Engines and Systems

VDMA

# Exhaust Emission Legislation
# Diesel- and Gas engines

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## 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.

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 ≤ $n_n$ < 2000** | 45.0 • $n_n^{(-0.2)}$ |
| **≥ 2000** | 9.8 |
| **Stage II, beginning from 1.1.2011** | |
| **< 130** | 14.4 |
| **130 ≤ $n_n$ < 2000** | 44.0 • $n_n^{(-0.23)}$ |
| **≥ 2000** | 7.7 |
| **Stage III, beginning from 1.1.2016[A] in Emission Control Areas (ECAs)** | |
| **< 130** | 3.4 |
| **130 ≤ $n_n$ < 2000** | 9 • $n_n^{(-0.2)}$ |
| **≥ 2000** | 2.0 |

[A] With 1.1.2016 only one ECA exists in US water. From January 1st 2021 onwards, ECAs are established in the Baltic Sea and the North Sea. After a proposal of all neighboring countries, more waters may be designated as ECAs in the future.

North American coastlines have been established as the first $NO_x$ emission control area with Tier III limits.

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.

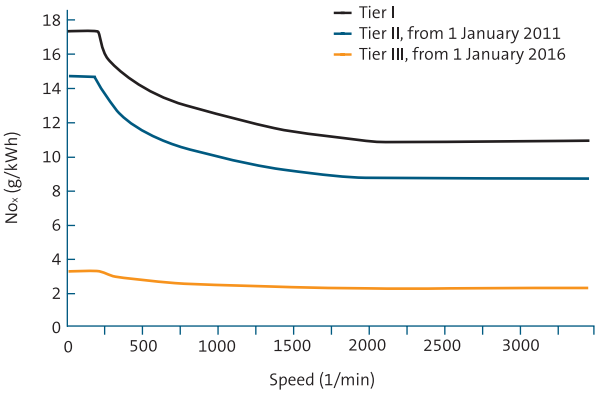
Replacement engine or additional engine:

- 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.

**IMO, $No_x$-Curve**




- $NO_x$ limit dependent on engine rated speed.
- Test cycle: ISO 8178-4, E2/E3/D2/C1 (according to engine operation).
- No limits for HC, CO, particulates and soot.
- 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.

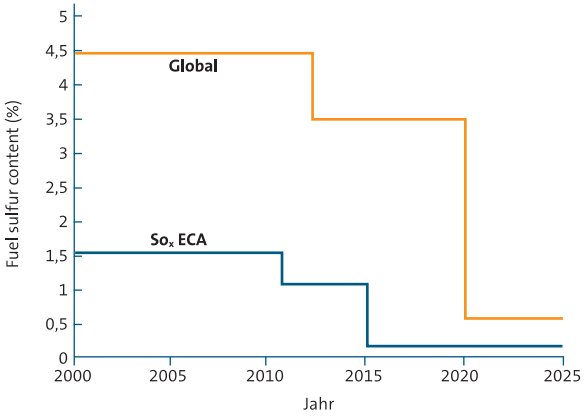
Global sulphur limit levels:

- 4.50 % (45,000 ppm) until 2012
- 3.50 % (35,000 ppm) beginning with 2012
- 0.50 % (5,000 ppm) beginning with 2020

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

**IMO, Sulfur limits**



## 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 displac. [L] Power [kW] | CO [g/kWh] | HC + $NO_x$ [g/kWh] | PM [g/kWh] | Date[A] |
|---|---|---|---|---|---|
| **V 1:1** | $V_{h,z} < 0.9$ | 5.0 | 7.5 | 0.4 | 2007 |
| | $P_n \geq 37$ | | | | |
| **V 1:2** | $0.9 \leq V_{h,z} < 12$ | 5.0 | 7.2 | 0.3 | 2007 |
| **V 1:3** | $1.2 \leq V_{h,z} < 2.5$ | 5.0 | 7.2 | 0.2 | 2007 |
| **V 1:4** | $2.5 \leq V_{h,z} < 5.0$ | 5.0 | 7.2 | 0.2 | 2009 |
| **V 2:1** | $5.0 \leq V_{h,z} < 15.0$ | 5.0 | 7.8 | 0.27 | 2009 |
| **V 2:2** | $15.0 \leq V_{h,z} < 20.0$ | 5.0 | 8.7 | 0.5 | 2009 |
| | $P_n < 3300$ | | | | |
| **V 2:3** | $15.0 \leq V_{h,z} < 20.0$ | 5.0 | 9.8 | 0.5 | 2009 |
| | $P_n \geq 3300$ | | | | |
| **V 2:4** | $20.0 \leq V_{h,z} < 25.0$ | 5.0 | 9.8 | 0.5 | 2009 |
| **V 2:5** | $25.0 \leq V_{h,z} < 30.0$ | 5.0 | 11.0 | 0.5 | 2009 |

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

- Alternatively, the limits of the Rhine Vessel Inspection Regulation may be applied (mutual recognition is agreed) until the date for placing on the market for Stage V engines.
- Test cycles: ISO 8178-4, E2/E3/D2/C1 (according to engine operation), also for (EU) 2016/1628 (Stage V).

With Regulation (EU) 2016/1628 the directive 97/68/EC has been withdrawn and the emission limits have been stringent further. They apply for propulsion and auxiliary engines.

| Power [kW] | CO [g/kWh] | HC[A] [g/kWh] | $NO_x$ [g/kWh] | Particulate [g/kWh] | Particulate [#/kWh] | Date[B] |
|---|---|---|---|---|---|---|
| | | NMHC + $NO_x$ | | | | |
| **Stufe V** | | | | | | |
| **$19 \leq P_n < 75$** | 5.00 | 4.70 | | 0.30 | – | 2019 |
| **$75 \leq P_n < 130$** | 5.00 | 5.40 | | 0.14 | – | 2019 |
| **$130 \leq P_n \leq 300$** | 3.50 | 1.00 | 2.10 | 0.10 | – | 2019 |
| **$P_n > 300$** | 3.50 | 0.19 | 1.80 | 0.015 | $1*10^{12}$ | 2020 |

[A] HC limit for fully and partially gaseous-fueled engines: Where an A-factor is defined, the HC limit is calculated by the formula HC = 0.19 + (1.5 x A x GER), the maximum allowed is HC = 0.19 + A. For a combined HC and NOx limit, the combined limit value for HC and $NO_x$ shall be reduced by 0.19 g/kWh and apply for $NO_x$ only. GER is the average gas energy ratio over the appropriate test cycle.

[B] Date for placing the engine on the market, type approval one year earlier.

**Exempted from the limits** are the following ships:

- Watercrafts with a hull length from 2.5 m to 24 m intended for sports and leisure purposes (see 2013/53/EU).
- Personal watercraft with a propulsion engine having a water jet pump and a hull length of less than 4 m (see 2013/53/EU).
- Ferries.
- Naval vessels.
- 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.
- All other crafts as defined in Directive (EU) 2016/1629 and not falling within its scope.

## EU – Recreational crafts

The Directive **2013/53/EU** (repealing Directive 94/25/EC -amended by Directive 2003/44/EC) defines construction and design prescriptions for **recreational crafts from 2.5 to 24 m hull length** and **personal water crafts** with a **hull length of less than 4 m**. The limits are valid for new propulsion engines, which will be installed or are specifically intended for installation in these crafts, as well as for already built in engines, that undergo major engine modifications, which potentially cause the engine to exceed the limits or increase the rated power 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 of craft designed before 1950.

**Limit values for CI engines according to 2013/53/EU (effective from 18.01.2016)**

| Cylinder displacement [L] | Power $P_N$ [kW] | CO [g/kWh] | HC [g/kWh] | $NO_x$ [g/kWh] | PM [g/kWh] |
|---|---|---|---|---|---|
| | | | HC + $NO_x$ | | |
| $V_{h,z}$ < 0.9 | $P_n$ < 37 | 5.0 | 1.5 + 2/$P_n^{0.5}$ | 9.8 | 1.00 |
| | 37 ≤ $P_n$ < 75[A] | 5.0 | 4.7 | | 0.30 |
| | 75 ≤ $P_n$ < 3700 | 5.0 | 5.8 | | 0.15 |
| 0.9 ≤ $V_{h,z}$ < 1.2 | $P_n$ < 3700 | 5.0 | 5.8 | | 0.14 |
| 1.2 ≤ $V_{h,z}$ < 2.5 | | 5.0 | 5.8 | | 0.12 |
| 2.5 ≤ $V_{h,z}$ < 3.5 | | 5.0 | 5.8 | | 0.12 |
| 3.5 ≤ $V_{h,z}$ < 7.0 | | 5.0 | 5.8 | | 0.11 |

[A] Alternatively a PM-limit of 0.20 g/kWh and a combined HC+$NO_x$ -limit of 5.8 g/kWh shall not be exceeded.

- Exhaust emissions are measured according to the harmonized standard ISO 8178-4:2007.
- For variable speed CI-engines test cycle E1 or E5 can be applied, alternatively test cycle E3 can be applied to engines above 130 kW.

## 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 [kW] | Speed $n_n$ [rpm] | CO [g/kWh] | HC [g/kWh] | $NO_X$ [g/kWh] | PM [g/kWh] |
|---|---|---|---|---|---|
| **37 ≤ $P_n$ < 75** | – | 6.5 | 1.3 | 9.2 | 0.85 |
| **75 ≤ $P_n$ < 130** | – | 5.0 | 1.3 | 9.2 | 0.70 |
| **$P_n$ ≥ 130** | 500 – 2800 | 5.0 | 1.3 | $45 \cdot n_n^{(-0.2)}$ | 0.54 |
| | ≥ 2800 | 5.0 | 1.3 | 9.2 | 0.54 |

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

| Power [kW] | Speed $n_n$ [rpm] | CO [g/kWh] | HC [g/kWh] | $NO_X$ [g/kWh] | PM [g/kWh] |
|---|---|---|---|---|---|
| **19 ≤ $P_n$ < 37** | – | 5.5 | 1.5 | 8.0 | 0.8 |
| **37 ≤ $P_n$ < 75** | – | 5.0 | 1.3 | 7.0 | 0.4 |
| **75 ≤ $P_n$ < 130** | – | 5.0 | 1.0 | 6.0 | 0.3 |
| **130 ≤ $P_n$ < 560** | – | 3.5 | 1.0 | 6.0 | 0.2 |
| **$P_n$ ≥ 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 |

- The limits are valid for all engines with a rated power ($P_n$) at or above 19 kW, which are installed in vehicles or machines aboard, unless there are no corresponding directives of the EU which affect the emission of gaseous pollutants or air particulates.
- 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).
- Only combustion engines which use fuels with a flashpoint above 55°C shall be installed.
- Test procedures are described in instruction No. 16 according to §1.07 RheinSchUO.
- Test cycle: ISO 8178-4, E2/E3/D2/C1 (according to engine operation).
- CCNR (Central Commission for the Navigation of the Rhine) is planning to adopt Directive (EU) 2016/1628.

## Lake Constance shipping ordinance (BSO)

### Stage I (SI and CI engines, which have been built before 31 December 1995)

| Power [kW] | CO $A \cdot P_n^{-m}$ [g/kWh] | | HC $A \cdot P_n^{-m}$ [g/kWh] | | $NO_x$ $A \cdot P_n^{-m}$ [g/kWh] | |
|---|---|---|---|---|---|---|
| | A | m | A | m | A | m |
| **$P_n < 4$** | 600 | 0.5 | 60.0 | 0.7747 | 15 | 0 |
| **$4 \leq P_n \leq 100$** | 600 | 0.5 | 39.39 | 0.4711 | 15 | 0 |
| **$P_n > 100$** | 60 | 0 | 10.13 | 0.1761 | 15 | 0 |

$P_n$ = rated power

- The calculated mass-emissions of spark ignited engines of group A (recreational craft) or group B (commercial craft and not group A), 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: K=2.1 $m^{-1}$ for naturally aspirated engines and K=1.0 $m^{-1}$ for supercharged engines.

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

For SI engines, the following limits apply:

| Power [kW] | CO $A \cdot P_n^{-m}$ [g/kWh] | | HC $A \cdot P_n^{-m}$ [g/kWh] | | $NO_x$ $A \cdot P_n^{-m}$ [g/kWh] | |
|---|---|---|---|---|---|---|
| | A | m | A | m | A | m |
| **$P_n < 4$** | 400 | 0.6505 | 30 | 0.6505 | 10 | 0.1505 |
| **$4 \leq P_n \leq 100$** | 400 | 0.6505 | 30 | 0.6505 | 10 | 0.1505 |
| **$P_n > 100$** | 20 | 0 | 3.375 | 0.1761 | 5 | 0 |

$P_n$ = rated power

For CI engines, the following limits apply:

| Power [kW] | CO $A \cdot P_n^{-m}$ [g/kWh] | | HC $A \cdot P_n^{-m}$ [g/kWh] | | $NO_x$ $A \cdot P_n^{-m}$ [g/kWh] | |
|---|---|---|---|---|---|---|
| | A | m | A | m | A | m |
| **$P_n < 4$** | 400 | 0.6505 | 30 | 0.6505 | 10 | 0 |
| **$4 \leq P_n \leq 100$** | 400 | 0.6505 | 30 | 0.6505 | 10 | 0 |
| **$P_n > 100$** | 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: K=1.3 $m^{-1}$ for naturally aspirated engines and K=0.8 $m^{-1}$ for supercharged engines.

- Smoke coefficient of CI-engines has to be determined in the peak load point (engine speed with highest load) according to ISO 8178-3.
- Test cycle: ISO 8178-4, E4 (SI-engines), E5 (CI-engines).

## USA –Marine engines

The US regulation covers the emission limit values for marine engines that are operated in commercial and recreational vessels, both for propulsion and auxiliary engines. US EPA has tightened the emission limits gradually in the past. The relevant parts of "Title 40: Protection of the Environment“ are summarised in the following table.

| Part | Content |
|---|---|
| **40 CFR part 89** | Emission limits and type approval requirements for Tier 1 and Tier 2 engines with $P_n$ < 37kW |
| **40 CFR part 94** | Emission limits and type approval requirements for Tier 1 and Tier 2 engines with $P_n \geq 37$kW |
| **40 CFR part 1042** | Emission limits and type approval requirements for Tier 3 and Tier 4 engines |
| **40 CFR part 1065** | Exhaust emission measurement procedures |

### Engine categories:

| Cat. | Cylinder displacement [L] | |
|---|---|---|
| | Tier 1-2 | Tier 3-4 |
| **C1** | $V_{h,z} < 5^A$ | $V_{h,z} < 7$ |
| **C2** | $5 \leq V_{h,z} < 30$ | $7 \leq V_{h,z} < 30$ |
| **C3** | $V_{h,z} \geq 30$ | |

[A] $P_n \geq 37$ kW

### Tier 1:

| Cat. | Power and displacement | speed [rpm] | Model year | $NO_x$ [g/kWh] | HC+$NO_x$ [g/kWh] | PM [g/kWh] | CO [g/kWh] |
|---|---|---|---|---|---|---|---|
| **Small** | $P_n$ < 8 kW | – | 2000 | – | 10.5 | 1.0 | 8.0 |
| | 8 kW ≤ $P_n$ < 19 kW | – | 2000 | – | 9.5 | 0.80 | 6.6 |
| | 19 kW ≤ $P_n$ < 37 kW | – | 1999 | – | 9.5 | 0.80 | 5.5 |
| **C1, C2, C3, Rec.** | $P_n \geq 37$ kW $V_{h,z} \geq 2.5$ L | $n_n \geq 2000$ | 2004 | 9.8 | – | – | – |
| | | 130 ≤ $n_n$ < 2000 | 2004 | $45 \cdot n_n^{-0.2}$ | – | – | – |
| | | $n_n$ < 130 | 2004 | 17.0 | – | – | – |

## Tier 2:

| Cat. | Cylinder displacement [L] | Power [kW] | Model year | HC+$NO_x$ [g/kWh] | PM [g/kWh] | CO [g/kWh] |
|---|---|---|---|---|---|---|
| Small | – | $P_n < 8$ | 2005 | 7.5 | 0.80 | 8.0 |
| | – | $8 \le P_n < 19$ | 2005 | 7.5 | 0.80 | 6.6 |
| | – | $19 \le P_n < 37$ | 2004 | 7.5 | 0.60 | 5.5 |
| C1 | $V_{h,z} < 0.9$ | $P_n \ge 37$ | 2005 | 7.5 | 0.40 | 5.0 |
| | $0.9 \le V_{h,z} < 1.2$ | – | 2004 | 7.2 | 0.30 | 5.0 |
| | $1.2 \le V_{h,z} < 2.5$ | – | 2004 | 7.2 | 0.20 | 5.0 |
| | $2.5 \le V_{h,z} < 5$ | – | 2007 | 7.2 | 0.20 | 5.0 |
| C2 | $5 \le V_{h,z} < 15$ | – | 2007 | 7.8 | 0.27 | 5.0 |
| | $15 \le V_{h,z} < 20$ | $P_n < 3300$ | 2007 | 8.7 | 0.50 | 5.0 |
| | $15 \le V_{h,z} < 20$ | $P_n \ge 3300$ | 2007 | 9.8 | 0.50 | 5.0 |
| | $20 \le V_{h,z} < 25$ | – | 2007 | 9.8 | 0.50 | 5.0 |
| | $25 \le V_{h,z} < 30$ | – | 2007 | 11.0 | 0.50 | 5.0 |
| Rec. | $V_{h,z} < 0.9$ | $P_n \ge 37$ | 2007 | 7.5 | 0.40 | 5.0 |
| | $0.9 \le V_{h,z} < 1.2$ | – | 2006 | 7.2 | 0.30 | 5.0 |
| | $1.2 \le V_{h,z} < 2.5$ | – | 2006 | 7.2 | 0.20 | 5.0 |
| | $2.5 \le V_{h,z} < 5$ | – | 2009 | 7.2 | 0.20 | 5.0 |

## Tier 2 and Tier 3 for marine C3-engines:

| Tier | Power [kW] | Speed [$min^{-1}$] | Model year | $NO_x$ [g/kWh] | HC [g/kWh] | CO [g/kWh] |
|---|---|---|---|---|---|---|
| 2 | – | $n_n \ge 2000$ | 2011 | 7.7 | 2.0 | 5.0 |
| | | $130 \le n_n < 2000$ | | $44.0 \cdot n_N^{-0.23}$ | | |
| | | $n_n < 130$ | | 14.4 | | |
| 3 | – | $n_n \ge 2000$ | 2016 | 2.0 | 2.0 | 5.0 |
| | | $130 \le n_n < 2000$ | | $9.0 \cdot n_N^{-0.20}$ | | |
| | | $n_n < 130$ | | 3.4 | | |

## Tier 3 for C1 CI engines in commercial and recreational vessels:

| Power [kW] | Cylinder displacement [L] | Model year | HC+$NO_x$ [g/kWh] | PM [g/kWh] | CO [g/kWh] |
|---|---|---|---|---|---|
| P < 8 | $V_{h,z} < 0.9$ | 2009 | 7.5 | 0.40 | 8.0 |
| 8 ≤ P <19 | | 2009 | 7.5 | 0.40 | 6.6 |
| 19 ≤ P < 37 | | 2009 | 7.5 | 0.40 | 5.5 |
| | | 2014 | 4.7[A] | 0.30[A] | 5.0 |
| 37 ≤ P < 75 | | 2009 | 7.5 | 0.40 | 5.0 |
| | | 2014 | 4.7[A] | 0.30[A] | 5.0 |

[A] Option: PM 0.2 g/kWh; $NO_x$ 5.8 g/kWh from 2014.

