# ADVANCED VEHICLE TESTING & EVALUATION

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**ECOTALITY NORTH AMERICA**

**MAY 15, 2012**

**VSS029**

# OVERVIEW – CURRENT AGREEMENT

## TIMELINE

Project Start; 10/1/05
Project End; 12/31/12
Percent Complete; 90%

## BUDGET

Total Project; $10,659,094
DOE Share; $8,659,094
Thru 12/31/11; $7,217,111
Remaining; $1,444,983

## BARRIERS

Contract End Date
Vehicle Availability

## PARTNERS

EZ Messenger
Idaho National Laboratory
Argonne National Laboratory

# OVERVIEW – NEW AGREEMENT

## TIMELINE

Project Start; 10/01/11
BP1 End; 01/31/13
Percent Complete; 2%

## BUDGET

Total Project; $33,088,218
DOE Share; $26,400,000
Cost Share; $6,688,218
BP1 Authorization; $3,000,000

## BARRIERS

Vehicle Availability
Vehicle Reliability
Infrastructure Requirements

## PARTNERS

EZ Messenger
Idaho National Laboratory
Argonne National Laboratory
Oak Ridge National Laboratory

# Relevance

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## OBJECTIVES

- Provide benchmark data for advanced technology vehicles
- Develop lifecycle cost data for production vehicles utilizing advanced power trains
- Provide fleet operations data to the Idaho National Laboratory
- Disseminate vehicle and infrastructure testing results to industry and other DOE programs

# Relevance

## MILESTONES

- 2011 (existing agreement)
  - Vehicles initiated in testing 12
  - Baseline tests completed 12
  - Ongoing fleet testing 42
  - Non-vehicle tasks completed 7
- 2012 (new agreement)
  - Vehicle model scheduled for test 11
  - Vehicles entering testing 44

# Approach

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## PROCEDURE DEVELOPMENT

- Administrative Procedures For Control Of Test Conduct
- Vehicle Specification Defining Key Performance And Safety Parameters
- Vehicle Test Procedures Defining Tests Verifying Vehicle Specification Requirements
- Battery Test Procedures Defining Implementation Of Standard Test Requirements

# Approach

## BASELINE TESTING

- Benchmark Performance
  - Acceleration
  - Maximum speed
  - Driving cycle range
    - With accessory loads
    - Without accessory loads
  - Braking
  - Gradeability

# Approach

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## ACCELERATED TESTING

- **Fixed Route Mileage Accumulation**

| Cycle (mi) | Urban (10 mi) | Highway (10 mi) | Charge (hr) | Reps (N) | Total (mi) | Reps (%) | Miles (%) |
|---|---|---|---|---|---|---|---|
| 10 | 1 | 0 | 4 | 60 | 600 | 37% | 11% |
| 20 | 1 | 1 | 8 | 30 | 600 | 19% | 11% |
| 40 | 4 | 0 | 12 | 15 | 600 | 9% | 11% |
| 40 | 2 | 2 | 12 | 15 | 600 | 9% | 11% |
| 40 | 0 | 4 | 12 | 15 | 600 | 9% | 11% |
| 60 | 2 | 4 | 12 | 10 | 600 | 6% | 11% |
| 80 | 2 | 6 | 12 | 8 | 640 | 5% | 12% |
| 100 | 2 | 8 | 12 | 6 | 600 | 4% | 11% |
| 200 | 2 | 18 | 12 | 3 | 600 | 2% | 11% |
| **Total** | **2,340** | **3,100** | **1,344** | **162** | **5,440** | | |
| Average | 43% | 57% | 8.3 | 18 | | | |

# Approach

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## FLEET TESTING

- Production Vehicles
- 160,000 Mile Current Duration
- 300,000 Mile Future Duration
- On Board Data Logger
- Fuel And Maintenance Logs

# Approach

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## BATTERY TESTING

- Hybrid Vehicles
  - $C_1$ capacity
  - Hybrid pulse power characterization
  - Vehicle new & end-of-test
- Start-Stop – $C_1$ capacity
- Battery Electric Vehicles
  - $C_1$ capacity
  - Peak power characterization

