The Value of Fleet Management for Plug-in Electric Vehicles

Usage, Charging, and Grid Integration

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Final Project Report
Commissioned by BMW of North America, LLC
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UCDAVIS
Electric Vehicle Research Center
Institute of Transportation Studies

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Executive Summary

Project overview

The purpose of this project was to understand the adoption of zero emission vehicles (ZEVs) in California state vehicle fleets and to explore the potential to manage these fleets in a unique way such that they can support holistic microgrid and campus sustainability goals.

This was achieved through integrating ten used BMW i3 battery electric vehicles (BEVs) into several different use-cases in the University of California, Davis (UC Davis) vehicle fleet, by reviewing policies and incentives relating to electric vehicles, by conducting interviews with managers of vehicle fleets throughout California, by surveying the users of UC Davis fleet vehicles, and collecting data on the UC Davis BMW i3 vehicles and electrical grid. UC Davis is on the leading edge of fleet electrification, and provides a willing partner for understanding fleet adoption and integration challenges for BEVs that can be generalized to other University, company, and governmental fleets.

Key findings

After evaluating the normal driving patterns of sedans in the campus fleet, ten used BMW i3 EVs were placed in three different use cases: hourly rental (6 vehicles), daily rental (1 vehicle), and department assignment (3 vehicles). To familiarize UC Davis fleet vehicle users with the BMW i3 BEVs we initiated driver training and campus outreach. The outreach educated drivers how to use the vehicles and promoted them to the campus community. The training and outreach, as well as supportive fleet manager, were key to a successful launch and smooth integration.

Vehicle data collection showed that utilization of the campus BMW i3 BEVs differed based on location of the vehicles, and the application. Department assigned vehicles saw the highest utilization rates (320 mi per month on average), hourly rental vehicles saw the second highest (99 mi per month on average). The daily rental vehicle was underutilized (51 mi per month) and was reassigned to a department assignment. We believe department assigned vehicles achieved the highest utilization as drivers became more comfortable using the vehicles. Hourly rental vehicles also seemed like an appropriate application for shorter range BEVs since the trip distances are typically shorter than daily rentals.

In surveying 242 users of UC Davis fleet vehicles we discovered an overall positive experience with using BMW i3 vehicles. Renters were satisfied with the vehicles, though did suggest a lower rental cost and longer driving range as improvements. Renting a BMW i3 BEV improved drivers perceptions of BEVs and motivated them to speak about their experience to friends, family, and colleagues. This suggests a fleet of shorter-range BMW EVs could positively impact private purchasing of electric vehicles.

Through interviews of 23 fleet managers from around California we gained insights into fleet electrification. Fleets are beginning to purchase electric vehicles, especially their light duty passenger vehicles/sedans. This is largely due to sustainability goals (e.g. those set by the city or county). Barriers to fleet electrification include difficulty and lack of familiarity with installing charging, a lack of time available to evaluate and understand the applicability of electric

Cover photo: (left to right) ITS-Davis Director Dan Sperling, BMW's Monterey Gardiner, EV Research Center Project Director Dahlia Garas, UC Davis Chancellor Gary S. May, and EV Research Center Director Gil Tal, in front of one of the all electric i3 BMWs UC Davis used in this study.

vehicles to the fleet, and institutional barriers such as the requirement to purchase the lowest cost vehicle in a competitive bid process. Many fleets had begun overcoming these barriers though, especially larger fleets with more resources and time available to them. Once fleets purchase electric vehicles and begin incorporating them into their fleets they report positive experiences, though note some issues of employee acceptance, something they overcome through education and training or by assigning the vehicles to particular people/departments. Fleets are apprehensive about purchasing a used electric vehicle, first purchasing a used vehicle would be a departure from the norm, and second fleets were concerned about purchasing vehicles without warranties.

Total cost of ownership analysis shows that used BMW i3 electric vehicles can have substantially lower operating costs than new electric vehicles and new conventional vehicles, even when considering their lower utilization rates. This suggests the vehicles could deliver benefits to fleets.
Regarding the University grid and sustainability goals; smart charging strategies could be implemented for both the battery-electric bus fleet and other chargers on campus. Smart charging could allow for flexible demand and could be used in conjunction with vehicle to grid (V2G) technologies. Although currently not in place yet, smart charging for BEVs, combined with V2G technology, has the potential to contribute towards meeting campus sustainability goals.

Key Takeaways

- Fleets in California are beginning to electrify their fleets with battery electric and plug-in hybrid electric vehicles, often due to sustainability goals, though increasingly due to legislative requirements. While some barriers remain for fleet electrification, many fleets are proactively overcoming these and successfully implementing electric vehicles in their fleet.
- Assigning electric vehicles to certain departments or individuals seems to be the most preferential for achieving acceptance of PEVs and higher utilization. Fleets who operated 'pools' of electric vehicles reported continually educating their employees about the vehicles to increase use of them.
- Since fleet managers report overall positive experiences with electric vehicles (especially lower maintenance and operating costs), we expect the electrification of fleet vehicles to continue.
- While barriers to fleets purchasing used BEVs do exist these could be overcome through educating fleet managers about the benefits of used BEVs (especially on a total cost of ownership basis) and through offering warranties on the used vehicles (where possible). In addition, a simple and consistent purchase system may help encourage fleets to purchase used vehicles rather than new vehicles.
- BEVs, smart charging, and V2G technologies (including battery storage) show potential in managing the grid impacts and contributing to entities reducing operating costs and meeting their sustainability goals. However, a minimum number of vehicles are needed to provide more benefit than other grid loads such as managing requirements for campus heating, ventilation, or air conditioning.

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Task 1: Vehicle Placement & Driver Training

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Executive Summary

As fleets look to adopt plug-in electric vehicles (PEVs) in increasing numbers, there are additional challenges beyond just purchasing vehicles and charging equipment. To explore potential solutions to some of these challenges, the fleet at the University of California at Davis incorporated 10 used BMW i3 electric vehicles with approximately 80 mi (129 km) driving range into three distinct use cases. Preliminary estimates reveal significant variation in total mileage and total reservations across the fleet of BMW i3 electric vehicles (EVs) depending on the location and application of the vehicle. Consequently, even in terms of energy use, the department assigned i3 EVs with highest monthly mileage also had the highest number of charging events and energy use. Overall the study aims to demonstrate the feasibility of used PEVs in a fleet to fleet managers as well as exposing users to the technology. For user feedback, we will focus on PEV utilization and feedback data gathered from a driver survey administered in January 2020.

Key Takeaways

- Training drivers is critical to the success of EV implementation into a fleet setting and can help alleviate feelings of anxiety and increase utilization rates of vehicles.
- Conducted outreach at several campus events, and developed a trifold handout to distribute at Fleet services and have available in the vehicles as a reference.

Introduction

The University of California at Davis (UCD) has set system-wide goals of achieving carbon-neutral building and vehicle fleet operations by 2025 through adopting renewable energy sources and improving energy efficiency across the ten UC campuses. To achieve this goal, the campus fleet has integrated multiple battery electric vehicles (BEVs) into their fleet. One of the challenges to BEV adoption is the initial purchase price of these vehicles. There is also uncertainty regarding maintenance costs, infrastructure integration the utilization of BEVs compared to other fuel technologies in a fleet.

The integration of used BMW i3 EVs with approximately 80 mi (129 km) of driving range allows us to explore some potential solutions to these challenges. It also allows us to demonstrate the utility of pre-owned BEVs for other fleets considering zero-emission vehicles to satisfy policy needs but constrained by high adoption cost.

Project kick-off

The project successfully launched with pick-up of the 10 vehicles on October 25th, 2018. Over the course of approximately the next month the vehicles were maintained while the registration, license plates, and job assignments were finalized.

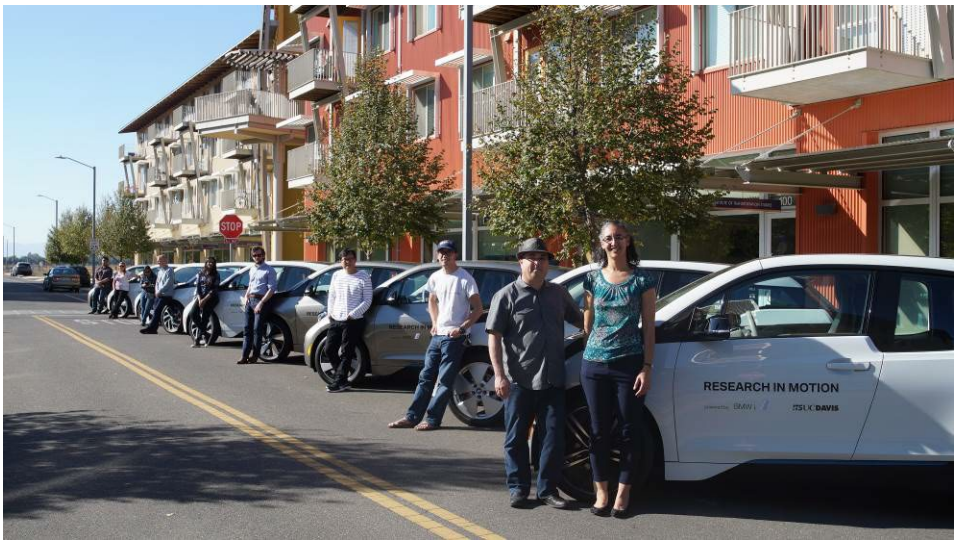


Figure 1: Pick up day on Oct. 25, 2018

On November 5th, 2018, we coordinated a photo shoot with campus Chancellor Gary S. May and Institute of Transportation Studies Director Dan Sperling, as well as BMW representative from the Palo Alto office Monterey Gardiner, and the PH&EV Center staff. This provided high quality photos to be used on websites, outreach material, and press releases coordinated with both UC Davis and BMW.

Figure 2: Samples of photos used in website, press, and outreach materials (photo credit: Karin Higgins, UC Davis)

On Dec. 5th, the campus published the project press announcement on our Climate Change website https://climatechange.ucdavis.edu/news/uc-davis-takes-10-electric-cars-on-extended-test-drive/ ITS website and social media pages, and the campus facilities news website https://facilities.ucdavis.edu/news/ucdrive-research-motion

The project was covered by several news outlets, including, but not limited to:
InsideEVs.com on Dec. 9, 2018.
https://insideevs.com/news/341446/uc-davis-to-study-how-to-integrate-evs-using-10-bmw-i3/

The ElectricCarsReport.com on Dec. 8, 2018
https://electriccarsreport.com/2018/12/uc-davis-takes-10-bmw-i3-evs-on-extended-test-drive/

The BMWblog.com on Dec. 7th, 2018
https://www.bmwblog.com/2018/12/07/bmw-loading-10-pre-owned-i3-cars-to-uc-davis-for-18-months/

Vehicle Allocation in the Campus Fleet

After evaluating the normal driving patterns of the sedans in the campus fleet, ten used BMW i3 EVs were placed in three different use cases as part of the campus fleet where fleet managers and researchers expect that they would be able to satisfy most of the daily driving

needs. Figure 1 and 2 below shows the allocation (time and purpose/location) of the ten BMW i3 EVs in the UC Davis campus fleet.

The i3 EVs were integrated into the fleet between Dec 2018 and May 2019 based on the deployment of charging infrastructure and departmental need. Six of the ten vehicles are now placed in an hourly rental application called UC Drive, and are available to rent on-demand for official use by any campus staff through either a website portal or phone application. All sedan-type vehicles are rented at the same rental rate, which varies by rental duration rather than powertrain type. The i3 EVs are rented at the same rate as diesels, plug-in hybrid electric, battery electric vehicles, and a variety of options are available at the three locations where the i3 EVs were initially placed. The campus does not operate any conventional Internal Combustion Engine (ICE) sedans in our fleet anymore. The rental cost details are specified in section of the report on Task 7 the vehicle cost analysis. The remaining four vehicles are placed in department assignments for exclusive use by specific departments who rented the vehicles on a monthly basis. Over the course of the project, researchers tracked utilization and adjusted the vehicle assignments if needed. For example, one of the i3 EVs was initially placed with the UC Davis Transportation Services (TAPS) but reallocated after 9 months due to a previous order of new pick-up trucks arriving.

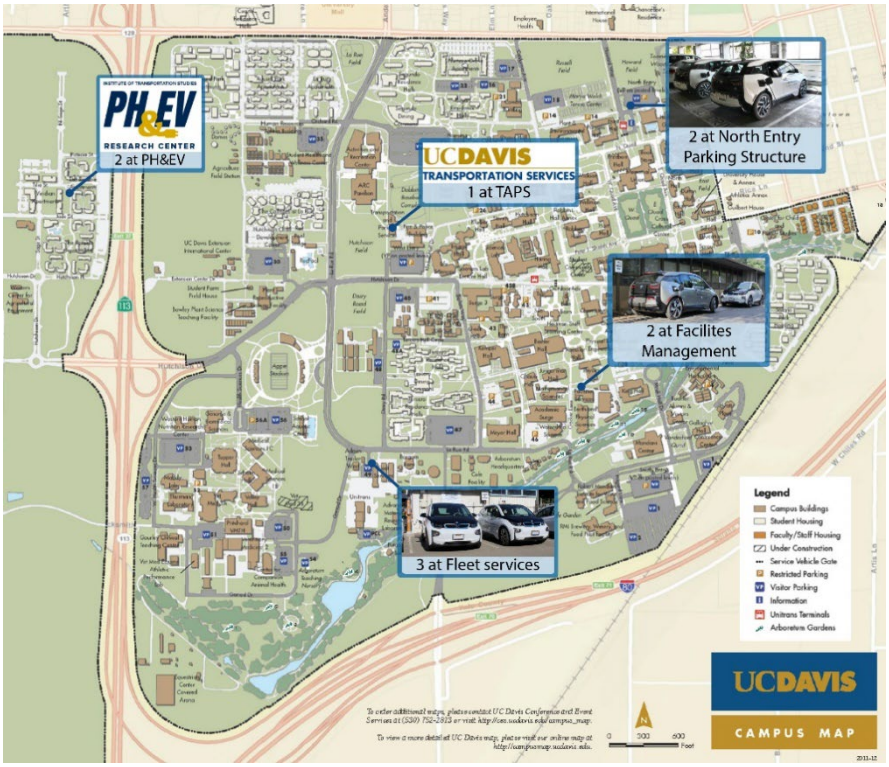


Figure 3: location of BMW i3 EVs in the three UC Drive locations, and fleet services daily rental location

Over the course of tracking vehicle utilization monthly, we learned that the hourly rental use case was the least frequently used and had the lowest monthly mileage. We were able to reassign this i3 into a departmental use case, which has led to much higher monthly utilization. Figure 4 below shows the location of the vehicles between hourly (UC Drive), daily (Fleet Services), and monthly rental assignments.

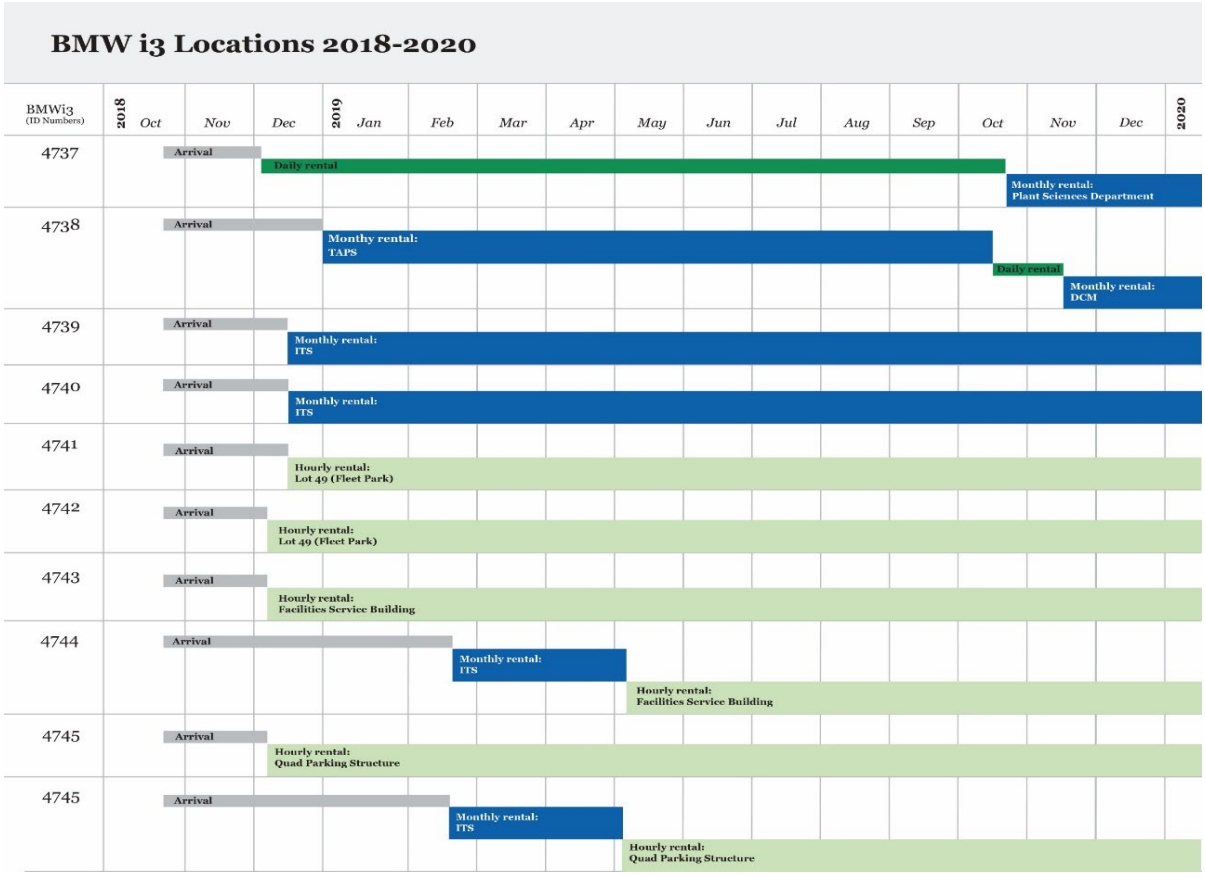


Figure 4: Timeline of vehicle integration

The two vehicles i3 EV- 4744 and i3 EV-4745 were delayed in their deployment into the UC Drive role they were expected to go to while we were waiting for infrastructure deployment. Initially they were at fleet services and available for daily rental. However, we realized that they were not being regularly used, so the Institute of Transportation Studies and the Energy and Efficiency Institutes used those two vehicles, in addition to the originally assigned i3 EV- 4739 and i3 EV- 4740 for approximately 2 months until the infrastructure was ready for their deployment into UC Drive.

2019 Total Travel	2019 Assignment (approx. months)	mi	km
i3 EV-4737	10 months- daily rental,2 months- monthly	721	1161
i3 EV-4738	11 months- monthly rental, 1 month- daily	2796	4499
i3 EV-4739	12 months - monthly rental	3206	5160
i3 EV-4740	12 months- monthly rental	6008	9669
i3 EV-4741	12 months- hourly	1164	1873
i3 EV-4742	12 months- hourly	1169	1882
i3 EV-4743	12 months- hourly	1400	2253
i3 EV-4744	2 months unused, 2 months monthly, 8 months hourly	1480	2382
i3 EV-4745	12 months hourly	1680	2704
i3 EV-4746	2 months unused, 2 months monthly, 8 months hourly	724	1165

Table 1: Total mi/km driven per vehicle in 2019

The total mi or km driven in 2019 is shown per vehicle, with the approximate months in each assignment in Table 1 above. It clearly shows that the vehicles in monthly assignments had the highest mileage on an annual basis for 2019.

Driver Training and Campus Outreach

The PH&EV Research Center developed informational handouts to announce the addition of the BMW i3 electric vehicles to the campus fleet and share information on the UC Drive program and specific information on i3 operations with potential campus users. We conducted outreach at the Research Expo on April 10, and the Campus Picnic Day event both in West Village and the Main Campus on April 13th. The introductory materials were distributed in UC Drive vehicles, at Fleet Services, and through outreach events, and are shown in **Figures 5** and **6** below. The PH&EV Research Center also developed a short introductory video which was featured on the Fleet Services website as well as ITS website and YouTube channel (https://youtu.be/rqIdg8HtklU).

Figure 5: First page of the tri-fold information handout on the i3's in UC Davis' fleet

Turning on and off the car

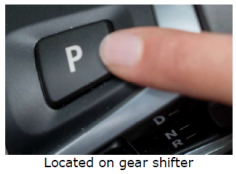
You don't need to insert the key into the vehicle, just press the Start/Stop button while your foot has pressure on the Brake pedal. The car is ready to drive when you see "READY" on the dashboard. The red parking brake light on the button in the Center Console will be on if the parking brake is set. Push down on the button to release the parking brake, and pull up gently to set the parking brake. To put the car in gear, just twist the knob on the gear stick to the right of the steering wheel to the appropriate gear, "Drive", "Neutral", or "Reverse" while keeping your foot on the brake.

Driving the car

Since this is an electric car its driving range is shorter than a typical gasoline car. We recommend not driving more than 60 miles total before recharging. This means the car is excellent for driving around Davis, Sacramento, Sacramento Airport, Vacaville, Woodland, Winters, Dixon, and the surrounding areas. We don't recommend taking this car further afield, for example to the bay area, unless you are experienced with using DC Fast Chargers.

Check Range

To see how much range you have in the car please look at remaining mileage bar under the speedometer.



Located on gear shifter

Located on center consolle

Stopping and Parking the car

To enter the "Park" gear, press the button on the top of the gear stick labeled "P". To engage the parking break pull up on the Parking Brake lever in the Center console. To turn the vehicle off press the "Start/Stop" button once with your foot on the brake pedal. The first push of "Start/Stop" will leave the vehicle accessories on. Don't worry if the radio or air conditioning is on when exiting the car, once you lock the car these will turn off. To completely turn off the car before exiting, remove your foot from the brake pedal and press the "Start/Stop" a second time.

Charging

Since this is an electric car it doesn't need gasoline to run, but it does need to be plugged in to electricity to charge. Please plug-in your vehicle at the end of your trip to ensure it is charged and ready for the next driver. When the vehicle is unlocked, simply press on the small door to reveal the charging port, which is on the rear-passenger side of the vehicle (it looks just like a gas filler cap). Remove the plastic cap and plug in the charger. The vehicle has a little white trim around the charge port that will light up blue when it is actively charging. Lock the vehicle after charging has begun.

If the charging door wont open when you press it, it is because the car is still locked. Make sure the car is unlocked and push the fuel door in gently.

Light around charge port

- Flashes yellow: charging process is being initialized
- Blue: charging process is started at a set time.
- Flashes blue: charging process active.
- Green: charging process completed.
- Flashes red: fault in the charging

Figure 6: Second page of the tri-fold information handout

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Task 2: Overview of Electric Vehicle Fleet Incentives & the Fleet Vehicle Market in California

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Executive Summary

In 2017 fleets in the US (which includes commercial fleets, government fleets, and rental fleets) purchased 2.53 million vehicles, though this was a slight decline vehicles fleets are a substantial portion of the US vehicle market. The state of California has 38,000 vehicles and a number of additional vehicles in private fleets. Additionally, the vehicles are driven more than private vehicles. Converting fleet vehicles to low and zero emission vehicles is an important aspect of the electrification of the transportation system.

This paper provides an overview of the market share of fleet vehicles in the U.S. as well as providing an outline of the various electric vehicle incentives that are available to fleets throughout the State of California.

This includes incentives for vehicle purchases as well as subsides for California electric vehicle charging infrastructure. Vehicle purchase incentives vary from a few thousand dollars for light-duty vehicles, to over a hundred thousand dollars for the electrification of heavy-duty vehicles. Fleets purchasing light duty vehicles can benefit from the up to $7,500 federal tax credit (if they have a tax liability). In California fleets can use the Clean Vehicle Rebate which offers between $750 to $4500 off the purchase of a light duty electric vehicle (with a maximum of 30 rebates per fleet per year). Incentive amounts for charging station incentives, vary from a few thousand dollars per Level 2 charging station to tens of thousands of dollars for DC fast charging stations. Additionally, given the recent focus that state agencies have placed on creating mandates for cleaner fleet vehicle purchases, the most prominent and upcoming regulations are discussed in the final section of this report. This includes an overview of SB 498 which directs CARB to provide recommendations for increasing ZEV purchases in fleets and directs the Department of General Services (DGS) to ensure at least 50% of state-owned light duty vehicle purchases each year are ZEVs by 2025.

Key Takeaways

- Compared to other nations (especially those in Europe) the fleet vehicle market is smaller in size. Most fleet vehicles are operated by public or private organizations. Fleet company cars are not prominent in the United States or California.
- There are 2.5 million fleet vehicle sales per year in the United States. Total vehicle sales are 17 million per year.

- Federal and State organizations are incentivizing EV purchases. The largest incentives include the US Federal Tax Credit (up to $7,500) and California clean vehicle rebate (up to $4,500).
- Incentive programs are also available for the purchase and installation of electric vehicle charging equipment.

Electric Vehicle Market Potential – Overview

In 2017, government, commercial, and rental fleets in the U.S. purchased 2.53 million vehicles, including 1.64 million in the truck category and 897,123 passenger cars [1]; accounting for approximately 37%, 38%, and 25% of the fleet vehicles respectively. Focusing on government fleets, in California, the Department of General Service (DGS) Office of Fleet and Asset Management (OFAM) offers state agencies with variety of asset management services including cost-effective vehicle purchase contracts. OFAM is also responsible for implementing statewide fleet policies, collecting vehicle related data, and approving fleet acquisition plans. As part of the State Fleet Asset Management program, OFAM promotes purchase and use of alternative fuel vehicles in the state's fleet. Some of the statewide fleet policies/regulations that the OFAM (DGS) is responsible for implementing include:

(1) *2016 ZEV Action Plan*: Issued in October 2016, the Plan: 1) requires that 50 percent of all state agency light-duty vehicle procurements be ZEV by 2025 (SB 498); 2) directs state agencies, in coordination with DGS, to install electric vehicle charging stations to comprise a minimum of 5 percent of all workplace parking spaces at state-owned facilities, and 3) directs DGS to evaluate and update Executive Order B-16-12's ZEV purchasing exemption for public safety vehicles with special performance requirements to ensure that ZEVs are integrated into public safety mobile assets under all feasible circumstances.

(2) *State Administrative Manual Sections 4121 – 4121.6*: institute a "ZEV and hybrid vehicle first" purchasing policy and increase the ZEV purchasing mandate annually by 5 percent so that it will be 50 percent by 2025. The "ZEV and hybrid first" purchasing mandate requires departments to purchase light-duty vehicles according to the following priority structure, when available on the statewide contract: (1) pure ZEVs, (2) PHEVs, and (3) hybrids.

To explore the potential market for used Plug-in Electric vehicles (PEVs) in fleets, the DGS fleet vehicle data from 2011 to 2017 is analyzed here. The total size of the DGS fleet between 2011 and 2017 was approximately 38,000 vehicles.[1] Figure 7 shows the distribution of different vehicle types in the California government fleet (as reported to DGS) for 2011-2014 and 2016-2017. While the use of the purchase contract (vehicle price and other conditions) offered by DGS is mandatory for state departments, it is optional for local governmental agencies like city councils, the California State Universities (CSUs) and

[1] DGS data on fleet vehicle purchase/lease transactions for state fleets is not publicly available for the year 2015. Also, from July 2015, data reporting to DGS is optional for campuses via the Fleet Asset Management System (FAMS). https://www.calstate.edu/cpdc/suam/SUAM9171.pdf

University of California (UC) system[2]. The latter can purchase vehicle from other vendors offering more competitive pricing options. The analysis presented below however, includes the set of vehicles purchased by DGS for some of the California State University campuses.

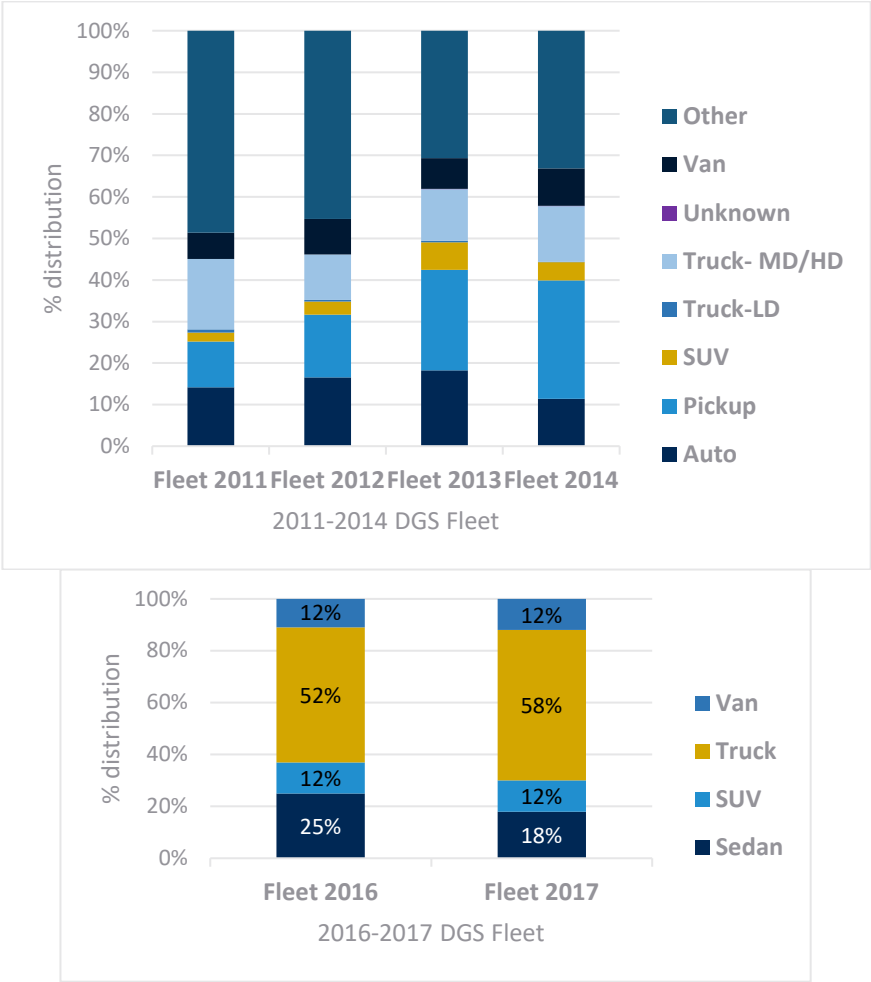

Figure 7: Distribution of vehicle types in the DGS Fleet

(Note: The other category includes off-road vehicles and equipment, buses, and motorcycles. In the fleet data for 2016-17, there is no distinction in terms of types of trucks and pickups and there is no information on off-road vehicles and equipment).

The share of sedans/autos in the fleet fluctuated between 11% and 18% between 2011 and 2014. It increased to 25% in 2016 but went back to 18% in 2017. The share of SUVs went up from 4% in 2014 to 12% in 2017. Considering the vehicle models available in the market at present, it is the car and SUV segment (in 2017, the combined share in the fleet was 30%) that will most likely be electrified to meet the regulatory requirements for state fleets. Vans were 9% of the fleet in 2014 but increased to 12% in 2017. Trucks had the highest share in the fleet. As automakers introduce in the market more vehicle models in the van and light-duty truck (LDT) segment, it should offer more options to the fleet manager to incorporate PEVs into their fleet to meet the SB 498 requirements.

[2] https://sacramento.granicus.com/MetaViewer.php?view_id=22&clip_id=4374&meta_id=550831

Though internal combustion engine (ICE) vehicles are approximately 90% of the fleet, other fuel types are also purchased or leased by fleet managers. **Figure 8** gives the distribution of alternative fuel vehicles (including conventional hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), battery electric vehicles (BEVs), and hydrogen fuel cell electric vehicles (FCEVs) in the DGS fleet for the periods 2011-2014 and 2016-2017 respectively. For Figure 9, off-road vehicles/equipment, bus, motorcycle, and unknown passenger vehicles are not considered in the share calculation.

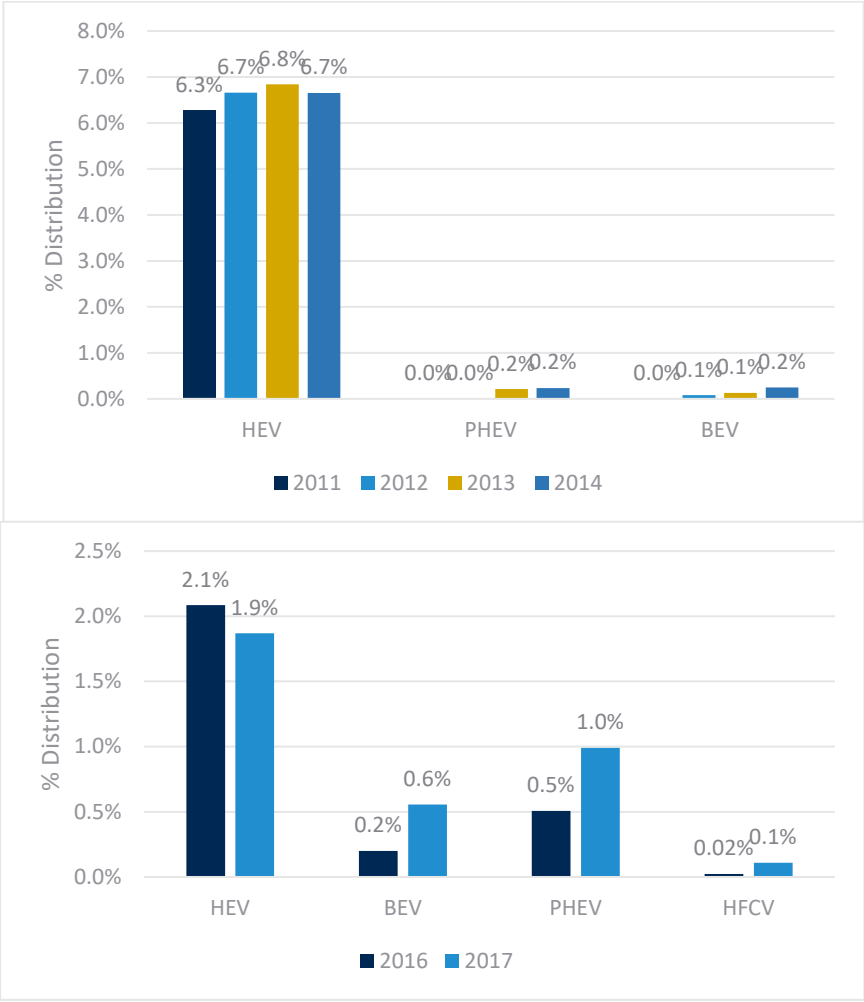

Figure 8: Distribution of Alternative Fuel Types in the DGS Fleet

DGS OFAM has a list of alternative fuel vehicles by make and model in each vehicle segment (sedan/cars, Vans/SUVs, and Trucks) that are available for purchase through the State of California contract. A majority of the alternative fuel vehicles (PEVs and conventional hybrids) are available for purchase through the state contracts and are part of the sedan/cars and Vans/SUV categories. Considering only these two vehicle segments, the market share is as follows: HEVs 6.3%, BEVs 1.9%, PHEV 3.3%, and FCEV 0.4% in 2017 (Figure 9).

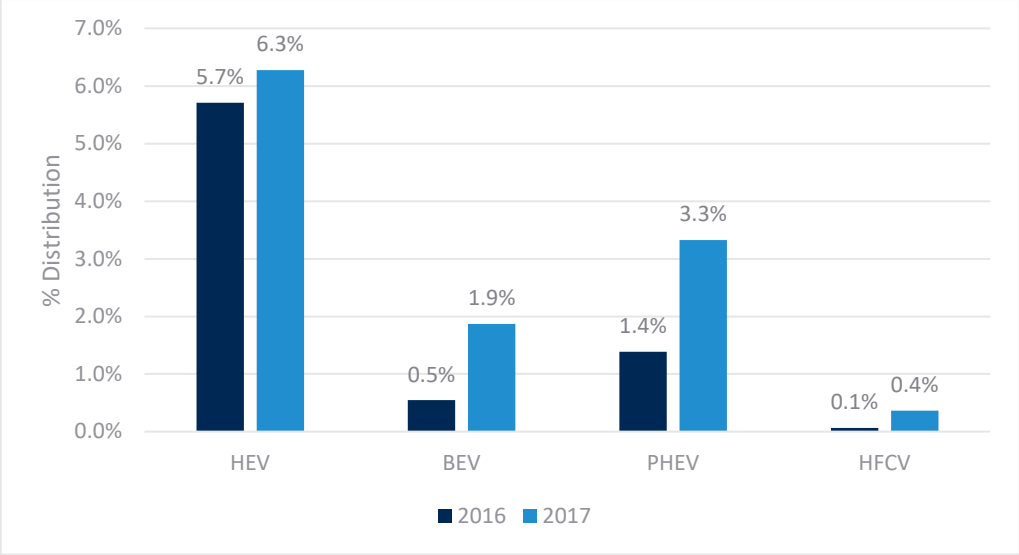

Figure 9: Distribution of Alternative Fuel Types in the Sedan and SUV Category (2016-2017)

The breakdown of vehicle models in the PHEV, BEV, and HEV fleet of DGS for the years 2011-2014 and 2016-2017 are given in **Figure 10** and **Figure 11**. In the HEV segment, the Toyota Prius has the highest share. The Chevrolet Volt constitutes on an average 88% of the PHEV fleet owned or leased by DGS while for BEVs, the Nissan Leaf has the highest share.

