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EPA Mass Reduction Analysis – Observations and Recommendations

CENTER FOR AUTOMOTIVE RESEARCH

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CAR's mission is to conduct independent research and analysis to educate, inform and advise stakeholders, policy makers, and the general public on critical issues facing the automotive industry, and the industry's impact on the U.S. economy and society.

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Background

The rulemaking establishing the national program for federal greenhouse gas (GHG) emissions and corporate average fuel economy (CAFE) standards for MY2017-2025 light-duty vehicles included a regulatory requirement for the U.S. Environmental Protection Agency (EPA) to conduct a Midterm Evaluation (MTE) of the GHG standards established for MY2022-2025. Through the MTE, EPA will determine whether the GHG standards for model years 2022-2025, which were established in 2012, are still appropriate. EPA's decision could result in one of three outcomes: the standards remain appropriate, the standards should be made less stringent, or the standards should be made more stringent. The draft Technical Assessment Report (TAR) published in July 2016 was the first formal step for the MTE; the report examined a wide range of technical issues relevant to the appropriateness of the GHG emissions standards for MY2022-2025. Even though the draft TAR was issued jointly by EPA, the National Highway Traffic Safety Administration (NHTSA), and the California Air Resources Board (CARB) – the technical analysis performed by NHTSA and EPA have significant differences. Caution must be taken in reading the draft TAR as one can get confused between the two very different analyses in the agencies' report.

EPA issued a proposed adjudicatory determination following the draft TAR on November 30, 2016. In the proposed determination, EPA decided that the GHG standards currently in place for MY2022-2025 remain appropriate under the Clean Air Act and thus need not be amended to be either more or less stringent. Only a 30-day public comment period was provided. On January 13, 2017, EPA signed the final determination in which it decided <u>not</u> to amend the regulations. Following the change in administration, EPA announced it intends to reconsider the final determination. EPA intends to make a new Final Determination regarding the appropriateness of the standards no later than April 1, 2018.

Purpose

In this report, CAR researchers assess the technical analysis for vehicle mass reduction performed by the U.S. Environment Protection Agency in the draft TAR. <u>CAR's internal research, as outlined in this document, focuses on mass reduction analysis only</u>. CAR's analysis finds that the EPA's approach is substantially incorrect and warrants significant revision. This report provides observations and recommendations designed to improve EPA's analysis. Among the shortcomings found in EPA's mass reduction analysis include:

- Establishing a baseline cost curve from two different vehicles with no evidence that these two are representative of the U.S. fleet
- Extrapolating lightweighting costs (the cost curve) from one vehicle to other vehicles with different, yet unknown lightweight technology
- Assuming all 2008 vehicles are at a common baseline of lightweight technology
- Relying on vehicle curb weight as a proxy for measuring the amount of lightweight material technology in a vehicle
- Adjusting curb weight only for footprint increase and previous safety regulations, but not considering mass add-backs for future safety and new vehicle content

CAR recommends that the EPA employ a material-based lightweighting cost analysis as recommended by the National Research Council (NRC), and reevaluate the cost to lightweight the U.S. fleet.

NHTSA AND EPA MASS REDUCTION – SIMILAR METHODOLOGY BUT DIFFERENT TOOLS

The analysis steps used by NHTSA and EPA are similar but the baselines, tools, statistical techniques, and assumptions used by each agency are significantly different, and have led to different results. In addition to different lightweighting cost curves, different assumptions were made limiting mass reduction because of safety concerns over lightweight vehicles. EPA limited vehicle weight to 3,200 pounds, while NHTSA used a different approach with sales-weighted average for a platform of not-less-than 2,800 pounds. The impact of all these differences produce very different mass reduction projections for the same U.S. vehicle fleet. EPA projected an average 9 percent mass reduction for GHG compliance (Proposed Determination, Nov 2016, pg. 2-413) while NHTSA projected a 6 percent mass reduction for CAFE compliance (2016 Draft TAR, Table ES-3). Figure 1 shows the general modeling strategy and the different tools used by the agencies.

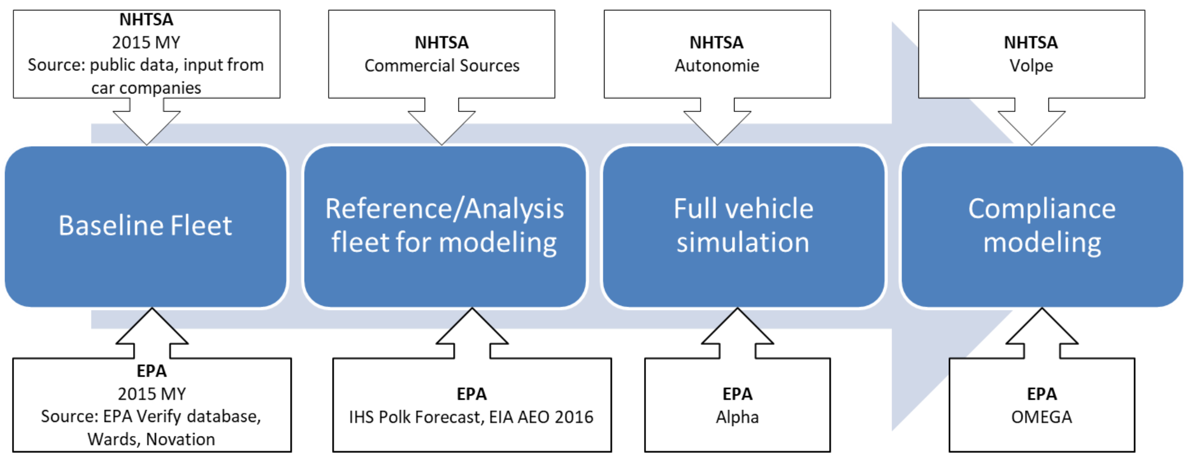

Figure 1: General Modeling Strategy

The first step to be determined in the modeling is defining the baseline fleet. EPA used MY2014 data in the draft TAR but updated the fleet to MY2015 in the Proposed Determination (published November 2016). The baseline fleet accounts for technologies already deployed in the fleet. All further analysis is performed on the baseline fleet.

