

DEPARTMENT OF GENERAL SERVICES  
OFFICE OF FLEET AND ASSET MANAGEMENT

# PLUG-IN HYBRID ELECTRIC VEHICLE RETROFIT DEMONSTRATION PROJECT

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SEMI-ANNUAL REPORT TO THE  
CALIFORNIA ENERGY COMMISSION

AGREEMENT NUMBER 600-09-001

(Revised March 22, 2010)

Prepared by the

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# Table of Contents

<b>Executive Summary</b>	<b>4</b>
<b>Project Overview</b>	<b>4</b>
<b>Conversions</b>	<b>4</b>
<b>Deployment</b>	<b>5</b>
<b>Operating Costs</b>	<b>6</b>
<b>Vehicles' Days of Use</b>	<b>6</b>
<b>Miles Driven</b>	<b>6</b>
<b>Energy or Fuel Consumption</b>	<b>7</b>
<b>Greenhouse Gas Emission Reduction</b>	<b>9</b>
<b>Petroleum Displacement</b>	<b>9</b>
<b>Operator Feedback</b>	<b>9</b>
<b>Malfunctions</b>	<b>10</b>
<b>Meeting State Business Transportation Needs</b>	<b>10</b>
<b>Other Issues</b>	<b>10</b>

## **Executive Summary**

The Department of General Services (DGS) is pleased to present the first semi-annual report about the Plug-in Hybrid Electric Vehicle (PHEV) Retrofit Project to the California Energy Commission (CEC). Fifty PHEVs were deployed throughout California in the final days of December 2009 so the data for this reporting period is very limited. Energy consumption for those days of use indicated no savings, but that is expected to change in the next reporting period once the PHEV users establish regular charging habits. There was a measurable decline in the greenhouse gas (GHG) emissions and this is also an area that is likely to improve with regular charging. Few significant problems were reported by the PHEV users other than two Original Equipment Manufacturer (OEM) battery failures and an accident, both unrelated to PHEV retrofits. Driver education will be conducted to encourage driving and battery charging habits that will maximize the performance of the PHEVs.

The DGS has reached out to the University of California - Davis, the Air Resources Board and the U.S. Department of Energy's Idaho National Laboratory (INL) to share information on this PHEV demonstration project. UC Davis and the INL have been granted access to the Global Positioning Systems (GPS) with telematics from the fifty PHEV demonstration fleet. The INL is providing the DGS with monthly summary feedback that is being used in conjunction with our own metrics to measure the impact of the PHEV on petroleum reduction and GHG emission reduction.

## **Project Overview**

The purpose of this project is to retrofit up to fifty state-owned hybrid vehicles to operate as PHEVs to extend their range of operation while using battery only power. In addition, GPS with telematics are being incorporated on these vehicles to assist in gathering required reporting information. The DGS is serving as the project manager and contractor to ensure the hybrid vehicles are retrofitted to PHEVs with GPS installed. Further, DGS has placed the vehicles into daily operation at various locations throughout the State to determine operator acceptance, fuel consumption, and vehicle performance in various climates and business situations.

It is the goal of this project to test the emerging PHEV technology in real-world conditions and measure the benefits of increased fuel economy and potential to reduce GHG emissions.

## **Conversions**

On October 12, 2009, the DGS began a phased-in delivery of fifty 2009 Toyota Prius hybrid vehicles to the three A123 Systems certified PHEV modifiers in California: Pat's Garage in San Francisco; A-Plus Japanese Automotive in San Carlos; and, THE DR. Independent Service & Sales in Fountain Valley. On October 16, 2009, the contract between the DGS and A123 Systems was fully executed and the three PHEV modifiers began the retrofit installations.

By December 7, 2009, all 50 Toyota Prius hybrid vehicles had been successfully retrofitted to operate as PHEVs, including the installation of Gridpoint V2 Green GPS tracking devices and engine/battery telemetry.

## Deployment

Table 1 (see below) lists each PHEV location and the State agency operating the vehicle.

