

Plug-In Hybrid Test Program: Central Vermont Public Service & Green Mountain College Report #1



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I. Overview

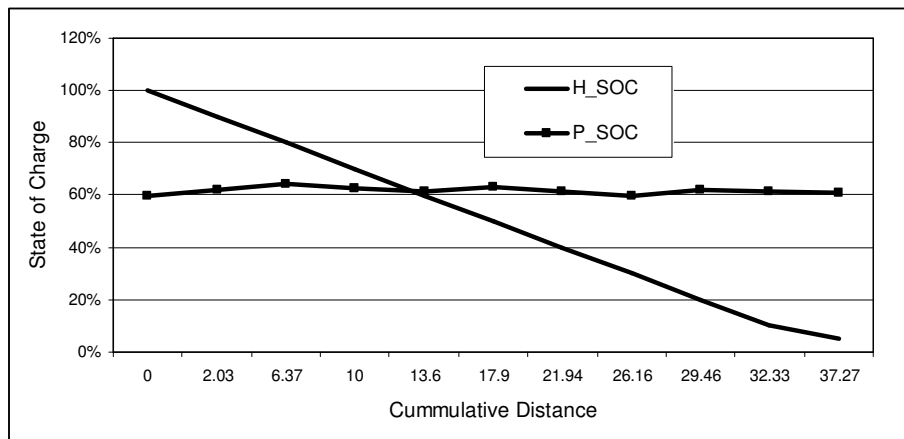
On June 11th Central Vermont Public Service (CVPS) and Green Mountain College (GMC) officially launched the Plug'n Go initiative to assess the opportunity that plug-in hybrid electric vehicle (PHEV) technology may represent here in Vermont. CVPS converted two conventional hybrid electric vehicles (Toyota Prius) to PHEVs using a Toronto-based company called Hymotion. The Hymotion conversion adds five kilowatt-hours of additional battery storage, with leading edge lithium ion battery technology, the control logic, and an external plug to allow charging from the electric grid.

One of the PHEVs is being used by CVPS as a pool vehicle, and the second vehicle was leased to GMC for a period of two-years. The PHEV in use by CVPS is referred to here as Plug' n Go 1 and the leased vehicle to GMC is referred to as Plug' n Go 2. The GMC leased PHEV is being used by GMC faculty in a regular commute pattern. The first driver had an above average commute distance—approximately 32 miles one-way—and drove the vehicle from September, 2007 through March, 2008. The second GMC drive has a below average commute of just 10 miles one-way, and began driving the vehicle in early April.

A PHEV differs from a conventional hybrid electric vehicle (HEV) commercially available today in two important ways. First, additional battery storage and a three-pronged plug allow a PHEV to displace gasoline purchased at the pump with electricity purchased from the electric grid. Conventional hybrids use the battery pack in what is described as a charge sustaining mode, meaning the battery pack is subject to shallow cycles of discharging and charging from the vehicle engine and the regenerative braking system. In contrast, a PHEV uses a charge depletion strategy, whereby it uses a much greater percentage of the battery pack for vehicle operations. Once the battery pack is nearing depletion, the vehicle reverts back to a charge sustaining mode similar to its non plug-in counterpart.

Each of the vehicles being analyzed here has two separate battery packs, the original one that comes with a standard Prius using a nickel metal hydride chemistry and the supplemental battery pack provided as part of the conversion by Hymotion, which uses a non-phosphate lithium ion chemistry manufactured by A123 Systems Inc. Data on the state of charge for each of these battery packs can be obtained from the on-board data loggers. Figure 1 below illustrates the difference between charge sustaining and charge depletion operation, providing data on the state of charge for both battery packs during a 37 mile trip in Plug' n Go 2.

Figure 1
State of Charge (SOC) for Hymotion Battery Pack vs. Prius Battery Pack



The data loggers installed in each vehicle measure a variety of information on the vehicles' performance. GMC has been collecting and analyzing the performance data on both vehicles since September of 2007. Due to difficulties with the data logging system and the enormous size of the data files, it has taken researchers longer than planned to gather and process the data.

The data files contain time series data on each drive cycle, or trip. When the engine is turned on a new file is created, collecting a variety of data during the trip, and the file is ended when the vehicle is turned off. The data in each file is compiled to provide summary statistics for each particular trip. Table 1 indicates the variables that are calculated from each of the individual trip files. In addition, a watt meter was used by the driver of Plug' n Go 2 to record the amount of energy in kWh used each evening to charge the vehicle.

