Re: DEPARTMENT OF TRANSPORTATION
National Highway Traffic Safety Administration
49 CFR Part 533
[Docket No. 2005-22144]
RIN 2127-AJ71
Light Truck Average Fuel Economy Standards–MODEL YEARS 2008–2011

22 November 2005, by upload to http://dms.dot.gov, and fax to 202 493 2251

Docket Management Facility
U.S. Department of Transportation
400 Seventh Street, SW., Nassif Building, Room PL-401
Washington, DC 20590-001

Dear NHTSA:

These brief comments supplement and update my comments of 26 April 2004 on the previous stage of this docket, and address the proposed rule NHTSA issued 23 August 2005. The 2004 comments summarize my background. Rocky Mountain Institute is an independent, nonpartisan, entrepreneurial, nonprofit applied research center that creates abundance by design, chiefly as a consultant to the private sector on advanced resource efficiency.

NHTSA is to be strongly commended for adopting a size- rather than weight-based structure for future light-truck CAFE standards. While the specific efficiency standards proposed can and doubtless will be criticized, probably severely, as falling far short of statutory requirements, NHTSA's proposal to base them on size, not weight, is an important advance. It will create an incentive for decoupling size from weight by adopting lighter-but-stronger materials and advanced designs—a hugely important step toward fuel-efficient cars and a competitive car industry. It will encourage manufacturers to make vehicles that are big, hence protective and comfortable, without also making them heavy, hence hostile and inefficient. Customers who want big vehicles will remain able to get them; there simply won't be an incentive to make big vehicles heavy nor light vehicles small. Size-basing will thus save lives, oil, emissions, and auto export prospects, whereas a weight-based system would in my opinion have degraded all these goals and proven disastrous for public health, national security, climate protection, and U.S. automakers' competitiveness. The 26 September 2005 *Wall Street Journal* page-one news story by Karen Lundegaard and the 28 September 2005 *Financial Times* editorial, both acknowledging the potential for lighter but safer vehicles, reflects a sea-change in industry attitudes that NHTSA is helping to lead. Congratulations and thank you!

Other commentators will doubtless argue that statute requires NHTSA to set CAFE standards much higher than it has done or proposes to do, in order to reflect both the private internal cost and the external value of fuel economy. I concur, and indeed I think the usual proposals for higher (≥40-mpg) standards are technically conservative. On 20 September 2004, my team at Rocky Mountain Institute published a detailed, independent, peer-reviewed, DoD-cosponsored, and so far uncontested analysis[1] showing that ~69% of the fuel forecast in EIA's January 2004 Reference Case to be used by light vehicles in 2025 could be saved (though not all by 2025, due to the dynamics of fleet turnover) by technologies costing an average of $0.57 per saved gallon (2000 $, 5%/y real discount rate). All these improvements compete on the short-run margin against EIA's forecast $26/bbl (2000 $) RAC oil price in 2025.

For example, we found that an uncompromised midsize crossover SUV[2], comparable to an 18.5-mpg 2004 Audi *Allroad 2.7T*, could achieve an EPA Combined City/Highway (55/45) rating of 66 mpg with a gasoline hybrid powertrain comparable to the 2004 Toyota *Prius*'s. Such an ultralight hybrid vehicle (curb weight 916 kg, 53% lighter

[1] A.B. Lovins, E.K. Datta, O.-E. Bustnes, J.G. Koomey, & N.J. Glasgow, *Winning the Oil Endgame: Innovation for Profits, Jobs, and Security*, Rocky Mountain Institute (Snowmass CO 81654-9199), free at www.oilendgame.com. See particularly pp. 44–73. Two dozen Technical Annexes, of which Chapter 5 presents all the underlying light-vehicle spreadsheets, are also posted at that URL, along with summaries, reviews, and other material.

