

Special Report

Meeting **CAFE** 2025

The U.S. government last summer finalized the most stringent vehicle fuel efficiency regulations yet in North America. How will the industry achieve the currently proposed 54.5 mpg fleet average within 12 years – a compressed timeframe that is barely three product cycles from today? Find the answer in this recently published 3-part feature series by Lindsay Brooke, Senior Editor, *Automotive Engineering International*.

Part 1

AEI's three-part series on the industry's pathways for meeting the aggressive new U.S. fuel efficiency regulations.



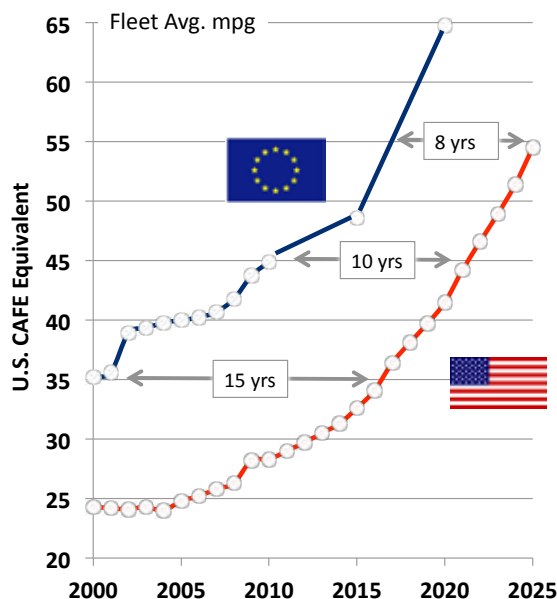
Is this the model passenger car for 2025 CAFE compliance? Hybrids and plug-ins such as Toyota's Prius family and Ford's 2013 C-Max Hybrid and PHEV (shown) are among only a few cars that currently fit into the 54.5-mpg window.

Mapping the road to **54.5 mpg**

Part 1 of AEI's three-part series looks at the CAFE challenge and the product-development options being weighed to meet it—while engineers look forward to the critical 2018 midterm review.

by Lindsay Brooke

The CAFE rules force the U.S. fleet to close the fuel efficiency gap with Europe



Source: Martec Group; ICCT conversion between NEDC and USEPA lab certification test procedures

In automotive product development, achieving a 5% increase in efficiency across a subsystem, or overall in the vehicle, is a very big deal. This is, after all, an industry in which engineers will practically kill to get an extra 1% out of anything. A 10% efficiency gain is cause for jubilation.

That's why the new U.S. Corporate Average Fuel Economy (CAFE) regulations that raised the auto industry's overall fleet fuel economy requirement from 25.3 mpg in 2010, to 34.1 mpg by 2016—the biggest CAFE increase since the 1978-84 period—were regarded as a very tough bogey. But it's nothing compared with what comes next.

The 54.5-mpg fleet-average fuel economy ultimately set for MY2025 was announced last August by the Obama

administration in a nearly 2000-page document. This second phase of the new CAFE, ramping up from 2017, represents a mighty 59% increase over the 2016 target. Remarkably, it is 99% higher than the 27.3-mpg standard of 2011.

The standards are the most aggressive in auto-industry history, according to a 2012 report by the strategic-analysis consultancy **Scenaria**. They are projected to save approximately 4 billion barrels of oil and 2 billion metric tons of greenhouse gas emissions (GHG) over the lifetime of the 2017-25 standards, according to the U.S. EPA.

While they establish certainty about fuel economy requirements, the new standards also create new headaches for the industry. Which technologies should automakers use to meet the new standards? How much cost will they add—and will the incremental cost drive up vehicle retail prices?

"This is a pretty tall hurdle, without doubt," said Dr. Gary Smyth, Executive Director of **General Motors'** North American Science Labs and a veteran powertrain engineer. "Getting even close to the new numbers, particularly for a full-line manufacturer like us, will require a combination of many solutions. And none of them will be inexpensive."

Part

1

Mapping the road to 54.5 mpg

MY2016-MY2025 Combined Passenger Car and Light Truck Greenhouse Gas and CAFE Standards

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
GHG standard (g/mi) ^a	250	243	232	222	213	199	190	180	171	163
GHG-equivalent fuel econ. (mpg equiv.) ^a	35.5	36.6	38.3	40	41.7	44.7	46.8	49.4	52	54.5
Fuel economy (CAFE) std. (mpg) ^a	34.1	35.4	36.5	37.7	38.9	41	43.0 ^b	45.1 ^b	47.4 ^b	49.7 ^b

Source: EPA and NHTSA, 2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards, Prepublication Version, August 28, 2012.

a Due to the complexity of the CAFE/GHG system, these numbers are based on projected sales of vehicles in different size classes. The standards are size-based, and the vehicle fleet encompasses large, medium, and small cars and light trucks. Thus if the sales mix is different from projections, the achieved CAFE and GHG levels would be different. For example, the CAFE numbers are based on NHTSA's projection using the MY2008 fleet as the baseline. A newer projection, based on the MY2010 fleet, leads to somewhat lower numbers (roughly 0.3—0.6 mpg lower for MY2017-2020 and roughly 0.7-1.0 mpg lower for MY2021 onward).

b Projected. NHTSA only has authority to set CAFE standards in five-year increments. Thus, only rules through MY2021 have been finalized. For MY2022 onward NHTSA must issue a new rule, which has not been proposed as of September 2012.

Observed Casey Selecman, an engineer and industry analyst with the **Martec Group**: “Having to increase fleet fuel economy by 4% per year, as called for by the new CAFE, is a massive task—particularly to do it on a six-year vehicle product cycle. Even Europe in its diesel heyday of the early 2000s wasn’t doing that,” he said.

The challenge of meeting 2017-25 CAFE, which industry leaders agree will require significant investment in technology resources, innovation—and potentially some breakthroughs—inspired *AEI* to create this three-part series of articles. Part 2, which looks at options for creating the 54.5-mpg passenger car, runs in the Nov. 6 print edition. Part 3 covers the even greater challenge of

light-truck compliance—and the future of the American pickup; it will appear in the Dec. 4 digital edition.

The majority of the nearly two dozen experts interviewed for this series predict the industry will be able to develop and bring to market technologies required to meet the aggressive 2017-25 CAFE standards. But all of them also questioned whether it can be done without unacceptably raising future vehicle prices.

Even the government seems unsure of whether the CAFE program will deliver sufficient consumer-payback value. As noted in the section of the regulations titled MY2017 and Later Final Rule, page 1110: “...we do not at this point have sufficient confidence in the estimates of



Powertrain “is going to be your biggest friend or your worst enemy in how you’re going to get to 54.5 mpg—powertrain and lightweighting initiatives,” said Sandy Munro, of Munro & Assoc. (Lindsay Brooke)

the role of fuel economy in consumers’ vehicle purchases to come to definitive conclusions about the impacts of the rule on vehicle sales.”

Separate-but-equal cars and trucks

As with the current phase of CAFE covering 2012-16, the rules now set for 2017-2025 are complex and loaded with technology credits aimed at promoting certain solutions over others (see sidebar). **And as with the 2012-16 rules, the second-phase regs are based on vehicle size.** This formula was established by the Bush administration under an MY2011 light-truck rule. It assigns each car and light truck a fuel-economy “target” based on its footprint, which is the vehicle’s track-width measurement

multiplied by its wheelbase.

The sales-weighted average of the targets for an automaker’s fleet is the CAFE average that the company must achieve in a given model year. In other words, no vehicle is required to meet a specific fuel economy number, and the average fuel economy required will vary among manufacturers.

Truck fleet fuel economy is calculated in a similar manner to that used for cars, but with a different formula. As currently proposed for 2025, the truck targets range from 30.2 to 50.4 mpg, compared with 21.1 to 27.1 mpg in 2011. The truck formula is designed so that the low end of the range rises less than the high end to help accommodate larger trucks.

Experts say the size-based criteria create a more complicated regulatory system than the previous one. **But it arguably discourages OEMs from simply making vehicles smaller to comply.** Many in the industry initially feared an extreme jump in CAFE regulations was designed to drive Americans into small cars while killing larger cars and full-size trucks. (See Part 2, “Creating the 54.5-mpg car.”)

