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DRIVING THE FUTURE?

With an array of propulsion systems driven by rising government regulations, the automotive industry and its consumer base have never been more confused or perplexed.

BY GARY WITZENBURG

WHAT PROPULSION SYSTEMS WILL POWER OUR CARS AND TRUCKS A

decade from now? Will the slow but steady parallel trend toward more powertrain electrification in the form of pure electric or hybrid electric vehicles accelerate in future years? And what about diesel engines, fuel cells, and alternative fuels?

Given all of the options, it may be the industry's most reliable workhorse over the last century — gas-powered internal combustion engines — will be riding off into the sunset, only to reappear periodically as part of a retrospective exhibit at science and history museums. Before the curtain falls, though, consider that the gas engines that are available today in smaller sizes and in far more efficient forms will continue to outpace alternative propulsion systems for years to come.

Over the last decade, global automakers have

replaced fuel-guzzling V6 and V8 powertrains with more fuel-efficient four-cylinder engines, many of them turbocharged for added power on demand. What's more, turbocharged three-cylinder engines are starting to appear in some small cars, while twin-turbo V6s have supplemented the V8s that long rumbled under the hoods of many large and luxury cars.

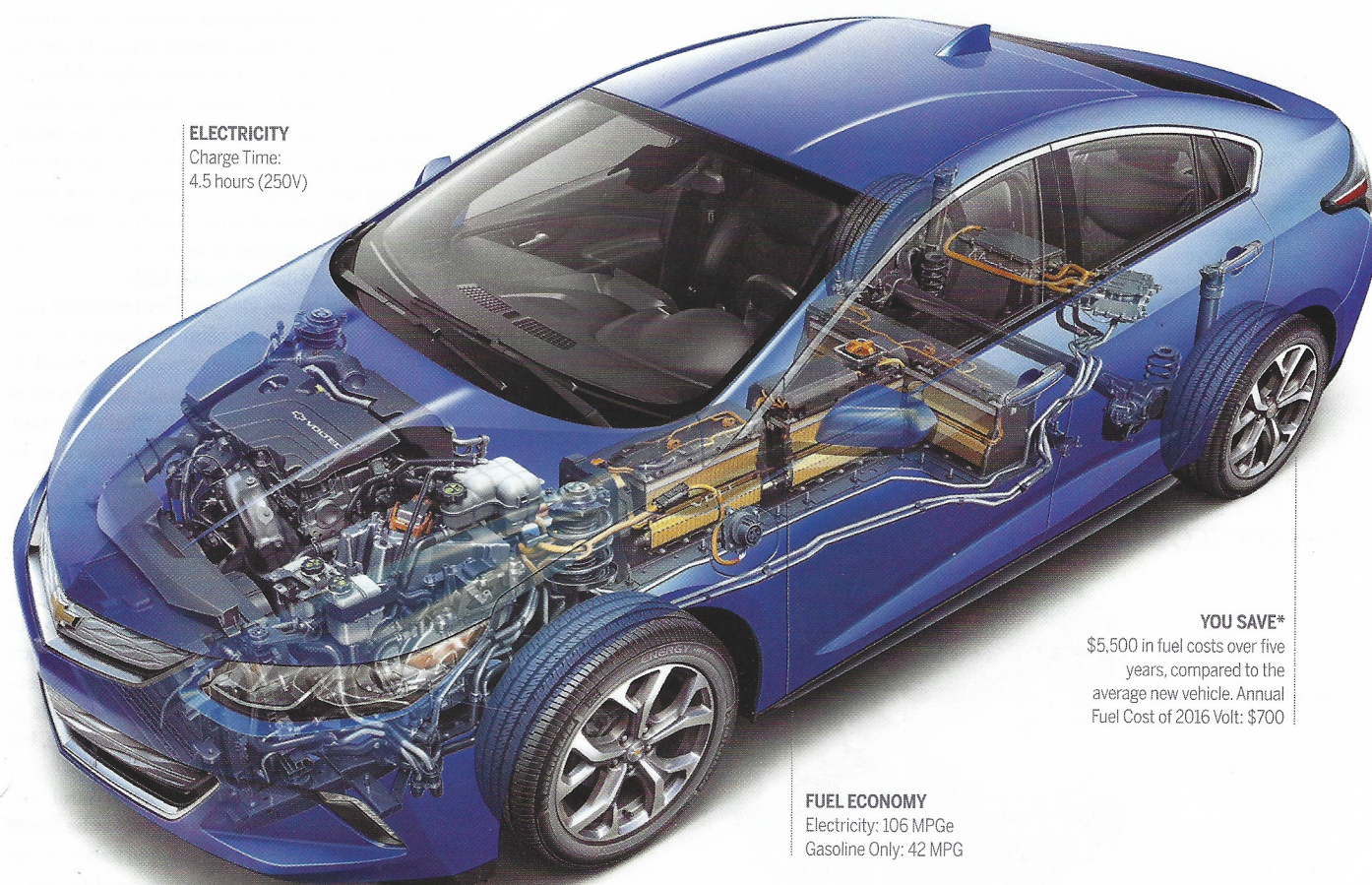
And what of the beefy V8 engine that Henry and Edsel Ford debuted in 1932? The throaty powertrain still draws sales, albeit representing a smaller share of the market, from enthusiasts of muscle cars, performance sports cars, pickup trucks, and large SUVs.

