Comments Concerning the Proposed Rulemaking to Revise Light-Duty Vehicle Greenhouse Gas Emissions Standards and Corporate Average Fuel Economy Standards: Technical Appendix

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These technical comments were prepared on behalf of the Union of Concerned Scientists by David W. Cooke, in consultation with Don Anair, Samantha Houston, David Reichmuth, and Alyssa Tsuchiya.

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I. Agencies have failed to propose maximum feasible standards

NHTSA is required by the EPCA, as amended by EISA, to issue "maximum feasible" standards for manufacturers' fleets by balancing a number of factors the must include technological feasibility, economic practicability, the effect of motor vehicle standards of the Government on fuel economy, and the need for the United States to conserve energy (49 USC 32902(a), (f)). NHTSA may consider additional factors, namely safety and consumer choice, as it has chosen to do in this proposed rulemaking (83 FR 43206). In Section V.A.(e), NHTSA discusses how it has "balanced" the four required factors alongside the two optional factors. On its face, the discussion might seem like a reasonable balance of factors. However, the Agency has seriously mischaracterized several of the factors under consideration, which has led to an erroneous conclusion about the appropriate stringency of a standard to satisfy the maximum feasibility requirement. Furthermore, it has ignored its statutory obligation to support the ultimate purpose of EPCA: energy conservation.[1] In the following sections, we demonstrate critical flaws in how the Agency's analysis of technological feasibility, economic practicability, effect of other standards, and need to conserve energy has been conducted.

While the arguments below are constructed around NHTSA's statutory requirements, all of the data supporting our conclusions about the technical feasibility, socioeconomic benefits, and interaction with other rules are directly relevant to EPA's statute as well. We have identified in specific instances where the precise rationale may be more pertinent to a particular agency, but generally these comments should be read as broadly relevant to both agencies' authority and obligations to set strong standards which will benefit the American people.

A. Agencies' modeling of the standards is overly conservative and does not accurately demonstrate the technological feasibility of stronger standards.

1. The agencies' characterization of the current state of technology is overly conservative and inconsistent with previous agency conclusions

The agencies have invited comment on "all aspects of the analysis discussed" in Section II.D Characterization of Current and Anticipated Fuel-Saving Technologies (83 FR 43022). In this section, we respond to the agencies' treatment of technology in modeling the proposed rule. In response to agencies' specific requests for comment on technology costs, effectiveness, and applicability to vehicles in the fleet (83 FR 43029), we demonstrate that the agencies have overestimated costs and underestimated the effectiveness and applicability of many fuel saving technologies considered. We further point out that agencies have failed to consider some technologies at all, including spark-assisted compression ignition and variable compression ratio engines. Such conservative treatment of included fuel-saving technologies and failure to consider other technologies at all leads the agencies to erroneous conclusions about the technological feasibility of strong vehicle standards.

In the 2017 Final Determination (EPA 2017a, b), EPA documented how manufacturers have responded to strong fuel economy and emissions standards. The manufacturers innovated—they have invested in robust research and development efforts that have yielded unforeseen technology developments,

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[1] ***CBD*** v. ***NHTSA***, 538 F. 3d 1172, 1197 (9th Cir. 2008). "Whatever method it uses, NHTSA cannot set fuel economy standards that are contrary to Congress' purpose in enacting the EPCA—energy conservation."

including high compression ratio engines, improved continuously variable transmissions, cheaper and wider deployment of lightweight materials, and more (EPA et al. 2016; EPA 2016a). Since the 2017 Final Determination, advancements in conventional vehicles have continued apace, with even further breakthroughs like spark-assisted compression ignition and variable compression ratio engines. Unfortunately, in the analysis supporting this NPRM, the agencies have chosen to ignore these advances and instead used conservative assumptions that underestimate the potential for future reductions in fuel use and emissions, as outlined below.

A) MILD HYBRIDIZATION

While the agencies have acknowledged in the supporting documentation some of the recent progress in mild hybridization, particularly with the addition of 48V mild-hybrid technology to the Volpe model, the costs included in this proposal are far too high. In practice, costs have continued to come down for 48V systems and today already match those projected for 2025 less than two years ago in EPA's analysis for the Final Determination (EPA 2017a). Continued volume-based learning will drive the cost down further (see presentations by Johnson Controls and FCA, Lee 2017), consistent with near-term plans from a number of manufacturers, including Fiat-Chrysler, Ford, General Motors (NemoTec presentation, Lee 2017).

Of particular interest, mild hybridization is also showing strong potential in pick-up trucks, proving that standards could be stronger for these vehicles. Recent deployment of a limited fleet of eAssist Silverado pick-ups in California shows not just significant emissions reductions in city driving (13 percent), but also yields significant benefit on the highway as well, for an overall improvement of 9 to 11 percent, dependent upon whether it is utilized on a 2WD or 4WD vehicle (GM 2016). This low-cost technology (GM offered it at just a $500 premium) can work synergistically with other technologies on the truck to further reduce fuel use—General Motors noted in its press materials, "the electric motor also enables the Active Fuel Management [cylinder deactivation] system on the 5.3L V-8 engine to operate in 4-cylinder mode for longer periods, resulting in additional fuel economy benefits" (GM 2016).

Such performance exceeds the agencies' assessment of the technology. The Autonomie modeling results estimated just a 6 to 7 percent improvement above the conventional engine across all vehicle classes (PRIA Figure 6-155), well below not only certification data from Ram and GM,[2] but below the latest assessments of the National Academies[3] and EPA,[4] and even previous Autonomie results

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[2] According to the test data submitted by General Motors, the eAssist system deployed on its heavy-duty pick-ups achieves a 10 percent reduction in fuel consumption on the CAFE cycle in its 2WD pick-ups and a 5.5 percent improvement on its 4WD pick-ups (comparing models 550/645, 551/646, 558/643, and 559/644) (EPA 2018a). FCA data shows that there is a 10 percent difference on the CAFE test cycle between similarly configured 2019 Ram 1500 4x2 and 4x4 pick-ups with and without their eTorque mild hybrid system (comparing models 504/505, and 506/507) (EPA 2018b).

[3] "The [2015 National Research Council] committee concludes that the effect of hybridization is a 10 percent reduction in fuel consumption for the mild hybrid." (p. 4-40, NAS 2015)

[4] In its Technical Support Documentation supporting the 2016 Proposed Determination, EPA found a technology effectiveness for mild hybrids of 7 to 9.5 percent (Table 2.90, EPA 2016a).

incorporated into NHTSA analysis.[5] This drastic departure from previous Autonomie results is especially notable in the case of crank-integrated starter generator (CISG) mild hybrids, which showed a 4 to 5 percent improvement over the belt-integrated starter generator (BISG) in previous analysis (ANL 2016), while the data supporting this proposal instead shows virtually no benefit whatsoever for CISG over BISG, and in many cases actually shows an ***increase*** in fuel consumption (PRIA Figure 6-155; FC1_Improvements.csv, NHTSA 2018a)—no explanation whatsoever is given in the technical support for the administration's proposed rule for this radical decrease in technology potential.

It is not just the effectiveness of this widely deployable and relatively low-cost conventional vehicle technology that has been inexplicably downgraded—the agencies' costs have also been raised substantially. Little documentation is available to support this change—the data presented in the PRIA for the choice of battery technology and cost of batteries conflicts with that presented in the proposal and provided as inputs to the Volpe model, as noted in an as-yet unfulfilled request for further information and clarity about the administration's proposal (Peter 2018).

The PRIA (Table 6-29) lists the direct manufacturing costs ("BatPaC DMC Cost") for a BISG battery as $391.12 and a CISG battery as $588.44, regardless of vehicle size or demand configuration. However, the input files for the Volpe model show battery costs (field "BatPaCCost") of $649.95 and $847.24 for BISG and CISG respectively (ANL 2017a—j). The source of the additional $258 cost is not explained.

Because these mild hybrid technologies are broadly adopted by the fleet (34 percent, PRIA Table 7-64), overestimation of the battery costs results in a substantial increase in vehicle cost that has broad ramifications for the efficacy of the regulation. Even the lower of the values presented in the PRIA overestimates the cost of mild hybrid batteries. A recent report by ANL (Islam et al. 2018a) for the US Department of Energy estimates the battery component cost for a mild hybrid system to be $159.35 (Component Cost, ANL 2017k). In a recent teardown study of the Chevrolet Malibu eAssist with BISG hybrid system (FEV 2014), the total battery subsystem direct costs were estimated to be $166, including thermal management. The battery modules, power distribution, and covers totaled $120 in direct manufacturing costs. These estimates for BISG battery costs from ANL and a teardown study are less than half the costs listed in the PRIA and approximately one quarter of the "BatPaCCost" value given in the ANL input files.

The agencies have not sufficiently explained why their newly presented data differs so substantially, not only from freely available public reports mentioned above, but costs previously presented in studies paid for by NHTSA (NAS 2015[6]) and published by both agencies (Table 5.131, EPA et al. 2016; Table 2.132, EPA 2016a).

B) CYLINDER DEACTIVATION

While the agencies have acknowledged the existence of dynamic cylinder deactivation, they have not appropriately included it as an available technology, dramatically limiting its availability and using

[5] On average, Autonomie modeling in support of NHTSA's analysis for the Draft Technical Assessment Report found that mild hybridization resulted in a 7 to 13 percent improvement over the conventional powertrain, with all but pick-ups in the high end of that range (11 to 13 percent) (ANL 2016 [data]; Moawad et al. 2016 [methodology]).

[6] The ***total*** direct manufacturing cost for the system (Table S.2, NRC 2015) is even lower than the integrated starter generator system's cost ***excluding the battery*** (i.e. only for the non-battery components; Table 6-30, PRIA).

"speculative" (PRIA, p. 232) modeling of the technology without providing any data or documentation in justification. These actions severely constrain the modeled adoption of the technology, an unnecessarily conservative approach which does not reflect the advanced state of technology in the industry.

Dynamic cylinder deactivation (ADEAC) is restricted to naturally aspirated, low-compression ratio engines—it cannot be combined with turbocharged engines, high compression ratio engines, or variable compression ratio engines due to pathway exclusivity in the Volpe model (PRIA, footnote 470). However, the first production application was for a turbocharged engine, ***which the agencies acknowledge***—to be clear, the first ever deployment of this technology ***is excluded as a possibility*** in the agencies' current model.

This restriction is not limited to dynamic cylinder deactivation—conventional cylinder deactivation (DEAC) has been deployed in combination with a high-compression ratio engine (2018 Mazda CX-5; Pleskot 2017), yet in the Volpe model DEAC cannot be combined with high-compression ratio engines (NHTSA 2018b, Table 13).

Modeling of the effectiveness of this technology further ignores real-world deployment. The agencies have simplistically assumed a constant 3 percent improvement for four-cylinder and 6 percent improvement for larger engines, above traditional cylinder deactivation. However, this ignores the complementary effect of dynamic cylinder deactivation, particularly with technologies like 48V systems which General Motors is already deploying this technology in its 2019 full-size pick-ups (Halvorson 2018). When combined with a 48V system, which can act synergistically with the dynamic cylinder deactivation, Delphi claims to achieve as much as a 20 percent reduction in fuel use and emissions (Birch 2017), at a cost roughly half that of other approaches to reducing emissions from conventional powertrains (Beckwith 2017).

C) ADVANCED BOOSTED ENGINES

Turbocharged engines were not deployed as quickly as anticipated by the agencies in the rulemaking for MY 2012-2016 because auto makers were able to utilize cheaper technologies to exceed the rules and build credits for future compliance. However, nearly every major manufacturer has taken steps to incorporate boosted engines into their portfolio as a relatively low-cost option to improve the efficiency of the internal combustion engine going forward. As more manufacturers have moved into this development, a number of new types of advanced boost have made their way into the market, including variable geometry turbochargers (e.g., Porsche Boxster S), electrically assisted turbochargers (or "e-boost", e.g., Audi SQ7), and supercharged engines (e.g., Volvo 2.0L T6 engine), all of which are available today.

Between the 2012 Final Rulemaking (FRM) for MY 2017-2025 vehicles (EPA and NHTSA 2012a) and the 2016 Proposed Determination (EPA 2016a), EPA adjusted its assessment of the advanced turbocharged engine to reflect the use of variable geometry turbocharging, which reflected an improvement to 24-bar engines that may be deployed in the nearer term than the 27-bar boosted engines identified in the FRM. Recent innovations in this space include the dual-volute turbocharger, which was recently ported over from diesel vehicles to the first four-cylinder engine in a full-size pick-up truck, indicating some of the further potential for downsizing (Sherman 2018). However, the agencies have incorporated no advancements beyond twin scroll turbos nor any supercharged engines whatsoever in its proposed rule, despite models from Volvo, Audi, and now GM all hitting the road with these features.

E-boost allows for a more rapid spin-up of the turbocharger, essentially eliminating the "turbo lag" which hinders both performance and efficiency. Suppliers like BorgWarner and Delphi have both developed multistage turbochargers which incorporate e-boost to help provide boost on demand, which improves the overall efficiency of the system by allowing for more "right sizing" of the engine relative to the power demands it will see in the real world. Because e-boost requires a significant amount of power, it is made possible in part by the development of 48V electrical systems, which allows for a synergistic effect that could rival the fuel economy improvements of a conventional hybrid (Kendall 2015).

There are also performance gains which could be made, such as in Valeo's recent demonstration on a Kia Optima (Lee 2017). Based on supplier data, International Council on Clean Transportation (ICCT) has estimated that this improvement could net an additional 5 percent reduction in fuel consumption at a cost of just $338, indicating its strong potential for adoption within the timeframe of the rule (Isenstadt et al. 2016a).

Supercharged engines are also available on the market, but are excluded from the agencies' analysis, again indicating a conservative approach. In some cases, the supercharger is a complement to a turbocharger. With Volvo's Polestar supercharged, turbocharged family of engines, the primary use is for performance; however, it is indicative of the potential for generating significant amounts of power in a very small engine, replacing a V8 with an I4 (e.g., Murphy 2017). Similarly, Eaton's Electrically Assisted Variable Speed (EAVS) supercharger system can be a complementary technology package to 48V mild hybrids. The EAVS supercharger allows for direct control of airflow in the engine without having to rely upon exhaust gas energy, and the National Academies committee identified it as a potential technology excluded from the agencies' 2017-2025 TSD which could be used for downsizing an engine by 50 percent (NAS 2015, p. 63). While the EAVS system is not on the market currently, OEMs are currently testing the technology for possible deployment (Truett 2017).

D) HIGH COMPRESSION RATIO ENGINES

Atkinson- and Miller-cycle engines are available on the market today and represent a cost-effective alternative to the strategy of deploying downsized, boosted engines, but the agencies' approach to date has been conservative in terms of the effectiveness of this technology. The Volpe model ignores advanced high-compression ratio (HCR) engines and limits the adoption of HCR to just the four manufacturers who have already deployed the technology, even though it is an incredibly cost-effective pathway (Section I.B, ICCT 2018).

EPA recently completed hardware testing on the "Advanced Atkinson Tech Package", which increases the compression ratio further and adds both cooled exhaust gas recirculation (CEGR) and cylinder deactivation (DEAC) (Schenk and Dekraker 2017). While the Alliance of Automobile Manufacturers asserted that "EPA's modeled effectiveness values for the ATK2+CEGR+DEAC pathway…are seriously overestimated," hardware testing rebuts this—EPA's data shows up to a 9.5 percent improvement over the baseline configuration of the Atkinson engine for a future vehicle, which taken together with the level of improvement of the Atkinson engine over the "null vehicle" well exceeds the 15 percent level of improvement claimed by the Alliance to be an "overestimate."[7] This is consistent with the range indicated by both the International Council on Clean Transportation (ICCT) (Isenstadt et al. 2016b) and NAS (2015).

While HCR2 was incorporated in previous analyses, the agencies are now claiming that this engine would potentially have durability issues if the engine were operated on Tier 3 fuel (PRIA, p. 302). To support this, the agencies cite a report that does not exist in the docket.[8] Because such information was not provided with the agencies' proposal, we will have to speculate on its assessment. The agencies appear to have relied upon the differences between anti-knock properties of Tier 2 and Tier 3 fuels, mistakenly focusing solely on octane while ignoring ethanol content. As will be described further in Section I.A.1.i), this fails to acknowledge the anti-knock benefit of charge cooling related to ethanol, which more than compensates for the change in octane. HCR2 therefore should not be omitted out of concerns around knock.

EPA's model of an advanced HCR engine is not the only engine which outlines the vast potential capability of high compression ratio engines beyond the baseline HCR technology—the 2018 Toyota Camry far exceeds the base level of HCR technology assumed by the agencies (German 2018). While this engine does not have all of the features of the HCR2 package constructed by EPA, it achieves similar levels of performance, thus rendering the agencies' rationale for excluding HCR2 moot—this is a production vehicle using Tier 3 fuel which achieves performance equivalent to HCR2.

E) NOVEL ENGINE DESIGNS

Moving beyond the high compression ratio SKYACTIV-G platform, Mazda recently announced its SKYACTIV-X engine, which utilizes a combination of compression ignition and spark ignition to improve engine efficiency by 20 to 30 percent over the current generation of SKYACTIV-G engines, with volumetric fuel efficiency matching that of their diesel engines (Mazda 2017). In another bold step beyond conventional engine platforms, Achates Power is testing its 2.7L opposed-piston diesel engine in an F-150, which it claims can both meet Tier 3 emissions standards and would achieve a 2-cycle test fuel economy of 37 mpg, about 10 percent higher than the level needed for fuel economy standards in 2025 (Brooke 2017). These and other developments speak to the ability for manufacturers to push conventional vehicles even further than anticipated.

While agencies have conservatively estimated high compression ratio engines, they have not incorporated variable compression ratios at all—the technology was not modeled, nor was it incorporated into the Volpe model underpinning the proposal. Currently, Nissan's VC-Turbo engine, found in both the 2019 Infiniti QX50 and 2020 Nissan Sentra, can vary the compression ratio of the engine (from 8:1 to 14:1) and can run under both Atkinson and Otto cycles, essentially allowing tuning of

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[7] The Alliance cites a 15 percent effectiveness relative to the "null vehicle," while the EPA study compares HCR1 to HCR2, indicating a 9.5 percent improvement from HCR1 to HCR2. HCR1 itself showed an improvement of about 9 percent in each vehicle class over the null vehicle (EPA 2016b), indicating that together these technologies well exceed the 15 percent threshold cited as "overestimated."

[8] PRIA, fn. 244: "IAV advanced engine modeling phase 3 test data comparison of cEGR and different combustion stability. Report submitted to docket." As of October 24, 2018, no such document has been uploaded to either agency docket.

the right mode of operation for the precise set of load conditions (Nissan 2017). Paired with a turbocharger to provide increased performance under high load, similar to a boosted and downsized engine, the VC-Turbo is part of a strategy to improve fuel efficiency by 30-35 percent over the previous model, enough for this luxury vehicle to exceed its regulatory targets without any credits. Given that this is being put in production in a high-volume vehicle, there is no reason for the agencies to exclude its adoption.

F) BATTERIES FOR HYBRID AND PLUG-IN ELECTRIC VEHICLES

The choice of materials for hybrid and electric vehicle battery cathodes and anodes (or “battery chemistry”) can have a large impact on performance and materials cost and therefore impact the modeled cost of drivetrain electrification (Vaalma et al. 2018). The choice of battery chemistries in the proposed rule contains internal inconsistencies, does not reflect current industry practice, and does not use the most recent model data (despite references to the contrary).

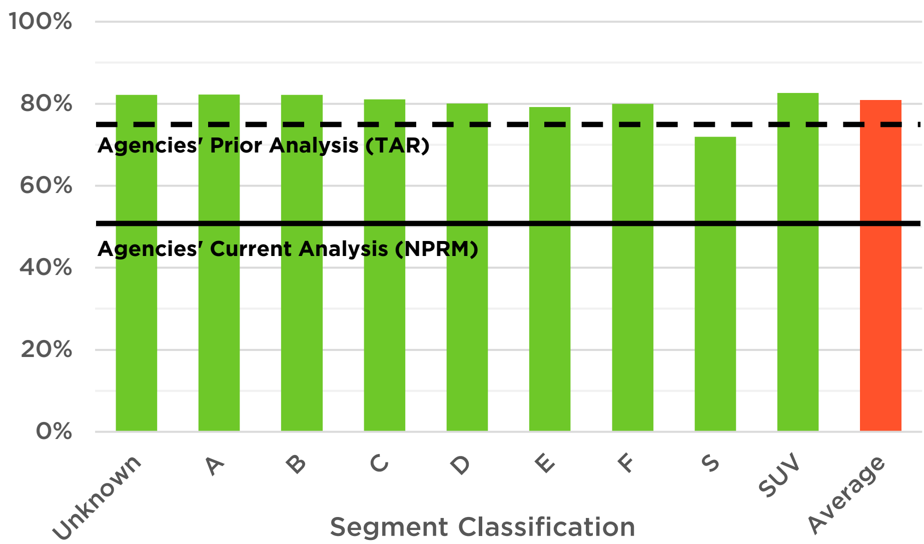
The choice of battery chemistry modeled in the proposed rule is unclear. In the PRIA (p. 368), plug-in hybrid electric vehicles (PHEV) and battery electric vehicles (BEV) are listed as using the NMC441-Gr chemistry. In the detailed description of the modeling, PHEV and BEV are listed as using NMC333-Gr chemistry (p. 210, Islam et al. 2018b). However, the rulemaking also states that the most recent version of ANL’s BatPaC model was used to estimate battery costs. The default lithium ion chemistry in the current BatPaC model is NMC622 (ANL 2018). The choice of NMC variant effects battery costs, as NMC622 replaces more expensive cobalt with nickel. Because the underlying BatPaC calculations are not available, and due to the inconsistency between the PRIA and ANL supporting information, it is not possible to determine the magnitude of the cost error in the PHEV and BEV battery pack costs, only that the costs are likely higher than current battery cost data supports. Previous requests for clarity in this matter have gone unfulfilled (Peter 2018).

The chemistry chosen for mild and strong hybrids also differs from those used in current and announced hybrids. All non-plug-in hybrids in the proposed rule analysis use lithium iron phosphate (LFP) chemistry. In practice, most hybrids on the road do not use this chemistry. The most prevalent strong hybrid, the Toyota Prius, does not use the LFP chemistry. Mild hybrids, like the new Ram 1500 pickup are also not using LFP chemistry (FCA 2018). The cost of strong hybrid batteries as modeled in this proposed rulemaking are greater than $1,200, even for the most efficient small car class, while an estimate from ANL in 2017 estimated current power-split hybrid battery pack costs at $614 (2017k). Because of the lack of detailed information on the battery cost modeling, it is not possible to determine if the choice of battery chemistry is responsible for this discrepancy, but what is clear is that there are serious concerns about the methods and results for battery costs.

G) MASS REDUCTION

There are a whole host of problems with the way in which the agencies have considered mass reduction, which we describe below. Many of these issues stem from a change regarding the fraction of the vehicle assumed to be the “glider” vehicle, which the agencies do not even attempt to justify yet has a profound effect on safety and technological feasibility.

FIGURE 1. Glider weight as a function of curb weight, for over 600 production vehicles



The share of a vehicle's curb weight assigned to the "glider" is shown to be greater than the agencies' current analysis for all vehicle segments. In fact, it is shown to be even greater than previous analyses for all segments except for S (Sport), for which lightweight materials are frequently already deployed—and even that class is only a marginally lower fraction (72 percent, compared to 75 percent in prior analyses).

Note: Glider is defined here as everything but the engine, transmission, clutch, cooling system, and fuel system.
SOURCE: A2MAC1 2018

(1) ***The agencies assumption that mass reduction can only be applied to 50 percent of the curb weight is unjustified and inaccurate***

In the NPRM, the agencies have determined that the "glider" of a vehicle, which is essentially everything minus the powertrain,[9] accounts for only 50 percent of the vehicle's curb weight. This is a substantial change from prior analyses, when the glider was assumed to represent 75 percent of the vehicle's curb weight, and this change is not justified by the agencies in any way.[10]

Incredibly, the agencies' own analysis in the NPRM disagrees with this fraction. The agencies base their analysis of the costs for lightweighting on two studies, one passenger car (2011 Honda Accord) and one light truck (2014 Chevrolet Silverado)—these studies themselves show the glider making up 79 percent of the vehicle in the case of the Accord (PRIA p. 393), and 73.6 percent of the curb weight for the Silverado (PRIA p. 399). Both of those percentages are substantially higher than 50 percent and essentially in line with the agencies' prior analyses.

This assumption also disagrees with industry data, which shows that not only does the glider represent a more significant share of the curb weight than assumed by the agencies in this analysis, but it even exceeds the share of curb weight assumed in prior analyses (Figure XXX). It should be noted that for its

[9] Formally, NHTSA's definition of the glider is everything but the engine, transmission, thermal systems, and some safety components.
[10] The change is acknowledged on p. 417 of the PRIA, but there is literally no documented explanation given for it.

own study of mass reduction, NHTSA had access to this database (PRIA Section 6.3.10.1.16)—it is therefore impossible to imagine that the agencies were unaware of such data and have instead arbitrarily and capriciously chosen to ignore it in order to assert a more conservative conclusion.

(2) *Reducing the glider fraction inaccurately limits the potential and applicability of mass reduction*

Representing the glider as a reduced fraction of the curb weight causes the agencies to significantly underestimate the potential for mass reduction. Because mass reduction is applied at the glider level, reducing the share of the glider inherently caps the potential reduction in the curb weight—this single change has cut the potential improvement from mass reduction by one-third (PRIA Table 6-57).

Previous agency analysis as well as analysis from independent organizations including CARB, the National Academies, and industry consultants has placed the total potential for mass reduction by 2025 at between 15.8 and 32 percent overall reduction in curb weight (Caffrey et al. 2013, Caffrey et al. 2015, Lotus 2012, NAS 2015, Singh et al. 2012, Singh et al. 2016, Singh et al. 2018,). In contrast, the NPRM claims a maximum reduction of 10 percent, well below not just the maximum potential identified, but even the lowest maximum potential identified by papers cited in agency analysis.

The agencies' assessment of the maximum achievable mass reduction is so low that the Ford F-150 was able to exceed that in 2015 through the deployment of aluminum alone, and a number of the vehicles identified by the agencies' as meeting its highest level of mass reduction in MY2016 (PRIA Table 6-58) have deployed little, if any, lightweight material (e.g., Nissan Versa, Kia Soul, Honda Civic). This is in stark contrast to the agencies' discussion of the maximum potential for lightweight materials (e.g., PRIA Sections 6.3.10.1.1.2 and 6.3.10.1.1.3.3)

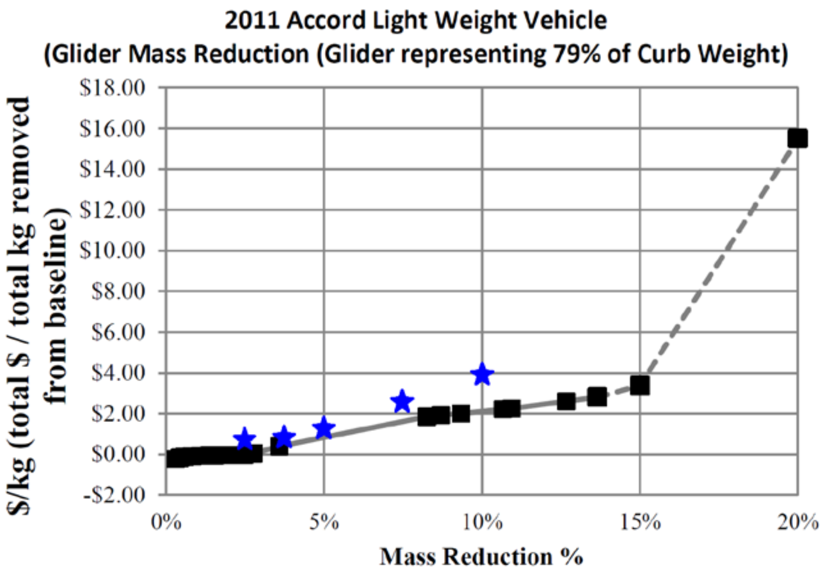
The impact of this is twofold: 1) as noted in Section I.A.1.j), increasing the fraction of vehicles in the baseline fleet which have already applied mass reduction significantly diminishes the future potential for the vehicle fleet; and 2) by capping the total potential for mass reduction at such a low level, much lower than in any previous analysis, it artificially reduces the potential for this cost-effective technology and therefore increases the required use of more expensive and advanced technologies.

