Data Collection Pilot Project for the Zero-Emission Assurance Project (ZAP)

Prepared by The Foundation for California Community Colleges

March 2024

FOUNDATION *for* CALIFORNIA
COMMUNITY COLLEGES

1102 Q Street
Sacramento, California 95811

www.foundationccc.org

Table of Contents

Project Background

The Foundation for California Community Colleges (FoundationCCC) was requested by the California Air Resources Board (CARB), in partnership with the Community Housing Development Corporation (CHDC), to provide an estimate for testing and measuring battery health over time for electric vehicles purchased through the local financing assistance pilot, the Driving Clean Assistance Program (DCAP). Following discussions with CARB and CHDC staff and COVID-19-related delays in project roll-out, the 18-month pilot project began in January 2022.

The data collected was intended for use by CARB to perform analysis on battery health and degradation with the goal of evaluating key performance metrics and indicators. The breadth of the data collected herein will allow CARB to estimate baselines for battery wear-and-tear and state of health (SoH) as well as gather insights on processes for engaging and educating EV drivers about their vehicles' battery health. Beyond this pilot project, there is an opportunity for comparisons to be made between the project's data and those data provided by other research entities, such as National Laboratories, as well as vehicle and/or battery manufacturers.

Project Implementation

FoundationCCC planned to collect battery and charging-related data from electric vehicle (EV) drivers who participated in CHDC's DCAP through the use of telematics, the remote transmission of data via satellite and global positioning system (GPS) technologies, over a nine (9) month period. FoundationCCC planned to leverage existing physical site locations through the Smog Check Referee Program for the installation of telematics devices into participants' vehicles.

Revised Deliverable Schedule:

#	Target Date	Deliverable
1	1/7/2022	Execute Contract with Telematics Service Provider
2	3/15/2022	Recruit 45 Participants
3	4/30/2022	Install 45 Telematics Devices and Kickstart Data Collection
4	9/16/2022	Reach Midway Point (4.5 Months) for Data Collection Period
5	7/31/2023	Collect 45 Telematics Devices
6	10/31/2023	Provide Completed Project Data & Final Report to CHDC

Revised by Amendment 01

An overview of participant recruitment is below:

- Ninety seven (97) submissions to the project's interest form.
- Fifty one (51) respondents indicated their interest in moving forward with their participation.
- Thirty six (36) informational calls were held via Zoom or phone.
- Ten (10) interest form respondents did not reply to follow-up emails
- Twenty four (24) respondents did not follow through with installations after their informational calls.

- Six (6) interest form respondents declined participation after informational calls.
- Fourteen (14) interest form respondents were ineligible to participate.

Methods

As part of the project proposal, FoundationCCC leveraged its trusted, on-the-ground network of trained automotive technicians through its Smog Check Referee Program, a partnership between the Foundation and the Bureau of Automotive Repairs. Being able to offer participants a public and reputable location for device installation, done by a trained automotive professional, helped to build trust and confidence in the project.

Initially, the following colleges were identified as potential installation sites due to their location within the DCAP service area as well as hosting Smog Check Referees:

- College of Alameda
- Las Positas College
- Cosumnes River College
- American River City College
- Evergreen College
- Skyline College
- Santa Rosa Junior College
- Solano Community College (Vallejo Auto Tech)

Unfortunately, due to COVID-19 restrictions and related impacts, several locations were not able to host installations. There were also issues with recruitment of enough participants to hold an installation day at several locations. For example, FoundationCCC was technically able to hold installations at American River City College and Skyline College, but there were not enough participants who selected these colleges as their preferred location for an installation. Given that each installation shift had to be at least four hours in length to satisfy work schedule requirements for the presence of Smog Check Referees to install the devices, there needed to be at least 8 interested participants for a given college site to be "activated." As of writing this report, only the College of Alameda was able to meet this threshold and was thus chosen as the primary location for device installation.

