Marketing Alternative Fueled Automobiles

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ABSTRACT

Marketing alternative fueled vehicles is a difficult challenge for automakers. The foundation of the market, the terms of competition, and the customer segments involved are still being defined. But automakers can draw lessons from other industries, previous examples, and recent launches of the Chevy Volt and Nissan Leaf to help guide them. Automakers can deploy new marketing tools to advance their understanding of the market, define the terms of competition, and listen in to their customers' needs. These new tools can help reduce the risk and uncertainty involved with launching new products like alternative fueled vehicles.

This thesis explores the major issues in marketing alternative fueled automobiles in several major parts. First it will look at the major drivers of alternative fueled vehicles and historical examples such as the Prius. While the market continues to change with each year, some trends emerge as key to defining the future of the industry. Second, it will look at the current strategic environment for alternative fueled vehicles, including an exploration of the various fuel types and vehicle offerings. Third, it will offer lessons learned for manufacturers based on the case study work done with two automotive manufacturers on real-life launches of a plug-in hybrid and a hydrogen vehicle. Some classical marketing frameworks, such as the innovation cycle, are used to help understand current puzzles, and new tools, such as semantic/perceptual maps, are used to help understand how open questions might be resolved in the next few years. Finally, it will explore a novel modeling tool developed for assessing potential adoption rates for alternative fueled vehicles by looking at costs and profits from both the owners and automakers' perspective.

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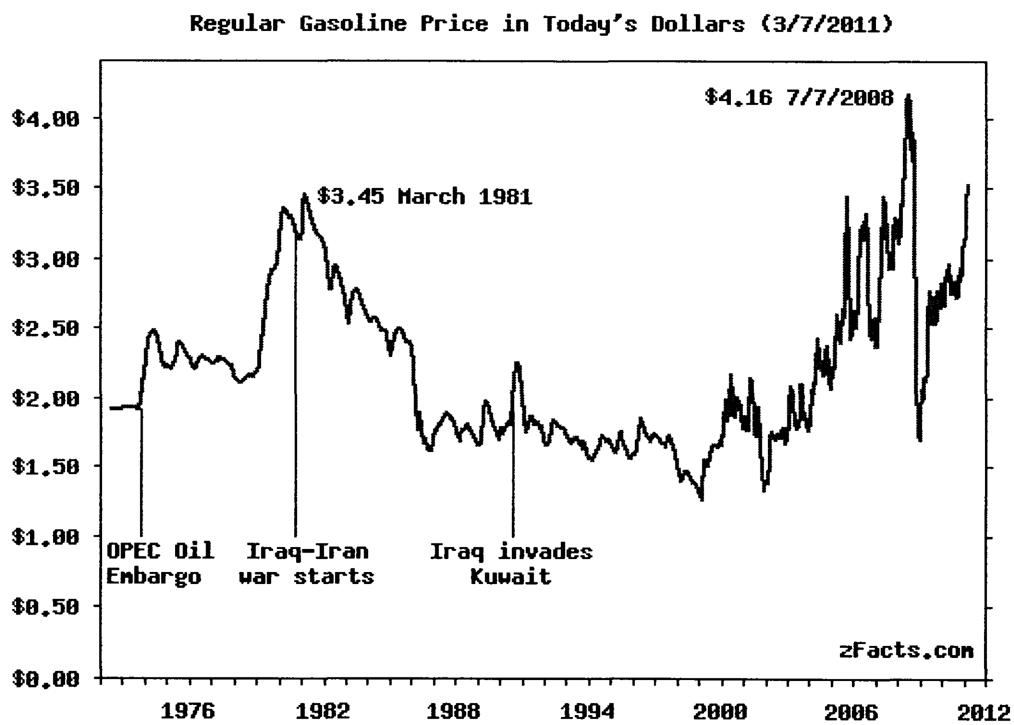
MAJOR DRIVERS AND HISTORICAL EXAMPLES

MAJOR DRIVERS

A number of macro-influences have re-energized the interest in alternative fueled vehicles that had experienced bursts of enthusiasm since the 1970s. Previous pushes towards alternative fuels, primarily driven by high oil prices, proved short lived once oil prices declined. The current interest in alternative fuels, driven by a wider variety of factors, appears to be more sustained and has resulted in long-term technological innovations and regulations which have altered the nature of the automotive sector.

GAS PRICES AND NATIONAL SECURITY

Gas prices have had fluctuations in the past, most notably in the 1970s decade during the Arab Oil Embargo and the Iranian Revolution. This created a temporary push for alternative fuels, and the establishment of the US Department of Energy to help explore "energy independence" and research new technologies for energy. The major result of that push was to largely eliminate the use of petroleum in electric power generation, replacing it with coal and natural gas. Petroleum consumption in transportation, however, continued to grow over the next few decades as population, car ownership, and miles traveled grew in the United States. The graph below shows typical US gas prices over time.



Historical US Gas Prices at Pump (Zfacts)

There are two main differences this time around that make the rise in gas prices more significant. The first is that the rise in gas prices has mainly been demand-driven instead of supply-driven. Growing demand for oil from the developing world (especially China and India) is expected to outpace supply expansion for the foreseeable future. The second major difference is that high gas prices are now more closely associated with national security concerns and terrorism, as a result of 9/11 and American intervention in the Middle East in Afghanistan and Iraq. Political tensions in other major oil producing states, such as Iran, Libya, and Venezuela further strain the case for the reliability of imported oil. These differences have pushed gas prices higher for the long-term.

CONSUMER CONSCIOUSNESS

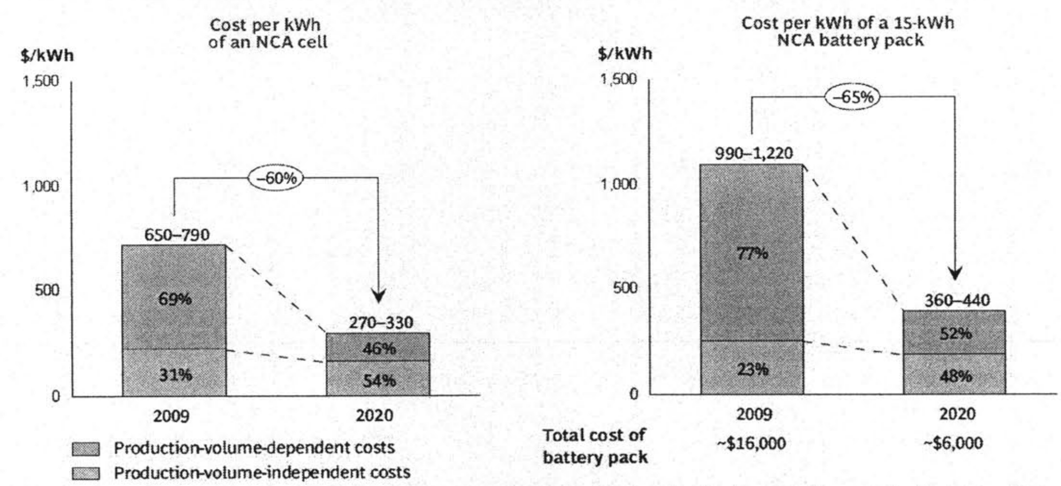
Consumer knowledge about major issues such as gas prices, national energy security, environmental impacts of oil and gas drilling, and global climate change has continued to grow as the issues gain greater media coverage and alternatives begin to present themselves. Consumer consciousness creates the demand-side pull for new products that offer solutions that fit their values and addresses their broader concerns. Consumer consciousness also extends to automakers, since their employees are consumers as well.

TECHNOLOGICAL ADVANCEMENT

The advancement of technology, specifically battery technology, has helped push forward the adoption of hybrids and electric vehicles. Much of the battery technology advancement was due to the widespread use of portable consumer electronics. These consumer electronics batteries, which are generally low-power and high-energy applications, must be adapted for automotive applications, which have higher power requirements. Recent innovations in battery chemistry and manufacturing have led to batteries that are smaller, lighter weight, lower cost, more durable, and have more desirable power and energy characteristics.

It is expected that battery technology will continue to advance and as a result that costs will decline over time. In the figure below, BCG projects that the cost of battery packs will fall by about 60% in the next 10 years.

Exhibit 4. Battery Costs Will Decline 60 to 65 Percent from 2009 to 2020



Sources: Interviews with component manufacturers, cell producers, tier one suppliers, OEMs, and academic experts; Argonne National Laboratory; BCG analysis.
Note: Exhibit assumes annual production of 50,000 cells and 500 batteries in 2009 and 73 million cells and 1.1 million batteries in 2020. Numbers are rounded.

BCG Projections for Battery Costs over Time (Martin)

Regulation

Regulation has undoubtedly been a major driver the adoption of alternative fueled vehicles. California's use of clean fuel standards in the 1990s spurred the initial development of electric vehicles, and further interest in energy independence in the 2000s helped push the development of hydrogen vehicles. Undoubtedly the increase in Corporate Average Fuel Economy (CAFE) standards of years has helped increase the adoption of hybrid electric vehicles, and the favorable rating of plug-in hybrid electric vehicles and full electric vehicles in CAFÉ standards has helped the adoption of those as well.

In general, a combination of these factors – gas prices, consumer consciousness, technological advancement, and regulation have helped to increase the adoption of alternative fueled vehicles.

Historical Examples

This section explores some of the historical alternative fueled vehicles launched by automakers.

GM EV1

The EV1 was GM's first major foray into the alternative fueled vehicle market. As an all-electric vehicle, it was a relatively small vehicle that was designed with the intention of meeting proposed stringent fuel-efficiency requirements in California. However, the vehicle may have been ahead of its time. Designed with heavy, expensive, and relatively unreliable lead-acid batteries, and using a primitive electric drive-train, it provided a sub-par level of performance for consumers while it cost an exorbitant amount of money to produce. At the same time, the design itself as a sports-coupe did not appeal to consumers and imposed additional technical challenges in terms of space.