# Accomplishments

## 2011 PROCEDURES

- US Postal Service Delivery Vehicle Acceptance Test
- US Postal Service Delivery Vehicle Baseline Test
- US Postal Service Delivery Vehicle Accelerated Reliability Test
- Battery Electric Vehicle Fast Charge Test
- Battery Energy Storage Performance Test For DC Fast Charge Demand Reduction

# Accomplishments

## 2011 BASELINE TESTS

- 5 US Postal Service Delivery Vehicles
- 2010 Honda Civic Ultra Battery HEV
- 2011 Hyundai Sonata HEV
- 2011 Ford Escape PHEV
- 2010 Smart For Two
- 2010 VW Golf Diesel
- 2011 Mazda 3
- Honda CRZ HEV

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2011 Honda CRZ Hybrid Electric Vehicle

VEHICLE SPECIFICATIONS

VEHICLE FEATURES
Base Vehicle: 2011 Honda CRZ EX Hybrid
VIN: JHMZF1C68BS002982
Seatbelt Positions: Two
Standard Features:
Air Conditioning
Power Locks
Power Steering
Power Brakes
Power Windows
Cruise Control
Front, Disc Brakes
Rear, Disc Brakes
Front, Wheel Drive
Regenerative Braking
Anti Lock Brakes
Traction Control
Air Bags
AM/FM Stereo with CD player
State of Charge Meter[1]

BATTERY
Manufacturer: Panasonic
Type: Nickel-Metal Hydride
Number of Modules: 84
Weight of Pack: 65 lbs
Pack(s) Location: Behind the rear passenger bays under the trunk floor
Nominal Module Voltage: 1.2 V
Nominal System Voltage: 100.8 V
Nominal Pack Capacity: 5.75 Ah
Electric Motor: 10 kW

WEIGHTS
Design Curb Weight: 2650 lbs
Delivered Curb Weight[2]: 2615 lbs
Distribution F/R[3] (%): 58.6/41.4
GVWR: 3164 lbs
GAWR F/R: 1797/1378lbs
Payload[4]: 564 lbs
Performance Goal: 400 lbs

DIMENSIONS
Wheelbase: 95.3 in
Track F/R: 59.6/59.1 in
Length: 160.6 in
Width: 68.5 in
Height: 54.9 in
Ground Clearance: 5.3 in
Performance Goal: 5.0 in

TIRES
Tire Mfg: Dunlop
Tire Model: SP Sport 1000m
Tire Size: 195 / 55 R16 86V
Tire Pressure F/R: 30/30 psi
Spare Installed: Yes

ENGINE
Model: 1.5 L I4
Output[5]: 122 hp @ 6000 rpm
Configuration: Inline Four cylinder
Displacement: 1.5 L
Fuel Tank Capacity: 10.6 gal
Fuel Type: Unleaded Gasoline

PERFORMANCE STATISTICS

Acceleration 0-60 mph[6]
Measured: 10.9 seconds
Performance Goal: 13.5 seconds

Maximum Speed[6]
At ¼ Mile: 79.3 mph
In 1 Mile: 108.0 mph
Performance Goal: 70 mph in one mile

Driving Cycle Range w/o Accessories[6]
Amp-Hours Out: 3.475 Ah[-1]
Amp-Hours In: 3.327 Ah[-1]
Cycle Fuel Economy: 44.4 mpg
Driving Range: 471 miles[7]

Driving Cycle Range w/ Accessories[6,8]
Amp-Hours Out: 6.563 Ah[-1]
Amp-Hours In: 0.731 A-h[-1]
Cycle Fuel Economy: 35.8 mpg
Driving Range: 379 miles[7]

Braking From 60 mph[6]
Controlled Dry: 116.8 feet

Gradeability (Calculated)[6]
Maximum Speed @ 3%: 82.6 mph
Maximum Speed @ 6%: 82.3 mph
Maximum Grade: 51.7 %

