Comments Concerning the Reconsideration of the Final Determination of the Mid-term Evaluation of Greenhouse Gas Emissions Standards for Model Year 2022-2025 Light-duty Vehicles and the Appropriateness of Model Year 2021 Greenhouse Gas Emissions Standards

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The 2012-2016 and 2017-2025 fuel economy and greenhouse gas emissions standards for light-duty vehicles represent the largest single policy step towards reducing greenhouse gas emissions and oil usage in the United States. In 2012, the Environmental Protection Agency (EPA) committed to a mid-term evaluation of its 2022-2025 greenhouse gas emissions standards, reviewing their standards in light of the availability, cost, and effectiveness of technology; the economic impact on the industry and country as a whole; the impact of the standards on reduction of emissions and fuel savings to consumers; and the feasibility of the standards, among other relevant factors.[1] In January, 2017, this review was completed, with EPA finalizing its determination that the 2022-2025 standards are feasible. After careful review of the robust evidence collected by EPA and the National Highway Traffic Safety Administration (NHTSA) as well as the comments put in the docket during the comment period on the Draft Technical Assessment Report (TAR) and in response to the Proposed Determination (PD) and accompanying Technical Support Document (TSD), the Union of Concerned Scientists strongly supported this conclusion.

Since the Final Determination, new data has only strengthened the case for the feasibility of the 2022-2025 standards—new studies continue to show how the agency previously overstated costs for compliance with those standards; new technologies have been developed by suppliers and manufacturers that continue to show how more efficient gasoline-powered vehicles can achieve those standards; and studies have shown that these regulations have tremendous benefits for the economy as a whole and, in particular, the financial health of lower-income households. The feasibility of this program is even more obvious when examining the 2021 standards, with which the industry is already quite well-positioned to comply, both through technological advancement and the vast sums of credits earned under the early years of the program, and which should not be under consideration as part of this mid-term review process.

Over the past six years, this regulatory program has saved consumers more than $45 billion in fuel costs and avoided 180 million metric tons of global warming emissions. At the same time, the auto industry has been thriving, adding 450,000 jobs in that same timeframe (BLS 2016a) while light-duty vehicle sales are likely to surpass 17 million vehicles for the third consecutive year, which would be an historic first. This is all occurring while gas prices are at historic lows, leading to an increasing marketshare for trucks and SUVs which underscores the absolute importance of improving the efficiency of *all* vehicles.

The standards are resulting in the deployment of the most efficient cars and trucks ever—but because the share of trucks and SUVs is much higher than anticipated, the nation is not on track to achieve an average of 163 grams CO2-equivalent per mile (g CO2e/mi), as anticipated in the final

[1] This is an abbreviated list. The full list may be found at 40 CFR 86.1818-12(h)(1).

rule in 2012, but instead on track for 175 g CO2e/mi. This will result in more than 226 million barrels of oil use and 100 million metric tons of emissions in 2040 more than expected in the FRM.[2] It is thus of utmost importance that EPA not further erode the environmental benefits envisioned with these standards through unnecessary weakening, either by direct reductions in stringency or by opening up new loopholes that could be exploited to indirectly reduce the stringency of the standards.

The data continue to show that manufacturers could exceed the 2022-2025 standards now on the books. In the text below, we outline the evidence in support of this conclusion, focusing on not just the robust body of evidence already cited by EPA in its Final Determination but new data, which continues to support this determination. Each section addresses either an area that EPA was required to consider in its assessment of the 2022-2025 standards as part of the mid-term evaluation or an area on which the Administrator and Secretary have requested specific comment, accompanied by the appropriate bulleted text for reference.

While many aspects of the automobile market have changed over the past six years, the evidence to-date clearly indicates that the standards for 2021-2025 remain feasible, and there is no rationale for making changes that would reduce the emissions reductions and oil savings from these successful standards.

Technology cost, effectiveness, and availability

The TSD highlights how manufacturers are deploying tremendous resources to research new technologies to reduce fuel use, which has resulted in technologies like variable compression ratio and high compression ratio engines that the agencies hadn't anticipated as well as significant improvements to the mechanics of continuously variable transmissions and the ability to integrate different types of advanced materials, which continue to push low-cost, effective technologies further than originally thought.

Since the TSD, advancements in conventional vehicles have continued apace, with suppliers and manufacturers alike announcing even further breakthroughs in design. 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). Achates Power also announced that it is getting ready for light-duty truck testing of a 2.7L

[2] UCS analysis; see summary figure in UCS 2016a.

opposed-piston diesel engine, which it claims can both meet Tier 3 emissions standards and would achieve a 2-cycle test fuel economy of 37 mpg, well above the level needed for CAFE standards (Brooke 2017). These and other developments speak to the ability for manufacturers to push conventional vehicles even further than anticipated.

The sections below respond to some of the latest data on technology developments over the past five years and their impact on manufacturers' ability to meet future standards.

Technology assumptions updated since the final rulemaking

- *The availability and effectiveness of technology, and the appropriate lead time for introduction of technology;*

As indicated in our comments on the PD (Cooke 2016d), a number of technology assumptions have changed since the rules were first written. This is largely due to a profound level of innovation on the part of manufacturers and suppliers, responding at least in part to the vehicle efficiency standards.

The TAR included a number of new technology assessments, including Atkinson- and Miller-cycle engines and a fresh look at both high-spread ratio automatic transmissions and continuously variable transmission. The TSD further added to this assessment, though there are still some technology assumptions that remain conservative which merit note, as detailed below.

CYLINDER DEACTIVATION

We continue to consider the exclusion of dynamic cylinder deactivation to be an unnecessarily conservative approach which does not reflect the advanced state of technology in the industry. Delphi has already announced that a "large, global manufacturer" will be deploying it in a car in 2018, with benefits of at least 8 percent reduction in fuel use and emissions, even for small, turbocharged engines (Beckwith 2017). When combined with a 48V system, which can act synergistically with the dynamic cylinder deactivation, the suppliers claim 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). It should also be noted that conventional cylinder deactivation has a synergistic relationship with mild hybridization as well—General Motors noted in its press materials for the 2016 Chevy Silverado pick-up with e-Assist, "the electric motor also enables the Active Fuel Management 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).

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 turbocharged, downsized engines, but the agencies' approach to date has been fairly conservative in terms of the effectiveness of this technology (Cooke 2016a, Cooke 2016d).

Significantly, EPA has 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," the hardware testing by EPA shows instead 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". This is consistent with the range indicated by both the International Council on Clean Transportation (ICCT) (Isenstadt, German, and Dorobantu 2016) and NAS (2015).

Both major automaker trade associations also took issue with the high penetration of Atkinson engines modeled in EPA's compliance analysis (AAM 2016, p. 50; AGA 2016, p. 27). However, the long lead-time provided not just by the Final Determination and 2025 but by the 13-year window provided by the finalization of the rules in the first place seems more than adequate for the "significant amount of time required to develop and integrate [an] engine into the vehicle line-up prior to its introduction" (AGA 2016, p. 27). In fact, contrary to the assertions posed, manufacturers would not be starting from scratch—rather, as we have previously noted, a large number of manufacturers are moving towards high- or variable-compression ratio engines (Cooke 2016a, II.C.1). Honda, Hyundai-Kia, Mazda, Nissan, Toyota, and Volkswagen all have engines in development which fall within a similar strategy—together, those companies represent nearly half of U.S. vehicle sales. Given that each and every vehicle within those companies will be redesigned at least once between now and 2025, and they are already deploying such technology, the penetration levels projected in EPA's OMEGA analysis are reasonable. Further, as EPA themselves indicated, the difference in cost-effectiveness between this strategy and the other dominant strategy for compliance for gasoline-powered vehicles in 2025 (turbo-downsizing) is not that significant, which is why analyses where the deployment is artificially limited to levels well below what is achievable in the industry do not result in significantly different costs (EPA 2017b, p. 53); therefore, the precise reasons for a manufacturer to adopt this strategy or another do not weigh heavily on the overall cost-effectiveness of the regulation.

