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How Much are Chevrolet Volts in the EV Project Driven in EV Mode?

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Key Conclusions

- A sample of 1,154 Chevrolet Volt drivers participating in The EV Project drove 73% of their total miles in electric vehicle (EV) mode over an 8-month study period.
- 70% of vehicles were driven more than 70% of their total miles in EV mode, while 131 vehicles (11%) were driven more than 95% of their miles in EV mode.
- Volt drivers who drove farther per day also tended to consume more charging energy, either through more frequent charging, longer charge sessions, or both.
- The average amount of energy delivered per charging event varied widely from vehicle to vehicle, even among vehicles whose batteries were typically fully depleted prior to charging.
- Drivers with a high percentage of miles in EV mode averaged fewer trips of shorter length between charging events. They also tended to charge more frequently for shorter durations.

Which vehicles are being studied?

Owners of Chevrolet Volts in 18 metropolitan areas across the United States are participating in The EV Project. They agreed to allow project researchers to monitor the usage of their vehicles throughout the project. In-use data collected between October 1, 2012 and May 31, 2013 from a sample of 1,154 participating Volts were analyzed to determine how these vehicles were being used. This set of privately owned vehicles drove more than 6 million miles and performed over 220,000 charging events in the 8 month study period.

How much do these vehicles drive in EV mode?

As an extended range electric vehicle, the Chevrolet Volt has two operating modes. When in electric vehicle (EV) mode, the vehicle is powered by electricity from the grid. In extended range mode, the vehicle's gasoline-powered auxiliary power unit produces electricity to power the vehicle. This offers drivers flexibility to drive as far as they like before recharging the battery from the grid. The Volt's EPA-estimated EV mode range is 35 miles for the 2011 - 2012 models and 38 miles for the 2013 model year. These range estimates are based on standardized testing. Actual EV mode range varies with driving style and conditions. To classify the amount of driving a vehicle does in EV mode, the number of miles driven in EV mode reported by participating EV Project Volts was divided by the total number of miles driven. For this paper, this metric is called EV%. For the selected set of Chevrolet Volts, the overall EV% was 73%. A distribution of EV% from vehicle to vehicle is shown in Figure 1.

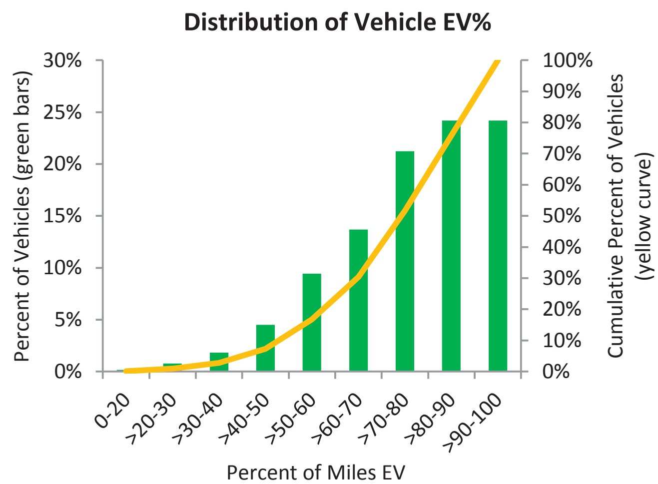

Figure 1: Histogram of EV% on a per-vehicle basis with cumulative distribution curve

Approximately 70% of Volt drivers drove more than 70% of their miles in EV mode. It was not uncommon for a vehicle's EV% to exceed 95%. In fact, there were more vehicles with an EV% above 95% (131) than below 50% (84).

Electronic displays in the Chevrolet Volt provide a considerable amount of information to the driver about the vehicle's mode of operation and efficiency. For example, the driver can see the amount of electricity and gasoline consumed and distance driven in EV mode versus extended range mode since the previous charging event. Cumulative fuel economy, in miles per gallon (mpg), is displayed to the driver as a measure of the vehicle's efficiency over time. This metric takes into account all miles driven and gasoline consumed since it was last reset by the driver. Because EV% is not displayed cumulatively, it is possible that some drivers do not have an inherent sense for their vehicle's long term EV%. However, a vehicle's EV% is directly proportional to its fuel economy. A larger fraction of miles in EV mode means the vehicle drives fewer miles powered by gasoline, and thus fuel economy is higher.

For this paper, fuel economy values were determined by dividing the total miles driven in either EV mode or extended range mode by the total gasoline used. The overall gasoline fuel economy for vehicles in the data set was 130 mpg. (Note that fuel economy shown considers gasoline consumption only – it is not comparable to EPA fuel economy estimates because it does not combine gasoline and electricity into equivalent miles per gallon [mpge].) Figure 2 shows the fuel economy distribution on a per-vehicle basis.

