

## PATH TO 2060:

# Decarbonizing the Automobile Industry

## The Future is Electric and it's Complicated

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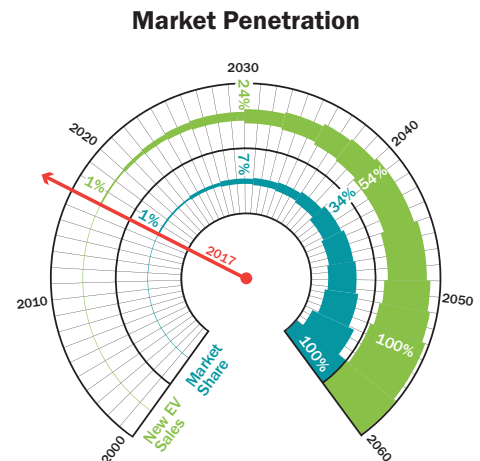
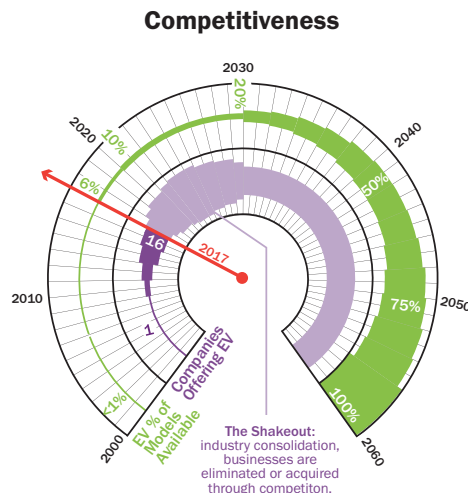
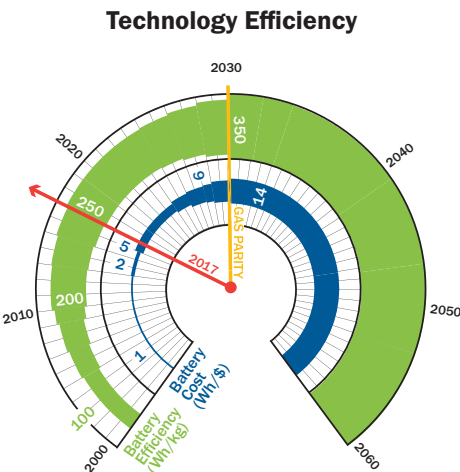
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The transportation sector accounts for a quarter of U.S. greenhouse gas emissions.<sup>1</sup> Electrification of this sector is underway and there is reason to believe that we can decarbonize the automobile industry by 2060. How long will it take and what levers can be pulled to help facilitate the transition from fossil fuels to electric technologies? What role have innovation and regulation played in electrifying automobiles, and what role might they play in the future?

This *Batten Briefing* summarizes the key findings from our report titled **Path to 2060: Decarbonizing the Automobile Industry**. In the report, we look at the evolution of electric vehicles and the policies and market conditions that paved the way for their adoption. We evaluate current electric vehicle technologies and the influence of autonomous driving, identifying the levers to support continued movement toward industry decarbonization.



# THE REVIVAL OF ELECTRIC

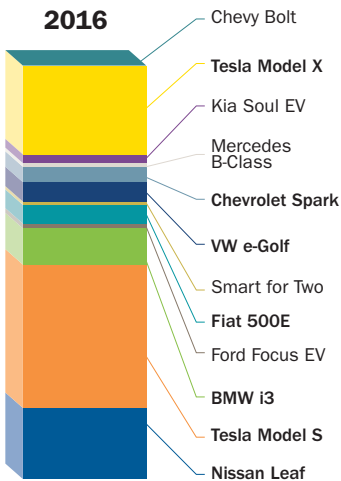
## U.S. Battery Electric Vehicle Sales

Source: U.S. DOE, Alternative Fuels Data Center, U.S. Plug-In Electric Vehicle Sales by Model, updated January 2016

2011



2016



**ELECTRIC VEHICLES HAVE BEEN AROUND** for over 100 years. They initially dominated the market until the introduction of the gas-powered Model T and discovery of Texas crude oil pushed electric to extinction by 1935. A second wave of electrics entered the market in the late 1990s, when GM introduced the EV-1 in response to a California zero-emission vehicle mandate. This mandate was relaxed following litigation, and automakers thus pulled vehicles from the road, discontinuing their electric ventures.