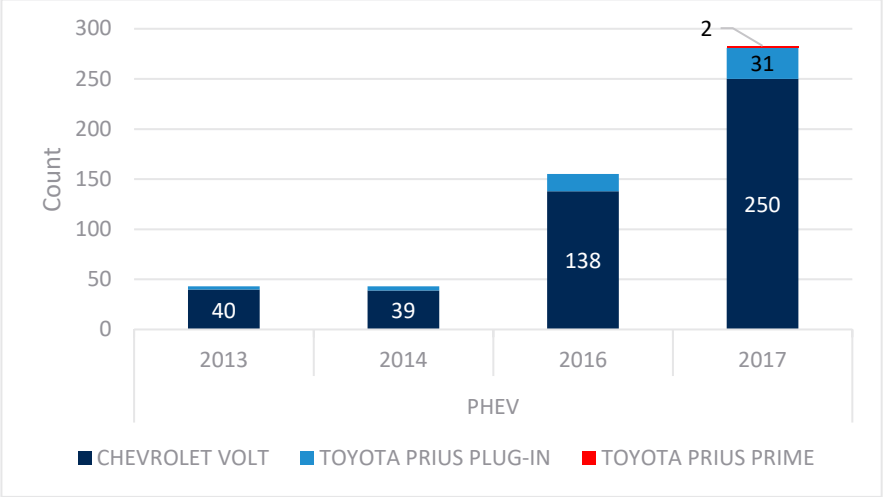

Figure 10: Breakdown of PHEV models in the DGS Fleet

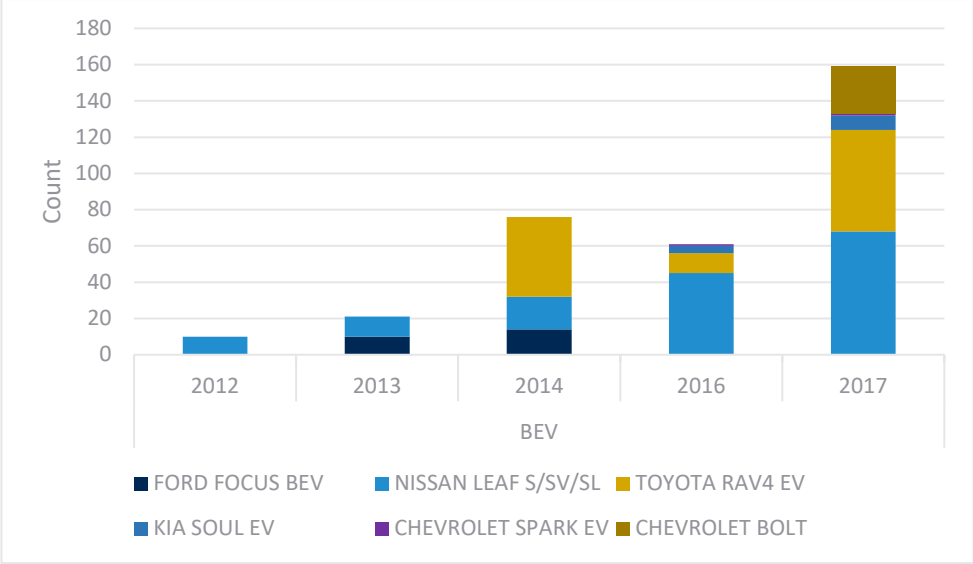

Figure 11: Breakdown of BEV models in the DGS Fleet

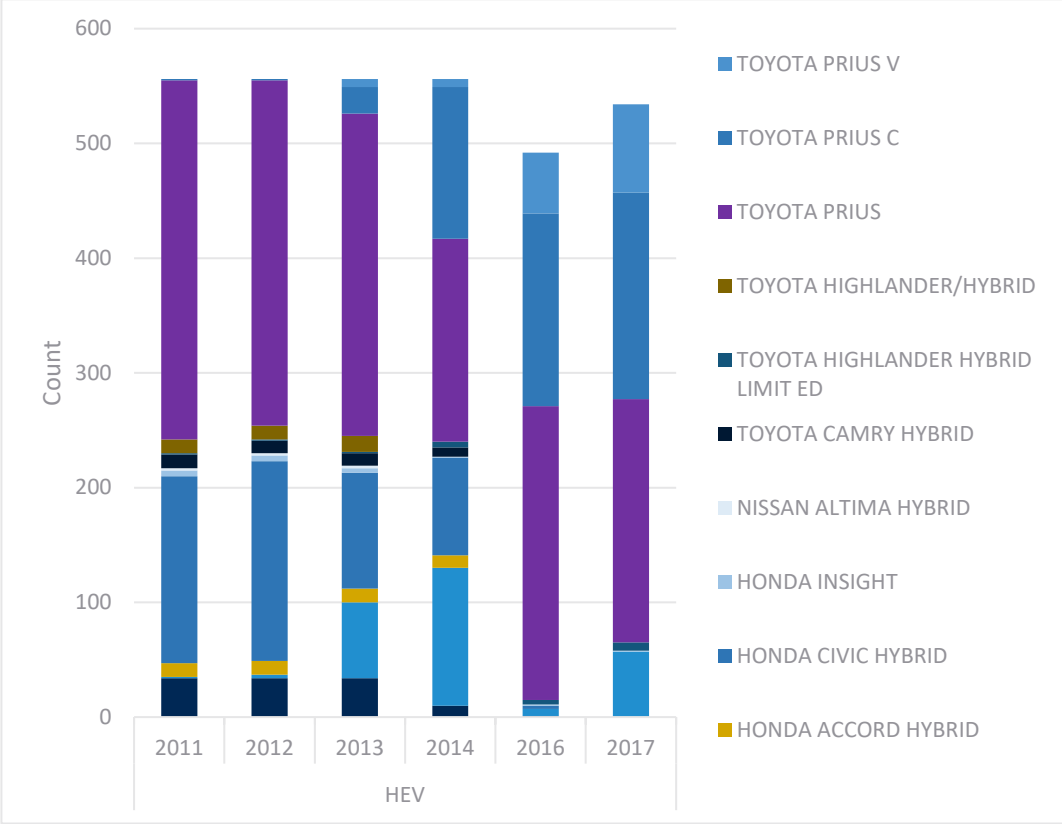

Figure 12: Breakdown of vehicle models in the HEV Fleet

Use of Alternative Fuel Vehicles

The figures below show the annual vehicle miles traveled (VMT) by fuel category for the 2011-2014 and 2016-2017 reporting period. The two sets of data are graphed separately because the former includes both on-road and off-road vehicles/equipment and the classification of the on-road vehicles are different. The average annual VMT for gasoline vehicles is not shown in Figure 13 due to the uncertainty of the vehicle types that are included in the non-alternative fuel vehicle segment in the 2011-2014 fleet data. **Figure 14** a comparative analysis of average annual VMT in the 2016-2017 reporting period for all the

alternative fuel types as well as the ICE vehicles in the DGS fleet. To calculate the annual VMT for the 2011-2014 reporting period (Figure 13), only vehicles of model years 2010-2015 are considered. For Figure 14, we include the five most recent model years.

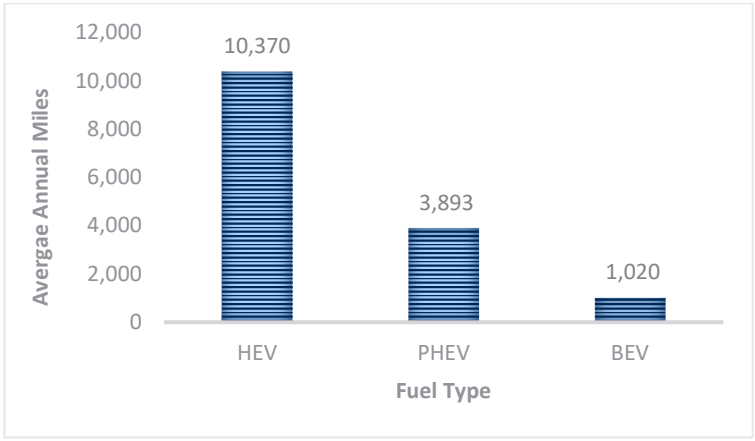

Figure 13: Annual miles driven by fuel category (using 2011-2014 fleet data)

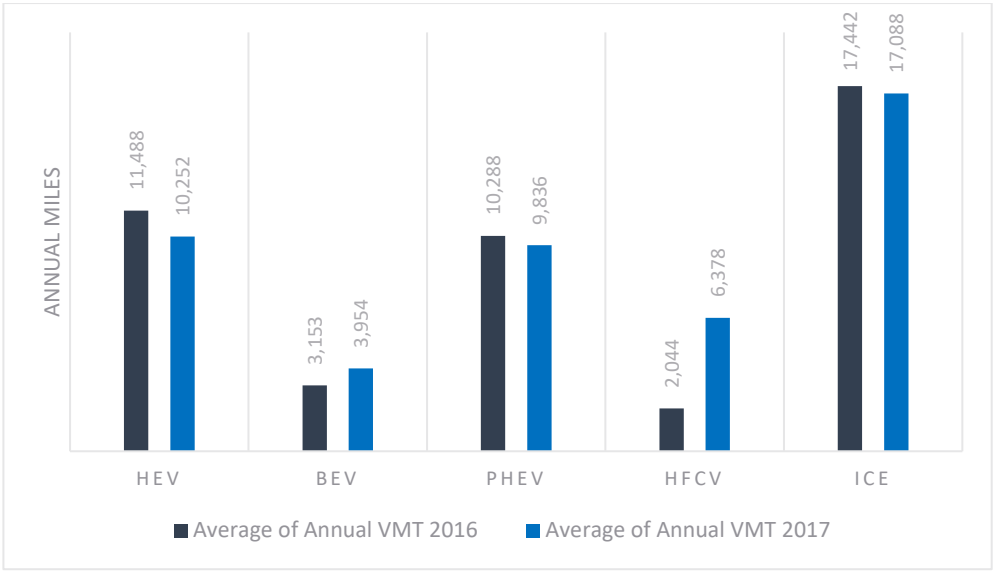

Figure 14: Annual VMT by fuel category (using 2016-2017 fleet data)

From 2016 to 2017 VMT decreased for all vehicles using gasoline, and only increased for all electric and hydrogen cars. Among the alternative fuel vehicles, the VMT for HEVs is highest followed by PHEVs. BEVs were driven more in 2017 compared to prior years, possibly because of the inclusion of higher range vehicles like the Chevrolet Bolt into the fleet.

In general, over the past few years state fleets have been increasing the share of PEVs in their fleet to meet the state policy goals. Since government fleets in California purchase vehicles following the list of vehicles available through State of California contract either using the purchase contract provided by DGS or a vendor offering the most competitive price, used PEVs can be a financially attractive option if available. Also, as the VMT analysis indicates, the use of PEVs in fleets, particularly BEVs is connected to the electric range of the vehicle. Thereby, if used PEVs with longer electric range (comparable to Chevrolet Bolt) are available for a competitive price, used PEVs can become a feasible option for fleets.

Electric Vehicle Fleet Incentives Overview

This section of the paper provides an overview of fleet incentives offered around the state of California and considers the Federal incentives which are most relevant for fleets in the state. The paper is divided into three main sections, the first of which is incentives for vehicle purchases, next the incentives for supporting electric vehicle charging infrastructure are discussed, followed by a discussion of fleet regulations in the state. The first section begins with an overview of the Federal incentives, followed by those offered by the State of California, and local municipalities. The second section provides an overview of incentives offered by the state as well as utilities. Finally, the paper concludes with a section on various policies and regulations that are currently being discussed and may affect the makeup of vehicle fleets going forward.

Note: For clarity, in this task, programs that apply to cars and SUVs are denoted with a *, those that apply to trucks and/or buses are denoted with **, and programs that apply to both of these vehicle types are denoted with ***.

Incentive Name	Agency	Specification	Number	Funding Amount	Project Funds	Details
Tax Credit	Internal Revenue Service (IRS)	New	No Limit	$2,500-$7,500	-	Rolling funds
Low or No Emission Vehicle Program	Federal Transit Administration	New, Used, Repower	No Limit	Varies	At least $55 Million/ year	Yearly allocation
Clean Vehicle Rebate Program (CVRP)	California Air Resources Board (CARB)	New	Up to 30 vouchers	$750-$7,000	$130 Million	Yearly allocation (max 30 per year for public fleets)
Hybrid and Zero Emission Truck and Bus Voucher Program (HVIP)	CARB	New	Up to 200 vouchers	$12,000 to $315,000	About $140 Million	Yearly Allocation
Transit and Intercity Rail Capital Assistance Program (TIRCP)	CalTrans	New	Varies	Varies	Estimated $450-500 Million	Funding historically increases in each phase
Low Carbon Transit Operations Program (LCTOP)	CalTrans		Varies	Varies	Varies	
School Bus Replacement Program	California Energy Commission (CEC)	New	Up to 10	Full bus costs	$75 Million	One-time allocation
Carl Moyer Program	CARB	New, Used, Repower	Varies	Varies	$60 million	Yearly Allocation
EV Fleet Rebate Program	Transportation Authority Marin	New and Used	Up to 5	Match for CVRP	Varies	Yearly Allocation from Registration Fees
Clean Fleets Program	Bay Area Air Quality Management District (BAAQMD)	New	10 or more	$1,000 to $5,000 per vehicle	$5 million	
On-Road Heavy-Duty Vehicles Program	BAAQMD	New, Used, Repower	Up to 85% of eligible costs	Up to $200,000		
Heavy-Duty Truck Replacement Program	San Joaquin Valley Air Pollution Control District (SJVAPCD)	New, Used	Up to $500,000/ entity/ year	$10,000 to $200,000	About $73 million	Increases as funds become available
New Alternative Fuel Vehicle Purchase Public Benefit Grant Program	SJVAPCD	New	Up to $100,000/ year	Up to $20,000 per Vehicle	Over $24 million	Increases as funds become available

Drive Clean! Rebate Program	SJVAPCD	New		$1,000 to $3,000	More than $19 million	Increases as funds become available
California Electric Vehicle Infrastructure Project (CALeVIP)- Southern California	CEC	DCFC	1 to 4 chargers/ site	$40,000 to $80,000	$29 Million	One-time allocation
CALeVIP – San Joaquin Valley		Level 2 or DCFC	4-10 ports/ site	$3,500 to $10,000	$15.3 Million	One-time allocation
CALeVIP - Sacramento		Level 2 or DCFC	$640,000	$5,000 to $80,000	$14 Million	One-time allocation
Electric Vehicle Charging Station Financing Program (EVCS)	California State Treasurer's Office	-	-	Up to $500,000 loan	-	
EV Fleet Program	Pacific Gas & Electric Co. (PG&E)	Level 2 or DCFC		Up to 50% of the costs up to $42,000	$236 million	One-time allocation
New commercial rate class	PG&E	-	-	-	-	-
Charge Ready: Business	PG&E	Level 1 or Level 2	Minimum 5 (DAC) or 10 (other)	Up to $4,376	Phase 1: $22 million Phase 2: $760 million	One-time allocation
Charge Ready: Transit	Southern California Edison (SCE)	Level 1 or Level 2	Varies	Up to $4,376		One-time allocation
ChargeUp LA!	Los Angeles Department of Water and Power	Level 2 or DCFC	Up to 40	$5,000 - $125,000	$2 million	One-time allocation
Commercial Charger Incentive Program	Pasadena Department of Water and Power	Level 2 or DCFC	Up to $50,000	$1,500 - $6,000		
EV Charging Discount	Alameda Municipal Power	-	No Limit	50% of the metered kWh	-	-
Zero Emission Airport Shuttle Regulation	CARB	100% ZEV by 2035	-	-	-	-
Light-Duty Fleets for State Vehicles	CARB	50% of new purchases by 2025		-	-	-
Innovative Clean Transit	CARB	100% by 2040	-	-	-	-
Proposed: Clean Miles Standard	CARB	Pending	-	-	-	-

Federal	State	Utility	Local

Table 2: Expanded Summary of California Fleet Incentives

Vehicle Rebates: Federal

Federal Tax Credit *(Car and SUV)

The electric vehicle tax credit offered by the federal government can be used for fleet applications under certain circumstances. For BEVs, the rebate is $7,500 and for PHEVs, the base rate for this incentive is $2,917 for vehicles with a battery capacity of at least 5 kWh, with an additional $417 for each additional kWh of capacity, up to a total of $7,500 per vehicle. This incentive is distributed as a liability against a company or individual's tax burden, so government agencies, non-profits, and other non-tax liable entities need to have the credit claimed by the vehicle's seller, who would then use the credit to lower the price of the vehicle for the purchasing entity [2].

Additionally, the credit can be claimed by businesses that operate in the United States, who are expected to claim about half of the funds distributed from the federal tax credit annually. This estimate includes instances where the sellers are claiming the credit for vehicles that are sold or leased to tax exempt entities. In instances where the vehicle is used partially for business and partially for personal use, the rebate amount is determined through the percentage of total miles driven for businesses multiplied by the total credit amount. The remaining funds are claimed for personal use. While the personal rebate must be claimed all at once, and cannot exceed tax liability for the year, the business tax credit can be rolled over to the next year if the entire credit is not claimed, which can be done for up to 20 years. There has not been any defined limit to the number of vehicles that can receive the federal tax credit per business [3].

Notably, this tax credit begins to phase out once a vehicle manufacturer has reached sales of 200,000 eligible vehicles in the US. This phase out period occurs over a one-year period beginning in the second quarter after this limit has been reached. In the first two quarters, the rebate is reduced to 50% of the original amount, and in the following two quarters it is reduced further to 25% of the original amount. Following this, vehicles sold by this manufacturer are no longer eligible for the federal tax incentive. As of the first quarter of 2020, the tax incentives for vehicles sold by both Tesla and General Motors have been phased out.

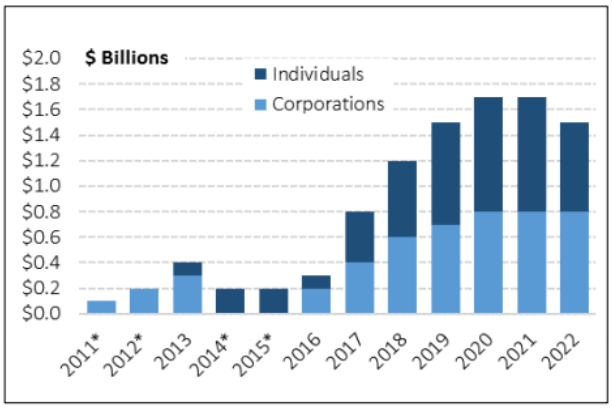

Figure 15: Estimated Tax Expenditures for the $7,500 Plug-In EV Tax Credits, FY 2011-2022

Local Government Electric Vehicle Fleet Project(Car and SUV)*

In 2017, this pricing method was used by the County of Alameda, who was able to successfully put out a bid for the procurement of 90 electric vehicles on behalf of ten different county and municipal public fleets. The Alameda County General Services

Agency conducted a single bid and evaluation process for three different PEV types; sedans that can utilize Level 2 charging, sedans that can use DC fast charging (DCFC), and electric cargo vans. In total, they were able to purchase 64 Ford Focus EV sedans for $31,361 each, and 23 Nissan Leafs for $33,947 each, as well as facilitating the procurement of PEV charging stations for these vehicles, and their associated installations [4].

The participating vendors were encouraged to claim the federal "qualified Plug-in Electric Drive Motor Vehicle Tax Credit," and then pass the value of the credit on to participating agencies to make their bid more competitive. These tax incentives are not directly available to government fleets, but can be claimed by, "the seller of a qualified plug-in electric drive motor vehicle… to tax-exempt organizations, [or] government unit… [4]." Only one of the bidders, Hansel Ford, utilized the tax discount as many lacked familiarities with the federal tax credit as well as the risk of receiving the credit after the vehicles were delivered. Some companies also had insufficient tax liability to be able to claim the rebates for these vehicles [4].

Jurisdiction or Agency	Vehicles Purchased
County of Alameda	26
Sonoma County	22
Sonoma County Water Agency	5
City of Santa Rosa	4
City of San Francisco	14
City of Concord	10
City of San Jose	3
City of Oakland	3
City of Fremont	2
Transportation Authority of Marin	1

Table 3: Number of Vehicles Purchased Under the Alameda County PEV Procurement Scheme

Dealer	Vehicle Type	Model	Number	Bid Price
Hansel Ford (Santa Rosa, CA)	Electric sedan (Level 2)	Ford Focus	64	$2,007,104 ($31,361/vehicle)
Gilroy European (Gilroy, CA)	Electric sedan (DC fast charge capable)	Nissan Leaf	23	$780,781 ($33,947/vehicle)
Zenith Sales (Indianapolis, IN)	Electric Cargo Van	Zenith Cargo Van	3	$289,800 ($96,600/vehicle)

Table 4: Bid Prices for Selected Dealerships Under the Alameda County PEV Procurement Scheme

Low or No Emission Vehicle Program**(Truck &/or Bus)

The Low or No Emission Vehicle Program operated by the Federal Transit Agency provides funding for state agencies, local governmental authorities, and Native American tribes to purchase or lease zero and low emission transit buses. While these buses can run on propane or compressed natural gas, hydrogen fuel cell and electric buses tend to result in greater emissions reductions and are therefore more likely to be funded [5]. Through 2020, a minimum of $55 million per year is available to support this program, which can be used to help cover up to 85% of the costs of the bus purchase, and also up to 90% of the costs associated with the charging or refueling facility construction, maintenance, workforce development and training, and administration expenses. The program seeks to maximize the number of projects that they can fund, so some projects receive only part of the funds requested, although there is no specific maximum funding amount [6].

Vehicle Rebates: State

Clean Vehicle Rebate Program*(Car and SUV)

California public agencies, businesses, car share fleets, and rental fleet operators can utilize the California Clean Vehicle Rebate Program (CVRP) to reduce the purchase price of a PEV. Public agencies can utilize the rebate for up to 30 vehicle purchases annually, with rental and car share fleets allocated up to 20 rebates per year, and private businesses limited to 1 rebate total. Public agencies include the Regents of the University of California, the Trustees of the California State University and California State Universities, counties, cities, districts, public authorities, public agencies, and any other political subdivision or public corporation in the state, including tribal government entities based in California. Table 5 below shows the rebate amounts which vary between $750 and $4,500 per vehicle based on the qualifying technology. Additionally, for fleets who operate in disadvantaged community census tracts, the rebate amount is increased by $2,500 per vehicle. Eligibility for the increased incentives depends on the primary location where the vehicle is owned and operated [7].

Public entities can only receive the CVRP on leased vehicles if they have a minimum lease term on the original agreement of greater than or equal to 30 months. Eligible applicants can apply for the rebate up to 3 months after it is purchased [7]. Remaining in compliance with the program after funds are received requires the fleet owner to retain ownership of the vehicle in California for a minimum of 30 consecutive months immediately after the vehicle purchase date. These vehicles must be purchased new and cannot have previously been registered out of state, although they can be either purchased or leased. Only 30 rebates are available per public fleet each calendar year, and they are not eligible for the reduced ownership provision [8]. Other fleets have different limits to the number of vehicles that are eligible for a rebate, and these are shown in Table 5.

The program's reduced Ownership Period Provision for Rental and Car Share Fleets states that rental and car share vehicles are eligible for the rebate if they are retained in California for a minimum of one year. This provision provides these companies with more flexibility than is provided to other applicants, however, the vehicles are only eligible for a reduced rebate amount, shown in Table 7 below, instead of the full amount. Fleets who own and operate their vehicles in the state for a minimum of 30 months are eligible for the full rebate amount [8].

Consumer Type	Maximum Number of Rebates
Individual or Business	1 total*
Public Fleet	30 per calendar year
Rental Fleet	20 per calendar year
Car Share Fleet	20 per calendar year

*Individuals or businesses that have met the rebate limit with a non-fuel cell vehicle may apply for one additional rebate for an eligible fuel cell vehicle.

Table 5: Maximum Number of Rebates per Entity Under the CVRP

			Vehicle Type			
	Filing Status	**Gross Annual Income Level**	**FCEVs**	**BEVs**	**PHEVs**	**ZEMs**
Increased Rebates for Low/Moderate Income	Gross annual household income ≤ 300 percent of the federal poverty level* (FPL)		$7,000	$4,500	$3,500	$750
Standard Rebates	Individual	300% of FPL* to $150K	$4,500	$2,000	$1,000	$750
	Head-of-Household	300% of FPL* to $204K				
	Joint	300% of FPL* to $300K				
Increased Rebates for Public Fleet Vehicles in Disadvantaged Communities	Vehicles must be domiciled at a facility within the boundaries of a ZIP code containing at least one underserved community[2] census tract		$7,000	$4,500	$3,500	Not Eligible
Income Cap	Individual	> $150K	$4,500	Not Eligible		
	Head-of-Household	> $204K				
	Joint	> $300K				

Table 6: CVRP Maximum Rebate Amounts

Vehicle Type	Maximum Rebate Amount Under Reduced Ownership
Fuel-Cell Electric Vehicle	$1,800
All-Battery or Range-Extended Electric Vehicle	$800
Plug-in Hybrid Electric Vehicle	$400
Zero-Emission Motorcycle	Not Eligible

Table 7: Rebate Amounts for Rental and Car Share Fleets Under the Reduced Ownership Provision

Hybrid and Zero Emission Truck and Bus Voucher Incentive Program**(Truck &/or Bus)

California's Hybrid and Zero Emission Truck and Bus Voucher Incentive Program (HVIP) provides a rebate of up to $300,000 for the purchase of low carbon clean trucks and buses. This point of sale price reduction can be applied to battery electric and hybrid trucks and buses as well as low NO_x natural gas engine vehicles, and is provided as a discount through the dealer, who then receives the rebate from the state. This incentive can be used for both public and private fleets that operate in California, with additional

funding available for fleets serving in disadvantaged communities. These fleets are limited to 200 vouchers and must stay in California for at least three years after they are put into service [9].

Participants can receive up to $10,000 in additional funding for their first three voucher requests, depending on the size of the vehicle being purchased. The amount of funding that is available depends on the gross vehicle weight rating, bus length, or energy storage capacity, as well as whether it is in a disadvantaged community [9]. The maximum price reductions can be found in the chart below, with additional details for zero emission school and shuttle buses as well as hybrid truck and bus purchases and conversion funding amounts can be found on the program's website.

	Base Vehicle Incentive		
	1 to 100 vehicles[1]		
GVWR (lbs)	Outside Disadvantaged Community	In Disadvantaged Community	>100 vehicles
5,001 – 8,500	$20,000	$25,000	$12,000
8,501 – 10,000	$25,000	$30,000	$18,000
10,001 – 14,000	$50,000	$55,000	$30,000
14,001 – 19,500	$80,000	$90,000	$35,000
19,501 – 26,000	$90,000	$100,000	$40,000
26,001 – 33,000	$95,000	$110,000	$45,000
>33,000	$150,000	$165,000	$70,000
Hydrogen Fuel Cell Electric Truck	$300,000	$315,000	$142,000

	Base Vehicle Incentive		
	1 to 100 vehicles[1]		
Bus Length and Bus Type	Outside Disadvantaged Community	In Disadvantaged Community	>100 vehicles
20 ft – 24 ft	$80,000	$90,000	$35,000
25 ft – 29 ft	$90,000	$100,000	$40,000
30 ft – 39 ft	$120,000	$135,000	$55,000
40 ft – 59 ft	$150,000	$165,000	$70,500
≥ 40 ft. Double Decker Bus	$175,000	$190,000	$82,250
≥ 60 ft. Zero-Emission Battery- Electric Articulating Transit Bus	$175,000	$190,000	$82,250
≥ 40 ft. Hydrogen Fuel Cell Electric Bus	$300,000	$315,000	$142,500

Table 8: Zero Emission Truck and Transit Bus Voucher Amounts

Transit and Intercity Rail Capital Program**(Truck &/or Bus)

The Transit and Intercity Rail Capital Program (TIRCP) is operated by the California Department of Transportation (Caltrans) and provides funding assistance for improvements that help to modernize California's intercity, commuter, and urban rail systems, as well as its bus and ferry transit systems. The goal of the program is to help reduce greenhouse gas emissions by reducing congestion and VMT in California [10]. Eligible applicants include public agencies that operate or have planning responsibility for existing or planned regularly scheduled intercity or commuter passenger transportation services. This includes construction authorities, transportation authorities, joint power agencies, and other public entities created by statute [10].

While these projects are not required to be zero emission, many of the previously funded projects have been for zero emission buses, as they are highly effective at reducing emissions. Additionally, the most competitive projects are those that are scalable, making transit bus projects ideal. There are no solicitations for this funding currently available, although more projects are likely to be made available in the future [10].

Low Carbon Transit Operations Program**(Truck &/or Bus)

The Low Carbon Transit Operations Program (LCTOP) receives an allocation of 5% of annual revenue through the Greenhouse Gas Reduction Fund (GGRF). This program provides both capital and operational assistance for transit agencies, helping them to reduce their overall greenhouse gas emissions, while improving mobility. Applicants must be transportation planning agencies and transit operators that are eligible for State Transit Assistance Funds, with priority given to those operating in disadvantaged communities. The funds can be used for new or expanded bus or rail services and can include projects such as equipment acquisition, fueling, maintenance, and other costs to operate the services and facilities. There are no fixed funding amounts for the program, and funds are based on the projects that agencies propose [11].

School Bus Replacement Program**(Truck &/or Bus)

The California Energy Commission's (CEC) School Bus Replacement Program was created by Senate Bill 110 and provides a total of $75 million for school districts and county offices of education to replace their old diesel school buses with newer, cleaner, buses. The new buses are mostly electric, although for routes that do not allow for an electric bus, a select amount of natural gas bus funding is available. The program requires that the old buses be removed from service and scrapped in order to eliminate the pollution source. Priority is given to the oldest school buses, and those that operate in disadvantaged communities [12].

This program also provides the funded schools with up to $60,000 per bus for new or additional PEV charging infrastructure to ensure that they are being used to their full potential. Additionally, the fleet operators, mechanics, and bus drivers are offered training to help them learn how to best operate and utilize the buses [12].

Carl Moyer Program**(Truck &/or Bus)

The Carl Moyer Program is a voluntary emissions reduction program that was set up to provide funding for clean air engines and equipment in California. The program is run by the California Air Resources Board (CARB) and administered through the local air districts, who oversee the selection of programs to fund. These funds may be used to support projects such as cleaner on-road trucks, school buses, transit buses, off-road equipment, marine vessels, locomotives, agricultural equipment, light-duty vehicle scrapping, and lawn mower replacement [13]. The program allows for each air district to use the funding in a way that works best for the community it is serving, while ensuring a common clean air goal.

Approximately $60 million is allocated for projects each year with funds raised through tire fees and smog impact vehicle registration fees. The funds can be used to cover up to 85% of the cost to repower engines and up to 100% of the costs to purchase

a retrofit device. There is also varying funding amounts for the purchase of new vehicles and equipment, which is based on the incremental cost of the clean air vehicle compared to a conventional vehicle.

Vehicle Rebates: Local

AB 2766 Motor Vehicle Fee Program***(Both Cars/SUVs and Trucks/Buses)

In 1990, the California State Assembly passed Assembly Bill 2766 which authorized the state's Air Pollution Control Districts (APCDs) and Air Quality Management Districts (AQMDs) to collect a $6 per vehicle registration fee [14]. This fee is split into two main parts, $2 goes to fund the Carl Moyer Program, and $4 is set aside for the AQMD to use to implement various programs to reduce air pollution from motor vehicles. These programs vary by air district, with one of the main implementers being the South Coast AQMD [15]. Out of the $4 per vehicle collected for the program, 40% is allocated for local government programs and 30% if used to fund their vehicle emission reduction programs. The remaining 30% of the funds to towards to Mobile Source Air Pollution Reduction Review Committee which was formed to help implement these programs [16]. A portion of the vehicle emission reduction program funds go towards grants that assist fleets in converting from conventionally fueled vehicles to electric and alternative fueled vehicles including compressed natural gas (CNG), propane, FCEV, and non-diesel hybrids. These funds are used to aid in this conversion on a case by case basis, with no specific grant amounts [17].

Transportation Authority of Marin

EV Fleet Rebate Program(Car and SUV)*

The Transportation Authority of Marin has a PEV fleet Rebate Program for public agencies who are replacing their conventional fuel vehicles with electric powered ones. Both FCEVs and PHEVs are eligible for this funding. In order to be eligible, participants must apply for a rebate through the CVRP, and if approved, then this program will provide match funding of up to $5,000 per vehicle, bringing the total rebate up to $10,000 off the cost of a new fleet vehicle [18]. Funding for this program comes from a $10 per vehicle registration fee.

The vehicles may be either purchased or leased and must be light-duty vehicles. All requirements for the CVRP must be met in order to qualify for this program, so they must be operated in California for a minimum of 30 months. Eligible agencies include Marin government entities and districts, school districts, colleges, and universities operating in the County of Marin. There is a limit of five vehicles eligible for the rebate per agency per year [18].

Bay Area Air Quality Management District

*Clean Fleets Program***(Both Cars/SUVs and Trucks/Buses)*

The Bay Area Air Quality Management District (BAAQMD) has a Clean Fleets Program which provides fleets that operate in their service district with grants to help offset the costs of purchasing or leasing new light-duty zero emission vehicles (ZEVs). Up to $5 million has been allocated for fiscal year 2018-19 to support qualifying vehicles and projects [19].

In order to be eligible, vehicles must be purchased or leased new, and have a gross vehicle weight rating of less than 14,000 lbs. Both BEV and FCEVs are eligible to

receive funding through the program, which is open to both public and private fleet owners. Each project must include the purchase or lease of 10 or more vehicles registered under a single owner. The vehicles and equipment must be maintained for a minimum of 3 years and meet a minimum usage requirement, which is correlated to the amount of funding that is awarded [19].

Each light-duty vehicle is eligible for up to $1,000 in rebates and requires a usage of at least 14,000 mi per year. Medium-duty vehicles can receive either $1,000 or $2,500 per vehicle, based on its gross vehicle weight rating. Motorcycles are also eligible for $5,000 in funding per vehicle and have a usage requirement of at least 3,000 mi per year. Additionally, the BAAQMD requires the fleet to provide match funding of at least 25% of eligible project costs after all other applicable manufacturer and local, state, or federal rebates and discounts are applied. The award amounts vary between $10,000 and $500,000, depending on the amount of work to be done. The first 85% of the award is distributed after the vehicle's infrastructure is purchased and the vehicle is placed into service, with the remaining 15% being distributed after the vehicles have completed their operational and usage requirements [20].

This funding can be used only to reimburse the costs of purchasing vehicles and infrastructure, as well as the installation of the infrastructure. The rebate cannot be used as a refund for consultant fees, maintenance repairs, operations, costs of electricity, network fees, or administrative costs [20].

*Carl Moyer Program**(Truck &/or Bus)*

The BAAQMD is also accepting applications for funding through the Carl Moyer Program for school bus upgrade and replacement projects. Additional funding for the program comes through the Community Health Protection Program and the Lower Emission School Bus Program. This funding can be used for replacing school buses, converting or repowering engines, retrofitting engines, replacing compressed natural gas tanks, and installing fueling or maintenance infrastructure. Up to 100% of the costs to install battery charging and alternative fueling infrastructure for the public school buses can be covered. This would include the costs associated with the design, engineering, equipment, installation, and meters or data loggers. The program requires that at least 50% of the energy provided by the project must be generated from wind or solar power [21]. The maximum funding amount per project can be found in Table 9 below.

Project Type	Maximum Funding (per piece of equipment)
School Bus Replacement (diesel)	$165,000
School Bus Replacement – with engines certified to any of the optional Low-NOx standards (i.e. 0.1,0.05, or 0.02 g/bhp-hr)	$220,000
Hybrid School Bus Replacement[1]	$220,000
Zero-Emission (electric or fuel cell) Bus Replacement or Conversion [1]	$400,000
School Bus Repower	$70,000
Diesel retrofit installation (per bus) [can include filter maintenance machinery or service contract up to $2,500 as part of the grant award]	$20,000
Natural gas fueling or battery-electric charging infrastructure, or vehicle-to-grid power infrastructure - with School Bus Replacement	up to 100%
On-board Natural Gas Fuel Tank Replacement [can include one-time replacement of deteriorating natural gas dispensers]	up to 100%

[1] Eligible for co-funding with other state (e.g., HVIP, CA Energy Comm.), federal or private incentive funding. State funds for private fleets are capped (contact our staff for details). For information about other funding options, visit https://www.arb.ca.gov/truckstop.

Table 9: Maximum Funding Amounts for Public School Bus Projects

*On-road Heavy-Duty Vehicles Program**(Truck &/or Bus)*

In addition to their light-duty fleet vehicle incentives, the BAAQMD has an On-road Heavy-Duty Vehicles Program. This project provides funding to help replace heavy-duty trucks, buses, transit vehicles, solid waste vehicles, utility trucks, emergency vehicles, and other on-road vehicles that have a gross vehicle weight rating of 14,000 lbs or more. The grants have a maximum funding amount of up to $1.5 million per year for public agencies and $500,000 per year for non-public entities. Up to 85% of eligible costs of vehicle replacement, engine repowering, and equipment conversion projects can be covered by the program. Part of these projects can include requests to install, convert, or expand battery charging stations or alternative fuel stations to support electric or alternative fuel equipment, which can be funded through this program with up to $5,000 of awarded funds per vehicle eligible for use in this way [22].

San Joaquin Valley Air Pollution Control District

*Truck Replacement Program**(Truck &/or Bus)*

The San Joaquin Valley Air Pollution Control District's (SJVAPCD) truck replacement program works to reduce the costs to replace diesel trucks with cleaner technology vehicles, or to expand fleets with the cleanest possible technology. San Joaquin, Stanislaus, Merced, Madera, Fresno, Kings, Tulare, and Kern counties are covered under the air district and are eligible for funding under the program [23].

New fleet expansion or replacement is for the purchase of class 4 through 8 advanced technology ZEV, hybrid, or low- NO_x trucks. These trucks must have been in operation for a minimum of two years and must be domiciled and registered within the air district's boundaries. The replaced vehicles must have operated at least 75% of the time in California and 50% of the time within district boundaries over the past two years. The new trucks must similarly be operated in California for at least 90% of the time and must operate within district boundaries at least 50% of the time. They must either be purchased or on a lease to own contract. For five years after the truck is purchased, applicants are required to submit annual reports to the district about the usage of the vehicle [23]. The vehicle incentive amounts are displayed in Table 9 below.

1. **Standard Replacement**

New Truck Options	GVWR Class 7 - 8	GVWR Class 6	GVWR Class 4-5
Zero Emission	$200,000	$100,000	$80,000
Hybrid – Zero Emission Mile	$150,000	$65,000	$50,000
Low-NOx – 0.02 NOx	$100,000	$50,000	$40,000
Hybrid	$80,000	$45,000	$35,000
Alternative Fuel – 0.20 NOx	$65,000	$40,000	$25,000
2010 Compliant Diesel - 0.20 NOx*	$50,000*	$30,000*	$20,000*

* Diesel Replacement Trucks - Not to exceed 35% of the total truck cost. Maximum eligible incentive amount is calculated up to the cost-effectiveness limit of $30,000.00 per ton of emissions reduced and may not reflect the maximum funding amount based on the aforementioned funding table.

2. **2010 Compliant Truck Trade-Up**

New Truck Options	GVWR Class 7 - 8	GVWR Class 6	GVWR Class 4-5
Zero Emission	$200,000	$100,000	$80,000
Hybrid – Zero Emission Mile	$150,000	$65,000	$50,000
Low-NOx – 0.02 NOx	$100,000	$50,000	$40,000
Hybrid	$80,000	$45,000	$35,000

3. **Fleet Expansion**

New Truck Options	GVWR Class 7 - 8	GVWR Class 4 - 6
Zero Emission	$20,000	$10,000
Hybrid-Zero Emission Mile		
Low-NOx– 0.02 NOx		
Hybrid		

Table 10: Truck Replacement Program Funding Amounts

Public Benefit Grant Program: New Alternative Fuel Vehicle Purchase(Car and SUV)*

In addition to their heavy-duty replacement program, the San Joaquin Valley Air Pollution Control District has a Public Benefit Grant Program for New Alternative Fuel Vehicle Purchases. This program helps to fund up to $20,000 per vehicle for the purchase of new BEV, PHEV, or alternative fuel vehicles for public agencies to promote clean air alternative-fuel technologies and the use of low or zero emission vehicles for public fleets. The grants are made available to public agencies including cities, counties, special districts, public educational institutions, or any other public agencies that are located within the geographic area of the SJVAPCD [24].

These grants have a three-year contract period during which they must own and operate the vehicle. The program does not provide funding for charging or refueling infrastructure, so the business must have existing charging or fueling infrastructure or have access to existing infrastructure to accommodate the new vehicles. All vehicles must be light-duty and must be domiciled or have at least 75% or more of its vehicle miles travelled or fuel consumption within the geographic region of the SJVAPCD. Applicants may apply for up to $20,000 for each new vehicle with a maximum funding per applicant of $100,000 per calendar year [24].

Rebate Program(Car and SUV)*

The SJVAPCD also has a rebate program specifically for residents, non-profits, government entities, and businesses in the district. This rebate can be used to purchase or lease a new “clean air vehicle,” including BEVs and FCEVs, which can both receive a rebate of up to $3,000 and PHEVs can receive a rebate of up to $2,000. Zero emission

motorcycles can receive a rebate of up to $1,000 per vehicle and natural gas vehicles can receive up to $1,500 or $2,000 based on their emissions rates [25].

The vehicles must have been purchased or leased within 18 months before the application is submitted, and the purchase or lease agreement must be at least 30 months long. The maximum funding is distributed according to the following schedule [25].

Vehicle Type	Incentive
BEV	Up to $3,000
FCEV	Up to $3,000
PHEV	Up to $2,000
Zero Emission Motorcycle	Up to $1,000
Super Ultra Low Emission Natural Gas Vehicles	Up to $1,500
Advanced Technology Partial Zero-Emission Natural Gas Vehicle	Up to $2,000

Table 11: SJVAPCD PEV Rebate Program Funding Amounts

Charging Incentives: State

California Electric Vehicle Infrastructure Project

The California Electric Vehicle Infrastructure Program (CALeVIP) is operated through the CEC and currently operates in five program regions: The San Joaquin Valley, the Central Coast, Northern California, Sacramento County, Sonoma Coast and Southern California. The regions and the counties included in each region are included in Figure 16.