[2] Described in A.B. Lovins & D. Cramer, "Hypercars®, Hydrogen, and the Automotive Transition," *Intl. J. Veh. Design* **35**(1/2):50–85 (2004), www.rmi.org/images/other/Trans/T04-01_HypercarH2AutoTrans.pdf.

than normal) could haul a half-ton up a 44% grade, accelerate 0–60 mph in 7.1 seconds, carry five adults in comfort and up to 96 ft^3 of cargo, provide versatile offroad performance with variable ride height and smart semi-active suspension, improve crashworthiness[3], and incur, after normal markups, an extra pretax retail price[4] of $2,544 (2000 $), paying back in two years at today's U.S. gasoline price. Nearly all this marginal cost is due to the hybrid powertrain, not the ultralight carbon-fiber structure. That structure does use costlier materials—high-performance continuous-carbon-fiber-reinforced thermoplastic composites—but they're paid for by simpler automaking and smaller powertrain, making the ultralighting essentially free. In this specific virtual design, for example, as described in refs. 1–2,

- the 57%-lighter (187-kg) Body-in-Black™ has only 14 main structural parts, each liftable with no hoist;
- making each part requires one low-pressure dieset, rather than an average of four high-pressure progressive steel-stamping diesets for each of the ~10–20-fold more parts in a steel unibody;
- the composite parts' clevis joints snap precisely together—self-fixturing and detoleranced in two dimensions—for adhesive bonding, eliminating the usual jigs, robots, and welders;
- color can be laid in the mold if desired.

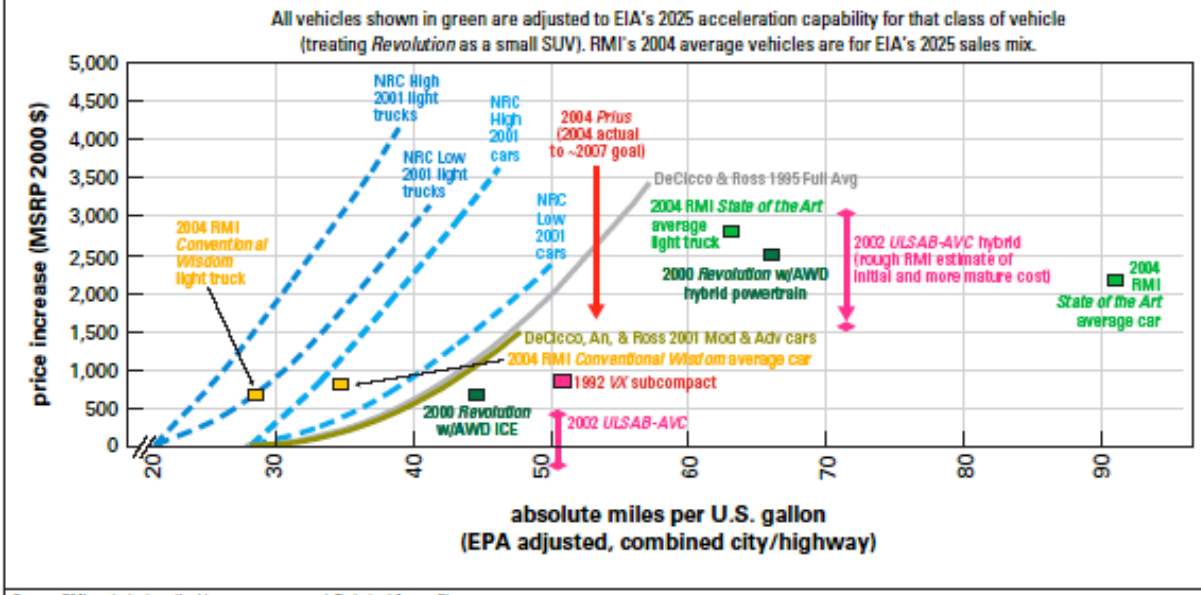
This elimination of the body shop and paint shop—the two hardest and costliest steps in automaking—cuts capital intensity by at least two-fifths below today's leanest plant, and also cuts optimal assembly-plant size by two-thirds, yielding a greatly improved risk/reward ratio.

