Final Paper
GM strategy with hybrid powertrain technology

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1 Introduction

The internal combustion engine (ICE) has had a long history as the dominant automotive powertrain. However, given the issues of global climate change, air pollution, and oil dependence, the dominance of the ICE has recently been challenged as a result of emerging alternatives. Hybrid-electric technology, the first alternative to an ICE only platform, is the first of these alternatives to move beyond the R+D phase and have profitable sales in the marketplace. Hybrids offer consumers the advantage of increased fuel efficiency while asking them to sacrifice very little in terms of behavioral change. Despite these benefits, however, the technology does come at a price. This price premium has, for long, been so well in excess of base ICE models that the HEV cost-benefit ratio has only just begun turning in favor of hybrids due to increasing fuel prices. Currently, Toyota is best positioned to reap the rewards of the growing hybrid market due to their intellectual property (IP) position, dominant design, breadth of offerings, and current market share. This situation leaves the question, however, as to how Toyota’s competitors, such as General Motors (GM) should compete and formulate their powertrain technology strategy within the current marketplace. This paper will focus on General Motors and their strategy when considering the Hybrid market. We decided to focus on GM’s perspective both because they are in a heated competition with Toyota for world automotive leadership, and because GM is the only company with near-term plans to market a vehicle entry with significant innovation in hybrid architecture. This entry is the Chevy Volt, a plug-in hybrid, utilizing Li-Ion battery technology and a series hybrid architecture. Thus far, GM has been an also-ran in the hybrid market. Their mild-hybrid alternatives have failed to gain a strong market foothold. Additionally, GM’s full-hybrid entries, which are recently entering the market, are doing so with a tremendous disadvantage to the market leader, Toyota. 

This paper will examine whether the Chevy Volt is the right move for GM, what they could do differently, and what their likely success will be.

2 Business Ecosystem Value Creation and Capture

In analyzing GM’s situation, we first considered the Business Ecosystem of the Hybrid Electric Vehicle (HEV) technology. To do this, we evaluated our analysis of the ecosystem’s key players, leaders and followers, and key values. As noted in the last short paper, the ecosystem in which the HEV powertrain operates is one that it dominated by both the battery manufacturers and the owners of the dominant technologies in terms of value capture (Reference Figure 1 for a graphical representation of the ecosystem). Additionally, it is Toyota, who has significant intellectual property domination and a significant
ownership in battery production, who is optimizing their value capture in this ecosystem. Given their investment in marketing, R+D, and production, Toyota has emerged as by far the leader within this ecosystem. Additionally, given their development of the key HEV technology, and their stake in battery production, Toyota is benefiting from strong value capture opportunities. However, despite Toyota’s current dominance, their relative position is not inimitable as Toyota’s product (assuming the profitability equation holds for competitors) in not completely physically unique, and in terms of comparison with GM Path Dependency, Causal ambiguity, and economic deterrence do not apply.

In evaluating GM’s position and value capture within the ecosystem, given their proposed HEV system is uniquely developed and patented technology, they will not suffer from licensing fees on the hybrid sales they make via the Volt. Additionally, given the potential benefits, GM could also capture value by licensing their technology to other OEMs, in the same manner Toyota does today. However, given their lack of stake in a major battery supplier, value capture may be less than is the case with Toyota in the current market.

**Figure 1: Hybrid-Electric Ecosystem**

**Value Creation and Value Capture** – As alluded to, GM is looking to create value in the
hybrid market space by being first to market with a series-hybrid design with plug-in capability. This new powertrain and technology will allow GM to create value through sales to customers who are seeking needs not yet met by HEV vehicles and who may have been displaced due to the closing of the Electric Vehicle market. GM can capture additional value can be captured should they seek to license their technology to other OEMs. Value Capture may subsequently decrease, however, should Toyota’s plan to convert Prius to Li-ion batteries as the MPG benefits the Volt has over the Prius will likely be eroded. Sales and MPG benefits are likely to further be eroded should Toyota successfully introduce their own plug-in version of the Prius. A recent prototype of the “Plug-In Prius” debuted in Detroit this past January.

