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Lightning in a Bottle Again: The Return of the Electric Car in America

by Gary Witzenburg

A century after its initial heyday, the electric car is igniting a spark of interest again despite some nagging challenges.

The electric car, which once enjoyed fairly broad patronage in America before giving way to gasoline-engine vehicles, is staging a limited comeback these days. This revival comes as no bolt from the blue, however. It has reached fruition only after decades of slow, sometimes frustrating, research; a changing ethic among some motorists; and, for better or for worse, the growing involvement of government.

Electric-vehicle (EV) sales peaked in the early twentieth century, then faded quickly. Improving road systems, increased fuel availability, and rapid advancement in mass-production techniques rendered gas-powered vehicles more practical and less expensive than the range-limited electrics from small-volume producers. Meanwhile, Hiram Percy Maxim's 1897 invention of the exhaust muffler and

Charles Kettering's 1912 electric starter made gas cars easier and more pleasant to operate. Not surprisingly, the demand for electrics fell to next to nothing.

Decades passed before World War II fuel shortages, especially in Europe, prompted a few fledgling efforts there and elsewhere. Postwar efforts for electric cars would focus on improving battery technology and developing small, light cars that would reduce power needs in order to increase driving range.

In 1947, Henri Andre of France developed a silver-zinc battery that, by the Fifties, allowed him to power a Panhard Dyna that could range 120 miles at 50 mph. Many more combinations of battery elements would be tried in coming decades with varying degrees of success. In 1959, American Motors Corporation and Sonotone Corporation experimented with an electric car powered by fast-charging sintered-plate nickel-cadmium batteries. That same year, Nu-Way Industries showed a prototype EV with a one-piece plastic body.

Still, the quickest way to get an electric car on the road in this period—and many

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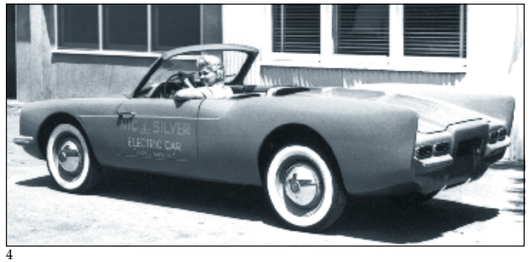

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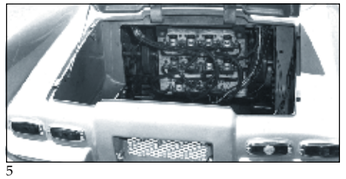

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Though tamped down by the Twenties, interest in electric cars never fully went away. *1, 2.* The 1959 Charles Townabout had an electric motor in a befinned fiberglass body molded from a Volkswagen Karmann-Ghia. *3-5.* The 1959 Pioneer was built by the Nic-L-Silver Battery Company, which was looking for a solution to the limitations of lead-acid batteries.

tried—was to rely on power generated by the heavy lead-acid (PbA) batteries that had served the pioneering-era electrics. The Charles Townabout, produced by Stinson Aircraft Tool & Engineering Corporation, used four 12-volt car-type batteries to fuel its tailfinned fiberglass adaptation of the Volkswagen Karmann-Ghia on an aluminum chassis. The National Union Electric Company, maker of Exide batteries, and Henney Motor Car Company, formerly a supplier of specialty bodies to Packard, teamed up to create the Henney Kilowatt. These were simply Renault Dauphines converted to electric power in 1959-60—not a half-bad choice considering that Renault was then the second-best-selling imported brand in the U.S. The 1960 72-volt version was good for almost 60 mph and 60 miles of range. One hundred Kilowatts were built but just 47 were sold initially; subsequent owners of the remaining cars were still advertising them for sale well into the Seventies.

As in electrics' pre-World War I heyday, light commercial vehicles were another prospective market. In 1964, Battronic Truck Company, a joint venture of the Boyertown Auto Body Works in Pennsylvania, Smith Delivery Vehicles, Ltd., of England (where there was also quite a history with electrics), and Exide, delivered its first electric truck to the Potomac Edison Company, a Maryland utility. It was capable of just 25 mph with a range of 62 miles and a payload of 2500 pounds. Smith and Exide pulled out of the venture within a few years, but Battronics continued to be made.