TEST NOTES:
1. Energy trimmed display and SOC Meter
2. Total battery discharge over SAE J1634 drive cycle
3. Value calculated based on fuel economy and fuel tank size
4. Air Conditioning on maximum with full blower
5. Payload does not include driver weight.
6. Performance number obtained on "Normal" mode.
7. Indicates coast down at the end of the cycle.
8. Combined engine (SAE net) + electric motor
9. Fuel tank approximately 97% full.

this vehicle meets all HEV America Minimum Requirements listed on back of this sheet

# Accomplishments

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## 2011 ACCELERATED TESTS

- **2010 Ford Escape PHEV**

**PHEV-15 Ford Escape** **Vin#: 1FMCU49369KB61181**

| Test Date | Cycle (mi) | Urban (10 mi) | Highway (10 mi) | Charge (Hr) | Repetitions (N) | Total (mi) | Repetitions (%) | Miles (%) | Cumulative (mi) | Electricity (kwh) | Fuel (E-85) | MPG | Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4/5-5/20/11 | 10 | 1 | 0 | 4 | 60 | 610 | 37% | 11% | 610 | 238.26 | 2.000 | 305.0 | |
| 2/15/11-4/4/11 | 20 | 1 | 1 | 8 | 30 | 621.6 | 19% | 11% | 1231.6 | 224.57 | 6.900 | 90.1 | car did not fully charge on 3 days |
| 1/24/-2/14/11 | 40 | 4 | 0 | 12 | 15 | 612.8 | 9% | 11% | 1844.4 | 186.12 | 3.200 | 191.5 | |
| 8/24-9/15/10 | 40 | 2 | 2 | 12 | 15 | 620 | 9% | 11% | 2464.4 | 171.74 | 7.300 | 84.9 | |
| 12/3/10- 1/7/11 | 40 | 0 | 4 | 12 | 15 | 632.6 | 9% | 11% | 3097 | 200.02 | 9.700 | 65.2 | |
| 11/17-12/2/10 | 60 | 2 | 4 | 12 | 10 | 624.2 | 6% | 11% | 3721.2 | 124.16 | 11.800 | 52.9 | |
| 9/16-9/27/10 | 80 | 2 | 6 | 12 | 8 | 664.1 | 5% | 12% | 4385.3 | 89.50 | 13.600 | 48.8 | *last day did not fully charge |
| 8/16-8/23/10 | 100 | 2 | 8 | 12 | 6 | 603 | 4% | 11% | 4988.3 | 64.01 | 13.700 | 44.0 | **shortened route low fuel |
| 8/1-8/3/10 | 200 | 2 | 18 | 12 | 3 | 557.2 | 2% | 10% | 5545.5 | 31.53 | 15.280 | 36.5 | **shortened route due to low fuel |
| | Total | 16 | 43 | 96 | 162 | **5546** | | | | | | | |

# Accomplishments

## 2011 FLEET TESTS

- 2 Gen III Prius HEV
- 2 Honda Insight HEV
- 1 Ford Fusion
- 2 Mercedes S400
- 2 Honda CRZ HEV
- 2 Hyundai Sonata HEV
- 21 SCAQMD Escape PHEV
- 2 Smart For Two Start-Stop
- 2 VW Golf Diesel Start-Stop
- 2 Mazda 3 Start-Stop
- 1 Ford Escape PHEV
- 1 Chevrolet Volt EREV
- 1 Nissan Leaf BEV

# Accomplishments

## 2011 BATTERY TESTS

- **Hyundai Sonata HEV**
- **Honda Civic Ultra Battery HEV**

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**2011 Honda Civic with UltraBattery Conversion - 5577**

**Hybrid BOT Battery Test Results**

**Hybrid System Specifications**

| Battery Specifications | Vehicle Specifications |
|---|---|
| Manufacturer: East Penn Manufacturing | Manufacturer: Honda |
| Type: Lead-Carbon | Model: Civic |
| Number of Cells: 84 | Year: 2011 |
| Number of Modules: 14 | Number of Motors[1]: 1 |
| Nominal Cell Voltage: 2.1 V | Motor Power Rating[2]: 14.9 kW |
| Nominal System Voltage: 176.4 V | VIN #: JHMFA3F24AS005577 |
| Nominal Pack Capacity: 7.5 Ah | |

