



# **Greenhouse Gas (GHG) Emission Requirements Heavy-Duty Engines**

Industry/EPA Workshop

Compliance Division

Washtenaw Community College

November 3, 2011



# Organization of Topics

<b>Topics</b>	<b>Slide Numbers</b>
Overview	3
Standards	4-12
Application for Certification	13-20
Credits	21-30
Reporting	31-34
Additional Information Sources	35-36
Appendix	37-47



# Applicability for Heavy-Duty Engines

1036.1, 1036.5, 1036.150(d), 1036.801

- Applicable to 2014 and later model year new heavy-duty CI engines and 2016 and later model year new heavy-duty SI engines
  - Specifically regulates emissions of carbon dioxide, nitrous oxide, and methane
- Excluded Engines are:
  - Engines used in medium-duty passenger vehicles
  - Engines that do not provide motive power
  - Aircraft engines
  - Engines that are not internal combustion engines, such as fuel cells
  - Engines in heavy-duty vehicles that are subject to light-duty GHG standards
  - Vehicles subject to light-duty greenhouse gas standards of 40 CFR part 86
  - Engines produced by small manufacturers qualifying under Small Business Administration regulations at 13 CFR 121
    - NAICS 333618 - manufacturing internal combustion engines (except automotive gasoline and aircraft) = 1,000 employees
    - NAICS 336312 - manufacturing and/or rebuilding gasoline motor vehicle engines = 750 employees



# **GHG STANDARDS**



# Heavy-Duty Engine Cycle Classification

## 1036.150(c)

- The GHG standards depend on the engine cycle classification per the definitions in 1036.801
  - Spark-ignition means relating to a gasoline-fueled engine or any other type of engine with a spark plug (or other sparking device) and with operating characteristics significantly similar to the theoretical Otto combustion cycle. Spark-ignition engines usually use a throttle to regulate intake air flow to control power during normal operation.
  - Compression-ignition means relating to a type of reciprocating, internal-combustion engine that is not a spark-ignition engine.
- Engines which meet the definition of spark-ignition per 1036.801, but are regulated as diesel engines under 40 CFR part 86 (for criteria pollutants) then are treated as compression-ignition engines for GHG standards.
- Engines which meet the definition of compression-ignition per 1036.801, but are regulated as Otto-cycle engines under 40 CFR part 86 then are treated as spark-ignition engines for GHG standards.



# Spark-Ignition Engine GHG Standards

1036.108

- The spark-ignition engine GHG emissions standards begin in 2016MY
- The GHG emissions for SI engines are evaluated over the Heavy-Duty Engine FTP cycle

Spark-Ignition Engines (g/hp-hr):

Model Year	CO2 Emissions	CH4 Emissions	N2O Emissions
2016 and Later	627	0.10	0.10

# Optional HD Chassis-Certification Path

## Loose Engine Provision

### 1037.150(m)

		Loose engines (for any HD vehicle class)
Spark-ignition	Criteria	<b>E</b>
	GHG	<b>C</b> (surrogate) or <b>E</b>
Diesel	Criteria	<b>E</b>
	GHG	

**E** = engine-certified (g/hp-hr) for criteria pollutants and treated as a vocational vehicle for GHG with separate engine certification (g/hp-hr) and vehicle certification with GEM (g/ton-mile)

**C** = chassis-certified (g/mile)

**C** OR **E** = manufacturer can choose between chassis-certification and engine-certification

- Spark Ignition and Diesel vehicles must engine certify for criteria emissions
- Diesel vehicles must:
  - Certify as a vocational vehicle for GHG emissions with separate engine certification and vehicle certification
- Spark ignition vehicles may choose to either:
  - Chassis certify for GHG emissions using the highest ETW vehicle powered by the engine as a surrogate GHG result (with maximum of 15,000 engines or 10% of total HD engine production of the family) –or –
  - Certify as a vocational vehicle for GHG emissions with separate engine certification and vehicle certification



# CI Engine Certification Pathways

- There are four options that a manufacturer may select to certify HD CI engines:
  1. Early Certification for 2013 MY per 1036.150(a), except prohibited if select Option #3 below
  2. Primary Standards and Phase-In per 1036.108
  3. Alternate Phase-In per 1036.150(e)
  4. Alternate Standards per 1036.620





