The Second Death of the Electric Car

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Tesla Model S

Fisker Karma

Nissan Leaf

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Introduction

Electrification of transportation has been a national goal in recent years. Electric cars were common in the early days of the automobile; however, the internal combustion engine eventually became the dominant power train. Streetcars and trolleys were the mainstay of early intra-city travel but over time were replaced by buses. “Light rail” continues to be a goal of some cities but implementation has lagged. High speed electric trains are more common in Europe, Japan, and now China, than in the US; but the growth in automobile usage continues unabated even in those countries.

From 1997 through 2003, almost 6,000 electric cars were produced, mainly for California, under the zero-emissions vehicle (ZEV) mandate set in 1990 by the California Air Resources Board (CARB). This mandate required that the seven major automobile suppliers in the US offer electric vehicles in order to continue sales of their gasoline-powered vehicles in California. In 2003, the CARB drastically scaled back the ZEV mandate and the auto companies withdrew their ZEV offerings. A movie entitled “Who Killed the Electric Car?” offers one perspective on this withdrawal, portraying manufacturers as acting in a conspiratorial manner. Another argument is that the availability of the Honda Insight Hybrid and the Toyota Prius Hybrid during the same time period, offered consumers a better alternative to electric cars.

In 2003, the same year that the seven major car companies began recalling their leased electric vehicles, the Tesla Motor Company was formed with the goal of reinvigorating the electric car by using lithium-ion batteries as a replacement for the range-limited nickel-metal-hydride (NiMH) batteries used to meet the CARB ZEV requirements. In 2006, Bob Lutz, Vice President at GM, inspired by both the Tesla announcement and the increasing success of the Prius, initiated the development program that led to the lithium-ion-based Pluggable Hybrid Electric Vehicle (PHEV).[1] The concept version was introduced in early 2007. The first production version, the Chevrolet Volt, was shipped in December of 2010. Nissan developed a lithium-ion-based Battery Electric Vehicle (BEV) program and shipped its first production Leaf model also in December, 2010. Tesla Motors shipped its first electric car, the Roadster, in 2008, although production was slow to ramp up. Another US startup, Fisker Corporation, delivered its PHEV car, the Karma, in 2011. The general name for PHEVs and BEVs (which were equivalent to the ZEVs of the CARB program) became known by the general name **plug-ins**.

In 2008, presidential candidate Barack Obama set a national goal of selling one million PHEVs in the US by 2015. After his inauguration, Obama’s administration allocated billions of dollars to support the development of batteries, electric cars and manufacturing facilities. Hundreds of millions of dollars in loans and grants were made to the companies building plug-ins, both PHEVs and BEVs.

The years 2011 and 2012 represent two full years of US plug-in vehicle deliveries, with total production of 76,030 units, far less than the volume needed to meet President Obama’s goal. The key lithium-ion battery company, A123, which was heavily funded by the government, went bankrupt in late 2012. Lithium-ion batteries were found to cost much more then expected. Additionally, recent environmental analysis shows that plug-ins generate more CO_2, both in manufacturing and in use, than equivalent conventional hybrids. This report analyzes the status of hybrids and plug-ins at the end of 2012 and suggests that the conventional hybrid car (best represented by the Toyota Prius family), has significant economic and environmental advantages over plug-ins.

Reviewing Conventional Hybrid Sales

An earlier report summarized conventional US hybrid sales from 1999 through 2010.[2] Thirty two models of hybrid vehicles were sold during that period. A summary from the report is shown in Table 1. The model entries in the table are ordered by their first shipment year.

Table 1: Hybrid Electric Vehicle (HEV) Sales by Model

Vehicle		1999/ 2000	2001/ 2002	2003/ 2004	2005/ 2006	2007 2008	2009/ 2010	Total
Honda Insight		3,805	6,942	1,783	1,388	0	41,534	55,452
Toyota Prius		5,562	35,675	78,591	214,868	339,795	280,610	955,101
Honda Civic			13,700	47,371	57,115	63,872	22,455	204,513
Ford Escape				2,993	38,946	38,559	25,969	106,467
Honda Accord				1,061	22,424	3,601	0	27,086
Lexus RX400h					40,835	32,491	29,583	102,909
Toyota Highlander					49,474	41,493	18,542	109,509
Mercury Mariner					4,172	6,051	2,583	12,806
Lexus GS 450h					1,784	2,323	774	4,881
Toyota Camry					31,341	100,749	37,474	169,564
Nissan Altima						17,207	16,067	33,274
Saturn Vue						7,323	2,706	10,029
Lexus LS600hL						1,844	387	2,231
Saturn Aura						1,057	581	1,638
Chevy Tahoe						3,745	4,726	8,471
GMC Yukon						1,610	3,154	4,764
Chevy Malibu						2,093	4,567	6,660
Cadillac Escalade						801	3,168	3,969
Chrysler Aspen						46	33	79
Dodge Durango							9	9
Ford Fusion							36,370	36,370
Mercury Milan							2,884	2,884
Lexus HS 250h							17,362	17,362
Sierra/Silverado							3,991	3,991
BMW ActiveHEV 7							102	102
BMW X6							205	205
Ford Lincoln MKZ							1,192	1,192
Honda CR-Z							5,249	5,249
Mazda Tribute							570	570
Mercedes ML450							627	627
Mercedes S400							801	801
Porsche Cayenne							206	206
Total		9,367	56,317	131,799	462,347	664,660	555,529	1,888,971

By the end of 2012, many of the hybrid models had been withdrawn by their manufacturers or had become “placeholders” with very low annual sales. These marginal models are listed in Table 2, according to judgment calls made by this author. Car companies might take issue.