## Tier 3 for C1 CI engines in commercial vessels (standard power density, < 35 kW/L):

| Power [kW] | Cylinder displacement [L] | Model year | HC+$NO_x$[A] [g/kWh] | PM [g/kWh] | CO [g/kWh] |
|---|---|---|---|---|---|
| **P ≥75** | $V_{h,z}$ < 0.9 | 2012 | 5.4 | 0.14 | 8.0 (P < 8 kW)<br>6.6 (8 ≤ P < 19 kW)<br>5.5 (19 ≤ P < 37 kW)<br>5.0 (P ≥ 37 kW) |
| – | 0.9 ≤ $V_{h,z}$ < 1.2 | 2013 | 5.4 | 0.12 | |
| | 1.2 ≤ $V_{h,z}$ < 2.5 | 2014 | 5.6 | 0.11[B] | |
| | 2.5 ≤ $V_{h,z}$ < 3.5 | 2013 | 5.6 | 0.11[B] | |
| | 3.5 ≤ $V_{h,z}$ < 7 | 2012 | 5.8 | 0.11[B] | |

[A] Tier 3 $NO_x$+HC standards do not apply to 2000–3700 kW engines.
[B] For engines <600 kW this value drops to 0.10 g/kWh from 2018.

## Tier 3 for C1 CI engines in commercial and recreational vessels (high power density, > 35 kW/L):

| Power [kW] | Cylinder displacement [L] | Model year | HC+$NO_x$[A] [g/kWh] | PM [g/kWh] | CO [g/kWh] |
|---|---|---|---|---|---|
| **P ≥75** | $V_{h,z}$ < 0.9 | 2012 | 5.8 | 0.15 | 8.0 (P < 8 kW)<br>6.6 (8 ≤ P < 19 kW)<br>5.5 (19 ≤ P < 37 kW)<br>5.0 (P ≥ 37 kW) |
| – | 0.9 ≤ $V_{h,z}$ < 1.2 | 2013 | 5.8 | 0.14 | |
| | 1.2 ≤ $V_{h,z}$ < 2.5 | 2014 | 5.8 | 0.12 | |
| | 2.5 ≤ $V_{h,z}$ < 3.5 | 2013 | 5.8 | 0.12 | |
| | 3.5 ≤ $V_{h,z}$ < 7 | 2012 | 5.8 | 0.11 | |

[A] Tier 3 $NO_x$+HC standards do not apply to 2000–3700 kW engines.

## Tier 3 for C2[A] marine CI engines:

| Power [kW] | Cylinder displacement [L] | Model year | HC+$NO_x$[A] [g/kWh] | PM [g/kWh] | CO [g/kWh] |
|---|---|---|---|---|---|
| **P < 2000** | 7 ≤ $V_{h,z}$ <15 | 2013 | 6.2 | 0.14 | 5.0 |
| **2000 ≤ P < 3700** | | | 7.8 | 0.14 | 5.0 |
| **P < 2000** | 15 ≤ $V_{h,z}$ <20 | 2014 | 7.0 | 0.34 | 5.0 |
| | 20 ≤ $V_{h,z}$ < 25 | 2014 | 9.8 | 0.27 | 5.0 |
| | 25 ≤ $V_{h,z}$ < 30 | 2014 | 11.0 | 0.27 | 5.0 |

[A] Option for C2-engines ≥ 1400 kW: Tier 3 PM/$NO_x$+HC at 0.14/7.8 g/kW in 2012, and Tier 4 in 2015.

**Tier 4 for C1 und C2 marine CI engines[A]:**

| Power [kW] | Model year | HC [g/kWh] | $NO_x$ [g/kWh] | PM [g/kWh] | CO [g/kWh] |
|---|---|---|---|---|---|
| P ≥ 3700 | 2014[B] | 0.19 | 1.8 | 0.12[C] | 5.0 |
| | 2016[B, D] | 0.19 | 1.8 | 0.06 | 5.0 |
| 2000 ≤ P < 3700 | 2014[B] | 0.19 | 1.8 | 0.04[E] | 5.0 |
| 1400 ≤ P < 2000 | 2016[B] | 0.19 | 1.8 | 0.04 | 5.0 |
| 600 ≤ P < 1400 | 2017[D] | 0.19 | 1.8 | 0.04 | 5.0 |

A Recreational marine diesel engines are exempted from Tier 4.
B Option for C2: Tier 3 PM/$NO_x$+HC at 0.14/7.8 g/kWh in 2012, and Tier 4 in 2015.
C This standard is 0.25 g/kWh for engines with 15 ≤ $V_{h,z}$ < 30 L.
D Optional compliance start dates can be used within these model years; see original regulative text.
E For model year 2014 and 2015 other PM limits apply: C1-engines, Tier 3 PM; C2-engines with $V_{h,z}$ < 15 L, Tier 3 PM; C2 engines with $V_{h,z}$ ≥ 15 L, Interim Tier 4 PM limits of 0.34 g/kWh for engines < 3300 kW and 0.27 g/kWh for engines ≥ 3300 kW.

- Test cycle: ISO 8178-4, C1/ D2/E2/E3 (according to engine operation).
- 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 (Tier 1/2) and 1.2 to 1.9 times (Tier 3/4) the cycle limit. These requirements come into force with 2007 model year and do not apply to C3-engines.
- ABT (Averaging, Banking and Trading): Emission credits ($NO_x$+HC and particulates) can be averaged, banked or traded.

## China – Seagoing ships

The chinese ministry of traffic and transportation has adopted new regulations for the sulphur content of fuels for seagoing ships in Chinese waters. The coastal waters and eleven ports in the areas of Yangtse delta, Bohai sea and the delta of the Pearl river are declared as sulphur cotrol areas.

| Coming into force | Ports | Chinese territorial waters |
|---|---|---|
| 1.1.2016 | Voluntary application of a limiting value of 0.5% sulphur for the fuel in ships at berth | – |
| 1.1.2017 | The formerly voluntary application becomes mandatory | – |
| 1.1.2019 | – | Seagoing ships in these control areas may use no fuel with a sulphur content of 0.5% or more |
| | In 2019 a decision is expected, if Chinese authorities lower the limiting value for sulphur in fuels to 0.1% | |

# China – Inland waterway vessels

## Tier I

| Category | Cylinder displ. [L] | Power [kW] | CO [g/kWh] | HC + $NO_x$ [g/kWh] | $CH_4$[A] [g/kWh] | Particle [g/kWh] | Date[B] |
|---|---|---|---|---|---|---|---|
| Category 1 | $V_{h,z}$ < 0.9 | $P_n \geq 37$ | 5.0 | 7.5 | 1.5 | 0.40 | 7/2019 |
| | 0.9 ≤ $V_{h,z}$ <1.2 | | | 7.2 | 1.5 | 0.30 | 7/2019 |
| | 1.2 ≤ $V_{h,z}$ < 5 | | | 7.2 | 1.5 | 0.20 | 7/2019 |
| Category 2 | 5 ≤ $V_{h,z}$ < 15 | | | 7.8 | 1.5 | 0.27 | 7/2019 |
| | 15 ≤ $V_{h,z}$ < 20 | $P_n$ < 3300 | 5.0 | 8.7 | 1.6 | 0.50 | 7/2019 |
| | | $P_n \geq 3300$ | 5.0 | 9.8 | 1.8 | 0.50 | 7/2019 |
| | 20 ≤ $V_{h,z}$ < 25 | | | 9.8 | 1.8 | 0.50 | 7/2019 |
| | 25 ≤ $V_{h,z}$ < 30 | | | 11.0 | 2.0 | 0.50 | 7/2019 |

[A] For gas engines.
[B] Date for placing on the market; Type approvals one year earlier.

## Tier II

| Category | Cylinder displ. [L] | Power $P_n$ [kW] | CO [g/kWh] | HC + $NO_x$ [g/kWh] | $CH_4$[A] [g/kWh] | Particle [g/kWh] | Date[B] |
|---|---|---|---|---|---|---|---|
| Category 1 | $V_{h,z}$ < 0.9 | $P_n \geq 37$ | 5.0 | 5.8 | 1.0 | 0.3 | 7/2022 |
| | 0.9 ≤ $V_{h,z}$ < 1.2 | | 5.0 | 5.8 | 1.0 | 0.14 | 7/2022 |
| | 1.2 ≤ $V_{h,z}$ < 5 | | 5.0 | 5.8 | 1.0 | 0.12 | 7/2022 |
| Category 2 | 5 ≤ $V_{h,z}$ < 15 | $P_n$ < 2000 | 5.0 | 6.2 | 1.2 | 0.14 | 7/2022 |
| | | 2000 ≤ $P_n$ < 3700 | 5.0 | 7.8 | 1.5 | 0.14 | 7/2022 |
| | | $P_n \geq 3700$ | 5.0 | 7.8 | 1.5 | 0.27 | 7/2022 |
| | 15 ≤ $V_{h,z}$ < 20 | $P_n$ < 2000 | 5.0 | 7.0 | 1.5 | 0.34 | 7/2022 |
| | | 2000 ≤ $P_n$ < 3300 | 5.0 | 8.7 | 1.6 | 0.50 | 7/2022 |
| | | $P_n \geq 3300$ | 5.0 | 9.8 | 1.8 | 0.50 | 7/2022 |
| | 20 ≤ $V_{h,z}$ < 25 | $P_n$ < 2000 | 5.0 | 9.8 | 1.8 | 0.27 | 7/2022 |
| | | $P_n \geq 2000$ | 5.0 | 9.8 | 1.8 | 0.50 | 7/2022 |
| | 25 ≤ $V_{h,z}$ < 30 | $P_n$ < 2000 | 5.0 | 11.0 | 2.0 | 0.27 | 7/2022 |
| | | $P_n \geq 2000$ | 5.0 | 11.0 | 2.0 | 0.50 | 7/2022 |

[A] For gas engines.
[B] Date for placing on the market; Type approvals one year earlier.

## 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 | Cylinder displacement / Power | CO [g/kWh] | HC + $NO_x$ [g/kWh] | Partikel [g/kWh] | Date[A] |
|---|---|---|---|---|---|
| **V 1:1** | $V_{h,z}$ < 0.9 L<br>$P_n \geq 37$ kW | 5.0 | 7.5 | 0.4 | 2010 |
| **V 1:2** | 0.9 L ≤ $V_{h,z}$ < 1.2 L | 5.0 | 7.2 | 0.3 | 2010 |
| **V 1:3** | 1.2 L ≤ $V_{h,z}$ < 2.5 L | 5.0 | 7.2 | 0.2 | 2010 |
| **V 1:4** | 2.5 L ≤ $V_{h,z}$ < 5.0 L | 5.0 | 7.2 | 0.2 | 2010 |
| **V 2:1** | 5.0 L ≤ $V_{h,z}$ < 15.0 L | 5.0 | 7.8 | 0.27 | 2010 |
| **V 2:2** | 15.0 L ≤ $V_{h,z}$ < 20.0 L<br>$P_n$ < 3300 kW | 5.0 | 8.7 | 0.5 | 2010 |
| **V 2:3** | 15.0 L ≤ $V_{h,z}$ < 20.0 L<br>$P_n \geq 3300$ kW | 5.0 | 9.8 | 0.5 | 2010 |
| **V 2:4** | 20.0 L ≤ $V_{h,z}$ < 25.0 L | 5.0 | 9.8 | 0.5 | 2010 |
| **V 2:5** | 25.0 L ≤ $V_{h,z}$ < 30.0 L | 5.0 | 11.0 | 0.5 | 2010 |

[A] Date for placing on the market.

## Russia – Marine

| Date | CO [g/kWh] | HC [g/kWh] | $n_n$ [rpm] | $NO_x$[A] [g/kWh] |
|---|---|---|---|---|
| **< 1.1.2016** | 3.5 | 1.0 | **< 130** | 17.0 |
| | | | **130–2000** | $45.0 \cdot n_n^{(-0.2)}$ |
| | | | **> 2000** | 9.8 |
| **≥ 1.1.2016** | 1.5 | 0.4 | **< 130** | 14.4 |
| | | | **130–2000** | $44.0 \cdot n_n^{(-0.23)}$ |
| | | | **> 2000** | 7.7 |

[A] $NO_x$ limit values do apply until/from 2011.

## 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 plants financed by the 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 | PM [$mg/m_n^3$] | $SO_2$ [$mg/m_n^3$] | $NO_x$ [$mg/m_n^3$] |
|---|---|---|---|
| **spark ignition** | – | – | 200 |
| **Dual Fuel-Mode** | – | – | 400 |
| **compression ignition** | – | – | 1600 |

### Diesel engines

| Bore [mm] | PM [$mg/m_n^3$] | $SO_2$ [$mg/m_n^3$] | $NO_x$ [$mg/m_n^3$] |
|---|---|---|---|
| **< 400** | | | 1460 |
| **< 400 and high efficiency** | 50 or 100[A] | 1.5–3 % S[B] | 1600 |
| **≥ 400** | | | 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 $mg/m_n^3$, 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).

## World Bank – EHS Guidelines for industry sectors: Power plants $P_n \geq 50\ MW_{th}$

The limit values are valid for power plants with a thermical capacity of **$P \geq 50\ MW_{th}$** 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 considerd 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[A] / Power [$MW_{th}$] | PM [$mg/m_n^3$][B] | S[C] [%] | $NO_x$ [$mg/m_n^3$][B] |
|---|---|---|---|---|
| Natural gas | SI | – | – | 200 |
| | CI/DF | | | 400 |
| Liquid fuels | $50 \leq P_n < 300$ | 30 | 0.5 | 400 |
| | $P_n \geq 300$ | | 0.2 | |
| Biofuels/gaseous fuels other than natural gas | SI, natural gas | 30 | – | 200 |
| | other | | | 400 |

[A] SI=Spark Ignition, CI=Compression Ignition, DF=Dual-Fuel.
[B] Dry gas excess 15% $O_2$ content.
[C] S%=fuel sulfur content.

### Plants in Non-Degraded Airsheds

| Fuel/ Power [$MW_{th}$] | Technology[A] / Bore size [mm] | PM [$mg/m_n^3$][B] | $SO_2$ [$mg/m_n^3$][B] | $NO_x$ [$mg/m_n^3$][B] |
|---|---|---|---|---|
| Natural gas | SI | – | – | 200 |
| | CI, DF | | | 400[C] |
| Liquid fuels $50 \leq P_n < 300$ | CI / < 400 mm | 50 | 1170 or < 2% S[D] | 1460 |
| | CI / ≥ 400 mm | | | 1850 |
| | DF | | | 2000 |
| Liquid fuels $P_n \geq 300$ | – | 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] SI=Spark Ignition, CI=Compression Ignition, DF=Dual-Fuel.
[B] Dry gas excess 15% $O_2$ content.
[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 | $NO_x$ [$mg/m_n^3$] |
|---|---|---|
| **SI (gas engines) $P_n > 1\ MW_{th}$** | Lean burn engines | 250 |
| | Others | 500 |
| **CI (Diesel / Dual fuel) $P_n > 5\ MW_{th}$** | Natural gas (Jet ignition engines) | 500 |
| | Heavy fuel oil | 600 |
| | Diesel or gas oil | 500 |

- 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 $O_2$ 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.

## EU – Industrial Emissions Directive

Since 6 January 2011, the Industrial Emissions Directive **(2010/75/EU)** came into force. This regulation includes the emissions from combustion plants with a rated thermal input of $P_n \geq 50$ $MW_{th}$ or more. The emission limit values are continuously updated via the process for the determination of the best available techniques (BREF process). Reference Oxygen is set to 15%.

**Gasmotoren, $P_n \geq 50MW_{th}$**

| Category | $NO_x$[A] [$mg/m_n^3$] | CO[A] [$mg/m_n^3$] |
|---|---|---|
| **Permit before 7 January 2013 or application before 7 January 2013 for operation not later than 7 January 2014** | 100 | 100 |
| **Permit or application after 7 January 2013** | 75 | 100 |

[A] Dry gas excess 15% O2 content.

- Excepted are gas engines for emergency use (<500 h/a) and on offshore platforms.
- For diesel engines no limits have been published.
- For all combustion plants covered by this Directive, Member States shall, from 1 January 2016, establish an annual inventory of the emissions.
- The BREF process for Large Combustion plants will expectedly be finished in 2017.
- New emission limit values are expected for: $SO_x$, $NO_x$, carbon monoxide, ammonia, particulates, methane and other volatile organic compounds.
- After publication of the reference documents for the best available technologies, EU-member states are obliged to amend their national regulations accordingly.

