Hydrogen Fuel Cells and the "Hydrogen Economy"

A Technological Dead End in the New Energy Age?

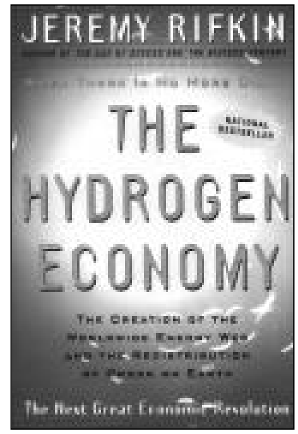
Eugene F. Mallove

A few weeks after "cold fusion" was announced in 1989 (the now verified excess energy and nuclear transformation phenomena is today more appropriately called LENR, low-energy nuclear reactions), several people who consider themselves to be environmentalists, who are presumably concerned with human welfare, made very negative remarks about the claimed discovery of Fleischmann and Pons[1]:

> "The fusion findings are the worst news that ever happened. Right when we are beginning to develop a global awareness of the problems of global society, here come some scientists saying we don't have to deal with those problems," extreme anti-technologist Jeremy Rifkin told the press. Amory Lovins of the environment/energy think-tank, The Rocky Mountain Institute of Snowmass, Colorado, had this to say: "Most of the costs of fusion will be the stuff you wrap around it to get electricity, from the turbine to the plant site, to the health physicists and other cleanup services you need, all of which will make it at least as expensive as fission. The right place for a fusion reactor is where we have one, 93 million miles away." He was glibly blasting cold fusion with *hot* fusion's well-known shortcomings, were thermonuclear fusion ever to be successfully developed. Biologist Barry Commoner of Queens College said, "Putting [a cold fusion device] in the basement or a car is nonsensical. . .As long as radiation is involved, you need major controls."

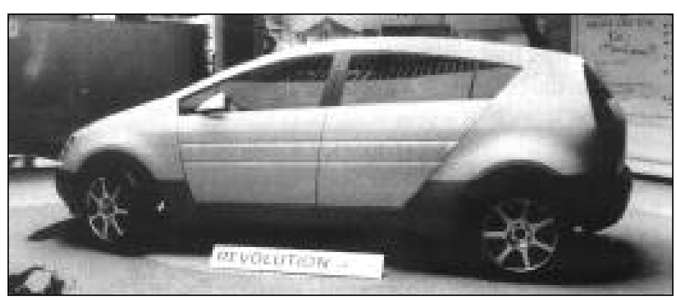
Mind you, these remarks were made in the early days of cold fusion, when it was not possible to know whether or not the claims of Fleischmann and Pons would be validated by independent testing—and, even if validated, what the likely course of technological development of cold fusion might be. It is crystal clear that these gentlemen were reacting in a knee-jerk fashion to something that was evidently threatening the entire intellectual frameworks on which they stood. By 2004, none of them had moved one millimeter in the direction of understanding or appreciating the New Energy revolution that is implicit in the validated new discoveries that came at and after the 1989 Utah announcement.

Jeremy Rifkin is a good example of a man with his head in the sand about New Energy. His "national bestseller" book, *The Hydrogen Economy: The Creation of the Worldwide Energy Web and the Redistribution of Power on Earth* (2002)[2] is mostly a political polemic, as one might expect given his outburst in the spring of 1989. Rifkin's "power" is not electrical power; it's political control. Strange to say, this is "power" of the very same type that has held back cold fusion/LENR—know-it-all government bureaucrats and academicians telling citizens what is right and what is wrong within science and rarely owning up to their mistakes. You'll find choice nuggets like this sprinkled throughout Rifkin's hydrogen opus, "The market economy, steeped in the exchange of goods and services, is found to be far too slow to accommodate the new speed of commercial life." Really?



The Rifkin hydrogen-hype thesis is that so-called renewable energy sources (specifically solar energy and windpower) will be used to generate hydrogen gas from the electrochemical splitting of water into hydrogen and oxygen. Then this hydrogen will be fed into a national—even international—grid of pipelines to power an energy-hungry world. At the user end in hydrogen fuel cells, the hydrogen is combined with atmospheric oxygen to produce electricity and some waste heat, with the main by-product of the reaction being water, which was the starting substrate. What's wrong with this picture? Lots, as we shall see.

