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National Highway Traffic Safety Administration

Mass Reduction and Safety Considerations for Setting Fuel Economy Standards

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Mass Reduction and Safety Considerations for Setting Fuel Economy Standards

Topics:

- Statutory Requirements
- Mass and Safety Considerations for Setting 2012 – 2016 Fuel Economy Standards
- Future Mass Reduction and Safety Studies

CAFE Statutory Background

1975: Congress enacted the Energy Policy and Conservation Act (EPCA)

- Gave authority to DOT (NHTSA) to establish fuel economy standards for passenger cars and light trucks
- Passenger car standards set by Congress at 27.5 mpg
- Light truck standards set by NHTSA at “maximum feasible level” for each model year
- Maximum feasible standards are based on
  - Technological feasibility
  - Economic practicability
  - Effect of other federal vehicle standards on fuel economy (emissions, safety, noise, and damageability standards)
  - Need for the US to conserve energy

CAFE Statutory Background

2007: Congress enacted the Energy Independence and Security Act (EISA)

- Amended EPCA to require substantial, continuing increases in fuel economy standards.
- Extended maximum feasible standards to both passenger cars and light trucks.
- Standards for 2011 – 2020

  Achieve total fleet 35 mpg by MY 2020

CAFE Statutory Background

2007: Energy Independence and Security Act (EISA), continued

- Standards for 2021 – 2030

  Maximum feasible for passenger car and light truck fleets individually

- Requires vehicle attribute-based standards.

  NHTSA selected Footprint =

  (average track width) x (average wheelbase)

2012 – 2016 CAFE

National Program

May 19, 2009, President Obama announced the National Fuel Efficiency Policy

- Goal to establish a harmonized and consistent National Program regulating both fuel economy and GHG emissions for model years 2012 - 2016.
- Supported by 10 automobile manufacturers and the State of California

April 1, 2010, NHTSA and EPA issued the final rule.

- Coordinated national standards which provide regulatory certainty and consistency for the auto industry.
- Automakers can meet NHTSA, EPA and California requirements with a single national fleet.

Projected Fleetwide Targets for NHTSA standards:

Model Year	Pass Car	Light Truck	Combined
2011	30.4	24.4	27.6
2016	37.8	28.8	34.1

2012 – 2016 CAFE

Fuel Economy Improving Technologies

Engine:

- Low friction lubricants
- Engine friction reduction
- Camshaft phasing control
- Valve lift control
- Cylinder deactivation
- Stoichiometric Gasoline Direct Injection
- Combustion restart
- Turbocharging and downsizing
- EGR boost
- Diesel

Transmission;

- 6-speed manual
- Improved automatic trans control
- Continuously variable transmission
- 6-, 7-, and 8-speed automatic
- Dual clutch transmission

Electrification and Accessories:

- Electric power steering
- Improved accessories

Hybrid Technologies:

- 12v micro hybrid (start-stop)
- Belt mounted integrated starter generator
- Crank mounted integrated starter generator
- Power split hybrid
- Plug-in hybrid
- 2-mode hybrid

Vehicle Technologies:

- **MASS REDUCTION**
- Aerodynamic drag
- Low rolling resistance tires
- Low drag brakes
- Secondary axle disconnect

2012 – 2016 CAFE

Main Categories of Mass Reduction

- Material Substitution:
  - Lower density and/or higher strength materials are utilized in a manner that preserves or improves the function of a component under consideration for redesign.

- Smart Design:
  - Improving structural strength and component designs through the use of computer aided design so as to better optimize load paths and reduce stresses and bending moments.

  - Better optimization of the dimensional aspects of the component (and thus its mass).

  - Integrate unique parts in a manner that reduces mass by combining functions or eliminating separate fasteners.

2012 – 2016 CAFE

Main Categories of Mass Reduction

- Content Optimization:
  - Achieve mass reduction through content optimization. Example: Replace a spare tire and tire change hardware with tire inflator kits.

- Vehicle Downsizing:
  - Mass reduction through reducing vehicle size.