Following initial recruitment of participants, as defined as confirmed interest in moving forward with a device installation, project staff sent out emails with a link to schedule an install, a project summary, and attachments, including the Participation Agreement and informational materials. Scheduling was done through Calendly, an online scheduling platform that allows for customizable scheduling processes. The project team set up a Calendly scheduling instance that enabled participants to receive email and text message reminders for their appointments. They also received detailed instructions for how to locate the installation location at College of Alameda. No participants reported being unable to locate the installation location.

Upon successful installation, FoundationCCC issued the first of two $100 payments to the participant via ACH/direct deposit or physical check. Participants were also provided with contact information in the event that they had any future questions and/or issues regarding their participation, including issues with the device itself. To-date, FoundationCCC received one call regarding an issue with the device beeping after successful installation. This issue was resolved remotely and immediately. Additionally, several participants' devices came "offline" or lost connection with the Geotab servers, thus temporarily halting data collection. FoundationCCC followed up with participants on a case-by-case basis to inquire about the disconnection and to help facilitate reconnection for continued data collection.

Other learnings from the installation process included the need to understand each unique vehicle's capability for on-board diagnostics, including the location of the OBD-II port where the Geotab device plugs into. Relatedly, most Tesla models lack an accessible OBD-II port, requiring physical removal of panels to install a device. For this reason, Teslas were not included in the data collection at the time of writing this report. However, Tesla does enable their drivers to collect relevant data themselves with manufacturer-approved services. This represents a future opportunity for gleaning additional data directly from EV drivers to compare to OEM-provided data.

Device Removal, Collection, and Participation Close-out

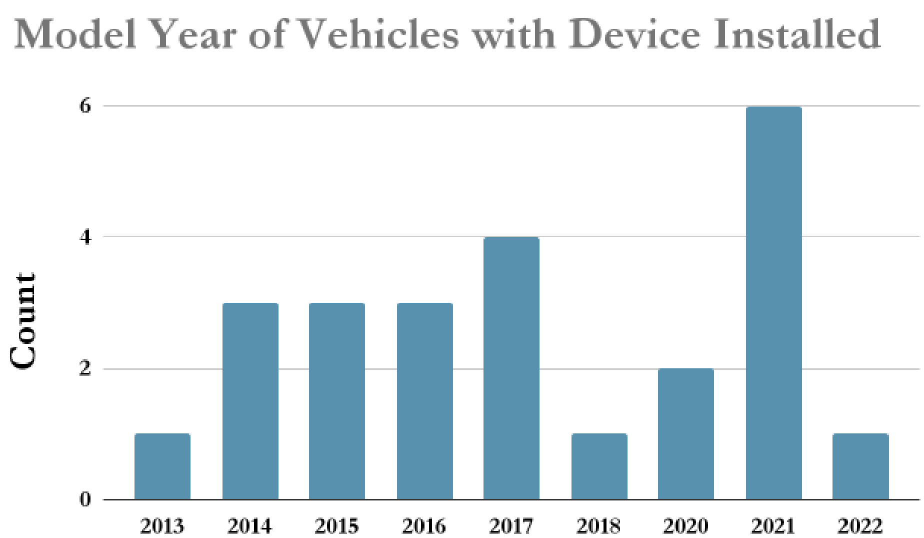
Ninety-two percent, or 22 of the 24 participants, completed their participation in the project, as defined by contributing at least 4 months of telematics data. Two participants did not provide the full amount of data. One of the two non-completion participants had a vehicle that could not communicate with the device after several failed attempts. The other regularly removed their device and did not follow the provided protocol for reconnecting their device, thus resulting in a lack of data collection from their vehicle.

One-third of the participants (8) returned their devices through a remote return process designed by the project team which consisted of sending the participant a padded package containing a return label. The participants were instructed to package their device and return using the designated return label. This process worked relatively well with only three of the participants requiring additional, personalized assistance to complete the remote return. The project team recognizes this as a potential methodology that CARB and/or future project administrators could use to facilitate device shipment and return in a cost-effective and efficient manner if desired in the future.