Driving the future of propulsion is the federal Corporate Average Fuel Economy law that mandates the average fuel economy of passenger vehicles sold in the U.S. be at least 54.5 mpg by model year 2025. That doesn't mean that each OEM's "sales fleet" must average that number or

better, only that the collective total of vehicles — whether domestic or foreign made — has to meet or exceed the threshold.

Failure to meet the future CAFE standards will lead to sizeable monetary penalties, although automakers can gain "credits" to offset the fines for such things as the use of "green" fluids and materials.

Supplanting previous CAFE standards that had climbed less aggressively since their beginning in 1975, and had flattened in recent years, this hugely complex and challenging law that was rewritten in the early years of the Obama administration mandates significant improvements in vehicle efficiency year after year between 2012 and 2025, along with a whopping 35 percent reduction in CO₂ emissions from 2011 levels. It has driven automakers to dramatically accelerate their efforts and investments to improve combustion and reduce friction and

**ELECTRICITY**

Charge Time:
4.5 hours (250V)

YOU SAVE*

\$5,500 in fuel costs over five years, compared to the average new vehicle. Annual Fuel Cost of 2016 Volt: \$700

FUEL ECONOMY

Electricity: 106 MPGe
Gasoline Only: 42 MPG

2017 CHEVROLET VOLT

other energy losses from gas engines, to squeeze ever more efficiency from them.

Because fuel efficiency is a full-vehicle equation, transmissions, drivetrains (including increasingly popular all-wheel drive models), vehicle bodies, and architectures are being re-engineered to reduce weight and optimize efficiency, while exterior shapes are constantly being subjected to wind-tunnel testing to reduce aerodynamic drag. Due in large part to the looming mandate, average new-vehicle transaction prices swelled to a record \$34,000 in 2016 from \$29,000 a decade ago, according to *Kelley Blue Book* senior analyst Karl Brauer.

Meanwhile, OEMs (those that can afford to) have collectively invested billions of dollars in designing and developing an array of electrified propulsion systems ranging from “mild” hybrids (powered by gas engines aided by small electric motors and batteries) to full parallel

hybrid-electrics with engines and motors working in tandem (like Toyota’s Prius and others), to plug-in hybrids with larger batteries and extended-range electrics with small gas engines that drive generators to power their motors after their batteries are depleted, to full battery electric vehicles. A few OEMs also have invested heavily in fuel-cell electric vehicles powered by electricity generated from hydrogen fuel cells.

Simply put, the federal government has injected an abundance of complexities into the marketplace that have translated into higher vehicle costs, along with increasing levels of battery size, hardware, software, and system complexities.

In turn, automakers are “compelled” to sell more electrified vehicles each year to meet the 2025 CAFE standards, along with introducing more zero-emissions vehicles, as mandated by California and other states that seek to

force OEMs to sell what people don’t want or can’t afford.

