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Pedal to the Metal: Accelerating the Transition to Electric Vehicles

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ACCELERATING THE TRANSITION TO ELECTRIC VEHICLES

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CHAPTER ONE: INTRODUCTION

Human emitted greenhouse gases (GHGs) such as carbon dioxide (CO_2) and methane have caused the earth to warm 1.0°C above pre-industrial levels. According to the Intergovernmental Panel on Climate Change's (IPCC) most recent report issued in October 2018, "Global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate" (IPCC, 2018, p. 4). Impacts from climate change can already be felt, including extreme temperatures and heat related deaths, extreme weather events, sea level rise, species loss, and more. At 1.5°C of warming these effects will harm every country, but at 2.0°C, 90 percent of coral reefs will die, the Antarctic and Greenland ice sheets will melt more quickly and become unstable, and more populations will be exposed to deathly heat waves (IPCC, 2018). Economically, climate change is predicted to cost an average of 1.2 percent of global GDP per additional 1°C of warming (Hsiang et al., 2017). Specific to the United States, without action to curb emissions, ten percent of the U.S. GDP could be destroyed. In comparison, the Great Recession knocked off less than five percent of U.S. GDP (Davenport & Pierre-Louis, 2018). Negative effects of climate change will increase as the world continues to warm, but effects will be less intense and easier to adapt to at 1.5°C compared to 2.0°C. In order to limit global warming to 1.5°C, global CO_2 emissions must decline 45 percent by 2030 (IPCC, 2018). The United States, as the world's largest cumulative historical and per-capita emitter of GHGs

(International Energy Agency, 2018), must rapidly reduce its emissions in order to limit warming and prevent the associated health and economic effects of climate change.

In the United States, transportation as a sector accounts for the largest source of CO_2 emissions. Within that source, passenger cars and light-duty trucks account for the majority of emissions (Greene, 2006). The transportation sector accounts for 28.5 percent of GHG emissions in the United States, closely followed by electricity production, which emits 28.4 percent of U.S. GHGs. In contrast to the decreasing trends in GHG emissions related to electricity production, GHGs related to transportation have been increasing since 1990, due to increased demand for travel. In fact, "the number of vehicle miles traveled (VMT) by light-duty motor vehicles (passenger cars and light-duty trucks) increased by approximately 45 percent from 1990 to 2016, as a result of a confluence of factors" (EPA, 2016). The U.S. transportation system is the largest in the world, with 5.4 trillion passenger-miles traveled each year. Most of these miles are traveled in fossil-fuel powered vehicles (Greene, 2006). To meaningfully reduce U.S. CO_2 emissions, emissions from the transportation sector will need to be addressed.

Transitioning from internal combustion engine vehicles (ICEVs) to electric vehicles (EVs) is one strategy to reduce transportation emissions so long as the electricity to power these vehicles comes from sufficiently low-emission electricity generation. Electric vehicles emit no CO_2 while they operate, and can therefore improve local air quality. Environmental effects from EVs depend on the way in which electricity is generated. If an EV is charged with power generated from a coal plant, the adverse environmental effects of that vehicle will be greater than if electricity is generated from wind or solar power, because coal plants emit a significant amount of CO_2. Egbue and Long (2012) found that concerns about potential power plant emissions raised doubts in many peoples' minds about whether EVs are, in fact, more environmentally friendly than ICEVs. However, lifetime analyses of EVs have found that even when coal is the primary source of electricity, EVs emit 50 percent less GHGs than ICEVs because EVs are more energy efficient than ICEVs (Egbue & Long, 2012). A separate study done by Dr. Messagie (2014) also showed that EVs powered primarily by coal resulted in fewer GHG emissions than ICEVs. Moreover, as electricity grids shift toward more renewables and as more and more coal-fired plants are retired and replaced by new gas-fired power plants, GHG emissions can be even more rapidly reduced compared to using current grid-supplied electricity today. Additionally, EVs can improve local air quality, especially in congested areas, because power plants and their emissions are usually located in less populous areas where human health is less likely to be affected by their emissions (Messagie, 2014).

Electric vehicles have been found to have eight times less impact on human health than conventional ICEVs, even when considering potential emissions from electricity generation: "Urban air quality is a serious problem for human health. As electric vehicles have no tailpipe emissions while driving in a city center, they have an opportunity to improve local air quality at a level that is impossible for conventional and alternative combustion engines" (Messagie, 2014). Furthermore, in the United States, renewable energy capacity is rapidly expanding. When EVs are powered by renewable electricity, these cars create no GHG emissions whatsoever. In 2017, renewable energy generated 18 percent of power, and solar and wind projects accounted for 62 percent of new power plant construction (Morris, 2018). Twenty-nine states and the District of Columbia also have Renewable Portfolio Standards, meaning that they impose a legal obligation on electricity retailers to derive some stated percentage of their electricity from renewable sources in a given year (Solar Energy Industries Association, n.d.). State support of renewable energy combined with falling costs are likely to increase the amount of power generated by renewable sources in the United States, giving EVs an even lower environmental footprint. As decarbonization of the electricity grid proceeds, EVs will likely become an increasingly sustainable option to reduce transportation emissions.

To fully examine the current landscape of EVs, I interviewed current stakeholders and experts in the transportation electrification industry. Because EVs are a relatively new and rapidly evolving technology, there is not a substantial amount of established literature. Therefore, I relied on interviews to ensure that my information is complete and up to date. In this thesis, I first focus on three of the main barriers to widespread EV adoption: awareness, range anxiety, and cost. Next, I explore various policy options to encourage EVs, and evaluate several states adoption rates and their corresponding policies. Finally, I suggest future policy actions that should be pursued at the national and state levels to rapidly increase EV adoption.

There are several different types of EVs. Hybrid electric vehicles (HEVs) are powered primarily by an internal combustion engine that is supplemented by battery-powered electric motor and drive-train features. These types of cars cannot be plugged in but instead rely on the gasoline-powered engine to keep the batteries sufficiently charged to operate the vehicle's electric motor features. HEVs come in many different technical configurations but all have higher fuel efficiency and less associated GHG emissions than conventional ICEVs. Plug-in hybrid electric vehicles (PHEVs) run on a battery powered engine and have a gasoline powered internal combustion engine that can take over when the battery is depleted. These vehicles act as fully electric vehicles within a shorter range and can be plugged in to recharge the battery when desirable to do so. Battery electric vehicles (BEVs) are fully electric and run only on electricity. These vehicles must be plugged in to recharge the batteries and vary in range and price (Department of Energy, n.d.). Fuel cell vehicles are also considered electric vehicles, as they use an alternative fuel, such as hydrogen, to produce electricity onboard the vehicle, which runs the engine (Union of Concerned Scientists, 2018). Although hydrogen fuel cell vehicles may increase in prevalence in the coming years, I will not focus on them as a solution, because analysts believe these vehicles will encounter substantially more barriers than EVs before they are widely used. This is in part due to a lack of fueling stations. While EVs can be charged at home, there are only 39 public hydrogen stations in the United States, with 35 of those in California. Because the infrastructure is so scarcely deployed, fuel cell vehicles are far less common than traditional battery powered EVs (Department of Energy, 2018). Furthermore, production of hydrogen using renewable electricity would involves a high amount of energy to split water molecules. This process involves a large loss of energy which can be avoided by simply using the renewable electricity to recharge EV batteries instead. In this paper, I will use EVs to refer to both PHEVs and BEVs, unless specification is needed. I will refer to HEVs separately, as they generate CO_2 during normal use and are not considered fully electric vehicles.

It bears mentioning that autonomous vehicles will likely play an important role within the transportation revolution. Autonomous vehicles are vehicles that use sensors and high computing power to safely drive without the constant control of a human operator. These cars have the potential to improve mobility for the mobility impaired, including elderly folks, kids below driving age, and the disabled. Additionally, autonomous cars could greatly reduce the need for car ownership, as the prices of ride-hailing services could decrease significantly if the full expense of drivers could be eliminated (Sperling, 2018). Currently, several companies including Uber and Google are operating autonomous vehicles in a few cities for ride hailing (Seba, 2018). Daniel Sperling theorizes that if pooling, or vehicle sharing, and automation were included in the transportation electrification revolution, car ownership would decrease, travel prices would become more affordable and accessible, and GHG emissions would plummet. However, without electrification, automation could increase the number of VMTs and increase GHGs by 50 percent (Sperling, 2018). Both Sperling and Tony Seba, author and keynote speaker at rEVolution 2018, a major vehicle electrification symposium, believe that autonomous vehicles are an inevitable development in the transportation sector and will be adopted within the next few years (Seba, 2018; Sperling, 2018). Fortunately, autonomous EVs are 2.5 time cheaper to produce than autonomous ICEVs, in part because EV engines are much simpler to build than ICEV engines, so the shift to autonomous vehicles will likely include and accelerate the shift to EVs (Seba, 2018). With the rise of autonomous vehicles and pooling techniques, car ownership may become a thing of the past in the near future (Seba, 2018; Sperling, 2018). However, for the purposes of this paper I will not assess the impacts of automation and pooling on the future of the vehicle market. I will instead focus on EVs with the assumption that all other factors will remain similar to the current status quo, and I will evaluate the main barriers and policy solutions to accelerate a transition from ICEVs to EVs.

CHAPTER TWO: AWARENESS AND BEHAVIORAL CHANGE

This chapter examines one of the three main barriers to rapid, widespread EV adoption: awareness. In this chapter, I will discuss models of behavioral change that describe several possible theories about how people begin to accept a new type of technology as the norm. I will also discuss the awareness barrier and current efforts to overcome that barrier to further encourage EV adoption.

Transitions and Models of Behavioral Change

This paper explores a transition from ICEVs to EVs. It is first necessary to define what a transition is and how it may come about. David Hess defines transitions as "fundamental changes, often lasting several decades, in a sociotechnical system and in the regime or rules that govern it" (Hess, 2012, p. 14). Regarding transportation, a transition to EVs could occur in various ways. It might consist of an increase in electric autonomous cars and car-sharing, growing public transit ridership, and other shifts (Sperling, 2018). Alternatively, the future transportation market might look very similar to the market today, with individual car ownership, the primary difference being that our vehicles are powered by electricity rather than petroleum. Because a transition involves the displacement of old technology – in this case ICEVs – with new technology, there will be winners and losers (Hess, 2012). Gas stations and auto makers will likely lose out in the shift to EVs, unless they are able to adapt and provide charging stations and sell EVs to their car customers. For its part, the general public will win due to a reduction in GHGs that cause climate change and health problems.

According to Hess, three aspects affect transitions: niches, sociotechnical regimes, and landscapes. Niches involve the incubation of new technology. Sociotechnical regimes are the rules that govern relationships between new technology and existing systems. Landscapes include the wider environment, or culture, demography, politics, and other factors. Transitions essentially involve niches becoming the new regime using opportunities at the landscape level and the relationship between advocates and opponents at the niche level (Hess, 2012). EVs are still a relatively new technology, and opportunities at the landscape level, such as increasing the amount of publicly available charging infrastructure, could encourage niche EVs to become the new regime. Technological change can also occur through hybridization with other regimes, reconfiguration in response to landscape changes, or internal evolution and innovation. It is also important to consider the role of community organizations in encouraging adoption of sustainable practices (Hess, 2012). All of these methods of change will likely affect the ways in which EVs are adopted and the speed of adoption.

Various authors have theorized about how and why behavioral change may occur. Some important models of behavioral change include the Transtheoretical Model of Change (TTM), Protection Motivation Theory (PMT), and the Norm Activation Model (NAM). Although the TTM and PMT were developed in relation to one's ability to quit smoking, they can easily be applied to society's shift toward EV adoption. TTM defines change as a process with six stages: precontemplation, contemplation, preparation, action, maintenance, and termination. The first four stages are applicable to EV adoption. In the precontemplation stage, the person may be unaware of the consequences of their actions (driving an ICEV). They may not understand the effects of climate change or the need for transportation emissions to be reduced. In contemplation, they are aware of the benefits of the change, but they are also aware of the costs, so although they intend change relatively soon, they may be ambivalent about the relationship between pros and cons. During preparation, they have a plan of action, whereas the action stage is the actual observable change of choosing an EV (Prochaska & Velicer, 1997). Understanding the phases a potential EV driver goes through as they make their decision can allow governments, auto manufacturers, and nonprofits to more successfully target consumer behavior when encouraging EV adoption. For example, if most consumers are in the precontemplation phase, actions to increase awareness should focus on the necessity of reducing transportation emissions and EVs as a solution to achieve this. However, if consumers are in the preparation stage, information should be distributed to ensure that consumers are aware of their options for an EV that appropriately fits their needs.

Another model, PMT, assumes that people will change in order to protect themselves from danger, in this case, climate change. There are four components of PMT that affect the likelihood of change: the severity of the threat, the probability that the threat will occur, how likely it is that the solution (switching to an EV) will assuage the threat, and the person's self-efficacy, or their ability to perform the behavior (Maddux & Rogers, 1983). Although it is likely that consumers will recognize that their single individual choice regarding purchasing an EV will not have an impact on the greater problem of climate change, Bockarjova and Steg (2014) found that PMT "is a relevant theory for modeling different indicators of full electric vehicle adoption" (Bockarjova & Steg, 2014, p. 276). This indicates that EV adoption strongly depends on how serious one believes the threat of climate change is, and its likely personal effects, regardless of the ability of one consumer's decision regarding EVs to effect change. Although all the factors outlined in the PMT affect how drivers may make decisions when deciding to purchase a new car, in order to encourage adoption, the severity of the threat of climate change and perceptions on the likelihood of the effects of climate change being felt should be emphasized. However, Bockarjova and Steg (2014) did their study in the Netherlands where climate change is more widely accepted and of greater concern than in the United States, so fear motivation may not be as strong an indicator for EV adoption in the U.S. Additionally, it is likely that levels of fear motivation vary between potential EV drivers, so incentives and tactics to encourage EV adoption cannot focus solely on fear of climate change.

Finally, the Norm Activation Model predicts individual behavior based on personal norms and awareness of consequences. According to the NAM, personal norms depend on the awareness of the consequences of taking or not taking action, and a subsequent feeling of responsibility. Personal norms combined with anticipated feelings like pride and guilt then determine the behavior (Onwezen, Antonides, & Bartels, 2013). It does bear mentioning that an economist assuming consumers act rationally would view a transition in terms of reactions to market signals. This would mean that until the cost of an EV were comparable or cheaper than the cost of an ICEV, consumers would resist change. Various policies can still incentivize a shift, including allowing access to HOV lanes, free parking, and reduced tolls, but under the market scenario, if these incentives did not make consumers view EVs as price comparable with ICEVs, they would not purchase an EV. However, the purely economic market model does not take into consideration factors that the NAM considers, including the feeling that switching to an EV may be "the right thing to do." The NAM considers whether taking action seems to be what other people are doing and states that behavior has to do with anticipated feelings of pride and guilt (Onwezen et al., 2013). Therefore, Onwezen et al. posit that "doing the right thing" may affect behavioral choices for at least a subset of consumers more than an economist may otherwise assume. It may therefore be important to advertise that choosing an EV is the right thing to do, and something that other people are doing. Ensuring that EVs are frequently visible through increased signage for public chargers and city government fleets would further convince consumers that other people are choosing EVs, and if they were to "join the trend," they would feel a sense of pride and belonging.

The TTM, PMT, and the NAM all theorize about how and why people may change their behavior. All of these theories partially explain ways in which society may begin to shift towards higher adoption of EVs. The TTM explains the need to improve awareness around the issue of climate change and the importance of reducing transportation emissions to meet GHG reduction goals. It also demonstrates that people will tend to weigh perceived pros and cons before deciding whether or not to take action. In terms of EVs, it will be important to educate consumers about the benefits of driving an EV so that in the contemplation stage, the pros are not outweighed by the cons (Prochaska & Velicer, 1997). PMT also demonstrates the need to increase awareness about the dangers of climate change, however, it suggest the use of fear motivation to change behavior. Still, it is not likely that consumers will believe that their singular action of purchasing an EV will solve climate change, so this theory may not fully explain behavioral change as relating to EV adoption (Maddux & Rogers, 1983; Bockarjova and Steg, 2014). Finally, the NAM relies on the idea that cultural norms will help change behavior, as anticipated feelings of pride or guilt can contribute to decision making. The NAM therefore emphasizes the importance of normalizing EV adoption as the "typical" choice and the "right thing to do," because people often choose to follow the norm and act based on what they see other people doing and what they believe is "right," regardless of market signals (Onwezen et al., 2013). All three theories discussed can help explain EV adoption and how awareness campaigns might focus on encouraging behavioral change. However, while both the TTM and PMT seem to suggest that messaging should focus on emphasizing the potential negative effects of climate change without action, Angela Konert, Vice President of Government and External Affairs at

BMW North America, mentioned that BMW no longer focuses on advertising the sustainability of EVs, because people that would choose a car based on environmental concerns have already adopted EVs (Konert interview). In part, this might signify the need to focus more heavily on the NAM to develop messaging techniques and change behavior, as green adopters have already switched to EVs, meaning that advertising should portray EVs as the new normal.

