Electric Vehicle Transportation Center

Economic Impacts of Electric Vehicle Adoption

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The objective of the Economic Impacts of Electric Vehicle Adoption project was to examine the predicted levels of electric vehicle adoption, to analyze the opportunity of using EVs as a grid stabilization tool for Hawaii and to evaluate GHG emissions impacts due to electric vehicles. The work also included an assessment of the factors that affect EVs adoption, including regulatory mechanisms. The work was conducted under a subcontract from the University of Central Florida by Dr. Makena Coffman, Principle Investigator, Dr. Paul Bernstein, Sherilyn Wee and Aida Arik of the University of Hawaii Economic Research Organization.

Final Research Project Report

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1.0 Abstract

The objective of the Economic Impacts of Electric Vehicle Adoption research project was to examine the predicted levels of electric vehicle (EV) adoption, to analyze the life cycle costs of EVs compared to internal combustion engine vehicles and to evaluate EV impacts on GHG emissions for Hawaii. The results were presented in three publications. The first report evaluated EV penetration rates and provided an assessment of expected EV penetration over time. The research also assessed factors that affect EVs adoption, including regulatory mechanisms. The results estimated there will be 140,000 EVs on the road in Hawaii by the year 2040 in the reference scenario. These results can be used to estimate the impact of EVs on Hawaii's economy and to determine the level of opportunity of EV's use as a grid stabilization tool. To complement the first report results, EV life cycle costs (LCC) were analyzed in the second report. This report also assessed the impact of the federal tax credit for EVs and of the benefits of household solar photovoltaic systems coupled with proposed time-of-use (TOU) electricity rates for EV owners. The third report estimated greenhouse gas (GHG) emissions of EVs in Hawaii to include comparisons with similar internal combustion engine (ICE) vehicles. In terms of GHG emissions, EVs offer an improvement over ICEs. However, the model that looks at GHG emissions by island community showed that hybrid electric vehicles (HEVs) outperform EVs on Oahu while EVs outperform HEVs on Hawaii Island. This final report highlights the detailed results presented in three publications.

2.0 Research Results

The research results are presented in three reports that have been completed and posted on the EVTC website. The citations for these three reports are as follows:

1. Coffman, M., Bernstein, P. & Wee, S., (2015). Factors Affecting EV Adoption: A Literature Review and EV Forecast for Hawaii (HNEI Rep. No. HNEI-04-15). Honolulu, HI: University of Hawaii.
2. Coffman, M., Bernstein, P. & Wee, S., (2015). Electric Vehicle Lifecycle Cost Assessment for Hawaii (HNEI Rep No. HNEI-07-15), Honolulu, Hi: University of Hawaii.
3. Coffman, M., Bernstein, P., Wee, S., & Arik, A., (2016). Electric Vehicle Greenhouse Gas Emission Assessment for Hawaii (HNEI Rep No. HNEI-10-16), Honolulu, Hi: University of Hawaii.

A summary of the findings from each of the reports follow.

Report 1 -- Factors Affecting EV Adoption: A Literature Review and EV Forecast for Hawaii -- Electric vehicles reduce or entirely negate gasoline or diesel use in the vehicle itself through integration with the electric grid. Plug-in Hybrid Electric Vehicles (PHEVs) draw from a battery as well as liquid fuel. Battery Electric Vehicles (BEVs) are solely powered through electricity. Both provide the opportunity for power-sharing with the electric grid and can be used to potentially ease grid integration from sources of intermittent renewable energy. EVs are also a potentially important technology to help reduce greenhouse gas (GHG) emissions, local air pollution, and vehicular noise.

The study provides a review of the factors that affect EV adoption. These factors are organized as internal and external factors, meaning characteristics of the EV vehicle itself and those that are out of the direct control of EV car manufacturers. Internal factors include battery costs, purchase price, driving range, and charging time. External factors include fuel prices, policy incentives, consumer characteristics, availability of charging stations, travel distance, public visibility, and vehicle diversity. Policy mechanisms available to support EV adoption are also reviewed. This review includes offering of subsidies and other incentives, supporting of infrastructure build-up and raising of public awareness.

In compiling this report, Hawaii researchers collected literature on vehicle adoption rates and practices for the U.S. and for Hawaii. The results provide an assessment of expected EV penetration in Hawaii to the year 2040, using three adoption pathways. As part of the calibration of the EV adoption forecast for Hawaii's vehicle market, researchers requested and received data from the Hawaii Department of Transportation on Hawaii's existing registered vehicles (over a million), including the vehicle makes and models. Data was gathered from the Hawaii Automobile Dealers Association. The results estimate there will be 140,000 EVs on the road in Hawaii by the year 2040 in the reference scenario. In the low scenario, the estimate is 110,000 EVs and, in the high scenario, 280,000 EVs. The vehicle adoption scenarios may also be used to determine EV impacts to Hawaii's electric sector and its overall economy.