## EU – Medium Combustion Plant Directive

The Medium Combustion Plant Directive **(MCPD 2015/2193/EU)** has entered into force on December 19th 2015. The emission of plants in the power range $1 \leq P_n < 50$ $MW_{th}$ are regulated. The reference oxygen is set to 15%. New medium combustion plants shall comply with MCPD from 20 December 2018. Existing plants with $P_n > 5$ $MW_{th}$ shall comply from 1 January 2025 and plants with $P_n \leq 5$ $MW_{th}$ from 1 January 2030.

## Gas Engines, $1 \leq P_n < 50\ MW_{th}$

| Fuel type | Category | $NO_x$ [$mg/m_n^3$] | PM [$mg/m_n^3$] | $SO_x$ [$mg/m_n^3$] | CO [$mg/m_n^3$] |
|---|---|---|---|---|---|
| Natural gas | Existing plants | 190[A] | – | – | Only monitored, no emission limit value defined |
| | New plants | 95[B] | – | – | |
| Other gases | Existing plants | 190[A] | – | 15 (Biogas: 60) | |
| | New plants | 190 | – | 15 (Biogas: 40) | |

[A] 380 $mg/m_n^3$ for Dual-fuel engines in gas-mode.
[B] 190 $mg/m_n^3$ for Dual-fuel engines in gas-mode.

## Engines operating on liquid fuels, $1 \leq P_n < 50\ MW_{th}$

| Fuel type | Category | Power [$MW_{th}$] | $NO_x$ [$mg/m_n^3$] | PM [$mg/m_n^3$] | $SO_x$ [$mg/m_n^3$] | CO [$mg/m_n^3$] |
|---|---|---|---|---|---|---|
| Diesel | Existing plants New plants | $P_n > 5$ | 190[A] | – | – | Only monitored, no emission limit value defined |
| | | $1 \leq P_n \leq 5$ | 250[A] | – | – | |
| | Existing plants | $P_n > 5$ | 190[B] | – | – | |
| | | $1 \leq P_n \leq 5$ | 190[B] | – | – | |
| Other liquid fuels | Existing plants New plants Existing plants | $P_n > 20$ | 190[A] | 10 | 120 | |
| | | $5 < P_n \leq 20$ | 225[B] | 20 | 120 | |
| | | $1 \leq P_n \leq 5$ | 250[A] | 20 | 120 | |
| | New plants | $P_n > 20$ | 190[B,C] | 10[D] | 120[E] | |
| | | $5 < P_n \leq 20$ | 190[B,C] | 10[D] | 120[E] | |
| | | $1 \leq P_n \leq 5$ | 190[B,C] | 20[D] | 120[E] | |

[A] 1850 $mg/m_n^3$ for the following cases:
a) Diesel engines, whose construction was started before May 18th 2006;
b) for dual fuel engines in liquid mode.
[B] 225 $mg/m_n^3$ for Dual-fuel engines in liquid-mode.
[C] 225 $mg/m_n^3$ for Diesel engines with a total thermal power equal or less than 20 MW with ≤ 1 200 rpm.
[D] 75 $mg/m_n^3$ until January 1st 2025 for Diesel engines, which are a part of small or micro isolated networks.
[E] 590 $mg/m_n^3$ until January 1st 2025 for Diesel engines, which are a part of small or micro isolated networks.

- Emission limit values are defined for $SO_x$, $NO_x$ und particulate matter, carbon monoxide is only monitored.
- MCPD requires registration of all affected plants.
- No aggregation rules for separate plants with $P_n < 1\ MW_{th}$.
- EU-member states may define exemptions for plants operating less than 500 hours per year. For isolated plants or plants for heat production during cold weather conditions the exemptions may be extended to 1000 operating hours per year.
- Until December 19th 2017 the minimum requirements stipulated by MCPD have to be transposed into national legislation of EU-member states.

## Germany

The "**Technische Anleitung zur Reinhaltung der Luft** (TA Luft)" is a common administrative regulation of the German government referring to the "Bundes-Imissionsschutzgesetz" (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 $P_n > 1\ MW_{th}$;
- other fuels (e.g. diesel fuels) with $P_n > 1\ MW_{th}$.
- 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.
- Emission limit values applied to normal operation conditions (usually nominal load conditions).
- Engines for emergency use, for covering peak loads or which are operated less than 300 hours per year are subject to a PM emission limit value of 80 $mg/m_n^3$. No emission limit values for $NO_x$ or CO are defined for these engine types.
- A $NO_x$ emission limit value of 800 $mg/m_n^3$ is applied to two-stroke engines.

### Gas engines

| Gas type | Engine type | Power [$MW_{th}$] | CO [$mg/m_n^3$] | $NO_x$ [$mg/m_n^3$] |
|---|---|---|---|---|
| Natural gas | Lean mix engine | | 300 | 500 |
| | Others | | 300 | 250 |
| Pit gas | Lean mix engine | | 650 | 500 |
| | Others | | 650 | 250 |
| Biogas / purification gas | Pilot injection | $P_n < 3$ | 2000 | 1000 |
| | | $P_n \geq 3$ | 650 | 500 |
| | Spark ignition | $P_n < 3$ | 1000 | 500 |
| | | $P_n \geq 3$ | 650 | 500 |
| Landfill gas | Lean mix engine | | 650 | 500 |
| | Others | | 650 | 250 |

**Diesel engines**

| Power [$MW_{th}$] | PM [$mg/m_n^3$] | CO [$mg/m_n^3$] | $NO_x$ [$mg/m_n^3$] |
|---|---|---|---|
| $P_n < 3$ | 20 | 300 | 1000 |
| $P_n \geq 3$ | 20 | 300 | 500 |

- An amended version of TA Luft is expected for 2017.
- The emission limit values for formaldehyde were tightened by an execution rule. New plants have to comply with an emission limit value of 30 $mg/m_n^3$ from February 5th 2016 and with an emission limit value of 20 $mg/m_n^3$ from January 1st 2020. Existing plants with formaldehyde emissions > 40 $mg/m_n^3$ or < 40 $mg/m_n^3$ have to comply with an emission limit value of 30 $mg/m_n^3$ from February 5th 2018 or February 5th, 2019 respectively.

## USA – Stationary diesel engines

New regulations for stationary Diesel engines (40 CFR Parts 06 Subpart IIII) have been published on July 11th 2006 by the US EPA. These regulations enter into force from September 11th 2006.

- The regulations do not allow the operation of uncertified engines. On-spot emission measurements cannot replace a US EPA certification of the engine manufacturer.
- Inducement override is allowed for certified product if there is an emissions control malfunction during a situation that can potentially result in a loss of life if the engine shuts down and the engines must comply with Tier 1 (Tier-I ≙ date of construction 1996 – 2001/2002) emissions levels during a malfunction.
- Regulations for engines with a displacement $V_{h,z} \geq 30$ liters per cylinder: US EPA has harmonised the provisions for stationary diesel engines with the revised IMO MARPOL Annex VI for engines of seagoing ships. (the respective $NO_x$ emission limit values are listed in section "IMO seagoing ships").
- US EPA has defined the limit values for the sulphur content in diesel fuel for the use in in stationary engines with a displacement $V_{h,z} \geq$ 30 liters per cylinder to 1,000 ppm from July 1st 2006 onwards.

## Diesel engines < 10 liters capacity per cylinder[A]

| Maximum Engine power [kW] | Date of construction | NMHC + $NO_x$ [g/kWh] | NMHC [g/kWh] | $NO_x$ [g/kWh] | CO [g/kWh] | Particulate [g/kWh] |
|---|---|---|---|---|---|---|
| P < 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 | 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 | 0.02 |
| | 2014 | – | 0.19 | 0.40 | 5.0 | 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 | 0.02 |
| | 2014 | – | 0.19 | 0.40 | 5.0 | 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 |
| P > 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 |

[A] The manufacturer may choose to skip the emission limit value of 0.30 g/kWh for engines in the power range 37 ≤ $P_n$ < 56 kW. The PM limit of 0.03 g/kWh would enter into force one year earlier in 2012. The Tier-3-limit value of 0.40 g/kWh would be valid until 2012.

[B] 50 % of the produced engines have to comply with the limit for $NO_x$+NMHC, and 50% of the produced engines have to comply with separate limits for $NO_x$ and NMHC.

[C] The emission limit values do not apply for engines in emergency use.

## Tier 1 requirements for diesel engines < 10 liters displacement per cylinder

| Maximum Engine power [kW] | Date of construction | NMHC + $NO_X$ [g/kWh] | NMHC [g/kWh] | $NO_x$ [g/kWh] | CO [g/kWh] | Particulate [g/kWh] |
|---|---|---|---|---|---|---|
| **P < 8** | 2000 | 10.5 | – | – | 8.0 | 1.0 |
| **8 ≤ P < 19** | 2000 | 9.5 | – | – | 6.6 | 0.8 |
| **19 ≤ P < 37** | 1999 | 9.5 | – | – | 5.5 | 0.8 |
| **37 ≤ P < 75** | 1998 | – | – | 9.2 | – | – |
| **75 ≤ P < 130** | 1997 | – | – | 9.2 | – | – |
| **130 ≤ P < 225** | 1996 | – | 1.3- | 9.2 | 11.4 | 0.54 |
| **225 ≤ P < 450** | 1996 | – | 1.3- | 9.2 | 11.4 | 0.54 |
| **450 ≤ P ≤ 560** | 1996 | – | 1.3 | 9.2 | 11.4 | 0.54 |
| **P > 560** | 2000 | – | 1.3 | 9.2 | 11.4 | 0.54 |

## Diesel engines < 10 liters displacement per cylinder

| Maximum Engine power [kW] | NMHC + $NO_X$ [g/kWh] | NMHC [g/kWh] | $NO_x$ [g/kWh] | CO [g/kWh] | Particulate [g/kWh] |
|---|---|---|---|---|---|
| **< 8** | 10.5 | – | – | 8.00 | 1.00 |
| **8 ≤ P < 19** | 9.5 | – | – | 6.60 | 0.80 |
| **19 ≤ P <37** | 9.5 | – | – | 5.50 | 0.80 |
| **37 ≤ P <56** | – | – | 9.20 | – | – |
| **56 ≤ P < 75** | – | – | 9.20 | – | – |
| **75 ≤ P < 130** | – | – | 9.20 | – | – |
| **130 ≤ P < 225** | – | 1.30 | 9.20 | 11.40 | 0.54 |
| **225 ≤ P < 450** | – | 1.30 | 9.20 | 11.40 | 0.54 |
| **450 ≤ P ≤ 560** | – | 1.30 | 9.20 | 11.40 | 0.54 |
| **P > 560** | – | 1.30 | 9.20 | 11.40 | 0.54 |

## Diesel engines with 10–30 liters displacement per cylinder (Year of manufacture from 2007)

| Cylinder displacement [L] Power [kW] | THC + $NO_x$ [g/kWh] | CO [g/kWh] | Particulate [g/kWh] |
|---|---|---|---|
| **5 ≤ $V_{h,z}$ < 15 complete power range** | 7.8 | 5.0 | 0.27 |
| **15 ≤ $V_{h,z}$ < 20 P < 3300 kW** | 8.7 | 5.0 | 0.50 |
| **15 ≤ $V_{h,z}$ < 20 P ≥ 3300 kW** | 9.8 | 5.0 | 0.50 |
| **20 ≤ $V_{h,z}$ < 25 complete power range** | 9.8 | 5.0 | 0.50 |
| **25 ≤ $V_{h,z}$ < 30 complete power range** | 11.0 | 5.0 | 0.50 |

## Tier 1 requirements for diesel engines with a displacement of $10 \leq V_{h,z} \leq 30$ liters per cylinder

| Cylinder displacement [L] | Maximum engine power [kW] | PM [g/kWh] | $NO_x$ + HC [g/kWh] | Date of manufacture |
|---|---|---|---|---|
| **$10 \leq V_{h,z} < 15$** | P < 2000 | 0.14 | 6.2 | 2013+ |
| **$10 \leq V_{h,z} < 15$** | 2000 ≤ P < 3700 | 0.14 | 7.8 | 2013+ |
| **$15 \leq V_{h,z} < 20$** | P < 2000 | 0.34 | 7.0 | 2014+ |
| **$20 \leq V_{h,z} < 25$** | P < 2000 | 0.27 | 9.8 | 2014+ |
| **$25 \leq V_{h,z} < 30$** | P < 2000 | 0.27 | 11.0 | 2014+ |

## Tier 2 requirements for diesel engines with a capacity of $10 \leq V_{h,z} \leq 30$ liters per cylinder

| Cylinder displacement [L] | Maximum engine power [kW] | PM [g/kWh] | $NO_x$ [g/kWh] | HC [g/kWh] | Date of manufacture |
|---|---|---|---|---|---|
| **all** | 600 ≤ P < 1400 | 0.04 | 1.8 | 0.19 | 2017+[A] |
| **all** | 1400 ≤ P < 2000 | 0.04 | 1.8 | 0.19 | 2016+[B] |
| **all** | 2000 ≤ P < 3700 | 0.04 | 1.8 | 0.19 | 2014+[B] |
| **< 15** | ≥ 3700 | 0.12 | 1.8 | 0.19 | 2014-2015[B] |
| **$15 \leq V_{h,z} < 30$** | | 0.25 | 1.8 | 0.19 | 2014-2015[B] |
| **All** | | 0.06 | 1.8 | 0.19 | 2016+[A] |

[A] According to 40 FCR 1042.101(a)(8), optional dates for engine compliance can be used for these years.

[B] Option: First stage PM/$NO_x$+HC at 0.14/7.8 g/kWh in 2012 and second stage in 2015.

## Diesel engines for stationary fire extinguisher pumps

| Maximum engine power [kW] | Date of manufacture | NMHC + $NO_x$ [g/kWh] | CO [g/kWh] | PM [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 +[A] | 3.5 | – | 0.30 |
| 75 ≤ P < 130 | 2009 and earlier | 7.8 | 3.7 | 0.60 |
| | 2010 +[A] | 3.0 | – | 0.22 |
| 130 ≤ P < 450 | 2008 and earlier | 7.8 | 2.6 | 0.40 |
| | 2009 +[A] | 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 |

[A] Engines with ≥ 2,650 rpm have to comply with the emission limit values after a transition period of three years.

## Distributed Generation (DG) Units: Diesel and gas engines (California):

| Inkrafttreten | $NO_x$ | VOC | CO | Unit |
|---|---|---|---|---|
| 1.1.2003 | 0.50[A] | 1.00 | 6.00 | lbm/MW-hr |
| | 0.23 | 0.45 | 2.70 | g/kWh |
| 1.1.2007[B] | 0.07 | 0.02 | 0.10 | lbm/MW-hr |
| | 0.03 | 0.01 | 0.05 | g/kWh |

[A] Value is increased to 0.70 for combined heat and power plants.
[B] For plants using combined heat and power cogeneration, heat is treated as electrical power.

- Distributed Generation Certification Program: adopted new sections 94200-94214, in article 3, subchapter 8, chapter 1, division 3, title 17 of California Code of Regulations, 2002.
- Emission of particulate matter may not exceed the emission levels of natural gas engines running on fuel with a sulfur content of 1 grain / 100 scf (e. g. PM < 0.5 mg/kWh)

## USA – Stationary SI engines

New regulations for Stationary SI engines (40 CFR Part 60 Subpart JJJJ) have been published on January 18th 2008 by the US EPA. These regulations enter into force from March 18th 2006.
These regulations apply to SI engines, which are fueled with gasoline, LPG, natural -, landfill - and biogas. The regulations differentiate between engines in regular operation and in emergency use.
The regulations do not allow the operation of uncertified engines. On-spot emission measurements cannot replace a US EPA certification of the engine manufacturer.

### Stationary SI engines P ≤ 19 kW

| Engine class [A] | HC + $NO_x$ [B] [g/kWh] | NMHC + $NO_x$ [B,C] [g/kWh] | CO [B] [g/kWh] |
|---|---|---|---|
| I | 16.1 | 14.8 | 610 |
| I-A | 50 | – | 610 |
| I-B | 40 | 37 | 610 |
| II | 12.1 | 11.3 | 610 |

[A] Engine class I-A: $V_h < 66$ cm³;
Engine class I-B: $66 \leq V_h < 100$ cm³;
Engine class I: $100 \leq V_h < 225$ cm³;
Engine class II: $V_h \geq 225$ cm³.

[B] Engines, which have been modified or rehashed before July 1st 2008, have to comply with the emission limit values stipulated for engines, which have been manufactured after July1st 2008.

[C] Engine manufacturers may choose to apply the emission limit values of NMHC+$NO_x$ instead the emission limit values of HC+$NO_x$ for engines fueled with natural gas.

## Stationary SI engines P >19 kW (25 bhp) (no emergency use, gasoline and LPG-engines with $\lambda$ >1)

| Engine power [bhp] | Date of manufacture | HC + $NO_x$[A,B] [g/kWh] | CO[A,B] [g/kWh] |
|---|---|---|---|
| 25 < P < 500[C] | 1.7.2008 | 2.7 | 4.4 |
| | 1.7.2008[E] (high performance) | 2.7 | 130.0 |
| P ≥ 500[D] | 1.7.2007 | 2.7 | 4.4 |
| | 1.8.2007[E] (high performance) | 2.7 | 130.0 |

A Engines may be certified according to the following formula: $(HC+NO_x)xCO^{0.784} \leq 8.57$. Limit values for HC+$NO_x$ and CO, which are used in the formula are rounded to 0.1 g/kWh and have to be complied with by the engines. The limit value for HC+$NO_x$ may not exceed 2.7 g/kWh and the limit value for CO may not exceed 20.6 g/kWh.

B The regulations in 40 CFR part 1048 permit engines with a maximum power ≤ 30 kW and a capacity ≤ 1000 ccm in order to meet the requirements in 40 CFR part 90.

C Modified or rehashed engines with a power between 25 and 500 bhp, which have been manufactured before July 1st 2008, have to comply with the emission limit values stipulated for engines, which have been manufactured after July1st 2008.

D Modified or rehashed engines with a power greater than 500 bhp, which have been manufactured before July 1st 2007, have to comply with the emission limit values stipulated for engines, which have been manufactured after July1st 2007.

E High performance engines are engines, which are for example used in cement saws, cement pumps or similar applications for air cooled engines.

