Electric Avenue: How to Make Zero-Emissions Cars Go Mainstream

Abstract (summary)

More than a century after the internal combustion engine won the battle to power transportation, the fight is starting up in earnest once again. In the last decade and a half, hybrid-electric vehicles have found their way onto the market and gained a small, if devoted, following. The good news is that advances in batteries, fuel cells, lightweight cars, and charging networks are making electric vehicles look more promising than ever before. To accelerate the economies of scale necessary for the widespread adoption of electric vehicles, the government currently subsidizes the production and consumption of such cars. But in the absence of major technological improvements, these policies have proved insufficient. If policymakers took the politically unpopular step of taxing people for the carbon their cars emit, electric vehicles would capture a larger market share.

Full Text

In 1896, a 33-year-old engineer working for the Detroit branch of Thomas Edison's Edison Illuminating Company traveled to New York for the firm's annual convention. The automobile was the obvious technology of the future by then, but it wasn’t yet clear what would propel it: steam, electricity, or gasoline. Edison had been tinkering with batteries that could power a car, so he was inter-ested to hear that the engineer from Detroit had invented a two-cylinder gasoline vehicle. After hearing a description of the car, Edison immediately recognized its superiority.

"Young man, that's the thing; you have it," Edison told the inventor. "Keep at it! Electric cars must keep near to power stations. The storage battery is too heavy. Steam cars won't do either, for they have to have a boiler and a fire. Your car is self-contained—it carries its own power plant—no fire, no boiler, no smoke, and no steam. You have the thing. Keep at it."
The engineer's name was Henry Ford, and he did keep at it. By 1908, the Ford Motor Company's Model T was the best-selling car in America. And for a century to come, the limitations Edison recited largely kept electric vehicles off the road.

Yet electric vehicles have a major inherent advantage over gasoline-powered ones: they use less energy to drive a given number of miles. The internal combustion engine wastes around 70 percent of its fuel on generating heat rather than thrust, whereas electric motors can waste as little as ten percent (although significantly more than that is wasted when one includes generating electricity back at the power plant and transmitting it). Moreover, because they can plug into the grid, electric vehicles can draw from multiple sources of power, including renewable energy. Switching from gas to electricity for transportation offers the potential to dramatically reduce carbon emissions, especially if the original energy source is clean.

And now, more than a century after the internal combustion engine won the battle to power transportation, the fight is starting up in earnest once again. In the last decade and a half, hybrid-electric vehicles have found their way onto the market and gained a small, if devoted, following. Because they rely on both an internal combustion engine and a battery, hybrid-electric vehicles have overcome the range problem that had plagued vehicles powered by only electricity. Such cars as the Honda Insight and the Toyota Prius, both released in the United States around 2000, tapped into consumers' desire to broadcast their concern for the environment or their technological progressiveness. Some U.S. states rewarded the owners of hybrids with access to high-occupancy-vehicle lanes, and the federal government offered them a tax credit of up to $3,400.

Companies soon began selling vehicles that burned even less gasoline. In 2010, General Motors reentered the electric vehicle market with a hybrid-electric vehicle called the Chevy Volt (the company famously killed its first attempt, the EV1, in the 1990s). The Volt is a plug-in hybrid-electric vehicle, meaning that it gets most of its energy from electricity, not gas. Unlike simple hybrid-electric vehicles, in which the internal combustion engine charges the battery, plug-in electric vehicles charge their batteries from the electricity grid.

Around this time, the Nissan Leaf and the Honda Fit EV, both of which are fully electric, also came on the market. All-electric vehicles are remarkably efficient. The Fit EV, for example, uses just 18 kilowatts per 100 kilometers of driving—the equivalent of 118 miles per gallon, according to the Environmental Protection Agency. It can travel 82 miles on a single charge. Newer companies, meanwhile, are building high-end electric cars. In 2012, Tesla Motors, founded by the entrepreneur Elon Musk, sold more than 2,500 of its Model S cars. These start at $70,000 and boast a range of up to 265 miles.

Yet last year, Americans bought only around 490,000 traditional hybrids, 49,000 plug-in hybrid vehicles, and 48,000 all-electric vehicles—a tiny fraction of the some 14 million cars and light trucks sold in the country every year. Electric vehicles serve mostly as status symbols. In order for the market to reach a size that makes a real difference to total carbon emissions, they will have to appeal to more than just green and technophilic drivers; they will need to make economic sense to the average buyer.