(3) *The agencies have inflated the costs of mass reduction, per their own analysis*

The agencies have based the costs for mass reduction on glider weight reduction; however, the need for more expensive materials and more advanced engineering and design strategies only results from the need for greater levels of absolute mass reduction on the vehicle. In effect, these costs have been derived from the assumption of reductions as great as 16.8 percent reduction in curb weight in the case of the Silverado (Singh et al. 2018) and as great as 18 percent reduction in curb weight in the case of the Honda Accord (Singh et al. 2016), but they have been applied to curb weight reductions approximately two-thirds that magnitude. This is completely invalid and significantly overstates the costs for mass reduction.

This is clearly demonstrable by examining the actual reports relied upon by the agencies, both of which refer to direct manufacturing costs as a function of curb vehicle weight, not just glider weight. The procedure the agencies have used to generate cost data is like arbitrarily scaling the ***x***-axis by a factor of 1.5, yielding the same costs at two-thirds the amount of mass reduction. In fact, in the case of the

FIGURE 2. Agency manufacturing costs for mass reduction of cars, compared to source



The agencies' costs for mass reduction (blue stars) are in direct conflict with the data cited as a source for those costs (black squares) because the agencies have improperly normalized them to different glider mass shares. This leads to costs for the highest levels of mass reduction that are nearly twice as large as those the agencies claim result from the source data.

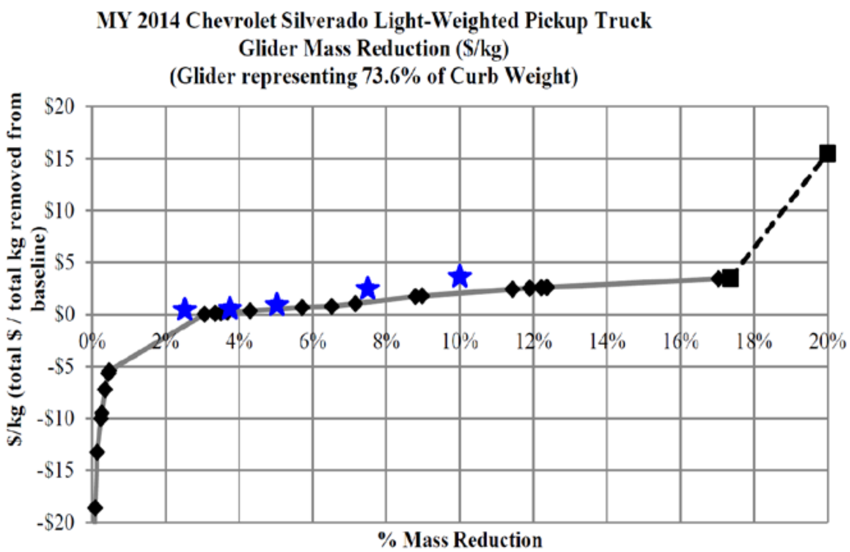
Note: Table 6-39 data is divided by 1.5 to account for the retail price equivalent (RPE) used by the agencies.
SOURCE: PRIA FIGURE 6-160, TABLE 6-39

Silverado, the agencies' study shows costs that are ***less than one-quarter the cost*** if one were to limit the total mass reduction to 10 percent as the agencies have done.[11] This is even evident in the data as presented by the agencies in PRIA Figures 6-161 and 6-163, which do not agree at all with the supposedly identical data in PRIA Tables 6-38 and 6-41, respectively (Figures 2 and 3).

It is also worth noting that while the agencies have listed a large number of studies that have examined the costs of and potential for the deployment of lightweight materials (PRIA Table 6-43), the entire cost basis for the agencies' analysis is in just two studies commissioned by NHTSA. While the agencies claim that "those studies often did not consider many important factors or…made unrealistic assumptions about key vehicle systems," the agencies have not specifically identified these factors or assumptions that should merit disregarding a much broader suite of evidence in assessing the costs of this technology. Moreover, these peer-reviewed studies were included previously in agency analysis as part

[11] Section 10.10 in Singh et al. 2018 notes the potential for up to 10.5 percent mass reductions in vehicle mass at a premium of $0.83 per kg as compared to $3.48 per kg for up to 16.8 percent; it is the latter value on which the agencies have relied to calculate the costs for mass reduction. For even further clarity, we can compare the value "derived from light truck light-weighting study" with the actual values in the study—PRIA Table 6-41 lists an estimated direct manufacturing cost of $3.09 per kg for a percentage mass reduction of 11.0 percent, leading to a total cost of $829.67, while the actual report shows a manufacturing cost increase of $0.83 per kg for a percentage curb weight reduction of 10.5 percent for a total cost of $212.

FIGURE 3. Agency manufacturing costs for mass reduction of trucks, compared to source



The agencies' costs for mass reduction (blue stars) are in direct conflict with the data cited as a source for those costs (black squares) because the agencies have improperly normalized them to different glider mass shares. This leads to costs for the highest levels of mass reduction that are approximately 70 percent larger than those the agencies claim result from the source data.

Note: Table 6-42 data is divided by 1.5 to account for the retail price equivalent (RPE) used by the agencies.
SOURCE: PRIA FIGURE 6-163, TABLE 6-42

of the record when deriving previous estimates for the costs of mass reduction (Section 2.2.7.4, EPA 2016a; Section 5.2.7.4.1, EPA et al. 2016).

(4) Assessing the impact of the agencies' inaccurate characterization of mass reduction

Because mass reduction is one of the most cost-effective strategies for reducing fuel use and greenhouse gas emissions from the fleet, any limits on or inaccuracies in the effectiveness of this technology can have a significant effect on the modeling results. Here, we attempt to quantify the modeling impact of a shift from prior agency assumption of a 75 percent glider share downwards to 50 percent.

The Autonomie model results used as inputs to the Volpe model were based on the application of each level of mass reduction technology (MR1, MR2, etc.) to a glider share of 50 percent. Therefore, it is necessary to revise these values to reflect an increased level of curb weight reduction for each MR level. Reductions in fuel use as a function of mass reduction have a generally linear response, making it fairly straightforward to extrapolate the results from ANL to different levels of curb weight reduction. In Figure 4, we illustrate the average fuel consumption improvement for packages compared to the "null vehicle" as a function of mass reduction. While there is a notable "kink" in the data around 5 percent, this is the direct result of the agencies' determination not to hold performance constant for low levels of mass reduction, meaning that a significant share of the benefit of a few percent reduction in mass has gone towards improved performance rather than improved fuel economy, leaving a substantial

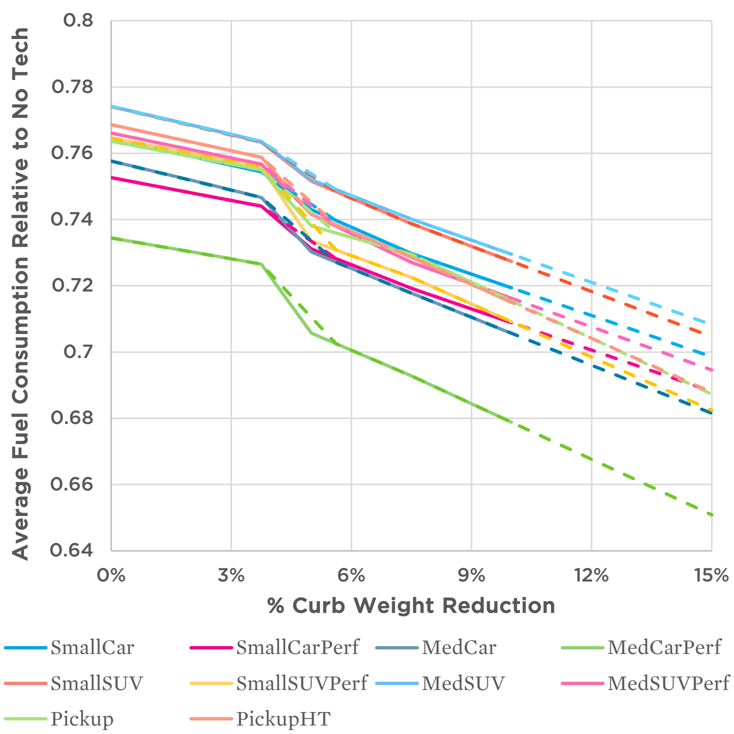
TABLE 1. Curb weight reduction for different shares of curb weight assigned to the glider

Tech	Glider mass reduction %	Agency defined		Adjusted	
		Glider share	Curb Weight Reduction	Glider Share	Curb Weight Reduction
MR0	0%	50%	0.000%	75%	0.000%
MR1	5%	50%	2.500%	75%	3.750%
MR2	7.5%	50%	3.750%	75%	5.625%
MR3	10%	50%	5.000%	75%	7.500%
MR4	15%	50%	7.500%	75%	11.250%
MR5	20%	50%	10.000%	75%	15.000%

Consideration of a glider share of 75 percent enables a 50 percent greater potential in curb weight reduction, up to 15 percent from just 10 percent for the highest level of technology applied in the Volpe model.

SOURCE: PRIA TABLES 6-39/6-42, AND UCS ANALYSIS

FIGURE 4. Fuel consumption relative to the "null vehicle," as a function of curb weight reduction



Fuel consumption modeled with Autonomie for different vehicle classes is strongly linear (solid lines), allowing for clear interpolation and extrapolation of the data (dashed lines). Mass reduction less than 5 percent total curb weight reduction resulted in significantly greater fuel consumption than might be expected from that modeled at higher levels of mass reduction due to a lack of performance neutrality.

SOURCE: SOLID LINES DERIVED FROM FC1_IMPROVEMENTS, NHTSA 2018A; DASHED LINES ARE UCS ANALYSIS

TABLE 2. Costs for compliance with current greenhouse gas standards, in MY2028, by manufacturer, after correcting for increased glider share of curb weight

Manufacturer	NPRM	Corrected	Diff	% Diff
BMW	$ 4,265	$ 4,055	$ (210)	-5 %
Fiat-Chrysler	$ 4,096	$ 3,532	$ (563)	-14 %
Ford	$ 3,437	$ 2,948	$ (490)	-14 %
General Motors	$ 3,151	$ 2,752	$ (399)	-13 %
Honda	$ 1,851	$ 1,529	$ (322)	-17 %
Hyundai	$ 1,201	$ 1,152	$ (48)	-4 %
Jaguar Land Rover	$ 4,994	$ 5,569	$ 575	12 %
Kia	$ 1,755	$ 1,644	$ (110)	-6 %
Mazda	$ 2,691	$ 2,147	$ (544)	-20 %
Mercedes	$ 4,485	$ 4,307	$ (178)	-4 %
Nissan-Mitsubishi	$ 1,141	$ 1,113	$ (28)	-2 %
Subaru	$ 1,247	$ 1,299	$ 52	4 %
Tesla	$ 4	$ 4	$ 0	3 %
Toyota	$ 2,235	$ 1,973	$ (262)	-12 %
Volkswagen	$ 5,004	$ 4,380	$ (623)	-12 %
Volvo	$ 3,538	$ 3,167	$ (371)	-10 %
INDUSTRY TOTAL	**$ 2,785**	**$ 2,477**	**$ (309)**	**-11 %**

Adjusting the mass reduction technologies to accurately reflect higher, more appropriate share of curb weight available for mass reduction results in substantially reduced costs for nearly every single manufacturer. as well as the industry as a whole.

Note: The substantial increase in cost for Jaguar Land Rover is the result of a correction to the baseline levels of mass reduction. The levels of mass reduction assumed for the Jaguar XJ platform in the NPRM baseline market data did not correspond to PRIA Table 6-58. We corrected this discrepancy, which thus reduced the availability for future mass reduction from jaguar land rover's fleet of vehicles, increasing cost for that specific manufacturer.

benefit of mass reduction underutilized and/or uncounted. For our correction, we have not altered this assumption.

While only the average data is shown in Figure 4 for simplicity, we have considered and modified every single package for every single modeled vehicle, interpolating/extrapolating the results according to the improvement relative to an equivalent package with 0 mass reduction (e.g., ";;;;;TURBO2;AT9;BISG;ROLL0;MR3;AERO0" vs. ";;;;;TURBO2;AT9;BISG;ROLL0;MR0;AERO0"). It should be noted that no interpolation was necessary for the adjusted MR1 and MR3 results, which correspond exactly to the agencies' MR2 and MR4 values.

In addition to adjusting the FC1_Improvements.csv file input into the Volpe model, it is also necessary to edit both the technology file and market data file (NHTSA 2018d). In the case of the technology file, we have simply corrected the glider share in the Parameters tab to reflect 0.75 (instead of 0.5), so that the costs for mass reduction are applied to an appropriate level of reduced mass. In the case of the market data file, we have had to correct the baseline vehicles who've "USED" a given level of mass reduction—these were adjusted based on the levels of mass reduction for each platform in PRIA Table 6-58. No adjustment to technology costs were necessary because, as was explained in Section I.A.1.g)(3), these costs already correspond to the adjusted technology levels detailed in Table 1.

Using the Volpe model provided in the NPRM with these updated datafiles yields a reduction in the average costs of compliance in MY2028 of about $300 (Table 2).

H) HIGH OCTANE FUEL

The agencies request comment on the impact of high-octane blends (83 FR 43041). While we agree there are exciting potential efficiency improvements associated with higher octane gasoline, particularly for high compression turbocharged cars (DOE 2017, Leone ***et al.*** 2015, Speth ***et al.*** 2014), it is premature to consider high octane fuels in this round of rulemaking.

An orderly transition to high-octane fuel would take several years to complete. It will take time for the necessary regulations to be finalized, for vehicles optimized for high-octane gasoline to come to market and to build out the fuel distribution infrastructure to make this fuel broadly available. And even once high-octane gasoline is in use, it will take more time for automakers to phase-in new models optimized for high-octane fuel and to fully replace the legacy E10 fleet. Another factor to consider is that the rising share of high-octane gasoline will be buffered by falling sales of gasoline, given increasing fuel efficiency, such that the overall demand for ethanol will change more slowly. Our expectation is that high-octane gasoline will not significantly enter commerce before 2026, and subsequently will only gradually gain market share through 2040.[12] There is no realistic prospect of completing this process before 2025 or 2026, the timeframe of this rulemaking. The appropriate context for this discussion within vehicle rules is the next round of fuel economy and emission standards. Even then, an expeditious rulemaking process will be required to achieve adequate regulatory clarity to facilitate rapid adoption post-2026.

We strongly oppose granting fuel economy credits based on the technical potential of vehicles to operate on high-octane fuel before there is clear evidence that high-octane fuel is in use and the potential fuel economy benefits are being realized on the road. The history of the CAFE flex-fuel vehicle (FFV) program provides clear evidence that credits given based on unrealized potential and in advance of adequate fuel distribution infrastructure are counterproductive. Recent analysis demonstrates that the FFV program actually increased gasoline consumption and emissions (Jenn, Azevedo, and Michalek 2016) without substantially increasing the use of alternative fuels. In its 2016 final Renewable Fuel Standard Program: Standards for 2017, EPA found that, despite the fact that 21 million FFVs on the road had the technical capacity to use up to 13 billion gallons of E85, only 275 million gallons of E85, or 2% of the potential, were likely to be used (EPA 2016c).

To determine the public costs and benefits of a high-octane gasoline program requires an examination of not only vehicle policy, but fuel policy as well. A transition of the light duty vehicle fleet to a higher

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[12] However, these qualitative expectations need to be quantified and subject to public review before such significant changes are used as the basis for revised fuel economy standards.

ethanol blend has obvious implications for the quantity of ethanol consumed in the United States. However, the implications are far more complex than simply increasing the use of ethanol by 150% compared to the ethanol blended into E10 today. A rapid expansion of fuel ethanol use that is supplied primarily by corn ethanol could have negative impacts on other users of corn as well as land use change impacts, water pollution and other problems, as occurred during the rapid transition to E10 between 2005 and 2010 (Martin 2016). We recommend a more predictable and gradual phase-in, which would allow for the parallel growth of lower carbon cellulosic ethanol sources and could supply increasing quantities of ethanol without the associated negative impacts.

I) AGENCIES HAVE INCORRECTLY ADJUSTED FOR A SWITCH FROM TIER 2 TO TIER 3 GASOLINE

The modeling packages have been improperly adjusted to reflect behavior related to differences between Tier 2 and Tier 3 fuels, primarily resulting from the lack of recognition in fuel properties.

(1) Adjustment related to energy content instead of carbon content

The agencies cite concerns from the Alliance of Automobile Manufacturers regarding a discrepancy between the Tier 2 fuel used for testing and the Tier 3 fuel to which manufacturers will be required to test and which is more reflective of the fuel used in the marketplace. Little information is available on precisely how the model handles the difference between Tier 2 and Tier 3 fuel. There are just two sentences in the PRIA describing what was done: “An adjustment factor was applied to the Autonomie simulation results to adjust them to reflect Tier 2 certification fuel. ANL adjusted the vehicle fuel economy results to represent certification fuel by using the ratio of the lower heating values of the test and certification fuels” (p. 257).

This adjustment factor completely ignores a detailed study by EPA on exactly this question, which found that while fuel consumption increases with the switch from Tier 2 to Tier 3 fuel, emissions are reduced (EPA 2018c). In fact, not only does the adjustment factor applied by Autonomie exaggerate the switch (converting solely with energy density would assume a 3.7 percent increase in fuel consumption compared to the observed 2.7 percent increase), but it actually goes ***in the wrong direction*** when applied to greenhouse gas emissions, which show a reduction of 1.4 percent on the test cycle as a result of the fuel switch.[13] As a result, Autonomie’s model is overstating greenhouse gas emissions on Tier 3 fuel ***by 4.2 percent***.

This issue underscores a key problem with the approach taken when it comes to a switch to Tier 3 fuel—the agencies are trying to account for it in the modeling data while ignoring its impacts in the certification tests, and therefore measurements of compliance. This effectively double counts any penalty in fuel economy (the rules are reduced by the factor because the modeling incurs the penalty, but then the measurements to comply with those are corrected to account for the switch, boosting the test value by exactly this penalty) and ignores the beneficial impact of CO_2 reductions at the tailpipe, which will result in an improvement on the test cycle.

Just two vehicles in the MY2016 test car database were certified using Tier 3 fuel (EPA 2017c), amounting to less than 1 percent of the market, so the impacts of this fuel switch moving forward will

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[13] To obtain the test cycle improvement, we have simply weighted the changes in the FTP and HWFET fuel consumption and emissions observed in EPA 2018cc by the 55/45 ratio used for the regulatory tests.

play a significant role in future emissions profiles. The CAFE test procedure already has an adjustment in place for fuel properties relative to the 1975 test fuel (40 CFR § 600.113-12(h)(1))—however, carbon-related exhaust emissions (CREE) do not have a similar corrective factor (40 CFR § 600.113-12(h)(2)), which means this fuel switch could play a significant role in reducing compliance if it is taken into account appropriately…or lead to drastically conservative fuel economy and greenhouse gas emissions curves if it is not.

(2) Adjustment related to knock threshold

The agencies have incorrectly modified the engine maps developed on Tier 2 fuel (83 FR 43036). In the discussion in the PRIA, they focus primarily on a single fuel property, octane (PRIA Section 6.3.2.2.17.4). However, of equal importance in the difference between Tier 2 and Tier 3 fuels are the unique properties of ethanol, including charge cooling. Unfortunately, the effect of charge cooling cannot be directly determined from the standard test of Research Octane Number (RON) ([Foong, et al. 2013]), and therefore it is inherently excluded from the agencies' discussion because of their singular focus on octane. Data on different fuel blends of ethanol shows that charge cooling can have a tremendous impact to reduce knock in direct injection engines—precisely the engines which the agencies have modified—resulting in an "effective octane" difference of +6 for E10,[14] thus potentially compensating for the difference in octane between Tier 2 (E0 93 AKI) and Tier 3 (E10 87 AKI) fuels (Kasseris and Heywood 2012). In fact, this is borne out in experiments comparing E0 91 and E10 87 fuels, where E10 87 actually exhibits *lower* knock intensity at high load, exactly where the agencies are claiming the fuel switch would have an adverse effect (Joshi 2017).

This error affects the efficiency of virtually ***all*** advanced engines—it was used to preclude the use of HCR2 (PRIA Section 6.3.2.2.20.18) as well as reduce the effectiveness of all turbocharged engines and engines with cooled EGR (PRIA, Figures 6-84, 6-89, 6-94). Without an A/B analysis, it is impossible to judge the severity of this error. However, at the very least the agencies should not exclude the HCR2 technology on such basis, and according to their own analysis, this correction alone would result in a reduction in MY2029 costs in the Baseline Standards of $700-$850 (PRIA Table 13-4), or about ***one-third*** of the difference in cost between the Baseline and Proposed Standards. Correcting the effectiveness of the affected engines would only further reduce costs—clearly this error has a significant impact on the ability for manufacturers to comply with future standards and should be corrected in future modeling efforts.

It should also be noted that there are a number of different strategies manufacturers can use when considering approaches to different fuels, and not all of them necessitate reductions in efficiency as the agencies ***a priori*** assumption suggests. The agencies even point out one such unique knock-reduction strategy for the 2014 SkyActiv-G on which their HCR data is based (PRIA Figure 6-43). An additional example of how engines can be reoptimized without suffering a penalty for using a lower octane fuel is in the spark-assisted compression ignition engine developed by Mazda—the managing executive in charge of powertrain and vehicle development and product planning even noted that "as a matter of fact actually, 91 RON give you better performance than 95 RON" (Mathioudakis 2017). This remark was consistent with the preliminary torque curves for the SkyActiv-X spark-assisted compression ignition

[14] E10 refers to gasoline with 10 percent ethanol. E0 refers to gasoline with 0 percent ethanol.

engine, a technology that the agencies have completely neglected despite it coming to production next year in a mass market vehicle (Mazda 2017).

J) ARBITRARY CHANGES IN THE WAY THE AGENCIES ASSESSED BASELINE TECHNOLOGY DEPLOYMENT OVERSTATES THE TECHNOLOGY ALREADY PRESENT IN THE FLEET

One of the major confounding aspects of the agencies' analysis is how much more advanced technologies appear to be required to comply with the 2025 regulations than in any previous analysis. This goes against all prior data from the agencies, which has shown that manufacturers have been able to comply with less technology than anticipated, at reduced costs, and with new technologies being developed constantly (e.g., EPA et al. 2016).

One reason the modeling in the NPRM erroneously requires greater technology adoption is that NHTSA technical staff have reassessed baseline technology improvements, claiming that many vehicles throughout the fleet already have more advanced technology than had been previously determined (e.g., PRIA Figures 6-168, 6-175, and 6-177). By attributing the baseline levels of fuel economy and greenhouse gas emissions to greater application of technology, agency staff are "baking in" those performance improvements related to the more cost-effective technologies, thus requiring the addition of less cost-effective technologies to compensate.

Because the previous version of the Volpe model used a MY2015 baseline, and the version supporting the NPRM uses a MY2016 baseline, there is some expectation of improved technologies—approximately 15 percent of the fleet will have been redesigned between the two model years, and there will also be discrepancies related to specific marketshare changes. However, there is much greater disparity between the two years than can be expected due to year-over-year sales shifts and product cycles.

While powertrain technologies generally have much clearer distinctions on marketshare and are therefore fairly objective to assess, marketshare of vehicle accessory and road-load reduction technologies are often highly subjective. And it is precisely these classes of technology which exhibit abnormal year-over-year deviations (Table AAA).

(1) Assessing the impact of this subjective analysis

It is difficult to quantify the exact impact this reassessment has on the modeled fleet because the incremental effectiveness of a technology is generally dependent upon the other technologies available on the vehicle. However, as a reasonable assessment, we can use the range of impacts used by the National Academies in its latest analysis (NRC 2015).

Table AAA lists the differences between the two baseline scenarios. This difference is then multiplied by the range of potential impacts identified in the National Academies study. These impacts are then aggregated using a multiplicative approach that takes into account the reductions from the other technologies.[15]

[15] Fuel consumption reduction $\boldsymbol{FCR}_{\mathrm{TOTAL}} = 1 - \prod(1 - FCR_i)$.

TABLE 3. Comparison of MY2015 and MY2016 baseline technology data from the Volpe model, including estimated impact of this additional assessment of technology.

				Cumulative NRC Impacts	
Technology	**2015 Baseline%**	**2016 Baseline%**	**Difference**	**Low**	**High**
Electronic Power Steering	38.5%	88.8%	+50.3%	0.4%	0.7%
Improved Accessories	0.0%	20.0%	+20.0%	0.2%	0.3%
Low-drag Brakes	0.0%	13.3%	+13.3%	0.1%	0.1%
Secondary Axle Disconnect	15.4%	5.4%	-9.9%	-0.3%	-0.1%
Rolling Resistance &&					
10%	0.0%	18.9%	+18.9%	0.4%	0.4%
20%	0.0%	27.1%	+27.1%	1.0%	1.0%
Mass Reduction **					
Level 2	9.6%	7.5%	-2.1%	-0.0%	-0.0%
Level 3	8.6%	9.0%	+2.4%	0.0%	0.0%
Level 4	8.2%	4.6%	-3.5%	-0.2%	-0.2%
Level 5	0.2%	7.7%	+7.5%	0.5%	0.7%
Aero Drag Reduction &&					
10%	5.7%	20.9%	15.2%	0.3%	0.3%
20%	1.8%	1.2%	-0.7%	-0.0%	-0.0%
CVT					
Level 1	20.4%	10.2%	-10.1%		
Level 2	0.0%	12.1%	+12.1%	0.4%	0.4%
			Total Shift in "Reassessed" Tech:	**3.1%**	**3.9%**

A comparison of the MY2015 and MY2016 baseline assessments indicates that NHTSA has significantly altered its criteria for assessing vehicle technologies, and that in doing so they have eliminated approximately 3.1 to 3.9 percent of improvement from the vehicle fleet. Such a level of improvement is comparable to the annual rate of performance improvement required under the fuel economy and emissions program, but data shows that there was no improvement whatsoever in the CAFE performance of the MY2016 fleet compared to the MY2015 fleet.

Note:

&& In the Draft TAR, rolling resistance and aerodynamic drag technologies were limited to 10 and 20 percent improvement levels. In the NPRM, those have been further refined to 5 percent increments. However, for consistency, we round down (e.g., AERO15 is considered as compared to the AERO10 bin from the Draft TAR).