Table 1
PHEV Performance Data per Trip: Collection and Recording Protocol

Variable	Description	Units
Date (D)	date of the trip	month_day_year
Trip Length (TL)	miles of travel per trip	miles
Trip Duration (TD)	number of minutes of the on/off event	minutes
Average Speed (MPH)	average speed of trip	mph (miles per hour)
Average Miles Per Gallon (MPG)	average fuel economy of trip	mpg (miles of travel per gallon)
Begin SOC Hymotion pack (B_H_SOC)	state of charge of the Hymotion battery pack at start of trip	percentage of usable energy remaining in battery pack
End SOC Hymotion pack (E_H_SOC)	state of charge of the Hymotion battery pack at end of trip	percentage of usable energy remaining in battery pack
Begin SOC Prius pack (B_P_SOC)	state of charge of the Prius battery pack at start of trip	percentage of usable energy remaining in battery pack
End SOC Prius pack (E_P_SOC)	state of charge of the Prius battery pack at end of trip	percentage of usable energy remaining in battery pack
kWh Used (kWh)	total energy used during the trip	kWh
Gasoline Consumed (GAS)	total fuel used during the trip	gallons

II. Key Findings

Several key findings resulted from analyses of the data. Summary data, as indicated in Table 1 above, was analyzed for 220 distinct trips. An additional variable was created by subtracting the state of charge (SOC) of the Hymotion battery pack at the end of the trip from the SOC of the pack at the beginning of the trip; this variable is called "SOC Change." This variable indicates how extensive the charge depletion was for a particular trip. For example a value of 90 or above would indicate a trip leading to a full depletion of the Hymotion pack.

The raw data is contained in appendix A of this report. The key findings include:

- for the entire dataset (including both Plug' n Go 1 and Plug' n Go 2) with summary data on 220 trips totaling 7,580 miles traveled, the average fuel economy was 55 mpg;

- the average fuel economy for the 84 trips where the variable SOC Change was 10 percent or more (these are trips with vehicle operation to a large degree in charge depleting mode) was 69.3 mpg, the average distance was 34.0 miles, and the average speed for these trips was 38.4 mph;
- the average fuel economy for the 136 trips where the SOC Change was less than 10 percent (these are trips with vehicle operation in charge sustaining mode) was 46.1 mpg, the average distance was 34.8 miles and the average speed for these trips was 40.2 mph;
- as a proxy for temperature the dataset was divided between trips recorded through October and those recorded after October 31st, 2007, average fuel economy dropped from 58.5 mpg to 51.5 mpg for these two time periods respectfully, resulting in a 12 percent drop in overall fuel economy due to colder weather and snow tires; and
- each charge cycle of a depleted Hymotion battery pack requires approximately 6 kWh of energy from the grid as measured through a watt meter, this translates into approximately 3.8 kWh of energy being delivered to the vehicle drive system, or a 63 percent wall to wheels conversion efficiency.

III. Discussion

The PHEVs being evaluated in this study deliver optimal fuel economy when the Hymotion battery pack is fully charged before the start of the trip and used in a charge depleting mode. On average the PHEVs used in this mode achieve approximately 70 mpg equivalent. The vehicles revert from charge depleting to charge sustaining mode when cumulative miles driven during a trip reach 37, although the terrain and driver behavior can influence this. Of the 21 trips recorded with fuel economy results of 80 mpg or higher, the trip lengths were equal to or less than 37 miles.

Given the PHEVs performance when in charge sustaining mode (operating like a conventional HEV), the additional battery storage and grid charging improves the efficiency by 50 percent—going from 46.1 mpg to 69.3 mpg. If we assume a 70 mile trip, the vehicle would consume about 1.5 gallons of fuel when operating in charge sustaining mode. With fuel prices at say \$3.25/gallon this trip would cost the driver \$4.88. Alternatively, this same 70 mile trip operating with a fully charged Hymotion battery pack in charge depleting mode would require one gallon of gasoline and 6 kWh of electricity. Again assuming the cost of gasoline at \$3.25 and electricity at 12¢/kWh, the cost of this trip would be just \$3.97. This translates into a fuel cost savings of 91¢ for a 70 mile trip.

The round trip inefficiency for these PHEVs is significant. The wall to wheels conversion efficiency was estimated to be 63 percent. For every kWh delivered to the drivetrain, 1.37 kWh must be purchased from the utility company. These losses result from inefficiencies in the charger and the power electronics that deliver power to the vehicle's drivetrain.