  NHTSA believes the 2012 – 2016 CAFE regulations do not encourage downsizing because the fuel economy targets are based on the footprint attribute, and the target curve requires technology improvements from all size vehicles.

2012 – 2016 CAFE

Maintaining Vehicle Functionality

- For NHTSA's rulemaking analysis, we try to ensure vehicle functionality could be maintained when manufacturers apply fuel economy improving technologies.
- Functionality attributes include:
  - Safety
  - NVH
  - Performance
  - Ride and Handling
  - Drivability
  - Features and Utility
  - Ergonomics
  - Aesthetics / Appearance
  - Durability
  - Serviceability and Repair ability
- Maintaining functionality also means that if the vehicle body mass is reduced, the powertrain is downsized to maintain equivalent vehicle performance.

2012 – 2016 CAFE Projected Mass Increase for FMVSS Regulations

Weight Additions Due to Final Rules or Likely NHTSA Regulations

Comparing MY 2016 to the MY 2008 Baseline fleet

Standard No.	Added Weight in pounds **Passenger Car**	Added Weight in kilograms **Passenger Car**	Added Weight in pounds **Light Trucks**	Added Weight in kilograms **Light trucks**
126	**3.08**	**1.40**	**0.75**	**0.34**
206	**0**	**0**	**0.11**	**0.05**
214	**0.48**	**0.22**	**3.37**	**1.53**
216	**11.65**	**5.28**	**11.65**	**5.28**
301	**1.11**	**0.50**	**1.11**	**0.50**
Ejection Mitigation	**1.28**	0.58	3.24	1.47
Pedestrian Protection	**?**	?	?	?
Total	**17.59**	**7.98**	**20.23**	**9.18**

FMVSS 126, Electronic Stability Control
FMVSS 206, Door Latches for Sliding Doors
FMVSS 208, 35 mph Belted Testing of 5th Female
FMVSS 214, Side Impact Oblique Pole Test
FMVSS 216, Roof Crush
FMVSS 301, Fuel System Integrity

2012 – 2016 CAFE

Mass Reduction Effectiveness

- When appropriate engine resizing is applied and vehicle performance is held constant:

10 % curb weight reduction improves fuel consumption by 6.5 %

- These estimates are supported in literature and reports on the subject of mass reduction, including:
  - National Research Council, “Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards,” National Academy Press, Washington, DC (2002).
  - “Impact of Vehicle Weight Reduction on Fuel Economy for Various Vehicle Architectures”, Research Report, conducted by Ricardo Inc. for the Aluminum Association, 2008-04and simulation work conducted by Ricardo, Inc.
  - “Benefit Analysis: Use of Aluminum Structures in Conjunction with Alternative Powertrain Technologies in Automobiles,” Bull, M. Chavali, R., Mascarin, A., Aluminum Association Research Report, May 2008.

2012 – 2016 CAFE

Mass Reduction Cost

- Three studies of down-weighting / material substitution and the associated cost were used to determine the cost for mass reduction.
  - The 2002 NAS report, estimated $ 1.50 per pound.
  - Sierra Research estimated a 10% reduction, with compounding, could be accomplished for a cost of $ 1.01 per pound.
  - MIT estimated that the weight of a vehicle could be reduced by 14%, with no compounding, for a cost of $ 1.36 per pound.

- An average of the three referenced studies was used for the final rule cost:

  Without indirect cost: $ 1.32 per pound

  With indirect cost: $ 1.48 per pound

  All costs are for MY 2012, stated in 2007 $

2012 – 2016 CAFE Projected Maximum Mass Reduction by Vehicle Class

Based on discussions with manufacturers and confidential business information submitted by manufacturers, NHTSA projected that manufacturers would implement larger percentage mass reductions on larger vehicles than on smaller vehicles.

This is consistent with our assumptions about approaches to mass reduction that would minimize adverse safety impacts.

