CALIFORNIA ENERGY COMMISSION

California Energy Commission

Clean Transportation Program

FINAL PROJECT REPORT

Plug-in Hybrid Electric Vehicle Retrofit Demonstration

Prepared for: California Energy Commission

Prepared by: Department of General Services, Office of Fleet and Asset Management

March 2023 | CEC-600-2023-001

California Energy Commission

Rick Shedd
Gary Fujii
Katrina Valentine
Phil Guenther
John Musser
Primary Authors

Department of General Services
707 3rd St.
West Sacramento
CA 95605
(916) 376-5000
Department of General Services Website https://www.dgs.ca.gov/

Contract Number: 600-09-001

Kevyn Piper
Commission Agreement Manager

Mark Wenzel
Branch Manager
LIGHT-DUTY ELECTRIC VEHICLE INFRASTRUCTURE AND ANALYSIS OFFICE

Hannon Rasool
Director
FUELS AND TRANSPORTATION

Drew Bohan
Executive Director

PREFACE

Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007) created the Clean Transportation Program. The statute authorizes the California Energy Commission (CEC) to develop and deploy alternative and renewable fuels and advanced transportation technologies to help attain the state's climate change policies. Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013) reauthorizes the Clean Transportation Program through January 1, 2024, and specifies that the CEC allocate up to $20 million per year (or up to 20 percent of each fiscal year's funds) in funding for hydrogen station development until at least 100 stations are operational.

The Clean Transportation Program has an annual budget of about $100 million and provides financial support for projects that:

- Reduce California's use and dependence on petroleum transportation fuels and increase the use of alternative and renewable fuels and advanced vehicle technologies.
- Produce sustainable alternative and renewable low-carbon fuels in California.
- Expand alternative fueling infrastructure and fueling stations.
- Improve the efficiency, performance and market viability of alternative light-, medium-, and heavy-duty vehicle technologies.
- Retrofit medium- and heavy-duty on-road and nonroad vehicle fleets to alternative technologies or fuel use.
- Expand the alternative fueling infrastructure available to existing fleets, public transit, and transportation corridors.
- Establish workforce-training programs and conduct public outreach on the benefits of alternative transportation fuels and vehicle technologies.

To be eligible for funding under the Clean Transportation Program, a project must be consistent with the CEC's annual Clean Transportation Program Investment Plan Update. The Department of General Services and the CEC jointly funded a project to test the performance of plug-in hybrid electric vehicles under various circumstances. The agreement was executed as 600-09-001 on August 11, 2009.

ABSTRACT

The California Energy Commission and California Department of General Services funded the Plug-in Hybrid Electric Vehicle Retrofit Demonstration Project to demonstrate the relationship between plug-in hybrid electric vehicle performance and the way those vehicles are operated. In December of 2009, fifty standard 2009 Toyota Priuses were converted to plug-in hybrid electric vehicles, and data on their performance in a variety of agencies, locations and operator habits was recorded by the Federal Department of Energy's Idaho National Laboratory. These results demonstrated a strong connection between vehicle operator habits and vehicle performance, showing average or better performance in vehicles operated by drivers that were more consistently vigilant about charging and driving speed, and worse performance in vehicles operated by higher speed drivers with worse battery charging habits, largely due to the additional weight of the new plug-in hybrid electric battery. Analysis of the data accrued from the project demonstrates that it is vital to monitor and provide drivers with feedback about their driving and charging habits, even though those habits may be difficult to change. However, pending future developments in plug-in hybrid electric vehicles, these problems may be resolved on their own.

Keywords: Plug-in hybrid electric vehicles, Department of General Services, Idaho National Laboratory, greenhouse gases, miles per gallon.

Shedd, Rick; Gary Fujii, Katrina Valentine, Phil Guenther, John Musser. 2023. *Plug-in Hybrid Electric Vehicle Retrofit Demonstration Project*. California Energy Commission. Publication Number: CEC-600-2023-001.

TABLE OF CONTENTS

Page

LIST OF TABLES

Page

EXECUTIVE SUMMARY

The California Department of General Services is pleased to present the final report on the Plug-in Hybrid Electric Vehicle Retrofit Project to the California Energy Commission.

