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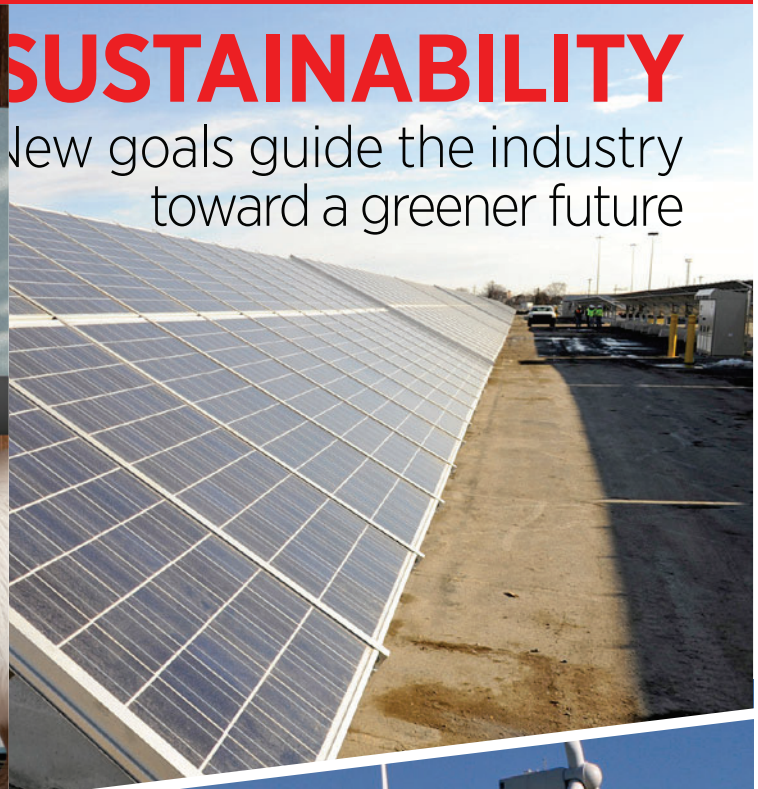
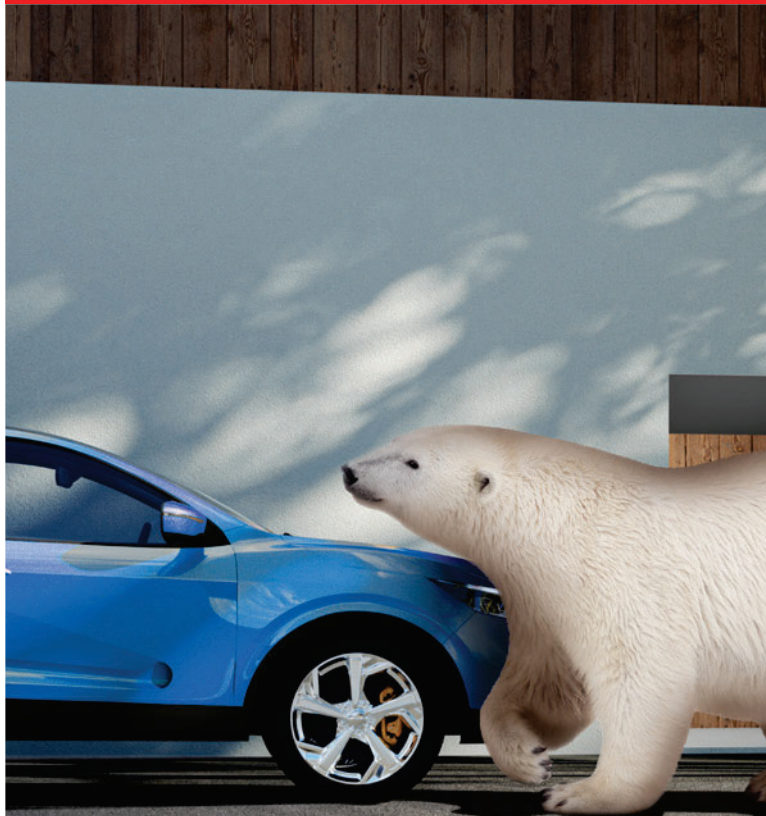
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**EU7 Brake Dust
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Reaching a sustainable future requires multi-modal solutions — EVs, hybrids, 'green' fuels, hydrogen and a range of grid/power-generation technologies. (Images: GM, Toyota, Leaflet/WikiCommons-wind farm)



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EDITORIAL

Engineering the 'sustainability thing'

Sustainable and sustainability are words that are fast becoming industry vernacular. They're woven into executive speeches, press releases, marketing, and engineers' messaging. That's because a gospel of sustainable practices is spreading fast among the leading automotive OEMs and their supply base. And as such a paradigm-setting trend deserves, we're focusing on it in this month's *Automotive Engineering*.

"Meeting the needs of the present without compromising the ability of future generations to meet *their* needs," is one definition of the term. In my view, sustainability is analogous to efficiency – of the product, of manufacturing and of human resources — the equitable treatment of employees and the community. At its heart is a circular economy that's not just about EVs and climate change.

Sustainability as an industry driver has been growing since the Clean Air Act and the lean-design focus of the 1970s-1980s. Then came the global focus on climate change. The UN's pact to limit Earth's warming to 1.5°C by 2050 requires a 60% reduction in carbon emissions by 2035 compared to 2019 levels. The call to action kindled by government policy now is a business process.

Efforts thus far are reflected in the many 2022 Sustainability Reports published by OEMs and Tier 1s that have flooded my inbox. One report, from Adient clearly charts how the global seating supplier has integrated sustainable processes across its enterprise. As a result, Adient has reduced emissions and waste, saved cost, and created an operational culture. VP of engineering Mike Maddelein gets into detail in our feature on page 32. He points out that the entire supply chain is needed for sustainability to affect real emissions reduction.

The OEMs and Tier 1s currently are

nudging their sub-tier vendors to get with the program. Sooner or later, Tier 2, 3, and 4 suppliers will be expected to follow the same Scope 3 and other guidance that vehicle makers expect of their Tier 1s. The Scope protocol is not yet law. Some expect it eventually will be as regulators tighten the emission screws going forward.

Engineers ask me if "the sustainability thing is really just green-washing BS," as one put it. No, it's the real deal. As Maddelein noted, sustainable activities now are "what we all just do." Industry-wide, roughly \$2 trillion is invested annually in existing technologies like batteries and renewable power. These address at

least half of GHG emissions. To reach net-zero by 2050, however, the world will need to commit an additional \$3.5 to \$5 trillion per year, according to BloombergNEF and McKinsey estimates. It's a heavy cost burden that's likely to get heavier.

The U.S. EPA's recently proposed tailpipe standards hope to spark a 60% rise in EV sales in the next nine years. That target

won't be met if vehicle prices are not reduced significantly. How much cost can engineers and suppliers wring out of batteries in the next two product cycles, so that today's \$60,000 average retail price of EVs drops to levels that mainstream buyers can afford?

Engineers solve problems. But as I've noted on this page, there is no 'silver bullet' in the mobility journey. Reaching a sustainable future requires multi-modal solutions. That includes EVs but also hybrids. 'Green' fuels, including biofuels and synthetics. Hydrogen. Gen-3 nuclear reactors on the grid side and in steelmaking. Innovation! Carbon capture is heretical to EV cultists — but what solution other than EVs *isn't* heretical to them? It is one option for mitigating the elephant in the

There is no 'silver bullet' in the mobility journey. Reaching a sustainable future requires multi-modal solutions.

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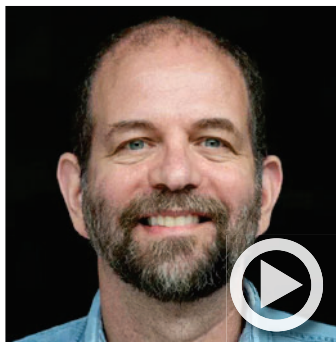
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On Sustainability: Video Interview Insights



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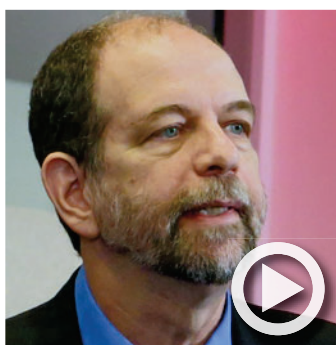
KRISTEN SIEMEN: Scope 3

Kristen Siemen is VP and chief sustainability officer, General Motors. An electrical engineer, she was previously executive director of GM's Global Energy Strategy, Certification & Compliance and Test Labs.



LARRY BURNS: Design Innovation

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PRATT: Standards

Toyota's chief scientist on the importance of standards in sustainable product development.



SIEMEN: Electrification

GM's CSO on sustainability and the mainstream EV future.



THE EDITOR: On Sustainability

SAE Media's editor-in-chief's views on sustainability and its many moving pieces.

room: the estimated 1 billion existing ICE-powered vehicles in the world.

Forecasters say perhaps 100 million more new vehicles, most with IC engines, will enter the world's streets this century. No button exists to simply make them disappear, to be replaced by EVs. The road to the sustainable future must support livelihoods and budgets in every corner of the world. Yet when the truly global OEMs argue this point, they get blasted by the NGO eco-lawyers who cluelessly demand finger-snap solutions.

The sustainable future is full of unknowns. Battery supply. Mineral sourcing. Mining risks. Human rights and safety. A fragile, Balkanized U.S. energy grid. Geopolitics. Wars and rumors of war. Cost. Natural resource issues such as water use in semiconductor manufacturing and lithium processing. Even truly "recyclable" plastic remains an unfulfilled promise in many cases.

For Sustainability to be industry's true North Star, leaders who preach the EV gospel should walk the walk. A recent

1,497-mile flight by Tesla's CEO from Austin, Texas, to Oakland, Calif., consumed nearly 10,000 pounds of jet fuel and emitted 15 tons of CO₂, according to an online report.

SAE itself is grappling with its own sustainable transition. Pride in the new EV charging station at SAE's Pittsburgh-area headquarters is tempered by the regional power utility's main sources of fuel to generate electricity: natural gas and "scrubbed" coal.

Lindsay Brooke, Editor-in-Chief

The four strategic choices facing suppliers

Has there ever been a period of automotive history where the shift in trajectory, technology envelope and level of risk assumed has been so high — and happening as rapidly as the transition to electric vehicles? I'll submit that the post-WWII boom and competitive shakeout, the 1970s oil embargos and subsequent focus on lightweighting, and the bankruptcies of a couple of major U.S. OEMs come close. But those events will pale in comparison to the impact of the ICE-to-BEV transformation.

The current [S&P Global Mobility BEV](#) production-share forecast for NA is almost 9% — up three percent from last year. By 2030, the forecast is for 39% of production to be battery-electrics. Of course, that leaves roughly 60% of production powered by IC engines, with most of them likely to be hybrids. Still, given this backdrop suppliers in the engine, transmission, driveline, fuel and exhaust spaces have been strategizing their future. Some are proactively making critical decisions while others are waiting for the dust to settle (and the next rounds of vehicle emissions and fuel-economy regulations to arrive). News flash! The dust has settled.

Virtually every supplier will be impacted by the changing value equation as electrified platforms are the focal point of most of the new capital and technology investments. Those suppliers in the BEV-negative (adversely affected by battery electric propulsion) sectors essentially have four strategic choices going forward. Forward-focused suppliers have already made a choice.

Choice 1: Lift and Shift

Given their position within the competitive market in the 'ICE' sector and/or their ability to transfer technology to BEV-agnostic or BEV-positive areas — these suppliers transfer their operations to new light vehicle sectors. Several major Tier 1 moves to date are evidence of this as they focus on technologies that promise a more profitable future. This includes e-motors, inverters, battery thermal management technologies and electrified chassis (braking, steering and suspension). The 'lift and shift' suppliers are using the success from the declining ICE



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Virtually every supplier will be impacted by the changing value equation.

business to transform into a new entity driving higher margins for the future.

Choice 2: Evacuate

Several suppliers looked toward their long-term future prospects — and opted to seek an exit. These suppliers reviewed several factors to make this decision: the age or the ambitions of company ownership; other, more lucrative options for their capital and technology; the level of risk they were willing to assume and their position versus competitors and customers as volumes decline. Given these realities, many decide that a strategic sale (selling to a competitor) or financial-markets entity is the best solution for all involved. Such sales may include the eventual wind-down of operations or product lines or re-investment in the enterprise to improve efficiency and raise margins.

Choice 3: Cash Cow

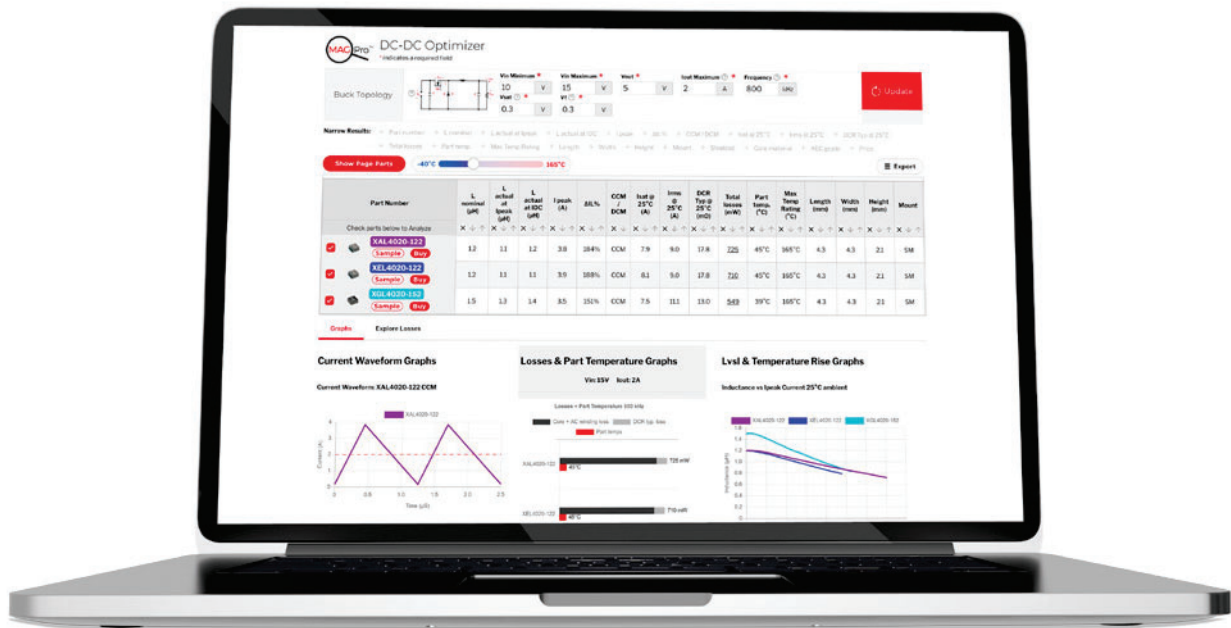
The 'cash cow' choice is fairly simple. Management may not believe that future volumes will decline as swiftly as forecasters predict. The ownership and executive team may determine that their best route is to 'milk' current assets, optimize their position through pricing and nominal investment and ride out the future. This decision is easier if there is a strong aftermarket demand for the product. As ICE production volumes wane, the aftermarket component of their business becomes more important. In the end, this decision will end in acquisition or wind-down of the operations.

Choice 4: Double Down

Choosing to invest new capital into the acquisition of competitor capacity, business relationships and technology is a bold choice. With a strong market position, several suppliers are strategically acquiring competitor capacity, technology and business relationships. Using this newfound leverage, suppliers are strengthening future financial performance through raising prices or consolidating less efficient capacity.