Honda Insight

The original Honda Insight was the first mass-produced hybrid to be on the road in the US. However, it suffered from many of the same problems as the EV1. Launched as a hybrid, it required much less infrastructure and smaller batteries than the EV1. However, it still used a form factor that was too small for the average car buyer, and due to its small tires, diminutive form factor, manual transmission, and low power, created a poor driving experience.

Toyota Prius

The Toyota Prius can be considered the first successful, mass-produced, alternative fueled vehicle in the US market. Its formula of creating a mass-market, widely appealing vehicle with characteristics similar to normal vehicles appears to have succeeded. It used nickel-metal hydride batteries, which were significantly better than lead acid batteries, and provided a performance advantage over previous hybrid vehicles. In addition, it provided better integration of the gas and electric engines, which allowed for improved performance and a more desirable driving experience.

Case Study: Early Prius Marketing

The early marketing of the Prius identified three likely segments as early adopters (Andidas):

Early Adopters / Technology Pioneers: Those who are interested in the latest technology, and must be the first to own it.

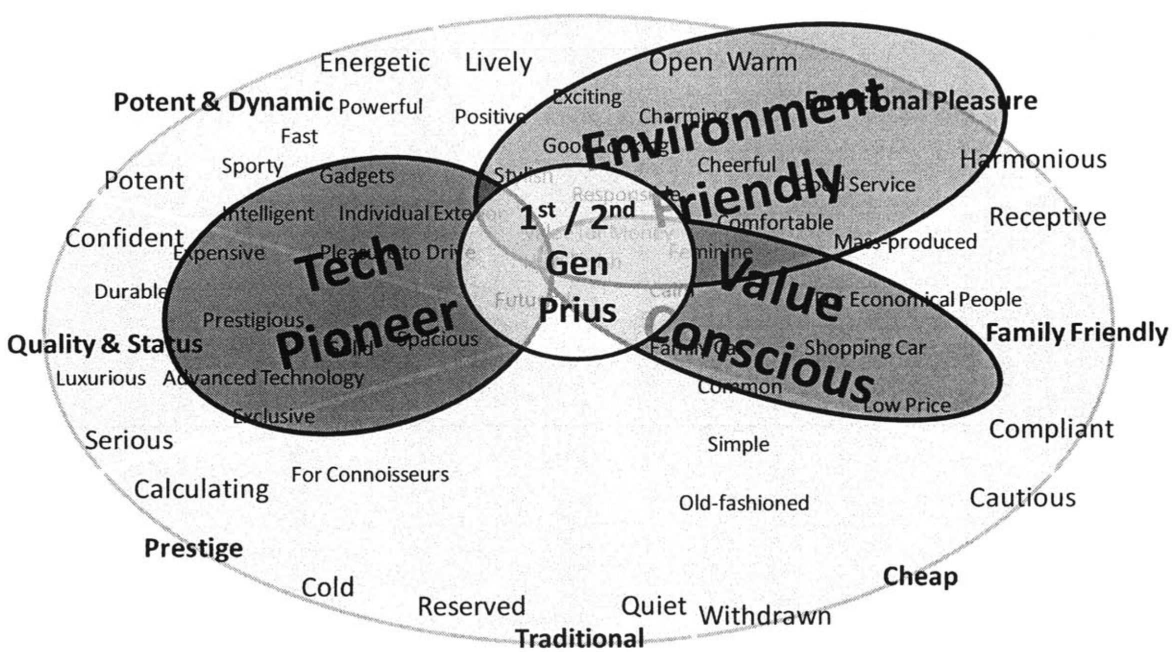
Environmentally Friendly: Those who recognize the environmental impact of transportation and are willing to spend extra for it. They want to do this without too much inconvenience, and are somewhat hesitant with new technologies.

Value Conscious: Mainly interested in low costs for a vehicle and would be interested in the Prius as an option for saving money on gas and maintenance.

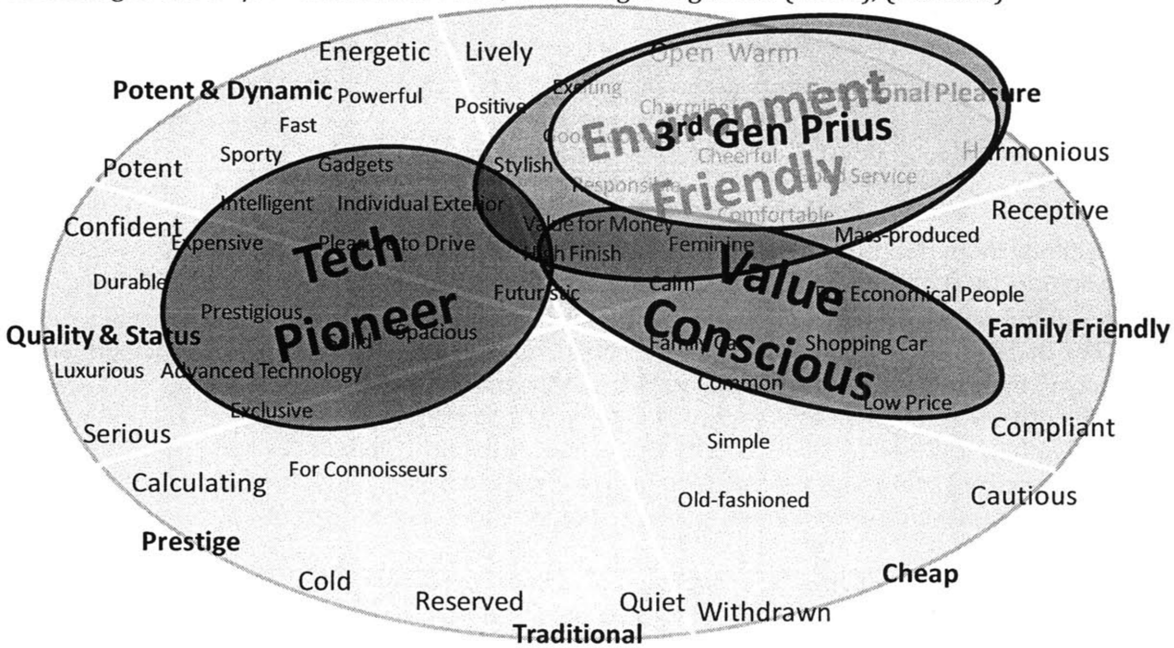
Of these three groups, the first segment, early adopters / technology pioneers, were deemed most likely to be the initial purchasers of the vehicle. There were three main reasons why the other segments would not be as likely to purchase the vehicle initially (Andidas):

1. The income of the other segments were lower, and the vehicle was expected to be priced at a premium relative to comparable vehicles in the market
2. The other segments were more hesitant to be early adopters of technologies that they were unfamiliar with, and for which there was some uncertainty about long-term performance
3. The price of gasoline at the time of launch was not yet high enough to economically justify the additional cost of the vehicle via fuel savings and maintenance alone.

Over the long-term, however, the Prius was unable to maintain its positioning as the "newest" vehicle technology-wise, as is often the case with new technologies. However, the Prius made a successful transition during its lifecycle from focusing on early adopters / technology pioneers, to focusing on the green / environmentally friendly segment. One could argue now that with the coming introduction of the Prius V, it is shifting its focus again to a more family-oriented vehicle. The figures below show the positioning of the 1st /2nd generation Prius (and the segments targeted) and the transition to the 3rd generation Prius on a perceptual mapping. The segment bubbles were placed based on segment descriptions provided in the Prius Marketing Plan, and the vehicle's positioning bubbles were placed based on the content of the advertising campaigns corresponding to those vehicles.



Positioning of the 1st /2nd Generation Prius, with Target Segments (Kiron), (Andidas)

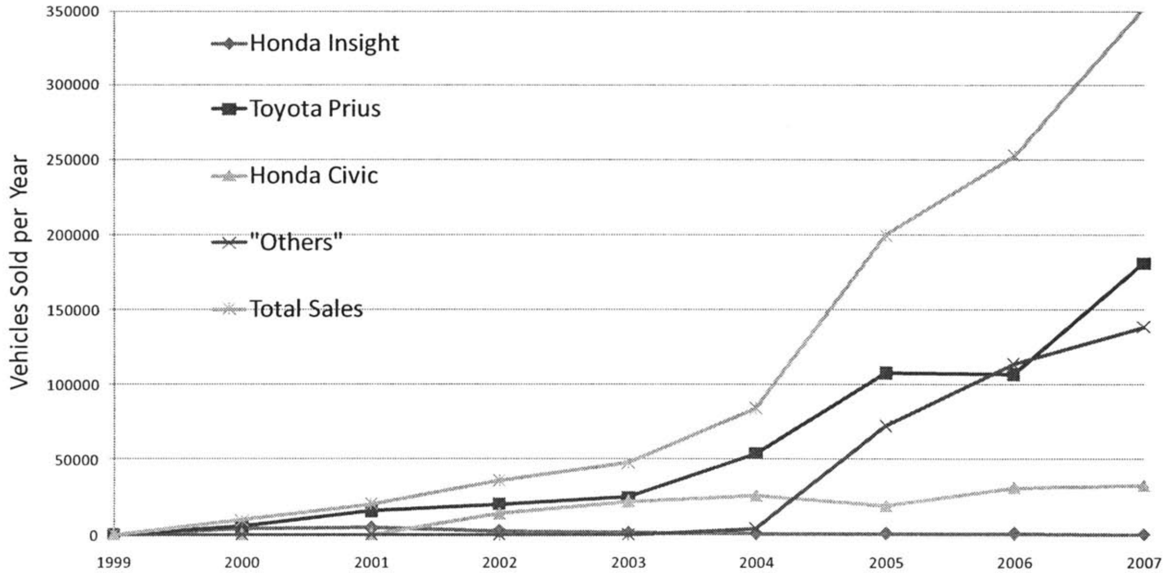


Positioning of the 3rd Generation Prius, with Target Segments (Kiron), (Andidas)