In December 2009, 50 new standard Toyota Priuses were converted to plug-in hybrid electric vehicles and deployed throughout California to measure their ability to produce higher than normal fuel economy results while being operated by a variety of drivers in a host of driving conditions. This project was funded by the California Energy Commission and the Department of General Services.

The Federal Department of Energy's Idaho National Laboratory monitored each vehicle through global position systems and engine telemetry and provided statistical feedback monthly.

A standard 2009 Prius is rated at 46 miles per gallon combined city/highway. This demonstration has shown that the partnership between the vehicle operators and the plug-in hybrid electric vehicles plays a crucial role in a plug-in hybrid electric vehicle's ability to achieve significant fuel economy. For example, 16 of the 50 vehicles achieved better than average fuel economy, with seven averaging between 50 and 56 miles per gallon. Several other plug-in hybrid electric vehicles, however, fell below the average miles per gallon ratings for a non-converted Prius as a result of being operated at higher speeds and without regard to battery charging.

The drivers that operated the plug-in hybrid electric vehicles in low-speed intercity conditions and who were vigilant about charging the vehicles' batteries on a daily basis achieved the best results. The less efficient results tended to center around those drivers that exceed the plug-in hybrid electric vehicle's speed limitations and operated their vehicles primarily on the internal combustion engine and/or neglected to routinely charge their batteries. Driving the plug-in hybrid electric vehicles above 35 miles per hour nullified the vehicle's ability to operate on battery power as did failing to charge the batteries. The increased weight that the plug-in hybrid electric vehicle battery pack added to the vehicle in those cases became a detriment to achieving optimal fuel economy.

There were very few problems reported by the plug-in hybrid electric vehicle operators other than two original equipment manufacturer battery failures and a vehicle accident, both unrelated to plug-in hybrid electric vehicle retrofits.

Overall, the plug-in hybrid electric vehicle demonstration project has confirmed that the technology is able to achieve higher than average fuel economy when the vehicles are driven at lower speeds by operators that charge the batteries frequently.

CHAPTER 1: Deployment

In December 2009, 50 2009 Toyota Priuses were converted to plug-in hybrid electric vehicles. Each of these vehicles were deployed throughout California to measure their ability to produce higher than normal fuel economy results while being operated by a variety of drivers in a host of driving conditions. This project was funded by the California Energy Commission and the Department of General Services. The Federal Department of Energy's Idaho National Laboratory monitored each vehicle through global position systems and engine telemetry and provided statistical feedback monthly. Table 1 (see below) lists each plug-in hybrid electric vehicle (PHEV) location and the state agency operating the vehicle.

Table 1: PHEV Locations and Agency

Vehicle	Location	Agency
A1	Sacramento	Peace Officers Standards and Training
A2	Sacramento	CA Department of Education
A3	Sacramento	Department of Military
A4	Sacramento	CA Energy Commission
A5	Sacramento	Water Resources Control Board
A6	Los Angeles	Department of General Services
A7	Sacramento	Department of General Services
A8	Sacramento	State Chief Information Office
A9	Sacramento	State Chief Information Office
A10	San Francisco	SF Bay Conservation
A11	San Diego	Department of Public Health
A12	Sacramento	Department of General Services
A13	Concord	Department of Industrial Relations
A14	Sacramento	Department of General Services
A15	Chico	Department of Social Services
C16	Irvine	University of California Irvine
C17	Irvine	University of California Irvine
C18	Irvine	Department of Transportation
C19	Los Angeles	Public Utilities Commission
C20	Santa Ana	Department of Industrial Relations
C21	Irvine	University of California Irvine

