Tesla: Supercharging the Future

by

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"I invented nothing new. I simply assembled the discoveries of other men, behind whom were centuries of work."

–Henry Ford

Introduction

The Inefficiency of Cars Today

Few innovations have had as profound an effect on our society as did the invention of the automobile. What began as a status symbol for the wealthy has revolutionized urban design, employment patterns, goods distribution and economic and foreign policy. Despite its vital role in our lives and enormous strides in technology, cars are still driven by the same internal combustion engine pioneered in 1879. "The internal combustion engine is a complex, amazing machine. In perfect concert, valves open, spark plugs ignite, pistons move, and the crankshaft turns".[1] Unfortunately, with this obsolete and tremendously inefficient technology, the vast majority of energy is lost to thermal leakage so that only about 20% of the power actually reaches the wheels.

There are over one billion vehicles in the world, and with a growing middle class in developing nations, this number will only increase in years to come; some estimates place over two billion vehicles on the planet by 2050.[2] Without a revolution in the auto industry, this means

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[1] Tesla Motors, *About the Size of a Watermelon, with a Lot More Juice*

[2] Brad Plumer, *One Billion Vehicles Hit the Road. Are We Ready for Two Billion?*

billions of barrels of oil and innumerable tons of harmful emissions to be released. However, for the first time in over a century, change is on the horizon. Almost every automaker, from behemoths like Toyota and GM to start-ups like Tesla and Fisker, is working on electric vehicles.

Thesis Objective

The question on every auto executive, policymaker and consumer's mind is whether electric vehicles are a cost-effective replacement for gasoline powered vehicles; if so, what will be the effects on our society? However, the transformation may have already begun, regardless of our intentions or potential ramifications. The install base for cars turns over every twenty years; some industry experts believe that within two decades the majority of new vehicles manufactured will be electric and that by within four decades, most vehicles on the road will be electric.[3] Other experts argue that the internal combustion engine is here to stay.

There is one company in particular that is boldly leading the charge towards an electric future: Tesla Motors. Thus, the focus will be on battery electric vehicles, also known as all-electric vehicles, as opposed to hybrid vehicles, which use both electricity and gasoline. For the sake of specificity, the main focus will be the electric vehicle industry in the U.S., although the global impact will also investigated. In order to better understand the dilemma, the gasoline powered vehicle base will be carefully examined; for instance, the costs to consumers, producers and the environment as well as the benefits of traditional cars are all critical in deciding the necessity for an alternative method of transportation. In addition, the paper will give a brief (and

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[3] Sarah Perez, *Elon Musk: Starting A Company Is Like Staring Into The Face Of Death*

hopefully, interesting) synopsis on the engineering behind electric cars; a better understanding of the technical components can provide insight into the potential for cost savings and risks of the new technology.

Thesis

There is a tremendous amount of excitement, as well as apprehension, in the air of the automotive world. We have reached a point where we can potentially change the world through a synthesis of technology and innovation. We need to carefully analyze the domestic, international and environmental effects of the transition if we are to change the world for the better. The only certainty is that, one way or another, our decisions today will shape the next hundred years of our future.

Tesla Motors offers an exceptional vision; as the first public American car company since Ford, Tesla has led the revolution by mass producing the first line of all-electric vehicles. The company has taken the notion of an electric future beyond theory and in doing so, has set into action the real world ramifications of fundamentally altering one of the most critical aspects of our society.

Tesla Motors will lead the global electric revolution, one which will reshape our national infrastructure, the world economy and the modern day understanding of transportation.

Research and Resources

Research Framework

The implications of revolutionizing our main form of transportation, national infrastructure and energy policies are vast. One of the key research issues will be the economics of energy. In addition to analyzing a gasoline powered vehicle base, the paper will also examine the feasibility of alternatives such as natural gas and hydrogen powered vehicles. More importantly, however, is the electricity that will power these new vehicles. Do electric vehicles offer a sustainable, environmentally-friendly form of transport, or do they merely shift our dependence from one limited resource to another? Both the short-term and long-term economics must be carefully scrutinized to decide if electric vehicles are in fact "greener" than traditional modes of transport.

The shift to battery-power vehicles will also dramatically effect the domestic and foreign policy of the United States. Domestically, we could potentially see a shift from gas stations to recharging stations, in both public spaces and the home. As the United States, the largest consumer of oil in the world (at 18.9 million barrels a day), shifts away from gasoline, the cost of oil would fall drastically; the magnitude of the price decrease and its broader impact on the macro-economy will be a fundamental aspect of the research paper. Finally, since transportation is one of the greatest contributors of air pollution, the environmental effects as well as the likely

change in federal policy are both factors that will play a role in assessing the benefits of electric vehicles.

Research Perspectives

For any revolution to take place, the two sides of the equation must meet: consumer and manufacturer, fashion and function, short-term and long-term. The paper will also provide a two-pronged viewpoint for the microeconomics of electric vehicles. On the consumer side, there is a focus on general consumer sentiment towards battery-powered cars; are they merely a passing trend, a toy for celebrities and millionaires or are they an emblem of a more responsible, greener future? From a quantitative perspective, the research will consider the stock of Tesla Motors, a publicly traded company, to better compare the company's value from an investor's outlook. From the production standpoint, the question comes down to profitability. How has the cost of materials, mainly batteries, decreased over time? After one hundred years of using the same technology, how can the auto industry realize economies of scale for these new vehicles?

Resources and Data

A broad variety of resources were utilized to provide the most holistic, balanced picture of the issue, for both the short and long-term. In analyzing the short-term, current U.S. policy will play a pivotal role, since many start-ups cannot survive without government subsidies; tax credits also influence both consumer and producer decisions. Data from manufacturers, including assembly expenses, research and development costs and consumer characteristics, will provide

further insight on the production side; this information will illustrate any short-term challenges and long-term obstacles that may hinder the proliferation of electric vehicles. Meanwhile, research regarding consumer sentiments contribute a qualitative, proletarian viewpoint. Finally, interviews with industry experts and those who work at Tesla offer an insightful perspective with regard to playing the role of entrepreneur in a sector dominated by industrial titans.

Tesla in Context

The Global Auto Industry

The automotive world has hundreds of players but power remains concentrated in the hands of a select few industrial titans; GM, Toyota and Volkswagen are the largest three firms and control a disproportionate amount of power in the value chain. In the traditional auto industry, consumer power is relatively high, given relatively low switching costs and a vast choice of relatively substitutable products. Meanwhile, the large amount of capital and extensive networks limit supplier power; many components of the automobile can be sourced from different suppliers, which maintains competitive input pricing. The high barriers to entry, due to the capital-intensive nature of development and manufacturing, prevent new entrants. Similarly, the entrenched nature and familiarity of internal combustion engines (ICEs) have neutralized any threats of substitutes for over a century. The dense concentration and high intra-industry rivalry has pressured the already narrow margins of the traditional auto industry.

However, the electric vehicle (EV) industry demonstrates a different type of dynamic. Consumer power is middling, due to slightly higher switching costs (since different vehicles have different charging accessories) and the limited selection of mass produced EVs currently available. Supplier power is slightly higher due to a limited number of battery producers but is partially remedied by long-term contracts. The threat of new entrants is much greater since both traditional automakers are entering the electric market, complemented by an ever-increasing number of start-ups. The threat of substitutes is also slightly higher since there are a number of different alternatives currently in development; while electric vehicles have thus far developed the greatest traction, hydrogen powered vehicles and natural gas powertrains are also viable prospects in the long-term. Intra-industry rivalry remains vicious, as automakers slash prices and invest in R&D to earn a first-mover advantage and establish their name in the burgeoning sector. However, with the recent demise of Fisker, Tesla is the only player in the high-end, luxury EV market; as its technology and convenience trickles down into its more affordable vehicles, Tesla should maintain a comfortable competitive advantage.

Tesla: The Innovative Disrupter

The EV industry is older than most people realize, older even than the traditional automotive industry.[4] The first rudimentary electric vehicles emerged in the 1830's, a full forty years before their gasoline counterparts. Around 1890, the first American electric car, powered by 24 batteries, had a range of 50 miles and went up to 20 mph, double that of the Karl Benz's gas-powered Patent-Motorwagen. Towards the beginning of the 20th century, electric cars

[4] PBS, *Timeline: History of the Electric Car*

accounted for a third of sales in the fledgling U.S. auto industry. However, in 1912, the EV industry began its century-long decline; in that year, Cadillac introduced "the car that has no crank" and electric cars lost their most compelling advantage: convenience. By the 1920's high cost, limited range and cheap oil contributed to a rapid demise for electric car sales. The final nail in the electric vehicle coffin was hammered in 1940 when Detroit Electric, which had shifted to commercial vehicles and outlasted all of its competitors, finally went out of business. Then, about 65 years later and two thousand miles away, Tesla Motors was founded.

