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From Horsepower to Shanks' Mare Power

Is the Automobile Doomed, or Is It Just Us?

by VICTOR WOUK

Twenty-five years ago Peter Kyropoulous, an associate professor of mechanical engineering at Caltech, wrote a perceptive article on cars "From Horses to Horsepower" for *Engineering and Science*. (I am taking an editorial guess that since the article *appeared* in February 1956, it was written in 1955, and thus I am celebrating a 25th anniversary. Nobody does a retrospective article after 24 years.) I thought it would be interesting to compare some of the descriptions of what Professor Kyropoulous considered important to discuss about cars in 1955 with what the situations are in 1980. He made some guarded predictions about cars in the immediate future as well as 10 to 20 years off, and I thought it would be fun to check his admitted "look into the crystal ball." The editors of *E&S* agreed with me that comparing some worldwide car statistics relevant then and now should be intriguing. Hence this article.

To me, the most outstanding fact of Peter's article is that he made no reference to the problem of air pollution from cars. A corollary is that he made no mention of government regulations of the auto industry. Since Peter knew whereof he wrote (after all, he left Caltech in 1957 to become executive in charge of technical development of styling for General Motors), I believe his omissions prove one of my favorite theses, to wit: The American driving public really doesn't give a hoot about automobile air pollution.

Air pollution became a politician's and an environmentalist's dream topic in the mid-1960s. It was better than motherhood and apple pie. With screams of "We'll all be asphyxiated if we don't clean up cars' exhaust," the state of California led the way — as it does in so many aspects of the American way of life — and the federal government followed in 1968 and 1970 with tough emission standards. In fact, politicians vied with each other in proposing tougher emission standards for cars or in condemning the Detroit monster as a fume belcher — or both. (A few years later the Detroit monster was being flagellated as a gas guzzler, but I'll discuss that later.) Suffice it to say that an important difference between then and now is that 25 years ago the automobile manufacturing industry was virtually free of government regulation. Now, car manufacturers declare, the design of automobiles is determined essentially in Washington, not Detroit.

It is only fair to inject here that I am particularly sensitive on the subject of air pollution from automobiles. I have been working on electric vehicles and heat-engine/battery-electric hybrids since 1962. I have lived through a decade of the federal government having spent $\$N \times 10^6$, where $30 \leqq N \leqq 200$, on developing "clean" cars. Not one gram of HC, CO, or NO_X has been removed from the air due to commercially produced products or systems developed with government funds. (This statement may be hyperbolic. When I called Washington for quantitative data, no call was returned, the man always being in conference . . . the well-known "call to Washington syndrome.") Some private millions of dollars, plus Detroit's hundreds of millions of dollars, have done the job of reducing auto emissions more than 80 percent since 1968 in order to meet government regulations. So far, improvements in fuel economy have followed the same pattern, but that's the subject of another article.

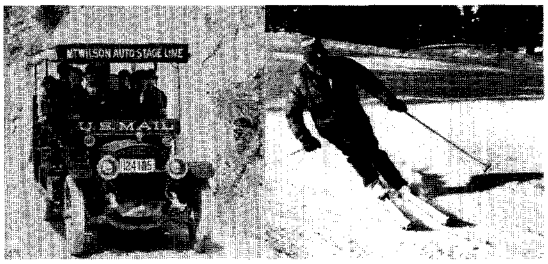
Here are some comparisons of vital statistics from Peter's 1955 writing:

SUBJECT	THEN	NOW
USA new cars/year	6 million	11 million
World new cars/year	10 million	30 million
Cars in USA	60 million	110 million
Cars in world	80 million	300 million
USA vehicular traffic death rate	7.1 per 100 million vehicular miles	No major difference
Average new car cost	\$2,720	\$6,000
Imports of foreign cars, % of total bought per year	0.55% (not a mistake)	25%
Volkswagen sales/yr in USA	0.15%	2.5%
Main reason for purchase	Economy (low price, good trade-in, low maintenance)	Low gas consumption
Average mileage/yr	9,000	10,000+

There are many more goodies in Peter's article. A point-by-point comparison would fill an issue of *E&S*, a goal deemed unnecessary by me and undoubtedly by the editors, if not the readers. However, before I get to the crystal ball, a few of the major changes since 1955 are worth noting. This will be done in the form of quotations from Peter (in italics) followed by an observation or comment by me.