Table 2: Hybrid Electric Vehicle (HEV) Sales by Model - 25 Marginal Models								
Vehicle		**1999/**	**2003/**	**2005/**	**2007**	**2009/**	**2011/**	**Total**
		2002	**2004**	**2006**	**2008**	**2010**	**2012**	
Ford Escape-32mpg			2,993	38,946	38,559	25,969	11,530	117,997
Lexus LS600hL-20mpg					1,844	387	138	2,369
Chevy Tahoe-21mpg					3,745	4,726	1,072	9,543
GMC Yukon-21mpg					1,610	3,154	1,158	5,922
Cadillac Escalade-21mpg					801	3,168	1,527	5,496
GMC Sierra-21mpg						522	635	1,157
GMC Silverado-21mpg						3,469	1,470	4,939
BMW ActiveHEV7-20mpg						102	569	671
BMW X6-18mpg						205	47	252
Mazda Tribute-32mpg						570	574	1,144
Mercedes S400-21mpg						801	430	1,231
Porsche Cayenne-21mpg						206	2,751	2,957
Buick Lacrosse-19mpg							13,811	13,811
Buick Regal-29mpg							2,687	2,687
Infiniti M35h-29mpg							1,069	1,069
Porsche Panamera-25mpg							622	622
VW Toureg Hybrid-21mpg							640	640
Mercury Mariner-27mpg				4,172	6,051	2,583	0	12,806
Saturn Vue-26mpg					7,323	2,706	0	10,029
Saturn Aura-27mpg					1,057	581	0	1,638
Chevy Malibu-27mpg					2,093	4,567	0	6,660
Chrysler Aspen-21mpg					46	33	0	79
Dodge Durango-21mpg						9	0	9
Mercury Milan-39mpg						2,884	0	2,884
Mercedes ML450-22mpg						627	21	648
Total		0	2,993	43,118	63,129	57,269	40,751	207,260

Table 3 lists the hybrid models currently being marketed as of December, 2012. The list does not include new models that will be delivered in 2013 and 2014. Note the generally higher MPG ratings as compared to the MPG ratings in Table 2.

Table 3: Hybrid Electric Vehicle (HEV) Sales by Model - 26 Current Models								
Vehicle		**1999/**	**2003/**	**2005/**	**2007**	**2009/**	**2011/**	**Total**
		2002	**2004**	**2006**	**2008**	**2010**	**2012**	
Honda Insight-42mpg		10,747	1,783	1,388	0	41,534	21,395	76,847
Toyota Prius-50mpg		41,237	78,591	214,868	339,795	280,610	283,966	1,239,067
Honda Civic-44mpg		13,700	47,371	57,115	63,872	22,455	11,859	216,372
Honda Accord-28mpg			1,061	22,424	3,601	0	0	27,086
Toyota Highlndr.-28mpg				49,474	41,493	18,542	10,470	119,979
Lexus RX400/450-30mpg				42,619	34,814	29,577	22,946	129,956
Toyota Camry-41mpg				31,341	100,749	37,474	54,897	224,461
Nissan Altima-33mpg					17,207	16,067	3,339	36,613
Ford Fusion-39mpg						36,370	25,386	61,756
Lexus HS 250h-35mpg						12,643	3,513	16,156
Ford Lincoln MKZ-39mpg						1,192	11,806	12,998
Honda CR-Z-35mpg						5,249	15,522	20,771
Hyundai Sonata-37mpg							40,427	40,427
Lexus CT 200h-42mpg							32,052	32,052
Toyota Prius v-42mpg							40,669	40,669
Toyota Prius c-50mpg							35,473	35,473
Ford C Max-47mpg							10,395	10,395
Kia Optima-36mpg							10,084	10,084
Lexus ES 300h-40mpg							7,041	7,041
Acura ILX-38mpg							972	972
Toyota Avalon-40mpg							747	747
Lexus GS450-31mpg						774	889	1,663
BMW AH 5-26mpg							404	404
BMW AH 3-28mpg							402	402
Audi Q5-26mpg							270	270
VW Jetta-45mpg							162	162
Total		65,684	128,806	419,229	601,531	502,487	645,086	2,362,823

A few models listed in Table 2 are significantly different from conventional hybrids and belong in a different category called “mild hybrids” or “stop/start hybrids”. These are listed in Table 4. Mild hybrids are discussed later in this report.

Table 4: Hybrid Electric Vehicle (HEV) Sales by Model - 3 Reclassified Models								
Vehicle		**1999/**	**2003/**	**2005/**	**2007**	**2009/**	**2011/**	**Total**
		2002	**2004**	**2006**	**2008**	**2010**	**2012**	
Buick Lacrosse-19mpg							13,811	13,811
Buick Regal-29mpg							2,687	2,687
Chevy Malibu-29mpg					2,093	4,567	0	6,660
Total					2,093	4,567	16,498	23,158

Table 5 is a summary of the total shipments of the three groups listed in Tables 2, 3 and 4. Note that the total shipments of the withdrawn or de-emphasized cars were only 207,260 units; the Ford Escape model represents 117,997 of this number. Subtracting the units shipped for that model, leaves 89,263 units. Allocating this number over 24 models gives an average number sold of 3,720 units per model. The 26 current models listed in table 3 have had sales of 2,363,823 units or about 90,000 units per model. This justifies the selection of cars that were discontinued or had minimal sales.

Table 5: Summary of Marginal, Reclassified and Current Models								
Class		**1999/**	**2003/**	**2005/**	**2007**	**2009/**	**2011/**	**Total**
		2002	**2004**	**2006**	**2008**	**2010**	**2012**	
Marginal		0	2,993	43,118	63,129	57,269	40,751	207,260
Reclassified		0	0	0	2,093	4,567	16,498	23,158
Current		65,684	128,806	419,229	601,531	502,487	645,086	2,362,823
Total		65,684	131,799	462,347	666,753	564,323	702,335	2,593,241

This analysis shows that there have been a surprisingly large number of unsuccessful hybrids introduced since 1999. This is not surprising for a new product concept. Further analysis shows that of the 26 models currently being marketed (Table 3), many have low sales and may not be viable. They may well join the list of marginal models in the not-too-distant-future. A company-by-company analysis will make this point obvious.

Company-by-Company Analysis: Hybrid Sales

The US hybrid market is dominated by Japanese manufacturers, particularly Toyota. The following table (Table 6) separates the units sold in paired years (2009/2010 and 2011/2012) from Table 3 into single years (2009, 2010, 2011 and 2012) and lists sales for each of these years. The bottom rows, 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. The order presented is by manufacturer, beginning with hybrid market leader, Toyota, who makes both the Toyota and Lexus brands.

