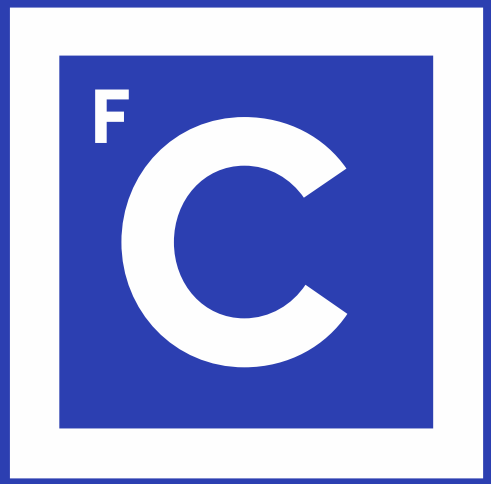


Ciências ULisboa

Faculdade
de Ciências
da Universidade
de Lisboa

DISCIPLINA MIEA 2016

Sustainable Mobility

Emission factors….g/pkm

European Environment Agency

EEA Report | No 21/2016

EMEP/EEA air pollutant emission inventory guidebook 2016

Technical guidance to prepare national emission inventories

ISSN 1977-8449

Emission factors….g/pkm

EMEP/EEA air pollutant emission inventory guidebook

- Part B: sectoral guidance chapters
  - 1. Energy
    - 1.A Combustion
      - 1.A.1 Energy industries [2.4 MB]
      - 1.A.2 Manufacturing industries and construction [893.2 KB]
      - 1.A.3.a Aviation 2016 [1.5 MB]
      - 1.A.3.b.i-iv Road transport 2016 [3.3 MB]
      - 1.A.3.b.i-iv Road transport Annex HDVs 2016 [3.0 MB]
      - 1.A.3.b.v Gasoline evaporation 2016 [861.2 KB]
      - 1.A.3.b.vi-vii Road tyre and brake wear 2016 [542.7 KB]
      - 1.A.3.c Railways 2016 [476.0 KB]
      - 1.A.3.d Navigation (shipping) 2016 [804.2 KB]
      - 1.A.3.e.i Pipeline transport 2016 [93.3 KB]
      - 1.A.4 Small combustion 2016 [3.5 MB]
      - 1.A.4 Non road mobile machinery 2016 [1.7 MB]
      - 1.A.4 Non road mobile machinery Annex [99.6 KB]

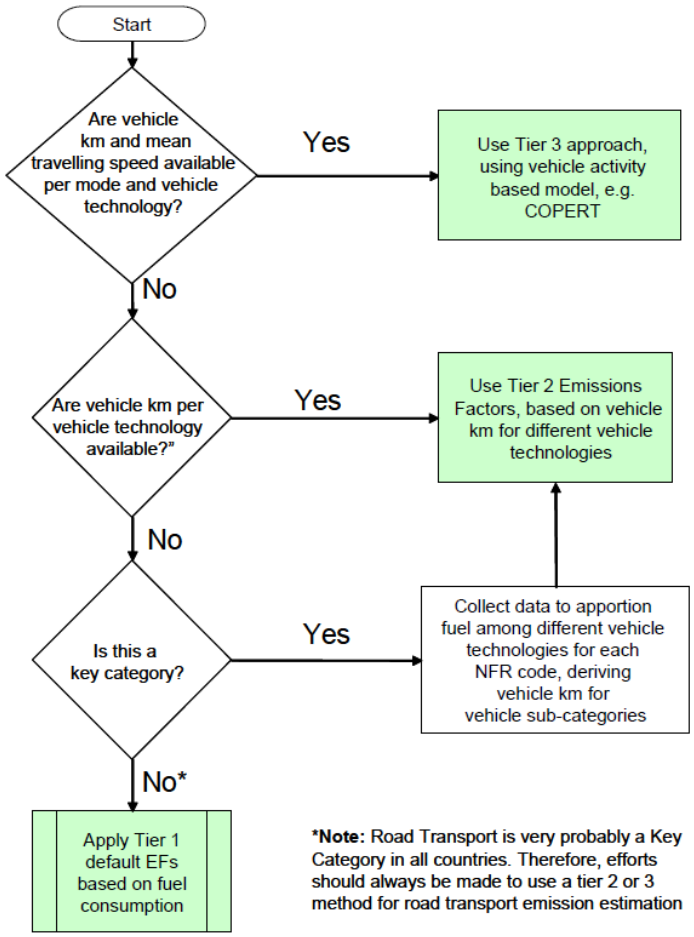
Not electric rail!

Road transport

1.A.3.b.i, 1.A.3.b.ii, 1.A.3.b.iii, 1.A.3.b.iv

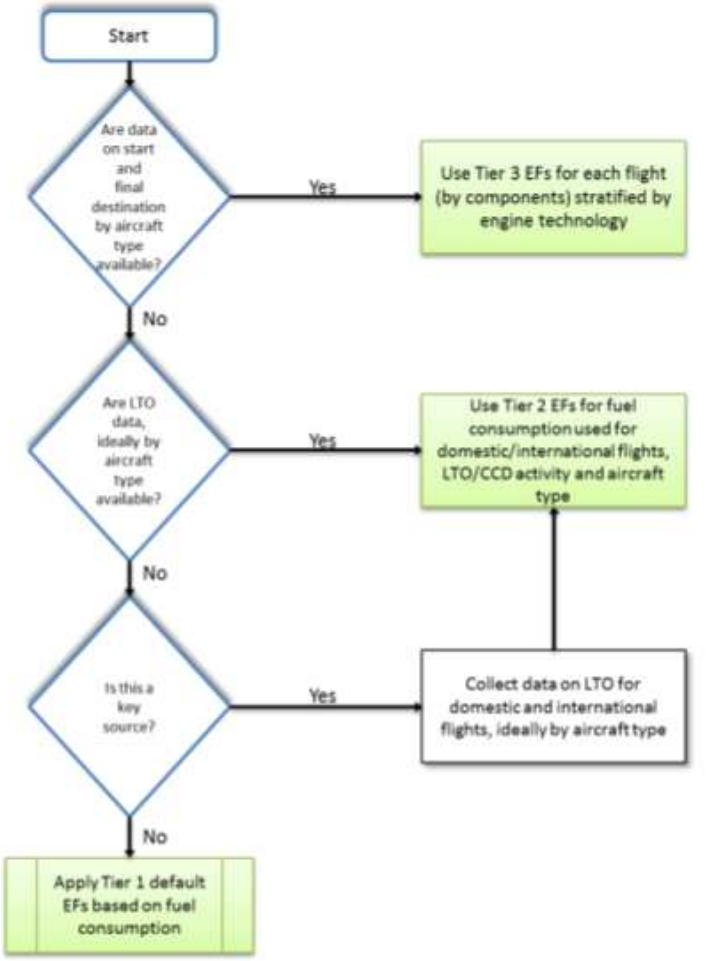
Passenger cars, light commercial trucks, heavy-duty vehicles including buses and motor cycles

Figure 3-1 Decision tree for exhaust emissions from road transport



Air transport

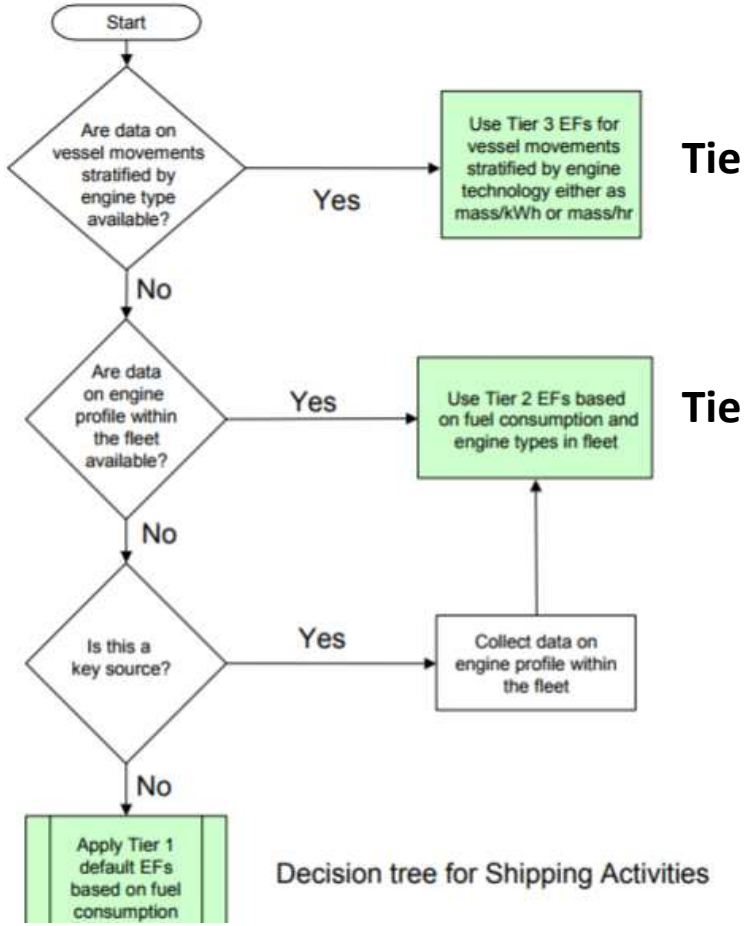
Figure 3.1 Decision tree for determining the appropriate tier method to apply



Note: EF – emission factor.

