An Electrifying Future? Disruptive Technologies as a Model for Electric Vehicle Adoption

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science, School of Engineering

Kevin Meyers

Spring 2020

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Advisor

Kathryn A. Neeley, Associate Professor of STS, Department of Engineering and Society

Introduction

> *"The electric vehicle is not for everybody. It can only meet the needs of 90 percent of the population." (Paine 2006)*

Since their introduction in the early 1990s, many have seen electric vehicles as the solution to the significant issues of tailpipe emissions and fossil fuel dependence that plague the automotive industry. However, electric vehicles have thus far failed to achieve mainstream market success. Despite having enough range and capability for 87 percent of daily trips taken in an automobile, they only account for about 2 percent of sales. (Needell et al. 2016)

As lithium-ion battery technology has improved, the continued prevalence of the internal combustion engine in new automobile sales is increasingly not explained simply by a lack of capability from electric vehicles.

In this paper, I argue that the adoption patterns of electric vehicles are not explained by the steady adoption of technology in new models that has historically characterized the automotive industry. Rather, it is more similar to Geoffrey Moore's "chasm" model for the adoption of significant, disruptive technologies seen in the tech-startup world. (2014) Therefore, I argue that applying this model presents a more accurate view of the current electric vehicle market and provides clearer insight into the path towards widespread adoption. Due to the unique aspects of environmentally friendly innovations, like the electric car, their advantages are realized by society as a whole rather than each individual user. While drivers recognize that driving electric cars beneficial to the environment, their lack of adoption suggests that, in effect, most drivers feel that everyone else should be driving an electric car. (Volvo Group 2019) The

Chasm model allows us to identify the most critical groups of users to the electric vehicles adoption, so that a positive value proposition can be targeted at those users.

Part 1: Electric Cars Have Not Achieved Widespread Adoption

Early Adoption Was Driven by Regulatory Standards

With its introduction in 1996, the General Motors EV1 marked what many thought would be the beginning of a new era in the automobile market. As the first commercially available electric vehicle, the EV1 offered consumers a claimed range of up to 90 miles on a charge. (Bartlett 1996) In an attempt to meet standards set by California requiring an increasing portion of new car sales to be zero emissions vehicles, several other manufacturers including Ford and Toyota began offering limited quantities of electric vehicles, based on the ranger and RAV4 respectively. (McConnell et al. 2019, p. 6) Due to the high cost of the batteries used in electric vehicle drivetrains as compared to combustion engines, these early electric vehicles were prohibitively expensive, and were sold at a loss exclusively in California to comply with the regulations. In 2003, the requirements were suspended following a successful suit led by several auto manufacturers. (McConnell et al. 2019 p. 7) With the repeal of the "ZEV Mandate," manufacturers ceased production, and many, including General Motors and Toyota, refused to let customers extend their leases or purchase the cars. Many of these cars were later crushed or donated to museums after being rendered inoperable. (Paine 2006)

The California Air Resources Board(CARB) was also responsible for the next wave of electric cars from mainstream manufacturers. Additionally, by the 2010s a number of other traditionally liberal states, such as Oregon and Washington, had adopted CARB's policies as their own. Beginning in 2012, manufacturers were again required to sell an increasing number of

plug in zero emissions vehicles(PZEVs) to comply with CARB regulations. While this period again saw a number of existing models such as the Fiat 500 and Ford Focus adapted with electric drivetrains, it also brought the introduction of the first US market mass production electric vehicle, the Nissan Leaf. (Vercellino 2009) Designed as an all new platform, the first generation leaf offered nearly 100 miles of range, with better drivetrain packaging offering increased cargo area compared to competitors. (Loh 2009)

2012 also marked the arrival of the Tesla Model S, a mass-market luxury car. Throughout the remainder of the decade, Tesla dominated the electric car market via the introduction of a crossover-SUV as well as a more affordable sedan, attracting buyers via brand loyalty transferred from lead investor and CEO Elon Musk's other successful ventures, PayPal and SpaceX. (Furr & Dyer 2020) While annual sales of electric vehicles have steadily increased, they have been lead primarily by Tesla's expansion into new sectors of the automotive market(crossovers and mass-market sedans). (McKerracher 2020)

