Vehicle Emission Standards

Europe
Regulatory Impact on Passenger Car Exhaust Emissions: European Gasoline Vehicles

Emissions, grams/kilometer

- NOx
  - Euro Stage 1 (est.)
  - Euro Stage 2 (est.)
  - Euro Stage 3
  - Euro Stage 4
  - Euro Stage 5?
    (undefined)

- CO/10
- HC

Year:
- '93
- '94
- '95
- '96
- '97
- '98
- '99
- '00
- '01
- '02
- '03
- '04
- '05
- '06
- '07
- '08
- '09
- '10
- '11

MECA World Regulations

TWCs → High efficiency TWCs → CC+UF with Adv. engine controls, OBD → Adv. TWCs, NOx traps, System optimization, Low S Fuels
Regulatory Impact on Passenger Car Exhaust Emissions: European Diesel Vehicles

Emissions, grams/kilometer

- Euro Stage 1 (est.)
- Euro Stage 2 (est.)
- Euro Stage 3
- Euro Stage 4
- Euro Stage 5? (undefined)

Year: '93 '94 '95 '96 '97 '98 '99 '00 '01 '02 '03 '04 '05 '06 '07 '08 '09 '10 '11

- DOCs, EGR, Direct fuel injection
- Adv. DOCs, DPFs, OBD, Adv. engine controls, High pressure injection
- NOx traps/SCR, Low S fuel

World Regulations
MECA
Regulatory Impact on Heavy-Duty Truck Exhaust Emissions: European Diesel Trucks

Emissions, grams/kilowatt hour

- Euro Stage 1
- Euro Stage 2
- Euro Stage 3
- Euro Stage 4
- Euro Stage 5


- PM
- NOx/10
- HC

Improved fuel injection & combustion technologies
Adv. engine controls, high pressure injection
DOCs, DPFs, EGR, SCR
EU Stage 1 Emission Standards
MVEG-A test cycle w/40 sec. idle before sampling

- This chart summarizes European Stage 1 standards for passenger cars and light commercial vehicles. Standards apply to both gasoline and diesel vehicles, except for the particulate standard (PM) which only applies to diesel vehicles. These Stage 1 standards are measured using the ECE portion (city only, no extra-urban drive cycle) of the European MVEG-A driving cycle (see chart under test cycles) with a 40 s idle period before emissions sampling begins. These standards were first introduced into Europe in 1992.
EU Stage 1 Emission Standards
MVEG-A test cycle w/40 sec. idle before sampling

Emissions, g/km

PM stds. only apply to diesels; RM=reference mass
EU Light-Duty Stage 2 Emission Standards
MVEG-A test cycle w/40 sec. idle before sampling

This chart summarizes European Stage 2 standards for passenger cars. Standards are shown for gasoline, indirect injection diesel (IDI), and direct injection diesel (DI) engines. Diesel standards include regulations on particulate matter (PM). These Stage 2 standards are measured using the European MVEG-A driving cycle (see chart under test cycles) with a 40 s idle period before emissions sampling begins.
EU Light-Duty Stage 2 Emission Standards
MVEG-A test cycle w/40 sec. idle before sampling

Emissions, g/km

- Gasoline: HC + NOx 0.50, CO/10 0.22
- Diesel-IDI: HC + NOx 0.70, CO/10 0.10, PM 0.08
- Diesel-DI: HC + NOx 0.90, CO/10 0.10, PM 0.10
EU Light-Duty Gasoline Emission Standards
MVEG-A test with sampling from key-on

- This chart compares Stage 2 standards for gasoline vehicles in Europe with Stage 3 (year 2000) and Stage 4 (year 2005) gasoline standards. Stage 2 levels have been "adjusted" to reflect the removal of the 40 s idle period present at the start of the MVEG-A driving cycle (see chart under test cycles). This 40 s idle period will be removed from the MVEG-A driving cycle for Stage 3 and Stage 4 applications. The Stage 3 and Stage 4 regulations were adopted in late 1998.
EU Light-Duty Gasoline Emission Standards
MVEG-A test with sampling from key-on

Emissions, g/km

<table>
<thead>
<tr>
<th>Stage 2 - estimate</th>
<th>Stage 3 - 2000</th>
<th>Stage 4 - 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.34</td>
<td>0.20</td>
<td>0.10</td>
</tr>
<tr>
<td>0.32</td>
<td>0.23</td>
<td>0.10</td>
</tr>
<tr>
<td>0.25</td>
<td>0.15</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Note: Stage 2 levels adjusted for new MVEG-A cycle

- This chart summarizes 2005 Euro 4 standards for gasoline passenger cars in Europe with proposed Euro 5 gasoline standards. Emissions for European Union-compliant gasoline passenger cars are measured using the MVEG-A driving cycle. The proposed Euro 5 regulations include small reductions in HC and NOx emissions relative to the Euro 4 limits. Also included in the proposed Euro 5 limits is a tight PM standard for partial lean burn gasoline vehicles. The Euro 5 proposal includes a durability requirement of 160,000 km, with an in-use compliance requirement for 5 years/100,000 km. Heavy gasoline passenger cars (e.g., SUVs) would also be required to meet these proposed Euro 5 light-duty emission limits. These Euro 5 regulations could be implemented by 2009.