Maritime transport

Figure 3-1 Decision tree for emissions from shipping activities



Decision tree for Shipping Activities

Road transport

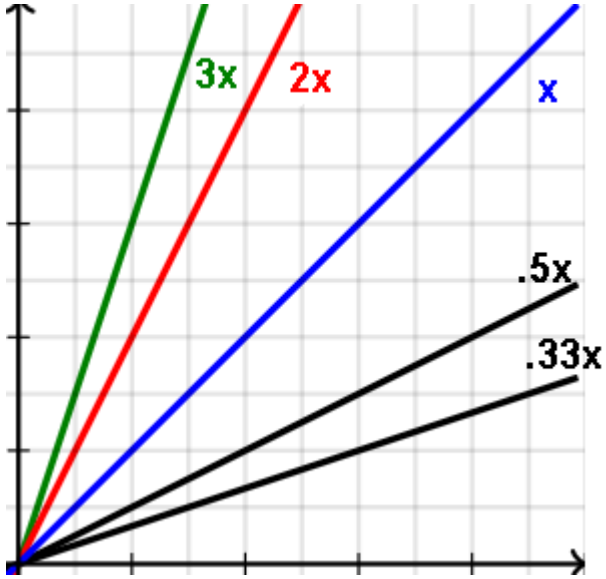
TIER 1

Apply Tier 1 default EFs based on fuel consumption

***Note:** Road Transport is very probably a Key Category in all countries. Therefore, efforts should always be made to use a tier 2 or 3 method for road transport emission estimation

$$\mathbf{EF} = \boldsymbol{f}(\boldsymbol{FC}) = \alpha \boldsymbol{FC}$$

Linear



Emission factors….g/pkm

EMEP/EEA air pollutant emission inventory guidebook (prior CORINAIR)

Table 3-2 Tier 1 emission factors for ships using marine diesel oil/marine gas oil

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	1.A.3.d.i	International navigation			
Fuel	Marine diesel oil/marine gas oil (MDO/MGO)				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex,				
Not estimated	NH3, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, Total 4 PAHs				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NOx	78.5	kg/tonne fuel	0	0	Entec (2007). See also note (2)
CO	7.4	kg/tonne fuel	0	0	Lloyd's Register (1995)
NMVOC	2.8	kg/tonne fuel	0	0	Entec (2007). See also note (2)
SOx	20	kg/tonne fuel	0	0	Note value of 20 should read
TSP	1.5	kg/tonne fuel	0	0	Entec (2007)
PM10	1.5	kg/tonne fuel	0	0	Entec (2007)
PM2.5	1.4	kg/tonne fuel	0	0	Entec (2007)
Pb	0.13	g/tonne fuel	0	0	average value
Cd	0.01	g/tonne fuel	0	0	average value
Hg	0.03	g/tonne fuel	0	0	average value
As	0.04	g/tonne fuel	0	0	average value
Cr	0.05	g/tonne fuel	0	0	average value
Cu	0.88	g/tonne fuel	0	0	average value
Ni	1	g/tonne fuel	0	0	average value
Se	0.1	g/tonne fuel	0	0	average value
Zn	1.2	g/tonne fuel	0	0	average value
PCB	0.038	mg/tonne fuel	0	0	Cooper (2005)
PCDD/F	0.13	ug I-TEQ/tonne	0	0	Cooper (2005)
HCB	0.08	mg/tonne fuel	0	0	Cooper (2005)

Notes

1. S = percentage sulphur content in fuel; pre-2000 fuels: 0.5 % wt. [source: Lloyd's Register, 1995]. For European Union as specified in the Directive 2005/33/EC:
   a. 0.2 % wt. from 1 July 2000 and 0.1 % wt. from 1 January 2008 for marine diesel oil/marine gas oil used by seagoing ships (except if used by ships crossing a frontier between a third country and a Member State);
   b. 0.1% wt. from 1 January 2010 for inland waterway vessels and ships at berth in Community ports.
2. Emission factor for NO_x and NMVOC are the 2000 values in cruise for medium speed engines (see Tier 2).
3. Reference: 'average value' is between Lloyd's Register (1995) and Cooper and Gustafsson (2004)
4. BC fraction of PM (f-BC) = 0.31. *Source: for further information see Appendix A*

Exercise

P#5 Find the yearly CO_2 NOx and PM2.5 of a fleet of SOFLUSA for the Lisbon –Barreiro-Lisbon rides.

Características principais | Características técnicas

Nomes dos navios: Damião de Goes, Miguel Torga, Fernando Namora, Gil Vicente, Jorge de Sena, Almeida Garrett, Fernando Pessoa e Antero de Quental

Classe navio: Catamarã
Serviço: Soflusa
Ligação: Barreiro – Terreiro do Paço
Entrada ao serviço: desde 2003
Capacidade: 600 passageiros
N.º de salões: 2
Outras caraterísticas: música ambiente, bar, instalações sanitárias, incluindo uma para pessoas com deficiência.

Exercise

Características principais | Características técnicas

Comprimento: 49,20m
Boca: 12,30m
Pontal: 3,30m
Calado: 1,58m
Arqueação Bruta: 713 tons
Catamarã em alumínio
Funcionamento e Sistema de Propulsão
Velocidade de Serviço: 22 Nós
Velocidade Máxima: 30 Nós
Motor Principal: mtu 16V40000M70
Propulsão: 2 jactos de água Hamilton
Construção: Estaleiro Damen Shipyards, Singapura

~ 40 km/h

Exercise

Tabela 11

Indicadores de eficiência energética da frota de navios – 2014 vs 2013

	Transtejo			Soflusa			Grupo		
Consumo Especifico da Frota de Navios	2014	2013	Δ 2014/13	2014	2013	Δ 2014/13	2014	2013	Δ 2014/13
Consumo médio por passageiro (l/p)	0,377	0,350	7,71	0,620	0,635	-2,36	0,481	0,470	2,34
Consumo por lugar quilómetro (l/lkm)	0,024	0,022	9,09	0,024	0,024	0,00	0,024	0,023	4,35
Consumo passageiro quilómetro (l/pkm)	0,088	0,081	8,64	0,062	0,063	-1,59	0,071	0,070	1,43
Consumo de combustível por viagem (l/vg)	53,846	51,026	5,53	142,401	146,353	-2,70	82,177	81,283	1,10

Consumo frota navios Soflusa: 221777 GJ

0.062 Ldiesel marine/pkm = 0.062*35 = 2.17 MJ/pkm

42 LHV MJ/kg * 0.84 kg/L

Exercise

CO_2?

221777 GJ → 221777 *10^3 MJ *3.14 $kgCO_2/kgFuel$/(42 MJ/kgFuel) =

16580 Ton CO_2 !!!

CnH2n

$$C_xH_yO_z + n(0.21O_2 + 0.79N_2) \rightarrow xCO_2 + yH_2O + 0.79 * nN_2$$

$$CO_2\ [g/L_{combustível}] = \frac{44*x}{12x+y+16z} * \rho$$

gfuel/Lfuel

$kgCO_2/kgfuel$
=44n/(12n+2n)
=3.14

Exercise

Total emissions per year

Tier 1 emission factor

NOx = 78.5 kg/tonFuel
PM2.5 = 1.4 kg/tonFuel

221777 *10^3MJ/42 MJ/kg = 5280 Ton maritime diesel fuel

NOx = 78.5 kg/tonFuel * 5280 tonFuel = 415 Ton/year

PM2.5 = 7.4 Ton/year

5 roundtrip flights → **32 ton NOx/year**

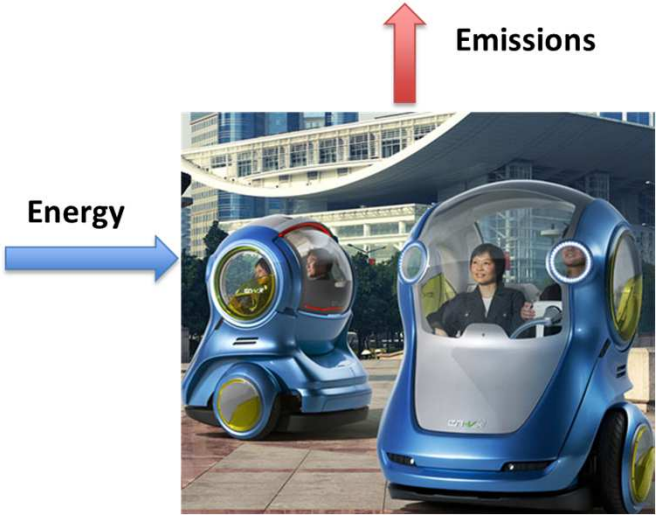
6.5 ton PM2.5/year

Exercise

Conclusions P#4 and P#5: Total emissions per year

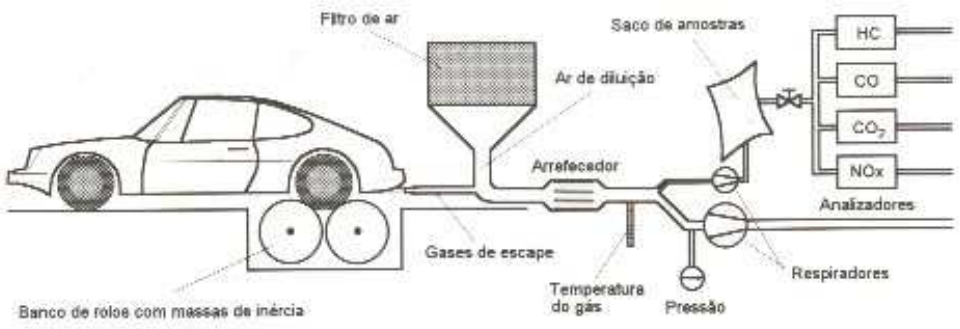
Emissions/Fleet	Lisbon-Porto TAP 	SofLusa Lisboa-Barreiro 
CO_2 (ton/year)	19 000	16 580
NOx (ton/year)	32	415
PM2.5 (ton/year)	6.5	7.4