Appendix A

Raw Data for Plug' n Go 1 & Plug' n Go 2

Plug n Go 1

D	ST	TL	TD	MPH	MPG	B_H_SOC	E_H_SOC	B_P_SOC	E_P_SOC	Gas	kWh
12/11/07	15:04:02	9.7	64.1	9.1	177.3	88	88	61.5	55	0.055	0.0000
11/27/07	18:30:18	4.3	12.7	20.2	85.7	88	71.5	63	63.5	0.050	0.6990
08/27/07	8:12:24	65.3	97.2	40.3	72.0	92.5	6	60.5	74.5	0.907	3.6093
01/09/08	12:05:32	30.5	40.5	45.2	70.4	77	5.5	64.5	62.5	0.433	0.6435
12/26/07	12:46:46	61.0	81.5	44.9	62.8	85.5	8.5	61.5	66	0.971	0.6872
09/19/07	5:58:00	35.2	53.9	39.2	62.3	100	10	67	63.5	0.565	3.7680
12/11/07	16:52:08	8.8	33.9	15.6	62.1	76.5	41	64	62.5	0.142	1.4879
11/14/07	16:33:46	69.0	89.1	46.5	61.0	100	8	70.5	65.5	1.131	3.8135
09/18/07	6:18:48	68.0	96.0	42.5	60.4	100	6	63	66	1.126	3.9025
11/28/07	7:01:38	6.9	23.2	17.8	59.3	71.5	43.5	63.5	62	0.116	1.1522
08/27/07	16:07:52	33.5	50.3	39.9	57.6	3	3	65	63.5	0.581	0.0000
01/11/08	18:09:36	35.1	58.9	35.8	57.0	70.5	7.5	65	76	0.616	0.5558
11/29/07	13:44:06	34.5	48.7	42.6	53.0	99.5	55	66.5	69.5	0.652	1.8917
09/19/07	14:09:16	39.8	63.3	37.7	52.8	3.5	3.5	69	72	0.752	0.0000
09/07/07	5:18:14	98.7	125.6	47.1	52.8	10	5	58	73.5	1.871	0.1835
09/07/07	12:40:26	99.6	136.7	43.7	52.7	84.5	2	63.5	59.5	1.890	3.4751
08/29/07	11:37:18	38.0	58.1	39.3	52.6	2.5	2.5	69.5	62.5	0.724	0.0000
11/19/07	10:44:08	56.2	70.1	48.1	52.4	100	8	70	65.5	1.073	3.7181
01/17/08	11:19:30	67.4	77.9	51.9	49.7	97.5	12.5	63	75.5	1.356	0.7572
12/14/07	17:19:08	65.5	103.7	37.9	49.7	99	11	72.5	76.5	1.319	3.6291
09/18/07	16:40:34	52.0	81.7	38.2	49.4	6	4	66	70.5	1.052	0.0791
12/26/07	16:22:54	63.5	88.5	43.1	49.4	8.5	8.5	60.5	65	1.286	0.0000
11/30/07	9:10:22	67.5	98.5	41.1	47.6	100	100	69.5	59.5	1.418	0.0037
08/27/07	15:17:04	40.1	49.4	48.6	47.5	3.5	3	45	65	0.843	0.0051
08/27/07	10:00:30	40.4	47.3	51.3	46.6	6	4.5	74.5	58.5	0.866	0.0469
01/09/08	6:29:24	30.9	40.4	46.0	46.6	22.5	9	62	71.5	0.664	0.1150
11/28/07	7:24:54	129.9	138.4	56.3	46.5	43.5	11.5	62	60.5	2.794	1.2621
12/11/07	7:09:04	65.0	107.3	36.4	46.3	100	99.5	59.5	61	1.406	0.0236
11/30/07	14:40:32	30.9	43.6	42.6	46.2	100	100	64.5	60	0.670	0.0000
12/12/07	9:08:20	86.0	131.7	39.2	45.5	40	40	59	65.5	1.890	0.0000
12/20/07	10:18:24	56.0	77.5	43.4	45.3	100	8.5	63.5	61.5	1.238	0.8114

D	ST	TL	TD	MPH	MPG	B_H_SOC	E_H_SOC	B_P_SOC	E_P_SOC	Gas	kWh
01/09/08	14:55:30	30.6	42.8	43.0	45.2	5.5	5.5	62.5	71	0.678	0.0000
11/28/07	15:58:56	78.5	105.7	44.6	45.1	8	7.5	75	63.5	1.741	0.0217
09/12/07	20:55:18	56.7	58.8	57.9	44.1	6	5.5	63.5	65	1.285	0.0232
11/19/07	15:07:58	56.3	74.7	45.2	44.1	8	6	65.5	69	1.278	0.0814
09/13/07	15:53:40	52.0	64.6	48.3	43.7	4	4	48.5	65	1.189	0.0000
11/29/07	11:41:50	32.5	42.7	45.7	43.7	100	99.5	63.5	66.5	0.745	0.0084
11/14/07	20:19:04	67.7	82.9	48.9	43.7	7	6	60.5	70	1.549	0.0250
12/05/07	15:01:26	35.0	47.8	44.0	43.3	100	100	68.5	69.5	0.809	0.0000
09/13/07	7:03:34	73.0	75.5	58.0	42.5	5.5	5	65	63	1.716	0.0259
12/12/07	16:35:10	67.6	81.6	49.7	42.4	10	8.5	69.5	68.5	1.595	0.0654
09/14/07	17:19:02	72.9	90.5	48.3	42.3	4	4	60	63.5	1.724	0.0000
12/08/07	8:19:48	32.0	41.8	46.1	41.7	100	100	69.5	61.5	0.768	0.0000
12/12/07	12:19:20	67.5	78.9	51.3	41.7	38	10	64	69.5	1.617	1.1077
09/19/07	8:47:30	51.9	49.9	62.3	40.8	7.5	4.5	63.5	76	1.272	0.1184
11/30/07	12:59:06	35.3	58.4	36.3	40.6	100	100	65	74.5	0.870	0.0000
12/11/07	22:00:12	24.7	46.6	31.7	40.5	41	41	54	58.5	0.609	0.0000
12/20/07	15:07:32	55.8	75.5	44.3	40.3	8.5	8.5	60	65	1.385	0.0000
11/28/07	14:45:38	55.7	54.5	61.2	40.1	11.5	8	60.5	75	1.387	0.1267
12/05/07	7:19:40	73.4	80.1	55.0	39.6	100	100	66.5	66.5	1.855	0.0000
09/19/07	13:08:00	63.4	57.7	65.8	38.3	3.5	3.5	68	69	1.656	0.0000
12/08/07	9:04:26	73.7	70.6	62.7	38.2	100	100	61.5	71	1.928	0.0000
08/29/07	6:40:20	114.8	120.4	57.2	38.0	2.5	2.5	56.5	62	3.023	0.0000
08/29/07	10:30:20	66.6	62.5	63.9	37.8	2.5	2.5	62	69.5	1.760	0.0000
12/14/07	12:01:12	31.7	55.7	34.2	37.8	99	99	65	64	0.840	0.0000
12/11/07	9:02:04	6.2	23.2	16.1	37.6	99.5	99.5	61	55	0.165	0.0000
12/05/07	12:41:50	51.9	49.9	62.4	37.5	100	100	67.5	68.5	1.384	0.0000
12/08/07	15:12:58	104.8	112.1	56.1	37.2	100	100	64.5	72.5	2.818	0.0000
12/05/07	10:53:36	33.4	36.2	55.5	35.8	100	100	66.5	71.5	0.935	0.0000
12/05/07	6:10:56	32.5	63.7	30.6	35.7	100	100	60	64.5	0.909	0.0000
12/14/07	13:38:02	37.2	35.4	63.0	33.9	99	99	64	72.5	1.097	0.0000
11/28/07	17:53:08	1.6	7.9	12.4	30.8	7.5	7.5	63.5	65.5	0.053	0.0000
11/14/07	18:23:10	1.9	6.8	17.0	24.5	8	7	65.5	60.5	0.078	0.0426