Amory Lovins, who is a good deal smarter technically than Rifkin and who should have been following LENR and other emerging new energy technologies all along, simply wants the world to get along on less energy, not more. He revels in his deserved appellation, "Mr. Negawatt." Lovins has been one of the leading proponents



The Hypercar Revolution, a mock-up of a fuel cell-powered sport utility vehicle.

of the "hydrogen economy." His aphorism is quoted approvingly by *The Economist's* latest wunderkind on the energy beat, V.V. Viatheeswaran[3]: "Negawatts are often cheaper than megawatts." In one section of his book, Viatheeswaran writes, "For some years now the Sage of Snowmass [Lovins] has been making another sweeping forecast for the future of energy, and again he is sounding fanciful, 'This breakthrough will be like the leap from the steam engine to the diesel locomotive, from the typewriter to the laptop computer. . .it's a really disruptive technology.' . . .With a flourish befitting a mad scientist he reveals his creation: The Hypercar." This is a no doubt well-engineered conception, in its own frame of reference, which is powered by conventional hydrogen chemistry in—you guessed it—hydrogen fuel cells. Fuel cells are the "Next Big Thing," puffs Viatheeswaran.

But just what is a fuel cell, which is said to be the corner-stone of the hydrogen economy? First, realize that fuel cells come in several different types, only a few of which have been touted for use in the proposed conventional "hydrogen economy." In purest form, one can think of a fuel cell as a reverse electrolysis cell. So instead of, for example, water being decomposed into hydrogen and oxygen (separately at two different electrodes) by the passage of electricity between the electrodes, in a fuel cell hydrogen may flow through and from an anode catalyst material (such as platinum), then through an intervening material substrate that allows the ionized hydrogen to move toward the cathode, where it is recombined with oxygen, producing water. The electron removed from the hydrogen at the anode then flows through the external power load of the fuel cell back to the cathode side, where it participates in the formation of the water by-product.

John Grove, discoverer of the basic fuel cell principle.

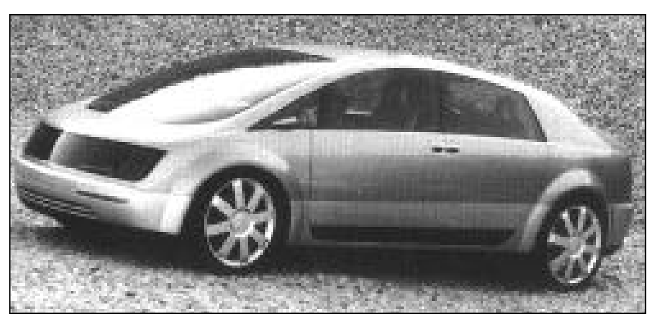
The basic fuel cell principle was actually discovered in 1839 in England by a research physicist friend of Michael Faraday, John Grove. But though the principle of the fuel cell has been known for a long time, there was apparently not a great technological need for electricity-producing fuel cells (called "gas batteries" originally) for over a century after their discovery. Chemical storage batteries or primary cells worked just fine for most applications.

But in recent years, in fact, "fuel-cell mania" seems to have captured the imagination of investors and the media, in what appears to be a head-long rush toward irrationality, cheered on by the likes of the Jeremy Rifkins of this world, who, in particular, don't want civilization to have command of larger energy resources. President Bill Clinton in 1997 bubbled, "Ballard Power and United Technologies are leading powers in developing fuel cells that are so clean. . .their own exhaust is distilled water." True enough, but usually not mentioned in the same breath of clean water vapor—even by U.S. Presidents (George W. Bush has most recently succumbed to this fuel cell malady)—is that some *other* energy source has to generate that hydrogen, and it might be a polluting source, admittedly not where the fuel cell was being operated, which is at least some advantage.

