Hypercar® Vehicles
Frequently Asked Questions (FAQs)

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What is a Hypercar® vehicle?

RMI has coined the term "Hypercar®" to describe a conceptual vehicle that combines ultralight and ultra-aerodynamic design, a hybrid-electric drivesystem, and other features to achieve very high fuel efficiency and very low emissions. Modeling by RMI suggests that full-sized Hypercar® vehicles should be able to get 90 miles per U.S. gallon of gasoline or equivalent (2.6 L/100 km) in the near term and 200 mpg (1.2 L/100 km) in the long term. How this is possible is explained in the next answer.

No Hypercar® vehicles have yet been built, but researchers at RMI and elsewhere have laid much of the conceptual groundwork for them, and there are good reasons to anticipate that Hypercar® vehicles will become commercially available within a few years (see "How long until I can buy a Hypercar® vehicle?").

Uniquely, the Hypercar® concept achieves high efficiency without sacrificing important vehicle characteristics such as safety, performance, affordability, durability, and comfort. Because Hypercar® vehicles are intended to be equal or superior to conventional vehicles in every significant respect, their success in the marketplace need not depend on the support of the minority of buyers who care about fuel efficiency.

The term "Hypercar®" refers to a new approach to designing and building vehicles, not a specific vehicle design. While RMI's work has focused mainly on typical four-to-five- and five-to-six-passenger sedans, the same principles are applicable to all vehicle types: larger luxury cars, family cars, minivans, sport utility vehicles, pickup trucks, small commuter vehicles, and even mass-transit vehicles.

For an eight-page semi-technical introduction to Hypercar® vehicles, see the RMI publication "Hypercar® vehicles: The Next Industrial Revolution."

How could Hypercar® vehicles attain such dramatically improved fuel economy?

A car's fuel economy can be improved by reducing any or all of the following:

- aerodynamic drag

- rolling resistance (due mainly to tires)
- drivesystem inefficiencies (the drivesystem includes the engine and all mechanical components connecting the engine to the wheels, such as the transmission and differential)
- energy lost during braking
- accessory loads (lights, audio system, climate control, instrumentation, etc.)

Minimizing these losses piecemeal is good, but redesigning the entire car for maximum overall efficiency—taking an integrated, "whole-system" approach—is much better.

The Hypercar® concept is based on a combination of ultralightweight and aerodynamic design, hybrid-electric propulsion, special low-rolling-resistance tires, and efficient accessories. Separately, these demonstrated features yield only modest improvements in fuel economy, and each has attributes that have prevented it from being widely adopted by the auto industry. But combining *all* of them in a whole-system approach captures impressive synergies, multiplying the fuel savings and avoiding the disadvantages of each. Some of these synergies are described below.

Ultralight Construction

Vehicle mass is a critical factor to minimize because it affects power requirements, overall drivesystem efficiency, tire rolling resistance, and the amount of energy used to accelerate that is later lost in braking. Ultralightweight design can be accomplished without making the car any smaller or less safe by replacing steel with new materials, such as advanced polymeric composites, in the car's body and chassis.

Making a component lighter allows for others to be made lighter as well. This principle is called "mass decompounding." For example, reducing the weight of the body allows the engine to be fractionally less powerful for equivalent performance. It also allows the car's transmission and other drivetrain components to be slightly smaller because they don't have to transfer as much power to the wheels. All these mass reductions in turn allow the car's body and suspension to be even lighter because it won't have to support as heavy an engine, etc.

Obviously, mass decompounding has a limit, but the limit is much lower than might be expected, because reducing a car's mass below a certain threshold makes possible new options and even the elimination of some systems altogether. For instance, a car that's light enough can utilize unconventional lightweight and efficient drivetrains and do without power steering. All told, it should be possible to make Hypercar® vehicles that are 50-65 percent lighter than conventional cars of the same size.

Aerodynamics and Rolling Resistance

Today's cars are already fairly sleek, but aerodynamic drag can be further cut by 40-50 percent or more through cab-forward design, a smooth underbody, a tapered rear end, minimized body seams, and aerodynamically designed air intakes, suspension, and wheel wells. These improvements could be achieved without significantly restricting the stylist's freedom to make attractive and distinctive-looking cars. Large improvements could be made by just smoothing the underbody, which is essentially invisible.