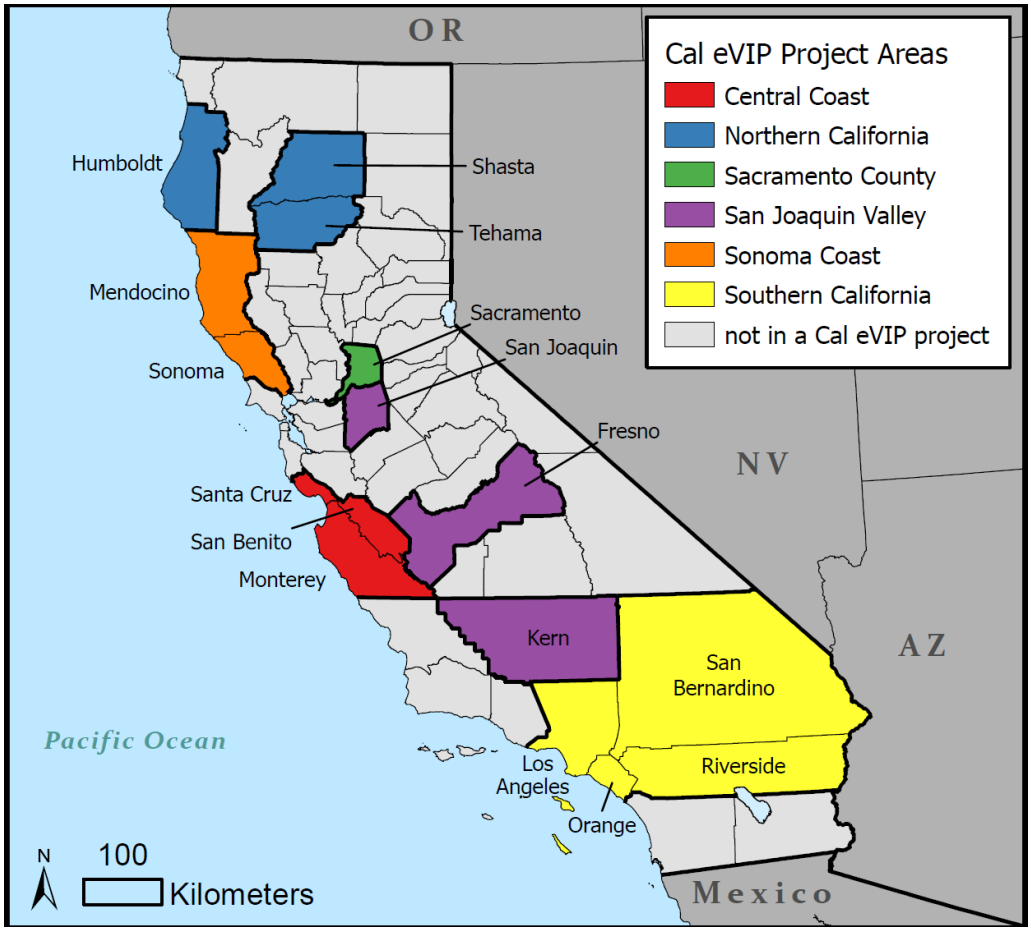

Figure 16: Map of Regions and counties included in the CALeVIP project in California

Southern California Incentive Project(Car and SUV)*

The Southern California Infrastructure Project operates in Los Angeles, Orange, Riverside, and San Bernardino Counties. Businesses in this project region can receive up to $80,000 for the purchase and installation of public DCFC charging stations. The funding amount varies based on the status and location of the site [26].

Rebates can be up to $70,000 per DCFC for installations at new sites and sites with a sub-out. Up to $40,000 per charger is available for installations at replacement and "make ready" sites. These sites must have all the necessary electrical infrastructure, wiring, and concrete work upgraded so that the stations can be mounted or installed. Installations at census tract designated disadvantaged communities (DACs) are eligible for rebates of up to $80,000 per DCFC regardless of the installation site type. This rebate can be used to cover the costs of the electric vehicle supply equipment, the installation, utility service order, planning and engineering design costs, project signage, advanced energy storage, networking agreements, and the warranty. Funding can be used to cover the costs of one new Level 2 PEV charging station at a site that is also installing a DCFC if the site host requests this [26]. Additional information on the rebate amounts can be found in Table 12 below.

Charger/Installation Type	DAC/Non-DAC Tract	Maximum Rebate Amount per Charger
New	DAC	$80,000
New	Non-DAC	$70,000
Stub-out	DAC	$80,000
Stub-out	Non-DAC	$70,000
Replacement/ Make-ready	DAC	$80,000
Replacement/ Make-ready	Non-DAC	$40,000

Table 12: CALeVIP Southern California Incentive Project Funds

All businesses must be based in California in order to be eligible, and the chargers must remain in service and be networked at the project site address for a minimum of 60 months. These businesses must be publicly available commercial or municipal facilities including commercial retail business sites, shopping centers, grocery stores, restaurants, gas stations, hospitals, airports, and police or sheriff stations. All chargers placed at these locations must always be publicly accessible [27].

There is a maximum number of chargers that are eligible for rebates in each county at a time. Once the business has received the rebate for those chargers, they are eligible to apply for the rebate again for additional chargers. Furthermore, businesses with locations in multiple counties can apply for the maximum number of stations per site in one county and the maximum in another county at the same time [27].

Once the funds have successfully been reserved, applicants have 12 months to complete the projects and submit all required documents. The total payout to the businesses is expected to be about 75% of the total actual costs of the project in non-DACs and 80% of the total actual costs for DAC applicants. These rebates must be accepted by the business directly and cannot be accepted by the equipment seller or the manufacturer [27].

County	New Site	Existing Site
Los Angeles and Orange	1-4	1-3
Riverside and San Bernardino	1-3	1-2

Table 13: CALeVIP Southern California Incentive Project Number of Chargers Eligible for Rebates per Site (min-max)

San Joaquin Valley Incentive Project(Car and SUV)*

Under the San Joaquin Valley Incentive Project, applicants in the Fresno, Kern, and San Joaquin counties are eligible for both DCFCs and Level 2 charging stations. This program offers a total of $15.3 million in funding for the installation of Level 2 and DCFC stations at businesses, non-profits, and government entities based in California, or with a California based affiliate. In DACs, this program currently offers up to $4,000 per connector for a Level 2 charger at a site that is classified as “new, stub-out, replacement, or make-ready” with an additional incentive of $1,000 per connector for multi-unit dwellings [28]. Additionally, these sites may receive up to $80,000 per DCFC, up to 80% of the total project costs. For sites that are located outside of DACs rebates of up to

$70,000 or 75% of the total DCFC costs can be received. The rebate for Level 2 charging stations is decreased to $3,500 per connector, with the additional rebate for multi-unit dwelling remaining the same, as shown in Table 13 below.

Level 2 project sites must be commercial, workplace, multi-unit dwellings, light-duty fleet, public facility, or curbside, and can receive a maximum rebate of 10 ports per site location. Additionally, DCFC sites include locations such as a shopping center, grocery store, restaurant, gas station, police station, public transit hub, or curbside with up to four charging stations available per site. An applicant can reserve up to $360,000 in rebates per county at a time, and once they receive this rebate, they may apply for up to this amount again. Level 2 stations must be networked for at least two years and DCFC stations must be networked for at least five years. After the application is accepted, the business has 9-15 months to complete their equipment installation and provide all required supporting documentation [28].

Charger Type	Non-DAC	DAC	MUD
Level 2	$3,500/connector	Additional $500/connector	Additional $1,000/connector
DCFC	$70,000/DCFC[3]	Additional $10,000/DCFC	Not applicable

Table 14: Rebates for Charging Stations Under the San Joaquin Valley Incentive Project

Sacramento County Incentive Project(Car and SUV)*

In January 2019, the CEC introduced the specifications for the third phase of CALeVIP, which operates in Sacramento County. This project was formally launched in April 2019, and provides rebates for both Level 2 and DCFC stations. Up to $6,500 can be received per Level 2 charging station connector and up to $80,000 can be receive per DCFC station. This project has a total budget of $14 million with $7.7 reserved for Level 2 charging station and $6.3 million reserved for DCFCs [29].

Charger Level	Disadvantaged Community	Non-disadvantaged Community
Level 2	Up to $5,500 per connector Additional $1,000 per connector for MUDs	Up to $5,000 per connector Additional $1,000 per connector for MUDs
DCFC	Up to $80,000 or 80% of total project costs	Up to $70,000 per DCFC or 75% of total project costs

Table 15: CALeVIP Sacramento County Incentive Project Rebate Amounts

Eligible applicants include businesses, nonprofits, California Native American tribes, and public entities based in California. All DCFCs must always be publicly accessible, however, the Level 2 chargers may be held for private business use, as long as they are shared use, which can allow them to be dedicated for fleet use. As with the other projects, these chargers must accept credit cards and at least one other form of payment if the site owner chooses to require payment for their use [29].

Funds can be used to cover costs associated with the purchase of the charging station, transformer upgrades, electric panel upgrades, energy storage equipment, installation costs, utility service orders, planning and engineering design costs, project signage, networking agreements, extended warranties, stub-outs, and demand

management equipment. All chargers purchased with these funds must be energy star certified. Provided available funding, there is no limit to the number of Level 2 rebates that can be received, but there is a maximum of $640,000 in rebates that can be applied for per active application. For Sacramento County DCFC stations, there is a maximum of four rebates [29].

This program will be expanded to an additional three project areas in the coming years including the Northern California Incentive Project, the Central Coast Incentive Project, and the Central Valley Incentive Project.

Electric Vehicle Charging Station Financing Program***(Both Cars/SUVs and Trucks/Buses)

The California State Treasurer's Office has an Electric Vehicle Charging Station Financing Program (EVCS), which works under the California Capital Access Program. These are short and long term loans for the design, development, purchase, and installation of electric vehicle charging stations at small businesses and multi-unit residences in California. It helps to reduce the costs of charging station acquisition and installation by providing both a loan and a rebate for charger installation projects. The program provides up to 100% coverage to lenders on certain loan defaults and allows borrowers to be eligible to receive a rebate of 10-15% of the enrolled loan amount after the loan is repaid [30].

In order to qualify for the loans, the business must make the charging stations accessible to the business owner's employees, the general public, or the tenants of a multi-unit dwelling. In order to qualify for the loan, the business must have less than 1,000 employees, which qualifies them as a small business. The program works to provide assurance to any participating federal or state chartered bank, savings association, certified Community Development Financial Institutions, or credit union and will provide an additional 10%, and up to 30% if the installation is in a multi-unit dwelling or located in a DAC [30].

This program works by having the business apply to a participating financial institution for the loan, and after it is repaid or after 48 months with no more than one 30-day late payment, the borrower is eligible for the rebate. The banks are provided with coverage of up to $500,000 per borrower though the CEC, helping to encourage the financial institutions to lend private capital to small businesses and multi-unit housing owners [31].

Charging Incentives: Utilities

There are a variety of EV and charger incentive programs run by the utility companies in California. The specific programs are discussed in detail below. There are three major investor-owned utilities in California, Pacific Gas & Electric (PG&E) in Northern California, and Southern California Edison (SCE) and San Diego Gas & Electric (SDG&E) in Southern California, there are also many locally-owned municipal utility companies. Figure 17 shows the territories covered by both the investor-owned and municipal utilities, and includes labels for the specific municipal utility programs that have programs discussed in this section.

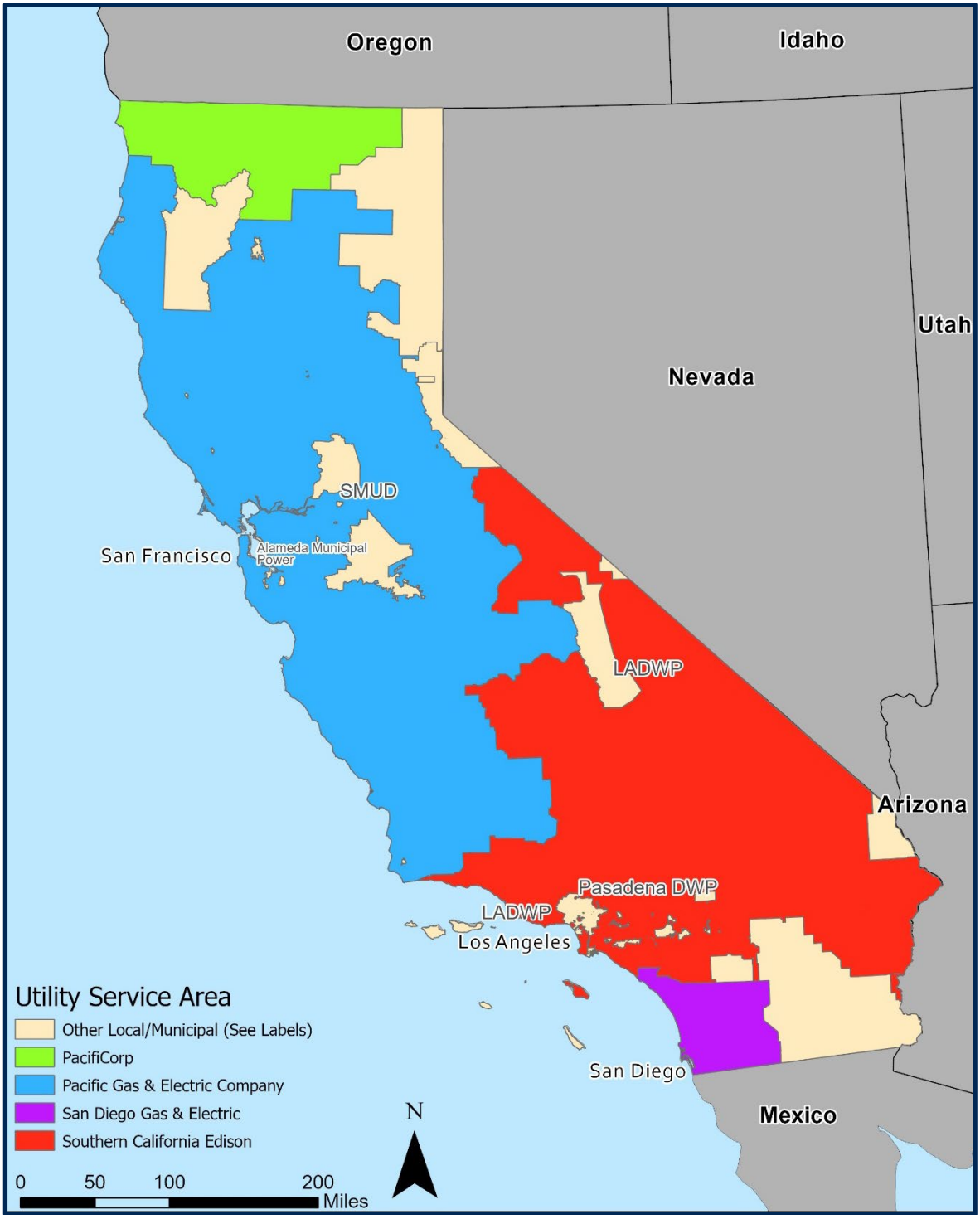

Figure 17: Map showing Investor-owned and Municipal Utility areas in CA

Pacific Gas and Electric Company

*EV Charge Network program***(Both Cars/SUVs and Trucks/Buses)*

Pacific Gas & Electric Company (PG&E) is beginning the final year of their EV Charge Network Program which provides make ready sites at workplaces and multi-unit dwellings around the state. This program is currently scheduled to run from 2018 through 2020, however, the program if fully subscribed and not accepting applications at this time. The program requires the conversion of a minimum of ten parking spaces and hast two main ownership structures: EV Charge Owner and EV Charge Sponsor. Under both ownership structures, PG&E will cover the costs of converting the parking spaces to

make-ready spaces, however, under the EV Charge Owner structure, the remaining costs of acquiring and installing the charging stations as well as the networking and electricity costs are the site owner's responsibility. Here, the site owner can receive a rebate of up to $1,150 per port for multi-unit dwellings and $575 per port at workplace locations. Both of these amounts are doubled for sites located in disadvantaged communities [32].

Under the EV Charge Sponsor structure, in addition to the make ready costs, PG&E will cover the costs of installing the charging infrastructure and the annual networking fees. Additionally, for multi-unit dwellings in a disadvantaged community, PG&E will cover the costs of the charging station hardware. For multi-unit dwellings who are not in disadvantaged communities and workplaces who are in a disadvantaged community, sites must pay $1,150 per port, but PG&E will cover all costs in excess of this. Sites who fall under this ownership structure are still responsible for paying for electricity costs incurred from the infrastructure. All workplaces and multi-unit dwellings in PG&E's service territory are eligible for the EV Charge Owner program, but only Multi-unit dwellings and program participants that are located in disadvantaged communities can participate in the EV Charge Sponsor program [32].

*EV Fleet Program**(Truck &/or Bus)*

PG&E is also beginning their $236 million make-ready infrastructure programs to support PEV charging for medium and heavy-duty electric vehicle fleets. The focus of this program is on school districts, transit agencies, delivery fleets, and other business customers to upgrade the infrastructure at their fleet's site. Under this program, PG&E will upgrade the electrical equipment from the grid to the meter and then supply a rebate for the charging station. Fleets can receive between $15,000 and $42,000 per charging station, depending on the power output, and not exceeding 50% of infrastructure costs, as shown in Table 16 below.

In addition to the rebates received for the charging infrastructure, each organization can receive up to 25 vehicle rebates per site, as shown in Table 17 below. These rebates range from $3,000 to $9,000 per vehicle depending on the vehicle type.

Power Output	**Rebate**
Up to 50 kW	50% of the cost of the charger, up to $15,000
50.1 kW to 150 kW	50% of the cost of the charger, up to $25,000
150.1 kW and above	50% of the cost of the charger, up to $42,000
Note: Limited to 25 vehicles per site	

Table 16: PG&E Fleet Charging Station Rebates

Vehicle Type	Per Vehicle Incentive Cap
Transit Buses and Class 8 Vehicles	$9,000 per vehicle
Transportation Refrigeration Unites (TRUs), truck stop electrification, airport ground support equipment, and forklifts	$3,000 per vehicle
School buses, local delivery trucks, and other vehicles	$4,000 per vehicle
Note: These incentives are available only to schools, transit agencies, and disadvantaged communities	

Table 17: PG&E Fleet Vehicle Rebates

*Commercial EV Charging Rate Class***(Both Cars/SUVs and Trucks/Buses)*

As a new way to encourage smart PEV charging, PG&E has proposed a new commercial rate class for PEVs, which they hope will allow for new investments in PEV infrastructure and commercial fleets. This plan is administered through a monthly subscription which allows customers to choose the amount of power that they will need for their charging stations. This subscription charge would replace the high demand charge that currently poses a significant challenge to PEV charging projects. The new rate is significantly lower than the current demand charge and allows for a simpler, and more consistent monthly cost [35].

This rate plan will charge customers overages if they exceed the electricity usage amount allocated under their plan, which provides subscriptions on a monthly rate instead of yearly. This allows customers to adjust their plans to avoid additional payments in the future as they gain additional insight into the amount of electricity that they will need. The new plan also allows businesses to scale up at any point in time if more charging stations are added [36].

Under this program, users can choose a subscription plan that is lower than their maximum charging capacity if they are able to use energy storage to cover and manage the remaining load. Under this rate structure, the basic time of use rate that is specifically designed to encourage PEV charging during off peak hours would still be in effect. Furthermore, the peak hours would run from 4pm until 10pm, which is an hour longer than the other customers experience

*EV Charging Collaboration Pilot- PG&E and San Joaquin Regional Transit District**(Truck &/or Bus)*

PG&E has recently begun a $3.35 million PEV pilot program with the San Joaquin Regional Transit District to help them meet their long-term transportation electrification goals. They plan to test smart charging and battery storage to see how effective it is at lowering operating costs and maximizing efficiency. Under this program, PG&E is also funding up to five new electric bus chargers and a battery energy storage system and will fund and build infrastructure from the electric grid to the chargers, as well as the storage system [37].

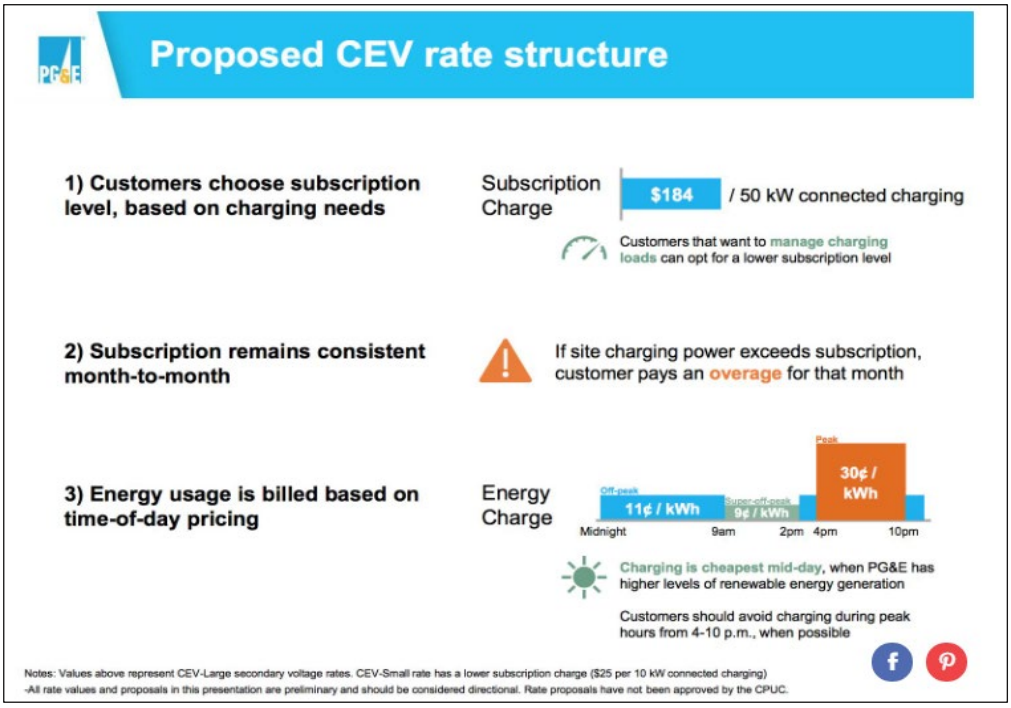

Figure 18: PG&E Commercial EV Rate Structure

The San Joaquin Regional Transit District is already operating 12 electric buses in their fleet and are working to reach their goals of operating entirely on electric vehicles by 2025. They plan to acquire five more electric buses in late 2018. This pilot program falls under PG&E's new Fleet Ready program and is targeted at charging for electric medium-duty, heavy-duty, and off-road fleets [38].

Southern California Edison

*Charge Ready: Business***(Both Cars/SUVs and Trucks/Buses)*

Fleets can also qualify for Southern California Edison's (SCE), Charge Ready Program. They will help support the deployment of a minimum of 10 charging stations per site at normal locations, and a minimum of 5 charging stations per site in disadvantaged communities. The site host is responsible for selecting and procuring the charging stations, which can be either Level 1 or Level 2, and must be procured from an approved vendor within 30 days of having the electrical upgrades. The new charging station must be installed on a new, dedicated circuit, that SCE will deploy with a separate meter, panel, and service [39].

SCE will cover the costs of installing the electric infrastructure upgrades as well as acquiring the permits and inspections. They also have a rebate to offset some or all the costs for the charging stations and charging station installations. Rebated chargers are required to be maintained in working order for the duration of the program, which lasts ten years. This includes a data management subscription plan with an approved PEV charging network service provider and participation in future demand response programs [39].

Under the agreement, the site host is responsible for covering operating costs such as equipment repairs, maintenance, PEV charging network subscriptions, and electricity costs. SCE will in turn be responsible for the installation and maintenance of the electric infrastructure that serves these locations [39]. While this program is currently

oversubscribed, and is not accepting any new applications, additional funding may be made available in the future.

*Charge Ready: Transport**(Truck &/or Bus)*

Additionally, SCE has a Medium and Heavy-Duty make ready program which authorizes them to spend $343 million to support make ready installations at a minimum of 870 sites in order to support the electrification of at least 8,490 medium and heavy-duty fleet vehicles by 2024. A minimum of 15% of this budget must serve transit agencies, at least 25% must serve vehicles operating at ports and warehouses, a maximum of 10% can be used to serve forklifts, and a minimum of 40% must be spent in DACs. They must additionally use program funds to offer rebates for up to 50% of the cost of the charging station for sites in DACs and sites that support electric transit and school buses [41].

This program is operated through their Charge Ready Program with a rebate for participating transit agencies to help offset the costs for installing and purchasing the electric bus charging equipment. The program will run for five years after the installation of the charging stations, during which time the transit agency must purchase at least one new plug-in electric transit bus to use at their new charging location [40].

Eligible transit agencies must have at least one bus route that impacts a DAC and must select an eligible time of use rate for EV charging. The programs require the company to provide an easement to SCE, deliver proof of purchase of the electric buses and charging equipment, and install at least one qualified charging station. The transit agency is also responsible for procuring the charging stations, which must meet national standards and be installed on a dedicated circuit with its own panel, meter, and service [40]. The program also requires that they cover operating costs for the equipment such as equipment repairs, maintenance, charging network subscriptions, and electricity costs. The Transit Bus Program covers the costs of all the electric infrastructure related to installing the new circuit as well as obtaining the permits and inspections.

Small Utilities

*ChargeUp LA!- Los Angeles Department of Water and Power***(Both Cars/SUVs and Trucks/Buses)*

The Los Angeles Department of Water and Power's (LADWP) ChargeUp LA! program provides both commercial and residential customers with rebates to aid in the deployment of PEV charging infrastructure at businesses, workplaces, multi-unit dwellings, and public parking lots. For light-duty vehicles, the program can provide up to $5,000 per Level 2 charging station (plus up to $750 per additional charge port) and up to $75,000 per DCFC station. Additionally, for medium and heavy-duty fleets who are looking to electrify, the program provides up to $125,000 per charging station.

In order to receive the first rebate for a Level 2 charging station, a minimum of three parking spaces are needed, with one more rebate available for each additional five parking spaces. The maximum number of chargers that can be rebated per site is 40. For the DCFC stations, at least two of the fast charging standard connector types are required (e.g. SAE CCS, CHAdeMO, Tesla). Up to three DCFC stations are allowed per site and only one of these charging stations can be blocked from public use.

For charging stations that serve medium and heavy-duty vehicles, the rebate amount varies significantly based on the power output, as shown in Table 18 below. For

each charging station rebate that is received, proof of purchase for one medium or heavy-duty PEV is required. There is a maximum rebate of $500,000 per site.

Charging Stations for Medium-and Heavy-Duty EVs	Output (kW)	Max Rebate Amount Per Charging Stations
AC-1	6 to 49	$10,000
AC-2	50 to 99	$20,000
AC-3	100 and above	$30,000
DC-1	20 to 49	$35,000
DC-2	50 to 99	$60,000
DC-3	100 to 149	$100,000
DC-4	150 and above	$125,000

Table 18: Medium and Heavy-Duty Charging Station Incentives Offered Through LADWP

The charging stations must be accessible to employees, tenants, visitors, customers, or the general public and cannot be used to charge golf carts, neighborhood carts, motorcycles, or electric scooters. They must be placed on a dedicated separate LADWP electric meter and must be purchased new. After installation, the chargers must remain in service at the specified location for a minimum of six months, unless the LADWP electric service account is closed. The rebates can be redeemed by a third-party company, such as the equipment seller, allowing them to reduce the upfront cost of the chargers in some cases. The program is currently scheduled to run through June 2021, or until funds run out [42].

Commercial Charger Incentive Program- Pasadena Department of Water and Power(Car and SUV)*

The Pasadena Department of Water and Power has a Commercial Charger Incentive Program which offers up to $50,000 for businesses to install EV chargers. This is provided through a $3,000 rebate for installing a smart Level 2 charging station at commercial workplaces, multi-unit housing developments, and for fleet customers. The rebate is offered per port, if each of the ports can charge at full capacity simultaneously. If the charging capacity of the ports is reduced with multiple users, then the additional rebates are not applied for each port [42].

As an increased incentive, Level 2 charging stations that are made publicly accessible during regular business hours can receive up to $6,000 per charging station. This increased rebate is also made available for any DCFCs equipped with a minimum of 2 charging ports and to charging stations that are accessible to students and patrons of schools. Chargers that are installed at housing complexes in DACs and those that serve 80% or more “very low income” customers are also eligible for the higher incentive

amount; these are people who are at or below 50% of the Los Angeles median income [42].

The $3,000 rebate requires the charging stations to be networked, although for areas where this is not possible, there is a decreased rebate amount of $1,500 for non-networked charging stations. Businesses with non-networked chargers can receive a maximum rebate amount of $15,000 per site per account [42].

*EV Charging Discount- Alameda Municipal Power***(Both Cars/SUVs and Trucks/Buses)*

The City of Alameda's municipal utility district provides an PEV charging rate discount for both residential and fleet customers. This electric discount applies only to light-duty vehicles, medium-duty vehicles, and golf carts. Residents can receive a discount of between $9 and $21 per vehicle per month while commercially owned golf carts and fleet vehicles can receive 50% off their electricity bill for their separately metered charging facility.

Under this charging scheme, customers must agree to only charge their vehicles during the off-peak hours of 8:00 pm to 8:00 am during weekdays and all hours on weekends and observed non-workdays observed by the city. As the utility transitions its customers to Time of Use rates, the program is being phased out and is set to be discontinued on June 30, 2020 [44].

Regulations for New Fleet Vehicle Acquisitions

Zero Emission Airport Shuttle Regulation**(Truck &/or Bus)

In June 2019, CARB adopted a regulation for zero emission airport shuttle buses. This rule applies to class 2B through class 8 commercial vehicles with a gross vehicle weight rating of 8,501 or higher and states that beginning in 2022, each airport shuttle fleet owner would need to report information on all of the vehicles in their fleet, including a summary of the proportion of ZEVs in the fleet. Under this rule, only BEV and FCEV shuttles qualify for compliance with the program [45].

It is estimated that there are around 1,000 public and private airport shuttles that operate at the State's 13 largest airports. This includes around 260 inter-airport shuttles and around 680 private airport shuttles, such as off-airport parking lots and courtesy hotel shuttles, all of which would fall under these regulations. Currently, there are around 110 ZEV airport shuttles in use or on order in the state [46].

This reporting would lead up to the January 1, 2023 regulation stating that all airport shuttles that are purchased, rented, or leased for use at a regulated airport must be ZEVs. By mandating ZEV purchases, CARB hopes to slowly increase the overall percentage of ZEVs in the airport shuttle fleets over time, reaching a 100% ZEV target by December 31, 2035. This rule applies to all regulated airports, so those that contract, lease, or permit airport shuttle services must require that these fleets comply with the regulations according to the specified schedule [45].

Proposed Compliance Schedule for Airport Shuttles	
Compliance Deadline	**Percent of Total Fleet That Must be BEV/ FCEV**
December 31, 2027	33%
December 31, 2031	66%
December 31, 2035	100%

Table 19: Compliance Schedule for Airport Shuttles Under the Proposed CARB Regulation

*Light and Heavy-Duty Fleet Regulation- State Vehicles***(Both Cars/SUVs and Trucks/Buses)*

In 2017, Assembly Bill 739 stated that starting in 2025, there is a requirement that 15% of a state agency's Heavy-Duty Class 6-8 vehicle purchases must be ZEVs, and by 2030, this number will increase to 30%. Additionally, Senate Bill 498, which is discussed in more detail below, requires that at least 50% of the light-duty vehicles purchased for the state-owned vehicle fleet each fiscal year be ZEVs beginning no later than the 2024-25 fiscal year. The percentage of the state's light-duty vehicles that need to be ZEVs increases each year up to this 50% target. While these ZEVs can be BEV, PHEV, FCEV, or alternative fuel vehicles, at least half of them must be "pure ZEVs," meaning that they must be either a BEV or a FCEV. The bill also directs CARB to develop policies and programs to increase ZEV adoption in private sector fleets [47]. The regulated adoption schedule is shown in Table 20 below.

Fiscal Year	EO B-16-12 ZEV Purchasing Requirements (CURRENT)	EO B-16-12 ZEV Purchasing Requirements (NEW)
2014/2015	10%	10%
2015/2016	10%	10%
2016/2017	10%	10%
2017/2018	10%	15%
2018/2019	10%	20%
2019/2020	25%	25%
2020/2021	25%	30%
2021/2022	25%	35%
2022/2023	25%	40%
2023/2024	25%	45%
2024/2025	25%	50%

Table 20: Compliance Schedule for Light-duty State-Owned Fleet Vehicles

Innovative Clean Transit**(Truck &/or Bus)

In December of 2018, CARB approved a state-wide goal for the state's 200 public transit agencies to transition to 100% ZEV bus fleets by 2040. These include either BEV or FCEV buses, and do not include hybrid buses. This rule applies to transit agencies that own, operate, lease, rent, or contract with another entity to operate buses in California [48]. Before the rule was announced, eight of the 10 largest transit agencies in the state were already operating zero emission buses, including both BEV and FCEV. There are about 12,000 buses operating state-wide that would be regulated under this rulemaking, which does not apply to rail vehicles, trolleybuses, school buses, local school districts, Amtrak, Caltrans, or Caltrain [49].

In order to assure that the agencies are prepared for this transition, each transit authority must submit a plan on how they intend to purchase and integrate these clean buses, acquire the necessary infrastructure, and train the required workforce by the 2040 deadline. Large transit agencies must submit their plans by 2020, while small transit agencies have until 2023 to submit their plans. New transit companies that enter the market will be required to submit their plans within 18 months of beginning operations. A transit agency is defined as large if it operates over 65 peak buses in the South Coast Air District or San Joaquin Valley, or over 100 peak buses in areas with populations over 200,000. Between 2023 and 2029, the zero emission bus purchases will be scaled up, with 2029 marking the date where 100% of annual new bus purchases must be zero emission [49].

Each of the bus purchases must be retained for at least five years from when it was placed in the active bus fleet in order to qualify. Up until January 1, 2026, cutaway, over the road, double decker, and articulated buses will not be subject to these restrictions, but after January 1, 2026, they will need to follow the same zero emission acquisition schedule.

Additionally, buses that are already in the fleets before the rule takes effect will receive bonus credits, which they can use to help them comply with the purchase requirements later on. Each fuel cell electric bus that was in the fleet by January 1, 2018 received two bonus credits while each fuel cell electric bus placed in service between January 1, 2018 and December 31, 2022 will receive one bonus credit. Battery electric buses placed in the fleet by January 1, 2018 received one bonus credit, electric trolleybuses placed in service before the same date received one bonus credit, and electric trolleybuses in service between January 1, 2018 and December 31, 2019 will receive one tenth of a bonus credit, which will expire on December 31, 2024. All of these bonuses, except for those gained from acquiring a trolleybus, can be used at any time until December 31, 2028 to help the transit company reach their required minimum number of zero emission buses. Each credit can be used one time to count as the purchase of one bus, and cannot be transferred to another transit agency, unless they are participating in a Joint Group to comply with the requirements.

There are a few exemptions to this rule in place to protect transit agencies if they are unable to meet these requirements for a reason outside of their control. This includes delays in bus deliveries caused by a setback in infrastructure construction, a lack of availability of zero emission buses that can meet their mileage or grade needs, a lack of buses available in the applicable weight class, and zero emission buses that cannot be purchased due to financial hardship. In order to meet this last requirement, the agency must be able to demonstrate that they cannot offset the incremental costs of purchasing any of the available zero emission buses when compared to the same type of conventional bus [48].

There is also a rule in place that the transit agency may opt to use a zero-emission mobility program instead of making a zero-emission bus purchase to meet their minimum number of required buses. This could potentially include the use of zero emission bicycles, scooters, or other zero emission vehicles with a gross vehicle weight rating of 14,000 pounds or less. The program must be directly operated by the agency or operated by a contractor of the agency and must be able to track and record zero emission passenger mi for each vehicle. A large transit agency must achieve at least 320,000 zero emission passenger mi per year in order to be eligible to receive each

mobility credit while small transit agencies must achieve at least 180,000 zero emission passenger mi per year per credit [48].

Additionally, the agencies may be eligible to receive up to $10,000 in rebates per zero emission bus each year through the low carbon fuel standard, although this is subject to change. An outline of the adoption schedule can be found in Table 21 below.

Compliance Schedule for Large Transit Operators	
Compliance Deadline	**Bus Purchases that must be Zero Emission**
January 1, 2023	25%
January 1, 2026	50%
January 1, 2029	100%

Table 21: Compliance Schedules for Transit Operators Under the Zero Emission Bus Fleet Regulation

Proposed Clean Mi Standard*(Car and SUV)

CARB has announced a regulation for limiting the emissions from transportation network company (TNC) fleets. This regulation came out of Senate Bill 1014, which directs CARB and the California Public Utilities Commission to, “develop a Clean Miles Standards and Incentive Program for transportation network companies.” The rule was presented to regulate the emissions associated with the rapid growth of these new mobility options [50].

By 2021, CARB must implement annual greenhouse gas reduction targets for these TNCs that would begin taking effect in 2023. All reductions will be measured against a 2018 baseline and are required to be set so that they are technically and economically feasible. The regulations are hoped to create an increasing number of passenger mi travelled using zero emission methods and should encourage, “pooling, active transport, and transit usage.” Under this program, TNCs would be required to develop a greenhouse gas emission reduction plan every two years, beginning in 2022 [50].

The regulations must further take into account the operation of driverless automated vehicles in TNC fleets and should encourage low emission vehicles for this technology. The hope is for the rule to promote collaboration between regional and local transit entities, TNC fleets, research institutions, and state agencies, as well as encouraging companies to expand both PEV charging and FCEV infrastructure [50].

SB 498***(Both Cars/SUVs and Trucks/Buses)

While the 50% ZEV purchase requirement set under SB 498 applies only to vehicles owned directly by the state, it also required CARB to make a series of recommendations on how to increase ZEV purchases in light-, medium-, and heavy duty fleets. These recommendations are outlined in the agency’s draft report on zero emission vehicle programs, released in December 2019 [52]. Among other things, this report recommended that ZEV targets for non-state government fleets be implemented as the number of available vehicle models that meet their needs grows. They write that it is important for local governments to be among the first to adopt ZEVs as they should lead by example and prepare for the increase in the number of ZEVs in their jurisdictions. They

also recommend that DGS should track state owned vehicle usage and establish a zero emission VMT target for state owned vehicles.

Another recommendation proposed by this report was for CARB to be directed to adopt zero emission mileage requirements for high-mileage and new mobility fleets, including those used for car sharing. They recommended that these requirements be supplemented with goals that aim to reduce overall VMT in these fleets. While each of these recommendations were aimed towards all fleet vehicles in California, CARB recommended specifically targeting investments towards the conversion of high mileage fleets. They also mentioned that fleets should investigate used electric vehicles which can help them lower the upfront costs of purchasing electric vehicles.

While the impact of these potential policies on non-state-owned fleets is not yet known, if implemented, they are likely to create a strong motivation for fleets to begin exploring electrification options.

