

Mobile Emissions Regulations and Legislation

Representatives of automobiles



**Gasoline fueled car:
Sonata of Hyundai Motors**



H₂-powered car: BMW 750hL



**Diesel fueled car:
Volkswagen Jetta TDI**



**CNG-powered car:
Honda Civic**



**LPG fueled car:
Camry of Toyota Motors**



**Gasoline-Electric Hybrid Car:
Prius of Toyota Motors (Oct. 2003)**

Representative mobile emission sources

Vehicles, trains and motor bicycles

- Gasoline engines
- Diesel engines
- CNG engines
- LPG engines



Ships

- Cargo vessels
- Tankships (Oil tankers)
- Ocean liners
- Cruise ships

Worldwide markets of gasoline and diesel automobiles



Fuel economy and mileage CO₂ emission limits*

For light-duty vehicles - new passenger cars and vans

| Country | | Implementation | | | | | | | | | | |
|------------------|------|----------------|------|------|------|------|-------|-------------------|------|------|------|------|
| | | 2004 | 2005 | 2007 | 2008 | 2010 | 2012 | 2015 | 2016 | 2017 | 2020 | 2021 |
| EU | Cars | | 186 | | 140 | | 132.2 | 130 ^a | | | | 95 |
| | Vans | | | 203 | | | 180.2 | | | 175 | 147 | |
| USA ^b | | 27.5 | | 27.5 | | 35.5 | 33.6 | 36.4 ^c | 38.2 | 39.6 | 44.2 | 46.1 |

Note. The unit is the respective g CO₂/km and mpg (mile per gallon fuel) for EU and USA.

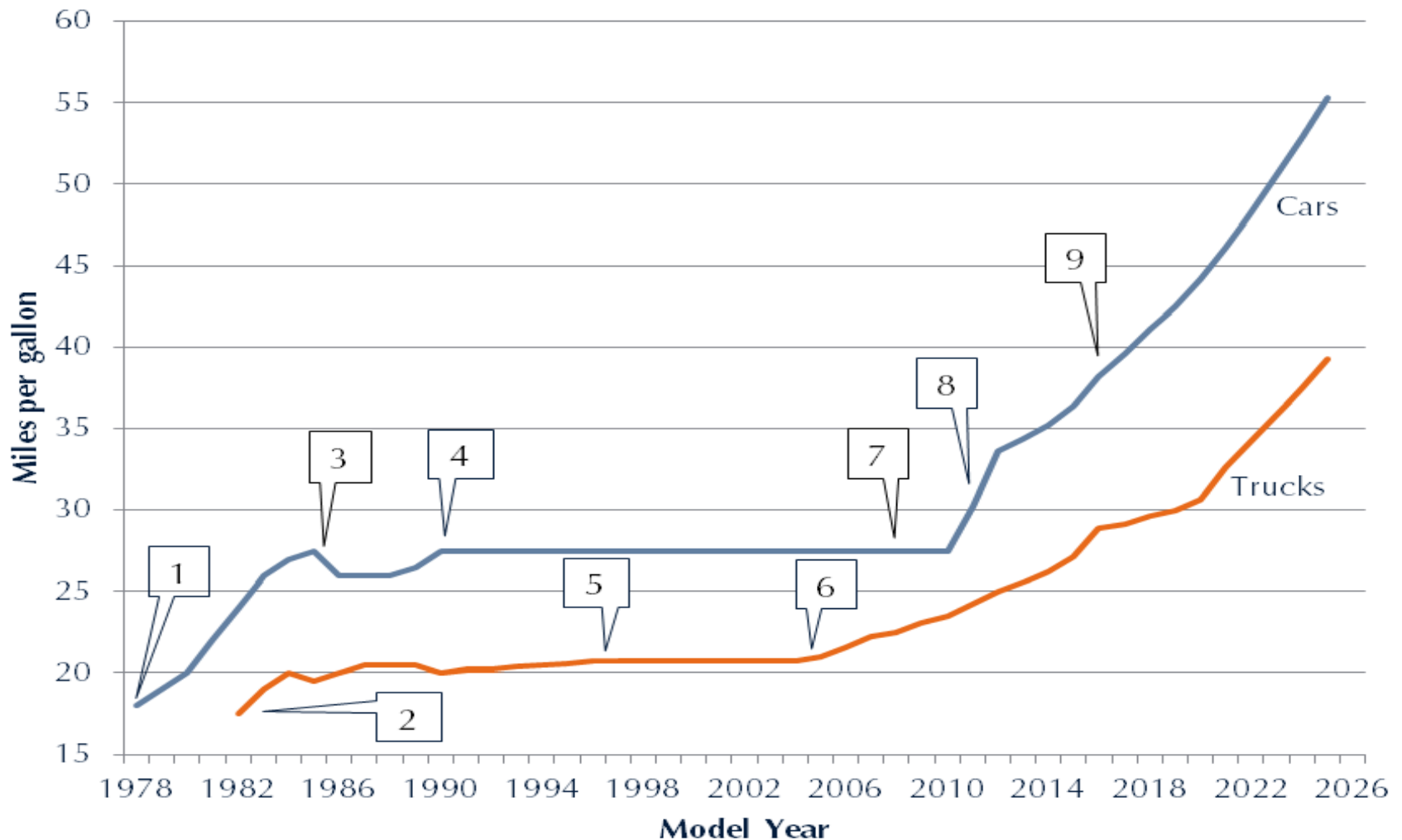
^a This target equates approximately 17.9 km/L for petrol cars.

