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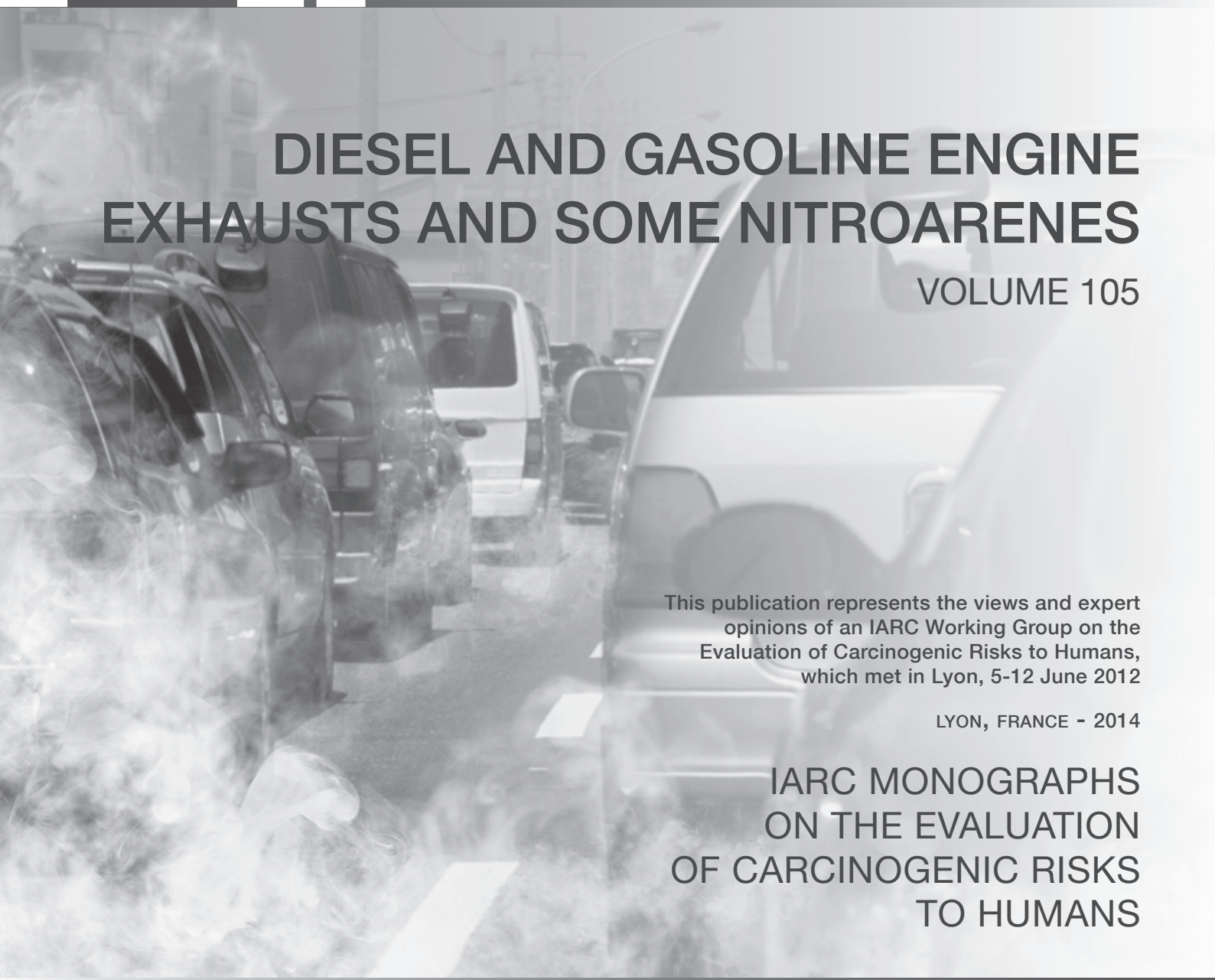

DIESEL AND GASOLINE ENGINE EXHAUSTS AND SOME NITROARENES

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ANNEX: EMISSION STANDARDS FOR LIGHT- AND HEAVY-DUTY VEHICLES

All the information presented in this Annex was retrieved in 2012 from the DieselNet web site (http://www.dieselnet.com/standards/), which is freely accessible, and where more detailed information on global emission standards can be found.

1. Europe

1.1 Light-duty vehicles

The European Union (EU) Stage 1–4 regulations on emissions for new passenger cars and light commercial vehicles that were adopted through 2004 were replaced in 2007 by Stage 5 and 6 regulations (Table 1). The standards apply to all vehicles in Categories M_1, M_2, N_1 and N_2 with a reference mass that does not exceed 2610 kg. The standards regulate both diesel and spark-ignition (fuelled with gasoline, natural gas, liquefied petroleum gas and ethanol) vehicles. The Euro Stage 5 and 6 regulations introduce particulate matter (PM) mass emission standards for spark-ignition vehicles with direct injection engines.

Emissions are tested using the New European Driving Cycle or the Motor Vehicle Emissions Group B test, and are expressed in grams per kilometre. Ultra-low sulfur gasoline and diesel fuels containing < 10 ppm sulfur became mandatory in 2009.

1.2 Heavy-duty vehicles and bus engines

The European heavy-duty vehicle and bus engine emission standards apply to all motor vehicles with a 'technically permissible maximum laden mass' greater than 3500 kg, equipped with compression-ignition engines or spark-ignition natural gas or liquefied petroleum gas engines (Table 2). The regulations were introduced in tiers from Euro I through to Euro VI, and were revised and consolidated in 2005. The most recent Euro VI standards, which become effective in 2013, were published in 2009, and are comparable in stringency to the USA 2010 standards. The European standards have undergone major revisions and changes with respect to test conditions, duty cycles and methods of measurement. Euro IV standards replaced the earlier steady-state engine test (ECE R-49) with the European stationary cycle (ESC) and the European transient cycle (ETC). Smoke opacity is evaluated using the European load response test. Euro III conventional diesel engines are evaluated using the ESC and European load response tests. Euro IV and later conventional diesel engines are evaluated under all three tests,

Table 1 European Union emission standards for passenger cars (category M1[a])

Stage	Date	CO (g/km)	HC (g/km)	HC + NO_x (g/km)	NO_x (g/km)	PM (g/km)	PN (#/km)
Compression ignition (diesel)							
Euro 1[b]	1992.07	2.72 (3.16)	–	0.97 (1.13)	–	0.14 (0.18)	–
Euro 2, IDI	1996.01	1	–	0.7	–	0.08	–
Euro 2, IDI	1996.01[c]	1	–	0.9	–	0.1	–
Euro 3	2000.01	0.64	–	0.56	0.5	0.05	–
Euro 4	2005.01	0.5	–	0.3	0.25	0.025	–
Euro 5a	2009.09[d]	0.5	–	0.23	0.18	0.005[e]	–
Euro 5b	2011.09[f]	0.5	–	0.23	0.18	0.005[e]	6.0×10^{11}
Euro 6	2014.09	0.5	–	0.17	0.08	0.005[e]	6.0×10^{11}
Positive ignition (gasoline)							
Euro 1[b]	1992.07	2.72 (3.16)	–	0.97 (1.13)	–	–	–
Euro 2	1996.01	2.2	–	0.5	–	–	–
Euro 3	2000.01	2.3	0.2	–	0.15	–	–
Euro 4	2005.01	1	0.1	–	0.08	–	–
Euro 5	2009.09[d]	1	0.10[f]	–	0.06	0.005[g,h]	–
Euro 6	2014.09	1	0.10[f]	–	0.06	0.005[g,h]	6.0×10^{11}[g,i]