Finally, as EPA noted in its support of the Final Determination, it has not considered variable compression ratio engines at all in its modeling, despite the technology being actively developed.

We agree with the agency that because "such technologies might reduce projected compliance costs if they prove to be more cost-effective than other technologies currently in the analysis, the lack of inclusion of some of these technologies lends a conservative feature to the analysis supporting the Determination" (e.g., EPA 2017b, p. 76).

ADVANCED BOOSTED ENGINES

Turbocharged engines have been deployed at rates below that identified in the agency pathways in the 2012-2016 rulemaking; 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. 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, electrically assisted turbochargers (or "e-boost"), and supercharged engines. Not fully incorporated these technology developments reflects a conservative approach which could force more expensive technologies to be deployed when further gains from traditional gasoline-powered vehicles could be realized.

Between the 2017-2025 FRM and the Final Determination, EPA did adjust its 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. However, the agency has incorporated neither the eBoost turbocharged engines nor any supercharged engines, both of which are deployable today.

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 (EPA-HQ-OAR-2015-0827-6318). Based on supplier data, 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 currently a feasible technology but excluded from EPA's 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 (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' original analysis which could be used for downsizing an engine by 50 percent (NAS 2015, p. 63). While not on the market currently, OEMs are currently testing the technology for possible deployment (Truett 2017).

TRANSMISSIONS

As previously noted, UCS continues to agree with the decision by EPA to categorize transmission technologies by "bins" (Cooke 2016a, Cooke 2016d). Regardless of the specific technologies, teardown costs indicate comparable costs for improvements to each type of transmissions and similar levels of possible improvement (EPA 2016b, Tables 2.85 and 2.87), and decisions as to the specific transmission type employed in a vehicle are related more to automaker decisions outside the cost effectiveness of a technology, including performance, internal v. external R&D expenditures, and deployment history. The use of such binning does not assume that these technologies are identical—rather, it is a useful way of assuming flexibility and diversity within different manufacturers' fleets while at the same time recognizing the capability for all transmission design to improve in the future.

MILD HYBRIDIZATION

EPA responded to some of the recent progress in mild hybridization, particularly with the addition of 48V mild-hybrid technology to the OMEGA modeling, but there additional developments have occurred since the Final Determination which paint the assumptions in the supporting TSD as conservative.

Costs continue to come down for 48V systems, already matching that used in EPA's analysis for the Final Determination, with continued volume-based learning to drive it down further (see presentations by Johnson Controls and FCA, EPA-HQ-OAR-2015-0827-6318). While not deployed in significant numbers yet in the United States, several manufacturers have them in their product plans over the next few model years globally, indicating that not only is it a viable technology, but manufacturers are deploying it well ahead of the time period covered under the mid-term review, including Fiat-Chrysler, Ford, General Motors (NemoTec presentation, EPA-HQ-OAR-2015-0827-6318).

Mild hybridization is also showing strong potential in pick-up trucks. For example, General Motors recently deployed a limited fleet of eAssist Silverado pick-ups in California (GM 2016). Not only does the vehicle show significant reductions in city driving (13 percent), but it 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. The regenerative capability and additional motor improve power and torque from the vehicle and allow for more 4-cylinder operation from the conventional cylinder deactivation, again showing how many of these technologies can have synergistic effects. It is also proving itself a low-cost option, with GM offering it at just a $500 premium compared to similarly equipped trim packages.

ELECTRIC VEHICLES

Electric vehicles (EVs) are not necessary to meet the federal vehicle efficiency standards. However, vehicle electrification coupled with efforts to reduce the carbon intensity of the electrical grid is a critical strategy for achieving the deep reductions in climate emissions that are needed over the next several decades to avoid the worst consequences of climate change. Therefore, regulatory agencies should continue to evaluate the progress of electric vehicle technology and ensure that the full potential of vehicle electrification is captured in future standards.

We have previously noted both the importance of state policies in increasing sales of electric vehicles and the resultant reductions in battery costs due to these increased volumes (Cooke 2016d). EPA should base their cost assessment on the latest available data, which has shown a continued, rapid reduction in both battery and non-battery costs. It should also continue to include state policies such as CA ZEV in its baseline—regardless of the stringency of federal regulations, ZEV will continue to drive investment in electrification, and those vehicles should be considered as part of the baseline fleet.

At the same time, it is important to consider how the federal program relates to the adoption of these vehicles. Manufacturers like Volvo, Ford (under the Lincoln brand), and Jaguar-Land Rover have all announced fleetwide pushes toward electrification in the near-term, ranging from mild hybrid offerings to full battery-electric vehicles. The emissions from the growing alternative fuel fleet thus must be considered in total in order to ensure we are driving reductions in greenhouse gas emissions commensurate with the anticipated benefits of this program.

To that end, we continue to assert that the agency must let the 0 g/mi and multiplier incentives for plug-in electric vehicles expire as planned. The 2022-2025 standards are able to be met largely via the deployment of fuel consumption reduction technologies to conventional, gasoline-powered vehicles, with very low penetration of EVs and with no changes to the existing EV incentives. Therefore, we oppose any extension or expansion of these incentive for 2022-2025, especially given that such changes would reduce the emissions reductions of the program.

Automakers have requested that the 0 g/mi upstream treatment of EV be made permanent (EPA 2015a, p. A-107). The Alliance, in particular, claims that including upstream emissions disadvantages EVs because conventional vehicles' upstream emissions are not counted—this is patently false: the attribution of upstream emissions to EVs per the 2017-2025 rule adjusts those emissions downward to account for gasoline vehicles' upstream emissions (*Fed. Reg.* **77** (199), p. 62822). Our own analysis shows that electric vehicles continue to be the most efficient vehicle choice in the vast majority of the country (Reichmuth 2017)—thus, manufacturers will continue to be incentivized to deploy this technology, but the incentive will be commensurate with the real-world emissions reductions of the vehicle.

The technology required to meet the 2025 standards

- *The feasibility and practicability of the standards;*

Automakers and trade groups have primarily relied upon the analysis of Novation Analytics (2015) to claim that EPA has significantly underestimated the level of technology necessary to achieve 2025 regulations (e.g., EPA-HQ-OAR-2015-0827-4089, EPA-HQ-OAR-2015-0827-4009). We have previously commented on the flaws with this analysis that make it overly conservative (Cooke 2016b, Cooke 2016d), and the agency pointed to a number of additional issues in its own analysis (EPA 2016a, p. 2-279).

In assessing the technology needed to achieve the standards, automakers continue to claim that greater penetration of electrification technologies are needed in order to achieve the standard, claiming that EPA's analyses are overly optimistic. However, as noted in the examples in the previous section, EPA's powertrain assumptions have consistently been conservative, often underestimating industry's ability to continue to eke out further improvements in well-developed technologies in addition to cutting-edge breakthroughs such as spark-assisted compression-ignition or variable-compression ratio engines. As will be discussed further, this is largely why the agencies' initial compliance paths were so much more reliant upon penetrations of hybridization has come to pass—manufacturers have been able to achieve comparable levels of fuel economy improvement more cheaply through unanticipated incremental improvements. This is not indicative of the agencies' analysis being too optimistic, as industry's consultants have suggested (e.g., Novation Analytics 2016, p. 51)—rather, it indicates the complete opposite, that the agencies significantly *under*estimated industry's capacity for innovation.

Recent research by the International Council on Clean Transportation (ICCT) shows how the agency has either underestimated the effectiveness and availability of technology in 2025 or overestimated its cost (Lutsey et al. 2017, Table 1). Figures 4 and 5 of that report illustrate how this acts to significantly reduce the costs needed to achieve the required levels of improvement,

meaning that there are both more cost-effective alternatives than estimated in the TSD and less need for the application of the most expensive technologies (electrification). These cost reductions are consistent with our own estimates described in the next section—manufacturers have been complying with the standards at costs much lower than originally anticipated.

As mentioned previously (Cooke 2017e), further proof of industry's ability to rely primarily upon gasoline-powered technology comes from their own consultants (Novation Analytics 2015, pp. 72-77). These scenarios *compliant with the regulations* emphasize the deployment of advanced gasoline-powered engines over hybrid- or battery-electric vehicles. While they do not include Atkinson- or Miller-cycle engines, these scenarios are generally consistent with EPA's technology pathways by deploying 24-bar turbocharged engines, stop-start, and high-ratio transmissions.