Plug' n Go 2

D	ST	TL	TD	MPH	MPG	B_H_SOC	E_H_SOC	B_P_SOC	E_P_SOC	Gas	kWh
10/9/2007	7:09:00	3.8	20.0	11.4	159.7	66.0	49.0	62.5	63.0	0.024	0.7067
8/17/2007	15:46:00	3.0	11.3	15.7	113.6	100.0	88.0	62.5	62.0	0.026	0.5034
8/28/2007	12:33:00	21.6	35.6	36.4	110.6	100.0	45.0	63.0	64.5	0.195	2.3108
10/15/2007	16:22:28	16.4	32.1	30.6	103.9	39.5	15.0	61.0	65.5	0.158	0.9928
10/4/2007	16:01:00	3.0	11.9	14.9	101.6	88.0	76.0	62.0	62.5	0.029	0.5081
1/17/2008	17:04:54	52.0	85.9	36.3	98.4	3.0	3.0	52.0	64.0	0.528	0.0003
10/15/2007	7:35:28	1.3	6.9	11.2	95.6	40.5	32.5	62.0	62.5	0.014	0.2176
10/8/2007	7:08:00	2.2	10.6	12.3	94.5	74.0	66.0	64.0	62.5	0.023	0.3338
9/10/2007	7:57:00	27.3	35.4	46.4	86.5	99.5	28.0	61.5	61.0	0.316	2.9854
9/5/2007	9:17:00	30.4	43.5	41.8	85.3	100.0	19.0	63.5	61.5	0.356	3.3591
9/5/2007	9:44:00	36.8	53.1	41.7	85.0	100.0	5.5			0.433	3.8904
8/17/2007	12:19:00	3.5	17.1	12.3	84.6	100.0	82.0	54.0	62.0	0.041	0.7549
8/13/2007	15:13:00	21.7	35.6	36.6	83.4	100.0	57.0	58.5	66.0	0.261	1.8159
10/5/2007	7:25:00	29.7	38.7	46.0	82.9	88.0	12.0	63.0	60.5	0.358	3.1124
9/3/2007	18:01:00	36.8	53.4	41.4	82.8	100.0	4.5	65.0	62.0	0.445	3.9425
9/3/2007	18:27:00	36.8	52.5	42.1	81.8	100.0	4.0	68.0	60.0	0.450	3.9521
9/3/2007	19:37:00	36.9	52.5	42.2	80.9	100.0	5.5	64.0	63.5	0.455	3.8759
9/4/2007	19:34:00	36.9	54.1	40.9	80.2	100.0	6.0	64.0	60.5	0.459	3.8633
9/4/2007	12:28:00	36.9	50.1	44.2	80.1	100.0	10.5	61.0	62.5	0.460	3.7082
10/8/2007	16:09:00	3.3	16.0	12.4	79.5	70.5	60.0	72.0	59.5	0.042	0.4443
10/5/2007	16:34:00	9.6	14.9	38.5	79.0	88.0	64.0			0.121	1.0093
8/17/2007	16:21:00	2.9	10.5	16.7	78.9	100.0	89.0	62.5	62.0	0.037	0.4588
9/3/2007	17:51:00	36.8	50.5	43.8	78.5	100.0	8.0	63.5	61.5	0.469	3.8190
10/10/2007	7:28:00	0.7	5.6	7.9	78.0	60.0	55.0	59.5	62.5	0.009	0.1915
9/15/2007	11:11:00	36.4	48.8	44.7	77.8	94.0	4.0	63.0	63.5	0.468	3.7271
9/4/2007	15:47:00	36.9	51.8	42.7	77.8	100.0	6.5	62.0	61.0	0.474	3.8519
9/6/2007	17:37:00	36.9	56.5	39.1	77.5	100.0	5.0			0.476	3.8959
9/12/2007	14:35:00	37.2	50.6	44.1	77.5	99.5	4.0	68.0	60.5	0.480	3.9316
9/4/2007	8:18:00	39.0	55.5	42.2	76.7	100.0	5.5	65.0	60.5	0.508	3.9084
9/12/2007	16:54:00	26.8	35.3	45.5	76.1	97.5	24.0	55.5	62.0	0.352	3.0785
9/9/2007	11:30:00	34.3	70.2	29.3	74.9	100.0	7.5	56.0	59.5	0.458	3.7252

