

### **ADVANCED VEHICLE TESTING & EVALUATION**

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Intertek Testing Services, North America

2015 Annual Merit Review

June 9, 2015

VSS029

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### **OVERVIEW**

#### TIMELINE

Project Start: Oct. 01, 2011 Project End: Sep. 30, 2018 Percent Complete: 35%

#### BUDGET: 80/20

Total Project: \$33,088,218 DOE Share: \$26,400,000 Cost Share: \$6,688,218 FY14 Total: \$4,209,032 FY15 Funding: \$6,334,001

#### BARRIERS

Vehicle Availability Vehicle Reliability Infrastructure Technology Availability

#### PARTNERS

EZ Messenger Total Transit Idaho National Laboratory Argonne National Laboratory National Renewable Energy Lab SAE





### OBJECTIVES

- Test and evaluate advanced vehicle technologies intended to advance vehicle efficiency and reduce the consumption of petroleum
- Provide vehicle operation data to the Idaho National Laboratory database in order to disseminate the results of vehicle and infrastructure testing & analysis
- Produce lifecycle fuel economy and cost data for vehicles that are utilizing these advanced technologies in fleets
- Provide benchmark data and performance trends for advanced technology vehicles and their interaction with their fueling infrastructure

# Relevance



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### **MILESTONES**

- 88 advanced technology vehicles on fleet test through March 2015
  - ◆ 34 BEV across 9 different years, makes, and models
  - 17 PHEV across 5 different years, makes, and models
  - 20 HEV across 5 different years, makes, and models
  - 17 ICE across 5 different years, makes, and models
- 5 vehicles have completed testing that were carried over from previous Advanced Vehicle Testing Activity
- Over 3.8 million miles recorded during fleet testing as of March 2015
- Completion of SAE J2953 AC Level 2 Interoperability testing using roundrobin testing between the vehicles and the EVSE units
  - SAE coordinated the vehicle OEMs and EVSE manufacturers for participation
  - 12 vehicle OEMs provided 14 vehicles
  - 11 EVSE manufacturers provided 13 units
  - Anonymous results provided to OEMs and EVSE manufacturers by SAE





### PROCEDURE/DOCUMENTATION DEVELOPMENT

- Administrative procedures for control of test conduct
- Vehicle specifications defining key vehicle and performance parameters
- Battery test procedures defining implementation of standard test requirements
  - Procedures updated to refledct USABC manuals and technical agreement with INL
- Interim Component Durability test procedures similar to baseline component testing





### **BASELINE TESTING**

- Baseline Vehicle Performance at outset of testing conducted at a proving ground location
  - Acceleration
  - Maximum speed
  - Braking
  - Deceleration in drive
  - Fully electric range (when applicable)
  - Vehicle coastdown testing to obtain drag coefficients for fuel economy testing on a chassis dynamometer
- End-of-Test Performance consisting of relevant testing for comparison to baseline





### FLEET TESTING

- Constraints on vehicle purchase availability overcome by utilizing Intertek California location to acquire some vehicles
- Production vehicles allocated to fleets for 3 years and 36,000 miles for BEVs, 160,000 miles for PHEVs, and up to 195,000 miles for HEVs/ICE vehicles
- Utilize on-board data logger with automatic data upload
  - Monitor vehicle CAN messages and energy storage system parameters
  - Monitoring 12V current to record loads on vehicles without high voltage batteries
- Update fuel, charging, and maintenance logs with fleet information
- Interim Component Durability testing dependent on vehicle technology
  - Battery capacity and performance testing for BEV, PHEV, and HEV
  - Compression testing for CNG-fueled vehicles
  - Fast charging at various temperatures for BEV and potentially PHEV in future



INL/MIS-15-34211 • January 2015

### Accomplishments



- 2013 Nissan Leaf
- 2013 Ford Focus EV
- 2013 Ford Fusion Energi
- 2014 Mazda Mazda3 with i-ELOOP
- 2014 Chevrolet Cruze Turbo Diesel

