US: NONROAD: EMISSIONS

History

Tier 1-3 Standards - The first federal standards (Tier 1, 40 CFR Parts 9 and 89) for new nonroad (or off-road) diesel engines were adopted in 1994 for engines over 37 kW (50 hp) and phased-in from 1996 to 2000. In 1996, a Statement of Principles (SOP) for nonroad diesel engines was signed between EPA, California ARB and engine makers. On August 27, 1998, EPA signed the final rule reflecting the provisions of the SOP and introduced Tier 1 standards to be phased in between 2000 and 2008 for equipment under 37 kW (50 hp) with subsequent, stricter Tier 2 and Tier 3 standards for all equipment. Tier 1-3 standards were met through advanced engine design, with no or limited use of exhaust gas aftertreatment (oxidation catalysts). Tier 3 standards for NOx+HC are similar in stringency to the 2004 standards for highway engines, however Tier 3 standards for PM were never adopted.

Tier 4 Standards - On May 11, 2004, EPA adopted Tier 4 emission standards to be phased-in between 2008 and 2015. Tier 4 standards require emissions of PM and NOx be reduced by 90% from Tier 1-3 standards. Tier 4 standards can be achieved through the use of control technologies - including advanced exhaust gas aftertreatment - similar to those required by the 2007-2010 standards for heavy-

duty highway engines. Detailed information about the Tier 4 regulations is available at the EPA Tier 4 website.

California - The federal Clean Air Act Amendments of 1990 preempted California's authority to control emissions from new farm and construction equipment under 175 hp. Clean Air Act Section 209 (e) required California's rules for other off-road sources to be approved by EPA. Additional information on California's interaction with EPA can be found at the California Waiver Federal Register website.

Technical Standards

Applicability

The nonroad standards cover mobile nonroad diesel engines of all sizes used in a wide range of construction, agricultural and industrial equipment. The EPA definition of the "nonroad engine" is based on the principle of mobility/portability, and includes engines installed on (1) self-propelled equipment, (2) on equipment that is propelled while performing its function, or (3) on equipment that is portable or transportable, as indicated by the presence of wheels, skids, carrying handles, dolly, trailer, or platform. In other words, nonroad engines are all internal combustion engines except motor vehicle (highway) engines, stationary engines (or engines that remain at one location for more than 12 months), engines used solely for competition, or engines used in aircraft.

Examples of regulated applications include farm tractors, excavators, bulldozers, wheel loaders, backhoe loaders, road graders, diesel lawn tractors, logging equipment, portable generators, skid steer loaders, or forklifts. Further information can be found in the legislative text.

California - Effective May 14, 2003, the definition of nonroad engines changed to also include all diesel powered engines - including stationary ones - used in agricultural operations in California. This change applies only to engines sold in the state of California; stationary engines sold in other states are not classified as nonroad engines.

Exemptions - The nonroad diesel emission regulations are not applicable to all nonroad diesel engines. Exemptions include:

- Engines used in railway locomotives - Subject to separate EPA regulations. See the US Locomotive Emissions page.
- Engines used in marine vessels - Subject to separate EPA regulations. Marine engines below 37 kW (50 hp) are subject to Tier 1-2, but not Tier 4, nonroad standards. Certain marine engines that are exempted from marine standards may be subject to nonroad regulations. See the US Marine Emissions page.
- Engines used in underground mining equipment - Diesel emissions and air quality in mines are regulated by the Mine Safety and Health Administration (MSHA).

- Hobby engines (below 50 cm^3 per cylinder)

Emission standards listed in the tables below must be met over the entire useful life of the engine. See Engine Useful Life below for more information.

Tier 1-3 Emission Standards

Tier 1 standards were phased-in from 1996 to 2000, Tier 2 from 2001 to 2006, and Tier 3 from 2006 to 2008 (Tier 3 standards apply only for engines with 37-560 kW).