## Stationary SI engines 19 kW < P < 75 kW (25 bhp < P < 100 bhp) (no emergency use, natural gas and LPG-engines with $\lambda$ >1)

| Engine power [kW] | Date of manufacture | HC + $NO_x$[A,B] [g/kWh] | CO[A,B] [g/kWh] |
|---|---|---|---|
| 19 < P < 75[C] | 1.7.2008 | 3.8 | 6.5 |
| | 1.7.2008 (high performance) | 3.8 | 200.0 |

A Instead of using the emission limit values from the table, the following formula may be applied: $(HC+NO_x)*CO^{0.781} \leq 16.78$. The emissions of HC+$NO_x$ may not exceed 3.8 g/kWh and the emissions of CO may not exceed 31 g/kWh.

B For engines fueled with natural gas, no NMHC or total carbon emissions have to be measured to prove compliance with the given table.

C Modified or rehashed engines which have been manufactured before July 1st 2008, have to comply with the emission limit values stipulated for engines, which have been manufactured after July1st 2008.

## Stationary SI engines ≥ 100 bhp (except those fueled with gasoline or LPG with $\lambda$ > 1), stationary SI landfill and biogas engines and stationary SI engines P > 25 bhp for emergency use

| Engine class and fuel type | Maximum engine power [bhp] | Date of manufacture | $NO_x$[A] [g/HP-hr (ppmvd bei 15 % $O_2$)] | CO[A] [g/HP-hr (ppmvd bei 15 % $O_2$)] | VOC[A] [g/HP-hr (ppmvd bei 15 % $O_2$)] |
|---|---|---|---|---|---|
| Non-emergency SI natural gas and non-emergency SI leanburn-LPG operation | 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 leanburn-natural gas and LPG-operation | 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 leanburn-LPG-operation (except leanburn with 500 ≤ P < 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 biogas operation (except leanburn with 500 ≤ P < 1350) | P < 500 | 1.7.2008 | 3.0 (220) | 5.0 (610) | 1.0 (80) |
| | | 1.1.2010 | 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 biogas operation (leanburn) | 500 ≤ P < 1350 | 1.1.2008 | 3.0 (220) | 5.0 (610) | 1.0 (80) |
| | | 1.7.2010 | 2.0 (150) | 5.0 (610) | 1.0 (80) |
| Emergency use | 25 < P < 130 | 1.1.2009 | 1.0[B] (–) | 387 (–) | – (–) |
| | P ≥ 130 | | 2.0 (160) | 4.0 (540) | 1.0 (86) |

[A] Owners and operators of uncertified spark ignited engines may choose the units of the indicated emission limit values: g/bhp-hr or ppmvd at 15 % residual oxygen.

[B] The emission limit values for emergency use engines with a power between 25 and 130 bhp have to be applied for $NO_x$+HC.

## USA – NESHAP for existing engines

The US EPA has published regulations for **existing internal combustion reciprocating piston engines** „National Emissions Standards for Hazardous Air Pollutions“ (NESHAPs, 40 CFR Part 63, Subpart ZZZZ). The emission limits are applied to

- Engines in **Area Sources**. Area Sources are plants, which emit less than 10 tpy (tons per year) of a single pollutant or less than 25 tpy pollutants in total.
- Engines in **Major Sources** with a power ≤ 500 bhp, built or redesigned before June 12th 2006. Major Sources emit more than 10 tpy of a single pollutant or more than 25 tpy pollutants in total.
- Plants with a power < 100 bhp and emergency use engines are excepted.

### CI engines

| Power [bhp] | Area Source | Major Source |
|---|---|---|
| $P_n$ < 100 | – | – |
| 100 ≤ $P_n$ < 300 | – | 230[A] ppm CO |
| 300 ≤ $P_n$ ≤ 500 | 49 ppm CO[A] or 70% reduction | |
| $P_n$ > 500[B] | 23 ppm CO[A] or 70% reduction | |

[A] At 15% residual oxygen.
[B] Engines in Major Sources built or rebuilt before December 19th 2002.

- Except Alaska, the use of Ultra-low-Sulfur-Diesel (ULSD) fuel is mandatory for plants with a power > 300 bhp.
- Systems for the prevention of emission from the crank shaft housing have tob e retro-fitted.

### SI engines in Area Sources, P>500

| Class | Limit values |
|---|---|
| 4-stroke, leanburn | 47 ppm CO[A] or 93% CO reduction |
| 4-stroke, stoich. mixture | 270 ppm CO[A] or 76% reduction |

[A] At 15% residual oxygen.

### SI engines in Major Sources, 100 ≤ P < 500

| Class | Plant power [bhp] | Limit value |
|---|---|---|
| 2-stroke, leanburn | 100 ≤ $P_n$ ≤ 500 | 225 ppm CO[A] |
| 4-stroke, leanburn | 100 ≤ $P_n$ ≤ 500 | 47 ppm CO[A] |
| 4-stroke, stoich. mixture | 100 ≤ $P_n$ ≤ 500 | 10.3 ppm Formaldehyd[A] |
| 4-stroke, stoich. mixture | 500 < $P_n$ | 350 ppb HCHO[A] |
| Landfill-/Biogas | 100 ≤ $P_n$ ≤ 500 | 177 ppm CO* |

[A] At 15% residual oxygen.

## Belgium

The Belgian law Vlarem 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 $mg/m_n^3$ and related to 15 % residual oxygen.
Plants simultaneously operating on multiple fuels are subject to the provisions stipulated under § 1 in article 5.43.3.16. Plants alternatingly operating on multiple fuels are subject to the emission limit values for each fuel type as described in the articles 5.43.2.3 to 5.43.2.14.

**Stationary SI engines (Gas engines and Dual-Fuel engines in gas-mode) with $P_n < 50\ MW_{th}$, operating more than 500 hours per year:**

| Initial registration | Power [$MW_{th}$] | $NO_x$ [$mg/m_n^3$] | CO [$mg/m_n^3$] | Organic substances [$mg/m_n^3$] |
|---|---|---|---|---|
| before 1.1.2000 | $0.3 \le P_n < 50$ | $500 \times \eta/30$ [A] | 500 | – |
| between 1.1.2000 and 1.1.2005 | $0.3 \le P_n < 50$ | $190 \times \eta/30$ [B] | 250 [D] | – |
| between 1.1.2005 and 1.1.2010 | $0.3 \le P_n \le 1$ | $190 \times \eta/30$ [B] | 250 [D] | 60 |
| | $1 < P_n < 50$ | 190 [B] | 250 [D] | 60 |
| between 1.1.2010 and 1.1.2014 | $0.3 \le P_n \le 1$ | $190 \times \eta/30$ [B] | 250 [D] | 60 |
| | $1 < P_n < 5$ | 190 [B] | 250 [D] | 60 |
| | $5 \le P_n < 50$ | 95 [B] | 250 [D] | 60 |
| from 1.1.2014 | $0.3 \le P_n \le 1$ | 190 [B] | 250 [D] | 60 |
| | $1 < P_n < 5$ | 95 [B,C] | 250 [D] | 60 |
| | $5 \le P_n < 50$ | 95 [B] | 250 [D] | 60 |

η nominal engine efficiency

[A] Deviating from these provisions:
Until December 31st 2018, gas engines which were permitted before January 1st 1993 are not subject to $NO_x$ emission limit values.
Gas engines fueled with Biogas, which were permitted between January 1st 1993 and January 1st 2000, are subject to an emission limit value for $NO_x$ of 1000 x η/30 $mg/m_n^3$

[B] The emission limit values for $NO_x$ for Dual-Fuel-engines are multiplied by factor 2.

[C] Engines fueled with biogas are subject to an emission limit value for $NO_x$ of 190 $mg/m_n^3$.

[D] Engines fueled with biogas are subject to an emission limit value for CO of 500 $mg/m_n^3$

## Stationary SI engines (gas engines and Dual-Fuel engines in gas-mode) with $P_n < 50$ $MW_{th}$, which are operated not more than 500 hours per year:[A]

| Initial registration | Power [$MW_{th}$] | $NO_x$ [$mg/m_n^3$] | CO [$mg/m_n^3$] | Organic substances [$mg/m_n^3$] |
|---|---|---|---|---|
| before 1.1.2000 | $0.3 \le P_n < 50$ | $500 \times \eta/30$[B] | 500 | – |
| after 1.1.2000 | $0.3 \le P_n < 50$ | $190 \times \eta/30$[C] | 250[D] | – |

η nominal engine efficiency

A The operator is obligated to record the operating hours.

B Deviating from these provisions:
Until December 31st 2018 gas engines, which were permitted before January 1st 1993, are not subject to $NO_x$ emission limit values.
Gas engines fueled with Biogas, which were permitted between January 1st 1993 and January 1st 2000, are subject to an emission limit value for $NO_x$ of 1000 x η/30 $mg/m_n^3$.

C The emission limit values for $NO_x$ for Dual-Fuel-engines are multiplied by factor 2.

D Engines fueled with biogas are subject to an emission limit value for CO of 500 $mg/m_n^3$.

## Stationary CI engines (diesel, other liquid fuels or Dual-Fuel engines in liquid mode) with $P_n < 50$ $MW_{th}$, which are operated more than 500 hours per year:

| Initial registration | Power [$MW_{th}$] | Dust [$mg/m_n^3$] | $SO_2$ [$mg/m_n^3$] | $NO_x$ [$mg/m_n^3$] | CO [$mg/m_n^3$] | Organic substances [$mg/m_n^3$] |
|---|---|---|---|---|---|---|
| Before 1.1.1993 | $0,3 \le P_n < 50$ | 115 | 60[A] | 1875 | 575 | – |
| Between 1.1.1993 and 1.1.2000 | $0,3 \le P_n < 50$ | 75 | 60[A] | 1500 | 375 | – |
| Between 1.1.2000 and 1.1.2005 | $0.3 \le P_n < 3$ | 20 | 60[A] | 1500 | 250 | – |
| | $3 \le P_n < 5$ | 20 | 60[A] | 750 | 250 | – |
| | $5 \le P_n < 50$ | 20 | 60[A] | 190[B] | 250 | – |
| Between 1.1.2005 and 1.1.2010 | $0,3 \le P_n < 5$ | 20 | 60[A] | 375 | 250 | 60 |
| | $5 \le P_n < 50$ | 20 | 60[A] | 190[B] | 250 | 60 |
| Between 1.1.2010 and 1.1.2014 | $0,3 \le P_n < 5$ | 20 | 60[A] | 375 | 250 | 60 |
| | $5 \le P_n < 50$ | 20 | 60[A] | 130[B] | 250 | 60 |
| After 1.1.2014 | $0,3 \le P_n \le 1$ | 20 | 60 | 375 | 250 | 60 |
| | $1 < P_n < 5$ | 20 | 60[C] | 190[B] | 250 | 60 |
| | $5 \le P_n < 50$ | 20 | 60 | 130[B] | 250 | 60 |

A Engines running on heavy fuel oil are not subject to the emission limit values for $SO_2$. The content of sulfur in the fuel may not exceed 1% of its mass.

B Dual-Fuel-Engines are subject to an emission limit value for $NO_x$ of 225 $mg/m_n^3$.

C Deviating from the provided rules, an emission limit value of $SO_2$ of 600 $mg/m_n^3$ is stipulated for engines running on heavy fuel oil, if:
1) Connection to the public grid is not possible, and
2) The ecological benefit is small compared to the economical effort when more environmentally friendly fuels are used, and
3) The operator has proved compliance with requirements 1) and 2).

## Stationary CI engines (diesel, other liquid fuels or Dual-Fuel engines in liquid mode) with $P_n$ < 50 $MW_{th}$, which are operated not more than 500 hours per year[A]:

| Initial registration | Power [$MW_{th}$] | Dust [$mg/m_n^3$] | $SO_2$ [$mg/m_n^3$] | $NO_x$ [$mg/m_n^3$] | CO [$mg/m_n^3$] |
|---|---|---|---|---|---|
| **Before 1.1.2000** | **0,3 ≤ P < 50** | 115 | 60[B] | – | 575 |
| **After 1.1.2000** | **0,3 ≤ P < 50** | 20 | 60[B] | 1500 | 250 |

[A] The operator is obligated to record the operating hours.
[B] Engines running on heavy fuel oil are not subject to the emission limit values for $SO_2$. The content of sulfur in the fuel may not exceed 1% of its mass.

## Stationary SI engines (gas Engines and Dual-Fuel engines in gas-mode) with $P_n$ ≥ 50 $MW_{th}$, which are operated more than 500 hours per year:

| Initial registration / date of bringing ino service | Power [$MW_{th}$] | $NO_x$ [$mg/m_n^3$] | CO [$mg/m_n^3$] | Organic substances [$mg/m_n^3$] |
|---|---|---|---|---|
| **Initial registration before 7.1.2013 and bringing into service before or on 7.1.2014** | **$P_n$ ≥ 50** | 95 | 100 | 60 |
| **Initial registration after or on 7.1.2013 and bringing into service after 7.1.2014** | **$P_n$ ≥ 50** | 75 | 100 | 60 |

## Stationary SI engines (gas engines and Dual-Fuel engines in gas-mode) with $P_n$ ≥ 50 $MW_{th}$, which are operated less than or equal to 500 hours per year:[A]

| Initial registration | Power [$MW_{th}$] | $NO_x$ [$mg/m_n^3$] | CO [$mg/m_n^3$] |
|---|---|---|---|
| **before 1.1.2000** | **$P_n$ ≥ 50** | 190 x η/30 | 250[B] |

η nominal engine efficiency
[A] The operator is obligated to record the operating hours.
[B] Engines running on biogas are subject to an emission limit value for CO of 500 $mg/m_n^3$.

### Stationary CI engines (diesel, other liquid fuels or Dual-Fuel engines in liquid mode) with $P_n \geq 50$ $MW_{th}$, which are operated more than 500 hours per year:

| Initial registration | Power [$MW_{th}$] | Dust [$mg/m_n^3$] | $SO_2$ [$mg/m_n^3$] | $NO_x$ [$mg/m_n^3$] | CO [$mg/m_n^3$] | Organic substances [$mg/m_n^3$] |
|---|---|---|---|---|---|---|
| **before 1.1.2010** | $P_n \geq 50$ | 125 | 60[A] | 190 | 250 | – |
| **after 1.1.2010** | $P_n \geq 50$ | 20 | 60 | 130 | 250 | 60 |

[A] Engines running on heavy fuel oil are not subject to the emission limit values for $SO_2$. The content of sulfur in the fuel may not exceed 1% of its mass.

### Stationary CI engines (diesel, other liquid fuels or Dual-Fuel engines in liquid mode) with $P_n \geq 50$ $MW_{th}$, which are operated less than 500 hours per year:[A]

| Initial registration | Power [$MW_{th}$] | Dust [$mg/m_n^3$] | $SO_2$ [$mg/m_n^3$] | $NO_x$ [$mg/m_n^3$] | CO [$mg/m_n^3$] | Organic substances [$mg/m_n^3$] |
|---|---|---|---|---|---|---|
| **before 1.1.2010** | $P_n \geq 50$ | 125 | 60[B] | 750[C] | 250 | – |
| **after 1.1.2010** | $P_n \geq 50$ | 20 | 60[B] | 750 | 250 | – |

[A] The operator is obligated to record the operating hours.
[B] Engines running on heavy fuel oil are not subject to the emission limit values for $SO_2$. The content of sulfur in the fuel may not exceed 1% of its mass.
[C] Diesel engines operating less than 250 hours per year are subject to an emission limit value for $NO_x$ of 1850 $mg/m_n^3$.

## Brazil

The resolution CONAMA Nr. 008 defines emission limit values for stationary sources, which burn coal or oil on national level. Authorities designate all areas to certain emission classes (Class I, II, III), for which different requirements are stipulated.

| Emission class | Power [$MW_{th}$] | $SO_2$ [$g/10^6$ Kcal[A]] | Dust [$g/10^6$ Kcal[A]] | Smoke (opacity) [Ringelmann 01] |
|---|---|---|---|---|
| **Class I (conservation unit)** | $P_n < 70$ | No permission of new plants | | |
| **Class I (resort area)** | | 2000 | 120 | 20% |
| **Class II, Class III** | | 5000 | 350 | 20% |
| **Class I (conservation unit)** | $P_n \geq 70$ | No permission of new plants | | |
| **Class I (resort area)** | | | | |
| **Class II, Class III** | | 2000 | 120 | 20% |

[A] The original regulation uses the unit 106 Kcal. The conversion factor to kWh reads: 106 Kcal = 1163 kWh.

## Finland

The emission guideline of the Finish environmental protection agency from October 2003 defines limits on $SO_2$-, $NO_x$- 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.
It should be noted that Finland as an EU-member state has to adopt the MCPD until December 2018.

### 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] | – | – | – | – |
| **SI** | < 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 | – | – | – | – |
| **SI** | < 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. It should be noted that France as an EU member state is obliged to adopt the provisions made by MCPD in national law. Therefor some emission limit might change.

### Emission limit values for $2 \leq P_n < 20$ $MW_{th}$ with effectiveness from 1.1.2016

| Fuel type | $NO_x$ [$mg/m_n^3$] | CO [$mg/m_n^3$] | HCHO [$mg/m_n^3$] | Dust [$mg/m_n^3$] | $SO_2$ [$mg/m_n^3$] |
|---|---|---|---|---|---|
| **Natural gas** | 100[A,B] | 250 | 15 | 10 | 10 |
| **Heating oil** | 225[C] | 250 | 15 | 30 | 60 |
| **Heavy oil** | 225[C] | 250 | 15 | 40 | 565[D] |

[A] Dual-fuel Engines in gas-mode: 130 $mg/m_n^3$.
[B] 130 $mg/m_n^3$ for plants operating less than 500 hours per year.
[C] 750 $mg/m_n^3$ for plants operating less than 500 hours per year.
[D] 1130 $mg/m_n^3$ in overseas areas, where 1999/30/EC is applicable.

- The emission limits refer to dry exhaust gas with 15 % residual oxygen.
- There is a regulation for existing plants.