Vehicle	Location	Agency
C22	Irvine	University of California Irvine
C23	Los Angeles	Public Utilities Commission
C24	Irvine	University of California Irvine
C25	Los Angeles	Department of Corrections and Rehabilitation
A26	Berkeley	Department of Toxic Substances Control
A27	Sacramento	Department of Fish and Game Purchased
A28	San Francisco	Public Utilities Commission
A29	Sacramento	Department of General Services
A30	San Francisco	Department of Justice
B31	Chico	Department of Social Services
B32	Sacramento	Department of General Services
B33	Sacramento	Department of General Services
B34	Sacramento	Department of General Services
B35	Sacramento	California Integrated Waste Mgmt. Board
B36	San Diego	Department of Fish and Game
B37	Indigo	Department of Corrections and Rehabilitation
B38	San Diego	Department of Industrial Relations
B39	Fresno	Department of Parole Hearings
B40	Sacramento	Department of General Services
A41	Richmond	Department of Public Health
A42	Richmond	Department of Public Health
A43	Sacramento	Department of General Services
A44	Sacramento	Department of Motor Vehicles
A45	Sacramento	Department of General Services
B46	Sacramento	Department of Fish and Game
B47	Sacramento	Department of General Services
B48	San Francisco	California Public Utilities Commission
B49	San Francisco	Department of General Services
B50	San Francisco	Public Utilities Commission

Source: California Department of General Services

Operating Costs

- Gasoline - From December 1, 2009 to March 31, 2011, the PHEVs in this demonstration project averaged $0.066 per mile to operate for a total of $46,924. This total was achieved using the following calculations:
  - 700,807 (total miles) divided by 46 totals 15,235 gallons of fuel, overall average miles per gallon (mpg),
  - 15,235 multiplied by $3.08 (average gallon price of California gasoline, all grades, from December 1 2009, to March 31, 2011)[1] = $46,924.
- Electricity - From December 1, 2009 to March 31, 2011, the total dollar amount spent on electricity to charge the PHEVs was $2,060. This total was achieved using the following calculation:
  - 15,836 alternating current (AC) kilowatt-hours (kWh) (total charging energy) multiplied by .13¢ (average price of electricity, per kWh, in California, from December 2009 to April 2011)1 = $2,060.

The total amount spent on gasoline and electricity from December 1, 2009, to March 31, 2011, was $48,984.

Vehicles' Days of Use

In order to obtain the objectives of this project, it was vital that the PHEVs be driven on a regular basis and under a variety of driving conditions. This is why the California Department of General Services (DGS) crafted the driver selection process to include drivers who would operate the vehicles on a daily, consistent basis. The monitoring of the vehicles' daily use allowed for the re-assignment of vehicles that were being under-utilized. The total number of days of use/average per vehicle is listed below, as are the total number of trips/average per vehicle.

From December 1, 2009, to March 31, 2011:

- Total number of days of use: 11,387,
- Average number of days of use per vehicle: 228,
- Total number of trips: 51,370,
- Average number of trips per vehicle: 1027.

Miles Driven

The number of miles driven by each PHEV is as equally important as the days of use and total trips made in determining whether PHEVs are a viable tool in reducing petroleum consumption and GHGs. Too few miles driven can result in an incomplete or inaccurate conclusion, whereas excessive miles driven can give a more accurate picture of performance. Again, the global positioning system tracking allowed the DGS to reassign any vehicles that weren't being driven a satisfactory number of miles. The total number of miles driven, and the average miles driven per vehicle are as follows:

From December 1, 2009, to March 31, 2011:

---

1 US Environmental Information Administration https://www.eia.gov/

- Total miles driven: 700,807,
- Average per vehicle: 14,016,
- Average miles driven per vehicle/per month: 876.

Energy or Fuel Consumption

The GPS tracking devices installed in each PHEV allowed the DGS to monitor the amount of electrical energy each vehicle used. In addition, each individual charging event was also recorded. These factors were crucial in examining the use of each PHEV and in determining whether the vehicle was being used in the most fuel efficient manner. The data shows that regular recharging of the batteries resulted in better performance and a higher overall mpg. The totals and averages for each PHEV are as follows:

From December 1, 2009, to March 31, 2011:

- Total charging energy (AC kwh): 15,836,
- Average charging energy per vehicle per month: 18.9,
- Total number of charging events: 5,402,
- Average number of charging events per vehicle per month: six,
- Overall gasoline fuel economy: 46 mpg,
- Lowest fuel economy: 28 mpg,
- Highest fuel economy: 56 mpg.

