

Requiem for Plug-In Cars

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Chevy Volt



Prius Plug-In



RAV4 EV



Ford Focus EV

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Introduction

Electrification of modern transportation is not totally new to the US – from 1997 through 2003, almost 6,000 electric cars were produced, mostly for the state of California, under the zero-emissions vehicle (ZEV) mandate established in 1990 by the California Air Resources Board (CARB). In 2003, CARB drastically scaled back the ZEV mandate and the auto companies withdrew their ZEV offerings. In the same year the Tesla Motor Company was formed with the goal of reinvigorating the electric car by using lithium-ion batteries as a replacement for the nickel-metal-hydrate (NiMH) batteries used to meet the CARB ZEV requirements. Based to some extent on Tesla's new EV commitment, GM initiated the development program in 2006 that led to the Chevrolet Volt – a lithium-ion-based Pluggable Hybrid Electric Vehicle (PHEV).¹

Pluggable Hybrid Electric Vehicles, also known as plug-in hybrids, became a top priority for the Obama administration. In 2008, Barack Obama (a presidential candidate at the time) set a national goal of one million plug-in hybrid cars on the road by 2015 that could get up to 150 miles per gallon.² His administration allocated billions of dollars to support the development of batteries, plug-in cars and manufacturing facilities for plug-ins.

The first model of a PHEV – the Chevrolet Volt – and the first model of a BEV – the Nissan Leaf – were shipped in December of 2010. Tesla Motors shipped its first product, the Roadster, in 2008; this was a limited edition car. Tesla's first major commercial car, the Model S, was shipped in 2012. Three full years of shipments (2011-2013) provide a basis for evaluating the sales success of the electrification of transport programs.

Actual versus Projected Plug-in Sales

In February 2011, the DOE in a report entitled “One Million Electric Vehicles by 2015” gave sales projections for eleven different models of battery electric vehicles and plug-in hybrids.

One Million Electric Vehicles By 2015

February 2011 Status Report



Figure 1

Table 1 shows the DOE forecasts for each projected model for the years 2011-2013 on the left side and the actual sales on the right side. These are not all the plug-in cars shipped in 2011-2013 – only the models that the government knew about at that time.

| Manufacturer and Model | DOE Forecast | | | | Actual Sales | | | |
|------------------------|--------------|---------|---------|---------|--------------|--------|--------|---------|
| | 2011 | 2012 | 2013 | Total | 2011 | 2012 | 2013 | Total |
| Fisker Karma PHEV | 1,000 | 5,000 | 10,000 | 16,000 | 1,000 | | | 1,000 |
| Fisker Nina PHEV | | 5,000 | 40,000 | 45,000 | | | | |
| Ford Focus EV | | 10,000 | 20,000 | 30,000 | | 685 | 1,580 | 2,265 |
| Ford Transit EV | 400 | 800 | 1,000 | 2,200 | | | | |
| GM Chevrolet Volt | 15,000 | 120,000 | 120,000 | 255,000 | 7,671 | 23,461 | 24,000 | 55,132 |
| Navistar eStar EV | 200 | 800 | 1,000 | 2,000 | | | | |
| Nissan Leaf EV | 25,000 | 25,000 | 50,000 | 100,000 | 9,674 | 9,819 | 20,081 | 39,574 |
| South EVs Newtron | 1,000 | 1,000 | 1,000 | 3,000 | | | | |
| Tesla Model S | | 5,000 | 10,000 | 15,000 | | 2,650 | 18,000 | 20,650 |
| Tesla Roadster | 1,000 | | | 1,000 | 1,000 | | | 1,000 |
| Think City EV | 2,000 | 5,000 | 10,000 | 17,000 | | | | |
| Total | 45,600 | 177,600 | 263,000 | 486,200 | 19,345 | 36,615 | 63,661 | 119,621 |
| Total PHEVs | | | | 316,000 | | | | 56,132 |
| Total BEVs | | | | 170,200 | | | | 63,489 |

Table 1

The Volt, the first PHEV delivered, is selling at about 20% of expectations with 55,000 actual units sold versus 255,000 units forecast. Ford Focus EV sales were 2,423 units rather than the 30,000 units forecast. Karma entered bankruptcy in 2013 having sold only about 2,000 cars, far below the forecasted 61,000 units.

The U.S. Energy Information Administration (EIA) is a principal agency of the U.S. Federal Statistical System responsible for collecting, analyzing, and disseminating energy information to promote sound policymaking, efficient markets, and public understanding of energy. It also measures energy interaction with the economy and the environment. Each year the EIA publishes an Annual Energy Outlook report (AEO) which provides projections and analysis of U.S. energy supply, demand, and prices through 2040. This annual outlook is based on the EIA's National Energy Modeling System.³

The projected electric vehicle sales for years 2011-2013 as given in the AEO reports are shown in figure 2. Note the large decrease in projections for 2013. Between 2011 and 2012 the sales targets remained high but the hockey stick nature of the curve shows actual sales were far less than hoped. The curve showed more than a 50% reduction in sales projections.

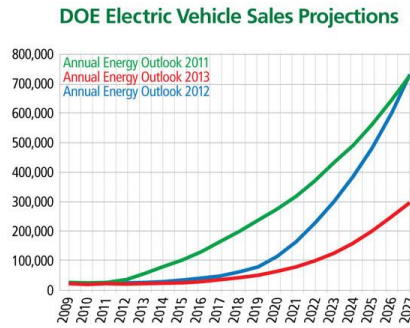


Figure 2

The AEO 2013 report projected market share for 2040 of 6% for hybrids, 2% for plug-in hybrids, and 1% for electric vehicles.⁴ The latest information from AEO 2014 shows a 50% cut in plug-in hybrid projections from 2% to 1%.⁵

| Source | Hybrids | Plug-in Hybrids | Electric Cars | Total |
|-------------------|---------|-----------------|---------------|-------|
| 2013 AEO Forecast | 6% | 2% | 1% | 9% |
| 2014 AEO Forecast | 5% | 1% | 1% | 7% |

Table 2

Plug-ins such as the Nissan Leaf, Tesla Model S, Chevrolet Volt, Prius PIP, Ford Fusion Energy and Ford C-max Energi have been technically successful. It is an impressive achievement to have tens of thousand of such cars on the road from four major manufacturers – GM, Nissan, Toyota, Ford – and an innovative start-up company, Tesla. These cars are being driven in all kinds of conditions with only minor difficulties. Manufacturing costs are higher than expected due mostly to expensive lithium-ion batteries. But reliability, an even more important factor, has been good so far. Still sales have been far below expectations. The reason may not be because of problems or limitations with plug-in cars but because of the success of conventional hybrid cars like the Toyota Prius.

Conventional Hybrids Limit Plug-In Sales

A J.D. Powers report in January 2014 said “For a third consecutive year, gas mileage continues to be the most influential purchase reason at the industry level (15%) and is the second-most-frequently cited reason for rejecting a vehicle, behind price. The question is if this is economics or environmental. More and more it is environmental.”⁶ Conventional hybrids offer an advantage over plug-in cars for environmental considerations but this advantage is not well understood because of the misrepresentation of fuel economy, measured in miles per gallon, for plug-in cars.

Toyota, inventor of the modern hybrid, sold six million conventional hybrids in the period 1997-2013. It is estimated that Toyota has a 70% share of the total market. This means

a total worldwide inventory of all hybrids from all manufacturers of about eight and a half million hybrid cars. Compare this to the approximate 400,000 or so plug-in cars on the roads which have been heavily subsidized by state and federal governments.

The fuel economy claims for plug-ins misrepresents the actual fuel economy normally measured in miles per gallon (MPG) for the cars. Obama's original goal of 150 MPG plug-in hybrids was based on misleading data from car companies and advocates. For example, GM's original announcement of the Volt fuel economy in August, 2009 was 250 MPG, later reduced to about 60 MPG. The EPA has the responsibility of determining the methods of calculating Miles per Gallon Equivalency, or MPGe for plug-in cars since they use mostly electricity. Such EPA ratings for PHEVs typically exceed 100 MPGe. By EPA policy, these MPGe estimates do not take into account the energy used to create electricity, typically coal or natural gas. This is obvious to the serious car purchaser, who often refers to plug-ins as "coal cars" reflecting their understanding of the source of electricity. Drivers interested either in economics or in environmental issues have chosen to purchase hybrids rather than plug-ins.

The Chevrolet Volt was marketed by General Motors (GM) as a "breakthrough" relative to the Toyota Prius. Plug-in hybrids like the Volt were positioned as advanced technologies relative to conventional hybrids (like the Prius) that were said to have "forgotten the plug". This is highly misleading as hybrids are innovative gasoline cars with higher MPG and lower CO₂ emissions than plug-in cars. Recent environmental analysis shows that plug-ins will have little observed effect on system wide U.S. CO₂ emissions.⁷

This report analyzes the status of hybrids and plug-ins at the end of 2013 and suggests that the conventional hybrid car (best represented by the Toyota Prius family), has significant economic and environmental advantages over plug-ins, resulting in relatively slow growth of the plug-in market compared to original expectations.