### Emission limit values for $P_n \geq 20$ $MW_{th}$ with effectiveness from August 2013

| Fuel type | Power [$MW_{th}$] | $NO_x$ [$mg/m_n^3$] | CO [$mg/m_n^3$] | $SO_2$ [$mg/m_n^3$] | Dust [$mg/m_n^3$] |
|---|---|---|---|---|---|
| **Natural gas** | **$20 \leq P_n < 50$** | 100[C,D] | 100 | 10 | 10 |
| | **$50 \leq P_n < 100$** | 75 | 100 | 10 | 10 |
| | **$100 \leq P_n < 300$** | 75 | 100 | 10 | 10 |
| | **$P_n \geq 300$** | 75 | 100 | 10 | 10 |
| **Other gases** | **$20 \leq P_n < 50$** | 100 | 250 | 10 | 10 |
| | **$50 \leq P_n < 100$** | 75 | 100 | 10 | 10 |
| | **$100 \leq P_n < 300$** | 75 | 100 | 10 | 10 |
| | **$P_n \geq 300$** | 75 | 100 | 10 | 10 |
| **Heating oil** | **$20 \leq P_n < 50$** | 225 [B] | 250 | 60 | 30 |
| | **$50 \leq P_n < 100$** | 225 | 250 | 60 | 30 |
| | **$100 \leq P_n < 300$** | 225 | 250 | 60 | 30 |
| | **$P_n \geq 300$** | 225 | 250 | 60 | 30 |
| **Other liquid fuels** | **$20 \leq P_n < 50$** | 225 [B] | 250 | 300 [A] | 40 |
| | **$50 \leq P_n < 100$** | 225 | 250 | 300 [A] | 40 |
| | **$100 \leq P_n < 300$** | 225 | 250 | 300 [A] | 40 |
| | **$P_n \geq 300$** | 225 | 250 | 300 [A] | 40 |

[A] Isolated systems (ZNI): 565 $mg/m_n^3$.
[B] Plants operating less than 500 hours per year: 750 $mg/m_n^3$.
[C] Plants operating less than 500 hours per year: 130 $mg/m_n^3$.
[D] Dual-Fuel engines in gas-mode: 130 $mg/m_n^3$.

- The emission limits refer to dry exhaust gas with 5 % residual oxygen.
- There is an emission limit value for formaldehyde of 15 mg/$m_n^3$ for engines.
- There is an emission limit value for ammonia of 20 mg/$m_n^3$ for engines.
- In case of unusual fuels (e. g. Biogas, coke oven gases) the authorities may stipulate emission limit values.

## 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 with $P_n \leq 800$ $kW_{th}$

| Power [kW] | Implementation | $NO_x$ [g/kWh] | HC [g/kWh] | CO [g/kWh] | PM [g/kWh] | Smoke opac.[A] [$m^{-1}$] |
|---|---|---|---|---|---|---|
| $P_n \leq 19$ | 1 Jul 2005 | 9.2 | 1.3 | 3.5 | 0.3 | 0.7 |
| $19 < P_n \leq 50$ | 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 |
| $50 < P_n \leq 176$ | 1 Jan 2004 | 9.2 | 1.3 | 3.5 | 0.3 | 0.7 |
| $176 < P_n \leq 800$ | 1 Nov 2004 | 9.2 | 1.3 | 3.5 | 0.3 | 0.7 |

[A] 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 $P_n > 800$ $kW_{th}$

| Date of order | $NO_x$ [ppmV] | NMHC [$mg/m_n^3$] | CO [$mg/m_n^3$] | PM [$mg/m_n^3$] |
|---|---|---|---|---|
| Before 1.7.2003 | 1100 | 150 | 150 | 75 |
| Between 1.7.2003 and 1.7.2005 | 970 | 100 | 150 | 75 |
| After 1.7.2005 | 710 | 100 | 150 | 75 |

### Limit values for Spark Ignited Engines in generator sets

| Displacement [$cm^3$] | Taking effect | $NO_x$ + HC [g/kWh] | CO [g/kWh] |
|---|---|---|---|
| $V_h \leq 99$ | 7.8.2013 | 12 | 250 |
| $99 < V_h \leq 225$ | 7.8.2013 | 10 | 250 |
| $V_h > 225$ | 7.8.2013 | 8 | 250 |

The following 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 $P_n$ < 50 $MW_{th}$

| Engine type | Power [$MW_{th}$] | PM [$mg/m_n^3$] | CO [$mg/m_n^3$] | $NO_x$ [$mg/m_n^3$] |
|---|---|---|---|---|
| Self-ignition | $P_n$ < 3 | 130 | 650 | 4000 |
| | $P_n$ ≥ 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 $P_n$ ≥ 50 $MW_{th}$

| Fuel type | | Power [$MW_{th}$] | PM [$mg/m_n^3$] | CO [$mg/m_n^3$] | $SO_2$ [$mg/m_n^3$] | $NO_x$ [$mg/m_n^3$] |
|---|---|---|---|---|---|---|
| liquid | | 50 ≤ $P_n$ < 100 | 50 | 650 | 850 | 400 |
| | | 100 ≤ $P_n$ ≤ 300 | 30 | 650 | 500-P | 200 |
| | | $P_n$ > 300 | 30 | 650 | 200 | 200 |
| gaseous | Natural gas | 50 ≤ $P_n$ < 100 | 5 | 100[A] | 35 | 75[A,B] |
| | | 100 ≤ $P_n$ ≤ 300 | 5 | 100[A] | 35 | 75[A,B] |
| | | $P_n$ > 300 | 5 | 100[A] | 35 | 75[A,B] |
| | Liquefied gas | $P_n$ > 50 | 5 | 100[A] | 5 | 75[A,B] |
| | Other gases | $P_n$ > 50 | 5 | 100[A] | 35 | 75[A,B] |

[A] Emission limit values tightened in 2014 by adoption of IED 2010/75/EU.
[B] Existing plants: 100 $mg/m_n^3$.

- Liquid fuels: Values relate to 3% residual oxygen in the exhaust gas flow.
- Gaseous fuels: Values relate to 15% residual oxygen in the exhaust gas flow.

## 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[A] | 200 |
| **≥ 400** | 1200 | 4900 | 100[A] | 200 |

[A] In certain regions 80 $mg/m_n^3$ (13 % $O_2$).

- Diesel engine plants with fuel consumption > 50 L/h.
- Local limits may be lower (Example: Tokyo: $NO_x$ = 470 $mg/m_n^3$).

### 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[A] | 38 |

[A] In certain regions 40 $mg/m_n^3$ (0 % $O_2$).

- Local limits may be lower (Example: Tokyo: $NO_x$ = 310 $mg/m_n^3$ [5 % $O_2$]).
- 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 $MW_{th} \leq P_n < 50\ MW_{th}$) with more than 500 running hours per year. It replaces BEES B, while BEES A applies for big emitters $P_n \geq 50\ MW_{th}$. Existing installations have to comply 1 January 2017 or when installation gets changed. SCR-Catalysts are considered as best available technology.

| Fuel type | Power [$MW_{th}$] | $NO_x$ [$mg/m_n^3$] | $SO_2$ [$mg/m_n^3$] | Partikel [$mg/m_n^3$] | HC [$mg/m_n^3$] |
|---|---|---|---|---|---|
| **Diesel** | $1 \leq P_n < 50$ | 450 | 200 | 50 | – |
| **Biogas** | $1 \leq P_n < 50$ | 340 | 200 | – | – |
| **Natural gas** | $P_n < 2{,}5$ | 340 | 200 | – | – |
| | $2{,}5 \leq P_n < 50$ | 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.

## Austria

The technical reference for the evaluation of emissions of stationary engines has been updated.
The technical reference document is not legally binding, it summarizes the knowledge of authorities and experts regarding exhaust gas emissions and presents possible pollution reduction measures.
Individual circumstances have to be evaluated by the authorities and therefore other measures may be defined.

### Emission limit values for engines running on diesel or heating oil[A]

| Mechanical power [kW] | Dust [mg/kWh] | CO [mg/kWh] | $NO_x$ [mg/kWh] | HC [mg/kWh] | $NO_x$+HC [mg/kWh] | $NH_3$[B] [mg/kWh] |
|---|---|---|---|---|---|---|
| **19 ≤ P < 37[C]** | 600 | 5500 | – | – | 7500 | – |
| **37 ≤ P < 56** | 25 | 5000 | – | – | 4700 | – |
| **56 ≤ P < 75** | 25 | 5000 | 400 | 190 | – | 15 |
| **75 ≤ P < 130** | 25 | 5000 | 400 | 190 | – | 15 |
| **130 ≤ P ≤ 560** | 25 | 3500 | 400 | 190 | – | 15 |
| **P > 560** | 25 | 3000 | 400 | 190 | – | 15 |

[A] Based on the results of a test cycle according to ISO 8178.
[B] Only for SCR.
[C] (Passive) Diesel particle filter are available for retro-fitting and also reduce CO and HC-emissions.

### Emission limit values for engines running on diesel or heating oil and which are operated less than 50 hours per year[A]

| Mechanical power [kW] | Dust [mg/kWh] | CO [mg/kWh] | $NO_x$ [mg/kWh] |
|---|---|---|---|
| **19 ≤ P < 37C** | 5500 | 7500 | 5500 |
| **37 ≤ P < 56** | 5000 | 4700 | 5000 |
| **56 ≤ P < 75** | 5000 | 4700 | 5000 |
| **75 ≤ P < 130** | 5000 | 4000 | 5000 |
| **130 ≤ P ≤ 560** | 3500 | 4000 | 3500 |
| **P > 560** | 3500 | 4000 | 3500 |

[A] Based on the results of a test cycle according to ISO 8178.
[B] (Passive) Diesel particle filter are available for retro-fitting and also reduce CO and HC-emissions.

### Emission limit values for gas engines

| Fuel type | Mechanical power | CO | $NO_x$ | NMHC |
|---|---|---|---|---|
| **Natural gas, Liquefied gas** | **[kW]** | **[mg/kWh]** | **[mg/kWh]** | **[mg/kWh]** |
| | **P < 1000** | 600 | 700 | 425 |
| | **P ≥ 1000** | 600 | 425 | 140 |
| **Sewage gas, Landfill gas** | **[kW]** | **[mg/$m_n^3$]** | **[mg/$m_n^3$]** | **[mg/$m_n^3$]** |
| | **P < 100** | 650 | – | – |
| | **P ≥ 100** | 400 | 500 | 150 |

- The pollutant content refers to dry exhaust with 5 % residual oxygen.
- Engines operating less than 50 hours per year are excluded from the requirements. For these engines no after-treatment systems are necessary.

## Russia – Industrial engines

For industrial engines the Russian standard GOST 31967-2012 applies.

| Date of production | CO [g/kWh] | HC [g/kWh] | $NO_x$ [g/kWh] |
|---|---|---|---|
| **< 1.1.2016** | 3.5 | 1.0 | 10.0 |
| **≥ 1.1.2016** | 1.5 | 0.4 | 6.0 |

## Switzerland

According to the Clean Air Directive (Luftreinhalteverordnung) dated 16 December 1985 (status: August 1st 2016) the following emission limits are valid for stationary combustion engines:

| Fuel type | Power [$MW_{th}$] | $NO_x$ [$mg/m_n^3$] | CO [$mg/m_n^3$] | PM [$mg/m_n^3$] |
|---|---|---|---|---|
| **Gaseous**[A] | P ≤ 0.1 | 250 | 650 | 10 |
| | 0.1 < P ≤ 1 | 150 | 300 | 10 |
| | P > 1 | 100 | 300 | 10 |
| **Other fuels** | P ≤ 0.1 | 400 | 650 | 10 |
| | 0.1 < P ≤ 1 | 250 | 300 | 10 |
| | P > 1 | 250 | 300 | 10 |

[A] Biogas, sewage gas, landfill gas, natural gas

- The pollutant content refers to dry exhaust with 5 % residual oxygen.
- For engines operating not more than 50 hours per year the authorities define separate emission limit values according to article 4 of the regulation.
- Engines operating not more than 50 hours per year are subject to an emission limit value for PM of 50 $mg/m_n^3$.
- Specifications for fuels that are used in stationary combustion engines have to be considered.
- If a device for the reduction of $NO_x$ is in use, the emission concentration of ammonia and ammonia containing compounds may not exceed 30 $mg/m_n^3$.

## Czech Republic

The Czech regulation of stationary engines has been updated by the act 415/2012 Sb. The new emission limit values become effective from December 1st, 2012.
The regulation makes provisions for existing plants, which were developed before May 17th 2006 and new plants, which have been developed and constructed after May 17th 2006.
The regulations apply to plants with a power levels of $0.3 \leq P_n < 50\ MW_{th}$ or $P \geq 50\ MW_{th}$. The reference oxygen is set to 5% in the former case and set to 15% in the latter case.

**Emission limit values for existing plants for which construction was started before May 17th 2006.**

| Engine category / Power | Fuel type | $SO_2$ [$mg/m_n^3$] | $NO_x$ [$mg/m_n^3$] | PM [$mg/m_n^3$] | $\Sigma C^A$ [$mg/m_n^3$] | CO [$mg/m_n^3$] |
|---|---|---|---|---|---|---|
| SI $0.3 \leq P_n < 1\ MW_{th}$ | liquid | B | 500 | – | – | 650 |
| | Natural gas | B | 500 | – | – | 650 |
| | Other gases | B | 1000 | – | – | 1300 |
| CI $0.3 \leq P_n < 1\ MW_{th}$ | Heavy fuel oil | B | 4000 | – | – | 650 |
| | Gas oil | B | 4000 | – | – | 650 |
| | Natural gas, mine gas C | B | 4000 | – | – | 650 |
| SI $1 \leq P_n \leq 5\ MW_{th}$ | liquid | B | 500 | 130 | 150 | 650 |
| | Natural gas | B | 500 | – | 150 | 650 |
| | Other gases | B | 1000 | 130 | 150 | 1300 |
| CI $1 \leq P_n \leq 5\ MW_{th}$ | Heavy fuel oil | B | 4000 | 130 | 150 | 650 |
| | Gas oil | B | 4000 | 130 | 150 | 650 |
| | Natural gas, mine gas C | B | 4000 | – | 150 | 650 |
| SI $P_n > 5\ MW_{th}$ | liquid | B | 500 | 130 | 150 | 650 |
| | Natural gas | B | 500 | – | 150 | 650 |
| | Other gases | B | 500 | 130 | 150 | 650 |
| CI $P_n > 5\ MW_{th}$ | Heavy fuel oil | B | 2000 | 130 | 150 | 650 |
| | Gas oil | B | 2000 | 130 | 150 | 650 |
| | Natural gas, mine gas C | B | 2000 | – | 150 | 650 |

A Total concentration of all organic substances except methane with a mass flow > 3 kg/h.
B The amount of sulfur in the fuel may not exceed the limit value stipulated by separate regulations. For Spark Ignited Engines the amount of sulfur may not exceed 0.05 % of the mass.
C With pilot fuel.

**Emission limit values for existing plants for which construction was started before May 17th 2006. Emission limit values for new plants are valid until December 31st 2017.**

| Engine category / Power | Fuel type | $SO_2$ [$mg/m_n^3$] | $NO_x$ [$mg/m_n^3$] | PM [$mg/m_n^3$] | $\Sigma C^A$ [$mg/m_n^3$] | CO [$mg/m_n^3$] |
|---|---|---|---|---|---|---|
| SI $0.3 \leq P_n < 1\ MW_{th}$ | liquid | [B] | 500 | – | – | 650 |
| | Natural gas | [B] | 500 | – | – | 650 |
| | Other gases | [B] | 1000 | – | – | 1300 |
| CI $0.3 \leq P_n < 1\ MW_{th}$ | Heavy fuel oil | [B] | 4000 | – | – | 650 |
| | Gas oil | [B] | 4000 | – | – | 650 |
| | Natural gas, mine gas[C] | [B] | 4000 | – | – | 650 |
| SI $1 \leq P_n \leq 5\ MW_{th}$ | liquid | [B] | 500[D] | 130 | 150 | 650 |
| | Natural gas | [B] | 500[D] | – | 150 | 650 |
| | Other gases | [B] | 500[D] | 130 | 150 | 1300 |
| CI $1 \leq P_n \leq 5\ MW_{th}$ | Heavy fuel oil | [B] | 600[D] | 130 | 150 | 650 |
| | Gas oil | [B] | 500[D] | 130 | 150 | 650 |
| | Natural gas, mine gas[C] | [B] | 500[D] | – | 150 | 650 |
| SI $P_n > 5\ MW_{th}$ | liquid | [B] | 500[D] | 130 | 150 | 650 |
| | Natural gas | [B] | 500[D] | – | 150 | 650 |
| | Other gases | [B] | 500[D] | 130 | 150 | 650 |
| CI $P_n > 5\ MW_{th}$ | Heavy fuel oil | [B] | 600[D] | 130 | 150 | 650 |
| | Gas oil | [B] | 500[D] | 130 | 150 | 650 |
| | Natural gas, mine gas[C] | [B] | 500[D] | – | 150 | 650 |

[A] Total concentration of all organic substances except methane with a mass flow > 3 kg/h.

[B] The amount of sulfur in the fuel may not exceed the limit value stipulated by separate regulations. For Spark Ignited Engines the amount of sulfur may not exceed 0.05 % of the mass.

[C] With pilot fuel.

[D] The emission limit value for $NO_x$ is valid since January 1st, 2008. This emission limit value is not to be applied for engines which operate less than 300 hours per year.

## Emission limit values for new plants (valid from January 1st 2018) with $P_n$ < 50 $MW_{th}$:

| Power [$MW_{th}$] | Fuel type | $SO_2$ [$mg/m_n^3$] | $NO_x$ [$mg/m_n^3$] | PM [$mg/m_n^3$] | $\Sigma C^A$ [$mg/m_n^3$] | CO [$mg/m_n^3$] |
|---|---|---|---|---|---|---|
| 0.3 ≤ $P_n$ < 1 | liquid | [B] | 400 | – | – | 450 |
| | gaseous. and liquefied gas | [B] | 500 | – | – | 650 |
| 1 ≤ $P_n$ < 5 | liquid | [B] | 400 | 50 | 150 | 450 |
| | gaseous. and liquefied gas | [B] | 500 | – | 150 | 650 |
| 5 ≤ $P_n$ < 50 | liquid | [B] | 400 | 20 | 150 | 450 |
| | gaseous. and liquefied gas | [B] | 500 | – | 150 | 650 |

[A] Total concentration of all organic substances except methane with a mass flow > 3 kg/h.