Vehicle Mass (Weight) Reduction as a Percent of Curb Weight Due to the Application of the MS1, MS2, and the Combination of Both Technologies

Vehicle Class	MS1 (%) Refresh/Redesign	MS2 (%)* Redesign only	Maximum Total Reduction (%)
Subcompact PC	1.5	3.5	5.0
Compact PC	1.5	3.5	5.0
Midsize PC	1.5	6.0	7.5
Large PC	1.5	8.5	10.0
Subcompact Performance PC	1.5	3.5	5.0
Compact Performance PC	1.5	3.5	5.0
Midsize Performance PC	1.5	6.0	7.5
Large Performance PC	1.5	8.5	10.0
Small LT	1.5	6.0	7.5
Midsize LT	1.5	6.0	7.5
Large LT and Minivan	1.5	8.5	10.0

2012 – 2016 CAFE Projected Mass Reduction by Vehicle Class in MY 2016

- NHTSA uses a model (the CAFE model) to project how manufacturers could comply with regulations. The model uses many inputs, which include technology effectiveness and cost for all technologies, and the mass reduction at refresh and redesign.

Total Average	**3.5%**
SubcompactPerfPC	3.3%
CompactPerfPC	1.4%
MidPerfPC	2.7%
LargePerfPC	8.7%
SubcompactPC	1.8%
CompactPC	1.3%
MidPC	2.9%
LargePC	6.2%
SmallLT	4.2%
MidLT	4.8%
LargeLT	4.3%
MiniVan	6.0%

ts a combination of technologies that manufacturers
ations.

e most cost effective combination of technologies.

not necessary to implement the maximum mass
s to meet regulations.

2012 – 2016 CAFE

Safety Considerations

- It is important to assess whether projected changes in the fleet resulting from regulations might affect safety.

- This includes vehicle performance to mandatory safety standards and voluntary safety performance tests.

  FMVSS

  NCAP

  IIHS

  Based on projected changes in the fleet, NHTSA believes manufacturers can continue to build vehicles that meet these standards and tests.

- For rulemaking, NHTSA also believes it is necessary to assess the effects of the rules on Societal Fatalities.

  Societal fatalities include the fatalities in all vehicles involved in crashes as well as bicyclists and pedestrians.

2012 – 2016 CAFE

Societal Fatalities – Mass, Size and Safety

For 2012 – 2016 rulemaking, the CAFE model was used to assess Societal Fatality effects.

CAFE Model Inputs:

- Two studies were considered that quantified the effect of vehicle mass and vehicle size on safety.

- Both studies relied on the statistical analysis of historical data.
  - Kahane

    Kahane, C.J. (2010). "Relationships Between Fatality Risk, Mass, and Footprint in Model Year 1991-1999 and Other Passenger Cars and LTVs" (Pages 464-542 of Final Regulatory Impact Analysis: Corporate Average Fuel Economy for MY 2012-MY 2016 Passenger Cars and Light Trucks, Washington: National Highway Traffic Safety Administration)

  - DRI

    "An Assessment of the Effects of Vehicle Weight and Size on Fatality Risk in 1985 to 1998 Model Year Passenger Cars and 1085 to 1997 Model Year Light Trucks and Vans". Paper No. 2005-01-1354. Warrendale, PA: Society of Automotive Engineers.

2012 – 2016 CAFE

Societal Fatalities – Mass, Size and Safety

- Because it is based on real world crashes, historical data provides the full range of crash dynamics and interactions that occur in the real world.

  NHTSA believes that this wide range of actual conditions provides better insight into the effects on societal fatalities than limited condition FMVSS, NCAP, IIHS testing and computer simulations.

- For the final rule the updated 2010 Kahane study was used for model inputs.

2012 – 2016 CAFE

Societal Fatalities – Mass, Size and Safety

- Important points related to the Kahane study:
  - "Cross-sectional" analyses track trend in fatality rates across the spectrum of vehicles on the road, from the lightest to the heaviest.

    They do not directly compare the fatality rates for a specific make and model before and after mass reduction.
  - Based on MY 1991-1999 vehicles which do not include all the technologies for mass reduction that might be used in future vehicles.
  - The various scenarios may be viewed as a plausible range of point estimates for the effects of mass reduction while maintaining footprint, but they should not be construed as upper and lower bounds.

