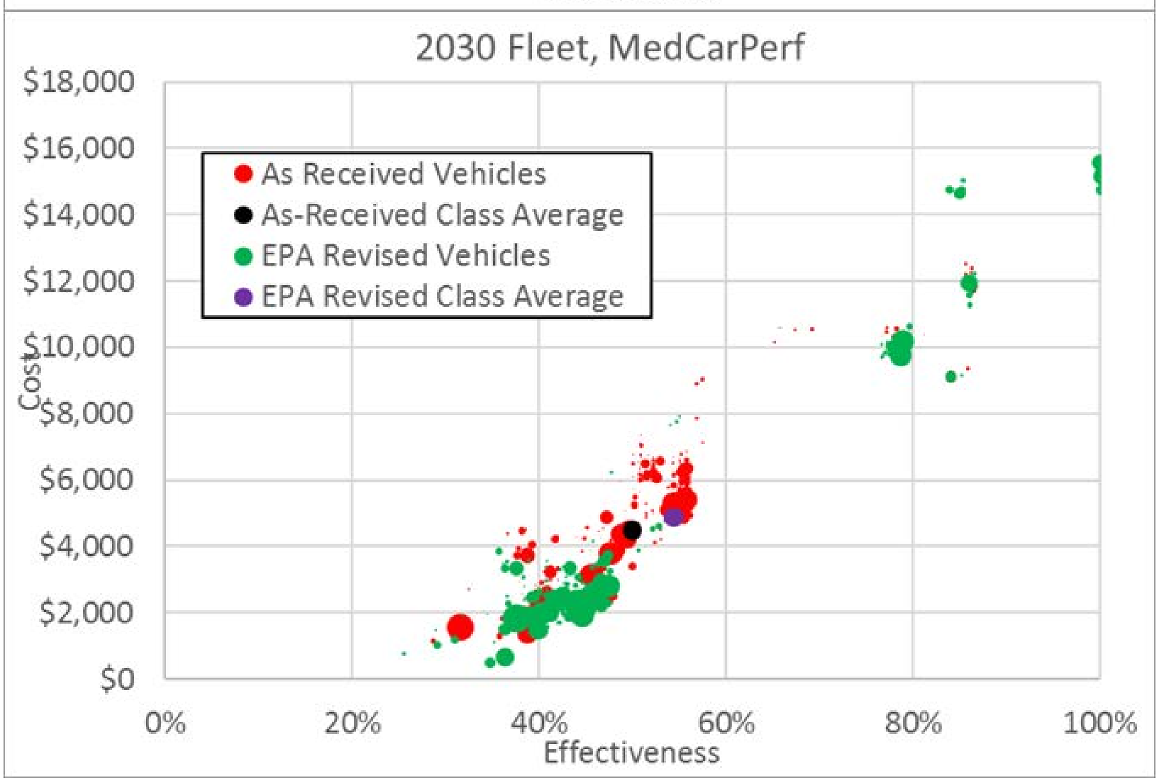


2030 Fleet, Small Car
As-Received Vehicles
As-Received Class Average
EPA Revised Vehicles
EPA Revised Class Average
Cost
$10,000
$9,000
$8,000
$7,000
$6,000
$5,000
$4,000
$3,000
$2,000
$1,000
$0
0%
10%
20%
30%
40%
50%
60%
Effectiveness



2030 Fleet, SmallCarPerf
As-Received Vehicles
As-Received Class Average
EPA Revised Vehicles
EPA Revised Class Average
Cost
$10,000
$9,000
$8,000
$7,000
$6,000
$5,000
$4,000
$3,000
$2,000
$1,000
$0
0%
10%
20%
30%
40%
50%
60%
Effectiveness


2030 Fleet, MedCar
$18,000
$16,000
$14,000
$12,000
$10,000
$8,000
$6,000
$4,000
$2,000
$0
Cost
As-Received Vehicles
As-Received Class Average
EPA Revised Vehicles
EPA Revised Class Average
0%
20%
40%
60%
80%
100%
Effectiveness


2030 Fleet, MedCarPerf
$18,000
$16,000
$14,000
$12,000
$10,000
$8,000
$6,000
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Cost
As Received Vehicles
As-Received Class Average
EPA Revised Vehicles
EPA Revised Class Average
0%
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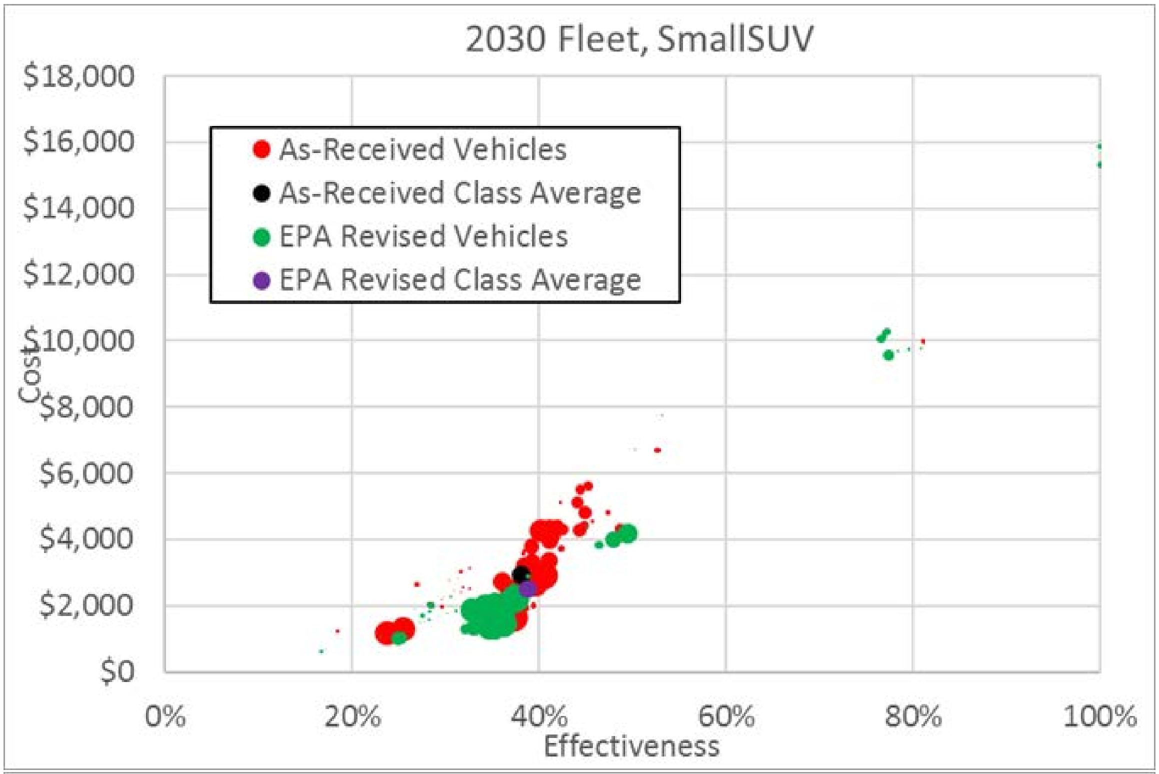
100%
Effectiveness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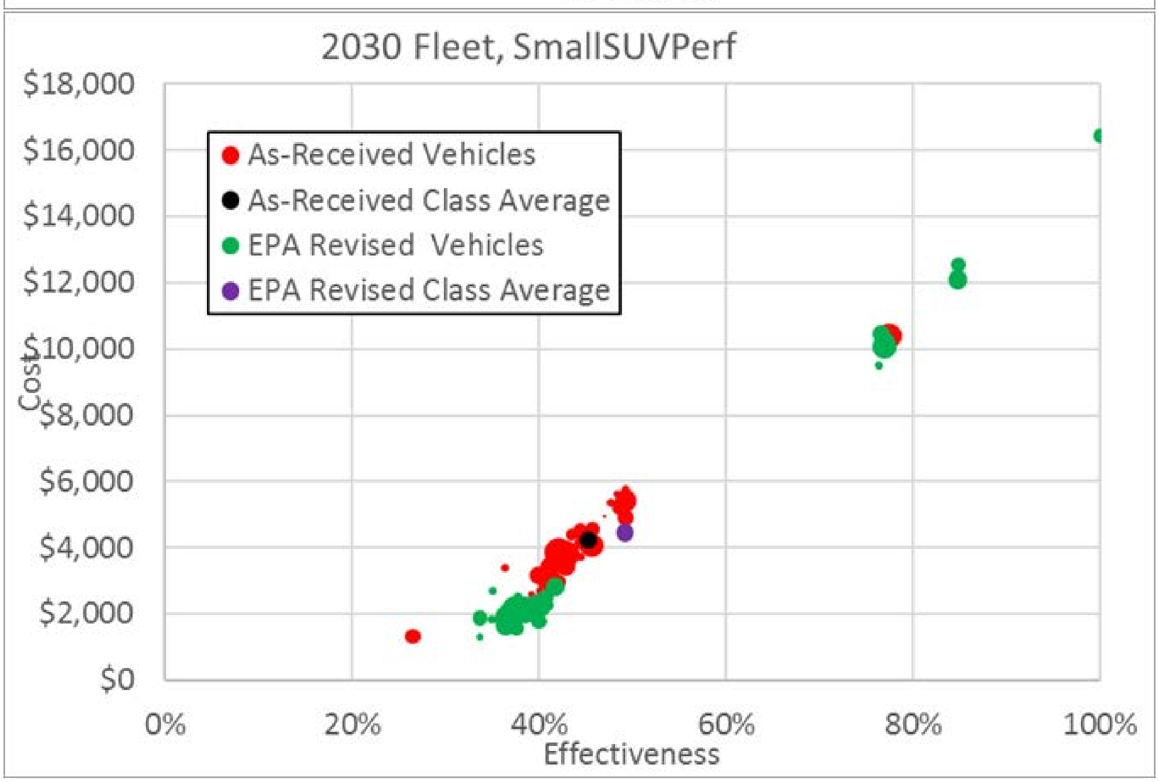
Effectiveness
As-Received Vehicles
As-Received Class Average
EPA Revised Vehicles
EPA Revised Class Average


2030 Fleet, SmallSUVPerf
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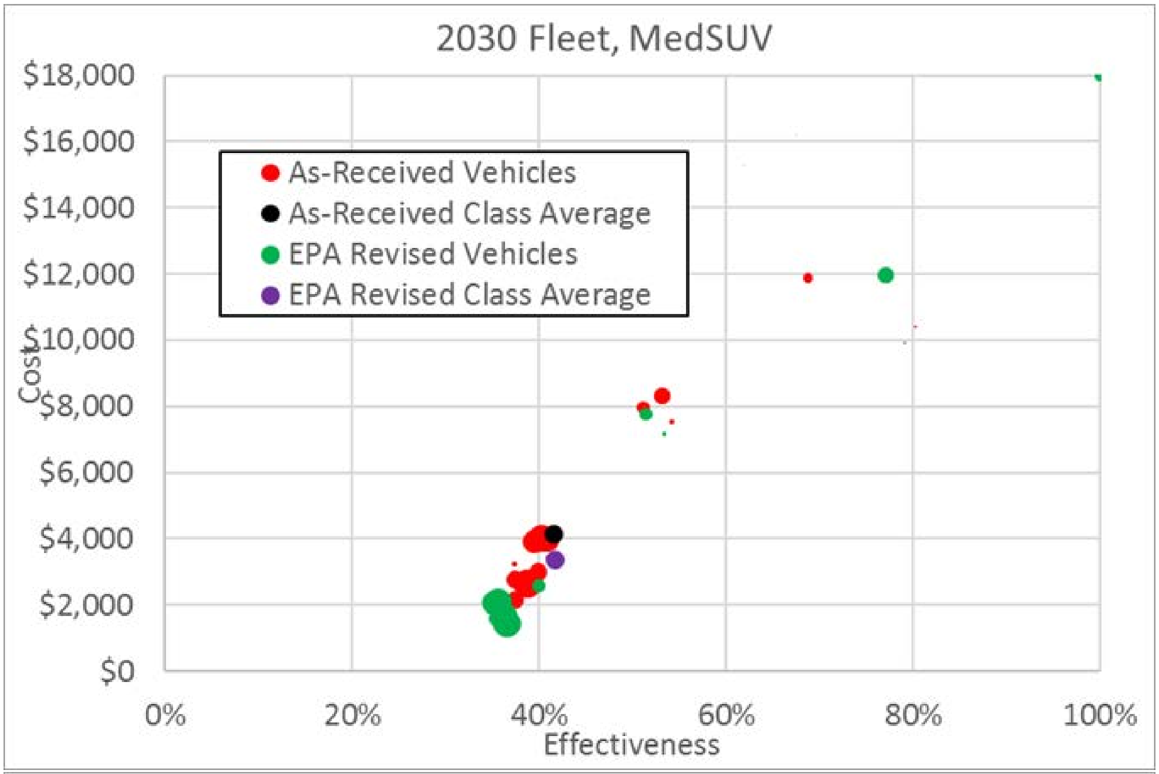
Effectiveness
As-Received Vehicles
As-Received Class Average
EPA Revised Vehicles
EPA Revised Class Average


2030 Fleet, MedSUV
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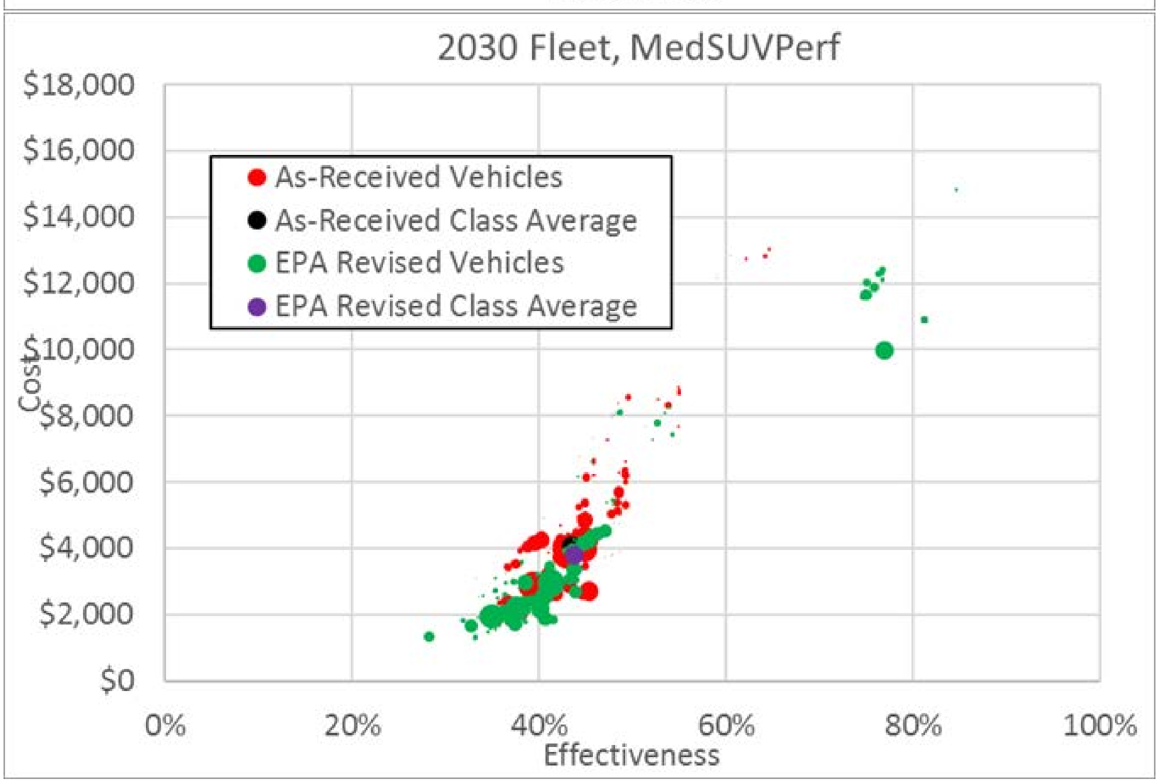
Effectiveness


2030 Fleet, MedSUVPerf
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As-Received Class Average
EPA Revised Vehicles
EPA Revised Class Average
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$8,000
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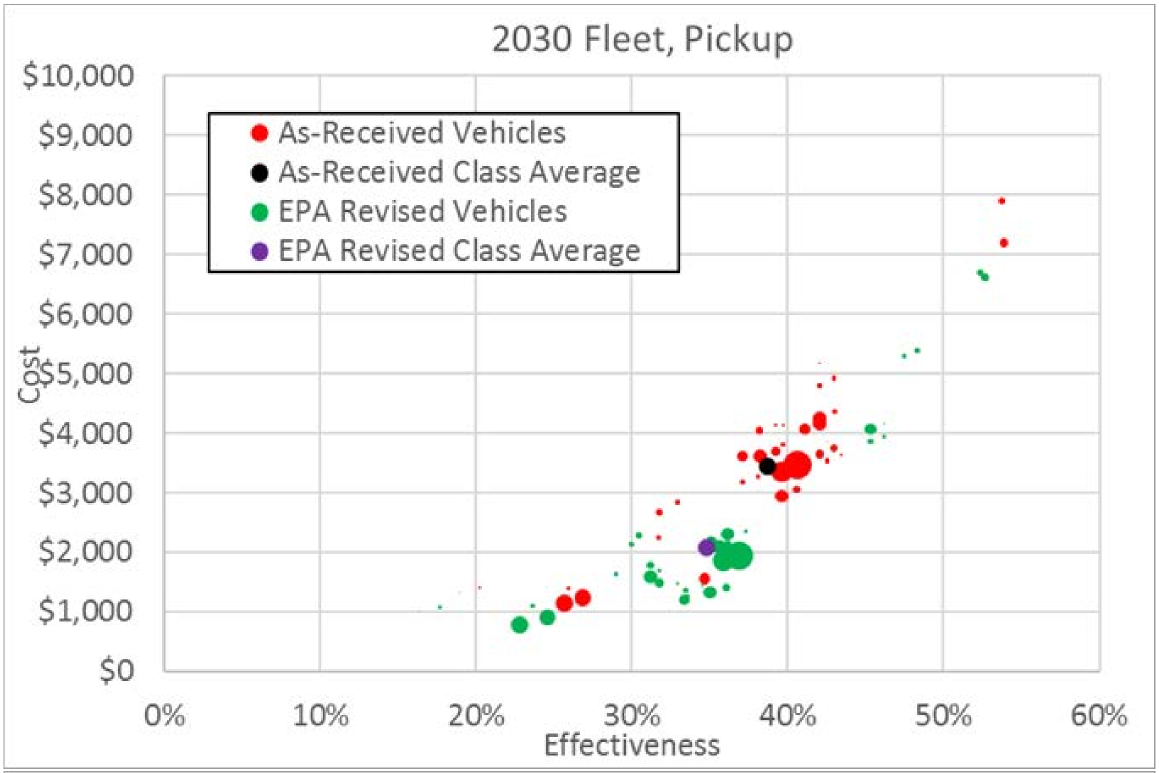
Effectiveness


2030 Fleet, Pickup
As-Received Vehicles
As-Received Class Average
EPA Revised Vehicles
EPA Revised Class Average
Cost
$10,000
$9,000
$8,000
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$6,000
$5,000
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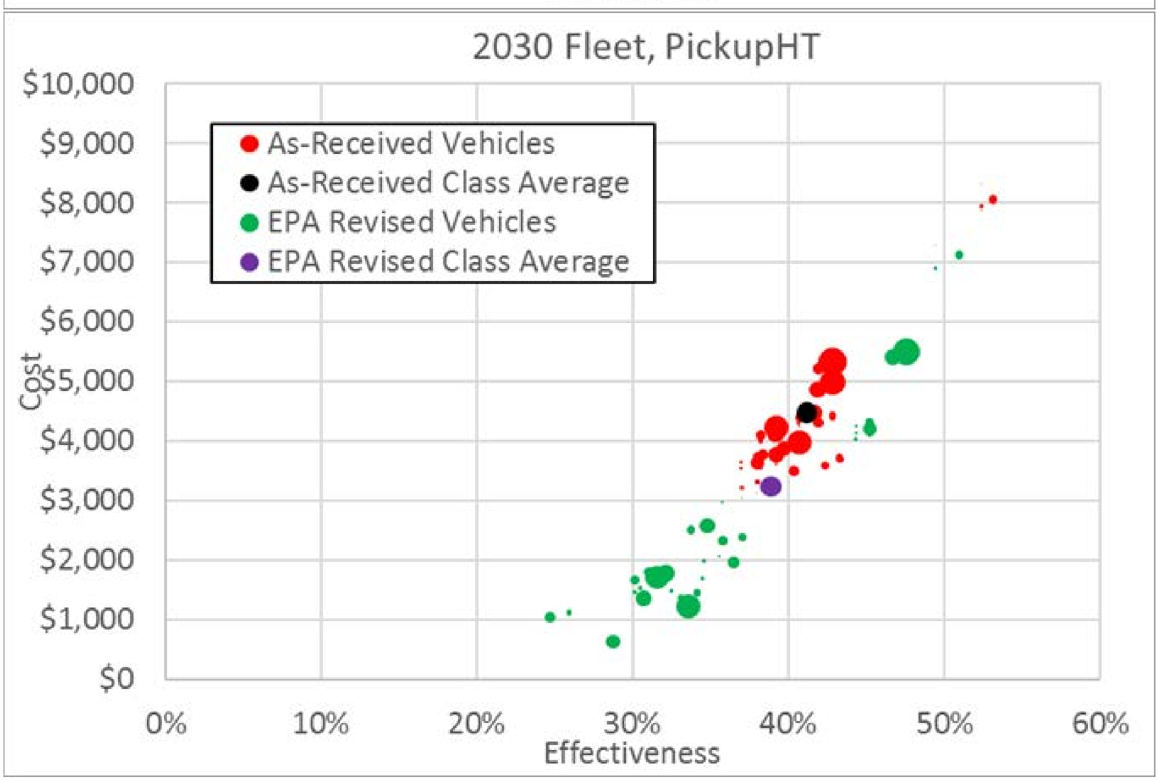
2030 Fleet, PickupHT
As-Received Vehicles
As-Received Class Average
EPA Revised Vehicles
EPA Revised Class Average
Cost
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$4,000
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Effectiveness

EPA Initial Review of CAFE Model & Inputs, February 9, 2018

Overview

This document summarizes EPA's initial findings from a review of the CAFE model and inputs, based on the materials provided on January 24th and February 1st by NHTSA. This is not intended to be a compressive assessment of the model, or the inputs and associated assumptions, but is instead meant to serve as the first step in an iterative review where the process of making observations and asking clarifying questions will lead to further exchanges of information. The following sections cover the four topic areas reviewed: the CAFE model in general, the representation of technologies, economic factors, and safety. Each section contains EPA's observations, along with supporting information where it may help to explain EPA's rationale for identifying a particular modeling element.

CAFE model: Overall observations and questions

Between January 24th and February 1st EPA received several files from NHTSA representing NHTSA's "January 22, 2018" runs. These files included four Excel files: 'analysis fleet', 'technologies', 'parameters', and 'scenarios'. In addition, NHTSA subsequently provided instructions for accessing tech package effectiveness and battery cost values embedded in the model. The overall observations and questions presented below are based on the information provided to-date.

In reviewing NHTSA's analysis, EPA has noted that many aspects of the CAFE analysis are similar to previously reviewed analyses and identified portions of the analysis that are new to the model's operation, these include the Fleet Scrappage Model, Dynamic Fleet Share, and Fleet Safety Fixed Model.

Observation 1: *When EPA utilizes the Jan 22 input files and executes the CAFE model with the default settings as provided by NHTSA, the resulting outputs do not match the values in the NHTSA-generated summary table. (see comparisons in Table 1 and Table 3)*

The EPA-generated "Price increase due to new CAFE standard" for a MY2030 vehicle shown in Table 3 is -$1,599 compared to the value of -$1,769 provided by NHTSA. The EPA-generated "Average Annual Fatalities CY's 2036-2045" value shown in Table 1 is -703 (relative to the no action alternative) compared to a NHTSA-provided value of -1,186. Overall, nearly every output variable summarized in Table 1 and Table 3 shows a difference of some degree between the EPA- and NHTSA-generated results. There are multiple possible explanations, including EPA's misinterpretation of the meaning of a particular row label, or potential differences in the selection of which output fields to include in a particular total cost or total benefit summation. Without additional information, EPA can not further evaluate the underlying reason for the difference in values seen. At the same time, an effective review of the CAFE model and inputs by EPA will depend on EPA's ability to correctly replicate and interpret the model outputs.

<u>Question/Information Request 1.</u> *Please provide the output files (contents of the 'reports-csv' directory) from the NHTSA-generated run that was used to populate the values shown in Table 1 and Table 3, along with the associated 'Summary.txt' run configuration description file.*

Table 1 Results of Standard Setting Run from 22-Jan-18 as summarized by NHTSA, and values produced by EPA's run of NHTSA-provided model with default settings

Source	As summarized by NHTSA		EPA-generated values	
Model Years	2022-2025	2021-2026	2022-2025	2021-2026
Annual Rate of Increase in Stringency	No Action	0.5%/Year PC 0.5%/Year LT	No Action	0.5%/Year PC 0.5%/Year LT
AC/Off-Cycle Procedures	No Change	No Change	No Change	No Change
Fuel Economy				
Average Required Fuel Economy – MY 2026+ (mpg)	46.6	38.2	46.8	38.1
Average Achieved Fuel Economy – MY 2030 (mpg)	47.6	40.6	46.5	40.7
Change in Physical Quantities Attributable to CAFE Alternative				
Fuel Consumption (b. gal)	baseline	76.4	baseline	74.8
Fuel Consumption (b. barrels)	baseline	1.8	baseline	1.8
CO_2 Emissions (mmt)	baseline	847	baseline	827
CH_4 Emissions (metric tons)	baseline	1,482,533	baseline	1,453,288
N_2O Emissions (metric tons)	baseline	12,214	baseline	16,761
Average Annual Fatalities CY's 2036-2045	baseline	(1,186)	baseline	(703)
Average Annual Fatalities CY's 2036-2045 without rebound	baseline	(395)	baseline	
Sales (millions)	baseline	1.0	baseline	0.9
Technology Use Under CAFE Alternative in MY2030 (total fleet penetration)				
Weight Reduction (not including powertrain)	17%	12%	16.4%	12.7%
High Compression Ratio Non-Turbo Engines	26%	13%	26.2%	20.9%
Turbocharged Gasoline Engines	60%	47%	61.9%	52.8%
Dynamic Cylinder Deactivation	6%	0%	5.0%	1.9%
Diesel Engines	1%	1%	0.6%	0.5%
Advanced Transmissions (Non-Hybrid)	72%	87%	68.0%	87.2%
Stop-Start 12V (Non-Hybrid)	15%	13%	14.2%	15.6%
Mild Hybrid Electric Systems (48v)	35%	1%	29.3%	4.7%
Strong Hybrid Electric Systems	20%	5%	26.9%	3.6%
Sum of Strong Hybrid and Mild Hybrid	**56%**	**5%**	**56.2%**	**8.3%**
Plug-In Hybrid Electric Vehicles (PHEVs)	5%	4%	1.4%	0.7%
Dedicated Electric Vehicles (EVs)	1%	1%	0.5%	0.5%
Sum of Plug-In Vehicles	**5%**	**4%**	**1.9%**	**1.2%**
Total of All Electrified Vehicles	***61%***	***10%***	***58.1%***	***9.5%***

Table 2 EPA's grouping assumptions for technology penetration summary in the table above, based on 'technology_utilization_report.csv' output file

Tech	Assumed Calculation
Weight Reduction (not including powertrain)	MR1*5%+MR2*7.5%+MR3*10%+MR4*15%+MR5*20%
High Compression Ratio Non-Turbo Engines	HCR1
Turbocharged Gasoline Engines	TURBO1+TURBO2+CEGR1
Dynamic Cylinder Deactivation	ADEAC
Diesel Engines	DSLI
Advanced Transmissions (Non-Hybrid)	All but AT5, AT6, DCT6, CVT
Stop-Start 12V (Non-Hybrid)	SS12V
Mild Hybrid Electric Systems (48v)	BISG
Strong Hybrid Electric Systems	SHEVP2+SHEVPS
Plug-In Hybrid Electric Vehicles (PHEVs)	PHEV30+PHEV50
Dedicated Electric Vehicles (EVs)	BEV200

Table 3 Results of Standard Setting Run from 22-Jan-18 as summarized by NHTSA, and values produced by EPA's run of NHTSA-provided model with default settings

Source	As summarized by NHTSA		EPA-generated values	
Model Years	2022-2025	2021-2026	2022-2025	2021-2026
Annual Rate of Increase in Stringency	No Action	0.5%/Year PC 0.5%/Year LT	No Action	0.5%/Year PC 0.5%/Year LT
AC/Off-Cycle Procedures	No Change	No Change	No Change	No Change
Consumer Costs and Savings for Average MY 2030 Vehicle				
Price Increase due to New CAFE Standards ($)	baseline	(1,769)	baseline	(1,599)
Increase in Other Ownership Costs ($)	baseline	(722)	baseline	(381)
Total Consumer Costs ($)	baseline	(2,492)	baseline	(1,980)
Discounted Fuel Savings to Owner ($)	baseline	(1,200)	baseline	(1,033)
Other Consumer Benefits ($)	baseline	(487)	baseline	(389)
Total Consumer Savings ($)	baseline	(1,687)	baseline	(1,422)
Discounted Net Savings to Owner ($)	baseline	805	baseline	558
Payback Period Relative to Baseline (years)	baseline		baseline	
Payback Period Relative to MY2016 (years)		13.0		5.6
Social Costs and Benefits (Total Through MY 2029)				
Technology Cost ($b)	baseline	(246)	baseline	(211)
Other Private Costs ($b)	baseline	(158)	baseline	(152)
Crashes, Noise and Congestion ($b)	baseline	(76)	baseline	(42)
Total Costs of New CAFE Standards ($b)	baseline	**(480)**	baseline	**(403)**
Fuel Savings ($b)	baseline	(138)	baseline	(132)
Other Private Benefits ($b)	baseline	(117)	baseline	(101)
Social Cost of Carbon ($b)	baseline	(4)	baseline	(4)
Other Environmental Damages ($b)	baseline	(2)	baseline	(4)
Petroleum Market Externalities ($b)	baseline	(22)	baseline	(21)
Total Benefits of New CAFE Standards ($b)	**baseline**	**(283)**	**baseline**	**(262)**
Net Benefits of New CAFE Standards ($b)	***baseline***	***197***	***baseline***	***141***
Additional Measures (Total Through MY 2029)				
Additional Fine Payments ($b)	baseline	0.0		

A full understanding of the model will require a review of the inputs and assumptions that are embedded within the executable file that EPA requested for this initial review. For example, details about the technology application decision trees are encoded within the CAFE model, and determine whether or not individual technologies (and associated costs) are included along a technology pathway. There are a number of examples of this type of embedded inputs and assumptions that EPA is aware of, and potentially others that EPA is not aware of.

Question/Information Request 2. Please provide the uncompiled CAFE model in the native code is (e.g. C#, Java, etc.)

Representation of technologies in the CAFE model and inputs

Technology effectiveness

The technology inputs provided by NHTSA on February 1 define effectiveness values for approximately 150,000 packages across ten vehicle classes. In addition, the 'technologies' input file contains the individual technology effectiveness values which are not modeled in full vehicle simulation such as electric power steering, improved accessories, low drag brakes, and low friction lubricants. A full evaluation of the assumed effectiveness values for individual technologies and their various combinations will require more time than the approximately one week that EPA has spent to-date and will require additional follow-up. The following summary of an effectiveness review conducted over the course of approximately one week is intended to highlight specific areas for further discussion and begin to identify additional information that is needed for a complete review.

Observation 2: *The incremental effectiveness of the more advanced turbocharged engine (TURBO2) compared to the less advanced version (TURBO1) engines is often negative.*

The technology inputs include two levels of turbocharged engines, TURBO1 and TURBO2. The incremental cost of TURBO2 hardware over TURBO1 hardware is about $350 to $700 in 2030; although it is unclear what specific technologies are represented by this cost, one would expect a generally higher effectiveness. However, depending on the package and car class, the actual incremental effectiveness values from the NHTSA technology inputs for the TURBO2 technology is often negative. The "Medium SUV" class, shown in Figure 1 has the most pronounced **effect, with the addition of the TURBO2 technology, on average, having a negative effectiveness.**

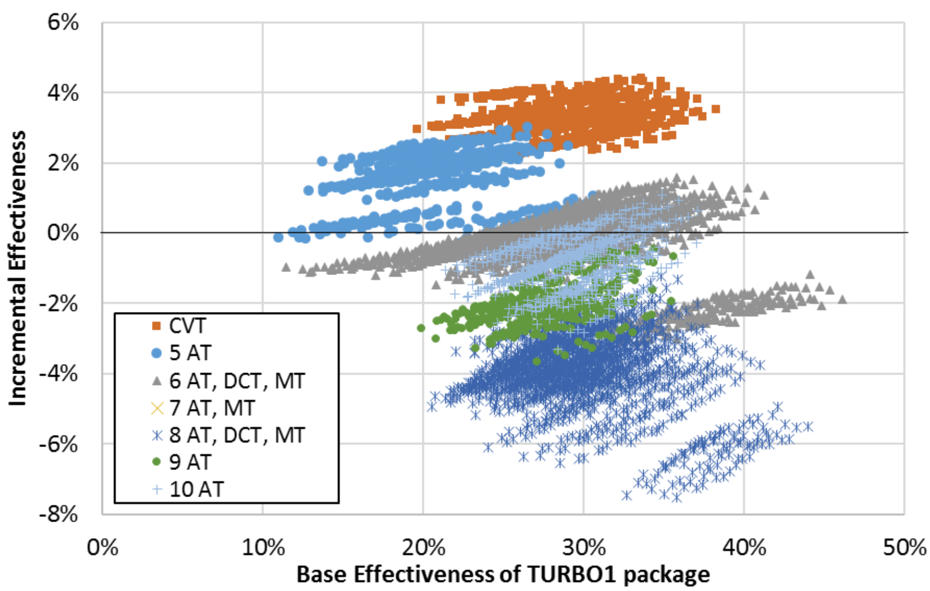


Figure 1 Incremental Effectiveness of TURBO1 to TURBO2 (MedSUV class)

Observation 3: *The addition of cooled exhaust gas recirculation (CEGR1) onto turbocharged engines (TURBO2) provides no relative benefit, despite the additional cost of the technology. Given this input assumption, the CAFE model outputs, as expected, do not show application of CEGR1.*

A cooled EGR package when added to the advanced turbocharged engine (TURBO2) has a cost of $334 in 2030. Cooled EGR is a technology that has been used in the market, and has a significant effect on CO_2 reduction. However, as illustrated in Figure 2, the incremental effectiveness is at or near zero for nearly all packages (and averaging zero for all packages). The “Medium Car Performance” class shown in the figure is representative of the near-zero effect of the technology for all classes.