Defining and Improving Awareness

In order for consumers to choose whether or not to switch to an EV, they must first be aware that EVs exist and can fit many different types of lifestyles. According to Josh Boone, Founding Executive Director of the nonprofit public-private partnership of VELOZ, which specifically tries to increase awareness of EVs among Californians, awareness that EVs even exist as a technology that is out on the road is low. In addition, more than half of Californians cannot name a single make or model of an EV. This suggests that fewer than 50 percent of Californians are actively considering switching to an EV (Boone interview). A survey undertaken by two researchers at the UC Davis Institute for Transportation Studies examined consumer awareness in California. Although the number of EVs on the road in California doubled between 2014 and 2017, the survey found that fewer respondents were able to name an EV model in 2017 than in 2014. This suggests that although California had added around 6,000 public chargers between 2014 and 2017 and more EVs were being driven, consumer awareness remained fairly stagnant (Gerdes, 2018). California has the highest rates of EV adoption in the U.S., but still suffers from low awareness, suggesting that other regions of the country might be facing even lower levels of awareness about EVs. In part due to low awareness about these vehicles, in 2015 only seven to eight percent of households shopping for new vehicles in California, Oregon, and the northeast (where much of the demand for EVs exists), shopped for or bought an EV (Sperling, 2018). This level of demand is not sufficient to lead to the level of adoption that could spur great reductions in GHGs in the meaningful future (Gerdes, 2018).

Awareness not only refers to the knowledge that EVs exist but an associated understanding and consideration that EVs may be viable for many different lifestyles. In California, the leading state in the EV market, there were 41 makes and models of EVs available in 2018, and several hundred are expected by 2025 (Boone interview). Though the number of makes and models of EVs is increasing every year, many people still think the only EVs available are Teslas, and therefore EVs are inaccessible to most households due to cost (Valdez interview). Although EVs can offer a good driving experience, with quiet, smooth driving and fast acceleration, in a 2014 California survey of new car buyers, only 2.5 percent reported extensive EV driving experience, and only ten percent reported more than cursory experience, suggesting that consumers may not have personally experienced the benefits of driving an EV. Even though California has been aggressively promoting EVs since the early 1990s with a wide range of policies and has the most available makes and models of any state, few new car owners had enough experience driving an EV to understand that it could potentially match their lifestyle (Sperling, 2018, p. 23). Even policies that seem as though they could promote EV sales may not be effective if consumer awareness is low. For example, though Germany enacted an EV subsidy in 2016, by the end of the year EVs had only captured 0.5 percent of sales, with the subsidy funds largely unused (Sperling, 2018, p. 24). Subsidies have proved popular in other countries and several U.S. states, so it could be that not enough Germans knew of the existence of the subsidies or knew enough about EVs to take advantage of the funds.

It may not be the responsibility of consumers to bear the full brunt of the blame for the lack of awareness and trust in EVs. To create a healthy dialogue with effective decision making, governments and scientific institutions are responsible for providing reliable information and creating the appropriate open and transparent environment to communicate with the public (Dickson, 2005). Additionally, communication between scientific institutions and governments must be a two-way dialogue, rather than a one-way, top-down approach in which the "ignorant" public is expected to adopt the "proper" attitude toward new technological advances and discoveries (Wynne, 2006). Rather than assume the public is ignorant and must be educated by scientists and other elites, trust in new developments like EVs must be developed through a two-way public dialogue where both sides have the opportunity to educate each other (Wynne, 2006). To jump start this conversation, BMW has an "iGenius" in many of their dealerships who specifically lends support to consumers considering purchasing one of the BMW "i" series EVs. This iGenius can answer any questions a potential EV driver may have about EV barriers, the technology, or potential benefits, without trying to sell an EV to the customer (Konert interview). Angela Konert, Vice President of Government and External Affairs for BMW North America in California, recognized that considering an EV requires more thought for most consumers due to perceived risk, which is one reason why the iGenius program was created (Konert interview). It will be important for organizations, companies, and governments working within the awareness and consumer engagement space to ensure that dialogue remains open and multi-directional, as well as accessible to people who may not have yet considered purchasing an EV. Trust and respect needs to be generated rather than taken for granted to allow for consumers to make informed decisions based off of facts that they feel they can trust (Dickson, 2005).

Organizations like VELOZ and Forth aim to accelerate transportation electrification by undertaking consumer awareness initiatives, including offering test drives. Both of these nonprofits involve auto makers as stakeholders, but do not aim to sell these vehicles. They merely aim to encourage multi-directional dialogue between producers and interested consumers (Boone interview). Forth, an organization attempting to improve consumer awareness in

Washington and Oregon, has a showroom in downtown Portland where the general public can schedule free test drives, ask questions about driving electric, and learn about the viability of electric vehicles from displays and knowledgeable employees available to discuss EVs (Henkin interview). Although the showroom is a useful tool for households already aware of EVs, the challenge is trying to reach those households that are not yet aware of EVs, and are therefore unlikely to visit the showroom (Gerdes, 2018). Additionally, although "there is evidence that comprehensive, locally focused information that is easily accessible within three or fewer clicks is best suited to support prospective electric vehicle buyers," (Slowik & Lutsey, 2018) it is also important to increase knowledge of EVs among households not actually actively searching for knowledge about EVs, but perhaps simply generally shopping for a new automobile.

VELOZ and Forth both aim to increase transportation electrification by improving consumer awareness of these vehicles in California and the Pacific Northwest, respectively. Both Boone and Konert claim that the greatest barrier to EV adoption is that consumers are not aware of the benefits of EVs, and are not aware of the many makes and models available that could fit their lifestyle (Boone interview; Konert interview). Instead of focusing on the rational side of the market, or technical benefits like longevity of brakes and GHG reductions, VELOZ focuses on promoting EVs in plain English that the public can identify with. Focusing on the benefits of EVs like quietness, speed, incentives, and a good driving experience, in addition to savings on fuel and maintenance costs, could help move the market from early adopters to mass adoption (Boone interview). When talking about EVs, the focus is often on problems with the technology and barriers, rather than the benefits and driving experience of EVs, factors that are important from a user perspective. In order to increase awareness and excitement among consumers, Angela Konert believes the conversation needs to shift to focus on education that paints EVs in a positive way (Konert interview). VELOZ highlights the benefits of driving an EV to potential consumers, including information about localized incentive programs. The organization increases awareness through social media and digital campaigns surround their website, webinars, and a coming TV spot targeted specifically by zip code and focusing at least 35 percent of efforts on low-income areas. Essentially, VELOZ is trying to "create a 'Got Milk?' campaign, but for electric cars" to accelerate electrification and encourage access to electrified transportation for low-income and disadvantaged communities (Boone interview).

Governments have also taken a role in increasing public awareness. At the moment, city level governments are taking the lead in improving awareness and spreading EV information. Many cities have some type of electric vehicle strategy, or action plan. For example, Portland, Oregon's EV action plan includes 2020 and 2030 goals, infrastructure improving actions, fleet acquisition, awareness events, and economic and innovation goals (The Bureau of Planning and Sustainability, 2016). It has been found that "awareness activities, including online informational materials and outreach events, help to increase familiarity and general understanding of electric vehicles and their features" (Slowik & Lutsey, 2018). Easily accessed, locally focused information best supports prospective EV buyers (Slowik & Lutsey, 2018). Government funded EV awareness and benefit campaigns could improve knowledge of EVs, as could transitioning government fleets to EVs and installing more public chargers in prominent locations. Though public chargers, for instance, are rarely used compared to home or workplace charging, the visibility of these chargers, along with the visibility of government-owned EVs, could make EVs seem more commonplace and trustworthy to the undecided new car purchaser (Sperling, 2018). The more commonly the public encounters the technology working as it should, the less strange it seems, as explained in the Norm Activation Model above. Government EV fleet integration can increase public encounters with EVs, and therefore increase awareness that the technology functions properly and is being deployed (Slowik & Lutsey, 2018). Some localities further encourage ride-hailing fleets to integrate EVs. This has the potential to increase electric vehicle-miles traveled, decrease pollution, and increase the public's exposure to EVs (Slowik & Lutsey, 2018).

Local governments often participate in outreach events, which can include "announcements by local officials, ribbon-cuttings for new public charging stations, charging station giveaways, ride-and-drives, and technology demonstrations" (Slowik & Lutsey, 2018). These types of awareness events effectively raise awareness and increase familiarity. Often, outreach events are held specifically in low-income communities (Slowik & Lutsey, 2018). Test-drive events can also help consumers drive an EV with no commitment, and can allow the public to test and learn about the viability of EVs. Last year, Forth held 18 test drive events in the Pacific Northwest, during which they brought eight cars to an event and collaborated with their partners to engage the public to learn about viability of EVs (Henkin interview). There is evidence that test-drive outreach events improve EV adoption. In 2017, the California Plug-In Electric Vehicle Collaborative found that within three months of a test drive, nine percent of those surveyed had bought or leased an EV. Another study done by the Center for Sustainable Energy found that regardless of income level, after a test drive consumers were more likely to buy or lease an EV in the future (Slowik & Lutsey, 2018).

National Drive Electric Week, occurring every year in September, is one of the biggest coordinated outreach events in the United States. In 2017, 240 such events took place across the country during this week (Slowik & Lutsey, 2018). The Week "is a nationwide celebration to heighten awareness of today's widespread availability of plug-in vehicles and highlight the benefits of all-electric and plug-in hybrid-electric cars, trucks, motorcycles, and more" (Plug-In America, Sierra Club, & Electric Auto Association, 2019). Events during the week are led by local drivers of BEVs and PHEVs and other advocates, and often include "some combination of

EV parades, ride-and-drives, electric tailgate parties, press conferences, award ceremonies, informational booths, and more" (Plug-In America et al., 2019). The Week aims to increase awareness in communities across the U.S. and encourage more people to go electric by spreading information, answering questions, offering test drives, and more. National Drive Electric Week holds events both in the U.S. and internationally, and allows consumers to learn about EVs from their peers who drive electric. These outreach events help engage the public, policymakers, and the media in a dialogue about EVs, increase EV awareness, and could contribute to getting EVs out of their niche stage as delineated by transition theory (Hess, 2012; Plug-In America et al., 2019).

Concluding Thoughts

Considering methods of transitions and behavioral change is important in understanding how consumer thinking about EVs might evolve as EV market share increases. Likely, it will be necessary to encourage local governments to adopt EVs as part of their fleets in order to promote visual reinforcement and therefore behavioral change under the Norm Activation Model. However, because EVs are still relatively new, awareness is a major barrier to mass EV adoption. Even though many incentives exist at state and local levels, consumers must be aware that these cars exist in order to take advantage of rebate programs, free parking, HOV lane access, and other perks (Konert interview). To tackle this barrier, governments and organizations have tried to reach out to consumers through the media and awareness campaigns including National Drive Electric Week (Slowik & Lutsey, 2018). It is important to note that governments, scientific and technological institutions, organizations, and companies all must play a role in increasing consumer engagement and fostering trust in a new technology such as EVs, and this dialogue must be open and multi-directional (Dickson, 2005; Wynne, 2006). As stated in transition theory, opportunities at the landscape level are important to consider when developing this type of dialogue in order to ensure that the new technology fits into existing social systems and creates a lasting societal transition (Hess, 2012). Unfortunately, it is not yet clear what effective means of communication may look like to increase awareness among potential car buyers who have not yet been exposed to EVs and their associated benefits.

CHAPTER THREE: RANGE ANXIETY AND CHARGING INFRASTRUCTURE

Research has identified range concerns as a primary barrier to EV adoption (Blackstrom interview; Bonges & Lusk, 2016; Egbue & Long, 2012; Jain interview). In fact, EVs are "highly beneficial due to their reliance on electricity and Climate Change response yet EV sales are lower than would be expected due to range anxiety" (Bonges & Lusk, 2016, p. 63). According to Bonges and Lusk (2016), range refers to how many miles a car can drive on one charge, and is affected by the actual amount of energy vehicles can store and a driver's ability to readily access a charging station to recharge the EV's batteries quickly when needed. Range anxiety is affected by the car's driving range along with the perception of how far a driver might need to drive from time to time and the uncertainty of whether they can quickly and easily charge their car when they need to do so to avoid being stranded (Bonges & Lusk, 2016). Anxiety over range is based on concerns about the ready availability of public charging stations along the path of an extended planned trip, or concerns among those considering switching to an EV that public charging stations will be necessary for daily use. Under routine circumstances most EV drivers will not struggle with range anxiety, and will prefer to charge at home for the regular daily use of their car (Morrissey, Weldon, & O'Mahony, 2016). Charging at home is convenient, as it allows EV drivers to refuel without having to make a separate trip to the gas station, and it can be cheaper than refueling at a gas station or even public charging station (Jennings interview; Thomas interview). Nonetheless, range anxiety will be a real concern for many drivers when they are considering the purchase of an EV because most drivers will anticipate the need to periodically take a trip longer than the range afforded by their car.

Although range anxiety is a major barrier to EV adoption, Egbue and Long (2012) found that the average vehicle travel per day was only 36 miles, which is easily within the range of most BEVs and PHEVs. In fact, for 78 percent of drivers in the United States, daily driving amounts to only 40 miles or less per day (Egbue & Long, 2012). Although daily driving is often under 40 miles per day, the average minimum desired range on one charge was 215 miles (Egbue & Long, 2012). This could suggest a disparity between actual and perceived necessary range, at least for typical commutes. However, drivers may also be concerned about how often they might need to exceed the range of their car. For example, if a driver must drive 200 miles for work once a month, range anxiety is likely to be a larger concern, especially considering the speed of vehicle charging. Drivers making longer trips often use highways, where many Direct Current Fast Chargers (DCFCs) are located that provide an option for relatively fast charging (Saxton, 2011). Though DCFCs charge vehicles much faster than the more common Level Two chargers, drivers may not feel comfortable knowing that their vehicle requires longer to recharge, especially because gas stations are much more ubiquitous and dispense gasoline much faster than EV chargers charge a battery (Jennings interview).

Even when public chargers[1] are available, charging an EV takes much longer than refueling an ICEV, making charging speed a potential concern for EV drivers. Currently, cars fueled with fossil fuels can refuel to capacity in 10 to 15 minutes at a gas station. EVs can only refuel to 80 percent capacity in about 30 minutes if using a fast charger, depending on how depleted the battery is and the total range of the car (Jennings interview). However, according to

[1] In this thesis, public chargers refer to chargers that are accessible by members of the general public. They may be funded by the government, nonprofits, or private entities, but they are in locations that can be accessed by EV drivers.

Josh Boone, Founding Executive Director of VELOZ, new fast chargers are becoming available that can charge a car to 80 percent capacity in 10 to 15 minutes, on par with the refueling speeds of an ICEV (Boone interview). In fact, in early December 2018, Electrify America opened a 350 kW fast charger in California, which has the potential to charge future EVs to 80 percent capacity in 15 minutes or less.[2] Volkswagen, which runs Electrify America, is installing these chargers before cars have the capability to accept this speed of charging so that when the new vehicles do hit the market, the infrastructure will already be in place and consumers will be familiar with it (Dow, 2018). Additionally, installing chargers in locations where people might normally spend 30 minutes or more, such as restaurants or shopping malls, might allow drivers to recharge their EVs without wasting time. Still, for long road trips ICEVs may still be preferred to EVs because of the speed of refueling and confidence in the technology and infrastructure (Jain interview).

There are three levels of chargers available. Level One charging involves plugging the car into a standard 120V household outlet. This type of charging adds to the electricity bill of the homeowners but does not require outlets to be reconfigured. However, charging a car to 80 percent capacity using this method can take 22 to 30 hours, depending on the size of the battery (Saxton, 2011). This works out to be between four and six miles of range added per hour of charging time (Smith & Castellano, 2015). Because of slow charging times, for drivers that plan to use their vehicle for more than 40 miles per day (about nine hours of charge time at Level One speeds), a Level Two charger might be preferable (Saxton, 2011). Level Two charging uses a 240V outlet, which can easily be installed in a home garage, and can charge a vehicle at much

[2] Current DCFCs are rated at a 150 kW rate in comparison to the 350 kW charger recently installed. These 350 kW super-fast chargers use 800 volts, while the normal EV battery uses 400 volts, meaning that no cars can currently charge at this rate. Existing EVs can still use these chargers to charge as fast as their battery allows, but they are not capable of charging at the full rate that 350 kW chargers could potentially achieve. Some cars scheduled to be released in 2019 will be able to charge at this rapid rate (Dow, 2018).

faster rates (Smith & Castellano, 2015). These chargers on average increase range by about 26 miles per hour of charging time. The majority of public chargers are Level Two chargers because they are much cheaper to install than DCFCs, but charge much more rapidly than Level One chargers. Level Two chargers are also generally located in areas where people might spend several hours, so they have time to “top off” their battery while they go about their daily activities, such as at a mall or a park (Saxton, 2011). Level Two chargers generally cost $400 to $6,500 to install, depending on state and local rebates and the varying costs of hardware and electrician services. Generally, home Level Two chargers cost $500 to $1,000 to install. The final level of chargers, DCFCs, can add about 40 miles of range in ten minutes, meaning that most EV batteries can reach 80 percent capacity in 20 to 30 minutes (Saxton, 2011). Although these chargers can refuel a car at a much higher speed, they are more expensive, and can cost between $10,000 and $40,000 to install, with an average price of $23,662 in 2015 (Smith & Castellano, 2015). Many government grants trying to incentivize EV infrastructure build out encourage the installation of DCFCs, especially along highways, where people may be traveling for long distances and require a quicker charge (Department of Energy, 2019).

A main concern among drivers is the lack of publicly available charging stations. There is an assumption that in order to meet the needs of most EV drivers, a “dense, elaborate network of charging stations” will be required. However, public charging infrastructure is rarely used, as more than half of U.S. homes have the ability to charge a plug-in vehicle at home (Green, Skerlos, & Winebrake, 2014, p. 563). Even though charging at home is the most likely scenario, visibility of public charging will likely be important to “establish a comfort level with consumers that they can get their charge” when they need it (Jennings interview). Although in 2013 there were 157,393 gas stations in the United States, there were only 6,883 public charging stations (Bonges & Lusk, 2016). By March of 2019 this number had increased to 20,920, a number that is constantly growing, but is still significantly lower than the total number of gas stations. Most public charging stations are also located in cities, especially on the two coasts, neglecting the needs of potential EV owners in the middle of the country or more rural areas. Additionally, there are only 2,696 publicly available DCFCs that can rapidly charge your car in a half hour or less (Department of Energy, 2019). According to a study conducted in Ireland, DCFCs were found to be the most commonly used public chargers, but public charging stations still only averaged 0.2 charges per day (Morrissey et al., 2016). Even though potential EV drivers might be concerned about the availability of public chargers, they are rarely used, suggesting that they are either located in inconvenient locations, or current EV drivers charge at home without issue.