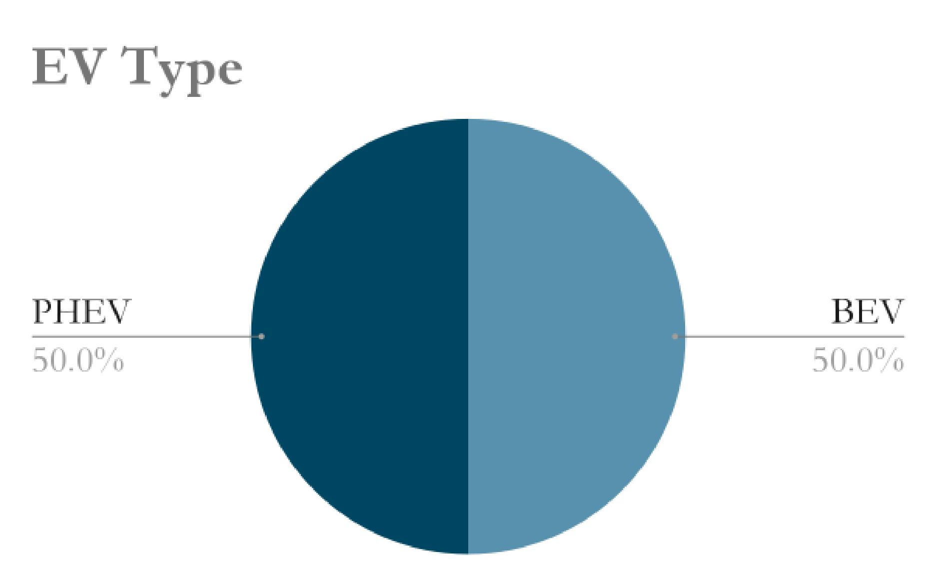
Upon successful return of their devices, participants received their final $100 participation stipend. One participant accidentally disposed of their device due to misunderstanding and confusion about the nature of the device return requirements. Upon further consideration and evaluation, the project team decided to still compensate the participant for their final stipend since the incident was determined to be accidental. No further issues were reported to the project team regarding device return, final compensation, or project close-out.

Study Population

The population of study vehicles (n = 24) with devices installed as of September 23, 2022 had a median age of 5 years (median model year = 2017) as shown in the chart below.



Regarding EV type, 50% (n = 12) of the vehicles in the study population as of September 23, 2022, were plug-in hybrid electric vehicles (PHEV) while 50% (n = 12) were battery electric vehicles (BEV) as shown in the pie chart below.



All vehicles were purchased by participants through their participation in a CARB-funded Low-Carbon Transportation Equity (LCTE) program.

Findings

Background on EV Charging

Most consumers use Alternating Current (AC) in their day-to-day lives as this type of power is what electric utility providers supply through the power grid. AC power is easier to transform and transmit over long distances than Direct Current power (DC).[1] Most are not familiar with the fact that small, everyday devices, like smartphones convert that AC power to DC power prior to storage in the device's battery. For EVs, this is also true. AC power must be converted to Direct Current (DC) power prior to storage in the EV's high-voltage (HV) battery. The conversion happens in the EV's on-board charger which is why charging with AC power, also known as "trickle charging" due its slower speed, takes much more time than DC fast charging, or DCFC. When EV drivers charge using DCFC they are supplying DC power directly to the EV without the need for conversion. This results in a faster charge with less wasted energy.

There is a lack of agreement within the EV sector about the effects of regular DCFC on the health and degradation of an EV's HV battery. Industry experts have reported minimal to no significant impact on battery health from regular DCFC usage.[2] However, the belief that DCFC usage results in damage to the HV battery persists. While copies of user warranties are hard to find and change regularly, anecdotal reports from online forums suggest that automakers and EV warranty providers have included language in their warranty agreements that reduce their responsibility to repair and/or replace an HV battery if an EV driver uses DCFC. Some EV drivers have also reported that their warranty claims have been denied as a result of using DCFC.