[a] At the Euro 1–4 stages, passenger vehicles > 2500 kg were type approved as Category N_1 vehicles.
[b] Values in brackets are conformity of production limits
[c] Until 30 September; after that date, DI engines must meet the IDI limits
[d] 2011.01 for all models
[e] 0.0045 g/km using the Particulate Measurement Programme procedure
[f] 2013.01 for all models
[g] And NMHC = 0.068 g/km
[h] Applicable only to vehicles using DI engines
[i] 6.0×10^{12} L/km within first 3 years from Euro 6 effective dates
CO, carbon monoxide; DI, direct injection; HC, hydrocarbons; IDI, indirect injection; NMHC, non-methane hydrocarbons; NO_x, nitrogen oxides; PM, particulate matter; PN, particle number
From DieselNet (2012)

while Euro III and later natural and liquefied petroleum gas engines are evaluated only using the ETC test. Durability and on-board diagnostic requirements were introduced in 2005. Technical requirements pertaining to durability and on-board diagnostics were also established using

Table 2 European Union Euro IV-VI emission standards for conventional heavy-duty diesel engines under the ESC test and diesel and gas engines under the ETC test (in g/kWh)

Tier, year	CO		NO_x		PM[a]		HC	NMHC	CH_4[c]
	ESC	ETC	ESC	ETC	ESC	ETC	ESC	ETC	ETC
Euro IV, 2005	1.5	4.0	3.5	3.5	0.02	0.03	0.46	0.55	1.10
Euro V, 2008	1.5	4.0	2.0	2.0	0.02	0.03	0.46	0.55	1.10
Euro VI, 2013	1.5	4.0	0.4	0.46	0.01	0.01	0.13	0.16[b]	0.50

[a] Not applicable for NG fuelled engines at Euro IV stage
[b] Total HC for diesel engines
[c] For NG engines only (Euro IV-V: NG only; Euro VI: NG and LPG)
CH_4, methane; CO, carbon monoxide; ETC, European transient cycle; ESC, European stationary cycle; LPG, liquefied petroleum gas; HC, hydrocarbons; NMHC, non-methane hydrocarbons; NG, natural gas; NO_x, nitrogen oxides; PM, particulate matter
From DieselNet (2012)

Table 3 European Union Stage III A, B and Stage IV standards for off-road diesel engines (in g/kWh)

Year[a]	Category	Net power (kW)	CO	HC	NO_x + HC	PM
Stage III A standards for off-road engines						
2006	H	$130 \leq P \leq 560$	3.5		4.0	0.2
2007	I	$75 \leq P \leq 130$	5.0		4.0	0.3
2008	J	$37 \leq P \leq 75$	5.0		4.7	0.4
2007	K	$19 \leq P \leq 37$	5.5		7.5	0.6
Stage III B standards for off-road engines						
2011	L	$130 \leq P \leq 560$	3.5	0.19	2.0	0.025
2012	M	$75 \leq P \leq 130$	5.0	0.19	3.3	0.025
2012	N	$56 \leq P \leq 75$	5.0	0.19	3.3	0.025
2013	P	$37 \leq P \leq 56$	5.0	-	4.7	0.025
Stage IV standards for off-road engines						
2014	Q	$130 \leq P \leq 560$	3.5	0.19	0.4	0.025
2014	R	$56 \leq P \leq 130$	5.0	0.19	0.4	0.025

[a] Dates for constant speed engines are: 2011 for categories H, I, K; 2012 for category J
CO, carbon monoxide; HC, hydrocarbons; NO_x, nitrogen oxides; PM, particulate matter
From DieselNet (2012)

a split-level approach, in which the standards and requirements were described separately.

The Euro VI regulation established a limit for ammonia concentration of 10 ppm that applies to diesel ESC- and ETC-certified engines and gas ETC-certified engines. The Euro VI standard established the first limit on particle number to supplement the mass standard. The limit on numbers prevents the Euro VI limit on PM mass being met using technologies such as open or partial filters that enable the passage of a high number of ultrafine particles and, unlike traditional diesel particle filters, do not effectively remove them. The Euro VI standard also states that the world-harmonized steady-state and transient cycles be used for Euro VI testing. The implementation of these regulations requires that correlation factors be included to adjust measurements made under the ESC and ETC test cycles.

1.3 Off-road diesel engines

The European standards for off-road diesel engine emissions are structured in gradually more stringent tiers known as Stages I–IV. Emission standards were also adopted for small, gasoline-fuelled off-road engines. Stage I was implemented in 1999 and Stage II was implemented from 2001 to 2004, depending on the power output of the engine. Equipment covered by the standard included industrial drilling rigs, compressors, construction wheel loaders, bulldozers, off-road trucks, highway excavators, forklift trucks, road maintenance equipment, snow ploughs, ground support equipment in airports, aerial lifts and mobile cranes. Agricultural and forestry tractors were covered by the same emission standards but had different implementation dates, while ships, railway locomotives, aircraft and generating equipment were not.

In 2002, emission standards were adopted for small, gasoline-fuelled utility engines below 19 kW and Stage II standards were extended to include constant speed engines. Stages III/IV, shown in Table 3, were adopted in 2004 and were

Table 4 US EPA Tier 1 emission standards for passenger cars and light-duty trucks measured over the FTP 75 (in g/mile)

	50 000 miles/5 years						100 000 miles/10 years[a]					
Category	**THC**	**NMHC**	**CO**	**NO_x[b] diesel**	**NO_x gasoline**	**PM[c]**	**THC**	**NMHC**	**CO**	**NO_x[b] diesel**	**NO_x gasoline**	**PM[c]**
Passenger cars	0.41	0.25	3.40	1.00	0.40	0.08	–	0.31	4.20	1.25	0.60	0.10
LLDT, LVW < 3750 lb	–	0.25	3.40	1.00	0.40	0.08	0.80	0.31	4.20	1.25	0.60	0.10
LLDT, LVW < 3750 lb	–	0.32	4.40	–	0.70	0.08	0.80	0.40	5.50	0.97	0.97	0.10
HLDT, ALVW < 5750 lb	0.32	–	4.40	–	0.70	–	0.80	0.46	6.40	0.98	0.98	0.10
HLDT, ALVW < 5750 lb	0.39	–	5.00	–	1.10	–	0.80	0.56	7.30	1.53	1.53	0.12

[a] Useful life 120 000 miles/11 years for all HLDT standards and for THC standards for LLDT
[b] More relaxed NO_x limits for diesel engines applicable to vehicles through to model year 2003
[c] PM standards applicable to diesel vehicles only
ALVW, adjusted LVW (the numerical average of the curb weight and the GVWR); CO, carbon monoxide; EPA, Environmental Protection Agency; FTP, Federal Test Procedure; GVWR, gross vehicle weight rating; HLDT, heavy light-duty truck (above 6000 lb GVWR); LLDT, light light-duty truck (below 6000 lb GVWR); LVW, loaded vehicle weight (curb weight + 300 lb); NMHC, non-methane hydrocarbons; NO_x, nitrogen oxides; PM, particulate matter; THC, total hydrocarbons
From DieselNet (2012)

extended to cover agricultural and forestry tractors in 2005. Further technical details on testing methods were also adopted for Stage IIIB and Stage IV engines, and amendments were made to the rules applied to agricultural and forestry tractors. Stage III standards were divided into IIIA and IIIB and were phased in from 2006 to 2013. The Stage III/IV standards were also applied to railroad locomotive engines and marine engines used for inland waterway vessels, but apply only to new vehicles and equipment; replacement engines to be used in machinery that is already in use (except for railcars, locomotives and inland waterway vessel propulsion engines) must comply with the limit values that the engine to be replaced had to meet when originally placed on the market.