This is not, of course, to blame the technologists of enterprising fuel cell companies for the excesses of the Rifkin-clique of modern-day Luddites. But it is true that fuel cell people can certainly be accused of amazing blindness for not at least casting wary or interested glances toward what is going on in the LENR field. After all, LENR research began, of course, with the work of some of the world's foremost electrochemists—Martin Fleischmann, Stanley Pons, John Applebee, and John O'M. Bockris. How could these fuel cell people *not* notice what is going on in LENR?! It is all the more ironic, because leading cold fusion pioneer Bockris was first to coin the very term "hydrogen economy" back in the 1970s. "Boiled down to its minimalist description, the 'Hydrogen Economy' means that hydrogen would be used to transport energy from renewables (at solar or nuclear sources) over large distances; and to store it (for supply to cities) in large amounts."[4]

It shows, perhaps, how thoroughly mind-deadening has been the DOE-launched assault on the LENR phenomenon. Now with the publicized DOE review of the cold fusion question pending in early 2004, perhaps the fuel cell community will at least reconsider what it is doing. One hopes it will. LENR could use its support. Recall that LENR (and associated energy-from-water claims, such as the BlackLight Power Corporation catalyzed shrunken hydrogen or "hydrino" process) posit energy reserves associated with hydrogen that range from hundreds to millions of times the energy release per unit mass of hydrogen in *conventional* chemical energy release. These phenomena utterly dwarf the piddling energy reserves of conventional hydrogen used in fuel cells. In fuel cells the fuel is not free, but in *new physics energy* hydrogen, the fuel *is* free, because only a tiny fraction of the energy produced need be tapped to self-produce fuel from water.

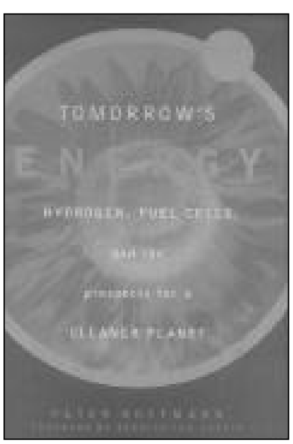
A two-page color advertising spread by General Motors in a recent *New York Times* (March 16, 2004, pp. C12-13) shows two little girls in a colorful plastic toy car tootling along a path through green grass with an expansive blue sky. The message written large in the heavens: "WHO'S DRIVING THE HYDROGEN ECONOMY?" More hype in the ad: "The hydrogen economy isn't a pipe dream. And it isn't the buzz du jour on the front page of the business section. The hydrogen economy is the endgame of a multi-faceted strategy GM set in motion years ago, with steps that are real, progressive, and well-underway. . .We're making sure children today are in cleaner cars tomorrow. And in the driver's seat of the hydrogen economy."



General Motors' five-passenger fuel cell-powered Hy-wire sedan.

So it goes with the media frenzy. But watch out, investors, for the fuel cell hype could become another dot-com fiasco! *The Economist* back in 1997 (October 25-31 edition) featured this hype on the cover: "How Hydrogen Power Can Change the World." It spoke of "the third age of fuel": "For 100 years the source of that power [for the industrial revolution] was coal. For almost another 100 it has been oil. But, as the revolution that [Matthew] Boulton helped to start enters its third century, it may be about to embrace a third fuel: hydrogen." *The Economist* gets it all wrong in its second paragraph, calling the fuel of the "hydrogen economy" "the main source of energy." Bah! Such carelessness. Hydrogen is not a *source* of energy in the classical physics, conventional use of hydrogen in fuel cells or combustion; *it is an energy carrier*. Sure, if you strip the hydrogen off hydrocarbons, as is done for some kinds of proposed fuel cell systems, then you are using hydrogen as a primary fuel—but you are really using hydrocarbon fuel (*e.g.* gasoline) again, and where has that gotten us? But if you are stripping H_2 out of water, then you are conventionally having to use another entirely different source of energy to get that hydrogen—and this will require much more energy than one gets back when the hydrogen is processed in the fuel cell. Ergo, hydrogen *per se* is *not* a fuel. (Editor's Note: My apologies to *IE* subscriber, heretical geologist Warren Hunt, who is convinced that deep within the Earth there are significant reserves of free hydrogen that we might ultimately learn to tap.)

