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Date: June 10, 2019

Mr. Linc Wehrly
Director, Light Duty Vehicle Center
Compliance Division
Office of Transportation and Air Quality
Environmental Protection Agency
2000 Traverwood Drive
Ann Arbor, Michigan 48105

Subject: Request for GHG credit for High Efficiency Alternator Technology

Dear Mr. Wehrly:

Pursuant to the provisions of 40 CFR § 86.1869-12(d), 49 CFR § 531.6(b), and 49 CFR § 533.6(c), Hyundai Motor Company (HMC), represented by the Hyundai America Technical Center, Inc. (HATCI), requests off-cycle greenhouse gas (GHG) credit for the use of a high efficiency alternator technology. Based on the test results and analysis provided in Attachment B and C, HMC requests credits equal to 0.16 grams CO_2 per mile for each 1% improvement in the VDA efficiency rating of alternators applied in HMC production vehicles compared to a baseline VDA efficiency level of 67%. The results of HMC testing and analysis, as well as the requested credit value, are consistent with results published by other manufacturers.

- Ford Motor Company received EPA's approval for off-cycle credit using high efficiency alternator technology in December 2017
- General Motors, Fiat Chrysler Automobiles, and Toyota Motor Company also received EPA's approval for off-cycle credit using high efficiency alternator technology in June 2018

HMC intends to apply credits for 2010 - 2017 model year HMC vehicles sold in the U.S. equipped with alternators that exceed the baseline of 67% VDA efficiency. If EPA approves HMC's current request for off-cycle credits, HMC intends to utilize the same methodology to apply off-cycle credits for high efficiency alternator technology in future model years. HMC also plans to submit a similar credit request to NHTSA for off-cycle CAFE credits for the appropriate model years.

Background

Greenhouse gas emission standards through 2025 represent a major initiative in US energy and climate policy. EPA and DOT have issued a joint rule-making that set greenhouse gas emissions and fuel economy standards for the largest sources of greenhouse gases from transportation, including cars, light trucks, and heavy-duty trucks. Over the course of the program, light-duty GHG regulations are projected to: cut 6 billion metric tons of GHG emissions, nearly double vehicle fuel efficiency while protecting consumer choice, reduce America's dependence on oil and provide significant savings for consumers at the fuel pump. To achieve these worthy goals, a key regulatory element is the ability for manufacturers to have a variety of options and flexibilities in meeting the standards.

A key flexibility is the off-cycle credits provision; off-cycle credits are an opportunity for manufacturers to generate credits for technologies that provide CO_2 reductions not captured by the traditional 2-cycle (FTP, HWFET) emissions tests conducted on a chassis dynamometer. There are three pathways by which a manufacturer may accrue off-cycle credits. The first is a pre-determined menu of credit values for specific off-cycle technologies. In cases where additional lab testing can demonstrate emission benefits of a technology, a second pathway allows manufacturers to use a broader array of emission tests known as 5-cycle testing, which captures more elements of real-world driving, including high speeds and hard acceleration (US06), solar loads, high temperature, and A/C use (SC03), and cold temperatures (cold

FTP). The third pathway allows manufacturers to seek EPA approval to use an alternative methodology for determining the off-cycle credits.

It has been well recognized in the automotive industry that high efficiency alternator technology is beneficial for improving fuel economy and reducing overall emissions of a vehicle's powertrain. While a reduction in CO_2 emissions can be realized for 2-Cycle testing, general electrical loads of a vehicle undergoing 2-Cycle testing on a chassis dynamometer are significantly lower than those demanded of a typical vehicle by the operator on U.S. public roads. Since high efficiency alternator technology is not included in the EPA's list of pre-defined and pre-approved technologies for GHG off-cycle credits, HATCI had to investigate the 5-cycle testing or alternative methodology to demonstrate the additional benefits of this technology. However, the 5-cycle method is limited in ability to demonstrate this technology's benefits, for the same reason as 2-Cycle testing; general electrical loads during 5-cycle testing are significantly lower than those exhibited in real world. For these reasons, HMC is pursuing additional off-cycle credits for the high efficiency alternator technology via the alternative methodology.