** Mass reduction has been reclassified in error as applied to just 50 percent of the vehicle, whereas previous classification estimated the glider weight to be 75 percent of the weight of the vehicle. Because of this, what was previously classified as MR1, which would result in 3.75 percent curb weight reduction, is now classified as MR2 in the NPRM. Similarly, MR3 is now classified as MR4. MR1 roughly corresponds to MR2 (5.625 percent compared to 5 percent), and MR4 approximately corresponds to MR5 (11.25 percent compared to 10 percent). The MR1 category in the NPRM is below the resolution previously considered, so therefore is excluded from this table.

This data indicates that an additional 3.1 to 3.9 percent of technology improvement was incorporated into the MY2016 baseline fleet compared to MY2015, even though there was ZERO change in the fleet CAFE performance (32.2 mpg in both MY2015 and MY2016, NHTSA 2018e). For comparison, the average annual fuel consumption reduction required by the 2017-2021 final and 2022-2025 augural fuel economy standards is 3.5 percent for trucks and 4.3 percent for passenger cars. This "engineering judgment" is comparable to manufacturers placing on one year's worth of technology improvements with absolutely nothing to show for it.

K) AGENCIES HAVE UNDERESTIMATED THE POTENTIAL FOR FUTURE INNOVATION

Generally, agencies have tended to overestimate the total costs of regulations (Carey 2016, pp. 12-13; Harrington ***et al.*** 1999). With regards to the Clean Air Act and the automotive industry in particular, automakers have shown an even worse track record, vastly overestimating the costs of compliance (Hwang and Peak 2016). As illustrated earlier in our comments on the agencies' proposal, this propensity for overestimation has continued—our analysis shows clearly that the costs for compliance are lower than originally anticipated by the regulators.

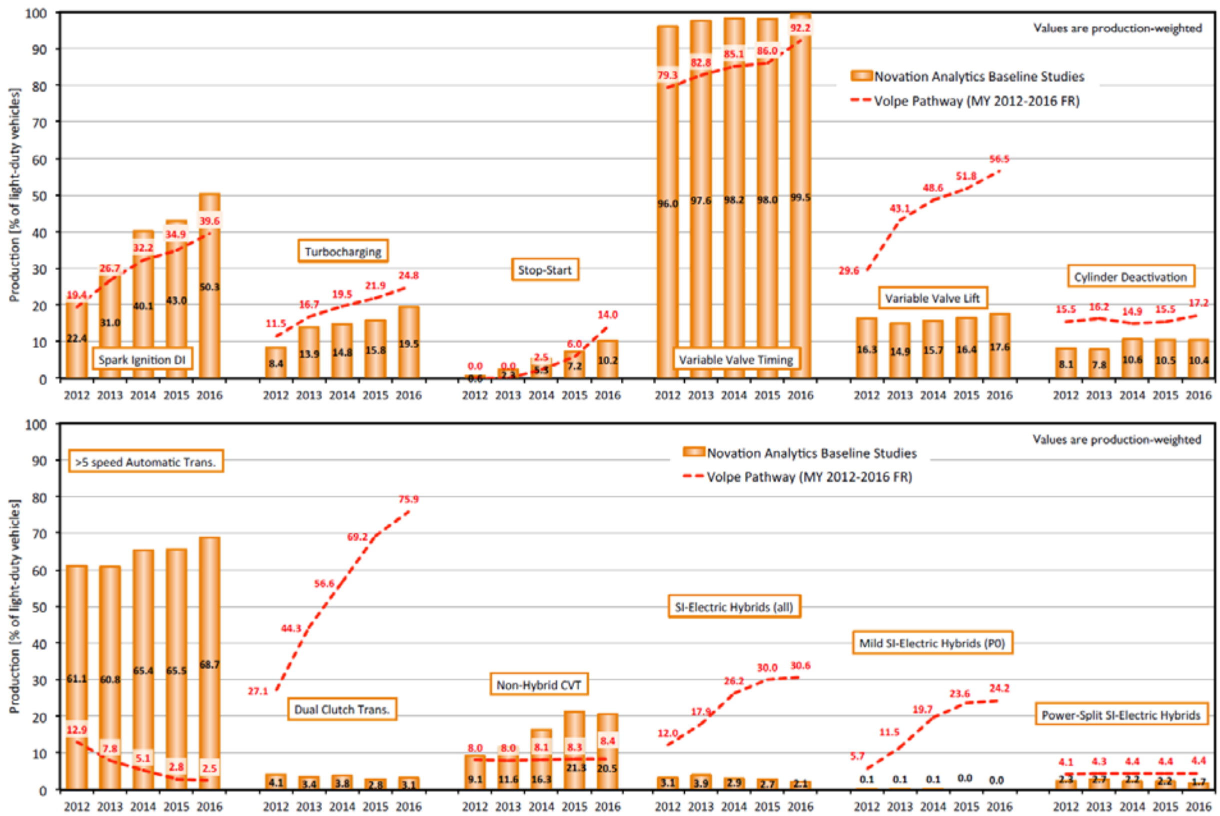
One way of illustrating the effect of innovation is to compare technology adoption to the pathways originally envisioned by the regulators. The pathways illustrated by the OMEGA and Volpe model represent particular low-cost analysis by EPA and NHTSA, respectively, resting almost entirely on the assumption that a rational manufacturer would choose the lowest-cost pathway to comply with the regulation. However, manufacturers may not necessarily choose this pathway, for a number of other constraints of which the agency could not possibly be aware, e.g., segment-specific strategies centered around a manufacturer's specific target markets, including global production. In fact, trying to impose some of these constraints designed to anticipate a manufacturer's mindset can lead to overly conservative analysis, as it will inevitably miss unforeseen technology developments.

Industry has repeatedly erred in its analysis of this historical look at whether the pathways projected by either the OMEGA or Volpe models have come true (e.g., Novation Analytics 2016). Mistakenly, the authors of the Novation Analysis consider the agencies' technology deployment rates as "over optimistic"; in truth, the data indicates that the agencies' technology assumptions were ***conservative.*** It is clear from Figure 5 that the agencies' pathways[16] differ from actual technology deployed in a number of significant ways:

- ***Cylinder control—***The Volpe model pathways projected that a higher penetration of both variable valve lift and cylinder deactivation would be needed for compliance; however, much lower penetrations of these technologies exist in the marketplace. The reason for this is simple—these technologies represent incremental steps up the cost ladder, and because manufacturers have been able to wring more out of the simpler, and cheaper, variable valve timing approach to cylinder control, ***less*** technology deployment was needed. This is representative of innovation used to reduce costs of compliance.
- ***Engine technology—***Similar to the above example, a greater penetration of the less expensive SIDI exists in the market, as compared to turbocharged engines and stop-start, which are represented in the Volpe model as more expensive steps up the efficiency curve. The Volpe

[16] Thought the rates of penetration shown are for the Volpe model, the OMEGA model for MY2012-2016 was qualitatively in agreement with the types and share of technology deployed in its pathway analysis, so we will treat the Volpe model results as representative of both agencies' analyses.

FIGURE 5. Production-weighted technology penetration for the 2016 model year



A comparison of the pathway modeled by NHTSA to comply with the MY2012-2016 regulations and the actual technology deployed in the fleet. Note that much lower penetration of expensive and complex technologies was needed to comply with the regulation, indicating that the technologies being deployed are more ***cost-effective than the agencies anticipated.***

SOURCE: NOVATION ANALYTICS 2016

model required that manufacturers would need to deploy these more expensive technologies at a greater rate for compliance than is actually required, again indicating that manufacturers are getting more effectiveness than anticipated out of the cheaper technologies.

- ***Transmissions***—In the agencies' original analysis for the 2017-2025 rule, dual-clutch transmissions were deemed more cost-effective than conventional automatic transmissions, and manufacturers like Ford, Volkswagen, Chrysler, and Honda all indicated plans to deploy the technology—therefore, the Volpe model inevitably selected this as the likely pathway to improving the efficiency of the transmission. After a number of quality problems and consumer complaints, however, the technology was not deployed as widely as industry anticipated (Sedgwick 2015). Instead, the market has still moved to transmission with wider gear spreads—they just largely happen to be conventional torque-converter automatics, although in some cases manufacturers have decided to go with a continuously variable transmission instead. Incidentally, this is an example of why we supported EPA's move to a more generic representation of transmissions in its OMEGA modeling (Cooke 2016a)—ATs, DCTs, and CVTs can all be made more efficient at relatively similar costs, and manufacturers choose which technology to deploy based on a range of factors beyond simple cost-effectiveness having to do with specifics about their target consumers of which regulators can simply not be aware. And at the end of the day, the 2012 Volpe model suggested that 87% of the market would need to move towards more efficient transmissions to comply with the regulations, only slightly less than the 92% deployed—this is a far smaller difference in total powertrain effectiveness than suggested by the differences in efficiency used in the Volpe model (an additional 5.5-7.5% fuel efficiency for DCTs compared to ATs; see Table 3-28), indicating that manufacturers again have been able to generate much greater effectiveness out of a technology than anticipated by regulators.

- ***Hybridization***—The figures on hybridization are perhaps the most telling and indicative of just how conservative the technology assumptions of the regulators were. Mild and full hybrids are one of the most costly technologies in the Volpe model—projecting that nearly a third of the fleet would have to deploy some type of hybridization to meet 2016 standards indicates that regulators felt these standards were relatively stringent. Because manufacturers have deployed less than 10% of these most costly technologies while complying with the regulations indicates that they were able to compensate for a tremendous amount of fuel savings with much less costly technologies.

The technology penetrations presented by industry are entirely consistent with our assessment that the agencies generally ***overestimate*** the costs of compliance. Target-based, technology neutral standards provide manufacturers with a goal, and they have proven capable of meeting it through unforeseen innovation that reduces the technology costs and enables greater efficiency from "low hanging fruit" than regulators have anticipated. If anything, this is an argument for regulators to err on the side of setting more aggressive standards than pathway modeling suggests is feasible.

L) THE AGENCIES HAVE GROSSLY MISCHARACTERIZED THE STATE OF ELECTRIC VEHICLES

The agencies' proposal to eliminate state Zero Emission Vehicle (ZEV) policies would damage a policy that is working to put California on a path to reducing climate changing emissions and improving public health. Such action is not only illegal (see Section II.C), but it is founded in a fundamentally inaccurate portrayal of the state of EV technology and its current success in the marketplace.

(1) ZEV is working to improve consumer choice

Despite the proposed rule's characterization of the ZEV regulations as "overly ambitious" (83 FR 43243), automakers to-date have substantially over-complied with the requirements, in both California and the other states that have adopted the ZEV program through Section 177 of the Clean Air Act. Analysis of the program in 2017 showed that manufacturers have banked ZEV credits and produced longer-range ZEVs, allowing compliance with ZEV regulations with less than 8 percent ZEV sales by 2025 (CARB 2017a). Plug-in sales in California were over 6 percent for the first half of 2018 (Pyper 2018), indicating that the ZEV requirements are achievable with current technologies.

Californian car buyers have more choices to choose an electric vehicle when they go to a dealership than buyers in any other state, both in the number of models and number of vehicles available

(Reichmuth and Anair 2016). Some automakers have restricted sales of ZEVs such that they were not available in all of the states that have adopted California's ZEV regulation. For example, the Fiat 500e battery electric car was only made available in California and Oregon. Other ZEV models were technically available outside of California but were available in short supply or needed to be special ordered. In a 2016 study of the availability of ZEV cars (based on a popular online car shopping website), prospective ZEV buyers in Boston would see 10 times fewer ZEVs available on dealers lots than buyers in the San Francisco-Oakland Bay Area. The increased availability of ZEV models and vehicles has contributed to higher sales in California and make ZEV sales outside of California a poor indicator of consumer interest in ZEVs in those states. Therefore, EPA's assertion that past market penetration of ZEV technologies in these states shows an inability of automakers to comply with the ZEV regulations is erroneous. In addition, the comprehensive review of the ZEV program by CARB has shown that compliance with ZEV will require less than 8 percent ZEV sales in 2025 in California and less than 7.5 percent sales in the other ZEV regulation states (CARB 2017a, p. A-15). Given the increasing number of ZEV models coming to market and availability of the vehicles outside of California, these requirements are not only achievable, but it is likely that they will be exceeded. The agencies' statement that the ZEV program is technologically infeasible (and therefore in violation of lead time requirements; see 83 FR 43240) is clearly false, and there is no data shown in the rulemaking to support this claim. On the contrary, CARB has provided extensive technical support for continuation of the ZEV regulations.

(2) The ZEV program has consumer and economic benefits

The ZEV program is not only beneficial for public health and reducing climate change. Consumers also benefit by having more choices in the market, including ZEVs. Plug-in vehicles can offer high performance while also saving drivers money by switching to a cheaper fuel. UCS analysis of gasoline prices and recharging costs shows that drivers could save on average almost $800 in fuel costs per year by switching from gasoline to electricity (Reichmuth 2017), and maintenance costs can also be reduced by going from a combustion engine to electric motor. Advanced vehicle technologies are also driving innovation and jobs in the U.S.—manufacturers like Tesla and Daimler have made significant investments in battery manufacturing facilities (DNA 2018, Lambert 2018). The ZEV regulations have been pivotal to bringing over 40 ZEV models to market in California, putting US automakers in a competitive position as major automotive markets like China and the European Union move towards increasing electrification.

The agencies have mischaracterized consumers' ability to identify these benefits (Section I.B.2.c), but even more importantly, the Proposal's elimination of the ZEV program would cut short technical developments which are working to provide significant social and economic benefit to the country, in addition to the obvious environmental and public health benefits of the program.

2. The agencies' compliance modeling is inadequate and irrational

While the assumptions regarding technology potential can be most generously described as "conservative," the way in which these assumptions are converted into potential paths for compliance borders on the absurd. The agencies have reduced their modeling effort to a single value, compromising robustness, and that model is so fraught with errors that it does not even perform its basic functions accurately. Basing a regulation on such an incomprehensibly inadequate modeling effort would be arbitrary and capricious.

A) THE AGENCIES' NPRM MODELING IGNORES ITS OWN UPDATED MODELING EFFORTS

In all three previous joint technical assessments, EPA and NHTSA relied upon separate, complementary modeling efforts. By using independent assessments guided by different expertise and technical assumptions, a comparison of the two results provided the agencies with clear, verifiable evidence as to the robustness of their findings. Unfortunately, the agencies are now relying upon a single set of technical inputs and a single modeled set of outputs, which results in extremely flawed analysis on both counts. Worse still, the agencies are ignoring the most up-to-date and state-of-the-art data available by ignoring recent peer-reviewed analysis and benchmarking data.[17]

(1) Full vehicle simulation

We have commented previously on the conservative technology assumptions used by NHTSA in its approach to modeling technology effectiveness with Autonomie (Cooke 2016b). The ANL work previously used outdated engine maps, and the lab has concentrated its benchmarking efforts on electrified powertrains, which are not especially relevant for the MY2022-2025 regulations. Furthermore, a number of additional flaws continue to exist with the Autonomie modeling, including that ANL's transmission shift strategy does not deploy gear-skipping or other more modern control strategies, which indicates that some if not many of the hard-coded assumptions in the model may be out-of-date. Perhaps recognizing some of these flaws, NHTSA utilized additional engine maps developed by IAV for DOE; however, these engine maps were not developed for this purpose and have not been benchmarked against the latest engines either on the road or in development, and as has already been described above in Section I.A.1.i)(2), these new engines maps have incorrectly "updated" these engine maps for Tier 3 fuel. , as described above in, and Lastly, all of these inputs represent a "black box"—it is impossible to verify, replicate, or alter the work done by Autonomie for NHTSA due to the expensive nature of the tools used and lack of open source or peer-reviewed output, and the underlying modeling work was finalized more than one year ago.[18] Perhaps this why the NPRM analysis does not even utilize the most recent ANL benchmarking data (Lohse-Busch et al. 2018a, 2018b)—not only isn't relying upon the most up-to-date industry data, but it doesn't even reflect the most recent data collected by the agencies themselves!

In contrast, EPA's ALPHA model has been thoroughly peer-reviewed and is constantly being updated to reflect the latest technology developments, thanks to the efforts of the National Vehicle and Fuel Emissions Laboratory. And because EPA has direct control over the model and its interface to OMEGA, EPA can better ensure that the inputs into OMEGA reflect the most up-to-date data, unlike the Autonomie work, which effectively has to be "locked in" before it can be deployed in the Volpe model. Moreover, the ALPHA model is readily downloadable, editable, and accessible to anyone with a

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[17] Peer review: RTI International 2018; benchmarking: Stuhldreher et al. 2018 (Honda L15B7 1.5L turbo), Dekraker et al. 2018 (Toyota TNGA 2.5L)

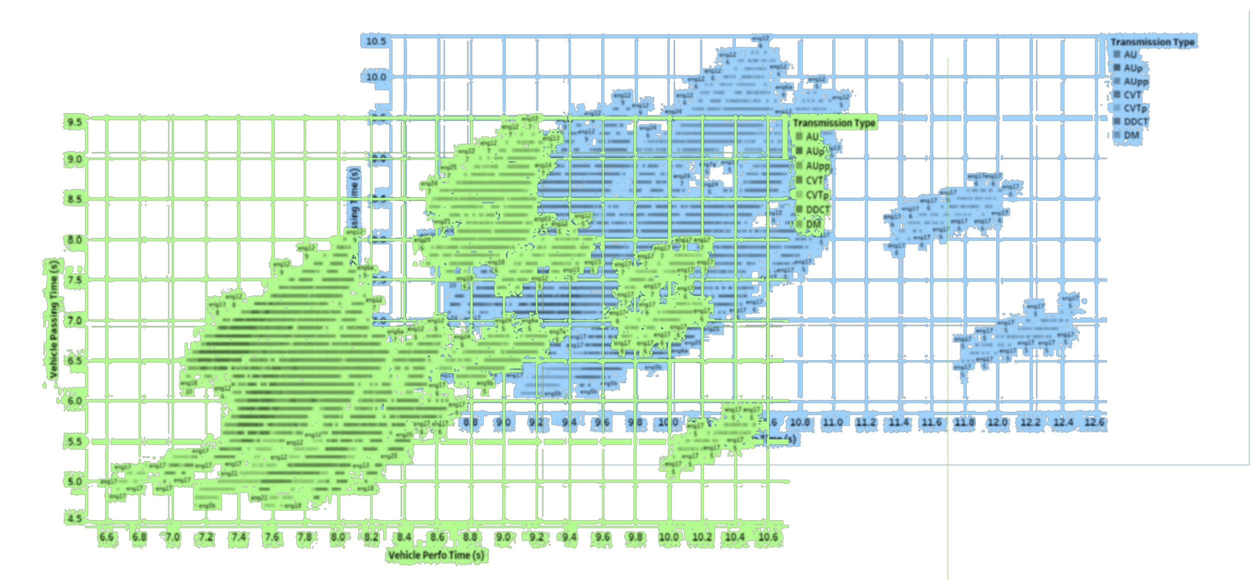
[18] The vehicle simulation database accompanying the Volpe model (NHTSA 2018a) is dated August 25, 2017, indicating that the data underpinning the Volpe model is significantly less recent than many of the peer-reviewed publications from EPA.

MATLAB license. It is also based on the GEM model, which is a model used to measure compliance with the heavy-duty vehicle regulations that has been meticulously reviewed and updated not just by EPA but by a number of heavy-duty vehicle manufacturers and suppliers. In fact, NHTSA has such confidence in the GEM model that they accept its simulation-based results as compliance with the heavy-duty fuel economy regulations.

The National Academies of Science noted that "the use of full vehicle simulation modeling in combination with lumped parameter modeling and teardown studies contributed substantially to the value of the Agencies' estimates of fuel consumption and costs, and [the committee] therefore recommends they continue to increase the use of these methods to improve their analysis" (NAS 2015, Recommendation 8.3). We agree that full vehicle simulation can significantly improve the estimates of technology effectiveness; however, we also think it critical that this process be as open and transparent as possible. Publishing results in peer-reviewed journals has provided the ALPHA modeling effort with significant and valuable feedback, particularly when it comes to assessing the most state-of-the-art engines. The "black box" approach by Autonomie does not lend itself to similar dialog, nor does it make it easy to assess the validity of its results.

There is an additional difference between how the full vehicle simulations are incorporated into their respective tools. In the case of the Volpe model, improvements in each vehicle are based on the

FIGURE 6. 0-to-60 and passing time of modeled compact vehicles



Performance "creep" in ANL's Autonomie modeling results in such dramatic changes in vehicle performance characteristics that technology packages applied to non-performance compact vehicles (blue chart) show significant overlap with technology packages applied to performance compacts (green chart) (figures have been aligned to share common x-y coordinates). These performance improvements can significantly diminish the potential reductions in fuel consumption, but remain unaccounted for as a benefit in the Volpe model.

SOURCE: ISLAM 2018B, FIGURES 241 AND 242.

improvements to an average vehicle in a given vehicle class—while the performance characteristics of vehicles within a class will differ which could significantly impact the relative fuel consumption of a particular technology (for example, based on a different power-to-weight ratio), only class average characteristics are considered (Islam et al. 2018b). Thus, in the Volpe model, the behavior of a particular technology package is severely stepped based on its classification by NHTSA staff—for example, applying TURBO2 to a vehicle with a 10-speed automatic, TURBO1, and BISG mild hybridization results in a 1.9 percent reduction in fuel consumption for a small performance car (and 30.8 percent below a "null vehicle") but only a 0.4 percent improvement for a small non-performance car (and 27.6 percent below a "null vehicle"). In the latest version of OMEGA, a vehicle's specific performance characteristics are taken into account through response-surface modeling based on relative deviation from the class average vehicle modeled in ALPHA (RTI International 2018), thus minimizing such step discontinuities.

It is also worth noting in this discussion that the modelers at ANL have allowed significant performance "creep" in their modeling—rather than maintaining performance neutrality with applied technology, vehicle characteristics can vary dramatically through increased technology adoption (Sectoin 11.5, Islam et al. 2018b). While some performance creep may be reasonable, many of these packages are so wildly different that they actually cause an overlap between performance and non-performance vehicles of the same size class (Figure 6). Performance characteristics in the OMEGA model as a result of ALPHA full vehicle simulation do not vary as significantly and are approximately held fixed.

(2) Pathway modeling

The Volpe and OMEGA models were designed for two very different objectives under different statutes. Volpe was designed with EPCA, as modified by EISA, in mind—for example, because of its focus on oil reduction, it does not appropriately model climate impacts from electrification or emissions from flex-fueled vehicles. Similarly, because the OMEGA model was designed under the "technology-forcing" paradigm of the Clean Air Act, it cannot allow manufacturers to pay fines in lieu of compliance, and it allows for the setting of more aggressive product cycles. Therefore, though these models can be complementary, one cannot be used in place of another and still meet the statutory obligations of each agency.

These models are largely constructed based on a similar foundational principle, that manufacturers will choose the most cost-effective technology pathway to comply with the regulations. However, the technology pathways produced by the two models will not necessarily agree due, in part, to the differences in structure of the models directly related to differences in statutory obligations. Furthermore, the latest version of the Volpe model indicates that it fails this basic task (see discussion in Section I.A.2.b)).

The Volpe model attempts to replicate in full a manufacturer's decisionmaking process across multiple platforms. To this end, the model uses rigid schedules as to when a vehicle can be updated and restricts initial deployment of technology to the "leader" of a platform, preventing other vehicles on that platform from adopting the technology even if their product cadence would allow it. The model also imposes phase-in caps to limit the rate at which a technology can be deployed. It also confines the decisionmaking process of a manufacturer to specific pathways—for example, there is no feasible way for a manufacturer to deploy a high-compression ratio engine with cylinder deactivation because the decision tree splits before this technology.

These rigid constraints represent conservative assumptions, often which do not prove true. For example, while historically a low-volume luxury model may have been first on a platform to receive a more expensive technology, a high-volume vehicle on that platform may now deploy the technology first in order to ensure compliance in the most rapid and cost-effective fashion. Similarly, while historically manufacturers may have stuck to rigid product redesign and refresh cycles, manufacturers are breaking that mold today.[19] For example, the Ford F-150 is having virtually continuous powertrain updates in its current cycle: it was redesigned in 2015, but in 2017 it gained both a 10-speed automatic transmission and a new, high-output engine, in 2018 they refreshed the vehicle by introducing four new engines, and by 2020 it will get a hybrid variant. Similarly, Hyundai has announced that it is cutting its product design cycle in half (Greimel 2017). And finally, the high-compression ratio engine with cylinder deactivation combo disallowed by the Volpe model is actually already deployed in the Mazda CX-5.

Another aspect of these constraints which makes the Volpe model susceptible to inaccuracies are that all of these constraints represent decisions made by the regulators based on Confidential Business Information (CBI) discussions with automakers. Manufacturers clearly have an incentive to provide conservative information to the regulators, but this is the primary source of data on which the Volpe modeling team is basing these constraints. This creates an asymmetric feedback loop which will always lead to conservative estimates: if the regulators err in a way in which automakers feel is “too aggressive”, they will provide CBI data to “correct” the assumption, but if the regulators err in a way which may be more conservative than automakers’ data, industry has no incentive to correct the record because such correction would inevitably result in stricter standards. This is why in the Volpe model the refresh and redesign cycle for the F-150 does not actually reflect what has transpired—Ford obviously knew its plans well in advance of the TAR for how it would be deploying its future powertrains to the vehicle, but they were not going to share it with the regulators. Even besides that, because there is little transparency on the data behind the “engineering judgments” made in the Volpe model assumptions, it is difficult to understand precisely why so many vehicles’ announced redesign/refresh cycles differ from that in the model, or the justification for skipping certain technologies on specific vehicles or even entire manufacturers’ product lines, as was done for the high-compression ratio engines.

The OMEGA model, on the other hand, is designed to be more consistent with EPA’s obligations to set technology-based standards under the Clean Air Act. It does not presuppose to know precisely how manufacturers may strategize their fleet decisions because it is clear that manufacturers keep much of this information to themselves and have a disincentive to provide accurate information to regulators. Instead, it starts from the simple premise that vehicles will essentially have the ability to significantly overhaul their powertrain and vehicle technologies once every five years through the redesign cycle. This acts as a complementary approach to the Volpe model, which is inherently conservative and no

[19] For further discussion on the ways in which the Volpe model does not accurately reflect manufacturers’ product cycles, see Baum 2018, Meszler and Baum 2018.

more predictive. And, it is more consistent with EPA's requirements under 202(a)—applying artificial constraints as is done in the Volpe model does not reflect technological feasibility but attempts to impose self-identified economic constraints which artificially constrict the actual technological possibilities.

One constraint that does exist in the OMEGA model explicitly because of the technological feasibility aspect of the statutory obligations underpinning the design of the model is that it does not allow for credit trading to reduce the costs of compliance. By requiring manufacturers to comply in its model on a technological basis, it inevitably increases the costs to comply. This is clearly a conservative assumption.

Aside from structural differences found in the models due to differences in legal obligations, there are differences in assumptions which underlie the models. For example, in the most recent version of the OMEGA model, EPA reclassified vehicles according to power and road load and incorporated power-to-weight ratio in its effectiveness modeling. This significantly improves the accuracy of its modeling and responds to one of the strongest industry concerns. This technique helps differentiate powertrain options within a given model, reflecting the diversity of consumers' choices and better representing the breadth of vehicle performance characteristics available within a given vehicle class. This strengthens the agency's results, both by narrowing the error bars and more accurately representing the real vehicle fleet.