Real-world mpg explained

Because the new CAFE is based on size, every automaker gets a different CAFE requirement based on product mix and the size of the car and truck models that are actually sold. For every model year, each OEM must calculate the CAFE requirement for its entire product portfolio, and then calculate the sales-weighted average for its actual mix. **In that way Ford, for example, with its hefty**

chunk of full-size pickups and SUVs, has a lower CAFE requirement than **Hyundai**, which (so far) relies mainly on small and midsize cars.

While the 54.5 mpg number gets the headlines, the combined “real world” mpg customers will see on a vehicle’s window sticker will be about 20% lower—45.4 mpg for cars and 32.1 mpg for light trucks under 8500 GVW, for a projected car/light truck fleet average of 40 mpg. That’s because the CAFE figures are based on the EPA’s city and highway fuel economy tests used since the 1970s, along with the results of three other emissions tests.

The calculations behind the 2017-25 regulations use CO₂ emissions (g/mi traveled), which convert to fuel economy in mpg. The numbers are derived from EPA’s determination that each gallon of gasoline burned produces 8887 g of CO₂. Thus the 35.5 mpg target for 2012-16 is based on reaching a cars/trucks fleet average of 250 g/mi (8887 divided by 250). The CO₂ emission target will drop in stages to 163 g/mi (54.5 mpg) for 2025, as the accompanying chart shows.

The new regs incorporate credits for various technologies not measured to a real-world extent with the EPA’s existing five-cycle testing. (See “The CAFE credit maze explained” sidebar.) The credit for such off-cycle items could amount to about 3 mpg if several are used—and even more if a manufacturer provides data to justify it.

There also are credits for the plug-in hybrid electric, battery electric, and fuel cell vehicles (FCVs). To incentivize their sales, the government incorporated a

The CAFE credit maze explained

The technology credits baked into the new CAFE regulations include fuel saved by idle-stop-start systems, friction losses reduced by faster warm-up times for engine and transmission oils, and many more. The credits aren’t just “giveaways,” as the old flex-fuel credits were often regarded. Most of them actually improve vehicle efficiency in real-world driving. Indeed, under the new regs flex-fuel vehicles will receive credits only if automakers can prove how much fuel their E85-capable vehicles actually burn in real-world use.

Major technology areas receiving credits include:

Air conditioning: A/C technology plays a significant role in the new CAFE formula, with two types of credits in the new rules. One is for efficiency, aimed at fuel economy. The other is for low-global-warming impact of the refrigerant. This is an EPA effort to encourage use of R-1234yf, with its global warming number of 4-10, in lieu of the present choice, R-134a, which is rated at 1430. The 4-10 number means the release of 1 g of R-134a would have the same global warming effect as releasing 4-10 g of CO₂. The lower the number, the less effect the refrigerant has on global warming.

The global-warming credits are tied to use of tight seals, so refrigerant leaks less into the atmosphere. Because R-134a is more reactive, even a tight-sealing system receives a credit of just 6.3 g/mi for cars, 7.8 g/mi for trucks. R-1234yf has such a small effect because if it leaks out, it dissipates quickly (in just a few days vs. many years for R-134a). So it gets larger credits—13.8 g/mi for cars, 17.2 g/mi for trucks.

Both refrigerants are used with technologies that improve operating efficiency—better heat exchangers, more efficient compressors, and occasionally for R-134a (but certainly for R-1234yf) the addition of an internal heat exchanger (IHx). More precise compressor controls will be needed to better match compressor output to cooling load, reducing energy wasted by cooling air to 32° F (0° C) and then reheating it to a cabin-comfort level. Because of this, both refrigerant systems can receive the same efficiency credits: 5 g/mi for cars and 7.2 g/mi for trucks (fleet average of 5.7 g/mi).

IHXs potentially produce a larger benefit for R-1234yf,



Behind this inconspicuous Malibu Eco grille is a technology—active-aero grille shutters—that counts for CAFE credits.

with 10,000 sold in that company's fleet fuel economy calculations. In 2020, each EV and FCV counts as 1.75 vehicles, and 1.5 in 2021. Plug-in hybrids (and CNG models that also run on gasoline) have a factor of 1.6 in 2017, dropping to 1.45 in 2020 and 1.3 in 2021.

Hybrid full-size pickup trucks get per-vehicle credits if sold in substantial numbers. The credit is 10 g/mi for mild hybrids and 20 g/mi for strong hybrids, respectively. There's also a performance-based incentive credit that achieves significant emissions reductions below the target level corresponding to the trucks' footprint. The credit is 10 g/mi for pickups achieving 15% lower CO₂ than their target, and 20 g/mi for pickups achieving 20% lower. Access to the hybrid- and performance-based credits in any model year is predicated on achieving a minimum penetration of the technology in a manufacturer's full-size pickup truck sales.

Solar/thermal control: A schedule of new credits for these technologies also was released, as a subset to the overall list of credits. The credits cover features such as solar-control glass, body reflective paint, active seat ventilation, and passive or active cabin ventilation. Active ventilation can be a fan system triggered by the in-car temperature sensor to moderate the vehicle's interior temperature.

A related example is a vehicle with solar panels that recharge the battery pack and/or keep the interior of the car cooler by running a fan to reduce cabin temperatures during a parked-in-the-sun heat soak. This will reduce the amount of cooling the A/C has to do when the car is operating, lowering the fuel consumption from that system. A 75-W solar panel array alone earns 2.5 g/mi if used for cabin ventilation and battery charging (3.3 g/mi if for battery charging only).

While the number of credits available from the solar/thermal a la carte technology menu amounts to 8.3 g/mi for cars and 4.3 g/mi for trucks, automakers can claim a total of only 3.0 g/mi for cars and 4.3 g/mi for trucks. This is designed to prevent a manufacturer from "overloading" a vehicle with credits. And those solar/thermal credits are part of the 10 g/mi total fleet average that a manufacturer may claim for all technology credits.

but pose a tough balancing act for A/C calibration engineers. **Cadillac**, the first domestic brand to install R-1234yf in the U.S. (used in the 2013 XTS), put a temporary hold on using R-1234yf in the 2013 ATS. GM engineers said they need to recalibrate the system for better performance with the IHX.

Idle-stop-start: These systems are grouped with a broad array of technologies expected to play an important role in raising vehicle fuel economy. They include high-efficiency exterior lighting; waste heat (exhaust) recovery; active engine and transmission oil warm-up systems; and active aerodynamic systems—grille shutters, deployable spoilers, air suspension, etc.—contributing to a minimum 3% drag, or Cd, reduction.

Car makers have asked for window-sticker credits for idle-stop-start systems, but U.S. EPA argues that would be "double dipping" since under CAFE stop-start already gets carbon credits—worth 2.0 g/mi on cars and 2.9 g/mi on trucks not equipped with an electric pump to circulate coolant, and 2.5 g/mi on cars (4.4 g/mi on trucks) with the coolant pump. The electric pump is no longer available as a separate (1.0 g/mi) credit. (EPA also still lacks a sufficient test cycle in which a window-sticker fuel economy rating for stop-start could be achieved.)

These technologies offer a theoretical credit total of 10.8 g/mi for cars (14.1 g/mi for hybrids, PHEVs, and EVs), 17.8 g/mi for trucks (21.1 g/mi for hybrids, including PHEVs and EVs). But as noted below, these credits are capped, to a limit of 10 g/mi for a vehicle fleet.