Table 6: Toyota Hybrid Shipments

Year	2009	2010	2011	2012	4 yr.Total
	Units	Units	Units	Units	Units
TOYOTA					
Toyota Prius Lftbk-50mpg	139,682	140,928	136,463	147,503	564,576
Toyota Prius v-42mpg				40,669	40,669
Toyota Prius c-50mpg				35,733	35,733
Toyota Camry-41mpg	22,887	14,587	9,241	45,656	92,371
Toyota Highlander-28mpg	11,086	7,456	4,549	5,921	29,012
Toyota Avalon-40mpg				747	747
Lexus CT 200h-42mpg			14,381	17,671	32,052
Lexus RX400/450h-30mpg	14,464	15,113	10,723	12,223	52,523
Lexus 250H-35mpg	1,980	10,663	2,864	649	16,156
Lexus GS450H-31mpg	469	305	282	607	1,663
Lexus 600HL-20mpg	258	129	84	54	525
Lexus ES 300h-40mpg				7,041	7,041
Total	190,826	189,181	178,587	314,474	873,068
Take Rate - Hybrids	67.82%	68.96%	66.63%	77.76%	
Take Rate - All Cars	1.83%	1.63%	1.40%	2.18%	

The second row from the bottom, % Year's Sales, shows Toyota's dramatic increase in market share, from 68% to 78%, in four years. This is a partial explanation for the large number of models that were withdrawn or marginalized in 2011 and 2012. One would expect competitors to be dropping out of a market so dominated by a single company. Toyota's market position was strengthened when Nissan, the second largest Japanese car company after Toyota, and GM elected to focus on plug-ins as the power trains for the future, assuming the conventional hybrid was merely a stepping stone to a new automobile architecture. This may prove to have been a major strategic error. Plug-in cars are not technology progressions from hybrids but rather competitors to hybrids.

Toyota hybrid sales increased 73% from 2011 to 2012. This may have been partially a response to the lukewarm interest in PHEV and BEV models in 2011 and the early part of 2012. Plug-ins are marketed heavily by industry and government but consumers have yet to make a commitment to that technology. Problems with lithium-ion batteries, including some fires, cast doubt on that technology. The battery costs for plug-ins were much higher than expected as were the CO_2 emissions from manufacturing lithium-ion batteries. Finally, increasing evidence showed that CO_2 emissions from operation of the plug-ins (including power-plant CO_2 emissions from generating electricity) were higher than from conventional hybrids. With the increasing worldwide concern about global

warming, recent car purchasers may have made decisions to choose hybrids over plug-ins based on the newly available environmental information.

Toyota is as experienced with plug-ins as any other manufacturer, maybe even more so. Toyota has been the world leader for hybrid cars but has also developed pure battery-electric cars as well. It produced the first electric car in Japan in the form of the RAV4 EV in 1997. The RAV4 EV car led in sales in the US under the CARB program; some are still in use. More RAV4 EVs were sold during the CARB years than GM's EV1. In 2010, Toyota made a major investment in Tesla and procured the Tesla technology for a new RAV4 EV, which was shipped in late 2012.[3] Toyota also has a significant partnership with battery maker Panasonic. [4]

Toyota also understands PHEV technology. Prior to introducing the Prius Plug-In (first shipped in 2012), it produced 500 trial vehicles that were tested world wide before the finalizing of the plug-in design. Although Toyota's offering arrived later in the market than the Volt, it may be more successful by designing a car with a smaller battery which is less expensive. Toyota has always had reservations about plug-ins, spelled out at the announcement of the Prius Plug-in in April 2010.[5] The company expressed doubts that lithium-ion battery technology was mature enough and cheap enough to support a plug-in industry. In spite of its concerns, the company continued to invest in research and development for plug-ins.

In September, 2012, Toyota announced significant cutbacks on many of its plug-in electrification plans.[6] Toyota had announced a BEV vehicle, the eW, in 2010, planning to sell several thousand; it now expects to sell about 100 in a limited release. Its single BEV market entry is the new RAV4 EV based on Tesla Motors technology. Toyota expects to sell only about 2,600 of RAV4 EVs over the next three years. Takeshi Uchiyamada, who directed Toyota's development of the Prius hybrid in the 1990s, is now Toyota's vice chairman and oversees vehicle development. He states "The current capabilities of electric vehicles do not meet society's needs, whether it may be the distance the cars can run, or the costs, or how it takes a long time to charge".

In the same announcement, Toyota also reported that it is well below its plug-in hybrid sales target. The automaker had planned to sell between 35,000 and 40,000 Prius Plug-in hybrids in 2012 in Japan; actual sales were about 10,000 units. In the US, Prius Plug-in sales for 2012 were 12,750 units for a 9-month sales year, compared to full-year sales of the Volt of 23,461 units. Total plug-in sales in the US in 2012 were 55,172 units out of 14,439,684 total units, or about 0.4% of the total US car market for that year.

By contrast, Toyota's conventional hybrid sales increased 73% in 2012. From the perspective of Toyota management, the market appears to have shown a clear preference for conventional hybrids over plug-ins. Thus it behooves the company to focus its R&D investments on this popular technology. Toyota's September 2012 announcements substantiate this view.

Table 7: Ford Hybrid Shipments					
Year	**2009**	**2010**	**2011**	**2012**	**4 yr.Total**
	Units	**Units**	**Units**	**Units**	**Units**
FORD					
Ford Fusion-39mpg	15,554	20,816	11,286	14,100	61,756
Ford Escape-32mpg	14,787	11,182	10,089	1,441	37,499
Lincoln MKZ-39mpg	0	1,192	5,739	6,067	12,998
Ford C-Max-47mpg	0	0	0	10,935	10,935
Mercury Milan-39mpg	1,486	1,416	0	0	2,902
Mercury Mariner-27mpg	1,693	890	0	0	2,583
Total	33,520	35,496	27,114	32,543	128,673
Take Rate - Hybrids	11.91%	12.94%	10.12%	8.05%	
Take Rate - All Cars	0.32%	0.31%	0.21%	0.23%	

Ford (Table 7) has a long history in the development of conventional hybrids. It successfully developed and marketed the Ford Escape Hybrid, selling 117,000 units over its lifetime. (The Escape Hybrid was withdrawn at the end of 2012, replaced by the C-Max Hybrid.)The company also developed two earlier models under the Mercury brand, which were withdrawn at the end of 2010. The Ford Fusion Hybrid and the C-Max Hybrid are the latest hybrid offerings. In late 2012 and early 2013 other models were introduced for delivery sometime in 2013. Ford has always attempted to be the major hybrid manufacturer in the US. Since Chrysler is barely in the running and GM is focused on plug-ins, their position is secure.