    Furthermore, being point estimates, they are themselves subject to uncertainties, such as, for example, the sampling errors associated with statistical analyses.
  - The report will be peer reviewed.

2012 – 2016 CAFE

Societal Fatalities – Mass, Size and Safety

Kahane Study Results

Fatality Increase per 100-Pound Reduction (%)

	Actual Regression Result Scenario	NHTSA Expert Opinion Upper-Estimate Scenario	NHTSA Expert Opinion Lower-Estimate Scenario
Cars < 2,950 Pounds	**2.21**	**2.21**	**1.02**
Cars ≥ 2,950 pounds	**0.90**	**0.90**	**0.44**
LTVs < 3,870 pounds	**0.17**	**0.55**	**0.41**
LTVs ≥ 3,870 pounds	**-1.90**	**-0.62**	**-0.73**

Actual Regression Result Scenario: Results of basic statistical analyses.

Upper Estimate Scenario:

Based on additional statistical analyses and judgment. NHTSA believes some of the basic analyses for LTVs yield inaccurate estimates. With adjustments for these estimates, NHTSA believes these coefficients more accurately estimate the average societal fatality rates.

It estimates the effect of future mass reduction if it were accomplished without any regard for safety (other than not to reduce footprint).

Lower Estimate Scenario:

NHTSA's judgment of the effect of safety-conscious future mass reduction.

2012 – 2016 CAFE

Societal Fatalities – Mass, Size and Safety

CAFE Model Results – Projected Increase in Societal Fatalities for 2012 – 2016 CAFE Regulations

	MY 2012	MY 2013	MY 2014	MY 2015	MY 2016
NPRM "Worst Case"	**34**	**54**	**194**	**313**	**493**
NHTSA Expert Opinion Final Rule Upper Estimate	**9**	**14**	**26**	**24**	**22**
NHTSA Expert Opinion Final Rule Lower Estimate	**2**	**4**	**(17)**	**(53)**	**(80)**
Actual Regression Result Scenario	**0**	**2**	**(94)**	**(206)**	**(301)**

2012 – 2016 CAFE

Societal Fatalities – Mass, Size and Safety

The final rule:

> "Based on the 2010 Kahane analysis … the agencies now believe that the likely deleterious safety effects of the MYs 2012-2016 standards may be much lower than originally estimated. **They may be close to zero, or possibly beneficial if mass reduction is carefully undertaken in the future and if the mass reduction in the heavier LTVs is greater (in absolute terms) than in passenger cars.** In light of these findings, we believe that the balancing is reasonable."

Future NHTSA Studies on Mass Reduction and Safety

- Interagency work team (NHTSA, EPA, DOE)
- Involve stakeholders (CARB, and others)
- Statistical analysis of historical data to assess the effects of mass and size on societal fatalities.
  - Independent assessment of Kahane and DRI methodology
  - Conduct statistical analysis study with newer data.

Future NHTSA Studies on Mass Reduction and Safety

- Modeling studies to determine the potential for mass reduction with functionality maintained, including
  - Feasibility and full cost assessment.
  - Performance to FMVSS, NCAP and IIHS tests.
  - Fleet crash simulation (impact with different size and mass vehicles).