While there are several variations of these strategies for BEV-negative suppliers, in the end suppliers are making these critical decisions either actively or passively. ■

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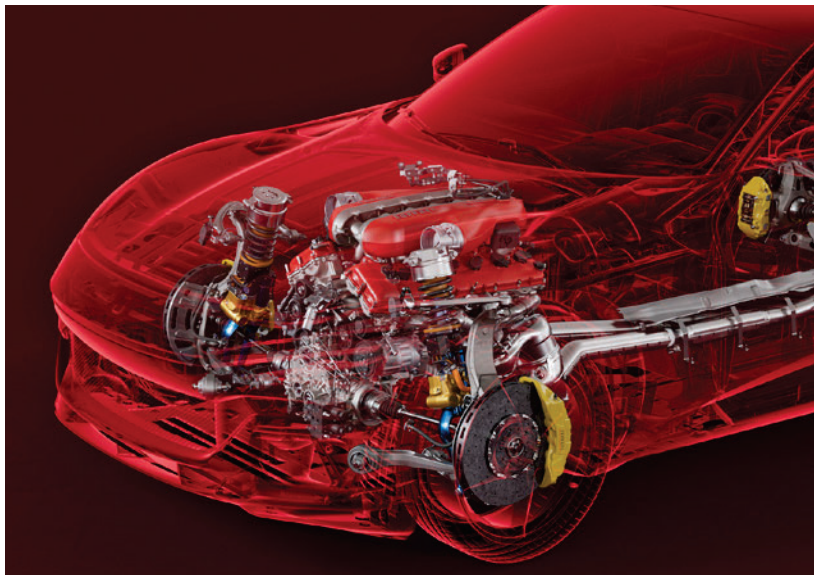
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Multimatic-made ‘legs’ for Ferrari’s new thoroughbred



Ferrari Purosangue front end showing PTU mounting on front of V12 and suspension corners with new Multimatic TASV active dampers.

The **Ferrari** Purosangue scurries up the snow-bound pitches of Italy’s Monte Bondone, the Alpine peak whose auto-hillclimb exploits date to 1925. Ferrari’s first “SUV” — really, more a genre-blurring crossover — slices through Bondone’s 38 devilish corners, gaining nearly 4,900 ft (1,494 m) of elevation over an 11.2-mile (18-km) workout. Its 715-hp (533-kW) V12 sings like the tragically-fated opera hero it is, to an 8,250-rpm height that’s as lofty as the surrounding Dolomites.

Emissions regulations may soon spell the end of that barrel-chested, 6.5-L engine, whose 12 naturally-aspirated cylinders describe every roadgoing Ferrari built between 1947 and 1973. But the rest is modern magic, the kind of prestidigitation that’s required to transform a 4,774-lb (2165-kg), AWD machine — the first Ferrari with four doors and four adult-sized seats — into a stunning performer that feels lighter and lithier than any driver would ever expect.

One showstopper is a world’s-first active suspension that traces not to Maranello, Ferrari’s hometown in northern Italy, but to a quiet suburb north of Toronto, Canada. The Purosangue’s ingenious, electrically activated dampers are the work of **Multimatic**, the publicity-shy supplier that long has strived to stay under the radar. But that’s become impossible after a string of successes that includes hand-building the **Ford** GT; key development roles in the **Aston Martin** One-77 and Valkyrie supercars and

building the bonkers, turnkey Ford Bronco DR Baja racer. And that’s when Multimatic isn’t cranking out parts for some of North America’s best-selling vehicle platforms, including more than 7 million ball joints annually.

48V dampers

For the Purosangue (pronounced “poor-oh-SANG-way:” thoroughbred) — Multimatic calls its technology TrueActive Spool Valve Dampers (TASV). The spool-valve part certainly isn’t new. From Formula 1 teams to the **Mercedes-Benz** AMG GT and **Chevrolet** Camaro ZL1 1LE, the company’s spring-loaded fluid valves allow predictable control over force-velocity curves inside each damper. Ferrari and other demanding customers can digitally spec and tailor the dampers for extremely specific applications, from rock crawling to road racing, versus the trial-and-error of older shim-stack designs. These patented dampers even run cooler, because of lower internal pressures, according to engineers.

What’s new is the “TrueActive” component. On the Purosangue, each damper integrates a liquid-cooled, 48-volt brushless electric motor, co-developed with Ferrari, with the dual spool valves that independently manage rebound and compression. The power-dense electric motors apply direct force to the Ferrari’s chassis and the dampers’ piston rods through a ball-screw and worm-gear assembly. That reduces weight and packaging space and eliminates any need

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for anti-roll bars or air springs to dynamically adjust body height. A dedicated radiator dissipates heat from the multi-tasking system.

As explained by Jacopo Canestri, Ferrari vehicle dynamics engineer, everything is controlled inside the dampers on multiple axes: body roll, pitch, yaw and vertical motions. Ferrari says the system can adjust the body and dampers in 50-ms bursts, faster and with greater control than any adaptive or semi-active suspension.

"The dampers are the backbone of the Purosangue's dynamics," Canestri told SAE Media.

The dampers' motor actuators take their commands from accelerometers at each corner that guide Ferrari's six-way Chassis Dynamic Sensor, which made its debut on the 296 GTB Hybrid. That sensor is the brains of the operation, tied to F1-derived helpers such as Side Slip Control 8.0, the predictive stability



The new AWD Purosangue crossover/SUV in a very un-Ferrari driving environment.

program that takes action before the Ferrari loses grip, rather than merely reacting to an impending slide.

Ferrari and Multimatic say the TASV dampers keep wheels in optimal contact with the ground, even as they expertly filter road imperfections from the cabin.

For the first time in a production vehicle, suspension stiffness essentially operates on an entirely independent circuit from body control. Ferrari engineers explained it this way: picture a traditional vehicle's wheel dropping into a pothole (or in New York or Detroit, multiple potholes).

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Purosangue front suspension corner. Each TASV damper integrates a liquid-cooled, 48-volt brushless electric motor with dual spool valves that independently manage rebound and compression.

What happens next? The body is forced to follow suit, as it does when a car chatters over a washboard surface. The new dampers apply a countervailing force to the body before the wheel even dips into the hole. The wheels follow the road surface, the body stays flat and passengers stay happy.

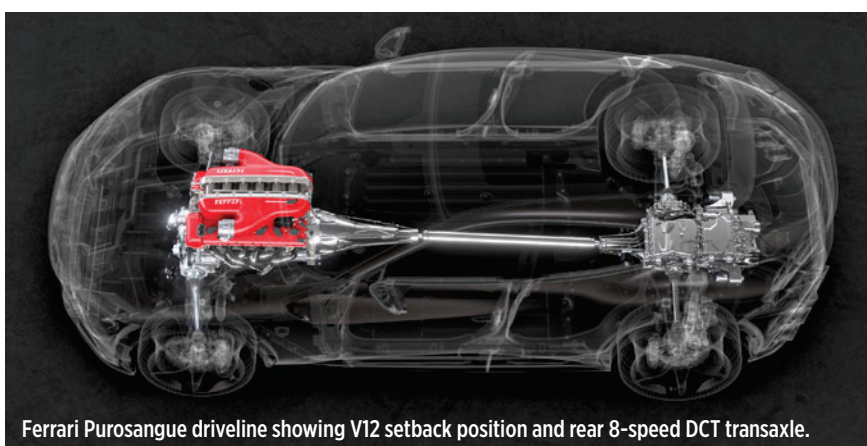
Below its dramatic clamshell hood, the Purosangue's 65-degree V12 is tucked entirely behind the front axle. It routes those 715 prancing horses through a rear transaxle and eight-speed, dual-clutch automated-manual gearbox. Front wheels boost traction and ease understeer via a power take-off unit and separate two-speed gearbox. Rear-wheel steering further boosts agility and control. The physics-scoffing result is a 3.3-s launch to 62 mph (100 km/h), 10.6 s to 124 mph (200 km/h) and a claimed top speed beyond 193 mph (313 km/h).

Pushbutton ride control

Like the 812 Superfast that shares much of its engine and technology, the Purosangue has a decided Jekyll-and-Hyde personality. Increasingly aggressive behavior is spurred via the brand's



TASV's electric motors apply direct force to the vehicle chassis and damper piston rods through a ball-screw and worm-gear assembly.



Ferrari Purosangue driveline showing V12 setback position and rear 8-speed DCT transaxle.

familiar "Manettino," a red-metal toggle on a gorgeous carbon-fiber-rimmed steering wheel. But where the Manettino's "Corsa" (Race) setting remains the route to full-blooded performance, the active suspension has one more trick up its sleeve. For the first time in a Ferrari, the Manettino adds a pushbutton function to let drivers select suspension stiffness.

Basically, the only reason it exists is to keep the Purosangue in its softest setting regardless of what the rest of the car is doing.

As revealed by Raffaele de Simone, Ferrari's esteemed chief development driver, the Purosangue covers ground as quickly in its cushiest ride setting — whether on road or the company's Fiorano test circuit — as it does in firmer modes. The only reason a driver might choose a rockier ride is to feel more jostles and pavement ripples through the steering wheel.

Naturally, we have to try Mr. Softie mode. On the slaloming backside of

Monte Bondone, the Purosangue flirts with 130 mph (209 km/h) on salt-crust-ed tarmac, before it's time to mash the sensitive by-wire brakes. That "self-learning" brake system constantly calculates grip and slip targets for hulking Michelin winter tires (22 in. front, 23 in. rear), even when we're nowhere near the limit, to best exploit the tires' longitudinal force when the limits are tested — a good thing in this nearly 2.5-ton 94482-lb/2033 kg) hunk of prime Italian beef. The Ferrari's active suspension automatically drops the body as much as 2 in. (50 mm) as it storms into curves, putting the roll center closer to that of a typical GT car. The ride remains pliable, the body flatter than the snowboards cruising on adjacent hills.

For the world's most-powerful SUV, it's the definition of an unfair fight. For regular folks, so is the Purosangue's price: \$398,350 to start, easily soaring past \$450,000 with options. At least the trick suspension comes standard.

Lawrence Ulrich

CLOCKWISE FROM TOP LEFT: FERRARI; MUTIMATIC; FERRARI



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EMISSIONS

Europe steps back from 2035 ICE ban

In a surprising move that paves the way for the European Union's adoption of a mandate to eliminate vehicle CO₂ emissions, on March 25 the EU reached an agreement with Germany to step back from a complete ban of combustion-engine vehicles starting in 2035. The EU agreed to permit sales and registration of IC-engine models after the 2035 deadline — provided those vehicles operate only on carbon-neutral fuels, often generically referred to as 'e-fuels.'

With a significant portion of its economy related to the historically ICE-based automotive industry, Germany had resisted the EU's total ban, although its Parliament's Green Party supported the forced sunset of ICE passenger vehicles. **Reuters** reported German Transport Minister Volker Wissing as tweeting, "We secure opportunities for Europe by preserving important options for climate-neutral and affordable mobility." In another Twitter post, Wissing reportedly added, "Vehicles with internal combustion engines can still be newly registered after 2035 if they fill up exclusively with CO₂-neutral fuels."

The e-fuels compromise also has implications for the pending Euro 7 vehicle-emissions regulations expected to come into effect by 2025 and that affect both passenger and commercial vehicles. **Reuters** reported Frans Timmermans, European Commission VP in charge of the European 'Green Deal,' as saying that after the deal with



Comparatively low-volume European OEMs such as Porsche and Ferrari see e-fuels as a possible path to retaining the combustion-engine attributes on which their brands are built.

Germany was reached, "we will work now on getting the CO₂ standards for cars regulation adopted as soon as possible." Italy and other EU entities also had supported an approach that provided for alternatives to EVs.

Critics of the compromise said the arrangement undermines environmental efforts in general and has potential to harm EU initiatives in other areas. "This rotten compromise undermines climate protection in transport, and it harms Europe," the German news agency dpa reported. Greenpeace mobility expert Benjamin Stephan as saying in Berlin on March 25.

Zero-emissions standard stands

Wire reports said that the deal between the EU and Germany means that the October 2022 agreement of EU mem-

ber states and the European Parliament that ostensibly mandated EVs will be adopted. German approval of the regulation means that other EU members opposing the ICE ban would not be able to coalesce a sufficient number of votes to veto the legislation. The EU next must create language on the provision for e-fuels in ICE vehicles to satisfy the zero-emissions stipulation.

At present, only a handful of pilot-manufacturing efforts are producing e-fuels, but proponents say that there will be larger-scale production long before the EU's 2035 requirement for the fuel that will allow ICE vehicles to continue for sale in Europe. It remains to be seen if other entities that have banned or are seeking to ban ICE vehicles — such as several European cities and the state of California — will consider exemptions for e-fueled ICE vehicles.

Germany's automaker association, the **VDA**, stressed that it supported options for how CO₂ neutrality is achieved by passenger vehicles. But the VDA conceded that production of carbon-neutral fuels needs to advance. "Now we have to enable e-fuel output at scale and at competitive prices," **Reuters** quoted the VDA as saying, "which can only happen with large range of strategic decisions. Brussels and Berlin need a maximum of stable energy partnerships in the many countries that have excellent conditions to produce e-fuels."

Bill Visnic



The European Commission's Frans Timmermans said an agreement with Germany will allow the EU's CO₂-eliminating regulations to proceed.

FROM TOP: PORSCHE; EUROPEAN COMMISSION

AUTOMATION

Honda reveals latest Autonomous Work Vehicle at CONEXPO

Honda revealed the prototype of its third-generation electric Autonomous Work Vehicle (AWV) at CONEXPO 2023 in Las Vegas. With the innovative machine, Honda aims to launch “a new category of capable work vehicle for companies that need autonomous operation or delivery solutions,” the company stated.

“As we continue to advance the Honda AWV platform, we want to meet with potential business partners and companies at CONEXPO that are interested in field testing the vehicle at their worksite,” said Jason VanBuren, systems engineering manager at American Honda Motor Co., Inc. “We believe the Honda AWV can be a valuable solution to supporting construction teams while also enhancing worksite efficiencies and safety.”

The third-generation AWV leverages the auto, motorcycle, and aerospace company’s autonomous technology to create a off-highway work vehicle that is designed to support construction-related activities and enhance work-force productivity. Honda and Black and Veatch, a global engineering and construction firm, [in 2021 conducted a month-long field test of second-generation AWV prototypes at a Black and Veatch solar-energy construction site in New Mexico.](#)

The new AWV reportedly can operate autonomously or manually via a remote control and could provide a wide range of services to industries that need autonomous operation or delivery solu-



The third-gen AWV features a larger bed that can accommodate up to two pallets and a greater loading capacity of 2,000 lb.

tions. Honda also is exploring the development of attachments and tools that could make the AWV a suitable platform for a wider array of work environments, but the company did not elaborate on specifics at the show.

Honda reported successful results from the field-test of the second-generation AWV at the Black and Veatch site in New Mexico. The company said it also conducted other field tests to verify that the AWVs can transport materials to precise points along a pre-set route. The third-gen machine has been refined based on this testing and features several new enhancements.

New features of the latest Honda AWV include a larger bed footprint that can accommodate up to two pallets and features a greater payload capacity of 2,000 lb. (907 kg). The bed also has been lowered for easier loading and improved ergonomics. The autonomous mode now

features a higher top speed of 10 mph (16 kph) and the battery’s specific energy has been increased to offer an operating time of up to 10 hours.

Honda said it also improved navigation accuracy with lidar sensors to aid operations in locations where GNSS (global navigation satellite system) service is weak or unavailable. The tablet-based programming interface reportedly also has been simplified and features cloud connectivity, while accident-avoidance functions also are upgraded.

The AWV employs an array of sensors for autonomous operation. The vehicle utilizes GPS for location, radar and lidar for obstacle detection and cameras for remote monitoring. The company anticipates further improvements to performance and design specifications as the development of the prototype progresses.

The Honda AWV measures 51 inches (1300 mm) wide, 119 inches (3025 mm) long and is 81 inches (2052 mm) in height. The load bed is 101 x 51 inches (2560 x 1300 mm). Unladen, the vehicle weighs 1765 lb. (800 kg). The battery has an 18.6 kWh capacity that can provide a range of up to 28 miles (45 km) fully loaded.

Honda hopes to sell the AWV commercially and is seeking partners to participate in field testing to improve functions and enhance vehicle performance. The vehicle attracted considerable attention at the company’s CONEXPO booth in Vegas.

Matt Wolfe



The latest AWV features a larger bed that can accommodate up to two pallets and a load capacity of 2,000 lb.

TOP: HONDA

Dodge is ready to sting the compact-SUV market



The 2023 Dodge Hornet GT injects a svelte shape into a compact-SUV segment that generally favors blockier bodywork.