3 Market Positioning and Demand Opportunity

GM’s Market Position - GM was founded in 1908, and through a series of mergers and acquisitions, quickly established itself as the U.S. leading automaker. It has remained the world’s largest automaker for almost a century. Through its history, GM has had its share of successes and failures. Most notable was its failure in preparing for both increasing oil prices and increasing concern about environmental issues in the 1960s and 1970s. Specifically, in the 1960s and 70s, public awareness of environmental concerns grew, the Clean Air Act Extension was signed into law in 1970, oil prices quadrupled, and sales of large, inefficient cars reduced significantly. Since the U.S. automakers were unprepared to satisfy growing demand for smaller cars, Japanese and European automakers began to export more cars to the U.S. In 1975, Congress enacted Corporate Average Fuel Economy (CAFE) regulations, which added even more burden to the struggling U.S. automakers, and GM was forced to redesign its entire lineup for better fuel economy.

Figure 2: Long-Term Oil Prices, 1861–2006
The conditions of the 1970s are somewhat similar to the current situation of today’s landscape. With sharp increase in oil prices, as well as renewed environmental concerns, company losses for 2007 were $39 billion. This was caused again by GM’s inability to adequately anticipate and prepare for these market influences. As echoed by Bob Lutz, GM’s Vice Chairman of Product Development, “GM needs a product that would boost both its financial standing as well as its position in the market” [1]. Additionally, given the growing concerns about the 2011 CAFE standards, GM must seek to improve its overall emissions portfolio which is somewhat strained given its current lineup (Ref Figure 3).

Figure 3: CAFE target versus current models [2]

Analysts Projections: A Growing Market - Now that we have reviewed both the core technology, and the ecosystem in which the Volt will operate, we must also evaluate the attractiveness of the market as a whole. According to recent projections by Booz Allen Hamilton, a management consulting firm, projections for hybrid Sales amongst major OEMs is expected to be at 20% of all auto sales by 2010, reaching 80% by 2015 [3]. However, given that Toyota (the dominant player in the HEV market) is roughly at 12% market share, and given that battery supply continues to provide a bottleneck to rapid hybrid expansion, we feel the 20% target to be rather overstated. While battery supply may be limiting Toyota’s hybrid share, other players such as Ford Motor Company may be limiting hybrid sales due to marketing and financial considerations. For example, in regards to Ford, lukewarm sales of the Escape and Mariner Hybrid, along with perceived issues around value capture may have made the venture to appear too unprofitable to expand HEV rapidly into additional market segments. Also, given their licensing agreement with Toyota to license HEV technology, branding implications along with perceived power implications may have concerned Ford when making considerations to integrate this technology into
their flagship vehicles such as the Explorer and the F-Series Trucks. The overall penetration of hybrid vehicles according to R.L. Polk is currently at 2% of all vehicles sold [4]. JD Power's estimate of 5% of all vehicle sales by 2015 is slightly more accurate [5]. Given JD Power’s more realistic estimate, the market still seems very promising. With an estimated 6 Million units by 2015 (at current and estimated growth rates for vehicle sales and hybrid penetration respectively), the hybrid market should be one that deserves consideration from, if nothing else, a volume perspective. Reference Figure 4 for a graphical representation of market growth.

![Figure 4: Worldwide Vehicle Sales vs. Hybrid Sales](image)

4 Technology Overview and Infrastructure

In 2007, almost the entire hybrid-electric vehicle (HEV) market of over 350,000 sales was made up of vehicles using the full-hybrid architecture developed by Toyota. The Toyota Prius alone accounted for half of these sales. The Prius architecture can best be described as using the following elements:

- A small gasoline engine as the sole power source.
- An electric machine in parallel with the engine. The electric machine is capable of acting as both a motor to assist the engine, and a generator to charge the battery pack.
- A NiMH battery-pack allowing fully electric operation for short periods of time.
- Regenerative braking
- A unique vehicle platform which exclusively uses hybrid-electric powertrains.
- Graphical display on the instrument panel allowing users to view operation of hybrid technology
The Chevy Volt is still under development, so it is not possible to confirm all aspects of the design. However, GM has released information to the media and internet, so for the purposes of this paper, we will assume that the available data can be relied upon. The Volt is described as having the following elements that differentiate it from the Prius:

- A small gasoline or E85 engine that will extend vehicle range by recharging the battery pack when necessary.
- An electric machine in series with the engine, which will act as the sole source of motive power for the driveline.
- A Li-Ion battery-pack allowing fully electric operation over commuting distances
- Plug-in recharging capability using common household 110V plug.
- The Volt is also going to be a unique vehicle platform designed to take maximum advantage of the series architecture [7].