In the second step, the agencies project the sales volumes of the vehicles they believe would exist in MY2022-2025, absent the application of regulations. The fleet with the projected volume but current technology is called the "reference fleet." EPA used IHS Polk Forecast and EIA Annual Energy Outlook 2016 to predict the sales. It is important to note that the agencies used publically available data to create the reference fleet. Thus, the reference fleet does not reflect any future model additions, subtractions or any significant changes in the MY2022-2025 vehicle mix. The agencies may have embraced this approach because being a public agency, they need to publish all data, hence cannot ask for confidential business information about future products. Not reflecting future model additions, subtractions or any changes in the MY2022-2025 vehicle mix is a shortcoming in the modeling. For example, Ford is expected to introduce the EcoSport SUV, Ranger pickup truck and Bronco SUV in the next few years and discontinue the Lincoln MKS. When new products are introduced, workload limitations may preclude redesigns for some existing models in a manufacturer's fleet.

In the third and fourth steps, the agencies account for technologies and corresponding increases in vehicle cost, and reductions in CO_2 emissions (EPA) or fuel consumption (NHTSA). To achieve this, EPA used two software models, the Advanced Light-Duty Powertrain and Hybrid Analysis (ALPHA) full vehicle simulation model and the Optimization Model for Reducing Emissions of Greenhouse Gases from Automobiles (OMEGA) model. ALPHA is a full vehicle computer simulation model based in MATLAB that can analyze various vehicle types with different powertrain technologies. ALPHA runs pre-determined vehicle drive cycles to determine fuel consumption values to calculate GHG CO_2 values. The output of the ALPHA model feeds into the OMEGA model which incrementally improves the effectiveness of vehicle models in the baseline fleet as technology packages are applied. The Technology Application Ranking Factor (TARF) is the factor used by the OMEGA model to rank packages and determine which are the most cost-effective to apply. The TARF is calculated as the net incremental cost (or savings) of a technology package per kilogram of CO_2 reduced by the impact of the previous package (2012 EPA RIA, p. 1-25). The OMEGA model also calculates the cost that is associated with applying technologies for the U.S. fleet to be compliant with the GHG standards.

NHTSA uses a similar methodology to determine cost and effectiveness of technologies to estimate pathways to CAFE compliance. The major differences with the EPA are in the analysis fleet and software tools. As opposed to ALPHA, NHTSA uses AUTONOMIE for full vehicle simulations. For compliance modeling, EPA uses OMEGA, whereas NHTSA uses the CAFE Volpe model.

Observation 1 – Rulemaking Should Be Based On One Set of Methodology and Tools

The automakers by law have to meet both EPA GHG and NHTSA CAFE regulations or cope with the consequences. On May 21, 2010, President Obama issued an Executive Order directing NHTSA and EPA to develop a "coordinated national program" of "joint Federal standards" to improve automobile fuel efficiency and reduce GHG emissions from light-duty vehicles. The national program was expected to be built on the premise of harmonization between the two programs. In the draft TAR, algorithms applied by EPA and NHTSA in their respective software are significantly different and thus produce different regulatory compliance pathways in terms of technology application and cost which will limit the realization of harmonized regulations.

Several of the key differences that exist between the EPA and NHTSA analysis are as follows:

- EPA's analysis includes consideration for compliance with CARB's ZEV regulation that has also been adopted by nine other states (in the baseline/reference fleet) while NHTSA's analysis does not.
- EPA's primary analysis uses Indirect Cost Multipliers (ICMs) and NHTSA's primary analysis uses Retail Price Equivalent (RPE).
- Compliance costs per vehicle for the MY2025 standards are projected by EPA to be $894 and by NHTSA to be $1,245 (2016 Draft TAR, pp. ES9-10).

EPA Mass Reduction Modeling Methodology

Lighter vehicles consume less fuel. Low fuel consumption accounts for low GHG emissions. Lighter vehicles can also accommodate downsized propulsion systems. EPA measures mass reduction by a decrease in curb weight. The agency used an effectiveness value of 5.2 percent for every 10 percent reduction in mass reduction. Figure 2 describes mass reduction general modeling strategy used by EPA.

