

# Mobile Emissions Regulations and Legislation

# Representatives of automobiles



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



**H<sub>2</sub>-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 CO<sub>2</sub> 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 <sup>a</sup>				95
	Vans			203			180.2			175	147	
USA <sup>b</sup>		27.5		27.5		35.5	33.6	36.4 <sup>c</sup>	38.2	39.6	44.2	46.1

*Note.* The unit is the respective g CO<sub>2</sub>/km and mpg (mile per gallon fuel) for EU and USA.

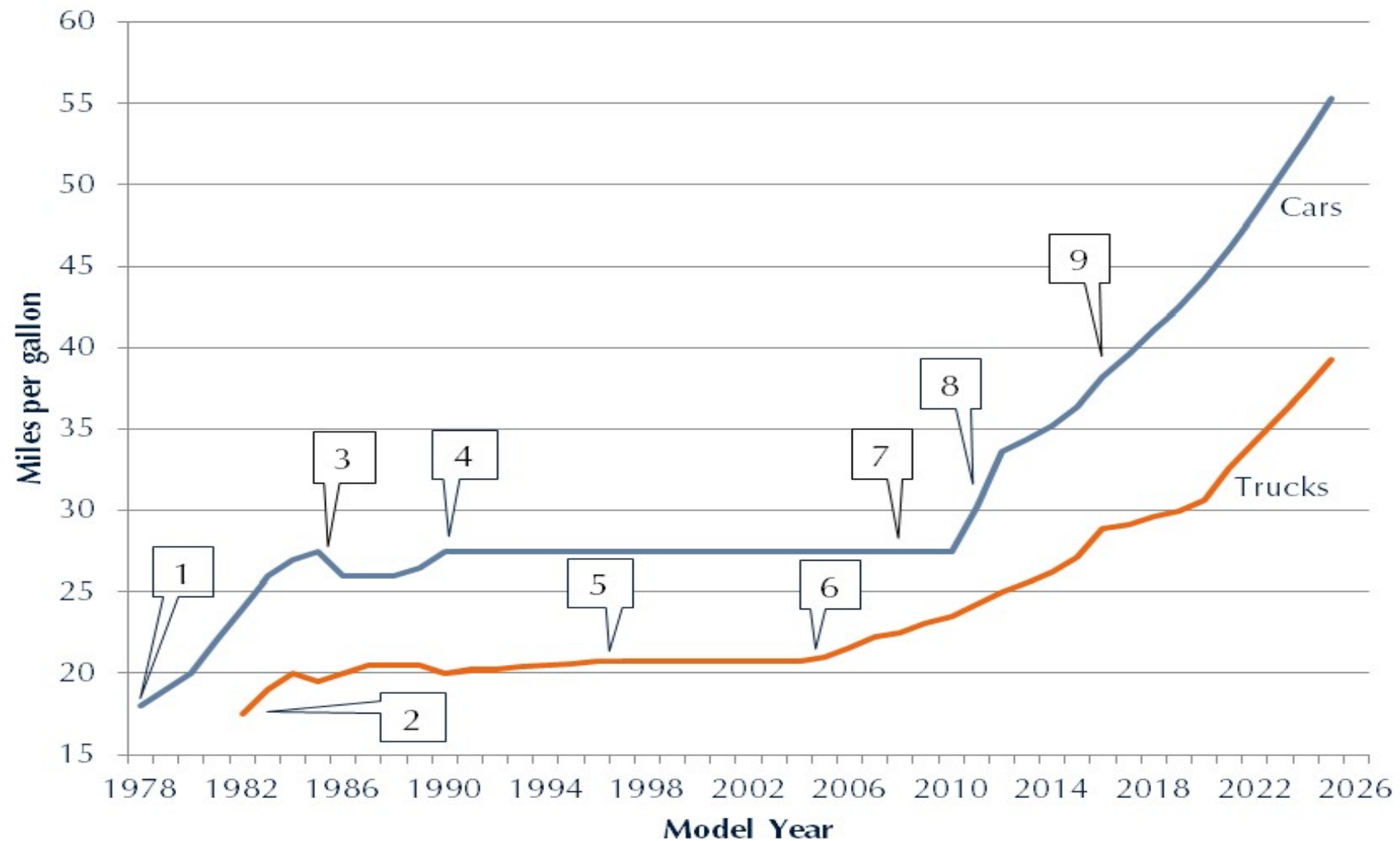
<sup>a</sup> This target equates approximately 17.9 km/L for petrol cars.

