RFF REPORT

Comments on Midterm Evaluation Draft Technical Assessment Report for Model Year 2022–2025 Light Duty Vehicle GHG Emissions and CAFE Standards

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Benjamin Leard, and Kenneth Gillingham

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RESOURCES FOR THE FUTURE

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Docket ID No. EPA–HQ– OAR–2015–0827 and
Docket No. NHTSA–2016–0068,

The Environmental Protection Agency and Department of Transportation present an impressive analysis for the Technical Assessment Report (TAR), which contains a lot of valuable information. We appreciate the opportunity to review the document and provide public comments.

As you may know, Resources for the Future (RFF) is a nonprofit and nonpartisan organization that conducts independent research—rooted primarily in economics and other social sciences—on environmental, energy, and natural resource policy issues. RFF neither lobbies nor takes positions on specific regulatory proposals, although individual researchers are encouraged to express their unique opinions—which may differ from those of other RFF experts, officers, and directors. All RFF research is available online, for free.

We are pleased to enclose two sets of comments. In the first set we focus on the discussion of opportunity costs in Chapter 4 and the rebound effect in Chapter 10. We make these comments jointly with Kenneth Gillingham of Yale University. The main comments and recommendations are as follows:

- The agencies have misinterpreted the literature on opportunity costs regarding its implications for innovation. We provide the correct interpretation in the comments.
- We summarize a straightforward approach the agencies could take to incorporate opportunity costs in their benefit–cost analysis.
- We believe it would be useful if the agencies provided further clarification and transparency around the calculation that is used to arrive at a 10 percent rebound.

The second set of comments focuses on California's Zero Emission Vehicle (ZEV) program and its implications for the estimated benefits and costs of the federal standards; the implications of gasoline prices for the benefits and costs of the standards; and crediting in the fuel economy and greenhouse gas programs. The main comments and recommendations are as follows:

- The agencies should report sensitivity analysis of the benefits and costs in which they make the same assumptions about whether ZEV is included in the reference fleet.
- The agencies should explain why their cost estimates differ from one another by more than a factor of two.
- The agencies should conduct a sensitivity analysis of the effect of gasoline prices on the benefits and costs of the standards, which includes behavioral responses by consumers and manufacturers.
- The agencies should report the estimated credit prices from their modeling of the standards, and explore ways to better harmonize the crediting provisions.

Sincerely,
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Comments on Opportunity Costs and the Rebound Effect

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Resources for the Future

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The following comments focus on two topics in the TAR: opportunity costs (discussed in Section 4.1.3), and rebound (discussed in Section 10.4). We argue that the agencies have misinterpreted the recent literature on opportunity costs of the standards in an important way. A correct interpretation of the literature suggests a straightforward approach to estimating opportunity costs within the benefit–cost framework the agencies currently use, which we outline below. A key aspect of this interpretation is that it would imply a more realistic reference case than the one EPA is using. The comments on the rebound literature request further information about how the agencies arrived at their preferred estimate of the elasticity of miles traveled to fuel economy.

1. Opportunity Costs

a. Background

In the TAR, the reference fleet is the projection of the vehicle fleet for 2022–2025, against which costs and benefits of the standards are estimated. The reference case fleet is constructed based on projections of the car/truck split and overall vehicle sales. The reference fleet meets the 2021 fuel economy standards, and then for the years 2022 to 2025, fuel economy of the fleet remains the same and other characteristics of vehicles such as horsepower also remain unchanged.