Sales of Gasoline Hybrids vs. Plug-ins 1997–2003

The marketing issue for electric cars is not the difference between conventional cars and plug-in cars but rather the difference between conventional hybrid and plug-in cars. This first became clear in the late 1990s during the period of the Zero Emissions Vehicle (ZEV) program established in California. Figure 3 shows the sales of ZEV cars, such as the GM EV-1 and the Toyota RAV4-EV, beginning in 1997 and ending in 2001. Hybrids became available in 2000 and sales grew dramatically, essentially killing off the ZEV cars. In 2003 hybrids sales were about 43,000 units – ten years later 2013 hybrid sales in the U.S. were about 460,000 units.

Hybrid vs. ZEV sales 1997-2003

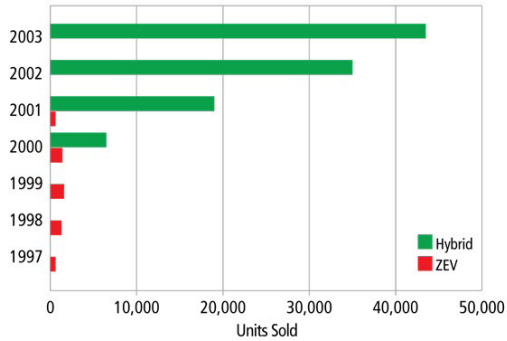


Figure 3

Plug-in hybrids were supposed to replace conventional hybrids. But for the three year period 2011-2013 during which they have been sold, both plug-in and battery vehicles have not sold well relative to hybrids as shown in figure 4. This is significant considering that the federal government provided a \$7,500 dollar subsidy for plug-in cars. (Some states provide additional subsidies).

Three-Year Sales Summary for Hybrid, EV, and Plug-in Hybrid

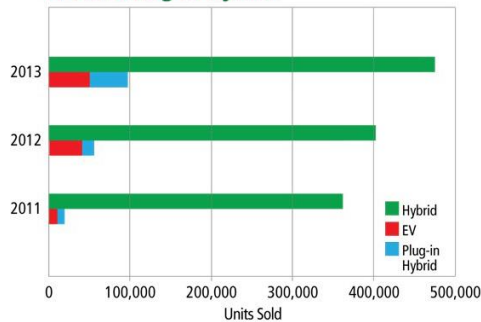


Figure 4

From 2011 to 2012 plug-in sales tripled from about 20,000 units to about 55,000 units, a growth rate of 175%. From 2012 to 2013, plug-in sales did not even double, growing from about 55,000 to about 98,000, a growth rate of 80%. Many forecasts estimate only a 60-70% increase in plug-in sales in 2014. Their market share growth rate will likely continue to decline as it becomes clearer that such cars do not compete well with hybrids based on environmental and economic concerns.

Reviewing Conventional Hybrid Sales 2000-2013

Table 3 shows conventional hybrid model U.S. sales beginning in the year 2003. The different models are ordered from top to bottom, first by year of introduction and second by sales. The first appearance of a sales number in a row represents the year of first shipment of the model. Years are at the top of the columns.

This table provides a visual reference to historical first customer shipment years and sales histories. The right-most column shows the total cars sold over a model's life time and provides comparisons of the sales of different models. For example, this table shows that total Prius lift back sales were about 2 million cars while the total Chrysler Aspen sales were 46 cars. (Lift back is the term for the original Prius and its follow-on models, used to separate this model from the Prius c, Prius v, and Prius P10. The bottom row shows annual sales of all hybrids.

Most of the early entrants in a new market do not succeed. In addition, some cars that have been classified as hybrids do not fit in the high-mileage mainstream hybrid architecture. These include the so-called mild hybrids (Aura, Vue, Malibu, Tahoe, Yukon) developed by GM. Of the 57 models listed in table 3, 40 of them fit in the categories of low sales, canceled models, or are not really hybrids. This is a relatively high number of unsuccessful models for a new drive train concept but it may be typical of a new technology introduction.

| U.S. Hybrids Sales by Date of Introduction 2000-2013 (in 1,000s) | | | | | | | | | | | | |
|--|------|------|------|------|------|------|------|------|------|------|------|-------|
| Vehicle(mpg) | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | Total |
| Toyota Prius(41) | 66 | 54 | 108 | 107 | 181 | 159 | 140 | 141 | 136 | 148 | 145 | 1,385 |
| Honda Insight 1(53)* | 12 | 1 | 1 | 1 | | | | | | | | 14 |
| Honda Civic(40) | 36 | 26 | 26 | 31 | 33 | 31 | 15 | 7 | 5 | 7 | 8 | 224 |
| Ford Escape(27)* | | 3 | 19 | 20 | 21 | 17 | 15 | 11 | 10 | 1 | | 118 |
| Honda Accord 1(28)* | | 1 | 17 | 6 | 3 | 0.2 | | | | | | 27 |
| Lexus RX400/450h(25) | | | 21 | 20 | 17 | 15 | 14 | 15 | 11 | 12 | 11 | 137 |
| Toyota Highlander(27)* | | | 18 | 31 | 22 | 19 | 11 | 7 | 5 | 6 | 5 | 125 |
| Mercury Mariner(28)* | | | 1 | 3 | 4 | 2 | 2 | 1 | | | | 13 |
| Toyota Camry(34) | | | | 31 | 54 | 46 | 23 | 15 | 9 | 46 | 44 | 269 |
| Lexus GS 450h(23)* | | | | 2 | 2 | 1 | 0.5 | 0.3 | 0.3 | 1 | 1 | 6 |
| Nissan Altima(34)* | | | | | 8 | 9 | 9 | 7 | 3 | 0.1 | | 37 |
| Saturn Vue(26)* | | | | | 4 | 3 | 3 | 0 | | | | 10 |
| Lexus LS600hL(21) | | | | | 1 | 1 | 0.3 | 0.1 | 0.1 | 0.1 | 0.1 | 3 |
| Saturn Aura(27)* | | | | | 1 | 0.3 | 1 | 0.1 | | | | 2 |
| Chevy Malibu(27)* | | | | | | 2 | 4 | 0.4 | 0.02 | 17 | 14 | 37 |
| Chevy Tahoe(21)* | | | | | | 4 | 3 | 1 | 1 | 1 | 0.4 | 10 |
| GMC Yukon(21)* | | | | | | 2 | 2 | 1 | 1 | 1 | 0.3 | 7 |
| Cadillac Escalade(20)* | | | | | | 1 | 2 | 1 | 1 | 1 | 0.4 | 6 |
| Chrysler Aspen(21)* | | | | | | 0.05 | | | | | | 0.05 |
| Ford Fusion(42) | | | | | | | 16 | 21 | 11 | 14 | 37 | 99 |
| Honda Insight 2(41) | | | | | | | 21 | 21 | 16 | 6 | 5 | 68 |
| Lexus 250h(35)* | | | | | | 2 | 11 | 3 | 1 | 0.01 | | 16 |
| Chevy Silverado(21)* | | | | | | | 2 | 2 | 1 | 0.5 | 0.1 | 5 |
| Mercury Milan(39)* | | | | | | | 1 | 1 | | | | 3 |
| Honda CRZ(37) | | | | | | | | 5 | 11 | 4 | 5 | 25 |
| Lincoln MKZ(39) | | | | | | | | 1 | 6 | 6 | 7 | 20 |
| Porsche Cayenne(21)* | | | | | | | | 0.3 | 2 | 1 | 1 | 4 |
| Mercedes S400HV(21)* | | | | | | | | 1 | 0.3 | 0.1 | 0.1 | 1 |
| Mazda Tribute(32)* | | | | | | | | 1 | 0.5 | 0.1 | 0.0 | 1 |
| GMC Sierra(21)* | | | | | | | | 1 | 0.2 | 0.5 | 0.1 | 1 |
| Mercedes ML450H(22)* | | | | | | | | 1 | 0.0 | 0.0 | 0.0 | 1 |
| BMW X6(18)* | | | | | | | | 0.2 | 0.04 | | | 0.3 |
| BMW Hybrid 7(20)* | | | | | | | | 0.1 | 0.3 | 0.2 | 0.03 | 1 |
| Toyota Prius v(42) | | | | | | | | | 8 | 41 | 35 | 84 |
| Hyunda Sonata(36) | | | | | | | | | 20 | 21 | 22 | 62 |
| Lexus CT200h(42) | | | | | | | | | 14 | 18 | 15 | 47 |
| Kia Optima(36) | | | | | | | | | 0.40 | 10 | 14 | 24 |
| Buick Lacrosse(29)* | | | | | | | | | 2 | 12 | 7 | 21 |
| Buick Regal(29)* | | | | | | | | | 0.12 | 3 | 3 | 6 |
| infiniti m35h(29)* | | | | | | | | | 0.38 | 1 | 0.5 | 2 |
| VW Touareg(21)* | | | | | | | | | 0.39 | 0.3 | 0.1 | 1 |
| Porsche Panam.(25)* | | | | | | | | | 0.05 | 1 | 0.1 | 1 |
| Toyota Prius c(50) | | | | | | | | | | 36 | 42 | 78 |
| Ford C-Max(40) | | | | | | | | | | 11 | 28 | 39 |
| Lexus ES 300h(40) | | | | | | | | | | 7 | 17 | 24 |
| Toyota Avalon(40) | | | | | | | | | | 1 | 16 | 17 |
| VW Jetta(45) | | | | | | | | | | 0.2 | 6 | 6 |
| Acura ILX(38) | | | | | | | | | | 1 | 1 | 2 |
| BMW 335ih(26)* | | | | | | | | | | 0.4 | 1 | 1 |
| Audi Q5(26)* | | | | | | | | | | 0.3 | 1 | 1 |
| BMW 535ih(26)* | | | | | | | | | | 0.4 | 1 | 1 |
| Honda Accord 2(47) | | | | | | | | | | | 1 | 1 |
| Infiniti QX60(26)* | | | | | | | | | | | 1 | 1 |
| Nissan Pathfinder(26)* | | | | | | | | | | | 0.3 | 0.3 |
| Infiniti Q50(31)* | | | | | | | | | | | 0.3 | 0.3 |
| Mercedes E400H(26)* | | | | | | | | | | | 0.3 | 0.3 |
| Chevrolet Impala(29)* | | | | | | | | | | | 0.1 | 0.1 |
| Total | 113 | 84 | 210 | 253 | 352 | 314 | 286 | 275 | 278 | 434 | 496 | 3,094 |