Stage I and II limits were harmonized in part with regulations in the USA, and Stage III and IV limits were harmonized with the USA Tier 3 and Tier 4 standards.

2. USA

2.1 Light-duty vehicles

The Clean Air Act Amendments of 1990 established Federal Tier 1 standards that were phased in between 1994 and 1997, and Tier 2 standards that were phased in from 2004 to 2009. The Tier 1 standards were applied to all new light-duty vehicles, including passenger cars, light-duty trucks, sport utility vehicles, minivans and pick-up trucks with a gross vehicle weight rating (GVWR) of < 8500 lb, and were further divided into light light-duty trucks with a GVWR below 6000 lb and heavy light-duty trucks with a GVWR above 6000 lb. Table 4 shows the Tier 1 federal standards for missions that were measured using the Federal Test Procedure (FTP) 75; the results are expressed in grams per mile.

The Supplemental Federal Test Procedure (SFTP) was phased in between 2000 and 2004

Table 5 US EPA Tier 1 emission standards for passenger cars and light-duty trucks, measured over the SFTP (in g/mile)

Category	Gasoline (diesel)			
	NMHC + NO_x (weighted)	CO		
		USO6	SCO3	Weighted
Passenger cars and LLDT, LVW 3750 lb	0.97/2.07 (0.65/1.48)	11.1 (9.0)	3.7 (3.0)	4.2 (3.4)
LLDT, LVW > 3750 lb	1.37 (1.02)	14.6 (11.6)	4.9 (3.9)	5.5 (4.4)
HLDT, ALVW < 5750 lb	1.44 (1.02)	16.9 (11.6)	5.6 (3.9)	6.4 (4.4)
HLDT, ALVW < 5750 lb	2.09 (1.49)	19.3 (13.2)	6.4 (4.4)	7.3 (5.0)

ALVW, adjusted LVW (the numerical average of the curb weight and the GVWR); CO, carbon monoxide; EPA, Environmental Protection Agency; GVWR, gross vehicle weight rating; HLDT, heavy light-duty truck (above 6000 lb GVWR); LLDT, light light-duty truck (below 6000 lb GVWR); LVW, loaded vehicle weight (curb weight + 300 lb); NMHC, non-methane hydrocarbons; NO_x, nitrogen oxides; SFTP, Supplementary Federal Test Procedure

From DieselNet (2012)

to measure emissions during aggressive highway driving (US06) and urban driving emissions when the air conditioning system of the vehicle was functioning (SC03). The Tier 1 SFTP standards applied to weighted non-methane hydrocarbons plus NO_x and to carbon monoxide with or without weighting are shown in Table 5.

Federal Tier 2 standards apply to all weight categories, whereby those for light-duty vehicles are extended to cover heavier vehicles (up to 10 000 lb). The same emission limits apply to all vehicles regardless of the fuel used, and emissions are expressed in grams per mile so that, to meet the standards, vehicles with larger engines are forced to use more advanced emission control technologies than those with smaller engines. Also, Tier 2 regulations included new standards for fuel quality. Since 2006, the sulfur content of gasoline fuel has been reduced to a corporate average of 30 ppm with a maximum of 80 ppm, and ultralow sulfur diesel fuel has been available since June 2006, with a maximum sulfur content of 15 ppm.

The Tier 2 standards are structured into eight permanent and three temporary certification bins (expired in 2008), and an average fleet standard for emissions of NO_x. Vehicles may be certified to any available bin. In 2009, the entire light-duty vehicle fleet sold by each manufacturer had to meet an average standard of 0.07 g/mile of NO_x (Table 6).

In addition to meeting the FTP cycle requirements, the environmental Protection Agency (EPA) introduced supplemental exhaust emission standards to be met under the US0G and SC03 driving cycles. Full useful-life Tier 2 SFTP standards for non-methane hydrocarbons plus NO_x, PM and carbon monoxide (CO) are based on both vehicle weight classification and the certification bin applicable to that vehicle. They are equal to the Tier 1 SFTP standards minus 35% of the difference between the Tier 1 and Tier 2 FTP standards:

SFTP Standard = Tier 1 SFTP – [0.35 × (Tier 1 FTP – Tier 2 FTP)]

2.2 Heavy-duty vehicles

Specific emission standards apply to new diesel engines used in heavy-duty highway vehicles. Natural gas-fuelled engines equipped with spark plugs are considered to be compression-ignition engines under this regulation. Heavy-duty refers to vehicles with a GVWR of above 8500 lb in the federal jurisdiction and above 14 000 lb in California (model year 1995 and later). Diesel engines used in heavy-duty vehicles are

Table 6 US EPA Tier 2 emission standards for light-duty vehicles, measured over the FTP 75 (in g/mile)

Intermediate life (5 years/50 000 mi)						Full useful life				
Bin No.	**NMOG**	**CO**	**NO_x**	**PM**	**HCHO**	**NMOG**	**CO**	**NO_x[a]**	**PM**	**HCHO**
Temporary bins										
11						0.28	7.3	0.9	0.12	0.032
MDPV[b]										
10[c,d,e,f]	0.125 (0.160)	3.4 (4.4)	0.4	–	0.015 (0.018)	0.156 (0.230)	4.2 (6.4)	0.6	0.08	0.018 (0.027)
9[c,d,f,g]	0.075 (0.140)	3.4	0.2	–	0.015	0.090 (0.180)	4.2	0.3	0.06	0.018
Permanent bins										
8	0.100	3.4	0.14	–	0.015	0.125	4.2	0.2	0.02	0.018
7	0.075	3.4	0.11	–	0.015	0.09	4.2	0.15	0.02	0.018
6	0.075	3.4	0.08	–	0.015	0.09	4.2	0.1	0.01	0.018
5	0.075	3.4	0.05	–	0.015	0.09	4.2	0.07	0.01	0.018
4	–	–	–	–	–	0.07	2.1	0.04	0.01	0.011
3	–	–	–	–	–	0.055	2.1	0.03	0.01	0.011
2	–	–	–	–	–	0.01	2.1	0.02	0.01	0.004
1	–	–	–	–	–	0	0	0	0	0

[a] Average manufacturer fleet NO_x standard is 0.07 g/mile for Tier 2 vehicles.
[b] An additional temporary bin restricted to MDPVs that expires after model year 2008.
[c] Bin deleted at the end of 2006 model year (2008 for HLDTs)
[d] The higher temporary NMOG, CO and HCHO values apply only to HLDTs and MDPVs and expire after 2008.
[e] Optional temporary NMOG standard of 0.195 g/mile (50 000) and 0.280 g/mile (full useful life) applies for qualifying LDT4s
[f] Optional temporary NMOG standard of 0.100 g/mile (50 000) and 0.130 g/mile (full useful life) applies for qualifying LDT2s
[g] 50 000 mile standard optional for diesel engines certified to bins 9 or 10
CO, carbon dioxide; EPA, Environmental Protection Agency; FTP, Federal Test Procedure; HCHO, formaldehyde; HLDT, heavy light-duty truck (above 6000 lb gross vehicle weight rating); MDPV, medium-duty passenger vehicles; NMOG, non-methane organic gases (hydrocarbons); PM, particulate matter
From DieselNet (2012)

further divided into service classes: light heavy-duty diesel engines, medium heavy-duty diesel engines and heavy heavy-duty diesel engines. Vehicles with a GVWR of up to 10 000 lb that are used for personal transportation have been classified as medium-duty passenger vehicles and are regulated under Tier 2 light-duty regulations. Therefore, the same model of diesel engine that is used for vehicles in the 8500–10 000-lb category may be classified as either light- or heavy-duty and certified to different standards, depending on their applications.

