

Harmonizing and Rationalizing Lightweighting within Fuel Efficiency Regulations Across NA, EU and China

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ABSTRACT

This study emphasizes the fact that there lies value and potential savings in harmonizing some of the inherent differences between the USA, EU, and China regulations with respect to the role of vehicle mass and lightweighting within Fuel Economy (FE) and Green House Gas (GHG) regulations. The definition and intricacies of FE and mass regulations for the three regions (USA, EU, and China) have been discussed and compared. In particular, the nuances of footprint-based, curb-mass-based, and stepped-mass-based regulations that lead to the differences have been discussed. Lightweighting is a customer benefit for fuel consumption, but in this work, we highlight cases where lightweighting, as a CO₂ enabler, has incentives that do not align with rational customer values. A typical vehicle's FE performance sensitivity to a change in mass on the standard regional certification drive cycles is simulated and compared across the three regions. A comparison of the regulatory and physical intricacies of the mass rules in the three regions is analyzed from various aspects, where we highlight the technical and financial challenges of an auto manufacturer when tailoring passenger cars to the region-specific regulations. A proposed unified solution across the three regions could be a "Footprint-based regulation with certification mass assigned in a way that fully utilizes the benefits of lightweighting.

KEYWORDS: USA, EU, China, Lightweighting, GHG, CO₂, Regulations, Footprint, Mass-based, Incentive, Harmonizing, Fuel Economy

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INTRODUCTION

Differing vehicle CO₂ regulations governing mass across global regions (North America (NA), EU, China) is a technical and engineering challenge for light duty vehicle manufacturers. The same product has to be significantly re-engineered and sold as a variant in order to comply with another region's specific regulations. The re-engineering for compliance sake adds costs to the vehicle production, and will continue as regulations become more difficult. Both the OEMs and the customer can earn savings if the CO₂ and light-weighting regulations are harmonized to some degree across geographic regions (viz. NA, EU, China). While the "one regulation suits all" approach may not be the ideal solution, we could still achieve savings by implementing partial harmonization of global mass regulations across regions (NA, EU, and China).

CO₂ and GHG emissions standards that drive light-weighting and exhaust after-treatment strategy are ubiquitously adhered to in vehicle design. They are critical to attaining fuel economy and environmental safety standards. CO₂ and fuel economy (FE) regulations in the U.S. and EU are stringent, compelling U.S. auto manufacturers to improve FE to over 38 mpg by 2020. Europe requires car OEMs to improve to 58 mpg by 2020 [1]. The next 5+ years will be marked by significant regulatory cost inflation, largely driven by FE mandates. The Deutsche Bank Markets Research team [1] in 2014 estimated at least a \$1000 per vehicle additional cost in the U.S. over the next 5 years,

and >\$2,000 per vehicle over the next 10 years, just to comply with FE standards and CO₂ regulations- not including the cost of safety and connectivity technology. In Europe, the analogous costs are \$1,200 and \$2,400 per vehicle over the same timeframes. The Draft TAR [2] projections in 2016 for the average per-vehicle cost of meeting the MY2025 standards (incremental to costs incurred when meeting the MY2021 standards) range from \$894-\$1245 for the GHG and CAFE programs. In the U.S., consumers may not pay for this content in a < \$3 /gal fuel price environment while in the EU, it is doubtful whether automakers will be able to pass along higher costs [1]. Technologies that improve the efficiency of conventional IC engines will most probably be promoted in the near future but, the declining cost of electrification is going to drive up the marginal cost of improving internal combustion [1].

