Attachment A

General Motors Request for 2010-2013 MY Off-Cycle Greenhouse Gas Credits Based on Alternative Methodologies

Descriptions of Methodologies Used in the Credit Request

High Efficiency Exterior Lights

Definition:

High efficiency exterior lighting means a lighting technology that, when installed on the vehicle, is expected to reduce the total electrical demand of the exterior lighting system when compared to conventional lighting systems.

Credits:

Credits are determined by comparing wattage of new high efficiency exterior lights to the wattage of the baseline lights that are replaced.

System Description:

GM uses bidirectional Xenon high intensity discharge (HID) lamps, which are approximately 30 percent more efficient than standard halogen bulbs. GM also uses light-emitting diode (LED) lamps, which are some of the most energy-efficient lighting sources, using only a small fraction of the electricity of traditional lighting methods.

Methodology:

GM identified uses of LED or Xenon HID lamps in the following components:

- Low beam
- High beam
- Parking/position
- Turn signal, front
- Side marker, front
- Tail
- Turn signal, rear
- Side marker, rear
- License plate

Off cycle credits were assigned for each lighting component that used Xenon HID or LED lights. The credits were based on EPA default credit values for the lighting component based on the calculations from the EPA/NHTSA Joint Technical Support Document (TSD) for the 2017-2025 greenhouse gas and fuel economy regulations.

The fleet credit is calculated based on credit for each type of vehicle, vehicle lifetime miles and U.S. sales volume for each applicable model year.

Active Aerodynamic Improvements (Grille Shutters)

Definition:

Active aerodynamic improvements means technologies that are automatically activated under certain conditions to improve aerodynamic efficiency (e.g., lowering of the coefficient of drag (Cd)) while preserving other vehicle attributes or functions.

Credits:

The credit for active aerodynamic improvements for passenger automobiles shall be calculated using the following equation, and rounded to the nearest 0.1 grams/mile:

Where: Car credit = 19.36 x $CD_{reduced}$

$CD_{reduced}$ is the percent reduction in the coefficient of drag (Cd), shown as a value from 0 to 1. The coefficient of drag shall be determined using good engineering judgment consistent with standard industry test methods and practices.

The credit for active aerodynamic improvements for light trucks shall be calculated using the following equation, and rounded to the nearest 0.1 grams/mile:

Where: Truck credit = 33.159 x $CD_{reduced}$

$CD_{reduced}$ is the percent reduction in the coefficient of drag (Cd), shown as a value from 0 to 1. The coefficient of drag shall be determined using good engineering judgment consistent with standard industry test methods and practices.

System Description:

Aerodynamic drag is reduced by closing electrically-actuated louvers placed in the vehicles' grille openings. The improvement in aerodynamic drag due to closing the shutter system varies approximately with the speed of the vehicle squared, thereby providing off cycle fuel economy benefits since aerodynamic improvement is largest at speeds above those in the city and highway fuel economy tests. The shutters also may assist with engine warm-up -- reducing parasitic losses from cold fluid viscosity effects and assisting windshield defrost performance.

The active shutter system has a variable position control system integrated into the powertrain control module. The strategy determines the shutter opening based on engine cooling requests. This strategy is integrated with the fan control system, determining the powertrain cooling needs based on key inputs such as engine coolant temperature, intake air temperature, ambient temperature, vehicle speed, throttle position, and air conditioner head pressure. The shutters also may be opened under braking events to take advantage of these powertrain cooling opportunities. Under potential snow and ice conditions the shutters are kept partially open to avoid freezing the shutters closed.

Methodology:

- Wind tunnel data collected on prototype vehicle with shutters disabled, then repeated with shutters enabled.
- Determined the aero benefits (counts of Cd).
- Utilized the EPA/NHTSA Joint Technical Support Document performance metric to determine the corresponding benefit in CO_2 reduction associated with the percent improvement for both cars and trucks.

The fleet credit is calculated based on credit for each type of vehicle, vehicle lifetime miles and U.S. sales volume for applicable model years.