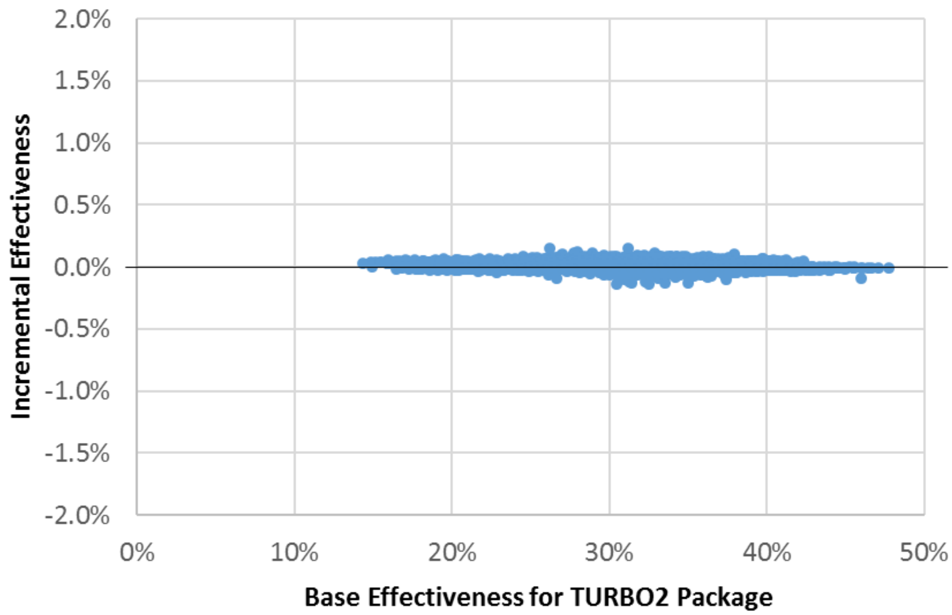


Figure 2 Incremental Effectiveness of TURBO2 to CEGR1 (MedCarPerf class)

Observation 4: *The effectiveness the most advanced eight-speed transmission (AT8L3) is only moderately more than the most advanced six-speed transmission (AT6L2).*

The modeled automatic transmissions include one “improved” level of a six-speed automatic (AT6L2) and two improved levels of eight-speed automatics (AT8L2 and AT8L3). The cost of the AT6L2 package (additional to an AT6) is $362 in 2030. The cost of the AT8L3 package (additional to an AT8) in 2030 is nearly the same ($358). Incremental to the AT6, the best eight-speed package is $485 (i.e.,$123 more than the AT6L2). However, on average, the technology inputs provided show that the AT8L3 is only 1% more effective than the AT6L2, and in some cases is worse (as shown by the Small SUV plot).

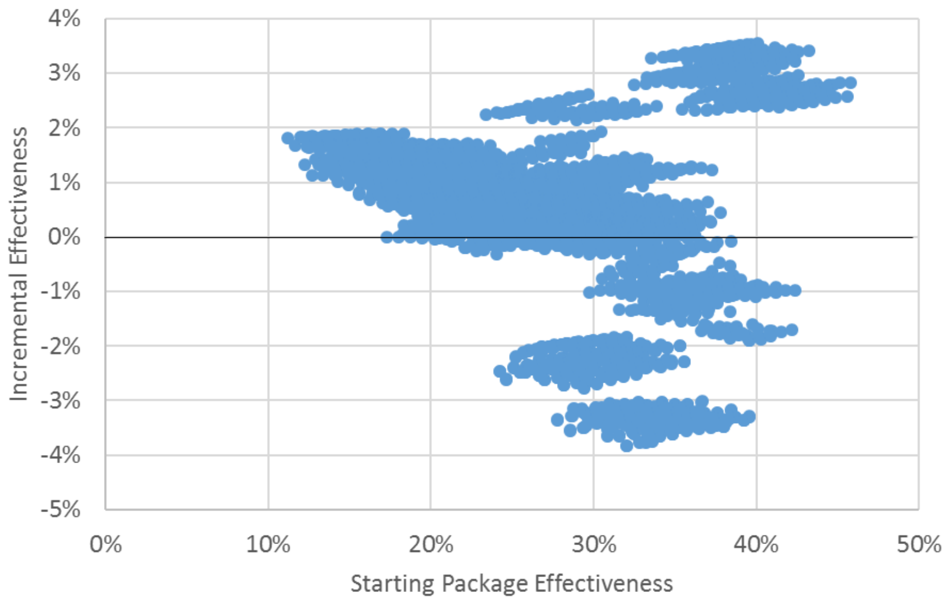


Figure 3 Incremental Effectiveness of the best six-speed (AT6L2) v. the best eight-speed (AT8L3) (Small SUV)

Observation 5: *The effectiveness improvement from a basic six-speed transmission (6AT) to a basic eight-speed (8AT) transmissions is unexpectedly low for trucks.*

The technology inputs provided seem to show that the incremental effectiveness associated with moving from a six-speed transmission (AT6) to an eight-speed transmissions (AT8) is noticeably different depending on class. The figure shows effectiveness for a medium car and a pickup; on average, the eight-speed effectiveness for the car is about twice that for the truck. This trend seems to hold for the small and medium car classes, which have AT8 effectiveness about twice that of the medium SUVs and trucks (with the small SUVs in between). This may be due to assumptions about front-and rear-wheel drive systems; however, comments from stakeholders have indicated that RWD systems should have greater potential for transmission effectiveness improvements, as packaging more gears in the space provided is less of a concern.

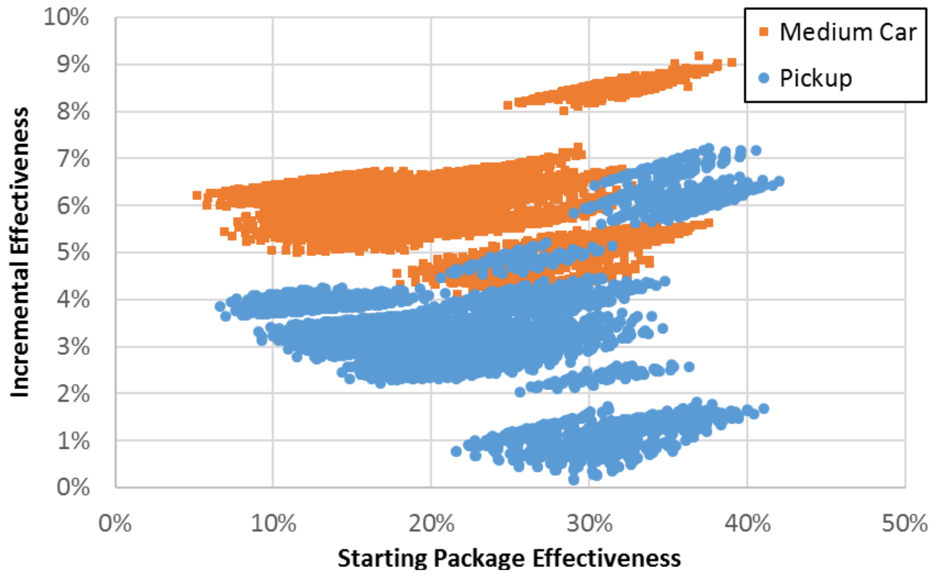


Figure 4 Incremental Effectiveness of six-speed (6AT) to eight-speed (8AT) for Pickup and Medium Car

Observation 6: *On average, 48V Mild Hybrid with a crank-integrated starter-generator (CISG) is the same, or slightly worse than with a belt-integrated starter-generator (BISG) despite having a higher cost.*

The cost of a crank-integrated starter-generator (CISG) system in 2030 is given as either $178 (for smaller vehicles) or $767 (for larger vehicles) in 2030, incremental to a belt-integrated starter-generator (BISG). Additional battery costs in 2030 are about $617 for the BISG and $805 for the CISG, making the incremental CISG battery cost an additional $187. The CISG is expected to provide additional effectiveness over the BISG because of the direct couple to the crank.

However, on average, the CISG is slightly less effective tan the BISG, although with a wide spread of effectiveness. The small car example shown in Figure 5 is typical, with the incremental effectiveness of most packages between about +1% and -1%.

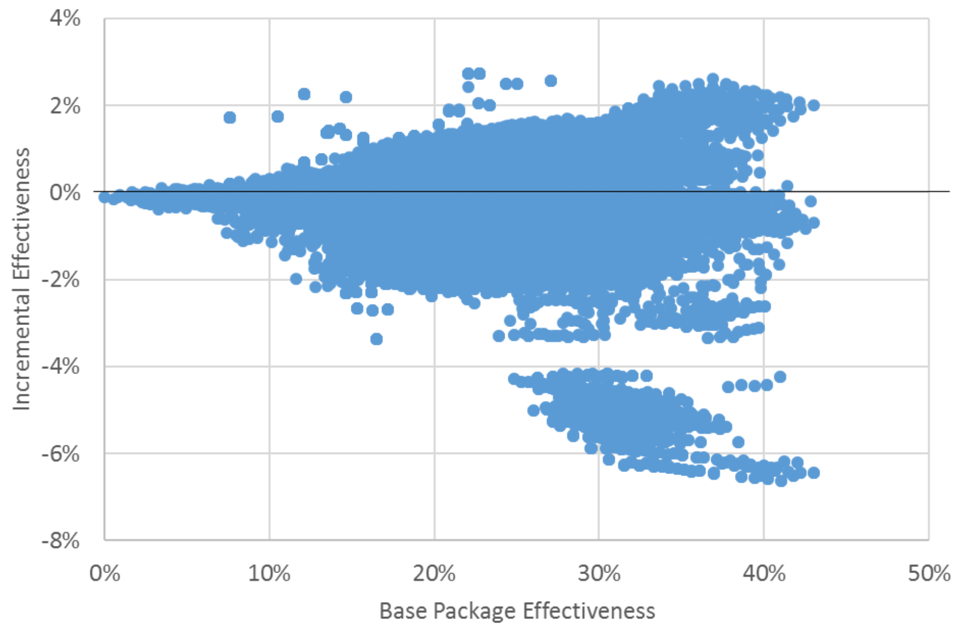


Figure 5 Incremental Effectiveness of 48V Mild Hybrid with belt-integrated starter-generator (BISG) to crank-integrated starter-generator (CISG) (Small Car class)

Observation 7: *Some 12V Stop-Start applications have negative effectiveness values.*

The cost of stop-start technology is either $466 or $521 in 2030, depending on vehicle class, plus about $582 in battery costs. However, there are some packages where the provided technology inputs indicate a negative effectiveness, as shown in Figure 6 for the small car class below. Moreover, there are a few packages in some classes that are clear outliers (see the medium SUV performance class), **either high or low.**

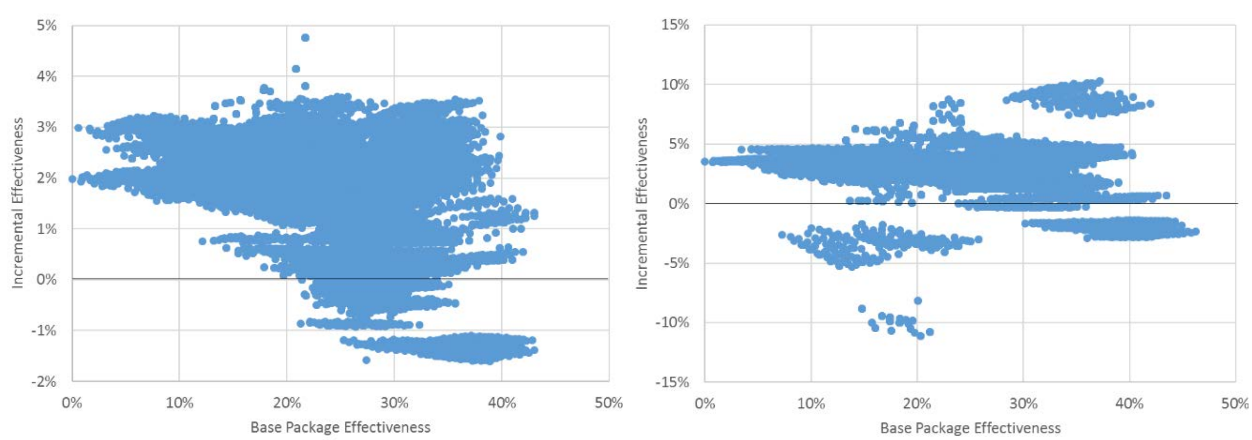


Figure 6 Incremental Effectiveness of CONV to SS12V for Small Car class (left) and Medium SUV Perf class (right)

<u>*Question/Information Request 3.*</u> *Please provide a description of the hardware that is assumed to be included in the technology packages highlighted in the observations above: TURBO2 (relative to*

TURBO1), CEGR1 (relative to TURBO2), AT8L3 (relative to AT8L), AT6L2 (relative to AT6), CISG (relative to BISG), and SS12V (relative to CONV)

Question/Information Request 4. *Please provide a table of the vehicle characteristics used simulate each of the 10 vehicle classes represented in this analysis (with MR0,ROLL0, AERO0). In particular test, weight, road load coefficients, power/acceleration/towing metrics, drive layout (RWD, FWD, AWD, 4WD), and any other specifications used when generating the 'FC1_Improvements.csv' file.*

Technology application constraints

In the CAFE model, the application of a technology may be constrained in order to reflect the lead-time required to achieve large-scale production and wide-spread penetration into the fleet. The broad application can be excluded from consideration by the specification of a year in which the technology is initially available, by setting a phase-in cap, or by the use of a 'FALSE' application flag value. Technologies can also be excluded from application to a specific vehicle by the platform, engine, and transmission sharing constraints, by the technology pathways encoded into the model, and by the explicit definition a "SKIP" flag to an individual vehicle-technology combination.

Observation 8: *Application of HCR1 is restricted for large portion of the fleet.*

Atkinson cycle engines with high geometric compression ratios (HCR) have proven to be a cost-effective pathway for reducing fuel consumption, with Mazda applying the technology to the majority their current vehicles, and Toyota announcing its plan for at least 60 percent application (by volume) by 2021. The 'analysis_fleet' file contains the 'SKIP' application flag for over 70 percent (by volume) of the fleet, while most other powertrain technologies are not similarly constrained (see Table 4.)

Table 4 Proportion of fleet volume with vehicle-specific technology application constraints ('SKIP' flag) with examples of high-compression ratio Atkinson cycle engines (HCR1) and strong hybrids

Application Flag in 'analysis_fleet' file	HCR1	Strong Hybrid (SHEVP2 +SHVEPS)	notes
USED	6.3%	1.8%	Assumed to be applied in MY2016
SKIP	70.6%	0%	Application not allowed in future
blank	23.0%	98.2%	Application allowed in future

Question/Information Request 5. *Why is the HCR1 technology highly constrained in the 'analysis-fleet' file relative to other technologies that are more complex and less cost-effective?*

Observation 9: *The packages available for consideration as inputs to the CAFE model do not include some significant technologies that are available in production vehicles today.*

For example, the 2018 Mazda CX-5 CUV and Mazda 6 sedan both are examples of non-hybrid electric vehicles that use Atkinson Cycle engines with cylinder deactivation. NHTSA's package designation for Atkinson Cycle is HCR1 and for cylinder deactivation is DEAC. In the 2016 Draft TAR analysis, NHTSA had a package designation of HCR2 for a combination of Atkinson Cycle, cooled EGR, and cylinder deactivation. The input files used in the most recent analysis do not allow any combination of DEAC and HCR1 and the HCR2 package is restricted from application through the use of a "FALSE" flag in the 'technologies' input file (also, no packages are built using HCR2.) In other words, a high-efficiency technology combination currently in production by Mazda for the 2018 model year will not be available for consideration in the CAFE model using the current input files.

Technology costs

> ***Observation 10:*** *The cost of Dynamic Cylinder Deactivation (ADEAC) is 2-4 times higher than industry quoted costs for the version of the technology which is going into production in MY2019.*

General Motors recently announced their implementation of ADEAC on two V8 OHV engines for the Silverado for MY2019 and EPA test drove and benchmarked an ADEAC-equipped GMC Yukon V8 OHV at NVFEL in 2017, verifying the effectiveness of the ADEAC system in drive cycle tests and the system's transparency to the driver. The supplier of the ADEAC system on the GMC Yukon (Tula/Delphi) quoted the 2017 cost for this system (manufacturing cost plus licensing fee), to which EPA applied a learning factor of 13.5% (from 2017 to 2025) and a manufacturer mark-up cost multiplier of 1.5, and this is shown on the far right in Figure 7. For this application (V8 OHV), the CAFE model marked-up cost is 4 times higher than the industry quoted manufacturer marked-up cost.

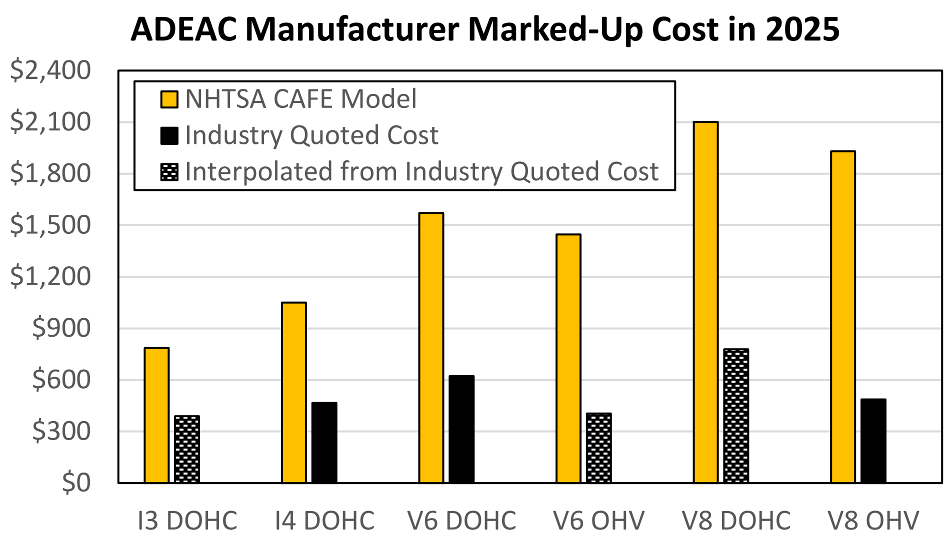


Figure 7 Comparison of Dynamic Cylinder Deactivation Costs

NHTSA's 2-4 times higher cost of ADEAC impacts the CAFE model's application of the technology. NHTSA's summary of CAFE model output (Table 1) shows a 6% market penetration of ADEAC in 2030 if current standards are kept in place and 0% if "alternative 1" standards are selected. (note that as shown in Table 1, EPA was unable to reproduce these results using provided input files and default CAFE model settings.)

The CAFE model's 0% penetration of "alternative 1" is unrealistic considering General Motors will be offering two engines for the Silverado with ADEAC in MY2019, and the sales of these engines (prior to ADEAC) was 767,000 in MY2016, or about 4.4% of the entire LDV fleet. Other manufacturers likely have similar plans, which will likely increase ADEAC market penetration well past 4.4% in the MY2019-2022 timeframe.

The CAFE model's 6% penetration in MY2030 using current standards may also be low, considering that it is much easier to apply a technology to subsequent engines after several examples have been developed and entered production. EPA believes the low penetration of ADEAC in the CAFE model may be due to the high ADEAC cost assumed by the CAFE model.

<u>*Question/Information Request 6.*</u> *Please provide details for how the costs for dynamic cylinder deactivation were estimated, particularly the $1,931 cost for V8 OHV engines.*

Economic factors in the CAFE model and inputs

Consumer choice modeling ('dynamic fleet share' and 'scrappage' models)

The effects of the standards on vehicle sales and market shares has been a recurrent question. On the one hand, the standards reduce operating costs; all else equal, that change should make new vehicles more attractive and increase sales. On the other hand, the standards increase technology costs; all else equal, that change should discourage new vehicle sales. Which effect dominates has been subject of a great deal of controversy. A key variable is the role of fuel economy in consumer purchases, measured either in payback period (the number of years of fuel savings that people consider when buying a new vehicle) or discount rate (how people discount the lifetime of future fuel savings). EPA has reviewed this literature, as has the National Academy of Sciences; in both cases, the finding was a very wide range, and no consensus, in the literature.

Academic and other researchers have developed a number of vehicle demand (consumer choice) models for the new and/or used vehicle markets to look at effects on sales and fleet mix. Rarely has there been any effort to validate these models, either for consistency across models, or for ability to predict out of sample. Recent academic research (Haaf et al. 2014, 2016), as well as work by EPA, has found that these models commonly perform worse, especially in the short run, than simply holding market shares constant. For these reasons – an absence of solid science supporting the use of vehicle demand models for predicting the effects of the standards on vehicle sales – neither EPA nor NHTSA has used consumer choice modeling in either the 2010 or 2012 rulemakings, or in the 2016 Draft TAR, or in previous CAFE rulemakings. The agencies have occasionally estimated the effects of the standards on new vehicle sales using a Total Cost of Ownership model, where the key parameter, as mentioned above, is the role of fuel savings in consumer purchase decisions. This approach was recently recommended by Dr. John Graham and others from Indiana University in their February 2016 report, "Rethinking Auto Fuel Economy Policy".

The CAFE model appears now to include a "Dynamic Fleet Share" model (which we think is a consumer choice model for new vehicles) and a "Scrappage" model (scrappage models estimate the effect of new vehicles on the used vehicle market). These have not previously appeared in the CAFE model.

> ***Observation 11:*** *From a review of the model outputs, the use of the 'Dynamic Fleet Share' and 'Scrappage' models appear to significantly impact overall sales, fleet volumes, and model mix, and therefore are important factors in the CAFE model's resulting net benefits, costs, and safety results.*

Sales increase for both the augural standards and the alternative standards, though they appear to increase slightly more for the alternative standards. In addition to total sales, sales mix changes between the augural and alternative standards (that is, sales for individual vehicles increase at different rates, though all increase). Price increases at least as much as technology costs for individual vehicles; in a number of cases, vehicle price increases more than technology costs, though we have not been able to figure out how those price increases are calculated (see below). These changes are likely to affect emissions and other model outputs.

Observation 12: *However, the inputs for these new modelling elements are not clear and the operation of the elements is also not clear to the model user.*

The "Dynamic Fleet Share" model coefficients for FP, HP, and MPG, seem to indicate that the sales response to changes in these variables for cars is opposite of the sales response for trucks. This table is the documentation presented for the DFS. It is our guess that these are regression coefficients used to predict vehicle sales for cars (LDV) and light trucks (LDT1/2a). It is further our guess that FP is footprint, HP is horsepower, CW is curbweight, MPG is miles per gallon. We do not have guesses what Rho and Dummy are associated with.

Coefficients	LDV	LDT1/2a
Constant	3.4468	7.8932
Rho	0.8903	0.3482
FP	0.1441	-0.4690
HP	-0.4436	1.3607
CW	-0.0994	-1.5664
MPG	-0.5452	0.0813
Dummy	-0.1174	0.6192

We observe that HP and MPG have negative signs for cars (i.e., more HP and more MPG reduce sales), while those coefficients are positive for trucks (i.e., more HP and more MPG increase sales). In contrast, FP increases car sales but reduces truck sales. These results are not what we would expect.

As discussed above, the role of fuel savings in vehicle demand modeling is critically important; it essentially determines the direction of new vehicle sales effects. As noted, it appears that more fuel economy is bad for cars but good for light trucks, with unexplained magnitudes.

Observation 13: *The scrappage model coefficients do not have consistent signs for cars, Vans/SUVs, Pickups*

It is not known exactly what the Scrappage model predicts: how many vehicles of which vintages are scrapped each year? The scrappage model appears to include 34 parameters, including new vehicle prices, vehicle age, CPM (cost per mile?), GDP growth rate, and interactions among these in polynomial forms. It is thus hard to evaluate. Below is a partial representation. Signs of the coefficients are again not consistent (see, e.g., Age, Age^2, Age^3, New Price, New Price*Age, New Price*Age^2), though how these affect predictions is not easy to determine.

Parameter	Cars	Vans/SUVs	Pickups
Estimate Scrappage	TRUE	TRUE	TRUE
Beta Coefs			
Age	0.616047051	-0.473441117	-1.119398279
Age^2	-0.057406753	0.032324147	0.037890057
Age^3	0.001582126	-0.000301894	0

ln(MY-1959)	-1.608885894	-3.946616362	-3.364968508
ln(MY-1959)*Age	0.213582275	0.504803381	0.34204715
ln(MY-1959)*Age^2	-0.006715995	-0.015159639	-0.008384946
ln(MY-1959)*Age^3	0	0	0
New Price	-0.000161276	0.000371589	-0.000303124
New Price*Age	7.84025E-06	-2.88675E-05	2.83304E-05
New Price*Age^2	1.00488E-07	5.91183E-07	-9.62014E-07
New Price*Age^3	-1.212E-08	0	0

Question/Information Request 7. *Please describe any previous rulemakings where these or similar models were used to examine impacts on sales and fleet mix.*

Observation 14: *The CAFE model vehicles_report output file provides vehicle price increases, which in some cases is the same as the tech cost increase, and other cases significantly higher.*

Question/Information Request 8. *Please provide an explanation of the methodology for individual determining price increases, and the relationship between the technology costs, fines, and price increases.*

Discount rates

In rulemakings, EPA and NHTSA have calculated and reported net benefits with a 3% discount rate for both benefits and costs, and separately with a 7% discount rate for both benefits and costs. These are intended to represent expectations of impacts of the standards.

Observation 15: *The summary tables provided by NHTSA includes a footnote for "Consumer Costs and Savings for Average MY 2030 Vehicle" stating, "Consumer Costs and Savings are discounted to net present value using a 7% discount rate." On the other hand, "Societal Costs and Benefits are discounted to net present value using a 3% discount rate."*

OMB Circular A-4 observes that the real discount rate of 7 percent "is an estimate of the average before-tax rate of return to private capital in the U.S. economy," that is, for private-sector business activity. On the other hand, according to Circular A-4, "When regulation primarily and directly affects private consumption (e.g., through higher consumer prices for goods and services), a lower discount rate is appropriate." On that basis, it seems inappropriate to use a 7 percent discount rate for "Consumer costs and savings."

As discussed above for consumer choice modeling, it may be reasonable to choose a different discount rate for fuel savings when analyzing sales impacts, as an alternative to using a limited number of years of future fuel savings (payback period). Such alternative rates are used to estimate how consumers behave when buying vehicles; they do not necessarily represent what consumers will experience once they have bought their vehicles. "Consumer Costs and Savings" should reflect what consumers are expected to experience; the Dynamic Fleet Share and Scrappage models already serve the function of estimating sales impacts.

Question/Information Request 9. *Please explain the basis for using a 7 percent discount rate for Consumer costs and savings, and how that satisfies the instructions of OMB Circular A-4. Also, the parameters input sheet includes “Consumer Discount Rates” of 0.03, 0.07, 0.12, and 0.15. Are 12 and 15 percent discount rates used? If so, where are they used, and what is the explanation for their use?*

VMT schedules

The assumptions made about how much the average vehicle is driven in each year over a vehicle lifespan is an important factor in the calculation of greenhouse gas emissions, fuel savings, and discounted net benefits. The accumulation of vehicle mileage earlier in a vehicle’s lifetime will tend to result in fuel savings and emissions benefits that are pulled ahead to earlier calendar years, and therefore discounted less in terms of net present value compared to a vehicle that accumulates more mileage later in its lifespan.

Observation 16: *The form of the mileage accumulation schedule provided in the ‘parameters’ input file is unexpected, and not consistent with mileage accumulation schedules in other data sources.*

The table of vehicle miles traveled (VMT) by vehicle age described in the ‘parameters’ input file shows a steep drop-off in annual VMT after age 6. NHTSA had first utilized a curve with that shape in the 2016 Draft TAR, and EPA understands the underlying data source is an IHS/Polk product based on odometer readings from individual vehicles. The drop-off in annual VMT in the NHTSA schedule shown in Figure 8 is not seen in other data sources, including the 2001 National Household Travel Survey (NHTS), and a DOE LBNL analysis based on odometer readings from DMV records of the Texas inspection an maintenance program. The 2009 NHTS data shows a decline that coincides with the NHTSA schedule, but of a much smaller magnitude.

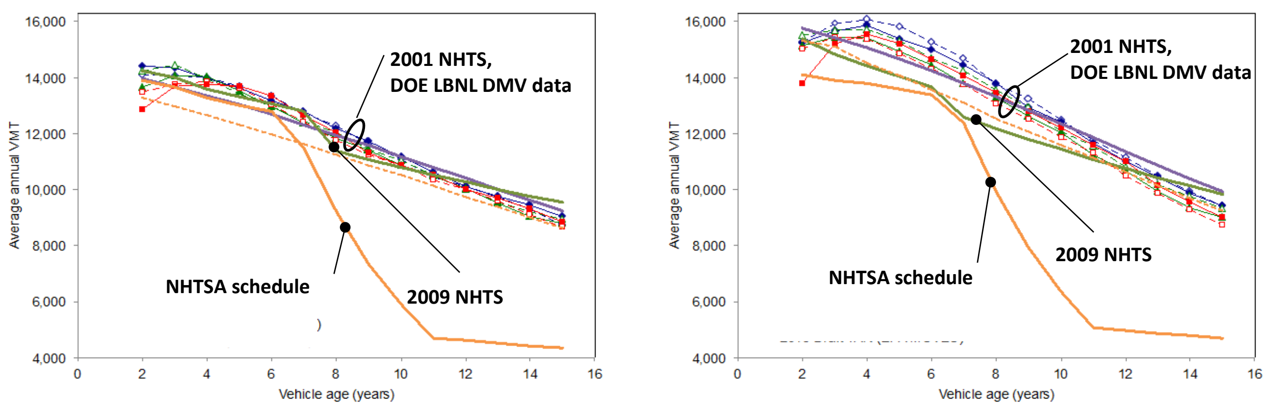


Figure 8 Comparison of NHTSA mileage accumulation schedule with data from other sources for cars (left) and trucks (right)

Question/Information Request 10. *Can NHTSA provide an explanation for why such a dramatic decline in annual VMT occurs after age 6, and considering that large decline why does NHTSA believe that the IHS/Polk data is more defensible than multiple other sources which are based on population-weighted samples of odometer readings of individual vehicles.*

Employment Analysis

In past rulemakings, NHTSA has based its employment analysis solely on sales volumes (the "output effect"): if sales are projected to change, employment would change in a constant ratio. Because EPA has not quantitatively estimated sales impacts in recent rulemakings, for reasons discussed above for "Consumer Choice Modeling," it has not quantified the effects of sales changes on employment. It has, however, estimated the proportion of technology costs that are labor costs – that is, the labor involved in the new technologies, known as the "cost effect" or "substitution effect" – and included estimates of those effects in its analysis. NHTSA has not included those effects in its employment analysis, even though labor costs are a significant fraction of technology costs. This initial review is based on an inspection of input files.

In the "parameters" spreadsheet, "Employment Values" includes information for revenue per employee for OEMs and suppliers. These parameters are not consistent with NHTSA's approach to the output effect in recent rules of using workers per vehicle, nor is it consistent with EPA's method of estimating the substitution effect.

The spreadsheet also includes multiplier values, which seek to measure the ripple effects of employment in the auto sector to other sectors in the economy. Multiplier effects are most suitable for situations, such as small regions, where it is reasonable to expect people to enter (or move into) and leave jobs in the area in response to changes in one sector. At the level of the U.S., multiplier effects depend on assumptions about the state of the macroeconomy at the time of impacts. If unemployment is high, as in 2009, then multiplier effects can happen, as people enter or leave the workforce. On the other hand, if unemployment is low, then it is unlikely that new jobs are created in response to changes in the auto sector; rather, workers will switch among sectors. The use of multipliers for auto sector job impacts thus requires assumptions about unemployment at the time of the changes.

Question/Information Request 11. *Please provide documentation for how NHTSA is calculating employment impacts. Is it based on revenue? If so, what is the method for doing so?*

Question/Information Request 12. *What do the employment numbers in the output sheets measure -- Auto sector? Multiplier effects? If multiplier effects are used in NHTSA's employement estimates, what assumptions are being made about the state of the macroeconomy at the time of impacts? What is the source of those assumptions?*

Question/Information Request 13. *Is NHTSA including in its analysis the employment effects associated with technology costs? If not, what is the explanation for this omission?*

VMT Rebound

In past LDV rulemakings in 2010 and 2012, and the Draft TAR published in July 2016, EPA, NHTSA and CARB jointly determined that an LDV VMT rebound estimate of 10% was the most appropriate value for assessing standards out to the 2025 timeframe. In the Summary Tables provided by NHTSA (the parameters spreadsheet, Economic Values for Benefits Calculations (2016$), Rebound Effect: VMT elasticity wrt fuel cost per mile), NHTSA doubled its estimate of VMT rebound to 20% for passenger cars, light trucks and light trucks 2b3.

Question/Information Request 14. *What is the basis that NHTSA used to double its estimate of the VMT rebound effect for this rulemaking? Are there new recent published studies on LDV VMT rebound* *effects since the 2016 Draft TAR that NHTSA used to update its estimate of the LDV VMT rebound effect? Please provide documentation for the updated methodology/rationale.*

Emissions impacts and costs

Effects of the standards on both CO_2 and other pollutants depend on not only the changes in technologies to vehicles, but also changes in the amount driven (rebound effect), changes in the number of vehicles and fleet mix (Dynamic Fleet Share and Scrappage models), and changes in fuels produced (upstream effects).

Observation 17: *In the "societal_effects_report," it appears, at least for 2025 and 2030, that, in going from the augural standards to the alternative standards, emissions of some pollutants (VOC, NOx, SO_2, PM, CO_2, CH_4, N_2O, DPM) increase, while emissions of others (CO, Acetaldehyde, Acrolein, Benzene, Butadiene, Formaldehyde) decrease.*

It seems peculiar that some increase while others decrease; it's especially counter-intuitive that toxics go down while VOC goes up.

Question/Information Request 15. Can NHTSA explain what contributes to this effect?

Observation 18: *It is unclear where NHTSA selected the unit values to monetize changes in PM-related criteria pollutant emissions (aka, benefit per ton values - BPT).*

NHTSA provides the following table for Emission Damage Costs:

Emission Damage Costs ($/metric-ton)	
Carbon Monoxide	0
Volatile Organic Compounds	2,000
Nitrogen Oxides	8,200
Particulate Matter	371,100
Sulfur Dioxide	48,000
Methane	0.0000
Nitrous Oxide	0.0000

They appear to be outdated (e.g., they include a unit value for VOCs, which EPA no longer monetizes due to uncertainty in the underlying air quality modeling); and they don't appear to account for how BPT values increase over time.

Question/Information Request 16. What is the source for these emissions damage costs, and does the CAFE model change the values over time?