The fact that even an analysis funded by the auto industry with conservative assumptions itself finds that the 2025 regulations promulgated in 2012 can be met with largely conventional technologies indicates that these standards can reasonably be met by automakers.

Costs of meeting the standards

- *The cost on the producers or purchasers of new motor vehicles or new motor vehicle engines;*

While it is critical to understand how manufacturers could meet standards for the future, it is helpful to take a retrospective look at compliance of the standards to date. Manufacturers have had no trouble meeting the 2012-2016 greenhouse gas emissions standards—in fact, they have exceeded them each year, resulting in an excess of emissions credits that can be used through the 2021 model year. In our previous comments, we tried to estimate the costs of that overcompliance and found that even with conservative assumptions, manufacturers were able to *exceed* the standards to-date at costs *less than* the agencies had anticipated in the final MY2012-2016 rule (Cooke 2016d).

Bottom-up cost retrospective—methodology

Our previous analysis relied upon an estimate of the marginal cost of compliance, based largely upon FCA's willingness to purchase credits from Tesla in lieu of developing and deploying its own technology. However, a more accurate picture of the costs to comply with the standards are possible by looking directly at the increased deployment of technologies in the industry.

Typically, bottom-up assessments are difficult because of the level of detail necessary to achieve a reasonable estimate; however, the detailed baseline studies underpinning the OMEGA and Volpe models offers a particular opportunity. In this case, we can compare directly all identified technologies and their deployment in both the 2008 model year and 2015.[3]

The detailed model year 2008 and 2015 data are provided in the Volpe model files accompanying the 2017-2025 rulemaking and 2022-2025 TAR, respectively. There are some minor differences in the categorization of technologies between the two iterations, but generally the list of available technologies is quite similar. In the 2015 data, we have assumed that all engines have undergone a level of friction reduction between 2008 and 2015, and 100 percent of 2015 transmissions have "improved internals" as identified by the National Academies (NAS 2015)—both of these represent conservative assessments of the 2008 vehicle fleet and serve to maximize the level of costs in this exercise.

We then applied costs equal to the differences in technology deployment between the two fleets. For a cost basis, we relied upon the MY 2015 costs from the Volpe model (v. 1.2016.6.1), with some modification. These costs represent a conservative assumption, as they do not reflect more recent analyses in the TSD nor even the most up-to-date analysis at the time of publication (Cooke 2016a), and all of the arguments delineated above for why even the TSD's costs are conservative still hold true; however, these costs are generally based upon a peer-reviewed consensus study by the National Academies (NAS 2015) and serve as a justifiable, if conservative, assessment of the technology costs. A further conservative assumption was that these costs were "unlearned" to account for reductions in cost from 2008 to 2015—we do this based on the learning curves in the rule, but again, this is a conservative assumption that is meant to account for the technology cost at the point the vehicle was updated, which could be as early as 2008.[4]

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[3] We have used the Volpe model's baseline because there is a notable difference in technology between the 2014 and 2015 model years, and this ensures that every model will have undergone a significant redesign. If anything, it is likely that the choice of a dataset based not on final certification but on mid-year reports would result in a projection of greater technology adoption, which is why we have previously identified concerns around the use of non-finalized data as a baseline for the model (Cooke 2016a). In this case, however, it serves to act as another *conservative* assumption in the cost analysis. In assessing the total costs, however, we have weighted the categories using the finalized MY2015 data from Trends, which had greater sales of both cars and truck SUVs than the mid-year report projected.

[4] Note that for assessing the costs of the 2008 vehicles, this is a particularly conservative assumption—most likely, the technology was actually more expensive for those vehicles when applied than assumed in our calculation, so the baseline vehicle's cost estimate is likely lower than would be expected. Most technologies applied in this timeframe are low-complexity and typically saw about 3 percent reduction in cost due to learning (in fixed dollars); however, technologies like stop-start and electric vehicles had much steeper learning curves. Some low complexity technologies like engine friction reduction have a flat learning curve.

In addition to the technologies identified in the Volpe model, manufacturers have used off-cycle technologies to comply with the regulation. The 2008 vehicle fleet is considered the baseline for the regulation, so we consider that none of the applicable technologies were available in that fleet—given that air-conditioning (A/C) efficiency and leakage credits were given for the 2009-2011 model years, this is again another conservative assumption. In assessing the costs of the A/C improvements, we have relied upon the TSD for the 2017-2025 rule (Tables 5-13—5-16), applied to A/C leakage and efficiency on a $/(g/mi) credit basis.

To assess the costs of the off-cycle credits, we have relied primarily upon analysis by ICCT (Osborne *et al.* 2016). The MY2015 compliance report (EPA 2016c) outlined the total credit given to each technology described in the report for both cars and trucks, so we have used this granularity to weight the relative average fleetwide cost of off-cycle credits for both the car and truck fleet. The ICCT report lists only a range of direct costs, so we have also applied the ICM for a low complexity multiplier, consistent with EPA's work in the Proposed Determination (EPA 2016a, Table 2.161). It should be noted that this bottom-up approach results in a much lower direct cost for off-cycle credits than assumed by the agency—$15-$45/(g/mi) for cars, and $13-$36/(g/mi) for trucks in direct costs compared to $45-$55/(g/mi). Further evidence that EPA's estimate for off-cycle credit costs are too high comes from the California Cool Cars program, which found that replacing a car's windows with thermally reflective glass would cost $60 in direct costs (CARB 2009)—this would lead to direct costs of about $28/(g/mi), well within both our calculated range and the range estimated in the ICCT study, and about half the cost assumed by EPA in its analysis.

Bottom-up cost retrospective—results

Taking all of this analysis together, we find that from 2008 to 2015, manufacturers have applied technology resulting on average in an additional $1,093-$1,156 in total cost to cars and $813-$910 in total cost to trucks, for a fleet average increase of $974-$1,051 (all values in 2007$).

To compare this to what the agencies projected, however, we must consider how this relates to compliance. For example, in the 2012-2016 regulations, agencies did not consider the cost of A/C improvements, nor did they allow for off-cycle credits in their compliance pathways. At the same time, manufacturers have also built hundreds of millions of metric tons worth of credits under the EPA program, which means they have applied more technology in the initial years of the program than required in order to draw upon those banks to offset future shortfalls. Therefore, it is not appropriate to simply look at how these costs compare to the 2015 values initially projected.

At today's sales levels, if manufacturers were to not change a thing about the 2015 fleet, the current credit bank would be sufficient for manufacturers to be able to comply with EPA's regulations

through at least 2018.[5] Therefore, it is appropriate to compare the increase in technology costs from 2008 to 2015 with the compliance cost for 2018. Based on the interpolated costs in the MY2017-2025 EPA RIA,[6] we find that EPA projected the total compliance costs in 2018 to be $1,132-$1,163 for cars, $1,194-$1,238 for trucks, and $1,154-$1,184 for the fleet overall (in 2007$).

Comparing the retrospective cost of compliance we have estimated to the agencies' projected cost, we find that *the agency's projections significantly overestimated industry's actual compliance costs.*

This is especially profound because of all the conservative assumptions we have made in our calculation. Moreover, manufacturers have continued to increase performance in the 7 years considered—for instance, the fleet average zero-to-60 acceleration dropped by 7 percent in the same time-frame, from 8.9s to 8.3s (EPA 2016d). Lastly, this also includes costs for compliance with California's Zero Emission Vehicle program, which is why the costs of compliance are so much higher for cars as compared to trucks—while compliance with ZEV helps to comply with the greenhouse gas emissions program, it represents a relatively high-cost technology compared to other available technology pathways.

This finding is consistent with our previous work (Cooke 2016d). It also stresses the importance of setting performance-based standards—manufacturers are able to find innovative strategies to meet the standards as they see fit, which leads to not just new technological developments but actually reduces compliance costs.

