JUST CHARGE IT: GLOBAL WARMING, PERSONAL TRANSPORTATION, AND ELECTRIC VEHICLES

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Introduction

Transportation accounts for nearly a third of the rapidly-increasing carbon dioxide emissions in the US.[1] Even as the CO2 emissions contribute to the threat of global warming, concern is growing about the depletion of oil reserves. While we may not actually run out of oil for decades, it is likely that oil prices will rise as the remaining oil becomes more difficult to extract. The physical structure of American communities makes it particularly complicated for us to alter the individual-car transportation system that we rely on because of the extensive rural and suburban population. In countries with more centralized population where people live within a few miles of the places where they work and shop, driving can be a relatively rare need and public transportation can serve most of the population. The development of suburbs in America has made it difficult for our scattered population to do without individual cars. To garner sufficient popular support to be successful, a technology replacing internal combustion cars will need to allow us to maintain similar driving habits. Current standards and policies encourage increased fuel efficiency, but internal combustion engines are not technologically capable of lowering emissions to an acceptable level, particularly considering the large and increasing number of cars on the roads. Further demonstrating the need for an innovative new technology, consumer preference tends toward the large and/or powerful cars with the worst mileage ratings.

Several alternative fuels have been developed, but the urgent nature of the environmental problems facing us limits the range of practicable solutions. Zero-emissions vehicles, those with no tailpipe emissions, constitute a greater shift in

[1] "Transportation and Climate | US EPA," http://www.epa.gov/otaq/climate/index.htm.

automotive engineering than switching to alternative liquid fuels that solve the problem of oil availability without satisfactorily addressing the environmental crisis. Battery electric cars and hydrogen fuel cell vehicles currently vie for prominence as the best zero-emissions vehicle for the consumer market, with hydrogen gaining a lot of good press as a technology for the mid-term future while recent battery innovations make electric cars viable right now. Both fuel cell and battery electric cars use electricity from the power grid, meaning that they are zero-emissions only from the tail pipe, but still entail some life-cycle emissions. However, some users choose to install solar panels to charge their electric cars, and renewable energy technologies for electricity generation are making advances all the time. Furthermore, even dirty power plants burn fossil fuels more efficiently and cleanly than internal combustion engines, so centralizing energy produced for transportation will mean lower total emissions. Centralized sources of pollution can be more easily regulated, particularly as they age and efficiency decreases. Developing all types of technology privately makes sense; the more avenues being explored, the more likely there is to be a breakthrough somewhere. Where limited government investment is available, though, battery electrics currently show the most promise and the fewest technological hurdles to overcome, making them a better choice for taxpayer dollars. Plug-in battery electric cars are currently the most technologically capable of fulfilling the needs and preferences of American drivers with the least environmental harm.

A shift to electric cars simplifies the range of problems contributing to pollution and global warming crises, though it does not solve them instantly. While far better than gasoline powered cars, and significantly better than any of the other proposed alternatives even when powered with electricity from coal-fired power plants, just how

environmentally friendly electric cars are depends on the source of electricity.[2] Electric cars plugged into a grid reliant on renewable solar or wind power would be truly zero-emissions. Generating electricity through renewable technology rather than continued use of fossil fuels, in combination with the use of electric cars for transportation, would allow us to maintain our basic standard of living without contributing to an impending climate crisis that would destroy that lifestyle. Now, there are two huge divergent aspects of our energy use that contribute heavily to global warming: transportation fuel and electricity generation. Technologically, alternatives to fossil fuels for electricity generation could still be improved, but are ready to be implemented whenever we have the political will to do so. All we have to do is build the wind farms and start installing solar panels wherever practical. As the windmills and solar panels are implemented on a large scale, further developments and cost reductions are likely, though we may have to accept higher energy prices to accompany our cleaner air and more stable climate. Liquid fuels from coal or plant matter to replace oil for transportation present few technological hurdles but they have proven inefficient and their impacts on the environment problematic. Shifting away from liquid fuels and internal combustion in favor of electrification in the transport sector presents the best opportunity to reconcile environmental concerns with the need for accessible and practical individual vehicles.

Since the technology for clean electricity and for electric cars is available, the remaining question is how to implement that technology so that it can compete successfully to replace the current polluters. Electric cars have been around for generations. Invented around the same time as gasoline powered cars, they competed

[2] See graph 1 for emissions comparison of internal combustion, hydrogen fuel cell cars, and battery electric cars based on power plants fed with coal, natural gas, or renewable energy.

with some success before being relegated to the status of hobbyist's toys for nearly a century, until concerns about global warming and smog renewed public and political interest. Electric cars briefly made a comeback in California in response to a legal quota demanding them as the state struggled with smog. When those regulatory demands were removed after a few years, car companies immediately pulled the electric vehicles from the market in favor of SUVs, pickups, and Hummers, with a middle ground of hybrids available from some manufactures.[3] Despite repeated failures to win a large consumer following, electric cars never fully disappeared. Major car companies as well as start-ups continued to occasionally attempt to resurrect the quiet, clean electric car, and a few enthusiasts supported those efforts, but they have not managed to compete on a large scale.[4] The exact form of the problem with electric cars changed over the years, but the range provided by the batteries and the time necessary to recharge them has long been the barrier to mass adoption of electric cars over internal combustion.[5]

In the early 20th century, electric cars were popular with and marketed to women because they were quieter and easier to drive, with an electric start rather than a crank engine.[6] As women's cars, they generally remained in towns while the ladies had tea or did shopping, presumably limiting the likelihood of range being a problem given their usage. However, relegating electrics to being ladies' vehicles for short errands hardly led

[3] "The History of Electric Cars," *Idaho National Laboratory: Advanced Vehicle Testing*, http://avt.inel.gov/pdf/fsev/history.pdf; "Timeline: History of the Electric Car . NOW | PBS," June 2006, http://www.pbs.org/now/shows/223/electric-car-timeline.html.
[4] "Timeline: History of the Electric Car . NOW | PBS."
[5] Michael Schiffer, *Taking Charge: the electric automobile in America* (Washington DC: Smithsonian Institute Press, 1994), 64-75.
[6] Ibid., 135-139.

to mass adoption and competitive advantage.[7] Men probably liked the noise, smell, dirtiness, and general masculine nature of early gasoline cars, and the gender divide would not have been helpful to the success of early electric cars. However, the primary advantage of gasoline cars was the relative ease and speed of refueling. A family could drive a long distance out into the countryside in their internal combustion vehicle and carry along a couple of containers of extra gasoline to ensure they would make it back home. Touring was a popular early use of automobiles.[8] Leaving the towns in an electric car meant counting on the batteries running out near an electricity outlet during a time before Franklin D. Roosevelt's investment in rural electrification. In 1920, slightly less than 40% of all households had electricity, and almost all of those homes were in cities and towns. Even in 1930, just10% of rural homes had electricity, a number that increased only with New Deal programs between 1935 and 1955. By that time, internal combustion was well-established as the dominant vehicle propulsion system.[9]

Running out of either battery or gasoline and being stranded would have been an even bigger ordeal then than it is now, given the lower population density and lack of cell phones and AAA memberships. Still, it would have been a little easier to have someone bring out a container of gasoline than to tow or push the vehicle to an electricity outlet and wait hours for it to recharge before driving home. Without fully developed infrastructure for either type of car, gasoline was a stronger competitor because it was easier to work around its faults. Before gas stations appeared on every corner, people could transport the gasoline to the car when necessary. Electric cars needed to be plugged

[7] Virginia Scharff, *Taking the Wheel: Women and the Coming of the Motor Age* (The Free Press, 1991), 37-43.
[8] Gijs Mom, *The Electric Vehicle: Technology and Expectations in the Automobile Age* (Johns Hopkins University Press, 2004), 45-53.
[9] Paul Wolman, "Rural Electrification in the United States: 1930-1950," March 8, 2006.

in, so even if electric outlets were more common than gas pumps, they were not easier to use for drivers away from home. Electric cars did have some advantages. Then as now, they could usually be charged at home, making most refueling easier and more convenient than refilling with gasoline. Even then, people complained occasionally about the noise and pollution from internal combustion cars, a complaint that was taken less seriously because of the gender divide between electric and gasoline cars.[10] In addition, the predecessor to cars of any kind, the horse, offered up enough smelly waste on the streets that either type of vehicle would have seemed like a significant improvement.

After gasoline became cheap and readily available and the electric starter for gasoline cars was invented, internal combustion was ensured dominance and continued improving, while electric cars gradually faded away and stagnated technologically.[11] Switching away from a dominant transportation form takes a great deal of effort. There needs to be an instigating force, either developmental breakthroughs from a competing transportation option or a major problem with the status quo. For decades, there was no reason to work seriously on competitors to internal combustion because gasoline powered cars suited the needs of the country and the world adequately. Oil shortages in the 1970s caused a brief surge of interest in electric cars, but the price of gasoline fell again before more than a few conversion vehicles could be made.[12] Meanwhile, some of the problems with range and batteries could have been solved through the development of other technology. Better computer equipment would allow drivers to accurately monitor their battery levels to prevent people from getting stranded. Rural electrification brought

[10] Scharff, *Taking the Wheel: Women and the Coming of the Motor Age*, 42.
[11] Jim Motavalli, *Forward Drive: the race to build "clean" cars for the future* (San Francisco: Sierra Club Books, 2000), 14.
[12] Ibid., 15-17.

electricity to the most remote reaches of the country, so people would rarely drive far from available outlets to recharge, albeit still slower than would have been desirable. Battery exchanges, in which depleted batteries could be swapped for fully charged batteries, have probably always been possible, but require sufficient density of cars with the same type of interchangeable batteries to be a successful business model. Electric cars could have been successful with the more readily available electricity and battery exchange programs, but gasoline was cheap and no one yet saw its emissions or importation as a serious enough problem to warrant elimination of internal combustion.

Now, a convergence of factors favors electric cars over internal combustion. The problems with gasoline are more urgent and more serious than ever before, making internal combustion a less attractive competitor despite the advantages of infrastructure and familiarity gained through the past century. Dependence on foreign oil poses a national security risk, both because most of the world's oil reserves lie under nations not generally considered friendly, trusted allies, and because the threat of peak oil no longer seems so distant. Climate change caused by the burning of fossil fuels, including oil for transportation, threatens the planet with rising sea levels, melting arctic ice, increased disease, increased extreme weather, and a slew of other potential catastrophes. The threat of climate change dwarfs other environmental problems, but more run-of-the-mill pollution from cars causes dangerous and unpleasant smog in urban areas, with frequent studies in the news to remind us of the health impacts of breathing polluted air. Recent high gas prices and high oil-company profits create greater antagonism toward gasoline, raising the popularity of any alternative that would allow us to stop giving our money to

the corporations that profited so excessively while 'regular people' struggled to afford their product.

Meanwhile, further advances in batteries, primarily discovered during research for new electronics, reduce the old problems of range and battery life further. New types of batteries have become available in recent years that store more energy but weigh less, including some that can recharge in minutes given a sufficiently high voltage power feed.[13] Nanotechnology offers the potential for greater batteries improvements, giving them a longer lifespan by greatly reducing the wear of the charge cycle.[14] Electric cars have always had some advantages. They can be charged very cheaply at home most of the time, certainly more convenient than stopping at a gas station every few days; they are quieter; they have no tailpipe emissions; acceleration rates can be quite impressive; and electric motors are inherently more efficient. Now, a combination of new technological advances and infrastructure development could make them a better choice for most consumers than internal combustion for the first time. A lack of understanding of the technology among consumers and many environmental leaders has created a set of false technological barriers so that people think of electric cars as futuristic concept cars unlikely to be successful in the near future. Chapter one will discuss the technology of electric cars, explaining the technical advances that make the old hurdles surmountable as well as the inherent advantages. It also analyzes other proposed alternatives to gasoline and compares their advantages and disadvantages with those of electric cars.

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[13] Samuel Moore, "A Rapid-Recharge Lithium Battery," *IEEE Spectrum Online*, March 2009, http://www.spectrum.ieee.org/mar09/8149; Duncan Graham-Rowe, "Charge a battery in just six minutes - tech - 07 March 2005 - New Scientist," *NewScientist*, March 7, 2005, http://www.newscientist.com/article/dn7081.

[14] Joseph Kejha, "High power high energy lithium-ion cell invention," http://www.freshpatents.com/High-power-high-energy-lithium-ion-cell-dt20080117ptan20080014507.php.

The Technology

The basic engineering of electric cars is actually simpler than that of internal combustion vehicles, with an electric motor and batteries to power the car. Internal combustion vehicles have many more components, with complexities added over the past century in response to higher environmental standards. Catalytic converters, oil changes, exhaust systems, and a slew of other things that make cars expensive to maintain would be eliminated. The first few electric cars on the market may have reliability issues as engineers work out the details of the best designs, but eventually, they could be an improvement on current cars in terms of maintenance costs because there are far fewer moving parts.[15] According to Tesla, the maker of an electric sports car currently being sold in California, the only moving part in the Roadster's engine is the rotor. Internal combustion engines have over one hundred moving parts susceptible to damage over time.[16] Electric cars could transform car ownership into a much less stressful experience without the reliance on mechanics to fix the mysterious inner workings of a vehicle that makes a strange noise or smell or develops a vibration or fails emissions testing or just won't start. On the other hand, battery packs may not last the life of the vehicle, and they are expensive, though prices are likely to drop when companies settle on the best technology and mass-production begins.

Batteries

[15] Early models of the Tesla had transmission problems until engineers settled on a different design. Real world driving conditions differ from factory test conditions, and it may take a couple of years for electric car makers to discover and resolve any unforeseen problems.
[16] Tesla Motors website, http://www.teslamotors.com/efficiency/how_it_works.php

Constant developments in battery technology have improved their charging capacity, range, and lifespan, so it is possible that longer-lasting batteries will be installed in a potential mass-produced electric car, eliminating the replacement problem. A number of battery options have been used, ranging from lead-acid batteries in the first electric cars of the modern era and in many home conversion kits to the brand-new lithium titanate anode batteries. Nickel Metal Hydride and Nickel Cadmium batteries briefly replaced lead acids in recent electric cars, including the GM EV1, made with Nickel Metal Hydrides to increase range and efficiency, but they have now been displaced by the still-cheaper, more efficient, and more environmentally friendly lithium ion battery.[17] Lithium ion batteries currently lead the market, both in electric cars and in common electronic devices, which will share the benefits from any new battery developments. A 2006 journal article explains the impacts of the invention of lithium ion batteries. "Since the birth of the lithium ion battery in the early 1990s, its development has been very rapid and it has been widely applied as power source for a lot of light and high value electronics due to its significant advantages over traditional rechargeable battery systems."[18] Lithium titanate batteries use the basis of lithium ions, but add a coating of nanomaterial to the anodes that vastly increases the surface area available to the ions.[19] Research into various other ways of tweaking lithium ion batteries to improve range and charging capabilities shows a great deal of promise.[20] With the new materials and

[17] A.M. Bernardes, D.C.R. Espinosa, and J.A.S. Tenorio, "Recycling of batteries: a review of current processes and technologies," *Journal of Power Sources* 130, no. 1-2 (May 2004): 291-298; Graham-Rowe, "Charge a battery in just six minutes - tech - 07 March 2005 - New Scientist."
[18] L.J. Fu et al., "Surface modifications of electrode materials for lithium ion batteries," *Solid State Sciences* 8, no. 2 (February 2006): 113-128.
[19] Nicolas Tran and et al, *1257.pdf (application/pdf Object)* (Moosburg, Germany: Sued Chemie AG), http://www.electrochem.org/meetings/scheduler/abstracts/214/1257.pdf.
[20] H.P. Zhang et al., "A novel sandwiched membrane as polymer electrolyte for lithium ion battery," *Electrochemistry Communications* 9, no. 7 (July 2007): 1700-1703; Fu et al., "Surface modifications of

increased surface area, batteries can recharge in only minutes, operate at more extreme temperatures, and last through far more recharges, while traditional lithium ion batteries undergo stress that diminishes their lifespan when subjected to flash-charging.[21]

The most discussed barrier to electric cars is the range provided by the batteries and the length of time required for recharging. New types of batteries have longer ranges with less weight than the old lead-acid batteries, helping ameliorate that concern. Now that batteries capable of recharging in less than the time it takes to fill a gas tank have been developed, range should no longer prevent electric cars from fulfilling consumer needs. Range depends upon the number of batteries, and adding more batteries increases the cost and weight of the vehicle, and, of course, there are limits to how many batteries can fit into a car. Enough batteries to provide between two and three hundred miles of range can fit into a small car (the small and high-powered Tesla Roadster has an estimated range of about 240 miles).[22],[23] Since most consumers will likely be able to charge their vehicles every night with little effort, it would be reasonable for people to choose cars with a range of slightly longer than their usual daily commute, preventing large, expensive battery packs from pushing electric cars above the price range of average consumers.

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electrode materials for lithium ion batteries"; Ki Tae Nam et al., "Virus-Enabled Synthesis and Assembly of Nanowires for Lithium Ion Battery Electrodes ," *Science* 312, no. 5775 (May 12, 2006): 885-888.

[21] "Power & Energy Systems," Altair Nano, *What can nanotechnology do for your batteries?*, http://www.b2i.us/profiles/investor/fullpage.asp?f=1&BzID=546&to=cp&Nav=0&LangID=1&s=236&ID=9307#recharge.

[22] "Tesla Motors," http://www.teslamotors.com/.

[23] A 300 mile range would be slightly on the low end of the typical range of gasoline vehicles on the market now. The 2009 Honda Civic has a range of about 370 miles; the Volkswagen Jetta's range is 330 miles; the Toyota Yaris's range is also about 330 miles; the Mazda Miata's range is 315 miles (automobiles.honda.com; www.mazdausa.com).

Another technology available in cars with battery packs, including current hybrids like the Toyota Prius, is regenerative braking. Regenerative braking allows the energy used to slow the car to recharge the batteries, extending the range and increasing the efficiency of electric cars. Instead of throwing away the car's momentum during braking, that energy is captured and sent to the batteries.

Lithium ion and lithium titanate batteries further eliminate concerns about toxicity and safety. The only hazard posed by lithium batteries is their potential flammability. They do not ignite easily, making it a fairly mild concern, but if they do ignite, the fire is difficult to extinguish.[24] Overall, lithium batteries are a huge improvement over previous battery technologies in terms of the environment, safety, and efficiency. While eating the batteries would not be recommended, they do not contain actively toxic materials and can be fully recycled, though only a few select facilities currently provide recycling services for them. They contain no heavy metals, and could legally be disposed of in landfills, but contain useful and valuable parts that make recycling cost effective. An engineer at Tesla wrote a very accessible description of the recycling process for their lithium ion batteries, beginning with the separation of electronic components that can be immediately reused. Next, local facilities recycle wires and metals, then the remaining bulk of the battery modules goes to a facility in British Columbia to be broken down chemically and manually, producing fluff, copper cobalt, and slurry. The 'fluff' consists mostly of plastic and will be land filled until quantities are great enough to make recycling or separation and reuse economical. The copper cobalt is sold for recovery of some types of metals,

[24] Bernardes, Espinosa, and Tenorio, "Recycling of batteries: a review of current processes and technologies."

and the slurry is reused in appliance coatings.[25] The process will probably be slightly different for the lithium titanate batteries, but they do not contain significantly different materials, and are also non-toxic, so presumably similar recycling methods will be applicable.

Electric Motors

The developments in battery technologies, particularly the elimination of the toxic lead acid batteries and the progress in creating a flash charge option, allow electric cars to be viable in the market place by removing the major competitive disadvantages. Electric motors provide distinct competitive advantages over internal combustion engines, even aside from the overall environmental benefit. Driving in city traffic in an electric-drive vehicle saves a tremendous amount of energy compared to driving a car with only a gasoline engine. They have full power available even before the rotor in the motor begins spinning, which means there is no need for the car to idle when stopped, as internal combustion vehicles must. Electric motors give the cars a linear torque curve, meaning that they have access to full power from the instant the driver touches the 'gas' pedal, making even those without exceptionally large motors capable of rapid acceleration. The redline of electric motors in current vehicles has mostly been set around 15,000 rpm, but electric motors can be designed to operate in a variety of speed ranges.[26] Because the motor can spin in a wider range of speeds than an internal combustion engine, traditional transmissions with several gears are unnecessary. Instead, a simpler single-gear, or possibly double-gear transmission, neither a standard nor automatic, can be used to

[25] Kurt Kelty and Director of Energy Storage Technologies, Tesla Motors, "Tesla Motors - touch," *Mythbusters Part 3: Recycling our Non-Toxic Battery Packs*, March 11, 2008, http://www.teslamotors.com/blog4/?p=66.
[26] Pat Wildfire, March 15, 2009.

translate the engine rotational speed to the wheel rotational speed.[27] The driver does not need to shift, and there is no complex automatic transmission robbing power and dexterity. There is no need for a reverse gear because electric motors can spin in both directions. The wiring to allow the driver to switch to reverse could be incorporated in a gear shift or added as a switch elsewhere, likely to be determined by consumer preference. Since no gear-changing takes place, the car can just keep increasing in speed, accelerating without pause until it reaches the desired rate of travel.