Safety assessment

Question/Information Request 17. How are the "fixed effects", as presented in the safety values sheet of the parameters input file estimated? Why are values flat from 2014 through 2021? Why do they decrease beyond 2021? Why the large step change reduction in 2026 with a flattening beyond 2026?

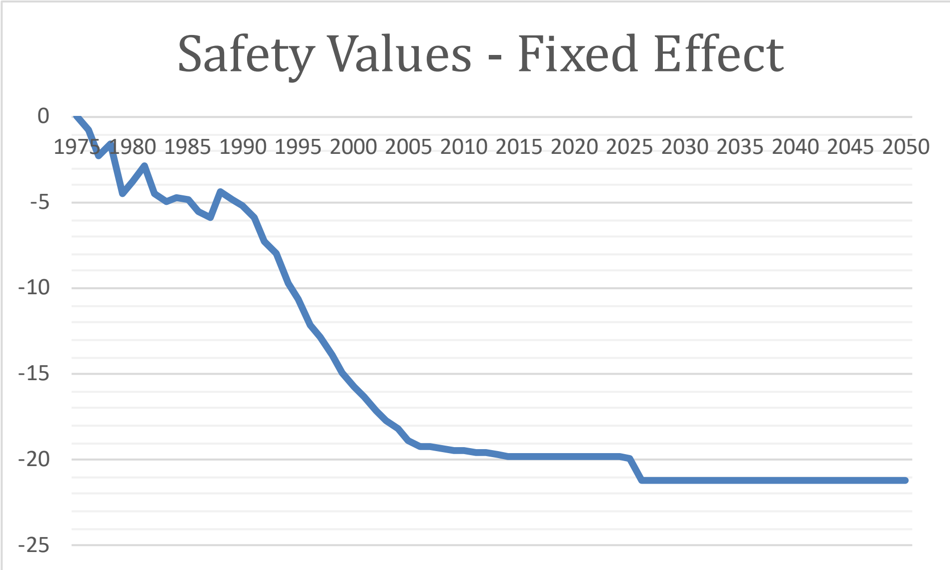


Figure 9 Fixed Effect Values used in the Safety Analysis

<u>Question/Information Request 18.</u> *Running the CAFE model with the DFS model turned OFF (and all other inputs as received by EPA) results in fewer fatalities in both the Augural and Alternative scenarios while simultaneously reducing sales in MYs 2017 through 2029 by ~18 million vehicles (see table below). Is there an explanation for why this would happen?*

Model inputs	**All inputs as received by EPA**			**DFS Model turned OFF**		
Scenario	Augural	Alternative	Delta	Augural	Alternative	Delta
Fatalities (avg/CY 2036-2045)	18,055	17,352	-703	16,259	15,556	-703
Sales (MY2017-2029, millions)	223.7	224.6	0.9	205.8	205.8	0.0

EPA Further Review of CAFE Model & Inputs, February 28, 2018

Overview

This document summarizes EPA's findings to-date from a review of the CAFE model and inputs, based on the materials provided on January 24th, and follow-up materials and discussions with NHTSA. EPA chose to use the available timeframe to focus on the modeling inputs and assumptions that are likely to have the most significant influence on the results, with particular attention to the effects on technology costs, net benefits, penetration of strong electrification technologies, and fatalities.

At this point, EPA cannot endorse the use of the CAFE model for an EPA NPRM. Given the application of new, unreviewed models, errors and anomalies in technology effectiveness, higher than expected costs for batteries and some conventional technologies, and dated nature of some of the inputs and indefensible technology application constraints, it is not possible for EPA to conclude that the current NHTSA analysis reflects the conclusions of the research performed by EPA over the last five years. We also note that EPA's review of the CAFE model is limited by our ability to review the CAFE model code, and we renew our request for the uncompiled CAFE model code to enable EPA to complete our review.

EPA's observations are grouped into four topic areas: the CAFE model in general, the representation of technologies, economic factors, and safety. The first four sections of this document cover the most significant observations and supporting information for each topic area. Additional observations are included four subsequent sections.

Executive Summary

While a significant amount of information has been shared between the two agencies, EPA feels that these results represent a limited understanding of the CAFE model. Some priority requests have been left unfulfilled and other information was received very late in the review process and has not been fully considered in the preparation of this summary. Under the category of unfulfilled requests, EPA feels that obtaining the CAFE model source code would provide the detailed level of understanding required to support a joint NPRM. With respect to critical analysis information, details on the scrappage model, safety factors, and engine maps were provided on the same day that EPA's analysis was scheduled to be completed. It is difficult to assess the significance that any individual concern we've raised would have on the outputs from NHTSA's modeling, given the limited amount we know. However, based on what we do know, EPA has two concerns that we believe have a highly significant impact on modeling results. First is NHTSA's reliance on new, untested models (i.e., fleet sales and scrappage): the outputs of these models can have a large effect on the policy choices the Administration makes, and we don't believe these models have received sufficient scrutiny to be used in such a significant policy process. And the second is the outdated, questionable quality of some of the tech inputs: relying on old technology, or preventing new technology from being used, has a material impact on the modeling outcomes, and therefore the policy options that will be presented to decision makers and the public.

In considering the NHTSA analysis results provided to EPA in late January it is important to keep in mind that there is approximately a $700 difference in estimated average vehicle cost between EPA's analysis and NHTSA's for existing GHG/augural CAFE standards, with NHTSA's being higher. A cost difference of this magnitude could be attributed to a number of significant differences in the modeling inputs and assumptions, and has a dominant effect on the range of projected effects presented by NHTSA for the existing/augural standards and for each alternative standard scenario modeled by NHTSA, including the projected CO_2 reductions, projected fuel savings, net benefits, vehicle sales, vehicle scrappage, employment, VMT and safety impact. EPA believes that if NHTSA were to limit the application of consumer effects models to sensitivities and not the primary analysis, correct errors in their assessment of technology effectiveness and to update key inputs with the latest available data, the per-vehicle costs projected by NHTSA's models would be substantially lower and the overall conclusions regarding the stringency of the standards would be significantly different.

There are aspects of NHTSA's analysis that are new and we have never seen before. These include a fleet model and a scrappage model. EPA is not aware of any previous NHTSA rulemaking for which these models have been applied. EPA did receive a short briefing on some aspects of the consumer effects on February 28th, however, there was no underlying documentation provided to justify NHTSA's conclusions. In addition, the tone of the briefing implied that there is considerable discretion being exercised by Volpe staff in the calibration and application of these critical models. At this time, we do not recommend using these elements of the CAFE model for setting policy.

EPA has observed and presented to NHTSA that several of their inputs regarding technology effectiveness are incorrect. These technologies include some applications of advanced transmissions, 12V stop/start, cooled EGR (CEGR), crank integrated starter generator (CISG), turbo-charged GDI engines, strong hybrids and the application of high compression ratio engines (HCR1). For each of these technologies EPA has identified either errors in the input data or incorrect assumptions regarding the application of the technology which are inconsistent with trends seen in the current vehicle market. Each incorrect technology input contributes to a higher estimate of average vehicle cost to meet future standards.

EPA has also noted that more recent and representative data are available. In their Draft TAR analysis, NHTSA applied engine maps developed by IAV in 2013 from a DOE-funded project unrelated to the assessment of CAFE standards. During the course of EPA's evaluation of the NHTSA analysis, NHTSA informed EPA that they were using the same IAV engine maps for their NPRM analysis. These maps were out of date at the time of the 2016 Draft TAR and we have additional, and newer data, further strengthening our conclusions that the engine maps used in the CAFE analysis are not representative of what the industry is currently producing and will be producing in the 2020~2030 time frame assessed in the CAFE model. This out-of-date characterization of modern engines also contributes to the higher estimated vehicle cost.

The "siloing" of technologies is also contributing to the higher projected compliance costs. NHTSA has adopted a modeling methodology that limits a manufacturer's ability to transition to an alternative technology, even if that technology is a more cost effective solution. For example, NHTSA assumes that a vehicle that is currently equipped with a turbo charged engine must remain turbo charged, even in the case of electrification to a hybrid electric vehicle. In the current and past light-duty fleet, only one turbo charged hybrid has ever been manufactured, with the majority of the hybrids being powered by a more cost effective Atkinson Cycle engine. This approach would not be appropriate for modeling through 2025, and is certainly not appropriate given that NHTSA projects technology and fuel economy performance out to 2032 MY. These assumptions regarding the application technology are overly constrictive and unrealistic.

EPA has also observed some volatility in the model results. EPA has noted in this document observations of projected results and impacts that do not appear to make sense, and EPA is concerned that sufficient quality assurance checks of the CAFE model have not occurred and the current version of the CAFE model may not be ready for use for rulemaking.

Finally, EPA's observations regarding the Safety Values – Fixed Effects curve continue to be a concern. EPA noted that the original January 22nd NHTSA analysis included a safety effects curve with a distinct kink in the curve in 2025 MY. NHTSA revised the curve to reflect a more gradual improvement in safety. On February 28th, NHTSA further explained that this curve represented an internal NHTSA estimate of improved vehicle safety based on anticipated safety regulations and safety improvements implemented by vehicle manufacturers of their own volition. Given the impact that this curve has on the projection of future fatalities and policy implications, EPA believes further review is required.

CAFE model: Primary observations and questions

Between January 24th and February 1st EPA received several files from NHTSA representing NHTSA's "January 22, 2018" runs. These files included four Excel files: 'analysis fleet', 'technologies', 'parameters', and 'scenarios'. In addition, NHTSA subsequently provided instructions for accessing tech package effectiveness and battery cost values embedded in the model, and a description of the runtime settings. The overall observations and questions presented below are based on the information provided to-date.

Observation 1: When EPA utilizes the Jan 22 input files and executes the CAFE model with the runtime settings as provided by NHTSA, many of the resulting outputs exactly match the values in the NHTSA-generated summary table. While this indicates that EPA is generating the same output files that were reference by NHTSA, EPA is not at this time able to replicate the net benefits value and several of the sub-items. EPA is not able to make a full judgment of the Jan 22 model and inputs before receiving some further description of which model outputs are used in generating the net benefits value (see comparisons in Table 1 and Table 3.)

The EPA-generated values for the "Physical Quantities Attributable to the CAFE standards" in Table 1, the Consumer Costs in Table 3, and many of the Social Cost, Total Cost, and Net Benefit values in Table 4 are different than the numbers provided by NHTSA. There are multiple possible explanations, including EPA's misinterpretation of the meaning of a particular row label, or potential differences in the selection of which output fields to include in a particular total cost or total benefit summation. Without additional information, EPA cannot further evaluate the underlying reason for the difference in values seen. At the same time, an effective review of the CAFE model and inputs by EPA will depend on EPA's ability to correctly replicate and interpret the model outputs.

<u>Question/Information Request 1.</u> *Please provide the calculations that NHTSA believes should be used to generate the change in physical quantities, the consumer costs and benefits and, importantly, the social cost and benefits results.*

Table 1 Results of Standard Setting Run from 22-Jan-18 as summarized by NHTSA, and values produced by EPA's run of NHTSA-provided model and runtime settings

Source	As summarized by NHTSA	EPA-generated values

Model Years	2022-2025	2021-2026	2022-2025	2021-2026
Annual Rate of Increase in Stringency	No Action	0.5%/Year PC 0.5%/Year LT	No Action	0.5%/Year PC 0.5%/Year LT
AC/Off-Cycle Procedures	No Change	No Change	No Change	No Change
Fuel Economy				
Average Required Fuel Economy – MY 2026+ (mpg)	46.6	38.2	46.6	38.2
Average Achieved Fuel Economy – MY 2030 (mpg)	47.6	40.6	47.6	40.6
Change in Physical Quantities Attributable to CAFE Alternative				
Fuel Consumption (b. gal)	baseline	76.4	baseline	122 (1)
Fuel Consumption (b. barrels)	baseline	1.8	baseline	2.9 (1)
CO_2 Emissions (mmt)	baseline	847	baseline	1,355 (1)
CH_4 Emissions (metric tons)	baseline	1,482,533	baseline	2,382,315 (1)
N_2O Emissions (metric tons)	baseline	12,214	baseline	26,857 (1)
Average Annual Fatalities CY's 2036-2045	baseline	(1,186)	baseline	(1,186)
Average Annual Fatalities CY's 2036-2045 without rebound	baseline	(395)	baseline	(395)
Sales (millions)	baseline	1.0	baseline	1.3 (1)
Technology Use Under CAFE Alternative in MY2030 (total fleet penetration)				
Weight Reduction (not including powertrain)	17%	12%	17%	12%
High Compression Ratio Non-Turbo Engines	26%	13%	26%	13%
Turbocharged Gasoline Engines	60%	47%	60%	47%
Dynamic Cylinder Deactivation	6%	0%	6.0%	0%
Diesel Engines	1%	1%	1%	1%
Advanced Transmissions (Non-Hybrid)	72%	87%	71%	83%
Stop-Start 12V (Non-Hybrid)	15%	13%	15%	13%
Mild Hybrid Electric Systems (48v)	35%	1%	35%	1%
Strong Hybrid Electric Systems	20%	5%	20%	5%
Sum of Strong Hybrid and Mild Hybrid	**56%**	**5%**	**56%**	**5%**
Plug-In Hybrid Electric Vehicles (PHEVs)	5%	4%	5%	4%
Dedicated Electric Vehicles (EVs)	1%	1%	1%	1%
Sum of Plug-In Vehicles	**5%**	**4%**	**5%**	**4%**
Total of All Electrified Vehicles	***61%***	***10%***	***61%***	***10%***

(1) Lifetime sum of MY2016 thru 2032 vehicles

Table 2 EPA's grouping assumptions for technology penetration summary in the table above, based on 'technology_utilization_report.csv' output file

Tech	Assumed Calculation
Weight Reduction (not including powertrain)	MR1*5%+MR2*7.5%+MR3*10%+MR4*15%+MR5*20%
High Compression Ratio Non-Turbo Engines	HCR1
Turbocharged Gasoline Engines	TURBO1+TURBO2+CEGR1
Dynamic Cylinder Deactivation	ADEAC
Diesel Engines	DSLI
Advanced Transmissions (Non-Hybrid)	All but AT5, AT6, DCT6, CVT
Stop-Start 12V (Non-Hybrid)	SS12V
Mild Hybrid Electric Systems (48v)	BISG
Strong Hybrid Electric Systems	SHEVP2+SHEVPS
Plug-In Hybrid Electric Vehicles (PHEVs)	PHEV30+PHEV50
Dedicated Electric Vehicles (EVs)	BEV200

Table 3 Results of Standard Setting Run from 22-Jan-18 as summarized by NHTSA, and values produced by EPA's run of NHTSA-provided model and Runtime Settings – Consumer costs & benefits

Source	As summarized by NHTSA		EPA-generated values	
Model Years	2022-2025	2021-2026	2022-2025	2021-2026
Annual Rate of Increase in Stringency	No Action	0.5%/Year PC 0.5%/Year LT	No Action	0.5%/Year PC 0.5%/Year LT
AC/Off-Cycle Procedures	No Change	No Change	No Change	No Change
Consumer Costs and Savings for Average MY 2030 Vehicle				
Price Increase due to New CAFE Standards ($)	baseline	(1,769)	baseline	(1,769)
Increase in Other Ownership Costs ($)	baseline	(722)	baseline	(722)
Total Consumer Costs ($)	baseline	(2,492)	baseline	(2,492)
Discounted Fuel Savings to Owner ($)	baseline	(1,200)	baseline	(1,200)
Other Consumer Benefits ($)	baseline	(487)	baseline	(203) (1)
Total Consumer Savings ($)	baseline	(1,687)	baseline	(1,403)
Discounted Net Savings to Owner ($)	baseline	805	baseline	1,089
Payback Period Relative to Baseline (years)	baseline		baseline	
Payback Period Relative to MY2016 (years)		13.0		13

(1) Drive value & Refuel value for scenario 1 (from societal_costs_report.csv) divided by sales for scenario 1 (from societal_effects_report.csv) for MY2030.

Table 4 Results of Standard Setting Run from 22-Jan-18 as summarized by NHTSA, and values produced by EPA's run using recently provided Runtime Settings – Social Costs & Benefits

Social Costs and Benefits (Total Through MY 2029)				
Technology Cost ($b)	baseline	(246)	baseline	(246)
Other Private Costs ($b)	baseline	(158)	baseline	(107) (1)
Crashes, Noise and Congestion ($b)	baseline	(76)	baseline	(54) (1)
Total Costs of New CAFE Standards ($b)	baseline	**(480)**	baseline	**(407)**
Fuel Savings ($b)	baseline	(138)	baseline	(167) (1)
Other Private Benefits ($b)	baseline	(117)	baseline	71 (1)
Social Cost of Carbon ($b)	baseline	(4)	baseline	(5) (1)
Other Environmental Damages ($b)	baseline	(2)	baseline	(5) (1)
Petroleum Market Externalities ($b)	baseline	(22)	baseline	(26) (1)
Total Benefits of New CAFE Standards ($b)	**baseline**	**(283)**	**baseline**	**(133)**
Net Benefits of New CAFE Standards ($b)	***baseline***	***197***	***baseline***	***275***
Additional Measures (Total Through MY 2029)				
Additional Fine Payments ($b)	baseline	0.0		

(1) Regarding certain calculations in the social costs and benefits analysis, we cannot line up our results with those from NHTSA. This makes impossible our ability to measure impacts on net benefits that result from changes to model inputs. For the values shown in this table where we do not line up, we have summed lifetime results through MY2029 as indicated in the NHTSA table. However, for fuel savings, we show a total of $167 billion foregone

savings under the alternative while NHTSA shows just $138 billion (see below, note that fuel savings are in thousands).

Scenario	Scenario Name	Model Ye:	Reg-Class	Fuel Type	Disc-Rate	Pre-Tax Fuel Cost
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2016	TOTAL	TOTAL	0.03	(2,836,290)
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2017	TOTAL	TOTAL	0.03	(1,872,290)
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2018	TOTAL	TOTAL	0.03	912,336
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2019	TOTAL	TOTAL	0.03	4,078,395
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2020	TOTAL	TOTAL	0.03	7,574,019
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2021	TOTAL	TOTAL	0.03	13,447,238
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2022	TOTAL	TOTAL	0.03	16,181,839
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2023	TOTAL	TOTAL	0.03	17,688,676
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2024	TOTAL	TOTAL	0.03	18,964,115
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2025	TOTAL	TOTAL	0.03	19,886,488
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2026	TOTAL	TOTAL	0.03	19,771,700
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2027	TOTAL	TOTAL	0.03	18,582,377
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2028	TOTAL	TOTAL	0.03	17,850,026
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2029	TOTAL	TOTAL	0.03	17,154,436
						167,383,063

For "Other Private Costs," which we take to include the Value Loss and Fatality metrics, we get a reduction in costs of $107 billion under the alternative standards (see below, again in thousands) while NHTSA shows a reduction of $158 billion.

Scenario	Scenario Name	Model Year	Reg-Class	Fuel Type	Disc-Rate	Value Loss	Fatality Costs
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2016	TOTAL	TOTAL	0.03	-	(5,579,037)
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2017	TOTAL	TOTAL	0.03	(85,982)	(5,661,031)
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2018	TOTAL	TOTAL	0.03	(226,894)	(5,777,711)
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2019	TOTAL	TOTAL	0.03	(519,234)	(6,012,709)
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2020	TOTAL	TOTAL	0.03	(921,765)	(6,154,718)
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2021	TOTAL	TOTAL	0.03	(1,538,953)	(6,726,540)
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2022	TOTAL	TOTAL	0.03	(2,206,332)	(6,617,918)
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2023	TOTAL	TOTAL	0.03	(2,992,146)	(6,223,186)
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2024	TOTAL	TOTAL	0.03	(3,476,281)	(5,495,693)
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2025	TOTAL	TOTAL	0.03	(3,995,487)	(4,845,146)
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2026	TOTAL	TOTAL	0.03	(3,873,721)	(3,740,354)
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2027	TOTAL	TOTAL	0.03	(3,808,261)	(4,333,430)
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2028	TOTAL	TOTAL	0.03	(3,717,691)	(4,531,423)
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2029	TOTAL	TOTAL	0.03	(3,635,122)	(4,762,389)
						(30,997,870)	(76,461,285)
							(107,459,155)

The "Other Private Benefits" metric, which we take to include the Drive Value and Refuel Value, NHTSA shows a reduced benefit of $117 billion under the alternative standards while we calculate an increased benefit of $71 billion (see below, again in thousands) which is, obviously, directionally incorrect since the benefits of both drive value and refuel value should be greater under the Augural standards.

Scenario	Scenario Name	Model Ye:	Reg-Class	Fuel Type	Disc-Rate	Drive Value	Refuel Value
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2016	TOTAL	TOTAL	0.03	(67,640)	(147,492)
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2017	TOTAL	TOTAL	0.03	166,432	(86,926)
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2018	TOTAL	TOTAL	0.03	917,760	64,921
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2019	TOTAL	TOTAL	0.03	1,903,584	220,240
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2020	TOTAL	TOTAL	0.03	2,905,072	412,011
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2021	TOTAL	TOTAL	0.03	4,893,307	710,993
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2022	TOTAL	TOTAL	0.03	5,754,881	861,510
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2023	TOTAL	TOTAL	0.03	6,206,744	940,341
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2024	TOTAL	TOTAL	0.03	6,510,542	1,007,954
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2025	TOTAL	TOTAL	0.03	6,763,880	1,053,943
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2026	TOTAL	TOTAL	0.03	6,714,204	1,044,039
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2027	TOTAL	TOTAL	0.03	6,645,349	977,869
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2028	TOTAL	TOTAL	0.03	6,588,414	934,162
1	0.50%/Y Pc And 0.50%/Y Lt During 2021-2026	2029	TOTAL	TOTAL	0.03	6,547,399	892,377
						62,449,928	8,885,942
							71,335,870

There is the possibility that EPA is misinterpreting the output files and how to pull together some of the results. We have requested guidance but have not yet received it. Without knowing how to calculate the net benefits, we are hindered in our ability to properly assess how different inputs to the model impact net benefits.

In reviewing NHTSA's analysis, EPA has noted that many aspects of the CAFE analysis are similar to the Draft TAR analysis. EPA has previously reviewed the Draft TAR analyses and the associated documentation and in this current review has reviewed the Draft TAR source code available on the NHTSA's website and identified portions of NHTSA's NPRM analysis that are new to the model's operation or significantly revised; primary among these changes and additions are the Fleet Scrappage Model, Dynamic Fleet Share Model, and Fleet Safety Fixed Effects Model. Observations on these new model elements are presented in the section on Economic Factors. A full understanding of the model will require a review of the inputs and assumptions that are embedded within the executable file that EPA requested for this initial review. For example, details about the technology application decision trees, assumptions for fleet scrappage model, and programmatic assumptions for GHG regulatory analysis are encoded within the CAFE model. These are a few examples of embedded inputs and assumptions that EPA is aware of, but there are potentially more that EPA is not aware of.

Question/Information Request 2. Please provide the uncompiled CAFE model in the native code (e.g. C#, Java, etc.)

In the CAFE Modeling Update presentation dated February 2, 2018, NHTSA noted that among the changes to the CAFE model since the 2012 Final Rule is the capability for "Full Simulation of EPA GHG program requirements and provisions." In order to evaluate the CAFE model for application in setting GHG standards, EPA needs to understand how the CAFE model has been updated to reflect the CAA statutory requirements and programmatic provisions for other GHGs, in addition to an understanding of the CAFE model and its basic operation. These provisions include one-time carry forward for credits, unlimited car/truck credit trading, treatment of other greenhouse gases such as hydrofluorocarbons (HFC), methane, and N_2O, credit multipliers for advanced technologies, off-cycle technologies, zero g/mi upstream emissions for xEVs and treatment of FFVs and diesel vehicles consistent with the GHG program.

<u>Question/Information Request 3.</u> *Please provide the uncompiled model and executable file which is configured to perform the GHG programmatic analysis*

Primary observations: Representation of technologies in the CAFE model and inputs

Technology cost, effectiveness and baseline

Observation 2: The use of EPA input values in the CAFE model which update and/or correct the anomalous inputs used in the NTHSA-reported runs from January 22 has a significant impact on several key output results: Relative to the Augural Standards, technology cost savings of Alternative standards are reduced and fatalities increase. Furthermore, the technology penetration of strong electrification is significantly reduced in the Augural standards with the use of updated input values.

EPA has identified a number of anomalies in the CAFE model effectiveness inputs, including negative effectiveness numbers for more advanced technology packages, duplicated effectiveness numbers for unrelated technology packages, and incremental effectiveness values in unexpected directions, both higher and lower. Additionally, EPA has identified technology cost values in the January 22 version of the CAFE model inputs that are higher than expected when considering data from DOE for battery costs, and teardown data for other conventional technologies. EPA has performed an iteration of the CAFE model in which the following updates and corrections were made to the input files: 1) corrected anomalous effectiveness input values in the FC1_Improvements.csv file, 2) allowed HCR1 technology to be available to all manufacturers in MY2030, 3) updated cost inputs for battery and conventional technologies, and 4) updated baseline fleet to use final MY2016 volumes and IHS projected volumes. Using these updated inputs, EPA also evaluated the effect of enabling the DFS and Scrappage models. The results shown in Table 5 indicate that the CAFE model results are heavily influenced by the use of updated input values.

Table 5 Key CAFE model outputs using updated and corrected input values (including corrected effectiveness values, final baseline volumes, and updated battery costs)

Source	As summarized by NHTSA		EPA-updated inputs w/ DFS and Scrappage models (44)		EPA-updated inputs w/o DFS and Scrappage models (44)	
Model Years	2022-2025	2021-2026	2022-2025	2021-2026	2022-2025	2021-2026
Annual Rate of Increase in Stringency	No Action	0.5%/Year PC 0.5%/Year LT	No Action	0.5%/Year PC 0.5%/Year LT	No Action	0.5%/Year PC 0.5%/Year LT
Price Increase due to New CAFE Standards ($/veh) MY2030	baseline	-$1,769	baseline	-$996	baseline	-$861
Weight reduction	17%	12%	16%	10%	15%	10%
HCR	26%	13%	50%	16%	44%	16%
Turbo-downsized	60%	47%	32%	28%	35%	29%
Dynamic Deac (DeacFC)	6%	0%	0%	0%	0%	0%
Diesel	1%	1%	1%	0%	1%	1%
Advanced transmissions	72%	87%	96%	93%	95%	93%
Stop-Start (12V)	15%	13%	1%	9%	4%	12%
MHEV48V	35%	1%	37%	2%	33%	4%
Strong HEV	20%	5%	2%	2%	2%	2%
Sum of mild and strong HEV	**56%**	**5%**	**38%**	**3%**	**34%**	**5%**
Sum of PEVs	**5%**		1%	1%	2%	2%
Average Annual Fatalities CY 2036-2045 without rebound	baseline	-395	baseline	-449	baseline	128
Net Benefits of New CAFE Standards ($b)	baseline	197	baseline	130	baseline	-149

Technology application constraints

In the CAFE model, the application of a technology may be constrained in order to reflect the lead-time required to achieve large-scale production and wide-spread penetration into the fleet. The broad application can be excluded from consideration by the specification of a year in which the technology is initially available, by setting a phase-in cap, or by the use of a ‘FALSE’ application flag value. Technologies can also be excluded from application to a specific vehicle by the platform, engine, and transmission sharing constraints, by the technology pathways encoded into the model, and by the explicit definition a “SKIP” flag to an individual vehicle-technology combination.

Observation 3: Even when modeling manufacturer decisions as far as 15 years in the future, the CAFE model severely limits the technologies considered for application based on the technologies present on the vehicle in MY2016.

The technology pathways defined in the CAFE model code have the effect of reducing the number of technologies available for consideration in the subsequent model year. While in some cases this might be a realistic representation of a firm’s actions for near term decision making, it is almost certainly not representative of the long term strategic planning approach that automaker’s apply when making product decisions for new vehicle platforms and powertrains. A manufacturer’s investment decisions for new engine, transmission, and electrification families 10 or more years into the future would account for, among other things, the availability for more cost effective technology packages that lie outside of the NTHSA-defined pathways. For example, a manufacturer of a turbocharged engine today would consider the opportunity for more potentially more cost-effective normally aspirated mild hybridization, or high compression ratio (HCR) engines – decisions which are not allowed in the CAFE model structure.

The only point at which choices can be made between turbocharging and HCR is for those vehicles equipped currently with naturally aspirated, non-HCR engines. This is not realistic between today and 2025, and is indefensible when modeling is carried out through Model Year 2032. Furthermore, should a vehicle need to hybridize in an effort to achieve compliance, the technology pathway constriction appears to apply hybrid technologies to the vehicles as they exist prior to the hybridization. In other words, even a TURBO2 with cooled EGR engine will add the hybrid system and not remove any of the very costly turbocharging technology. Again, this is unrealistic since any vehicle that moves to hybridization would reasonably remove any costly and unnecessary turbocharging technology and still achieve over 40 percent effectiveness as do hybrids on the road today.

Observation 4: Application of HCR1 is restricted for large portion of the fleet.

Atkinson cycle engines with high geometric compression ratios (HCR) have proven to be a cost-effective pathway for reducing fuel consumption, with Mazda applying the technology to the majority their current vehicles, and Toyota announcing its plan for at least 60 percent application (by volume) by 2021. The 'analysis_fleet' file contains the 'SKIP' application flag for over 70 percent (by volume) of the fleet, while most other powertrain technologies are not similarly constrained (see Table 7.) For example, the strong hybrid technology, which is far more complex and requires more investment to implement on a vehicle, is allowed on all future vehicles with no restriction.

Table 6 Proportion of fleet volume with vehicle-specific technology application constraints ('SKIP' flag) with examples of high-compression ratio Atkinson cycle engines (HCR1) and strong hybrids

Application Flag in 'analysis_fleet' file	HCR1	Strong Hybrid (SHEVP2 +SHVEPS)	notes
USED	6.3%	1.8%	Assumed to be applied in MY2016
SKIP	70.6%	0%	Application <u>not</u> allowed in future
blank	23.0%	98.2%	Application allowed in future

<u>*Question/Information Request 4.*</u> *Why is the HCR1 technology highly constrained in the 'analysis-fleet' file relative to other technologies that are more complex and less cost-effective?*

Observation 5: The packages available for consideration as inputs to the CAFE model do not include some significant technologies that are available in production vehicles today.

For example, the 2018 Mazda CX-5 CUV and Mazda 6 sedan both are examples of non-hybrid electric vehicles that use Atkinson Cycle engines with cylinder deactivation. NHTSA's package designation for Atkinson Cycle is HCR1 and for cylinder deactivation is DEAC. In the 2016 Draft TAR analysis, NHTSA had a package designation of HCR2 for a combination of Atkinson Cycle, cooled EGR, and cylinder deactivation. The input files used in the most recent analysis do not allow any combination of DEAC and HCR1 and the HCR2 package is restricted from application through the use of a “FALSE” flag in the ‘technologies’ input file (also, no packages are built using HCR2.) In other words, a high-efficiency technology combination currently in production by Mazda for the 2018 model year will not be available for consideration in the CAFE model using the current input files.

Battery Costs

Observation 6: The cost of batteries for hybrid and plug-in vehicles is in most cases significantly higher than expected based on the most recent projections derived from DOE’s BatPaC model.

EPA examined the NHTSA battery cost inputs listed in the file “Battery_Costs.csv” of the CAFE modeling package. The costs in this file represent total cost (direct manufacturing cost marked up by an RPE of 1.5) in a future base year. To compute costs for a specific year, the CAFE model multiplies these figures by a corresponding learning factor, found in the Battery Cost Learning Rates Table in the file “technologies.xlsx.” The learning factor approaches 1.0 in MY2029, indicating that the listed costs represent a base year of approximately MY2029. For comparison, EPA developed an alternate set of battery costs using the latest DOE BatPaC-derived direct manufacturing costs as a basis, which BatPaC attributes to MY2021.

On average, the projected MY2029 NHTSA total cost for BISG batteries is almost 40% higher than BatPaC projects for MY2021. Total cost for SHEVP2 batteries is about 20% higher when compared on the same basis. Given the potential importance of these technologies, these differences could have a significant impact on projected technology penetrations and costs across the analysis.

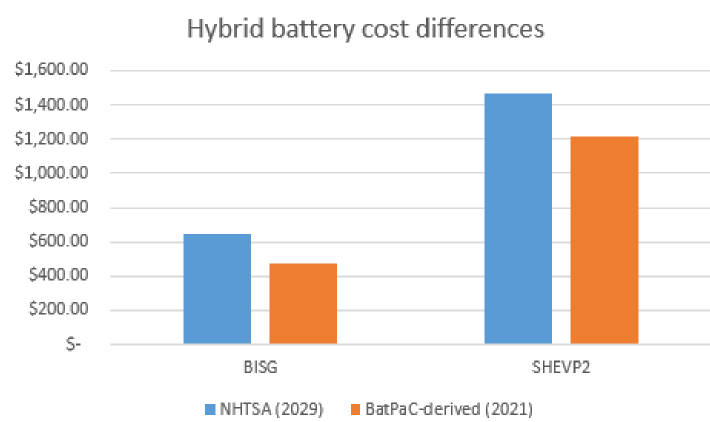


Figure 1. Comparison of HEV battery costs

Similarly, the average projected total cost for BEV200 batteries in MY2029 is almost 40% higher than BatPaC-derived figures for MY2021. This is particularly concerning given that NHTSA defines the 200 mile range as a 2-cycle laboratory range, which could be achieved with a smaller battery than the 200-mile real-world (“label”) range modeled by EPA.

The base year battery cost for the NHTSA PHEV30 (2 cycle range) is similar to that of EPA’s PHEV20 (which would have a comparable 2-cycle range of about 28.5 miles). However, the NHTSA

PHEV50 (with a 50-mile 2-cycle range) shows a 23% higher average battery cost than the EPA PHEV40 (which would have an approximately 57-mile 2-cycle range).

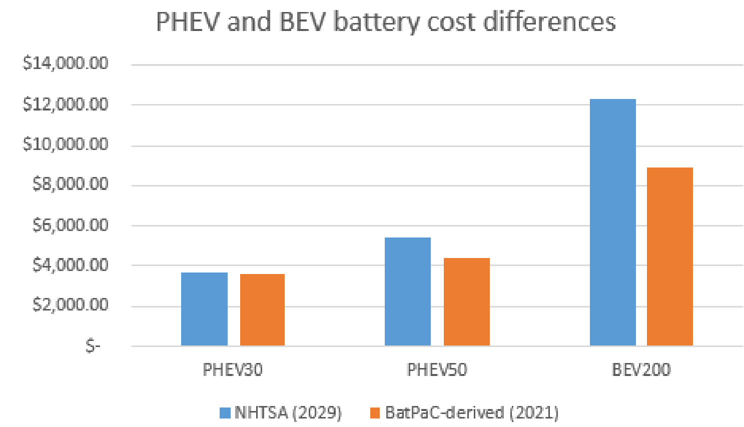


Figure 2 Comparison of PHEV and BEV battery costs

As previously noted, the NHTSA cost figures represent a MY2029 base year while the EPA figures represent a MY2021 base year. If the NHTSA costs are adjusted to MY2021 by applying the learning factor of 1.43 (from the Battery Cost Learning Rates Table), the differences for HEVs, PHEVs, and BEVs are larger, as seen in the following figures.