A new definition of a compression-ignition (diesel) engine was used in the regulatory language starting with Tier 2 that was consistent with definitions established for highway engines. The definition focuses on the engine cycle, rather than the ignition mechanism, with the presence of a throttle as an indicator to distinguish between diesel-cycle and otto-cycle operation. Regulating power by controlling the fuel supply in lieu of a throttle corresponds with lean combustion and diesel-cycle operation. This language allows the possibility that a natural gas-fueled engine equipped with a sparkplug is considered a compression-ignition engine.

The regulations include several other provisions, such as averaging, banking and trading of emission credits and maximum “family emission limits” (FEL) for emission averaging.

Tier 1-3 emissions limits are listed below. Nonroad regulations are in the metric system of units, with all standards expressed in grams of pollutant per kWh. Engines of all sizes must also meet smoke standards of 20/15/50% opacity at acceleration/lug/peak modes, respectively.

EPA Tier 1-3 Nonroad Diesel Engine Emission Standards, g/kWh (g/bhp·hr)							
Engine Power	**Tier**	**Year**	**CO**	**HC**	**NMHC+NOx**	**NOx**	**PM**
kW < 8 (hp < 11)	Tier 1	2000	8.0 (6.0)	-	10.5 (7.8)	-	1.0 (0.75)
	Tier 2	2005	8.0 (6.0)	-	7.5 (5.6)	-	0.8 (0.6)
8 ≤ kW < 19 (11 ≤ hp < 25)	Tier 1	2000	6.6 (4.9)	-	9.5 (7.1)	-	0.8 (0.6)
	Tier 2	2005	6.6 (4.9)	-	7.5 (5.6)	-	0.8 (0.6)
19≤ kW < 37 (25 ≤ hp < 50)	Tier 1	1999	5.5 (4.1)	-	9.5 (7.1)	-	0.8 (0.6)
	Tier 2	2004	5.5 (4.1)	-	7.5 (5.6)	-	0.6 (0.45)
37 ≤ kW < 75 (50 ≤ hp < 100)	Tier 1	1998	-	-	-	9.2 (6.9)	-
	Tier 2	2004	5.0 (3.7)	-	7.5 (5.6)	-	0.4 (0.3)
	Tier 3	2008	5.0 (3.7)	-	4.7 (3.5)	-	-†
75 ≤ kW < 130 (100 ≤ hp < 175)	Tier 1	1997	-	-	-	9.2 (6.9)	-
	Tier 2	2003	5.0 (3.7)	-	6.6 (4.9)	-	0.3 (0.22)
	Tier 3	2007	5.0 (3.7)	-	4.0 (3.0)	-	-†
130 ≤ kW < 225 (175 ≤ hp < 300)	Tier 1	1996	11.4 (8.5)	1.3 (1.0)	-	9.2 (6.9)	0.54 (0.4)
	Tier 2	2003	3.5 (2.6)	-	6.6 (4.9)	-	0.2 (0.15)
	Tier 3	2006	3.5 (2.6)	-	4.0 (3.0)	-	-†
225 ≤ kW < 450 (300 ≤ hp < 600)	Tier 1	1996	11.4 (8.5)	1.3 (1.0)	-	9.2 (6.9)	0.54 (0.4)
	Tier 2	2001	3.5 (2.6)	-	6.4 (4.8)	-	0.2 (0.15)
	Tier 3	2006	3.5 (2.6)	-	4.0 (3.0)	-	-†
450 ≤ kW < 560 (600 ≤ hp < 750)	Tier 1	1996	11.4 (8.5)	1.3 (1.0)	-	9.2 (6.9)	0.54 (0.4)
	Tier 2	2002	3.5 (2.6)	-	6.4 (4.8)	-	0.2 (0.15)
	Tier 3	2006	3.5 (2.6)	-	4.0 (3.0)	-	-†
kW ≥ 560 (hp ≥ 750)	Tier 1	2000	11.4 (8.5)	1.3 (1.0)	-	9.2 (6.9)	0.54 (0.4)
	Tier 2	2006	3.5 (2.6)	-	6.4 (4.8)	-	0.2 (0.15)

EPA Tier 1-3 Nonroad Diesel Engine Emission Standards, g/kWh (g/bhp·hr)							
Engine Power	**Tier**	**Year**	**CO**	**HC**	**NMHC+NOx**	**NOx**	**PM**
Notes: † Not adopted, engines must meet Tier 2 PM standard.							