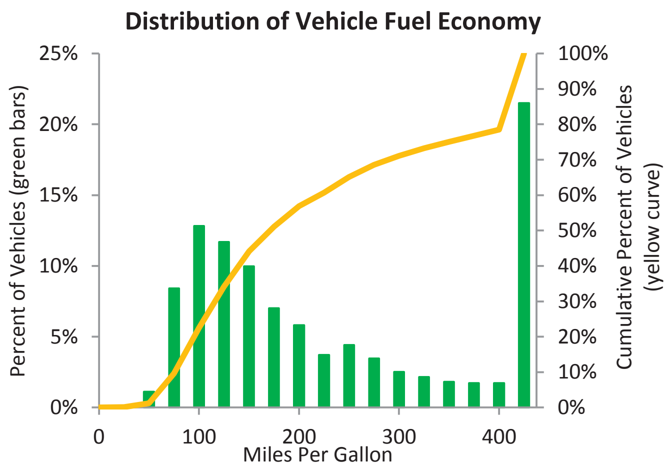

Figure 2: Histogram of fuel economy on a per-vehicle basis with cumulative distribution curve

More than 90% of the Volts in this set achieved greater than 75 mpg. A significant portion of vehicles saw fuel economy well into the triple digits. In fact, over 20% of vehicles averaged over 400 mpg, including a small number of vehicles with 99% of their miles driven in EV mode and near zero gasoline consumed.

Regardless of whether drivers were concerned with EV-only driving or fuel economy (or neither), the vehicles in this study drove a significant number of miles powered solely by electricity.

How are drivers achieving these results?

A vehicle's EV% is determined by the combination of its driving and charging. Figure 3 shows the relationship between driving and charging for each vehicle in the study set.

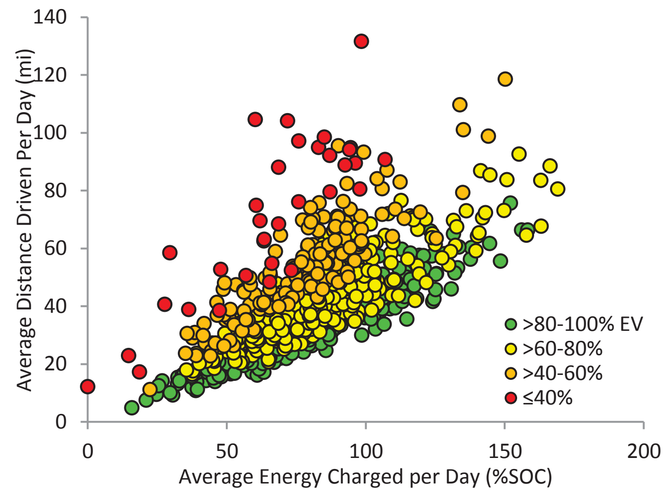

Figure 3: Average daily driving and charging for each vehicle, with EV% denoted by color

The average distance driven per day for each vehicle was plotted against the average amount of energy charged from the grid each day, in terms of battery state of charge (SOC). Only days when a vehicle were driven were considered. SOC used in this plot and other calculations in this paper is the battery's usable SOC. It ranges from 0% to 100%, where 0% represents the point when the vehicle switches from EV mode to extended range mode. Figure 3 also shows the actual EV% each vehicle achieved, represented by the color of each data point.

It is apparent that drivers who drove farther per day also tended to consume more charging energy. However, not all drivers drove and charged at proportional rates. Vehicle usage varied widely because drivers' daily routines and needs for their vehicle vary widely. Driver motivation to charge varies, as well.

It appears that some drivers valued driving in EV mode, as demonstrated by frequent charging and high EV%. For example, one driver had 94% of miles in EV mode when averaging 66 miles per day, because he consumed energy equivalent to 1.6 full charges each day. This vehicle was charged, on average, 4.3 times each day driven with an increase of 37 %SOC each charge. Another vehicle was driven the same distance per day, charged the same energy, and achieved the same EV%. However, this second vehicle averaged 1.7 charges per day driven and an average increase of 91 %SOC each charge.

Other drivers do not seem as motivated toward high EV%. As extreme examples, one vehicle was never charged in the study period and two other vehicles averaged only 1 charge in every 4 days when the vehicle was driven.

In addition to the total amount of energy charged, the order in which driving and charging occur is an important factor in determining EV%. After all, the amount of driving performed in a day does not matter to the vehicle, but rather the amount of driving before the next charge. As illustrated in the examples above, vehicle batteries can be charged any number of ways: by long infrequent charging sessions, by short frequent charging sessions, or any combination of frequency and duration. Charging frequency is best described in terms of how far a vehicle has driven between charges (rather than how much time has elapsed). Figure 4 shows the average distance each vehicle traveled between consecutive charging events and the average energy consumed per charging event. Each vehicle's EV% is represented by the color of each data point.