## HYBRIDS SERVE AS A BRIDGE BETWEEN OLD AND NEW

With electric on its way out, Toyota saw an opportunity to offer a new kind of alternative fuel vehicle, one that would be more readily accepted by consumers—the hybrid. Initially, sales in the U.S. were slow but with the help of rising gasoline prices, entry of other incumbents, and tightening environmental regulation, annual sales exceeded 350,000 by 2007,<sup>2</sup> representing 3% of total new car sales for that year.<sup>3</sup> Tax incentives starting in 2010 gave hybrids a much-needed boost following the U.S. recession. More recently, hybrid sales in the U.S. have slowed. There could be many reasons for this, including the notion that they are serving as a bridge technology between gasoline and electric vehicles, causing some consumers to wait for newer, all-electric technology before switching from 100% gasoline-powered vehicles.

Globally, we are seeing more of an interest in hybrids, particularly in China where the middle class and vehicle ownership overall are growing, but in the context of major air quality challenges. We are also seeing growth in Japan and Europe. Government incentives in these regions are helping to spur both interest and sales. The global hybrid market is projected to grow to 7 million vehicles by 2023.<sup>4</sup>

## ELECTRIC GETS ITS BIG BREAK

The success of hybrids opened the door to electric vehicles once again in 2008 with Tesla's introduction of the Model S. That, along with the 2009 announcement of more stringent U.S. fuel efficiency standards through 2025, made industry incumbents take notice. After 100 years, automakers would begin innovating and reimagining how cars could be operated and fueled.

In 2010, Chevy and Nissan responded with the Volt and Leaf. Shortly after, President Obama set a goal in 2011 of being the first country to reach 1 million electric cars on the road by 2015. Backed by \$2.5 billion in R&D funding, this announcement set the course toward electrification.

<sup>1</sup> U.S. EPA, Sources of Greenhouse Gas Emissions, Greenhouse Gas Emissions website (accessed September 13, 2017), <https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions#transportation>.

<sup>2</sup> U.S. DOE, Alternative Fuels Data Center, Hybrid Vehicle Sales by Model, updated January 2016, <https://www.afdc.energy.gov/data/?q=Sales>.

<sup>3</sup> U.S. DOT, Bureau of Transportation Statistics, Table 1-15: Annual U.S. Motor Vehicle Production and Factory Sales, [https://www.rita.dot.gov/bts/sites/rita.dot.gov/bts/files/publications/national\\_transportation\\_statistics/html/table\\_01\\_15.html\\_mfd](https://www.rita.dot.gov/bts/sites/rita.dot.gov/bts/files/publications/national_transportation_statistics/html/table_01_15.html_mfd).

<sup>4</sup> JATO Dynamics, "The Spark Ignites, EV & Hybrid Global Market Results", November 2016.

# THE BATTLE FOR ELECTRIC: BATTERY VS. FUEL CELL

**WHILE TESLA AND OTHER ESTABLISHED AUTOMAKERS** have invested heavily in battery electric vehicles, Toyota and other Asian-based manufacturers are focusing efforts on fuel cell development. We will likely see a standards battle for electric vehicle market share unfold over the next decade. Both Tesla and Toyota have opened their patents for use by other companies with the goal of advancing their respective technologies more quickly. There are benefits, and limitations, of both electric options. At the end of the day, it will come down to price, user compatibility, and access to fueling infrastructure.

Battery technology plays a significant role in price and user satisfaction. Li-ion battery efficiencies are continuing to improve while the cost of battery packs is declining. Range (miles/charge) is also increasing, but finding the right balance with price is still a challenge. Market analysts predict that the cost of electric vehicles will fall below gasoline by 2026.<sup>5</sup>

Charging infrastructure has scaled with battery electric car sales, growing from 3,394 charging stations in 2011 to more than 50,000 outlets in the U.S. today. Government incentives in China and Europe have helped ramp up charging infrastructure worldwide.

Battery electric is the early leader relative to fuel cells, with global sales projected to increase from 1% today to 54% by 2040.<sup>6</sup> However, some believe that the Li-ion battery will reach its energy density limit before it can truly compete with gasoline vehicles. Longer range and higher power densities can mean more space and weight, which do not bode well for car design, and thus expanding markets could be a challenge. This is an area of continued focus and investment by industry leaders.

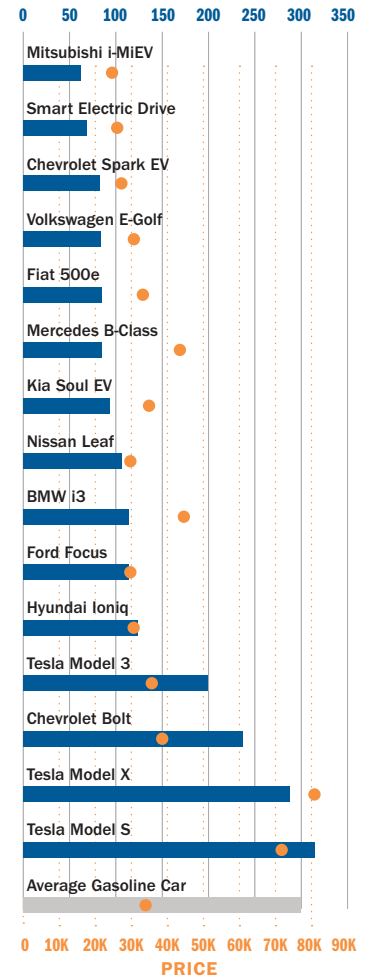
While improvements in fuel cell technology and manufacturing have driven down costs in recent years, price continues to be a major market barrier. There are currently only three fuel cell models on the market offered by Toyota, Honda, and Hyundai. Furthermore, unlike battery electric, a national hydrogen fuel network doesn't yet exist and will need to be built at considerable expense.

