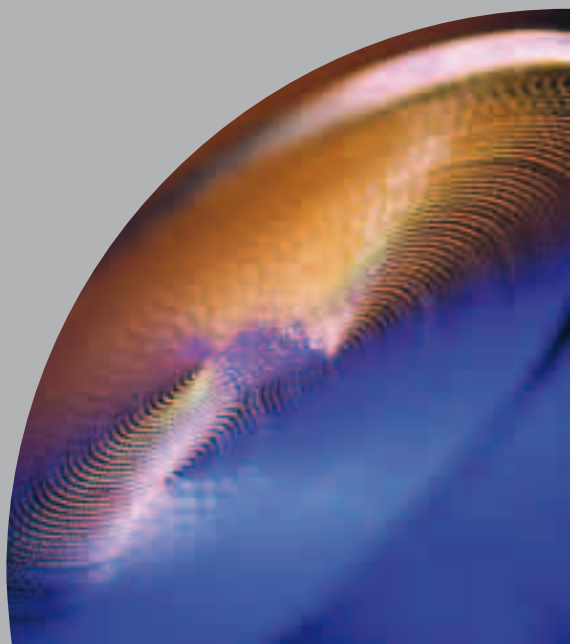


Engines and Systems



Exhaust emission legislation Diesel and gas engines



Overview

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No responsibility is taken for the correctness of this information.

This brochure is for information only. It does not replace any official laws, regulations or standards.

Date of issue: April 2010

2 MARINE

EU – Inland waterway vessels

The emission limits are valid for propulsion engines of inland waterway vessels in EU watercourses (Nonroad Directive 97/68/EC, amended by 2004/26/EC). The limits and the classification of the engines correspond to stage 2 (Tier 2) of the US-EPA Final Rule for inland marine vessels.

Category	Cylinder Displ. Power	CO g/kWh	HC + NO _x g/kWh	PM g/kWh	Date ^A
V 1:1	$V_{h,z} < 0.9 \text{ l}$	5.0	7.5	0.4	2007
	$P_n \geq 37 \text{ kW}$				
V 1:2	$0.9 \text{ l} \leq V_{h,z} < 1.2 \text{ l}$	5.0	7.2	0.3	2007
V 1:3	$1.2 \text{ l} \leq V_{h,z} < 2.5 \text{ l}$	5.0	7.2	0.2	2007
V 1:4	$2.5 \text{ l} \leq V_{h,z} < 5.0 \text{ l}$	5.0	7.2	0.2	2009
V 2:1	$5.0 \text{ l} \leq V_{h,z} < 15.0 \text{ l}$	5.0	7.8	0.27	2009
V 2:2	$15.0 \text{ l} \leq V_{h,z} < 20.0 \text{ l}$	5.0	8.7	0.5	2009
	$P_n < 3300 \text{ kW}$				
V 2:3	$15.0 \text{ l} \leq V_{h,z} < 20.0 \text{ l}$	5.0	9.8	0.5	2009
	$P_n \geq 3300 \text{ kW}$				
V 2:4	$20.0 \text{ l} \leq V_{h,z} < 25.0 \text{ l}$	5.0	9.8	0.5	2009
V 2:5	$25.0 \text{ l} \leq V_{h,z} < 30.0 \text{ l}$	5.0	11.0	0.5	2009

^A Date for placing on the market; Type approvals one year earlier.

Exempted from the limits are the following ships:

- Vessels intended for passenger transport carrying no more than 12 people in addition to the crew
- Recreational craft with a length of less than 24 meters (see 94/25/EC)
- Service craft belonging to supervisory authorities
- Fire-service vessels
- Naval vessels
- Fishing vessels on the fishing vessels register of the Community
- Sea-going vessels, including sea-going tugs and pusher craft operating or based on tidal waters or temporarily on inland waterways, provided that they carry a valid navigation or safety certificate.

For the national implementation of the directive, the exceptions have not been fully adopted by all member states.

- The limits also apply to marine auxiliary engines above 560 kW. For other auxiliary engines the limits for nonroad mobile machinery apply.
- Alternatively, the limits of the Rhine Vessel Inspection Regulation may be applied (mutual recognition is agreed).

- Test cycles: ISO 8178-4, E2/E3/D2/C1 (according to engine operation)
- Test condition: air temperature 25°C / water temperature 25°C

EU – Recreational crafts

The directive 94/25/EC (as amended by 2003/44/EC) includes construction- and design-prescriptions for **recreational crafts from 2.5 to 24 m hull length** and **personal water crafts**. The emission limits are valid for new propulsion engines, which will be installed or are specifically intended for installation on or in recreational crafts and personal watercrafts, as well as for already built in engines, which are installed on or in these crafts and that undergo major engine modifications (could potentially cause the engine to exceed the emission limits or increases the rated power of the engine by more than 15%). The directive does not apply for submersibles, air cushion vehicles, hydrofoils, racing boats (intended solely for racing), experimental craft (provided that they are not subsequently placed on the Community market), craft specially intended to be crewed and to carry passengers for commercial purposes and original historical craft and individual replicas (not in mass-production) designed before 1950.

Limits (valid since 1 January 2005)

Type	CO [g/kWh]	HC [g/kWh]	NO _x [g/kWh]	PM g/kWh
Compression Ignition	5.0	$1.5 + 2/P_n^{0.5}$	9.8	1

P_n = Engine rated power in kW

Exhaust emissions are measured according to the harmonised standard ISO 8178-1.

For engines above 130 kW the exhaust emissions can be measured either according to test cycle E3 (IMO) or E5 (water sports) of ISO 8178-4.

IMO – Seagoing ships

MARPOL (MARine POLLution) is an international convention for prevention of the pollution of the sea from ships. It establishes rules for the protection of the environment valid for international shipping. The text of the convention regulates the basic conditions while the practical relevant issues are handled in the annexes.

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MARPOL has to be followed primarily by ships, which run under the flag of an IMO member country. If a ship runs under another authority but navigates in watercourses of member countries, this ship has to adopt MARPOL too.

Nitrogen oxides (NO_x)

Marine diesel engines with a power of more than 130 kW are affected by this regulation depending on the date of their keel laying. Engines in lifeboats or other rescue equipment and vessels that are operated in national waters are exempted.

n_n 1/min	NO _x [g/kWh]
Stage I, beginning from 1. 1. 2000	
< 130	17.0
130–2000	$45.0 \cdot n_n^{(-0.2)}$
> 2000	9.8
Stage II, beginning from 1. 1. 2011	
< 130	14.4
130–2000	$44.0 \cdot n_n^{(-0.23)}$
> 2000	7.7
Stage III, beginning from 1. 1. 2016^A in Emission Control Areas (ECAs)	
< 130	3.4
130–2000	$9 \cdot n_n^{(-0.2)}$
> 2000	2.0

^A Review of date of entry into force in 2012.

Existing vessels shall be modified so that they fulfil Tier I emission limit values if

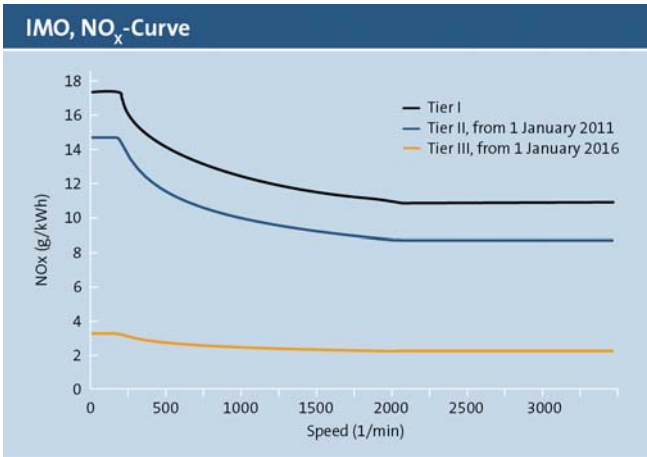
- they have been built between 1990 and 2000,
- they have ≥ 90 l displacement per cylinder and
- they have an engine power of >5.000 kW and
- a retrofit kit at a reasonable price has been approved by the engine manufacturer and certified by the authorities.

Replacement engine or additional engine

- In case of replacement by an identical engine the same requirements apply as for the former one
- In case of replacement by a non-identical engine or installation of an additional engine the standards in force at the time of the installation shall apply.
- Replacement engines only: On or after 1 January 2016 Tier II will be applicable if it can be proven that it is not possible to meet Tier III.

Major engine conversion:

- Engines on ships constructed prior to 1 January 2000 shall meet Tier I
- Engines on ships constructed on or after 1 January 2000 shall meet the standard in place at the time the ship was constructed.



- NO_x limit dependent on engine rated speed.
- No limits for HC, CO, particulates and soot.
- Test cycle: ISO 8178-4, E2/E3/D2/C1 (according to engine operation).
- Test condition: 25°C air temperature / 25°C water temperature
- Particulate and SO_x emissions are limited via fuel quality.

Sulphur oxides (SO_x)

The SO_x emission is regulated by the sulphur content in the fuel. The following limits for the sulphur content have been adopted in October 2008.

Global sulphur limit levels:

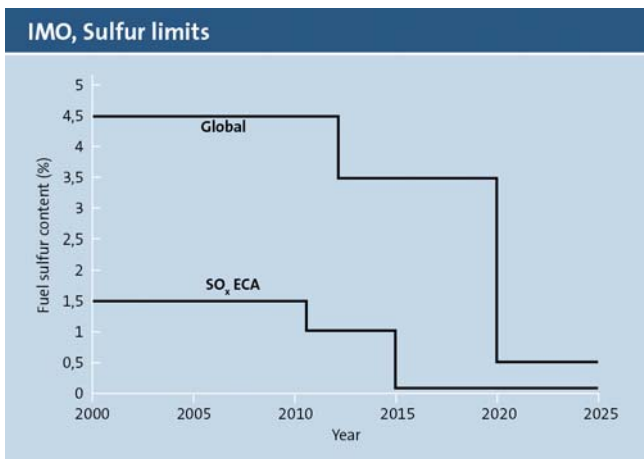
- 4.50 % (45.000 ppm) until 2012
- 3.50 % (35.000 ppm) beginning with 2012
- 0.50 % (5.000 ppm) beginning with 2020*

* Review of the date of entry into force in 2018. In case of non-availability of sufficient low sulphur fuel the introductory date will be postponed to 2025.

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In SO_x-Emission-Control-Areas (SECAs)

- 1.50 % (15.000 ppm) before 1 July 2010
- 1.00 % (10.000 ppm) beginning from 1 July 2010
- 0.10 % (1.000 ppm) beginning from 2015
- Alternatives (e.g. scrubber) are allowed if they can meet the same reduction rates



Rhine vessel inspection regulation

The emission limits of combustion engines are established in § 8a of the Rhine Vessel Inspection Regulation (RheinSchUO).

Stage I (since 2003)

Power P _n kW	Speed n _n rpm	CO g/kWh	HC g/kWh	NO _x g/kWh	PM g/kWh
37–75	–	6.5	1.3	9.2	0.85
75–130	–	5.0	1.3	9.2	0.70
> 130	500 – 2800	5.0	1.3	45 · n _n ^(-0.2)	0.54
	≥ 2800	5.0	1.3	9.2	0.54

- Only combustion engines which use fuels with a flashpoint above 55°C shall be installed.
- The limits are valid for all engines with a rated power (P_n) at or above 37 kW, which are installed in vehicles or machines aboard, unless there are no corresponding directives of the European Union which affect the emission of gaseous pollutants or air pollutant particulates.

- For engines with a rated power less than 130 kW, the limits correspond to EU Directive 97/68/EC (mobile machinery), stage 1.
- For engines with a rated power of more than 130 kW and a rated speed between 500 and 2800 rpm, the NO_x limit corresponds to the IMO convention.
- Test cycle: ISO 8178-4, E2/E3/D2/C1 (according to engine operation)
- Test condition: air temperature 25°C /water temperature 25°C

Stage II (as of 1 July 2007 [Date of putting in service of the ship])

Power P _n kW	Speed n _n rpm	CO g/kWh	HC g/kWh	NO _x g/kWh	PM g/kWh
18–37	–	5.5	1.5	8.0	0.8
37–75	–	5.0	1.3	7.0	0.4
75–130	–	5.0	1.0	6.0	0.3
130–560	–	3.5	1.0	6.0	0.2
> 560	< 343	3.5	1.0	11.0	0.2
	343 – 3150	3.5	1.0	$45 \cdot n_n^{-0.2} - 3$	0.2
	≥ 3150	3.5	1.0	6.0	0.2

- Test cycles and test conditions as for stage I
- Alternatively, the limits for inland waterway vessel engines of EU Directive 97/68/EC, as amended by Directive 2004/26/EC, may be applied (mutual recognition is agreed).

Lake Constance shipping ordinance (BSO)

The compound of the detected carbone monoxide, of the detected hydrocarbons and of the detected nitrogen oxides, as well as the exhaust-gas opacity of diesel engines, may not exceed the following exhaust emission limits for diesel and gasoline engines, which are to be tested according to the prescriptions.

Stage I (Engines, which have been built before 31 December 1995)

Power P _n kW	CO		HC		NO _x	
	A	m	A	m	A	m
< 4	600	0.5	60.0	0.7747	15	0
4–100	600	0.5	39.39	0.4711	15	0
> 100	60	0	10.13	0.1761	15	0

P_n = rated power

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The calculated mass-emissions of spark ignited engines of group A or group B, as well as the mass-emissions of diesel engines of group A may not exceed the following values:

4500 g/h for carbon monoxide CO

290 g/h for hydrocarbons HC

1100 g/h for nitrogen oxides NO_x

Smoke limit for diesel engines: The Bosch-Unit may not exceed 4.0 for naturally aspirated engines and 3.0 for supercharged engines.