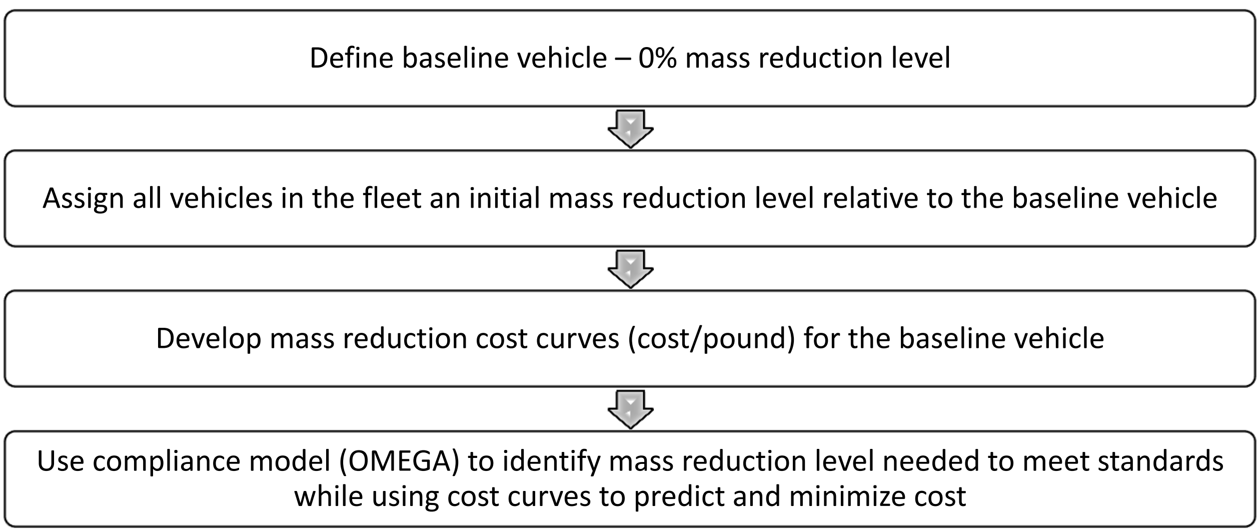

Figure 2: EPA Mass Reduction Modeling Methodology

The process begins with defining a baseline model year which is a "null vehicle," starting with 0 percent mass reduction; the baseline uses MY2008 vehicles. In the next step, every vehicle in the analysis fleet (MY2015) is assigned a mass reduction level in comparison to its MY2008 counterpart. EPA determines this by comparing curb weight between MY2015 and MY2008 for every vehicle in the fleet. To predict the cost to lightweight, the cost curves generated by various teardown studies sponsored by EPA and NHTSA are utilized. These curves are developed for MY2008/2010 era vehicles. For vehicles which have already achieved some mass reduction in the MY2015 analysis fleet (in comparison to MY2008), the cost curves are shifted upwards to recognize higher cost for additional mass reduction, given that the low mass reduction costs have already been implemented. In the final step, the OMEGA model is used to predict the mass reduction required by vehicles to be compliant with the GHG regulations. OMEGA simultaneously uses the cost curves to predict the cost of lightweighting. The average mass reduction projected in the EPA's Proposed Determination is approximately nine percent. The following sections will discuss each step in detail.

BENCHMARK VEHICLES AND COST CURVES

EPA's mass reduction analysis uses two cost curves, one cost curve for cars and non-towing crossover utility vehicles (CUVs), and a different cost curve for light-duty trucks. The vehicles and component designs for 2008-2010 era vehicles are assumed to represent the "null" technology for mass reduction.

Car and CUV cost curve

The car/CUV direct manufacturing cost curve is built on EPA's midsize CUV study based on the Toyota Venza, and NHTSA's passenger car study based on the Honda Accord. Both of these vehicles are 2008 design era. EPA combined the two cost curves into a single curve for cars and CUVs. In Figure 3, the green curve is the cost curve for cars/CUVs.

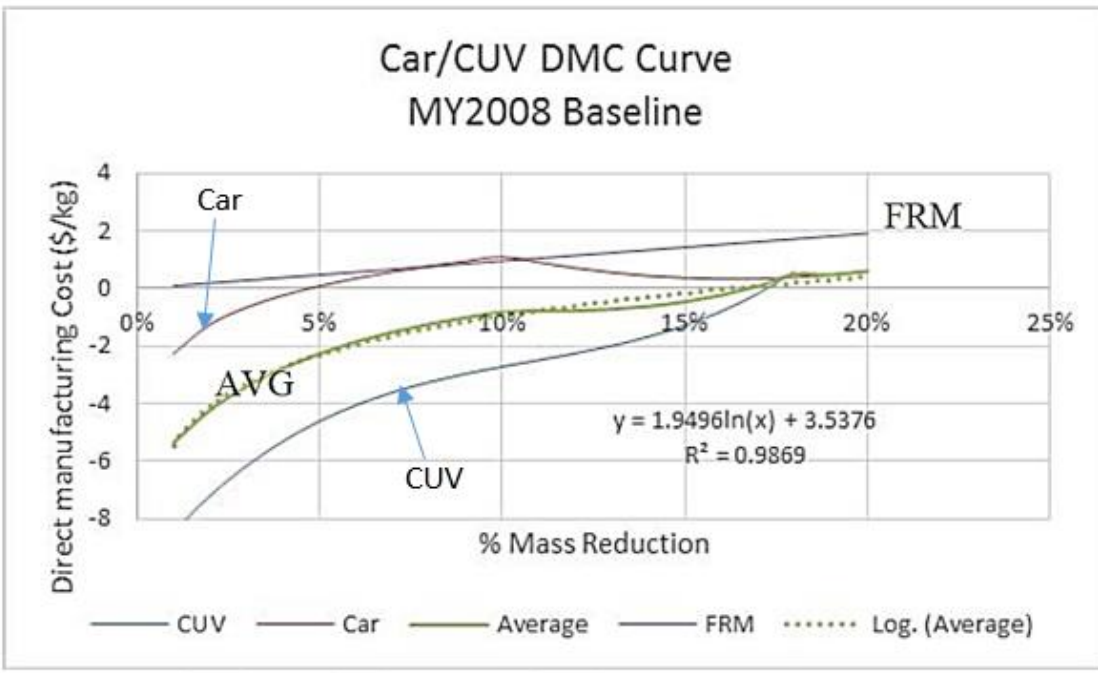

Figure 3: Car/CUV cost curve used by EPA (FRM = Final Rulemaking for MY2017-2025, August 2012)

Light-Duty Truck Cost Curve

The second EPA mass reduction cost curve for the light-duty truck (LDT) direct manufacturing cost curve was created by combining the results of the EPA MY2011 base LDT and NHTSA MY2014 base LDT lightweighting studies. Both studies used the Chevrolet Silverado as the test vehicle. In Figure 4, the blue line is the cost curve used by EPA for LDT.

