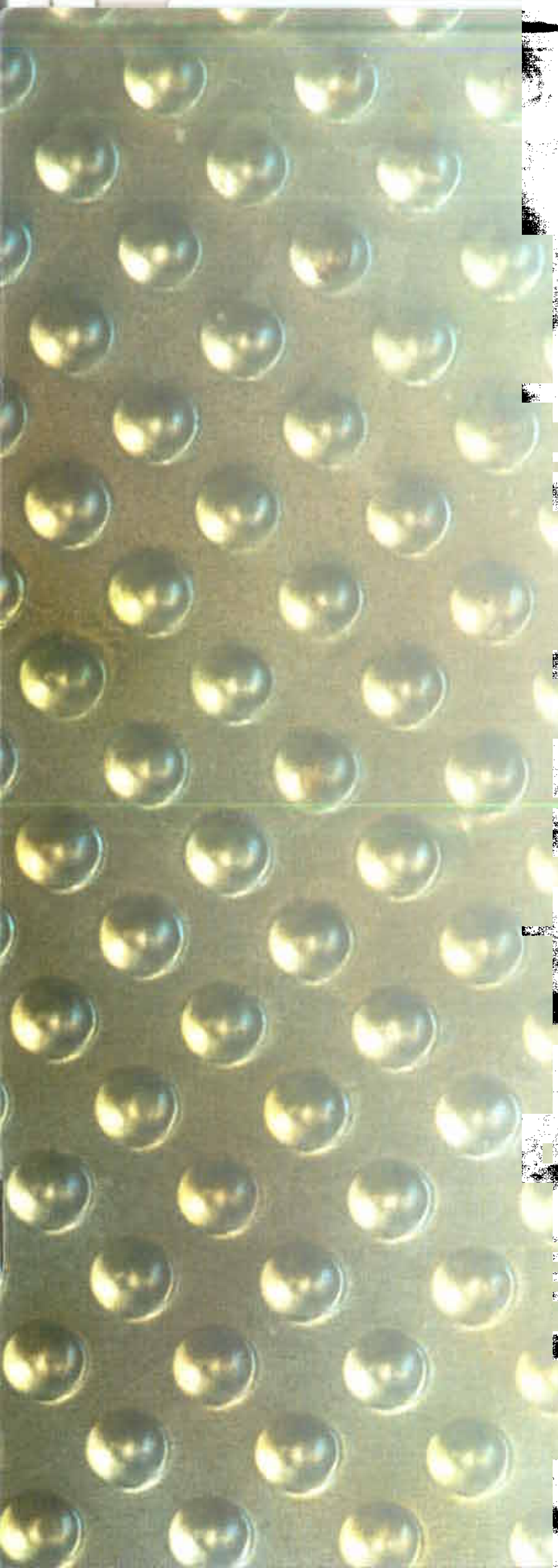
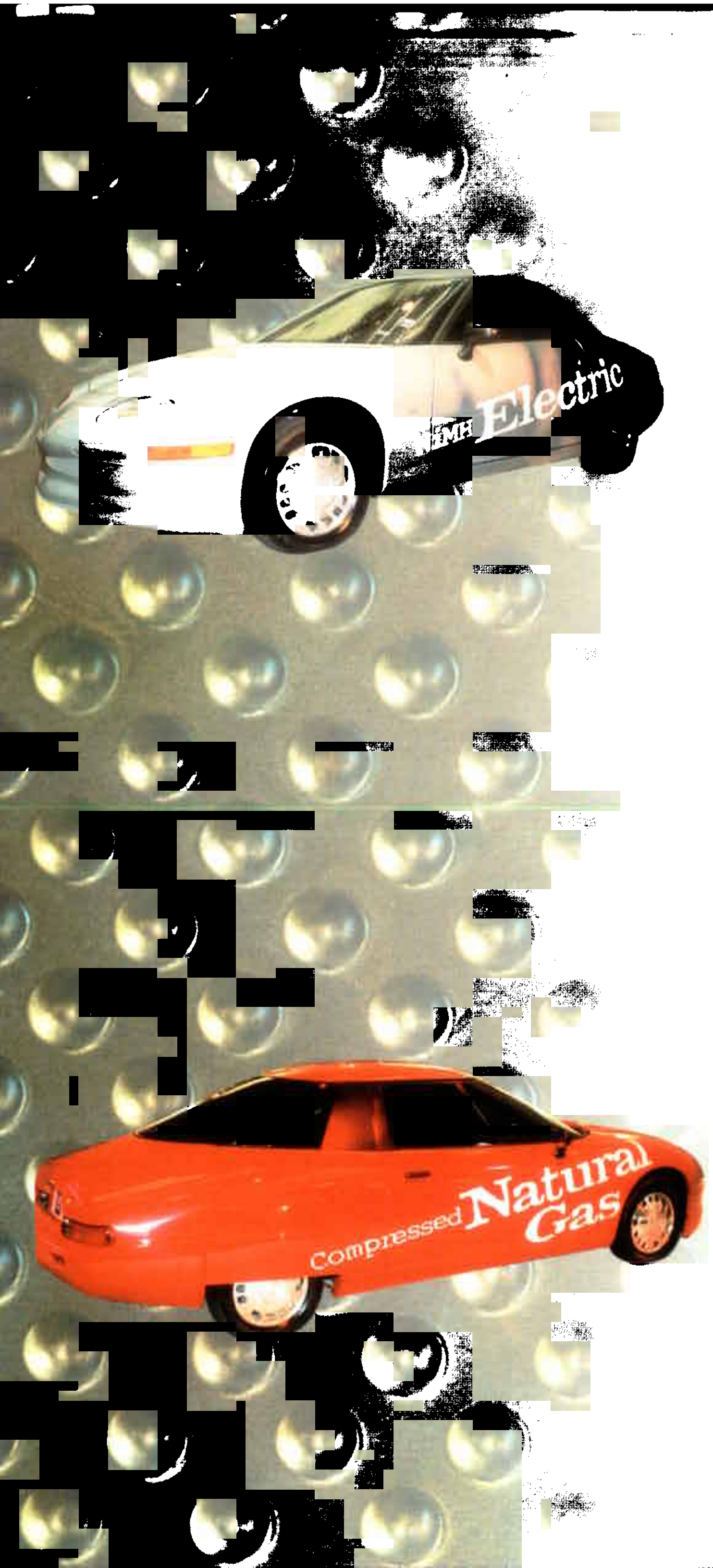