In 1966 , the U.S. Congress passed a bill recommending the use of EVs to reduce

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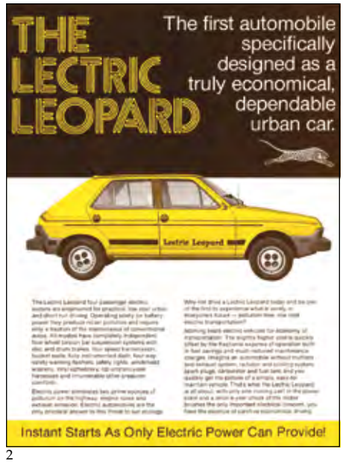

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air pollution. A Gallup poll around that time indicated that millions of Americans would be interested in using electrics.

While they had made their fortunes on the production of cars and trucks with internal-combustion engines, the major American automakers were cognizant of these developments. They had, in fact, been doing some EV research for a number of years.

Ford Motor Company President Arjay Miller revealed in 1966 that company engineers had developed a light sodium-sulphide battery that, reported *Motor Trend*, "has a cruising range equal to a 'tank of gas.'" Meanwhile, in England, Ford developed a prototype minicar called the Comuta.

Also in '66, General Motors rolled out the Electrovair II, an electrified Chevrolet Corvair four-door hardtop. It differed from the Electrovair I, built from a '64 sedan, by adopting silver-zinc batteries and improved system controls. It delivered good performance and up to 80 miles of range, but the batteries were expensive and short-lived. In a 1968 report on EV developments, *Motor Trend* noted that the Electrovair project led to the first motor designed specifically for use in an electric car, a 100-horsepower alternating-current unit.

A concurrent GM project, the Electrovan, was likely the world's first fuel-cell

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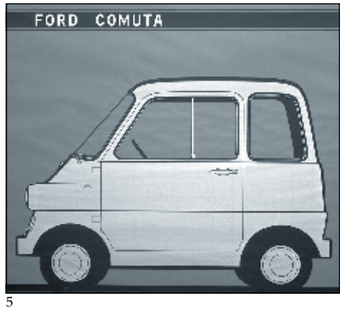

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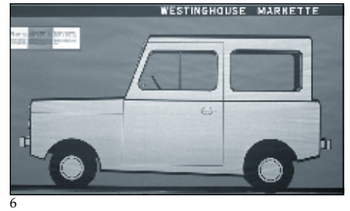

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1, 2. Some small electric-car producers packed batteries in existing compacts like the Renault Dauphine-derived Henney Kilowatt (1, renamed in a 1975 ad) and the Fiat Strada-based Lectric Leopard (2). *3.* The big car companies were paying some heed, too. AMC's Amitron prototype generated headlines. *4.* The Amitron had staying power. In '77 it was revived as the Electron. *5, 6.* In '67, General Motors was weighing the experimental EVs of other manufacturers. *7.* The electric car's finest hour in the Seventies came on the moon.

electric vehicle. A compact GMC Handi-Bus was gutted to make room for a massive 550-pound five-kW Union Carbide fuel cell—super-cooled by large tanks of liquid hydrogen and liquid oxygen—and 550 feet of piping. All this barely left room for a driver and one passenger, but reactions in the fuel cell powered electric motors that allowed the Electrovan to reach 70 mph with a range of 120 miles.

In 1969, GM completed the 512 E Urban Electric, a tiny two-seat prototype just 86 inches long and 56 inches wide on a midget 52-inch wheelbase. Its Delco-Remy lead-acid battery pack delivered 84 volts to a direct-current-series motor for a range of 58 miles at 25 mph.

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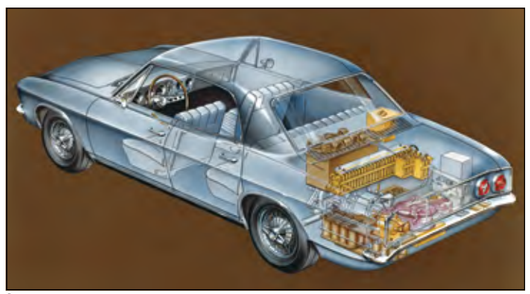