Auto manufacturers who want to sell vehicles across the globe have to design the same vehicle in significantly different ways in order to comply with the regional regulations. The OEMs are currently mired in this "re-engineering" swamp that drives up the development cost of the vehicle and ultimately, its retail price. For instance, regulatory differences between the U.S. and EU can act as non-tariff barriers to trade, effectively putting a "trade tax" on products sold across the Atlantic [3]. In order to mitigate these large additional costs, we believe that harmonization of some of the CO₂ and FE regulations across regions will lead to savings to the car manufacturer and

thereby, reduce the sticker price of the vehicle. In order to achieve a rational harmonization of regulatory standards, it is essential to develop a mutual recognition of the nuances of variation in the regional compliance standards. Harmonization of regulations requires altering current standards of different regulatory bodies in order to develop a common set of regulations in regards to standards and compliance procedures. Mutual recognition ensures that any product lawfully sold in a region covered by one set of regulations can be sold in another region due to parties accepting the results of one another's compliance procedures [4]. In fact, the Alliance of Automobile Manufacturers along with the European Automobile Manufacturers' Association (ACEA) and American Automotive Policy Council (AAPC) were engaged with the U.S. and EU governments since 2013 to determine if certain standards could be mutually recognized by the EU and U.S. and to seek a regulatory harmonization component in the Transatlantic TIP agreement [3]. The Center of Automotive Research (CAR) conducted a study where it (1) estimated the costs linked to complying with both U.S. and EU vehicle Safety regulations and their impacts on the automotive industry, and (2) assessed the potential cost savings and additional benefits of mutual recognition between U.S. and EU vehicle safety regulations. CAR concluded [4] that the mutual recognition of US-Europe automotive regulations would lead to significant cost savings for both the industry and consumers in the United States and the EU. The CAR surveyed 16.6 million vehicles (data obtained from 5 companies spanning 172 vehicle variants) sold across the European and U.S. markets in 2014, and calculated the total additional annual cost incurred from divergence in safety regulations to lie between \$3.3-4.2 billion. Per-cross-market-sale, this implies an additional cost of \$648-873 per vehicle (see Ref. [4] for assumptions used in calculations) in materials, development and tooling. While similar numbers specific to the context of differing vehicle "mass" regulations across the globe do not exist, the potential savings from harmonizing the global mass regulations should be significant.

Light-weighting is a mandatory consideration in today's vehicle design and has evident benefits such as fuel economy, component cost savings due to reduced sizes, reduced rolling resistance of tires, and improved braking efficiency. Note that all the fuel economy and CO₂ emission standards are indexed to either the size or weight of the vehicle [5]. Therefore, the global FE and GHG regulations value 'mass' and 'light-weighting' differently due to the varying CO₂-target setting methods. This adds to the workload and potentially drives decisions that do not follow a rational customer model. Size-based and mass-based efficiency standards create different technology incentives. Mass-based standards actually decrease the options available to improve efficiency depending on the slope of the CO₂-target-line. The size-indexed standards are more effective in promoting light-weighting technologies, as lightweighting will not induce a more difficult target. The differences between size-based and mass-based efficiency standards should be carefully studied for guiding future standards [5]. For example, Brooker et. al. of the National Renewable Energy Lab performed a thorough model analysis of vehicle efficiency for four kinds of powertrain at varying levels of light-weighting; and identified that weight reductions fetch greater efficiency benefits in case of conventional IC engine vehicles than in EVs/HEVs/PHEVs. Note that determining vehicle efficiency entails computing the drag, acceleration, ascent, and rolling

resistances at every point on standard EPA certification cycles (UDDS, HWFET). Per the model analysis in Ref. [6], light-weighting is cost-effective when it costs less than \$6 per kg [6]. One of the light-weighting strategies includes choosing aluminum (alternate material) over high-strength steel (HSS). While there exist conflicting opinions on the 'upfront-cost-disadvantage' of using aluminum over steel in vehicle bodies [7, 8], both materials have their own merits. Several automakers, including General Motors and Ford, are trying to achieve a healthy mix of the two metals in vehicle bodies or components. For example, GM is the first OEM to have invented a method to weld aluminum and steel using resistance spot welding equipment. GM has introduced this new technology in some parts of the new Cadillac CT6 luxury sedan model [7, 8].

