The Plug-In Scam: GM and EPA Misrepresentation of the PHEV

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First Experimental PHEV – December 1974

First Production PHEV – December 2010

January 2012

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Introduction

In a March 2010 article, “Plug-In Vehicles: The First Great Fraud of the New Millennium,” author John Petersen discussed the weaknesses of the plug-in hybrid or pluggable hybrid electric vehicle (PHEV).[1] He followed this with a Feb 14, 2011 article, “Why Plug-In Vehicles Are a Luxury No Nation and No Investor Can Afford,” [2] and then an August 25, 2011 article, “It’s Time to Kill the Electric Car, Drive a Stake Through Its Heart and Burn the Corpse.” [3] The PHEV is a new car architecture that has been lauded by utilities, coal companies, “greens,” car companies, activists, environmentalists, and politicians – both liberal and conservative. The PHEV may not be the first great fraud of the millennium—possibly that could be reserved for credit default swaps and other financial chicanery. But “fraud” or “scam” is an applicable word to describe the evolution of the PHEV. This section reviews the PHEV’s history and shows how the EPA labeling system for the PHEV was even more flawed and suspect than that for the battery electric vehicle (BEV). This report brings a badly needed perspective to the excessive Miles per Gallon equivalent (MPGe) claims of PHEV vehicles.

The enthusiasm for the PHEV is based principally on highly misleading MPGe claims. In 2008, presidential candidate Barack Obama promised to commit the United States to building one million pluggable hybrids, averaging 150 MPG, by 2015.[4] In August 2009, Fritz Henderson, president of General Motors (GM), at that time the largest auto manufacturer in the world, claimed 230 miles per gallon for the Chevrolet Volt, the world’s first commercial PHEV, which shipped in December, 2010.[5] These numbers are bogus; they are based on arcane algorithms developed by manufacturers, PHEV advocates, and government agencies. To understand the propaganda of car, coal, and power companies, an “apples to apples” comparison is needed. It is important to bring the current misleading MPGe comparison for the PHEV to scientific measures, such as CO_2 generated or BTUs (British thermal units) consumed per mile traveled. And all the energy used, including fuel for the power plants that generate the electricity for electric cars, must be included.

Pluggable Hybrid Electric Vehicle History

In a late 2008 news article, *Car Talk* radio hosts Ray and Tom Magliozzi wrote, “But if [we were] to simplify it, [we’d] say that today’s gasoline electric hybrids use electricity to supplement a gasoline engine, whereas tomorrow’s plug-in hybrids will use a gasoline engine to supplement electric power.” This is a good layperson’s summary but with a questionable assumption. It assumes that a PHEV is a follow-on or improved version of a contemporary hybrid, an idea fostered by PHEV advocates. This implies that cars such as the Toyota Prius were simply a stepping stone to some future technology, which is not the case. Paraphrasing Ray and Tom’s description slightly and removing the time progression (today and tomorrow), one might say that gasoline electric hybrids like the Prius use electricity to supplement a gasoline engine while electric vehicles like GM’s Volt use a gasoline engine to supplement an electric motor. This second wording suggests two competing technologies, one focused primarily on existing hybrid technology and the other on a new kind of car—a BEV with an added gasoline engine operating an electricity generator.

The history of pure BEVs that get all their power from the electric power grid as well as more recent proposals for PHEVs, which use electricity from the grid and also burn gasoline, goes back several decades.[6] In 1972, scientist Victor Wouk concluded that battery electric vehicles were not commercially viable due to battery limitations that resulted in very short trips. He began thinking about combining the low-emissions benefits of an electric car (ignoring power plant gases) with the power of a gasoline engine to produce a vehicle powered mostly from the charged batteries. Wouk was given a government contract to build a prototype. He combined a 1972 Buick Skylark body, lead acid batteries, and a Mazda Wankel engine to build an electric hybrid vehicle, which he completed in 1974.[7] Although it passed EPA emissions tests, further EPA funding did not materialize.

Wouk has been called the "father of the hybrid car," but possibly the title is not completely accurate. Wouk's system was not an early gasoline hybrid car, as implemented in the late 1990s by Toyota (Prius) and Honda (Insight), but an electric vehicle whose batteries were charged from the power grid as well as an auxiliary gasoline-powered generator—the kind of power train used in the Chevrolet Volt.

Possibly Wouk's title should be changed to "father of the PHEV," the title currently bestowed by some on Andrew Frank, professor of Mechanical and Aeronautical Engineering at the University of California at Davis.[8] According to author Sherry Boschert, Frank had students build a version of a PHEV when he began teaching at the University of Wisconsin in the late 1960s. In the ensuing decades,[9] Frank modified nine other gasoline vehicles to run on externally charged batteries with a gasoline engine powering an electric generator to extend the range. Whether Wouk or Frank was first or whether one design was better than another is not important. What *is* important is that the PHEV concept is 36 years old. No major breakthroughs came during this period as automotive technological improvements are usually incremental and rarely can be rushed.

The idea of electric and hybrid cars was not limited to universities, research labs, and tinkerer's garages. In 1976, the U.S. Congress enacted Public Law 94-413, the Electric and Hybrid Vehicle Research, Development, and Demonstration Act. Among the law's objectives were to work with industry to improve batteries, motors, controllers, and other hybrid-electric components.[10] Seventeen years later, in 1993, under the leadership of President Bill Clinton, the government and the domestic auto industry formed the Partnership for a New Generation of Vehicles (PNGV) to produce family-sized fuel-efficient diesel hybrid vehicles that could get 80 MPG. [11,12,13] Involved parties included Department of Energy (DOE) national laboratories, universities, suppliers, and the United States Council for Automotive Research (USCAR, a legal partnership between DaimlerChrysler Corporation, Ford Motor Company, and General Motors Corporation. GM, Ford, and Chrysler each successfully developed a high-mileage diesel hybrid concept car.

In 2000, GM completed the Precept,[14] which achieved 80 MPG. Ford's Prodigy was also completed in 2000 and achieved 72 MPG.[15] Chrysler's ESX-3 also achieved 72 MPG.[16] All three cars were diesel HEVs with architectures similar to the gasoline hybrid Toyota Prius, also initiated in 1993. A variety of other innovative technologies were tried in the three vehicles, including lower vehicle weight, increased engine efficiency, and regenerative braking, a process in which deceleration is used to help charge the battery. In a 2001 speech, Al Gore summarized the work done, emphasizing the success of the

diesel hybrid technology.[17] During the entire Clinton-Gore term (1993–2001), the U.S. car companies that developed some variations of hybrids and electric vehicles were partially funded by the government. [18,19]

The PNGV program to build diesel hybrids was cancelled in 2001 (at the beginning of President George W. Bush's administration) at the request of GM, Ford, and Chrysler. It was replaced the following year by a new cooperative automotive research partnership called Freedom CAR, chartered to develop technologies for hydrogen-powered fuel cell electric vehicles.[20] (CAR stands for Cooperative Automobile Research.) In addition to the DOE, partners included oil companies (BP America, Chevron, ConocoPhillips, and Exxon Mobil Corporation), Shell Hydrogen LLC, and the members of USCAR (GM, Ford, and Chrysler). This combination of the U.S. government, oil companies, and car companies were committing to a new fuel cell technology and abandoning the diesel hybrid cars that had been under development for eight years. Bush's rejection of the diesel hybrid car, supported by U.S. car companies, may go down in U.S. automotive history as a watershed decision that allowed Japanese manufacturers to dominate the hybrid market for a decade—dominance that still continues.