# Primary CI Engine CO2 Standards

1036.108

- The compression-ignition engine CO2 emissions standards are based on:
  - GVWR of the vehicle for which the engine is primarily designed – 1036.140
  - Whether the engine is designed for installation in a vocational vehicle or combination tractor
- The CO2 emissions for vocational engines are measured over the Heavy-Duty Engine FTP cycle
- The CO2 emissions for tractor engines are measured over the Heavy-Duty Engine SET cycle

Compression-Ignition Engines (g/hp-hr):

Model Years	Light Heavy-Duty	Medium Heavy-Duty – Vocational	Heavy Heavy-Duty – Vocational	Medium Heavy-Duty – Tractor	Heavy Heavy-Duty – Tractor
2014-2016	600	600	567	502	475
2017 and later	576	576	555	487	460



# Alternate Phase-In CI Engine CO2 Standards

## 1036.150(e)

- This provision allows a manufacturer to align the GHG emissions development with the OBD schedule.
- Must certify all 2013MY engines within a given primary intended service class to the alternate phase-in standards
- The alternate phase-in standards are applicable for 2013 through 2016 model years. If a manufacturer wants to select this pathway, then the engines must be certified in 2013 MY and continue through 2016 MY to the alternate phase-in standards. Once this path is selected, manufacturer cannot choose to opt out of these standards.
- No early credits can be earned on engines certified to this alternate phase-in

### Alternate Phase-In CI Engine Standards (g/hp-hr):

Tractors	LHD Engines	MHD Engines	HHD Engines
Model Years 2013-2015	NA	512 g/hp-hr	485 g/hp-hr
Model Years 2016 and later <sup>a</sup>	NA	487 g/hp-hr	460 g/hp-hr
Vocational	LHD Engines	MHD Engines	HHD Engines
Model Years 2013-2015	618 g/hp-hr	618 g/hp-hr	577 g/hp-hr
Model Years 2016 and later <sup>a</sup>	576 g/hp-hr	576 g/hp-hr	555 g/hp-hr



# Alternate CI Engine CO2 Standards

1036.620

- Available in 2014, 2015, and 2016 MYs only
- Available for averaging sets that do not have a balance of credits, which include the following:
  - Banked credits earned in the averaging set from previous model years
  - Early credits earned in the averaging set
  - Innovative credits earned in the averaging set
  - Advanced Technology credits earned in the averaging set
  - Advanced Technology credits earned outside the averaging set, up to 60,000 Mg per year
- The Alternate CI standards are:
  - LHD and MHD vocational engines =  $0.975 * \text{Adjusted CO}_2 \text{ Emissions from 2011 MY}$
  - HHD vocational engines =  $0.970 * \text{Adjusted CO}_2 \text{ Emissions from 2011 MY}$
  - MHD and HHD tractor engines =  $0.970 * \text{Adjusted CO}_2 \text{ Emissions from 2011 MY}$



# CI Engine N<sub>2</sub>O and CH<sub>4</sub> Standards

1036.108

- The N<sub>2</sub>O and CH<sub>4</sub> emissions for all CI engines are measured over the Heavy-Duty Engine FTP cycle

Compression-Ignition Engines (g/hp-hr):

Model Years	CH <sub>4</sub> Emissions	N <sub>2</sub> O Emissions
2014 and Later	0.10	0.10



# CERTIFICATION



# GHG Certification/Compliance Timeline

- Prior to the beginning of model year (as early as possible):
  - Complete application package, including filling out template and submitting additional support documents
  - If all regulatory requirements are satisfied, EPA will issue a certificate of conformity which allows your engine to be entered into US commerce
- 90 days after end of model year:
  - Submit report including production volumes of engine families
- 270 days after end of model year:
  - Submit final report

Application for Certification Templates for input and attaching documents, and End of Model Year Report Templates will be available at [www.epa.gov/otaq/certdat2.htm](http://www.epa.gov/otaq/certdat2.htm)



# Application for Certification 1036.205

On-highway Engine and Greenhouse Gas Certification Template

Test	Suppl. test	<b>GHG</b>	Models	Parts	Te
------	-------------	------------	--------	-------	----



# Engine Family

1036.230, 86.001-24, 1036.150(f)