Industry protections show a slower market growth trajectory for fuel cell electric cars relative to battery electric vehicles. By 2032, cumulative sales are projected to reach 22 million<sup>7</sup> which pales in comparison to the projected 60 million in battery electric sales expected in 2040.<sup>8</sup>

For fuel cells it could be slow and steady wins the race. Fuel cell vehicles are more in line with customer expectations for both the fueling infrastructure and range, and the technology itself is easily scalable to larger footprints without adding weight or taking up additional space. The storage potential of hydrogen also provides an opportunity for fuel cells to support the growth and intermittency of renewables, as the national electricity grid changes in the way energy is generated and stored.

## Electric vs. Gasoline Cars: Mileage Range & Price

Source: Plug-In Cars.com, Compare Electric Cars and Plug-in Hybrids by Features, Price, Range (August 2017).



<sup>5</sup> Tom Randall, "The Electric Car Revolution Now Faces Its Biggest Test", Bloomberg, April 24, 2017, <https://www.bloomberg.com/news/articles/2017-04-24/the-electric-car-revolution-tesla-began-faces-its-biggest-test>.

<sup>6</sup> Bloomberg New Energy Finance, "Electric Vehicle Outlook 2017", July 2017, [https://data.bloomberglp.com/bnef/sites/14/2017/07/BNEF\\_EVO\\_2017\\_ExecutiveSummary.pdf](https://data.bloomberglp.com/bnef/sites/14/2017/07/BNEF_EVO_2017_ExecutiveSummary.pdf).

<sup>7</sup> Research and Markets, "Global Market for Hydrogen Fuel Cell Vehicles 2017 - Research and Markets", Business Wire, April 18, 2017, <http://www.businesswire.com/news/home/20170418006120/en/Global-Market-Hydrogen-Fuel-Cell-Vehicles-2017>.

<sup>8</sup> Bloomberg New Energy Finance (note 6)

This briefing is the first in a series of sector-focused reports authored by the Batten Institute for Entrepreneurship and Innovation at the University of Virginia Darden School of Business. Upcoming research will take a look at the energy sector. Please visit [www.darden.virginia.edu/innovation-climate](http://www.darden.virginia.edu/innovation-climate) to listen to a podcast discussing the findings of this report and to learn more about Darden's Business Innovation & Climate Change Initiative.

## CAUTION: ANOTHER DISRUPTOR AHEAD

One technology that could speed up market adoption of electric vehicles is autonomous driving. Although the technology is fuel-neutral, the electric car is a natural partner in creating the next generation smart car. Electric vehicles offer the ability to charge without human interaction as well as a simplified system of electronic controls. Both of these characteristics align well with autonomous systems. The hype around autonomous is attracting start-ups and more established IT companies into the automobile industry.<sup>9</sup> The entry of these new players, willing to take risks with novel ideas, will help drive innovation in an industry that historically has moved slowly.

# ELECTRIC WILL DECARBONIZE THE AUTOMOBILE INDUSTRY, BUT WHEN?

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OVERALL, WE BELIEVE THAT RAPID MATURITY and decreasing costs of electric vehicle technologies as well as a strong global demand, particularly in Asia, will drive the transition to electric vehicles.

How long will it take? Even if all vehicles sold were electric starting today, it would take at least 20 years to completely decarbonize the automobile industry as the stock of more than 1 billion existing vehicles turns over slowly.

Continued investment, both public and private, in R&D and charging infrastructure, will help get us there more quickly. And for fuel cell vehicles, this investment and government incentives will be critical for the technology to become cost-competitive in this market.

We are optimistic that meeting the 2060 target is possible, but will be challenging. Make no mistake—the automobile industry will be electrified. It's just a matter of when and which technology will be in the driver's seat when it happens.

<sup>9</sup> Taylor Stewart, "263 Self-Driving Car Startups to Watch", Comet Labs, May 10, 2017, <https://blog.cometlabs.io/263-self-driving-car-startups-to-watch-8a9976dc62b0>.