D	ST	TL	TD	MPH	MPG	B_H_SOC	E_H_SOC	B_P_SOC	E_P_SOC	Gas	kWh
9/5/2007	8:58:00	36.9	51.1	43.3	73.1	100.0	12.0	64.5	61.0	0.505	3.6425
9/5/2007	12:17:00	17.4	22.9	45.7	73.1	100.0	60.5			0.238	0.7535
9/3/2007	15:10:00	36.9	51.9	42.6	71.5	100.0	4.5	65.5	60.5	0.516	3.9337
9/5/2007	16:25:00	8.3	13.6	36.5	71.4	100.0	88.0			0.116	0.4852
9/15/2007	9:18:00	36.6	54.2	40.5	70.4	95.5	5.5			0.520	3.6856
9/5/2007	7:57:00	37.5	58.7	38.4	70.0	100.0	30.0	54.5	65.0	0.536	2.9400
10/7/2007	11:14:00	2.0	8.3	14.2	69.6	82.0	74.0	62.0	64.0	0.028	0.3341
9/5/2007	10:13:00	36.9	50.0	44.3	69.5	100.0	4.0			0.531	3.9452
9/6/2007	7:41:00	36.9	51.4	43.1	69.1	100.0	5.5			0.534	3.8724
9/6/2007	18:49:00	37.3	54.8	40.8	69.1	100.0	5.0			0.539	3.8946
9/12/2007	19:50:00	36.2	49.2	44.2	68.4	95.5	6.5	61.0	62.0	0.529	3.6445
9/6/2007	21:52:00	37.3	49.2	45.5	67.0	100.0	5.0			0.557	3.8895
10/7/2007	14:12:00	38.2	57.2	40.1	66.7	81.5	6.5	63.5	60.5	0.572	3.0606
10/11/2007	16:31:28	25.9	35.0	44.4	66.3	51.5	4.5	62.5	66.0	0.390	1.9217
9/15/2007	10:27:00	36.3	56.4	38.7	66.1	95.0	6.0	64.0	61.0	0.549	3.6286
9/8/2007	18:43:00	37.3	51.2	43.7	65.5	100.0	10.0	64.5	63.5	0.570	3.6385
10/4/2007	7:08:00	24.3	35.6	41.0	65.1	89.0	35.0	62.0	58.0	0.374	2.2618
10/3/2007	17:32:00	37.3	51.0	43.9	64.9	91.5	10.5	63.5	62.5	0.575	3.2925
9/8/2007	14:02:00	30.8	42.6	43.4	64.5	100.0	14.0	62.5	62.0	0.477	3.4861
9/9/2007	10:01:00	37.2	80.8	27.6	64.1	100.0	7.0	55.0	60.5	0.581	3.7780
9/6/2007	21:06:00	30.7	43.2	42.6	63.8	100.0	18.0			0.482	3.3613
9/15/2007	14:33:00	37.3	49.3	45.4	63.8	92.5	6.0			0.585	3.5285
10/12/2007	7:04:22	12.0	36.2	19.9	63.4	49.0	17.0	64.0	59.5	0.190	1.3146
10/9/2007	15:57:00	36.9	51.2	43.2	61.7	61.5	6.0			0.598	0.4528
9/9/2007	7:03:00	37.3	52.0	43.1	61.4	100.0	8.5	62.0	63.0	0.608	3.7309
9/15/2007	12:24:00	36.5	54.7	40.1	60.4	94.0	6.0	61.5	62.5	0.605	3.5713
9/7/2007	21:53:00	30.8	42.8	43.1	60.1	100.0	20.5	69.0	63.0	0.512	3.2543
9/8/2007	12:55:00	37.4	48.9	45.8	59.9	100.0	11.5	63.5	61.0	0.623	3.5946
10/12/2007	15:25:34	2.0	7.5	15.7	59.2	49.0	42.5	63.0	63.5	0.033	0.2629
9/6/2007	21:28:00	7.1	13.6	31.3	57.9	100.0	6.5			0.123	0.4551
8/13/2007	15:29:00	11.2	18.6	36.0	57.2	100.0	70.5	50.0	72.0	0.195	1.2389
10/10/2007	17:30:16	17.4	23.2	45.1	56.8	56.0	6.5			0.307	1.9770
11/13/2007	8:20:06	31.4	46.6	40.5	55.0	3.5	3.5	63.0	61.0	0.571	0.0000