So, what, if anything, is wrong with hydrogen fuel cells? First of all, as we have seen, they *do not* represent a new source of energy, but that is precisely how they are often billed in some publications that hype them. Jeremy Rifkin blurts out at one point in his book, crossing the line from insidious deception to outright falsehood: "For the first time in human history, we have within our grasp a ubiquitous form of energy, what proponents call the 'forever fuel.'"(p. 217) Hydrogen is not a "ubiquitous form of energy"—it is merely a carrier of energy, once it is obtained at the cost of other energy input from some other source. Today, for example, the least expensive way to make hydrogen is by steam reformation of natural gas (methane). Electrolysis produces a more purified form of hydrogen, but this requires a source of electric power—solar, nuclear, chemical, etc.

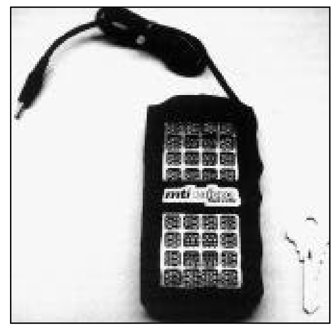


The person who coined the term "forever fuel," back in the 1980s is, by contrast, a man of great integrity and carefully assembled knowledge about fuel cells, Peter Hoffman, Editor of the monthly publication, *The Hydrogen Fuel Cell Letter* (www.hfcletter.com). His book, from which Rifkin drew inspiration, was *The Forever Fuel: The Story of Hydrogen* (Westview Press, 1981). This work has been updated by Hoffman in *Tomorrow's Energy: Hydrogen, Fuel Cells, and the Prospects for a Cleaner Planet*. He states explicitly, as all discussions of *conventional chemical hydrogen* should: "Hydrogen is not an energy 'source,' a mistake still made fairly often by otherwise sophisticated, well-informed people. That is, it is not primary energy (like natural gas or crude oil), existing freely in nature. It is an energy *carrier*—a secondary form of energy that has to be manufactured (like electricity, which doesn't exist freely in usable form either)."

There is nothing inherently "bad" about fuel cells, in fact they are quite elegant solutions to generating electricity in particular applications. Though the invention of the fuel cell hearkens back to the mid-nineteenth century, they were pretty much a curiosity until NASA found a use for them in manned spacecraft, for generating electricity, and regenerating water from the original hydrogen and oxygen stocks (stored in liquid form, cryogenically) that are brought along at great expense in the chemically propelled spacecraft. Some rocket systems today, like the space shuttle main engines, ironically also use hydrogen and oxygen in combination as a high specific-impulse propellant.

Hydrogen and Hydrogen Fuel Cells in the Context of *New* Energy

Without venturing much further into the territory of exactly where hydrogen fuel cells and other kinds of fuel cells stand today in the marketplace—costs are said to be falling towards or below $1,000 per kilowatt of electrical power in fuel cell stacks—let us be completely clear about a devastating and fundamentally unavoidable logical equation:



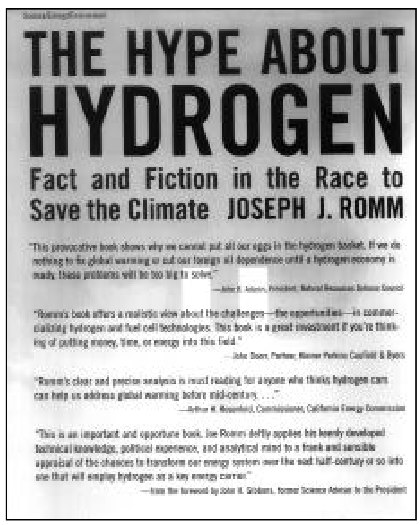
Mechanical Technology's methanol micro-fuel cell prototype.

***IF (1):** There comes into existence a truly new energy source, in the sense that it works on radically unsuspected physics principles (such as, for example, LENR), and if that new energy source is able to provide energy from effectively *free* sources, for example, from water, or from the vacuum of space, or from the ambient thermal heat (without recourse to a lower-temperature exhaust reservoir—*i.e.* an extension or violation of the Second Law), and **IF (2):** the *new* source of energy has *at least as much as but perhaps more than the power density of ordinary chemical energy*, then it follows that any energy source that depends on an energy fuel that is *not free* will suffer greatly, probably catastrophically in comparison. This will be true precisely because the conventional fuel cannot be obtained for *free*—whether this be oil, coal, natural gas, hydrogen, or fission nuclear power. (We'll be generous and admit that hot fusion's fuel is free—but hot fusion technology will be very, very expensive, if it is ever built at all.)