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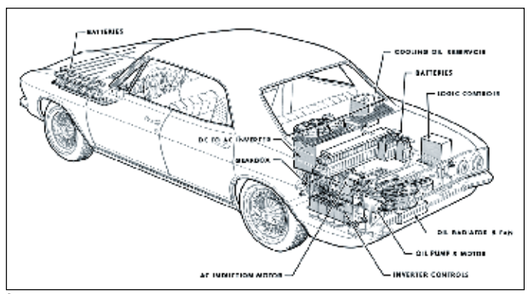

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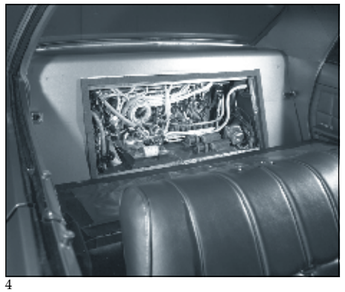

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1. GM turned a couple of Chevrolet Corvairs into electrics to study battery characteristics and power-regulation problems. The first was built around 1964. *2-5.* It took a cargo hatch full of batteries to power the 1966 Electrovair II. With costly silver-zinc batteries and improved system controls, the Electrovair II had an effective range of up to 80 miles on a charge.

AMC, working with Gulton Industries, announced the Amitron "city car" prototype in 1967. Eighty-five inches long and rolling on eight-inch wheels, the wedge-shaped Amitron was powered by a combination of nickel-cadmium and lithium batteries, both of which had different desirable characteristics. It was the first U.S. electric to make use of regenerative braking, in which kinetic energy from stopping is used to recharge the battery, and it had and an impressive range of 150 miles at 50 mph. Two years later, AMC had an electric Rambler station wagon running on nickel-cadmium batteries.

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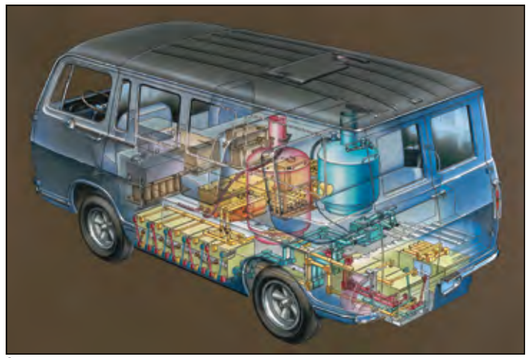

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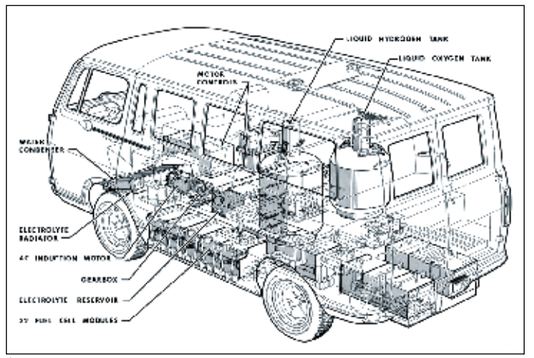

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1-3. At around the same time as the Electrovair project, other GM engineers packed a GMC Handi-Bus with the workings of a hydrogen fuel cell, likely the first such application in a motor vehicle. *4-6.* Chemical reactions in the fuel cell generated electric energy that drove the specially equipped van to as much as 70 mph and a range of 120 miles.

During the Seventies, rising oil prices—particularly after the 1973 and 1979 fuel shortages—and growing concern about air quality combined to increase interest in EVs. In 1976, Congress passed the Electric and Hybrid Vehicle Research, Development and Demonstration Act to spur development of batteries, motors, and other EV components.