The differences between the two models encourage complementary analysis, ensuring that between the two analyses, a diverse set of possible technology pathways are assessed. Having two analyses thus strengthens the argument for the feasibility of these standards, even if the eventual pathway is not precisely identified, since a diversity of hidden decisionmaking processes by manufacturers will inevitably sort the pathways as relevant to each manufacturer's precise overall goals, only one of which is compliance with the standards. And speaking to the strength of these complementary assessments, in the end both models yield generally similar costs for compliance—the agencies themselves showed this in the MY2017-2025 rulemaking (Section I.D.3), although the raw values disagreed substantially due to different underlying regulatory constraints. This further underscores that it will be the unknown OEM decisions which will help define the path, rather than solely the most cost-effective strategy, of which the agencies' complementary analyses prove there are many.

By restricting themselves to a single model, the agencies have undermined the natural complementarity of the approaches, enforcing only a single, more conservative approach that lacks robustness, transparency, and ultimately exposes the agencies to a series of modeling errors that would have been caught had the agencies appropriately considered their full complement of expertise and models.

B) THE VOLPE MODEL DOES NOT PRODUCE ECONOMICALLY RATIONAL RESULTS

The basic purpose of the Volpe model according to NHTSA "is to facilitate estimation of the potential impact of new CAFE standards" (NHTSA 2018f, p. 1). As part of this process, the model "estimate[es] ways each manufacture[sic] <u>could</u> (not 'should' or 'is projected to') respond to standards," which it does by "appl[ying] technologies based on their relative cost-effectiveness…subject to a variety of user-controlled constraints" (NHTSA 2018b, p. 1).

The model's constraints play a significant role in the estimation of these costs and generally serve to drive costs upwards by limiting the application of technologies. NHTSA claims that "because the CAFE model simulates a wide range of actual constraints and practices related to automotive engineering, planning, and productions…the analysis produced by the CAFE model provides a transparent and realistic basis to show pathways manufacturers could follow," (83 FR 43001). But there are numerous examples of behavior modeled by Volpe which do not comport with realistic product deployment. These errors flow from both erroneous inputs to the model (such as inaccurate product design cycles (Baum and Meszler 2018) and erroneous "engineering judgment" regarding technology uptake and manufacturer decisionmaking (Meszler 2018)) and intrinsic behaviors from the coding of the model (including irrational product application due to hardcoded pathways (Meszler 2018) and deficient coding of credit banking and trading, further discussed below).

Most fundamental to the rational operation of the model, however, is the algorithm determining the order in which technologies are applied by a manufacturer. Clearly, the optimal strategy chosen by a manufacturer would result in the lowest costs of compliance, within a given set of constraints—indeed, this is precisely how the model is described in its earliest incarnations, with manufacturers applying technology "based on comparative estimated cost-effectiveness" (p. VI-13, NHTSA 2006), and "identifying the 'best next' (in terms of cost-effectiveness) technology available on each of the parallel technology paths…and applying the best of these" (p. VI-13, NHTSA 2006). This is also precisely the recommendation of the National Academies: "All else equal, it would be economically efficient to implement first the technology that offered the greatest reduction in fuel consumption per dollar of cost" (NAS 2011, p. 125).

Unfortunately, the algorithm governing the current iteration of the Volpe model falls well short of a rational, cost-effective pathway (even within the engineering constraints imposed by the model), as illustrated below. We also provide a new, more efficient algorithm to replace this flawed approach.

(1) Flaws in the efficiency algorithm

We are not the first to point out that the efficiency algorithm does not work as it should—technical staff at EPA provided the Office of Management and Budget pages of detailed analysis illustrating that the algorithm does not function properly (Charmley 2018). There are two primary operational failures in the Volpe model's algorithm, one which affects modeling of both the CAFE and GHG programs, and one which solely affects the model's ability to model compliance with the GHG program. Each of these failures individually results in completely irrational behavior that must not be used to underpin major regulatory action.

(a) The Volpe model does not consider overcompliance in estimating efficiency

The efficiency of technology application in the previous iteration of the Volpe model appears in the formula (NHTSA 2016a, p. 25):

$$COST_{eff} = \frac{\sum_{i \in k}\left(\sum_{j=baseMY}^{j=MY} TECHCOST_{i,j} - TECHVALUE_{i,j} - (VALUE_{FUEL})_{i,j} + \Delta FINE_{MY}\right)}{TOTALSALES}$$

A similar formula appears in the model documentation accompanying the version of the Volpe model used to support the NPRM (Section 5.3.2, NHTSA 2018):

$$EffCost = \frac{TechCost_{Total} - FuelSavings_{Total} - \Delta Compliance}{AffectedSales_{Total}}$$

The ***TECHVALUE*** term representing “the net change in consumer valuation” (NHTSA 2016a, p. 25) has been removed from the formula. Previous versions of Volpe had set this term to zero for virtually all technologies, so it did not have a significant impact on the calculation of cost-effectiveness in previous rulemakings. But given the completely inaccurate and inflated assumptions regarding consumer welfare for hybrid and plug-in electric vehicles in ***this*** Proposal (see Section I.B.2.c)), it is likely that this term was eliminated because it resulted in absurd and irrational behavior of the model. However, because there is no documentation of this change, it is impossible to say for certain NHTSA’s rationale for the sudden and unexplained exclusion.

The ∆***Compliance*** term is set equal to the ∆***FINE*** term when calculating compliance with the CAFE program, but its value under the GHG program (defined as ∆***CO2CreditValue*** in the source code) is irrational and discussed in more detail in the next section. However, both definitions of ∆***Compliance*** suffer the same deficient behavior when it comes to handling overcompliance.

If a manufacturer undercomplies with the CAFE program, it can pay fines in lieu of compliance. In this scenario, however, the manufacturer then does not receive money for overcompliance—the manufacturer simply need not pay fines. Therefore, the fines paid by a manufacturer under any scenario have a floor of zero. But because the model imposes this floor on ***all*** methods of compliance, it irrationally caps gains from all forms of overcompliance, i.e., if a manufacturer moves from a situation of undercompliance (e.g., a fleet 10,000 vehicles averaging 0.5 mpg below the standard, for ***FINE*** = $14/(0.1 mpg)/vehicle × 5(× 0.1 mpg) × 10,000 vehicles = $700,000), to a situation of overcompliance (e.g., that same fleet of 10,000 vehicles now overcomplying by 0.5 mpg), the ∆***FINE*** value of the technology application only considers the value of the reduced fines ($700,000), ignoring the additional benefit of 0.5 mpg in credited overcompliance for the fleet.

This floor thus means that a technology which would result in significant overcompliance is dramatically undervalued, since that overcompliance is banked and available in later years for compliance. And because the algorithm supplies no benefits for overcompliance, it also prioritizes technologies not on how cost-effective they might be overall, but how close the technology’s effectiveness matches the gap in compliance (i.e., how closely the technology approaches the algorithm’s artificial ceiling for compliance benefits).

For example, take two technologies: Technology A costs $200 per vehicle and results in a benefit of 1 mpg on average across the fleet; Technology B costs $150 per vehicle and results in just 0.5 mpg improvement on average across the fleet. Clearly, Technology A is more cost-effective—it offers twice the level of improvement at just one-third more the cost. However, according to the Volpe formula, because both technologies do nothing more than reduce the fine in our 10,000-vehicle fleet example by the same amount ($700,000), the ∆***FINE*** term will prioritize the superficially “cheaper” Technology B, ignoring the additional benefit of overcompliance.

This deficiency in the algorithm and its impact were promptly identified by the technical staff at EPA during interagency review (Figure 10, Charmley 2018). NHTSA’s response to this criticism was wholly

TABLE 4. Costs for compliance with current greenhouse gas standards, in MY2028, by manufacturer, when correcting to consider overcompliance for technology application

Manufacturer	NPRM	Corrected	Diff	% Diff
BMW	$ 4,265	$ 4,039	$ (226)	-5 %
Fiat-Chrysler	$ 4,096	$ 3,139	$ (956)	-23 %
Ford	$ 3,437	$ 2,672	$ (765)	-22 %
General Motors	$ 3,151	$ 2,459	$ (692)	-22 %
Honda	$ 1,851	$ 1,738	$ (114)	-6 %
Hyundai	$ 1,201	$ 1,031	$ (169)	-14 %
Jaguar Land Rover	$ 4,994	$ 5,162	$ 167	3 %
Kia	$ 1,755	$ 1,511	$ (243)	-14 %
Mazda	$ 2,691	$ 1,778	$ (913)	-34 %
Mercedes	$ 4,485	$ 3,972	$ (512)	-11 %
Nissan-Mitsubishi	$ 1,141	$ 1,107	$ (34)	-3 %
Subaru	$ 1,247	$ 1,262	$ 15	1 %
Tesla	$ 4	$ 3	$ (1)	-23 %
Toyota	$ 2,235	$ 1,849	$ (386)	-17 %
Volkswagen	$ 5,004	$ 4,383	$ (620)	-12 %
Volvo	$ 3,538	$ 3,283	$ (254)	-7 %
INDUSTRY TOTAL	**$ 2,785**	**$ 2,307**	**$ (478)**	**-17 %**

Altering the Volpe "effective cost" algorithm to consider overcompliance results in substantially reduced costs for nearly every single manufacturer, as well as the industry as a whole. The two manufacturers who showed increases in costs were of marginal significance (3 percent for JLR and 1 percent for Subaru, both of whom are relatively low-volume manufacturers), while many of the largest manufacturers saw costs reduced by 20 to 30 percent.

inadequate to this criticism, ignoring the substance of the critique (#28, NHTSA 2018g). Moreover, NHTSA's response tacitly acknowledges that the model does not fully value a manufacturer's overcompliance ("the compliance simulation algorithm applies a ceiling at 0 (zero) to each calculated value of the CO_2 credits"), but bizarrely tries to justify the oversight by identifying another, self-inflicted flaw in the model: the lack of manufacturer-to-manufacturer trading that, if permitted, would "raise" the ceiling for compliance benefits (see further discussion of this in Section I.A.2.c)(2)(c)). But NHTSA is legally obligated to model regulated parties with respect to reality and to the facts of manufacturer compliance, which do not change merely because the agency says as much in ***other*** flawed analyses. And in any event, the agency's "two wrongs make a right" mentality ignores that the manufacturer themselves—not their potential trading partners—would be the more likely beneficiary of these banked credits.

The real proof that NHTSA ignored EPA's criticism can be found by simply running the model with and without eliminating this "ceiling." If NHTSA is correct in its rebuttal—that eliminating this ceiling would result in additional costs—then the output would validate the agency's argument. However, as shown in Table 4, costs of compliance when eliminating this ceiling are reduced significantly.[20] This is an indication that the algorithm at the core of the Volpe model is sub-optimal, with nearly every single manufacturer accruing greater technology costs as a result of this error.

Averaged across the fleet, the results of NHTSA's irrational modeling decision yield costs of compliance that are more than 20 percent higher than if the Volpe modeling staff had heeded the advice of the interagency reviewers. Knowingly inflating the costs of regulation by choosing to use a sub-optimal algorithm is clearly an arbitrary and capricious decision. Any future modeling efforts by the agency must more reasonably reflect a rational strategy for technology adoption by manufacturers.

(b) Efficiency for technologies in the GHG program are derived from CAFE fines

According to NHTSA, "the model uses an estimated value of CO2 credits to place a value on progress toward compliance with CO2 standards" (#28, NHTSA 2018g). However, this value is fixed in a given model year for all manufacturers and is explicitly tied to the value of CAFE fines in that model year, neither of which is a reasonable estimate of how a manufacturer will value compliance with the greenhouse gas standards. The flaws in this approach are numerous and were identified by EPA in interagency review (Charmley 2018, pp. 22-23). We concur with these criticisms. Moreover, NHTSA did not defend the validity of the approach used in the Volpe model, nor did the agency provide any justification for translating the value of CAFE fines directly into \$/g CO_2-equivalent, even while acknowledging that "noncompliance with CO2 standards effectively means a prohibition on sales rather than a potentially-manageable civil penalty" (#28, NHTSA 2018g).

Manufacturers will compare technologies based on the marginal cost-effectiveness of that technology (i.e., the "bang for your buck" from a given technology). In the case of the greenhouse gas standards, where credits are defined as megagrams (Mg) of CO_2-equivalent, this amounts to an efficiency in dollars per metric ton, where the "cost" term in the numerator is simply the perceived difference in profit by applying a technology, $\boldsymbol{TechCost}_{\text{Total}} - \boldsymbol{FuelSavings}_{\text{Total}}$.

Modeling the cost-effectiveness in this way ensures that there is no pre-ordained "value" of CO_2—each manufacturer will value compliance relative to the technology pathways and credit strategies available to it to reduce tons of emissions, and it is precisely this marginal cost that is important when evaluating a strategy. It also ensures that manufacturers' "value" of greenhouse gas reduction ***increases*** over time, reflecting that compliance with more stringent emissions standards becomes more challenging as options are exhausted and that only after the low hanging fruit is utilized will manufacturers see economic value in more expensive emissions reductions pathways.

The above strategy is precisely the recommendation given by the National Academies (NAS 2011). Deploying the more accurate model in place of the default algorithm in the Volpe model results in reduced costs of compliance (Table 5), indicating that at its core the Volpe model is fundamentally flawed.[21]

[20] See Appendix A-1 for corrections to the source code.
[21] See Appendix A-2 for corrections to the source code.

TABLE 5. Costs for compliance with current greenhouse gas standards, in MY2028, by manufacturer, utilizing a "cost per ton" algorithm

Manufacturer	NPRM	Corrected	Diff	% Diff
BMW	$ 4,265	$ 3,988	$ (277)	-6 %
Fiat-Chrysler	$ 4,096	$ 3,945	$ (151)	- 4 %
Ford	$ 3,437	$ 2,612	$ (825)	-24 %
General Motors	$ 3,151	$ 2,277	$ (874)	-28 %
Honda	$ 1,851	$ 1,741	$ (110)	-6 %
Hyundai	$ 1,201	$ 973	$ (227)	-19 %
Jaguar Land Rover	$ 4,994	$ 4,849	$ (145)	-3 %
Kia	$ 1,755	$ 1,447	$ (308)	-18 %
Mazda	$ 2,691	$ 1,753	$ (938)	-35 %
Mercedes	$ 4,485	$ 3,991	$ (494)	-11 %
Nissan-Mitsubishi	$ 1,141	$ 1,147	$ 6	1 %
Subaru	$ 1,247	$ 1,246	$ (1)	0 %
Tesla	$ 4	$ -	$ (4)	-100 %
Toyota	$ 2,235	$ 1,810	$ (425)	-19 %
Volkswagen	$ 5,004	$ 4,478	$ (525)	-11 %
Volvo	$ 3,538	$ 3,043	$ (495)	-14 %
INDUSTRY TOTAL	**$ 2,785**	**$ 2,360**	**$ (425)**	**-15 %**

Replacing the Volpe "effective cost" algorithm with a "cost per ton" algorithm results in substantially reduced costs for nearly every single manufacturer, as well as the industry as a whole. The only manufacturer which showed an increased cost was Nissan-Mitsubishi, which saw a mere $6 difference, while many of large manufacturers saw costs reduced by 20 to 30 percent.

(2) Evidence of irrational behavior in the current Volpe model

In the sections above, we illustrated that the Volpe model's algorithm is sub-optimal and does not produce the most economically efficient behavior. While we have illustrated examples of how to correct this behavior and lower costs, it is perhaps even more illustrative to demonstrate the types of irrationality that drive the increased costs in the model.

Due to errors in the Autonomie model, many simulations of improved transmissions and turbocharged engines show little incremental improvement over less complex technologies (e.g., Figures 6-119 (CEGR1) and 6-151 (AT8 and better)), yet the model routinely adopts these technologies at significant cost: in the NPRM analysis, 0 percent of vehicles had an AT6L2 transmission while 52.4 percent adopted AT10L2 transmissions, even though the latter supplies virtually identical modeled efficiency but is hundreds of dollars more expensive (Table 6-22, PRIA).

Under the model, it is actually possible to significantly reduce the cost of compliance by prohibiting the adoption of the entire AT8+ branch (AT8, AT8L2, AT8L3, AT9, AT10, AT10L2) as well as CEGR (Table

TABLE 6. Costs for compliance with current greenhouse gas standards, in MY2028, by manufacturer, when preventing the adoption of advanced transmissions and cooled EGR

Manufacturer	NPRM	Low Tech	Diff	% Diff
BMW	$ 4,265	$ 4,126	$ (139)	-3 %
Fiat-Chrysler	$ 4,096	$ 3,624	$ (472)	-12 %
Ford	$ 3,437	$ 2,809	$ (628)	-18 %
General Motors	$ 3,151	$ 2,769	$ (382)	-12 %
Honda	$ 1,851	$ 1,649	$ (203)	-11 %
Hyundai	$ 1,201	$ 1,390	$ 189	16 %
Jaguar Land Rover	$ 4,994	$ 4,710	$ (284)	-6%
Kia	$ 1,755	$ 1,678	$ (77)	-4 %
Mazda	$ 2,691	$ 2,008	$ (684)	-25 %
Mercedes	$ 4,485	$ 4,011	$ (473)	-11 %
Nissan-Mitsubishi	$ 1,141	$ 1,026	$ (115)	-10 %
Subaru	$ 1,247	$ 1,246	$ (0)	0 %
Tesla	$ 4	$ 4	$ (0)	0 %
Toyota	$ 2,235	$ 2,024	$ (211)	-9 %
Volkswagen	$ 5,004	$ 4,598	$ (405)	-8 %
Volvo	$ 3,538	$ 3,104	$ (433)	-12 %
INDUSTRY TOTAL	**$ 2,785**	**$ 2,474**	**$ (311)**	**-11 %**

Preventing manufacturers from adopting advanced transmissions and cooled EGR results in substantially reduced costs for nearly every single manufacturer, as well as the industry as a whole. The only manufacturer which showed an increased cost was Hyundai, which saw increased costs as a result of significant adoption of mild hybrids to replace the synergistic benefits of its high population of HCR engines with advanced transmissions. Most large manufacturers saw costs reduced by about 10 percent, or nearly 20 percent in the case of Ford.

6).[22] This makes absolutely no sense whatsoever: by restricting the pool of technology a manufacturer can choose, costs should always go up. The only way costs can go down by eliminating technology availability is if the manufacturer inexplicably selects more expensive, less cost-effective technologies, ***which is completely irrational behavior.*** But this is exactly what these modeling results indicated—manufacturers were modeled as unnecessarily applying hundreds of dollars in additional technology.

(3) Creating a more efficient model

Combining the two approaches we recommended above yields to further reduced costs (Table 7). This approach is merely a first attempt at correcting the many flaws in the Volpe model. Because the agencies did not accept our request for an extension of the comment period, we were unable to both fully assess why the model behaves so irrationally, and how to fix such problems in the source code itself. It is all but certain that many potential improvements remain.

[22] To prevent adoption of these technologies, we modified the technologies file (NHTSA 2018d), replacing the applicability of each technology in the branch (as well as CEGR) with "FALSE" in every vehicle class to create a premature stopping point in the technology selection pathways.

TABLE 7. Costs for compliance with current greenhouse gas standards, in MY2028, by manufacturer, when preventing the adoption of advanced transmissions and cooled EGR and utilizing a cost-per-ton algorithm

Manufacturer	NPRM	Combined	Diff	% Diff
BMW	$ 4,265	$ 3,867	$ (398)	-9 %
Fiat-Chrysler	$ 4,096	$ 2,729	$ (1,366)	-33 %
Ford	$ 3,437	$ 2,327	$ (1,111)	-32 %
General Motors	$ 3,151	$ 2,182	$ (969)	-31 %
Honda	$ 1,851	$ 1,391	$ (461)	-25 %
Hyundai	$ 1,201	$ 1,271	$ 70	6 %
Jaguar Land Rover	$ 4,994	$ 4,245	$ (749)	-15 %
Kia	$ 1,755	$ 1,653	$ (102)	-6 %
Mazda	$ 2,691	$ 1,591	$ (1,101)	-41 %
Mercedes	$ 4,485	$ 3,958	$ (526)	-12 %
Nissan-Mitsubishi	$ 1,141	$ 1,093	$ (48)	-4 %
Subaru	$ 1,247	$ 1,255	$ 8	1 %
Tesla	$ 4	$ -	$ (4)	-100 %
Toyota	$ 2,235	$ 1,817	$ (417)	-19 %
Volkswagen	$ 5,004	$ 4,021	$ (983)	-20 %
Volvo	$ 3,538	$ 3,451	$ (87)	-2 %
INDUSTRY TOTAL	**$ 2,785**	**$ 2,103**	**$ (682)**	**-25 %**

Combining a more efficient algorithm while preventing the unnecessary adoption of some more advanced technologies substantially reduced costs for nearly every single manufacturer, as well as the industry as a whole. The domestic manufacturers saw costs cut by more than 30 percent, while the industry as a whole cut its costs by 25 percent.

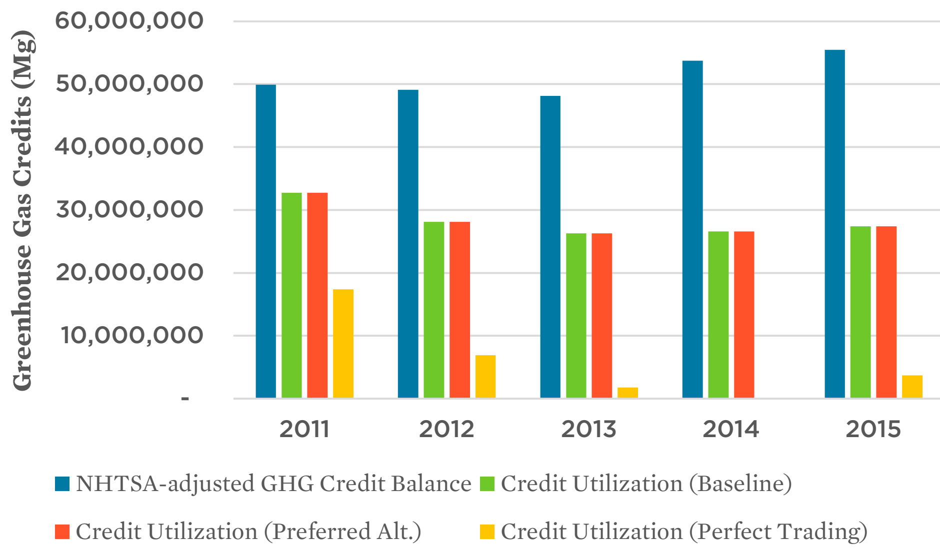
In the meantime, because the Volpe model remains severely flawed and incapable of performing its core function appropriately, we recommend that any modeling effort by the agencies draw upon the additional models developed by EPA explicitly to assess compliance with the greenhouse gas emissions rules, the ALPHA and OMEGA models. These models are both 100 percent transparent and available to the public and have each been updated and peer-reviewed since the finalization of the mid-term review in 2017.[23] This "latest and greatest" scientific data is exactly what the agencies should be relying upon, and we recommend that the ALPHA and OMEGA models be made available as part of the rulemaking and be incorporated into the final rule. This additional layer of complementary analysis would provide a layer of robustness clearly lacking from the agencies' current, flawed proposal.

[23] Peer review: EPA-HQ-OAR-2018-0283-0025; benchmarking: SAE 2018-01-0319 (Honda L15B7 1.5L turbo), SAE 2018-01-1412 (Toyota TNGA 2.5L)

C) THE VOLPE MODEL DOES NOT ACCURATELY REFLECT THE BANKING AND TRADING PROVISIONS FOR COMPLIANCE WITH FUEL ECONOMY OR EMISSIONS STANDARDS

The latest version of the Volpe model does not correctly utilize credits in its projections of how manufacturers would comply with future standards, including credits for overcompliance which have

FIGURE 7. The total of banked credits for model years 2011-2015 under different scenarios



NHTSA attempted to model the greenhouse gas credit balance for manufacturers in MY2011-2015 based on anticipated usage (blue bars). However, for both the Baseline Standards and the Preferred Alternative (green and red bars, respectively), roughly half of manufacturers' banked credits are allowed to expire, something which directly conflicts with manufacturers' rationale for generating that overcompliance in the first place. This effect is even more pronounced when "perfect trading" is considered (yellow bars), where the industry as a whole is able to minimize its compliance costs—in that case, the industry is assumed by the model to use virtually none of its banked credits.

already been banked by manufacturers under the current program. As such, it exaggerates the costs of compliance, assuming that manufacturers will apply additional technologies and allow credits to expire, something which no rational manufacturer would do, particularly under the Clean Air Act where-in non-compliance does not result in an undervalued fine but can result in a stop-sale of vehicles in the United States. This inexplicable behavior was previously observed in interagency review,[24] but no corrective measures were identified by NHTSA in response.

NHTSA staff have acknowledged that they are not accurately reproducing credits in the Volpe model—for example, even though EPA allowed a one-time exemption of the five-year credit lifetime for MY2010-2015 to be carried through to MY2021, the Volpe model does not reflect this (83 FR 43183). NHTSA staff then modified the EPA greenhouse gas credit banks to "anticipate the years in which those credits might be needed" (83 FR 43183)—as is shown in the following discussion, this "guessing"

[24] Charmley 2018, p. 9: "The model tends to produce fleets that overcomply and make sub-optimal use of available credits, resulting in an unrealistic over-estimation of costs."

method is inadequate to accurately replicate rational manufacturer behavior, and artificial limits set within the Volpe model exacerbate this "finger-in-the-air" methodology, as is described below.

(1) The Published Volpe Model Inexplicably Lets Credits Expire

Figure 7 details both the credit bank defined by NHTSA staff in the Volpe model inputs and the credit trading outputs, compiled from the debugging files associated with running the model.[25] Here we show the credits utilized in three different modeling cases, compared to the default inputs: 1) the baseline case (EPA standards as they stand today), 2) the preferred alternative (holding standards flat after MY2020), and 3) the baseline case with perfect trading (further described below). Because the default inputs limit credit lifetime to 5 years and both the preferred alternative and the baseline case have the same standards through 2020 (the year when NHTSA's GHG credit bank would expire), there is no difference whatsoever in credit application from the 2011-2015 bank between those two scenarios. However, it is clear in all scenarios that credits are not fully utilized.

As is apparent from the figure, significantly fewer credits are being applied by the model than are available to manufacturers. This is a serious flaw. Essentially, the model is saying that manufacturers are willing to let nearly half of their credits expire, which is simply not rational. What rational manufacturer would leave all of this money on the table? And why would a Board of Directors exercising their fiduciary responsibilities allow such financial folly to occur? Yet the model allowed 141 million Mg of credits to expire, while at the same time overcomplying with the regulations by 188 million Mg—clearly there is an arbitrary and outright irrational projection.

Currently, these credits trade at approximately $42 per metric ton, directly to the manufacturer (Cooke 2016a, p. 7)—this would put the value of these expired credits at nearly **$6 billion**, in the case of the Baseline Standards. In this same time period (MY2016-2021), the model projects that manufacturers applied technology at a direct cost of $275 per metric ton in order to over-comply with the standards as an industry. Using that average cost, manufacturers applied nearly **$40 billion** in direct technology costs to make up for the difference in expired credits.

This modeling suggests that manufacturers were willing to discard $6 billion in sunk costs and pay an additional $40 billion to make up for that difference—under no economic theory is such behavior rational. Manufacturers could have applied credits at a net cost of zero in order to eliminate approximately 75 percent of the technology costs accrued in these model years—instead, the model has evaluated these credits to be worthless.