Efforts to sell small European cars as cheap transportation are not particularly successful as long as people can get a full-sized car for less money.

Comments: First, it should be noted that Japanese-built cars were virtually non-existent in 1955. Second, we now



willingly pay more for the smaller VW than the full-sized American car because of our fear of gasoline shortages.

As far as the individual family car is concerned, fuel economy is a grossly overrated item. By changing from 15 mpg to 20 mpg we only change the cost per mile from 8.3¢ per mile to 7.8¢ per mile (based on 10,000 miles per year), a difference which is hardly worth all the bragging that it brings about.

Comments: This is as true today as it was then. Peter took into account, when calculating costs per mile, not only the variable costs of fuel, oil, maintenance, and tires, but — quite properly — the fixed costs of insurance, license fees, and — the greatest cost of all — depreciation (for new cars). Triple all costs for 1980, and the difference between 15 and 20 mpg is 24.9¢ to 23.4¢. Going from 20 mpg to 40 mpg drops the 23.4¢ to 22¢ per mile.

Today it is the fear of lack of availability of gasoline that is driving (double entendre deliberate) motorists to smaller cars, not the cost of the fuel. The first year's depreciation of a $6,000 car, $2,400, equals 1,600 gallons of gasoline at $1.50 per gallon. At 20 mpg this is 32,000 miles, or three years of driving. Depreciation is still a major consideration even at $1.50 or $2.00 per gallon. It is interesting that the AAA (Average American Autoist) is not sensitive to this financial fact of life. But gasoline lines! That's another matter.

Now we come to an uncannily prescient statement by Peter:

Looking at fuel economy from the point of view of natural resources, *rather than individual savings, we get a different picture indeed.*

In 1954 the gasoline used by automobiles in the USA amounted to 13.5 billion dollars (including 3.5 billion in taxes). All central power stations and railroads paid a fuel bill of 1.5 billion dollars.

A fuel saving of 10 percent in the automobiles of the country saves more fuel than the fuel cost of all central power stations and railroads.

Comment: Peter was talking about savings of money. But by bringing in the *national* use of gasoline, he may have been the first to recognize the impact of the automobile on national, or indeed worldwide, problems. Today the automobile's thirst for petroleum is a major contributor to worldwide inflation, political unrest, and, according to prophets of doom, World War III. Petroleum use for personal transporation is greater than usage for any other single purpose.

The highest-powered vehicles, while driven more frequently in the high speed ranges, are not driven at any greater maximum speeds than the lower-priced cars, except perhaps for those under 100 hp.

Comment: As true today as then. Those "300 horses under the hood," prevalent before Detroit began to make cars for lowered fuel consumption, were not there so that cars could go 120 mph, or more. Such useless and dangerous high top speeds were incidental. The engine was that powerful because it gave the car pep or rapid acceleration. "Pep" sold. At 30¢ per gallon, a mere 8 mpg was no problem. Acceleration pedals were, and still are, depressed heavily for acceleration and then relaxed as much as 75 percent for highway driving. (Readers who do *not* drive with a heavy foot will please excuse me. You are in a minority.)

All attempts to develop safety devices are good, but they cannot substitute for a sensible driver.

Comment: This is still true, despite all the safety features that have been introduced as a result of Ralph Nader and his followers. Seat belts are useless if they are not employed. The attempt to legislate their use in 1974 models by mechanical fiat (the driver and front seat passengers had to buckle up or the car wouldn't start) was a miserable fiasco. The law was repealed faster than any other in-out action of Congress since 1782. (Maybe I'm wrong here, but I'm not far off.) And air bags! There is still more hot air generated in debates on air bags than will be expended by their being inflated in anticipated car crashes during the next $\sqrt{e^{\pi}}$ years.

Now, development [of cars] is concerned with refinements, rather than dramatic changes. Utility is taken for granted.

Comment: As true today as in 1955. This complex mechanical device, a modern car, is taken for granted. Despite all the jokes and complaints, cars are amazingly reliable.

There have been no major developments in automobile technology since 1955. I do not consider eight-track tapes of major consequence, nor are electrically operated front seats an earthshaking advance (except possibly for teenagers).

During the last few years it has become fashionable to denounce the American automobile with a fervor usually reserved only for political and religious controversy.

Comment: How true. Recently, modish speakers decry USA cars with a passion normally assigned to discussions of state or church.