Table 3

Reviewing Hybrid Winners 2000-2013

Table 4 represents a subset of the cars listed in table 3. These are the most successful cars in terms of sales over a given period. Of the total of 57 hybrids listed in table 3, these 17 are the “hybrid winners” of the 2000-2013 years.

| U.S. Hybrids Sales by Date of Introduction 2000-2013 (in 1,000s) Most Successful | | | | | | | | | | | | |
|--|-----------|------|------|------|------|------|------|------|------|------|------|-------|
| Vehicle(mpg) | 2000-2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | Total |
| Toyota Prius(50) | 66 | 54 | 108 | 107 | 181 | 159 | 140 | 141 | 136 | 148 | 145 | 1,385 |
| Honda Civic(44) | 36 | 26 | 26 | 31 | 33 | 31 | 15 | 7 | 5 | 7 | 8 | 224 |
| Lexus RX400/450h(30) | | | 21 | 20 | 17 | 15 | 14 | 15 | 11 | 12 | 11 | 137 |
| Toyota Camry(41) | | | | 31 | 54 | 46 | 23 | 15 | 9 | 46 | 44 | 269 |
| Ford Fusion(42) | | | | | | | 16 | 21 | 11 | 14 | 37 | 99 |
| Honda Insight 2(42) | | | | | | | 21 | 21 | 16 | 6 | 5 | 68 |
| Honda CRZ(37) | | | | | | | | 5 | 11 | 4 | 5 | 25 |
| Lincoln MKZ(45) | | | | | | | | 1 | 6 | 6 | 7 | 20 |
| Toyota Prius v(42) | | | | | | | | | 8 | 41 | 35 | 84 |
| Hyunda Sonata(38) | | | | | | | | | 20 | 21 | 22 | 62 |
| Lexus CT200h(42) | | | | | | | | | 14 | 18 | 15 | 47 |
| Kia Optima(38) | | | | | | | | | | 10 | 14 | 24 |
| Toyota Prius c(50) | | | | | | | | | | 36 | 42 | 78 |
| Ford C-Max(40) | | | | | | | | | | 11 | 28 | 39 |
| Lexus ES 300h(40) | | | | | | | | | | 7 | 17 | 24 |
| Toyota Avalon(40) | | | | | | | | | | 1 | 16 | 17 |
| VW Jetta(45) | | | | | | | | | | | 6 | 6 |
| Acura ILX(38) | | | | | | | | | | 1 | 1 | 2 |
| Honda Accord 2(47) | | | | | | | | | | | 1 | 1 |
| Total | 101 | 80 | 154 | 190 | 286 | 252 | 228 | 226 | 248 | 388 | 460 | 2,612 |

Table 4

The total number of cars sold for this group of 17 cars is 2.6 million units versus 3.1 million cars sold for all 57 hybrids noted in table 3. These 17 cars sold 156,000 cars each on average while the 40 other cars sold on average about 12,000 cars each. Some lines were discontinued by the manufacturers. The mild hybrid cars from GM have been removed from the popular list of hybrid cars as they are not representative of hybrid technology, as shown by their relatively low miles per gallon. At this point in time, there is a consolidation, with the weakest competitors leaving the market deliberately or being forced out by the competition.

Note that the MPG value for a model in table 4 is higher than the corresponding MPG value of the same model in table 3. This reflects improved year to year MPG over time for a model. There has been about a 20% improvement in MPG from the early versions of a model to the current 2014 versions. The top four models listed in table 5 are also the top sellers as shown in table 4.

| Model | 2003-2005 MPG | 2014 MPG |
|--------------|---------------|----------|
| Toyota Prius | 41 | 50 |
| Honda Civic | 40 | 44 |
| Lexus 450h | 25 | 30 |
| Toyota Camry | 34 | 41 |

Table 5

Toyota's Dominance of the Hybrid Market

The original hybrid effort in Japan began as a result of a Clinton/Gore program that was called Partnership for a New Generation of Vehicles (PNGV). This program began in 1993 with the goal of developing cars with a fuel economy near 80 MPG. With government subsidies, GM, Ford and Chrysler each built a diesel-fueled prototype hybrid car that achieved MPG values between 72 MPG and 80 MPG. Toyota had asked to join the PNGV but was refused entry – PNGV was to be limited to US companies. This led Toyota and Honda to initiate their own hybrid programs.

In 2001, the PNGV program was cancelled and the government refocused its effort on fuel cell technology. Both Toyota and Honda had maintained their focus on the gasoline hybrid car and by 2001 it was clear their products would be successful (figure 3). Early hybrids in the U.S. included the Toyota Prius, the Honda Civic and the Honda Insight.

Toyota eventually dominated the market because its hybrid technology was superior to Honda's. Six million Toyota hybrid cars were built from 1997-2013. Other companies have attempted to penetrate the market with very limited success. Toyota in some sense **is** the hybrid market having made more than 70% of the hybrid cars on the road today. Figure 5 illustrates the success of the Toyota.

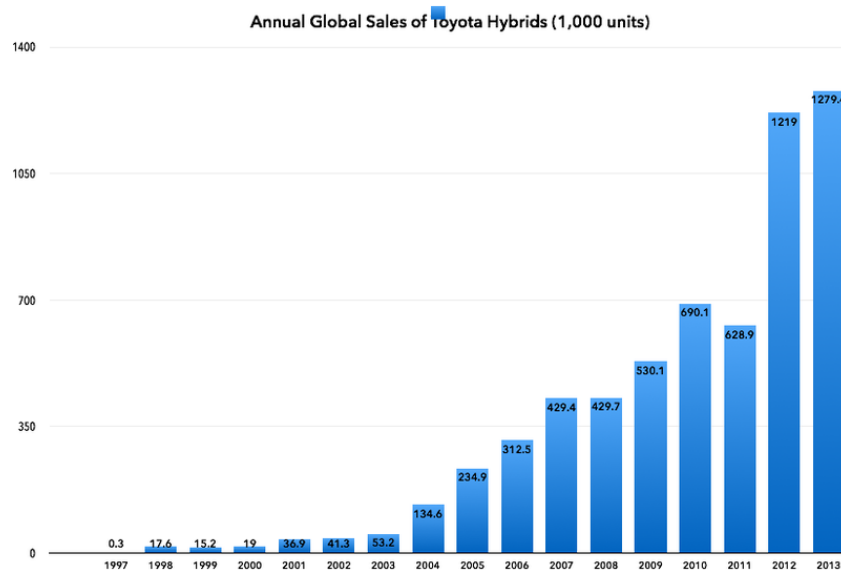


Figure 5: Toyota Annual Global Hybrid Sales

Toyota Hybrids are sold worldwide. The major purchaser of Toyota hybrids has been Japan, followed by the U.S.⁸ Europe has been slower to adopt the technology, partially because of the high number of diesel-powered cars in that region of the world. Table 6 shows yearly sales for four regions.