<sup>b</sup> Known as the corporate average fuel economy (CAFE) program since 1975.

<sup>c</sup> This mpg corresponds to ca. 146 g CO<sub>2</sub>-e/km.

**\* In USA, mileage CO<sub>2</sub> emission limits were phased-in to PCs and LDTs from MY 2009 and will be complete in 2016.**

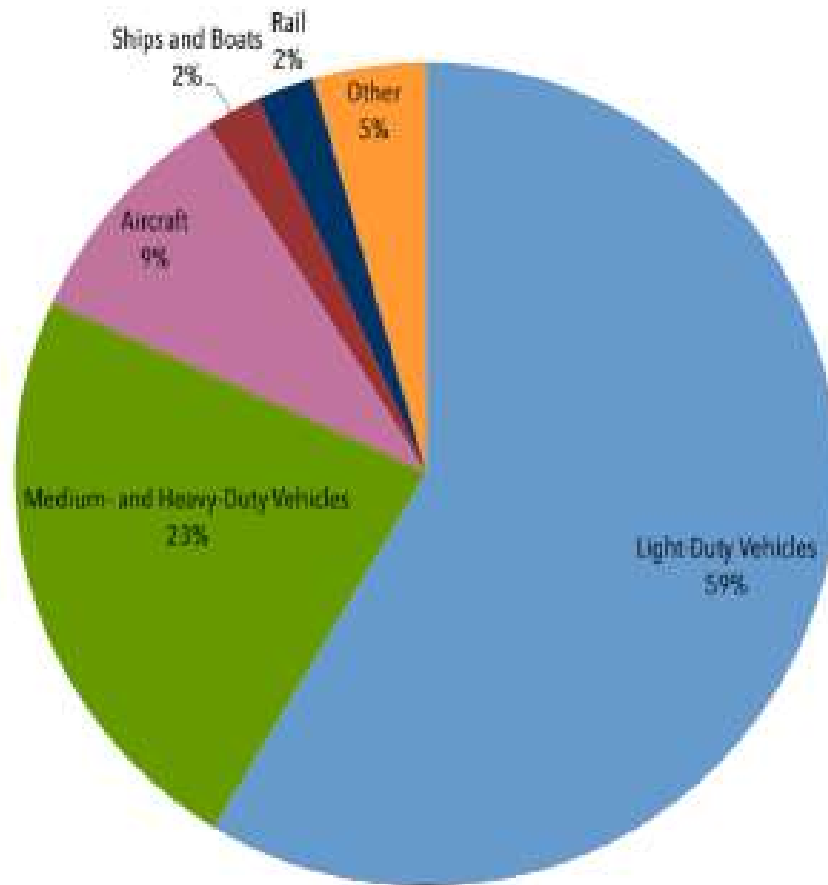
# Current and Future USA CO<sub>2</sub> emission legislation



Source: NHTSA MY 2017 – 2025 Factsheets

# Total U.S. transportation sector emissions in 2018

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- The transportation sector surpasses the power sector in 2015.
- Cars and light-duty trucks (including pickups and SUVs) are responsible for about 59% of transportation emissions.
- Medium- and heavy-duty vehicles, which include tractor-trailers, large pickups and vans, delivery trucks, buses, and garbage trucks, produce about 23% of transportation emissions.

Source: EPA, "Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2018", 2020.

# Safer Affordable Fuel Efficient (SAFE) Vehicles Rule

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- In October 2012, EPA and NHTSA (National Highway Traffic Safety Administration) finalized the second set of national program standards for model year 2017–2025 light-duty vehicles with the cooperation of major automakers and the state of California.
- Now replaced by **the Trump Administration's 2021–2026 standards**, these standards aimed to raise the combined average fleet fuel efficiency to 46.7 mpg for model year 2025.
- In April 2018, the Trump administration issued a reconsideration of the midterm evaluation for greenhouse gas emission standards for model year 2022–2025 light-duty vehicles. EPA concluded that the standards were based on outdated information and that more recent information suggested that the current standards may be too stringent, making vehicles less affordable. EPA concluded that since the 2012 rulemaking finalizing the initial standards, expectations about gas prices and consumer adoption of advanced technology vehicles had changed.