A third consideration beyond the current Toyota Prius and the upcoming Chevy Volt, is the potential for upgrades to the Prius in response to the Volt. We can assume that two changes are likely:

- Prius will add a plug-in recharging capability
• Prius will obtain a Li-Ion battery-pack that will improve its electric-only range

The first element in understanding GM’s strategy is determining what advantages and compromises are inherent in these technological differences.

**Purchase Price** – The Chevy Volt is going to be a much more expensive vehicle than the Toyota Prius. Indications are that without subsidies the price tag will come in at around $48,000 [8]. In order for “probit” adoption to occur, the cost-benefit ratio must offer a clear advantage. Already the Prius faces significant resistance to wider adoption due to the ~$7000 cost premium versus other compact cars. The Volt technologies must offer compelling benefits to justify the more extreme price premium. Most of the cost premium is driven by the battery pack required for significant electric-only range, so any future plug-in Prius will be subject to the same price premium as Volt.

**Customer Benefit: Fuel Economy** – The Toyota Prius is the most fuel efficient vehicle available on the U.S. market, and its hybrid-electric powertrain provides improvements in the range of 30-50%, although its advantages are heavily dependent on drive cycle. [9] The fuel economy of the Chevy Volt is difficult to assess due to the nature of a plug-in hybrid. If the vehicle is charged overnight and never goes beyond the range of its battery-pack, then an infinite miles per gallon can be achieved. One can assume some average drive cycle and come up with a figure, but this ignores the energy that is still being drawn from the power grid. GM is claiming “triple digit” fuel economy, with a home electric bill of $300. The fundamental consideration is that the wells-to-wheels efficiency of the Prius is limited by the gasoline engine that provides its power. The Volt is limited by the wells-to-wheels efficiency of the power grid, supplemented by a gas engine that can be run at a steady-state for higher efficiency than the Prius. For the consumer, this comes down to operating cost driven by the cost of fuel and the cost of electricity. One cannot say whether the Volt will be good enough in this regard without a more in-depth analysis. Also, in comparison to a plug-in Prius, the Volt should still provide an overall advantage in fuel economy. This will also be drive cycle dependent, with long distance highway driving erasing most of advantages of the Volt.

**Behavioral Change** – The Toyota Prius requires very minimal adjustment by drivers that have grown up with ICE vehicles. Engine shut-off during idle along with no immediate engine start can be disconcerting, but does not really force any change in behavior. On the other hand, in order to get the full benefit of the Chevy Volt’s capabilities, one must plug in the vehicle when not in use. Unlike the EV1, GM has minimized this issue by planning for charging using standard 110V outlets. This avoids any necessity for additional infrastructure, along with any standards battle with other automakers. Also, because the Volt is a plug-in hybrid rather than a fully electric vehicle, the range and charge time issues
that plague EV’s are avoided. Any future plug-in Prius will be subject to the same level of behavioral change, along with standards issues with 110V outlets are not used.

**Interior Package** – In designing the Prius, Toyota took care to develop a platform with an especially roomy interior for its size. However, hybrid powertrains hold a fundamental disadvantage in the extra space taken within the vehicle. Space is at a premium in any automobile, and the electric machine, battery pack, electronics, and other components take up space that would otherwise be available. The Chevy Volt will be at both an advantage and disadvantage. Even with a more efficient Li-Ion battery-pack, the energy storage is going to take up more space than in the Prius in order to give significant electric-only range. However, the series architecture allows flexibility in driveline layout, including the ability to place the ICE almost anywhere in the vehicle. Regarding space-claims, the internal space of a Volt and Prius are probably very similar. A future plug-in Prius however is going to be at a disadvantage if Toyota wants to match the electric-only range of the Volt.

**Exterior Body Styling** – Exterior body styling is very important to the typical vehicle consumer, as it is seen as a way to make a personal statement and can become one of the most critical factors in the final decision as to which vehicle gets purchased. Consumer research suggests that one of the primary reasons for the lack of acceptance for the Honda Insight was the lack of appealing exterior aesthetics. Thus far the aesthetics of the Volt concept have been well received; the production vehicle could end up being significantly different. The Volt does appear to have a more sporty, aggressive appearance than does the Prius, indicating that GM plans to position the Volt a little differently than Toyota does the Prius. [10]