Road vehicles

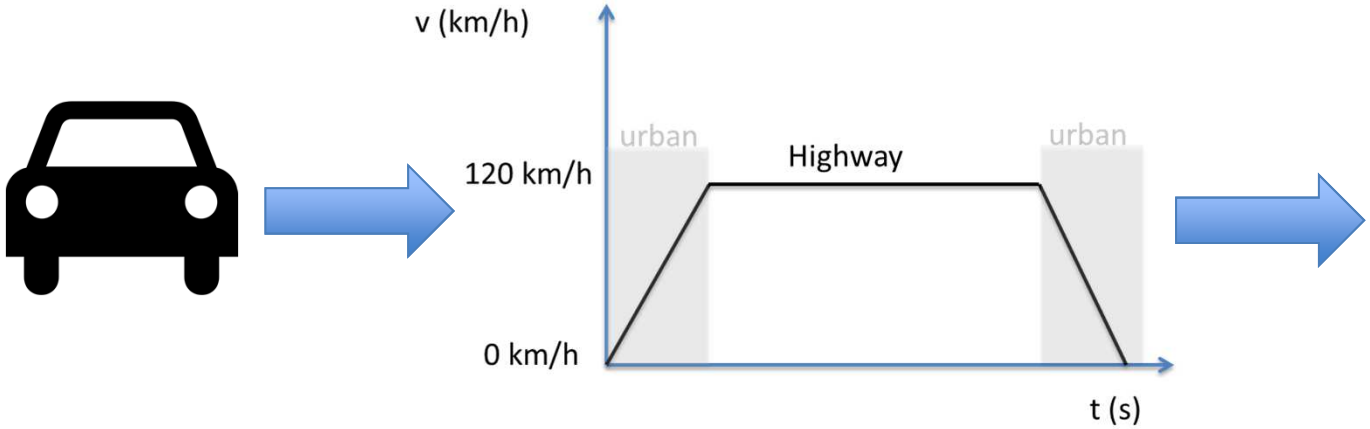


REGULATIONS

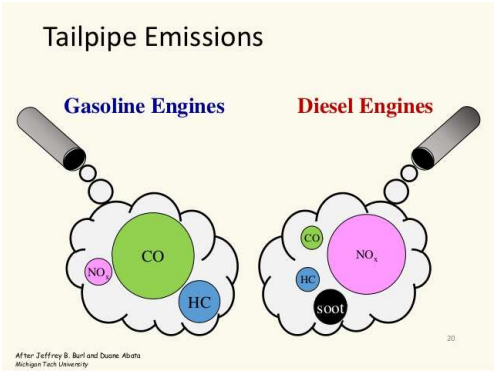
www.dieselnet.com



REGULATIONS



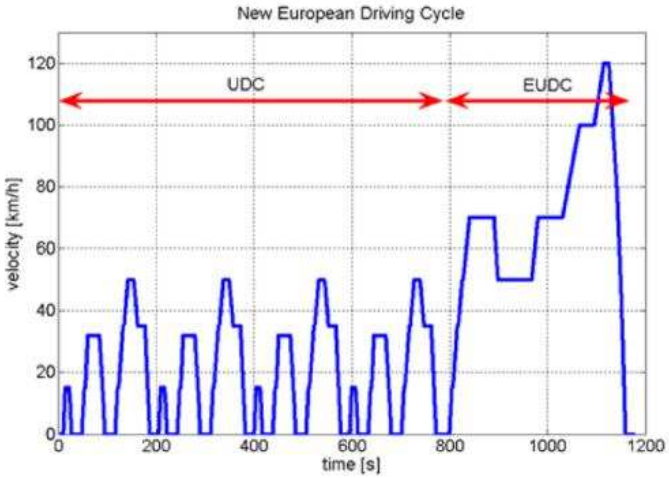
Driving cycle



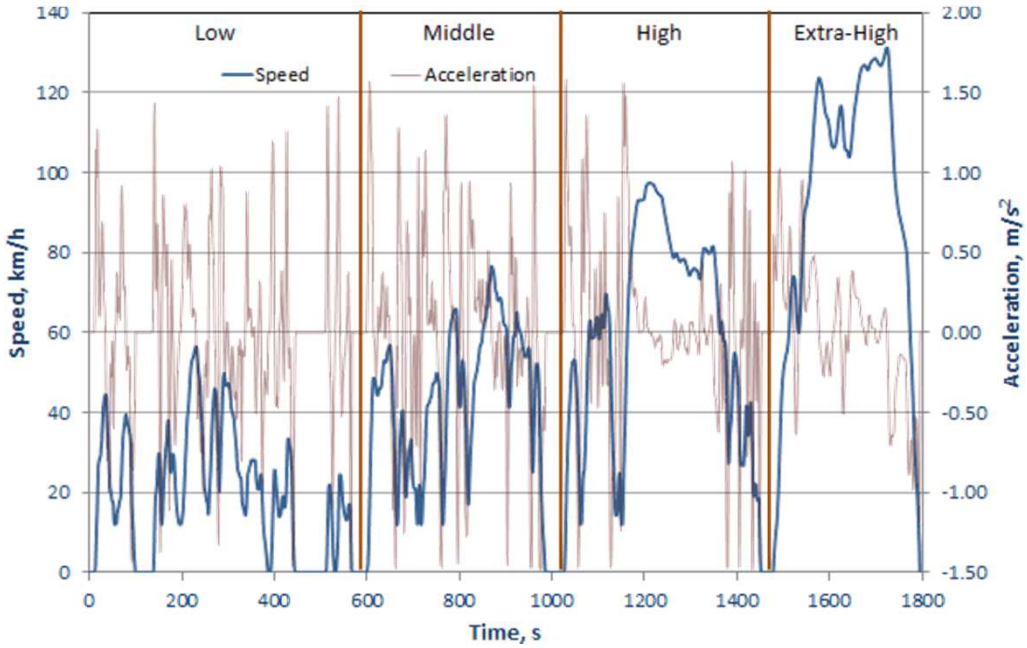
	UDC	EUDC	Artemis Urban	WLTC low*	WLTC
Duration [s]	780	400	993	589	1800
Length [km]	4.00	6.9	4.87	3.09	23.27
Average speed [km/h]	18.4	62.6	17.7	18.9	46.5
Max speed [km/h]	50	120	57.3	56.5	131.3
Idle time [%]	23.1	8.7	20.7	24.8	12.6
Cruising time [%]	25.1	49.2	9.7	15.8	25.3
Acceleration time [%]	27.2	29.8	35.9	28.4	31.9

Regulations

- Europe – Light-duty



Worldwide Harmonized Light Vehicles Test Procedure (WLTP)-Class 3
P/Weight>34



Worldwide Harmonized Light Vehicles Test Cycle (WLTC)

EU

September 2017	September 2018	January 2019
WLTP/NEDC	WLTP all new vehicles	WLTP-CO_2 values only

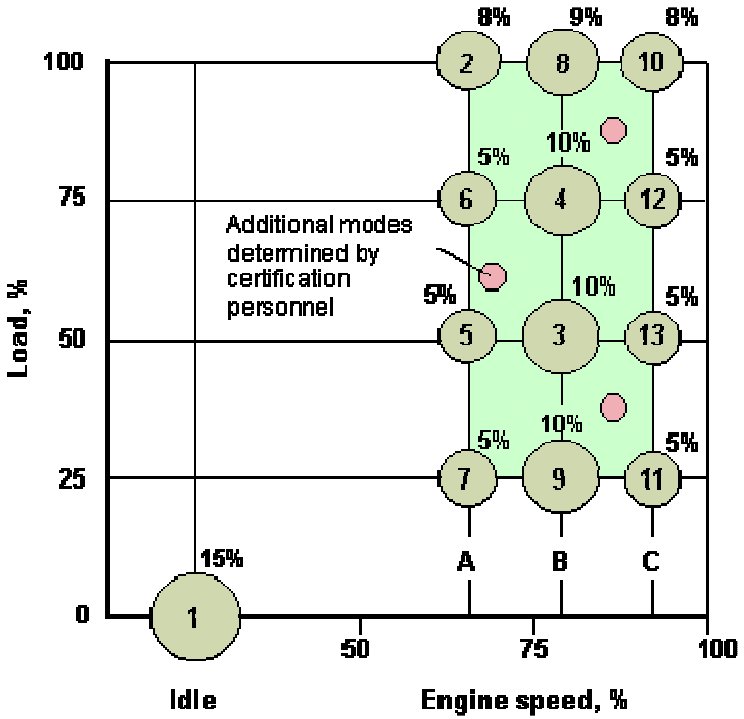
Regulations

EU Emission Standards for Passenger Cars (Category M_1*)

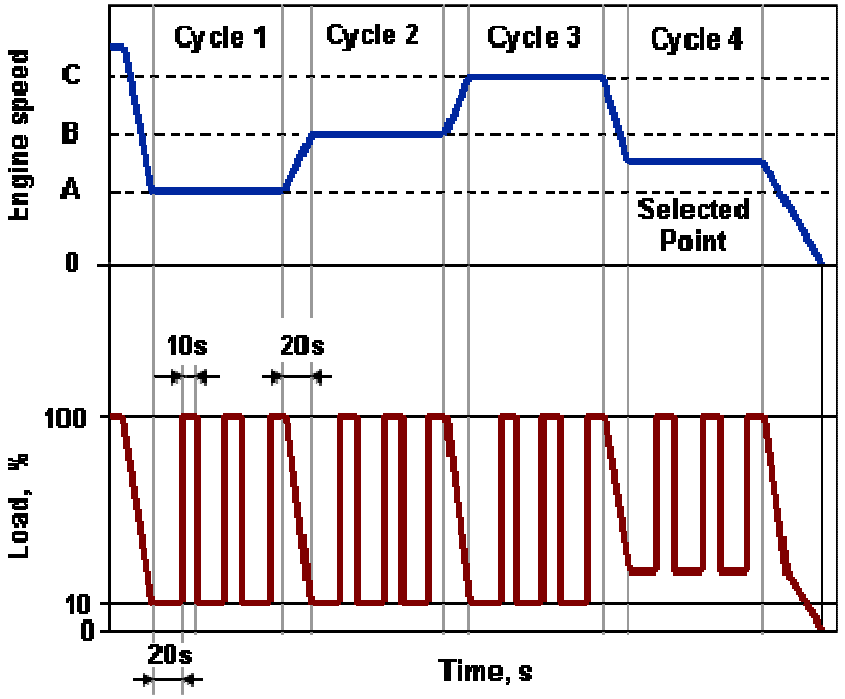
Stage	Date	CO	HC	HC+NOx	NOx	PM	PN
		g/km					*#/km*
Compression Ignition (Diesel)							
Euro 1†	1992.07	2.72 (3.16)	-	0.97 (1.13)	-	0.14 (0.18)	-
Euro 2, IDI	1996.01	1.0	-	0.7	-	0.08	-
Euro 2, DI	1996.01[a]	1.0	-	0.9	-	0.10	-
Euro 3	2000.01	0.64	-	0.56	0.50	0.05	-
Euro 4	2005.01	0.50	-	0.30	0.25	0.025	-
Euro 5a	2009.09[b]	0.50	-	0.23	0.18	0.005[f]	-
Euro 5b	2011.09[c]	0.50	-	0.23	0.18	0.005[f]	6.0×10^{11}
Euro 6	2014.09	0.50	-	0.17	0.08	0.005[f]	6.0×10^{11}
Positive Ignition (Gasoline)							
Euro 1†	1992.07	2.72 (3.16)	-	0.97 (1.13)	-	-	-
Euro 2	1996.01	2.2	-	0.5	-	-	-
Euro 3	2000.01	2.30	0.20	-	0.15	-	-
Euro 4	2005.01	1.0	0.10	-	0.08	-	-
Euro 5	2009.09[b]	1.0	0.10[d]	-	0.06	0.005[e,f]	-
Euro 6	2014.09	1.0	0.10[d]	-	0.06	0.005[e,f]	6.0×10^{11} [e,g]