Current Strategic Environment

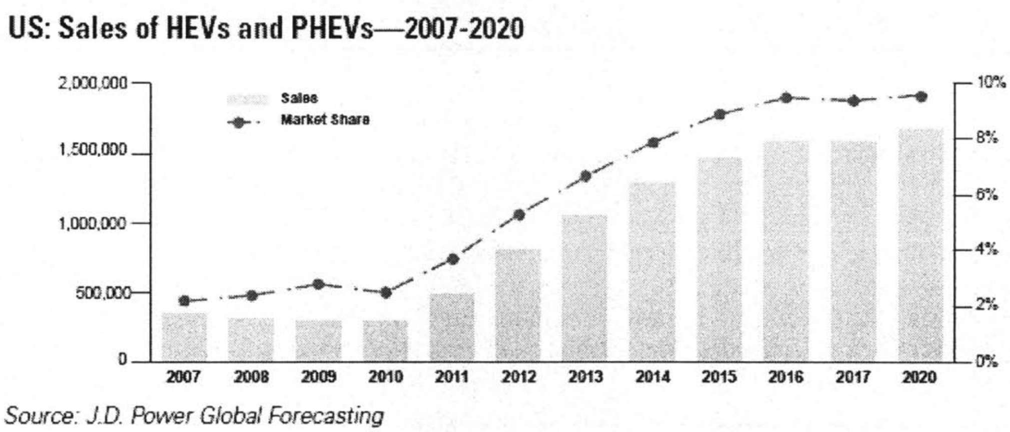
Evolution of Competition in the Hybrid Market

Since the launch of the Prius, there has been significant entry into the hybrid market. Most of these hybrids have not reached the volume or success of the Prius, but nonetheless automakers recognize the importance of this segment and have devoted significant R&D amounts to it. The graph below shows US hybrid sales per year by nameplate.



US hybrid sales per year with total (US DOE)

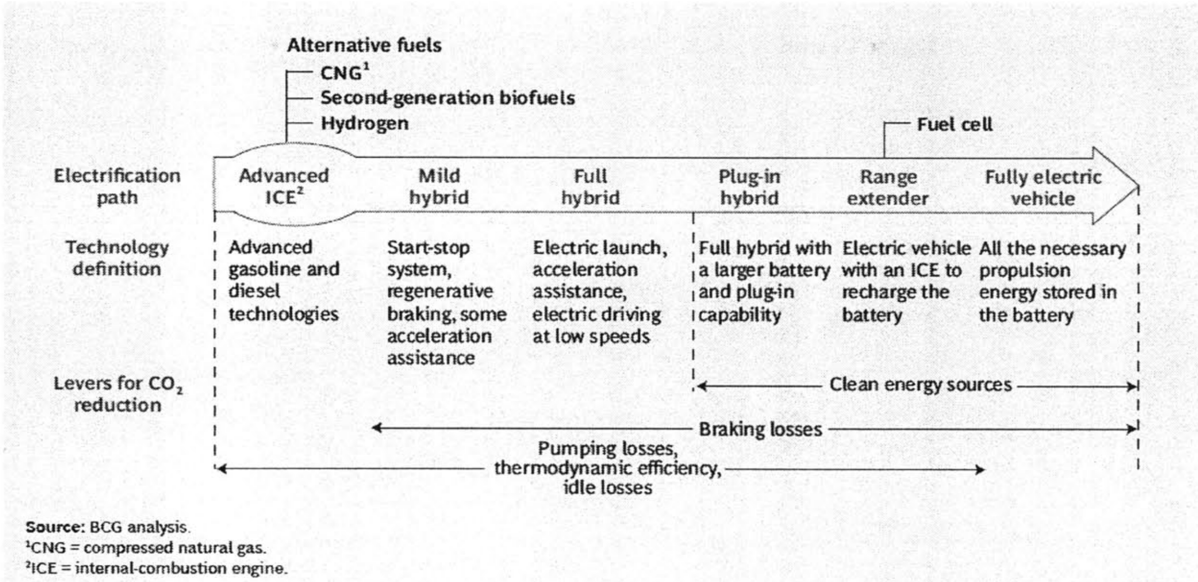
Sales are expected to continue to grow, but amongst a more fragmented group of nameplates. The growth of the purple line, or "other" category, represents a large number of hybrid nameplates that each have a small volume of sales. This includes the "hybrid version" of a number of popular vehicles like the Toyota Camry or the Ford Escape. Creating a hybrid version of an existing vehicle costs much less than developing a pure-hybrid platform, and has been a favored strategy of the majority of automakers for entering the market. At this point, the only automakers with dedicated hybrid-only vehicles are Toyota (Prius) and Honda (Insight). The figure below shows a projection of the long-term sales of hybrids and plug-in hybrids in the US.



Projected US Hybrid and PHEV Sales (JD Power)

Alternative Fuel Technologies

The figure below shows an overview of various alternative fuel technologies



A Variety of Alternative Fuel Options (Groll)

Mild hybrid – These vehicles use a very basic set of technologies to primarily focus on fuel economy. The major technologies employed are usually start-stop systems that turn off the engine during idling periods such as red lights, and regenerative braking systems that store energy usually lost during braking. Many automakers choose not to market these as hybrids at all, since they involve minimal modifications to the drive-train. For example, GM markets mild-hybrids on their Buick-line as simply an added "e-Assist" option.

Full hybrid – Full hybrids, or conventional hybrids, like the Toyota Prius, are traditional hybrid vehicles that employ small battery packs, and all the same technologies as a mild hybrid, but to a greater degree. These hybrids do not have to be plugged in, but do have a short all-electric range (usually 1-2 miles), although this is generally not advertised. In general, these vehicles use a combination of the gas and electric motors to drive the vehicle forward.

Plug-in Electric Hybrid (PHEV) – These vehicles take the full hybrid concept and increase the battery size, such that it can sustain an all-electric range that is further. The term PHEV generally refers to a parallel hybrid, which means that the gas engine can power the drive train directly. The electric engine operates in parallel with the gas engine, also providing motive force. The Prius PHEV uses this platform, and has an advertised 14 mile electric range (Stevens).

Range Extender – This vehicle type has a number of names, including series hybrid, and Extended Range Electric Vehicle (EREV). In these vehicles, the gas engine is replaced with a gas generator, whose only role is to charge the batteries for the electric motor. The electric motor provides all of the motive force for the vehicle. In other words, the electric motor operates in series with the gasoline generator, serving distinctly separate roles. The Chevy Volt is advertised as this type of vehicle, with an all electric range of about 40 miles (General Motors). In theory, the range extending function can be provided by energy sources other than gasoline, such as natural gas or hydrogen.

The figure below compares a plug-in hybrid electric vehicle, the Toyota Prius PHEV, with an extended range electric vehicle, the Chevy Volt.

Specifications	Chevy Volt	Toyota Prius PHEV
Vehicle Class (GI)	C	C
Range	40 miles electric (between 20 and 50) + 260 miles gas range	13 miles electric + 500 miles gas range
Horsepower	150 hp	134 hp
Torque	273 lb-ft	105 lb-ft
Fueling / Recharging	120V / 240 V In-home charger $2000	120 V / 220 V
Price	$350 / month + $2,500 $33,500 (with subsidy)	$27,000 - $34,000 (without subsidy)*
Availability	11,000 in 2011, 45,000 in subsequent years	24,000 per year, starting in 2012
Top Speed	100 mph	100 mph

Comparison of the Chevy Volt EREV and the Toyota Prius PHEV (General Motors), (Stevens)

Fully Electric Vehicle – This vehicle type is also known as a Battery Electric Vehicle (BEV) or sometimes fairly ambiguously as an Electric Vehicle (EV). This vehicle does not have a gas engine or gas generator. Instead, it relies fully on its battery packs to provide the electricity needed to run the electric motor. All of the motive force on this vehicle comes from the electric motor. The primary example of this today is the Nissan Leaf vehicle, with an electric range of about 100 miles (Nissan).

Electric vehicles, including plug-in hybrids, range extenders, and fully electric vehicles require charging infrastructure to support their electricity needs. While the fundamental electric power infrastructure is in place to support this, it needs to be adapted for the specific needs of electric vehicles. Specifically, quick-charging infrastructure that allows electric vehicles to charge quickly at high voltages needs to be installed. In many cases, this requires upgrades to the supporting grid infrastructure to allow it to adapt to these rapid load changes.
The figure below shows some technical specifications for the only full-electric vehicle currently in mass production, the Nissan Leaf:

Specifications	Nissan Leaf
Vehicle Class (GI)	C
Range	100 miles (varies between 62 and 138)
Horsepower	110 hp
Torque	210 lb-ft
Fueling / Recharging	120V / 240V In-home charger $2200
Price	$349 / month + $2000 $25,280 (with subsidy)
Availability	20,000 at launch
Top Speed	90 mph

Technical Specifications for the Nissan Leaf (Nissan)

Hydrogen Vehicles – Hydrogen vehicles can take two major forms. The first is as a modified internal combustion vehicle, where the combustion fuel is hydrogen instead of gasoline. Ford, BMW, and other companies have explored this form of hydrogen propulsion in concept vehicles. The gains from using hydrogen in this form are a higher combustion octane and lower emissions. The second form of hydrogen vehicles uses fuel cells as its power source. General Motors, Honda, and other companies have explored this. Fuel cells take hydrogen and oxygen and produce electricity to power an electric motor, so vehicles using fuel cells are essentially electric vehicles. However, due to the relatively inflexible nature of electricity production from fuel cells, a battery pack or capacity pack is generally required to help buffer the power consumption of the vehicle. Thus, all hydrogen fuel cell vehicles are generally range-extender vehicles rather than fuel-cell only vehicles. However, incorporating both hydrogen fuel cells and batteries in a single vehicle makes it more expensive than sticking with a single technology, such as batteries, or coupling that technology with relatively cheap, existing gasoline generators.

