

An Analysis of Battery Electric Vehicle Production Projections

By

John Shamus Cunningham

Submitted to the Department of Mechanical Engineering in Partial Fulfillment of the
Requirements for the Degree of

Bachelor's of Science in Mechanical Engineering
At the
Massachusetts Institute of Technology

June 2009

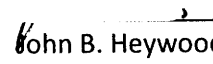
© John Shamus Cunningham. All rights reserved

The author hereby grants to MIT permission to reproduce
and to distribute publicly paper and electronic copies of this
Thesis document in whole or in part.

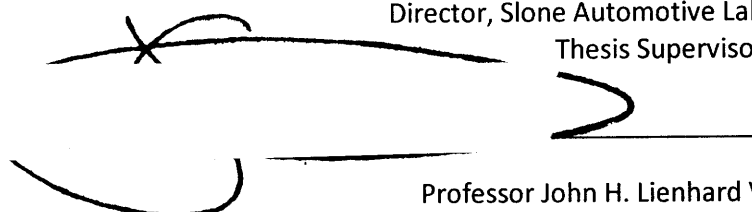
Signature of the Author _____

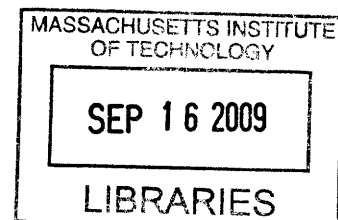

Department of Mechanical Engineering
May 11, 2009

Certified by: _____


John B. Heywood
Sun Jae Professor of Mechanical Engineering
Director, Slone Automotive Lab
Thesis Supervisor

Accepted by: _____


Professor John H. Lienhard V
Professor of Mechanical Engineering
Chairman, Undergraduate Thesis Committee



Contents

List of Figures	3
List of Tables	3
Abstract.....	4
Introduction	5
Government Involvement in BEV Development.....	6
Battery Electric Vehicle Growth Projections.....	7
The Transition to Electric Vehicles.....	10
Modeling Automotive Technology Growth Rates	11
Case Studies in Adopting New Automotive Technologies.....	11
France’s Transition from Gasoline to Diesel.....	11
Growth of the American Hybrid Market.....	13
BEV Growth Model	17
Established Automotive Manufacturers- Announced BEV Plans.....	18
Ford	18
Chrysler	18
Honda.....	19
Mitsubishi.....	19
Nissan.....	19
Toyota	20
Mini	20
New Automotive Manufacturers- Announced BEV Plans.....	21
Tesla Motors	21
Detroit Electric	22
Th!nk	22
Growth Rates Required to Meet Projections.....	24
Evaluation of Growth Rates Required to Meet 2020 Projections.....	27
Works Cited.....	28

An Analysis of Battery Electric Vehicle Production Projections

By

John Shamus Cunningham

Submitted to the Department of Mechanical Engineering in
Partial Fulfillment of the Requirements for the Degree of
Bachelor's of Science in Mechanical Engineering

Abstract

In mid 2008 and early 2009 Deutsche Bank and The Boston Consulting Group each released separate reports detailing projected Battery Electric Vehicle production through 2020. These reports both outlined scenarios in which BEVs gained significant market share (1-2%) by the end of the decade. To analyze the magnitude of the annual growth rates needed to obtain these sales figures, similar case studies were identified and evaluated. The transition from gasoline to diesel power in France between 1970 and 2005 (11% average annual growth) as well as the introduction of Hybrid Gasoline-Electric vehicles to the US (46% average annual growth) were selected as relevant points of comparison.

Through a review of all major automotive manufacturers, as well as BEV-focused startups, press releases best case and worst case estimates for total BEV production in 2010 and 2011 were obtained. Using these figures it was determined that in a best case, near term production scenario annual production rates would need to average 35 to 40% annual growth over the next 10 years, and in a worst case near term production scenario would need to average in excess of 45% annual growth to reach production estimates.

Thesis Supervisor: John B. Heywood

Title: San Jae Professor of Mechanical Engineering

Director, Sloan Automotive Lab

List of Figures

Figure 1: Sales Share of Hybrid Light-duty Vehicles by Type in Three Cases.....	9
Figure 2: Exponential Growth Model.....	11
Figure 3: French Diesel Market Share Growth 1970-2005	12
Figure 4: French Diesel Growth 1980-2005	13
Figure 5: Total Hybrid Market Share 2000-2009	14
Figure 6: Total Hybrid Sales 2000-2009	14
Figure 7: US Hybrid Monthly Sales & Average US Monthly Gasoline Prices.....	15
Figure 8: Yearly Hybrid Sales by Model.....	16
Figure 9 : Summary of Near Term EV Production Based Upon Corporate Press Releases.....	23
Figure 10: BEV Projections - 2500 Initial Sales in 2010.....	25
Figure 11: BEV Projections - 5000 Initial Sales in 2010.....	25
Figure 12: BEV Projections - 10,000 Initial Sales.....	26
Figure 13: BEV Projections - 20,000 Initial Sales.....	26

List of Tables

Table 1: BCG 2020 North American Sales Projections.....	8
Table 2: Deutsche Bank 2015-2020 BEV Projections.....	9

Introduction

Recent increases in transportation fuel prices and the growing importance of reducing carbon dioxide emissions has led the auto industry and world governments to reexamine the role of Battery Electric Vehicles (BEVs) in the world automotive marketplace. The introduction of new battery technology, particularly the advancement of Lithium-Ion batteries, has greatly improved the energy density of the battery stacks and excited both automotive designers and executives. This excitement was displayed when nine BEV concepts were debuted to the public at the 2009 North American International Auto Show, a record high. Despite the coverage and enthusiasm expressed in the media, and government and press releases of the major automotive manufacturers, less than a thousand BEVs will be sold in 2009. These sales will represent less than 0.01% of total US light duty vehicle sales. In order for BEVs to make a significant impact on US carbon dioxide emissions and US dependence on foreign oil sources, BEV sales must comprise a much larger percentage of new vehicle sales.

Existing projections released by both the Boston Consulting Group and Deutsche Bank predict pure electric vehicles to encompass 1 to 5 % of North American auto sales by 2020 depending on government regulation decisions and global energy prices. This growth requires the sale of an estimated 200,000 to 1 Million BEVs by 2020. Battery Electric Vehicle sales also represent a portion of the Obama administration's stated goal of placing 1 Million "Plug-In" capable cars (BEVs and Plug-in Hybrid Electric Vehicles) on the road by 2015. The growth rates necessary to reach 2020 BEV production levels will be evaluated relative to historical data on automotive technology adoption rates. The French transition to diesel powered light duty vehicles and the American adoption of Hybrid technology over the past decade will be used as points of comparison to the BEV projected growth rates.

Government Involvement in BEV Development

The Obama administration and governments around the world are seeking to push the advancement of alternative powertrain technologies. As part of the 2009 US Economic Stimulus Package, the government has allocated \$2 Billion in grants for the development of advanced automotive battery technologies in order to benefit Hybrid, Plug-In Hybrid and BEVs, as well as \$400 Million for “transportation electrification demonstration and deployment projects”. Finally, in addition to government sponsorship of technological research, the administration has provided individual incentives for purchasing a PHEV or BEV by offering a \$7,500 tax credit for the first 200,000 families who do so (Obama 2009).

Internationally, governments are also encouraging electric vehicle adoption through specific tax breaks and infrastructure construction projects. Israel has teamed with Silicon Valley startup Better Place and Nissan/Renault to build a nationwide charging and battery swap infrastructure capable of handling 100,000 BEVs and PHEVs by 2011. The Israeli government has agreed to incentivize BEV purchases by reducing the automotive tax from 78% to 10% for electric vehicles. Sales to the public through Better Place will begin in 2010 and must increase very quickly to meet their sales targets. Israel was identified by the EV startup as valuable partner and testing ground because 90% of its citizens drive less than 70km per day and all major urban centers are within 150km of one another. Thus, the vast majority of Better Place’s customers will be able to meet their needs with the help of the planned 500,000 charging spots. Israel is also extremely sensitive to national energy security and thus is highly receptive to plans which will reduce petroleum imports. Better Place has similar infrastructure agreements in Denmark, Australia, California, Hawaii and Ontario, Canada (Roth 2008, 6).