Mass Reduction and Safety Considerations for Setting Fuel Economy Standards

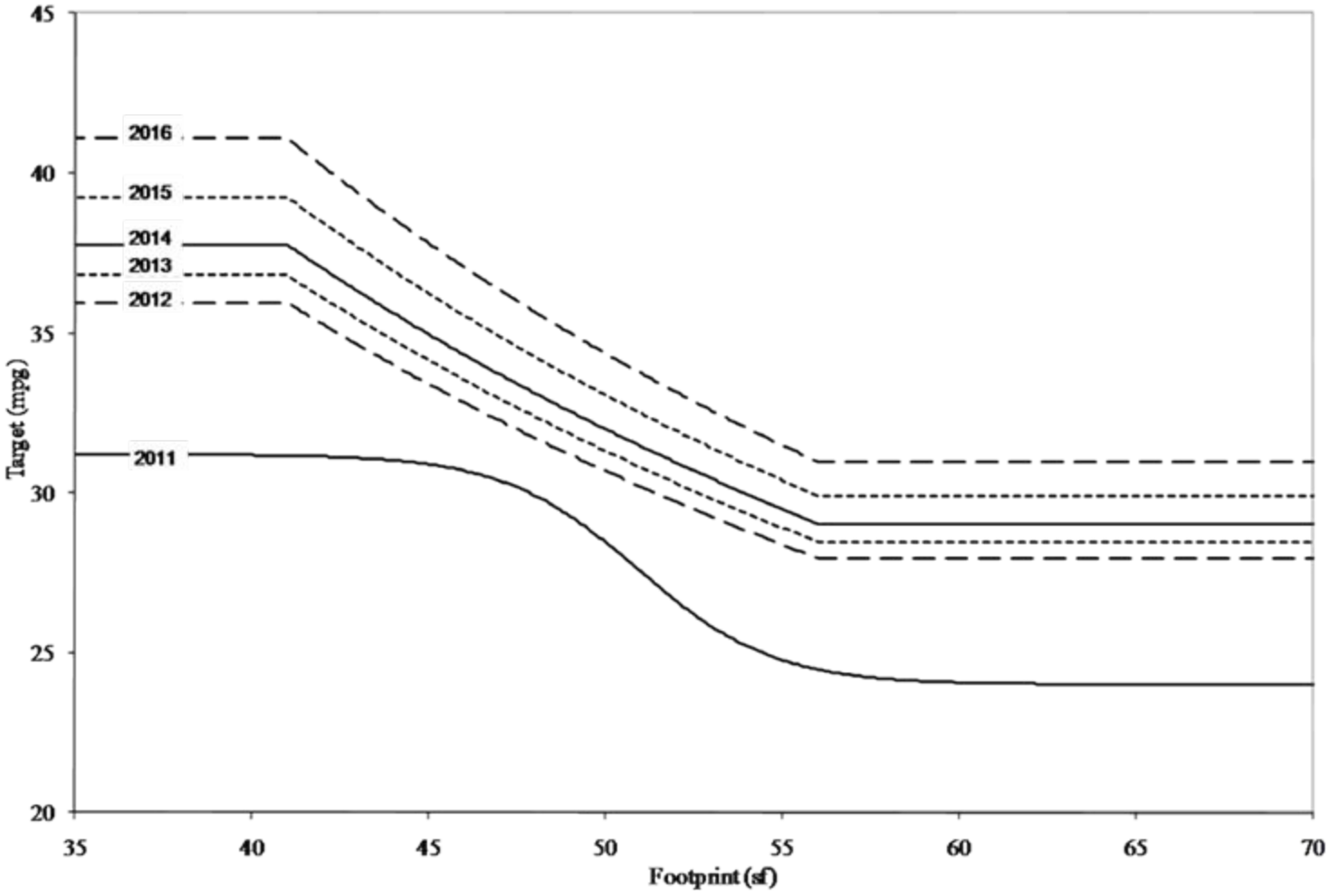
Thank you!