Rolling resistance is affected by the mass of the vehicle, the type of tires, and the amount of friction in the bearings and idle brakes. In addition to minimizing the vehicle's mass, special tires, wheel bearing assemblies, and brakes can be employed to reduce overall rolling resistance by more than 50 percent. Such changes would be mostly transparent to the driver, since low-rolling-resistance tires are designed to provide traction and durability comparable to conventional tires.

Hybrid-Electric Drivesystem

Another of the Hypercar® vehicle's key divergences from today's cars is its drivesystem. Conventional automotive drivesystems consist of an internal combustion engine (ICE) mechanically coupled to the drive wheels through a multi-speed transmission. Such a drivesystem's efficiency suffers from having to operate over a wide speed and power range. The engine can be tuned to operate efficiently under specific operating conditions (say, at constant highway speed on a level road with two passengers), but it must be run far from this "sweet spot" of efficiency much of the time. The engine's efficiency is further impaired because it must be grossly oversized so that it can accelerate the heavy steel vehicle quickly.

To improve the efficiency of converting fuel into traction at the wheels, the Hypercar® vehicle would use a hybrid-electric drivesystem. Like a battery-electric car, a hybrid-electric car is powered by an electric motor or motors, but the electricity, rather than being drawn from batteries recharged from the grid, is generated onboard with a small engine or other device. This offers two big advantages over a battery-electric car: the hybrid car doesn't have to haul around hundreds of pounds of batteries, nor is its range limited by the need to recharge them.

The hybrid-electric drivesystem also has at least two big advantages over conventional ICE systems. First, the engine (technically called the auxiliary power unit, or APU) runs over a smaller range around its most efficient operating point, and can even be turned off when not needed. Any extra power required can be provided by a small electrical buffering or load-leveling device (LLD). The engine can either be coupled directly to the wheels, as in today's cars, or be connected to a generator that produces electricity for separate electric motors connected to the wheels. The first case is called a *parallel hybrid* because both the APU and one or more electric motors drive the wheels simultaneously. The second is called a *series hybrid* because the APU, motor(s), and wheels are connected in series—the APU produces electricity for the motor(s) and keeps the LLD charged, and they in turn power the wheels, but the engine has no mechanical link to the wheels.

A second advantage of hybrids is that they can recover part of the braking energy that would otherwise be lost as heat in the brakes. Some experimental vehicles have demonstrated up to 70 percent peak energy recovery, but recovery of about 50 percent is seen by many experts as a more realistic goal. Hypercar® vehicles would probably still use conventional brakes, but much less, so they'd last longer.

Accessory Loads
Currently, little attention is paid to designing cars for minimized heating and cooling loads or making their accessories energy-efficient. But in a Hypercar® vehicle, where the power needed for propulsion is minimized, standard accessory loads would become an important part of total power consumption. Through careful choice and integration of efficient components, however, the accessory loads could be reduced to no more than about one-fourth of the current average, while providing equivalent or better functions.

For a more detailed technical discussion of these concepts, see the RMI publication "Vehicle Design Strategies to Meet and Exceed PNGV Goals."

Would there be tradeoffs in performance or styling?

The fundamental thesis underlying the Hypercar® concept is that high fuel efficiency and low emissions can be achieved without compromising the car's marketable features (such as performance) and without imposing burdensome constraints on its body styling. RMI bases its fuel-efficiency modeling on a vehicle that would perform equivalently to, or better than, a current five-to-six-passenger touring-class sedan, such as the full-featured versions of the Ford Taurus, Chevrolet Lumina, or Chrysler Concorde.

While some changes would be required to improve aerodynamics, the body designer would still have significant stylistic freedom. Features like thinner body seams, a smooth underbody, recessed windshield wipers, and flow-optimized air intakes and wheel wells would be relatively transparent to the user, but could significantly lower the car's aerodynamic drag. Further changes such as partially covered wheel wells, cab-forward design, and a tapered rear end would also lower drag, and could be implemented to the extent that they are accepted by consumers.