The main impediment to hydrogen vehicles currently is a lack of infrastructure. There are only a handful of hydrogen fueling stations in the nation, and they sometimes operate on differing standards. While some concepts have been proposed for in-home hydrogen fueling via natural gas reforming (Honda), these concepts are still somewhat expensive and have yet to become compact enough for most homeowners. In addition, producing the hydrogen from natural gas decreases the emissions reduction benefit, and can be expensive compared to gasoline depending on the price of natural gas.

The figure below compares technical specifications for several hydrogen vehicles. Unlike the previous comparisons, these vehicles are only in limited production, not mass production.

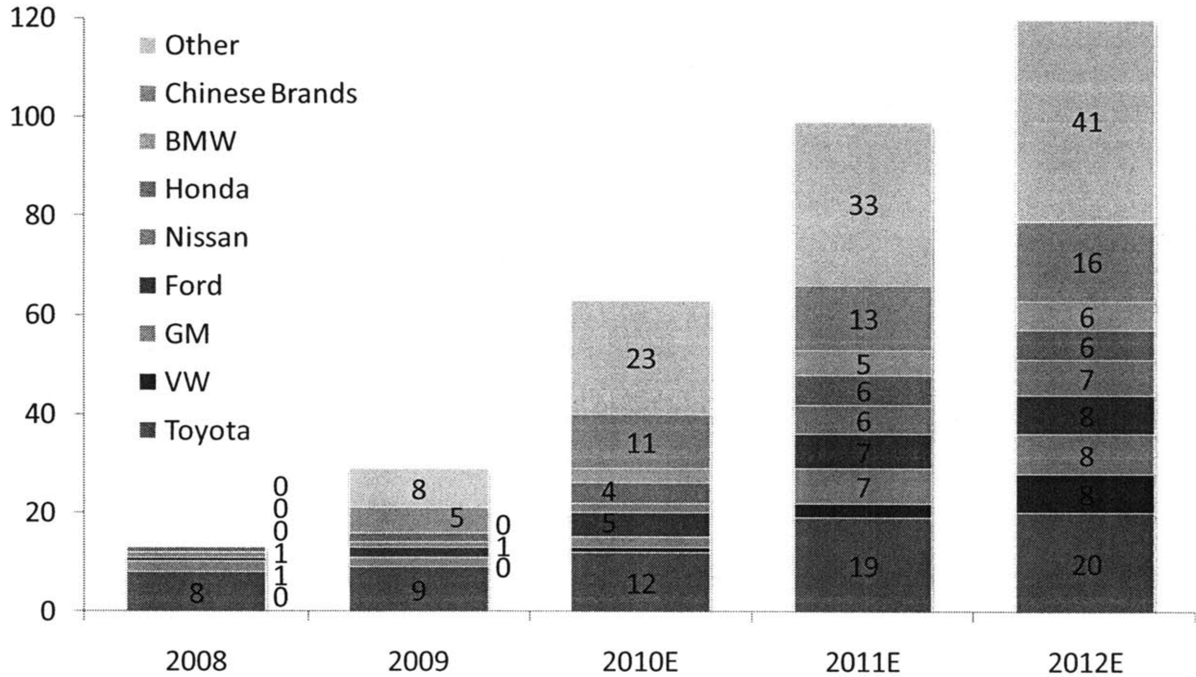
Specifications	Honda FCX Clarity	MB B-Class F-Cell	MB A-Class F-Cell (previous gen)
Vehicle Class (GI)	C	C	C
Range	170 – 220 miles	~250 miles	~110 miles
Horsepower	134 hp	136 hp	87 hp
Torque	189 lb-ft	215 lb-ft	156 lb-ft
Fueling Pressure	5,000 psi / 35 MPa	10,000 psi / 70 MPa	5,000 psi / 35 MPa
Price	$600/month	$600-$800/ month (fuel included)	n/a
Availability	200 people, primarily CA	200 people, primarily CA	60 cars
Top Speed	100 mph	106 mph	87 mph

Technical Specifications for Various Hydrogen Vehicles (Honda), (Mercedes Benz)

Others – Other alternative fuels, such as bio-fuels (ethanol, biodiesel, etc), natural gas, petroleum derivatives, compressed air, and others are available. However, I will not explore these in detail as they are generally not considered viable long-term, mass-market alternative fuels that could replace gasoline and reduce greenhouse gas emissions. They may indeed have important applications in niche markets in the future, and those should not be ignored. However, they are not within the scope of this analysis.

Competition in the Current Market

The market for alternative fueled vehicles continues to become more crowded, and is expected to continue to crowd over the next few years. While the hybrid market continues to saturate, the PHEV, EREV and full-electric market are currently much less saturated. However, most automakers have publicly announced plans to enter the PHEV, EREV, EV markets with one or multiple offerings. The figure below shows historical and projected nameplates in the hybrid and electric vehicle market (includes PHEVs and EREVs).



Hybrid and Electric Vehicle Historical and Projected Nameplate Count (JD Power)

Other includes Hyundai, Mistubishi, Fisker, Tesla, Diamler, etc
Chinese Brands include BYD, Chery, SAIC, Tianjin, Geely, etc

These new market entrants represent a wider diversity of form factors, propulsion options, and price points, which will generally make alternative fueled technologies more available to the general public. However, from an automaker perspective, this means that the terms of competition will become more varied and intense. A number of competitive factors emerge as key variables to distinguish between various automakers. I label these factors as either convergent (automakers will agree on a standard level of performance or quality) or divergent (automakers will use this factor to differentiate their product).

- Size – While most PHEV and EV vehicles released so far have been C segment vehicles (Volt, Prius PHEV, Leaf), it is almost certain that as the technology becomes more compact and higher energy and power densities become cost effective, both larger and smaller vehicles will become electrified. In general I believe this will be a divergent factor.
- Propulsion Technology – Drivetrain and propulsion technology has become increasingly fragmented as a result of different visions about the future of alternative fuels. In general, I believe that drive-train technologies will converge upon electric propulsion due to the cost-effectiveness of deployment versus other technologies, but within that there will be wide divergence as to the extent and method of electrification. The model for this is hybrid technology, which now has diverged tremendously to mild hybrids, full hybrids, and plug-in hybrids. This provides the advantage of industry-level and firm-level economies of scale and learning effects in electric vehicles, but allows automakers to differentiate their product by changing the implementation.
- Range – This is an area where automakers compete, especially for fully electric vehicles. It is an easy measure of performance for electric vehicles, since it combines fuel efficiency and

battery pack size. I believe this is an area for competitive differentiation and thus divergence for automakers.

- Price – Pricing for alternative fueled vehicles is tightly bound on the lower end by higher costs of the vehicle, and on the higher end by the price of comparable vehicles. Given that many automakers are taking the shared platform approach for electrification (making an electric version of an existing vehicle, rather than creating a dedicated electric vehicle), there is often an easy comparable in the gas version of the vehicle. Thus, I expect this to be an area of convergence for automakers.
- Positioning – While the first entrants into this market have successfully taken the "green" or "high tech" monikers, later entrants will have to position against the market leader. For example, once the Prius had established its lead in the hybrid market as a green leader, it was difficult for secondary hybrids to enter as "greener" on the same attribute without a significant leap in technology. Secondary entrants in the PHEV, EREV, and EV market will have to position against the Prius PHEV, Volt, and Leaf, respectively. It is likely that they will choose other attributes, such as sportiness/performance, interior space, design/style, or luxury to create a perceived difference between themselves and the existing market leader / first entrant. This will result in divergent positioning in the market.

Lessons Learned for Automakers

Understanding Consumers

Buyers of alternative fueled vehicles are unlike other buyers in the traditional automotive market. They have unique characteristics, needs, and backgrounds that present new challenges for automakers. At the same time, their higher level of involvement and education present opportunities for automakers to engage them for feedback at higher levels than the general population.

Managing Early Adopters

Within the automotive market, we expect early customers for alternative fueled vehicles to be somewhat different from typical automotive consumers. Compared to the typical population, one study found that early adopters for new automotive technologies tend to (Williams):

- Be wealthier, with typical household incomes above $100 K
- Be older, with typical ages 35-55
- Have more cars, with 2 or more cars per household
- Have a higher level of education attainment, mostly with a college degree
- Have a higher rate of home ownership

However, we also need to note that these characteristics could also describe the difference between the general new car buyer population and the general public. In theory, these early adopters should be even more pronounced on these factors. However, catering to high-income, highly-educated customers can pose problems for a brand whose typical customers are not of that segment. Specifically, the dealer show-room is an area where high-end users may find the buying experience to be lacking. In that regard, there are a number of things that automakers can do:

- Provide specialty training to dealers – It is expected that early buyers would be highly knowledgeable and have complicated questions about the vehicle. Early Volt dealers were given a specialized training including separate materials in order to help prepare them for the Volt.
- Provide a "show-room within a showroom" experience – A separate mini-showroom can be provided to funnel these buyers too. This is analogous to creating a "micro-site" within a website to host the new buyers.
- Go to the customer directly – Some automakers, like Hyundai, are using this approach to sell vehicles that don't normally fall within its customer range. Its Equus sedan, which is a very high end luxury car with 2-3 times the normal price of its vehicles, is sold directly to consumers. Specially trained salespeople drive the car to the customer's home at a pre-arranged test-drive appointment. This custom service is consistent with the individualized luxury experience that many of these customers desire
- Lean on online experiences – Increasing online content is an important part of satisfying the information needs of these early buyers. However, online experiences alone often cannot satisfy these needs, as the automotive sector in particular is a high-interaction industry. Creating websites with plentiful content, however, can help customers feel more involved and informed, especially for new technologies that they do not necessarily understand.