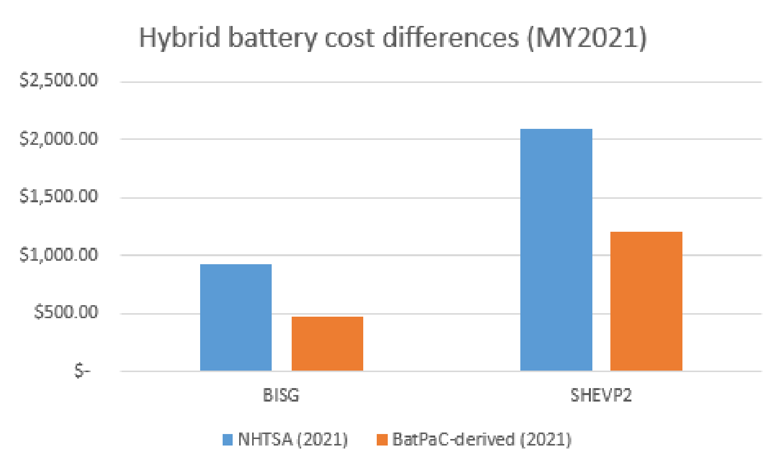


Figure 3 HEV battery cost differences for MY2021

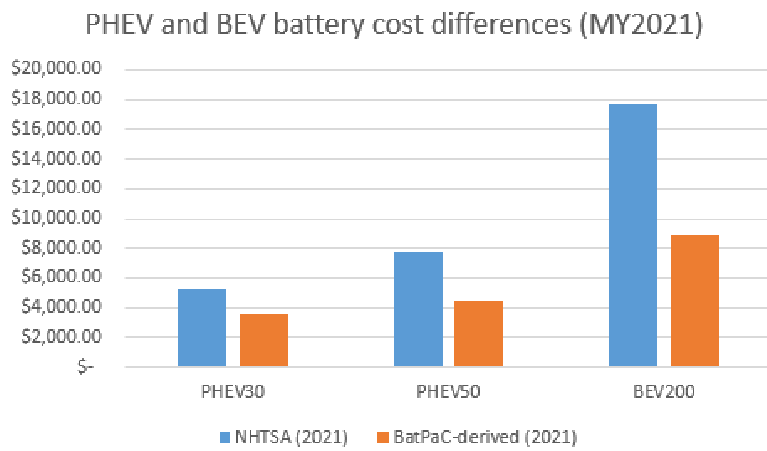


Figure 4 PHEV and BEV battery cost differences for MY2021

Although there are differences in the exact power requirements and curb weights of the vehicle classes as respectively defined by EPA and NHTSA, they do not seem sufficient to account for these differences. In order to fully understand the source of these differences it would be necessary to know the capacity, power, and battery design assumptions employed by NHTSA in developing these estimates.

Primary observations: Economic factors in the CAFE model and inputs

Consumer choice modeling ('dynamic fleet share' and 'scrappage' models)

The effects of the standards on vehicle sales and market shares has been a recurrent question for many years. On the one hand, the standards reduce operating costs; all else equal, that change should make new vehicles more attractive and increase sales. On the other hand, the standards increase technology costs; all else equal, that change should discourage new vehicle sales. Which effect dominates has been subject of a great deal of controversy. A key variable is the role of fuel economy in consumer purchases, measured either in payback period (the number of years of fuel savings that people consider when buying a new vehicle) or discount rate (how people discount the lifetime of future fuel savings). EPA has reviewed this literature, as has the National Academy of Sciences; in both cases, the finding was a very wide range, and no consensus, in the literature.[1]

[1] National Academy of Sciences, Finding 9.3: "The results of recent studies find that consumers' responses vary from requiring payback in only 2 to 3 years to almost full lifetime valuation of fuel savings" (p. 9-36). For interim results of EPA's ongoing work on willingness to pay for vehicle characteristics, see: https://www.epa.gov/sites/production/files/2017-03/documents/sbca-mtg-will-to-pay-2017-03-16.pdf (presentation at Society for Benefit-Cost Analysis, 2017); http://te3conference.com/wp-content/uploads/2017/11/TE3WTPVEhicleAttributes17Oct2017.pdf (presentation at University of Michigan Transportation Economics, Energy, and Environment conference, 2017).

Academic and other researchers have developed a number of vehicle demand (consumer choice) models for the new and/or used vehicle markets to look at effects on sales and fleet mix. Rarely has there been any effort to validate these models, either for consistency across models, or for ability to predict out of sample. Recent academic research,[2] as well as work by EPA,[3] has found that these models commonly perform worse, especially in the short run, than simply holding market shares constant. These models are also highly inconsistent in their estimates of the role of various vehicle attributes in the vehicle purchasing process, as the citations in Footnote 1 indicate. Due to an absence of solid science supporting the use of vehicle demand models for predicting the effects of the standards on vehicle sales, neither EPA nor NHTSA has used consumer choice modeling in either the 2010 or 2012 rulemakings, or in the 2016 Draft TAR, or in previous CAFE rulemakings. The agencies have occasionally estimated the effects of the standards on new vehicle sales using a Total Cost of Ownership model, where the key parameter, as mentioned above, is the role of fuel savings in consumer purchase decisions. This approach was recently used by Dr. John Graham and others from Indiana University in their February 2016 report, “Rethinking Auto Fuel Economy Policy.”

The CAFE model now includes a “Dynamic Fleet Share” model and a “Scrappage” model. These have not previously appeared in the CAFE model.

Observation 7: From a review of the model outputs, the use of the “Dynamic Fleet Share” (DFS) and “Scrappage” (S) models appear to significantly impact overall sales, fleet volumes, model mix, and vehicle miles traveled, and therefore are important factors in the CAFE model’s resulting net benefits, costs, and safety results.

- The DFS model forecasts future new vehicle sales and changes the fleet mix.
    - The Alternative standards have higher new vehicle sales and a higher share of cars relative to light trucks.
- Using the S model leads to a larger overall fleet and to higher vehicle miles traveled (VMT) relative to not using it, and to a larger overall fleet with the Augural standards than with the Alternative standards.
    - The S model does not affect new vehicle sales.

Observation 8: However, the inputs for these new modelling elements are not clear and the operation of the elements is also not clear to the model user.

The “Dynamic Fleet Share” model coefficients for FP, HP, and MPG, seem to indicate that the sales response to changes in these variables for cars is opposite of the sales response for trucks. This table is the documentation presented for the DFS. It is our guess that these are regression coefficients used to predict vehicle sales for cars (LDV) and light trucks (LDT1/2a). It is further our guess that FP is footprint, HP is horsepower, CW is curb weight, MPG is miles per gallon. We do not have guesses what “Rho” and “Dummy” are associated with.

Coefficients	LDV	LDT1/2a

[2] Haaf, C.G., J.J. Michalek, W.R. Morrow, and Y. Liu (2014). “Sensitivity of Vehicle Market Share Predictions to Discrete Choice Model Specification.” Journal of Mechanical Design 136: 121402-121402-9; Haaf, C.G., W.R. Morrow, I.M.S. Azevedo, E.M. Feit, and J.J. Michalek (2016). "Forecasting light-duty vehicle demand using alternative-specific constants for endogeneity correction versus calibration." Transportation Research Part B 84: 182-210.

[3] Helfand, Gloria, Changzheng Liu, Marie Donahue, Jacqueline Doremus, Ari Kahan, and Michael Shelby (2015). “Testing a Model of Consumer Vehicle Purchases.” EPA-420-D-15-011, https://nepis.epa.gov/Exe/ZyPDF.cgi/P100NNOZ.PDF?Dockey=P100NNOZ.PDF.

Constant	3.4468	7.8932
Rho	0.8903	0.3482
FP	0.1441	-0.4690
HP	-0.4436	1.3607
CW	-0.0994	-1.5664
MPG	-0.5452	0.0813
Dummy	-0.1174	0.6192

We observe that HP and MPG have negative signs for cars (i.e., more HP and more MPG reduce sales), while those coefficients are positive for trucks (i.e., more HP and more MPG increase sales). In contrast, FP increases car sales but reduces truck sales. These results are not what we would expect.

As discussed above, the role of consumer valuation of fuel savings in vehicle demand modeling is critically important; it essentially determines the direction of new vehicle sales effects. As noted, it appears that more fuel economy is bad for cars but good for light trucks, with unexplained magnitudes.

Observation 9: The scrappage model coefficients do not have consistent signs for cars, Vans/SUVs, Pickups

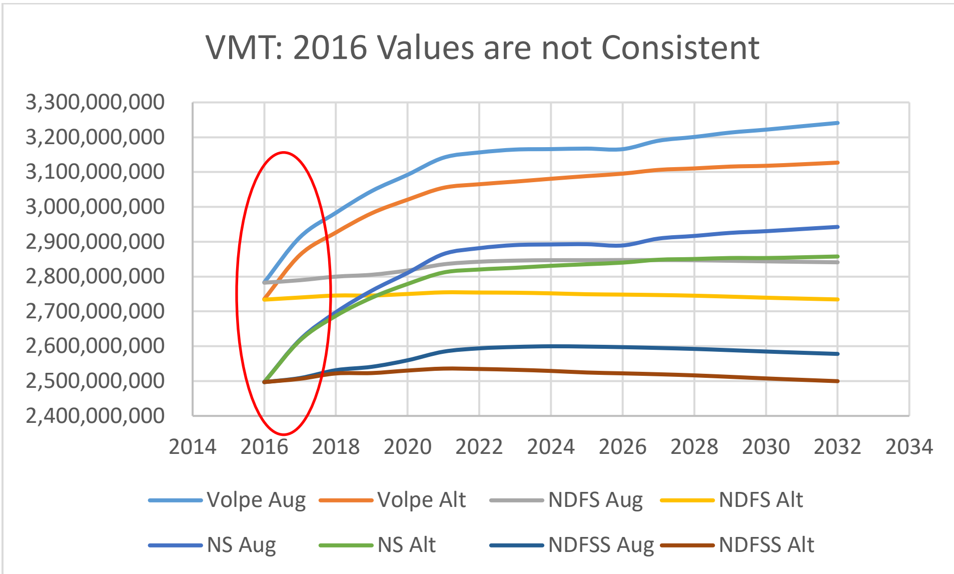
It is not known exactly what the Scrappage model predicts: how many vehicles of which vintages are scrapped each year? The S model appears to include 34 parameters, including new vehicle prices, vehicle age, CPM (cost per mile?), GDP growth rate, and interactions among these in polynomial forms. It is thus hard to evaluate. Below is a partial representation. Signs of the coefficients are again not consistent (see, e.g., Age, Age^2, Age^3, New Price, New Price*Age, New Price*Age^2), though how these affect predictions is not easy to determine.

Parameter	**Cars**	**Vans/SUVs**	**Pickups**
Estimate Scrappage	TRUE	TRUE	TRUE
Beta Coefs			
Age	0.616047051	-0.473441117	-1.119398279
Age^2	-0.057406753	0.032324147	0.037890057
Age^3	0.001582126	-0.000301894	0
ln(MY-1959)	-1.608885894	-3.946616362	-3.364968508
ln(MY-1959)*Age	0.213582275	0.504803381	0.34204715
ln(MY-1959)*Age^2	-0.006715995	-0.015159639	-0.008384946
ln(MY-1959)*Age^3	0	0	0
New Price	-0.000161276	0.000371589	-0.000303124
New Price*Age	7.84025E-06	-2.88675E-05	2.83304E-05
New Price*Age^2	1.00488E-07	5.91183E-07	-9.62014E-07
New Price*Age^3	-1.212E-08	0	0

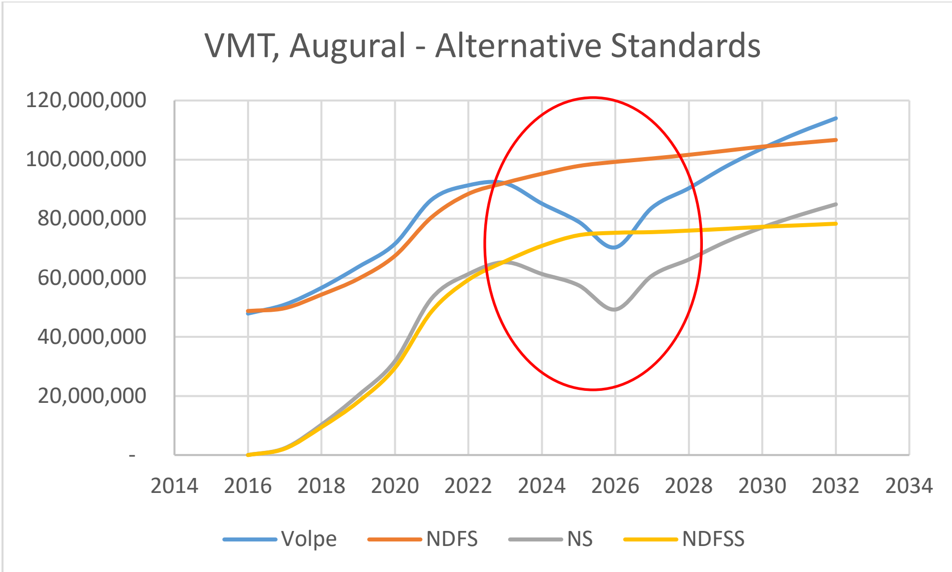
Some observations related to the DFS and S models suggest questionable findings:

- The smaller overall fleet with the Alternative standards relative to the Augural standards implies that more people give up used vehicles than are buying new vehicles – that is, relative to the Augural standards, lower new vehicle prices shrink the overall fleet. Why does the overall fleet shrink when switching to the Alternative standards from the Augural standards?

- In 2016, which has already passed, initial VMT levels change depending on the use of the DFS and S models, and the scenarios modeled. The graph below shows VMT from the Societal Effects Reports under various scenarios: The Jan. 22 Volpe results (Volpe), which uses both the DFS and the S models; turning off the DFS (NDFS); turning off the S (NS); and turning off both DFS and S (NDFSS), for both the Augural (Aug) and Alternative (Alt) standards. Note the different baseline levels of VMT for these different scenarios.



- The graph below shows differences in VMT between the Augural and Alternative standards. It finds that the change in the new vehicle fleet modeled by the DFS leads to a smaller difference in VMT during the period of the Augural or Alternative standards than before or after, although the Augural standards have a larger overall fleet, more rebound driving, and, using the DFS, a higher proportion of light trucks.



EPA does not support the use of the CAFE consumer choice and scrappage model for a primary analysis for the NPRM standard setting. Academia, EPA, NHTSA, vehicle manufacturers and others have for many years worked on developing these tools. The literature is clear that there is no consensus on consumer willingness to pay (WTP) for fuel economy and other attributes, a primary symptom indicating that the quality and robustness of the models vary widely. In addition, the new CAFE models, to the best of our knowledge, have never been publicly reviewed and/or applied to create policy, and may suffer from the same limitations as the many similar models available in the public domain. Our review to date of the scrappage model identifies counter-intuitive results that raise questions about its suitability for policy modeling. Therefore, it is our recommendation that the DFS and S models be used in sensitivity analyses and not to inform the primary analysis.

Question/Information Request 5. Please describe any previous rulemakings where these (DFS and S) or similar models were used to examine impacts on sales and fleet mix.

Primary observations: Safety assessment

Question/Information Request 6. How are the "fixed effects", as presented in the safety values sheet of the parameters input file estimated? Why are values flat from 2014 through 2021? Why do they decrease beyond 2021? Why the large step change reduction in 2026 with a flattening beyond 2026?

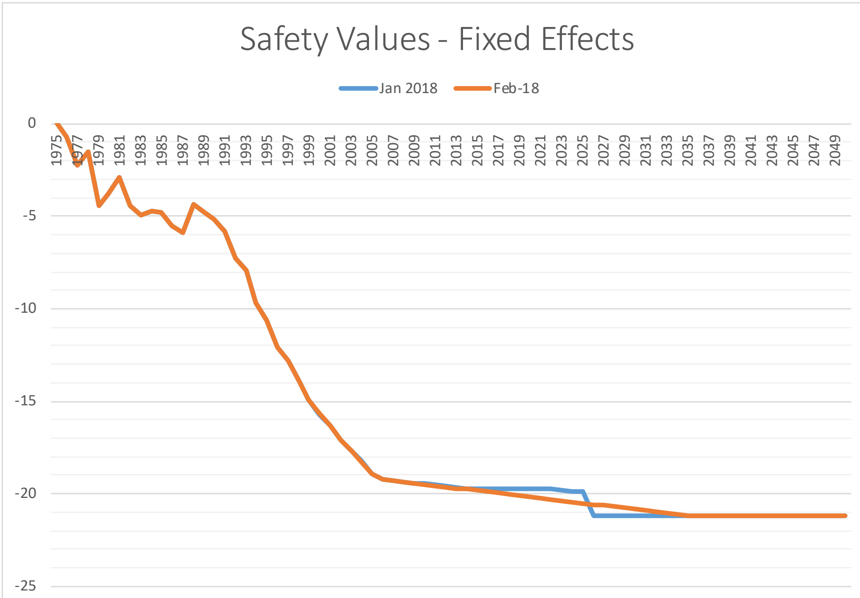


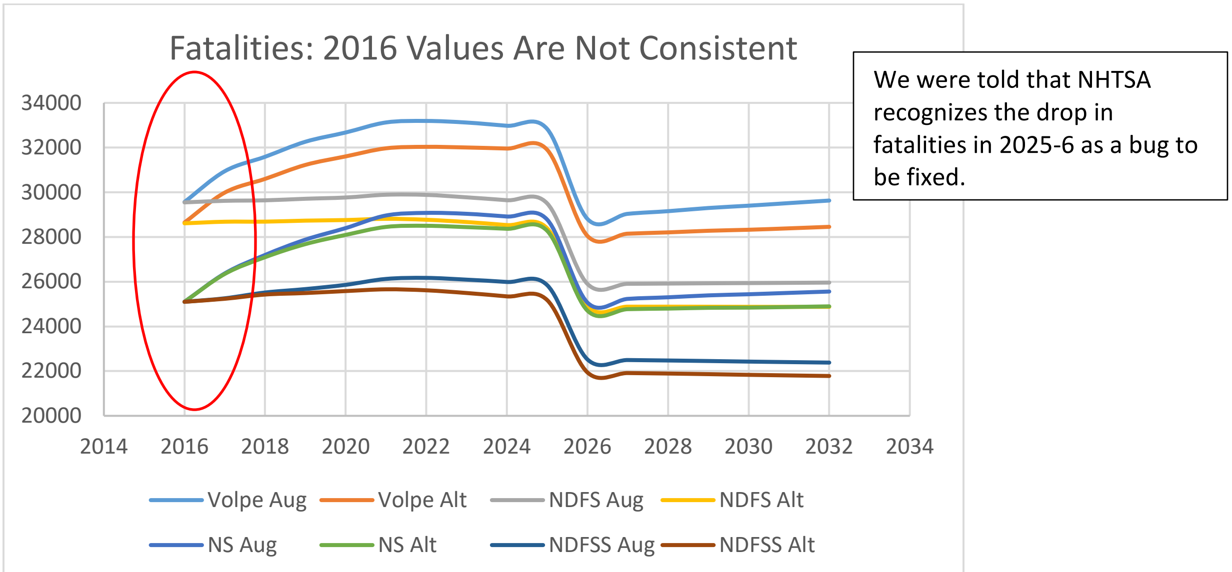
Figure 5 Fixed Effect Values used in the Safety Analysis

EPA's initial observation with regard to the safety values in Figure 7 are noted above. Since that time NHTSA has modified the data and provided a brief description of how the revised curve was created. NHTSA explained that the curve was developed in consideration of future NHTSA safety regulations and the belief that manufacturers would improve the safety of their vehicles of their own volition. In addition, NHTSA explained that the majority of the increased fatalities associated with older vehicles is the result of driver demographics and use. For example, older vehicles which are involved in fatalities also tend to be operated under the influence of alcohol. EPA has requested a full explanation of how this curve was developed, including both the quantitative estimates of safety improvements due to regulation and the subjective estimates of safety improvements.

Question/Information Request 7. Running the CAFE model with the DFS model turned OFF (and all other inputs as received by EPA) results in fewer fatalities in both the Augural and Alternative scenarios while simultaneously reducing sales in MYs 2017 through 2029 by ~18 million vehicles (see table below). Is there an explanation for why this would happen?

Model inputs	**All inputs as received by EPA**			**DFS Model turned OFF**		
Scenario	Augural	Alternative	Delta	Augural	Alternative	Delta
Fatalities (avg/CY 2036-2045)	18,055	17,352	-703	16,259	15,556	-703
Sales (MY2017-2029, millions)	223.7	224.6	0.9	205.8	205.8	0.0

As with VMT, the number of fatalities *in 2016* depends on the use of the DFS and S models and on the scenario being studied.



Here are a couple of charts showing fatality and CO_2 impacts of running with DFS/S=True; DFS/S=False; Rebound=20%; Rebound=0%. Notice that the No DFS/S with 0% rebound run actually ***increases*** fatalities under the alternative standards. Also, 0% rebound shows *higher* CO_2 under the alternative standards relative to augural, regardless of DFS/S setting. These charts used all of the default runtime settings with the exception of toggling DFS/S and rebound. The fatalities are annual averages during the CYs 2036 thru 2045. The CO_2 values are lifetime sums of MY2016-2032 vehicles.

Additional observations: CAFE model

Additional observations: Representation of technologies in the CAFE model and inputs

Technology effectiveness

The technology inputs provided by NHTSA on February 1 define effectiveness values for approximately 150,000 packages across ten vehicle classes. In addition, the 'technologies' input file contains the individual technology effectiveness values which are not modeled in full vehicle simulation such as electric power steering, improved accessories, low drag brakes, and low friction lubricants. A full evaluation of the assumed effectiveness values for individual technologies and their various combinations will require more time than the approximately one week that EPA has spent to-date and will require additional follow-up. The following summary of an effectiveness review conducted over the course of approximately one week is intended to highlight specific areas for further discussion and begin to identify additional information that is needed for a complete review.

Observation 1: The incremental effectiveness of the more advanced turbocharged engine (TURBO2) compared to the less advanced version (TURBO1) engines is often negative.

The technology inputs include two levels of turbocharged engines, TURBO1 and TURBO2. The incremental cost of TURBO2 hardware over TURBO1 hardware is about $350 to $700 in 2030; although it is unclear what specific technologies are represented by this cost, one would expect a generally higher effectiveness. However, depending on the package and car class, the actual incremental effectiveness values from the NHTSA technology inputs for the TURBO2 technology is often negative. The "Medium SUV" class, shown in Figure 8 has the most pronounced effect, with the addition of the TURBO2 technology, on average, having a negative effectiveness.

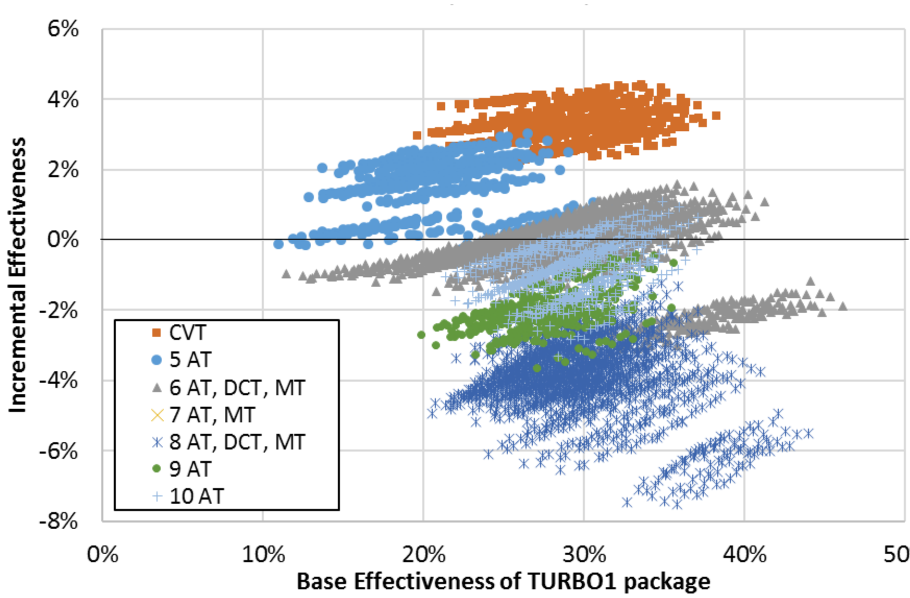


Figure 6 Incremental Effectiveness of TURBO1 to TURBO2 (MedSUV class)

Observation 1: The addition of cooled exhaust gas recirculation (CEGR1) onto turbocharged engines (TURBO2) provides no relative benefit, despite the additional cost of the technology. Given this input assumption, the CAFE model outputs, as expected, do not show application of CEGR1.

A cooled EGR package when added to the advanced turbocharged engine (TURBO2) has a cost of $334 in 2030. Cooled EGR is a technology that has been used in the market, and has a significant effect on CO_2 reduction. However, as illustrated in Figure 9, the incremental effectiveness is at or near zero for nearly all packages (and averaging zero for all packages). The "Medium Car Performance" class shown in the figure is representative of the near-zero effect of the technology for all classes.

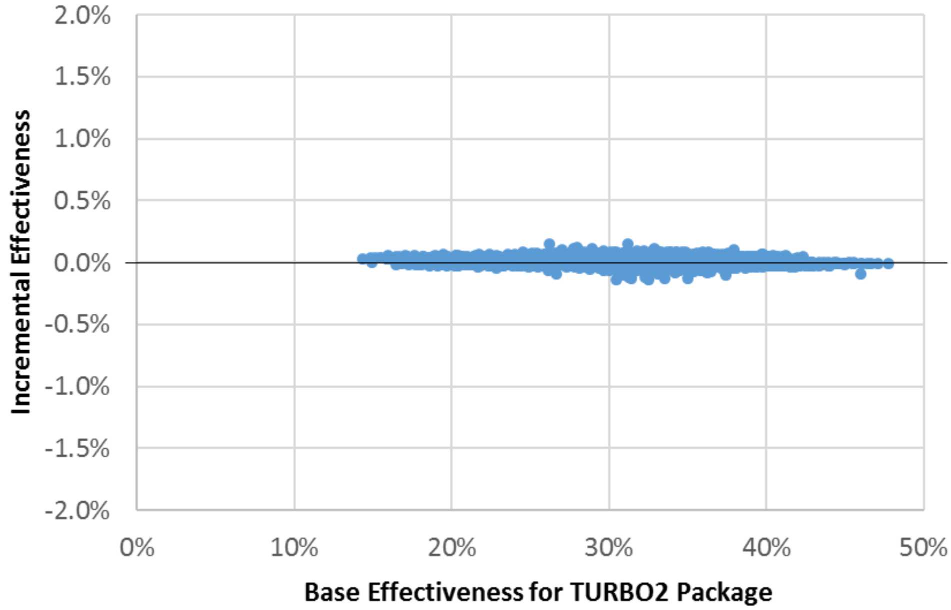


Figure 7 Incremental Effectiveness of TURBO2 to CEGR1 (MedCarPerf class)

When this original observation was communicated to NHTSA staff, NHTSA replied that "there was little/no opportunity to add Cooled (external) EGR in the two-cycle operating region, because operation was at/near combustion stability limits," and therefore the effectiveness of CEGR was limited because "Cooled EGR improves efficiency under higher speed and load (off-cycle) conditions."

However, cooled EGR has been used in production engines at lower speeds and loads to significantly lower fuel consumption. As an example, the Mazda 2.5L turbocharged engine in the 2016 CX-9 incorporates cooled EGR, both for high speed/load combustion stability (off-cycle) and for low and mid-range speed/load fuel efficiency (on cycle). Restricting the use of cooled EGR to only high speed/load combustion stability effectively ignores this feasible technology.

An external cooled EGR control strategy that favors internal EGR as was used in NHTSA's modeling is completely different than what is used in current production applications (for example Toyota and Hyundai offerings), differs from EGR strategies described in the peer-reviewed literature, and differs from what was used in EPA's peer-reviewed developmental programs that applied cooled EGR systems to both naturally aspirated and turbocharged engine applications. Cooled EGR can be used as part of knock mitigation and to reduce pumping losses. Internal (hot) EGR can also reduce pumping losses but can exacerbate knocking combustion and require additional spark retard. Hot EGR also requires intake and exhaust cam timing with significant overlap. The use of overlap for internal EGR limits the available range of intake cam phasing. The strategies used during EPA's engine development program all favored cooled external EGR except at very light load conditions (e.g., below 2 bar BMEP) where the increased combustion speed from use of hot, internal EGR can improve combustion stability. As a result, there was significant opportunity to add cooled (external) EGR over the two-cycle operation region while maintaining measured COV of IMEP to acceptable levels (<3% in the case of the turbocharged cooled-EGR engine development).

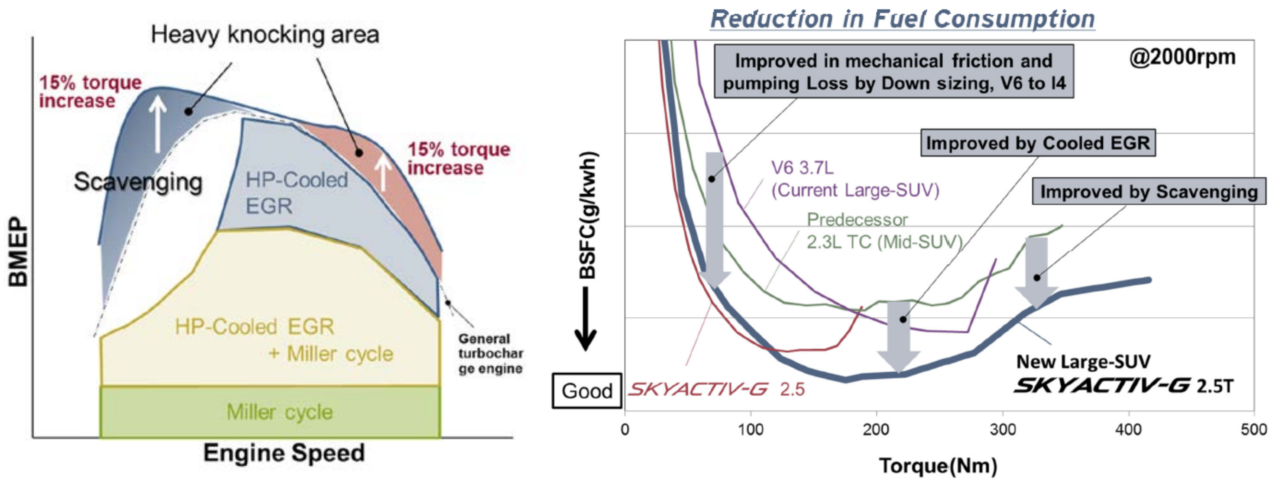


Figure X: Areas of cooled EGR usage for the Mazda CX-9 (left) and characterization of fuel consumption improvements at mid-range loads doe to cooled EGR (right). Both figures from Mazda.

Observation 2: Observation 2: The effectiveness the most advanced eight-speed transmission (AT8L3) is only moderately more than the most advanced six-speed transmission (AT6L2).

The modeled automatic transmissions include one "improved" level of a six-speed automatic (AT6L2) and two improved levels of eight-speed automatics (AT8L2 and AT8L3). The cost of the AT6L2 package (additional to an AT6) is $362 in 2030. The cost of the AT8L3 package (additional to an AT8) in 2030 is nearly the same ($358). Incremental to the AT6, the best eight-speed package is $485 (i.e.,$123 more than the AT6L2). However, on average, the technology inputs provided show that the AT8L3 is only 1% more effective than the AT6L2, and in some cases is worse (as shown by the Small SUV plot).

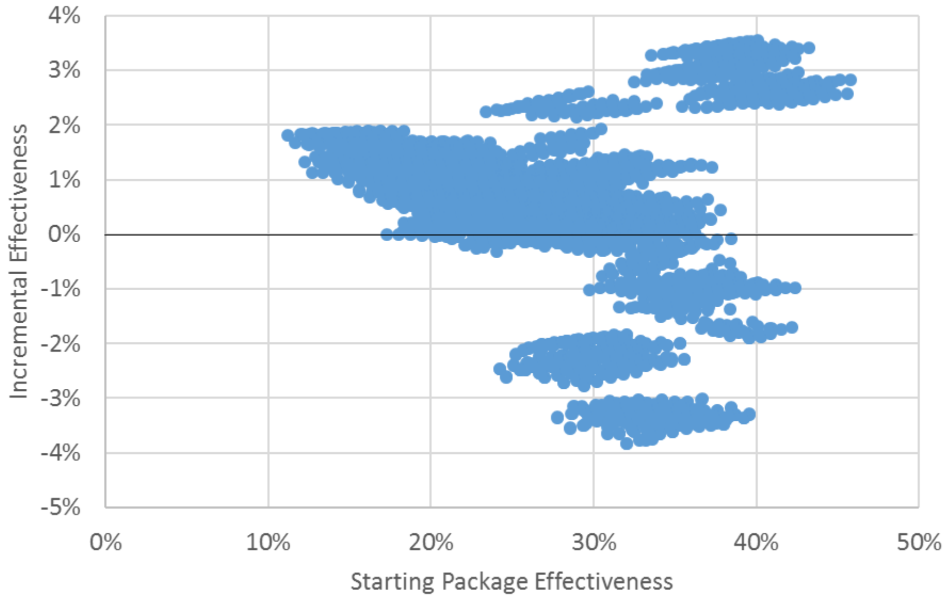


Figure 8 Incremental Effectiveness of the best six-speed (AT6L2) v. the best eight-speed (AT8L3) (Small SUV)

Observation 3: The effectiveness improvement from a basic six-speed transmission (6AT) to a basic eight-speed (8AT) transmissions is unexpectedly low for trucks.

The technology inputs provided seem to show that the incremental effectiveness associated with moving from a six-speed transmission (AT6) to an eight-speed transmissions (AT8) is noticeably different depending on class. The figure shows effectiveness for a medium car and a pickup; on average, the eight-speed effectiveness for the car is about twice that for the truck. This trend seems to hold for the small and medium car classes, which have AT8 effectiveness about twice that of the medium SUVs and trucks (with the small SUVs in between). This may be due to assumptions about front-and rear-wheel drive systems; however, comments from stakeholders have indicated that RWD systems should have greater potential for transmission effectiveness improvements, as packaging more gears in the space provided is less of a concern.