(a) <u>Defining the Volpe Model Compliance Strategy</u>

At the core of the Volpe model is a series of steps which is responsible for the decisionmaking process assumed manufacturers will take to comply with the regulations. These compliance steps are the key source of much of the dysfunctional and irrational behavior of the model, so it is worth defining in plain terms the assumptions and order of the process as clearly as possible.[26]

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[25] i.e. (Output directory)\debug-logs\credit_trades_sn#.csv, where # represents the scenario number.

[26] This is a plain text description of the RunManufacturer() method within Compliance.cs (lines 528-719) of the provided source code (NHTSA 2018c). While ostensibly such discussion should occur in the accompanying NHTSA

The model breaks the process for manufacturers to determine a strategy for compliance into 5 steps, which are laid out below. However, we will sub-divide these steps further in order to more clearly assess the way in which compliance is processed:

1) Apply all cost-effective solutions, regardless of manufacturer's compliance

   All technologies which pay for themselves within the assumed payback period are applied to all manufacturers, regardless of credit status.

2) Register manufacturer and year with "credit bank"

   In this version of the Volpe model, the credit bank is not used. Currently, it appears to be designed solely for CAFE compliance (`CreditBank.cs`), and references to this module consist in the main methods solely as "`//TODO:`" statements outlining future development.

3) A three-step credit application process: a) apply expiring credits; b) apply all credits from oldest to newest, preferentially choosing carrying forward credits over fleet transfers; and c) for the GHG program only, credits are transferred between car and truck fleets within the same model year.

   The degree to which each of these steps do what they are purportedly designed to do is a key factor in the inefficiency and irrationality of the Volpe model.

4) Apply non-cost-effective technologies until compliance is achieved.

   This is the model's algorithm for effective cost, by which it ranks technology application. The hard-wired inefficiencies in this algorithm unnecessarily result in more and/or more costly technologies being selected.

5) Transfer all available credits.

   This is not explicitly called out as "Step 5" in the model, but it occurs at the same level as the other steps in the procedure and represents a catch-all of sorts.

Step 1 is curious because it assumes that manufacturers will apply cost-effective technologies towards fuel economy despite no historical precedent for such behavior, as is discussed elsewhere in this comment. However, this function can be easily overridden in the input files, where payback is declared—in fact, in previous rulemakings, NHTSA has assumed that manufacturers would only apply technologies with just a one-year payback or less once in compliance with the standards (see NHTSA 2012a, NHTSA 2016a, NHTSA 2016c).

Step 4 is a critical mis-step, as was already discussed in detail in Section I.A.2.b)(1).

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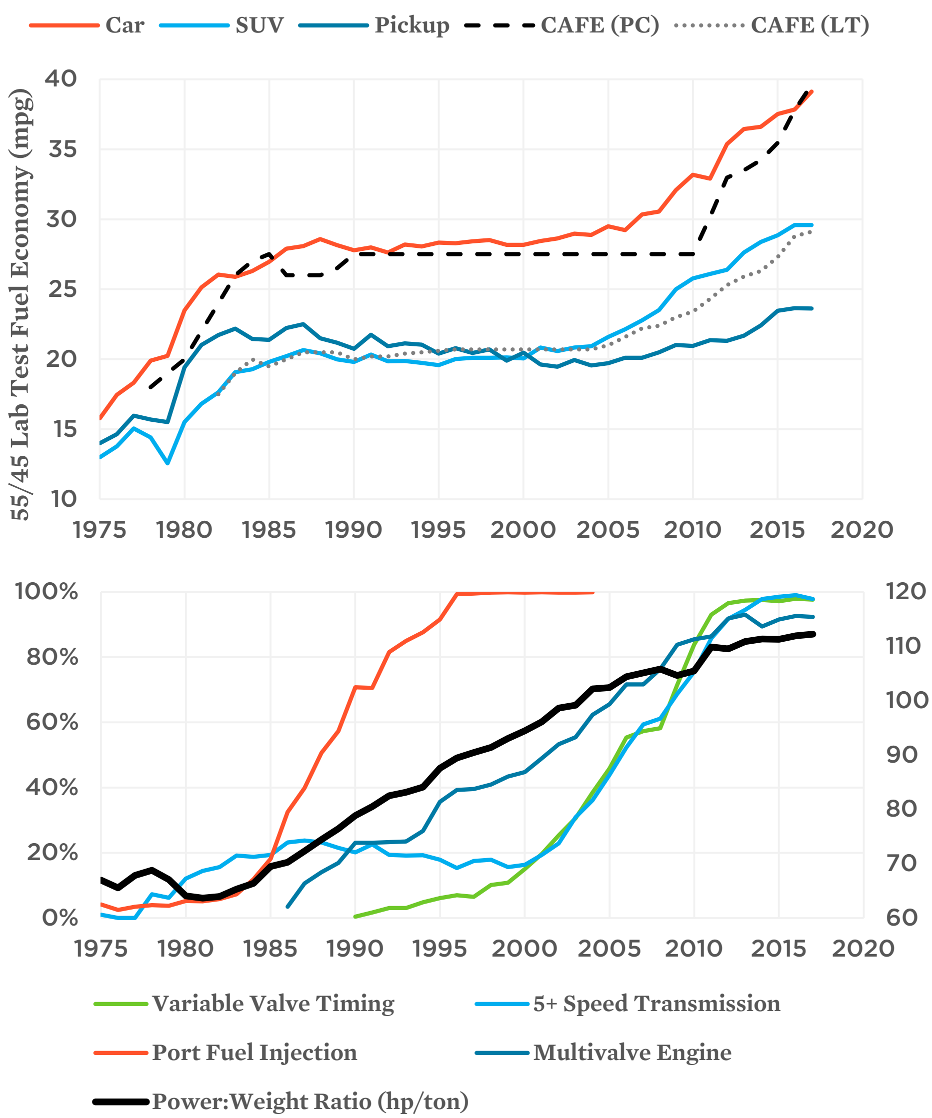
documentation, (e.g., Section S5.3, NHTSA 2018b), the most complete description is Figure 10, which is not the most straightforward diagram to assess quickly.

Steps 3 and 5 deal directly with credit trading, and deficiencies in these processes are described below because they go to the core of why model is not accurately applying credits already earned by manufacturers in lieu of forcing additional compliance costs by adding technology.

FIGURE 8. Fuel economy and technology penetration for conventional technologies, since 1975



(Top) Lab test fuel economy has not historically changed irrespective of changes in regulatory stringency. (Bottom) At the same time, technology advances did not stop in the interim—rather, manufacturers applied cost-effective engine technologies like variable valve timing, port fuel injection, and multivalve engine design to improving performance (indicated by power-to-weight ratio, right axis), rather than fuel economy. Technologies like improved transmissions which did not translate as directly to improved performance characteristics did not see the same deployment until increases in fuel economy and emissions standards again necessitated them to be a (cost-effective) strategy for compliance.

SOURCE: EPA 2018d

(2) Why Manufacturers Do Not Fully Utilize Credits in the Volpe Model

There are a number of interacting bugs in the Volpe model's programming that cause it to behave irrationally when it comes to credit application. These are described below.

It is important to note that in the model credits can only be applied to a fleet with a deficit—therefore, a number of these issues are in essence pushing fleets into overcompliance via the application of technology, preventing the use of credits manufacturers have already earned.

(a) "Cost-effective" technology application is prioritized above credit utilization, bucking historic trends

The first step of compliance within the model assumes that manufacturers will apply technology deemed by the model's algorithm to be "cost-effective." There are questions raised by the agency about the efficiency of the algorithm itself which are explored in Section I.A.2.b)(1), but this step means that manufacturers incur additional technology costs ***regardless of a manufacturer's level of compliance within its fleet or a specific regulatory class***.

This step defies historical precedent—without binding fuel economy and greenhouse gas emissions standards, manufacturers have not historically applied ***any*** technology towards improving fuel economy (Figure 8). Even at historic lows in gas prices, a number of cost-effective technologies were available that pay for themselves in short order (less than one year) and were capable of providing significant gains in fuel economy (e.g., NAS 1992). Manufacturers applied these technologies towards improved performance instead of improved fuel economy. It was not until California's landmark passage of California Assembly Bill 1493, which pushed the state to adopt global warming emissions standards for vehicles in 2004, and increased fuel economy standards first finalized in 2003, that manufacturers began to again improve fuel economy of their vehicles.

No justification is given by NHTSA for this behavior in the model. Furthermore, the input files used in the proposal represent a shift in behavior from previous versions of the model, when manufacturer behavior regarding the application of "efficient" technology was dependent upon whether or not the manufacturer was already in compliance.[27]

(b) NHTSA did not accurately reflect unique attributes of EPA's credit bank

As was mentioned earlier, in its input files NHTSA did not accurately reflect either the full bank of credits accrued by manufacturers under EPA's greenhouse gas program or the actual expiration timeframe for these credits, which were granted a one-time exemption to the five-year credit lifetime (40 CFR § 86.1865-12(k)(6)(ii)). The credits earned in 2010 and 2011 represented nearly one half of the credit balance available to manufacturers entering the 2016 year. However, a five-year lifetime would have resulted in the expiration of the vast majority of these credits, since the vast majority of manufacturers' car and truck fleets remained in compliance with the 2016 standards. While NHTSA adjusted the Volpe model credit balance to try to limit the effect of this five-year expiration, again it

[27] While manufacturers would prioritize such application in either case, previous versions of the model considered different payback periods, using a much shorter assumed payback period for such voluntary technology deployment (one year, compared to three years under binding standards) (e.g., NHTSA 2012a).

results in a number of credits being expired simply because manufacturers are already overcomplying in the early years modeled by Volpe, planning to reserve these earlier credits for the 2019-2021 timeframe. While 100 percent of the EPA credit bank would have been available to manufacturers in this transition period between the two phases of the program, only 42 percent of NHTSA's approximation to this bank is still available in this timeframe because the 2011-2013 credits are incorrectly given a five-year lifetime.

The impact of this is so severe that even when credits are the ***only*** available compliance option (i.e. no technology is allowed to be applied to meet the current 2021-2025 standards), nearly 12 percent of them are allowed to expire. Similarly, this is why the credit utilization under a scenario of "perfect trading" is so low—manufacturers do not develop a strong enough net deficit before the vast majority of credits expire.

The source of this issue may be related to a mistake made by NHTSA in the source code to the Volpe model. Its model applies a single credit lifetime to all credits earned prior to any modeled year of compliance due to an unnecessary "`if`" statement (Appendix A-3). This error likely led to NHTSA to jury-rig a workaround to the fact that their code as-is cannot accurately reflect the use of credits banked under the GHG program. As noted already, this resulted in a miscalculation of how those credits would be used in the future.

The effect of this is, simply, to raise the cost of compliance by mischaracterizing manufacturers' plans to utilize banked credits already earned for overcompliance. We have corrected the source code (Appendix A-3) and the parameters Excel input file (NHTSA 2018d) which further ignored the uniqueness of EPA's one-time carryforward lifetime exemption.

Because the Volpe model analyzes MY2016, it would not be appropriate to utilize the MY2016 credit bank (EPA 2018e)—these credits reflect the ***outcome*** of MY2016, including manufacturers' use in MY2016 of credits carried forward from the credit bank, which we would expect the model to simulate. However, credit trading did occur which manufacturers may have used to comply with MY2016. Therefore, our modeled credit bank takes the final credits banked entering MY2016 (Table 5-2, EPA 2016d), and adjusts to reflect credit trading updated in the MY2016 compliance report (differences between Table 4-1 in EPA 2016d, 2018e). Though credits under the EPA program are freely transferable between passenger cars and light trucks and are reported only in aggregate, the Volpe model splits credits between the two classes; therefore, we have allocated those credits based on proportional levels of under/overcompliance in each vehicle class as approximated by using the data in EPA 2013, 2014, 2015a, 2015b, 2016d, 2018e and accounting for any credit trades.[28]

[28] This data is not 100 percent consistent with the credit banks in EPA 2018 due to impacts of infractions by Hyundai, Kia, FCA, and Volkswagen, as well as because some manufacturers like Toyota have carried forward credits from an early model year to offset compliance in one category while maintaining net overcompliance overall, which affects the relative "age" of available credits but is not explicitly tracked by EPA in its compliance reports (only final credit tallies are shown). However, it is a reasonable estimate for credit usage, and because credits are freely transferred between the two classes in the GHG program, such an estimated allocation does not have a significant impact on the ability for manufacturers to comply ***if the model is accurately representing credit usage as a compliance pathway.***

(c) Credits are not traded between manufacturers

As even EPA admits, credit trading between manufacturers represents a key provision designed to allow the industry to comply with the standards at as low a cost as possible while preserving reductions in oil use and emissions (83 FR 43231). However, this flexibility is entirely absent from the Volpe model's implementation of the greenhouse gas program. The effect of this is to prevent manufacturers who've already complied in cost-effective ways to use their advantageous position to deploy further reductions in emissions at a lower cost than their competitors. It is also a constraint entirely disconnected from the reality of how the program is currently functioning.

Through the 2016 model year, more than 30 million Mg of credits have been traded between manufacturers (EPA 2018e). While this may seem small (comparable to just over 10 percent of the net overcompliance to date), manufacturers are still determining their product plans for 2021 and beyond, and since the vast majority of manufacturers have been credit generators through MY2016, it is unlikely that most manufacturers would solicit credits from their competitors until there is more certainty around the actual deficit they would be facing in a given model year.

It is possible to model perfect trading between manufacturers in order to assess the impact of neglecting this feature of the greenhouse gas regulations, by considering all brands as part of a single manufacturer. This preserves the Volpe model's constraints around shared platforms, vehicle leaders, etc., but it allows for more efficient deployment of technology industrywide by using the most cost-effective strategy (as deemed by the Volpe model).

Because of deficiencies within the Volpe model's cost-effectiveness algorithm (Section I.A.2.b)(1)), modeling trading in such a way creates substantially less fleet deficits (by implicitly correcting them with current-year fleet trading), negating the need for using banked credits. This is why the utilization of banked credits in such modeling runs drops to virtually zero (Figure 7).

In order to circumvent this failure of the model, it is possible to force the use of banked credits by preventing technology adoption. In this way, it is possible to show that, according to the Volpe model, manufacturers can comply with EPA's greenhouse gas regulations through 2020 ***without changing the MY2016 fleet*** thanks to the credits they've already earned under the EPA greenhouse gas program.

It is even possible to adapt the Volpe model to incorporate credit trading among manufacturers as a path to compliance, more accurately reflecting the real world, where we have seen such trading occur. For credit trading between manufacturers to occur, we assume two central features: 1) a manufacturer will only trade credits if the cost of compliance of the other manufacturer (per ton CO2-equivalent) exceeds its own marginal cost of compliance (ensuring that selling such credits would be profitable to a manufacturer) and 2) the credits are set to expire in the year traded. Such restrictions still allow some credits to expire, which is improbable in reality (expiration of a significant amount of credits is not likely since one would suppose a rational manufacturer would aim to achieve at least marginal return for that investment rather than nothing at all), but enabling at least some form of manufacturer-to-manufacturer trading serves to both lower the total compliance cost and provide a rational, albeit conservative, basis for trading. The changes to the source code necessary for this trading can be found in Appendix A-4.

TABLE 8. Actual credit trading through MY2016

Credits dispursed

Manufacturer	2010	2011	2012	2013	2014	2015	2016
CODA			5,524	1,727			
HONDA	14,182,329	6,590,901					
NISSAN-MITSUBISHI	950,000	1,345,570	250,000	1,000,000			
TESLA	35,580	14,192	177,941	1,049,384	1,020,296	1,337,853	2,452,519
TOYOTA	2,507,000				831,358		
Total 33,752,174	**17,674,909**	**7,950,663**	**433,465**	**2,051,111**	**1,851,654**	**1,337,853**	**2,452,519**

Credits acquired

Manufacturer	2010	2011	2012	2013	2014	2015	2016
BMW	2,000,000						
DAIMLER	3,985,580	814,192	427,941	1,000,000			
FERRARI	265,000						
FCA	11,424,329	7,090,901		1,049,384	1,020,296	1,337,853	2,452,519
GENERAL MOTORS			5,524	1,727			
JLR		39,063			831,358		
McLAREN		6,507					
Total 33,752,174	**17,674,909**	**7,950,663**	**433,465**	**2,051,111**	**1,851,654**	**1,337,853**	**2,452,519**

Just over 30 million Mg worth of credits have been traded to date under EPA's greenhouse gas program. This represents just over 10 percent of the total overcompliance with the standards thus far.

SOURCE: EPA 2018d

Table 8 shows the trading that has occurred to date. Table 9 outlines trading of credits that occurs under the simulated compliance pathways through MY2021, which is when banked credits expire and is therefore most similar to the scenario to date.

A few things are apparent when looking at the data of modeled credit trading:

1) Though manufacturers carried nearly 300 million Mg of overcompliance into MY2016, the vast majority of those credits are utilized by the earning manufacturers, with our modeled manufacturer trading resulting in only 54 million Mg of utilization by manufacturers other than those who earned the credits through overcompliance (18 percent).

TABLE 9. Modeled manufacturer-to-manufacturer trading MY2016-2021 using banked credits

Credits dispursed

Manufacturer		2010	2011	2012	2013	2014	2015	2016
FORD				386,226		751,885	980,697	
HONDA		100	911,989	2,346,013	2,297,323	1,881,029	2,052,383	
HYUNDAI		4,890,103	4,012,969	348,728	353,607	75,430	54,131	
KIA			1,726,043					
MAZDA		2,102,696	208,773	14,339				
NISSAN-MITSUBISHI		5,353,515	812,460	1,057,202	807,013	668,140	974,284	
SUBARU		1,454,845	2,106,676		1,165,481	3,001,354	1,580,583	
TOYOTA		9,232,715					1,456	
Total	**53,610,188**	**23,033,974**	**9,778,910**	**4,152,508**	**4,623,424**	**6,377,838**	**5,643,534**	**-**

Credits acquired

Manufacturer		2010	2011	2012	2013	2014	2015	2016
DAIMLER		1,867,095	1,810,307	14,339				
FCA		12,578,370	812,460	1,057,202	2,896,152	2,549,169	3,028,123	
GENERAL MOTORS		3,777,463	1,619,296	2,346,013	1,261,523	1,407,588	54,131	
JLR		4,191,367	3,122,441	608,923	5,772	2,421,081	2,561,280	
VOLVO		93,451			165,389			
VWA		526,228	2,414,406	126,031	294,588			
Total	**53,610,188**	**23,033,974**	**9,778,910**	**4,152,508**	**4,623,424**	**6,377,838**	**5,643,534**	**-**

Our model of manufacturer-to-manufacturer trading results in a level of future trades comparable to that seen to date, incorporating many of the same manufacturers on both the "dispursed" and "acquired" categories.

SOURCE: EPA 2018d

2) The manufacturers which our modified version of the model suggests would buy credits (Table 9) have nearly all already previously purchased credits from other manufacturers (Table 8). The two exceptions are Volvo, who is entering 2017 at a slight overall deficit, and Volkswagen,

whose MY2016 deficit was comparable to its remaining credit bank (EPA 2018e). Thus, the model is predicting a reasonable selection of buyers on the credit market.

3) Similarly, of those modeled as selling credits, three have run a surplus in every single one of the five years of the EPA program (MY2012-2016), and three more are sitting on three of the largest four banks of credits for overcompliance entering MY2017, indicating that such manufacturers would be in a significantly better position of compliance than their competitors. The remaining two manufacturers represent just 7.5 percent of credits traded between manufacturers.

(d) NHTSA does not model credit carryback for compliance

Manufacturers are able to maintain a deficit for up to three years before they are required to offset the deficit, assuming no credits are already available to offset the deficit (40 CFR § 86.1865-12(k)(8)(i)). This allows manufacturers to offset past shortfalls with future overcompliance, a provision known as credit "carryback".

In the peer review of the Volpe model, this issue was raised by one of the reviewers, Wally Wade: "It has been my experience in the corporate compliance world that manufacturers do use carry back" (NHTSA 2018f, p. 47). To this suggested change, NHTSA responded that "thus far, Volpe Center staff have not attempted to include simulation of credit carry-back in the CAFE model, but have provided some of the placeholder material with a view toward potentially doing so in the future if we decide that it is appropriate to consider.

The Volpe model used in the two prior rulemakings has considered this flexibility in its approach to multiyear modeling.[29] Nowhere in the modeling documentation (NHTSA 2018b) is it explained why NHTSA has abruptly discontinued support of this method of compliance—in fact, in the source code itself, it is explicitly called out as a failure of the EPA compliance module but not the CAFE module.[30]

The implication of this failure is that manufacturers are generally incentivized to overcomply, regardless of whether carrying forward a deficit to be compensated by later overcompliance would be a more cost-effective method of compliance. Manufacturers such as Jaguar-Land Rover and Volvo are currently carrying forward deficits under the EPA greenhouse gas program (EPA 2018e), indicating that this is a strategy manufacturers are choosing to take in order to reduce compliance costs—by eliminating this pathway, the Volpe model both reduces the use of credits to offset deficits and, as a result, forces more technology adoption by manufacturers than would be expected under the most cost-effective compliance strategy.

(3) Conclusions on credit inefficiencies

The laundry list of flaws listed above for how the Volpe model handles credits speaks directly to the question of whether the model accurately reproduces rational behavior for how manufacturers would comply with the standards—put simply, it does not.

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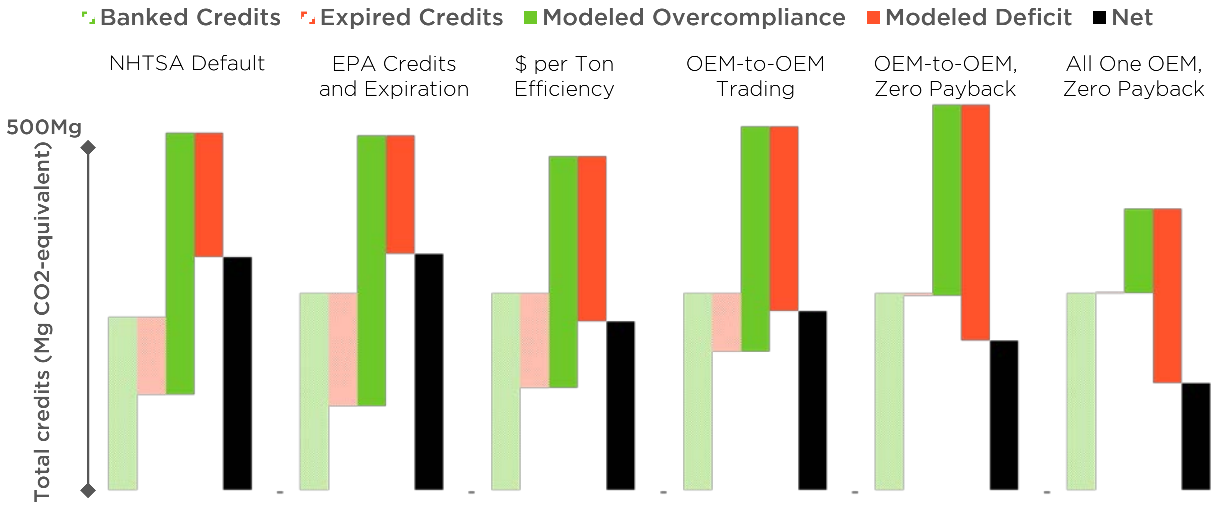
[29] See CT_CarryBackward() method in CreditTrading.cs of NHTSA 2012b, 2016b.

[30] `CreditTradingCO2.cs` ln 18: "`Stages 3 and 4 (carry back and mfr trading) are not supported.`"

FIGURE 9. Credit balances under compliance with current standards through 2025



Compliance with the Baseline Standards using the Volpe model with different modifications helps illustrate the different suboptimal strategies the model utilizes for manufacturers and how that can be corrected through modification. Under improvements in credit trading, increased prioritization of credits, and improved algorithm for assessing technology efficiency, it is possible to reduce aggregate overcompliance by more than half (54 percent).

Given the constraints of the model's design and implementation, as well as the limited window of time to incorporate any modifications into our comments, it is not expected that these modifications can solve all of the irrational behavior in the model. Much of the limitations on credit use ultimately come down to artificial limiting behaviors intrinsic to the design of the Volpe model itself, such as the inefficient and irrational way in which it applies technologies across the fleet. However, it is possible to try to describe how much more efficient these modifications make the model.

Because of the 3-year carryback, compliance with 2025 regulations does not need to be finalized until 2028. However, any credits earned and unused through 2028 represent overcompliance—these are credits in excess of what was necessary for manufacturers to comply. A perfectly rational manufacturer would achieve zero overcompliance in an ideal scenario—one would expect that a model such as Volpe would be targeting precisely this ideal, since it is unencumbered by the uncertainty which may cause manufacturers to hedge against doing the barest minimum for compliance (i.e., maintaining a buffer as insurance against unanticipated shifts in the market). However, it is clear that the target would be minimization of this overcompliance as much as possible, since such credit is wasted technology expense.

Figure 9 depicts credit activity while complying with the 2025 Baseline Standards,[31] under different modifications to the Volpe model: 1) the default scenario; 2) utilizing EPA's actual credit bank and one-time carryforward exemption (Appendix A-3); 3) modifying the efficiency algorithm to weight

[31] Credit balances shown are through 2028, the last year in which manufacturers would be able to use carryback to comply with the 2025 standards.

technologies on \$/ton reduction (see Section I.A.2.b)(3) and Appendix A-2); 4) using \$/ton and allowing manufacturers to trade with each other to lower overall industry compliance costs (Appendix A-4); 5) including manufacturer-to-manufacturer trading while eliminating manufacturers' application of technology while in compliance;[32] and 6) perfect trading[33] while assuming no application of technology while in compliance.

There is little difference in net credit usage between using the more accurate credit bank (2) and the NHTSA default (1)—this is because credit utilization in the early years is limited by the lack of deficits, so while there are more credits available, those credits are simply forced to expire due to limitations of the Volpe model provided with the NPRM. This is a similar issue when modifying the efficiency algorithm (3); however, shifting the algorithm to \$/ton decreases the amount of overcompliance in all years, allowing for greater reliance upon credits. Enabling trading between manufacturers does not drastically shift the net credit usage, but it has the effect of shifting overcompliance to manufacturers with lower marginal costs and therefore allowing those manufacturers with greater costs to generate greater deficits to be offset with credits purchased from other manufacturers. By assuming that manufacturers will not adopt any technology voluntarily, it is possible to eliminate virtually all expiration of credits entirely, since it is this Volpe model assumption that is preventing deficit generation prior to the expiration of the banked credits—this also helps reduce unnecessary levels of overcompliance. Assuming a perfect model of trading between manufacturers ensures even more efficient technology adoption to reduce industry costs. In total, these factors help cut the net "extra" credits accrued through 2028 in half compared to the unmodified Volpe model (a 54 percent reduction).

