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Electric vehicles and natural disaster policy implications

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ABSTRACT

Despite their many advantages, electric vehicles may pose a challenge for their owners during natural disaster events, when access to electricity may be curtailed for several days or weeks. Evacuation distances for those escaping the affected areas may exceed the range of an electric vehicle on a single charge, and charging stations could become swamped or unavailable due to outages. Additionally, electric car users themselves may pose a risk of overloading the grid in the event of a mass evacuation. We highlight the issues of electric vehicle use during an evacuation event, not to discourage adoption, but to raise awareness of the issues so that public policy makers can take them into consideration. We use a hurricane evacuation scenario from Key West, FL as an example case. This paper shows the need for more electric charging stations in known evacuation regions and demonstrates that electric cars have become widespread enough to warrant a larger share of public policies.

1. Introduction

Electric Vehicles (EVs) are moving onto the U.S. market quickly, with a predicted one million EVs hitting the road by 2020 (Shepardson, 2017). EVs have been gaining popularity for several reasons, from lower maintenance costs to reducing the amount of imported petroleum and eliminating carbon emissions (Li et al., 2015). EVs convert 59–62% of the electric energy from the grid to power at the wheels, compared with 17–21% for gasoline vehicles. With no exhaust, EVs emit no pollutants, provide stronger acceleration, and require less maintenance. In the United States, the biggest contributor to carbon dioxide emissions is now the transportation sector, making EVs an important part of the overall solution toward reducing those emissions (U.S. Energy Information Administration – EIA – Independent Statistics and Analysis, 2017).

However, alongside the many benefits of EVs there are a few drawbacks. EVs do not have a long driving range (defined as the total distance an electric vehicle can travel in miles after receiving a full charge). On average, they can go between 62 and 107 miles, except the Tesla models, which range between 234 and 270 miles on a single charge. The recharging time of EVs can take from thirty minutes to several hours, requiring extended access to an electric charging station.

Charging stations are not as readily available as gas stations. In 2017, the number of publically accessible charging stations in the United States surpassed 15,943, totaling more than 42,550 outlets (Electric Vehicle Charging Station Locations, 2017). (These numbers may be different by the time of publication due to the frequency of updating.) In comparison, as of 2012 there were 114,000 gas stations in the U.S., according to the U.S. Census. While private charging stations offer a bit more flexibility, without access to readily available public charging stations, the locations that an EV can reach are limited.

One implication of a lack of charging stations that has not been discussed or explored fully is how EVs will fare during an evacuation from a location such as the Florida Keys, or with a long power outage after an event such as a tropical storm or a hurricane. Natural disasters often cause electricity outages, which could leave EV owners unable to evacuate from a dangerous area, or without transportation for long periods of time following the outage event. As of yet, public policy regarding natural disasters does not take into account the growing number of EVs or provide contingency plans for EV drivers unable to follow the same evacuation plans as owners of gasoline vehicles. This includes emergency management at the local, state, and federal level (FEMA), public utilities, and the host communities. For instance, Florida's Division of Emergency Management publishes regional evacuation studies, none of which take into account EVs. In contrast, gasoline vehicles are accounted for by Florida state law (Florida Statues 526.143), which requires that certain gasoline fueling stations located near major evacuation routes must be capable of operating using backup power. It is one of the aims of this paper to investigate this discrepancy and explore ways in which it can be corrected.

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1.1. Adoption of electric cars

The number of alternative fuel vehicles has steadily risen in the past several years, primarily due to federal and state policies that encourage and incentivize the manufacture, sale, and use of vehicles that run on non-petroleum fuels (Emergency Economic Stabilization Act 2008; Al-Alawi and Thomas, 2013). The electric car sector in particular has grown widely, with a number of car manufacturers marketing these vehicles. California currently accounts for most of the EVs in the United States. Fig. 1 shows the recent growth of Battery Electric Vehicles (BEV) and Plug-in-Hybrid Vehicles (PHEV), with Fuel Cell Vehicles (FCEV) making a small impact.

The adoption of EVs has been spurred by tax incentives and carpool benefits, such as allowing EVs to be driven with a sole driver in the high occupancy vehicle lane. Fig. 2 outlines some of the incentives available from several states (California, Colorado, Delaware, Louisiana, Massachusetts, Oregon, Pennsylvania, Rhode Island, Utah), including some combination of reduced vehicle licensing fees, sales tax, and excise exemptions. The federal incentives for consumers were provided by the Emergency Economic Stabilization Act of 2008 (Srivastava et al., 2010), which added a tax credit for electric vehicles.