The CO₂ emissions performance on a standard drive cycle is a critical consideration when certifying a vehicle. Typical certification drive cycles are the FTP (Federal test Procedure), HWFET (Highway Fuel Economy Test), UDDS (Urban Dynamometer Driving Schedule), WLTP (Worldwide Harmonized Light Vehicles Test Procedure) and NEDC (New European Driving Cycle). Performance on these regional drive-cycles affects a vehicle's ability to meet the CO₂ targets in that region.

Lightweighting is a customer benefit for fuel consumption, but in this work, we highlight cases where lightweighting, as a CO₂ enabler, has incentives that do not align with rational customer values. For example in the US, there is no regulatory value to lightweighting vehicles within a Test Weight Classification (TWC). If a vehicle mass lies just over a TWC, the auto manufacturer will be overly incentivized to re-engineer the vehicle to drop into the next lower weight classification. In the EU on the other hand, there is regulatory disincentive to reducing weight within an Inertia Weight Classification (IWC), as lightweighting will not offset the CO₂ target reduction due to the curb-mass-based regulation.

This paper discusses in detail the (i) inherent differences between size (footprint) and mass-based CO₂/FE regulations and how they impact the vehicle design or adoption of new technology, (ii) typical light-weighting strategies and their impact on CO₂ emissions, (iii) differences between the CO₂/FE regulations between US, EU and China, (iv) implications of these differences to the customer and automaker, (v) effects of mass reduction on CO₂ targets and test weight classification, (vi) varying drive cycle sensitivity to vehicle weight and finally, (vii) value and potential savings from harmonizing some of the regulation differences across regions. The primary goal of this study is to appeal to the reader to realize the value of harmonizing some of the key differences between regional CO₂/FE regulations prevalent in the US, EU and China. This study could have included Japan, Korea, Brazil and other countries as well but, we feel that the lack of regulation harmonization in those regions will be similar to the differences emphasized in this work. The customers as well as light-duty vehicle manufacturers can derive significant potential savings from this harmonization. Conversely, a lack of harmonization adds cost that may get passed on to the customer. The discussion has been segmented in five categories. The specific objectives of this paper, therefore, are to investigate and analyze the



following 5 areas in case of passenger vehicles, identify gaps/misses in these areas, and highlight to the reader what value harmonization of global regulations can fetch us in context of these gaps:-

1. Definition of certification weight with respect to content, models and governing regulations
2. Mass-based vs. Footprint-based CO₂ requirements
3. Drive cycle differences with varying weight sensitivity to energy consumption
4. How weight reduction affects CO₂ target and output within a IWC/TWC

The value of harmonizing regulations across regions (U.S., EU and China) and aligning to a more rational customer model

1. DEFINITION OF CERTIFICATION WEIGHT

In order to discuss the implications of mass sensitivity and regulatory impacts of weight, one must first understand what constitutes 'Certification Mass'. The FE and mass regulations in the three regions (USA, EU and China) are illustrated below one-by-one. This paper focuses only on the light-duty passenger vehicle regulations for the three regions. Including the commercial and truck segments would add more complexity to the analysis.

North America (US and Canada)

The world's first fuel economy standard, CAFE program, was established after the oil crisis in 1975 with the objective of reducing energy consumption by enhancing the fuel economy of cars and light trucks. The CAFE program maintains distinction between passenger cars and light trucks with each one accounting for about 50% of the US market.

Until 2007, the CAFE standard for passenger cars and light trucks used to be 27.5mpg and 22.2mpg respectively ([Federal Register, 2012](#)). In 2006, the NHTSA adopted a reformed CAFE scheme for light trucks in the US that was based on the vehicle's footprint (area between four wheels). A formula relating FE targets with vehicle size was applied.