Public chargers are not evenly spread throughout the United States. Most public charging stations are located in cities in liberal states on the coasts, or large states like Texas and Florida. Chargers are frequently found in states that rank high in EVs as a percent of total car market share, and lacking in states that rank low in EVs as a percent of market share (Department of Energy, 2019; EVAdoption, 2018). However, the causal implications of this correlation are ambiguous. On the one hand, this correlation of availability of public charging stations with higher EV adoption could be interpreted to suggest that policies that encourage public charging infrastructure could encourage higher EV adoption. Alternatively, higher EV adoption might spur an increase in charging infrastructure build out. California has heavily invested in electric vehicle charging infrastructure in order to accelerate EV adoption to reach its goal of 1.5 million EVs on the road by 2025. As such, by December of 2016, the California Energy Commission (CEC) had awarded more than $64 million toward installation of 8,000 charging stations with 9,000 outlets within the state (California Energy Commission, n.d.). Consequently, California leads the United States as the state with the most public electric charging outlets, offering 19,761 charging outlets as of March 2019. Texas comes in a distant second with 3,057 public charging outlets (Alternative Fuels Data Center, 2019). In an effort to ease anxiety about charging during longer road trips, Washington, Oregon, California, and British Columbia have partnered to set up the West Coast Electric Highway, a network of DCFCs every 25 to 50 miles along main North-South highways, including Interstate 5 and the 101. The goal of this highway network is to give "electric vehicle drivers 'range confidence' that recharging is available should they want to travel between communities or make long distance road trips." Because many of the chargers are DCFCs, drivers can charge their batteries to 80 percent capacity in about 30 minutes (West Coast Green Highway, n.d.). In fact, many of the DCFC chargers that are not in cities are placed along highways, suggesting that governments, utilities, and infrastructure developers have identified the potential need for fast charging stations on longer range trips using highways (Department of Energy, 2019).

Along with charging speeds, battery technology is also improving, with Tesla's Model S having a range of 335 miles per charge (EZ EV, 2018). In fact, since EVs began hitting the market in earnest in 2010, battery ranges have increased dramatically. In 2011, only three BEVs existed, with ranges from 63 miles to 94 miles on a full charge. The median range was 73 miles. Six year later, in 2017, the median range had increased to 114 miles, with a span of 58 to 335 miles on a single charge [See Figure 1] (Vehicle Technologies Office, 2017). According to BMW's market projections, globally "the battery market is growing rapidly, driven principally by increased demand for electric vehicles. Significant increases in the supply of automotive-grade batteries are planned worldwide in anticipation of future demand, but the magnitude of the demand is unclear – driven by consumer preferences, cost and governmental policies. Competition in battery manufacturing and increased scale will continue to drive down costs at the cell and pack level" (Konert interview). Furthermore, storage technologies designed in conjunction with renewable energy projects require batteries similar to those used for EVs, meaning that as technological advances allow for storage ability for renewables to increase, the battery costs for EVs seem likely to fall even further (Kitahara & Beltran interview). As battery production increases, economies of scale and research and development in battery technology and manufacturing will allow for growth in the battery market.

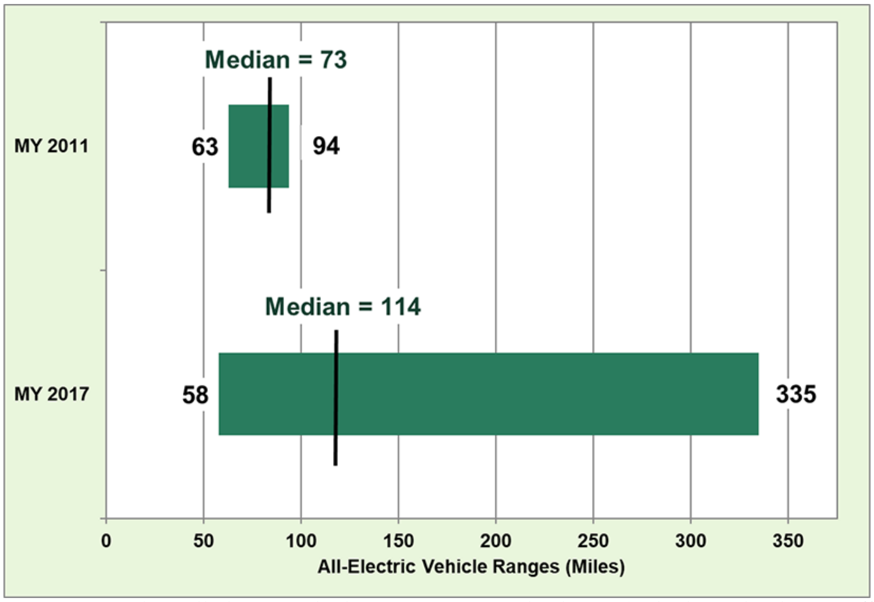

Figure 1: Median all electric vehicle ranges on a single charge (Vehicle Technologies Office, 2017).

Although many people can charge at home, solutions need to be created for those who do not live in a single family home. Multi-Unit Dwellings (MUDs) include apartments, condominiums, duplexes, or other buildings that house several families. Oftentimes these residents have assigned parking spaces, and their landlord may not be willing to spend the money to install EV chargers for residents, decreasing the likelihood that these people will view EVs as a viable option for their lifestyle (California Plug-In Electric Vehicle Collaborative, 2013). It would not be efficient to build several chargers at various parking spaces that are assigned to EV owners when building one charger with several cords attached could serve more residents for a cheaper cost. However, assigned parking spaces can make it difficult to install central charging systems. Additionally, rewiring parking lots to install outlets that can serve EVs can be expensive (California Plug-In Electric Vehicle Collaborative, 2013). PCS Energy is one company that builds chargers in apartment and office buildings. Although the sunk cost of the charger is an expense for the company, the cost of installing a level-two EV charger in an apartment building can be fully recouped in seven or eight years. Rebates from utilities might further mitigate that fixed cost (Jennings interview). Potentially, landlords could install an EV charger in a common location where it could reach four to eight parking spaces, and designate those spaces specifically for tenants who own or lease EVs (California Plug-In Electric Vehicle Collaborative, 2013). Additionally, if an EV owner's assigned parking space in near an electrical service access point, the landowner may work out an agreement to allow for vehicle charging, or the resident could attempt to trade assigned parking with a resident whose assigned spot is near the electrical access point. To avoid losing money on the installation, landowners can set up a system that charges residents for the energy they use plus an additional usage fee to cover the installation costs (California Plug-In Electric Vehicle Collaborative, 2013). In cases where a landlord resists installing charging or the logistics are too complicated, it might be necessary to create public areas with many public chargers, or charging plazas. These plazas would have 20 to 30 outlets with DCFCs, be well lit, and have security cameras (Boone interview). Similar to gas stations, these plazas could be built in areas with many MUDs and off highway exit ramps, and even at old gas station locations once they become obsolete. Especially as charging speeds decrease, these types of charging plazas could become a viable option for people living in MUDs or with only curbside parking (Boone interview).

Paul Jennings, Principal at PCS Energy and an owner of several EVs said that although EVs take much longer to fully recharge than the time it takes to refuel an ICEV, most drivers prefer to charge at home, so public charging stations may only be necessary to "top off" cars for several minutes in order to complete a longer trip. He believes that range anxiety is a purely psychological issue and expanding charger visibility may ease concerns by assuring drivers that they have the ability to charge when and where they may need (Jennings interview). Therefore, expanding a public charging network may not be necessary to meet charging needs so much as create consumer confidence that they will not be stranded if they choose to drive an EV. Many folks who do drive EVs have an ICEV as well. This suggests that people might feel uncomfortable having just an EV, and so own an ICEV as "backup." An ICEV in this situation may be a type of security blanket to assuage range concerns relating to owning just an EV. However, many people do not have the ability to own more than one vehicle, so the psychological wish to own an ICEV as a backup may prevent single vehicle owners having the confidence to choose an EV as their only vehicle (Kitahara & Beltran interview). Regardless, once drivers become used to driving an EV and recognize that it can fit their lifestyle needs, they tend to prefer the electric car, due to superior performance in acceleration, smoothness, quietness, and a variety of other factors (Boone interview; Jennings interview; Kitahara & Beltran interview; Swanton interview). Based on the interviews I have conducted, there seems to be a general consensus that drivers find EVs more enjoyable to drive, once barriers such as cost and range anxiety have been overcome (Boone interview; Jennings interview; Kitahara & Beltran interview; Konert interview; Swanton interview). As consumer awareness about the cars and the availability of charging grows, people may begin to prefer EVs and see them as better performing and equally functional when compared to traditional ICEVs (Boone interview; Konert interview).

CHAPTER FOUR: THE COSTS OF PURCHASING AND OPERATING AN EV

Upfront cost is an important barrier to widespread EV adoption. EVs cost more than a comparably sized gas-powered car. However, just as ICEVs have become considerably less expensive over time (adjusting for tremendous improvements in quality), it is reasonable to expect that the cost of EVs will likewise decline even as the vehicles improve in quality (Kitahara and Beltran interview). EV technology and battery technology are rather new, and batteries strong enough to power cars and hold enough of a charge for long-range driving are expensive. Battery costs are the primary driver of higher upfront EV costs, and as battery technology improves, the cost of batteries, and therefore EVs, will likely come down. Once batteries become stronger and cheaper, automakers will be able to produce a variety of EV body shapes including SUVs and pick-up trucks at comparable cost. Right now, many EVs are hatchbacks because that body type is more aerodynamic and allows for a less powerful and less expensive battery than the battery that would be required for other vehicle body types. Hatchbacks are popular in Japan and Europe, but less so in America, which could help explain slower adoption of EVs in the U.S. (Kitahara and Beltran interview).

Battery Costs

Battery costs are falling rapidly as EVs gain popularity and more automakers introduce electric models. The cost of the lithium batteries required to operate vehicles has dropped by 90 percent in the past five years, and is expected to fall further as technology improves (Jennings interview). Once the price of batteries falls to between $125 and $150 per kilowatt-hour (kWh), the upfront cost of EVs will be comparable to the upfront cost of ICEVs. Forecasts expect that this price parity could be reached as early as 2020. As of 2018, EV batteries cost between $190 and $205 (Union of Concerned Scientists, 2018). However, the battery market depends on production scale. As more batteries are produced more efficiently, the cost of production will go down, but more units are unlikely to be produced until demand increases. Like charging infrastructure, this is another chicken-and-egg problem (Kitahara and Beltran interview). Auto manufacturers are not incentivized to produce batteries at the scale that would allow further cost decreases because demand for EVs is not high enough and most, if not all, manufacturers already lose money on production of electric vehicles (Konert interview).

Since 2014, production capacity for batteries has skyrocketed, while costs have fallen faster than analysts expected. Manufacturing has grown by six times, while the costs of batteries have fallen 20 percent per year (Seba, 2018). This annual 20 percent decline is likely due to a combination of three factors: (1) static economies of scale due simply to larger production, (2) low-tech "learning-by-doing" advances in fabrication economics, and (3) high-tech" advances in battery design. Tesla's new Gigafactory in Nevada will have the capacity to produce more lithium-ion batteries each year than the total global production of batteries in 2013 (Sperling, 2018). These are signs that battery production levels are beginning to increase, which will likely lead to further expected cost decreases. Demand for renewable energy storage that uses similar battery technology to EVs will also likely lead to breakthroughs in research and development (R&D) and lower costs (Jennings interview). Until production levels and demand increase and battery prices fall, the auto industry will necessarily continue to price EVs lower than the actual production cost in order to sell them, creating negative profits for these models. The cost tipping point where manufacturers no longer lose money by producing EVs will likely be in the early 2020s (Sperling, 2018).

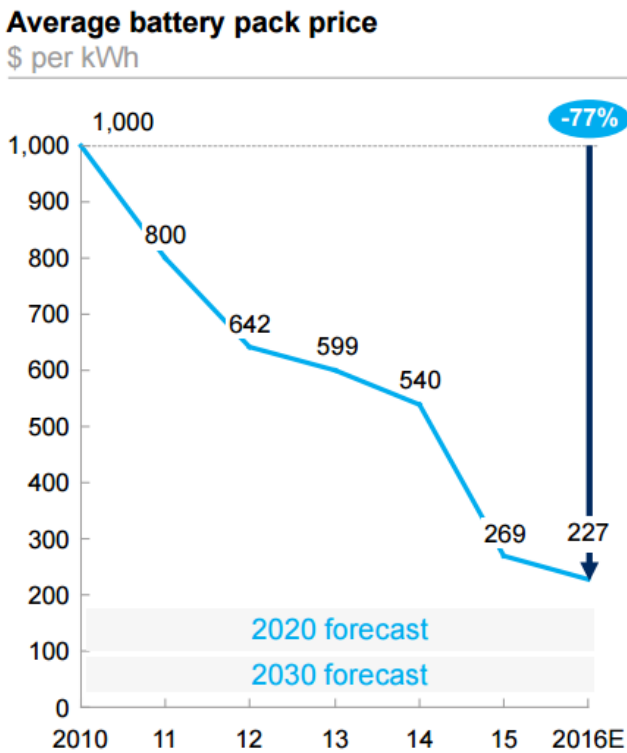

Figure 2: Price of electric vehicle battery packs over time with projected 2020 and 2030 cost expectations (Lambert 2017).

Automakers continue to sell EVs at a loss in order to comply with more strict tailpipe standards and zero emissions vehicle (ZEV) mandates. ZEV mandates have been implemented in several states with large markets, including California, requiring manufacturers to continue to produce EVs (Sperling, 2018). States with a ZEV mandate require automakers to sell a certain number of ZEVs as a percentage of their total sales. If they cannot meet that quota, they must pay a fine or buy credits from another company that has produced and sold more than their quota of ZEVs, such as Tesla, whose entire production consists of BEVs [see more in Chapter Five] (Konert interview). Fully electric vehicles cost about $10,000 more to produce than comparable ICEVs, but as battery costs continue to fall, EVs will become cheaper to produce (Sperling, 2018; Seba, 2018). Though EVs are not yet profitable to produce from an automakers point of view, policies like ZEV mandates have led to increased production of EVs, which has forced improvements in battery technology to reduce the size of manufacturers' negative profit margins on EVs (Sperling, 2018). Furthermore, "a growing number of analysts foresee demand for EVs accelerating sharply in the coming years as costs continue to fall, driving ranges increase, and governments become more insistent," and automakers aim to stay ahead of this trend (Sperling, 2018, p. 22).

According to Tony Seba (2018), award winning author and keynote speaker at rEVolution 2018, technology is generally adopted on an S curve, meaning that EV adoption will start gradually and then, once it hits the inflection point, adoptions will increase at an increasing rate. The last major technological disruption in transportation occurred in 1900. Previously, horses were the normal means of transportation, but once the automobile came along, New York City transitioned from mostly horses to mostly cars in just 13 years (Sperling, 2018; Seba, 2018). Smartphones were also adopted from a niche high-tech tool in 2007 to almost universal deployment 10 years later. Seba predicts that based on the current cost curves of batteries, by 2020 a new EV will be cheaper than the median new ICEV, with fueling and maintenance costs for EVs one-tenth of the cost for ICEVs (Seba, 2018). Currently, batteries account for 43 percent of the total vehicle cost, down from 49 percent in 2016 (Statista, 2018). Though some experts may argue that Seba's predictions are ambitious, he claims that many different types of technology are being adopted quickly, and the S curves are becoming steeper. Seba assumes that EVs, which some claim offer a superior driving experience along with cheaper maintenance and fuel costs, will follow that pattern (Seba, 2018). Daniel Sperling (2018) more modestly predicts that EVs will become cost comparable by 2025 or earlier. However, both authors predict that upfront EV price parity with ICEVs will likely occur within the next six years at most (Sperling, 2018; Seba, 2018). When considering life cycle costs of owning and operating an EV, these vehicles may already be cost comparable due to lower maintenance and fuel costs ((Jennings interview).

Financial Incentives

On the consumer side, federal and state tax rebates can make the upfront purchase cost of an EV more comparable. Unfortunately, some consumers cannot take full advantage of available rebates, including the federal tax rebate, as they may not pay enough in taxes to claim the maximum amount. The federal tax rebate allows for EV consumers to credit up to $7,500 of their annual income tax, so consumers that pay less than $7,500 in federal income tax cannot claim that full incentive. Regardless, financial incentives can be a powerful policy tool to mitigate the cost barrier, and many states offer additional incentives and rebates on top of the federal tax rebate. Several states also waive sales taxes or offer rebates unrelated to tax. According to Angela Konert of BMW, the market is not yet mature, so without financial incentives it would be unlikely that EVs would reach more than one percent of global market penetration. Regardless of the financial situation of the consumer, a financial stimulus provided by the government can increase confidence in the market, especially because cars are expensive, and therefore a large purchase decision (Konert interview). When financial incentives are removed, demand drops dramatically. In the Netherlands, the government believed the EV market was mature and stopped offering financial incentives. This caused customers to rapidly return to ICEVs, even though EVs had been highly prevalent (Konert interview). The state of Georgia also removed a generous state income tax rebate that, when combined with gas savings, made leasing some EVs almost free. This incentive was removed four years ago, and since then, demand for both leased and purchased EVs has dropped dramatically in Georgia (Kitahara and Beltran interview; Joyner, 2017). Another option to mitigate the cost of an EV is to buy a used vehicle. Used EVs are often cost comparable with ICEVs. For example, a used 2012 Nissan Leaf sold for less than $7,000 with less than 43,000 miles on it (AutoTrader, n.d.). In contrast, a used 2012 Honda Civic with 58,000 miles was listed at $10,495 (CarGurus, n.d.). Though prices vary, as the EV market continues to grow, even more used EVs will become available, allowing those who cannot afford to purchase a new car the chance to own an EV (Jennings interview).