Emissions, g/km

<table>
<thead>
<tr>
<th></th>
<th>Euro 4 - 2005</th>
<th>Proposed Euro 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>HC</td>
<td>0.10</td>
<td>0.075</td>
</tr>
<tr>
<td>CO/10</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>NOx</td>
<td>0.08</td>
<td>0.06</td>
</tr>
<tr>
<td>PM std.</td>
<td></td>
<td>0.005</td>
</tr>
</tbody>
</table>

PM std. only applies to partial lean burn gasoline vehicles
EU Light-duty Diesel Emission Standards
MVEG-A test with sampling from key-on

- This chart summarizes Stage 2 standards for diesel vehicles in Europe with Stage 3 (year 2000) and Stage 4 (year 2005) diesel standards. Stage 2 levels have been "adjusted" to reflect the removal of the 40 s idle period present at the start of the MVEG-A driving cycle (see chart under test cycles). This 40 s idle period will be removed from the MVEG-A driving cycle for Stage 3 and Stage 4 applications. The Stage 3 and Stage 4 regulations contained in the chart were adopted in late 1998. Note that starting with Stage 3 standards all diesel engines will need to meet a single set of standards (no differences in standards between IDI and DI diesel engines).
EU Light-duty Diesel Emission Standards
MVEG-A test with sampling from key-on

Emissions, g/km

<table>
<thead>
<tr>
<th></th>
<th>Stage 2-IDI</th>
<th>Stage 2-DI</th>
<th>Stage 3</th>
<th>Stage 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO/10</td>
<td>0.106</td>
<td>0.106</td>
<td>0.064</td>
<td>0.050</td>
</tr>
<tr>
<td>HC + NOx</td>
<td>0.63</td>
<td>0.100</td>
<td>0.064</td>
<td>0.050</td>
</tr>
<tr>
<td>NOx</td>
<td>0.81</td>
<td>0.56</td>
<td>0.50</td>
<td>0.025</td>
</tr>
<tr>
<td>PM</td>
<td>0.080</td>
<td>0.050</td>
<td>0.050</td>
<td>0.025</td>
</tr>
</tbody>
</table>

Note: Stage 2 levels adjusted for new MVEG-A cycle

2000 2005

Stages

CO/10: 0.106 0.106
HC + NOx: 0.63 0.100
NOx: 0.81 0.56
PM: 0.080 0.050

0.00 0.20 0.40 0.60 0.80 1.00
Proposed Euro 5 Light-duty Diesel Standards vs. 2005 Euro 4 Diesel Standards

- This chart summarizes 2005 Euro 4 standards for diesel passenger cars in Europe with proposed Euro 5 diesel standards. Emissions for European Union-compliant diesel passenger cars are measured using the MVEG-A driving cycle. The proposed Euro 5 regulations include small reductions in HC+NOx and NOx emissions, and a significantly tighter PM limit relative to the Euro 4 requirements. The Euro 5 proposal includes a durability requirement of 160,000 km, with an in-use compliance requirement for 5 years/100,000 km. These Euro 5 regulations could be implemented by 2009.
Proposed Euro 5 Light-duty Diesel Standards vs. 2005 Euro 4 Diesel Standards

Emissions, g/km

- CO/10
- HC + NOx
- NOx
- PM

Euro 4 2005
- CO/10: 0.050
- HC + NOx: 0.30
- NOx: 0.25
- PM: 0.025

Proposed Euro 5
- CO/10: 0.050
- HC + NOx: 0.25
- NOx: 0.20
- PM: 0.005
EU Light-Duty Cold HC & CO Emission Standards (-7°C)

- This chart summarizes European Union cold HC and CO emission standards for light-duty vehicles (gasoline & diesel). These standards limit HC and CO emissions during vehicle operation at -7°C (20°F). Emissions are measured using only the first 800 seconds of the ECE urban driving cycle (Euro 3 cycle with sampling from key-on) at a test temperature of -7°C.
EU Light-Duty Cold HC & CO Emission Standards (-7°C)

**Emissions, g/km**

![Bar chart showing HC and CO emissions](image)

- Emissions measured over first 800 s of ECE drive cycle only
EU LDT Stage 2 Emission Standards-Class 2
MVEG-A test cycle w/40 sec. idle before sampling

This chart summarizes European Stage 2 standards for light-duty trucks (light commercial vehicles) with reference weights (RW) from 1251 kg to 1700 kg. Standards are shown for gasoline, indirect injection diesel (IDI), and direct injection diesel (DI) engines. These Stage 2 standards are measured using the European MVEG-A driving cycle (see chart under test cycles) with a 40 s idle period before emissions sampling begins.
EU LDT Stage 2 Emission Standards-Class 2
MVEG-A test cycle w/40 sec. idle before sampling

Emissions, g/km

Gasoline

Diesel-IDI

Diesel-DI

Class 2: 1251-1700 kg RW
Effective 10/1/98 - 10/1/99

1.20
1.00
0.80
0.60
0.40
0.20
0.00

HC + NOx
CO/10
PM
EU LDT Class 2 Gasoline Emission Standards - Euro 3, 4, and proposed Euro 5 limits

◆ This chart summarizes Euro 3 & 4 emissions standards for Class 2 gasoline light-duty trucks (light commercial vehicles). Class 2, Euro 3 & 4 standards are delayed one year relative to Euro 3 & 4 standards for passenger cars. Also note that the reference weight class for Class 2 vehicles has been adjusted for Euro 3 & 4 standards relative to the weight class established for Euro 2 standards. Emissions for Euro 3, 4, and proposed Euro 5 requirements are measured using the MVEG-A driving cycle (see chart under test cycles) without the 40 s idle period at the beginning of the test cycle. The proposed Euro 5 regulations include small reductions in HC and NOx emissions relative to the Euro 4 limits. Also included in the proposed Euro 5 limits is a tight PM standard for partial lean burn gasoline vehicles. The Euro 5 proposal includes a durability requirement of 160,000 km, with an in-use compliance requirement for 5 years/100,000 km. These Euro 5 regulations could be implemented by 2009.
EU LDT Class 2 Gasoline Emission Standards – Euro 3, 4, and proposed Euro 5 limits

From 2001, Class 2 Light Commercial Vehicles: 1305 kg < RW < 1760 kg; PM std. only applies to gasoline partial lean burn vehicles
EU LDT Class 2 Diesel Emission Standards – Euro 3, 4, and proposed Euro 5 limits

- This chart summarizes Euro 3 & 4 emissions standards for Class 2 diesel light-duty trucks (light commercial vehicles). Class 2, Euro 3 & 4 standards are delayed one year relative to Euro 3 & 4 standards for passenger cars. Also note that the reference weight class for Class 2 vehicles has been adjusted for Euro 3 & 4 standards relative to the weight class established for Euro 2 standards. Emissions for Euro 3, 4, and proposed Euro 5 requirements are measured using the MVEG-A driving cycle (see chart under test cycles) without the 40 s idle period at the beginning of the test cycle. The proposed Euro 5 regulations include small reductions in HC+NOx and NOx emissions, and a significantly tighter PM limit relative to the Euro 4 requirements. The Euro 5 proposal includes a durability requirement of 160,000 km, with an in-use compliance requirement for 5 years/100,000 km. These Euro 5 regulations could be implemented by 2009.
EU LDT Class 2 Diesel Emission Standards – Euro 3, 4, and proposed Euro 5 limits