Stage II (engines, which have been built after 1 January 1996)

For spark ignition engines, the following limits apply:

Power P _n kW	CO		HC		NO _x	
	A•P _n ^{-m} (g/kWh)		A•P _n ^{-m} (g/kWh)		A•P _n ^{-m} (g/kWh)	
	A	m	A	m	A	m
< 4	400	0.6505	30	0.6505	10	0.1505
4–100	400	0.6505	30	0.6505	10	0.1505
> 100	20	0	3.375	0.1761	5	0

P_n = rated power

For gasoline engines, the following limits apply:

Power P _n kW	CO		HC		NO _x	
	A•P _n ^{-m} (g/kWh)		A•P _n ^{-m} (g/kWh)		A•P _n ^{-m} (g/kWh)	
	A	m	A	m	A	m
< 4	400	0.6505	30	0.6505	10	0.1505
4–100	400	0.6505	30	0.6505	10	0.1505
> 100	20	0	3.375	0.1761	10	0

P_n = rated power

- The calculated mass-emissions of spark ignited engines of group A or group B, as well as the mass-emissions of diesel engines of group A may not exceed the following values:
 - 1500 g/h for carbon monoxide CO
 - 95 g/h for hydrocarbons HC
 - 360 g/h for nitrogen oxides NO_x
- Smoke limit for diesel engines: The Bosch-Unit may not exceed 3.5 for naturally aspirated engines and 2.5 for supercharged engines.
- Test cycle: ISO 8178 Part 4, E5

USA –Marine engines

On 6 May 2008 US EPA has published the final rule „40 CFR Parts 9, 85”, for marine engines less than 30 liters per cylinder. This rule regulates amongst others the emission limit values for marine engines that are operated in commercial and recreational vessels. The regulation covers propulsion and auxiliary engines.

Tier 1:

Cat.	Power and displacement	speed min^{-1}	Model year	NO_x g/kWh	HC- NO_x g/kWh	PM g/kWh	CO g/kWh
Small	$P_n < 8 \text{ kW}$	–	2000	–	10.5	1.0	8.0
	$8 \text{ kW} \leq P_n < 19 \text{ kW}$	–	2000	–	9.5	0.8	6.6
	$19 \text{ kW} \leq P_n < 37 \text{ kW}$	–	1999	–	9.5	0.8	5.5
C1, C2, C3, Rec.	$P_n \geq 37 \text{ kW}$ und $V_{h,z} \geq 2.5 \text{ l}$	$n_n \geq 2000$	2004	9.8	–	–	–
		$130 \leq n_n < 2000$	2004	$45 \cdot n_n^{-0.2}$	–	–	–
		$n_n < 130$	2004	17.0	–	–	–

Tier 2:

Cat.*	Cylinder displacement	Power kW	Model year	HC+ NO_x g/kWh	PM g/kWh	CO g/kWh
Small	–	$P_n < 8$	2005	7.5	0.8	8.0
	–	$8 \leq P_n < 19$	2005	7.5	0.8	6.6
	–	$19 \leq P_n < 37$	2004	7.5	0.6	5.5
C1	$V_{h,z} < 0.9$	$P_n \geq 37$	2005	7.5	0.4	5.0
	$0.9 \text{ l} \leq V_{h,z} < 1.2 \text{ l}$	–	2004	7.2	0.3	5.0
	$1.2 \text{ l} \leq V_{h,z} < 2.5 \text{ l}$	–	2004	7.2	0.2	5.0
	$2.5 \text{ l} \leq V_{h,z} < 5 \text{ l}$	–	2007	7.2	0.2	5.0
C2	$5 \text{ l} \leq V_{h,z} < 15 \text{ l}$	–	2007	7.8	0.27	5.0
	$15 \text{ l} \leq V_{h,z} < 20 \text{ l}$	$P_n < 3300$	2007	8.7	0.5	5.0
	$15 \text{ l} \leq V_{h,z} < 20 \text{ l}$	$P_n \geq 3300$	2007	9.8	0.5	5.0
	$20 \text{ l} \leq V_{h,z} < 25 \text{ l}$	–	2007	9.8	0.5	5.0
	$25 \text{ l} \leq V_{h,z} < 30 \text{ l}$	–	2007	11.0	0.5	5.0
Rec.	$V_{h,z} < 0.9 \text{ l}$	$P_n \geq 37$	2007	7.5	0.4	5.0
	$0.9 \text{ l} \leq V_{h,z} < 1.2 \text{ l}$	$P_n \geq 37$	2006	7.2	0.3	5.0
	$1.2 \text{ l} \leq V_{h,z} < 2.5 \text{ l}$	$P_n \geq 37$	2006	7.2	0.2	5.0
	$2.5 \text{ l} \leq V_{h,z} < 5.0 \text{ l}$	$P_n \geq 37$	2009	7.2	0.2	5.0

* No Tier-2-Standards for Category 3

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Tier 3 for C1 marine diesel engines in commercial vessels (standard power density, < 35 kW/l):

Power [kW]	Cylinder displacement [L]	Model year	HC+NO _x ^D g/kWh	PM g/kWh	CO g/kWh
<19	< 0.9	2009	7.5	0.40	5.0
19–75	< 0.9 ^A	2009	7.5	0.30	5.0
		2014	4.7 ^B	0.30 ^B	5.0
75–3700	<0.9	2012	5.4	0.14	5.0
	0.9 < V _h < 1.2	2013	5.4	0.12	5.0
	1.2 < V _h < 2.5	2014	5.6	0.11 ^C	5.0
	2.5 < V _h < 3.5	2013	5.6	0.11 ^C	5.0
	3.5 < V _h < 7	2012	5.8	0.11 ^C	5.0

^A <75 kW engines at or above 0.9 L/cylinder are subject to the corresponding 75–3700 kW standards.

^B Option: 0.20 g/kWh PM/5.8 g/kWh NO_x+HC in 2014.

^C This standard level drops to 0.10 g/kWh in 2018 for <600 kW engines.

^D Tier 3 NO_x+HC standards do not apply to 2000–3700 kW engines.

Tier 3 for C1 marine diesel engines commercial and recreational (high power density, > 35 kW/l):

Power [kW]	Cylinder displacement [L]	Model year	HC+NO _x g/kWh	PM g/kWh	CO g/kWh
<19	< 0.9	2009	7.5	0.40	5.0
19–75	< 0.9 ^A	2009	7.5	0.30	5.0
		2014	4.7 ^B	0.30 ^B	5.0
75–3700	<0.9	2012	5.8	0.15	5.0
	0.9 < V _h < 1.2	2013	5.8	0.14	5.0
	1.2 < V _h < 2.5	2014	5.8	0.12	5.0
	2.5 < V _h < 3.5	2013	5.8	0.12	5.0
	3.5 < V _h < 7	2012	5.8	0.11	5.0

^A <75 kW engines at or above 0.9 L/cylinder are subject to the corresponding 75–3700 kW standards.

^B Option: 0.20 g/kWh PM/5.8 g/kWh NO_x+HC in 2014.

Tier 3 for C2^A marine diesel engines:

Power [kW]	Cylinder displacement [L]	Model year	HC+NO _x ^B g/kWh	PM g/kWh
<3700	7 < V _h < 15	2013	6.2	0.14
	15 < V _h < 20	2014	7.0	0.27 ^C
	20 < V _h < 25	2014	9.8	0.27
	25 < V _h < 30	2014	11.0	0.27

^A Option for C2: Tier 3 PM/NO_x+HC at 0.10 / 5.8 g/bhp-hr (0.14/7.8 g/kW-hr) in 2012, and Tier 4 in 2015.

^B Tier 3 NO_x+HC standards do not apply to 2000–3700 kW engines.

^C For engines below 3300 kW in this group, the PM Tier 3 standard is 0.25g/bhp-hr (0.34 g/kW-hr).

Tier 4 for C1 und C2 marine diesel engines^E:

Power [kW]	Model year	HC g/kWh	NO _x g/kWh	PM g/kWh
≥ 3700	2014 ^C	0.19	1.8	0.12 ^A
	2016 ^{B,C}	0.19	1.8	0.06
2000 ≤ P < 3700	2014 ^{C,D}	0.19	1.8	0.04
1400 ≤ P < 2000	2016 ^C	0.19	1.8	0.04
600 ≤ P < 1400	2017 ^B	0.19	1.8	0.04

^A This standard is 0.19 g/bhp-hr (0.25 g/kW-hr) for engines with 15–30 liter/cylinder displacement.

^B Optional compliance start dates can be used within these model years; see discussion below.

^C Option for C2: Tier 3 PM/NO_x+HC at 0.10 / 5.8 g/bhp-hr (0.14/7.8 g/kW-hr) in 2012, and Tier 4 in 2015.

^D The Tier 3 PM standards continue to apply for these engines in model years 2014 and 2015 only.

^E Recreational marine diesel engines are exempted from Tier 4.

- Test cycle: ISO 8178-4, E2/E3/D2/C1 (according to engine operation).
- Test condition: air temperature 25°C / water temperature 25°C
- For recreational crafts the test cycle E5, ISO 8178-4 is valid.
- NTE (Not to exceed): In certain sections of the engine performance map, emissions may not exceed 1.2 to 1.5 times the cycle limit. These requirements come into force with 2007 model year.
- ABT (Averaging, Banking and Trading): Emission credits (NO_x+HC and particulates) can be averaged, banked or traded.
- Voluntary Standards: Engines, which meet clearly lower limits, may use the “Blue Sky Series” label. Therefore engines have to meet Tier 3. For engines with no Tier 3 standards a calculated level corresponding to a 40% reduction beyond Tier 2 will be used.

12 MARINE

Turkey – Inland waterway vessels

The emission limit values (Regulation 97/68/AT, amended by 2004/26/AT) for propulsion engines of inland waterway vessels in Turkish watercourses and the categorisation of the engines are identical with the European Directive 97/68/EC and 2004/26/EC respectively and with the Tier 2 US EPA inland waterway regulation. The date of coming into force for all categories is 2010 so one to three years later than regulated in the European Directive.

Category	Category displacement per cylinder power	CO g/kWh	HC + NO _x g/kWh	PM g/kWh	Date*
V 1:1	$V_{h,z} < 0.9 \text{ l}$ $P_n \geq 37 \text{ kW}$	5.0	7.5	0.4	2010
V 1:2	$0.9 \text{ l} \leq V_{h,z} < 1.2 \text{ l}$	5.0	7.2	0.3	2010
V 1:3	$1.2 \text{ l} \leq V_{h,z} < 2.5 \text{ l}$	5.0	7.2	0.2	2010
V 1:4	$2.5 \text{ l} \leq V_{h,z} < 5.0 \text{ l}$	5.0	7.2	0.2	2010
V 2:1	$5.0 \text{ l} \leq V_{h,z} < 15.0 \text{ l}$	5.0	7.8	0.27	2010
V 2:2	$15.0 \text{ l} \leq V_{h,z} < 20.0 \text{ l}$ $P_n < 3300 \text{ kW}$	5.0	8.7	0.5	2010
V 2:3	$15.0 \text{ l} \leq V_{h,z} < 20.0 \text{ l}$ $P_n \geq 3300 \text{ kW}$	5.0	9.8	0.5	2010
V 2:4	$20.0 \text{ l} \leq V_{h,z} < 25.0 \text{ l}$	5.0	9.8	0.5	2010
V 2:5	$25.0 \text{ l} \leq V_{h,z} < 30.0 \text{ l}$	5.0	11.0	0.5	2010

* Date for placing on the market.

Russia – Marine

Date	Carbon monoxide CO [g/kWh]	Hydrocarbon HC [g/kWh]	NO _x [g/kWh]
< 1 Jan 2000	6.0	2.4	17.0

Date	Carbon monoxide CO [g/kWh]	Hydrocarbon HC [g/kWh]	n _n 1/min	NO _x [g/kWh]
≥ 1 Jan 2000	3.0	1.0	< 130	17.0
			130 – 2000	$45.0 \cdot n_n^{(-0.2)}$
			> 2000	9.8

World Bank – General EHS Guidelines

The World Bank Group consists of five organisations. Their main issue is to boost the economic development of the less developed member countries with financial and technical help and consulting.

The emission limit values are valid for stationary engine driven power plants (gas and diesel engines) with 3–50 MW_{th} (at 15% residual oxygen).

The emission limits will come into force for stationary engine driven power plant financed by World Bank in a country where no national emission limit values for those installations exist or where limits are available but less strict than those stipulated by World Bank.

Emission bonuses for NO_x are granted for power plants with high efficiency (currently no World Bank definition, will be set project related). The emission limit values are to be met for power plants that are operated more than 500 hours per year.

Gas engines

Operation mode / bore [mm]	PM	SO ₂	NO _x
	mg/m _n ³	mg/m _n ³	mg/m _n ³
spark ignition	–	–	200
Dual Fuel-Mode	–	–	400
compression ignition	–	–	1600

Diesel engines

Bore [mm]	PM	SO ₂	NO _x
	mg/m _n ³	mg/m _n ³	mg/m _n ³
< 400	50 or 100 ^A	1.5–3 % S ^B	1460
< 400 and high efficiency			1600
≥ 400 mm			1850

^A if justified by project specific considerations (e.g. Economic feasibility of using lower ash content fuel, or adding secondary treatment to meet 50, and available environmental capacity of the site)

^B if justified by project specific considerations (e.g. Economic feasibility of using lower S content fuel, or adding secondary treatment to meet levels of using 1.5 percent sulphur, and available environmental capacity of the site)

14 STATIONARY POWER PLANTS

World Bank – EHS Guidelines for industry sectors: Power plants > 50 MW_{th}

The limit values are valid for power plants with a thermal capacity of **more than 50 MW** and more than 500 operating hours per year.

When host country regulations differ from the levels and measures presented in the EHS Guidelines, projects are expected to achieve whichever is more stringent. If less stringent levels than those provided in these EHS Guidelines are appropriate a detailed justification is needed as part of the site-specific environmental assessment.