In its 2015 report, the National Research Council (NRC) recommends that the agencies consider how to develop a reference fleet that includes improvements in vehicle characteristics, other than fuel economy, which occur over time when standards are maintained at certain levels. Several recently published studies, which the agencies cite, document the steady improvements in horsepower and acceleration time that have occurred over the past 30 years. These changes reflect the adoption by vehicle manufacturers of technology that allows them to increase horsepower or reduce acceleration time without reducing fuel economy. Moreover, these changes have occurred during time periods when the stringency of the standards was not changing. **Therefore, the agencies' assumption that vehicle characteristics are unchanged in the reference case is inconsistent with past evidence.**

As the NRC recognizes, including changes in vehicle characteristics in the reference case would account for opportunity costs of foregone improvements in the policy case (i.e., the scenarios that include the standards). In the policy cases, the agencies assume that fuel economy increases relative to 2021, but that other characteristics are unchanged. Because fuel economy is higher in the policy case than the reference case, consumers benefit from lower fuel costs. However, one might expect that consumers also incur an opportunity cost, because vehicles purchased after 2021 in the policy case have lower levels of non-fuel economy characteristics than those vehicles would have had in the reference case. For example, if recent trends continue, manufacturers would continue to improve performance or other desired vehicle characteristics between 2021 and 2025 in the reference case, in which standards are maintained at 2021 levels. Therefore, performance would be lower in the policy case than the reference case in this example. The foregone performance represents an opportunity cost that is not included in the current benefit–cost framework. We use performance here as a broad measure of desirable vehicle characteristics that do not improve with fuel efficiency, such as acceleration time, responsiveness or handling.

In the TAR, the agencies discuss the literature relevant to estimating reference case vehicle changes, but they do not develop a reference fleet that includes improvements in vehicle attributes other than fuel economy. **In these comments, we argue that the agencies have misinterpreted the literature in an important way, and we summarize a straightforward approach the agencies could take to incorporate opportunity costs in benefit–cost analysis.** This approach would not require any major changes to the current structure and would be based on recently published research.

b. Interpretation of the Literature

Several recent papers, including Knittel (2011), MacKenzie and Heywood (2015), and Klier and Linn (2016), have attempted to estimate efficiency improvements over time in the US markets for cars and light trucks. The analysis relies on a version of a production possibilities frontier for fuel efficiency for a particular vehicle. The manufacturer can move along the frontier by trading off fuel economy for other attributes, such as 0-60 mph time or horsepower. In other words, moving along the frontier, the manufacturer can add fuel economy but has to reduce the performance. Another possibility is that instead of moving along the frontier, the manufacturer can add fuel-saving technology that causes the frontier to shift—allowing for higher fuel economy without sacrificing other attributes. Of course, adding technology raises the vehicle's production costs, although costs are not examined explicitly in this literature. (In some papers it is assumed that production costs do not vary along the frontier and, in others, that fuel-saving technology is constant, but this difference isn't important for the purposes of our comments.) The studies differ a bit in data sources and methodology, but they reach a common conclusion that efficiency has improved steadily over time, by about 1–2 percent per year. They also document tradeoffs between fuel economy and other attributes along the frontier, again differing in the extent of the tradeoffs. Partly, that difference reflects the underlying source of identification—tradeoffs tend to be greater when comparing closely related vehicles (for example, versions of a particular model) as compared to versions of different models. Tradeoffs also differ according to the definition of performance.

What does this analysis imply for the construction of the reference case and for calculating opportunity costs of the regulations? In the TAR, the agencies correctly distinguish between the concept of innovation, as the development of new technology, and adoption of existing technology. **However, the agencies incorrectly interpret the literature as suggesting that frontier shifts imply that innovation has occurred.** None of the papers cited in the TAR try to distinguish between adoption of new technologies, and adoption of existing technologies. In fact, they document efficiency improvements that result from technology adoption. Whether that technology represents innovation is not assessed. This is primarily for data reasons, that the available data do not directly link adoption and innovation. Moreover, as Whitefoot et al. (2013) point out, the tradeoff curves represent outcomes from the market, and are not true technology frontiers that represent technical tradeoffs between attributes.

Consequently, the fact that the frontiers shifted over time does not by itself indicate that innovation has occurred. For example, Klier and Linn (2016) estimate that the frontier shifted by about 2 percent between 2012 and 2013. This shift is likely to have occurred at least in part because of the adoption of cylinder deactivation in light trucks. This technology existed and was used in the market prior to 2012, so it is not appropriate to describe that as innovation. Surely some amount of innovation has occurred over the long period of time that these papers analyze, which has expanded the set of technologies available to manufacturers. But the year-to-year efficiency improvements reflect the adoption of technologies including the technologies discussed in the Fuel Economy Trends reports.