**Fossil Fuel Dependency** – Even if the Prius is able to burn fuel more efficiently than a traditional ICE vehicle, there is still dependency on petroleum products and production of greenhouse gases. The Volt is able to draw upon the power grid, with all the advantages and disadvantages inherent. Overall this is seen as an advantage, although nuclear power has its own issues, and many fossil fuels are used to supply the grid, including coal, natural gas, and oil. One must also consider that both vehicles could be made to use bio-fuels (with E85 planned for the Volt). Bio-fuels have many disadvantages and a mixed environmental record right now, but with process innovations being researched, bio-fuel could become a viable alternative to petroleum, erasing some of Volt’s advantages. Also, a future plug-in Prius would largely erase any advantage that the Volt holds in the area of fossil fuel dependency.
5 Strategic Options and Considerations

Before jumping in to fully analyzing the strategic options that lay before GM, we must first recap GM’s current market position. Given GM’s current model line-up and relatively low volume of vehicles that exceed the 2011 CAFE requirements, there is a need for a high volume, high efficiency vehicle as to put GM in a comfortable position. Additionally, through our market analysis, so long as fuel prices remain high (motivated by global demand increases), demand for hybrid vehicles is expected to grow to a conservative estimate of 6% global vehicle penetration. This will result in a healthy volume of 6 million units per year. Additionally, when considering the HEV ecosystem, we see that currently it is those players who have a stake in the battery market and those OEM’s who have developed their own HEV platform technology who are capturing the value in this market. Given GM’s development of such technology, they have a potential to make their entrance into the full HEV market a very lucrative one, despite not playing in the battery market. Also, conceptually, GM can enter a number of different HEV market niches, such as luxury hybrids, simply by modifying the Volt technology to create a hybrid version that satisfies the needs in this niche. In short, from a purely market potential standpoint, GM has the option to benefit strongly from entering this market with their new Volt powertrain architecture. While the market potential seems promising, additional analysis is necessary to evaluate various aspects of technology strategy, especially in comparison to the current Dominant Design, the Toyota Prius.

Disruptive Innovation – Disruptive technology, as defined by Clay Christensen in The
Innovator’s Dilemma, follows a very specific model of offering ancillary benefits at a low cost when traditional performance parameters exceed the needs of most consumers. This is usually done with a product that gains an initial foothold outside of the traditional market, where the ancillary benefits hold greater importance. GM is not following this path with the Chevy Volt. The Volt appears to be aimed for the mass market, with ancillary benefits (fuel economy & electric drive) but with a high price tag. Christensen’s model would predict the failure of the Volt, and would recommend some changes to GM’s approach. GM’s cost and incentive structure is not set up to support disruptive innovation, and these sorts of vehicles should be developed by a subsidiary better equipped for modest sales figures and low-cost architecture. GM should also avoid taking on the ICE or the Prius head-on, but rather find a secondary market to develop the technology, such as micro-cars or neighborhood electric vehicles. This is in line with the strategy that Ford Motor Company took with Th!nk, but later withdrew from. However, it should be noted that Christensen’s model does not cover all possibilities, and other high-cost high-performance technologies have been successfully introduced, such as fuel injection for automotive powertrains. Thus while initially GM may wish to participate in a specific niche segment, in may benefit from its existing product line development when considering mass market expansion.

Product Tradeoffs and Parameters - As discussed, the initial tradeoffs for this technology are clear. First of all, despite the improved MPG performance, the Volt and the new technology are expected to fetch a very expensive price during its early launch. The price, in excess of $50k, well exceeds $20k(+) sticker of the Prius. Additionally, for local driving experiences, consumers are required to expend local electricity to charge their vehicles adding to the overall cost of vehicle ownership. While the charging of the vehicle may prove cheaper than fuel costs, the price premium and the average electricity costs must be factored when weighing a Volt versus that of the current dominant design. Additionally when comparing this to a standard sub-compact or low MPG vehicle (Often at the $15k mark), the costs trade-offs become even more bleak.