The guidelines differ in installations in

- **Degraded Airsheds (DA):** (poor air quality); Airshed should be considered as being degraded if nationally legislated standards are exceeded or, in their absence.
- **Non-degraded Airsheds (NDA)**

Plants in Degraded Airsheds (DA), areas with poor air quality

Fuel	Technology ^B / Power [MW _{th}]	PM mg/m _n ^{3A}	S% ^C	NO _x mg/m _n ^{3A}
Natural gas	SI	–	–	200
	CI/DF			400
Liquid fuels	50 ≤ P < 300	30	0,5	400
	P ≥ 300		0,2	
Biofuels/gaseous fuels other than natural gas	SI, natural gas	30	–	200
	other			400

^A dry gas excess 15% O₂ content

^B SI=Spark Ignition, CI=Compression Ignition, DF=Dual Fuel

^C S%=fuel sulfur content

Plants in Non-Degraded Airsheds

Fuel/ Power [MW_{th}]	Technology ^B / Bore size [mm]	PM mg/m_n^{3A}	SO ₂ mg/m_n^{3A}	NO _x mg/m_n^{3A}
Natural gas	SI	–	–	200
	CI, DF			400 ^C
Liquid fuels $50 \leq P < 300$	CI / < 400	50	1170 or < 2% S ^D	1460
	CI / ≥ 400			1850
	DF			2000
Liquid fuels $P \geq 300$	–	50	585 or < 1% S ^D	740
Biofuels/gaseous fuels other than natural gas	–	50	–	30% higher limits than those for natural gas and liquid fuels

^A dry gas excess 15% O₂ content

^B SI=Spark Ignition, CI=Compression Ignition, DF=Dual Fuel

^C Compression Ignition (CI) engines may require different emissions values which should be evaluated on a case-by-case basis through the environmental assessment process.

^D S%=fuel sulfur content

UN-ECE Gothenburg Protocol

In the Convention on Long-range Transboundary Air Pollution (CLRTAP), which was adopted in 1979, emission ceilings for the Parties to the Protocol are set and NO_x limit values for facilities with stationary engines have been defined. The Gothenburg Protocol is intended to abate acidification, eutrophication and ground-level ozone. The Protocol has been adopted in 1999, became effective on 17 May 2005, and sets limit values for specific emission sources. Parties to the Protocol are all EU countries, Eastern Europe states, USA and Canada.

Limit values (Annex 5, issue 12)

Engine type	Fuel type / Mode of operation	NO _x mg/m_n^3
Spark ignition (gas engines) $MW_{th} > 1$	Lean burn engines	250
	Others	500
Compression ignition (Diesel / Dual fuel) $MW_{th} > 5$	Natural gas (Jet ignition engines)	500
	Heavy fuel oil	600
	Diesel or gas oil	500

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- Regenerative gases like biogas, purification gas and landfill gas also have to meet the limits for natural gas.
- Limit values do not apply to engines running less than 500 hours a year.
- The O₂ reference is 5 %.
- As an alternative, a Party to the Protocol may apply different emission reduction strategies that achieve equivalent overall emission levels for all source categories together.

Germany – Stationary power plants

The “Technische Anleitung zur Reinhaltung der Luft (TA Luft)” is a common administrative regulation of the German government referring to the “Bundes-Immissionsschutzgesetz” (BImSchG). It contains limit values for emission and imission of pollutants from stationary plants and defines the respective measurement and calculation procedures.

Subject to TA Luft are combustion engine power plants using

- oil residues and landfill gas independent from the rated power
- biogas, natural gas, purification gas with $MW_{th} > 1$
- other fuels (e.g. diesel fuels) with $MW_{th} > 1$
- The emission limits refer to dry exhaust gas with 5 % residual oxygen.
- Dust means cumulative dust, including the part of cancer-producing, inheritance-changing and reproduction-toxic substances.

Gas engines

Gas type	Engine type	MW _{th}	CO	NO _x
			mg/m _n ³	mg/m _n ³
Natural gas	Lean mix engine		300	500
	Others		300	250
Pit gas	Lean mix engine		650	500
	Others		650	250
Biogas / purification gas	Jet ignition	< 3	2000	1000
		≥ 3	650	500
	Spark ignition	< 3	1000	500
		≥ 3	650	500
Landfill gas	Lean mix engine		650	500
	Others		650	250

Diesel engines

MW _{th}	Dust mg/m _n ³	CO mg/m _n ³	NO _x mg/m _n ³
< 3	20	300	1000
≥ 3	20	300	500

- Limit values applicable to normal operation (i. e. normally at rated power)
- For emergency plants and plants that are operated up to 300 hours per year to cover peak demands (e.g. power generation, gas or water supply) the dust limit is 80 mg/m_n³. The NO_x- and CO-limits do not apply.
- The NO_x-limit for two-stroke engines is 800 mg/m_n³
- The limit for formaldehyde emissions of biogas engines has been lowered. From 1 January 2009 they must not exceed 40 mg/m_n³. For other engines the limit of 60 mg/m_n³ is still in force.

Belgium

The Belgian law Vlareem 2 regulates the emission limit values of permanently installed stationary (gas and diesel) engines subject to their operating hours per year. The law distinguishes furthermore in engines that have been installed before 31 December 2007 and after 1 January 2008. The emission limit values are given in mg/m_n³ and related to 5 % residual oxygen.

Stationary gas engines installed before 31 December 2007 and operated 360 or more operating hours per year:

Categorie Gas engine	Engine power [MW _{th}]	NO _x mg/m _n ³	CO mg/m _n ³	Organic substances
first licence for operation granted before 1 Jan 1993	–	–	2600	–
first licence for operation granted on or after 1 Jan 1993 and before 1 Jan 2000	–	2600 · η/30	1300	–
first licence for operation granted on or after 1 Jan 2000 and before 1 Jan 2005	–	500 · η/30	650	–
first licence for operation granted on or after 1 Jan 2005	1	500 · η/30	650	150
	> 1	500	650	150

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Stationary gas engines installed after 1 January 2008 and operated 360 or more operating hours per year:

Category Gas engine	Engine power [MW _{th}]	NO _x mg/m _n ³	CO mg/m _n ³	Organic substances
first licence for operation granted before 1 Jan 2000	–	1300 * η/30 *	1300	–
first licence for operation granted between 1 Jan 2000 and 1 Jan 2005	–	500 · η/30	650	150
first licence for operation granted on or after 1 Jan 2005	1	500 · η/30	650	150
	> 1	500	650	150

* As a departure from this emission limit value, for gas motors for which the first licence for operation was granted before 1 January 1993 to 31 December 2018 no NO_x emission limit value is applicable.

Stationary diesel engines installed before 31 December 2007 and operated 360 or more operating hours per year:

Category Diesel engine	Engine power [MW _{th}]	Dust	SO ₂ with gas oil*	SO ₂ with heating oil*	NO _x	CO	Organic subst.
		mg/m _n ³	%	%	mg/m _n ³	mg/m _n ³	mg/m _n ³
first licence for operation granted before 1 Jan 1993	≥ 0.3	–	0.2	1.00	–	2600	–
first licence for operation granted between 1 Jan 1993 and 1 Jan 2000	≥ 0.3	200	0.2	1.00	4000	1000	–
first licence for operation granted between 1 Jan 2000 and 1 Jan 2005	0.3–3	50	0.2	–	4000	650	–
	≥ 3	50	0.2	–	2000	650	–
first licence for operation granted on or after 1 Jan 2005	0.3–3	50	0.2	–	1000	650	150
	≥ 3	50	0.2	–	500	650	150

* maximum S-level in fuel (in mass %)

Stationary diesel engines installed after 1 January 2008 and operated 360 or more operating hours per year:

Category Diesel engine	Engine power [MW _{th}]	Dust	SO ₂ with gas oil*	SO ₂ with heating oil*	NO _x	CO	Organic subst.
		mg/m _n ³	%	%	mg/m _n ³	mg/m _n ³	mg/m _n ³
first licence for operation granted before 1 Jan 1993	≥ 0.3	300	0.1	0.60	5000	1500	–
first licence for operation granted between 1 Jan 1993 and 1 Jan 2000	≥ 0.3	200	0.1	0.60	4000	1000	–
first licence for operation granted between 1 Jan 2000 and 1 Jan 2005	0.3–3	50	0.1	–	4000	650	–
	≥ 3	50	0.1	–	500	650	150
first licence for operation granted on or after 1 Jan 2005	0.3–3	50	0.1	–	1000	650	150
	≥ 3	50	0.1	–	500	650	150

* maximum S-level in fuel (in mass %)

Stationary gas engines installed before 31 December 2007 and operated less than 360 operating hours per year:

Category Gas engine	NO _x mg/m _n ³	CO mg/m _n ³
first licence for operation granted before 1 January 2000	–	2600
first licence for operation granted on or after 1 January 2000	$500 \cdot \eta/30$	650

Stationary gas engines installed after 1 January 2008 and operated less than 360 operating hours per year:

Category Gas engine	NO _x mg/m _n ³	CO mg/m _n ³	Organis substances
first licence for operation granted before 1 January 2000	$1300 \cdot \eta/30$ *	1300	–
first licence for operation granted on or after 1 January 2000	$500 \cdot \eta/30$	650	150

* For gas motors for which the first licence for operation was granted before 1 January 1993 the above mentioned emission limit value for NO_x is replaced by 10.000 mg/m_n³.

Stationary diesel engines installed before 31 December 2007 and operated less than 360 operating hours per year:

Category Diesel engine	Engine Power [MW _{th}]	Dust	SO ₂ with gas oil*	SO ₂ with heating oil*	NO _x	CO
		mg/m _n ³	%	%		
first licence for operation granted before 1 Jan 2000	≥ 0.3	300	0.2	1.00	–	1500
first licence for operation granted on or after 1 Jan 2000	0.3–3	50	0.2		4000	650
	≥ 3	50	0.2		2000	–

* maximum S-level in fuel (in mass %)

Stationary diesel engines installed after 1 January 2008 and operated less than 360 operating hours per year:

Category Diesel engine	Engine Power [MW _{th}]	Dust	SO ₂ with gas oil*	SO ₂ with heating oil*	NO _x	CO
		mg/m _n ³	%	%		
first licence for operation granted before 1 Jan 2000	≥ 0.3	300	0.1	0.60	–	1500
first licence for operation granted on or after 1 Jan 2000	0.3–3	50	0.1		4000	650
	≥ 3	50	0.1		2000	–

* maximum S-level in fuel (in mass %)

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Finland

The emission guideline of the Finish environmental protection agency from October 2003 defines limits on SO₂-, NO_x- and particle emissions of **small combustion plants**, which shall be reached by using so called “best available techniques”. A small combustion plant within this regulation means a plant unit, consisting of one or more combustion components (steam boilers, engines, gas turbines) on a single location with MW_{th} < 50 and a flue gas evacuation through a common stack. This guideline is **not a law, only a recommendation**, because in Finland local authorities assign the operating licence for plants of this size. The authorities should orientate on the following limits. All limits refer to a 15 % residual oxygen content in the exhaust gas.

Limits for new diesel and gas engines

Engine type	NO _x Primary		NO _x Secondary		SO ₂		Particulates	
	mg/MJ	mg/m _n ³	mg/MJ	mg/m _n ³	mg/MJ	mg/m _n ³	mg/MJ	mg/m _n ³
Oil diesel	< 1400 ^A	< 1600 ^A	< 650 ^B	< 750 ^B	< 500	< 600	< 50	< 60
Gas diesel	< 1400 ^A	< 1600 ^A	< 650 ^B	< 750 ^B				
Spark ign.	< 150	< 175						
Dual fuel	< 150	< 175						

^A primary methods: engine internal measures (for normal applications)

^B secondary methods: methods outside the engine (for special application, e.g. urban areas)

Limits for already existing diesel and gas engines

Engine type	NO _x		SO ₂		Particulates	
	mg/MJ	mg/m _n ³	mg/MJ	mg/m _n ³	mg/MJ	mg/m _n ³
Oil diesel	< 2000	< 2300	< 500	< 600	< 60	< 70
Gas diesel	< 1500	< 1750				
Spark ign.	< 160	< 175				
Dual fuel	< 160	< 185				

There are no specific test-cycles. The limits are given for 100 % load as maximum measured values or as values, which can be reached if the reduction of the emissions is based on a “best available technique”.

France

The French Arrêté 2910 defines emission limits for stationary diesel engines and gas engines.

Limit values

Operating time h/year	Power MW _{th}	NO _x mg/m _n ³			CO mg/m _n ³	NMHC mg/m _n ³	Dust mg/m _n ³
		Nat. gas	Liquid fuel	Dual Fuel			
> 500	20–100	350	1000	1000	650	150	100
	> 100	250	600	750	650	150	100
≤ 500	20–100	875	2500	2500	650	150	100
	> 100	625	1500	1875	650	150	100

- The emission limits refer to dry exhaust gas with 5 % residual oxygen.
- The NO_x limit for plants operated up to 500 hours per year is multiplied with the coefficient 2.5.
- If the plant is operated as a combined heat and power generation plant, the respective limit value in the table above can be exceeded by 30 mg/m_n³.
- The NO_x limit for plants which have been licensed before 4 December 2000 and which consume liquid fuel amounts 1900 mg/m_n³ (independent from the power of the plant).
- The NO_x limit for plants that have been licensed before 4 December 2000 and that consume natural gas can be defined by a person in charge from the responsible regulating authority up to 500 mg/m_n³ if the operator of the plant can prove by a techno-economic analysis that it is impossible to observe the emission limit in the table above.
- If special fuel is used (e.g. biogas or coke oven gas), the person in charge of the responsible authority can define the maximum limit values separately.
- The limit for VOC in the exhaust gas is 20 mg/m_n³, for plants with more than 50 MW_{th} per year and a mass flow of organic compounds of more than 0.1 kg/h.

Limit values for sulphur oxide SO

Fuel type	Natural gas	Fuel oil	Heavy fuel
limit value [mg/m _n ³]	35	300	1500

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India

The Central Environmental Protection Agency, which is mandated by the Ministry of Environment and Forest, is responsible for the emission limit regulation. The following content refers to diesel engines for power generation.