Battery Electric Vehicle Growth Projections

Projections of US BEV growth have been popular with American media sources but their predictions have remained highly variable due to both gasoline price volatility and the dramatic decrease in automotive sales in 2008 and the early part of 2009. Two main public reports have been issued which project large numbers of BEVs being sold in the next ten years. The widely cited January 2009 Boston Consulting Group report “The Comeback of the Electric Car?: How Real, How Soon, and What Must Happen Next” details three scenarios for electric car production levels in the year 2020. The market slowdown projection (Scenario 1) describes a situation in which oil remains at low levels (\$60 per barrel range), concern over climate change diminishes at the national and individual level, and the automotive industry is not seen as a root cause of global warming. In this scenario BEV and PHEV production fail to reach 1% market penetration and hybrid sales plateau at 18%. BCG’s Scenario 2 outlines a steady pace of alternative automotive powertrain development and concern over climate change intensification, resulting in increased tax incentives to reduce CO₂ emissions and oil prices returning to the \$150 per barrel levels of mid 2008. In this steady pace scenario BCG projects 2% market penetration for EVs in North America. Finally, in the accelerated growth Scenario 3, CO₂ emissions become an urgent issue, resulting in high levels of government regulation and tax subsidies for CO₂ reduction and oil prices rising to the \$300 per barrel range. In this new energy paradigm, BCG projects BEVs to obtain 5% penetration by 2020 in North America (Book, et al. 2009).

Table 1: BCG 2020 North American Sales Projections

		Scenario 1	Scenario 2	Scenario 3
		Slow Down	Steady Pace	Acceleration
Pure EV	(raw sales)	62,100(est)	399,510	1,035,000
-	(Market penetration)	<1% (est .3%)	1.9%	5.0%
PEHV	(raw sales)	62,100 (est)	621,000	1,035,000
-	(Market penetration)	<1% (est .3%)	3.0%	5.0%
Hybrid	(raw sales)	3,726,000	538,2000	6,624,000
-	(Market penetration)	18.0%	26.0%	32.0%
Total Electrified (raw sales)		3,850,200	6,402,510	8,694,000
-	(Market penetration)	18.0%	30.9%	42.0%

In June of 2008 Deutsche Bank released a public projection of BEV sales and their impact on the Li-Ion battery market. Deutsche Bank's predicted sales levels in 2020 were at very similar levels to the steady pace BCG projections (Scenario 2). Unlike the BCG sales projection, this projection extends from 2015 through 2020. As seen in Table 2 and Figure 10, Deutsche Bank is expecting linear growth between 2015 and 2020 and high growth rates between 2009 and 2015. These projections were made in mid 2008 and as such probably were not able to account for the marked sales decline in the automotive industry as a whole or for the dramatic decrease in the price of gasoline from 2008 peaks. In their model they assumed the cost of the battery to be approximately \$11,000, as stated in the US Automotive Battery Consortiums objectives for 20-25kWh batteries, and that Government aid and new business models such as Better Place would aid in the development of the EV market. While Deutsche Bank's BEV sales numbers are similar to BCG's Scenario 2, the estimate of total electrified vehicle sales is much larger than even BCG's accelerated growth model (Deutsche Bank 2008). Deutsche Bank research analyst Rod Lache characterizes the electric car market as having the potential to bear fruit for the ailing auto industry and expects to see "Tremendous Growth" of electrified cars with sales rising to 20% of the market by 2012 (Jones 2009).

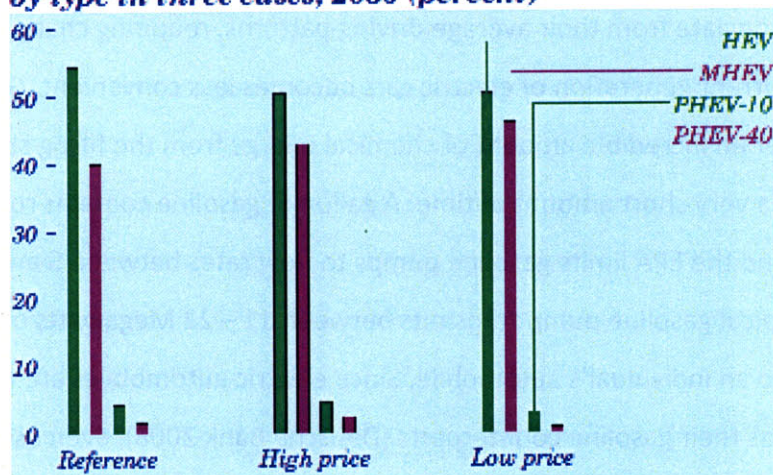
Table 2: Deutsche Bank 2015-2020 BEV Projections

	2015	2016	2017	2018	2019	2020
Pure EV (Raw Sales)	188,000	230,000	312,000	359,000	406,000	414,000
- (Market penetration)	1.0%	1.2%	1.6%	1.8%	2.0%	2.0%
Total Electrified (Raw Sales)	4,129,000	5,361,000	6,444,000	7,967,000	9,142,000	10,154,000
- (Market penetration)	22.0%	28.0%	33.0%	44.0%	45.0%	49.0%

The US Department of Energy has released expected sales figures for both Hybrid and Plug-In Hybrid vehicles through 2030. The DOE has not released BEV projections in their “Annual Energy Outlook 2009 with Projections to 2030”. The DOE foresees Hybrid vehicle sales growing to 50-54% of total sales by 2030 with PHEVs comprising 3.7-6.8% of that figure.

Figure 1: Sales Share of Hybrid Light-duty vehicles by type in three cases (Department of Energy 2009, 70)

Figure 53. Sales shares of hybrid light-duty vehicles by type in three cases, 2030 (percent)



The Transition to Electric Vehicles

The transition to pure electric vehicles will require significant advances in technology as well as changes in driving habits and expectations by the public. Unlike Hybrid Gasoline-Electric vehicles, BEVs will require an infrastructure of charging stations separate from the existing gasoline distribution network. Additional planning on the part of the vehicles owners will be required initially due to the shorter driving range and slower recharging rates of current battery technology when compared to equivalent gasoline vehicles. While there are some drawbacks, an electric vehicle with a 100 or 200 mile range has the potential to fit the daily lifestyle of the vast majority of Americans. A 1990 US Department of Transportation survey found that 50% of the public travels less than 25 miles per day and 80% drive less than 50 miles per day. This survey also found the average trip was only 9.8 miles and that the average daily total was 32.7miles (Davis, Diegel and Boundy 2008). These relatively short average trip distances fall well within the ranges of many proposed electric vehicles and thus would allow charging at an individual's home to be the only form of energy input many consumers would need.

When consumers deviate from their average driving patterns, requiring charging away from their home, the current generation of electric cars becomes less convenient. Gasoline stations are able to transfer an incredible amount of chemical energy from the filling station to an individual's car in a very short amount of time. A gallon of gasoline contains roughly 132×10^6 joules of energy and the EPA limits gasoline pumps to flow rates between 5 and 10 gallons per minute. Thus a typical gasoline pump transmits between 11 – 22 Megawatts of chemical power from the station to an individual's automobile. Since electric automobiles are roughly three times as efficient as their gasoline counterparts (Deutsche Bank 2008), even using a high voltage 480 V charging station, a similar power output would require 6000 to 7000 amps. This would place extreme stress on the electric grid as well as on a car's battery pack and, as such, is not currently an option. Full battery replacement, which would occur on the scale of 5-10 minutes has also been proposed but that would require many additional industry wide standards. Current press releases from Tesla Motors claim that even on a quick charge 480 Volt system, a

complete recharge of their upcoming Model S will necessitate a 45 minute stop (Tesla Motors 2009).

Modeling Automotive Technology Growth Rates

The data for both the French adoption of Diesel technology as well as the American adoption of Hybrid technology was fit to an exponential growth model which assumed a constant annual growth rate. This simple model allows for easy comparison of the data sets and closely follows the opening stages of a product's introduction to market. Because the timelines which have been evaluated in these case studies are relatively short, the exponential growth model will approximate the introduction of these new technologies quite well, as it describes only the opening stages of the technology lifecycle.

$$Y = Ae^{rt}$$

Figure 2: Exponential Growth Model

Where:

Y = Market Share or Total Vehicle Sales

A = Market Share or Total Vehicle Sales at Time t=0 (first year of data)

r = Annual Growth Rate

t = Number of Years Since t=0

Case Studies in Adopting New Automotive Technologies

France's Transition from Gasoline to Diesel

One striking example of large scale changes in an automotive marketplace is the transition of France from gasoline to diesel powered light duty vehicles. This transition was encouraged by the government through a tax reduction on diesel fuel and the introduction of improved diesel technology. Common rail diesel engines raised injection pressures, which improved both the economy and drivability of the diesel powertrain. The government lowered diesel fuel taxes in order to encourage a reduction in total energy consumption as well as CO₂ emissions. In 2005 diesel prices were roughly 12% less than gasoline prices (Green Car Congress 2006) and diesel

engines have maintained a 30-35% efficiency gain over similar gas models in this period. (US Department of Energy n.d.) As a result of these two changes, diesel automobiles grew from 1% of total light vehicle automotive sales in 1970 to 4.4% in 1980 and finally 47% in 2005. This dramatic change in the automotive fleet required relatively few changes in manufacturing processes, when compared to vehicle electrification, but did necessitate a change in the public perception of diesel technology.