Maintenance and Fuel Costs

Though the upfront price tag of an EV may be higher than that of a comparable ICEV, the maintenance and fuel costs associated with an EV are just ten percent of the costs of driving and owning an ICEV (Seba, 2018). An electric motor is far more efficient at converting electricity into kinetic energy than the combustion in an ICEV, and electrons are cheaper to create and manipulate than diesel or gasoline molecules (Seba, 2018). Furthermore, EVs recapture energy during braking (Sperling, 2018). More energy efficient vehicles reduce costs for consumers, and this trend is expected to continue as the efficiency of EVs improves further (Sperling, 2018). When taking into consideration volatile and high gas prices and maintenance costs for services like oil changes, which EVs do not require, the life cycle costs of owning an EV are actually lower than owning an ICEV (Konert interview). EVs do not wear down brakes or tires as quickly as ICEVs, and most car manufacturers include warranties of five years or 100,000 miles or more for their batteries (Jennings interview). Batteries for EVs can last for 500,000 miles or more, though the average American only drives 10,000 miles a year (Seba, 2018). This means that EVs can last up to five longer than an ICEV, and may be a good option for fleets that drive many more miles per year than the average person. Furthermore, EVs are mechanically much simpler than ICEVs, with 20 moving parts compared to more than 2,000 (Seba, 2018). This allows manufacturers to use just three vehicle platforms to manufacture an electric vehicle, compared to the ten or 20 platforms required for ICEVs (Sperling, 2018). Not only are EVs more efficient than ICEVs, with a longer possible lifetime, but parts and manufacturing costs are predicted to continue to decrease significantly (Sperling, 2018; Seba, 2018; Jennings interview), which will likely further reduce upfront price tags for consumers. However, until upfront price tags become more cost comparable to ICEVs, the evidence suggests that consumers are unlikely to rapidly adopt these vehicles without significant financial incentives (Konert interview). While the lifetime costs of an EV may be less than an ICEV, consumers do not tend to take into account the cost savings they may accrue from driving a car for many years compared to how expensive the car seems right off the bat. Luckily, more efficient manufacturing demonstrates the potential for cost reductions for EVs in the near future (Sperling, 2018; Seba, 2018).

Fueling an EV with electricity is significantly cheaper than paying to fuel a car with gas (Thomas interview). More than half of U.S. homes have the ability to charge EVs at home (Green, Skerlos, and Winebrake, 2014), and EV drivers generally prefer to charge their vehicles at home, meaning that charging costs reflect their typical home electricity costs (Bockarjova and Steg, 2014). If paying for use of a public charging station or one located in an apartment building garage, drivers might pay 20 cents per kWh. Depending on the efficiency of the car,[3] this is equivalent to paying about six to ten cents per mile, about one third of the cost of gasoline, though this can vary depending on local gas prices (Jennings interview). If charging at home, the average cost of electricity in the U.S. is 12 cents per kWh, making the cost of refueling at home lower than refueling using a public charger. An EV owner might therefore spend $20 or less on fuel each month, depending on how often the car is driven and whether it is charged at home or

[3] Different makes and models of cars can go different distances per kWh. For example, a Nissan Leaf usually can drive three miles per kWh, while a Tesla generally gets about one mile per kWh (Jennings interview).

at public pay-to-charge stations (Jennings interview). Charging your vehicle at home through the special EV-only rates offered by some utilities can cut charging costs even further. The utility Southern California Edison offers EV-specific charging rates that cost an average of $564 less in fueling per year when compared to a gas powered car averaging 30 miles per gallon (Thomas interview). In some instances, per kilometer it can be as little as ten percent as expensive to charge an EV than fuel an ICEV (Seba, 2018). As more electricity is produced from cheap renewable sources like solar and wind, the cost of refueling an EV is expected to drop even farther, and the environmental benefits will increase as well (Jennings interview).

Niche Markets and Environmentalism

The role of niche markets may be important in accelerating the adoption of EVs. Currently most policies in the United States target the demographics most common to new vehicle purchases rather than specific niche markets and early adopters like green consumers. Green, Skerlos, and Winebrake (2014) believe that EV purchasers fit a specific subset of early adopters and green consumers, so public policies broadly targeting mainstream automobile markets are inefficient and expensive. Therefore, they posit that targeting mainstream markets for EV adoption will not achieve efficiently achieve policy goals to improve market penetration and the associated societal benefits. Rather than attempting to make plug-in hybrids (PHEVs) and EVs comparable to ICEVs, Green, Skerlos, and Winebrake (2014) argue that policies should instead focus on a target audience that is willing to accept tradeoffs. They argue that if we can nurture this niche market and focus on the needs and wants of early adopters, EVs will become more affordable, word-of-mouth endorsements based on actual driving experiences will spread, and governments will not need to spend as much pursuing relatively ineffectual policies (Green, Skerlos, and Winebrake, 2014). However, interviews with various experts has suggested that

EVs may have now moved past the niche market phase and into mainstream markets, at least in high adopting states such as California. For example, Jennings and Kitahara and Beltran believe that EVs have moved past the niche market phase and are ready for mainstream consumers (Jennings interview; Kitahara and Beltran interview). Most automakers now offer at least one model of EV, with plans to roll out new models this year (Kitahara and Beltran interview). Angela Konert, Vice President of Government and External Affairs California of BMW North America believes that EVs have become mainstream in California, but there is not enough political activity at all levels of government for EVs to penetrate the mass market across all U.S. states. The discrepancy between demand for EVs in urban areas to improve air pollution and take advantage of incentives, and lack of demand in rural areas is prevalent both in the U.S. and globally. Rural and urban markets are going in different directions so in the future, it may be necessary for automakers to evaluate and change their marketing strategy based on location (Konert interview). Additionally, rural consumers may be more wary of purchasing an EV due to concerns about lack of charging infrastructure and range anxiety.

Environmentalism has also been a factor encouraging acquisition of EVs by early adopters. In addition to fewer tailpipe emissions from BEVs and PHEVS, BMW has improved the sustainability of their vehicles by using recycled and more sustainable materials to build their cars. Though they attempted to use their goal of net-zero emission cars to increase sales when they began improving sustainability, they quickly found out that “sustainability does not draw people to a new brand for mass adoption” (Konert interview). Although early adopters may have chosen cars based on sustainability, BMW found that these customers had already purchased EVs, and, though mass adopters would gladly accept sustainability if it were offered to them for free, sustainability itslef is not an important selling point (Konert interview). Once they have purchased an EV, consumers will brag about being “green,” but if the purchase and use of the car does not make sense economically, they are unlikely to choose an EV solely for environmental reasons. Therefore, climate change is not a selling point for these consumers, though they will claim credit for being personally sustainable (Jennings interview). In California, environmentalism may be a slightly more important factor. Californians are generally more concerned with the environment, especially because they are known for being a car-heavy state with considerable air pollution. Within the state, there is a "cool factor" of owning an EV. Consumers enjoy the "cache of being green," and the Californian government also offers many incentives to promote EV sales through HOV lane access, financial rebates, parking incentives, and more (Kitahara and Beltran interview; Boone interview). Conversely, in southern, more conservative states, it may be difficult to sell EVs based on the green factor, because climate change is not as much of a cultural concern. In the South, it will be necessary for vehicles to be competitive in more conventional ways, including superior driving experience, long ranges, and lower price tags (Kitahara and Beltran interview).

CHAPTER FIVE: POLICY OPTIONS FOR PROMOTING ADOPTION OF EVS

Policy incentives have been found to positively affect EV adoption. The purpose of this chapter is to analyze different local, state, and federal policy tools used to encourage EVs, and the effectiveness of these tools. First, I will explore the two broad categories of policies, and how they affect EV adoption. Next, the chapter will analyze extrinsic and intrinsic consumer motivation, and how policies can affect consumer choice. In the following section, the main barriers to EV adoption will be revisited, along with examples of policies that have been implemented and proposed in various localities in order to combat these barriers. Finally, I will explore ways in which various states have tried to promote EV use and access among low-income communities.

Types of Policies and Motivation

Policies can be split into two main types: purchase-based incentives, and use-based incentives. Purchase-based incentives affect the upfront net purchase cost of the vehicle, while use-based seek to reduce EV operating costs or offer additional "perks" (such as preferred parking or access to HOV lanes) to encourage EVs (Langbroek, Franklin, & Susilo, 2016). A significant barrier to EV adoption lies in the fact that EVs often cost much more than ICEVs. In fact, Egbue and Long found that this was the second highest barrier to EV adoption, second only to concern about range (Egbue & Long, 2012). Other sources have cited the cost barrier as *the* most significant barrier to EV adoption, and therefore, incentives bringing down upfront cost could help alleviate a major roadblock to large-scale adoption (Konert interview; Keddie interview; Jennings interview; Henkin interview). Purchase-based incentives are common and apply to everyone within the country or state to which that incentive applies, though certain states apply income restrictions. They include strategies like subsidies and tax rebates (Langbroek et al., 2016). In the United States, a federal tax credit exists to offset $2,500 to $7,500 of the cost of a new plug-in vehicle, up to a certain quota per automaker. This credit applies to both PHEVs and BEVs (Department of Energy, n.d.).

The other major type of policy used to affect EV adoption is a use-based incentive. These types of policies decrease the marginal costs associated with owning an EV, meaning they create non-monetary perks like free parking and charging or HOV lane use. Usually these types of policies are location-based, meaning they are confined to a certain jurisdiction, and their effectiveness may be greater based on the local context (Langbroek et al., 2016). For example, the city of Sacramento offers free or reduced-price parking for PHEVs and BEVs, so within that locality, these drivers enjoy an additional benefit. This is a highly effective incentive in encouraging drivers to choose to drive electric in Sacramento because parking is expensive and often costs more than an EV lease (Keddie interview). Though use-based incentives do not directly address the higher upfront-cost barrier of EVs compared to ICEVs, these policies are popular because they often cost less for the government to implement, and the cost of implementation is spread out over time (Langbroek et al., 2016). They may also be more effective when designed and implemented based on local context like HOV lane access in high-traffic areas or free parking in cities with limited or expensive parking (Kitahara & Beltran interview). In the United States, EV incentives and policies vary dramatically by state.

Policies can affect how much extrinsic motivation consumers have to purchase an EV. Extrinsic motivation is affected by outside factors, and can be manipulated by increasing incentives or policies. On the other hand, intrinsic motivation varies by person and can be influenced by factors like technology, social or personal matters, cost, context, or environmental motivation. While intrinsic motivation reflects someone's internal motivation to do something, extrinsic motivation is related to outside factors aiming to change behavior (Langbroek et al., 2016). Extrinsic motivation can be affected by legislators, as policy incentives influence the generalized costs of using an EV. Increasing extrinsic motivation factors by implementing purchase and use-based policies increases total motivation. However, because intrinsic motivation varies among people, the level of extrinsic motivation added by various policies may or may not add enough additional motivation to bring about a change in behavior (Langbroek et al., 2016). Therefore, the number of policies required to get the consumer to actually switch to an EV depends on the specific person and can vary greatly [Figure 3]. For example, those that have already adopted an EV may require fewer policy incentives to buy another, because they may have a demonstrated high level of intrinsic motivation. As people gain awareness of using EVs, policies have a varying effect on decision making (Langbroek et al., 2016).

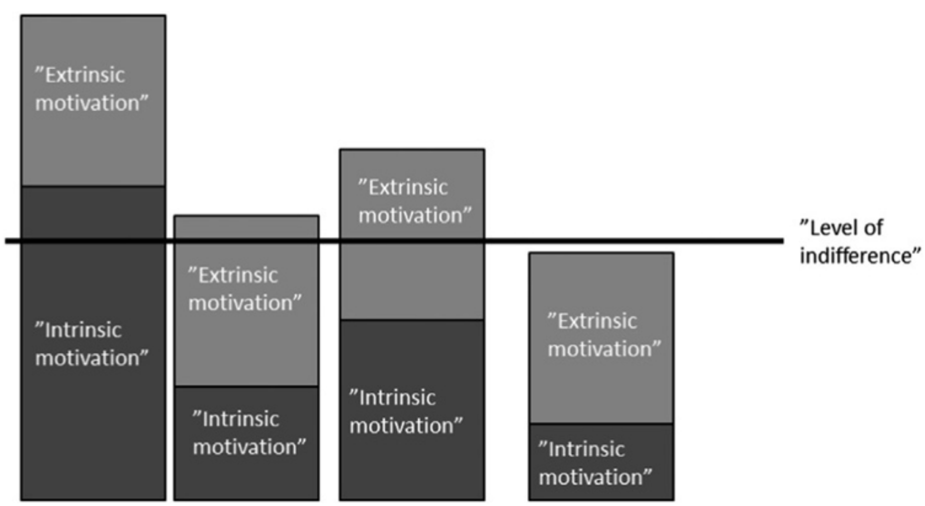

Figure 3: Policies required to motivate people to buy an EV over an ICEV based on intrinsic and extrinsic motivation (Langbroek et al., 2016).

Barriers and Corresponding Tools to Overcome Them

Based on available research as well as interviews with EV drivers and experts in the industry, there are three main barriers to widespread EV adoption. These barriers are affordability, range anxiety, and awareness (Jain interview; Konert interview; Bonges & Lusk, 2016; Daniel Sperling, 2018; Egbue & Long, 2012; Keddie interview; Boone interview; Kitahara & Beltran interview; Langbroek et al., 2016; Blackstrom interview; Jennings interview; Sierzchula, Bakker, Maat, & van Wee, 2014). Affordability refers to the upfront price of an EV. Although historically EVs have cost more than comparable ICEVs, more EV options at more affordable prices have been released and are planned to be released in the near future (Blackstrom interview). However, it is still unclear how soon these models might materialize and how close they may be in price to ICEVs. There are used EVs available though, and these vehicles are often cost comparable to used ICEVs, especially when considering full life-cycle maintenance and fuel costs (AutoTrader, n.d.; CarGurus, n.d.; Jennings interview). The next barrier, range anxiety, refers mainly to charging availability and how much charging equipment is available, where it is located, and whether or not consumers are concerned about access to appropriate infrastructure (Blackstrom interview). Michael Blackstrom, Managing Director of Energy and Environmental Policy at Southern California Edison, believes that although there are charging policies available in California, they may not be as effective as necessary, because the main barriers to increasing charging access are the speed of getting programs and approvals into place and a complicated and slow permitting process for personal and commercial installation of charging infrastructure. For example, in Los Angeles, the permitting process of installing a Level Two charger can require a six-month wait (Blackstrom interview). The third major barrier to adoption is awareness. As elaborated in Chapter Two, awareness refers to a broad understanding of which models of vehicles are available, EV capability in terms of range and cost, and the association of EVs as a category of vehicle that can fit many different lifestyles (Blackstrom interview). To battle the awareness barrier, several organizations have been created to increase EV knowledge and confidence in various states by offering test drives, information, and outreach to consumers and specifically low-income communities (Jain interview; Boone interview; Henkin interview).

Financial incentives are a valuable policy tool to encourage EV adoption. Several experts interviewed believe that these types of incentives are the most important policy tool to accelerate EV sales (Konert interview; Keddie interview; Jennings interview; Henkin interview). Because the upfront cost of EVs is still generally higher than the cost of comparable ICEVs [see Chapter Four], any incentive that can make EVs cost comparable can help encourage consumers to choose electric. In general, emerging technologies such as EVs compare poorly to the existing technology (ICEVS) in terms of price. Early adopters must therefore pay a premium. Industries that can take advantage of learning-by-doing and scale economies can then rapidly lower costs and improve performance as early adopters create a substantial market niche (Sierzchula et al., 2014). California, the highest adopter of EVs in terms of absolute numbers and percent of market share (EVAdoption, 2018), has achieved such high adoption in part due to its generous rebate program. The California Clean Vehicle Rebate Program has distributed nearly half a billion dollars in rebates applying to hundreds of thousands of cars. State tax rebates and other financial mechanisms including waving sales taxes have also proved successful (Keddie interview). Through the middle of 2015, Georgia was second in the nation in EV adoption and sales. This was primarily due to the generous $5,000 state income tax rebate. When this tax credit was repealed and replaced with the highest EV registration fee in the nation, sales and leases of EVs plummeted by over 90 percent, according to the Department of Revenue (Joyner, 2017). As such, Georgia has been held up as a poster child for the effectiveness of financial policy incentives in encouraging the market, and for the negative effects of the removal of such incentives. Washington State, which is now the state with the second highest percent of market share for EVs, recently ended its waiver of sales tax on EV sales (Washington State Department of Revenue, 2018). The state legislature has begun negotiating an extension of this program (Valdez interview). Similar to other markets that have removed financial incentives, Washington may experience a drop in EV sales if that policy is not reinstated by the state legislature. Regardless of the political and environmental context of different states, offering financial incentives to consumers to make EVs cost comparable to ICEVs can encourage more risk-averse consumers to choose EVs. “Anything that brings down the purchase price of a ZEV has the potential to be effective in [many] states” (Keddie interview). Though the existing federal tax credit is offered nationwide, EV adoption is further encouraged by states offering reduced registration fees, sales tax exemptions or reductions, rebates, and tax credits (Keddie interview; Kitahara & Beltran interview; Henkin interview).