Limit values for engines up to 800 kW rated power

Rated engine power	Implementation	NO _x g/kWh	HC g/kWh	CO g/kWh	PM g/kWh	Smoke opac.* m ⁻¹
≤ 19 kW	1 Jul 2005	9.2	1.3	3.5	0.3	0.7
19–50 kW	1 Jan 2004	9.2	1.3	5.0	0.5	0.7
	1 Jul 2004	9.2	1.3	3.5	0.3	0.7
50–176 kW	1 Jan 2004	9.2	1.3	3.5	0.3	0.7
176–800 kW	1 Nov 2004	9.2	1.3	3.5	0.3	0.7

* Light absorption coefficient measured at full load. All other values are measured according to test-cycle ISO 8178-4 D2, 5-Mode

Limit values for engines with more than 800 kW rated power

Date of order	NO _x ppmV	NMHC mg/m _n ³	CO mg/m _n ³	PM mg/m _n ³
Before 1 July 2003	1100	150	150	75
Between 1 July 2003 and 1 July 2005	970	100	150	75
After 1 July 2005	710	100	150	75

The following two agencies are able to implement type approvals:

- Automotive Research Association of India, Pune
- Vehicle Research and Development Establishment, Ahmednagar

The emission limits refer to dry exhaust gas with 15 % residual oxygen.

Italy

Internal combustion engines < 50 MW_{th}

Engine type	MW _{th}	PM	CO	NO _x
		mg/ m _n ³	mg/m _n ³	mg/m _n ³
Self-ignition	P < 3	130	650	4000
	P ≥ 3	130	650	200
other 4 stroke		130	650	500
other 2 stroke		130	650	800

- Values relate to 5% residual oxygen in the exhaust gas flow..
- Emission values are not applicable to emergency generators and other stationary internal combustion engines used only for emergency.

Internal combustion engines ≥ 50 MW_{th}

Fuel		MW _{th}	PM	CO	SO ₂	NO _x
			mg/ m _n ³	mg/m _n ³	mg/m _n ³	mg/m _n ³
liquid		50 ≤ P < 100	50	650	850	400
		100 ≤ P ≤ 300	30	650	500-P	200
		P > 300	30	650	200	200
gaseous	Natural gas	50 ≤ P < 100	5	650	35	150
		100 ≤ P ≤ 300	5	650	35	150
		P > 300	5	650	35	100
	Liquefied gas	P > 50	5	650	5	200
	Other gases	P > 50	5	650	35	200

- Values relate to 3% residual oxygen in the exhaust gas flow.

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Japan

Diesel engines

Bore mm	NO _x ppm (13 % O ₂)	NO _x mg/m _n ³ (5 % O ₂)	Particulates mg/m _n ³ (13 % O ₂)	Particulates mg/m _n ³ (5 % O ₂)
< 400	950	3900	100*	200
≥ 400	1200	4900	100*	200

* In certain regions 80 mg/m_n³ (13 % O₂)

- Diesel engine plants with fuel consumption > 50 l/h
- Local limits may be lower
(Example: Tokyo: NO_x = 470 mg/m_n³ [5 % O₂])

Gas engines

NO _x ppm (0 % O ₂)	NO _x mg/m _n ³ (5 % O ₂)	Particulates mg/m _n ³ (0 % O ₂)	Particulates mg/m _n ³ (5 % O ₂)
600	940	50*	38

* In certain regions 40 mg/m_n³ (0 % O₂)

- Local limits may be lower!
(Example: Tokyo: NO_x = 310 mg/m_n³ [5 % O₂])
- Gas engine plants with fuel consumption > 35 l/hr

Netherlands

The BEMS has been set in force on 1 April 2010 for medium sized installations (1 MW_{th} < p < 50 MW_{th}) with more than 500 running hours per year. It replaces BEES B, while BEES A applies for big emitters over 50 MW_{th}. Existing installations have to comply 1 January 2017 or when installation gets changed.

Fuel type	Power MW _{th}	NO _x	SO ₂	PM	HC
		mg/m _n ³	mg/m _n ³	mg/m _n ³	
Diesel	1 – 50	450	200	50	–
Biogas	1 – 50	340	200	–	–
Natural Gas	< 2.5	340	200	–	–
	> 2.5	100	200	–	1500

- 2019 for offshore installations and OCAP (organic carbon dioxide assimilation for plants)
- All limits refer to 3% residual oxygen content in the exhaust gas.

Russia – Industrial engines

Date	Carbon monoxide CO [g/kWh]	Hydrocarbon HC [g/kWh]	NO _x [g/kWh]
< 1 Jan 2000	6.0	2.4	16.0
≥ 1 Jan 2000	3.0	1.0	10.0

Switzerland

According to the clean air directive (Luftreinhalteverordnung) dated 16 December 1985 (status: 12 July 2005) the following emission limits are valid for stationary combustion engines with a thermal capacity of more than 100 kW per engine:

Fuel type	NO _x mg/m _n ³	CO mg/m _n ³	Dust mg/m _n ³
Gas fuels*	400	650	50
Other fuels	250	650	50

* Biogas, purification gas, landfill gas, natural gas

- The pollutant content refers to dry exhaust with 5 % residual oxygen.
- For emergency engines that are operated up to 50 hours per year, the limits above are not valid.
- Specifications for fuels that are used in stationary combustion engines have to be considered.

Czech Republic

The current Czech emission regulation for stationary engines has been updated with the order 146/2007 Coll. The new emission limit values in the order came into force on 1 January 2008. The emission regulation sets limits for existing installations, that have been developed and constructed before 17 May 2006 and furthermore new installations whose development and construction has been started after 17 May 2006.

Existing installations whose construction has been started before 17 May 2006:

Engine type/ power category	Fuel type	SO mg/m _n ³	NO _x mg/m _n ³	SP mg/m _n ³	ΣC mg/m _n ³	CO mg/m _n ³
spark ignition 0.2–1 MW _{th}	liquid fuel	^B	500	130	–	650
	natural gas	^B	500	–	–	650
	biogas, landfill gas	^B	1000	130	–	1030
compression ignition 0.2–1 MW _{th}	heavy fuel oil, gas oil	^B	4000	130	–	650
	natural gas, degasifying gas ^C	^B	4000	130	–	650
spark ignition < 1–5 MW _{th}	liquid fuel	^B	500	130	150 ^A	650
	natural gas	^B	500	–	150 ^A	650
	biogas, landfill gas	^B	1000	130	150 ^A	1300
compression ignition > 1–5 MW _{th}	heavy fuel oil, gas oil	^B	4000	130	150 ^A	650
	natural gas, degasifying gas ^C	^B	4000	130	150 ^A	650
spark ignition > 5 MW _{th}	liquid fuel	^B	500	130	150 ^A	650
	natural gas	^B	500	–	150 ^A	650
	biogas, landfill gas	^B	500	130	150 ^A	650
compression ignition > 5 MW _{th}	heavy fuel oil, gas oil	^B	2000	130	150 ^A	650
	natural gas, degasifying ^C	^B	2000	130	150 ^A	650

^A Total concentration of all organic substances except methane with a mass flow over 3 kg/h

^B The sulphur content in fuel shall not exceed the limit values laid down in special legislation and, in diesel fuel shall not exceed 0.05 % by mass

^C With injection ignition

**New installations whose construction has been started after
17 May 2006:**

Engine type/ power category	Fuel type	SO mg/m _n ³	NO _x mg/m _n ³	SP mg/m _n ³	Σ C mg/m _n ³	CO mg/m _n ³
spark ignition 0.2–1 MW _{th}	liquid fuel	c	500	130	^B	650
	natural gas	c	500	–	^B	650
	biogas, landfill gas	c	1000	130	^B	1300
compression ignition 0.2–1 MW _{th}	heavy fuel oil	c	4000	130	^B	650
	gas oil	c	4000	130	^B	650
	natural gas, degasifying gas ^D	c	4000	130	^B	650
spark ignition < 1–5 MW _{th}	liquid fuel	c	500 ^A	130	150 ^B	650
	natural gas	c	500 ^A	–	150 ^B	650
	Biogas, landfill gas	c	500 ^A	130	150 ^B	1300
compression ignition > 1–5 MW _{th}	heavy fuel oil	c	600 ^A	130	150 ^B	650
	gas oil	c	500 ^A	130	150 ^B	650
	natural gas, degasifying gas ^D	c	500 ^A	130	150 ^B	650
spark ignition > 5 MW _{th}	liquid fuel	c	500 ^A	130	150 ^A	650
	natural gas	c	500 ^A	–	150 ^A	650
	biogas, landfill gas	c	500 ^A	130	150 ^A	650
compression ignition > 5 MW _{th}	heavy fuel oil	c	600 ^A	130	150 ^A	650
	gas oil	c	500 ^A	130	150 ^A	650
	natural gas, degasifying ^D	c	500 ^A	130	150 ^A	650

^A The emission limits for NO_x applies from 1 January 2008. The emission limits shall not apply to engines operated for less than 500 hours per annum.

^B Total concentration of all organic substances except methane with a mass flow over 3 kg/h.

^C The sulphur content in fuel shall not exceed the limit values laid down in special legislation and, in diesel fuel shall not exceed 0.05 %.

^D With injection ignition.

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USA – Stationary diesel engines

US EPA has published on 11 July 2006 a new legislation for stationary diesel engines (40 CFR Parts 60, 85 et al.). It entered into force on 11 September 2006.

The regulation includes emission limit values for all new and updated stationary diesel engines. The intended effect of the standard is to require all new, modified, and reconstructed stationary CI ICE to use the best demonstrated system of continuous emission reduction, considering costs, non-air quality health, and environmental and energy impacts, not just with add-on controls, but also by eliminating or reducing the formation of these pollutants.

Diesel engines < 10 Liter displacement (effective from model year 2007 with ≤ 3000 bhp and effective from model year 2011 with > 3000 bhp)

Maximum engine power [kW]	Model year	NMHC + NO _x	NMHC	NO _x	CO	PM
		g/kWh	g/kWh	g/kWh	g/kWh	g/kWh
< 8	2007	7.5	–	–	8	0.80
	2008+	–	–	–	–	0.40
8 ≤ P < 19	2007	–	–	–	6.6	0.80
	2008+	–	–	–	–	0.40
19 ≤ P < 37	2007	7.5	–	–	5.5	0.60
	2008–2012	–	–	–	–	0.30
	2013+	4.7	–	–	–	0.03
37 ≤ P < 56	2007	7.5	–	–	5	0.40
	2008–2012	4.7	–	–	–	0.30 ^A
	2013+	–	–	–	–	0.03
56 ≤ P < 75	2007	7.5	–	–	–	0.40
	2008–2011	4.7	–	–	–	–
	2012, 2013	–	0.19 ^B	0.40 ^B	5	0.02
	2014	–	0.19	0.40	5	0.02
75 ≤ P < 130	2007	4.0	–	–	–	0.30
	2008–2011	4.0	–	–	–	0.30
	2012–2013	–	0.19 ^B	0.40 ^B	5	0.02
	2014	–	0.19	0.40	5	0.02
130 ≤ P < 560	2007–2010	4.0	–	–	3.5	0.20
	2011–2013	–	0.19 ^B	0.40 ^B	–	0.02
	2014	–	0.19	0.40	–	0.02
> 560	2007–2010	6.4	–	–	3.5	0.20
Except generator sets	2011–2014	–	0.40	3.5	–	0.10
	2015+	–	0.19	3.5	–	0.04
Generator sets 560 < P ≤ 900	2007–2010	6.4	–	–	3.5	0.20
	2011–2014	–	0.40	3.5	–	0.10
	2015+	–	0.19	0.67	–	0.03
Generator sets P > 900	2007–2010	6.4	–	–	3.5	0.20
	2011–2014	–	0.40	0.67	–	0.10
	2015+	–	0.19	–	–	0.03

- The emission limit values are valid for non-emergency diesel engines

- ^A A manufacturer has the option of skipping the 0.30 g/KW-hr PM standard for all 37–56 KW (50–75 HP) engines. The 0.03 g/KW-hr standard would then take effect 1 year earlier for all 37–56 KW (50–75 HP) engines, in 2012. The Tier 3 standard (0.40 g/KW-hr) would be in effect until 2012.
- ^B 50 percent of the engines produced have to meet the NO_x + NMHC standard, and 50 percent have to meet the separate NO_x and NMHC limits.

Diesel engines with < 10 Liter displacement (model year before 2007 and model years 2007–2010 with >3000 bhp)

Maximum engine power [kW]	Model year	NMHC + NO _x	NMHC	NO _x	CO	PM
		g/kWh	g/kWh	g/kWh	g/kWh	g/kWh
< 8	2007–2010	10.5	–	–	8.00	1.00
8 ≤ P < 19	2007–2010	9.5	–	–	6.60	0.80
19 ≤ P < 37	2007–2010	9.5	–	–	5.50	0.80
37 ≤ P < 56	2007–2010	–	–	9.20	–	–
56 ≤ P < 75	2007–2010	–	–	9.20	–	–
75 ≤ P < 130	2007–2010	–	–	9.20	–	–
130 ≤ P < 225	2007–2010	–	1.30	9.20	11.40	0.54
225 ≤ P < 450	2007–2010	–	1.30	9.20	11.40	0.54
450 ≤ P ≤ 560	2007–2010	–	1.30	9.20	11.40	0.54
P > 560	2007–2010	–	1.30	9.20	11.40	0.54

Diesel engines with 10–30 Liter displacement (model year beginning with 2007)

Cylinder displacement [L] Power [kW]	THC + NO _x	CO	PM
	g/kWh	g/kWh	g/kWh
5 ≤ V _H ≤ 15 all power bands	7.8	5.0	0.27
15 ≤ V _H ≤ 20 P < 3300 kW	8.7	5.0	0.50
15 ≤ V _H ≤ 20 P 3300 kW	9.8	5.0	0.50
20 ≤ V _H ≤ 25 all power bands	9.8	5.0	0.50
25 ≤ V _H ≤ 30 all power bands	11.0	5.0	0.50

30 STATIONARY POWER PLANTS

Diesel engines for stationary emergency fire pumps

Maximum engine power [kW]	Model year	NMHC +	CO	PM
		g/kWh	g/kWh	g/kWh
<8	2010 and earlier	7.8	6.0	0.75
	2011 +	5.6	–	0.30
8 ≤ P < 19	2010 and earlier	7.1	4.9	0.60
	2011 +	5.6	–	0.30
19 ≤ P < 37	2010 and earlier	7.1	4.1	0.60
	2011 +	5.6	–	0.22
37 ≤ P < 75	2010 and earlier	7.8	3.7	0.60
	2011 +*	3.5	–	0.30
75 ≤ P < 130	2009 and earlier	7.8	3.7	0.60
	2010 +*	3.0	–	0.22
130 ≤ P < 450	2008 and earlier	7.8	2.6	0.40
	2009 +*	3.0	–	0.15
450 ≤ P < 560	2008 and earlier	7.8	2.6	0.40
	2009 +	3.0	–	0.15
P > 560	2007 and earlier	7.8	2.6	0.40
	2008 +	4.8	–	0.15

* Emergency fire pump engines with a rated speed of greater than 2650 rpm are allowed an additional 3 years to meet these standards.