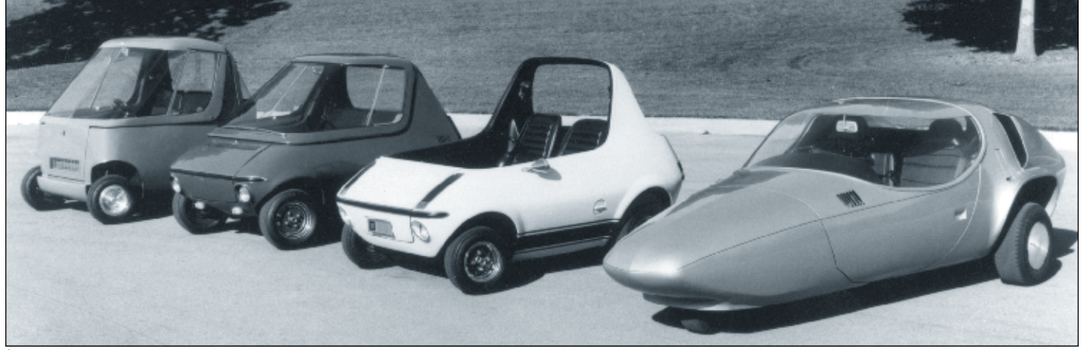
Ironically, the most famous electrics of the decade had nothing to do with the concerns of this world. They were the four Lunar Roving Vehicles developed by Boeing and Delco Electronics for the Apollo 15, 16, and 17 missions (plus one for spare parts) in 1971 and '72. Two 36-volt silver-zinc potassium-hydroxide nonrechargeable batteries and a DC drive motor in each wheel provided power. The first three are still on the moon.

Still, it was a busy period for experimentation and dissemination of EVs. In 1972, Victor Wouk built a gas/electric hybrid from a 1972 Buick Skylark provided by GM for the 1970 Federal Clean Car Incentive Program. The following year, Battronic and General Electric built the first of 175 electric utility vans and 20 passenger buses they would produce between then and 1983.

From 1974 to 1977, about 2300 tiny doorstop-shaped two-seat Vanguard Sebring Citicars were built in Sebring, Florida. They could run up to 44 mph with a 50-60-mile range. Then Commuter Vehicles, Incorporated bought the design, renamed it Comuta-Car, and made an estimated 2144 more from 1979 to '82—including some Comuta-Vans for the U.S. Postal Service (USPS).

With an immense fleet of vehicles burning fossil fuels, the postal service had a vested interest in seeking ways to reduce petroleum use. In 1975, AMC's AM General Division produced 350 Jeep EVs with a 50-mph top speed and 40 miles of range at 40 mph for a USPS test program.

Meanwhile, thoughts of electric cars for the general market continued to percolate in Detroit. In 1976, GM converted a subcompact Chevrolet Chevette into a prototype EV, the Electrovette, with a top speed of 53 mph and 50 miles of range at 30 mph. It was considered for production



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as a hedge against potential future fuel shortages and much higher prices, but ultimately not approved. In '77, AMC showed the Electron, an update of the Amitron from a decade earlier.

Very few of these EV efforts reached production, and none found sales volume or profitability due mainly to the persistent bugaboos of high battery cost, limited speed and range, and long recharge times. For September 1979, *Motor Trend*, in yet another of its checks on the state of the electric automobile, listed several promising battery types but had to concede, "At present, the lead/acid battery is still the best storage system. . . . It provides a reasonable range, recharges easily and has a fairly high recycle rate and low initial cost."

One of the possible alternative sources of electric power under study turned out to be the sun. In 1987, the GM Sunraycer—jointly developed by General Motors, Hughes Aircraft (which GM had purchased in 1985), and California high-tech research firm AeroVironment—handily won the world's first race for solar-powered electric cars across Australia.

However, before the decade ended, there came a major development in the story of the electric car in America. In 1988, CEO Roger Smith announced that GM would fund research to create a practical electric car and partnered with AeroVironment to develop a prototype.

The result was a bullet-shaped, two-seat EV concept called the Impact, which bowed in January 1990 at the Los Angeles Auto Show. It zipped from zero to 60 mph in eight seconds, and achieved a remarkable 125 miles of range in one test under ideal conditions at GM's Mesa, Arizona, proving grounds. So positive were press and public reactions to it that Smith announced at the National Press Club on April 22—Earth Day—GM's intent to produce such a car.

Nineteen ninety was the year Congress passed amendments to the Clean Air Act

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1-3. A GM exhibit in '72 displayed vehicles with multiple alternate power technologies (1), including the all-electric 512 (2) and the XP-833 (3) with electric or gas/electric-hybrid possibilities. *4.* In the period between Seventies gas crises, an Electovette version of the Chevrolet Chevette subcompact was eyed for a time. *5.* The EXAR-1 with lead-acid batteries and a Frua design got to this prototype stage.

