PV, EV, and Your Home at Less Than $1 a Gallon

by James M. Fenton

In the *Interface* article "The Society on Wheels"[1] that appeared in the summer of 1996, it was shown how each of the Society's Divisions and their technical areas play an important role in the manufacture, operation, and life of our automobiles. In the *Interface* article "Two Fuel Cell Cars in Every Garage?"[2] that appeared in the fall of 2005, the authors pointed out that "In 1928, U.S. presidential candidate Herbert Hoover promised growing prosperity represented by 'a chicken in every pot and two cars in every garage.'" The authors then suggested that "We now find ourselves at a point in history wondering if and when the power for those cars will come from fuel cells *instead of internal combustion engines*." (Emphasis added.) Increased funding for fuel cell research was made possible because, in 2003, President George W. Bush promoted the environmental promise of cars running on hydrogen, the universe's most abundant element. "The first car driven by a child born today," he said, "could be powered by hydrogen, and pollution-free." Now, ten years later, 2015, we have a scenario wherein "the wheels on the car go round and round,"[3] powered by electric motors that use electrons! Today those electrons come from grid[4] charged batteries (mostly fossil fuel generated electrons), gasoline range extender electric generators, or regenerative braking. Fuel cells are still around the corner (the child born in 2003 is not sixteen years old until 2019!),[5,6] but there have been sightings of fuel cell vehicles; fuel cells also make good range extenders.

PV and zero-energy homes—In 1996, U.S. residential electricity was 8.36 ¢/kWh, the installed cost of a residential PV system was >$12/W (~48¢/kWh),[7] gasoline cost $1.23 per gallon, the average fuel efficiency of light vehicles was 21 mpg,[8] and the Toyota Prius (the bestselling hybrid electric vehicle with over 5 million units globally) had not yet debuted (1997 Japan, 2000 worldwide) (Fig. 1). In 2005, residential electricity was 9.45¢/kWh, the installed cost of a residential PV system was $9/W (~23-32¢/kWh), gasoline cost $2.30 per gallon, and Hummer (a large sport utility vehicle with poor gas mileage) sales were at their peak. In 2005, President George W. Bush said, "One day, technologies like solar panels and high-efficiency appliances and advanced insulation could even allow us to build 'zero-energy homes' that produce as much energy as they consume." The goal of the Bush Administration's Solar America Initiative was to reduce the cost of solar photovoltaic technologies so that they become cost-competitive by 2015.

Today, residential electricity is 11.88¢/kWh, you can purchase a net-zero energy home, the installed cost of a residential PV system is $3.73/W [~12¢/kWh, the levelized cost (LCOE) for residential PV with the federal income tax credit is the same as the cost of electricity "out of the wall," *i.e.,* most of the U.S. is at grid parity], gasoline costs $3.60 per gallon (Jan.–Sept. 2014) or ~$3.00 per gallon (Oct.–Nov. 2014), and the Hummer is gone.

Back to the future—The DeLorean time machine is a fictional electricity-powered automobile-based time travel device featured in the *Back to the Future* movie trilogy.[9] In 1955, the automobile time-machine was provided with electricity from a bolt of lightning; in 1985, a nuclear fission reaction; in 2015, it was supplied by a nuclear fusion generator that uses garbage. Like the Hummer, the DeLorean is gone, but today there are nearly 20 models of electric plug-in vehicles[10] offered in more than a dozen different brands—and in a range of sizes, styles, price points, and powertrains to suit a wide range of consumers. The question now is where do we get the electricity and how much does it cost? Will the nuclear fusion generator called the SUN be our source of transportation fuel?

Many of the states in the United States have not had a strong renewable energy policy in place, primarily because renewable energy was thought to be too expensive and we thought only biomass could be used to make transportation fuel. We were wrong! It's gasoline (often imported from other states or countries) and electricity produced from coal and natural gas (also, often imported) that are too expensive. Transportation fuel can and should be electrons or hydrogen because it is cheaper!