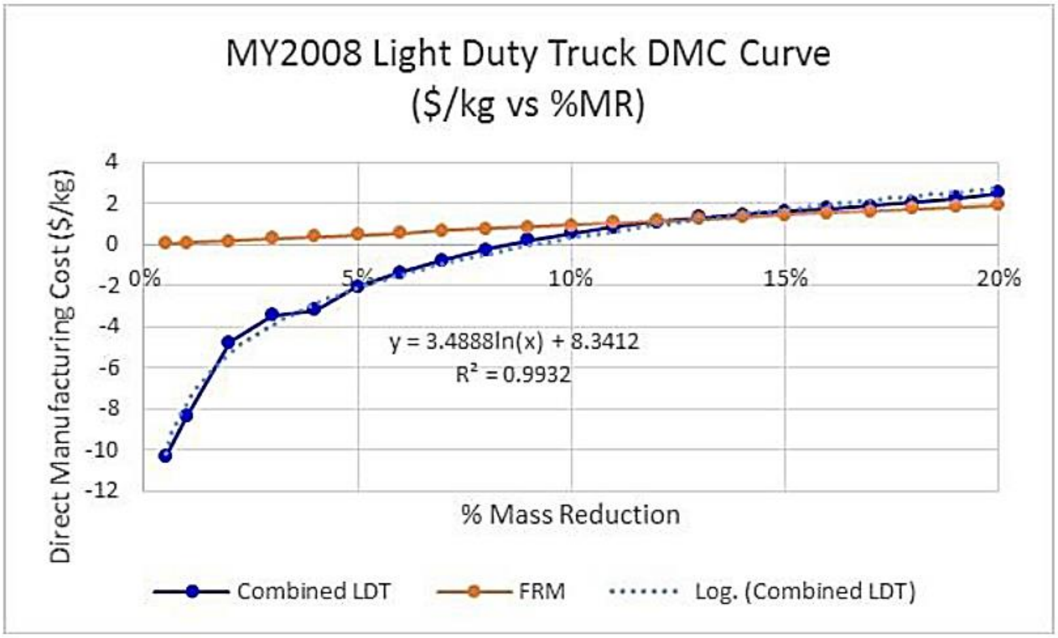

Figure 4: Light duty truck cost curve used by EPA

Observation 2 – Cost Curves Assumptions Should Be Based on Current and Unbiased Vehicle Pools

The selection of any one vehicle to tear-down to gain insight into lightweighting pathways and costs is arbitrary, given there are hundreds of vehicles on the market. No argument was made, or can be made, that the 2009 Toyota Venza was representative of the U.S. fleet. The Venza carried over design content from the Toyota Camry and Highlander and was **not** "optimized" for weight. Additionally, the tear-down Venza contained the smaller 2.7-liter engine versus the larger 3.5-liter engine (larger engines require additional mass to accommodate the power of the bigger engine) that most consumers purchase, and the lightweighted design was only designed to accommodate the smaller engine. The Venza was not a clean-sheet design, thus it offered numerous low-cost lightweighting opportunities that would not be considered in a more representative car. The second vehicle studied for mass reduction was the MY2011 Honda Accord. Successive changes were made to the Accord study results based largely from Honda's comments that raised concerns over feasibility and degraded safety and performance of the proposed "engineering solution." Honda challenged nearly half of the proposed lightweight design recommendations, but did not comment about the associated cost analysis.

The 2011 Silverado was a platform that was engineered 21 years ago (in 1996) for a mild steel architecture. It was upgraded in 2006 with several components made of high strength steel using the original architecture; in other words, like the Toyota Venza, it too, was not optimized. EPA blended the MY2011 Silverado cost curve with the MY2014 Silverado cost curve. The new 2014 Silverado is an all new architecture that makes extensive use of ultra-high strength steel. A blending of the old with the new Silverado would result in a low lightweighting cost relative to the current 2014 Silverado, and especially the aluminum intensive Ford F-150. The 2016 Draft TAR explains that "the overall cost is reduced due to the initial points being all cost save items" (p. 5-391). Again, the chosen cost curves that were blended are biased on the low side and arbitrary relative to the LDT industry.

The range of design factors and cost implications depend on many factors, including: the technology baseline, business constraints, and automaker capabilities, resulting in a complex distribution of cost implications. Making an arbitrary selection of two vehicles and combining their lightweight cost curves to represent the U.S. industry grossly over-simplifies the complexity of engineering and cost analysis for lightweighting. Tear-down studies provide excellent insight into opportunities to lightweight the vehicle under study, but not necessarily other vehicles in the fleet. Combining cost curves for cars and CUVs results in a cost curve that is not representative of either vehicle. At the lower levels of mass reduction, the combined cost curve introduces errors of approximately $2/kg (or 50 to 100 percent errors at 6-7 percent mass reduction, typical of the fleet average). The range in design objectives and vehicle technology leads to a wide range observed by different cost estimates. Since 2012, automakers and regulatory agencies have used cost estimates for 5 percent lightweighting that range from "**free"** to over $2.40/pound. For a 3,500-pound vehicle, the total range of cost would be "free" to over $420 per vehicle. This discrepancy reflects the complexity in the industry and cannot be reflected in a single simplified cost curve.

Finally, consultants often take an unrealistic approach to minimize the cost to lightweighting focusing solely on optimization. If an automaker only designs (optimizes) a vehicle for lightweight, it would look significantly different than it does today. Traditionally, vehicles have not been optimized solely for lightweighting because, as consumer products, there are numerous attributes that must be considered (see Figure 6, Vehicle Content). Multi-attribute optimization may be appropriate but the results cannot be applied to different vehicles since they are all uniquely designed and are at different starting points based on their segment. When solely focusing on one attribute, such as lightweighting, the opportunity will overstate the real potential and produce results at a lower cost than can be realistically achieved. Randomly choosing a vehicle for a teardown study and applying only lightweight optimization will provide results that are aggressive for the vehicle under study, and cannot be extrapolated to the fleet. This issue is raised in the 2015 NRC Study[1], finding 6.9, that states:

*" . . . substantial differences in the starting point of vehicle models, the varied materials in current designs, and individual business considerations—such as global platforms and maintaining vehicle NVH (*noise, vibration, and harshness*)—mean that such studies must be supplemented with other analysis. There is high potential for misinterpretation of the cost estimates resulting from these vehicle-specific studies if they are applied to other vehicle designs in a general fashion, and this potential is much greater for mass reduction techniques than it is for other types of technologies."*

[1] National Research Council (NRC), "Cost, Effectiveness, and Deployment of Fuel Economy Technologies for Light-Duty Vehicles," National Academies Press, 2015

Observation 3 – Cost Estimates Should Not Be Extrapolated from One Model to the Fleet

The EPA combines two individual vehicle teardown studies each for car/CUV, and light duty truck to develop a simple, generalized cost curve applicable to the U.S. fleet. The complexity of different market segments, design objectives and continuously advancing lightweight technology prevents a simplistic analysis of randomly selecting cost curves from two vehicles to combine. A single, simple cost curve line is inadequate to represent the true distribution of costs.