If you accept that the oddball and odd-sized Journey never was a legit rival for the likes of the Honda CR-V, Toyota RAV4 and Ford Escape — and it wasn't — **Stellantis' Dodge** brand hasn't played in the compact SUV segment, one of the largest and most competitive in the U.S. That strategic gap is set to be filled by the 2023 Hornet, Dodge's performance-slanted attempt to peel out some sales volume from among the C-segment utilities that are typified by mundane and softly-tuned top-sellers.

The Hornet's not just about having a little more engine power, either. Its platform is shared with the **Alfa Romeo** Tonale. Like Hornet, the Tonale slated to be in showrooms sometime in spring 2023 and incorporates chassis finery such as standard **Koni**-supplied Frequency Selective Damping (FSD) dampers. Specifically tuned, genuine by-wire braking (for the R/T trim) reduces curb weight by 9 lb. (4 kg) and improves steering feel via direct-action ratios from the electronic power steering; Stellantis claimed the Hornet GT's ratio, at 13.6:1 (shared with the Tonale) is the most direct in the segment.

Brian Del Pup, vehicle synthesis senior

engineer, emphasized to SAE Media that the Hornet's platform with standard all-wheel drive delivers a near-ideally balanced 52% front/48% rear weight distribution for the plug-in hybrid R/T trim. It's a rare attribute in a class dominated by inherently front-heavy architectures. Even with an added 276 lb (125 kg) coming from its 15.5-kWh lithium-ion battery pack, the R/T's 4,140-lb (1878-kg) curb

weight is 160 lb (73 kg) lighter than the top trim of **Toyota's** RAV4 Prime, the segment's most comparable model to the Hornet R/T.

Horses still count

To inject the brand's style of verve into the segment, Dodge hasn't neglected propulsion's role, however. With a turbocharged 2.0-L "Hurricane" aluminum-block I-4 generating 268 hp and 295 lb-ft (400 Nm), the base Hornet GT trim delivers the most standard power in the segment, Dodge claims. Working through the ZF-supplied 9-speed automatic transmission, the Hurricane 4-cyl. gets the job done to the tune of 6.5 s from 0-60 mph (0-97 km/h) and can romp the Hornet GT on to 140 mph (225 km/h).

In real-road situations, however, the engine rarely feels more than adequate and any "hurricane" here demonstrates to be comparatively brief. Despite an electronic wastegate, there's not much turbo boost below 3000 rpm and the redline lives at disappointingly low 5500 rpm.

More interesting and more propulsive is the Hornet R/T's PHEV setup. Its turbocharged 1.3L 4-cyl. is rated at 123 hp, but when combined with 44 hp



The 2024 Hornet R/T is a plug-in hybrid that couples a 1.3L 4-cyl. with a starter-generator motor and a rear e-axle.

BOTH IMAGES: STELLANTIS

from a belt-starter generator in the driveline's P1 position and the rear axle motor's 121 hp, total system power is a maximum 288 hp. The 199 lb-ft (270 Nm) generated from the ICE part of the equation is channeled to the front wheels through a 6-speed automatic transmission, with another maximum of 184 lb-ft (249 Nm) available from the electric rear axle, for a total of 383 lb-ft (519 Nm).

If that's not enough drivetrain circumlocution, the "PowerShot" feature — activated when the driver pulls and holds the steering-column-mounted shift paddles — can temporarily summon an additional 30 hp from the battery and rear axle for as long as 15 sec. The feature is easy to use and Dodge said it's good for cutting 1.5 sec from the 0-60 time, pulling it down to 5.6 sec. PowerShot may be particularly useful when accelerating from a standstill, but the effect seems less pro-



The Hornet GT cabin is highlighted by crisp digital displays and reasonably rich material choices.

nounced when on the move, although it might offer some added confidence in certain maneuvers.

In addition to a "sport" driving mode for both Hornet trims, the R/T has the

options of hybrid, electric and "E-Save" modes to blend electrification; E-Save prioritizes battery charging. Dodge said the Hornet R/T's electric-only driving range is approximately 30 miles (48 km).

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The Hornet's standard AWD incorporates "dynamic" torque vectoring for both GT and R/T trims. If the Sport driving mode is selected, the system also provides an electronically controlled limited-slip differential function. Either Hornet trim has a firmer ride than some customers in the compact segment might expect, but the standard Koni FSD dampers and the optional driver-selectable 2-stage dampers supplied by **Marelli** brilliantly blend control with reasonable comfort.

The Hornet's base braking system, as well as the Brembo-caliper upgrade setup, both seemed stronger and more confident than the braking capability typical of the segment.

"I got a lot of push from senior leadership outside the brand — I'm talking about within [Stellantis North America] engineering — to make sure that it had the correct sporty characteristics for a Dodge. Not only I would say 'direction,' but 'support,'" Del Pup stressed. "Support to make sure that we did very unique things with this vehicle to make sure it was true to the Dodge name.

"You want tight steering, you want good performance, you want a 0-to-60 [attributes]," he added. "We don't want an appliance."

With a 103.8-in (2636-mm) wheelbase and overall length of 178 in (4528 mm), the Hornet is a couple of inches shorter in both dimensions than Toyota's RAV4 Prime. Hornet R/T's



Underhood of the 2024 Hornet R/T plug-in hybrid, with space occupied mostly by the 1.3L 4-cyl. engine.

6.1 in. (155 mm) of ground clearance means offroad excursions probably should be well-planned.

But the Hornet's slightly tighter dimensions make themselves apparent when driving briskly — or when parking, where its sculpted and low roofline take a toll on cargo space when compared to blockier competitors.

Interior trim and materials for even the Hornet GT have appearance and feel appropriate to the SUV's just-less-than-\$30,000 starting price. Particularly impressive is the crispness and clarity of the standard 12.3-in. digital display for the gauge cluster. The accompanying 10.25-inch center display features the fifth generation of the company's excellent Uconnect user interface.

Other cabin standouts included the grippy material covering the perfectly-shaped steering wheel and exceptionally supportive seats, even in the base GT trim. Typical for the segment, however, are rear seats without much shape and merely adequate legroom that also might be a symptom of the Hornet's tighter exterior dimensions.

The Hornet's assembly plant is in Pomigliano d'Arco, Naples, Italy. Perhaps owing to distance considerations, initial GTs on sale in early spring are designated as 2023 model-year vehicles, while the R/Ts said to be available in showrooms in late spring are 2024 models.

Bill Visnic

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Toyota launches longer-range 2023 Prius Prime



The 2023 Prius Prime can travel up to 44 miles solely on battery power, versus 25 miles for the previous-generation Prime.

Toyota's rollout of the 2023 Prius is a two-phase affair. Although the company didn't say it outright, the launch seems targeted to address two distinct Prius customers. Those who just want a stylish hybrid got [the fifth-generation 2023 Prius](#) in all its sexy-new-sheetmetal, 6%-more-powerful glory. And for hard-core hybrid fans, phase two brings the Prime (e.g. plug-in) variant: big battery for serious electric-only driving range, same shocking new shape.

The conventional 2023 Prius has serious newfound power. The plug-in hybrid Prime — starting at just over \$33,000 in base SE trim — is about more EV driving range, namely a 75% boost to 44 miles (71 km) for the 17-inch-wheeled SE, 40 miles (64 km) for the XSE and PSE grades with 19-inch wheels. Power for the Prime's 161-hp permanent-magnet AC synchronous motor that drives the front wheels and handles regenerative-braking duty, comes from a 13.6-kWh lithium-ion battery pack that has substantially greater capacity. The previous-generation Prius Prime's 8.8-kWh pack enabled just an estimated 25 miles (40 km) of electric driving range.

The Prime's pumped-up battery pack is situated a little more forward and under the rear seats than the previous model, where the pack sat mostly under

the cargo floor, chief engineer Satoki Oya told SAE Media. That and the repositioned fuel tank and revised rear section that comes with the second-generation version of the Toyota New Generation Architecture mean that all-wheel drive — available for the non-plugged 2023 Prius — unfortunately can't happen for the Prime, Oki said.

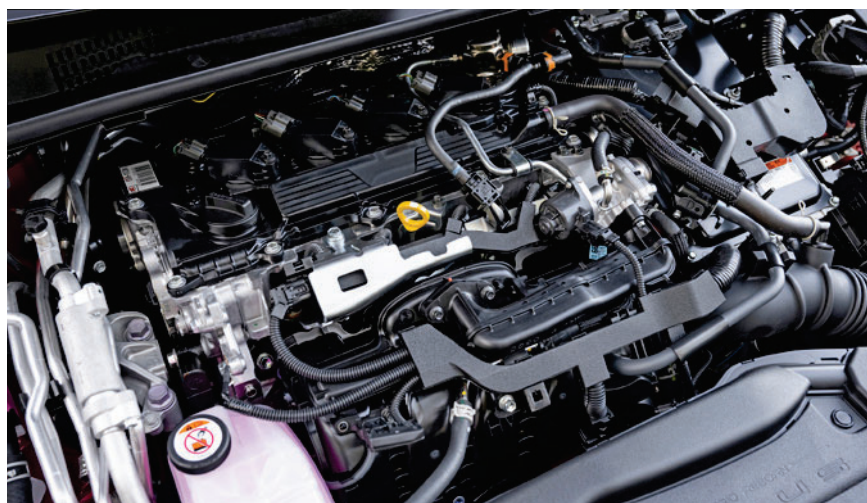
More battery per pound

Even if the 2023 Prius Prime's underside is too crowded for AWD, it seems Oki's team nonetheless managed some

magic with the lithium-ion batteries since the fourth-generation Prime's pack was engineered. The outgoing Prime's battery weighed a listed 265 lb (120.2 kg), while the new Prime's pack is claimed to have nearly 60% more energy capacity yet weighs just 19 lb (8.6 kg) more.

The power-dense battery matches the Prime's overall muscled-up powertrain. As with the conventional Prius, the Prime uses a 2.0L Atkinson-cycle I-4 (up from 1.8L in the previous-gen Prius) that generates 150 hp versus the 1.8L's 96 hp. Total engine and electric motor power for the new Prius Prime is 220 hp, compared with 121 hp for the 2022 Prius Prime. Even though there's the inevitable curb-weight gain — the new Prime in top XSE Premium trim weighs 3571 lb (1620 kg), a significant 196 lb (89 kg) more than the previous-generation Prime's top trim 3375 lb — the new Prime can make the 0-60 mph (0-97 km/h) run in a reasonably brisk 6.6s, according to Toyota.

There's a price to be paid, though, for more power, more weight — and more electric driving range. Toyota's specs say the most-efficient Prime SE trim is rated 53/51/52 city/highway/combined mpg and 127 mpg-e. The previous-gen Prime was good for 55/53/54 mpg and



The 2023 Prius Prime upgrades to a 2.0L four-cylinder that generates 54 hp more than the previous 1.8L's 96 hp.



The Prius Prime's gauge cluster and steering wheel combine for what can seem an unconventional driving position, but the wide central screen available on the XSE and XSE Premium trims helps balance the cabin's functionality.



A revised TNGA platform for the 2023 Prius Prime makes room for a larger battery and enables more cargo space but precludes the possibility of all-wheel drive.

133 mpg-e. What's more, the 2022 Prime's total driving range was estimated at 640 miles (1030 km), while the new 2023 Prime manages 600 miles (966 km). Even considering the new Prime's 75% boost in EV-only driving range, its lower mpg and mpg-e ratings might suggest to some that the 2023 Prime isn't a full step forward in

the efficiency game.

Mixed suburban and freeway driving generated something between 3.1 and 3.3 miles per kWh said the Prime's efficiency indicator, which places it on par with many fairly efficient pure EVs. Once the battery is depleted by EV-only driving, however, the Prime is slow to return much energy to the

battery while on the go. When the "auto" energy mode is selected — telling the Prime to decide how best to blend electric and ICE power — the system will warn the driver not to expect electric assistance. In short, to genuinely replenish the Prime's relatively large battery, a grid connection is vital.

Tech, features advance

There may be more weight for the 2023 Prius Prime, but the poundage does translate to increased levels of technology and feature content. All Primes have rain-sensing wipers and a heated steering wheel. The standard 7-in (178-mm) LCD "gauge" cluster is crisp and bright (even if many of its minor icons are excruciatingly small). The nifty Traffic Jam Assist system — operable at speeds up to 25 mph (40 km/h) — also is standard for all Prime trim levels. The SE trim's 8-in (203-mm) central touchscreen is adequate for multimedia duty, but it makes an appealing case for the 12.3-in (312-mm) upgrade screen that comes with the middle XSE trim.

It's generally agreed the new-generation Prius' driving position is awkward in relation to the driver's gauge cluster. But even the SE trim's seats are supportive and helpful in isolating front-seat occupants from the Prime's rather stiff ride on 19-in wheels (chief engineer Oki said the Prime's suspension tuning is revised compared to the conventional Prius). And although the gearshift is helpfully moved to the center console from its previous dash-mounted position, it still makes three-point turns a fuss.

Available at \$640 only for the Prius Prime XSE Premium is a solar-charging sunroof that can generate up to 185 watts. Oki said the roof power goes to the traction battery if the Prime's ignition is off. Whenever the ignition is on, power is channeled to the vehicle's 12-volt battery. Heated rear seats also are optional for the XSE Premium grade, as is a digital rearview mirror.

Toyota executives said the Prime makes up about 30% of total Prius sales. The 2023 Prime is scheduled to arrive in U.S. showrooms in May.

Bill Visnic

BOTH IMAGES: TOYOTA

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Finding solutions for Sustainable Mobility

The SMS team leverages SAE International's proven tools – respected industry-wide convening, standardization, professional development – along with new assets such as data management and analytics.

SAE created its SMS team to help industry rethink itself as part of the new industrial revolution and the EV transition within it.

by Lindsay Brooke

SAE International has established a new, dedicated practice aimed at helping the transportation industry become truly sustainable, as OEMs and suppliers in automotive, aerospace and commercial vehicles work to meet net-zero climate goals. And the 118-year-old organization created its new group, SAE Sustainable Mobility Solutions (SMS), in a radical way.

"I resigned from my previous job — gave up my duties — then hired on as first employee of the new group," explained SMS president Frank Menchaca, formerly SAE's chief growth officer. An unconventional thinker with MIT training in sustainability and free-jazz guitarist and composer, Menchaca defines sustainability as "the convergence of many different systems — the vehicle, the entire manufacturing process, materials, the infrastructure, communications and regulations. We have to look at the constituent units of the entire industry in order to make it sustainable. And that goes beyond the electric vehicle."

Sustainability, he asserted, "is helping industry to rethink itself as part of the next industrial revolution, which I firmly believe we're in the midst of."

A springboard for launching SMS was SAE's decades-long work across the Electrification space. Creating the J1772 standard for ubiquitous EV charging expanded [SAE's involvement beyond the vehicle](#) into the critical areas of infrastructure and energy.

"We thought that it's important for SAE to look at the bigger picture; in fact, we were being asked by our stakeholders to take a

bigger role in this," Menchaca noted. As the focus on, and funding of, global electrification efforts skyrocketed, "that catalyzed a lot of activity," he said.

SMS was born with a mission to "germinate, incubate, develop and socialize" new initiatives — putting traction underneath them before they're handed off to other organizations to fully augment. Within SAE, the nascent SMS group is considered an "innovation unit." The motivated team leverages SAE's proven tools — respected industry-wide convening, standardization, professional development — along with new assets such as data management and analytics.

"We bring those tools to bear on a very defined set of problems and challenges related to sustainability," Menchaca explained. Think of SMS as a group that plugs in wherever there is a solution to be created."

One of the 'biggest opportunities'

Since its official launch in late 2022, SMS has put a string of collaborative initiatives, many focused on professional knowledge and technical training, into motion with industry partners and SAE affiliates. Practical deliverables that SMS is engaged on include contributing to a national electric vehicle charging

TORY IRWIN



Frank Menchaca leads SAE's new SMS 'innovation unit.'

“Think of SMS as a group that ‘plugs in’ wherever there is a solution to be created.”

experience consortium that's being set up with the U.S. national labs and the joint office of the U.S. departments of Energy and Transportation (sidebar). Having endured the widely criticized, sketchy public charging network as an EV owner himself, Menchaca is an activist for [an effective series of standards](#), now in development, related to improving charging reliability.