GOOD, CLEAN FUN

Driving the Next Generation of Automotive Technology

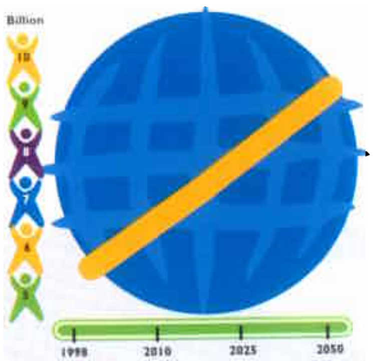


How does a global automotive company like General Motors prepare to meet the environmental and energy challenges of the 21st century?

With global research and development, of course.

General Motors is drawing advanced technology from all around the globe to develop a family of clean car options that will meet the needs of customers worldwide. GM is leveraging its size, expertise, and global R&D resources to create a range of low-emission, high-performance vehicles.

WORLD POPULATION: PROJECTED GROWTH

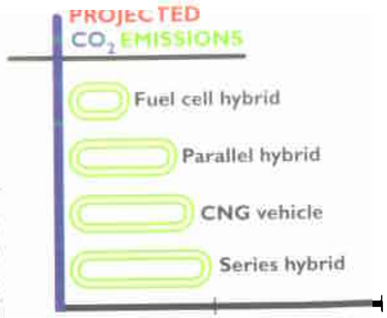


At General Motors, we believe that change is coming – and the change will be profound.

As the world's population expands and economic development proceeds, concerns about global warming, energy consumption, and conservation of the earth's natural resources are growing. As a global company, General Motors has a big stake in helping to develop solutions to these challenges.

At General Motors, we are committed to developing long-term, sustainable market solutions that balance the interests of environmental stakeholders, corporate stockholders, and, most importantly, our customers. Our goal is to use advanced technology to foster sustainable development so that the present generation does not compromise the ability of future generations to meet their own needs.

We've already taken the lead in clean and efficient automotive technology with the EV1, the first production electric car of modern times. While we are justifiably proud of our leadership in EV technology, it's just the first milestone in our drive toward the future. Today, we are investing in a whole range of propulsion and technology options that show great promise to increase fuel economy, lower exhaust emissions, and reduce greenhouse gases.

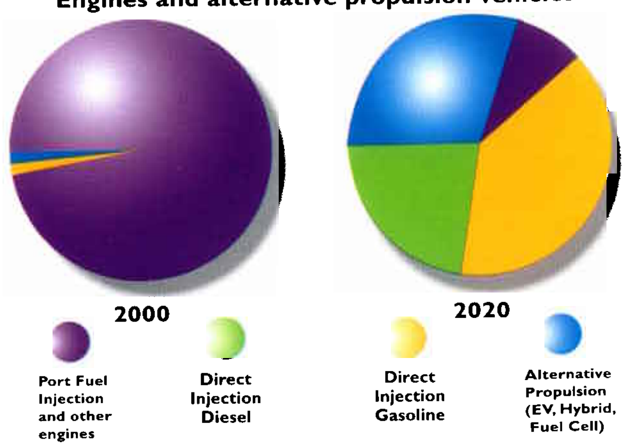


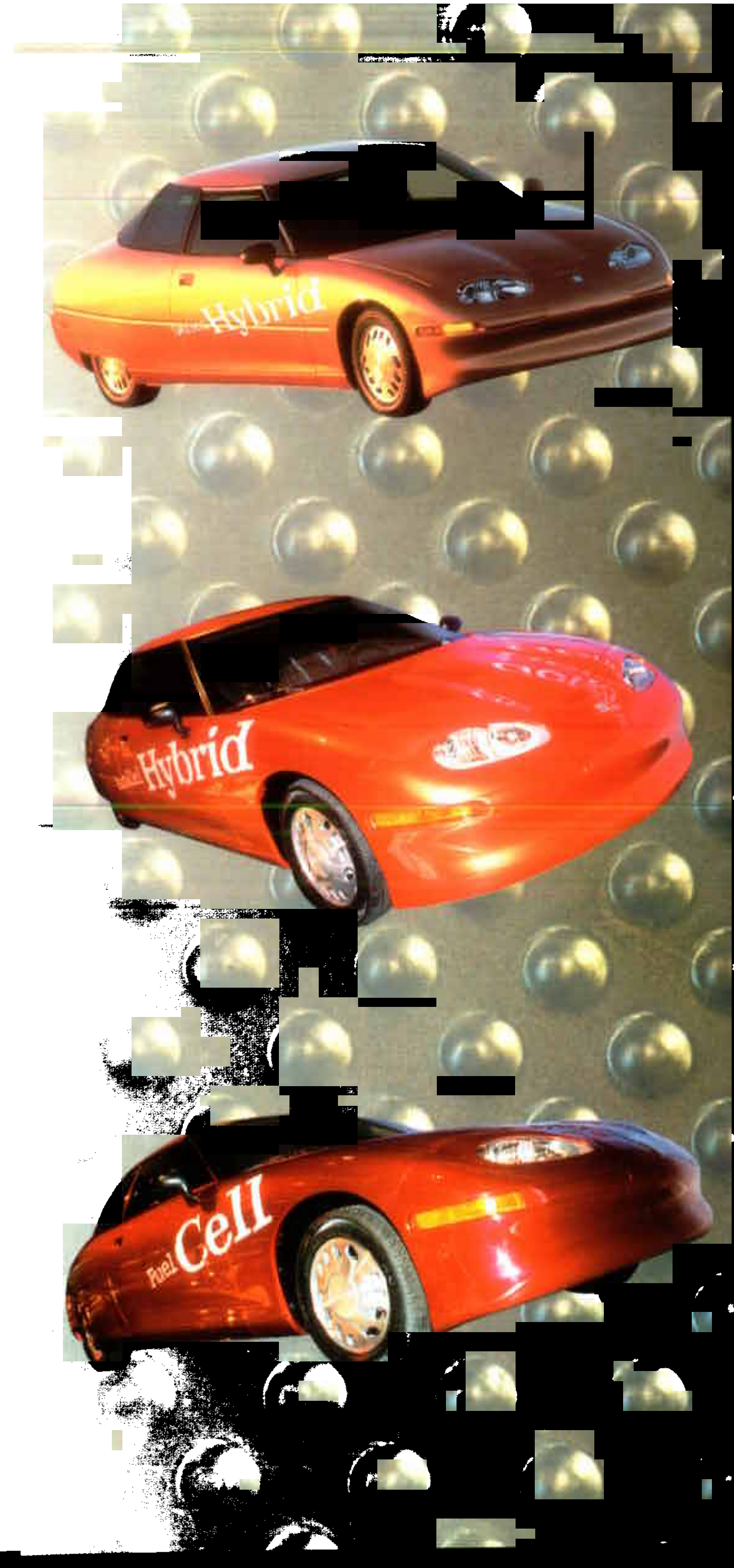
Compared to Conventional Gasoline Vehicle (rated at 26 mpg)

