ELECTRIC VEHICLES TECHNOLOGY

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5/8/2017

INTRODUCTION

A new electrical energy transportation world appears right around the corner. Pure electrical, hybrids, plug-in hybrids and extended-range electric cars are appearing on the world highways. Their modes of operation differ in the acceleration, cruising and deceleration phases. They also differ according to whether the chemical battery is in a charged or depleted state.

The main components in these designs include an internal combustion engine, an electrical generator, an electric motor, a fuel tank and a chemical battery.

Electrical hybrids vehicles such as Toyota's Prius are a common sight. The major automakers are proposing a next generation of hybrids that can be plugged in to extend their electric range and vastly improve their fuel economy.

Figure 1. Lithium-ion battery pack of the Volt car. Source: GM.

The first type of plug-in hybrid, labeled “Plug-in Hybrid,” is basically a conventional hybrid vehicle with a larger battery pack. Companies such as Toyota and Ford are developing hybrids of this type.

For heavy acceleration and high speed, these vehicles rely on power from both an internal combustion engine and an electric motor. But a larger battery pack in plug-in hybrids allows them to rely much more on electricity than conventional hybrids do.

“Extended-Range Electric” vehicles represent a radical departure from conventional hybrids. Whereas in conventional hybrids, the wheels are turned by an electric motor, an internal combustion engine, or both; the wheels in these newer designs will be turned only by a large electric motor. For short trips, the motor will run on battery power alone. For longer trips, an internal combustion engine-powered generator kicks in to supply electricity.

Instead of gasoline powered hybrids there exists a need to develop a diesel-electric vehicle much like existing train locomotives and diesel-electric submarines.

Learning from the aerospace industry, the reciprocating internal combustion engine should be replaced by rotating turbo machinery that would more efficiently couple to the rotating electrical motors and generators used in the different versions of electrical vehicles. This would allow heavier loads and longer cruising ranges.

USAGE TRENDS AND JUSTIFICATION

In 1960, passenger cars got about 14 miles to the gallon, traveled 587 billion miles all for 180 million people. They used 41.1 billion gallons of gasoline. In 2010, passenger cars got about 23 mpg, traveled 2025 billion miles to service 309 million people. They used 86.8 billion gallons of gasoline. This is more than three times the number of cars registered and a little more than twice the use of fuel. The USA went on a car buying spree, added a lot of people but forgot to raise the mpg far enough to cover the increase in travel miles.

For Electric Vehicles (EV's) to go as far as the 2010 cars, it would cost 73 billion dollars in electricity. The USA drivers spent $348 billion on gasoline in 2010 and $448 billion on gasoline in 2011, and $337 billion was spent on gasoline in 2015. It appears that the savings on gasoline would pay for a full replacement of cars with EV's, especially since it is expected go up in price again. It would pay for the USA public to shift to EV's, which is better than eventually paying $6-10 for a gallon of gasoline. With falling production and increasing cost for oil production, it is best to remain out of the demand end of the situation.

Before the gasoline prices reach $6-10 per gallon there will be several generations and improvement in electric car cost and performance as well improvements in the power distribution such as grid level storage. The utilities would need to increase the number of power plans by an estimated 40 percent. In the long run, unlike Internal Combustion Engines the power for EV's can be easily locally generated in a distributed system of solar and wind installations.

The diesel-electric locomotive and automobile internal combustion engines had large advantages over coal fired steam locomotives, so coal faded as a transport fuel without a large price rise. The EV's large potential advantages over gasoline engines, especially since we are at the peak production time and gasoline will only become more expensive over time.

ALL-ELECTRICAL, AE VEHICLES

The TeslaMotors Roadster is a sports car, but reaches a 200 miles cruising range, 125 mph top speed, 130 mpg equivalent.

The sticker price for the base model was $109,000and the fully loaded special version $155,000.

The Roadster uses 6,831 little LiIon batteries arranged in 12 modules. They can be recharged in 3-4 hrs from a 240V/70A power line.

The Roadster motor sits directly between the rear wheels, as the axle. It weighs about 115 lbs including its cooling system and reaches about 280 HP.