Vehicle Performance

While the 50 vehicles involved in this project achieved an overall mpg average of 46, several vehicles accomplished a much higher average up to 56 mpg. There were some occasions where drivers turned off the battery kit contained within their PHEV. During these times those vehicles did not have an opportunity to operate under the PHEV battery power and functioned solely on the original equipment manufacturer hybrid gasoline/electric mode. There were also vehicles that were not plugged in daily or were driven at higher than optimal speeds. Tables 2, Table 3, Table 4 and Table 5 on the following pages display average mileage as grouped by performance. DGS provided additional feedback to those drivers that were not charging their PHEVs regularly. In some cases, charging intervals increased but some drivers failed to increase their charging practices after being notified repeatedly. This inaction by a subset of the vehicle operators demonstrates the critical relationship between the PHEV and a motivated operator to maximize the fuel economy potential of the vehicle.

Table 2: Idaho National Laboratory Information for 50 to 56 MPG Vehicle

Vehicle	Days of Use	Miles Driven	Trips	Charging Energy (AC kwh)	Charging Events	Overall MPG
DGSB38	280	32214	1580	698.9	147	56
DGSA4	321	9173	2233	1396.8	521	53
DGSA10	229	10310	849	786.9	223	52
DGSA28	219	8888	734	712.0	181	51

Vehicle	Days of Use	Miles Driven	Trips	Charging Energy (AC kwh)	Charging Events	Overall MPG
DGSA5	166	9758	509	460.8	166	50
DGSA15	258	21553	1122	887.9	221	50
DGSC25	192	19516	761	460.4	156	50
Totals	**1,665**	**111,412**	**7,788**	**5,403.7**	**1,615**	**Average = 51.2**

Source: Idaho National Laboratory

Table 3: Idaho National Laboratory Information for 47 to 49 MPG Vehicles

VEHICLE	DAYS OF USE	MILES DRIVEN	TRIPS	CHARGING ENERGY (AC kwh)	CHARGING EVENTS	OVERALL MPG
DGSA2	117	939	360	241.0	124	49
DGSA12	146	3686	469	367.2	121	49
DGSB31	261	25118	1193	921.1	227	49
DGSC20	278	17825	1166	1143.9	255	48
DGSA3	282	6139	785	639.2	211	47
DGSA13[2]	111	3765	341	0	0	47
DGSA26	183	11420	613	218.8	103	47
DGSA30	188	17625	626	411.7	122	47
DGSB35	213	15610	811	390.4	149	47
Totals	**1,779**	**102,127**	**6,364**	**4,333.3**	**1,312**	**Average = 47.7**

Source: Idaho National Laboratory

Table 4: Idaho National Laboratory Information

VEHICLE	DAYS OF USE	MILES DRIVEN	TRIPS	CHARGING ENERGY (AC kwh)	CHARGING EVENTS	OVERALL MPG
DGSA1	265	3192	970	202.2	100	46
DGSB32	262	28073	1316	243.0	80	46

2 There were no charging events recorded by this vehicle.

VEHICLE	DAYS OF USE	MILES DRIVEN	TRIPS	CHARGING ENERGY (AC kwh)	CHARGING EVENTS	OVERALL MPG
DGSB34	247	27225	1282	299.0	102	46
DGSA44	261	22150	1097	343.1	113	46
DGSB46	78	4961	400	17.3	5	46
DGSB49	261	25362	1424	448.9	147	46
Totals	**1,374**	**110,963**	**6,489**	**1,553.5**	**547**	**Average = 46**

Source: Idaho National Laboratory

Table 5: Idaho National Laboratory Information 45 MPG and Under

VEHICLE	DAYS OF USE	MILES DRIVEN	TRIPS	CHARGING ENERGY (AC kwh)	CHARGING EVENTS	OVERALL MPG
DGSA6	202	3982	615	117.8	49	41
DGSA7	278	37944	1487	370.3	91	45
DGSA8	252	6305	1020	308.4	280	45
DGSA9	207	6354	1546	13.8	11	39
DGSA11	340	16384	1257	42.1	22	45
DGSA14	226	10251	926	229.8	64	45
DGSC16	226	2146	1481	146.2	45	31
DGSC17[3]	26	181	69	24.1	13	42
DGSC18	269	20127	1529	384.5	151	42
DGSC19	284	15158	1285	347.8	149	45
DGSC21	243	2445	969	48.0	46	32
DGSC22	194	1688	587	142.9	38	35
DGSC23	284	23639	1175	500.3	165	44
DGSC24	252	2017	1583	111.6	59	28
DGSA27	291	10363	883	36.7	11	45
DGSA29	236	19978	1097	145.2	76	44
DGSB33	277	33533	1504	97.6	47	45

