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Dr. Rosenbaum and Professor Aldrich:

The following report contains Faraday Consulting's research and discussion on the electric automobile industry.

The data shows that sales have increased by more than a factor of ten within as many years, and as time goes on, it's inevitable that they will increase. Many aspects of the industry that are currently bottlenecked, such as battery production and charging stations, will grow as time passes and the infrastructure and research necessary to improve becomes available.

Another reason that this industry is so strong is that many of the fixed factors of production already exist. All current car manufacturers have built their highly specialized and automated factories, and with the enormous expenditures of producers such as Tesla in the field of extra-high-capacity batteries, the profit margin on electric cars will become much larger very quickly.

The market for electric vehicles is very solid and can be classified as an oligopoly. Because the market has high barriers to entry, investing in new entrants is unlikely to yield long term gains, and investing in the current leaders, Tesla, Nissan, and Chevrolet, is a much safer bet. The three top competitors comprise 76% of the total market, with other major producers of vehicles making up the other 24% of the market.

We hope that this will be useful for your decision-making in the near future. Please reach out to us if you have any questions regarding the report, or wish to discuss the industry in more detail.

Sincerely,

Brady Klein Walter Mays Caleb Ricketts Jacob Sullivan

FARADAY
Consulting

The Electric Vehicle Industry.

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Executive Summary

This report contains Faraday Consulting's analysis of the electric vehicle industry. Since 2010, this market has grown exponentially, and has become one of the fastest growing segments of the automobile industry. The report is comprised of the following sections:

Industry Leaders

After determining that the EV market is an oligopoly, the three firms which make up the core group of producers are examined more in depth. Next, the respective market shares of each core company are discussed, further confirming that Tesla controls an immense section of the EV market, as shown in Figure 1 and in Table 1.

Business Practices

Within material costs (see Figure 2 for more information on cost breakdown), the report shows that once battery costs hit $100/kWh, EVs will attain price parity with combustion vehicles ("Tesla's Gigafactory May Hit $100/kWh Holy Grail Of EV Batteries, Report Predicts," 2014). Also discussed is how much of their respective budgets GM, Tesla, and Nissan devote to research and development, as in Table 2. Finally, Tesla's shockingly successful marketing and production strategies are analyzed, determining why it is doing so much better than the other core competitors.

Demand for EVs

Based upon the multiple regression analysis, the following have been identified as factors of demand: years since 2010, price of the battery per kWh of capacity, price of gasoline, and the price of combustion cars. Though the analysis is useful, it only draws on six years of data, since the market is so new. Because of this, more data would yield more accurate results. The actual data is included in Appendix A.

Overall, the research conducted shows this is a market that likely will continue to grow, due to the large portion of fixed factors of production which already exist, preexisting growth in sales, and strong competition in this oligopolistic market.

Furthermore, based upon the research conducted, consumers will move to electric vehicles as time goes on; the lower costs, lower carbon footprint, and sizable government subsidies for families which purchase such vehicles will all lead to the widespread adoption ("Average Annual Miles per Driver by Age Group," 2018).

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1 Introduction

This report examines the industry leaders for Fully Electric Vehicles (FEVs) in regards to their business practices and technological competition. It also analyzes the FEV market to determine major factors that influence industry demand. For the purpose of this report, a FEV (sometimes referred to as an electric vehicle or EV) is a publicly available automobile which uses electricity as its sole means of propulsion.

Most major automobile manufacturers are developing their own form of electric car; however, the market is currently dominated by three major companies: Tesla, Nissan, and Chevrolet.

This report examines relative costs, overhead costs, business practices, allocation of resources, and industry trends. All information presented is estimated based on reports published by the respective companies and industry averages.

2 Industry Leaders

2.1 Market Competition

The electric vehicle industry is a subset of the world-wide, multi trillion-dollar motor vehicle industry. The overall automobile market is comprised of a core group of vehicle companies that recognize their interdependence on each other, meaning it is an oligopoly.

Oligopolies are characterized as having similar but not identical products, a core group of producers which comprises the majority of the market, and high barriers to entry and exit into this core group. All of these traits are embodied by the EV industry.

Though these firms compete against each other, they also have to compete with the combustion vehicle market as a whole. Lowering prices is paramount for EV companies; all EV companies are attempting to cut costs as much as possible as the current total cost of producing an EV is significantly higher than the current total costs of a comparable internal combustion vehicle.

The largest manufacturers of electric automobiles in the United States are Tesla, Chevrolet, and Nissan. Together, the three companies comprise approximately 76% of the electric vehicle market (McCarthy, n.d.); Figure 1 shows the market share for each of these three companies.