Diesel- and gas engines (California)

Date	NO _x	VOC	CO	Unit
2003	0.50*	1.00	6.00	lbm/MW-hr
	0.23	0.45	2.70	g/kWh
2007**	0.07	0.02	0.10	lbm/MW-hr
	0.03	0.01	0.05	g/kWh

* For installations with CHP (combined heat and power) this values increases to 0.70

** For CHP installations the heat energy is treated like electric energy

- Partical emissions not higher than for natural gas with sulphur content of 1 grain / 100 scf (= PM < 0,5 mg/kWh)

USA – Stationary spark ignition internal combustion engines

On 18 January 2008 the US EPA has published a new law for stationary spark ignition engines (40 CFR Parts 60, 63, 85 et al.). It came into force on 18 March 2008.

The regulation covers emission limit values for spark ignition engines that are operated with gasoline, LPG, natural gas, landfill gas and digester gas. Moreover the regulation distinguishes between emergency and non-emergency engines.

Stationary spark ignition engines ≤19 kW

Engine class ^A	HC + NO _x ^B	NMHC + NO _x ^{B, C}	CO ^B
	g/kWh	g/kWh	g/kWh
I	16.1	14.8	610
I-A	50	—	—
I-B	40	37	—
II	12.1	11.3	—

^A Class I-A: Engines with displacement less than 66 cubic centimeters (cc); Class I-B: Engines with displacement greater than or equal to 66 cc and less than 100 cc; Class I: Engines with displacement greater than or equal to 100 cc and less than 225 cc; Class II: Engines with displacement greater than or equal to 225 cc.

^B Modified and reconstructed engines manufactured prior to 1 July 2008, must meet the standards applicable to engines manufactured after 1 July 2008.

^C NMHC+NO_x standards are applicable only to natural gas fueled engines at the option of the manufacturer, in lieu of HC+NO_x standards.

Stationary spark ignition engines > 19 kW
(Non-emergency SI gasoline engines and rich burn LPG engines)

Maximum engine power [bhp]	Manufacturer date	HC + NO _x ^{A, B} [g/kWh]	CO ^{A, B} [g/kWh]
25 < P < 500 ^C	1 July 2008	2.7	4.4
	1 July 2008 ^E (severe duty)	2.7	130.0
P ≥ 500 ^D	1 July 2007	2.7	4.4
	1 July 2007 ^E (severe duty)	2.7	130.0

^A Optionally engines may be certified according to the following formula instead of the standards in Table 2 of this preamble: $(\text{HC} + \text{NO}_x) \text{CO}^{0.784} \leq 8.57$. The HC+NO_x and CO emission levels you select to satisfy this formula, rounded to the nearest 0.1 g/KW-hr, become the emission standards that apply for those engines. You may not select an HC+NO_x emission standard higher than 2.7 g/KW-hr or a CO emission standard higher than 20.6 g/KW-hr.

^B Provisions in 40 CFR part 1048 allow engines with a maximum engine power at or below 30 KW (40 bhp) with a total displacement at or below 1,000 cubic centimeters (cc) to comply with the requirements of 40 CFR part 90.

^C Modified and reconstructed engines between 25 and 500 bhp manufactured prior to 1 July 2008, must meet the standards applicable to engines manufactured after 1 July 2008.

^D Modified and reconstructed engines greater than or equal to 500 bhp manufactured prior to 1 July 2007, must meet the standards applicable to engines manufactured after 1 July 2007.

^E Severe-duty engines are engines used in, for example, concrete saws, concrete pumps, and similar severe applications where air-cooled engines must be used.

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Stationary non-emergency SI natural gas engines and lean burn LPG engines 19 < KW < 75 (25 < bhp < 100)

Maximum engine power [kW]	Manufacturer date	HC + NO _x ^{A,B} [g/kWh]	CO ^{A,B} [g/kWh]
19 < P < 75 ^C	1 July 2008	3.8	6.5
	1 July 2008 (severe duty)	3.8	200.0

- ^A The following formula may be applied to determine alternate emission standards that apply to your engines instead of the standards in paragraph in Table 3 of this preamble: $(HC+NO_x)CO^{0.791} \leq 16.78$. HC+NO_x emission levels may not exceed 3.8 g/kW-hr and CO emission levels may not exceed 31.0 g/kW-hr.
- ^B For natural gas fueled engines, it is not required to measure non-methane hydrocarbon emissions or total hydrocarbon emissions for testing to show that the engine meets the emission standards of Table 3 of this preamble; that is, it is assume HC emissions are equal to zero.
- ^C Modified and reconstructed engines between 25 and 100 HP manufactured prior to 1 July 2008, must meet the standards applicable to engines manufactured after 1 July 2008.

Stationary SI engines ≥ 100 bhp (except gasoline and rich burn LPG), stationary SI landfill/digester gas engines and stationary emergency engines > 25 bhp

Engine type and fuel	Max. engine power [bhp]	Manu- factur date	NO _x [*] g/HP-hr (ppmvd at 15 % O ₂)	CO [*] g/HP-hr (ppmvd at 15 % O ₂)	VOC [*] g/HP-hr (ppmvd at 15 % O ₂)
Non-emergency SI natural gas and non-emergency SI lean burn LPG	100 ≤ P < 500	1.7.2008	2.0 (160)	4.0 (540)	1.0 (86)
		1.1.2011	1.0 (82)	2.0 (270)	0.7 (60)
Non-emergency SI lean burn natural gas and LPG	500 ≤ P < 1350	1.1.2008	2.0 (160)	4.0 (540)	1.0 (86)
		1.7.2010	1.0 (82)	2.0 (270)	0.7 (60)
Non-emergency SI natural gas and non-emergency SI lean burn LPG (except lean burn 500 ≤ HP < 1350)	P ≥ 500	1.7.2007	2.0 (160)	4.0 (540)	1.0 (86)
		1.7.2010	1.0 (82)	2.0 (270)	0.7 (60)
Landfill and digester gas (except lean burn 500 ≤ HP < 1350)	P < 500	1.7.2008	3.0 (220)	5.0 (610)	1.0 (80)
		1.1.2011	2.0 (150)	5.0 (610)	1.0 (80)
	P ≥ 500	1.7.2007	3.0 (220)	5.0 (610)	1.0 (80)
		1.7.2010	2.0 (150)	5.0 (610)	1.0 (80)
Landfill and digester gas lean burn	500 ≤ P < 1350	1.7.2008	3.0 (220)	5.0 (610)	1.0 (80)
		1.1.2011	2.0 (150)	5.0 (610)	1.0 (80)
Emergency	25 < P < 130	1.1.2009	10.0** (-)	387 (-)	- (-)
	P ≥ 130		2.0 (160)	4.0 (540)	1.0 (86)

- * Owners and operators of stationary non-certified SI engines may choose to comply with the emission standards in units of either g/ bhp -hr or ppmvd at 15 percent O₂.
- ** The emission standards applicable to emergency engines between 25 bhp and 130 bhp are in terms of NO_x+HC.

USA – NESHAP for existing engines

For existing reciprocating internal combustion engines US EPA has published „National Emissions Standards for Hazardous Air Pollutions“ (NESHAPs) on 17 Februar 2010. Standards für SI engines will follow.

The emission limits are valid for

- Engines in area sources. Area Sources are facilities that emit less than 10 tpy (tons per year) of a single air toxic or less than 25 tpy of a combination of air toxics.
- Engines in major sources having a site rating less than 500 bhp, constructed or reconstructed before 12 Juni 2006. Major sources are facilities that emit more than 10 tpy of a single air toxic or more than 25 tpy of a combination of air toxics.
- Engines in major sources having a site rating more than 500 bhp, constructed or reconstructed before 19 December 2002.
- Engines < 100 bhp and emergency engines are excepted.

Site rating [bhp]	Area Source	Major Source
P < 100	–	–
100 ≤ P < 300	–	230* ppm CO
300 ≤ P ≤ 500	49 ppm CO* or 70% CO reduction	
P > 500	23 ppm CO* or 70% CO reduction	

* At 15% O₂.

- Engines > 300 bhp must use Ultra-low-Sulfur-Diesel (ULSD), except in Alaska.
- Systems preventing emissions from the crankcase have to be installed.

EU – Nonroad-Directive

97/68/EC (as amended by 2004/26/EC)

Diesel engines

Power P_n kW	NO _x g/kWh	HC g/kWh	CO g/kWh	Particulates g/kWh	Date*
NO _x + NMHC					
Stage I					
$37 \leq P_n < 75$	9.2	1.3	6.5	0.85	Apr 99
$75 \leq P_n < 130$	9.2	1.3	5.0	0.70	1999
$130 \leq P_n \leq 560$	9.2	1.3	5.0	0.54	1999
Stage II					
$18 \leq P_n < 37$	8.0	1.5	5.5	0.8	2001
$37 \leq P_n < 75$	7.0	1.3	5.0	0.4	2004
$75 \leq P_n < 130$	6.0	1.0	5.0	0.3	2003
$130 \leq P_n \leq 560$	6.0	1.0	3.5	0.2	2002
Stage III A					
$19 \leq P_n < 37$	7.5		5.5	0.6	2007
$37 \leq P_n < 75$	4.7		5.0	0.4	2008
$75 \leq P_n < 130$	4.0		5.0	0.3	2007
$130 \leq P_n \leq 560$	4.0		3.5	0.2	2006
Stage III B					
$37 \leq P_n < 56$	4.7		5.0	0.025	2013
$56 \leq P_n < 75$	3.3	0.19	5.0	0.025	2012
$75 \leq P_n < 130$	3.3	0.19	5.0	0.025	2012
$130 \leq P_n \leq 560$	2.0	0.19	3.5	0.025	2011
Stage IV					
$56 \leq P_n < 130$	0.4	0.19	5.0	0.025	Oct 2014
$130 \leq P_n \leq 560$	0.4	0.19	3.5	0.025	2014

* Date for placing the engine on the market, type approval one year earlier

- Engines above 560 kW are not regulated.
- Stationary test cycle: ISO 8178-4, C1/D2 (according to engine operation)
- Transient test cycle: NRTC (mandatory for stage IIIB). By the choice of the manufacturer this test can be used also for stage IIIA and for the gaseous pollutants in stages IIIB and IV.
- Test condition: Air temperature 25°C
- NTE (Not to Exceed): Starting with stage IIIB limits in the performance map will be applied (max. 100 % above cycle limit).
- For constant speed engines (e.g. mobile gensets) the limits of stage II will be applied as of 2007, the limits of stage IIIA as of 2011. Category J (37-75 kW) is exempted, for this category stage IIIA will come into force 2012.
- For agricultural tractors Directive 2000/25/EC (as amended by 2005/13/EC) is valid. The emission limits are equivalent to those in Directive 97/68/EC.
- As of stage IIIA compliance with the limits must be demonstrated over the useful lifetime of the engine.