The Hypercar® vehicle's aerodynamic body design would enable it to achieve high speeds more easily, and its light weight and electric propulsion (which provide very high torques, especially at low speeds) would provide sporty acceleration. These attributes, plus nimble handling and short stopping ranges, should be welcome in the marketplace. Furthermore, ultralight body materials can typically provide superior acoustics, stiffness (hence comfortable ride and refined handling), fit and finish, and resistance to corrosion and fatigue.

In summary, fuel efficiency is only one feature of the Hypercar® concept—equivalent or superior performance is also integral. Some styling changes will be necessary to improve the car's aerodynamics, but the Hypercar® concept does not prescribe a single body design to enable it to work.

For more technical details, see the RMI publication "Ultralight Hybrid Vehicles: Principles and Design."

Why a hybrid-electric instead of a battery-electric vehicle?

Battery-electric vehicles (BEVs) suffer from limits of battery cost, life, and energy per kilogram that make them unsuitable as all-purpose cars for most people. Recently, their performance has significantly improved, opening certain niche markets, but they're still far from being widely attractive.

However, ultralight hybrid-electric cars can achieve the important advantages of electric propulsion—building on the same technological foundation—without the disadvantages of batteries. As explained in the previous answer, hybrids wouldn't need the massive storage batteries that are largely responsible for BEVs' short range, increased cost, and other limitations. Technical modeling by RMI suggests that hybrid-electric Hypercar® vehicles could meet or even beat the cost and performance criteria of comparably sized conventional cars.

BEVs' big selling point is their low emissions, and it's with BEVs in mind that California regulators have mandated that 10 percent of cars sold in that state must be "zero-emission vehicles" by 2003. But of course the term "zero-emission vehicle" is a misnomer, since all cars produce emissions somewhere; battery-electric cars simply displace them from the tailpipe to the power plant. RMI calculates that a BEV adds about as much to Southern California's pollution, in the form of local power-plant emissions, as a modern car getting about 90 mpg would. Recognizing that cars capable of getting that mileage or better may be feasible, California is in the process of rewriting its regulations to allow any vehicle that runs as clean as a "zero-emission vehicle" (taking into account the energy-supply systems of both) to qualify as one.

Hypercar® vehicles, then, can achieve comparably low emissions without BEVs' drawbacks. This should lead to a more positive overall environmental benefit, since the Hypercar® vehicle's potential market is much larger than the BEV market.

For a more on this, see "Vehicle Design Strategies to Meet and Exceed PNGV Goals" or the shorter (but more recent) "Ultralight Hybrid Vehicles: Principles and Design."

What fuels would Hypercar® vehicles use?

Hypercar® vehicles could be designed to run on almost any type of fuel—liquid or gaseous, renewable or non-renewable. Although emissions depend on fuel choice, the Hypercar® platform would be so efficient to begin with that it would be much less polluting than a conventional car even if it used standard gasoline or diesel. Hypercar® vehicles' high fuel-to-traction efficiency would also make cleaner gaseous fuels (such as methane) more feasible, because smaller, lighter, and cheaper storage tanks could be used without compromising range. (The same reasons would make hydrogen an attractive Hypercar® fuel, especially if converted to electricity via an onboard fuel cell—see the next answer.)

Many factors are likely to influence which fuels are used in Hypercar® vehicles, including fuel price, market preference, fuel distribution and refueling infrastructure, and public policy. In Europe, for instance, early Hypercar® vehicles might be powered by small diesel engines, since European automakers are very good at building relatively clean diesels. In the United States, compressed natural gas or unleaded gasoline engines might be preferred in the near term.

But in the medium to long term, hydrogen looks like the most promising fuel for Hypercar® vehicles because it produces very low to no emissions and can be made using renewable energy. More on this in the next answer.

Are fuel cells being considered in Hypercar® vehicles?
Yes, vigorously, by both RMI and automakers. Fuel cells are an exciting APU (auxiliary power unit—i.e., engine) option because they're very efficient, produce zero or near-zero emissions (depending on the type and origin of the fuel used), could be extremely reliable and durable (since they have almost no moving parts), and could offer a high degree of packaging flexibility. Currently, however, they're very expensive because they're not produced in volume, and a widespread refueling infrastructure doesn't yet exist for some of the fuels considered for their use.