Vehicle Rebates	Incentive Name	Agency
Federal	Tax Credit	IRS
	Low or No Emission Vehicle Program	Federal Transit Administration
State	Clean Vehicle Rebate Program (CVRP)	CARB
	Hybrid and Zero Emission Truck and Bus Voucher Program (HVIP)	CARB
	Transit and Intercity Rail Capital Assistance Program (TIRCP)	Caltrans
	Low Carbon Transit Operations Program (LCTOP)	Caltrans
	School Bus Replacement Program	CEC
	Carl Moyer Program	CARB
	AB 2766 Motor Vehicle Fee Program*	Air Districts
	Volkswagen Environmental Mitigation Trust for California*	CARB
Local	EV Fleet Rebate Program	Transportation Authority Marin
	Clean Fleets Program	BAAQMD
	On-Road Heavy-Duty Vehicles Program	BAAQMD
	Heavy-Duty Truck Replacement Program	San Joaquin Valley Air Pollution Control District
	New Alternative Fuel Vehicle Purchase Public Benefit Grant Program	San Joaquin Valley Air Pollution Control District
	Drive Clean! Rebate Program	San Joaquin Valley Air Pollution Control District
Charging Rebates		
State	California Electric Vehicle Infrastructure Project (CALeVIP)- Southern California	CEC
	CALeVIP- San Joaquin Valley	CEC
	CALeVIP- Sacramento	CEC
	CALeVIP- Central Coast*	CEC

	CALeVIP- Northern California*	CEC
	Electric Vehicle Charging Station Financing Program	California State Treasurer's Office
Utility	EV Fleet Program	PGE
	New Commercial rate class	PGE
	Charge Ready: Business	SCE
	Charge Ready: Transit	SCE
	ChargeUp LA!	LADWP
	Commercial Charger Incentive Program	Pasadena DWP
	EV Charging Discount	Alameda Municipal Power
Regulations		
State	Zero Emission Airport Shuttle Regulation	
	Light-duty Fleets for State Vehicles	
	Innovative Clean Transit	
	Proposed: Clean Miles Standard	

*Not discussed in this report

Table 22: Summary of Electric Vehicle and charging Station Rebates for Fleets in California

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Task 3, Part 1: Vehicle Data Collection

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Executive Summary

The fleet at the University of California at Davis incorporated 10 used BMW electric vehicles with approximately 80 mi (129 km) driving range into three distinct use cases. Using a variety of data sources, we gathered utilization on the vehicles in hourly, daily and monthly rental uses. Preliminary estimates reveal significant variation in total mileage and total reservations across the BMW i3 EVs depending on the location and application of the vehicle. Consequently, even in terms of energy use, the department assigned i3 EVs with highest monthly mileage also had the highest number of charging events and energy use. Primarily in this section we focus on the six vehicles deployed in our hourly rental program "UC Drive" which provided the most thorough data set for comparison available. In part two of Task 3, we gathered user feedback from a fleet driver survey administered in January 2020.

Key Takeaways

- Vehicle utilization depended heavily on finding the 'right' application. Hourly rentals and department assigned vehicles saw the most rentals and miles driven.
- Daily rental vehicles saw lower utilization rates, indicating this was not an ideal application for a 80 mile range EV. Underutilized vehicles were reassigned to departmental use, where use rates increase.
- The six BMW i3 EVs assigned to UC Drive (hourly rental) were regularly used with the total vehicle miles traveled accumulating to 6,474 mi. There were total 212 unique users of the vehicles at UC Drive and approximately 550 reservations between Jan 2019 and Feb 2020

Fleet Utilization Data

Each vehicle was equipped with data logging equipment, either the standard logger used by all of the vehicles in the UC Davis fleet, or specialized loggers for comparative testing the departmentally assigned vehicles. These loggers allowed us to gather information on trip mileage, trip frequency, state of charge, and location. Our focus is on the data from the i3 EVs placed with UC Drive (six of the ten vehicles) due to higher quality data on trips, as well as the ability to compare to the trips taken by the other hourly rental and department assigned vehicles.

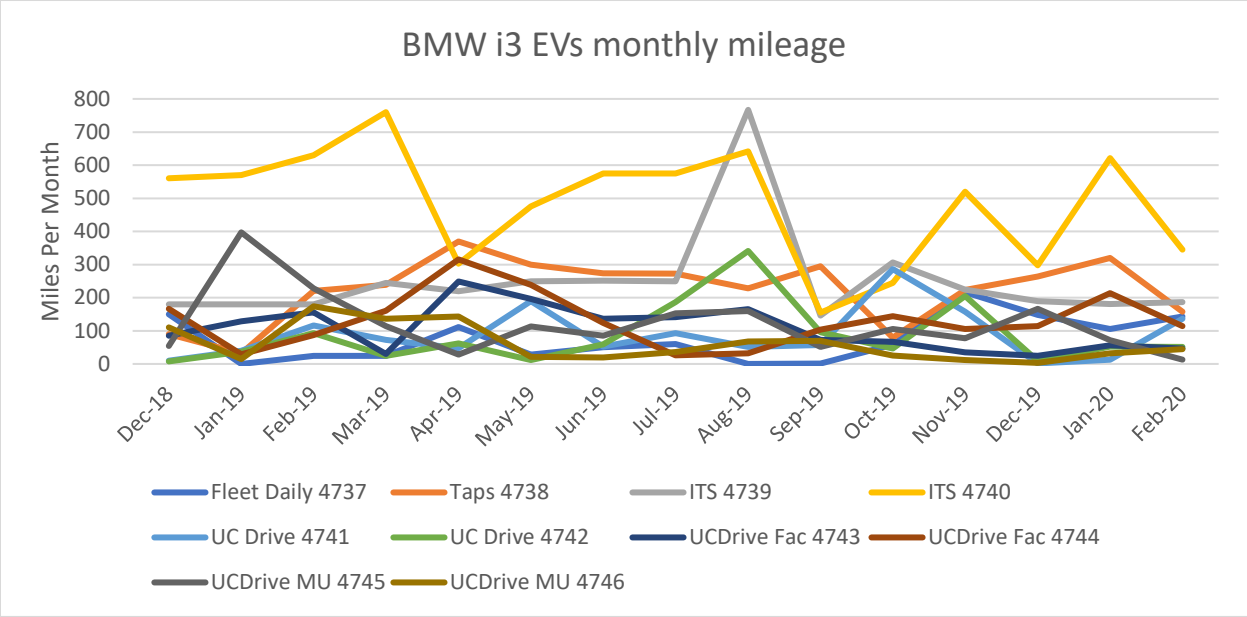

Figure 19: Monthly mileage for all ten BMW i3 vehicles from initial placement Dec. 2018 through Feb. 2020

Figure 19 above shows that the vehicles assigned to departments, (ITS 4739 and ITS 4740, Fleet 4737 after October 2019, and TAPS 4738 from Feb. to Oct 2019) saw the highest monthly mileage compared to the vehicles used in daily or hourly rental. The six vehicles deployed in hourly rental were used regularly throughout the project period and the vehicle in Fleet daily rental pool (Fleet 4737 until Oct. 2019) saw the lowest usage. Departments which have monthly rentals are likely to be the departments with the highest utilization of vehicles, both in terms of frequency and miles driven. We believe that drivers who had access to a BMW i3 as part of a departmental lease were also likely to be more comfortable with the functionality and range of the BMW i3.

Monthly Average Travel	mi	km
Departmental assigned mileage avg.	320	515
Avg. daily rental mileage per month	51	82
Avg. UC Drive (hourly rental)	99	159

Table 23: Average monthly mileage based on assignment type

The average monthly distances traveled is represented in Table 23 in both mi and km. Once we realized that the daily rental mileage was insufficient, we worked with fleet services to find a

different assignment for the vehicles that were originally assigned to be a daily rental vehicle. Therefore, the average monthly mileage for the vehicle in the daily rental fleet is not over the same period of time, 15 months, as was used to calculate the other averages.

Vehicle Charging Data

The data on vehicle charging and energy use is provided by BMW from their onboard system BMW Fleetview. The data allows us to track the time and location of plug-in, the energy use, and the mileage between each charging event.

Tracking Vehicle Utilization & Charging

Vehicle Utilization

The utilization of the BMW i3 EVs varied greatly depending on their assignment as either a departmental vehicle, hourly rental, or daily rental vehicle. Those ones which were departmentally assigned had the highest mileage (322 miles (mi) or 519 kilometers (km)) and most frequent use, whereas the BMW i3 in the daily rental application saw the lowest mileage (51 mi or 81 km) and lowest number of trips monthly. Over the course of one year (Jan 19-Feb 2020) the BMW i3 EVs for hourly rentals had an average monthly mileage of 103 mi (166 km). Focusing on the group of i3 EVs placed with UC Drive (hourly rental) we observe significant monthly variation in the number of reservations and total mi travelled (Figure 20). Here, we only consider regular reservations and not those made for cleaning or maintenance services.

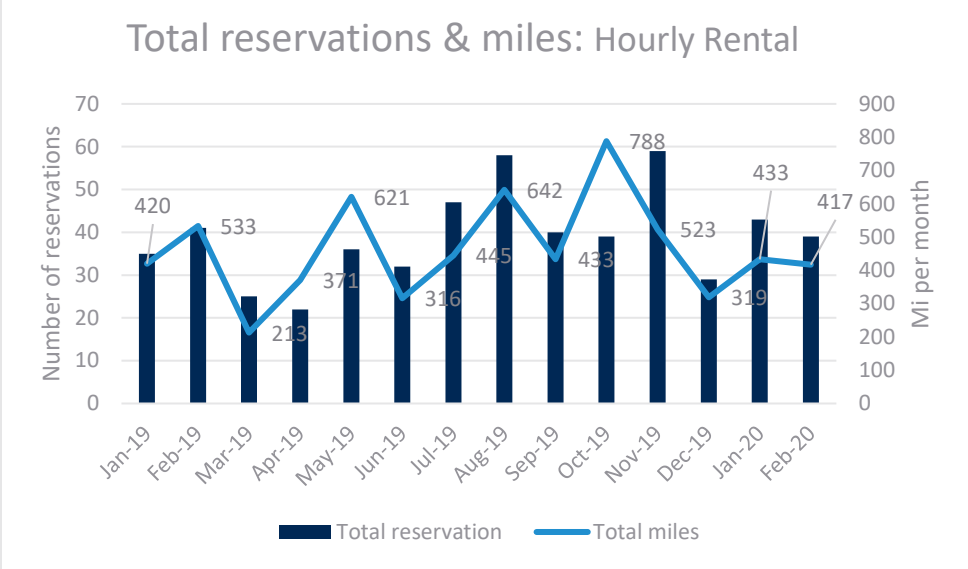

Figure 20: Monthly reservations and miles for all i3 EVs

We observe a drop in the total number of reservations in March, June, and December of 2019. The drop may have been caused by campus closures due to end of academic year, or quarter break. It should be noted that not all the i3 EVs were operational in the UC Drive fleet for the same period. Four i3 EVs were initially placed with hourly rental in January 2019. Subsequently, three more i3 EVs were added in May 2019. As a result, we see a higher

cumulative number of miles in the later months except June and December. It is worth noting that these fluctuations correlate with the campus schedule: March includes a one-week spring break, June a one-week summer break before summer session begins, and December a three-week winter break. While campus staff are still working during these breaks, the correlation between "quiet campus" times and lower vehicle mileage is noticeable.

Breaking down the usage for each of the i3 EVs, we observe significant variation in terms of reservations and miles across the months the vehicle was in operation.[3] As mentioned earlier, during the months coinciding with end of quarter breaks, both the number of reservations and total miles driven fall compared to other months of operation. The average number of reservations varied from 3.2 to 10.9 per month (Figure 21) with the ones placed with Facility Management having higher number of reservations compared to other locations.

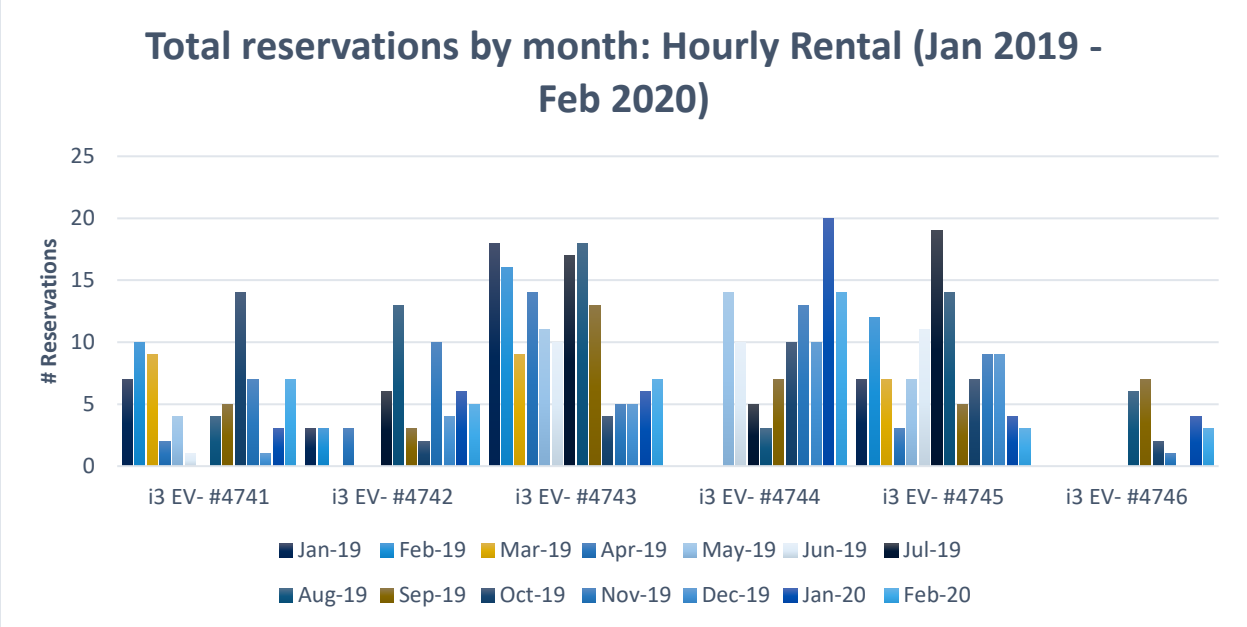

Figure 21: Hourly rental reservations (includes 4 i3's from Jan –April 2019, 6 i3's beginning in May 2019)

In terms of total miles per month, average monthly mileage varied from 32.8 mi to 116 mi. There is no clear pattern in terms of location with one of the vehicles placed in Memorial Union (MU) doing 116 mi per month on an average while the other is doing only 32.8 mi per month (accounting for the months in operation). The i3 EVs placed with Facilities Management are doing 104.8 and 112.7 mi on an average per month.

[3] There is no data on monthly mileage for November. As a result, the estimates of total mi or average mi reported in this draft will be lower than the actual number. The estimates will be revised for the final draft.

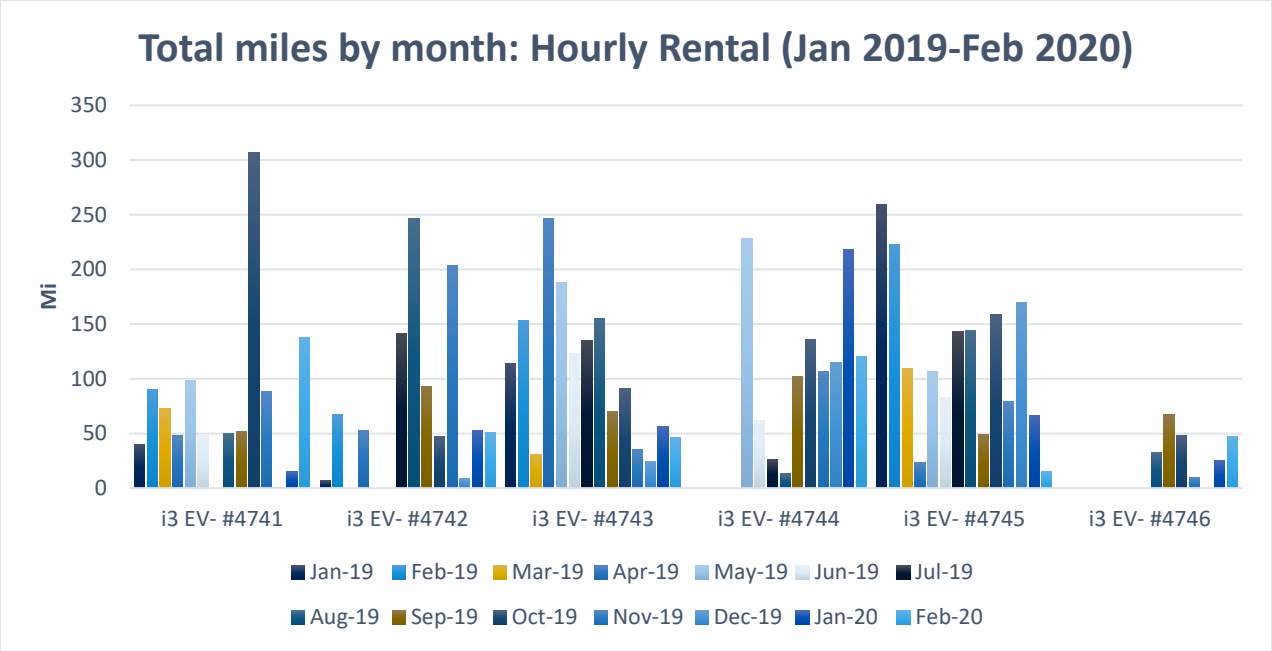

Figure 22: Monthly miles (includes 4 i3's from Jan –April 2019, 6 i3's beginning in May)

Next, we consider how the i3 EVs are being used compared to other vehicles offered in the hourly rental service. On an average, the BMW i3 EVs have similar number of reservations as the Chevrolet Bolt, the only other electric vehicle in the fleet and the Ford Fusion plug-in hybrid (Figure 23). Though there is not much difference in the number of reservations, we observe significant difference in the average distance of trips for which the i3 EVs are used compared to the Bolt or vehicles in the fleet (Figure 24). Also, the plug-in hybrids like the Chevrolet Volt or the Honda Clarity are used for longer trips than any of the electric vehicles in the fleet.

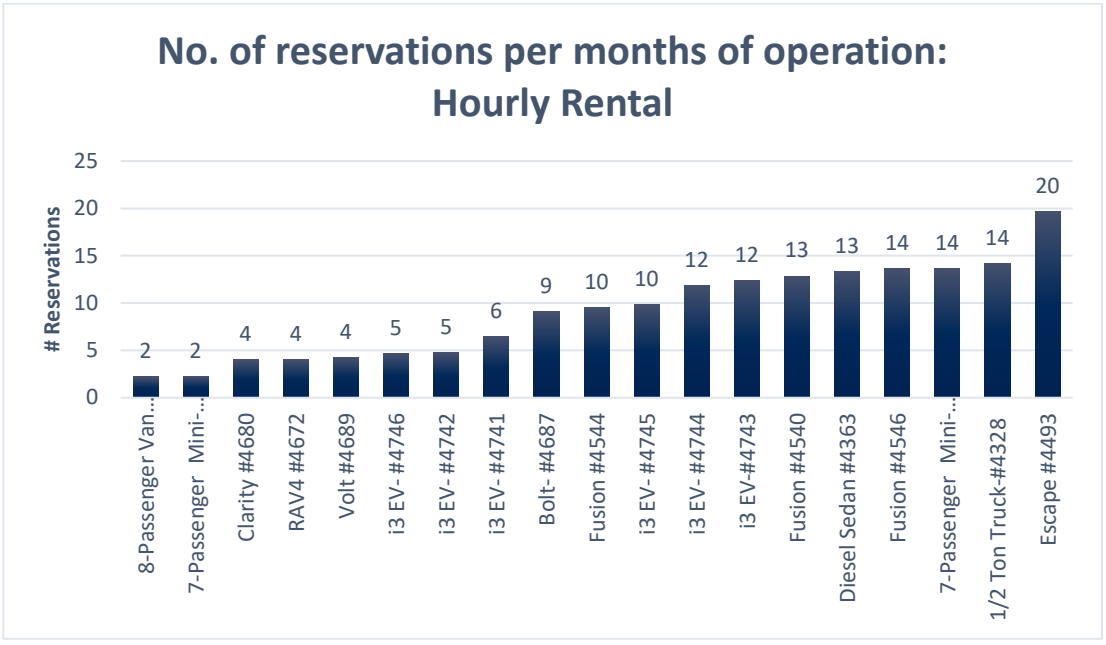

Figure 23: Average number of reservations per month

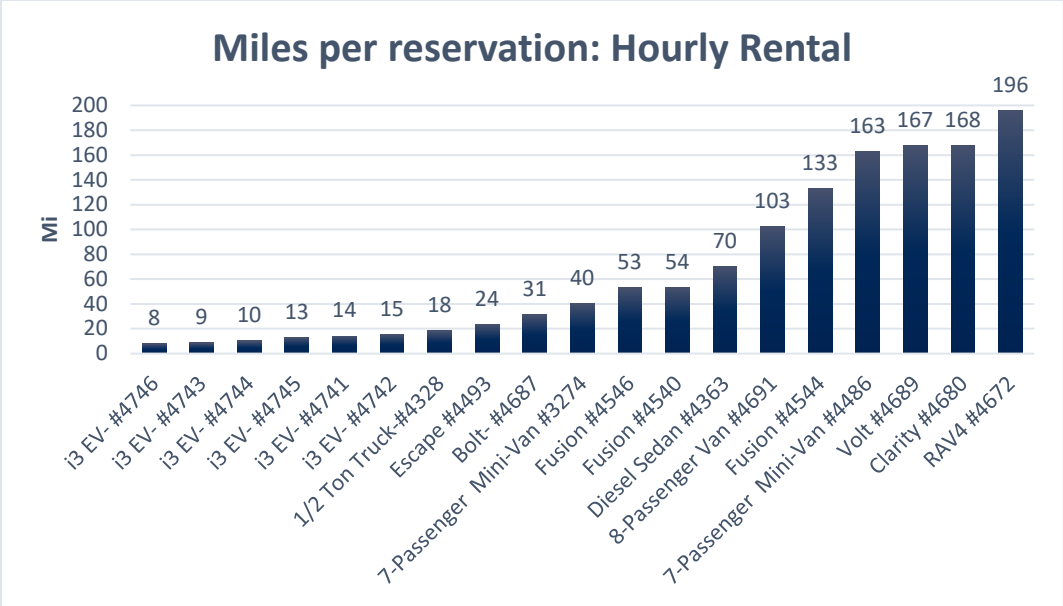

Figure 24: Average miles driven per reservation.

Considering the wide variation in the average trip distance per reservation for electric and vehicles of other fuel type, we explored the potential differences in the reason for rental as stated by the respondent/UC Drive user (Figure 25). “Outreach/Meeting” is the main reason for rentals across all the vehicles except the ½ ton truck. As expected, we observe that the i3 EVs are never used for any pickup/delivery or transportation services. SUVs, pick-up trucks, and vans are preferred for these activities.

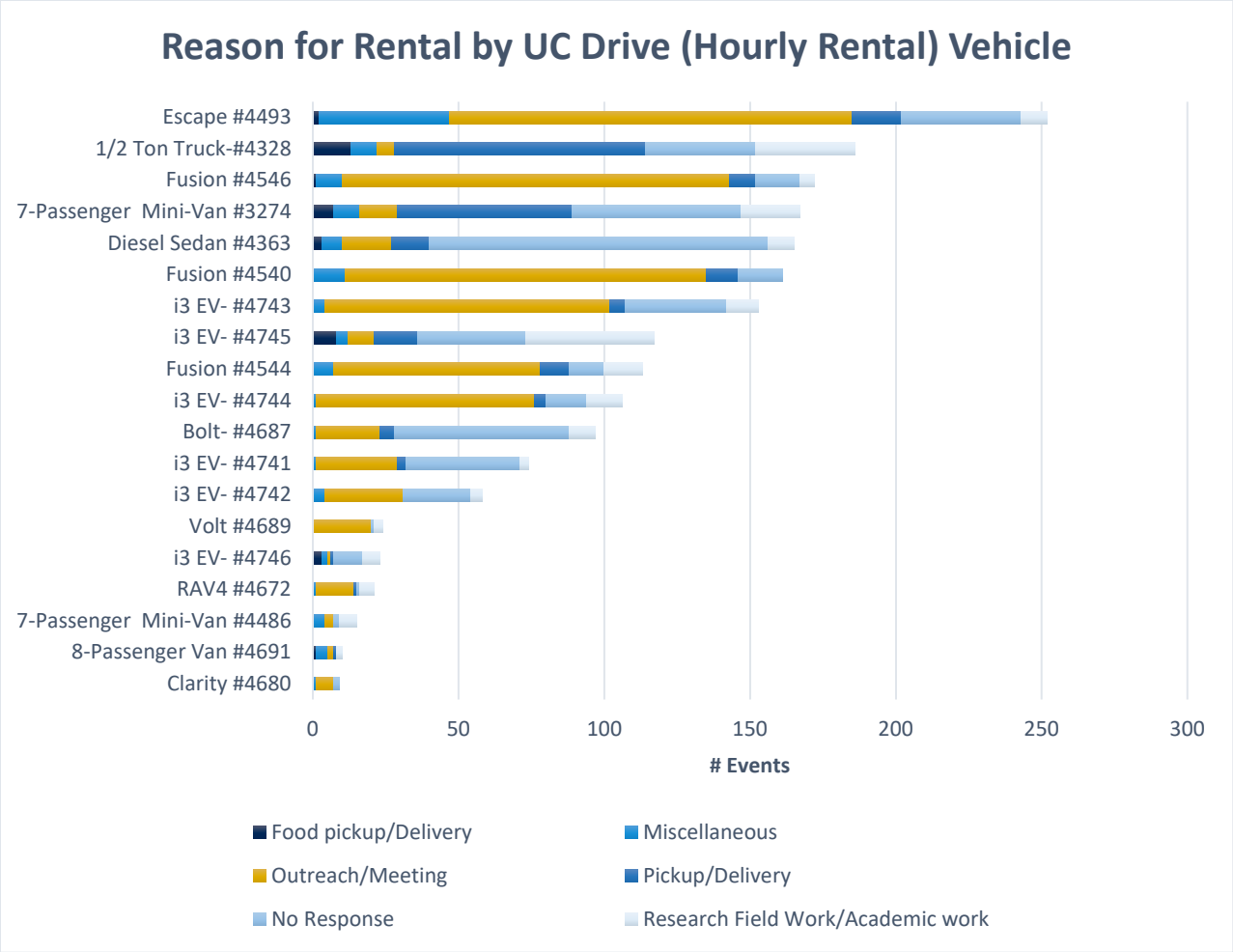

Figure 25: Reported reason for rental for UC Drive vehicles

Vehicle Charging

The charging data from BMW FleetView gives us a snapshot of the charging sessions for all the tens i3 EVs from January to October 2019 and for January and February 2020. Considering four out of the ten vehicles were deployed for 8 months (since May 2019) and not 12 months, the total number of charging events would vary considerably. Also, the number of events and energy use for charging varies by location. The i3 EV hosted by Institute of Transportation Studies (i3 EV # 4740) has the highest number of charging events and energy use. This corresponds to the vehicle usage statistics whereby the department assigned vehicles had the highest mileage.

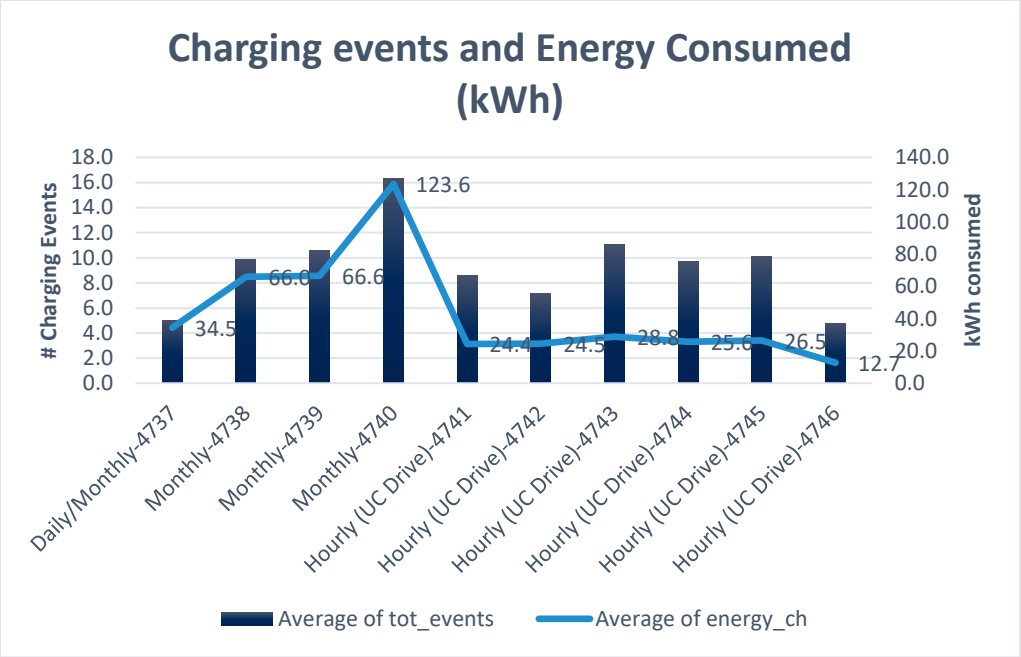

Figure 26: Average charging events and Average energy use per month for all BMW i3 EVs

The i3 EVs assigned to the Institute of Transportation (#4739 and #4740) also had considerably higher average mileage and energy use per charging event than the other vehicles (Figure 27 and Figure 28).

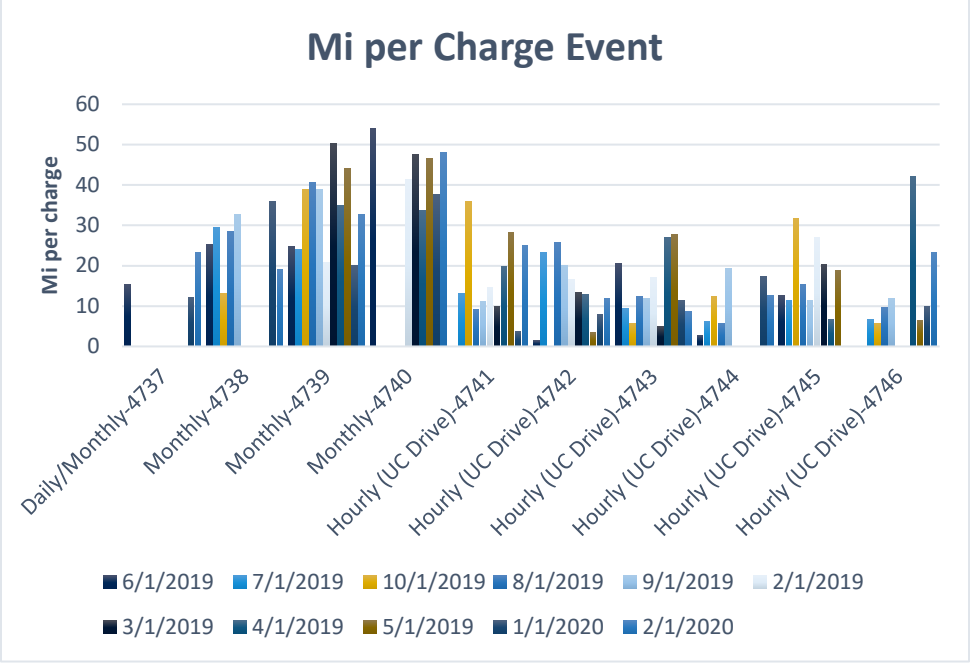

Figure 27: Miles per charging event for all BMW i3 EVs

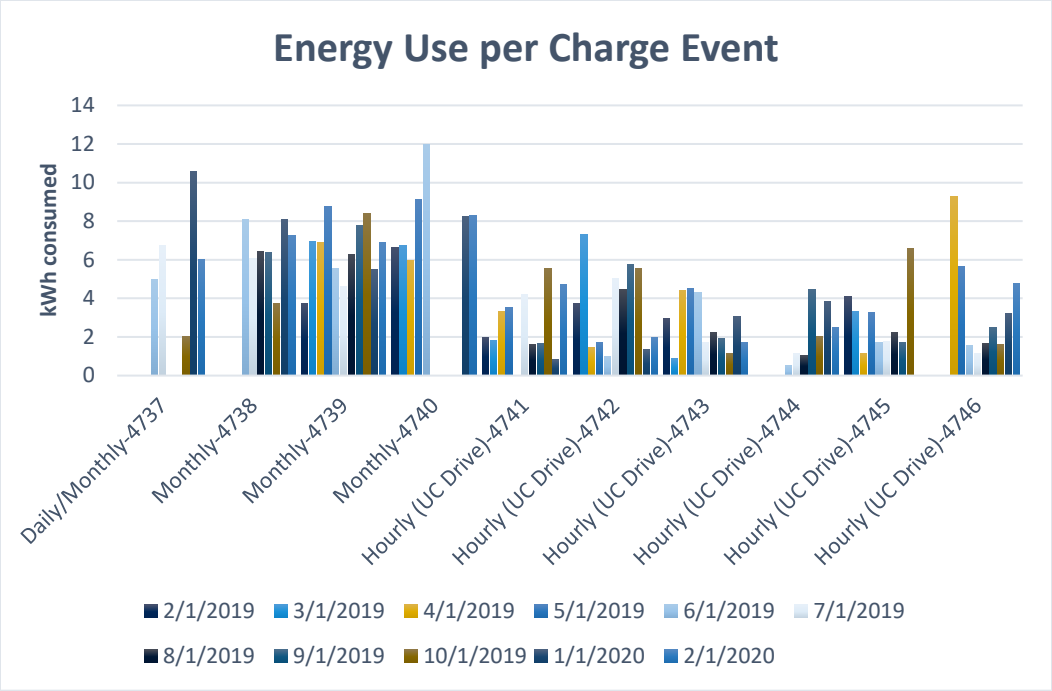

Figure 28: Energy use per charging event for all BMW i3 EVs

Conclusion

In this chapter we analyze how the ten BMW i3 EVs placed in three different fleet applications were used over a one-year period. Wide variation is observed in terms of miles traveled between the department assigned and the rest of the applications. This can be caused mainly by two factors-first, these departments have more travel needs and thereby have assigned rental vehicles and second, the users in these departments due to regular use become more comfortable with the functionality and range of the i3 EV. Considering the BMW i3 EVs in the UC Drive, the main takeaway is that used BMW i3 EVs can be a good fit for fleet applications where there is demand for vehicles for short distance trips. Also, given the vehicle design it may also be appropriate for certain types of activities like official meetings more than for transporting goods. In other words, fleet managers considering incorporating used electric vehicles like the BMW i3 EV would need to identify the applications and activities for which the i3 EV is a feasible option and deploy accordingly.

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Task 3, Part 2: Driver Surveys

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Executive Summary

In January 2020 we surveyed 242 users of University of California, Davis (UC Davis) daily or hourly rental vehicles. These vehicles include internal combustion engine vehicles (ICEs), battery electric vehicles (BEVs) which included BMW i3 BEVs, plug-in hybrid electric vehicles (PHEVs), and fuel cell vehicles (FCEVs). Vehicles are mostly rented by UC Davis staff members and are used for travel to and from meetings, to conduct field work, and to transport people.

Renters of the BMW i3 indicated they were satisfied with vehicle range, ease of charging, the vehicle interface, and interior space of the vehicle. Close to 80% of respondents indicated they are very likely to rent a BMW i3 again, though they indicated a longer driving range would make them even more likely to do so. 60% of respondents indicated the vehicle was plugged-in to charge prior to their vehicle rental, over 80% indicated they plugged the vehicle in after the rental, and only 1 respondent used electric vehicle charging away from UC Davis campus. 2/3 of those that used a BMW i3 indicated they had previously driven a BEV. This was either driving a family members or friends BEV or renting one from the University fleet previously. 80% of BMW i3 renters spoke to colleagues about their rental, and close to 70% spoke to friends or family members. This is substantially higher than for other rented BEVs, PHEVs, or ICEs. 75% of those that rented a BMW i3 indicated that they had more favorable attitudes towards BEVs after their vehicle rental, this is similar for renters of other BEVs and PHEVs. No renters of plug-in vehicles became less favorable toward them after renting the vehicle. Few respondents had seriously considered purchasing a BEV (regardless of the vehicle they rented), though more BMW i3 and BEV renters had given some consideration to buying a BEV compared to renters of ICEs or PHEVs.

Key Takeaways

- In surveying users of the UC Davis BMW i3 EVs we discovered users were positive about their experiences and were likely to use the vehicles again.
- 80% of those who rented the BMW i3 discussed the vehicles with colleagues, and 70% discussed it with family members. This may also have increased overall interested in purchasing an EV.
- More survey respondents indicated the BMW i3 was their favorite vehicle compared to any other vehicle they used, no respondents selected a conventional vehicle as their favorite.
- The only suggested improvement was to vehicle range, overall we believe the experience of renting a BMW i3 EV in a fleet improved perceptions of EVs.

Introduction to Driver Surveys

After the introduction of plug-in electric vehicles in 2008-2012, battery electric vehicles and plug-in electric vehicles have become more common for private and public use. Existing research has focused primarily on private use and adoption of PEVs, but research lacks in fleet PEV use. Fleet PEV use may be beneficial to adoption because potential buyers don't have the downsides of actual ownership and can treat rentals similar to test drives at dealerships. The Fleet User Survey hopes to gain insight into how renters of PEVs – specifically the BMW i3 – are affected by rentals of PEVs.

The purpose of the driver survey was to understand vehicle rental purpose, perceptions of vehicle range, and convenience of vehicle charging. We also gathered data on other aspects of electric vehicle rental and use, and on respondent's prior experiences with PEVs and whether they have considered purchasing a PEV for their own personal vehicle.

Method

Data Collection

The following results are taken from a survey performed at UC Davis conducted by the Plug-in Hybrid & Electric Vehicle Research Center. The survey was sent to 1023 people who previously rented a vehicle from either the Fleet Services or UC Drive rental services. 286 people responded to the survey, and 242 people finished the survey. The survey start rate was 28 percent of those we contacted, and of those who started the survey 85 percent completed it in full. Average time to complete the survey was 9 minutes, and 45 seconds.

Survey Outline

The survey was comprised of the following sections: background information, rental purpose and destination, satisfaction with the vehicle rented, UC Drive charging experience, private purchase experience and consideration, and sociodemographic information of respondents.

The background information section gathered information about the respondent's association with UC Davis and vehicle rental information. Because multiple vehicles are available for rental, this section determined the primary vehicle the remainder of the survey would be based upon. If a respondent had rented the BMW i3, that vehicle was chosen as the respondent's primary vehicle. If the respondent had rented more than one vehicle, their most recent rental would be their primary vehicle.

The rental purpose and destination section asked about the actual rental itself, including the service and vehicle qualities. The respondent was asked to rate several vehicle attributes on a likert scale. Respondents were also asked how likely they were to rent the vehicle again, and if the respondent didn't answer "very likely," the respondent was asked follow-up questions about what would make them more likely to rent the vehicle.

The UC Drive Charging experience section asked about respondent's interactions with the vehicles and charging structure. This section is only asked to UC Drive renters because UC Drive is self-service.

The private purchase experience and consideration section was comprised of questions about the respondent's previous experiences with PEVs, including BEVs, PHEVs, and FCEVs. This

section explores past and current perspectives about PEVs, including whether they have considered purchasing one.

Socio-demographic questions asked about the respondent's characteristics, such as income, house type, gender, and zip code. This information can be potentially useful in determining if a particular group of respondents has certain characteristics through analysis. Respondents were incentivized by being allowed to compete in a raffle for one of twenty $20 CoHo coffeehouse gift cards.

Results

Sample Description

We performed a survey analysis of the 242 respondents who completed the survey. A breakdown of respondent's primary vehicle rented is shown in Table 24. The table does not include all vehicles provided or rented by UC Davis Fleet Services or UC Drive, and instead lists the primary vehicle chosen by methods outlined in the *Survey Outline* section. For example, the Toyota Mirai Fuel Cell was available for rent and was rented by respondents, but was not the most recent rental of the respondent so therefore not displayed in Table 24. The vehicles shown below are the vehicles from which we asked further questions about, including regarding driver satisfaction with vehicle attributes. The most commonly rented vehicle is the full-size van, which is an ICE, followed by the Chevrolet Volt PHEV, and then the gasoline fueled sedan. The BMW i3 was rented by 24 survey takers or approximately 10% of those who responded.

The sociodemographic profile of survey takers is shown in "Survey Appendix I: Sociodemographic information for the survey sample."