Another major barrier to EV adoption is range anxiety, elaborated in Chapter Three. Aayushi Jain of Los Angeles Cleantech Incubator (LACI) and Michael Blackstrom of Southern California Edison both believe that this is the greatest barrier for the EV market to overcome, so policies encouraging charging infrastructure will be most effective to encourage EV adoption (Jain interview; Blackstrom interview). LACI has created the Transportation Electrification Partnership, a coalition of various vehicle electrification stakeholders that created a Zero Emissions 2028 Roadmap, with the goal of reducing transportation related GHG emissions in the Los Angeles area by 25 percent by the 2028 Olympics (Jain interview). One core focus of the Roadmap is the expansion of charging infrastructure. This includes encouraging the installation of chargers, working with utilities to help them transition to their new role as transportation fuel providers, and focusing on placement of chargers. In order to be effective and actually utilized by consumers, public chargers need to be placed in locations where people spend more time, like malls or grocery stores, rather than a coffee shop where they might just stop for five to ten minutes (Jain interview). LACI encourages buildout of chargers solely within the Los Angeles area, and much of its funding comes from the city of Los Angeles and the Los Angeles Department of Water and Power (Jain interview). Other governments and nonprofits should focus on expanding charging infrastructure nationwide and especially along major intercity highway routes to further encourage adoption. In order to reduce range anxiety, Bonges and Lusk (2016) suggest a number of policies to improve the efficiency of infrastructure and better serve EV owners. A barrier to charging is often that chargers are located in the corner of a parking lot, where the charger can only reach one space. If there is an EV occupying that space, no one else is able to use that charger. A more efficient design might be "octopus chargers," or chargers with many different cords, located in the middle of the parking lot so that multiple cars may charge at the same time and consumers won't have to worry whether the proper space will be available for them to charge while they run their errands. Implementing policies that increase raw numbers of charging stations and encourage more efficiency planning for existing charging stations may reduce range anxiety and encourage EV adoption by more risk-averse consumers (Bonges & Lusk, 2016; Jain interview). Further, manufacturers and government policies should focus on building infrastructure to assure consumers that they will have reliable access to charging stations if they need one.

In order to further combat the range anxiety barrier, governments need to focus on improving the effectiveness of the charging infrastructure system rather than just absolute quantity of chargers (Bonges & Lusk, 2016). Some policies may even discourage efficient charging behavior and turnover at EV accessible locations. One barrier to EV charging is that in some states and localities it is illegal to unplug another driver's EV, even when it is fully charged. Policies preventing drivers from unplugging other cars save drivers from liability. If they were to accidentally scratch the car or somehow break the plug of another driver's car when unplugging, they could be liable for a large sum of money. Unfortunately these policies also prevent drivers from unplugging another fully charged EV in order to charge their own vehicle when there may not be an open charger available (Bonges & Lusk, 2016). Some EV owners have courtesy cards that they fill out detailing when another driver can unplug their car if the other driver needs the charger. For instance, a courtesy card might mention that if it is 3 PM and the car is fully charged, someone else is welcome to unplug their car so that the new driver can charge as well. However, these cards are becoming less popular as EVs become more mainstream and good public-spirited etiquette starts to decrease (Bonges & Lusk, 2016). Additionally, Washington State has a policy charging a $124 fine to anyone parked in an EV parking space not connected to the charger. Though EV-designated spots may be a draw for EV drivers because they are often in convenient locations, requiring a driver to plug in to allow them to use the spot means that drivers with a full charge may plug in to avoid a fine, therefore preventing a driver requiring a charge from using that plug (Electric vehicle charging stations—Signage—Penalty., 2013). Policies like the one in Washington could mean chargers are not being used efficiently by those who need to use them. As of this writing, there are no policies or mechanisms in place to prevent drivers from simply plugging into a charger to avoid a fine, discouraging efficient use of chargers. Bonges and Lusk (2016) argue that policies should focus not just on total quantity of chargers, but on the effectiveness of deployment. Furthermore, Bonges and Lusk believe EV infrastructure build-out should focus on encouraging potential new EV owners and reassuring them about charging ability and efficiency, rather than EV enthusiasts who already have knowledge about range and charging requirements (Bonges & Lusk, 2016).

The Center for American Progress conducted statistical analyses tests to determine which policies meaningfully affect EV adoption. Two tests were conducted: one including California and one without, as the state is a high adopter and has a large car market, so a policy that is successful in California but not in other states may appear to be significant in spurring adoption even if the policy may only encourage EVs specifically in California. With California included in the analysis, the existence of an HOV lane access policy was found to have significant positive effects on EV adoption in the retail EV market, meaning that creating a program allowing EVs to access carpool lanes even on single-occupant trips meaningfully spurs adoption of EVs in California. However, when excluding California from the analysis, HOV lane access was not found to significantly affect EV adoption (Cattaneo, 2018). This suggests that HOV lane access strongly encourages EV adoption in California, but may not be as meaningful a policy tool in other states. In cities without major traffic problems, HOV lane access is not a useful incentive for people to purchase an EV, so local governments need to analyze commuter needs to create useful incentives like HOV access or free parking, depending on specific local challenges (Kitahara & Beltran interview). Regardless, implementing HOV lane access is not a difficult or expensive task (Milhoan interview), and may have some positive effect on retail EV markets, so it could be a useful tool for governments to implement. Other policies that were found to have significant positive effects on the overall EV market included charging infrastructure and infrastructure rebates and grants, vehicle rebates, and vehicle tax credits (Cattaneo, 2018). Excluding California from the analysis, the zero-emissions vehicle (ZEV) mandate, which is neither a purchase nor use-based incentive, has so far been found to be the most effective policy in increasing EV market share (Cattaneo, 2018).

ZEV mandates require automakers to produce and sell a certain number of PHEVs, BEVs, or fuel-cell electric vehicles to fulfill a quota based on total sales in states with the mandate. Angela Konert of BMW North America believes that without ZEV mandates, EV technology would be lagging behind, because automakers are forced to produce low-emission vehicles regardless of their own economic benefit or consumer demand. This encourages research and development (R&D) because vehicles with longer ranges earn more credits (Keddie interview; Konert interview). This means that it may be advantageous for automakers to produce fewer EVs with longer range in order to sell those vehicles to consumers, who prefer longer ranges, as well as earn more credits toward their requirement. In this way, ZEV mandates are a technology forcing policy, encouraging automakers to produce cars with longer ranges to fulfill their requirements (Keddie interview). Tech forcing policies like ZEV mandates are critical to improving technology, because in a capitalist system, firms tend to underinvest in R&D of new technologies due to uncertainty and positive knowledge spillover (Sierzchula et al., 2014). Positive knowledge spillover occurs when a business creates an innovation that has public benefits that do not outweigh the private benefits to the company. Other companies will be able to copy the innovation to some extent and reap the benefits of the innovation without having invested capital and time into R&D (Sierzchula et al., 2014). Due to public knowledge spillover, without policy requirements to develop and produce EVs, firms would not have much of an incentive to invest in the R&D required to create EVs that have acceptable ranges (Konert interview; Sierzchula et al., 2014). Although only ten states have adopted ZEV mandates,[4] these states make up a significant portion of the U.S. auto market, and have encouraged automakers to continue to develop new EV makes and models (Konert interview; Union of Concerned Scientists, 2016)

[4] These states are: Connecticut, Maine, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, and Vermont (Union of Concerned Scientists, 2016).

Equal Access for Low-Income Communities

As the transition to EVs gains momentum, it will be important to ensure equal access to these vehicles for low-income folks to fully transition the transportation system to electric and because negative effects of climate change are often felt the most by these communities. There has been concern that the shift to EVs may not encourage access to clean transportation options for low-income communities though they are the most susceptible to the negative effects of climate change and unhealthy air (Valdez intervew). To combat this potential inequality, California has taken several steps to encourage low-income EV adoption (Keddie interview). Though the state has rebates available to all new EV buyers under a certain income level, low-income individuals are eligible for an additional $2000 rebate if their income falls below a certain threshold and they choose to purchase a new BEV or PHEV (Alternative Fuels Data Center, n.d.). For individuals who do not have the ability to purchase a new vehicle, the Enhanced Fleet Modernization Program (EFMP) aims to “incentivize lower-income California motorists to scrap their older, high-emitting cars and replace them with newer, cleaner and more fuel efficient cars” (Alternative Fuels Data Center, n.d.). In exchange for their older cars, low-income Californians can earn a rebate voucher that they can apply to purchase a new or used cleaner vehicle, including EV models (California Air Resources Board, 2018). With used EVs becoming more affordable, these vehicles can be a viable option for low-income drivers (Jennings interview). The amount rebated increases depending on the fuel efficiency of the replacement car, with PHEVs and BEVs having the highest possible rebates (California Air Resources Board, 2018; Keddie, 2018). Since the EFMP was implemented, more than half of the cars that have been retired were replaced by some sort of plug-in vehicle, demonstrating that this program is successful in encouraging low-income residents to switch fuel inefficient cars for BEVs and PHEVs [Figure 4] (California Air Resources Board, 2018).

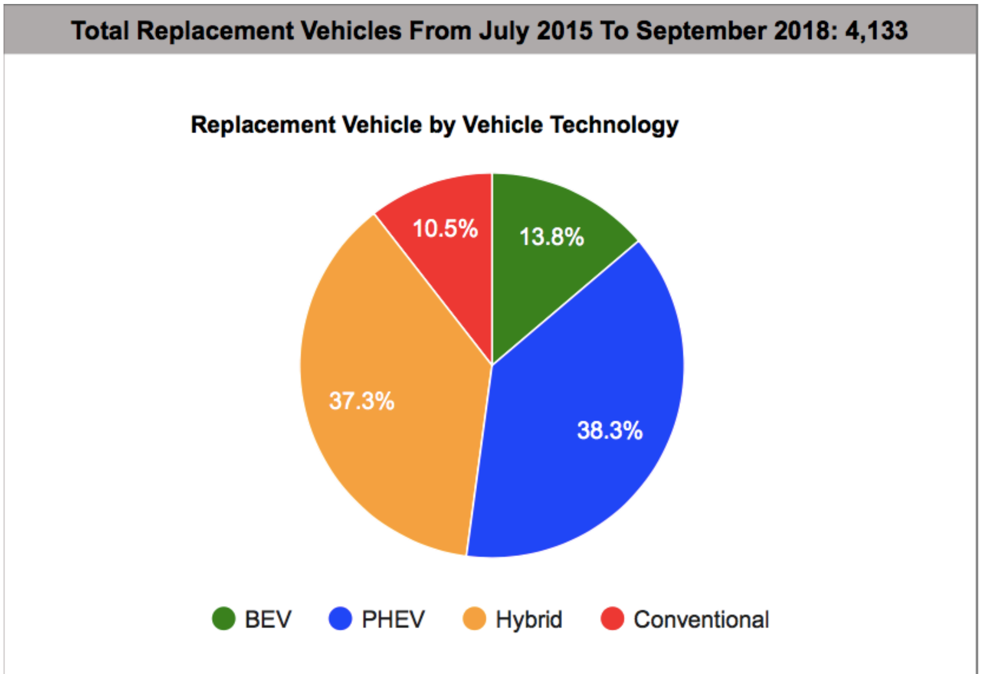

Figure 4: Replacement vehicle technology in the EFMP in California from July 2015 through September 2018 (California Air Resources Board, 2018). BEV = Battery Electric Vehicle, PHEV = Plug-in Electric Vehicle, Conventional = ICEV/internal Combustion Vehicle

California has also encouraged expanding access to charging infrastructure in low-income communities to ensure that residents that drive an EV have easy access to fueling options. The California Public Utilities Commission allocated $42 million to utilities throughout the state to create charging for electric school buses and vehicles in low-income neighborhoods. Additionally, CARB approved a $200 million clean vehicle investment plan using money from the Volkswagen (VW) dieselgate scandal,[5] with 35 percent of the funds going toward "EV awareness campaigns, charging stations, and a 'Green City Initiative' to increase use of electric mobility" in disadvantaged communities (Espino, 2018). Utilities have also committed to

[5] After years of cheating on emissions tests, VW was ordered to pay settlements amounting to over $30 billion. $3 billion was allocated to U.S. states to cut pollution from transportation, awarded based on how many VW's were registered within each state's borders. Many states plan to use the funds to build out EV charging stations and replace shipping and public transport vehicles with cleaner or electric models (Jackson, 2018).

installing certain percentages of chargers in low-income neighborhoods, so that these neighborhoods are not left behind as charging infrastructure expands (Jain interview; Joel Espino, 2018). In addition, organizations like VELOZ and Forth have conducted test drives specifically for low-income residents in their neighborhoods in order to spread awareness about EVs and show that they are viable options for lower-income drivers (Boone interview; Henkin interview). Representative Valdez believes that the only EVs available are Teslas, and therefore EVs are only accessible to the rich (Valdez interview). Regardless of this common misconception, in California 43 EV models were available in 2018, with hundreds more models planned for release in 2019 and 2020, and used EVs are sold at lower cost in many areas (Jennings interview; Keddie interview). Furthermore, there are various local and statewide policies in place to encourage EV adoption by low-income communities and the associated charging infrastructure. Policies designed to encourage low-income access to EVs vary greatly by locality. Although California has many programs in place offering financial assistance and expanded infrastructure, these policies are not implemented in every state, so low-income access to EVs likely varies greatly nationwide (Alternative Fuels Data Center, n.d.).

Concluding Thoughts

There are many different policies that have been implemented across the United States to encourage EVs. Many of these policies have been implemented at the state or local level, resulting in a patchwork of permitting requirements and incentive programs. Based on the available research literature and interviews of experts in the EV arena, financial incentives and policies encouraging charging infrastructure and efficiency appear to be the most effective tools for encouraging higher EV adoption rates. In general, the awareness barrier has so far been addressed mostly by nonprofits through educational campaigns and free test drives, with few public policies directed toward outreach and awareness efforts (Boone, 2018; Henkin, 2018). Although awareness is a clear barrier, comprehensive local or federal government policies to tackle this barrier have not yet been proposed. During the transition to an EV future, it will be necessary to keep in mind low-income communities, who often suffer the most from local pollution and may not have easy access to EVs as a solution (Valdez interview). To address this potential class barrier, California and some nonprofit organizations and utilities have taken steps to encourage low-income residents to transition to clean vehicles and to ease that transition by building the necessary infrastructure in disadvantaged neighborhoods (California Air Resources Board, 2018; Keddie interview; Joel Espino, 2018). Although local context varies greatly among states, it seems that any federal policy attempting to encourage EV adoption should focus on charging infrastructure, financial incentives, awareness, and low-income specific policies to ensure that the transition to EVs is rapid and equitable.

CHAPTER SIX: CASE STUDIES ACROSS FOUR SELECTED STATES

In the U.S., most policies designed to encourage or discourage EVs exist at a local or state level. There are, however, several federal policies relating to EVs. The first is a federal tax rebate for consumers that ranges from $2,500 to $7,500 depending on battery capacity and the vehicle's weight rating. This credit will be phased out for each manufacturer in the second quarter following the quarter in which that manufacturer sells 200,000 or more qualified EVs (Public Law 112-240, Section 403; and 26 U.S. Code 30D) (Department of Energy, n.d.). Recently, several large utilities wrote to Congress asking for an increase in the statutory cap on rebates, arguing that it could harm more mature EV automakers such as Tesla, an American company, because Tesla is the only manufacturer to have reached this limit, meaning their new customers will no longer be eligible for a tax rebate. The federal government also offers a federal tax credit covering up to 30 percent (but not more than $30,000) of the cost of installing alternative fueling equipment, which can include charging stations installed for public or private use (Smith, 2018).

Another federal incentive offers financial assistance for research, demonstration, and deployment projects relating to low emissions vehicles, as long as those vehicles are used for public transportation and reduce energy consumption or harmful emissions. This incentive aims to encourage innovation within the alternative fuel sector (Public Law 113-159, Public Law 114-94, 49 U.S. Code 5312, and 49 U.S. Code 5339(c)) (Department of Energy, n.d.). Finally, the federal government offers a Clean Cities program to support local initiatives aiming to reduce petroleum use in the transportation sector. Clean Cities is a network of coalitions to encourage more sustainable transportation fuels, and "provides information about financial opportunities, coordinates technical assistance projects, updates and maintains databases and websites, and publishes fact sheets, newsletters, and related technical and informational materials" (Department of Energy, n.d.). In addition to these federal policies, many states also offer additional programs and incentives, but these vary greatly from state to state. To analyze what effect state policies might have on adoption, I will look at the EV policy landscape of four states. I chose these states based on their percentage of market share for EVs as of 2017. California leads every state in EV adoption, with 5.02 percent of new car sales being EVs in 2017. Washington came in second, with a 2.51 percent EV market share. Oklahoma and Mississippi are tied for last, with a 2017 market share percentage of 0.10 (EVAdoption, 2018). It is important to note that percent market share does not refer to total percentage of electric vehicles on the street. This percentage refers to the percent of new vehicles sold that were electric in a given year. Figure 5 identifies the percentage of the vehicles sold in 2017 that were electric.