- Families are defined by:
  - Engine families used for criteria pollutants under 40 CFR part 86
  - Hybrid engines cannot be included in the same engine family as conventional engines
  - An engine family with both vocational and tractor engines must be split into two separate subfamilies
    - If instead these engines are certified as two separate families, then the families are treated as one for determining OBD requirements and in-use testing
  - Each configuration within a family must use equivalent GHG emissions controls
- May combine engines used in vehicles under 14,000 GVWR which are certified separately from non-OBD engines into a single engine family





# Engine FCL and FEL

1036.108 (b)

- The Family Certification Level (FCL) is equal to or greater than the certified emission level for the family
  - FCLs are used to determine credits
  - A FCL is the standard for certification and confirmatory testing
- The Family Emission Limit (FEL) is equal to the FCL multiplied by 1.03
  - A FEL is the standard for selective enforcement audits and in-use testing



# GHG Certification

1036.235, 1036.241, 1036.150(b), 1036.530

- GHG testing:
  - A single emission-data engine from each family is selected
  - The configuration must represent at least one percent of total actual US directed production volume for the engine family (verified at end of year)- 1036.205(e)
  - The GHG standards only apply to this tested configuration
  - May show compliance with the N2O standards with engineering analysis in 2014 MY and earlier
  - Do not apply infrequent regeneration adjustment factors to the GHG results
  - Adjust the CO2 emission rates for the measured test fuel properties per 1036.530(b)
- Demonstrating Compliance:
  - FCLs are considered to be the applicable emission standard with which you must comply for certification.
  - The engine family is considered in compliance with the standards if all emission-data engines representing the tested configurations have official test results and deteriorated emission levels at or below the standards



# Deterioration Factor

1036.150(g), 1036.241

- May use an assigned additive DF of 0.0 g/hp-hr for CO<sub>2</sub> emissions if the engine does not include innovative or advanced technologies.
  - May use DF of 0.0 g/hp-hr for CO<sub>2</sub> emissions of engines with innovative or advanced technologies if we determine that it is consistent with good engineering judgment
- May use an assigned additive DF of 0.02 g/hp-hr for N<sub>2</sub>O and for CH<sub>4</sub> emissions from any engine.
- If an assigned deterioration factor is not used, you may apply an additive or multiplicative factor.
  - If a sawtooth deterioration pattern is indicated, then follow the procedures in 1036.241(c)(3)
- Please note that assigned DF values removes the burden of developing the DF for a given engine. However, it does not remove the manufacturer's responsibility for the engine to meet the FEL in-use.



# Warranty and Maintenance

## 1036.115

- Warranty and Maintenance requirements of 40 CFR part 86 apply to GHG standards



# CREDITS



# CO2 Credits

Sum of six independent calculations (calculated separately for each averaging set) = total credits in a model year

1. Averaging, Banking, and Trading – 1036.701, 1036.705
  - Credits cannot be generated for tractor engines installed in vocational vehicles – 1036.705(b)(4)
2. Early Credits – 1036.150(a)
3. Innovative Technology Credits – 1036.610
4. Advanced Technology Credits – 1036.615
5. CO2 credits to show compliance with CH4 and/or N2O standards – 1036.705(d)
6. Low N2O emissions credits - 1036.150(i)

Credits are rounded to the nearest whole megagrams (Mg) after the intermediate calculations



## Subcategory

Standards are based on Subcategory

### 4 Engine Subcategories

- Light Heavy-Duty CI Engines (Cl. 2b-5)
- Medium Heavy-Duty CI Engines (Cl. 6-7)
- Heavy Heavy-Duty CI Engines (Cl. 8)
- Spark Ignited Engines

## Averaging Set

ABT, Early, N2O, and Innovative Credits must stay within an Averaging Set

### 4 Engine Averaging Sets

- Light Heavy-Duty CI Engines (Cl. 2b-5)
- Medium Heavy-Duty CI Engines (Cl. 6-7)
- Heavy Heavy-Duty CI Engines (Cl. 8)
- Spark Ignited Engines

## Service Class

Advanced Technology credits may move among averaging sets, but moves from one service class to another are restricted to 60,000 Mg per model year

### 3 Service Classes

- SI Engines, Light Heavy –Duty Vehicles and CI Engines (Cl. 2b-5)
- Medium Heavy-Duty Vehicles and CI Engines (Cl. 6-7)
- Heavy Heavy-Duty Vehicles and CI Engines (Cl. 8)