As shown in Figure 3 and Figure 4, diesel sales in France grew at an average annual rate of 11% from 1970 to 2005 but averaged only 9.5% from 1980 to 2005. The data fit the exponential growth model with R^2 values of .98 for both exponential trend lines. These sustained high growth rates have led to the second highest diesel penetration in Europe. (Green Car Congress 2006)

Figure 3: French Diesel Market Share Growth 1970-2005 (Observatoire Économique, 2007)

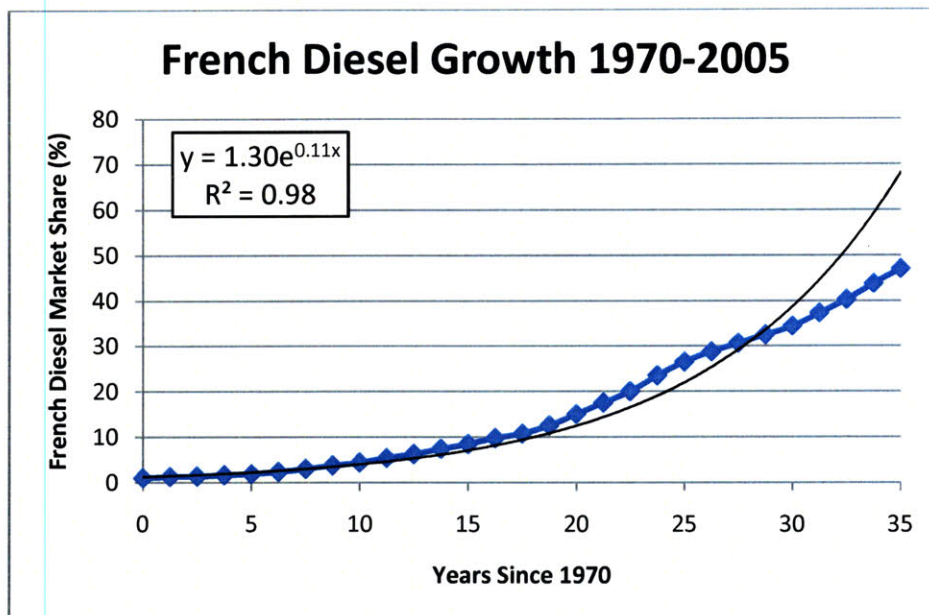
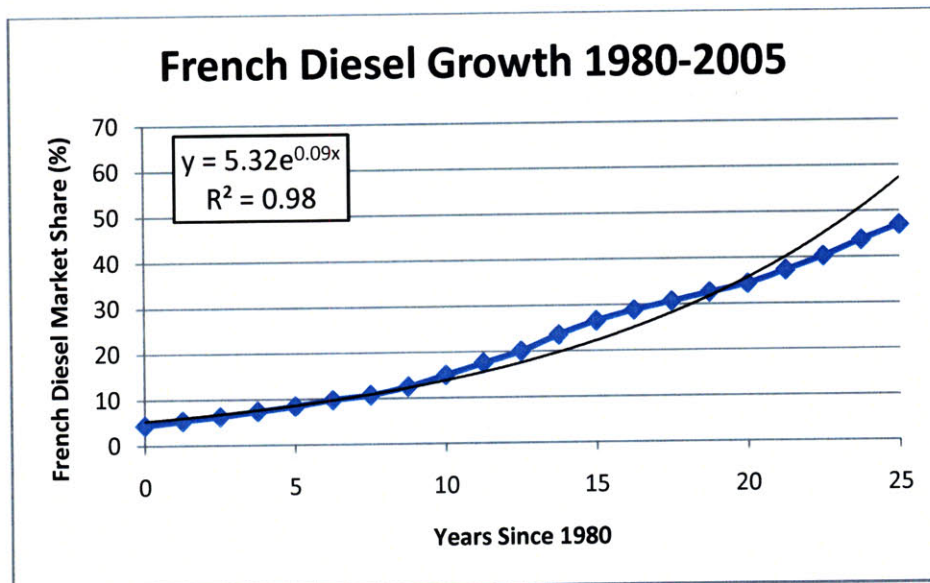


Figure 4: French Diesel Growth 1980-2005 (Observatoire Économique, 2007)



Growth of the American Hybrid Market

A second example of a large scale adoption of a new automotive technology has been the successful introduction of Gasoline-Electric Hybrid vehicles into the American market. Hybrid vehicles utilize an internal combustion engine as well as an electric motor and battery, which is charged while decelerating, to drive the wheels of the vehicle. The first Hybrids came to the US in 2000 when Honda introduced the Insight and Toyota introduced the Prius. Hybrids sales grew every year between 2000 and 2007 with only a slight decrease in total sales in 2008, which can be attributed to a weakness in the overall of the automobile market. Due to the similarity in components between BEVs and Hybrids (batteries, high power electronics and electric motors) the adoption rates found in Figures 5&6 provide the best case study as to how fast BEVs could potentially grow as a segment in the US marketplace.

Figure 5: Total Hybrid Market Share 2000-2009 (Green Car Congress 2009), (Insight Central 2008), (Toyota News Release 2008), (Wards Auto 2009)

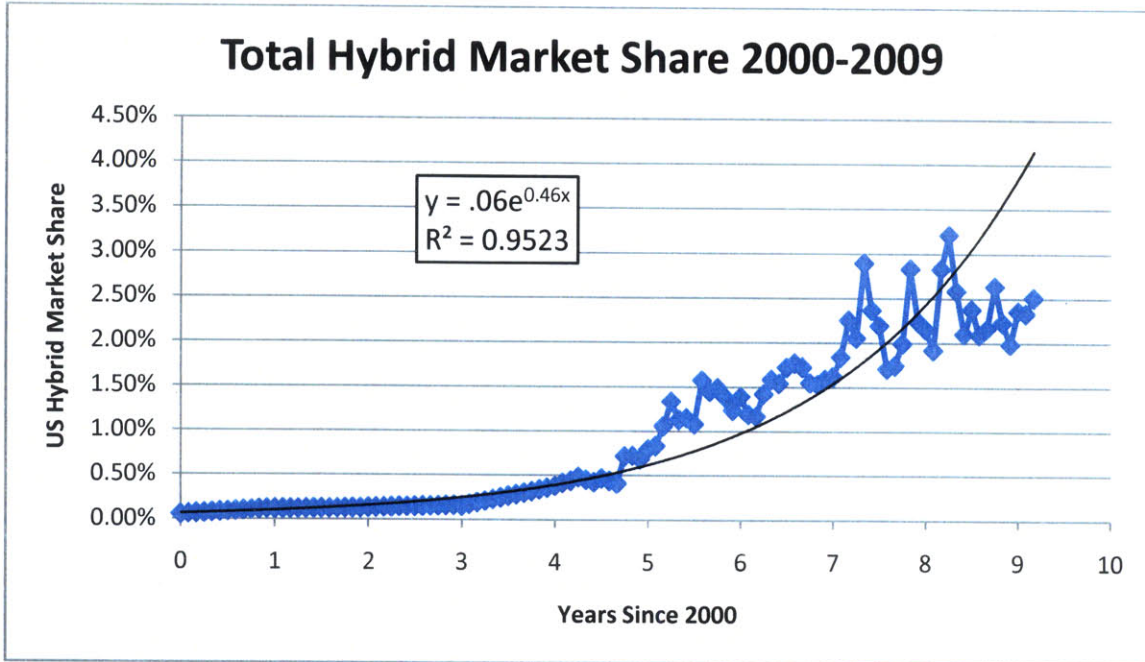


Figure 6: Total Hybrid Sales 2000-2009 (Green Car Congress 2009), (Insight Central 2008), (Toyota News Release 2008)