Electrification: To incentivize sales of electrified vehicles, CAFE assigns a temporary "technology multiplier" to the sale of each battery-, fuel-cell- (FCV), and CNG-powered vehicle, with the value of the multiplier descending each model year from 2017-21. For example, for EVs a factor of 2 is applied, meaning if an automaker sells 5000 EVs it will be credited

Paul Weissler

EPA Projections for Fleetwide Tailpipe Emissions Compliance with CO₂ Standards – Combined Passenger Cars and Light Trucks, g/mi

Model Year	Projected CO ₂ Compliance Target	Incentives			Projected Achieved CO ₂	Credits			Projected 2-cycle CO ₂
		Advanced Technology Multiplier	Pickup Mild HEV + Strong HEV	Intermediate Volume Provision		Off Cycle Credit	A/C Refrigerant	A/C Efficiency	
2016 (base)	250	0	0	-	250	0.5	5.8	4.8	261
2017	243	0.4	0.0	0.1	243	0.6	7.5	5.0	256
2018	232	0.7	0.1	0.3	234	0.8	9.9	5.0	249
2019	222	1.0	0.1	0.1	223	0.9	11.7	5.8	242
2020	213	1.0	0.1	0.1	214	1.0	13.4	5.8	234
2021	199	0.8	0.2	-	200	1.1	15.0	5.8	222
2022	190	0.0	0.2	-	190	1.4	15.0	5.8	212
2023	180	0.0	0.2	-	181	1.7	15.0	5.8	203
2024	171	0.0	0.2	-	172	1.9	14.9	5.7	194
2025	163	0.0	0.3	-	163	2.3	14.9	5.7	186

multiple of 2 on each EV or FCV sold in MY2017. So 5000 units sold will be counted as 10,000 for an automaker's fleet fuel economy calculation. The multiplier reduces to 1.5 by 2021. For PHEVs, the multiplier begins at 1.6 in 2017 and phases down to 1.3 in 2021.

By incorporating language for plug-in electrics and FCVs, the federal government struck a balance in satisfying California's zero-emissions vehicle (ZEV) mandate—getting the state's air-quality regulators to buy into the national rules—while maintaining a standard set of rules across all 50 states, noted Suzanne Cole, CEO of the regulatory-affairs firm **Miller Cole LLC**.

"This was really a win for the industry, as it desperately sought to avoid gravitating back to a California-vs.-the-other-states situation—two sets of regulations that would be hugely expensive," she said.

Cole noted that automakers can choose to comply with the rules by buying ZEV credits from each other. The rules also

provide specific incentives for mild- and strong-hybrid light-duty trucks if sales are sustained above a certain level.

Martec Group's Selecman asserts that the ZEV credits aren't an effective way of complying with CAFE. "The difference in consumption between a conventional car's 55 mpg and a plug-in's 100 e-mpg equivalent, in terms of the CAFE calculation, is fractional," he said. "So adding those e-mpg's instead of having a lot of 55-mpg cars will really have a minimal impact on the overall compliance. It doesn't move the needle enough."

Overall, the powertrain component "is going to be your biggest friend or your worst enemy in how you're going to get to 54.5 mpg—powertrain and lightweighting initiatives," said Sandy Munro, CEO and founder of **Munro & Associates**, a product development and technology consultancy.

The critical 2018 midterm review

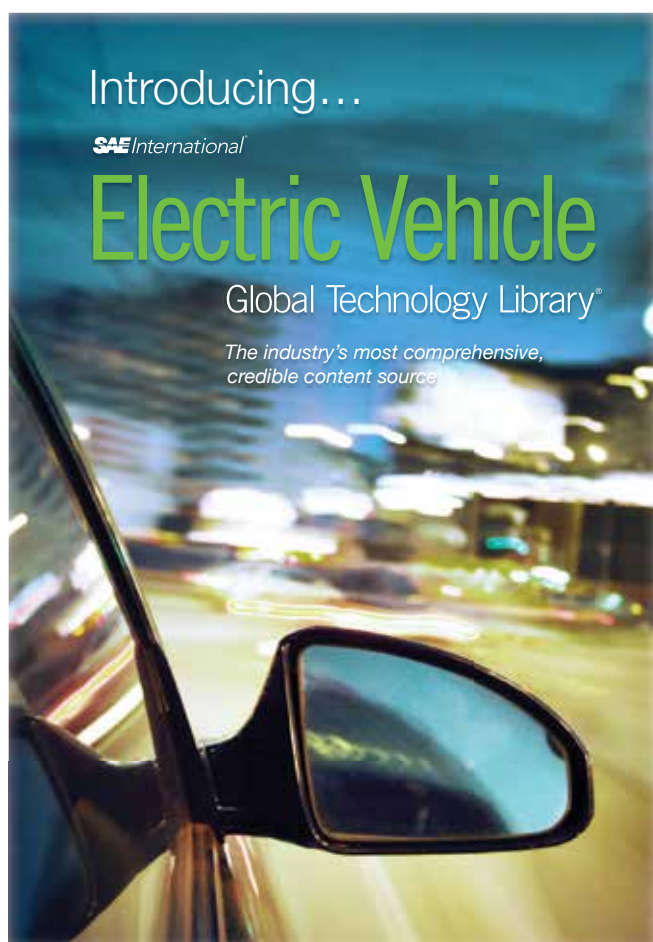
Product planners, engineers, and company leaders generally agree that the

2017-25 CAFE standards are a tough set of challenges. And they're almost unanimous about the importance of the midterm review of the program that's set for the 2018 time frame. The review — another win for the industry — will determine whether the 2021-25 phase remains technically feasible, cost-effective, and ultimately saleable to the end customer.

"Frankly, we think the 2018 review is one of the most important, if not the

most important, aspects of the program," Tom Baloga, Vice President of Engineering for **BMW North America**, told *AEI* in spring 2012. "Right now, no one really knows whether we'll need some technologies that haven't yet been invented or proven. The industry and government may need to make adjustments by then." **AEI**

Part 2 of the Meeting CAFE 2017-25 series appears in the Nov. 6 print edition of AEI.



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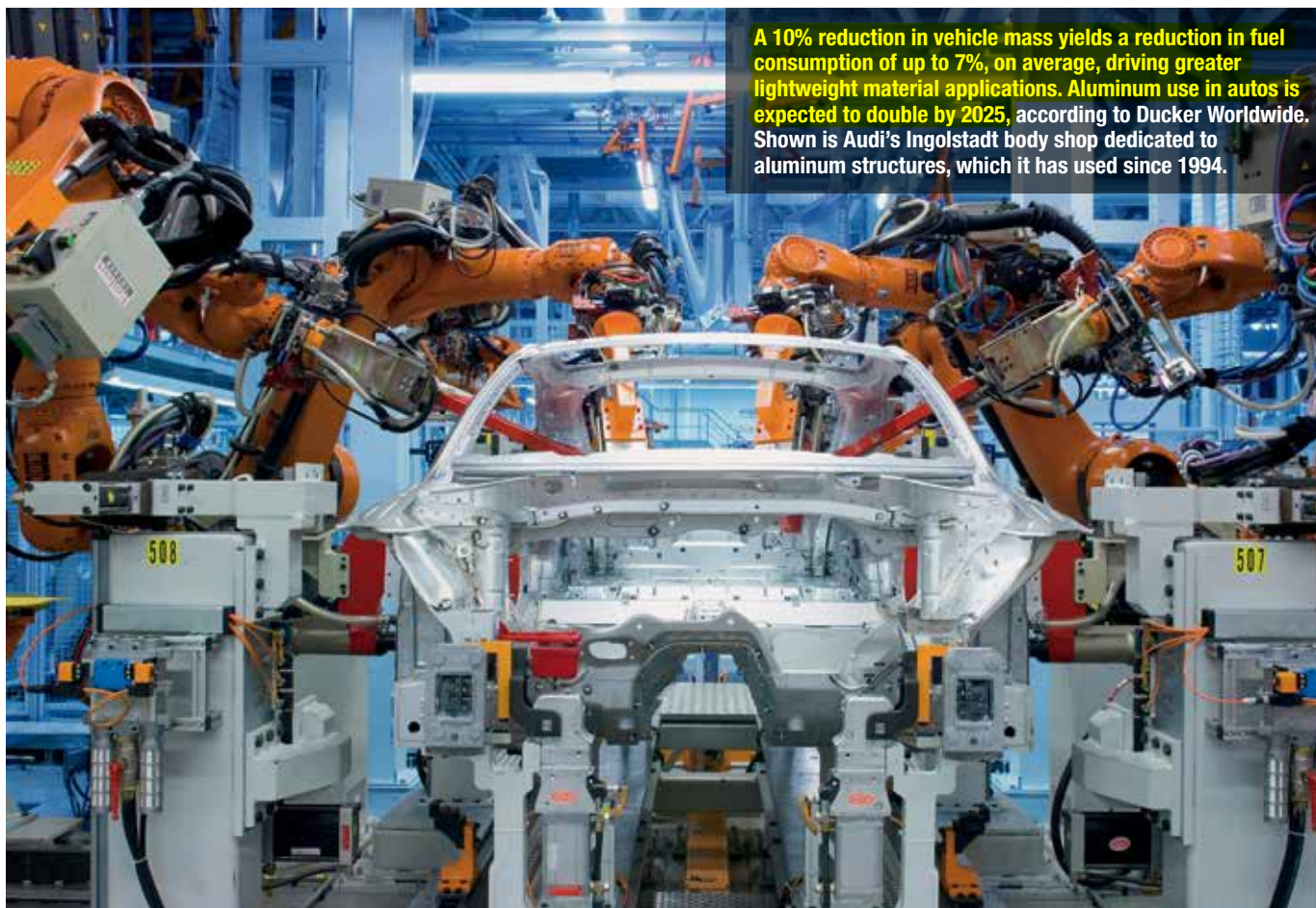
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A 10% reduction in vehicle mass yields a reduction in fuel consumption of up to 7%, on average, driving greater lightweight material applications. Aluminum use in autos is expected to double by 2025, according to Ducker Worldwide. Shown is Audi's Ingolstadt body shop dedicated to aluminum structures, which it has used since 1994.