In his January 2003 State of the Union speech, Bush predicted that "the first car driven by a child born today could be powered by hydrogen, and pollution-free." The fuel cell effort continued for another six years until May, 2009, when the Obama administration redirected the nation's automotive future away from the fuel cell to the PHEV.[21] The automobile industry, with the support of the U.S. government, spent six years on fuel cell development, followed by eight years on diesel hybrid development, that is, a total of fourteen years on two technologies that were eventually abandoned.

The Modern PHEV

The government and major car companies have now moved in a new technological direction—the PHEV. GM had begun prototype work for a PHEV in 2006 under the direction of Bob Lutz, a long-time innovative leader in the auto industry, who had scorned HEVs like the Toyota Prius since their inception.[22] The success of the Prius and the founding of a new company Tesla, formed to make high-performance BEVs using lithium ion batteries, affected Lutz's views. The PHEV movement was also being pushed by utility companies. Not surprisingly, the electric power industry saw great opportunity in cars that used electricity rather than gasoline. President Obama kept his campaign promise by providing massive subsidies to the industry as well as tax credits to buyers. GM committed to building a PHEV, the Chevrolet Volt, not much different from the EV1 they had canceled a few years before. In fact, the basic architectural prototype for the Volt was a research version of the EV1 with four seats rather than two and with a small engine generating electricity to charge the batteries.[23]

The Electric Power Research Institute (EPRI) may have played a significant role in GM's and Obama's decision. EPRI is a nonprofit organization, funded by the nation's electrical utilities and established in 1973 to advance the technology of electricity production. As the American Petroleum Institute is the main U.S. trade organization for the oil and natural gas industry, so EPRI is the key trade organization for electrical utilities. EPRI conducts research and advocates for its positions with local, regional, and national organizations, including car manufacturers and government agencies. Its purpose is: [24]

> The Electric Power Research Institute (EPRI) leads research, development, and demonstration of technical and operational solutions in electricity generation, delivery, and use. The focus and application of EPRI's research and activities span virtually every aspect of the power industry, including reliability, safety, the environment, and energy efficiency. The Institute's collaborative model engages EPRI members, participants, scientists, and engineers, along with experts from academia and other business sectors. As an independent, nonprofit center for public-interest energy and environmental research, EPRI's work is supported both by its members, which represent more than 90 percent of the electricity generated in the United States, and by growing international participation, representing more than 15 percent of EPRI's program support.

EPRI has collaborated with government organizations, auto manufacturers, and electric utilities in the development, testing, and demonstration of electricity-fueled transportation technologies.[25] The institute's electric vehicle program began in 1976 as an effort to understand the benefits and challenges of electricity as a transportation fuel. In 1991 EPRI joined with GM, Ford, Chrysler, and DOE to found the U.S. Advanced Battery Consortium (USABC). USABC's purpose was to advance electric and hybrid vehicle battery technologies. In 1999, EPRI formed the Hybrid Electric Vehicle Working Group with utilities Southern California Edison, the New York Power Authority, and Southern Company, along with members of the automotive industry, the U.S. government, regulatory agencies, and university research organizations. This consortium focused on PHEV and BEV technology and marketing. In 2003, EPRI developed a partnership with DaimlerChrysler to design, develop, test, and demonstrate the PHEV Sprinter, a Mercedes-Benz light, commercial vehicle prototype.

EPRI defined its role and the early PHEV concepts in a key 2001 report entitled "Comparing the Benefits and Impacts of Hybrid Electric Vehicle Options."[26] Other organizations that participated in the preparation of that report included Arthur D. Little, Inc., Southern California Edison, the University of California at Davis Hybrid Electric Vehicle Center, GM, Ford, Argonne National Laboratory, National Renewable Energy Laboratory (NREL), Applied Decision Analysis, DOE, and the Sacramento Municipal Utility District. Key individuals who participated included Fritz Kalhammer and Robert Graham (both with EPRI at the time) as well as Andrew Frank and Mark Duvall from the University of California at Davis. This document laid out the rationale for PHEVs and BEVs. It defined different PHEVs based on their distance driven on batteries as well as their configuration architecture (serial or parallel). The year 2001 was the same year that GM, Ford, and Chrysler moved away from the PNGV's diesel hybrids. It was also the year that GM made the decision to cancel the EV1 program.

In the past, car companies, oil companies, and various U.S. governmental agencies cooperated in pushing the private car over mass transportation options. It should be no surprise to discover a relationship between coal companies and electric utilities to push for electric cars to replace gasoline vehicles. Nor is it a surprise that the lobbying is focused on a business opportunity rather than on reducing CO_2 emissions or fossil fuel consumption. EPRI continues to lobby for electric vehicles.[27]

Various private groups have also been formed to support the PHEV concept. CalCars (California Cars Initiative) is a nonprofit organization founded in 2002 by Felix Kramer, a provider of communications, business development, and marketing services for startup

companies. Kramer intended to promote what he calls the clean, advanced technology of PHEVs as a key to addressing global warming.[28] CalCars focused on advocacy to prove market demand and on technology development to demonstrate that PHEVs can be extensions of current model lines. The organization's stated intention was to force car makers to build PHEVs, by applying public pressure and enacting government legislation. Kramer worked closely with Mark Duvall, who had moved from the University of California to the position of director of electric transportation at EPRI.

In September 2004, Kramer and a few California engineers converted a 2004 Toyota Prius into a PHEV, which they labeled Prius+. The CalCars website said that the Prius+ achieved roughly double the fuel economy of a standard Prius and could make trips of up to nine miles using only electric power. This was achieved by adding 300 pounds of lead acid batteries to the car and connecting these batteries to the electric motor of the Prius. However, the maximum speed was 34 miles per hour for the modified car when operating under battery power (a detail rarely mentioned in the press). CalCars called the PHEV a "hybrid with a plug."

In May 2006, CalCars flew a new version of the Prius+ that used lithium ion batteries to Washington, D.C. Numerous governors, senators, and members of the House of Representatives drove the car around the capital. There was tremendous enthusiasm generated by the PHEV presentations and demonstration rides. During this trip Kramer and Duvall, together with Andrew Frank, met with members of Congress and spoke to congressional committees. Senators expressed their amazement at the Prius+. Its proponents were extolled as visionary geniuses who, in a backyard, had developed products that global car manufacturers such as Toyota could not.

What made the car such a resounding success was the banner painted on the car stating "100+ miles per gallon" (see fig. 1, a common theme on PHEV websites and in PHEV literature. The 34 mile per hour (mph) maximum speed was not part of the label on the car nor emphasized in the literature. Congressional members thought they were viewing a car that got almost five times the average 21 MPG of the existing U.S. car fleet and that it could be done for existing cars at a cost of several thousand dollars! The repeated messages of "the technology is here" or "just around the corner" or "it's proven" was reassuring but much exaggerated. By the end of this public relations campaign, both presidential candidates were committed to high-tech PHEVs. The PHEV marketing campaign of CalCars, EPRI, and others was successful in reaching top politicians with sales rhetoric that was effective but, unfortunately, not accurate.

Figure 1: Banner for CalCar Prius + [29]

CalCars claims that their work led to the development of the 2010 Chevrolet Volt and the 2012 Toyota Plug-In Prius. The first CalCars Prius+ modification was made in 2004 and the first sizable shipments of the Volt were in 2011. The "technology that was here now" may have demonstrated the concept, but it took seven more years to develop a marketable product.