Environmentally, electric cars have two advantages: the power source is cleaner, with the potential to be completely emissions free, and they use that power much more efficiently than internal combustion cars, which waste much of the energy they consume. Just as technology for electric cars has improved in recent years with the extra research interest because of the onset of climate change, technology for capturing renewable energy sources like wind and solar has also improved. If we have the political will and the dedication to the environment necessary to change our transportation system to electric cars (not at all a sure thing) then we will probably also have the will to embark on a similar process with our electricity generation. However, even if charged in a grid reliant on the dirtiest coal-fired power plants, electric cars produce lower life-cycle emissions than either internal combustion or hydrogen fuel cell cars.[28] Fuel cell cars are also considered zero-emissions vehicles, but actually use more life-cycle electricity than electric cars.

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[27] "2010 Chevrolet Volt Reviews, Pictures and Prices," *U.S. News Rankings and Reviews*, http://usnews.rankingsandreviews.com/cars-trucks/Chevrolet_Volt/; Wildfire, interview.
[28] "Tesla Motors - well-to-wheel," *Well to Wheel Energy Efficiency*, http://www.teslamotors.com/efficiency/well_to_wheel.php; Stephen Eaves and James Eaves, "A Cost Comparison of Fuel-Cell and Battery Electric Vehicles," *Journal of Power Sources* 130, no. 1-2 (May 2004): 208-212.

Hydrogen Fuel Cells and Other Alternatives

Fuel cell vehicles compete with battery electrics in the minds of policy makers and environmentalists, but our legislation lags further behind, with tax subsidies and grants available for alternative liquid fuels meant to replace oil. Each of the liquid fuels proposed creates more problems than it solves. Coal-to-liquids produces a rough equivalent of diesel fuel through an energy intensive process, releasing carbon dioxide both in the conversion process and in tailpipe emissions. While it may be possible to capture and sequester the carbon dioxide produced at the facility making the fuel, the tailpipe greenhouse gas emissions remain about the same as current emissions from gasoline and diesel vehicles. Without the carbon capture and sequestration, liquid coal fuels produce twice as much carbon dioxide as their traditional counterparts.[29] Reducing dependence on foreign oil is an important goal, but doing so at the expense of the environment rather than working to solve both problems simultaneously makes little sense.

Bio-fuels create fuel from organic matter, most prominently ethanol from corn, though other sources of organic matter can be more efficient. Emissions from burning ethanol are lower than those from burning oil, but that improvement is nearly completely negated by the high energy cost of growing, transporting, and processing corn into ethanol.[30] In addition to having a modest effect on emissions, using any food source as a fuel source creates supply problems and high prices for the food. Compressed natural gas

[29] James MIT Coal Energy Study Advisory Committee, "The Future of Coal: Options for a Carbon-Constrained World" (Massachusetts Institute of Technology, 2007), 153-157, http://web.mit.edu/coal/The_Future_of_Coal.pdf.
[30] Daniel Sperling and Debra Gordon, *Two Billion Cars: Driving Toward Sustainability* (New York: Oxford University Press, 2009), 97-99.

offers another alternative to oil, and one with lower emissions, but creates safety and engineering problems. Resource scarcity would also be a problem with natural gas were we to attempt to use it in the transportation sector on a large scale, particularly since many people rely on already-pricey natural gas to heat their homes.[31] None of these options compete with battery electric cars on an environmental front, and moving away from liquid fuels is the best way to eliminate the tailpipe emissions that are difficult to reduce.

Hydrogen fuel cells offer a zero-emissions alternative to battery electric cars, and, on the surface, sound very attractive. The fueleconomy.gov website describes hydrogen fuel cells in glowing terms: "But while battery electric vehicles use electricity from an external source (and store it in a battery), FCVs create their own electricity…FCVs fueled with pure hydrogen emit no pollutants; only water and heat."[32] In reality, though, obtaining the hydrogen that allows fuel cell vehicles to create their own electricity uses a significant amount of electricity, and transporting and storing that hydrogen adds to the energy consumption. In the end, fuel cell vehicles use more than twice as much electricity as electric vehicles that use it directly to charge batteries.[33] Hydrogen fuel cell vehicles have more steps in the transfer of energy that increase the inefficiency in comparison to electric cars. Electrolysis, in which the hydrogen is separated from water, is 72% efficient; a hydrogen pipeline, the most efficient method of transporting hydrogen, is 84% efficient; the hydrogen storage and fuel cell system is 54% efficient; and the electric drive train is 89% efficient, by one set of calculations. Electric cars, meanwhile, transport the

[31] Ibid., 94.
[32] "Fuel Cell Vehicles," http://www.fueleconomy.gov/feg/fuelcell.shtml.
[33] Eaves and Eaves, "A Cost Comparison of Fuel-Cell and Battery Electric Vehicles."

electricity through existing power lines at 92% efficiency; use an 89% efficient battery charger; lithium ion batteries with 94% efficiency; and also use the 89% efficient electric drive train.[34] In the end, sending 60 kWh to the wheels uses 202 kWh of energy in hydrogen fuel cell vehicles and only 79 kWh in battery electric cars.[35]

Further reducing their environmental standing, fuel cell vehicles do emit water vapor, a fact proponents spin in a positive tone with statements like, "The vehicle's only emission is water."[36] Water vapor, while not nearly as bad as carbon dioxide, is still a greenhouse gas. Internal combustion engines already emit water vapor, so it would not be a new emission, though the quantity could change. Further research into the impact of water vapor on the climate is necessary before concluding it is not potentially harmful. Recent climate modeling and research suggests that water vapor may have a stronger feedback effect than previously believed, increasing its impact on global warming.[37] Any changes in cloud cover would also impact the climate and precipitation patterns, though modeling the impact of clouds on global warming has been difficult to do with accuracy because the height of the clouds appears to alter their impact.[38] It is apparent to people with little scientific knowledge that *electric* cars will use electricity, and therefore will not be completely free of pollution. Hydrogen fuel cells are more of a blank page and can be made to sound far better for the environment than they actually are.

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[34] Ibid.
[35] See Figure 2: Well-to-Wheels Efficiency Comparison, with numbers from Eaves and Eaves
[36] "Honda Worldwide | January 13, 2008 "Honda CR-Z Hybrid and FCX Clarity Fuel Cell Vehicle Introduce Detroit to Next-Generation Green Cars "," *Honda News Release*, January 13, 2008, http://world.honda.com/news/2008/4080113Next-Generation-Green-Cars/.
[37] "Water Vapor Confirmed As Major Player In Climate Change," *Science Daily*, November 18, 2008, http://www.sciencedaily.com/releases/2008/11/081117193013.htm.
[38] Anna Martini, "Geology 9: Environmental Science Case Studies" (Amherst College, Spring 2006).

Hydrogen fuel cells may actually produce higher greenhouse gas emissions than internal combustion cars, depending on the source of electricity used to produce the hydrogen.[39] They share with electric cars a dependence on developments in electricity generation for improved environmental status, though they are more energy intensive regardless of the energy source. With renewable energy, hydrogen fuel cell vehicles, like electric cars, can be truly zero-emissions. They also use electric motors, which, as previously discussed, have many performance benefits. However, the use of hydrogen creates a slew of safety problems, as well as engineering difficulty. Because hydrogen is the lightest of the elements, storing enough of it to give vehicles a reasonable range would require about four times as much space as a gas tank providing the same amount of energy.[40] Few if any known materials are dense enough to prevent leakage, which could lead to explosions. Hydrogen molecules are very small, allowing them to escape from most containers, and if hydrogen leached out from the tank into a contained space, like a garage, and the car's owner lit a cigarette, there could be a fairly serious explosion.[41] Tank rupture in case of an accident could be similarly dangerous. Engineers may be able to find ways to ensure the reasonable safety of hydrogen fuel cell vehicles, at least so that they are on par with gasoline cars, but these issues make the large-scale development of fuel cell vehicles both expensive and a prospect for the future rather than the present. Given the urgent need to reduce greenhouse gas emissions significantly before the climate reaches a tipping point at which feedback cycles make it impossible to halt global warming, we would do better to invest in the easier and more readily available

[39] See figure 1.
[40] "Hydrogen (7-Dec-2008)," http://www-formal.stanford.edu/jmc/progress/hydrogen.html.
[41] Pat Wildfire, "Investigation into the Lack of Practicality of Hydrogen as a Fuel for Internal Combustion Engines in Vehicles " (West Virginia University, Fall 2007).

technology of battery electric vehicles, particularly since they do not have any major drawbacks.

Hybrids

E-hybrids, sometimes called plug-in hybrids, could constitute a half-way point to the development of full electric cars using technology similar to that used in current hybrids like the Toyota Prius. The Prius uses batteries to take advantage of regenerative braking and an electric motor combined with a traditional gasoline engine to run the car, with both motors working in varying degrees depending on the speed and power demand. A different hybrid design further reduces gasoline use by using the electric motor and batteries all the time, with a gasoline engine used as a generator to recharge the batteries when necessary, a design that works well with a plug-in component.[42] One example being developed by a major car company is the Chevy Volt, expected to be available in 2010. E-hybrids make use of both an electric motor and an internal combustion engine to increase fuel efficiency dramatically without any of the problems with range associated with full electric cars, but include a plug-in component to better take advantage of the electric motor and batteries. The Volt will be able to travel 40 miles with only the electric motor on fully charged batteries, then will switch to the gasoline engine.[43] However, as previously discussed, flash charges of batteries eliminates the problems with range, making full electric cars viable for almost any consumer. Combining the two technologies increases the complexity of the car rather than simplifying it, escalating the potential for problems and eliminating the electric car's advantage of lower maintenance

[42] Motavalli, *Forward Drive: the race to build "clean" cars for the future*, 67-68.
[43] "Chevrolet | Electric Car - Chevy Volt. Fully Charged 2010," http://www.chevrolet.com/electriccar/.

needs. In addition, building cars with internal combustion engines and all the accompanying equipment plus electric motors and battery packs cannot be cost competitive without major subsidies. One car with two drivetrains, even if both are smaller, will be more expensive than a car with only one drivetrain.

On the other hand, e-hybrids could ease the transition for both consumers and car makers, lessening the fear of sudden change and the riskiness of creating something too new and different. While they help people get used to the idea of electric cars and learn more about them, successful e-hybrid programs could prompt the development of the infrastructure that will be necessary for full electric cars, helping resolve the chicken-and-egg problem so that charging stations would be available by the time people begin buying full electric cars as their sole vehicles. People could still buy gasoline when necessary, but plug-in hybrids might create demand for charging stations at frequent roadside stops like restaurants and hotels near interstates. Plug-in hybrids could further provide a chance for both the auto industry and government policy makers to gauge consumer behavior. Do people plug in their cars during off-peak hours? Do they regularly plug in at all, or mostly rely on the gasoline engine? Early consumers of e-hybrids may not be a representative sample of the average car buyers whose behavior would be important if the nation switched to electric cars. Still, if those more environmentally conscious buyers fail to use the e-hybrids efficiently, it would indicate the need for an eventual electric car infrastructure that requires the least possible consumer effort.

Despite their technological and environmental advantages, electric cars will struggle to compete with internal combustion because of inertia in the market. Continuing to use a dominant technology provides significant advantages to both automakers and

consumers, and being the trendsetter than attempts to introduce a new technology carries a great deal of risk. Developing and producing electric cars will be expensive, and early models are likely be costlier than comparable internal combustion cars unless some of the externalized costs of continued gasoline use are internalized. In the next chapter, government policies that could help electric cars overcome the barriers to entering the market will be explored.

Government Policy

Some sort of push from the government to either encourage or mandate the production of electric cars will likely be necessary to start large scale manufacturing. Producing electric cars would be a risky undertaking for carmakers. What if they invest lots of money into research and development, factory refitting, employee training, marketing, and supplies, then the cars don't sell? As long as none of the major automakers offer competitively-priced electric cars, consumers will have no choice but to continue buying internal combustion vehicles. Historically, the automotive industry (and most other industries) tends not to voluntarily implement positive environmental technologies, preferring to continue using established, low-risk technologies until forced to change by consumer preference, competition, or government regulation. Even relatively inexpensive safety technology like seatbelts and airbags were slow to catch on within the industry. Ideas for the best types of policy come from a variety of sources: historical experience with emissions standards from the Clean Air Act, California's efforts to lower emissions and promote zero-emissions vehicles, current legislation, and policy proposals from think tanks. The range of possibilities include grants and low-interest loans for research and development, infrastructure development, quotas forcing automakers to produce a percentage of electric cars, education programs, punitive measures on internal combustion cars (i.e. a very high gas or carbon tax), or tax subsidies on electric cars. Probably the most effective way to help electric cars succeed will involve a combination of policies designed to partially compensate for their shortcomings while also addressing the externalities of internal combustion. Such policies would lower

the cost of electric cars to consumers, provide or encourage the private sector to provide infrastructure, and create a mechanism to direct the costs of pollution to drivers of internal combustion vehicles.

The environmental crisis of the 1970s was also caused by the burning of fossil fuels, particularly in cars, but proved more easily solved than global warming is likely to be. Emissions causing smog can be removed with catalytic converters and other emissions equipment, but even this fairly slight change in car design created great controversy and dire warnings. Carmakers claimed that the emissions control requirements mandated in the Clean Air Act would bankrupt Detroit and drastically increase the cost of cars, making them unaffordable for many families.[44] In addition to concerns about the costs of implementing emissions equipment, automakers claimed, as they do today, that making cars more environmentally friendly would require the sacrifice of safety. John Adamson of American Motors is quoted as saying that he "would not let [his] wife drive one of the test models [they were] working with."[45] A Chamber of Commerce spokesman, John Coffey, testified to Congress that the Clean Air Act could destroy certain industries: "Such may be the case for the present automobile industry if the emissions standards required by the clean air act amendments of 1970 cannot be met. This possibility may be remote, but the prospects for the internal combustion engine cannot be wholly optimistic."[46]

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[44] "Auto Makers Backed on Pollution-Act Plea," *New York Times*, January 16, 1972; David Bird, "Ford Official Urges a Major Loosening of Emission Regulations to Avert 'Shutdown of U.S. Auto Industry'," *New York Times*, February 16, 1973; Mobil Oil Corp., "The $66 Billion Mistake," *New York Times*, January 24, 1973, sec. Display Ad.
[45] "Auto Makers Backed on Pollution-Act Plea."
[46] John Coffey, as quoted in "Pollution Laws Called A Threat to Industries," *New York Times*, May 19, 1971.

Clean Air Act emissions standards may not have killed the internal combustion engine, but the assumption underlying Coffey's statement holds true: internal combustion engines and environmental values are ultimately incompatible. Automakers dragged their feet and managed to get some delays and concessions in the 1970s, but they eventually complied with relatively stringent smog regulations. Car prices did not skyrocket; autoworkers did not lose their jobs; and emissions equipment did not detract from the cars' reliability or safety.[47] The relevant lesson from the history of the auto industry and the Clean Air Act is that sometimes the government does need to be forceful. There is no reason to believe that simply suggesting and encouraging voluntary environmental improvements will be effective. Industry groups may whine about compulsory regulations, but mandates instigate necessary changes and improvements, preventing the industry from stagnating. So, if we need policy changes and government regulations to promote the development of electric cars, what form should such policies take? A variety of options are available, each with some degree of tradeoff between effectiveness and likely political popularity.

Mandates or Quotas

California often leads the rest of the country in progressive pollution-control legislation, in part because of the seriousness of vehicle pollution in and around Los Angeles. Beginning in the early 1990s, California mandated that a small percentage of the vehicles sold in the state by each automaker be zero-emissions vehicles. The Zero Emissions Vehicle (ZEV) mandate stated that 2% of vehicles sold in California in 1998

[47] M. Shelef and R.W. McCabe, "Twenty-Five Years after Introduction of Automotive Catalysts: What Next?," *Catalysis Today* 62, no. 1 (September 25, 2000): 36.

had to qualify as zero-emissions, with the percentage increasing every few years.[48] Battery electric or hydrogen fuel cell cars are currently the only zero-emissions vehicle technologies available. In the early 1990s, hydrogen fuel cell vehicles were even more of a distant dream than they are today, putting the focus on battery electric vehicles. Through intensive lobbying efforts and a lack of cooperation from automakers, the California Air Resources Board (CARB) relaxed the standards and shifted the emphasis to encourage investment in the more distant fuel cell vehicles, despite scientific evidence supporting battery electrics.[49] However, a reasonably successful electric car program began and persisted in California for a few years before the CARB lowered the standards, permitting companies to stop producing and selling battery electric vehicles. Several companies produced a few electric cars, including electric versions of the Ford Ranger pickup truck, the Toyota RAV4, and newly designed electric vehicles from Nissan, Honda, and GM.[50] Probably the most notable of the electric vehicles produced in response to the California regulations, the GM EV1 garnered a great deal of attention and a few devoted followers, but never quite became mainstream. It is unclear whether a lack of interest from consumers or from General Motors prevented the EV1 from increasing sales, though GM did display some eagerness in ending their electric vehicle program as soon as regulations permitted.[51]

Despite their ultimately underwhelming effect, the CARB rules displayed the effectiveness of mandates as long as the policy-makers and enforcers remain steadfast

[48] "Fact Sheet: The Zero Emission Vehicle Program-2008" (California EPA Air Resources Board), http://www.arb.ca.gov/msprog/zevprog/factsheets/2008zevfacts.pdf.
[49] Alec Brooks, "CARB's Fuel Cell Detour on the Road to Zero Emission Vehicles," May 2004, http://www.evworld.com/library/carbdetour.pdf.
[50] "The History of Electric Cars."
[51] Chris Paine, *Who Killed the Electric Car?* (Sony Classics).

and immune to lobbying from industry. A national quota requiring all car manufactures to sell a gradually increasing number of electric cars (or, less specifically, zero-emissions vehicles) bypasses many of the impediments to market-based success of electric cars. Creating infrastructure would be a valuable, relatively low-risk investment given the advance knowledge of how many electric cars would be for sale each year. Each individual automaker would not be at risk of losing business to other makers and placing themselves at a competitive disadvantage if consumers do not respond well to electric cars. In addition, a national quota would force automakers to invest on a larger scale than the CARB standards, which affected only the cars sold in California. Because the regulations only applied in one state, companies had to create a separate set of products in compliance with those standards, while maintaining their usual offerings for the wider national market.

There are both political and practical drawbacks to the mandate proposal. Politicians would likely be hesitant to order private-sector companies to make certain products.[52] Because any new technology is more expensive in its early stages, consumers might not be appreciative of such heavy-handed measures, and if people don't buy the cars, it would hardly be reasonable to demand that companies produce them. Without offering accompanying aid to assist the companies in retooling factories and retraining workers, plus tax breaks or subsidies to help price the cars competitively, legislation mandating production of zero-emissions vehicles could easily fail. In addition to being

[52] One potential way to use mandates without the political fallout would be to tie zero-emission vehicle development to ongoing government bailouts of auto companies. Demanding that private companies produce certain products might appear beyond the prescribed role of Congress, but the government deserves a larger say in how businesses are run if taxpayer money is preventing the mismanaged companies from entering bankruptcy.

potentially impractical, a poorly handled mandate could tarnish the image of electric cars as another government boondoggle, similar to corn-based ethanol.

