The Energy-Climate Crisis is Your Business

Part VI: A Vehicle Revolution Is Part of the Solution-Fuel Cell Cars[1]

James A. Cusumano, PhD

"Be careful what you wish for, you just might get it!"

Anonymous

AUTHOR'S NOTE

Oil prices have plunged over the last few months from $147 per barrel to less than $40 per barrel today. That's not good. Why? Because history teaches us from what followed the Arab oil embargoes of 1974 and 1978 that governments, industry and citizens will be lulled into believing that prices will remain low. They will not – especially this time – and here is why.

The International Energy Agency (IEA), the ultraconservative representative of major oil companies in the developed world recently issued its World Energy Outlook report, and it expresses a deep concern for the future price of oil[2, 3, 4] and the sever climate cost of a 'business as usual' policy[5].

Oil Price – In a study of 800 oil fields around the world, the IEA warns that the current lack of investment into new sources of oil will bring about a supply crunch worst than that which rocketed oil prices to $147 this past July. The current price of oil ($42 per barrel on December 18) is causing companies from Kazakhstan to Canada to cancel their investment in oil and gas projects. The IEA concludes that the global credit crunch has put the world "on a bad path."

The report maintains that demand from OECD countries has peaked and most of the growth in demand for oil until 2030 will come from developing countries. Even with corrections in the global financial markets, China will contribute 43 % of this growth in demand, India and the Middle East, each 20%, with the remainder coming from other emerging economies in Asia.

Figure 1

Tesla Roadster Fully-Electric Vehicle

One particularly hard–hit area is Canadian tar sands, only months ago called the "Saudi Arabia of heavy oil." At a production cost of $80 per barrel, things were great with $100+ oil, but now the production cost exceeds current oil prices by more than $30 per barrel.

The IEA report concludes that the current low price of oil is temporary and will jump to triple digits within the next 2 years, and it projects $200 per barrel by 2030 (The present author projects even higher prices by then.).

OPEC will have to much to do with this change. Saudi Arabia requires oil at $60/barrel just to meet its national budget; Russia needs $75 oil to keep its accounts in balance; Iran needs $100 oil to meet its payroll; and Venezuela requires $125 oil to cover its national outlays. Oil will begin its climb in 2009.

Climate Impact – On top of the bad new concerning oil prices, the IEA issued a warning that "business as usual" policies will have "shocking" consequences for climate change, raising average global temperatures by 6 °C[6]. Warming at that scale would have catastrophic consequences, causing melting of both the North and South poles.

Nobuo Tanaka, IEA's executive director points out that maintaining the current global atmospheric concentration of greenhouse gases at 450 parts per million (ppm), a level consistent with a 2 °C rise in temperature, would require sever cuts in emissions. A level of 550 ppm would be much easier to achieve, require no new technologies, but implies a global temperature rise of 3 °C, with damaging effects, including droughts in some parts of the world and flooding in others. To have a positive impact, the IEA concludes that the price on carbon emissions would have to be set at $180 per ton as opposed to the current price of $23.

Alternative Energy – To make things even more challenging, the current credit crunch and low oil price is resulting in the same short-sighted actions that have occurred before in the areas of energy efficiency and the development of alternative energy technologies. The two previous Arab oil embargoes catalyzed a transition of the American public from large cars to small ones. Small Honda Civics and diesel-powered cars were in high demand. Tens of billions of dollars were saved over a short period of time by increases in energy efficiency. But just a few short years later, when oil prices fell, Detroit turned its attention to sport utility vehicles (SUV), and look where it has brought them.

Now more than ever, governments must encourage the commercial success of alternative energy technologies. This strategy will create a new growing industry, generate new jobs, and stimulate the global economies. How could we not pursue this approach?

FULLY–ELECTRIC VEHICLES

In the last issue, we described the need for increased fuel efficiency, a move away from fossil fuels, and the incredible benefit of hybrid–electric vehicles. Close 'cousins' to the hybrids are the fully-electric and fuel-cell powered vehicles.

The very first automobiles invented during the late 19^{th} century used electric battery power, but the discovery of cheap oil and the development of petroleum refining technologies changed that. Now, with emergence of the energy-climate crisis, diminishing oil reserves, a growing appetite for energy, and advancements in new battery technologies, we have come full circle. The epitome of a modern high-performance electric car is the Tesla Roadster, developed in Silicon Valley by Elon Musk, co-founder of Pay Pal and Space Exploration technologies (SpaceX). The first Teslas, priced at $109,000 rolled off the assembly line this year with a 248 hp electric engine, powered by a 450 kg lithium-ion battery. Top speed is electronically limited to 200 km/h (120 mph) and the car boasts an incredible acceleration rate of 0–100km/h (60 mph) of 4 seconds. Over a 1000 cars have been ordered (see **Figure 1**)[7].