The PHEV MPG Sales Efforts Supporters

It was not simply EPRI and CalCars that influenced the presidential candidates. Senator Joseph Lieberman in a Loewy Lecture at Georgetown University on October 7, 2005 said, "And then we must remake our automobile engines as well. Vehicles that get 500 miles per gallon—or that use *no* refined crude oil—are within our grasp."

He further noted:

> But we can do even better—dramatically better—with the plug-in hybrid that is just now on the threshold of commercialization. Like the present hybrids, it would use both a gasoline and electric motor. But the plug-in hybrid would be able to use the battery exclusively for the first 30 miles of a trip. That means a plug-in hybrid would use zero—zero—gallons of gas or any combustible fuel for the vast majority of its trips. And experts tell me it could effectively get the 500 miles per gallon on longer trips. This isn't pie in the sky. These vehicles could be in your garage within a couple of years. [30]

It is important to note that the 500 MPG is derived by replacing gasoline with ethanol and biodiesel. It does not include the fuels used to make electricity at power plants.

Lieberman's speech included the phrase "experts tell me that . . ." Two of the experts responsible for the 500 MPG quote are R. James Woolsey, ex-CIA director, and George Schultz (ex-Secretary of Labor, the Treasury, and State). They are co-chairs of the Committee on the Present Danger of which Joseph Lieberman is an honorary co-chair. In a 2005 policy paper entitled "Oil and Security," Woolsey and Schultz developed the 500 MPG claim.[31] Author Sherry Boschert, in her 2006 book *Plug-in Hybrids: The Cars That Will Recharge America,* quotes from this policy paper, saying:

> A hybrid that gets 50 miles per gallon could get 100 miles per gallon if made from carbon composites that would be lighter but no more expensive than conventional materials. Run that lightweight hybrid on 85 percent cellulosic ethanol or a similar proportion of biodiesel, and it would get hundreds of miles per gallon of gasoline or petroleum derived fuel. Upgrade that car to a plug-in hybrid that runs 30 miles on electricity before tapping the liquid fuel and it might get 1,000 miles per gallon of gasoline.[32]

In a *Wall Street Journal* article entitled "Gentlemen, Start Your Plug-ins," Woolsey states, "A 50-MPG hybrid, once it becomes plug-in, will likely get over 100 MPG of gasoline (call it "MPGg"); if it is also a flexible fuel vehicle using 85 percent ethanol (E-85), its MPGg rises to around 500."[33] Two years later Woolsey penned another *Wall Street Journal* article with Paula Dobriansky, noting that PHEVs would get more than 100 MPG and 500 MPG with E85.[34]

Another well-known energy expert is Joseph Romm, author of the 2004 book *The Hype About Hydrogen: Fact and Fiction in the Race to Save the Climate*. Romm and Andrew Frank co-authored a paper entitled "Hybrid Vehicles Gain Traction,"[35] which included the following statement:

> These kinds of vehicles could travel 500 miles on one gallon of gasoline blended with five gallons of ethanol and thus continue a long-term strategy for dealing with the inevitable peak and subsequent decline in world oil supplies.

Romm commented further on the PHEV in a paper he and Peter Fox-Penner wrote for *Electric Wheels,* with the title "America needs to reduce its gasoline consumption. But how? By promoting plug-in hybrid electric vehicles."[36] The authors refer to the PHEV as one emerging technology with the potential to trigger transformative change in just five to ten years if government takes a few smart steps to spur its commercialization. They note,

> In all-around driving, plug-in hybrids could average between 80 [MPG] and 160 MPG, compared with about 45 MPG for the best-known of today's conventional hybrids, the Toyota Prius. The gasoline savings could be even greater if plug-in hybrids were designed to run on biofuels; they could travel 500 miles on a gallon of gasoline blended with five gallons of ethanol.

One regional utility, Austin Energy Company, took a significant role in the branding effort of the PHEV as the supercar of the future. Austin Energy provides electricity to the capital city of Texas. It is a municipally owned electric utility that serves 388,000 residential and commercial customers with 2,600 megawatts (MW) of generation capacity from its interests in three gas-fired plants, a coal-fueled facility, and 16 percent ownership of a nuclear-powered electrical generating plant.[37] Renewable energy sources include wind power (214 MW) and landfill methane (13 MW). Power deregulation took effect in Texas in 2002, but as a city-owned utility, Austin Energy was not required to participate.

In January 2006, Roger Duncan, general manager of Austin Energy, formed Plug-In Partners to advocate for the PHEV by influencing other cities and garnering support to put pressure on manufacturers to build the cars. Part of their program was to get what they called "soft orders," essentially small refundable deposits for mythical PHEVs, which were to show manufacturers that high public interest existed. The program ended in October 2008.[38] The results, as reported on the Plug-In Partners website, showed that "The Plug-In Partners effort over the last three years that enlisted 631 partners, signed up 38,312 petitions and made 11,333 soft purchase orders and participated with outreach and educational efforts in over 88 conferences and expositions has been a critical success." [39] The soft purchase orders showed that after three years of marketing, fewer than 12,000 out of hundreds of millions of drivers were willing to make a refundable deposit. Nonetheless, this was heralded as a major triumph with Austin Energy stating that they had accomplished their mission and were now ending the program.

Plug In America is a nonprofit organization that also advocates for PHEVs. In a presentation to the California Air Resources Board in 2006, Plug In America stated that "Plug-in vehicles are practical, proven, and ready," noting that consumer demand is

already demonstrated (presumably by the small number of people who were driving early versions of battery vehicles).[40] The same presentation notes that 150 million emissions-free *consumer* miles have already been driven. This number was derived not from PHEVs but from the earlier BEVs made as a result of the CARB program. One hundred fifty million miles had certainly not been driven in PHEVs! This is symptomatic of the overstatements of PHEV advocates. In 2008, Plug In America received their 501c3 designation and hired their first employee. [41]

PHEV Exaggerations Exposed

The idea of entrepreneurs in home garages modifying complex products like the Prius to develop a fully functional pluggable hybrid is impressive, but without independent analysis or verification, it should be treated more as public relations than as real product development. As noted earlier, The CalCars modified Prius+ built in 2004 was limited to a maximum of 34 mph in electric mode. The first conversion of a Prius that could run at freeway speeds did not take place until June, 2009,[42] more than four years after CalCars had claimed the PHEV concept was now proven.

Some organizations have carefully monitored the performance of experimental plug-in cars. In May 2008, Seattle mayor Greg Nickels announced a plan to test plug-in hybrid electric vehicles in his city.[43] Seattle joined with the Port of Seattle, King County, and the Puget Sound Clean Air Agency to test the performance of PHEVs in an urban area. The DOE's Idaho National Laboratory (INL) provided matching funds. Thirteen Priuses were converted at a cost of $12,000 each by A123Systems, a battery company located in Watertown, Massachusetts.

Nine months later (February 2009), in an article entitled "Reality Check on Plug-in Cars," Danny Westneat discussed the results.[44] He noted that the cars were advertised as getting more than 100 or 150 MPG but the actual results were about 51 MPG, close to the mileage of a standard Prius. (Contrast this to CalCars 100 MPG+ claim.) The plug-in Priuses were driven a total of 17,636 miles. They used standard gas/battery hybrid Priuses with an extra battery charged by using a 120-volt wall socket. Westneat also reported on the experience of the Internet company Google with nine plug-in Prius hybrids the company operated that averaged 54.9 MPG.[45] He quotes Tom Turrentine, director of the Plug-In Hybrid Electric Vehicle Research in Davis, California, as saying,

> Google is now sort of embarrassed about their results. I think we all need to be more careful. When we say we're going to get 100 or 150 miles per gallon, then that's setting expectations way too high. It just leads to disappointment. We need to deal in reality.