# GHG Credit Programs

## Early Credits – 1036.150 (a):

- 2013 MY only
- Must either certify:
  - Entire averaging set
  - or-
  - For an individual CI engine family may generate credit based on an improvement in CO2 emissions between 2012 MY and 2013 MY
- 1.5x multiplier

## Restrictions:

- Credits stay in averaging set – 1036.740(a)
- 5 year credit life - 1036.740(d)
- Only a single 1.5x multiplier may be used for early credits which are also eligible for Advanced Technology Credits - 1036.150(h)

## Innovative Technology Credits – 1036.610:

- Vehicle or engine technology which is not captured on the engine test and not in common use in 2010 MY HD engines
- Preapproval of test method required
- No multiplier

## Restrictions:

- Credits stay in averaging set – 1036.740(a)
- 5 year credit life - 1036.740(d)

## Advanced Technology Credits – 1036.615:

- Engines with Rankine cycle and hybrid powertrains
- Only a single certifier (either of the engine or the vehicle) may establish credits for an advanced technology
- 1.5x multiplier – 1036.150(h)

## Restrictions:

- Credits can go into any averaging set, except only 60,000 Mg CO2 credits can come into a service class from another service class per model year - 1036.740(c)
- 5 year credit life – 1036.740(d)





## GHG Credit Programs (cont.)

### CO2 Credits to Offset CH4 and/or N2O

#### FEL – 1036.705(d):

- Calculate the CH4 and/or N2O emission credits needed (negative credits) using the equation:

$$\text{Emission credits (Mg)} = (\text{Std} - \text{FEL}) \cdot (\text{CF}) \cdot (\text{Volume}) \cdot (\text{UL}) \cdot (10^{-6})$$

- Use 25 Mg of positive CO2 credits to offset 1 Mg of negative CH4 credits.
- Use 298 Mg of positive CO2 credits to offset 1 Mg of negative N2O credits.

#### Restrictions:

- CO2 Credits must come from averaging set – 1036.740(a)

### CO2 Credits for Low N2O – 1036.150(i):

- May earn CO2 credits for N2O FELs less than 0.04 g/hp-hr

- $\text{CO2 credits} = (0.04 - \text{N2O FEL}) \cdot \text{CF} \cdot \text{Volume} \cdot \text{Useful Life} \cdot 10^{-6} \cdot 298$

#### Restrictions:

- 2014, 2015, 2016 MYs only
- Credits stay in averaging set – 1036.740(a)
- 5 year credit life - 1036.740(d)



# Advanced Technology Demonstration

1036.525, 1036.615, 1037.510, 1037.525, 1037.550, 1066

- Engine testing
  - Follow the procedures in 1036.525
- Chassis testing
  - Refer to procedures in 1037.510, including the weighting factors for the duty cycles
  - Provisions for vehicles with a power take-off (PTO) are included in 1037.525
- Powerpack testing
  - Refer to procedures in 1037.550



# Innovative Technology Credits

1036.610

- Credits for CO<sub>2</sub>-reducing technologies where CO<sub>2</sub> reduction is not captured in the test procedures, e.g., off-cycle
- Subject to EPA approval, technology must:
  - not be in common use with HD engines prior to 2010 MY
  - not be reflected in engine test cycles (HD FTP and SET)
  - be effective for full useful life and deterioration – if any – must be accounted for
- Process
  - A to B testing of engines or vehicles differing only with respect to the innovative technology is recommended
    - Calculate either an improvement factor or separate credit
  - Test procedure must be robust and verifiable and approved by EPA
  - May be subject to notice and comment through Federal Register notice



# Credit Banking

1036.715

- Credits are earned at the end of the model year and maintained and reported separately
- Total credits in each category is the sum of:
  - ABT credits
  - Optional credits (Early, Innovative, Advanced Technology, N<sub>2</sub>O, and CH<sub>4</sub>/N<sub>2</sub>O compliance)
- Credits may be banked for five years after model year in which they were earned
  - Example: Credits earned in 2014 may be used in any of the 2015 through 2019 model years. Credits remaining unused at end of 2019 must expire.
- Banked credits retain the designation of the averaging set in which they were generated, unless they are an Advanced Technology credit



