Mobile Emissions Regulations and Legislation

Representatives of automobiles

Gasoline fueled car:
Sonata of Hyundai Motors

H_2-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)

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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 automotives

Fuel economy and mileage CO_2 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 CO_2/km and mpg (mile per gallon fuel) for EU and USA.

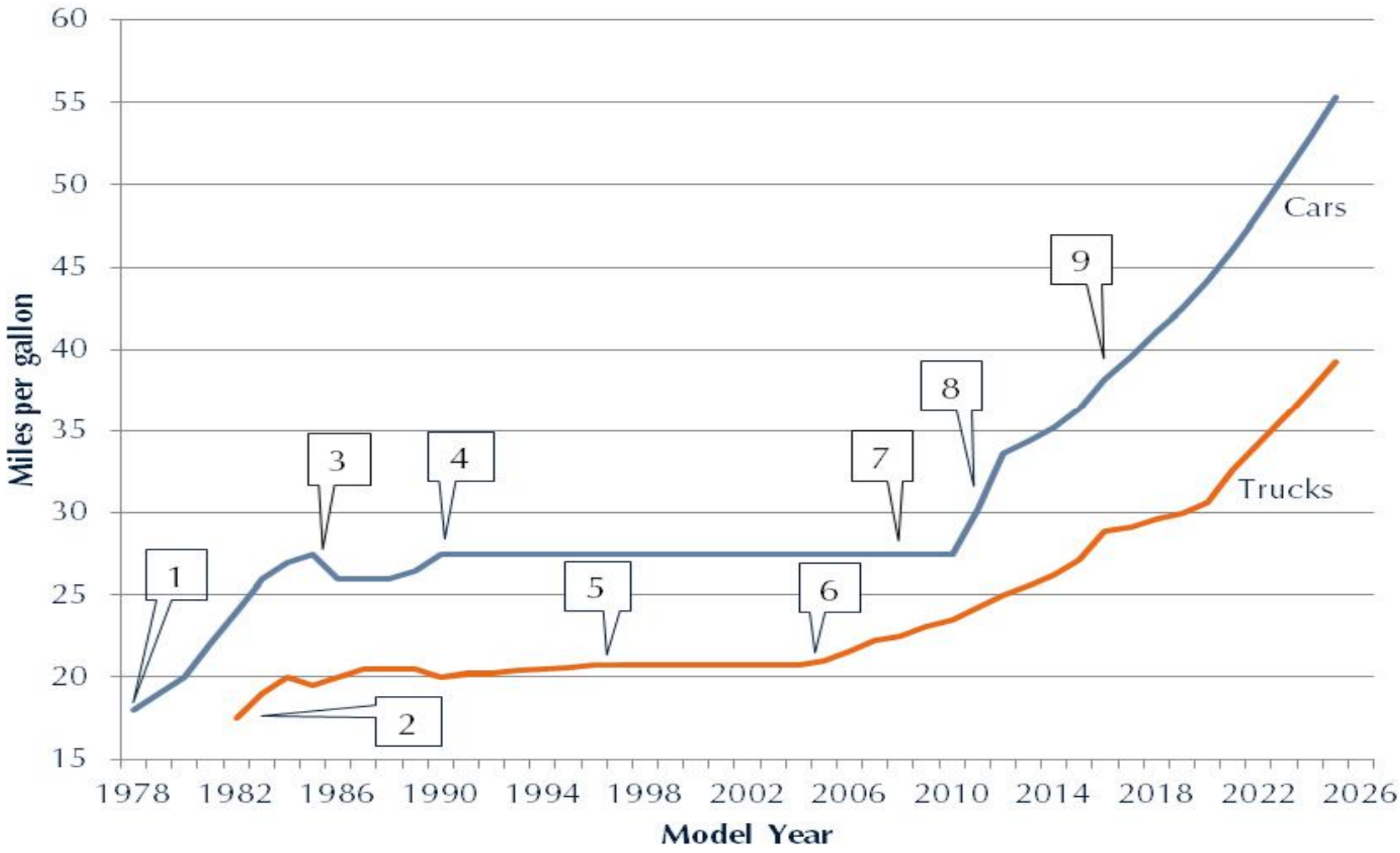
[a] This target equates approximately 17.9 km/L for petrol cars.

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

[c] This mpg corresponds to ca. 146 g CO_2-e/km.

*** In USA, mileage CO_2 emission limits were phased-in to PCs and LDTs from MY 2009 and will be complete in 2016.**

Future USA CO_2 emission legislation



Source: NHTSA MY 2017 – 2025 Factsheets

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CO_2 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.

[a]Phase-in until 2010.

[b]Phase-in until 2009.

[c]Interim step prior to Tier 4 standards.

[d]Being underway to determine limit values for engine-out emissions.

[e]From 2000 to 2004.

[f]2006 for Korean (Korean automobile manufacturers associaition, KAMA) car makers.