Advanced Vehicle Testing Activity		
	2013 Ford Fusion Energi cle Testing – Baseline Vehicle Te	acting Recults
Auvanceu ven	the resting - Dasenne venicle re	isonig Results
	-0-0	
	VEHICLE SPECIFICATIONS <sup>1</sup>	
Vehicle Features	Battery	Weights
VIN: 3FA6P0PU2DR373776	Manufacturer: Panasonic	Design Curb Weight:
Class: Midsize Car	Type: Lithium-ion (NMC)	3,913 lb
Seatbelt Positions: 5	Cathode /Anode Material: LiMn <sub>2</sub> O <sub>4</sub> /Hard	Delivered Curb Weight:
Type <sup>2</sup> : Blended PHEV	Carbon	3,934 lb
CARB <sup>3</sup> : TZEV	Number of Cells: 84	Distribution F/R (%): 51/49
EPA Fuel Economy: 370 Wh/mi	Cell Configuration: Series	GVWR: 4,910 lb
(Charge-Depleting Mode,	Nominal Cell Voltage: 3.7 V	GAWR F/R: 2,435/2,485 I
Combined); 38 mpg (Charge-	Nominal System Voltage: 310.8 V	Max. Payload: 850 lb
Sustaining Mode, Combined)	Rated Pack Capacity: 26 Ah	Dimensions
Engine	Rated Pack Energy: 7.6 kWh	Wheelbase: 112.2 in
Model: 16 Valve DOHC	Weight of Pack: 272 lb	Track F/R: 62.3 in/62.0 in
Duratec with Intake Variable	Pack Location: In Trunk Area	Length/Width: 191.8 in/
Camshaft Timing (iVCT)	Cooling: Active – Forced Cabin Air	72.9 in
Displacement: 2.0 L	Motor/Generator 1	Height: 58.0 in
Cycle: Atkinson	Type: Permanent Magnet AC Synchronous	Ground Clearance: 5.8 in
Power: 105 kW @ 6,000 rpm	Max. Power/Torque: 88 kW/ 240 Nm @	Tires
Torque: 174 Nm @ 4,000 rpm	6,000 rpm	Manufacturer: Michelin
Configuration: Inline 4-Cylinder	Cooling: Active - Liquid Cooled	Model: Energy Saver
Fuel Tank Capacity: 14 US gal	Motor/Generator 2	Size: P225/50R17
Fuel Type: Regular Unleaded	Type: Permanent Magnet AC Synchronous	Pressure F/R: 35 psi/35 psi
Transmission	Cooling: Active - Liquid Cooled	Spare Installed: Sealant and
HF35 eCVT Hybrid Powersplit		Inflator

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# Accomplishments



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### 2014-2015 FLEET TEST VEHICLES

 Overall fuel economy for fleet vehicles through February 2015

Note that Wh/mile for PHEVs includes gasoline miles

	YEAR	MAKE	MODEL	FUEL TYPE	<b>Overall MPG</b>	Overall Wh/mile
	2011	Chevy	Volt	ELECTRIC/GAS	40.10	82.38
•	2011	Nissan	Leaf (3.3)	ELECTRIC	-	268.82
	2013	Chevy	Malibu ECO	GAS	29.15	-
	2012	Honda	Civic CNG	CNG	36.05	-
	2013	Chevy	Volt	ELECTRIC/GAS	41.05	66.05
	2013	VW	TDI Jetta	DIESEL	35.93	-
	2013	Honda	Civic Hybrid	GAS	39.63	-
	2013	Toyota	Prius Plug-In	ELECTRIC/GAS	49.53	12.38
	2013	VW	Jetta Hybrid	GAS	36.60	-
	2012	Mitsubishi	i-MiEV	ELECTRIC	-	268.25
	2013	Nissan	Leaf (6.6)	ELECTRIC	-	281.18
	2013	Ford	C-Max Hybrid	GAS	37.13	-
	2013	Ford	C-Max Energi	ELECTRIC/GAS	38.70	21.22
	2013	Ford	Focus EV	ELECTRIC	-	340.61
	2013	Ford	Fusion Energi	ELECTRIC/GAS	38.63	20.83
	2014	Smart	ED	ELECTRIC	-	288.78
	2014	Chevy	Cruze Diesel	DIESEL	36.10	-
	2014	Mazda	Mazda3 i-ELOOP	GAS	32.48	-

# Collaborations



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# NATIONAL LABORATORIES

- DOE Idaho National Laboratory
  - Procedure development and refinement
  - Data collection & analysis
  - Reporting
- DOE Argonne National Laboratory
  - Vehicle Test Procedure development and refinement
  - Fuel economy testing with a chassis dynamometer
  - Level 2 AC charging interoperability test development
- DOE National Renewable Energy Laboratory
  - Contacting medium and heavy duty fleets for future hybrid conversions of ICE vehicles





# **INDUSTRY PARTNERS**

### EZ Messenger

- Document delivery fleet in multiple locations throughout southwest U.S. for varied fleet information
- EVSE for opportunity and overnight charging
- Mileage accumulation
- Total Transit
  - Taxi service
  - Mileage accumulation