From 2001, Class 2 Light Commercial Vehicles: 1305 kg < RW < 1760 kg
This chart summarizes European Stage 2 standards for light-duty trucks (light commercial vehicles) with reference weights (RW) greater than 1700 kg. Standards are shown for gasoline, indirect injection diesel (IDI), and direct injection diesel (DI) engines. These Stage 2 standards are measured using the European MVEG-A driving cycle (see chart under test cycles) with a 40 s idle period before emissions sampling begins.
EU LDT Stage 2 Emission Standards-Class 3
MVEG-A test cycle w/40 sec. idle before sampling

Emissions, g/km

<table>
<thead>
<tr>
<th></th>
<th>HC + NOx</th>
<th>CO/10</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>0.70</td>
<td>0.50</td>
<td></td>
</tr>
<tr>
<td>Diesel-IDI</td>
<td>1.20</td>
<td>0.15</td>
<td>0.17</td>
</tr>
<tr>
<td>Diesel-DI</td>
<td>1.30</td>
<td>0.15</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Class 3: > 1700 kg RW
Effective 10/1/98 - 10/1/99
EU LDT Class 3 Gasoline Emission Standards - Euro 3, 4, and proposed Euro 5 limits

- This chart summarizes Euro 3 & 4 emissions standards for Class 3 gasoline light-duty trucks (light commercial vehicles). Class 3, Euro 3 & 4 standards are delayed one year relative to Euro 3 & 4 standards for passenger cars. Also note that the reference weight class for Class 3 vehicles has been adjusted for Euro 3 & 4 standards relative to the weight class established for Euro 2 standards. Emissions for Euro 3, 4, and proposed Euro 5 requirements are measured using the MVEG-A driving cycle (see chart under test cycles) without the 40 s idle period at the beginning of the test cycle. The proposed Euro 5 regulations include small reductions in HC and NOx emissions relative to the Euro 4 limits. Also included in the proposed Euro 5 limits is a tight PM standard for partial lean burn gasoline vehicles. The Euro 5 proposal includes a durability requirement of 160,000 km, with an in-use compliance requirement for 5 years/100,000 km. These Euro 5 regulations could be implemented by 2009.
EU LDT Class 3 Gasoline Emission Standards – Euro 3, 4, and proposed Euro 5 limits

Emissions, g/km

From 2001, Class 3 Light Commercial Vehicles: RW > 1760 kg
PM std. only applies to gasoline partial lean burn vehicles
EU LDT Class 3 Diesel Emission Standards – Euro 3, 4, and Proposed Euro 5 limits

- This chart summarizes Euro 3 & 4 emissions standards for Class 3 diesel light-duty trucks (light commercial vehicles). Class 3, Euro 3 & 4 standards are delayed one year relative to Euro 3 & 4 standards for passenger cars. The chart also contains the proposed Euro 5 standards for Class 3 diesel light-duty trucks. Note that the reference weight class for Class 3 vehicles has been adjusted for Euro 3 & 4 standards relative to the weight class established for Euro 2 standards. Emissions for Euro 3, 4, and proposed Euro 5 requirements are measured using the MVEG-A driving cycle (see chart under test cycles) without the 40 s idle period at the beginning of the test cycle. The proposed Euro 5 regulations include small reductions in HC+NOx and NOx emissions, and a significantly tighter PM limit relative to the Euro 4 requirements. The Euro 5 proposal includes a durability requirement of 160,000 km, with an in-use compliance requirement for 5 years/100,000 km. These Euro 5 regulations could be implemented by 2009.
EU LDT Class 3 Diesel Emission Standards – Euro 3, 4, and Proposed Euro 5 limits

Emissions, g/km

From 2001, Class 3 Light Commercial Vehicles: RW > 1760 kg
EU Heavy-Duty Diesel Emission Standards - Stage 1 & 2
ECE R49 13 Mode Engine Test

- Euro 1 and Euro 2 standards for heavy-duty diesel engine vehicles are summarized in this chart. Emissions for heavy-duty diesel engines are measured using the R49 13 mode engine test cycle. These Euro 1 and Euro 2 standards apply to vehicles with GVW > 3500 kg. Euro 1 standards were first introduced in June 1992 with Euro 2 levels established in October 1995. These standards include limits on particulate matter (PM) for diesel engines. Two sets of PM standards are included in these regulations. For Euro 1 a higher PM standard applies to engines with power ratings > 85 kW. For Euro 2 the higher PM level applies to engines with displacements < 700 cc and a speed rating > 3000 rpm.
### EU Heavy-Duty Diesel Emission Standards - Stage 1 & 2

**ECE R49 13 Mode Engine Test**

#### Emissions, g/kWh

<table>
<thead>
<tr>
<th></th>
<th>Euro 1- 6/92</th>
<th>Euro 2- 10/95</th>
</tr>
</thead>
<tbody>
<tr>
<td>HC</td>
<td>1.10</td>
<td>1.10</td>
</tr>
<tr>
<td>CO/10</td>
<td>0.45</td>
<td>0.40</td>
</tr>
<tr>
<td>NOx/10</td>
<td>0.80</td>
<td>0.70</td>
</tr>
<tr>
<td>PM</td>
<td>0.36</td>
<td>0.15</td>
</tr>
<tr>
<td>PM(a)</td>
<td>0.61</td>
<td>0.25</td>
</tr>
</tbody>
</table>