**Table 1**

<b>Vehicle</b>	<b>Location</b>	<b>Agency</b>
A1	Sacramento	Peace Officers Standards and Training
A2	Sacramento	Dept. of General Services
A3	Sacramento	Dept. of Military
A4	Sacramento	CA Energy Commission
A5	Sacramento	Water Resources Control Board
A6	Los Angeles	Dept. of General Services
A7	Sacramento	CA Children & Families Commission
A8	Sacramento	State Chief Information Office
A9	Sacramento	State Chief Information Office
A10	San Francisco	SF Bay Conservation
A11	San Diego	Dept. of Public Health
A12	Sacramento	Dept. of General Services
A13	Concord	Dept. of Industrial Relations
A14	Sacramento	Dept. of General Services
A15	Chico	Dept. of Social Services
C16	Irvine	UC Irvine
C17	Irvine	UC Irvine
C18	Irvine	Dept. of Transportation
C19	Los Angeles	Public Utilities Commission
C20	Santa Ana	Dept. of Industrial Relations
C21	Irvine	UC Irvine
C22	Irvine	UC Irvine
C23	Los Angeles	Public Utilities Commission
C24	Irvine	UC Irvine
C25	Los Angeles	Dept. of Corrections and Rehabilitation
A26	Berkeley	Dept. of Toxic Substances Control
A27	Sacramento	Dept. of Fish & Game Purchased
A28	San Francisco	Public Utilities Commission
A29	Sacramento	CA Energy Commission
A30	San Francisco	Dept of Justice
B31	Chico	Dept. of Social Services
B32	Sacramento	CA Energy Commission
B33	Sacramento	Dept. of General Services
B34	Sacramento	Dept. of General Services
B35	Sacramento	CA Integrated Waste Mgmt. Board
B36	San Diego	Dept. of Fish and Game
B37	Indigo	Dept. of Corrections and Rehabilitation
B38	San Diego	Dept. of Industrial Relations

B39	Fresno	Dept. of Parole Hearings
B40	Sacramento	Dept. of General Services
A41	Richmond	Dept. of Public Health
A42	Richmond	Dept. of Public Health
A43	Sacramento	Dept. of General Services
A44	Sacramento	Dept. of Motor Vehicles
A45	Sacramento	Dept. of General Services
B46	Sacramento	Dept. of Fish & Game
B47	Sacramento	CA Energy Commission
B48	San Francisco	CA Public Utilities Commission
B49	San Francisco	SF Bay Conservation
B50	San Francisco	Public Utilities Commission

### Operating Costs

From December 1 to December 31, 2009, the PHEVs in this demonstration project averaged \$0.076 per mile to operate for a total of \$1,832.68. The U.S. Department of Energy calculates that it costs \$0.056 per mile to operate a standard 2009 Prius but assumes a gasoline price of \$2.58 per gallon. Adjusting that figure to reflect the 20% higher cost of fuel in California would result in a cost of \$0.067 per mile to operate a standard Prius in California.

### Vehicles' Days of Use <sup>1</sup>

In order to obtain the objectives of this project, it is vital that the PHEVs be driven on a regular basis and under a variety of driving conditions. This is why the 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 allows for the re-assignment of vehicles that are 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 to December 31, 2009:

- Total # of days of use = 498.
- Average # of days of use per vehicle = 10.82
- Total # of trips = 2012.
- Average # of trips per vehicle = 43.73

### Miles Driven <sup>1</sup>

The amount 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. Again, the GPS tracking system will allow the DGS to reassign any vehicles that aren't being driven a satisfactory number of miles. The total number of miles driven and the average miles driven per vehicle are as follows:

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<sup>1</sup> See Table 2, Information gathered by the Idaho National Laboratory.

From December 1 to December 31, 2009:

- Total miles driven = 24,074.
- Average per vehicle = 523.34

There are six drivers with miles and trips logged but no charging sessions or electricity used.

**Energy or Fuel Consumption <sup>1</sup>**

The GPS tracking devices installed in each PHEV allows the DGS to monitor the amount of electrical energy each vehicle is using. In addition, each individual charging event is also recorded. These factors are crucial in examining the use of each PHEV and in determining whether the vehicle is being used in the most fuel efficient manner. The totals and averages for each PHEV are as follows:

From December 1 to December 31, 2009:

- Total charging energy (AC kwh) = 886.10 AC kwh.
- Average charging energy per driver = 19.26 AC kwh
- Total # of charging events = 318
- Average # of charging events per vehicle = 6.91.
- Average fuel economy = 46.56 mpg
- Lowest fuel economy = 25mpg/ Highest fuel economy = 64mpg

**Table 2, Idaho National Laboratory Information**

PRIUS PHEV DATA FOR 12/01/09 – 12/31/09						
VEHICLE	DAYS OF USE	MILES DRIVEN	TRIPS	CHARGING ENERGY (AC kwh)	CHARGING EVENTS	OVERALL MPG
DGSA1	14	186	45	0	0	43
DGSA2	7	39	20	18.9	7	25
DGSA3	19	234	56	34.4	20	26
DGSA4	19	489	135	92	36	50
DGSA5	11	815	36	22.9	6	47
DGSA6	15	172	39	6.2	2	41
DGSA7	16	2139	72	62.5	13	45
DGSA8	10	259	43	36.9	16	55
DGSA9	NA	NA	NA	NA	NA	NA
DGSA10	5	187	20	19.7	12	55
DGSA11	20	1364	83	11.7	7	46
DGSA12	8	257	25	3.1	4	40