There are no known studies that support this approach of allowing the study of one vehicle and applying the results to another across different automakers and different vehicle segments**. In fact, Finding 6.8 in the 2015 NRC Study specifically recommends that this not be done, and that, "extrapolating results from one or two studies to the entire fleet would be problematic."** The problem is due to the wide range in material technology in vehicle models across the fleet. In a study by CAR, several unique attributes of the teardown vehicles are cited suggesting that these vehicles are anything but representative.[2] In the past, recommendations have been made (for example, see chapter 6 in the 2015 NRC Study) regarding the insight that can be gleaned from teardown studies, but the interpretation and extrapolation of the results to the U.S. fleet is a separate matter.

ADJUSTMENTS FOR PREVIOUS MASS REDUCTION EFFORTS

In the draft TAR, EPA states that – "It is important to account for any mass reduction that has been applied beyond the "null" mass reduction level typical of MY2008 era vehicles." EPA estimates mass reduction for each vehicle model in the MY2015 baseline fleet to the corresponding MY2008 vehicle. If a vehicle did not have a MY2008 counterpart, then the sales weighted average percent of mass reduction over the OEM's nameplate product line is used to represent the expectations of the amount of mass reduction technology within the vehicle. About half of the models in the MY2015 fleet do not have a match in MY2008 by which to determine a mass reduction change (percent change in curb weight).

EPA adjusts the 2015 curb weight data for two factors to reflect credit changes in vehicle attributes between MY2008 and MY105:

1. Footprint increase – a kg/square foot credit was applied to footprint differences between the 2008 and 2014 vehicles. Table 1 contains the foot adjustment values used by EPA.

Avg FP Density	Small	Midsize	Large	Pickups	Small MPV	Large MPV/Truck
lb/sqft	18.56	20.07	21.13	11.88	20.72	23.56
kg/sqft	8.43	9.12	9.60	5.40	9.42	10.71

Table 1: Footprint adjustment values used by EPA (2016 Draft TAR, pg. 5-396)

[2] Baron, J., "Identifying Real World Barriers to Implementing Lightweighting Technologies and Challenges in Estimating the Increase in Costs," January, 2016, CAR.

2. Safety Regulations – mass credit was given to account for safety regulations that came into effect between 2008 and 2014. These include the Federal Motor Vehicle Safety Standards (FMVSS) and the Insurance Institute for Highway Safety (IIHS) small overlap test. Table 2 contains the mass credit values used by EPA.

ESTIMATED VEHICLE WEIGHT IMPACT OF FMVSS SAFETY REGULATIONS and IIHS Small Overlap (kg)			
Final Rules by FMVSS No.	Passenger Cars Added Weight (kg)	Light Trucks Added Weight (kg)	Compliance Dates
214 Side Pole	5.64	5.25	Sept 2009-2012
216 Roof Crush	5.28	5.28	Sept 2012-2015
226 Ejection Mitigation	0.91	1.07	Sept 2013-2017
Final Rules Subtotal	**11.83kg**	**11.6kg**	
IIHS small overlap On ~20% lightweight vehicle	6.9kg	22 kg	2012/2014 for Top Safety
Total Mass Increase Est*	**18.73kg**	**33.6kg**	

Table 2: Mass credit for safety regulations (2016 Draft TAR, pg. 5-398)

Observation 4 – Curb Weight is a Poor Indicator of Lightweight Technology in a Vehicle

CAR research supports the importance of accounting for any mass reduction that has been applied beyond the baseline (baseline is MY2008 era vehicles for EPA). However, estimating mass reduction technology purely on the basis of curb weight difference is inaccurate. There are several issues with this approach:

1. Since the EPA cost curves are based on a progression of lightweighting technology, the starting point for the baseline should be based on lightweight technology – not curb weight. The EPA has developed cost curves based on adding lightweight technology into the vehicle (such as additional aluminum, high strength steel, etc.). Since the cost curves are non-linear, and in fact, exponential, the starting point for where a vehicle is on the cost curve is important in determining the incremental cost to reduce weight. Yet, in determining the amount of mass reduction for the 2015 fleet relative to 2008, the EPA adjusts the cost curve based on changes in curb weight – not based on lightweight technology. There is an assumption that changes in curb weight is a proxy for changes in lightweight technology. CAR research shows that this is not the case.

2. CAR research on 42 different models from nine global automakers shows that curb weight is a poor indicator of lightweight technology in the vehicle (See Figure 5).[3] Some cars can be seen as "heavy," yet have significantly advanced lightweight technology, and therefore will incur much higher costs to reduce weight while optimizing for all the other required vehicle attributes that may add weight (see Figure 6 for examples of vehicle content). There is a significant population of vehicles in the MY2015 U.S. fleet which have state-of-the-art lightweighting technology but are not as lightweight as EPA estimates. Based on CAR data, Table 3 shows two vehicles with similar curb weight but very different lightweighting technology. Vehicle A/Company A has a similar curb weight to Vehicle B/Company B, but Vehicle A has much more advanced lightweight technology. This will incur a much higher cost to reduce additional weight relative to Vehicle B. If Vehicle A had a similar lightweight technology to Vehicle B, it would weigh considerably more than it does now.

Recommendation 6.3 in the 2015 NRC Study proposes a "materials-based approach that looks across the fleet to better define opportunities and costs for implementing lightweighting techniques." The EPA uses a curb weight approach that looks across the fleet, and curb weight is <u>not</u> correlated to material technology in the vehicle.