In Europe the automobile has not developed into a necessity and a household appliance . . . . In practice more than 90 European cars out of 100 are purchased with company funds, but used for both business and pleasure.

Comment: The Europeans are catching up with us to a substantial degree. We average 516 cars per 1,000 people. In Europe it's 244 cars per 1,000 people.

Outside America, there have . . . been few developments in motor roads. In France under 100 miles of new road have been built since the war, and in England expenditure has been almost entirely confined to the erection of "Danger" and "No Parking" signs.

Comment: My, how things have changed! England has a few thousand kilometers of "M" high-speed Motorways, similar to our Interstates, as does France with its Autoroutes. Because the countries are smaller than the USA, the total road lengths are much less. There the dissimilarity ends. The "Ms" and Autoroutes are multiple lane (up to five in some places), limited access, and free of intersections. The French and British are also blessed with bumper-to-bumper traffic in and around urban areas during daily rush hours and during homecoming hours on weekends and holidays.

Now let's look into Peter's crystal ball. Peter introduced his extrapolations with the following caveat:

C. F. Kettering suggests this method of predicting the future of automotive engineering: "Considering all the factors, use the best extrapolation you can, push it as high as you can, and, if you live to see it accomplished, you will be amazed that you missed it so far.

Peter predicted:

Gas turbines are here to stay; will find their most suitable use in trucks, buses, military and earth-moving vehicles, perhaps in racing and sports cars.

What happened: There is no commercial application of turbines in road transportation. There have been experimental buses and sports cars. In the 1970s a turbine car, raced in the Indianapolis 500, was in a position to beat the field by many laps, and to set a new Indy 500 record, when the turbine failed and the car did not finish. Turbines were subsequently barred from the Indy 500. Turbine superchargers are another story.

The federal government, first through the Environmental Protection Agency (EPA), and now through the Department of Energy (DOE), has spent more than $100 million to develop a turbine for the automobile. The goal of the EPA was a clean engine, spurred on by the fact that the Brayton cycle (fancy word for a turbine) is basically an external combustion engine. In an external combustion engine, burning can be more complete and cleaner than in an ICE (internal combustion engine).

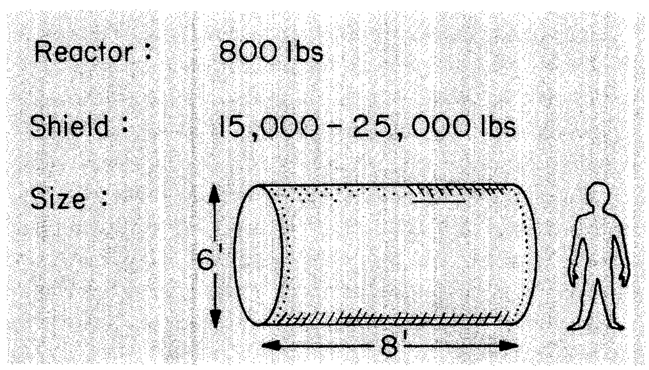
The DOE is excited about the prospects of the turbine because the Brayton cycle can be inherently more efficient than the Otto cycle (conventional piston engine) of the ICE. Cars will use less gasoline! Let's go at it!

The turbine has run up against a stone wall of technology and a paper wall of finances. The stone wall is more accurately a ceramic wall — an attempt to develop ceramic blades for the turbine. A turbine must operate at very high temperatures and speeds, and to date, only expensive metal alloys have been usable. It's OK for the metal in the turbine in the friendly skies, tucked inside the engine of a commercial jet, to cost $50,000, but the metal cost is prohibitive for automobile purposes. Ceramics, which could operate at high temperatures and high mechanical stresses, in principle could be cheap or at least inexpensive. So, hope springs eternal in the breasts of the contract issuers in Washington. Their jobs may also be eternal, but that's only conjecture.

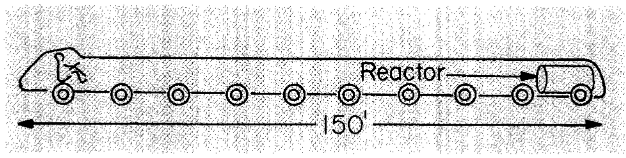
Nuclear power could become an attraction if a small reactor can be built. With it the reciprocating steam engine may return from its somewhat undeserved oblivion.