This Roadster produces no CO_2 during operation, and even if one calculates the CO_2 emissions generated at the power plant when recharging the battery, it produces less than half the amount of greenhouse gases generated by the greenest petrol cars available. And, if the power plant were to generate its power from a renewable fuel such as biomass, Tesla's CO_2 footprint would be even lower.

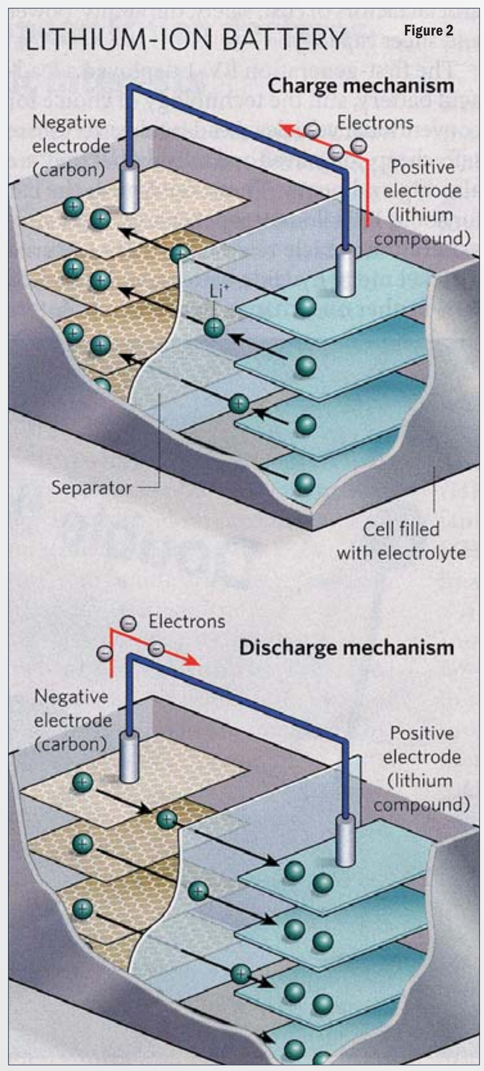


Figure 2

Proton exchange membrane fuel cell

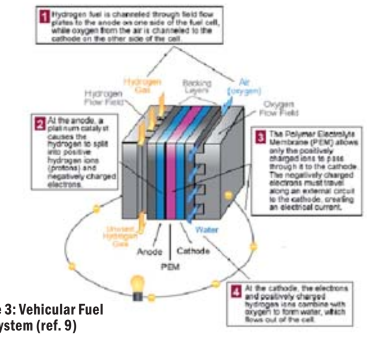


Figure 3: Vehicular Fuel Cell System (ref. 9)

Fuel economy is impressive. It costs less than 2 cents/km to operate. Compare this with a conventional fossil fuel vehicle with a consumption of 9 l/100 km (26 mpg) and petrol at $3.60/gal, which results in a cost of more than 8 cents/km to drive – 4 times more expensive than the electric vehicle.

Clearly, the Tesla Roadster is expensive, but it was only meant to demonstrate that commercial high–performance electric cars can be a reality. Within 3 years, Tesla plans to introduce a family sedan that will sell for $60,000, and then subsequently a compact that will sell for $30,000.

A number of other companies are developing all-electric vehicles. GM, if it survives the current global financial crisis, plans to launch in 2010 its Chevy Volt, which has a lithium-ion battery that propels the car from 0 to 100 km/h in less than 9 seconds, and has a maximum speed of 160 km/h. When the battery runs low, a small petrol-powered motor kicks in to recharge the battery, thereby providing a range of 575 kilometers (345 miles). The fuel efficiency of the petrol engine is 4.8 l/100 km (50 mpg)[8].

The key innovations that have made electric cars economically viable, and in fact, advantageous vis-à-vis a fossil-fuel powered car, involve advancements in the lithium-ion battery. As shown in **Figure 2**, the concept behind the battery is simple. A chemical bond is used to trap positive lithium ions at the negative carbon electrode (cathode). When the battery is hooked into a circuit, lithium ions break the chemical bond and flow through a special separator to the positive electrode (anode), made from a lithium compound. In breaking this bond, electrons are released at the cathode and flow as electricity through an external circuit, power an electric motor, and end up at the anode. When this process is complete, the lithium battery requires external recharging to recover the original charged condition. Key factors that had to be overcome were cost, safety, durability, power density, i.e. high power and low weight.

Sony was the first to pioneer high energy density lithium batteries and introduced the lithium-cobalt-oxide battery in 1991 to power its Handy-Cam video camera. However, cobalt is expensive and toxic, and lithium cobalt batteries were known to catch fire or explode. This led to the replacement of cobalt oxide with manganese oxide or iron phosphate.