Ford may have stumbled with the recent introduction of the C-Max Hybrid. The company's claims of competitive fuel-economy advantages have been challenged.[7] Complaints have been made that the MPG numbers in the high 40s are overstated and that MPG is actually in the high 30s. [8] 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. [9]

The EPA has launched an investigation of the Ford MPG claims and a lawsuit has been filed against the company.[10] [11] [12] This could limit market penetration of the new models until the MPG fuel economy issue is clarified. The MPG controversy is also calling into question the EPA methodology of determining MPG values, which allows the manufacturers to do the testing and reporting. Ford has argued that it is following EPA rules.[13] The company emphasized that driving styles make a difference. But the fact that the hybrids are overpowered relative to the Toyota Prius raises the concern that Ford may be focusing on acceleration and power rather than on fuel economy. Ford representatives have noted that "fun to drive" is part of the Ford "DNA", with that "fun" being a euphemism for rapid acceleration measured in the number of seconds to go from 0 MPG to 60 MPG and "lead foot" driving. Ford may have been attempting to differentiate its hybrid products from those of Toyota, which focuses on fuel economy. In April, 2012, in an indication of further difficulty, Alan Mulally, president of Ford, indicated that lithium-ion battery packs cost $12,000 to $15,000 for each Focus EV.[14]

Table 8: Honda Hybrid Shipments					
Year	**2009**	**2010**	**2011**	**2012**	**4 yr.Total**
	Units	**Units**	**Units**	**Units**	**Units**
HONDA					
Honda Civic-44mpg	15,119	7,336	4,703	7,156	34,314
Honda Insight-42mpg	20,572	20,962	15,549	5,846	62,929
Honda CR-Z-35mpg		5,249	11,330	4,192	20,771
Acura ILX-38mpg				972	972
Honda Accord-45mpg	0	0	0	0	0
Total	35,691	33,547	31,582	18,166	118,986
Take Rate - Hybrids	12.68%	12.23%	11.78%	4.49%	
Take Rate - All Cars	0.34%	0.29%	0.25%	0.13%	

Honda (Table 8) developed its initial hybrid products at about the same time as Toyota in the late 1990s. For the first four years Honda sold about 2/3's as many hybrids as Toyota. Since 2005, Toyota has increased its hybrid market share relative to Honda. Honda has recently resurrected the previously discontinued Accord Hybrid with an EPA rating of 45 MPG, better than any of its other offerings. Honda is also committed to plug-ins with the Fit EV. Although the company has sold over one million hybrid units around the world[15], its overall hybrid market share dropped to 4.49% in 2012.

Table 9: Hyundai/Kia Hybrid Shipments					
Year	**2009**	**2010**	**2011**	**2012**	**4 yr.Total**
	Units	**Units**	**Units**	**Units**	**Units**
HYUNDIA/KIA					
Hyundai Sonata-37mpg			19,672	20,754	40,426
Kia Optima-36mpg	0	0	0	10,084	10,084
Total	0	0	19,672	30,838	50,510
Take Rate - Hybrids	0.00%	0.00%	7.34%	7.63%	
Take Rate - All Cars	0.00%	0.00%	0.15%	0.21%	

Hyundai (Table 9) is a Korean manufacturer that holds a significant stock position in Kia, another Korean car manufacturer. Both companies have had a MPG problem similar to that experienced by Ford, although not as severe. They admitted to overstating MPG ratings for several models.[16] This experience points out again that MPG testing is not done by the EPA but by the manufacturer. Congress began an investigation of the MPG discrepancy. [17] One lawsuit for $775 million in damages has been filed.[18] The combined Hyundai and Kia share of market growth was about 8% from 2009-2012.

Table 10: GM Hybrid Shipments					
Year	**2009**	**2010**	**2011**	**2012**	**4 yr.Total**
	Units	**Units**	**Units**	**Units**	**Units**
GM					
Chevy Silverado-21mpg	1,598	1,871	1,001	469	4,939
GMC Sierra-21mpg	0	522	164	471	1,157
Chevy Tahoe-21mpg	3,301	1,426	519	533	5,779
Cadillac Escalade-21mpg	1,959	1,210	819	708	4,696
GMC Yukon-21mpg	1,933	1,221	598	560	4,312
Saturn Aura-27mpg	527	55			582
Saturn Vue-26mpg	2,656	50			2,706
Total	11,974	6,355	3,101	2,741	24,171
Take Rate - Hybrids	4.26%	2.32%	1.16%	0.68%	
Take Rate - All Cars	0.11%	0.05%	0.02%	0.02%	

Recent sales of GM hybrids (Table 10) have been marginal and GM market share has dropped significantly. Many of the current hybrid models may disappear. GM is now focused on plug-ins such as the PHEV Chevrolet Volt and the BEV Chevrolet Spark (to be shipped in 2013). A new Cadillac PHEV will be shipped in 2013, possibly using the Volt power train. Plug-ins may be an optimum strategy for GM. Note that this list does not include the “mild hybrid” cars such as the Malibu, which are discussed later.

Table 11: Nissan Hybrid Shipments					
Year	**2009**	**2010**	**2011**	**2012**	**4 yr.Total**
	Units	**Units**	**Units**	**Units**	**Units**
NISSAN					
Infiniti M35h-29mpg			324	691	1,015
Nissan Altima-33mpg	9,357	6,710	3,236	103	19,406
Total	9,357	6,710	3,560	794	20,421
Take Rate - Hybrids	3.33%	2.45%	1.33%	0.20%	
Take Rate - All Cars	0.09%	0.06%	0.03%	0.01%	

Nissan (Table 11) has been a long-term hybrid contender with the Nissan Altima Hybrid, which sold almost 20,000 units in the period 2009-2012. An additional 15,000 Altima Hybrid units were sold in earlier years. Like GM, Nissan has made a strong commitment to plug-ins.