^b Known as the corporate average fuel economy (CAFE) program since 1975.

^c This mpg corresponds to ca. 146 g CO₂-e/km.

*** In USA, mileage CO₂ emission limits were phased-in to PCs and LDTs from MY 2009 and will be complete in 2016.**

Future USA CO₂ emission legislation



Source: NHTSA MY 2017 – 2025 Factsheets

CO₂ emissions from domestic sales cars

| Car model | Car maker | Fuel | Engine Displacement (cm ³) | Fuel economy (km/L) | CO ₂ emissions (g/km) |
|-------------------------|-----------------|----------|--|---------------------|----------------------------------|
| Prius Hybrid | Toyota | Gasoline | 1798 | 29.2 | 80 |
| Avante 1.6 LPI Hybrid | Hyundai | LPG | 1591 | 17.8 | 99 |
| Civic Hybrid | Honda | Gasoline | 1339 | 23.2 | 101 |
| Morning 1.0 | KIA | Gasoline | 999 | 21.2 | 110 |
| Martiz 1.0 DOHC MT | GM-Daewoo | Gasoline | 995 | 21.0 | 111 |
| Golf 1.6 TDI Bluemotion | Volkswagen | Diesel | 1598 | 21.9 | 122 |
| 308 1.6 HDi MCP E5 | Peugeot | Diesel | 1560 | 21.2 | 127 |
| Accent 1.6 GDI | Hyundai | Gasoline | 1591 | 18.2 | 128 |
| i30 1.6 | Hyundai | Diesel | 1582 | 20.5 | 131 |
| Avante 1.6 GDI | Hyundai | Gasoline | 1591 | 16.5 | 142 |
| Golf 2.0 TDI | Volkswagen | Diesel | 1968 | 17.9 | 150 |
| K5 2.0 | KIA | Gasoline | 1998 | 13.8 | 170 |
| SM3 | Renault-Samsung | Gasoline | 1998 | 13.2 | 177 |
| Passat 2.0 TDI | Volkswagen | Diesel | 1968 | 15.1 | 178 |
| Sonata 2.0 | Hyundai | Gasoline | 1998 | 13.0 | 180 |
| Camry | Toyota | Gasoline | 2494 | 12.0 | 196 |
| K7 2.7 | KIA | Gasoline | 2656 | 11.0 | 212 |
| Eguus 3.8 | Hyundai | Gasoline | 3887 | 9.3 | 252 |
| Benz E300 | Benz | Gasoline | 3498 | 9.2 | 254 |

Note. The fuel economy values may vary slightly with transmission types and gross vehicle weights.

Source: <http://bpm.kemco.or.kr/transport/>.

Implementation of automotive emission standards

| | Year | | | | | | | | | | | | |
|------------------------------|-----------------------|----------------------|------|------|---------------------|------|----------------------|------|------|------|-----------------------|------|-----------------------|
| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
| Emission standard California | LEV II ^a | | | | | | | | | | | | |
| USA | Tier 2 ^b | | | | | | | | | | Tier 3 ^{c,d} | | Tier 4 ^d |
| EU | EURO III ^e | EURO IV ^f | | | EURO V ^g | | EURO VI ^d | | | | | | EURO VII ^d |

Note. LEV: low emission vehicle.

^aPhase-in until 2010.

^bPhase-in until 2009.

^cInterim step prior to Tier 4 standards.

^dBeing underway to determine limit values for engine-out emissions.

^eFrom 2000 to 2004.

^f2006 for Korean (Korean automobile manufacturers association, KAMA) car makers.

^gA preliminary draft proposal for the standards has been produced by the European Commission on July, 2005.