Engine Idle Start-Stop

Definitions:

Engine idle start-stop means a technology which enables a vehicle to automatically turn off the engine when the vehicle comes to a rest and restarts the engine when the driver applies pressure to the accelerator or releases the brake. Off-cycle engine start-stop credits will only be allowed for a vehicle if the Administrator has made a determination under the testing and calculation provisions in 40 CFR Part 600 that engine start-stop is the predominant operating mode for that vehicle.

Credits:

The default predetermined passenger automobile credit for engine idle start-stop systems is 2.5 grams per mile, provided that the vehicle is equipped with an electric heater circulation system (or a technology that provides a similar function). For vehicles not equipped with such systems the credit is 1.5 grams per mile.

The default predetermined light truck credit for engine idle start-stop systems is 4.4 grams per mile, provided that the vehicle is equipped with an electric heater circulation system (or a technology that provides a similar function). For vehicles not equipped with such systems the credit is 2.9 grams per mile.

System Description:

GM start-stop systems are an energy conserving technology that shuts off the engine when the vehicle is stopped and idling with the foot on the brake, and automatically re-starts the engine when the driver releases the brake. The GM vehicles included in this credit request include several variations of our two-mode hybrid full-size trucks (Chevrolet Silverado and Tahoe, GMC Sierra and Yukon, and Cadillac Escalade). The request also includes start-stop systems on the eAssist hybrid models of the Buick Lacrosse, Buick Regal and Chevrolet Malibu. In addition, credit is also requested for the start-stop system in the Chevrolet Volt plug-in hybrid vehicle.

With the two-mode hybrid system, there was no deactivation button that allowed the driver to disable the start-stop system. Thus, start-stop was the predominant operating mode, since the start-stop feature was always active, and would always turn the engine off at idle provided that a set of other conditions was met. In limited situations, the control system would keep the gasoline engine on during idle in order to maintain a specific set of parameters such as battery state-of-charge and temperature. However, because these situations are limited, start-stop is the predominate operating mode for these vehicles, and these vehicles meet all the requirements for credit according to the definitions contained in 40 CFR 86.1869-12(b)(4). These vehicles have already been receiving a credit for their electric heater circulation pump based on specific five-cycle testing and a separate EPA approval, so the start-stop credit being requested for the two-mode trucks in the current application is for the 2.9 grams CO_2 per mile that is the default predetermined truck credit without an electric heater circulation pump.

The start-stop system on the eAssist hybrid cars also had no deactivation button that allowed the driver to disable the start-stop system. Thus, start-stop was the predominant operating mode, since the start-stop feature was always active, and would always turn the engine off at idle provided that a set of other conditions was met. In limited situations, the control system would keep the gasoline engine on during idle in order to maintain a specific set of parameters such as battery state-of-charge and temperature. However, because these situations are limited, start-stop is the predominate operating mode for these vehicles, and these vehicles meet all the requirements for credit according to the definitions contained in 40 CFR 86.1869-12(b)(4). These vehicles have already been receiving a credit for their electric heater circulation pump based on specific five-cycle testing and a separate EPA approval, so the start-stop credit being requested for the eAssist cars in the current application is for the 1.5 grams CO_2 per mile that is the default predetermined car credit without an electric heater circulation pump.

The start-stop system on the Chevrolet Volt also has no deactivation button that would allow the driver to disable the start-stop system. Thus, as with the two-mode and eAssist hybrids, since the start-stop feature is always active, and always turns the engine off at idle provided that a set of other conditions is met. In limited situations, the control system keeps the gasoline engine on during idle in order to maintain a specific set of parameters such as battery state-of-charge and temperature. However, because these situations are limited, start-stop is the predominate operating mode for these vehicles, and these vehicles meet all the requirements for credit according to the definitions contained in 40 CFR 86.1869-12(b)(4).

The Volt start-stop system includes an electric heater circulation pump which enables start-stop operation in cold weather, while maintaining cabin heat. In addition, other cabin heating features using electric power are included on the Volt to supply cabin heat when in battery electric-only mode (when the engine coolant may be cold), and these electric heating features contribute to the enabling of start-stop operation to actually shut off the gasoline engine at idle in cold weather. Accordingly, the start-stop credit requested for the Volt is the 2.5 grams CO_2 per mile default credit from the predetermined list for a passenger car with a start-stop system that includes an electric heater circulation pump.