Our portfolio of advanced technology vehicles includes pure and fuel cell electric vehicles, parallel and series hybrids that combine electric drive with advanced internal combustion engines, and compressed natural gas-fueled (CNG) vehicles.

These concept cars are a practical demonstration of our long-term commitment to provide earth-friendly vehicles for GM customers – wherever they may live on the planet. All in the name of good, clean fun . . . for today and tomorrow.

Potential market penetration: Engines and alternative propulsion vehicles





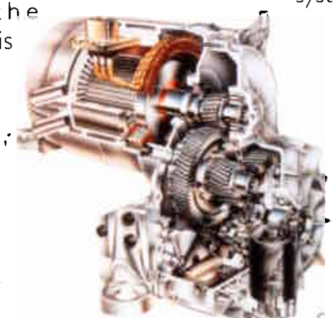
EV1 Electric

Introduced into the marketplace in December 1996, the EV1 continues to set the electric-vehicle benchmark for range and performance. 1998 will see the phase-in of nickel-metal hydride batteries in these pioneering EVs.

Some of the technical breakthroughs that helped make the EV1 the world's most advanced, most energy-efficient automobile also provide the foundation for our electric, hybrid, and fuel cell concept cars:

Drive Unit

The EV1's 137-horsepower, three-phase, alternating current induction motor is integrated into a drive unit that contains a single-speed, dual-reduction gear-set with a ratio of 10.946:1. The drive unit has several key attributes: It's light (the entire unit weighs just 150 lbs.). Compact (the motor's rotor is about the size of a coffee can). Quiet. And highly efficient (rated at 102 kW peak). And, of course, there are no exhaust emissions.



GM Advanced Technology Vehicles (ATV) recently announced the development of a Generation II electric drive system that offers the same performance as today's unit at roughly half the cost, half the size, and using one-third fewer parts. It represents the first significant step in lowering the cost of technology to a level that will make next-generation vehicles an attractive purchase decision for the consumer and a desirable business proposition for the auto manufacturer and its shareholders.

Power Electronics Bay

The GM ATV Power Electronics Bay is an assembly of three major modules – the power inverter module, the power steering control module, and the auxiliary power module – mounted directly atop the EV1's electric motor. In practice, it is the heart of the vehicle's electrical system.

GM ATV is today working to incorporate the functions of this assembly into a single, smaller unit. Generation II will also have application to future hybrid and fuel cell vehicles.

Braking System

Forget vacuum pumps. The EV1's power-assisted brakes are electrically applied. The engineering team took GM's heralded ABS-VI anti lock brake system and adapted it to operate at all times. It energizes whenever the brake pedal is depressed. The front disc brakes are hydraulic. The rear drums have fully electric actuation, an industry first.

In addition to conventional friction braking, the EV1 features regenerative braking. This "regen" feature temporarily transforms the drive motor into a generator, which converts the vehicle's kinetic energy into electrical energy. The electrical energy recharges the batteries and extends vehicle range. Using computer control to blend friction and regenerative forces, driving range is increased by up to 20 percent.

Lightweight Structure

One of the main enemies of range is mass. The EV1 relies on an innovative all-aluminum structure to help keep mass to a minimum. The entire structure, which is secured by a combination of spot welds and aerospace adhesive bonding, is extraordinarily stiff but very lightweight. The structure is durable, meets crash test standards, and is recyclable.

Low Aerodynamic Drag and Rolling Resistance

Two other enemies of range are wind and rolling resistance. With a drag coefficient of just 0.19, the EV1 is the world's most aerodynamic production vehicle. Low rolling-resistance tires were developed by Michelin especially for the EV1. They run at high pressure (50 psi), yet deliver contemporary levels of wet and dry traction. They're also self-sealing for normal punctures. (To minimize mass, the EV1 has no spare tire or jack.) A low tire pressure warning system can detect losses as small as 5 psi.

Steering

The EV1's rack-and-pinion steering uses a hydraulic pump driven by its own AC induction motor for power assist. Because the pump doesn't have to depend on an engine for power, it is programmed to run only as much as required. This reduces energy demand by as much as 80 percent compared to traditional systems.