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that included support for development of "alternative-fuel" vehicles including EVs. However, even before those measures were signed into law in November, the California Air Resources Board (CARB) issued a mandate that required the seven top-selling automakers in the state to make a portion—two percent starting in 1998, ramping up to 10 percent by 2003—of their California sales "zero-emissions" vehicles (ZEVs). What CARB hadn't quite worked out was how it was going to guarantee buyers for all these vehicles, but the terms of the mandate made it pretty certain that the cars and trucks would have to be electrics.

Each affected automaker developed at least one prototype: Ford Ranger and Chevrolet S-10 EV pickups, Chrysler TEVan, Honda EV Plus hatchback, Nissan

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1. Another General Motors styling study from 1983 for a potential nickel-zinc-battery car. *2.* The GM Sunraycer soaked up solar energy. *3.* In the Nineties, Ford built a small test fleet of Ecostar delivery vans to test a problematic sodium-sulfur battery. *4.* More practical was the Ford Ranger EV pickup, built to meet California emissions mandates. It used lead-acid batteries.

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Altra EV miniwagon, Toyota RAV4 crossover, and the Impact. Some eventually reached very limited production, and some came with nickel-metal-hydride (NiMH) batteries that doubled energy storage compared to lead-acid but at much higher cost. Only the Impact—later renamed EV1—was purpose-built as an electric car from its tire patches up.

In August 1990, Robert Stempel succeeded Smith as CEO. Stempel assigned Ken Baker, then head of Advanced Vehicle Engineering for GM's Chevrolet-Pontiac-Canada group, to lead the production-EV effort. Baker was wary; he had been chief engineer for the Electrovette program and was reluctant to take on this huge new challenge until he was convinced that GM leadership was committed to it.

"We recognized the obvious shortcomings of EVs," he said years later. "Our plan was to be battery agnostic, take the best available, and focus on engineering the world's most-efficient vehicle, which would give dramatically better performance once a better battery came along. The goal was to do a new car in a new way and see how quickly and efficiently we could do it."

But on December 7, 1992, with GM bleeding money and borrowing to make its payroll due to a severe business slump, Baker emotionally told his 400-member team that the program was being shelved after 27 months of hard work. While nearly everyone inside and outside the company wrote the EV program off, a core team of about 100 engineers relocated to a facility in Troy, Michigan, and continued working on it in virtual secrecy. Baker, promoted to vice president of research and development the following April, kept the effort alive under his auspices.

Then, in March 1994, with the corporation's finances recovering, new CEO Jack Smith (no relation to Roger) and GM's board of directors appointed head corporate-strategy executive Bob Purcell to revive the production-EV program. One key factor influencing that decision was a series of rave reviews from the previous year's press drives of early "proof of concept" cars [see sidebar]. Purcell's mission was to make EVs a sustainable and profitable part of GM's product program. The plan was to lead the industry in EV technology and sell it to other automakers that chose not to invest billions of dollars to develop their own.

The EV team became GM's Advanced Technology Vehicles (ATV) Division and began restaffing. "There were two fundamental challenges," Purcell said. "Technical feasibility: Can you make it work? And commercial viability: Can you make it at a cost that people can afford and shareholders can get returns on their investments? Those two themes ran through everything we did." His business case that won approval that June was for a first-generation car with PbA batteries for 1996 and a more-advanced gen-II car with NiMH for 1998.

Because its 1175-pound pack of 27 advanced PbA batteries—26 for propulsion and one for accessories—held the energy equivalent of just a half gallon of gasoline, the production EV1 would have to be an incredibly efficient teardrop-shaped two-seater to achieve even barely acceptable range. It was.

ATV engineers rethought and, in many cases, redesigned virtually every element of the modern automobile. Every part and subsystem was exhaustively optimized for weight and energy efficiency, a process that led to such breakthrough technologies as the first automotive heat-pump heater/air conditioner, electrohydraulic power steering, power-blended electrohydraulic regenerative braking, and an astoundingly low aerodynamic drag coefficient of 0.19. "In every way," Purcell said, "that car was the ultimate statement of energy efficiency," though analysis showed stretching it to accommodate four passengers would have reduced its modest range some 25 percent due to added weight and aero drag.

Even with standard traction control; cruise control; AM/FM/CD/cassette audio; antilock power brakes; tire-inflation monitoring (EV1 was GM's first production vehicle with no spare tire); power windows, mirrors, and steering; and dual air bags, the car's total weight with battery pack was just 2970 pounds. Its aluminum structure—162 pieces bonded together with aerospace adhesive, spot welds, and rivets—accounted for less than 10 percent of that total. Exterior panels were dent-resistant corrosion-proof composites.