Tesla Motors defied the almost universal trend of being named after its founder; rather, it is named after one of the greatest, and perhaps most under-appreciated, innovators of his time: Nikola Tesla. He, fittingly enough, was one of the key contributors to modern-day alternating current (AC) electricity; the AC induction motor was first patented by Nikola Tesla in 1888.[5] As opposed to direct current electricity, which flows in only one direction, AC current periodically alternates the direction of the electric charge. The main benefit of the AC motor is that it operates a simpler design without friction, making it both durable and inexpensive. Known for letting people use his patents without payment and tearing up contracts for the greater good, Mr. Tesla deserves to be remembered for his intentions to make the world a better place; having his name attached to one of the most ambitious sustainability projects of our generation seems to be a fitting way to do so.

Sparking the Electric Revolution

[5] UNSW School of Physics, *Electric Motors and Generators*

Tesla Motors, founded in 2003 by a syndicate of engineers and entrepreneurs, galvanized the auto industry towards a more sustainable future, and in the process, challenged every conception as to what a car really is. Upon its IPO in 2010, Tesla became the first public American car company in over fifty years, since Ford in 1956. But when compared to the Big Three American auto titans, GM, Chrysler and Ford, Tesla has proven different in every way imaginable. Beyond its obvious aversion to traditional internal combustion engines, Tesla opted to manufacture in California, far from the influences of Detroit, home of the Big Three. The company headquarters in Palo Alto capture Tesla's distaste for the status quo, as well as the emphasis on cutting edge technology.

Elon Musk, who also serves as Product Architect, had no intentions of building the world's best electric vehicle; he wanted to design the world's best vehicle, with neither compromise nor excuse. But there is a far larger movement in play; Tesla was founded, in Musk's own words, "to accelerate the advent of electric cars".[6] Every model designed, every vehicle manufactured had to be more than competitive; it had to be flawless. A single defect could set the electric movement back decades, as it had been in the past.

The Man Behind the Machine

Elon Musk

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[6] Automobile Magazine, *Q and A: Elon Musk, CEO, Tesla*

Elon Musk: equal parts visionary and rocket scientist, billionaire and environmentalist, philanthropist and playboy as well as the inspiration for Tony Stark of Iron Man fame. Granted, not quite yet a household name, but very likely one that will go down in history as one of his generation's greatest minds. Those who know him often draw comparisons to Howard Hughes, due to the sheer magnitude of his vision and disdain for the status quo; still others see hints of Thomas Edison in the diversity of his pursuits or perhaps Steve Jobs in his love of simple and elegant design.

Then there's the possibility that Mr. Musk is a new breed of innovator altogether... an entrepreneur who brings his vision to life by aligning the proper intellectual and financial capital, fueling their amalgamation with social media and inter-industry synergy. Ask a random person on the street if the name "Elon Musk" means anything to them and they may well shrug it off; however, there's a good chance one of his innovations has already played a role in their lives and a near certainty that his vision will shape the future they live in.

Entrepreneur from the Start

Born and raised in South Africa, but educated at the University of Pennsylvania in both economics and physics, Elon Musk dropped out of Stanford University, abandoning a PhD in Applied Physics and Materials Science, to start his first venture.[7] Success did not take long to find; Zip2, an online content publishing software, was sold to Compaq in 1999 for around $300 million in cash. Later that year, Musk created a website specializing in online financial services

[7] ElonMusk.com, *Elon Musk*

and e-mail payments; he soon refocused the company to specialize in a global payment system, one which he believed to be both inevitable and imperative to realize the true potential of internet-based transactions.

By 2002, the company known as PayPal, was acquired by eBay for $1.5 billion. Musk, the company's largest shareholder, owned 11.7% of PayPal's shares and walked away with over $100 million.[8] At that point, he could have easily walked away and lived comfortably on the interest for the rest of his days, having already established his legacy with PayPal and its role in facilitating online business. Instead, however, he put every dollar he had into the most pressing social issues he believed the world faces today. Musk sought to combat global warming by provided the initial concept and serving as chairman for SolarCity, which specializes in designing, financing and installing solar energy systems. However, it is his dual quest is to remake the auto industry with electric vehicles and to privatize space travel that will profoundly, and irreversibly, alter the world we live in. Mr. Musk founded Tesla Motors to combat the first issue and SpaceX for the second.

Space X

Space Exploration Technologies Corporation, or SpaceX, is a space transport company that made history in 2012, a mere decade after its founding, to become the first private company to dock with the International Space Station.[9] Under the assumption that the world has a growing population but a finite number of resources, Elon Musk believes that the interplanetary

[8] Owen Thomas, *Tesla's Elon Musk: "I Ran Out of Cash"*

[9] SpaceX, *Company Overview*

colonization is the next step, and an inevitable one, for the human race. The main issue is not setting up a greenhouse on another planet, such as Mars, but rather getting there; the problem is that rocket ships have traditionally been treated as “disposable”, leading to near prohibitive costs.

In order to control quality and costs, SpaceX designs, tests and fabricates the majority of its components in-house. The Falcon launch vehicles, which carry the Dragon spacecraft, were designed from conception to eventually become reusable to make interplanetary travel affordable. SpaceX is reported to have nearly $2 billion in government and private contracts on the books and has a demonstrated track record of successful launches; with no shortage of customers, a limited number of competitors and demonstrated competency in its core business, SpaceX is positioned to thrive. Meanwhile, Tesla is taking on a mature industry with many competitors and excess capacity in uncertain economic times. The automobile business requires huge investments on products that sell for relatively small margins.

Tesla Motors Overview

Company Offerings

Tesla was able to infiltrate a densely-concentrated, highly competitive arena with a three-phase trickle down strategy. The first step was the Roadster, a low-volume, high-price sports car that garnered much critical acclaim but was known to relatively few. The next phase was a couple of mid-range vehicles, one sports sedan and one sport utility vehicle; these vehicles

would be critical in proving Tesla's capability to mass produce high quality EVs while keeping prices competitive. However, the most important phase, the one which will determine Tesla's legacy, is the third and final one. Internally codenamed Project BlueStar, the low-price, mass-produced vehicle will be produced in the hundreds of thousands. If successfully executed, Project BlueStar could singlehandedly revolutionize the auto industry.

Phase I. Roadster

Five years after its establishment, the company released the Tesla Roadster. The Roadster was based on the Lotus Elise, a traditional British sports car, and modified to run on an all-electric drive system. Roughly 2,300 vehicles were produced, a drop in the ocean compared to the one billion cars around the world. Yet its razor-sharp handling, class-leading speed and eerily silent powertrain sparked a small but fiercely loyal group of followers. The sports car was discontinued in 2012 as the company geared up for the next step in its entry strategy. While not necessarily revolutionary, the Roadster was instrumental in establishing the Tesla brand and proving, once and for all, that electric vehicles were not inherently compromises.

Phase II. Models S and X

The next phase was a pair of mid-volume, mid-price vehicles that could serve as a affordable, everyday drivers with no compromises. The Model S is a seven-seat sports sedan that competed with Mercedes, Audi, and BMW in the $50,000 to $100,000 price range. The Model X

is an SUV based on the Model S platform that sought to capitalize on American consumers' proclivity towards large vehicles.

Model S:

As the world's first practical non-combustion vehicle, the Model S has earned a place alongside game-changing vehicles like the 1886 Benz Patent-Motorwagen (recognized as the first combustion-powered automobile) and the 1908 Ford Model T (which set the standard for automobile manufacturing for the next century). The Model S was the company's first clean-sheet design, designed and built from the ground up entirely by Tesla. Arguably the most critically lauded vehicle of the year, the Model S won myriad awards both inside and outside the automotive industry, including the 2013 *Automobile of the Year* and *Time's 25 Best Inventions of 2012*; in particular, when the Model S was elected *Motor Trend's* 2013 Car of the Year by a unanimous vote of all eleven judges, it was a victory for not just Tesla but also the United States, as a "testament to innovation and entrepreneurship, the very qualities that once made the American automobile industry the largest, richest and most powerful in the world".

Model X:

The Model X was designed to combine the best attributes of minivans and SUVs with the performance and efficiency that only an electric car can provide. Equipped with all-wheel drive and offloading capabilities, the Model X has enough differentiating features from the Model S to prevent intracompany sales cannibalization. Moreover, very much like its sedan sibling, the

Model X was designed to look like nothing else currently available. From its “falcon-wing doors”, which open up and out of the way, to the use of cameras instead of side mirrors, the SUV continues the Tesla tradition of integrating function and style. But perhaps its most distinguishing contribution is its rejection of the status quo: gas-guzzlers and SUVs need not be synonymous.