Climate Control

How do you provide air conditioning in an ultra-efficient vehicle? EV1 engineers opted for a heat pump. A first of its kind in a mobile application, the pump uses a high-efficiency, variable-speed compressor to provide heated and cooled air to the vehicle's occupants – at one-third the energy of a conventional air-conditioning compressor.

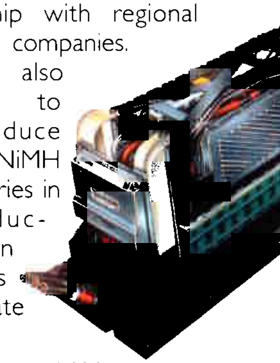
Advanced Nickel-Metal Hydride (NiMH) Batteries

With the introduction of advanced nickel-metal hydride batteries, GM's EV1 will offer the greatest driving range of any production electric vehicle in the world. With a specific energy rating of 70 Wh/kg (versus 35 for the lead-acid), the NiMH-battery is expected to double the EV1's driving range to 160 miles. The new battery will also provide a specific power of 230 W/kg (equivalent to lead-acid) so the switch to NiMH means the EV1 will continue to have spirited responsiveness.

NiMH batteries provide several other noteworthy advantages. They have a cycle life three times longer than that of lead-acid batteries. They hold their charge significantly better in colder temperatures. They have good tolerance to abuse (such as overcharging). And they accept high-rate charging very well – 15-20 minutes of charging at 50kW may be enough to boost the state of charge to the 80-percent level, under optimal conditions.

The batteries are sealed, require no maintenance, and can be safely recycled after their useful life.

GM has begun to evaluate NiMH batteries in the real world in a "Field Test" of EV1 cars and Chevrolet S-10 electric pickups. The test fleet is being deployed nationwide in partnership with regional utility companies. GM also plans to introduce the NiMH batteries in production EV1's in late 1998.



The NiMH batteries are manufactured by

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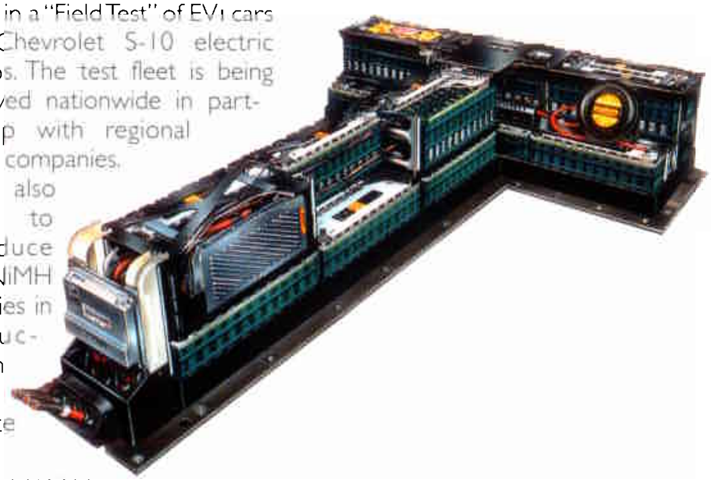


The NiMH batteries are manufactured by GM Ovonic, with research support from the U.S. Advanced Battery Consortium. GM Ovonic is a joint venture between General Motors and the Ovonic Battery Company, a subsidiary of Energy Conversion Devices, Inc. of Troy, Michigan. (The NiMH battery was patented in 1986 by Stanford Ovshinsky, currently president and CEO of Energy Conversion Devices.)

EV1 Battery Pack

The standard EV1 battery pack – consisting of 26 sealed nickel-metal hydride batteries – is located in a compartment between and behind the driver and passenger. The pack, shaped like the letter "T", weighs about 1,100 lbs.

Hybrid EV1 Battery Pack

GM's hybrid concept cars carry 44 nickel-metal hydride batteries specially designed for operation in hybrid vehicles. The battery pack's I-formation down the center of the car clears the way for a second power unit at the rear of the vehicle.

Compressed Natural Gas

While electric propulsion will make 21st century cars and trucks cleaner and more fuel-efficient, the internal combustion (IC) engine will also continue to be part of tomorrow's transportation fleet. In fact, it may play an important role for some time to come, even beyond hybrid-electric combinations. To test the potential of a stand-alone IC propulsion system to meet future environmental and energy requirements, GM engineers combined the world's most efficient production platform (the EV1) with an advanced internal combustion engine fueled by compressed natural gas (CNG). The result is a vehicle that delivers exhaust emissions far below ULEV standards. And with additional development, the IC engine option is expected to provide even higher levels of cleanliness and efficiency.

CNG is an excellent fuel choice because it's clean-burning, has a high octane rating (which translates to higher efficiency), and is readily available – at only two-thirds the cost of gasoline (on an energy-equivalent basis). Another benefit is the potential to refuel at home – using a compressor to tap into a home's existing natural gas line. A commercial fueling system can refuel a vehicle in 3.5 minutes.

Engine

The CNG EV1 is powered by a turbocharged, 1.0-liter, three-cylinder, sequential port fuel-injected engine.

Transmission

The engine is directly coupled to a continuously variable transmission (CVT) with a 5.0:1 ratio range. The CVT was selected because it comes closest to matching the smooth and stepless power delivery of the standard EV1. Instead of gears, the transmission uses a steel belt connecting two V-shaped pulleys. The CVT approach delivers excellent performance, high fuel efficiency, and no need for the driver to manipulate a clutch or gear shift.

Fueling

The fuel system consists of a fuel-fill nozzle, two fuel tanks located in the central tunnel and behind and parallel to the seats, and a high-efficiency filter, all designed for a maximum operating pressure of 3,000 psi. The two fuel cylinders hold 670 standard cubic feet of natural gas.