Technology Description

The high efficiency alternator technology reduces fuel consumption and CO_2 emissions by reducing mechanical and electrical losses in the energy conversion process in vehicles. Alternators in vehicles convert mechanical energy generated from an internal combustion engine to electrical energy for the vehicle's electrical systems. The efficiency of the alternator, the ratio of the alternator output power to the power supplied to the alternator, is measured by Verband der Automobilindustirie (VDA) efficiency test procedure which is the accepted industry standard for measuring alternator efficiency. The VDA efficiency rating is the weighted average of the efficiencies measured in component bench tests, measured at 50% of maximum current charge, at four different alternator speeds as follows:

Alternator speeds	@ 1,800 rpm	@ 3,000 rpm	@ 6,000 rpm	@ 10,000 rpm
Weight	25%	40%	25%	10%

The high efficiency alternator for the purpose of this credit petition is defined as any alternator that exceeds a baseline VDA efficiency rating of 67% based on the Federal Register Final Rule for 2017-2025 GHG standards and EU methodology.

- In the Federal Register Final Rule for 2017-2025 GHG standards, EPA stated that 68% VDA would be an appropriate starting point when evaluating high efficiency alternator off-cycle credit.
- The European Commission released methodology for calculating the eco-innovation credit for high efficiency alternator with a baseline VDA efficiency rating of 67%.

Test Methodology

The test methodology used to quantify the technology benefit consists of 2 steps:

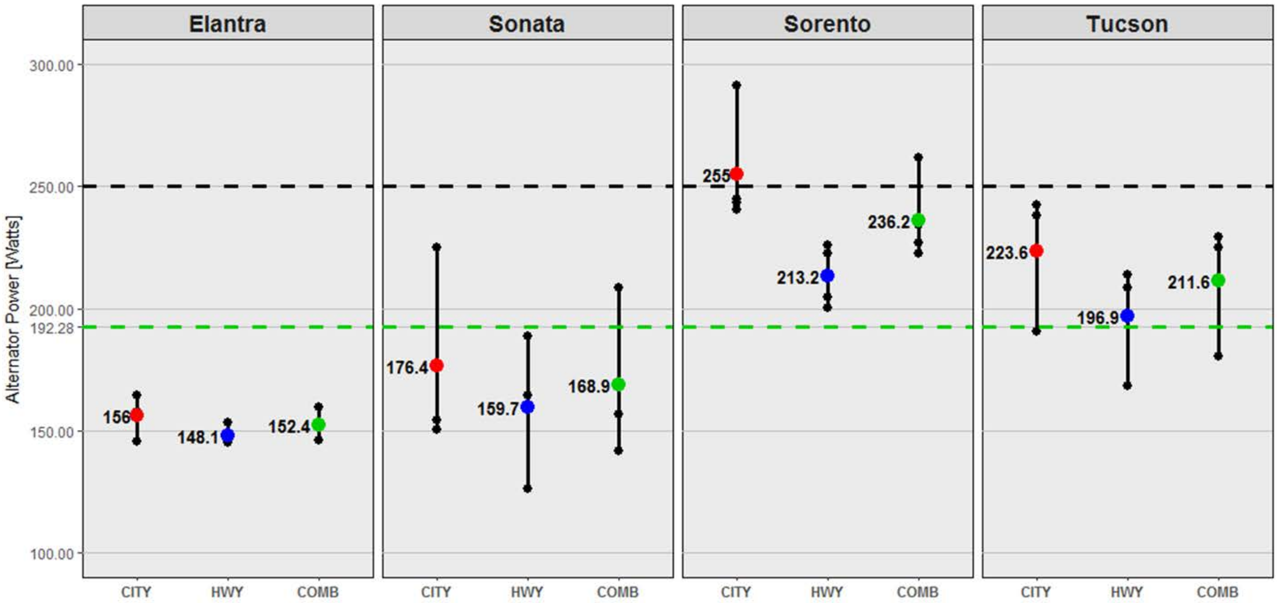
1. On-cycle testing to validate high efficiency alternator performance to support the alternator power assumptions for conducting simulation with various powertrain configurations
2. Simulation with EPA ALPHA and AVL Cruise to validate high efficiency alternator performance and determine initial off-cycle credit estimate with various powertrain configurations

① On-cycle testing

HATCI conducted on-cycle testing to validate Production vehicle high efficiency alternator performance against the 250W on-cycle assumption used in simulations. HATCI tested four vehicles for this on-cycle testing, covering a wide range of body and drivetrain types: Elantra 2.0L 6AT FWD, Sonata 2.4L 6AT FWD. Sorento 3.3L 6AT AWD and Tucson 1.6L 7DCT FWD

Each vehicle conducted multiple FTP75 & HWFE tests. Alternator performance was assessed across three tests for Elantra, Sonata, and Tucson, and across four tests for Sorento.

