2013 Ford Fusion Energi

Advanced Vehicle Testing – Baseline Vehicle Testing Results

VEHICLE SPECIFICATIONS[1]

Vehicle Features

VIN: 3FA6P0PU2DR373776
Class: Midsize Car
Seatbelt Positions: 5
Type[2]: Blended PHEV
CARB[3]: 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

Transmission

HF35 eCVT Hybrid Powersplit

Battery

Manufacturer: Panasonic
Type: Lithium-ion (NMC)
Cathode /Anode Material: $LiMn_2O_4$/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[4,5]	
"EV NOW" TEST RESULTS[6]	**"EV LATER" TEST RESULTS[6]**
Acceleration 0-60 mph[6] Measured Time: 16.7 s Performance Goal: ≤13.5 s Peak Power from Battery: 66.8 kW **Maximum Speed** At ¼ Mile: 65.5 mph At 1 Mile[7]: 94.3 mph Performance Goal: ≥90 mph at 1-mile mark **Braking at 50% SOC from 60-0 mph[8]** Measured Time: 3.8 s Distance: 124 ft Peak Power into Battery: 23.3 kW **Braking at 100% SOC from 60-0 mph[8]** Measured Time: 4.2 s Distance: 125 ft Peak Power into Battery: 19.4 kW **Deceleration 60-10 mph[9]** Measured Time: 79.1 s Distance: 3,476 ft Peak Power into Battery: 14.7 kW Total Energy into Battery: 108.3 Wh	**Acceleration 0-60 mph[6]** Measured Time: 8.7 s Performance Goal: ≤13.5 s Peak Power from Battery: 51.2 kW **Maximum Speed** At ¼ Mile: 88.2 mph At 1 Mile[7]: 103.0 mph Performance Goal: ≥90 mph at 1-mile mark **Braking at 90% SOC from 60-0 mph[8]** Measured Time: 3.9 s Distance: 123 ft Peak Power into Battery: 5.1 kW **Deceleration 60-10 mph[9]** Measured Time: 78.8 s Distance: 3,479 ft Peak Power into Battery: 10.2 kW Total Energy into Battery: 83.7 Wh

NOTES (also from the previous page):

1. Vehicle specifications were supplied by the manufacturer, measured, or derived from a literature review.
2. 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 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 vehicle odometer reading of 4,311 miles. The ambient temperatures ranged from 53 °F to 85 °F. No accessories were used except for headlights as required by track regulation.
6. 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.
9. 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.

Values in red indicate that the Performance Goal was not met.

CONSTANT-SPEED RANGE AND CHARGE TESTING IN CHARGE-DEPLETING MODE[1]

	45 mph Test[2]	60 mph Test[3]	70 mph Test[4]
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)[5,7,9]:	5.4	5.2	5.0
(A+) Total DC energy out of battery (kWh)[5,7,9]:	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)[6,8,10]:	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)[11]:	255	339	421
DC electricity consumption rate (Wh/mi)[12]:	215	271	344
(A+/D) Battery Roundtrip Efficiency[13]:	100%	95%	98%
(D/C) On-Board Charger Efficiency[14]:	84%	85%	83%
(A+/C) Overall Trip Efficiency[15]:	84%	80%	82%