Tax Breaks/Subsidization

Whether instead of or in addition to mandates, a fairly easy risk-free government policy of lowering or removing taxes from zero-emissions vehicles would help equalize the cost to consumers trying to choose new cars. Families might be interested in an electric car but unwilling or unable to spend several thousand dollars more than they would pay for an internal combustion vehicle. Temporary subsidies or tax write-offs in amounts sufficient to put electric cars within the same price range as equivalent traditional cars would make electric cars an option for the middle class. Current hybrids provide a model of how tax credits and rebates could work, though the exact system would probably be designed somewhat differently.

Purchasers of new hybrids receive an income tax credit of up to $3400, with the credit decreasing after the manufacturer has sold 60,000 vehicles, then disappearing entirely beyond the fifth calendar quarter after that threshold.[53] This credit helps manufacturers sell the first vehicles of a new line of hybrids, and it helps the early consumers pay for the vehicles before costs are reduced through mass production. It does not, however, offer continuous support for consumers who would prefer to buy a still-more-expensive hybrid a few years after the company puts it on the market. In addition, the tax credits were not sufficient to bring early models of hybrids into the mainstream. Toyota sold early models of the Prius at a significant loss until they became popular with

[53] "New Energy Tax Credit for Hybrids," *US Dept. of Energy; US Environmental Protection Agency*, http://www.fueleconomy.gov/Feg/tax_hybrid.shtml; "Alternative Motor Vehicle Credit," Internal Revenue Service, http://www.irs.gov/newsroom/article/0,,id=157632,00.html.

consumers and cheaper to produce.[54] Similarly strong commitments from automakers will likely be necessary for the successful introduction of electric cars.

Because the batteries used in electric cars will be very expensive until they can be mass-produced, and the manufacture of the cars themselves will require new infrastructure, early electric cars will be expensive to make. Tax credits can be used to subsidize higher prices, encouraging consumers to buy the cars even if they cost several thousand dollars more than comparable internal combustion vehicles. A subsidy at the time of purchase would likely be most effective in limiting the initial price disparity, but consumers might also be attracted to a yearly tax rebate for the use of an electric car as a primary vehicle. Government assistance with the early high costs of new green technologies could be directed at the producers as well. While Toyota had the commitment and financial strength to subsidize the Prius internally until it became profitable, the government could offer subsidies to carmakers to moderate the high costs of developing electric cars. Grant funding and partnerships between government agencies like the Department of Energy and car companies could encourage investment in research and development of electric cars and advanced battery systems. Government funding could also be made available to help companies retrofit factories to manufacture electric cars in the place of gas-guzzling models.

Gas Tax

Tax credits and subsidization can help make electric cars competitive with internal combustion vehicles, but will cost the government a lot of money. Instead of or

[54] David Magee, "Favor Long-Term Strategies Over Short-Term Fixes," in *How Toyota Became #1: Leadership Lessons from the World's Greatest Car Company* (Penguin Group, 2007), 108-111.

in addition to spending money encouraging good behavior from consumers and companies, the government could impose a tax to discourage use and production of gas-guzzling vehicles. High gas prices should result in increased public demand for alternative vehicles and reductions in gasoline consumption, with more people buying greener cars, carpooling, or taking public transportation.[55] Increasing the cost of gasoline to take into account the societal costs of emissions and global warming would help consumers more accurately consider the full costs of internal combustion vehicles. Electric cars have much lower emissions, reducing the problem of externalities. Because the operation costs of internal combustion vehicles would be higher with a gas tax, consumers would demand an alternative. The advantages of electric cars over other transportation options make them the most likely choice, particularly if interest is prompted in part by expensive gasoline. Joseph Romm, an expert on hydrogen and former Acting Assistant Secretary of Energy, estimates the refueling costs of hydrogen fuel cell vehicles to be between $4 and $12 per gallon-equivalent, and biofuels tend to be relatively expensive as well.[56] The price of electric cars is very likely to go down in time, but implementation of a gas tax would make lifetime ownership costs of more expensive initial models of electric cars comparable to internal combustion vehicles since the refueling costs of electric cars would be so much lower.[57] In addition to reduced fuel costs, electric car owners will also save on maintenance, with no need for oil changes or most other typical tune-up jobs, and reduced likelihood of malfunction because of the

[55] Energy Information Administration, *Short-Term Energy Outlook Supplement: Motor Gasoline Consumption 2008: A historical perspective and short term projections* (Department of Energy, April 2008), http://www.eia.doe.gov/emeu/steo/pub/special/2008_sp_02.pdf; Sperling and Gordon, *Two Billion Cars: Driving Toward Sustainability*, 54-55.
[56] Joseph Romm, *Reviewing the Hydrogen Fuel and FreedomCAR Initiatives* , 2004, 4-5, http://74.125.95.132/search?q=cache:S9sbKzi2awMJ:www.brdisolutions.com/Site%2520Docs/romm.pdf+joe+romm+price+of+hydrogen&hl=en&ct=clnk&cd=13&gl=us.
[57] See figure 3 for a graphical comparison of ownership costs of battery electrics and internal combustion.

simpler design. Increasing ownership costs of internal combustion cars via a gas tax would help make the gap in post-purchase costs of electric and internal combustion cars obvious to consumers.

One policy study suggests that consumers do not accurately value the lifetime fuel costs of efficient versus inefficient vehicles, but instead pay more attention to the initial price of the vehicle.[58] If people choose to buy a car that costs a thousand dollars less, but will use two thousand dollars worth of additional fuel, a gas tax might not be an effective way to convince people to pay the higher price of early electric cars, though it would still be likely to heighten interest in vehicles that do not use gasoline. Given that claim, a tax could be imposed at the time of vehicle purchase, rather than distributed over time as a gas tax is, to increase the cost of using too much fuel at the time consumers will be most easily swayed. A 'gas-guzzler' tax imposed on all new vehicles would assess the cost of emissions in advance, discouraging the purchase of large SUVs and encouraging the purchase of low and zero-emissions vehicles, like electric cars.[59]

An advantage to a gas tax, whatever its form, is that it does not attempt to directly control the vehicles companies produce and consumers can buy. Such heavy-handed measures from government tend to be unpopular and difficult to justify. While mandating production of electric cars would benefit society, similar mandates have been politically rather than scientifically motivated, resulting in advancement of technologies that are not particularly helpful, like corn-based ethanol. Placing a tax on the problem reduces the externality of pollution, allowing solutions to succeed or fail on their merits rather than

[58] David Greene et al., "Feebates, rebates and gas-guzzler taxes: a study of incentives for increased fuel economy," *Energy Policy* 33, no. 6 (April 2005): 757-775.
[59] Ibid.

the support of sometimes misguided policy makers. Creating conditions in which the most environmentally advanced vehicle has economic advantages over its competitors would benefit electric cars, as the lowest-emissions vehicles ready to begin production. Switching to electric cars for the purpose of reducing carbon emissions and dependence on foreign oil requires that those problems be incorporated into the costs of continuing to drive internal combustion vehicles. If someone invents a new transportation technology with greater benefits than electric cars, then the tax on gasoline would promote the development of that technology, keeping pace with developments rather than requiring a new policy for each new innovation.

Perhaps to an even greater extent than mandates, however, a gas tax directed at consumers would be extraordinarily difficult to garner sufficient political support. Though it would aid in the transfer to cleaner technologies, the initial impact would be to increase the costs of driving, a necessary activity for most Americans. When gas prices were quite high in 2006-2008, people gradually changed their behavior, choosing more efficient vehicles and driving less, demonstrating the effectiveness of high prices.[60] However, the narrative surrounding the high prices wasn't gratitude that they helped instigate better habits, or acceptance that gas should be a pricey resource, but rather anger and demands for political action. People wanted their government to 'do something' to return gas prices to lower levels. The popularity ratings of the President and the Congress fell dramatically as gas prices rose, though of course those ratings encompass many factors.[61] It is unlikely that elected officials would risk angering their constituents by

[60] Energy Information Administration, *Short-Term Energy Outlook Supplement: Motor Gasoline Consumption 2008: A historical perspective and short term projections*.
[61] Lydia Saad, "Congressional Approval Hits Record-Low 14%," *Gallup News*, July 16, 2008, http://www.gallup.com/poll/108856/Congressional-Approval-Hits-RecordLow-14.aspx.

supporting a new tax during an economic downturn, particularly since people would be reminded of the tax every time they purchased gasoline. A February news article about a proposed increase in the Massachusetts gas tax with a public comment section had thirty-three comments, all but one of them strongly opposed, despite Massachusetts's reputation as a liberal, environmentally conscious state.[62]

Adding to the general unpopularity of taxes, a gas tax disproportionately impacts the poor, who must spend a greater percentage of their incomes on necessities, including gasoline.[63] Policy makers would be able to lessen the negative effects on low income people by redistributing the revenue from the tax, perhaps into rebates to help people afford cleaner cars or an income tax rebate for those with incomes below a certain level. Clever accounting and progressive tax policies could eliminate the problem of economic injustice, but they would not resolve political unpopularity. Even finding ways to return the money to those who need it would be unlikely to assuage public anger at a new gas tax from people of all income levels. A carbon tax or cap and trade system might be easier to pass since it would create a separation between the higher price and the consumer, though the ultimate effect would be the same.

Carbon Tax/Cap and Trade

Policies designed to curtail carbon emissions could either tax them directly or impose a cap on overall emissions and allow industries to trade limited carbon credits. Either system places a price on carbon dioxide emissions, making high-emissions

[62] The Republican Newsroom, "Mass. Gov. Deval Patrick eyes 27-cent gasoline tax increase - MassLive.com," *MassLive*, February 9, 2009, http://www.masslive.com/news/index.ssf/2009/02/post_6.html.
[63] Kelly Sims Gallagher et al., "Policy Options for Reducing Oil Consumption and Greenhouse-Gas Emissions from the U.S. Transportation Sector," in *Energy Technology Innovation Policy research group* (Harvard University, 2007), 20.

technologies less attractive and less competitive where alternatives are available. While the end result in the case of gasoline prices and vehicle technologies would be similar to that of a gas tax, with higher gasoline prices prompting development of electric cars as the most viable low-emissions alternative, consumers would be less likely to view carbon curtailment policies as punitive tax increases. Though the impact on gas prices would be similar, and the justifications would be identical, people are more likely to see carbon taxes as necessary measures to promote innovation and better behavior from industries that care more about profit than the environment. Gas taxes, meanwhile, directly target average Americans who may not feel they have much ability to alter their habits or the options given to them by industrial leaders. They have to drive internal combustion cars because there is no viable alternative being produced right now, and punishing them with higher prices does not seem fair. Of course, it is difficult to predict the reaction of anti-gas-tax consumers in the months following implementation of a carbon cap and trade system that increases gas prices. If it prompted quick development of comparatively priced green technologies, presumably consumers would be accepting of higher energy prices. In the case of cars, development of electric vehicles could happen promptly, but they are likely to be more expensive in the early years, leaving low-income consumers the choice of either paying more for gasoline or buying expensive new cars, which they are unlikely to be able to afford. As with the gas tax, some form of rebate or subsidization to help poor people deal with the higher costs would be necessary.

Subsidies and rebates for the poor can ensure the equity of new taxes and regulations, but they cannot ensure that the policy is designed in the most effective possible way. A general carbon tax or cap and trade system would effectively reduce

overall carbon dioxide emissions, but would probably not raise gas prices sufficiently to prompt adoption of electric cars. A policy discussion paper from the Belfer Center at Harvard University explains,

> "The reason that economy-wide carbon prices do not have a significant impact on transportation-sector CO_2 emissions is that the carbon content of petroleum is less than that of coal and there are fewer cost-competitive low-carbon technology alternatives in the short-to-medium term in transportation than in other sectors, such as electricity generation. Even a relatively small economy-wide carbon price causes a noteworthy increase the cost of coal, and so reducing emissions from coal-burning facilities becomes the most economically-rational choice."[64]

Though a general carbon tax or cap and trade system might not help bring electric cars to the market, it would improve their environmental standing once there. Such carbon curtailment policy measures would ensure that utilities use clean, renewable sources of electricity as much as possible, pushing electric cars ever closer to the aspiration of truly zero-emissions transport. Electrifying the transport sector reduces greenhouse gas emissions compared to internal combustion regardless of the electricity source, but we need the drastic emissions reductions that would come with a greener energy grid. No matter how advanced our cars, if we still rely on coal-fired power plants without carbon capture and sequestration technology in a few decades, we will have trouble stemming the tide of global warming.

Instead of imposing a flat tax on carbon across the entire economy, the tax or cap and trade scheme could vary between sectors to ensure that each reduces emissions as much as possible. Without raising the price of carbon significantly for all sectors of the economy, those that can reduce emissions to very low levels would not have an incentive to do so. Because of the high tax on the carbon emissions of vehicles under a sector-based carbon tax, the more efficient electric engines would become more attractive. Meanwhile, those

[64] Kelly Sims Gallagher and Gustavo Collantes, "Analysis of Policies to Reduce Oil Consumption and Greenhouse-Gas Emissions from the U.S. Transportation Sector," in *Energy Technology Innovation Policy research group* (Cambridge, MA: Belfer Center for Science and International Affairs, 2008), 15, http://belfercenter.ksg.harvard.edu/files/2008_Gallagher_Collantes_AutoPolicyModelingResults.pdf.

industries that do not presently have low-carbon alternatives could be taxed at a lower rate or given more carbon credits. Some increase in cost would be a good idea to encourage innovation and to provide revenue to the government, helping pay for an overall reduction of carbon, but raising costs excessively when no alternative is available is unlikely to be either helpful or popular.

Because a well-designed cap and trade system or carbon tax would reduce emissions in all sectors of the economy, it would be a good way for the government to target the problem without specifying the solution. Policy makers do not always choose the best "winners" when they attempt to dictate to businesses, as evidenced by continuing support for corn-based ethanol, which is expensive and has life-cycle carbon emissions similar to gasoline.[65] A carbon tax or cap and trade system would have conflicting impacts on the development of electric cars, but would help promote the best overall environmental conditions. Higher gas prices would encourage use of electric motors, which are more efficient and use less overall energy. Carbon curtailment in electricity generation would raise the costs of the electricity used to charge the batteries of electric cars. However, electric cars emit less overall carbon than internal combustion cars, so they would continue to have an advantage, and cleaner forms of electricity would make them even more beneficial for the environment. In addition, electric cars would retain their environmental and economic advantages over hydrogen fuel cell vehicles, which use more life-cycle electricity.[66]

Very High CAFE Standards

[65] Sperling and Gordon, *Two Billion Cars: Driving Toward Sustainability*, 98.
[66] Eaves and Eaves, "A Cost Comparison of Fuel-Cell and Battery Electric Vehicles"; Mikhail Granovskii, Ibrahim Dincer, and Marc Rosen, "Economic and Environmental Comparison of Conventional, Hybrid, Electric, and Hydrogen Fuel Cell Vehicles," *Journal of Power Sources* 159, no. 2 (2006): 1186-1193; Brooks, "CARB's Fuel Cell Detour on the Road to Zero Emission Vehicles."

Another policy option focusing on encouraging automakers to adopt better technologies without obviously raising prices for consumers is a large increase in Corporate Average Fuel Economy (CAFE) standards. Raising CAFE standards to a very high level would make it more difficult for automakers to manufacture internal combustion cars, making electric cars a more viable option for them. Instead of retooling their factories and going to the expense of trying to further alter internal combustion vehicles, they could retool their factories and invest in electric cars, which would meet any environmental standard with greater ease. Internal combustion engines are inherently inefficient, making them much more difficult to clean up because they use extra energy. In fact, the only cars sold in the United States that currently meet the thirty-five mile-per-gallon standard recently mandated for 2020 are the Toyota Prius hybrid, the hybrid version of the Honda Civic, and the Smart Fortwo, with a couple of other hybrids nearly ready to go on sale and join the list.[67]

If hybrids and mini-cars like the Smart Fortwo are the only vehicles currently able to meet even the relatively low thirty-five mile per gallon standard, moving beyond internal combustion will likely be inevitable with the much higher standards that are needed to adequately address global warming. Small changes in existing technology added at relatively low expense, plus a transition to smaller vehicles, could probably permit automakers to meet a thirty-five mpg standard (as many do in other countries), but more drastic changes will be necessary for a potential fifty or sixty mpg standard.[68] Hybrids increase fuel economy, but still retain the inefficient internal combustion engine and associated heavy emissions control equipment. The costs of battery production will decline over time with mass production and

[67] "In the 35 MPG Future, Which Cars Make the Cut? - FOX Car Report," *Fox News*, January 26, 2009, http://www.foxnews.com/story/0,2933,483085,00.html.
[68] Peter Fairley, "The New CAFE Standards: Fuel standards will likely be achievable but won't encourage innovation," *Technology Review: MIT*, January 15, 2008, http://www.technologyreview.com/energy/20067/.

technological stability, which will be achieved when companies settle on the best type of battery and innovative developments slow down. After the battery prices are eliminated as barriers to electric cars, they will be much cheaper and easier to produce than hybrids, which require two separate drivetrains. Like carbon curtailment policies and gas taxes, high CAFE standards address the problem of vehicle emissions without picking the technological 'winners,' permitting the policy to remain relevant even as technological developments alter the landscape for industry. One problem with CAFE standards as opposed to taxes on emissions is that industry has no incentive to improve beyond the regulation. To combat the tendency to meet and not exceed the standards, regulations could be set high enough that it would be cheapest to phase out traditional internal combustion entirely, or the standards could increase regularly to encourage constant innovation.

Emissions standards have not been significantly raised since 1984 and loopholes exempted the worst polluters, Sports Utility Vehicles.[69] Average fuel consumption has actually increased slightly in recent years with the boom in popularity of pickup trucks, minivans, and SUVs, which automakers could build cheaply because they do not need to meet pollution standards. Instead of using improved efficiency technology to reduce fuel consumption, automakers have used it to increase vehicle size, weight, and horsepower, leaving us with a peak in fuel economy from 1987.[70] As Daniel Sperling and Deborah Gordon outline in their book, "*Two Billion Cars: Driving Toward Sustainability,"* the shift toward large vehicles began in the 1980s with minivans, which were "cheaper to make and buy, thanks to the gentler energy, emissions, and safety regulations, and their exemption from

[69] Fairley, "The New CAFE Standards: Fuel standards will likely be achievable but won't encourage innovation"; Sperling and Gordon, *Two Billion Cars: Driving Toward Sustainability*.
[70] Joe Benton, "U.S. Fuel Economy Stagnant for 12 Years," *Consumer Affairs*, July 18, 2006, http://www.consumeraffairs.com/news04/2006/07/fuel_economy.html.

the gas-guzzler tax."[71] Policy makers hoping to limit the damage of global warming by reducing transportation emissions with higher CAFE standards, or any other policy, will need to guard carefully against such loopholes. The current fuel economy standards enacted in 2007 mandate a combined thirty-five mile-per-gallon average for cars and light trucks by 2020, eliminating the loophole that gave rise to SUVS and other light trucks.[72] That law is a good start, but much higher standards are necessary to rapidly reduce emissions.

Somewhat stricter standards with more imminent deadlines have been proposed in California and other states, but delayed by the Bush Administration.[73] Their proposals directly regulate emissions of greenhouse gases, rather than mandating a set miles-per-gallon average, ensuring that the goals of the policies are embodied in their language. Automakers have argued against permitting individual states to enact stricter regulations than the nation as a whole because such rules force them to offer different product lines in different areas.[74] Carmakers may prefer not to make expensive changes, just as they argued against emissions regulations in the Clean Air Act, but such regulations prompt necessary innovations and development.

A 68% majority of Americans supports increases in auto emissions standards, making high CAFE standards a politically viable policy, despite the likelihood that higher production

[71] Sperling and Gordon, *Two Billion Cars: Driving Toward Sustainability*.
[72] Nick Rahall, *Energy Independence and Security Act of 2007*, *110-140*, 2007, http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=110_cong_public_laws&docid=f:publ140.110.
[73] Janet Raloff, "California May Yet Get The First Greenhouse Gas Limits For Cars," *Science News: Magazine of the Society for Science and the Public*, February 6, 2009, http://www.sciencenews.org/view/generic/id/40664/title/California_may_yet_get_the_first_greenhouse_gas_limits_for_cars.
[74] "Auto Alliance Statement in Support of Federal Fuel Economy/CO2 Standards," *Auto Alliance Press Release*, January 26, 2009, http://www.autoalliance.org/index.cfm?objectid=13F558B3-1D09-317F-BBB4A55F78DF68FB.

costs would be passed on to consumers.[75] While high CAFE standards would not generate any government revenue to help pay for other emissions reduction programs and subsidies, they also do not cost the government any money. The language of "fuel economy" and "miles per gallon," while not preventing development of electric cars by any means, is somewhat problematic in that it perpetuates the idea of internal combustion vehicles as the normal standard by which to measure all things automotive. Rephrasing, as California has done, to direct attention at greenhouse gas emissions, preferably life-cycle emissions, would easily eliminate the supposition that cars will be powered with gasoline.