When this design is extrapolated to the various vehicle subclasses calibrated to EIA's projected 2025 characteristics, the resulting supply curve for light-vehicle efficiency changes dramatically, far surpassing the low-cost potential found by NRC in 2001, let alone NHTSA's more conservative assumptions: as shown in Ref. 1's Fig. 21,

[3] Industry-standard simulation tools employed by the Tier One prime contractor predicted that the vehicle would experience no damage to the passenger compartment in a 35-mph head-on crash into a fixed barrier, and achieve FMVSS 30-mph fixed-barrier passenger deceleration limits in a 30+30-mph (60-mph combined) head-on collision with a steel vehicle twice its weight. As discussed in ref. 1, pp. 57–60, these carbon-reinforced composites can absorb, in the right shapes, up to 250 kJ/kg—12 times steel—and use the crush stroke up to nearly twice as efficiently.

[4] Objectively determined, as described in ref. 1, pp. 65–73, largely by anonymous bid requests from the Tier One prime contractor to the supply chain for the 499-line-item Bill of Materials.

Figure 21: 1990–2004 comparison of absolute mpg vs. incremental costs for new U.S. light vehicles: ultralighting doubles the savings. The studies (curves) and the two market vehicles (red) shown in Fig. 11, contrasted with the *Revolution* crossover-vehicle virtual design (dark green), this report's findings (light green, 2025 sales mix), and the steel industry's virtual design (magenta). Prior studies didn't consider the potential for ultralight designs to save more fuel at lower cost. Note that the *Revolution* hybrid, and the *State of the Art* light vehicles inferred from it, all cost about the same as today's ordinary-weight *Prius* hybrid. This means that advanced composites' fuel- and life-saving advantages—opening up the new design space on the right-hand half of the graph—are roughly free. The *ULSAB-AVC* 52-mpg gasoline-internal-combustion-engine steel design (magenta) illustrates another path to saving fuel, and implies the scope for a more efficient hybrid version whose attributes RMI roughly estimates as shown. Please see text for citations.



Source: RMI analysis described in text, pp. 62–73 and *Technical Annex*, Ch. 5.

Thus the average 2025 ultralight-hybrid car would get 92 mpg, *vs.* the 2004 *Prius*'s 55, at virtually the same marginal cost, which is due to its hybrid powertrain. (*Prius*'s many buyers obviously find that cost worthwhile.) Also graphed in magenta is the steel industry's ultralight-steel *Taurus*-class car—recalculated by RMI as a ~72-mpg hybrid—that would be a worthy competitor and a conservative technological backstop to the carbon-fiber ultralight.

Since my April 2004 comments, the manufacturing techniques for cost-effective carbon-composite structures have also made important advances. A small Colorado private firm[5] has received U.S. patents (6607626, 19 Aug 03, and 6939423, 6 Sep 05) on a proprietary tailored-blank-and-thermoforming process[6] that appears able, when matured and scaled, to beat aluminum in cost per part at any volume, steel in cost per autobody at midvolume, and steel in cost per *car* (when assembly, painting, and powertrain credits are also counted) at any volume. The firm is selling samples, small pilot runs, and development services to both OEMs and Tier Ones, and has been featured in several recent and pending trade-press articles.[7] Its all-composite seat bucket was featured at Johnson Controls' private booth at the January 2005 Detroit Auto Show (NAIAS) as the core of JCI's *Genus* concept seat. Industry interest in the process is growing rapidly. As size-based standards increase industry incentives to adopt ultralight materials, NHTSA should become familiar with such innovative opportunities for American technological leadership.