Westneat goes on to say that a lot of green projects will turn out to be hype. For some years there was no independent analysis made of the successes and failures of the conversions of Priuses or any other conversions of different car models. In late 2009, an extensive study was completed by independent researchers at the National Renewable Energy Laboratory (NREL) and Idaho National Laboratory (INL).[46] This report evaluated the performance of about 100 modified Priuses. The average mileage was reported to be about 51 MPG, much lower than the 150 MPG claim by President Obama for PHEVs and the 230 MPG claim for the Volt by GM.

This is an example of technical euphoria combined with enthusiastic people making unsubstantiated claims.

How MPG Numbers Were Misrepresented

PHEVs would be interesting laboratory concept cars except for one thing—the unrealistic claims of very high PHEV MPG numbers. EPRI, CalCars, Austin Energy, and Plug In America, as well as individuals such as Romm, Woolsey, Schultz, Kramer, Frank, and Duvall have also been extremely successful in using highly inflated MPG numbers in marketing the PHEV concept. Their spiel is based on the idea of a "proven" technology (based on a few backyard modifications). CalCars in particular had a strong effect on the positive perception of the PHEV. Their story is simple—the MPG obtained with a modified Prius is more than double that of a conventional Prius, i.e., "100+ MPG." Their modes of calculation are suspect and have never been published. However, they can be easily derived, as I will show.

AFS Trinity Power MPG hype was not limited to the Prius+. In November 2008, AFS Trinity Power Corporation, a Bellevue, Washington company, withdrew their plug-in hybrid (a modified Saturn Vue SUV) from the Los Angeles Auto Show after the show management refused to allow them to advertise their product as a 150+ MPG car. AFS had been showing the car for about a year, taking it to Washington in April of 2008 to lobby Congress, repeating CalCars visit in 2006. AFS implied that the position of the auto show management was based on jealousy or the wish to hide AFS's technical advances. AFS parked the modified car display on the roadway near the convention and provided test rides and literature.[47]

AFS explained their position in a press release pointing out that the show sponsors wanted the companies' mileage claims verified by the EPA, which measures mileage standards.[48] The AFS Trinity mileage calculation method is illustrated in a graphic, figure 2, from the AFS website.[49] AFS assumes a distribution of 80 percent electricity (powered by the batteries) and 20 percent normal mode (powered by the gasoline engine). The car selected for modification had a rating of 30 MPG.

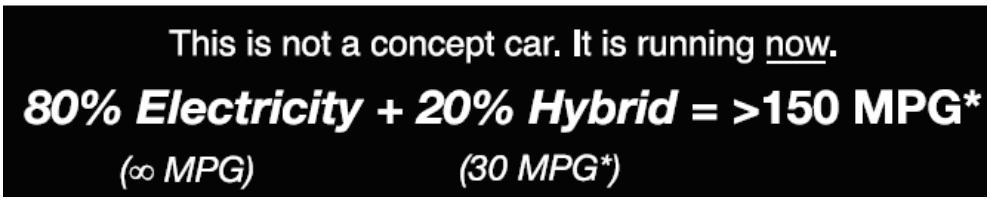

Figure 2: Method for Calculating MPG (AFS Website)

The AFS claim of 150 MPG is derived by using a very simplistic formula:

$$PHEV_{mpg} = EPA_{mpg} \; / \; (\; Dist_{gas} / Dist_{total})$$

$PHEV_{mpg}$ is the number to be derived. EPA_{mpg} is a car's MPG rating set by the EPA for every car manufactured. $Dist_{total}$ is the total distance traveled for an MPG test and $Dist_{gas}$ is the distance traveled for the MPG test using only the gasoline engine. The distance traveled using only electricity would be $Dist_{total}$ minus $Dist_{gas,}$ but it is not a component of

this formula. In this particular example, in figure 3.2, there is no trip distance given; however, the ratio of 20 percent hybrid and 80 percent electricity suffices because the particular distance is not important but only the ratio of $Dist_{gas}$ to $Dist_{total}$ for any arbitrary distance. Assuming a 100-mile trip (any number would give the same result of the ratio in this example), the evaluated formula for the AFS Trinity, using the ratio and MPG from figure 2 is:

150 MPG = 30 MPG / (20 miles/100 miles)

The AFS website notes that the question **"**Does it really get 150 miles per gallon?"[50] is the question most frequently asked by prospective buyers. Their response to the question includes another AFS example that can be used to test the formula. In this example someone drives 40 miles a day, 6 days a week, and 80 miles on one weekend day, giving a total weekly distance of 320 miles. The first 280 miles are all electric. The next 40 miles, on one weekend day, will use the gasoline engine, which might consume two gallons of gasoline for the week. From this brief statement, two numbers can be derived. First, if the gasoline engine uses two gallons of gasoline to drive 40 miles, then the car used in this example gets 20 MPG, which is the EPA_{mpg}. The gasoline engine is used for 40 miles, which is $Dist_{gas}$, out of a total distance driven of 320 miles, which is $Dist_{total}$. Substituting these numbers in the formula gives:

160 MPG = 20 MPG / (40 miles/320 miles)

For this example, the AFS website says that the evaluation uses a more conservative 150 MPG to take into account that MPG will vary depending on where and how fast a car is driven. AFS says they are "comfortable" that 150 MPG of gasoline is a good number for 78 percent of American drivers driving the way most Americans drive. The website shows four other examples of different trip lengths and different distances driven, using gasoline to get different results for $PHEV_{mpg}$. Example A gets infinite miles per gallon, example B gets 320 MPG, example C gets 73 MPG, and example D gets 60 MPG. All these mileage numbers are obtained driving the same car presumably at the same speed. One might reasonably wonder why there is such a spread of MPG values for the same car. The reason is that the difference in the MPG calculated is determined only by the ratio of miles driven using gasoline to total miles driven.

Volt MPG Misrepresentations

The quoted MPG numbers for the Chevrolet Volt have changed dramatically over time. The chronology of announcements is reviewed below.

Chevrolet Volt –150 MPG In 2007, GM vice-chairman Bob Lutz introduced the Volt concept at the North American International Auto Show [51] as a "battery-powered, four-passenger electric vehicle that uses a gas engine to create additional electricity to extend its range." (This is not a bad definition of a PHEV.) At the time Lutz was making presentations on the Volt, the MPG number given by GM was 50 MPG, using the gasoline engine, and the range possible from a fully charged battery was 40 miles. Lutz noted, "If you lived within 30 miles from work (60 miles round trip) and charged your vehicle every night when you came home or during the day at work, you would get 150 miles per gallon." [52] Lutz stated it slightly differently on another occasion saying, "By our calculation, if a person does a 60-mile trip, so that the internal combustion engine has to

help for the last 20, we figure the equivalent mileage would be about 150 miles per gallon." [53] In this example, EPA_{mpg} is 50 MPG, $Dist_{total}$ is 60 miles and $Dist_{gas}$ is 20 miles. Plugging these numbers into the formula ($PHEV_{mpg} = EPA_{mpg} / (Dist_{gas} / Dist_{total})$ gives the following result:

150 MPG = 50 MPG / (20 miles /60 miles)

This misleading formula seems to assume that the energy that comes from electricity is somehow free—that fossil fuels (oil, coal, natural gas) are not being used so they are not included in the formula.