As part of the review process with NHTSA, NHTSA requested additional information and specific examples of vehicle technologies that did not follow the logical progression of transmission technology and commensurate effectiveness. In response EPA provided Figure 9: EPA observations of transmission effectiveness below. This figure shows that as advanced transmission technologies are applied to several powertrain types, there are instances where the more advanced transmission demonstrates lower effectiveness than the less advanced transmission. In addition, to this chart EPA also provided the exact technology package references from the CAFE model inputs. As of this summary, NHTSA has not yet responded to this observation.

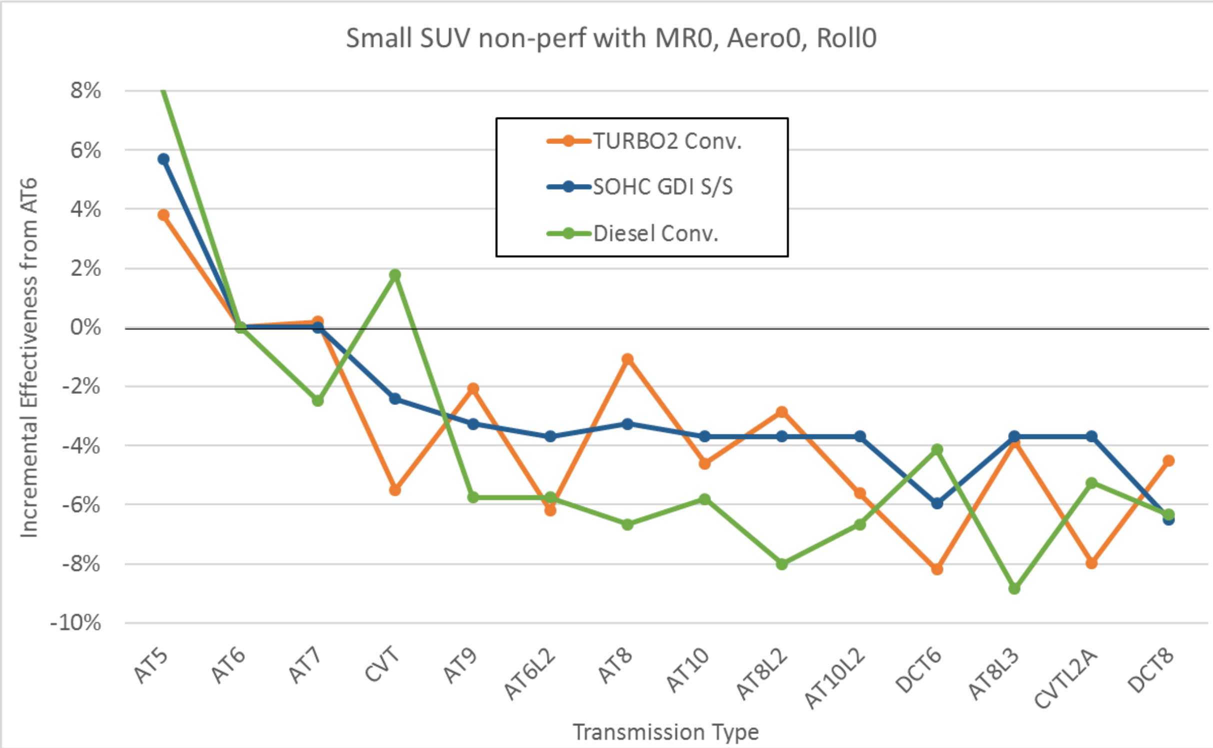


Figure 9: EPA Observations of Transmission Effectiveness

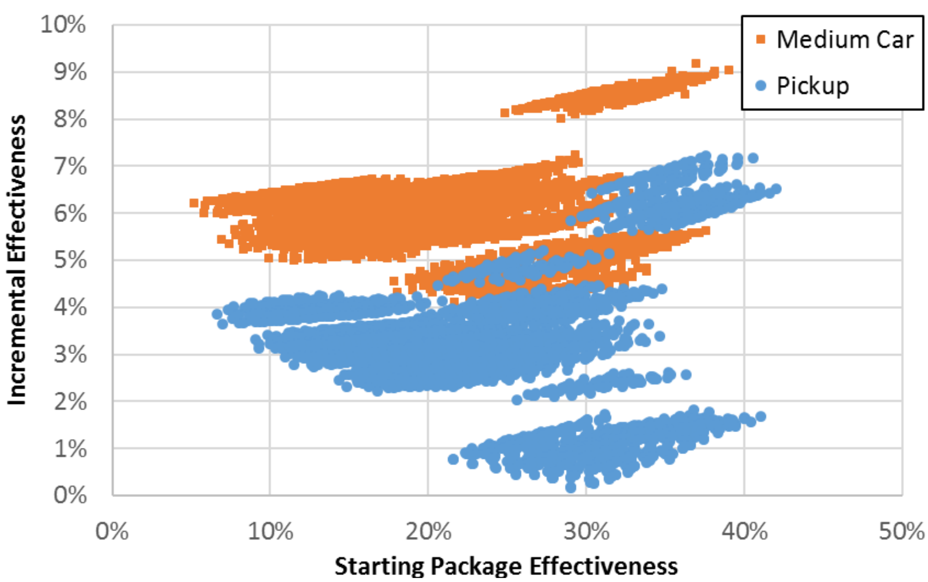


Figure 10 Incremental Effectiveness of six-speed (6AT) to eight-speed (8AT) for Pickup and Medium Car

Observation 4: On average, 48V Mild Hybrid with a crank-integrated starter-generator (CISG) is the same, or slightly worse than with a belt-integrated starter-generator (BISG) despite having a higher cost.

The cost of a crank-integrated starter-generator (CISG) system in 2030 is given as either $178 (for smaller vehicles) or $767 (for larger vehicles) in 2030, incremental to a belt-integrated starter-generator (BISG). Additional battery costs in 2030 are about $617 for the BISG and $805 for the CISG, making the incremental CISG battery cost an additional $187. The CISG is expected to provide additional effectiveness over the BISG because of the direct couple to the crank.

However, on average, the CISG is slightly less effective than the BISG, although with a wide spread of effectiveness. The small car example shown in Figure 12 is typical, with the incremental effectiveness of most packages between about +1% and -1%.

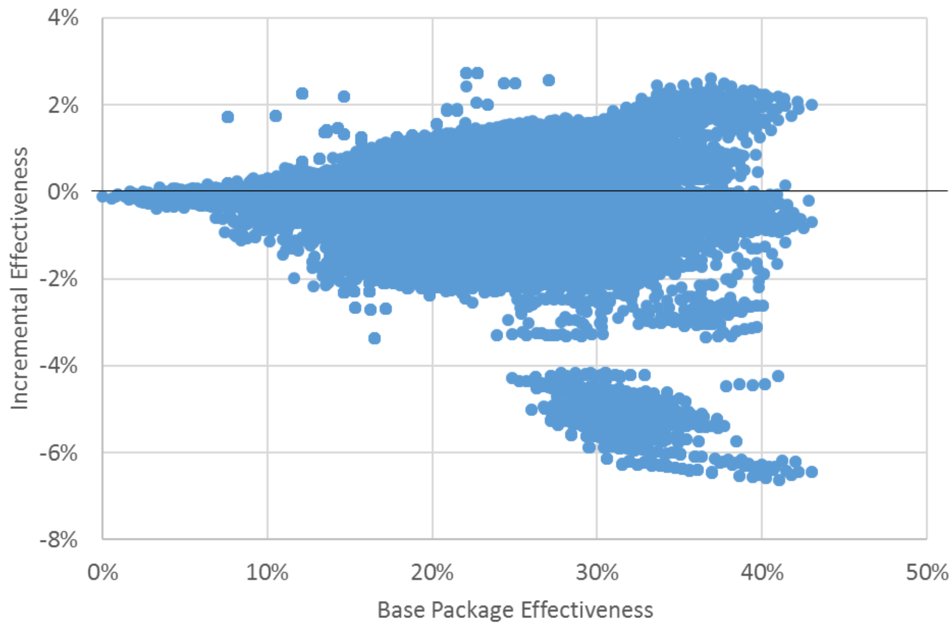


Figure 11 Incremental Effectiveness of 48V Mild Hybrid with belt-integrated starter-generator (BISG) to crank-integrated starter-generator (CISG) (Small Car class)

Observation 5: Some 12V Stop-Start applications have negative effectiveness values.

The cost of stop-start technology is either $466 or $521 in 2030, depending on vehicle class, plus about $582 in battery costs. However, there are some packages where the provided technology inputs indicate a negative effectiveness, as shown in Figure 13 for the small car class below. Moreover, there are a few packages in some classes that are clear outliers (see the medium SUV performance class), either high or low.

In addition to examples of unexpected transmission effectiveness estimates, NHTSA also requested examples of observed negative 12V start-stop effectiveness. In Figure 12: EPA's Observations of Negative Effectiveness for Start/Stop Packages, below, EPA has identified 12V start/stop packages that demonstrate negative effectiveness. These results are not rational. There are not situations under which turning off the engine instead of allowing the engine to idle would result in increased fuel consumption. In addition, for those packages with the same engine and positive effectiveness, it is also unexpected to observe such large variation in start/stop effectiveness. A SOHC GDI S/S should consume the same amount of fuel at idle independent of being mated to an AT8 transmission or an AT8L2 transmission.

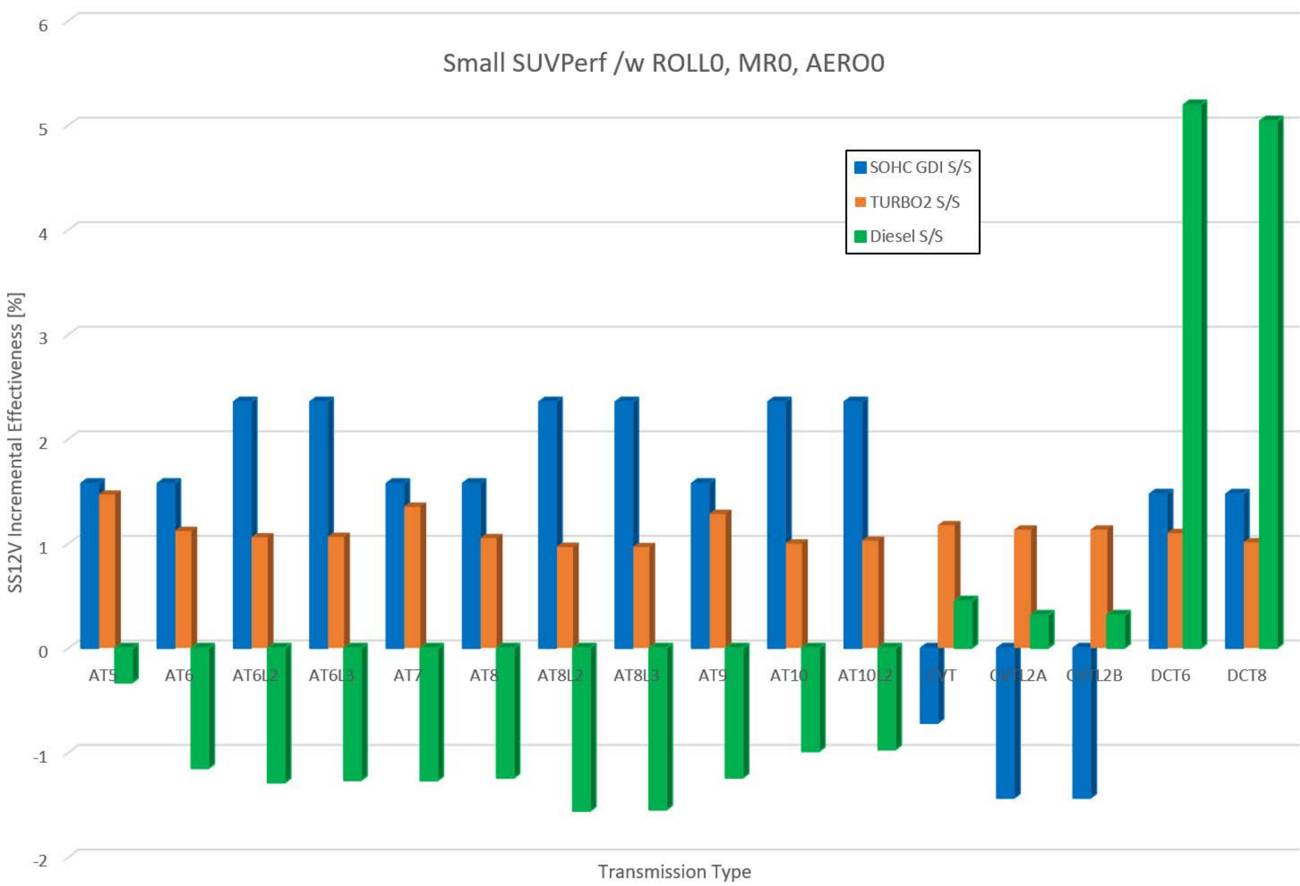
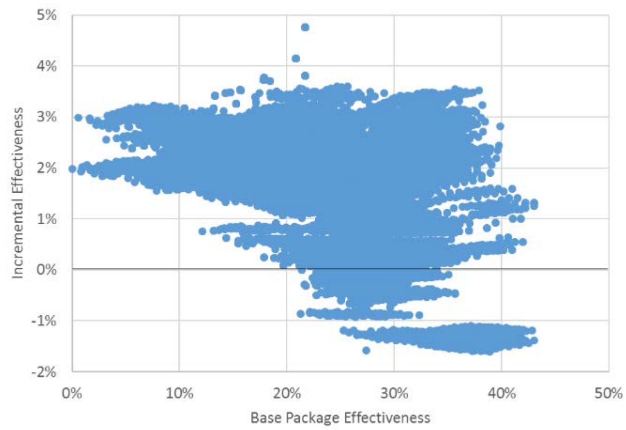


Figure 12: EPA's Observations of Negative Effectiveness for Start/Stop Packages



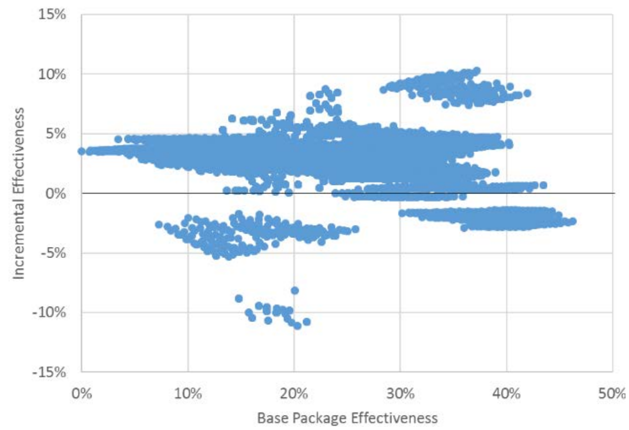


Figure 13 Incremental Effectiveness of CONV to SS12V for Small Car class (left) and Medium SUV Perf class (right)

Observation 6: Incremental effectiveness improving GDI powertrains to Atkinson powertrains is significantly greater than benchmarked engines.

Shown in Table 5 and Table 6, improving a GDI powertrain to an Atkinson powertrain is significantly different for the EPA analysis using benchmarked inputs and the CAFE analysis. The following observations have more detail on this subject.

Table 7 Effectiveness comparison improving GDI 6-speed powertrain to Atkinson 6-speed powertrain

CAFÉ Package Code (Medium Car)	EPA Benchmarked CO_2	CAFE CO_2	EPA Effectiveness	CAFE Effectiveness
DOHC;VVT;;SGDI;;;AT6;CONV;ROLL0;MR0;AERO0	241.87	222.40	0%	0%
;;;;;HCR1;AT6;CONV;ROLL0;MR0;AERO0	231.32	197.14	4.4%	11.4%

Table 8 Effectiveness comparison improving GDI 8-speed powertrain to Atkinson 8-speed powertrain

CAFÉ Package Code (Medium Car)	EPA Benchmarked CO_2	CAFE CO_2	EPA Effectiveness	CAFE Effectiveness
DOHC;VVT;;SGDI;;;AT8;CONV;ROLL0;MR0;AERO0	226.49	209.12	0%	0%
;;;;;HCR1;AT8;CONV;ROLL0;MR0;AERO0	212.61	184.53	6.1%	11.8%

Based on typical GDI maps and the Mazda Atkinson map, an expected effectiveness for an Atkinson engine incremental to a GDI engine is near 5% (but varying depending on the associated transmission, which determines where the engine operates).

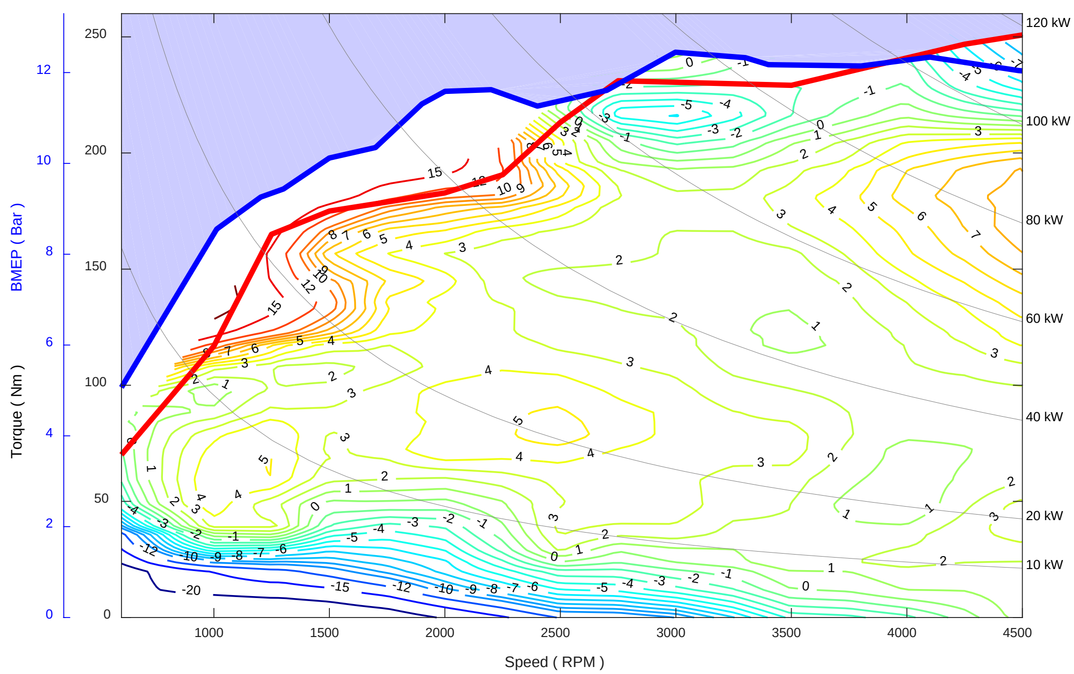


Figure 14 Percent fuel consumption difference between a typical GDI engine (from a 2013 Chevrolet Malibu) and an Atkinson engine (from a 2014 Mazda 3). Engine maps have been scaled to match peak power and adjusted to match heating values. The percentage difference in fuel consumption tends to be around 5% in the heart of the "on-cycle" portion of the map (50-100 Nm and 1000-2000 rpm).

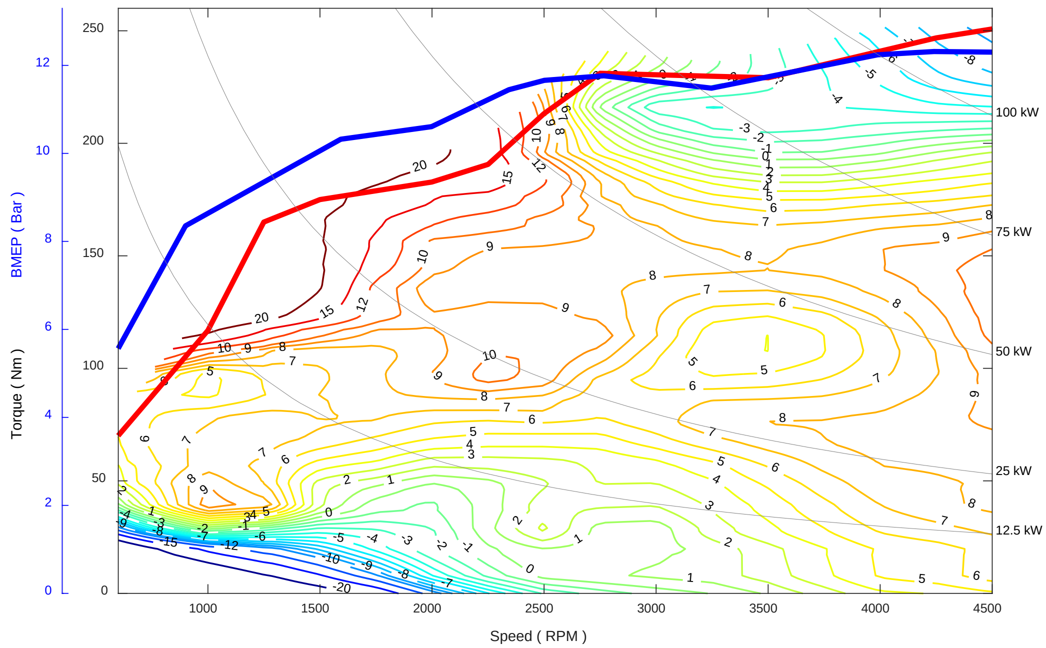


Figure 15 Percent fuel consumption difference between a typical GDI engine (from a 2013 Chevrolet Malibu) and an Atkinson engine (from a 2018 Toyota Camry). Engine maps have been scaled to match peak power and adjusted to match heating values. The percentage difference in fuel consumption tends to be around 7-8% in the heart of the "on-cycle" portion of the map (50-100 Nm and 1000-2000 rpm).

<u>Question/Information Request 8.</u> Please provide a description of the hardware that is assumed to be included in the technology packages highlighted in the observations above: TURBO2 (relative to TURBO1), CEGR1 (relative to TURBO2), AT8L3 (relative to AT8L), AT6L2 (relative to AT6), CISG (relative to BISG), and SS12V (relative to CONV)

<u>Question/Information Request 9.</u> Please provide a table of the vehicle characteristics used to simulate each of the 10 vehicle classes represented in this analysis (with MR0, ROLL0, AERO0). In particular test, weight, road load coefficients, power/acceleration/towing metrics, drive layout (RWD, FWD, AWD, 4WD), and any other specifications used when generating the 'FC1_Improvements.csv' file.

Technology costs

Observation 7: The cost of Dynamic Cylinder Deactivation (ADEAC) is more than double the cost publicly quoted to EPA by industry (Delphi/Tula, the suppliers of ADEAC to 2019 GM Silverado).

General Motors recently announced their implementation of ADEAC on two V8 OHV engines on the MY2019 Silverado and EPA test drove and benchmarked an ADEAC-equipped GMC Yukon V8 OHV at NVFEL in 2017, verifying the effectiveness of the ADEAC system in drive cycle tests and the system's transparency to the driver. The supplier of the ADEAC system on the GMC Yukon (Delphi/Tula) quoted the 2017 cost for this system (manufacturing cost plus licensing fee), to which EPA applied a learning factor of 4% (from 2017 to 2019) and a manufacturer mark-up cost multiplier of 1.5, and this is shown on the far right in Figure 14. For this application (V8 OHV), the CAFE model's output file shows a marked-up cost of $1101, while the supplier quoted cost (with learning factor and manufacturer mark-up factors applied) is $541.

Alongside the V8 OHV engine, the V6 OHV engine is an attractive candidate for near-term adoption of ADEAC technology. The CAFE model's output file also shows a significantly higher cost of ADEAC on V6 OHV engines as compared to costs calculated from supplier data ($815 versus $449). CAFE model cost and supplier quoted cost are better aligned for other engine types, e.g., I4 DOHC, but it is surprising that the CAFE model's cost is higher for a V8 OHV engine than a I4 DOHC engine when each engine requires the same number of deactivatable components: 16 solenoids + 16 deactivatable roller finger followers for a I4 DOHC and 16 solenoids + 16 deactivatable hydraulic lash adjusters for a V8 OHV.

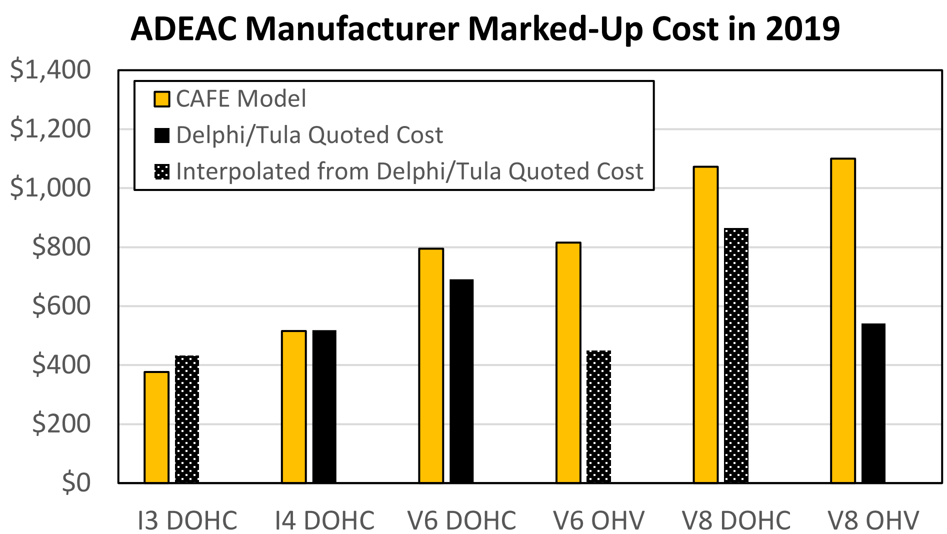


Figure 16 Comparison of Dynamic Cylinder Deactivation Costs

NHTSA's high cost of ADEAC suppresses the CAFE model's application of the technology. NHTSA's summary of CAFE model outputs (Table 1) shows 6% market penetration of ADEAC in 2030 if current standards are kept in place and 0% for "alternative 1" standards.

The CAFE model's 0% penetration for "alternative 1" is unrealistic considering General Motors will be offering two engines for the Silverado with ADEAC in MY2019, and the sales of these engines (prior to ADEAC) was 767,000 in MY2016, or about 4.4% of the entire LDV fleet. Other manufacturers have similar plans, which will likely increase ADEAC market penetration well past 4.4% in the MY2019-2022 timeframe.

The CAFE model's 6% penetration in MY2030 if current standards are maintained is likely also low, considering that it is much easier to apply a technology to subsequent engines after several examples have entered production. EPA believes the low penetration of ADEAC in the CAFE model is due to the high ADEAC cost assumed by the CAFE model.

Furthermore, the cost of ADEAC for V8 OHV engines shown in the CAFE model output ($1101) does not agree with the cost of ADEAC for V8 OHV provided by NHTSA in their "NHTSA Feedback on NPRM Analysis – February 22, 2018" letter ($1008).

Question/Information Request 10. *Please provide details for how the costs for dynamic cylinder deactivation were estimated, particularly the $1101 cost for V8 OHV engines.*

Additional observations: Economic factors in the CAFE model and inputs

Employment Analysis

In past rulemakings, NHTSA has based its employment analysis solely on sales volumes (the "output effect"): if sales are projected to change, employment would change in a constant ratio. Because EPA has not quantitatively estimated sales impacts in recent rulemakings, for reasons discussed above for "Consumer Choice Modeling," it has not quantified the effects of sales changes on employment. It has, however, estimated the proportion of technology costs that are labor costs – that is, the labor involved in the new technologies, known as the "cost effect" or "substitution effect"[4] – and included estimates of those effects in its analysis, based on data from the Bureau of Labor Statistics (BLS) and the Census Bureau. NHTSA has not included those effects in its employment analysis, even though labor costs are a significant fraction of technology costs. This review is based on an inspection of input files.

Our understanding, based on our 2/28/18 discussion, is that NHTSA now includes employment impacts due to technology costs via a calculation of revenues per worker in the manufacturing and parts supplier sectors, as well as estimates of dealership employment based on new vehicle sales.

In EPA's observations of the NHTSA modeling, employment values in the model start at about 1.1 million in 2016, and increase to about 1.3 million under the Augural standards in 2025, and about 1.25 million under the Alternative standards in 2025, a difference of about 50,000 jobs. The Dynamic Fleet Share (DFS) model affects employment values, as shown below; the Scrappage model appears not to affect employment.

[4] Berman, E. and L. T. M. Bui (2001). "Environmental Regulation and Labor Demand: Evidence from the South Coast Air Basin." Journal of Public Economics 79(2): 265-295; Morgenstern, Richard D., William A. Pizer, and Jhih-Shyang Shih (2002). "Jobs Versus the Environment: An Industry-Level Perspective." Journal of Environmental Economics and Management 43: 412-436.

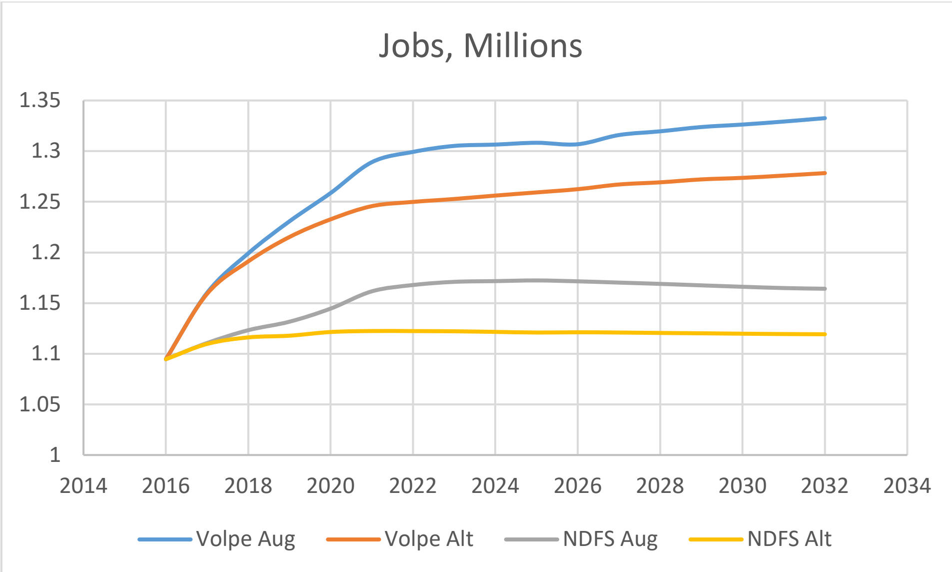


Figure 17: Jobs (Millions) using Volpe settings (including DFS) and No DFS (NDFS, or DFS off)

Question/Information Request 11. According to BLS data for 2016, total employment in the Motor Vehicles and Parts sector (NAICS 3361, 2, 3) was about 950,000; Automobile Dealers (NAICS 4411) had about 1.3 million; and Motor Vehicle and Parts Dealers (NAICS 441) about 2.0 million. The NHTSA jobs values do not correspond to these values; to what do they correspond?

Discount rates

In previous rulemakings, EPA and NHTSA have calculated and reported net benefits with a 3% discount rate for both benefits and costs, and separately with a 7% discount rate for both benefits and costs. These are intended to represent expectations of impacts of the standards.

Observation 8: The summary tables provided by NHTSA includes a footnote for "Consumer Costs and Savings for Average MY 2030 Vehicle" stating, "Consumer Costs and Savings are discounted to net present value using a 7% discount rate."

OMB Circular A-4 observes that the real discount rate of 7 percent "is an estimate of the average before-tax rate of return to private capital in the U.S. economy," that is, for private-sector business activity. On the other hand, according to Circular A-4, "When regulation primarily and directly affects private consumption (e.g., through higher consumer prices for goods and services), a lower discount rate is appropriate." On that basis, it seems inappropriate to use a 7 percent discount rate for "Consumer costs and savings."

As discussed above for consumer choice modeling, it may be reasonable to choose a different discount rate for fuel savings when analyzing sales impacts, as an alternative to using a limited number of years of future fuel savings (payback period). Such alternative rates are used to estimate how consumers behave when buying vehicles; they do not necessarily represent what consumers will experience once they have bought their vehicles. "Consumer Costs and Savings" should reflect what consumers are expected to experience; the Dynamic Fleet Share and Scrappage models already serve the function of estimating sales impacts.

Question/Information Request 12. *Please explain the basis for using a 7 percent discount rate for Consumer costs and savings, and how that satisfies the instructions of OMB Circular A-4.*

VMT schedules

The assumptions made about how much the average vehicle is driven in each year over a vehicle lifespan is an important factor in the calculation of greenhouse gas emissions, fuel savings, and discounted net benefits. The accumulation of vehicle mileage earlier in a vehicle's lifetime will tend to result in fuel savings and emissions benefits that are pulled ahead to earlier calendar years, and therefore discounted less in terms of net present value compared to a vehicle that accumulates more mileage later in its lifespan.

Observation 9: The form of the mileage accumulation schedule provided in the 'parameters' input file is unexpected, and not consistent with mileage accumulation schedules in other data sources.

The table of vehicle miles traveled (VMT) by vehicle age described in the 'parameters' input file shows a steep drop-off in annual VMT after age 6. NHTSA had first utilized a curve with that shape in the 2016 Draft TAR, and EPA understands the underlying data source is an IHS/Polk product based on odometer readings from individual vehicles. The drop-off in annual VMT in the NHTSA schedule shown in Figure 16 is not seen in other data sources, including the 2001 National Household Travel Survey (NHTS), and a DOE LBNL analysis based on odometer readings from DMV records of the Texas inspection and maintenance program. The 2009 NHTS data shows a decline that coincides with the NHTSA schedule, but of a much smaller magnitude.