Methodology:

We apply the default credit values from the EPA predetermined credit list for each vehicle equipped with start-stop, as described above. These default values are calculated according to the methodology described in the Joint TSD. The fleet credit is calculated based on the credit for each type of vehicle, vehicle lifetime miles and U.S. sales volume for applicable model years.

Active Engine Warm-Up

Definition:

Active engine warm-up means a system using waste heat from the vehicle, to warm up targeted parts of the engine. This reduces engine friction losses and enables the closed-loop fuel control more quickly allowing for a faster transition from cold operation to warm operation, thereby decreasing CO_2 emissions, and increasing fuel economy.

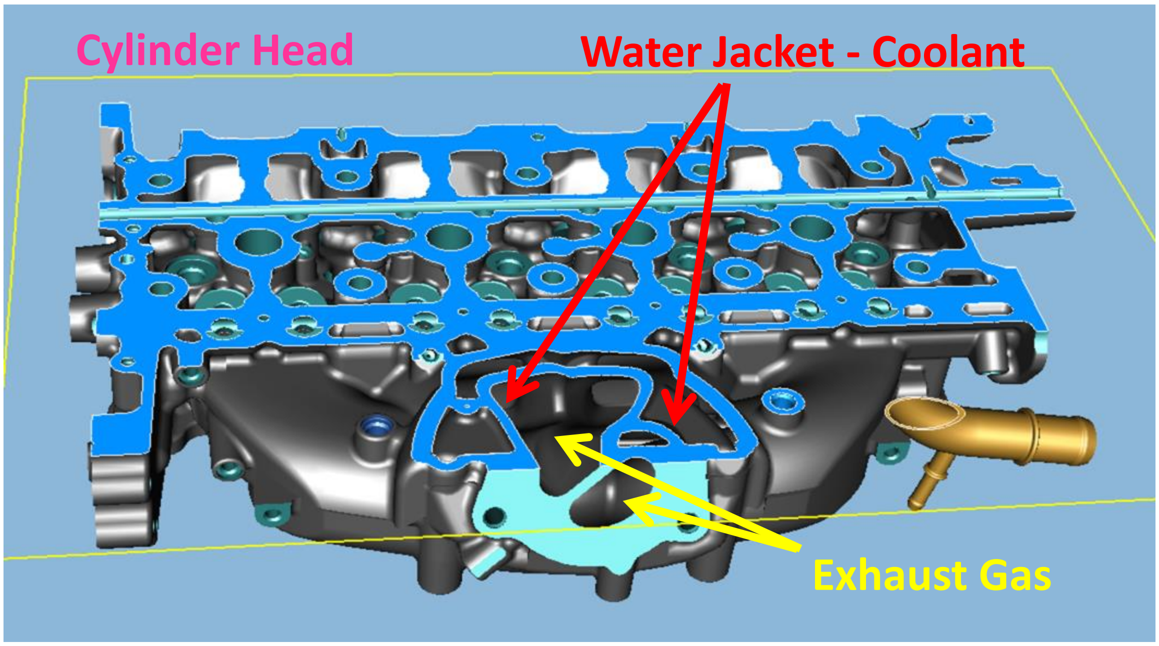
Credits:

The default predetermined passenger automobile credit for active engine warm-up is 1.5 grams per mile.

The default predetermined light truck credit for active engine warm-up is 3.2 grams per mile.

System Description:

An Integrated Exhaust Manifold (IEM) is a technology which incorporates a conventional exhaust manifold and cylinder head into a single component. The integrated exhaust manifold features internal cooling jackets which surround the exhaust port runners. Waste exhaust heat is captured and transferred to the coolant and circulated back through the cooling circuit to accelerate engine warm-up time.



Integrated Exhaust Manifold

Due to higher cold-start exhaust temperatures and faster catalyst warm-up, IEMs enable reduced operation in the less efficient modes used for initial catalyst light-up. In addition, with more heat rejection into the coolant, engine warm-up is accelerated. This reduces total frictional losses and assists the climate control system in heating and defrosting situations.

Methodology:

We apply the default credit values from the EPA predetermined credit list, as shown above, for each vehicle equipped with an IEM, which affords active engine warm-up. These default values are calculated according to the methodology described in the Joint TSD. The fleet credit is calculated based on the credit for each type of vehicle, vehicle lifetime miles and U.S. sales volume for applicable model years.