SIZING UP THE OPTIONS

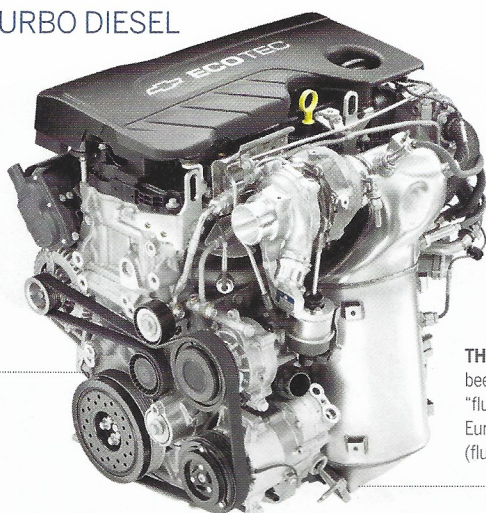
For U.S. consumers who have long favored the efficiencies of gasoline engines, breaking that love affair will be difficult.

Diesel engines, which are more fuel-efficient

54.5 MPG
BY 2025

ECOTEC 1.6L TURBO DIESEL

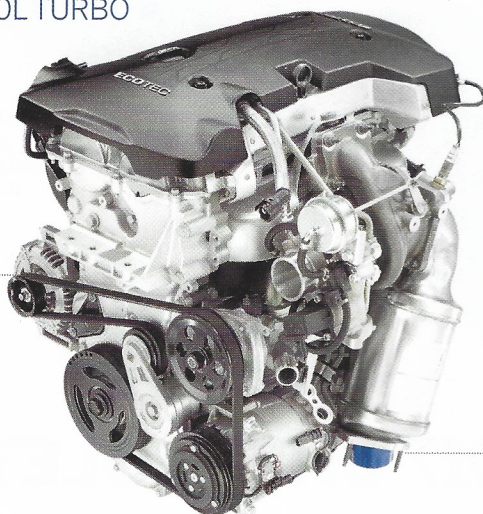
THE NEW ECOTEC 1.6L turbo diesel will be available in upcoming models of the Chevrolet Cruze and Equinox.



THE ENGINE HAS been called the "fluesterdiesel" in Europe for its "whisper" (fluester) quiet sound.

THE ECOTEC 2.0L TURBO

THE ECOTEC 2.0L TURBO engine is one of the highest specific output engines available today.



AT 138 HP PER LITER (for a total of 275 hp) the engine provides the Chevrolet Camaro's performance surpassing V6 and even some V8 engines of yesteryear.

2.7-LITER ECOBOOST® V6



FORD'S 2.7-LITER ECOBOOST® V6 engine in the Fusion Sport produces 325 HP and an impressive 380 pound-feet of torque.

than their gasoline counterparts, offer enticing advantages, but they've never been big sellers in the U.S. marketplace (except in working trucks) due to higher sticker prices, lingering poor perceptions (made worse when Volkswagen was recently caught cheating on diesel emissions), and sizeable prices at the pump over gasoline. As a result, diesel engines will remain minor players in passenger cars, especially as the cost of super-cleaning diesel exhaust systems needed to meet ultra-tough U.S. emissions standards remain high.

Dan Nicholson, vice president of global propulsion systems at General Motors Co. in Detroit, remains a strong advocate of diesel in light trucks. "North America can afford a bit of growth in diesel in light-duty trucks," he says, "so it would be a pity if the recent notoriety (by VW) causes diesels to go backward here."

Bob Lee, vice president of global powertrain at FCA US in Auburn Hills, says diesel-powered engines will continue to fill niches in the marketplace. "For certain products, that's what you need to do the work," he says. "If you want to tow a large boat or work with construction equipment, diesel is the most efficient. Gas engines will continue to get closer to diesels in terms of burn rates and cylinder pressures, but there's more energy in diesel fuel."