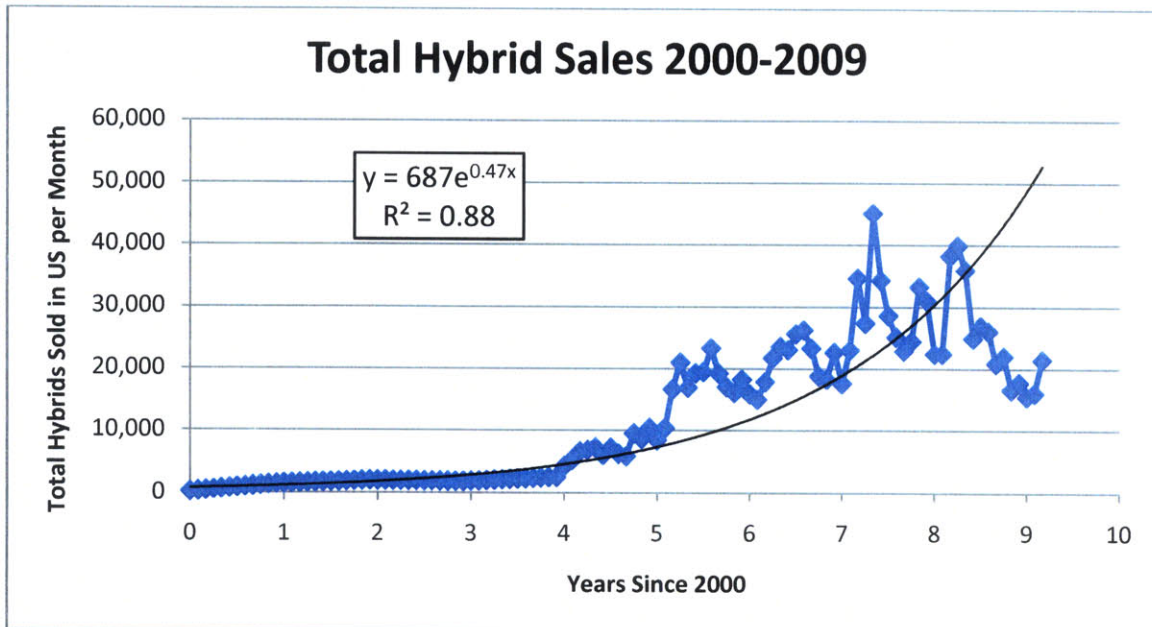


Figure 7: US Hybrid Monthly Sales & Average US Monthly Gasoline Prices (Green Car Congress 2009), (Insight Central 2008), (Toyota News Release 2008), (Wards Auto 2009), (Energy Information Administration 2009)

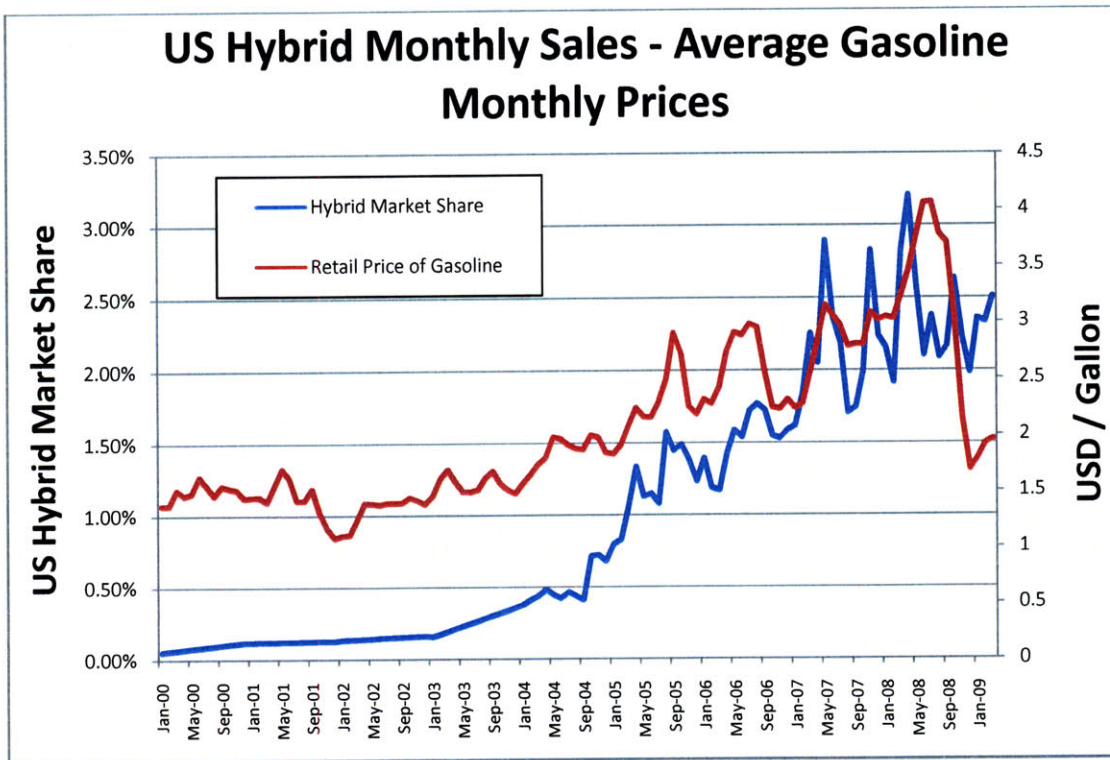
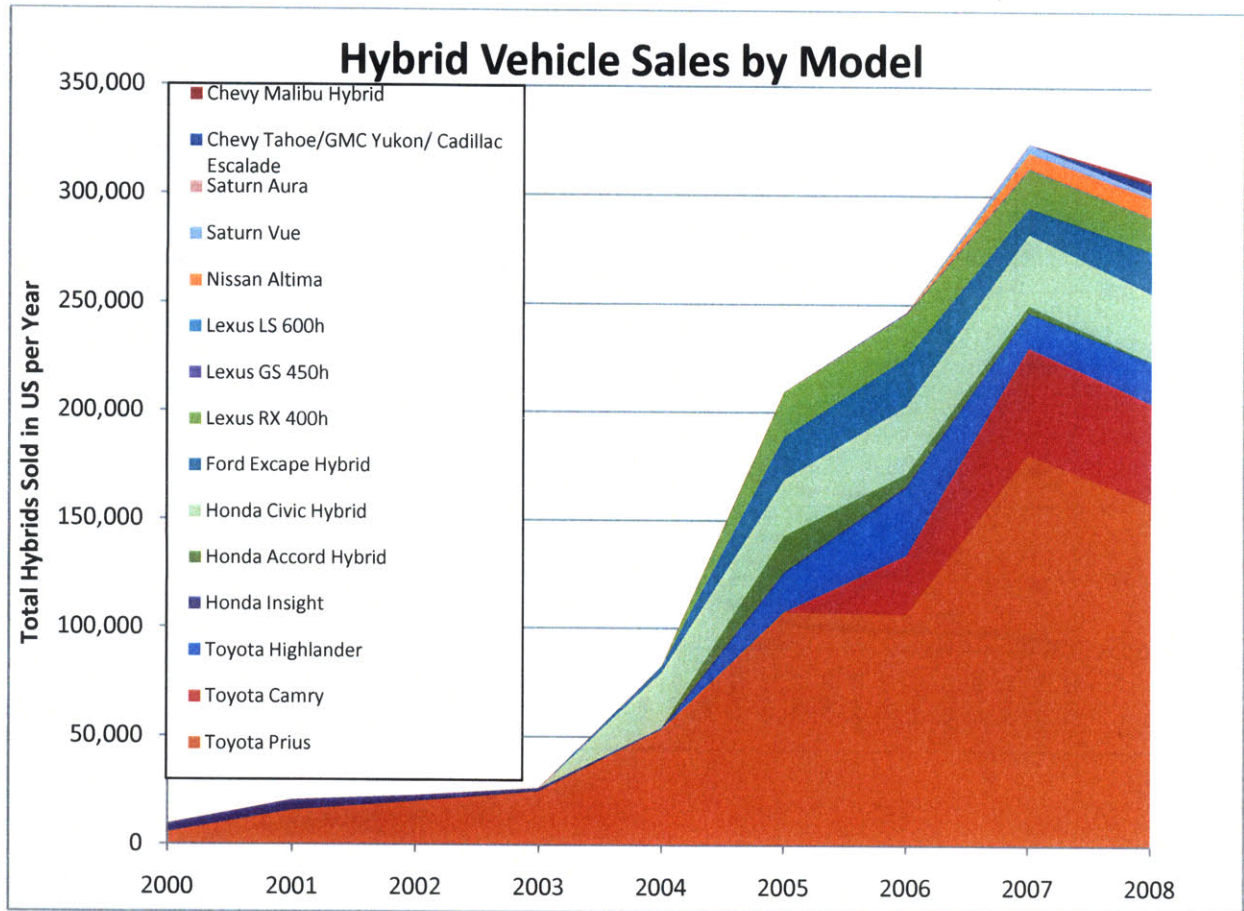


Figure 8: Yearly Hybrid Sales by Model (Electric Drive Transportation Association 2009), (Insight Central 2008), (Toyota News Release 2008)



Examining the yearly sales rates in Figure 8, one can see that between 2000-2003 sales remained fairly constant as the technology was introduced to the marketplace with first generation hybrid vehicles being purchased by innovators and early adopters. This learning phase was important not only for the public to become aware of the new technology and its benefits, but it also encouraged Honda and Toyota to design more advanced second generation products which improved upon the initial shortcomings and increased mass market appeal. It is also clear from Figure 8 just how much of an impact the Toyota Prius has had on the hybrid segment as a whole. Its popularity has been one of the driving forces in the increase of hybrid market share. The Prius has accounted for over half of all hybrid sales nearly every year, with the exception being 2006 when it accounted for 43%, since its introduction in 2000.