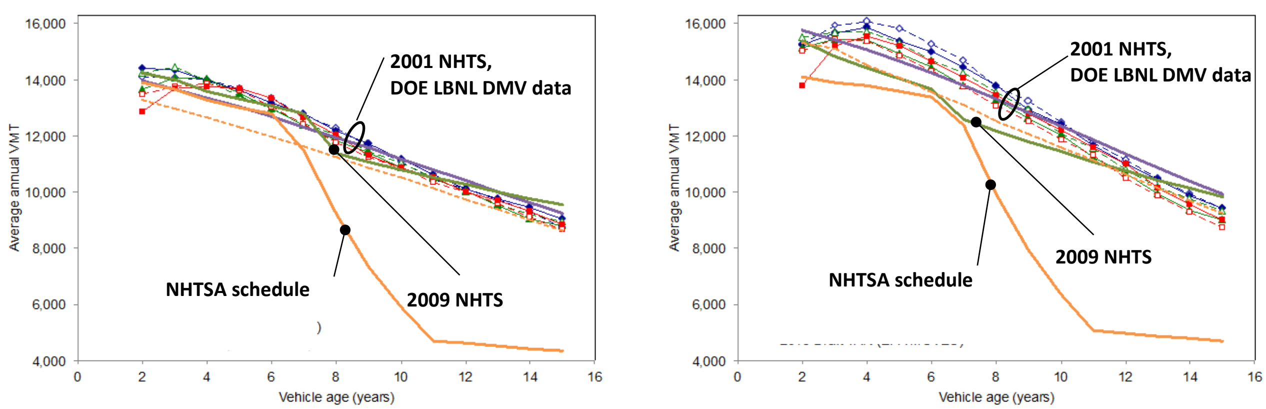


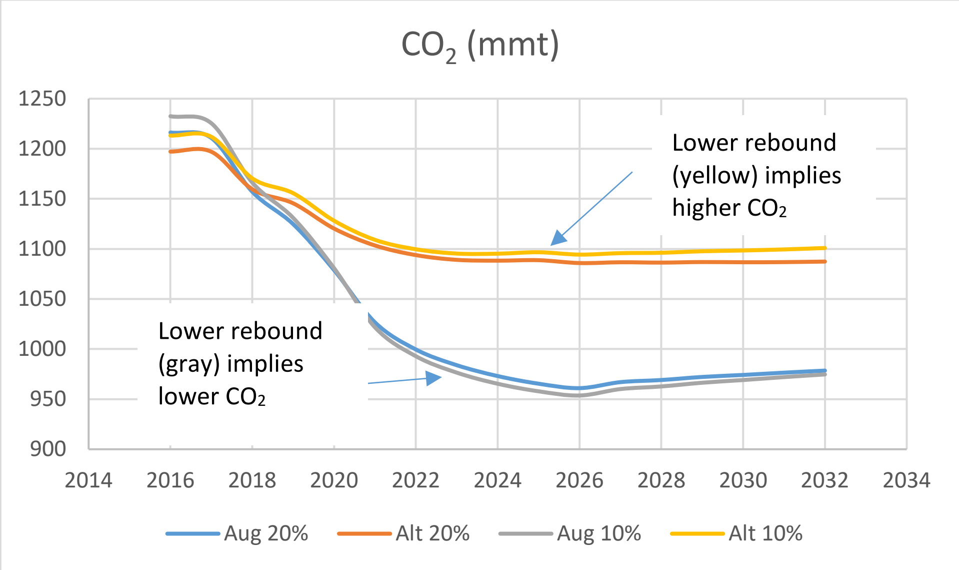
Figure 18 Comparison of NHTSA mileage accumulation schedule with data from other sources for cars (left) and trucks (right)

Question/Information Request 13. *Can NHTSA provide an explanation for why such a dramatic decline in annual VMT occurs after age 6, and considering that large decline why does NHTSA believe that the IHS/Polk data is more defensible than multiple other sources which are based on population-weighted samples of odometer readings of individual vehicles.*

VMT Rebound

Changing the rebound value from 20% to 10% has the expected effect, for the Augural standards, of reducing CO_2 emissions, because of reduced rebound driving. However, the same change for the

Alternative standards leads to *greater* CO_2 emissions, although, as noted previously in the discussion of the DFS and S models, new vehicle sales are higher, and the overall fleet is smaller, under the Alternative standards. The same pattern exists for fuel use.



Emissions impacts and costs

Effects of the standards on both CO_2 and other pollutants depend on not only the changes in technologies to vehicles, but also changes in the amount driven (rebound effect), changes in the number of vehicles and fleet mix (Dynamic Fleet Share and Scrappage models), and changes in fuels produced (upstream effects).

Observation 10: In the "societal_effects_report," it appears, at least for 2025 and 2030, that, in going from the augural standards to the alternative standards, emissions of some pollutants (VOC, NOx, SO_2, PM, CO_2, CH_4, N_2O, DPM) increase, while emissions of others (CO, Acetaldehyde, Acrolein, Benzene, Butadiene, Formaldehyde) decrease.

It seems peculiar that some increase while others decrease; it's especially counter-intuitive that toxics go down while VOC goes up.

Question/Information Request 14. *Can NHTSA explain what contributes to this effect?*

Observation 11: It is unclear where NHTSA selected the unit values to monetize changes in PM-related criteria pollutant emissions (aka, benefit per ton values - BPT).

NHTSA provides the following table for Emission Damage Costs:

Emission Damage Costs ($/metric-ton)	
Carbon Monoxide	0
Volatile Organic Compounds	2,000
Nitrogen Oxides	8,200
Particulate Matter	371,100
Sulfur Dioxide	48,000

Methane	0.0000
Nitrous Oxide	0.0000

They appear to be outdated (e.g., they include a unit value for VOCs, which EPA no longer monetizes due to uncertainty in the underlying air quality modeling); and they don't appear to account for how BPT values increase over time.

<u>Question/Information Request 15.</u> *What is the source for these emissions damage costs, and does the CAFE model change the values over time?*

EPA review of CAFE model with “GHG” settings (08-Mar ver.)

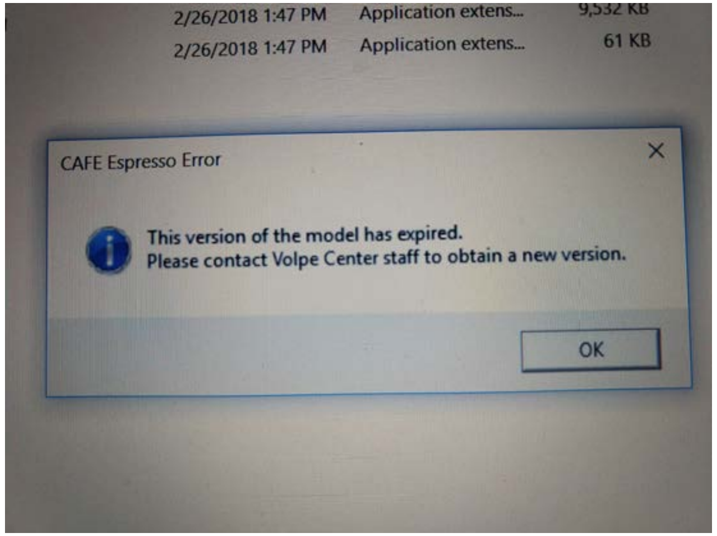
Meeting with Office of Management and Budget/OIRA

4/16/2018

Agenda

- Overview
- Review of CAFE model Safety Analysis
- Review of CAFE model Realism
- Review of CAFE representation of GHG program
- Summary of CAFE model results ‘cost walk’
  - Contributions of the identified issues to large overestimation in program costs
- Other observations
  - Performance
  - Effectiveness
  - Battery costs and sizing
- Appendix: Update on LDV Rebound

Overview (slide 1 of 2)



- EPA began reviewing CAFE model in late January
  - Shared very initial observations with OMB on February 9, raising many significant concerns, and requesting:
    - (1) technology descriptions for a handful of key technologies
    - (2) description of components included in net benefits summary
    - (3) model code
  - EPA has received neither of the requested items

- DOT provided a "GHG" version of the CAFE Model March 8
  - Intent is to properly model the EPA CO_2 program provisions
  - EPA discovered on March 31 model had a built-in "expired" date.
  - EPA requested on April 2 a workable version of the model
  - There has been no response to EPA request from DOT

Overview (slide 2 of 2)

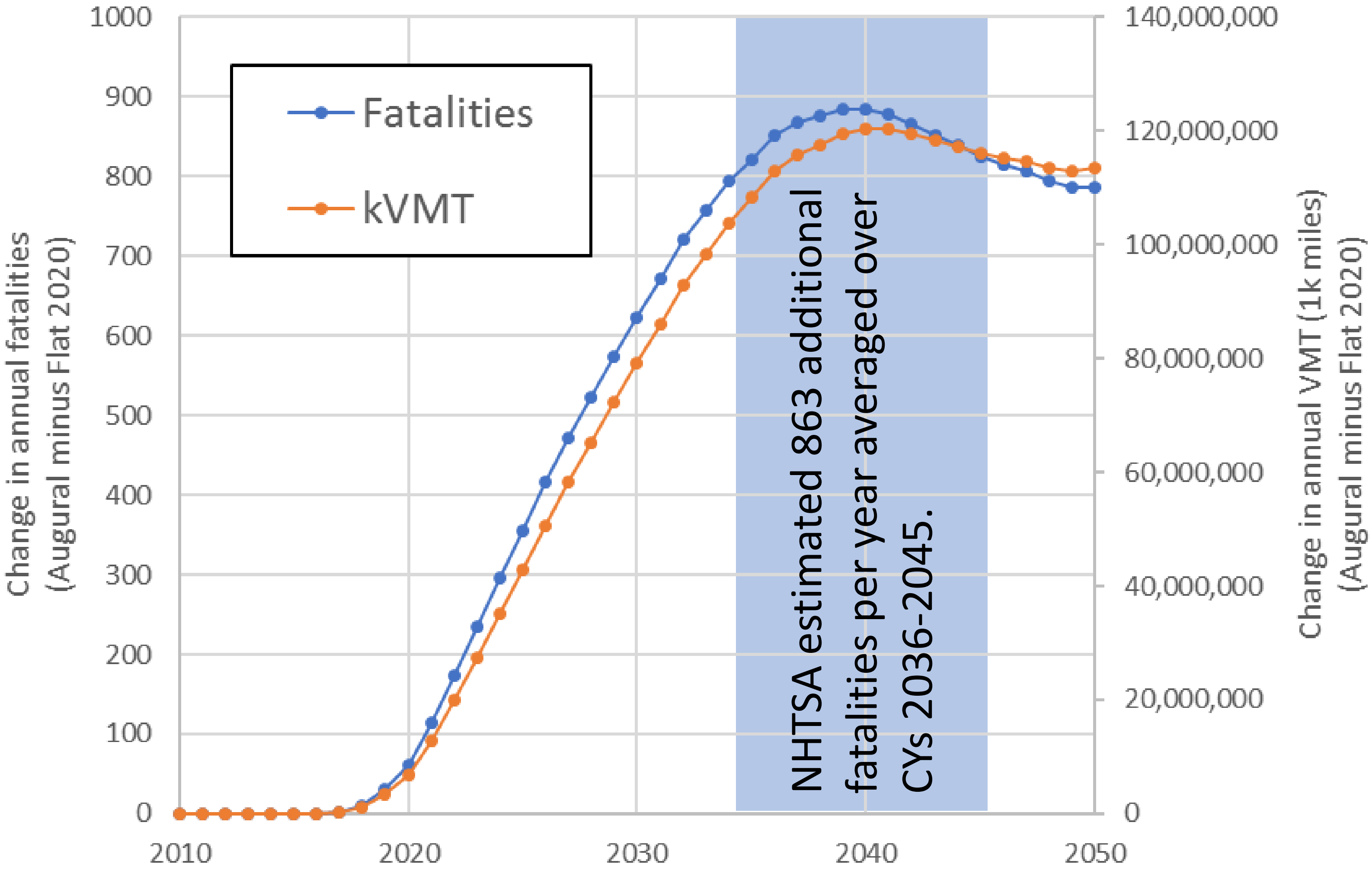
- EPA analysis to date shows significant and fundamental flaws in CAFE model (both the CAFE version and the "GHG version")
  - These flaws make the CAFE model unusable in current form for policy analysis and for assessing the appropriate level of the CAFE or GHG standards

- DOT has provided OMB draft preamble and RIA Chapter assessments for the upcoming CAFE and GHG NPRM
  - The underlying technical basis for the policy decisions and the proposed standards is the CAFE model, which has significant and fundamental flaws that must be addressed before being used for informing policy
  - EPA will not be providing comments on the draft material, as the underlying basis (CAFE model) is flawed, and thus comments are of no value until the technical basis is fixed

- DOT has drafted preamble language in which DOT repeatedly speaks for the EPA Administrator
  - DOT speaks for the EPA Administrator's views on the appropriate level of the EPA standard, EPA's interpretation of the Clean Air Act, EPA's views on what factors are relevant in determining EPA's program design and the EPA standards
  - EPA will be drafting the EPA Administrators views for the upcoming rulemaking, and we will not be starting from the DOT draft text

Relationship between miles traveled and total fatalities

- Total fatalities are highly correlated with total VMT
- CAFE model improperly estimates the VMT impact of the Augural standards (following slides)
- The safety metric of 'fatalities per mile'[1] is unaffected by anomalies in VMT projection, and is therefore a more reliable metric of safety for this review

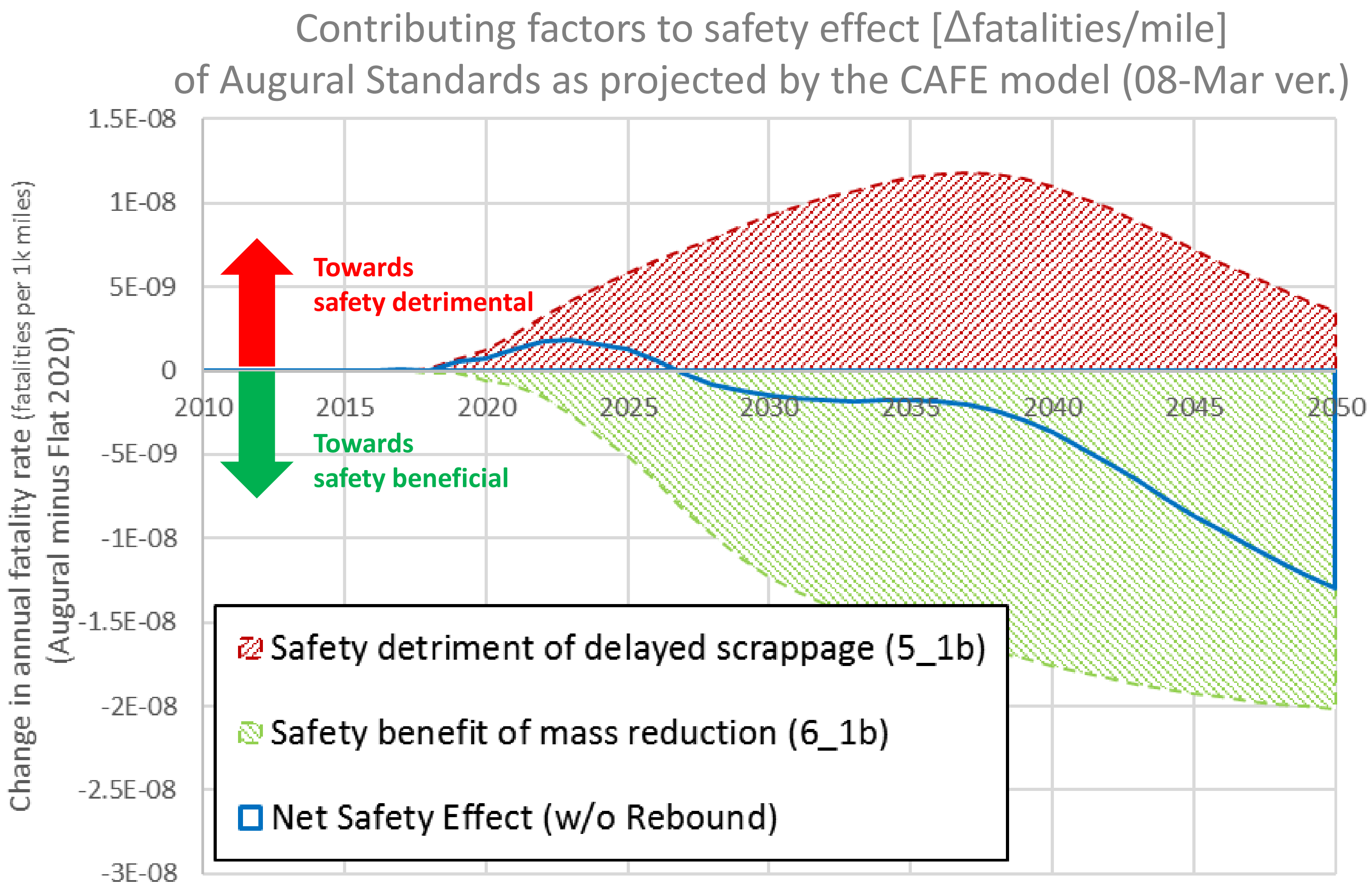


1 NHTSA has previously used a fatality rate metric when estimating the safety impact of changes in vehicle characteristics. Refer to the June 2016 report cited in the Draft TAR, "Relationships between Fatality Risk, Mass, and Footprint in Model Year 2003-2010 Passenger Cars and LTVs."

Review: CAFE safety analysis

Effects of delayed scrappage and mass reduction (excluding rebound)

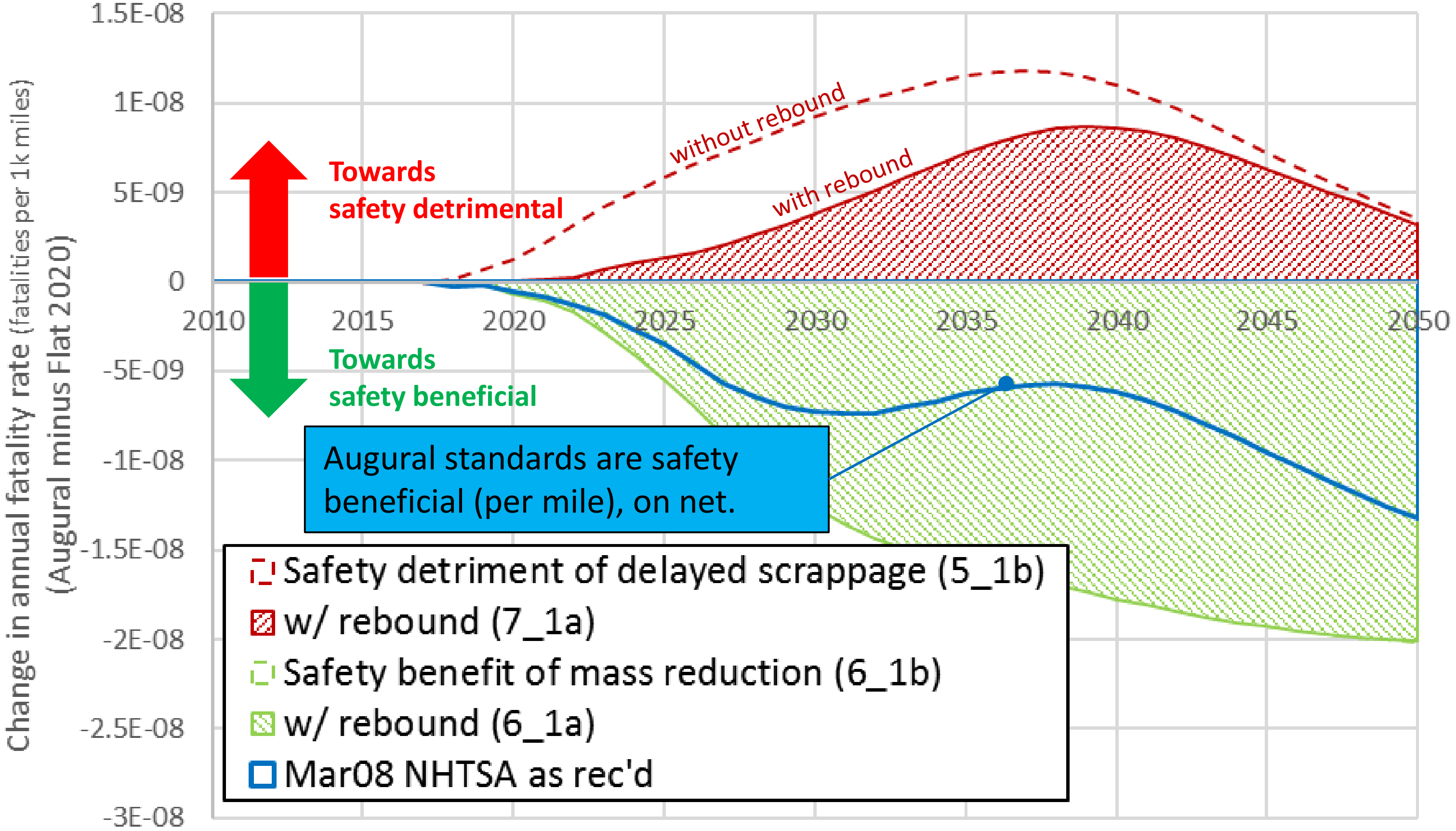
- The augural standards provide an overall safety benefit, relative to flat standards
- Mass reduction provides a safety benefit due to the greater amount of weight removed from larger vehicles (relative to smaller vehicles) and the resulting improvement in crash compatibility
- Any detriment due to delayed scrappage is more than offset by the benefit of mass reduction
- The benefit of mass reduction extends perpetually into the future, while the detriment of delayed scrappage becomes smaller over time



Effects of delayed scrappage and mass reduction (including rebound)

- The use of a 20% rebound value in the CAFE model reduces the safety detriment of delayed scrappage
- As in the case of excluding rebound, the augural standards provide an overall safety benefit, relative to flat standards when rebound is included

Contributing factors to safety effect [Δfatalities/mile]
of Augural Standards as projected by the CAFE model (08-Mar ver.)

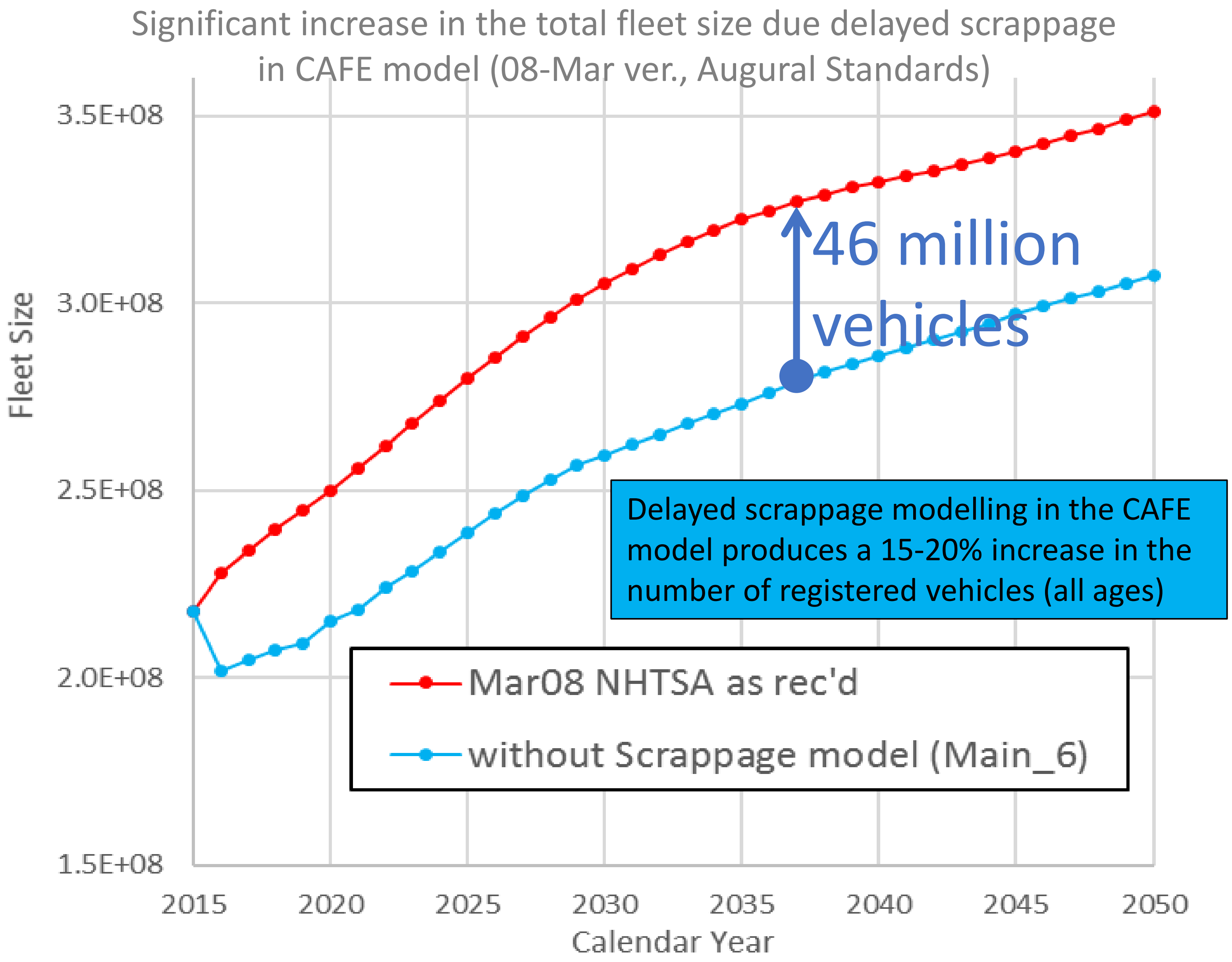


Review:
CAFE model
realism

Realistic fleet size projections

<u>Real-world</u> : The total number of registered vehicles would not change significantly as a result of consumer decisions to retain used vehicles longer instead of purchasing new vehicles.

<u>CAFE model implementation</u>: The use of the scrappage model produces a 15-20% increase in the total fleet size. The 2016 fleet increases by 26 million vehicles, and the 2030 fleet increases by 46 million



Review: CAFE model realism

Realistic travel activity (VMT) projections

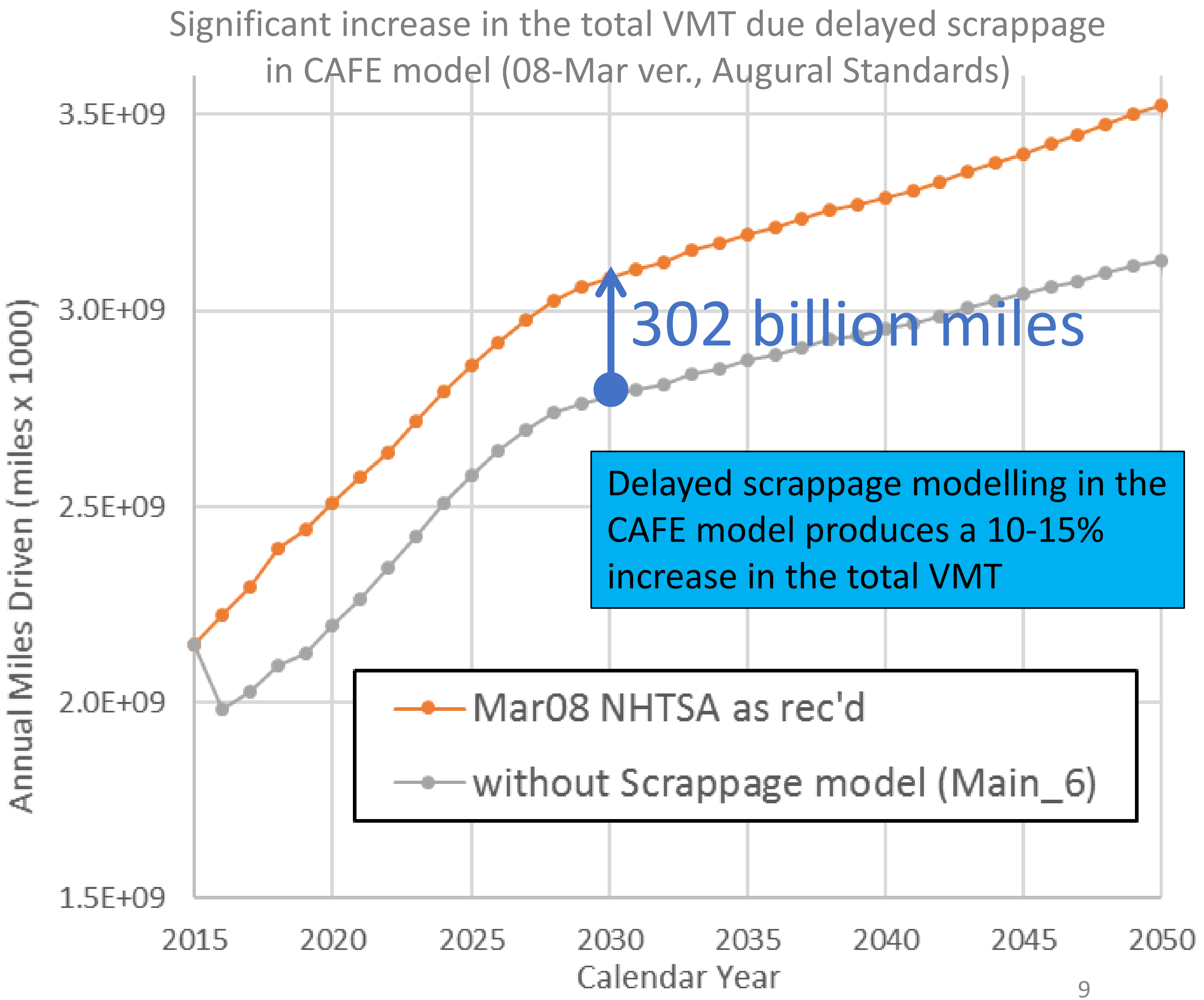
Real-world : The total number of vehicle miles travelled (VMT) would not change significantly as a result of consumer decisions to retain used vehicles longer instead of purchasing new vehicles.

CAFE model implementation: The use of the scrappage model produces a 10-15% increase in total VMT.

The 2016 VMT increases by 239 billion miles, and the 2030 VMT increases by 302 billion miles

Implication of this Error: The unexplained VMT disconnect is clearly wrong, and is driving incorrect fatality estimates[1].

[1]Because of the disconnect with the vehicles sales projections (DFS model), the use of the scrappage model causes an inappropriate increase in the fatalities impact of the Augural standards, and an inappropriate underestimation of the fuel savings and emissions benefits.



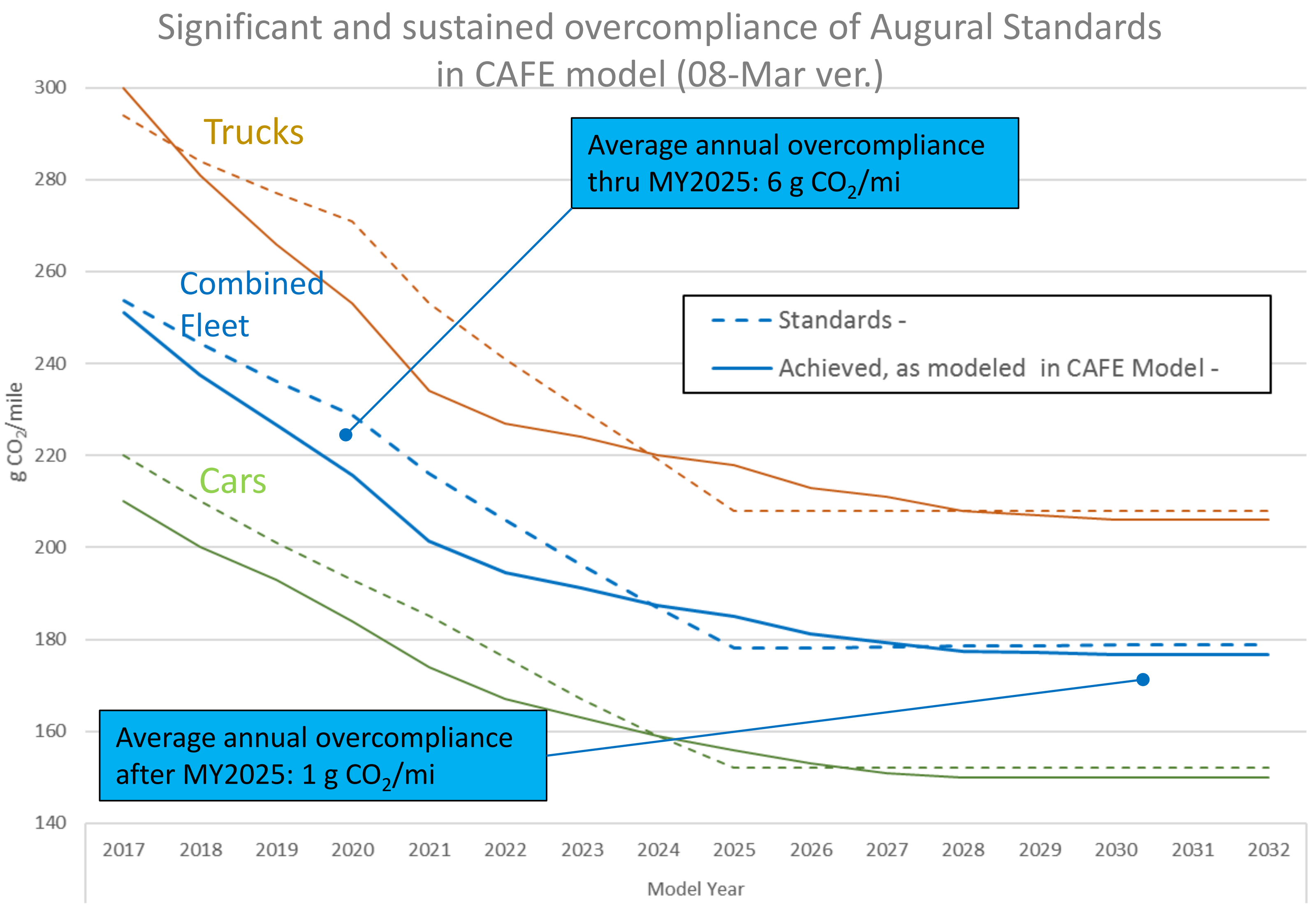
Review:
CAFE model
realism

Manufacturer year-by-year compliance strategy projects

<u>Real-world</u>: Manufacturers will consider future vehicle model plans and compliance strategy when introducing technology, transferring credits from year-to-year as needed and avoiding significant over-compliance, on average.

<u>CAFE model implementation</u>: Technology in excess of what is necessary for compliance is applied in nearly every year, particularly prior to MY2024 when lead time is more limited. This sustained and significant overcompliance projected by the CAFE model implies that the industry will not make use of the large quantity of banked credits, or year-to-year credit transfer provisions.

<u>Implication of this overcompliance</u>: Significant overestimation in industry costs. CAFE model is not properly accounting for banked credits in GHG program, which firms clearly do today.



Note: The 'Achieved' emissions represented in the CAFE model include tailpipe CO2, AC efficiency and leakage credits, and off-cycle credits. Banked credits are not included in the 'Achieved' value.