3 There were data transmission failures from this vehicle from March 1, 2010 through December 31, 2010.

VEHICLE	DAYS OF USE	MILES DRIVEN	TRIPS	CHARGING ENERGY (AC kwh)	CHARGING EVENTS	OVERALL MPG
DGSB36	264	12731	1221	314.2	85	45
DGSB37	377	17773	2269	57.8	15	39
DGSB39	125	13579	436	12.5	7	44
DGSB40	221	9294	1202	76.3	61	43
DGSA41	174	2369	486	41.7	11	39
DGSA42	76	1944	178	57.5	24	45
DGSA43	220	21225	1123	117.0	47	45
DGSA45	246	23642	1356	212.2	83	44
DGSB47	207	21061	1421	93.1	92	45
DGSB48	336	18556	1362	280.4	111	45
DGSB50	236	21640	1022	215.4	75	44
Totals	**6,569**	**376,309**	**31,089**	**4,545.2**	**1,928**	**Average = 41.8**

Source: Idaho National Laboratory

Greenhouse Gas (GHG) Emission Reduction

Out of the 50 vehicles, the PHEVs in Table 6 achieved the highest average mpg and the highest reduction of GHG emissions, followed by the vehicles in Table 3. The following charts compare the amount of GHG emissions produced by a standard 2009 Prius to that of a 2009 PHEV Prius.

The PHEVs in Table 2 produced 42,215 pounds of CO_2, while a standard 2009 Prius, as shown in Table 6 below, driven the same number of miles would produce 46,987 pounds of CO_2. This resulted in a reduction of 4,772 pounds of GHG emissions.

Table 6: Vehicles (50-56 MPG)

12/01/09 to 03/31/11	Total Miles Travelled	Combined MPG	Gallons of Gasoline	CO_2/gal[4]	Pounds CO_2
Standard 2009 Prius	111,412	46	2,422	19.4	46,987
PHEVs (shown in Table 2)	111,412	51.2	2,176	19.4	42,215

Source: Idaho National Laboratory

4 US Environmental Protection Agency Climate Website http://EPA.gov/

The PHEVs in shown in Table 3 produced 41,536 pounds of CO_2, while a standard 2009 Prius driven the same number of miles would produce 43,071 pounds of CO_2, as shown in Table 7 below. This resulted in a reduction of 1,535 pounds of GHG emissions.

Table 7: Vehicles (47–49 MPG)

12/01/09 to 03/31/11	Total Miles Travelled	Combined MPG	Gallons of Gasoline	CO_2/gallon	Pounds O_2
Standard 2009 Prius	102,127	46	2,220	19.4	43,071
PHEVs (shown in Table 3)	102,127	47.7	2,141	19.4	41,536

Source: Idaho National Laboratory

By capitalizing on the vehicles ability to operate on electric power alone, petroleum consumption was reduced, and the vehicles produced less GHG emissions.

Petroleum Displacement

The PHEVs in Table 2 and Table 3 both achieved some petroleum displacement. The PHEVs in Table 2 used 246 gallons of gasoline, less than a standard 2009 Prius would use over the same distance, while the PHEVs in Table 3 used 79 gallons of gasoline, less than a standard Prius.

This petroleum displacement can be attributed to the higher mpg achieved by the vehicles, which, conversely, can be accredited to the additional battery power of the PHEVs. Frequent charging of the batteries helped play a role in reducing petroleum consumption. The data shows that there was a much higher fuel economy when the PHEVs were operated in charge depleting mode (58 mpg) than when operated in charge sustaining (44 mpg) modes. Charge depleting mode is where the entire trip had a charged battery pack to utilize while charge sustaining mode refers to when the battery is depleted, and the vehicle is not using the battery to move forward. The higher ratings associated with charge depleting mode are what can be expected overall from the PHEV operators who kept the plug-in battery packs fully charged.