Table 12: BMW, VW/Porsche, Mercedes, Mazda Hybrid Shipments					
Year	**2009**	**2010**	**2011**	**2012**	**4 yr.Total**
	Units	**Units**	**Units**	**Units**	**Units**
BMW					
BMW Hybrid 7-20mpg		344	1,571	1,180	3,095
BMW Active Hybrid 3-28mpg			52	570	622
BMW Active Hybrid 5-26mpg				270	270
BMW X6-18mpg				162	162
Total	0	344	1,623	2,182	4,149
Take Rate - Hybrids	0.00%	0.13%	0.61%	0.54%	
Take Rate - All Cars	0.00%	0.00%	0.01%	0.02%	
Year	**2009**	**2010**	**2011**	**2012**	**4 yr.Total**
	Units	**Units**	**Units**	**Units**	**Units**
VW/PORSCHE					
Porsche Cayenne-21mpg		344	1,571	1,180	3,095
Porsche Panamera-25mpg		0	52	570	622
Audi Q5 Hybrid-26mpg				270	270
VW Jetta Hybrid-45mpg				162	162
VW Touareq Hybrid-21mpg			390	250	640
Total	0	344	2,013	2,432	4,789
Take Rate - Hybrids	0.00%	0.13%	0.75%	0.60%	
Take Rate - All Cars	0.00%	0.00%	0.02%	0.02%	
Year	**2009**	**2010**	**2011**	**2012**	**4 yr.Total**
	Units	**Units**	**Units**	**Units**	**Units**
MERCEDES					
Mercedes S400-21mpg		955	309	121	121
Mercedes ML450-22mpg		766	1	20	20
Total	0	1,721	310	141	141
Take Rate - Hybrids	0.00%	0.63%	0.12%	0.03%	
Take Rate - All Cars	0.00%	0.01%	0.00%	0.00%	
Year	**2009**	**2010**	**2011**	**2012**	**4 yr.Total**
	Units	**Units**	**Units**	**Units**	**Units**
MAZDA					
Mazda Tribute-32mpg	0	655	484	90	90
Total	0	655	484	90	90
Take Rate - Hybrids	0.00%	0.24%	0.18%	0.02%	
Take Rate - All Cars	0.00%	0.01%	0.00%	0.00%	

Total market share for these four companies (Table 12) in 2012 was 1.3% with none of them achieving 1%. These companies are not leaders in the hybrid market at this time.

Conventional Hybrid Market Summary

The hybrid market grew slowly during the 1999-2004 period (Table 13). In the 2007-2012 period sales increased significantly. In 2012, the take rate (percent of the total car market) for hybrids was 3.0%.[19] [20] Much of this was due to the resurgence of Toyota sales after recovering from the tsunami of 2011. Total Toyota hybrid sales to date are now approximately five million vehicles worldwide.[21]

Table 13: Hybrid Electric Vehicle (HEV) Sales - Take Rate of All Cars

Vehicle	1999/ 2002	2003/ 2004	2005/ 2006	2007 2008	2009/ 2010	2011/ 2012	Total
Hybrids	65,684	131,799	462,347	664,660	559,756	685,837	2,570,083
All Cars (millions)	68.2	33.5	33.5	29.3	22.0	27.2	213.7
Take Rate - All Cars	0.1%	0.4%	1.4%	2.3%	2.5%	2.5%	1.2%

Hybrid fuel-economy performance seems to be improving. It is difficult to compare the Prius to a non-Prius conventional car. However, it is possible to compare the Toyota Camry and Lexus models. In both cases, the MPG differences between conventional versions and hybrids have increased in recent years. In terms of the Lexus, the new 2013 ES 300h gets 40 MPG while its comparable conventional car, the ES 350, gets 24 MPG. The price difference is $2,750 and the annual fuel cost savings for the hybrid are $800, resulting in a 3.4-year payback. Assuming a 14 year life, lifetime fuel savings would be $11,200. The Camry Hybrid gets 41 MPG while its comparable equivalent, the conventional Camry, gets 28 MPG, a savings of $550 annually in fuel costs.[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 somewhat surprising. The average car sold in America today has a fuel economy of about 23 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. The Prius c won the award for best value in 2012 from Consumer Reports in its February 2013 magazine. [24] 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. 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.

The situation is different in Japan. The Toyota Aqua, the equivalent of the Prius c in this country, was the most popular car in Japan in November 2012. [25] Toyota's cumulative hybrid sales in Japan are over two million units.[26] Interest in fuel economy is much higher in other parts of the world and appears to be increasing faster than in the US. The increase in 2012 hybrid sales may reflect decisions by consumers worldwide to stick with hybrid technology over plug-in technology based on the first two years of experience with plug-ins.

Plug-In (PHEV and BEV) Sales and Analysis

Table 14 shows the US plug-in sales in the period 2009-2012. Tesla Motors was the first company to deliver a plug-in in 2008; but today its sales are far below its plug-in competitors GM, Toyota and Ford. Tesla was formed in 2003 which gives a point in time for the re-born EV effort after the CARB change in strategy. Tesla Motors will be remembered as the company that proposed lithium-ion as the watershed technology for the electric car, now a questionable prediction.

Table 14: US Plug-in Electric sales 2009-2012

Manufacturer	Model	2009	2010	2011	2012	Total
		Units	Units	Units	Units	Units
BEVs						
Nissan	Leaf		19	9,674	9,819	19,512
Tesla	Roadster	900	700	700		2,400
Tesla	Model S				2,400	2,400
Mitsubishi	I EV			80	588	668
Mercedes	Smart EV			388	139	527
BMW	ActiveE				671	671
Ford	Focus				685	685
Toyota	RAV4 EV				192	192
Honda	Fit EV				93	93
	Total BEV	900	819	11,542	14,587	27,148
PHEVs						
Chevrolet	Volt		326	7,671	23,461	31,458
Toyota	Prius Plug In				12,750	12,750
Fisker	Karma			400	2,000	2,400
Ford	C-Max Energi				2,374	2,374
	Total PHEV	0	326	8,071	40,585	48,982
	Total Plug Ins	300	945	19,613	55,172	76,030

It has been five years since the first Tesla Roadster (announced to the public in 2006) was delivered to co-founder and current president Elon Musk in February 2008. (The $110,000 base-price Roadster is no longer being marketed.) 2,400 units of the less expensive Model S have been sold in the US, all in the last half of 2012. Tesla's net income losses have been high: $30M in 2006, $78M in 2007, $83M in 2008, $56M in 2009, $154M in 2010, $254M in 2011 and $383M in 2012.[27] In the five year period of 2008 through 2012, Tesla shipped only 5,000 cars, about half of them Roadsters and half the Model S sedan. This is a very small sales volume for a company founded in 2003.