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- In response, a California-led group of 17 states and the District of Columbia sued in federal court to challenge EPA's reconsideration.
  - The group includes California, Connecticut, Delaware, the District of Columbia, Illinois, Iowa, Maine, Maryland, Massachusetts, Minnesota, New Jersey, New York, Oregon, Pennsylvania, Rhode Island, Vermont, Virginia, and Washington. The lawsuit alleges that EPA's decision lacked scientific justification. In November 2019, the DC Circuit dismissed the lawsuit.
  - California also announced in May 2018 it would consider amending its regulations so that only automakers that comply with the Obama administration greenhouse gas emissions standards will be “deemed to comply” with California standards and that **compliance with any new emissions standards set under the Trump administration may not equate to compliance with California standards.**

# Safer Affordable Fuel Efficient (SAFE) Vehicles Rule

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- In March 2020, EPA and NHTSA (National Highway Traffic Safety Administration) issued new greenhouse gas emission standards and fuel economy standards for new passenger cars and light-duty trucks.
- **The SAFE rule requires automakers to improve fuel efficiency 1.5 percent annually from model years 2021 through 2026.**
- **This rule is less stringent than the Obama-era rule that would have required automakers to improve fuel efficiency 5 percent annually for model year 2020–2025 vehicles.**

# Fleet-wide CO<sub>2</sub> and Fuel Economy Standards

Projected 2021–2026

Vehicle	Standard	2020	2021	2022	2023	2024	2025	2026
Passenger Cars	CO <sub>2</sub> (g/mi)	187	178	175	171	168	167	165
	CAFE (mpg)	43.6	44.2	44.9	45.6	46.3	47.0	47.7
Light Trucks	CO <sub>2</sub> (g/mi)	268	257	253	250	248	245	240
	CAFE (mpg)	31.1	31.6	32.1	32.6	33.1	33.6	34.1
Combined Cars & Light Trucks	CO <sub>2</sub> (g/mi)	224	214	211	207	204	202	199
	CAFE (mpg)	36.8	37.3	37.9	38.5	39.1	39.8	40.4

# CO<sub>2</sub> emissions from domestic sales cars

Car model	Car maker	Fuel	Engine Displacement (cm <sup>3</sup> )	Fuel economy (km/L)	CO <sub>2</sub> 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 standardCalifornia	LEV II <sup>a</sup>												
USA	Tier 2 <sup>b</sup>										Tier 3 <sup>c,d</sup>		Tier 4 <sup>d</sup>
EU	EURO III <sup>e</sup>	EURO IV <sup>f</sup>			EURO V <sup>g</sup>		EURO VI <sup>d</sup>						EURO VII <sup>d</sup>

Note. LEV: low emission vehicle.

<sup>a</sup>Phase-in until 2010.

<sup>b</sup>Phase-in until 2009.

<sup>c</sup>Interim step prior to Tier 4 standards.

<sup>d</sup>Being underway to determine limit values for engine-out emissions.

<sup>e</sup>From 2000 to 2004.

<sup>f</sup>2006 for Korean (Korean automobile manufacturers association, KAMA) car makers.