It is also expected that these early adopters will push their vehicles far beyond the typical performance characteristics that they were designed for, and even begin to modify the vehicles internally. This was the case with the Prius, where many early adopters decided to add battery packs, change the battery control mechanisms, and reconfigure the vehicle to better suit their needs. Much can be learned from these lead user innovations, but support must be provided for them. Some examples of what automakers can do to support these innovative early adopters are:

- Provide designated test or beta vehicles early on - The Volt provided early test models to universities, labs, and some companies like Google to see what they would do with it. These users can provide additional R&D to the automaker at little or no additional cost. Their innovations can sometimes be incorporated into the final product with few modifications.
- Provide separate product support for the first batch of users – The first set of users will likely have highly technical questions, and will want support beyond what typical dealers and customer support staff can provide. It makes sense to provide a direct line for customers to call in or e-mail to, staffed with technically sophisticated staff.
- Merge educational and marketing materials – Some automakers are choosing to provide educational content for these early adopters directly through their marketing. For example, automakers can directly mimic the in-home fueling experience for users by recreating an in-home fueling station / garage in their dealers, and showing customers how it will work. This provides a visible marketing platform as well as an educational experience for users.
- Provide rapid-response problem solving for early adopters – Some early adopters are expected to push their vehicles beyond the suggested limits. This may result in stranded vehicles, for example, that can end up in the press. To avoid this problem with their Leaf vehicle, Nissan has deployed specially-equipped tow trucks for their early Leaf customers, to provide a rapid charge to a stranded vehicle that allows it to get home. This type of rapid-response contingency planning helps to avoid negative early adopter experiences.
- Filter your early adopters – This is difficult to some extent, but a good marketing campaign should also define who it is not targeting, or who should not be part of the customer base. In this case, users that are not likely to be able to adapt to the technology quickly and accept flaws in early versions may have negative experiences with the product. Customers that do

not fit the target segment should be filtered out or referred to other vehicles that better suit their needs.

THE GREEN PREMIUM

Another major open question in the automotive community is how large the so-called "green premium" is, and how many people would be willing to pay it. According to a recent study by GfK Automotive Research, the landscape is mixed (DeVeaux):

- 42% of consumers plan to buy a large vehicle with a conventional engine
- 22% of consumers plan to buy a small vehicle with a conventional engine
- 36% of consumers plan to buy an alternative fueled vehicle, of those:
  - 67% of consumers say it is because they want better gas mileage
  - 25% of consumers say it is because of the environment
  - 7% of consumers say it is because of the technology

From this it can be said that 9% of new car buyers would buy an alternative fueled vehicle primarily for environmental reasons.

The second factor that is important is how much extra they would be willing to pay for these environmental values. A recent review of academic studies about the green premium reveals that on average, studies find that typical consumers will pay about 10% extra for a green product assuming that quality and performance are otherwise similar (Cotte). An unrelated study by Deloitte found that when younger car buyers were asked how much more they would pay for an environmentally-friendly vehicle, that:

- 11% would pay "a lot more"
- 36% would pay "somewhat more"
- 33% would pay "slightly more"
- 20% "would not pay any more"

This suggests that there may be a segment of the population, perhaps 9%-11% that is truly willing to pay significantly more for a green vehicle, perhaps in excess of 20% of the base price of the vehicle. However, to reach the rest of the population, a smaller premium would have to be charged for green technology, perhaps no more than 10% of the base price of the vehicle.

The 10% of the population willing to pay a large premium (>20%) for green are referred to by many as the "dark green" or "deep green" segment. They use environmental performance as their primary decision criteria when making purchases, are well informed about the environmental performance of their options, and are concerned more about actual environmental impact than just the image of being green. They are willing to make significant compromises on other factors in order to get truly green performance. An example of a product that is successful with this group is the Seventh Generation line of bathroom tissue. This product is generally much more expensive than conventional bathroom tissue, is much rougher than competitors, and does not last as long per purchase. However, on the environmentally friendly aspect, it far outperforms other brands, and is made from 100% recycled paper, is whitened without chlorine, and does not contain dyes or fragrances (Seventh Generation). Dark Green consumers are willing to pay more while sacrificing other factors, such as comfort, convenience, and usability in order to fill their green value.

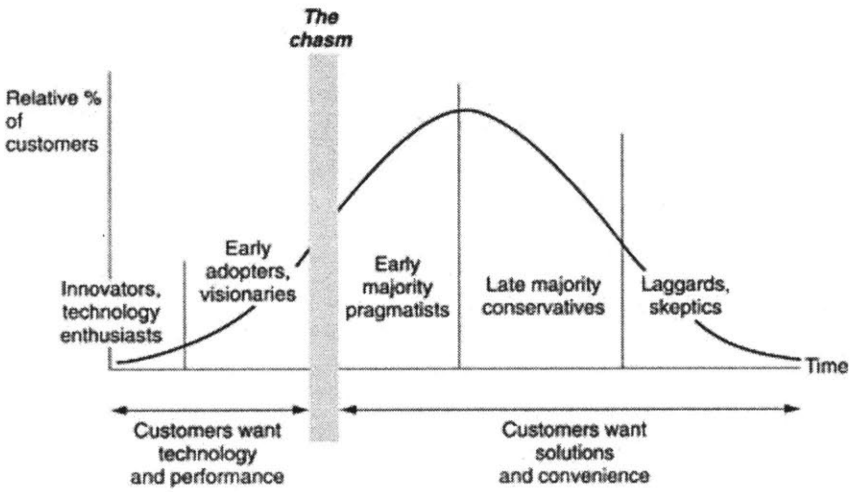
The next segment of the population, who are willing to pay an above-average green premium (10-20%) for a vehicle, I will label the green-plus-x segment. These people are willing to pay a premium for green but generally want to see green coupled with something else that they value, like fuel efficiency, savings, new technology, or social prestige. For them, environmental performance is not the primary criteria for purchases, but is definitely one of the top five criteria. They may be willing to compromise on some factors to get green performance, but a significant compromise is out of the question. This segment is much larger than the Dark Green segment, composing between 25%-35% of the population by my estimate. An example of an existing, successful product that appeals to these consumers is compact fluorescent light-bulbs, or CFLs. CFLs offer environmental benefits through reduced energy consumption, but have other primary benefits such as reduced electricity bills, longer operating life, and greater durability. There is a small tradeoff in that the light does not come to full power instantaneously. Nonetheless, a large portion of the population now successfully uses CFLs for their lighting needs, and is willing to pay a reasonable upfront premium for them. The combination of green-plus-savings-plus-technology-plus-durability qualities appeal to the green-plus-x segment. That is not to say that there is a single unifying X factor that appeals to all members of the segment. X will vary within the segment, but there are several X's that are common to the group, and a combination of these valued added factors can greatly expand the appeal of a product.

The third segment is only willing to pay slightly more for green (<10%), and comprises about a third of the population. I call this segment the light-greens. This group is sometimes interested in green, but as a second-tier attribute. They generally do not do extra research to find out about green attributes, but sometimes remember when they are told through advertising and the media. They are generally unwilling to compromise much if anything to get green performance. Often they wait for green attributes to go "mainstream" before they purchase products with them. One example of a product that has been successful with this segment is recycled paper. Recycled paper now is largely indistinguishable from virgin paper, and most paper on store shelves contains at least some recycled content. Most people will not have to pay extra for recycled paper, but in many cases the vast majority of people will pay slightly more for recycled paper over virgin paper if all other attributes are equal. This is an example of a mainstream green product.

The final segment of people, comprising about 20% of the population, will not pay anything extra for green attributes. I call them green-offs. If they are to purchase green products, it is likely due to regulatory changes or widespread adoption and normalization. They do not seek information about green products, and they do not care. An example of a green product that has been successful with this group are catalytic converters, which are now mandated by law on all vehicles. Regardless of whether or not these customers want to pay extra for this product, they must due to regulations.

Managing the Innovation Cycle

The divide mentioned in the previous section between the four major segments maps nicely to the innovation cycle theory of new products. The figure below shows a typical innovation cycle. Different user segments choose to adopt the technology or not depending on their receptiveness to new technology. Over time, however, the adoption of each group influences the eventual adoption of subsequent groups. New technologies must successfully cross "the chasm" of adoption in order to penetrate the mass market.



The Innovation Cycle by Customer Segment (Moore)

There is another interesting pattern that can help to explain the shape of this innovation curve. That has to do with the pattern costs over time, subject to the learning curve and economies of scale, and the resulting impact on the end customers' total cost of ownership. Given that the cost of ownership is expected to decline over time more quickly for alternative fueled vehicles than conventional vehicles, later customers will face a lower economic premium than early adopters. This means that the consumer benefit from buying an alternative fueled vehicle over a conventional vehicle can be lower for later adopters.

Cost of Ownership

It is apparent that eventually, the alternative fueled vehicle becomes cheaper to own and operate than a conventional vehicle. In this case, that case changes in approximately 2018. However, in reality that point is quite uncertain. In addition, a lower total cost of ownership an alternative fueled vehicle does not necessarily imply widespread adoption. Fuel efficient vehicles today have a lower total cost of ownership than gas guzzlers, but they do not always sell as well, because of other important criteria that consumers hold. Nonetheless, all else being equal, the fact that the alternative fueled vehicle becomes cheaper in the future implies that there may eventually be an economic case for segments that do not necessarily regard environmental performance as their top criteria (ie: the green-plus-x and the light-greens) to consider adopting these vehicles. The point at which the auxiliary benefits from these vehicles are compelling enough to cause the majority of consumers to choose them over conventional vehicles can be considered a tipping point for their adoption. Reaching this tipping point is a function of the cost and price decline of the vehicles, macro factors, and the relative preferences of consumers with respect to the relevant dimensions of the vehicle. In other words, consumers are constantly evaluating the tradeoff between green vehicles and their alternative conventional vehicles. When they consider the package of attributes offered by the green vehicle to be superior to the package of attributes offered by the conventional vehicle and align their purchasing behavior to reflect that view, the green vehicle will have reached a tipping point in consumer adoption.