EURO VI: 2010 → 2012 → 2014 (as of 2015)

Tier 3: 2014 → 2016 (as of 2015)

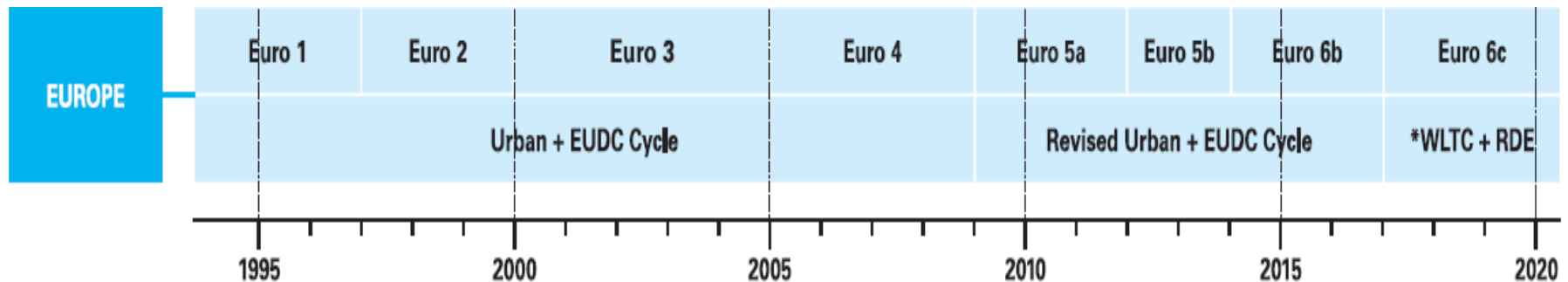
Source: M.H. Kim, Korean J. Chem. Eng., 24 (2007) 209.

Implementation plans of automotive standards

EURO VI: 2010 → 2012 → 2014

Tier 3: 2014 → 2016 → 2017 (phase-in up to 2025)

※ closely aligned with California LEV III standards



* Euro 6c test cycle WLTC: to be confirmed



Source: M.H. Kim, Korean J. Chem. Eng., 24 (2007) 209 and updated as of 31 December 2020.

Tier 2 full useful life emission standards

| | Bin # | Limit values (g/mile) | | | | |
|----------------|---------------------|-----------------------|-------------|---------|-------------|------|
| | | NO _x | NMOG | CO | HCHO | PM |
| Temporary Bins | 11 ^a | 0.9 | 0.280 | 7.3 | 0.032 | 0.12 |
| | 10 ^{b,c,d} | 0.6 | 0.156/0.230 | 4.2/6.4 | 0.018/0.027 | 0.08 |
| | 9 ^{b,e,f} | 0.3 | 0.090/0.180 | 4.2 | 0.018 | 0.06 |
| Permanent Bins | 8 ^e | 0.20 | 0.125/0.156 | 4.2 | 0.018 | 0.02 |
| | 7 | 0.15 | 0.090 | 4.2 | 0.018 | 0.02 |
| | 6 | 0.10 | 0.090 | 4.2 | 0.018 | 0.01 |
| | 5 | 0.07 | 0.090 | 4.2 | 0.018 | 0.01 |
| | 4 | 0.04 | 0.070 | 2.1 | 0.011 | 0.01 |
| | 3 | 0.03 | 0.055 | 2.1 | 0.011 | 0.01 |
| | 2 | 0.02 | 0.010 | 2.1 | 0.004 | 0.01 |
| | 1 | 0.00 | 0.000 | 0.0 | 0.000 | 0.00 |

Note. NMOG: non-methane organic gases. Multiple each limit value by 0.622 to compare it to that in Table 2.

^aThe Bin # applies only to MDPVs and expires after model year 2008.

^bDeleted at end of 2006 for LDVs and LLDTs, and 2008 for HLDTs.

^cThe higher NMOG, CO and HCHO values apply only to HLDTs and expire after 2008.

^dOptional temporary NMOG standard of 0.280 g/mile applies for qualifying LDT4s only.

^eThe higher NMOG value applies only to HLDTs and expires after 2008.

^fOptional temporary NMOG standard of 0.130 g/mile applies for qualifying LDT2s only.

Source: M.H. Kim, Korean J. Chem. Eng., 24 (2007) 209.