### **OTHER PARTNERS**



- AC L2 EVSE interoperability and procedure development
- Investigate DC L2 EVSE interoperability and procedure development







### **REMAINING CHALLENGES**

#### Fueling infrastructure availability

- CHAdeMO and SAE Combo Connector plug availability for fast charging locations
- Quantity of fast charge units at fleets and public use
- Quantity of AC Level 2 EVSE units at fleets
- Future availability of advanced vehicle technology infrastructure
  - Hydrogen fueling stations for Fuel Cell vehicles

# Future Work



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### **CONTINUOUS IMPROVEMENT**

- Publish updated test methods
- Develop new test procedures for new technologies and vehicle types, such as fuel cell vehicles
- Continue to automate test reporting and improve fidelity of fleet data
- Identify & expand test fleet operators
- Expand scope to include medium duty and heavy duty vehicles with cooperation of NREL

# Future Work



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### **ONGOING TESTING**

- Over 50 vehicle models scheduled for evaluation throughout the life of the project
- Continue current vehicles in fleet test for minimum of 3 years along with reaching mileage accumulation targets
- Advanced technology vehicles planned through March 2016 include the 2016 Chevrolet Volt, PHEV sedans and SUVs, BEVs and Fuel Cell vehicles depending on availability
  - Fuel Cell vehicles would operate in California where Hydrogen refueling infrastructure is available





#### 2014 AMR Reviewers' Comments and Responses

- The reviewer observed that the plan for this project covered all of the relevant technical aspects of performance of advanced vehicles in use. The reviewer would have liked to see a bit more about the people aspects. The reviewer asked if the drivers charged when needed, if the vehicles did the required functions well, and if there were any operational problems.
  - Implementation of EVSE at fleet sites allows for increased opportunity charging. Our largest fleet is currently rotating vehicles with their EVSE units. Additional units are being installed to accommodate charging needs, along with a Storage-Assisted Vehicle Recharging unit at the largest fleet location to study the impact on the fleet and the avoidance of demand charges.
- The reviewer wished there was more information about the standards for the tests (test protocols), whether they were nationally accepted (or established by consensus-standards organizations), why and how they were chosen, and what the baseline is (how the baseline was established) rather than an emphasis on the numbers of vehicles and types of vehicles tested and miles driven.
  - Test protocols for baseline track testing are based on SAE standards and are reviewed with INL and NETL technical personnel for relevance to the type of vehicle being tested. Each vehicle follows procedures that have been utilized through the history of the Advanced Vehicle Testing Activity.



#### 2014 AMR Reviewers' Comments and Responses

- This reviewer stated that progress on this project had been very good. A total of 54 vehicles had been tested in the field and 6 vehicles had baseline testing complete. There was no data presented in the presentation except for miles driven by the Toyota Prius. It would have been good to present the baseline testing and field testing that had been generated.
  - The baseline testing is specific to each vehicle type. An example baseline testing report is included in the Technical Backup Slides. For fleet testing information, fuel economy from each vehicle type has been added to the presentation.
- According to this reviewer, the vehicle testing and analysis team was top-notch. The reviewer would have liked to see a more varied set of users, beyond taxis and messengers. The reviewer knew the team wanted high mileage, but normal consumers, like commuters, would have been useful as well.
  - Coordinating with individual commuters would not be conducive to collecting the accurate fuel and charging data required for this project. Each fleet provides the quality control necessary to have accurate fuel and charging information for the project.



### 2015 AMR SUMMARY

- As of March 2015, over 88 vehicles representing 24 models are placed in test fleets employing 5 different technologies and various strategies to reduce petroleum consumption
- Over 3.8 million vehicle miles recorded during fleet testing
- Completed SAE J2953 AC Level 2 Interoperability testing using roundrobin testing between vehicles and the EVSE units
- Expanded current fleet partner locations to include colder climates than Phoenix, Arizona
- Implemented monitoring loads on 12V systems without high voltage energy storage systems
- Utilized Intertek office in California to acquire California-only vehicles that were delaying vehicle timing
- Continued to auto-populate test reports with ANL & INL
- Test results posted to AVTA Website after review by INL