Furthermore, if the safety, environmental, and power density characteristics of the *new* energy source are such as to be acceptable for consumer use, and have the properties as well of being decentralized energy, *i.e.* not electric grid-dependent, or pipeline-dependent, time-of-day-dependent or weather-dependent, then it will be difficult or impossible for the non-new energy source to be competitive for virtually all purposes. This is not to say, as an example, that even in a raging New Energy Age, people might not employ mini-fuel cells using hydrogen or methanol fuel in portable computers or digital cell phones. There may be niche markets for other old energy too, *e.g.* the fragrant old ceremonial wood fire in one's mountain cabin wood stove, or the natural gas flame in a simulated wood fire in a suburban fireplace.

However, it seems to me that with the advent of truly New Energy, such as the much-discussed paradigm of the small LENR home power source, or the vacuum energy electric generator in one's basement, mere conventional chemical energy—such as are *all* fuel cells—has no chance at all to become a dominant energy carrier/source. Ergo, fuel cells are, indeed, fundamentally a technological dead-end. That fuel cell people have not recognized this is attributable only to their ignorance—willful or otherwise—of what is going on in New Energy. The only "comfort" that fuel cell people can take today is that New Energy has not—not yet—put them out of business. We don't deny, of course, that continued willful neglect of New Energy by the greenies and abuse by Establishment academics—and infighting even within New Energy!—can continue to delay the *real* energy revolution.

It is noteworthy that of several books dealing with hydrogen that I recently examined, including and beyond the Rifkin book,[3,5,6] *none* of them made any mention whatsoever of cold fusion or any other provocative new energy source—not that I expected them to do so. Furthermore, few of these mentioned, even in passing, the infamous *hot* fusion; that *did* surprise me.



Fuel Cell Infrastructure and Hype

If one is planning for a "hydrogen economy," the first issue that must be addressed is what *other* energy sources will be used to generate hydrogen from water electrolysis or steam reformation of natural gas. Here is where the hydrogen-hypers are most devious with their facts and figures. But retired University of Connecticut Professor Howard Hayden, who writes the monthly newsletter *The Energy Advocate*, has not been coy. In a recent issue[7] (February 2003), he writes of water electrolysis: "If all processes involved occurred at 100% efficiency, it would require about 140 megajoules (140 MJ) of energy input to produce a single kilogram of hydrogen. In the real world, electricity—from some source—can be used to produce hydrogen by electrolysis. If the efficiency were 100% (and it isn't), the efficiency of electrical production certainly is not. That efficiency varies from about 85% (hydropower) to about 5% to 10% for photovoltaic (PV) cells, with conventional electrical energy from fossils [power plants] and nukes coming in at around 30% to 40%. Optimistically, we'll use 40%; this means that we have to put in 350 MJ to produce a kilogram of hydrogen." He points out that hydrogen combustion would recover only 100 MJ of heat, while some 20 MJ would be lost as water vapor. The overall efficiency from fuel to heat is then only 34%.

But for fuel cells the math is different. Hayden says that a 60% efficient fuel cell will use 84 MJ of that original 140 MJ, so our original 350 MJ cost gives us only 84MJ of electric power, for a net efficiency of just 24%. Since electric motors, as used in electric vehicles can be 80 to 90% efficient, other losses bring the overall transportation energy efficiency from original fuel energy to motive power down to 20% to 22%. And remember, these figures used robust efficiency—40%—at the origination of the energy production. The picture is so much bleaker for hydrogen when PV's are the starting point.