The nature in which the vehicles were used was also a factor in achieving a higher mpg. Vehicles that were driven primarily in the city maintained a greater mpg average than those which operated primarily on the highway. Highway speeds trigger the gasoline engine to engage whereas the vehicle can operate solely on battery power at lower city speeds.

The vehicles in Tables 4 and 5 did not displace any petroleum due to their lower mpg averages. In addition to the highway driving conditions vs. city driving conditions mentioned above, there are other factors which contributed to a decreased overall mpg average including the additional weight of the battery kit. The battery kit weighs 200 pounds, and a standard 2009 Prius has a maximum load capacity (passengers and cargo) of 810 pounds. The battery kit alone reduces the PHEV’s maximum load capacity by almost 25 percent to 610 pounds.

Given that the average body weight of an adult in the United States is 179.70 pounds[5] and that the 2009 Prius seats five passengers, the PHEV's maximum load capacity could be easily exceeded when transporting a full accompaniment of passengers and related cargo.

In addition, certain operating procedures caused the PHEVs to function in gasoline-only mode. These included the use of the air conditioning/heating units and rapid acceleration by the drivers. These dynamics resulted in decreased overall mpg averages for some vehicles.

Operator Feedback/Education

A questionnaire was sent to each of the PHEV users and 17 responses were received. Each user was asked the following questions:

- What do you like about the PHEV most?
- Have you come across any issues while operating the PHEV?
- Have you come across any issues while charging the PHEV?
- Do you feel that you were educated enough when the garage staff completed the PHEV demonstration for you?
- Do you have any suggestions to improve the PHEV Program?

The responses were all generally very positive about their initial experiences with the PHEVs. The most common response regarding what they liked most about the PHEV (question one) was the excellent fuel economy. No other response to the questionnaire repeated in any significant number except that six respondents indicated that they received little or no instructions from the garage staff when picking up the vehicle (question four).

Driver feedback was provided during this project. The DGS monitored the use of each PHEV and maintained contact with each operator. This allowed the project team to stress the importance of plugging in the vehicles on a regular basis and offered the opportunity to remind drivers of the proper ways to operate the vehicles and keep the battery kits activated. In addition, vehicles that were underutilized were reassigned to drivers that could drive more miles during the demonstration.

Malfunctions

The following were the malfunctions reported since deployment of the PHEVs:

- Two had dead original equipment manufacturer batteries that needed replacing,
- Two had telemetry problems (one had a loose wire, the other needed a new part),
- One did not hold an electric charge and was returned to the battery pack installer for repair/replacement,
- Two were involved in accidents (one minor, one major and both needed to have their battery packs removed before body work could be done),
- Two were returned by their operators due to the inability to operate the heater without shutting off the battery,
- One required service on its electric plug connector,

---

5 US Center for Disease Control official website http://www.cdc.gov/nchs/fastats/bodymeas.htm

Meeting State Business Transportation Needs

The business needs of each potential PHEV assignment were examined prior to assigning the vehicle to ensure that there were no requirements that could not be met by a standard mid-size sedan. The PHEVs in this project met the State's business needs based upon the operator feedback.

CHAPTER 2: Conclusion

All 50 PHEV's were deployed across California and served in a variety of government business uses and operators were educated on proper driving techniques and encouraged to plug-in the PHEV's at every opportunity. A final interview was conducted with the drivers who achieved the highest fuel economy.

There were several factors that the vehicle operators shared in achieving high mpg rates. All of the operators responded that their vehicles were used primarily by one driver. This is evidence that an operator practicing conservative driving habits can obtain a greater mpg. When asked whether the vehicles were driven primarily in the city or on the highway, the answer was unanimously "the city". This shows that the PHEV technology is best utilized at lower speeds. All of the operators responded that they made a conscientious effort to charge the vehicles on a daily basis. Again, the PHEV technology is best exploited when the vehicle is fully charged. Vehicle #DGSA2 achieved slightly less than 1,000 miles on a single tank of gas. Vehicle #DGSB38 had the highest overall mpg (56 mpg) and also logged the third highest miles driven (32,214). Both of these drivers operated their vehicles at lower speeds and practiced regular charging.