Investment in Infrastructure

To further the cause of changing public and corporate mindsets about vehicles, the government could invest in the infrastructure needed to support electric cars. Much of the infrastructure needed for electric cars already exists in people's homes, providing one of the many advantages of electric cars over hydrogen fuel cell vehicles. However, for electric cars to be viable as the dominant individual transportation method, flash-charge plug-in stations would be necessary, and in some places, the electric grid would need to be updated. Public parking meters could be wired to allow people to pay for parking and charging while running errands. Such developments are difficult for private companies that fear the risks involved in betting heavily on a new technology that may not be successful in the marketplace. They are, however, necessary to encourage automakers to build electric cars and consumers to buy them. The other type of infrastructure development, in renewable

[75] "Gallup's Pulse of Democracy: Energy," *Gallup Poll*, July 2008, http://www.gallup.com/poll/2167/Energy.aspx.

energy sources, isn't necessary for the viability of electric cars, but would help make them even cleaner in addition to broader environmental benefits.

Creating infrastructure for charging electric cars is the most important first step. Adoption of electric cars will likely be gradual enough to gauge the electricity grid needs over time, but automakers and consumers need a guarantee of charging infrastructure before they will invest in electric cars. Automakers are unlikely to build cars without market research assuring them that there will be a market. Consumers are unlikely to choose electric cars as primary vehicles until they know they will be able to charge them whenever necessary and won't be left stranded on long trips. Fueling stations and other private companies are unlikely to spend the money required to install high-powered charging stations until the demand is there, in the form of reasonable numbers of electric cars on the road. Pushing electric cars beyond their status as toys for wealthy people and into the realm of primary vehicle for commuters and families requires that someone provide charging infrastructure, and the government is in the best position to take that risk. Public-private partnerships between the government and companies interested in building electric car infrastructure could bring the level of risk to an acceptable level without nationalizing a new industry that the government may not be in the best position to maintain permanently.[76]

As more and more people begin using electric cars, new power stations and better transmission lines will probably be needed. For the most part, costs and new demand can be limited by charging at off-peak hours, but eventually, the supply of electricity will need to increase, preferably from renewable sources. To ensure that people use off-peak electricity, home charging equipment will need to include a timer that allows people to

[7676] Better Place, a company designing charging and battery exchange stations, is working to form partnerships with the auto industry and with local and national governments around the world. Their business plan is discussed in more detail in Chapter 4.

set the charge to start after 10 pm, rather than as soon as they arrive home from work and plug in the car. The owner's manual for the Teslas already being sold instructs owners, "If you don't want the vehicle to begin charging immediately after you plug it in, you can set a charge start time. This is a useful way to charge the vehicle during non-peak hours when there is less demand on your electrical system and your electricity may cost less."[77] Beyond ensuring that buyers use their electric cars wisely to minimize the chances that they will push electricity use beyond the capacity of utilities, the government can accomplish dual goals by investing in and/or subsidizing renewable energy sources. Such investments would prevent shortages and help reduce emissions from electricity generation. In addition to encouraging private development of wind and solar through subsidies and federal purchasing guarantees, the government can form partnerships with utilities to help pay for the initial costs of new, clean power plants and renewable energy facilities.

In addition to investment in projects that directly aid electric cars, expanding mass transit systems would improve our transportation system and increase the viability of electric cars as replacements for internal combustion vehicles. Mass transit and electric cars complement each other well because public transportation fills the gaps left by electric cars. Electric cars will not be ideal for everyone because, even if flash-charging stations are available, slow charges during non-peak hours at home will be cheapest for consumers and will require less expansion of the electricity grid. Those who do not have garages or other means of charging at home often live in cities, where public transportation offers the greatest benefits in reducing congestion and gridlock. Public transportation does not work as well for those who live in small towns and rural areas,

[77] *2008 Tesla Roadster Owner's Manual* (San Carlos, CA: Tesla Motors, 2008).

where apartment buildings without a convenient place to plug in a car are rare. Encouraging the abolishment of internal combustion vehicles in favor of battery electrics without also promoting expanded public transport systems would be irresponsible and increase the odds of failure, as many city-dwellers could find them prohibitively inconvenient.

Policy Analysis

Any of these policies would help promote electric cars and/or cleaner transportation methods, but some combination of policies from different categories would be most effective.[78] Those listed can be divided into overlapping categories: those that encourage industry development (subsidies and research and development funding; infrastructure development), those that increase costs of internal combustion vehicles (gas tax, carbon tax or cap and trade, CAFE standards), those that force development (mandates or quotas, very high CAFE standards), those that impact consumers directly (gas tax, carbon tax or cap and trade, subsidies and tax rebates), those directed at industry (carbon tax or cap and trade, CAFE standards, subsidies and research and development funding), those that create government revenue (gas or carbon taxes, some designs of cap and trade), and those that cost the government money (subsidies and tax rebates, infrastructure development). Pairing the policies wisely can ensure success without placing excessive pressure on any of the stakeholders.

For example, infrastructure development, which costs the government money but improves the conditions for industry involvement, could be paired with a measure that

[78] Gallagher and Collantes, "Analysis of Policies to Reduce Oil Consumption and Greenhouse-Gas Emissions from the U.S. Transportation Sector," 23-24.

provides revenue, perhaps a higher gas tax. The higher gas tax, in addition to providing the revenue that would help pay for infrastructure development, raises the costs of continuing to use internal combustion vehicles for consumers and producers. Tax rebates on the purchase of electric cars combined with sector specific carbon taxes could be revenue neutral and very effective, with rebates encouraging consumer interest in electric cars as the carbon tax raises the cost of driving a gasoline-fueled car and provides the money for the rebates. Adding research and development subsides would further encourage automakers to produce electric cars, if consumer interest were to fail to be sufficient. Such a system would avoid being excessively costly to taxpayers, consumers, or producers while maximizing effectiveness by targeting automakers and car buyers with both incentives for electric cars and disincentives for status-quo internal combustion vehicles.

While it is only one example of many potential policy packages, the combination of tax rebates for the purchase of zero-emissions vehicles, research and development funding, and a carbon tax has the added advantage of avoiding the most politically difficult policy options. Any policy has some negative features, whether instigating consumer anger, costing the government too much, or asking the government to 'pick winners,' a task at which it does not always excel. A gas tax probably must be excluded as an available policy due to political realities in America, despite its probable effectiveness and attractive simplicity. Americans tend not to appreciate new taxes, particularly on goods on which they depend, and would be unwilling to accept a high gas tax modeled on those in many European nations. Politicians are unlikely to support a measure so unpopular with their constituents. Fortunately, carbon cap and trade systems,

high CAFE standards, and gas-guzzler fees imposed at purchase can accomplish many of the same goals without the political fallout because they create the illusion of distance between consumers and rising energy and vehicle costs. In the case of the gas-guzzler tax, consumers might be more willing to accept a punitive tax directed only at those who choose inefficient vehicles, similar to vice taxes on cigarettes.

Mandates and quotas are another effective policy choice that might not work well in the real world. Congressional dictates to private businesses appear heavy-handed, particularly given Congress's perpetually low public approval ratings.[79] The advantage of policies like carbon taxes is that they help electric cars even if politicians have other technologies in mind because electric cars are the best way to reduce carbon dioxide emissions in the transportation sector. If Congress chooses to enact mandates for green transportation choices, they could just as easily continue with quotas for billions of gallons of corn-based ethanol or demand that car companies invest in hydrogen fuel cell vehicles. Even if they did choose the current best technology of electric cars, technological development can move quickly. Maybe a year from now, someone will figure out how to teleport, or invent an efficient non-hydrogen based fuel cell with lower emissions and lower production costs. Car companies would still be required to produce electric cars until Congress got around to changing the policy, despite the new technology. A variety of policies that promote electric cars specifically, green technology in general, and increase restrictions and costs of emissions can help electric cars compete with, and eventually displace, internal combustion vehicles.

[79] Lydia Saad, "Congress' Approval Rating Ties Lowest in Gallup Records," *Gallup News*, May 14, 2008, http://www.gallup.com/poll/107242/Congress-Approval-Rating-Ties-Lowest-Gallup-Records.aspx.

Such policies are not relegated to the distant future for environmentalists to dream about. The 2007 Energy Independence and Security Act increased CAFE standards significantly, though probably not high enough to prompt development of electric cars on its own. It also included provisions for appropriations to pay for subsidies, grants, and loan guarantee programs for the production of electric vehicles and their components, most notably batteries. However, the bill includes hydrogen fuel cell vehicles in the definition of 'electric vehicles' to be promoted, and another section related to transportation focuses on biofuel development and implementation.[80] Inclusion of funding for fuel cells and biofuels could be a good way to hedge our bets with multiple alternative transport technologies, or it could encourage unnecessary detours as we struggle to sharply reduce greenhouse gas emissions before too much irreversible damage is done to the climate. Biofuels, at least, can be construed positively because they could be used in long-distance trucking, for which battery costs and recharging inconvenience could be prohibitive. More needs to be done beyond the provisions of the Energy Independence and Security Act, but the most recent auto show featured several plug-in hybrid and full electric car prototypes slated for production early in the next decade, possibly indicating positive reaction to the legislation (or the recent Presidential election, high gas prices, popularity of current hybrids, or other factors).

Whether policy changes encourage greater public acceptance or public demand encourages policy changes, public opinion will be vital to the success of electric cars. Currently, though many people are interested in electric cars, there is no strong interest group promoting them to both the public and the government. While some politicians

[80] Rahall, *Energy Independence and Security Act of 2007*.

might promote green transportation legislation in the hopes that their constituents will appreciate their efforts, others will pay little attention to the issue until some interest group begins lobbying them. Just as legislators need to be educated about electric cars and encouraged to support them, the public also needs to hear from popular leaders to develop trust in the 'new' technology. With the support of interest groups with the power to influence the public, government officials will be more likely to take strong action to promote development of electric cars without fear that voters will consider their efforts to be more wasteful spending of tax dollars. The two general interest groups most likely to fulfill this role of encouraging both government action and public interest are car enthusiasts and environmentalists. Current opinion within those groups and their potential roles in educating themselves and others about electric cars will be discussed in the next chapter.

Environmentalists and Car Enthusiasts: Special Interest Consumers and Public Opinion

Car enthusiasts and environmentalists do not have a great history of working collaboratively toward common goals, or even having many common goals. The two groups would be approaching the question of electric cars from very different angles, and finding common ground might be difficult. However, part of the value of electric cars is that they can appeal to both groups, and the public is more likely to appreciate the new technology if it is being praised by both environmentalists and car enthusiasts. Environmentalists need to be assured that electric cars really will reduce greenhouse gases sufficiently, and will do so more effectively than competing technologies without creating any new environmental catastrophes. Car enthusiasts need to be assured that electric cars will not be slow, underpowered, and boring to drive, that high-end electric cars can be as exciting as high-end internal combustion cars. After the members and leaders of the interest groups are convinced with a greater stake in learning about alternative technologies become convinced that electric cars satisfy their concerns, they will conceivably have the ability to advise less-informed friends and neighbors. If Jay Leno and Al Gore both endorse and promote electric cars, regular people who are a little skeptical of new technology and do not always take the time to learn exactly how it works will be more likely to believe they are a valuable solution.

Environmentalists and car enthusiasts have divergent interests with respect to internal combustion vehicles because more powerful sports cars use the most gasoline, harming the environment. Car enthusiasts want technical development that makes cars faster, with cool accessories and great handling, while environmentalists want a method

of getting around that does not spew greenhouse gases or fumes into the air. Electric cars have the torque (as discussed in the first chapter) to accelerate rapidly while also eliminating tailpipe emissions, allowing them to appeal to both groups. However, because internal combustion cars are dominant in everyone's minds, environmentalists tend to dislike powerful vehicles, as though there is something inherently sinful about driving a fast car. Car enthusiasts, meanwhile, can be hostile to environmental regulations limiting emissions, which discourage production of the eight-cylinder engine sports cars they love to drool over. Of course, there are details about electric cars that concern both groups, but overall, each group is suspicious of any technology promoted by the other, an attitude that does little for the development of a technological solution to the problem of desirable individual transport in a carbon-constrained world. In this chapter, I will outline both the real and perceived costs and benefits from the perspective of both interest groups and discuss the ways in which each group can lead the way toward large-scale adoption of electric vehicles. Support from car enthusiasts, both the well-known public figures and private hobbyists, can reassure the public that electric cars will not be a regression in automotive technology. Environmentalists may also influence public acceptance, as well has taking a larger political role in encouraging policy changes.

Car Enthusiasts[81]

The level of concern amongst car enthusiasts regarding environmental issues varies, but probably correlates well with the general population. They have an interest in emissions policy, which does one of two things on an individual level: either they want

[81] General information about ideas coming from car enthusiasts is from a review of recent threads, articles, and video clips about electric cars and green automotive technology on: carforums.net; lotustalk.com; forum.miata.net; saturnfans.com/forum; Car and Driver; MotorTrends; Jay Leno's Garage; and Top Gear

green cars that do not pollute but are still exciting, or they try to find reasons that their internal combustion cars are acceptable, whether through climate change skepticism or a defeatist nothing-can-be-done-anyway attitude. However, within the subgroup of car enthusiasts that thinks about alternative fuel vehicles and new technology, the electric drivetrain is very popular. There is still a lack of consensus about whether hydrogen or batteries are the best way to fuel the electric motor, and about whether electric cars would be a positive development or a downgrade in relation to current internal combustion vehicles. Hydrogen fuel cell vehicles and battery electric cars will be dealt with together as "electric cars" in the first part of this section because the shared technology of an electric drivetrain makes them basically equivalent from the performance perspective. Car enthusiasts with an interest in engineering and environmental questions debate the comparative costs and benefits of hydrogen versus batteries, which will be discussed at the end of this section. Several issues come up frequently in talks by high-profile 'car guys' like Jay Leno as well as in online car forums and discussion boards. Enthusiasts appreciate the torque that allows cars with electric motors to accelerate rapidly; the near-silence of the cars tends to be less popular; and the lack of a standard transmission is occasionally frowned upon (though electric cars do not have automatic transmissions either—they are generally made with simple one gear transmissions).[82]

The major benefit of electric cars from the perspective of car enthusiasts is their impressive low-end torque. With an electric motor, the car has access to full power from the moment the driver touches the accelerator, allowing for impressive 0-60 times. In internal combustion cars, power increases with higher RPMs (rotations per minute),

[82] "2010 Chevrolet Volt Reviews, Pictures and Prices"; "Tesla Motors - Efficiency," *How It Works*, http://www.teslamotors.com/efficiency/how_it_works.php.

giving most cars full access to the engine's capacity only as the car approaches redline. The powerful Tesla Roadster sports car goes from 0-60 in under four seconds, comparable to high-end sports cars like Lamborghinis; even the more economy-minded GM EV1 clocked in under eight seconds, considerably quicker than the 2000 average of ten seconds for all US cars.[83],[84],[85]

Fast acceleration makes electric cars a popular concept among drag racers. A few demonstrations at the track by Tesla engineers helped prompt increasing interest in electric drive as a positive development for both formal and informal racers.[86] An article in Car and Driver referencing the upcoming Chevy Volt (a plug-in hybrid with constant electric drive) outlines the various options for modification available to creative and mechanically-inclined hot-rodders. The author's enthusiasm is apparent:

> Let's imagine a suitably modified plug-in hybrid with a 16-kWh battery. With half of that energy—to preserve the battery life—available to power the car, coupled to an upsized 400-hp electric motor, you can enjoy full power for 96 seconds. That's enough to run 0 to 60 in the four-second range and continue on to 170 or 180 mph, depending on the car and whether its gearing supports such a high speed (another area for potential modification)."[87]

Whether people modify them or not, those enthusiasts who follow the development of electric cars and get an early model will enjoy shocking their fellow drag racers with a nearly silent environmentally-friendly car that can win at the track.

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[83] Gary Witzenburg, "At Witz' End: GM EV1 - The Real Story, Part III," *Auto Blog Green*, September 5, 2008, http://www.autobloggreen.com/2008/09/05/at-witz-end-gm-ev1-the-real-story-part-iii/; "Tesla Motors."
[84] Sperling and Gordon, *Two Billion Cars: Driving Toward Sustainability*, 68
[85] See Appendix B for pictures of these cars.
[86] Iain Morrison, "Drag-Racing in the Roadster: A First Person Account," *Tesla Motors - Engineering*, November 10, 2008, http://www.teslamotors.com/blog4/?p=69.
[87] Csaba Csere, "Fearless Prediction: Plug-In Hybrids Will be the Hot Rods of the 21st Century - Column/C/D Columns/Columns/Features/Car and Driver - Car And Driver," *Car and Driver*, May 2008, http://www.caranddriver.com/features/columns/c_d_columns/fearless_prediction_plug_in_hybrids_will_be_the_hot_rods_of_the_21st_century_column.

When enthusiasts test drive the Tesla Roadster, the GM EV1, and other electric cars, there tends to be a tone of surprise at the power and acceleration, as though they expected another boring 'green' car. Jay Leno said of the Tesla, "I like it, it's a sports car. It's not some dorky little four door econo-box…and it's environmentally safe, so there's something to be said for that."[88] A MotorTrends review of the GM EV1 from 1996 states that, "Depression of the accelerator pedal is rewarded with brisk, linear acceleration devoid of the typical peaks and valleys of a traditional reciprocating engine as one climbs through the power curves in each gear. [It] renders obsolete thoughts of electric cars as having feeble golf-cart-like performance."[89] A Car and Driver article about enthusiasts who race homemade electric car conversions describes impressive performance that overcomes low expectations and negative preconceptions:

> This is gonna be *terrible.* The Ford's a beast, and you only have two puny electric motors — and *no noise*…Suddenly, you're looking straight down the length of your nose at the drag strip ahead, your helmet pinned back against the headrest so hard you can't pull down your chin. The rear tires *yaiiiieeeee-yipe!* The nose lifts. Your front wheels are stationary (you're told later), while you positively *devour* asphalt. The drivetrain makes violent mechanical juddering. Which gets worse. And as hard as you try, you can't lower your chin…*Far* in the distance behind you: one really pissed Mach 1.[90]

Those stories of test drives and races in which electric cars compete favorably with internal combustion cars have made electrics the favored alternative for enthusiasts, but they are not yet necessarily willing to trade in their modified Corvettes or Mustangs. The culture and mystique of cars is based on internal combustion, and that will take time

[88] Jay Leno, *Jay Leno's Garage: 2008 Tesla Roadster*, http://www.jaylenosgarage.com/video/video_player.shtml?vid=229709.
[89] Jack Keebler and Jeff Bartlett, "General Motors EV1 - Driving Impression: Your Electric Car Is Here. Is It As Good As Promised?," *Motor Trend Magazine*, 2, http://www.motortrend.com/auto_news/112_9606_general_motors_ev1/index.html.
[90] Ted West, "Batteries Included - Feature," *Car and Driver*, May 2007, 1, http://www.caranddriver.com/reviews/hot_lists/car_shopping/green_machines/batteries_included_feature/(page)/1.

to change. Speed and power can compete, but a car enthusiast likes to look under the hood and see the complex inner workings of a gasoline engine and all the ancillary equipment.[91] The simplicity of electric cars holds its own attraction for some; others are unimpressed by the electric motor, battery pack, and computer module, all flat and enclosed, with no oil, no spark plugs, none of the hundreds of complicated bits of metal under the hood of an internal combustion car.[92] Being able to fix and modify their cars is important for hobbyists, and they would have to re-learn the principles of how cars work. The term "grease monkey" would become a relic of the past with the clean electric cars. Most of these changes will not be major long-term negatives, but they are all issues that cause hesitation for some car enthusiasts deciding what to think about electrics.