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 speed and then cruise control is used to maintain the speed. Range is considered reached when either (1) the vehicle transitions from charge-depleting (CD) mode to charge-sustaining (CS) mode or (2) the engine turns on, whichever occurs first.
2. During the 45 mph range test, the maximum battery temperature was 25 °C and the average ambient temperature was 27 °C. During the post-test charge, the maximum battery 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 was 37 °C. During the post-test charge, the maximum battery 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 was 35 °C. During the post-test charge, the maximum battery 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 drive from test prep area to point at which vehicle test speed is achieved and maintained. After the range at 45 mph was completed, the vehicle is in CS mode, but there is still ESS energy throughput during the drive to return the vehicle to the test prep area and the EVSE unit for the post-test charge. The pre-test drive required 0.33 kWh while the post-test drive required 0.05 kWh, and these energy inputs can be added to the energy consumed during the range test **(A)** to obtain the total output from the battery (5.8 kWh, denoted as **(A+)**) that is used in the calculations discussed in Notes 13-15.
6. In addition to the range measured for the 45 mph test, the pre-test drive required 0.96 miles from test prep area to point at which vehicle test speed is achieved and maintained. After the range at 45 mph was completed, the post-test drive required an additional drive of 0.97 miles to return to the test prep area and the EVSE unit for the post-test charge. These distances can be added to the distance traveled during the range test **(B)** to obtain the total distance traveled (27.0 miles). However, the energy consumption values consider only the distance traveled during the test itself, or value **(B)**.
7. In addition to the energy discharged from the battery during the 60 mph test, energy was discharged during the drive from test prep area to point at which vehicle test speed is achieved and maintained. After the range at 60 mph was completed, the vehicle is in CS mode, but there is still ESS energy throughput during the drive to return the vehicle to the test prep area and the EVSE unit for the post-test charge. The pre-test drive required 0.51 kWh while the post-test drive had no net energy throughput, and these energy inputs can be added to the energy consumed during the range test **(A)** to obtain the total output from the battery (5.7 kWh, denoted as **(A+)**) that is used in the calculations discussed in Notes 13-15.
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 point at which vehicle test speed is achieved and maintained. After the range at 60 mph was completed, the post-test drive required an additional drive of 2.45 miles to return to the test prep area and the EVSE unit for the post-test charge. These distances can be added to the distance traveled during the range test **(B)** to obtain the total distance traveled (22.9 miles). However, the energy consumption values consider only the distance traveled during the test itself, or value **(B)**.
9. In addition to the energy discharged from the battery during the 70 mph test, energy was discharged during the drive from test prep area to point at which vehicle test speed is achieved and maintained. After the range at 70 mph was completed, the vehicle is in CS mode, but there is still ESS energy throughput during the drive to return the vehicle to the test prep area and the EVSE unit for the post-test charge. The pre-test drive required 0.62 kWh while the post-test drive required 0.07 kWh, and these energy inputs can be added to the energy consumed during the range test **(A)** to obtain the total output from the battery (5.9 kWh, denoted as **(A+)**) that is used in the calculations discussed in Notes 13-15.
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 point at which vehicle test speed is achieved and maintained. After the range at 70 mph was completed, the post-test drive covered an additional drive of 9.06 miles to return to the test prep area and the EVSE unit for the post-test charge; albeit powered mostly by the gasoline engine. These distances can be added to the distance traveled during the range test **(B)** to obtain the total distance traveled (25.0 miles). However, the energy consumption values consider only the distance traveled during the test itself, or value **(B)**.
11. The AC electricity consumption rate is calculated by dividing the DC electricity consumption rate (in Wh/mi) by the Overall Trip Efficiency for that particular set speed.
12. The DC electricity consumption rate is calculated by dividing the DC energy from the battery at set speed **(A)** by the range at set speed **(B)**.
13. Battery Roundtrip Efficiency is calculated by dividing the DC energy out of the battery **(A+)** by the DC energy from the on-board charger into the battery **(D).**
14. On-Board Charger Efficiency is calculated by dividing the DC energy from the on-board charger into the battery **(D)** by the AC energy from the EVSE **(C).**
15. Overall Trip Efficiency is calculated by dividing the DC energy out of the battery **(A+)** by the AC energy from the EVSE **(C)**.

CHARGE-DEPLETING DYNAMOMETER TESTING PERFORMANCE STATISTICS[1,2]

Cycle Results[3]

	72 °F	20 °F	95 °F + 850 W/m^2
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		

Energy Consumption at Steady-State Speed, 0% Grade

10 mph	178.5 Wh/mi		50 mph	269.5 Wh/mi
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[4]	N/A

Duration of Passing Maneuver at Grade[5]

	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 Speed at 25% Grade from Stop: 11.1 mph (Engine Off); 53.1 (Engine On)			

NOTES:

1. Performance numbers based on "Normal" vehicle mode.
2. Dynamometer testing occurs after the track testing 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/, titled "Chassis Dynamometer Testing Reference Document". The ABC coefficients derived from track coastdown testing and matched on the dynamometer were A: 31.3971 lb, B: 0.5381 lb/mph, and C: 0.0138 lb/mph^2. All electrical consumption values are given in AC Wh/mi; for the steady-state speed table, a charging efficiency of 80% is assumed since a charge event did not immediately follow.
3. The Cycle Results table presents the fuel economy achieved by the vehicle on three 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 Auto, and (3) 95 °F with vehicle climate-control set to 72 °F Auto. For (3), the vehicle is also subjected to 850 W/m^2 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.
4. The engine came on during the 80 mph 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 required for the vehicle to transition from the first to the second speed, at the specified grade.

Values in red indicate that the Performance Goal was not met.

CUMULATIVE FUEL ECONOMY DYNAMOMETER PERFORMANCE STATISTICS[1]

UDDS			HWFET		
Miles	**Cumulative Fuel Economy (mpg)**	**Cumulative Electricity Consumption Rate (AC Wh/mi)**	**Miles**	**Cumulative Fuel Economy (mpg)**	**Cumulative Electricity Consumption Rate (AC Wh/mi)**
5	N/A[2]	300.5	**5**	N/A[2]	329.4
10	N/A[2]	283.2	**10**	N/A[2]	307.8
15	N/A[2]	268.6	**15**	N/A[2]	291.7
20	N/A[2]	271.0	**20**	N/A[2]	288.8
25[3]	47,917.5	268.4	**25[5]**	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[4]	128.2	159.3	**41.1[6]**	128.7	179.7

NOTES:

1. 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 J1711 methodology at 72 °F. 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 "Miles" column 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 vehicle 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 Goal is to complete two UDDS cycles or 14.90 miles in charge-depleting mode.
4. The consecutive UDDS testing ended at 44.9 miles, after six consecutive cycles.
5. During the consecutive HWFET cycles, the engine came on at 24.43 miles, after 2.4 HWFET cycles (the full HWFET cycle is 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 Goal is to complete two HWFET cycles or 20.50 miles in charge-depleting mode.
6. The consecutive HWFET testing ended at 41.1 miles, after four consecutive cycles.