CONVENTIONAL HYBRID VEHICLES

At low speed, an electric motor using the charge in a battery provides enough power to rotate the wheels without help from an internal combustion engine.

After about a mile distance, the battery is depleted enough that the internal combustion engine kicks in to drive the wheels and to power a generator that charges the battery.

During gradual acceleration at low speeds, the electric motor provides enough power on its own. For very fast acceleration or once speed reaches about 35 mph, the internal combustion engine kicks in to provide added power.

At higher speeds power to the drive train comes primarily from the internal combustion engine.

During deceleration and braking, the internal combustion engine turns off and the wheels spin the motor to recharge the battery.

PLUG-IN VEHICLES

Charged Battery State

At low speeds, the electric motor provides enough power for electric only operation.

While standard hybrids only store enough charge for a mile or two of all-electric driving, a larger battery allows the car to continue in the all-electric mode for 10-40 miles, depending on the size of the battery.

During gradual acceleration at low speeds, the electric motor provides enough power on its own. For very fast acceleration or once speed reaches about 35 mph, the internal combustion engine kicks in to provide added power.

At high speeds, power can come from the internal combustion engine and the electric motor at the same time.

During deceleration and braking, the internal combustion engine turns off and the wheels spin the motor to recharge the battery.

Depleted Battery State

At low speeds the electric motor provides enough power for electric-only operation.

After a mile or so the battery is depleted enough that the internal combustion engine kicks in to drive the wheels and power a generator that charges a battery/

During gradual acceleration at low speeds the electric motor provides enough power on its own. For very fast acceleration or once speeds reach 35 mph, the internal combustion engine kicks in to provide added power.

At higher speeds power to the drive train comes primarily from the internal combustion engine.

During deceleration and braking, the internal combustion engine turns off and the wheels spin the motor to recharge the battery.

RANGE EXTENDED ELECTRIC VEHICLES, SERIAL HYBRID VEHICLES

Charged Battery State

The car starts in the all-electric mode using the battery without using the internal combustion engine.

While standard hybrids only store enough charge for a mile or two of all-electric driving, a larger battery allows the vehicle to continue in the all-electric mode for 10-40 miles, depending on the size of the battery.

The electric motor provides enough power for heavy acceleration.

At high speeds, the electric motor continues to draw down the charge in the battery.

During deceleration and braking, the internal combustion engine turns off and the wheels spin the motor to recharge the battery.

Depleted Battery State

When the battery in an extended range vehicle is largely depleted, it can still provide enough power for short distances without the help of an internal combustion engine.

Once the battery has discharged to a minimum level, it is recharged by an onboard generator powered by an internal combustion engine. In addition, the electrical generator provides power to drive the wheels. Sometimes the battery provides additional power, preventing the generator from running at inefficient speeds.

As power demand increases, the internal combustion engine and generator continue to provide electrical power. For heavy acceleration, the generator may be pushed beyond its optimal operational range.

The internal combustion engine and electrical generator supply the electrical energy needed by the electrical motor.

During deceleration and braking, the internal combustion engine turns off and the wheels spin the motor to recharge the battery.

CHEVROLET VOLT

The Chevrolet Volt is an electric vehicle that runs on batteries charged from an ordinary power outlet for trips shorter than 40 miles.

For longer journeys, an onboard gasoline or ethanol-powered generator will recharge the battery.

Two battery companies, LG Chem and A123 Systems, based in Watertown, Massachusetts, have been in the running to supply the key component of a battery pack or the individual battery cells for the Volt. Hundreds of such cells must be wired together and paired with control electronics to create the vehicle's 16kW-hour battery pack.

Initially, cells from LG Chem will be assembled into battery packs by a subsidiary of LG Chem: Compact Power, based in Troy, Michigan. Once a new manufacturing plant is built, General Motor (GM) itself will assemble cells into battery packs

General Motor's decision is part of a strategic shift by the company toward the electrification of its automobiles, which will range from cars that rely on electric motors and batteries for brief bursts of power to those that run on electricity alone.

The company also plans to increase its in-house battery development by building a 31,000-square-foot battery lab and hiring hundreds of battery engineers. The lack of qualified and experienced battery engineers in the USA has been one of the big challenges facing battery startups such as A123 Systems. Most advanced battery production takes place in Asia, and this could hold back a switch from conventional vehicles to electric ones in the USA.