For added safety, a single-stage pressure regulator lowers the system pressure from 3,000 to 75 psi. In-tank solenoids shut off the fuel during refueling and when the engine is not operating. A pressure relief device located in the tanks provides over-temperature and pressure relief.

With the two-tank fuel system, the CNG has a highway range of 400 miles – outstanding for a CNG vehicle. On an energy equivalent basis, the fuel capacity is about equal to seven gallons of gasoline.

Aftertreatment

The exhaust aftertreatment system includes two custom, single-brick catalytic converters. The inlet of the first, close-coupled converter is attached directly to the turbocharger outlet for fast warm-up and sustained light-load operations. The second converter is mounted in the underfloor position. To achieve ULEV targets and reduce greenhouse gases, the catalyst formulation was specially designed for high methane-oxidation activity in CNG exhaust.

Series Hybrid

Developing a hybrid electric that is highly efficient, low in emissions, and provides excellent all-around vehicle performance is something of a "moon shot." So it's not too surprising that GM has leveraged aerospace technology in developing a series hybrid electric concept car.

In GM's series hybrid, the turbine engine is not directly connected to the vehicle wheels. Instead, it produces only electricity, which the vehicle controller allocates to the drive motor or the NiMH battery pack. The series architecture allows the vehicle to be operated either as an "infinite"-range hybrid or as a zero-emissions, electric-only vehicle. The driver simply flips a switch to disable the auxiliary power unit (APU), allowing the car to be driven in EV mode for up to 40 miles.

In hybrid mode, the APU automatically starts and produces power whenever the battery pack's state-of-charge drops below 40 percent. After the unit is running, it normally delivers just enough electrical power to run the propulsion motor and return the batteries to a 50-percent state-of-charge. A 6.5-gallon tank holds the reformulated gasoline that fuels the APU, providing more than 350 miles of continuous highway range – better than many cars on the road today.

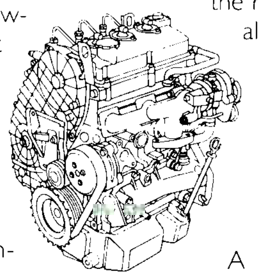
Auxiliary Propulsion Unit (APU)

The 220-lb. APU is the smallest, lightest, most fuel-efficient device of its kind ever built. The unit combines a single-stage, single-shaft, recuperated gas turbine engine with a high-speed, permanent-magnet, alternating current generator. Running between 100,000 and 140,000 rpm, it is a smooth, quiet device that delivers up to 40kW of electrical energy – enough to power the car's electric drive unit and accessories and/or charge its batteries at speeds up to 80 mph.

The GM-Williams gas turbine is the product of a three-year joint effort by GM and Williams International, an aerospace turbine engine maker in Walled Lake, Michigan.

Parallel Hybrid

General Motors engineers have concluded that a direct-injection diesel, parallel hybrid propulsion system in an advanced, ultra-efficient vehicle is a promising configuration for achieving very high fuel economy. So they added a small diesel engine in parallel with the EV1's electric propulsion system to create GM's parallel hybrid. It's a powerful combination that provides 219 horsepower, giving this parallel system the capability to beat both the fuel economy and performance provided by conventional vehicles.



In the standard "hybrid" mode, the car is run primarily by the highly efficient diesel after the electric motor is used to accelerate from a stop. The batteries are maintained at a nominal 80-percent-of-charge by operating the engine at higher or lower speeds, and by using an extra engine-driven motor/generator that's part of the parallel configuration. For passing acceleration, the three propulsion devices – front - mounted electric motor, and rear-mounted turbo-diesel and motor/generator – collaborate to supply power. For extra traction (to climb a slippery grade, for example), the power sources at each end of the car also can provide four-wheel-drive.

In "zero-emission vehicle" (ZEV) mode, with the engine inhibited from running, the vehicle can be driven for about 40 miles on electric power alone.

Engine

An Isuzu 1.3-liter, three-cylinder turbocharged diesel engine that produces 75 horsepower drives the rear wheels of the parallel hybrid. The engine has a DOHC 12-valve cylinder head with common-rail direct injection for complete combustion.

Motor/Generator

A 6.5-horsepower (continuous), permanent-magnet, direct-current brushless motor/generator helps drive the rear wheels at maximum acceleration, charges the battery pack, starts the diesel engine, and regeneratively brakes the wheels.

Transmission

The parallel hybrid's manual automatic transaxle, designed by Opel, uses electronically controlled actuators to provide fully automatic gear selection and clutch engagement. The transmission passes power from the engine and motor/generator to the rear wheels, and from the rear wheels to the motor/generator when the vehicle is using regenerative braking.

Additional Systems

The parallel hybrid EV1 incorporates several new systems specially developed for this concept vehicle: a new strut-type independent rear suspension; twin side-mounted radiators to cool the engine; a third heat-exchanger for the motor/generator; a seven-gallon fuel tank with a left-side filler port; intake and exhaust plumbing and venting; and new electronic controllers for the transmission, engine, and motor/generator.

Fuel

Before diesel engines can reach their full potential in hybrid applications, new fuels are required to achieve the emissions levels required in North America. That's why General Motors is working in conjunction with the petroleum industry to take on the challenge of developing cleaner diesel fuels that can help reduce particulate and oxides of nitrogen emissions in next-generation vehicles.

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and supplemental energy from the batteries.

The GM fuel cell electric uses methanol fuel because it's an ideal source for the hydrogen needed by the cell. It's readily available and has fewer impurities than gasoline or other hydrocarbon fuels.