D	ST	TL	TD	MPH	MPG	B_H_SOC	E_H_SOC	B_P_SOC	E_P_SOC	Gas	kWh
9/8/2007	8:04:00	37.2	90.2	24.8	55.0	100.0	6.0	66.5	56.0	0.677	3.7961
9/8/2007	17:15:00	37.3	57.3	39.1	54.8	100.0	9.0	59.0	65.0	0.680	3.6918
11/12/2007	19:39:54	34.2	54.4	37.7	54.6	3.5	3.5	65.5	64.0	0.626	0.0000
1/24/2008	8:12:24	5.7	10.3	33.2	54.6	2.5	2.5	62.4	63.0	0.104	0.0000
9/8/2007	11:02:00	37.4	50.6	44.3	54.2	100.0	10.5	52.5	63.0	0.690	3.6079
9/9/2007	11:50:00	34.1	53.3	38.4	53.3	100.0	21.5	62.5	65.5	0.640	3.2064
9/9/2007	12:06:00	30.8	42.7	43.3	52.4	100.0	26.0	72.5	63.5	0.588	3.0030
11/14/2007	8:35:44	36.9	50.4	43.8	52.2	3.5	3.5	64.5	65.0	0.706	0.0012
11/7/2007	18:30:10	37.5	55.5	40.5	52.0	4.0	3.0	60.5	64.5	0.721	0.0377
1/28/2008	8:24:48	8.7	15.7	33.4	51.5	2.5	2.5	55.5	61.5	0.170	0.0000
10/26/2007	15:54:28	57.8	80.0	43.4	51.5	6.0	4.5	62.0	67.5	1.123	0.0519
10/11/2007	7:16:12	0.6	5.3	7.1	51.4	52.0	49.0	64.0	64.0	0.012	0.1117
1/17/2008	8:23:28	20.9	32.2	38.9	51.1	3.0	3.0	67.5	57.5	0.409	0.0001
11/4/2007	18:34:22	36.9	51.3	43.1	51.0	4.5	4.5	60.5	65.0	0.723	0.0070
11/3/2007	18:59:44	36.3	48.3	45.1	50.9	4.5	4.5	55.0	64.5	0.713	0.0000
2/7/2008	8:23:56	36.8	51.7	42.8	50.9	2.5	2.5	48.5	65.0	0.724	0.0000
10/24/2007	17:13:26	37.1	56.4	39.5	50.2	7.0	7.0	64.0	61.5	0.740	0.0000
2/12/2008	17:13:52	37.2	52.6	42.4	50.0	1.5	1.5	52.5	68.0	0.745	0.0037
11/1/2007	7:10:40	27.4	34.0	48.2	49.8	5.0	3.5	62.5	61.0	0.549	0.0467
11/1/2007	16:04:08	32.1	50.4	38.2	49.7	5.0	4.5	63.5	63.5	0.646	0.0109
11/2/2007	7:20:48	33.1	50.0	39.8	49.6	5.0	5.0	66.5	66.5	0.668	0.0000
10/22/2007	16:11:20	36.8	53.5	41.3	49.5	7.0	7.0	58.0	62.5	0.743	0.0000
1/22/2008	8:15:42	36.8	55.1	40.1	49.5	3.0	3.0	57.0	59.5	0.744	0.0078
1/30/2008	16:14:24	34.4	33.7	61.3	49.2	2.5	2.5	53.0	60.5	0.700	0.0012
1/22/2008	17:04:00	36.8	62.0	35.6	49.1	3.0	3.0	55.5	59.0	0.749	0.0000
11/7/2007	16:35:14	36.8	51.4	43.1	48.7	4.0	4.0	49.0	69.0	0.756	0.0000
11/13/2007	17:28:32	36.8	54.4	40.7	48.5	3.5	3.5	60.0	65.0	0.759	0.0068
2/5/2008	14:16:32	19.5	29.7	39.4	48.4	2.5	2.5	58.0	63.5	0.403	0.0020
11/5/2007	9:16:06	37.3	50.6	44.2	48.3	4.5	4.5			0.771	0.0086
1/21/2008	17:02:26	36.8	51.1	43.2	48.0	3.0	2.5	54.5	63.5	0.768	0.0107
1/16/2008	16:52:46	3.7	11.4	19.3	47.7	3.0	3.0	63.5	67.5	0.077	0.0002
10/20/2007	15:09:12	36.8	50.9	43.4	47.6	7.0	7.0	48.5	66.5	0.773	0.0011
11/12/2007	8:27:18	27.6	34.0	48.9	47.6	3.5	3.0	66.0	62.0	0.580	0.0176