Declining Nissan Leaf sales in the US from 2011 to 2012 were a surprise for BEV supporters. Total sales for the Leaf worldwide to date are approximately 50,000 units.[28] There have been some concerns about battery degradation of the Leaf in hot climates.[29] But these do not appear to be major issues, considering the newness of the technology. Nissan's CEO Carlos Ghosn admits confusion himself about the reasons for slow sales and acknowledges that Nissan will not meet its 2013 sales target.[30] 2013 will be a critical

year for the Nissan Leaf. There are newer entrants from other BEV companies that shipped in 2012 but their small shipments to date provide little data for evaluation.

PHEVs have been more successful than BEVs. 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 seems to be effectively out of business, having not sold or made a car since July of 2012. The company is cutting staff deeply and looking to be acquired. [31] 2012 sales numbers show a tendency for consumers to select PHEVs over BEVs, possibly representing "range anxiety" and possibly representing awareness of the higher battery costs and emissions of BEVs.

Recently the question of CO_2 emissions from lithium-ion battery-powered plug-ins has been raised. Government agencies and car manufacturers have colluded in misrepresenting plug-ins as "clean cars". TV advertisements emphasize the lack of emissions. The EPA MPG methodology for calculating plug-ins MPG has been challenged in earlier white papers. To create consumer interest, plug-ins 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 CO_2 emissions, consumers are becoming much more aware of the methods for generating electricity. And they are learning that, when apples-to-apples comparisons are made, plug-ins generate more CO_2 than conventional hybrids. Car companies and manufacturers continue to compare plug-ins to conventional non-hybrid cars, avoiding the market reality of the strong competition between plug-ins and conventional hybrids.

In comparisons with non-hybrids, plug-ins 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 so that plug-in power trains do not have an advantage over hybrids. This becomes more apparent when CO_2 emissions are compared.

Three recent papers have contributed greatly to this new understanding. The Union of Concerned Scientists prepared a report that shows comparisons of plug-ins to hybrids. [32] 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 emissions [33] leads to the conclusion that hybrids and small-battery PHEVs are preferred car architectures. A report from researchers at the Norwegian University of Science and Technology [34] [35] [36] suggests that plug-ins energized by grid electricity rather than by renewable technologies contribute much more to environmental problems than gasoline cars.

Such new 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. US 2012 sales data show shipments of 223,000 Toyota Prius Lift-back, Prius c, and Prius v compared to 46,000 units of the three top plug-ins (Volt, Leaf and Prius Plug-in). More interesting is the fact that there were 147,503 Prius Lift-backs sold, compared to 12,750 Prius Plug-ins.

Even the government is less optimistic about plug-in prospects. Dr. Thomas Smith of the Washington State Department of Transportation reviewed the Annual Energy Outlook 2013 Early Release (AEO 2013) from the US Energy Information Agency (EIA) and compared it to the 2012 version.[37] Dr. Smith provided this author with the following chart that shows the EIA perspective on plug-ins. See Figure 1. The top line shows the Annual Energy Outlook 2011 forecast, the middle line shows the Annual Energy Outlook 2012 forecast, and the bottom line shows the Annual Energy Outlook 2013 Early Release forecast.

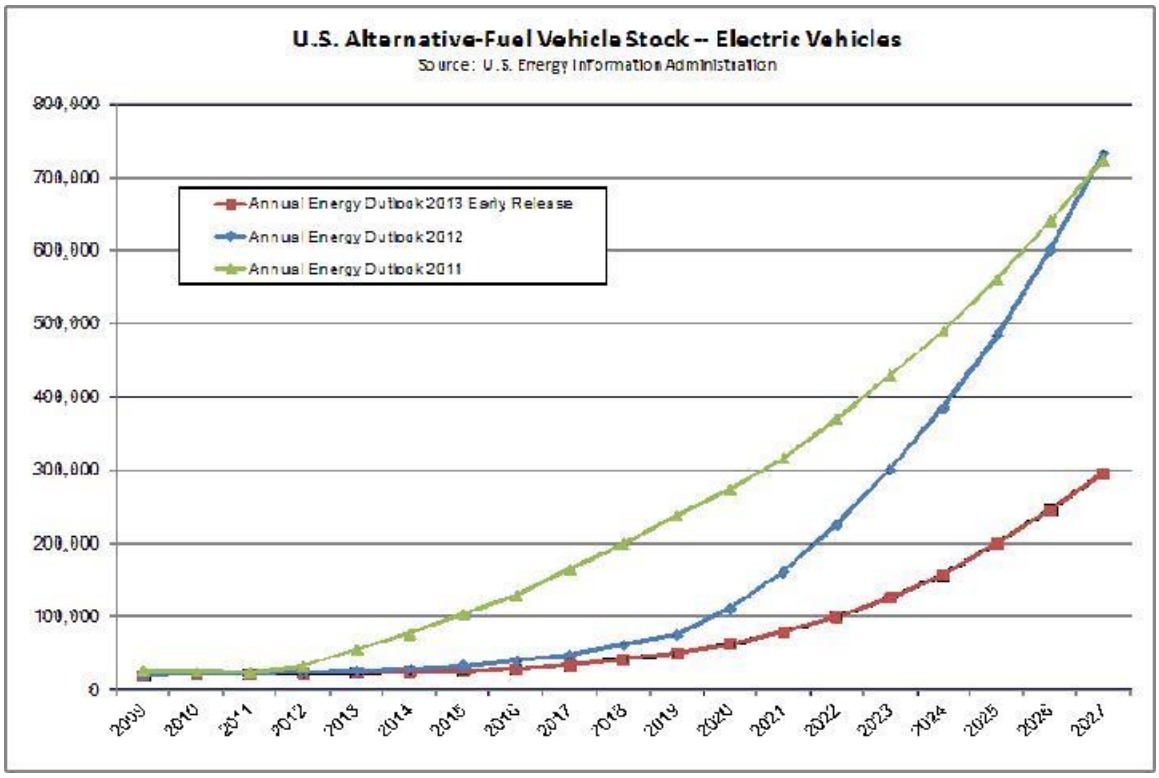

Figure 1 Electric Cars

This yearly projection first shows a change in the slope of the curve between 2011 and 2012, which is then followed by a very sharp decrease in projections for the 2013 release. 2013 will be a key benchmark year for future government projections.