Creating the 54.5mpg car

Part 2 of AEI's three-part series looks at how vehicle engineers are facing a "stress test" as the countdown to 2025 CAFE begins. How will the aggressive new regulations influence U.S. passenger cars in the next decade—and what will they cost to implement?

by Lindsay Brooke

“ Michael Phelps has a pretty easy job ahead of him, compared with what our industry is facing with the upcoming CAFE regulations,” said Gary Rogers, the outspoken President and CEO of FEV Inc., when he addressed a conference of auto industry executives last summer.

Rogers, whose company helps automakers develop and test new technologies for improving vehicle efficiency, believes meeting the new 54.5-mpg Corporate Average Fuel Economy fleet average is an “onerous task” far more daunting than the ace American swimmer’s gold-medal prospects were in the 2012 Olympics. His view is shared by many product planners, designers, and engineers charged with improving vehicle fuel efficiency by a total of 50% through MY2025, when the peak of the CAFE regulations must be implemented.

Engineers know how challenging it is to raise the efficiency of anything by 1%, let alone 4% per year. The kicker with the new CAFE, however, is how to do it in less than three model-year life cycles, without constricting consumer choice, and

Powertrain evolution for cars and light trucks beyond 2012: The 3 interlinked phases of change required to meet CAFE



Short-term: 2012-17

- Downsizing & boosting:
 - Turbocharging
 - Supercharging
- Low-speed torque enhancements
- Stop-start & low-cost micro-hybrid technology
- Friction reduction
- Advanced thermal control
- Niche HEV, PHEVs, EVs
- More transmission gears (2013 ZF 9-spd shown)
- Return of the CVT



Mid-term: 2017-25

- High-efficiency advanced combustion ICEs:
 - Lean stratified SI
 - Low temperature combustion
- Combined turbo/supercharging systems (VW 1.4L Twincharger shown)
- Low-carbon fuels
- PHEVs in premium & performance products
- EVs for city vehicles
- Electric transmissions



Post-2025

- PHEVs and HEVs dominate:
 - Purpose-built, high-specific power ICEs
- Range of application-specific low-carbon fuels
- Exhaust & coolant energy recovery
- Advanced thermodynamic cycles
- Split cycle engines?
- Heat pumps?
- Practical EV charging infrastructure emerges

Sources: Ricardo, automakers, AEI reporting

Powertrains are evolving toward 54.5 mpg with many key technologies already in production or in the works. But while 9-speed transmissions can help sell a car in the showroom, the same can't be said for cooled EGR, or variable compression ratio cylinder heads, or waste-heat-recovery systems. The industry will have to find a way to either absorb the cost of many of CAFE's enabling technologies, or find ways to make them profitably.

(most importantly) without pricing most buyers out of the new-car market.

(Under CAFE, light trucks can improve at a slower 2.5-2.7% annual rate until 2021, when the plan calls for trucks to improve at a rate of 5% a year to catch up. Part Three of this series next month will discuss light-truck options under the new regulations. Part One can be found at <http://www.sae.org/mags/aei/11461>.)

“The auto industry's challenge isn't only inventing technology or materials that can get the job done—it is convincing consumers to pay the price for those changes,” observed Gerry Conover, a technology consultant and former competitive-intelligence analyst at **Ford** and the **U.S. Army**.

The Obama administration estimates the retail-price burden of CAFE to be about \$1800 a vehicle by 2025. That figure has been widely debated by industry analysts, nongovernmental organizations, and academics, some of whom believe it underestimates the cost and readiness of some technologies or misses others entirely. Consumers who buy 2025 models can expect to save more than \$8000 over the life of a car in greater fuel efficiency compared to 2011 models, the administration calculates, more than offsetting higher purchase costs.

But as Conover and other experts observe, the government notoriously is a poor estimator of market conditions, particularly future ones. If vehicle costs end up double the federal estimate, and gasoline prices and driving patterns in 2025 also differ from the predictions—i.e., by half—a \$3600 cost compared to \$4000 in lifetime fuel savings is far from compelling.

“If we pass on more than about \$2000 extra cost per vehicle, at most, the NADA [National Automotive Dealers' Association] says demand for new cars will significantly di-



By offering its 1.0-L, 92-kW (123-hp) 3-cylinder gasoline engine in the 192-in-long (4877-mm-long), 3285-lb (1490-kg) 2013 Mondeo (a D-segment sedan), Ford is probing the bandwidth of engine displacement vs. vehicle size to meet stringent new CO₂ regs. Might the 1.0-L Mondeo be a harbinger for a future CAFE-compliant U.S. Fusion?

minish. Our industry will contract,” said Dr. Jay Baron, President and CEO of the **Center for Automotive Research** (CAR). In 2011, CAR published a report on the estimated impact of CAFE's technology costs on vehicle retail sales in 2025, which sparked a highly critical response from the **International Council on Clean Transportation**, which was followed by a point-by-point challenge from CAR, demonstrating how contentious the new regulations have become.

Steel innovates to compete for lighter, stronger bodies

"Meeting the 2025 CAFE standards will be tough for the industry, but regulatory challenges force us to innovate," observed Ron Krupitzer, Vice President Automotive Applications at the **Steel Market Development Institute**. "You'll see a mix of lightweight solutions, including aluminum and composites, to achieve higher fuel economy, and it's giving everybody a chance to really optimize their body structure strength and mass through redesign."

That is **Volkswagen Group's** approach with its new modular body architecture and related manufacturing/sourcing strategy, known as MQB. The recently introduced 2013 Golf, VW's highest-volume product, sheds 220 lb (100 kg) as a result of moving to the MQB platform, which includes greater use of high-strength and ultra-high-strength steel alloys and aluminum, and fully mass-optimized components and subsystems. VW expects that trimming Golf's mass is worth a 23% reduction in fuel consumption.

MQB will be extended to more than 40 small and mid-sized models, or about 3.5 million vehicles, according to the company. The shared architecture is expected to lower production costs by 20%, manufacturing time by 30%, and fixed costs by 20%. The savings will help finance upgrades of in-car entertainment systems and the development of new generations of VW vehicles, VW engineers told AEI at an MQB backgrounder in Wolfsburg last spring.

About 82 lb (37 kg) of the Golf's weight loss came from the body structure. To balance the cost of added high-strength steels (and to mitigate some of their formability issues), VW engineers developed a new metal-forming process, called warm forming, for the car's steel unibody.

The warm-forming process heats the steel to 1740°F (967°C) just prior to stamping. The stamping die must then be cooled to ambient temperature before stamping the next panel. While the process allows engineers to tailor the part (increasing wall thickness and strength where needed while trimming excess mass), warm-forming also limits part-to-part production speed to one stamped part per minute—restricting its volume aspirations for the near-term.

The pathway to CAFE will be full of similar technology hurdles.