EV Battery Warranties

Virtually all new EVs come with some degree of warranty coverage on their batteries. These warranties are provided directly by the manufacturer. Furthermore, the State of California will require model year 2026 vehicles and newer to have "an 8-year/100,000-mile warranty on the battery will be required for all battery-electric vehicles."[3] There is a lack of clarity, however, amongst stakeholders as to the appropriate threshold that would trigger the need for activation of an EV battery warranty. As stated above, there are concerns with ambiguous language in warranties as well as lack of consensus on real impacts to EV battery health from charging behavior.

[1] https://wallbox.com/en_catalog/faqs-difference-ac-dc
[2] https://www.recurrentauto.com/research/impacts-of-fast-charging
[3] https://ww2.arb.ca.gov/resources/documents/cars-and-light-trucks-are-going-zero-frequently-asked-questions

State of Health and Battery Degradation

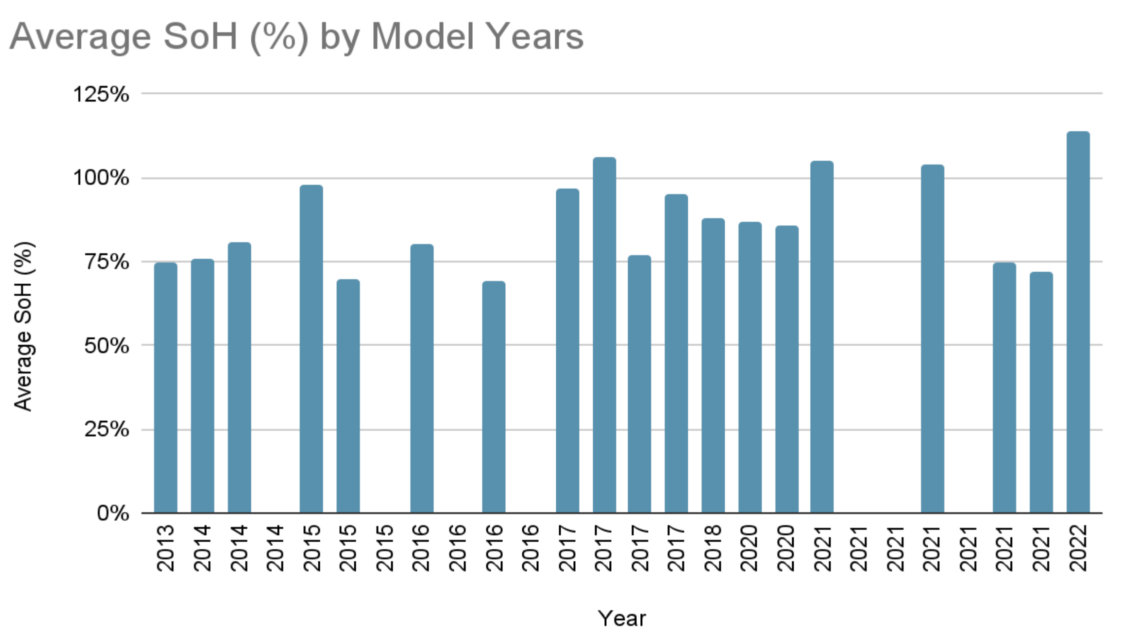
There is not a standard definition for the State of Health (SoH) of a battery. SoH refers to the "ratio of total maximum capacity (in kWh) at any given time over beginning of life capacity (or rated capacity)." [4] Battery data collected from participants' vehicles included the amount of energy in the EV battery at the start and end of a charging session (kWh). Additionally, most vehicles provided percentage estimates of battery capacity level remaining at the start and end of a charging session.