* At the Euro 1..4 stages, passenger vehicles > 2,500 kg were type approved as Category N_1 vehicles
† Values in brackets are conformity of production (COP) limits
a. until 1999.09.30 (after that date DI engines must meet the IDI limits)
b. 2011.01 for all models
c. 2013.01 for all models
d. and NMHC = 0.068 g/km
e. applicable only to vehicles using DI engines
f. 0.0045 g/km using the PMP measurement procedure
g. 6.0×10^{12} 1/km within first three years from Euro 6 effective dates

Regulations

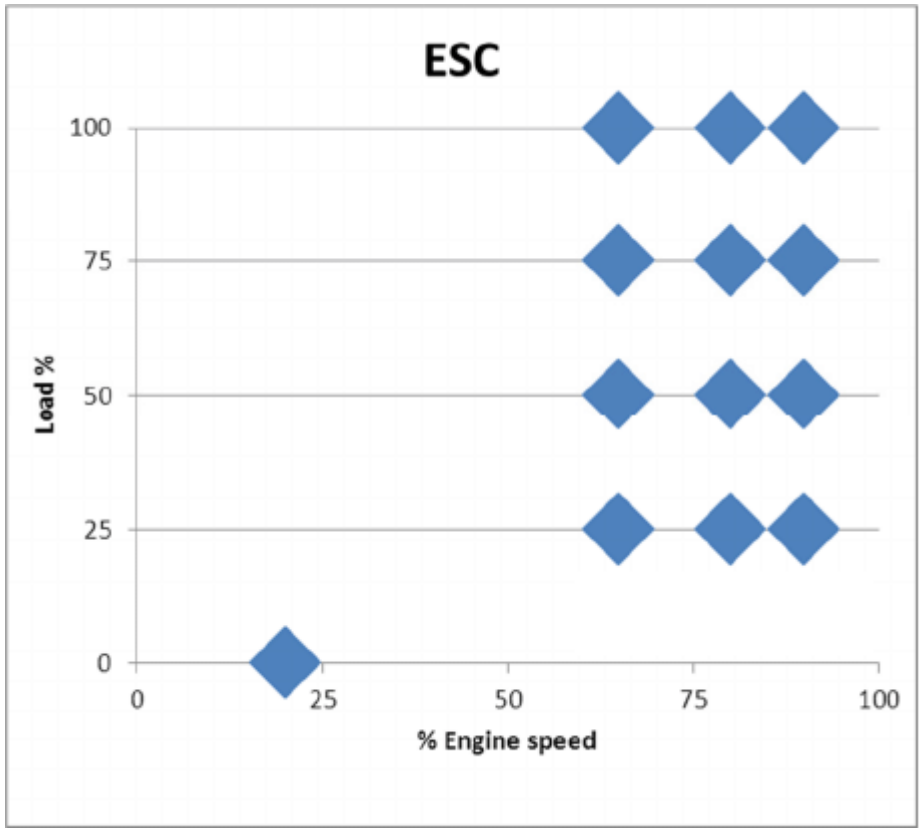


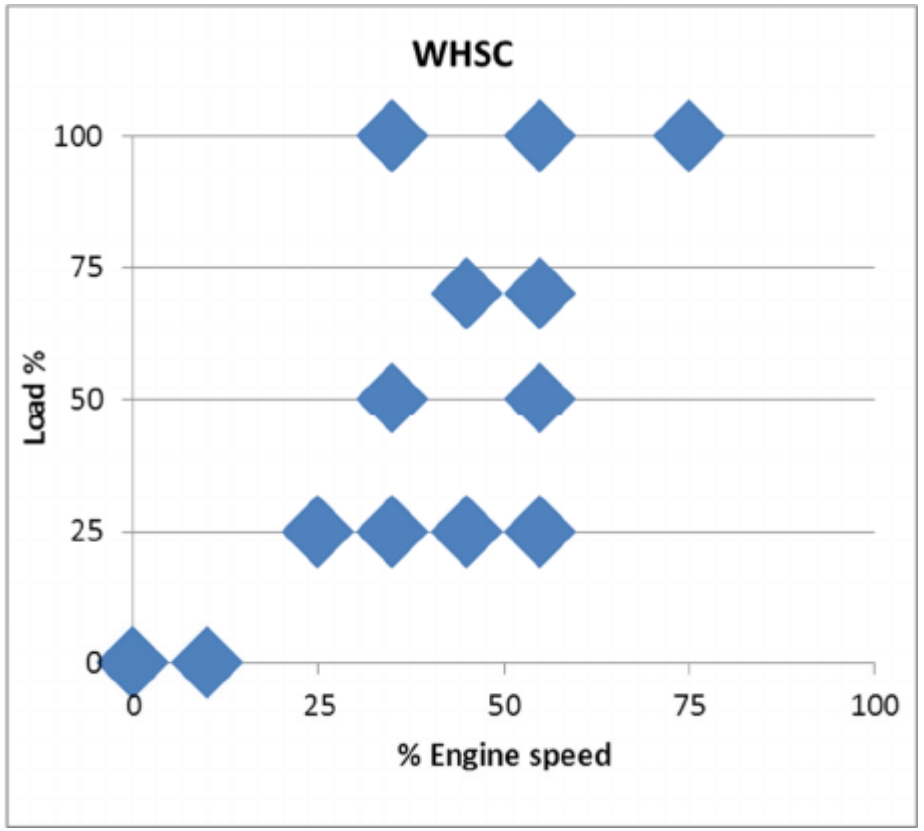
European Stationary Cycle (ESC)



European Load Response (ELR) engine tes

World Harmonized Stationary Cycle (WHSC)





World Harmonized Stationary Cycle (WHSC)

- Europe Heavy-duty

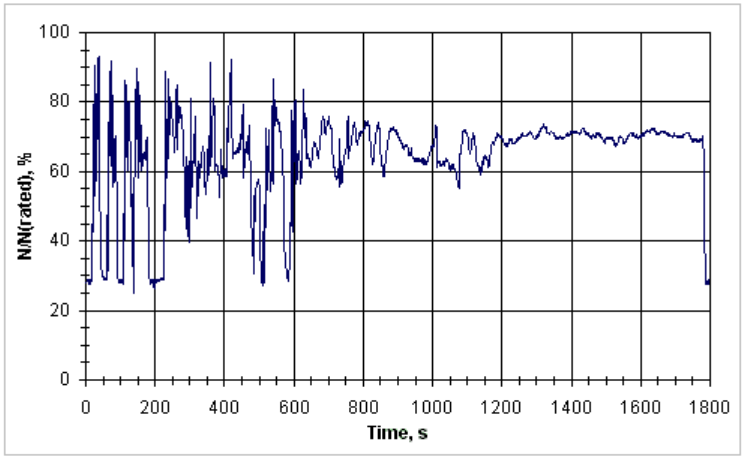
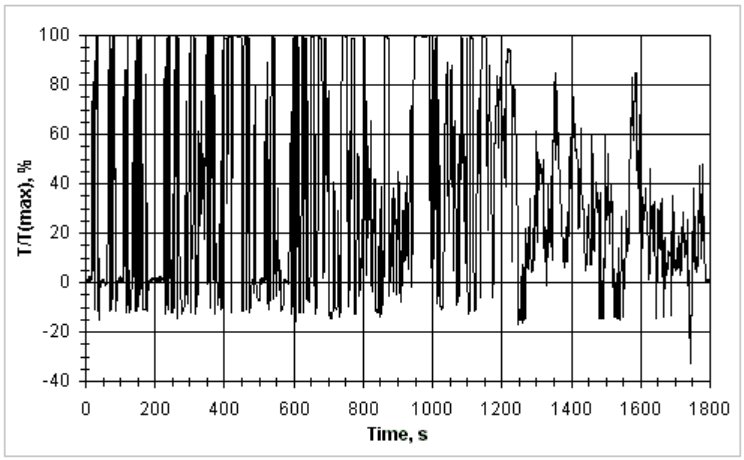
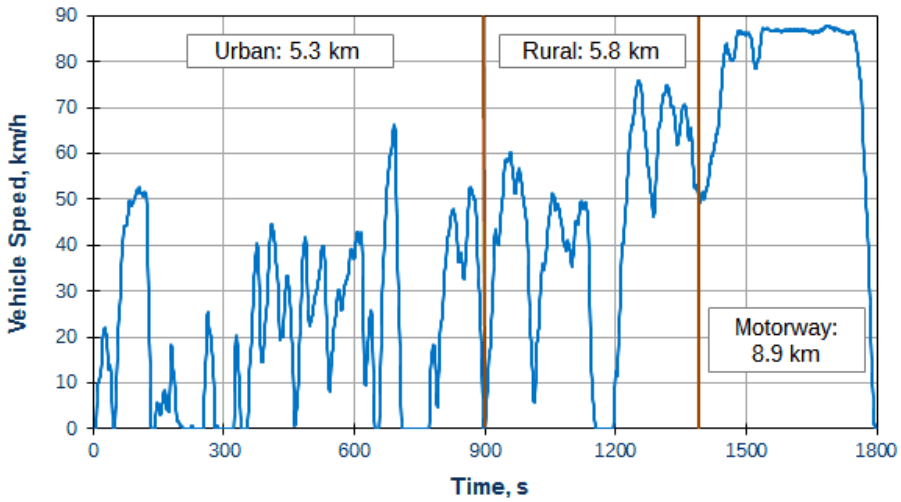