Lindsay Brooke



The new VW Golf's steel-intensive MQB body structure features low-carbon sheet (shown in gray), hardened sheet (blue), ultra-high-strength (red), hot-formed steel (purple, note A-pillar roof rails), and high-strength alloys (green).

2013 vehicle templates for 2017

The cars and light trucks in 2020-2025 will be a lot like today's vehicles. The majority will burn gasoline or a liquid biofuel blend (including the growing number of hybrids) and carry the same number of passengers. But the engines will be smaller, the bodies lighter, and the sticker prices higher—perhaps much higher. And since B-pillars made from 1500-MPa high-strength steel, front structures fabricated in extruded aluminum, and cross-car beams rendered in magnesium aren't likely to ignite showroom traffic on their own, the industry will have to find a way to either absorb the cost of CAFE's enabling technologies, or find ways to make them profitably.

"We have to start cutting the energy demand of the vehicle and optimize the vehicle at the lowest cost," stated Bob Lee, **Chrysler's** Vice President of Engine and Electrified Propulsion Engineering. "Affordability is the biggest focus for us going forward."

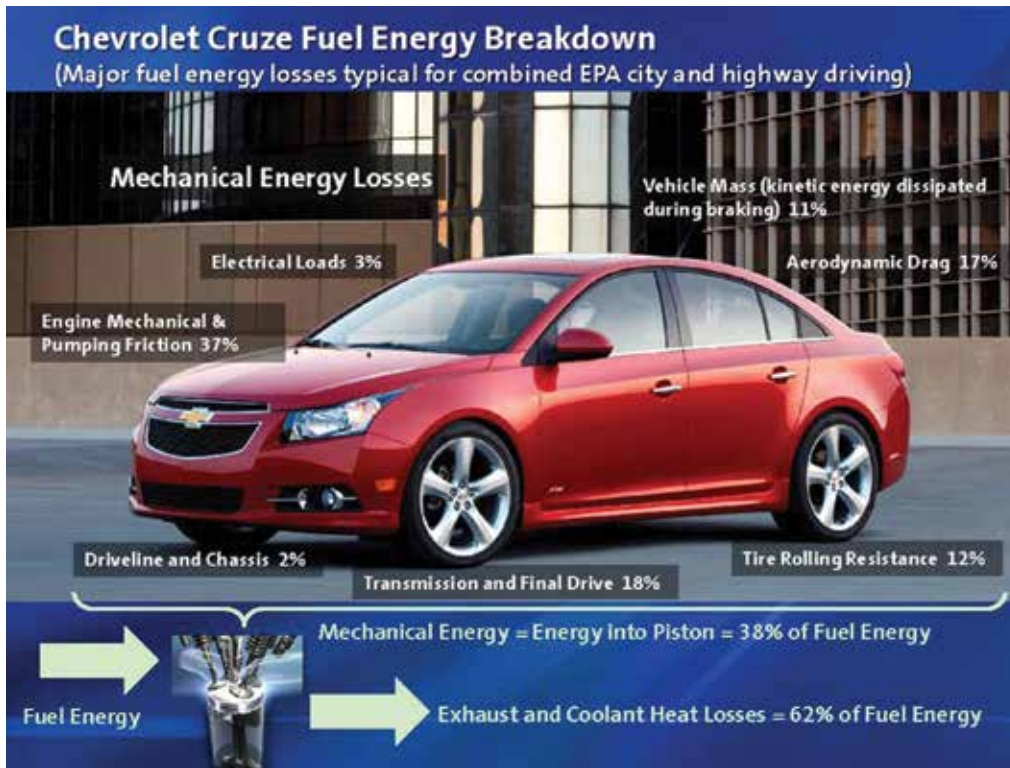
The urgency of meeting the CAFE challenge means "the industry needs production-ready solutions for the next vehicle cycle," Jeff Moyer, Vice President of Business Development and Engineering at **Meridian Lightweight Technologies**, told AEI. Fortunately, automakers and suppliers had anticipated a big bump in U.S. fuel efficiency since 2007, when Congress passed the Energy Independence and Security Act. The EISA mandated that vehicle fuel economy increase annually from the longstanding 27.5 mpg beginning in MY2011, to a fleet average of at least 35 mpg by MY2020.

That's still a considerable leap to the 54.5 mpg embodied in 2025 CAFE, even though that number will equate to a real-world fleet average of about 39 mpg, as noted in Part One of this series. Yet many of the key building blocks for creating CAFE-beating passenger cars—downsized and boosted gasoline engines, cylinder deactivation, waste-heat recovery, new 7-, 8-, 9-, and even 10-speed automatic transmissions, active grille shutters, and electrified powertrains—are already in play, or in the works across the global industry, noted Casey Selecman, automotive analyst with the **Martec Group**.

"The North American industry is certainly facing a 'stress test' because it doesn't have Europe's level of fuel taxes as a market signal," he observed. "A lot of the basic technologies and materials are on the shelf because the European industry has used them for years, but they need to be integrated and made more cost-effective."

Selecman suggests the 2013 European car fleet provides a basic indicator of what the 2025 U.S. fleet will look like. So does the Toyota Prius range, which is already comfortably in the 50-mpg space, he noted.

For a template of how a typical U.S. sedan might be sized and configured to meet the new CAFE, Selecman offers up the European-spec Audi A4. In Europe the A4 offers 10 gas and diesel engine variants, with both Multitronic continuously variable transmissions (CVTs) and 8-speed planetary automatic transmissions. A base-trim A4 with 1.8-L fuel stratified injection (FSI) gasoline engine and CVT (3509-lb/1592-kg curb weight, 185-in/4699-mm overall length) is rated at 134 g/



Engineers are focused on reducing energy demand in all vehicle subsystems, while reducing cost, as they aim to hit the CAFE targets. The levels shown in this GM-supplied graphic are typical across product segments. As one engineer noted, “You can’t change physics.”

km CO₂ emissions (approximately 49 mpg) on the NEDC test cycle. Its claimed 0-60 mph (0-97 km/h) acceleration is around 8.3 s, and the base A4 is capable of 140-mph (225-km/h) top speed.

“The current A4 could be better optimized for mass, and it doesn’t yet offer a de-rated engine—one that’s further downsized, not as fast, and even more efficient,” he said. “Such ‘eco’ base powertrains with super-low CO₂ numbers already proliferate in Europe, and will be offered increasingly in the U.S. as MY2017 approaches.” An example is Ford’s new D-segment European Mondeo that’s offered with the 1.0-L Ecoboost triple.

The A4 and Mondeo examples support the widely held view that the U.S. market’s passenger-car “sweet spot” will be the C and D segments going forward. Despite more new sub-compact A- and B-segment entries, Americans will continue to favor larger cars.

Powertrain challenges and trade-offs

The issue that will keep B-cars from being a dominant segment in the U.S. through 2017-25 is the fact that “there’s no penalty for vehicle size here,” said Jim Hall, Managing Director of the auto-consulting firm 2953 Analytics. “And the majority of cars in the U.S. have automatics; one thing that hurts A- and B-cars is it’s tough to package a transmission with more than five speeds because of the lack of physical space to fit the wider gearbox.”

This challenge of packing up to nine gears in a B-car (even with the new “nested” gearset designs such as the one ZF uses in its new 9-speed) is one reason the Ford Fiesta and

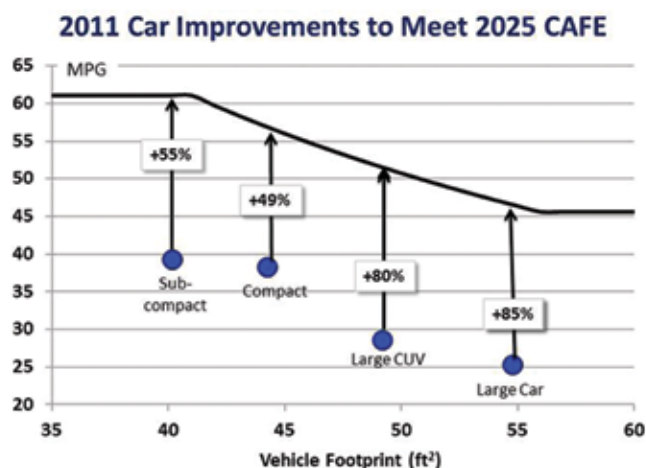
Chevrolet Sonic don’t approach the 40-mpg fuel efficiency of the compact Ford Focus and Chevy Cruze. And it’s why Focus and Cruze can’t top the economy of the mid-sized D-segment Fusion and Malibu, which also offer engineers better aerodynamics.