Chevrolet Volt – 230 MPG In August 2009, GM president Fritz Henderson made a major announcement as part of a marketing campaign extolling the miles per gallon for the upcoming Volt PHEV. A fuel economy of 230 MPG was given (considerably above the 150 MPG quoted by Bob Lutz in 2007) with reference made to a new EPA rating for PHEVs and electric cars. The EPA shortly thereafter noted it had not yet tested the Volt. [54] GM said that it was not backing away from the 230 MPG statement and that it was unlikely that the EPA would come out with a much lower number when they actually tested a Volt. Furthermore, Henderson noted that GM believed that coming out with the 230 MPG rating at this time is one way to change people's perception of "what kind of car the Volt is."

The fact that the EPA did not immediately challenge the 230 MPG number shows the government support for GM. At that time the U.S. government essentially owned GM; it probably did not want to challenge the company's CEO. As far as the idea of telling people what kind of car the Volt is, it says more about what kind of company GM was at the time, quoting 230 MPG for a car that was eventually labeled by the EPA at 60 MPG in November 2010. [55] Both GM and the EPA knew the misrepresentation came from a formula used to calculate fleet mileages but this was never acknowledged.[56] This methodology has been around since 2000 and is available on the EPA website.[57]

The 230 MPG claim of GM and the supportive response by EPA led to a storm of criticism concerning the hyped PHEV MPG claims. This led other agencies of the government to try to develop better measures.[58] Researchers from the DOE's National Renewable Energy Laboratory (NREL), Idaho National Laboratory (INL), and Argonne National Laboratory (ANL) cooperatively developed a method for predicting the real-world fuel and electricity consumption of PHEVs. NREL's method estimated fuel consumption of 4.2 L/100 km (55 MPG) and electricity consumption of 5.5 kWh/100 km (89 kWh/mi). The 55 MPG rating is well below GM's 150-MPG (Bob Lutz) and 230-MPG (Fritz Henderson) claims.

Chevrolet Volt – 60 MPG In November 2010, the first window label for the Volt was published by the EPA (see fig. 3). The label included a new term "combined composite," which gave the total average MPG number for the Volt, taking into consideration the mileage driven using the gasoline engine and the mileage driven on electricity. This number, somewhat hidden in the lower left hand part of the label, is 60 MPG. GM eventually accepted this MPG number, dropping the 230 MPG claim.[59]

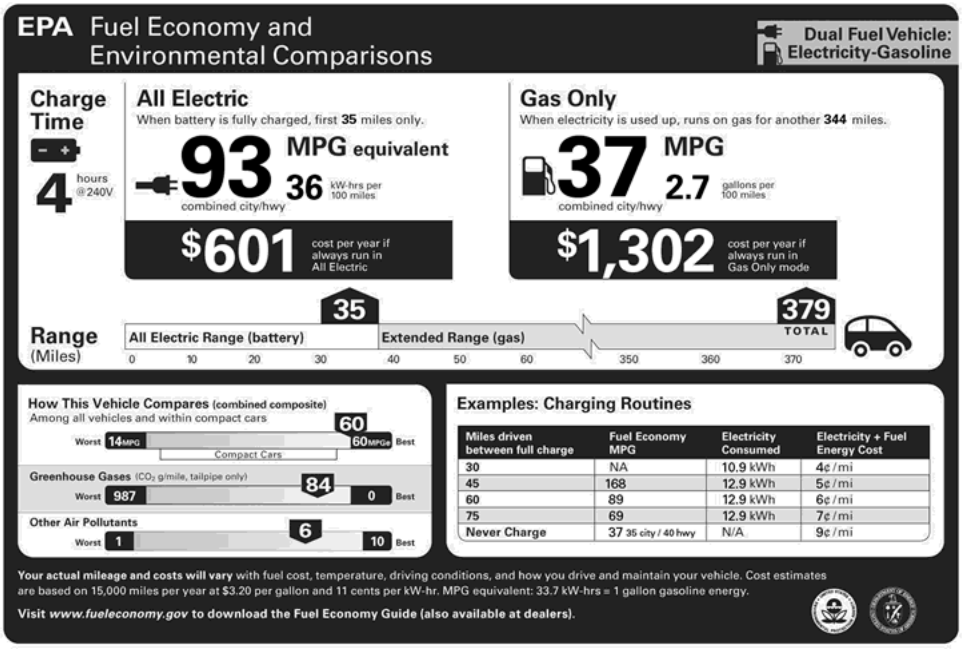

Figure 3: November 2010 EPA Label for Volt[60]

However, there were other misleading statements on the label in the "Examples: Charging Routines" box in the lower right. The Fuel Economy MPG (column 2) is derived using the same misleading methods that AFS and GM used. Columns 1–4 of table 1 contain the information from the four columns of the box "Example: Charging Routines."

Col 1	Col 2	Col 3	Col 4	Col 5	Col 6
Data from November 2010 Label				**New Data**	
Miles Driven Between Fuel Charge Dist	Fuel Economy MPG	Electricity Consumed	Electricity & Fuel Energy Cost	Miles Driven Gasoline	$PHEV_{mpg}$
30	NA	10.9 kWh	$.04/mile	0	NA
45	168	12.9 kWh	$.05/mile	10	167
60	89	12.9 kWh	$.06/mile	25	89
75	69	12.9 kWh	$.07/mile	40	69
Never Charge	37	N/A	$.09/mile		

Table 1: Volt "Charging Routine" Analysis

I have added two other columns to support the derivation that follows. Column 5 shows the miles driven using gasoline, or $Dist_{gas}$ in the formula for calculation $PHEV_{mpg}$, which is being used here. A Volt can be drive 35 miles before the battery is exhausted (this is less than the 40 miles used in an earlier example to evaluate Bob Lutz's 2007 claim).

Entries in this column are determined by subtracting 35 from the entries in column 1 (Miles Driven Between Fuel Charge Dist). The result in the first row for the 30 mile trip is –5 and is set to 0 because no gasoline is used. The Miles Driven Gasoline in column 5, or $Dist_{gas}$ for the 45, 60 and 75 mile entries in column 1 are 10 miles (45 minus 35), 25 miles (60 minus 35) and 40 miles (75 minus 35), respectively.

Column 6 is the result of calculating MPG using the following formula:

$$PHEV_{mpg} = EPA_{mpg} \ / \ (Dist_{gas} / Dist_{total})$$

and the data from the label. The bottom entry of 37 in column 2 (with heading of Never Charge) is the value for EPA_{mpg} in the formula. (In an earlier Lutz analysis, 50 MPG was given as the gasoline MPG). Note that the calculated results in column 6 are almost identical to the values from the label in column 2, verifying the formula.

To the reader who may be confused by this and wonder exactly what the point is, I emphasize that the point is to show the techniques used by the EPA and GM to provide misleading information to consumers. The mileage of a car is not dependent on the portion of a trip driven with gasoline but on the speed driven, the efficiency of the engine or motor, and the fuel that is used. This misleading MPG calculation was done to attract buyers to PHEVs, not to show actual MPG.

The November 2010 Volt window label was also the first window label to show CO_2 emissions—unfortunately, also in a misleading way. The Volt emissions are given as the number 84 on a bar entitled “Greenhouse Gases (CO_2 g/mile, tailpipe only).” The label includes a definition in the lower, dark part of the label that reads “MPG equivalent = 33.7 kWh for one gallon of gasoline,” showing that source versus site energy consumption for electricity is not incorporated. (Source and site descriptions were presented in an earlier report on the BEV under the section EPA MPGe Methodology.) Thus, the 84 CO_2 grams per mile is understated by about three times. The label now includes the logos of the EPA and DOE, indicating that two government agencies are misrepresenting the Volt’s MPG and CO_2 emissions.