In other words, the frontier shifts include the adoption of the very same technologies that are the basis of the fuel economy and greenhouse gas standards. If the agencies wish to claim that the literature has documented innovation, for consistency, they would have to say that innovation would be required to meet the standards—that is, the literature and the agencies are largely talking about the very same technologies.

Rather, the correct interpretation is that efficiency has improved in the absence of tightening standards. This reflects adoption of existing as well as new technology. This research directly speaks to the determination of the reference fleet, because it suggests how efficiency would increase if the stringency of the standards did not change over time. This point is discussed further in the next section.

In contrast to the strong and consistent evidence of technology adoption when standards do not change, the literature currently provides no evidence that standards have caused innovation. Klier and Linn (2016) show that standards accelerate the rate of technology adoption, but the analysis in that paper says nothing about innovation. That is not to say that the standards do not cause innovation, just that the literature has not demonstrated this effect. Therefore, whereas constructing a reference case that includes improvements in vehicle attributes would be entirely consistent with the literature, asserting that the standards cause innovation currently has no direct support in the literature on passenger vehicles. The TAR correctly notes the broader literature on regulation and innovation, which indicates that in many contexts regulation can affect innovation. But unfortunately this literature does not provide enough information to generate quantitative estimates of the effect of the standards on innovation.

A less important issue is that the agencies appear to prefer estimation of the technological frontier that does not control for fuel/power type (diesel fuel, hybrid, etc.), as in MacKenzie and Heywood (2015). **They argue that controlling for fuel type would obscure the effects of shifting to more efficient fuel or power types. But, from the perspective of characterizing the reference fleet, this is a specious argument.** The linear regression models these papers use are essentially decompositions of changes in fuel economy (i.e., the dependent variable) into various sources: efficiency improvements, changes in horsepower or weight, and changes in other attributes such as fuel type. For example, Klier and Linn (2016) control for hybrid fuel type, and the coefficients on weight and horsepower capture tradeoffs within a fuel or power type. Omitting the control for hybrid power type would yield a different interpretation of those coefficients. Despite the fact that controlling for fuel/power type affects the interpretation of the tradeoff coefficients, including these controls should not affect the change in reference fleet fuel efficiency, as long as the estimation results are used properly. In particular, if the analysis includes fuel/power type controls, then the overall increase in efficiency between two years includes two terms: a) within fuel/power type efficiency improvements and b) across fuel/power type improvements. Both factors should be included when estimating the overall efficiency improvements across the fleet. Alternatively, if fuel/power type is not controlled for, (a) and (b) would be jointly estimated. As long as both (a) and (b) are included in the first type of analysis, it would yield the same estimate of the average rate of frontier shift as the second type of analysis.

c. Framework for Incorporating Opportunity Costs in Benefit–Cost Analysis

Before proposing a framework for incorporating opportunity costs, it is useful to consider as a benchmark a hypothetical economic model that fully integrates manufacturer and consumer decisions. Such a model would be dynamic, in which manufactures would choose prices, technology, and characteristics for each vehicle in the market, anticipating future consumer demand for their vehicles. Consumers would choose which vehicle to purchase given the prices and characteristics of the vehicles. Equilibrium in each model year would occur when prices and vehicle characteristics balance vehicle demand and supply. The model could include such features as staggered redesign schedules, uncertainty in fuel prices or other parameters, and a detailed representation of technology choice. If the agencies had such a model, they could simulate the model under alternative scenarios—with and without tighter standards—and estimate costs and benefits of the standards by comparing the model output across the two scenarios. This comparison would yield an internally consistent estimate of benefits and costs of tighter standards.

Such a model does not exist, of course. In its absence, we suggest how the agencies can modify their existing benefit–cost framework and produce estimates that approximate the opportunity costs that would be estimated from such a model. This approach rests on the recent literature.