Vehicle Type	Number of renters in sample
Full-size van	57
Chevrolet Volt Plug-in Hybrid	30
Gasoline-fueled Sedan	27
BMW i3 Electric	24
Pick-up Truck	17
'Other' vehicle	16
Minivan	16
Honda Clarity Plug-in Hybrid	15
Chevrolet Bolt Electric	12
Gasoline-fueled SUV	11
Ford Fusion Energi Plug-in Hybrid	9
Toyota Prius Plug-in Hybrid	7
Mitsubishi i-MiEV ES Electric	1

Table 24: Most recently rented vehicle by survey takers. Note survey takers were asked follow up questions about their most recently rented vehicle, unless they rented an i3 in which case they were asked questions about the i3 rental. The numbers below therefore indicate which vehicles survey takers were asked about.

Rental Purpose and Destination

The tables below summarize respondent rental information, association with UC Davis, and vehicle rental frequency (for UC Drive Vehicles and for Fleet Vehicle Rentals). 166 respondents said they had not used the UC Drive service, meaning a large proportion of respondents used only Fleet Services (see Table 28). Fleet Services is a daily rental whereas UC Drive is a self-service, hourly rental. A majority of respondents are staff, and rented a vehicle in order to conduct research, attend a meeting, or transport others (see Table 25, Table 26, Table 27, Table 28). Note, respondents could have rented a vehicle from both Fleet Services and UC Drive or only one of them, so if a respondent says they never rented a vehicle from Fleet Services for example, they did rent from UC Drive.

	BMW i3 Electric	ICE	BEV	PHEV
Faculty	2 (0.83%)	10 (4.15%)	2 (0.83%)	4 (1.66%)
Graduate student	3 (1.24%)	34 (14.11%)	1 (0.41%)	7 (2.90%)
Other	0 (0.00%)	7 (2.90%)	0 (0.00%)	0 (0.00%)
Staff	17 (7.05%)	75 (31.12%)	8 (3.32%)	48 (19.92%)
Undergraduate student	2 (0.83%)	18 (7.47%)	2 (0.83%)	1 (0.41%)

Table 25: Respondent Association to UC Davis for BMW i3, ICE, BEV*, and PHEV vehicle renters.

*Note, the BEV category does not include the BMW i3 and includes the Chevrolet Bolt Electric and Mitsubishi i-MiEV

	BMW i3 Electric	ICE	BEV	PHEV
Attend a meeting	11 (4.56%)	17 (7.05%)	4 (1.66%)	25 (10.37%)
Conduct research (e.g. field work)	7 (2.90%)	43 (17.84%)	4(1.66%)	16 (16.64%)
Moving equipment	1 (0.41%)	12 (4.98%)	1 (0.41%)	2 (0.83%)
Other	2 (0.83%)	20 (8.30%)	2 (0.83%)	14 (5.81%)
Pick up catering or event supplies	2 (0.83%)	3 (1.24%)	0 (0.00%)	1 (0.41%)
Transporting people	1 (0.41%)	49 (20.33%)	2 (0.83%)	2 (0.83%)

Table 26: Respondent Travel Purpose for BMW i3, ICE, BEV, and PHEV vehicle renters.

	BMW i3 Electric	ICE	BEV	PHEV
More than once a week	0 (0.00%)	2 (0.83%)	0 (0.00%)	0 (0.00%)
Once per week	0 (0.00%)	3 (1.24%)	0 (0.00%)	4 (1.66%)
1-3 times per month	2 (0.83%)	26 (10.79%)	3 (1.24%)	13 (9.13%)
1-3 times per quarter	5 (2.07%)	43 (17.84%)	2 (0.83%)	22 (6.64%)
1-3 times per year	7 (2.90%)	54 (22.41%)	5 (2.07%)	16 (1.24%)
Less than once per year	4 (1.66%)	11 (4.56%)	1 (0.41%)	3 (1.24%)
Never	6 (2.49%)	5 (2.07%)	2 (0.83%)	2 (0.83%)

Table 27: Rental Frequency of Fleet Services Respondents for BMW i3, ICE, BEV, and PHEV vehicle renters.

Rental Frequency UC Drive	BMW i3 Electric	ICE	BEV	PHEV
More than once a week	2 (0.83%)	0 (0.00%)	1 (0.41%)	0 (0.00%)
Once per week	2 (0.83%)	3 (1.24%)	0 (0.00%)	0 (0.00%)
1-3 times per month	10 (4.15%)	6 (2.49%)	1 (0.41%)	1 (0.41%)
1-3 times per quarter	5 (2.07%)	5 (2.07%)	2 (0.83%)	1 (0.41%)
1-3 times per year	4 (1.66%)	13 (5.39%)	6 (2.49%)	2 (0.83%)
Less than once per year	0 (0.00%)	6 (2.49%)	3 (1.24%)	2 (0.83%)
Never	1 (0.41%)	111 (46.06%)	0 (0.00%)	54 (22.41%)

Table 28: Rental Frequency of UC Drive Respondents or BMW i3, ICE, BEV, and PHEV vehicle renters.

Satisfaction with Vehicle Rental

Survey takers were asked to rate the vehicle they had rented for six vehicle attributes: electric driving range, ease of charging, interior space, user interface, driving experience, and overall experience. Figure 29 displays a radar chart that compares satisfaction of the vehicle rented between different types of vehicle (BMW i3, PHEVs, ICE vehicles, and BEVs). Questions about charging and driving range were only asked to respondents whose primary vehicle was a BEV or PHEV. The figure was created by converting the likert scale to a numerical scale and taking an average of the responses. The BMW i3 performed better than other vehicle types for ease of charging and electric driving range, and worse than other vehicle types for interior space and user interface, though users were still satisfied with these attributes.

Figure 29: Satisfaction for Vehicle Rentals on Likert Scale from "Very Unsatisfied" in the center of the chart to "Very Satisfied on the edge of the chart".

Respondents were also asked about their likeliness to rent the vehicle again (see Figure 30). All respondents indicated they were slightly likely or very likely to rent the BMW i3 again, the majority of which were likely to do so. No respondents were unlikely to rent the vehicle again. The likelihood to rent the BMW i3 again is similar to the likelihood to rent a PHEV, BEV, or an ICE vehicle.

To understand any vehicle attributes that could be improved, respondents who answered anything other than very likely, were asked follow-up questions about what they would change about the vehicle. Of those asked what they would like to see changed, respondents were asked to agree if they would like to see an attribute change (see Figure 32). Figure 32 suggests that

amongst those who weren't very likely to rent the BMW i3 again, 60 percent of respondents wanted to see a longer electric driving ranges, 20% indicated they would like to rent a larger vehicle, and 40% suggested they would like to see a lower rental cost. 20% of respondents indicated they would prefer to rent a gasoline vehicle, which could be related to the desire for a longer electric driving range in the BMW i3.

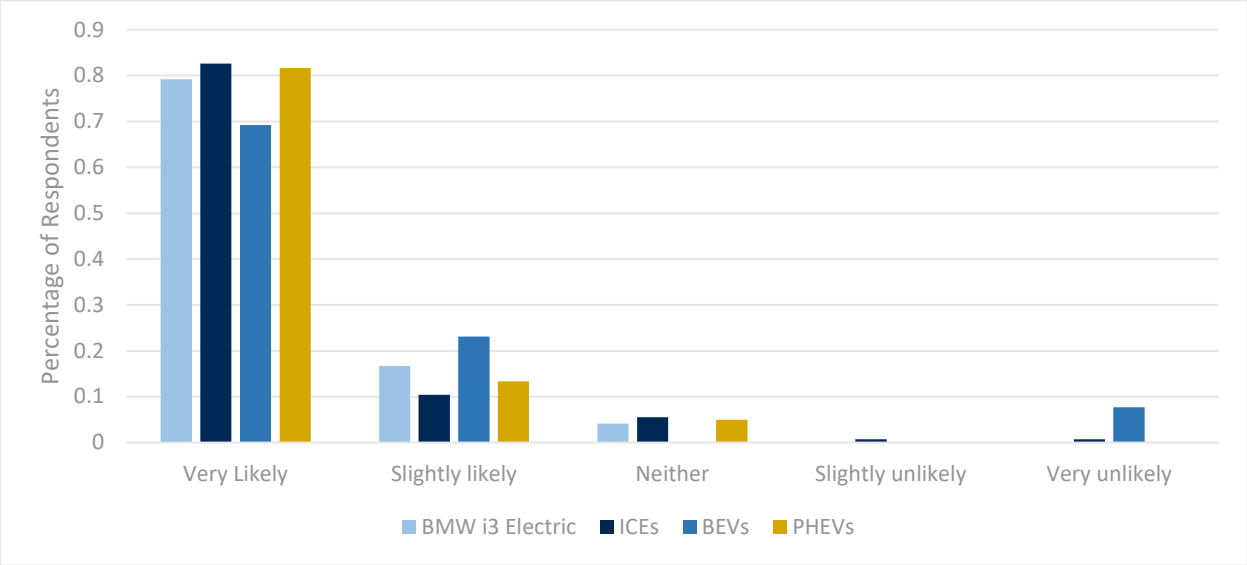

Figure 30: Likeliness of Respondent to Re-rent the Primary Vehicle

Respondents that had rented multiple vehicles from either Fleet Services or UC Drive were asked to select their favorite vehicle of the vehicles they rented (see Figure 31). Amongst those who had rented the BMW i3 and other vehicles the BMW i3 is a favorite. The other vehicles in the graph are also PEVs, indicating that vehicle renters are purposely seeking out PEVs. No respondents who had rented multiple vehicles, indicated that a conventional vehicle was their preferred vehicle.

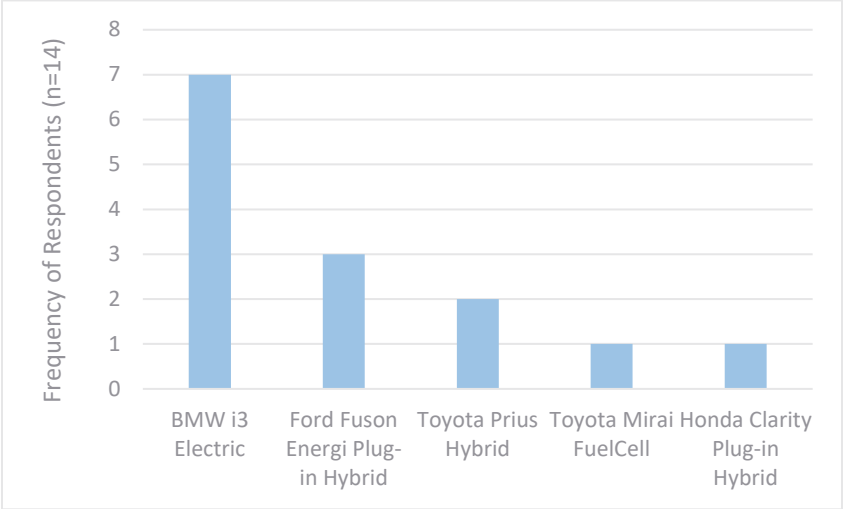

Figure 31: Answers to "You've indicated you've rented multiple types of vehicles. Which of the following vehicles do you prefer the most?"

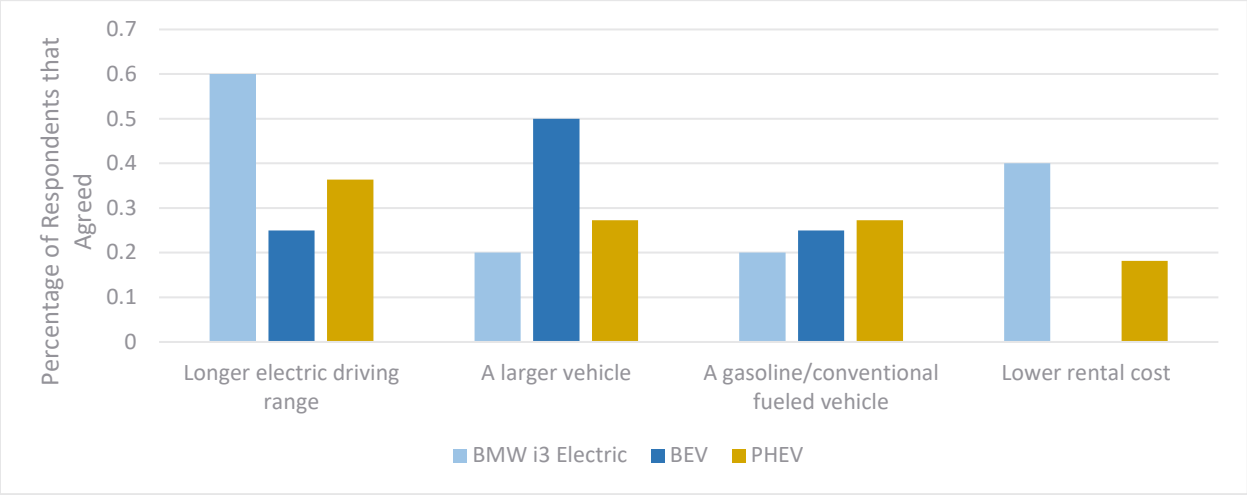

Figure 32: Answers to "You indicated that you are not very likely to rent this vehicle again. Would any of the following changes to the vehicle increase your likelihood of renting it again?" This question was asked to BMW i3 renters, renters of BEVs (which are mostly Chevrolet Bolt BEVs, and PHEVs).

UC Drive Charging Experience

Because the UC Drive rental service is a self-service rental service, and the vehicles need to be plugged-in to charge, we asked respondents about their interactions with the vehicles and charging infrastructure. This question was asked to renters of the BMW i3, Chevrolet Bolt, and Ford Fusion Plug-in Hybrid. 38 respondents were shown this question, and the majority indicated the vehicle was plugged in when they started the rental and that they plugged the vehicle in after the rental (see Figure 33). Only 1 individual indicated they charged the vehicle at an off-campus location, indicating the vehicles primarily use their infrastructure. This is likely due to the vehicles being used on shorter trips less than the driving range of the BEV, and PHEVs not needing to be charged when their electric range is depleted.

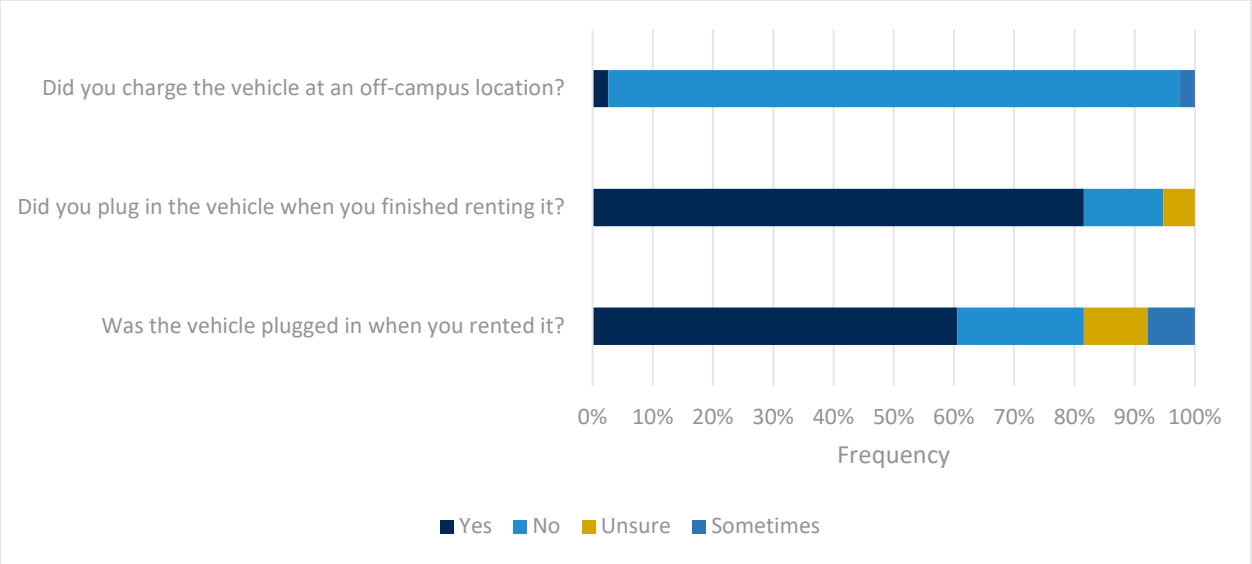

Figure 33: Whether the PEV being rented through UC Drive was plugged in to charge off campus during the rental, whether respondents plugged in the vehicle after renting it, and whether the vehicle was plugged in when the rental was started.

Prior PEV Experiences

Respondents were asked about their experiences with PEVs prior to renting one in the university fleet. Figure 34 shows whether renters of PHEVs, BEVs, ICEs, and the BMW i3 had rented a PEV previously. The BMW i3 showed the highest number of respondents who had previously driven a PEV prior to renting it. Figure 35 shows where respondents had driven a PEV (broken down by the fuel types of the vehicle they rented from UC Davis). Close to 60% of BMW i3 users indicated that they had driven a PEV in the university fleet before, and a similar percentage indicated they had driven a friend or family members PEV previously. 50% of those that rented an ICE vehicle had previously used a BEV, mostly through the university fleet services, fewer ICE renters had driven a friend or family members BEV. These results suggest that BMW i3 users have more prior experience with BEVs than those that rented other vehicles. Additionally, a higher number of BMW i3 users have driven a BEV belonging to a family member.

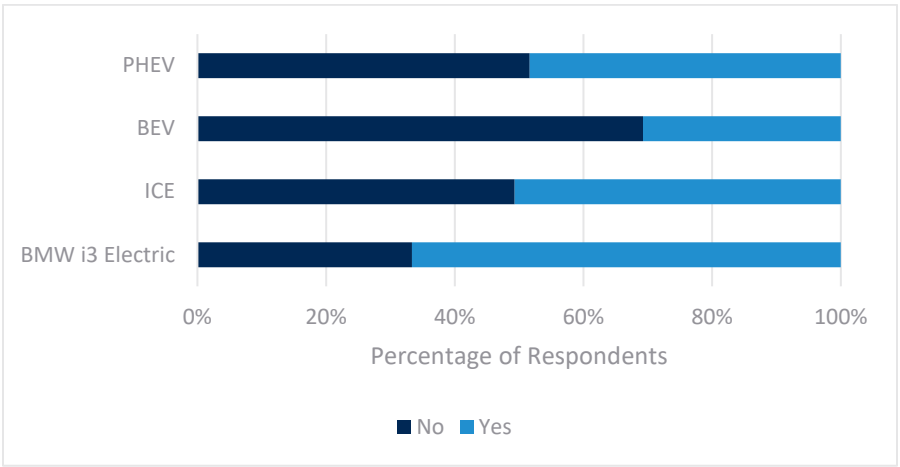

Figure 34: Answers to "Had you driven a plug-in hybrid or electric vehicle prior to renting the vehicle from UC Drive or Fleet services?"

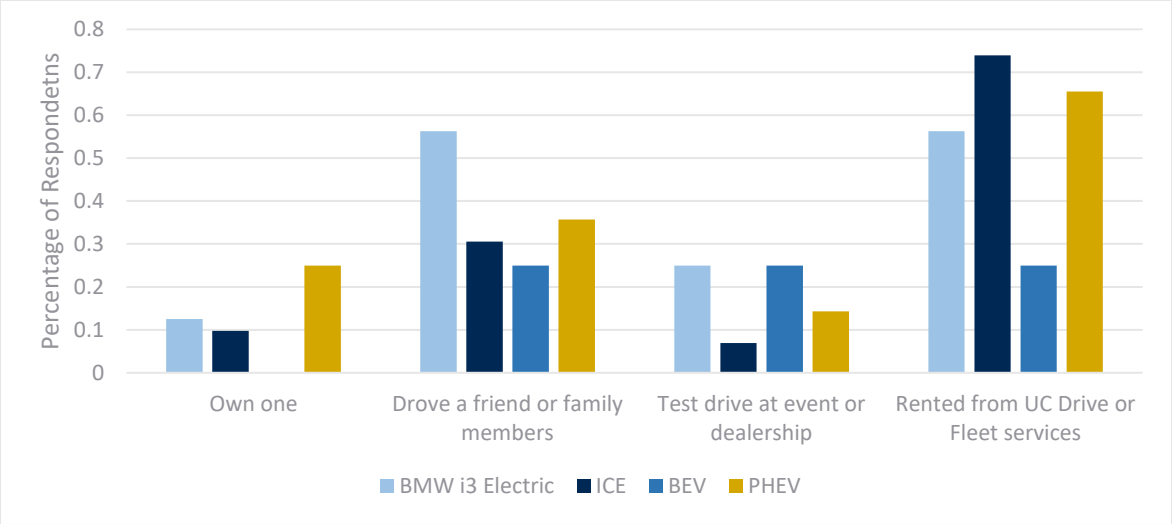

Figure 35: Where respondents who indicated they had previously driven a PEV had done so broken down by the vehicle they rented.

Consideration to purchase a PEV

To understand the impact the rental may have had on drivers, respondents were asked about whether a respondent had discussed their rental with others (see Figure 36). The question was multiple choice, respondent could select "No," "Yes, with colleagues," "Yes, with friends or family," or either option. The BMW i3 had the highest percentages of drivers who had discussed their vehicles rental with others. 80% of those who rented the i3 discussed the vehicles with colleagues, and 70% discussed it with family members. This may suggest the BMW i3 BEVs created interest in electric vehicles which respondents were motivated to share with others. Word of mouth could have the potential to positively impact BEV market growth. More research may be needed to see in what context people are talking about their vehicle rentals. (Note from the interviews in task 5, some fleet managers reported after incorporating BEVs into their fleets, more employees purchased BEVs for their private use).

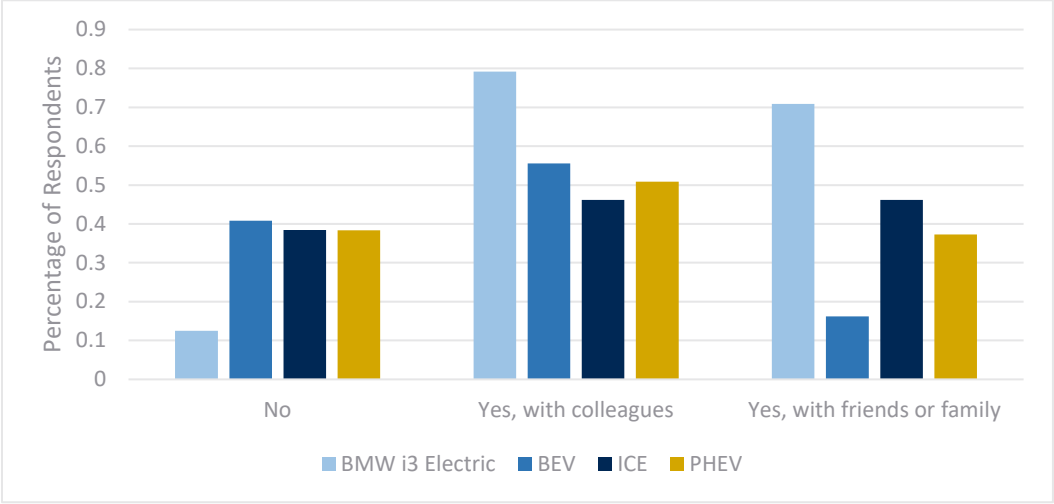

Figure 36: Respondents who Discussed their Rental with Others.

Respondents were asked if their preference towards BEVs or PHEVs had changed after they had rented a BMW i3, BEV, or PHEV (see Figure 37). For all vehicle types, Figure 37 shows that a rental setting can be beneficial for potential consumers perceptions of BEVs and PHEV. No respondents indicated the rental made them less favorable towards plug-in vehicles. It should be noted Figure 37 includes relatively small sample sizes (Table 29).

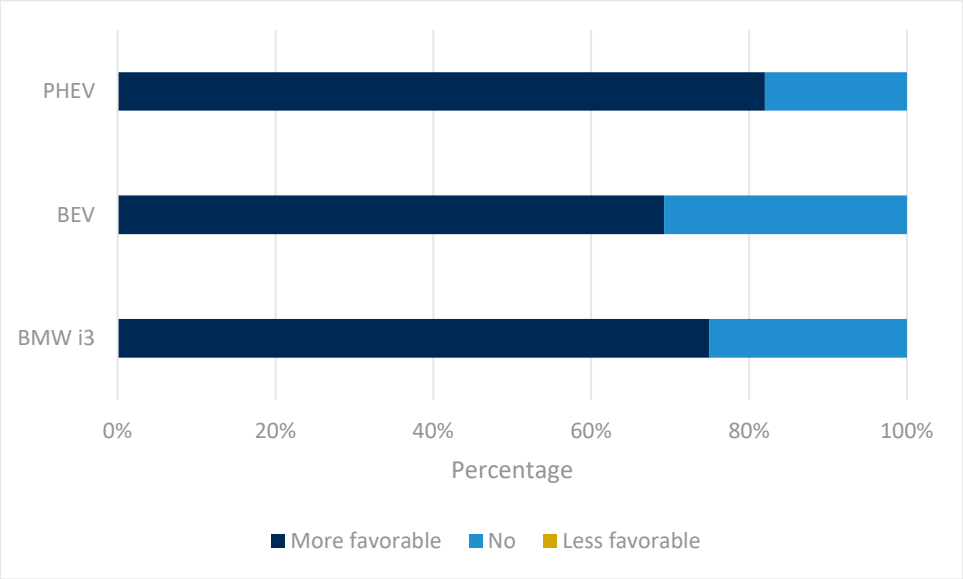

Figure 37: Answers to "Did Driving the BMW i3 (or BEV or PHEV) Change Your Preference Towards BEVs?"

Figure 38 shows whether survey takers had considered purchasing a BEV in the past, broken down by whether they rented a BMW i3, PHEV, BEV, or an ICE vehicle. No renters of the BMW i3 and BEV indicated that they "have not – and would not consider buying a BEV". Whereas 17% of ICE renters and 13% of PHEV renters indicated they would not consider a BEV. Additionally, the BMW i3 and PHEV respondents have the highest percentages of respondents who already own a BEV. For "I (we) have not considered a BEV, but maybe someday will", more ICE and PHEV renters selected this option compared to i3 and BEV renters. More i3 and BEV renters selected "Started to gather information about BEVs, but haven't really gotten serious yet" or "The idea has occurred, but no real steps have been taken to shop for a BEV" compared to ICE and PHEV renters. Too few renters of any vehicle type indicated they have shopped for a BEV or already own one to draw conclusions. The results suggest that households who have rented a BEV or a BMW i3 are more interested in purchasing a BEV for their own household, though they haven't begun to take more serious steps to make this purchase.

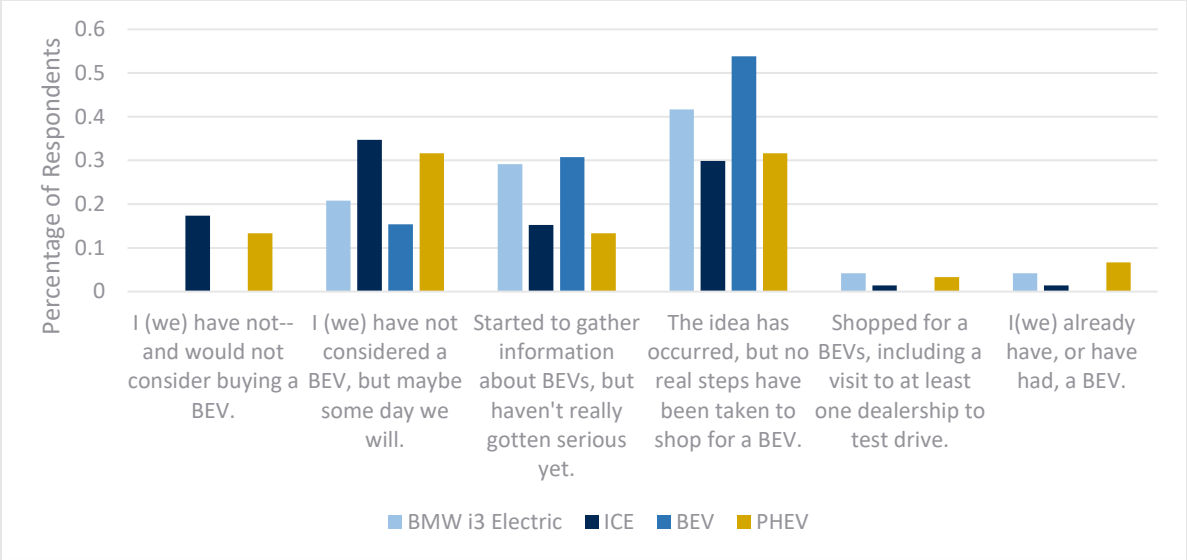

Figure 38: Answers to "Have you considered buying a BEV for your household?"

Conclusion

The BMW i3 user survey shows that vehicle users generally had a positive perception of the vehicles they have rented. Renters of the BMW i3 indicated they were satisfied with vehicle range, ease of charging, the vehicle interface, and interior space of the vehicle. Though respondents did indicate a longer driving range would make them even more likely to rent the vehicle again in the future.

A high number of BMW i3, and other BEV users indicate they have prior experience with a Plug-in Electric Vehicle (PEV). While this is encouraging it could mean that those who have not driven a plug-in vehicle previously are less likely to rent a BEV. This might mean that work needs to be done to educate those who have not driven a BEV before about renting a BEV.

It is unclear if driving a BMW i3 has a positive impact on consumer's consideration to purchase a PEV. Before driving an BMW i3 many survey takers have previously driven a BEV, which is perhaps why they chose to rent a BEV. Renters of the BMW i3 reported a positive experience renting the vehicle overall, they indicated speaking to others about the vehicle, and were mostly more positive about BEVs after the rental. It is possible that this led to some people considering purchasing a BEV for their own household.

Survey Appendix I: Sociodemographic information for the survey sample

For continuous variables, the means were calculated of relevant categories. The results are shown in Table 29.

	BMW i3	BEV	ICE	PHEV
N	24	13	144	60
Income ($)	126737	112273	97287	109804
Age (years)	41	40	38	40
Number of Drivers in the respondent's household	2.04	2.00	2.03	2.00
Number of vehicles in the respondent's household	1.50	1.62	1.60	1.82

Table 29: Sociodemographic Characteristics of BMW i3 Renters, BEV, ICEV, and PHEV renters.

The below tables summarize respondent answers for categorical variables. A greater fraction of respondents does not have solar, are Democratic, and live in a detached house (see Table 30, Table 31, Table 32, and Table 33). A larger number of BMW i3 respondents own their home than the remainder of respondents (see Table 32). Additionally, the larger population of California Electric Vehicle buyers are male, but the distribution of male and female respondents is more even here (see Table 34).

	BMW i3 Electric	BEV	ICE	PHEV
Male	12 (5.04%)	4 (1.68%)	56 (23.53%)	22 (9.24%)
Female	11 (4.62%)	9 (3.78%)	85 (35.71%)	35 (14.71%)
Genderqueer/non-binary	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)
Decline to state	1 (0.42%)	0 (0.00%)	3 (1.26%)	0 (0.00%)

Table 30: Respondent Political Preference for BMW i3 Renters, BEV, ICEV, and PHEV renters.

	BMW i3 Electric	BEV	ICE	PHEV
Democratic	12 (4.98%)	8 (3.32%)	92 (38.17%)	41 (17.01%)
Republican	2 (0.83%)	1 (0.41%)	7 (2.90%)	0 (0.00%)
Other	1 (0.41%)	1 (0.41%)	6 (2.49%)	2 (0.83%)
I'd prefer not to answer	4 (1.66%)	2 (0.83%)	18 (7.47%)	11 (4.56%)
None	5 (2.07%)	1 (0.41%)	21 (8.715)	6 (2.49%)

Table 31: Respondent House Type BMW i3 Renters, BEV, ICEV, and PHEV renters.

	BMW i3 Electric	BEV	ICE	PHEV
Apartment or Condo	4 (1.69%)	3 (1.27%)	40 (16.88%)	10 (4.22%)
Attached house	6 (2.53%)	2 (0.84%)	23 (9.70%)	7 (2.95%)
Detached house, also called a single family home	14 (5.91%)	8 (3.38%)	77 (32.49%)	43 (18.14%)

Table 32: Frequency of Respondent House Ownership BMW i3 Renters, BEV, ICEV, and PHEV renters.

	BMW i3 Electric	BEV	ICE	PHEV
Own	18 (7.44%)	6 (2.48%)	55 (22.73%)	34 (14.05%)
Rent	6 (2.48%)	7 (2.89%)	83 (34.30%)	24 (9.92%)
Lease	0 (0.00%)	0 (0.00%)	8 (3.31%)	1 (0.41%)

Table 33: BMW i3 Renters, BEV, ICEV, and PHEV renters

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	BMW i3 Electric	BEV	ICE	PHEV
No	20 (8.30%)	10 (4.15%)	125 (51.87%)	51 (21.16%)
Yes	4 (1.66%)	3 (1.24%)	19 (7.88%)	9 (3.73%)

Table 34: Respondent Who Have Solar Installed in their Home and the vehicle type they rented.

	BMW i3 Electric	BEV	ICE	PHEV
Male	12 (5.04%)	4 (1.68%)	56 (23.53%)	22 (9.24%)
Female	11 (4.62%)	9 (3.78%)	85 (35.71%)	35 (14.71%)
Non-binary	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)
Decline to state	1 (0.42%)	0 (0.00%)	3 (1.26%)	0 (0.00%)

Table 35: Gender of survey respondents and the vehicle type they rented.

Survey Appendix II: Survey Questions

Below is an outline of the questions asked in the survey and the possible answer responses. Note, items inside brackets "[]" represent survey logic. For example, "[main vehicle]" refers to the vehicle the respondent was asked questions about after the background information section.

Survey Question	Possible Responses
1. What is your primary association with UC Davis?	Undergraduate student
	Graduate Student
	Staff
	Faculty
	Other (open text option)
2. How often do you rent any vehicle from the Fleet Motor pool (daily rental)?	More than once a week
	Once a week
	1-3 times per month
	1-3 times per quarter
	1-3 times per year
	Less than once per year
	Never
3. How often do you use the UC Drive (hourly rental) ?	More than once a week
	Once a week
	1-3 times per month
	1-3 times per quarter
	1-3 times per year
	Less than once per year
	Never
4. Which vehicle or vehicles do you rent from UC Drive? [If response not never for q3]	Ford Fusion Energi Plug-in Hybrid

	BMW i3 Electric
	Chevrolet Bolt Electric
	Pick-up Truck
	Diesel Sedan
	Minivan
	Unsure
	Other (open text option)
5. Which vehicle or vehicles do you rent from Fleet services [if response != never q2]	Ford Fusion Energi Plug-in Hybrid
	BMW i3 Electric
	Nissan Leaf Electric
	Toyota Mirai Fuel Cell
	Chevrolet Volt Plug-in Hybrid
	Toyota Prius Plug-in Hybrid
	Honda Clarity Plug-in Hybrid
	Mitsubishi i-MiEV ES Electric
	Pick-up Truck
	Diesel Sedan
	Gasoline-fueled Sedan (including hybrids)
	Gasoline-fueled SUV (including hybrids)
	Minivan
	Full-size van
	Unsure
	Other (open text option)
6. You've indicated you rented multiple vehicles. Which of the following did you rent most recently? [If q4 or q5 != BMW i3]	[Selected vehicles from q4 and q5]
7. When did you start using UC Drive?	[select date]

8. When did you first rent the BMW i3 through UC Drive?	[select date]
9. Were you aware that UC Drive offered an hourly vehicle rental program? [If never q4]	Yes No
10. What is your most common travel purpose when renting the [main vehicle]	Conduct research (e.g. field work) Moving equipment Transporting people Pick up catering or event supplies Attend a meeting Other (open text option)
11. In addition to yourself, how many additional passengers do you typically travel with when you rent the [main vehicle]	0 1 2 3 4 5 6 or more
12. Considering the options below: How satisfied were you with your experience driving the [main vehicle]?	Very satisfied Slightly satisfied Neutral Slightly dissatisfied Very dissatisfied
Overall experience	
Electric driving range [PHEV or BEV]	
Ease of use charging [PHEV or BEV]	
Interior space	
Cargo space	
Dashboard/User interface	
Driving experience	

13. How likely are you to rent the vehicle again?	Very likely Slightly likely Neither Slightly unlikely Very unlikely
14. You indicated that you are not highly likely to rent this vehicle again. Would any of the following changes to the vehicle increase your likelihood of renting it again? [If q13 != Very likely]	Longer electric driving range A larger vehicle A gasoline/conventional fueled vehicle Lower rental cost Other (open text option)
15. How likely would you be to recommend renting the [main vehicle] to colleagues?	Very likely Slightly likely Neither Slightly unlikely Very unlikely
16. Have you discussed your experience with the [main vehicle] with others? Click all that apply.	No Yes, with colleagues Yes, with friends or family Other (open text option)
17. How satisfied were you with the following for UC Drive? [if q5 != never] Vehicle rental process Distance from your office Availability of vehicles Hourly cost of rental	Very satisfied Slightly satisfied Neutral Slightly dissatisfied Very dissatisfied
18. Please provide any additional comments about your UC Drive experience below	[Open text response]

19. How satisfied were you with the following for Fleet Services? [if q4 != never] Vehicle rental process Distance from your office Availability of vehicles Hourly cost of rental	Very satisfied Slightly satisfied Neutral Slightly dissatisfied Very dissatisfied
20. Please provide any additional comments about your Fleet Services experience below	[Open text response]
21. Was the [main vehicle] plugged in when you rented it? [if vehicle was rented from UC Drive and was a BEV or PHEV]	Yes No Unsure Other (open text option)
22. Did you plug in the [main vehicle] when you finished your rental? [if vehicle was rented from UC Drive and was a BEV or PHEV]	Yes No Unsure Other (open text option)
23. Did you charge the [main vehicle] at an off-campus location? [if vehicle was rented from UC Drive and was a BEV or PHEV]	Yes No Unsure Other (open text option)
24. Had you driven a plug-in hybrid or electric vehicle prior to renting the [main vehicle] from the UC Drive or Fleet services? [If main vehicle was a PHEV or BEV]	Yes No
25. Had you driven a plug-in hybrid or electric vehicle previously? [if main vehicle was not a PHEV or BEV]	Yes No
26. Specifically: [if q24 or q25 = yes]	Own one Drove a friend or family member's

	Test drive at event or dealership
	Rented from UC Drive or Fleet services
	Other (open text option)
27. How many vehicles does your household currently own or lease, that are driven at least once per week? (Count cars, trucks, vans, minivans, or sport utility vehicles, but do not include motorcycles, recreational vehicles, or motor homes.).	0
	1
	2
	3
	4 or more
28. Of the vehicles from the previous question, how many did your household buy or lease as a new vehicle since January 2014?	0
	1
	2
	3
	4 or more
	I am not sure, but at least 1
29. Of the vehicles from the previous question, how many did your household buy or lease as a used vehicle since January 2014?	0
	1
	2
	3
	4 or more
	I am not sure, but at least 1
30. You've indicated you've rented multiple types of vehicles. Which of the following vehicles do you prefer the most?	[responses from q4 and q5]
31. Battery electric vehicles (BEVs) run only on electricity; they plug-in to charge their batteries. Have you considered buying a BEV for your household? Select one.	I (we) have not—and would not consider buying a BEV.
	I (we) have not considered a BEV, but maybe some day we will.