Again, Peter was prescient, this time in discussing in an offhand manner the possibility of a cute little nuclear reactor to generate steam to operate a steam engine. For a lot of reasons the steam engine, for cars, remains in oblivion. But the nuclear power plant ranks with petroleum sources as a major problem in our industrial civilization. There are the problems of waste disposal, and potential terrorist use of nuclear weapons obtained from recycled fuel elements.

The cute little nuclear reactor for a car is out of the question. In 1967 I presented a paper to the AAAS (American Association for the Advancement of Science) session on "Man and Transportation in the 21st Century." The subject of the paper was "Electric or Nuclear Power for Automobiles?" The man-shield comparison shown below gives an idea of how large a reactor would have to be for



about 50 kW of useful output — just about enough to drive a reasonably sized car. The shield would weigh 8 to 12 tons. But this was for SNAP-8, a nuclear power plant in space that would be located 100 feet away from astronauts in a space capsule. In a car it would look like this:



I was flippant in that paper, saying that one of the problems would be accidents and the spilling of radioactive wastes. Also, what a field day for thieves who wanted to peddle enriched uranium for blackmail purposes! These two problems, radioactive wastes and nuclear proliferation, are the major hurdles to our being able to solve The Energy Problem in the world, but let's drop that subject so we can remain friends.

The electric car may come in for some attention for short haul service. We have learned a few things about batteries and should be able to produce an acceptable vehicle.

Peter hit the nail on the head!

Since 1970, within his time frame of 10-20 years from 1955, electric *vehicles*, not cars, have "come in for some attention for short haul service," particularly electric delivery vans. The DOE is implementing the Electric and Hybrid Vehicle Research, Development and Demonstration Act of 1976 with $160 million. It is hoped that, by pump-priming, an electric vehicle industry will grow in the USA. Currently 20 electric service vans are being successfully operated by AT&T in Culver City, California.

Since most cars are driven less than 40 miles per day in the USA (some areas of southern California are an exception to this and other American norms), battery-powered cars could satisfy much daily driving. This would be particularly true if there existed networks of electrical outlets for charging the batteries when the vehicle is not in use. This process, "biberonnage" (from the French, meaning "bottle feeding," or, more colloquially, "a quick one for the road"), is being experimented with seriously in Germany. Biberonnage makes electric cars practical with present lead batteries.

The "few things we have learned about batteries" have defied intensive efforts over more than a decade to come up with a commercially producible better battery. It has been "five years away" for the past 15 years, and still is according to General Motors.

By a curious coincidence, my involvement with electric cars was a direct result of the requirement for better batteries, Caltech's preeminence in chemistry, and Dr. DuBridge's interest in the concept of an electric car.

In 1962 I was approached by a well-known industrialist who had built 30 electric cars, converting Renault "Dauphines" by removing the engine, transmission, etc., and putting in batteries, an electric motor, and a speed control. His reasoning was that air pollution from cars was going to be a serious problem, and electric cars would solve the problem. He thought that at *least* electric utilities would buy the cars for meter-reading, where the driver does not have to go far nor fast. He expected the cars to sell like hotcakes. They sold like coldcakes. Why? A top speed of 35 mph and a range of 25 miles was not enough, even for meter-reading.

The industrialist had been told that the poor performance was due to the old-fashioned speed control that wasted too much of the energy stored in the batteries. He needed a modern, electronic speed control, which should be more efficient. I was suggested as knowledgeable in the field, as in 1962 I had presented a paper on what are called "switching regulators" at an IRE (now IEEE) conference. I examined the car, drove in it, and concluded that the problem was not the speed control, but the battery. There just was not enough energy stored in the batteries. I was asked if there was an inherent limitation to the electrochemical process that would make a better battery impossible. Good question, because if better batteries were not possible, he'd give up his electric car project.

I did not know the answer, but thought that someone at Caltech might. So I wrote to Dr. DuBridge, who replied that the consensus at Caltech was that theoretically much better batteries could be built. There are electrochemical couples available that have energy densities at least 10 times that of the lead battery. It was a matter of engineering ingenuity, time, effort, and money. The quantitative story of gasoline vs batteries is expressed in watt hours per pound (Wh/lb) of stored energy. Roughly, a pound of gasoline has 1000 watt hours, i.e., a 100-watt lamp would be lit for 10 hours, if 1 pound of gasoline is burned and converted to electricity. Lead batteries have 10 Wh/lb, i.e., a 100-watt lamp could be lit for 1/10 hour before a 1-pound battery would discharge.