Federal regulations require that engines be certified when operated on a dynamometer over the transient FTP; however, a complete heavy-duty diesel vehicle with a GVWR of < 14 000 lb may be certified on a chassis dynamometer. Emissions measured on an engine dynamometer test are expressed in grams per brake horse power-hour (g/bhp-h). Chassis certification emissions are expressed in grams per mile. Additional requirements include the Supplemental Emission Test and the Not-to Exceed test.

For model year 2007 and beyond, heavy-duty highway engines are required to meet the following emission standards: PM, 0.01 g/bhp-h; NO_x, 0.20 g/bhp-h; CO, 15.5 g/bhp-h; and non-methane hydrocarbons, 0.14 g/bhp-h. The standards for non-methane hydrocarbons and NO_x were phased in for diesel engines between

Table 7 US EPA Tier 1–3 emission standards for off-road diesel engines (in g/kWh; g/bhp-h)

Engine Power	Tier	Year	CO	THC	NMHC + NO_x	NO_x	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)	–	–[a]
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)	–	–[a]
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)	–	–[a]
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)	–	–[a]
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)	–	–[a]
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)

[a] Not adopted, engines must meet Tier 2 PM standard.
bhp, brake horse power; CO, carbon monoxide; EPA, Environmental Protection Agency; hp, horse power; NMHC, non-methane hydrocarbons; NO_x, nitrogen oxides; PM, particulate matter; THC, total hydrocarbons
From DieselNet (2012)

2007 and 2010.Very few engines met the 0.20 g/bhp-h requirement for NO_x before 2010 because most manufacturers decided to meet the Family Emission Limit of between 1.2 and 1.5 g/bhp-h of nitrogen oxides for most of their engines, and a few manufacturers certified some of their engines at levels as high as 2.5 g/bhp-h NO_x plus non-methane hydrocarbons. The standards include certification under the FTP test and the Supplemental Emission Test and the Not-to-Exceed tests.

2.3 Off-road engines

The 1998 Federal off-road engine regulations are structured as a three-tiered progression (Table 7). Each tier involves a phase-in (by hp rating) over several years. Tier 1 standards were phased in from 1996 to 2000, Tier 2 from 2001 to 2006 and Tier 3 from 2006 to 2008. The Tier 3 standards apply only to engines of 37–560 kW. In 2004, the EPA established Tier 4 standards that are being phased in over the period 2008–15, and require a further 90% reduction in emissions of PM and NO_x compared with Tier 3 (Table 8). With effect from June 2012, all off-road (including marine and locomotive) diesel fuels must contain 15 ppm sulfur or less.

Table 8 US EPA Tier 4 emission standards for engines up to 560 kW (in g/kWh; g/bhp-h)

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	2008	5.5 (4.1)	–	7.5 (5.6)	–	0.3 (0.22)
(25 ≤ hp < 50)	2013	5.5 (4.1)	–	4.7 (3.5)	–	0.03 (0.022)
37 ≤ kW < 56	2008	5.0 (3.7)	–	4.7 (3.5)	–	0.3[b] (0.22)
(50 ≤ hp < 75)	2013	5.0 (3.7)	–	4.7 (3.5)	–	0.03 (0.022)
56 ≤ kW < 130 (75 ≤ hp < 175)	2012–14[c]	5.0 (3.7)	0.19 (0.14)	–	0.40 (0.30)	0.02 (0.015)
130 ≤ kW < 560 (175 ≤ hp < 750)	2011–14[d]	3.5 (2.6)	0.19 (0.14)	–	0.40 (0.30)	0.02 (0.015)

[a] Hand-startable, air-cooled, direct injection engines may be certified to Tier 2 standards through to 2009 and to an optional PM standard of 0.6 g/kWh starting in 2010.
[b] 0.4 g/kWh (Tier 2) if the manufacturer complies with the 0.03 g/kWh standard from 2012-05-17.
[c] PM/CO: full compliance from 2012; NO_x/HC: Option 1 (if banked Tier 2 credits used)–50% of engines must comply in 2012–13; Option 2 (if no Tier 2 credits claimed)–25% of engines must comply in 2012–14, with full compliance from 2014.12.31.
[d] PM/CO: full compliance from 2011; NO_x/HC: 50% of engines must comply in 2011–13.
bhp, brake horse power; CO, carbon monoxide; EPA, Environmental Protection Agency; HC, hydrocarbon; hp, horse power; NMHC, non-methane hydrocarbons; NO_x, nitrogen oxides; PM, particulate matter
From DieselNet (2012)

The standards cover mobile off-road diesel engines of all sizes that are used in a wide range of construction, agricultural and industrial equipment. In 2003, the definition of off-road engines in the State of California was changed to include all diesel-powered engines, including stationary engines used in agricultural operations. This change applies only to engines sold in

Table 9 US EPA Tier 0–2 locomotive emission standards implemented in 2000 (in g/bhp-h)

Duty-cycle	HC[a]	CO	NO_x	PM
Tier 0 (1973–2001)				
Line-haul	1	5	9.5	0.6
Switch	2.1	8	14	0.72
Tier 1 (2002–04)				
Line-haul	0.55	2.2	7.4	0.45
Switch	1.2	2.5	11	0.54
Tier 2 (2005 and later)				
Line-haul	0.3	1.5	5.5	0.2
Switch	0.6	2.4	8.1	0.24
Non-regulated locomotives (1997 estimates)				
Line-haul	0.5	1.5	13.5	0.34
Switch	1.1	2.4	19.8	0.41
Smoke standards,% opacity (normalized)				
	Steady-state	30-s peak	3-s peak	
Tier 0	30	40	50	
Tier 1	25	40	50	
Tier 2 and later	20	40	50	

[a] HC standard is in the form of THC for diesel engines.
bhp, brake horse power; CO, carbon monoxide; EPA, Environmental Protection Agency; HC, hydrocarbons; NO_x, nitrogen oxides; PM, particulate matter; THC, total hydrocarbons
From DieselNet (2012)

Table 10 US EPA Tier 0–4 locomotive emission standards implemented in year 2008 (in g/bhp-h)

Tier	Model year	Date	HC	CO	NO_x	PM
Line-haul locomotives						
Tier 0[a]	1973–92[b]	2010[c]	1	5	8	0.22
Tier 1[a]	1993[b]–2004	2010[c]	0.55	2.2	7.4	0.22
Tier 2[a]	2005–11	2010[c]	0.3	1.5	5.5	0.10[d]
Tier 3[e]	2012–14	2012	0.3	1.5	5.5	0.1
Tier 4	2015 or later	2015	0.14[f]	1.5	1.3[f]	0.03
Switch locomotives						
Tier 0	1973–2001	2010[d]	2.1	8	11.8	0.26
Tier 1[g]	2002–04	2010[d]	1.2	2.5	11	0.26
Tier 2[g]	2005–10	2010[d]	0.6	2.4	8.1	0.13[h]
Tier 3	2011–14	2011	0.6	2.4	5	0.1
Tier 4	2015 or later	2015	0.14[i]	2.4	1.3[i]	0.03