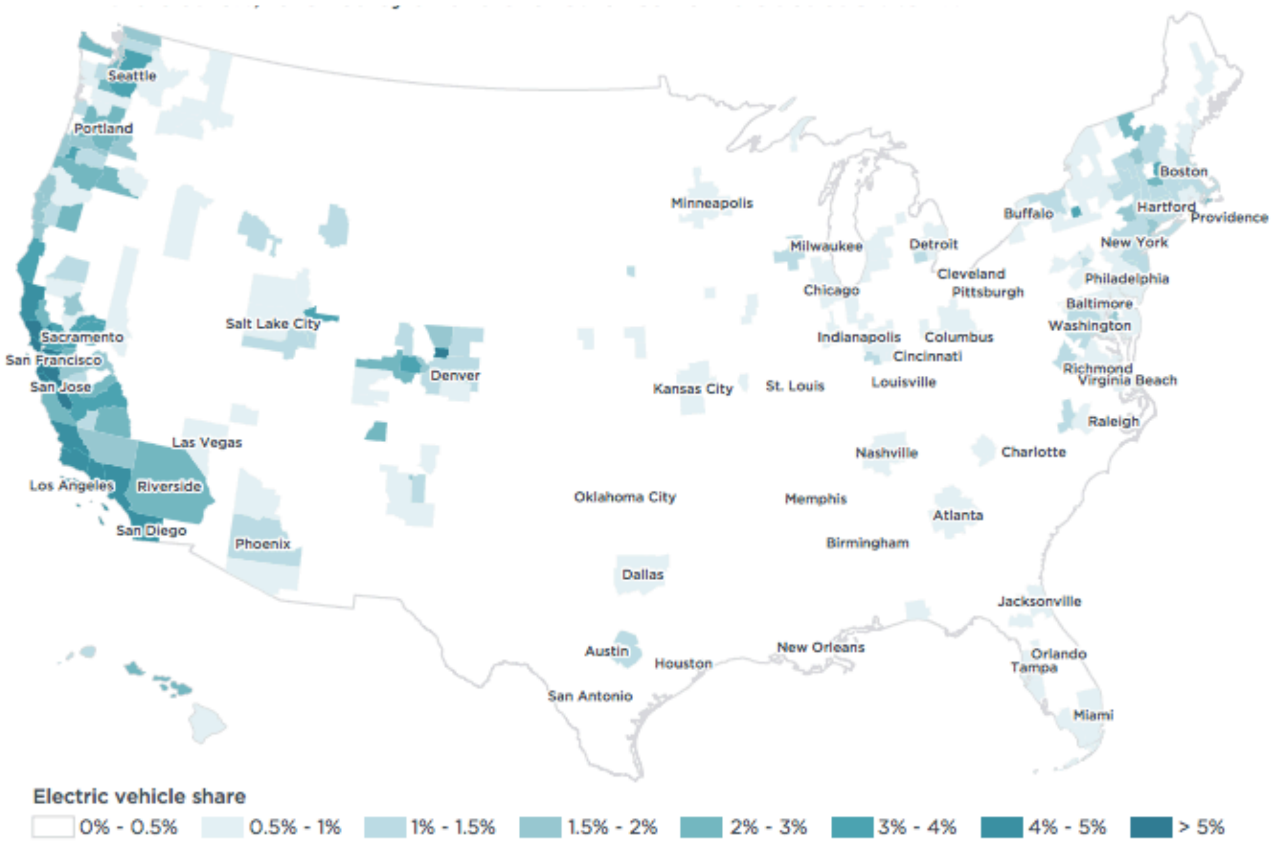

Figure 5: EV share of new 2017 vehicle registrations by metropolitan area (Slowik & Lutsey, 2018).

California

California leads all states in terms of absolute number of EVs on the road, percent market share of EVs (EVAdoption, 2018), and number of state laws and incentives related to alternative fuels and advanced vehicles (Alternative Fuels Data Center, n.d.). California has 123 laws relating to alternative vehicles and fuels, while the next closest states in terms of numbers of policies are Colorado and Washington, with 39 and 38, respectively. Not all of these policies relate specifically to increasing EV adoption within the state, however. Some unrelated policies include a tire inflation requirement to increase efficiency, autonomous vehicle testing and operation requirements, and a compressed natural gas credit, among others. Still, many of these policies incentivize EV or infrastructure development. Policies in California can be divided into three categories: state incentives, which are incentives passed by the legislature, utility/private incentives, which utilities and other private stakeholders have implemented to encourage EV adoption, and laws and regulations, which include mandates and requirements to increase fuel efficiency and decrease emissions. (Alternative Fuels Data Center, n.d.) Elise Keddie, Manager of Zero Emissions Vehicle Implementation Sector at the California Air Resources Board, believes that policies encouraging EV adoption are responsible for rapid EV deployment in California. Specifically, she mentioned the effectiveness of the HOV lane access decal program, local free or reduced parking policies, and the state rebate for EVs, all of which fall under the state incentives category. A mix of policies has spurred adoption and many incentive programs continue to be hugely popular (Keddie interview).

California offers a rebate on EVs and fuel-cell vehicles in addition to the federal tax rebate. Fuel-cell electric vehicles qualify for a $5,000 rebate, BEVs qualify for $2,500, and PHEVs qualify for $1,500. These rebates are not offered to consumers with an income over $150,000 per year for a single filer or $300,000 per year for joint filers. For individuals with incomes of less than or equal to 300 percent of the federal poverty level, the rebates are increased by $2,000 to encourage EV adoption by low-income communities. Unlike the federal tax credit, the California rebate is not provided in the form of a tax credit. This means that low-income individuals, who are eligible to earn a larger rebate, can claim that entire incentive regardless of how much they owe in state or federal taxes (Alternative Fuels Data Center, n.d.). Additionally, most EV owners can earn a Clean Fuel rebate from their utility. The three largest utilities in the state offer rebates to residential customers of $50 to $200 per year for San Diego Gas & Electric, $800 one time for Pacific Gas & Electric customers, and $450 per car for three years for Southern California Edison (SCE) (Department of Energy, n.d.). These rebates are offered through the utilities' Clean Fuel Rebate programs as part of the State of California Low Carbon

Fuel Standard and can be used to pay for fueling vehicles or to upgrade a home charger to level 2. This Standard aims to encourage the adoption of alternative fuels for transportation in order to reduce GHGs. This incentive is offered to customers “for their use of electricity as a clean transportation fuel” (PG&E, 2018), and can further convince EV utility customers that they would save money by switching to an EV.

A lack of charging infrastructure has been cited as a major barrier to EV adoption, and building this infrastructure can be more difficult than simply obtaining electric cars due to cost and volume needs (Chirazi, Samulon, & Kincaid, 2018). Several California policies offer financial assistance for building out charging infrastructure. In addition to local attempts to streamline permitting processes and some local rebates, California offers a statewide Electric Vehicle Supply Equipment (EVSE) Loan and Rebate Program. This program “provides loans for the design, development, purchase, and installation of EVSE at small business locations in California.” The EVSE Loan and Rebate Program generally rebates 10 to 15 percent of the cost of the loan after the charger has been built and the loan has been paid back. The program also can rebate small businesses up to 50 percent of the cost of the charger if they meet several additional requirements (Department of Energy, n.d.). By providing loans to build charging infrastructure and then subsidizing the cost of the equipment, California is trying to encourage buildout of chargers where businesses see a need.

In addition to financial incentives for infrastructure and the cars themselves, California offers several non-monetary perks to EV drivers. One of the most popular incentives is the HOV lane access decal program. Qualifying low-emission vehicles can get a decal that allows them to travel in the HOV lane regardless of occupancy. These decals may also enjoy reduced or free tolls in high-occupancy toll lanes (Department of Energy, n.d.). In a state such as California, where traffic is a notorious problem, “HOV lane access is the most efficient form of encouragement to promote adoption" (Williams interview). In fact, the decal program is so popular that BMW has had customers specifically ask about eligibility of certain cars when in the dealership (Konert interview). The program has become so popular that the legislature has decided to create a four year eligibility limit on decals, determined by color, so that the HOV lanes do not get overly crowded by EVs (Milhoan interview; Swanton interview). This policy is easy for the government and Department of Motor Vehicles to implement, and has been shown to have significant positive effects on increasing EV adoption within the state (Cattaneo, 2018; Milhoan interview).

Another crucial policy to encourage EV adoption in California is the Zero Emissions Vehicle (ZEV) Mandate. Without this regulatory requirement, automakers would not produce the number of EVs that are currently available, in part because car companies do not believe there is enough demand for these vehicles (Keddie interview). The ZEV mandate, elaborated in Chapter Five, requires manufacturers to produce a certain number of ZEV and PHEV credits every year. This number is calculated as a percentage of their total Californian car sales, and is ratcheted up from 4.5 percent in 2018 to 22 percent by 2025 (California Air Resources Board, 2018; Keddie interview). This mandate forces automakers to produce EVs regardless of demand, even if they are not yet economically profitable [see Chapter Four]. Additionally, the ZEV mandate encourages automakers to produce cars with longer electric ranges (Keddie interview; Konert interview). Due to the effectiveness of this policy, nine additional states have adopted California's ZEV mandate, representing almost a third of total new car sales in the United States (California Air Resources Board, 2018). [6]

[6] Importantly, President Trump has stated plans to revoke the waiver that allows California to impose higher tailpipe standards on vehicles sold within the state. This waiver also allows California to implement ZEV mandates, and allows other states to follow suit. This controversy will likely not be resolved soon, as California has signaled plans to pursue litigation against the Trump administration. Meanwhile, plans to roll back the waiver will likely affect EV production as auto manufacturers look toward weaker potential fuel efficiency standards in the future (Cama, 2019).

California may have also achieved such high adoption rates due to the "California attitude." The state of California is considered by many to be a leader in technological innovation, car culture and design, and environmental activism (Boone interview). According to Boone, Californians have a pioneering and leadership spirit, and, as the world's fifth largest economy, often act as a national and international model. California also has a history with terrible air pollution. Even before the creation of the EPA, the state government created the California Air Resources Board (CARB) in an attempt to combat the air pollution public health crisis in Southern California. CARB quickly recognized that in order to clean up its air, California would need to reduce transportation emissions, and as climate change has emerged as an ever more pressing issue, California has continued to lead the way in encouraging the EV and alternative transportation market as a way to reduce GHGs (Boone interview). Josh Boone, Founding Executive Director of VELOZ, a public-private partnership aiming to increase consumer awareness of EVs, believes that EV adoption will follow a similar path to the rapid proliferation of solar panels in recent years. In the early years, both stick and carrot policies will be needed, including the ZEV Mandate (stick) and monetary and non-monetary incentives (carrots) (Boone interview). Local and statewide incentives will sustain the market, and combined with executive orders like the 5 million EVs by 2030 order issued by Governor Jerry Brown in 2018, these actions will lead to new technical innovation and a more mature market. This is similar to the Million Solar Roofs Executive Order from Schwarzenegger in the mid-2000s. California leadership and strong policies are likely to encourage rapid adoption. As the market matures, these incentives may have to sunset, but the idea is that with help, EVs will become cost competitive, and once the incentives sunset, market factors will take over (Boone interview). Overall, California has the most policies of any state aimed at encouraging EVs, and its market is well ahead of other states. However, some of this high adoption is likely due to contextual and cultural factors specific to California, including a history of air quality issues and environmental activism, and an economy based on cutting-edge innovation.

Washington

The second highest adopter of EVs based on percent of market share is Washington State. In 2017, electric vehicles accounted for 2.51 percent of total new vehicle sales. Interestingly, this is only about half of the market share of EVs in California, further showcasing California's extremely high adoption rate (EVAdoption, 2018). Washington has 38 policies relating to alternative fuel vehicles. Many of these relate only tangentially to vehicle electrification. For example, the Volkswagen Settlement Allocation is a law passed that designates 15 percent of the use of Washington's portion of the Volkswagen Mitigation Trust Fund to specifically create, operate, and maintain EV charging infrastructure. The remaining 85 percent will be used by the state Department of Ecology for several air pollution and emissions reduction schemes, and for accelerating the adoption of EVs and their equipment (Alternative Fuels Data Center, n.d.). Other policies include adoption of California's tailpipe standards without their ZEV Mandate, an exemption for charging stations from environmental review, support for autonomous vehicles, and more. The adoption of California's tailpipe standards without the ZEV Mandate means that Washington requires stricter tailpipe standards than the federal requirements, but does not require manufacturers to produce and sell any amount of ZEVs within the state (Alternative Fuels Data Center, n.d.). Many of Washington's policies do not specifically aim to accelerate adoption of EVs or charging infrastructure. The state does have a Plug-In Electric Vehicle (PEV) Charging Infrastructure Funding Pilot Program, however, which aims to expand the West Coast Electric Highway network by building out more public Direct Current Fast Chargers (DCFCs) along Washington highways (Alternative Fuels Data Center, n.d.). This pilot program has awarded $2.5 million in grants for the 2017-2019 phase to help install 15 new fast charging stations at exits about 40 miles apart on several highways in the state (Washington State Department of Commerce, n.d.).

Washington State has a goal to achieve 50,000 EVs by 2020. In order to do so, the state aims to increase its fast charging network and make EVs accessible to everyone within the state. Washington was an early leader in EV sales. With public EV charging available and a sales tax exemption, the state reached nearly 120,000 EV sales and leases by 2014. In fact, from 2013 to 2014, the number of EV registrations in Washington increased by more than 50 percent (Buell, 2015). Part of this early adoption was spurred by the sales tax exemption, but that recently expired. Washington State has a high sales tax exceeding ten percent in some counties. Until June 1st, 2018, EVs and alternative fuel vehicles purchased or leased for a base retail price of less than $42,500 were exempt from paying sales or use tax. This allowed essentially every new EV driver other than Tesla owners to avoid paying several thousand dollars of sales tax, amounting to a rebate of up to $4,200, depending on the price of the car. As of March of 2018, 7,500 vehicles had taken advantage of this exemption, prompting the policy to expire based on limits set within the legislation (Washington State Department of Revenue, 2018). Financial incentives have been shown to positively encourage adoption, so removing a financial incentive may slow the growth of the EV market in Washington (Cattaneo, 2018; Sierzchula, Bakker, Maat, & van Wee, 2014).

Though Washington has the second highest percent of market share for EVs, there are currently only three incentive policies specifically relating to encouraging EVs in the state. The first relates to EV charging and parking regulations. EV charging stations must be properly signed and spots must be lined in green (Alternative Fuels Data Center, n.d.). Additionally, vehicles must be connected to the charging equipment to park in these locations, or they can be fined [see Chapter Three for an in-depth look at problems with this policy]. The second policy exempts EVs from state emissions control inspections (Alternative Fuels Data Center, n.d.). This type of policy has not been shown to significantly affect EV adoption (Cattaneo, 2018). The final Washington policy was an incentive allowing Pacific Power customers and employees to obtain a $3,000 rebate when they purchased a 2018 Nissan Leaf at participating Nissan dealerships through January 2, 2019 (Alternative Fuels Data Center, n.d.). These policies do not seem to promote EV adoption as aggressively as policies in California. Other than the recently expired sales tax exemption and Pacific Power rebate for Leafs, Washington State does not offer any financial incentives. Additionally, Pacific Power does not serve many cities in the state, and serves mainly rural areas, so this incentive, while it seems like it could encourage Leaf purchases, is unlikely to reach many people, especially considering where adoption is strongest within the state [See Figure 5] (Pacific Power, n.d.).

Financial incentives, charging infrastructure, and local presence of production facilities are significantly positively correlated to EV market share (Sierzchula et al., 2014). Washington State does not have financial incentives or local production facilities other than a carbon fiber plant that makes materials used in BMW’s i series (Konert interview). However, the West Coast Electric Highway expansion pilot program has led to the proliferation of chargers and may be partially responsible for Washington’s high rate of adoption, especially as charging infrastructure is the most strongly related factor for EV adoption (Sierzchula et al., 2014). Still, it is unclear whether or not the loss of the sales tax exemption will negatively impact EV sales. In the past, removing financial incentives has caused the market to fall. In the cases of Georgia and the Netherlands, when governments removed financial incentives, consumers returned to ICEVs and demand immediately fell (Konert interview). In August of 2018, though EV market share had risen to 3.54 percent in Washington, Oregon overtook Washington as the state with the second highest percent market share, at 4.12 percent (EVAdoption, 2018). Though more vehicles were sold in Washington due to a larger population, it is important to note that Oregon does have a state rebate of up to $2,500 that may help encourage adoption (Department of Energy, n.d.). It is also possible that high adoption rates in Washington are partly fueled by environmentalism rather than specific EV policies. Sustainability and climate change are important issues to many Washingtonians west of the Cascade Mountains and could account for some of the high adoption rates in these regions (Valdez interview).

Mississippi and Oklahoma

Mississippi and Oklahoma are tied for last in EV adoption as measured by percent of market share. Neither state has any tax credits or other incentives relating to EVs other than federal policies (Department of Energy, n.d.). Oklahoma has several programs designed to encourage compressed natural gas (CNG) vehicles and ethanol and biofuel programs (Alternative Fuels Data Center, n.d.). In terms of electric cars, the Oklahoma Department of Environmental Quality is accepting applications to repower or replace diesel school buses with alternative fuels, which can include electric, propane, or CNG vehicles. These buses may be reimbursed for 25 to 50 percent of the cost depending on the project (Oklahoma Department of Environmental Quality, n.d.). The $4.1 million program, which is funded by Oklahoma's portion of the Volkswagen Environmental Mitigation Trust, also includes possible funding for electric bus charging infrastructure. Also funded by the VW settlement is the ChargeOK Grant Program. This program offers $3.1 million toward projects that will install EV chargers throughout the state, especially along transportation corridors (Oklahoma Department of Environmental Quality, n.d.). Oklahoma seems to be focusing on increasing charging infrastructure with its few EV-friendly grant programs. As it has a very low percent market share of EVs, it makes sense that the government aims to encourage EVs by building out charging infrastructure, which has been shown to be the strongest correlated factor for improving EV adoption (Sierzchula et al., 2014). Building out charging infrastructure also allows the state to accommodate EV drivers as they travel through Oklahoma. This means that Oklahoma is beginning to develop its EV ecosystem, but EV adoption will not occur on a meaningful scales until all aspects of this ecosystem come together (Blackstrom interview). Until charging infrastructure is readily available and visible, it is unlikely that Oklahoma will see rapid mass market adoption.