More practically , if we can go 300 miles at 50 mph on a tankful of gasoline, we would go 3 miles on a "tankful of batteries." Modern electric cars go 30 miles or more at 50 mph, because the batteries in the car weigh 10 times as much as a tank of gasoline.

The following chart sums it up:

MATERIAL	WH/LB
Lead batteries	10
Some experimental exotic batteries	100
Gasoline	1000

Dr. DuBridge's statement was accurate. By 1970, because of intensive work done in many laboratories, there were individual cells, such as liquid sodium and liquid sulfur with a ceramic electrolyte, yielding 100 Wh/lb. By 1980 there were produced modules of cells using high temperature (300°C) materials connected to provide 100 volts, which would propel an electric car 150 miles. So, we might project that by 1990 such batteries will be available as a physical reality. The price may be prohibitive. We discuss this when *I* do crystal-ball gazing at the end.

With the increase in super-highway mileage we will need automatic steering. The car might be rolling along a beam produced by a buried cable. Once on the beam, the driver would push the control out of the way and relax. There will have to be proximity warning devices and emergency over-rules but, all in all, this is not very complex. It will take a lot of monotony out of long distance driving; people can doze without wrapping themselves around trees.

These things are probably 10 to 20 years off.

The petroleum problem has put the kibosh on automatic steering even if it were technically feasible, which it is not at present. At 55 mph we can expect the driver to remain alert so as to avoid accidents. With fuel being expensive or rationed, commonplace cross-country trips will go the way of tail fins.

In the immediate future we will see more power, levelling off around 450 hp, the upper limit of what the two rear wheels can comfortably transmit.

Bull's-eye!

Gasoline injection will appear in one form or another – may well turn out to be a fad, rather than a real step forward.

On the nose again! Not a fad. Fuel injection was first introduced for emission control (uniform fuel mixture in all cylinders improves emissions) and now is a big thing for improvement of fuel economy (uniform fuel mixture in all cylinders improves fuel economy).

Compression ratios will go up and so will gasoline octane numbers. I am guessing at 15 to 20:1.

Optimistic. Compression ratios peaked at 11 or 12:1, and now have been backed off to 7 or 8:1, to reduce the nitrous oxides in the exhaust.

Why not Diesel? Because at any compression ratio the spark ignition cycle has a higher thermal efficiency than the compression ignition cycle of the same compression ratio. (Note to the readers who like to write to the editor. Before you break into loud snorts of indignation over this one, consult an elementary thermodynamics text.)

Where did Peter go wrong about the diesel? He didn't. The key is the phrase "of the same compression ratio." ICEs never did get up to the compression ratios of the diesel. Hence, the Volkswagen Rabbit diesel is rated at $\boxed{42}$ mpg, whereas the gasoline-engine Rabbit, even with fuel injection, is only $\boxed{32}$ mpg. Remember, these figures may vary with the degree of my laziness about going to the EPA mileage rating charts.

The possible gains in performance (acceleration, fuel consumption) from lightweight construction may well come in for some attention. This calls for more than a "material substitution program." It will require a lot of re-designing of components and development of aluminum die-casting of large parts.

Again, correct in all principles. Lightweight materials have been introduced, but plastics seem to be the glamor material rather than die-cast aluminum. But then, "The Graduate" *did* take place in California.

In any event, there are not going to be any dull moments.

Peter was right. There weren't, and now I make some bold predictions for the years 1990 and beyond (all subject to instant change, depending upon the political situation in the Persian Gulf):

There are not going to be any dull moments.

As I wrote in the AAAS paper in 1967, I believe the personal automobile is here to stay. Why? Because it represents freedom of mobility. We are not going to give up this freedom, which is fundamental to our socio-economic structure, as long as there is a choice. Without a car, our present way of life is doomed. There *is* a choice. Use a fuel other than limited fossil energy sources.

Between 1980 and 1990 it's easy to predict that cars will be smaller ("downsized" — ugh!). Liquid hydrocarbons, whether fossil or synthesized from coal, biomass, or the like, will be used more and more for societal purposes . . . to run agricultural equipment for food production, planes, interstate trucking and busing, etc. Batteries will be improved, and electrics and hybrids will be in car showrooms

by 1990, though not in large numbers, because of the price. The "better battery" will be expensive.