Fuel Processor

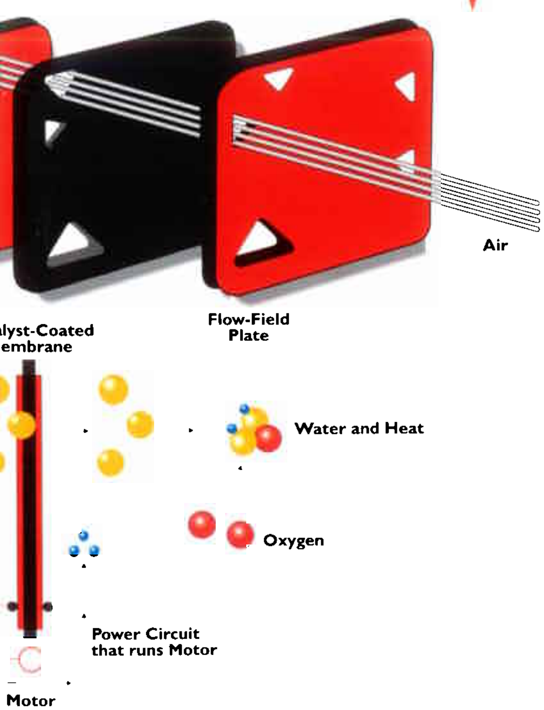
The multi-stage fuel processing system converts the methanol into a hydrogen-rich mixture called "reformate."

Fuel Cell Stack

The fuel cell stack consists of many individual cells electrically connected in series to provide an appropriate voltage. The cells are fed the "reformate," along with filtered compressed air (the oxygen source). The hydrogen and oxygen react within the fuel cell to form water and create a voltage across each cell. The electricity created by this chemical reaction powers the vehicle's electric motor.

Expander/Compressor

The expander/compressor is designed to capture energy that would otherwise be lost in the exhaust gases from the fuel cells. All remaining hydrocarbons are combusted, resulting in a hot stream of water-rich gas that is used to heat the reformer. The gas is then run through an expander that cools it by removing energy as mechanical force, much like a steam-powered turbine-generator. The mechanical force is used, in addition to an electric motor, to drive a compressor that supplies the compressed air to the fuel cells.



Magne Charge™ Inductive 50kW Fast Charger

The 50kW charger is the next milestone in the evolution of Magne Charge inductive charging technology for electric and hybrid vehicles. It will recharge an electric vehicle in minutes rather than hours.

The new charger can add an additional 60 miles of range to an EV1 battery pack in approximately ten minutes – compared to two-three hours with the current 220 volt/6.6kW charger.

GM ATV introduced inductive charging to the public in 1994 during its PrEView Drive electric vehicle demonstration program. Program results confirmed that inductive charging is safe, reliable, and user-friendly. In fact, inductive charging and the EV1 charge port are the first EV-related charging components to be UL-listed in the hundred-year history of the Underwriters Laboratory. In 1995, the Society of Automotive Engineers endorsed the GM system as the first established American national standard for EV charging (SAE Recommended Practice J-1773).

Since the market launch of the EV1 and S-10 electric pickup, there are more than 2,000 Magne Charge inductive chargers in customer use. Today, GM is partnering with the California South Coast Air Quality Management District, CAL-START, Edison EV, and Southern California Edison to conduct a test fleet demonstration with the new 50kW Fast Charge system.

The Magne Charge technology was developed by GM's Delphi Delco Electronics.

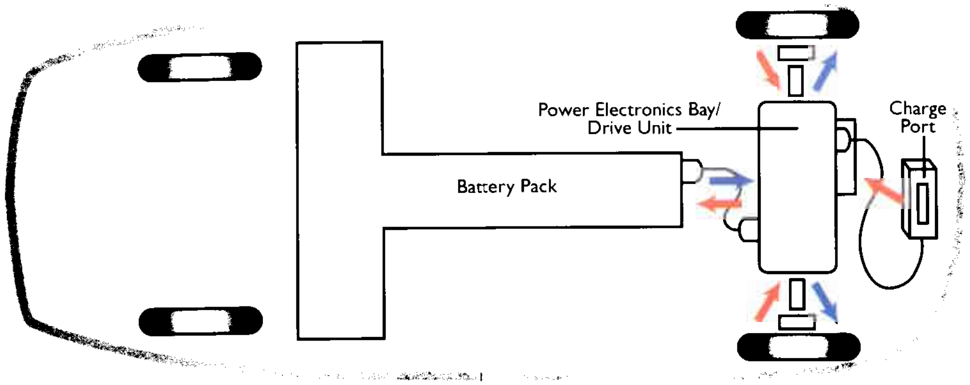
Performance Highlights

	EV1 with NiMH	CNG EV1	Series Hybrid EV1	Parallel Hybrid EV1	Fuel Cell EV1
Highway Fuel Economy	N/A	60 mpg (gasoline equivalent)	60 mpg	80 mpg (gasoline equivalent)	80 mpg
Emissions	ZEV	1/10 ULEV	1/10 ULEV	Tier II	1/10 ULEV
Fuel	Electricity	Compressed natural gas (CNG)	Reformulated gasoline	Diesel fuel	Methanol
Range	Up to 160 miles ZEV	More than 400 miles	More than 350 miles (up to 40 miles ZEV)	More than 550 miles (up to 40 miles ZEV)	More than 300 miles
Acceleration	0-60 mph in 8.5 seconds	0-60 mph in 11 seconds	0-60 mph in 9 seconds	0-60 mph in 7 seconds	0-60 mph in 9 seconds
Top Speed	80 mph (regulated)	80 mph (regulated)	80 mph (regulated)	80 mph (regulated)	80 mph (regulated)
Horsepower	137 horsepower	72 horsepower	137 horsepower	219 horsepower	137 horsepower
Curb Mass	2,850 lbs.	2,375 lbs.	2,950 lbs.	3,200 lbs.	3,030 lbs.
Seating	2	2	4	4	4