[a] Tier 0–2 line-haul locomotives must also meet switch standards of the same tier
[b] 1993–2001 locomotive that were not equipped with an intake air coolant system are subject to Tier 0 rather than Tier 1 standards.
[c] As early as 2008, if approved engine upgrade kits become available.
[d] 0.20 g/bhp-h until 1 January 2013 (with some exceptions)
[e] Tier 3 line-haul locomotives must also meet Tier 2 switch standards.
[f] Manufacturers may elect to meet a combined NO_x + HC standard of 1.4 g/bhp-h.
[g] Tier 1–2 switch locomotives must also meet line-haul standards of the same tier.
[h] 0.24 g/bhp-h until 1 January 2013 (with some exceptions)
[i] Manufacturers may elect to meet a combined NO_x + HC standard of 1.3 g/bhp-h
bhp, brake horse power; CO, carbon monoxide; EPA, Environmental Protection Agency; HC, hydrocarbons; NO_x, nitrogen oxides; PM, particulate matter
From DieselNet (2012)

California; stationary engines sold in other states are not classified as off-road. Engines that are not regulated include locomotives, marine engines, mining equipment and hobby engines below 50 cm^3 per cylinder.

2.4 Locomotives

The USA standards for railroad locomotive emissions are similar in structure to the other USA standards, in that they are tiered. Tiers 0–2 became effective in 2000 and apply to locomotives manufactured from 1973 onwards (Table 9). The standard includes engines that are manufactured or re-manufactured. Tier 0–2 standards are met though engine development without the use of exhaust gas aftertreatment. Tier 3–4 standards are more stringent. Tier 3 standards took effect in December 2011; Tier 4 standards will take effect in 2015 and are expected to require some form of exhaust aftertreatment.

Locomotive emissions are measured over two steady-state test cycles that represent two different types of service, including line-haul and switch locomotives. The duty cycles include different weighting factors for each of the eight throttle notch modes, idle and dynamic brake modes. The use of ultralow sulfur (15 ppm) diesel fuel has been required as of June 2012.

The 2008 regulation (Table 10) introduced Tier 3 and 4 standards and strengthened the Tier 0–2 standards for existing locomotives when they are re-manufactured, established more restrictive standards for newly built and re-manufactured locomotives, and established standards for newly built and re-manufactured locomotives of the future. Tier 3 standards are expected to be met by improvements in engine technology, while Tier 4 standards are expected to require

Table 11 Marine engine categories used in the USA for establishing emission standards

Category	Displacement per cylinder (D) in dm³		Basic engine technology
	Tier 1–2	Tier 3–4	
1	D < 5	D < 7	Land-based off-road diesel
2	5 ≤ D < 30	7 ≤ D < 30	Locomotive engine
3	D ≥ 30		Unique marine engine design

From DieselNet (2012)

the use of exhaust gas aftertreatment technologies. The opacity regulations remain unchanged.

2.5 Marine engines

Similarly to the other USA engine emission standards, those for marine engines are tiered and broken down by engine category. In addition, the categories consider cylinder displacement and engine technology, i.e. off-road diesel engine, locomotive or unique marine design (Table 11). Category 3 marine diesel engines are very large, typically ranging in size from 2500 to 70 000 kW (3000 to 100 000 hp). These engines are used in ocean-going vessels and emission control options are very limited. The residual fuel for these large vessels is not regulated by the EPA. The fuel has a high viscosity and density, and high ash, sulfur and nitrogen contents in comparison with other types of marine distillate fuel. The EPA estimated that residual fuel can increase engine emissions of NO_x from 20–50% and those of PM from 750% to 1250% (sulfate particulates) compared with distillate fuel. Category 1 and 2 marine diesel engines range in size from about 500 to 8000 kW (700 to 11 000 hp).

Emissions from marine diesel engines are regulated by several rules that are applied to the engine categories, and may overlap with those for mobile, land-based off-road engines described previously. For engines in Categories 1 and 2, the land-based off-road and locomotive engines serve as guidelines for the Tier 2 standards as shown in Table 12. The standards for recreational engines

Table 12 US EPA Tier 2 emission standards for marine engines

Category	Displacement per cylinder (D) dm³	Year	Standard (g/kWh)		
			CO	NO_x + THC	PM
1	Power ≥ 37 kW				
	D < 0.9	2005	5	7.5	0.4
	0. ≤ D < 1.2	2004	5	7.2	0.3
	1.2 ≤ D < 2.5	2004	5	7.2	0.2
	2.5 ≤ D < 5.0	2007[a]	5	7.2	0.2
2	5.0 ≤ D < 15	2007[a]	5	7.8	0.27
	Power < 3 300 kW				
	15 ≤ D < 20	2007[a]	5	8.7	0.5
	Power ≥ 3 300 kW				
	15 ≤ D < 20	2007[a]	5	9.8	0.5
	20 ≤ D < 25	2007[a]	5	9.8	0.5
	25 ≤ D < 30	2007[a]	5	11.0	0.5

[a] Tier 1 certification requirement started in 2004.

CO, carbon monoxide; EPA, Environmental Protection Agency; NO_x, nitrogen oxides; PM, particulate matter, THC, total hydrocarbons

From DieselNet (2012)

Table 13 US EPA Tier 2 emission standards for recreational marine engines

Displacement per cylinder (D) dm³	Standard (g/kWh)			Year
	CO	NO_x + THC	PM	
0.5 ≤ D < 0.9	5	7.5	0.4	2007
0.9 ≤ D < 1.2	5	7.2	0.3	2006
1.2 ≤ D < 2.5	5	7.2	0.2	2006
D ≥ 2.5	5	7.2	0.2	2009

CO, carbon monoxide; EPA, Environmental Protection Agency; NO_x, nitrogen oxides; PM, particulate matter, THC, total hydrocarbons
From DieselNet (2012)

are summarized in Table 13. These regulations were phased in beginning in 2006, depending on the size of the engine, and are similar to the Tier 2 standards for Category 1 commercial vessels. Recreational engines are also subject to Not-to-Exceed limits, but not to smoke requirements.