Professional Development for all facets of the EV ecosystem “is maybe one of the biggest opportunities, and challenges, we [industry] face in sustainability,” Menchaca asserted. “Finding, training and enabling people to do the new work of the industry is, I think, one of the biggest things in front of us.” He cited as an example the estimated 300,000 new jobs that experts believe will be needed to generate lithium-ion EV batteries in the U.S. “About 25 percent of those people can be retrained from ICE work; maybe another 10-15 percent can come from associated industries,” he noted. “The rest are going to have to be found and trained.”

It's a significant opportunity for people who are interested in green-tech jobs, which are emerging faster than they can be filled. For employers desperately in need of training support in their “human infrastructure,” help is available from the SMS, Menchaca noted.

For example, the acute need for technicians in the EV-charging field prompted SMS and the SAE affiliate Probitas Authentication (part of SAE's Industry Technologies Consortium-ITC) to create a certification program for technicians. Service techs who complete training courses at specialist firms such as ChargerHelp! then take the SAE exam. Those who complete it are certified by SAE as possessing the requisite skills and competencies required to do EVSE maintenance, operations and diagnostic work. In the future, SAE may develop its own professional-development courses in this growing area.

There will be long-term demand for filling the EV, battery and electric-grid technology jobs. It's important, Menchaca said, to prepare not only the current generation of workers but also their successors. “We have to embed interest, enthusiasm, and an understanding of the opportunities at a much earlier age,” he said. “So, SMS fits beautifully with SAE's long history of programs like A World in Motion [AWIM],” which teach the basics of movement and transportation to children as young as kindergarten age.

“I think we're at an inflection point, as a culture and a country,” he observed. “We need the next generation of workers that are going to go into these roles to see STEM jobs as a reality for themselves. The way children see themselves, many of them don't have a sense that they can actually go out and get these [green tech] jobs. Exposure to the importance of STEM-oriented work in secondary schools also is hugely important. SAE has been doing that for a long time and we need to continue doing it.”

Sustainable successes thus far

SAE/InnoEnergy Battery Academy: A comprehensive, 22-course training program to advance fundamental knowledge and skills for practical application in the e-mobility and battery industries. The program offers more than 200 CEU-qualified hours covering theoretical, technical and application-based knowledge on battery fundamentals, grid and utility energy storage, EV batteries, battery management systems, and cybersecurity and energy data. SAE partner Netherlands-based EIT [InnoEnergy](#) is a leading innovation engine in sustainable energy, bringing the technology and knowledge and skills training required to accelerate progress towards decarbonization goals and improve energy security.

SAE/Public Key Infrastructure projects: SAE is organizing the international EV charging sector, as well as public and research ensuring the interface points between EV drivers and EV charging infrastructure are secure and trusted—the critical connection between the mobility and energy in-

dustries. PKI is a best practice used across industries to ensure a high level of trust between entities in an ecosystem by providing message authentication among trusted devices. SAE's PKI Cooperative Research Projects (CRP) are joint ventures with industry partners that perform targeted, pre-competitive research to develop solutions. An ongoing project with the National Renewable Energy Laboratory (NREL) encompasses [the designing and testing of a worldwide EV charging platform](#) that is secure, robust, scalable, and interoperable. The project is intended to deliver an operational PKI method agnostic to the charging platform that is available to industry worldwide.

SAE/Dekra on global EV regs, standards and cyber: Three new online professional courses from SAE and its partner [Dekra](#), a Stuttgart-based international organization known for its testing and certification, include 'Introduction to the Electric Vehicle Infrastructure' (a course that



looks at global regulations and standards), a course on cybersecurity related to EV charging, and a course in DC fast charging.

Lindsay Brooke

Battery harmonization

Sustainability is an international initiative for SAE. In early April, the SMS team and SAE's ITC engaged with the U.S. DoE and the European Commission to form a working group for contributing to the EU's recently launched Battery Passport. Conceived by the Global Battery Alliance in 2019, Battery Passport is a multi-stakeholder collaboration across the battery value chain. It is aimed at establishing key sustainability performance indicators related to the battery carbon footprint and child labor and human rights due diligence, as set out in the Greenhouse Gas rulebook and the Child Labor and Human Rights indices. Sharing this data with OEMs will enable them "to make more informed purchasing decisions and drive sustainable sourcing, processing and manufacturing practices in the industry in the future," the GBA said in a release.

"Because SAE is a neutral organization and we think on a global level, we're looking for ways to harmonize that [the Battery Passport] with the rest of the world because countries and regions have different regulations and requirements," he said. "Industry operates slightly differently. But that doesn't mean we can't leverage work that's going on in other areas into the U.S. and into the rest of the world."

Industry's reaction to SAE's new Sustainable Mobility Solutions venture has been overwhelmingly positive, according to Menchaca.

"We have found industry willing and open to working with us in a collaborative way. For example, a dozen companies gave their time on a voluntary basis to work with us on the technical study of EV charging reliability. They are very much in tune with the directions we're taking – we're taking a lot of cues in that direction from industry. We're in a constant dialogue."

Menchaca's vision for SMS in the near term includes mapping of new industrial processes aimed at making the transportation sector more sustainable. One is embedding the full battery lifecycle part into engineers' design and development work. Another aspiration is the design and deployment of "a very reliable EV charging system" in the U.S. And Menchaca concedes that sustainability extends beyond the batteries-and-EVs realm. It includes emerging concerns such as water use in semiconductor manufacturing and lithium processing, and sourcing truly recyclable plastics in vehicles.

"We have to think holistically; sustainability is not one process or sector," he said. "I'd love to see sustainability embedded in every business unit within SAE, all pointed to one direction: to help the transportation industry on its journey to net-zero emissions." ■

TORY IRWIN

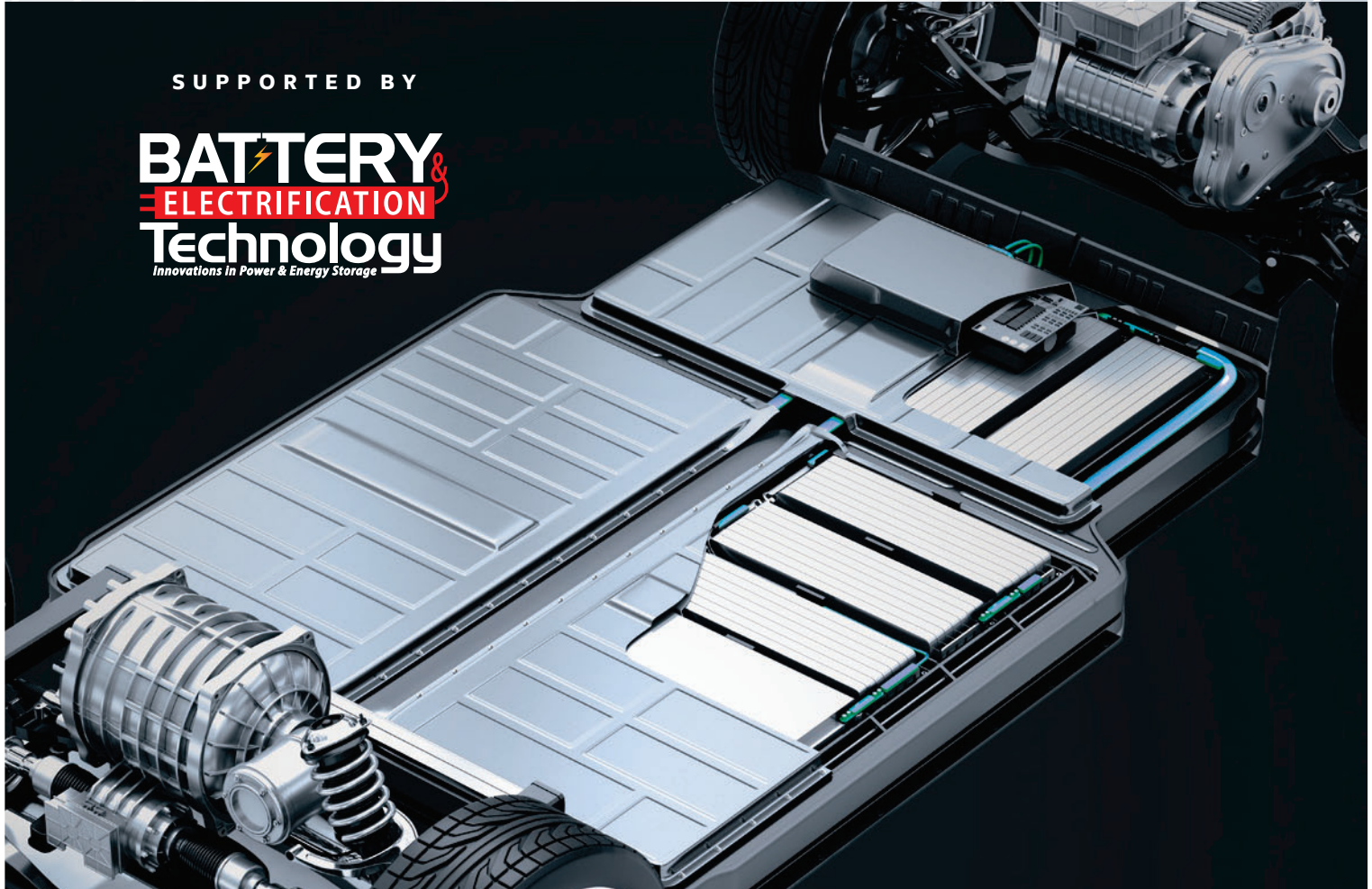


Battery Recycling & Reuse Summit 2023

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An Exclusive Online Event from the Leaders in Sustainable Mobility

As the ground vehicle industry continues its shift to electric vehicles (EVs), finding reliable methods to extend and renew battery life are more critical than ever. SAE International's inaugural Battery Recycling & Reuse Summit will explore the latest issues related to the environmental and economic impacts and opportunities that arise when a battery reaches the end of its life.

Topics covered during the FREE online event include:

- Traceability in the battery lifecycle
- Machine learning-approaches for battery life assessment
- The potential for battery second use
- Building a domestic supply chain for lithium-ion batteries

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Decarbonizing the EV battery SUPPLY CHAIN

It will take continued urging from many industries and governments but using energy from clean sources — unlike this coal power plant — can remove the lion's share of the carbon from the battery manufacturing process.

Altering manufacturing processes and using a much higher percentage of low emission energy can help the battery industry get greener rapidly, according to a new McKinsey & Co. report.

by Chris Clonts

A report from consultants at McKinsey & Co. strikes an optimistic tone that major reductions in carbon emissions from the electric vehicle battery supply chain can be attained in the next five to 10 years.

The recently released report, authored by five members of the firm's Automotive and Assembly Practice, said that production of the massive lithium-ion batteries currently favored by OEMs account for 40% to 60% of total production emissions. "Making batteries can generate as much emissions as producing all the other materials that go into making an EV — or even more," the authors noted.

Producing the body of an EV or an IC engine vehicle results in five to 10 tons of CO₂ emissions, the report said. But the authors estimate that "producing the average EV battery today emits up to 100 kg (220 lb.) of CO₂ emissions per kWh," or more than 7,000 kg (7.7 tons) of CO₂ for a typical 70-kWh battery. That's 40% more than a typical car that gets 22 mpg emits in a year, according to the U.S. EPA.

Four primary areas of change

Overall, the report recommends that battery manufacturers focus on four areas for the biggest potential change:

- Mining and refining
- Active material production
- Components and logistics
- Cell manufacturing

SAE Media spoke about the report with Andreas Breiter, a leader in McKinsey's Center for Future Mobility. He said that much of the gain could come from the development of the 200-plus battery gigafactories — depending on their size — that must be built to meet global industry demand.

He said two of the largest factors that could help new factories

produce lower carbon emissions are energy supply — the report cites "low emission electricity" for all four focus areas — and location. "New gigafactories help if you put those in places where there is carbon neutral or at least carbon-friendly energy, because energy is a big part of the carbon footprint," Breiter said. "The second part is that it helps if we build those factories more locally, which is the trend we now see. So these factories [now] are often not co-located with the OEM assembly plants, but they are at least in the same region, so for example, [a location in] the same state or just across the state border. And that reduces the transportation and means we don't have to ship across the country or from overseas. Manufacturing relatively locally helps in that sense, quite a lot."

Breiter said the momentum appears to be growing beyond the automotive industry for cleaner electricity. "Semiconductors are going toward decarbonization," he noted. "And the auto OEMs themselves are doing the same. They are now tracking, very closely, carbon in the whole supply chain. I think it's just a general trend for all of those industries combined, if they demand renewable energy sources, and also have a certain willingness to pay for that. Because there is value in that. I think then then definitely, yes, that could actually have a big pool for more renewables."

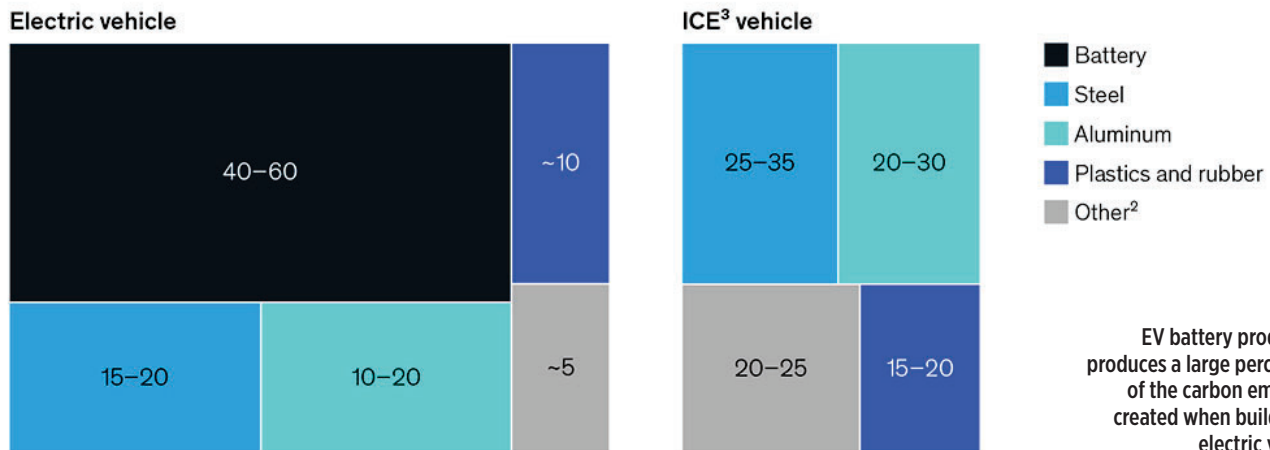
A competitive advantage

The report stressed that decisions by OEMs on a range of factors including design choices, vehicle types and

SHUTTERSTOCK

Batteries account for up to 60 percent of embedded greenhouse-gas emissions in electric-vehicle production.

Typical upstream battery-electric-vehicle emissions,¹%



¹Including all upstream emissions from raw material extraction to the OEM, including logistics.

²Including glass, copper, electronics, textiles, and logistics.

³Internal-combustion engine.

Source: McKinsey analysis

target ranges join the two factors above as major possibilities for near-term improvement. It also said that increasingly, manufacturers see low-carbon battery production as a competitive advantage, with “some leading players aiming to cut emissions below 20 kg (44 lb.) CO₂ per kWh.” That’s 10 times less than the current highest-emission OEMs.