**Battery Lab Test Results**

| HPPC Test | Static Capacity Test |
|---|---|
| Peak Pulse Discharge Power @ 10s[3]: 9.1 kW | Measured Average Capacity: 7.55 Ah |
| Peak Pulse Discharge Power @ 1s[3]: 10.0 kW | Measured Average Energy Capacity: 1260 Wh |
| Peak Pulse Charge Power @ 10s[3]: 8.2 kW | **Vehicle Mileage and Testing Date** |
| Peak Pulse Charge Power @ 1s[3]: 16.2 kW | Vehicle Odometer: 0 mi[4] |
| Maximum Cell Charge Voltage: 2.45 V | Date of Test: September 2, 2011 |
| Minimum Cell Discharge Voltage: 1.8 V | |

**Analysis Notes:**

1. Motor refers to any motor capable of supplying traction power.
2. Motor power rating refers to the manufacturer's peak power rating for the motor(s) supplying traction power.
3. Calculated value based on selected battery voltage limits and at 50% SOC.
4. Actual vehicle odometer was greater than zero. Mileage was previously accumulated with a separate battery pack.

# Accomplishments

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## 2011 SPECIAL TESTS

- USPS Long-Life Vehicle Prototypes
- Start-Stop Fuel Economy Study
  - Dynamometer Testing
    - Fuel Economy Test Cycles
    - USA, Europe, Japan
  - Fleet Testing Validation
    - With & Without Start-Stop Enabled
    - Real World Validation

# Collaborations

## NATIONAL LABORATORIES

- Idaho National Laboratory
  - Procedure development
  - Data collection & analysis
- Argonne National Laboratory
  - Procedure development
  - Dynamometer testing
- Oak Ridge National Laboratory
  - USPS dynamometer testing

# Collaborations

## INDUSTRY PARTNERS

- **EZ Messenger**
  - **Mileage accumulation**
  - **Route design**
- **Discount Cab**
  - **Mileage accumulation**

# Future Work

## CONTRACT CHANGE

- Current Contract Closeout
  - Complete fleet testing of 41 vehicles
  - Complete 6 non-vehicle tasks
- New Contract Launch
  - Update all test procedures
  - Write 2 battery test procedures
  - Place 35 vehicles in testing
  - Initiate 4 infrastructure tests

# 2011 SUMMARY

- 13 Major Tasks Completed
- One Million Fleet Test Miles Accumulated
- 41 Vehicles Tested
- Testing Conducted Using Four Different Fuels
- Testing Conducted For BEV, PHEV, EREV, HEV & Start-Stop Vehicle Configurations
- All Test Results Posted To AVTA Website

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# TECHNICAL BACKUP SLIDES

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VEHICLE TECHNOLOGIES PROGRAM

# HEV Fleet Testing - Summary Fact Sheet

Advanced Vehicle Testing Activity

## 2010 Toyota Prius

VIN# JTDKN3DU2A5010462

### Vehicle Specifications

**Engine:** 1.8 L 4-cylinder
**Electric Motor:** 60 kW
**Battery:** NiMH
**Seatbelt Positions:** Five
**Payload:** 885 lbs
**Features:**
- Regenerative braking
- Traction control

### Fleet Performance

**Operating Cost:**

Purchase Cost: $29,174 (7/09)*

Kelley Blue Book: $8,944 (1/12)