Then there is the problem of the vast distribution and storage of hydrogen. Much technological development in support of fuel cells (and for the less efficient internal combustion hydrogen engine) has gone into figuring out how to store hydrogen at high density and safely, both for home and automotive use. But that is just one needed step in the hydrogen infrastructure. Thousands of hydrogen fueling stations will be required, costing many billions of dollars. An article in *The Wall Street Journal*[8] says that General Motors and Shell have estimates ranging from $10 billion to $19 billion just to begin the fueling station infrastructure for hydrogen vehicles. GM proposes 11,700 new hydrogen fueling stations ("so a driver would always be within two miles of a station in a major urban area," with highway station separations of some 25 miles). Shell, by contrast, proposes converting some 44,000 existing stations in the U.S. *WSJ* journalist Jeffrey Ball writes, "Byron McCormick, GM's executive director of fuel cell activities, likened investment in building a hydrogen infrastructure in the 21st century, to investment in the railroads in the 19th century or in the interstate highway system in the 20th century." He's right about that! Think about how much easier it will be when *real* new energy makes its debut. There will be no significant fueling infrastructure to deal with.

It is a great irony that the most devastating critique of the "hydrogen economy" comes from one Dr. Joseph J. Romm (an MIT-trained physicist), who oversaw hydrogen and transportation fuel cell research in the Department of Energy during the Clinton administration. His recent book, *The Hype About Hydrogen: Fact and Fiction in the Race to Save the Climate*[6] tells all. His overall message is that "commercially viable and environmentally beneficial hydrogen vehicles are in the post-2035 future." His perspective is driven by his assessment (which many would question) that "climate problems [global warming] could become irreversible." He was quoted in *The New York Times* (February 6, 2004, p. A19), "People who want to build 'hydrogen highways' and drive a hydrogen car in 10 or 15 years on a mass scale, are just kidding themselves." Also, "Fuel cell cars will not be environmentally desirable for decades, because there are better uses for the fuels you can make the hydrogen out of."

From the summary "Fact Sheet" which accompanied Romm's book:

> **What are the current barriers to emission-free hydrogen fuel cell-powered vehicles?**
>
> **Technology:* Currently, fuel cells are 100 times more expensive than gasoline engines and there is no substance known to humankind that can store

enough hydrogen to make a practical hydrogen fuel tank for a car.

Lack of environmental benefit: More than 95% of U.S. hydrogen is currently produced from natural gas, and vehicles running on fossil-fuel derived hydrogen will not reduce greenhouse gases compared to hybrids—like the Toyota Prius—running on gasoline. Thus, until the U.S. becomes far more heavily invested in renewable energies such as wind or solar power, there will be no environmental incentive for the consumer to purchase hydrogen fuel cell vehicles.

Distribution: There is no fueling infrastructure built around current hydrogen technologies, and creating one would be costly: $600 billion to cover 40% of the cars on the road, according to Argonne National Laboratory.

Safety: Hydrogen is a very leaky gas that is highly flammable and burns invisibly. Very onerous codes and standards are required for handling and distribution.

Cost: Currently, hydrogen as a fuel is prohibitively expensive—equal to gasoline at $4 to $6 per gallon for hydrogen from pollution-emitting fossil fuels and equal to gasoline at $6 to $10 for hydrogen from pollution-free renewable sources.

Romm says that hydrogen hype is bad for the climate change energy policies that he favors, because it could divert financial resources from better policy directions. He fears a backlash from consumers, if hydrogen cars are introduced prematurely. He opposes diverting our limited natural gas reserves to make hydrogen for hydrogen cars—such natural gas is better used, he says, in cleaner power plants. He writes, "A megawatt-hour of electricity from combined cycle natural gas plants releases about 800 pounds of carbon dioxide, whereas a megawatt-hour from even new coal plants can release more than 2200 pounds."

Romm's final recommendations, which do not, of course, include New Energy (since his alma mater's snow job against cold fusion, in favor of its pet white elephant, hot fusion, has been so effective): "Take a long-term, conservative perspective on hydrogen; Sharply increase research and development into other clean energy technologies; Launch a major national effort to use electricity and natural gas more efficiently; Start reducing carbon dioxide emissions now by using low-cost strategies; Begin a national effort to encourage combined heat and power; Phase-in carbon dioxide related standards for cars and light trucks; Prepare the public for tough choices ahead." Well, there's some hope for him in his reference to those "other clean technologies"; he might stumble across LENR or the other shockers at www.infinite-energy.com. Maybe we'll even see him at ICCF11 in Marseilles in October/November. Someone should buy him a ticket!