To attempt to estimate SoH, the max capacity of the battery was estimated (kWh) using the amount of energy delivered in a charging session (kWh) and the difference in capacity level reported by the vehicle (%). This value was then divided by the rated capacity of the battery to get SoH (%). The two formulas are shown below:

$$Max\ Capacity\ Estimate\ (kWh) = \frac{Energy\ Delivered\ (kWh)}{Change\ in\ Capacity\ Percentage\ (\%)}$$

$$State\ of\ Health\ (\%) = \frac{Max\ Capacity\ Estimate\ (kWh)}{Rated\ Capacity\ (kWh)}$$

Appendix A contains a table with the Max Capacity Estimate and State of Health calculations for each participant's vehicle. Some vehicles did not have SoH calculations due to factors including not charging during the study period (PHEV-only issue) and errors in the data reported from the vehicle. The results are also shown in the table below with SoH values for each vehicle ordered by model year (n = 19).



[4] https://dlt.mobi/wp-content/uploads/2023/07/MOBI-SOH0001WP2022-Version-1.3.pdf

There is a slight trend of newer vehicles having a higher SoH value which would be expected as use of the vehicle and battery factor prominently in degradation. Older vehicles, with presumably higher usage, would have more degradation and lower SoH values, on average. Additionally, some vehicles had SoH percentages that exceeded 100%. While this may be due to the fact that rated capacity represents the total energy *available* to the vehicle with additional capacity unavailable for operation of the vehicle, the more likely reason for values exceeding 100% is inconsistencies in the capacity percentage remaining reported by the vehicle's computer system. Despite inconsistencies with the data and concerns of accuracy, the overall trend is consistent with prior research.

Considering the impact such findings might have on implementing a statewide EV battery assurance program, the volume of vehicles with SoH values below 80% is an important metric to assess. Seven (7) of the vehicles with data available had SoH values under 80% while three (3) vehicles had SoH values under 75%, as shown in the chart above as well as in Appendix A. This equates to 37% and 16%, respectively.

All of the seven vehicles with SoH values below 80% were PHEVs. No BEVs had SoH values below 80%. This makes sense from a theoretical perspective as PHEV batteries are more likely to be exhausted to low energy levels and may be charged with less frequency as the battery is not the sole source of energy for the vehicle (e.g., gasoline). As stated earlier, some vehicles were excluded from the SoH calculations due to zero charging sessions during the study period. These vehicles were all PHEVs as every BEV was charged during the study period.

Furthermore, the same absolute decrease in battery capacity in kWh would result in significantly different changes in SoH (calculated as a percentage). This is due to the fact that PHEV batteries are much smaller in capacity. Thus, a reduction in capacity of 1 kWh could result in double-digit reductions in SoH for some models with capacities less than 10 kWh in total.

At first read, the finding that the risk of meaningful degradation in EV batteries is less of an issue for BEVs as compared to PHEVs may suggest there is not an immediate need for an EV battery assurance program. If all-electric BEVs have less concern of impactful battery degradation, then maybe there is not such a need for state intervention. However, utilization rates of all-electric driving modes for PHEV drivers determine the degree of climate and air quality-related benefits resulting from the operation of these vehicles. If PHEV drivers, particularly those of used models, find their battery to be impractical and rely on gas-only operation of the vehicle, then those vehicles are essentially operating as conventional hybrids without the benefit of all-electric driving.