# Credit Trading

1036.720

- Credits may be traded to another manufacturer (or any other party)
  - Annual report must provide details of transfers
  - Trades must involve credits that are available (either generated or purchased by the trader) and must not result in a deficit
  - Traded credits retain the designation of averaging set in which they were generated
- Important! If a manufacturer generates credits, they must use those credits to offset any existing deficit before considering banking or trading



# Credit Deficits

1036.745

- Like credits, earned at the end of the model year and maintained and reported
- Deficits may be carried forward into the three model years after the year generated
  - Example: A deficit accrued in MY2014 may be carried forward through MY2017. If not offset by end of MY2017 then penalties may apply.
- May only apply surplus credits to the deficit
- May be carried forward only after all banked credits are used up
- Certificates may be voided *ab initio* if a deficit is not offset – by credits generated or purchased – by the required model year



# REPORTING



# Compliance Information

- EPA is committed to both protecting CBI and to achieving transparency in implementation of the GHG program
- EPA currently publishes:
  - Compliance Report
  - Certification data (certification testing summary)
- EPA does not consider emissions data to be CBI
- For GHG, EPA intends to publish as much non-CBI information for each manufacturer after the end of the model year possible





# End of Year and ABT Reports

## 1036.250, 1036.730

- The end of year report must be submitted within 90 days after the end of the model year and include the following information:
  - Report production volumes of total U.S. directed production by serial number and engine configuration
  - A final report must be sent within 270 days
- End of Year and Final Reports for engine families that participate in ABT must include the following information:
  - Engine family designation and averaging set
  - Emission standards for the engine family
  - CO2 FCL
  - Production volumes of total U.S. directed production by serial number and engine configuration
  - Transient cycle conversion factor for each engine configuration
  - Useful life
  - Credits or debits for the engine family
  - Resultant credit/debit balance



# End of Year Report Credit Summary

Example End of Year Report - Banking and Trading Credits Summary

Engine Family	Model Year	Applicable Standard (g/hp-hr)	Manufacturer CO2 FCL (g/hp-hr)	U.S. Production Volume	Credit (Deficit) (Mg)	Low N2O Credits (Mg)	CO2 Credits used for CH4 or N2O Compliance (Mg)	Early Credits (Mg)	Innovative Technology Credits (Mg)	Credit Balance Restricted to Averaging Set (Mg)	Advanced Technology Credits (Mg)	Credit Balance Available to Other Averaging Sets (Mg)	Date Credits Were Earned	Comments
XXX	2014	475	470	1000	14,138	0	0	0	5,000	19,138	0	0	12/31/2014	
YYY	2014	567	567	5000	0	0	0	0	8,000	8,000	0	0	12/31/2014	
ZZZ	2014	475	472	10000	84,825	0	0	0	12,000	96,825	10,000	10,000	12/31/2014	



## Future Guidance

- EPA will issue guidance on future subjects when and if necessary.



## For More Information:

- A copy of this presentation will be available at [www.epa.gov/otaq/climate/regulations.htm](http://www.epa.gov/otaq/climate/regulations.htm)
- See GHG rulemaking documents at [www.epa.gov/otaq/climate/regulations.htm](http://www.epa.gov/otaq/climate/regulations.htm)
- See Federal Register 76 FR 57106, September 15, 2011
- See Code of Federal Regulations, 40 CFR Part 1036
- Contact your EPA team member



# APPENDIX



# Small Manufacturer Provisions

## 1036.150(d)

- Manufacturers meeting the small business criteria specified in 13 CFR 121.201 for “Gasoline Engine and Engine Parts Manufacturing” or “Other Engine Equipment Manufacturers” are not subject to the greenhouse gas standards
- Qualifying manufacturers must notify the Designated Compliance Officer each model year before introducing these excluded vehicles into U.S. commerce. This notification must include a description of the manufacturer’s qualification as a small business under 13 CFR 121.201.
- Excluded engines must include a label with the following statement: “THIS ENGINE IS EXCLUDED UNDER 40 CFR 1036.150(d).”