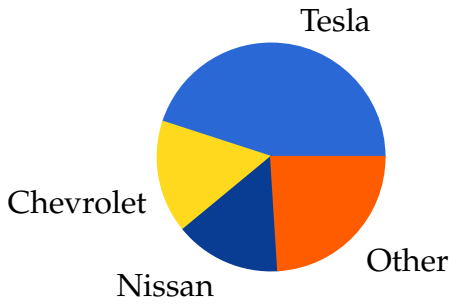

Figure 1. EV Market Share

2.1.1 Tesla

Tesla, a relatively new competitor in the Electric Vehicle market, began operations

in 2003 with a small group of engineers. Five years later, they released the world's first fully-electric sports car, the Tesla Roadster. Since the release of the Roadster, Tesla has continued to pave the way of the industry by releasing the most efficient electric vehicles worldwide. In 2016, they continued to solidify their foundation in electric-only vehicles with the creation of their Gigafactory in Nevada, which will help the company significantly reduce overhead costs over time. Today, Tesla holds 45% of the Electric Vehicle market, and currently sits as the leader in the electric vehicle industry (McCarthy, n.d.).

2.1.2 Chevrolet

Chevrolet has been researching and producing electric vehicles since the late 1990's. In 1996, Chevrolet began commercially producing and renting electric vehicles, but due to very high prices and low customer satisfaction, they quietly shut the program down in 2003 (Voelcker, n.d.).

Chevrolet announced their revitalized entry to the electric vehicle market in late 2010 with the Chevrolet Volt. Since then, they have been steadily producing and improving their electric vehicle lines. Currently, they hold 16% of the total electric vehicle market, due to their Chevrolet Bolt (McCarthy, n.d.).

2.1.3 Nissan

Nissan's EV offering, the Leaf, has its origins in the early 1990's. Nissan's beginning in electric vehicles started in 1991 with the unveiling of the FEV, or the Fully Electric Vehicle at the Tokyo Motor Show. In 2010, the Nissan Leaf was officially unveiled to the public, beginning sales in Q1 2011. Since then, Nissan has taken hold of a respectable 15% of the total electric vehicle market ("Nissan's Electric Vehicle History," 2012).

2.2 Total Market Share

According to data from Statista, the overall market shares for these EV companies are as follows: Tesla: 45%; Chevrolet: 16%; Nissan: 15% (McCarthy, n.d.). Of these, Tesla is the only company that is focused solely on electric cars; the others focus more on traditional internal combustion vehicles.

Table 1. Sales and Percentages of Electric Cars. (in thousands USD)

	Tesla	Nissan	Chevrolet
Total Sales	54,715	1,440,049	596,438
EV Sales	54,715	11,230	14,006
EV Sales %	100.00%	0.78%	2.36%

Table 1 shows the total sales of cars from each company, total sales of electric cars, and the percentage of total sales comprised of electric vehicles. From this data, we can clearly see that Tesla is the leader in electric cars; its car sales are more than triple the number of electric cars sold by Chevrolet. Furthermore, we can compare the two conventional companies on their percentage of electric

cars sold. We see that Chevrolet, while selling a higher percentage of EV's, doesn't actually sell that many more units than Nissan.

3 Business Practices

3.1 Production Process

Material, labor, and overhead costs must be considered in the production of electric vehicles. Due to the high-skill, high-cost nature of the car manufacturing industry, labor will represent a significantly higher percentage of costs than low-skill labor industries (i.e. the majority of retail positions).

3.1.1 Material Costs

The main costs of electric automobiles are the battery and drive train. With recent technological innovations, battery prices have decreased significantly; even so, the cost of manufacturing high-performance, high-capacity batteries remains significant. Tesla, the manufacturer with the least battery overhead, produces batteries that cost approximately $120/kWh. This price point leads to a higher cost compared to internal combustion vehicles; however, once costs reduce to approximately $100/kWh, electric vehicles will reach price parity over their total lifetime ("Tesla's Gigafactory May Hit $100/kWh Holy Grail Of EV Batteries, Report Predicts," 2014).

The drive train, including the electric motor, energy transfer mechanisms, and steering, comprises the rest of the essential inner workings of an electric automobile. These components also comprise a large portion of the total cost of the vehicle.

Cars also require additional features, including a chassis, body, interior, and so on. Figure 2 shows the cost breakdown of manufacturing three of the leading EV models, as well as the cost of overheads.