Phase III. Project BlueStar

Without a doubt, the most imperative vehicle in the Tesla fleet, as well as the most mysterious, is the yet-to-be-named Project BlueStar. Designed using the lessons learned from the previous two generations, the high-volume, low-price entry level vehicle is intended to be Tesla’s best selling vehicle. At an estimated base price of $30,000 (the average selling price of a new vehicle today), the EV will target the mass market from the BMW 3-Series to the Toyota Prius; what it lacks in brand recognition, it will make up for with better performance, greater mileage and luxury appointments found in no other car, regardless of price. While details remain scarce, the Generation III EV will begin production in 2014 and eventually ramp up production to 400,000 vehicles a year by 2020.

How It Works: The Model S

The Design

As Tesla's first original design and mainstream offering, the Model S serves as both the inspiration and template for the future; more importantly, it transitioned Tesla from a niche product to one that competes on the world stage. As the brainchild of Elon Musk and the engineers at Tesla, as well as the face of the fledgling company, the Model S was designed from the ground up. [See Figure 1] From its flush door handles (for both aerodynamic and style purposes) that pop out when the driver approaches to the aptly named "frunk" (the front trunk space as a result of no engine), nothing was taken for granted. There is no ignition for the key fob nor a button to start the vehicle; as the driver sits down, the car senses the driver's weight as well as the proximity of the key and simply powers up; starting the car may seem like a small step, but one which had grown superfluous and was promptly eliminated. The Model S can outrace a Porsche Carrera, coast smoother than a Rolls-Royce Phantom, hold more than a Chevrolet Equinox and is more efficient than a Toyota Prius; the flowing exterior design, often compared to Jaguar, also does not hurt.

The most stunning centerpiece is its massive 17-inch touchscreen that controls everything from the suspension to the sunroof and eliminates the need for any buttons in the car, save for the hazard lights and glovebox opener. Using the impressive, responsive and intuitive screen often draws comparisons to the impact when the first iPhone was released. In addition, the internet-connected Model S has been effectively future-proofed: more functionality is only a software update away. For instance, in its first major update, Tesla added a new "sleep" state which powers down the displays and other non-essential electronics for a boost in range of around eight miles per day. Tesla demands security and integrity are given priority; software downloads take

place over a VPN and the firmware bundle is signed by Tesla while both private and public keys validate its authenticity.

The Mechanics

Mechanically, the car was designed atop the "skateboard" architecture with a flat battery pack (composed of seven thousand rechargeable lithium-ion cells) spanning the length and width of the car, fitted beneath the floor in between the wheels. [See Figure 2] The skateboard creates design and dynamic advantages, meaning future electric cars can have unprecedented styling; the flat cabin floor (no transmission tunnel) allows for huge boot space, allowing legroom for two children in the optional rear-facing jump seat, making the Model S the first seven seater sedan in history. With no engine located in the front or back of the vehicle, the car benefits from an extraordinary center of gravity, on par with the Ford GT supercar (around 17.5 inches), as well as increased space and safety for drivers and passengers alike.[10] The vehicle was designed with an athlete in mind: lightweight and nimble despite a 4600 lb. curb weight thanks to a class-leading point 24 coefficient of drag; aerodynamics also benefit from an air suspension (closed loop and fully air) which correlates ride height with speed to increase efficiency.

While a gas-powered engine has many components, electric cars have relatively few moving parts, leading to more efficient use of energy; about 75% of the battery's energy goes into moving the car compared to 20% in a gas-powered car. When the driver hits the accelerator (the term "gas pedal" is hardly applicable), the top level 85-kWh battery sends 270kW of energy

[10] Tesla Motors, *Model S Specs*

to the rear-mounted AC inductor motor, which was pioneered by none other than Nikola Tesla himself. Maximum torque (443 lb. ft. of it) is instantly recognized at 0 RPM, leading to acceleration times typically reserved for hundred-thousand dollar sports cars. In addition, the Model S benefits from regenerative braking which slows the car down and converts the rolling momentum back into electric energy, which it feeds back to the battery. This not only allows the driver to slow down without using the brake pedal, but it also extends the range of the car. However, assuming a typical inverter efficiency of around 80 percent, the regen process wastes about a third of the energy it processes; for example, 100 watt-hours of kinetic energy from the car turns into 80Wh of electricity back into the battery, which delivers 64Wh of energy back to the wheels.

Having said that, future software updates should greater optimize the regenerative braking process. The center touchscreen already has an energy chart that maps acceleration and regenerative braking patterns to maximize energy efficiency.[11] Tesla, aware of the unfamiliar nature of the process, allows drivers to customize the level of regen. For instance, when shifted into neutral, the Model S is one of the best, if not the very best, coasting car on the planet, due to its aerodynamic drag coefficient, low-resistance tires (inflated to 45 psi, the highest tire pressure on any production car) and flat underside with no drive shaft or exhaust system to disrupt airflow. In addition, the Model S appears to lose no more than 10% to 20% of its range capacity during the winter, dramatically better than the Chevrolet Volt, which loses up to 50% of its range in winter, as does the Nissan Leaf.[12]

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[11] Tesla Motors, *Model S Specs*

[12] David Noland, *I Was Surprised By A Few Things In My New Tesla Model S*

The result of all these features, innovations and designs is a sum greater than the individual parts. At the end of the day, it was the Model S that proved "Tesla, like Apple in the electronic device realm, the sort of ambitious and fearlessly innovative company"[13].

How Did They Do It?

Defining "It"

Before answering how Tesla did "it", one must first determine what exactly "it" is. There are two aspects to what Tesla aimed to do and both are closely intertwined. The first was the creation of a better car, one which demonstrated to critics and consumers alike exactly how obsolete our automotive technology had become... and the imperative need to reignite innovation in the industry. Perhaps most impressively, Tesla did so in a intensely competitive and low-margin sector, surpassing international conglomerates that had immense capital budgets, extensive networks and decades of experience.

Which leads to the second half of the "it": singlehandedly beginning a revolution within the automotive industry which will force established names to reinvent themselves, while pushing the less adaptive and flexible companies into the history books. In the longer term, this shift extends beyond the industry and could very well reshape the United States' infrastructure and potentially shift the global economy.

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[13] Motor Trend, *2013 Motor Trend Car of the Year: Tesla Model S*

Elon Musk's Vision

There is no Tesla without Elon Musk. His role as a talent magnet and his vision of a completely fresh consumer experience enabled Tesla to become what it is today as well as what it will become tomorrow. Mr. Musk's reputation for reinventing the status quo has become a magnet for the best and brightest minds in the industry; recruiting engineers and innovators from both automotive stalwarts like GM and technology firms like Apple alike, Tesla's talent acquisition strategy still more closely resembles that of a small start-up rather than a multi-billion dollar enterprise. Quite simply, people want to work with him; they believe in his vision and are inspired by his passion. In an interview for this paper, an employee who elected to remain anonymous claimed there is a saying at SpaceX "No matter how hard you work, someone else is working harder"... one might imagine who that someone else is. Despite Musk's meticulous attention to detail, bordering on obsessive-compulsive, perhaps best demonstrated by his personal inspection of each and every Model S to roll off the assembly line, his emphasis on loyalty and hard work allows a certain level of independence for employees. After all, given his 50/50 time split for each Tesla Motors and SpaceX, Musk has to delegate accordingly assuming a certain level of trust for his team.

Tesla also benefitted from its isolation from the industry and the norms that have hindered the advancement of other vehicles; as an entrepreneur not backed into narrow traditional business thinking, Musk designed the Model S from a clean slate. During an interview, Martin Eberhard, co-founder and former CEO of Tesla Motors, claimed the traditional

automakers inability to create a better car was “a classic case of the ‘Innovator’s Dilemma’; these companies make all their money selling gasoline and diesel cars...thus, they see no short-term benefit from presenting a car that suggests that their gasoline cars will perhaps be obsolete soon”. The short-sighted rationale and shiftless complacency lead to “all sorts of internal logical mistakes” that remained unchecked for decades, until one car company decided to question the status quo.