On the alternate fuel front, natural gas, propane, and alcohol will continue to be minor players in the marketplace due to lower energy content (less driving range) vs. gasoline, and a lack of availability at service stations and other consumer-centric locations. "We've sought to provide technologies to support what is available in the market and what our customers demand," says Tom McCarthy, chief engineer of powertrain research and advanced engineering at Ford Motor Co. in Dearborn, "but it's a chicken-and-egg dilemma. Do you develop technology in case the infrastructure appears, or wait for infrastructure before developing the technology?"

What's more, fuel cells are expensive and hydrogen-refilling opportunities are rare outside of Southern California. While propulsion-capable EV batteries will come down in cost over time, they will remain relatively expensive. They also contain a tiny fraction of the energy of a tank of liquid fuel, and they are very time-consuming to refill.

Most everyone agrees vehicle propulsion systems are highly important to customer satisfaction, brand image, and reputation — and, as a result, sales and profits. Consumers rightfully expect their new cars and trucks to deliver satisfying balances of performance, capability,

and efficiency. If their vehicles disappoint in one way or another, that setback can drive buyers away from a brand or a company.

"(Powertrains are) the heart and soul of the vehicle," says Mark Reuss, GM's executive vice president of global product development, purchasing, and supply chain. "How integrated it is with the vehicle and how well it meets expectations is the price of entry."

WHAT'S NEXT?

When the Obama administration, working with Congress, set the 54.5-mpg mandate, it allowed — at the automotive industry's insistence — a mid-term evaluation of the CAFE law's technical feasibility, which began with a preliminary report in mid-2016. From there, the law will be finalized no later than April 2018. Left unclear is the role the Trump administration and a Republican-controlled House and Senate will have on the law, and whether the new threshold is achievable with vehicles that people will want and can afford to buy.

"We have a good plan to achieve (the mandate)," Reuss says. "There's enough flexibility in how you can do it that I think it can be achievable, and we've been focused on being agile enough to meet whatever the lawmakers decide. I'm pretty proud of that, because it's not an easy deal."

At Ford, McCarthy says no one is predicting whether the rules might change. Rather, the automaker is working hard to make sure it can meet whatever standards are in place. "There's no silver bullet that will address all future requirements," he says. "We're trying to address fuel consumption and criteria emissions while preserving drivability and performance. Obviously, putting in more technology will raise costs, and ultimately the market will tell us how it's received. We look at it as an ensemble of technologies that will create the best value for customers. It's hard to speculate what will happen, since the whole industry is required to meet these mandates."

Lee says there's no technical reason why FCA can't make the numbers. "It's a physics problem that we know how to solve," he says. "But businesswise, it will be a stretch. People want fuel economy, and if you ask whether they want more, they say, 'Sure, why not?' But if you ask, 'Will you pay \$100 for it?,' they ask, 'How much fuel economy?' If you say, 'Half a mile per gallon,' they say, 'Maybe' — but maybe not, if it will cost \$500. Unless fuel prices head up, we're going to have a hard time shoving out the more than 15 percent penetration of electrified products that we'll need to make those (CAFE) numbers. It