Fuel cells generate electricity directly by chemically combining stored hydrogen with oxygen from the air to produce electricity and water. The hydrogen can be either stored onboard or derived by "reforming" gasoline, methanol, or natural gas (methane). Reforming carbon-containing fuels generates more emissions than using hydrogen created directly with renewable energy, but these fuels are much more readily available and may be used as a transitional step until a hydrogen infrastructure develops.

Fuel-cell technology has advanced significantly in the past few years, and a handful of automakers have shown prototype fuel-cell-powered vehicles. However, these prototypes have been quite heavy, requiring large (and therefore expensive) fuel-cell powerplants, which has led some observers to predict that it may take 15 to 20 years for fuel cells to become economical. Yet Hypercar® vehicles could accelerate the adoption of fuel cells, because the Hypercar® vehicle's much lower power requirements would require far less fuel-cell capacity than a heavy, high-drag conventional car. This could make fuel cells affordable much earlier in Hypercar® vehicles than in conventional vehicles.

For a longer (but still non-technical) discussion of fuel cells and Hypercar® vehicles, see "Hypercars: The Next Generation" (Summer 1996 RMI *Newsletter*), which is posted on RMI's web site, www.rmi.org.

Why advanced composites?
Polymeric composites combine superior strength and stiffness with light weight by embedding very strong reinforcing fibers in a supporting "matrix" of plastic. The fibers can be chosen and oriented to match the mechanical properties required, improving performance still further. Hypercar® vehicles' bodies would probably use mainly "advanced" composites, which contain carbon, aramid (Kevlar), or similar fibers, making them stiffer and stronger per kilogram than glass-fiber-reinforced composites. The composites would probably be molded into a "monocoque"—a shell that is itself the structure and requires no separate frame or chassis. Advanced composites are already widely used in aerospace and in high-performance boats and sporting goods.

Advanced composites have many benefits, both technical and strategic:

- **Ultralight weight.** Advanced composites offer the greatest potential for mass reduction. Reducing a vehicle's mass makes it peppier and/or more fuel-efficient to drive, nimbler to handle, and easier to stop. Experts from various U.S. and European car companies have estimated that advanced composite autobodies could be up to 67 percent lighter than today's steel versions. In comparison, aluminum is estimated to be able to achieve a 55-percent mass reduction, and optimized steel around 25-30 percent. So for mass reduction and fuel economy, advanced composites look especially promising. Their superior mechanical properties allow them largely to decouple size from mass—enabling cars to be roomy, safe, *and* ultralight.
- **Lower capital requirements.** Composites require about two to ten times less capital for manufacturing equipment (more than five times less for Renault's L'Espace van, for example). While some composite manufacturing processes require pressure, the pressures required are much lower than for forming metals, and only one or two steps are needed to form a composite part, as opposed to multiple hits from a series of huge stamping presses and expensive stamping tools to form a metal part. This all results in a cheaper and less complex manufacturing process, making smaller production volumes economical and hence leading to more agile and market-responsive product lines with lower financial risk.

· **Parts count reduction.** Composites' greater formability also helps reduce the number of separate tools, the number of process steps, and the assembly costs through radical parts reduction. Since metal stamping cannot form geometrically complex parts, a typical car body contains many hundreds of parts that are welded together. Composites allow for far more complex molding, so that while the preparations for molding can be more involved than inserting a steel sheet into a press, many subassembly steps needed for a metal car would become unnecessary.

· **Design flexibility.** Composites' "anisotropy" (directionally oriented performance characteristics) and formability offer unprecedented design flexibility for the car designer. The properties of the material can, to a degree, be tailored to the loads that a part will experience, which allows the designer to maximize the benefit of using these expensive materials. Composite manufacturing processes can also be made to fit much tighter tolerances than steel parts, allowing for thinner seams between parts than in today's cars. This improves both aesthetics and aerodynamic drag.

· **Crashworthiness.** When properly designed, advanced composites could provide excellent crashworthiness. They have several properties, including crash energy absorption of around five times that of steel per kilogram, that are ideal for safety applications. In fact, several automakers are exploring the possibility of putting advanced composites in their steel cars to make them safer. (More on this in the next answer.)