The agencies would begin by assuming that manufacturers in 2021 have a set of available technologies that can improve the efficiency of the vehicles in the market. In the policy case, manufacturers would adopt technology that improves fuel economy, and adopt sufficient technology to meet the 2025 standards (or exhaust the set of available technologies). This framework for the policy case is identical to the framework the agencies currently use.

The reference case would differ from the reference case the agencies describe in the TAR. In the reference case we outline here, manufacturers begin with the fleet in 2021 and can choose among the same set of technologies as in the policy case (it is conceivable that the agencies could argue that a particular technology would only be available following innovation induced by the regulation; it could be removed from the set of technologies available in the reference case, but such an argument would have to be grounded in the literature). The difference between the policy and reference cases is that in the reference case the manufacturers can use those technologies to boost other vehicle attributes, such as performance.

The agencies would have to choose a proxy for performance—for example, horsepower, or the ratio of horsepower to weight, or the 0-60 mph time. Having chosen a proxy for performance, the agencies would convert the efficiency improvement that arises from the reference case technology adoption (in mpg) to a performance improvement. This conversion could be made using the estimated fuel economy/performance tradeoffs in the literature or by other means (for example, engine simulation tools). The agencies may also compare results using alternative definitions of performance.

The assumption that the manufacturers choose from among the same set of technologies in the reference and policy cases is consistent with the literature, which documents year-to-year efficiency improvements that stem from technology adoption, but does not attempt to analyze whether standards have caused innovation that would change the set of technologies available to manufacturers. Note that although the manufacturers choose from among the same technologies in the reference and policy cases, they will not necessarily adopt the same technologies in the two cases. And, as stated above, if evidence can be found for a particular technology that relies on the induced innovation, then this technology can be excluded from the set to add further realism.

How much technology do manufacturers adopt in the reference case? If the agencies were using an integrated model of demand and supply as described above, the amount of technology adoption in the reference case would be determined within the model. But without such a model, the agencies could approximate the amount of technology adopted in the reference case by assuming that efficiency improvements proceed at historical rates. The literature documents fairly steady efficiency improvements over more than 30 years, including periods of unchanging standards, which supports an assumption that efficiency improvements in the reference fleet occur at the historical rate.

This analysis yields two fleets: the reference fleet, which includes performance improvements between 2021 and 2025 but no fuel economy improvements; and the policy fleet, which includes fuel economy improvements between 2021 and 2025, but no performance improvements. That is, in both fleets, manufacturers add fuel-saving technology, such as advanced transmissions. In the reference fleet, manufacturers use that technology to increase performance while maintaining a constant level of fuel economy, which is consistent with past evidence. For example, they may begin with a vehicle that has a 4-cylinder engine, switch to a 6-cylinder engine and add enough fuel-saving technology that the 6-cylinder engine has the same fuel economy as the original 4-cylinder engine.

In the policy fleet, manufacturers use that technology to increase fuel economy while maintaining performance at 2021 levels; this is consistent with the agencies' current approach, which maintains performance at pre-policy levels. Note that to construct the policy case we have assumed that the stringency of the standards increases at a faster rate than the historical rate of efficiency improvements. This is consistent with the 2021–2025 standards and with historical rates of efficiency improvement.

The benefits to consumers would include the value of the fuel savings that arise from the policy fleet relative to the reference fleet. **The opportunity costs would be the willingness to pay for the difference in performance between the reference and policy fleets.** To calculate the opportunity costs the agencies would need to assume a willingness to pay for performance. The literature has yielded a wide range of willingness to pay estimates, and the agencies could choose a central value from the literature and perform sensitivity analysis around that assumption. This approach would be similar to that taken in Whitefoot and Skerlos (2012) and Klier and Linn (2016).

Finally, the agencies would compute the costs to manufacturers of complying with the standards, which would be the difference between the costs of producing the policy and reference fleets. For example, suppose the reference case includes 2 percent improvements in efficiency per year, and the standards require 4 percent improvements per year. The costs to manufacturers would reflect the additional cost of 4 percent improvement, relative to 2 percent improvement.