# Useful Life

1036.108(d)

- CO2 standards are full useful life standards
- Useful life values are those applicable to criteria pollutant standards in 40 CFR part 86:
  - For engines primarily intended for vehicles with a GVWR at or below 19,500 pounds: 10 years/110,000 miles
  - For engines primarily intended for vehicles with a GVWR greater than 19,500 pounds and less than or equal to 33,000 pounds: 10 years/185,000 miles
  - For engines primarily intended for vehicles with a GVWR above 33,000 pounds: 10 years/435,000 miles



# In-Use GHG Standards

## 1036.108(e)

- The FEL serves as the emission standard for the engine family for all testing other than certification and confirmatory





# Penalties & Non-compliance

- In-use Compliance
  - Where we find higher in-use FELs than the certified level, you must forfeit CO<sub>2</sub> emission credits based on the difference between the in-use FEL and the otherwise applicable FEL. - 1036.625
    - Calculate the amount of credits to be forfeited using the applicable equation in §1036.705, by substituting the otherwise applicable FEL for the standard and the in-use FEL for the otherwise applicable FEL
- End-of-year CO<sub>2</sub> Credit Deficits -1036.745
  - The certificate for an engine family for which you do not have sufficient CO<sub>2</sub> credits may be voided *ab initio* if you do not remedy the deficit within three model years. We will void the certificate only with respect to the number of engines needed to reach the amount of the net deficit.
- Penalties are discussed in the preamble at 76 FR 57290, September 15, 2011
- Certification and enforcement provisions of 1036.750 also apply
  - Must meet in-use standards, keep records, send reports and information, etc.



# Defeat Devices

- The CAA 203 (Title 42, Chapter 85, Subchapter II, Part A, Section 7522(a)(3)(B) includes a provision which prohibits defeat devices
  - “...for any person to manufacture or sell, or offer to sell, or install, any part or component intended for use with, or as part of, any motor vehicle or motor vehicle engine, where a principal effect of the part or component is to bypass, defeat, or render inoperative any device or element of design installed on or in a motor vehicle or motor vehicle engine in compliance with regulations under this subchapter, and where the person knows or should know that such part or component is being offered for sale or installed for such use or put to such use; ...”
- Preamble reads as follows (76 FR 57267, September 15, 2011):
  - “Manufacturers are further required to attest that their auxiliary emission control devices are not “defeat-devices,” which are intentionally targeted at reducing emission control effectiveness.”



# Running Change Requirements 1036.225

- Must amend an application before:
  - Add an engine configuration to an engine family
  - Change an engine configuration already included in an engine family in a way that may affect emissions or change components described in the application
  - Modify a FCL and FEL for an engine family
- Send relevant information to the Designated Compliance Officer



# Warranty, Defect Reports & Recall

CAA section 207(a); 1037.15; 1037.120; 1037.601; 1068.501

- **Defect Warranty:**
  - Applies to emission-related parts, components, systems, software or elements of design which must function properly to assure continued compliance with GHG requirements.
  - Applies to emission-related components, systems, software or elements of design used to obtain credits for advanced technology vehicles, off-cycle technologies and early credits.
- **Defect Reporting & Voluntary Emission-Related Recall Reporting Requirements:**
  - Applies to emission-related parts, components, systems, software or elements of design which must function properly to assure continued compliance with GHG requirements.
  - Applies to emission-related components, systems, software or elements of design used to obtain credits for advanced technology vehicles, off-cycle technologies and early credits.
- **Recall:**
  - Applies to emission-related components, systems, software or elements of design which must function properly to assure compliance with GHG requirements.



# ABT Example

$$\text{Emission credits (Mg)} = (\text{Std-FCL}) \times (\text{CF}) \times (\text{Volume}) \times (\text{UL}) \times (10^{-6})$$

Where:

Std = the emission standard associated with the engine subcategory (g/hp-hr).

FCL = the family certification level for the engine family (g/hp-hr).

CF = cycle conversion factor, which is total integrated horsepower-hour over the duty cycle divided by 6.3 miles for SI engines and 6.5 miles for CI engines.

Volume = U.S.-directed production volume of the engine family.

UL = useful life of the vehicle (435,000 miles for HHD, 185,000 miles for MHD, and 110,000 miles for LHD).

An example:

The 2014MY HHD CI tractor engine standard is 475 g/hp-hr. A manufacturer produces 1,000 engines in one family within this averaging set with a FCL of 474 g/hp-hr during the 2014 model year.