### **TECHNICAL BACKUP SLIDES**

VSS029



#### 2013 Ford Fusion Energi

Advanced Vehicle Testing - Baseline Vehicle Testing Results



#### VEHICLE SPECIFICATIONS<sup>1</sup>

#### Vehicle Features Battery VIN: 3FA6P0PU2DR373776 Manufacturer: Panasonic Class: Midsize Car Type: Lithium-ion (NMC) Seatbelt Positions: 5 Type<sup>2</sup>: Blended PHEV CARB<sup>3</sup>: TZEV EPA Fuel Economy: 370 Wh/mi (Charge-Depleting Mode, Combined); 38 mpg (Charge-Sustaining Mode, Combined) Engine Model: 16 Valve DOHC Duratec with Intake Variable Camshaft Timing (iVCT) Displacement: 2.0 L Cycle: Atkinson Power: 105 kW @ 6,000 rpm Torque: 174 Nm @ 4,000 rpm Configuration: Inline 4-Cylinder Fuel Tank Capacity: 14 US gal

Fuel Type: Regular Unleaded

HF35 eCVT Hybrid Powersplit

Transmission

Cathode /Anode Material: LiMn<sub>2</sub>O<sub>4</sub>/Hard Carbon Number of Cells: 84 Cell Configuration: Series Nominal Cell Voltage: 3.7 V Nominal System Voltage: 310.8 V Rated Pack Capacity: 26 Ah Rated Pack Energy: 7.6 kWh Weight of Pack: 272 lb Pack Location: In Trunk Area Cooling: Active - Forced Cabin Air Motor/Generator 1 Type: Permanent Magnet AC Synchronous Max. Power/Torque: 88 kW/ 240 Nm @ 6,000 rpm Cooling: Active – Liquid Cooled Motor/Generator 2 Type: Permanent Magnet AC Synchronous Cooling: Active - Liquid Cooled

Weights Design Curb Weight: 3.913 lb Delivered Curb Weight: 3.934 lb Distribution F/R (%): 51/49 GVWR: 4.910 lb GAWR F/R: 2,435/2,485 lb Max. Payload: 850 lb Dimensions Wheelbase: 112.2 in Track F/R: 62.3 in/62.0 in Length/Width: 191.8 in/ 72.9 in Height: 58.0 in Ground Clearance: 5.8 in Tires Manufacturer: Michelin Model: Energy Saver Size: P225/50R17 Pressure F/R: 35 psi/35 psi

Spare Installed: Sealant and

Inflator

#### CHARGE-DEPLETING TRACK PERFORMANCE STATISTICS<sup>4,5</sup>

"EV NOW" TEST RESULTS <sup>6</sup>	"EV LATER" TEST RESULTS <sup>6</sup>
Acceleration 0-60 mph <sup>6</sup>	Acceleration 0-60 mph <sup>®</sup>
Measured Time: 16.7 s	Measured Time: 8.7 s
Performance Goal: ≤13.5 s	Performance Goal: ≤13.5 s
Peak Power from Battery: 66.8 kW	Peak Power from Battery: 51.2 kW
Maximum Speed	Maximum Speed
At ¼ Mile: 65.5 mph	At ¼ Mile: 88.2 mph
At 1 Mile <sup>7</sup> : 94.3 mph	At 1 Mile <sup>7</sup> : 103.0 mph
Performance Goal: ≥90 mph at 1-mile mark	Performance Goal: ≥90 mph at 1-mile mark
Braking at 50% SOC from 60-0 mph <sup>8</sup>	Braking at 90% SOC from 60-0 mph <sup>8</sup>
Measured Time: 3.8 s	Measured Time: 3.9 s
Distance: 124 ft	Distance: 123 ft
Peak Power into Battery: 23.3 kW	Peak Power into Battery: 5.1 kW
Braking at 100% SOC from 60-0 mph <sup>8</sup>	Deceleration 60-10 mph <sup>9</sup>
Measured Time: 4.2 s	Measured Time: 78.8 s
Distance: 125 ft	Distance: 3,479 ft
Peak Power into Battery: 19.4 kW	Peak Power into Battery: 10.2 kW
Deceleration 60-10 mph <sup>9</sup>	Total Energy into Battery: 83.7 Wh
Measured Time: 79.1 s	
Distance: 3,476 ft	
Peak Power into Battery: 14.7 kW	
Total Energy into Battery: 108.3 Wh	