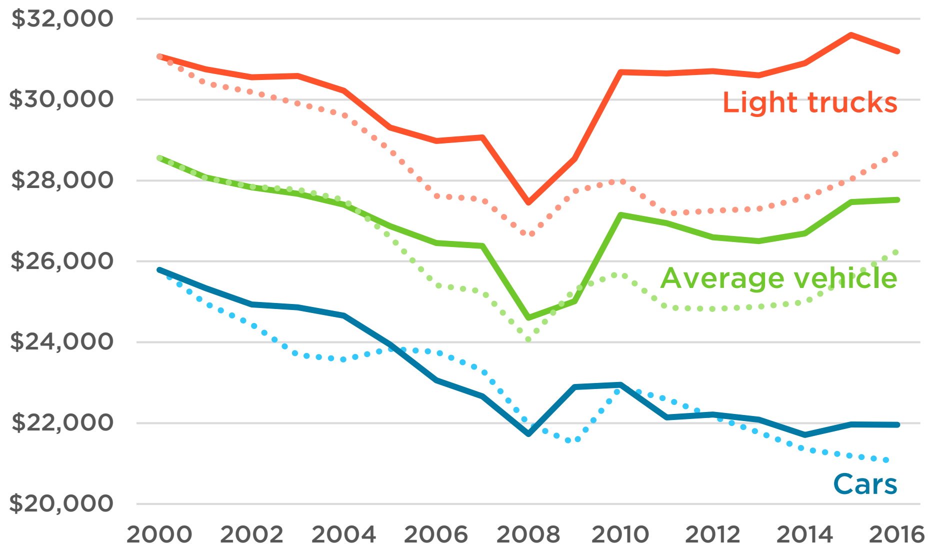
As a result of this more reasonable (yet still sub-optimal) assessment of credit trading and usage within the Volpe model, the industry's total cost of compliance with the current standards is ***reduced by \$60 billion***, or 16 percent of the agencies' modeled technology costs (MY2016-2028). Compliance with the agencies' Preferred Alternative ("rollback") is reduced by \$30 billion, a reduction of more than one-third of the total cost (34 percent)—these reduced costs of compliance for the rollback are only 6 percent greater (\$3.1 billion) than what the agencies project manufacturers would adopt without any standards in place, emphasizing that these standards are nowhere near maximum feasible.

B. The agencies have underestimated the social and economic benefits of fuel economy and greenhouse gas emissions standards

Footprint-based fuel economy and greenhouse gas emissions standards increase consumer choice, ensuring that the vehicles available for purchase in every vehicle class continue to get more efficient. This results in both greater investment and jobs in the automotive sector and fuel savings which can be reinvested in more job-creating sectors than the oil industry. It also improves consumers' overall outcomes by increasing resiliency in a volatile oil market.

[32] To restrict the voluntary adoption of technologies, we restrict manufacturers' assumed consumer payback to zero. This means that the only technologies adopted while in compliance are those with negative cost to a manufacturer and positive greenhouse gas benefits.
[33] Perfect trading is defined here by treating all manufacturers as a single entity—while each manufacturer maintains their unique platforms, this allows the model to determine the lowest cost pathway for the industry to follow as a whole.

FIGURE 10. New light-duty vehicle price, by class, in constant dollars (2007$)



A comparison of the prices for new light-duty vehicles (solid lines) and the expected consumer price based solely on improvements in quality (dotted lines; see BLS n.d.). The price for new cars largely maps the improvements in quality, but a growing gap appears in the light truck segment, which is increasingly mirrored in the new average vehicle price as the share of light trucks has increased.

SOURCE: UCS ANALYSIS, BLS 2016, BEA 2017 TABLE 7.2.5S

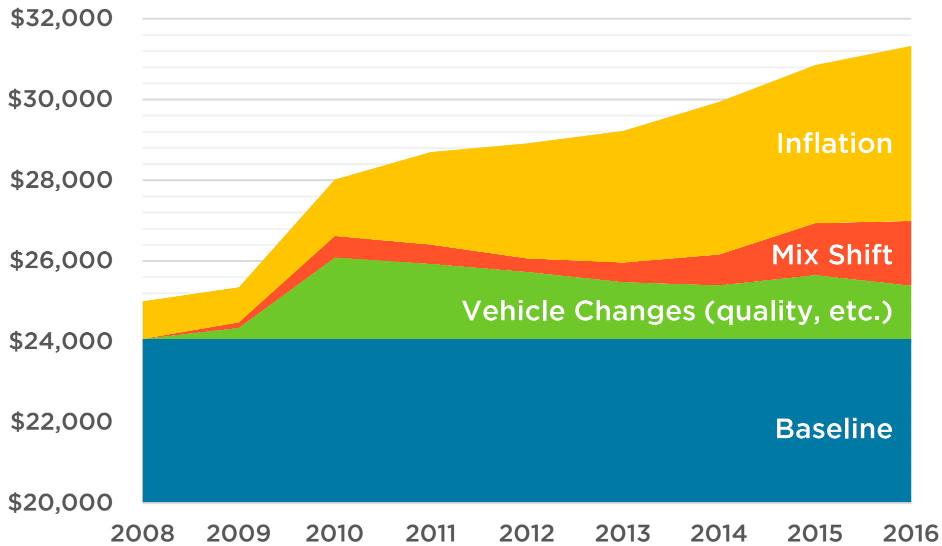
The agencies have greatly underestimated consumers' interest in and willingness to pay for these fuel-efficient vehicles, while ignoring additional benefits many of these technologies provide, leading to a significant overestimate of any potential negative impact on sales which could result from new standards. They have also greatly overstated the degree to which manufacturers will incorporate these technology costs into vehicle price, further overstating any potential impacts on sales.

Finally, they have mischaracterized the impact of new vehicle sales on transportation behavior overall, wildly overestimating social impacts by utilizing an inaccurate, untested model which has neither been peer-reviewed nor is consistent with established literature in this space. Such extrapolation not only leads to incredible erroneous results—it violates basic economics.

1. *Agencies overestimate costs to consumers and underestimate consumer benefits of stronger standards*

The agencies have requested comment "on the relationship between price increases, fuel economy, and new vehicle sales" (83 FR 43075). We demonstrate that increasing fuel economy standards have not led to the vehicle purchase price increases modeled in the agencies' proposal. Relative to inflation, the cost of the average new vehicle has not increased significantly over the past two decades. In fact, for new cars, the average retail price has increased at a rate less than inflation and essentially matches any

FIGURE 11. Average new light-duty vehicle price to consumers for 2008-2016



An examination of the factors underlying the recent nominal price increases of the average new vehicle. It is clear from the data that general inflation is the greatest factor, but mix shift plays a greater role than improvements in the vehicle related to compliance with the fuel economy and greenhouse gas standards.

SOURCE: UCS ANALYSIS

changes in price one would expect for improvements in quality (Figure 10).[34] This supports previous agency conclusions that "the low-priced vehicle segment still exists…[but] appear to be gaining more content" (Section B.1.6.4, EPA 2016e). This has also been affirmed by recent work from Consumers Union (Comings and Allison 2017).

Even in recent years, when there has been a slight increase in the average new vehicle transaction price, the cost of compliance is a small fraction of the total increase. Since the first phase (MY 2012-2016) of the coordinated CAFE and Greenhouse Gas Emission Standards were set in 2010, the largest contribution to price increases by far is inflation, as indicated in data from the Bureau of Labor and Statistics, which tracks changes to vehicle price over time (BLS 2016). Figure 11 shows vehicle price from 2008 to 2016, broken down into the major contributions to total price:

- Baseline: This is the cost of the average new 2008 vehicle, in 2007$ (as determined by OECD 2017).
- Vehicle Changes: These are improvements to the vehicle over time, including improvements in quality, safety, or additional features like entertainment technologies.

[34] Here we define quality in the same way as the Bureau of Labor and Statistics, which tracks in detail prices paid by manufacturers and consumers for vehicles and considers factors including improvements related to increased fuel economy, safety, and both standard and optional equipment (BLS 2016b).

- Mix Shift: The average vehicle is a mix of cars and light trucks—because the sales of light trucks has increased, and the average price of light trucks well exceeds that of cars, mix shift has significantly raised the average transaction price (Zummallen 2017).
- Inflation: This represents the different in price in constant dollars (2007$) compared with what the consumer actually sees, which is nominal dollars. As noted in BLS 2016, manufacturers see the cost of inflation in supplied parts and pass that on to consumers.

The average new vehicle price to consumers rose from $25,536 in 2008 to $31,394 in MY2015 (nominal$), which equates to a difference of $2,862 in 2007$.[35] As indicated in Figure 11, nearly half of this difference is directly related to the mix shift, which at $1,277 (2007$) is actually larger than the cost of compliance with the regulation assessed in the previous section. This is consistent with previous agency discussion of price increases noting the significant impacts on transaction price from factors such as the mix shift or additional push towards high-end trim packages (Section B.1.6.2, EPA 2016e). This result is further reinforced by analysis from Baum and Associates that showed the rise in high-end trim packages over this time period (Baum and Luria 2016).

2. Agencies inconsistently evaluate and arbitrarily utilize consumers' willingness to pay for fuel economy technologies to generate predetermined, conservative outcomes

The agencies have requested comment on the degree to which consumers value fuel savings, and to what extent they should consider the value of fuel savings as a social good (83 FR 43074). They also request comment on how to incorporate such estimates into the rulemaking (83 FR 43180). It is clear from the literature that there is vast uncertainty about consumers' willingness to pay (WTP); however, the agencies appear to incongruously rely upon conclusions about WTP and inconsistently apply the literature in order to consistently produce more conservative results.

A) ESTIMATES FROM THE LITERATURE

There have been a number of studies that explore purchasing decisions examines a consumer's WTP for different attributes, including a recent literature review funded by EPA (Greene et al. 2018). These studies help to illuminate the relative values that consumers place on different choices in a purchase and whether they are willing to pay more for performance or fuel savings, in particular. This latest analysis shows that there is wild inconsistency in the results of these studies—nearly every attribute had a WTP whose average value was less than the standard error in the estimate (Greene et al. 2018). Not only does this show that there is no consensus in the literature regarding WTP, but it provides a strong warning to anyone about "cherry-picking" a particular study or analysis on which to draw conclusions.

A recent study paid for by the auto industry (Carley ***et al.*** 2017) acknowledges the broad assessment in the literature, citing both recent work that indicates myopic consumer behavior and work which "find[s] very little evidence" of such behavior (Section 4.8222). At the same time, the authors recognize the difficulty in trying to infer future consumer behavior based on past market behavior—for example, they find that hybrid sales fall below what one would expect from a rational consumer model, but they

[35] Here we have used the Bureau of Economic Analysis data from Table 7.2.5S, weighting average new car and new truck expenditure to consumers (lines 46 and 22) by the relative sales volumes to consumers.

cannot distinguish between whether that is because of an undervaluation of fuel savings or other characteristics of the hybrid vehicle which perhaps do not make the comparison truly "performance neutral" (Section 4.8222).

This perspective seems consistent with the view of the National Academies of Science, which noted that "to support effective policy making, a much better understanding of how markets and technology will interact is likely to be highly beneficial" (NAS 2013, p. 127), but "empirical knowledge of the barriers to major energy transitions is currently inadequate to make robust assessments of public policies" (p. 129). Given such uncertainty, such analysis may be qualitatively illustrative but is not robust enough to fundamentally determine the costs and benefits of a given policy.

B) HOW THE AGENCIES HAVE INCONSISTENTLY EVALUATED WILLINGNESS TO PAY

The agencies acknowledge the uncertainty about consumers' WTP for fuel economy and other vehicle attributes (83 FR 43071; PRIA p. 943: "Published literature has offered little consensus about consumers' willingness-to-pay for greater fuel economy"); however, this result is applied inconsistently throughout their analysis.

The agencies have requested comment on consumer choice modeling (83 FR 43077)—appropriately, the uncertainty around consumer WTP is especially important with regards to consumer choice modeling, of which both agencies are well aware. EPA previously examined the possibility of marrying the OMEGA model with a consumer choice model—in the peer review for that model, significant emphasis was placed on the need for adequate caveats around the large uncertainty of the model, and one reviewer noted that "it is not possible to know whether any ***apparent*** differences in the point estimates in the baseline versus the alternative scenarios are actually substantive (statistically different from zero)" (EPA 2012). It turns out that this concern was justified—when EPA attempted to validate the predictive powers of the model, the agency found that the null hypothesis (no change in marketshare) was a better predictor of the future (Helfand et al. 2015). Similarly, NHTSA developed its own consumer choice model—it found as well that at best the model was "suitable for short-term (2-3 model years) forecasting of market response to higher standards, but longer-term forecasts require projecting changes in joint distributions of household characteristics" (Tamm 2014), which means that long-term forecasts are extremely sensitive to unknown, forecasted demographic characteristics. This is consistent with EPA's assessment on different approaches to such models: "Vehicle choice models that incorporate demographic factors and vehicle attributes may be better suited to testing across time; on the other hand, when they are ultimately used for simulation purposes, such models require projections of those demographic factors and vehicle attributes, which may not be of great reliability" (Helfand et al. 2015).

This is all consistent with the historical record on consumer choice models—one such analysis of the predictive power of these models noted "the models we construct are fairly poor predictors of future shares" (Helfand et al. 2015). Thus, trying to forecast consumer behavior in response to these standards appears at this time to be a fool's errand. Extrapolating this forecast into secondary impacts on vehicle sales seems like it would only further exacerbate this uncertainty—and in fact, that's precisely what independent evaluation of the agencies analysis concludes, finding that the agencies' outcomes are statistically insignificant based upon the uncertainty in their models.[36]

The latest Volpe model, however, treats these impacts as certain, ignoring all of the data presented above about the validity of consumer choice:

- it ignores the historical record on cross-subsidization across a fleet even while acknowledging that this is an ongoing facet of manufacturers' compliance strategies (83 FR 43083, 43222);
- it treats manufacturer assumptions on consumer payback as monolithic across all vehicles, despite acknowledged inhomogeneity in consumers and uncertainty about such valuation (83 FR 43077); and
- it relies upon extrapolated data that are statistically insignificant according to its own model.[36]

In addition to this, the agencies selectively include or exclude consumer willingness-to-pay solely in ways which increase costs to consumers and/or decrease the benefits of fuel economy and greenhouse gas emissions standards:

- Agencies assess a "cost burden" for electrification, citing scant and erroneous analysis of costs related to plug-in electric vehicles (83 FR 43084), thus causing the adoption of any such technology to result in a social cost;
- Agencies model performance improvements as a result of the application of technologies without assessing any potential benefit to consumers or reduction in cost as a result (Islam et al. 2018b), implicitly assuming that consumers do not value performance and ensuring that more technology is required to achieve reductions in fuel usage and emissions;
- Agencies assume that consumers do not value fuel economy in both developing and applying its sales and scrappage model (83 FR 43075), a declarative statement that runs counter to its argument about the uncertainty of such a proposition (and at the very least, one which merits a sensitivity analysis assuming that consumers ***do*** value fuel economy), and one which is not supported by the literature cited by the agencies (83 FR 43093);
- In contrast, the agencies have explicitly highlighted a particular subset of studies they say are better able "to isolate differences in…fuel economy from the many other attributes," noting that "these studies point to a somewhat narrower range of estimates…consistently suggest[ing] that buyers value a large proportion—and perhaps even all—of the future savings that models with higher fuel economy offer," (83 FR 43072) questioning "the degree to which private fuel savings should be considered as private benefits of increasing fuel economy standards" (83 FR 43074); and
- Agencies assume that manufacturers can recoup the costs of 30 months of fuel savings from consumers (83 FR 43179), implicitly assigning a floor to consumer WTP, but this fuel savings is ignored in its model of how consumers will respond to increasing costs, wherein it is assumed not the ***net*** cost but merely the retail price increase that factors into a consumers' decision, i.e. assigning a 0 month payback.

[36] See comments to the docket from Drs. David S. Bunch and David L. Greene.

Each and every example above serves to exaggerate the impact of increased technology costs on sales by devaluing the benefits for consumers. Such modeling is arbitrary and capricious and must be corrected before any final rulemaking.

C) THE "TECHNOLOGY COST BURDEN" ASSOCIATED WITH ELECTRIFICATION IS BIASED, INACCURATE, AND DOES NOT REFLECT THE TECHNOLOGY INCLUDED IN THE RULEMAKING

The agencies use a flawed assessment of the willingness of consumers to consider electrified powertrains, particularly their assessment of plug-in electric vehicles. A regression analysis of used car prices using MY2013 through MY2016 is used to infer a consumer's willingness to pay more for electrification technologies. However, the analysis of battery electric vehicles (BEVs) is fundamentally flawed. Tesla vehicles were excluded from the analysis, leaving only shorter range BEVs (less than 100 miles) in the analysis, since longer range BEVs from manufacturers other than Tesla (like the Chevrolet Bolt) were not available until MY2017. Therefore, the WTP metrics listed in Table II-37 of the NPRM are only applicable to first-generation, short-range battery electric vehicles, but the agencies propose to use this data to evaluate the willingness to consider ***all*** BEVs. For example, the rule states: "In general, the incremental willingness-to-pay falls well short of the costs currently projected for HEVs, PHEVs, and BEVs; for example, BEV technology can add roughly $18,000 in equipment costs to the vehicle after standard retail price equivalent markups (with a large portion of those costs being batteries), but the estimated willingness-to-pay is only about $3,000" (83 FR 43084). The BEV technology examined in the current proposed rule assumes mature 200 mile-range electric vehicles, but the agencies explicitly compare the costs of this technology to the willingness-to-pay for a 75-mile BEV. If the agencies had considered Tesla vehicles, they would likely find a much higher willingness-to-pay. Based on depreciation data, the Tesla Model S has retained more value than similar gasoline cars (NADA 2016).

3. *The proposed standards will decrease employment and reduce economic output*

The agencies have requested comment on "assumptions and approaches in the labor analysis" (83 FR 43079) as well as on the "potential for changes in stringency to result in new jobs..." (83 FR 43436). We agree with the agencies conclusion that reducing stringency will result in a loss of employment in the auto sector.[37] This is consistent both with recently observed employment trends during implementation of existing fuel economy standards as well as with independent macroeconomic analysis of existing standards through 2025 that show increasing stringency results in increased employment in the auto sector. However, the agencies fail to examine the broader macroeconomic impacts of the proposed weakening of standards. Not only will weaker efficiency and greenhouse gas standards result in automotive sector job losses as noted, but increased consumer spending on gasoline and diesel result in even greater negative economy wide impacts on labor and gross domestic product.

A) CURRENT EMPLOYMENT BENEFITS FROM EXISTING STANDARDS

The current fuel economy and greenhouse gas emissions standards have been a boon for automotive jobs, and for U.S. manufacturing jobs more broadly, as evident by the strong growth in automotive jobs since the standards were enacted. A recent 2017 study from the NRDC and the Bluegreen Alliance found that "the past seven years have constituted the first period of sustained growth in automotive

[37] 83 FR 43436: "...the reduced outlays for fuel-saving technology slightly reduce estimated U.S. auto sector labor..."

manufacturing jobs—and in U.S. manufacturing jobs as a whole—since 1999" (BGA and NRDC 2017). One-third of total automotive manufacturing jobs in the U.S.—more than 288,000 workers—are in facilities that engineer, manufacture, and supply the fuel-efficient technology that automakers use to meet the standards. The authors go on to note that EV component manufacturing in the U.S. has increased and that "[c]ontinuing this progress will be important to building U.S. jobs as the industry grows globally." Strong vehicle efficiency standards have been and continue to be critical to growing U.S.-based employment in automotive jobs, and U.S. manufacturing in general. Promulgating weaker standards would put automotive supplier jobs at risk.

Over the past five years, the auto industry has emerged from the economic crisis even while over complying with the regulations. Nearly half of the jobs added since the crisis have been in the manufacture of parts and assembly of vehicles, which remains a strong and diverse part of the American economy. Nearly 300,000 workers, in more than 1200 facilities spread across 48 states, are working to supply fuel efficiency technology to help automakers comply with these regulations (BGA and NRDC 2017).

B) POSITIVE FUTURE EMPLOYMENT BENEFITS FROM EXISTING STANDARDS

Moving forward, the existing Baseline Standards will continue to increase employment in the auto industry, as well as the U.S. economy as a whole. Analysis of federal and state fuel economy and emissions standards for model years 2017 through 2025 show that existing regulations are expected to result in an additional 122,000 job-years economy-wide by 2025 and more than 250,000 by 2035 (Synapse 2018a). Gross Domestic Product (GDP) also will increase by an estimated $14 billion in 2025 and $16 billion in 2035. These positive economic gains are a result of direct investment in the automotive industry as well as the even greater consumer fuel savings on gasoline and diesel fuel. Notably this study shows economic gains in both the short- ***and*** long-term. An earlier study by researchers from Indiana University found only longer-term economic gains (Carley ***et al.*** 2017). However, as described below, this study did not account for vehicle financing and consumer valuation of fuel economy in their macroeconomic modeling.

C) SHORTCOMINGS OF MACROECONOMIC ASSESSMENT BY CARLEY, ET AL.

The Carley study paid for by the Auto Alliance (Carley ***et al.*** 2017) also finds positive employment impacts from existing standards. The study examines the potential changes in vehicle sales from both state and federal vehicle standards as well as possible changes in employment, GDP, and income. Overall, the direction of the long-term macroeconomic impacts from vehicle standards is positive, primarily a result of fuel savings and industry investment outweighing increased vehicle technology costs, even with lower projected fuel prices than anticipate in 2012 and higher technology cost assumptions which do not reflect the most current estimates. The negative employment impacts from reduced spending in the oil and gas sectors are more than offset by reinvesting those savings in other sectors of the economy which employ more people per dollar of output (Figure 3). However, the Carley study also finds small negative near-term macroeconomic impacts resulting primarily from projected decreases in vehicle sales. There are numerous reasons why these near-term projections are questionable and do not accurately reflect the impact of vehicle standards.

The primary flaws in the macroeconomic REMI modeling by Carley et. al are related to two factors: the way in which they have handled vehicle price increases in the macroeconomic modeling and their treatment and cost estimates of the Zero Emission Vehicle program. These flaws are further compounded in their treatment of "Total Cost of Ownership" (TCO) modeling in trying to assess more specifically the vehicles sales and jobs impact on the automotive sector. These issues are outlined in full below. While the agencies have not explicitly considered this study in its analysis, it is representative of the type of macroeconomic impacts the agencies should consider, and many of the flaws contained in the report are mirrored in the agencies' own economic analysis, including an undervaluation of fuel savings benefits to consumers, lack of recognition of the importance of vehicle financing in the economic model, and lack of sufficient proof of the model's fidelity and predictability through backcasting.

Figure 8.16 in the study illustrates the range of jobs impacts projected by the researchers. While they all show a small initial decrease in employment (impacted by flawed assumptions about upfront vehicle price effects, as described in the following section), it is clear from this picture that even extremely conservative assumptions about the way in which manufacturers would comply with both federal and state light-duty vehicle greenhouse gas emissions programs results in a ***positive*** impact on the economy and leads to job growth.

This finding, of course, is in direct conflict with job loss numbers cited by the automakers in communications with the agencies (Bainwol 2017), which stemmed from the deeply flawed study by McAlinden, ***et al.*** (2016), on which we have previously commented (Cooke 2016).

(1) Concerns around IU's model of vehicle price effects

One of the curious characteristics of the REMI modeling undertaken by Carley et. al. is the fact that the 2017-2025 standards immediately result in a reduction of employment. This is a curious fact because the price increases moving forward are actually less in the initial years than we have already seen to date, so if the model were backcast, it would have predicted a reduction in employment over the past six years, contrary to the hundreds of thousands of jobs that have been created in the industry since the Great Recession (BLS 2018), not to mention the continued economic growth. While one would be tempted to argue that there could be a decrease masked by greater macroeconomic effects, it is worth noting the levels of employment reduction in the short-term the IU model predicts are quite significant compared to the magnitude of the job growth over the past 8 years.

The most apparent reason for this discrepancy can be found in Figure 8.5 of the report, which shows a large reduction in disposable personal income. For a typical loan, a new car buyer is actually saving money in fuel that is greater than the increase in loan payment, (Comings and Allison 2017) so there should actually be an ***increase*** in disposable personal income. As noted in the footnote for Table 7.11, Carley et. al. have not taken into account the financing of the new vehicles, but rather front-loaded any purchase price increases. This will significantly magnify any potential for decreases in vehicle sales and short-term job losses. Incorporating vehicle financing into the modeling would spread-out the upfront vehicle technology costs over several years instead of resulting in an immediate decrease in disposable personal income equivalent to the vehicle purchase price.

Not only are the effects of vehicle financing ignored in the REMI modeling, but consumer valuation of fuel economy benefits are also ignored. As a result, the REMI model simply assumes a negative impact in vehicle sales for a given increase in vehicle price with no accounting for the fact that vehicle purchaser will receive a return on investment in future fuel savings. The price elasticity assumed in the REMI modeling is also outside the range of recent estimates for automobile purchases (-0.30 to -1.28; see Fujita 2015) and is significantly higher than that assumed in the total cost of ownership (TCO) calculations carried out separately in the study (-1.65 for REMI modeling vs -1.0). The impact of this REMI modeling limitation is most acute in the early years of modeling since fuel savings accrue over the life of the vehicles and increase in significance overtime. Eventually, the combination of fuel savings and investment in innovation overwhelm the erroneous reductions in vehicle sales leading to long-term economic benefits.

One curious aspect of this is that the authors acknowledge these limitations of their REMI modeling and cite these limitations as a rationale for carrying out a separate TCO modeling effort (page 110). However, they have not "closed the loop" between the REMI and TCO models to ensure consistency between the results and yet still point to the short-term macroeconomic results from the REMI modeling as valid. The study authors further point to regionalized REMI results, in particular pointing out the larger negative near-term job impacts in the auto-sector heavy upper East North Central region (ES-3 and page 94). However, for the same reasons above, these results are misleading and inaccurate as they derive from incorrect assessment of the impact on vehicle sales in the REMI model.

Several of these biases and flaws in the REMI modeling and TCO modeling are pointed out in comments by Synapse Energy Economics, Inc. (Synapse 2017). Synapse points to the study's use of higher discount rates (as high as 10 to 15 percent in some cases compared standard practice of 3 and 7 percent) and above average vehicle financing interest rates (7 percent versus a current rate which is below 4.5 percent) which negatively bias vehicle sales results. In addition, analysis by the American Council for an Energy Efficient Economy (ACEEE 2017) demonstrates that with more reasonable input assumptions to TCO modeling, the impact on vehicle sales are actually positive rather than negative.

While the agencies have not relied upon Carley et al. 2017 significantly in the NPRM, they have made many of the same mistakes, including ignoring vehicle financing and consumer fuel savings in their own economic models, even while refusing to assess any macroeconomic analysis of the impacts of rolling back the Baseline Standards.

(2) Concerns around IU's treatment of compliance with state zero-emission vehicle regulations

In both the "2016 Low" and "2016 High" cases, the Carley et. al. study has included costs for ZEV compliance in line with that projected in Table 7.8 of that report. However, these values are far too high for real compliance with the program, for two clear reasons.

First, they ignore interactions between the ZEV program and the EPA program—compliance with ZEV will reduce the additional technology costs needed under EPA's program, so while the state regulations will spur adoption of the more expensive EV technology which would not occur as a result of pure minimization in the cost-curve, you would still need to subtract off the compliance costs for those technologies which are not needed. It may be that this is part of the reason why the COMET costs for EV compliance are lower than outlined in Table 7.8 (Carley et al. 2017, p. 83).