The first hybrid and electric vehicles used nickel hydride batteries, which are safer, but have lower power density. The Chevy Volt is based on the lithium-ion battery, as are many of the new electric and hybrid vehicles. GM has put a large investment into the Volt and its strategy is to leapfrog its competitors, especially Toyota, which last year, helped by sales of its hybrid-electric vehicles such as the Prius and the Lexus, became the largest automotive company in the world.

Currently, 75 electric cars have been announced and are projected to enter the marketplace by 2013. However, companies that have developed these vehicles have been slow to commit to firm orders for batteries, and this is where governments can help by intervening to make it easier to launch electric vehicles. GM tested batteries from every lithium battery producer in the world and narrowed it down to LG Chem in Korea and A123 Systems in Massachusetts. Only in late October did it commit to LG Chem.

Ultimately, manufactures intend to move away from hybrid-electric cars to total electric vehicles because the latter are much less complex, cheaper to manufacture, and produce lower emissions. The key will be continued improvements in the lithium-ion battery.

FUEL–CELL VEHICLES

During the early 1960s, General Electric produced the fuel cell electrical power system for the Gemini and Apollo space capsules, and to this day fuel cells provide both reliable power and drinking water in all space stations and launch modules.

The fuel cell is a simple device in concept. It generates energy by converting a fuel, e.g. hydrogen gas, which is fed to the anode of the cell, while an oxidant, e.g. oxygen gas is fed to the cathode. The only product in this instance is electricity, and the only by-product is pure water. Some fuel cells use other fuels such as methanol or natural gas, but the hydrogen fuel cell is the most desirable for vehicular use.

As shown in **Figure 3**, hydrogen gas [1] is fed to the surface of the platinum catalytic anode, where a single electron is stripped off each hydrogen atom[9]. The electrons flow as electricity through an external circuit to power the vehicle. When an electron is pulled from a hydrogen atom, it yields a positive hydrogen ion (H^+) called a proton [2]. These protons migrate through a polymer membrane [3] to the cathode compartment where they combine with negatively-charged oxygen atoms, formed by feeding oxygen gas to the cathode [4]. Oxygen atoms react catalytically at the cathode with electrons that have flowed from the cathode in the external power circuit as electricity. The only byproduct is pure water. Just as with batteries, fuel cells can be combined in series to form a fuel-cell stack, which can provide high levels of power. The beauty of the fuel-cell car is that it is truly a zero emissions vehicle, and if its hydrogen fuel comes from a renewable energy process, such as biomass gasification, or wind-powered or solar-powered electrolysis of water, it contributes essentially zero CO_2. This is clearly the 'next step' after hybrid-electric and fully-electric vehicles. Most automobile companies have fuel-cell vehicles in development.

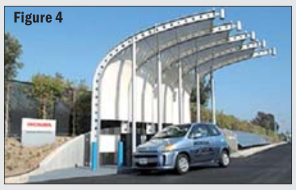
However, before fuel-cell powered vehicle can become a broad commercial reality several challenges must be addressed. They are: (1.) boost on-board hydrogen storage so that 500 km (300 miles) range is achieved; (2.) cut the cost of fuel-cell engines by a factor of 3; (3.) increase the fuel cell operating lifetime by 5 times; (4.) create a viable hydrogen fueling infrastructure. These are significant challenges, but the U.S. Department of Energy and manufacturers believe they will be met by 2015.

Progress has been significant. In 1990, the cost per kilowatt for producing fuel cells was $3,000 ($2,250/hp), compared to internal combustion engines, which cost $25–35/kW ($19–26/hp) to manufacture. However, keep in mind that the internal combustion engine has been under development for more than 100 years. Today, fuel cells can be manufactured for as low as $50/kw ($38/hp). Areas where improvements are foreseen are in the polymer membrane, which represents 35 % of the cost, and in reducing or eliminating the level of platinum used in the anode catalyst. Platinum constitutes 40 % of the fuel cell cost.

By far, the most challenging issues have been on-board hydrogen storage to achieve 500 kilometers (300 miles) range, and developing a hydrogen fueling infrastructure. A significant breakthrough was recently announced by Toyota for its FCHV car, which it now leases in limited numbers. The fuel-cell powered car now achieves 780 kilometers (470 miles) range. Toyota achieved this by developing a means to store twice as much hydrogen, and increasing fuel economy by 25%.