Three aspects of this approach are noteworthy. The first regards the source of performance increases in the reference fleet. The proposed methodology has the advantage of consistency between the reference and policy cases—in the two cases, manufacturers choose from the same set of fuel-saving technologies. This framework is consistent with the literature on efficiency improvements discussed above, which has documented strong evidence of technology adoption but has not addressed the question of whether fuel economy standards affect innovation.

Second, this approach, relative to the current approach, would yield lower net benefits to consumers (i.e., value of fuel savings less opportunity costs) because it includes the opportunity costs of foregone performance improvements in the policy case. However, the approach would also yield lower costs to manufacturers because the reference case includes technology adoption that is absent from the current framework.

Third, and following from the second, the greater the rate of technology adoption in the reference case, the greater the opportunity costs of the standards and the lower the costs to manufacturers. To see this, suppose for illustrative purposes that the standards require 2 percent fuel economy improvement per year. Suppose further that the agencies assume 2 percent efficiency improvement in the reference case. Then comparing the policy and reference cases would imply that the standards do not impose any cost on manufacturers—they would adopt the same amount of technology without or with the tighter standards. But the cost would show up as foregone performance in the reference case—that is, as an opportunity cost. Alternatively, suppose the reference case includes 1 percent efficiency improvements per year. In the policy case, manufacturers would have to improve efficiency at twice the rate as in the reference case (2 percent versus 1 percent). Manufacturers would incur the cost of faster technology adoption, but consumers would face lower opportunity costs compared to the first example. The overall implications of these effects for net benefits would have to be estimated in the proposed framework.

2. Rebound

The agencies review the extensive rebound literature, focusing on recent estimates. They characterize estimates as ranging from 10–30 percent, which we agree is a reasonable description. The agencies then use 10 percent as the rebound effect, focusing on recent work by Hymel and Small (2015), and arguing that rising income will reduce the magnitude of the rebound effect. We believe it would be useful if the agencies provided further clarification and transparency around the calculation that is used to arrive at a 10 percent rebound. One argument could start with the midpoint of the range, or 20 percent and then use estimates from the literature to model how increases in income going forward translate into a lower rebound effect.

It would also be useful to discuss whether the rebound effect being used is a short-run, medium-run, or long-run rebound effect. Similarly, it would be useful to discuss whether the estimate accounts for the indirect rebound effect or just the direct rebound effect.

Comments on the Zero Emission Vehicle (ZEV) Program, Gasoline Prices, and Credits

Virginia McConnell, Joshua Linn,
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Resources for the Future

1. Treatment of ZEV Requirement in Assessment of the Augural Standard

In the TAR, NHTSA and EPA use different reference cases for analysis of the 2022–2025 regulations. NHTSA does not assume that California and the other Section 177 states will have met the ZEV requirements when constructing its baseline or reference case, whereas EPA does. EPA assumes that the electric vehicles that the ZEV program requires will be part of the new vehicles fleet from 2022–2025 even without the CAFE regulations. NHTSA does not include the ZEV-mandated vehicles in its reference case. Thus, the EPA includes ZEV in the baseline but NHTSA does not.

We believe that the amount of credits for electric vehicles that the ZEV program ultimately requires between 2022 and 2025 is highly uncertain. The amount is probably more than zero, which is implicitly the NHTSA assumption for its reference fleet. But given the history of the program and potential changes to the program, it is possible that the amount is less than that currently required by ZEV. But because the agencies can make different assumptions about how to treat the ZEV mandate when constructing the reference case, and because it is uncertain how quickly the ZEV program will successfully be implemented through all of the states that have adopted it, it seems that some sensitivity around the reference fleet would be appropriate. For example, both agency models have the ability to assess costs and benefits of the standards both with and without the ZEV requirements as part of the reference or baseline.

Notwithstanding the suggestion above, it is important to look at what the agencies have each estimated separately for costs and benefits. We show some of the aggregate components of costs and benefits below. We find that it is difficult to reconcile the separate assessments by EPA and NHTSA in the current TAR. In particular, the vehicle plus maintenance cost estimates differ by more than a factor of two. Both of these sets of estimates use RPE for vehicle cost mark up, and a 3 percent discount rate.