	Vehicle A - Company A				Vehicle B - Company B			
	Curb Weight: 3086				Curb Weight: 3092			
Component	**Technology Package**	**Score**	**Weight**	**Weighted Score**	**Technology Package**	**Score**	**Weight**	**Weighted Score**
A Pillar	HF 1300 / HS / RSW	90	10	900	DP 590 / CS / RSW	34	10	340
B Pillar	HF 1300 / HS / RSW	90	10	900	HF 1200 / HS / RSW	90	10	900
Floor	Steel 340 / CS / RSW	50	10	500	Mild 140 / CS / RSW	0	10	0
Front Bumper Structure	HF 1300 / HS / Fastener	90	10	900	AHSS 1180 / RF / RSW	90	10	900
Roof Panel	Steel 300 / CS / RSW	20	5	100	Mild 140 / CS / RSW	0	5	0
Front Door Inner	Steel 330 / CS	80	5	400	Mild 270 / CS / RSW	60	5	300
Front Door Outer	Steel 350 / CS / Hemming	80	5	400	Mild 270 / CS / Hemming	0	5	0
Hood	Steel 300 / CS / Hemming	40	10	400	Mild 270 / CS / RSW	10	10	100
Decklid	Steel 300 / Cast / LW	45	6	270	Mild 270 / CS / RSW	10	6	60
Fender	Steel 350 / CS / Fasteners	60	5	300	Mild 140 / CS / RSW	0	5	0
Engine Cradle	Steel 480 / CS / Weld	60	7	420	HSS 540 / CS / Weld	70	7	490
Instrument Panel Beam	Steel 480 / Tube bend / Weld	70	8	560	AHSS 980 / Tube bend / Weld	90	8	720
Front Seat Frame	HSS various / CS / Weld	65	8	520	HSS 440 / CS / Weld	30	8	240
	CAR Technology Score			**6570**	**CAR Technology Score**			**4050**

Table 3: Similar curb weight but different lightweight technology

[3] Baron, J., and Modi, S. "Assessing the Fleet-wide Material Technology and Costs to Lightweight Vehicles," September, 2016, CAR.

3. Previous CAR research has shown that there is a large range of, and significant differences in, material technology in the MY2015 fleet. Figure 5 shows the range of vehicles scores (based on material technology) in the 2015/2016 era vehicles. It is important to note that all of the newer vehicles have advance material technology in comparison to the MY2011 Honda Accord (a base vehicle for an NHTSA-sponsored teardown study). Based on CAR's database of actual materials used in vehicles, it is clear that the curb weight (adjusted for footprint) of the vehicle is <u>not</u> correlated with the material technology (R^2 = 0.0398).

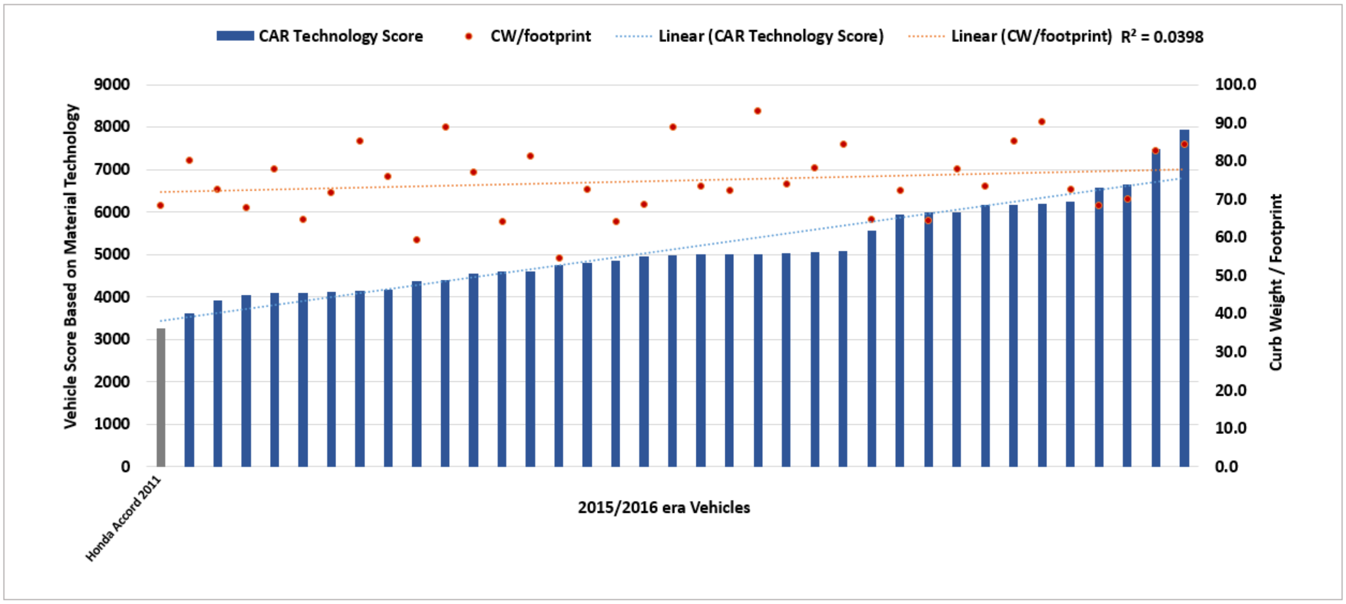

Figure 5: Lightweight Technology (Unibody): Large Range

4. In the draft TAR, EPA has given mass credit for only footprint increases and safety regulations between 2008 and 2014. There are no adjustments made for vehicle content. Figure 6 lists examples of content that affect weight in the vehicle. **While these technologies are not mandated, the list indicates those technologies in demand by consumers and several improve safety.** In the Draft TAR, EPA has estimated mass increase due to future mandated safety regulations in the range of 7.08-9.51 kg. However, this adjustment was not considered for the Proposed Determination. OEMs estimate that 113-136 kg (250-300 pounds) might be added to future vehicles for autonomous driving technology. "Global sales of autonomous vehicles will reach nearly 600,000 units in 2025," according to Egil Juliussen, Ph.D. and director of research at IHS Automotive.[4] Assuming half of these are in the United States, the autonomous vehicles are projected to have a penetration rate of only 1.8 percent by 2025. This suggests that the potential mass increase due to autonomous vehicles will become a concern beyond MY2025.