The good news is that advances in batteries, fuel cells, lightweight cars, and charging networks are making electric vehicles look more promising than ever before. To accelerate the economies of scale necessary for the widespread adoption of electric vehicles, the government currently subsidizes the production and consumption of such cars. But in the absence of major technological improvements, these policies have proved insufficient. If policymakers took the politically unpopular step of taxing people for the carbon their cars emit, electric vehicles would capture a larger market share.

DRIVING RANGE
The key challenge with electric vehicles involves figuring out how to store more energy in less mass—in other words, increasing what is known as energy density—and how to make the result—ing battery affordable. Although it is possible that some breakthrough will change everything, at current rates of improvement in the battery market, it is likely to take another decade or two before electric vehicles can match the range and cost per distance of gas-powered cars. Moore's law, which predicts a doubling of computing power every two years or so, doesn't apply to batteries.

Still, energy density is getting better, doubling every ten years or so. Over the last six decades, the maximum energy density of rechargeable batteries increased from 25 watt-hours per kilogram to 210. At that rate, by 2030, the figure should reach 500 watt-hours per kilogram—the point at which the range for battery-powered cars will be comparable to that for gas-powered cars.

Onboard batteries are only one possible technology for powering electric vehicles. Ultracapacitors, which store energy in electric fields, charge and discharge quickly, thereby enabling vehicles to accelerate faster and capture more energy from braking. Ultra-capacitors, however, have a shorter life span than batteries and don't store as much energy. But new materials may overcome these restrictions. Besides, cars could use both batteries and ultra-capacitors, a combination that might prove better than either on its own.

Fuel cells, which convert such chemicals as hydrogen into electricity, could also propel cars. In the late 1990s, excitement surrounding hydrogen fuel cells peaked. But although their cost has fallen, fuel cells have yet to be cost effective in comparison with batteries, much less internal combustion engines.

In many places, liquid biofuels generated from biomass such as corn, sugar cane, algae, switchgrass, and wood are already used for transportation. In Minnesota, for instance, E10, a fuel that is ten percent corn-based ethanol and 90 percent gasoline, is standard, and E22, comprised of 22 percent sugar cane, is common in Brazil. When filled with 100 percent ethanol, flexible-fuel vehicles, which can use a wide range of mixes of ethanol and gasoline, are typically 20 percent less fuel-efficient than when filled with gasoline. But over the long run, cars using only ethanol approach the point of being carbon neutral, since the carbon emitted through burning biofuels is reabsorbed by plants, which can again be turned into fuel. That said, such fuels entail the not insignificant costs of planting, growing, harvesting, and shipping.

As the shale boom takes hold, trucks are increasingly running on natural gas, which emits less pollution and carbon dioxide than conventional gasoline. When liquefied or compressed, natural gas can be transported easily. Across the United States, companies are constructing networks of liquefied natural gas fueling stations for long-distance trucking. For the moment, given the lack of distribution points, liquefied natural gas makes more sense for fleet vehicles, which return to their bases every day, providing a convenient fueling place. Natural gas can also be produced from biomass, such as manure and crop waste. When purified into a gas called biomethane, it has an even lower carbon impact.

One solution to electric vehicles' range problem is to simply move less mass and therefore consume less energy. It doesn’t make sense to push two tons of metal and plastic just to transport one or two people, and some automakers are miniaturizing their offerings. Weighing in at just 1,600 pounds, the Smart ForTwo is one of the smallest mass-produced cars on the market. Although the vehicle hasn’t quite caught on in the United States, where sales have been below 1,000 per month, it has in Europe, where space is at a premium and government policy discourages the use of cars.

Two-wheel electric vehicles, which weigh even less, are enormously popular in developing countries, where they fill the gap between bicycles and automobiles. But they have not yet gained traction in the developed world, where the same infrastructure that supports bicycles—bicycle lanes, bike-sharing networks, and so on—could be adapted for electric bikes. Electric bicycles are unlikely to catch on in the United States anytime soon. Land-use patterns there are not conducive to bicycling, and drivers may be
reluctant to downsize too much, in part due to concerns about safety. Until self-driving vehicles alleviate most safety risks, American cars will remain big.

The range problem for electric vehicles could also be solved by the construction of a comprehensive network of charging stations. First, however, the automotive industry needs to agree on a standard, just as it did for the size of fuel-pump nozzles. Currently, different plug-in cars use different charging devices, although the industry is making progress on standardization. It is also working on technology that charges batteries quickly, but so-called fast-charging stations are fast only compared to conventional charging. They still take upward of 30 minutes for an 80 percent charge, much longer than it takes to fill up at the pump.