| Toyota Hybrid World Wide Sales by Region 1997-2013 (in 1000s) | | | | | |
|--|---------------|--------------|----------------------|---------------|----------------------|
| Year | Global | Japan | North America | Europe | Rest of World |
| 1997 | 0 | 0 | | | 0 |
| 1998 | 18 | 18 | | | 0 |
| 1999 | 15 | 15 | | | 0 |
| 2000 | 19 | 13 | 6 | 1 | 0 |
| 2001 | 37 | 18 | 16 | 2 | 0 |
| 2002 | 41 | 20 | 20 | 1 | 0 |
| 2003 | 53 | 27 | 25 | 1 | 1 |
| 2004 | 135 | 69 | 56 | 8 | 2 |
| 2005 | 235 | 59 | 150 | 23 | 3 |
| 2006 | 313 | 72 | 198 | 36 | 7 |
| 2007 | 429 | 82 | 288 | 49 | 11 |
| 2008 | 430 | 104 | 255 | 58 | 13 |
| 2009 | 530 | 251 | 205 | 55 | 19 |
| 2010 | 690 | 392 | 196 | 70 | 32 |
| 2011 | 629 | 316 | 185 | 83 | 45 |
| 2012 | 1,219 | 678 | 345 | 107 | 90 |
| 2013 | 1,279 | 679 | 358 | 153 | 89 |
| Total | 6,073 | 2,814 | 2,302 | 647 | 310 |

Table 6: Toyota Annual Sales by Region 1997-2013

There is a difference in acceptance of hybrids in different regions, often reflecting the tax policies of different nations. Note that between 2004 and 2005 a large jump in Toyota hybrid sales occurred in the US. From 2007-2011, hybrid sales declined followed by another jump in sales in 2012. A large sales increase occurred in 2008 with a second jump from 2011 to 2012. Total hybrids sales in Japan are 25% higher than US hybrid sales. In recent years (2012 and 2013) Japan hybrid sales have been almost twice that of the U.S.

Table 7 shows the cumulative Toyota hybrid sales by model. Note that the Prius family dominates sales, a capture rate of just under 70%.

| Toyota Hybrid World Wide Sales by Model 1997-2013 (in 1000s) | | | | | |
|--|--------|-------|---------------|--------|---------------|
| Hybrid Models | Global | Japan | North America | Europe | Rest of World |
| Prius | 3,167 | 1,408 | 1,405 | 269 | 86 |
| Prius α, Prius v, Prius + | 405 | 289 | 91 | 22 | 3 |
| Aqua, Prius c | 634 | 529 | 83 | | 21 |
| Camry | 419 | 36 | 294 | | 89 |
| Alphard | 45 | 43 | | | 1 |
| Auris | 128 | | | 124 | 4 |
| Yaris | 75 | | | 73 | 2 |
| Avalon | 17 | | 17 | | |
| Highlander, Kluger | 138 | 3 | 133 | | 2 |
| Vellfire | 17 | 17 | | | |
| Sai | 71 | 71 | | | |
| Estima | 105 | 105 | | | |
| Crown | 78 | 78 | | | |
| Harrier | 24 | 24 | | | |
| Crown Mild ⁴ | 6 | 6 | | | |
| Crown Majesta | 3 | 3 | | | |
| Corolla Axio | 9 | 9 | | | |
| Corolla Fielder | 21 | 21 | | | |
| Lexus LS 600h/LS 600hL | 35 | 24 | 3 | 4 | 5 |
| Lexus GS 450h/GS 300h | 39 | 14 | 7 | 12 | 5 |
| Lexus RX 400h/RX 450h | 289 | 27 | 145 | 86 | 30 |
| Lexus HS 250h | 62 | 39 | 22 | | 0 |
| Lexus CT 200h | 169 | 38 | 51 | 41 | 39 |
| Lexus ES 300h | 47 | | 25 | 0 | 22 |
| Lexus IS 300h | 17 | 9 | | 6 | 2 |
| Total | 6,019 | 2,793 | 2,277 | 638 | 310 |

Table 7 ⁹

Japan, with a population of 128 million people, has far more Toyota hybrids on the roads (2.8 million units) than the U.S. with a population of 314 million people. 2013 sales of all cars in Japan in 2013 were 5.38 million units. 2013 sales of all cars in the US were 15.6 million units.¹⁰ The US has three times the sales volume of Japan for all cars but sells fewer Toyota hybrids. In 2012 16-20% of Japanese car purchases were hybrids (all models) compared to 3% in the U.S. and 1% in Europe.¹¹

Toyota intends to provide a hybrid version for every one of its conventional models. It has followed its technology strategy set in 1993 and it may be very difficult for other companies to catch up. Some companies, including Ford and Nissan, originally bought Prius technologies for their early hybrid models. It may be that the Toyota Hybrid Synergy Drive could be used by other manufacturers. This may happen after an impartial assessment of plug-in market success.

Hybrid Fuel Economy – How Good?

The evaluation of hybrids has often been on a five-year financial payback period. Typically payback time (or period) is determined by the number of years required for the savings in the cost of gasoline to equal the difference between the purchase price of a conventional model and the purchase price of its hybrid equivalent.

The Prius has no equivalent conventional model; sometimes comparisons are made between a Prius and a similar-sized Toyota model. Other analysis compares only the hybrids that have a conventional model equivalent, such as the Toyota Camry. The “apple to orange” comparisons of two different models often show a much greater cost for a hybrid than an “apple to apple” comparison of a conventional model that has a hybrid version.

DOE, EPA and plug-in car advocates consistently compare plug-ins to conventional gasoline cars, emphasizing the advantages of plug-ins in terms of MPG and CO₂ emissions. But plug-in cars compete with hybrids, not just with ordinary gasoline cars. Toyota conventional models that also have a hybrid version with the Hybrid Energy System drive train show a significant fuel economy improvement – in the range of 40% energy savings.

The second most popular hybrid that is not a member of the Prius family is the Toyota Camry (table 4), with a MPG rating from EPA’s fuel economy.gov web site of 41 MPG. Other popular Toyota hybrid models are the Avalon and the Highlander. Table 8 shows the miles per gallon rating, hybrid and conventional, for each of these cars taken from fueleconomy.gov using 2014 models.

| Model (2014 year) | Conventional MPG | Hybrid MPG | Ratio |
|-------------------|------------------|------------|-------|
| Camry | 28 | 41 | 1.46 |
| Avalon | 25 | 40 | 1.60 |
| Highlander | 20 | 28 | 1.40 |

Table 8

The fuel economy of hybrids compared to their conventional models is rarely discussed in the media. For Toyota, a 40% fuel economy advantage seems to be the average for most of its models. For most hybrid buyers, the most important metric is miles per gallon. Some observers suggest that Toyota hybrids are bought for economical reasons such as lower gasoline bills. Others suggest that the reasons for purchase are based on environmental reasons, since better fuel economy means a reduction in CO₂ emissions.

Hybrids cost more than an equivalent non-hybrid car; they have both a gasoline engine and an electric motor. Hybrids also have an extra battery to store energy when the car is decelerating – energy later used to accelerate the car. Both add to the manufacturing cost of the vehicle. But the question is not one simply of the initial costs of the car but of “value” – a vague concept used infrequently in the automobile industry.

A Question of Value

Consumer Reports Magazine writes extensively on cars. Their December 2013 report notes: “The Prius’ 44 mpg overall is the best fuel economy of any non-plug-in car that Consumer Reports has tested,” said Consumer Reports Automotive Editor Rik Paul. “Though it’s not particularly cheap to buy, the Prius’ depreciation is so low that it costs less to own over the first five years than its initial MSRP. We call that a bargain.”¹² Consumer Report uses its own testing methodology for MPG which is typically results in fuel economy numbers lower than those of the EPA.

The February 2014 issue of Consumer Reports Magazine shows some of the values mentioned in the December reports. Under the article title of “What makes a great value?” the magazine considers three factors – road test score, predicted reliability score, and five-year owner cost. The road test score reflects how good a vehicle is overall. It includes measures for performance, comfort, convenience, fuel economy, fit and finish, cargo space, etc. The predicted reliability score forecasts how well new models are likely to hold up. This information comes from a history of subscribers’ ratings. Five-year owner costs include all major expenses during a five-year period. Included are depreciation, fuel, insurance premiums, interest on financing, sales tax, maintenance and repair.

Consumer Reports has evaluated hybrids for a long time. In the Consumer Reports of April 2011 the Prius was number 1 in family cars with 44 cents per mile rating.¹³ In the February 2014 issue, the Prius c is top rated. In general the high-performing hybrid cars offer best value, including costs, but many other factors as well. Depreciation is by far the largest owner-cost factor.¹⁴ And the reliability and high resale value of the top-of-the line hybrid models adds to this value. Toyota hybrids are also the most economical of all the different kinds of cars made.

There is also a question of other values that impact purchasing decisions. Some drivers need to have a luxury car regardless of its reliability and cost. Others want a Prius for a statement of their environmental policy. But the values will more and more become survival values and at that point the Prius and other Toyota hybrids will stand out from all other hybrid offerings.

Hybrid Sales and Trends by Company

The following tables show comparisons of hybrid cars by company. Each table shows the units sold yearly for the period 2009-2013. This information is taken from table 3 and table 4. The bottom row, entitled Take Rate–Hybrids and Take Rate–All Cars, are the percent of the total hybrid sales captured and the percent of the total of all cars captured for each year. The order presented is by manufacturer, beginning with hybrid market leader, Toyota. It includes the miles per gallon for each model. The cars are listed from top to bottom in order of 2013 sales.