The Tier 3 standards are shown in Table 14 and Table 15. They began to be phased in beginning in 2009 and this will be completed by 2014. In addition to the NO_x plus hydrocarbons and PM standards shown in the tables, the following CO emission standards apply for all Category 1/2 engines starting with the applicable Tier 3 model year: 8.0 g/kWh for engines < 8 kW, 6.6 g/kWh for engines ≥ 8 kW and < 19 kW, 5.5 g/kWh for

Table 14 US EPA Tier 3 emission standards for marine diesel category 1 commercial, high and recreational power densities

Commercial standard power density ≤ 35 kW/dm³				
Power (P) in kW	**Displacement per cylinder (D) in dm³**	**NO_x+HC[a] (g/kWh)**	**PM (g/kWh)**	**Year**
P < 19	D < 0.9	7.5	0.4	2009
19 ≤ *P* < 75	D < 0.9[b]	7.5	0.3	2009
		4.7[c]	0.30[c]	2014
75 ≤ *P* < 3700	D < 0.9	5.4	0.14	2012
	0.9 ≤ D < 1.2	5.4	0.12	2013
	1.2 ≤ D < 2.5	5.6	0.11[d]	2014
	2.5 ≤ D < 3.5	5.6	0.11[d]	2013
	3.5 ≤ D < 7	5.8	0.11[d]	2012
P < 19	D < 0.9	7.5	0.4	2009
19 ≤ *P* < 75	D < 0.9[b]	7.5	0.3	2009
		4.7[c]	0.30[c]	2014
75 ≤ *P* < 3700	D < 0.9	5.8	0.15	2012
	0.9 ≤ D < 1.2	5.8	0.14	2013
	1.2 ≤ D < 2.5	5.8	0.12	2014
	2.5 ≤ D < 3.5	5.8	0.12	2013
	3.5 ≤ D < 7	5.8	0.11	2012

[a] Tier 3 NO_x + HC standards do not apply to 2000–3700 kW engines.
[b] < 75 kW engines ≥ 0.9 dm³/cylinder are subject to the corresponding 75–3700 kW standards.
[c] Option: 0.20 g/kWh PM and 5.8 g/kWh NO_x + HC in 2014
[d] This standard level drops to 0.10 g/kWh in 2018 for < 600 kW engines.
CO, carbon monoxide; EPA, Environmental Protection Agency; HC, hydrocarbons; NO_x, nitrogen oxides; PM, particulate matter
From DieselNet (2012)

Table 15 US EPA Tier 3 emission standards for marine diesel category 2 engines[a]

Power (P) kW	Displacement per cylinder (D) in dm³	NO_x + HC[b] (g/kWh)	PM (g/kWh)	Year
$P < 3700$	$7 \leq D < 15$	6.2	0.14	2013
	$15 \leq D < 20$	7	0.27[c]	2014
	$20 \leq D < 25$	9.8	0.27	2014
	$25 \leq D < 30$	11	0.27	2014

[a] Option: Tier 3 PM/NO_x+HC at 0.14/7.8 g/kWh in 2012, and Tier 4 in 2015
[b] Tier 3 NO_x + HC standards do not apply to 2000–3700 kW engines.
[c] 0.34 g/kWh for engines below 3300 kW
CO, carbon monoxide; EPA, Environmental Protection Agency; HC, hydrocarbons; NO_x, nitrogen oxides; PM, particulate matter
From DieselNet (2012)

engines ≥ 19 kW and < 37 kW, and 5.0 g/kWh for engines ≥ 37 kW.

The Tier 4 standards for commercial marine engines at or above 600 kW, which will require aftertreatment, will be phased in from 2014 to 2017.

2.6 State of California standards

The State of California is considered in addition to the national standards because it has the authorization to, and frequently does, set lower emission standards than those of the USA. Furthermore, other states have the option to adopt California emission standards in place of national standards, for which they often set

Table 16 US State of California LEV emission standards for light-duty vehicles, measured with FTP 75 (in g/mile)

Category	50 000 miles/5 years					100 000 miles/10 years				
	NMOG[a]	CO	NO_x	PM	HCHO	NMOG[a]	CO	NO_x	PM	HCHO
Passenger cars										
Tier 1	0.25	3.4	0.4	0.08	–	0.310	4.2	0.60	–	–
TLEV	0.125	3.4	0.4	–	0.015	0.156	4.2	0.60	0.08	0.018
LEV	0.075	3.4	0.2	–	0.015	0.090	4.2	0.30	0.08	0.018
ULEV	0.04	1.7	0.2	–	0.008	0.055	2.1	0.30	0.04	0.011
LDT1, LVW < 3750 lbs										
Tier 1	0.25	3.4	0.4	0.08	–	0.310	4.2	0.60	–	–
TLEV	0.125	3.4	0.4	–	0.015	0.156	4.2	0.60	0.08	0.018
LEV	0.075	3.4	0.2	–	0.015	0.090	4.2	0.30	0.08	0.018
ULEV	0.04	1.7	0.2	–	0.008	0.055	2.1	0.30	0.04	0.011
LDT2, LVW > 3750 lbs										
Tier 1	0.32	4.4	0.7	0.08	–	0.40	5.5	0.97	–	–
TLEV	0.16	4.4	0.7	–	0.018	0.20	5.5	0.90	0.1	0.023
LEV	0.1	4.4	0.4	–	0.018	0.13	5.5	0.50	0.1	0.023
ULEV	0.05	2.2	0.4	–	0.009	0.07	2.8	0.50	0.05	0.013

[a] NMHC for all Tier 1 standards
CO, carbon monoxide; FTP, Federal Test Procedure; HCHO, formaldehyde; LEV, low emission vehicles; LDT, light-duty truck; LVW, loaded vehicle weight (curb weight + 300 lb); NMHC, non-methane hydrocarbons; NMOG, non-methane organic gases; NO_x, nitrogen oxides; PM, particulate matter; TLEV, transitional low emission vehicles; ULEV, ultra low emission vehicles
From DieselNet (2012)

Table 17 US State of California emission standards for medium-duty vehicles, measured with FTP (in g/mile)

Category	50 000 miles/5 years					100 000 miles/10 years				
	NMOG[a]	CO	NO_x	PM	HCHO	NMOG[a]	CO	NO_x	PM	HCHO
MDV1, 0–3750 lb										
Tier 1	0.25	3.4	0.4	–	–	0.360	5.0	0.55	0.08	–
LEV	0.13	3.4	0.4	–	0.015	0.180	5.0	0.60	0.08	0.022
ULEV	0.08	1.7	0.2	–	0.008	0.107	2.5	0.30	0.04	0.012
MDV2, 3751–5750 lb										
Tier 1	0.32	4.4	0.7	–	–	0.460	6.4	0.98	0.10	–
LEV	0.16	4.4	0.4	–	0.018	0.230	6.4	0.60	0.10	0.027
ULEV	0.10	4.4	0.4	–	0.009	0.143	6.4	0.60	0.05	0.013
SULEV	0.05	2.2	0.2	–	0.004	0.072	3.2	0.30	0.05	0.006
MDV3, 5751–8500 lb										
Tier 1	0.39	5.0	1.1	–	–	0.560	7.3	1.53	0.12	–
LEV	0.20	5.0	0.6	–	0.022	0.280	7.3	0.90	0.12	0.032
ULEV	0.12	5.0	0.6	–	0.011	0.167	7.3	0.90	0.06	0.016
SULEV	0.06	2.5	0.3	–	0.006	0.084	3.7	0.45	0.06	0.008
MDV4, 8501–10 000 lb										
Tier 1	0.46	5.5	1.30	–	0.028	0.660	8.1	1.81	0.12	–
LEV	0.23	5.5	0.70	–	0.028	0.330	8.1	1.00	0.12	0.040
ULEV	0.14	5.5	0.70	–	0.014	0.197	8.1	1.00	0.06	0.021
SULEV	0.07	2.8	0.35	–	0.007	0.100	4.1	0.50	0.06	0.010
MDV5, 10 001–14 000 lb										
Tier 1	0.60	7.0	2.0	–	–	0.860	10.3	2.77	0.12	–
LEV	0.30	7.0	1.0	–	0.036	0.430	10.3	1.50	0.12	0.052
ULEV	0.18	7.0	1.0	–	0.018	0.257	10.3	1.50	0.06	0.026
SULEV	0.09	3.5	0.5	–	0.009	0.130	5.2	0.70	0.06	0.013

[a] NMHC for all Tier 1 standards

CO, carbon monoxide; FTP, Federal Rest Procedure; HCHO, formaldehyde; LEV, low emission vehicles; MDV, medium-duty vehicle (with maximum gross vehicle weight from 8500 to 14 000 lb; the MDV category is divided into five classes, MDV1–MDV5, based on vehicle test weight; the definition of 'test weight' in California is identical to the Federal adjusted loaded vehicle weight; ALVW); NMHC, non-methane hydrocarbons; NMOG, non-methane organic gases; NO_x, nitrogen oxides; PM, particulate matter; ULEV, ultra low emission vehicles; SULEV, super ultra low emission vehicles

From DieselNet (2012)

the pace. California implemented the first light-duty vehicle emission standards in 1963 with the requirement for positive crankcase ventilation that recycles previously discharged blow-by emissions. It also introduced the first emission standards in 1966 for CO, hydrocarbons and NO_x. Although these standards are on average more stringent than the EPA requirements, they are similar to the Federal standards in many respects.