ELECTRIC VEHICLES TECHNOLOGY BREAKTHROUGH

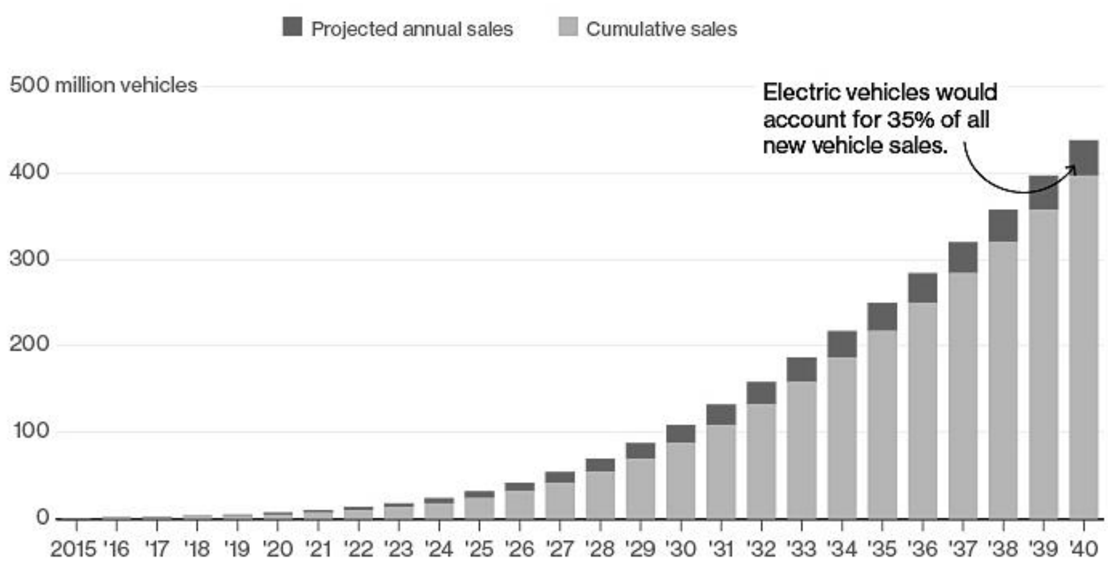

Figure 2. Electric Vehicles (RVs) future sales projection. Source: Bloomberg.

The 2020s may be the decade of the electric car. Battery prices fell 35 percent in 2015 and are on a trajectory to make unsubsidized electric vehicles as affordable as their gasoline counterparts in the 2016-2022 period. By 2040, long-range electric cars will cost less than $22,000 in present day’s dollars. Thirty-five percent of new cars worldwide will have an electrical connection plug [1].

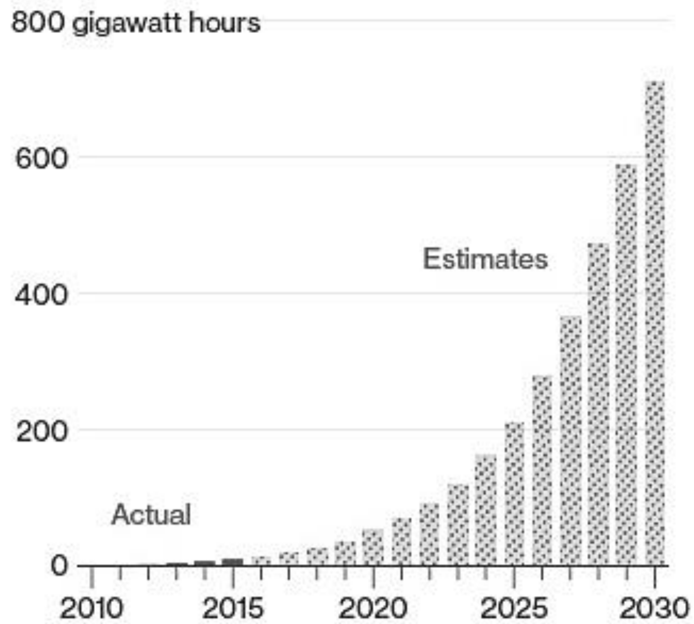

Figure 3. Electric cars yearly demand of energy from renewable and conventional sources. Source: Bloomberg business.