[On-cycle testing result]



	Alternator Power Average (W)	MY17 Elantra 2.0L 6AT FWD	MY18 Sonata 2.4L 6AT FWD	MY17 Sorento 3.3L 6AT AWD	MY16 Tucson 1.6T 7DCT FWD
City	203	156	176	255	224
Highway	179	148	160	213	197
Combined	192	152	169	236	212

HATCI calculated the mean combined alternator power output from FTP75 & HWFE tests. Combined alternator power is the weighted arithmetic mean of city with 0.55 weight and highway with 0.45 weight. Across all four vehicles, mean of estimated combined alternator power load is 192.28W (green dashed line), which is less than the 250W assumption used for simulation (black dashed line). From this testing, HATCI determined that a 250W average alternator power assumption should be used for AVL CRUISE simulation as a conservative measure.

② Simulation with AVL CRUISE

HATCI utilized internal vehicle models which were simulated with AVL CRUISE, across seven vehicle configurations.

Vehicle Model	Model Year	Engine	Transmission
Elantra	2016	2.0	6 AT
Sonata	2016	2.4	6 AT
Santa Fe	2019	2.0 T-GDI	8 AT
Santa Fe	2019	2.4 GDI	8 AT
Sorento	2016	3.3 GDI	6 AT
Tucson	2016	1.6 T-GDI	7 DCT
Telluride	2019	3.8	8 AT

The table below lists averages across all configurations, showing the gCO_2/mile attributed to the alternator over a range of total electrical loads.

VDA	On-Cycle (250W)	On-Road (750W)	Off-cycle electrical load (On-Road – On-Cycle)	Improvement versus baseline	CO_2 reduction per 1% VDA
67%	8.5	23.3	14.8	Baseline	-
72%	8.0	21.8	13.8	0.9	0.188
80%	7.3	19.9	12.6	2.1	0.162

As a conservative measure, HATCI selected an electrical load of 250W for on-cycle, even though the tested vehicles showed lower average power consumption from internal on-cycle tests (192W). 750W on-road assumption determined from EU Eco Innovation efficient alternator credit methodology.