As shown in Figure 5, hybrid market share growth again follows an exponential curve. With an R^2 value of 0.95 the model showed average annual growth rates of 46%. The raw sales numbers (Figure 6) did not fit the exponential growth curve as well with an R^2 of 0.88. Raw sales showed an annual growth rate of 47%. Not only did the number of hybrids sold increase between 2000 and 2009 but the variety of cars equipped with hybrid drivetrain architecture increased greatly as well. Hybrids were introduced to the luxury sports car segment (Lexus GS and Lexus LS), the small SUV segment (Ford Escape and Toyota Highlander), the large SUV segment (Lexus RX and Chevy Suburban), and the midsize family car segment (Toyota Camry, Honda Accord, Nissan Altima and Saturn Aura) by 2008. As seen in Figure 7 hybrid sales were clearly affected by short term changes in gasoline prices. Monthly hybrid market share closely followed the increases and decreases in gasoline prices, especially between May of 2006 and August of 2008. Between 2000 and 2009 the US government incentivized sales of hybrid cars. Between 2001 and 2006 the federal government offered a flat tax credit of \$2000 for any hybrid vehicle purchased. The system was modified in 2007 to a graduated rebate program with incentives ranging from \$650 to \$3400, depending on the model of car (US Department of Energy 2009).

BEV Growth Model

In order to determine the annualized growth rates necessary to reach the projections of BCG and Deutsche Bank, a baseline sales figure must be found to act as "A" in our growth model (see Figure 2). Many traditional automotive companies as well as newer startups have made public announcements over the past 6 to 12 months outlining their plans for BEV introduction timelines and occasionally their planned production levels. After cataloging these announcements it became clear that 2010 and 2011 will represent the beginning of commercially viable large scale BEV sales in the marketplace.

Established Automotive Manufacturers- Announced BEV Plans

Ford

As part of their 2009 business plan submitted to the US Congress, Ford has announced two BEVs will be coming to market near term. In 2010 they plan to launch an electric version of their European Transit Van in the American market and in 2011 plan to release a BEV version of the popular Focus model. Ford also recently announced a \$550 million plan to retool their Michigan Assembly Plant from SUV production to production of small compact cars and electric vehicles (Blanco, Ford invests \$550 million to retool Michigan plant for Focus, all-electric car 2009). The 2010 Transit Connect EV will use a 24 kWh lithium



Picture 2: Ford Transit Connect EV



Picture 1: Ford Focus BEV

ion-iron phosphate battery to reach a range of about 100 miles and will be available to commercial fleet customers (Abuelsamid, Ford confirms Transit Connect EV with Smith Electric for 2010 2009). The 2011 Focus BEV is expected to be sold in “the thousands” and be available for fleet and individual purchase (Abuelsamid, Most important vehicle of 2009 Detroit show? I pick the Focus EV mule 2009).

Chrysler

At the 2009 North American International Auto Show, Chrysler introduced 1 BEV and 4 PHEVs some of which they claim will come to market in the next 2 years. The first of their offering will be a Lotus Europa based sports car, renamed the Dodge Circuit, which will be very similar in nature to the Tesla Roadster. It is projected to be available for purchase by the end



Picture 3: Dodge Circuit

of 2010. The Circuit will use a Li-Ion battery pack, developed specifically for Chrysler, of unspecified capacity to reach a range of 150-200 miles and its 200kW motor will provide sports

car levels of acceleration. It is expected to have very low production numbers and be a tool to introduce electric vehicle technology to the Chrysler brand (Bailey 2009).

Honda

Honda has not currently announced plans for any BEVs. Honda Chief of R&D, Masaaki Kato has stated that current battery technology, even the most advanced Lithium-Ion models, still have poor energy density levels which will relegate battery electric vehicles to limited city use. He also foresees the BEV segment comprising less than 1% of the total market by 2015 (Kaufmann 2008). Honda has committed extensive resources to researching Fuel Cell Electric Vehicles, which transform hydrogen to electricity, and has a current fleet of 100-200 FCX Clarity models which use this technology in Southern California. These advanced vehicles are available to the public through a \$600 per month lease (O'Dell 2007).

Mitsubishi

Mitsubishi has outlined an aggressive plan to bring the i-MiEV, a BEV, to Japan and Europe by 2010 and to the US before 2012. Mitsubishi announced worldwide production goals of 2,000 units in 2009, 5,000 by 2010 and as many as 30,000 by early 2013. They claim the major limiting factor in ramping up production is the fabrication of battery packs by their partner GS Yuasa (Blanco, New York 2009: Mitsubishi details global iMiEV plans 2009). The i-MiEV uses a 330 Volt Li-Ion battery to give the vehicle a range of 128-160 km with a top speed of 130km/hr.



Picture 4: Mitsubishi i-MiEV

Nissan

Nissan has made two important announcements about future BEV vehicles. First it has announced that it will introduce a test fleet of BEV compact crossover vehicles in the third quarter of 2010 which will eventually go on sale to the general public by 2012. The EV-02, test vehicle, uses a 35kWh battery pack to achieve a



nominal range of approximately 100 miles. Nissan envisions very quick growth rates and anticipates that as much as 10% of all Nissan sales could be BEVs by 2015 (Abuelsamid, Quick Drive: Nissan EV-02 prototype 2009). Second, a partnership with Better Place, a battery charging and swap service, has led to the announcement that the Nissan-Renault alliance will make BEVs available to Better Place customers in 2011. Nissan is currently testing BEV Renault Megane and BEV Nissan Rogue models in Israel (Roth 2008).

Toyota

As part of an attempt to stay at the forefront of eco-friendly transportation technology, Toyota announced at the 2009 North American International Auto Show that it is planning to bring an electric vehicle to market in 2012. The car will be based on the four seat iQ currently sold in the Japanese market. Although BEVs will be part of Toyota's future automobile offerings, the company does not see the near term growth as being as substantial as other automakers have predicted "although BEVs and new smaller vehicles like the iQ will be a key component of Toyota's sustainable mobility strategy, the conventional gas-electric hybrid, like the all new third-generation Prius, is considered Toyota's long-term core powertrain technology." (Toyota Motor Sales U.S.A. Inc. 2009)

Mini

Under the oversight of BMW, Mini in October of 2008 introduced a test fleet of 450 fully electric Mini-E vehicles available for \$850 per month 1 year leases. These models replace the rear seats of the Mini Cooper with a 35kWh Li-Ion battery capable of 150 miles between charges. The Mini is powered by a 150kW engine which resides where the 4 cylinder engine is situated in the standard car. Following the 1 year test leases, the cars will undergo a thorough review in Germany in order to determine the viability of introducing the model as a normal production offering (McCausland 2008).



Picture 5: Mini E

New Automotive Manufacturers- Announced BEV Plans

Tesla Motors

As the most popularly celebrated electric vehicle manufacturer in the United States, Tesla Motors has succeeded in producing a very fast electric sports car and has announced plans to produce a sedan by 2011. The first Tesla roadster was delivered in February of 2008 and as of April of 2009 Tesla has delivered 320 vehicles. The roadster seats two and uses a 53kWh Li-ion cobalt oxide battery pack comprised



Picture 6: Tesla Roadster

of 6,831 cells, similar to those used in laptops and other personal electronics. Tesla claims the battery pack has an expected lifetime of 7 years or 160,000 km and quotes the current replacement cost as \$30,000 (Abuelsamid, Tesla offers laundry list of new options, \$12k prepaid battery replacement 2009). The Roadster lists a base price of \$101,500 and has a wait list of “almost 1000” (van der Sande 2009).

In March of 2009 Tesla announced plans to produce a 7-passenger sedan targeted at the mass market. The new sedan, the Model S, is currently scheduled to come to market in 2012. With a base price of \$49,900, after a \$7,500 federal rebate, the Model S has generated a significant amount of public interest. Tesla received 520 reservation deposits in the first week following the



Picture 7: Tesla Model S Concept

model’s introduction (Tesla Motors 2009). The Model S plans to use battery technology similar in nature to the existing Tesla Roadster and have a driving range of 260 to 480 km depending on the battery specifications a customer chooses. Model S plans call for it to be capable of quick battery swaps and have the ability to be recharged using 110V, 220V and 480V sources.