Powered by a 137-bhp three-phase AC induction motor through a dual-reduction gearset, it delivered strong, smooth performance (like the Impact concept, about eight seconds 0-60); an energy-saving electronically limited 80-mph top speed; and respectable ride and handling on its narrow 50-psi low-rolling-resistance tires. Gently driven in warm ambient temperatures, it could manage 50 to 70 miles of real-world range—more if "hypermiled"—and it could be fully recharged in three to four hours using GM's innovative all-weather "inductive" charging.

Everyone at ATV understood that demand for an expensive two-seater with very limited range would not be strong. But they also knew from a 1993-94 "PrEView Drive" program, which put 50 Impact prototypes into consumer use for three months at a time in 12 U.S. cities, that people loved the cars and learned to live with their limitations. Market research showed that most daily commutes were well within EV1's range, and it would be most households' second, third, even fourth vehicle, with other vehicles used for longer drives.

They also knew that long-term success would depend completely on better battery technology. The '99 EV1's expensive available NiMH battery pack held nearly twice the PbA pack's energy, stretching its range to a still-limited 100-140 miles. Unfortunately for the program's future, lithium-polymer units being developed by 3M Corporation and others that promised gasoline-competitive size, weight, cost, and range never panned out.


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For several reasons, including limited production volume due to component (especially battery) availability, unacceptable cold-weather range, and very limited public-charging opportunities offered by cooperative electric utilities, EV1s were marketed at first only in Los Angeles and the Arizona cities of Phoenix and Tucson. Two more cities, San Francisco and Sacramento, California, soon followed, but the optional '99-model NiMH batteries were not offered in Arizona because, at that very early stage of their development, they performed poorly in hot weather.

Just 500 of the high-priced, low-range, two-seat 1997 EV1s were built, and 400 leased. That dismal performance was followed by about the same numbers of '99


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1-4. In 1988, General Motors GEO Roger Smith said the company would work to create a viable electric car from scratch. The result appeared in 1990 as the Impact. The beetle-like two-passenger car was capable of up to 125 miles on a charge under ideal conditions. *5, 6.* Ultimately, a run of 50 Impacts, with their centrally aligned battery packs, were built by hand for a test program that let members of the public drive them for a three-month period.

cars (there was no '98 model), some with optional NiMH batteries. At that point, GM gave up and pulled EV1's, ahem, plug. Lacking sufficiently practical and affordable battery technology, plans for EV2 and EV3 cars were also scrapped. Not surprisingly, Toyota, Honda, Ford, Chrysler, and every other automaker with volume EV aspirations gave up for the same reasons. CARB was sued and eventually abandoned—temporarily—its ZEV sales mandate.

GM chose to lease, not sell, the EV1. It recalled and destroyed them when their leases were up for three very good reasons: serious liability risks that could arise from aging 300-plus-volt batteries, state laws that require parts and service support for at least a decade after sale, and the near certainty that competitors would reverse-engineer the EV1's proprietary technologies. Not surprisingly, that made some of the 800-odd EV1 lessees who passionately loved the cars extremely unhappy. Their collective anger led to public protests and the 2006 documentary film *Who Killed the Electric Car?* that accused GM, the oil companies, CARB, the feds, and others of snuffing EVs.

Following the EV1 customer protests, Toyota offered the last 328 RAV4 EVs for public sale through November 2002, and continued to support them, while a handful of converted Chevy S-10 EVs that GM sold or leased for fleet usage are still in use. Otherwise, almost all other Nineties production EVs were withdrawn from the market and destroyed by their makers, or deactivated and donated to schools and museums.

Many view the $1 billion-plus GM spent on the EV1 effort as a costly failure, yet a rich body of learning came from it. "People don't realize how much was accomplished and how much we got out of it, both technically and commercially," Purcell—now chairman and CEO of electric-wheel-motor maker Protean Holdings Corporation—has said. "There was tremendous learning that is fundamental to what [GM has done since] with hybrid and fuel-cell systems. For example, we designed the gen-II controllers and power electronics for battery EV and hybrid applications and gen-III for all three classes of electric vehicles—battery, hybrid, and fuel cell."