Active Seat Ventilation

Definition:

Active seat ventilation, a device which draws air, forces air or transfers heat from the seating surface which is in contact with the occupant and exhausts it to a location away from the seat. At a minimum, the front driver and passenger seat must utilize this technology for a vehicle to be eligible for credit.

Credit:

The default predetermined passenger automobile credit for active seat ventilation is 1.0 grams per mile.

The default predetermined light truck credit for active seat ventilation is 1.3 grams per mile.

System Description:

Active occupant cooling is achieved by incorporating two thermoelectric modules, one in the cushion and the other in the lumbar region of the seat. Each module is comprised of a thermal electric chiller and the air distribution system matched to the seat foam and trim. The blower draws cabin air and forces the air across the thermal electric chiller exchanger. The air travels through the distribution layer across the lower side of the seat and then uses passages in the foam to bring the cooled air to the surface of the seat. The seat trim is also perforated to allow the air to reach the seat occupant, providing supplemental thermal comfort, thus reducing HVAC load. The technology is used in both the driver and front passenger seats.

Methodology:

Per the methodology described in the Joint TSD regarding credit determination, we apply the pre-defined credit listed above for each vehicle with active seat ventilation in both the driver and front passenger seats. The fleet credit is then calculated based on credit for each type of vehicle (car or truck), vehicle lifetime miles and U.S. sales.

Thermal Control Glass or Glazing

Definition:

Glass or glazing technologies which can reduce the amount of solar heat gain in the cabin by reflecting or absorbing some of the infrared solar energy. One measure of solar load-reducing potential for glazing is Total Solar Transmittance, or Tts, which expresses the percentage of solar energy which passes through the glazing.

Credits:

For this application, GM uses the formulae for credit determination established in the Joint Technical Support Document (TSD). Credits are calculated based on the Total Solar Transmittance (Tts) and Daylight Opening Area (DOA) of each piece of glass. The maximum passenger automobile credit is limited to 2.9 grams CO_2 per mile and the maximum light truck credit is limited to 3.9 grams CO_2 per mile.

System Description:

Glass applications are designed in accordance with FMVSS and ANSI glazing standards for passenger cars, SUV and trucks. General Motors specifies solar absorbing technology for thermal management in all window glass applications in the U.S.

Methodology:

Tts values are provided by glass suppliers. Values are based on ISO 13837.

Credits due to solar management glass for each application are calculated based on glass locations, glass Ttsbase and Ttsnew and total glass area G for each location. Glass area, G, for each location represents the daylight opening area (DLO) vs total glass area. Glass or glazing credits are calculated using the following equation, and rounded to the nearest 0.1 grams per mile:

$$\text{Credit} = \left[Z \times \sum_{i=1}^{n} \frac{T_i \times G_i}{G} \right]$$

Where: Credit = the total glass or glazing credits in grams per mile rounded to the nearest 0.1 grams/mile. The credit may not exceed 2.9 g/mi for passenger automobiles or 3.9 g/mi for light trucks:

Z = 0.3 for passenger automobiles and 0.4 for light trucks

Gi = the measured glass area of window i. in square meters and rounded to the nearest tenth

G = total glass area of the vehicle, in square meters and rounded to the nearest tenth.

Ti = the estimated temperature reduction for the glass area of window i. determined using the following formula:

$$Ti = 0.3987 \times (Ttsbase - Ttsnew)$$

Where: Ttsnew = the total solar transmittance of the glass. Measured according to ISO 13837, “Safety glazing materials – Method for determination of solar transmittance”

Ttsbase = 62 for the windshield, side-front, side-rear, rear-quarter, and backlite locations. Ttsbase = 40 for rooflite locations.

EPA considers the baseline Ttsbase to be 62% for all glazing locations except for rooflites and rear side glazings of CUV’s, SUV’s, and minivans, which have a baseline Tts of 40%.

The fleet credit is calculated based on credit for each type of vehicle, vehicle lifetime miles and U.S. sales volume for applicable model years.