Chevrolet Volt –36 MPG Getting close to reality Possibly due to negative press analysis of the first label, the EPA tried again with a new window sticker design in May 2011 (fig. 4). This most recent label includes the logos of the EPA and DOE, as well as a third government agency, the Department of Transportation (DOT), showing that three key government agencies are cooperating in providing misrepresentative consumer information. The November 2010 component “Example: Charging Routines” has been eliminated from the May 2011 label. Also gone is the combined-composite number, which was noted as 60 MPG on the November 2010 label.

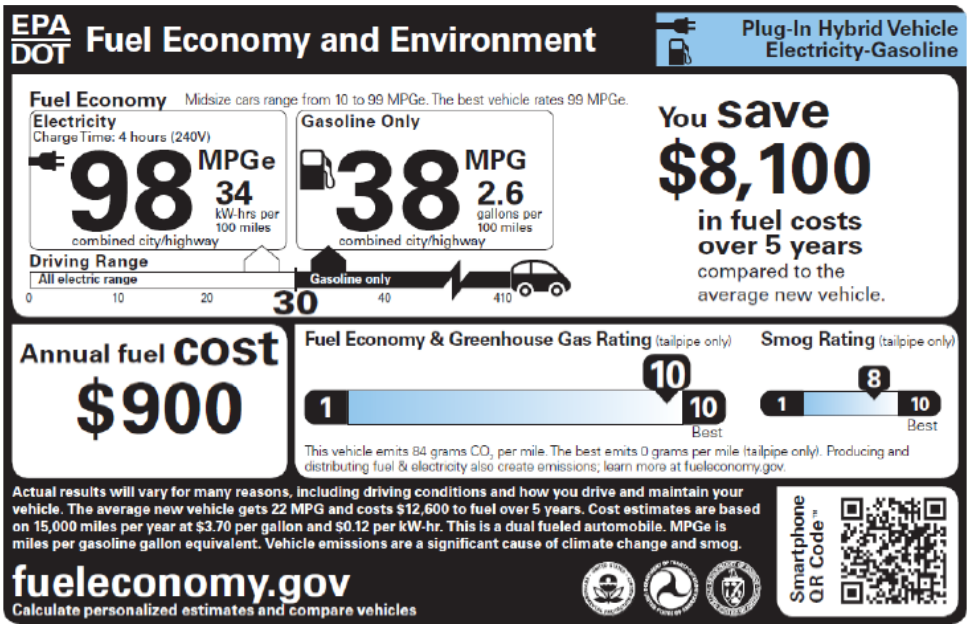

Figure 4: May 2011 EPA Label for PHEV

Figure 4 values are very close to the Volt numbers but not exactly. There was no Volt window sticker available on the EPA web site; therefore this figure must be modified with information from the EPA website. The Volt's 94 MPGe using electricity and 37 MPG using gasoline were obtained separately using fueleconomy.gov.[61, 62] There is no composite number in this latest version which may mean the EPA may be backing off its support for the questionable methodology previously mentioned. The agency may well be strategizing as to how to better present PHEV and BEV numbers.

Table 2 is similar to the tables in the report on BEVs where the derivation was shown. Using the same methodology and accounting for source energy, the MPGe is developed.

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7
Car Year/ Model	**Mode**	**kWh/ 100 miles**	**kWh/ mile**	**Miles/ kWh**	**33.7 kWh MPGe**	**12.3 kWh MPGe**
Volt	City	36	0.36	2.78	94	34
Volt	Highway	37	0.37	2.70	91	33
Volt	Combined	36	0.36	2.78	94	34

Table 2: Volt Adjusted MPGe

Assuming an average of 50 percent electric power and 50 percent gasoline power, the most accurate measure for a Volt would be 36 MPG—the average of the 34 MPGe for electricity and the 37 MPG gasoline engine value. Note these are my computations and do not reference any EPA numbers.

Chevrolet Volt 40-50 MPG Using CO_2 numbers The May 2011 label includes the statement "This vehicle emits 84 grams CO_2 per mile," reflecting in a slightly different form the same CO_2 information presented on the November 2010 label. A new statement has been added to the May 2011 label: "Producing and distributing fuel and electricity also creates emissions; learn more at fueleconomy.gov." This is a little more specific than using the qualifier "tailpipe only" as was done on the November 2010 version. For the first time, there is a hint to the consumer that the CO_2 emissions measurement is incomplete.

The information about MPG and CO_2 emissions for a wide range of vehicles and different fuels is well known to the EPA and other government agencies. The data in the following table are taken from a recent DOE report that compares CO_2 generated for different kinds of vehicles, including PHEVs.[63] In this table, the Volt is roughly the equivalent of a PHEV with a 40-mile range. There is a huge contradiction between the emissions numbers for a PHEV 40 and the emissions numbers from the label—270 grams of CO_2 per mile versus 84 grams of CO_2 per mile. The fact that the CO_2 numbers given are so different for the same car points out the disinformation and resulting confusion.

Fuel	**Grams of CO_2-Equiv. per Mile**
Gasoline (today's vehicle)	450
Gasoline (new vehicle)	340
HEV	235
PHEV 10 mile range	230
PHEV 40 mile range	270

Table 3: Comparing CO_2 of Various Architectures

Most of the information for my argument about misleading information is from EPA and DOE, two of the three agencies that produced the label. In fact, the correct numbers for total CO_2 emissions can be found by going to the fueleconomy.gov site, selecting Site Map at the top right, then selecting Beyond Tailpipe Emissions, and entering a ZIP code. The CO_2 emissions for that ZIP code are provided along with the average emissions for the country. The average emission for the Volt is 260 grams/mile, three times the 84 grams/mile from the window label and more than a HEV.[64] The value for a Prius is 230 grams per mile, slightly less than the generic HEV number in table 3.

It is a straightforward process to work backwards from CO_2 numbers to develop kWh per mile and from that the MPGe number. This shows the Volt to be in the 35–40 MPG, close to my 36 MPG estimate from the preceding energy evaluation.

The High-Risk Volt PHEV Architecture

GM's Volt PHEV architecture was based on an extension to the EV1 to make it into what is called a "series hybrid" car.[65] The changes included lengthening the car to provide a back seat, as well as adding an Auxiliary Power Unit (APU) and a small gasoline fuel tank. The APU was a gasoline-powered turbine engine that started automatically when

the battery charge dropped below 40 percent and powered a generator that delivered 40 kW of electrical power, enough to achieve speeds up to 80 mph. It also recharged the car's NiMH (nickel-metal hydride) battery cells. Using the modified Magliozzi definition mentioned earlier, this prototype was an " . . . electric vehicle . . . using a gasoline engine to supplement electric power."

In answer to an interviewer who asked what his worst decision was, former GM president Rick Wagoner responded, "Axing the EV1 electric-car program and not putting the right resources into hybrids.[66] It didn't affect profitability, but it did affect image." A March 2007 report about GM notes,[67] "GM R&D chief Larry Burns . . . now wishes GM hadn't killed the plug-in hybrid EV1 prototype his engineers had on the road a decade ago: 'If we could turn back the hands of time,' says Burns, 'we could have had the Chevy Volt 10 years earlier.'" GM positioned the Volt as an improved electric vehicle with a propulsion system that allowed the driver to continue beyond the range of the battery. In a 2008 article in *The Economist,* about Rick Wagoner, the magazine quotes GM[68] as saying, "And in 2010 GM is due to launch its revolutionary Chevrolet Volt, an electric car with a 'range-extending' internal-combustion engine that promises to make the Toyota Prius look like yesterday's technology."