[B] The amount of sulfur in the fuel may not exceed the limit value stipulated by separate regulations. For Spark Ignited Engines the amount of sulfur may not exceed 0.05 % of the mass.

## Limit values for new build plants with $P_n$ ≥ 50 $MW_{th}$:

| Power [$MW_{th}$] | Fuel type | $SO_2$ [$mg/m_n^3$] | $NO_x$ [$mg/m_n^3$] | PM [$mg/m_n^3$] | ΣC [$mg/m_n^3$] | CO [$mg/m_n^3$] |
|---|---|---|---|---|---|---|
| 50 ≤ $P_n$ < 100 | liquid | 350 | 300 | 20 | 150 | 175 |
| | Liquefied gas | 5 | 300 | 5 | 150 | 175 |
| | Other gases | 35 | 75 | 5 | 150 | 100 |
| | Natural gas | 35 | 75 | 5 | 150 | 100 |
| 100 ≤ $P_n$ ≤ 300 | liquid | 200 | 150 | 20 | 150 | 175 |
| | Liquefied gas | 5 | 150 | 5 | 150 | 175 |
| | Other gases | 35 | 75 | 5 | 150 | 100 |
| | Natural gas | 35 | 75 | 5 | 150 | 100 |
| $P_n$ > 300 | liquid | 150 | 100 | 10 | 150 | 175 |
| | Liquefied gas | 5 | 150 | 5 | 150 | 175 |
| | Other gases | 35 | 75 | 5 | 150 | 100 |
| | Natural gas | 35 | 75 | 5 | 150 | 100 |

The emission limit values are not applied to engines operating less than 300 hours per year.

# EU – Nonroad-Regulation

The Directive 97/68/EC (as amended by 2012/46/EC) is repealed with effect from 1 January 2017. It is replaced by Regulation (EU) 2016/1628 which shall apply from the same day, setting emission limits for Stage V.

## Diesel engines

| Power [kW] | CO [g/kWh] | HC [g/kWh] | $NO_x$ [g/kWh] | Particulate [g/kWh] | Particulate [#/kWh] | Date[A] |
|---|---|---|---|---|---|---|
| | | NMHC + $NO_x$ | | | | |
| **Stage I** | | | | | | |
| **37 ≤ $P_n$ < 75** | 6.5 | 1.3 | 9.2 | 0.85 | – | Apr. 99 |
| **75 ≤ $P_n$ < 130** | 5.0 | 1.3 | 9.2 | 0.70 | – | 1999 |
| **130 ≤ $P_n$ ≤ 560** | 5.0 | 1.3 | 9.2 | 0.54 | – | 1999 |
| **Stage II** | | | | | | |
| **18 ≤ $P_n$ < 37** | 5.5 | 1.5 | 8.0 | 0.8 | – | 2001 |
| **37 ≤ $P_n$ < 75** | 5.0 | 1.3 | 7.0 | 0.4 | – | 2004 |
| **75 ≤ $P_n$ < 130** | 5.0 | 1.0 | 6.0 | 0.3 | – | 2003 |
| **130 ≤ $P_n$ ≤ 560** | 3.5 | 1.0 | 6.0 | 0.2 | – | 2002 |
| **Stage III A** | | | | | | |
| **19 ≤ $P_n$ < 37** | 5.5 | 7.5 | | 0.6 | – | 2007 |
| **37 ≤ $P_n$ < 75** | 5.0 | 4.7 | | 0.4 | – | 2008 |
| **75 ≤ $P_n$ < 130** | 5.0 | 4.0 | | 0.3 | – | 2007 |
| **130 ≤ $P_n$ ≤ 560** | 3.5 | 4.0 | | 0.2 | – | 2006 |
| **Stage III B** | | | | | | |
| **37 ≤ $P_n$ < 56** | 5.0 | 4.7 | | 0.025 | – | 2013 |
| **56 ≤ $P_n$ < 75** | 5.0 | 0.19 | 3.3 | 0.025 | – | 2012 |
| **75 ≤ $P_n$ < 130** | 5.0 | 0.19 | 3.3 | 0.025 | – | 2012 |
| **130 ≤ $P_n$ ≤ 560** | 3.5 | 0.19 | 2.0 | 0.025 | – | 2011 |
| **Stage IV** | | | | | | |
| **56 ≤ $P_n$ < 130** | 5.0 | 0.19 | 0.4 | 0.025 | – | Oct. 2014 |
| **130 ≤ $P_n$ ≤ 560** | 3.5 | 0.19 | 0.4 | 0.025 | – | 2014 |
| **Stage V** | | | | | | |
| **0 ≤ $P_n$ < 8** | 8.00 | 7.50[C] | | 0.40[B] | – | 2019 |
| **8 ≤ $P_n$ < 19** | 6.60 | 7.50[C] | | 0.40 | – | 2019 |
| **19 ≤ $P_n$ < 37** | 5.00 | 4.70[C] | | 0.015 | $1*10^{12}$ | 2019 |
| **37 ≤ $P_n$ < 56** | 5.00 | 4.70[C] | | 0.015 | $1*10^{12}$ | 2019 |
| **56 ≤ $P_n$ < 130** | 5.00 | 0.19[C] | 0.40 | 0.015 | $1*10^{12}$ | 2020 |
| **130 ≤ $P_n$ ≤ 560** | 3.50 | 0.19[C] | 0.40 | 0.015 | $1*10^{12}$ | 2019 |
| **$P_n$ > 560** | 3.50 | 0.19[D] | 3.50[E] | 0.045[F] | – | 2019 |

[A] Date for placing the engine on the market, type approval one year earlier.
[B] 0.60 for hand-startable, air-cooled direct injection engines.
[C] A = 1.10 for gas engines.
[D] A = 6.00 for gas engines.
[E] 0.67 for gensets.
[F] 0.35 for gensets.

- From stage V, all power categories are regulated for the first time.
- From Stage V, variable speed and constant speed engines are treated equally.
- HC limit for fully and partially gaseous-fuelled engines: Where an A-factor is defined, the HC limit is calculated by the formula HC = 0.19 + (1.5 x A x GER), the maximum allowed is HC = 0.19 + A. For a combined HC and $NO_x$ limit, the combined limit value for HC and $NO_x$ shall be reduced by 0.19 g/kWh and apply for NOx only. GER is the average gas energy ratio over the appropriate test cycle.
- Spark Ignited Engines, Stage V: The above illustrated emission limits do also apply for engines with a rated power greater 56 kW. Engines below < 56 kW are also regulated.
- Test cycle, variable speed engines: C1, optionally G2 for Stage V engines below 19 kW, for engines from 19 kW to 560 kW NRTC cycle must be applied additionally from Stage III B onwards.
- Test cycle, constant speed engines: D2
- For agricultural tractors the Delegated Regulation (EU) 2015/96 amending Regulation (EU) 167/2013 applies. (EU) 2015/96 needs to be adjusted to account for the provisions of EU Stage V Regulation. European Commission is planning to in the first half of 2017.
- As of stage III A compliance with the limits must be demonstrated over the useful lifetime of the engine.
- NTE (Not To Exceed): Starting with Stage IIIB, limits in the performance map will be applied (max. 100 % above cycle limit).

# USA – EPA Nonroad Regulation

## (40 CFR 89, 40 CFR 1039 and 40 CFR 1068)

### Diesel engines

| Power [kW] | $NO_x$ [g/kWh] | HC [g/kWh] | CO [g/kWh] | Particulates [g/kWh] | Date as of model year |
|---|---|---|---|---|---|
| | $NO_x$ + NMHC | | | | |
| **Tier 1** | | | | | |
| $P_n < 8$ | 10.5 | | 8.0 | 1.0 | 2000 |
| $8 \le P_n < 19$ | 9.5 | | 6.6 | 0.80 | 2000 |
| $19 \le P_n < 37$ | 9.5 | | 5.5 | 0.80 | 1999 |
| $37 \le P_n < 75$ | 9.2 | – | – | – | 1998 |
| $75 \le P_n < 130$ | 9.2 | – | – | – | 1997 |
| $130 \le P_n \le 560$ | 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 | 0.80 | 2005 |
| $8 \le P_n < 19$ | 7.5 | | 6.6 | 0.80 | 2005 |
| $19 \le P_n < 37$ | 7.5 | | 5.5 | 0.60 | 2004 |
| $37 \le P_n < 75$ | 7.5 | | 5.0 | 0.40 | 2004 |
| $75 \le P_n < 130$ | 6.6 | | 5.0 | 0.30 | 2003 |
| $130 \le P_n < 225$ | 6.6 | | 3.5 | 0.20 | 2003 |
| $225 \le P_n < 450$ | 6.4 | | 3.5 | 0.20 | 2001 |
| $450 \le P_n \le 560$ | 6.4 | | 3.5 | 0.20 | 2002 |
| $P_n > 560$ | 6.4 | | 3.5 | 0.20 | 2006 |
| **Tier 3** | | | | | |
| $P_n < 8$ | no further reduction | | | | |
| $8 \le P_n < 19$ | no further reduction | | | | |
| $19 \le P_n < 37$ | no further reduction | | | | |
| $37 \le P_n < 75$ | 4.7 | | 5.0 | 0.40 | 2008 |
| $75 \le P_n < 130$ | 4.0 | | 5.0 | 0.30 | 2007 |
| $130 \le P_n \le 560$ | 4.0 | | 3.5 | 0.20 | 2006 |
| $P_n > 560$ | no further reduction | | | | |
| **Tier 4 interim** | | | | | |
| $19 \le P_n < 37$ | 7.5 | | 5.5 | 0.30 | 2008 |
| $37 \le P_n < 56$ | 4.7 | | 5.0 | 0.30[A] | 2008 |
| $56 \le P_n < 130$ | 3.4 | 0.19 | 5.0 | 0.02 | 2012[B, C] |
| $130 \le P_n \le 560$ | 2.0 | 0.19 | 3.5 | 0.02 | 2011[C] |
| $P_n > 560$ | 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 |

| Power [kW] | $NO_x$ [g/kWh] | HC [g/kWh] | CO [g/kWh] | Particulates [g/kWh] | Date as of model year |
|---|---|---|---|---|---|
| | $NO_x$ + NMHC | | | | |
| **Tier 4** | | | | | |
| $P_n < 8$ | 7.5 | | 8.0 | 0.40[D] | 2008 |
| $8 \le P_n < 19$ | 7.5 | | 6.6 | 0.40 | 2008 |
| $19 \le P_n < 37$ | 4.7 | | 5.5 | 0.03 | 2013 |
| $37 \le P_n < 56$ | 4.7 | | 5.0 | 0.03 | 2013 |
| $56 \le P_n < 130$ | 0.40 | 0.19 | 5.0 | 0.02 | 2014[E] |
| $130 \le P_n \le 560$ | 0.40 | 0.19 | 3.5 | 0.02 | 2014[F] |
| $P_n > 560$ | 3.5 | 0.19 | 3.5 | 0.04 | 2015 |
| **Tier 4 - Genset** | | | | | |
| $P_n > 560$ | 0.67 | 0.19 | 3.5 | 0.03 | 2015 |

[A] Optional 0.40 g/kWh (Tier 2), if manufacturer complies with 0.03 g/kWh (Tier 4) starting in 2012.

[B] No Tier 2 credits claimed. If Tier 2 credits are claimed, manufacturer must comply to $NO_x$ limit of 2.3 g/kWh until end of model year 2013, with full compliance to Tier 4 from 2014.

[C] Optional to $NO_x$ Phase in/ Phase out, all engines must be certified to this limit.

[D] 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.

[E] Optional to Tier 4 interim: 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.

[F] Optional to Tier 4 interim: PM/CO: full compliance from 2011; $NO_x$/HC: 50 % engines must comply in 2011–2013.

- 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 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.
- 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.

## Brazil

On 13 July 2011 the Brazilian Environmental Council (CONAMA) has published Resolution No. 433, the first regulation on emissions from new agricultural and construction machinery. The limits are equivalent to EC stage IIIA for mobile machinery.

| Power [kW] | HC + $NO_x$ [g/kWh] | CO [g/kWh] | PM [g/kWh] |
|---|---|---|---|
| **19 ≤ $P_n$ < 37** | 7.5 | 5.5 | 0.6 |
| **37 ≤ $P_n$ < 75** | 4.7 | 5.0 | 0.4 |
| **75 ≤ $P_n$ < 130** | 4.0 | 5.0 | 0.3 |
| **130 ≤ $P_n$ ≤ 560** | 4.0 | 3.5 | 0.2 |

Dates of introduction:

- Construction machinery ≥ 37 kW from 1 January 2015, between 19 and 37 kW from 1 January 2017.
- Agricultural machinery ≥ 75 kW from 1 January 2017, between 19 and 75 kW from 1 January 2019.

## China

| Power [kW] | CO [g/kWh] | HC [g/kWh] | $NO_x$ [g/kWh] | Particulate [g/kWh] | Date[A] |
|---|---|---|---|---|---|
| | | $NMHC + NO_x$ | | | |
| **Stage I** | | | | | |
| **$0 < P_n < 8$** | 12.3 | 18.4 | | – | Oct. 2007 |
| **$8 \le P_n < 18$** | 8.4 | 12.9 | | – | Oct. 2007 |
| **$18 \le P_n < 37$** | 8.4 | 2.1 | 10.8 | 1.0 | Oct. 2007 |
| **$37 \le P_n < 75$** | 6.5 | 1.3 | 9.2 | 0.85 | Oct. 2007 |
| **$75 \le P_n < 130$** | 5.0 | 1.3 | 9.2 | 0.70 | Oct. 2007 |
| **$130 \le P_n \le 560$** | 5.0 | 1.3 | 9.2 | 0.54 | Okt. 2007 |
| **Stage II** | | | | | |
| **$0 < P_n < 8$** | 8.0 | 10.5 | | 1.0 | Oct. 2009 |
| **$8 \le P_n < 18$** | 6.6 | 9.5 | | 0.8 | Oct. 2009 |
| **$18 \le P_n < 37$** | 5.5 | 1.5 | 8.0 | 0.8 | Oct. 2009 |
| **$37 \le P_n < 75$** | 5.0 | 1.3 | 7.0 | 0.4 | Oct. 2009 |
| **$75 \le P_n < 130$** | 5.0 | 1.0 | 6.0 | 0.3 | Oct. 2009 |
| **$130 \le P_n \le 560$** | 3.5 | 1.0 | 6.0 | 0.2 | Oct. 2009 |
| **Stage III** | | | | | |
| **$P_n < 37$** | 5.5 | 7.5 | | 0.60 | Oct. 2015 |
| **$37 \le P_n < 75$** | 5.0 | 4.7 | | 0.40 | Oct. 2015 |
| **$75 \le P_n < 130$** | 5.0 | 4.0 | | 0.30 | Oct. 2015 |
| **$130 \le P_n \le 560$** | 3.5 | 4.0 | | 0.20 | Oct. 2015 |
| **$P_n > 560$** | 3.5 | 6.4 | | 0.20 | Oct. 2015 |
| **Stage IV** | | | | | |
| **$P_n < 37$** | 5.5 | 7.5 | | 0.60 | n/a |
| **$37 \le P_n < 56$** | 5.0 | 4.7 | | 0.025 | n/a |
| **$56 \le P_n < 75$** | 5.0 | 0.19 | 3.3 | 0.025 | n/a |
| **$75 \le P_n < 130$** | 5.0 | 0.19 | 3.3 | 0.025 | n/a |
| **$130 \le P_n \le 560$** | 3.5 | 0.19 | 2.0 | 0.025 | n/a |
| **$P_n > 560$** | 3.5 | 0.40 | 3.5[B] | 0.10 | n/a |

[A] Date for production and placing the engine on the market, type approval one year earlier.
[B] 0.67 for CI-engines with $P_9 > 900$ kW, used in mobile generator sets.

- Nationwide implementation dates for Stage IV have not yet been set. If necessary, provinces can introduce Stage IV ahead of time.
- From 1 April 2016 only mobile machinery may be produced, imported and sold having at least a Stage III engine installed.
- Test cycle, variable speed engines: ISO 8178-4 C1, optionally G2 for engines below 19 kW, Stage IV engines with a reference power ≤ 560 kW must additionally be certified to the NRTC cycle.
- Test cycle, constant speed engines: ISO 8178-4 D2.

## India

On 21 September 2006 the emission limit values for diesel engine driven mobile machinery (CEV) in India have been published and entered into force.

| Power [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 | 1.0 | Oct 2008 |
| **8 ≤ $P_n$ < 19** | 9.20 | 1.30 | 6.60 | 0.85 | Oct 2008 |
| **19 ≤ $P_n$ < 37** | 9.20 | 1.30 | 6.50 | 0.85 | Oct 2007 |
| **37 ≤ $P_n$ < 75** | 9.20 | 1.30 | 6.50 | 0.85 | Oct 2007 |
| **75 ≤ $P_n$ < 130** | 9.20 | 1.30 | 5.0 | 0.70 | Oct 2007 |
| **130 ≤ $P_n$ ≤ 560** | 9.20 | 1.30 | 5.0 | 0.54 | Oct 2007 |
| **Bharat Stage III (CEV)** | | | | | |
| | **HC + $NO_x$ [g/kWh]** | | | | |
| **$P_n$ < 8** | 7.5 | | 8.0 | 0.80 | Apr 2011 |
| **8 ≤ $P_n$ < 19** | 7.5 | | 6.60 | 0.80 | Apr 2011 |
| **19 ≤ $P_n$ < 37** | 7.50 | | 5.50 | 0.60 | Apr 2011 |
| **37 ≤ $P_n$ < 75** | 4.70 | | 5.0 | 0.40 | Apr 2011 |
| **75 ≤ $P_n$ < 130** | 4.0 | | 5.0 | 0.30 | Apr 2011 |
| **130 ≤ $P_n$ ≤ 560** | 4.0 | | 3.50 | 0.20 | Apr 2011 |

- Test cycle: ISO 8178-4 C1 and D2.
- 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).
- COP selection procedure shall be as per MoSRTH/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 [kW] | Durability [h] Emission resistance |
|---|---|
| $P_n < 19$ | 3000 |
| $19 \leq P_n < 37$ (constant speed) | 3000 |
| $19 \leq P_n < 37$ (variable speed) | 5000 |
| $P \geq 37$ | 8000 |

- Engines must comply with emissions standards throughout the defined durability period. Optionally, the following deterioration factors may be applied.