Figure 2. ETC Transient Cycle—Engine Speed



Worldwide Harmonized Heavy-duty Test Procedure (WLTP)-Class 3
P/Weight>34



Carla Silva camsilva@fc.ul.pt

Regulations

- Europe Heavy-duty

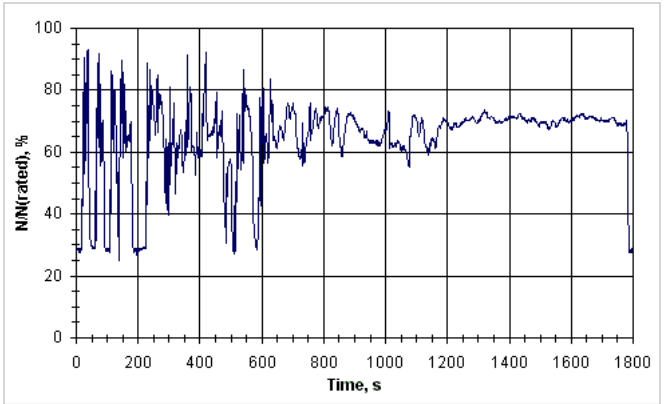
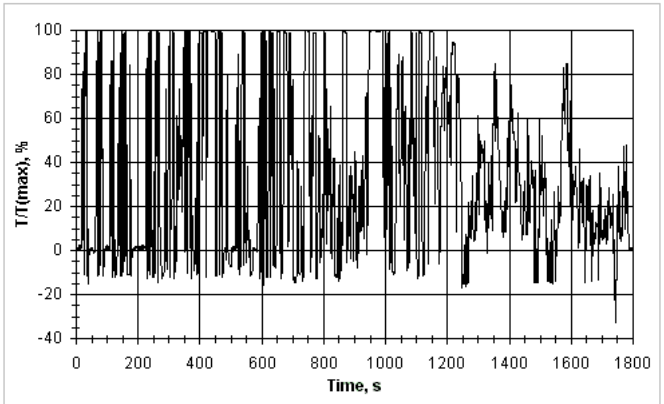


Figure 2. ETC Transient Cycle—Engine Speed



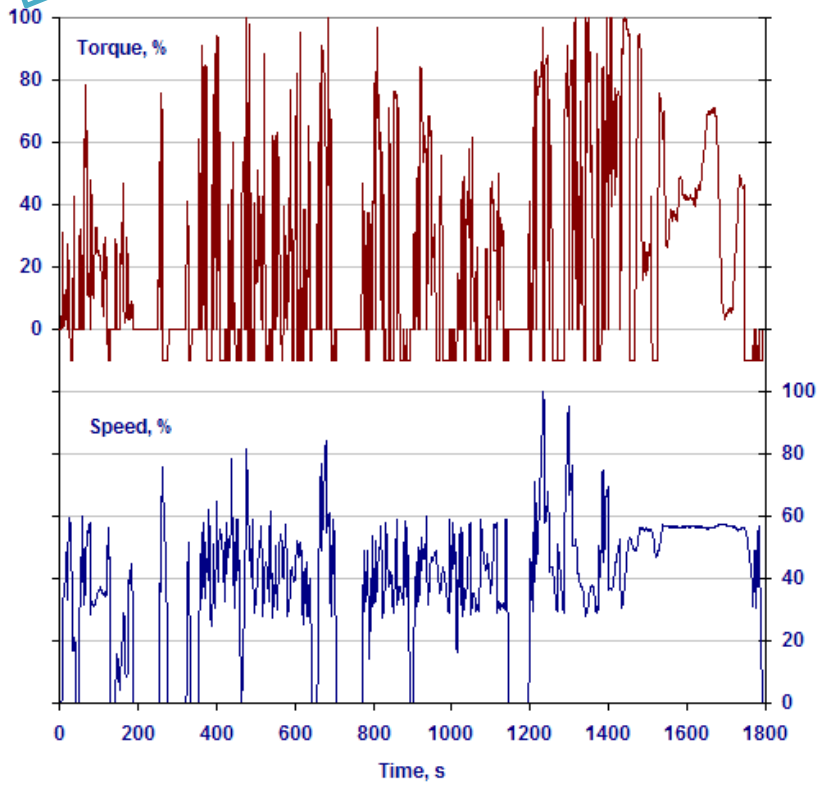


Figure 1. World Harmonized Transient Cycle (WHTC)

Table 1

EU Emission Standards for Heavy-Duty Diesel Engines: Steady-State Testing

Stage	Date	Test	CO	HC	NOx	PM	PN	Smoke
			g/kWh				*1/kWh*	*1/m*
Euro I	1992, ≤ 85 kW	ECE R-49	4.5	1.1	8.0	0.612		
	1992, > 85 kW		4.5	1.1	8.0	0.36		
Euro II	1996.10		4.0	1.1	7.0	0.25		
	1998.10		4.0	1.1	7.0	0.15		
Euro III	*1999.10 EEV only*	ESC & ELR	*1.5*	*0.25*	*2.0*	*0.02*		*0.15*
	2000.10		2.1	0.66	5.0	0.10[a]		0.8
Euro IV	2005.10		1.5	0.46	3.5	0.02		0.5
Euro V	2008.10		1.5	0.46	2.0	0.02		0.5
Euro VI	2013.01	WHSC	1.5	0.13	0.40	0.01	8.0×10^{11}	

a - PM = 0.13 g/kWh for engines < 0.75 dm^3 swept volume per cylinder and a rated power speed > 3000 min^{-1}

Table 2

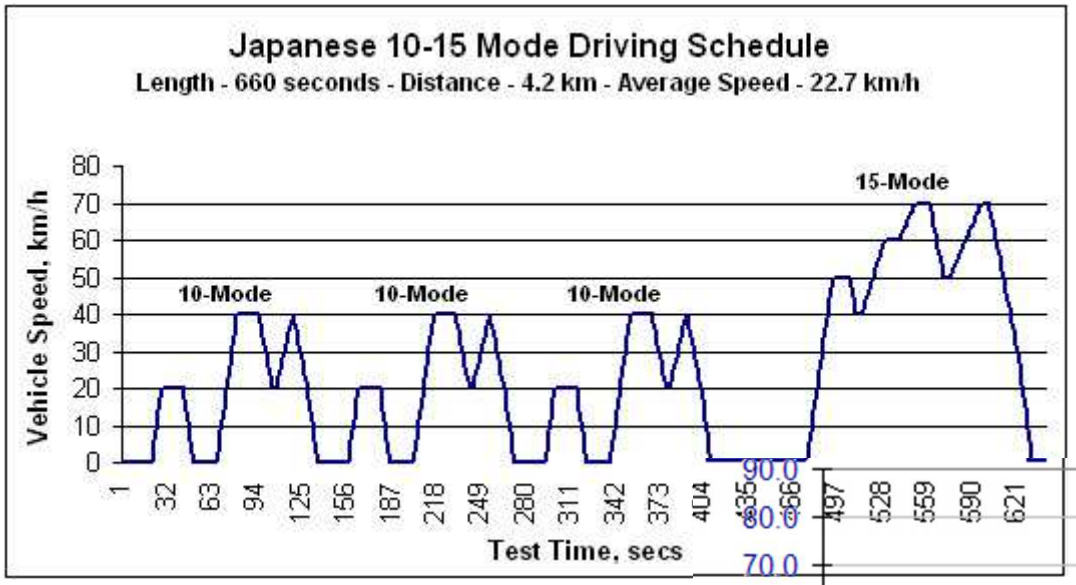
EU Emission Standards for Heavy-Duty Diesel and Gas Engines: Transient Testing

Stage	Date	Test	CO	NMHC	CH_4[a]	NOx	PM[b]	PN[e]
			g/kWh					*1/kWh*
Euro III	*1999.10 EEV only*	ETC	*3.0*	*0.40*	*0.65*	*2.0*	*0.02*	
	2000.10		5.45	0.78	1.6	5.0	0.16[c]	
Euro IV	2005.10		4.0	0.55	1.1	3.5	0.03	
Euro V	2008.10		4.0	0.55	1.1	2.0	0.03	
Euro VI	2013.01	WHTC	4.0	0.16[d]	0.5	0.46	0.01	6.0×10^{11}

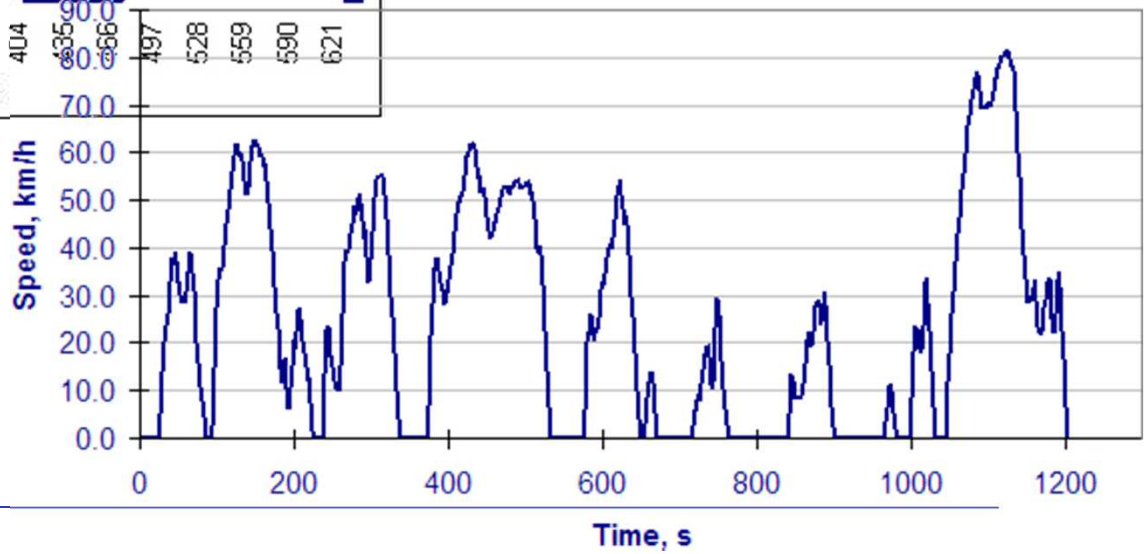
a - for gas engines only (Euro III-V: NG only; Euro VI: NG + LPG)
b - not applicable for gas fueled engines at the Euro III-IV stages
c - PM = 0.21 g/kWh for engines < 0.75 dm^3 swept volume per cylinder and a rated power speed > 3000 min^{-1}
d - THC for diesel engines
e - for diesel engines; PN limit for positive ignition engines TBD