· **Other characteristics.** Composites' durability (they can be highly resistant to rust and fatigue), and their high stiffness and favorable noise, vibration, and harshness (NVH) characteristics lead to more marketable and comfortable cars. For example, GM attributes the Ultralite's superior NVH characteristics to its all-advanced-composite body.

Advanced composites' main disadvantages are their high material cost, steel-based automakers' unfamiliarity with them, and the fact that high-volume manufacturing processes haven't yet been demonstrated for similar applications. Two RMI newsletter articles posted at this site, "Hypercar® Economics 101" and "Overcoming Cultural Inertia," touch on this subject. Both articles summarize longer technical publications which can be ordered through our online catalog.

Would Hypercar® vehicles be safe? What would happen in a collision between a Hypercar® vehicle and a steel car twice as heavy?

Safety is critical, and it is part of RMI's ongoing Hypercar® research. We believe that any new vehicle concept should not just equal but exceed the safety of today's vehicles, and that Hypercar® vehicles can do so.

Ultralightweight vehicle design, while presenting new challenges, does not preclude crashworthiness. Using proven technologies for energy absorption, force-limiting occupant restraints, and rigid passenger-compartment design, light vehicles could surpass the safety of today's cars in many types of collisions.

In a head-on collision with a vehicle much heavier than itself, a Hypercar® vehicle would have to absorb proportionally more energy to protect its occupants. Although this puts the Hypercar® vehicle at an initial disadvantage, other features can more than compensate. For example, since the hybrid drivesystem can be small and modular, a larger portion of the space under the hood can be used to absorb energy and slow down the vehicle—instead of being filled with a large, uncrushable engine. Composites can make the most of this extra space because they can absorb many times more energy per pound as steel, and can do so more smoothly, thus using the crush space more efficiently. These two features, along with other benefits of composites, could make it possible for a Hypercar® vehicle to protect its occupants adequately in a head-on collision with a car roughly twice its mass. (Other kinds of collisions require additional engineered safety features that are already available.) We are currently investigating what the practical lower limit to a Hypercar® vehicle's mass would be for safety reasons, given the current mix of vehicles on the road, but believe better design and materials will prove an adequate substitute for the "juggernaut strategy."

Over the long term, replacing conventional cars with lightweight Hypercar® vehicles would markedly improve safety for all road users. Heavy cars protect their occupants at the expense of the occupants of other cars with which they might collide, but lighter Hypercar® vehicles would pose less threat to the safety of others (including pedestrians and cyclists). Lightweight, but very strong and protective, Hypercar® vehicles would thus be a win-win situation for both parties in a collision.

How long until I can buy a Hypercar® vehicle?

Early Hypercar® vehicles could start appearing within about four years. Light battery-electric vehicles like GM's EV-1 production model (released in late 1996), Honda's four-seat EV (scheduled for release in 1997), and Solectria's all-composite four-seat Sunrise (1998) are two-thirds of the way there—they have ultralight, aerodynamic bodies and electric propulsion. Replace the heavy batteries with a small engine, generator, and buffer storage device and you've got a functional Hypercar® vehicle. Adapting an existing battery-electric vehicle would still involve many technical hurdles—development and testing would take at least an extra year or two—but it would be easier than building a Hypercar® vehicle from scratch.

We wouldn't be surprised to see this sort of modified battery-electric vehicle officially come on the market by the year 2000. GM announced in November 1996 that the EV-1 will be the first of a series of battery- and hybrid-electric cars with halved weight and drag—early Hypercar® vehicles in all but name. Such first-generation Hypercar® vehicles would probably be manufactured in small volumes, and hence would be relatively expensive and not widely available; as such, they'd probably appeal more to "early adopters" than to the average motorist. However, hints from Toyota suggest that that automaker is contemplating starting production of 80-mpg (3L/100 km) Corolla-class hybrids at a rate of tens of thousands per year as early as the end of 1997, which would really fast-forward the Hypercar® future.

In any event, affordable, production-volume Hypercar® vehicles are likely to appear in the first few years of the next decade. Industry/government collaborations, foreign competition, and flexible regulatory incentives are compelling America's Big Three to converge toward production Hypercar® vehicles—some of them aggressively. Within one to two decades, we could see a diverse range of quite refined Hypercar® vehicles incorporating all-advanced-composite bodies and probably fuel cells.