Detroit Electric

Detroit Electric, a new electric car company expecting to bring a significant number of electric cars to the US market, has announced plans to partner with Proton cars of Malaysia and Lotus Cars of England. They announced plans in March of 2009 to produce two small sedans, the e63 and



Picture 8: Detroit Electric Concept

the e46, by early 2011 at a cost of \$23,000 for a 177 km range and \$30,000 for a 322 km range. Detroit Electric has ambitious plans to produce 40,000 units in 2011 and 270,000 units by 2012 (Korzeniewski 2009). Detroit Electric has also announced that they are searching for 150 new dealers in the United States according to Ward's Auto (Blanco, Detroit Electric looking for 150 U.S. Dealers 2009).

Th!nk

Th!nk, a Norwegian based automotive manufacturer that produces a small two seat electric city car, in March of 2009 announced plans to locate a factory in the US which will be capable of producing 60,000 units for American consumption by 2012. The current City car, which is on sale in Europe, has a range of 180km and a top speed of



Picture 9: Th!nk City

100km. Th!nk's current production plans outline US sales of 2,500 in 2010 rising to 16,000 by 2012. The Th!nk City will reportedly retail for under \$20,000 along with a \$80-90 per month lease for the battery (Th!nk 2009).

Figure 9 : Summary of 2009-2012 BEV production Based on Corporate Press Releases

Parent Corporation	Planned BEV Models	2009	2010	2011	2012
Ford ^{1,2}	Transit Connect		?	?	?
	Focus BEV			1000	2000
Chrysler ³	Circuit		?	?	?
Honda					
Mitsubishi ⁴	MiEV			?	?
Nissan ⁵	EV-02		?	?	?
Toyota ⁶	iQ-EV				?
Mini ⁷	Mini E	450			
Tesla Motors ^{8,9}	Roadster	1000	1500	?	?
	Model S			?	?
Detroit Electric ¹⁰	e63 and e46			10000	50000
Th!nk ¹¹	City Car		2500	?	?
Best Case Estimate		1,450	10,000	15,000+	?
Worst Case Estimate		600	2,000	3,000	?

¹ (Abuelsamid, Ford confirms Transit Connect EV with Smith Electric for 2010 2009)

² (Abuelsamid, Most important vehicle of 2009 Detroit show? I pick the Focus EV mule 2009)

³ (Bailey 2009)

⁴ (Blanco, New York 2009: Mitsubishi details global iMiEV plans 2009)

⁵ (Abuelsamid, Quick Drive: Nissan EV-02 prototype 2009)

⁶ (Toyota Motor Sales U.S.A. Inc. 2009)

⁷ (McCausland 2008)

⁸ (van der Sande 2009)

⁹ (Abuelsamid, Tesla offers laundry list of new options, \$12k prepaid battery replacement 2009)

¹⁰ (Korzeniewski 2009)

¹¹ (Th!nk 2009)

Growth Rates Required to Meet Projections

Given that the projected near term production figures for pure EVs are very low relative to the long term production estimates forecasted in BCG, Deutsche Bank and US Government projections, some consistent long term growth will be required to meet 2020 sales estimates. In order to evaluate the range of annualized growth rates necessary to meet those projections a range of initial 2010 production figures as well as growth rates were plotted (See Figures 10 to 14). With initial sales in 2010 and 2011 on the low end of the sales spectrum (Figure 9) 2500 to 5000 BEV sales in 2010, annualized growth rates on the order of 45% to 55% will be required to meet the BCG Scenario 2 and Deutsche Bank projections. If some of the newer electric vehicle manufacturers such as Detroit Electric and Th!nk deliver on their recent statements to place thousands of cars on the road in the very near term, thus raising the total number of BEVs sold in 2010 and 2011 into the 10,000 to 20,000 unit range, much lower average annualized growth rates, on the order of 30% to 37%, will be required to meet Deutsche Bank and BCG Scenario 2 projections.