Technical Highlights

	EV1 with NiMH	CNG EV1	Series Hybrid EV1	Parallel Hybrid EV1	Fuel Cell EV1
Power Unit (Front)	3-phase, 137-h.p. AC induction motor using a single-speed, dual reduction gear-set with a ratio of 10.946:1	1.0L, 3-cylinder, sequential port fuel-injected, turbo-charged, 72-h.p. engine	3-phase, 137-h.p. AC induction motor using a single-speed, dual reduction gear-set with a ratio of 10.946:1	3-phase, 137-h.p. AC induction motor using a single-speed, dual reduction gear-set with a ratio of 10.946:1	3-phase, 137-h.p. AC induction motor using a single-speed, dual reduction gear-set with a ratio of 10.946:1
Power Unit(s) (Rear)	N/A	N/A	Williams 54-h.p., single-shaft, recuperative gas turbine coupled directly to high-speed, permanent magnet AC generator	Isuzu 1.3L, 3-cylinder, 75-h.p. direct-injection diesel engine; 6.5-h.p. (continuous) permanent-magnet, DC brushless motor/generator	Fuel cell stack consisting of hundreds of fuel cells electrically connected in series; Multi-stage fuel processor converts methanol into a hydrogen-rich mixture; Expander/compressor converts exhaust energy from fuel cells to mechanical force, which drives system's air compressor
Transmission	N/A	Continuously variable transmission with a 5.0:1 ratio range	N/A	Opel five-speed manual transaxle with fully automatic gear selection and clutch engagement	N/A
Power Electronics	Insulated gate bipolar transistors	N/A	Insulated gate bipolar transistors	Insulated gate bipolar transistors	Insulated gate bipolar transistors
Brakes	ABS	ABS	ABS	ABS	ABS
(Front)	Solid discs with floating-piston calipers, hydraulically applied	Vented discs with floating-piston calipers, hydraulically applied	Solid discs with floating-piston calipers, hydraulically applied	Solid discs with floating-piston calipers, hydraulically applied	Solid discs with floating-piston calipers, hydraulcally applied
(Rear)	Metal matrix (aluminum) drum brakes, electrically applied				
Regenerative Braking	Blended, with conventional brakes (front wheels only)	N/A	Blended, with conventional brakes (front wheels only)	Blended, with conventional brakes (all four wheels)	Blended, with conventional brakes (front wheels only)
Suspension (Front)	Short/long arm with coil spring-over-shock absorber; coil spring and shock absorber mounted separately				
(Rear)	Multi-link and Panhard rod located aluminum beam; coil spring and shock absorber mounted separately	Multi-link and Panhard rod located aluminum beam; coil spring and shock absorber mounted separately	Multi-link and Panhard rod located aluminum beam; coil spring and shock absorber mounted separately	McPherson strut independent, tri-link	Multi-link and Panhard rod located aluminum beam; coil spring and shock absorber mounted separately
Steering	Rack-and-pinion, speed-sensitive, variable effort, electro-hydraulic (Electric motor-driven hydraulic pump)	Rack-and-pinion, without power assist	Rack-and-pinion, speed-sensitive, variable effort, electro-hydraulic (Electric motor-driven hydraulic pump)	Rack-and-pinion, speed-sensitive, variable effort, electro-hydraulic (Electric motor-driven hydraulic pump)	Rack-and-pinion, speed-sensitive, variable effort, electro-hydraulic (Electric motor-driven hydraulic pump)
Electronics	Serial data-linked microprocessors; junction-block wiring harness system; dedicated system-level central microprocessor	Serial data-linked micro-processors; dedicated system-level central micro-processor	Serial data-linked microprocessors; junction-block wiring harness system; dedicated system-level central microprocessor	Serial data-linked microprocessors; junction-block wiring harness system; dedicated system-level central microprocessor	Serial data-linked microprocessors; junction-block wiring harness system; dedicated system-level central microprocessor
Interior	One-piece urethane-covered instrument panel; Central high-mounted display; 3D-knit seat fabric with Scotchguard treatment; Magnesium steering wheel frame and seat cushion frames				
Restraint Systems	Dual airbags; 3-point lap/shoulder belts				
Climate System	Heat pump system with pre-conditioning - provides both heating and air conditioning; R-134a refrigerant	Engine-driven A/C compressor with R-134a refrigerant; engine coolant for heating	Heat pump system with pre-conditioning - provides both heating and air conditioning; R-134a refrigerant	Heat pump system with pre-conditioning - provides both heating and air conditioning; R-134a refrigerant	Heat pump system with pre-conditioning - provides both heating and air conditioning; R-134a refrigerant
Body Structure	Welded and bonded aluminum alloy spaceframe 290 lbs. (132 kg)	Welded and bonded aluminum alloy spaceframe 290 lbs. (132 kg)	Welded and bonded aluminum alloy spaceframe 310 lbs. (141 kg)	Welded and bonded aluminum alloy spaceframe 310 lbs. (141 kg)	Welded and bonded aluminum alloy spaceframe 310 lbs. (141 kg)
Exterior Panels	Dent/corrosion-resistant composites (hood, roof, doors, and trunk lid of sheet molding compound; fascias, fenders, and quarters of reinforced reaction-injection molded polyurethane)				
Tires	Self-sealing, puncture-resistant with check tire pressure system; 175 / 65 R14; 345kPa (50 psi); No spare tire or jack				
Wheels	8.5-lb. Squeeze-cast aluminum 14 x 4.5				
Charging	MagneCharge™, inductively coupled per SAE J-1773	N/A	MagneCharge™, inductively coupled per SAE J-1773	MagneCharge™, inductively coupled per SAE J-1773	MagneCharge™, inductively coupled per SAE J-1773
Battery Pack	GM Ovonic NiMH 26 13.2-volt modules	N/A	GM Ovonic NiMH 44 6.6-volt modules	GM Ovonic NiMH 44 6.6-volt modules	GM Ovonic NiMH 44 6.6-volt modules