The Battery Dilemma

Science writer Seth Borenstein summarizes the long history of the storage battery in his article entitled “What holds energy tech back? The infernal battery.” [38] Batteries involve complex chemistry, expensive manufacturing, detailed engineering, a variety of different materials (liquids, solids, metals, organic chemicals), lengthy testing, stringent safety standards, and cost problems. Borenstein makes the point that the limitations of batteries are the reason why electric cars are not clogging the roads. He recalls the years 2006 and 2007, when more than 46 million cell phone batteries and 10 million laptop batteries, all lithium-ion technology, were recalled because of the risk of overheating, short-circuiting and exploding. He also notes the recent grounding of the Boeing 787 Dreamliner, precipitated by fires in its two on board lithium-ion batteries.

Lithium-ion batteries are small enough to fit into cell phones and hand tools. To power bigger items, smaller components must be grouped together, increasing safety risks. Lithium-ion batteries contain more flammable liquids than the materials of older types of batteries. Borenstein quotes scientist and consultant George Blomgren, who says “Big advances in battery technology happen rarely. It's been more than 200 years and we have maybe five different successful rechargeable batteries". Borenstien reminds us that lithium-ion technology has been around for 25 years. By comparisons, the lead acid car battery has been used for 150 years.

Much of the rationale for new PHEVs and BEVs was the assumed availability of reliable and cost-effective lithium-Ion batteries for cars. Lithium-ion is used in vast quantities for consumer electronics, as measured in billons of batteries produced. It appeared straightforward to scale these up for automotive applications. So far, this has not happened. Some scientists argue that the lithium-ion battery represents the end of the line on lithium-ion chemistry and that it has not been, and will not be, effective in powering automobiles.

Battery expert and investment counselor John Petersen lists the problems of the lithium-ion battery industry. [39] He notes that in 2012 Ener1 filed for bankruptcy; Panasonic wrote off $3.7 billion in the lithium-ion battery and solar cell businesses it acquired from Sony; Valence Technology filed for Chapter 11; Borsch and Samsung dissolved their lithium-ion joint venture; Panasonic closed three battery plants; A123 filed for bankruptcy (and was taken over by China’s Wanxiang Corporation); and Sony began looking for a Chinese buyer for its lithium-ion business. Peterson notes that many of the lithium-ion problems were experienced by companies new to the battery industry, but that Samsung, Sony and Panasonic/Sanyo have been industry leaders in consumer batteries for decades and collectively account for about 60% of global production.

Petersen points out that manufacturers overbuilt lithium-ion capacity based on demand that did not materialize when consumers balked at the high cost and limited utility of electric cars. Improvement in energy density and battery performance did not occur as hoped. He says that the last few years have been a textbook example of a “hype cycle,” based on hopes that lithium-ion batteries would be a breakthrough panacea solution that would create a thriving electric car industry, while painlessly freeing us from fossil-fuel limitations and climate-change problems. He recalls that today's best batteries are only four or five times better than the batteries Thomas Edison manufactured a century ago. He further suggests that applying the logic of the information-technology revolution to batteries is not possible. Petersen notes that the market has rejected the panacea

hypothesis and future extreme claims, such as those promising five times the energy at one-fifth the cost in five years, are no longer believed. He further notes that, while lithium-ion batteries appear to be a dead-end for transportation applications, advanced lead-acid batteries are finding new automotive applications.

Recently Pike Research published a report on advanced lead-acid batteries noting that such batteries represent a technology beyond the conventional lead acid batteries used in every car.[40] The company projects an $18 billion market in 2020, with most of the sales being in transportation. A plethora of new terms and technologies is discussed such as enhanced flooded batteries (EFBs) and absorbent glass mat batteries (AGM) as well as fast charging lead-acid batteries.

John Petersen points out that historically, lead-acid batteries have been flooded devices, in which lead electrodes are immersed in an electrolyte bath, a technology that is the backbone of the lead-acid battery industry. Petersen points out that many incremental improvements have been made over the years that can boost conventional battery performance by 50% to 100%. A second class of permanently sealed, maintenance free lead-acid batteries was invented in the 1970s; in these the electrodes were not immersed in an electrolyte bath but used an absorbent fiberglass mat to carry the electrolyte, thus the term “AGM batteries”. Over the last five years the manufacturing capacity for AGM battery makers has grown to tens of millions of batteries per year.

A new class of advanced lead-acid battery has been developed over the last ten years that represents a fundamental change in lead-acid technology. While flooded and AGM batteries use pasted lead grids for their positive and negative electrodes, third generation batteries use pasted lead grids for the positive electrodes and carbon compounds for the negative electrodes. These “lead-carbon” batteries have somewhat less energy storage capacity but have cycle lives that are five to ten times longer and charge-acceptance rates that are ten to twenty times better than conventional, enhanced flooded, and AGM batteries. Lead-carbon devices change the way lead-acid batteries work, but they do not change the way lead-acid batteries are manufactured. Such third-generation technologies can be easily integrated into existing infrastructure. These products are not widely available yet because testing in the battery industry is extremely rigorous and lengthy. However, validation testing is progressing. Should these new products prove themselves, lithium-class performance could be available at an affordable price for applications where size and weight are not critical constraints, as they are in consumer electronics.

There are three public companies that manufacture first and second generation lead-acid batteries. First is Johnson Controls which has a dominant position in the automotive OEM market. Johnson Controls’ annual revenues are in the $6 billion range; 14% of its revenue is from batteries. Second largest is Exide Technologies, with $3 billion in revenues, two-thirds of that from automotive batteries. The third largest is Enersys with $2.3 billion in revenue. An innovation leader is Axion Power International, a small company that has been developing its patented PbC battery since 2003.

The point of this discourse on batteries is that there exists a very large existing battery industry devoted to transportation. That industry is developing new and presumably less risky products. This evolution may yield technological advances that will permit less environmentally problematic electrical energy use in cars.

The Mild-Hybrid Battery Alternative

One example of a different performance improvement path has been labeled “Mild Hybrids”. This describes automotive applications that improve MPG performance by implementing some but not all the aspects of the conventional hybrid. As noted earlier, some of the cars were removed from the list of early hybrids list and reclassified in Table 4. Table 15 reformats Table 4 to show yearly sales for the period 2009-2012.