As viewed through the review of literature, there is much work yet to be done in understanding whether consumers will adopt EVs in a critical mass. The forecast provided was meant as a first-cut at understanding possible EV adoption scenarios in Hawaii, though it is fraught with uncertainty in regards to assumptions of technology acceptance, EV cost and performance, and required infrastructure build-up. Nonetheless, providing a range of possible future adoption rates helps to frame the conversation to understand a reasonable set of uptake scenarios for policy and planning purposes. This study specifically avoided failure of technology adoption scenarios as a lower bound. This means that the low scenario is not representative of a true lower bound, but rather of a low(er) level of technology acceptance. Even this case assumes some level of federal subsidy and improvements in EV technologies and infrastructure.

In addition, many of the studies from which this study draws information are from outside the U.S. such as Europe where gasoline prices are more expensive. While it is difficult to translate entirely to the case of Hawaii, where both gasoline and electricity are tied to the price of oil, it is evident from the literature that relative fuel price is a primary driver of expected EV adoption. World oil prices are currently in a period of decline (Reference 1). For this reason, it seems reasonable to caution against reliance on the high EV adoption scenario. On the other hand, there may be strong reason to believe that range anxiety related to travel distance may be lessened in Hawaii's island geography. Moreover, Hawaii's early emphasis on public EV charging stations may help to quell this concern. This may have implications on both the total level of EVs sold in Hawaii as well as the ratio of PHEVs to BEVs. Continued evaluation will better understand the uniqueness of Hawaii's economy and geography and how it affects EV ownership, cost and likely EV adoption.

Report 2 -- Electric Vehicle Lifecycle Cost Assessment for Hawaii -- To complement the EV-adoption scenarios, an analysis was conducted on comparing the total life cycle costs (LCC) of ownership of EVs to ICE vehicles and HEVs in Hawaii. The scenarios assessed the impact of the federal tax credit for EVs, differences in purchase price, finance and lease options, impacts of household solar photovoltaics (PV) and the use of Hawaii utility's proposed TOU electricity rates for EV owners. The model includes a forecast for future gasoline and electricity prices using a scenario planning approach. Results showed that EVs on average cost more than ICE vehicles or HEV counterparts, but the federal tax credit largely closes this gap. And, even though electricity rates in Hawaii are substantially higher than the national average, having residential PV can substantially bring down the cost of EV ownership.

The LCC study was based on the model presented by Raustad and Fairey (Reference 2) for "Electric Vehicle Life Cycle Cost Assessment" with tailored input for the Hawaii case. Raustad and Fairey developed an excel spreadsheet model which calculates life cycle costs for vehicles including purchase/finance, insurance, maintenance, and resale value. The time frames considered are 5, 10 and 15 years of ownership. It also has a module to assess the impact of using residential solar photovoltaics power to reducing EV ownership costs. In this work, extensions were also made to assess decisions regarding vehicle leasing as well as to analyze Hawaii's largest utility's proposed TOU rates for households with EVs.

The question of how to best structure electricity rates for EVs as well as other uses is important to utilities in Hawaii and around the country due to increasing use of renewable energy. In the case of Hawaii, where wind and solar are abundant, there may be a desire to shift EV load charging to either nighttime (to capture potentially excess wind energy) or during midday (to capture potentially excess solar PV). In order to acquire some data, Hawaiian Electric conducted a pilot TOU rate program that discouraged daytime charging. As of December 2014, 11% of EV owners have signed up for the pilot EV TOU rate program (Reference 3). Note is made that TOU rates may be more beneficial if they encouraged daytime charging with equal rates to post-peak nighttime charging.

In addition Hawaiian Electric is considering an effort toward TOU rates, where on-peak prices are raised by $0.12/kWh. Researchers will continue to evaluate the important program considerations of how consumers react, both in terms of willingness to sign on to what is now a voluntary program and to whether load shifting is possible and in what magnitude.

Key findings were:

- LCCs for EVs were on average more than ICE or hybrid electric vehicles, though this gap is substantially reduced with the federal tax credit.

- The Nissan Leaf is cost competitive without the federal tax credit and has the lowest lifecycle vehicle cost when incorporating the federal tax credit (among all vehicles considered).
- Electricity rates in Hawaii are much higher than the national average due to Hawaii's historic relationship between oil prices and electric rates. Using the Energy Information Administration's range of forecasts (Reference 4) for future oil prices (low, reference and high), a set of future electricity and gasoline prices was determined. The model found that when oil prices are at the low or reference levels, lifetime fuel costs are higher for EVs than other vehicles. When oil prices are high, EVs offer notable cost savings.
- Having residential PV substantially brings down the cost of EV ownership, even considering the capital expenditure for PV panels.
- The proposed TOU rates offered by the utility reduce lifecycle EV fuel costs by about 10% on average (about $1,000). It is most beneficial for a household with average electricity consumption (modeled as 18 kWh/day) to opt for the single-meter on the TOU rate (for both EV charging and household electricity use) and EVs with smaller batteries benefit much less from the pilot TOU program.