	The idea has occurred, but no real steps have been taken to shop for a BEV.
	Started to gather information about BEVs, but haven't really gotten serious yet.
	Shopped for a BEVs, including a visit to at least one dealership to test drive.
	I (we) already have, or have had, a BEV.
32. Did your thoughts towards BEVs change after driving the [main vehicle]? [asked if main vehicle was a BEV]	No
	Yes it made me more favorable towards BEVs
	Yes, it made me less favorable towards BEVs
33. Plug-in hybrid vehicles (PHEVs) run on electricity and gasoline; you can both plug them in to charge their batteries and refuel them at a gasoline station. Have you considered buying a PHEV for your household? Select one.	I (we) have not—and would not consider buying a PHEV.
	I (we) have not considered a PHEV, but maybe some day we will.
	The idea has occurred, but no real steps have been taken to shop for a PHEV.
	Started to gather information about PHEVs, but haven't really gotten serious yet.
	Shopped for a PHEVs, including a visit to at least one dealership to test drive.
	I (we) already have, or have had, a PHEV.
34. Did your thoughts towards PHEVs change after driving the [main vehicle]? [asked if main vehicle was a PHEV]	No
	Yes it made me more favorable towards PHEVs
	Yes, it made me less favorable towards PHEVs
35. Fuel Cell vehicles (FCEVs) run only on hydrogen fuel cells; they are propelled through hydrogen fuel. Have you considered buying a FCEV for your household? Select one.	I (we) have not—and would not consider buying a FCEV.
	I (we) have not considered a FCEV, but maybe some day we will.
	The idea has occurred, but no real steps have been taken to shop for a FCEV.

	Started to gather information about FCEVs, but haven't really gotten serious yet.
	Shopped for a PHEVs, including a visit to at least one dealership to test drive.
	I (we) already have, or have had, a FCEV.
36. Did your thoughts towards FCEVs change after driving the [main vehicle]? [asked if main vehicle was a FCEV]	No
	Yes it made me more favorable towards FCEVs
	Yes, it made me less favorable towards FCEVs
37. How would you describe the building in which you live?	Detached house, also called a single family home
	Attached house, for example duplexes, triplexes, row houses
	Apartment or Condo
	Mobile Home
	Other (open text option)
38. Does the building you live in have solar panels to produce electricity?	Yes
	No
39. Do you own, rent, or lease the building in which you live?	Own
	Rent
	Lease
	Other (open text option)
For the following questions, please consider your household as all of those who currently live with you, including yourself. If you do not make vehicle decisions with other members of your household, consider your household as just yourself.	1
	2
	3
	4
	5
	6
	7
40. How many people in your household are over the age of 16?	8 or more
41. How many people over the age of 16 have driver's licenses?	[number options up to answer from q40]
42. How many people in your household are under the age of 16?	1
	2
	3
	4

	5 6 7 8 or more
43. Think about your household's decisions about buying (or leasing) motor vehicles. Which of these statements best describes your role in these decisions?	I am the only decision maker in my household regarding motor vehicle purchases. I am one of the people in my household to decide about motor vehicle purchases. I make these decisions with one or more people who don't live in my household. I don't take part in decisions about whether my household buys motor vehicles
44. How do you and the other person (or other people) make these decisions? Please choose the one that seems the most correct.	We share decisions about motor vehicles together equally I generally play a larger role in these decisions, with some input from others. I generally play a smaller role in these decisions, providing input to someone else who plays the larger role. If I will be the primary driver of the vehicle, I play a larger role with input from others, but if someone else will be the primary driver, I play less of a role.
45. What is the highest level of formal education you have completed?	Grade 8 or less Some High School High School Graduate or GED Some College College Graduate Some Graduate School Masters, Doctorate, or Professional Degree Prefer not to answer
46. What is your age?	15 to 18 19 to 29 30 to 39 40 to 49 50 to 59 60 to 69 70 to 79 80 or older

47. What is your gender?	Decline to state Female Male TransMale/Transman TransFemale/Transwoman Genderqueer/non-binary Decline to state Other (open text option)
48. What was your household's pre-tax income for the past tax year? *Please click the slider at the far right to movie it to the point on the line that matches your answer.*	[Slider option]
49. Whether you are a member or not, with what political party do you most strongly identify?	Democratic Republican None I'd prefer not to answer Other
50. In what zip code does your household reside?	[enter zip code]

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Task 4: Fleet Operator Interview/Focus Group Development

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Executive Summary

The interview protocol developed here aimed to understand vehicle fleet information, how fleets purchase vehicles, their decision-making process, their preferences towards electric vehicles and used electric vehicle, and other topics. The protocol was developed in such a way to allow interviewees (i.e. fleet managers) to reveal what is most important to them. We ruled out conducting focus groups and chose to focus on interviews due to ease of sampling, this allowed us to sample 23 fleets, rather than the 10-15 initially stated in the SOW. The protocol was developed in collaboration with the team from BMW such that it met their requirements.

Interview Protocol

General Information on Fleet and Procurement of Vehicles

- Vehicle fleet information
    - Number of light duty vehicles in fleet, number of purchases per year
    - Number of cars
    - Range of light duty vehicle costs
    - Number of drivers
    - Vehicle uses
    - Average, minimum, and maximum VMT of vehicles in the fleet?
        - How predictable are the vehicle use patterns?
    - Does the fleet have any special requirements for vehicles?
- Fleet vehicle purchase decision process
    - Total costs
    - Purchase Price
    - Maintenance costs
    - Reduced reliability
    - Improved image
    - Climate protection
    - Reduced comfort
    - Reduced safety
    - Improved employee motivation
    - Operational capabilities
    - Meeting Regulations
- Does the fleet purchase vehicles from any particular place?
    - Any requirements to buy from specific organization?

Sustainability Questions

- Fleet environmental or sustainability goals
- Organization environmental or sustainability goals
    - EX: Reducing energy use or carbon intensity

Alternative Fuel Vehicle Questions

- Does the fleet have any alternative fuel vehicles?
    - If no EV: Thoughts on how plug-in electric vehicles could fit in the fleet?
        - Driving patterns
        - Special vehicle needs
        - Pros and cons of the vehicles
        - Barriers to adoption
        - If you were to purchase an EV, what price would you want to pay in comparison to the average vehicle in the fleet?
    - If yes EV: How was the decision to purchase electric vehicles made? Why did the fleet buy them?
        - What experiences have you had using the EVs in the fleet?
            - Driving patterns
            - Special vehicle needs
            - Pros and cons of the vehicles
            - Barriers to use
        - How are the vehicles charged?
        - Compared to the typical vehicle in your fleet, how much did the EV cost?
        - Have you used any subsidies/ grants/ purchase programs?
            - If no, why not?
- Are you aware of the public/ private fleet requirements?
    - If yes, what are they?
        - EX: State-owned light duty: 50% of annual purchases by 2024-2025
- Have you ever procured a second hand or used vehicle?
    - Thoughts on used electric vehicles?
    - Compared to a new gasoline vehicle what would you want to pay for a used electric vehicle?

Fleet Management Information and Software

- What information do you use to track vehicles in the fleet?
    - Such as maintenance, costs, mileage
- Do you use any management tools/software for the fleets?
- What information would you like to see for electric vehicles?
- How do you see the profile of the fleet changing over the next couple of years?

Interaction Questions (Optional, time pending)

- Interaction with others in the organization? (Facilities, energy, management, etc.)
- How often do they speak to fleet managers in other organizations?
    - Have you spoken about electric vehicles?

Task 5: Vehicle Fleet Manager Requirements and Use Cases

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Executive Summary

This report presents the results from a series of semi-structured interviews with managers from 23 fleets (up from the initial 10-15 planned in the SOW) that were conducted across California in 2019, which examined various aspects of how fleets around California are making the transition to electric vehicles. This includes a review of how fleet managers make their vehicle purchase decisions, the barriers and opportunities to the adoption of Plug-in Electric Vehicles (PEVs) in fleets, what information fleet managers use when tracking their vehicles, and whether fleet managers would purchase used electric vehicles. These interviews showed that the most commonly mentioned motivation for PEV adoption by fleets was to meet an organization's sustainability and environmental goals, as well as setting an example as a "green leader". While most fleets had adopted at least one PEV, there are still substantial barriers to electrification including the lack of time and monetary resources needed to properly evaluate this option. Furthermore, while PEVs may provide a reduced total cost of ownership, the structured allocation of costs between departments in many organizations may prevent them from being able to truly realize these savings.

Further exploring fleets' attitudes towards purchasing used vehicles, these interviews revealed that about 30% of fleets reported being open to purchasing used electric vehicles, with an additional 13% saying that they were unsure whether they would. They reported the three main barriers to this as being the lack of warranty on the vehicles, the risk of purchasing outdated technology, and the lack of a way to competitively bid the vehicles.

Key Takeaways

- California vehicle fleets are beginning to electrify, predominately with their light duty passenger vehicles at first.
- EV purchasing is driven by sustainability goals set within the organization, though fleets regulated by the state also must comply with these requirements.
- The purchase of a used electric vehicle represents an unfamiliar situation for fleet managers, who are not always used to EV purchase and are not used to purchasing used vehicles.
- Fleet managers concerns about used vehicles could be addressed by selling multiple of the same vehicle as a package thus creating a more standardized experience for the fleets, selling vehicles in the range of 20-50% less of their new price, offering training on the vehicles, and offering extended warranties or assurances on vehicle reliability

Introduction

In this task report, we summarize the results of a series of interviews into the adoption of Plug-in Electric Vehicles (PEVs), including Battery Electric Vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs), by examining the issues and benefits for integrating these vehicles into California fleets. This includes an overview of how organizations make their purchase decisions and whether PEVs fit into these larger goals. We examine the issues and benefits that fleets who have already procured PEVs have experienced and look at the perceived barriers to adoption for fleets that have not yet made the decision to purchase a PEV. This includes an overview of how these vehicles are being integrated into the fleets, the management tools used by fleets, and the opportunities for the integration of used vehicles into these fleets.

The high average mileage of fleet vehicles, as well as their generally quicker turnover rates, makes the replacement of these vehicles with low and zero emission equivalents an important milestone for meeting California's tightening emissions standards [53]. To date most PEV research has focused on consumer adoption, meaning fleets have been overlooked and their electrification potential is not fully understood [54-55]. Given the centralized purchasing of fleet vehicles, there is a greater opportunity to electrify a large number of vehicles with a smaller number of people involved.

This study helps create a broader understanding of the motivations behind the decision to purchase a PEV and discusses ways to overcome barriers and foster growth for current incentive programs and support PEV adoption in fleets.

Methods

The data for this project comes from a series of 23 semi-structured hour-long interviews that were conducted with fleet managers in California over a seven-month period, concluding in September 2019. As shown in Figure 39, participants were selected from three main regions, including the Sacramento Area, the San Francisco Bay Area, and the greater Los Angeles Area, with two additional interviews conducted in the Central Valley. These interviews were conducted with fleets of various sizes and structures, ranging from approximately 250 to 50,000 vehicles and pieces of equipment. Theses interviews focus mostly on public organizations such as cities and counties, as shown in Figure 40, and explored topics such as how fleets make their vehicle purchase decisions, how they are managed, user experiences with the vehicles thus far, experiences with used vehicles, and the fleet manager's thoughts on how PEVs could fit into their fleet, among other topics. The interview protocol used in these interviews can be seen in Task 4.

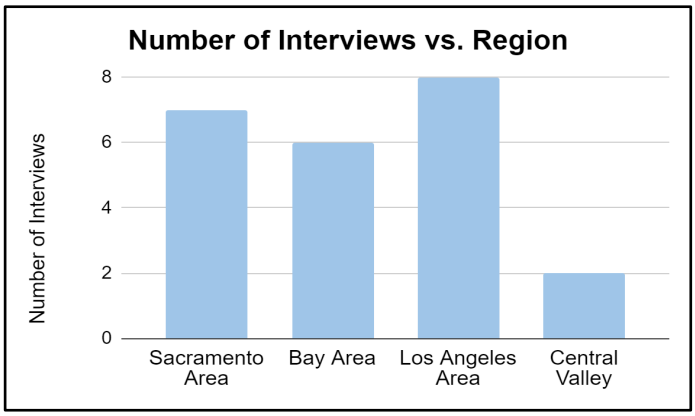

Figure 39: Interview Participants by Location.

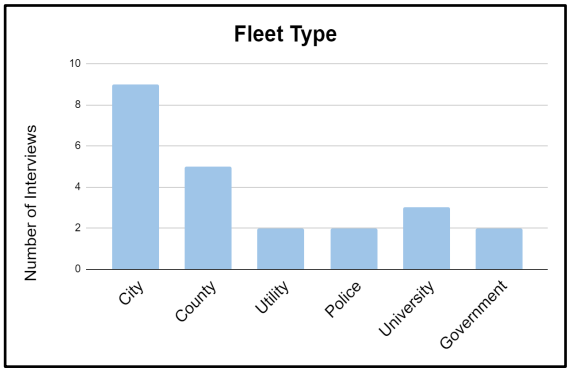

Figure 40: Interview Participants by Organization Type.

Table 36 shows an overview of the 23 fleets interviewed in this study, with a combined fleet size of over 85,000 vehicles. All fleets include a combination of light, medium, and heavy-duty vehicles. These fleets were composed mostly of light and medium duty vehicles, with a smaller number of heavy-duty. The number of light-duty vehicles in the fleet ranged from 40 to 4,000, making up between 3% and 98% of the total fleet, with an average of 46%. The type of vehicles and their uses largely corresponded to the fleet type, for example, city, county, and university fleets generally include a similar makeup of sedans, trucks, police, fire, and maintenance vehicles. Utility fleets were commonly composed of more specialized vehicles such as those used in maintaining electrical infrastructure, including a large number of medium duty chassis cabs with specialist equipment built on.

The majority of light duty vehicles in this study were “sedans,” although we note that fleet managers had varying definitions of what constitutes a “sedan.” For the purpose of this paper, a sedan is classified as any light duty passenger vehicle including sedans, compacts, SUVs, but excluding pickup trucks. The use of sedans in the fleets interviewed included administrative work (attending meetings, travel for business, etc.), police vehicles (patrol, detective, and administrative), and pool vehicles for employees to use on an hourly or daily basis for various purposes. Many fleets also included pickup trucks in their count of light duty vehicles, which are used for more diverse applications, such as moving equipment.

Fleet Number	Fleet Type	Location	Number of Vehicles	Number of Light Duty Vehicles	Vehicle Sizes	Vehicle Uses
1	University	Sacramento Area	850	350	Light, Medium, and Heavy Duty	Sedans, police, fire, pick-up trucks, vans
2	City	Sacramento Area	2,400	650	Light, Medium, and Heavy Duty	Fire, police, refuse, pool cars (sedans), maintenance, bucket trucks
3	County	North Bay Area	328	216	Light, Medium, and Heavy Duty	County operations (sedans), police, off road
4	County	Sacramento Area	2,600	1,200	Light, Medium, and Heavy Duty	Police, refuse, maintenance, general, welfare, airport vehicles etc.
5	Utility	Sacramento Area	1,000	250	Light, Medium, and Heavy Duty	Utility maintenance, pool cars, maintenance and inspection
6	City	Sacramento Area	250	40	Light, Medium, and Heavy Duty	Fire, police, paratransit, administrative (sedans)
7	Police	Greater Los Angeles Area	5,500	4,000	Light, Medium, and Heavy Duty	Police and administration
8	County	Greater Los Angeles Area	3,600	900	Light, Medium, and Heavy Duty	Road, sewer, traffic signal maintenance, administrative, rental pool
9	University	Greater Los Angeles Area	400	200	Light, Medium, and Heavy Duty	Maintenance, research, administrative, general travel, rental pool
10	City	Greater Los Angeles Area	2,100	700	Light, Medium, and Heavy Duty	Refuse, police, fire, street sweeper, helicopter, administrative, towing, parking enforcement, boats
11	University	Greater Los Angeles Area	1,180	50-100	Light, Medium, and Heavy Duty	Trucks, vans, carts, police, ambulance, box trucks
12	State	State Wide	12,000	300-500	Light, Medium, and Heavy Duty	500 different types of vehicle
13	City	North Bay Area	800	600	Light, Medium, and Heavy Duty	Lawnmower, fire truck, administrative, police, bucket trucks, construction
14	Police	East Bay Area	250	200	Light, Medium, and Heavy Duty	Patrol cars, detective cars, admin cars, under cover cars, SWAT, large command center, vans for transport
15	City	Greater Los Angeles Area	1275	600	Light, Medium, and Heavy Duty	Utilities, police, administrative, fire, street cleaning
16	Utility	Greater Los Angeles Area	5,000	1,500	Light, Medium, and Heavy Duty	Diggers, boom trucks, cranes, administrative
17	City	Greater Los Angeles Area	500	178	Light, Medium, and Heavy Duty	Fire/ PD/ administrative/ sewer
18	City	Central Valley	436	35	Light, Medium, and Heavy Duty	Lawnmower, fire, buses, sewer, police, etc.
19	City	East Bay Area	1825	1100	Light, Medium, and Heavy Duty	Everything
20	County	North Bay Area	1,350	986	Light, Medium, and Heavy Duty	Pool cars (sedans) excavators, crane, sweeper, police
21	County	Central Valley	1,100	800	Light, Medium, and Heavy Duty	Police, administrative, dump truck, etc.
22	State	State-wide	4,500	4,410	Light, Medium, and Heavy Duty	Law enforcement and everything else
			50,000	30,000	Light, Medium, and Heavy Duty	Law enforcement and everything else
23	City	South Bay Area	2,800	1,600	Light, Medium, and Heavy Duty	Police, fire, library, buses, public works,

Table 36: Overview of fleets interviewed including fleet type, location, number of vehicles and number of light duty vehicles in the fleet, vehicle sizes, and vehicle uses.

Note: Fleet 22 included 4,500 of their own vehicles and also oversaw 50,000 more vehicles in the fleet.

Results

Fleet Overview

These interviews covered a wide range of fleets with annual turnover rates of just under 3% to around 20%. This turnover rate depends largely on the lifetime of the vehicles, which varies based on vehicle type and usage patterns. For example, a typical administrative vehicle is maintained in the fleet for a period of 10 years or more while a typical police patrol vehicle is kept for approximately 3 years due to the more demanding driving conditions. A summary of these turnover rates can be found in Table 37 below.

Fleet Number	Fleet Type	Location	Number of Vehicles	Number of Light Duty Vehicles	Vehicle Purchases per Year	Vehicle Lifespan	Percent Annual Turnover
1	University	Sacramento Area	850	350			
2	City	Sacramento Area	2,400	650	240	10	3%
3	County	North Bay Area	328	216	20-23	12 Years	6%
4	County	Sacramento Area	2,600	1,200	260	10 Years	
5	Utility	Sacramento Area	1,000	250	28	9 Years	3%
6	City	Sacramento Area	250	40	20-25	10-12 Years	9%
7	Police	Greater Los Angeles Area	5,500	4,000	100-600	6-12 Years	6%
8	County	Greater Los Angeles Area	3,600	900	450	8 Years	12%
9	University	Greater Los Angeles Area	400	200	20	8-10 Years	5%
10	City	Greater Los Angeles Area	2,100	700	200	10 Years	9%
11	University	Greater Los Angeles Area	1,180	50-100	118	10 Years	10%
12	State	State Wide	12,000	300-500	Varies		
13	City	North Bay Area	800	600	50	6-14 Years	6%
14	Police	East Bay Area	250	200	50	5 Years	20%
15	City	Greater Los Angeles Area	1275	600	140	4-5 for PD, 10 for admin	11%
16	Utility	Greater Los Angeles Area	5,000	1,500	400-500	8-12 Years	8%
17	City	Greater Los Angeles Area	500	178	38	3 Years	8%
18	City	Central Valley	436	35	60	10 Years	14%
19	City	East Bay Area	1825	1100	180	10 Years	10%
20	County	North Bay Area	1,350	986	85-270	5-16 Years	13%
21	County	Central Valley	1,100	800	110	10 Years	10%
22	State	State-wide	4,500	4,410			
			50,000	30,000			
23	City	South Bay Area	2,800	1,600	270	10 Years	10%

Table 37: Overview of Reported Fleet Turnover Rates

Fleet Vehicle Purchase Process

Fleet managers indicated that there are three main avenues for fleets to purchase new vehicles in California, the first of which is the competitive bid process in which the fleet is required to obtain a certain number of bids (typically 3) from dealerships in order to facilitate the lowest purchase price for a vehicle that meets the criteria outlined in the bid request. Under this contract type, fleets are often required to select the vehicle with the lowest purchase cost, although they are generally allowed to set restrictions on vehicles based on previous experiences with the vehicles, such as their maintenance requirements and dealer support. For example, if a fleet knows that vehicles from a certain manufacturer have historically required more maintenance than others, they can avoid these vehicles in future purchases, regardless of their lower purchase costs.

At a larger scale, fleet vehicle purchases are often done through pre-negotiated cooperative purchasing contracts, which allow for large scale leveraging of fleet purchasing power. In California, there are two major contracts that are used, at the state level, a fleet can procure vehicles at a pre-negotiated price through the California State Contract, which is managed by the California Department of General Services (DGS). At the national level, Sourcewell works to streamline the vehicle purchasing process through competitive solicitations held amongst vehicle manufacturers [64]. The most commonly mentioned of these was Sourcewell, 8 fleets indicated they purchased their vehicles through Sourcewell while the California Department of General Services (DGS) was mentioned by 7 fleets.

Table 37 shows fleets and their purchase requirements and where they purchase the vehicles from.

While the majority of fleets indicated that they purchase their vehicles upfront, one fleet mentioned that they have moved to leasing their vehicles through Enterprise's Fleet Management Program. This system is used for general fleet purchases, but not for specialized vehicles such as large equipment and police vehicles. This fleet mentioned that by leasing these vehicles, they are able to focus more on providing adequate maintenance for the more specialized vehicles and equipment, which they would otherwise be unable to adequately maintain.

Fleet Number	Fleet Type	Location	Purchase Requirements	Purchase Location
1	University	Sacramento Area	Competitive bid process	State bid/ local dealerships/Sourcewell
2	City	Sacramento Area	Lowest bid (min. three bids), 5% discount for local dealers	Sourcewell/ State Bid
3	County	North Bay Area	Lowest bid, 5% discount for local dealers	Local dealerships preferred, NJPA
4	County	Sacramento Area	Competitive bid process	Sourcewell, DGS, other agencies (city of Sac)
5	Utility	Sacramento Area	Competitive bid process	Mainly buy from dealers through DGS contract prices
6	City	Sacramento Area	State Contracts	State contracts
7	Police	Greater Los Angeles Area	Competitive bid process	
8	County	Greater Los Angeles Area	Competitive bid process	All over Southern California
9	University	Greater Los Angeles Area	None	None
10	City	Greater Los Angeles Area	Competitive bid process	Mostly Ford dealerships
11	University	Greater Los Angeles Area		
12	State	State Wide	State Contracts	DGS
13	City	North Bay Area	None	DGS contract or 3 bid but they do DGS
14	Police	East Bay Area	Competitive bid process	Sourcewell
15	City	Greater Los Angeles Area	Competitive bid process	Sourcewell
16	Utility	Greater Los Angeles Area	Competitive bid process	Phoenix
17	City	Greater Los Angeles Area	Competitive bid process (leased vehicles)	Enterprise
18	City	Central Valley	Competitive bid process	Sourcewell or CAMS
19	City	East Bay Area	Competitive bid process	Bid, Sourcewell, CAMS, or other Corporative bid
20	County	North Bay Area	Competitive bid process	Bid process
21	County	Central Valley	Competitive bid process	Bid, Sourcewell, local dealers
22	State	State Wide	State Contracts	DGS
			State Contracts	DGS
23	City	South Bay Area	Competitive bid process	DGS/ Sourcewell/ Caltrans/ competitive bid process

Table 38: Fleets and the purchase requirements and location fleets purchased their vehicles.

Fleet Vehicle Purchase Decisions

Fleet managers were asked to describe how they choose new vehicle purchases for their fleet. Figure 41 shows a count of the most common considerations for new vehicle purchases.

Vehicle Compatibility

The most commonly mentioned purchase consideration was that the vehicle was fit for its purpose and could meet the requirements of the application it was intended for. We refer to this as 'compatibility of use'. Often fleet managers would develop specifications they required in a vehicle prior to purchase, and would select the vehicle that most closely fit that.

"So we actually have a unit within our fleet that are specification writers, and they develop the equipment specification." (Fleet 8, County)

"So I'll spec out let's just say an F250, and I'll say I want a 5.4 liter V8, I want a lumber rack, I want the tool bed, I want the spray-in liner, and I want a tow hitch." (Fleet 3, County)

Purchase Price

The next most commonly mentioned purchase consideration was purchase price. Fleet managers indicated that through a competitive bid process they were often compelled to purchase the lowest cost vehicle that met their needs. There were situations in which fleet managers could circumvent this lowest cost bid requirements, for example if the vehicle was known to have higher maintenance costs than others, or if the fleet was seeking to standardize to a particular vehicle manufacturer.

"Well, if you put in the request for purchase price, the lowest bidder wins the contract for x amount of years." (Fleet 7, Police)

"We put in a request for quotes on the website and then whoever bids we go with the lowest bid." *(*Fleet 18, City)

Maintenance Costs

Next, fleet managers indicated that maintenance costs were a highly ranked consideration when making their purchase decisions. All of the fleets that were interviewed mentioned that they had their own in-house maintenance team and maintenance facilities, but many noted that they also relied on support from the dealerships to keep up with maintaining the vehicles. Here, some fleets mentioned that they were able to circumvent the lowest bid requirements for vehicles that were known to them to have historically high maintenance costs. This is because purchasing vehicles with lower maintenance requirements was seen as beneficial for reducing the upfront and hourly maintenance costs for parts and workers, who were often responsible for maintaining a large number of vehicles. Fleet 18, for example, had four maintenance workers who oversaw maintenance for 436 pieces of equipment.

"So we looked at which vehicle we spent less time fixing and then we went that way." (Fleet 18, City)

"What products are out there that will meet their needs, and, total cost of ownership cost, acquisition costs, maintenance and repair costs, fuel costs, resale value, which when you take all that into consideration, financially you are minimizing your investment in the fleet asset." (Fleet 20, County)

Standardization

The high ratio of vehicles to maintenance workers was also seen as a reason for fleets to seek to standardize their vehicles. Fleet managers also mentioned the desire to maintain their fleet with as few different vehicle manufacturers as possible. We refer to this as 'standardization'. According to fleet managers, having fewer vehicles reduces the amount of

space required to store parts, lessens the training burden for fleet technicians, and enables workers to become more competent in maintaining the fleet vehicles, which also leads to a reduction in the time spent working on the fleet. They additionally mentioned that standardizing on vehicles from a few manufacturers makes it easier for fleets to become a certified warranty center for those manufacturers. This further reduces the cost of repairs by allowing them to make certain warranty repairs without sending the vehicle back to the dealer, which can be burdensome if they are not close by.

"For the maintenance side of things, it's the parts that we carry and we don't carry a lot of parts but you don't want to have to be having to remember 100 different parts." (Fleet 3, City)

*"When you look at the major fleets in the country, they standardize, that's the least cost to do business and we do the same. We only buy 50 police cars each year, but I don't want to buy 50 Fords this year and buy 50 Chevy's next year and then we'll buy 50 Dodges the year after that, it doesn't do us any good and logistically it becomes tough." (*Fleet 2, City)

"The reason that we are a 'Ford fleet', for purposes of training, parts, and support it's much easier to have 1 single make to support. Especially as complex as vehicles are nowadays the diagnostic software that we use, the computers and the support equipment that we use to maintain it and to diagnose it and so forth, all that is a significant investment. And the training that we do every year, so it makes sense to kind of go with one manufacturer." (Fleet 10, City)

Sustainability

Managers from ten fleets mentioned that they considered sustainability when purchasing new vehicles. The motivation to purchase sustainable vehicles was often due to goals set within the organization that the fleet belonged to. Fleet managers often referred to purchasing 'green' vehicles, which, for light duty sedans, typically meant conventional hybrids, BEVs, or PHEVs, which we discuss in more detail in *Electrification of Fleets*. For medium and heavy-duty vehicles, 'green' vehicle purchases often included renewable diesel, CNG, or LNG fuel types. Fleet managers also reported additional benefits beyond fuel savings by going 'green'. Those that had purchased hybrid vehicles reported lower maintenance costs and maintenance down time compared to conventional vehicles.

*"We've been directed by the board basically, to go green. It's kinda crazy because at first I wasn't buying into any of that stuff so, but I've gotten in the groove. The fact of the matter is, the reason I've gotten into the groove is the Toyota Priuses and the Camrys, we change oil and put tires on them, the maintenance on them is so little, they're great cars, you know." (*Fleet 3, City)

"We do have a formal goal about how many will be alt-fuel, its 45% percent right now of the total fleet, and the reason it's not higher is because, you might think well why isn't it 90% or 100% or something, you said you have a green fleet and so on, it's because it's not available." (Fleet 10, City)

"*We have what we call a green fleet policy here at the City so you know we obviously want to try to do green things so the first thing we do is you know look for what are our options for a green you know hybrid electric vehicle."* (Fleet 13, City)

Total cost of ownership

Prior to the interviews, it was expected that total cost of ownership (TCO) would be a prominent consideration for fleet managers, especially considering the size of the fleets and

potential savings from operating vehicles with the lowest TCO. Therefore, all fleets were specifically asked whether this was something that they considered when purchasing a vehicle. The other purchase considerations (discussed above) were not specific questions and were mentioned by interviewees without any cue from the interviewer. It was surprising that of the 23 fleets interviewed, only 8 indicated that they use TCO calculations in their purchase process.

"It's all total costs of ownership, absolutely yeah it's not based strictly on the original purchase costs." (Fleet 13, City)

One of these 8 fleets had only recently started to consider TCO in their vehicle purchase decisions, and they were developing a model to help project the running costs of their vehicles.

"Actually just this year, um really it's [TCO] starting to influence how we make decisions around buying those light duty or SUV or pickups." (Fleet 5, Utility)

The 15 fleets who reported that they did not use TCO in their central purchase decisions offered several reasons why this was the case. First, the requirement to purchase the lowest cost vehicle often excluded vehicles that had a higher purchase price, even though they may have lower operating costs. Secondly, the desire to standardize the vehicle fleet would omit vehicles from different automakers even if their TCO was lower than the fleets chosen vehicle manufacturer. Third, some fleet managers stated that there was no substantial difference in the running costs of new vehicles, so they did not see the value in conducting a TCO analysis.

Some fleets additionally indicated that it was difficult for them to calculate the TCO of a vehicle prior to owning it. Often fleets had detailed information on the TCO of vehicles in their fleets, but they were unable to project the running costs of vehicles they were looking to purchase. Fleets used the TCO information on vehicles they currently own to determine when to dispose of a vehicle, and whether to purchase the vehicle again.
Fleets also reported that they were more concerned with ensuring the vehicle met the needs of the fleet than reducing the overall costs.

"*We don't look at that* [TCO] *that much, we just make sure that it does the jobs we need it to.*" (Fleet 18, City)

A final reason that was mentioned was due to the disconnect between vehicle purchase price, maintenance costs, and fuel costs. In many fleets the vehicle was purchased by the fleet department, but fuel is paid for by the user departments. This makes purchasing a more fuel-efficient vehicle with a higher purchase price less favorable to the fleet department as they do not receive any benefits from the lower fuel expenditure.

Other purchase considerations

The 'other' column in **Figure 41** refers to lesser mentioned considerations from fleet managers, these include: fuel economy, resale value, preferring American made vehicles, the expected time the vehicle will be delivered in, and vehicle build quality. Other purchase considerations that were only mentioned by one fleet, and thus are excluded from the figure include: maintenance training requirements which is closely related to standardization,

vehicle reliability which is closely related to maintenance costs, a preference for local dealers, and vehicle safety.

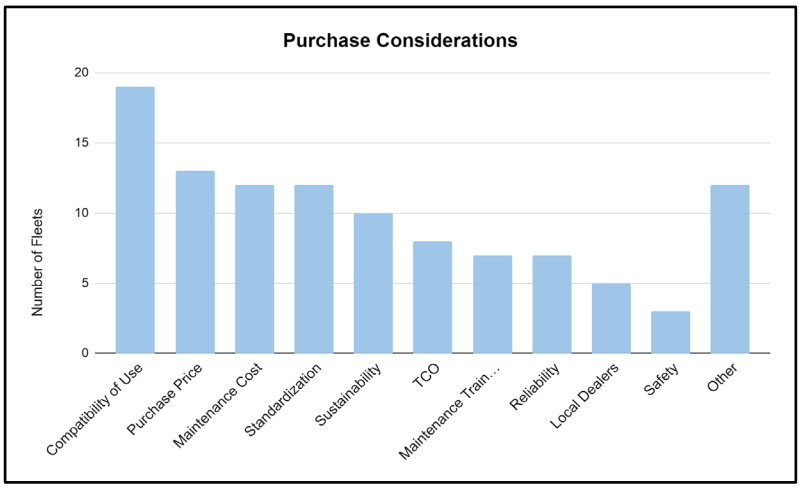

Figure 41: Fleet Managers Considerations when Procuring New Fleet Vehicles.

Fleet Management Software

When asked about how they track vehicle metrics, fleet managers reported using several management applications, the most common of which include Assetworks (7 fleets), Verizon Network fleet (3 fleets), Faster (4 fleets), and Getotab (4 fleets). While each of these management platforms provided a different set of information, the most commonly mentioned metrics include maintenance costs and schedules, vehicle down time, number of idle hours, residual vehicle value, fuel costs, travel distance, and GPS location. In addition to the base software offered under each of these programs, there are various additional packages that can be added on to enhance what fleet managers can track, these often included information such as accident reporting and harsh driving.

Most fleet managers used just one fleet management software. Fleets who tracked the use of their electric vehicles often had two fleet management software packages because their original fleet management software was incompatible with electric vehicles. These fleet managers expressed a desire for electric vehicles to be integrated into their original software so they would only need one software package.

When asked about what additional information they would like to see for electric vehicles in comparison to conventional gasoline vehicles, fleet managers often reported that they could not think of anything that they would want to see that they could not already get from their current software. In a few interviews, managers reported that if they could receive additional information about electric vehicles they would like to see the vehicle's state of charge which they could use to determine how much driving range remained in the vehicles as well as when and where they are charging.

Electrification of Fleets

Out of the 23 fleets interviewed, 22 have adopted at least one PEV with the majority reporting overall positive experiences. Additionally, all but one fleet indicated that they have conventional hybrid vehicles (HEVs) and six fleets reported having hydrogen vehicles. Managers also mentioned having CNG, LNG, propane, and renewable diesel fueled vehicles in their fleet (**Figure 42**).

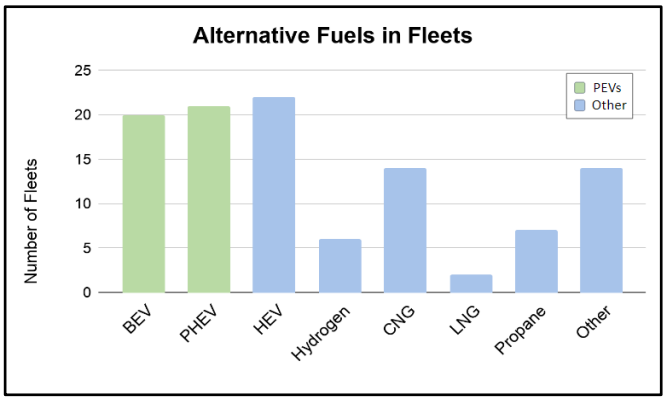

Figure 42: Alternative fuel vehicle types in interviewees fleets.

Electric vehicle purchase motivations

Figure 43 shows that the primary motivating factor for fleet electrification was to meet the organization's sustainability and climate goals as well as to be a "green leader" and set an example for other agencies and the public to follow. For these organizations, economic drivers were a secondary motivation or justification for their purchase decisions, but not the primary driver.

Sustainability goals were the most commonly mentioned reason for purchasing PEVs. Typically, these sustainability goals came from within the organization in which the fleet resided, and not from external sources, such as federal or state regulations[4]. As most of these organizations were public, the sustainability goals were set by those in higher administrative positions within the city, county, utility, or university, such as by the Board of Advisors, City Council, or Mayor's office. For the two state fleets, these sustainability goals include those that are mandated by the broader state goals, such as those outlined in SB 498 and Executive Orders.

"*We have a formal directive that we should buy green whenever possible, that's in a city regulation, and there's a tradition, I've been here for about 5 years, and there's a tradition of buying as green as we could anyway. So we aggressively go out and look for the green options.*" (Fleet 10, City)

"It is definitely for the reduction in cost and it is definitely for the reduction in emissions cuz it's the right thing to do environmentally, but the overarching reason is from what our CEO describes as demonstrating leadership." (Fleet 5, Utility)

Some fleets developed their own green vehicle purchasing requirements, these appear to result from the personal motivation of the fleet manager to transition to 'greener' vehicles in the fleet.

"We wrote it, it's gone through some, you know, a couple revisions but it's going through the process of getting finalized right now any talks about right sizing the fleet so you know really understanding are we getting the most usage out of the fleet so it talks about that, you know, looking at the greenest vehicle in that class." (Fleet 13, City)

[4] At the time these interviews were conducted, non-state-owned fleet vehicles were not covered under state or federal regulations.

The interviews revealed that one of the primary differences in the operational and purchase decisions amongst fleets are the size and resources available to their organization. Smaller fleets often lack the adequate time and monetary resources needed to fully consider the benefits of integrating PEVs into their fleets, and how they can overcome the barriers to adoption. Many smaller fleets were unaware of or did not utilize the incentive programs that are available for PEV purchases and did not consider vehicle running costs when making their purchase decisions. This may prevent fleets from purchasing these vehicles, given their generally higher upfront costs compared to a gasoline powered vehicle.
As shown in Figure 41 after meeting the requirements for the job ("Compatibility of Use"), most fleet's purchase decisions were driven by obtaining the lowest purchase price through the competitive bid process, lowering maintenance costs, and standardizing the fleet. These findings suggest that a lower total cost of ownership for PEVs may have less of an influence on their market share of fleet vehicles than previously thought [65].

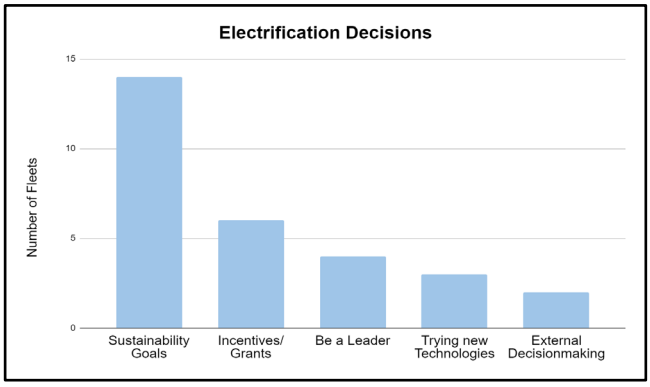

Figure 43: Motivations for Electrification in Fleets.

Use of incentives for electric vehicle purchase

The second most commonly mentioned motivation for electrifying fleet vehicles was the availability of grant and incentive programs. Some fleets indicated that they initially began converting their fleet to electric and alternative fuels when they heard about the availability of these programs, for example, when asked about how they made the decision to purchase electric vehicles, the manager for fleet 21 described their experience when attending workshops on a grant being offered through the air district.

"So I went to a couple of those and I was like 'hey they're giving money away, let's get this free money and go buy a car,' and it's like, wow it worked, we got a car, let's do it again." (Fleet 21, County)

Other fleets offered similar sentiments, writing, *"almost everything that we've done with our charging stations or electric vehicles there has been some sort of grant or other voucher program that we use"* (Fleet 20, County).

Despite the overall satisfaction with the incentives they received, some fleets mentioned having difficulties with the large number of charging station installations that they need to commit to when receiving grants from the utilities. Many fleets also raised complaints about the process of finding and applying for these programs, stating that they were too administratively burdensome and that the funds were not enough to cover the difference in costs.

"So we're continuously trying to see ways of winning grants it's just very complicated and tedious process, and it's also costly as well." (Fleet 15, City)

"Um we do when we have the opportunity to, a lot of times by the time everything goes through those funds are exhausted anyway, but if we do get the opportunity to use those rebates and credits then we do use them." (Fleet 23, City)

There was additionally a lack of knowledge about what incentives were available to fleets, with many reporting that they were only eligible for a few different grant and rebate programs. Much of this concern comes from a lack of awareness of the various programs that fleets are eligible for. There were many different factors that played into the extent of a fleet's knowledge about these programs, for example, a few fleets reported that they had a specific person who was in charge of finding and applying to all relevant programs to help save the fleet money. These fleets were often the ones who reported using the highest number of programs.