Developing a hydrogen infrastructure is being pioneered by the state of California, which, by 2010 will make hydrogen fuel available on 21 of its interstate highways. Honda, which has developed its FCX fuel cell car, and is leasing the vehicle, has developed its own versions of a hydrogen filling station, one for home use, and another for commercial use. In the latter, solar panels power an electrolysis system that converts water to hydrogen and oxygen gases. The hydrogen is then pressurized, and stored for fueling vehicles (see **Figure 4**). The beauty of this approach is that the hydrogen is produced by renewable energy, and then converted to power in a fuel-cell engine. The result is zero emissions. A recent breakthrough at MIT may provide the technological basis for producing hydrogen directly from water using sunlight and a novel proprietary catalyst[10].

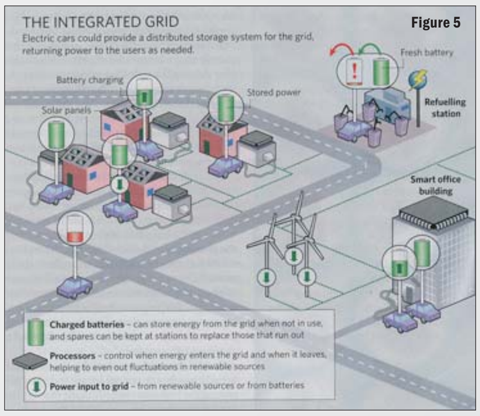
Figure 4



Solar-Powered Water Electrolysis Hydrogen Fueling Station

Hybrid-electric, fully-electric, and fuel-cell cars all provide a unique benefit for both car owners and electric power companies. It is possible to interface these vehicles with utility companies through the power grid system (see **Figure 5**)[11]. Most recharging of batteries would occur at night, which creates a new source of revenue for the utility company at a time when there is usually excess capacity. During the day, fuel-cell vehicles could "plug into the grid" when parked at home or at the office building, and generate emission-free electricity from its on board hydrogen, feeding the electricity to the power company for a fair price of compensation. A study by the Electric Power Research Institute in Palo Alto, California demonstrates that for example, if 60 % of the U.S. automobile market were electric transport vehicles, they would consume only 8 % of the nation's electricity. The nation would use 15–20 % less oil and reduce its annual greenhouse gas emissions by 450 million tons, which is equivalent to pulling 83 million of the current 250 million internal combustion vehicles off the road.

Figure 5



There is no question that the internal combustion engine has seen its day and it will be replaced by much more efficient, cleaner and ultimately lower costing electric engines based on batteries and fuel cells. The time scale for this transition is really up to us.

James A. Cusumano, PhD

---

[1] *Parts I and II of this series outline the Global Energy Security and Climate Change issues, respectively; Part III provides a summary of a workable solution; Part IV presents an analysis of nuclear power; and Part V describes the role of vehicular transportation with a focus on hybrid-electric cars. See Leaders Magazine 2, 3, 4, & 5, 2008.*
[2] *Javier Blas and Carola Hoyos, "Oil at $200 will shift Power to OPEC," Financial Times, November 6, 2008.*
[3] *Carola Hoyos, Javier Blas and Ed Crooks, "Crash in oil exploration puts world 'on bad path,'" Financial Times, November 13, 2008.*
[4] *Javier Blas and Carola Hoyos, "Oil price forecast to bounce back with recovery," Financial Times, November 6, 2008*
[5] *Ed Crooks, "IEA warns on severe climate cost of 'business as usual' policy," Financial Times, November 13, 2008.*
[6] *Op. Cit, reference 5.*
[7] *Jim Giles, "Born to be Wired," NewScientist, September 20, 2008, pp. 26–33.*
[8] *Ibid*
[9] *http://en.wikipedia.org/wiki/File:PEM_fuelcell.svg*
[10] *Kevin Bullis, "Sun + Water = Fuel," Technology Review, November/December 2008, pp. 56–61*
[11] *Jeff Tollefson, "Charging the Future," Nature, Vol. 456, November 27, 2008, pp. 436–440.*

About the Author: James A. Cusumano is Chairman and owner of Chateau Mcely (www.ChateauMcely.Com), chosen in 2007 by the European Union as the only "Green" 5-star luxury hotel in Central and Eastern Europe and in 2008 by the World Travel Awards as the Leading Green Hotel in the World. He is a former Research Director for Exxon, and subsequently founded two public companies in Silicon Valley, one in clean power generation, the other in pharmaceuticals manufacture via envi-ronmentally-benign, low-cost, catalytic technologies. While he was Chairman and CEO, the latter – Catalytica Pharmaceuticals, Inc. – grew in less than 5 years, to a $1 billion enterprise with 2,000 employees. He is co-author of "Freedom from Mid-East Oil," recently released by World Business Academy Press (www.WorldBusiness.Org) and can be reached at Jim@ChateauMcely.Com.

českou verzi naleznete na www.leadersmagazine.cz