The Targeting Decision

The targeting decision for alternative fueled vehicles can be difficult. While it may seem intuitive to simply go from highest willingness to pay to lowest, targeting the dark greens initially, then moving to the green-plus-x's, and then the light greens and the green-offs, this is not always possible. Specifically, if the environmental innovation being sold is an incremental innovation rather than a fundamental innovation, it may be difficult to convince the dark greens that the innovation truly is good for the environment. For example, in the automotive segment, many dark greens choose not to use automobiles altogether, instead using public-transportation, bicycles, ride-sharing, and other modes of transportation. Convincing them that an electric vehicle is as good for the environment as their bicycle is a difficult if not impossible task. In addition, dark greens are often not as receptive to new technologies as their spot on the innovation cycle might imply.

Thus, companies may want to start by marketing to the green-plus-x segments, based on their relatively high willingness to pay for the green premium, and also their affinity for other factors. If car companies can take the green attributes and use them to produce other synergistic attributes, such as greater fuel efficiency, more space, quieter operation, or other factors that green-plus-x consumers value, then that may result in a broader target market and wider adoption than going after skeptical dark greens directly. The dark greens may become later adopters, in this case, once the environmental credibility of the new product is proven. This became the case with the Toyota Prius, for which the green-plus-technology segment proved to be the key early adopter, and then later drew in dark greens with subsequent versions.

Positioning and Brand Considerations

Is it actually possible for a single vehicle to fill all of these different positioning locations over its product lifecycle? Most new products do transition through various user groups over the course of their lifecycle. The people who rush out to buy a new product at launch may not be the same as the steady state customer base that still buys the product three years after launch. Companies that know this can prepare for it and adjust their marketing materials accordingly. The Toyota Prius went through this kind of transition, progressively becoming "greener" as its credibility and fuel efficiency improved. It seems that vehicle refresh points can act as natural break-points for transitioning the vehicle positioning from one type to another.

The brand may also need to shift in order to accommodate the new vehicle, but this is not always undesirable. Chevy, for example, intentionally tried to use the Volt to position its entire brand as more green, high-tech, and youth-oriented. The brand hoped that the Volt could bring new buyers into the show-room that wouldn't have otherwise considered Chevy vehicles. Since "green" is generally considered a positive attribute, it hoped that its new ultra-green car would have a "halo-effect" on its other vehicles. The vehicle also had an interesting effect during General Motors' bankruptcy and bailout, where it provided a tangible reason for employees to keep going. Employees felt they were building the "car of the future", and as a result felt that helped justify their company's reason for continued existence. These kinds of intangible employee motivators are often not considered during vehicle development decisions, but may provide additional benefits to otherwise costly projects.

Marketing Tools

A number of interesting new marketing tools were explored as part of this thesis. These include semantic/perceptual maps (used to map the competitive landscape), innovation cycle management (used to understand the evolution of customer segments over time), learning curve based cost modeling (used to understand the evolution of costs to the automaker over time), and total cost of ownership modeling (used to understand the user's purchase decision's evolution over time).

LEAD USER INNOVATIONS

Perhaps the most interesting new tool explored here has been the use of lead users to help drive innovation during the early stages of a launch. These innovations can come in the form of changes to the design, custom modifications in key features, or constructive criticisms. A number of auto companies have actively adopted this approach in recent times, including:

- Honda, which has leased a limited number of FCX Clarity hydrogen vehicles to selected customers in Southern California
- Mercedes, which has leased a limited number of its B-Class hydrogen F-Cell vehicles to customers for a limited time span
- BMW / MINI, which ran a very successful MINI-E program that leased a limited production run of MINI electric vehicles to customers
- Toyota, which has leased several hundred RAV4-EV models to users

Lead-users are often easy to find because they express interest early on in a product, and will sometimes approach the company without prior solicitation. In addition, early adopters can tend to be geographically and demographically clustered, which makes them easier to organize and address.

However, lead user innovation also comes with risks. Namely, the EV-1 experience of GM shows some of the potential downsides of having a lead user program. When the EV-1 lease program was ended, many participants complained, and a movie was even produced to document the dissatisfaction of these participants.

More recent examples show that a well managed lead user program can significantly reduce the risk of these kinds of problems. Key issues for automakers to consider are:

- Providing adequate technical support for lead users
- Carefully selecting and filtering the initial set of lead users, to avoid bad apples or users with ulterior motives
- Providing a community/forum for lead users to talk with each other
- Providing public recognition for lead users to reinforce positive behavior
- Reducing the number of constraints on lead users, to allow them to make modifications that would normally not otherwise be permitted
- Engaging lead users early enough in the product design process that their changes can be incorporated
- Providing a dedicated feedback channel for users to submit their feedback
- Making expectations about the program clear from the outset, and setting the timeframe for ownership clearly up-front
- Pointing users to similar alternatives upon exit from the program, even if these alternatives are made by competitors

INNOVATIVE PROMOTION ACTIVITIES

Throughout the course of this study, I have also run across a number of innovation promotion activities that have now become more commonplace. These promotion activities are meant not just to promote awareness amongst potential customers, but also to take them the next step and bring them into a show-room. These activities include:

- Micro-sites: The opening of a separate website to provide a customized experience for the new product. The Nissan Leaf used this tactic to differentiate itself from the rest of the Nissan Line. The Nissan Leaf website is separate in both location and design from the rest of the Nissan site, providing a unique and complex experience for those interested in the new technology.
- Building pre-order lists: Both the Nissan Leaf and the Chevy Volt used this method to create a buzz about the product before launch. Due to limited production runs initially, both were sold out for a long period in advance of their launches, leading to additional positive publicity.
- Physical promotion tactics: The Toyota Prius highly visible, physical objects such as giant flower sculptures that provided wireless internet in public and ran on solar power to help promote their 3rd generation Prius launch. This may seem to run counter to the increasing trend of online advertising, but Toyota actually used the free Wi-Fi to help drive customers to its Prius website. Coupling a physical promotion for a short-term impression with an online channel for establishing a long-term connection appears to be an effective way of pushing past the hordes of online advertisements.
- Establishing sub-brands: Taking the brand credibility built by the first launch and using it to market similar vehicles makes sense. The Toyota Prius line is becoming a sub-brand of its own with the launch of additional Prius line vehicles such as the Prius V. The Volt may also take this tactic and expand to a family-sized model as well.
- Localizing promotion content: Due to the limited production of these vehicles, many are initially launched in limited geographical areas. Instead of running national promotions for a limited geographical area, automakers can focus some of their advertising and promotion activities on a limited geographical region where the product will be available. The automaker may still want people in other parts of the country to be aware that they are launching such a vehicle, but much of the direct-engagement marketing can be focused in a certain region, which would result in a higher impact.

Modeling and Simulation

In order to understand the trade-offs and decisions that automakers and automotive customers must make in thinking about alternative fueled vehicles, a model was developed. This model allows users to understand the impact of macro influences, cost changes, pricing, and technology changes on the overall adoption of alternative fueled vehicles. The model takes two simultaneous perspectives:

- The automaker: Primarily concerned about maximizing profits, but willing to take a long time horizon when it comes to alternative fueled vehicles because of societal or brand benefits
- The automotive customer: Assuming equal performance otherwise, primarily concerned about minimizing costs, but willing to take a long time horizon to recoup savings when it comes to alternative fueled vehicles because of societal or personal benefits

Key Features of the Model

The model takes a novel approach to modeling by introducing the cost of ownership perspective of the buyer, which has generally been ignored in the automotive literature. It combines this with the profit perspective of the automotive company to provide a realistic view of whether an automaker would actually engage in such a project, and whether an automotive customer would really choose the vehicle over a similar benchmark vehicle. Other key features of the model include:

- The ability to input assumptions for PHEVs, EVs, and Hydrogen vehicles separately
- The modeling of separate learning-by-doing rates for each technology
- The ability to modify the baseline comparison vehicle without changing major assumptions
- The ability to look at cost-of-ownership tradeoffs between technologies for customers

The model essentially allows users to take a rational economic view towards alternative fueled technologies rather than a more qualitative approach.

INPUTS

The model allows users to customize macro baseline assumptions for the analysis, including factors such as gas prices, miles traveled per year, and a comparator baseline vehicle. It also allows users to input vehicle technology specific factors, such as vehicle utility factors for PHEVs (which designate the % of vehicles traveled under gas versus electric), battery costs, hydrogen costs, and other factors.

The figure below shows the inputs to the spreadsheet and their default values.