A Fuel Cell Car Experiment Kit—Drive It Yourself!

In thinking about this abbreviated coverage of the very intricate yet oh-so-simple fuel cell matter, it dawned on us that *Infinite Energy* readers would like to know about a fuel cell-powered car that they can already purchase for only about $160.00, and which they could build in their leisure time. We have even pictured the sparkling gadget on the cover of this issue. This Thames & Kosmos Fuel Cell Car and Experiment Kit features a plastic-bodied table-top vehicle that one can build, and perform various instructive experiments.

Of course, the car has to come equipped with a small solar cell PV panel that is used to make electricity to split water in its "fuel tank"—so that the hydrogen from the electrolysis can be used in the supplied fuel cell. Thus, the kit provides a tangible insight into this obvious shortcoming of fuel cells—the need for some *other* energy source. But it was very ingenious of the kit-makers in Germany to think of this educational device at all and to illustrate its wonderful, highly user-friendly instruction manual. The hype on the kit manual is endearing: "Build your own model Fuel Cell car that runs on water! Learn how emission-free vehicles, power stations, machines and power tools could soon be used around the world. Through a series of simple experiments, you will learn how Fuel Cells work and how they might power the future!"

If this editor can ever get out from under the harsh taskmaster of editorial deadlines, he might have some time to play with this wondrous toy. Either that or his now very young grandchildren may inherit it as an antique! By then, one hopes, New Energy will have made the concepts illustrated in the kit a quaint laughing stock.

Even better, one hopes that people in the New Energy field will have been motivated by this article to come up with small demonstration devices that will power small toy cars like this—which will go hundreds of meters further than any conventional fuel cell toy car, even further than one equipped with solar cells on a bright sunny day could ever travel. Perhaps we

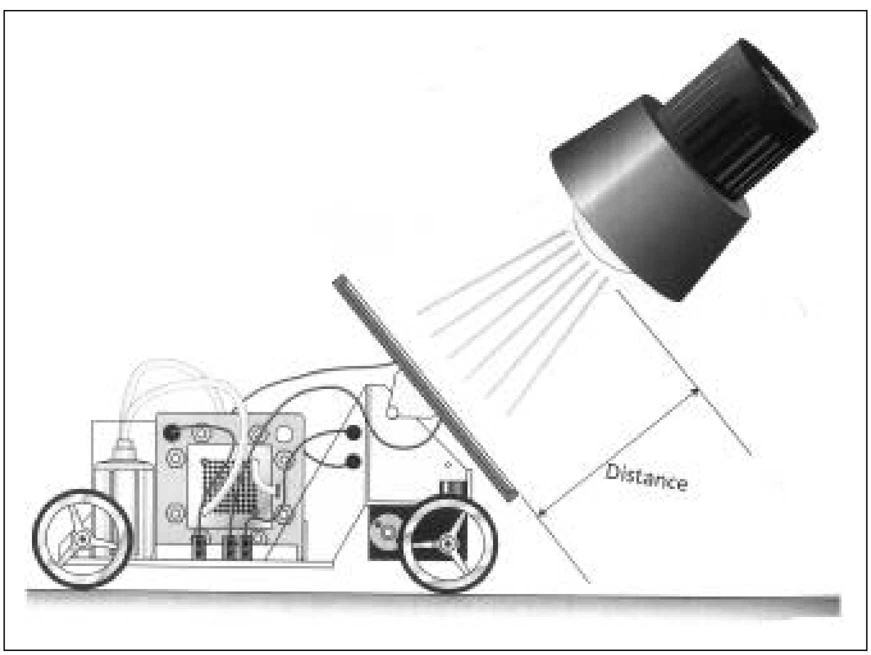


Illustration from Thames & Kosmos "Fuel Cell Car and Experiment Kit" makes the point that fuel cells are dependent on another energy source–in this case an electric light.

should offer a New Energy Demonstration Car Grand Prix, a prize for the first self-powered New Energy toy car that travels ΔX-meters further than a conventional hydrogen-fueled/solar car like this one will go—round and round in broad daylight on a flat surface? Think about it. . .Is anyone up for offering such a prize?