Regulations

- Japan light-duty



JC08



Regulations

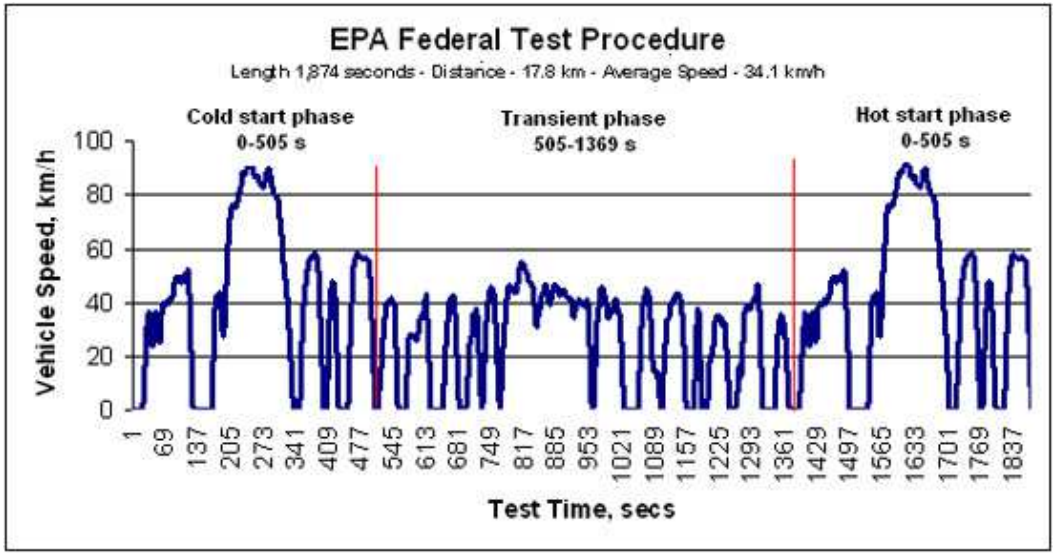
Japanese Emission Standards for Diesel Passenger Cars, g/km

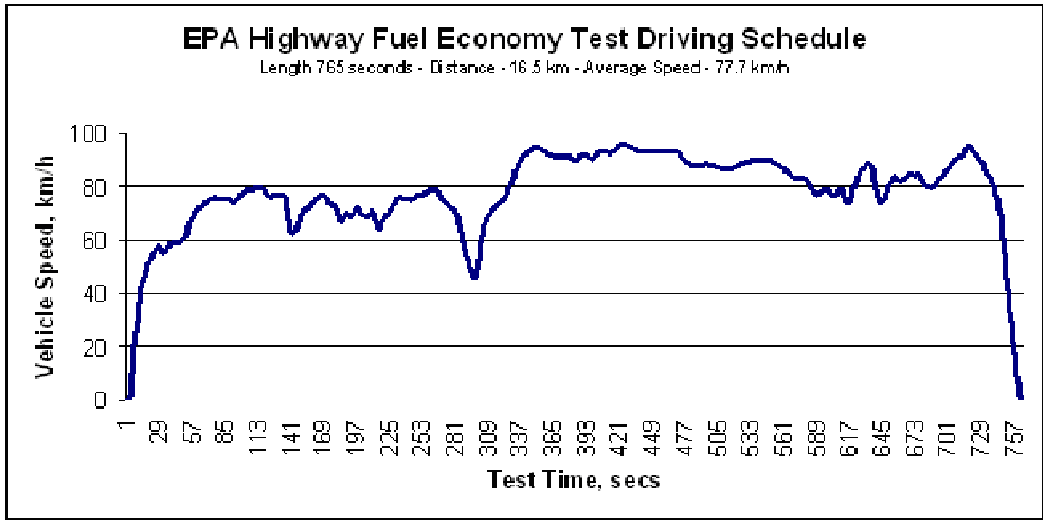
Vehicle Weight	Date	Test	CO	HC	NOx	PM
			mean (max)	*mean (max)*	*mean (max)*	*mean (max)*
< 1250 kg*	1986	10-15 mode	2.1 (2.7)	0.40 (0.62)	0.70 (0.98)	
	1990		2.1 (2.7)	0.40 (0.62)	0.50 (0.72)	
	1994		2.1 (2.7)	0.40 (0.62)	0.50 (0.72)	0.20 (0.34)
	1997		2.1 (2.7)	0.40 (0.62)	0.40 (0.55)	0.08 (0.14)
	2002[a]		0.63	0.12	0.28	0.052
	2005[b]	JC08[c]	0.63	0.024[d]	0.14	0.013
	2009		0.63	0.024[d]	0.08	0.005
> 1250 kg*	1986	10-15 mode	2.1 (2.7)	0.40 (0.62)	0.90 (1.26)	
	1992		2.1 (2.7)	0.40 (0.62)	0.60 (0.84)	
	1994		2.1 (2.7)	0.40 (0.62)	0.60 (0.84)	0.20 (0.34)
	1998		2.1 (2.7)	0.40 (0.62)	0.40 (0.55)	0.08 (0.14)
	2002[a]		0.63	0.12	0.30	0.056
	2005[b]	JC08[c]	0.63	0.024[d]	0.15	0.014
	2009[e]		0.63	0.024[d]	0.08	0.005

* - equivalent inertia weight (EIW); vehicle weight of 1265 kg
a - 2002.10 for domestic cars, 2004.09 for imports
b - full implementation by the end of 2005
c - full phase-in by 2011
d - non-methane hydrocarbons
e - 2009.10 for new domestic models; 2010.09 for existing models & imports

Regulations

- **US-Brasil**
  - Urban (55%)
  - Extra Urban (45%)





- **US - California**

LEV Emission Standards for Light-Duty Vehicles, FTP-75, g/mi

Category	50,000 miles/5 years					100,000 miles/10 years				
	NMOG[a]	CO	NOx	PM	HCHO	NMOG[a]	CO	NOx	PM	HCHO
Passenger cars										
Tier 1	0.25	3.4	0.4	0.08	-	0.31	4.2	0.6	-	-
TLEV	0.125	3.4	0.4	-	0.015	0.156	4.2	0.6	0.08	0.018
LEV	0.075	3.4	0.2	-	0.015	0.090	4.2	0.3	0.08	0.018
ULEV	0.040	1.7	0.2	-	0.008	0.055	2.1	0.3	0.04	0.011
LDT1, LVW <3,750 lbs										
Tier 1	0.25	3.4	0.4	0.08	-	0.31	4.2	0.6	-	-
TLEV	0.125	3.4	0.4	-	0.015	0.156	4.2	0.6	0.08	0.018
LEV	0.075	3.4	0.2	-	0.015	0.090	4.2	0.3	0.08	0.018
ULEV	0.040	1.7	0.2	-	0.008	0.055	2.1	0.3	0.04	0.011
LDT2, LVW >3,750 lbs										
Tier 1	0.32	4.4	0.7	0.08	-	0.40	5.5	0.97	-	-
TLEV	0.160	4.4	0.7	-	0.018	0.200	5.5	0.9	0.10	0.023
LEV	0.100	4.4	0.4	-	0.018	0.130	5.5	0.5	0.10	0.023
ULEV	0.050	2.2	0.4	-	0.009	0.070	2.8	0.5	0.05	0.013

a - NMHC for all Tier 1 standards

Abbreviations:
LVW - loaded vehicle weight (curb weight + 300 lbs)
LDT - light-duty truck
NMOG - non-methane organic gases
HCHO - formaldehyde

- **Brasil - PROCONVE**

Table 1
PROCONVE Emission Standards For Passenger Vehicles
(FTP-75; Durability: 80,000 km/5 years)

Tier	Date	Idle CO	CO	THC	NMHC	NOx	HCO	PM
		% vol	g/km					
L-4	1.1.2007[1,2]	0.50	2.0	0.30	0.16	0.25[3]/0.60[4]	0.03	0.05
L-5	1.1.2009[5]	0.50	2.0	0.30	0.05	0.12[3]/0.25[4]	0.02	0.05
L-6	1.1.2013[6]	0.20	1.3	0.30	0.05	0.08	0.02	0.025

Idle CO limits apply to Otto cycle engines only
THC limits apply to natural gas vehicles only
Aldehydes (HCO) limits apply to Otto cycle engines only; Natural gas vehicles exempted
PM limits apply to Diesel cycle engines only
(1) 1.1.2005: at least 40% of annual production (passenger vehicles + light commercial vehicles)
(2) 1.1.2006: at least 70% of annual production (passenger vehicles + light commercial vehicles)

LEV Emission Standards for Light-Duty Vehicles, FTP-75, g/mi

Category	50,000 miles/5 years					10(	
	NMOG[a]	CO	NOx	PM	HCHO	NMOG[a]	CO
Passenger cars							
Tier 1	0.25	3.4	0.4	0.08	-	0.31	4.2
TLEV	0.125	3.4	0.4	-	0.015	0.156	4.2
LEV	0.075	3.4	0.2	-	0.015	0.090	4.2
ULEV	0.040	1.7	0.2	-	0.008	0.055	2.1

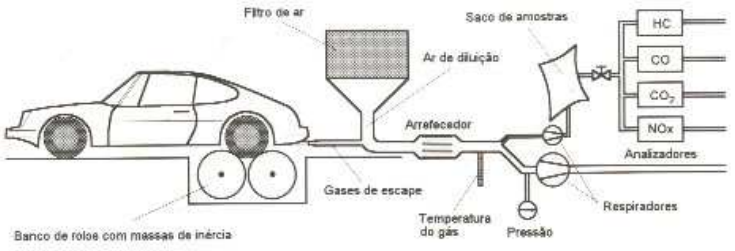
2.11 g/km
1.06 g/km

EU Emission Standards for Passenger Cars (Category M_1*)

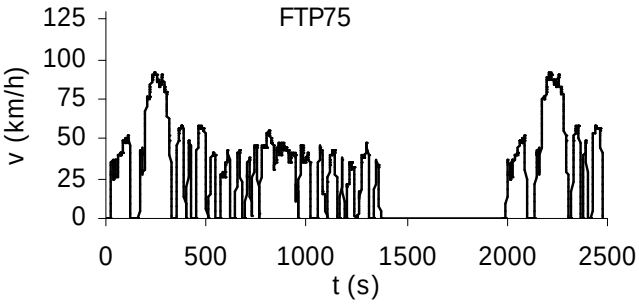
		CO	HC	HC+NOx	NOx	PM	PN
		g/km					#/km
Euro 6	2014.09	0.50	-	0.17	0.08	0.005[f]	6.0×10^{11}
Positive Ignition (Gasoline)							
Euro 1†	1992.07	2.72 (3.16)	-	0.97 (1.13)	-	-	-
Euro 2	1996.01	2.2	-	0.5	-	-	-
Euro 3	2000.01	2.30	0.20	-	0.15	-	-
Euro 4	2005.01	1.0	0.10	-	0.08	-	-
Euro 5	2009.09[b]	1.0	0.10[d]	-	0.06	0.005[e,f]	-
Euro 6	2014.09	1.0	0.10[d]	-	0.06	0.005[e,f]	6.0×10^{11} e,g