The Low Emission Vehicle (LEV) Standards were applied through to model year 2003 for light- and medium-duty vehicles with the following emission categories: Tier 1, transitional LEV, LEV, ultra LEV, super ultra LEV and zero emission vehicles. The standards for gaseous pollutants applied to diesel- and gasoline-fuelled vehicles while the PM standards applied to diesel vehicles only. Emissions were measured over the FTP 75 test and were expressed in grams per mile, and the standards were tiered based upon the

Table 18 US State of California LEV II emission standards for passenger cars and light-duty vehicles < 8500 lb, measured with FTP 75 (in g/mile)

Category	50 000 miles/5 years					120 000 miles/5 years				
	NMOG	CO	NO_x	PM	HCHO	NMOG	CO	NO_x	PM	HCHO
LEV	0.075	3.4	0.05	-	0.015	0.090	4.2	0.07	0.01	0.018
ULEV	0.040	1.7	0.05	-	0.008	0.008	2.1	0.07	0.01	0.011
SULEV	-	-	-	-	-	0.010	1.0	0.02	0.01	0.004

CO, carbon monoxide; FTP, Federal Test Procedure; HCHO, formaldehyde; LEV, low emission vehicles; NMOG, non-methane organic gases; NO_x, nitrogen oxides; PM, particulate matter; SULEV, super ultra low emission vehicles; ULEV, ultra low emission vehicles
From DieselNet (2012)

vehicle weight and mileage as shown in Table 16 and Table 17. The additional SFTP procedures were phased in in California between 2001 and 2005. A percentage of vehicles was required to be certified to increasingly more stringent emission categories based on the average emissions of vehicle manufacturers' fleets. Tier 1 and transitional LEV standards were eliminated after 2003. LEV II and LEV III standards were implemented for successive time periods and are discussed below.

LEV II emission standards were applied to model years 2004–10. Light-duty and medium-duty vehicle categories below 8500 lb gross weight were reclassified and had to meet passenger car requirements, as shown in Table 18 and Table 19. This was phased in by 2007. As a result, most pick-up trucks and sport utility vehicles were required to meet the passenger car emission standards. More stringent emission standards were defined: ultra LEV and super ultra LEV. Partial zero emission vehicles have the same test emission levels as super ultra LEV, including evaporative emission control and a 150 000 mile/15 years emission durability. The standards apply to all vehicles regardless of the fuel used, and gasoline vehicles are no longer exempt from the PM standard. Light-duty LEVs and ultra LEVs are certified for a 0.05 g/mi standard for NO_x that was phased in starting with the 2004 model year. The LEV II emission standards can only be met by vehicles with advanced emission control strategies.

LEV II standards also included provisions to reduce vehicle fleet emission levels each year through to 2010. The LEV II programme is similar in structure to the Federal Tier 2 legislation, except that the Federal approach uses eight certification 'bins' (with Tier 2 Bin 5 being similar to California's LEV, and Tier 2 Bin 2

Table 19 US State of California LEV II emission standards for medium-duty vehicles, durability 120 000 miles (in g/mile)

Weight (GVW)	Category	NMOG	CO	NO_x	PM	HCHO
8500–10 000 lb	LEV	0.195	6.4	0.2	0.12	0.032
	ULEV	0.143	6.4	0.2	0.06	0.016
	SULEV	0.100	3.2	0.1	0.06	0.008
10 001–14 000 lb	LEV	0.230	7.3	0.4	0.12	0.040
	ULEV	0.167	7.3	0.4	0.06	0.021
	SULEV	0.117	3.7	0.2	0.06	0.010

CO, carbon monoxide; GVW, gross vehicle weight; HCHO, formaldehyde; LEV, low emission vehicles; NMOG, non-methane organic gases; NO_x, nitrogen oxides; PM, particulate matter; SULEV, super ultra low emission vehicles; ULEV, ultra low emission vehicles.
From DieselNet (2012)

Table 20 US State of California proposed LEV III particle standards[a]

Year	Compliance option	
	PM (g/mile)	SPN (1/mile)
2014	0.006	6×10^{12}
2017	0.003	3×10^{12}

[a] Particulate matter standards: the PM mass emission standard will be tightened and an SPN limit will be introduced. SPN emissions are to be measured over the FTP driving cycle using a sampling approach patterned after the European Particulate Measurement Programme methods. Manufacturers would demonstrate compliance using only one standard – either PM or SPN – of their choice. The more stringent standards will ensure that there is no increase in PM emissions from future engine technologies and that particulate filters are used on all diesel engines. In gasoline direct-injection engines, meeting the PM standard of 3/mile should still be possible without the need for a particulate filter. Durability: the LEV III standards would phase in a new 150 000-miles durability requirement, compared with the LEV II 50 000- and 120 000-miles standards. Evaporative emissions: all light-duty vehicles would have to meet a more stringent zero evaporative standard, while using more challenging test fuels, such as E10.

LEV, low emission vehicles; PM, particulate matter; SPN, single particle number

From DieselNet (2012)

similar to super ultra LEV) to allow averaging across greater diversification of emission levels in the fleet. The Federal fleet average non-methane organic gas emissions (around 0.090 g/mi, based on Bin 5) can be more than twice as high as those of LEV II.

The proposed LEV III emission standards, to be phased in over 2014–22, would modify the LEV II standards by: (1) combining the non-methane organic gas and NO standards, (2) introducing a more stringent fleet average requirement for non-methane organic gas plus NO_x combined, (3) adding several emission standard bins and (4) increasing the durability requirements for emission control systems. A significant change proposed in the LEV III standards is a tightening of the PM standards by the introduction of a solid particle number standard similar to that in Europe introduced by the Particle Measurement Programme. Manufacturers would select either

Table 21 People's Republic of China phase-in schedule for light-duty emission standards

Stage	Date	Region	Comments	Reference
China 1	2000.01 (2000.07[a])	Nationwide		Euro 1
China 2	2002.08	Beijing		Euro 2
	2003.03	Shanghai		
	PI: 2004.07**b** (2005.07**a**) CI: 2003.09	Nationwide		
China 3	2005.12	Beijing	European OBD from 2006.12	Euro 3
	2006.10	Guangzhou	With European OBD	
	2007.01	Shanghai	With European OBD	
	2007.07	Nationwide	European OBD: Type 1 2008.07; Type 2 2010.07	
China 4	2008.03	Beijing		Euro 4
	2009.11	Shanghai		
	PI: 2011.07 CI: 2015.07	Nationwide		
China 5	2012[c]	Beijing		Euro 5