These new technologies for saving oil, lives, emissions, insecurities, and money simultaneously, while potentially restoring the competitive health of U.S. automakers, may inspire others to press NHTSA, through litigation if necessary, for far higher CAFE standards. However, RMI's analysis in ref. 1 (pp. 178–190) found that revenue- and size-neutral feebates would be an even more effective and attractive approach. Feebates are already receiving strong in-

[5] Fiberforge, Inc. (Glenwood Springs, Colorado), www.fiberforge.com. Full disclosure: I am its nonexecutive Chairman and own <0.1% of its stock, and my employer, Rocky Mountain Institute, owns about a fifth.
[6] Summarized in A. Burkhart & D. Cramer, "Feasibility of Continuous-Fiber-Reinforced Thermoplastic Tailored Blanks for Automotive Applications," 12 Sept. 2005, Society of Plastics Engineers Automotive Composites Conference, www.fiberforge.com/DOWNLOADS/ACCE05.pdf.
[7] Links at www.fiberforge.com/pages/who.html to *Composites Technology*, *Reinforced Plastics*, *Automotive Design and Production*, and *Modern Plastics*, as well as to a *Newsweek International* story featuring Fiberforge as "one of 10 innovations that may change the way we live," and an earlier World Technology Network Award.

terest from many State governments, and I hope NHTSA will encourage wide and rapid experimentation. Size-based efficiency standards harmonize naturally with efficiency-based feebates.

Well-designed feebates can make more profit for OEMs, creating both producer and consumer surpluses, as found by the DOE/ORNL model cited in ref. 1 (pp. 182–185, Greene *et al.* 2004). An ideal outcome both for the public interest and for automakers would be for feebates, and the other policy innovations we describe there, to surpass critics' CAFE goals so decisively that the level of CAFE standards becomes moot. Yet this prospect, however realistic, doesn't relieve NHTSA of its statutory obligations, which the Courts may be called upon to construe in due course as the widening gap between CAFE standards and market realities becomes impossible to overlook. Recent slight increases in standards, and EPA's proposal to narrow the test-*vs.*-on-the-road mpg gap, will help somewhat, but EIA's January 2004 Reference Case forecast that new U.S. light vehicles will spend the next 20 years becoming 0.5 mpg more efficient than they were in 1987 is ludicrously out of touch with technology, regulation, customer demands, and the state of the world. To be sure, EIA's model must reflect only current regulations, and it forecasts prices econometrically (like driving by looking in the rear-view mirror), but its failure to reflect disruptive technologies or competitive strategies is a serious flaw that undercuts its usefulness both for DOE and for other agencies.

Leaving aside the very modest level of the standards NHTSA is proposing, Rocky Mountain Institute suggests the following structural improvements in the proposed Rule:

1. *Cars* should switch to size-based standards just like light trucks. If NHTSA feels it lacks statutory authority to do this, and no other agency thinks it has such authority, then that authority should be requested. If, as I believe, the size-based approach is sound, then it is sound regardless of the vehicle's styling (car, truck, crossover, or whatever). To be sure, DOE projects that 55% of growth in U.S. oil use will be caused by light trucks, *vs.* only 3% by cars, but there's no obvious rationale for maintaining two different structures of efficiency rules, thus creating artificial and unpredictable incentives to game which category a vehicle will fall into. CAFE rules should be structured to save fuel, not to distort and confuse OEMs' design choices. Thus the car/light-truck distinction should be abolished wherever possible. If it ever had a sound rationale, that's quickly vanishing as designers endlessly create crossovers and other new vehicle categories.

2. *All 8,500-10,000-lb GVW light trucks* should be included and treated exactly like vehicles up to 8,500 lb. There is no rationale and no statutory basis to exclude them. It is not even true that imposing CAFE regulation on these heavy "light" vehicles would disadvantage their makers…nearly as much as they will be disadvantaged by such products' increasing conflict with standards in main world markets, such as China, where they're illegal already or will become so in 2008. I see no sound reason for exempting >8,500-lb "light" vehicles from any safety, efficiency, or emissions regulation that applies below that weight, nor from the Gas Guzzler Tax, nor from mpg disclosure to buyers. No such exemption can be consistent with common sense and sound public policy, nor with emerging technology and market developments.