Among the other “quick wins” the report said the industry could realize were:

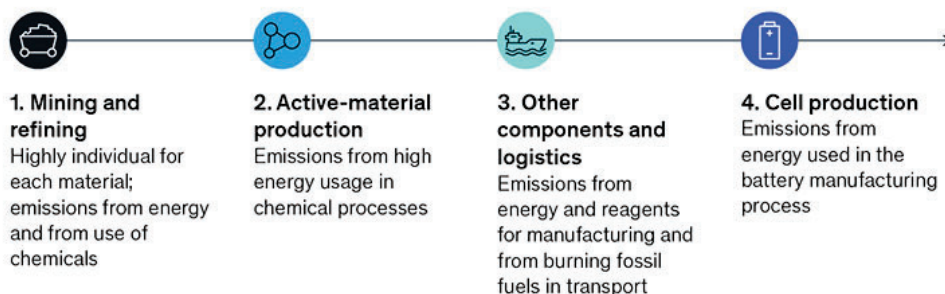
- **Cell manufacturing:** Most non-electric emissions currently come from the electrode drying process, the report stated, which requires temperatures between 122 deg. F (50 C) and 320 deg. F (160 C). That temperature is achieved, generally, by burning natural gas. Switching to electric heat sources, as well as using dry coating “or switching from conventional binders such as polyvinylidene fluoride to water-soluble alternatives, could significantly lower energy consumption and cost.”
- **Chemistry:** The report observed that nickel-manganese-cobalt (NMC) batteries have a 30% to 40% higher energy density, “while lithium-iron-phosphate (LFP) cells have a longer expected charging-cycle lifetime and, on average, 15 to 25% lower carbon emissions.” The report suggested this is due to fewer embedded emissions in the cathode.
- **Recycling:** The report said that with hundreds of new factories coming online, the amount of scrap produced would finally make recycling a cost-effective



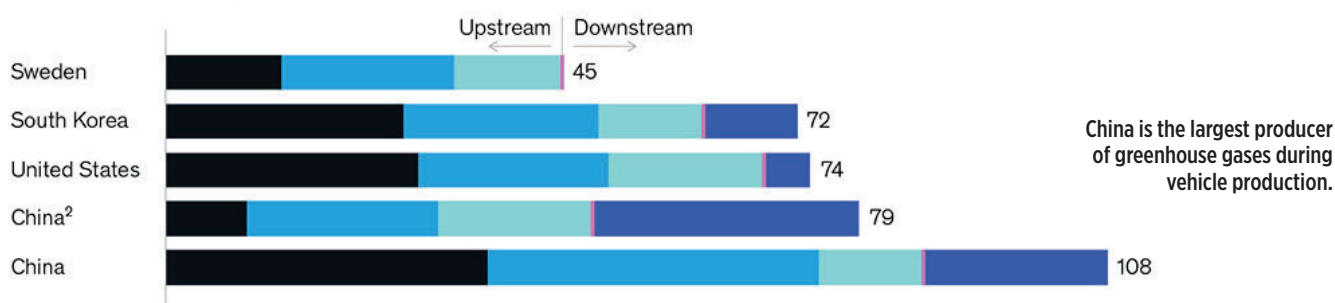
Though Ford and Volvo were first to partner with Redwood Materials for their battery-pack recycling facility in California, the company said it would accept batteries from any manufacturer.

endeavor. “The carbon footprint of recycled battery materials is typically four times smaller than that of other raw materials,” the authors wrote. Even before the massive factory buildout, OEMs and recycling companies are making progress toward creating a circular supply chain. **Redwood Materials**, which has prominently partnered with **Ford**, **Volvo** and **VW**, has a recycling and manufacturing facility in Nevada. And **Li-Cycle** last year partnered with **Ultium** to co-locate its innovative recycling process with **GM**’s Ultium manufacturing plant in Ohio.

Emissions in the battery value chain are primarily driven by production location and sources of raw materials and energy.



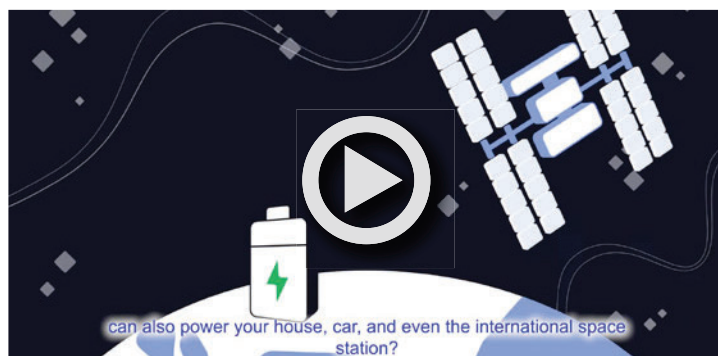
Emission intensities, kg CO₂e/kWh¹



¹Bottom-up modeling of cell-level emission intensities in individual "gigafactories." Emission intensities were estimated based on existing supply agreements with providers of raw materials, active materials, and energy. Market average has been taken where no information on the source of raw materials or energy was available.

²Based on a nickel-free battery; all other examples are based on nickel-rich batteries.

Source: Greenhouse gases, Regulated Emissions, and Energy use in Technologies (GREET); MineSpans by McKinsey; McKinsey Battery Insights



Li-Cycle says its EV battery recycling method is a drastic improvement over processes that use smelting, because it maximizes retention of usable chemicals and minimizes the creation of polluting waste.

One potentially controversial area the report discusses is in battery size/vehicle range. The longest-range EV currently can travel more than 405 miles (662 km) on a single charge. And in 2022, the number of EV models available with a range longer than 300 miles (483 km) tripled. But it's well known that the average daily driving distance for U.S. commuters is less than 40 miles (64 km). The report calls that delta a plainly underused resource.

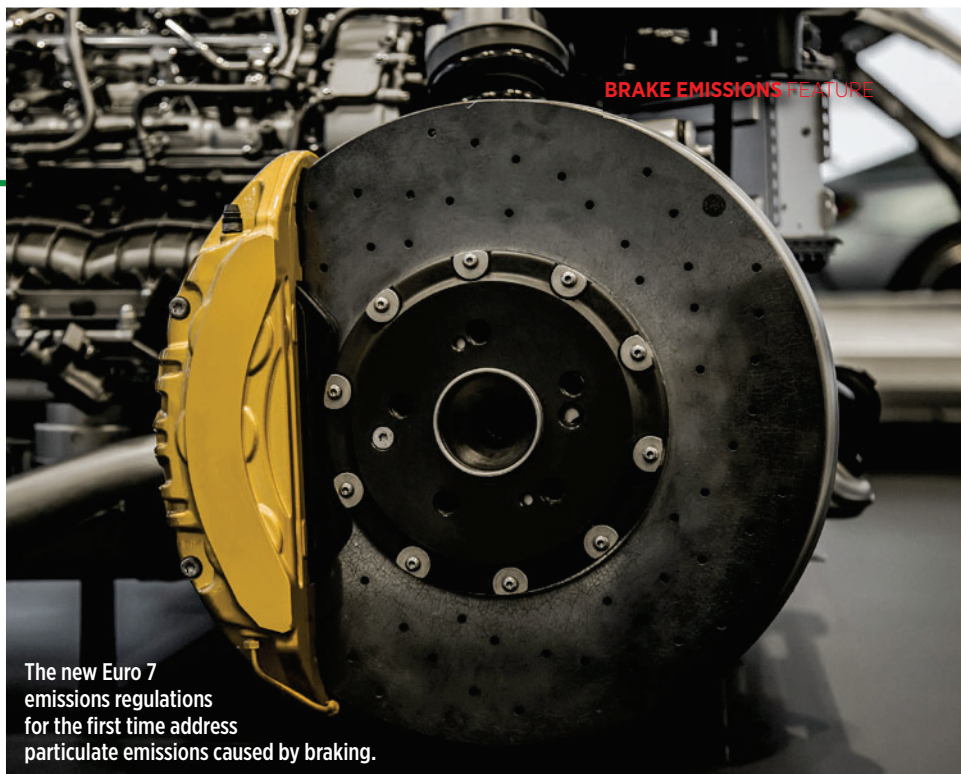
"One radical way to reduce emissions would be to build smaller battery

"With hundreds of new factories coming online, the amount of scrap produced would finally make recycling a cost-effective endeavor."

packs tailored more toward consumer needs," the report suggested, citing that in China, the best-selling EV in 2021 was the **Wuling** Hongguang Mini EV, with a 14-kWh battery and a range of 75 to 106 miles (121 to 171 km).

Breiter said that there is a segment of the industry where the range of current products matches the use-case: "If you look at the range of all of those last-mile delivery vehicles, which are now being electrified, those never have such a long range as passenger cars," he said. "Last-mile delivery vehicles are often specified with a range starting at about 100 miles (161 km). This is completely sufficient for the use case. And those cars are driving all day through the city," Breiter said. He added that it would take concerted communications efforts from the industry, media and government to make the case that would, hopefully, convince consumers to ask why they want to pay for such unused range. ■

EUROPE'S DUST BUSTER



The pending Euro 7 vehicle-emissions regulations include a significant new sustainability wrinkle: first-ever restrictions for PM emissions from brakes.

by Bill Visnic

In a proposal submitted in November of 2022, the European Commission detailed its new Euro 7 vehicle emissions standard, which is widely expected to be approved by the European Parliament and Council and begin phase-in starting on July 1, 2025. Another phase of emissions legislation is nothing new, but one critical element of Euro 7 is new to the regulation chessboard: first-ever limits on how much particulate matter (PM) can be generated by a vehicle's brakes.

This element of Euro 7 has auto and commercial-vehicle brake-component suppliers scurrying. Commercial vehicles are subject to their own compliance levels as they interpret how the new regulations will impact their existing technologies and what new solutions will be required. The proposed Euro 7 regulations also address the emissions of fine microplastic particles created by tire friction on the road. As of late Spring 2023, however, the EC had yet to assign permissible values for tire particulates.

[A 2022 European Environment Agency report on air quality in Europe](#) said that in the EU in 2020, "96% of the urban population was exposed to levels of fine particulate matter above the health-based guideline level set by the **World Health Organization**." The EEA added that exposure to concentrations of fine particulate matter above the 2021 World Health Organization guideline level "resulted in 238,000 premature deaths in the EU-27."

A widely cited 2020 study by U.K.-based **Emissions Analytics** found that tire particulate emissions can be substantially greater than particulates now emitted from ever-cleaner vehicle tailpipes. Foreshadowing, however, the potential impact of the world's expanding share of EVs (effectively are mandated for EU passenger vehicles starting in 2035) was a follow-up statement the firm made in May 2022 regarding EVs in relation to tire PM emissions: "Greater vehicle mass and [propulsion] torque delivered can lead to rapidly increasing tire particulate emissions. Half a tonne of battery weight

can result in tire emissions that are almost 400 more times greater than real-world tailpipe emissions, everything else being equal."

Brake emissions typically are sized in the PM10 range (inhalable particulate matter of 10-micron diameter or smaller; think common dust and pollen) or PM 2.5 (fine dust of 2.5 microns or smaller) band. The Euro 7 standard seeks to reduce particulate emissions by 27% — a maximum of 7 mg per kilometer until 2035. Starting in 2035, the brake-emissions limit is further reduced to 3 mg/km.

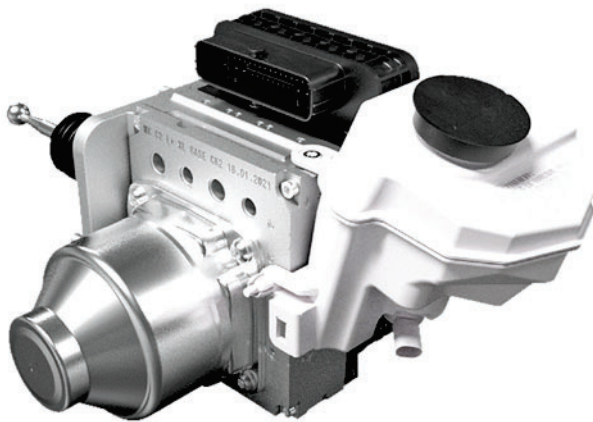
Automakers and braking suppliers are much more concerned with 2025 than 2035, said analyst Patricio Barbale, Chassis Team Lead at **S&P Global Mobility**. "The most important impacting factor is the timing — you have one year, a year-and-a-half, to be compliant."

Electrification factor

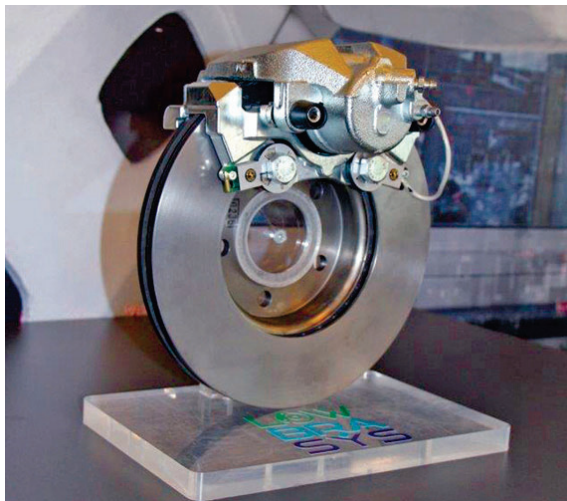
Barbale cited what he believes will be the two central strategies for Euro 7 brake-emissions compliance: vehicle electrification and friction-materials innovations.

He explained that the Euro 7 rules allow for a correction factor that subjects vehicles with varying levels of electrification to different levels of permitted brake-particulate emissions. This aspect hasn't been explained in most broad discussions of the new Euro 7 regulation. "In theory, the most important thing is that there is a correction coefficient for the type of engine in the vehicle," he said. "If you have an electric vehicle, it is not the same as an ICE vehicle. If you have a pure electric vehicle, only 15 percent [of total emissions are] considered."

EUROPE'S DUST BUSTER



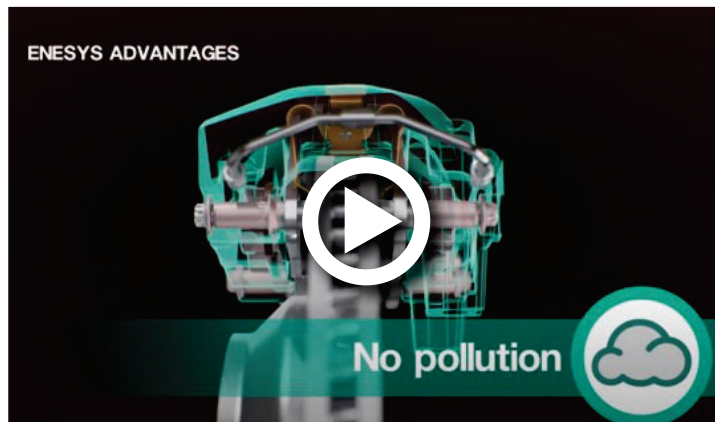
The control/booster unit for Continental's MK C2 braking system, which also uses zero-drag calipers to cut brake emissions.



Brembo's Lowbrasys braking system, the result of a collaborative project, combines materials innovations, software and filtering technology to achieve significant brake-particulate emissions reductions.

Euro 7 offers a ladder of compliance-correction factors for brake emissions based on degrees of vehicle electrification, in effect making this portion of the regulations another inducement to transition to EVs. A pure ICE vehicle is treated under the rules on a 1:1 ratio: if its brake emissions are measured at 10 mg/km, for example, the ICE vehicle is rated by its entire output and would have to find a way to get to the 7 mg/km maximum allowed in Euro 7.

Conversely, an EV emitting the same 10 mg/km is rated at just 0.15 of its measured output, so Euro 7 would consider its baseline brake emissions just 1.5 mg/km — far less than the 7 mg/km allowed in 2025 and even comfortably meeting the 2035 maximum of 3 mg/km. Following EVs are plug-in hybrids (PHEVs) with a correction factor of 0.3; conventional hybrids



Brembo Enesys braking system.

(HEVs) are corrected at 0.4 and mild hybrids at 0.6.

"Having an electric vehicle is a big advantage for this regulation," Barbale stressed. "Of course, the complete battery electric vehicle is expensive. But if you think about a mild-hybrid vehicle that is [essentially] a traditional ICE vehicle plus a small 48-volt battery, it's not a big addition to the vehicle. And, you [are allowed] a reduction of 40 percent of the emissions."

The generous correction factor for EVs and high-voltage HEVs is a nod to the expected high degree of regenerative braking theoretically available with those vehicles — braking that happens with zero particulate emissions because the friction brakes are not used. **Bosch**, a major braking-system developer, indicated that vacuum-independent [i.e. fully electric] regenerative braking systems "can decrease brake dust emission by even more than 95 percent."