Second, Carley et. al. have incorrectly modeled compliance with ZEV based on the assumption that 16% of new vehicles sales would be required in all ZEV states by 2025 (Table 7.7). However, electric vehicles have evolved much faster than CARB anticipated, as noted in its mid-term assessment of the ZEV program: "While this revised compliance picture reflects a lower volume of vehicles than originally projected in 2012, the resultant improvements in ZEV and PHEV attributes, such as all-electric range and vehicle price, are expected to further broaden the appeal of these vehicles beyond the initial consumers and help achieve necessary future market expansion" (CARB 2017b, p. ES-7). This is further complicated by the credit glut which manufacturers currently enjoy (CARB 2017b, Figure 11). Annual sales in California are expected to be just over 140,000 total electric vehicles in 2025 (CARB 2017a, Figure 3), compared to an original projection of nearly 250,000 vehicles (CARB 2017a, Figure 2) or the equivalent of 7.5 percent new vehicle sales in CA and the 177 states by 2025. Even when combined with the annual ZEV sales in the Section 177 states (CARB 2017a, p. A-15), that amounts to a total nationwide fraction of ZEVs of 7.5% × 30% = 2.25 percent needed to comply with the state programs, less than half of the 4.62 percent assumed in the IU study. At a minimum, the cost estimates by IU for the ZEV program are at least two times too high.

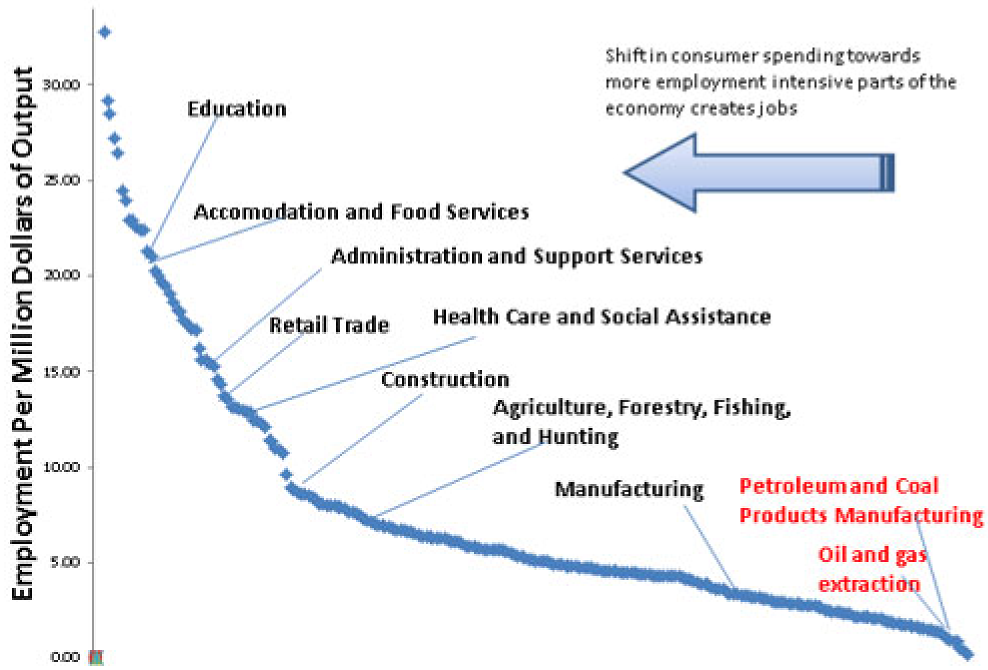
D) EPA AND NHTSA UNDERESTIMATE THE NEGATIVE EMPLOYMENT IMPACTS OF ITS PREFERRED ALTERNATIVE

A decision to weaken the standards would put jobs and the global competitiveness of U.S. auto manufacturing at risk. Strong vehicle efficiency standards provide the certainty necessary to foster investment in fuel-saving technologies. Currently, regulations are on a path that is driving relatively consistent standards around the globe (Wilson 2017). These standards in the U.S., Europe, and Asia allow automakers and their suppliers to leverage the efficiency of global platforms and powertrains, adding scale and reducing costs to lower prices and increase profits. Further, with ongoing innovation and higher volumes of fuel-saving components that are required to meet U.S. standards, domestic manufacture of these fuel-saving technologies becomes more likely. Strong standards through 2025 and beyond will help make sure that investments in technology and the jobs needed to make new components are sustained.

The agencies' NPRM analysis shows that less labor will be required in the U.S. auto industry as a result of weakened standards (83 FR 43436-7). By 2030, the agencies' Preferred Alternative results in 56,000 fewer job-years under the CO2 program (Table VIII-40) and 60,000 fewer job-years under the CAFE program (Table VIII-39) compared to the Baseline Standards. These deleterious effects on employment are the result of fewer investments in automotive technologies resulting from weaker standards.

However, there are additional macroeconomic impacts the agencies failed to examine in their analysis including those from changes in spending on gasoline and diesel. Under its Preferred Alternative, Americans will spend an estimated $20 billion more in 2025 and nearly $50 billion more in 2035 than under the Baseline Standards (Synapse 2018b). As illustrated in Figure 12, a shift in spending to the petroleum sector from other more job-intensive sectors of the economy results can results in a net decrease in employment. Economic modeling by Synapse Energy Economics, Inc finds that the net decrease in economy wide employment from the Preferred Alternative would total an estimated 60,000 job-years in 2025 and 126,000 job-years in 2035, significantly more than estimated employment decreases in the auto industry alone by the agencies (Synapse 2018b). Furthermore, reduced investment

FIGURE 12. Job intensity by economic sector



Petroleum refining and oil and gas extraction have relatively low employment levels per million dollars of economic output. As a result, a dollar saved on gasoline reinvested in the other sectors of the economy can have a net positive effect on jobs.

SOURCE: UCS ANALYSIS, BLS 2017

in the U.S. auto industry and increases in consumer spending on petroleum would reduce U.S. gross domestic product by an estimated $8 billion in 2025 and 2035.

The agencies' economic modeling is inadequate to assess the employment impacts of the proposed rules. Most importantly, it fails to include the effects of changes in consumer spending on gasoline and diesel which are much greater in magnitude than the changes in cost to the auto industry sector, which is the only economic sector examined by the agencies.

4. The agencies' cost-benefit model is fundamentally flawed

The Volpe model used to assess the cost and benefits of future fuel economy and greenhouse gas emissions standards has been drastically modified since not just the last rulemaking in which it was used, but also since the joint Technical Assessment Report (EPA et al. 2016), which showed the significant benefits of the Baseline Standards. These modifications include a complete revision of the dynamic fleet-share model, which modifies the relative marketshare of passenger cars and light trucks; doubling the "rebound effect," which reflects an increase in travel as a result of reduced costs of driving; projecting future new vehicle sales through the use of a statistical extrapolation; and projecting changes in the overall vehicle fleet as a result of changes in vehicle scrappage.

While the agencies in many of these alterations attempt to justify these modifications by pointing to peer-reviewed literature, these changes themselves have not been peer-reviewed. Moreover, many of the agencies' interpretations of the literature and the way in which this literature is reflected in the model are incorrect and frequently run counter to accepted economic theory and common sense.

Fundamentally, the completely erroneous outputs of the Volpe model underpin the agencies' proposal. Until these errors are corrected and the final model peer reviewed, reliance upon this untested and inaccurate model in its rulemaking can only be seen as arbitrary and capricious.

A) THE AGENCIES' MODEL GOES AGAINST BASIC ECONOMIC THEORY

It does not take a great economic scholar to assess the fundamentally absurd conclusions reached by the agencies' model, nor to understand why the model arrives at such erroneous results. The model separately considers new vehicle technologies, new vehicle sales, scrappage of old vehicles, and miles traveled by the vehicle fleet—despite the fact that all of these aspects of light-duty vehicle travel inherently interact. By failing to consider these interactions, the model yields fleet results which go against basic economic theory, both in the size of the total light-duty vehicle fleet and the miles traveled by these vehicles.

(1) Total light-duty vehicle fleet size

The simple explanation given by the agencies of its vehicle scrappage model is that fuel economy and greenhouse gas emissions standards will drive up the costs of new vehicles, which will in turn drive down the sales of new vehicles, and therefore result in more older vehicles remaining on the road (83 FR 43093). However, this simplistic explanation ignores the market interaction of all these terms and the fundamental economic drivers of any of this behavior.

As mentioned in Section I.B.2.b), the agencies do not consider consumers' willingness to pay for fuel economy in the sales model, even though they assume that manufacturers can recoup the costs from consumers for 30 months of fuel savings and that they believe a subset of the literature strongly supports that consumers value a large proportion of fuel savings. Therefore, any increased costs for technology result in decreased sales, thus ignoring the benefits resulting from these costs.

If increased new vehicle prices result in decreased new vehicle sales, this will in turn raise the price of used vehicles as well, due to increasing demand from buyers at the margins of the new vehicle market who will now choose to buy used vehicles. As a result of increased prices of used vehicles, those at the margins of the used vehicle market will choose not to enter the market, either holding onto a vehicle that otherwise would have been scrapped or shifting travel demand to alternative modes of transportation. While this model does suggest there could be an increase in the average age of the total vehicle fleet, because the prices of both new and used vehicles increase, there is less demand for light-duty vehicles overall, and therefore the total vehicle fleet should shrink, ***in contrast to the large growth exhibited by the Volpe model.***

If instead, consumers are enticed to the market by improvements to vehicles as a result of the standards (e.g., because they value greater fuel savings than assumed by manufacturers, as proposed by the agencies' own rationale), then vehicle sales will actually go up despite an increase in vehicle price. This added value will drive new people to the market, increasing demand for new vehicles but decreasing demand for used vehicles. Thus, used car prices will decrease, which will lead to folks at the margin to enter the used vehicle market and purchase a car that otherwise might not have occurred. This will result in an increase in the vehicle park, again counter to the agencies' model.

In both cases, the agencies have gotten the sign wrong when it comes to the impact of new vehicle sales on the total vehicle fleet by ignoring that consumers will enter/exit the market at the margins as a result of pricing effects in the market.[38]

(2) Fleet vehicle miles traveled

Even more important than fleet size is the extent to which vehicles in that fleet are driven. Here again the agencies' model leads to fundamentally irrational behavior because they have disconnected a service (travel) from demand.

Setting aside the effect of rebound, travel demand should be independent of vehicle fleet mix, being generally related to the state of the economy on the whole.[39] How that economically driven demand for transportation is shared amongst passenger vehicles and other modes of transportation is then dependent upon relative price that could relate to factors including fuel economy of the fleet. The agencies, however, do not consider travel demand as part of their modeling effort—instead, demand for travel is assumed to be directly connected to the size of the vehicle fleet, with a vehicle of a given age and model year traveling a fixed quantity of miles for the years it is on the road. As noted in the section above, because they mischaracterize the market for vehicles, the agencies get wrong the direction of the change in the fleet size—this leads to a proportional error in miles traveled.

More correct would be to recognize that it is demand for travel which fuels the car market, not the other way around.[40] As noted above, an increase in the overall price of owning a vehicle will reduce demand for light-duty vehicles. Therefore, total LDV VMT should decline in the absence of rebound, with some VMT shifting to alternate modes of transportation. However, the agencies' modeling inexplicably shows LDV VMT increasing with increasing costs, even in the absence of a rebound effect (Sensitivity Case 00, NHTSA 2018h). This is clear evidence that the model does not behave in a reasonable way.

(3) Engineering scrappage

In deriving their statistical model for scrappage, the agencies describe two separate forms of scrappage, engineering scrappage and cyclical scrappage (83 FR 43093). Cyclical scrappage stems from macroeconomic effects, while engineering scrappage is related to the useful life of the vehicle, specifically the cost to maintain a vehicle compared to its replacement (which, as mentioned above, does not necessarily mean a new vehicle but simply a substitute for its demand for travel).

By treating each aspect of the vehicle market independently, the agencies have misjudged the impact of fuel economy standards on scrappage, specifically with regards to engineering scrappage. The agencies have considered engineering scrappage to be a function of vehicle age; however, this is grossly

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[38] This argument is further elaborated upon in comments to the docket from Dr. Ken Gillingham and the Institute for Policy Integrity.

[39] In fact, the agencies even acknowledge the challenge of trying to tease out behavior related to fuel economy because of the strong dependency of sales on macroeconomic conditions (83 FR 43074). Even the agencies acknowledge that such analysis is inherently "noisy," consistent with the analysis of Dr. David Bunch (see comments submitted to the docket).

[40] For a more thorough discussion of this, see comments submitted to the docket by Dr. David Bunch.

inaccurate because engineering scrappage is largely a function of ***miles traveled***. This creates a form of diminishing returns which acts to bind the degree to which use of an older vehicle can replace miles which, in the absence of a change in vehicle price, would have been covered by a newer vehicle. Furthermore, this means that the rebound effect actually acts to accelerate scrappage in a way that is not considered by the agencies.

For example, if we compare the Baseline Standards to the Proposed Standards, the average vehicle sold in 2028[41] will achieve about 36 mpg on-road for the Baseline Standards as compared to about 30 mpg for the Proposed Standards. This difference of 17 percent in cost-per-mile leads to a 3.3 percent increase in travel according to the agencies' 20 percent rebound effect. That means MY2028 vehicles will accrue lifetime VMT 3.3 percent faster under the Baseline Standards than the Proposed Standards, meaning that for an equivalent quality of vehicle, one would expect the rebound effect to "pull forward" the rate of scrappage, something which is not considered in the agencies' model. This is consistent of course with literature cited in the NPRM (Jacobsen and van Bentham 2015), even though this effect is not discussed by the agencies.

B) THE AGENCIES' MODEL IS INCONSISTENT WITH ACADEMIC LITERATURE

In addition to yielding results that do not make sense given basic economic theory, the agencies have mischaracterized and/or misapplied much of the literature which is cited to support their modeling effort. For simplicity we focus upon the two most significant areas of change from previous rulemakings, scrappage and rebound.

(1) Literature data on modeling scrappage

While the agencies have shown a superficial understanding of the Gruenspecht effect as it pertains to scrappage, they have ignored the constraints imposed by Gruenspecht and other researchers who've adopted this. These constraints help bound the model—ignoring them leads to precisely the types of absurd behavior outlined above. Moreover, the agencies have not developed a bottom-up approach rooted in economic theory but merely a top-down mathematical fit unconstrained by economic rigor, which further explains why the model yields irrational, inconsistent results.

Though the agencies cite the Gruenspecht effect for its basis for the scrappage model, they ignore a central constraint of Gruenspecht's work—namely, his assumption that ***fleet size and total VMT are insensitive to price***.[42] Thus, it would be completely inappropriate to extrapolate the model to "slower non-replacement scrappage rates" for the exact same reason as the agencies recognized was impossible for the California Air Resources Board study (83 FR 43094-5). Similarly, Jacobsen and van Bentham themselves note that their work cited by the agencies does not estimate any impact on total fleet size and should not be interpreted as doing so.[43]

[41] MY2028 is chosen because manufacturers have a three-year carryback period for which they can rely on overcompliance to offset deficits, so therefore it will not be until MY2028 that manufacturers will have to fully comply with MY2025 standards.

[42] See comments submitted to the docket by the Institute for Policy Integrity for further detail.

[43] See letter submitted by Drs. Mark Jacobsen and Arthur Van Bentham to the agencies: EPA-HQ-OAR-2018-0283 and NHTSA-2018-0067-7788.

While the agencies acknowledge that the Gruenspecht effect is only relevant to "any increase in price (net of the portion of reduced fuel savings valued by consumers)" (83 FR 83093), the agencies do not recognize this constraint in their modeling of the effect. This is grossly negligent behavior. Furthermore, two additional studies cited by the agencies emphasize the importance of adjusting for quality improvements (Bento et al. 2018, Greenspan and Cohen 1996)—in fact, while the agencies explicitly chose not to use the new vehicle price index (PRIA, p. 1017-8), Greenspan and Cohen 1996 emphasized that Parks 1977 (which the agencies also cite) shows clearly that the ratio of the new vehicle price index to the cost of repair index is "highly significant in explaining total scrappage." Thus, the agencies are not only not justified in using transaction price data in their model, but they are 1) explicitly going against what the literature utilizes and 2) potentially ignoring a critical factor to assess rates of scrappage as a result.

(2) Rebound

The agencies have selectively culled the literature data used to support a 20 percent rebound effect and, in many cases, have misinterpreted and/or mischaracterized the basis for this data. Furthermore, by giving the studies selected equal weight, the agencies have neglected to actually interpret or consider the robustness and applicability of the various data, choosing to list a range of values without consideration of merit. This is why experts in the field "urge the agencies to adopt a more rigorous approach to evaluating the recent literature."[44]

One example of the way such an approach results in erroneous data can be found in the subset of papers by Dr. Kenneth Small, et al.—in Table II-44 the agencies claim that Hymel and Small 2015 yields a "range of estimate" of 18 percent, when in fact as Dr. Small himself pointed out, "it finds a long-run rebound effect of 18 percent under a simpler model but 4.0 percent or 4.2 percent under two more realistic models that are supported by the data."[45] The agencies have similarly misinterpreted the work of Dr. Kenneth Gillingham, citing a 2014 report with a range of 22 to 23 percent which the author himself notes "is inappropriate to use for the rebound effect" in place of Gillingham 2011 (with a rebound estimate of 1 percent) and Gillingham, et al. 2015 (yielding an estimate of 10 percent).[46]

In addition to misinterpretation of the data, the agencies have included a significant number of less relevant studies (such as those studying the rebound effect in Europe) and have ignored a number of more recent studies.[46] Similarly, in a number of instances the agencies have included the same papers as were included in previous rulemakings but have inexplicably come to different conclusions.[47] Taking all of this into account, the data is much more supportive of a rebound effect of no more than 10 percent.

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[44] Quoted from the letter of Dr. Joshua Linn to the agencies (EPA-HQ-OAR-2018-0283-1642 and NHTSA-2018-0067-7188); however, the comment submitted to the docket by Dr. Kenneth Gillingham echoes the remark.
[45] See letter from Dr. Kenneth Small, submitted to the docket; EPA-HQ-OAR-2018-0283-2698 and NHTSA-2018-0067-7789.
[46] See comment submitted to the docket by Dr. Kenneth Gillingham.
[47] See comment submitted to the docket by EDF et al. (including UCS).

C) IMPLICATIONS OF THESE FLAWS ARE VIRTUALLY THE ENTIRE PURPORTED "BENEFIT" OF THE STANDARD

The impact of these untested and deeply flawed models are significant—the vast majority of the net benefits identified by the agencies are net benefits which are purported to accrue not to vehicles explicitly covered by the regulation, but vehicles already on the road today. That these benefits are included at all is legally questionable, and the net social benefits of the agencies' Preferred Alternative on the vehicles actually covered by the Proposal are actually negative relative to the Baseline Standards (83 FR 43434-5).

C. Agencies mischaracterize the relationship between fuel economy and greenhouse gas regulations and other federal laws

The agencies have heavily relied upon an argument that safety is a main reason to rollback the fuel economy and greenhouse gas regulations. However, this argument is heavily overstated due to flaws in the Volpe model, and the agencies further ignore the benefits to public health and welfare due to state Zero Emission Vehicle policies which the Proposal eliminates.

1. Agencies have mischaracterized the impact of fuel economy and greenhouse gas emissions standards on safety

The agencies have noted "safety" as a key benefit of the proposal (e.g., 83 FR 42995); however, as has been emphasized in Section I.B.4, the model underpinning these assertions is deeply flawed. Moreover, the impacts which the agencies characterize as "safety" stem primarily from consumers driving less[48] (and therefore crashing less), which the agencies themselves acknowledge is a net cost of the proposal (83 FR 43067). The agencies' own analysis shows that the sales and scrappage model, which are in conflict with basic economic theory, represent 93.5 percent of the total fatalities presented in the Proposal (83 FR 43148). Historically, fuel economy standards have been shown to yield a net safety ***benefit*** (Bento et al. 2017)—while the agencies cite this paper in the Proposal (83 FR 43016), they have not sufficiently explained why this would no longer hold true.

2. Agencies have erroneously ignored the interaction between Zero Emission Vehicle standards and federal requirements of the Clean Air Act

Electrification of the light-duty vehicles has been identified by CARB and regional air quality control boards as a key strategy to meet federal ozone and particulate matter standards. California's San Joaquin Valley and South Coast air basins are classified as nonattainment areas for both PM and ozone, including an extreme nonattainment status for the 8-hour ozone standard in the San Joaquin Valley. The proposed rule correctly notes that "California continues to be in widespread non-attainment with Federal air quality standards" (83 FR 42999). While the fleet tailpipe LEV III standards serve as a limit on direct vehicle emissions, ZEV standards provide additional criteria pollutant reductions from upstream emissions reductions such as refining, fuel transportation, and refueling operations. In the 2015 CARB waiver application for the Advanced Clean Cars regulations (including ZEV), the Board

[48] See comments submitted to the docket by the American Council for an Energy-Efficiency Economy, which notes that the overall safety of the fleet remains fairly flat, in spite of the agencies' incorrect assessment of the impacts of mass reduction. This leads to changes in VMT being a far more substantial factor in the total number of fatalities in the Proposal.

estimated that ZEV regulations would by 2030 reduce smog-forming criteria pollution in the state by 10 tons per day beyond the LEVIII tailpipe standards alone (CARB 2012, p. 16).

Given the continuing challenges California faces in reducing both criteria and climate pollution, it is entirely inconsistent with the Clean Air Act to impede or remove regulations that will lead to significant reductions in air pollution. Because of the need for the state to address both air quality and climate pollutants, the EPA has approved over 100 waivers, including five waivers or in-scope determinations allowing ZEV regulations (EPA 2017d). There is no evidence in the proposed rule that disproves the benefits of the ZEV program for public health and reduction of climate changing pollution, and therefore no basis for the unprecedented withdrawal of the properly granted waivers.

The ZEV program is designed to complement other pollution control standards by ensuring that light-duty vehicles move from combustion-based engines to inherently cleaner electric drive motors. ZEVs result in lower emissions even when upstream emissions from electricity generation are considered. For example, the average plug-in vehicle in California produces global warming emissions equal to a 109 MPG gasoline car, when considering the emissions from driving, gasoline production, and electricity generation. Criteria air pollution is also reduced by switching from gasoline to California's increasingly clean electricity, both from the reduction in tailpipe emissions and reduced gasoline refining and transport within California. Overall, CARB projects that electric-drive vehicles would displace on-road vehicle emissions of over 1,200 tons per year of reactive organic gases and 720 tons per year of NOx by 2030 in California alone. For these reasons, California's State Implementation Plan for Federal Ozone and PM2.5 Standards relies heavily on electrification programs like the ZEV regulations and the local air districts in the state are reliant on these state-level standards to control mobile source pollution. For example, the San Joaquin Valley Air Pollution Control District's 2016 Plan for the 2008 8-Hour Ozone Standard relies on reducing mobile source emissions 70 and 76 percent for reactive organic gases and NOx respectively. In the South Coast AQMD, the plan to meet NOx emissions targets relies on 100 percent adoption of the SULEV-20 standard by 2031, significant increases in vehicle electrification (approximately 40 percent of new car sales), and an additional 5 tons per day of NOx reductions from the light duty fleet that have yet to be identified. Impairing California's ability to move forward with vehicle electrification standards would make an already difficult air quality problem even harder to solve.

D. Agencies mischaracterize the need for the nation to conserve energy

The fourth factor in setting maximum feasible standards, "[t]he need of the nation to conserve energy" includes the issues of consumer costs and fuel prices and environmental implications such as climate change (42 FR 63184, 63188). However, the NPRM states: "Given the discussion above, NHTSA of the U.S. to conserve energy may no longer function as assumed in tentatively concludes that the need previous considerations of what CAFE standards would be maximum feasible" (83 FR 43216). We fundamentally disagree with this assessment on all counts. The United States is still consuming millions of barrels of oil every day; consumers are spending billions at the pump every year; and climate change is threatening our communities and our planet. NHTSA has completely misunderstood the implications of a global marketplace for oil and the stabilizing role fuel economy standards can play in reducing demand and therefore limiting the United States' economic exposure, and it has similarly exaggerated the benefits of increased U.S. production of tight oil (Bordoff 2018).

Compared to the augural fuel economy standards and baseline greenhouse gas standards the agencies' preferred alternative would:

- Increase consumer spending on gasoline by about $20 billion in 2025 and nearly $50 billion by 2035 (Synapse 2018b);
- Increase oil consumption by about one million barrels per day in 2040, or a cumulative total of 200 billion gallons of gasoline by 2040—that's as much oil as we've imported from the Persian Gulf since the standards were first finalized in 2010 (Cooke 2018a); and
- Increase global warming emissions by 2.2 billion metric tons by 2040, equivalent to keeping 43 coal-fired power plants online (Cooke 2018a).

We strongly encourage the agencies to look beyond the temporary dip in oil prices and scarcity and to commit to creating a future in which we live in healthier communities, prosper from a strong economy, and help safeguard our planet against the disastrous effects of climate change. Cutting our oil use also means that we have an insurance policy against oil price shocks and the dramatic rise in prices and economic impacts that accompany them.

II. The agencies' proposal suffers from critical legal errors

The Proposal's legal underpinnings are badly flawed and flatly incompatible with the requirements set forth by Congress in the Clean Air Act, the Energy Policy Conservation Act, the Administrative Procedure Act, and several other statutes. Detailed accountings of these errors are available in the joint legal comments (supplied by UCS, the Environmental Defense Fund, and other NGOs) in response to both the Proposal and its Draft Environmental Impact Statement. UCS joins these comments in full and incorporates them here by reference. For purposes of the below submission, however, UCS highlights four particularly egregious oversights in the Proposal's legal analyses.

A. Withdrawal of the California waiver would be unprecedented, unwarranted attack on state authority

The Proposal illegally withdraws the waiver for more stringent GHG and ZEV standards initially supplied to California and later adopted by several states under Clean Air Act Section 177. EPA's efforts on this score are a direct affront to the citizens of those states, to their sovereign governments, and to Congress, which drafted the Clean Air Act and its amendments to ***encourage*** novel means of safeguarding human health and welfare. It is therefore unsurprising that the revocation authority recently "discovered" by EPA exists nowhere in the statute itself or in any "inherent" agency powers. ***See Util. Air Reg. Grp. v. EPA***, 573 U.S. 302 (2014) ("We expect Congress to speak clearly if it wishes to assign to an agency decisions of vast economic and political significance.") (quotation omitted). And even if EPA possessed the authority to strip California citizens of decades-old environmental protections, revocation in this instance is patently illegal, since the waiver at issue represents an unassailable judgment by local decisionmakers that cleaner cars will meaningfully protect their communities from both local pollutants and the worst effects of global climate change.

B. Vehicle emission standards are not inherently fuel economy standards and therefore are not pre-empted by EPCA

The Proposal unlawfully contends that EPCA preempts the Clean Air Act and thus permits the EPA to shirk its obligations under Section 209 of that Act. But for over four decades, Congress has consistently tailored EPCA to preexisting requirements in the Clean Air Act, not vice versa. That is why EPCA's plain text, its volumes of legislative history, and agency practice to-date ***predicate*** NHTSA's fuel economy standards on independent scientific judgments concerning human health. EPA's sudden and misguided supplication to NHTSA on this score not only disregards almost a half century of authority across all three branches of government, but also misapprehends rudimentary concepts like the relationship between "fuel economy standards," "actual fuel economy," and "emissions standards." These threadbare readings of federal law and transportation policy fall well short of the demanding standard for statutory preemption. ***See, e.g.***, ***Blanchette v. Conn. Gen. Ins. Corps.***, 419 U.S. 102, 134 (1974).