### Deterioration factors

| CO | HC | $NO_x$ | PM |
|---|---|---|---|
| 1.10 | 1.05 | 1.05 | 1.1 |

### Emission limit values for agricultural tractors

| Power [kW] | $NO_x$ [g/kWh] | HC [g/kWh] | CO [g/kWh] | Particulate [g/kWh] | Date |
|---|---|---|---|---|---|
| **Bharat Stage I (Trem)** | | | | | |
| all | 18.00 | 3.50 | 14.0 | – | Oct. 1999 |
| | $HC + NO_x$ [g/kWh] | | | | |
| **Bharat Stage II (Trem)** | | | | | |
| all | 15.0 | | 9.0 | 1.0 | Jun. 2003 |
| **Bharat Stage III (Trem)** | | | | | |
| all | 9.50 | | 5.50 | 0.80 | Oct. 2005 |
| **Bharat Stage III A (Trem)** | | | | | |
| $P_n < 8$ | 8.5 | | 5.5 | 0.80 | Apr. 2010 |
| $8 \leq P_n < 19$ | 8.5 | | 5.5 | 0.80 | Apr. 2010 |
| $19 \leq P_n < 37$ | 7.5 | | 5.5 | 0.60 | Apr. 2010 |
| $37 \leq P_n < 56$ | 4.7 | | 5.0 | 0.40 | Apr. 2011 |
| $56 \leq P_n < 75$ | 4.7 | | 5.0 | 0.40 | Apr. 2011 |
| $75 \leq P_n < 130$ | 4.0 | | 5.0 | 0.30 | Apr. 2011 |
| $130 \leq P_n \leq 560$ | 4.0 | | 3.5 | 0.20 | Apr. 2011 |

- Test cycle: ISO 8178-4, C1.
- For Stage IIIA (Trem) the durability period and the deterioration factors of Stage III (CEV) apply.

## Japan

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

| Power [kW] | CO [g/kWh] | $NO_x$ [g/kWh] | HC[A] [g/kWh] | PM [g/kWh] | Smoke [%] | Date[B] | Date for imported machines and vehicles[C] |
|---|---|---|---|---|---|---|---|
| **Stage I** | | | | | | | |
| **19 ≤ $P_n$ < 37** | 5.0 | 8.0 | 1.5 | 0.80 | 40 | Oct. 03 | – |
| **37 ≤ $P_n$ < 56** | 5.0 | 7.0 | 1.3 | 0.40 | 40 | Oct. 03 | – |
| **56 ≤ $P_n$ < 75** | 5.0 | 7.0 | 1.3 | 0.30 | 40 | Oct. 03 | – |
| **75 ≤ $P_n$ < 130** | 5.0 | 6.0 | 1.0 | 0.30 | 40 | Oct. 03 | – |
| **130 ≤ $P_n$ < 560** | 3.5 | 6.0 | 1.0 | 0.20 | 40 | Oct. 03 | – |
| **Stage II** | | | | | | | |
| **19 ≤ $P_n$ < 37** | 5.0 | 6.0 | 1.0 | 0.40 | 40 | Oct. 07 | 01.09.08 |
| **37 ≤ $P_n$ < 56** | 5.0 | 4.0 | 0.7 | 0.30 | 35 | Oct. 08 | 01.09.09 |
| **56 ≤ $P_n$ < 75** | 5.0 | 4.0 | 0.7 | 0.25 | 30 | Oct. 08 | 01.09.10 |
| **75 ≤ $P_n$ < 130** | 5.0 | 3.6 | 0.4 | 0.20 | 25 | Oct. 07 | 01.09.08 |
| **130 ≤ $P_n$ < 560** | 3.5 | 3.6 | 0.4 | 0.17 | 25 | Oct. 06 | 01.09.08 |
| **Stage III** | | | | | | | |
| **19 ≤ $P_n$ < 37** | 5.0 | 4.0 | 0.7 | 0.03 | 25 | Oct. 2013 | 01.09.2015 |
| **37 ≤ $P_n$ < 56** | 5.0 | 4.0 | 0.7 | 0.025 | 25 | Oct. 2013 | 01.11.2014 |
| **56 ≤ $P_n$ < 75** | 5.0 | 3.3 | 0.19 | 0.02 | 25 | Oct. 2012 | 01.04.2014 |
| **75 ≤ $P_n$ < 130** | 5.0 | 3.3 | 0.19 | 0.02 | 25 | Oct. 2012 | 01.11.2013 |
| **130 ≤ $P_n$ < 560** | 3.5 | 2.0 | 0.19 | 0.02 | 25 | Oct. 2011 | 01.04.2013 |
| **Stage IV** | | | | | | | |
| **19 ≤ $P_n$ < 37** | 5.0 | 4.0 | 0.7 | 0.03 | 0.5$m^{-1}$ | Oct. 2016 | 01.09.2017 |
| **37 ≤ $P_n$ < 56** | 5.0 | 4.0 | 0.7 | 0.025 | 0.5$m^{-1}$ | Oct. 2016 | 01.09.2017 |
| **56 ≤ $P_n$ < 75** | 5.0 | 0.4 | 0.19 | 0.02 | 0.5$m^{-1}$ | Oct. 2015 | 01.09.2017 |
| **75 ≤ $P_n$ < 130** | 5.0 | 0.4 | 0.19 | 0.02 | 0.5$m^{-1}$ | Oct. 2015 | 01.09.2017 |
| **130 ≤ $P_n$ < 560** | 3.5 | 0.4 | 0.19 | 0.02 | 0.5$m^{-1}$ | Oct. 2014 | 01.09.2016 |

[A] From Stage III the limits apply to NMHC.
[B] For newly certified machines.
[C] Including already produced machines.

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

## Canada

Canada has issued the Off-Road Compression-Ignition Engine Emission Regulations (SOR/2005-32), which refers to the US EPA non-road Regulation and aligns with its emission standards and transition provisions. However, the implementation dates were later, especially for Tier 2 and Tier 3 engines.

For US EPA-certified engines, an EPA emission label is accepted if at least one engine of the same family is sold both in the United States and Canada.

## Korea (South)

| Power [kW] | $NO_x$ [g/kWh] | HC [g/kWh] | CO [g/kWh] | Particulates [g/kWh] | Date as of model year |
|---|---|---|---|---|---|
| | $NO_x$ + NMHC | | | | |
| **Tier 1[A]** | | | | | |
| $19 \le P_n < 37$ | 9.5 | | 5.5 | 0.8 | 2004 |
| $37 \le P_n < 75$ | 9.2 | – | 5.5 | 0.6 | |
| $75 \le P_n < 130$ | 9.2 | – | 5.0 | 0.6 | |
| $130 \le P_n < 225$ | 9.2 | 1,3 | 5.0 | 0.54 | |
| $225 \le P_n < 560$ | 9.2 | 1,3 | 5.0 | 0.54 | |
| **Tier 2[A]** | | | | | |
| $19 \le P_n < 37$ | 7.5 | | 5.5 | 0.6 | 2005 |
| $37 \le P_n < 75$ | 7.5 | | 5.0 | 0.4 | |
| $75 \le P_n < 130$ | 6.6 | | 5.0 | 0.3 | |
| $130 \le P_n < 225$ | 6.6 | | 3.5 | 0.2 | |
| $225 \le P_n < 560$ | 6.4 | | 3.5 | 0.2 | |
| **Tier 3** | | | | | |
| $19 \le P_n < 37$ | 7.5 | | 5.5 | 0.6 | 2009[B] |
| $37 \le P_n < 75$ | 4.7 | | 5.0 | 0.4 | |
| $75 \le P_n < 130$ | 4.0 | | 5.0 | 0.3 | |
| $130 \le P_n < 560$ | 4.0 | | 3.5 | 0.2 | |
| **Tier 4** | | | | | |
| $P_n < 8$ | 7.7 | | 8.0 | 0.4 | 2015 |
| $8 \le P_n < 19$ | 7.5 | | 6.6 | 0.4 | |
| $19 \le P_n < 37$ | 4.7 | | 5.5 | 0.03 | |
| $37 \le P_n < 56$ | 4.7 | | 5.0 | 0.03 | |
| $56 \le P_n < 130$ | 0.40 | 0.19 | 5.0 | 0.02 | |
| $130 \le P_n < 560$ | 0.40 | 0.19 | 3.5 | 0.02 | |

[A] Applicable to construction machinery.
[B] 2013 for agricultural equipment.

- Test cycle: ISO 8178-4, C1; as off Tier 4 additionally NRTC.

## Russia

A new standard of the Eurasian Economic Union (EEU) has been developed for tractors. The emission limit values are defined in TR-TS 031-2012 "On the safety of agricultural and forestry tractors and the associated trailers". The **limit values IIIA (less than 37 kW) or IIIB should be taken over and applied as of 15 February 2017**. This standard is under revision at the time of printing this brochure, confirming introductory dates and limit values is therefore not possible.

## Switzerland – Construction machinery

The emissions from construction machineries are regulated by the Clean Air Directive (Luftreinhalteverordnung 814.318.142.1). The limits correspond with the Directive 97/68/EC (amended by 2012/46/EC).

**Particulate Matter**

Emissions should also not exceed the number of $1 \times 10^{12}$ particles with diameters> 23 nm per kWh. Requirements for particle filter systems are also prescribed in the regulation.

Switzerland is planning to accept regulation (EU) 2016/1628 (EU Stage V) without changes.

## Turkey

Turkey has adopted the emission limit values of the European non-road Directive 97/68/EC. Differing are solely the dates of coming into force, which have been further delayed by 3 years for stages IIIB and IV.

| Power [kW] | $NO_x$ [g/kWh] | HC [g/kWh] | CO [g/kWh] | PM [g/kWh] | Date[A] |
|---|---|---|---|---|---|
| | $NO_x$ + NMHC | | | | |
| **Stage I (Faz I)** | | | | | |
| **37 ≤ $P_n$ < 75** | 9.2 | 1.3 | 6.5 | 0.85 | 5 Apr 2003 |
| **75 ≤ $P_n$ < 130** | 9.2 | 1.3 | 5.0 | 0.70 | 5 Apr 2003 |
| **130 ≤ $P_n$ ≤ 560** | 9.2 | 1.3 | 5.0 | 0.54 | 5 Apr 2003 |
| **Stage II (Faz II)** | | | | | |
| **18 ≤ $P_n$ < 37** | 8.0 | 1.5 | 5.5 | 0.8 | 2007 |
| **37 ≤ $P_n$ < 75** | 7.0 | 1.3 | 5.0 | 0.4 | 2007 |
| **75 ≤ $P_n$ < 130** | 6.0 | 1.0 | 5.0 | 0.3 | 2007 |
| **130 ≤ $P_n$ ≤ 560** | 6.0 | 1.0 | 3.5 | 0.2 | 2007 |
| **Stage IIIA (Faz III A)** | | | | | |
| **19 ≤ $P_n$ < 37** | 7.5 | | 5.5 | 0.6 | 2011 |
| **37 ≤ $P_n$ < 75** | 4.7 | | 5.0 | 0.4 | 2011 |
| **75 ≤ $P_n$ < 130** | 4.0 | | 5.0 | 0.3 | 2011 |
| **130 ≤ $P_n$ ≤ 560** | 40 | | 3.5 | 0.2 | 2011 |
| **Stage IIIB (Faz III B)** | | | | | |
| **37 ≤ $P_n$ < 56** | 4.7 | | 5.0 | 0.025 | Oct. 2018 |
| **56 ≤ $P_n$ < 75** | 3.3 | 0.19 | 5.0 | 0.025 | 2012[B] |
| **75 ≤ $P_n$ < 130** | 3.3 | 0.19 | 5.0 | 0.025 | 2012[B] |
| **130 ≤ $P_n$ ≤ 560** | 2.0 | 0.19 | 3.5 | 0.025 | 2011[B] |
| **Stage IV (Faz IV)** | | | | | |
| **56 ≤ $P_n$ < 130** | 0.4 | 0.19 | 5.0 | 0.025 | Oct 2019 |
| **130 ≤ $P_n$ ≤ 560** | 0.4 | 0.19 | 3.5 | 0.025 | 2019 |

[A] Date for placing on the market of engines.
[B] Stage IIIB only optional.

- Test cycle: ISO 8178-4, C1/D2.

# 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. Directive 97/68/EC is repealed by **Regulation (EU) 2016/1628**.

## Locomotive propulsion engines

| Stage | Power<br>Cylinder displ. | $NO_x$ [g/kWh] | HC [g/kWh] | CO [g/kWh] | PM [g/kWh] | PN [#/kWh] | Date[A] |
|---|---|---|---|---|---|---|---|
| | | HC + $NO_x$ [g/kWh] | | | | | |
| III A | 130 ≤ $P_n$ ≤ 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<br>$V_{h,z}$ > 5 L | 7.4 | 0.4 | 3.5 | 0.2 | – | 2009 |
| III B | $P_n$ > 130 kW | 4.0 | | 3.5 | 0.025 | – | 2012 |
| V | $P_n$ > 0 kW | 4.00[B] | | 3.50 | 0.025 | – | 2021 |

[A] Date for placing on the market of engines, type approval one year earlier.
[B] A = 6.00 for gas engines.

## Railcar propulsion engines

| Stage | Power | $NO_x$ [g/kWh] | HC [g/kWh] | CO [g/kWh] | PM [g/kWh] | PN [#/kWh] | Date[A] |
|---|---|---|---|---|---|---|---|
| | | HC + $NO_x$ [g/kWh] | | | | | |
| III A | $P_n$ > 130 kW | 4.0 | | 3.5 | 0.20 | – | 2006 |
| III B | $P_n$ > 130 kW | 2.0 | 0.19 | 3.5 | 0.025 | – | 2012 |
| V | $P_n$ > 0 kW | 2.00 | 0.19[A] | 3.50 | 0.015 | $1*10^{12}$ | 2021 |

[A] Date for placing on the market of engines, type approval one year earlier.
[B] A = 6.00 for gas engines.

- No stage I and II.
- Stage V test cycle for locomotives: ISO 8178-4, F (variable speed) respectively D2 (constant speed).
- Stage V test cycle for railcars: ISO 8178-4, C1 (variable speed) respectively D2 (constant speed).
- HC limit for fully and partially gaseous-fuelled engines: Where an A-factor is defined, the HC limit is calculated by the formula HC = 0.19 + (1.5 x A x GER), the maximum allowed is HC = 0.19 + A. For a combined HC and NOx limit, the combined limit value for HC and $NO_x$ shall be reduced by 0.19 g/kWh and apply for $NO_x$ only. GER is the average gas energy ratio over the appropriate test cycle.
- 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.

| Stage | Power, Speed | $NO_x$ [g/kWh] | HC [g/kWh] | CO [g/kWh] | PM [g/kWh] | Date |
|---|---|---|---|---|---|---|
| UIC II | $P_n \leq 560$ kW | 6.0 | 0.6 | 2.5 | 0.25 | 1 Jan 2003 |
| | $P_n > 560$ kW<br>$n_n > 1000$ rpm | 9.5 | 0.8 | 3.0 | 0.25 | 1 Jan 2003 |
| | $P_n > 560$ kW<br>$n_n \leq 1000$ 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.
- 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).

# USA

On 30 June 2008 the US EPA has published the final rule „40 CFR Parts 1033" for locomotive engines less than 30 liters per cylinder. This law stringent the emission limit values for existing Tier 0-2 rail diesel engines further and introduces new Tier 3 and Tier 4 emission limits.

## Line-haul Locomotives

| Engine category | Model year[C] | Date | PM [g/bhp*hr] | $NO_x$ [g/bhp*hr] | HC [g/bhp*hr] | CO [g/bhp*hr] |
|---|---|---|---|---|---|---|
| **Remanufactured Tier 0 engine[A]** | 1973-1992 | 2010[E] | 0.22 | 8.0 | 1.00 | 5.0 |
| **Remanufactured Tier 1 engine[A]** | 1993[D]-2004 | 2010[E] | 0.22 | 7.4 | 0.55 | 2.2 |
| **Remanufactured Tier 2 engine[A]** | 2005-2011 | 2010[E] | 0.10 | 5.5 | 0.30 | 1.5 |
| **New Tier 3 engine[B]** | 2012-2014 | 2012 | 0.10 | 5.5 | 0.30 | 1.5 |
| **New Tier 4 engine** | 2015+ | 2015 | 0.03 | 1.3[F] | 0.14[F] | 1.5 |

[A] Line-haul engines must also meet the switch-haul standards of the same Tier.
[B] Tier 3 line-haul engines must also meet Tier 2 switch standards.
[C] Of the locomotive.
[D] Locomotives of model year 1993-2001 and with engines not equipped with an intake air coolant system are allowed to comply with Tier 0 standards.
[E] As early as 2008 if approved engine upgrade kits become available.
[F] Optionally $NO_x$+HC ≤ 1.4 g/bhp*hr.

## Switch-haul locomotives

| Engine category | Model year[B] | Date | PM [g/bhp*hr] | $NO_x$ [g/bhp*hr] | HC [g/bhp*hr] | CO [g/bhp*hr] |
|---|---|---|---|---|---|---|
| **Remanufactured Tier 0 engine** | 1973-2001 | 2010[C] | 0.26 | 11.8 | 2.10 | 8.0 |
| **Remanufactured Tier 1 engine[A]** | 2002-2004 | 2010[C] | 0.26 | 11.0 | 1.20 | 2.5 |
| **Remanufactured Tier 2 engine[A]** | 2005-2010 | 2010[C] | 0.13 | 8.1 | 0.60 | 2.4 |
| **New Tier 3 engine** | 2011-2014 | 2011 | 0.10 | 5.0 | 0.60 | 2.4 |
| **New Tier 4 engine** | 2015+ | 2015 | 0.03 | 1.3[D] | 0.14[D] | 2.4 |

[A] Switch-haul engines must also meet the line-haul standards of the same Tier.
[B] Of the locomotive.
[C] As early as 2008 if approved engine upgrade kits become available.
[D] Optionally $NO_x$+HC ≤ 1.4 g/bhp*hr.