3. *The size metric* will be gamed no matter what it is, but I still think *interior volume*—not yet seriously considered, to judge from the narrower alternatives discussed on pp. 91–92—is a better surrogate for customer utility, and less likely to be easily gamed, than shadow or (as NHTSA proposes) "footprint"—the product of wheelbase times average track width. The footprint definition would almost certainly cause manufacturers simply to move wheels out to the corners, loosening efficiency requirements without significantly improving customer utility or vehicle dynamics. This would "fail to achieve our goals of enhancing fuel economy and safety with a Reformed CAFE program" (p. 92). I agree that *ultimately* any increase in vehicle size (as NHTSA proposes to define it) will tend to be limited by handling, parking, garage size, and other constraints, but there's no obvious reason to prefer NHTSA's footprint definition to interior volume, and good reason not to. Given existing and future rollover and other stability requirements and market demands on styling, I'm not unduly concerned about manufacturers' gaming an interior-volume standard by making vehicles taller (floor to roof) or boxier; and of course any increase in effective frontal area will compromise efficiency, especially at high speed, thus limiting OEMs' appetite for that tactic. Nonetheless, "interior volume" would need careful definition, taking account of pickup trucks. And since the main goal is to save gallons of fuel, I'd urge that the metric be *gallons per mile*, not miles per gallon, per ft^3 of interior volume: there's no reason to introduce a geometric-ratio distortion into the metric.

4. Viewed in isolation, the size-based metric should be a continuous function, not segregated into size classes. Again, any metric will be gamed, but there is no public-policy purpose to be served by creating an additional incentive to intensify gaming around the boundaries of artificial size categories. However, NHTSA should not view CAFE in isolation. If, as I hope, CAFE is supplanted (at least in practical effect) by fee-

bates, then ref. 1's analysis suggests it would be highly desirable to make those feebates neutral in both revenue and size, so that buyers are not rewarded for buying vehicles of a different size than they want, but only for buying a more efficient vehicle within the size class they want. For this purpose, size classes would be required to ensure size-neutrality, so I'm inclined to think that CAFE rules should set those size classes. However, the number of size classes should be relatively limited, perhaps to ~4–6, since the more there are, the more vehicles will fall near a boundary and invite gaming.

5. The *flat-floor loophole* should be abolished. Designers should feel free to exercise creativity, meet shifting market demands, and adopt new technologies without any artificial distortion by efficiency rules. NHTSA should bear in mind that if distributed-powertrain designs like GM's "skateboard" become widespread, virtually every vehicle could get a flat floor. As I commented in 2004: "The 'flat floor' criterion (NR:64ff) is an historic artifact that should no longer influence fuel-economy regulation. The rise of alternative, notably hybrid and fuel-cell, powertrains will make powertrain packaging so flexible that it'll become increasingly attractive to offer flat floors in a wide range of light vehicles regardless of their size and functionality. I see no reason to deter or favor this development, whether in crossover vehicles or otherwise, nor to discourage manufacturers from providing removable seats and flexible interior design and packaging to meet evolving customer value needs. But since I don't think the car/light-truck distinction should be maintained—both should meet the same mpgs—this shouldn't matter."

6. The *alternative-fuel-capable loophole* should be abolished for all light vehicles. I realize that the proposed standards will decrease the potential efficiency loss when minivans and the car-like *PT Cruiser* are classified as trucks, hence the incentive to game the classification, but the loophole still makes no sense. Fuel efficiency and fuel flexibility are *both* in the national interest, and should both be encouraged without trading off one for the other. NHTSA should also require OEMs, using existing recall-mailing databases, to notify owners of flexible-fuel vehicles that they actually own one (press reports of recent surveys indicate that ~70% of owners don't know their vehicle has this capability) and to explain what kinds of fuels these vehicles can use and how to find alternative fuels in their area. NHTSA should open a rulemaking on requiring all vehicles to be "totalflex," like those that now have over 50% market share in Brazil (mainly from GM and VW) and are proposed for rapid expansion in Sweden (from Volvo and Saab). Totalflex vehicles can burn any blend from 100% gasoline to 100% ethanol, so the fuels offered in each locale would depend only on climate and distribution details—but the fleet would become ready for likely rapid growth in cellulosic ethanol production, forestalling a serious bottleneck in deploying diverse domestic fuels.