[a] Production conformity

[b] First registration

[c] Proposed

CI, compression ignition (diesel); OBD, on-board diagnostics; PI, positive ignition (gasoline, natural gas)

From DieselNet (2012)

Table 22 People's Republic of China emission standards for heavy-duty engines (in g/kWh)

Standard	Test cycle	CO	HC	NMHC	NO_x	PM	Smoke opacity (1/m)
China III	ESC + ELR	2.1	0.66	–	5.0	0.10/0.13[a]	0.8
	ETC	5.42	–	0.78	5.0	0.16/0.21[a]	–
China IV	ESC + ELR	1.5	0.46	–	3.5	0.02	0.5
	ETC	4.0	–	0.55	3.5	0.03	–
China V	ESC + ELR	1.5	0.46	–	2.0	0.02	0.5
	ETC	4.0	–	0.55	2.0	0.03	–

[a] For engines with a per cylinder displacement of < 0.75 dm^3 and rated speed > 3000 pm.
CO, carbon monoxide; ELR, European load response; ESC, European stationary cycle; ETC, European transient cycle; HC, hydrocarbons; NMHC, non-methane hydrocarbons; NO_x, nitrogen oxides; PM, particulate matter
From DieselNet (2012)

a PM or solid particle number method to determine compliance. These proposed standards (Table 20) ensure no increase in PM emissions from future engine technologies and that particulate filters are used on all diesel engines.

3. Other countries

3.1 People's Republic of China

Chinese emission standards for new passenger cars and light-duty commercial vehicles are based on European regulations. Light-duty vehicle categories are based on the EU classification, with changes for the classifications based upon gross vehicle weight. The light-duty emission standards follow the EU standards exactly but came into force a few years later. Their strictest standards follow Euro 5 and took effect in 2012 (Table 21).

Chinese heavy-duty emission standards are based on the similar test cycles to those used by the EU but with slightly different levels. The strictest standards for NO_x and PM proposed to date are 2.0 and 0.02 g/kWh, respectively (Table 22), compared with 0.4 and 0.01 g/kWh for the corresponding Euro VI standards. The phase-in dates for Chinese heavy-duty emission standards are given in Table 23.

Table 23 People's Republic of China phase-in schedule for heavy-duty emission standards

Standard		Implementation date				Initial schedule
		Beijing	Shanghai	Guangzhou	Nationwide	
China I					2000.09	
China II					2003.09	
China III	Gasoline	2010.07			2007.07	2007.07
	Diesel	2006.01				2007.01
China IV	Gasoline	2011.01				2010.01
	Diesel	2011.01	2009.11	2010.08		2010.01
China V		2013.02 [a]				

[a] Estimate
From DieselNet (2012)

Table 24 Indian emission standards for light-duty vehicles (in g/kWh)

Year	Reference	CO	HC	HC + NO_x	NO_x	PM
Diesel						
1992	–	17.3–32.6	2.7–3.7	–	–	–
1996	–	5.0–9.0	–	2.0–4.0	–	–
2000	Euro 1	2.72–6.90	–	0.97–1.70	–	0.14–0.25
2005[b]	Euro 2	1.0–1.5	–	0.7–1.2	–	0.08–0.17
2010[b]	Euro 3	0.64	–	0.56	0.50	0.05
		0.80		0.72	0.65	0.07
		0.95		0.86	0.78	0.10
2010[c]	Euro 4	0.50	–	0.30	0.25	0.025
		0.63		0.39	0.33	0.04
		0.74		0.46	0.39	0.06
Gasoline						
1991	–	14.3–27.1	2.0–2.9	–	–	–
1996	–	8.68–12.4	–	3.00–4.36	–	–
1998[a]	–	4.34–6.20	–	1.50–2.18	–	–
2000	Euro 1	2.72–6.90	–	0.97–1.70	–	–
2005[b]	Euro 2	2.2–5.0	–	0.5–0.7	–	–
2010[b]	Euro 3	2.3	0.20	–	0.15	–
		4.17	0.25		0.18	
		5.22	0.29		0.21	
2010[c]	Euro 4	1.0	0.1	–	0.08	–
		1.81	0.13		0.10	
		2.27	0.16		0.11	

[a] For catalytic converter fitted vehicles
[b] Earlier introduction in selected regions
[c] Only in selected regions
CO, carbon monoxide; HC, hydrocarbons; NO_x, nitrogen oxides; PM, particulate matter
From DieselNet (2012)

3.2 Brazil

Brazil is noteworthy because diesel engines are banned in passenger cars; however, it has regulatory standards for diesel passenger car emissions because some neighbouring countries that do not ban diesel passenger cars use Brazilian emission standards. Brazil does allow diesel engines in heavy-duty vehicles (trucks and buses) and light commercial vehicles, and establishes its own unique emission standards that are based on Euro standards but tend to be somewhat less stringent.

3.3 India

The first light-duty standards were imposed in India in 1992 (Table 24). Since 2000, India has started adopting EU emission and fuel regulations for four-wheeled light-duty and for heavy-duty vehicles (Table 25). It has also adopted standards applying to two- and three-wheeled vehicles.

3.4 Other countries

Argentina bases its emission regulations on Euro standards.

Table 25 Indian emission standards for heavy-duty engines (in g/kWh)

Year	Reference	Test	CO	HC	NO_x	PM
1992	-	ECE R49	17.3–32.6	2.7–3.7	-	-
1996	-	ECE R49	11.20	2.40	14.4	-
2000	Euro I	ECE R49	4.5	1.1	8.0	0.36[a]
2005[b]	Euro II	ECE R49	4.0	1.1	7.0	0.15
2010[b]	Euro III	ESC	2.1	0.66	5.0	0.10
		ETC	5.45	0.78	5.0	0.16
2010[c]	Euro IV	ESC	1.5	0.46	3.5	0.02
		ETC	4.0	0.55	3.5	0.03

[a] 0.612 for engines below 85kW
[b] Earlier introduction in selected regions
[c] Only in selected regions
ECE R49, 13-mode steady-state diesel engine test cycle introduced by ECE Regulation No. 49; CO, carbon monoxide; ESC, European stationary cycle; ETC, European transient cycle; HC, hydrocarbons; NO_x, nitrogen oxides; PM, particulate matter
From DieselNet (2012)

Australian regulations follow the EU regulations.

Canadian regulations follow the USA standards.

Chile has its own regulations that generally follow USA and Euro standards but are not necessarily equivalent, and, in some cases, allows certification to either regulation.

Japan has adopted its own regulations, which generally follow the USA and EU standards.

Peru has switched from a combination of USA and Euro standards to base its regulations on Euro standards.

Russian regulations follow the EU standards for light-duty vehicles, heavy-duty engines and off-road equipment. The allowable sulfur content of fuel is higher and 50 ppm sulfur fuel will not be required until the end of 2015.

Turkish regulations also follow the EU standards, with the Euro 4 light-duty gasoline and diesel regulations being implemented in 2008. The allowable sulfur content of fuel of 50 ppm was enforced in 2008, with higher levels (1000 ppm) for agricultural equipment.

Reference

DieselNet (2012). *Emission Standards: Summary of Worldwide Emission Standards*. Available at: www.dieselnet.com/standards/. Accessed 29 July 2013.