Sale Price: In Operation

Maintenance Cost: $0.03/mile

Operating Cost: $0.12/mile**

Total Ownership Cost: $0.32/mile

**Operating Performance:**

Total miles driven: 136,181

Cumulative MPG: 45.6

**Major Operations & Maintenance Events:**
None

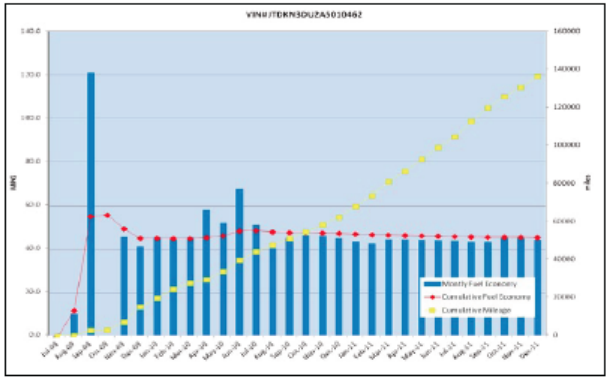
**Purchase includes dealer price with options plus taxes. It does not include title, license, registration, extended warranty or delivery fee costs.*

***Operating costs includes insurance, fuel, and registration costs*

**Description:**

This vehicle is operated throughout the valley of Phoenix, Arizona by EZ Messenger, a legal document courier business. It is operated five days a week, transferring documents between courts, law offices, and medical facilities on city streets and urban freeways.

*See HEVAmerica Baseline Performance Fact Sheet for more information*




Monthly MPG = (miles driven)/(gallons of fuel purchased). Monthly variation in reported MPG may occur due to the difference in fuel tank level at the beginning and end of the month.

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EERE Information Center
1-877-EERE-INF (1-877-337-3463)
www.eere.energy.gov/informationcenter

TOYOTA PRIUS FLEET TEST – SUMMARY FACT SHEET

# TOYOTA PRIUS FLEET TEST – RESULTS PAGE 1

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## HEV Fleet Testing

**2010 Toyota Prius**
**VIN: 462**

**Fleet Testing Results To Date**

### Operating Statistics

Distance Driven[1]: 133,232
Average Trip Distance[2]: 13.9 mi
Stop Time with Engine Idling[2]: 5%
Trip Type City/Highway[2]: 82%/18%

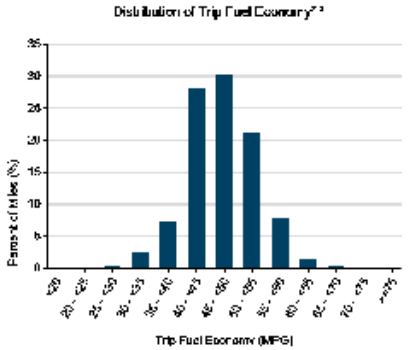
### Operating Performance

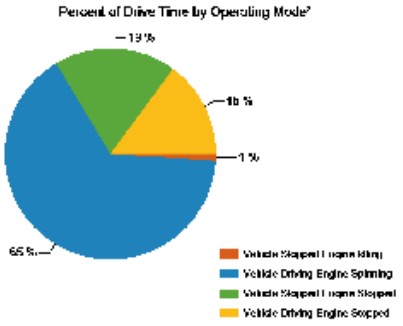
Cumulative MPG[1]: 47.5

*See HEV America Baseline Performance and Fleet Testing Fuel Economy fact sheets for more information on vehicle specifications and fuel usage reporting, available at http://avt.inl.gov/*

### Test Notes

1. Calculated over the life of the vehicle based on odometer reading and fuel logs. More information available in Fleet Testing Fuel Economy sheet.
2. Calculated from electronic data logged over a subset of total miles traveled equal to 126,791 miles.
3. Fuel economy calculated for this figure using mass air flow over dynamic vehicle operation.
4. Calculated from battery current data logged over a subset of total miles traveled, equal to 102,536 miles.

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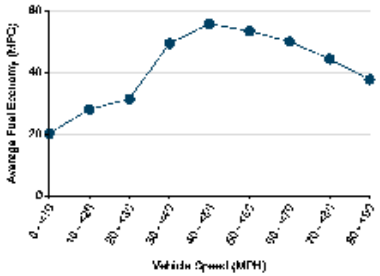
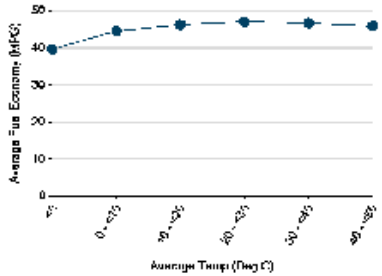
# TOYOTA PRIUS FLEET TEST – RESULTS PAGE 2