**USA – EPA Nonroad Regulation
(40 CFR 89, 40 CFR 1039 and 40 CFR 1068)**

Diesel engines

Power P_n kW	NO _x g/kWh	HC* g/kWh	CO g/kWh	Particulates g/kWh	Date as of MY
	NO _x + NMHC				
Tier 1					
$P_n < 8$	10.5		8.0	1.0	2000
$8 \leq P_n < 19$	9.5		6.6	0.8	2000
$19 \leq P_n < 37$	9.5		5.5	0.8	1999
$37 \leq P_n < 75$	9.2	–	–	–	1998
$75 \leq P_n < 130$	9.2	–	–	–	1997
$130 \leq P_n \leq 560$	9.2	1.3	11.4	0.54	1996
$P_n > 560$	9.2	1.3	11.4	0.54	2000
Tier 2					
$P_n < 8$	7.5		8.0	0.8	2005
$8 \leq P_n < 19$	7.5		6.6	0.8	2005
$19 \leq P_n < 37$	7.5		5.5	0.6	2004
$37 \leq P_n < 75$	7.5		5.0	0.4	2004
$75 \leq P_n < 130$	6.6		5.0	0.3	2003
$130 \leq P_n < 225$	6.6		3.5	0.2	2003
$225 \leq P_n < 450$	6.4		3.5	0.2	2001
$450 \leq P_n \leq 560$	6.4		3.5	0.2	2002
$P_n > 560$	6.4		3.5	0.2	2006
Tier 3					
$P_n < 8$	no further reduction				
$8 \leq P_n < 19$	no further reduction				
$19 \leq P_n < 37$	no further reduction				
$37 \leq P_n < 75$	4.7		5.0	0.4	2008
$75 \leq P_n < 130$	4.0		5.0	0.3	2007
$130 \leq P_n \leq 560$	4.0		3.5	0.2	2006
$P_n > 560$	no further reduction				
Tier 4 interim					
$19 \leq P_n < 37$	7.5		5.5	0.30	2008
$37 \leq P_n < 56$	4.7		5.0	0.30	2008
$56 \leq P_n < 130$	3.4	0.19	5.0	0.02	2012
$130 \leq P_n \leq 560$	2.0	0.19	3.5	0.02	2011
$P_n > 560$	3.5	0.4	3.5	0.10	2011
Tier 4 interim - Genset					
$P_n > 900$	0.67	0.4	3.5	0.1	2011

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Power P_n kW	NO _x g/kWh	HC g/kWh	CO g/kWh	Particulates g/kWh	Date as of MY
	NO _x + NMHC				
Tier 4					
$P_n < 8$	7.5		8.0	0.4*	2008
$8 \leq P_n < 19$	7.5		6.6	0.4	2008
$19 \leq P_n < 37$	4.7		5.5	0.03	2013
$37 \leq P_n < 56$	4.7		5.0	0.03	2013
$56 \leq P_n < 130$	0.4	0.19	5.0	0.02	2015**
$130 \leq P_n < 560$	0.4	0.19	3.5	0.02	2014***
$P_n > 560$	3.5	0.19	3.5	0.04	2015
Tier 4 - Genset					
$P_n > 560$	0.67	0.19	3.5	0.04	2015

- ^A hand-startable, air cooled direct injection 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 PM/CO: full compliance from 2012; NO_x/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 31 December 2014
- ^C PM/CO: full compliance from 2011; NO_x/HC: 50 % engines must comply in 2011–2013
- Optional for Tier 3 / 4: 37–56 kW, PM = 0.3 g/kWh as of 2008; 56–560 kW Phase in / Phase out
 - Additionally to particulate measurement, a transient smoke test is required. As of Tier 4 this is only necessary if particulate emissions exceed 0.07 g/kWh. Engines which are operated at constant speed are generally excluded.
 - Stationary test cycle: ISO 8178-4, C1/D2/E3. As of Tier 4 the appropriate Ramped Mode Cycle (see chapter 6) may be used alternatively.
 - Transient test cycle: NRTC; all engines as of Tier 4, except engines above 560 kW and constant speed engines of any power category.
 - Test condition: Air temperature 25°C
As of Tier 4: Air temperature 20°C–30°C,
Ambient pressure 0.8–1.03 bar
 - Compliance with the emission limits has to be guaranteed over the useful lifetime of the engine.
 - ABT (Averaging, Banking and Trading): Emission credits (CO, NO_x+HC and particulates) can be averaged, banked or traded
 - NTE (Not to Exceed): As of Tier 4, the emissions may not exceed 1.25 to 1.5 times the cycle limit.
 - The regulations of Tier 4 allow open crankcase ventilation if these emissions are measured and added to the exhaust emissions.

India

On 21 September 2006 the emission limit values for diesel engine driven mobile machinery in India have been published and came into force. The Indian law defines a construction machine as equipment driven by a diesel engine as propulsion engine (constant or variable speed) that provides power for both movement of vehicle and intended operations. The equipment can be rubber tyred (including pneumatic tyred), rubber padded or steel drum wheel mounted. The equipment can be developed for the on- and the nonroad-sector.

Power P_n kW	NO_x g/kWh	HC g/kWh	CO g/kWh	PM g/kWh	Date
Bharat Stage II (CEV)					
$P_n < 8$	9.20	1.30	8.00	1.00	Oct 2008
$8 \leq P_n < 19$	9.20	1.30	6.60	0.85	Oct 2008
$19 \leq P_n < 37$	9.20	1.30	6.50	0.85	Oct 2007
$37 \leq P_n < 75$	9.20	1.30	6.50	0.85	Oct 2007
$75 \leq P_n < 130$	9.20	1.30	5.00	0.70	Oct 2007
$130 \leq P_n < 560$	9.20	1.30	5.00	0.54	Oct 2007
Bharat Stage III (CEV)					
	HC + NO_x [g/kWh]				
$P_n < 8$	7.50		8.00	0.80	Apr 2011
$8 \leq P_n < 19$	7.50		6.60	0.80	Apr 2011
$19 \leq P_n < 37$	7.50		5.50	0.60	Apr 2011
$37 \leq P_n < 75$	4.70		5.00	0.40	Apr 2011
$75 \leq P_n < 130$	4.00		5.00	0.30	Apr 2011
$130 \leq P_n < 560$	4.00		3.50	0.20	Apr 2011

- Test cycle: ISO 8178 part 4 C1-8 and ISO 8178 part 4 D2-5
- The test shall be on engine dynamometer.
- The test procedure for measurement of gross power (without fan) shall be as per Part IV of MoSRTH/CMVR/TAP-115/116 Issue No. 3.
- The test procedure for measurement of emission of visible and gaseous pollutants and Particulate Matter shall be as per MoSRTH/CMVR/TAP-115/116 Part X (sub part B).
- The emission of visible pollutants shall not exceed the limit values given in sub-rule (3) of rule 115A when tested on engine dynamometer at eighty per cent load at six speeds as per sub-rule (3) of rule 115A.

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- To meet the Bharat Stage III (CEV) standards with effect from 1 April 2011 engine manufacturer may opt for an engine test as mentioned in the table below for evaluating deterioration factors as per Annex V of Part X, sub part B of MoSRTTH/CMVR/TAP-115/116 issue No. 3.
- There shall be no relaxation of norms for COP (Conformity of production) purposes.
- COP selection procedure shall be as per MoSRTTH/CMVR/TAP-115/116 Part VI.
- COP-frequency:
 - a) for equipment with annual production up to 200: once in two years per engine family.
 - b) for equipment with annual production exceeding 200: once in every year per engine family

Power band [kW]	Durability Emission resistance
< 19	3000
19 < P < 37 (constant speed)	3000
19 < P < 37 (variable speed)	5000
> 37	8000

Deterioration factors

CO	HC	NO _x	PM
1.10	1.05	1.05	1.1

Emission limit values for agricultural tractors

	NO _x g/kWh	HC g/kWh	CO g/kWh	PM g/kWh	Date
	HC + NO _x [g/kWh]				
Bharat (Trem) Stage I	18.0	3.5	14.0	–	Oct 99
Bharat (Trem) Stage II	15.0		9.0	1.0	Jun 03
Bharat (Trem) Stage III	9.5		5.5	0.80	Oct 05

- Test cycle: ISO 8178 C1-8

Japan

Emission limit values stipulated by Ministry of Land, Infrastructure, Transport and Tourism (MLIT) for "**Special Motor Vehicles**" and by MLIT, Ministry of the Environment (MOE) and Ministry of Economy, Trade and Industry (METI) for "**Nonroad Motor Vehicles**":

Power P_n kW	CO g/kWh	NO _x g/kWh	HC g/kWh	PM g/kWh	Smoke %	Date	Date for imported machines and vehicles
Stage I							
$19 \leq P_n < 37$	5.0	8.0	1.5	0.80	40	Oct. 03	–
$37 \leq P_n < 56$	5.0	7.0	1.3	0.40	40	Oct. 03	–
$56 \leq P_n < 75$	5.0	7.0	1.3	0.30	40	Oct. 03	–
$75 \leq P_n < 130$	5.0	6.0	1.0	0.30	40	Oct. 03	–
$130 \leq P_n < 560$	3.5	6.0	1.0	0.20	40	Oct. 03	–
Stage II							
$19 \leq P_n < 37$	5.0	6.0	1.0	0.40	40	Oct. 07	01. Sep. 08
$37 \leq P_n < 56$	5.0	4.0	0.7	0.30	35	Oct. 08	01. Sep. 09
$56 \leq P_n < 75$	5.0	4.0	0.7	0.25	30	Oct. 08	01. Sep. 10
$75 \leq P_n < 130$	5.0	3.6	0.4	0.20	25	Oct. 07	01. Sep. 08
$130 \leq P_n < 560$	3.5	3.6	0.4	0.17	25	Oct. 06	01. Sep. 08

- Test cycle and measurement: Special Vehicle Diesel 8 mode
- Definition „Special Motor Vehicles“: self propelled nonroad vehicles and mobile machinery that run on public roads.
- Definition „Nonroad Motor Vehicles“: self propelled nonroad vehicles and mobile machinery that don't run on public roads.

Emission limits of the MLIT for **construction machinery**:

Power P_n kW	CO g/kWh	NO _x g/kWh	HC g/kWh	PM g/kWh	Smoke %
Stufe II					
$8 \leq P_n < 19$	5.0	NO _x +HC: 7.5		0.80	40
$19 \leq P_n < 37$	5.0	6.0	1.0	0.40	40
$37 \leq P_n < 56$	5.0	4.0	0.7	0.30	35
$56 \leq P_n < 75$	5.0	4.0	0.7	0.25	30
$75 \leq P_n < 130$	5.0	3.6	0.4	0.20	25
$130 \leq P_n < 560$	3.5	3.6	0.4	0.17	25

- Test cycle and measurement: ISO 8178-4,C1
- The emission limit values for engines with 19-560 kW are identical with the limits stipulated by the MLIT according to Special Motor Vehicles and Nonroad Motor Vehicles Stage II,

Turkey

The Turkish Ministry of Industry and Trade is responsible for the emission legislation of non-road mobile machinery in Turkey. The Ministry has adopted the emission limit values of the European non-road Directive 97/68/EC. Differing are solely the dates of coming into force of stages I – IIIA. The dates of coming into force for stage IIIB and stage IV are identical to those in the European legislation.

Power P_n [kW]	NO _x g/kWh	HC g/kWh	CO g/kWh	PM g/kWh	Date*
	NO _x + NMHC				
Stage I (Faz I)					
$37 \leq P_n < 75$	9.2	1.3	6.5	0.85	5 Apr 2003
$75 \leq P_n < 130$	9.2	1.3	5.0	0.70	5 Apr 2003
$130 \leq P_n \leq 560$	9.2	1.3	5.0	0.54	5 Apr 2003
Stage II (Faz II)					
$18 \leq P_n < 37$	8.0	1.5	5.5	0.8	2007
$37 \leq P_n < 75$	7.0	1.3	5.0	0.4	2007
$75 \leq P_n < 130$	6.0	1.0	5.0	0.3	2007
$130 \leq P_n \leq 560$	6.0	1.0	3.5	0.2	2007
Stage III A (Faz IIIA)					
$19 \leq P_n < 37$	7.5		5.5	0.6	2010
$37 \leq P_n < 75$	4.7		5.0	0.4	2010
$75 \leq P_n < 130$	4.0		5.0	0.3	2010
$130 \leq P_n \leq 560$	4.0		3.5	0.2	2010
Stage III B (Faz IIIB)					
$37 \leq P_n < 56$	4.7		5.0	0.025	2013
$56 \leq P_n < 75$	3.3	0.19	5.0	0.025	2012
$75 \leq P_n < 130$	3.3	0.19	5.0	0.025	2012
$130 \leq P_n \leq 560$	2.0	0.19	3.5	0.025	2011
Stage IV (Faz IV)					
$56 \leq P_n < 130$	0.4	0.19	5.0	0.025	Oct 2014
$130 \leq P_n \leq 560$	0.4	0.19	3.5	0.025	2014

* Date for placing on the market.

- Engines >560 kW are not regulated
- Test cycle: ISO 8178-4, C1/D2

Russia – mobile machinery and small tractors

The limits became effective at 1 July 2001.

Power	Carbon monoxide CO [g/kWh]	Carbon monoxide HC [g/kWh]	NO _x [g/kWh]
all power bands	11.0	6.0	18.0

EU – Rail

The directive 97/68/EC (as amended by 2004/26/EC) applies for compression ignition engines installed on railway vehicles with a rated power of more than 130 kW for propulsion engines, and at least 19 kW for engines running at constant speed. For engines that are operated at constant speed the limits apply as of 31 December 2006.

Locomotive propulsion engines

Stage	Power P_n Cylinder displ.	NO _x	HC	CO	PM	Date*
		g/kWh	g/kWh			
		HC + NO _x [g/kWh]				
IIIA	$130 \leq P_n < 560$ kW	4.0		3.5	0.2	2007
	$P_n > 560$ kW	6.0	0.5	3.5	0.2	2009
	$P_n > 2000$ kW $V_{h+z} > 5$ l	7.4	0.4	3.5	0.2	2009
IIIB	$P_n > 130$ kW	4.0		3.5	0.025	2012

Railcar propulsion engines

Stage	Power P_n	NO _x	HC	CO	PM	Date*
		g/kWh	g/kWh			
		HC + NO _x [g/kWh]				
IIIA	$P_n > 130$ kW	4.0		3.5	0.2	2006
IIIB	$P_n > 130$ kW	2.0	0.19	3.5	0.025	2012

* Date for placing on the market of engines, type approval one year earlier.

- No stage I and II
- Test cycle: ISO 8178-4, C1 (railcars) respectively F
- Test condition: air temperature 25°C
- As of stage IIIB there are limits in the performance map (NTE).
- Compliance with the limits must be demonstrated over the useful lifetime of the engine.

UIC – International Union of Railways

UIC code 624V establishes emission limits for railway propulsion engines, which are mandatory for all UIC members. The UIC stage III corresponds to the stage IIIA of the EU – Nonroad-Directive 97/68/EC (see above).

Stage	Power P_n Speed n_n	NO _x g/kWh	HC g/kWh	CO g/kWh	PM g/kWh	Date
UIC II	$P_n > 560$ kW	6.0	0.6	2.5	0.25	1 Jan 2003
	$P_n > 560$ kW $n_n > 1000$ rpm	9.5	0.8	3.0	0.25	1 Jan 2003
	$P_n > 560$ kW $n_n \leq 1000$ rpm	9.9	0.8	3.0	0.25	1 Jan 2003

- UIC II: test cycle ISO 8178-4, F
- The UIC stage III corresponds to the stage IIIA of the EU – Nonroad-Directive 97/68/EC (see above).
- UIC III: test cycle ISO 8178-4, F (C1 for railcars, corresponding to EU – Nonroad-Directive 97/68/EC)
- Test fuel corresponding to ISO 8178-5
- Test condition: air temperature 25°C
- Exempted are engines with a rated power of less than 100 kW as well as engines installed in special locomotives (e.g. refinery- or mining-locomotives).