[4] IHS Markit, "IHS Clarifies Autonomous Vehicle Sales Forecast," http://news.ihsmarkit.com/press-release/automotive/autonomous-vehicle-sales-set-reach-21-million-globally-2035-ihs-says

What Drives Vehicle Content?

- Crashworthiness
- Aesthetics
- NVH (road noise, smoothness of ride, vibration)
- Stiffness of Structure
- Center of Gravity
- Seating Capacity
- Corrosion Resistance
- Durability
- Consumer Comfort Features
- Visibility
- Autonomous Technologies (cameras etc.)
- Lighting Requirements and Design

Figure 6: Examples of Vehicle Content

5. EPA in the draft TAR states that:

   "The percent mass reduction is based on a change in curb weight in MY2014 from MY2008 (along with an allowance for safety compliance and vehicle footprint increase), and not the amount of mass reduction technology applied. The reason for this is that the mass reduction technologies are not always evident by the eye in the vehicle and the benefits of mass reduction are not achieved unless the overall vehicle is lighter."

   While it is true that mass reduction technology is not always evident to the human eye, it is possible to get broad material technology details for vehicles that represent the majority of the U.S. fleet. Organizations like CAR, A2Mac1, and Munro & Associates have large databases of vehicles with their inherent lightweighting technology. Such organizations can provide a better picture of mass reduction efforts taken up by the auto manufacturers between MY2008 and MY2015.

6. The 2015 NRC Study report noted that "It is generally acknowledged that the cost to reduce mass <u>increases</u> for each additional unit of mass eliminated on a vehicle." EPA agrees that this is the case; however, the agency also notes that in order for the benefits of mass reduction to be achieved, the actual curb weight of the vehicle must actually decrease. It is true that lower curb weight usually translates to lower fuel consumption, but automakers can achieve better fuel economy by increasing powertrain efficiency or by using alternate propulsion systems. Figure 7 from the draft TAR shows that over the last decade, the weight of an average vehicle has not changed but both fuel economy and performance have drastically improved. Significant money and efforts have been invested by automakers for lightweighting, yet curb weight didn't change because the weight reduction was offset by weight added due to improved performance, efficient powertrain, safety, features for customer driving experience, etc.

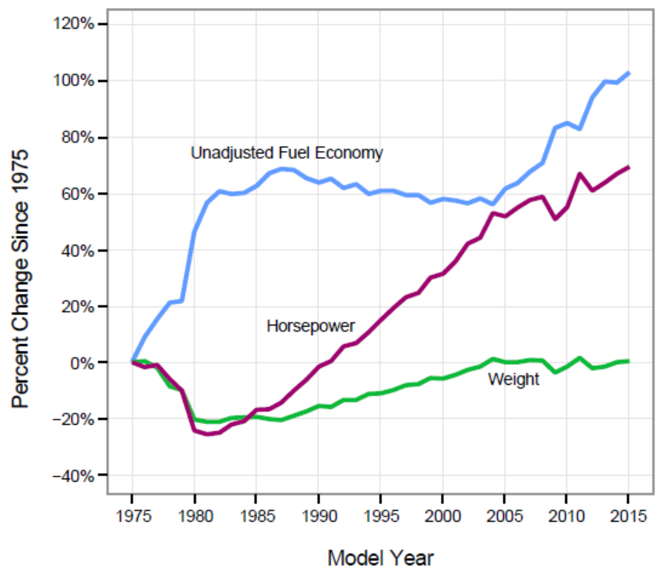

Figure 7: Average New Vehicle Fuel Economy, Weight and Power (Source: Draft TAR 2016)

Cost Curve Adjustments

Once the initial mass reduction percentage for vehicles in the MY2015 fleet is determined by the curb weight approach, the cost curves developed can be adjusted to reflect higher mass reduction cost for vehicles which are lighter than their MY2008 counterparts. While the percent baseline mass reduction is determined on a vehicle specific basis (in 0.5 percent MR increments), the amount of cost curve adjustment ($/vehicle) used in EPA modeling is based on a vehicle type basis. Figure 8 shows the shifted cost curve (blue) for vehicles with 5% mass reduction in MY2014 relative to MY2008 baseline.

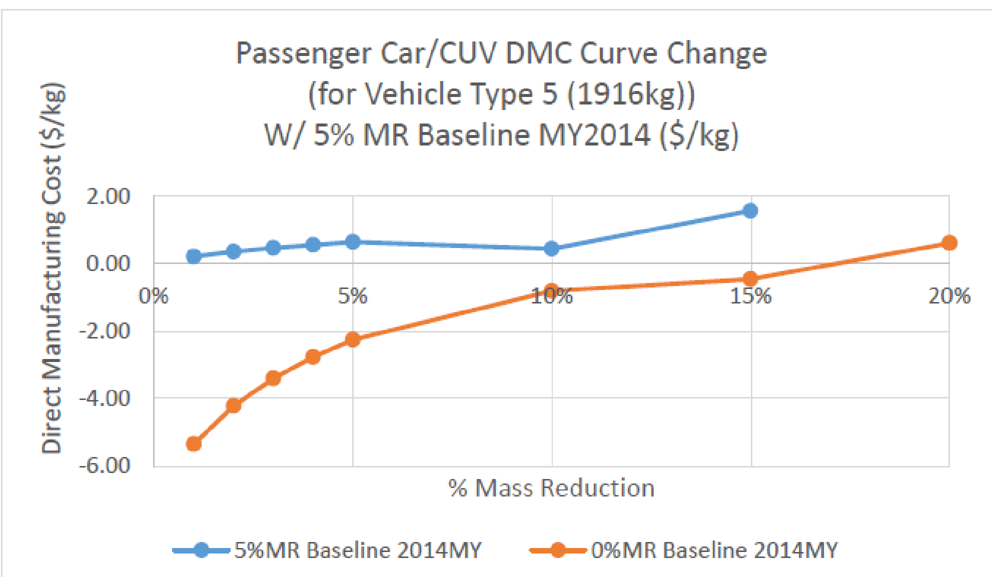

Figure 8: Cost curve with 5% MR in MY2014 relative to MY2008 (Note: EPA updated the analysis fleet to MY2015 in the Proposed Determination.)