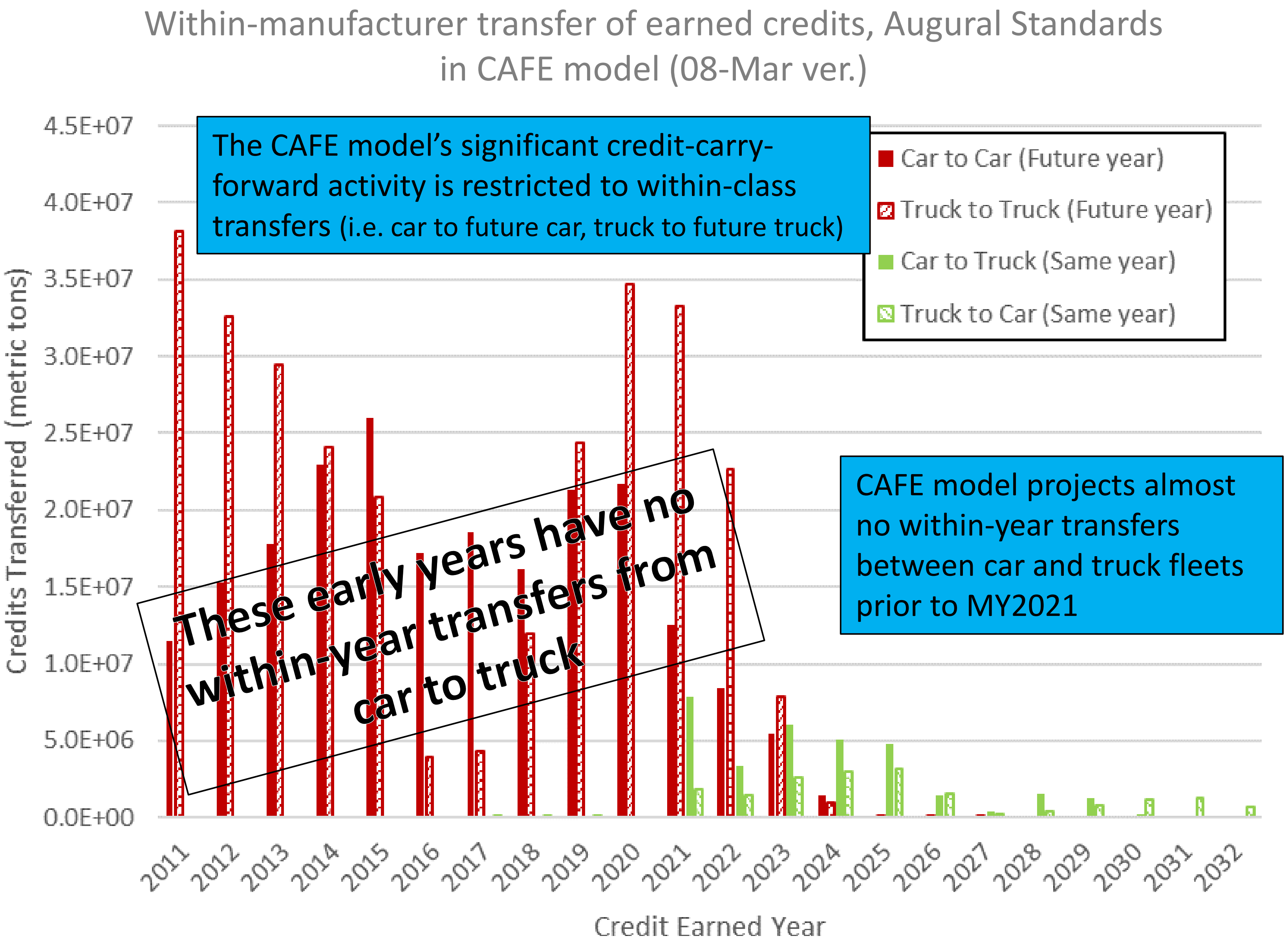
Review: CAFE model realism

Realistic management of credits by manufacturers

Real-world : Manufacturers will manage their credit banks to even out compliance status given staggered introduction of technology. It is unlikely that manufactures will consistently add excess technology in the earlier years in order to maintain a large credit bank into the future.

CAFE model implementation: Manufacturers are projected to strongly prioritize the carry-forward of credits into future years, relative to within-year transfers between car and truck fleets. The CAFE model projects almost no within-year transfers between car and truck fleets prior to MY2021

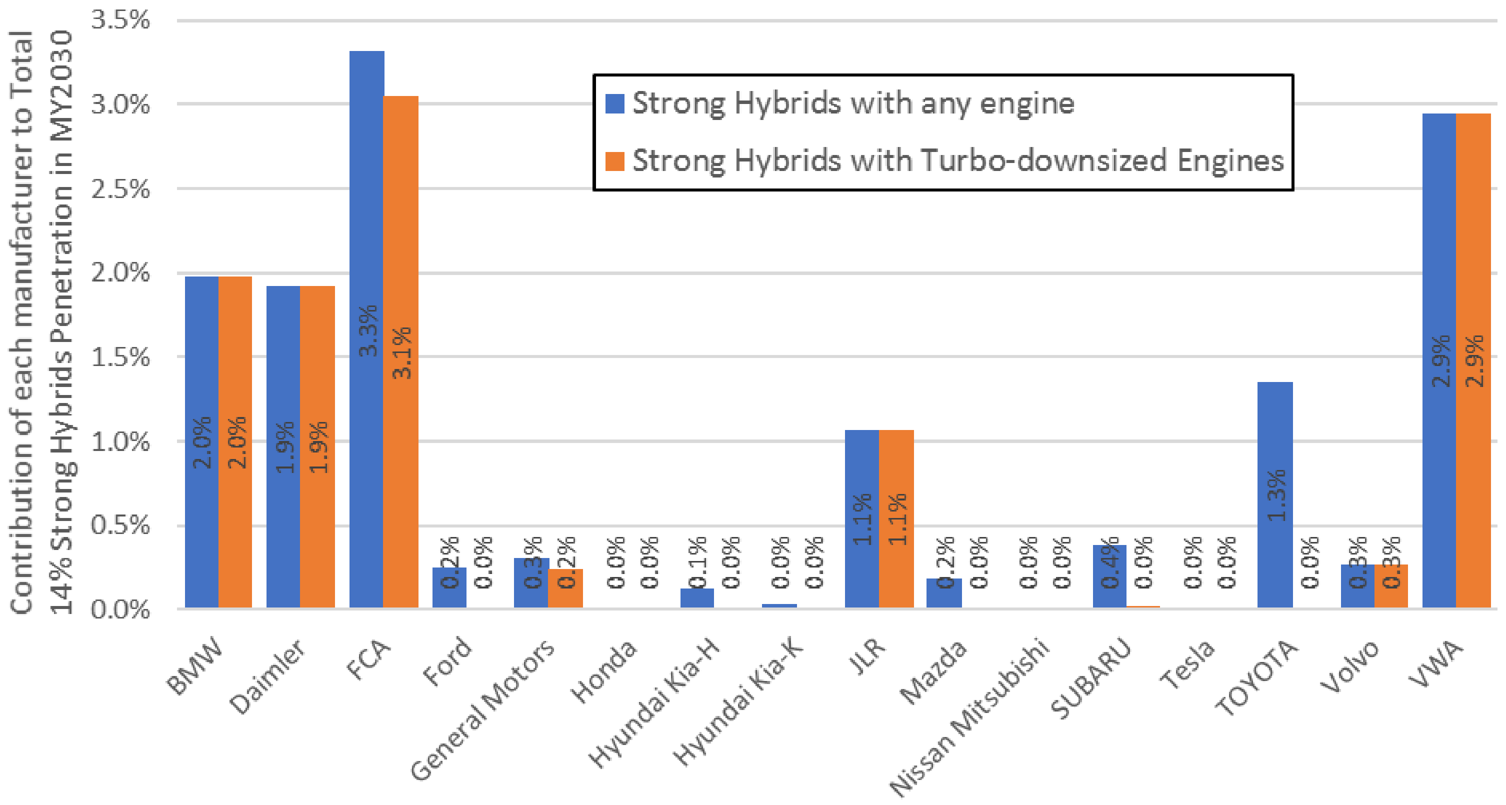
Implication of unrealistic credit carry-forward: Overestimation of GHG standards cost. CAFE model not taking advantage of car-truck credit transfer, which firms are clearly doing today



CAFE Model Does Not Choose Cost-effective Pairing of Engines and Strong Hybridization (1 of 2)

CAFE model implementation: Over 80% of the strong hybrid packages applied in the Augural case include turbo-downsized engines (11.5% of 14% fleet-wide strong-hybrid penetration)

Strong Hybrid Technology Pathway Comparison: Turbo vs. non-Turbo: Augural Standards in CAFE model (08-Mar ver.)



Review: CAFE model realism

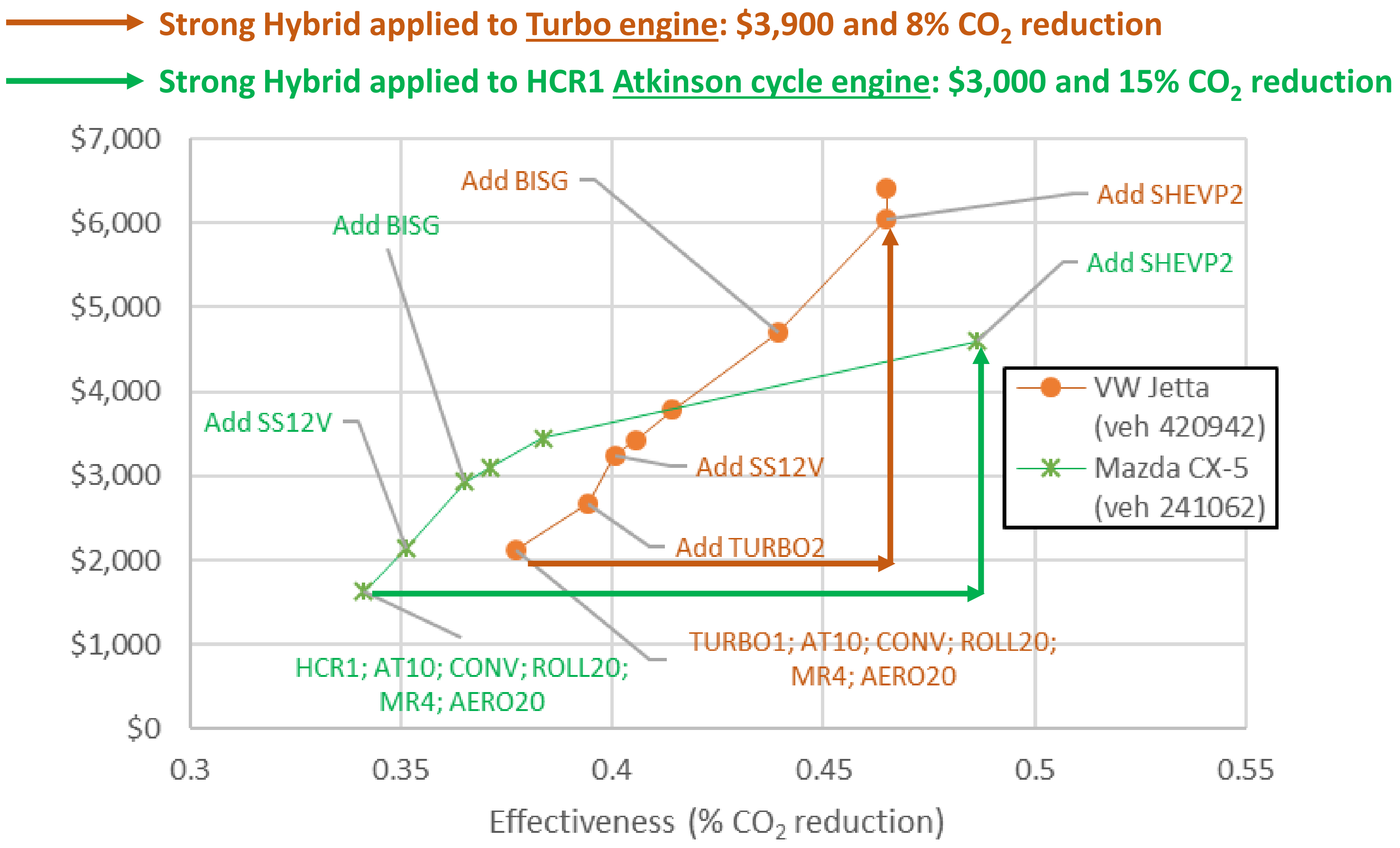
CAFE Model Does Not Choose Cost-effective Pairing of Engines and Strong Hybridization (2 of 2)

Real-world : The effectiveness benefits of strong hybridization (P2HEV and PSHEV) is dependent on the base engine technology to which the technology is applied. In typical applications, manufacturers will pair strong hybridization with efficient, but low cost Atkinson cycle engines.

CAFE model implementation: Due to the CAFE model's pre-defined technology pathways, strong hybridization is applied almost exclusively to turbocharged downsized engines, resulting in strong hybrid packages that are significantly higher costs and less effective than the vast majority of real-world implementations.

Implication of strict technology pathways: Overestimation of GHG standards cost. CAFE model is forcing combinations of technologies that are highly cost-ineffective.

Strong Hybrid Technology Pathway Comparison: Turbo vs. non-Turbo: Augural Standards in CAFE model (08-Mar ver.)



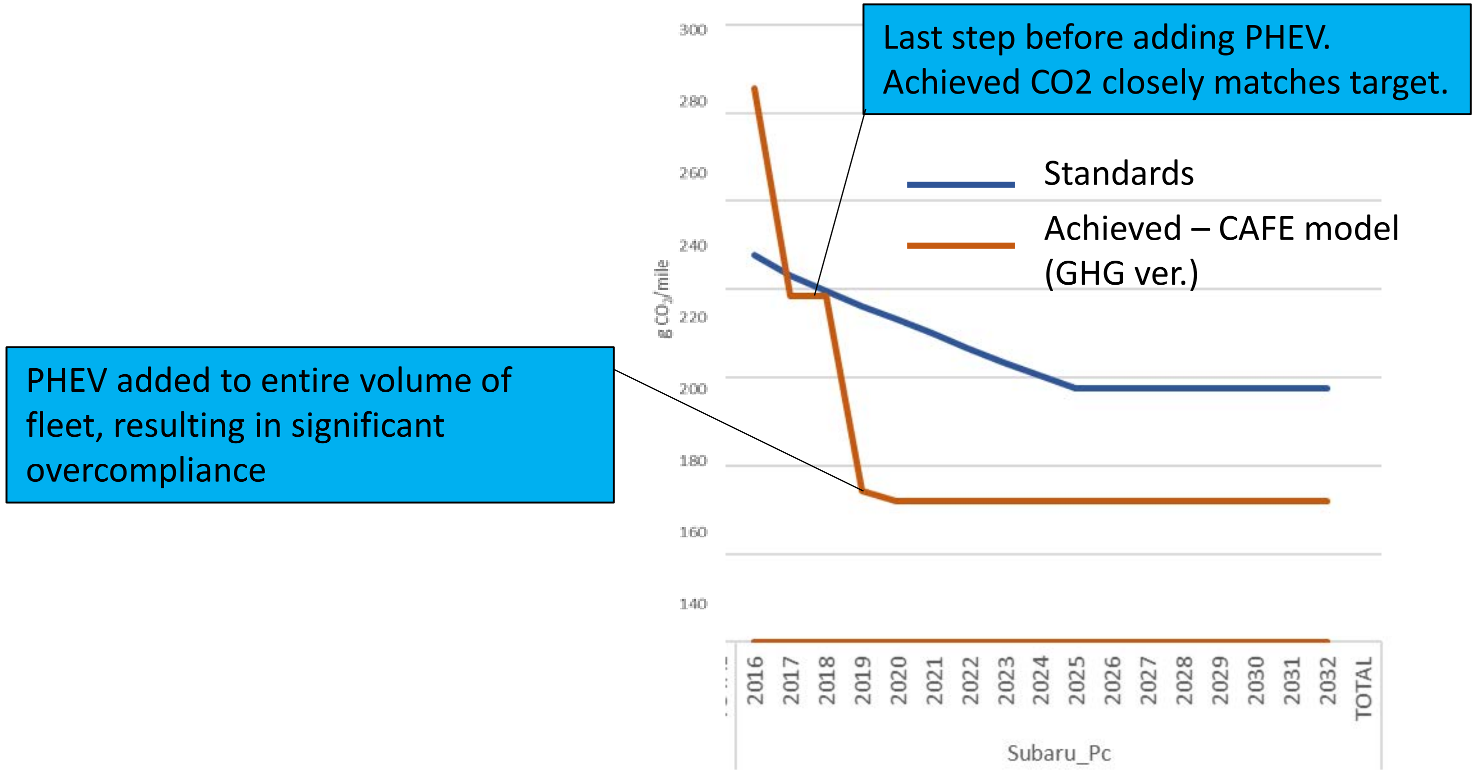
Review: CAFE model realism

Addition of plug-in electrification in reasonable volumes

<u>Real-world</u> : Plug-in vehicles (PEV's) provide significant compliance benefits due to low or zero emissions and multiplier incentives. Mainstream manufacturers will likely continue adopt PEV's in a strategic fashion, without drastically exceeding the volumes needed for compliance

<u>CAFE model implementation</u>: PEV technology is applied to platforms in 'all-or-nothing' manner, resulting in an inability to track the standards closely, and producing overcompliance levels ranging from moderate to very high.

<u>CASE Study</u>: Single vehicle manufacturer

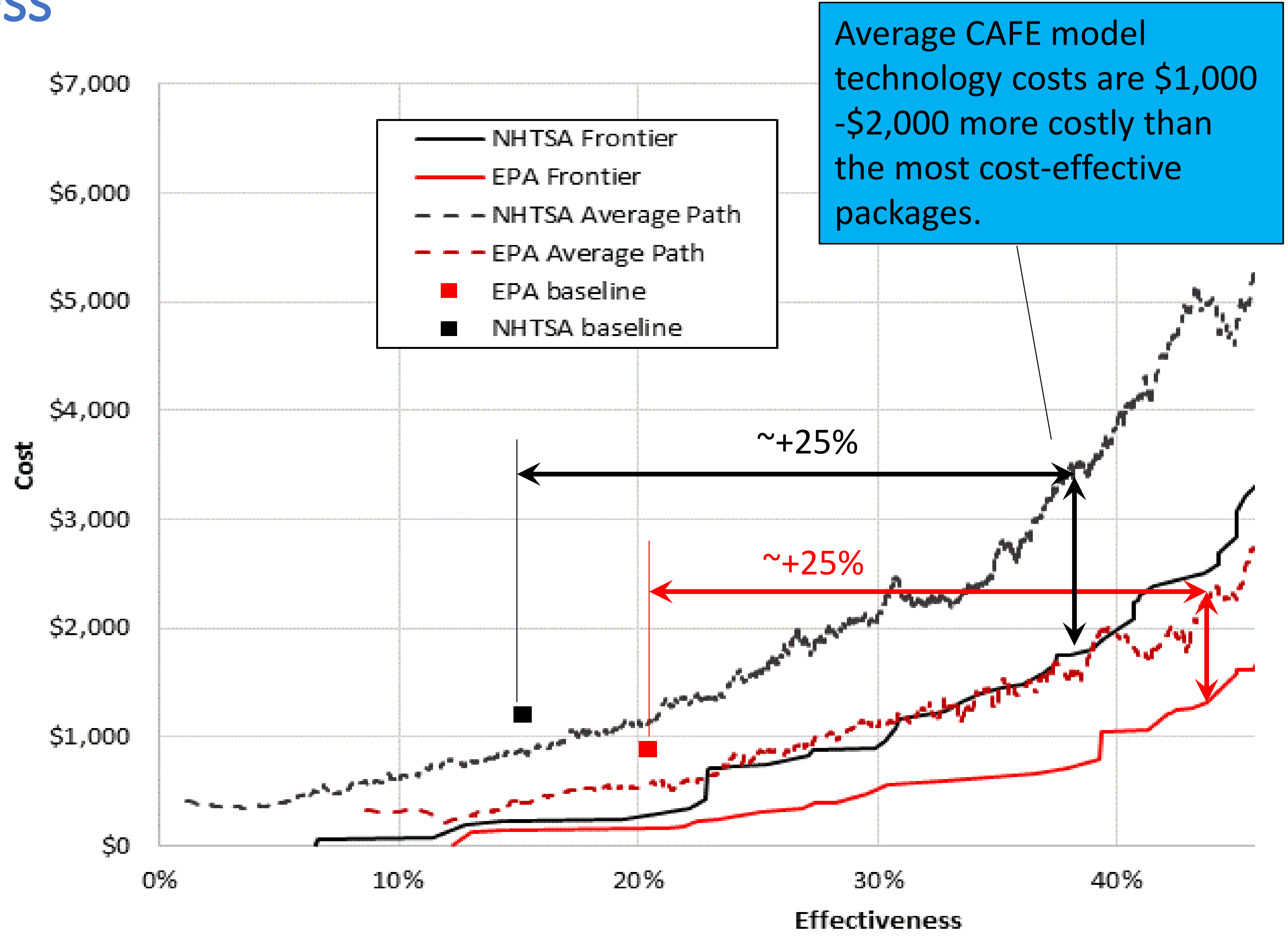


Review:
CAFE model
realism

Manufacturer consideration of technology package cost-effectiveness

<u>Real-world</u> : Manufactures will apply technology packages that are within a reasonable cost range of the most cost-effective technologies (e.g. well within $2,000)

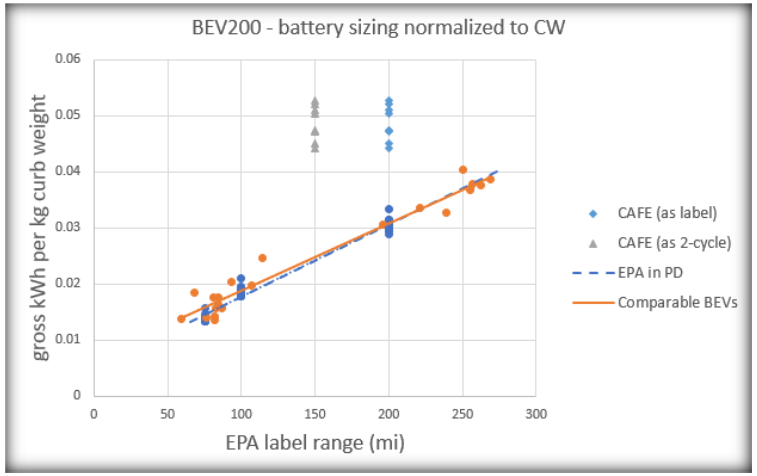
<u>CAFE model implementation</u>: Using the NHTSA inputs, as provided, manufacturers are projected to apply, on average, technology packages that are $1,000-$2,000 more costly than the most cost-effective packages.

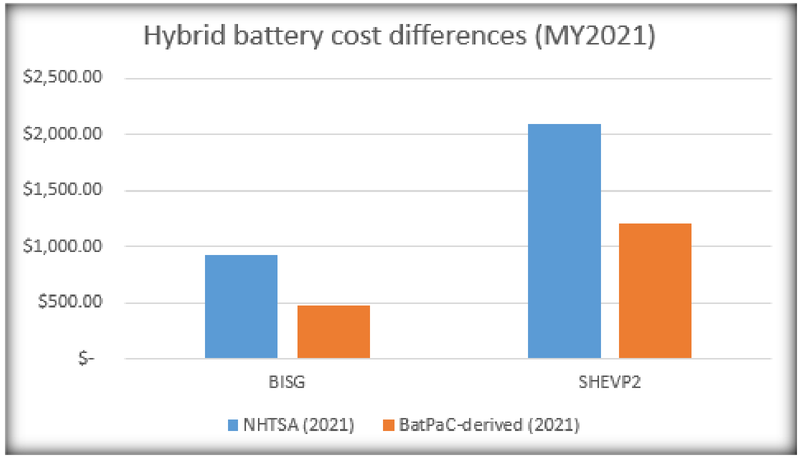


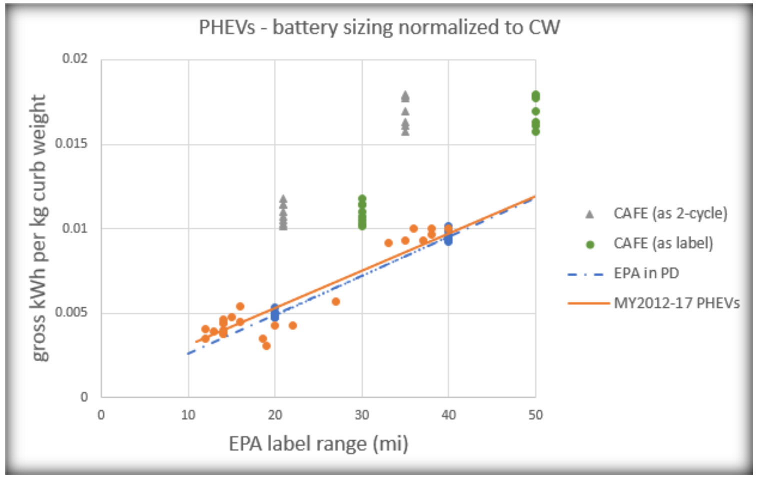
Review:
CAFE model
realism

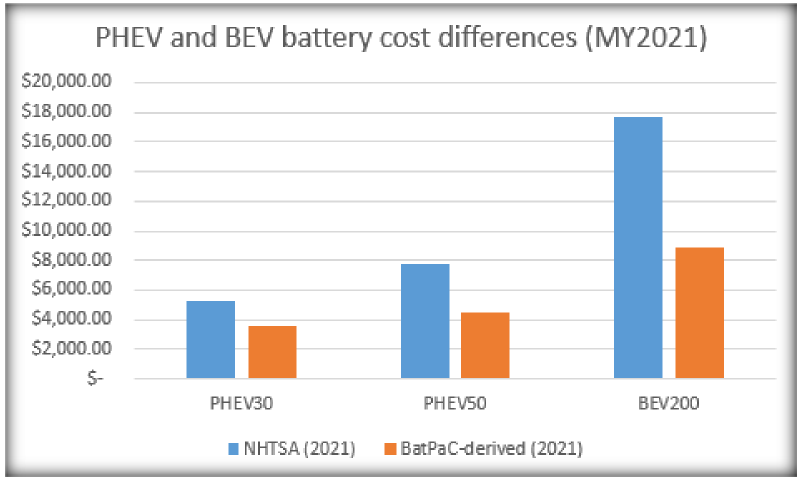
Battery Costs

- *The cost of batteries for hybrid and plug-in vehicles is in most cases significantly higher than expected based on the most recent projections derived from DOE's BatPaC model and battery sizes are substantially larger than observed in the current LD fleet.*









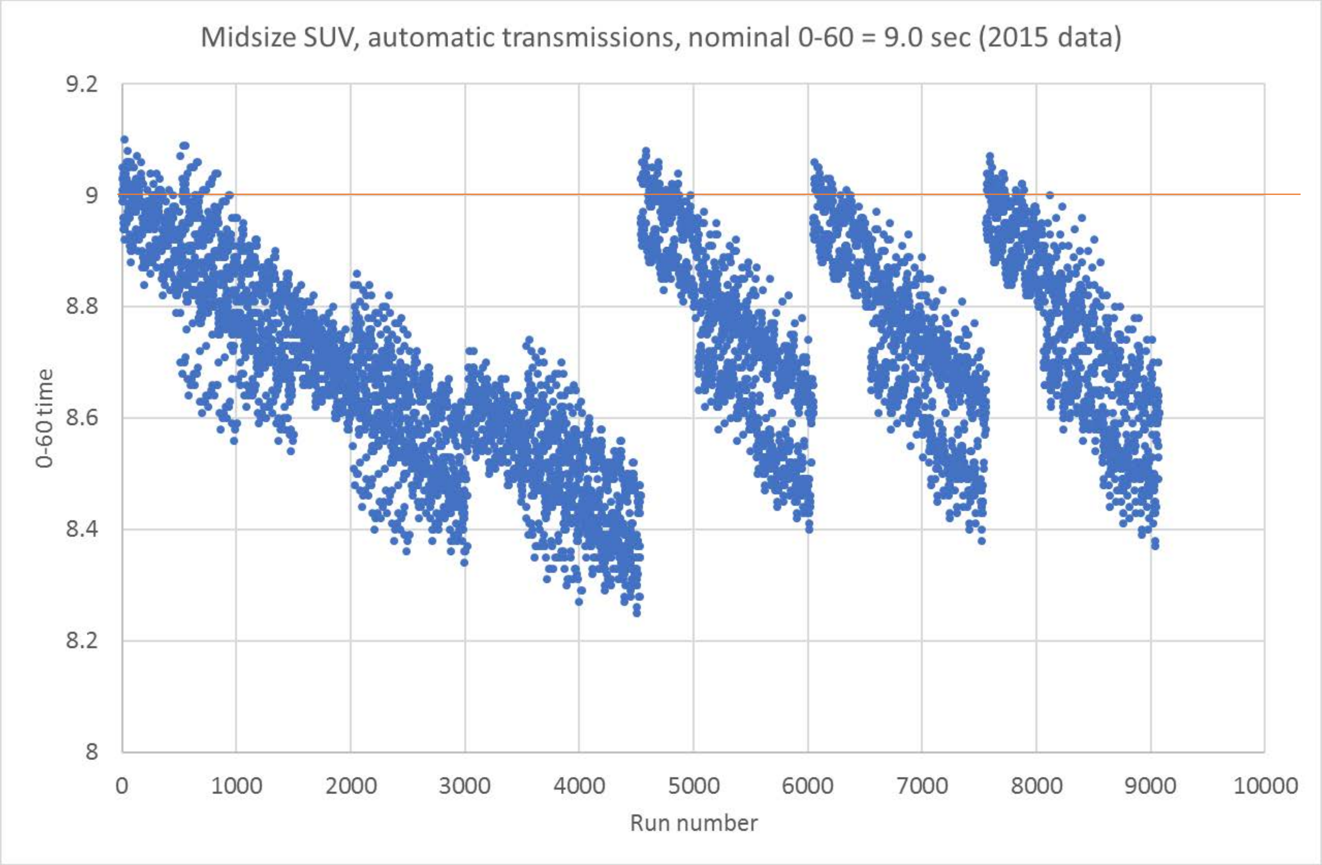
CAFE Model Projects Unquantified and Unmonetized Increase in Vehicle Performance

In the modeling for CAFE, engines are re-sized in two circumstances:

- When constructing an initial conventional or hybrid package.
- When applying over 7.5% mass reduction.

However, applying lower levels of mass reduction, advanced transmissions, or other load reduction will <u>increase acceleration performance</u>.

This additional benefit is <u>not accounted</u> for in the CAFE model.



Target 0-60 time for this class is 9.0 seconds. Actual DOT Autonomie simulations show 0-60 accelerations much better than the target for many technology packages.

Summary of the representation of GHG Program elements in the CAFE model

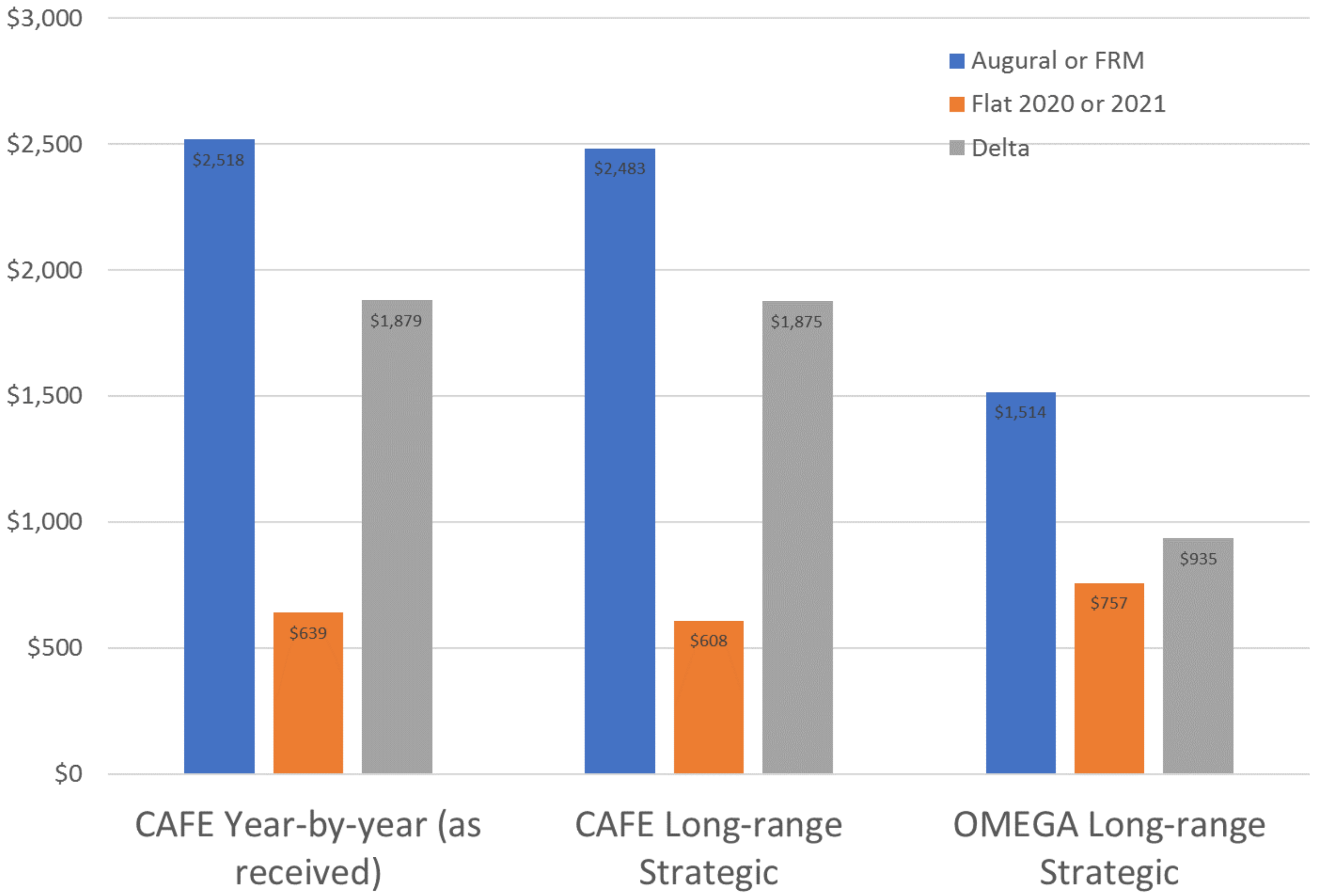
Program element	CAFE model implementation issues
BEV and PHEV Advanced Vehicle Technology Multipliers	CAFE model only adjusts the fleet average emissions to account for the multiplier values. For proper accounting of credits, the multipliers must also be incorporated into the GHG target.
Accounting for plug-in vehicle (PEV) upstream emissions	CAFE model does not have any inputs or apparent mechanism for accounting for the upstream emissions of PEVs, as required by the EPA regulations
A/C credits (efficiency and leakage)	The input files, as received from NHTSA, assume that all manufacturers earn a constant credit from AC efficiency and leakage in all years. However, the inputs for the standard footprint curves are adjusted for AC efficiency and leakage that increases over time. As a result, the standards defined in the CAFE model, as received, are less stringent than the actual standards.
Unlimited transfer is allowed within a manufacturer between car and truck fleets	CAFE model does not realistically account for car-truck credit transfers within a manufacturer (as described in earlier slide.) This likely contributes to the model's overall overcompliance, and the associated increase in costs.
Off-cycle Emission Credit caps	CAFE model inappropriately applies the credit cap (10g/mi) separately to each manufacturer's car and truck fleets. The GHG regulations specify that the cap is applied to a manufacturer's combined fleet.