Russia – Locomotives

Date	Carbon monoxide CO [g/kWh]	Hydrocarbon HC [g/kWh]	NO _x [g/kWh]
< 1 Jan 2000	6.0	2.4	18.0
≥ 1 Jan 2000	3.0	1.0	12.0

USA

On 6 May 2008 the US EPA has published the final rule „40 CFR Parts 9, 85, et al.” for locomotive engines less than 30 liters per cylinder. This law regulates the emission limit values for all rail diesel engines.

Line-haul Locomotives

Engine category	Take effect in year	PM [g/bhp-hr]	NO _x [g/bhp-hr]	HC [g/bhp-hr]
Remanufactured Tier 0 without separate loop intake air cooling	2008, as available 2010 required	0.22	8.0	1.00
Remanufactured Tier 0 with separate loop intake air cooling	2008, as available 2010 required	0.22	7.4	0.55
Remanufactured Tier 1	2008, as available 2010 required	0.22	7.4	0.55
Remanufactured Tier 2	2008, as available 2013 required	0.10	5.5	0.30
New Tier 3	2012	0.10	5.5	0.30
New Tier 4	2015	0.03	1.3	0.14

Switch-haul locomotives

Engine category	Take effect in year	PM [g/bhp-hr]	NO _x [g/bhp-hr]	HC [g/bhp-hr]
Remanufactured Tier 0	2008, as available 2010 required	0.26	11.8	2.10
Remanufactured Tier 1	2008, as available 2010 required	0.26	11.0	1.20
Remanufactured Tier 2	2008, as available 2013 required	0.13	8.1	0.60
Tier 3	2011	0.10	5.0	0.60
Tier 4	2015	0.03	1.3	0.14

- Test specification: US EPA Part 1065: Test Procedures

Turkey

The rule 97/68/AT (2004/26/AT) is valid for rail vehicles propelled with diesel engines with 130 kW (propulsion engine).

The dates of coming into force for the emission stage Faz IIIA are both for locomotives and railcars consistently in 2010. That is 1–4 years after the appropriate dates in the EU legislation. The dates for the emission stage Faz IIIB are identical with the appropriate dates in the EU legislation.

Propulsion engines for locomotives

Stage	Power P_n	NO _x	HC	CO	PM	Date
		g/kWh	g/kWh			
		NO _x + HC g/kWh		g/kWh	g/kWh	
Faz IIIA	$130 \leq P_n \leq 560$ kW	4.0		3.5	0.2	2010
	$560 < P_n \leq 2000$ kW	6.0	0.5	3.5	0.2	2010
	$P_n > 2000$ kW $V_{h+z} > 5$ l	7.4	0.4	3.5	0.2	2010
Faz IIIB	$P_n > 130$ kW	4.0		3.5	0.025	2012

Propulsion engines for railcars

Stage	Power P_n	NO _x	HC	CO	PM	Date*
		g/kWh	g/kWh	g/kWh	g/kWh	
IIIA	$P_n > 130$ kW	4.0		3.5	0.20	2010
IIIB	$P_n > 130$ kW	2.0	0.19	3.5	0.025	2012

* Date for placing on the market.

- No emission stages I and II

EU – Heavy-Duty Vehicles

Directive 88/77/EEC (as amended by 2005/78/EC)

Applies to heavy-duty vehicles with a gross weight over 3.5 t. Compression ignition and gas engines are treated as propulsion engines within this directive.

Limits for **ESC- and ELR-test:**

Stage	CO g/kWh	HC g/kWh	NO _x g/kWh	PM g/kWh	Smoke m ⁻¹	Date ^A
Euro IV	1.5	0.46	3.5	0.02	0.50	1 Oct 2006
Euro V	1.5	0.46	2.0	0.02	0.50	1 Oct 2009
Euro VI	1.5	0.13	0.4	0.01		1 Jan 2013

^A Date for placing on the market, type approval one year earlier.

Limits **ETC-test:**

Stage	CO g/kWh	NMHC g/kWh	CH ₄ ^B g/kWh	NO _x g/kWh	PM ^C g/kWh	Date ^A
Euro IV	4.0	0.55	1.1	3.5	0.03	1 Oct 2006
Euro V	4.0	0.55	1.1	2.0	0.03	1 Oct 2009
Euro VI	4.0	0.16 ^D	0.5	0.4	0.01	1 Jan 2013

^A Date for placing on the market, type approval one year earlier.

^B Only for natural gas engines.

^C Not valid for gas-driven engines of stages IV and V.

^D THC for diesel engines

Gaseous emissions of gas engines are measured using the ETC-test.

From stage Euro IV all new vehicle types have to be equipped with an “On-Board-Diagnosis-System” (OBD) or an “On-Board-Monitoring-System” (OBM) to control the exhaust emissions during operation.

From stage Euro IV for new vehicles and engines the operational reliability of emission-relevant components has to be guaranteed for the useful lifetime of the vehicle or the engine to get the corresponding type approval.

USA

The limits apply for heavy-duty vehicles with a gross weight of more than 3,856 t (8500 lbm). The vehicles are separated in the following **sub-categories**:

- Light heavy-duty diesel engines:
8500 lbm (California: 14500 lbm) < LHDDE < 19500 lbm
- Medium heavy-duty diesel engines:
19500 lbm ≤ MHDDE ≤ 33000 lbm
- Heavy heavy-duty diesel engines (including urban buses):
HHDE > 33000 lbm

Compliance of the limits has to be demonstrated over the **useful lifetime** of the engine, respectively **mileage** (depending on which occurs first):

- LHDDE: 110000 miles / 10 years
- MHDDE: 185000 miles / 10 years
- HHDE: 435000 miles / 10 years / 22000 hours

Limits

Model year MY	NO _x g/kWh	NMHC g/kWh	CO g/kWh	PM g/kWh
2007	0.27	0.19	20.8	0.013

- Test standard: US-FTP transient test procedure for heavy-duty diesel engines as of 2007, additionally SET (Supplemental Emission Test). In addition to the particulate measurement, a transient smoke test is required.
- NTE (Not to exceed): In a certain map area (operating range), pre-defined upper emission limits must not be exceeded.
- ABT (Averaging, Banking and Trading): Emission credits (NO_x+HC and particulates) can be averaged, banked or traded.
- NCP (Non-conformance penalties): Compensation payment is possible if the limits are exceeded.

Japan

The limits apply to heavy-duty vehicles with a gross weight of more than 3.5 tons (2005) respectively 2.5 tons (2003).

Date** of type test	CO g/kWh	HC g/kWh	NO _x g/kWh	PM g/kWh
Oct 2003	2.22	0.87	3.38	0.180
Oct 2005	2.22	0.17*	2.00	0.027

* Non-methane hydrocarbons

** Different dates for different weight classes

- Testing with the Japanese 13-mode test, respectively from 2005 with the Japanese transient test JE05 (Duration: 1800 s, measuring point defined as speed of the vehicle at certain points of time.)
- In addition a smoke limit must be met.

TEST CYCLES

ISO 8178

- Part 4 of ISO 8178 deals with the test cycles for different non-road engine applications.
- The test cycles for the measurement and evaluation of gaseous and particulate exhaust emissions in reciprocating internal combustion engines are established, if the power is determined with a dynamometer.
- The tests are carried out under steady state operation.
- Engines for motor vehicles primarily designed for road use are excluded.
- The **engine** has to **warm-up** to the rated power used in the test cycle, according to the recommendations of the manufacturer, to **stabilise** the engine **operating-parameters**.
- The **test conditions** are established in ISO 8178-1 and ISO 8178-2.

Classification of the test cycles:

- A Heavy-duty diesels in road vehicles (compare ECE R49)
- B Universal, includes all test modes of cycles A, C, D, F, E1 and E2 without weighting, and can be used as the basis for calculating emissions for these test cycles
- C Vehicles (except on-road vehicles) and industrial equipment
 - C1 Nonroad vehicles and industrial equipment with diesel engines
 - C2 Nonroad vehicles and industrial equipment with spark-ignition engines and rated power above 20 kW
- D Constant speed
 - D1 Gensets, irrigation pumps
 - D2 Units with intermittent load
- E Marine engines
 - E1 Diesel engines for craft less than 24 m, except engines for tug/push boats
 - E2 Heavy-duty, constant-speed engines for marine propulsion, without restriction of vessel length
 - E3 Heavy-duty engines running on the propeller curve for marine main propulsion, without restriction of vessel length,
 - E4 Spark-ignition engines for craft less than 24 m, except engines for tug/push boats
 - E5 Diesel engines for craft less than 24 m, except for tug/push boats

- F Rail engines
- G Engines with a rated power usually less than 20 kW, for utility, lawn and garden equipment
 - G1 Non hand-held applications with intermediate speed
 - G2 Non hand-held applications with rated speed
 - G3 Hand-held applications with rated speed

Weighting factors (mean pressure referenced to full-load curve)

Test mode B-cycle	Speed	Mean pr. $p_{me}/p_{meP\ max}$	Cycle						
			C1	C2	D1	D2	E1	E2	F
1	Rated speed	1	0.15		0.3	0.05	0.08	0.2	0.15
2		0.75	0.15		0.5	0.25	0.11	0.5	
3		0.5	0.15		0.2	0.3		0.15	
4		0.25		0.06		0.3		0.15	
5		0.1	0.1			0.1			
6	Intermediate speed	1	0.1	0.02					
7		0.75	0.1	0.05			0.19		
8		0.5	0.1	0.32			0.32		0.25
9		0.25		0.3					
10		0.1		0.1					
11	Low idle	0	0.15	0.15			0.3		0.6

Intermediate speed:

- For engines which are designed to operate over a speed range on a full-load torque curve, the intermediate speed shall be the declared maximum torque speed if it occurs between 60 % and 75 % of rated speed.
- If the declared maximum torque speed is less than 60 % of rated speed, then the intermediate speed shall be 60 % of the rated speed.
- If the declared maximum torque speed is greater than 75 % of the rated speed then the intermediate speed shall be 75 % of rated speed.
- For engines which are not designed to operate over a speed range on the full load torque curve at steady state conditions, the intermediate speed will typically be between 60 % and 70 % of the maximum rated speed.
- For engines to be tested on cycle G1, the intermediate speed shall be 85 % of the maximum rated speed.

50 TEST CYCLES

Weighting factors (for test cycles based on the propeller curve)

Test mode	Speed n/n_n	Power P/P_n	Cycle	
			E3	E5
1	1.00	1.00	0.20	0.08
2	0.91	0.75	0.50	0.13
3	0.80	0.50	0.15	0.17
4	0.63	0.25	0.15	0.32
5	idle	0.00		0.30

ECE R49 – Test cycle

Stationary heavy-duty vehicle test (Euro II) corresponding to ISO 8178, A-cycle

Test mode	Speed n/n_n	Mean pressure $p_{me}/p_{me, max}$	Weighting factor
1	Low idle	0.00	0.25/3
2	Intermediate speed	0.10	0.08
3		0.25	0.08
4		0.50	0.08
5		0.75	0.08
6		1.00	0.25
7		Low idle	0.00
8	Rated speed	1.00	0.10
9		0.75	0.02
10		0.50	0.02
11		0.25	0.02
12		0.10	0.02
13	Low idle	0.00	0.25/3

ECE/EU Smoke measurement (ECE R 24/03 and 97/20/EC respectively)

Measurement of the light-absorption coefficient (opacity) of the exhaust-gas for all vehicles with diesel engines (commercial vehicles up to Euro II)

1. Testing at constant speeds under full load

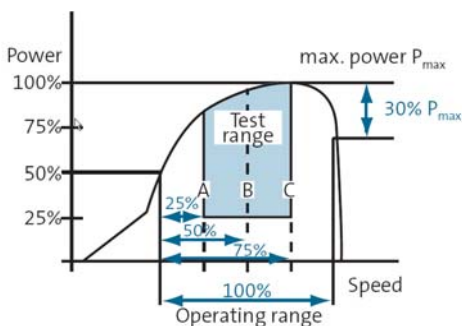
- Measurement of the full-load smoke at six different constant speeds between rated speed and 45 % of the rated speed, or at 1000 rpm.
- For ECE R 24/03: the 7th measuring point at maximum torque.

2. Testing at free acceleration

- Measurement of smoke at free acceleration of the engine from idle to maximum speed.
- Limit specified only for engines with turbocharger.

ESC – European Steady State Cycle

Stationary heavy-duty vehicle test cycle. Operating range, test range and test speeds A, B and C are defined as follows within the full-load curve.



Test range	Speed	Mean pr: $p_{me}/p_{me,max}$	Weighting factor	Test time minutes
1	Low idle	0	0.15	4
2	A	1.00	0.08	2
3	B	0.50	0.10	2
4	B	0.75	0.10	2
5	A	0.50	0.05	2
6	A	0.75	0.05	2
7	A	0.25	0.05	2
8	B	1.00	0.09	2
9	B	0.25	0.10	2
10	C	1.00	0.08	2
11	C	0.25	0.05	2
12	C	0.75	0.05	2
13	C	0.50	0.05	2

NO_x emission is measured at three additional points in the test range. The values measured at these points may exceed the values interpolated from the four neighbouring points by max. 10 %.

ELR – European Load Response Test

- Transient smoke test for diesel engines of commercial vehicles with a gross weight of more than 3.5 tons.
- Torque-increasing of 10 percent on the maximum torque at each constant testing-speeds A, B and C (compare with ESC-test).
- Additionally, smoke is to be tested at a speed between A and C and another speed that is freely selectable by the tester.
- Measurement is to be repeated three times.
- The exhaust-opacity is measured in m^{-1} .
- The opacity which is measured at the free selectable speed may not exceed the value of the neighbouring speeds more than 20 percent and may not exceed the limit value more than 5 percent.