While these are just rough estimates, we can say with confidence that automakers have strong incentives—chiefly profit and market share—to move very quickly. If you're looking to improve your fuel economy in the meantime, you can choose from among several conventional cars on the market that get better than 40 mpg (5.9L/100 km).

How much would a Hypercar® vehicle cost?

Although our current analyses are quite preliminary, we expect the cost of a Hypercar® vehicle to be close to that of a comparable conventional car. An initial cost study by RMI and IBIS Associates focused on the manufacturing and lifecycle costs of the Hypercar® body alone. You can read a brief summary of the results of that study in "Hypercar® Economics 101" (Fall/Winter 1995 RMI *Newsletter*). For a detailed report, order the RMI paper "Costing the Ultralight in Volume Production: Are Composite Bodies-in-White Affordable?". In the near future, we will be refining our whole-car cost analyses to provide a more accurate Hypercar® vehicle cost estimate.

Far more certain is the potential for large savings during the Hypercar® vehicle's operation—mostly from reduced fuel consumption, but also from reductions in oil, spark plugs, hoses, belts, and many other fluids and parts needed by conventional cars. Besides lowering the cost of owning a car, reducing or eliminating the need for these items could result in greater reliability and would help the environment.

Would Hypercar® vehicles be recyclable?

Whether a Hypercar® vehicle—or any car—is recyclable depends on many factors. Three of the most crucial ones are briefly discussed below. For more detail, see the RMI publication "Ultralight-Hybrid Vehicle Design: Implications for the Recycling Industry."

Design and Constituent Materials

Since they'll be starting from a clean slate, Hypercar® vehicle designers will have the opportunity to incorporate recyclability into the entire car. For example, they could make the Hypercar® vehicle from materials that can be recycled together or that are easily separable. (The more dismantling effort required, the harder it is to recycle a car economically.) The advanced composite materials RMI proposes to use in Hypercar® vehicles are very different from those currently used, and thus will require a new recycling infrastructure, so attention to recycling is of even greater importance.

Recycling Technologies Available

The perception that composite materials are unrecyclable is due in part to the problems of recycling plastic packaging and containers. But while the issues may be similar, the economics are very different. Junked cars, regardless of what they're made of, have considerable salvage value. Roughly 90 percent of vehicles retired each year in the United States end up at a dismantler's yard, where their salvageable parts are removed for remanufacture or reuse—unlike plastic packaging, which typically isn't worth the cost of collecting it. Since the advanced composites proposed for use in the Hypercar® vehicle are expensive, there would be an even stronger incentive to find an economical means of recycling them.

At least two such technologies exist—low-temperature catalytic pyrolysis and solvolysis—and both appear to provide the required attributes.

Standard pyrolysis breaks down polymers at very high temperatures in the absence of oxygen. The result is low-value "pyro-oil" (a mix of petrochemicals whose exact composition depends on the feedstocks), ash, and heat. While technically feasible, standard pyrolysis would not be desirable for recycling scrapped advanced-composite autobodies because the fibers could not be recovered. However, a handful of innovative processes based on pyrolysis have shown great promise by reducing the operating temperatures so that the fibers are not destroyed.

Solvolysis is used to break down a variety of polymers at high temperature and pressure and with an appropriate solvent. Solvolysis has proved successful on a small scale for recycling pure, unmixed manufacturing scrap and some post-consumer plastics. Research is being done to adapt the process to handle certain mixed-plastic streams and to be more tolerant of contaminants. Despite some success with unmixed plastics, solvolysis has never been used to recycle advanced composites. More research on this application is needed.

Markets for Recycled Materials

Processes such as low-temperature pyrolysis demonstrate the technical feasibility of advanced composite recycling, but markets for the recycled material are essential in order to justify implementing the technologies. While predicting the future of such markets is difficult, current trends suggest the economics will be favorable.

For resins, some recycling processes already in existence could return recycled material to the polymer fabricator at a cost competitive with virgin feedstocks—encouraging evidence that the polymers in a Hypercar® vehicle could be economically recycled. For fibers, the markets for chopped and milled versions are strong. Fibers recycled through the low-temperature pyrolysis process could potentially be sufficient for this market and others, but at a fraction of the current price. Preliminary cost estimates indicate that chopped recycled carbon fiber could be profitably supplied at less than a fifth of the current virgin price.