*Heavy-duty vehicles defined as GVW > 3500 kg*

*PM(a): for Euro 1- engines <85kW; for Euro 2- engines <700 cc with rated speed >3000 rpm*
The Euro 3, 4, and 5 regulations for heavy-duty diesel engines for the European Union countries are summarized in this chart. These standards apply to conventional diesel engines (with or without oxidation catalysts). Euro 3 levels were phased-in in the 2000/2001 timeframe, Euro 4 levels in the 2005/2006 timeframe and Euro 5 levels in the 2008/2009 timeframe. As in the Euro 2 standards, heavy-duty diesel vehicles are defined as those vehicles with GVW > 3500 kg. Particulate matter standards (PM) are included in all stages for heavy-duty diesel engines. In the Euro 3 standards, separate PM standards are included for engines with displacements < 750 cc and speed ratings > 3000 rpm. This PM standard for smaller engines was delayed until the 2005 timeframe for Euro 3. The emission standards for diesel engines in this heavy-duty class shown in this chart are measured using the OICA test cycles. This test cycle combines a load response test (ELR test cycle) and a steady-state engine schedule (ESC test cycle).
Euro 3, 4, 5 Heavy-Duty Diesel Emission Stds. ESC and ELR (OICA) Engine Tests

Emissions, g/kWh

- HC
- CO/10
- NOx/10
- PM
- PM(a)

Euro 3-2000/01  Euro 4-2005/06  Euro 5-2008/09

Heavy-duty vehicles defined as GVW > 3500 kg

Above standards apply to conventional engines with & without oxidation catalysts

PM(a): for Euro 3- engines < 750 cc with rated speed > 3000 rpm, delayed until 2005
The Euro 3, 4, and 5 regulations for heavy-duty diesel engines for the European Union countries are summarized in this chart. These standards apply to diesel engines equipped with advanced aftertreatment technologies (e.g., particulate traps, deNOx catalysts) and diesel engines fueled by gaseous fuels like natural gas. Euro 3 levels were phased-in in the 2000/2001 timeframe, Euro 4 levels in the 2005/2006 timeframe and Euro 5 levels in the 2008/2009 timeframe. As in the Euro 2 standards, heavy-duty diesel vehicles are defined as those vehicles with GVW > 3500 kg. Particulate matter standards (PM) are included in all stages for heavy-duty diesel engines. In the Euro 3 standards, separate PM standards are included for engines with displacements < 750 cc and speed ratings > 3000 rpm. This PM standard for smaller engines is delayed until the 2005 timeframe for Euro 3. The methane standards shown in the chart above apply only to engines fueled with natural gas. The emission standards for diesel engines in this heavy-duty class shown in this chart are measured using the ETC test cycle. The ETC test cycle is a transient engine dynamometer schedule.
Euro 3, 4, 5 Heavy-Duty Diesel Emission Stds.
ETC Engine Test

PM stds. only apply to diesels; CH4 stds. only apply to NG engines
Above standards apply to engines with advanced aftertreatment or gaseous fuel
PM(a): for Euro 3- engines<750 cc with rated speed>3000 rpm, delayed until 2005
European Union standards for so-called "Enhanced Environment Vehicles (EEV)" are presented in this chart. These standards are either equivalent or below the Euro V heavy-duty standards that are effective starting in 2008 for European Union members. These voluntary EEV levels can be used by member states to encourage the use of low emission heavy-duty vehicles especially in crowded city centers. Member states can use tax incentives to promote the introduction and sale of these low emission vehicles. Like the Euro IV and V heavy-duty standards, these EEV standards include limits for the European steady-state test cycles (ESC & ELR) and the European transient test cycle (ETC).
Euro EEV Heavy-Duty Emission Standards
GVW > 3500 kg

ESC & ELR Test Cycles
PM stds. only apply to diesels; CH4 stds. only apply to NG engines
ESC & ELR test cycles apply to conventional engines with or without oxidation cats.
ETC test cycle applies to engines with advanced aftertreatment or gaseous fuel
European Union Euro 1 emission standards for motorcycle are summarized in this chart. Separate standards are provided for two stroke and four stroke engines. The European Union used the ECE 40 driving cycle to measure motorcycle emissions for these standards with a specified warm up cycle. The driving cycle itself contains the same series of four driving cycles found in the urban phase of the European driving cycle used for passenger cars (MVEG-A drive cycle - urban portion only; see Europe test cycles in this database for details). Each cycle contains a series of three driving "hills." For motorcycles, the warm up period consists of driving two of these cycles followed by a 40 second idle period. The ECE 40 cycle continues after this idle period. Sampling of exhaust begins after the 40 second idle and ends at the conclusion of the fourth cycle. The motorcycle emission standards shown here were put into law in 1997 and apply to all motorcycles with engine displacements larger than 50 cc. These standards were first enforced for new motorcycle models in June 1999.
Euro 1 Motorcycle Emission Standards
Two-Stroke & Four-Stroke Engines

Emissions, g/km

- **HC**
- **CO/10**
- **NOx**

<table>
<thead>
<tr>
<th></th>
<th>Two-stroke</th>
<th>Four-stroke</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HC</strong></td>
<td>4.0</td>
<td>3.0</td>
</tr>
<tr>
<td><strong>CO/10</strong></td>
<td>0.8</td>
<td>1.3</td>
</tr>
<tr>
<td><strong>NOx</strong></td>
<td>0.1</td>
<td>0.3</td>
</tr>
</tbody>
</table>
2003 Euro 2 Motorcycle Emission Standards

- 2003 European Union Euro 2 emission standards for two-wheeled motorcycles are summarized in this chart. Standards apply to both two stroke and four stroke engines. These 2003 motorcycle standards are separated into two classes based on engine displacement: 50 cc < engine displacement < 150 cc, and engines > 150 cc in displacement. Note that motorcycles with engines < 50 cc are classified as mopeds and have their own emission standards (see European moped standards in this database). For these 2003 standards the European Union uses the ECE 40 driving cycle to measure motorcycle emissions with a specified warm up cycle. The driving cycle itself contains the same series of four driving cycles found in the urban phase of the European driving cycle used for passenger cars (MVEG-A drive cycle - urban portion only; see Europe test cycles in this database for details). Each cycle contains a series of three driving "hills." For motorcycles, the warm up period consists of driving two of these cycles followed by a 40 second idle period. The ECE 40 cycle continues after this idle period. Sampling of exhaust begins after the 40 second idle and ends at the conclusion of the fourth cycle.
2003 Euro 2 Motorcycle Emission Standards