Comparison of compliance costs to other factors

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 changes in price one would expect for improvements in quality (Figure 1).[7] This supports the conclusions reached by EPA in Section B.1.6.4 of the PD on entry level vehicles, which have also been affirmed by recent work from Consumers Union (Comings and Allison 2017).

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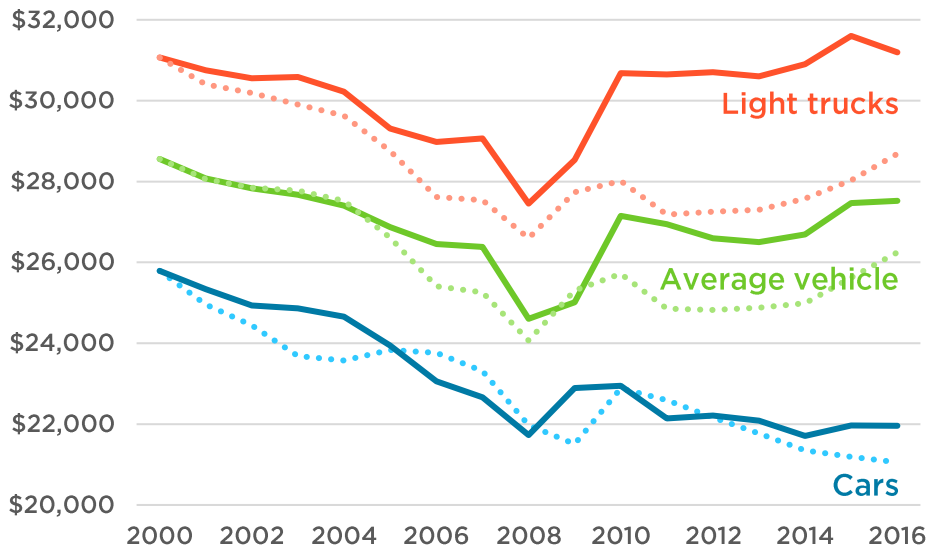
[5] Given the preliminary data for MY2016 and the lower projected sales volumes for MY2017 and beyond, it is likely that manufacturers will easily comply through MY2019 with minimal changes in their fleet, as noted in EPA 2017c. However, we have chosen MY2018 as a conservative estimate.

[6] EPA only provided interpolated costs for the MY2017-2025 regulation (Tables 5.1-6—5.1-8). To assess the total cost of compliance with the program, we must include the costs for compliance with the MY2016 regulations as well and have used the scalars provided in Table 5.1-4 and the values in Table 3.6-1.

[7] 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).

FIGURE 1. New light-duty vehicle price, by class, in constant dollars (2007$)



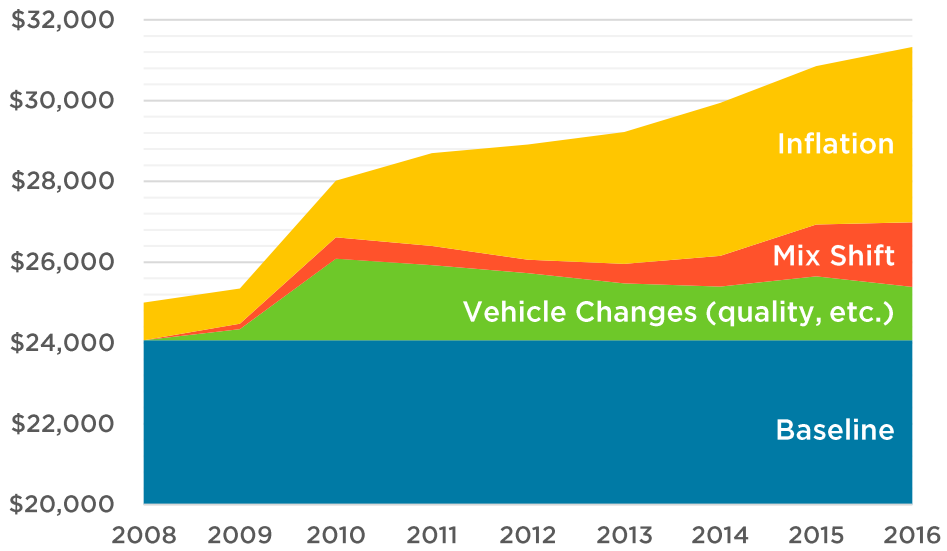
A comparison of the prices for new light-duty vehicles (solid lines) and the expected consumer price based solely on improvements in quality (dotted lines; see BLS n.d.). The price for new cars largely maps the improvements in quality, but a growing gap appears in the light truck segment, which is increasingly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

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

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. By far the largest contribution is inflation, as indicated in data from the Bureau of Labor and Statistics, which tracks changes to vehicle price over time (BLS 2016b). Figure 2 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.
- 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 2016b, manufacturers see the cost of inflation in supplied parts and pass that on to consumers.

FIGURE 2. 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

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 $2,862 in 2007$.[8] As indicated in Figure 2, 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 EPA's discussion of price increases in Section B.1.6.2 of the PD, which notes the significant impacts on transaction price from factors such as the mix shift or additional push towards high-end trim packages. This is further reinforced by analysis from Baum and Associates that showed the rise in high-end trim packages (Baum and Luria 2016b).

Reductions in emissions and oil use

- *The impact of the standards on reduction of emissions, oil conservation, energy security, and fuel savings by consumers;*

[8] 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.

These vehicle standards are the country's most successful initiative to reduce greenhouse gas emissions and oil use. To-date, our analysis shows that the rules have avoided 185 million metric tons of greenhouse gas emissions—that means consumers have saved about $47 billion in fuel costs thanks to these standards. By finalizing strong standards, EPA would ensure even greater savings to come.

Low gas prices have been cited by automakers as reason to weaken these standards; however, it is precisely because gas prices are low that these standards remain as critical as ever. When Hurricane Harvey hit, gasoline prices spiked by $0.281, on average, around the country (EIA 2017)—that immediately cost consumers about $300-$400 million. In that same weeklong timeframe, our analysis shows that these standards saved consumers about $330 million, nearly canceling out the immediate economic impact of that catastrophic event on drivers nationwide.[9]

Fuel efficient cars save drivers money even in times of cheap gasoline, and doubly so when the prices spike—these standards act as a hedge against exactly that uncertainty. We have already seen what happens when manufacturers do not invest in efficiency—in 2008, it nearly resulted in the collapse of the American auto industry and required government intervention at taxpayers' expense (UCS 2016b). These standards help protect consumers from the volatility of the oil market and all of the adverse impacts that accompany our overreliance on fossil fuels. And analysis shows that this can be done not just without affecting the profitability of the automotive industry but by actually enhancing its resilience no matter future fuel price (Baum and Luria 2016a).

Cost-effective standards help reduce the impact of a volatile oil market on the whole economy. Whatever drivers spend at the pump, they cannot spend on housing, food, or other goods and services. UCS analysis shows that by 2030, the standards will net the public about $350 billion each year even after considering additional technology costs—that equates to $2500 per household (2016b). Those financial savings translate into economic growth. All told, UCS estimates the standards will increase the GDP by $25–$30 billion by 2030, creating 650,000 full-time jobs (UCS 2016c).

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[9] It should of course be noted that the total economic toll of Hurricanes Harvey and Irma goes well beyond the fuel costs to drivers, and by no means can vehicle efficiency standards mitigate against those losses. At the same time, with evidence mounting that the impacts of climate change could be fueling some of the most catastrophic aspects of these storms (Caldas 2017), it would also be foolish not to emphasize how these storms help further emphasize the immediate need to mitigate the release of global warming emissions through government policies like EPA's light-duty vehicle greenhouse gas emissions program.

Supported by automakers, unions, national security groups, and environmentalists when they were finalized, the standards set through 2025 stand to net tremendous reductions in fuel use, resulting in benefits to the environment and the economy. There is no reason to put these benefits at risk.