# Testing Results 2013 Ford Fusion (Page Energi Baseli $\mathbf{N}$ 0

#### NOTES (also from the previous page):

- 1. Vehicle specifications were supplied by the manufacturer, measured, or derived from a literature review.
- The vehicle classification is "Blended PHEV" because the all-electric operation cannot occur at all speeds and accelerations. In charge-depleting (CD) mode, the engine is used to supplement the electric motor to satisfy speed and acceleration demands in a "blended" manner.
- 3. The vehicle was classified as a Transitional Zero Emission Vehicle (TZEV) by the California Air Resources Board (CARB).
- 4. Performance numbers based on "Normal" vehicle mode. Performance numbers are averages from multiple tests.
- 5. Vehicle track testing occurs when the vehicle has achieved its "break-in mileage" of between 4,000 to 6,000 miles, and at the delivered curb weight plus 332 ± 10 b (including driver and test equipment), distributed in a manner similar to the original curb leading of the vehicle. Track testing took place between April 14 and April 24, 2014 with a beginning vehicle odometer reading of 4,311 miles. The ambient temperatures ranged from 53 °F to 15 °F. No accessories were used except for headinght as required by tack regulation.
- The acceleration is measured from the point at which the vehicle begins to move. The acceleration and maximum speed results were averaged from 12 runs. The peak power value
  was taken from a single run.
- 7. The maximum speed was reached before the one-mile mark.
- 8. Controlled braking on dry surface. For the "EV Now" mode, brake testing was performed when the battery was at 50% state of charge (SOC) and also at 100% SOC. For the "EV Later" mode, brake testing was performed when the battery was at 90% SOC. The peak power into the battery values were taken from a single run.
- Coasting in 'Drive' on dry surface. Test run data were cut off when the vehicle reached 10 mph, as vehicle creep speeds are typically below this threshold. The peak power into the battery value and total energy into the battery value were both taken from a single (but different) run.

	45 mph Test <sup>2</sup>	60 mph Test <sup>3</sup>	70 mph Test*
Average DC power out of battery at set speed (kW):	9.8	16.2	23.9
(A) DC energy out of battery at set speed (kWh) <sup>3,7,9</sup>	5.4	5.2	5.0
(A+) Total DC energy out of battery (kWh) <sup>3,7,9</sup>	5.8	5.7	5.9
Battery capacity discharge at set speed (Ah):	17.4	17.0	16.8
(B) Range at set speed (mi) <sup>6,0,10</sup> :	25.1	19.2	14.5
(C) Post-test charge AC energy from EVSE @ 240 V to onboard charger (kWh):	6.9	7.1	7.2
(D) Post-test charge DC energy into battery from onboard charger (kWh):	5.8	6.0	6.0
Post-test charge duration (HH:MM):	02:18	02:22	02:20
AC electricity consumption rate (Wh/mi) <sup>11</sup> :	255	339	421
DC electricity consumption rate (Wh/mi)12:	215	271	344
(A+/D) Battery Roundtrip Efficiency <sup>13</sup> :	100%	95%	98%
(D/C) On-Board Charger Efficiency <sup>14</sup> :	84%	85%	83%
(A+/C) Overall Trip Efficiency <sup>15</sup> :	84%	80%	82%

#### CONSTANT SPEED PANCE AND CHARCE TESTING IN CHARCE DEPI ETING MODE<sup>1</sup>

#### NOTES

1. See Note 4 and Note 5 on page 2. This testing is performed on a track. The vehicle is accelerated to the desired apconsidered reached when either (1) the vehicle transitions from charge-depleting (CD) mode to charge-sustaining (5