Some changes in EPA Tier 3 standards

☐ Both the certification limits (bins) and the fleet average standards

- expressed using the sum of NMOG+NOx emissions

☐ The bins

- named using their corresponding NMOG+NOx limit in mg/mi
- the highest emission bin—Bin 160 (NMOG+NOx = 160 mg/mi), equivalent to Tier 2 Bin 5

☐ The fleet average NMOG+NOx emissions

- must reach 30 mg/mi (Bin 30 = Tier 2 Bin 2) by 2025

☐ The required emission durability

- increased to 150,000 mi up from 120,000 mi

☐ Gasoline vehicles for exhaust and evaporative emissions

- tested using gasoline containing 10% of ethanol (E10)

Tier 3 certification bin standards (FTP cycle, 150,000 miles)

| Bin | NMOG+NOx | PM* | CO | HCHO |
|---------|--------------|--------------|-------------|--------------|
| | <i>mg/mi</i> | <i>mg/mi</i> | <i>g/mi</i> | <i>mg/mi</i> |
| Bin 160 | 160 | 3 | 4.2 | 4 |
| Bin 125 | 125 | 3 | 2.1 | 4 |
| Bin 70 | 70 | 3 | 1.7 | 4 |
| Bin 50 | 50 | 3 | 1.7 | 4 |
| Bin 30 | 30 | 3 | 1.0 | 4 |
| Bin 20 | 20 | 3 | 1.0 | 4 |
| Bin 0 | 0 | 0 | 0 | 0 |

* In MYs 2017-20, the PM standard applies only to that segment of a manufacturer's vehicles covered by the percent of sales phase-in for that model year, Table 3.

Tier 3 fleet average NMOG+NOx standards

| Vehicle Category | 2017* | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
|--|-------|------|------|------|------|------|------|------|------|
| LDV, LDT1 | 86 | 79 | 72 | 65 | 58 | 51 | 44 | 37 | 30 |
| LDT2, LDT3, LDT4, MDPV | 101 | 92 | 83 | 74 | 65 | 56 | 47 | 38 | 30 |
| * For LDVs and LDTs over 6,000 lbs GVWR and MDPVs, the fleet average standards apply beginning in MY 2018. | | | | | | | | | |

- ☐ The fleet average limits must be met by each manufacturer.
- ☐ The final phase-in year standard is applicable to all vehicle categories—an important change from the Tier 2 regulation.

Tier 2 exhaust averaging sets

| | Year | | | | | | | | | Average fleet NO _x standard (g/mile) |
|----------------------------|---------------------------|---------------------------|---------------------------|-------------|-------------|-------------|-----------|-------------|------------|--|
| | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009+later | |
| LDV/LLDT (Interim) | NLEV | NLEV | NLEV | 75% max. | 50% max. | 25% max. | | | | 0.30 |
| LDV/LLDT (Tier 2+Evap.) | <i>early banking</i> a | <i>early banking</i> a | <i>early banking</i> a | 25% | 50% | 75% | 100% | 100% | 100% | 0.07 |
| HLDT (Tier 2+Evap.) | <i>early banking</i> a | <i>early banking</i> a | <i>early banking</i> a | a | a | a | a | 50% | 100% | 0.07 ^b |
| HLDT (Interim) | Tier 1 a | Tier 1 a | Tier 1 a | 25% c,d | 50% d | 75% d | 100% d | 50% max. | | 0.20 ^{b,e} |
| MDPV (Interim) | HDE | HDE | HDE | | | | | | | |
| MDPV (Tier 2+Evap.) | <i>early banking</i> a | <i>early banking</i> a | <i>early banking</i> a | a | a | a | a | 50% | 100% | 0.07 ^b |

Note. Bold lines around shaded areas indicate averaging sets.

^aAlternative phase-in provisions permit manufacturers to deviate from the 25/50/75% 2004-2006 and 50% 2008 phase-in requirements and provide credit for phasing in some vehicles during one or more of these model years.

^bHLDTs and MDPVs must be averaged together.

^cRequired only for manufacturers electing to use optional NMOG values for LDT2s or LDT4s and MDPV flexibilities during the applicable interim program and for vehicles whose model year commences on or after the fourth anniversary date of the signature of this rule.

^dDiesels may be engine-certified through the 2007 model year.

^e0.60 NO_x cap applies to balance of LDT3s/LDT4s, respectively, during the 2004-2006 phase-in years.

Source: M.H. Kim, Korean J. Chem. Eng., 24 (2007) 209.