Safety and Lightweight Materials

- *The impacts of the standards on automobile safety;*

Historically, much ado has been made about concerns that more efficient cars means lighter cars, and that somehow those lighter cars will be less safe. In fact, automakers themselves have repeatedly raised this specter in their fight against government regulations, even at one point staging misleading crash videos as part of an ad campaign against raising fuel economy standards.[10]

However, history has proven this trade-off a false dichotomy. In fact, the National Academies even noted in their most recent study that one of the reasons automakers were interested in moving towards lightweight materials was specifically for "their potential to improve safety and crashworthiness" (NAS 2015).

EPA and NHTSA have written at length about the impact of lightweight materials on safety throughout the course of the 2012-2016 and 2017-2025 rulemakings, in addition to the mid-term review, noting in the Draft TAR: "A large body of traffic safety literature exists that examines the relationship between vehicle mass and traffic fatality rates....In general, these studies come to varying conclusions regarding the sign of the relationship between average vehicle mass and overall fatality rates, but *all conclude that the magnitude of this relationship is relatively modest* [emphasis added]."

In the latest analysis by Tom Wenzel of Lawrence Berkeley National Laboratory (LBNL), in fact, *none* of the effects of mass reduction are statistically significant at the 95 percent confidence level, emphasizing just how "modest" this relationship actually is, even using NHTSA's own modeling approach (Wenzel 2016). Alternative approaches by Dynamic Research Inc. and LBNL result in even further reduced societal risk to lightweighting, indicating that more lightweighting is likely possible than the agencies have modeled without increasing overall safety risk.

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[10] In 1991, the Motor Vehicle Manufacturers Association hired a public relations firm, which created the campaign, Coalition for Vehicle Choice. As part of this campaign, the group arranged with the Department of Transportation to stage multiple crashes between large and small vehicles to generate footage that showed damage to the small car which they could use in a public ad campaign. However, the first crash tests between the vehicles actually showed that the small car performed *better* than the large car, implicating not just the automakers but the Department of Transportation in this misleading campaign. (Doyle 2000, p. 263)

While the agencies have appropriately recognized that manufacturers are increasingly moving to lightweight materials, they continue to employ conservative assumptions in their modeling of this technology, restricting themselves to no increases in risk on the most conservative approach possible, when the most recent data shows that further mass reduction is possible (TAR Table 8.7, 2016 baseline and 2016 DRI measures, Scenario 6). In fact, EPA has previously acknowledged the conservative nature of their current approach (EPA 2016a, p. A-97).

It should also be noted that this approach excludes levels of mass reduction which are already being pursued by industry (Isenstadt *et al.* 2016b), ensuring that the modeled fleet is not representative of the technology path manufacturers are employing towards compliance with the regulations.

"Harmonization" and One National Program

- *The impact of the greenhouse gas emission standards on the Corporate Average Fuel Economy standards and a national harmonized program;*

Throughout this mid-term evaluation process, the notion of One National Program has been misconstrued by the automakers as a guarantee that if a fleet complies with one program, it should follow that it complies with the other program—this quite obviously is and should not be the case, and it has never been the intention of the program to provide this guarantee.

The Notice of Intent to conduct a joint rulemaking makes quite clear what it means to be harmonized: "these standards would represent a harmonized and consistent national policy pursuant to the separate statutory frameworks under with EPA and DOT operate" (FR 74 24007). Recognition of the separate statutory frameworks sets the bounds of possible harmonization—given the differences in statutory obligations for each agency, it is impossible to guarantee that a single fleet will comply with both regulations. In fact, the Notice further recognizes that this is not the goal—rather, the goal is to allow for manufacturers to intention is "to allow manufacturers to build a single light-duty national fleet that would satisfy all requirements under both programs."

Ultimately, the onus for compliance with both programs is put quite appropriately on manufacturers, not the regulators. Flexibilities between the two programs are restricted to the authorities granted each agency by Congress—it is ultimately the responsibility of a manufacturer to develop a compliance strategy for its fleet that takes into consideration these differences.

The differences between the programs administered by EPA and NHTSA are even highlighted specifically in the regulatory text (e.g., 2012-2016 FRM, Section I.C.4 and 2017-2025 FRM, Section

I.B.4)—the manufacturers have no excuse for not being cognizant of these differences, all of which exist because the agencies have different statutory obligations. For example—

- Reducing emissions of hydrofluorocarbons (HFCs), allowed under CAA but not EPCA (FR 75 25330, FR 77 62649);
- Unlimited credit trading between cars and trucks under the CAA but limits on fleet credit transfers under EISA (FR 75 25339, FR 77 62648);
- One-time carryforward of credits beyond 5 years, adopted by EPA but prevented under EISA's modification to EPCA (FR 77 62648);
- Treatment of flex-fuel vehicles, which are gradually phased out under EPCA (as modified by EISA) by 2019 but immediately phased out by EPA after 2015 (FR 75 25340);
- EPA's Temporary Lead-time Allowance Alternative Standard (TLAAS), which reduces the stringency of EPA's standard but has no analog under the CAFE program, as it is not permitted under EPCA (FR 75 25340 fn 39);
- EPA's advanced technology vehicle incentive program (multipliers, 0 g/mile), which is not allowable under NHTSA's statutory requirements (FR 77 62651);
- Manufacturers are required to meet a minimum domestic passenger car standard under CAFE, while there is no analogous standard under EPA's program (FR 75 25614);
- NHTSA is precluded from considering CAFE credits, battery electric vehicles, and pre-MY2019 plug-in hybrid electric vehicles when determining the maximum feasible CAFE stringency (FR 77 62666);
- Manufacturers are allowed to pay civil fines in lieu of compliance with CAFE, while this is not allowed under the CAA (FR 77 62666);

It should be noted that most of these provisions allow manufacturers greater flexibility under one program than another under the guise of reducing costs of compliance to manufacturers; however, it is in many cases within the agencies' statutory authorities to instead "harmonize" to the less flexible standard. If manufacturers claim difficulty in crafting a compliance strategy which achieves the goals of both programs, we would encourage the agencies to explore reducing flexibility in the context of harmonization to provide more clear guidance.

One area of harmonization which EPA should particularly consider adopting is the elimination of the exception to the five-year credit lifetime. The agency instituted this provision to "help manufacturers resolve lead-time issues they might face in the early model years of today's program as the transition from the 2016 standards to the progressively more stringent standards for MY2017 and later" (FR 77 62788). However, manufacturers are entering the 2016 model year with nearly 300 million metric tons worth of credits, indicating that they are not having any issues with the

initial phase of the program. The vast majority of these credits were generated under the "early credit" program, which EPA instituted to better align with NHTSA's program,[11] and therefore they should expire after five years as required by EPCA, as modified by EISA. Furthermore, manufacturers have continued to generate excess credits in MY2012-2015, which will not expire until MY2017-2020, respectively, so they are not in any apparent immediate need for relief. At the very least, EPA should require that MY2010-2015 credits expire before any adjustments to future year standard are made.

Impact of standards on the economy

As explained in the sections above, the technical data shows quite clearly that the cost of meeting the standards finalized in 2012 for model years 2022-2025 has come down significantly over the past four years (EPA 2016b, Table IV.5; EPA, NHTSA, and CARB 2016, Table 12.44). Our analysis above indicates that costs for compliance to date has also been reduced from levels originally anticipated, even when additionally considering impacts of the CA ZEV regulations, which falls outside the purview of this evaluation. Despite these reduced costs, it is still important to assess whether there will be any meaningful impact on the industry.

Given the low technical costs of meeting the standards on the book and the resultant fuel savings for a vehicle owner, it is quite clear that the standards more than pay for themselves over the lifetime of the vehicle—EPA estimated a range of scenarios based in part on fuel price scenarios and found paybacks between 3-8 years (EPA 2016b, Appendix C.2.4); however, for the reference case, EPA finds that the typical car buyer who finances their vehicle will see net savings the moment he/she drives off the lot (EPA 2016a, Tables C.69-C.72). This is consistent with independent analysis from Consumers Union, which looks at the standards compared to vehicles today (Synapse 2016).