First mover concerns for GM - Despite being second to the US market, Toyota was the first mover in the HEV Global Market. Subsequently, they have become the dominant design, and dominant player occupying large market share in the HEV market. Concerns this first mover advantage may bring for GM is that Toyota has capitalized upon their first-mover advantage by not only branding themselves as an environmental leader, but also establishing a perception of core competency in hybrid systems. This coupled with Toyota’s leadership in QRD (Quality, Reliability, and Dependability), in addition to successful technology licensing agreements with major OEMS such as Ford and Nissan, has positioned
Toyota well in terms of HEV technology leadership [11]. As theorized by Suarez and Lanzolla in *The Half-Truth of First-Mover Advantage*, being first to market can provide competitive advantage during several situations based upon the pace of both technological and market evolution. Suarez and Lanzolla contest that when the pace of technological evolution and market evolution are both slow, a calm water situation emerges. First movers have the benefit in that later entrants will have difficulty differentiating their products, and the slow pace of market growth also tends to favor the first mover by allowing it to identify and adapt to new markets. In this case, Toyota has had the opportunity to do both. Given that the Prius is the current dominant design, the Volt will have the burden to prove its benefits to consumers over that of the established Prius. Additionally, Toyota’s first mover advantage has allowed it to seek entrance into several market niches including luxury.

![Figure 7: Combined Effects of Market and Technological Change](image)

**Adoption Concerns for GM** - Looking past the first mover advantage that GM will need to overcome, GM must also evaluate customer adoption for the Volt product itself. Currently, according to the GM website, for customers driving fewer than 40 miles per day, all energy needs can be met by a battery-pack which can be recharged via a 110 volt household plug. While the benefits of this option are significant, the required change in consumer behavior is also significant. This same situation was a significant concern for Toyota when launching Prius. The early consumer consideration population for the Prius was very concerned about purchase, due to a perceived need to change their daily behavior. Thus when Prius launched in the US, much of the pre-launch advertising was pulled and re-launched with voiceovers communicating the fact that a Prius “Never needs to be plugged in” [13]. However, as confirmed by Gourville, should the benefit of higher MPG be significantly better than that of the current dominant design (the Prius), consumers will be willing to make the sacrifice to individual behavior. However, GM must note that adoption in these
“long haul” cases is slow [14].

![Figure 8: Behavioral Change versus Adoption](image)

**Adoption Rate** - When the second generation Prius launched, it opened to fanfare of the Hollywood types and activists alike. As stated by Leonardo DiCaprio at a Hollywood Awards Banquet in 2001, “I arrived here in my Hybrid Electric Vehicle”. Both groups, in addition to members of the early adopter market, felt that the Prius was a movement by an OEM to reduce the harmful affects of the automotive industry on the environment, and was a sign of OEM responsibility. As stated by head of the Union of Concerned Scientists, “When you drive a Prius, you feel you are part of a movement” [15]. Thus early in its lifecycle, the Prius experienced Epidemic Adoption by some customers who were willing to purchase the vehicle despite the high cost premium and without fully analyzing the environmental impact. Given the initial hype and popularity has already largely been given to the Prius, we see early majority adoption to be more probit in nature as opposed to the epidemic adoption of the innovators and early adopters. Customers considering the Volt will now weigh their options in terms of costs and benefits with current low MPG gas models, and the current dominant design of the Prius.

This understanding also becomes important as GM looks to reach the mass market consumers who are even more discriminating in their purchase factors. According to Mike Jackson, chief executive of a large U.S. public dealership network, “customer do care about fuel economy, but most don't want to pay for it, and don't want to give up anything they have - horsepower, speed and size”. Additionally, Marketing Research suggests interior conveniences, like heated seats and cup holders, are higher in priority (73%) for shoppers, than fuel efficiency (67%) [16].
6 Recommendations

Based on review of the business ecosystem for hybrid powertrain technology, as well as the expected innovation trajectories for the evolution of this technology under the assumption of increasing fuel costs and emissions regulations into the future, we are providing the following recommendations: **We believe it is vitally important for GM to enter the hybrid powertrain technology market with a design of their own and to establish a dominate role in this market space.** This is because this move will allow GM to capitalize on a growing market, and allow GM, through its new technology to position itself as a technical innovator within the marketplace. This move would then bring additional benefits to GM as a result of the Halo Effect, surrounding the image of corporate responsibility that playing in this market will bring. Additionally, given the potential for disruption, GM may just possess the technology which will become the foundation from which all future evolution of the powertrain technology will build upon. However, to ensure all of this, GM must first take the following steps.