Electricity at $0.99 per gallon—Electric cars run so efficiently on electricity that they are significantly less expensive to operate than an equivalent sized gasoline car (Fig. 2). The efficiency of the average car on the road is 25 mpg and the efficiency of the average electric car is 3 miles per kWh.[11] At $3.60 (or $3.00) per gallon and 11.88 ¢/kWh for residential electricity, the gasoline car costs 14.4 (or 12.0) cents per mile to drive while the electric car costs 3.96 cents per mile. This shows that electricity is 27.5% (or 33%) of the cost of gasoline or that residential electricity is equivalent to $0.99 per gallon gasoline! The energy consumption of our homes can be cost-effectively reduced through energy retrofits at less than 5 ¢/kWh,[12] which is equivalent to fueling your car at $0.42 per gallon.

PV, EVs, buildings, and the grid—If we embrace this transformation from (a) expensive fossil fuels for transportation and (b) utility only production of electricity, to that of cheaper utility and rooftop solar plants for electricity for transportation *and* to power our energy

	80s and 90s	1996	2005	2014 (Jan – Sept)	2014 (Oct - Dec)	2020
Gasoline	$1/gal	$1.23/gal	$2.30/gal	$3.60/gal	$3.00/gal	($6.00/gal)
Electricity	6-8¢/kWh	8.36¢/kWh	9.45¢/kWh	11.88¢/kWh		(14.5¢/kWh)
Residential PV	(LCOE = $2.90 - 55¢/kWh)	$12/W Installed (LCOE = 48¢/kWh)	$9/W Installed (LCOE = 23 -32¢/kWh)	$3.73/W Installed (LCOE = 12¢/kWh w/ ITC)		$1.50/W Installed (LCOE = 7¢/kWh) No ITC

Fig. 1. *Gasoline, electricity, and PV prices.*

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efficiency retrofitted buildings and homes, we will be able to manufacturer the solar PV panels, energy efficiency products, batteries, and vehicles locally. If we delay, we will be trading our addiction to expensive and often imported fossil fuels to imported PV panels, and batteries, but at least the installation jobs would not be outsourced. The question then is will nations get out in front and surf the wave created by the solar and EV tsunami or will they drown? Will electric utilities succumb to a "Utility Death Spiral"?[13] (As more customers adopt distributed generation installed behind the customer's utility meter, utilities' costs to maintain and operate the grid must be spread across a smaller customer base, raising customer rates and increasing the economic incentive to cut the connection to the grid.) Or can we all work together and look at the future as an opportunity?[14] "The electric grid will be just as important in the years to come because the grid is becoming the platform that makes it possible for people to plug in solar panels, batteries, and charging stations," said Ellen Hayes, a Pacific Gas and Electric Company spokeswoman. "Having a solar panel that isn't connected to the grid is like having a computer that's not connected to the Internet."[15]

	Fuel Efficiency	Fuel Price	Cost per Mile	Cost per 12,000 Miles
Gasoline Car 	25 mpg	\$3.60 per gal	14.4¢ per mile	\$1,728
	25 mpg	\$3.00 per gal	12.0¢ per mile	\$1,440
Electric Car 	3 miles per kWh	11.88 ¢/kWh (\$0.99 per gal equiv.)	3.96¢ per mile	\$475
Retrofit of House	3 miles per kWh	5.0 ¢/kWh (\$0.42 per gal equiv.)	1.67¢ per mile	\$200

Fig. 2. *Efficiency of gasoline and electric vehicles.*

The Electrochemical Society can lead us into the future—In 1996, "The Society on Wheels" showed how each of the Society's Divisions and their technical areas play an important role in the manufacture, operation, and life of our automobiles. In this issue of the *Interface*, we look at the role of, and opportunities for, the ECS community in electric vehicles, the buildings near which our vehicles are parked, the electric fueling infrastructure, the role of solar energy, grid-scale electricity storage, fuel cells and hydrogen, sensing, and communication infrastructure. The future is indeed vibrant for the members of our Society.

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