1998 Consent Decrees

On 22 October 1998, the Department of Justice and the EPA announced a settlement with seven major manufacturers of diesel engines who will spend more than one billion dollars to resolve claims that they installed illegal computer software on heavy duty diesel engines that turned off the engine emission control system during highway driving. Manufacturers who signed the 1998 Consent Decrees with EPA were potentially required to meet Tier 3 standards one year ahead of schedule (i.e. beginning in 2005).

Blue Sky Series Engines

In 2002, EPA established a stricter set of voluntary "Blue Sky" standards, listed below. Blue Sky Series Engines have lower emission levels than the mandatory standards—usually at least 40 percent cleaner. Meeting this voluntary standard earns manufacturers a Blue Sky Series designation for these engines. Manufacturers who choose to get this certification agree to keep these engines at Blue Sky levels throughout their useful life.

Blue Sky Series exist for the following engines:

- land-based nonroad diesel engines (40 CFR part 89)
- recreational and commercial marine diesel engines (40 CFR part 94)
- land-based nonroad spark-ignition engines over 25 hp (40 CFR part 1048)

EPA Blue Sky Voluntary Emission Standards for Nonroad Diesel Engines, g/kWh (g/bhp·hr)		
Rated Power (kW)	**NMHC+NOx**	**PM**
kW < 8	4.6 (3.4)	0.48 (0.36)
8 ≤ kW <19	4.5 (3.4)	0.48 (0.36)
19 ≤ kW <37	4.5 (3.4)	0.36 (0.27)
37 ≤ kW < 75	4.7 (3.5)	0.24 (0.18)
75 ≤ kW <130	4.0 (3.0)	0.18 (0.13)
130 ≤ kW < 560	4.0 (3.0)	0.12 (0.09)
kW ≥ 560	3.8 (2.8)	0.12 (0.09)

Tier 4 Emission Standards

The phase-in of Tier 4 emission standards began in 2008 and will be fully in effect in 2015. Tier 4 standards introduce substantial reductions of NOx (for engines above 56 kW) and PM (above 19 kW), as well as more stringent HC limits. CO emission limits remain unchanged from Tier 2-3. Tier 4 emission standards for engines up to 560 kW are listed below.

Tier 4 Emission Standards—Engines up to 560 kW, g/kWh (g/bhp-hr)						
Engine Power	**Year**	**CO**	**NMHC**	**NMHC+NO_x**	**NO_x**	**PM**
kW < 8 (hp < 11)	2008	8.0 (6.0)	-	7.5 (5.6)	-	0.4[a] (0.3)
8 ≤ kW < 19 (11 ≤ hp < 25)	2008	6.6 (4.9)	-	7.5 (5.6)	-	0.4 (0.3)
19 ≤ kW < 37 (25 ≤ hp < 50)	2008	5.5 (4.1)	-	7.5 (5.6)	-	0.3 (0.22)
	2013	5.5 (4.1)	-	4.7 (3.5)	-	0.03 (0.022)
37 ≤ kW < 56 (50 ≤ hp < 75)	2008	5.0 (3.7)	-	4.7 (3.5)	-	0.3[b] (0.22)
	2013	5.0 (3.7)	-	4.7 (3.5)	-	0.03 (0.022)
56 ≤ kW < 130 (75 ≤ hp < 175)	2012-2014[c]	5.0 (3.7)	0.19 (0.14)	-	0.40 (0.30)	0.02 (0.015)
130 ≤ kW ≤ 560 (175 ≤ hp ≤ 750)	2011-2014[d]	3.5 (2.6)	0.19 (0.14)	-	0.40 (0.30)	0.02 (0.015)