General	User Input Values	Default Values	Units
Initial Price of Gasoline	$3.50	$3.50	/gallon
Gas Price Escalation	3%	3%	/year
Price of Electricity (base)	$0.118	$0.118	/kWh
Electricity Price escalation	2%	2%	/year
Miles Driven per Year	12,000	12,000	miles/year
Miles Driven per Day	33	33	miles/day
Increase in Miles Driven	0%	0%	/year
Discount Rate	10%	10%	/year
Initial Fuel Economy	33	33	MPG
Fuel Efficiency Improvement Rate	3%	3%	/year
Gas Use Per Year	364	429	gallons/year
Cost of Producing Baseline Vehicle	$18,000	$15,000	$
Price of Baseline Vehicle	$23,000	$20,000	$
Cost of Battery Packs	$500	$500	$/kWh
Cost of H2 Storage	$900	$900	$/kG
Price Premium Erosion Rate	5%	5%	%/year
Starting Year	2010	2015	year
PHEV Specific			
PHEV Electric Fuel Efficiency	5.00	5.00	miles/kWh
PHEV Gas Fuel Efficiency	37	37	mpg
PHEV Initial Max Electric Range	40	40	miles
PHEV Battery Pack Size	16	16	kWh
PHEV Usable Battery Pack Portion	8	8	kWh
% of miles gas	55%	55%	%
% of miles electric	45%	45%	%
PHEV Charging (daily)	2.96	2.96	kWh/day
PHEV Charging (annual)	1,080	1,080	kWh/year
PHEV Gas Use per Year	178	178	gallons/year
PHEV Efficiency Improvement Rate	2%	2%	/year
Initial PHEV Price Premium	$18,000	$18,000	$
PHEV Subsidy	$7,500	$7,500	$
PHEV Subsidy Expiration Year	2030	2020	Year
Progress Ratio	87%	87%	ost multipler per doublin

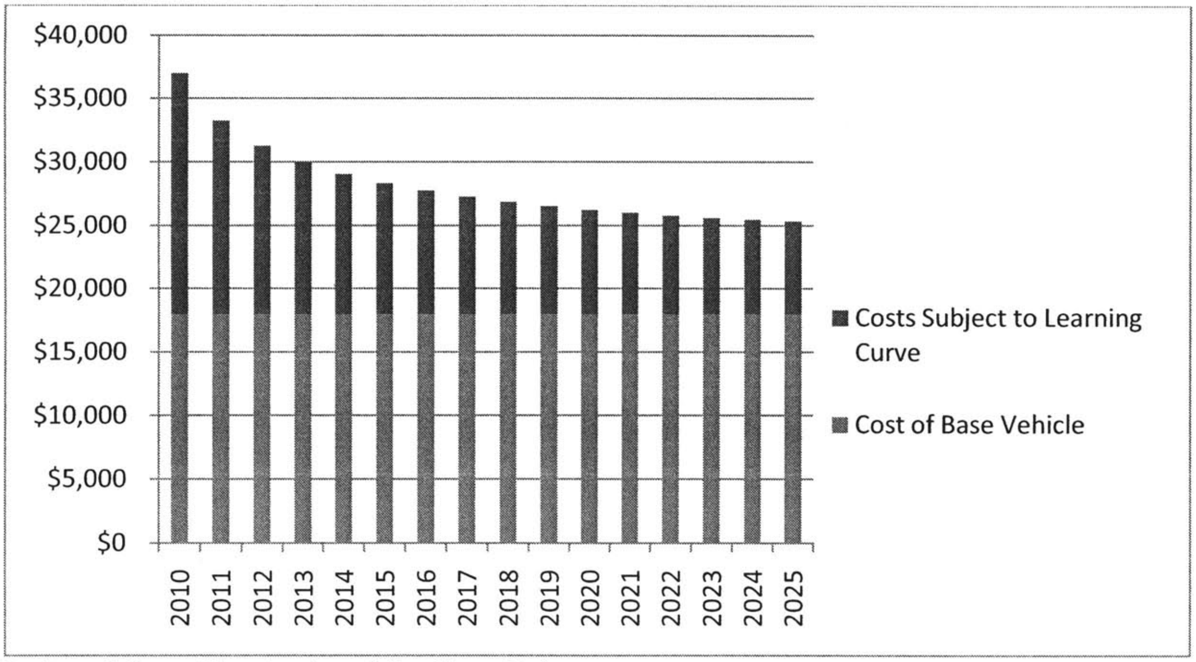
EV Specific			
EV Electric Fuel Efficiency	5.56	5.56	miles/kWh
EV Battery Pack Size	24	24	kWh
Usable Battery EV Portion	18	18	kWh
EV Range	100	100	miles
EV Charging (annual)	2,160	2,160	kWh/year
EV Efficiency Improvement Rate	2%	2%	/year
Initial EV Price Premium	$16,000	$16,000	$
EV Subsidy	$7,500	$7,500	$
EV Subsidy Expiration Year	2020	2020	Year
Progress Ratio	87%	87%	ost multipler per doublin
H2 Specific			
H2 Fuel Efficiency	50	50	miles / kg
H2 Range	200	300	miles
H2 Storage Size	4	6	kg H2
Cost of Hydrogen	$5.00	$5.00	$ / kg
Cost of Hydrogen Escalation	1%	1%	%/year
H2 Consumption (annual)	240	240	kg H2
H2 Efficiency Improvement Rate	2%	2%	/year
Initial H2 Price Premium	$20,000	$20,000	$
H2 Subsidy	$7,500	$7,500	$
H2 Subsidy Expiration Year	2020	2020	Year
Progress Ratio	87%	87%	ost multipler per doublin

Users can vary inputs in the input tab, or directly make changes to the inter-workings of the spreadsheet. It is generally advisable that users default to using the input tab to make changes, because those are easier to reverse if they result in undesirable or unrealistic outcomes.

COST MODELING

The model can look at the cost evolution for specific vehicles over time, as production ramps up, subsidies change, or learning by doing effects. The model looks at both production costs for the automaker and costs of ownership for the automotive customer.

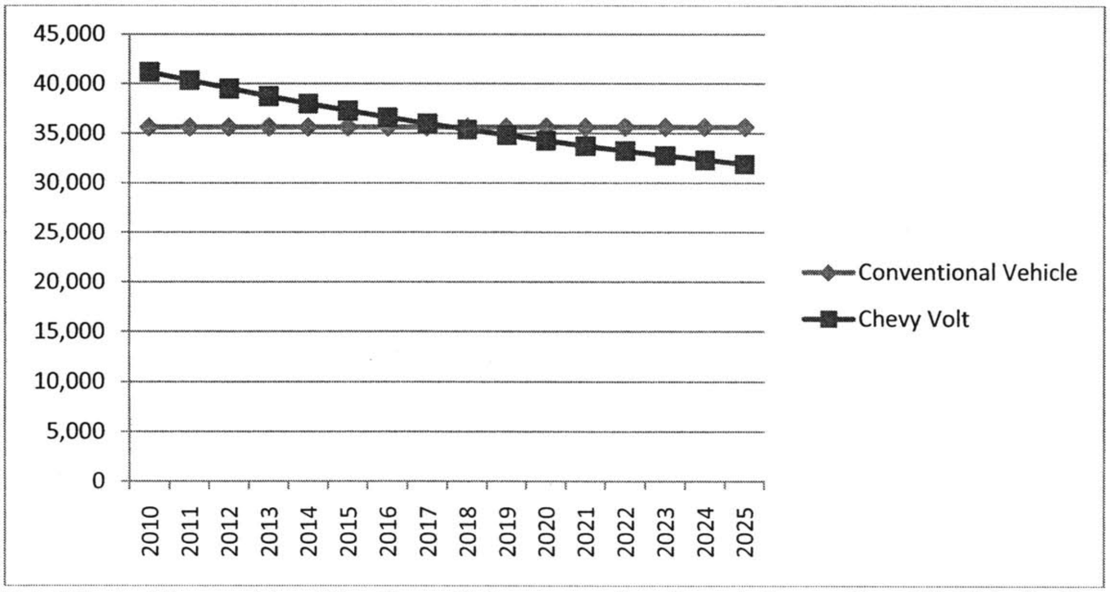
The Chevy Volt is used here as an example. Having been just introduced in late 2010, the Volt is priced at $40,280, or $32,780 after $7,500 federal government subsidy. This is a problem for many car buyers who cannot afford this. The model projects that the current cost of producing the Volt is about $37,000, which results in a low profit margin for GM. However, the costs are expected to fall dramatically over time as a result of learning effects, which are incorporated by the model. The graph below shows the projections for the production cost of the Volt as time goes on, based on a learning curve. It divides this cost between the base vehicle cost and the portion of the vehicle subject to the learning curve.



Projected Cost of Production of the Chevy Volt

It is clear from the figure above that costs are expected to fall rapidly in the first few years, as can be expected with any new technology. Specifically, by the third full year of production, 2013, vehicle costs have already fallen to about $30,000. If pricing is maintained at about $40,000 (before subsidy), this would result in strong profits for the automaker. However, prices are unlikely to stay at $40,000 due to expiring subsidies and competitive entry into the segment. Thus, prices can be expected to fall in a pattern similar to the underlying costs based on pricing pressure from competitive entry. In theory, prices in the market can also be modeled by a learning curve when underlying costs are subject to learning (Sweeney). However, in reality these pricing decisions are strategic variables that do not necessarily track cost declines. The automotive industry is also attempting to move away from the traditional "push" model of automotive sales, which uses heavy incentives to move product when demand falls. The new "pull" model that is closer to on-demand production may result in more steady profit margins for automakers.

The falling price over time, along with changing macro factors such as the price of gasoline, the price of electricity, and the number of miles traveled per year change the cost of ownership equation for consumers. At some point the Chevy Volt will probably become cheaper to own and operate over the lifetime of a vehicle than a conventional vehicle. The figure below shows the model's projected total cost of ownership based on the year of purchase of the vehicle, and assuming 15 year vehicle ownership (approximately the useful lifetime of a new automobile).



Total Cost of Ownership of the Chevy Volt versus a Benchmark Conventional Vehicle, by Year of Purchase based on Expected Changes in Price and Macro Factors

Comparative Modeling

The model can also be used to compare various vehicle options. The model allows users to assess the economics of the vehicle year-by-year as well as over its product lifetime. For example, the analysis below compares the profitability of the Nissan Leaf, Chevy Volt, and Honda FCX Clarity with respect to the automaker, and the cost of ownership with respect to the automotive customer.