Each table is divided into two sections – “sustaining/growing” and “declining/disappearing”. Some of the models have been withdrawn by the manufacturer – others have been removed based on projections of the author. The sustaining/growing category includes the 17 models show in table 4. The declining/disappearing category

consists of the are the 40 models from table 3 that are marked with an asterisk (*) next to the MPG value in column 1.

Toyota:

The following chart shows the units sold the five year period from 2009-2013. Toyota hybrid cars are available under two different brand names – Toyota and Lexus. Toyota has three other brands that do not include hybrid versions.

| TOYOTA | | | | | | |
|-------------------------------|---------|---------|---------|---------|---------|------------|
| Year | 2009 | 2010 | 2011 | 2012 | 2013 | 5 yr.Total |
| | Units | Units | Units | Units | Units | Units |
| Sustaining/Growing | | | | | | |
| Toyota Prius | 139,682 | 140,928 | 136,463 | 147,503 | 145,172 | 709,748 |
| Toyota Camry(41) | 22,887 | 14,587 | 9,241 | 45,656 | 44,448 | 136,819 |
| Toyota Prius c(50) | | | | 35,733 | 41,979 | 77,712 |
| Toyota Prius v(42) | | | | 40,669 | 34,989 | 75,658 |
| Toyota Avalon(40) | | | | 747 | 16,468 | 17,215 |
| Lexus CT 200h(42) | | | 14,381 | 17,671 | 15,071 | 47,123 |
| Lexus ES 300h(40) | | | | 7,041 | 16,562 | 23,603 |
| Lexus RX400/450h(30) | 14,464 | 15,113 | 10,723 | 12,223 | 11,307 | 63,830 |
| Sub Total | 177,033 | 170,628 | 170,808 | 307,243 | 325,996 | 1,151,708 |
| Declining/Disappearing | | | | | | |
| Toyota Highlander(28) | 11,086 | 7,456 | 4,549 | 5,921 | 5,070 | 34,082 |
| Lexus 250H(35) | 1,980 | 10,663 | 2,864 | 649 | 5 | 16,161 |
| Lexus GS450H(31) | 469 | 305 | 282 | 607 | 522 | 2,185 |
| Lexus 600HL(20) | 258 | 129 | 84 | 54 | 115 | 640 |
| Sub Total | 13,793 | 18,553 | 7,779 | 7,231 | 5,712 | 53,068 |
| Total | 190,826 | 189,181 | 178,587 | 314,474 | 331,708 | 1,204,776 |
| Take Rate - Hybrids | 67.82% | 68.95% | 66.83% | 77.98% | 70.30% | |
| Take Rate - All Cars | 1.83% | 1.63% | 1.40% | 2.18% | 2.14% | |

Table 9

The second row from the bottom, Take Rate – Hybrids, shows Toyota’s dramatic increase in market share, from 68% in 2009 to 78% in 2012 with a decline in 2013 to 70%. This 2013 decrease mirrors the increase made by Ford with its Fusion and C-Max hybrids.

Toyota makes the third most popular plug-in car – the Prius Plug-in. But the company sees the future as hybrid cars and is reducing its investments in plug-in development, both pure battery and plug-in hybrids. From the perspective of Toyota management, the market appears to have shown a clear preference for conventional hybrids over plug-ins. By the end of 2013, Toyota had sold over six million hybrid cars worldwide. Toyota sold 2.24 million vehicles in the U.S. in 2013. ¹⁵

Ford

Ford took market share from Toyota in the US in 2013. Toyota’s market share decline of 7% of 2013 sales is reflected in Ford’s increase in market share for that year of slightly more than 7%.

| FORD | | | | | | |
|-------------------------------|--------|--------|--------|--------|--------|------------|
| Year | 2009 | 2010 | 2011 | 2012 | 2013 | 5 yr.Total |
| | Units | Units | Units | Units | Units | Units |
| Sustaining/Growing | | | | | | |
| Ford Fusion(47) | 15,554 | 20,816 | 11,286 | 14,100 | 37,270 | 99,026 |
| Ford C(Max)(43) | | | | 10,935 | 28,056 | 38,991 |
| Lincoln MKZ(45) | | 1,192 | 5,739 | 6,067 | 7,469 | 20,467 |
| Subtotal | 15,554 | 22,008 | 17,025 | 31,102 | 72,795 | 158,484 |
| Declining/Disappearing | | | | | | |
| Ford Escape(32) | 14,787 | 11,182 | 10,089 | 1,441 | | 37,499 |
| Mercury Milan(39) | 1,486 | 1,416 | | | | 2,902 |
| Mercury Mariner(27) | 1,693 | 890 | | | | 2,583 |
| Subtotal | 17,966 | 13,488 | 10,089 | 1,441 | 0 | 42,984 |
| Total | 33,520 | 35,496 | 27,114 | 32,543 | 72,795 | 201,468 |
| Take Rate - Hybrids | 11.91% | 12.94% | 10.15% | 8.07% | 15.43% | |
| Take Rate - All Cars | 0.32% | 0.31% | 0.21% | 0.23% | 0.47% | |

Table 10

Ford has a longer history in the development of conventional hybrids than many other companies. It successfully developed and marketed the Ford Escape Hybrid, no longer marketed, selling 117,000 units over its lifetime from 2004 through 2012. The Ford Fusion Hybrid and the C-Max Hybrid are the latest hybrid offerings. Unfortunately the company's claims of competitive fuel-economy advantages for the C-max have been challenged.¹⁶ According to Consumer Reports, the 2013 Ford Fusion Hybrid and Ford C-Max Hybrid have, of all current hybrid models, the largest discrepancies between overall MPG results and the estimates published by the EPA.¹⁷ Nonetheless, both cars are selling well.

HONDA

Honda was the second manufacturer to develop hybrid cars, delivering its Insight shortly after Toyota delivered the Prius. Its cars were outclassed by Toyota and its sales have declined steadily. Insight sales have declined to the extent that the model will be discontinued at the end of the 2014 model year. The venerable Civic is still sold in hybrid and conventional versions.

| HONDA | | | | | | |
|-------------------------------|--------|--------|--------|--------|--------|------------|
| Year | 2009 | 2010 | 2011 | 2012 | 2013 | 5 yr.Total |
| | Units | Units | Units | Units | Units | Units |
| Sustaining/Growing | | | | | | |
| Honda Civic(44) | 15,119 | 7,336 | 4,703 | 7,156 | 7,719 | 42,033 |
| Acura ILX(38) | | | | 972 | 1,461 | 2,433 |
| Honda Accord(47) | | | | | 979 | 979 |
| Subtotal | 15,119 | 7,336 | 4,703 | 8,128 | 10,159 | 45,445 |
| Declining/Disappearing | | | | | | |
| Honda Insight 2(42) | 20,572 | 20,962 | 15,549 | 5,846 | 4,802 | 67,731 |
| Honda CRZ(35) | | 5,249 | 11,330 | 4,192 | 4,550 | 25,321 |
| Subtotal | 20,572 | 26,211 | 26,879 | 10,038 | 9,352 | 93,052 |
| Total | 35,691 | 33,547 | 31,582 | 18,166 | 19,511 | 138,497 |
| Take Rate - Hybrids | 12.68% | 12.23% | 11.82% | 4.50% | 4.14% | |
| Take Rate - All Cars | 0.34% | 0.29% | 0.25% | 0.13% | 0.13% | |

Table 11

Honda developed its initial hybrid products at about the same time as Toyota in the late 1990s. For the first four years Honda sold about 2/3rds as many hybrids as Toyota. Since 2005, Toyota has increased its hybrid market share relative to Honda. Although the company has sold over one million hybrid units around the world¹⁸, its overall hybrid market share dropped from 12.68% in 2009 to 4.18% in 2013.