Notes:

a - hand-startable, air-cooled, DI engines may be certified to Tier 2 standards through 2009 and to an optional PM standard of 0.6 g/kWh starting in 2010

b - 0.4 g/kWh (Tier 2) if manufacturer complies with the 0.03 g/kWh standard from 2012

c - PM/CO: full compliance from 2012; NOx/HC: Option 1 (if banked Tier 2 credits used)—50% engines must comply in 2012-2013; Option 2 (if no Tier 2 credits claimed)—25% engines must comply in 2012-2014, with full compliance from 2014.12.31

d - PM/CO: full compliance from 2011; NOx/HC: 50% engines must comply in 2011-2013

MY 2011 compliance requirements are referred to as ‘interim Tier 4’ (or ‘Tier 4i’), ‘transitional Tier 4’ or ‘Tier 4 A,’ while the final standards (NOx/HC compliance) are sometimes referred to as ‘Tier 4 B.’

As an alternative to introducing the required percentage of Tier 4-compliant engines, manufacturers may certify all their engines to an *alternative NOx limit* in each model year during the phase-in period. These alternative NOx standards are:

Engines 56-130 kW:

- Option 1: NOx = 2.3 g/kWh = 1.7 g/bhp-hr (Tier 2 credits used to comply, MY 2012-2013)
- Option 2: NOx = 3.4 g/kWh = 2.5 g/bhp-hr (no Tier 2 credits claimed, MY 2012-2014)

Engines 130-560 kW:

- NOx = 2.0 g/kWh = 1.5 g/bhp-hr (MY 2011-2013)

Tier 4 Emission Standards—Engines Above 560 kW, g/kWh (g/bhp-hr)

Year	Category	CO	NMHC	NO_x	PM
2011	Generator sets > 900 kW	3.5 (2.6)	0.40 (0.30)	0.67 (0.50)	0.10 (0.075)
	All engines except gensets > 900 kW	3.5 (2.6)	0.40 (0.30)	3.5 (2.6)	0.10 (0.075)
2015	Generator sets	3.5 (2.6)	0.19 (0.14)	0.67 (0.50)	0.03 (0.022)
	All engines except gensets	3.5 (2.6)	0.19 (0.14)	3.5 (2.6)	0.04 (0.03)

Other Provisions

- Existing Tier 2-3 smoke opacity standards and procedures continue to apply in some engines. Exempted from smoke emission standards are engines certified to PM emission standards at or below 0.07 g/kWh (because an engine of such low PM level has inherently low smoke emission).

- The Tier 4 regulation does not require closed crankcase ventilation in nonroad engines. However, in engines with open crankcases, crankcase emissions must be measured and added to exhaust emissions in assessing compliance.

- Similarly to earlier standards, the Tier 4 regulation includes such provisions as averaging, banking and trading of emission credits and FEL limits for emission averaging.

- Tier 4 nonroad engines will also have to meet not-to-exceed (NTE) standards, which are measured without reference to any specific test schedule. The NTE standards are effective for engines above 130 kW in 2011; 56-130 kW engines in 2012; and engines below 56 kW in 2013. In most engines, the NTE limits are set at 1.25 times the regular standard for each pollutant (in engines certified to NOx standards below 2.5 g/kWh or PM standards below 0.07 g/kWh, the NTE multiplier is 1.5). NTE standards apply to engines at the time of certification and throughout the useful life of the engine.

The purpose of the added testing requirements is to prevent the possibility of "defeating" the test cycle by electronic engine controls and producing off-cycle emissions.