- 2. During the 45 mph range test, the maximum hattery temperature was 25 °C and the average ambient temperature w temperature was 42 °C, and the average ambient temperature was 23 °C.
- 3. During the 60 mph range test, the maximum battery temperature was 60 °C and the average ambient temperature we temperature was 47 °C, and the average ambient temperature was 30 °C.
- 4. During the 70 mph range test, the maximum battery temperature was 38 °C and the average ambient temperature w temperature was 39 °C, and the average ambient temperature was 27 °C.
- 5. In addition to the energy discharged from the battery during the 45 mph test, energy was discharged during the driv achieved and maintained. After the range at 45 mph was completed, the vehicle is in CS mode, but there is still ES test propages and the EVSE unit for the post-test charge. The pre-test drive required 0.33 kWh while the post-test ( the energy consumed during the range test (A) to obtain the total output from the battery (5.3 kWb, denoted as (A+)
- 6. In addition to the mage measured for the 45 mph test, the pre-test drive required 0.96 miles from test propares to p the range at 45 mph was completed, the post-test drive required an additional drive of 0.97 miles to return to the test distances can be added to the distance traveled during the range test (B) to obtain the total distance traveled (27.0 m distance traveled during the test itself, or value (II).
- 7. In addition to the energy discharged from the battery during the 60 mph test, energy was discharged during the driv achieved and maintained. After the range at 60 mph was completed, the vehicle is in CS mode, but there is still ESI test prep area and the EVSE unit for the post-test charge. The pre-test drive required 0.51 kWb while the post-test d added to the energy consumed during the mage test (A) to obtain the total output from the battery (5.7 kWh, denote Duration of Passing Maneuver at Grade 5
- 8. In addition to the range measured for the 60 mph test, the pre-test drive required 1.21 miles from test prep area to po the range at 60 mph was completed, the post-test drive required an additional drive of 2.45 miles to return to the test distances can be added to the distance traveled during the range test (II) to obtain the total distance traveled (22.9 m distance traveled during the test itself, or value (II).
- 9. In addition to the energy discharged from the battery during the 70 mph test, energy was discharged during the driv achieved and maintained. After the range at 70 mph was completed, the vehicle is in CS mode, but there is still ES test prop area and the EVSE unit for the post-test charge. The pre-test drive required 0.52 kWh while the post-test ( the energy consumed during the range test (A) to obtain the total output from the battery (5.9 kWb, denoted as (A+)
- 10. In addition to the range measured for the 70 mph test, the pre-test drive required 1.47 miles from test prep area to p the range at 70 mph was completed, the post-test drive covered an additional drive of 9.06 miles to return to the test powered mostly by the gasoline engine. These distances can be added to the distance traveled during the range test energy consumption values consider only the distance traveled during the test itself, or value (II).
- 11. The AC electricity consumption rate is calculated by dividing the DC electricity consumption rate (in Wh/mi) by th 12. The DC electricity consumption rate is calculated by dividing the DC energy from the battery at set speed (A) by th
- 13. Battery Roundtrip Efficiency is calculated by dividing the DC energy out of the battery (A+) by the DC energy from
- 14. On-Board Charger Efficiency is calculated by dividing the DC energy from the on-board charger into the battery (D
- 15. Overall Trip Efficiency is calculated by dividing the DC energy out of the battery (A+) by the AC energy from the

#### CHARGE-DEPLETING DYNAMOMETER TESTING PERFORMANCE STATISTICS<sup>12</sup>

Cycle Rest	<u>alts</u>	1 40.00	
	72 °F	20 °F	95 °F + 850 W/m <sup>2</sup>
UDDS	225.3 Wh/mi	435.0 Wh/mi, 40.6 mpg	339.6 Wh/mi
HWFET	283.9 Wh/mi		
US06	298.0 Wh/mi, 146.8 mpg	]	

	10 mph	178.5 Wh/mi	50 mph	269.5 Wh/mi
11	20 mph	167.4 Wh/mi	60 mph	320.4 Wh/mi
	30 mph	191.5 Wh/mi	70 mph	377.4 Wh/mi
	40 mph	229.8 Wh/mi	80 mph	N/A

	0% Grade	3% Grade	6% Grade
35-55 mph	4.5 s	5.0 s	5.3 s
55-65 mph	3.2 s	3.8 s	4.6 s
35-70 mph	7.8 s	8.8 s	10.2 s
55-80 mph	7.7 s	8.9 s	11.4 s
Maximum Sp	eed at 25% Gri gine Off); 53.1	ade from Stop: (Engine On)	

Performance numbers haved on "Normal" vehicle mode.

- 2. Dynamometer testing occurs after the track testing is siretplate. Dynamometer testing begas on 2xly 15, 2014, with the vehicle odometer reading 4,805 miles. A comprehensive explanation of the dynamometer facility and methodology can be found at http://www.trumportation.anl.gov/D3/, titled "Channin Dynamometer Testing Enformed Document". The ABC coefficients derived from track countdown testing and matched on the dynamometer ware A: 31.3971 (b, B: 0.5381 [b/mph, and C: 0.0138 [b/mph]<sup>2</sup>. All electrical consumption values are given in AC Whitni; for the standy-state speed table, a charging efficiency of 80% is assumed since a charge event did not immediately follow.
- The Cycle Results table presents the fael accounty achieved by the vehicle on three IZA drive cycles at three different ambient temperatures: (1) 72 'T with vehicle dimate-control off. (2) 20 T with vehicle dimensionered art to 72 T Auto, and (3) 97 T with vehicle climate control art to 72 T Auto. For (3), the vehicle is also subjected to 850 Wite<sup>2</sup> of solar load to simulate direct surlight. The drive cycles include a cold start due to be used for the vehicle to be fully charged at the beginning of the cycle.
- The engine came on during the 80 moh steady-state speed test at 0% grade; the test results are not reported because gasoline was consumed
- 5. The passing maneuver value indicates the amount of time monited for the vehicle to transition from the first to the second speed, at the specified grade.