Consumer Preferences are Shifting Towards SUVs and Light Trucks

While electric car sales have been slowly increasing, American consumers' overall preferences have been moving away from the small sedans and hatchbacks available in electric versions in favor of larger crossovers, sport utility vehicles, and pickup trucks. According to LMC Automotive, SUVs surpassed 50% market share in the 4th quarter of 2019, and are projected to continue to grow in popularity. (LMC Automotive) When combined, SUVs and light trucks account for 65% of the US light vehicle market, which has prompted American automakers General Motors and Ford to dramatically cut passenger car production in reaction to consumer preferences. (Eisenstein 2018) (Wharton School 2018)

Discontinuous Innovation in the Auto Industry is Historically Through Incremental Improvement

Throughout the history of the automotive industry, there have been a number of significant, discontinuous innovations. One of the most significant was the widespread shift from body-on-frame to unibody passenger cars. Driven by increasing fuel economy standards amidst higher expectations of safety, manufacturers began shifting from body on frame vehicles, where a body is hung on an independent chassis, to unibody vehicles, where the entirety of the vehicle serves a structural purpose. (Mackenzie et al. 2014) While this represented a dramatic shift in engineering and manufacturing, like many automotive innovations it had little effect on all but the most astute consumers. Therefore, it occurred over a significant period of time, with increasing market share as old designs were phased out and new designs incorporated the superior technology. Unibody cars began to see widespread use in the 1970s, and the last body on frame passenger car would not be retired until 2011. (Valdes-Dapena 2011)

Part 2: "Disruptive" Innovations Provide a Model for Technology Adoption

As seen in figure 1 below, the traditional model for technology adoption follows a standard bell curve, with users broken into 5 distinct groups (innovators, early adopters, early majority, late majority, and laggards) based on their psychographic profile, which is "a combination of psychology and demographics that makes its marketing responses different from those of the other groups." (Moore 2014) While there are, in most cases, a number of smaller social groups within each of these segments, they are categorized in this manner due to common overall attitudes towards discontinuous innovation.

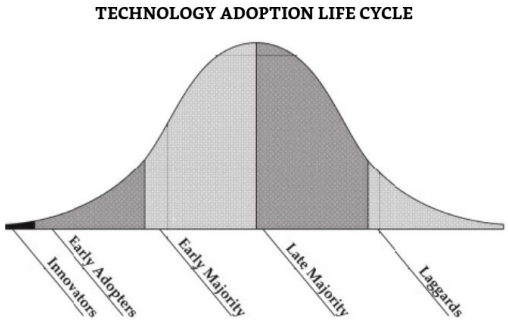

Figure 1: Classical Technology Adoption Cycle (Moore 2014 p. 14)

Innovators are typically willing to use a technology before it is fully developed, often acting as "beta testers" for a product prior to its widespread release. Early adopters are frequently begin using an innovation before other groups, "rely[ing] on their own intuition and vision" to make purchasing decisions. This can be contrasted to members of the early majority, who are open to new technology, but take a pragmatic approach, adopting new technology only when it is clearly beneficial. While members of the early majority are willing to adopt an innovation because it is better than the alternative, the late majority will typically wait until the new technology has become a standard, making it more difficult to continue without switching. Laggards are intensely resistant to new technology, and will often deliberately avoid it despite evidence of its benefits.

The "Chasm" Model for Technological Adoption

In Crossing the Chasm, Geoffrey Moore argues that, while the traditional technology adoption model correctly identifies the segments of a market, it fails to account for the varying difficulties in progressing from one group to the next. (2014) A particular focus of Moore's work is the gaps that exists between each group. According to Moore, while there is a relevant gap between every group, the most significant one, the "chasm," occurs between the early adopters and the early majority. The modified diagram reflecting this significant gap can be seen in figure

2 below. This gap is significant because while the first group invests in a new technology at least in part to act as a change agent, the latter group is driven by a desire for a smooth transition to a superior product, wanting references from other similar users. This, Moore argues presents a problem, as "the only suitable reference for an early majority customer, it turns out, is another member of the early majority, but no upstanding member of the early majority will buy without first having consulted with several suitable references." When trying to win over the early majority, new innovations also face the possibility that the early adopters have "put up with" a flaw that will hinder future progress, such as the Segway's inability to traverse stairs.