7. The proposal to adjust CAFE levels for *towing capability and cargo-hauling capacity* (p. 95) is a very bad idea and should be scuttled, for three reasons: these new loopholes would be almost infinitely gameable, and NHTSA should reduce, not increase, incentives and methods for gaming CAFE; these are capabilities that, like fuel flexibility, will probably be seldom or never used by many customers, and are simply two of enormously many vehicle attributes that customers may desire, may be persuaded to buy, or may be bundled so they're bought whether desired or not; and most importantly, there's simply no public-policy rationale for letting vehicles with these attributes achieve worse fuel economy. Customers who desire particularly large or heavy-duty vehicles should know that worse fuel economy may come with the territory (chiefly through larger, worse-part-loaded powertrains), and should accept its consequences. That choice should not impose burdens on buyers of other vehicles; rather, *all* the consequences of choice should be internalized to the buyer of each vehicle so as to inform mindful markets.

8. The gratuitous claim (p. 150) that states—even California with its unique Clean Air Act authority—are preempted from regulating vehicles' CO_2 emissions is legally and technically unsound, is obviously based on political instruction rather than defensible reasoning, and should be deleted. The Federal government will have plenty of opportunity to put this view before the Courts in the Pavley Act litigation in California. There's no reason to muddy this rulemaking by injecting the issue here.

In addition, this Rule should shift NHTSA's R&D priorities:

- NHTSA should launch a well-focused effort to learn about the safety attributes of the new designs and materials likely to enter lighter-weight, including ultralight (roughly halved weight or better) vehicles and the new safety philosophies and designs rapidly emerging abroad.
- NHTSA should task analysts like Dr. Kahane, in collaboration with industry and independent analysts, to understand from its large crash-safety database why, as my 2004 comments pointed out, there's a several-fold scatter in fatalities per unit of driving *at any given curb weight*, across a huge range. This scatter indi-

cates important but unanalyzed ways in which design affects safety, even using a relatively narrow palette of materials. Better understanding these design-to-safety causal links—which Dr. Kahane told me were indeed interesting but he'd never been asked or funded to examine—should expose enormous opportunities for improving crashworthiness without increasing cost. After all, *every* market platform is by definition cost-effective to its buyers, and all the platforms in NHTSA's database are or have been widely sold, so if some are far safer than others of the same weight, NHTSA has a duty to determine why.

- NHTSA should start thinking about how plug-in hybrid-electric powertrains, rechargeable from the electric grid to save liquid fuel, could affect the interpretation of CAFE rules, in light of not just the oil-saving but also all the other policy objectives underlying CAFE.
- NHTSA should carefully incorporate the potential for feebates, particularly revenue- and size-neutral feebates, into its CAFE design so as to ensure their compatibility.

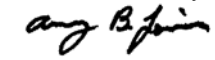
In conclusion, let me return to the public-policy criteria suggested in my 2004 comments. Those urged that "good science, the rapidly emerging ultralight vehicular structural options described below, the need to take market economics seriously, and common sense would all suggest that any CAFE modifications should:

- be performance-based, not prescriptive
- be at least neutral as to vehicle mass, rigorously avoiding any incentives for a further 'mass arms race'
- if they *do* influence mass, favor its *downward* rather than upward harmonization
- if fuel-economy choices are desired to be decoupled from vehicle-size-class choices, then do so by normalizing to *size—e.g.*, to gal/mi per interior ft^3—*not* to mass, so as to encourage size/mass decoupling
- be technology-neutral but preferably (in the national interest) technology-forcing."

NHTSA has made a commendable start structurally (if not yet numerically) on turning policy in these directions, and has fortunately avoided the major blunder of the weight-based system originally proposed. Now NHTSA needs to finish the job.

I would be pleased to discuss these comments with appropriate NHTSA officials if desired.

Sincerely,



Amory B. Lovins
Chief Executive Officer