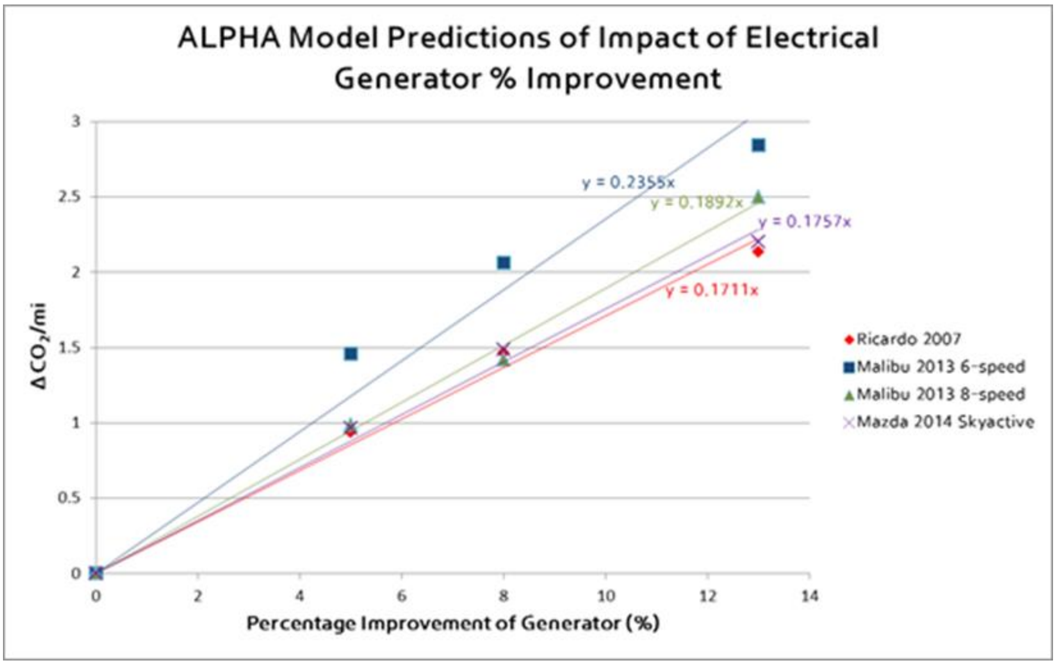
③ Simulation with EPA ALPHA 2.0 model

The version 2.0 EPA ALPHA model was utilized to simulate the off-cycle fuel and CO_2 saving from alternator efficiency improvements, based on assumed electrical loads of 350W on-cycle and 750W in the real world. 350W and 750W assumptions determined from EU Eco Innovation efficient alternator credit methodology.

The model was internally evaluated in order to see potential amounts of credit through ALPHA. As the following tables show, the credits calculated range from a low of 0.17 gCO_2/mile per 1% alternator VDA efficiency improvement, up to a high of 0.24 gCO_2/mile.

HATCI selected the most conservative result from our own AVL simulation result, 0.16 gCO_2/mile per 1% alternator VDA efficiency improvement, as its scaling credit value.

Model Type	Ricardo	Malibu 6spd	Malibu 8spd	Mazda
gCO_2/mi per % Efficiency Improvement	0.17	0.24	0.19	0.18



Durability

Durability of the high efficiency alternator technologies has been thoroughly tested by the various component suppliers, and HMC has already implemented this technology in production vehicles since 2010 model year. Alternators applied on HMC vehicles meet all the durability requirements of 40 CFR §86.1869-12(d) and are not subject to any deterioration factors that would reduce the benefits of the high efficiency alternators. Durability testing is conducted by the suppliers to meet HMC specifications.

Conclusion

Based on vehicle test data presented in this application, combined with the final analysis and technology summary, Hyundai Motor Company, represented by HATCI, hereby requests that the EPA approve an off-cycle GHG credit of 0.16 grams CO_2 per mile for each 1% improvement in the VDA efficiency rating of alternators applied in HMC production vehicles for 2010 and subsequent model years compared to a baseline VDA efficiency level of 67%. The requested off-cycle credit has been estimated to be representative of the fuel savings and subsequent GHG emissions reduction that can be expected from this technology in real-world usage on U.S. public roads.

Thank you for your consideration of this application for off-cycle GHG credits.

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Attachments:

Attachment A: Confidential listing of 2010-2017 HMC Vehicles with High Efficiency Alternator Technology, Sales Volumes and Credits