Figure 10: BEV Projections - 2500 Initial Sales in 2010

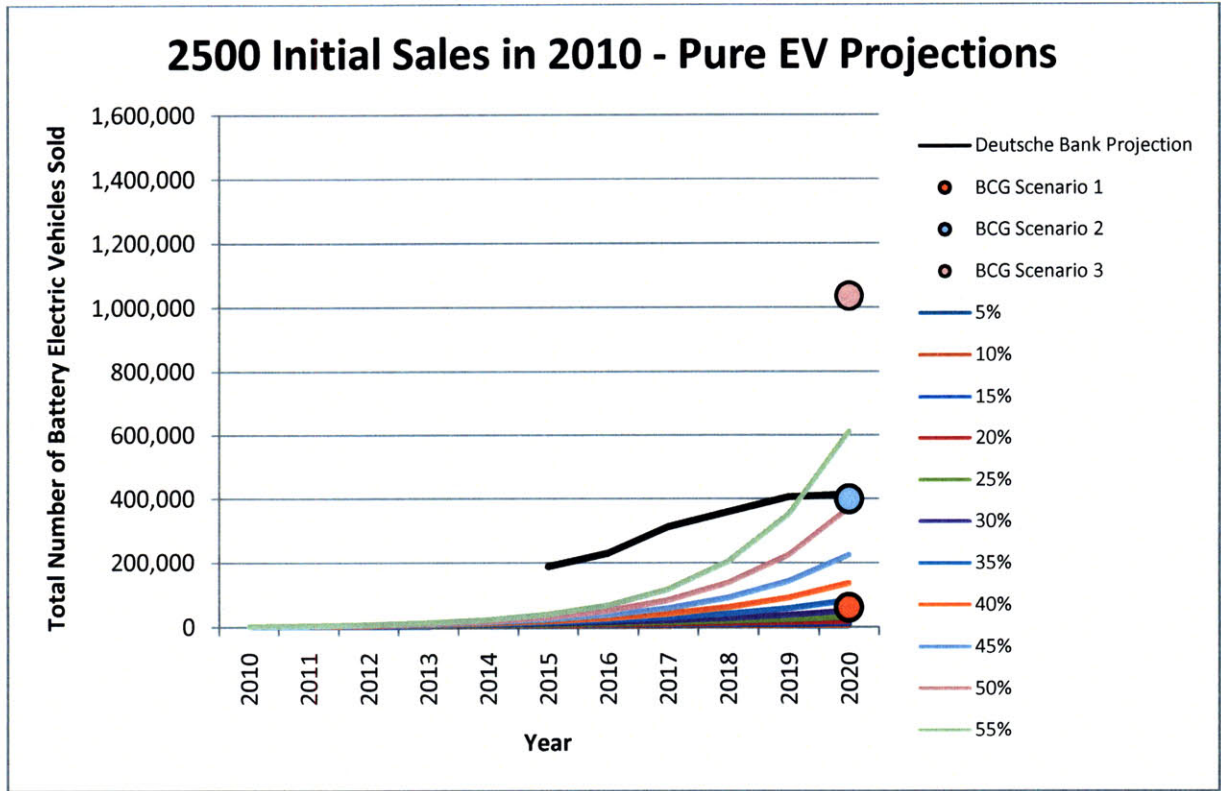


Figure 11: BEV Projections - 5000 Initial Sales in 2010

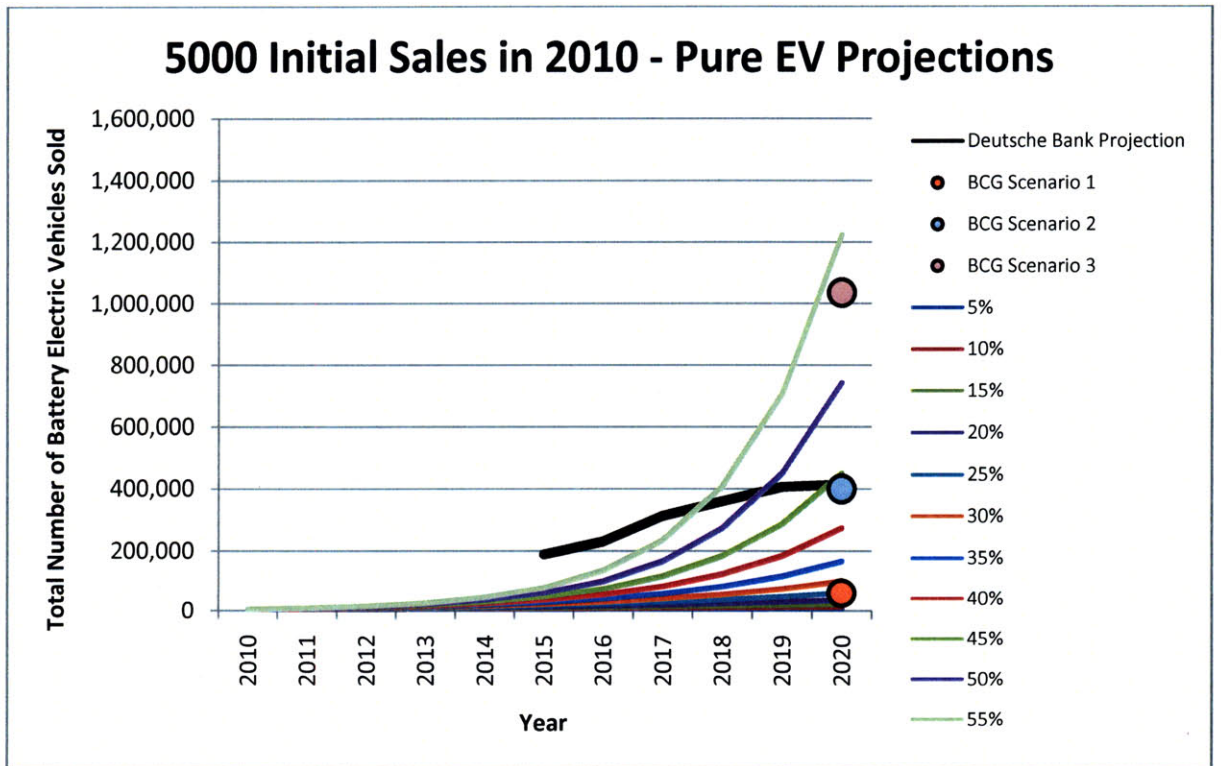


Figure 12: BEV Projections - 10,000 Initial Sales

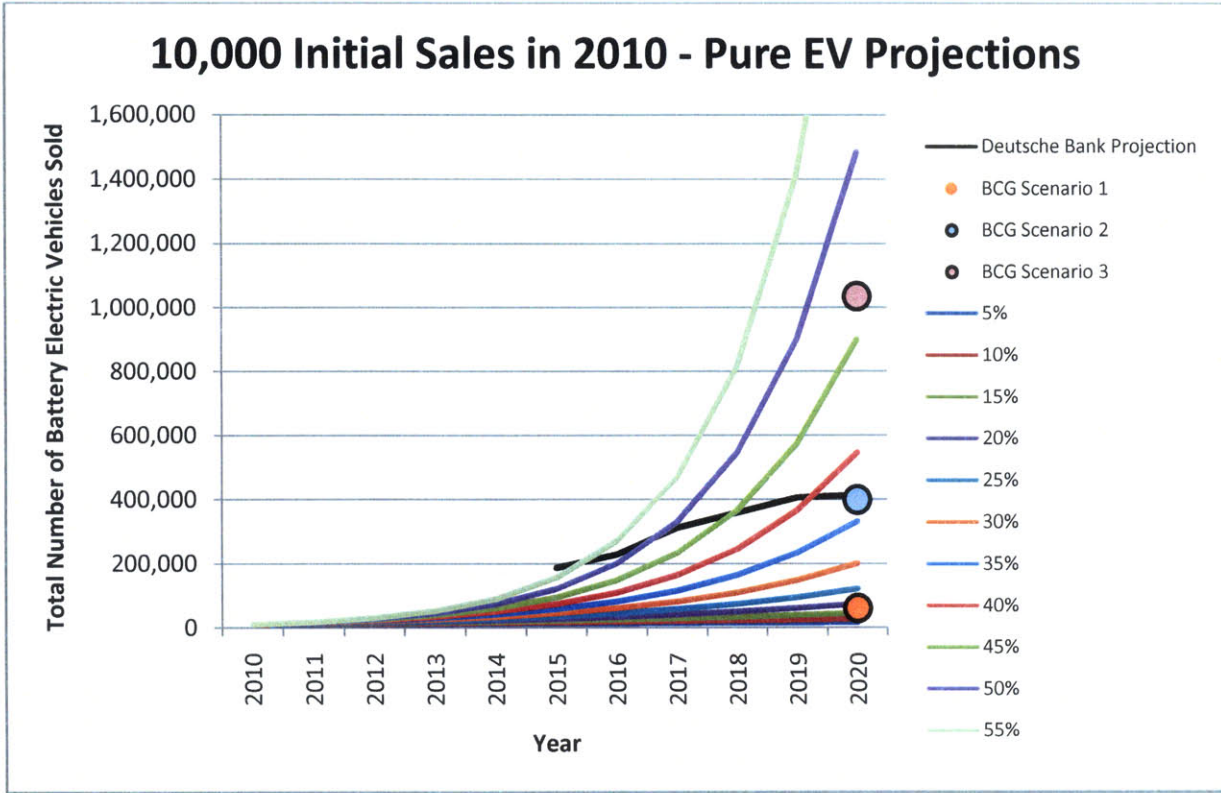
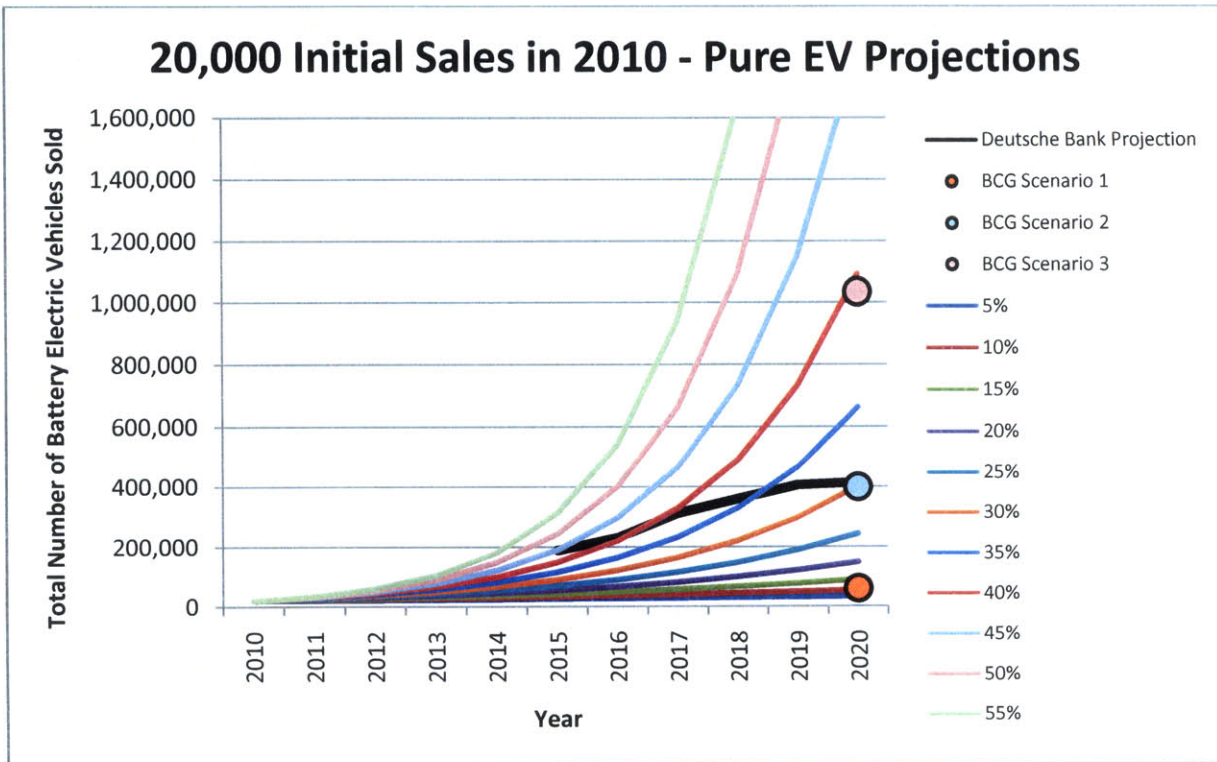


Figure 13: BEV Projections - 20,000 Initial Sales



Evaluation of Growth Rates Required to Meet 2020 Projections

The introduction and relatively quick adoption of hybrid technology in the United States and the longer term growth of diesel technology in France provide baselines by which one can anticipate the annual growth rates needed to place significant numbers of BEVs on US roads and highways by 2020. In order to meet midlevel projections of 2020 BEV production rates, consistent annualized growth rates in excess of 30%, and quite possibly in the range of 45-50%, will be required over the next decade. These growth rates will be of the same magnitude as the growth rate of hybrid vehicles in the United States between 2000 and 2009. These BEV growth rates will be well in excess of the 9% to 11% annual growth rate of diesel vehicles in France which was consistently maintained between 1970 and 2005. That transformation saw diesel market share grow from less than 1% to 47% of light vehicle sales, but that required much less technical innovation than a transition to BEVs will necessitate. Due to the non trivial change in driving habits that BEVs will require from their owners, as well as the current lack of infrastructure to support large scale fleets of BEVs, the BCG Scenario 2, BCG Scenario 3, and Deutsche Bank production projections could be seen as highly optimistic. Even if CO₂ emission reduction becomes an increased priority at the federal, state and local levels and oil prices return to \$150 per barrel levels, the automotive industry will have to change its product portfolio from gasoline and hybrid powertrains to BEVs at a very quick rate. Finally, industry-wide concerns over the production of automotive scale Li-ion battery packs, and the rate at which their production can be increased, has the potential to slow growth rates in the near term as well. While BEVs may indeed hold the key to long term CO₂ emissions reductions, the timescale on which their impact will be felt could be significantly longer than is currently forecast.