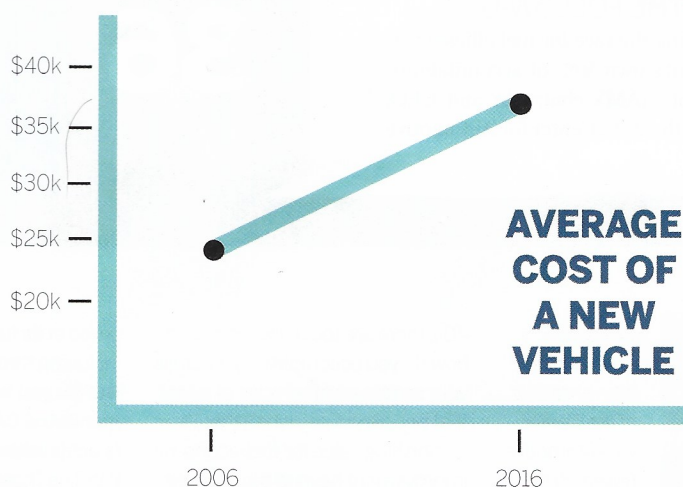
BY THE NUMBERS



The number of models that get 30-plus MPG on the highway

490+

35%
reduction
in CO₂
emissions
from 2011
levels



**AVERAGE
COST OF
A NEW
VEHICLE**

MOST FUEL-EFFICIENT VEHICLES ON THE ROAD IN 2017*



GASOLINE

Smart fortwo coupe
Toyota Yaris iA
Ford Fiesta SFE FWD
All 35 combined MPG



HYBRID

Hyundai Ioniq Blue
58 combined MPG
Toyota Prius Eco
56 combined MPG
Pacifica Plug-in
52 combined MPG



ELECTRIC

Hyundai Ioniq Electric
136 combined MPG
BMW i3 BEV
124 combined MPG
Fiat 500e
112 combined MPG

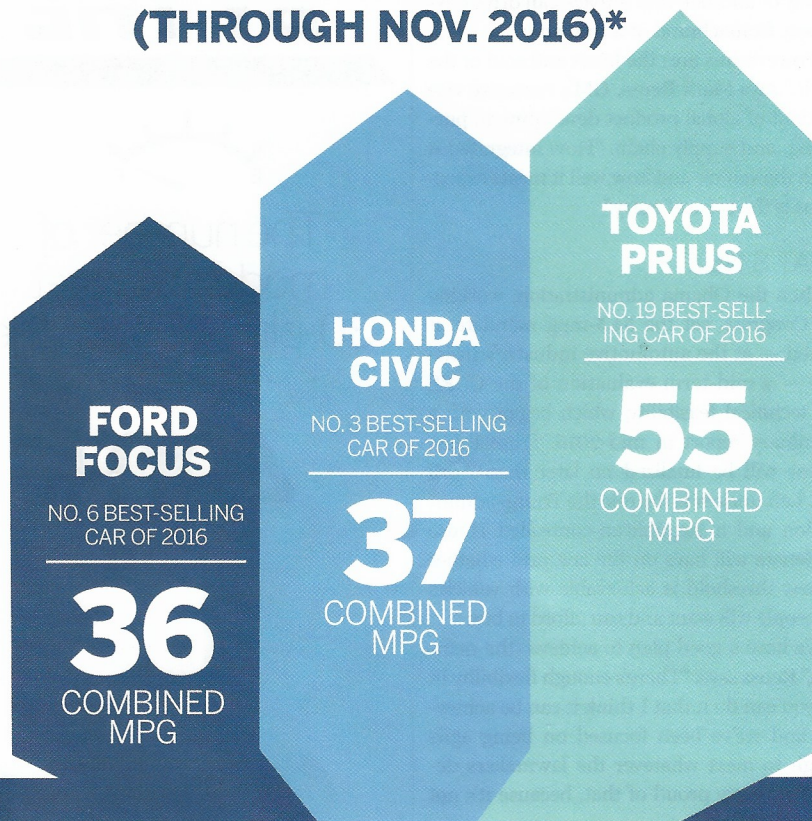
doesn't look like it's going to be there."

Wade Newton, senior director of communications for the Alliance of Automobile Manufacturers, which represents the three U.S. OEMs, Toyota, VW, and other major players, says the industry is looking at every possible option when it comes to meeting the "aggressive" CAFE standards. "Affordability is critical," he says. "CAFE is a sales-weighted average. It doesn't measure what we put in showrooms; it measures what people put in their driveways. Having products that the consumer wants to buy is critical to any automaker meeting CAFE. We've already invested billions of dollars in new technologies, so we're eager to see consumers embrace them. The number of models that get 30-plus mpg on the highway is now more than 490, a 600-percent increase from 2006."

WHERE'S THE FOLLOW-UP?

Compounding the race for fuel efficiency is the government's own lack of accountability. Mitch Bainwol, AAM's chairman and CEO, pointed out at the 2016 Center for Automotive

TOP 3 FUEL-EFFICIENT MODELS (THROUGH NOV. 2016)*



Q&A



Dr. David E. Cole is chairman emeritus of the Center for Automotive Research in Ann Arbor, and

former director of the Office for the Study of Automotive Transportation at the University of Michigan Transportation Research Institute. Before that, he was a professor of engineering at U-M. He has worked extensively on internal combustion engines, vehicle design, and overall automotive industry trends. Here, he provides his view on future automotive propulsion systems.