But there is a flipside: EVs are significantly heavier than their non-electrified counterparts. Their weight can cause friction brakes, when used, to work harder. One **Organization for Economic Cooperation and Development** (OECD) study concluded EVs will emit from 3% to 8% more brake- and tire-related PM 2.5 because of their weight.

While the conversation about EVs' actual brake-emissions reductions will continue, expect a new generation of Euro 7-inspired hybrids to quickly arrive on the scene. "One thing that will happen is that many vehicles will move from traditional ICE to mild hybrid," Barbale believes. "We will see after 2025 more mild-hybrid vehicles than expected."

Materials, software solutions

Rimsa, a Barcelona, Spain-based supplier of specialty additives for several sectors, including the friction industry, cited the United Nations Economic Commission for Europe's Particle Measurement Program group as saying contemporary foundation brake systems emit more than 10 mg/km of PM10.

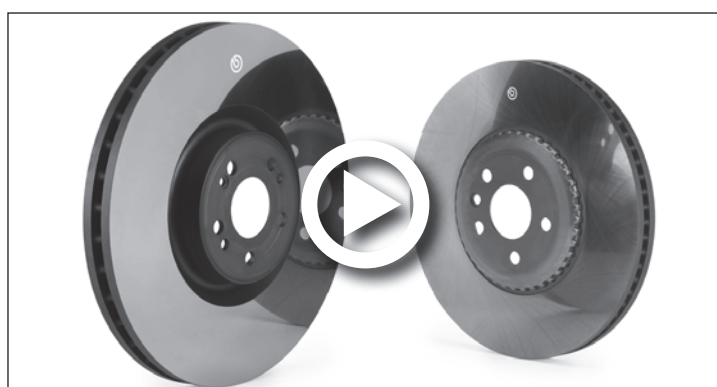
"To face this issue, several strategies have been implemented," Rimsa said. "However, the most outstanding are coated rotors, the development of new friction materials and advanced brake control."

SAE Media reached out to several brake-component suppliers for comment about the Euro 7 brake-particulate regulations. Some did not respond in time for this story's production deadlines. At least one chose not to comment publicly.

Table 1: NET CHANGE IN TOTAL NON-EXHAUST EMISSION FACTORS OF BEVS RELATIVE TO GASOLINE ICEVS (percentage points)

	Assumed electric vehicle weight	Passenger cars	Sport utility vehicles	Light commercial vehicles
PM2.5	Lighter weight	-12.8	-11.2	-13.3
	Heavier weight	+2.6	+7.5	+7.8
PM10	Lighter weight	-17.8	-18.0	-19.3
	Heavier weight	-6.5	-4.5	-5.5

The Euro 7 regulations credit EVs with an 85% reduction in brake particulates. These calculations from the OECD suggest EVs will have a more modest impact.



Brembo's Greentive brake rotors employ a special coating developed to markedly reduce rotor wear and the resultant PM emissions, the company claims. The coating also delivers a unique mirror-like finish.

Braking components supplier **Brembo** has been developing innovations to address the general sustainability of braking. A focus on foundation components such as rotors and pads with revised materials to reduce particle emissions also has, in many instances, direct benefits for fuel efficiency and maintenance costs. Some of Brembo's latest advances, in both OEM and aftermarket applications, claim reduction in brake particulate.

Their Greentive ("green" and "distinctive") brake rotor employs a proprietary coating applied by a High-Velocity Oxy Fuel (HVOF) process. The Greentive discs offer new "high technical characteristics" that significantly reduce surface wear, and the ensuing particle emissions, the company claims. Brembo doesn't quantify the reduction, but does state that the Greentive rotors' coating offers a high level of corrosion resistance, "a feature particularly appreciated in the new generation of electric cars, where the braking system is used differently."

Brembo also has a unique caliper design called Enesys (Energy Saving System). The Enesys-equipped caliper has a special spring engineered to retract the pads off the brake disc once the brakes are released, eliminating the brake "drag" that's common to most disc-brake systems.

The virtual elimination of brake drag contributes to lowering vehicle emissions because, according to the company, "it limits brake pad and disc wear, decreasing the brake dust generated by residual friction."

Braking systems supplier **Continental** also targets brake drag with its MK C2 brake-by-wire system. The MK C2's architecture supports use of "true zero-drag calipers, further decreasing emissions," according to company media material. For brake-energy regeneration,

Continental claims the MK C2 is 100% efficient.

Developed jointly with the **BMW Group**, the MK C2 went into production with BMW in July 2022. It is used across all vehicle segments regardless of propulsion architecture.

Braking supplier **ZF's TRW** brand also has a zero-drag caliper design using its low-abutment clip with active spring return. The low-abutment clip supports the roll-back function of the brake piston, ensuring that the brake pad doesn't rest against the disc while driving. This design helps avoid "unnecessary abrasion and reduces fine-dust emissions and fuel consumption," TRW claims.

Since 2019, Brembo has been involved in the Lowbrasys (low environmental impact braking system) project, a high-tech proposal that employs ceramic braking materials and filters to actively capture particulate emissions.

In the Lowbrasys, braking will be controlled by software that optimizes pad and disc wear. An app assesses driving performance in real time, "reporting whether it implies excessive brake wear, and with the recovery of the dust produced, sending it to a filtering point," according to Brembo.

Additionally, an app connected to the system assesses driving style to help operators drive more "sustainably."

Brake-PM reductions from such component advances alone may be sufficient to bring some new or existing vehicles into Euro 7 compliance, but they likely also will be paired with hybridization to achieve the necessary cuts. S&P Global's Barbalet worries, however, that new and revised pad or disc materials aimed at low emissions may affect performance in a way that's not satisfactory for some high-performance vehicle marques.

Meanwhile, if electrification and innovations in friction materials aren't enough (particularly to meet the 2035 maximum), other methods already are being explored. These include "active" particulate vacuuming and filtering systems for brake PM and even the semi-enclosure of tires to facilitate the collection of their microplastic particulates. ■



Highlights of the OECD's study on non-exhaust particulate emissions



A bottle of e-fuel developed by Karlsruhe Institute of Technology's Institute for Micro Process Engineering.

E-fueling for the future

The development of carbon-neutral e-fuels enjoyed a major boost from European regulators, but production cost and scale remain issues.

by Bill Visnic

Synthetic and bio-based liquid “e-fuels” have in various forms enjoyed fits and starts of industry attention and R&D investment in recent years. They got the most significant boost ever in March 2023 when a politically charged deal between the European Union and Germany brokered an exemption in the EU’s mandate for sales only of EVs starting in 2035. The agreement allows manufacturers to continue selling internal-combustion models after the 2035 deadline — but only if they run on carbon-neutral e-fuels.

In an instant, e-fuels were guaranteed a market all to themselves. It remains to be seen whether e-fuels — at least in their current state of technology — can answer the call. But as some supporters enthused after the EU’s escort of e-fuels into the post-EV landscape, developers have more than a decade to address technical challenges and concerns about production cost and scale.

Maybe most critically, the lifeline that e-fuels represent for internal combustion assures that IC propulsion remains at least “legally” acceptable should EVs not prove to be the expected transportation-sector climate panacea in the short-to-mid term. It remains to be seen whether other aggressive regulatory entities such as the state of California see the EU’s strategy as pragmatic or merely procrastinating. But e-fuel R&D certainly has a new mandate: Germany’s Transport Minister Volker Wissing said the new e-fuels deal presents “opportunities for Europe by preserving important options for climate-neutral and affordable mobility.”

Porsche spearheads e-fuel production

At the moment, **Porsche** is at the vanguard of e-fuel development. The brand is the majordomo of what currently is the most ambitious and mature e-fuels production project at Punta Arenas, in Chile’s Patagonian region. The site was selected largely due to the presence of strong wind an average of 270 days per year that allows windmills to operate “at full capacity.” The electricity generated from the windmills is vital to the production process’ guarantee of creating e-fuel

that Porsche pragmatically claims allows the “nearly CO₂-neutral operation of petrol engines.”

The process at the site Porsche calls Haru Oni is the manifestation of investment from a variety of partners that include **ExxonMobil** and **Siemens Energy**. The facility owner is Santiago, Chile-based **HIF Global**. The HIF process uses wind power — from a 3.4-megawatt Siemens-manufactured windmill — for electricity to obtain hydrogen from water via electrolysis.

Wind energy also powers system that captures CO₂ from the atmosphere in a direct air-capture process; the CO₂ is combined with the hydrogen obtained from electrolysis to create liquid methanol. The methanol is superheated and directed over an ExxonMobil-developed catalyst that converts it into synthetic gasoline.

“We will only meet our ambitious decarbonization goals if we factor currently existing vehicles into the decarbonization effort as well and operate them as close to net carbon neutral as possible,” said Karl Dums, senior manager and sustainability team leader at Porsche AG, in a company interview. He asserted that e-fuels are the same as petroleum-based fuels in their basic properties, but are nearly carbon-neutral.

“Porsche was one of the first companies to address the issue [of continuing the use of IC engines running on e-fuel] on political, regulatory and business levels,” Dums said. “We wanted to communicate that from the outset and create incentives for other companies to get involved.”

The pilot phase of the Haru Oni plant is earmarked to produce 130,000 liters (34,342 gal.) of e-fuel, according to Porsche. All of that capacity is directed to be used in the Porsche Mobil 1 Supercup racing series



Porsche's sustainability team leader Karl Dums displays a bottle of e-fuel.

and at Porsche's Experience Centers. Porsche, which in 2022 invested \$75 million in HIF, said it expects to hike e-fuel production at Haru Oni to 55 million liters (roughly 14.5 million gal.) and 550 million liters (145 million gal.) two years later.

In April 2022, HIF announced a site in Matagorda County, Texas for its first North American e-fuels facility. The company projected some 200 million gal. of e-fuel-derived gasoline will be produced annually when the production site, which represents a \$6-billion investment, is fully operational. Construction was scheduled to begin in 2023.

Expanding reach

The automotive sector is not the only potential target for e-fuels. There is expanding interest in the aviation and shipping sectors, both of which cannot be efficiently transitioned to electrification with contemporary battery technology.

In 2021, a **KLM** airlines flight represented what was claimed as a world-first commercial-aviation use of synthetic fuel to transport passengers from Amsterdam to Madrid. The aircraft mixed conventional aviation gasoline with 500 liters (132 gal.) of synthetic kerosene produced by **Royal Dutch Shell** in a carbon-hydrogen synthesis process similar to that of HIF.

Major automotive suppliers such as **Bosch**, **ZF** and **Mahle** are members of the eFuel Alliance industry coalition, as are oil and gas majors including **ExxonMobil**, **Repsol** and energy developers such as **Siemens Energy**. The Alliance's website indicates more than a dozen e-fuel projects are underway on five continents.

Meanwhile, **BMW** has invested \$12.5 million in e-fuel



The Haru Oni e-fuels production facility in Chile owned by HIF Global.

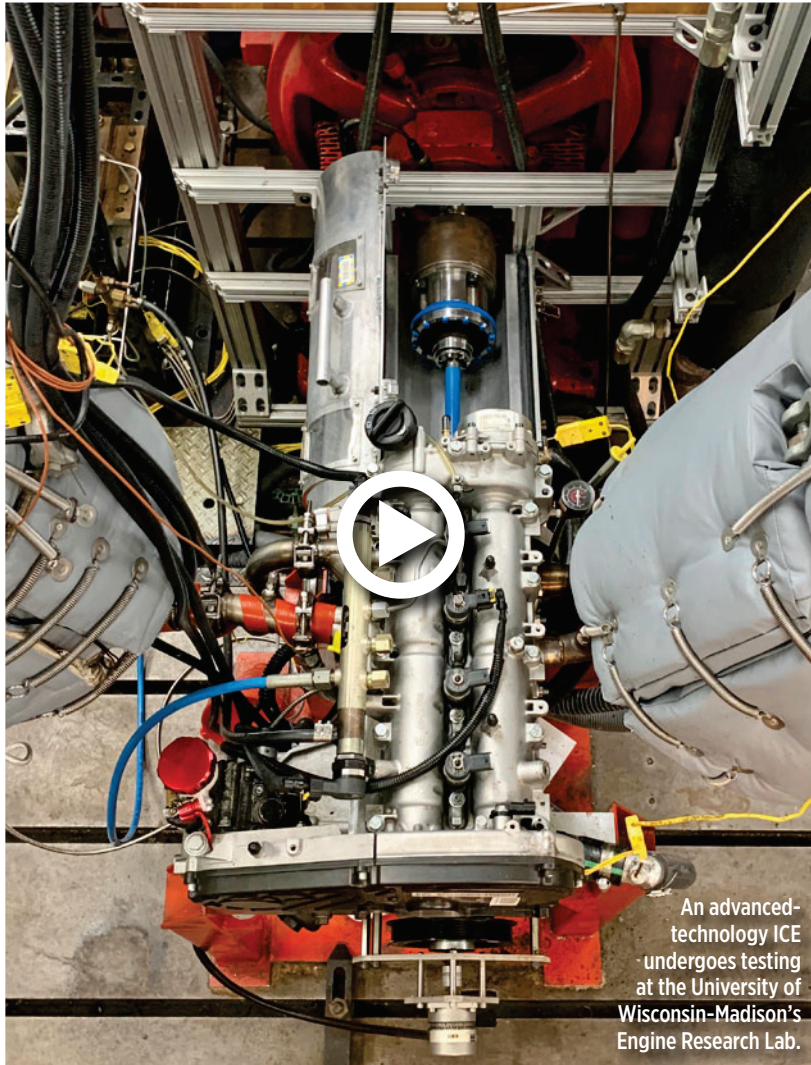


The HIF-developed e-fuels production process.

startup **Prometheus Fuels** and Germany's Copernicus Project, engaging researchers and industry to transition the country to a carbon-neutral economy by 2025. It is actively engaged in e-fuel development, largely through its P2X (power to everything) research to transfer electricity to other energy carriers. Among other things, the P2X program is trying to develop water-splitting electrolyzers that reduce or eliminate expensive iridium without sacrificing conversion efficiency that today is around 65%.

At the moment, all efuels are titanically costly and the related processes comparatively inefficient. An early stage in Copernicus' P2X reportedly requires 10 kW of electricity to produce about seven liters (1.85 gal.) per day. A near-term goal is said to be 1600 liters (423 gal.) from a megawatt (1000 kW).

Porsche's initial estimate of a cost of 10 euros per liter equates to approximately \$45 per gal. — and that is cost, not price to the end user. Fine for boutique use, but still out of practical range, even for regions with high costs for today's petroleum fuels. Scale and increased efficiencies are projected to reduce the cost by a factor of five or more, according to a Porsche executive in a public statement. The eFuel Alliance, perhaps not surprisingly endorses a 10-year tax break for hydrogen and e-fuel proposed by the European Commission to help ease initial cost stressors. ■



An advanced-technology ICE undergoes testing at the University of Wisconsin-Madison's Engine Research Lab.

Fuels to transition the global legacy fleet

The EV bandwagon has obscured potential solutions for decarbonizing the enormous global ICE legacy fleet.

by Lindsay Brooke

Put the promise of mass vehicle electrification and its myriad challenges aside for a moment, and consider: What if most IC-engine vehicle owners don't switch to EVs as the industry and regulators hope they will?

And how long will it take to alter the existing global vehicle parc, estimated at more than one billion mostly ICE-powered vehicles, to the extent its greenhouse-gas emissions are insignificant in the crusade to achieve net-zero (and thwart global warming) by 2050?

Some unavoidable truths: Simply ending sales of ICE vehicles, as some OEMs say they will do within the next decade, won't solve the vehicle-emissions challenge, analysts and powertrain engineers tell SAE Media. In the U.S., the fleet is aging steadily. The average light-duty vehicle on the street today is 12.2 years old, according to forecasters S&P Global, up from 9.6 years in 2002. Engineered to last longer than ever, the roughly 15 million new gasoline-fueled cars and light trucks sold last year are expected to survive for 20 years or more, on average, as they're cycled through successive owners. Thousands end up in foreign markets, bringing their worn valve guides and non-functioning exhaust aftertreatment with them.