Works Cited

- Abuelsamid, Sam. *Ford confirms Transit Connect EV with Smith Electric for 2010*. February 9, 2009. <http://www.autobloggreen.com/2009/02/09/ford-confirms-transit-connect-ev-with-smith-electric-for-2010/> (accessed March 21, 2009).
- . *Most important vehicle of 2009 Detroit show? I pick the Focus EV mule*. January 19th, 2009. <http://www.autobloggreen.com/2009/01/19/most-important-vehicle-of-2009-detroit-show-i-pick-the-focus-ev/> (accessed March 21, 2009).
- . *Quick Drive: Nissan EV-02 prototype*. May 4, 2009. <http://www.autobloggreen.com/2009/05/04/quick-drive-nissan-ev-02-prototype/> (accessed May 4, 2009).
- . *Tesla offers laundry list of new options, \$12k prepaid battery replacement*. January 17, 2009. <http://www.autobloggreen.com/2009/01/17/tesla-offers-laundry-list-of-new-options-12k-prepaid-battery-r/> (accessed March 21, 2009).
- Bailey, Shaun. *Dodge Circuit EV*. January 31, 2009. http://www.roadandtrack.com/article.asp?section_id=15&article_id=7416 (accessed March 21, 2009).
- Blanco, Sebastian. *Detroit Electric looking for 150 U.S. Dealers*. April 13, 2009. <http://www.autobloggreen.com/2009/04/13/detroit-electric-looking-for-150-u-s-dealers/> (accessed April 21, 2009).
- . *Ford invests \$550 million to retool Michigan plant for Focus, all-electric car*. May 6, 2009. <http://www.autobloggreen.com/2009/05/06/ford-invests-550-million-to-retool-michigan-plant-for-focus-al/> (accessed May 6, 2009).
- . *New York 2009: Mitsubishi details global iMiEV plans*. April 11, 2009. <http://www.autobloggreen.com/2009/04/11/new-york-2009-mitsubishi-details-global-imiev-plans/> (accessed April 22, 2009).
- Book, Michael, Marcus Groll, Xavier Mosquet, Dimitrios Rizoulis, and Georg Sticher. *The Comeback of the Electric Car?: How Real, How Soon, and What Must Happen Next*. Boston Consulting Group, 2009.
- Davis, Stacy C., Susan W. Diegel, and Robert G. Boundy. *Transportation Energy Data Book: Edition 27*. Oak Ridge, Tennessee: U.S. Department of Energy, 2008.
- Department of Energy. "EIA - Annual Energy Outlook 2009." Washington D.C., 2009.

- Deutsche Bank. *Electric Cars: Plugged In*. Markets Research, Automobiles Auto Manufacturing , Deutsche Bank, 2008.
- Electric Drive Transportation Association. "Hybrid Sales Figures/Tax Credits for Hybrids." *ETDA*. March 2009.
http://www.electricdrive.org/index.php?ht=d/Articles/cat_id/5514/pid/2549 (accessed March 15, 2009).
- Energy Information Administration. "Gasoline Components History." *Energy Information Administration Official Energy Statistics from the US Government*. March 2009.
<http://tonto.eia.doe.gov/oog/info/gdu/gaspump.html> (accessed March 15, 2009).
- Green Car Congress. "US Hybrid Sales in March 2009 Down 44% Year-on-Year; Monthly New Vehicle Market Share of 2.5%." *Green Car Congress*. April 3, 2009.
<http://www.greencarcongress.com/2009/04/us-hybrid-sales-in-march-2009-down-44-yearonyear-monthly-new-vehicle-market-share-of-25.html#more> (accessed April 6, 2009).
- Green Car Congress. *Diesel Auto Sales Trending to Exceed Gasoline in Europe in 2006*. January 30, 2006. http://www.greencarcongress.com/2006/01/diesel_auto_sal.html (accessed March 20, 2009).
- Insight Central. "Sales Statistics." *Insight Central*. 2008.
<http://www.insightcentral.net/KB/sales.html> (accessed March 15, 2009).
- Jones, Roland. *Automakes All Charged Up Over Electric Cars*. January 16, 2009.
<http://www.msnbc.msn.com/id/28659906> (accessed March 15, 2009).
- Kaufmann, Alex. *Honda opts out of EV production until batteries mature*. September 8, 2008.
<http://www.motorauthority.com/honda-will-not-build-ev-while-battery-technology-remains-inefficient.html> (accessed March 15, 2009).
- Korzeniewski, Jeremy. *Detroit Electric sign deal with Proton, plans 2 new electric cars*. March 30, 2009. <http://www.autobloggreen.com/2009/03/30/detroit-electric-signs-deal-with-proton-plans-2-new-electric-ca/> (accessed April 21, 2009).
- McCausland, Evan. *Green: 2009 Mini E Electric Vehicle*. October 18, 2008.
http://www.automobilemag.com/green/news/0810_2009_mini_e_electric_vehicle/index.html (accessed March 21, 2009).
- Obama, Barack. "Obama Prepared Remarks at Tour of the Electric Vehicle Technical Center." Pomona, California, March 19, 2009.
- Observatoire Économique et Statistique des Transports. 2007. Fleet-level data for France provided by Lee Schipper, Research Director, EMBARQ

- O'Dell, John. *Honda's Fuel-Cell Electric Car is No Trailer Queen*. November 26, 2007.
<http://www.edmunds.com/insideline/do/Drives/FirstDrives/articleId=123662> (accessed March 21, 2009).
- Roth, Daniel. *Driven: Shai Agassi's Audacious Plan to Put Electric Cars on the Road*. August 18, 2008.
http://www.wired.com/cars/futuretransport/magazine/16-09/ff_agassi (accessed April 2009).
- Tesla Motors. "Tesla take more than 500 Model S reservations in a week." *Tesla Motors*. April 2, 2009.
http://www.teslamotors.com/media/press_room.php?id=1299 (accessed April 21, 2009).
- . "Tesla unveils world's first mass-produced, highway-capable EV." *Tesla Motors Press Room*. March 26, 2009. http://www.teslamotors.com/media/press_room.php?id=1284 (accessed April 21, 2009).
- Th!nk. "Think Announces U.S. Factory Plans." *Th!nk*. March 12, 2009. <http://www.think.no/think/Press-Pictures/Press-releases/Think-Announces-U.S.-Factory-Plans> (accessed March 21, 2009).
- Toyota Motor Sales U.S.A. Inc. "Detroit 2009: Toyota's iQ based FT-EV concept to hit production in 2012." *Autoblog Green*. January 10, 2009. <http://www.autobloggreen.com/2009/01/10/detroit-2009-toyotas-iq-based-ft-ev-concept-to-hit-production/> (accessed March 16, 2009).
- Toyota News Release. "Worldwide Prius Sales Top 1 Million Mark." *Toyota*. May 15, 2008.
<http://www.toyota.co.jp/en/news/08/0515.html> (accessed March 15, 2009).
- US Department of Energy. *Diesel Vehicles*. http://www.fueleconomy.gov/feg/di_diesels.shtml (accessed March 21, 2009).
- . *New Energy Tax Credits for Hybrids*. April 15, 2009.
http://www.fueleconomy.gov/feg/tax_hybrid.shtml (accessed April 16, 2009).
- van der Sande, Michael. *Sales Update - Buuying a Tesla Roadster just got easier*. March 26, 2009.
<http://www.teslamotors.com/blog2/?p=71> (accessed April 11, 2009).
- Wards Auto. "U.S. Light Vehicle Sales Summary." *Wardsauto.com*. 2009.
<http://wardsauto.com/keydata/USSalesSummary0903/> (accessed March 15, 2009).