ETC – European Transient Cycle

- Transient test cycle for diesel engines from commercial vehicles with a gross weight more than 3.5 t (Euro III and IV), consisting of 1800 secondly changing load stages with specification of rotation speed and engine torque.
- The city, country and super-highway/motorway engine loads are simulated.
- Power and exhaust-gas emissions are integrated over the cycle.
- As of Euro III the ETC-test is mandatory only for engines with particulate filter and/or DeNO_x catalytic converter. As of Euro IV the ETC-test is mandatory for all engines.

RMC – Ramped Mode Cycle

- Stationary Nonroad test cycle, created by the EPA (for Nonroad-engines, Tier 4).
- The test modes of the ISO test cycles are connected by transition periods of 20 seconds (ramps).
- The whole test sequence has to be performed in a specified time without interruption.

NRTC – Nonroad Transient Cycle

- Dynamic test for mobile machinery.
- Is valid in the USA (Tier 4) for measurement of particulate and gaseous emission.
- To use for the EU-stages III B and IV for measurement of particulate emission at all engines for mobile machinery except engines with constant speed, rail engines and propulsion engines of inland navigation vessels.
- The manufacturer can use this test also for measurements in EU-stage IIIA and for measurement of gaseous pollutants in EU-stages III B and IV.

US – Smoke test (commercial vehicles and nonroad engines)

- Measurement of the exhaust-gas opacity at transient engine operation on a test stand.
- Starting at idle, the engine is accelerated in two phases with a brief interruption (acceleration-mode).
- The engine is then operated at rated speed and power and subsequently lugged down through increasing of the load until the intermediate speed (Lugging-mode).
- Thereupon, the engine is decelerated to idle speed.
- This cycle is repeated three times. From the values measured during all three runs, the average opacity for acceleration, lugging and the maximum figure (peak) are calculated.

US transient test (FTP) for commercial vehicle engines

- Since 1985, a dynamic testing procedure in the USA is used for engines of commercial vehicles.
- The test cycle lasts 1200 seconds, whereas speed and clutch-torque are defined for each second.
- The city traffic operation modus as well as highway driving should be represented.
- The major operation frequency focus on eight points in the performance map, which are dedicated primarily to the rated speed and speeds above idle.
- The speed at maximum torque, which has a high weighting factor in ECE R49, practically does not exist.

US stationary test (SET) for commercial vehicle engines

The Supplemental Emission Test (SET) corresponds to the European ESC test and will be mandatory in the US as of MY 2007.

US locomotive test cycle

As a result of the special operating conditions of locomotives in the USA, EPA has worked out a separate test cycle.

Test mode	Throttle setting	Duration (minutes)	Weighting factor Line-haul cycle	Weighting factor Switch cycle
Warm-up	Notch 8	5 ± 1	0 ^A	0 ^A
Warm-up	Lowest idle	max. 15	0 ^A	0 ^A
1a	Low idle ^B	6	0.190	0.299
1	Normal idle ^C	6	0.190	0.299
2	Dynamic braking	6	0.125	0
3	Notch 1	6	0.065	0.124
4	Notch 2	6	0.065	0.123
5	Notch 3	6	0.052	0.058
6	Notch 4	6	0.044	0.036
7	Notch 5	6	0.038	0.036
8	Notch 6	6	0.039	0.015
9	Notch 7	6	0.030	0.002
10	Notch 8	max. 15	0.162	0.008

^A no measurement

^B not applicable if equipped differently

^C for applications with only one idle speed, the weighting factor is doubled

Cycle value calculation

The cycle value E_x (g/kWh) is calculated as follows using the pollutant mass flows M_{xi} (g/h) that are measured at the cycle points 1 to i with power P_i and weighting factor W_i :

$$E_x = \frac{\sum_{n=1}^i M_{xi} \cdot W_i}{\sum_{n=1}^i P_i \cdot W_i}$$

FUELS

EU – Directives 98/70/EC (as amended by 2003/17/EC) and 2005/33/EC

- **Diesel fuels:** Gasoils which belong to KN-Code 27 10 19 41 and which are used for propulsion of vehicles for the purpose of the directives 70/220/EEC and 88/77/EEC.
- The member states ensure, that at the latest on **1 January 2005** diesel fuel with a maximum sulphur content of 10 ppm is placed on the market in their sovereign territory. In all other aspects, the fuel has to comply to the specifications stated below.
- As of **1 January 2009** only diesel fuel may be placed on the market, which complies with the specifications below and has a maximum sulphur content of 10 mg/kg (= 10 ppm).

Attribute ^A	Unit	Minimum ^B	Maximum ^B
Cetane number		51	–
Density at 15°C	kg/m ³	–	845
Boiling characteristics: 95 % (v/v) re-extracted at	°C	–	360
Polycyclic aromatic hydrocarbons	% m/m	–	11
Sulphur content	ppm	–	50 10 ^C

^A Test procedure according to EN 590:1999

^B “Effective Values” according to ISO 4259

^C As of 1 January 2009 the regulated maximum sulphur content has to be satisfied by every diesel fuel that is placed on the market.

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- Furthermore, the Member States shall assure that the gasoils which are placed on the market for use in **mobile machinery** or in **agricultural tractors** have a maximum sulphur content of 2000 mg/kg (= 2000 ppm).
- As of **1 January 2008** the maximum sulphur content of the above mentioned gasoils is 1000 mg/kg (= 1000 ppm).
- As of 1 January 2010 the maximum sulphur content of fuels for **inland navigation vessels** is 1000 mg/kg (= 1000 ppm) as regulated in the directive 2005/33/EC.
- For **seagoing vessels** the directive 2005/33/EC regulates for special areas (so called **SO_x Emission Control Areas (SECA)**) the following limits for the sulphur content: 1.5 % sulphur content for the North Sea (11 August 2007) and the Baltic Sea and also for passenger ships at regular service between Community Ports (11 August 2006); 0.1 % for all ships at berth in Community Ports (1 January 2010).

USA 40 CFR

- For mobile machinery the sulphur limit is 500 ppm as of 2007 and 15 ppm as of 2010.
- For trains and ships the sulphur limit is 15 ppm as of 2012.

IMO – Marine fuels

The IMO is further reducing the sulphur level in marine fuels. For details see chapter “Marine”.

CONVERSION FORMULAS

For sulfur free diesel fuel (10 ppm sulfur) corresponding to EN 590 with a density of $\rho = 830 \text{ kg/m}^3$ (15° C), the following applies approximately:

Conversion of g/m_n^3 (5 % O₂) to g/kWh:

$$EP_i = EA_i \cdot b_{\text{eff}} \cdot \frac{m_n^3}{73\text{g}} \qquad EA_i = EP_i \cdot \frac{73\text{g}}{m_n^3 \cdot b_{\text{eff}}}$$

Conversion with differing residual oxygen content (as per “TA Luft”):

$$EA_i = EX_i \cdot \frac{21-5}{21-X}$$

Conversion of ppm to g/kWh:

$$EP_i = EV_{i,d} \cdot \frac{M_i}{M_{\text{Exh,d}}} \cdot \frac{\dot{m}_{\text{Exh,d}}}{P_{\text{eff}}} = EV_{i,w} \cdot \frac{M_i}{M_{\text{Exh,w}}} \cdot \frac{\dot{m}_{\text{Exh,w}}}{P_{\text{eff}}}$$

- EP_i Pollutant mass, i, referenced to P_{eff} (g/kWh)
- EA_i Pollutant mass, i, referenced to exhaust volumes based on dry exhaust with 5 % residual oxygen under standardized conditions (g/m_n³)
- EX_i Pollutant mass, i, referenced to exhaust volumes based on dry exhaust with X % residual oxygen under standardized conditions (g/m_n³)
- EV_i Exhaust emission value of components, i, as volume share (ppm)
- M_i Mol mass of the components, i, (kg/kmol)
- M_{Exh} Mol mass of the exhaust (kg/kmol)
- \dot{m}_{Exh} Exhaust mass flow (kg/h)
- P_{eff} Power output (kW)
- b_{eff} Specific fuel consumption (g/kWh)
- Index d: dry
- Index w: wet

Component	Mol mass kg/kmol	Remarks
NO ₂	46.006	NO _x treated as NO ₂
CO	28.0104	
HC	13.876	HC 1
SO ₂	64.061	
Exhaust dry	30.21 / 29.84	5 % O ₂ / 9.6 % O ₂
Exhaust wet	28.84 / 28.82	5 % O ₂ / 9.6 % O ₂

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- At 5 % residual oxygen (corresponding to an excess air ratio of 1.3 : 1) and $b_{\text{eff}} = 210 \text{ g/kWh}$, the following applies approximately:

$$\frac{\dot{m}_{\text{Exh, d}}}{P_{\text{eff}}} = 3873 \text{ g/kWh}$$

$$\frac{\dot{m}_{\text{Exh, w}}}{P_{\text{eff}}} = 4160 \text{ g/kWh}$$

- 1000 ppm NO_x,
measured wet, corresponds to 2310 mg/m_n³, d, 5 % (6.60 g/kWh)
- 100 ppm HC,
measured wet, corresponds to 70 mg/m_n³, d, 5 % (0.20 g/kWh)
- 100 ppm CO,
measured dry, corresponds to 125 mg/m_n³, d, 5 % (0.36 g/kWh)

- At an excess air ratio of 1.8 : 1 (residual oxygen content corresponding to 9.6 %) and $b_{\text{eff}} = 210 \text{ g/kWh}$ the following applies approximately:

$$\frac{\dot{m}_{\text{Exh, d}}}{P_{\text{eff}}} = 5400 \text{ g/kWh}$$

$$\frac{\dot{m}_{\text{Exh, w}}}{P_{\text{eff}}} = 5710 \text{ g/kWh}$$

- 1000 ppm NO_x,
measured wet, corresponds to 9.10 g/kWh (3150 mg/m_n³, d, 5 %)
- 100 ppm HC,
measured wet, corresponds to 0.27 g/kWh (95 mg/m_n³, d, 5 %)
- 100 ppm CO, measured dry, corresponds to 0.51 g/kWh
(176 mg/m_n³, d, 5 %)

Units:

Energy	1 J	= 1 Nm	= 1 Ws	= 1 VAs
	1 Wh	= 3.6 kJ		
	1 kWh	= 3.6 MJ		
Power	1 W	= 1 VA	= 1 J/s	= 1 Nm/s
Force	1 N	= 1 kgm/s ²		
Pressure	1 Pa	= 1 N/m ²		
	1 bar	= 10 ⁵ Pa		

Conversion of non-SI units:

Length

Inch	1 in	= 25.4 mm	
Foot	1 ft	= 304.8 mm	= 12 in
Yard	1 yd	= 914.4 mm	= 3 ft
Statute mile	1 mi	= 1609.34 m	= 1760 yd
Nautical mile	1 nm	= 1852 m	

Surface

Square inch 1 sq in = 645.16 mm²

Volume

Cubic inch 1 cu in = 0.016387 Liter

Gallon (US) 1 gal (US) = 3.78541 Liter

Gallon (UK) 1 gal (UK) = 4.54609 Liter

Liquid barrel (US) 1 liq bbl = 119.24 Liter

Barrel Petroleum 1 bbl = 158.99 Liter

Mass

Grain 1 gr = 64.7989 mg

Ounce 1 oz = 28.3495 g

Pound mass 1 lbm = 0.45359 kg = 16 oz = 7000 gr

Hundredweight (US) 1 cwt (US) = 45.3592 kg = 1 short cwt = 100 lbm

Hundredweight (UK) 1 cwt (UK) = 50.8023 kg = 1 long cwt = 112 lbm

Ton (US) 1 ton (US) = 907.185 kg = 1 short ton = 2000 lbm

Ton (UK) 1 ton (UK) = 1016.05 kg = 1 long ton = 2240 lbm

Force

Pound force 1 lbf = 4.44822 N

Pressure

Atmosphere 1 atm = 1.01325 bar

Water column 1 mm WS = 9.80665 Pa

Mercury column 1 mm Hg = 133.322 Pa = 1 Torr

Psi 1 lbf / in² = 6894.76 Pa pound per square inch

Energy

Calorie 1 kcal = 4186.8 J

Foot pound-force 1 ft lbf = 1.35582 J

British thermal unit 1 Btu = 1055.06 J

Mineral coal unit 1 kg SKE = 29.3076 MJ = 8.141 kWh

Oil equivalent 1 kg OE = 41.868 MJ = 11.63 kWh

Power

Horsepower (metric) 1 PS = 735.499 W

Horsepower, HP 1 bhp = 745.70 W = 550 ft • lbf/s

Temperature

T (K) = t (°C) + 273.15

t (°C) = 5/9 • (t(°F) – 32)

Glossary

Exhaust emission components

CO	Carbonmonoxide
HC	Hydrocarbons
NO _x	Nitrogen oxides
NMHC	Non-Methane-Hydrocarbons
PM	Particulate matter
SO _x	Sulfur oxide
THC	Total Hydrocarbon
VOC	Volatile organic components (equals HC)

Regulations

BSO	Bodensee Schifffahrtsordnung, Lake Constance Shipping Ordinance
CFR	Code of Federal Register (US regulations)
RheinSchUO	Rhine vessel inspection regulation
TA-Luft	Technische Anleitung zur Reinhaltung der Luft (German clean-air standard for approval authorities)

Authorities and organizations

EU	European Union
EC	European Commission
ECE	Economic Commission for Europe (UN economic commission for Europe)
EPA	Environmental Protection Agency (US environmental authority)
CARB	California Air Resources Board
IMO	International Maritime Organization
CCNR	Central Commission for the Navigation on the Rhine
UIC	Union International des Chemins de Fer (International Union of Railways)

Engine parameters

MY	Model year
m _n ³	standard cubic meter
MW _e	Megawatt electrical
MW _{th}	Megawatt thermal
P _n	Engine rated power [kW]
n _n	Engine rated speed [rpm]
V _{h,z}	Swept volume per cylinder (cyl. displacement) [liter]

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