Designs that allow empty batteries to be quickly swapped out for charged ones may help, too. The idea dates back to 1900, and it was revived in 2007 by the Israeli entrepreneur Shai Agassi, whose company hoped to develop a network of battery-exchange centers before it went bankrupt in 2013. In order for quick-swap batteries to take hold, batteries will have to be standardized so that the economies of scale kick in. Until automakers converge on an interchangeable standard for batteries or one firm comes to dominate the industry, drivers arriving at exchange centers will risk finding out that their battery type is not in stock. Although that happens with other car parts, such as tires, the difference is that garages don’t promise to replace tires in a matter of minutes.

Another way to make electric cars practical is even more speculative: a rental service of self-driving cars that could be ordered on demand. In such a scheme, travelers would receive fully charged electric vehicles for their trips and, for long journeys, a replacement vehicle along the way. It would work much like the Pony Express, the mid-nineteenth-century mail service linking Missouri to California, which swapped out horses at a series of relay stations. Self-driving vehicles should enter the high end of the car market around 2020 and become standard by around 2030. These "robo-cars" need not be electric, but as cars get smarter, they should be able to charge themselves, alleviating some of the concerns associated with electric vehicles. And if the range problem persists, perhaps drivers will use something other than cars, or will stay with liquid fuel for the few long trips they make.

TAX TIME

If technological progress is coupled with smart government policy, then these high-tech dreams could become everyday reality. When it comes to funding research on alternative-fuel vehicles, the United States has pursued the right strategy. The federal government has wisely avoided putting all its eggs in one basket, instead spreading research grants across a variety of technologies, most of which do not seem terribly promising but each of which has its partisans. Many small bets are more likely to find a winner than a few large ones; this is not the time for a new Manhattan Project or Apollo program.

As for consumer incentives, the U.S. government provides an infant-industry subsidy of $2,500 in tax credits for buyers of plug-in electric vehicles and has in the past provided other subsidies for buyers of fuel-efficient vehicles. Several U.S. states and some foreign countries provide additional subsidies.

A better, although more politically difficult, policy would be to charge those who burn gasoline and diesel fuel for the full economic and social cost of their decision. Right now, pollution is essentially free in the United States; drivers don’t pay anything for the emissions that come from their tailpipes, even if they’re driving a jalopy from the 1970s. If the government were to charge people for the health-damaging pollutants their cars emit and enact a carbon tax, the amount of pollution and carbon dioxide produced would fall. Consumers would drive less, retire their old clunkers, and be more likely to purchase electric vehicles. (An increase in oil prices due to a lack of new discoveries, increasing demand in the developing world, or something else would have the same effect.)
The United States already has a modest gas tax, which, although it was not designed for this purpose, does have the side effect of disincentivizing carbon emissions. But many economists favor a full-fledged carbon tax on fuels, the revenue of which could be used to fund environmental agencies' efforts to mitigate damages from pollution and climate change. It could be offset by tax cuts elsewhere. Yet if raising taxes were politically easy, this would have been done long ago.

The government cannot rely on the gas tax forever. Since its 1919 debut, in Oregon, the tax has come to serve as the main source of road funding at the state and federal levels. Already, transportation funding is beginning to shrink due to improvements in fuel economy, and the Highway Trust Fund is teetering on the brink of insolvency. With the rise of alternative-fuel vehicles, the current funding arrangement will fail.

The immediate solution is for policymakers to take the politically unpopular step of raising the gas tax. In the long run, however, something else will need to be done. There is no reason to move away from the tax now, but as gasoline engines eventually lose market share, the government should think of and organize roads as a public utility, like electricity and natural gas. That would mean making drivers pay user fees, such as a per-mile charge that varied by the time of day and the type of vehicle used.

Assuming that the economy continues to grow and companies continue to innovate, vehicles powered by electricity or other non-oil-based energy sources will eventually become a mainstay of the American garage. As the market adjusts and early adopters experiment with new vehicles, each energy source may come to temporarily dominate a market niche. But in the end, economies of scale suggest that one technology will win out for a long time. And so the battle for the automobile now looks much like it did at the beginning of the twentieth century. The definition of victory—the invention of an energy-efficient method of getting around—is clear. But the eventual winner—whether it be electricity, fuel cells, biofuels, natural gas, or something else—is not.∂

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