Emissions, g/km

< 150 cc

- HC: 1.2
- CO/10: 0.55
- NOx: 0.3

> 150 cc

- HC: 1.0
- CO/10: 0.55
- NOx: 0.3
2003 Euro 2 - 3 and 4 Wheel Motorcycle Emission Standards

- 2003 European Union Euro 2 emission standards for three and four-wheel motorcycles are summarized in this chart. Standards apply to both two stroke and four stroke engines. These 2003 standards provide separate limits for gasoline and diesel engines on three and four-wheel motorcycles. For these 2003 standards the European Union uses the ECE 40 driving cycle to measure motorcycle emissions with a specified warm up cycle. The driving cycle itself contains the same series of four driving cycles found in the urban phase of the European driving cycle used for passenger cars (MVEG-A drive cycle - urban portion only; see Europe test cycles in this database for details). Each cycle contains a series of three driving "hills." For motorcycles, the warm up period consists of driving two of these cycles followed by a 40 second idle period. The ECE 40 cycle continues after this idle period. Sampling of exhaust begins after the 40 second idle and ends at the conclusion of the fourth cycle.
2003 Euro 2 - 3 and 4 Wheel Motorcycle Emission Standards

Emissions, g/km

<table>
<thead>
<tr>
<th></th>
<th>Gasoline</th>
<th>Diesel</th>
</tr>
</thead>
<tbody>
<tr>
<td>HC</td>
<td>1.5</td>
<td>1.0</td>
</tr>
<tr>
<td>CO/10</td>
<td>0.7</td>
<td>0.2</td>
</tr>
<tr>
<td>NOx</td>
<td>0.40</td>
<td>0.65</td>
</tr>
</tbody>
</table>

[Graph showing emissions for Gasoline and Diesel]
2006 Euro 3 Motorcycle Emission Standards

- 2006 European Union Euro 3 emission standards for two-wheeled motorcycles are summarized in this chart. Standards apply to both two stroke and four stroke engines. These 2006 motorcycle standards are separated into two classes based on engine displacement: 50 cc < engine displacement < 150 cc, and engines > 150 cc in displacement. Note that motorcycles with engines < 50 cc are classified as mopeds and have their own emission standards (see European moped standards in this database). For these 2006 standards the European Union uses the same ECE 40 driving cycle used for the 2003 EU motorcycle standards, with some modifications. For motorcycle with engine displacement < 150 cc, emissions are measured across all six modes of the test cycle (no warm-up modes). For motorcycles with engine displacement > 150 cc, emissions are measured across the six modes of the ECE 40 cycle and the EUDC drive cycle used for light-duty vehicles. In the EUDC portion of the test maximum speed is limited to 120 km/h. These 2006 motorcycle standards also include a 5 year/30,000 km durability requirement.
2006 Euro 3 Motorcycle Emission Standards

**Emissions, g/km**

- **< 150 cc**
  - HC: 0.8
  - CO/10: 0.2
  - NOx: 0.15

- **> 150 cc**
  - HC: 0.3
  - CO/10: 0.2
  - NOx: 0.15

Durability requirement of 30,000 km/5 years
EU Moped Emission Standards
June 1999 Levels vs. June 2002 Levels

- June 1999 and June 2002 standards for moped/motor scooters in the European Union are summarized in this chart. These standards apply to small motorized bikes with engine displacements of 50 cc or less. Unlike the European motorcycle standards, the moped standards contain no separate provisions for two and four stroke engines. Emissions for this class of mopeds are measured using the ECE R47 test cycle. This cycle contains two steady speed modes. The bike is accelerated very quickly to 50 km/hr and cruised at this speed for about 50 seconds. This cruise is followed by a deceleration to 20 km/hr cruise condition that is maintained for about 35 seconds. The bike is decelerated to an idle from this second cruise. For the ECE R47 test cycle, a warm up phase consists of four of this two mode cruise cycles. Following this warm up, emissions are sampled during an additional four, two mode cruises to complete the ECE R47 test.
EU Moped Emission Standards
June 1999 Levels vs. June 2002 Levels
2007 Euro 3 Motorcycle Emission Standards: Optional Alternate Test Cycle

- 2007 European Union Euro 3 emission standards for two-wheeled motorcycles certified with an optional alternate test cycle are summarized in this chart. Standards apply to both two stroke and four stroke engines and provide an option of using the World Motorcycle Test Cycle (WMTC) instead of the ECE 40 driving cycle. These 2007 emission standards with the optional motorcycle test cycle are separated into two classes based on maximum speed of the engine: max. speed < 130 kph and max. speed of 130 kph or greater. These standards will take effect on July 1, 2007.
2007 Euro 3 Motorcycle Emission Standards: Optional Alternate Test Cycle

Emissions, g/km

Durability requirement of 30,000 km/5 years
Euro 1 Nonroad Gasoline Engine Emission Standards:
Engines up to 19 kW (Class 1, 2, & 3 handheld devices)

- Euro 1 emission standards for small utility gasoline engines are summarized in this chart. These Euro 1 standards cover Class 1, 2, & 3 non-road gasoline engines used in handheld devices such as lawn and garden equipment. Engines with power ratings of up to 19 kW (25 hp) make up these three application classes. Class 1 engines have displacements < 20 cc, Class 2 engines have displacements from 20 cc up to 50 cc, and Class 3 engines have displacements from 50 cc and larger. Euro 1 standards are identical to U.S. EPA Tier 1 standards for handheld equipment. Type approval of new engine families in these classes must meet the Euro 1 standards starting in August 2004, with all new engines required to meet the standards in February 2005. A steady-state test cycle is used to evaluate emission performance for these types of engines based on the ISO 8178 test protocols (e.g., ISO 8178 G1, G2, or G3). No durability requirement is associated with these Euro 1 standards.
Euro 1 Nonroad Gasoline Engine Emission Standards:
Engines up to 19 kW (Class 1, 2, & 3 handheld devices)