The state of California develops its own emission regulations, although it is still required to apply for a waiver from the federal government. Engine and vehicle emission regulations are adopted by the CARB- a regulatory body within the California EPA. Other states have a choice to either implement the federal emission standards, or to adopt California requirements. The EPA and NHTSA are working to harmonize their standards with the Californian approach.

The greenhouse gas (GHG) emission standards also apply to passenger cars, light-duty trucks, and medium-duty vehicles weighing 8500-10000 lbs. The EPA and NHTSA have enacted two coordinated sets of national standards (CO₂, CAFE) for light-duty-vehicle model years 2017-25. As described above, the CO₂ and CAFE standards are based on a vehicle's 'footprint' or size. The standards target an average 163g/mile of CO₂ (industry-fleet-basis) by 2025. The CO₂

compliance values associated with the footprint curves are reduced by (i) approximately 5% each year for passenger cars for MY 2016 onward, and (ii) an average of 3.5% per year for light-duty trucks for MY 2016-21 and 5% per year for MY 2022 onward [11]. The intent of this approach was to allow manufacturers to build a single light-duty national fleet that satisfies all requirements under both programs (CO₂, CAFE), and provides significant reductions in GHGs and oil consumption.

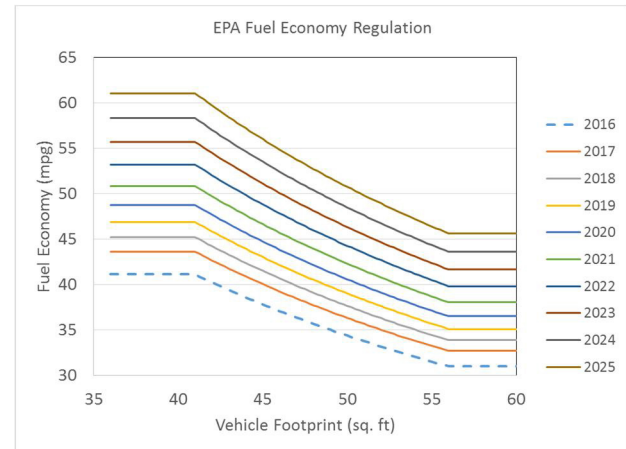


Figure 1. CAFE Fuel Economy Regulation vs Model Year and Footprint for Car Fleet (derived from Ref. [9]).

Europe

Europe bases their fuel efficiency regulations on GHG emissions. With the necessity for increased synergy and coherence in reporting under other legal instruments, in particular with Directive 2003/87/EC of the European Parliament and GHG emission allowance trading [12], the European Council has endorsed a binding target of at least 40% domestic reduction of GHG emissions by 2030 compared to that in 1990. It also mandates at least a 27% share of renewable energy consumption and at least 27% energy savings compared with the business-as-usual scenario [13]. Figure 2 below elucidates how EU handles GHG requirements through the metric of CO₂ Emissions.

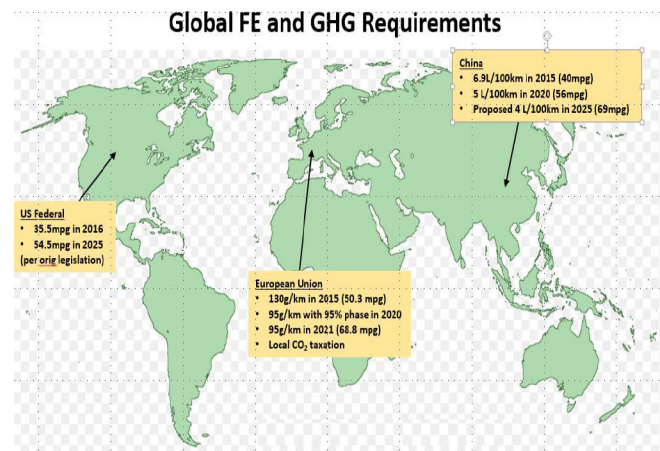


Figure 2. Fuel economy and GHG regulation targets in the three regions.