The first Allison hybrid bus, the forerunner of GM's later advanced (but expensive) two-mode light-truck hybrid system, began with EV1 componentry, and the company earned back some of its investment by licensing hybrid technology and systems to other automakers. A lot of talented technical people who worked on the EV1 are working on GM's plug-in EVs, hybrids, and other programs today. "They made it much easier to crank up the programs for two-mode hybrids and extended-range electric vehicles," said Andrew Farah, who was ATV group manager for propulsion software and controls (and later battery and charging systems) before leading the Chevrolet Volt engineering program.

Jon Bereisa, ATV's propulsion chief engineer in the EV1 days, and now president and CEO at Auto Lectrification LLC, adds that both technical and customer considerations gleaned from the EV1 were applied to Volt and other GM electric-vehicle efforts. "Two big things came out after we launched the car and started talking to people," he says. "We had to solve range anxiety, and we had to provide exciting driving. On EV1, we had software limitations on acceleration and top speed to protect range, because all the energy we had on board was in the battery. Basically, the Volt is all about taking the knowledge that we got on EV1 and making sure to remove those impediments."

"I don't know of anything that will compete with a tank of gas from an energy-density standpoint," Purcell summed up. "That is the physics. Did a battery materialize in that time frame that would overcome range anxiety for most people at an affordable cost? No. But did we get [information] out of it that we wanted? The answer is yes."

Through the early years of the twenty-first century, U.S. government policies, especially increasingly tough Corporate Average Fuel Economy (CAFE) requirements, have in effect mandated increasing numbers of electrified vehicles. Meanwhile, California and several other states have reestablished ZEV sales targets that essentially do the same thing.

At GM, ATV built several prototype gas/electric hybrid cars out of stretched four-seat EV1s in 1998, then the hugely advanced—but impractical and unaffordable—2000 Precept 80-mpg mid-size concept car in response to the feds' Partnership for the Next-Generation Vehicle program that ran from 1993 to 2001. (Partnership members Ford and Chrysler also developed high-mileage cars that, like the Precept, were diesel/electric hybrids.) In all cases, though, their costs were too high to justify their

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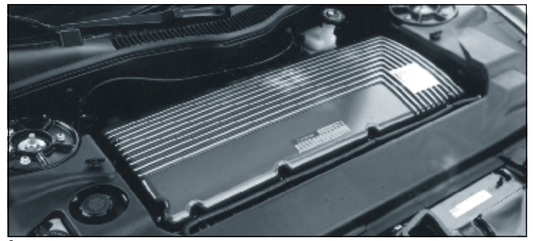

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Plugged in to the EV1: An Insider's View

Through the nearly 20 years of my former career as an automotive engineer, easily my most exciting, challenging, and inspiring assignment was managing vehicle test and development for what became General Motors's EV1. I joined the program in April 1991 and began pulling together a small team of engineers and technicians at GM's proving grounds near Milford, Michigan.

One vivid early memory was piloting the original Impact concept car down a long, steep hill early one August morning on the way to demonstrate it to the corporation's board of directors. As I sped downhill toward a sweeping curve that I routinely drove fairly hard nearly every day on my way to test tracks, I remembered that the Impact rolled on skinny, low-rolling-resistance experimental tires and a cobbled-up suspension, and had almost no brakes. Visions of a career-ending crash flashed through my head until I remembered the variable regenerative-braking dial between the seats; cranking that up to full coast-down regen retarded the slippery little bullet enough to make that turn. Whew!

In fall 1993, my team planned and coordinated a series of briefings and test drives for selected media in "proof of concept" early development cars. The resulting articles were highly positive. "GM's hard-charging Impact is practical, fun to drive and a master stroke of engineering," said *Popular Mechanics*. "The world's best electric car," gushed *Popular Science*. Even auto-enthusiast magazines were pleasantly surprised.

Next we prepped and tested a fleet of 50 handbuilt prototypes for a 1994 "PrEView Drive" program that loaned them to members of the public for three months at a time in a dozen U.S. cities. Though a risky and expensive effort, it paid off handsomely by accumulating significant real-world experience, engineering data, and feedback on how the cars performed, how people used them, and what they liked and disliked about them.