The only policy in Mississippi that relates to EVs is the Fuel Efficient and Alternative Fuel Vehicle Use program. Through this program the State Bureau of Fleet Management is directed to promote fuel efficiency when state agencies purchase, lease, or use vehicles. The Bureau is directed to encourage alternative fuels, which can include electricity, and 75 percent of all vehicles titled under the Bureau must be rated to achieve at least 40 miles per gallon for highway driving (Alternative Fuels Data Center, n.d.). It is important to note that the Bureau is directed merely to encourage fuel efficient and hybrid vehicles, and is not specifically directed to encourage EV adoption for state vehicles. Though there is a 40 mile per gallon requirement for fuel efficiency for 75 percent of vehicles that the Bureau holds title to, this requirement can be easily met by many hybrids, and excludes other state agency vehicles. As of March 2019, Mississippi does not have any grant programs or incentives to build out charging infrastructure, even though there are only 152 public charging stations statewide (Alternative Fuels Data Center, 2019; Mississippi Department of Environmental Quality, 2018). Every state did receive money in the lawsuit against Volkswagen, and many states have chosen to use this money to build out charging infrastructure or otherwise encourage EVs. Mississippi has not yet determined how they will spend their allocated funds, but they may choose to use their VW settlement money to encourage charging infrastructure, similar to Oklahoma (Mississippi Department of

Environmental Quality, 2018). Out of all the states studied in this case study, Mississippi has the least governmental support for EVs and the associated infrastructure.

Electric Vehicle Registration Fees

Every state studied in these case studies has also attempted to impose an additional registration fee on BEVs and PHEVs. In Oklahoma, the bill that created an annual fee of an additional $100 for BEV drivers and an additional $30 for PHEVs and HEVs was struck down after its passage in 2017 by the Oklahoma Supreme Court because it “did not meet the constitutional mandates that govern the passage of a revenue bill due to two constitutional violations in the State of Oklahoma” (Hartman & Pula, 2018). The other three states in these case studies successfully increased annual registration fees on EVs. In total, 19 states impose various additional fees on EVs or HEVs in order to make up for the associated decrease in gas tax revenue. Gas tax revenues generally pay for infrastructure and road upkeep, and to make up for the loss in revenue from increasingly efficient cars, many states have included additional EV fees in larger transportation funding bills (Smith, 2018). Mississippi recently passed a new annual fee of $150 for EVs and $75 for hybrids in lieu of raising the gas tax (10News Staff, 2018). Washington’s annual fee is an additional $150 per year for all EVs that can travel 30 miles or more on just electricity. California recently raised its gas tax and simultaneously passed an annual $100 EV fee that will take effect beginning in 2020 (Spector & Pyper, 2017).

Several states have explored methods to make up for falling gas tax revenues without penalizing EV adoption, as the fees add “additional cost to a product [EVs] that has yet to reach mass-market scale” (Spector & Pyper, 2017). Vermont and Oregon have tackled the gas tax problem by exploring charging fees based on vehicle miles traveled (VMT), which has the potential to equitably charge drivers for road use and upkeep, but could be difficult and expensive to implement (Spector & Pyper, 2017). Both states exploring VMT fees are, however, in the top five states for percent market share captured by EVs, with Oregon ranking third and Vermont fifth (EVAdoption, 2018). The combination of federal and state incentives and rebates with the additional annual registration fees for EVs creates a confusing cost framework for drivers interested in saving money by fueling their vehicles with electricity rather than petroleum. States will necessarily continue to find new ways to tax road use for infrastructure funding; as of now, it is unclear how additional annual EV fees will affect the EV market (Spector & Pyper, 2017).

Concluding Thoughts

Oklahoma and Mississippi do not have incentive policies available for EV drivers (Alternative Fuels Data Center, n.d.). Based on current rates of adoption, low levels of EVs in these states might be in part due to the lack of incentivizing policies. However, it would be a mistake to assume that policies alone create differing levels of adoption. Washington state does not have many incentive policies available to EV drivers, but still has high rates of adoption (Alternative Fuels Data Center, n.d.; EVAdoption, 2018). This could be due to the fact that western Washington, where most of the state's adoption occurs, has a culture of environmental consciousness (Henkin interview; Valdez interview). Adoption does tend to be higher in populated areas, especially on the west coast, which are generally more concerned about and have more dialogue about climate change than in other areas [See Figure 5] (Popovich, Schwartz, & Schlossberg, 2017; Slowik & Lutsey, 2018). California and Oregon, both of which have high rates of EV adoption, are also known for being very environmentally conscious, and the west coast has high rates of technological innovation (Boone interview; EVAdoption, 2018; Popovich et al., 2017; Slowik & Lutsey, 2018). Financial incentives are also likely important to adoption. When Georgia, an early high adopter of EVs, got rid of its state income tax rebate, EV sales plummeted (Joyner, 2017; Sierzchula et al., 2014). Washington state recently ended its sales tax exemption financial incentive, but the effects on the EV market within the state have not yet been observed (Washington State Department of Revenue, 2018). Overall, although policies can definitely speed adoption and will be necessary to encourage the EV market (Sperling, 2018), policies alone cannot explain EV adoption, and individual state's cultures and environmental consciousnesses may factor in to the speed of the transition to EVs.

CHAPTER SEVEN: POLICY RECOMMENDATIONS AND CONCLUSION

In the course of examining how to accelerate EV adoption in the United States, the three main barriers of awareness, range anxiety, and upfront cost must be overcome. These significant barriers can be mitigated through various policy and market factors. However, policies to accelerate EV adoption will likely be the most effective to accelerate change at this point (Keddie interview). This is in part because without regulations and subsidies, auto manufacturers will be reluctant to invest in EV R&D and consumers will be reticent to invest in what they view as an unproven technology (Konert interview). As shown through the case studies and through the analyses of various policies, although culture accounts for EV adoption to a point, comprehensive policies to encourage EV adoption like those implemented in California have the ability to rapidly grow the EV adoption rate. Some policies, including financial incentives and the ZEV mandate, have changed the EV market nationwide: "Analysts have observed that the EV market in the United States is pushed more by California's ZEV mandate than by federal regulations. Indeed, the ZEV mandate has continued to play a central role in the transition to EVs" (Sperling, 2018, p. 38). Without ZEV regulations, automakers would not produce the number and variety of EVs that are currently available (Keddie interview). This chapter will focus on policy recommendations to accelerate the transition to EVs.

Awareness: Media Campaign

Because EVs are a relatively new technology, there is some consumer concern around their trustworthiness, so consumer awareness and confidence needs to be improved among the general public (Boone interview). Currently, most of the early adopters planning to transition to EVs for primarily environmental reasons and willing to make tradeoffs in areas like upfront cost and driving range have already adopted this new type of vehicle (Konert interview). Therefore, the general public needs to be better informed that this type of vehicle can be adapted to fit many different lifestyles. Although the number of EVs on the road has more than doubled since 2014 (Gerdes, 2018), more than half of Californians cannot name a single EV make or model (Boone interview). This suggests that consumers are not interested in exploring the possibility of driving an EV, as they do not feel the need to familiarize themselves with available options. Without the knowledge that many different models of EVs are available, consumers will not transition to driving EVs. An open and transparent multi-directional dialogue must be created among governments, the public, and scientific institutions in order to communicate the availability and viability of this technology (Dickson, 2005).

To increase awareness, I suggest that state and federal governments collaborate with auto manufacturers to fund a media campaign surrounding EVs. Similar to the "Got Milk?" campaign of the 1990s and 2000s, this campaign would require a catchy slogan and be funded by both public and private entities to encourage driving electric. If done before and in conjunction with National Drive Electric Week in September, this media blitz could culminate in nationwide test drive events allowing people to actually try out the vehicles that they have been hearing about on their social media accounts and television. A central focus of a national media campaign surrounding EVs would focus on their functionality while still highlighting a "cool factor". People need to understand that EVs are not just Teslas and available only to the wealthy, but are functional, practical, convenient to operate, and can give them a superior driving experience.

Nationwide ZEV Mandate

Another policy that has been shown to be effective in promoting EV adoption is the ZEV mandate. Creating a nationwide ZEV mandate would force automakers to produce more ZEVs and bring them to market throughout the country. It also would place less of a burden on car manufacturers than a patchwork of individual state ZEV mandates, as they would be able to sell ZEVs in places where more ZEVs would likely be demanded. Adoption will not occur at the same speed throughout the country, and a nationwide ZEV mandate would allow EVs to proliferate in areas where infrastructure and cultural factors facilitate more rapid adoption, further incentivizing other areas to improve their infrastructure. Additionally, with more auto manufacturers required to produce a greater number of EVs with higher ranges, improvements in battery technology will occur more frequently, making EVs even more desirable. With more ZEVs on the street, drivers will begin to see them as commonplace and no longer a new technology, creating visual reinforcement. Therefore, this mandate would also contribute toward resolving the awareness barrier, because drivers will see that ZEVs exist and are an increasingly viable option.

Financial Incentives

In addition to a media campaign and ZEV mandate, until EVs are upfront cost comparable to ICEVs, financial incentives need to be sustained. Currently, the federal tax credit offers up to a $7,500 tax credit to purchasers of a new EV. This incentive is designed to last for each automaker until the second quarter after that company sells 200,000 EVs in a single quarter (Department of Energy, n.d.). Unfortunately, this has the potential to punish companies that improve their technology and are successful at selling EVs. It also will punish the American company Tesla, as the company hit the 200,000 vehicle threshold in July 2018, triggering a phase out of the tax credit (Lekach, 2018). It has been shown that when financial incentives are removed, demand for EVs drops dramatically (Bockarjova & Steg, 2014; Joyner, 2017; Kitahara & Beltran interview). Therefore, the government should maintain financial incentives until EVs make up a sizable portion of all vehicles. The current federal tax credit also disproportionately helps the wealthy, as the full credit can only be claimed if the claimant pays at least $7,500 in income taxes. Instead, the government should change the program to a rebate similar to the one found in California [see Chapter Six]. A rebate should be offered to purchasers of new EVs, with a higher amount offered to lower-income drivers. By basing the amount of a rebate on income level, the government could encourage EV adoption by all socio-economic classes and decrease the risk of EVs being branded as elitist. Other than through upfront rebates, cost as a barrier does not need to be aggressively targeted, because based on market trends and improvements in battery technology, costs for EVs will continue to drop, making them more cost comparable to ICEVs in the near future.

Range Anxiety: Expanding Infrastructure

A final barrier that needs to be addressed is range anxiety and the prevalence of charging infrastructure. Charging infrastructure is very unevenly distributed among states and cities. Currently there is a notion that charging creates an inconvenience and is a drawback of owning an EV. However, charging should be viewed as an advantage. Because most EV drivers charge at home, drivers do not need to make an additional trip to get their fuel as they would for an ICEV at a gas station. Rather than longer charging times cutting into an EV driver's day, electricity as fuel allows a driver to plug in at home, at work, or during errands to top off their tank while going about their normal life. This hands-free convenience changes the model of operating a car to make it easier for a driver to ensure that their car constantly has the fuel it needs.

In order to ensure that people living in multi-unit dwellings (MUDs) can access this same type of charging convenience, the government should amend building codes to require that every new parking structure or apartment building parking lot is built with the capacity to install chargers. Atlanta, Georgia, and several other U.S. cities have passed ordinances that require new parking structures to be wired properly to allow for easily installed charging infrastructure, otherwise known as Electric Vehicle Supply Equipment (EVSE) (Torres & Ruiz-Craig, 2017). Rewiring and retrenching parking lots to allow for EVSE installation is expensive, and ensuring that this capacity is created as the parking lot is built will eliminate a lot of future expense and resistance (Riley, 2018). This will encourage people living in areas without a lot of public charging infrastructure to consider purchasing an EV, as the ability to charge at home is expanded, which will in turn cause the local government to encourage more infrastructure build out. The federal government should also offer a grant program to encourage public charger build out, where grants are offered to local governments that provide a plan of where and why public EVSE should be installed in specific locations. For example, a local government might request a grant for an octopus charger in a large mall to allow multiple EVs to charge while their owners spend several hours running errands. In this way, infrastructure will be expanded, which will further encourage EV adoption.

Final Thoughts

There are several policy options that can be pursued by federal and state governments to encourage EV adoption. Many of these policies have successfully been implemented at a local level or in other countries and can be scaled to the national level to encourage U.S. EV adoption.

While public transit and the decarbonization of freight vehicles will also play a role in reducing the country's transportation emissions, successfully transitioning light-duty personal vehicles to electric could result in rapid GHG emissions reductions. The barriers analyzed in this paper are significant, and contribute to slow adoption up to this point, but they can likely be overcome with various policy options that have been laid out. To avert the catastrophic effects of climate change, the U.S. and world need to rapidly cut emissions. By decarbonizing transportation, the U.S. could become a world leader in new technology and engineering, while fighting climate change. Future papers should explore cost-effectiveness analyses to ensure that transportation decarbonization is achieved effectively and at the lowest cost.

APPENDIX A: GLOSSARY OF ACRONYMS

BEV – Battery electric vehicle

CARB – California Air Resources Board

CNG – Compressed natural gas – an alternative fulel that releases fewer emissions than petroleum

CO_2 – Carbon dioxide

DCFCs – Direct current fast chargers – level 3 chargers that can charge an EV to 80 percent capacity in 20 to 30 minutes

EFMP – Enhanced Fleet Modernization Program – a policy implemented in California

EV – Electric vehicle – includes BEVs and PHEVs but, for this paper only, not fuel cell vehicles such as hydrogen cell vehicles

EVSE – Electric Vehicle Supply Equipment – charging infrastructure

GHGs – Greenhouse gases

HEV – Hybrid electric vehicle

ICEV – Internal combustion engine vehicle

IPCC – International Panel on Climate Change – a coalition of scientists brought together by the UN to compile the most up to date climate research

kWh – Killowatt-hour

MUDs – Multi-unit dwellings

NAM – Norm Activation Model – a model of behavior change

PHEV – Plug-in hybrid electric vehicle

PMT – Protection Motivation Theory – a model of behavior change

SCE – Southern California Edison – a utility serving a major portion of Southern California including the Los Angeles area

TTM – Transtheoretical Model of Change – a model of behavior change

VMT – Vehicle miles traveled

VW - Volkswagen

ZEV – Zero Emissions Vehicle – often used in reference to the ZEV mandate, which does include fuel cell vehicles as zero emission vehicles

APPENDIX B: LIST OF INTERVIEWS

Blackstrom, Michael. (2018, November 16). *Southern California Edison,* Managing Director of Energy and Environmental Policy [Phone].

Boone, Josh. (2018, December 5). *VELOZ,* Founding Executive Director of Nonprofit Public-Private Partnership of VELOZ [Phone].

Henkin, Zach. (2018, December 12). *Forth,* Deputy Director [Phone].

Jain, Aayushi. (2018, November 13). *Los Angeles Cleantech Incubator: Zero Emissions Roadmap,* Manager of Market Transformation [In Person].

Jennings, Paul. (2018, November 7). *PCS Energy,* Principal [Phone].

Keddie, Elise. (2018, December 26). *California Air Resources Board,* Manager of Zero Emissions Vehicle Implementation Section [Phone].

Kitahara, Keiichi, & Beltran, Davin. (2018, November 14). *Nissan,* Director of OEM Development and Regulatory Compliance & Senior Manager of Regulatory Compliance [Phone].

Konert, Angela. (2018, November 20). *BMW of North America,* Vice President of Government and External Affairs California [Phone].

Milhoan, Christian. (2018, November 15). *California Department of Motor Vehicles,* Administrator of the Clean Air Vehicle Decal Program [Email].

Swanton, John. (2018, December 10). *California Air Resources Board,* Communications Specialist [Phone].

Thomas, Robert. (2018, December 7). *Southern California Edison EV Specific Rates,* Rate Expert in Regulatory Affairs [Phone].

Valdez, Javier. (2018, December 19). *Washington State House Representative,* Democratic Representative of the 46th Legislative District [In Person].

WORKS CITED

10News Staff. (2018, October 13). Hybrid, electric vehicle drivers in Mississippi getting hit with additional tax | wtsp.com. *Channel 10 News*. Retrieved from https://www.wtsp.com/article/news/hybrid-electric-vehicle-drivers-in-mississippi-getting-hit-with-additional-tax/67-604034428

AB-2127 Electric vehicle charging infrastructure: assessment. , Public Resources Code § 25229 (2018).

Alternative Fuels Data Center. (2019, March 8). Electric Charging Station Locations by State. Retrieved December 9, 2018, from U.S. Department of Energy website: https://afdc.energy.gov/data/10366

Alternative Fuels Data Center. (n.d.). State Laws and Incentives. Retrieved December 2, 2018, from https://afdc.energy.gov/laws/state

AutoTrader. (n.d.). Used 2012 Nissan Leaf SL for sale in Lennox, CA 90304: Hatchback Details - 493397074. Retrieved December 19, 2018, from Autotrader website: https://www.autotrader.com/cars-for-sale/vehicledetails.xhtml?listingId=493397074&zip=90304&makeCode1=Nissan&modelCode1=Leaf&dealerId=64221227

Blackstrom, M. (2018, November 16). *Southern California Edison* [Phone].

Bockarjova, M., & Steg, L. (2014). Can Protection Motivation Theory predict pro-environmental behavior? Explaining the adoption of electric vehicles in the Netherlands. *Global Environmental Change*, *28*, 276–288. https://doi.org/10.1016/j.gloenvcha.2014.06.010

Bonges, H. A., & Lusk, A. C. (2016). Addressing electric vehicle (EV) sales and range anxiety through parking layout, policy and regulation. *Transportation Research Part A: Policy and Practice*, *83*, 63–73. https://doi.org/10.1016/j.tra.2015.09.011

Boone, J. (2018, December 5). *VELOZ* [Phone].