D	ST	TL	TD	MPH	MPG	B_H_SOC	E_H_SOC	B_P_SOC	E_P_SOC	Gas	kWh
11/8/2007	11:52:12	36.9	50.2	44.1	47.3	4.0	4.0			0.779	0.0000
11/8/2007	8:12:40	36.9	51.5	42.9	47.0	4.0	3.5	49.0	62.0	0.784	0.0008
1/21/2008	8:23:52	24.8	34.1	43.7	46.9	3.0	2.5	68.0	62.0	0.529	0.0055
11/2/2007	18:21:56	37.7	51.6	43.8	46.3	5.0	5.0	55.5	68.0	0.814	0.0000
11/4/2007	22:09:04	36.9	51.2	43.2	46.3	4.5	4.0			0.797	0.0084
10/27/2007	13:55:48	30.8	44.1	41.9	46.2	6.0	6.0	63.5	66.5	0.666	0.0005
11/12/2007	9:13:38	29.5	33.9	52.2	46.2	3.5	3.0	65.5	66.5	0.638	0.0162
1/23/2008	17:19:46	19.4	34.5	33.8	46.0	2.5	2.5	41.5	62.5	0.422	0.0000
10/29/2007	16:05:14	31.2	33.8	55.4	46.0	5.5	4.5	69.0	62.5	0.679	0.0359
11/6/2007	17:04:18	37.7	56.0	40.4	45.9	4.5	4.5	45.5	70.5	0.821	0.0033
10/26/2007	7:20:40	37.7	52.2	43.3	45.7	6.5	4.0			0.823	0.0740
10/17/2007	17:16:08	36.8	50.1	44.0	45.7	8.0	8.0	58.5	65.5	0.805	0.0027
10/29/2007	7:20:00	37.1	51.5	43.3	45.7	6.0	6.0	55.5	66.0	0.813	0.0000
10/22/2007	7:24:58	36.8	52.7	41.9	45.6	7.0	7.0	64.0	61.5	0.807	0.0000
11/9/2007	17:02:08	36.7	50.9	43.2	45.6	4.0	4.0			0.804	0.0000
11/5/2007	17:24:20	36.7	51.0	43.2	45.6	4.5	4.5	51.0	64.5	0.806	0.0000
1/16/2008	13:27:16	37.7	53.6	42.2	45.6	3.5	3.5			0.826	0.0000
11/14/2007	18:09:28	37.3	53.0	42.2	45.4	3.5	3.5			0.821	0.0000
10/27/2007	9:31:16	37.4	52.8	42.4	45.4	6.0	5.5	62.5	63.5	0.823	0.0163
10/24/2007	7:50:34	36.8	48.4	45.7	45.0	7.0	7.0	62.5	66.0	0.818	0.0000
10/30/2007	16:15:56	37.4	51.0	43.9	44.6	5.5	5.5	45.5	69.0	0.838	0.0000
1/17/2008	17:59:54	35.3	33.6	62.9	44.5	3.0	2.5	64.0	62.0	0.792	0.0000
10/25/2007	16:03:50	38.3	49.5	46.4	44.4	7.0	7.0	59.5	66.0	0.863	0.0000
2/11/2008	19:10:20	65.1	86.9	44.9	44.4	2.5	2.5			1.467	0.0000
11/7/2007	10:24:08	31.3	33.8	55.6	44.2	4.0	3.5	69.0	63.5	0.708	0.0212
10/31/2007	16:00:34	34.7	33.6	62.0	43.6	5.0	4.0	56.5	61.0	0.796	0.0350
10/25/2007	7:14:10	36.7	50.0	44.1	43.6	7.0	6.5	60.0	66.5	0.843	0.0103
11/6/2007	7:59:26	37.4	49.9	44.9	43.5	4.5	4.5	58.0	68.5	0.859	0.0000
10/18/2007	7:25:52	37.4	51.5	43.6	43.3	8.0	8.0	63.0	67.0	0.863	0.0095
10/20/2007	9:35:06	34.3	66.6	30.9	43.3	7.5	6.0	59.5	67.0	0.792	0.0495
11/3/2007	16:38:48	22.2	34.2	38.9	43.2	4.5	3.5	58.0	62.0	0.514	0.0319
9/7/2007	7:56:00	1.7	7.4	13.9	43.1	100.0	92.5			0.040	0.3056
9/12/2007	13:22:00	10.3	38.8	20.9	43.1	99.5	58.0	62.0	65.5	0.240	1.7485