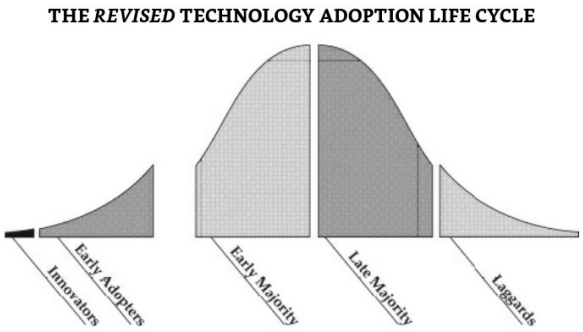

Figure 2: Chasm Model for Technology Adoption (Moore 2014, p. 21)

As shown in figure 3 below, the chasm model illustrates that the defining point in a technology's development occurs in this chasm, with technologies that fail doing so because they could not bridge the gap to the early majority. Applying this model to a new technology enables the identification of factors which could lead to its successful or unsuccessful adoption.

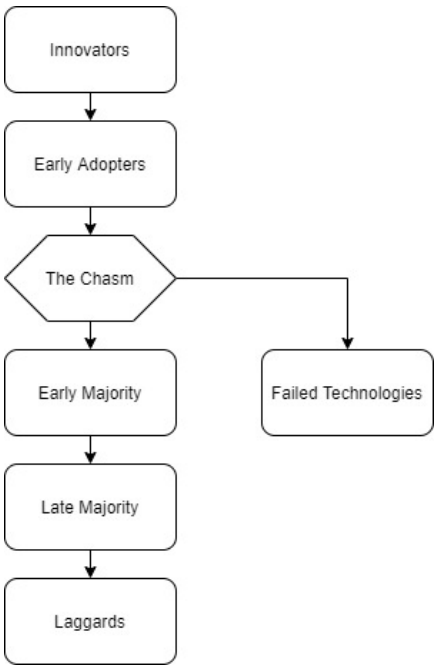

Figure 3 Adoption Pathway of New Technology

Successful Innovations: the iPhone

Prior to the release of the Iphone, Apple had success marketing its other devices as easy to use alternatives to existing products from companies like Microsoft. Capitalizing on this brand image, Apple was able to generate significant publicity prior to the launch of the iPhone, with more than 250,000 devices sold in its first 30 hours on sale. Apple then significantly cut the iPhone's price, leading to another surge in orders. (West & Mace 2010, p. 277) This method mirrors the "D-day" analogy referenced by Moore, in which it is critical that a product spend as little time in the chasm as possible. While the iPhone's lack of a physical keyboard represented a significant difference from existing cell phones and PDAs, charismatic CEO Steve Jobs was able to pitch this to many as an advantage, due to the larger screen that accommodated a standard web browser. (West & Mace 2010) Less than a year later, Google reported that iPhone users accounted for more searches daily than those of every other mobile device combined, suggesting

that consumers found benefit in this type of web browser experience. (Helft 2008) Following the introduction of several subsequent models, the iPhones market share has grown to over 40%, despite a surge in lower priced competitors. (Counterpoint 2020)

Failed Innovations: Google Glass

Steve Jobs often said "People don't know what they want until you show it to them." (Ciotti 2014) While this proved accurate in the case of the iPod, and later the iPhone, these both presented a clear value proposition prior to adoption by the early majority. Google Glass, one of the first iterations of wearable smart glasses, failed to do so. Despite being the best option for customers looking for smart glasses, Google failed to clearly articulate what problem the glasses solved. (Altman 2016) While Google Glass successfully made inroads with early adopters interested in it solely because it represented improved technology, the pragmatic nature of the early majority meant that the glasses would never progress towards widespread popularity.

Part 3: The Chasm Model Allows Us to See a Path Towards Widespread Adoption

The Innovators

As the first production electric vehicle, the General Motors EV1 marked the beginning of electric vehicle adoption. Only available in the Los Angeles area, the car, and similar alternatives from other manufacturers, served as something similar to the "beta-test" frequently employed in the software world. With its low quantities and limited capability, (while the cars themselves had similar range to later models, there was limited to no charging infrastructure) these early models primarily targeted the innovators group as described by Moore. Motivated by both a desire for lower emissions as well as an interest in the "cool factor" of the technology, these early users were outspoken proponents of electric vehicles, one of the key values of innovators as described

by Moore. In fact many were such staunch supporters of the technology that, when automakers ceased production and leases of these early electric vehicles, they began converting existing internal combustion engine cars to electric vehicles. (Paine 2006) By the time manufacturers like Nissan and Tesla would bring a mass-production electric car to market in the early 2010s, these innovators had been espousing the virtues of electric vehicles for more than a decade.