This same description could apply to GM's experimental EV1 with an added APU. Basically, the Volt is using the same concept that Victor Wouk experimented with decades ago. It is a BEV with an added gasoline engine and an electricity generator—a competitor of HEVs such as the Prius rather than an improvement on it. There is a real question if this kind of design can be effective relative to fuel economy.

Improvements will occur, but it will be because of lithium ion battery technology that is superior to the lead acid and NiMH battery technologies of the late 1990s, not because of a new design. However, the same battery breakthrough will also be applied to the Prius, enabling it to operate at times as a BEV. This may result in two mixed-mode car architectures: one, a mostly gasoline-based vehicle with battery assist and possibly the ability to drive some distance on battery power (an enhanced Prius such as the recently announced Prius PHV) and the other, a mostly battery electric vehicle with a gasoline assist (the Volt). It is unclear which technology will win out. But it is a mistake to think that the Volt represents a more advanced version of the Prius. The success of the Volt is not assured, especially because its quoted miles per gallon are highly exaggerated.

It is possible that GM has different priorities than saving energy. The company has had a poor reputation for fuel efficiency compared to its major competitor, Toyota. GM vehicles in 2009 averaged 31.3 MPG versus Toyota's 35.9 MPG for domestic passenger cars and 33.0 MPG versus Toyota's 38.1 MPG for imported passenger cars.[69] Lutz was vice chairman of GM and had overall responsibility for the Volt. But he was not concerned with making a very fuel efficient car. In early 2008, Lutz made a now famous comment that "Global warming is a crock of shit."[70] He also said that GM had made a mistake by allowing Toyota to seize "the mantle of green respectability and technology leadership," with its market-leading Prius hybrid[71] and that hybrid cars like those made by Toyota "made no economic sense because their prices would never come down."[72] Lutz had said earlier that forcing automakers to sell smaller cars would be "like trying to address the obesity problem in this country by forcing clothing manufacturers to sell smaller, tighter sizes." He said that he was motivated more by the desire to replace imported oil than by the CO_2 argument.[73] In another interview where the reporter asked about his "crock" comment, Lutz noted that his motivations might include climate change, energy

independence, and conservation but the common denominator was a desire to get away from oil as a primary source of energy. He also said that fuel economy is valued by just a small, altruistic segment of the population.[74] In a 2010 book, "Chevrolet Volt: Charging into the Future," Lutz is quoted as saying:

> This is not about maximizing range or computationally getting the maximum efficiency. This is about permitting the average American to drive fully electrically most of the time but with the backup of a gasoline engine. . . . It's not about trickily trying to get the best EPA number or the furtherist range or being able to say overall it consumes fewer BTUs than any other vehicle on the planet. That's not what it's about. It's about electric drive with the assurance of gasoline backup.[75]

Lutz's previous development success was the muscle car "Camaro" with a V8 engine that gets 18 MPG. Possibly this kind of car is more in tune with his philosophy.

GM's Volt is at its core a BEV—the wheels are turned by electricity from batteries similar to the way the EV1 and other electric cars of the 1990s and early 2000s worked. It uses lithium batteries and incorporates a gasoline engine that powers an electricity generator.[76] To some extent, the Volt's performance was set at the very beginning when it chose a design based on a research EV1 series hybrid car with an AUM range extender. As noted earlier, the car did not achieve its original 50 MPG gasoline mileage—it settled for 37 MPG. The more accurate MPG rating for electric mode (MPGe) is closer to 34 MPGe than to the 96 MPGe on the label when the energy to generate electricity is included. Combining the gasoline and electric performance, it may be roughly a 36 MPG car. The GM mindset was very different from that of Toyota, which selected fuel economy and reduced CO_2 emissions as its priorities. The Volt architecture is yet to be proven, and other architectures are coming, the most threatening one to GM being the Toyota Prius Plug In, scheduled for 2012 shipment.

In an article entitled "Electro-Shock Therapy" in the July/August 2008 *Atlantic*, author Jonathan Ranch described the risks being taken by GM with the Volt. This is a "bet your company" situation.[77] Our government may be starting to become more realistic. The *Presidential Task Force on the Auto Industry* was an ad hoc group of senior officials formed in February 2009 to direct the financial bailout of GM and Chrysler. One of its conclusions about the Volt was:

> GM is at least one generation behind Toyota on advanced, "green" power train development. In an attempt to leapfrog Toyota, GM has devoted significant resources to the Chevy Volt. While the Volt holds promise, it is currently projected to be much more expensive than its gasoline-fueled peers and will likely need substantial reductions in manufacturing cost in order to become commercially viable.[78, 79]

John Petersen in an article entitled "U.S. Energy Information Administration: Electric Drive Forecasts Running in Reverse Since 2009," [80] shows that the government is backing off its earlier forecasts for PHEVs. His analysis of the yearly forecast for HEVs, PHEVS, and EVs from the Annual Energy Outlook[81] of the Energy Information Agency is shown in table 4.

Forecast Year	2010	2015	2020	2025	2030
	(000s)	(000s)	(000s)	(000s)	(000s)
2007 HEV Forecast	512.0	723.7	965.7	1,227.9	1,526.7
2008 HEV Forecast	572.6	1,322.3	2,220.6	2,452.2	2,667.9
2009 HEV Forecast	287.0	886.0	1,614.2	2,429.6	3,262.4
2010 HEV Forecast	286.5	744.0	985.0	1,226.7	1,508.7
2011 HEV Forecast	273.1	573.3	654.6	789.6	916.2
2007 PHEV Forecast	0.0	0.0	0.0	0.0	0.0
2008 PHEV Forecast	0.0	0.4	1.1	1.9	3.6
2009 PHEV Forecast	0.0	181.2	216.8	321.6	427.9
2010 PHEV Forecast	0.0	89.2	142.4	276.3	408.5
2011 PHEV Forecast	0.0	40.7	93.5	194.1	291.0
2007 EV Forecast	5.8	6.2	6.6	7.0	7.4
2008 EV Forecast	0.1	0.2	0.1	0.2	0.2
2009 EV Forecast	0.1	0.2	0.2	0.2	0.2
2010 EV Forecast	0.1	0.1	0.1	0.2	0.2
2011 EV Forecast	0.1	27.0	47.0	91.3	112.8

Table 4: EIA Forecasts for HEV/PHEV/EV

There has been a great deal of misleading information provided for the GM Volt and other PHEVS. At the same time, competition in the form of better hybrids, such as a 50-MPG version of the Prius, as well as pure BEVs are threatening the success of the Volt. In addition, Toyota is developing a less risky PHEV version.

Toyota's PHEV Strategy

Toyota, the world's undisputed leader in hybrid technology, is not ignoring the PHEV. In July 2007, an experimental Prius PHEV was certified for public road use by Japan's Ministry of Land, Infrastructure, and Transport. It used a NiMH battery pack and had an all-electric range of eight miles with a maximum speed of 62 mph.[82] (Recall that all the U.S. modified Priuses were limited to a maximum speed of 34 mph until the summer of 2009.) After certifying the car in Japan, Toyota formed a partnership with Électricité de France (EDF) to evaluate PHEVs in Europe.[83] Road trials began in France in autumn 2007. EDF and Toyota developed a charging and invoicing system, installed in each of the test vehicles, that is compatible with a new generation of public charging stations. A year later EDF and Toyota extended these trials to the United Kingdom.[84] Toyota had taken a more measured approach to its PHEV research, saying that the concept was not yet proven. Compare this to the attitude of EPRI, GM, and CalCars, who in 2004 claimed that the concept was already proven. The Seattle and Google experience with third-party modified versions of the Prius+ disproved that point.