	UDDS			HWFET			
Miles	Cumulative Fuel Economy (mpg)	Cumulative Electricity Consumption Rate (AC Wh/mi)	Miles Fuel Economy (mpg) Consumpti			Electricity sumption Rate Miles Fuel Economy Consum	Cumulative Electricity Consumption Rate (AC Wh/mi)
5	N/A <sup>2</sup>	300.5	5	$N/A^2$	329.4		
10	N/A <sup>2</sup>	283.2	10	N/A <sup>2</sup>	307.8		
15	N/A <sup>2</sup>	268.6	15	N/A <sup>2</sup>	291.7		
20	N/A <sup>2</sup>	271.0	20	N/A <sup>2</sup>	288.8		
25 <sup>3</sup>	47,917.5	268.4	255	1639.5	280.9		
30	395.0	240.4	30	261.2	235.6		
35	200.4	204.6	35	164.6	199.4		
40	149.7	179.0	40	133.3	175.9		
44.9 <sup>4</sup>	128.2	159.3	41.1 <sup>6</sup>	128.7	179.7		

#### CUMULATIVE FUEL ECONOMY DYNAMOMETER PERFORMANCE STATISTICS<sup>1</sup>

#### NOTES:

 See Note 1 and Note 2 on page 4. Values for fuel aconomy and electricity consumption rate obtained from drive cycle data without accessories and using SAE J7711 methodology at 72 %. The vehicle is driven on consecutive drive cycles, starting with a full charge in CD mode and continuing through the transition to CS mode and ending in CS mode, with fuel economy and electricity consumption rates calculated for each cycle. As the distances travelled and noted in the "Mile" columns are during a drive cycle, the values have all been interpolated.

2. In some cases of blended CD mode, no fuel is used.

3. During the consecutive UDDS cycles, the engine came on at 26.41 miles, after 3.5 UDDS cycles (the full UDDS cycle is 7.45 miles long), in CD mode. However, as this which is a blended PHEV, the engine can be on during CD mode. The vehicle transitioned from CD to CS mode at 29.70 miles, after 4.0 UDDS cycles (due to rounding, the transition occurred near the end of the fourth consecutive UDDS cycle). The Performance Coal is to complete two UDDS cycles or 14.90 miles in charge-deplicing mode.

4. The consecutive UDDS testing ended at 44.9 miles, after six consecutive cycles.

5. Daring the consecutive HWFET cycles, the engine same on at 24.43 million, after 2.4 HWFET cycles (the full HWFET cycles (to 10.25 miles long), in CD mode. However, as this vehicle is a blended PHEV, the engine can be on during CD mode. The vehicle transitioned from CD to CS mode at 27.02 miles, after 2.6 HWFET cycles. The Performance Couli is to complete two HWFET cycles or 20.50 miles in based-tepleting mode.

6. The consecutive HWFET testing ended at 41.1 miles, after four consecutive cycles.

#### CUMULATIVE FUEL ECONOMY DYNAMOMETER PERFORMANCE STATISTICS<sup>1</sup>

US06					
Miles	Cumulative Fuel Economy (mpg)	Cumulative Electricity Consumption Rate (AC Wh/mi)			
5²	99.7	300.5			
10	127.2	283.2			
15	158.6	268.6			
20	142.4	271.0			
25	92.1	268.4			
30	76.6	240.4			
32.1 <sup>3</sup>	72.0	204.6			

#### NOTES:

 See Note 1 and Note 2 on page 4. Values for fuel economy and electricity consumption rate obtained from drive cycle data without accessories and using SAE 17171 methodology at 72 °F. The which is driven on consecutive drive cycles, starting with a full charge in CD mode and confirming through the transition to CS mode and enting in CS mode, with fuel accessory and electricity consumption rates calculated for each cycle. As the distances travelled and noted in the "Miles" column are during a drive cycle, the values have all been interpolated.

 During the consecutive US06 system, the majors came on at 0.2 million, when 0.04 US06 system is the full US06 system is 0.01 million long), in CD mode. However, as this vehicle is a blandad PHEV, the engine cam be on during CD mode. The vehicle transitional from CD to CS mode at 27.20 million, ather 3.5 UDDS system. The Performance Goal is to complete two UDDS system F4.50 million in charge-depleting mode.