* At the Euro 1..4 stages, passenger vehicles > 2,500 kg were type approved as Category N_1 vehicles
† Values in brackets are conformity of production (COP) limits
a. until 1999.09.30 (after that date DI engines must meet the IDI limits)
b. 2011.01 for all models
c. 2013.01 for all models
d. and NMHC = 0.068 g/km
e. applicable only to vehicles using DI engines
f. 0.0045 g/km using the PMP measurement procedure
g. 6.0×10^{12} 1/km within first three years from Euro 6 effective dates

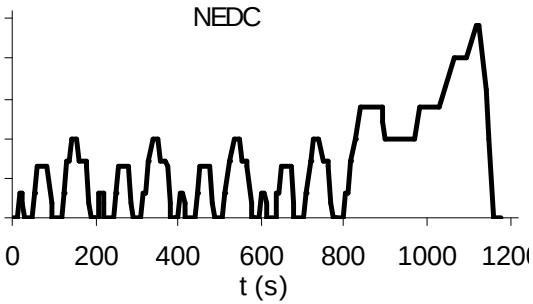
World scenario/Legislation



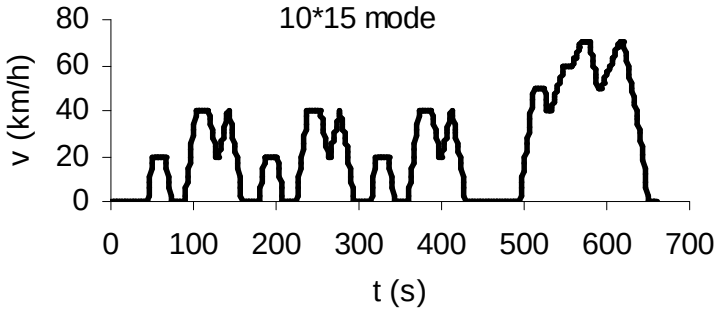
US



EU

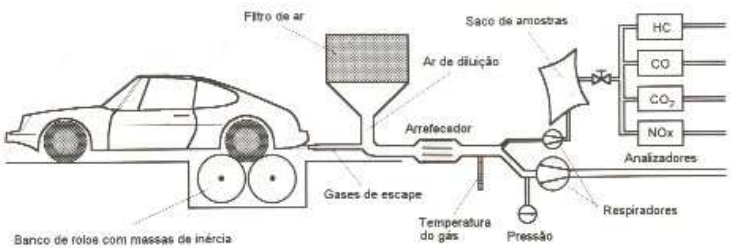


Japan



Driving cycle	FTP75	NEDC	10*15 mode
Maximum speed (km/h)	91.2	120	70
Average speed (km/h)	34.1	33.6	22.7
Distance (km)	17.8	11.05	4.16
Time (s/min.)	2479/ 41.3	1180/19.7	660/11
Maximum acceleration (m/s^2)	1.48	1.06	0.79
idle (s)	361	298	215

World scenario/Legislation



EU

Índia

China

Turkey

Russia

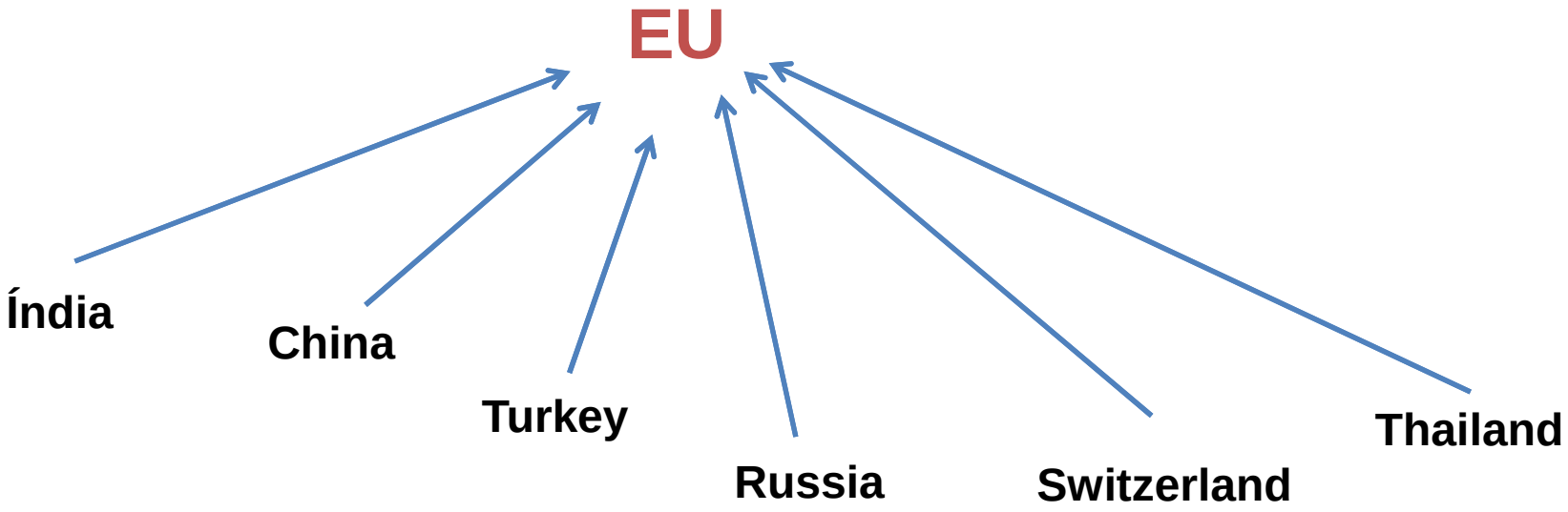
Switzerland

Thailand

Worldwide Harmonized Light Vehicles Test Cycle (WLTC)

Table 1
WLTC test cycles

Category	PMR, W/kg	v_max, km/h	Speed Phase Sequence
Class 3b	PMR > 34	v_max ≥ 120	Low 3 + Medium 3-2 + High 3-2 + Extra High 3
Class 3a		v_max < 120	Low 3 + Medium 3-1 + High 3-1 + Extra High 3
Class 2	34 ≥ PMR > 22	-	Low 2 + Medium 2 + High 2 + Extra High 2
Class 1	PMR ≤ 22	-	Low 1 + Medium 1 + Low 1



World scenario/Legislation

Worldwide Harmonized Light Vehicles Test Cycle (WLTC)

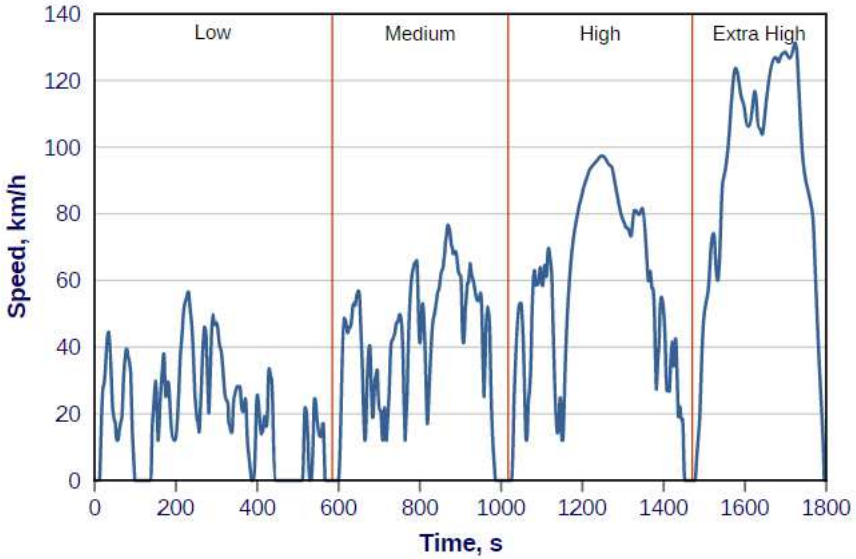


Figure 1. WLTC cycle for Class 3b vehicles

Índia

China

Turkey

Russia

Switzerland

Thailand

Worldwide Harmonized Light Vehicles Test Cycle (WLTC)

EU

September 2017	September 2018	January 2019
WLTP/NEDC	WLTP all new vehicles	WLTP-CO_2 values only

Worldwide Harmonized Light Vehicles Test Cycle (WLTC)

CD

CS

Table 5
WLTC test matrix for hybrid and electric vehicles

		WLTP		WLTP city
		Charge-depleting	Charge-sustaining	Charge-depleting
		Criteria Emissions, FC, CO_2, AER, EAER, R_{CDC}, R_{CDA}, E_{AC}	*Criteria Emissions, FC, CO_2*	*AERcity, E_{AC}city*
OVC-HEV	Class 3a	Low 3 + Medium 3-1 + High 3-1 + Extra High 3	Low 3 + Medium 3-1 + High 3-1 + Extra High 3	Low 3 + Medium 3-1
	Class 3b	Low 3 + Medium 3-2 + High 3-2 + Extra High 3	Low 3 + Medium 3-2 + High 3-2 + ExtraHigh 3	Low 3 + Medium 3-2
NOVC-HEV	Class 3a	--	Low 3 + Medium 3-1 + High 3-1 + ExtraHigh 3	--
	Class 3b	--	Low 3 + Medium 3-2 + High 3-2 + Extra High 3	--
PEV	Class 3a	Low 3 + Medium 3-1 + High 3-1 + Extra High 3	--	Low 3 + Medium 3-1
	Class 3b	Low 3 + Medium 3-2 + High 3-2 + Extra High 3	--	Low 3 + Medium 3-2

Abbreviations:
AER - All-electric range
EAER - Equivalent all-electric range
E_{AC} - Recharged energy
FC - Fuel consumption
NOVC-HEV - not off-vehicle charging hybrid electric vehicle
OVC-HEV - off-vehicle charging hybrid electric vehicle
PEV - pure electric vehicle
R_{CDA} - Charge-depleting actual range
R_{CDC} - Charge-depleting cycle range

Worldwide Harmonized Light Vehicles Test Cycle (WLTC)