Fuel Cell Mania as a Diversion from Real New Energy: The End of the "Hydrogen Economy"

Yes, fuel cells, elegant as their makers may build them—and we really appreciate the tough engineering and science that has gone into them—are no substitute for New Energy. They are a diversion, but their proponents have not seen the light. But soon the functional equivalent of the Wright flyer will be in the skies, and the era of "trains" will be circumscribed. For now, these cells hold a great attraction for their devotees. Yes, they do work *today* in powerful systems, we'll grant that, which is more than can be said about New Energy. But recall that transistors didn't run radios either when they crawled out of Bell Laboratories in 1947. Small important effects, if prized highly enough, eventually are made into robust technologies.

Let us conclude this assessment of fuel cells and the hydrogen economy with some of Jeremy Rifkin's historic, already obsolete words. His paean to conventional hydrogen: "Hydrogen is the lightest and most ubiquitous element found in the universe. When harnessed as a form of energy, it becomes 'the forever fuel.' It never runs out, and because it contains not a single carbon atom, it emits no carbon dioxide. Hydrogen is found everywhere on Earth, in water, in fossil fuels, and all living things. Yet it rarely exists free-floating in nature [Ed. Note: he means, on Earth]. Instead, it has to be extracted from natural sources." Note the use of the word "extracted." (p. 8) *Not once* in his entire duplicitous tome on hydrogen is there a formal, *explicit* statement that it takes much more energy to split hydrogen from a water molecule than one gets back when one consumes hydrogen in fuels cells or combusts it in an engine.

Taking his cues from the financial furor over the worldwide web, he writes: "The worldwide energy web (HEW) will be the next great technological, commercial, and social revolution in history." There never will be any such web. He says, "Since hydrogen is found everywhere and is inexhaustible if properly harnessed, every human being on Earth could be 'empowered,' making hydrogen energy the first truly democratic energy regime in history. . .Effectively harnessing it as a source of power would provide humanity with a virtually unlimited source of energy—the kind of energy elixir that has long eluded alchemists and chemists alike." Blah, blah, blah. . .Well, as it turns out, the LENR modern alchemists have done the ancient alchemists one better.

It is a nice idea, quite romantic, while it lasts, this concept of a conventional hydrogen economy. I fully expect that this hydrogen economy will be passed over by the arrival of real New Energy, long before thousands of hydrogen fueling stations are built, and too many more $billions are wasted on research. But the most rabid proponents, steeped in rigid ideas about the limits on energy defined by the present "laws of physics," will babble on for some time until they receive their wake-up call and their much-deserved oblivion.

Here is how Jeremy Rifkin thinks about the constraints on energy facing civilization, "The fact is, there are ironclad rules that govern the flow of energy, and if those rules are breached, civilizations can perish. The laws of thermodynamics tell us what, in the final analysis, the upper limits are in the pursuit of human power over the environment. Societies that reach beyond the constraints imposed by their own energy regimes risk breakdown." Oh, he knows so much about the limits of physics—impressive. He knows from nothing! More, "The days of cheap energy are passing—and with that passage it is unrealistic to expect the kind of economic growth that was experienced during the 20th century." How sad, such an errant economic seer. And, "In the future, we may have to make uneasy tradeoffs between personal mobility and eating." I recall that Sir Arthur C. Clarke said that we should learn to "eat oil, not burn it," but that was a New Energy message, not about fuel cells. And more from Rifkin, "When future generations look back at this period, tens of thousands of years from now, the only historical legacy we will have left them in the geological record is a qualitative change in Earth's climate." Ending this sad refrain, "There is no foreseeable scenario on the horizon in which oil—or for that matter, natural gas, coal, heavy oil, tar sand, or nuclear power—can reverse the trend and provide enough energy per capita to bring the growing world population back up to the peak reached in 1979." "Never, never, never, never. . ." is all he knows. He is in good company with the academic physicists.

Yet ever so dimly, this "hydrogen economy" man perceives a truth, which one hopes will be brought home to him in his lifetime: "When every human being on Earth can be producer of his or her own energy, the very nature of commercial life changes." He's right about that, but that cannot happen in the way he and his fuel cell comrades imagine. The future holds many unsettling surprises for them, but for now they are riding high—right into the setting sun.

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