The silence of electric cars bothers many enthusiasts used to recognizing a fast car in part by its loud exhaust and the noise of the engine. While the neighbors of car enthusiasts might greatly appreciate the near-silent whirr of an electric motor compared to the roar of a gasoline engine, the sounds of a powerful, well-tuned engine would be missed by the car buffs themselves. Some articles and forum posts interpret the silence positively, as an added competitive advantage when racing because it offers the element of surprise, the ability to "sneak up" on another fast car.[93] More often, the quietness is described as "eerie", with some going so far as to suggest blasting a CD of Ferrari sounds. During a test drive of the Tesla Roadster, Jay Leno suggests, "You can imagine

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[91] Leno, *Jay Leno's Garage: 2008 Tesla Roadster*; Jay Leno, *Jay Leno's Garage: 2009 Mini E*, http://www.jaylenosgarage.com/video/video_player.shtml?vid=1052621.
[92] Leno, *Jay Leno's Garage: 2008 Tesla Roadster*; Leno, *Jay Leno's Garage: 2009 Mini E*.
[93] Johny Drama, "Coming of age, silent cars. What do you think? - ," *Motor Trend The General Forum Forum*, March 12, 2009, http://forums.motortrend.com/70/7447618/the-general-forum/coming-of-age-silent-cars-what-do-you-think/index.html; "National Electric Drag Racing Association - News," http://www.nedra.com/nedra_news.html.

that electric car noise is a supercharger whine if you want. You know what you could do, you could get like a CD of car noises, like a Bugatti or a Ferrari."[94]

The other thing 'missing' from electric cars that car enthusiasts like in their internal combustion cars is the standard transmission. Car buffs tend to have negative opinions about automatic transmissions, considering stick shifts superior and denigrating automatics as cars for people who do not know about or appreciate cars.[95] Because electric motors can run at much higher RPMs, they do not need transmissions with the four, five, or six speeds that internal combustion engines require. They can have a simple gearbox to translate the engine rotational speed to the wheel rotational speed, eliminating the need for shifting without adding the complex, power-robbing automatic transmission that takes control away from the driver.[96] The root of the dislike for automatics is that they are not always geared optimally for performance and speed, and the driver does not control that aspect of the car. That concern is eliminated with the one-speed transmissions of electric cars. However, shifting is one of the aspects of driving that enthusiasts enjoy, part of the charm and pleasure of cars. All of the ingrained ideas of what a car should be based on the limitations of internal combustion are difficult to overcome as long as electric cars are relegated to a very small niche market. The Tesla Roadster and other electric sports cars help overcome those ideas because the performance specifications and designs are attractive to enthusiasts. As more cars are sold and become visible driving on

[94] Leno, *Jay Leno's Garage: 2008 Tesla Roadster*; Drama, "Coming of age, silent cars. What do you think? - ."
[95] "sweet automatics?," *CarForums.net - Automotive Chat Forum*, March 10, 2009, http://www.carforums.net/showthread.php?t=77591&highlight=automatics.
[96] "Chevrolet | Electric Car - Chevy Volt. Fully Charged 2010"; Wildfire, interview.

our streets and highways, they will gradually transform the ways in which Americans culturally construct cars.[97]

Jay Leno said of the Tesla Roadster, "It's a real sports car, it handles good, it's fast, and hey, if this is the future, I'm not that worried."[98] His statement implies recognition of the eventual inevitability of some form of strict environmental standards for cars. However, car enthusiast magazines and forums often have a slightly libertarian tone, with many posters arguing against government interference.[99] This anti-government attitude makes it unlikely that they will endorse and work to pass legislation raising CAFE standards, for example, which may be necessary to prompt companies to move beyond internal combustion technology. They may be more likely to support subsidies and tax rebates that help make electric cars more competitive with internal combustion, but policies that deal directly with the externality of greenhouse gas emissions are unpopular with car enthusiasts, who do not want high gas prices or high MPG requirements. While such policies combined with continued demand for performance vehicles would be likely to lead to the production of electric cars eventually, they would create a period of time during which companies produce slower internal combustion vehicles, sacrificing power for energy efficiency. Early electric cars produced during that time period would probably still be too expensive until enough are sold to begin to make

[97] Examples of similar shifts in social opinions: attitudes about smoking have shifted over the past few decades, with fewer people adopting the habit and far less smoking associated with 'good' characters on TV and in movies; or even changing trends in hairstyles or baby names based on celebrity choices. To a limited extent, 'eco-chic' is already becoming a trend. People choose the Prius in part to make a statement about their environmental consciousness, and certain products designed to help people lessen their environmental impact (Nalgene water bottles, canvas grocery bags) have become popular.
[98] Leno, *Jay Leno's Garage: 2008 Tesla Roadster*, 8:00
[99] Commenters on car forums are of all stripes politically, but less regulation about cars, and most other things, gets a lot of support. Several sites with 'off topic' sections had many threads supporting Ron Paul, with relatively few negative responses.

up for the high costs of development and new equipment. While car enthusiasts may not appreciate the government intervention necessary to make electric cars happen, and may not appreciate giving up eight cylinder sports cars that get ten MPG, they recognize electric cars as the best long-term option for maintaining performance and fun within a carbon-constrained world. Even if they do directly support legislation designed to advance the cause of electric cars, car enthusiasts make that legislation possible by leading public opinion about cars of all types.

Hydrogen vs. Batteries

The other concern that often arises on websites and in articles aimed at car enthusiasts, as well those for environmentalists and the general public, is the question of whether battery electric vehicles are the best technology. Chapter one addressed that concern in detail, but this section will outline some of the common misconceptions. First, as noted previously, there is general agreement among both car enthusiasts and environmentalists that electric drive, whether powered by hydrogen fuel cells or batteries or incorporated into a hybrid, is the best alternative to internal combustion, which leaves debate constrained primarily to the comparative benefits of hydrogen versus batteries (hybrids are generally seen as a temporary bridge necessary until fuel cells or batteries improve enough to be mass-marketed reasonably cheaply). The negatives of hydrogen are not all well known, and there are several outdated concerns about battery electric cars that have been eliminated as problems by recent technological development.

The only negative misperception commonly expressed about hydrogen fuel cells is that they cannot be made safe, with frequent allusions to the Hindenburg. Joseph

Romm, a vocal critic, provides evidence that the Hindenburg explosion was not directly caused by hydrogen, but by highly flammable paint used on the blimp, though the hydrogen certainly helped the explosion along.[100] While it is true that hydrogen is highly explosive and has properties that create challenges for safety-minded engineers, those problems are probably not impossible to overcome in the long term. With a combination of further technical development and consumer education, the safety of hydrogen fuel cell vehicles can probably be roughly equivalent to, or at least not too much worse than, that of current gasoline cars, which also carry risks of explosion and fire in accidents.[101] They are not there yet, and safety issues will undoubtedly occupy the attention of engineers at those companies planning hydrogen fuel cell cars, but the idea that they are mobile hydrogen bombs is certainly overblown. Hydrogen is very light, making it difficult to contain without leakage for long periods of time, but also permitting it to dissipate very quickly if it does leak out of its tank. Safety is a legitimate concern with hydrogen, but not one that should eliminate it is an alternative option to gasoline because the potential for major accidents can probably be limited to an acceptable level.[102] If hydrogen were the best alternative in every way other than safety, it would be worth the research costs to continue intensively studying methods to increase the safety.

False positive beliefs about hydrogen are far more common, in part because of misleading rhetoric from supporters. The primary benefit people claim hydrogen fuel cells have compared to battery electrics is that there is plenty of readily available

[100] Joseph Romm, *The Hype about Hydrogen: Fact and Fiction in the Race to Save the Climate* (Island Press, 2004), 103-109.
[101] Peter Hoffman and Tom Harkin, *Tomorrow's Energy: Hydrogen, Fuel Cells, and the Prospects for a Cleaner Planet* (MIT Press, 2001), 236-247.
[102] Ibid.

hydrogen without the power-plant pollution that charging batteries will entail. In reality, there is plenty of hydrogen, but not in usable form. The most common ways of separating hydrogen from other elements are reforming natural gas or electrolyzing water. Reforming natural gas involves limited amounts of fossil fuel emissions but takes advantage of a scarce resource that people use to heat their houses. Using natural gas to power cars, whether directly with cars run on compressed natural gas or indirectly with hydrogen from natural gas would increase the price, making it difficult for low-income families to afford to heat their homes, as well as accelerating the rate at which we diminish natural gas reserves.[103] Electrolyzing water to separate the hydrogen uses huge amounts of energy, more than twice as much electricity as required to charge batteries to send the same amount of power to the wheels.[104]

Because natural gas supplies are finite and relatively expensive, electrolysis is the only currently viable long term method of obtaining the pure hydrogen necessary for fuel cells. A frequent argument from those who recognize that hydrogen is not naturally in usable form is that we can use renewable sources of electricity, eliminating all potential pollution from fuel cell vehicles.[105] However, if we can assume solar and wind energy will be used to separate hydrogen, it seems reasonable to also assume that smaller amounts of renewable energy would be used to charge the batteries of plug-in electric cars.

[103] Sperling and Gordon, *Two Billion Cars: Driving Toward Sustainability*, 94.
[104] Joseph Romm, " The Last Car You Would Ever Buy--Literally," MIT Technology Blog, *Technology Review*, June 18, 2008, http://www.technologyreview.com/blog/guest/22087/.
[105] Sperling and Gordon, *Two Billion Cars: Driving Toward Sustainability*, 107.

Misconceptions about hydrogen fuel cells make them appear to some to be the ideal environmental solution to transportation issues, the "holy grail" that creates a car without an environmental impact.[106] People who believe that fuel cells are the best long-term solution naturally prefer not to invest heavily in battery electric cars, which are closer to ready technologically but still expensive to develop. Given the expense of retrofitting factories, conducting research and development, training workers, beginning production of new materials, and building new infrastructure, choosing the right technology is important. Furthermore, no consumer wants to invest in a technology or purchase from a company that may not last. They would be left unable to obtain parts or service for their vehicle, severely lowering its value. Whether fuel cells or batteries can lower emissions more effectively is an environmental concern, but it is also important to non-environmentalists that automakers and policy makers settle on the best technologies without too many false starts and failed attempts. Those car enthusiasts, environmental activists, and general consumers who have done the research on hydrogen and batteries often post in response to those who rhapsodize over the wonders of hydrogen. There is no way of knowing how much good their efforts do; more respected journalists need to correct, and stop perpetuating, the myths about hydrogen. Jay Leno test-drove the Honda FCX Clarity fuel cell vehicle and described it in glowing environmental terms without mentioning the source of hydrogen.[107] A New York Times article states that the Clarity

[106] Ibid., 35.
[107] Jay Leno, *Jay Leno's Garage - Honda FCX Clarity*, http://www.jaylenosgarage.com/video/video_player.shtml?vid=205255.

has an advantage over electric cars which use electricity, never questioning where the hydrogen for the Clarity will come from.[108]

Environmentalists[109]

Beyond the debate over whether hydrogen or batteries most efficiently powers electric cars, environmentalists have doubts about the true environmental credentials of electric cars. Just as car enthusiasts hesitate to embrace a technology identified as 'green' because environmentally friendly internal combustion cars generally had poor performance specifications, environmentalists hesitate to embrace cars powerful enough to appeal to enthusiasts. If the car is powerful, some reason, it must be using extra energy, and energy use pollutes. Some environmental forums demonstrated an attitude of moral superiority based on members' willingness to sacrifice modern conveniences to better protect the environment. A commenter on the Sierra Club's blog brags, "I walked just about everywhere, even on wet and cold, dreary days. I love the small-town lifestyle of getting around easily on your bike or feet, being able to buy local produce from your friends or get it from your garden."[110] People seemed almost to argue that taking public transportation or driving slow, small cars helped atone for the sins of humanity. The culture of consumption in the developed world has caused tremendous environmental damage, and some environmentalists believe that culture has to be destroyed, not only its negative impacts. Finding technology that can save us without requiring sacrifice would

[108] Martin Fackler, "Latest Honda Runs on Hydrogen, Not Petroleum ," *New York Times*, June 17, 2008, sec. World Business, http://www.nytimes.com/2008/06/17/business/worldbusiness/17fuelcell.html.
[109] Information about opinions from environmentalists is from a review of relevant websites, magazines, and news articles, including: www.sierraclub.org, including the blog section, www.greenpeace.org, also including the blog section; www.nrdc.org; www.theenvironmentsite.org; Auto Blog Green, Grist, and Mother Jones.
[110] Cerise McLaren, "Hey Mr. Green: EVs vs. Gas-Powered Cars: No Ride to Utopia," September 4, 2008, http://sierraclub.typepad.com/mrgreen/2008/09/evs-vs-gas-powe.html?no_prefetch=1.

be cheating, while living a more ascetic lifestyle would enhance our collective moral standing. Not all environmentalists are concerned with such encompassing cultural ideas, however. Many would be happy to advocate for technologies that resolve our problems without sacrifice, but distrust any claims that sound too good to be true, including electric cars.

Environmental activists spend a great deal of time advocating against bad technologies, and are skilled at seeing through environmental rhetoric from polluting industries, so they approach claims of technological solutions with suspicion. A lack of scientific acumen can sometimes prevent environmentalists from gaining the full understanding necessary to accurately compare competing technologies or to evaluate conflicting claims about the environmental impact of those technologies. Because environmental activists are not always experts (and even experts often have conflicting information), environmental news outlets and websites contain negative 'facts' about electric cars that are either outdated or false, though there are valid concerns as well. Misinformation prevents activists from weighing the true costs and benefits of available technology and becoming strong, united advocates for the best alternative method of transportation. The primary concerns from environmentalists about electric cars are toxicity from the batteries and the source of electricity used to charge them.

Recent developments in battery technology have greatly diminished the basis for concern about battery toxicity. The batteries most commonly used until about a decade ago, and those still used in internal combustion cars, are lead-acid batteries, which are toxic and present environmental problems. A few intervening battery types with varying

levels of toxicity muddy the issue, but the current best available batteries are lithium-ion, which are recyclable and non-toxic, as well as longer-lasting between faster recharges.[111] However, people naturally think of the batteries that have been around longer, the ones they see under the hood of their current internal combustion cars. They vaguely remember learning that batteries are bad because they are toxic, and that everyone needs to be careful not to throw any type of battery in the trash because the toxins will leach out in the landfill. Then people apply that knowledge to battery electric cars. One poster promoting biofuels and ethanol on a Greenpeace forum writes, "…has anyone got any idea about the amount of energy and horrible chemicals it takes to make all the stuff that goes into an electric car? In a few years time when you have to scrap them they're going to cause a huge headache for people."[112] Environmental forums have plenty of well-informed commenters too, and few bits of false information go uncorrected, but it is difficult to know whether the misinformed posters change their minds or whether the average site visitor can distinguish the uninformed guess from the knowledgeable response.

The more serious concern expressed on environmental sites and in news articles involves the environmental impact of the electricity used to charge the batteries. Environmentalists are concerned that our government policies and automakers will promote the development of "zero-emissions" vehicles that actually cause higher overall emissions if our electricity continues to come from primarily from coal. One commenter on The Environment Site states that, "Electric cars are a good idea, as long as they are

[111] Graham-Rowe, "Charge a battery in just six minutes - tech - 07 March 2005 - New Scientist"; Bernardes, Espinosa, and Tenorio, "Recycling of batteries: a review of current processes and technologies."
[112] fridgefreezer, "Why not all cars," *Greenpeace*, July 24, 2006, http://members.greenpeace.org/phpBB2/viewtopic.php?t=338.

recharged with renewable energy. Otherwise there isn't much of a point to making them."[113] There are dual responses to the issue of where the electricity comes from. First, electric cars are highly efficient. Even those powered by coal use less energy that a car powered by gasoline, because the electric motor uses power more efficiently than an internal combustion engine. Plug-in electric cars produce significantly lower emissions than either hydrogen fuel cells or internal combustion.[114] Secondly, electricity generation can be done cleanly, and that is a fight that environmentalists need to win. The technology is there; electric car makers cannot be held accountable if power generation fails to shift as quickly as transportation. If we care enough about the environment to switch to electric cars, we should care enough about the environment to switch to renewable energy for power plants as well. Even coal can, potentially, be burned with minimal emissions through the implementation of carbon capture and sequestration, though further technological development and safety assurances are needed. Nuclear power is another traditional energy source with environmental tradeoffs: it does not contribute to global warming, but cannot be part of a truly environmentally responsible electricity grid until we find a way to deal with the waste. Cleaning up traditional energy sources can supplement renewable energy. Wind, solar, hydro, and geothermal power generation can all be implemented to varying degrees in different parts of the world. These options, as well as electric cars, primarily make use of technology that is available right now. Environmentalists' hesitation to trust technology limits their effectiveness in directing their lobbying efforts.

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[113] GeminiPress, "The Comeback of the Electric Car ," *The Environment Site*, October 21, 2008, http://www.theenvironmentsite.org/forum/environmental-news-discussion-forum/13787-comeback-electric-car.html.

[114] See Figure one for graphical representation of the emissions of internal combustion cars compared to battery electric and hydrogen fuel cells given various electricity feeds.

Another major concern among environmentalists regards whether electric cars will sell and how much they will cost, whether only the rich will be able to afford electric cars. Creating a new technology that can only be used by a small portion of the population would not be a wise investment, as market domination will be necessary to sufficiently reduce greenhouse gas emissions. However, in this case, the short-term problem is part of the long-term solution. Early electric cars probably will be sold to people with money, but those people are subsidizing the expense of bringing a new product to market. The fact that electric cars can be made to appeal to the rich is a vital advantage for them in the long run, precisely because any new technology will be more expensive at the outset, requiring wealthy buyers to keep production going until costs fall with mass production and product stability. Pessimism about how quickly a new technology can become mainstream ignores a plethora of examples: computers made tremendous advances over the course of only a few years, as did cell phones. People go out and spend hundreds or thousands of dollars on new televisions every time an advance is made (flat screen, HDTV, etc). Electric cars may take a few more years to phase in as most consumers would prefer to continue driving their current internal combustion cars until they are ready to buy a new one, when they would consider an electric model. Still, there is no reason to believe more than a decade or two would be necessary for a transition to electric cars to approach completion, with the gradual displacement of smaller numbers of internal combustion vehicles lowering emissions during the process.

Despite concern among some environmentalists about certain aspects of electric cars, for the most part, environmental activists are very supportive. For every negative comment, there are a dozen positive comments, either correcting the false negative

information, expressing eagerness to buy a reasonably priced mass-produced electric car, or just generally supporting the concept of electric cars for any number of reasons. More environmental activists draw the connections missed by general consumers and car enthusiasts: electric cars are seen as part of a wider set of changes in how we live. They wonder whether solar panels could be incorporated in the cars or whether electric cars could become energy storage and transfer devices to help with the intermittence problem of many renewable energy sources.[115] Many of the comment threads turn into lists of links traded between people interested in finding an electric car to buy or a conversion kit for their internal combustion car.[116],[117]

As a group, however, environmentalists hardly present a united demand for electric cars. While most who write about electric cars are supportive, fairly high proportions of those writing about hydrogen fuel cells, bio-fuels, hybrids, elimination of private cars, and various (mostly far-fetched) vehicles supposedly powered by air or water are also positive. Electric cars and plug-in hybrid electrics probably get the most positive coverage and have the highest level of support, with relatively few strongly negative comments. Many of the negative concerns previously discussed are phrased as questions: "If the electricity comes from coal, are electric cars an improvement over gasoline cars?" Well-known leaders of the environmental movement could answer those questions and eliminate concern from most casual environmentalists who would be

[115] Gar Lipow, "Transforming the automobile: How to transform personal transportation with existing tools," *Grist: Environmental News and Commentary*, November 16, 2006, http://gristmill.grist.org/story/2006/11/16/9531/4735.
[116] Amos Kenigsberg, "I Want My ZEV ," *Mother Jones*, January 14, 2007, http://www.motherjones.com/environment/2001/01/i-want-my-zev.
[117] Electric car conversions use traditional vehicles, removing the engine and exhaust equipment and adding batteries and an electric motor. They are often done with less advanced batteries, adding a lot of weight and limiting range and speed.

willing to trust and follow their endorsement of electric cars. Al Gore has voiced support for electric cars, but he does not make it a major talking point.[118] The very well-publicized Pickens Plan mentions electric cars as a possible long term solution while focusing more on natural gas for the present.[119] Most organizations seem to be keeping their options open with support for electric cars, particularly in combination with renewable energy initiatives, as well as the better methods of bio-fuel production, and an open mind toward hydrogen.[120]

Having many alternative-energy options has advantages, but choosing the best and lobbying heavily to garner support from the general public and politicians could be a more valuable and effective method of promoting positive environmental change. Any of the proposed alternatives to internal combustion will require some development of infrastructure, in addition to research and development costs. Choosing one technology allows everyone to use the same infrastructure, rather than developing networks for the distribution of both hydrogen and electricity to charge batteries. Consumers would also feel more comfortable with a new technology if they see a consensus of support from all interested parties. If even environmental activists cannot decide which technology is best, or whether a particular technology is worthwhile, then how can they expect the public to take action for environmental causes? People do not know which technology they should be keeping an eye on to consider for a new car purchase in a few years. Environmentalist activists should devote a little time to doing the research and learning the advantages and

[118] Marc Geller, "Al Gore calls for electric cars," *Auto Blog Green*, July 17, 2008, http://www.autobloggreen.com/2008/07/17/al-gore-calls-for-electric-cars/.
[119] "PickensPlan: The Plan," http://www.pickensplan.com/theplan/.
[120] From multiple news sources, as well as browsing of websites for Greenpeace, Sierra Club, and National Resources Defense Council

disadvantages of alternative technologies, allowing them to offer informed opinions to their friends and neighbors, as well as to their elected officials.