Despite this clear and incontrovertible result, it does not mean that the average consumer will rationally incorporate this benefit into his/her decision to purchase a vehicle. Consistently, fuel economy is rated as a key consideration of a purchasing decision (literature summarized in NAS 2015, pp. 325-327); however, understanding any possible impact on sales of the increased costs for improved fuel economy requires explicitly understanding the value consumers place on that

[11] In response to concerns that the early credit program amounted to a windfall for manufacturers, it was noted that "EPA believe that early credits provide a valuable incentive for manufacturers that have implemented fuel efficient technologies in excess of their CAFE compliance obligations prior to MY 2012." (FR 75 25341)

improvement. An examination of the literature on consumers' willingness to pay (WTP) is an appropriate foundation for this key data—however, this data varies widely even within studies, raising concerns over the robustness of any stated WTP values..

Consumer willingness-to-pay

- *The extent to which consumers value fuel savings from greater efficiency of vehicles;*

There have been a number of studies that explore purchasing decisions examines a consumer's WTP for different attributes. 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.

The latest analysis of the literature, commissioned by EPA, shows that there is wild inconsistency in the results of these studies—in the preliminary analysis of these results, nearly every attribute had a WTP whose average value was less than the standard error in the estimate (Green, Hossain, and Beach 2016). 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, they 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 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.

This 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-420-R-12-013). 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 (EPA-420-D-15-011). 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" (NHTSA 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" (EPA-420-D-15-011).

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" (EPA-420-D-15-011). 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.

Impact of standards on sales and employment

- *The impact of the standards on the automobile industry;*

While there are some studies claiming that these standards would result in reductions in sales (Furth and Kreutzer 2016, McAlinden *et al.* 2016, Walton and Drake 2016), this is largely predicated on the assumption that consumers would not value fuel economy improvements. However, as noted above, the literature does not support this assumption, with the fuel savings from the rule exceeding the technology cost even after consideration of the literature estimates of payback period or discount rate, though with great uncertainty.

INDUSTRY-FUNDED JOBS STUDY BY INDIANA UNIVERSITY

A recent study paid for by the Auto Alliance (Carley *et al.* 2017), examined both 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

FIGURE 3. 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 2016C

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 study also finds small negative near term macroeconomic impacts resulting primarily from projected decreases in vehicle sales. There are numerous reasons why these 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., (2017) are related to three factors: the way in which they have handled vehicle price increases in the macroeconomic modeling, their treatment and cost estimates of the Zero Emission Vehicle program, and their use of their own COMET model as a sensitivity case. 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.

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 the job loss numbers cited by the automakers in their letter to Adminstrator Pruitt (Bainwol 2017), which stemmed from the deeply flawed study by McAlinden, *et al.* (2016), on which we have previously commented (Cooke 2016d).

Concerns around IU's model of vehicle price effects

One of the curious characteristics of the REMI modeling undertaken by the Indiana University (IU) researchers is the fact that these 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 (this is the purpose of early overcompliance, to delay the deployment of more expensive technologies), so if the model were backcast, it would have predicted a reduction in employment over the past six years, contrary to the 700,000 jobs that have been created in the industry since the Great Recession, 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 their model are quite significant compared to the magnitude of the job growth over the past 6 years.

The most apparent reason for this discrepancy can be found in Figure 8.5, which shows a large reduction in disposable personal income. Since we have already pointed out that for a typical loan a new car buyer is actually saving money in fuel that is greater than the increase in loan payment, there should actually be an *increase* in disposable personal income. As noted in the footnote for Table 7.11, IU has 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 and likely have minimal impacts on overall positive cumulative job impacts, but it would dampen, or reverse, the negative near term macroeconomic indicators evaluated by the IU study authors.

Not only are the effects of vehicle financing ignored in the REMI modeling, 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 the comments submitted October 4, 2017 by Synapse Energy Economics, Inc. 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, comments submitted on October 5 by the American Council for an Energy Efficient Economy (ACEEE) demonstrate that with more reasonable input assumptions to TCO modeling, the impact on vehicle sales are actually positive rather than negative.

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

In both the "2016 Low" and "2016 High" cases, the IU study has included costs for ZEV compliance in line with that projected in Table 7.8. 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 (see p. 83).

Second, IU has 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 2017a, p. ES-7). This is further complicated by the credit glut which manufacturers currently enjoy (CARB 2017a, Figure 11). Annual sales in California are expected to be just over 140,000 total electric vehicles in 2025 (CARB 2017b, Figure 3), compared to an original projection of nearly 250,000 vehicles (CARB 2017b, 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 2017b, p. A-15), that amounts to a total nationwide fraction of ZEVs of 7.5% × 30% = 2.25% needed to comply with the state programs, less than half of the 4.62% assumed in the IU study. At a minimum, the cost estimates by IU for the ZEV program are at least two times too high.

It is worthwhile to reiterate here that in terms of evaluating the cost and benefits of the federal standards under review, the agencies must consider the state-based ZEV program in the baseline as noted above on pages 8 and 29.

FURTHER EVIDENCE FOR THE POSITIVE IMPACT OF THE STANDARDS ON THE AUTO INDUSTRY

Over the past five years, the auto industry has emerged from the economic crisis even while overcomplying 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).

These standards have already spurred innovation and investment not just by automakers but especially by suppliers, and that means more jobs—in fact, motor vehicle manufacturing jobs have grown more than 19 percent since 2012 (Wilson 2017). This is expected to grow in the future as well thanks to further investment, leading to an increase between 240,000 and 400,000 jobs in the automotive supply chain by 2025 (Carley *et al.* 2017, p. 97).

A decision to weaken the standards could put these 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.

Additional Factors Specified in the Notice of Reconsideration

- *The impact of the standards on compliance with other air quality standards;*

EPA's Tier 3 regulations appear to be the air quality standard most relevant to the light-duty vehicle greenhouse gas emissions regulations—these set minimum standards for both tailpipe emissions and fuel properties, including test fuels.

Tailpipe standards

The tailpipe standards for Tier 3 are identical to California's LEV III standards in the timeframe of this rule, and manufacturers have already been required to meet the LEV III standards in California and states which adopted the standards under Section 177 of the Clean Air Act. In total, the impact of meeting these standards is minimal—the National Academies' committee estimated up to a 0.31 percent increase in fuel consumption may result from achieving the standards (NAS 2015, Appendix P), which amounts to less than a 1 g/mi potential increase in global warming emissions. Further minimizing the potential for very small negative impacts on fuel usage is the fact that Tier 3's requirements for lower sulfur standards can act as an enabler for lean-burn technology, which would reduce fuel consumption.

Changes in test fuel between Tier 2 and Tier 3

EPA has previously shown that there is little difference between tests on Tier 2 and Tier 3 fuel when factoring in energy content as required by the regulatory test procedures (e.g., TSD Appendix D).

LEV III and Tier 3 require the use of E10 as a test fuel, mimicking real-world behavior. However, EPA has long included an R factor in its tests to compensate for the differences between the certification fuel and the original 1975 certification fuel. While there is a difference in energy content between Tier 2 and Tier 3 / LEV III fuels, this R factor compensates for that difference.

At the same time, there are differences in octane, which the Alliance claims have a significant impact on the certification tests for vehicles, particularly those which use direct-injection and/or are boosted. EPA specifically tested this claim, testing an EcoBoost Ford F-150, a 1.5L turbo Honda Civic, and a SkyActiv-powered Mazda3. All three engines actually showed a statistically significant *decrease* in CO_2 emissions over the 2-cycle test (FTP75 + HWFET). If anything, this data shows that manufacturers may be experiencing an advantage over the test procedure when switching

from Tier 2 to Tier 3 certification fuel. This is further supported by additional preliminary test data mentioned in the TSD

Interestingly, Mazda's latest SkyActiv-X engine supports this data—Ichiro Hirose, the managing executive officer in charge of powertrain and vehicle development and product planning noted that "As a matter of fact actually, 91 RON gives you better performance than 95 RON" (Mathioudakis 2017). This is consistent with the preliminary torque curves for SkyActiv-X, which shift the peak power to lower speeds (Mazda 2017). This data serves to underscore that there is plenty of potential for manufacturers to address knock in high-compression ratio engines with low-octane fuels.