Additional Findings

In addition to the collection of battery and charging-related data from the participants, the project team was able to gain insights into other relevant areas of concern for EV drivers, specifically those who have participated in one of CARB's LCTE programs. Through conversations and emails with participants during the recruitment and participation phases of the project, several areas of concern were identified. The following categories emerged as potentially important areas of concern for CARB to consider moving forward:

Area of Concern	Saliency*	Examples
Charging	High	*"I need info on how to fully charge it."* *"Haven't charged since receiving vehicle and don't plan to charge."*
EV Battery	Medium	*"The battery hardly has power… It drives fine, but this is the only issue."* *"I often wonder about my car's battery life. I'm ill-informed."*
Range Anxiety	Medium	*"My ev is a commuter car. I would not be able to drive to the specific locations listed above because of the distance. My car only gives me 85 miles per change."*
Financial	Medium	*Participant said that she no longer has her Volt... she got behind on payments during covid.*
Data Privacy	Medium	*Participant was very against having the device installed in her vehicle due to privacy considerations.*
Project Device	Low	*Participant asked questions about the device and if it would be visible.*
Warranty	Low	*Participant was interested but very hesitant that having the device installed in her car could void her 5 year warranty as it could be seen as a modification to the car.*

**Saliency was defined as how many times the area of concern was brought up by a prospective or confirmed participant. Low saliency = at least once; Medium saliency = at least twice but less than five times; High saliency = five or more times.*

Opportunities for State Action and Support

The following are areas of opportunity for governmental action and support regarding EV battery health and consumer confidence, especially as it relates to used EVs and low-to-moderate income drivers who receive their EVs through participation in CARB-funded programs.

Identifying and Adopting a Standard for State of Health

There is no standard calculation for assessing the state of health of EV batteries. Without such a standard, a statewide assurance program for EV batteries remains untenable. Irrespective of a statewide program, though, the lack of a standard calculation puts consumers at risk of unfair warranty enforcement practices. If automakers set the standard for how their own SoH is calculated, there is potential for methodologies that may suggest a lack of issues for EV drivers despite meaningful impacts to their lives due to reduced battery capacity. This is especially true for drivers of older EV models, who tend to be lower in income. For participants in CARB's LCTE programs, who represent communities most impacted by current and historical inequities, there is a need to provide objective, third-party support for battery-related issues. Adopting a standard methodology for calculating SoH is paramount to support EV drivers most at-risk of battery-related issues.

Repurposing and Replacing LCTE Participants' EV Batteries

When EV battery capacity drops below 70% of original capacity, the battery is considered inappropriate for continued usage in the vehicle. Most warranties and those required by California law will replace batteries with less than 80% of their original capacity. Given that many of the vehicles purchased through CARB's LCTE programs are used EVs, there is a concern that participants may inadvertently acquire vehicles close-to-or-below the 80% threshold.

A statewide assurance program could support the replacement of eligible participants' EV batteries by using program funds to pay for the procurement and installation of new EV batteries, when appropriate. Additionally, prorated payments to participants could be used to enable the purchasing of a replacement vehicle in cases where such a solution is more reasonable. In either case, the value of the used EV battery could be leveraged by the program to offset costs.

At levels below 70% of original capacity, EV batteries can still be used for many purposes including residential and small-scale commercial energy storage. Even when unusable, the batteries retain value from recyclable materials, like cobalt and lithium, that can then be extracted and reprocessed into new batteries or other products.

The California Energy Commission and the U.S. Department of Energy have funded research and development for the recycling and repurposing of EV batteries which retain a considerable amount of value at both second-life (SL) and end-of-life (EOL). However, reported challenges have included a lack of sustained feedstock or supply of used EV batteries. The statewide assurance program could support a more consistent feedstock or supply of used EV batteries for SL and EOL markets. The program could help address the feedstock issue through a sustained model of replacing vehicles and/or vehicle batteries when necessary and selling those assets to companies who work on SL and EOL EV batteries.

Equitable Workforce Development and the Right to Repair

The need for EV technicians who can work on EV batteries will increase as adoption of these vehicles increases. The program could support a more transparent, equitable, and consumer protection-oriented EV workforce by promoting third-party training and certification for EV technicians, including training for the safe removal and installation of high-voltage batteries. Most

EV drivers must go to a dealership or other location affiliated with the manufacturer of their vehicle. This is true even if they purchased the vehicle used in a secondary market. This is due, in part, to the lack of third-party training and employment for EV technicians and is compounded by a lack of standardization across battery technologies.