One of the most important aspects of the Model S’ development was the thought process that produced it: reasoning by first principles. Reasoning by first principles is a physics concept in which concepts are first boiled down to their most fundamental truths and then reasoned up from there, a process which takes more mental energy but allows for far greater innovation. Reasoning by analogy, rather than by first principles, would have eliminated cars in favor of horses, which had been the norm and were best supported by the present infrastructure... the same way the status quo very nearly almost eliminated electric cars. Instead of accepting the conventional wisdom that batteries would always be expensive, Musk broke them down into their core components (cobalt, nickel, aluminum, carbon etc.) and their prices to calculate the cost per kWh and deemed them financially feasible.[14]

Reasoning by first principles allowed for a completely new consumer experience and a new level of synergy between seemingly unrelated industries. Mr. Musk applied his training as a engineer and best practices from SpaceX to apply theories of rocket science to the production of cars. Tesla recently ordered laser calibration devices so the manufacturing division can literally calibrate the dimensions of the car within tenth of millimeters; if there are any errors, they can

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[14] Foundation 20, *Elon Musk*

trace the error to the point of origin and fix it. While this may be extreme for the car business, it's something that Elon Musk does every day at SpaceX. Musk also allowed for inter-industry synergy by using his other company, SolarCity to develop, manufacture and install the solar cells that power Tesla's fast-charge electric charging stations, called Superchargers. In this manner, Tesla accomplished what no other company in the industry could do because it was not limited to the automotive sector; rather it was an union of synergy and innovation from the clean tech, space exploration and manufacturing industries.

Re-Imagining the Product Experience

For Tesla, a better car was just the beginning; equally important was the accessibility of the product and the retail experience. Everything, from the purchase of the car to starting it for the first time to sending it in for servicing, had to be designed from the ground up. Tesla, much like Apple did with consumer tech, is reinventing the actual retail experience of the auto industry by bypassing the traditional dealer network; again rather than viewing the lack of an established network as a downside, Tesla viewed it as an opportunity to rethink what the purchasing experience should feel like. The Tesla stores themselves were designed by George Blankenship, "best known as the chief strategist behind Apple's revolutionary retail stores, one of the most successful, brand-bolstering retail growth plans in history".[15] At Tesla, George's goal is to re-imagine the way people buy cars, forgoing the traditional dealership model in favor of stylish, consumer-focused showrooms. The number one fear of consumers is being cheated by the dealer; by selling all products through proprietary stores and eliminating third party salesmen,

[15] Tesla Motors, *Executives*

Tesla was able to establish a no-haggle pricing policy that means all clients pay exactly the same for the same service.

One of the main issues that had to be contended with was price; even without haggling, many people view EVs to be more expensive than their gasoline counterparts, largely due to the upfront costs of a battery, despite the fact that many of those costs are often recovered in lower energy consumption. However, to mitigate the greater upfront expenses, Tesla established a new financing option that aimed to combine the "best aspects of car leasing and ownership" and thus broaden the affordability of its products; in a press release, Musk said he "expects around half of the Model S sales in the US to be this new lease-like option". Under the new pricing structure, the 10% down payment is covered by U.S. federal and state tax credits starting at $7,500. "When considering the savings from using electricity instead of gasoline, depreciation benefits and other factors, the true net out of pocket cost to own a mid-range Model S drops to less than $500 per month".[16] After 36 months, as a guarantee of value the company will offer consumers the right, but not the obligation, to sell the vehicle to Tesla at a residual value higher than that of any luxury sedan, particularly those offered by Mercedes, BMW, Audi, Lexus or Jaguar. "Not only is Tesla guaranteeing that resale value, but Elon Musk is personally standing behind that guarantee to give customers absolute peace of mind about the value of the asset they are purchasing".

Given any remaining concerns about affordability, resale value and technological defects, Tesla has created what may be the world's best warranty. As part of its service program, Tesla will seamlessly valet the loaner cars to the owner's location, offering top of the line Model S Performance sedans or Tesla Roadsters as temporary replacements. Should customers enjoy the

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[16] Tesla Motors, *Tesla Unveils Revolutionary New Finance Product*

service loaner more than their other car, they are welcome to keep it at a discounted price, based on the replacement's age and milage. From Tesla's perspective, this is an opportunity to ensure "that the service fleet is constantly refreshed and gives customers the best optionality". Again, a service never before offered in the auto industry but one which serves as a win-win situation for both the consumer and producer, a net surplus for both parties. Moreover, the program now includes an unconditional warranty for the Model S battery, even for user error, which should alleviate any customer concerns that EVs are any less reliable.

The Perfect Storm for an Impending Revolution

Regardless of its necessity, no product can flourish without the proper environment. Similarly, Tesla could not have flourished, or survived for that matter, without the proper confluence of external factors. The political environment, economic conditions and evolving consumer preferences all met to form the perfect storm that would help Tesla Motors find its footing in the automotive world.

The financial crisis served to help Tesla on a number of grounds; while 2008 was marked by crisis in the auto industry, including the bailout of GM and Chrysler under the Troubled Asset Relief Program (TARP), Tesla took the opportunity to grow while its competitors were downsizing. Tesla had initially intended to bring the Model S to market via the capital markets but the Great Recession precluded the notion of commercial funding. Instead, as a part of the Obama Administration's Stimulus Act in early 2009, Advanced Technology Vehicle Manufacturing (ATVM) loans were "intended by the President and Congress to accelerate the

market introduction of promising automotive technologies"[17]. Thus, it was through federal funding that Tesla was able to accomplish the timely launch of the Model S. However, the government policy was not met with unanimity, even though Tesla had received the smallest loan compared to Ford's loan for $5.9 billion, Nissan's for $1.4 billion, and Fisker's for $529 million. Presidential candidate Mitt Romney labeled Tesla a "loser" during the debates, taking issue with the $465 million loan Tesla received from the U.S. Department of Energy.[18] Yet, as of February 2013, Elon Musk announced the company "will pay off the Department of Energy loan five years early, twice as fast as required by the original 2010 loan agreement signed by Tesla and the DOE".

Evolving consumer tastes also served as a catalyst for Tesla's rapid rise to prominence. Part of Elon Musk's motivation were the negative externalities of internal combustion engines: "since we are not appropriately pricing the CO2 capacity of the oceans and atmosphere, then the only way to address that was with innovation". Consumers, whether through concern for the environment or self-interest in the face of rising gas prices, have come to a similar conclusion. In a recent survey, AAA concluded "half of U.S. adults consider gas prices to be 'too high' when it reaches $3.44 per gallon... 90% believe gas is too high when the price reaches $4.00 per gallon", indicating a potential breaking point for gas prices.[19] Inevitably, as energy demand increases and our finite supply of oil decreases, more and more drivers will look to alternatives to the traditional internal combustion cars. Moreover, shoppers are also seeking unique products and experiences to substantiate the additional cost of a premium vehicle. In other words, the car itself

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[17] U.S. DOE, *Tesla Motors*

[18] U.S. DOE, *Tesla Motors*

[19] Michael Green, *AAA Identifies Motorist Breaking Point on Gas Prices in New Consumer Index*

is no longer the product; a more intimate dealer relationship and pleasant purchasing experience, such as the class-leading program designed by Tesla, serves as a determining factor when selecting a brand. Automotive journalists and customers alike have likened their first Model S experience to the first time using an iPhone, the technology that not only propelled Apple to the pinnacle of the consumer tech world, but also redefined exactly what a smartphone should be. The Model S could serve as a similar catalyst, one which defines a vehicle worthy of the technology today as well as the dealer experience that should accompany it... and in doing so, set Tesla at the zenith of the automotive world.

Moving Away from the Oil Economy

The Oil Industry

Tesla Motors has created an incredible car with the Model S and promises an even more impressive pipelines of products. But the ramifications of Tesla, and the revolution it is sparking, extend far beyond the automotive industry alone. The energy industry is perhaps the one that will be impacted most profoundly, with the oil sector in particular facing a rapidly changing future. The multi-billion dollar oil industry all begins with marine plants and animals, which lived millions of years ago, that have been covered by layers of silt; “heat and pressure from these layers helped the remains turn into crude oil; hence, the word ‘petroleum’ means ‘rock oil’ or ‘oil

from the earth'".[20] After being collected, the crude oil is sent to a refinery, by either ship or pipeline, to be developed. At a refinery, different parts of the crude oil are separated into useable petroleum products. "Refineries in the United States produce about 19 gallons of gasoline from every 42-gallon barrel of crude oil that is refined... the rest of the barrel gets turned into other petroleum products like diesel fuel, heating oil, jet fuel, and propane".[21] [See Figure 3]

The United States' Thirst for Oil

Currently "about 40% of the energy consumed in the United States is supplied by petroleum, and that proportion has remained approximately the same since 1950... also unchanged is the almost total dependence of the transportation sector on petroleum, mostly gasoline".[22] [See Figure 4] To truly understand the magnitude of petroleum's role in energy production from both a domestic and international perspective, the United States is the world's largest oil consumer using around 18.9 million barrels of oil per day, double that of the next most power hungry nation, China, which has a daily consumption of 8.9 million barrels.[23] [See Figure 5]