Table 15: Mile Hybrid Sales				
Year	**2009**	**2010**	**2011**	**2012**
	Units	**Units**	**Units**	**Units**
GM Mild Hybrids				
Chevy Malibu-29mpg	4,162	405	24	16,664
Buick Lacrosse-29mpg	0	0	1,801	16,664
Buick Regal-29mpg	0	0	123	2,564
Total	4,162	405	1,948	35,892

Note that these new mild hybrids have significantly lower MPG than conventional hybrids. That is because they do only a small part of the work done by a full hybrid. GM labels this method as eAssist, which uses a small lithium-ion battery in the trunk connected by a cable to a small electric motor, which serves as both a motor and a generator. The small motor is mounted on the engine. The engine turns the motor/generator to charge the battery and provide power for accessories. When the car stops, the gasoline engine shuts off. When the driver presses the gas pedal to move forward, the motor/generator can turn the gasoline engine and drive the car until the gas engine restarts, which is almost immediately.[41] The mild hybrid performance is well below that of a conventional hybrid.[42] Estimates of mild-hybrid MPG improvements range from 5% to 15%.

This mild-hybrid technology is more popular in Europe. Johnson Controls, Inc. has sold more than 18 million Absorbent Glass Mat (AGM) batteries since the technology launched in 2001, exceeding 4.5 million sales annually in Europe. The advanced AGM lead-acid battery is suited for Start-Stop systems, which supposedly improve fuel economy in vehicles by 5 to 10%. (Start-Stop is a subset of mild-hybrids which stop and restart the engine when the car comes to a temporary halt.) Start-Stop vehicle technology has become popular in Europe and it is expected that more than 70% of the new cars built by 2017 in Europe will include the capability. John Petersen reports on a Lux Research report forecasting 39 million start-stop vehicles by 2017. 5,000,000 mild-hybrids were sold worldwide in 2011, mainly in Europe. [43]

Unfortunately, such small improvements do not address the severity of climate change. Mild-hybrids may simply be products offered by manufacturers who are unable to compete effectively in the full-hybrid marketplace. Thus, they become marketing placebos to some extent. It seems unwise to make cars that will last 14 years that do not effectively address the ever-increasing environmental threats. Governments should set MPG levels that force manufacturers to provide much more efficient cars.

Summary

It sometimes seems that every US presidential administration change of leads to a proposal for a new automobile technology, typically justified by the failure of the technology proposed by the preceding administration. Each president in his inaugural speech, or shortly thereafter, refers to the fact that all previous presidents, at least from the time of Richard Nixon, have promised big changes in automobiles that never materialized. This is followed by a bold statement that under the new administration, things will be different. Nixon promulgated the hydrogen fuel cell car. During the Clinton–Gore administration (1993-2001), the fuel-cell car was deemphasized, and the Program for a New Generation of Vehicles (PNGV) was begun to build 80 MPG diesel hybrids. George Bush, during his administration (2001-2009), refocused government car development efforts back on the fuel cell car. Obama abandoned this fuel-cell effort [44] and committed to the plug-in hybrid gasoline car (PHEV), promising a million PHEVs would be on the roads by 2015. There is little chance of this occurring.

In a paper analyzing government successes and failures in alternative energy development programs[45], author Peter Grossman pointed out that presidents seem to want to make impressive claims. But he noted the risk of this. This seems to be borne out again in current times. The programs generate tremendous promises, for example, the quadrupling of MPG ratings. In reality these promises are rarely met. At the same time, since these are political decisions from new presidents, government agencies, such as the Department of Energy (DOE) and the Department of Transportation (DOT), must support the new car technologies of the moment.

These government programs are not particularly expensive when evaluated in terms of all automotive R&D. In 2011, worldwide automobile R&D expenditures were $77 billion, about 4.7% of the world automobile revenue of $1,650 billion.[46] GM and Ford together spent about $10 billion in R&D with combined revenues of $295 billion; their R&D percent of sales is about the same as other auto companies. US government expenditures for the total plug-in program were far less than this amount for basic R&D, ignoring funding of manufacturing plants. The plug-in program has had very little effect on the total automobile industry or US industry. This has been true of earlier automotive technology advancement efforts pushed by the government.

As a power or drive train, the electric car is easy to build. There are countless electric motors in use in all kinds of applications, from fork lifts to locomotives. The real challenge is the battery. The plug-in program was based on the hopes, not realized, for a breakthrough battery. The government is aware of this although naturally reluctant to acknowledge failure. In November, 2012, DOE selected a multi-partner team led by Argonne National Laboratory to establish a new Batteries and Energy Storage Hub, to be known as the Joint Center for Energy Storage Research (JCESR).[47] JCESR will combine the R&D capabilities of five DOE national laboratories, five universities, and four private firms in an effort to achieve revolutionary advances in battery performance for electric cars. The goal is to "*develop batteries that are five times more powerful and five times cheaper within 5 years. Factors of five are what we need to transform transportation and the power grid.*" The likelihood of this happening is very small.

In November, 2012, the Congressional Budget Office published a report on the government's funding of the EV.[48] It noted that $7.5 billion would eventually be expended, but no significant benefit would be achieved. The funding served as a moral

booster that has not led to major change. This misapplication of resources is unfortunate but not tragic. Essentially the market determines final success; the government has limited power. It is possible that government investments in other technologies such as diesel hybrids and fuel cells represent some contribution. However, it is more likely that Toyota's development and production of the Prius have contributed far more to the auto industry as a whole than the efforts of the US government.

It seems appropriate for the government to fund and direct some research for different car options. Although the R&D budget of the automobile industry is very large, much of this is only for continuation and incremental improvements. But forcing a product to market by the government is different than basic research. Among the risks of bringing a product to market prematurely and overselling it to consumers is the cost to early adopters. There are 76,000 consumers who spent somewhere in the range of $30,000 after rebates to purchase plug-ins. This is an investment near $2,200,000,000. If the cars due not perform as advertised, there could be no resale market to recover the investment of these early adopters. There may also be a loss of prestige of such buyers who will move from early innovators to people who made foolish purchase decisions. The government may lose its billions in investments in manufacturing facilities, but that is allocated across the total population. Better that the plug-in cars had remained in research laboratories until all aspects of the technology were proven.

Plug-ins will contribute somewhat to automotive technology. Battery advancements are always welcome. But the high MPG market belongs to the Toyota Hybrid Synergy Drive. 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, [49] the environmentally concerned consumer's contribution is to buy a conventional Prius and use public transportation when possible.

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