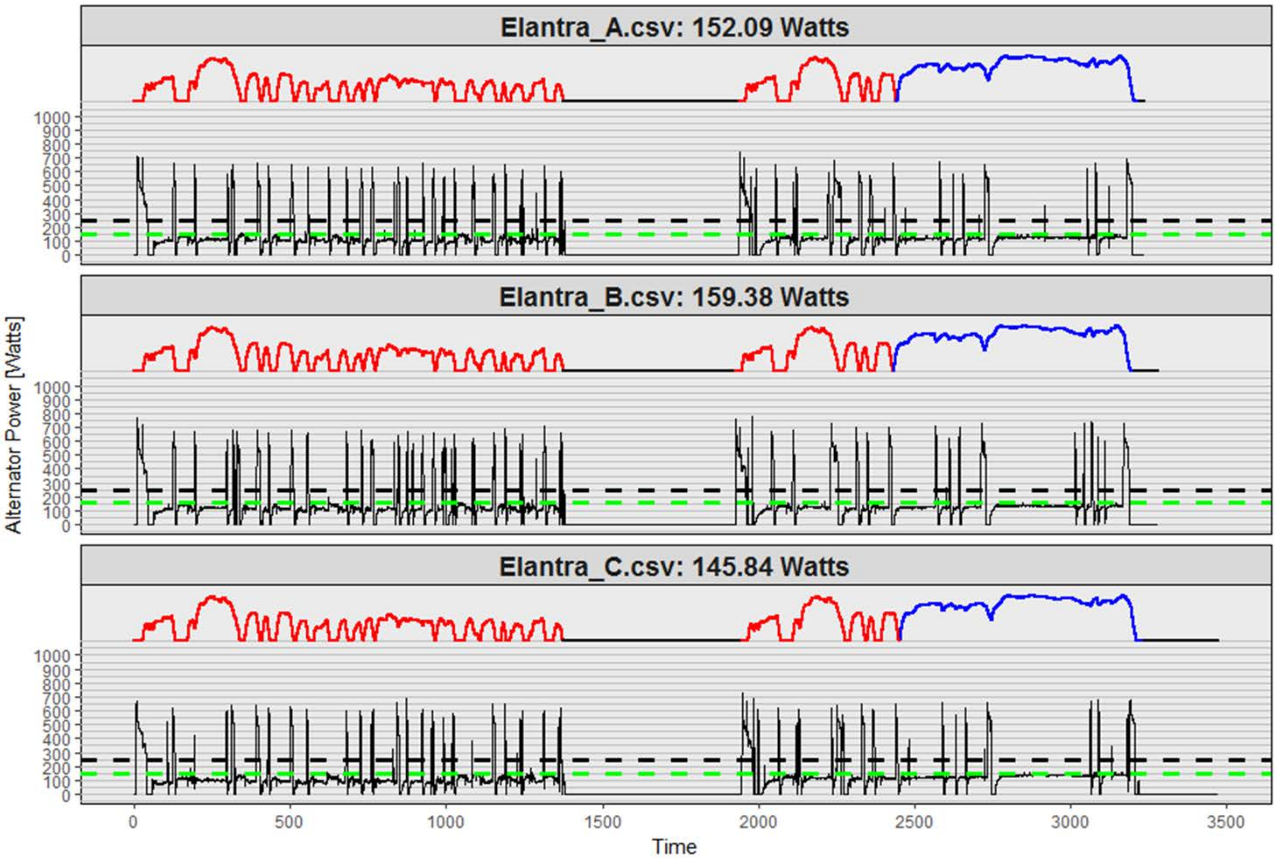
Attachment B: Test Vehicle Information for On-Cycle Test and On-Cycle Test Results