Critics of this thirst often point out that the U.S. "consumes 20% of the world's oil but owns only 2% of global reserves", leading to a dependence on foreign oil that proved detrimental

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[20] U.S. Energy Information Administration, *Oil: Crude and Petroleum Products Explained*

[21] U.S. Energy Information Administration, *Gasoline Explained*

[22] Carl E. Behrens, *U.S. Energy: Overview and Key Statistics*

[23] U.S. Energy Information Administration, *Countries' Oil Consumption*

for the economy and hazardous to national security.[24] In 2011, "the US consumed 97 quads (1 quad = quadrillion btu) of energy, but produced only 78 quads; fossil fuels made up more than 80% of the total energy consumption", with oil alone representing over one third of total energy consumption.[25] The deficit must be bridged with "the imports of oil to make up the shortfall of energy production... this is not a sensible energy strategy for the country since oil is an expensive resource with a very hazy long-term supply outlook".[26]

The recent surge in U.S. production of oil seems to have turned the tables, inspiring hope of falling gas prices. After all, basic economics stipulates that as supply rises, given a constant demand, prices must fall. Unfortunately, "when thinking of 'big oil', most Americans think first of multinational corporations such as BP, Chevron, ExxonMobil, Shell, or Total. But the 13 largest oil companies in the world, measured by their reserves, are owned and operated by governments".[27] As these state-owned enterprises "own the world's largest oil companies and control three-quarters of the world's energy reserves", they will do whatever it takes to maximize revenue.[28] Boosting profits from from oil sales by is often achieved by "restraining production and propping up prices; Saudi Arabia, for example, can often profit more by producing less oil... because oil is traded globally, prices ultimately depend on how much is produced in the entire world, not just in the U.S.".[29]

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[24] Michael Levi, *Why More U.S. Oil May Not Mean Cheaper U.S. Gas*

[25] Jack Collins, *EIA Breakdown of US Energy Consumption*

[26] Jack Collins, *EIA Breakdown of US Energy Consumption*

[27] Ian Bremmer, *State Capitalism Comes of Age*

[28] Ian Bremmer, *State Capitalism Comes of Age*

[29] Michael Levi, *Why More U.S. Oil May Not Mean Cheaper U.S. Gas*

Therefore, with the United States controlling a negligible amount of the world's oil production and the governments imposing constraints to maximize profits, the supply will likely not rise dramatically in the near-future. However, given an ever-increasing population and growing middle classes driving cars in developing countries, it is safe to say that demand for energy will only ever go up. Again, basic economics stipulates that, given a constant supply and increasing demand, prices must rise. Unfortunately, the economic and political analysis fails to fully incorporate the added burden of negative externalities fueled by oil consumption. "In 2011, U.S. greenhouse gas emissions totaled 6,702 million metric tons", representing a cost far greater than the billions of dollars America spends each year on petroleum imports.[30] Unless action is taken, the earth future generations inherit will be unrecognizable from our own.

A Fossil Fuel Free Future

Yet the future is still in our hands. If Tesla gains traction and the company's vision is realized, the world of tomorrow may be brighter than the one we have today. Elon Musk has predicted "that more than half of new cars manufactured will be fully electric in 20 years... a bet he will put money on".[31] For the record, the last time Musk made a bet, it was with *The Wall Street Journal* writer Dan Neil that the Model S would be released on time; needless to say, Mr. Musk won. If he is correct, and if Tesla succeeds, the United States will shift away from oil, leading to what could be a worldwide movement towards renewable energy in place of fossil fuels. As a result of falling demand from America, and given a steady global supply, as "prices

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[30] United States Environmental Protection Agency, *National Greenhouse Gas Emissions Data*

[31] Zachary Shanan, *Tesla's Elon Musk Predicts 50% of New Cars EVs in 20 Years*

are inclined to fall, some oil-exporting countries will prop them up by cutting back their own supplies".[32] This "strategic cooperation" will lead to a decrease in supply and higher prices, which may be profitable for oil producers in the short-term but will only accelerate the shift towards alternative energy, which will lead to a virtuous cycle: more investment in renewables, leading to falling energy prices, leading to increased consumption of alternative energies which loops back to greater investment in them and the cycle repeats. Already, in the past twenty years there has been an exponential increase in wind electricity output which as of 2011, generates nearly 125 billion kilowatt-hours of energy. [See Figure 6] Should this be the future we choose, the ramifications will be immense, affecting not just the automotive and energy industries but also entire national infrastructures and the modern-day understanding of transportation.

Long-Term Ramifications

The Redevelopment of National Infrastructure

In the eyes of Peter Carlsson, VP of Supply Chain for Tesla, "people want to drive environmentally-friendly vehicles... they just need the opportunity." In part, the opportunity is driven by products; they need to be better than combustion or hybrid alternatives and they need to extend to segments beyond the Model S. But it will also require investments in charging equipment and national infrastructure. The big question is, when gas stations disappear, what will stand to replace them. Tesla, in an attempt to quell range anxiety, perhaps best understood as a

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[32] Michael Levi, *Why More U.S. Oil May Not Mean Cheaper U.S. Gas*

dead battery in the middle of nowhere, has already started to answer that question: The Superchargers. The Supercharger network is "a game-changing solution to a common question – how to enable long road trips in an electric vehicle without long stops; the answer is simple: more power, and a faster path to your battery" by bypassing the onboard charging equipment.[33] Capable of recharging an EV's battery to half of its capacity within 30 minutes, many of the Superchargers run purely on solar power, installed by none other than Elon Musk's own SolarCity; thus, after the initial installation cost of around $250,000, the marginal cost of running a charging station is near zero. Tesla owners benefit from free energy while the rest of the world benefits from fewer carbon emissions; moreover, the system is so efficient, it may even feed power back into the grid.

The Supercharger network can be envisioned as a replacement for gas stations, running on a range of different sources to produce electricity, and enabling cross-country road trips at zero cost. While currently only available at select cities in California and New York, the goal is to strategically deploy them across the nation to allow point-to-point traveling without any range anxiety. [See Figure 7] As other car companies follow Tesla's precedent and the government increases its involvement in the development of the nation's newly electric infrastructure, the concern of range will no longer hinder consumers from purchasing EVs. It is worth noting that the source of the electricity that powers the grid is as important as the grid itself. After all, electricity produced from oil or coal is not the sustainable future that Tesla strives for; however, regardless of the source, an electric generator is still more efficient than a combustion engine

[33] Tesla Motors, *Supercharger*

with a conversion rate of 80% as opposed to 20%, leading to a net gain for both the consumer and environment.

"A generator powered by renewable energy is the dream" of Peter Carlsson. While the U.S. relies mostly on coal for electricity generation, many states in Europe are able to drive with zero environmental impact. According to Mr. Carlsson, one of the biggest markets for Tesla is Norway, which has the highest percentage of EVs in the world and benefits from an electricity grid powered by hydropower. In particular, the United States, Canada and Europe (specifically the region north of the Alps), "have a high level of environmental consciousness along with high fuel prices" which make them ideal candidates for EVs and the deployment of an electric grid powered by alternative energy. During an interview for this paper, Mr. Carlsson added that the Chinese government has been offering many incentives and promoting their electric infrastructure, two factors which have prompted Tesla to begin its penetration of the nation's EV market; Tesla plans to open stores in Beijing and Shanghai, with the first deliveries scheduled for the third quarter of 2013. As these nations move away from the inefficiencies of combustion engines and decrease their dependence on fossil fuels, the world will begin along a path that is far more sustainable than the one it is currently on.

Scalability of Electric Technology

Eventually, however, the electric revolution must extend beyond cars alone. Elon Musk has insinuated the feasibility of electric trucks in the future. However, both light and commercial trucks would require an entirely new platform to be designed from scratch; while the mechanics

and powertrain Tesla currently uses could be readily adapted, the unibody that the Model S rides on will not support a heavy duty vehicle. Moreover, in addition to the research to build a new platform, Tesla would likely have to invest in a new factory with different equipment, a capital expenditure that is not very feasible for the company as of right now. In Eberhard's view, "trucks split into two categories: short-haul trucks and delivery trucks are good candidates for electrification, especially true trucks with predictable routes". However, unlike his successor Elon Musk, Eberhard believes, given the current technology "long-haul trucks use a lot of energy... and so the batteries are not yet practical." Whether this problem could be solved with the development of the Supercharger network, Mr. Eberhard did not comment.