Hyundai/Kia

These two Korean manufacturers share a common drive train. The Kia Optima is a version of the Hyundai Sonata. Hyundai holds a significant stock position in Kia. Both companies have admitted to overstating MPG ratings for several models.¹⁹ This experience points out that MPG testing is not done by the EPA but by the manufacturer. The MPG for both cars has been restated and both cars continue to sell well.

| HYUNDIA/KIA | | | | | | |
|---------------------------|-------|-------|--------|--------|--------|------------|
| Year | 2009 | 2010 | 2011 | 2012 | 2013 | 5 yr.Total |
| | Units | Units | Units | Units | Units | Units |
| Sustaining/Growing | | | | | | |
| Hyundai Sonata(38) | | | 19,673 | 20,754 | 21,761 | 62,188 |
| Kia Optima(38) | | | 403 | 10,084 | 13,919 | 24,406 |
| Total | 0 | 0 | 20,076 | 30,838 | 35,680 | 86,594 |
| Take Rate - Hybrids | 0.00% | 0.00% | 7.51% | 7.65% | 7.56% | |
| Take Rate - All Cars | 0.00% | 0.00% | 0.16% | 0.21% | 0.23% | |

Table 12

General Motors (GM) – Conventional Hybrids

GM conventional hybrid sales have declined steadily. This is not surprising since GM made a vital strategic decision to focus on plug-in hybrids and did not develop conventional hybrid models.

| GM | | | | | | |
|-------------------------------|--------|-------|-------|-------|-------|-------------|
| Year | 2009 | 2010 | 2011 | 2012 | 2013 | 5 yr. Total |
| | Units | Units | Units | Units | Units | Units |
| Declining/Disappearing | | | | | | |
| Chevy Silverado(21) | 1,598 | 1,871 | 1,001 | 469 | 104 | 5,043 |
| GMC Sierra(21) | 0 | 522 | 164 | 471 | 65 | 1,222 |
| Chevy Tahoe(21) | 3,301 | 1,426 | 519 | 533 | 376 | 6,155 |
| Cadillac Escalade(21) | 1,959 | 1,210 | 819 | 708 | 372 | 5,068 |
| GMC Yukon(21) | 1,933 | 1,221 | 598 | 560 | 288 | 4,600 |
| Saturn Aura(27) | 527 | 55 | 0 | 0 | 0 | 582 |
| Saturn Vue(26) | 2,656 | 50 | 0 | 0 | 0 | 2,706 |
| Total | 11,974 | 6,355 | 3,101 | 2,741 | 1,205 | 25,376 |
| Take Rate - Hybrids | 4.26% | 2.32% | 1.16% | 0.68% | 0.26% | |
| Take Rate - All Cars | 0.11% | 0.05% | 0.02% | 0.02% | 0.01% | |

Table 13

General Motors (GM) – Mild Hybrids

GM attempted to maintain a hybrid position by offering what is called a Mild Hybrid. These cars provide one or two of the functions of a high fuel economy hybrid. Sales peaked in 2012 and declined in 2013. (table 14) It is not expected that mild hybrids will affect sales being only a marginal 5% of the hybrid market. These cars are not included in any hybrid sales numbers in this document. They include the Chevy Malibu and Impala as well as the Buick Lacrosse and Regal.

| GM Mild Hybrids | | | | | | |
|-------------------------------|-------|-------|-------|--------|--------|-------------|
| Year | 2009 | 2010 | 2011 | 2012 | 2013 | 5 yr. Total |
| | Units | Units | Units | Units | Units | Units |
| Declining/Disappearing | | | | | | |
| Chevy Malibu(29) | 4,162 | 405 | 24 | 16,664 | 13,779 | 35,034 |
| Buick Lacrosse(29) | 0 | 0 | 1,801 | 12,010 | 7,133 | 20,944 |
| Buick Regal(29) | 0 | 0 | 123 | 2,564 | 2,893 | 5,580 |
| Chevy Impala(29) | 0 | 0 | 0 | 0 | 56 | 56 |
| Total | 4,162 | 405 | 1,948 | 31,238 | 23,861 | 61,614 |
| Take Rate - Hybrids | 1.48% | 0.15% | 0.73% | 7.75% | 5.06% | |
| Take Rate - All Cars | 0.04% | 0.00% | 0.02% | 0.22% | 0.15% | |

Table 14

Some vehicles have been introduced, or will be introduced in the future, to the car market as hybrids, but really only use some conventional technology improvements to gain marginal fuel economy improvements. Such improvements would be useful if introduced as standard options throughout a model fleet even though the improvements would not be impressive. For a company to make these improvements to only a small number of vehicles and use the "hybrid label" as a position device detracts from the integrity of the hybrid market. Some writers label these vehicles as "hollow hybrids". GM vehicles that fit this category include the Sierra and Silverado pickups as well as the old Saturn Vue and Aura models. The Malibu model also fits in this category.

Nissan

Nissan made a major strategic decision to compete in the conventional battery electric car with its Leaf product just as GM did for the plug-in hybrid. Nissan U.S. Leaf sales were slower to grow than GM's Volt sales since early Leaf sales were in Japan. But in 2013, the Leaf sales surpassed those of the Volt. From 2007-2012 Nissan sold 36,613 units of its Altima hybrid but withdrew it from the market. The Altima is being reintroduced in 2014 utilizing an all-new, Nissan-developed hybrid drive train option. It will also be used on the 2014 Pathfinder model.

Pre-2011 Ford and Nissan hybrids used technology from the Toyota Prius under a licensing agreement, including technology for the transmission, power inverter, battery, and charging control unit. Nissan has focused so long on the Leaf and BEV technology that it is unlikely to be able to compete effectively with a conventional hybrid in the near future.

| NISSAN | | | | | | |
|-------------------------------|-------|-------|-------|-------|-------|------------|
| Year | 2009 | 2010 | 2011 | 2012 | 2013 | 5 yr.Total |
| | Units | Units | Units | Units | Units | Units |
| Declining/Disappearing | | | | | | |
| Nissan Altima(33) | 9,357 | 6,710 | 3,236 | 103 | 0 | 19,406 |
| Infiniti M35h(29) | | | 324 | 691 | 475 | 1,490 |
| Infiniti Q50s(30) | 0 | 0 | 0 | 0 | 307 | 307 |
| Nissan Pathfinder(26) | | | | | 334 | 334 |
| Infiniti Qx60(26) | 0 | 0 | 0 | 0 | 676 | 676 |
| Subtotal | 9,357 | 6,710 | 3,560 | 794 | 1,792 | 22,213 |
| Total | 9,357 | 6,710 | 3,560 | 794 | 1,792 | 22,213 |
| Take Rate - Hybrids | 3.33% | 2.45% | 1.33% | 0.20% | 0.38% | |
| Take Rate - All Cars | 0.09% | 0.06% | 0.03% | 0.01% | 0.01% | |

Table 15

BMW

BMW has had a token position in the hybrid market. Although marketing its new I series, it is unclear to what extent BMW intends to compete in the conventional hybrid market.

| BMW | | | | | | |
|-------------------------------|--------------|--------------|--------------|--------------|--------------|-------------------|
| Year | 2009 | 2010 | 2011 | 2012 | 2013 | 5 yr.Total |
| | Units | Units | Units | Units | Units | Units |
| Declining/Disappearing | | | | | | |
| BMW Hybrid 7(20) | | 101 | 338 | 231 | 31 | 701 |
| BMW 335ih(26) | | | | 402 | 905 | 1,307 |
| BMW 535ih(26) | | | | 404 | 520 | 924 |
| BMW X6(18) | | 248 | 43 | 4 | 0 | 295 |
| Subtotal | | 349 | 381 | 1,041 | 1,456 | 3,227 |
| Total | | 349 | 381 | 1,041 | 1,456 | 3,227 |
| Take Rate - Hybrids | 0.00% | 0.13% | 0.14% | 0.26% | 0.31% | |
| Take Rate - All Cars | 0.00% | 0.00% | 0.00% | 0.01% | 0.01% | |

Table 16

VW/Porsche

The Porsche, Audi and early VWs have not been successful. Possibly the Jetta, with its high MPG and good first year sales will be a hybrid contender.

| VW/PORSCHE | | | | | | |
|-------------------------------|--------------|--------------|--------------|--------------|--------------|-------------------|
| Year | 2009 | 2010 | 2011 | 2012 | 2013 | 5 yr.Total |
| | Units | Units | Units | Units | Units | Units |
| Sustaining/Growing | | | - | | | |
| VW Jetta Hybrid(45) | | | | 162 | 5,655 | 5,817 |
| Subtotal | | | | 162 | 5,655 | 5,817 |
| Declining/Disappearing | | | - | | | |
| Porsche Cayenne(21) | | 344 | 1,571 | 1,180 | 615 | 3,710 |
| Porsche Panamera(25) | | 0 | 52 | 570 | 78 | 700 |
| Audi Q5 Hybrid(26) | | | | 270 | 854 | 1,124 |
| VW Touareq Hybrid(21) | | | 390 | 250 | 118 | 758 |
| Subtotal | | 344 | 2,013 | 2,270 | 1,665 | 6,292 |
| Total | | 344 | 2,013 | 2,432 | 7,320 | 12,109 |
| Take Rate - Hybrids | 0.00% | 0.13% | 0.75% | 0.60% | 1.55% | |
| Take Rate - All Cars | 0.00% | 0.00% | 0.02% | 0.02% | 0.05% | |

Table 17

Mercedes

Mercedes does not offer a good hybrid contender and may choose not to compete in this market segment.

| MERCEDES | | | | | | |
|-------------------------------|--------------|--------------|--------------|--------------|--------------|-------------------|
| Year | 2009 | 2010 | 2011 | 2012 | 2013 | 5 yr.Total |
| | Units | Units | Units | Units | Units | Units |
| Declining/Disappearing | | | | | | |
| Mercedes S400(21) | | 955 | 309 | 121 | 64 | 1,449 |
| Mercedes ML450(22) | | 766 | 1 | 20 | 11 | 798 |

| | | | | | | |
|----------------------|-------|-------|-------|-------|-------|-------|
| Mercedes E400H(26) | | | | | 282 | 282 |
| Subtotal | | 1,721 | 310 | 141 | 357 | 2,529 |
| Total | | 1,721 | 310 | 141 | 357 | 2,529 |
| Take Rate - Hybrids | 0.00% | 0.63% | 0.12% | 0.03% | 0.08% | |
| Take Rate - All Cars | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | |