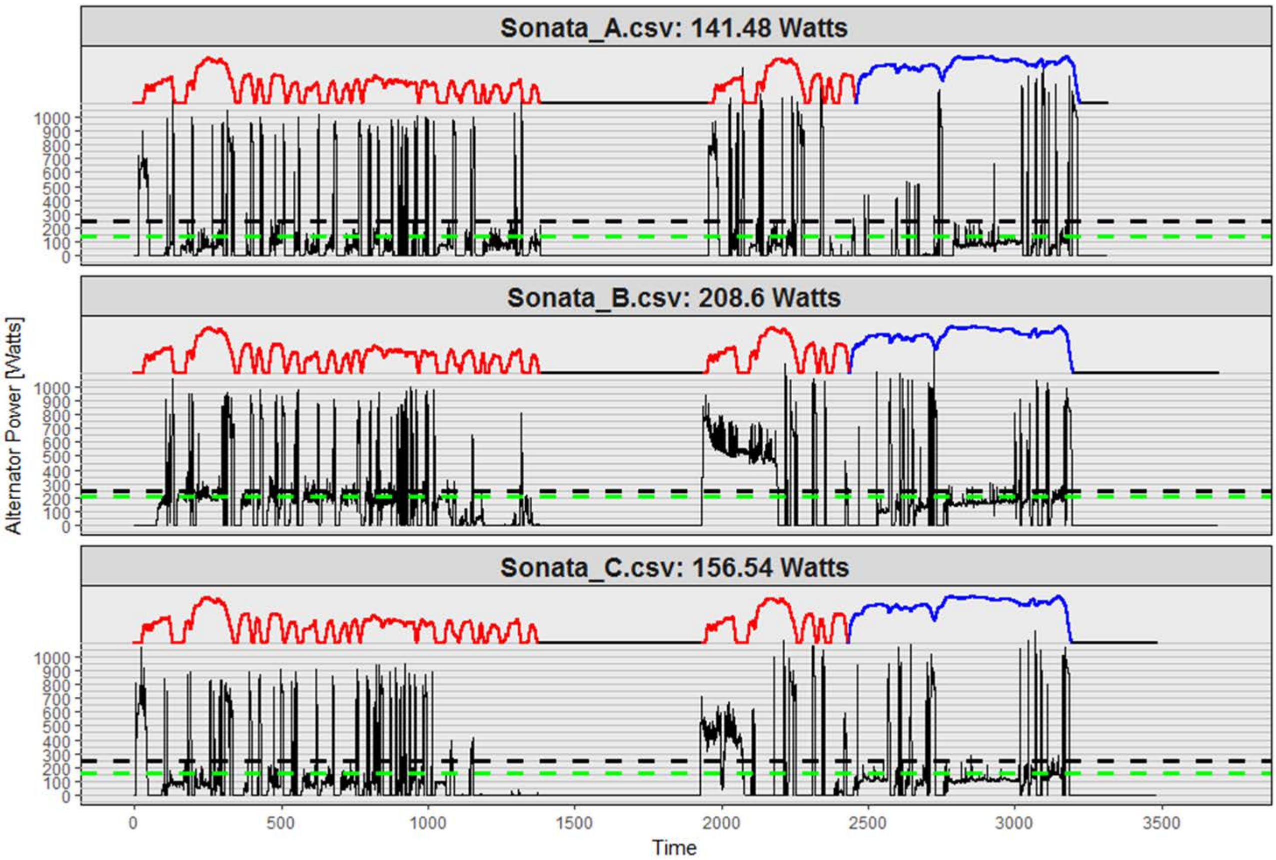
Attachment C: Simulation Results

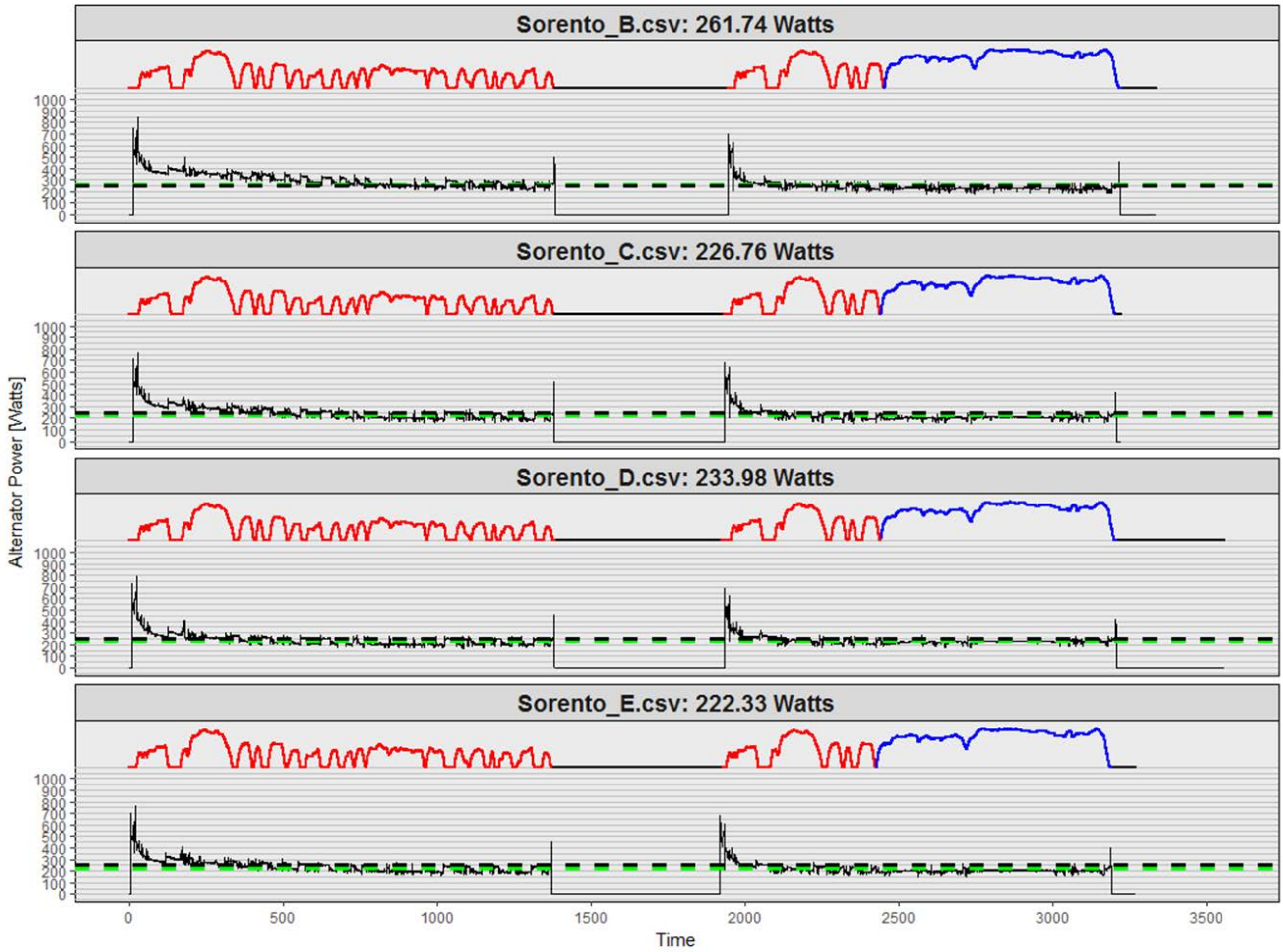
Attachment B: Test Vehicle Information for On-Cycle Test and On-Cycle Test Results
[Test Vehicle Information]