The Early Adopters

As described above, 2012 brought the arrival of a number of mainstream electric vehicles. Capitalizing on a growing concern about technology's effect on the planet amidst warming temperatures and rising sea levels, as well as a significant federal tax credit, Nissan and Tesla began marketing the electric vehicle as a viable alternative to the combustion engine. Similarly to many of Apple's products, these were cars that were easier to use than the homemade contraptions that had previously dominated the electric vehicle scene, requiring no more technical knowledge than any other car. While these electric vehicles lacked the range and ability to quickly refuel common to combustion engine powered vehicles, both Tesla and the overall electric vehicle found success in marketing to early adopters willing to compromise on those aspects to drive the "car of the future." (Turchetta 2012) Tesla in particular promised a growing network of fast-chargers, on top of a comparatively higher battery range, to alleviate concerns about range anxiety on longer trips, something many customers of the significantly higher priced luxury vehicles wanted. (Siddiqui 2020)

The Chasm

In recent years, despite improved vehicle performance, the electric vehicle market's growth has slowed. While Tesla has still experienced significant sales increases, these have been

through expanding into new markets with vehicles like the Model X SUV and the upcoming Cybertruck. (McKerracher 2020) Geoffrey Moore notes that this lateral expansion to previously untapped groups of early adopters is one of the pitfalls that can derail a technology's adoption. He argues that "there are still sales opportunities here—other visionaries who can be sold to. But each one is going to have a unique dream, leading to unique demands for customization, which in turn will overtax an already burdened product development group." In the case of Tesla, the company has chosen to expand into new types of vehicles rather than providing the pragmatic early majority with a positive value proposition. While this will position Tesla to take advantage of shifting consumer preferences, it pulls developmental resources away from improving cars in areas that they already have a foothold with early adopters, limiting their ability to bridge the gap into widespread adoption in that market. When Tesla's sales are removed, the electric vehicle's growth has largely stalled, signaling a failure to reach a new group of more pragmatic buyers. (McKerracher 2020)

The Early Majority can Be Reached Through Tax Incentives

Until 2015, Georgia offered a state income tax credit for new electric vehicles that, when combined with the federal credit, brought the net cost of a lease on a Nissan Leaf to nearly $0. (Sheinin 2016) This was significantly buoyed by Nissan dealers, who took the opportunity to significantly increase sales volume via these leases in order to hit their own corporate sales incentives. Many dealers ran advertising programs targeted at making local car buyers aware of the tax credit's potential. In 2013, a higher percentage of new car sales in Georgia were electric vehicles than in any state other than California, a state that traditionally has high electric vehicle sales due to CARB regulations. (McConnell et al. 2019) (de Zeeuw & Wheeler 2015) As shown in figure 4 below, this tax credit helped make Georgia a leader in electric vehicle sales within the

United States. Other states with similar electric vehicle penetration either subscribe to CARB regulations (California, Oregon, Washington) or have a significantly different automobile use pattern that limits the effect of range limitations (Hawaii, due to limited road distance based on island size)

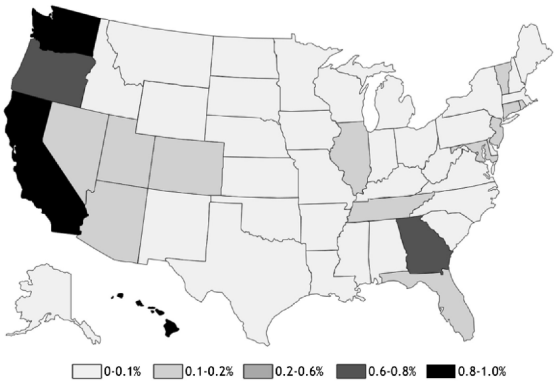

Figure 4: 2010-2014 Cumulative Electric Vehicle Sales by State (Vergis & Chen 2015, p. 57)

After the tax credit expired at the end of 2015, electric vehicle sales in Georgia fell nearly 80%, returning to levels seen by other southeastern states. This could provide a model for accessing the early majority on a broader scale, whether via tax incentives for electric vehicles or disincentives for internal combustion engine vehicles. As seen in Georgia, consumers respond to economic incentives. This case mirrors Geels' argument that "It is… unlikely that environmental innovations will be able to replace existing systems without changes in economic frame conditions." (2011)