Table 18

Mazda

Mazda is no longer a contender in hybrids.

| MAZDA | | | | | | |
|-------------------------------|-------|-------|-------|-------|-------|------------|
| Year | 2009 | 2010 | 2011 | 2012 | 2013 | 5 yr.Total |
| | Units | Units | Units | Units | Units | Units |
| Declining/Disappearing | | | | | | |
| Mazda Tribute(32) | 0 | 655 | 484 | 90 | 0 | 1229 |
| Total | 0 | 655 | 484 | 90 | 0 | 1229 |
| Take Rate - Hybrids | 0.00% | 0.24% | 0.18% | 0.02% | 0.00% | |
| Take Rate - All Cars | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | |

Table 19

Hybrid Share of Market

The U.S. hybrid market declined from 2009 to 2012. 2013 sales increased 10% from 2012 and may mark a resurgence of interest now that plug-in cars have not met expectations.

| SUMMARY DATA | | | | | | |
|-------------------------------|------------|------------|------------|------------|------------|------------|
| Year | 2009 | 2010 | 2011 | 2012 | 2013 | 5 yr.Total |
| Total All Hybrids - this data | 281,368 | 274,358 | 267,208 | 403,260 | 471,824 | 1,698,018 |
| Yrly Totals - All Car HC | 10,429,014 | 11,588,783 | 12,734,356 | 14,439,684 | 15,500,000 | 64,691,837 |
| CkSum All Cars% | 2.70% | 2.37% | 2.10% | 2.79% | 3.04% | |

Table 20

With mild hybrids removed, the hybrid sales for 2011, 2012 and 2013 were respectively about 267,000, 403,000 and 472,000 units. Market share of all cars for those three years respectively was 2.1%, 2.8% and 3.0%. This 3.0% was only about 10% more than the 2.7% of 2009. Hybrid sales grew rapidly from 2005 to 2009.²⁰ The percent of sales respectively for 2005, 2006, 2007, and 2008 were 1.4%, 1.8%, 2.5%, and 2.6%. For the first time since hybrid vehicles entered the market, the share of hybrid registrations declined in 2010 – from 2.9% in 2009 to 2.6% in 2010. It could be possible that sales declined as the market waited to measure the effectiveness of plug-ins. The jump in sales in both 2012 and 2013 provide some basis for this view.

The 17 models listed in Table 4, when considering their high MPG, may support another substantial increase in sales in 2014. A new Prius generation from Toyota due in 2015 may also add to hybrid market growth. Toyota will likely continue to

dominate the hybrid market worldwide.²¹ Hybrid fuel-economy performance continues to improve from all vendors and cost differences between conventional and hybrid versions of the same model are decreasing.²² (About 12% of Camry purchases are hybrids).²³

A relatively small 3.0% take rate at a time of rapidly increasing worldwide concern about global warming is not encouraging. The average light duty vehicle car sold in America in today has a fuel economy of about 24 MPG. Almost all the Toyota hybrid models are in the 40-50 MPG range with the Prius lift-back and Prius c averaging 50 MPG.

| Year | 1975 | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2013 |
|-----------|------|------|------|------|------|------|------|------|------|
| Fleet MPG | 13.1 | 19.2 | 21.3 | 21.2 | 20.5 | 19.8 | 19.9 | 22.6 | 24.0 |

Table 21²⁴

The Prius c won the award for best value in 2012 from Consumer Reports, announced in its February 2013 magazine.²⁵ Its value was \$.49 per mile while the BMW Li was \$1.80. Value is the summation of all costs (including purchase, maintenance, insurance, and fuel) divided by miles driven. The Prius has been in first or second place for some years in terms of the value rating in Consumer Reports, which typically reviews 300-400 cars in its annual car issue. Yet only a small portion of the population is buying these low-energy vehicles. Value and fuel economy are not yet important enough to most American citizens for them to change their approach to car purchases.

Plug-In (PHEV and BEV) Sales and Analysis

U.S.

By 2002 the market for BEVs had disappeared – lost to the Toyota Prius and Honda Insight. It was not long before a new BEV contender emerged. Tesla Motors was formed in 2003 to build an electric car using lithium-ion batteries, two years after the original CARB program was cancelled leading to the withdrawal from the market of all electric cars. The company introduced its first product, the Roadster, in 2006 and shipped its first production version of the Roadster in 2008. Possibly embarrassed by this new upstart, GM began its plug-in hybrid Volt effort in 2006, demonstrated a concept vehicle in January 2007, introduced the production version in September 2008, and shipped the first production cars in December 2010.²⁶ A rough development time estimate based on this data is five years to first shipment followed by three full years of production (2011-2013). (Tesla delivered about 2,800 Roadsters and discontinued the product when Model S production began.) Table 22 lists the cars sold in the 2011-2013 period. The table is divided into Battery Electric Vehicles (BEVs) and Pluggable Electric Hybrid Vehicles (PHEVs) also known as plug-in hybrids.

| BEV AND PHEV SALES – 2011-2013 | | | | | |
|--------------------------------|----------------|--------|--------|--------|---------|
| Manufacturer | Model | 2011 | 2012 | 2013 | Total |
| | | Units | Units | Units | Units |
| BEVs | | | | | |
| Nissan | Leaf | 9,674 | 9,819 | 22,610 | 42,103 |
| Tesla | Model S | | 2,400 | 18,650 | 21,050 |
| Ford | Focus | | 685 | 1,738 | 2,423 |
| Mitsubishi | i | 80 | 588 | 1,029 | 1,697 |
| Mercedes | Smart EV | 388 | 139 | 923 | 1,450 |
| Toyota | RAV4 EV | | 192 | 1,096 | 1,288 |
| Honda | Fit EV | | 93 | 569 | 662 |
| Chevrolet | Spark | | | 539 | 539 |
| Honda | Accord Plug-in | | | 526 | 526 |
| Fiat | 500e | | | 405 | 405 |
| Porsche | Panamera | | | 86 | 86 |
| | Total BEV | 10,142 | 13,916 | 48,171 | 72,229 |
| PHEVs | | | | | |
| Chevrolet | Volt | 7,671 | 23,461 | 23,094 | 54,226 |
| Toyota | Prius Plug In | | 12,750 | 12,088 | 24,838 |
| Ford | C-Max Energi | | 2,374 | 7,154 | 9,528 |
| Ford | Fusion Energi | | | 6,089 | 6,089 |
| | Total PHEV | 7,671 | 38,585 | 48,425 | 94,681 |
| | Total Plug Ins | 17,813 | 52,501 | 96,596 | 166,910 |

Table 22

World Sales:

Jose Pontes of EV sales blog has provided detailed shipments for a much wider variety of cars than those in table 22. He estimates 2012 sales were twice 2011. This implies world-wide sales of about 400,000 units in the three-year period 2011-2013.

| 2012 ²⁷ | | 2013 ²⁸ | |
|-------------------------|----------------|---------------------------|----------------|
| Model | Units | Model | Units |
| Chevrolet Volt | 29,597 | Nissan Leaf | 47,484 |
| Toyota Prius Plug-In | 27,100 | Chevrolet Volt | 28,252 |
| Nissan Leaf | 26,973 | Toyota Prius Plug-In | 23,075 |
| Renault Twizy | 9,020 | Tesla Model S | 22,186 |
| Mitsubishi i-Miev | 7,924 | Mitsubishi Outlander PHEV | 18,444 |
| Renault Kangoo ZE | 5,674 | Renault Zoe | 8,869 |
| Tesla Model S | 2,503 | Volvo V60 Plug-In | 7,437 |
| Ford C-Max Energi | 2,374 | Ford C-Max Energi | 7,353 |
| Renault Fluence ZE | 2,086 | Ford Fusion Energi | 6,206 |
| Fisker Karma | 1,840 | Renault Kangoo ZE | 5,886 |
| BYD E6 | 1,690 | Chery QQ3 EV | 5,007 |
| Bolloré Blue Car | 1,543 | Mitsubishi I-Miev | 4,769 |
| Mitsubishi Minicab Miev | 1,307 | Smart Fortwo ED | 4,130 |
| BYD F3 DM | 1,201 | Renault Twizy | 3,062 |
| BMW Active E | 867 | JAC J3 EV | 2,500 |
| Ford Focus Electric | 685 | Ford Focus Electric | 1,894 |
| Mia Electric | 455 | BYD e6 | 1,684 |
| Smart Fortwo ED | 298 | Mitsubishi Minicab Miev | 1,464 |
| Roewe E50 | 238 | Volkswagen e-Up! | 1,465 |
| Toyota RAV4 EV | 192 | BMW i3 | 1,318 |
| TOTAL Units 2012 | 123,567 | TOTAL Units 2013 | 210,817 |

Table 23

Renault is a French company with an historical strong record in electric vehicle sales in Europe. Renault sold almost 19,000 electric vehicles in 2013, most of them in Europe.²⁹ About 10,000 of these were the new ZOE, with first deliveries in 2013.³⁰ The Fluence Z.E. was canceled. Sales of the Kangoo were relatively flat from 2012, about 6,000 units. The Twizy sales went from about 9,000 in 2012 to about 3,000 in 2013. Renault sold 11% more EVs in 2013 than it did in 2012 but its market leadership is threatened by the Leaf.