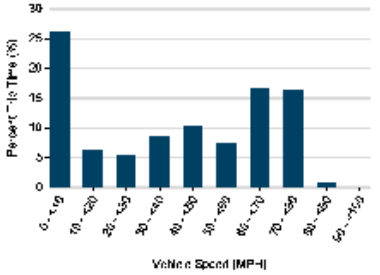
Average Fuel Economy at Speed[2,3]



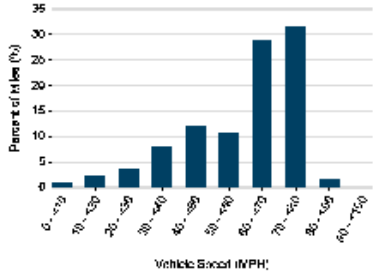

Average Fuel Economy vs Average Temp[2,3]



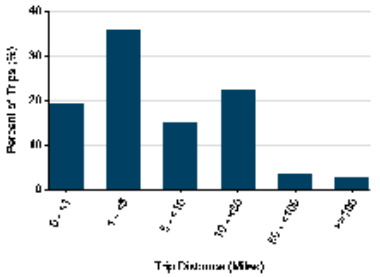

Distribution of Vehicle Speed[4]



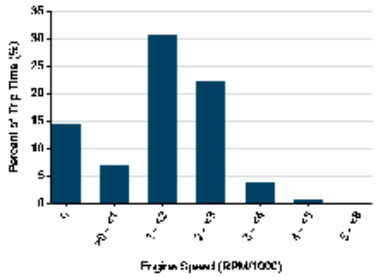

Distribution of Vehicle Speed[4]



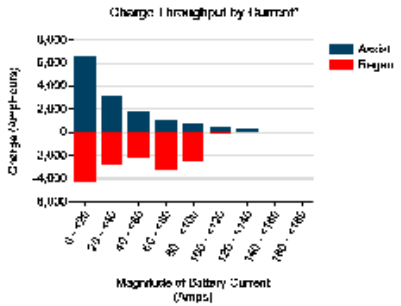

Distribution of Trip Distance[2]

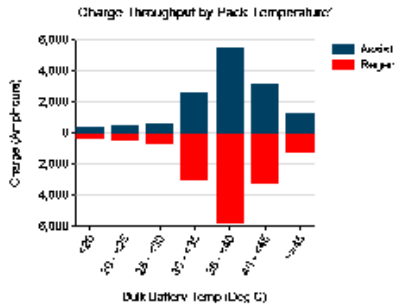


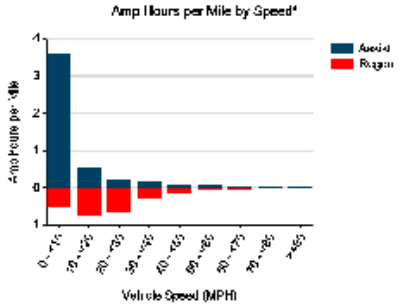

Distribution of Engine Speed When Vehicle is Moving[2]

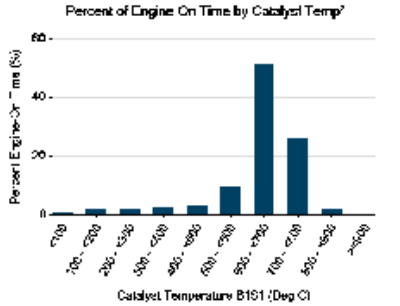


# TOYOTA PRIUS FLEET TEST – RESULTS PAGE 3




Total charge into battery pack (Ah)*: 15,150
Total charge out of battery pack (Ah)*: 13,950
Battery round trip efficiency*: 92%