Costs and Benefits of the Augural 2022–2025 Standards

EPA (page 12–67)

Vehicle costs:	$39 billion
Fuel savings:	$88.8 billion
GHG benefits	$4–56 billion

NHTSA (page 13–103)

Vehicle costs:	$93 billion
Fuel savings:	$122 billion
GHG benefits:	$27 billion

We can think of at least three (not mutually exclusive) reasons why the cost estimates could differ by so much. The first is that EPA includes ZEV in the reference case but NHTSA does not. We would expect that the costs of having the ZEV vehicles as part of the reference case would lower the costs of meeting the 2022–2025 augural standards. Manufacturers do not have to increase fuel economy and reduce emissions as much to meet the federal standards because ZEV already gets them part of the way. If this is the only or the major reason for the difference, this would imply that the costs of the ZEV program are very high.

A second interpretation is that the two agencies use different assumptions about the costs of the technologies themselves or how they are implemented. The NHTSA analysis does include the cost of other model year (MY) vehicles as part of the cost of meeting the 2022–2025MY standards (see table 13-25 on page 13-103). But its analysis assumes the least-cost approach by the manufacturers, as does EPA's analysis. This interpretation would suggest that NHTSA is much more pessimistic about the costs of the technologies, and it also indicates the magnitude of the uncertainty about the potential costs of the standards—that costs could vary by a factor of two.

A third possibility is that the NHTSA standards are more difficult to attain. The agencies coordinate the levels of the standards so that their stringencies increase at about the same rates over time. However, there are multiple differences between the two programs, particularly related to crediting for specific technologies or vehicle types. Therefore, it is possible that after one takes account of all of these differences, it turns out that the NHTSA standards are more costly than the EPA standards. This interpretation would indicate that the agencies have not sufficiently coordinated the programs.

This raises a more general point, that comparing the EPA and NHTSA cost and benefit estimates is important. As it stands, the analyses are completely separate and it is not clear how they are different and what explains any differences.

Have the agencies considered how the models could be coordinated or at least made more comparable? Or, perhaps a coordinated single model and assessment could be used by both agencies.

2. The Effects of Fuel Prices on Costs and Benefits of Standards

The dramatic decline in oil prices since 2014 indicates the importance of gasoline prices for the 2022–2025 standards. Lower fuel prices reduce consumer demand for high fuel–economy vehicles, and reduce the cost of driving, causing consumers to drive their vehicles more miles. Low prices will also influence how much manufacturers will have to raise fuel economy and reduce emissions to meet the standards. The reason is that a vehicle's fuel economy or emissions requirement depends on its footprint, and changes in fuel prices do not necessarily affect the level of fuel economy that consumers choose and the fuel economy requirement by the same amount. For example, suppose there are two versions of a model, one with a 4-cylinder and one with a 6-cylinder engine. A reduction of fuel prices could cause consumers to shift from the 4 to 6-cylinder version reducing the sales-weighted average fuel economy across the two versions, but leaving the sales-weighted requirement unchanged. This effect raises the cost of compliance to manufacturers.

In the TAR, both agencies have improved their assessments of the effects of fuel prices on the costs and benefits of the standards. Both agencies now account for how lower fuel prices are likely to affect the mix of cars and trucks by using the car/truck sales mix from the AEO 2015 high and low fuel price forecasts and associated car truck sales mix. These sales mixes are inputs to their analyses of the effect of fuel prices on outcomes of the proposed rule for 2022–2025. This change in sales mix then affects the standard that each manufacturer's fleets must meet. In addition, NHTSA allows fuel prices to influence costs and benefits of the rule in a number of ways: the mix of technologies used to meet the standard, the extent of overcompliance with the rule by some manufacturers, and the amount paid in fines by other manufacturers.