CAFE model results 'walk'

Year-by-year vs. Long-range Strategic Modelling

- Specification of redesign cycles and year-by-year compliance considerations have a minimal effect on the projected 2025 compliance costs in the CAFE model.

- Differences between NHTSA and EPA cost projections are the result of modeling inputs, constraints and anomalies within the CAFE model (see other EPA slides).



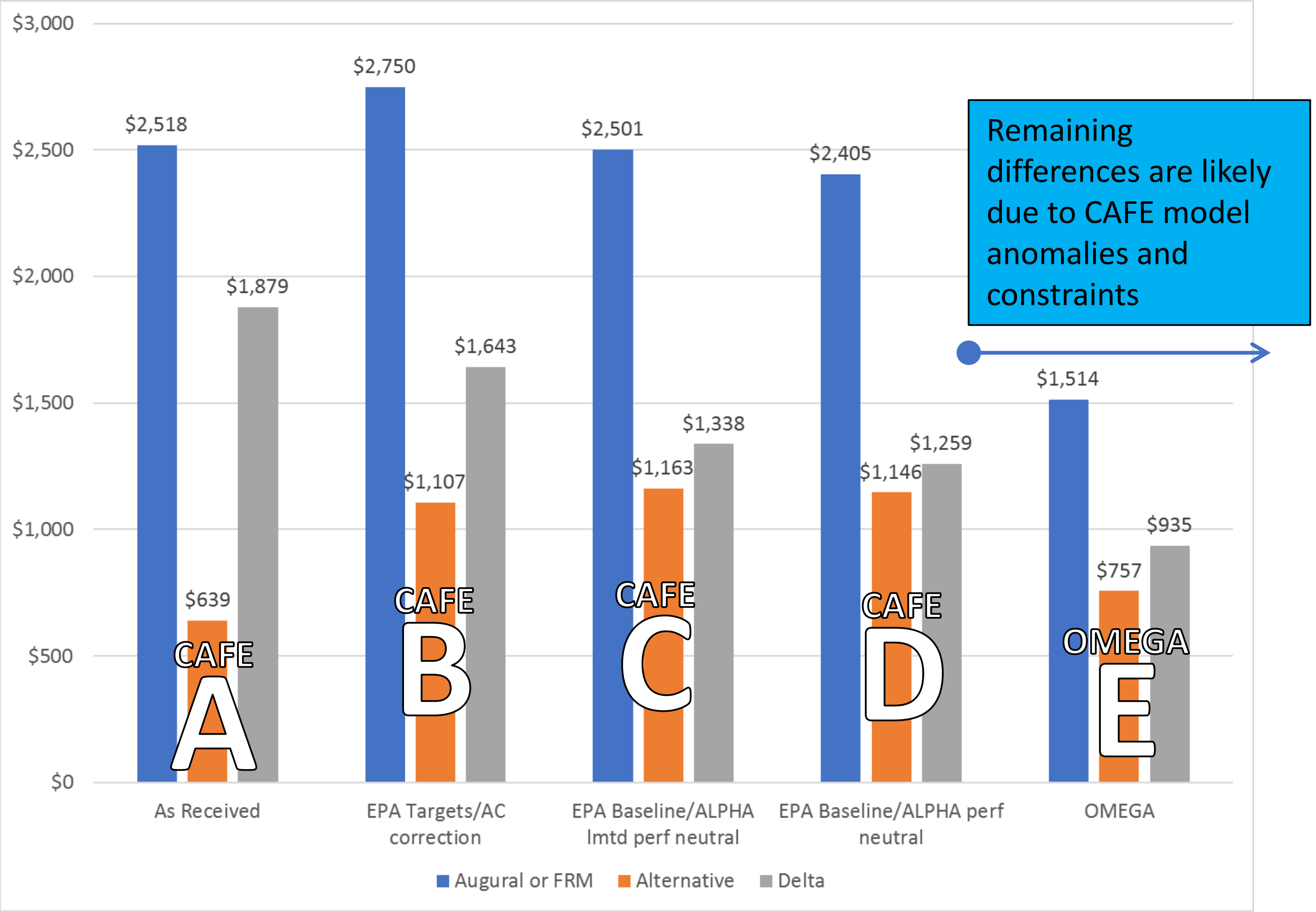
CAFE model results 'walk'

CAFE model runs with EPA settings and inputs

Run A: CAFE (GHG ver.)

"As received" from NTHSA which uses:

- Augural standards as the reference case
- Flat 2020 forward as the alternative case
- NHTSA/Volpe effort at characterizing the A/C provisions of the GHG standards
- Engine effectiveness estimates are compared against targets incorporating A/C efficiency expectations
- A/C leakage values not properly reflected

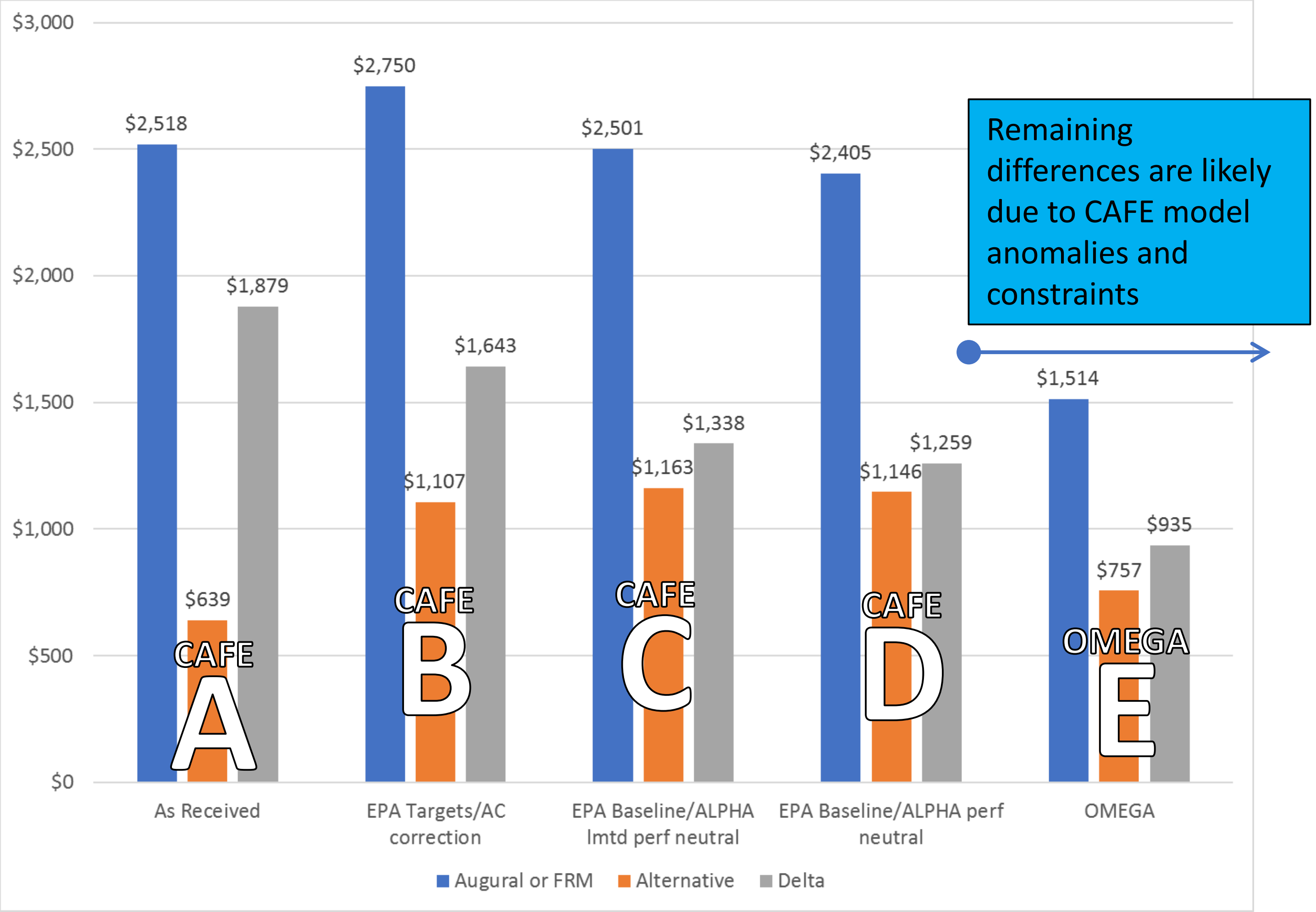


CAFE model results 'walk'

CAFE model runs with EPA settings and inputs

Run B: CAFE (GHG ver.)

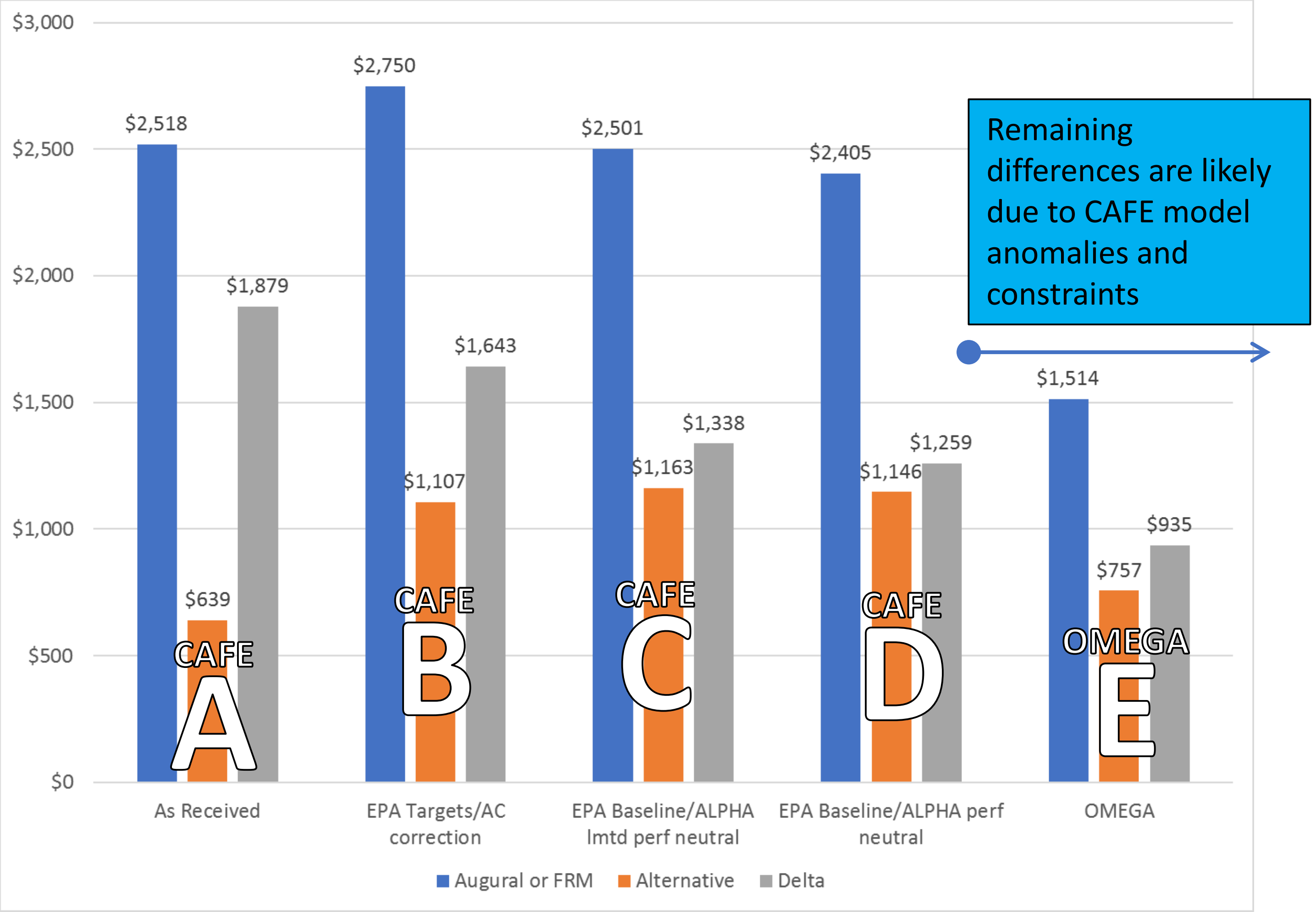
- EPA's 2022-2025 FRM targets as the reference case
- EPA's 2021 and later FRM targets as the alternative case
- EPA characterization of the A/C provisions of the GHG standards
- Engine effectiveness estimates are appropriately applied to 2-cycle targets that ignore influence of A/C efficiency expectations
- A/C leakage values corrected



CAFE model runs with EPA settings and inputs

Run C: CAFE (GHG ver.)

- Use of EPA's baseline fleet which incorporates a higher level of technology
- Use of EPA's cost input estimates including more recent BatPaC results
- Use of EPA's ALPHA modeling of effectiveness, but with NHTSA's engine resizing approach which does not maintain performance neutrality

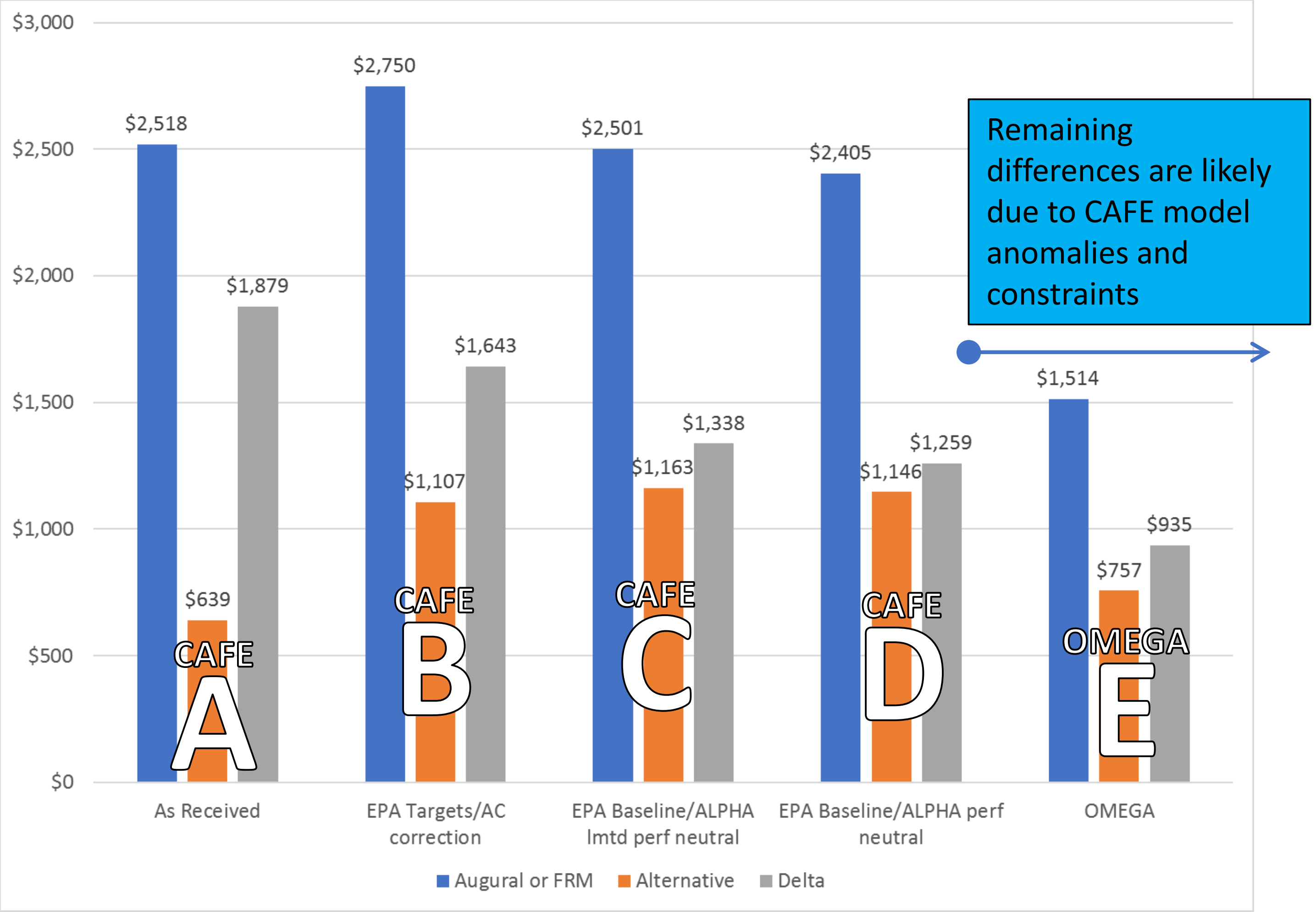


CAFE model results 'walk'

CAFE model runs with EPA settings and inputs

Run D: CAFE (GHG ver.)

- Use of EPA's baseline fleet as in the "C" set
- Use of EPA's cost inputs as in the "C" set
- Use of EPA's ALPHA modeling of effectiveness, maintaining performance neutrality

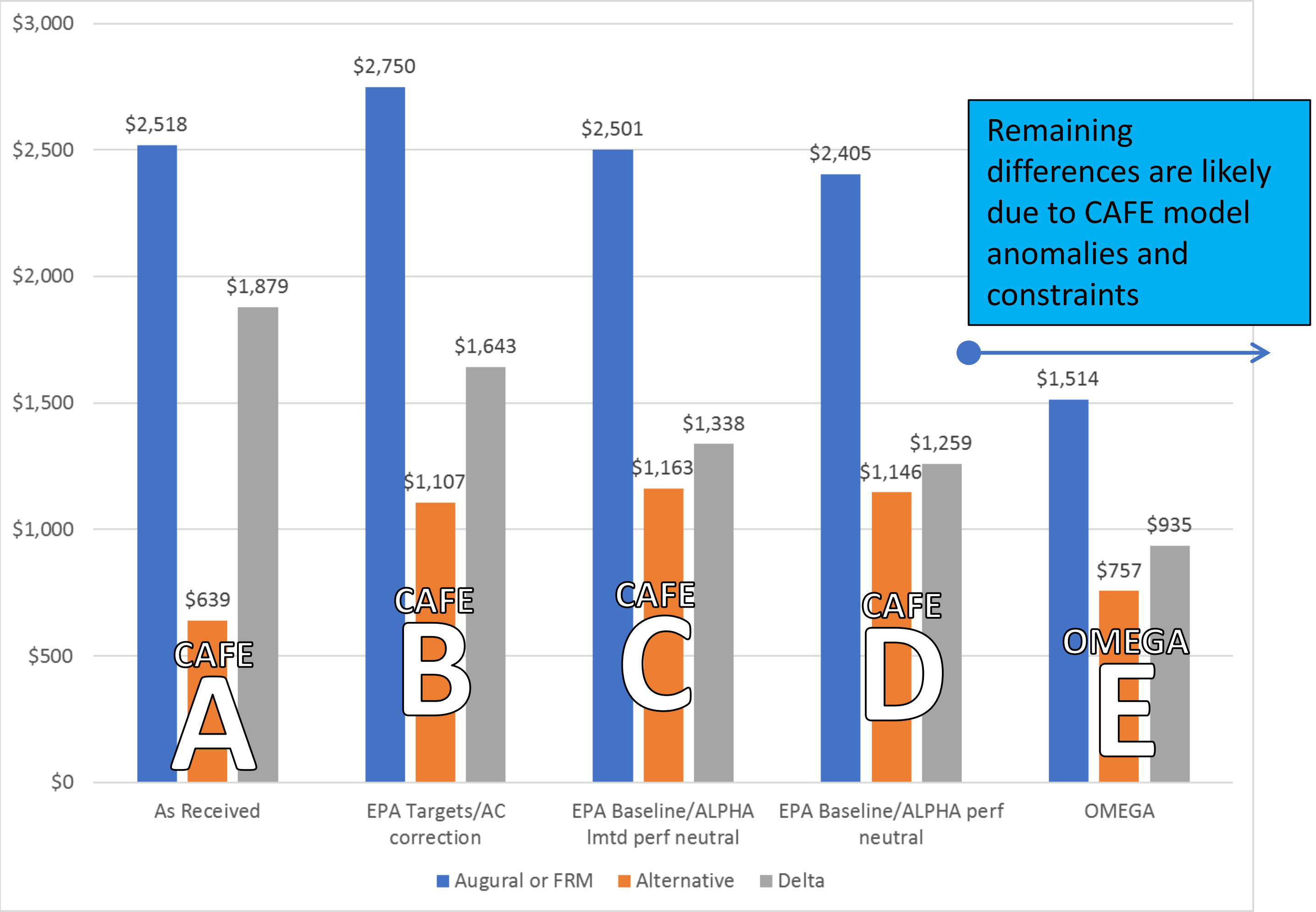


CAFE model results 'walk'

CAFE model runs with EPA settings and inputs

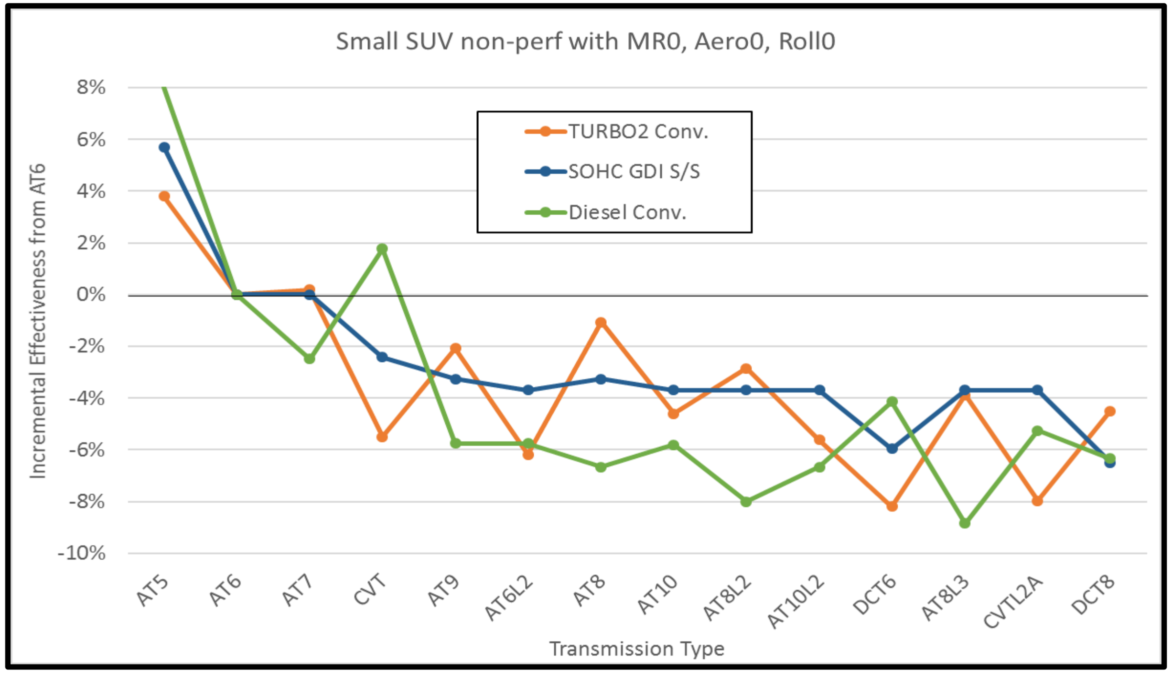
Run E: CAFE (GHG ver.)

- Full use of ALPHA and OMEGA



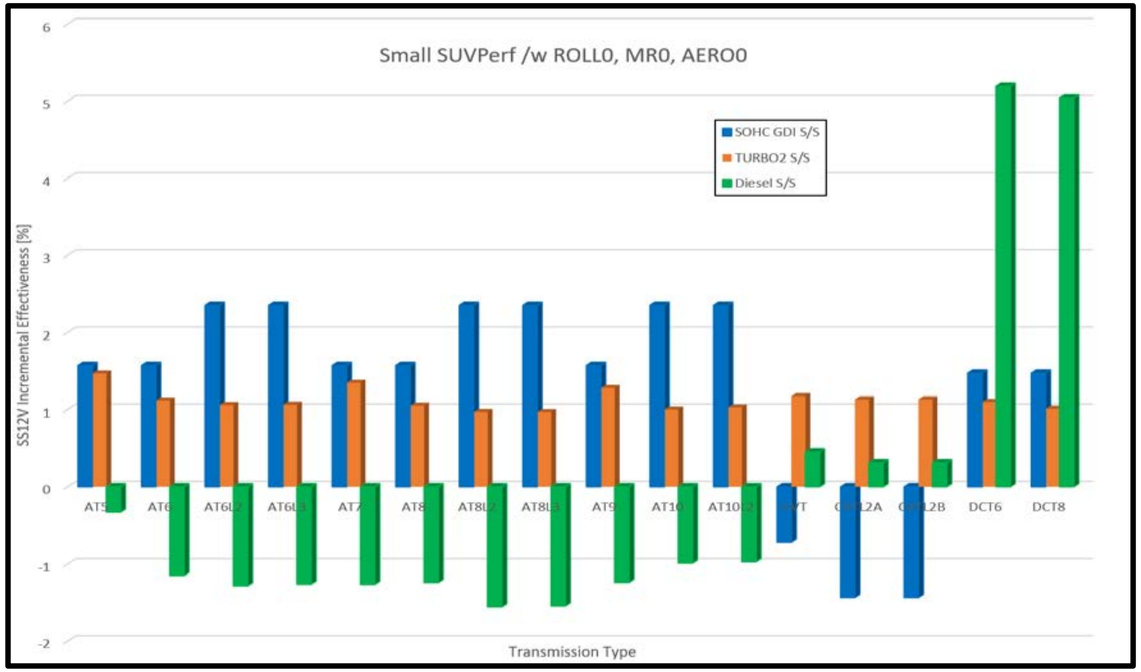
Technology Effectiveness

- *EPA has also identified specific technology effectiveness observations that are inconsistent with expected performance.(examples provided below)*



Observations of Transmission Effectiveness

- Consistent values could indicate lack of resolution in modeling (single values being applied broadly).
- Additional technology does not follow a logical progression of improvement.



Observations of Stop/Start Effectiveness

- Effectiveness of stop/start should be consistent independent of the transmission (for a given engine).
- Stop/start can never produce a negative effectiveness.

CAFE Model Observations

From EPA's March 1st summary status report of CAFE model review:

The use of EPA input values in the CAFE model which update and/or correct the anomalous inputs used in the NTHSA-reported runs from January 22 has a significant impact on several key output results:

Relative to the Augural Standards, technology cost savings of Alternative standards are reduced and fatalities increase.

Source	As summarized by NHTSA		As run by EPA (as received)		EPA-updated inputs w/ DFS and Scrappage models [44]		EPA-updated inputs w/o DFS and Scrappage models [44]	
Model Years	2017-2025 (current standards)	2021-2026	2017-2025 (current standards)	2021-2026	2022-2025	2022-2025	2022-2025	2022-2025
Annual Rate of Increase in Stringency	No Action	0.0%/Year PC 0.0%/Year LT	No Action	0.0%/Year PC 0.0%/Year LT	No Action	0.0%/Year PC 0.0%/Year LT	No Action	0.0%/Year PC 0.0%/Year LT
Price Increase due to New CAFE Standards ($/veh) MY2030	baseline	-$1,879	baseline	-$1,879	baseline	-$1,236	baseline	-$1,259
Weight reduction	19% (not including powertrain)	12% (not including powertrain)	19% (not including powertrain)	12% (not including powertrain)	14% (including powertrain)	11% (including powertrain)	14% (including powertrain)	11% (including powertrain)
HCR	26%	12%	26%	12%	36%	26%	32%	26%
Turbo-downsized	62%	46%	62%	46%	33%	33%	36%	36%
Dynamic Deac (DeacFC)	7%	0%	7%	0%	0%	0%	0%	0%
Diesel	1%	1%	1%	1%	1%	1%	1%	1%
Advanced transmissions	82%	93%	82%	88%	59%	76%	64%	79%
Stop-Start (12V)	10%	13%	10%	13%	23%	11%	14%	11%
MHEV48V	41%	2%	41%	2%	23%	9%	33%	13%
Strong HEV	14%	2%	14%	2%	17%	7%	14%	7%
Sum of mild and strong HEV	55%	5%	55%	5%	40%	16%	47%	19%
Sum of PEVs	1%	1%	1%	1%	13%	5%	14%	6%
Average Annual Fatalities CY 2036-2045 without rebound	baseline	-150	baseline	-150	baseline	-156	baseline	+60
Average Annual Fatalities per Billion Miles CY 2036-2045 without rebound		not reported	baseline	+0.004	baseline	+0.016	baseline	+0.021
Average Annual Fatalities CY 2036-2045 with rebound		-863	baseline	-863	baseline	-911	baseline	-649
Average Annual Fatalities per Billion Miles CY 2036-2045 with rebound		not reported	baseline	+0.007	baseline	+0.017	baseline	+0.023

Appendix:
Update on LDV Rebound

4/16/2018

What is LDV Rebound…and Why Care?

- Buy a more fuel-efficient car, drive more because it's cheaper to drive; this is what is typically meant by the LDV rebound effect
- More driving means:
  - Less energy savings/more greenhouse gas emissions
  - Increase in consumer benefits (i.e., you can drive more, since it is cheaper to use your vehicle)
  - More air pollution (NO_x, PM, etc.)/congestion/refueling costs
- Large number of academic papers have attempted to estimate the LDV rebound effect
  - Early studies, starting in 1970s, focused mainly on oil price shocks, gasoline taxes
  - Over the last decade, 12 relevant U.S. studies quantified rebound effect/6 international studies
  - Most studies look at how drivers respond to fuel costs/fuel prices (not actual fuel efficiency of vehicles)

Types of Rebound Studies

- **Aggregate, Time Series Studies**
  - Estimate rebound effect based upon national LDV travel patterns over time; in U.S., data is available at the national/state level
  - Able to account for trends in key variables influencing rebound (e.g., fuel costs/income/congestion etc.) over time
  - Studies that rely on a system of equations (e.g., travel, size of vehicle stock, fuel efficiency, congestion) have some of the best capabilities of controlling for variables causing rebound effect
  - U.S. studies provide "ready-made" national rebound estimates for LDV rulemakings
- **Per Vehicle Studies (single year or time series)**
  - Most studies use odometer readings from smog check data/individual vehicles/state level; most accurate measure of travel
  - Data rich; can address some issues of heterogeneity: how rebound varies with some characteristics of vehicles (e.g., age); households (e.g., income); geography (e.g., residential density)
  - Results from individual states are unlikely to be representative for national, U.S. rebound estimates

Types of Rebound Studies

- **Household Studies (single year or time series)**
- Most studies use cross sectional, single year household survey data
- Like Per Vehicle studies, data rich; can address issues about how characteristics of households/vehicles affect rebound (e.g., heterogeneity)
- Tend to see a wider range/higher rebound estimates than aggregate studies
- Even well executed, single year studies have difficulty in controlling for factors influencing rebound effect (e.g., limited to looking at one year effect)
- Most recent studies based upon National Household Travel Survey (NHTS) (2009)
    - Time Period: unique set of circumstances with the onset of the Great Recession
        - Fuel prices fluctuated dramatically from $3.30/gallon in March 2008 to $4.10 gallon in summer of 2008, followed by a decline to ~$1.70/gallon in the late 2008/early 2009 period
        - U.S. GDP fell 1% growth rate to -7.5% annualized growth rate
        - U.S. unemployment increased from 4% to 10%

EPA Selection Criteria for Rebound Estimates

- There are a wide variety of estimates of the rebound effect, in part due to the many different methodologies/data sources used to try to quantify this impact
- Given the broad range of values, EPA believes it is important to critically evaluate which studies are most likely to be reflective of the rebound effect of future GHG/fuel economy standards
  - In other words, we can't just take the "average" rebound estimates from literature
- **Geographic/Timespan relevance**: Priority given to U.S. vs. state/international studies; studies that can project based upon U.S. demographic/land use patterns in LDV rulemakings timeframe (e.g., 2020-2040)
- **Model relevance**:
  - Priority given to studies that measure driving response to changes in fuel economy, the variable of interest, rather than to changes in fuel price/costs
  - Priority given to studies that measure driving response to increases to fuel economy (i.e. "asymmetry") over studies that assume uniform response to increases/decreases
- **Time period of study**: Priority given to recent rebound studies (in the last decade)
- Priority given to studies with **strong statistical/methodological basis**
- **Data source type**: Priority given to studies based upon time series data vs. single-year studies

Recent Rebound Studies

Author/Date	Nation	Time Period	Type of Study	Time Span	Range of Estimates
Hymel and Small (2015)	U.S.	2003-2009	Aggregate	Time series	4%/18%
Greene (2012)	U.S.	1966-2007	Aggregate	Time Series	10%
Gillingham (2014)	California	2001-2009	Per Vehicle	Time Series	22-23%
Gillingham et al. (2015)	Pennsylvania	2000-2010	Per Vehicle	Time Series	10%: One year
Wenzel (2017)	Texas	2005-2010	Per Vehicle	Time Series	9-16%
Bento (2009)	U.S.	2001	Household	Single Year	21-38%
Waddud (2009)	U.S.	1984-2003	Household	Times Series	1-25%
West and Pickrell (2011)	U.S.	2009	Household	Single Year	9-34%
Su (2012)	U.S.	2009	Household	Single Year	11-19%
Linn (2016)	U.S.	2009	Household	Single Year	20-40%
Liu (2014)	U.S.	2009	Household	Single Year	39-40%
West et al. (2015)	U.S.	2009	Household; Cash for Clunkers	Single Year	0%
Barla et al. (2009)	Canada	1990-2004	Aggregate	Time Series	8-20%
De Borger (2016)	Denmark	2001-2011	Household	Time Series	8-10%
Wang et al. (2012)	Hong Kong	1993-2009	Aggregate	Time Series	45%
Anjonvic and Haas (2012)	E.U.	1970-2007	Aggregate	Time Series	44%
Frondel and Vance (2013)	Germany	1997-2009	Household	Time Series	46-70%
Weber and Farsi (2014)	Switzerland	2010	Household	Single Year	19-81%

- Aggregate; U.S. - Per Vehicle; U.S. - Household Studies; U.S. - International

Summary

- There are a wide variety of estimates of the rebound effect, in part due to the many different methodologies/data sources used to try to quantify this impact
- Within the existing literature, aggregate, time series studies of the U.S. provide the most reliable estimates of the rebound effect for use in LDV rulemakings
  - Results from individual states are unlikely to be representative of national, U.S. rebound estimates
  - Even well executed U.S. studies using single year data, particularly from the NHTS 2009 time period with the onset of the Great Recession, have difficulties in providing reliable estimates of the U.S. rebound effect
    - Recent studies using the same data set, NHTS (2009), find rebound estimates that range from 9-40%
  - Even well executed international studies do not provide reliable estimates of the U.S. rebound effect, as the U.S. has different travel patterns from other countries due to a variety of factors
- Recent U.S. aggregate, time series studies find a rebound effect lower than 20%