Comparison Year	2010	Year		
Buyer's Perspective		Honda FCX Clarity	Nissan Leaf	Chevy Volt
	Coventional	H2	EV	PHEV
Year Purchased	2010	2010	2010	2010
Purchase Price	$23,000	$43,000	$39,000	$41,000
Subsidy	$0	$7,500	$7,500	$7,500
NPV of Variable Costs	$12,614.54	$10,713	$3,009	$7,700
Total Cost of Ownership	$35,615	$46,213	$34,509	$41,200
Automaker's Perspective				
	Conventional	H2	EV	PHEV
Year Purchased	2010	2010	2010	2010
Average Sale Price	$23,000	$43,000	$39,000	$41,000
Cost of Production	$18,000	$41,600	$38,000	$37,000
Profit Made per Vehicle	$5,000	$1,400	$1,000	$4,000

Comparison of Cost of Ownership and Automaker Profit for One Year across Technologies

In this particular case, for the year 2010, it looks as if the EV (Nissan Leaf) provides the lowest cost of ownership for the buyer, but the PHEV (Chevy Volt) has the highest profit for the automaker. This kind of difference is important to determine, because it can provide misaligned incentives between customers and automakers.

The model also shows a more fully fledged model of the financial implications of such a program on automakers. That includes recovery of initial investments in product development and marketing.

Comparison Year	2010	Year		
	Coventional	H2	EV	PHEV
Year	2010	2010	2010	2010
Sales ($)	$115,000,000	$215,000,000	$195,000,000	$205,000,000
COGS ($)	$90,000,000	$208,000,000	$190,000,000	$185,000,000
Gross Profit ($)	$25,000,000	$7,000,000	$5,000,000	$20,000,000
Gross Profit ($M)	$25	$7	$5	$20
Total NPV Profits (DCF $B) First 15 years	$1.15	$1.59	$1.37	$1.80
2020 Sales Revenue ($B)	$0.69	$1.16	$1.07	$1.11
2025 Sales Revenue ($B)	$1.15	$1.76	$1.64	$1.70
Fixed Cost of Development Conventional ($B)	$0.70			
Fixed Cost of Development Alternative ($B)	$1.50			
Fixed Costs Marketing & Advertising ($B)	$0.10			
Other Fixed Costs ($B)	$0.10			
Total Fixed Costs Conventional ($B)	0.9			
Total Fixed Costs Alternative ($B)	1.1			
	Coventional	H2	EV	PHEV
IRR (First 15 Years)	13.1%	14.8%	12.8%	16.8%
NPV With Fixed Costs ($B)	$0.25	$0.49	$0.27	$0.70

Projected Financials for Automaker across Various Technologies

The figure above shows the financial impact of the vehicle development program, across various technologies. In this case, the automaker appears to benefit most from the development of a PHEV (Chevy Volt), which is consistent with the earlier analysis that PHEVs provide the highest profit margin. One potential conclusion from this analysis is that the maker of the EV (Nissan Leaf) is pricing too low, and is making less profit than it could be if it were either pricing at a higher point or producing a comparably priced PHEV instead. It may also reveal differing assumptions within the industry about costs, learning effects, and potential future sales. In this case, it would appear that Nissan is taking a more aggressive stance on the future evolution of costs, and as such is pricing lower than its competitors.

MAIN FINDINGS FROM THE MODEL

A number of major lessons emerged from the model that may be useful to automakers and policy-makers. They are based on a number of scenarios, as well as the baseline model that assumes that deployment of alternative fueled vehicles largely follows the Obama administration's policy projection, which expects 1 million PHEVs on the road by 2015 (Korzeniewski).

- Consumers are very sensitive to assumptions about future gas prices - If most consumers assume a fairly modest rate of increase in gas prices (0%-1% per year) versus a more realistic price increase (3%-5% per year), the resulting disconnect results in a fairly wide difference in valuation of cost of ownership. For example, a customer that estimates the growth rate of the price of gas as 1% instead of 5% is underestimating the 15 year cost of ownership by about $3000.

- Price premiums due to higher costs matter less for luxury vehicles - Because luxury vehicles have a higher margin than mass market vehicles, they experience less % increase in cost and price relative to other vehicles when converted into alternative fueled vehicles. This is because the additional cost to convert a similar sized vehicle is more or less constant across price segments, resulting in a dilutive effect at higher price points.
- Subsidy is the most important for the first five years – Because the learning by doing effect is strongest during the initial scale-up in production volume, the initial cost premium is heavily eroded during the first five years. In the Chevy Volt example, the model projects a cost decline of about $15,000 in the first five years. Thus the government subsidy is expected to have the most impact during the first five years, when the premium is the highest.
- Cost savings for consumers are heavily weighted towards later years – Because the price of gas is still low relative to the price of electricity for many states, initial operating are lower than savings in later years. For example, the one-year operating cost of a baseline gasoline vehicle in 2010 is about $1400, compared to $350 for a Nissan Leaf. Compare that to 2020, when the expected annual cost of operating the gasoline vehicle has grown to $2,200 versus a cost of $400 for the Nissan Leaf.
- Early adopter markets are not always the best economically for consumers – Early adopter markets such as California and New York actually offer a worse economic case than other states because their electricity prices are high relative to their gasoline prices, when compared with other states like Washington or Oregon. California has tried to resolve this by offering additional state-level incentives for buyers of alternative fueled vehicles, but this is an expensive way to deal with the problem.
- Hydrogen vehicles initially may benefit from offering a hybrid or plug-in hybrid mode – Because hydrogen components are so expensive initially and hydrogen infrastructure is so sparse, hydrogen vehicles may benefit from offering an additional on-board gas generator or plug-in battery pack to help reduce costs and improve range. This would make hydrogen vehicles more competitive with PHEVs and EVs in early years.
- Electric vehicles are currently underpriced – Relative to other alternative fuel offerings such as hydrogen vehicles and PHEVs, current electric vehicles (especially the Nissan Leaf) are charging a much lower price premium than the market will bear. This may be an intentional strategy to deter entry, or increase volume to gain learning benefits, but the logic of doing so is questionable when early adopters are willing to pay a higher premium.

The model has a number of implications for automakers and automotive customers in its current form, but could easily be adapted to offer further insights.

Potential Areas for Future Development

While the model takes a first approach at developing a rational economic analysis for alternative fueled vehicle purchase and production decisions, it is still a simplification of the realities involved in the process. There are several areas for potential improvement, including:

- Improved modeling of the learning by doing and economy of scale components – Currently the model assumes primarily learning by doing from internal activities. In reality, much of the learning may occur at an industry scale, and as a result cross-over of learning by doing savings may be limited.
- Improved assumptions about component pricing – Current, components are lumped into "components subject to learning" and "components not subject to learning", and then a

learning curve is applied to the "components subject to learning". In reality, each component should have its own learning assumptions and its costs should reflect those.

- Monetization of externalities – The explicit monetary value of externalities such as greenhouse gas emissions are not taken into account in this model. While it seems unlikely at the present time that a monetary value will be attached to these, the capability could be added in the model if it became a reality.
- More detailed handling of subsidies – Currently the model uses a "phase-out" year for subsidies, to be determined by the user. Alternative arrangements could include a phase-out quantity, a tiered phase-out of the subsidy, or other arrangements.
- Incorporation of multiple vehicle launches – The current model only accounts for a single vehicle launch, in a single year. In reality, automakers push refreshes approximately every 3 years and new models approximately every 6 years. The model could be revised to reflect additional costs for the development of vehicle refreshes and revisions, and the adoption rates that result from those changes. The model would also have to assess what fraction of the learning effects are passed along from model to model.
- Improved modeling of pricing– The model currently takes price and quantity as exogenous variables. In reality there may be very real constraints that prevent automakers from determining price and quantity arbitrarily. Many automakers determine pricing based on a number of factors, including model age, competitive offerings, and the vehicle segment. These factors should not be ignored in making a pricing decision, as they constrain the flexibility of the automaker significantly. In addition, automaker incentives should be taken into account as part of their pricing strategy.
- Bass model for improved modeling of quantity - The model could be improved by incorporating a bass model for the diffusion and adoption of new products. The Bass model would provide a more likely accurate model for the sales of the product, and could be modified to include the impact of phased regional launches, multiple vehicle nameplate launches, vehicle refreshes, and other factors. In addition, the Bass model could be used to better understand the dynamics of the industry or market for alternative fueled vehicles as a whole, especially as additional competitors enter the market. Users could input parameters to a Bass model and receive the resulting sales projection, or they could input their own sales projections if they believed that it would follow a different path based on another model.
- Improved competitive response modeling – The model currently assumes that the impacts of competitive response are exogenous and incorporated in price and quantity calculations. It may be infeasible to fully incorporate the impacts of competition in such a model, but the first order impacts could be included.
- Multiple baseline capabilities – Currently the model assumes the same baseline for each of the three vehicle technologies. Instead, it could break out the baseline and allow the user to specify a separate baseline for each vehicle technology. While this would reduce the comparability of the three options, it would improve the accuracy of comparisons to actual vehicles such as the Chevy Volt.
- Addition of other fuel types – The model currently only handles EV, PHEV, and Hydrogen vehicle types. Other vehicle fuel modeling could follow the same fundamental framework, but would have to incorporate additional assumptions and inputs to accurate depict the changes over time.

CONCLUSIONS

Marketing alternative fueled vehicles is a difficult challenge for automakers. The foundation of the market, the terms of competition, and the customer segments involved are still being defined. But automakers can draw lessons from other industries, previous examples, and recent launches of the Chevy Volt and Nissan Leaf to help guide them. Automakers can deploy new marketing tools to advance their understanding of the market, define the terms of competition, and listen in to their customers' needs. These new tools can help reduce the risk and uncertainty involved with launching new products like alternative fueled vehicles.

This thesis has explored the major drivers of alternative fueled vehicles and historical examples of them, assessed the current strategic landscape, offered lessons for automakers based on case studies done on two vehicle launches, and developed a model to understand potential adoption rates for alternative fueled vehicles.

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