DGSA13	7	82	14	0	0	48
DGSA14	7	141	24	1	1	41
DGSA15	12	638	49	20.5	8	47
DGSC16	2	41	3	2.7	2	41
DGSC17	5	70	12	7.1	5	56
DGSC18	13	728	72	6	3	39
DGSC19	NA	NA	NA	NA	NA	NA
DGSC20	12	807	41	47	10	49
DGSC21	3	41	4	7.4	2	64
DGSC22	2	42	3	6.8	2	54
DGSC23	16	622	65	48	14	46
DGSC24	2	42	3	3.2	3	60
DGSC25	18	2086	86	61.9	17	48
DGSA26	10	97	34	4.2	3	46
DGSA27	19	266	52	9	4	44
DGSA28	NA	NA	NA	NA	NA	NA
DGSA29	11	260	34	17.1	5	46
DGSA30	5	547	20	15.8	6	49
DGSB31	11	822	46	18.8	7	45
DGSB32	9	570	31	11.3	3	43
DGSB33	24	1479	88	29.4	10	46
DGSB34	4	523	19	0	0	43
DGSB35	8	771	45	21	7	42
DGSB36	9	876	31	30.7	9	50
DGSB37	24	1095	150	36.5	9	43
DGSB38	14	1070	63	41.4	10	56
DGSB39	4	458	14	0	0	45
DGSB40	16	597	103	12.9	12	43
DGSA41	8	40	15	3.1	1	56
DGSA42	8	46	16	9.5	3	49
DGSA43	10	201	29	7.3	2	42
DGSA44	11	694	44	0	0	43
DGSA45	15	505	54	12.6	5	42
DGSB46	2	41	5	6.5	3	52
DGSB47	NA	NA	NA	NA	NA	NA
DGSB48	20	580	77	39	13	45
DGSB49	3	91	12	13	8	58
DGSB50	11	964	80	27.1	8	48

### Greenhouse Gas Emission Reduction

The PHEVs in this project emitted 7% less GHG than that expected from a standard 2009 Prius driven the same number of miles. The PHEVs emitted 11,923 pounds of Equivalent Carbon Dioxide (CO<sub>2</sub>e) while a standard Prius driven the same distance would emit 12,816 pounds using U.S. Department of Energy emission ratings (0.533 pounds/mile of CO<sub>2</sub>e for a standard 2009 Prius). (See Table 3)

**Table 3**

December 2009	Combined MPG	Greenhouse Gas Emission	GHG for 24,074 mi.
Standard 2009 Prius	46.00	.533 lbs./mi	12,816 lbs.
PHEV Prius Fleet	46.56	.5 lbs./mi	11,923 lbs.

A more dramatic reduction of GHG is expected in future months of this project because of an expected higher reliance on battery power. The PHEVs were just being deployed in December 2009 and are expected to be driven fully charged more frequently once operators develop the habit of plugging-in the vehicle after every use.

### Petroleum Displacement

Data from December does not yet reflect any significant petroleum displacement by the PHEVs. The U.S. Department of Energy has rated a standard 2009 Prius at 46 miles per gallons while the PHEVs in this project achieved 46.56 mpg overall.

However, the data shows that there is much higher fuel economy when the PHEVs are operated in charge depleting (53 mpg) or charge sustaining (51 mpg) modes. Charge depleting mode is where the entire trip had a charged battery pack to utilize while charge sustaining mode is where a part of the trip could do so before the battery was completely discharged. These higher ratings are what can be expected overall from the PHEVs once operators develop the habit of keeping the plug-in battery packs fully charged.

Two PHEVs (DGSA2 and DGSA3) had unusually low fuel economy ratings of 25 and 26 MPG respectively. This is likely attributed to their unique operating patterns. Both vehicles took several very short trips and were not fully warmed up to take advantage of the battery electric power. And, in some instances, the battery had been turned off so even if the vehicle had reached its normal operating temperature, battery power was unavailable.

### Operator Feedback

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

1. What do you like about the PHEV most?
2. Have you come across any issues while operating the PHEV?
3. Have you come across any issues while charging the PHEV?
4. Do you feel that you were educated enough when the garage staff completed the PHEV demonstration for you?

5. 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 1) 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 garages (question 4).

### **Malfunctions**

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

- Two that have had dead OEM batteries that needed replacing
- Two had Gridpoint 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 that have been in accidents (one minor, one major which needed to have the battery pack removed before body work could be done)
- Two returned by the user due to the inability to operate the heater without shutting off the battery.

### **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-side sedan. The PHEVs in this project are currently meeting the State's business needs based upon the operator feedback.

### **Conclusions**

The PHEV demonstration project is now in full swing with all 50 Prius' deployed across California in a variety of business uses. With limited data received thus far, it is premature to identify any significant results either pro or con. It does seem evident, however, that increased driver training and feedback to the drivers about their vehicle's performance is needed. Driver education will be conducted to encourage driving and battery charging habits that will maximize the performance of the PHEVs. Statistical feedback will be provided to each driver so they are aware of their vehicle's performance each month as well as the statistics for all other PHEVs in this project for comparison.