Appendix

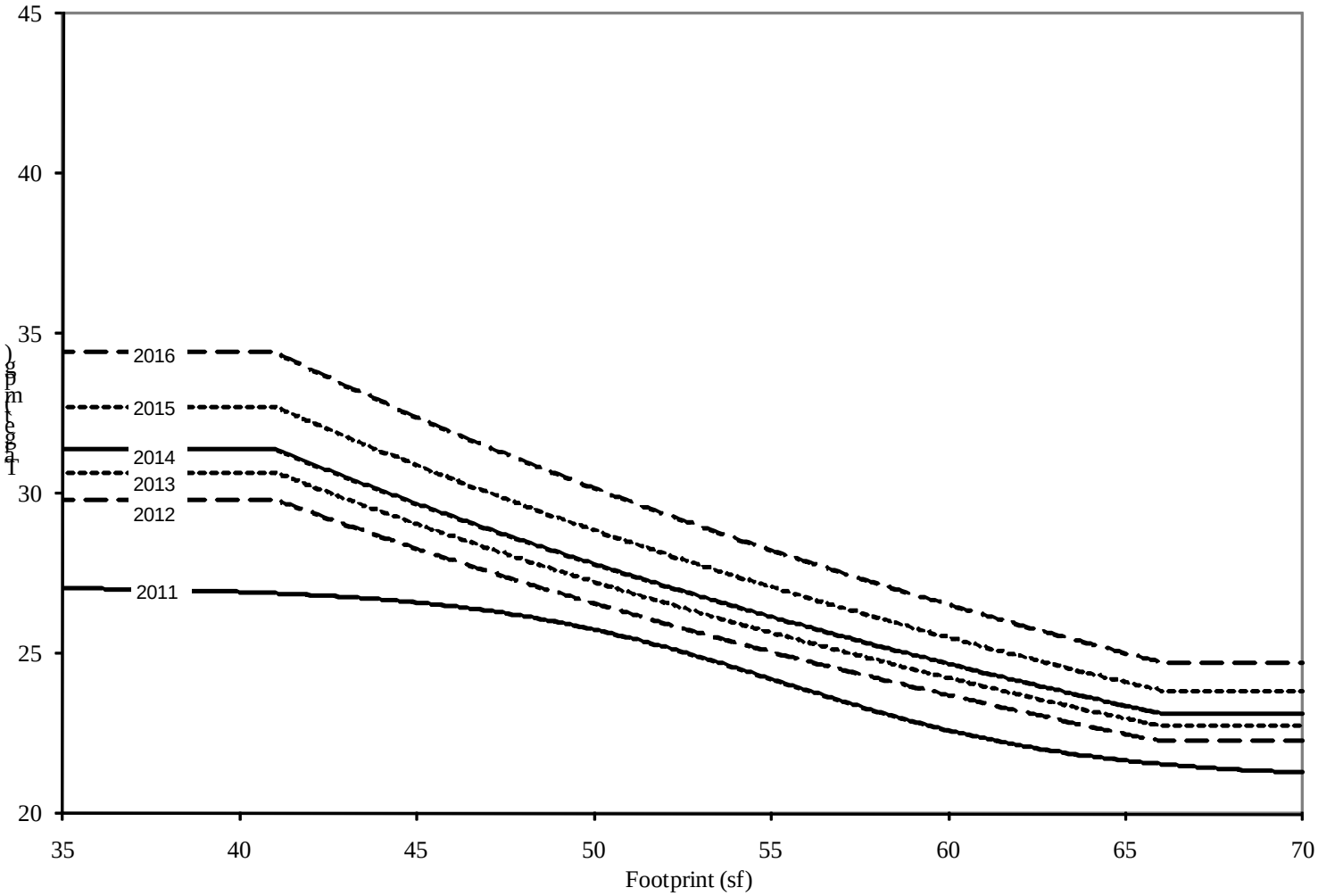
2012 – 2016 CAFE Safety Considerations – Footprint Based Standards

- Attribute based standards:
  - NHTSA selected Footprint = (average track width) x (average wheelbase)
  - Stringency increases for every size of vehicle
  - Maintains consumer choice of vehicle size and utility
  - Encourages application of technologies to all vehicles
  - Reduces safety effects of fuel economy regulations by reducing the incentive for manufacturers to change vehicle size solely to meet regulations

2012 – 2016 CAFE Footprint Based Target Curves – Passenger Car



2012 – 2016 CAFE Footprint Based Target Curves – Light Truck



2012 – 2016 CAFE

Mass Reduction Compounding

At redesign, manufacturers typically employ a systematic approach to mass reduction - full vehicle optimization

- Primary mass reduction to a components
- Enables mass reduction of indirect ancillary systems and components, effectively compounding or obtaining a secondary mass reduction.
- For example, the mass reductions of the body, engine and drivetrain reduce stresses on the suspension components, steering components, wheels, tires and brakes, allowing reductions in the mass of these subsystems.
- Use of a smaller, lighter engine with lower torque output subsequently allows the use of a smaller, lighter-weight transmission and drive line components.