<sup>g</sup>A 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)**

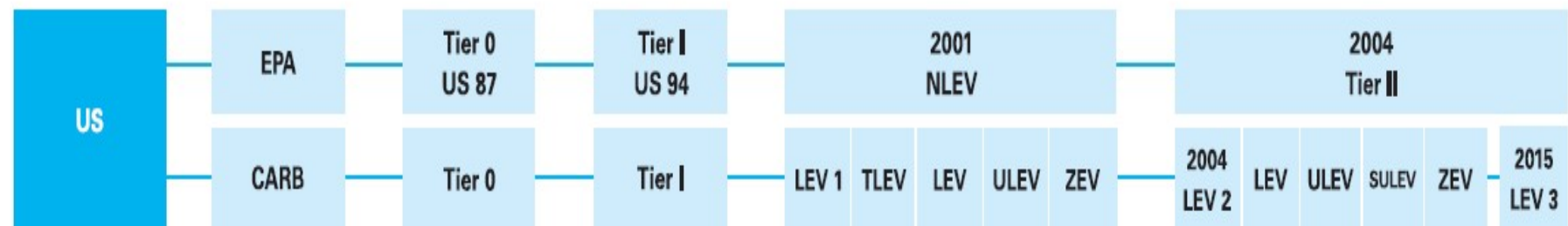
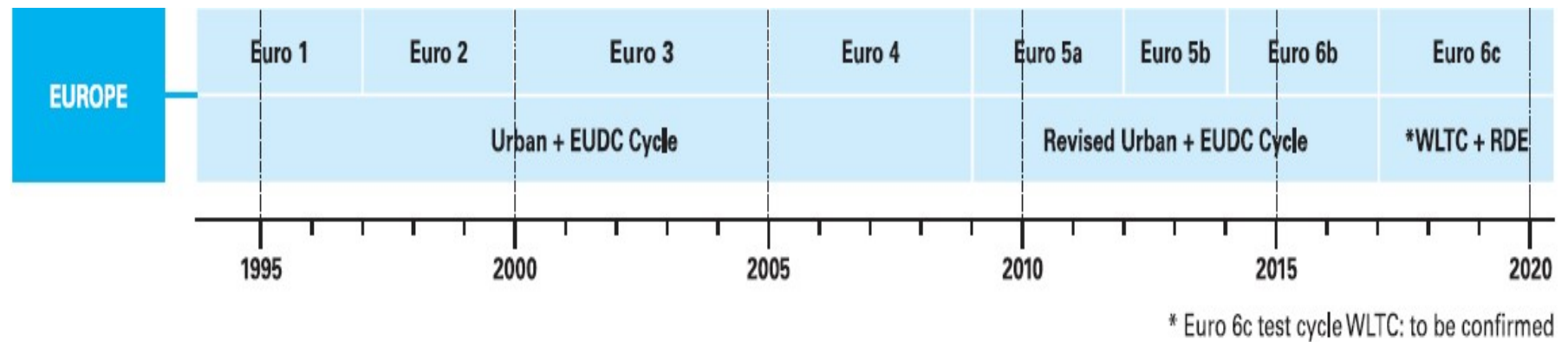
Source: M.H. Kim, Korean J. Chem. Eng., 24 (2007) 209.

# 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



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 <sub>x</sub>	NMOG	CO	HCHO	PM
Temporary Bins	11 <sup>a</sup>	0.9	0.280	7.3	0.032	0.12
	10 <sup>b,c,d</sup>	0.6	0.156/0.230	4.2/6.4	0.018/0.027	0.08
	9 <sup>b,e,f</sup>	0.3	0.090/0.180	4.2	0.018	0.06
Permanent Bins	8 <sup>e</sup>	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.

<sup>a</sup>The Bin # applies only to MDPVs and expires after model year 2008.

<sup>b</sup>Deleted at end of 2006 for LDVs and LLDTs, and 2008 for HLDTs.

<sup>c</sup>The higher NMOG, CO and HCHO values apply only to HLDTs and expire after 2008.

<sup>d</sup>Optional temporary NMOG standard of 0.280 g/mile applies for qualifying LDT4s only.

<sup>e</sup>The higher NMOG value applies only to HLDTs and expires after 2008.

<sup>f</sup>Optional 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

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- 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

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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 <sub>x</sub> 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 <sup>b</sup>
HLDT (Interim)	Tier 1 a	Tier 1 a	Tier 1 a	25% c,d	50% d	75% d	100% d	50% max.		0.20 <sup>b,e</sup>
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 <sup>b</sup>

Note. Bold lines around shaded areas indicate averaging sets.

<sup>a</sup>Alternative 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.

<sup>b</sup>HLDTs and MDPVs must be averaged together.

<sup>c</sup>Required 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.

<sup>d</sup>Diesels may be engine-certified through the 2007 model year.

<sup>e</sup>0.60 NO<sub>x</sub> 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.