Even optimistic EV-adoption scenarios concede that hundreds of millions of new ICE vehicles, increasingly hybrid-electric, will enter use worldwide by 2035 and beyond. Strategies already are being bandied by policymakers and enviro-NGOs for cleansing the global parc of its enormous piston-engine legacy. In discussion are the U.S. EPA's recently proposed tailpipe regulations, stiff CO₂ taxes, trade-in "clunker" scrapping schemes and combustion-vehicle user fees.

The question isn't whether the transition to EVs can be done; "it's how fast can it be done," the Alliance for Automotive Innovation warned in early April. The automaker trade group was anticipating the proposed EPA vehicle emission regulations for 2027-2032 and a new round of more aggressive fuel economy standards from the NHTSA, both of which are aimed at spurring the shift.

'Green' fuels

The EV may seem to be the forgone conclusion for a sustainable, carbon-free mobility future, but it's not the only, nor necessarily the optimum way forward, argues SAE Fellow Kelly Senecal, co-author (with Felix Leach) of the book *Racing Toward Zero: The Untold Story of Driving Green*. There is no 'silver bullet;' all propulsion technologies, from ICE and hybrids to BEVs and fuel cell EVs, impact the environment. Given the enormity of the gasoline- and diesel-powered vehicle parc, improving the ICE and its fuels must be a "main route on the road to zero emissions," the authors assert.

The mobility future, as Senecal and Leach see it, requires a balanced approach. It's not a matter of choosing between combustion or electrification; it's a combination of the two. "The future is eclectic," they

maintain. Using the attributes of both technologies, including low-carbon fuels, will enable the industry to achieve net-zero goals as quickly as possible.

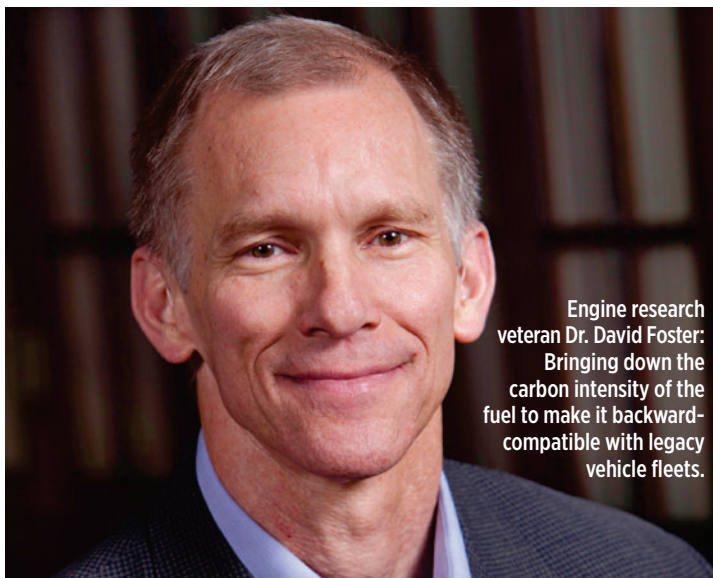
David Foster, professor emeritus at the University of Wisconsin-Madison's Engine Research Center, is one of many engineers who see logic in a multi-mode approach to CO₂ reduction. "As much as EVs as the ultimate solution are wonderful, the constraints surrounding their mass adoption — mineral resources, mining activities, charging infrastructure, battery cost — are delaying them," he said. "And that means legacy vehicles will be around even longer, exacerbating CO₂ emissions.

"EVs can be great — but they won't be great for everything and everyone," Foster observed. He and others support development and deployment of "green fuels" to help reduce the global legacy fleet's emissions footprint during the long shift to EVs. Green fuels encompass synthetic and electrofuels (e-fuels) — liquid or gaseous fuels produced with electricity from renewables and/or biomass. Examples include synthetic natural gas (SNG), green methanol and green hydrogen. Green fuels are carbon-neutral when burned, emitting only the amount of CO₂ absorbed during their production. So-called 'drop-in gasoline' contains constituents produced from biomass sources through a variety of biological, thermal, and chemical processes.

"If we look at making synthetic fuels, using the term in a broad sense, there is a very strong argument for engaging with the energy industry in doing this," Foster noted, "because the more we can make the synthetic fuels compatible with today's engines, the faster we can start bringing down the total CO₂ emission. The legacy fleet worldwide is huge," he said, and is vital for millions of vehicle users.

Foster explained that a drop-in fuel solution would be where the fuel feedstock is introduced at the refinery or is sufficiently compatible where it is added as a mixing agent after the refinery. "You'd bring down the carbon intensity of the fuel, and that fuel would be backward-compatible with legacy fleets. Those fleets are going to be around for a long, long time," he said. eFuels can be used in existing infrastructure, he added.

There is much activity in 'green' fuels in Europe and the first production plant was launched by **Porsche, Siemens Energy** and partners in December 2022 in Chile (see page 28). Interest is growing in North America, particularly in the commercial vehicle, power generation and marine sectors, and from those seeking a way to progressively mitigate the legacy fleet's fuel and emission needs. The technology's potential, Foster said, is "to progressively lower the carbon intensity of fuel. "The goal would be to make a net-zero carbon fuel, one which is a hydrocarbon —



Engine research veteran Dr. David Foster: Bringing down the carbon intensity of the fuel to make it backward-compatible with legacy vehicle fleets.

"Legacy vehicles will be around for a long time, exacerbating CO₂ emissions."

like methanol for example, but where you're getting the carbon out of the atmosphere [the Porsche e-fuel process does this]. If you were to capture that carbon and turn it around and put it into a fuel, there would be no net increase in carbon because of that fuel."

A hot topic

"E-fuels are a hot topic, offering a way for an industry undergoing enormous change to get some politically useful concessions from regulators," Al Bedwell, director of global powertrain forecasting at **LMC Automotive**, commented in a recent blog post. "But the evidence today points to e-fuels in Europe's light-vehicle sector being backed into a very small corner, or not getting off the ground at all."

Cost is a major hurdle. Making e-fuels requires renewable electricity to split hydrogen molecules from H₂O and combine it with carbon. The process at present scale is expensive and relatively inefficient; according to BloombergNEF, the current wholesale price of synthetic diesel in Europe is up to seven times that of conventional diesel fuel. Analyst Bedwell estimates retail e-fuel for light-vehicle use will remain roughly four times more expensive than traditional gasoline even as production scale increases. Meanwhile, battery technologies continue to improve, bringing down EV cost.

Multi-solutions advocate Foster remains pragmatic as he views the transition to BEVs. As the challenges of global electrification, economics, human behavior and geopolitical realities become apparent, hundreds of millions of legacy vehicles should be part of the decarbonization discussion and its quest for equitable solutions. ■



Sustainability in strong supply

Design innovation and an exclusive new tool for measuring carbon footprint have made Adient a sustainability leader among Tier-1s.

by Lindsay Brooke

Adient is investigating a transition to fully sustainable electricity to further decarbonize its operations.

Sustainability no longer is a vague aspiration for OEMs and suppliers looking for a 'green' veil. It's rapidly become a guiding tenet of product innovation, and ESG progress, as the industry pushes toward net-zero carbon goals in most major markets.

"Currently, it's coming mainly from the European OEMs and the European legislature," explained Mike Maddelein, VP engineering, Americas, at seating systems Tier 1 **Adient**. "They're driving carbon-footprint reduction and the industry is getting very, very serious about it. The European OEMs are starting to specify sustainability targets in their RFQs." North America is probably two years behind, he believes, but will follow Europe's sustainability plan — if not through direct legislation, then by the OEMs themselves.

Maddelein, a 30-year seating-systems veteran, said sustainability in product development is now determined by what he calls "specification and regulation" set by the OEMs. The Scope 1, 2, and 3 guidelines, though not mandates, are being cascaded down through the vehicle makers' supply chains. [Scope 1 relates to direct greenhouse-gas emissions from sources owned or controlled by a company, such as manufacturing plants; Scope 2 are emissions from energy a company purchases and consumes in its operations; Scope 3 emissions are those associated with a company's activities including the emissions of its supply chain.]

Adient's engineering team tracks the Scope guidelines and incorporates them in its sourcing and product strategies. He said Scope 1 and 2 account for only about 10% of the company's sustainability footprint. "The rest is all in materials," he said.

[Adient's 2022 Sustainability Report](#) is a benchmark in terms of clarity and message and provides a useful roadmap for suppliers just

entering a sustainability regimen. The company's initiatives have positioned it as a sustainability leader among interior suppliers, according to an OEM customer who spoke off the record with SAE Media. Adient's commitment to sustainability starts at the top, with CEO Doug DelGrosso and Adient VP Global Sustainability, Tammi Dukes. Engineering champions sustainability integration into product design as "one of the pillars we look at to satisfy customer requirements," Maddelein said.

That pillar plays a key role in driving innovation at the bill-of-material level, where roughly 70% of Adient's seating cost resides.

The Carbon-Footprint Tool

As the focus on sustainability expands, the industry still is without a common way of measuring and reporting carbon footprint at the component level. Adient also realized it needed a way to provide options for its customers to reduce the carbon footprint in the company's seats. Thus was born the Carbon Footprint Tool, data-based software that shows a proprietary link between product engineering, manufacturing footprint and CO₂ intensity. Developed by Adient in-house, the tool takes the full bill of materials and identifies the carbon footprint of every single part in it. This gives designers, engineers and customers a

ADIENT

Vehicle seat breakdown — 1st and 2nd row



Breakdown of a seat as shown on Adient's Carbon Footprint Tool dashboard.

view of the true carbon footprint of a seat.

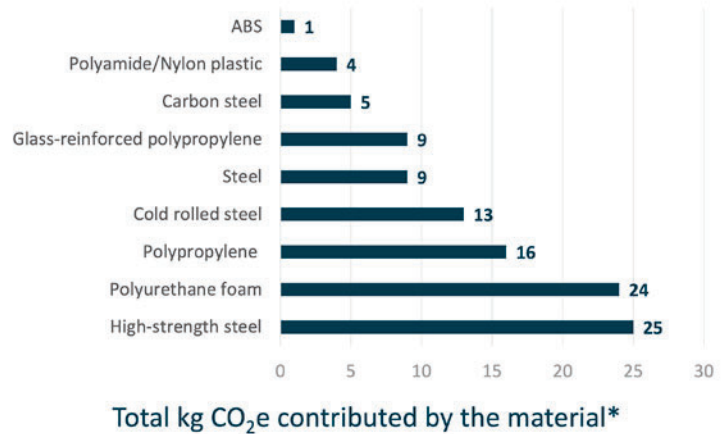
"The tool helps us make the right decisions to reduce the carbon footprint of our product portfolio," Maddelein told SAE Media. It identifies CO₂ drivers (and carbon-reduction opportunities) for each stage of the product's lifecycle: raw materials, transportation, manufacturing and assembly, packaging, and waste, and delivers specific results by commodity (seat structure, foam, trim, plastics, etc.). The tool also conforms with ISO 14040/14044 standards.

Currently, the CFT is Adient intellectual property, but Maddelein said other users, including some suppliers, are interested in it. "Right now, the industry is all over the map for how sustainability and recyclability are being interpreted," he observed. "Different companies are interpreting sustainability, recycled, and renewable in their products differently. So, we're trying to push the industry toward the common denominator of CO₂e with the tool — and we've been successful doing this in Europe."

Maddelein showed a CFT-generated carbon-footprint analysis of a lower-midrange vehicle seat set with fabric seating surface. An on-screen dashboard displayed a detailed manifest of each component and raw material in the unit, drilling far down to the Tier 4 supply level and listing the carbon content of each. The seat set weighed 70.5 kg (155.4 lb) and contained 214 kg of carbon (214 kg CO₂e). According to Maddelein, 91% of the 214 kg of carbon is in the bill of raw material.

The CFT incorporates estimates of material suppliers' carbon content using GaBi, a lifecycle analysis (LCA) database tool. "We know all the materials from

Top materials driving vehicle seat emissions



*Figures are NOT carbon intensities, but rather absolute emissions contributed by the top materials.



Mike Maddelein,
Adient VP
Engineering,
Americas.

an engineering standpoint, but what we don't get out of that from suppliers is Scope 1 and 2 — what manufacturing energy they're using to create their product," Maddelein said. "That's what we'll have to drive down into the supply base for, but it's a low percentage of the whole GHG story for us."

Green materials

"Metal, plastics, trim and foam are what make up most of our carbon footprint in seats, besides other things like wiring harnesses and switches," Maddelein explained. Reducing steel's carbon footprint in steel is all in its processing. Steel suppliers who use renewable energy offer so-called 'green steel.' And to use less of it requires new designs while maintaining occupant safety, he noted.

Lightweighting and sustainability go hand-in-hand, but there are cost,

Sustainability in strong supply

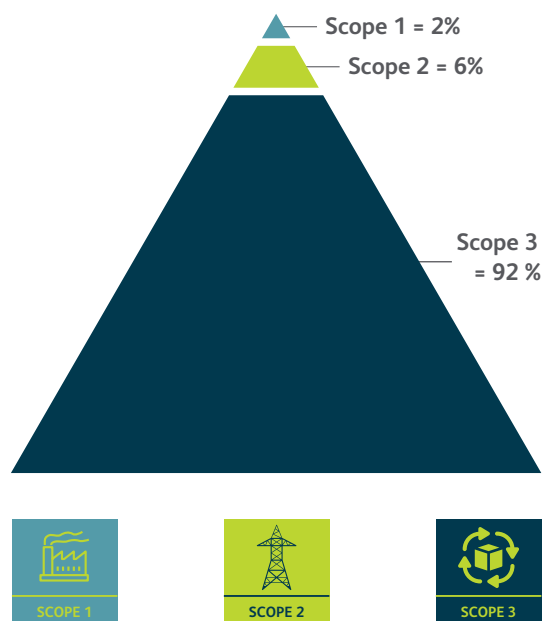


Adient calls its 2022 Altair Award-winning UltraThin seat a major shift from traditional foam and trim seat construction to cushion and back comfort panels made of recyclable thermoplastic elastomers. The thin design saves cabin space and can reduce block height up to 45mm while delivering 25kg of carbon reduction over 12.4% percent of the entire seat, the company claims.

mass, and emissions tradeoffs in the equation. Switching from a steel seat frame to magnesium, for example, can reduce weight by 40% but cost and emissions go up considerably, Maddelein said. Innovation by design is a big factor in sustainability. As an example, Adient's 'sound in seat' product puts small audio speakers in the seat headrests, which gives better more personalized sound while reducing the total number of speakers and wiring in a vehicle, saving about 8 kg (18 lb) on average and cost. Likewise, designing climate control into the seat reduces HVAC power demand by cooling the occupant using convection, not conduction.

Epitomizing the importance of product design to sustainability, Adient's new UltraThin seat features a 100% recyclable thermoplastic that serves multiple duties. It replaces the suspension in the seat, incorporates all attachment points for the trim and integrates the vent and lumbar systems. "The Ultrathin design uses the product itself as the seat 'basket' and integrates as many components as we can to eliminate parts for sustainability," Maddelein explained. "That reduces cost and time to manufacture, which is my Scope 2. And I can recycle Ultrathin and put it back into the exact same product at about 40% cost." It also reduces the amount of foam in the seat while maintaining comfort, creating space to increase battery capacity by 3-10%. The

Total CO₂e Emissions Makeup by Scope Fiscal Year 2022



Product materials BoM accounted for most of Adient's 2022 Scope 3 emissions profile.

seat has not yet entered production and has attracted four OEMs, Maddelein said.

Polyurethane-based foams as used in seat cushions have long been an R&D focus of seat suppliers, as it is difficult to recycle and typically ends up as shredder residue after a vehicle is scrapped. Adient and its suppliers are studying new chemistries, including industrializing polyols with recycled CO₂ content. In 2019 Adient and Dow jointly developed Specflex, a new seating low-carbon-footprint foam product.

"Each OEM has a different focus on sustainability for seats," Maddelein noted. **Ford**, for example, believes it can meet its interiors targets by specifically focusing on foam and plastics, he noted. Ford is targeting 15-20% renewable plastics and 20% recycled and renewable foam by 2025 but has not yet provided details.

Sustainable plastics is another area of development at Adient, whose innovations include new 'soft' materials such as polyethylenes (PET) replacing hard polypropylenes (PP) for seatback panels and side valences. "The plastics industry is stepping up with new blends and fillers, hemp being a new idea," Maddelein said. And new vinyl blends and BIO-polymer rolled goods that give "premium appearance and lower cost" are replacing cowhide as OEMs move away from leather.