The lackluster fuel economy of the underperforming vehicles can be attributed to three conditions: undesirable driving habits such as rapid acceleration; inadequate battery charging; and, driving at higher speeds primarily on highways. This project has demonstrated that if the retrofitted PHEVs are utilized for low speed city driving and correct driving habits are employed, including keeping the batteries frequently charged, the PHEV technology is a viable method that the State could use to reduce its petroleum consumption and cut its greenhouse gas emissions.

The ability for the State to monitor PHEV performance on a large scale is problematic. This demonstration project pointed out that it is vital to monitor and provide drivers with feedback about their driving and charging habits. Even when this occurs it is difficult to change driving or charging habits that are detrimental to achieving higher than average fuel economy. The added weight that the PHEV's additional battery pack adds to a standard hybrid cannot overcome drivers that operate mostly on highways and fail to charge their vehicles' batteries with constant regularity. For State agencies to monitor the driving and charging habits of their staff, and then to manage changes where necessary would be challenging at best.

While the PHEV technology has shown that it can outperform a standard hybrid's fuel economy ratings, it can only do so in the hands of conscience drivers operating in specific conditions. This may prove limiting to widespread adoption at the state level. However, should speed limitations be overcome in future PHEV offerings, this concern would become moot.

GLOSSARY

ALTERNATING CURRENT (AC)—Flow of electricity that constantly changes direction between positive and negative sides. Almost all power produced by electric utilities in the United States moves in current that shifts direction at a rate of 60 times per second.

CALIFORNIA DEPARTMENT OF GENERAL SERVICES (DGS)—serves the public by providing a variety of services to state agencies through procurement and acquisition solutions; real estate management and design; environmentally friendly transportation; professional printing, design and web services; administrative hearings; legal services; building standards; oversight of structural safety, fire/life safety and accessibility for the design and construction of K-12 public schools and community colleges; funding for school construction; and disability access.[6]

CALIFORNIA ENERGY COMMISSION (CEC)—The state agency established by the Warren-Alquist State Energy Resources Conservation and Development Act in 1974 (Public Resources Code, Sections 25000 et seq.) responsible for energy policy. The CEC's five major areas of responsibilities are:

1. Forecasting future statewide energy needs.
2. Licensing power plants sufficient to meet those needs.
3. Promoting energy conservation and efficiency measures.
4. Developing renewable and alternative energy resources, including providing assistance to develop clean transportation fuels.
5. Planning for and directing state response to energy emergencies.

Funding for the CEC's activities comes from the Energy Resources Program Account, Federal Petroleum Violation Escrow Account, and other sources.

CARBON DIOXIDE (CO2)—A colorless, odorless, non-poisonous gas that is a normal part of the air. Carbon dioxide is exhaled by humans and animals and is absorbed by green growing things and by the sea. CO2 is the greenhouse gas whose concentration is being most affected directly by human activities. CO2 also serves as the reference to compare all other greenhouse gases (see carbon dioxide equivalent).

GREENHOUSE GASES (GHG)—Any gas that absorbs infra-red radiation in the atmosphere. Greenhouse gases include water vapor, carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), halogenated fluorocarbons (HCFCs), ozone (O3), perfluorinated carbons (PFCs), and hydrofluorocarbons (HFCs).

KILOWATT-HOUR (kWh)—The most commonly-used unit of measure telling the amount of electricity consumed over time. It means one kilowatt of electricity supplied for one hour. In 1989, a typical California household consumes 534 kWh in an average month.

MILES PER GALLON (MPG)—A measure of vehicle fuel efficiency. Miles per gallon or MPG represents "Fleet Miles per Gallon. "For each subgroup or "table cell," MPG is computed as the ratio of the total number of miles traveled by all vehicles in the subgroup to the total number

---

6 Department of General Services Website https://www.dgs.ca.gov/

of gallons consumed. MPGs are assigned to each vehicle using the EPA certification files and adjusted for on-road driving.

PLUG-IN HYBRID ELECTRIC VEHICLE (PHEV)—PHEVs are powered by an internal combustion engine and an electric motor that uses energy stored in a battery. The vehicle can be plugged in to an electric power source to charge the battery. Some can travel nearly 100 miles on electricity alone, and all can operate solely on gasoline (similar to a conventional hybrid).