DB: What do you see as the trend through the next decade?

DC: It's very uncertain. Considering the 2017 mid-term review, what CAFE (Corporate Average Fuel Economy) will we really be shooting for in 2025? It's a very complex regulation, and we're probably talking 40-something mpg real-world, not 54.5. But even in the

40s, there are tough issues of cost; how do you accomplish that across your spectrum of vehicles at a cost that people will pay when there's diminishing value for fuel-economy improvement beyond the 35-mpg range? People aren't going to pay a lot for small improvements.

DB: That mid-term review requires good faith efforts from automakers.

DC: Yes, and we have two groups: a lot of companies that are pushing hard with electrification and hybrids, and some that can't afford to play that game. At least in the reasonably near term, most manufacturers are focused on plug-in hybrids that get reasonable range on pure EV but can extend it with liquid fuel. The rate of improvement is difficult to assess between manufacturers and different types of technologies, and not all advanced technologies are focused on EVs and hybrids. The conventional ICE engine still has much to give if we can get at

some of its fundamental losses, including throttling losses.

DB: Do you believe that the mandated CAFE of 54.5 mpg is achievable?

DC: The "haves" — the automakers who still can afford it — are on a full-court press, using every conceivable technology to try to achieve it. Whether that requirement is backed off a bit will be defined by economics, (and) the value the customer sees vs. the added cost to a vehicle to achieve it. The government has no concept of economics in this industry, or thermodynamics, or the laws of physics, and the decreasing dollar value to the consumer as fuel economy improves is not well-understood.

DB: Will more sophisticated powertrains adversely impact Michigan jobs?

DC: Outside of normal progress in assembly labor productivity, I don't see a huge change. We've become so efficient in assembling big stuff

— cars, trucks, appliances — that even if we assembled them in China at near-zero labor cost, the transportation cost is greater than the labor cost savings. You can put a box of computers or phones on a plane and ship it anywhere in the world, but you can't do that with a car. One important Michigan asset is about 450 supplier engineering operations. They want to be close to the core of the industry, and we have six OEMs with major engineering centers here — the domestic three, plus Nissan, Hyundai, and Toyota. So we pretty much have the intellectual homeroom for the industry. Michigan can be very competitive in building things and, increasingly, can have a competitive advantage in engineering if we have appropriately educated people. We're at a point where if you don't have a community college or associate degree, you might have a hard time finding a job in any manufacturing operation. ■

—Gary Witzenburg

Research Management Briefing Seminars that the National Highway and Traffic Safety Administration, the EPA, and the California Air Resources Board failed to harmonize their fuel economy and CO2 standards as they promised when the 2012-2025 CAFE law was implemented.

"When the companies embraced CAFE, we did so because we felt it served a public purpose," he says. "But (the rules) aren't harmonized. That produces regulatory friction, which drives up the cost of the product. ... There has to be a balance. We've got to get this right. It's about employment, it's about saving lives on the road. There are many, many factors at stake, and we've got to make sure to consider all the factors and reach a conclusion that works for everyone."

AAM and CAR contend that meeting 2025 CAFE standards is impractical.

"Even though there's new technology on the shelf, the industry can only absorb so much introduction at any one launch," says Jay Baron, CAR's president and CEO. "We only have so

many engineers, and every new technology has a certain development time and level of risk associated with it. The (automakers) already (have) a lot of R&D sunk into achieving 54.5 mpg. And (the CEOs) have said they promise to make this work. They're not going back on that promise. However, I think the cost is going to be greater than everyone says it will be, even with mass production. ... If all of a sudden the car I want to buy is \$4,000 to \$5,000 more, that's going to change what I do. And it's going to change the industry."