What the Interest Groups Can and Cannot Do

In discussing the need for interest groups to develop a better understanding of electric cars, it is important to recognize both their power and their limitations. Much of the potential power of interest groups in the case of electric cars comes from the combination of previously-divergent groups that can reach more people if they are sending out the same message. Stereotypes about electric cars are diminished by the fact that both car enthusiasts and environmentalists like them, demonstrating that they will not be wimpy cars or energy-hogging cars. However, average consumers look beyond performance and mileage specifications when selecting new cars, examining reliability, safety, comfort, convenience, and a slew of other features. They may be more likely to support electric car policies based on the advice of car enthusiasts and environmentalists, but not necessarily more likely to actually buy one as soon as they go on the market.

The power of interest groups in influencing the political process is perhaps their most important role. Whether or not they can convince anyone to buy the cars is irrelevant if the cars never make it to the market. Environmentalists are more suited to the task of lobbying state and federal government for electric car-friendly legislation because environmentalism is already a political force, with groups organized around political activism. Car enthusiasts may individually write to their representatives to express their opinions, they may even have the occasional online sticky to “call your representative today about issue X,” but they are not a unified political group. Car enthusiasts do not

share a base set of political beliefs. Environmentalists tend to be liberal and tend to like certain Congresspeople, usually Democrats, and dislike others, usually Republicans. They can advocate for a whole set of related issues, one of which should be electric cars. Car enthusiasts are libertarians, liberal, conservatives, anarchists—liking cars does not fall exclusively into any one party's political platform. They are unlikely to endorse a candidate who promises subsidies for electric cars even if they do like that policy because not all members of a group of car enthusiasts will agree with that candidate's entire platform. S/he might also be pro-life, alienating the pro-choice car enthusiasts, or in favor of a carbon tax, alienating others.[121]

Even if car enthusiasts chose to focus exclusively on the issue of electric cars, pressuring all politicians equally without bias for either party, they would have a hard time organizing politically. People do not go to the race track to discuss politics, nor do they focus on political matters on their message boards. Environmental groups form in order to advocate for political change; car enthusiasts are not even necessarily in a group. They are merely a set of people brought together at times because they share a hobby. What car enthusiasts can do well takes advantage of their specialized knowledge as individuals, rather than as a group. They can become electric-car believers at the prompting of shows like Top Gear or Jay Leno's Garage, magazines like Car and Driver and MotorTrends, and with the personal experience of seeing or driving electric cars at

[121] These generalizations about the political leanings of each interest group come from a review of the previously mentioned blogs, forums, and news sources. I noted political statements within the threads about electric cars and browsed for off-topic political threads, mostly from the 2008 presidential election. Nearly all of the environmental activists were left-leaning, though there was an occasional tone of dissatisfaction with the political process. That tone was present with car enthusiasts as well, though they were more likely to interpret government problems as too much, rather than too little, government involvement. Overall, the most common political advocacy on car enthusiast sites was libertarian, but there was significant representation from all political groups.

the track. As individuals, they can reach out to the acquaintances who save car questions for them. When the family next door wants to know if an electric car would be safe, they can explain why it would. When a coworker wants to know whether an electric car would be reliable, they alleviate their concerns. People who do not know much about a subject often prefer to ask someone they know rather than to do research or trust the media, and car enthusiasts can be public ambassadors for electric cars within their own circles.[122]

After environmentalists and politicians work to create policies designed to bring electric cars to the market and interest groups work together to create demand for them, the last piece is finding companies to make them. While this chapter discussed public interest groups, the next chapter focuses on private, profit-based interest groups: established members of the automotive industry, and start-up companies hoping to join their ranks or even displace them. Chapter four describes the electric cars currently being produced and sold, prototypes slated for production in the next few years, and discusses industry attitudes.

[122] Ray Reagans and Bill McEvily, "Network Structure and Knowledge Transfer: The effects of cohesion and range," *Administrative Science Quarterly* 48, no. 2 (2003)

Current Landscape

Automakers occasionally consider producing electric cars, usually when high gas prices or new government regulations change the playing field enough that they see potential for profitability. Without heavy prompting or very low sales of internal combustion cars, there is no incentive to make the large investment necessary to bring a new type of car full of new components to market. Some combination of factors likely to increase the potential popularity of electric cars and factors that decrease the popularity of internal combustion cars will be necessary to convince the existing major automakers to absorb the cost of transferring resources from traditional cars to electric cars. Electric cars could, however, be made by new car companies that are not wedded to internal combustion. Start-up companies have some advantages in innovation and niche appeal, while major automakers have resource advantages, an existing distribution network, and a customer base. This chapter will explore the advantages and disadvantages of big versus small car companies in bringing a new type of car to market and attaining large-scale market penetration, as well as the factors necessary for successful introduction of electric cars by both types of companies. In doing so, it includes descriptions of the various types of electric cars being considered for production, as well as infrastructure proposals.[123]

Both small start-ups and major automakers have tried unsuccessfully in past decades to produce electric cars. Electricity is the prime competitor of gasoline, but until climate change, the only way it could 'win' was through high gas prices. Electric cars

[123] A photographic guide to electric cars being produced and some still in the prototype stage is available in Appendix B.

would briefly catch the interest of consumers and automakers when gas prices were very high, then fall out of favor as soon as the price of oil went back down. Oil is a finite resources and will undoubtedly eventually become too expensive to out-compete electricity, but until that happens, the oil industry will always increase output, leading to a drop in price, when threatened with the prospect of a real alternative taking hold in the market. Climate change adds a point in favor of electric cars, and one that the oil companies can do little to combat. Nearly any policy designed to limit greenhouse gas emissions and halt or diminish climate change would deal a major blow to the internal combustion engine and oil companies, and electric cars appear to be the favored replacement of automakers as well as environmentalists and car enthusiasts. The likelihood of policies mandating reductions in greenhouse gas emissions in at least a few countries and states creates an incentive for companies of any size to get an early start on electric cars in order to be in a strong competitive position when such policies take effect. A well-funded small start-up can take big risks with the knowledge that payoffs could be tremendous if their specialized experience with electric cars allows them to compete against the major companies. The major company that invests the most in electric cars now will have the best electric car available when the time comes that high gas prices, limited oil supply, or climate change regulations make them the dominant vehicle choice. Early research efforts confer additional advantages when they allow companies to control important patents. Whether small start-ups or existing automobile companies compete for the future electric car market, the different strengths of both will likely be valuable in shifting consumer and producer culture in positive ways.

Start-up Electric Car Companies

Starting a car company is complex and expensive, particularly a car company producing a new type of car that does not yet have a consumer base. Despite the special challenges they face, start-ups could play an important role in the electric car market. A convergence of factors make electric cars more viable now that they have been in the past, with technological advances, particularly in batteries, paired with more negative feeling around oil dependence. At the same time, domestic automakers are struggling financially and have lost a lot in terms of reputation, making it possible for domestic start-ups to take advantage of displaced 'buy-American' sentiment. A well-funded start-up producing cars that people want to buy could succeed, particularly given government support for domestically-produced alternative fuel vehicles, including electric cars. Even if the start-ups do not succeed in becoming major carmakers, they can bring electric cars into the public consciousness and spark enough interest to prompt changes in the major automakers. A start-up that fails to make a profit but succeeds in making a few good cars before going out of business proves that good electric cars can be built, demonstrating what could be done if the resources of Ford or General Motors were behind a similar effort. Start-ups are often bought out by major companies, which is another way products from an innovative but financially insolvent company can enter the mainstream, creating large-scale change in the automotive world.

Start-ups producing limited numbers of vehicles, with limited resources, need to appeal to a niche market. Those currently producing or preparing to produce cars have taken a variety of avenues to find different niche markets. Some, like Tesla Motors and Fisker Automotive, build luxury cars that can command high prices, helping alleviate the costs without mass production. Others take advantage of the inherent strengths of electric

cars and build small, easy-to-maneuver city cars, which can be cheaper because they do not use as many batteries, instead accepting limited ranges, usually under one hundred miles. Still others envision electric cars as ideal fleet vehicles, again avoiding the expense of fully correcting the range issue while taking advantage of corporations' desires to portray themselves as 'green'. While appealing to niche markets and switching a few people to electric cars for some trips makes a difference in oil consumption, the more important role of start-ups is in their ability to move beyond the niche. Whether they themselves produce cars that appeal to a wider range of consumers as primary vehicles, start-ups with their diverse niche appeal can educate even consumers who are not ready to buy electric cars by making them visible and demonstrating the range of things electric cars can do.

Electric Sports Cars

The company that has garnered perhaps the most press coverage recently is Tesla, producing the Roadster. It is also one of the very few companies actually producing electric cars now, though currently only in California and not in particularly large numbers yet. The Roadster is a luxury sports car, designed to appeal to wealthy people concerned with the environment who want a performance vehicle in addition to their other car(s). A National Public Radio report even used the Tesla as an example of the benefits rich people confer on society: by purchasing the powerful and luxurious Roadster, they keep the innovative company alive to eventually produce more affordable environmentally friendly cars for the rest of us.[124] The average Tesla owner might have

[124] Jeff Tyler, "Marketplace: Why the rich do matter" (National Public Radio, March 16, 2009), http://marketplace.publicradio.org/display/web/2009/03/16/pm_why_rich_matter/.

previously had a garage with a Ferrari and a Prius, separating the two goals of fun and environmental consciousness that Tesla unites into one vehicle. Because the Roadster competes with Ferraris and Lamborghinis in terms of performance and design, Tesla can charge over $100,000, which is important for early electric cars made before battery prices fall and mass production further reduces costs.

Tesla does not push electric cars into the mainstream—most car buyers cannot afford a $109,000 car, and most car buyers need more than two seats. A high performance luxury electric sports car fills a very narrow niche market, which at first glance makes it seem like a minor contribution to the effort to create a shift toward an environmentally acceptable alternative to the internal combustion engine. However, in the battle for consumer attitudes, starting with very well-publicized production of the Tesla Roadster paves the way for a fleet of electric cars far more effectively than advertisements or countless dry, factual statements and press releases about the performance abilities and advantages of electric cars.[125] American consumers fear that switching to an electric car will be somehow trading down, sacrificing, that they will be forced to drive wimpy cars by a bunch of environmentalists out to control the world and ruin their lives. When the electric car getting the most attention in the press compares to a Ferrari rather than a Geo Metro, it undercuts that fear. One commenter on a car forum sums up what the Tesla does for consumer attitudes about electric cars: "For the longest time the thought of driving an electric car was something that would make me ill. Then along came the Tesla."[126] Most tellingly, the poster was not commenting to a question

[125] See Chapter 1 for discussion of the advantages of electric cars.
[126] techguy, "Should the RX-8 Go Electric?," *The MX-5 Miata Forum*, February 26, 2009, http://forum.miata.net/vb/showthread.php?t=319031.

about the Tesla. The thread was about the possibility of making another car, the Mazda RX-8, electric, demonstrating that Tesla is successfully marketing the electric vehicle concept, not just its own product. The Tesla Roadster is fast and sexy, a car that most people can't buy, but wish they could. It catches the interest of the public and paves the way for a more modestly priced, and more modestly equipped, family sedan or economy car by eradicating long-standing prejudices against 'green' cars.

The Roadster is also a good way to appeal to the "guinea pig" market because it is new, special, and exciting. Some consumers want to get the next new big thing first, to be the trendsetter, while others prefer to wait for the glitches to get worked out and the price to go down. Starting with the Roadster gives electric cars the chance to appeal to those with disposable income who can afford a fancy, exciting car before it is well tested. The Roadster doesn't make a good primary vehicle. It is a plaything, a toy for car lovers who want to do the right thing environmentally and look good while they do it. Cautious buyers trying to decide between Toyota and Honda for their next family car would not be ready to consider an electric car yet anyway, for the most part, but a few years of hearing positive news stories about Tesla could bring electrics onto their list of cars to consider in the near future. Tesla has plans to produce a more modest, in both design and price, sedan in the near future, and perhaps their experience and reputation from the Roadster will help make that endeavor successful. Even that car, though, will still be directed more at high-end consumers at $50,000—more the Lexus market than the basic Toyota market.[127]

[127] See Figure 2 in Appendix A for a graph of the fuel savings of electric cars. Drivers will probably save about $1000 per year, not enough to compensate for cars priced in the $50,000 range.

The drawbacks of a small start-up are also apparent in Tesla, though the major automakers do not seem to be doing much better right now. The Roadster was delayed several times before the first production unit made it onto the roads, and the date at which Tesla expects to begin to be profitable also has been repeatedly postponed.[128] The CEO and initial investor, founder of PayPal Elon Musk, has invested vast sums of his own fortune to prevent the company from going into bankruptcy, and rumors of financial problems continue to abound.[129] Given that the Roadster is Tesla's only product, the company cannot transfer profits from other sources to help fund it during the difficult early stages as a large, well-established automaker could. If the Roadster fails, then Tesla fails, and Musk and his investors are out a lot of money, losses that cannot be recouped with other successful products. On the other hand, that reliance on the Roadster, and electric drive more generally, makes Tesla less likely to give up prematurely. They experienced some serious setbacks: the original transmission they planned to use had problems and needed to be redesigned, and the company went through several top executives until Musk, the largest shareholder, took over. Those setbacks might have been enough for a company with plenty of other cars on the market to cut their losses and give up on the electric car, but a start-up will not give up their only product until they actually go bankrupt and have no choice.

Tesla is not the only company trying to take advantage of the fast acceleration of electric motors and deep pockets of wealthy luxury car connoisseurs, though it is the only one currently producing such cars. Fisker Automotive plans to produce a plug-in hybrid

[128] Michael Copeland, "Tesla's Wild Ride," *Fortune Magazine*, July 9, 2008, http://money.cnn.com/2008/07/07/technology/copeland_tesla.fortune/index.htm.
[129] Ibid.

capable of running the first fifty miles exclusively on electric charge, after which a gasoline generator will kick in to charge the batteries, extending the range.[130] Like the Tesla, the Fisker is designed for performance, though it is not a full electric car. Wrightspeed's X1 prototype similarly focuses on performance, and even puts an environmental twist on that focus.

> The fuel consumption problem is not that the current hybrid cars only get 50 mpg. That's not where the fuel is going. Look around you on the freeway, and count the 10-15mpg cars. That's where the fuel is going. If we can replace a 10mpg car with an electric car, at roughly 100mpg well-wheels equivalent, *we save 9 times as much fuel per mile* than if we replace the 50mpg hybrid commuter car. At Wrightspeed, we will do exactly that, starting with extreme performance supercars.[131]

The UK-based Lightning is another example of an upcoming electric sports car, with the design based in part on Formula One race cars. Like the others, it will be quite expensive if it makes it into production, with an estimated price of £120,000 (~175,000 USD).[132]

Electric Fleet Vehicles

Phoenix Motorcars targets a different niche market by selling their upcoming fully electric trucks and SUVs as fleet vehicles. Corporate customers may be more willing to pay a premium for early electric vehicles because it demonstrates commitment to the environment, generating positive publicity. In addition, businesses can take advantage of more tax incentives for purchasing electric cars. Some are available specifically for fleet purchases, and a business's accountant is likely to do a better job of finding all available rebates than an individual customer. Fleet customers also offer a more controlled environment for Phoenix to test their vehicles, observing the usage

[130] "Karma by Fisker Automotive," http://karma.fiskerautomotive.com/.
[131] "Wrightspeed Inc. | Company," http://www.wrightspeed.com/company.html.
[132] "Lightning Car Company," http://www.lightningcarcompany.co.uk.

patterns and needs more closely than would be possible with diverse private buyers. Phoenix uses Altair Nanotechnologies' lithium titanate batteries, which can flash-charge in minutes with a 250 KW off-board charger—not a power feed most people have in their garages, but something that might be worth investing in for fleet customers.[133] Utility companies are frequent electric-vehicle customers and provide an ideal market with their readily available electricity and vested interest in the success of electric cars.

Smith Electric Vehicles, based in the UK, has been producing electric commercial vehicles for over eighty years.[134] They offer a range of vans and large trucks, mostly used in urban environments where the faster acceleration and smoother, quieter motor are more important than the shorter range. As fleet vehicles, the environment is more controlled, making it more likely that they are used as intended under optimal conditions, while individual drivers might be more likely to ignore some of the suggestions in the owner's manual when they do not seem convenient. Examples of customers of Smith include Royal Mail, DHL, airports, and utilities, all of which focus on short-distance driving, playing into the natural advantages of electric vehicles without needing the newer range-extending and flash-charging technology. A DHL press release demonstrates what companies hope to gain by investing in electric vehicles:

> This zero emission vehicle will not only help reduce the impact of retailers' operations on the environment, but it is exempt from the London Congestion Charge, London parking costs and the road fund licence, so also presents financial advantages. The vehicle's first three-month trial with Burberry Retail UK, where it is delivering to its central London, West End and Heathrow stores, has proved both cost effective and time efficient as there is less time spent refueling and maintaining the vehicle….Testing and developing new technologies such as

[133] "Electric Cars, Green Vehicle," *Phoenix Motorcars*, http://www.phoenixmotorcars.com/vehicles/suv-specifications.php.
[134] "Smith Electric Vehicles," http://www.smithelectricvehicles.com/.

> electric vehicles is one of the key elements of DHL's climate protection strategy. With its new GoGreen climate protection program, Deutsche Post World Net, the parent of DHL, aims to improve carbon efficiency of its own as well as its subcontractors' operations by 30% by the year 2020.[135]

If the usage of the vehicle is well-suited to electrics with primarily urban driving, electric vehicles may actually be more convenient and less expensive, taking into account various rebates and savings directed at low-emissions vehicles. Consumers who see and hear about companies they trust adopting electric vehicles may be more likely to consider electric cars themselves. After all, wanting to project a green image can only be part of a company's decision, with practicality and profitability always maintaining positions of importance in the minds of decision-makers.

Neighborhood and Urban Electric Vehicles

Other electric car companies are trying to create a niche market for small urban vehicles, which are similar to some of the fleet vehicles in focusing on the natural strengths of electrics without attempting to correct the weaknesses. They do not attempt to extend the range or come up with creative solutions like flash-charging or battery exchanges, instead marketing the vehicles specifically for urban drivers who do not need to go long distances or drive at high speeds. Electric city cars are small, easy to park, and nimble for maneuvering through city traffic. Regenerative braking turns the stop-and-go of city driving into an advantage, and electric motors do not use energy while idling, another advantage most applicable to urban settings. The electric urban vehicle model envisions electric cars being used for most trips, errands, and commuting, with hybrids or internal combustion continuing to be used for long drives. People who drive small and

[135] "DHL Invites Retailers to Trial Zero Emission Vehicle," *Press Release: DHL Ireland*, May 12, 2008, http://www.dhl.ie/publish/ie/en/press/release/2008/120508.high.html.

mid-sized cars rent U-Hauls or trucks on the relatively rare occasions when they need a vehicle capable of hauling large objects. People who do most of their driving in cities could similarly own an electric car and use mass transit or rentals for the rare long trip, rather than trying to make one vehicle fill all their potential transportation needs.