CUMULATIVE FUEL ECONOMY DYNAMOMETER PERFORMANCE STATISTICS[1]

US06		
Miles	**Cumulative Fuel Economy (mpg)**	**Cumulative Electricity Consumption Rate (AC Wh/mi)**
5[2]	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[3]	72.0	204.6

NOTES:

1. 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 J1711 methodology at 72 °F. 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 "Miles" column are during a drive cycle, the values have all been interpolated.
2. During the consecutive US06 cycles, the engine came on at 0.32 miles, after 0.04 US06 cycles (the full US06 cycle is 8.01 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 27.70 miles, after 3.5 UDDS cycles. The Performance Goal is to complete two UDDS cycles or 14.90 miles in charge-depleting mode
3. The consecutive US06 testing ended at 32.13 miles, after four consecutive cycles.

CHARGE-SUSTAINING PERFORMANCE STATISTICS[1]

TRACK TESTING[2]

Acceleration 0-60 mph[3]

Measured Time: 9.2 s

Performance Goal: ≤13.5 s

Peak Power from Battery: 44.3 kW

Maximum Speed

At ¼ Mile: 85.3 mph

Maximum Speed[4]: 103.1 mph

Performance Goal: ≥90 mph at 1-mile mark

Braking from 60-0 mph[5]

Measured Time: 3.7 s

Distance: 124 ft

Peak Power into Battery: 26.5 kW

Deceleration 60-10 mph[6]

Measured Time: 73.7 s

Distance: 3,250 ft

Peak Power into Battery: 10.0 kW

Total Energy into Battery: 77.3 Wh

DYNAMOMETER TESTING[7]

Cycle Results[8]

	72 °F	20 °F	95 °F + 850 W/m^2
UDDS (Cold Start)	-5.0 Wh/mi, 48.9 mpg	-27.5 Wh/mi, 27.4 mpg	-8.1 Wh/mi, 32.0 mpg
UDDS	-5.3 Wh/mi, 54.7 mpg	9.0 Wh/mi, 42.7 mpg	-2.2 Wh/mi, 41.7 mpg
HWFET	1.47 Wh/mi, 56.6 mpg	-0.8 Wh/mi, 45.4 mpg	-2.0 Wh/mi, 51.6 mpg
US06	-0.65 Wh/mi, 39.8 mpg	-1.0 Wh/mi, 35.1 mpg	-1.39 Wh/mi, 36.6 mpg
SC03			2.4 Wh/mi, 39.0 mpg

Fuel Economy at Steady-State Speed, 0% Grade

15 mph	83.5 mpg		60 mph	44.6 mpg
30 mph	70.9 mpg		75 mph	36.3 mpg
45 mph	52.6 mpg			

Duration of Passing Maneuver at Grade[9]

	0% Grade	3% Grade	6% Grade
35-55 mph	4.8 s	5.0 s	5.6 s
55-65 mph	3.6 s	3.5 s	4.3 s
35-70 mph	8.6 s	9.5 s	11.2 s
55-80 mph	8.2 s	9.4 s	13.8 s
Maximum Speed at 25% Grade from Stop: 46.1 mph			

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 vehicle odometer reading of 4,311 miles. The ambient temperatures ranged from 53 °F to 85 °F. No accessories were used except for headlights as required by track regulation.
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 runs. 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.
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 battery value and total energy into the battery value were both taken from a single (but different) run.
7. Dynamometer testing occurs after the track testing 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/, titled "Chassis Dynamometer Testing Reference Document". The ABC coefficients derived from track coastdown testing and matched on the dynamometer were A: 31.3971 lb, B: 0.5381 lb/mph, and C: 0.0138 lb/mph^2. All electrical consumption values are given in AC Wh/mi; 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 fuel 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 Auto, and (3) 95 °F with vehicle climate-control set to 72°F Auto. For (3), the vehicle is also subjected to 850 W/m^2 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 maneuver value indicates the amount of time required for the vehicle to transition from the first to the second speed, at the specified grade.

Values in red indicate that the Performance Goal was not met.

As a production vehicle, this vehicle is assumed to meet all Federal Motor Vehicle Safety Standards (FMVSS) for Plug-in Hybrid Electric Vehicles.

This information was prepared with the support of the U.S. Department of Energy (DOE) under Award No. DE-EE0005501. However, any opinions, findings, conclusions or recommendations expressed herein are those of the author(s) and do not necessarily reflect the views of the DOE.