Plug-in cars make up just one-tenth of 1 percent of the global car market today. They are a rarity on the streets of most countries and still cost significantly more than similar gasoline burners. OPEC maintains that electric vehicles (EVs) will make up just 1 percent of cars in 2040 [1].

However, Tesla, General Motors, and Nissan plan to start selling long-range electric cars in the $30,000 range. Other carmakers and technology companies are investing billions on dozens of new models. By 2020, some of these will cost less and perform better than their gasoline counterparts. The aim would be to match the success of Tesla’s Model S, which outsells its competitors in the large luxury class in the USA. The question then is how much oil demand will these cars displace, and when will the reduced demand be enough to tip the scales and cause the next oil crisis [1].

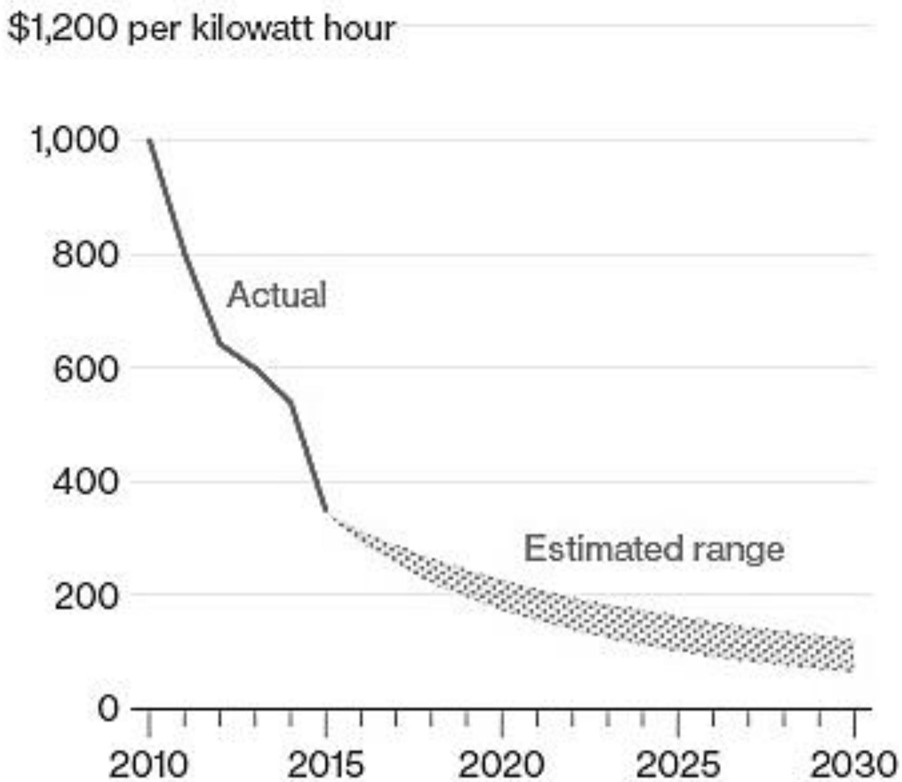

Figure 4. Price of Li-ion battery packs for electric vehicles use. Source: Bloomberg.

In 2015 EV sales grew by about 60 percent worldwide. That is about the annual growth rate that Tesla forecasts for sales through 2020, and it is the same growth rate that helped the Ford Model T cruise past the horse and buggy technology in the 1910s. For comparison, solar panels are following a similar curve at around 50 percent growth each year, while LED light-bulb sales are soaring by about 140 percent each year [1].

At a continued 60 percent growth, electric vehicles could displace oil demand of 2 million barrels a day as early as 2023. That would create a glut of oil equivalent to what triggered the 2014 oil crisis [1]. Compound annual growth rates as high as 60 percent cannot hold up for long, so it is a very aggressive forecast. Crossing the oil-crash benchmark of 2 million barrels is forecast a few years later in 2028 [1].