- *The distributional consequences on households;*

As described in the section on the costs of compliance, vehicle price has roughly remained flat, in constant dollars—for cars in particular, the real price has actually gone down over time (Figure 1). In terms of new vehicle purchases, the price for entry level models has remained essentially constant (Comings and Allison 2017).

EPA has responded appropriately to potential concerns about vehicle affordability (EPA 2016b, Section 4.3). Some attempts have been made to link rising nominal vehicle prices with the standards to date, and has been but this increase in transaction price is clearly associated with a mix shift towards more expensive trucks and SUVs (Baum and Luria 2016b). At the same time, a number of entry-level sedans remain in the market at unchanged prices, now loaded with a number of new features (Comings and Allison 2017). This indicates that for the most price-sensitive new car customers, there remain a number of vehicle options, and they are more feature-rich than ever.

Additionally, it is important to look beyond the new car market when assessing affordability, since it is not "affordability" about which we are most concerned but rather "equitability"—what is the impact of these regulations for different economic demographics? When one looks at the used car market, the benefits of these regulations become even clearer. Generally lower-income buyers purchase used vehicles—this limits households who may be most concerned with fuel costs to choices dictated by upper income individuals. For this and other reasons, the benefits of passenger vehicle efficiency regulations accumulate disproportionately to lower income individuals (Greene and Welch 2016). These regulations are helping to mitigate the transportation costs for precisely the most economically vulnerable communities.

- *The appropriate reference fleet;*

We have previously commented on the appropriate reference fleet (Cooke 2016a)—of importance are two key concerns: 1) the agencies should exclusively utilize finalized manufacturer data, and 2)

the agencies should include compliance with California's Zero Emission Vehicle (ZEV) program in the baseline.

The agencies should only utilize finalized data to craft the baseline specifically because preliminary data is based on product plans that are often delayed are altered, which could mean the technology "baked in" to the agencies' baseline may not accurately reflect the real deployment, which would inadvertently raise compliance costs in the analysis. We continue to have concerns about updating the baseline fleet to more recent finalized data due to performance creep—as explained previously (Cooke 2016c), while manufacturers have the choice to increase performance of their fleet, incorporating it into the baseline has the effect of increasing costs of compliance and assigning all of the costs associated with this discretionary behavior to the regulation instead of to the manufacturers. If the agencies continue to update to the most recent, finalized data, they should examine ways to compensate for manufacturers' choice to increase performance at the expense of fuel economy in order to avoid inadvertently attributing the costs resulting from such decisions to the regulation.

California's ZEV program is the biggest single driver of electrification today. Manufacturers are obligated to comply with the program in the future—as such, the agencies have an obligation to consider this compliance as part of their baseline assumptions. They should also be sure to update any assumptions about the fraction of electric vehicles deployed nationally to comply with this program to ensure it reflects the most up-to-date understanding of manufacturers' deployment strategies. Because technology has evolved at a rate much faster than originally anticipated, the numbers of ZEVs deployed to comply with the program will be far less than originally thought.

- *The impact of the standards on advanced fuels technology, including but not limited to the potential for high-octane blends;*

Analysis from DOE's CoOptima program, automakers, and universities (DOE 2017, Leone *et al.* 2015, Speth *et al.* 2014) highlights potential efficiency improvements associated with higher octane gasoline, particularly for high compression turbocharged cars. As described in a recent UCS article (Martin 2016b), blends of gasoline with 25% ethanol have the potential to offer reduced carbon pollution and per gallon fuel prices without a loss in miles per gallon using engine technology that is increasingly prevalent. However, realization of this technical potential requires a practical plan to coordinate the introduction of the new fuel and vehicles designed to use it. Such a plan needs to address demand (e.g. vehicles compatible with or optimized for high-octane E25), distribution infrastructure, regulatory issues, and supply (e.g. availability of sufficient low carbon ethanol and appropriate gasoline blend-stocks). While much of the necessary technical basis for such a plan exists, there is still considerable work required to make specific decisions, move these through

several relevant regulatory processes and allow market participants (vehicle makers, fuel producers, and fuel distributors and retailers) time to adapt to the new fuel.

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 gradually gain market share through 2040.[12] There is no realistic prospect of completing this process before 2025, in the timeframe of the mid-term evaluation. The appropriate context for this discussion within vehicle rules is the next round of fuel economy standards, beginning in 2026. 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 2016d).

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 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

[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.

the rapid transition to E10 between 2005 and 2010 (Martin 2016a). 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.

- *The availability of realistic technological concepts for improving efficiency in automobiles that consumers demand, as well as any indirect impacts on emissions;*

UCS interprets this request as referring to technologies which may exist in the marketplace but do not result in direct emissions reductions for a specific vehicle. The request for comment itself seems a contradiction—a technology which improves efficiency of an automobile must inherently result in direct emissions reductions, or it cannot be considered an efficiency improvement. However, it is possible that the request for comment is meant to refer to improving the efficiency of the transportation system as a whole; this is to what our comments below respond.

Technologies which do not directly reduce emissions

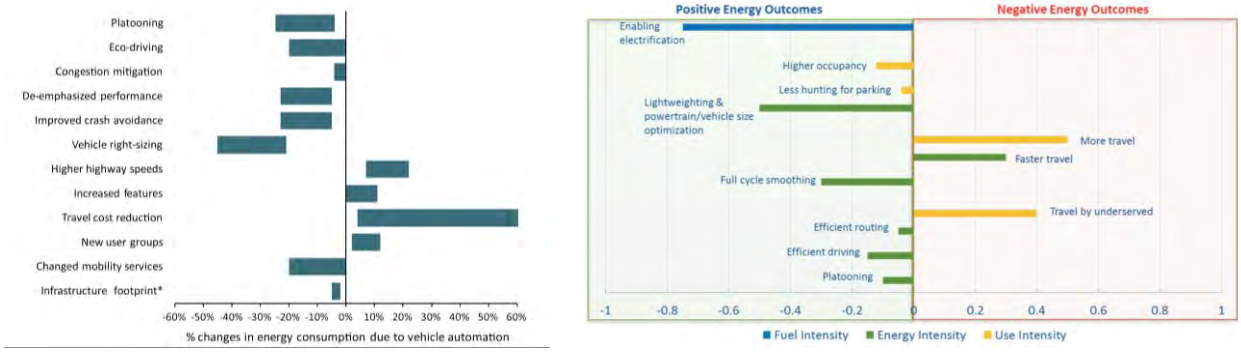
Technologies which could improve the transportation system include those related to safety, such as crash avoidance or lane-departure, as well as features that are better described as semi-autonomous or autonomous vehicle features, ranging from SAE Level 1 features that are widespread in the marketplace 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 4a) and Brown, Gonder, and Repac 2014 (Figure 4b), which illustrate much of the range of uncertainty around potential (dis)benefits of vehicle automation.

In nearly all technology scenarios, illustrated in Figure 3, 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

FIGURE 4. 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)

would otherwise have been required and the widespread use of bio-based ethanol as a fuel (E85) never materialized (Jenn, Azevedo, and Michalek 2016).

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 discrediting a manufacturer for all of its owners' inefficient driving behaviors as well.

Finally, the data previously provided by manufacturers (e.g., EPA-HQ-OAR-2010-0799-9483-A1) 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.

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 (2017-2025 FRM, Section II.F.2.g). 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.