The manufacturer also produces 1,500 engines in a second family within this averaging set with a FCL of 473 g/hp-hr during the 2014 model year. Lastly, the manufacturer produces 1,000 engines in another family within this averaging set with FCL of 476 g/hp-hr during the 2014 model year.

$$\text{Family \#1 Emission credits} = (475 - 474 \text{ g/hp-hr}) \times (6.5 \text{ miles}) \times (1,000 \text{ engines}) \times (435,000 \text{ miles}) \times (10^{-6}) = 2,827.5 \text{ Mg}$$

$$\text{Family \#2 Emission credits} = (475 - 473 \text{ g/hp-hr}) \times (6.5 \text{ miles}) \times (1,500 \text{ engines}) \times (435,000 \text{ miles}) \times (10^{-6}) = 8,482.5 \text{ Mg}$$

$$\text{Family \#3 Emission credits} = (475 - 476 \text{ g/hp-hr}) \times (6.5 \text{ miles}) \times (1,000 \text{ engines}) \times (435,000 \text{ miles}) \times (10^{-6}) = -2,827.5 \text{ Mg}$$

$$\text{Total Emission credits} = 2,827.5 + 8,482.5 + -2,827.5 \text{ Mg} = 8,483 \text{ Mg}$$



# Early Credits Example

## Entire Averaging Set

$$\text{Emission credits (Mg)} = (\text{Std-FCL}) \times (\text{CF}) \times (\text{Volume}) \times (\text{UL}) \times (10^{-6}) \times 1.5$$

Where:

Std = the emission standard associated with the engine subcategory (g/hp-hr).

FCL = the family certification level for the engine family (g/hp-hr).

CF = cycle conversion factor, which is total integrated horsepower-hour over the duty cycle divided by 6.3 miles for SI engines and 6.5 miles for CI engines.

Volume = U.S.-directed production volume of the engine family.

UL = useful life of the vehicle (435,000 miles for HHD, 185,000 miles for MHD, and 110,000 miles for LHD).

An example:

The 2013 MY HHD CI tractor engine standard is 475 g/hp-hr. A manufacturer produces 1,000 engines in one family within this averaging set with a FCL of 474 g/hp-hr during the 2013 model year. The manufacturer also produces 1,500 engines in a second family within this averaging set with a FCL of 473 g/hp-hr during the 2013 model year.

$$\text{Family \#1 Emission credits} = (475 - 474 \text{ g/hp-hr}) \times (6.5 \text{ miles}) \times (1,000 \text{ engines}) \times (435,000 \text{ miles}) \times (10^{-6}) \times 1.5 = 4,241.25 \text{ Mg of credits}$$

$$\text{Family \#2 Emission credits} = (475 - 473 \text{ g/hp-hr}) \times (6.5 \text{ miles}) \times (1,500 \text{ engines}) \times (435,000 \text{ miles}) \times (10^{-6}) \times 1.5 = 12,273.75 \text{ Mg of credits}$$

$$\text{Total Emission credits} = 4,241.25 + 12,273.75 \text{ Mg} = 16,965 \text{ Mg}$$



# Advanced Technology Credit Example

## 1037.615

Emission credits (Mg) = (Std-FCL) × (CF) × (Volume) × (UL) × (10<sup>-6</sup>) × 1.5 multiplier

Where:

Std = the emission standard associated with the engine subcategory (g/hp-hr).

FCL = the family certification level for the engine family with the hybrid (g/hp-hr).

CF = cycle conversion factor, which is total integrated horsepower-hour over the duty cycle divided by 6.3 miles for SI engines and 6.5 miles for CI engines..

Volume = U.S.-directed production volume of the engine family.

UL = useful life of the vehicle (435,000 miles for HHD, 185,000 miles for MHD, and 110,000 miles for LHD).

An example:

A manufacturer produces 100 HHD hybrid engines for use in a vocational vehicle. The HHD vocational engine standard is 567 g/hp-hr. The hybrid emits 482 g/hp-hr over the HD FTP cycle.

Advanced Technology Emission credits = (567 – 482 g/hp-hr) × (6.5 miles) × (100 engines) × (435,000 miles) × (10<sup>-6</sup>) × 1.5 = 36,051 Mg of credits