Buell, T. (2015). *Washington State Electric Vehicle Action Plan 2015-2020*. Retrieved from Washington State Department of Transportation website: http://www.wsdot.wa.gov/NR/rdonlyres/28559EF4-CD9D-4CFA-9886-105A30FD58C4/0/WAEVActionPlan2014.pdf

California Air Resources Board. (2018a). *The Zero Emission Vehicle (ZEV) Regulation Fact Sheet*. Retrieved from https://www.arb.ca.gov/msprog/zevprog/factsheets/zev_regulation_factsheet_082418.pdf

California Air Resources Board. (2018b, December 6). Enhanced Fleet Modernization Program. Retrieved January 7, 2019, from https://www.arb.ca.gov/msprog/aqip/efmp/efmp.htm

California Plug-In Electric Vehicle Collaborative. (2013). *Plug-in Electric Vehicle Charging Infrastructure Guidelines for Multi-unit Dwellings*. Retrieved from http://www.veloz.org/wp-content/uploads/2017/08/MUD_Guidelines4web.pdf

Cama, T. (2019, February 21). Trump administration ends talks with California over car emissions rule. *The Hill*. Retrieved from https://thehill.com/policy/energy-environment/430970-trump-administration-ends-talks-with-california-over-car-emissions

CarGurus. (n.d.). Used Honda Civic For Sale. Retrieved December 19, 2018, from CarGurus website: https://www.cargurus.com/Cars/l-Used-Honda-Civic-d586

Cattaneo, L. (2018, June 7). Plug-In Electric Vehicle Policy. Retrieved September 21, 2018, from Center for American Progress website:

https://www.americanprogress.org/issues/green/reports/2018/06/07/451722/plug-electric-vehicle-policy/

Chirazi, J., Samulon, M., & Kincaid, C. (2018, December). *'Tis the season to go electric. Hear how San Diego, Los Angeles, and the Central Valley encourage electric cars*. Webinar presented at the VELOZ Webinar series.

Davenport, C., & Pierre-Louis, K. (2018, November 23). U.S. Climate Report Warns of Damaged Environment and Shrinking Economy. *New York Times*. Retrieved from https://www.nytimes.com/2018/11/23/climate/us-climate-report.html

Department of Energy. (2018, January 29). Fact of the Month #18-01, January 29: There Are 39 Publicly Available Hydrogen Fueling Stations in the United States. Retrieved November 11, 2018, from Office of Energy Efficiency & Renewable Energy website: https://www.energy.gov/eere/fuelcells/fact-month-18-01-january-29-there-are-39-publicly-available-hydrogen-fueling-stations

Department of Energy. (2019, March 7). Alternative Fuels Data Center: Alternative Fueling Station Locator. Retrieved from https://www.afdc.energy.gov/stations/#/find/nearest?fuel=ELEC&country=US

Department of Energy. (n.d.-a). Electric Vehicle Basics. Retrieved November 11, 2018, from Office of Energy Efficiency & Renewable Energy website: https://www.energy.gov/eere/electricvehicles/electric-vehicle-basics

Department of Energy. (n.d.-b). Electric Vehicles: Tax Credits and Other Incentives. Retrieved October 21, 2018, from Office of Energy Efficiency & Renewable Energy website: https://www.energy.gov/eere/electricvehicles/electric-vehicles-tax-credits-and-other-incentives

Dickson, D. (2005, June 27). The case for a "deficit model" of science communication. *PCST (Public Communication of Science and Technology) Working Symposium on "Strategic Issues in Science and Technology Communication."* Retrieved from https://www.scidev.net/global/communication/editorials/the-case-for-a-deficit- model-of-science-communic.html

Dow, J. (2018, December 6). VW's Electrify America opens California's first 350kW ultra-fast charger, before cars can actually use it. *Electrek*. Retrieved from https://electrek.co/2018/12/06/electrify-america-first-350kw-charger-california/

Egbue, O., & Long, S. (2012). Barriers to widespread adoption of electric vehicles: An analysis of consumer attitudes and perceptions. *Energy Policy*, *48*, 717–729. https://doi.org/10.1016/j.enpol.2012.06.009

Electric vehicle charging stations—Signage—Penalty. , 60 RCW § 46.08.185 (2013).

EPA. (2016). Sources of Greenhouse Gas Emissions [Overviews and Factsheets]. Retrieved November 11, 2018, from Environmental Protection Agency website: https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

Espino, J. (2018, January 19). EV Update: Charging Stations Coming to Low-Income Communities. Retrieved January 7, 2019, from The Greenlining Institute website: http://greenlining.org/blog/2018/pge-to-deploy-ev-charging-stations-in-low-income-communities/

EVAdoption. (2018, August). EV Market Share by State. Retrieved December 2, 2018, from EVAdoption website: http://evadoption.com/ev-market-share/ev-market-share-state/

EZ EV. (2018, January 29). 12 Longest Range Electric Cars Available in The Market in 2018. Retrieved October 23, 2018, from https://ez-ev.com/tips/12-longest-range-electric-cars-available-in-the-market-in-2018

Gerdes, J. (2018, February 26). Consumers Lack EV Awareness, Even in the Nation's Largest Market. *Greentech Media*. Retrieved from https://www.greentechmedia.com/articles/read/consumers-lack-ev-awareness-even-in-the-nations-largest-market

Green, E. H., Skerlos, S. J., & Winebrake, J. J. (2014). Increasing electric vehicle policy efficiency and effectiveness by reducing mainstream market bias. *Energy Policy*, *65*, 562–566. https://doi.org/10.1016/j.enpol.2013.10.024

Greene, D. L. (2006, April). *Reducing Greenhouse Gas Emissions From Transportation*. Microsoft Powerpoint presented at the Presentation to the Legislative Commission on Global Climate Change, Raleigh, North Carolina. Retrieved from https://ncleg.net/documentsites/committees/LCGCC/Meeting%20Documents/2005-2006%20Interim/25%20April%202006/Presentations/LCGCC-%20Greene.pdf

Hartman, K., & Dowd, E. (2017, September 27). State Efforts To Promote Hybrid and Electric Vehicles. Retrieved December 3, 2018, from National Conference of State Legislatures website: http://www.ncsl.org/research/energy/state-electric-vehicle-incentives-state-chart.aspx

Hartman, K., & Pula, K. (2018, November 12). New Fees on Hybrid and Electric Vehicles. *National Conference of State Legislatures*. Retrieved from http://www.ncsl.org/research/energy/new-fees-on-hybrid-and-electric-vehicles.aspx

Henkin, Z. (2018, December 12). *Forth* [Phone].

Hess, D. J. (2012). *Good Green Jobs in a Global Economy: Making and Keeping New Industries in the United States*. Cambridge: Massachusetts Institute of Technology Press.

Hsiang, S., Kopp, R., Jina, A., Rising, J., Delgado, M., Mohan, S., … Houser, T. (2017). Estimating economic damage from climate change in the United States. *Science*, *356*(6345), 1362–1369. https://doi.org/10.1126/science.aal4369

Intergovernmental Panel on Climate Change. (2018). *Global Warming of 1.5 °C* (Special Report No. IPCC SR1.5). Retrieved from IPCC website: http://report.ipcc.ch/sr15/pdf/sr15_spm_final.pdf

International Energy Agency. (2018). *CO2 Emissions From Fuel Combustion Overview* (No. 2018 Edition; pp. 1–14). Retrieved from International Energy Agency website: https://webstore.iea.org/download/direct/1082?filename=co2_emissions_from_fuel_combustion_2018_overview.pdf

Jackson, B. (2018, July 6). States Got $3 Billion in VW Scandal. Here's How They'll Spend It. *Bloomberg*. Retrieved from https://www.bloomberg.com/news/articles/2018-07-06/states-got-3-billion-in-vw-scandal-here-s-how-they-ll-spend-it

Jain, A. (2018, November 13). *Los Angeles Cleantech Incubator: Zero Emissions Roadmap* [In Person].

Jansson, J., Nordlund, A., & Westin, K. (2017). Examining drivers of sustainable consumption: The influence of norms and opinion leadership on electric vehicle adoption in Sweden. *Journal of Cleaner Production*, *154*, 176–187. https://doi.org/10.1016/j.jclepro.2017.03.186

Jennings, P. (2018, November 7). *PCS Energy* [Phone].

Joyner, C. (2017, January 12). Here's why electric car sales are plummeting in Georgia. *Atlanta Journal-Constitution*. Retrieved from https://www.ajc.com/news/state--regional-govt--politics/here-why-electric-car-sales-are-plummeting-georgia/lNGjfnDMALGkv2iUzwwXIO/

Keddie, E. (2018, December 26). *California Air Resources Board* [Phone].

Kitahara, K., & Beltran, D. (2018, November 14). *Nissan* [Phone].

Konert, A. (2018, November 20). *BMW of North America* [Phone].

Lambert, F. (2017, January 30). Electric vehicle battery cost dropped 80% in 6 years down to $227/kWh - Tesla claims to be below $190/kWh. *Electrek*. Retrieved from https://electrek.co/2017/01/30/electric-vehicle-battery-cost-dropped-80-6-years-227kwh-tesla-190kwh/

Langbroek, J. H. M., Franklin, J. P., & Susilo, Y. O. (2016). The effect of policy incentives on electric vehicle adoption. *Energy Policy*, *94*, 94–103. https://doi.org/10.1016/j.enpol.2016.03.050

Lekach, S. (2018, December 28). Want a Tesla? Buy it before the $7,500 tax credit gets cut in half. Retrieved April 4, 2019, from Mashable website: https://mashable.com/article/tesla-tax-credit-end-of-2018-deadline/

Lutsey, N. (2015). Transition to a global zero-emission vehicle fleet: A collaborative agenda for governments. *International Council on Clean Transportation*, 48.

Maddux, J. E., & Rogers, R. W. (1983). Protection motivation and self-efficacy: A revised theory of fear appeals and attitude change. *Journal of Experimental Social Psychology*, *19*(5), 469–479. https://doi.org/10.1016/0022-1031(83)90023-9

Messagie, M. (2014). Life Cycle Analysis of the Climate Impact of Electric Vehicles. *Journal of Life Cycle Assessment*. Retrieved from https://www.transportenvironment.org/sites/te/files/publications/TE%20-%20draft%20report%20v04.pdf

Milhoan, C. (2018, November 15). *California Department of Motor Vehicles* [Email].

Mississippi Department of Environmental Quality. (2018). VW Mitigation Trust. Retrieved December 6, 2018, from https://www.mdeq.ms.gov/air/vw-mitigation-trust/

Morris, D. Z. (2018, February 18). Renewable Energy Surges to 18% of U.S. Power Mix. *Fortune*. Retrieved from http://fortune.com/2018/02/18/renewable-energy-us-power-mix/

Morrissey, P., Weldon, P., & O'Mahony, M. (2016). Future standard and fast charging infrastructure planning: An analysis of electric vehicle charging behaviour. *Energy Policy*, *89*, 257–270. https://doi.org/10.1016/j.enpol.2015.12.001

Oklahoma Department of Environmental Quality. (n.d.). Volkswagen Settlement. Retrieved December 6, 2018, from http://www.deq.state.ok.us/aqdnew/vwsettlement/

Onwezen, M. C., Antonides, G., & Bartels, J. (2013). The Norm Activation Model: An exploration of the functions of anticipated pride and guilt in pro-environmental behaviour. *Journal of Economic Psychology*, *39*, 141–153. https://doi.org/10.1016/j.joep.2013.07.005

Pacific Power. (n.d.). Service Area Map. Retrieved December 6, 2018, from Pacific Power website: https://www.pacificpower.net/about/cf/sam.html

PG&E. (2018). Clean Fuel Rebate for fueling electric vehicles. Retrieved December 6, 2018, from https://www.pge.com/en_US/residential/solar-and-vehicles/options/clean-vehicles/electric/clean-fuel-rebate-for-electric-vehicles.page?WT.mc_id=Vanity_cleanfuelrebate-ev

Plug-In America, Sierra Club, & Electric Auto Association. (2019). National Drive Electric Week. Retrieved January 18, 2019, from National Drive Electric Week website: https://driveelectricweek.org/

Popovich, N., Schwartz, J., & Schlossberg, T. (2017, March 21). How Americans Think About Climate Change, in Six Maps. *The New York Times*. Retrieved from https://www.nytimes.com/interactive/2017/03/21/climate/how-americans-think-about-climate-change-in-six-maps.html, https://www.nytimes.com/interactive/2017/03/21/climate/how-americans-think-about-climate-change-in-six-maps.html

Prochaska, J. O., & Velicer, W. F. (1997). The Transtheoretical Model of Health Behavior Change. *American Journal of Health Promotion*, *12*(1), 11.

Riley, J. (2018, March 3). How Much Do EV Charging Stations Cost? Retrieved October 6, 2018, from Commercial Electric Vehicle Charging Stations, Commercial Electric Vehicle Charging Station Installer, installation in San Diego, Los Angeles, Riverside, Orange County website: https://triggerenergy.com/how-much-do-ev-charging-stations-cost/

Roberts (Dustin) of the House, & Bice of the Senate. Motor Vehicle Registrations. , Pub. L. No. Title 47, § 1132.7, H.B. No. 1449 Oklahoma (2017).

Saxton, T. (2011, January 31). Understanding Electric Vehicle Charging. Retrieved December 10, 2018, from Plug In America website: https://pluginamerica.org/understanding-electric-vehicle-charging/

Seba, T. (2018, March). *Clean Disruption: Technology Megatrends Leading to the Disruption of Public and Private Transportation*. Presented at the rEVolution, Amsterdam. Retrieved from https://www.youtube.com/watch?v=ox5LtxqQNHw

Serra, J. V. F. (2013). *Electric Vehicles : Technology, Policy and Commercial Development*. https://doi.org/10.4324/9780203125755

Sierzchula, W., Bakker, S., Maat, K., & van Wee, B. (2014). The influence of financial incentives and other socio-economic factors on electric vehicle adoption. *Energy Policy*, *68*, 183–194. https://doi.org/10.1016/j.enpol.2014.01.043

Slowik, P., & Lutsey, N. (2018). *The continued transition to electric vehicles in U.S. cities* [White Paper]. Retrieved from International Council on Clean Transportation website: https://www.theicct.org/sites/default/files/publications/Transition_EV_US_Cities_20180724.pdf

Smith, A. (2018, July). Electric Vehicle Incentives and Fees. *Legisbrief*. Retrieved from http://www.ncsl.org/research/transportation/electric-vehicle-incentives-and-fees.aspx

Smith, M., & Castellano, J. (2015). Costs Associated With Non-Residential Electric Vehicle Supply Equipment. *U.S. Department of Energy*, 43.

Solar Energy Industries Association. (n.d.). Renewable Energy Standards. Retrieved November 11, 2018, from SEIA website: /initiatives/renewable-energy-standards

Spector, J., & Pyper, J. (2017, July 5). Updated: 17 States Now Charge Fees for Electric Vehicles. *Greentech Media*. Retrieved from https://www.greentechmedia.com/articles/read/13-states-now-charge-fees-for-electric-vehicles

Sperling, D. (2018). *Three Revolutions: Steering Automated, Shared, and Electric Vehicles to a Better Future*. Washington D.C.: Island Press.

Statista. (2018). Battery share of large EV costs 2030. Retrieved December 16, 2018, from Statista website: https://www.statista.com/statistics/797638/battery-share-of-large-electric-vehicle-cost/

Swanton, J. (2018, December 10). *California Air Resources Board* [Phone].

The Bureau of Planning and Sustainability. (2016, December). *2017 City of Portland Electric Vehicle Strategy*. Retrieved from https://www.portlandoregon.gov/bps/article/619275

Thomas, R. (2018, December 7). *Southern California Edison EV Specific Rates* [Phone].

Torres, A., & Ruiz-Craig, A. (2017, November 21). *City of Atlanta Passes "EV Ready" Ordinance into Law*. Retrieved from https://www.atlantaga.gov/Home/Components/News/News/10258/1338?backlist=/

Union of Concerned Scientists. (2016, October 31). What is ZEV? Retrieved February 26, 2019, from Union of Concerned Scientists website: https://www.ucsusa.org/clean-vehicles/california-and-western-states/what-is-zev

Union of Concerned Scientists. (2018, March 14). How Do Hydrogen Fuel Cell Vehicles Work? Retrieved November 11, 2018, from Union of Concerned Scientists website: https://www.ucsusa.org/clean-vehicles/electric-vehicles/how-do-hydrogen-fuel-cells-work

Valdez, J. (2018, December 19). *Washington State House Representative* [In Person].

Vehicle Technologies Office. (2017, December 18). Median All-Electric Vehicle Range Grew from 73 Miles in Model Year 2011 to 114 Miles in Model Year 2017. Retrieved December 11, 2018, from Department of Energy website: https://www.energy.gov/eere/vehicles/articles/fotw-1008-december-18-2017-median-all-electric-vehicle-range-grew-73-miles

Washington State Department of Commerce. (n.d.). Electric Drive Washington. Retrieved December 6, 2018, from Electric Drive Washington website: https://www.commerce.wa.gov/growing-the-economy/energy/electric-vehicles/

Washington State Department of Revenue. (2018, April 24). Tax exemption ending for alt-fuel, electric, and plug-in hybrid vehicles. Retrieved December 6, 2018, from https://dor.wa.gov/about/news-releases/2018/tax-exemption-ending-alt-fuel-electric-and-plug-hybrid-vehicles

West Coast Green Highway. (n.d.). West Coast Electric Highway. Retrieved December 10, 2018, from West Coast Green Highway website: http://www.westcoastgreenhighway.com/electrichighway.htm

Williams, M. (2018, November 26). *California Air Resources Board - ZEV Branch* [Phone].

Wynne, B. (2006). Public Engagement as a Means of Restoring Public Trust in Science – Hitting the Notes, but Missing the Music? *Public Health Genomics*, *9*(3), 211–220. https://doi.org/10.1159/000092659