Beyond road-going vehicles, there are three other modes of transportation: ships, trains and airplanes. Mr. Eberhard who once claimed on the *Tesla Founders Blog* that "without plug-in capability, a hybrid is just a gasoline-powered car with some fancy hardware" believes that scalability is more "a political problem more than anything" but remains a necessary component of moving forward towards a sustainable future. Despite the fact that many of these transportation industries rely on resources other than gasoline, including diesel, natural gas or coal, there are two key issues that remain. First, the energy source is more often than not a finite resource that has a strongly detrimental effect on our environment; second, the conversion process from fuel to movement is still often inefficient due to the energy lost in thermal leakage. Most of these transportation methods would benefit from the increased productivity of an electric powertrain, as well as the increased variety of sustainable energy resources. "Trains are, of course, already electric in much of the world. This is not a technological problem... it's a political one", continued Eberhard. While trains are among the most efficient modes of transportation,

especially when electric, they are often limited in terms of flexibility and cannot adapt to changing distribution patterns the way cars or planes can. In addition, they require high capital expenditures to install and may in interrupt current urban infrastructure. Thus, the true emergence of an electric world will be marked by the day larger, longer-range vehicles, such as trucks or jets, run on electric powertrains rather than fossil fuels.

In an interview during the research phase, Eberhard also said, "scalability is a function of the required energy storage; a jet, for example, consumes a lot of energy - more than is feasible to store in batteries in the foreseeable future." However, the 'foreseeable future' may be arriving a bit earlier than Mr. Eberhard may have initially anticipated. Mr. Carlsson, the man in charge of battery sourcing at Tesla, said that capacity improves around 7% to 8% every year; compounded annually, batteries should double capacity around every ten years. Musk has already commented that a "500-mile battery — nearly twice as good as the best they can offer today — could be available at about the 4-5 year mark in the life of Model S", around 2016.[34] However, these calculations operate under the assumption of current technological bounds. Phinergy, an Israeli tech firm has "developed an electric vehicle that can travel 1,000 miles on a single charge"; like the Model S, the vehicle uses a "traditional lithium-ion battery but also uses as an aluminum-air energy system that uses the energy released by the reaction of aluminum with oxygen to generate power".[35]

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[34] Mark Rogowsky, *Tesla: Better Warranty? Check! Upgradeable Cars? Sure! 500-Mile Batteries? Maybe Soon!*

[35] Jeff Siegel, *Tesla, Graphene, and the 1,000 Mile EV*

Tesla has been working on similar 'metal-air' batteries and has filed eight patent applications since 2012, using this dual-source system.[36] A direct excerpt from the filing details "optimizing the operation of the power source of an electric vehicle... where the power source is comprised of a first battery pack (a non-metal-air battery pack) and a second battery pack (a metal-air battery pack)". At the very least, the patent demonstrates that Tesla is not resting on its laurels at the zenith of the EV industry and is innovating in ways few other companies on the planet are capable of. More importantly, the filings indicate the immediacy with battery technology is advancing with, far more expeditiously than even the most optimistic assumptions. Innovations like a metal-air battery, along with "the new micro-battery recently developed at the University of Illinois [which] is essentially a millimeter-sized battery... that can shrink battery sizes down by 30 times while allowing electric vehicles to charge 1,000 times faster than what's available today" indicate an entirely new type of electric power.[37] Given the restraints of today's technology, an electric jet is simply not feasible. In ten years, however, the idea hardly seems like any stretch of the imagination. And that is how Tesla thinks, not in quarters or years, but in decades.

Risks to the Vision

There are several factors that could pose a risk to Tesla's vision, either directly to the company itself or to the emergence of electric vehicles. First, it is worth noting the rapidly evolving and intensely competitive industry that Tesla competes within; while the traditional

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[36] Galileo Russell, *Tesla Patent Applications Reveal Next Generation EV Technology*

[37] Jeff Siegel, *Tesla, Graphene, and the 1,000 Mile EV*

automotive sector remains extremely saturated, with most of the volume and profit going to a handful of manufacturing behemoths, the overall competitive dynamic for the EV sector has yet to be determined. However, it would not be a stretch to envision an EV sector as aggressively cutthroat as its internal combustion counterpart. Traditional manufacturers, as they catch on to the burgeoning movement, can leverage their expertise and scale to offer competitive products at or below Tesla's cost.

To further compound the competition, start-ups will continue to try and enter the marketplace while the EV trend is still in its early phases; Fisker Automotive's recent failed attempt to mass produce its flagship sedan will likely be the first of many ventures, from both domestic and international competitors. There are rumors of China's own BYD Auto entering the U.S. while Detroit Electric, a company that ceased operations in 1939, was recently revived; the newly resurrected Detroit Electric will begin production in 2014, starting with a sports car built of a Lotus Elise... the exact platform Tesla's Roadster was built upon. Detroit Electric is also partnering with Chinese automaker Geely Automobile group, signaling an entirely new dynamic within the EV sphere, one which transcends not just technological barriers but national ones as well.[38] As these companies and ventures gain traction around the globe, competition will intensify, margins will narrow and Tesla may lose the competitive advantage that had propelled it to the pinnacle of the automotive world.

Of course, the greater risk is that the EV movement fails to gain momentum altogether, in which case Tesla won't face diminishing profits but absolute losses. One of the main risk factors is the viability of traditional and alternative energy sources; given the widespread acceptance of

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[38] Paul Lienert, *Detroit Electric Forms EV Venture with China's Geely*

gasoline and familiarity of ICEs, a decrease in oil prices, could slow the adoption of electric technology. Risk-averse consumers will always choose the safer, cheaper route even in face of a better technology. Then there is the question of other alternative energy powertrains; natural gas is currently one of the biggest threats to EVs but natural gas powertrains are only marginally more effective than their gasoline counterparts. While the resource may be more readily available than oil, the engine itself still has more moving parts, and thus thermal leakage, than electric powertrains. Companies such as BMW and Aston Martin are also experimenting with hydrogen powered vehicles, which produce near zero environmental impact but have yet to be implemented on a mass production scale.

There are certain difficulties in adapting to a new powertrain; not only is the switch from a gasoline pump to charging station a rather jarring transition but the driving experience also requires adjustment. The lack of a start button for instance, while small, can easily turn away consumers who are find comfort in familiarity; in addition, aggressive regeneration often slows the car down, thus requiring a constant pressure on the accelerator leading to a different driving style. The complete silence of an electric powertrain, compared to the visceral roar of a combustion engine, has already drawn more than its fair share of ire from automotive enthusiasts. Finally, there is the risk that the early success of Tesla, and to a less extent Nissan and GM, was due to the novelty factor; as this novelty fades with time, demand may decrease proportionally, making EVs a less profitable investment; naturally, decreased interest from consumers would disincentivize automakers from pursuing EV projects, a vicious cycle that had all but killed the electric car in the past. While all of these factors remain relevant in the analysis of the future of the automotive industry, the confluence of environmental factors, economic

policy, political relationships and consumer trends point towards a future lead by the electric vehicle.

Concluding Thoughts

Redefining Success

Tesla is only just beginning its stratospheric rise as the company transforms everything that is taken for granted in the automotive sector and tech world. Its innovative vehicles, lean operations and relentless pursuit of a brighter future will continue to redefine standards across industries. The only question that remains, when or perhaps how, will Tesla identify success? There are two perspectives to consider in quantifying success; the first is from the perspective of the company's owners: shareholders. From the investors' perspective quantifying success is quite easy. Anyone who bought Tesla's stock at its IPO at $17 in July of 2010 would have more than quintupled their money as of May 2013, when the stock traded at $87. Even those who owned Tesla at the beginning of 2013 would have seen their money double in a matter of five months. Needless to say, from a financial perspective, in light of the company's profitable operations despite heavy spending on R&D and the Supercharger infrastructure, Tesla has succeeded.

However, Tesla Motors was founded for a greater purpose that reporting a positive cash flow. Again, in the words of Elon Musk, Tesla was founded to "accelerate the advent of electric vehicles". So when can Tesla officially declare the emergence of EVs a success? Waiting for the

complete disappearance of ICEs is unrealistic, simply because the wind down and eventual extinction will take decades, if ever, to fulfill. A more realistic benchmark will be the 'tipping point', the moment when the volume of electric vehicles produced is greater than the number of gasoline cars manufactured. Elon Musk foresees this milestone within twenty years, by 2032. The idea of entirely turning over the install base of vehicles within two decades, especially given fewer than 1% of cars produced are EVs, may initially seem outlandish; however, in light of inevitably rising fuel prices, stricter environmental regulation and exponentially more efficient batteries, 2032 may seem to be a rather conservation estimate. One thing remains certain: until, and even after, the transition is accomplished Tesla will continue to innovate with relentless drive.