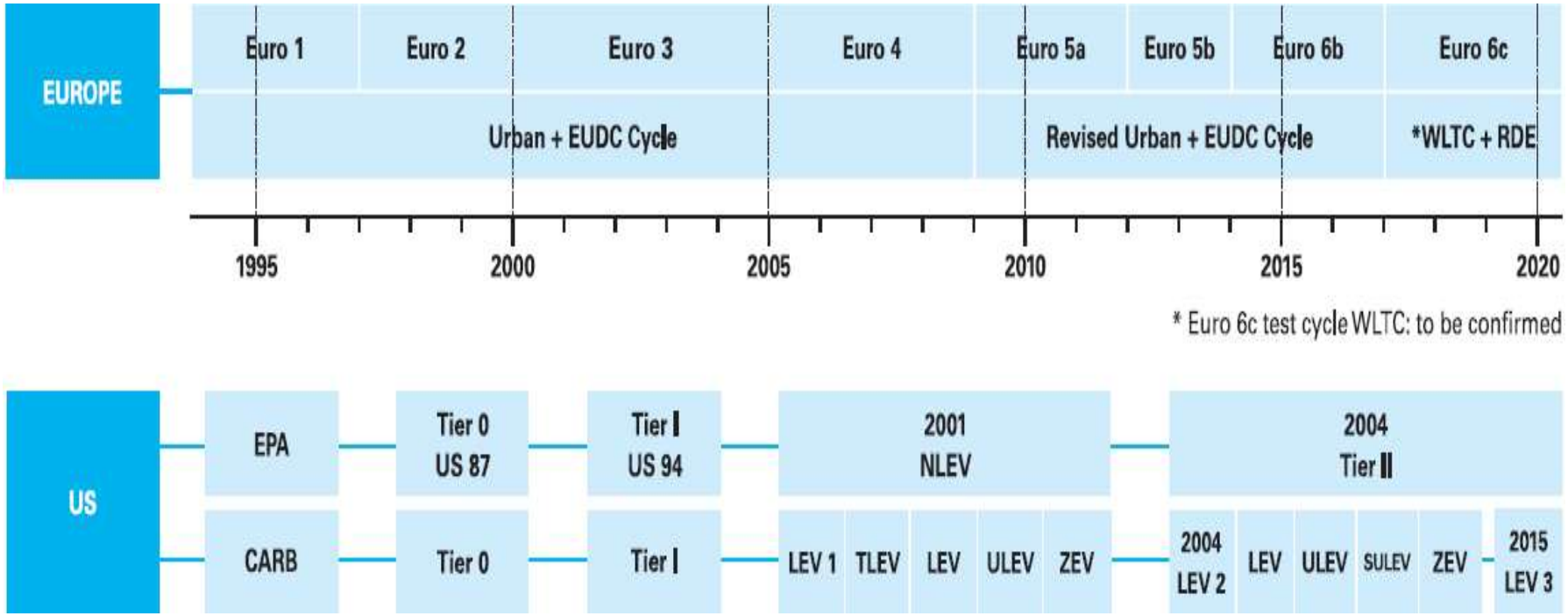
[g]A preliminary draft proposal for the standards has been produced by the European Commission on July, 2005.

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 (as of 2012)
Tier 3: 2014 → 2016 (as of 2012)



Source: M.H. Kim, Korean J. Chem. Eng., 24 (2007) 209 and updated as of 31 December 2015.

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.

[a]The Bin # applies only to MDPVs and expires after model year 2008.

[b]Deleted at end of 2006 for LDVs and LLDTs, and 2008 for HLDTs.

[c]The higher NMOG, CO and HCHO values apply only to HLDTs and expire after 2008.

[d]Optional temporary NMOG standard of 0.280 g/mile applies for qualifying LDT4s only.

[e]The higher NMOG value applies only to HLDTs and expires after 2008.

[f]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.

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.)	***early banking*** **a**	**a**	**a**	**25%**	**50%**	**75%**	**100%**	**100%**	**100%**	0.07
HLDT (Tier 2+Evap.)	***early banking*** **a**	**a**	**a**	**a**	**a**	**a**	**a**	**50%**	**100%**	0.07[b]
HLDT (Interim)	Tier 1 a	Tier 1 a	Tier 1 a	**25%**	**50%**	**75%**	**100%**	**50%**		0.20[b,e]
MDPV (Interim)	HDE	HDE	HDE	**c,d**	**d**	**d**	**d**	**max.**		
MDPV (Tier 2+Evap.)	***early banking*** **a**	**a**	**a**	**a**	**a**	**a**	**a**	**50%**	**100%**	0.07[b]

Note. Bold lines around shaded areas indicate averaging sets.

[a]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.

[b]HLDTs and MDPVs must be averaged together.

[c]Required only for manufacturers electing to use optional NMOG values for LDT2s or LDT4s and MDPV flexibilities during the appli cable interim program and for vehicles whose model year commences on or after the fourth anniversary date of the signature of this rule.

[d]Diesels may be engine-certified through the 2007 model year.

[e]0.60 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 (g/km)		THC (g/km)		NMHC (g/km)		NO_x (g/km)		$HC + NO_x$ (g/km)		PM (g/km)		PM (#/km)	
				Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel
EURO III	M[a]		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	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	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	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.