No durability requirement, stds. initiated in August 2004 for new engine families and in February 2005 for all new engines.
Euro 1 Nonroad Gasoline Engine Emission Standards: Engines up to 19 kW (Class 1, 2, 3, & 4 non-handheld devices)

- Euro 1 emission standards for small utility gasoline engines are summarized in this chart. These Euro 1 standards cover Class 1, 2, 3, & 4 non-road gasoline engines used in non-handheld devices such as lawn mowers or riding tractors. Engines with power ratings of up to 19 kW (25 hp) make up these four application classes. Class 1 engines have displacements < 66 cc, Class 2 engines have displacements from 66 cc up to 100 cc, Class 3 engines have displacements from 100 cc up to 225 cc, and Class 4 engines have displacements from 225 cc and larger. Euro 1 standards for Classes 3 & 4 are identical to U.S. EPA Tier 1 standards for non-handheld equipment. Type approval of new Class 3 and 4 engine families must meet the Euro 1 standards starting in August 2004, with all new engines in Classes 3 & 4 required to meet the Euro 1 standards in February 2005. Class 1 & 2 engines use the same implementation schedule but must meet Euro 2 standards. A steady-state test cycle is used to evaluate emission performance for these types of engines based on the ISO 8178 test protocols (e.g., ISO 8178-G1, G2, or G3). No durability requirement is associated with these Euro 1 standards.
Euro 1 Nonroad Gasoline Engine Emission Standards:
Engines up to 19 kW (Class 1, 2, 3, & 4 non-handheld devices)

Emissions, g/kW-hr

<table>
<thead>
<tr>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
<th>Class 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 66 cc</td>
<td>≥ 66 cc, &lt; 100 cc</td>
<td>≥ 100 cc, &lt; 225 cc</td>
<td>≥ 225 cc</td>
</tr>
</tbody>
</table>

No durability requirement,

stds.initiated in August 2004 for new Class 3 & 4 engine families
and in February 2005 for all new engines
Euro 2 Nonroad Gasoline Engine Emission Standards: Engines up to 19 kW (Class 1, 2, & 3 handheld devices)

- Euro 2 emission standards for small utility gasoline engines are summarized in this chart. These Euro 2 standards cover Class 1, 2, & 3 non-road gasoline engines used in handheld devices such as lawn and garden equipment. Engines with power ratings of up to 19 kW (25 hp) make up these three application classes. Class 1 engines have displacements < 20 cc, Class 2 engines have displacements from 20 cc up to 50 cc, and Class 3 engines have displacements from 50 cc and larger. Euro 2 standards are identical to U.S. EPA Tier 2 standards for handheld equipment. Type approval of new engine families in these classes must meet the Euro 2 standards starting in August 2007 for Class 1 & 2 engines, and in August 2008 for Class 3 engines. All new engines are required to meet the standards six months following these type approval dates. A steady-state test cycle is used to evaluate emission performance for these types of engines based on the ISO 8178 test protocols (e.g., ISO 8178 G1, G2, or G3). Durability requirements can be 50, 125, or 300 h depending on the application.
Euro 2 Nonroad Gasoline Engine Emission Standards:
Engines up to 19 kW (Class 1, 2, & 3 handheld devices)

50, 125 or 300 h durability requirement,
stds. begin in August 2007 (Class 1 & 2) or August 2008 (Class 3) for new engine families
and six months later for all new engines
Euro 2 Nonroad Gasoline Engine Emission Standards:
Engines up to 19 kW (Class 1, 2, 3, & 4 non-handheld devices)

- Euro 2 emission standards for small utility gasoline engines are summarized in this chart. These Euro 2 standards cover Class 1, 2, 3, & 4 non-road gasoline engines used in non-handheld devices such as lawn mowers or riding tractors. Engines with power ratings of up to 19 kW (25 hp) make up these four application classes. Class 1 engines have displacements < 66 cc, Class 2 engines have displacements from 66 cc up to 100 cc, Class 3 engines have displacements from 100 cc up to 225 cc, and Class 4 engines have displacements from 225 cc and larger. Euro 2 standards for non-handheld equipment are identical to U.S. EPA Tier 2 standards for non-handheld equipment. Type approval of new engine families in Class 1 & 2 must meet the Euro 2 standards starting in August 2004, with all new Class 1 & 2 engines required to meet the standards in February 2005. Type approval of new Class 3 & 4 engine families begin in August 2007 and August 2008, respectively, with all new engines in these classes required to meet Euro 2 standards six months later. A steady-state test cycle is used to evaluate emission performance for these types of engines based on the ISO 8178 test protocols (e.g., ISO 8178 G1, G2, or G3). Durability requirements can be 50, 125, 250, 300, 500, or 1000 h depending on the application.
Euro 1 Nonroad Gasoline Engine Emission Standards: Engines up to 19 kW (Class 1, 2, 3, & 4 non-handheld devices)

Emissions, g/kW-hr

<table>
<thead>
<tr>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
<th>Class 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 66 cc</td>
<td>≥ 66 cc, &lt; 100 cc</td>
<td>≥ 100 cc, &lt; 225 cc</td>
<td>≥ 225 cc</td>
</tr>
</tbody>
</table>

50, 125, 250, 300, 500, or 1000 h durability requirement, stds. begin in August 2004 (Class 1 & 2), August 2007 (Class 3), or August 2008 (Class 4) for new engine families and six months later for all new engines.
EU Non-Road Mobile Machinery Emissions: Stage IIIA Constant and Variable Speed Engines

- European Stage IIIA emission standards for constant and variable speed non-road mobile machines are summarized in this chart. The implementation of the standards for constant speed engines will begin in January 2011 and will be completely phased in by January 2012. Implementation for engines variable speed engines began in January 2006 and will be completed by January 2008. The Non-Road Steady Cycle (NRSC) will be used to evaluate Stage IIIA engines or manufacturers may choose to use the Non-Road Transient Cycle (NRTC).
EU Non-Road Mobile Machinery Emissions: Stage IIIA Constant and Variable Speed Engines