We think there are additional ways low gasoline prices may affect the outcome of the standards. We have explored the effects of low gasoline prices on costs and benefits of the standards in a recent paper, focusing on consumer and producer responses to lower fuel costs (Leard et al. 2016), Our analysis incorporates three types of consumer and manufacturer responses to fuel prices, which are only partially incorporated in the agencies assessments in the TAR. First, we use evidence of the effect of lower fuel prices on model level vehicle sales shares to capture effects of fuel prices not just on the car-truck split but on sales shifts within those categories. Second, we use recent estimates of fuel cost elasticities of miles traveled to account for the effects of lower fuel prices on vehicle miles traveled. Third, we estimate that in the short run lower fuel costs open a gap between the fuel economy that consumers choose and the level of fuel economy that manufacturers must attain to meet the standards. We estimate the costs to manufacturers of making up this gap. We estimate the effect of fuel prices on costs and benefits of the standards for only one model year, 2015, to illustrate the nature of the behavioral responses and their potential magnitudes.

We find that the 25 percent decrease of the fuel price forecast reduced the value of fuel savings on net by less than 25 percent because of consumer responses such as the types of vehicles purchased, and the amount of driving, and because of the change in the required standard. Two other results also highlight the importance of including behavioral responses. First, lower gasoline prices raise the cost to manufacturers of achieving the standards, and second, lower prices result in larger GHG emissions reductions. The higher manufacturer costs arise because the level of fuel economy demanded falls by more than the reduction of the fuel economy requirement, and manufacturers have to make up the difference (for example, by adding more fuel-saving technology). This raises costs by about $0.5 billion per year, or about 9 percent of total net benefits of the program. Higher emissions reductions occur because lower gasoline prices cause people to drive more, so emissions fall by more under the standards.

One issue that emerged in our analysis is the importance of the reference (EPA) or baseline (NHTSA) case to which the costs and benefits of the standards are compared. If fuel prices are lower than expected, the reference or baseline cases will be different. With no change to the standards after 2021, there will be different mix of cars and trucks, and also a different size and fuel efficiency mix of vehicles within each of these categories, if we compare low and moderate fuel price scenarios. For consistency, the agencies should account for the effects of fuel prices not only on the policy fleet but also on the reference or baseline fleet.

We applaud the agencies for their efforts to examine more carefully at the effect of fuel prices on the costs and benefits. Based on our analysis, and on our reading of the agencies' methods in the TAR, we suggest the following (we focus on low prices because that appears to be the issue for the 2022–2025 rule):

1. Design the reference or baseline for the low fuel price case to be a true counterfactual – what would the world be like if there were significantly lower prices than some midrange prediction. This should include the effect on how much cars are driven, on the mix of vehicle size and fuel efficiency within the car and truck categories. This change to the

reference fleet would be consistent with evidence of the effects of low fuel prices from the literature.

2. Account for the effects of fuel prices on the difference between the fuel economy in the reference case and the fuel economy required by the standards, in both the midrange fuel price and the low fuel price case. Based on our analysis, we expect that lower fuel prices will increase the difference in fuel economy between the policy and reference fleets, raising costs for manufacturers. Yet, EPA has the incremental cost per vehicle of cars lower under low gasoline prices than reference gasoline prices: additional cost due to meeting 2022-2025 standard in 2025 is $789 in the reference fuel price case and $782 in the low fuel price case (using the RPE). The difference is in the same direction and even larger for trucks (see pages 12-38 and 12-39). These costs differences seem to be the opposite of what we would expect.
3. Account for the effect of low fuel prices on the amount of fuel savings and on CO2 benefits in both the reference and rule cases, accounting for changes in miles traveled. We expect that lower fuel prices increase the amount of driving, which is consistent with the literature on gasoline demand and vehicle miles traveled. In our analysis, this effect dominates other behavioral responses that affect total fuel savings and CO2 benefits, such that lower fuel prices increase the fuel savings and CO2 benefits.

Behavioral responses to the standards themselves as well as to fuel prices are important in determining the overall benefits and costs of the standards. They may even be as important as the costs and performance of individual technologies to the success of the regulations. Both are unknown in the future, but both can be predicted with data, models and analysis. We urge the agencies to continue to model and estimate the consumer and producer responses both to these changes in fuel prices and in other parts of the assessment as well.