Transportation's Future

Another question that needs to be answered is, are cars really the future? Regardless of their powertrain, bearing in mind the rising congestion and increased energy needs that arises with a rapidly increasing population, cars may not be the most efficient mode of transportation. In a move that may in fact drive his own company into obsolescence, Elon Musk proposed a fifth mode of transportation, called the 'hyperloop'. As a revolutionary transport system, the hyperloop is immune to weather delays, never crashes, runs off solar power and can transport people from Los Angeles to San Francisco in thirty minutes, less than ten percent of the six hour drive currently required.[39] Most impressively, it can be constructed for $6bn, one tenth the price

[39] Tesla Motors, *Elon Musk's Hyperloop*

of the proposed electric train California has proposed. So, is the hyperloop the real face of transportation's future?

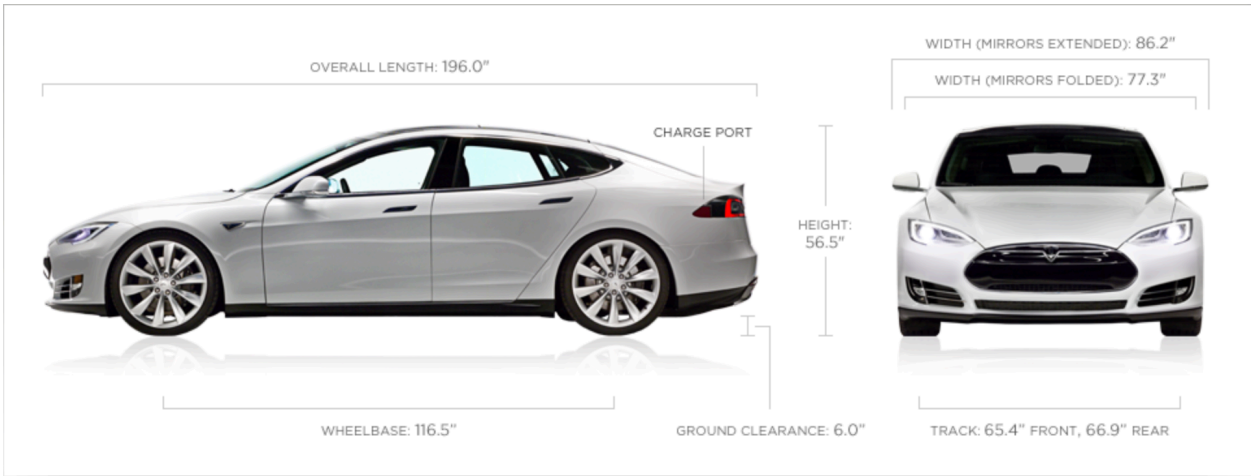
Maybe one day, but not yet. An official design has not yet been proposed and considering the years it would take to implement, the auto industry is in no danger. Furthermore, to implement across the country would take decades, so it is more than likely that cars are here to stay. Beyond their practical uses of getting people from Point A to Point B, cars today serve a number of other purposes; they are fashion statements and status symbols, a form of self-expression. They are sources of enjoyment, for both spectators and enthusiasts alike. And they are nothing less than art, archetypical relics of the era in which they were created; from the iconic 1964 Aston Martin DB5 to the modern classic 2008 Morgan Aero SuperSports, these vehicles are the materialization of a vision that defined their generation. The true question is not whether cars will exist one hundred years from now; it is, what will the cars *feel* like one hundred years from now? And for an answer, one needs to look no further than their local Tesla store.

"Life shouldn't just be about solving problems... It should be exciting and inspiring."

–Elon Musk

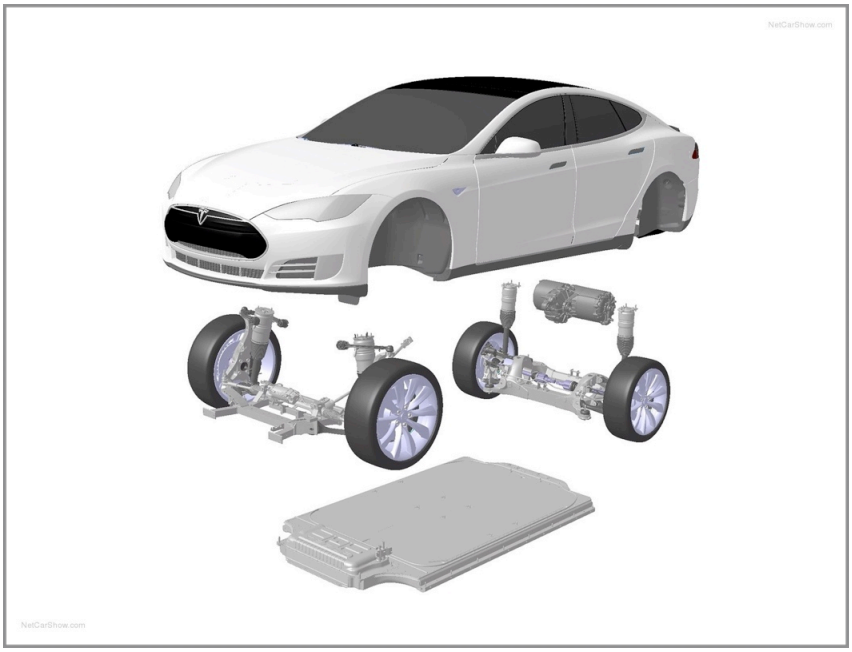
Appendix

Figure 1:



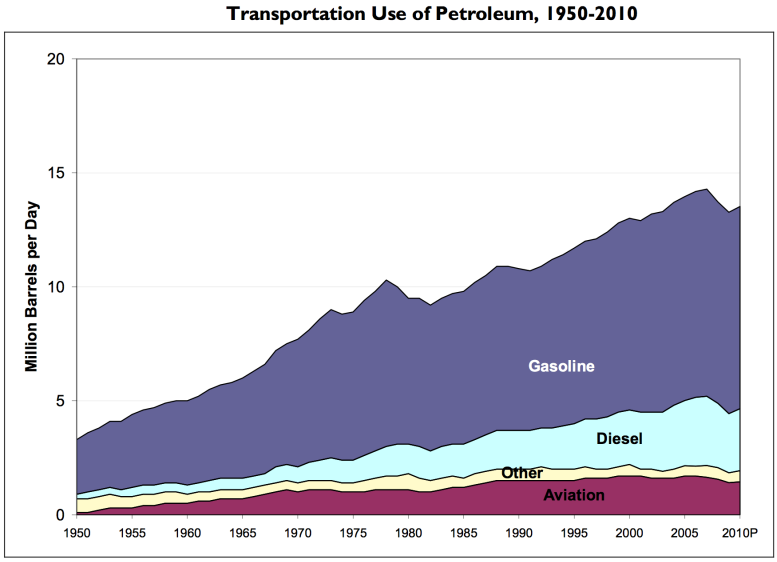
Source: Tesla Motors, *Model S Specs*

Figure 2:



Source: Tesla Motors, *Model S Specs*

Figure 3:

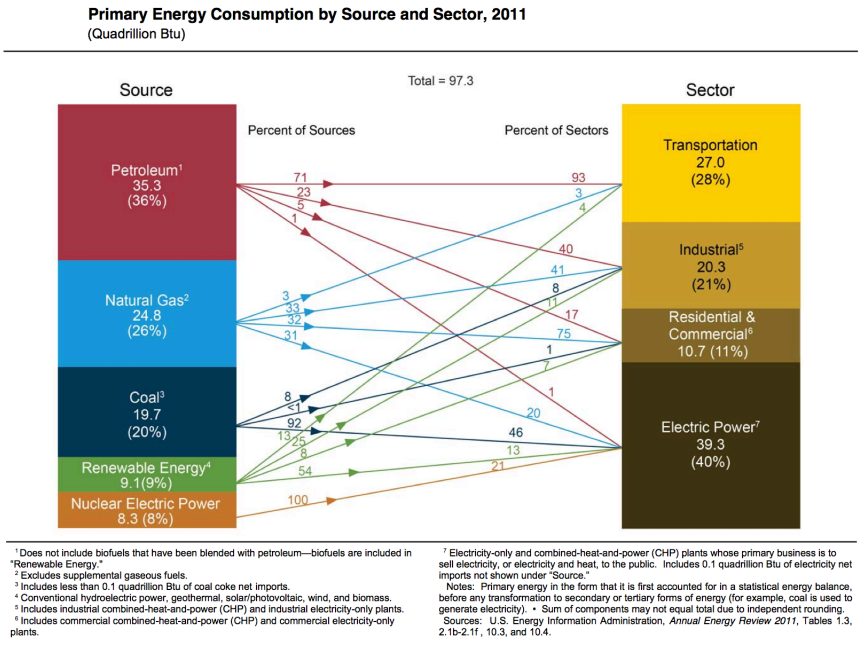


Source: EIA, *Annual Energy Review 2010*, Table 5.13c.