- Test specification: US EPA Part 1065: Test Procedures

## Russia – Locomotives

| Date | CO [g/kWh] | HC [g/kWh] | $NO_x$ [g/kWh] |
|---|---|---|---|
| **< 1.1.2016** | 3.5 | 1.0 | 12.0 |
| **≥ 1.1.2016** | 1.5 | 0.4 | 7.4 |

## 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 to 4 years after the appropriate dates in the EU legislation. The dates for the emission stage Faz IIIB are indentical with the appropriate dates in the EU legislation.

### Propulsion engines for locomotives

| Stage | Power / Cylinder displ. | $NO_x$ [g/kWh] | HC [g/kWh] | CO [g/kWh] | PM [g/kWh] | Date[A] |
|---|---|---|---|---|---|---|
| | | $NO_x$ + HC [g/kWh] | | | | |
| **Faz III A** | $130 \le P_n \le 560$ kW | 4.0 | | 3.5 | 0.2 | 2010 |
| | $560 < P_n \le 2000$ 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 III B** | $P_n > 130$ kW | 4.0 | | 3.5 | 0.025 | 2012 |

[A] Date for placing on the market of engines.

### Propulsion engines for railcars

| Stage | Power | $NO_x$ [g/kWh] | HC [g/kWh] | CO [g/kWh] | PM [g/kWh] | Date[A] |
|---|---|---|---|---|---|---|
| **III A** | $P_n > 130$ kW | 4.0 | | 3.5 | 0.20 | 2010 |
| **III B** | $P_n > 130$ kW | 2.0 | 0.19 | 3.5 | 0.025 | 2012 |

[A] Date for placing on the market of engines.

- No emission stages I and II.

## ISO 8178

- The 3rd edition of ISO 8178-4 contains steady state and transient test cycles for different non-road engine applications.
- The **test conditions** have been transferred to ISO 8178-4 as well.
- 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.
- Engines for motor vehicles primarily designed for road use are excluded.

**Classification of the test cycles according to ISO 8178-4:**

- **C** Vehicles (except on-road vehicles) and industrial equipment
  - **C1** Non-road vehicles and industrial equipment with diesel engines
  - **C2** Non-road vehicles and industrial equipment with spark-ignition engines and rated power above 19 kW
- **D** Constant speed
  - **D1** Gensets
  - **D2** Gensets with intermittent load, irrigation pumps
- **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 19 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
- **H** Snowmobile
- **I** Transport refrigeration unit

## Weighting factors

| Test mode B-cycle | Speed | Torque[B] | Cycle | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | C1 | C2 | D1 | D2 | E1 | E2 | F | G1 | G2 | G3 |
| 1 | Rated speed (or MTS[A]) | 100 % | 0.15 | | 0.3 | 0.05 | 0.08 | 0.2 | 0.15 | | 0.09 | 0.85 |
| 2 | | 75 % | 0.15 | | 0.5 | 0.25 | 0.11 | 0.5 | | | 0.2 | |
| 3 | | 50 % | 0.15 | | 0.2 | 0.3 | | 0.15 | | | 0.29 | |
| 4 | | 25 % | | 0.06 | | 0.3 | | 0.15 | | | 0.3 | |
| 5 | | 10 % | 0.1 | | | 0.1 | | | | | 0.07 | |
| 6 | Inter-mediate speed | 100 % | 0.1 | 0.02 | | | | | | 0.09 | | |
| 7 | | 75 % | 0.1 | 0.05 | | | 0.19 | | | 0.2 | | |
| 8 | | 50 % | 0.1 | 0.32 | | | 0.32 | | 0.25 | 0.29 | | |
| 9 | | 25 % | | 0.3 | | | | | | 0.3 | | |
| 10 | | 10 % | | 0.1 | | | | | | 0.07 | | |
| 11 | Low idle | 0 % | 0.15 | 0.15 | | | 0.3 | | 0.6 | 0.05 | 0.05 | 0.15 |

[A] Maximum Test Speed.
[B] Except F-cycle, there Power.

**Intermediate speed:**

- For engines that are designed to operate over a speed range on a full-load torque curve, the intermediate speed shall be the maximum torque speed if it occurs between 60 % and 75 % of rated speed.
- If the maximum torque speed is less than 60 % of rated speed, then the intermediate speed shall be 60 % of the rated speed.
- If the maximum torque speed is greater than 75 % of the rated speed then the intermediate speed shall be 75 % of rated speed. Where the engine is only capable of operation at speeds higher than 75 % of rated speed the intermediate speed shall be the lowest speed at which the engine can be operated.
- For engines that 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 rated speed.
- For engines to be tested on cycle G1, the intermediate speed shall be 85 % of the rated speed.

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

| Test mode | Speed | Power | Cycle | |
|---|---|---|---|---|
| | | | E3 | E5 |
| 1 | 100 % | 100 % | 0.20 | 0.08 |
| 2 | 91 % | 75 % | 0.50 | 0.13 |
| 3 | 80 % | 50 % | 0.15 | 0.17 |
| 4 | 63 % | 25 % | 0.15 | 0.32 |
| 5 | idle | 0 % | | 0.30 |

- For all steady-state test cycle the **engine** has to be warmed up according to manufacturer's recommendation until engine temperatures have stabilized.
- At the choice of the manufacturer, a steady-state test cycle may be run as a discrete-mode cycle or a ramped-modal cycle (RMC).

**Discrete mode**

- The test shall be performed in ascending order of mode numbers as set out for the test cycle.
- Each mode has a mode length of at least 10 min, except for G-cycles where the minimum mode length is 3 min.
- After stabilization of the operating parameters of the engine the emissions shall be sampled for 1 min to 3 min, except for G-cycles where the at least the last 2 min shall be sampled.

**Ramped modal cycle (RMC)**

- Applicable to cyles C1, C2, D2, E2, E3, E5, F, G1, G2, H and I
- The transition from one mode to the next shall be done linearly (ramp) in 20 s.
- The relative total time at each mode and its preceding transition match the weighting of the discrete mode steady state cycles.
- The gaseous and particulate emissions shall be measured and sampled continuously during the RMC test cycle.

**Transient test cycles according to ISO 8178-4:**

**NRTC (Non-road transient cycle)**

- Dynamic test for mobile machinery.
- May be applied to variable-speed compression-ignition or spark ignition engines with a maximum power output between 19 kW and 560 kW and a maximum engine speed ≤ 3 400 rpm that are also subject to the C1 cycle.
- The transient test cycle shall be run twice after completion of pre-conditioning, with a cold-start and a hot-start.
- Composite weighted emissions shall be computed by weighting the cold start results by 10 % and the hot start results by 90 %.

**LSI-NRTC (large spark ignition non-road transient cycle)**

- May be applied to variable-speed spark-ignition with a maximum power output between 19 kW and 560 kW that are also subject to the C2 cycle.
- After pre-conditioning of the engine followed by a 3 min warm-up period and a 30-sec idling period the test cycle is run from the beginning.

## 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.

## 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.

## Smoke number according to Ringelmann

U.S. Bureau of Mines Ringelmann smoke chart. [Washington] U.S. Dept. of the Interior, Bureau of Mines [1967], 4 p. (U. S. Bureau of Mines. Information circular 8333) Revision of I. C. 7718: Kudlich, Rudolf. Ringelmann smoke chart. 1955. TN23.U71 no. 8333 622.06173, U. S. Dept. of the Int. Library.

- Tool for the evaluation of the opacity with five optical scales.
- The Ringelmann-scale is determined by a chart with four quadrants, each of them with a grid of black lines. Ringelmann-scale no 1 is represented by a chart, where the black lines cover 20% of the area. For Ringelmann-scales no 2-5 are the area covered by the black lines corresponds to 40%, 60%, 80% and 100% respectively.

- The charts are placed into the smoke plume at a distance at which the black lines seem to merge into different shades of grey for the observer.
- After placing the charts into the smoke plume, the observer looks through the plume and notes the no of the chart, that matches the shade of the smoke best.

## 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 (see cfr 40 Part 1033).

| Test mode | Notch setting | Time (minutes)[A] | Sample period (sec.)[A] | Weighting factor Line-haul cycle | Weighting factor Switch cycle |
|---|---|---|---|---|---|
| **Idle** | Lowest idle | 10-15[B] | 0[C] | 0[C] | 0[C] |
| **A** | Low idle[D] | 5-10 | 300±5 | 0.190 | 0.299 |
| **B** | Normal idle | 5-10 | 300±5 | 0.190[E] | 0.299 |
| **C** | Dynamic brake[D] | 5-10 | 300±5 | 0.125[E] | 0 |
| **1** | Notch 1 | 5-10 | 300±5 | 0.065 | 0.124 |
| **2** | Notch 2 | 5-10 | 300±5 | 0.065 | 0.123 |
| **3** | Notch 3 | 5-10 | 300±5 | 0.052 | 0.058 |
| **4** | Notch 4 | 5-10 | 300±5 | 0.044 | 0.036 |
| **5** | Notch 5 | 5-10 | 300±5 | 0.038 | 0.036 |
| **6** | Notch 6 | 5-10 | 300±5 | 0.039 | 0.015 |
| **7** | Notch 7 | 5-10 | 300±5 | 0.030 | 0.002 |
| **8** | Notch 8 | 10-15 | 600±5 | 0.162 | 0.008 |

[A] The time in each notch and sample averaging period may be extended as needed to allow for collection of a sufficiently large PM sample.
[B] Alternate pre-test provisions are possible.
[C] Not applicable.
[D] Omit if not so equipped.
[E] If the locomotive is not equipped with dynamic brake, the weighting factor mode B is 0.315 and for mode C it is 0.

As an alternative to the discrete mode cycle a ramped modal cycle (RMC, see ISO 8178) may be applied, combining multiple test modes of a discrete-mode steady-state into a single sample period.

## RMC for Line-haul locomotives:

| RMC phase | Weighting factor | RMC mode | Notch setting | Time [seconds] |
|---|---|---|---|---|
| **Pre-test idle** | – | – | Lowest idle[A] | 600-900 |
| **Phase 1 (Idle test)** | 0.380 | A | Low idle[B] | 600 |
| | | B | Normal idle | 600 |
| **Phase Transition** | | | | |
| **Phase 2** | 0.389 | C | Dynamic brake[C] | 1000 |
| | | 1 | Notch 1 | 520 |
| | | 2 | Notch 2 | 520 |
| | | 3 | Notch 3 | 416 |
| | | 4 | Notch 4 | 352 |
| | | 5 | Notch 5 | 304 |
| **Phase Transition** | | | | |
| **Phase 3** | 0.231 | 6 | Notch 6 | 144 |
| | | 7 | Notch 7 | 111 |
| | | 8 | Notch 8 | 600 |

[A] Alternate pre-test provisions possible.
[B] Operate at normal idle if not equipped with multiple idle settings.
[C] Operate at normal idle if not equipped with a dynamic brake.

## RMC for Switch locomotives:

| RMC phase | Weighting factor | RMC mode | Notch setting | Time [seconds] |
|---|---|---|---|---|
| **Pre-test idle** | – | – | Lowest idle[A] | 600-900 |
| **Phase 1 (Idle test)** | 0.598 | A | Low idle[B] | 600 |
| | | B | Normal idle | 600 |
| **Phase Transition** | | | | |
| **Phase 2** | 0.377 | 1 | Notch 1 | 868 |
| | | 2 | Notch 2 | 861 |
| | | 3 | Notch 3 | 406 |
| | | 4 | Notch 4 | 252 |
| | | 5 | Notch 5 | 252 |
| **Phase Transition** | | | | |
| **Phase 3** | 0.025 | 6 | Notch 6 | 1080 |
| | | 7 | Notch 7 | 144 |
| | | 8 | Notch 8 | 576 |

[A] Alternate pre-test provisions possible.
[B] Operate at normal idle if not equipped with multiple idle settings.

- Time in each notch is proportional to weighting factors of the discrete mode.
- For each Phase a separate PM filter is required.

### Standard Notch Power Levels

| Test mode | % of Rated Power $P_n$ |
|---|---|
| **Normal Idle** | 0.00 |
| **Dynamic brake** | 0.00 |
| **Notch 1** | 4.50 |
| **Notch 2** | 11.50 |
| **Notch 3** | 23.50 |
| **Notch 4** | 35.00 |
| **Notch 5** | 48.50 |
| **Notch 6** | 64.00 |
| **Notch 7** | 85.00 |
| **Notch 8** | 100.00 |

## 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 $W_i$:

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

## EU – Directives 98/70/EC (as amended by 2009/30/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.
- **Gas oils** intended **for use by non-road mobile machinery (including inland waterway vessels), agricultural** and **forestry tractors**, and **recreational craft**: any petroleum-derived liquid, falling within CN codes 2710 19 41 and 2710 19 45, intended for use in compression ignition engines referred to in Directives 94/25/EC, 97/68/EC and 2000/25/EC.
- Member States shall ensure that diesel fuels may be placed on the market within their territory only if it complies with the specifications set out below.

| Parameter[A] | Unit | Minimum[B] | Maximum[B] |
|---|---|---|---|
| **Cetane number** | | 51 | – |
| **Density at 15°C** | kg/m³ | – | 845.0 |
| **Boiling characteristics: 95 % (v/v) re-extracted at** | °C | – | 360.0 |
| **Polycyclic aromatic hydrocarbons** | % m/m | – | 8.0 |
| **Sulphur content** | ppm | – | 10.0 |
| **FAME-Gehalt – EN 14078** | % v/v | – | 7.0[C] |

[A] Test procedure according to EN 590:2004.
[B] "Effective Values" according to ISO 4259:2006.
[C] Member States may permit the placing on the market of diesel with a FAME content greater than 7 %. FAME shall comply with EN 14214.

- Furthermore, the Member States shall assure that the gas oils which are placed on the market for use in **non-road mobile machinery (including inland waterway vessels), agricultural** and **forestry tractors**, and **recreational craft** or in **agricultural tractors** have a maximum sulphur content of 1000 mg/kg (= 1000 ppm) as of **1 January 2008.**
- **As of 1 January 2011** the maximum sulphur content of above mentioned gas oils is 10 mg/kg (= 10 ppm).
- For **seagoing vessels** the directive 2012/33/EU (as revision of 2005/33/EC) regulates the requirements for the fuels of seagoing ships. Until December 12th 2019 in territorial waters or exclusive economic zones of the EU fuels of a maximum sulphur content of 3.5% mass may be used without measures for emission reduction. From January 1st 2020 the maximum sulphur content is set of 0.5%. In so called **S**$O_x$ **E**mission **C**ontrol **A**reas (SECA), like the North sea or the Baltic sea, a maximum sulphur content of 0.1% is allowed. For passenger or liners operating between EU-ports until

December 12th 2019 a maximum Sulphur content of 1.5% is allowed. For ships at berth in EU-ports a maximum sulphur content of 0,1% is allowed. If measures for emission reduction are applied the airborne emission equivalents to the fuel Sulphur content are given in a separate table.

## USA 40 CFR

- For mobile machinery the sulphur limit is 500 ppm as of June 2007 and 15 ppm as of June 2010.
- For trains and ships the sulphur limit is 15 ppm as of June 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 ρ = 830 kg/m³ (15° C), the following applies approximately:

Conversion of g/$m_n^3$ (5 % $O_2$) to g/kWh:

$$EP_i = EA_i \bullet b_{eff} \bullet \frac{m_N^3}{73g} \qquad EA_i = EP_i \bullet \frac{73g}{m_N^3 \bullet b_{eff}}$$

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

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

Conversion of ppm to g/kWh:

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

$EP_i$ 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/$m_n^3$)
$EX_i$ Pollutant mass, i, referenced to exhaust volumes based on dry exhaust with X % residual oxygen under standardized conditions (g/$m_n^3$)
$EV_i$ 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 % $O_2$ |

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

$$\frac{\dot{m}_{Exh,d}}{P_{eff}} = 3873\,g/kWh \qquad \frac{\dot{m}_{Exh,w}}{P_{eff}} = 4160\,g/kWh$$

- 1000 ppm $NO_x$,
  measured wet, corresponds to 2310 mg/$m_n^3$, d, 5 % (6.60 g/kWh)
- 100 ppm HC,
  measured wet, corresponds to 70 mg/$m_n^3$, d, 5 % (0.20 g/kWh)
- 100 ppm CO,
  measured dry, corresponds to 125 mg/$m_n^3$, d, 5 % (0.36 g/kWh)

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

$$\frac{\dot{m}_{Exh,d}}{P_{eff}} = 5400\,g/kWh \qquad \frac{\dot{m}_{Exh,w}}{P_{eff}} = 5710\,g/kWh$$

- 1000 ppm $NO_x$,
  measured wet, corresponds to 9.10 g/kWh (3150 mg/$m_n^3$, d, 5 %)
- 100 ppm HC,
  measured wet, corresponds to 0.27 g/kWh (95 mg/$m_n^3$, d, 5 %)
- 100 ppm CO, measured dry, corresponds to 0.51 g/kWh (176 mg/mmg/$m_n^3$, 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 $mm^2$ |

**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 / $in^2$ | = 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**

| | |
|---|---|
| EC | European Commission |
| ECE | Economic Commission for Europe (UN economic commission for Europe) |
| EEU | Eurasian Economic Union |
| EPA | Environmental Protection Agency (US environmental authority) |
| EU | European Union |
| 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 and technologies**

| | |
|---|---|
| CI | Compression Ignition |
| DF | Dual-Fuel |
| $m_n^3$ | standard cubic meter |
| $MW_{th}$ | Megawatt thermal |
| $n_n$ | Engine rated speed [rpm] |
| $P_n$ | Engine rated power [kW] |
| SI | Spark Ignition |
| $V_h$ | Swept volume (displacement) [liter] |
| $V_{h,z}$ | Swept volume per cylinder (cyl. displacement) [liter] |

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