Emissions, g/kW-hr

Constant: 1/01/2011
Variable: 1/01/2006

Constant: 1/01/2011
Variable: 1/01/2007

Constant: 1/01/2012
Variable: 1/01/2008

Constant: 1/01/2011
Variable: 1/01/2007

World Regulations
EU Non-Road Mobile Machinery Emissions: Stage IIIIB Variable Speed Engines

- European Stage IIIIB emission standards for variable speed, non-road mobile machines are summarized in this chart. Implementation of this standard began in January 2006 and will be completed in January 2013. Emissions limit for engines of 19 kW to 37 kW remain at Stage IIIA levels. For all other engine classes, there will be HC+NOx emission reduction of up to 45% and a new PM limit of 0.025g/kW-hr. The Non-Road Steady Cycle (NRSC) will be used to evaluate gaseous pollutants only and the Non-Road Transient Cycle (NRTC) will be used to evaluate particulate emissions.
EU Non-Road Mobile Machinery
Emissions: Stage IIIB Variable Speed Engines

Emissions, g/kW-hr

<table>
<thead>
<tr>
<th>Power Range</th>
<th>Emissions, g/kW-hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>130kW ≤ P ≤ 560kW</td>
<td>3.5, 2.0, 2.5</td>
</tr>
<tr>
<td>75kW ≤ P ≤ 130kW</td>
<td>0.19, 3.3, 2.5</td>
</tr>
<tr>
<td>56kW ≤ P ≤ 75kW</td>
<td>0.19, 3.3, 2.5</td>
</tr>
<tr>
<td>37kW ≤ P ≤ 56kW</td>
<td>4.7, 4.7, 2.5</td>
</tr>
</tbody>
</table>

1/01/2011 1/01/2012 1/01/2012 1/01/2013
EU Non-Road Mobile Machinery Emissions: Stage IV Variable Speed Engines

- European Stage IV emission standards for variable speed, non-road mobile machines are summarized in this chart. Implementation of this standard will begin in January 2013 and will be phased in by October 2014. Stage IV combines the 56 kW to 75 kW and 75 kW to 130 kW engine power classes. Emission limits for engines of 19 kW to 56 kW remain at either Stage IIIA (19kW-37kW) or Stage IIIB (37kW-56kW) levels. The Non-Road Transient Cycle (NRTC) will be used to evaluate particulate emissions and manufacturers may also choose to use the NRTC for gaseous pollutants.
EU Non-Road Mobile Machinery Emissions: Stage IV Variable Speed Engines

Emissions, g/kW-hr

- **CO**
- **HC**
- **NOx**
- **PM x 100**

### 130kW ≤ P ≤ 560kW

- CO: 3.5
- HC: 0.19
- NOx: 0.4
- PM x 100: 2.5

1/01/2014

### 75kW ≤ P ≤ 130kW

- CO: 5.0
- HC: 0.19
- NOx: 0.4
- PM x 100: 2.5

10/01/2014
EU Non-Road Mobile Machinery Emissions: Stage IIIA for Inland Waterway Vessel Engines (up to 2.5 L/cyl.)

- European Stage IIIA standards for engines up to 2.5 L/cylinder used in inland waterway vessels are summarized in this chart. Inland waterway vessels are defined as \( \geq 20 \) meters long and \( \geq 100 \text{ m}^3 \) by volume, or tugs or pusher craft built to tow or to push or to move alongside vessels of \( \geq 20 \) meters. Implementation of this standard began in January 2006 and will be phased in by January 2007. Test procedures specified by ISO 8178-4:2002 and IMO MARPOL 73/74 Annex VI (NOx Code) must be used.
EU Non-Road Mobile Machinery
Emissions: Stage IIIA for Inland Waterway Vessel Engines
(up to 2.5 L/cyl.)

Emissions, g/kW-hr

<table>
<thead>
<tr>
<th>SV&lt;0.9 l/cyl;P&gt;37kW</th>
<th>0.9≤SV&lt;1.2 l/cyl.</th>
<th>1.2≤SV&lt;2.5 l/cyl.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO</td>
<td>HC</td>
<td>NOx</td>
</tr>
<tr>
<td>5.0</td>
<td>4.0</td>
<td>3.0</td>
</tr>
<tr>
<td>7.5</td>
<td>5.0</td>
<td>7.2</td>
</tr>
<tr>
<td>7.5</td>
<td>5.0</td>
<td>7.2</td>
</tr>
<tr>
<td>5.0</td>
<td>3.0</td>
<td>7.2</td>
</tr>
<tr>
<td>0.9</td>
<td>7.2</td>
<td>7.2</td>
</tr>
<tr>
<td>2.0</td>
<td>7.2</td>
<td>7.2</td>
</tr>
</tbody>
</table>

Phase-in Complete: 1/01/2007
EU Non-Road Mobile Machinery Emissions: Stage IIIA for Inland Waterway Vessel Engines (> 2.5 L/cyl.)

- European Stage IIIA standards for engines greater than 2.5 L/cylinder used in inland waterway vessels are summarized in this chart. Inland waterway vessels are defined as \( \geq 20 \) meters long and \( \geq 100 \) m\(^3\) by volume, or tugs or pusher craft built to tow or to push or to move alongside vessels of \( \geq 20 \) meters. Implementation of this standard began in January 2006 and will be phased in by January 2009. Test procedures specified by ISO 8178-4:2002 and IMO MARPOL 73/74 Annex VI (NOx Code) must be used.
# EU Non-Road Mobile Machinery
## Emissions: Stage IIIA for Inland Waterway Vessel Engines (>2.5 L/cyl.)