In a recent study, CAR defined nine fuel price and technology cost estimate scenarios, eight of which suggest the potential for significant job losses, with the most extreme scenario predicting a loss of as many as 1.1 million jobs in the U.S. "Costs for mass reduction greatly exceed those estimated to date by regulators, and incremental mass reductions come at (an) exponentially higher cost," the study projects. "CAR's research demonstrates the industry has made significant progress in implementing fuel economy technologies. However, this

progress comes at (a) greater cost and with lower efficiencies than has been recognized by regulators, and given current fuel prices, consumers are largely unwilling to pay for fuel economy technologies."

The ultimate fear of many, both inside and outside the industry, is that CAFE compliance will drive new-vehicle prices to a place where consumers can't afford them.

Or, put another way: If someone is driving a perfectly reliable and satisfying vehicle that delivers 35-plus-mpg efficiency, will he or she purchase a much more expensive model that does slightly better? Or will people just invest in parts and service as needed to keep their existing cars and trucks going?

"If the value of fuel savings to the new vehicle buyer falls short of the cost of mandated fuel economy technologies," says Sean McAlinden, CAR's chief economist and lead author of the study, "then U.S. automotive sales (and) production, (along with) manufacturing and retail employment, will fall — with serious consequences for the U.S. economy." **db**



IHS Automotive senior analyst Stephanie Brinley, who has 23 years of automotive experience, 13

of them in analysis, addresses future propulsion systems.

DB: How important is powertrain to customer satisfaction, image, and sales?

SB: It comes down to meeting customers' needs, which leads to the dichotomy between regulations and consumer demand. Regulations compel automakers to meet both consumer and government expectations in different countries around the world, which are not aligned.

DB: U.S.-market automakers must achieve a CAFE (Corporate Average Fuel Economy) of 54.5 mpg by 2025, but is that number likely to change?

SB: It's not a matter of each automaker having to get to 54.5 mpg.

EPA controls emissions, NHTSA controls fuel economy — two different regulatory bodies giving automakers two different targets. While the EPA has set its emissions regulations, NHTSA hasn't finalized fuel economy targets for 2025. The 54.5 is what EPA's math said would happen if everybody met their emission targets, which are based on sales assumptions, and that was communicated to the public as "everyone has to meet 54.5 in 2025."

DB: Is such a number physically achievable with vehicles that remain affordable?

SB: We think they can make the number, but there will have to be more electrification than the EPA currently assumes.

DB: As CAFE drives up costs, and therefore vehicle prices, will new vehicles become so expensive that people will stop buying them?

SB: Yes, the sales proposition gets dicey. The average car now is about \$34,000, where a decade ago it

was maybe \$21,000, yet we still have a very healthy 17-million-unit market. But when interest rates go up, we'll see a change in behavior, whether it's people buying smaller vehicles or fewer options.

DB: What do you see as the powertrain mix by segment?

SB: According to IHS Automotive's global powertrain production forecast, in the D (midsize) segment, four cylinders were dominant even in 2009, and that trend is increasing. In 2020, we expect that to be about 15.4 million four-cylinder and 5 million six-cylinder. We also have seen the E (full-size) class shifting from six cylinders to four cylinders globally.

DB: Given the cost of electrification, will we see more hybrids in more expensive segments?

SB: That's a logical assumption, but hybridization started in the C (compact) segment, with the Prius. Buyers in more expensive segments are less sensitive to fuel-price costs; they need another

motivation for selecting hybrid or pure electric. For pure electrics, we expect global production of about 75,000 units in the B (subcompact) segment in 2016, basically zero of the 16.8 million that will be built.

In 2026, we see that as about 1.2 percent pure EV and 5.7 percent hybrids, and the C segment about the same. We don't see huge increases in pure electric all the way through the forecast.

DB: What about ZEV (zero-emission vehicle) mandates?

SB: That's more difficult. The mandate from California and the states that have signed on with it is a complicated, multilayered math problem based on how many ZEVs you sell, offset by credits earned or purchased. It's designed to push people to buy electrics and fuel cells, but the take rate on those, so far, is very low. California doesn't like to back down and hasn't indicated that it will, so we'll have to wait and see what happens. ■

—Gary Witzenburg