Batteries account for a third of the cost of building an electric car. For EVs to achieve widespread adoption, one of four options must happen [1]:

1. Governments must offer incentives to lower the costs,
2. Manufacturers must accept extremely low profit margins,
3. Customers must be willing to pay more to drive electric,
4. The cost of batteries must come down.

The first three options are happening now in the early-adopter days of electric vehicles, but they cannot be sustained. Fortunately, the cost of batteries is headed in the right direction.

DISCUSSION

By 2040, electric cars will draw 1,900 terawatt-hours of electricity, equivalent to 10 percent of humanity's electricity produced in 2015. Since 2013, the world has been adding more electricity-generating capacity from wind and solar than from coal, natural gas, and oil combined. Electric cars will reduce the cost of battery storage and help store intermittent sun and wind power [1].

Regarding the lithium and other finite materials used in the batteries there are not an issue. Through 2030, battery packs will require less than 1 percent of the known reserves of lithium, nickel, manganese, and copper. They require 4 percent of the world's cobalt. After 2030, new battery chemistries will probably shift to other source materials, making packs lighter, smaller, and cheaper [1].

Autonomous cars and ride-sharing services like Uber and Lyft, would put more cars on the road that drive more than 20,000 miles a year. The more miles a car drives, the more economical battery packs become. If these new services are successful, they could boost electric-vehicle market share to 50 percent of new cars by 2040 [1].

More electric cars are expected to hit the road, with less demand for hydrocarbon fuels.

A transition to plug-in hybrids or All-Electrical (AE) vehicles will place a burden on the existing electrical grid. There will be a need to upgrade the electric distribution system to supply electricity to the added load of thousands of plug-in hybrids. The present electrical distribution system in the USA does not have the capacity in most regions with the electric power capacity reserves at a record low levels.

REFERENCE

1. Tom Randall, "Here's how Electric Cars Will Cause the Next Oil Crisis. A shift is under way that will lead to widespread adoption of EVs in the next decade," Bloomberg Business, February 25, 2016.

APPENDIX

ALL OUR PATENTS ARE BELONG TO YOU

by Elon Musk

Yesterday, there was a wall of Tesla patents in the lobby of our Palo Alto headquarters. That is no longer the case. They have been removed, in the spirit of the open source movement, for the advancement of electric vehicle technology.

Tesla Motors was created to accelerate the advent of sustainable transport.

If we clear a path to the creation of compelling electric vehicles, but then lay intellectual property landmines behind us to inhibit others, we are acting in a manner contrary to that goal. Tesla will not initiate patent lawsuits against anyone who, in good faith, wants to use our technology.

When I started out with my first company, Zip2, I thought patents were a good thing and worked hard to obtain them. And maybe they were good long ago, but too often these days they serve merely to stifle progress, entrench the positions of giant corporations and enrich those in the legal profession, rather than the actual inventors. After Zip2, when I realized that receiving a patent really just meant that you bought a lottery ticket to a lawsuit, I avoided them whenever possible.

At Tesla, however, we felt compelled to create patents out of concern that the big car companies would copy our technology and then use their massive manufacturing, sales and marketing power to overwhelm Tesla. We couldn’t have been more wrong.

The unfortunate reality is the opposite: electric car programs (or programs for any vehicle that doesn’t burn hydrocarbons) at the major manufacturers are small to non-existent, constituting an average of far less than 1% of their total vehicle sales.

At best, the large automakers are producing electric cars with limited range in limited volume. Some produce no zero emission cars at all.

Given that annual new vehicle production is approaching 100 million per year and the global fleet is approximately 2 billion cars, it is impossible for Tesla to build electric cars fast enough to address the carbon crisis. By the same token, it means the market is enormous.

Our true competition is not the small trickle of non-Tesla electric cars being produced, but rather the enormous flood of gasoline cars pouring out of the world’s factories every day.

We believe that Tesla, other companies making electric cars, and the world would all benefit from a common, rapidly-evolving technology platform.

Technology leadership is not defined by patents, which history has repeatedly shown to be small protection indeed against a determined competitor, but rather by the ability of a company to attract and motivate the world’s most talented engineers. We believe that applying the open source philosophy to our patents will strengthen rather than diminish Tesla’s position in this regard.

Elon Musk