1 - **Initially compete as a niche player by launching one product line.** Given Toyota is the dominate player in the existing business ecosystem and has a superior reputation for reliability, GM should initially avoid going head-on with Toyota and target their Volt for a “niche” segment of the hybrid market space that Toyota has yet to occupy. This segment will be unique in that it can capture the now fleeting “plug-in” niche consumers whose needs have not been met since the retiring of the Toyota Rav4 EV. These customers have the need for vehicles who utilize little to no petroleum for daily trips of fewer than 40 miles. It also has the ability to target consumers whose needs fall in between that of the traditional hybrid and the EV vehicle, for example, those customers who stay at the “just over 40 miles per day” trips. During this phase, the pricing of the vehicle should be, and is expected to be, higher than the general HEV vehicles currently on the market given the high recouping of R+D costs and initial marketing and training costs.

2 - **Expand into the general hybrid market upon customer acceptance.** As GM has successfully educated a large majority of customers as to the benefits and technology differentiation that its product brings, it can then begin to attack the general hybrid market and other niches within this ecosystem in which Toyota and other OEMs currently play. To stay in this market it is critical GM continue to advance their series-hybrid powertrain technology and begin offering other vehicle models built on this platform that will appeal to even more of the consumer population. GM may then expand hybrid offering to higher profit margin areas.

3 - **Reduce parts cost by introducing Modular System Architecture.** By introducing the series-hybrid architecture, which is inherently more modular, GM is better positioned...
for incorporating different types of ICE and/or alternate fuel engines. As new types of engines, such as advanced diesel, fuel cells, or engines operating on bio-fuels begin to establish themselves on the U.S. market, GM can easily modify its vehicles to use such engines. Also by establishing standards for modular components, they can benefit from wider supply chain, and reduce time to bring to market innovations and benefit from lower part costs from a variety of suppliers. However, GM will need to be careful with this approach, as history has shown with the IBM System/360 that a modular system architecture can be wildly successful and even drive other competitors out of the market, but without strategic planning this same approach can undermine their dominance in the long term by allowing the emergence of plug-compatible modules by third parties. GM will need to strategize on ways to maintain control over the key value added features, and ensure that they are capable of capturing value from key components, such as batteries.

4 - Market the product benefits and technical innovation. One key hurdle GM has to overcome is the appearance of inferiority due to being a “me too” product. As previously stated, in the somewhat “Calm Waters” of the competitive landscape, Toyota has had the time to position themselves as the clear superior product. For this reason, GM must convince consumers about the additional benefits their technology provides in addition to positioning themselves as a revolutionary technical product. Only by doing this will they help spark the halo affect of corporate responsibility once provided to Toyota, and only then will customers see GM as innovative and not continually compare their performance to that of Toyota’s.

5 – Educate the Consumer. One issue that may perhaps slow customer acceptance of the technology is the required behavior change necessary to use the technology. To help overcome this, GM must continue to educate consumers to the process for customer use, in addition to finding ways to simplify the user process. To do this, a marketing campaign is necessary upon initial release followed by continued user studies as to facilitate the process around the Plug-In Portion of the user experience. As more cars, such as the Plug-in Prius, enter the market place, GM can benefit from competitive education programs and reduce their overall education spend.

6 - Conduct Public Relations (PR) Campaign Stressing GMs Environmental Responsibility. To benefit from the halo effect generated by their “environmental efforts,” it is also imperative for GM to advertise the steps they have taken to reduce emissions and fuel consumption. Thus, a PR campaign is proposed similar to that of both Toyota and GE.

7 - Adapt a “Blue Ocean Strategy”. Given the potential for increased competition, GM may also consider adapting a form of the “Blue Ocean Strategy” as to maintain value capture from its newly developed powertrain. The corner-stone of “Blue Ocean Strategy” is the concept of “Value Innovation”, which
proposes that innovation must create value for the market, while simultaneously reducing or eliminating features and services while doing so at lower costs. In evaluating GM’s hybrid powertrain with respect to this market strategy, it is important to notice the technology innovation trajectory within the automotive powertrain space. As seen in Figure 2, as fuel prices increase, and as government regulation on emissions increases, powertrain innovation will continue to evolve toward fully electric vehicles, hydrogen fuel cell vehicles, or even ICEs fueled by microorganism produced ethanol as promised by Coskata. GM’s series-hybrid architecture is better positioned to more easily incorporate these advances, than the Prius parallel-hybrid architecture. With the series-hybrid, all power to the wheels is from the electric motors and the batteries are charged by the ICE-generator which can easily be changed with future innovations to these other electric power sources. Thus, GM can continue to innovate and create value at lower costs than Toyota on the existing Prius parallel-hybrid platform.

**Figure 9: Stages of Evolution in Powertrain Technology Over Time [17]**

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