1.2. Issues with electric vehicles

Although the adoption of electric vehicles may have the benefit of reducing emissions and lessening the country's dependence on gasoline, EVs still have a more limited range than gas powered vehicles and are dependent on access to reliable electricity. If that access is disrupted, so is the use of the vehicle.

We identified three main areas where EVs present new issues when dealing with a natural disaster requiring an evacuation.

- **Evacuation routes** – The shorter range of EVs compared to gasoline vehicles necessitates the availability of charging points along current evacuation routes.
- **Electricity availability** – During a natural disaster, power supply to charging stations may be disrupted. Evacuation plans may need to provide backup routes to functioning charging stations. Additionally, the loads on charging stations, and ultimately the grid, need to be considered in the event of a mass evacuation. Long-term disruption of charging stations following an outage event may interfere with EV owners' ability to carry on daily activities, such as getting to work – another reason for making sure that enough charging stations are available.
- **Electricity storage** – One of the most common things mentioned while preparing for a natural disaster event is to stock up on gasoline, but how does one stock up on electricity without massive battery storage? We discuss battery storage and alternative ways to power electric charging stations.

1.3. Background research

A review of existing literature shows no previous articles on the topic of access to electric charging stations during a natural disaster event. Policy issues surrounding electric vehicles have centered on the challenges of integrating electric vehicles and hybrid electric vehicles into the grid (Srivastava et al., 2010). There are multiple articles describing charging station power levels, topology, and infrastructure for plug-in electric vehicles and hybrids (Yilmaz and Philip, 2013). Rahman et al. (2016) present multiple difficulties in the electric vehicle charging infrastructure.

The unique challenges of the impact of large-scale electric vehicle deployment into the electric power system are discussed in Garcia-Valle and Peças Lopes (2012), namely the impact of the EV charging station on system demand; the paper also discusses the regulatory framework and business models for integrating EVs into the power system. Coffman and Wee (2017) highlights the fact that public charging infrastructure is one of the main factors holding back EV adoption. It also discusses the lack of guidance for the government to enable the supply of EV infrastructure. The National Academy of Engineering published a report on "Overcoming the Barriers to Electric Vehicle Deployment", which was requested by Congress and tasked to the Department of Energy (National Research Council, 2015). The report identified many technical, social, and economic challenges slowing down the widespread adoption of electric vehicles. The challenges identified include: vehicle cost, limited driving range, long charging times, and the need for charging infrastructure.

Likewise, research addressing emergency response does not yet include EVs. Several papers discuss the computation of evacuation time estimates using private vehicles and the behavior of risk area population that should be taken into account when calculating evacuation times (Lindell and Prater, 2007). Creation of emergency response models that can be used by an office of emergency responses to evaluate the effectiveness of emergency preparedness compared to the proposed model is described by Tovia (2007). However, these scenarios have yet to be applied specifically to electric vehicles, particularly in the case of a hurricane evacuation.

When electric vehicles have been mentioned in the context of natural disasters, it has been in their role as an asset for disaster relief. After a tsunami and earthquake hit Japan in March 2011, the New York Times reported on the use of EVs following a shortage of gasoline when oil refineries were out of service (Belson, 2017). Ustun et al. (2015) describe the potential use of electric vehicles during a natural disaster, sabotage, or warfare as an improvised micro-grid. The potential uses of EVs in case of a natural disaster only make it more necessary to thoroughly examine their liabilities and potential points of failure during such an event.

It is the purpose of this paper to bring the areas of research concerning electric vehicles and natural disasters into contact, by

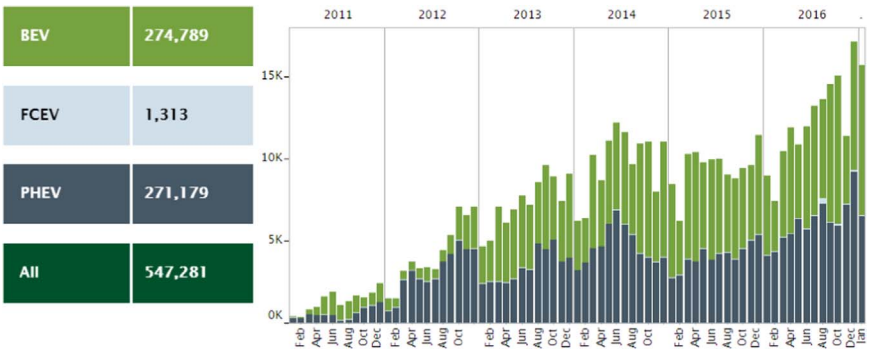

Fig. 1. Monthly sales of zero emission vehicles (ZEV) from 2011 to January 2017.