Hall noted that the higher retail pricing of mid-sized C- and D-segment cars allows automakers to recover more of their technology development costs. Jim Federico, General Motors’ Global Chief Engineer for small cars, agrees. He said the need to put more refinement into small cars, to meet American customers’ expectations for low NVH, is often at odds with increasing their fuel efficiency.

“We added near triple-digits of mass to the [C-segment] Buick Verano in various places to help create a quiet interior, compared with our NVH strategy for the [B-segment] Chevy Sonic, for example,” he said. “The extra weight doesn’t affect Verano’s highway mpg, but it does affect us on city fuel economy.”

Engineers say the areas of greatest opportunity to achieve 2017-25 CAFE are electrification and lightweighting, in conjunction with the further evolution of the combustion-engine-based powertrain (see “2012-2050 Powertrain Tech” graphic). Battery cost remains the big issue for the future of hybrids and electric vehicles, if they are ever to move beyond their current global niche.

“Whether plug-in vehicles ever become profitable will depend on battery costs,” CAR’s Dr. Baron said. “The decline of lithium-ion battery costs has been forecast many times—a few years ago the U.S. Department of Energy and Argonne National Laboratory were forecasting a drop from over



In the new CAFE footprint-based vehicle efficiency metrics, compact cars have to undergo the least amount of improvement to meet the 2017-25 regulation. The smaller A- and B-segment cars are inherently challenged by their brick-like aerodynamics and tight confines that currently impede some technologies, such as the new 8- and 9-speed transmissions.

\$1000/kW·h to \$150-\$200. They just took a few points and extrapolated them many years out. Well, extrapolating beyond your boundaries scares me as an engineer.”

Battery-industry executives tell AEI that Li-ion costs are typically \$500-\$700/kW·h.

FEV's Rogers believes some level of vehicle electrification is essential for meeting CAFE, noting that the incumbent European car fleet (about 55% diesel, 80% manual transmissions, and primarily C-segment and smaller cars) still struggles to meet the EU's current 130-g/km (43.5-mpg) fleet target—with fuel prices sustained above \$7/gal. Europe's next regulatory step moves down to 95 g/km CO₂ emissions.

Materials, manufacturing choices

Lightweight materials are center stage in the 2025 CAFE discussion, as engineers cite the rough rule of thumb that fuel consumption can be reduced approximately 2% per 100 lb (45 kg) of weight reduction. (Oak Ridge National Laboratory estimates a 7% increase in vehicle fuel economy for every 10% drop in mass.)

Targets of opportunity for weight loss exist across the vehicle. According to Scott Miller, GM's Global Director of Mass, Energy, and Aerodynamics, a typical subsystem mass distribution is led by the body (37%), followed by the chassis (30%), powertrain (14%), interior (12%), electrical (4%), and HVAC and powertrain cooling (3%). For design engineers, every component is a target for trimming fat—from fasteners to seat assemblies.

“In the quest for lower-mass vehicles and more fuel efficiency, the NHTSA won't compromise on vehicle safety—in

fact, crashworthiness will be expected to improve going forward,” CAR's Baron told AEI. These parallel bogies have helped drive unprecedented collaboration among OEMs, materials suppliers, and U.S. federal research labs, as well as strategic M&A activity.

Some promising development partnerships have recently emerged, emulating the steel industry's pioneering automotive efforts. They include the **Coalition of Automotive Lightweighting Materials (CALM)**, which aims to optimize the combined benefits of aluminum and plastics. GM invested in **NanoSteel Co.**, a Rhode Island-based firm that has developed a new steel alloy technology with unique strength-to-mass properties. There are also a growing number of ventures around advanced composites, primarily carbon fiber—Audi with **Voith**; BMW, Toyota, and Volkswagen with **SGL Carbon Fibers**; Daimler and Toyota with **Toray**; Ford with **Dow**; and GM with **Teijin**, to name the major ones.

Long used in racecars and aircraft, carbon fiber's low mass (typically 50% lighter than steel for a given geometry), and mass/strength/stiffness qualities have made it a Holy Grail for CAFE-thinking designers. However, the material's costs (\$12-\$30/lb), volatile commodity pricing, lengthy part-to-part processing times, and lack of capacity to support global automotive volumes, have kept it a niche material while also helping to accelerate R&D across the industry.

In a Chrysler analysis of carbon-fiber body components versus steel and aluminum, a carbon-fiber minivan hood “would cost us about as much as a complete body-in-white in steel (about \$1000), compared with about \$10 for the production steel hood, and about \$30 for an aluminum hood,” noted Saad Abouzhar, Chrysler's Senior Manager of Materials Engineering.

New processing technology that eschews the traditional autoclave has the potential to reduce carbon-fiber cycle times by 75%, according to Gary Lownsdale, Chief Technology Officer at **Plasan Carbon Composites**. (See “Higher-volume vehicle gets carbon-fiber body panels produced in less time” at <http://www.sae.org/mags/aei/11315>.) GM is expected to announce a carbon-fiber body on the base version of the 2014 C7 Corvette, with panels supplied by Plasan.

“That would be a fairly major step for advanced composites, but still minor in terms of global production volume,” observed CAR's Baron. “Significant hurdles remain. As an engineer, it's a phenomenal thing for me to watch complete 8-ft-long steel bodysides, with dimensional variation of less than 1 mm, coming off a transfer press every 30 seconds. The industry didn't learn to do this overnight.”

With the clock ticking louder toward 2017, the traditionally risk-averse auto industry will commit to the new materials and technologies needed to meet 2025 CAFE and other aggressive CO₂-reduction challenges.

“They're conservative for a reason,” Baron said. “If automakers find a way to get weight out of their vehicles and consume less fuel, they're going to jump on it—but only if the cost is right.” **AEI**

Unique to the North American market, the highly profitable full-size pickup truck will undergo radical technical and design changes to meet the new federal fuel-efficiency regs for MY2017-2025. Engineers pledge not to compromise the truck's utility in the process.



Reinventing the **American pickup truck**

The conclusion of *AEI's* three-part series looks at how planners and engineers are already rethinking the classic full-size U.S. pickup so it can survive the CAFE crunch.

by Lindsay Brooke

Can the full-size pickup truck survive the MY2017-25 U.S. CAFE regulations? Or put another way, what technological changes will America's most iconic and profitable vehicle have to undergo—and at what cost—for the trucks to deliver above 30 mpg while maintaining their utility and affordability?

On the issue of cost, **NHTSA** (U.S. National Highway Traffic Safety Administration) in its final fuel-efficiency ruling published last August estimates that the price of a new pickup truck will rise \$2059 on average by 2025, compared with \$1836 for a passenger car, to meet the stringent new rules. (See Part 1 of this series, "Mapping the road to 54.5 mpg," in *AEI's* Oct. 23 digital edition—<http://www.nxtbook.com/nxtbooks/sae/12AEID1023>. Part 2 was published in *AEI's* Nov. 6 print edition, which can be viewed at <http://www.nxtbook.com/nxtbooks/sae/12AEID1106>.)

And the payoff to



Long-neglected aerodynamics are now getting serious design focus in pickup truck development. Extensive wind-tunnel work helped engineers hone the 2013 Ram 1500's claimed best-in-class 0.363 Cd, compared with 0.386 for the 2012 truck. Every count of aero is prized in the quest for higher fuel economy.

consumers? The government estimates that vehicle owners will save, on average, \$5700 to \$7400 (7% and 3% discount rates, respectively) in fuel, for a net lifetime savings of \$3400 to \$5000. This assumes retail gasoline prices of \$3.87 per gal in 2025 with small increases most years throughout the vehicle's lifetime.

Environmental groups, as might be expected, are even more bullish on the fuel-savings payback—the **Union of Concerned Scientists** is betting that more than \$8000 will be saved over the lifetime of a new 2025 vehicle after paying the price premium for the more fuel-efficient technology.