**Emissions, g/kW-hr**

<table>
<thead>
<tr>
<th>Emissions Type</th>
<th>CO</th>
<th>HC</th>
<th>NOx</th>
<th>PM x 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5≤SV&lt;5 l/cyl.</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>5≤SV&lt;15 l/cyl.</td>
<td>7.2</td>
<td>7.2</td>
<td>7.2</td>
<td>7.2</td>
</tr>
<tr>
<td>15≤SV&lt;20 l/cyl. P&lt;3300kW</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>15≤SV&lt;20 l/cyl. P&gt;3300kW</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>20≤SV&lt;25 l/cyl.</td>
<td>8.7</td>
<td>8.7</td>
<td>8.7</td>
<td>8.7</td>
</tr>
<tr>
<td>20≤SV&lt;30 l/cyl.</td>
<td>9.8</td>
<td>9.8</td>
<td>9.8</td>
<td>9.8</td>
</tr>
<tr>
<td>0.0≤SV&lt;20 l/cyl.</td>
<td>11.0</td>
<td>11.0</td>
<td>11.0</td>
<td>11.0</td>
</tr>
</tbody>
</table>

**Phase-in Complete: 1/01/2009**
EU Non-Road Mobile Machinery
Emissions: Railcar Engines

European standards for non-road mobile machine emissions from railcars are summarized in this chart. Implementation of this standard began in January 2006 and will be phased in by January 2012. The standard will be implemented in two stages. An 8-mode test cycle of various load stages at rated and intermediate speeds plus an idle will be used to evaluate railcar engines.
Non-Road Mobile Machinery Emissions: Railcar Engines

Emissions, g/kW-hr

- CO
- HC
- NOx
- PM x 10

P>130kW

III A: 1/01/2006

P>130kW

III B: 1/01/2012
European standards for non-road mobile machine emissions from locomotive engines are summarized in this chart. Implementation of this standard begins in January 2007 and will be phased in by January 2012. The standard will be implemented in two stages. A three mode test cycle (full load at rated speed; 50% load at intermediate speed; and idle) is used to evaluate locomotive engines.
Non-Road Mobile Machinery Emissions: Locomotive Engines

Emissions, g/kW-hr

<table>
<thead>
<tr>
<th>Power Range</th>
<th>CO</th>
<th>HC</th>
<th>NOx</th>
<th>PM x 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>130kW ≤ P &lt; 560kW</td>
<td>3.5</td>
<td>4.0</td>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td>P &gt; 560kW</td>
<td>3.5</td>
<td>0.4</td>
<td>6.0</td>
<td></td>
</tr>
<tr>
<td>P &gt; 2000kW; SV &gt; 5 l/cyl.</td>
<td>3.5</td>
<td>0.4</td>
<td>7.4</td>
<td></td>
</tr>
<tr>
<td>P &gt; 130kW</td>
<td>3.5</td>
<td>4.0</td>
<td>4.0</td>
<td>0.25</td>
</tr>
</tbody>
</table>

European Union Fuel Sulfur Caps

European Union fuel sulfur limits for gasoline and diesel are summarized above. Sulfur caps began in 2000 and are reduced significantly in 2005 to 50 ppm max. for both fuel types. Further reductions in fuel sulfur level begin in 2009 with both gasoline and diesel on-road fuels limited to 10 ppm S max.
European Union Fuel Sulfur Caps

Max. Fuel S levels, ppm

<table>
<thead>
<tr>
<th>Year</th>
<th>Gasoline</th>
<th>Diesel</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>150</td>
<td>350</td>
</tr>
<tr>
<td>2005</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>2009</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>
The European driving cycle is broken into two parts. Part 1 (ECE) is the urban or city driving cycle. This cycle is low speed and features 4 similar series of accelerations and decelerations. Part 2 (EUDC) is the highway cycle which includes vehicle speeds up to 120 km/h. Current Stage 2 standards employ this complete driving cycle with a 40 s idle period before sampling of the exhaust tailpipe gases begin. This idle period provides for some degree of converter warm-up before emissions sampling begins. As noted above with the onset of Stage 3 standards this 40 s idle period will be eliminated, placing greater importance on the cold-start vehicle operation. In general the European driving cycle's urban driving sequence is "colder" than Bag 1 of the FTP due to its lower driving speeds.
European MVEG-A Driving Cycle
ECE + EUUDC

(ECE cycle = City driving cycle)

Part 1

Part 2

(EUUDC)

Duration of cycle (total) = 1220 s
Length of cycle (total) = 11.007 km
V_{average} = 32.5 km/h
V_{max} = 120 km/h

1) EUUDC = Extra Urban Driving Cycle (EUUDC)
2) Begin of sampling (after 40 s)
3) End of sampling (1220 s)

Note: 40 sec. idle eliminated for Stage III (2000) & Stage IV (2005) standards
Russia Light-Duty Emission Standards based on Euro 2 MVEG-A test cycle w/40 sec. idle before sampling

- This chart summarizes European Stage 2 standards for passenger cars. Standards are shown for gasoline, indirect injection diesel (IDI), and direct injection diesel (DI) engines. Diesel standards include regulations on particulate matter (PM). These Stage 2 standards are measured using the European MVEG-A driving cycle (see chart under test cycles) with a 40 s idle period before emissions sampling begins. Euro 2 standards became effective in Russia starting January 1, 2006. The Russians have indicated their intent to introduce Euro 3 standards for light-duty vehicles in 2008 and Euro 4 standards in 2010.
Russia Light-Duty Emission Standards based on Euro 2 MVEG-A test cycle w/40 sec. idle before sampling
Euro 2 standards for heavy-duty diesel engine vehicles are summarized in this chart. Emissions for heavy-duty diesel engines are measured using the R49 13 mode engine test cycle. These Euro 2 standards apply to vehicles with GVW > 3500 kg. These standards include limits on particulate matter (PM) for diesel engines. Two sets of PM standards are included in these regulations. For Euro 2 standards, the higher PM level applies to engines with displacements < 700 cc and a speed rating > 3000 rpm. Russia introduced these Euro 2 heavy-duty diesel engine standards starting January 1, 2006. Russia has announced their intention to implement Euro 3 standards in 2008, Euro 4 standards in 2010, and Euro 5 standards for heavy-duty engines in 2014.
Russia Heavy-Duty Diesel Emission Standards Based on Euro 2: ECE R49 13 Mode Engine Test

Emissions, g/kWh

Euro 2 - 1/1/06
Heavy-duty vehicles defined as GVW > 3500 kg
PM(a): engines<700 cc with rated speed>3000 rpm