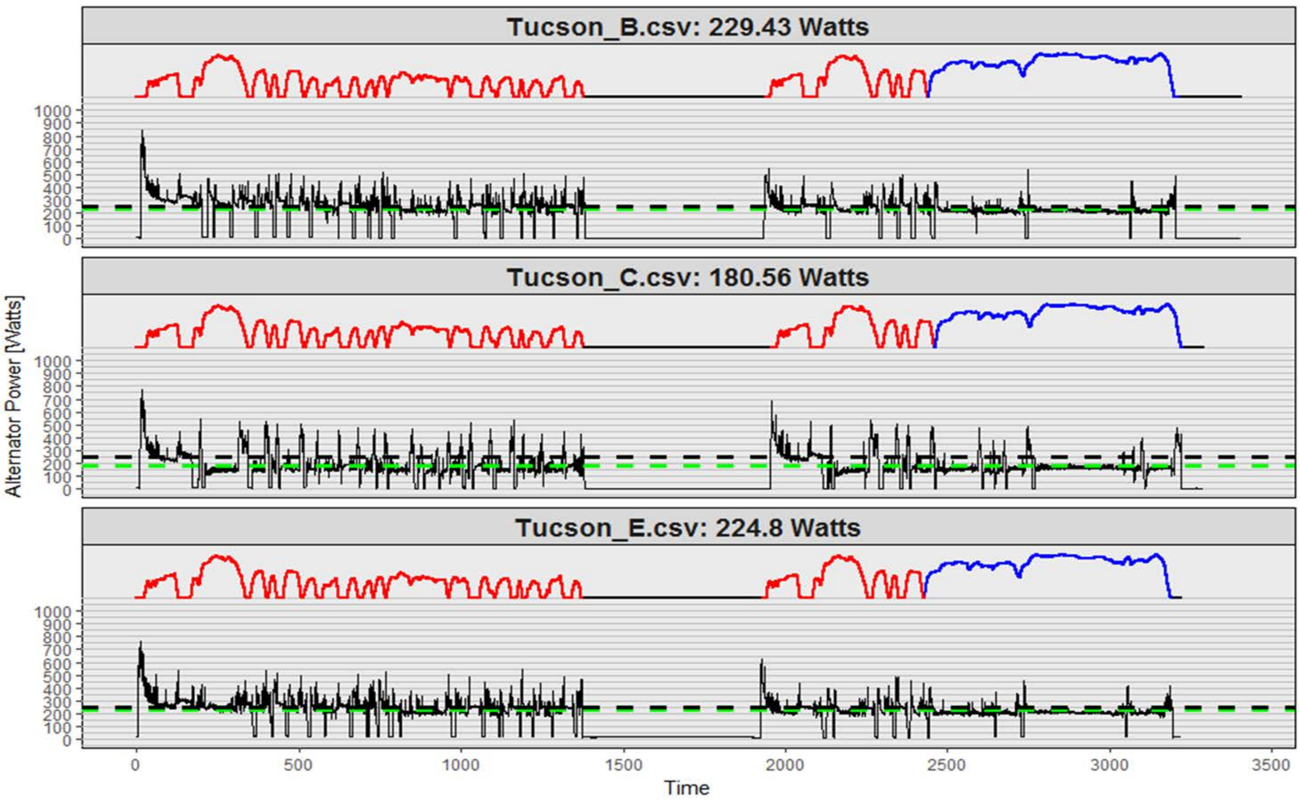
Test Vehicles	Vehicle Information	
Elantra	Trim	MY2017 Elantra SE
	VIN	KMHD74LF9HU394649
	Engine	G4NHHU625745 (2.0L DOHC 4-Cylinder)
	Transmission	6-speed AT w/ SHIFTRONIC®
	Tires	P195/65R15
Sonata	Trim	MY2018 Sonata Sport
	VIN	5NPE34AF0JH602733
	Engine	G4KJHK146463 (2.4L GDI 4-Cylinder)
	Transmission	6-speed AT w/ SHIFTRONIC® & Paddle Shifters
	Tires	P215/55R17
Sorento	Trim	MY2017 Kia Sorento LX AWD
	VIN	5XYPGDA50HG322316
	Engine	G6DHHS547234 (3.3L GDI 6-Cylinder)
	Transmission	6-speed AT with Sportmatic™
	Tires	P235/65R17
Tucson	Trim	MY2016 Tucson Sport FWD
	VIN	KM8J33A23GU049740
	Engine	G4FJFU353148 (1.6T GDI 4-Cylinder)
	Transmission	7-speed EcoShift® DCT
	Tires	P245/45R19