"So we have a consultant on board that has a process to see what kind of grants that are out there for municipalities for um, for CNG and for electric as well." (Fleet 12, City)

"On the City side we have a department that just focuses on all this, sustainability and all that and they're constantly looking at grants." (Fleet 14, Police)

In contrast to these fleets, others reported that they were far too busy to find time to identify and apply for grant programs, and that they were having a hard time managing the fleet in its current state, so they were unable to think about all the work required to transition the fleet to alternative fuels.

"Unfortunately we're short staffed and I haven't really pursued, I have helped with acquiring, my previous job, a grant for CNG school buses so, but I know they have the grants that are out there that we should be applying for." (Fleet 9, University)

Overall, it was found that the most commonly used incentive program for fleets was the California State rebate, which 64% of fleets reported using. While the availability of incentives varies by location, the overall knowledge about these programs was quite low, with 45% of fleets receiving grants from the air districts, 35% receiving grants from the utilities, and just one fleet having used a local rebate program.

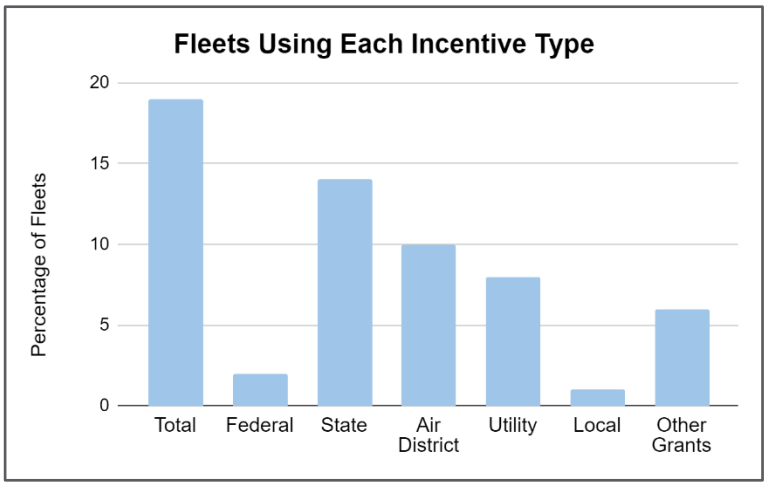

Figure 44: Number of fleets who used incentives from each category. The "Other Grants" category includes programs that were only mentioned once, including those from the Green Cities Coalition, the California Energy Commission, Electrify America, NRG Energy, internal subsidies, etc.

Incentives at the federal level also had low participation rates, with just two fleets reporting having used funds from the federal government. One fleet received a grant for PEV charging infrastructure through the federal Congestion Mitigation and Air Quality Improvement (CMAQ) Program. Additionally, only one fleet reported having used the federal tax incentive. While this incentive is often used by private consumers and private fleets to help fund PEV adoption, this process is more complicated in a public fleet setting, as government agencies have no federal tax liability. This means that in order to receive the tax incentive, the organization would have to lease the vehicle from a dealership or manufacturer, which is not commonplace.

"When we bought the Nissan Leafs we would have prefered to lease them, which is it's own uh, bureaucratic nightmare." (Fleet 12, State)

Benefits of fleet electrification

Fleet managers reported having initial hesitations with the vehicle's limited range and the perceived time and expenses required to install charging infrastructure. Despite these hesitations, they reported that after integrating them into the fleet, they had overall positive experiences with the electric vehicles. They mentioned that the drivers generally preferred them due to the increased acceleration rates and quieter driving experience. In addition, the fleet managers reported that the most important benefit of the electric vehicles is their decreased maintenance time and costs. This was seen as a major benefit due to the difficulties that fleets reported in recruiting maintenance workers.

"I think a big part of it [EV adoption] ties in longer term on what's happening with the technicians that we have, a lot of them are retiring, it's hard to find people that are going into the profession, particularly on the heavy duty side. So the more we can keep people, or these vehicles out of our shops, the better off it is." (Fleet 4, County)

"Yeah and it's great for us because there's so much less maintenance on them that it alleviates a lot of backlog of work within our shops." (Fleet 23, City)

"We haven't done brakes, nothing really, we do bring them in about 2-3 months for a safety inspection, but mechanically, no issues. We're really happy with that." (Fleet 18, City)

These reduced maintenance requirements also lead to a reduction in the maintenance and repair costs of the PEVs over the conventional gasoline vehicles, which further helped to reduce the total cost of ownership of the PEVs. While TCO was not one of the major driving factors for vehicle purchase price, this was seen as an important factor that was used in deciding whether or not to purchase the same vehicle again in the future. This generally led to fleet managers intending to continue purchasing electric vehicles in the future.

Barriers to fleet electrification

While there are many common themes between electrification for fleets and private consumers, there are also many challenges that are unique to the fleet perspective. While many private consumers may be motivated to purchase a PEV based on the lower fuel costs associated with electric vehicles, some organizations have a system in which the central fleet purchases the vehicles, but individual departments pay for the vehicle's fuel costs. This can decrease the cost savings associated with the vehicle from the perspective of the central fleet manager and can impact potential TCO and vehicle operation cost calculations. Additionally, the seven main barriers to electrification, as shown in Figure 45, were identified, the largest of which were that the fleet experienced difficulties obtaining charging infrastructure, a lack of employee buy-in, and the limited vehicle range.

Fleet managers reported that their ability to purchase these vehicles was limited by the time and capital investment required to install charging stations for these vehicles. Some fleets reported that while they wanted to purchase more electric vehicles, this requires more coordination with different departments in their organization, such as public works, who was often in charge of purchasing and installing the infrastructure. This issue is further compounded as many organizations have a limited annual vehicle budget, which does not include any funds for purchasing charging infrastructure. Therefore, if fleets wish to install infrastructure for their vehicles, they need to go out and look for grants, which requires a large commitment of time and human resources. In organizations where these charging stations were already in place, there was little to no mention of issues with the time required to charge the vehicles themselves.

"The only negative thing is the ability to get to charging stations, so the infrastructure and trying to coordinate because a lot of the vehicles are parked at downtown city garages, the City doesn't own the garages so coordinating with the building owner to be able to install charging stations, and then do you make them public or private, and so if you make them public then you may not be able to get to it and so the infrastructure is the biggest challenge and coordinating efforts." (Fleet 19, City)

"The planning and the implementation for infrastructure is an issue. It's an issue because it's expensive and it's time consuming and we in fleet don't have that knowledge." (Fleet 10, City)

"Would say just the infrastructure, I mean you can't have more vehicles than you can charge so that's the big barrier." (Fleet 4, County)

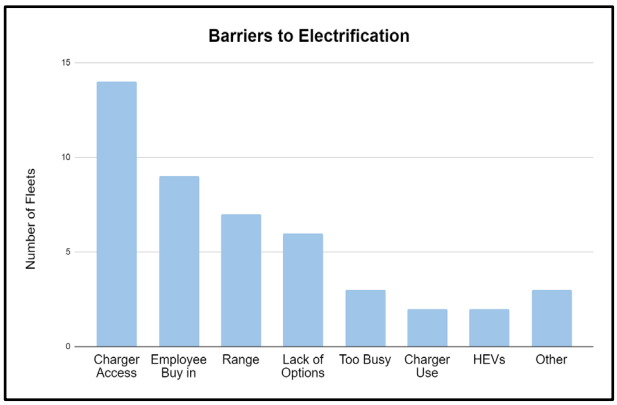

Figure 45: Perceived Barriers to Electrification in Fleets.

The limited vehicle range was also reported as one of the largest barriers to fleet adoption of electric vehicles. While many organizations, such as cities, have a fairly limited range that they travel within, other organizations, such as counties and utilities, have much more diverse driving territories and conditions. For example, fleet 20 reported that because of the large geographic area they cover, the vehicles are often left at the work sites overnight instead of coming back to a central location to charge. In this case, the vehicle's range would need to be able to support the multiple trips taken in the vehicle without stopping for charging each night. Range can be especially problematic in fleets with larger territories, such as those that cover the whole state, as these vehicles are often moved around to different job sites and taken to meetings where the distance far exceeds the offered range of current electric vehicles.

Another commonly mentioned barrier was the initial lack of employee buy-in. When the vehicles were first purchased, many employees were hesitant to use the electric vehicles if another option was available. In some organizations, management teams worked to overcome this through outreach and education efforts while in others the vehicles were assigned to certain people or departments so that they could get used to driving them. After using the vehicles on a few trips, fleet managers reported that the employees got used to driving the vehicles and had a greater understanding of their range and were taking the vehicles out more frequently. This shows that education efforts are key to ensuring that the vehicles are successfully integrated into the fleets. Some fleets reported that they spent time taking the vehicles to each department to show them how they are used and charged before assigning them, while others said that they just put the vehicles into the fleet and tried to encourage their use. While both strategies have the potential for success, the fleets with more education efforts often reported that their employees enjoyed the vehicles more and were more likely to purchase an electric vehicle for their personal use.

"2014 we placed 22 Ford Focus EVs in our fleet and the range was sold as 88 mi or 86 mi and then real world fleet condition it was between 45 to 50 miles, significantly less so when you are telling the customers plan on needing to recharge after 44-50 miles, they get range anxiety because in their minds they want to make sure they're only driving 30 mi so they don't get stuck someplace so then vehicle could go 70 mi but nobody is willing to drive it past 30 which then limits the number of vehicles that have that duty cycles, there's not very many of them." (Fleet 20, County)

"You know you can take the best technology in the world and shove it somebody, but you have to work with them and that's what we do here in fleet is to try to get people to understand there's other options, there's other technology, and work together to, to make everyone happy." (Fleet 2, City)

"New employees, as they use these, the front office employees are awesome because they know about these issues so as they come in to get these vehicles, they tell them about it, they go hey just a reminder, this vehicle is this or this vehicle is that." (Fleet 20, County)

Some fleets also reported that despite their desire to electrify as many of their vehicles as possible, they were limited in their ability to do so because of the lack of vehicle options. They found that while they were able to electrify nearly all their passenger vehicles, there are little to no options for electrification of pickup trucks, as well as medium and heavy-duty vehicles. This was especially restricting for fleets, such as the utilities, whose primary function was performing construction and other industrial services and who have a large proportion of medium and heavy-duty vehicles in their fleet. One fleet specifically reported that even though there were a few light duty pickup trucks that will be on the market in the coming years, these vehicles would not work for them because one of the areas that used to be for storage had been removed in order to make room for the batteries. Many of the fleets in these larger classes of vehicles have specific needs and stated that they would need to work with companies to modify the base vehicles in order to meet these needs.

Used Vehicles

Potential Barriers

When asked about their experiences with used vehicles in the fleet, some fleet managers reported that they had purchased used vehicles in the past, but that these were only for specialized purposes, and not for general fleet use. The most commonly mentioned application of these vehicles was for undercover police work, where secondhand vehicles were used in the fleet in order to more easily blend in with the general population. Other fleets mentioned purchasing them in order to gain access to high occupancy vehicle lanes, to transport children, or to test if road infrastructure can withstand collisions.

Further asking about their considerations of purchasing a used PEV, it was found that roughly 27% of fleet managers reported that they would be open to purchasing a used electric vehicle with about 59% saying that they would not consider purchasing a used PEV. The remainder of fleets said that they were either unsure if this would work, or that they had not previously considered this. Many reported that they found it too difficult to integrate used vehicles into their fleet, and that it would be even harder to integrate used electric vehicles.

"I'm really a fan of buying new stuff, I mean if we got a deal on something we might try it, it's not like we've never bought anything used before that's for sure." (Fleet 21, County)

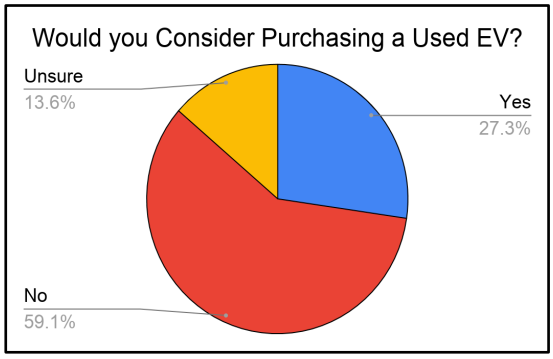

Figure 46: Fleet Managers Considerations of Used Electric Vehicles.

One of the main concerns about purchasing both used conventional and used electric vehicles for fleets, is that they cannot be competitively bid due to the unique circumstances of each vehicle. This often means that for each vehicle purchased, the fleet must go through an exemption process through the organization's leadership. They also said that this would be too risky and that the lack of warranty on used vehicles would make the unknown maintenance history too large of an unknown for them to accept.

In addition to the complexities and risk associated with purchasing used vehicles, the rapid advancements in technology for PEVs means that many fleets are unable to begin purchasing used electric vehicles. Given how new the technology is, features such as the vehicle's range and charging speed are still greatly increasing. Fleet managers reported this being an important factor as using a PEV in a fleet setting is often one of the first experiences with these vehicles that employees encounter, so using older vehicles may not provide the best possible experience.

"No, we wouldn't do that since basically the technology changes so quickly. You know, in 3 years, just taking the BMW for example, the car range went from 60 to 80 to almost I think the last group was 160 last year." (Fleet 7, Police)

Recommendations

While many fleets reported that they would not consider purchasing used vehicles under current conditions, they many said that under the right conditions they would be willing to consider looking into them.

"Yeah so it depends, if we could find a good one, of course we're always open to that, to repurposing and not just getting new and dumping out so." (Fleet 11, University)

"I mean yeah it's not something I would be opposed to, I mean I think it's worth looking at if it fits the operational needs and the costs are right sure." (Fleet 12, City)

They often reported that if there was more support for these vehicles, then they may be willing to purchase them. For example, when asked about their willingness to purchase these vehicles, nearly all fleets mentioned that the lack of warranty on these vehicles made them a riskier investment.

"I suppose it still needs to have some warranty to it, you know, you'd have to have something there to give you some security that you're not buying something that then, two months later we're gonna have to spend ten grand for whereas if we just bought it outright we would have our full warranties, we would be covered, you know the risk of saving some money, uh, I'd want to make sure that there's warranties attached to that. Strong warranties." (Fleet 3, County)

"We like to keep the vehicles at least 10 years so we look at reliability and make sure we can get at least that." (Fleet 18, City)

In order to address these concerns, used electric vehicles that are inspected and sold through certified dealerships could be given an extended warranty period. Alternatively, the manufacturer could provide a type of used vehicle maintenance insurance under which the fleet pays a fixed monthly price in exchange for maintenance support from the dealerships. Another commonly mentioned barrier to the adoption of both used electric and gasoline vehicles is the unconventional purchase process. For the majority of fleet purchases, the

vehicles are competitively bid from dealerships or are purchased through a cooperative purchase program.

"It's a, kind of a procurement issue because how do you do a competitive bid for a used vehicle, um, so that's one of the reasons why." (Fleet 12, state)

Given that the availability of used vehicles depends highly on the market availability, there is no way to reliably provide a steady flow of vehicles, and the vehicles that are available often vary in age and condition. This makes it difficult to create a standardized price that is reasonable from both the manufacturer and the fleet perspectives. In larger metropolitan areas, it may be possible that there is a high enough turnover rate to provide a relatively consistent stream of used vehicles.

Selling multiple of the same vehicle as a package helps create a more standardized experience for the fleets, which, as discussed above, helps reduce maintenance costs. This issue can also be overcome through manufacturer support for parts delivery. The high utilization rates of fleet vehicles means that any time the vehicle is in the shop for maintenance, it is not being used to help support the organization's needs. Therefore, by ensuring that local dealerships and auto parts stores are able to carry the parts needed for these vehicles, the used vehicles can have less downtime.

While many fleets have already begun to purchase electric vehicles, they also reported that they could not purchase them as quickly as they wanted to due to a lack of available charging infrastructure. While this barrier is not unique to used vehicles, manufacturers can help promote the purchase of used electric vehicles by pairing them with incentives for charging infrastructure. This could include partnering with a charging station hardware company or installer to provide the equipment or services at a discounted price.

Willingness to Pay

Some fleets stated that they would be more willing to purchase a used vehicle if it was electric because the vehicles have less moving parts, and therefore, require less maintenance than internal combustion engine vehicles. Other fleets said that they would be less likely to purchase a used electric vehicle than they would be to purchase a used gasoline vehicle. These fleets reported that since the technology in electric vehicles was advancing so quickly, it would not make sense to purchase one until attributes like range and purchase price stabilize. Many fleets reported that they would purchase a used electric vehicle if they were in the range of 20-50% less than the price of a new vehicle.

"In reality, any time even if you buy a good used electric vehicle your probably in that 50-75% range, um, which I think would be fair." (Fleet 2, City)

Some fleets acknowledged that purchasing a used vehicle could be a good way for their organization to benefit from incentive programs that they would not otherwise be eligible for. This is often used in reference to the federal tax credit, which many public agencies are not eligible for since they have no tax liability. One fleet also mentioned that they would be willing to purchase used vehicles from other fleets that they knew had kept up with maintaining them. This fleet mentioned that it would be an added advantage if the fleet who had previously owned the vehicle were able to qualify for the increased incentive amount that is provided to certain businesses buying electric vehicles in low income census tracts. This way, the additional incentive amount could be passed on through a lower price of the vehicle when it is sold.

"I'm not saying there aren't applications for it, it's a good idea, especially since we as a state agency can't collect or, can't use the federal tax credit. So getting that tax credit passed on basically through the resale value or price, I think would be cost effective for us, it's just it's not just something state agencies have typically done so I don't think they have looked at it that much." (Fleet 22, State)

Conclusion

Studies of private consumers have shown the largest barriers to adoption, among others, as being a lack of awareness of electric vehicles, a lack of access to adequate charging infrastructure, limited vehicle ranges, higher purchase prices, and lack of vehicle options [14]. While these same barriers are often also seen as issues for fleets, there are many barriers that are unique to their perspective. These include issues with employee-buy-in, procurement under the competitive bid process, the need for standardization, and difficulties in installing charging infrastructure while ensuring that users charge the vehicles.
Fleet managers in California appear to have begun electrifying their fleets and are looking to pursue a greater penetration of PEVs, however, there are still many obstacles that they face. By performing an in-depth analysis of the barriers to PEV adoption in fleets, policymakers and vehicle manufacturers can work to mitigate these issues. Furthermore, identifying the rationale behind electrification for organizations that have chosen to do so will allow these initiatives to be further pursued, thus allowing for further electrification. Based on the findings, it is recommended that additional resources be made to inform fleet managers of the fleet specific incentives that are available to them. Furthermore, regulations could be brought about to encourage organizations to create and adopt sustainability and electrification plans.

Since the interview sample is comprised mostly of public fleets (with the exception of the Utility fleets) more research is needed to fully understand vehicle purchasing and the incorporation of electric vehicles in private fleets. In the utility fleets we sampled we did not observe any remarkable differences between their vehicle purchasing or attitudes towards electric vehicles. Private fleets may have more flexibility in their vehicle purchasing options and have fewer regulations they are required to follow. This could lead to differences, however, private companies also face pressure to be "green", so their attitudes towards their vehicles are not likely to be significantly different. They are also similarly financially constrained as their purpose is to generate profits, so we do not anticipate large differences between these fleet types. These findings further suggest that the BMW i3 BEVs would be compatible for use in a fleet setting. Given the limited range of these vehicles, they would not be able to replace all administrative vehicles in the fleet, as there is often a need for fleets to travel outside of their given jurisdiction, which requires a longer range. If these vehicles meet these and other requirements set out for the fleet's vehicles in general (e.g. four doors, white, availability, etc.), then there should be limited barriers to integrating them into the fleets.

Given the growing need for sustainability in both public and private organizations, more research is needed to create a broader understanding of how specific measures are influencing the adoption of PEVs in fleets around the world.

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Task 6: Grid Data Collection and Analysis

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Executive Summary

To support the larger project of BMW's work to integrate used Plug-in Electric Vehicle (PEVs) into fleets and the University of California – Davis (UC Davis) goals to provide a greener campus, this paper presents a study of the operation of the UC Davis campus grid and opportunities to integrate PEVs and their batteries. Campus utilities personnel were interviewed and campus resources for understanding how power is demanded throughout campus were reviewed. This paper presents a list of all current EV chargers on campus, insights into the operation of the campus grid at large, and an inventory of the power demand and energy use of the top ten electricity loads on campus. To guide this project, BMW provided specific research questions. These questions are explored specifically and addressed at the end of the report.

Key Takeaways

- UC Davis, as well as all other UC campuses and most other universities are working toward significantly cleaner or even carbon-neutral operations over the next few decades.
- Although the technology is not in place yet, EVs and smart charging strategies, combined with V2G technology, have an opportunity to contribute towards meeting campus goals for carbon neutrality.
- We believe that smart charging to balance the demands of fleet and commuter light-duty vehicle charging with the demands of future electric bus charging will be a larger load-balancing opportunity.

Introduction

As the number of Plug-in Electric Vehicles (PEVs) increases, new opportunities will arise for owners and operators of large PEV fleets in the field of vehicle-grid integration. A large fleet of PEVs could operate as a stationary power storage device to support the electric grid. Some potential applications include peak shaving and peak shifting to reduce grid demand and energy costs, increasing the stability of the grid, or serving as an on-site backup for critical electrical loads. Batteries from retired PEVs can likewise be re-used for these purposes. In support of the larger project on integrating used PEVs into fleets, BMW would like to understand how the batteries from PEVs in a fleet can be used to support the UC Davis microgrid and the greater University of California goal of becoming carbon neutral by 2025 as part of the Carbon Neutral Initiative (CNI). The CNI was adopted by the University of California as a system-wide goal covering all UC campuses in November 2013, with the goal of emitting net-zero greenhouse gases from its buildings and vehicle fleet by 2025. Notably, the CNI does not apply to commutes to the campus.

This task supports that goal by developing an understanding of the ways a PEV fleet can support the UC Davis microgrid. To accomplish this, a set of questions were defined by BMW to guide the research into the campus grid. Interviews were carried out with campus utilities personnel and as much information as possible was gathered from other campus resources. This task required that UC Davis summarize and provide campus and building energy consumption profiles where there are designated campus EV Charging stations. Through a series of meetings with the campus utilities office, we found that the campus does not effectively connect EVSE's with individual buildings. This research did lead to extensive new knowledge about how the campus interacts with the various energy providers, and the campus' goals for renewable and carbon-free energy. The campus has goals for GHG reductions, clean air, and quiet streets, as well as specifically electrifying the campus-operated city-wide bus service, Unitrans, and having carbon neutrality for on-campus travel.

Methods

Question Development

To begin the project, BMW developed a set of guiding questions to ensure that the research addressed the specific issues they were interested in. These questions were presented in the form of a research matrix for the three main categories of electricity consumption within UC Davis: the main campus grid, the Sacramento medical campus, and the auxiliary UC Davis buildings located in south Davis. For each of those locations, the following questions were asked:

1. What is the cost structure for electricity at the location?
    a. What are the tariffs and demand charges?
    b. From the perspective of the energy provider, what is the average load curve on a summer and winter day?
    c. What are the largest consumption sinks at each location?
    d. What are the critical loads at each location?
2. What are flexible or demand response technologies that are already installed at each location?
3. What are the on-site carbon dioxide (CO_2) emissions, including backup generator operation and testing?
4. What are the off-site CO_2 emissions?

5. What are the transportation fuel costs associated with campus vehicles (not Unitrans or other external organizations)?
6. What are the future developments and foreseeable issues facing the grid?

These questions were used as guidelines for completion of the task.

Gathering Information

To get the information, a variety of sources were used. Where possible, members of the UC Davis facilities management team were interviewed, and their expertise was used to develop answers to these questions. Where individuals familiar with the operation of the campus grid could not provide information, supplemental materials were gathered to address gaps in the knowledge. The answering of the initial guiding questions led to follow-up questions and further information gathering. The sum total of that information gathering is described below.

Campus EVSE's

The campus implemented an add-on permit for EV drivers for 2019-20 Academic year. These permits are $10 per month in addition to regular parking permit fees, for unlimited access to EV charging on campus. EV charging is limited to 4hrs per vehicle per charging, but enforcement of this time limit is inconsistent. Currently there are 218 holders of these EV Permit add-ons. The campus estimates, based on responses to the annual campus travel survey, that there are 430 BEV and 416 PHEV commuters traveling to campus.

The UC Davis campus currently hosts 42 - 110V plugs (Level I) and 95 – 240 V (Level II) in various lots on the main campus, as well as south Davis and West Village.
The campus currently has no DC Fast Chargers, no smart chargers, and no master plan for charging installations and management. The parking lots or structures with chargers are at the locations indicated with a blue lightning pin on the following map shown in Figure 47 and the equipment is listed in detail in Table 38.

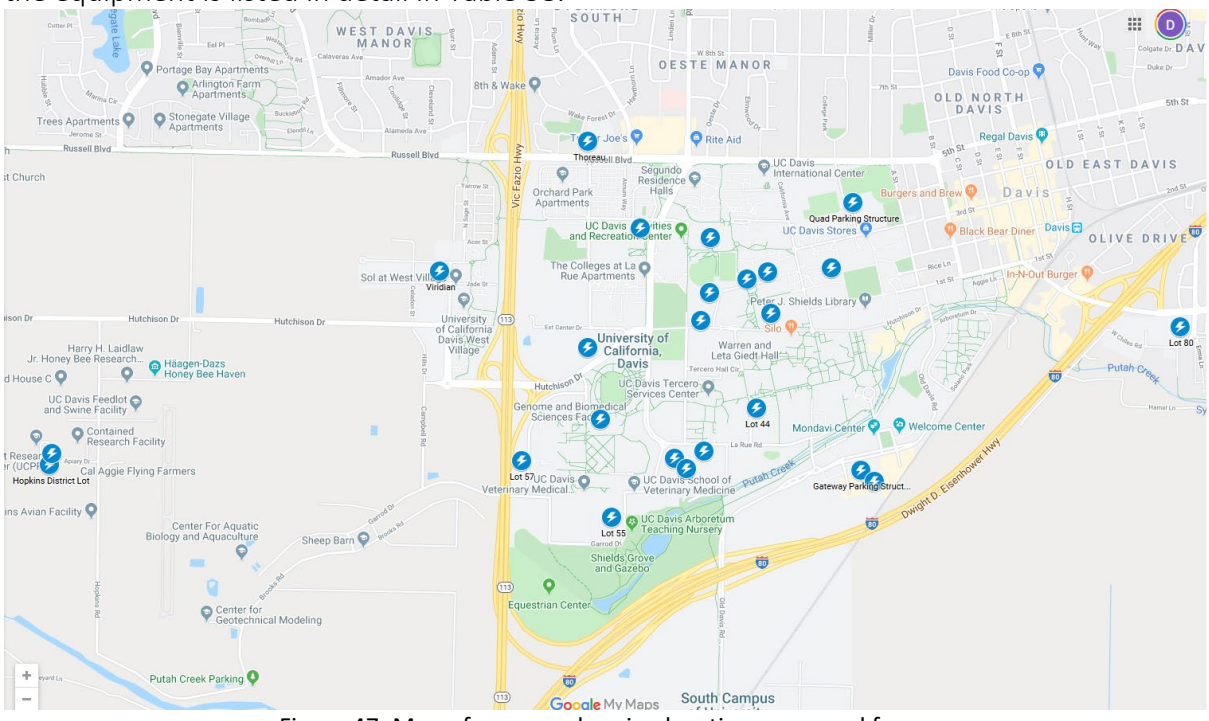

Figure 47: Map of campus charging locations accessed from:
https://www.google.com/maps/d/u/0/viewer?mid=1GmVtnUCAxJmHAI7jusf8ns4S3DbNVhtH&ll=38.53912638659245%2C-121.76871905000002&z=14

Most of the campus electric vehicle chargers are available to any PEV with a campus parting permit and the EV charging add-on permit. Some are limited to campus-owned and operated vehicles, such as those operated by campus facilities or the UC Drive vehicles, and these are noted as "limited access" chargers in Table 38below since they are not available to campus commuters.

Gateway Parking Structure (I-80/Mondavi)	16 chargers (2 x 120V, 12 x 240V, 2 limited access)
Quad Parking Structure (Memorial Union)	10 chargers (3x 120V, 5x240V, 2 limited access)
Pavilion Parking Structure (Hutchison/Silo)	14 chargers (4x 120V, 6x240V, 4 limited access)
Lot 1	18 chargers (2 x120V, 16 x 240V)
Lot 25 (ARC/Rec Hall)	16 chargers (16 x 240V)
Lot 26	1 charger (1 x120V)
Lot 27	4 chargers (3 x 240V, 1 limited access)
Lot 31	2 chargers (1 x 120V, 1 x 240V)
Lot 35	2 chargers (1 x 120V, 1 x 240V, 1 limited access)
Lot 44	3 chargers (2 x 120V, 1 x 240V)
Lot 49	11 chargers (2 x 120V, 9 x 240V)
Lot 55	2 chargers (1 x 120V, 1 x 240V)
Lot 56	2 chargers (1 x 120V, 1 x 240V)
Lot 57	2 chargers (1 x 120V, 1 x 240V)
Lot 80 (South Davis)	4 chargers (1 x 120V, 3 x 240V)
Hopkins District Lot (Remote West Campus)	2 chargers (2 x 240V)
Bargain Barn/Custodial	3 chargers – limited access
Bowley Science Center	2 chargers (2 x 120V)
CR Hopkins	1 charger (1 x120V) – limited access
Fire/Police	1 charger (1 x120V)
Sciences Lab/Haring Hall	1 charger (1 x120V)
University Garage	8 chargers (8x 120V)
Wickson Hall	2 chargers (2 x 120V)
Thoreau (Dormitory)	1 charger (1 x240V)
Viridian (West Village)	13 chargers (3 x120V, 10x240V) – 2 limited access

Table 39: EVSE equipment at each parking location

In addition to the above chargers located on main campus, there are an additional 4 chargers located at the UC Davis Medical Center in Sacramento. Figure 48 below shows the locations of these chargers.

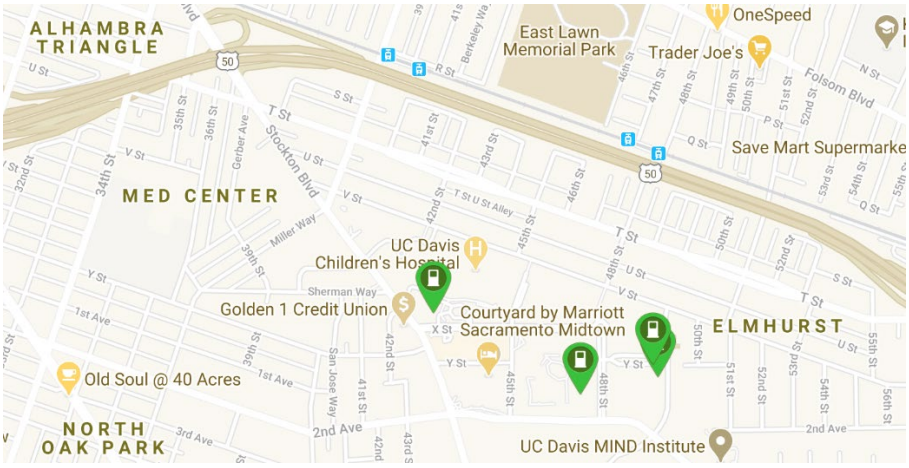

Figure 48: Locations of Chargers in the UC Davis Medical Center in Sacramento (map credit: https://www.plugshare.com)

The UC Davis Power Providers

UC Davis has three broad categories of electricity sources: Hydroelectric, Large Solar, and Grid power. Each of these categories has their own tariff structure. Figure 49 below shows the breakdown of power generated for campus use.

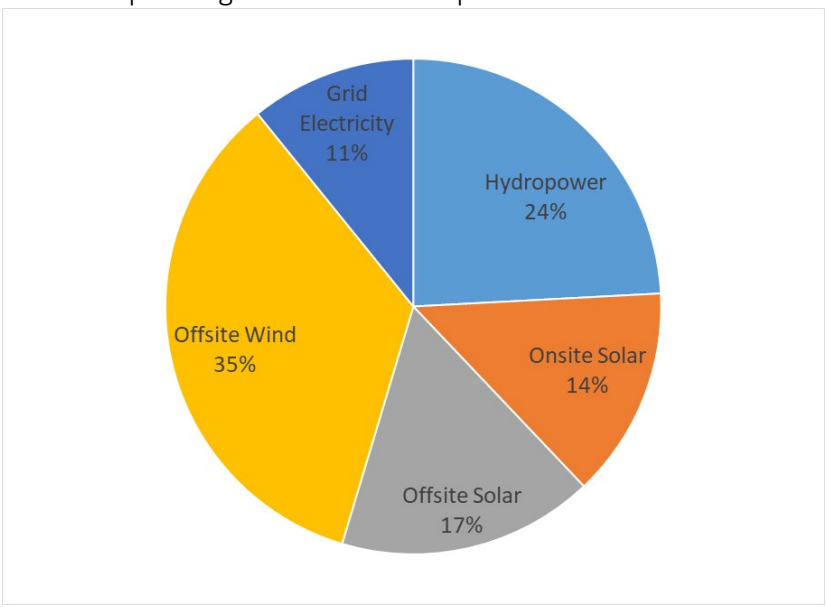

Figure 49: Breakdown of Power Generated for UC Davis Campus Use (2019)

Hydroelectric Power

Hydroelectric power is provided to the University through the Western Area Power Administration (WAPA). In particular, the University gets its power from the Central Valley Project (CVP) and Washoe Dams.

Currently, the hydroelectric tariffs average out to a price of around $0.03 per kilowatt-hour (kWh) over the course of the last three years, with a transmission tariff of an additional $0.04 per kWh. On December 31, 2024, current WAPA contracts will expire. In response, WAPA has provided a new Power Marketing Plan that will go into effect in 2025 [67]. Although none of the associated documents mention the University of California system in particular, campus experts do not project any major shift in these tariffs in the future.

In general, a second-life battery system would not impact the hydroelectric rate. The hydroelectric power is supplied by WAPA on an allocation basis and customers pay for their allocated power, even if they don't use it [68]. This means that a battery system would not affect the WAPA power unless the dams produced more power than the university required to meet its regular demands. While this can happen a few times over the course of a year, it is impossible to predict when and how much, as the amount of available hydroelectric power is driven by both seasonal and transient rainfall, which makes it nearly impossible to predict accurately. This impact is small enough that it can be neglected, as under most ordinary conditions, all power generated by WAPA will be used by the campus.

Solar Power

Solar power is generated onsite, and tariffs are driven by a power purchase agreement (PPA) that has a set price through 2034, shown in **Figure 50**.

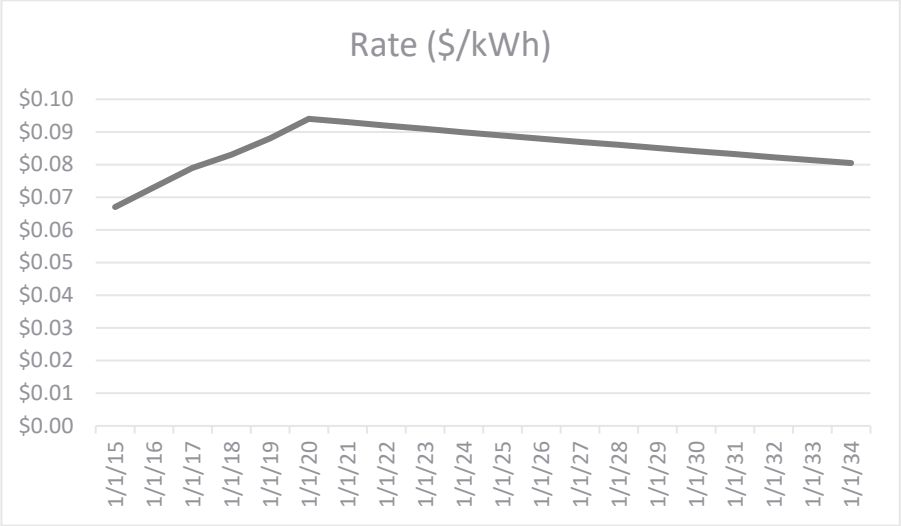

Figure 50: PPA for UC Davis Large Solar

As **Figure 50** shows, solar tariffs are peaking at a price of $0.094 per kWh and will start declining until a price of just over $0.08 per kWh in 2034. There is no transmission charge associated with the UC Davis solar farms. This PPA is in line with other PPAs for large (> 3MW) solar installations (for example, the city of Palo Alto has a PPA to purchase solar power at $0.089 per kWh for large solar installations over a 20-year term).

The UC Davis large solar installation was installed in 2015 and dedicated on Nov. 20th, 2015. The 16.3 MW solar power plant was installed in partnership with SunPower, which owns and operates the project and sells the power to UC Davis. It is estimated to generate 14% of the campus' electricity needs. At the time, it was the largest solar installation in the UC system, and in addition to meeting 14% of the UC Davis campus electricity needs, it is expected to reduce the campus carbon footprint by 9% or 14,000 metric tons. In addition to the 16 MW plant, UCD also has about 1 MW of solar panels on top of carports and other campus buildings. The West Village neighborhood is not part of the campus grid, but is served by PG&E directly, and has an additional 4 MW of rooftop SunPower solar panels on the carports and apartment buildings.

EVs have the ability to aid in solar integration into a grid like UC Davis's by serving as power storage in times when they are not being used. Excess solar power that may be generated during the peak solar times can be stored in the vehicle batteries, and these batteries can help supplement power during the evening or nighttime. Using EV batteries to

store excess solar power could allow the campus to maximize and optimize the solar generation on-site.

Grid Power Tariffs

Campus operates on the open market system for buying grid power. It is a buyer through the California Independent System Operator (CAISO). The way the fees are structured in CAISO is a two-part system as far as the University is concerned, as UC Davis does not participate in Ancillary Services (functions that keep the grid running reliably and stably), Congestion Revenue Rights (CRRs, financial instruments that allow the holder to manage variability in congestion costs due to local fluctuations or congestion), or Convergence Bidding (also called Virtual Bidding, a means to purchase power at a speculative price and sell it for the real-time price). First, a "day-ahead" forecast is made for energy use on campus by WAPA and a bid is made for energy need through CAISO. A price is reached on the market, and the university commits to buying that forecasted energy at that price. When the time comes to use that energy, the forecasted demand is frequently not a perfect match to the actual demand. In the case where less power is requested than is needed, after using the forecasted amount, CAISO sells the difference at a different, real-time market price based on the situations of the grid. If more power is requested than is needed, CAISO buys the unused capacity at the real-time market price. Both of these prices have a high degree of volatility, especially the real-time price. In a dataset containing prices the campus paid for real-time power demand, the prices varied from $-20.00 per megawatt-hour (MWh) up to over $600 per MWh (that is, between -$0.02 per kWh and $0.60 per kWh) over the course of a year. The negative price indicates that there is a large excess of power capacity available and power sinks can be paid to 'use up' that power. Additionally, transmission fees of between $0.03-$0.04 per kWh apply to any grid transactions (these fees are published by Pacific Gas & Electric and are not controllable by UC Davis).

Other Campus Locations

The UC Davis Medical Center (UCDMC) is located in Sacramento and is serviced by the Sacramento Municipal Utility District (SMUD). The single largest hospital load is for the MRIs at the hospital. Further information on the particular agreement or tariffs that UCDMC has with SMUD are unavailable. The related office buildings are fed as standard SMUD customers.

The off-campus buildings located in South Davis are serviced by the Pacific Gas and Electric Company (PG&E). Specific information about the plans those buildings are serviced by was unavailable. EVSE for these locations are discussed in a previous section.

Carbon Intensity of Servicing Grids

SMUD and PG&E both supply the overall proportions of the sources of their electricity. Those makeups and the carbon intensities of the fuels are shown below in Table 39.