Current and future EU standards for passenger cars and light commercial vehicles

| Tier | Category | Class | Reference weight (kg) | Limit values for mandatory tailpipe emissions | | | | | | | | | | | | | |
|----------|-----------------------------|-------|--------------------------|---|--------|----------|--------|----------|--------|-----------------|--------|----------------------|--------|--------------------|--------|----------------------|----------------------|
| | | | | CO | | THC | | NMHC | | NO _x | | HC + NO _x | | PM | | PM | |
| | | | | (g/km) | (g/km) | (g/km) | (g/km) | (g/km) | (g/km) | (g/km) | (g/km) | (g/km) | (g/km) | (g/km) | (g/km) | (#/km) | (#/km) |
| | | | | Gasoline | Diesel | Gasoline | Diesel | Gasoline | Diesel | Gasoline | Diesel | Gasoline | Diesel | Gasoline | Diesel | Gasoline | Diesel |
| EURO III | M ^a | All | All | 2.30 | 0.64 | 0.20 | – | – | – | 0.15 | 0.50 | – | 0.56 | – | 0.05 | – | – |
| | N ₁ ^b | I | RW ≤ 1,305 | 2.30 | 0.64 | 0.20 | – | – | – | 0.15 | 0.50 | – | 0.56 | – | 0.05 | – | – |
| | | II | 1,305 < RW ≤ 1,760 | 4.17 | 0.80 | 0.25 | – | – | – | 0.18 | 0.65 | – | 0.72 | – | 0.07 | – | – |
| | | III | 1,760 < RW | 5.22 | 0.95 | 0.29 | – | – | – | 0.21 | 0.78 | – | 0.86 | – | 0.10 | – | – |
| EURO IV | M ^a | All | All | 1.00 | 0.50 | 0.10 | – | – | – | 0.08 | 0.25 | – | 0.30 | – | 0.025 | – | – |
| | N ₁ ^b | I | RW ≤ 1,305 | 1.00 | 0.50 | 0.10 | – | – | – | 0.08 | 0.25 | – | 0.30 | – | 0.025 | – | – |
| | | II | 1,305 < RW ≤ 1,760 | 1.81 | 0.63 | 0.13 | – | – | – | 0.10 | 0.33 | – | 0.39 | – | 0.04 | – | – |
| | | III | 1,760 < RW | 2.27 | 0.74 | 0.16 | – | – | – | 0.11 | 0.39 | – | 0.46 | – | 0.06 | – | – |
| EURO V | M ^a | All | All | 1.00 | 0.50 | 0.100 | – | 0.068 | – | 0.060 | 0.180 | – | 0.230 | 0.005 ^c | 0.005 | | |
| | N ₁ ^b | I | RW ≤ 1,305 | 1.000 | 0.500 | 0.100 | – | 0.068 | – | 0.060 | 0.180 | – | 0.230 | 0.005 ^c | 0.005 | | |
| | | II | 1,305 < RW ≤ 1,760 | 1.810 | 0.630 | 0.130 | – | 0.090 | – | 0.075 | 0.235 | – | 0.295 | 0.005 ^c | 0.005 | | |
| | | III | 1,760 < RW | 2.270 | 0.740 | 0.160 | – | 0.108 | – | 0.082 | 0.280 | – | 0.350 | 0.005 ^c | 0.005 | | |
| EURO VI | M ^a | All | All | 1.000 | 0.500 | 0.100 | – | 0.068 | – | 0.060 | 0.080 | – | 0.170 | 0.045 ^c | 0.045 | 6.0x10 ¹¹ | 6.0x10 ¹¹ |
| | N ₁ ^b | I | RW ≤ 1,305 | 1.000 | 0.500 | 0.100 | – | 0.068 | – | 0.060 | 0.080 | – | 0.170 | 0.045 ^c | 0.045 | 6.0x10 ¹¹ | 6.0x10 ¹¹ |
| | | II | 1,305 < RW ≤ 1,760 | 1.810 | 0.630 | 0.130 | – | 0.090 | – | 0.075 | 0.105 | – | 0.195 | 0.045 ^c | 0.045 | 6.0x10 ¹¹ | 6.0x10 ¹¹ |
| | | III | 1,760 < RW | 2.270 | 0.740 | 0.160 | – | 0.108 | – | 0.082 | 0.125 | – | 0.215 | 0.045 ^c | 0.045 | 6.0x10 ¹¹ | 6.0x10 ¹¹ |

^a Except vehicles the maximum mass of which exceeds 2,500 kg.

^b And those Category M vehicles which are specified in note ^a.

^c PM mass standards apply only to vehicles which use lean burn (LB) direct injection engines.

Source: M.H. Kim, Korean J. Chem. Eng., 24 (2007) 209 and updated as of 31 December 2014.

Joint rulemaking for automotive emission standards



Recently, the US and EU began a joint rulemaking process to harmonize fuel economy, greenhouse gases (GHG) emissions and auto exhaust emissions regulations.