The government's cost estimates are widely debated among product planners and engineers, some of whom believe the actual price increases will be nearly double to cover the cost of more expensive lightweight materials and more sophisticated systems.

Trucks get a slight break in the annual fuel-economy hike that is ramping up the overall fleet average toward 54.5 mpg; they're expected to increase 3.5% annually,

Off-cycle Credit Defined Technologies for Trucks in U.S. CAFE			AEI
Technology	Proposed rule (g/mi)	Final rule (g/mi)	
Active aerodynamic improvements	1.0 (for 3% aero gain)	1.0 (for 3% aero improvement)	
Engine idle stop-start	4.5	4.4 (w/ electric heater circulation) 2.9 (w/o electric heater circulation)	
Electric heater circulation pump	1.5	Included in engine stop-start credit	
Waste heat recovery	0.7	0.7	
Active transmission warm-up	1.8	3.2	
Active engine warm-up	1.8	3.2	
High-efficiency exterior lighting	1.1	1	
Solar thermal control	up to 4.3	up to 4.3	
Solar panels ¹	3	3.3 for battery charging only 2.5 for battery charging and active cabin ventilation	
Total theoretical credits for HEV, PHEV, EV	16.7	17.8	

¹Solar panel credit limited to HEV, PHEV, and EV. Values based on 75-W panel. Credits for dual-purpose panels can be combined with active cabin ventilation. Credit cap: 10 g/mi per year on a combined car/truck fleet-wide average basis

compared with 5% for cars. The climb from the 25-mpg-highway ratings on the most fuel-efficient 2012 full-size pickups to the 30.2-mpg average expected of trucks in 2025 is steep indeed. But it's also pushing engineers to develop solutions that may never have been investigated for trucks.

"If we didn't have the pressure from the regulations, we wouldn't be going in this direction technologically. We're getting better vehicles overall from the new standards," said Jim Hall, Managing Director of **2953 Analytics**.

Hall believes the new CAFE will bring "a lot of unintended outcomes—some desirable, some not—that are not part of the plan. The lightweight pickup truck is dangerous, for example, because you're adding a tremendous amount of cost to achieve it."

Truck aero comes of age

Getting full-size pickups solidly into the

30-mpg space without losing their classic attributes "is a heck of a challenge," observed Chris Theodore, former head of **Ford** North America Car Product Development and Senior Vice President of Platform Engineering at **DaimlerChrysler**. He noted that "engineers and product planners only have so many 'knobs' that they can turn," primarily weight reduction, more efficient powertrains (see sidebar, p. 37), and improved aerodynamics.

Vehicle-development teams also will rely on various technology credits included in the rules for trucks (see table above), some of which are showcased in **Chrysler's** 2013 **Ram** 1500. It's the first pickup to enter production that was developed with the new CAFE as a primary bogey, and the rest of the industry is expected to follow suit.

The Ram features an engine idle stop-start system and eight-speed automatic. Aerodynamics is improved using an air



Weight-saving aluminum ladder frames have been optional on over-the-road Class 8 trucks since the 1940s, but pickup frames (2013 Ram 1500 shown) are expected to remain a mix of steel alloys for strength, durability, and cost.

suspension system lifted from the **Jeep** Grand Cherokee that lowers the truck's ride height at highway speeds to reduce drag. The Ram's sidestep rails also were lengthened using wind-tunnel data for the same reason.

Active grille shutters improve airflow when cooling is not required, and accelerate engine warm-up. They're part of a cleverly designed package that includes an active transmission warm-up system with an oil-coolant heat exchanger.

The sophisticated controls required for these technologies are putting greater demands on systems engineering, software development, and calibration engineers, said Dr. Mircea Gradu, Chrysler Group's Head of Virtual Analysis, Transmission, and Driveline Engineering.

New full-size pickups from **General Motors** (the 2014 **Chevrolet** Silverado and **GMC** Sierra) and Ford (2015 F-150) will follow the Ram's lead in adopting

similar fuel-saving features. Their engineers' efforts are supported by an emerging ethos among truck buyers: Fuel economy is firmly in their top-10 purchase decisions, according to a 2012 study by **J.D. Power** that is echoed by other independent industry analysts.

The shift has surprised OEM product planners. Ford planners boast that 2012 sales of EcoBoost V6-powered F-150s are approaching 50% of the truck's mix. For MY2013 the 3.5-L turbocharged, direct-injected V6 will cost F-150 buyers an extra \$2095, up about \$350 from when the package launched two years ago.

The potential commercial use of pickup trucks skews their design and construction toward extreme duty cycles they may never actually face. And truck customers have been trained through decades of "bigger, more rugged, and more powerful" marketing to expect more capability in their vehicles than they may actually need.



Ford Chairman Alan Mullaly announced that the company is looking to slash up to 700 lb (318 kg) of mass from its F-150 by switching to an aluminum-intensive body and some suspension components. Ducker Worldwide materials analysts have identified these areas as candidates for the lightweight metal.

Charge of the light materials

These issues have traditionally limited engineers' options for dramatically trimming their products' curb weight. Ford engineers were tasked earlier this year by company CEO Alan Mullaly to reduce the next generation F-150's curb weight by up to 700 lb (318 kg) in order to meet the 2020-25 phase of CAFE. Such an achievement would reduce the current 4685-lb (2125-kg) base 2WD model to 3985 lb (1808 kg)—almost svelte by comparison.

Detroit-area tooling suppliers with knowledge of Ford's plans confirmed to AEI that the automaker is planning an aluminum-intensive body solution, as Land Rover has done to cut mass of its 2013 Range Rover. The British SUV's all-aluminum body-in-white weighs 397 lb (180 kg)—39% lighter than its steel predecessor. (See <http://www.nxtbook.com/nxtbooks/sae/12AEID1023>.) But the light metal carries a hefty price penalty vs. steel, as does the rivet-bonding process used to manufacture the SUV's body shell.

Unibody pickup history is heavy with compromises



The unibody 1986-92 Jeep Comanche was based on the mass-efficient Jeep XJ SUV but was far heavier than its ladder-frame competitors.

Moving from the traditional, brawny body-on-frame truck architecture to unibody construction is one option for engineers looking to reduce curb weight while maintaining strength in light-duty pickups. It also offers the promise of building trucks and cars in the same body shops. While it's possible to shed hundreds of pounds of mass by going to a unibody platform (as was proven in passenger cars), the path also can be full of compromises.

If not properly executed, unibody can lead to a heavier and in some cases less capable truck. Vehicle development consultant Chris Theodore, former head of Ford North America Car Product Development and Senior Vice President of Platform Engineering at DaimlerChrysler, once proposed a unibody pickup variant of the Chrysler Town & Country minivan. "The idea was to pick up a significant part of the vehicle structure and take advantage of the strength of the [monocoque] sections, and even the quarter panels that are part of the unibody," he told *AEI*. "But it's often not a direct carryover. And you still can incur a weight penalty."

In the late 1970s and early 1980s, Volkswagen and Chrysler created unibody pickup versions of their Golf and Dodge Omni hatchback cars. Those small "lifestyle" pickups lacked payload, towing capability, and a removable cargo bed favored by most pickup enthusiasts. Following the VW and Dodge Rampage pickups was the 1986-92 Jeep Comanche, considered by Theodore to be the first truly practical unibody pickup. It was based directly on the Jeep Cherokee (XJ), which had pioneered the lightweight unibody SUV.

"The Comanche used the XJ's body structure and exterior panels from the B-pillar forward," he said. AMC's Jeep engineering staff designed a frame-like rear structure to support the Comanche's removable cargo box, which was available in 7- and 6-ft (2133- and 1829-mm) lengths. Called



Honda's Ridgeline unibody pickup is based on the Pilot SUV. Significant reinforcing of its body structure for pickup duty makes Ridgeline more than 120 lb (54 kg) heavier than a comparable full-frame Dodge Dakota.

"uniframe" by Jeep, the rear chassis structure consisted of stamped, spot-welded rails that were greater than 8 in (203 mm) deep in section—1.25 in (31.8 mm) deeper than the rails of Jeep's full-framed J-10 full-size pickup.