In early 2008, Toyota's president, Katsuaki Watanabe, said the company would introduce a test fleet of several hundred next-generation plug-in Prius hybrids that would use lithium ion battery packs made by Panasonic.[85] These test Prius PHEVs went to governmental, academic, and commercial fleets in Asia, Europe, and the United States for large-scale field testing. In 2009, EDF and Toyota expanded the PHEV demonstration efforts in Strasbourg, France[86] and included the delivery of about 100 units of next-generation PHEVs. Also in 2009, Toyota began leasing 200 plug-in

versions of its Prius PHEV in Japan.[87] An additional 150 were leased in Europe and another 150 in the United States. In January 2011, Toyota announced the Prius plug-in version, branded as a Prius PHV, would be available for purchase in 2012.[88] It will have a range of 13 miles with a maximum speed of 62 MPG. It will be significantly cheaper than the Volt and will have a fuel economy figure for gasoline-only driving of 50 MPG versus the Volt's 37 MPG.

Petersen points out that Toyota is the biggest manufacturer of hybrid electric vehicles (HEV),[89] with more than 2 million sold since 1997. He notes that Toyota is also the world's biggest manufacturer of advanced automotive battery packs, owning a majority share in Panasonic. Petersen described the plug-in Prius as a PHEV-13, meaning that it has 13 miles of electric drive range as opposed to the 35-mile electric range of the GM Volt. Toyota explains this, saying:

> Toyota is of the belief that the smaller the battery in a PHV the better, both from a total lifecycle assessment (carbon footprint) point of view, as well as a cost point of view. Research has shown that plug-in hybrid vehicles with smaller batteries, charged frequently (every 20 miles or less) with average U.S. electricity produce less green house gas emissions than conventional hybrid vehicles (according to a 2009 Carnegie Mellon University study). And as battery size increases, so does the battery cost resulting in higher overall vehicle cost.[90]

Toyota described its extensive research efforts, using hundreds of early vehicle releases:

> The Prius PHV [Toyota's designation for PHEV] will come to market in 2012. The PHV demonstration program is designed to gather real-world driving data and customer feedback on plug-in hybrid technology. In addition, the program will confirm the overall performance of the first-generation lithium-ion battery technology in a variety of use cases. Toyota must ensure that the vehicle/battery meets customers' expectations before it is brought to market. The results of this program will make sure that the vehicle coming to market in 2012 will exceed customer's expectations and meet plug-in customers' demands.

Toyota has taken a much more conservative approach than GM. The Japanese automaker notes some of the reasons for its conservative approach, saying:

> Toyota believes that PHVs can be part of a solution to climate change and for energy security, for certain customers, in certain geographic areas, with certain grid-mixes, with certain drive-cycles, and with access to charging. There will be an important role for PHVs, but it will not be in high volume until there are significant improvements in overall battery performance . . . and battery cost reduction.

Toyota provided pricing and updated specifications on the plug-in Prius PHV in September 2011.[91, 92] The announcements noted that since 1997, Toyota has sold more than 3.3 million full hybrid vehicles worldwide (80 percent of all global hybrid sales) and 2.3 million of these cars are Priuses. For comparison, Toyota noted that the standard Prius CO_2 generation is 89g/km, while the PHV is targeted at 49 g/km. More

exact calculations were not provided. The new lithium ion battery holds 4.4 kWh and is estimated to provide 15 miles of driving; maximum EV speed is 62 mph. If one divides 15 by 4.4 kW, the result is .34 miles per kWh, which is similar to the values for the Volt and Leaf (see table 2.8).

Toyota took very careful steps in developing its PHEV. It may be that its more conservative approach, using the world's most economical hybrid car, the Prius, as a platform, will be a strong competitor to the Volt. The company is in a strong position, offering a standard hybrid car and a plug-in optional version. It can let the market decide. GM does not have an alternative to a standard HEV such as the Prius. This deficiency puts GM in a very risky position.

Conclusion

The PHEV, particularly as represented by the Chevrolet Volt, is a combination of technology, hope, and hype. GM's goal was not to reduce greenhouse gases but to remove the nation's dependence on foreign oil, ignoring the fact that coal would be the substitute. The Volt has been marketed by deliberately misrepresenting fuel economy. One of the main perpetrators of this misrepresentation is the electric power industry through its organization EPRI. Very small advocacy organizations along with well-known individuals, have sold Americans on a "breakthrough" technology that offers mileage claims in the hundreds of miles per gallon. The government, at all levels, starting with the President of the United States and including DOE, DOT, and the EPA, have supported the misrepresentation of the so-called "electrification of transport" effort.

Honesty and full transparency means the MPG numbers for PHEVs must include the source and site energy consumed along with the source and site CO_2 generated. If (MPGe) is used, it must be done in a way similar to the way the energy industry uses barrels of oil equivalent (boe) when comparing different fossil fuels used to generate electricity, including coal, natural gas, and oil. PHEVs should also include the CO_2 generated on a "wells to wheels" basis using source energy CO_2 emissions. "Wells to wheels" analysis incorporates all the energy components and stages. Fuel economy labels should make CO_2 generation numbers as prominent as MPG numbers, using the same fonts and font sizes.

The national fuel mix for electricity-generating power plants differs from one region to another while MPG for gasoline cars is the same in all regions. Thus CO_2 emissions per mile for PHEVs will differ in different places. The different values are easily obtained being updated annually by various government agencies.[93] National CO_2 emissions should be on all window stickers with regional CO_2 emissions available from the fueleconomy.gov website. Arguments from graphic designers about label sizes and styles should not be allowed to keep this information from the public.

Some PHEV proponents reluctantly acknowledge that the PHEV lags HEV technology in terms of present mileage and emissions but offer a counterargument stating that even though CO_2 emissions are not reduced with battery cars today, they will be someday in the future when renewable energies such as wind and solar PV are in large supply. Alternatively, it is suggested that carbon capture and storage (CCS) will remove the CO_2 emissions from the atmosphere. Such massive changes to the electrical grid may or may not be possible. Tens of millions of wind generators will be needed. CCS must be proven

to work. All this is hypothetically possible but is likely to be some decades into the future. And we will need renewables to fill our other electrical needs. More likely, we will build a relatively small number of EVs and PHEVs, powered mostly by electricity from coal, which will help get us off Middle East oil over which our control is limited. This will improve our so-called energy security, but our climate insecurity from increased CO_2 emissions will continue to increase. Whatever mileage improvements come will probably be based on the decade-old and now somewhat well established Hybrid cars.

Volt sales have been affected by the furor in the press calling out the perceived deception of the government's fuel economy numbers. Volt sales have been lackluster, with only 7,671 sold in its first year (2011). [94] Higher sales of a car that is being marketed by its manufacturer and the U.S. government would have been expected. However, the current label still ignores the question of source versus site energy (power plant versus car usage) and total CO_2 emissions.

Eventually, we can expect a new label that will show an MPGe for electric operation of about 33 MPG and CO_2 emissions near 200 grams of CO_2 per mile rather than the current 93 MPG and the 84 grams of CO_2 per mile on the current label.

I have referred frequently to the government and industry efforts over three decades that have been ineffective, including the fuel cell car, the diesel hybrid, and the electric car. The pluggable hybrid may turn out to be the failure of the second decade of the new millennium. If it does, it may share the common pattern of misdirection associated with the other "also ran" automobile technology efforts.

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