Some automakers have attempted to block the use of third-parties in the maintenance and repair of their vehicles. These attempts have been challenged in the judicial system as well as legislatively. The creation of a statewide assurance program for EV batteries must consider the current landscape of "Right to Repair" laws, especially California's own Right to Repair Act (SB 244) which goes into effect July 1, 2024.[5] This law will enable the creation of third-party training programs at community colleges and trade schools. By aligning an assurance program with existing EV workforce development programs and upcoming changes to repair laws, greater impact can be made to support low-income EV drivers and equitably expand this sector of California's workforce.

EV Warranties and Third-Party Assurance Programs

Newly purchased EVs come with manufacturer warranties which are required by the State of California.[6] However, the mandated warranties do not apply to older, used EVs which are the focus for CARB's LCTE programs. Extended warranties can be purchased for used EVs which could be subsidized by a statewide assurance program in lieu of providing direct assurance of its own. There are potential issues with automaker and third-party warranty and assurance programs, however. There is an incentive to decline claims, as is the case for any for-profit insurance model. Having the automaker or third-party provider conduct the evaluation of the EV battery may result in fewer approved claims and contribute to negative perceptions of EVs.

There is a need for independent evaluators of EVs and EV batteries to evaluate claims and mediate appeals, especially for participants of CARB's LCTE programs. Independent evaluation of EVs and EV batteries could be modeled off of the Bureau of Automotive Repair's Smog Check Referee Program. Participants of CARB's LCTE programs would benefit from an independent source of evaluation to determine the health of their EVs and EV batteries.

[5] https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202320240SB244
[6] https://ww2.arb.ca.gov/sites/default/files/2021-12/draft%20zev%20warranty%201962.8.pdf

Appendix A: Vehicle Population

Vehicle ID	Year	Make	Model	Battery Size (kWh)	Average Remaining Capacity (kWh)	Average SoH (%)
32057	**2013**	**Chevrolet**	**Volt**	**16.5**	**12.31**	**75%**
16436	**2014**	**Chevrolet**	**Volt**	**16.5**	**12.52**	**76%**
54386	2014	Chevrolet	Volt	16.5	13.31	81%
73057	2014	Fiat	500	24	–	–
72749	2015	Fiat	500	24	23.53	98%
04382	**2015**	**Ford**	**Fusion**	**7.6**	**5.36**	**70%**
64863	2015	Ford	Fusion	7.6	–	–
41780	2016	Audi	A3 e-tron	8.8	7.01	80%
29358	2016	Ford	Fusion	7.6	–	–
30019	**2016**	**Ford**	**Fusion**	**7.6**	**5.27**	**69%**
57411	2016	Ford	Fusion	7.6	–	–
89202	2017	Chevrolet	Volt	16.5	16.02	97%
90493	2017	Chevrolet	Bolt	60	63.67	106%
52212	**2017**	**Ford**	**Fusion**	**7.6**	**5.82**	**77%**
53926	2017	Volkswagen	e-Golf	35.8	33.84	95%
03205	2018	Nissan	Leaf	40	35.03	88%
141297	2020	Chevrolet	Bolt EUV	66	57.34	87%
147195	2020	Chevrolet	Bolt EUV	66	56.44	86%
45245	2021	Ford	Mustang Mach-E	98.8	103.84	105%
45245	2021	Ford	Mustang Mach-E	98.8	–	–
56881	2021	Nissan	Leaf	62	–	–
18193	2021	Polestar	2	75	77.79	104%
67066	2021	Subaru	Crosstrek	8.8	–	–
67707	**2021**	**Toyota**	**Prius Prime**	**8.8**	**6.58**	**75%**
77740	**2021**	**Toyota**	**Prius Prime**	**8.8**	**6.33**	**72%**
20980	2022	Chevrolet	Bolt EUV	65	74.21	114%