3. The consecutive US06 testing ended at 32.13 miles, after four consecutive cycles.

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CHARGE-SUSTAINING PERFORMANCE STATISTICS <sup>1</sup>								
TRACK TESTING <sup>2</sup>	DYNAMOMETER TESTING <sup>7</sup>							
Acceleration 0-60 mph <sup>3</sup>	Cycle Results	•						
Measured Time: 9.2 s		72 °F	20 °F	95 °F + 8	50 W/m <sup>2</sup>			
Performance Goal: ≤13.5 s	UDDS	-5.0 Wh/mi,	-27.5 Wh/m	ui, -8.1 W	h/mi,			
Peak Power from Battery: 44.3 kW	(Cold Start)	48.9 mpg	27.4 mpg		_			
Maximum Speed	UDDS	-5.3 Wh/mi,	9.0 Wh/mi	2				
At ¼ Mile: 85.3 mph	54.7 mpg 42.		• •		mpg			
Maximum Speed <sup>4</sup> : 103.1 mph	HWFET	HWFET 1.47 Wh/mi,		*	-2.0 Wh/mi, 51.6 mpg			
Performance Goal: >90 mph at 1-mile	1 56.6 mpg		45.4 mpg					
mark	US06							
Braking from 60-0 mph <sup>5</sup>	SC03			2.4 W				
Measured Time: 3.7 s	3005			39.01	mpg			
Distance: 124 ft	Fuel Economy	r at Steady-Stat	e Speed, 0% C	Grade				
Peak Power into Battery: 26.5 kW	15 mph	83.5 mpg	60 mph	44.6 mpg				
Deceleration 60-10 mph <sup>6</sup>	30 mph	70.9 mpg	75 mph	36.3 mpg				
Measured Time: 73.7 s	45 mph	52.6 mpg						
Distance: 3,250 ft	Duration of Passing Maneuver at Grade <sup>9</sup>							
Peak Power into Battery: 10.0 kW	0% Grade 3% Grade 6% Grade							
Total Energy into Battery: 77.3 Wh	35-55 mph	4.8 s	5.0 s	5.6 s	]			

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Testing Results (Page

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#### NOTES

- 1. Performance numbers based on "Normal" vehicle mode. Performance numbers are averages from multiple tests.
- 2. Vehicle track testing occurs when the vehicle has achieved its "break-in mileage" of between 4,000 to 6,000 miles, and at the delivered curb weight plus 332 ± 10 lb (including driver and test equipment), distributed in a manner similar to the original curb loading of the vehicle. Track testing took place between April 14 and April 24, 2014 with a beginning whicle odometer reading of 4,311 miles. The ambient temperatures ranged from 53 °F to 15 °F. No accessories were used except for headlights as required by track regulation.

3.6 s

8.6 s

8.2 s

Maximum Speed at 25% Grade from Stop: 46.1 mph

3.5 s

9.5 s

9.4 s

4.3 s

11.2 s

13.8 s

- 3. The acceleration is measured from the point at which the vehicle begins to move. The acceleration and maximum speed results were averaged from 6 rans. The peak power value was taken from a single run.
- 4. The maximum speed was reached before the one-mile mark.
- 5. Controlled braking on dry surface. The test is not run at a set SOC value in CS mode. The peak power into the battery value was taken from a single run.

55-65

35-70 mph 55-80 mph

mph

6. Coasting in 'Drive' on dry surface. Test run data were cut off when the vehicle reached 10 mph, as vehicle creep speeds are typically below this threshold. The peak power into the hattery value and total energy into the battery value were both taken from a single (but different) run.

7. Dynamometer testing occurs after the track meting is complete. Dynamometer testing began on July 15, 2014, with the vehicle odometer reading 4,805 miles. A comprehensive explanation of the dynamometer facility and methodology can be found at http://www.transportation.anl.gov/D3/, filed "Chausis Dynamometer Testing Reference Document". The ADC coefficients derived from track coastdown testing and matched on the dynamometer were A: 31.3971 h, II: 0.5381 h/mph, and C: 0.0138 h/mph<sup>2</sup>. All electrical consumption values are given in AC Whim; for the steady-state speed table, a charging efficiency of 80% is assumed since a charge event did not immediately follow.

8. The Cycle Results table presents the fael economy achieved by the vehicle on five EPA drive cycles at three different ambient temperatures: (1) 72 °F with vehicle climate-control off, (2) 20 °F with vehicle climate-control set to 72°F Anto, and (3) 95 °F with vehicle climate-control set to 72°F Anto. For (3), the vehicle is also subjected to 850 W/m<sup>2</sup> of solar load to simulate direct sunlight. The drive cycles include a cold start due to the need for the vehicle to be fully charged at the beginning of the cycle.

9. The passing managever value indicates the amount of time required for the vehicle to transition from the first to the second speed, at the specified grade.