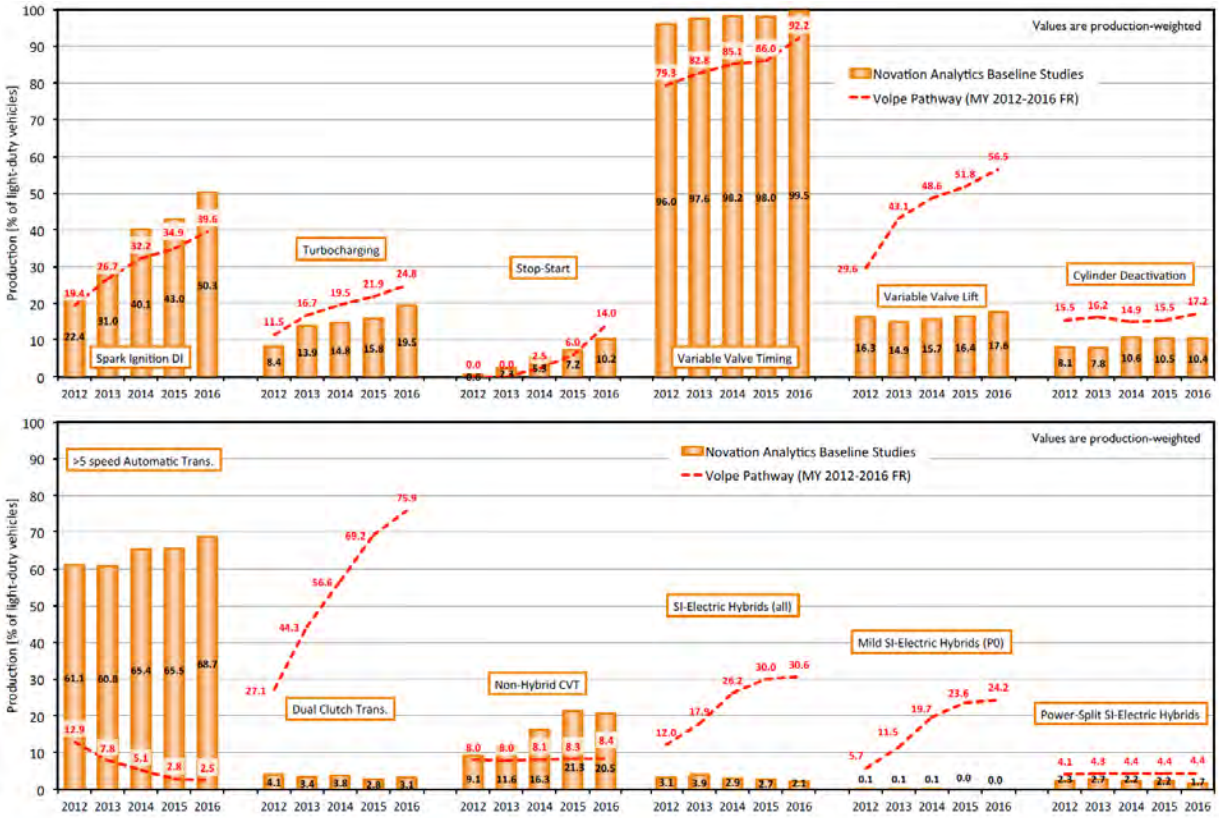
Second, all technologies credited under the off-cycle program result in direct emissions impacts for the vehicle in question, which are verifiable and attributable to the technology deployed. The agencies did not consider indirect improvements for the fleet as a whole because those improvements are "not 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 (NHTSA-2016-0135-0002). 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.

- *The advantages or deficiencies in EPA's past approaches to forecasting and projecting automobile technologies, including but not limited to baseline projections for compliance costs, technology penetration rates, technology performance, etc.;*

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, this propensity for overestimation has continued—our analysis shows clearly that the costs for compliance are lower than originally anticipated by the regulators.

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 2016B

It should be noted that the agencies have not previously projected technology penetration rates, so it seems erroneous to include a request for comment on this subject. If this is referring to an historical look at whether the pathways projected by either the OMEGA or Volpe models have come true, then this represents a serious misunderstanding in how these models are used and what they represent. Incidentally, industry repeatedly mischaracterizes these models in the exact same way (e.g., Novation Analytics 2016).

The pathways illustrated by the OMEGA model represent a particular low-cost analysis by EPA, 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.

The Novation MY2016 baseline study is a very useful look at how conservative the agencies' historical approach has generally been. Mistakenly, the authors 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[13] 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 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' analysis, dual-clutch transmissions were 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

[13] 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.

manufacturers have decided to go with a continuously variable transmission instead. Incidentally, this is an example of why we support EPA's move to a more generic representation of transmissions (Cooke 2016d)—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 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 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.

- *The use of alternative methodologies and modeling systems to assess both analysis inputs and the standards, including but not limited to the Department of Energy's (DOE's) Argonne National Laboratory's Autonomie full vehicle simulation tool and DOT's CAFE Compliance and Effects model.*

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 2016a). The ANL work

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, its transmission shift strategy does not deploy gear-skipping or other more modern control strategies, indicating 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. 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.

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 MATLAB license. It is also based on the GEM model, which 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.

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.

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. 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, that high-compression ratio engine with cylinder deactivation combo disallowed by the Volpe model is actually part of Mazda's announced product plan for the SkyActiv engine, and is a configuration being tested by EPA's vehicle team (Schenk and Dekraker 2017).

Another aspects 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 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 in which

may be more conservative than automakers' data, they have 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 shift 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 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. To our knowledge, NHTSA has not made any similar changes to the Volpe model.

The differences between the two models encourages 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), althought 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.

The feasibility of the model year 2022-2025 standards

Based upon the data in the PD and TSD, complemented by what we've outlined above, it is clear that the standards finalized in 2012 are technically feasible and cost-effective even under the conservative assumptions made by EPA. In fact, manufacturers are capable of meeting even stronger standards.

Technology has outpaced initial expectations, with manufacturers investing to respond to these standards. Consumers value the fuel economy these technologies bring, purchasing efficient vehicles in *all* classes at record numbers. These standards will continue to bring positive economic benefits to the United States through the fuel saved at the pump, money which could be re-injected into the economy to yield economic growth. And most importantly, strong 2025 standards will reduce our national carbon footprint, avoiding hundreds of millions of metric tons of emissions that lead to global climate change.

Nearly nine months after the Final Determination, the conclusions remain the same:

> "The record clearly establishes that, in light of technologies available today and improvements we project will occur between now and MY2022-2025, it will be practical and feasible for automakers to meet the MY2022-2025 standards at reasonable cost that will achieve the significant GHG emissions reduction goals of the program, while delivering significant reductions in oil consumption and associated fuel savings for consumers, significant benefits to public health and welfare, and without having material adverse impact on the industry, safety, or consumers." (EPA 2017b)

The feasibility of the model year 2021 standards

All of the above arguments supporting the feasibility of the 2022-2025 standards remain true for the model year 2021 standards. However, additional considerations are worth noting in light of the abbreviated lead-time for compliance with the model year 2021 standards.

It is well-established that manufacturers plan for compliance well in advance of the regulation, as noted by the Alliance of Automobile Manufacturers:

> "Designing vehicles requires multiple years of lead-time before production. This is recognized by Congress in its requirement that NHTSA set standards at least 18 months in advance. See 49 U.S.C. 32902(a). **Product plans through 2021 are essentially already in place, and changes that would significantly alter those plans would be difficult to implement** [emphasis added]." (AAM 2017)

Thus, altering MY2021 standards would do little to change technology deployment in the near-term, as manufacturers acknowledge they already have compliance plans in plans for the current MY2021 standards. This certainty was provided explicitly because these rules were finalized 9 years in advance, giving manufacturers nearly two full product cycles to prepare for compliance. If those standards are weakened, this would merely create a credit windfall for manufacturers, which could then be used to alter the compliance strategy in later years in favor of reduced investment in technology, a strategy that would be possible with these windfall credits.

Additionally, EPA offered manufacturers the flexibility to carry forward credits earned in the early years of the program all the way through model year 2021 (40 CFR 86.1865-12(k)(6)(ii)). Manufacturers have accrued credit offsets of more than 300 million metric tons of emissions under this provision, with EPA extending the lifetime of these credits in order to "help manufacturers resolve lead-time issues they might face in the early model years of [the 2017-2025] program as they transition from the 2016 standards to the **progressively more stringent standards for MY 2017 and later** [emphasis added]" (EPA and NHTSA 2012, p. 62788). However, this flexibility is predicated on the notion that manufacturers will be complying with "progressively more stringent standards"—weakening the MY2021 standards would thus negate the need for such a flexibility and necessitate that any credits earned under this program should expire no later than a year earlier.

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