Test Cycles and Fuels

Nonroad engine emissions are measured on a steady-state test cycle that is nominally the same as the ISO 8178 C1, 8-mode steady-state test cycle. Other ISO 8178 test cycles are allowed for selected applications, such as constant-speed engines (D2 5-mode cycle), variable-speed engines rated under 19 kW (G2 cycle), and marine engines (E3 cycle). Full descriptions of US test cycles can be found under the US Test Cycle category.

The 1998 rule for Tiers 2 and 3 changed from measuring total hydrocarbons to measuring nonmethane hydrocarbons (NMHC). Since there is no standardized EPA method for measuring methane in diesel engine exhaust, manufacturers can either use their own procedures to analyze nonmethane hydrocarbons or measure total hydrocarbons and subtract 2% from the measured hydrocarbon mass to correct for methane.

Transient Testing - Tier 4 standards have to be met over both the steady-state test and the Nonroad Transient Cycle, (NRTC). The transient testing requirements begin with MY 2013 for engines below 56 kW, 2012 for 56-130 kW, and 2011 for 130-560 kW engines. Engines above 560 kW are not tested on the transient test.

Also constant-speed, variable-load engines of any power category are not subject to transient testing. The NRTC protocol includes a cold start test. The cold start emissions are weighted at 5% and hot start emissions are weighted at 95% in calculating the final result.

Fuels - Fuels with sulfur levels no greater than 0.2 wt% (2,000 ppm) are used for certification testing of Tier 1-3 engines. To enable sulfur-sensitive control technologies in Tier 4 engines - such as catalytic particulate filters and NOx adsorbers - EPA mandated reductions in sulfur content in nonroad diesel fuels, to be phased-in between 2007 and 2010:

- 500 ppm effective June 2007 for nonroad, locomotive and marine (NRLM) diesel fuels
- 15 ppm (ultra-low sulfur diesel) effective 2010

Engine Useful Life

Emission standards must be met over the entire useful life of the engine. EPA requires the application of deterioration factors (DFs) to all engines covered by the rule. The DF is a factor applied to the certification emission test data to represent emissions at the end of the useful life of the engine.

The engine useful life and the in-use testing liability period, as defined by EPA for emission testing purposes, are listed below for different engine categories. The Tier 4 rule maintains the same engine useful life periods.

Useful Life and Recall Testing Periods					
Power Rating	**Rated Engine Speed**	**Useful Life**		**Recall Testing Period**	
		hours	*years*	*hours*	*years*
< 19 kW	all	3000	5	2250	4
19-37 kW	constant speed engines ≥3000 rpm	3000	5	2250	4
	all others	5000	7	3750	5
>37 kW	all	8000	10	6000	7

Impacts and Evaluation

1998 Regulation - At the time of signing the 1998 rule, EPA estimated that by 2010 NO_x emissions would be reduced by about a million tons per year, the equivalent of taking 35 million passenger cars off the road. The costs of meeting the emission standards were expected to add under 1% to the purchase price of typical new nonroad diesel equipment, although for some equipment the standards may cause price increases on the order of 2-3%. The program was expected to cost about $600 per ton of NO_x reduced.

Tier 4 Regulation - When the full inventory of older nonroad engines are replaced by Tier 4 engines, annual emission reductions are estimated at 738,000 tons of NOx and 129,000 tons of PM. By 2030, 12,000 premature deaths would be prevented annually due to the implementation of the proposed standards. The estimated costs for added emission controls for the vast majority of equipment was estimated at 1-3% as a fraction of total equipment price. For example, for a 175 hp bulldozer that costs approximately $230,000 it would cost up to $6,900 to add the advanced emission controls and to design the bulldozer to accommodate the modified engine. EPA estimated that the average cost increase for 15 ppm S fuel will be 7 cents per gallon. This figure would be reduced to 4 cents by anticipated savings in maintenance costs due to low sulfur diesel.

Source: http://transportpolicy.net/index.php?title=US:_Nonroad:_Emissions