EV1 ELECTRIC

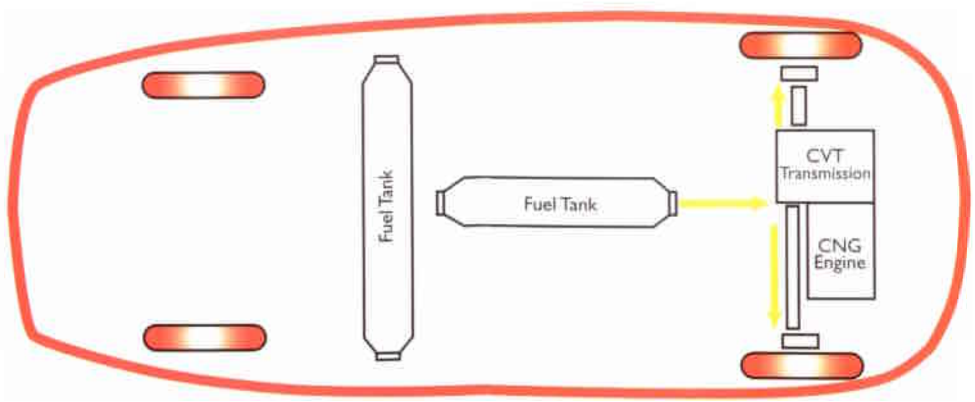


ENERGY FLOW

Zero Emission Propulsion

Charging/Regenerative Braking

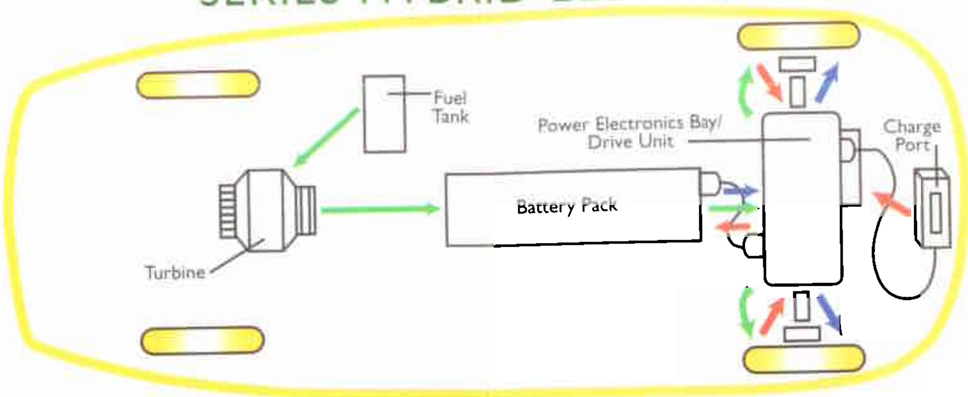
COMPRESSED NATURAL GAS



ENERGY FLOW

CNG Propulsion

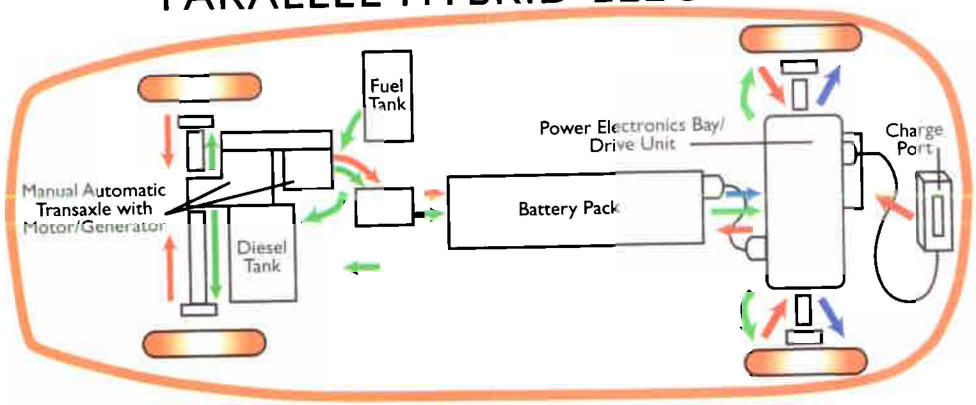
SERIES HYBRID ELECTRIC



ENERGY FLOW

Hybrid Propulsion → Zero Emission Propulsion → Charging/Regenerative Braking →

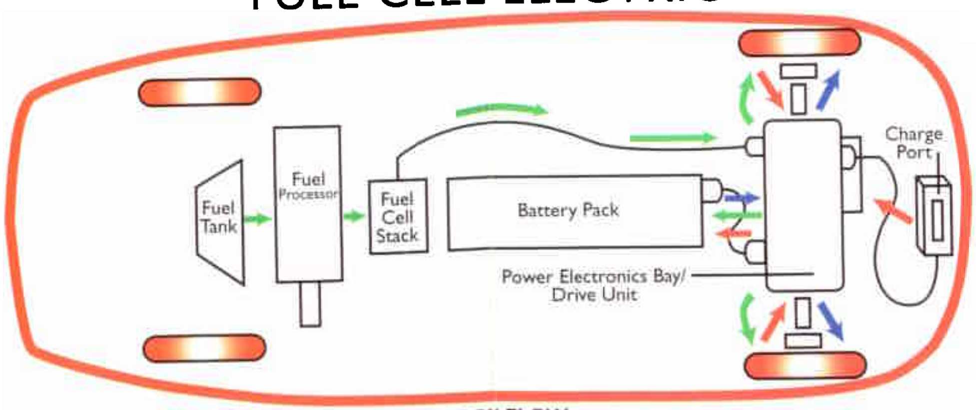
PARALLEL HYBRID ELECTRIC



ENERGY FLOW

Hybrid Propulsion → Zero Emission Propulsion → Charging/Regenerative Braking →

FUEL CELL ELECTRIC



ENERGY FLOW

Zero Emission Propulsion → Charging/Regenerative Braking →