Power Source	SMUD	PGE	Carbon Intensity (lb CO_2 per million BTU generated[3])
Biomass and Biowaste	8%	4%	0[4]
Geothermal	2%	4%	16.99
Eligible (Small) Hydroelectric[1]	1%	3%	0[5]
Solar	2%	18%	0
Wind	7%	10%	0
Coal	0%	0%	214.7
Large Hydroelectric[1]	26%	13%	0[5]
Natural Gas	54%	15%	117.0
Nuclear	0%	34%	0[5]
Other	0%	0%	*
Unspecified[2]	<1%	0%	*
Total	100%	100%	*

Table 40: Mix of Power Sources of SMUD and PG&E for 2018, and the Carbon Intensity of those Sources [4,5]

[1]California differentiates between small hydro (< 3MW) which is considered renewable, and large hydro (> 3MW) which is not.

[2]"Unspecified sources of power" refers to electricity which is not traceable to specific generation sources.

[3]Source: United States Energy Information Administration, 2019. Emissions do not include procurement of fuel or construction of facility.

[4]Emissions are considered offset by carbon captured in the biomass.

[5]Emissions from these sources are considered too small to be counted.

Attributing specific sources of power to specific loads on a grid is impossible, so it can be assumed that the general electricity mix of the buildings serviced by these grids is proportional to the mix of the grids as a whole.

California in-state generation has shifted away from coal as a result of the 2006 Senate Bill 1368, which established emissions performance standards for California power generation. Since the passage of that bill, coal generation statewide decreased in share of total power generation by 18%, with a current share of 0.15% statewide [76].

Campus Buildings and Equipment

Building Load Profiles

The UC Davis Facilities Management Energy Conservation Office's Campus Energy Education Dashboard (CEED) allows users to look at energy consumption of individual buildings on campus [69]. It is possible to access a view of every building on campus and select individual buildings to view their power consumption.

Campus buildings are supplied by chilled water from the Central Heating and Cooling Plant (CHCP) which provides cooling. The 8 chillers used to create this chilled water is the single largest campus energy load. The campus also uses steam condensate in the HVAC system to heat the buildings and heat hot water used in each building. Electricity powers the lights, plug-loads and fans in the HVAC system. As a result, the electricity loads of the campus buildings are relatively consistent month to month, but more dependent on time of day. Energy use data for the CHCP was not available.

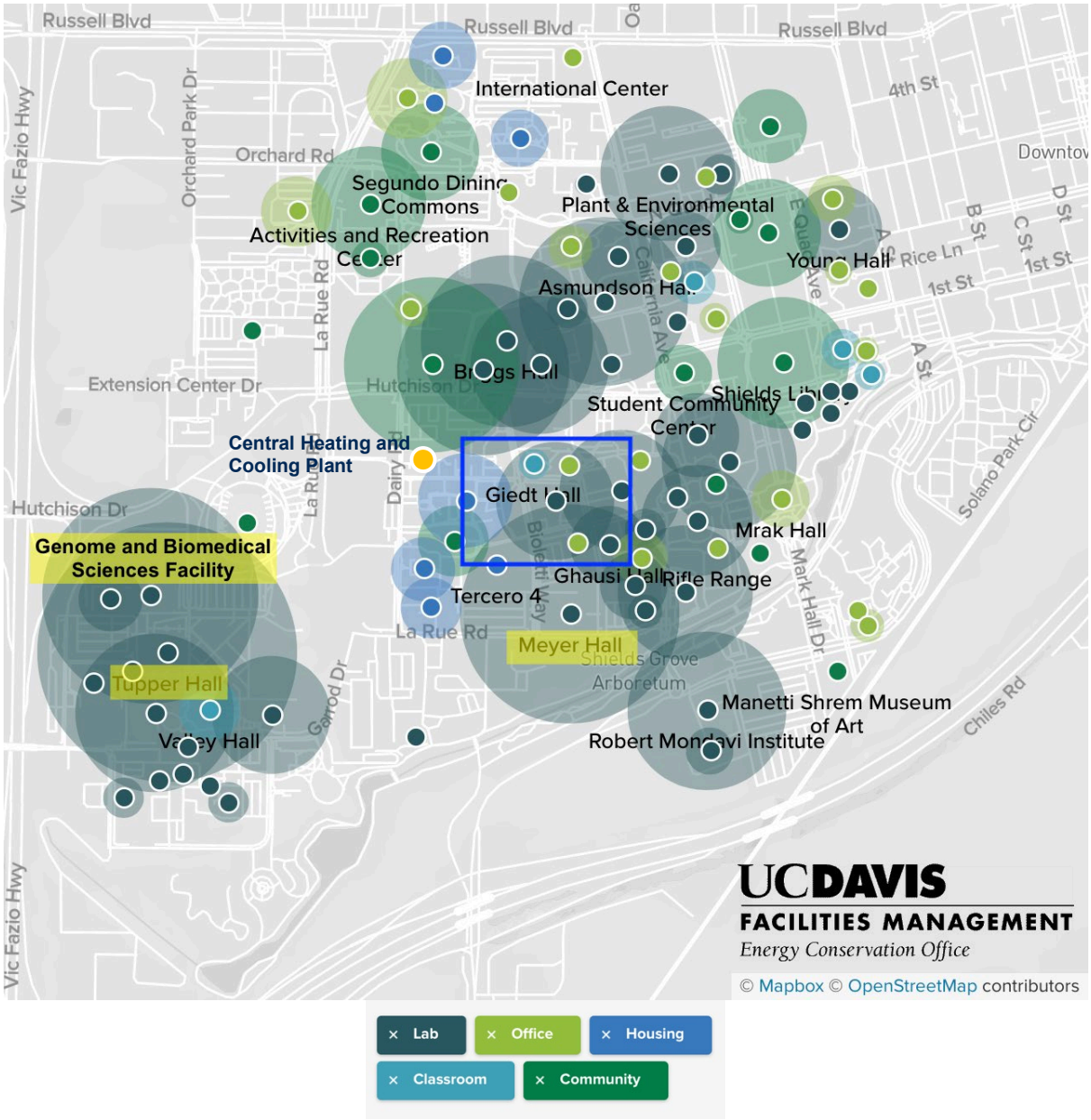

Figure 51: A map of the annual energy use (AEU) of different buildings on campus, with top three loads highlighted in yellow [3] and the Central Heating and Cooling Plant added (orange). Scale of circle denotes relative total annual energy use.

Energy consumption is viewable on an annual energy use (AEU) basis or an energy use intensity (EUI) basis, which normalizes energy use by building size. More detailed information about electricity use for individual buildings can be viewed with a control panel.

Figure 52: A graph of a week of energy use from Bainer Hall, an engineering building with classrooms, offices, and laboratories [3] Electricity use is available on a daily, weekly, and monthly basis.

Buildings with High Electricity Demand

Using the UC Davis CEED system, a table of the ten buildings with highest electricity use on campus was generated. Table 40 shows the key characteristics of these buildings, including the energy use in 2019, EUI (described above) for the building in general and its electricity use in particular, and information about the building's age, size, and use. For reference, the Pavilion parking structure is also included for comparison on the scale of energy used there, which includes 14 EVSEs compared to the highest energy using buildings. Other buildings in this table do not have EVSE data captured. Campus EVSE is not tied to specific buildings, but to parking lots and structures.

Building Name	Absolute Electricity Use 2019 (MWh)	Energy Use Index (EUI)	Electricity EUI 2019	Building Built Year	Building Square Footage	Building Primary Usage	Building Secondary Usage	Other Usages (Not Recorded)
Genome and Biomedical Sciences Facility (GBSF)	7200.7	353	106	2004	229,662	Lab (69%)	Office (21%)	10%
Tupper Hall	7017.1	428*	249*	1977	237,714	Lab (72%)	Office (22%)	6%
Meyer Hall	5994.5	350	95	1987	217,503	Lab (63%)	Office (25%)	12%
Briggs Hall	5211.4	243	93	1971	191,082	Lab (81%)	Office (17%)	2%
Life Sciences	4986	415	136	1997	125,969	Lab (80%)	Office (20%)	0%
Veterinary Medicine 3A (VetMed)	4051.2	208	84	2007	163,965	Lab (38%)	Office (8%)	54%
Mondavi Institute	3578.3	309	82	2008	147,315	Lab (80%)	Office (20%)	0%
Shields Library	2984	78	25	1940	410,015	Study (82%)	Office (15%)	3%
Chemistry Annex	2951.1	296	98	1971	108,313	Lab (87%)	Office (10%)	3%
Plant and Environmental Sciences Building (PESB)	2759.1	184	74	2002	141,214	Lab (78%)	Office (20%)	2%
Pavilion Parking Structure	633.6	108	108	2006	493,567	Parking (99%)	Office (1%)	0%

Table 41: Buildings with highest electricity demands at UC Davis, and a parking structure

*There was an equipment error recording the electricity use in Tupper Hall for December 2018. This may affect the EUI values for the building, as they are cumulative and cannot exclude bad data

Monthly energy use and hourly power demand data were accessed for these ten buildings. Figure 53 and Figure 54 show these curves.

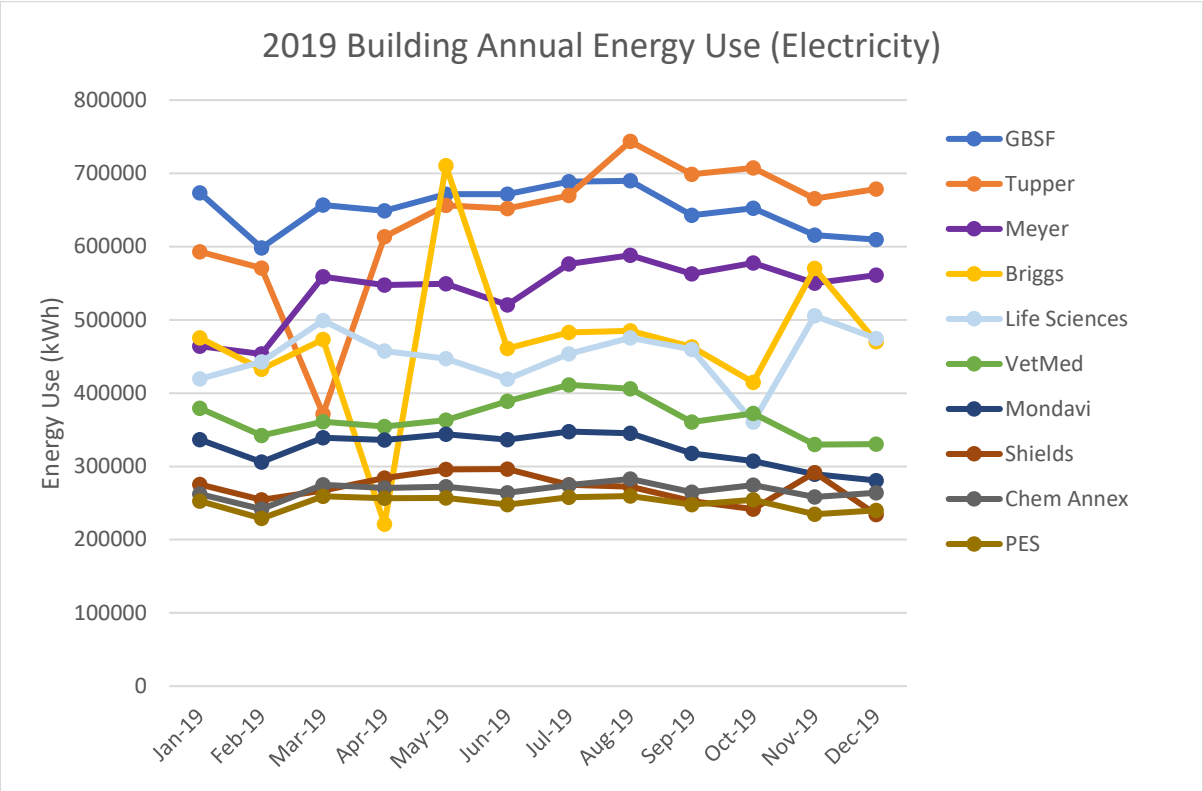

Figure 53: 2019 energy use of the ten largest electricity demanders on campus

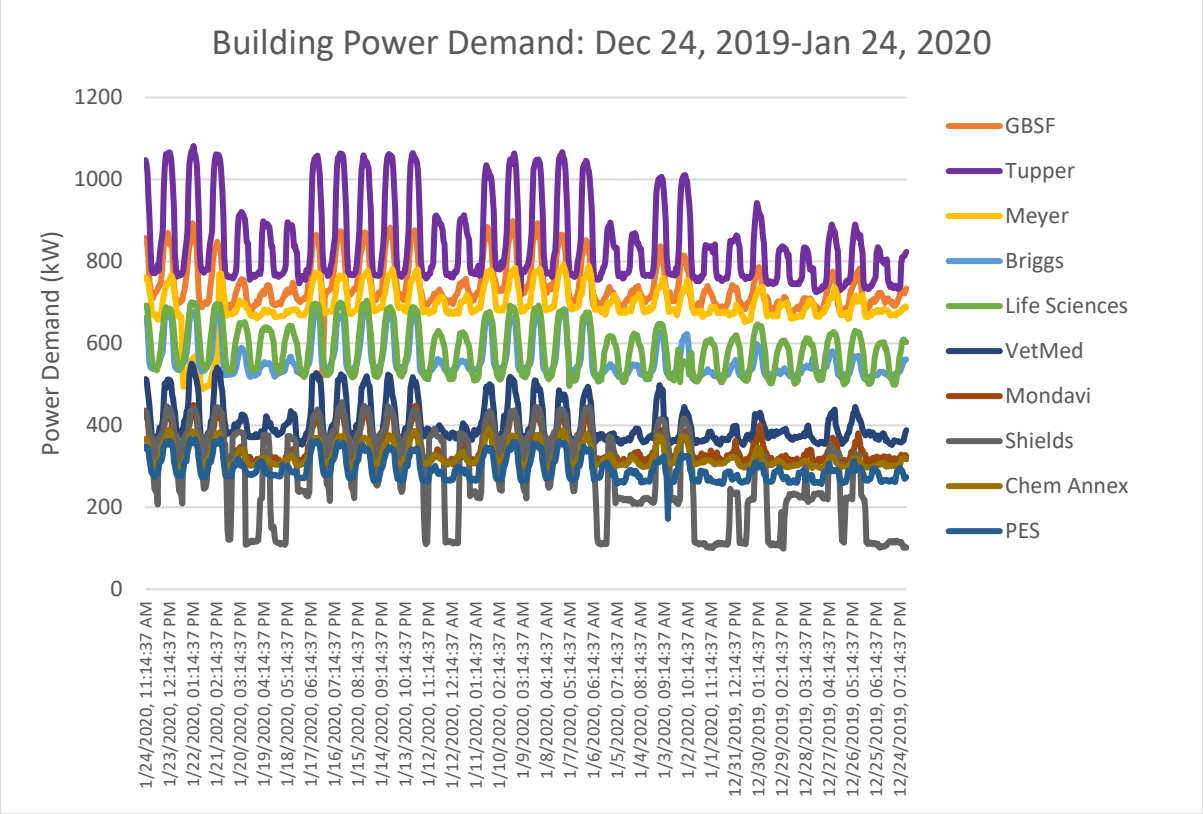

Figure 54: Power demand curve of the ten largest electricity demanders on campus

Using the EUI data from CEED, the three buildings with the combination of the largest electricity demands and lowest overall efficiencies are the Life Sciences building, Tupper Hall, and the Genome and Biomedical Sciences Facility. These buildings may be a good focus for future analysis.

Electric Vehicle Charger Loads

Currently, EV chargers installed in open parking lots are not tracked for demand by the UC Davis through the CEED system, as EVSE is considered part of the parking lot or structure in which it is located, rather than any of the nearby buildings. Data from the parking structures that predates the chargers is not available. t is possible to track the electricity use of parking structures where EV chargers are installed, but electricity used by other structure loads (primarily lighting and climate control) are not separated from charging loads. Individuals from the UC Davis Campus Facilities Office were unable to provide more detailed tracking of individual loads.

Backup Generators

The university does operate several backup generators. Currently, it appears that no 'Master List' of all of them is easily accessible, or shareable due to security concerns. However, campus facilities explained that the issue with using second-life batteries for a generator is twofold: First, second-life systems in general are not of adequate size to meet the university backup power needs. Due to the nature of the equipment that is common in university labs and the requirements for length of time that power can be provided, the battery system would need to be unreasonably large to provide an adequate amount of energy storage to most of these laboratory buildings. Second, there are currently issues with university testing and safety requirements for backup generators and similar devices that currently precludes using a battery as the primary backup device for a building. New requirements, especially for testing for readiness, would have to be developed before such a system could be deployed at scale. At the moment, there is no regulation that is requiring the University to cease operation of its diesel generators. Although discussions to move away from diesel as a backup power source are underway, no firm plans have been established.

The new program of PG&E implementing "Public Safety Power Shutoffs" (PSPS) as a fire prevention strategy did lead to high concern from some professors and laboratories for their critical power needs. There is no campus hierarchy of priority of critical loads, and the feasibility of prioritizing campus research electricity needs is uncertain and would need to tie into the specific electrical systems on campus. Back-ups for the case of PSPSs is of interest to some end users, but less so to the campus utility operators due to the constraints mentioned previously. Davis is unlikely to experience a PSPS due to its location within the state's electrical grid. Figure 55shows the layout of major transmission lines in California ("major" defined as lines carrying 220 kV or more)

Esri, USGS | Esri, HERE, Garmin, FAO, NOAA, USGS, Bureau of Land Management, EPA, NPS

Figure 55: A map of transmission lines in California for high voltages (>220 kV) [9]

As the map in Figure 55 shows, the Sacramento area is on a different transmission cable than the San Francisco area. Sacramento and its surrounding areas (including Davis) are primarily served by a transmission line that runs up the middle of the San Joaquin Valley. This area has low forestation relative to the lines serving San Francisco, and the land is more easily defensible. The combination of these factors results in Sacramento being a 'low-risk' area for major fires to start as a result of electrical equipment failure, and it is unlikely that PG&E will need to shut that transmission line down for a PSPS.

Flexible Energy Storage

The largest energy storage installation present on campus at the moment is the thermal energy system that takes the form of cold-water storage used for cooling buildings on campus. The campus has a 5-million-gallon storage tank that is used to store the cold water. The sheer size of the thermal mass prevents the temperature from changing quickly, leading to an overall efficient system. The water is charged and discharged daily (chilling takes place at night, when energy is cheaper and when ambient temperature is lower).

Additionally, Campus Utilities has control over certain large building loads throughout the day. This is predominantly HVAC control, and Utilities can modify (or turn off) these loads at times when energy is expensive. Although energy isn't being stored, this is a form of demand-response management that Utilities has control over. Currently, laboratory equipment and similar loads are not under the control of Utilities, and there is no system in place to incentivize running such equipment in an energy-efficient manner.

Looking into the future, the University is considering the purchase of electric buses to gradually replace the Unitrans fleet. If these buses are purchased, their battery packs are large enough that a vehicle-to-grid (V2G) system could theoretically be used to provide demand-response flexible storage at a significant scale. Currently, there are no detailed plans

for a V2G or flexible storage system for the future electric buses. Additionally, smart charging strategies could be implemented for both the battery bus fleet and other chargers on campus. The results of this smart charging system would be a flexible demand and could be used in conjunction with the V2G system theorized above to serve as a flexible storage option. Currently, no plans to install such a system at a large scale exist.

Future Developments and Policy Impacts

California's call to be carbon-neutral by 2045 implies that operational changes must occur between now and then. In general, interviewed experts identified two possible outcomes:

1. The grid regionalizes: In this case, one of the potential ways that carbon neutrality could be met would be using out-of-state (or out-of-region) resources that can offset carbon-intensive demands in-state (or in-region). An example of such a project would be a wind farm in a state like New Mexico, which could provide significant relief in terms of balancing the carbon budget.
2. The grid does not regionalize: In this case, more projects like large solar installations become attractive options. There are some potential side-effects to this, including PPA prices dropping very low due to the influx of solar power generation, which could hurt the economics of solar power.

In general, most of the problems on the horizon for the energy sector are not technological problems, but policy concerns. There have been contradicting policies and poor outcomes in the past due to an overall lack of alignment around the US (for example, the US could have saved a lot of money now if there had been a bigger push for connecting east-coast and west-coast grids in the past, allowing for smarter flow of energy).

More locally, the bankruptcy of Pacific Gas and Electric (PG&E) is unlikely to have a major impact on any project at UC Davis. The company has been 'bailed out' by the government, and projects can consider the future to be "business as usual" as far as PG&E is concerned. One change has been the increase in Community Choice Aggregation (CCA) power options. These options have allowed for some communities to have the option of buying their power from companies other than PG&E. At the moment, there hasn't been a huge change as a result of the increase in these CCAs, but it has been theorized that one of the impacts of this change has been the increase in Direct Access (DA) options available. These options allow for customers to choose their source of power more freely while only paying PG&E for use of the infrastructure to transmit the power. Generally, these contracts are reserved for larger commercial or industrial customers, and have historically been rare contracts available by a lottery system. In the past, PG&E and other companies have fought against direct access, as it posed a form of competition that they didn't want to fight. However, the increase in CCAs may have changed the minds of these companies, as CCAs have the potential to be very disruptive in the industry when PG&E contracts expire and must be renegotiated. It has been theorized that direct access may be a way to mitigate the disruption caused by CCAs by allowing the power companies some form of access to revenue. In any case, neither CCAs nor direct access options are likely to impact the way UC Davis operates its power grid in any meaningful way.

Discussion

UC Davis, as well as all other UC campuses and most other universities are working toward significantly cleaner or even carbon-neutral operations over the next few decades. They are motivated by both internal goal-setting, and statewide requirements, particularly targeting efficient buildings and zero-emission vehicle fleets. Universities will be working toward finding flexible, cost-effective clean solutions for integrating electric vehicles with their campus electrical systems. In our research, we have found relevant campus departments are interested and willing to engage in finding innovative solutions to support campus goals. The key factors that would affect their adoption would be cost and ease of implementation or integration. Although the technology is not in place yet, EVs and smart charging strategies, combined with V2G technology, have an opportunity to contribute towards meeting campus goals for the CNI. In particular, if the campus moves forward with electric bus adoption, the charging demand for those buses is likely to occasionally be very high, and utilizing smart charging to prioritize bus charging and de-prioritize campus fleet or commuter vehicle charging could be one solution to minimize the impacts of these high demands. Since the campus already strategically manages the chillers to optimize the timing, pricing, and efficiency of the system, chiller management is unlikely to be able to provide significant balancing for new demands added from additional electric vehicles and buses. We believe that smart charging to balance the demands of fleet and commuter light-duty vehicle charging with the demands of future electric bus charging will be a larger load-balancing opportunity.

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Task 7: Vehicle Cost Analysis

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Key Takeaways

- Used electric vehicles have a positive total cost of ownership for fleets compared to new conventional and new electric vehicles.
- This suggests the vehicles are beneficial for fleets to purchase, communicating this information to fleet managers may increase their willingness to purchase a used EV.

Total Cost of Ownership from a Fleet Perspective

Introduction

We will be considering and comparing the inclusion of a new Electric Vehicle, a used Electric Vehicle, and a new plug-in hybrid vehicle in a fleet application. Our analysis will be based on in-use data from a Chevrolet Bolt, used BMW i3, and Ford Fusion Energi in the hourly rental use "UC Drive" at UC Davis.

The Factors we will be considering are:
Purchase price – The initial vehicle purchase price, since most fleets purchase their vehicles rather than lease. The initial vehicle purchase price is based on the actual purchase price for our comparison vehicles, and the vehicle value at lease signing for the used i3s. For comparison purposes, we are treating all of the vehicles as if they were purchased, since leasing is not a standard operation for fleets. While leases were not ruled out by the UC Davis fleet manager, they are not the common or preferred way of procuring vehicles for the fleet.

Maintenance – Maintenance costs for replacement parts, including new diagnostics tools, and should include a comparison of days out of service for regular maintenance, malfunction, and repairs. New diagnostics equipment can range from $1,600 to $2,500, but is not included in our comparison table. These are often purchased as an annual subscription from each manufacturer, and may motivate fleets to focus on vehicles from a select few manufacturers in order to minimize the diagnostics equipment needed, as well as additional training needed. Based on our maintenance costs, we have filled out the table below, however, it does not include any repairs that were completed by the dealership during the lease of the vehicles, or covered under warranty for the purchased vehicles we are using to compare. This maintenance calculation also assumes the same maintenance cost in the following 6 years as we have measured data for the first 1-3 years of operation, a recognizable weakness for this calculation.

Training – Fleets may need to conduct or pay for their mechanics to have additional training in diagnostics and repair for electric vehicles. The cost of this training should be included in the cost analysis for adopting electric vehicles. A two-day training is available for approximately $275 per mechanic.

Infrastructure – The cost of installing a charging station, or fueling station to fuel the vehicles added to the fleet. In the case of electric or plug-in hybrid vehicles, the charging

infrastructure cost should consider whether the infrastructure installed is one charger per vehicle, at what charging level, with or without a battery backup to alleviate demand charges and whether or not it is a "smart" controlled or "dumb" charger if it serves multiple vehicles. In the case of our analysis, for comparison we will try to assume a portion of the total cost to maintain existing on-site gasoline fueling infrastructure, which easily serves many vehicles. We assume each vehicle has a charger, at $2,500, and the plug-in hybrid also pays a component of gas fueling infrastructure costs.

Fuel costs – For our analysis, we will assume the campus electricity rates are approximately equal to $.03/mi for electric vehicles, and based on actual fuel cost per mile, we use an average fuel cost of $0.083/mi for gasoline for the Ford Fusion, and $0.03/mi for electricity costs. The fuel costs for the Ford Fusion were calculated based on 31% of annual mi driven using electricity and 69% gasoline powered (Raghavan and Tal, 2020).

Incentives – Fleets may qualify for different purchase incentives than individual consumers. The new plug-in vehicles purchased by UC Davis have qualified and received rebates through California's Clean Vehicle Rebate Program (CVRP), which is included in our calculations. Some used incentives may be available, but are highly variable, and are therefore left out of this cost comparison calculation.

Rental Revenue – Our operating cost analysis will focus on the revenue from the UC Drive hourly rental use case at UC Davis. This is the use case with the most detailed data available, and which proved to be more valuable for our Fleet than the daily rental.

The hourly rental rates are the same for electric vehicles as for all conventional, hybrid or plug-in hybrid sedans, currently at $11.25 per hour with an $0.08/mile charge. This decision was made for three primary reasons when implementing the project. First, this simplified the implementation and deployment of the BMW i3 EVs into our existing rental process, second, this took away cost as a factor when people were choosing which vehicle to rent, and finally, this allowed the campus to balance the lower fuel costs for EVs with the higher cost of adding fueling infrastructure for the vehicles.

Type of Vehicle	Hourly	Per Mile Charge
Sedans	$11.25	$0.08
Vans - Passenger/Cargo	$10.25	$0.27
SUV Hybrids	$8.75	$0.15
1/2 Ton Pickups	$9.50	$0.26

Table 42: Hourly Rental Rates at UC Davis as of July 2019

For reference, though not included in our cost analysis, the daily rental rates are as follows for various vehicle types in the UC Davis fleet. As with the UC Drive, the BMW i3 EVs were rented at the same rate as all other sedans.

Vehicle Type	Rates	Charge per Mile
Sedans	$72.00	$0.08
Electric GEM	$59.00	N/A
Vans – 8 Passenger/Cargo/Mini Passenger/Mini Cargo	$66.00	$0.27
Vans – 12 Passenger/Cargo/Full Size Cargo	$84.00	$0.27
SUV Hybrids	$56.00	$0.15
4x4 SUV	$60.00	$0.20
1/2 Ton Pickup	$61.00	$0.26
3/4 Ton Pickup	$71.00	$0.29

Table 43: Daily rental Rates at UC Davis as of July 2019

Departmentally assigned vehicles were found in our deployment to have the highest monthly mileage. The fuel is not included in the monthly lease costs, but is available from Fleet at low recharge prices. The monthly mileage is likely higher because only departments that frequently drive for work purposes will have a departmentally assigned vehicle, but in the case of EV's in particular, the use may also be impacted by individual users' comfort level with the electric vehicles over time.

Vehicle Type	Lease Per Month	Insurance Per Month	Total Assigned Monthly Cost
Sedans	$642.00	$56.58	$698.58
Electric GEM	$521.00	$45.25	$566.25
Vans – 8 Passenger/Cargo/Mini Passenger/Mini Cargo	$587.00	$56.58	$642.58
Vans – 12 Passenger/Cargo/Full Size Cargo	$745.00	$84.75	$829.75
SUV Hybrids	$495.00	$56.58	$551.58
4x4 SUV	$526.00	$56.58	$549.16
1/2 Ton Pickup	$540.00	$56.58	$596.58
3/4 Ton Pickup	$620.00	$84.75	$704.75

Table 44: Monthly Rental Rates at UC Davis as of July 2019

Our analysis looks at the actual revenue between Jan. and Dec. 2019 for the BMW i3's, the Chevrolet Bolt, and a Ford Fusion, on the basis of average revenue per month per vehicle. The graph below compares just these three models, and takes into account the revenue collected for rental events for these vehicles over a one-year period.

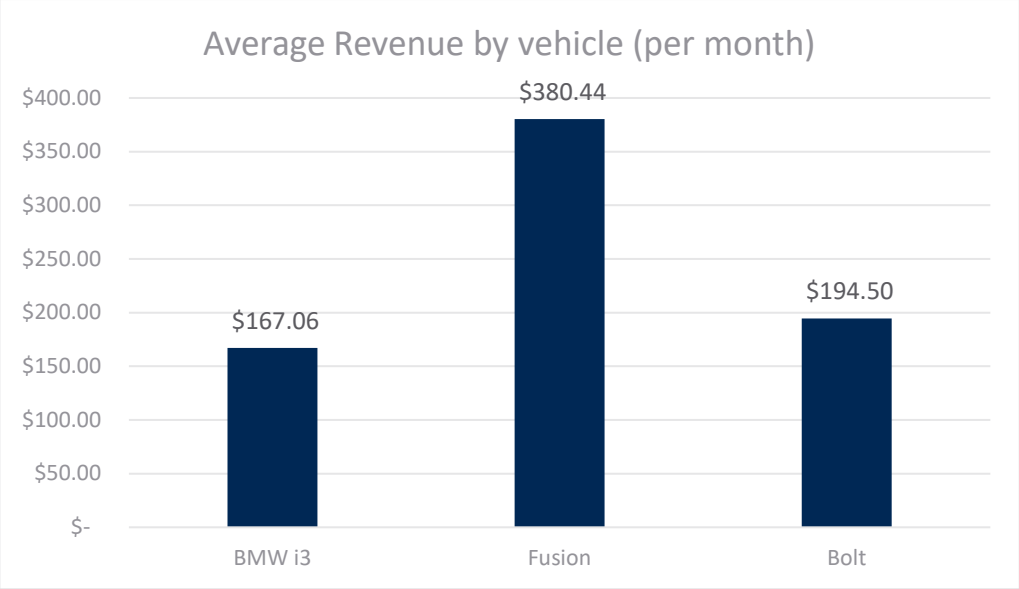

Figure 56: Average monthly revenue per vehicle for three comparative vehicles models based on 2019 data

Based on these data the i3 EV has an annual rental revenue of $2,005, the Bolt EV has an annual revenue of $2,334, and the Fusion PHEV has an annual rental revenue of $4,565. We assume consistent use over the lifetime of the vehicle, so multiply this annual data over the 9 year expected life of the vehicle to calculate the revenue value shown below. Again, the assumed consistency of revenue, use, maintenance, and fuel costs is a weakness of this simple cost analysis. The UCD campus does not currently operate any conventional internal combustion engines sedans in the fleet, and due to the campus goals and University of California Carbon Neutrality Initiative, the campus does not plan to operate any ICEs in the future. No operational data on conventional ICEs is available to compare with the advanced powertrains we are comparing in this analysis.

Resale value – At the end of the designated life of the vehicle in the fleet application, we will take into account the residual value of the vehicle when it is retired out of the fleet. We will assume a nine-year life in fleet application, and a 10% of initial purchase price for the residual value at resale, which is the typical residual value attained by Fleet services.

In the cost comparison analysis, we used data or estimates provided by fleet services to estimate the lifetime operating costs or revenues for each of the three example vehicles. Each of the factors discussed above was estimated based on the information available over a 7-year life for the BMW i3 electric vehicle purchased used, and over a 9-year life for vehicles purchased new, so that the vehicles end of life is equal at 9 years old. This simplified cost analysis does not factor in any increase in maintenance, or decrease in rental revenue over time, but is based on a simple multiplier of the average expense per month for the months UC Davis had these vehicles in operation.

Factor	Used BMW i3 (~2016) (7 year fleet life)	New Chevrolet Bolt (2018) (9 year fleet life)	New Ford Fusion (2017) (9 year fleet life)
Initial Purchase Price	-$20,350	-$35,692	-$32,436
Maintenance Costs	-$3,944	-$11,233	-$17,560
Training Cost	-$275.00	-$275.00	-$275.00
Infrastructure	-$2,500.00	-$2,500.00	-$2,600.00
Fuel Costs	-$377.00	-$1,110.00	-$8,578.00
Incentive for EV purchase	$0	$2,500.00	$1,500.00
Lifetime UC Drive Fleet Rental Revenue	$14,033	$21,006	$41,088
10% Residual Value at Fleet Retirement	$2,035.00	$3,569.00	$3,243.00
Net Value to Fleet	-$11,378.32	-$23,735.26	-$15,617.51

Table 45: Cost comparison summary table showing expenses in red and revenue in black

In the cost comparison summary table shown in Table 44 costs are shown in red, and revenues are shown in black. This cost analysis demonstrates that used electric vehicles have the lowest net operating cost over the assumed life of the vehicle, followed by the Ford Fusion PHEV, and the Chevrolet Bolt EV. In this case, this was largely a factor of maintenance and fuel costs. No conventional ICE was included in the cost comparison because UC Davis does not operate any sedans in the fleet, and therefore does not have data available. In California, most fleets of similar size are also moving to hybridization and electrification of sedans where possible, and certainly any fleets that fall under SB498 regulation oversight would not be expected to purchase ICEs in the future.

Conclusion

The net result is that the BMW i3 electric vehicles, despite their lower annual use, and therefore lower annual revenue appear be a valid choice for fleets to consider, with a smaller net operating cost loss compared to either a new PHEV or new EV. While the new EV is used more frequently and therefore generates more revenue for the fleet, the added revenue and incentive does not outweigh the much higher purchase price. The huge burden that plug-in vehicles must overcome is not just the higher purchase price of a new vehicle, but also the much larger fuel costs associated with gasoline use compared to affordable campus electricity prices.

The challenge for adopting used electric vehicles for fleets comes down to fleet operations consistency, purchase simplicity, and a need to overcome “usual” operations. For Fleets to adopt used electric vehicles requires them to make two major leaps forward, first, to adopt a new vehicle technology, with all of the upfront investment costs associated with it, and second, to purchase used vehicles is a non-standard, and therefore uneasy process for

many fleets. Finally, the upfront investment, in infrastructure, mechanic training, and maintenance equipment, may also require additional support or incentivization to overcome. Though this project was conducted with leased vehicles, our recommendation is that fleets do not lease vehicles, but purchase vehicles used. The current leasing process, particularly through conventional dealerships, is designed for individuals not fleets, and will likely lead to unexpected challenges for fleet managers, including unpredictable fees and return, and a communications process that is not streamlined or designed for fleets. Automotive manufacturers who seek to maximize their secondary market through resale to fleets, particularly motivated state-mandated fleets, need to create a clear and simple process that treats fleets as a unique customer requiring standard equipment, communications, and processes, rather than trying to duplicate the private-buyer dealership experience.

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Project Summary & Key Takeaways

This project integrating previously-owned BMW i3 electric vehicles into the campus fleet provided a unique opportunity to learn about various aspects of used electric vehicle adoption by fleets. The initial program of understanding current travel patterns to identify appropriate use-cases was followed by integration into several uses which were expected to be beneficial. Fleet managers are used to going through a very familiar process, though prescribed channels to purchase their fleet vehicles currently. Integrating used electric vehicles requires fleet managers to not only transition to a new, and possibly unfamiliar vehicle technology, but also purchase them in an unfamiliar process. In order to simplify their integration at UC Davis, other than the purchase process, integration into the fleet followed the existing UC Davis process as closely as possible, using the same GeoTab data loggers, rental system, pricing, and registration process. As researchers, we learned that the registration process can delay deployment into the fleet by at least a month, which would discourage leasing compared to purchasing, since the campus can clearly recognize a month where a lease payment is made, but no revenue is generated. Early in the process, we also recognized that the standardization of resale procedures and vehicle features would be beneficial to fleets. In this case, some of the previously-owned vehicles were not fully reset to factory standards ahead of their transfer to UC Davis, and required an additional step to train staff and then go out and clear the history of each vehicle after deployment. Finally, in terms of the lease process, the campus received 10 copies of documents encouraging lease continuation or buy-out, rather than a single letter addressing all of the vehicles in our fleet, and a wide array of repair costs at the lease-end which is very challenging to plan for or accommodate as a fleet. All of these small challenges could easily be addressed if auto manufacturers decided to create a program targeting fleets for adoption of lease-returned electric vehicles, and would smooth the adoption process for fleet managers.

The data collected on vehicle utilization showed that the used electric vehicles were used frequently, and their utilization was heavily dependent on the use case. We expect that the reason departmentally assigned vehicles were used so much more is due not just to mileage-heavy departments self-selecting into monthly rental agreements, but was also due to users becoming more familiar with the vehicle leading to increased comfort using the vehicle for longer trips. In the daily rental, which saw the lowest use, additional training, outreach and active fleet management could likely increase the vehicle use somewhat (something we also learned other fleets are doing in the fleet manager interviews), but a longer vehicle range would probably be the factor that lead to more miles in that application. The survey results from fleet users found that nearly all had a positive experience leading to them being likely to rent the BMW i3 again. Approximately half of all PHEV or BEV drivers at UC Davis experience the technology for the first time through a fleet rental opportunity, and the BMW i3 had the highest response of drivers discussing their experience with others afterward. Perhaps most importantly, this fleet experience with a new technology lead to about 70% of BMW i3 EV drivers opinion of BEV technology becoming more favorable, while none had a less favorable opinion of the technology after their fleet driving experience. This reinforces our hypothesis that fleet adoption is not only functional and beneficial at the fleet level, but could provide the exposure and experience to drivers to potentially influence their private purchase decisions.

Finally, the integration of electric vehicles with a campus, city or corporate grid system is perhaps the most challenging aspect of adopting and maximizing the potential benefits of electric vehicles. To maximize vehicle reliability and utilization of the electric

vehicles, they each need their own dedicated charger, or a well-established system to rotate vehicles through a smaller number of chargers. While smart and controlled charging may allow for better grid integration, UC Davis' unique grid interactions and lack of demand charges mean that the costs of smart chargers negatively outweigh the benefits they would provide. For many fleets the challenge of demand charges may make smart charger systems more appealing. All fleets, however, will need to contend with interoperability of any vehicle-grid management system they adopt, which will have to work with any vehicle in the fleet. In the near term, simple solutions such as time-delayed charging or human-managed charging may suffice as the industry works toward affordable, integrated, and interoperable solutions.

In summary, this study found that electric vehicles can be, and are being, adopted by most California fleets. While adoption appears to start on a trial basis as indicated by, the mostly positive experiences with the vehicles means fleets plan to, and are, continuing to move toward electrifying their light duty fleet. Previously owned electric vehicles require the fleet manager and fleet systems to adopt not just a new technology, but a new purchase or leasing process. These challenges can be overcome with thoughtful and comprehensive new processes that are fleet-focused, through education and outreach (e.g. on the beneficial TCO of the used i3 vehicles), and by offering extended warranties. Any process should simultaneously address the vehicle technology and charger acquisition, as well as the concerns raised by fleet managers; the need for training, interoperability, reliability, and potential cost savings over the vehicle lifetime.