Of course, a few factors could devalue the materials recycled from Hypercar® vehicles. First, Hypercar® vehicles wouldn't be retired in large numbers for 20 years or more, by which time the price of virgin materials is likely to be much lower than it is today. It's impossible to predict whether the price of recycled materials will keep pace. Second, products not designed with recyclability in mind, such as composite autobodies with combinations of fibers that aren't easily separable, could make materials recovery very difficult, thus less economic. Third, the profitability of dismantling could be affected by rapid technological progress, causing demand for components from older cars to plummet. It's worth noting, however, that these forces could affect the viability of any automobile recycling system, not just one based on Hypercar®

vehicles. Moreover, although Hypercar® vehicles would not be technically suited to the current car-recycling infrastructure, there would be plenty of time to adapt existing methods and equipment.

In any case, Hypercar® vehicles may prove to be so durable and so readily upgradable in both hardware and software that they could undergo many "reincarnations" before requiring remanufacturing or recycling. And even if none of this were true, and if Hypercar® vehicles, after removal of valuable components, were simply chopped up whole and landfilled at the end of the same lifespan as steel cars, our modeling suggests they would still generate roughly the same amount of shredder "fluff" (unsalvageable and unrecyclable material) as today's cars.

How has RMI been involved in developing the Hypercar® concept?

RMI seeks and implements ways to make the use of natural resources more efficient and sustainable. Since transportation is a heavy user of energy and raw materials, the Institute has long viewed transportation as an especially promising area for improving resource efficiency.

Transportation is really about mobility and access—to jobs, goods, services, recreation, and other people. While automobiles arguably are neither the most efficient nor the cheapest way to provide access, they're a fact of life in many countries and are the only means of access in much of the United States. In recent years, therefore, RMI has temporarily narrowed its scope to developing more efficient automobiles.

In 1991, RMI Research Director Amory Lovins made the first conceptual breakthrough in the development of what are now called Hypercar® vehicles* when he began examining the synergistic benefits of combining two known and demonstrated techniques—ultralight, ultra-aerodynamic construction and hybrid-electric drive. Since then, an RMI team led by Lovins has been developing the Hypercar® concept with funding from the Compton, Nathan Cummings, Energy, Heinz, Joyce, Surdna, W. Alton Jones, and other foundations.

During 1991-93, the team refined the concept, entered into an extensive *pro bono* technical dialogue with a major automaker, and obtained peer review by scores of industry and independent experts. In 1993, the concept was publicly released with supporting details at a European energy-efficiency conference. In 1994, RMI formed an in-house division dedicated to Hypercar® vehicles. The mission of this division, called The Hypercar® Center, is to support the wide, rapid, and responsible commercialization of ultralight-hybrid vehicles.

Before the auto industry can be expected to make the huge financial and cultural leap from conventional cars to Hypercar® vehicles, it needs confidence that the technical, economic, and marketing challenges can be overcome. The Hypercar® Center therefore emphasizes technical analyses to anticipate and address industry's key concerns. Staff have presented their findings in technical journals, at industry conferences, and in executive briefings for manufacturers, parts makers, and other companies eyeing the Hypercar® market. RMI is currently in various stages of discussion and collaboration with about two dozen corporations worldwide, which collectively have committed more than $1 billion to developing ultralight hybrids.

* RMI originally called this concept a "supercar," but changed the name in 1994 to avoid confusion with two other usages: in the racing world, "supercar" means a street-licensed Formula One racecar (which gets a couple of hundred miles per hour, not per gallon), and in the popular press, it is loosely but increasingly used to mean a car of any design with modestly improved fuel economy.

How can RMI help those with a commercial interest in Hypercar® vehicles?

If you think your firm might be interested in developing Hypercar® vehicles or Hypercar® components, we'd like to hear from you. The Hypercar® Center's mission is to assist just such efforts. The Center provides a variety of proprietary written products (such as a 450-page developer's primer), software, and consulting services to more than 20 corporations worldwide.

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