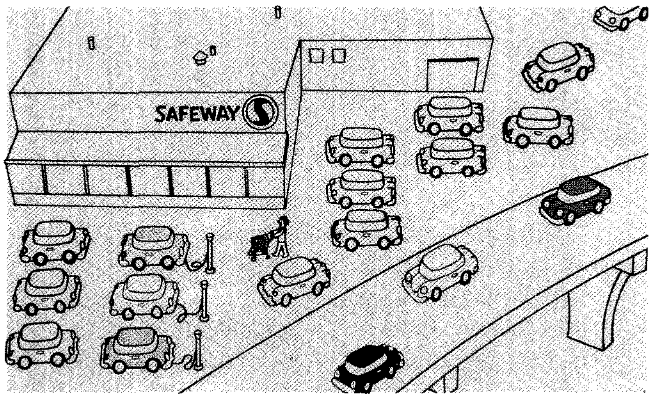
Now, for 25 years hence, and the year 2005: Specifically, we must recognize that our customary profligate use of petroleum in autos just can't continue. I disagree that the common car will be a two-seater microcar, using synfuels and getting 80 mpg, suitable for shopping, short commuter drives, and family activities usage. It doesn't make sense to use scarce liquid hydrocarbons for anything when electricity will perform the job.

I agree that the large-sized car for visiting grandma a few hundred miles away will be a rental, a community-owned car, or the like. If the full-sized car as we know it is to be commonplace, it will have to be a hybrid. The hybrid is a combination of a small ICE and electric drive, in a full-sized car. (See the article in *Caltech News*, Vol. 12, No. 6, September 1978.) The hybrid will have all the highly touted improvements of the conventional auto — light weight, better engine, and the like. In normal usage it will run mainly on battery power. For long trips, the $8 per gallon gasoline of the year 2000 will be rationed, and hoarded ration coupons splurged for the occasion.

The Jet Propulsion Laboratory is running a $10 million program for the DOE to develop hybrids. These vehicles do not have the range limitations of all-electrics and may save up to 80 percent of petroleum by letting the batteries discharge during the driving mission. The batteries are charged by biberonnage or overnight, at home. No gas is used on short trips. On long trips a smaller engine is satisfactory, averaging 40 mpg in a full-sized car. Over the course of a year, on-board fuel economy of 50 or more mpg is envisioned for a family-sized car.

The "first" car and "second" car will be all-electric by 2005. We will buy "range" when we buy a car, just as until recently we bought "performance" — that is, horsepower — after basic transportation needs were met. Since range is determined by battery size and weight, it will be ridiculous to buy a "100-mile electric" when 95 percent of the time the car is used for less than 40 miles. The extra battery weight for the 100-mile range will mean a cost of 10¢ per mile for electricity rather than 5¢ per mile. If you buy a car for status, OK; Caddy-electrics will be 120-mile-range vehicles, and Chevette-electrics will have 40-mile ranges.

I predict that biberonnage outlets will be widespread in



public parking areas. There is no reason why they cannot be installed in a supermarket parking lot, as shown above. The hosts at dinner parties will set out a long charging-outlet strip for the guests' cars in the driveway. The electricity consumed by those cars will cost only about 1/10th that of the drinks and wine consumed by the guests.

I will not belabor the point. Electricity is a fuel, or secondary source of energy, available almost anywhere in an industrialized society. The primary sources of energy to generate electricity are abundant, and some are inexhaustible. A ton of coal converted to electricity by burning in a power station will drive an electric car twice as far as will the same ton converted to synfuel to drive an ICE. Synfuels will be out for private transportation.

How soon can we implement electrics and hybrids? As soon as political pressure is great enough. That means we need the public to demand it, or at least to applaud the politicians' statements.

A member of the EPA said to me when my company was developing a hybrid for low pollution, "Don't waste your money. Even if the car works, so what? If Detroit won't build it, what good is it?" He was right. The car worked, had low emissions and good fuel economy. Detroit said, "Ho hum." When petroleum *really* begins to run out, they'll say, "Ho ho" to electrics and hybrids.

Finally, will there be any conventional automobiles, ICEs, or diesels? Yes, again for societal purposes — police, fire, military, sanitation, ambulances, for example. Maybe one of the more salutary results will be the drop of crimes such as bank robbery, because of the unavailability of high-speed getaway cars. I end on that upbeat note. □