Observations 5 – Vehicles in MY2008 Fleet Had Different Material Technology

1. The cost curves developed by the teardown studies are based in part on future improvements in material technology used in the vehicle. These cost curves are extrapolated for the entire U.S. fleet. To account for lightweighting efforts between 2008 and 2015, the cost curves are adjusted based on curb weight reduction. This approach makes an intrinsic assumption that every vehicle in the MY2008 fleet was using similar material technology - which is not true. For example, the MY2008 Toyota Venza was predominantly a mild steel vehicle; MY2008 Cadillac CTS had high strength steel in major components; MY2008 BMW X6 was a mixed material vehicle with applications of steel, aluminum, and thermoplastic; and Jaguar's XJ was all-aluminum.

2. The cost curves developed from teardown studies of 2008/2010 era vehicles may underestimate the cost to lightweight very advanced vehicles in the MY2015 fleet even after adjustments based on curb weight difference have been made. For example, Ford has made a significant investment in tooling and its supply chain to develop an aluminum-intensive F-150 truck. Lightweighting this already state-of-the-art truck by using better materials like carbon fiber may not be practical until the next major redesign and will require significant investment and market pull. The average redesign cycle for cars is six years, whereas trucks can be 10 years or more. Shortening of redesign lifecycles and the introduction of higher cost technologies —driven in part by rapidly increasing regulatory scope and stringency—will make it difficult to meet internal rates of return or levels of return on invested capital.

SUMMARY

Automakers are striving to cost-effectively meet both GHG and CAFE standards. EPA and NHTSA are required to assess the cost of regulations before finalizing the rules. EPA and NHTSA jointly issued the Draft Technical Assessment Report describing their analyses on technologies and cost for meeting the standards. Even though the draft TAR is one document, the analyses by EPA and NHTSA are significantly different. In order to predict vehicle mass reduction and associated cost required to meet the regulations, EPA and NHTSA used similar methodologies but different modeling tools. EPA used MY2015 as the analysis fleet and MY2008 as the baseline fleet for mass reduction analysis. Curb weight difference between MY2008 and MY2015 vehicles (corrected for footprint increase and safety) were used to account for mass reduction efforts already implemented. Unfortunately, advanced lightweight vehicles in 2008 were considered equivalent to old-technology vehicles, all at a zero starting point. Manufacturers that were aggressive early at implementing technology by 2008 were penalized (with low projected costs for additional lightweighting), given that they were already further up the exponential lightweighting cost curve for additional lightweighting.

In contrast to EPA's analysis based on curb weight difference between MY2008 and MY2015 vehicles (corrected for footprint increase and safety) to account for mass reduction efforts already implemented, NHTSA's analysis to account for diverse progress on mass reduction is based on the following regression statistics: footprint, power, strong HEV, PHEV, BEV, Battery pack size, AWD, RWD, Convertible (2016 Draft TAR, Table 4.47). By defining the different starting points, additional weight savings opportunities will have different starting points (on the cost curve). NHTSA's method appears to be an improvement over EPA's method based on only curb weight. However, recognition of material technology (discussed below) would enhance NHTSA's method.

EPA sponsored several teardown studies to develop two different cost curves for cars/CUV and light-duty trucks. The OMEGA model was used to predict mass reduction required to meet the standards and associated cost.

CAR research showed that curb weight is not an effective indicator of material technology in the car. The National Research Council recommends against extrapolation of cost curves generated from vehicle teardown studies to other vehicles, yet this is done anyway by the EPA.

Expensive teardown studies were conducted on the Toyota Venza, Honda Accord and different non-optimized and dated model years of the Silverado truck. The 2009 Venza and 2011 Silverado, by all accounts, are high impact and low cost teardowns because of the design objectives (Venza – with significant carryover components) and dated design (Silverado – 21-year-old design). Cost curves from either of these two vehicles are not indicative of today's lightweighting technology, and should not be included in the EPA cost analysis.

Estimating lightweighting costs of the U.S. fleet, given the range of today's lightweight technology, and the speculation over future technology is a large and complex undertaking. Even establishing today's baseline for the fleet is non-trivial. However, given the huge consequences and range of cost estimates (from free to over $420 per vehicle for 5% weight reduction), a reevaluation of lightweighting cost analysis is needed. The teardown studies, particularly from the 2011 Honda Accord and 2014 Silverado, offer good insight that can be used to establish a material pathway adaptable to a material-based study. There are major complexities associated with:

- Today's starting technology baseline in terms of lightweighting technology;
- The appropriate family of cost curves for this distribution of baseline technology in today's fleet;
- Recognition of future technology, including autonomous technologies that will improve safety and performance, yet add weight;
- Cost consequences due to stranded capital as the industry moves into higher strength steels, aluminum, and composites;
- Constraints connected to resource availability and product development timing.

Note: HEV: Hybrid Electric Vehicle, PHEV: Plugin Hybrid Electric Vehicle, BEV: Battery Electric Vehicle, AWD: All Wheel Drive, RWD: Rear Wheel Drive

CAR believes additional analysis is needed to recognize the fleet in terms of material technology, as recommended by the 2015 NRC Study. Adjustments should be made for content added to the vehicle for performance and customer expectations over comfort, safety, and entertainment features. A more careful approach is needed before a single cost curve is applied to different vehicles made by different automakers aimed at different vehicle segments.