[On-Cycle Test Result]






Sorento_B.csv: 261.74 Watts
Sorento_C.csv: 226.76 Watts
Sorento_D.csv: 233.98 Watts
Sorento_E.csv: 222.33 Watts
Alternator Power [Watts]
Time


Tucson_B.csv: 229.43 Watts
Tucson_C.csv: 180.56 Watts
Tucson_E.csv: 224.8 Watts
Alternator Power [Watts]
Time

Attachment C: Simulation Results for Hyundai Motor Group vehicles

Sonata (1.6L)	CO_2@0W	CO_2@250W	CO_2@750W	Off-cycle electrical load	Improvement versus baseline	CO_2 reduction per 1% VDA
67%	239.2	245.5	259.3	13.8	baseline	baseline
72%	239	244.8	257.8	13	0.9	0.17
80%	238.7	243.8	255.5	11.7	2.1	0.16

Elantra (2.0L)	CO_2@0W	CO_2@250W	CO_2@750W	Off-cycle electrical load	Improvement versus baseline	CO_2 reduction per 1% VDA
67%	199.3	206.4	219.3	12.9	baseline	baseline
72%	199.2	205.7	217.8	12.1	0.9	0.17
80%	198.9	204.9	216	11.1	1.8	0.14

Santa Fe (2.0L)	CO_2@0W	CO_2@250W	CO_2@750W	Off-cycle electrical load	Improvement versus baseline	CO_2 reduction per 1% VDA
67%	290.1	298.7	315.1	16.5	baseline	baseline
72%	289.8	297.7	313	15.4	1.1	0.22
80%	289.3	296.5	310.4	14	2.5	0.19

Santa Fe (2.4L)	CO_2@0W	CO_2@250W	CO_2@750W	Off-cycle electrical load	Improvement versus baseline	CO_2 reduction per 1% VDA
67%	281	287.5	301.4	13.9	baseline	baseline
72%	280.7	286.7	299.6	12.9	1	0.2
80%	280.3	285.7	297.4	11.7	2.2	0.17

Telluride (3.8L)	CO_2@0W	CO_2@250W	CO_2@750W	Off-cycle electrical load	Improvement versus baseline	CO_2 reduction per 1% VDA
67%	280.6	294.1	307.7	13.6	baseline	baseline
72%	280.3	293.3	306	12.7	0.9	0.19
80%	279.9	292.1	303.8	11.7	2	0.15

Sorento (3.3L)	CO_2@0W	CO_2@250W	CO_2@750W	Off-cycle electrical load	Improvement versus baseline	CO_2 reduction per 1% VDA
67%	323	331.9	347.9	16	baseline	baseline
72%	322.5	330.8	345.9	15.1	0.9	0.19
80%	321.7	329.2	343.1	13.9	2.1	0.16

Tucson (1.6L)	CO_2@0W	CO_2@250W	CO_2@750W	Off-cycle electrical load	Improvement versus baseline	CO_2 reduction per 1% VDA
67%	223.6	232.5	249.1	16.5	baseline	baseline
72%	223.4	231.7	247.4	15.6	0.9	0.18
80%	223.1	230.6	245.1	14.5	2	0.16