C. Zero Emission Vehicles standards are not inherently fuel economy standards and therefore are not pre-empted by EPCA

The ZEV program in particular is mischaracterized by the agencies as a fuel economy regulation. The ZEV regulation is part of the Advanced Clean Cars (ACC) regulations, which are permissible motor vehicle emissions regulations, designed to limit generation of criteria air pollutants and global warming emissions. The ZEV regulation is designed to encourage the necessary development of technologies to meet target in the California's air quality attainment plans and reduce the harmful emissions of climate-changing pollutants. The regulations also provide surety for infrastructure and component providers that the needed technology will be sold and deployed. As such the regulation requires the adoption of technologies that eliminate or reduce combustion, irrespective of the impacts on fuel efficiency. Credits are assigned in the ZEV program for the inclusion of certain low emissions technologies, not on the elimination or reduction of fuel use. For example, ZEV-compliant plug-in hybrids receive credits solely based on having qualifying electric drive systems and the electric range of the vehicle. The efficiency of the plug-in hybrid's engine (and therefore the fuel economy of the vehicle) is not considered in the ZEV regulations, as this part of the ACC regulations only consider the deployment of advanced technologies.

Underlying the ZEV program is an understanding that switching vehicles from petroleum-based fuel combustion to electric drive allows for the use of low-carbon and non-combustion energy sources. Electric drive systems (both plug-in and fuel cell) allow vehicles to be powered by a number of clean sources, like solar, wind, and hydroelectric power. The ZEV regulation requires the inclusion of technologies that allow for this switch to reduce air pollution and GHG emissions but does not mandate the fuel economy of these vehicles.

D. The technical basis for the Proposal is fundamentally flawed

Particularly relevant to these comments (and to UCS' mission), the Proposal is consummately irrational and anti-scientific, the product of agenda-driven decisionmaking instead of reasonable disagreements as to the underlying data. To take only a few examples, the Proposal conspicuously overlooks well publicized developments in relevant automobile technology, substitutes political for expert judgments vis-à-vis consumer behavior, and deploys an untested scrappage model with no "rational relationship to the real world." ***W. Va. v. EPA***, 362 F.3d 861, 866–67 (D.C. Cir. 2004) (quotation omitted). Taken individually, any one of these many mistakes would suffice to render the agencies' radical prescriptions for fuel economy arbitrary and capricious. Together, the mistakes corroborate an unlawful effort to "cloak . . . fiat judgments" in agency expertise, and render the Proposal void on its face. ***Tennessee Gas Pipeline Co. v. FERC***, 926 F.2d 1206, 1211 (D.C. Cir. 1991).

III. Additional requests for comment

The agencies have requested comment on a number of issues which do not have a significant impact on the merits of the Proposal—we have included our input on a select number of those requests below. Had the agencies granted respondents additional time for comment, as requested, we would have been able to respond to a number of other requests for comment.

A. Incentives for autonomous and connected vehicle technologies

EPA has requested comment on flexibilities and incentives related to autonomous and connected vehicle technologies (83 FR 43464). The evidence to-date does not warrant incentivizing such technologies—there is no provable environmental benefit of such technologies, and the agencies have previously correctly acknowledged that any such potential impacts would be related to indirect benefits, which raise serious concerns about compliance and enforcement to ensure the integrity of the program.

1. Autonomous and connected vehicle technologies do not directly reduce emissions

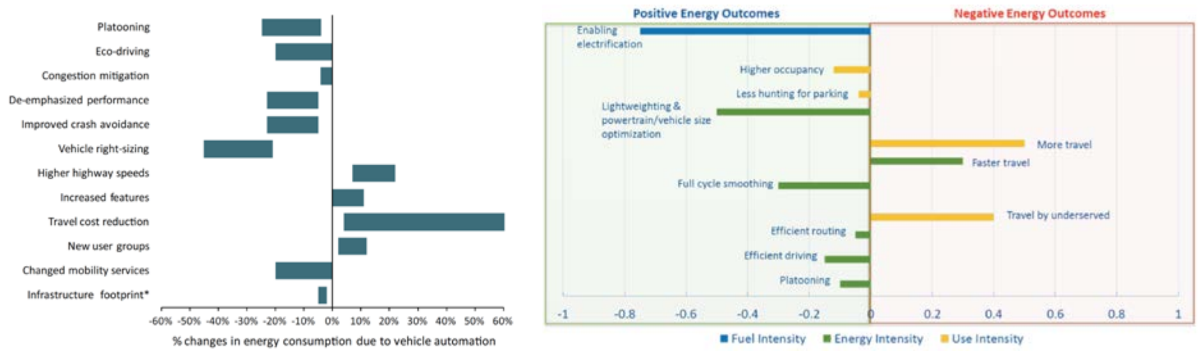
Technologies which could improve the transportation system include those related to safety, such as crash avoidance or lane-departure, as well as features that are better described as semi-autonomous or autonomous vehicle features, ranging from SAE Level 1 features that are widespread in the marketplace like adaptive cruise control to SAE Level 5 full automation which at present does not exist.

It should be emphasized that while these features ***could*** improve the efficiency of the transportation system, it is by no mean guaranteed to be the case. This has been explained at length in studies such as Wadud et al. 2016 (Figure 13a) and Brown, Gonder, and Repac 2014 (Figure 13b), which illustrate much of the range of uncertainty around potential (dis)benefits of vehicle automation.

In nearly all technology scenarios, impacts to energy consumption could be relatively small, and in many potential scenarios, there may actually be a net energy increase, especially for fully automated vehicles which could significantly increase the amount of miles of travel for the fleet.

Given these uncertainties, it seems particularly problematic to credit manufacturers for reductions which "might" happen. Such a credit program would be akin to the flex-fuel vehicle credit granted under CAFE for many years, which was supposed to lead to reductions in oil consumption but instead led to an ***increase***, as manufacturers were able to comply with less efficient vehicles than would otherwise have been required and the widespread use of bio-based ethanol as a fuel (E85) never materialized (Jenn, Azevedo, and Michalek 2016).

FIGURE 13. The uncertain impacts of autonomous vehicles



Numerous studies indicate the inherent uncertainty surrounding the impacts on energy and emissions from the adoption of autonomous vehicles. Differences in future technology and use could result in dramatically different possibilities; as such, it would be imprudent to credit such potential technology (dis)benefits with such wildly uncertain outcomes.

SOURCE: WADUD, MACKENZIE, AND LEIBY 2016 (LEFT) AND BROWN, GONDER, AND REPAC 2014 (RIGHT)

Furthermore, crediting a manufacturer for the use of a technology creates an inherent asymmetry—today, we do not credit a vehicle based on whether it is sold to a driver with a "lead foot" or whether it is sold to a hypermiler, and yet driving behavior can affect a vehicle's fuel use and emissions by nearly 30 percent (Dunkle Werner 2013). Similarly, the agency should not credit a vehicle for the use of a "computer driver" without similarly discrediting a manufacturer for all of its owners' inefficient driving behaviors as well.

Finally, the data previously provided by manufacturers (e.g., Mercedes 2011) is at odds with the evidence to-date. For example, Mercedes noted in its comments on the 2017-2025 FRM that lane-assist and crash avoidance technologies were becoming widespread, and indeed we are seeing that across the industry. However, in that same timeframe, vehicle miles traveled have increased and the rate of traffic fatalities (per mile traveled) has increased (FHWA 2016), and congestion has ultimately gotten worse (FHWA 2017), increasing real-world emissions. While this does not necessarily speak to the efficacy of the technology itself, it may be that features being deployed by manufacturers such as increased infotainment may be creating a countervailing effect by increasing distracted driving (AAA 2017), and again shows the inherent asymmetry problem in such credits. Either way, there is no strong basis for the proposed "congestion reduction credits", and the agencies should continue not to credit them under the fuel economy and emissions program.

2. *The agencies have previously appropriately excluded crediting indirect emissions*

As noted above, the agencies have already weighed in on the issue of indirect credits and appropriately excluded them from the National Program (77 FR 62732). It bears repeating some of the reasoning behind that decision.

First, the deployment of these technologies is already being appropriately incentivized by NHTSA under its safety obligations. There is no need to provide a manufacturer additional incentive such as off-cycle credits to deploy these technologies when NHTSA is already promoting some of them through its New Car Assessment Program (NCAP) and has extensive procedures in place for analyzing the potential safety impacts and accelerating their deployment.

Second, all technologies credited under the off-cycle program result in direct emissions impacts for the vehicle in question, which are verifiable and attributable to the technology deployed. The agencies did not consider indirect improvements for the fleet as a whole because those improvements are "not reliably quantifiable, and may be speculative (or in many instances, non-existent)." There is no reasonable way for EPA to verify that these emissions reductions are occurring in the real-world, which could significantly undermine its obligations under the Clean Air Act.

This reasoning remains consistent with the intent of the off-cycle program, the principles of which have been previously laid out in comments directly responding to automaker requests to alter the off-cycle program (ACEEE et al. 2017). Those principles, summarized, are: 1) demonstration of off-cycle benefits must be rigorous and fully documented; 2) off-cycle credits should be limited to new and innovative technologies; and 3) to be eligible for credit, a technology must reduce emissions from the vehicle receiving the credit. The program was established on these three principles, and they continue to remain prudent in order to ensure that real-world reductions in fuel use and emissions are achieved.

B. Incentives for hybrid and alternative fuel vehicles

The agencies have requested comment on a number of incentives already adopted in some form in the greenhouse gas program (e.g., 83 FR 43461, 43464, 43465). We strongly discourage the agency from such incentives, broadly—the technologies in question are not new to the market, and these incentives directly undermine the benefits of the rule by crediting vehicles with benefits incommensurate with the actual greenhouse gas emissions from these vehicles. More specific points related to individual requests for comment are detailed in brief below.

1. Hybrid incentives

The first mass market hybrid vehicle was developed over 20 years ago, reaching the United States shortly thereafter. Since then, hybrid-electric vehicles have appeared in every class, including Small SUVs (MY2005 Ford Escape), Large SUVs (MY2009 Chevy Tahoe/GMC Yukon), and Pickups (MY2005 Chevrolet Silverado/GMC Sierra). Currently, the gap between a conventional "strong" hybrid and "mild" hybrids including 48V systems offer nearly as much benefit as many of the earliest generation systems, and the gap between non-electrified powertrains and hybrid powertrains has also closed, as a result of continuous evolution of internal combustion engines and diminishing returns on strong hybrids. With technology as seamless and effective as the mild hybrid systems on vehicles like the 2019 Ram 1500 and Chevrolet Silverado, in addition to hybrid versions of powerful vehicles like the F-150 and Mustang on the way, it seems that there is no need to incentivize this long-established technology. Hybrids are not innovators or game-changing vehicles—they are simply one of many strategies by which manufacturers can reduce emissions and should not receive special treatment.

2. Natural gas vehicles

Natural gas is a potent greenhouse gas, and any direct emissions of methane pose a significant threat to any effort to limit climate change. As was noted in comments on heavy-duty vehicle regulations, these direct emissions upstream significantly undermine any potential benefit that could come from the pump-to-wheel benefits of displacing gasoline or diesel with natural gas. Furthermore, the technology underpinning any natural gas-powered vehicle is exceptionally mundane—natural gas has been deployed previously in vehicles like the Honda Civic, and aftermarket CNG conversions have long been available on the market. Again, there is no critical hurdle to overcome with CNG powered vehicles, and there is little if any benefit to any such incentives. We strongly recommend that EPA eliminate all incentives for natural gas vehicles and instead ensure such vehicles are credited commensurate with their impact on the environment.

3. Incentives for electric vehicles

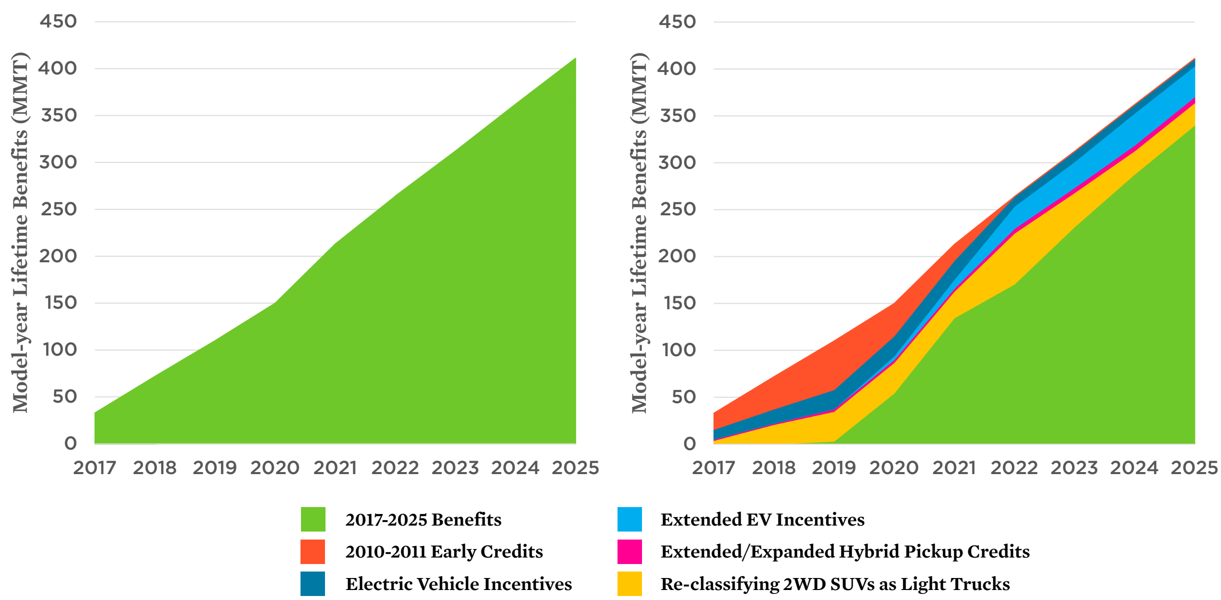
UCS strongly supports electrification of light-duty vehicles, recognizing the long-term potential electric vehicles have in moving towards a more sustainable transportation future. However, current electric vehicle adoption is being driven by state, not federal regulatory policies, so current federal EV incentives within the fuel economy and emissions standards serve not to drive additional adoption but largely only give extra credit for meeting requirements already in place. To date, more than half of the electric vehicles sold have been in California and the states that have adopted California's ZEV standards; however, federal standards ignore the upstream emissions for all vehicles sold, no matter what is driving their adoption. Furthermore, multipliers that began to take effect with MY2017 significantly enhance the amount of emissions reductions given away as an incentive to each EV, effectively treating them as negative emissions vehicles in a manufacturer's fleet. Comparing the total emissions given away to the fraction of vehicles sold in states that have not already mandated electric vehicles be sold yields a ratio of lost benefits that is nearly 6:1. This has a significant impact on the efficacy of the standard, and extending these regulatory incentives are more likely to result in a credit giveaway than they are to drive additional deployment of electric vehicles.

4. Combined impact of incentives

Given the potential interaction for a number of incentives, it is important to consider the potential impact of any such "flexibility" on the overall stringency of the regulation. For example, in Figure YYY, we summarize a number of flexibilities either already granted by EPA or requested by automakers (Cooke 2018b). The total impact of these flexibilities in full is nearly equivalent in reduction of greenhouse gas benefits to the freeze proposed by the agencies in its Preferred Alternative—yet on paper, manufacturers under such a scenario would be compliant with MY2025 standards.

Given the potential for widespread harm, credits within the program should be severely limited, and the agencies' assessment of the impacts of such incentives should be extremely conservative in order to best ensure the environmental benefits of the fuel economy and greenhouse gas emissions standards.

FIGURE 14. Annual greenhouse gas emissions benefits under the 2017-2025 standards finalized by EPA compared to those under possible incentive programs



While some benefits have already been given away (such as early credits and EV incentives), incentives requested by automakers including extension of multipliers for EVs, exclusion of upstream emissions, expanded credits for hybrid light trucks, and reclassification of 2WD small SUVs would erode the benefits of the 2017-2025 greenhouse gas emissions standards nearly as much as the agencies' current, deeply flawed and harmful proposal.

C. Disclosure of credit trading under the CAFE program

NHTSA is requesting comment on disclosure of credit trading under the CAFE program (83 FR 43450). We strongly support increased information availability related to manufacturer credit trading, under both the CAFE and EPA programs. Such information aids manufacturers in assessing the current market for credits, which makes compliance for the industry more efficient (Leard and McConnell 2017), and such disclosure also improves transparency for assessing the ways in which manufacturers are complying with the program. While the CAFE Public Information Center is a substantial improvement upon the previous form of disclosure, there is little clarity about how manufacturers may be dividing up credits to offset shortfalls in their other vehicle fleets or whether they may instead be selling these credits. Increased transparency is especially important given that "manufacturers have largely traded or transferred credits in lieu of paying civil penalties" since the introduction of such flexibilities (83 FR 43451). We strongly encourage NHTSA to disclose at least as much information as is currently disclosed by EPA under its program (volume and vintage bought or sold by a given manufacturer) and encourage the agency to further include regulatory class (which is more relevant to NHTSA's program because of transfer caps and the domestic minimum passenger car standard) as well as transaction price, in order to ensure the market operates more efficiently. We would also encourage EPA to adopt such price disclosure, as it relates directly to the marginal cost of compliance.

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APPENDIX A: Modifications to Volpe model source code

There were a number of noted deficiencies in the version of the Volpe model released with the proposal. We have been able to correct a number of these flaws and have included these corrections to the source code below. These corrections are referred to in the main text of our comments, along with the rationale for such corrections.

A-1: Modification to consider overcompliance in cost-effectiveness

Replace line 604 of `ComplianceFinding.cs` with:

```
deltaCO2CreditValue[rc] = this._newCO2CreditValue[rc] - this._curCO2CreditValue[rc];
```

A-2: Modification to utilize a cost-per-ton algorithm in place of effective cost

Replace line 692 of `ComplianceFinding.cs` with:

```
this._efficiency = cp.IsCO2() ? (this._techCost - this._totalFuelSavings) /
(this._newCO2Credits.Total - this._curCO2Credits.Total) : (this._techCost -
totalDeltaComplianceValue - this._totalFuelSavings) / this._totalAffectedSales;
```

A-3: Modification to correct inaccurate assignment of carryforward expiration

Replace `if{}` procedure at lines 160-163 of `CreditTradingCO2.cs` and lines 162-165 of `CreditTrading.cs` with:

```
carryFwdYears = scen.ScenInfo[rc].CreditCarryFwd[i];
```

In the code provided with the NPRM, all years prior to the first modeled year of compliance were given the default expiration value rather than the value provided in the scenario file, which would prevents the correct application of expiration to banked credits under EPA's one-time carryforward exemption.

A-4: Modifications made to support manufacturer trading as a compliance tool

In the "manufacturer loop", line 564 of `Compliance.cs` is replaced with:

```
// creditBank.RegisterMfr(mfr, year);
```

and before line 680 of `Compliance.cs` the following is inserted:

```
double eff = finding.Efficiency;

List<int> tradingMfrs = CreditTradingCO2.CheaperMfr(eff, mfr.Index, MfrCount, scenData,
year, this.Settings);

foreach (int nextMfrIdx in tradingMfrs)
   {
   Manufacturer uMfr = scenData[year.Index].Manufacturers[nextMfrIdx];
   CreditTradingCO2.CT_CarryForwardM2M(scenData, scen, year, nextMfrIdx, mfr.Index,
this.Settings, true, year); // expiring credits only, from this year
```

```
  if(mfr.GetNetCO2Credits().Total > 0) { break; } // if mfr is in net compliance, break

  }

if (mfr.GetNetCO2Credits().Total > 0) { break; } // if mfr is in net compliance, break
```

A number of new methods are added to `CreditTradingCO2.cs` as a result:

- CheaperMfr() — Creates a list of manufacturers with compliance costs per ton less than finding
- CT_CarryForwardM2M() — An adapted version of the CT_Carryforward() function which trades between two different manufacturers within a regulatory class, carrying forward credits from earning manufacturer until compliance in using manufacturer.
- Mfr2MfrTransfer() — Trades credits between manufacturers; 2-OEM analog to DoTransfer() helper method. Includes updated logging routine which separately logs earned and used credit manufacturers on two different lines.
- costPerTonCO2() — Calculates a manufacturer's average cost of compliance to date based on total costs and total CO2 reductions from baseline, scaled to reflect current fleet sales to diminish impact of mix shift.

```
public static List<int> CheaperMfr(double eff, int mfrIdx, int mfrCount, Industry[]
modelData, ModelYear year, ModelingSettings settings)
{
   Manufacturer mfr = modelData[year.Index].Manufacturers[mfrIdx];

   List<int> mfrList = new List<int>();

   int minComplianceYearIndex = modelData[year.Index].MinYear - ModelYear.MinYear;
   int minBankedCredYearIndex = mfr.Description.BankedCO2CreditsMinYear -
ModelYear.MinYear;
   int minYearIndex = Math.Min(minComplianceYearIndex, minBankedCredYearIndex);

   for (int i = 1; i < mfrCount; i++)
   {
      int nextMfrIdx = (mfrIdx + i) % mfrCount; // resets at length of array

    Manufacturer nextMfr = modelData[year.Index].Manufacturers[nextMfrIdx]; //
transferring retiring credits from previous years i to expiring year

    double costPerTonNextMfr = costPerTonCO2(nextMfr, modelData, year, settings);

    if(costPerTonNextMfr < eff) { mfrList.Add(nextMfrIdx); } // add manufacturer to
list of mfrs with costs less than current finding
   }

   if (mfrList.Count <= 1) return mfrList; // don't randomize list with one or no
items

   Random rnd = new Random();

   for (var m=0; m < mfrList.Count; m++) // loop randomly swaps items in list to
minimize trading bias
   {
      var temp = mfrList[m];
      int n = rnd.Next(m, mfrList.Count);
      mfrList[m] = mfrList[n];
      mfrList[n] = temp;
   }
```

```
    return mfrList;
}

public static void CT_CarryForwardM2M(Industry[] modelData, Scenario scen, ModelYear
year, int mfrIndex, int mfrIndex2,ModelingSettings settings, bool expiringOnly, int
expiringYrIndex)
{
    CT_CarryForwardM2M(RC.AllPassengerCar, modelData, scen, year, mfrIndex, mfrIndex2,
    settings, expiringOnly, expiringYrIndex);
    CT_CarryForwardM2M(RC.LightTruck, modelData, scen, year, mfrIndex, mfrIndex2,
    settings, expiringOnly, expiringYrIndex);
    CT_CarryForwardM2M(RC.LightTruck2b3, modelData, scen, year, mfrIndex, mfrIndex2,
    settings, expiringOnly, expiringYrIndex);
}

/// <summary>
/// Performs a credit carry forward operation into a compliance category defined by
the specified model
/// year, between two manufacturers (mfrSource, mfrReceive), into regulatory class rc.
/// A carry forward operation will only be performed if credit trading settings allow
and the destination
/// compliance category is at a deficit.
/// </summary>
public static void CT_CarryForwardM2M(RC rc, Industry[] modelData, Scenario scen,
ModelYear year, int mfrSource, int mfrReceive, ModelingSettings settings, bool
expiringOnly, int expiringYrIndex)
    {
    CreditTradingValues ct = settings.Parameters.CreditTradingValues;
    if (!settings.OperatingModes.AllowCreditTrading ||
    settings.OperatingModes.LastCreditTradingYear < year.Year || !ct.AllowCarryForward)
    { return; }

    Manufacturer mfr = modelData[year.Index].Manufacturers[mfrSource];
    Manufacturer uMfr = modelData[year.Index].Manufacturers[mfrReceive];

    double credits = uMfr.GetNetCO2Credits(rc);

    // the fleet has positive credits (is in compliance) for this reg-class
    if (credits >= 0) { return; }

    // scan each year to see if credits can be carried forward
    int minComplianceYearIndex = modelData[year.Index].MinYear - ModelYear.MinYear;
    int minBankedCredYearIndex = mfr.Description.BankedCO2CreditsMinYear -
    ModelYear.MinYear;
    int minYearIndex = Math.Min(minComplianceYearIndex, minBankedCredYearIndex);
    //
    for (int i = minYearIndex; i < year.Index; i++)
    {  // get carry forward years
        int carryFwdYears = 0;
      carryFwdYears = scen.ScenInfo[rc].CreditCarryFwd[i]; // determined by input file
      if (carryFwdYears == 0)
      {  // no scenario/year specific value defined -- use global setting
           carryFwdYears = ct.CarryForwardYears;
        }

      // if only expiring credits should be used, skip all other years
      if (expiringOnly && (i > expiringYrIndex - carryFwdYears)) { continue; }

      // if credits already expired, skip year
      if (i + carryFwdYears < year.Index) { continue; }

      Manufacturer pMfr = null;
      double eCredits = 0;
```

```
      bool useBank = false;
      if (i >= minComplianceYearIndex)
      {  // checking one of analysis years -- check for credits generated during
   compliance
          pMfr = modelData[i].Manufacturers[mfrSource];
          // **note: when computing available credits from previous years,
       CO2CreditsIn should not be considered,
          // since there is no way of tracking where they came from or their
       expiration
          eCredits = Math.Max(0, pMfr.ModelData.CO2Credits[rc] -
          pMfr.ModelData.CO2CreditsOut[rc]);
       }
       else
       {  // checking a year prior to start of modeling -- check for banked credits
          pMfr = mfr;
          eCredits = mfr.Description.GetBankedCO2Credits(rc, i + ModelYear.MinYear);
          useBank = true;
      }

       // continue to the next year if did not earn any credits in the "i-th" year
      if (eCredits <= 0) { continue; }

      // perform a credit transfer between the two manufacturers
       Mfr2MfrTransfer(settings, scen, eCredits, -credits, rc,
       ModelYear.NewFromIndex(i), pMfr, useBank, rc, year, uMfr);

      // update credits; if compliance achieved, return
      credits = uMfr.GetNetCO2Credits(rc);

       if (credits >= 0) { return; }

   } // next i (carry forward credit year)
}

public static double costPerTonCO2(Manufacturer mfr, Industry[] modelData, ModelYear
year, ModelingSettings settings)
{
   int minComplianceYearIndex = modelData[year.Index].MinYear - ModelYear.MinYear;

   Manufacturer mfr0 = modelData[minComplianceYearIndex].Manufacturers[mfr.Index]; //
   clone for baseline year

   var mmd = mfr.ModelData;
   var mmd0 = mfr0.ModelData;

   double BaselineCO2PC = mmd0.CO2RatingSum.CalcSum(RC.AllPassengerCar);
   double BaselineCO2LT = mmd0.CO2RatingSum.CalcSum(RC.LightTruck);
   double CurrentCO2PC = mmd.CO2RatingSum.CalcSum(RC.AllPassengerCar);
   double CurrentCO2LT = mmd.CO2RatingSum.CalcSum(RC.LightTruck);

   double MfrTonsRedux = (BaselineCO2PC / mmd0.Sales[RC.AllPassengerCar] -
   CurrentCO2PC / mmd.Sales[RC.AllPassengerCar]) * StandardsCO2.GetVMT(settings, year,
   RC.AllPassengerCar) * mmd.Sales[RC.AllPassengerCar] + (BaselineCO2LT /
   mmd0.Sales[RC.LightTruck] - CurrentCO2LT / mmd.Sales[RC.LightTruck]) *
   StandardsCO2.GetVMT(settings, year, RC.LightTruck) * mmd.Sales[RC.LightTruck]; //
   calculates tons of reductions to date, relative to baseline and scaled to current
   sales

   double costPerTon = mfr.ModelData.TechCost.Total / MfrTonsRedux; // divides
   manufacturer's tech cost in current model year by tons of reduction

   return costPerTon;
}
```