Several companies offer low-speed electric vehicles at relatively low cost. Global Electric Motorcars (GEM) sells golf-cart like vehicles, intended to be driven only on roads with speed limits below thirty-five mph, for $7,500.[136] ZAP makes electric cars and scooters, most with top speeds around thirty miles per hour and ranges of around thirty to forty miles per charge. Their Xebra 'sedan' is classified as a three-wheel motorcycle, uses lead-acid batteries to provide a twenty-five mile range, and sells for $11,700. Their Zapino electric scooter has a top speed of thirty miles per hour, a range of thirty miles, weighs just under 300 pounds, and sells for $3,495.[137] Think, a Norwegian company, produces the somewhat more practical Think City electric car, and sells it in the European cities they deem the most electric-vehicle friendly. The top speed is 100 kilometers/hour (roughly 60 mph), and the range is 180 kilometers (110 miles), making it a practical commuter vehicle for people whose drive includes highways.[138] All of these vehicles may work well for some, but they are unlikely to push electric cars into the mainstream in the U.S., where most people drive on interstates and highways at least occasionally. The Think is most promising because it moves beyond the city-vehicle niche by extending the range and increasing the possible speed, but it is still unlikely to be able to compete with traditional cars for most consumers because it requires too many

[136] "Global Electric Motorcars : Affordability : Cost of Ownership," *GEM: The Electric Choice for Greener Driving*, http://www.gemcar.com/affordability/default.asp?ID=355.
[137] "ZAP Electric Cars | Green Electric Car | Electric Scooters," http://www.zapworld.com/.
[138] "TH!NK city / TH!NK city / Home - Website Interface," http://www.think.no/think/content/view/full/290.

sacrifices in range, size, and speed. Still, city vehicles are cheaper and easier to produce with fewer technological hurdles. They could be important in an electric-car future if the market of people who want cars exclusively for short trips grows. Low speed, short range electric vehicles could also be more popular in Europe, where they could displace scooters and motorcycles currently used for short drives.

Any of these start-up niche market electric car companies are valuable in lowering emissions from a particular piece of the transport sector, but electrifying a larger proportion of cars is necessary to adequately address climate change and oil dependence. Start-ups can be part of that effort, but they have to move beyond narrow market appeal to produce cars that fulfill more of the needs of average consumers. The high-powered sports cars prove that power, speed, and range are possible in electric cars, and the neighborhood and city cars prove that they can be cost-competitive. A vehicle that compromises somewhat on the luxury and speed to save money could sell for a more reasonable price, especially if mass-production lowers costs, without limiting the range and speed so much as to make the vehicle impractical for most people like many of the current neighborhood electric vehicles. Whether one of these companies or another start-up ever manages to produce the practical electric car, they help promote the cause of electric cars by pushing the idea in the public consciousness and proving the various capabilities of electric drive. If these start-ups create demand for electric cars, major automakers are likely to respond by producing their own electric cars designed for the masses.

Major Automakers

Major automakers can market to a broader base of customers, pushing electric cars firmly into the mainstream. Right now, most electric cars available in the U.S. are being sold in California, where policies are most favorable and money from Hollywood and the Silicon Valley helps fund the innovative companies producing them. Major automakers have the distribution systems to bring electric cars to the rest of the country and around the world and the resources to begin mass production. Whether any of the start-ups are successful or not, major automakers will be involved with making electric cars if we begin using them exclusively for individual transportation. If major companies begin making them even before it is clear that they will be popular, they can accelerate the process of normalizing and popularizing electric cars. Some consumers will probably be a little nervous about a new type of car; buying from a new, untested company will be too risky for many. Consumers with brand loyalty to a particular carmaker will be more likely to consider an electric car from the name they trust when they see one on the lot of the dealer they have formed a relationship with.

Most of the major car companies have released plans to produce some form of electric-drive vehicle in the next few years, though not all are promising full battery-electric cars. The 2009 Detroit Auto Show was full of green vehicle prototypes with plug-in hybrids, fuel cells, battery electrics, and other alternative energy vehicles. Given the current state of the auto industry, choosing the right technology and marketing it well could determine which companies survive the next few years. Sales have been down for all types of vehicles,[139] and the new CAFE standards will soon make production of traditional internal combustion vehicles more expensive and more difficult.[140] The

[139] "U.S. Car Sales," *Automotive News Data Center*.
[140] "In the 35 MPG Future, Which Cars Make the Cut? - FOX Car Report."

companies that make new cars that people want to buy and manage to make them profitable relatively quickly will be at a major advantage, while those that continue on their current path will risk bankruptcy.

In a report on cleaner transportation alternatives, Matthew Kromer and John Heywood of MIT write that, "The rising interest in developing electric powertrains is not merely a function of negative externalities. In parallel with these increasing external pressures, electric powertrains have made significant strides towards competing with conventional technology on their own merits."[141] There seems to be general agreement that electric drive will eventually replace internal combustion because of those 'negative externalities' and the performance and efficiency benefits of electricity over other alternatives. Ford CEO Bill Ford, quoted in the New York Times, even stated of making electric cars, "Frankly, I think it's a gamble not to do it. It's clear that society is headed down this road."[142] Timing is important for companies to grasp a competitive advantage in the electric car market. Coming out with an electric car too soon, before the technology is fully refined or before consumers are ready could damage the company's reputation for quality alternative energy vehicles, as some critics believe was the case with GM's EV1. Reviews of the EV1 at the time were mixed, with most agreeing that the range was too short and unreliable to make the car practical, though much of the damage to GM's reputation resulted from their handling of the decision to pull the cars from the market.[143]

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[141] Matthew Kromer and John Heywood, *Electric Powertrains: Opportunities and Challenges in the U.S. Light-Duty Vehicle Fleet* (Sloan Automotive Laboratory for Energy and the Environment: Massachusetts Institute of Technology, May 2007), 22, http://web.mit.edu/sloan-auto-lab/research/beforeh2/files/kromer_electric_powertrains.pdf.

[142] Bill Vlasic, "Detroit Goes for Electric Cars, but Will Drivers? ," *New York Times*, January 10, 2009, http://www.nytimes.com/2009/01/11/business/11electric.html?_r=1&ref=us.

[143] Witzenburg, "At Witz' End: GM EV1 - The Real Story, Part III"; Keebler and Bartlett, "General Motors EV1 - Driving Impression: Your Electric Car Is Here. Is It As Good As Promised?"; Dan Neil, "The 50 Worst Cars of All Time," *Time Magazine*, September 6, 2007,

An electric car program that does not culminate in a well-selling profitable vehicle drains the company financially because of the huge research and development costs of developing a car that requires so many new components, and few car companies at present have large reserves of disposable money. On the other hand, waiting too long allows another company to corner the market on environmentally-friendly vehicles, as Toyota has done to a certain extent with hybrids. 75% of hybrids in the U.S. are still made by Toyota, though other companies are working to expand their sales.[144] Hybrids are one way companies are attempting to transition smoothly into an electric future, in addition to offering small numbers of leased vehicles initially before beginning mass production of new types of cars.

General Motors has experience with electric cars from the past, but has not been very successful with innovation or environmentally friendly vehicles in recent years. The car they hope will change their fortunes is the Chevy Volt, a plug-in hybrid that runs forty miles on electricity alone. Unlike current hybrids, it will be a series hybrid, which means that the electric motor is always the drive motor. The gasoline engine acts as a generator to recharge the batteries rather than a second engine to run the car, a design that increases efficiency.[145] Hybrids resolve the range problem without requiring the expensive infrastructure needed for full electric vehicles. Full electric vehicles would need public charging stations, some with high power feeds to charge batteries quickly, or a battery exchange system, both prospects few will be willing to invest in without

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http://www.time.com/time/specials/2007/article/0,28804,1658545_1658544_1658535,00.html; *Top Gear Review of the EV1*, 1997, http://electricaid.ning.com/video/top-gear-review-of-the-ev1; Paine, *Who Killed the Electric Car?*

[144] Sebastian Blanco, "Toyota to Ford: 100,000 hybrids? That's cute. We've sold a million in the U.S.," *Auto Blog Green*, March 11, 2009, http://www.autobloggreen.com/2009/03/11/toyota-to-ford-100-000-hybrids-thats-cute-weve-sold-a-milli/.

[145] "2010 Chevrolet Volt Reviews, Pictures and Prices"; "Chevrolet | Electric Car - Chevy Volt. Fully Charged 2010."

assurances that electric cars will succeed in replacing internal combustion on a large scale. Hybrids like the Volt continue to use gas stations outside the home, where people can plug in conveniently overnight, using off-peak power to charge the batteries. The Volt could act as a bridge between gasoline and electricity powered cars, or it could hinder progress toward full electric cars by further delaying the need for new infrastructure and advancing the idea that gasoline is necessary for cars to travel sufficiently long distances. In the long-term, hybrids are unlikely to out-compete full electric cars because of costs. Right now, batteries are very expensive, and hybrids require fewer batteries, making them cost competitive. If the price of batteries goes down as new battery technologies stabilize and mass production begins, hybrids will be far more expensive because they include two separate powertrains. Full electric cars eliminate components (gas tank, exhaust system, catalytic converter, etc) that would need to be retained even in a series hybrid like the Volt.

Toyota also plans to continue focusing primarily on hybrids, though they have also released prototypes for full electric city cars.[146] They plan to add a plug-in component to the Prius, requiring more batteries while retaining the parallel hybrid technology that combines both the electric and the internal combustion motors to power the vehicle. Like the Volt, the Toyota hybrids are unlikely to be cost competitive in the long run because of the expense of using two drivetrains in each car. The biggest service hybrids like this do for electric cars is increasing investment in batteries, encouraging mass production and further technical advances. Though battery technology is capable of

[146] Joann Muller, "2009 Detroit Auto Show: Toyota Charges Up New Models," *Forbes*, January 10, 2009, http://www.forbes.com/2009/01/10/toyota-hybrid-autos-biz-manufacturing-cz_jm_0110toyota.html.

powering electric cars already, it could still use further development, particularly to lower costs.

Honda already has a few hydrogen fuel cell cars leased in California, which combine the advantages of electric drive with the serious disadvantages of hydrogen which have been discussed elsewhere.[147] Their fuel cell investment is likely to go the way of ethanol and be seen as a waste of resources down the wrong path away from oil, but at least it further demonstrates the commitment of the auto industry to alternatives. The FCX Clarity is a fairly well-designed car, and showcases the way electric drive can work. If they switched to batteries rather than hydrogen fuel cells, thus saving large amounts of electricity or natural gas, the car would be a good example of a mid-range, slightly sporty, family commuter car.

Nissan, Ford, Chrysler and BMW have all announced plans to produce battery electric cars in the next few years.[148] BMW is producing an electric version of their Mini Cooper, minimizing costs of producing a new car since the body designs will be basically identical.[149] The Mini Cooper is also a vehicle that appeals to environmentalists with its small size and good fuel economy, making it a good choice for an electric car targeted to the same group of consumers. A Ford spokesperson summarized the hoped-for process of electric car adoption: "I think it's like any new technology. You are going to have the early adopters who are really into it for whatever reason, and as they have success with it, others—that next group that watches the early adopters—starts to get involved in it. Then you get to that tipping point, right? People say, 'this has got everything I need. I want

[147] Romm, " The Last Car You Would Ever Buy--Literally"; "Honda Hybrid and Alternative Fuel Vehicles – Official Honda Web Site," http://automobiles.honda.com/alternative-fuel-vehicles/.
[148] Vlasic, "Detroit Goes for Electric Cars, but Will Drivers? ."
[149] "MINI E | MINIUSA.com," http://www.miniusa.com/minie-usa/.

one.'"[150] Nissan-Renault has demonstrated their global commitment to the electric car by announcing a partnership with Better Place, a company that intends to build the needed infrastructure, in addition to their electric car, slated for model year 2010.[151]

Infrastructure and the Electricity Grid

Shai Agassi, founder of Better Place, envisions a network of user-friendly computerized metered charging stations, as well as battery swaps for the occasional long or unexpected trip.[152] Like Elon Musk of Tesla, Agassi made a fortune during the tech boom and is channeling his mind and his money into the electric car business.[153] In the U.S., California and Hawaii have already partnered with Better Place to help build the infrastructure for upcoming electric cars to conveniently recharge while drivers shop, dine, or work.[154] By partnering with companies planning to produce electric cars, Better Place ensures that the cars will be designed with battery exchange in mind, so companies might consider limiting the number of different types of batteries, as well as placing the battery packs with convenient access for quick swaps. A driver who needs a few extra miles and has a half hour to spare would use the inexpensive charging station, while someone who needs to travel farther or has only minutes to "refuel" would take advantage of the battery swap. Battery exchange infrastructure removes another electric car concern, that of battery longevity, by assuring people that they will not have to spend thousands of dollars on fresh batteries after a few years. Those costs could be

[150] Bill Vlasic, *Ford's New Electric Car* (New York Times, 2009), http://video.nytimes.com/video/2009/01/10/automobiles/1231544889183/ford-s-new-electric-car.html.
[151] "Renault Nissan And Project Better Place Prepare For First Mass Produced Electric Vehicles," *Better Place press release*, January 21, 2008, http://www.betterplace.com/press-room/press-releases-detail/renault-nissan-and-project-better-place-prepare-for-first-mass-produced-ele.
[152] "Better Place," http://www.betterplace.com/.
[153] Daniel Roth, "Driven: Shai Agassi's Audacious Plan to Put Electric Cars on the Road," *Wired Magazine*, August 18, 2008, http://www.wired.com/cars/futuretransport/magazine/16-09/ff_agassi.
[154] "Better Place."

incorporated into the Better Place subscription plan, which would perhaps be subsidized in part by the automakers and battery recyclers who could take back the batteries when capacity diminishes below a certain point. Such details will not become important until years after the first electric cars get on the road and begin using Better Place.

Since most driving falls within the 100-mile range that Better Place conservatively assumes electric cars will provide, their services will be used fairly rarely by each driver individually. On those occasions when a person does need it, though, Better Place will provide a vital service without which a complete switch to electric cars would be impractical. In addition, their system allows drivers, as well as the batteries used in exchanges, to feed power back into the grid during peak hours for rebates. Others have suggested similar systems of using the batteries in electric cars as storage mechanisms for off-peak renewable energy to be stored and cycled into the grid during peak hours, resolving the problem of energy storage for wind and solar power and helping smooth energy demand.[155] People would fully charge their cars overnight and enter their round-trip destinations into a GPS in the morning, which would tell them whether and when they would need a top-up charge or a battery swap, or how much energy they could sell back to the grid during the day while they work. A person with a car with a 150 mile range and a fifteen mile round trip drive to and from work would probably be able to make a profit selling off-peak energy back to the grid every day. A smart enough grid would be able to give and take power from cars plugged in all day. The driver would enter the amount of time the car was going to be parked and the range required at the end of that time, and when extra power is available, it would charge the

[155] Kromer and Heywood, *Electric Powertrains: Opportunities and Challenges in the U.S. Light-Duty Vehicle Fleet*, 22; "PG&E and Tesla Motors Co-Pilot Vehicle-to-Grid Research," *PG&E Press Release*, September 12, 2007, http://www.pge.com/about/news/mediarelations/newsreleases/q3_2007/070912.shtml.

batteries. When power is needed, it could come from the batteries, cycling in and out for the eight hour workday until the driver went home and plugged in to their garage charger, with a similar process taking place. The summer evening air conditioning could be powered by the leftover electric car batteries, while the excess solar during the day and wind, hydro, or nuclear at night would charge the battery.

By partnering with utilities, car companies, battery manufacturers, and local, state, and federal governments, Better Place unites the parties necessary for a full electric car infrastructure. Already, California, Hawaii, Canada, Denmark, Israel, and Australia have committed to Better Place.[156] For carmakers, the promise of a user-friendly electric car charging infrastructure removes one potential way for electric cars to fail. Without a company like Better Place, or governments, coordinating the roles, there is a chicken-and-egg problem in which carmakers do not want to make electric cars without customers, who do not want to buy electric cars without charging infrastructure, and gas stations or other companies do not want to invest in charging stations until there are enough electric cars to guarantee business. Even with all the partnerships, Agassi is taking a potentially expensive risk by investing so much money in electric car infrastructure when electric cars may not become popular, or consumers may reject some aspects of his scheme.

How well any of these business plans succeeds depends in part on outside circumstance. The price of oil will undoubtedly play a role in public perception of electric cars as either a much-needed alternative or a risky new technology to try out later. Technological developments will also have an impact. Battery technology has already improved enough to make electric cars feasible; further improvements could help

[156] "Better Place."

them overcome the advantages internal combustion has built up over time. Various international political issues could help or hinder the growth of lithium ion batteries, the current favorite.[157] If lithium reserves are discovered in friendly countries, or if Bolivia, with the most known reserves, chooses to permit their exploitation, input costs for batteries will fall. If the nations with lithium reserves ration them, the improvement over oil in terms of dependence on sometimes-unfriendly foreign nations will be slight.[158] Domestic political decisions hold a quite important position in the electric car market. California is the state that has made the most progress in getting electric cars to consumers, and most of the currently-produced electric cars are being sold exclusively in California because of their friendlier legislation. Gas taxes are higher, vehicle credits are greater, infrastructure investment is more advanced, and emissions regulations are stricter. Adopting federal legislation that does an even better job of promoting electric cars through a combination of measures punitive toward high-emissions internal combustion vehicles and rewarding toward zero-tailpipe-emissions vehicles would help the rest of the country catch up to and surpass California's current level of progress.

Major automakers' interest in profitability guides their decisions regarding what types of cars to produce. Even if they were sure electric cars would sell as well as internal combustion cars do, the expense of switching to a different technology would discourage them. They need to be convinced that electric cars can be more profitable than internal combustion cars, profitable enough to absorb all the research and development and infrastructure costs incurred in the process of getting a new type of car with many new

[157] Bolivia holds around half of the world's known lithium reserves, and the government does not currently seem friendly to the idea of international capitalistic exploitation of those reserves, preferring to keep the process in the hands of the indigenous locals.
[158] Damian Kahya, "Bolivia holds key to electric car future," *BBC News*, November 9, 2008, http://news.bbc.co.uk/2/hi/business/7707847.stm.

components to market. Small start-ups can prove the market viability of electric cars, and they can gradually compete with the major automakers, pushing them to offer equivalent products or risk losing a portion of the market. Government regulations that increase the costs of internal combustion relative to the costs of electric cars would undoubtedly sway major automakers in favor of electrics. If new regulations requiring better gas mileage or placing a price on carbon emissions are strict enough to force carmakers to significantly alter the technology of their internal combustion cars, then alternative types of vehicles like electric become more viable because internal combustion loses the status-quo advantages. The current interest in electric cars from small start-ups and the major automakers implies that leaders of the auto industry believe electric cars will be important in the future. Major automakers may not end up producing those they develop, but they appear to be convinced that having an electric car ready to go into production is a good business decision. If and when the market shifts and demand for electric cars grows, the carmaker with the best technology ready the earliest will have an advantage until others begin to compete. Early producers may retain an advantage in reputation as the company most focused on electric cars, much as Toyota retains an advantage with hybrids because they entered the market seriously earlier than their competitors. Electric cars appear to be ahead in the search for an alternative to internal combustion, but the current state of affairs within the struggling auto industry creates additional difficulties and raises the stakes of decisions about expensive new technologies. A successful mass-production electric car could save a company, while a failed attempt could drive the company over the edge into bankruptcy.

Conclusion

The current economic downturn has stalled car sales for all companies, but its impact has been particularly devastating for the American companies that were struggling to compete even before the economy collapsed. Domestic automakers lost a large share of their former market, losing their reputation for making quality vehicles with cutting edge technology in the process. Japanese companies are in a good position with hybrids and efficient small cars, but that advantage does not necessarily correspond to an advantage with electrics, beyond the advantage of better financial status resulting from greater profitability in recent years. Development of a new technology could help American companies reclaim their former dominant position in the auto market, or it could provide an advantage for new countries beginning to produce cars. Companies that have been around for years and have established their system of production around internal combustion may change too slowly, allowing new companies that can begin with the new technology to leapfrog ahead.