Report 3 -- Electric Vehicle Greenhouse Gas Emission Assessment for Hawaii -- In terms of GHG emissions, EVs in Hawaii offer an improvement over ICE vehicles. However, in a model that looks at GHG emissions by island communities, HEVs outperform EVs on Oahu (which has the highest EV penetration). However, on the Hawaii Island, EVs outperform HEVs due to the high level of geothermal electricity.

This report presents estimates of GHG emissions from EVs compared to GHGs from other popular and similar ICE vehicles. The estimates were done for vehicles that were driven 150,000 miles. The GHG benefits of EVs depend critically on the electricity system from which they derive their electrical power. The analysis showed that EVs statewide are an improvement in GHG emissions over similar and popular ICE vehicles.

The lifetime GHG emissions results in the report are calculated for the same set of vehicles and driving assumptions used in Report 2 on LCCs. The potential for reducing GHG emissions by EVs depends on the sources of electricity generation. Hawaii provides an interesting illustration on the GHG impacts of EVs because its islands have varied sources for electricity generation with no current ability for power-sharing. In addition, Hawaii has an aggressive Renewable Portfolio Standard (RPS) goal to meet 40% of its net electricity sales through renewable energy by 2030 and 100% by 2045.

Given the current Hawaiian electricity generation mix, the key findings are:

- Statewide, EVs provide an improvement in GHG emissions over ICEs.
- On Oahu, the best performing EV (Nissan Leaf) emits 5 Metric Tons CO_2 more over its lifetime than the best performing HEV (Toyota Prius).
- On Hawaii Island, all EVs perform better than HEVs. The Nissan Leaf's lifetime emissions are 6 MT CO_2 less than that of the Toyota Prius. But, at about $2,000/MT CO_2 abated, it is a costly GHG emissions reduction strategy.
- On Kauai, GHG emissions produced by EVs fall in the same range as HEVs, while some EVs on Maui perform better than HEVs.

Oahu, the most populace island, has the most EVs on the road. Hawaii Island, where there are few EVs on the road, shows a clear GHG benefit from EVs because of its high penetration of low carbon sources for electricity. This difference in benefits comparing islands suggests that policies supporting EV uptake should consider impacts per island, based on available types of electricity generation. For example, because EVs on the Hawaii Island provide near to mid-term GHG benefits, there should be an assessment of fast-charging stations to overcome potential range anxiety. And, until Oahu substantially transitions towards greater penetration of renewable sources for electricity, it may be too early to tout EVs on Oahu as a GHG emissions reduction strategy. This of course depends on the type of vehicle from which drivers switch to EVs. If EV drivers largely pull from potential HEV consumers, as is suggested in prior studies, then there is no gain in GHG emissions reduction. On the other hand, if EV consumers switch from ICEs, there are GHG emissions savings. Oahu's electricity generation mix must become similar to that in carbon intensity of Kauai and Maui to make high performing EVs at least comparable to high performing HEVs in GHG emissions. Note is made that Hawaii's statewide RPS law allows for pooling of electricity grids between Oahu, Maui and Hawaii Island, but this may not occur until after the 2030 time-frame.

Although Hawaii Island's electricity generation mix is most favorable to supporting EVs as a GHG emissions reduction mechanism, it has the lowest rate of EV uptake per capita and 160 vehicles on the road as of 2015. This is likely due to the size of the island at about 4,000 square miles and thus longer driving distances. Maui, on the other hand, spans 730 square miles, and Oahu, 600 square miles. Given that the limited driving range of EVs is a major barrier to adoption, the longer driving distances and more sparsely located urban cores on Hawaii Island likely exacerbates "range anxiety." The availability of adequate charging infrastructure is crucial to EV adoption, with considerations for reasonable charging time. Whereas Hawaii Island has 58 charging station ports, Oahu and Maui host 275 and 117, respectively; Kauai has the least number of ports, totaling 34. Maui has the most fast-charging ports (35)—reducing recharging time for a larger population of EV drivers—compared to Oahu (15), Hawaii Island (2), and Kauai (1). Maui also has the highest penetration rate for EVs on a per capita basis.

3.0 Impacts/Benefits

1) The forecast for EV adoption can be used to help inform policy-makers of expectations for EV penetration. This is important, for example, in right-sizing public charging infrastructure and policy decisions.

2) The lifecycle cost study for vehicles provides insight into expectations for EV adoption with policy implications for EV support measures. For example, the impact of the federal tax credit subsidy.

3) The GHG study provides insights into the potential mismatch between EV support policies and GHG outcomes. Though EVs are found to be an improvement in GHG emissions over ICEs, HEVs overall offer more GHG reductions based on population distribution and the portfolio of electricity generation within Hawaii's system.

4.0 References

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