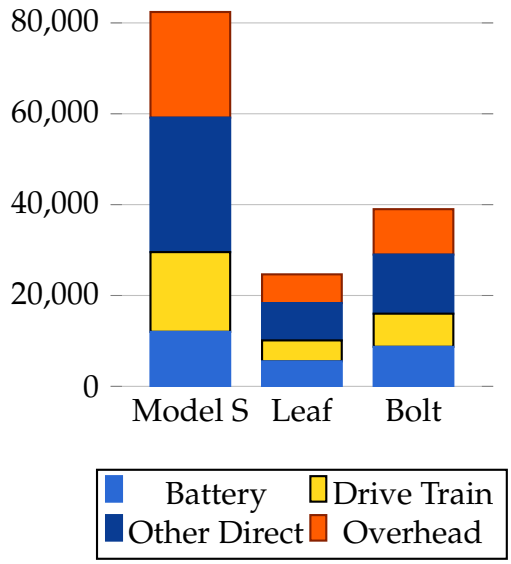

Figure 2. Breakdown of Costs. (in USD)

3.1.2 Company Comparison

Figure 2's data illustrates the position of each of the companies. Tesla, the newest entrant to the market, has the highest overhead per unit, while General Motors and Nissan have substantially lower costs. The costs also demonstrate the differences between the models: the Model S is more of a luxury car (as are

all currently manufactured Tesla cars), while the Chevrolet and Nissan models are more affordable. Tesla's current high costs are in part due to their GigaFactory, which will produce a greater number of units as time goes on, thereby decreasing overhead per unit.

3.2 Resource Allocation

Each company attempting to remain competitive invests a sizeable portion of its retained earnings into research and development. Table 2 shows the revenue for each company, the amount spent on research and development, and R&D spending as a percentage of total revenue ("SEC Filing Database," n.d.). Note that the values for General Motors includes Chevrolet, as well as all other General Motors subsidiaries.

Table 2. Research and Development Spending. (in millions USD)

	Nissan	Tesla	GM
Revenue	51,720	7,000	145,600
R&D	208	803	7,300
R&D %	0.40%	11.92%	5.01%

General Motors's overall R&D expenditures are nearly an order of magnitude larger than Tesla's, but comprise only 5% of GM's revenue. Tesla's R&D budget is relatively larger, due to the facts that it is still offering a limited product line and that it had no prior research in that area, unlike Nissan and GM. Nissan, on the other hand, is spending money on research and development relatively conservatively; its R&D expenditure is less than one percent of its total revenue.

As electric automobiles continue to grow in scope, other car manufacturers will eventually join the increasing market. Tesla is likely to lead the market for the immediate future, but this will depend on the reliability, scalability, and affordability of its vehicle line. The burgeoning EV market is, for the moment, quite volatile.

3.3 Competitive Strategies

Two of the main firms, Nissan and Chevrolet, are also major producers of combustion vehicles. As such, their allocation of funding for advertising revenue can be significantly higher than that of Tesla, which is a significantly smaller company. However, Tesla's CEO, Elon Musk, has built a name for himself with SpaceX, a private space transportation company. This connection has proven useful for Tesla's advertising strategy: SpaceX's highly publicized launch of its Falcon Heavy rocket included a Tesla Roadster.

EV firms' largest point of competition is technology. Given the current state of electric vehicle technology, these vehicles can compete with combustion vehicles from a performance standpoint, but not from a price standpoint. To be truly marketable, electric vehicles will require intense research and development. Again, Tesla has advantages over the other two companies. Due to its GigaFactory, Tesla can now construct all the materials

required for battery production at lower costs than its competitors. Tesla's more advanced technology, specifically battery production technology, means that it is the most innovative competitor in the market.

4 Demand for EVs

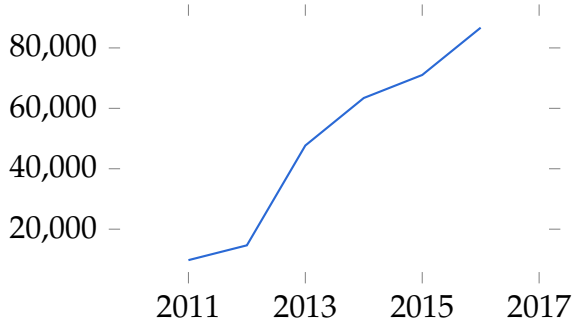

Figure 3. Consumer Demand for Electric Vehicles

4.1 Consumer Demand

Since the inception of the EV market, consumer demand for electric automobiles has grown exponentially. Figure 3 shows FEV sales between 2011 and 2016.

4.2 Demand Factors

The following factors were hypothesized to likely be significant factors in consumer demand. Note that all dollar amounts are adjusted for inflation using the Consumer Price Index (CPI).