# EURO emission standards vehicle categories

Category	Description
M	Motor vehicles with at least four wheels designed and constructed for the carriage of passengers
M <sub>1</sub>	Vehicles designed and constructed for the carriage of passengers and comprising no more than eight seats in addition to the driver's seat
M <sub>2</sub>	Vehicles designed and constructed for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass ("technically permissible maximum laden mass") not exceeding 5 tonnes
M <sub>3</sub>	Vehicles designed and constructed for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass exceeding 5 tonnes
N	Motor vehicles with at least four wheels designed and constructed for the carriage of goods
N <sub>1</sub>	Vehicles designed and constructed for the carriage of goods and having a maximum mass not exceeding 3.5 tonnes
N <sub>2</sub>	Vehicles designed and constructed for the carriage of goods and having a maximum mass exceeding 3.5 tonnes but not exceeding 12 tonnes
N <sub>3</sub>	Vehicles designed and constructed for the carriage of goods and having a maximum mass exceeding 12 tonnes
O	Trailers (including semi-trailers)
O <sub>1</sub>	Trailers with a maximum mass not exceeding 0.75 tonnes
O <sub>2</sub>	Trailers with a maximum mass exceeding 0.75 tonnes but not exceeding 3.5 tonnes
O <sub>3</sub>	Trailers with a maximum mass exceeding 3.5 tonnes but not exceeding 10 tonnes
O <sub>4</sub>	Trailers with a maximum mass exceeding 10 tonnes
G*	Off-Road Vehicles
* Combined designation—Symbol G is combined with either symbol M or N. For example, a vehicle of category N <sub>1</sub> which is suited for off-road use is designated as N <sub>1</sub> G.	



# 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 <sub>x</sub>		HC + NO <sub>x</sub>		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 <sup>a</sup>		All	2.30	0.64	0.20	–	–	–	0.15	0.50	–	0.56	–	0.05	–	–
	N <sub>1</sub> <sup>b</sup>	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 <sup>a</sup>		All	1.00	0.50	0.10	–	–	–	0.08	0.25	–	0.30	–	0.025	–	–
	N <sub>1</sub> <sup>b</sup>	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 <sup>a</sup>		All	1.00	0.50	0.100	–	0.068	–	0.060	0.180	–	0.230	0.005 <sup>c</sup>	0.005		
	N <sub>1</sub> <sup>b</sup>	I	RW ≤ 1,305	1.000	0.500	0.100	–	0.068	–	0.060	0.180	–	0.230	0.005 <sup>c</sup>	0.005		
		II	1,305 < RW ≤ 1,760	1.810	0.630	0.130	–	0.090	–	0.075	0.235	–	0.295	0.005 <sup>c</sup>	0.005		
		III	1,760 < RW	2.270	0.740	0.160	–	0.108	–	0.082	0.280	–	0.350	0.005 <sup>c</sup>	0.005		
EURO VI	M <sup>a</sup>		All	1.000	0.500	0.100	–	0.068	–	0.060	0.080	–	0.170	0.045 <sup>c</sup>	0.045	6.0x10 <sup>11</sup>	6.0x10 <sup>11</sup>
	N <sub>1</sub> <sup>b</sup>	I	RW ≤ 1,305	1.000	0.500	0.100	–	0.068	–	0.060	0.080	–	0.170	0.045 <sup>c</sup>	0.045	6.0x10 <sup>11</sup>	6.0x10 <sup>11</sup>
		II	1,305 < RW ≤ 1,760	1.810	0.630	0.130	–	0.090	–	0.075	0.105	–	0.195	0.045 <sup>c</sup>	0.045	6.0x10 <sup>11</sup>	6.0x10 <sup>11</sup>
		III	1,760 < RW	2.270	0.740	0.160	–	0.108	–	0.082	0.125	–	0.215	0.045 <sup>c</sup>	0.045	6.0x10 <sup>11</sup>	6.0x10 <sup>11</sup>

<sup>a</sup> Except vehicles the maximum mass of which exceeds 2,500 kg.

<sup>b</sup> And those Category M vehicles which are specified in note <sup>a</sup>.

<sup>c</sup> 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

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