Development of electric cars could broaden the market beyond the current dominance of the US, Japan, and a few smaller European companies. China is putting energy into the development of electric cars, which would be ideal for their own populace as well as potentially taking over a growing portion of the global market.[159] Most Chinese car buyers have not previously owned a car, removing the issue of a car culture built around internal combustion. Intercity trips over long distances are also rarer in China than in the United States, limiting the need for complex infrastructure to remove the range

[159] Keith Bradsher, "China Vies to Be Leader in Electric Vehicles," *New York Times*, April 1, 2009, sec. Global Business, http://www.nytimes.com/2009/04/02/business/global/02electric.html?ref=global; Stuart Burns, "China Pouring Resources Into Developing Electric Car Manufacturing By 2011," *MetalMiner*, April 6, 2009, http://agmetalminer.com/2009/04/06/china-pouring-resources-into-developing-electric-car-manufacturing-by-2011/.

barrier before electric cars can be successful.[160] The domestic Chinese market provides buyers for new automakers producing lower cost electric cars with less developed battery technology, shorter range, and lower top speeds, allowing them to save costs while developing the type of cars that would appeal to American buyers. The fact that China is currently "behind" in vehicle technology and production could be an advantage with electric cars because it gives them the chance to leapfrog into the newest and most promising technology without the expenses existing prominent companies incurred in developing and marketing intermediate alternative technologies. Of course, the currently dominant companies have advantages as well, with trained workforces and infrastructure that would need to be altered rather than built from scratch.

American companies have a disadvantage in that they are approaching bankruptcy and would have a hard time accepting temporary losses while building a long-term profitable electric car program. However, they also have significant advantages. GM has already produced a reasonably well-designed electric car with their GM EV1 in the 1990s, experience that could help them in the present and future. Start-ups like Tesla and Better Place, both with CEOs who built personal fortunes in the technology industry, demonstrate the potential for alliances between high-tech and electric car sectors. Batteries for electric cars and electronic devices share the same needs, and developments in battery technology benefit both industries. Electric cars will also need advanced computers to optimize efficiency, and the Better Place charging infrastructure model makes use of computerized systems to keep track of energy used by customers.

American companies could invest heavily in electric cars and have better cars available before their competitors because they have some advantages in technology, in

[160] Bradsher, "China Vies to Be Leader in Electric Vehicles."

skilled workers, and in existing infrastructure. However, GM, Chrysler, and Ford do not have money to throw around right now, making it difficult for them to invest in multiple technologies in the effort to save their companies. Choosing a technology that the American public does not immediately embrace could send a company into bankruptcy, even if it produces a good product that consumers would like given time to adjust to the newness. Because domestic automakers had been struggling before the current financial crisis, it is clear that they need to change their business model, and electric cars could be an important part of that effort, but predicting consumer reactions is difficult. People might be more likely to buy a new car that is significantly different than their old car, justifying the large purchase with the fact that buying new is the only way to obtain the product. American automakers need to remake their reputation, both in terms of vehicle quality and in terms of environmental consciousness, but their poor reputation for quality and reliability could make consumers less trusting of innovative product offerings that could help improve the environmental reputation.

Because Americans are accustomed to internal combustion and American companies cannot afford risky business decisions, creativity in introducing cars to the American public gradually will be necessary. Car companies could contract with rental companies, with both gaining positive publicity for their green business decisions. Consumers curious about electric cars could rent one while travelling, experimenting with them in a low-risk situation rather than buying one based on a brief test drive and a salesman's enthusiastic spiel.[161] The government could agree to purchase a certain

[161] A similar method was successful in the lumber industry. Home Depot committed to improving the environmental standards of lumber they sold, and as the largest single retailer, their action forced logging companies and construction contractors to provide and purchase, respectively, "green" lumber. Car rental

number of domestically produced electric cars, jump-starting production in the US while protecting automakers from the unpredictable whims of the public.[162] Government fleets would put enough electric cars on the roads that the public would begin to become familiar with them. People would see electric cars driving at normal highway speeds, sitting quietly at stoplights, accelerating rapidly, and looking like 'regular' cars in parking lots. Marketing electric cars to large corporate and government buyers not only provides a stable market for automakers, but also sells an image along with the cars. By purchasing early electric cars, they display their commitment to the environment.

A few large fleet buyers, particularly the government, would provide a market for the infrastructure necessary for electric cars to become practical for everyday use. Federal and state government purchasers could include police, school systems, postal service, and other highly visible and high volume agencies. Such contracts would inform companies like Better Place, and any business catering to travelers, that charging stations would be a worthwhile investment. The guarantee of a significant number of electric cars on the road in advance would resolve the chicken-and-egg problem of needing infrastructure and cars at the same time. If private companies fail to provide the necessary charging and battery exchange stations, government investment in that area as well as in purchasing the cars themselves could provide the push necessary to start a large-scale transition to electric cars.

Because the government has some level of control over many of the factors likely to influence the success or failure of electric cars, it is in a good position to provide lower-risk loans or infrastructure development. While venture capital groups investing in

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agencies could push for electric cars from automakers, as well as introduce them to consumers. (www.homedepot.com/ecooptions)

electric cars have no control over gas prices, fuel economy standards, or regulation of greenhouse gas emissions, the government can synchronize funding and regulations to maximize effectiveness. Combinations of regulations designed to make explicit the currently-externalized costs of pollution from internal combustion engines with programs to encourage the development of electric cars specifically or of alternative fuel vehicles in general would help balance costs and correct market failures. Using both sorts of legislation could make government involvement in the development of electric cars revenue neutral, with money garnered from carbon permits or gas-guzzler taxes, for example, spent on rebates for zero-emissions vehicles or grants for research into advanced batteries. Discouraging the purchase and production of internal combustion cars is an important aspect of potential government involvement because of the price differential of early electric cars. Internal combustion has an advantage in costs in part because the factories are already there and workers are already trained, but it also externalizes high costs in pollution. Incorporating the costs of the smog in Los Angeles into the costs of internal combustion cars would make electrics a more attractive alternative in comparison.

The government can help instigate production, but electric cars will need support from consumers eventually. Their technological qualities should attract consumers interested in environmental quality or performance initially, and the simple design with few moving parts should ensure the reliability necessary to attract general consumers. Still, any new technology needs early adopters and support from key communities willing to advocate for the product within their social circles. Fleet purchases can provide some of those early consumers, which will lead to consumer reviews and records regarding the

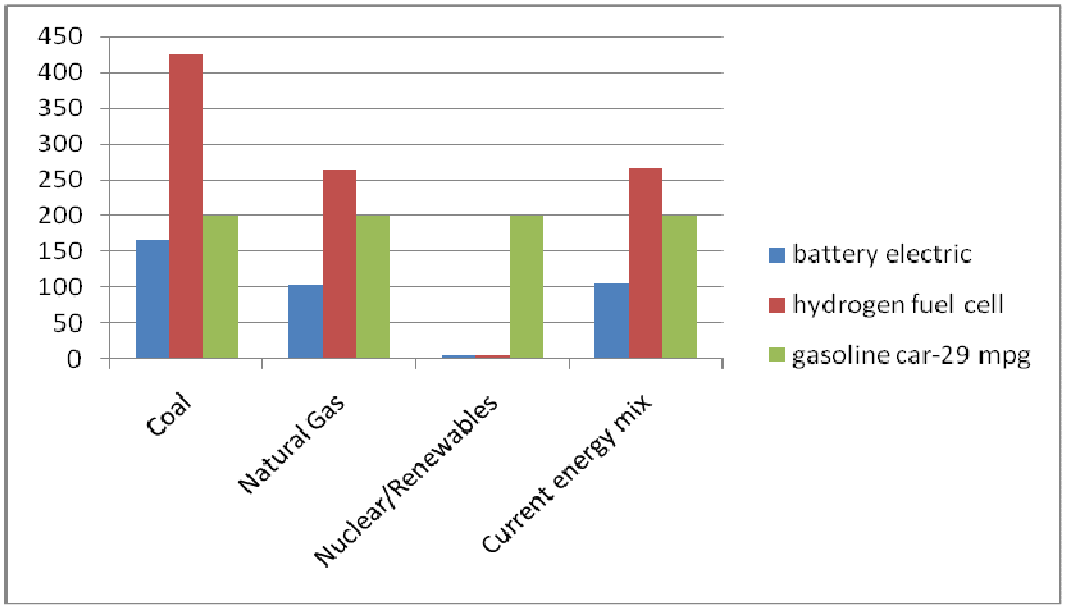
quality and reliability. Environmentalists and car enthusiasts are also likely to be early adopters and active promoters of electric cars.

Just as combinations of policies can be more effective than any of the policy options individually, combinations of consumers and marketing techniques can push electric cars into the mainstream. The electric sports car appeals to car enthusiasts, whose support is likely to prompt interest from general consumers. Electric sports cars banish preconceived notions of efficient and environmentally friendly vehicles as inevitably underpowered and poorly made. Fleet cars can demonstrate the viability of more familiar and basic daily-driver cars, necessary to complement the high-end sports cars to diminish the impression that electric cars are toys for the rich but impractical for everyday buyers. In urban areas, as well as many other countries, small urban commuter vehicles with a shorter range and lower speed can be a cost-effective transportation option, especially if the household owns a second vehicle with a longer range. European and Asian countries with more urban populations favor such vehicles, and it is possible that the market for electric cars will be divided. Domestic companies could provide the sports cars and larger, extended range vehicles likely to be demanded by many American consumers, while foreign companies focus on smaller, lower cost cars designed for urban driving. Even plug-in hybrid vehicles like the Chevy Volt can help ease the transition to electric cars by helping drivers grow accustomed to electric drive and to charging their cars. In the long term, hybrids are unlikely to be cost effective because they use two drivetrains, and the more complex mechanics will result in higher maintenance costs, but high initial battery costs make hybrids that use gasoline to extend a relatively short range a reasonable solution.

A variety of electric cars can meet the needs of most drivers, but other alternatives to internal combustion will be necessary to completely transform the American transportation system. Long distance trucking does not fit well with electrification because tractor trailers travelling hundreds of miles every day would require too many heavy batteries and would strain the electricity grid by demanding frequent charges during peak hours. Compressed natural gas or sophisticated bio-fuels could power our trucks, though updating our rail system would be a more efficient long-term solution. In addition to environmental benefits, reducing truck traffic on highways would increase safety, reduce congestion, and improve road quality, saving money on highway repairs. An advanced light-rail system for long-distance intercity travel combined with better urban and suburban mass transit would complement electric cars by providing options that would allow many people could do without cars entirely. Adding bike lanes and sidewalks to more streets and highways would encourage healthier as well as cleaner methods of personal transport for short distances. The combination of a variety of electric cars, mass transit, and alternative fuels or a transition to rail for shipping has the potential to provide us with an oil-free transportation system using existing technology. All we need is the political will, and we could have that transportation system within the next few years. Electric cars can become the technology of the present, not relics of the past or abstract future aims.

Appendix A: Graphs and Figures

Figure 1: Pounds of CO2 emitted to provide well-to-wheels energy for 300 miles of travel



Assumptions: 300 miles of travel requires 60 kW sent to the wheels for battery electric and hydrogen fuel cell vehicles or 10.34 gallons of gasoline. Hydrogen fuel cell vehicles require 202 kWh to send 60 kWh to the wheels; battery electrics require 79. [163] The current grid mix is based on 50% coal, 20% natural gas, and 30% nuclear and renewable.[164] This chart is generous towards gasoline emissions because they are calculated from the gas pump-to-wheels rather than with the power plant-to-wheels analysis used for electricity for both fuel cell and battery electric cars.

Emissions by power source are as follows: [165]

Source:	lbs CO2/kWh
Coal	2.117
Natural gas	1.314

Gasoline: 19.4 lbs/gallon[166]

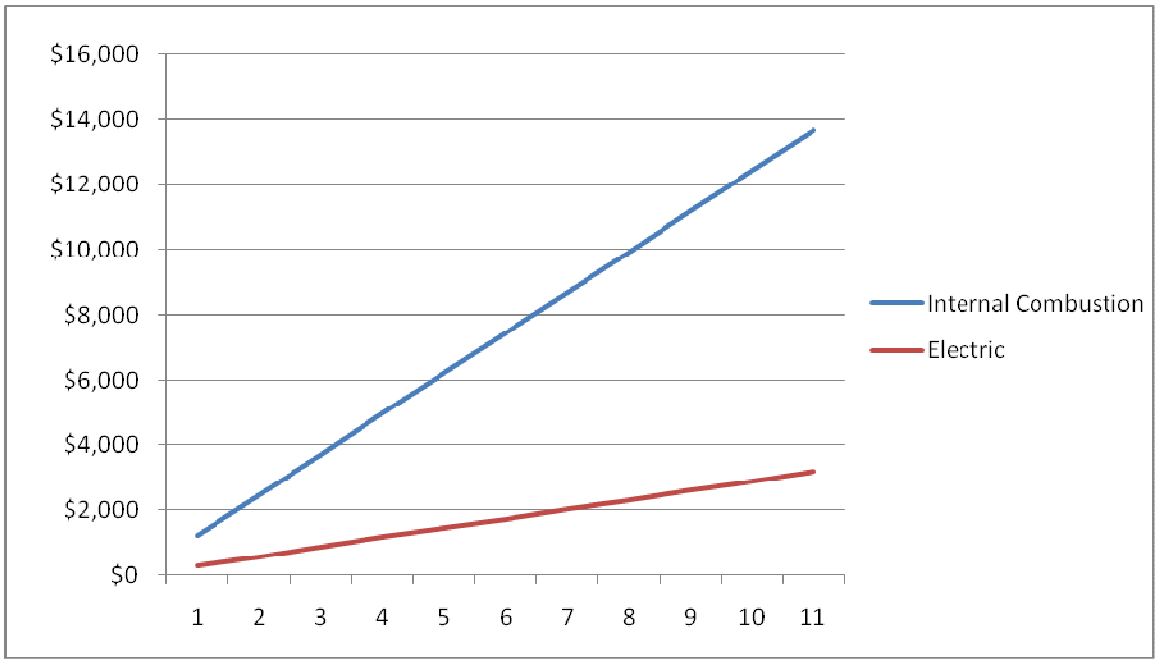
[163] Eaves and Eaves, "A Cost Comparison of Fuel-Cell and Battery Electric Vehicles."
[164] "EPA Chart: US Fuel Mix," http://www.epa.gov/solar/images/pie_chart_fuel_mix.gif
[165] *Carbon Dioxide Emissions from the Generation of Electric Power in the United States* (Department of Energy; Environmental Protection Agency, July 2000), http://www.eia.doe.gov/cneaf/electricity/page/co2_report/co2report.html
[166] "Emission Facts: Average Carbon Dioxide Emissions Resulting from Gasoline and Diesel Fuel ," US EPA, http://www.epa.gov/OMS/climate/420f05001.htm

Figure 2: Well-to-Wheels Efficiency Comparison of Fuel Cell and Battery Electric Vehicles

Well-to-Wheels Efficiency Comparison[167]	
Fuel Cell Vehicle • 202 kWh needed to send 60 kWh to the wheels • Electrolysis is 72% efficient • H2 Pipeline: 86% • H2 storage and Fuel Cell system: 54% • Electric drivetrain: 89%	Battery Electric Vehicle • 79 kWh needed to send 60 kWh to the wheels • Power lines: 92% efficient • Battery charger: 89% • Li-ion batteries: 94% • Electric drivetrain: 89%

[167] Eaves and Eaves, "A Cost Comparison of Fuel-Cell and Battery Electric Vehicles."

Figure 3: Post-Purchase Ownership Cost Comparison of Internal Combustion and Electric Cars



Assumptions for electric vehicle: Electricity costs $0.10/kWh.[168] Consumers pay for the plug-to-wheels electricity needs (using Eaves' numbers, this includes the kilowatts sent to the wheels and the inefficiencies of the drivetrain, batteries, and battery charger, but not the inefficiency in power line transmission—approximately 73 kWh for 300 miles of travel).[169] 0.2433 kWh/mile * 12,000 miles per year * $0.10/kWh = $292/year charging costs of electric vehicle.

Assumptions for internal combustion car: Gasoline costs $3/gallon. Assume 29 mpg (Honda Civic's EPA rating), and 12,000 miles/year. (12,000/29) * $3 = $1241/year fuel costs.

Note: Electric cars produce additional ownership savings because of lower maintenance needs.

[168] *Electric Power Monthly - Average Retail Price of Electricity to Ultimate Customers by End-Use Sector, by State* (Energy Information Adminstration, March 24, 2009), http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_a.html
[169] Eaves and Eaves, "A Cost Comparison of Fuel-Cell and Battery Electric Vehicles."

Appendix B: Photographic Guide to Electric Vehicles

GM EV1.[170] Image available http://www.evworld.com/press/gm_ev1_pair.

The EV1 was produced in the late 1990s in response to a regulatory requirement in California. GM's decision to eliminate the program and crush the remaining cars after the requirement was rescinded provoked the movie, "Who Killed the Electric Car."
Specs:
Range: ~80 miles
0-60: 7.7 seconds
Price: $33,995 (1997, only available for lease)

[170] Keebler and Bartlett, "General Motors EV1 - Driving Impression: Your Electric Car Is Here. Is It As Good As Promised?."

Electric Sports Cars - Tesla

The Tesla Roadster.[171] Image from www.teslamotors.com

The Tesla Roadster is currently being sold in California, with dealerships scheduled to open in major US and European cities in the next few months and years.
Specs:
0-60: 3.9 seconds
Range: 240 miles
Price: $109,000

Pictured left: the prototype of the Tesla Model S Sedan, which seats 7 and is expected to be priced at around $50,000. Information and picture from Tesla website.

[171] "Tesla Motors."

Electric Fleet Vehicles

Smith Electric Vehicle.[172] Image from http://www.blogcdn.com/www.autobloggreen.com/media/2009/02/smith-electric-vehicles-newton.jpg

Smith Electric, based in the UK, has been producing electric fleet vehicles ranging in size from vans to large trucks for 80 years.

Specs for pictured vehicle:
Range: 150 miles
Top speed: 50 mph
Acceleration faster than comparable diesel
Range and top speeds vary—some vehicles have ranges as low as 100 miles, and some have top speeds over 70 mph.

[172] "Smith Electric Vehicles."

Phoenix Sports Utility Truck.[173] Image and specs available: http://www.phoenixmotorcars.com/vehicles/

Phoenix is marketing their Sports Utility Trucks and Sports Utility Vehicles as fleet vehicles. They will be made with lithium titanate batteries capable of flash-charging in minute.
Specs:
Range: 100 miles
0-60: under 10 seconds
Top speed: limited at 95 mph

[173] "Electric Cars, Green Vehicle."

Neighborhood and Urban Electric Vehicles

Th!nk City urban electric car.[174] Image and information from http://www.think.no/think/

The Th!nk City is currently being sold in Norway, with plans for expansion into electric-friendly European cities, and eventually the US.
Specs:
Range: 110 miles
Top speed: 62 mph

GEM Neighborhood Electric Vehicle.[175] Image and information from http://www.gemcar.com/models/details.asp?MID=4&ID=309

The GEM comes in several sizes, but all are intended for light, local driving.

Specs (vary slightly between models):
Range: 30 miles
Top speed: 25 mph
Price: $7500

[174] "Th!nk City Technical Data," *Think City*, http://www.think.no/think/TH!NK-city/Specifications/Technical-data
[175] "Global Electric Motorcars : Affordability : Cost of Ownership."

Major Automakers

The Chevy Volt.[176] Image from
http://reviews.carreview.com/files/2008/04/chevy_volt_concept_3_med.jpg

The Chevy Volt is a plug-in hybrid, not a full electric vehicle. It will be powered with the electric drivetrain, with a gasoline engine acting as a generator to extend the range. The Volt is expected to go on sale in 2010.
Specs:
Electric range: 40 miles
Top speed: 100 mph

[176] "Chevrolet | Electric Car - Chevy Volt. Fully Charged 2010."

Nissan Denki Cube Electric Vehicle.[177] Image from:
http://www.greencarsite.co.uk/GREENNEWS/NewsPhotos/Nissan-cube.jpg

The Denki Cube is scheduled to go on sale in 2010/2011 as the first of a lineup of full-electric vehicles from Nissan. The design is based on the Cube, already sold in Japan and offered in the US beginning spring 2009. Specs are not yet available.

[177] "Nissan/Infiniti News Room," March 19, 2008, http://www.nissannews.com/newsrelease.do;jsessionid=813369B0CE14A76B84AA314A52EDDD97?id=369

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