BOTH IMAGES: ADIENT

North America will follow Europe's sustainability plan — if not through direct legislation, then by the OEMs themselves.

Getting the sub-tiers on board

In general, the march to sustainability has been inconsistent for many Tier 2, 3 and 4 suppliers. "Some of them are ready for Scope 1, 2 and 3; some are not," Maddelein said. "But to be truly effective, it has to permeate through the supply base. As the OEMs start driving requirements down into component supply, we're going to have to do the same with our supply base. We realized early on that we had to get to this point," he asserted.

Maddelein cited the IMDS requirement as an example of how the entire supply chain previously came together for a common goal. The International Material Data System is an online database used by the auto

Adient's sustainability progress

According to the company's recently released 2022 Sustainability Report, Adient had reduced its global Scope 1 and 2 absolute CO₂e emissions by 25%, and its Scope 3 absolute CO₂e emissions by 12% as of Sept. 30, 2022, compared with base year 2019. The supplier's emissions targets — a 75% reduction in absolute Scope 1 and 2 emissions at its manufacturing plants by 2030 and a 35% reduction in its Scope 3 emissions by 2030, were validated by SBTi. The report showcased recent sustainable innovations, including the Altair Award-winning UltraThin seat and related components.

Lindsay Brooke

industry to manage information on materials and substances used in vehicles. It was developed in 2000 to comply with environmental regulations such as the EU's End-of-Life Vehicles directive and the Restriction of Hazardous Substances (RoHS) directive. To comply with the regs, OEMs needed detailed information about the composition of materials used in their products.

IMDS currently includes at least 62 global OEMs and now is standard practice. "We all just do it," Maddelein stated. "Sustainability will eventually follow a similar scenario." ■

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HONDA'S H₂ PROGRESS

CASE VP Jay Joseph outlines dramatic cost reductions in fuel-cell systems, the move into stationary power, and new models for mobile and residential energy.

by John Dinkel

Is the long-promised “hydrogen economy” still 15 years away, as it reportedly has been for... more than 15 years? Or is it just around the corner? SAE Media traveled to **Honda's** U.S. campus in Torrance, California, to see the company's latest progress. This was the introduction of Honda's zero-emission stationary fuel-cell power station, which now is in service as a backup power source for the company's data center.

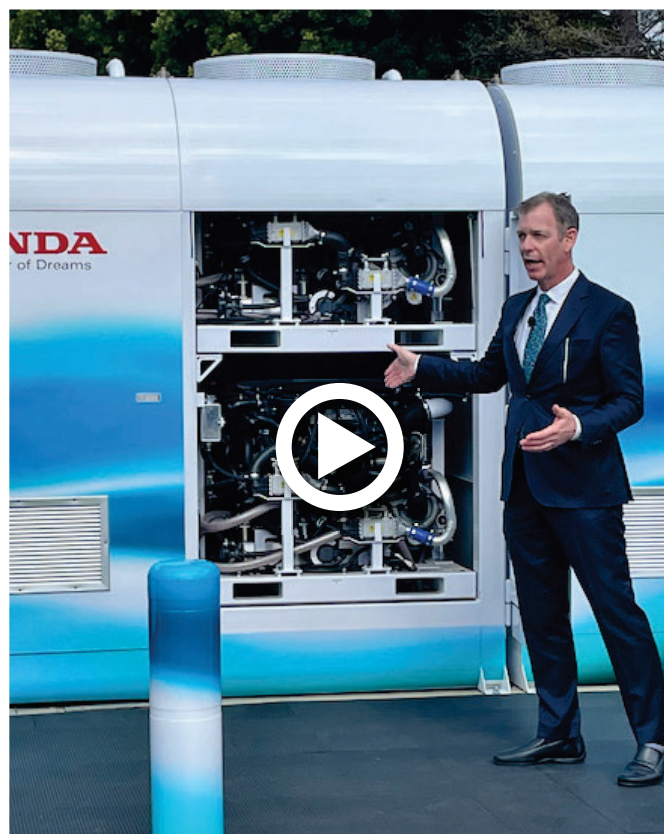
Honda's FCX was the world's first production fuel-cell vehicle when it debuted in 2002. Since then the company's hydrogen developments have continued. Honda began collaborating on fuel-cell systems in 2013 and the two OEMs share a fuel-cell manufacturing joint venture. The Torrance event also presented the opportunity to speak with Jay Joseph, Honda's VP of Connected, Autonomous, Shared and Electrified (CASE) technologies. Our interview began with a focus on the new fuel-cell power station, which repurposes fuel-cell stacks from Honda Clarity FCVs and has an approximate generating capacity of 500 kW. Highlights of our conversation follow.

Do the stacks eventually wear out, like batteries?

Part of what is going on inside the stack is a catalyst reaction. There are seals that operate under pressure, so there is a wear component over time.

Can the stacks be recycled?

Yes. It's expensive, but there are precious metals and other materials used in the manufacturing of a fuel-cell stack and in theory all of that material could be recovered. In practice, most of it can be recovered now and we are working on pathways to make them 100% recyclable. Stationary fuel-cell power is a secondary use for a good fuel cell, so if a vehicle runs the course of its lease and there is some reason the vehicle wouldn't continue in service, absolutely, we can take a good fuel cell stack and put it into a stationary use. We actually did the hard part first.



Honda CASE VP Jay Joseph unveils the new stationary hydrogen fuel cell power station at the company's Torrance, California, campus.

How so?

Mobile use is much more complex than stationary use because you have to make the cooling and everything else compact. And the management system has to be more compact so that it can fit into a mobile application like a car. Working on a stationary system is much easier because all the inputs can be controlled. We actually did the hard part first. So, the Clarity fuel cells are a very good system to apply in a stationary setup.

Could this technology be downsized for home use? And not just for backup, but for primary power?

Yes, it could. For a typical U.S. home, 500 kW is probably too much, even for peak energy demands, and you would probably have a battery for offsetting peak usage. But theoretically you could. This is a pretty big system for a home. I think it would make more sense for a neighborhood or a community. Theoretically it's possible, but there is more work to be done to get more energy out of a system like that to supply several homes. The home would have to be relatively efficient to begin with.

Even with a Tesla Battery Wall you can't power a whole house for an extended period.

Yes. You're not necessarily home during the day when you've got sunshine. And then you're still dependent upon good weather and other factors. And when you're home at night, there is no solar, so you're not producing any energy. So, let's say that 40 to 50 years from now, it probably would not be one solution but multiple overlapping solutions that would provide

DINKEL



The new stationary power station repurposes fuel cell stacks from Honda's Clarity FCV.

energy in an area to a group of homes.

Clean energy created in a neighborhood because you are using the excess renewable energy from solar or wind or other sources; hydro if you are living near the Columbia River. It depends upon what is available and what makes sense in that area. But hydrogen can act as a battery because you can produce it with low-value electricity and then you've got it whenever you need it. It can be used like an energy store.

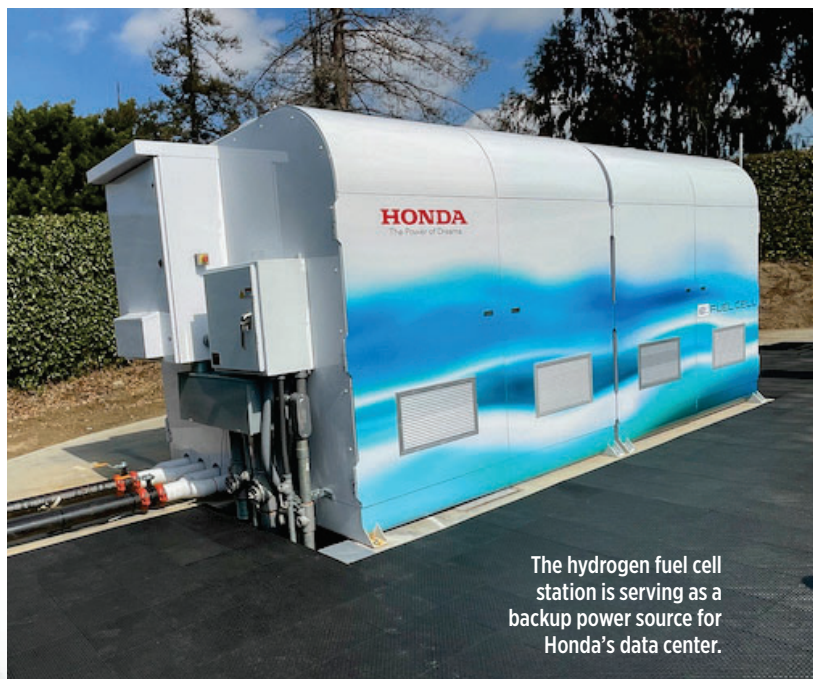
What does a system like that [the Honda installation] cost?

We're not talking cost.

Is it less expensive than battery backup from solar panels, for a house for instance?

We can't compare it to that yet. But what I can give you is some dimensionless comparisons just for a sense of scale. Just for a sense of direction, our next generation fuel cell system, the one in the Honda CR-V we will sell about a year from now [early 2024] will cost about two-thirds less and be twice as reliable as the fuel cells in this system from the Clarity.

The generation we bring to market at the end of this decade will be half-again that cost and twice as



The hydrogen fuel cell station is serving as a backup power source for Honda's data center.

reliable again. So, we're improving the performance and reducing cost dramatically.

If I had a Ford F-150 Lightning, I could plug it into my house in times of emergency. Could I plug a Clarity into my house?

We're a little early to talk about it, but probably not a whole house yet. But theoretically, yes. We'll share more detail about how we are approaching that as we get closer to the launch of the CR-V plug-in FCEV early in 2024. There are exciting new features coming that will contribute to people's lives in new ways. We have to wait until closer to next year to talk about that.

Are you planning on producing hydrogen using electrolysis?

No. What we are trying to do is create an ecosystem with partners. We don't want to, short term, enter the hydrogen-production business. We want to create demand that makes it an attractive investment for others to do. We have invested in **First Element Fuels** as a hydrogen distributor now. We haven't tackled the hydrogen-production challenge yet — it needs to be addressed. We're focused more on the solutions and working with partners who will help us deliver 'green' H₂ ideally, but we are not creating the technology for production yet.

Perhaps hydrogen is a more realistic solution than batteries.

Batteries have come a long way. Charging will improve as we get to 350-volt systems. We will increase the throughput of the charging systems and improve the battery technology so that it can receive energy faster. It's getting better — but it's still not good enough. There are some very promising technologies. We're working on solid-state batteries that are highly recyclable, with faster charging times and better energy density, but that's still down the road.



Fuel cell vehicle refueling station installed earlier at Honda's Torrance facility.

If you've got a "gas" station with cars expecting to fill up with "electricity" in five minutes, you are going to need a generation plant somewhere close that's going to be providing all the electricity those cars will require.

This is a multiple-variable equation, and it's not a simple equation. One, battery electric cars will all have 80 kWh or larger batteries. Let's say 80- to 120-kWh batteries. Where I'm headed with this: We will have high-range vehicles with high-capacity batteries, yet our driving behavior will not change dramatically. Most trips will be less than 25 miles, which means we can look at the batteries in vehicles as an energy resource we can manage throughout the day. Once we have bi-directional charging, which is only a couple of years away, we're almost there. That's on the foreseeable horizon.

Once we can use energy that goes in and out of those vehicles frequently, we've got a situation where cars are not drawing demand at

"There are exciting new features coming that will contribute to peoples' lives in new ways."

the worst times and are contributing energy to the grid system at the best times. Our relationship with energy for the last 100 years has been: I put gas in a big hole in the side of the car that gets pumped through a pipe to my propulsion unit that carries me and the other occupants in the car and whatever cargo I have. That gas has one energy value: It has the value of the energy when I pumped it into my tank and only that value.

Electricity is very different. We have to change our relationship with energy for mobility dramatically, because our electricity value fluctuates throughout the day. We can arbitrage that on behalf of our customers if we're managing that energy and if they trust us a little bit. We can now put money in their pocket by saying, hey, I want you to charge overnight when you're taking excess grid energy. And I want you to charge during the day when the sun's shining and nobody's using electricity. Top off your battery. You tell me what your comfort level is. I'm going to leave you margin and I never want to take away from your mobility.

You want to be able to go to lunch on a whim or you want to make sure you can pick up your kid from soccer practice. You figure out what margins you need and you let us manage the rest of that energy remotely from somewhere else, and we're going to put money in your pocket every day. And we're also going to reduce peak demand, because we're going to supply energy to the grid when it's needed. And we'll use that low-demand energy to top off those batteries.

Just imagine how different our relationship with energy for mobility is in that circumstance. From our perspective we have, as an industry, said to our customers for 120 years, 'Thank you for buying a car. Now you go pick your energy source.'

We don't have to do that now.

Now we can have a relationship with our customers where we help them manage their energy needs throughout the vehicle life. We can put money in their pocket. We can offset the cost of ownership.

There are so many things we can contribute to our customers' lives if we earn their trust. ■

Scaling the solid-state battery FEST

Start-up battery developer [Factorial Energy](#)'s workforce of engineers, chemists and other technology specialists has topped 100 with recent hirings in the Asia-Pacific region. A pilot manufacturing plant for the firm's solid-state lithium-metal batteries is slated to launch later this year. And, **Hyundai Motor Co.**, **Stellantis** and **Mercedes-Benz** have invested in the Woburn, Massachusetts-based company and its proprietary Factorial Electrolyte System Technology, trademarked FEST. CEO Siyu Huang recently spoke with SAE Media's Kami Buchholz. Condensed highlights of the interview:

What are the targeted benefits of FEST?

Our technology has three major attributes. Number one is energy density. We're delivering approximately 20 to 50 percent higher energy density compared to today's lithium-ion manufacturers. Number two is safety. All of the prior recalls due to battery safety situations have taken a toll, so we've put substantial emphasis on battery safety. Number three, our system is highly compatible with today's lithium-ion manufacturing process, which means we will be able to save in development costs and bring this technology to market faster.

How does FEST differ from today's Li-ion batteries?

With an up to 50 percent energy density improvement versus traditional lithium-ion, that can translate to a substantially higher driving range compared to existing electric vehicles. We have 60-plus patents and patent applications on file. The patents and pending patents address material technology, cell design and the cell manufacturing process.

There are a lot of unique attributes in the solid-state materials. With a traditional lithium-ion battery, the liquid electrolyte is very volatile and more flammable between 60-75 degrees Celsius. For our system, the electrolyte is not flammable until at least 200 degrees Celsius. So that makes the system inherently stable from a material perspective, and it's also armed with a novel cell design and manufacturing process. FEST has been successfully scaled in 40-Amp-hour cells at room temperature. The long-term goal is for FEST to be scaled in 100-Amp-hour cells.



Siyu Huang, CEO of Factorial Energy.

“Our development partners are helping us bring the cells to the module level for vehicle integration.”

What are key aspects of the pilot plant?

It's a very sizable plant, 60,400 square feet. In the initial phase, we plan to produce about 300,000 pouch and large format cells per year. Our up to 200-MWh facility in Methuen, Massachusetts, will have a manual assembly line and a semi-automated pilot production line. We expect to be operational in 2023.

What about the production equipment?

Most of the equipment will be similar to what's used today for Li-ion manufacturing. Probably less than 20 percent of the equipment will need to be modified to accommodate our proprietary process. Equipment modifications require a lot of internal engineering, and we have a great engineering and technology team. We've recruited many talented people with extensive battery experience. Our leadership team also has extensive experience in the automotive and battery industries.

Talk about the value legacy automakers bring to a start-up.

Mercedes-Benz, Stellantis and Hyundai are really good partners. They bring a lot of support from organizational, investment and business perspectives. Our joint development partners have provided a combined \$200 million investment, giving us a substantial cash flow for pilot production capabilities and our core engineering work force. Our development partners are helping us bring the cells to the module level for vehicle integration. And they're helping with many other things, such as the supply chain, government relations and sustainability factors. We're really grateful to have their strong support. ■



Factorial Energy's 40-Ah battery cell uses the company's FEST.