Notes: Data for 2010 are preliminary.

Source: Behrens, Carl and Carol Glover, *U.S. Energy: Overview and Key Statistics*

Figure 4:



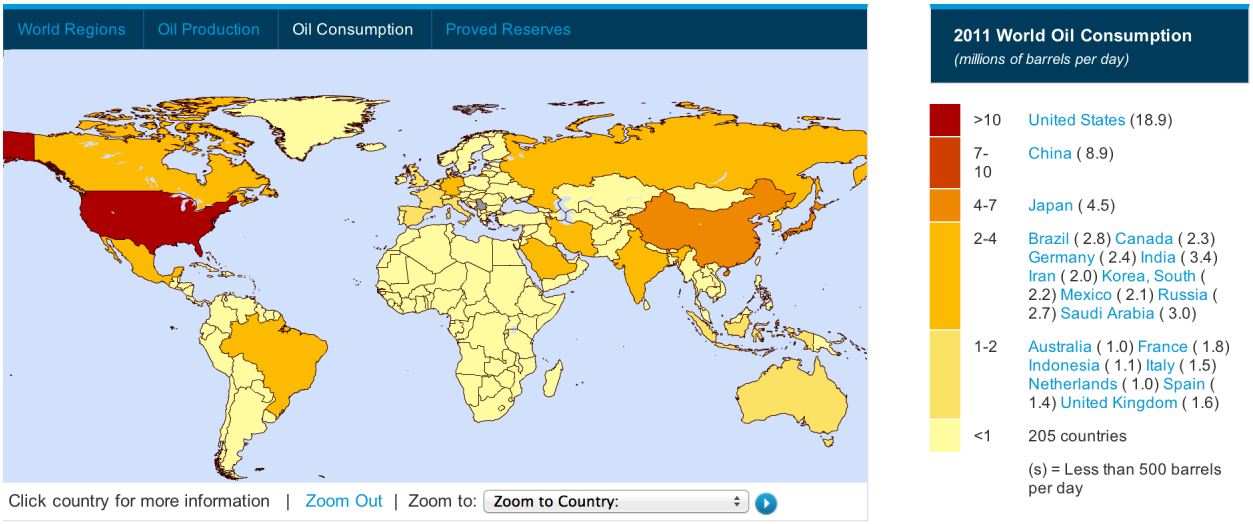
[1] Does not include biofuels that have been blended with petroleum—biofuels are included in "Renewable Energy."
[2] Excludes supplemental gaseous fuels.
[3] Includes less than 0.1 quadrillion Btu of coal coke net imports.
[4] Conventional hydroelectric power, geothermal, solar/photovoltaic, wind, and biomass.
[5] Includes industrial combined-heat-and-power (CHP) and industrial electricity-only plants.
[6] Includes commercial combined-heat-and-power (CHP) and commercial electricity-only plants.
[7] Electricity-only and combined-heat-and-power (CHP) plants whose primary business is to sell electricity, or electricity and heat, to the public. Includes 0.1 quadrillion Btu of electricity net imports not shown under "Source."

Notes: Primary energy in the form that it is first accounted for in a statistical energy balance, before any transformation to secondary or tertiary forms of energy (for example, coal is used to generate electricity). • Sum of components may not equal total due to independent rounding.

Sources: U.S. Energy Information Administration, *Annual Energy Review 2011*, Tables 1.3, 2.1b-2.1f, 10.3, and 10.4.

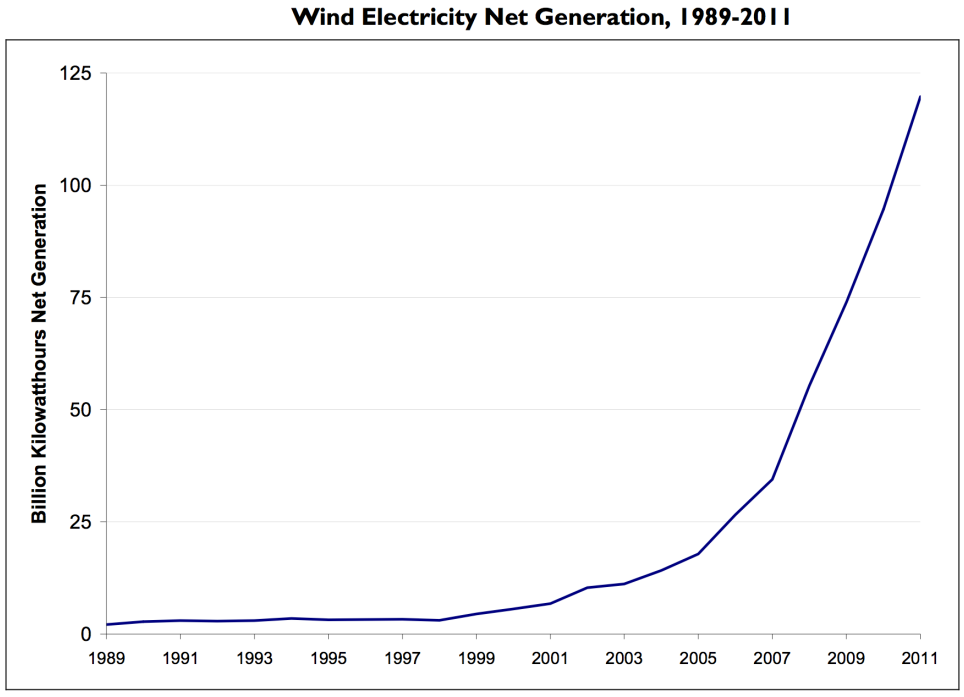
Source: U.S. Energy Information Administration, *Annual Energy Review*

Figure 5:



Source: U.S. Energy Information Administration, *Countries' Oil Consumption*

Figure 6:

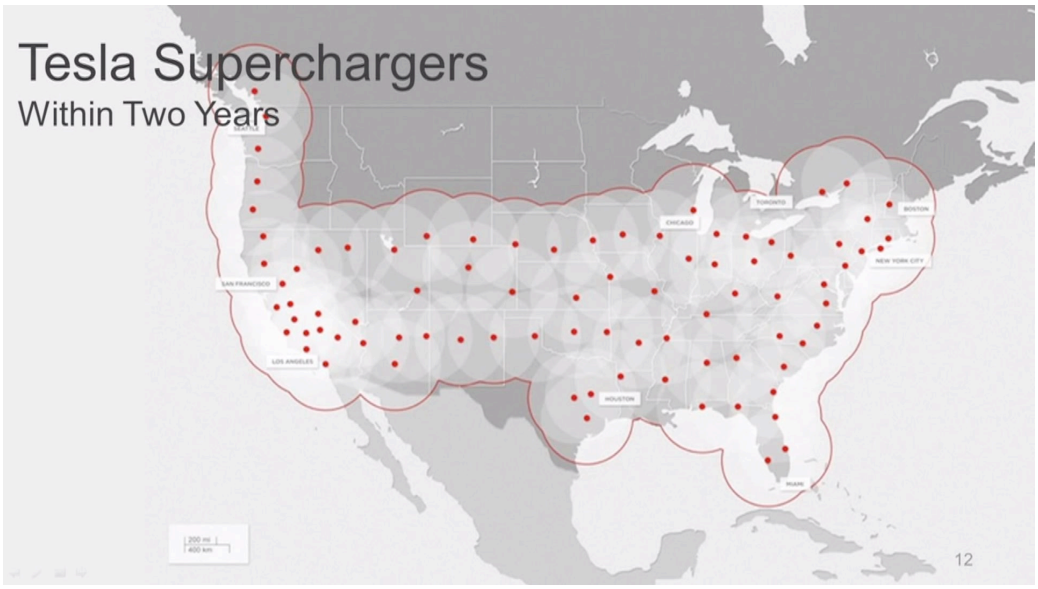


Source: EIA, *Monthly Energy Review*, March 2012, Table 7.2a.

Notes: Data are for electric utilities, independent power producers, commercial plants, and industrial plants.

Source: Behrens, Carl and Carol Glover, *U.S. Energy: Overview and Key Statistics*

Figure 7:



Source: Tesla Motors, *Supercharger*

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