3. Inferring Costs from the Credits Programs

The modeling of compliance by both agencies now attempts to include manufacturers' use of averaging, banking and trading of credits. Both agencies model the use of credits for transfer between cars and trucks, and the trading of credits among companies. Implicit in this analysis is a cost or shadow price of those credits. For example, if a manufacturer overcomplies with its truck fleet and transfers those credits to its car fleet, the models have information on the cost of additional controls on the trucks and the cars, and therefore the "price" of the traded credit (or additional cost of last units of emissions or fuel reduced). Have the agencies examined these prices? We believe it is important to capture and report these prices since prices should reflect the costs of complying at the margin for different companies. These marginal costs are important for understanding the differing incentives for technology adoption that the two standards create.

At the end of Chapter 11, the agencies acknowledge that there are different flexibilities allowed in granting and using credits between the two programs. These differences raise the overall costs of complying with the two programs—that having two programs jointly regulate essentially the same thing increases the cost of meeting that objective. We have a recent paper that discusses the differences in the two program and some of the costs these differences create (Leard and McConnell, 2016). Are the agencies looking at the differences in the crediting programs, the potential costs and at ways to better harmonize them?

For example, under NHTSA rules a single manufacturer will not be able to trade credits between cars and trucks freely to minimize costs because the NHTSA rules impose a limit on the number of credits that can be traded between the two vehicle types. EPA does not have a limit on this type of trade. Because a manufacturer has to comply with both rules, in this case the NHTSA rule will be binding and the manufacturer will face higher costs than if the credits could be fully traded. EPA in its sensitivity analyses starting on page 12-37 provides an estimate of the costs of no trading between cars and trucks compared to the cost of freely tradable credits between cars and trucks. They show the technology used and the average cost per vehicle when credits can be fully traded and when they cannot be traded at all. The cost per vehicle is $703 with full trading of credits, and $775 with no trading, an increase of about 10 percent. Because the NHTSA rule does allow some trading, this probably overstates the cost of NHTSA's trading restriction, but it gives an idea of how restrictions that are different in one program may raise the costs of compliance in the other program. We suggest that the agencies do more to explore the costs or inefficiencies that arise because of the differences in crediting between the two programs as a way to identify the most significant areas for harmonization.

References

Hymel, K. and K. Small. 2015. "The rebound effect for automobile travel: Asymmetric response to price changes and novel features of the 2000s." *Energy Economics*, vol. 49: 93-103.

Klier, T. and J. Linn. (2016). "The Effect of Vehicle Fuel Economy Standards on Technology Adoption." *Journal of Public Economics* 133: 41-63.

Knittel, C. R. (2011). "Automobiles on Steroids: Product Attribute Trade-Offs and Technological Progress in the Automobile Sector." *American Economic Review* 101(7): pp. 3368–3399.

Leard, B., J. Linn and V. McConnell. 2016. "Fuel Prices, New Vehicle Fuel Economy, and Implications for Attribute-Based Standards," RFF Discussion Paper, DP 16-04, and provisional acceptance, *Journal of the Association of Environmental and Resource Economists.*

Leard, B. and V. McConnell. 2016. "New Markets for Pollution and Energy Efficiency: Credit Trading under Automobile Greenhouse Gas and Fuel Economy Standards" Resources for the Future Discussion Paper No.15- 16_Rev.

McKenzie, D. and J. Heywood. (2015). "Quantifying efficiency technology improvements in U.S. cars from 1975-2009." *Applied Energy* 157: 918-928;

Whitefoot, K. and S. Skerlos. 2012. "Design incentives to increase vehicle size created from the US footprint-based fuel economy standards." *Energy Policy* 41: 402-411.

Whitefoot, K., M. Fowlie, and S. Skerlos. 2013. "Compliance by design: Industry response to energy efficiency standards", Technical Report, UC Berkeley, College of Natural Resources.