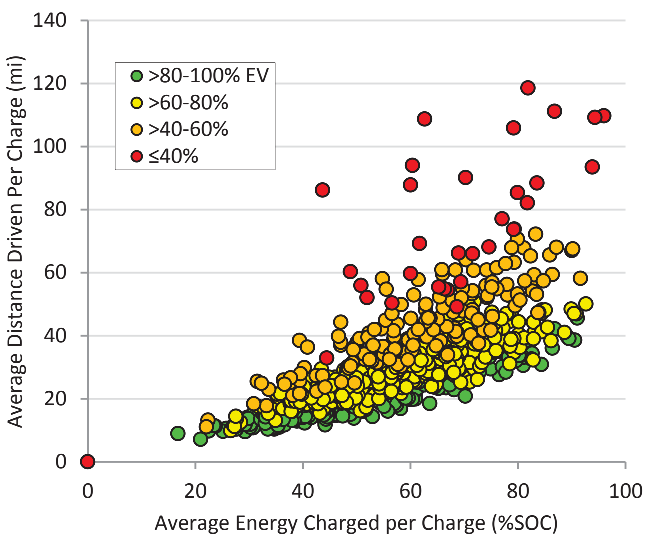

Figure 4: Average distance driven between charging and average charging energy per charge for each vehicle, with EV% denoted by color

The majority of vehicles in Figure 4 were driven relatively short distances between charging events. In fact, 75% of drivers averaged less than 35 miles between charges. However, not all vehicles consumed the same amount of energy per charge. Many vehicles were consistently charged enough per charging event, relative to miles driven prior to charging and driving conditions, to maintain high EV%. These vehicles are represented by green data points. Other vehicles were charged at the same mileage interval, but averaged less energy per charging event. This variation in charging energy consumed from vehicle to vehicle results in varying EV% for the same distance driven. This is also a reason why some vehicles achieved an EV% of far less than 100%, even though they were consistently driven less than the expected EV range of the vehicle prior to recharging.

Vehicles averaging over 50 miles before charging would be expected to often have fully depleted batteries by the time they charge. Ideally, these vehicles would have their batteries fully recharged each charging event, resulting in a high average SOC increase per charge. However, Figure 4 shows that many vehicles averaging over 50 miles between charging events averaged less than 70 %SOC per charge. Drivers of these vehicles may not have had time to fully recharge their vehicles or may not have had access to charging equipment in convenient locations. Volt driver preference for charging equipment type and location is the subject of another paper.

Further inspection of the data revealed additional patterns in behavior between groups of vehicles with varying EV%. Table 1 shows several driving and charging metrics for vehicles in the data set, grouped by EV%.

Table 1: Overall driving and charging metrics for vehicles in each group of EV%

EV%	≤40%	>40-60%	>60-80%	>80-100%
Vehicles (% of Vehicles)	32 (3%)	161 (14%)	403 (35%)	558 (48%)
Charges per Day	1.0	1.4	1.5	1.5
%SOC per Charge	66%	59%	57%	51%
Trips per Charge*	5.0	3.6	3.2	3.0
Miles per Trip*	14.0	11.0	8.8	7.2

* Trips are defined as the intervals between key-on and key-off where the vehicle traveled farther than 0.1 mile.

Drivers of vehicles with high EV% typically took fewer trips of shorter length between charging events. They also charged more frequently for shorter durations.

About The EV Project

The EV Project is the largest electric vehicle infrastructure demonstration project in the world; designed and managed by ECOtality North America (ECOtality), with a budget of over $230 million USD, equally funded by the United States (U.S.) Department of Energy (DOE) through the American Recovery and Reinvestment Act and ECOtality and its partners. The EV Project will deploy and study approximately 13,000 AC Level 2 EVSE charging stations for residential and commercial use, as well as 200 dual-port DC Fast Chargers in conjunction with the usage data from 8,000 Nissan LEAF™ and Chevrolet Volts. This project will collect and analyze data, and publish lessons learned on vehicle and EVSE use, and driver behavior. This material is based upon work supported by the DOE under Award Number DE-E0002194.

Company Profiles

ECOtality, Inc. (NASDAQ: ECTY), headquartered in San Francisco, California, is a leader in clean electric transportation and storage technologies. Its subsidiary, Electric Transportation Engineering Corporation (eTec) dba ECOtality North America (ECOtality), is a leading installer and provider of charging infrastructure for PEVs. ECOtality has been involved in PEV initiatives since 1989 in North America and is currently working with major automotive manufacturers, utilities, the U.S. DOE, state and municipal governments, and international research institutes to implement and expand the presence of this technology for a greener future.

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For more information, visit www.theevproject.com