Japan represents a large market for plug-ins as shown in table 24. But the Japanese customer prefers hybrids to plug-ins as shown in table 6 and table 7. Note that Mitsubishi is a key player in Japan and Europe but not in the US. Yet when compared to hybrid sales in Japan (679,000 in 2013 (table 6), plug-in success is limited.

| Japan Plug-In Sales 2013 | |
|-------------------------------|---------------|
| Nissan Leaf | 13,021 |
| Mitsubishi Outlander PHEV | 9,608 |
| Toyota Prius Plug-In | 3,538 |
| Mitsubishi I-Miev | 1,486 |
| Mitsubishi Minicab Miev | 1,461 |
| Mitsubishi Minicab Miev Truck | 602 |
| Nissan NMC | 45 |
| Total | 29,761 |

Table 24

The Leaf is now the leading plug-in contender, having sold 100,000 cars worldwide in the period 2011-2013.³¹ Leaf sales in Japan for 2013 were 13,021 and cumulative Japanese sales of the Leaf for the period 2011-2013 were 34,465 units.³² Cumulative Leaf sales in the US in the same three-year period were 42,122 units. Europe accounted for about 23,000 units sold.

Mitsubishi is strong in Japan with 13,157 units, slightly above Nissan’s Leaf. But it has not penetrated the market to the extent that Nissan has, and does not offer the Outlander in the US. Mitsubishi has delayed selling the Outlander in the US until 2015, due to battery shortages.³³ Mitsubishi could be a strong competitor against the Volt and Ford Energi models.

PHEV and BEV balance in the U.S.

Volt sales are primarily in the US and sales there declined from 23,461 units in 2012 to 23,094 units in 2013 as shown in table 25. Toyota’s Plug-in Prius also declined from 12,750 units in 2012 to 12,088 units in 2013. The Ford Energi cars grew in sales, supporting a growth rate of about 25% between 2012 and 2013. It is noteworthy that the year to year sales growth for plug-ins was only 25%.

| Company | Model | 2011 | 2012 | 2013 | Total |
|----------------|---------------|-------------|-------------|-------------|--------------|
| Chevrolet | Volt | 7,671 | 23,461 | 23,094 | 54,226 |
| Toyota | Prius Plug In | | 12,750 | 12,088 | 24,838 |
| Ford | C-Max Energi | | 2,374 | 7,154 | 9,528 |
| Ford | Fusion Energi | | | 6,089 | 6,089 |
| Total | | 9,682 | 40,597 | 50,438 | 94,681 |

Table 25 – PHEV sales

PHEVs were more successful than BEVs in 2012; this changed in 2013. US sales of all BEVs in 2010-2012 were at 27,148 units while US PHEV sales in the same period were at 48,982 units. Volt sales increased significantly from 2011 to 2012. Toyota entered the PHEV market in 2012 with the Prius Plug-In, a product long in development. Fisker, the luxury plug-in hybrid, has gone out of business.³⁴

In 2012 total sales of the Toyota’s plug-in Prius, whose first-year sales of 27,181 units which exceeded 25,435 units of the Leaf, the leader in 2011.³⁵ It may be that the plug-in hybrid is not meeting its performance claims. Battery-only cars grew faster. Note how two cars dominate the market.

| Company | Model | 2011 | 2012 | 2013 | Total |
|----------------|--------------|-------------|-------------|-------------|--------------|
| Nissan | Leaf | 9,674 | 9,819 | 22,610 | 42,103 |
| Tesla | Model S | | 2,400 | 18,650 | 21,050 |
| Others | | 468 | 1,697 | 6,991 | 9,076 |
| | | 10,142 | 13,916 | 48,251 | 72,229 |

Table 26: BEV cars

CO₂ Emissions and Plug-Ins

The question of CO₂ emissions from manufacturing the lithium-ion batteries that power plug-ins has been discussed extensively. Government agencies and car manufacturers have colluded in misrepresenting plug-ins as “clean cars”. TV advertisements emphasize the lack of “tailpipe” emissions. The EPA MPG methodology for calculating plug-ins MPGe has been challenged repeatedly. To create consumer interest, plug-in cars are normally shown with a MPG equivalent in excess of 100 MPGe. (MPGe is a way of comparing electric cars to gasoline cars.) The high MPGe is arrived at by ignoring the energy used to generate electricity, mostly from coal and natural gas.

As more plug-in cars become available and as the EPA fueleconomy.org web site begins to list the CO₂ emissions, consumers are becoming much more aware of the implications of how electricity is generated. And they are learning that, when apples-to-apples comparisons are made, plug-in cars generate more CO₂ than conventional hybrids on a national basis. Car companies and manufacturers continue to compare plug-ins to conventional non-hybrid cars, avoiding the market reality of the dominance of conventional hybrids.

In comparisons with non-hybrids, plug-in cars do have an advantage over conventional cars, although it is not as great as many imagine. Briefly summarized, the efficiency of electric cars equals the efficiency of the power plant and transmission lines multiplied by the efficiency of electric motors. Roughly, efficiency is about 33% for power plant and transmissions lines and 80% for motors. The product of the two numbers is about 26%, above the typical gasoline engine, often rated as 15-25%. But hybrid engines are much more efficient than conventional car engines, nearly 40%, so that plug-in power trains do not have an advantage over hybrids on a national basis. This becomes more apparent when CO₂ emissions are compared.

Three papers have contributed greatly to this new understanding. The Union of Concerned Scientists prepared a report that shows comparisons of plug-ins to hybrids.³⁶ One of the report’s most valuable contributions is to show that such comparisons are dependent on the part of the country in which the driver lives. This area comparison is not an analysis of weather or of topographic features but of the kinds of fuels used to generate electricity in each area. A Carnegie Mellon report on life-cycle air emissions³⁷ leads to the conclusion that hybrids and small-battery PHEVs are preferred car architectures. A third report from researchers at the Norwegian University of Science and Technology^{38 39 40} suggests that plug-ins energized by grid electricity rather than by renewable technologies contribute much more to environmental problems than gasoline cars. A more recent report models plug-in vehicle deployment in the US and finds there is not a clear consistent trend toward lower CO₂ emissions.⁴¹

Such information adds uncertainty to the car-buying decision. A plug-in car is a major investment, even if partially subsidized by governments. It is much safer (and cheaper) for the environmentally-concerned purchaser to buy a conventional hybrid. Early 2014 projections are not good, showing another decline in the growth rate. IHS automotive forecasts a 67% growth rate for 2014.⁴² These seem to be in line with the projections of AEO Outlook 2014. Finally, resale values for plug-in cars are not as good as conventional cars or hybrids.

Summary

Government programs such as those which support plug-ins are not particularly expensive when evaluated in terms of all automotive R&D. Nor do they make much of a difference in the automotive world which is typically manufacturing 400-800 different models across the globe. In 2011, worldwide automobile R&D expenditures were \$77 billion, about 4.7% of the world automobile revenue of \$1,650 billion.⁴³ U.S. expenditures are possibly 1-2% of this amount. Neither the U.S. government nor the CARB programs in California have impacted car sales to any meaningful degree. In November, 2012, the Congressional Budget Office published a report on the government's funding of the EV.⁴⁴ It noted that \$7.5 billion would eventually be expended, but no significant benefit would be achieved.

Among the risks of bringing a product to market prematurely and overselling it to consumers is the cost to early adopters. There are about 200,000 consumers in the U.S. who spent somewhere in the range of \$30,000 after rebates to purchase plug-ins, an investment in the range of \$6,000,000,000. Resale values of plug-ins are lower than hybrids or conventional cars and much of this investment will be lost prematurely.

Plug-in cars are at a disadvantage relative to their main competitor – the gasoline hybrid. The high MPG, low CO2 market belongs to the Toyota Hybrid Synergy Drive for at least another generation. It does not appear that fuel cells, diesel cars or electric drive trains will be able to provide the benefits of this innovative idea anytime in the near future. Meanwhile, as pointed out in an earlier white paper,⁴⁵ the environmentally concerned consumer's contribution is to buy a conventional Prius and use public transportation when possible. The Prius and other Toyota hybrids will offer greater value than conventional cars or plug-ins for some time. Until electric power plants can generate much cleaner electricity in large volumes (decades away), conventional hybrids will continue to outsell plug-in cars.

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