Solar Reflective Surface Coatings

Definition:

Solar reflective surface coating means a vehicle paint or other surface coating which reflects impinging infrared solar energy, as determined using ASTM standards E903, E1918–06, or C1549–09. The coating must be applied at a minimum to all of the approximately horizontal surfaces of the vehicle that border the passenger and luggage compartments of the vehicle, (e.g., the rear deck lid and the cabin roof).

Credit:

A passenger car with solar reflective paint Total Solar Energy Rejection (TSER) rating of 59% or higher qualifies for an off cycle credit of 0.35 grams CO_2 per mile.

Passenger cars with TSER ratings below 59% are given credits based on a declining formula:

$$\text{Car Credit} = 0.35 \text{ grams } CO_2\text{/mile} \times (TSER/59\%)$$

A light truck with solar reflective paint Total Solar Energy Rejection (TSER) rating of 59% or higher qualifies for an off cycle credit of 0.4 grams CO_2 per mile.

Light trucks with TSER ratings below 59% are given credits based on a declining formula:

$$\text{Truck Credit} = 0.4 \text{ grams } CO_2\text{/mile} \times (TSER/59\%)$$

System Description:

TSER ratings based on appropriate ASTM standards were obtained from paint suppliers for all General Motors surface coatings for each model year. These typically vary from product to product and from assembly plant to assembly plant due to factors such as the coating application processes in various facilities, undercoatings, etc. Each color from the GM paint palette in each model year was assigned a specific TSER rating based on the supplier data. In cases where the same color had varying TSER ratings at different facilities, the worst case TSER reflectivity rating was used for all applications of that color. This was done to simply the data processing. Convertibles were excluded from receiving solar reflective surface coating credits in this petition.

Methodology:

General Motors uses in this petition the credit methodology from FCA's approved request for 2009-2013 model year off cycle credits. As stated previously, EPA deemed this methodology to be "sound and appropriate". This methodology is based on the research published by John P. Rugh, Lawrence Chaney and Jason Lustbader of NREL (see attached SAE 2007-01-1194, "Reduction in Vehicle Temperature and Fuel Use from Cabin Ventilation, Solar-Reflective Paint and a New Solar-Reflective Glazing"), supported by a "cool car" study by the California Energy Commission. The NREL study used a solar reflective film with a TSER rating of 59% installed on the roof of a typical vehicle. This film lowered the average vehicle cabin air breath temperature by 1.2^{o} C. NREL also calculated a 2.2% air conditioner fuel consumption reduction for each degree Celsius reduction in cabin temperature. Combining the reduction in breath temperature of 1.2^{o} C with the air conditioner fuel consumption reduction of $2.2\%/^{o}$ C (and the EPA national average air conditioner greenhouse gas impact of 13.2 grams CO_2 per mile) yields a passenger car credit of 0.35 grams CO2 per mile for a paint with 59% TSER, according to the following formulae:

$$1.2^{o}\ C \times 2.2\%/^{o}\ C = 2.64\% \text{ air conditioner fuel consumption reduction}$$

$$13.2\ gCO_2/\text{mile} \times 2.64\% = 0.35 \text{ grams } CO_2 \text{ per mile}$$

Similar calculations were performed by FCA for light trucks, using the EPA estimate of 15.2 grams CO_2 per mile for average light truck air conditioner fuel consumption, resulting in a credit of 0.4 grams CO_2 per mile for trucks with a paint TSER of 59%:

$$15.2\ gCO_2/\text{mile} \times 2.64\% = 0.40 \text{ grams } CO_2 \text{ per mile}$$

Both of these car and truck credit calculations based on the NREL experiments with 59% TSER film where then used to construct formulae for credits for coatings with solar reflectivity ratings below 59%, as shown above. No credits were calculated or applied for paints with TSER ratings of 10% or lower.

FCA cited similar research by the California Energy Commission to bolster the NREL findings. The CEC study used a 58% solar reflective paint (compared to NREL's 59%)

and determined a relationship whereby each 1^{o}C cabin temperature reduction resulted in 2.3% lower compressor load (compared to NREL's 2.4% lower MAC fuel consumption).

The fleet credit is calculated based on credit for each type of vehicle, vehicle lifetime miles and U.S. sales volume for applicable model years.