Cooperation is Needed to Cross the Chasm

Because the early majority is dependent on references from other similar users, it is critical that any push for widespread electric car adoption be a cohesive effort from all actors to reach a critical mass of users as quickly as possible. As seen in the early 2000s in California, a mandate will not be effective so long as it is actively resisted by manufacturers. Rather, we will

need an approach similar to Nissan's in Georgia, where dealers push consumers to take advantage of the incentives associated with an electric car. Additionally, the adoption of electric vehicles in Georgia shows that it is critical that the electric vehicle provide a positive value proposition to the end user in comparison to other cars. While electric cars may never surpass the range or refueling ability of the internal combustion engine, regulatory policy can be used to tip the scales in favor of electric vehicles. This could be done via tax credits, as seen in Georgia, but it could also be done by disincentivizing the purchase of combustion engine vehicles through increased gas taxes or heightened emissions regulations, as seen in California.

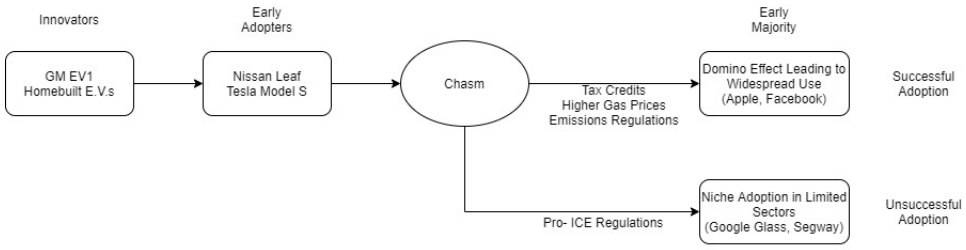

Figure 5 Possibilities for Future E.V. Adoption

Conclusion

"The time is right for electric cars - in fact the time is critical."

-Former Nissan CEO Carlos Ghosn (Associated Press 2009)

Throughout this paper, I argue that the Chasm model provides a more accurate view of the electric vehicle landscape than the incremental improvement model traditionally seen in the automotive industry. In applying the history of electric vehicle to the actors described in Moore's model, with the early users as innovators and the users of current electric vehicles as early adopters, it is apparent that the electric vehicle has now entered the "chasm." The differences between the motivations of current users of electric vehicle and those that must be converted to reach widespread use must be understood by both automakers and policymakers. As noted by

Moore, it is critical that the transition into the early majority happen as quickly as possible, as technologies that linger in the chasm become less and less likely to succeed. (2014, p. 53)

In order to reach a future where the automotive industry is not dominated by fossil fuels, policymakers and automakers must work together to establish an attractive value proposition to pragmatic car buyers if the electric vehicle is to succeed. This will require a combination of a continued emphasis on improving the range and functionality of the vehicles from automakers, as well as new regulatory policy from state and federal governments to create a market where the electric car is cheaper than internal combustion engine cars without significantly sacrificing performance.

References

Altman, I. (2016, August 3). Why Google Glass Failed And Why Apple Watch Could Too. Forbes. Retrieved March 5, 2020, from https://www.forbes.com/sites/ianaltman/2015/04/28/why-google-glass-failed-and-why-apple-watch-could-too/#3cfde7ba44c4

Associated Press. 'Electrification Coalition' lobbies for shift. (2009, November 17). Retrieved from http://www.nbcnews.com/id/33994118/ns/us_news-environment/t/electrification-coalition-lobbies-shift/#.XmFWoqhKg2w

Bartlett, J. (1996, June 1). General Motors EV1 - Driving Impression. Motor Trend Magazine. Retrieved March 5, 2020, from https://www.motortrend.com/news/general-motors-ev1/

Ciotti, G. (2014, September 28). Why Steve Jobs Didn't Listen to His Customers. HuffPost. Retrieved March 5, 2020, from https://www.huffpost.com/entry/why-steve-jobs-didnt-list_b_5628355

Counterpoint. US Smartphone Market Share By Quarter. (2020, February 27). Retrieved March 5, 2020, from https://www.counterpointresearch.com/us-market-smartphone-share/

de Zeeuw, M., & Wheeler, L. (2015). *Georgia's Tax Credit for Zero- and Low- Emission Vehicles*. Georgia State University andrew Yound School Fiscal Research Center.