Comanche was a unibody truck but Chrysler marketing insisted that the cargo box be bolted on and removable, "because that's what pickup customers wanted," Theodore said. "The rear uniframe had to be reinforced so much to make it a worthy pickup truck, so we lost the weight benefits of unibody." He explained that while a Cherokee SUV weighed 400 lb (181 kg) less than its body-on-frame competitor, the Comanche pickup weighed about 400 lb more than a Chevrolet S-10.

Theodore noted similar trade-offs encountered by Honda's Ridgeline midsize pickup launched for MY2006. The Ridgeline is based on the unibody Honda Pilot SUV, but its stamped-steel underbody structure combines unibody and ladder-frame characteristics. Honda claims this "hybrid" chassis gives Ridgeline 20 times the torsional rigidity of a body-on-frame pickup of similar size, while retaining the BOF's payload capability.

"What happened with the Ridgeline is Honda ended up reinforcing the structure quite a bit to get their payload and towing numbers, to where it incurred a weight penalty," said Theodore. The base all-wheel-drive 2012 Ridgeline's curb weight is 4513 lb (2047 kg), which is 121 lb (54.9 kg) heavier than the body-on-frame Dodge Dakota 4x4 with extended cab.

At least one OEM is investigating a unibody full-size pickup for the 2020-25 time frame, *AEI* has learned. They should study the Honda and Jeep experiences.

Lindsay Brooke



Midsize pickups present a gamble for OEMs in the truck CAFE game. They cost about as much to build as a full-size truck and profit margins traditionally have been lower. Ford's new Global Ranger (shown) is 9/10 the size of the F-150, is 21 in (533 mm) shorter, and rides on an 18-in (457-mm) shorter wheelbase. It was not designed to meet U.S. safety regulations and currently is not in U.S. product plans.



Unlike Ford, General Motors will play the midsize-truck card with the 2014 Chevrolet Colorado (shown). One iteration of the new Wentzville, MO-built pickup is expected to be capable of 30 mpg highway.

Some of the high cost of the material and expensive build process will be offset by the Range Rover's premium retail price. Ford doesn't have the same luxury with its pickup truck. And body-structure experts suggest Ford may have to up-gauge and reinforce an aluminum F-150 body to ensure durability, which could minimize the material's weight-reduction benefits.

"For meeting CAFE in general, it's going to be a battle primarily between

aluminum and the new high-strength and ultra-high-strength steels," predicted Dick Schultz, Managing Director of **Ducker Worldwide's** automotive materials practice. "But on pickup trucks, everybody's going to take a different approach. Some may just use aluminum for the closures and roof panel—which would save a lot of weight." (See F-150 photo p. 34)

Schultz noted that aluminum hoods are at 30% penetration across the industry,

New diesels, 10-speeds gear up to power trucks toward CAFE mandate



U.S. Energy Secretary Steven Chu called CNG a “no brainer” for light truck fuel, but the pressurized gas has trade-offs. GM developed its new dual-fuel-capable Chevrolet Silverado to run on gasoline or CNG. Its cylindrical pressure tanks are located transversely in the front of the cargo bed, compromising the truck’s utility.



GM is dusting off its 4.5-L diesel V8 for potential use in the light-duty Silverado. The innovative engine was originally slated for 2010 production before the company’s financial crisis put it on the shelf.



CAFE planners baked in hefty technology credits for truck electrification. But vehicle planners wince at the cost of adding big-ticket systems such as GM’s two-mode hybrid transmission (shown).

Downsized, boosted four-cylinder gasoline engines. New-generation diesels capable of meeting LEV3 emissions. Ten-speed automatic transmissions. Various levels of hybridization and powertrain thermal management such as engine, gearbox, and drive axle heaters. These and even more radical solutions are in the works for getting full-size pickups into the low-30-mpg range required for post-2017 CAFE.

“The truck fuel-economy challenge is significant, and it’s forcing the auto companies to pull out all the stops in terms of engines and transmissions,” observed Eric Fedewa, **IHS Automotive’s** Director of Global Powertrain and Components Forecast.

Fedewa noted that dieselization in light-duty pickups “is going to be an option from what we’re hearing. Everybody’s dusting off their diesel plans again for the 2017 time frame. If it’s determined that we have to go to 54.5 mpg in the 2020-25 period, you’ll see more dieselization of light trucks.”

The move to six-speed automatics in trucks during the past five years is being superseded by transmissions with eight or more ratios, according to IHS North American transmission industry analyst Dave Petrovski. He noted **Chrysler’s** lead application of the ZF 8HP in the 2013 **Ram**, as well as **Ford’s** ten-speed development program. The Ford ten-speed is aimed at rear-drive vehicles, most likely F-Series and Mustang. That unit is currently among other advanced eight-, nine-, and ten-speed gearboxes being

evaluated by **General Motors** and Ford as part of their pending joint transmission development alliance.

Prototypes from both OEMs are part of a “bake off” to be completed by the Christmas holiday, aimed at confirming that the mutual targets can be met, according to insiders familiar with the discussions.

There are various hybridization incentives for light trucks in general in the new regs, but hybrid systems alone will not get the full-size pickups into mid-30-mpg territory, Fedewa said.

“If trucks were removed from the vehicle mix, the industry would get to 54.5 mpg with much less effort,” he surmised.

Technology investigations for truck powertrain are even extending to fuel cells, which two OEMs are said to be pursuing for the 2020-25 time frame “in case the 2018 review period provides no relief from 54.5 mpg,” a source at one company told *AEI*.

Lindsay Brooke

and about 1 million new units (the 2014 GM full-size pickups) will be added next year. “We’re talking 60% penetration by 2020. You can’t roll steel thin enough to compete with aluminum on hood panels. It’s a natural for this material,” he said.

GM recently announced a new approach to aluminum spot-welding, based on a new conical welding tip (<http://www.sae.org/mags/aei/11408>) that will enable more of the lightweight metal to be used on its high-volume pickup body structures, as well as other products. Schultz expects a “strong and well-done counterattack” from the steel industry to protect its dominant share of the light-truck market from aluminum in the wake of the CAFE pressures. He said truck development teams will have to figure out how to make low cost and light weight compatible attributes for product programs going forward.

One major part of the new pickup trucks that is expected to remain in steel is their separate ladder frame, due to OEMs’ strength and long-term durability requirements. “You might have a crossmember or two in aluminum, but towing and payload dictate steel for pickup frames,” said Schultz, a former engineer at **Alcoa** who helped develop the aluminum frame for Chrysler’s 1997-2002 Prowler roadster.

He doesn’t see future truck frames migrating much to the new steels. He expects frames to continue to be primarily HSLA (high strength, low alloy) and dual-phase material up to DP980.

“They’re going to use dual phase selectively,” predicted Ron Krupitzer, Vice

Engineers working on next-gen pickups are targeting up to 100 lb (45 kg) of potential mass reduction in the cab interior. Seating is a prime focus. Johnson Controls’ ComfortThin seats replace traditional seat foam with pocketed coil springs. The design offers a 5-20% weight reduction from the seat unit and up to 10 lb (4.5 kg) more from the vehicle body due to space saved.



President of Automotive Applications at the **Steel Market Development Institute**.

The 2018 midterm review: Bring good data

Ask a vehicle-development engineer what she or he is looking forward to the most about the 2017-2025 CAFE regulations, and they’re likely to say the midterm review. Scheduled for April 2018, the midterm review process will bring industry and government representatives

together to evaluate the standards.

They'll discuss and debate what's been achieved, what's still out of reach, and the status of enabling technologies in order to determine whether the MY2022-2025 standards are still appropriate or should be modified.

The review will be totally data-driven, according to an industry executive who spoke with NHTSA chief David Strickland last October. "[Strickland] told me, 'Everybody brings their data to the table in the next two to four years related to how they've improved fuel economy, what the costs really are, and where the

state of technology is,'" the exec (who asked not to be identified) told AEI.

The executive then asked NHTSA's chief what he thought the odds will be in 2018 that the industry is on track to meet 54.5 mpg.

Strickland's reply: "I think the odds really are 50/50—we might even raise the requirement above 54.5 if we're ahead of schedule. But we're going to be practical and fine-tune the regulation if that's what is necessary." AEI

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