TOYOTA PRIUS MAINTENANCE REPORT PAGE 1

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# HEV Fleet Testing

## Advanced Vehicle Testing Activity

## Maintenance Sheet for 2010 Toyota Prius

VIN# JTDKN3DU2A5010462

| Date | Mileage | Description | Cost |
|---|---|---|---|
| 11/23/2009 | 5,935 | Changed oil and filter, rotated tires, and inspected brakes | $31.75 |
| 12/18/2009 | 13,330 | Changed oil and filter and inspected brakes | $36.94 |
| 1/22/2010 | 19,549 | Changed oil and filter, inspected brakes, and replaced air filter | $57.88 |
| 3/16/2010 | 26,896 | Changed oil and filter | $48.74 |
| 3/29/2010 | 28,250 | Replaced and balanced one tire | $100.94 |
| 4/6/2010 | 28,288 | Recall on ABS actuator ECU | n/c |
| 5/20/2010 | 32,160 | Changed oil and filter | $57.85 |
| 6/17/2010 | 38,302 | Changed oil and filter | $57.85 |
| 7/23/2010 | 43,789 | Changed oil and filter and rotated tires | $77.85 |
| 9/13/2010 | 48,766 | Changed oil and filter | $60.12 |
| 10/21/2010 | 54,049 | Changed oil and filter and rotated tires | $77.85 |
| 12/1/2010 | 59,307 | Changed oil and filter | $62.31 |
| 12/9/2010 | 60,481 | Replaced four tires | $455.82 |
| 1/6/2011 | 64,378 | Changed oil and filter and rotated tires | $82.31 |
| 2/2/2011 | 69,797 | Changed oil and filter | $62.31 |
| 3/3/2011 | 75,211 | Changed oil and filter and rotated tires | $73.32 |
| 3/30/2011 | 80,249 | Changed oil and filter | $58.32 |
| 4/28/2011 | 85,894 | Changed oil and fitler and rotated tires | $74.51 |
| 5/23/2011 | 91,795 | Changed oil and filter, replaced cabin filter and 90K service | $209.34 |
| 5/24/2011 | 91,801 | Replaced one tire | $31.49 |
| 6/24/2011 | 96,843 | Changed oil and filter | $60.27 |

# TOYOTA PRIUS MAINTENANCE REPORT PAGE 2

| Date | Mileage | Description | Cost |
|---|---|---|---|
| 7/29/2011 | 104,247 | Changed oil and filter and rotated tires | $75.27 |
| 8/18/2011 | 109,150 | Changed oil and filter | $60.27 |
| 8/29/2011 | 112,047 | Replaced left front low beam bulb | $9.21 |
| 9/26/2011 | 118,626 | Changed oil and filter and rotated tires | $77.57 |
| 10/19/2011 | 123,278 | Replaced tire under warranty and purchased a new warranty | $28.76 |
| 10/21/2011 | 123,576 | Changed oil and filter | $64.98 |
| 11/9/2011 | 126,973 | 120 K mile service | $498.59 |
| 11/10/2011 | 126,973 | Installed new front brake pads and resurfaced rotors | $194.78 |
| 11/21/2011 | 129,050 | Replaced rear tire | $133.69 |
| 11/21/2011 | 129,056 | Changed oil and filter and rotated tires | $77.66 |
| 11/15/2011 | 127,769 | Replaced left and right front low beam bulbs | $33.86 |
| 12/20/2011 | 134,242 | Changed oil and filter | $62.64 |

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# TOYOTA PRIUS FUEL ECONOMY REPORT

## Toyota Gen III Prius HEV Accelerated Testing – September 2011

Two model year 2010 Toyota Generation III Prius hybrid electric vehicles (HEVs) entered Accelerated testing during July 2009 in a fleet in Arizona. Each Gen III Prius will be operated for 160,000 miles, at which point their traction batteries will be tested before they are retired (one battery is also tested when new). One-page vehicle maintenance logs are posted on nearby www pages. This information includes the date and mileage for all maintenance and repairs performed on the vehicles. The two Gen III Prius HEVs have been driven a total of 229,000 miles and the cumulative average fuel economy is 44.3 mpg. Note that initial mileage accumulation was slow due to baseline performance and battery testing. Note that during late April and May 2010, fueling event timing and fleet management realignment resulted in exaggerated swings in monthly mpg.