D	ST	TL	TD	MPH	MPG	B_H_SOC	E_H_SOC	B_P_SOC	E_P_SOC	Gas	kWh
1/23/2008	8:18:58	34.1	58.5	34.9	42.9	3.0	3.0	62.0	66.5	0.794	0.0000
1/31/2008	8:21:14	11.9	34.6	20.6	42.7	2.5	2.5	51.5	60.0	0.278	0.0020
10/18/2007	15:39:18	37.7	52.1	43.4	42.6	7.5	7.5	60.5	67.5	0.886	0.0000
10/17/2007	7:30:50	34.3	53.7	38.3	42.1	21.5	10.0	65.5	72.5	0.815	0.4126
2/7/2008	18:28:30	65.0	87.0	44.8	41.7	2.5	2.5			1.559	0.0000
2/4/2008	8:19:22	8.6	15.8	32.8	41.5	2.5	2.5	65.5	62.5	0.208	0.0000
11/3/2007	8:19:48	36.2	33.5	64.8	41.4	4.5	3.0	65.5	63.0	0.874	0.0474
11/7/2007	8:25:56	23.1	34.1	40.7	41.1	4.0	3.5	57.0	60.0	0.562	0.0069
11/5/2007	9:00:06	21.3	26.5	48.3	40.9	4.5	4.0			0.521	0.0111
1/31/2008	17:44:24	33.1	33.7	59.1	40.7	2.5	2.5	66.0	63.5	0.814	0.0015
1/18/2008	8:22:20	22.7	24.8	54.8	40.7	3.0	3.0	64.0	60.5	0.557	0.0066
11/14/2007	8:46:22	21.7	26.3	49.6	39.9	3.5	3.5			0.544	0.0000
10/31/2007	7:16:10	22.2	28.1	47.4	39.5	5.5	5.0	53.5	66.5	0.563	0.0087
1/30/2008	8:22:58	0.5	6.2	4.8	38.8	2.5	2.5	67.0	58.5	0.013	0.0000
1/28/2008	17:04:14	15.5	22.9	40.7	36.6	2.5	2.5	61.5	68.5	0.424	0.0000
2/4/2008	17:04:16	6.5	11.0	35.4	35.4	2.5	2.5	62.5	65.5	0.183	0.0000
2/11/2008	8:09:34	14.1	22.2	38.1	34.5	2.5	2.5			0.408	0.0000
2/12/2008	8:13:54	8.0	13.1	36.8	33.7	2.5	2.5			0.239	0.0000
2/5/2008	8:14:32	8.3	15.2	33.0	30.4	2.5	2.5	65.5	64.0	0.275	0.0000
11/15/2007	8:14:16	3.3	9.2	21.3	29.7	3.5	3.5			0.110	0.0281
1/25/2008	14:32:56	1.3	7.4	10.5	28.8	2.5	2.5	55.0	55.5	0.045	0.0000
1/25/2008	8:13:16	1.2	7.0	9.9	21.1	2.5	2.5	50.0	56.0	0.055	0.0014
10/30/2007	7:16:48	0.5	12.4	2.4	17.6	5.5	5.5	50.0	54.5	0.028	0.0000
1/24/2008	17:11:40	0.7	5.1	8.0	17.2	2.5	2.5	63.0	51.5	0.040	0.0021
1/18/2008	17:20:02	1.4	9.0	9.5	11.3	3.0	3.0	54.0	49.5	0.125	0.0033

Appendix B

Exit Survey from First Plug' n Go 2 Driver

Plug-In Hybrid Electric Vehicle Research Project

Driver Exit Survey

Thank you for your participation in the plug-in hybrid (PHEV) research project. Please take a moment to complete this exit survey.

Name: Jennifer Sellers

Age: 32

How many miles did you typically commute each day in the plug' n go (PHEV)? 76

Did you notice an increase in your monthly electric bills once you began charging the plug' n go in at night? Yes / No

Did you ever forget to plug the vehicle in at night when you returned home from campus? Yes / No

If yes, approximately how many times over the period that you were driving the plug' n go did you forget to plug the vehicle in at night? 2-3 times (of these, sometimes I didn't push the plug in all the way such that it didn't charge)

On a scale from 1 to 5 rate the inconvenience of plugging in the car at the end of your daily commute.

Very Inconvenient

No Inconvenience

1

2

3

4

5

Can you estimate roughly how much money you likely saved each month driving the plug' n go? \$ 125

Would you ever consider buying a plug-in hybrid vehicle if they were offered by car manufacturers at a competitive price? Yes / No

Please indicate what things you enjoyed about driving the plug' n go vehicle.

I loved saving money and I loved saving time when I filled up at the pump. I filled up less often and it's quite a small tank. I also enjoyed knowing that there was one less gass guzzler on the road thanks to this opportunity. Parking was a breeze. The computerized console is pretty fun and it was interesting to see where the energy was going/coming from.

Please indicate what things you did not like about driving the plug' n go vehicle.

The only things I didn't like have more to do with small cars in general. On windy days, or when the roads were fairly icy or snowy, the car could be difficult to handle. With that said, traction control and anti-lock brakes certainly kicked in when they needed to. Also, on very cold days

the heater had a tough time warming the car up. Lastly, it was sometimes a challenge fitting everything I needed to in the car, including really tall people. A tad more cargo room would have been nice, especially if they could figure out a way to make it bigger and just as fuel efficient. (One last minute point, not sure if you even care about this one, but some of the buttons on the steering wheel are a little awkward. Sometimes the radio would get really loud before I figured out I was resting my hand on the volume.)