Eisenstein, P. A. (2018, April 29). Ford to stop making all passenger cars except the Mustang. NBC News. Retrieved March 5, 2020, from https://www.nbcnews.com/business/autos/ford-stop-making-all-passenger-cars-except-mustang-n869256

Furr, N., & Dyer, J. (2020, February 18). Lessons from Tesla's Approach to Innovation. Harvard Business Review. Retrieved March 5, 2020, from https://hbr.org/2020/02/lessons-from-teslas-approach-to-innovation

Geels, F. W. (2011). The multi-level perspective on sustainability transitions: Responses to seven criticisms. *Environmental Innovation and Societal Transitions*, *1*(1), 24–40. doi: 10.1016/j.eist.2011.02.002

Helft, M. (2008, January 14). Google Sees Surge in iPhone Traffic. New York Times. Retrieved March 5, 2020, from https://www.nytimes.com/2008/01/14/technology/14apple.html?ref=todayspaper

LMC Automotive. US sales: what to expect in 2020? (n.d.). Retrieved March 5, 2020, from https://lmc-auto.com/news-and-insights/us-sales-2020/

Loh, E. (2009, September 9). 2010 Nissan Leaf First Look. Motor Trend. Retrieved March 5, 2020, from https://www.motortrend.com/news/2010-nissan-leaf-first-look/

Mackenzie, D., Zoepf, S., & Heywood, J. (2014). Determinants of US passenger car weight. *International Journal of Vehicle Design*, *65*(1), 73. doi: 10.1504/ijvd.2014.060066

McConnell, V., Leard, B., & Kardos, F. (2019). *California's Evolving Zero Emission Vehicle Program: Pulling New Technology into the Market*. Washington, DC: Resources for the Future.

McKerracher, C. (2020). *Bnef Talk 2020*. *BNEF Talk 2020*. San Francisco. Retrieved from https://about.bnef.com/summit/sanfrancisco/videos/?vid=316624242

Moore, G. A. (2014). *Crossing the chasm: marketing and selling disruptive products to mainstream customers*. New York, NY: HarperBusiness, an imprint of HarperCollins Publishers.

Needell, Z. A., Mcnerney, J., Chang, M. T., & Trancik, J. E. (2016). Potential for widespread electrification of personal vehicle travel in the United States. *Nature Energy*, *1*(9). doi: 10.1038/nenergy.2016.112

Paine C. (2006). *Who killed the electric car?* Sony Pictures Classics

Sheinin, A. G. (2016, September 4). Electric vehicle sales fizzle after Georgia pulls plug on tax break. Atlanta Journal Constitution. Retrieved March 5, 2020, from https://www.ajc.com/news/state--regional-govt--politics/electric-vehicle-sales-fizzle-after-georgia-pulls-plug-tax-break/HC0We2aNiekLEn6VoNsa6M/

Siddiqui, F. (2020, January 10). Teslas still go much farther on a single charge than their competitors. But the strategy carries risks. Washington Post. Retrieved March 5, 2020, from https://www.washingtonpost.com/technology/2020/01/10/tesla-battery-range/

Turchetta, D. (2012). *The Car of the Future, Today* (Vol. 76). Washington, DC: U.S. Department of Transportation Federal Highway Administration.

Valdes-Dapena, P. (2011, September 15). Ford's last Crown Victoria rolls off the line. CNN. Retrieved from https://money.cnn.com/2011/09/15/autos/last_crown_victoria/index.htm

Vercellino, M. (2009, October 9). Chrysler, Fiat Working on Electric Car. Retrieved March 5, 2020, from https://www.wsj.com/articles/SB10001424052748703746604574461140385979318

Vergis, S., & Chen, B. (2015). Comparison of plug-in electric vehicle adoption in the United States: A state by state approach. *Research in Transportation Economics*, *52*, 56–64. doi: 10.1016/j.retrec.2015.10.003

Volvo Group. (2019). *The State of Electric Vehicles in America*. Gothenburg, Sweden.

West, J., & Mace, M. (2010). Browsing as the killer app: Explaining the rapid success of Apples iPhone. *Telecommunications Policy*, *34*(5-6), 270–286. doi: 10.1016/j.telpol.2009.12.002

Wharton School. Why General Motors Shifted Gears in Its Manufacturing Strategy. (2018, November 30). Retrieved March 5, 2020, from https://knowledge.wharton.upenn.edu/article/general-motors-closings/