4.2.1 Year

EVs are a new market (Rapier, n.d.) ("U.S. Plug-in Electric Vehicle Sales by Model," n.d.). Current sales are limited by vehicle production. As newer companies like Tesla grow their factory input and established companies convert more of their resources to EV production, sales will increase as a result of increasing availability.

4.2.2 Price of Battery per kWh

Batteries are the largest bottleneck for EVs ("Lithium-Ion Battery Costs and Market," 2017). When EVs first entered the market in 2010, batteries cost approximately $900/kWh to manufacture. As batteries comprise approximately 19.73% of the manufacturing costs, on average, high battery prices led to increased price and decreased demand.

4.2.3 Number of Charging Stations

One hurdle for adoption of EVs is a lack of charging stations ("Number of publicly available fast electric vehicle chargers (EVSE) in the United States from 2007 to 2016 (in units)," n.d.). As of 2016 there were 168,000 gas stations in the United States, while there were only 42,011 electric charging stations, most of which are located in California due to its high demand for electric vehicles. While drivers can charge their cars in their own homes, not being able to stop during a long road trip and refuel would be a drawback for many American drivers.

4.2.4 Price of Combustion Cars

Fluctuations in prices of internal combustion vehicles can be assumed to inversely correlate with demand for EVs, as these two products are substitute goods in the motor vehicle market ("What's Hot Off the Lots," n.d.).

4.2.5 Discarded Factors

There are several other factors which might affect consumer demand for EVs; however, regression analysis requires that the total number of variables be kept lower than the years of data. Thus the following factors were not used during analysis due to limited variation in the data or lack of quantifiable metrics.

Google Trends results for "Electric Vehicles," "Tesla Motors," and similar searches proved statistically insignificant in the regression analysis. Median income and average price of gasoline fluctuated very little over the monitoring period and thus were not considered. Consumer expectations for such a new market proved unquantifiable.

Average price of gasoline and annual insurance rates were also considered as factors, due to their integral part in demand for motor vehicles. However, these factors varied little in the period in which they were observed, and so were left out to limit the number of variables required.

4.3 Regression Analysis

Years since 2010 has the largest coefficient in the calculated regression. This supports the hypothesis that the largest factor of current EV sales is time, due to the recent inception of the EV market. Sales are projected to increase for the immediate future ("Global EV Outlook," 2017).

Increased price of combustion vehicles also correlates with an increase in EV sales. The factor is smaller than that of the time variable, but is still statistically significant.

Higher prices of gasoline, which may be assumed to lead to increased demand for EVs, instead leads to *decreased* demand in the calculated model. The correlation with price of batteries is also counterintuitive; increased battery prices apparently correlate with increased sales of EVs.

Sales for EVs are projected to increase for the immediate future. Additional research is necessary to determine further predictions due to limited yearly data from the electric vehicle market. More data could lead to more accurate long-term predictions about this market.

5 Conclusion

Since approximately 2008, sales of electric vehicles have increased exponentially. Although Nissan, General Motors, and Tesla hold a majority of the market, Tesla dominates in sales, and its growth is only projected to increase. Its current negative profit margins are due to the

high costs of creating the manufacturing facilities from scratch (most notably their GigaFactory). General Motors and Nissan have a much lower percentage of up-front cost due to their existing facilities. Tesla's increased future output will offset the cost of building their factories, leading to higher profits and earned revenues.

Furthermore, as battery prices continue to drop, prices of electric vehicles will also decrease. Once the input cost of EV batteries decreases to approximately $100/kWh, the total input costs to manufacture an EV will be on par with internal combustion vehicles. When car manufacturers lower their total production costs, they will either recognize more profit by maintaining higher prices or increase consumer demand by selling more vehicles at a lower cost.

A Regression Analysis

Using a multi-dimensional linear regression solver, we formulated the equation in figure 4.

$$Q = -2,710,946 + 97,303.72T + 429.93P_b - 48,599P_g + 90.01P_c$$

Figure 4. EV Demand Equation

T stands for years after 2010, P_b is the price of the battery per kWh, P_g is the price per gallon of of gasoline, and P_c is the average price of internal combustion vehicles. Each of these correlations is statistically significant: the T statistics are all well above 2, and the overall R^2 value is 0.998. Table 3 shows the data used in this calculation.

Table 3. Market Data for Regression

Year	EV Sales	Avg. Battery Price per kWh	Gas Price per Gal.	Combustion Car Price
2010	0	$1,000	2.78	25,676
2011	17,763	800	3.52	27,082
2012	14032	642	3.62	26,873
2013	46,148	599	3.62	26,873
2014	118,882	540	3.36	26,017
2015	115,262	350	2.43	25,489
2016	149,663	227	2.14	25,332

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