Some critics contend that GM didn't try hard enough to publicize the EV1. The advertisements were good, and our public relations team worked hard with media to get the word out and provide test vehicles to auto writers in areas where the car was available. The EV1 ad budget may have been limited after its launch (a lot of volume GM products needed promotion at the time), but I'm sure that potential customers knew that EV1s were available at Saturn dealers in those five markets.

Some also believe that GM wanted EV1 to fail. You don't conceive it, table it, revive it, then do everything we did—and invest at least a *billion* precious development dollars—on a product you don't want to succeed. From CEO Jack Smith down to those of us who worked their proverbial tails off to make it work, we all desperately wanted it to.

Gary Witzenburg

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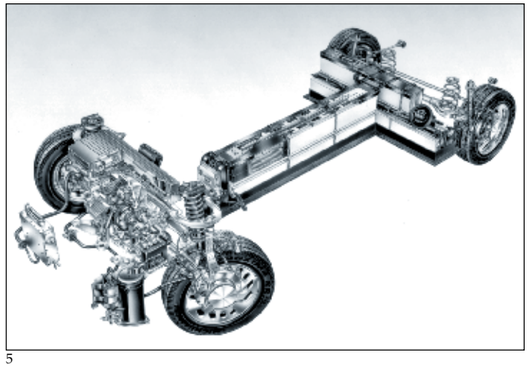

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1, 2. The last step before gas-electric hybrids and plug-in electric cars began appearing in major manufacturers' showrooms in recent years was the GM EV1, a sales-ready—or rather lease-ready—version of the Impact, launched in 1997. *3.* Available through Saturn dealers in select markets, drivers saw the control module when they opened the hood. *4-8.* Several charging devices were designed for the EV1, including a portable "convenience" unit.

fuel-efficiency benefits. GM chose to bypass production hybrids while launching a very serious fuel-cell EV program.

Meanwhile, Honda and Toyota, seeing great public-relations value in fuel-saving gas/electric hybrids, even if at first they could not be built and sold profitably, made the opposite decision. That resulted in Toyota's Prius hybrid, which went on sale in Japan in 1997 and North America in 2000, and Honda's Insight hybrid, which beat the Prius to the U.S. in 1999. That first Insight—like EV1, a highly aerodynamic two-seater—was not a strong seller, but Toyota has evolved the parallel-hybrid Prius into an image-enhancing high-volume green-vehicle icon that has spawned hybrid versions of nearly every other Toyota vehicle, and, along with U.S. CAFE and ever-tightening European CO_2 regulations, spurred automakers around the globe to develop competing technologies.

As in earlier decades, small start-up electric-car companies have come and gone in recent years, but luxury-EV maker Tesla is the only one to survive so far. One interesting example that didn't was the tiny egg-shaped three-wheeled Corbin Sparrow, built by Corbin Motors from 1999 to 2002. Powered by 13 conventional 12-volt lead-acid batteries and weighing just 1350 pounds, Sparrows were quick and fun to drive with a top speed of 75 mph and a 30-mile range. Just 285 were built before the company filed for bankruptcy in '02.

As of early 2014, 17 plug-in vehicles were available in U.S. showrooms. Seven—Toyota Prius, Ford C-Max and Fusion Energi plug-in hybrids; Nissan Leaf, BMW i3, and Tesla Model S pure electrics; and the Chevrolet Volt series-hybrid extended-range EV—are relatively good sellers. Six more—Cadillac ELR (which shares Volt technology), Ford Focus EV, Honda Accord plug-in hybrid, Mitsubishi i, Porsche Panamera S E-Hybrid, and Smart ForTwo EV—sell at much lower volume. Four others—Chevrolet Spark EV, Fiat 500e, Honda Fit EV, and a new Toyota RAV4 EV—are confined to California and a few other states primarily to meet ZEV sales mandates.

The confluence of government regulations, increasing public interest driven by both environmental concern and high fossil-fuel prices, and advancing battery technology—particularly the currently popular lithium-ion type—has opened up a new age for electrically driven vehicles. (Even the director of *Who Killed the Electric Car?* had to recognize as much in his 2011 follow-up *Revenge of the Electric Car*.) Range, charging time, and cost issues still stand in the way of mass appeal for electrics, but there will be many more of them to come. CA

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