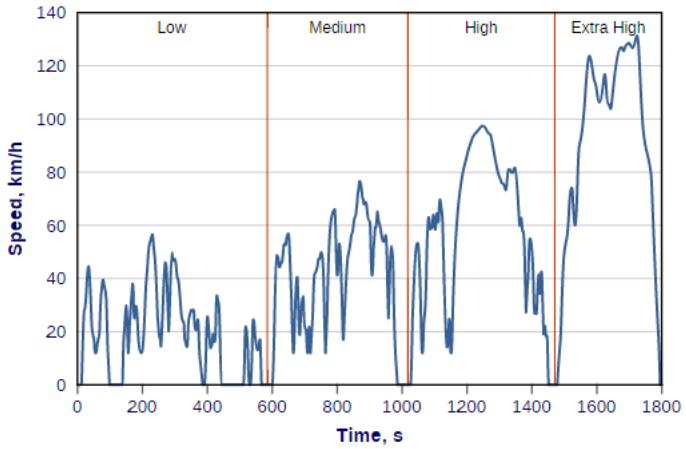


Figure 1. WLTC cycle for Class 3b vehicles

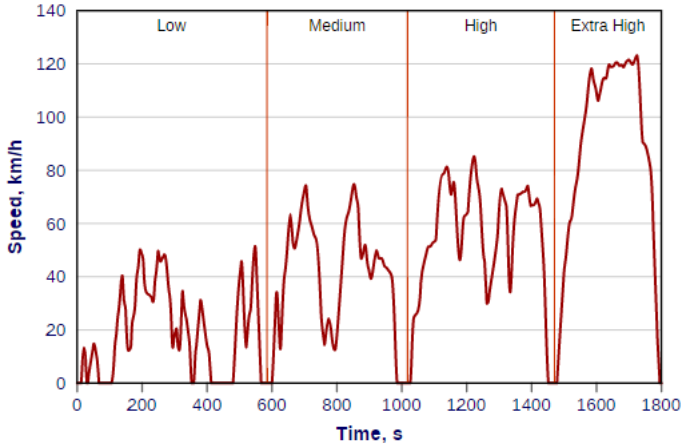


Figure 2. WLTC cycle for Class 2 vehicles

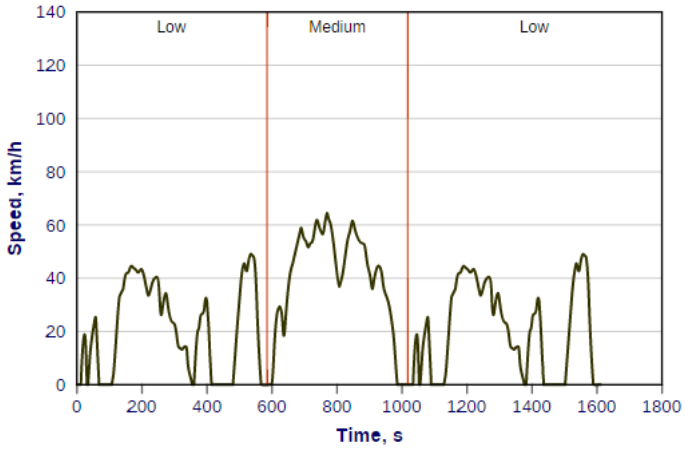


Figure 3. WLTC cycle for Class 1 vehicles

PHEV or off vehicle charging hybrid electric vehicle

$$mpg_{CD} = \frac{D}{V_{fuel} + \frac{E_{charge}}{E_{gasoline}}}$$

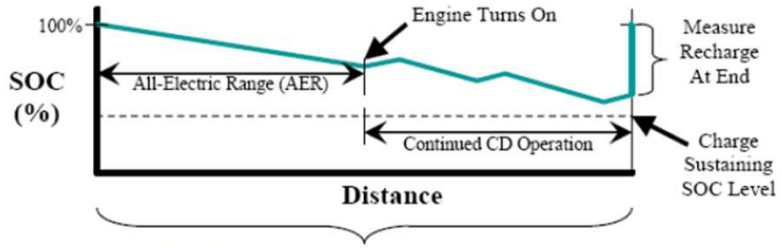
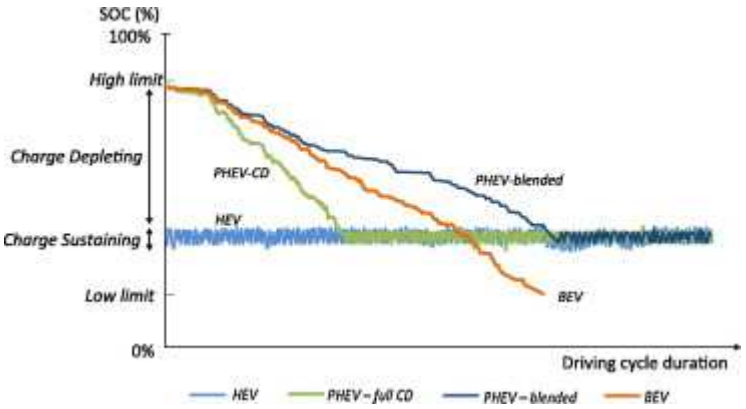


Figure 3: FCT to measure Charge-Depleting (CD) fuel economy, illustrated with application to the UDDS or HWFET test cycles

SOC - STATE OF CHARGE



$$mpg_{CS} = \frac{D}{V_{fuel}}$$

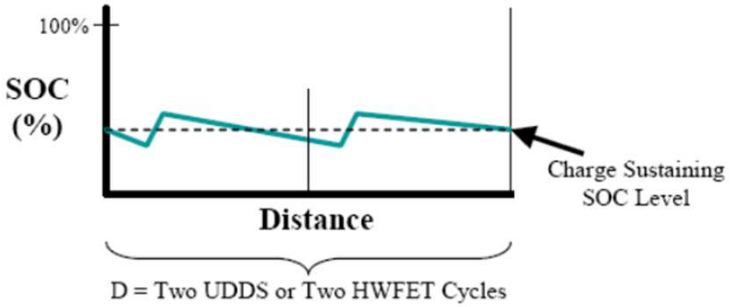
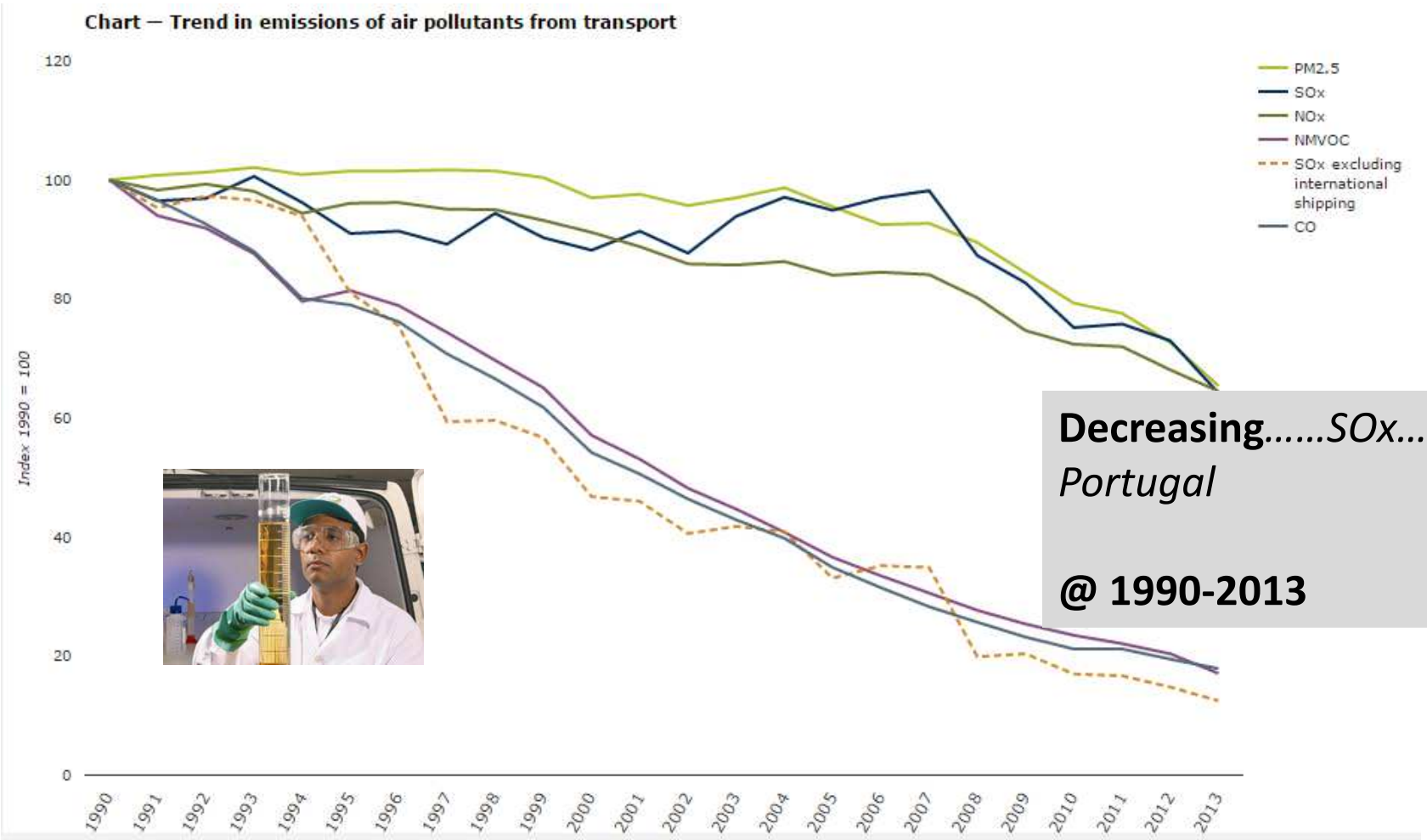


Figure 2: PCT to measure Charge-Sustaining (CS) vehicle fuel economy; illustrated with application to the UDDS or HWFET test cycles

LOCAL EMISSIONS



Decreasing……*SOx*…..
Portugal

@ 1990-2013

H_2 production in Portugal …2050

Porto and Sines refinery

~ 9-12 kg CO2eq/kg H_2

Emissions

Energy

Steam methane reforming

~ 180 MJ/kg H_2

(efic. 68%)

$$CH_4 + H_2O(1100^oC) \rightarrow CO + 3H_2 \quad (\Delta H=+206.16\ kJ/molCH4) \quad (1)$$

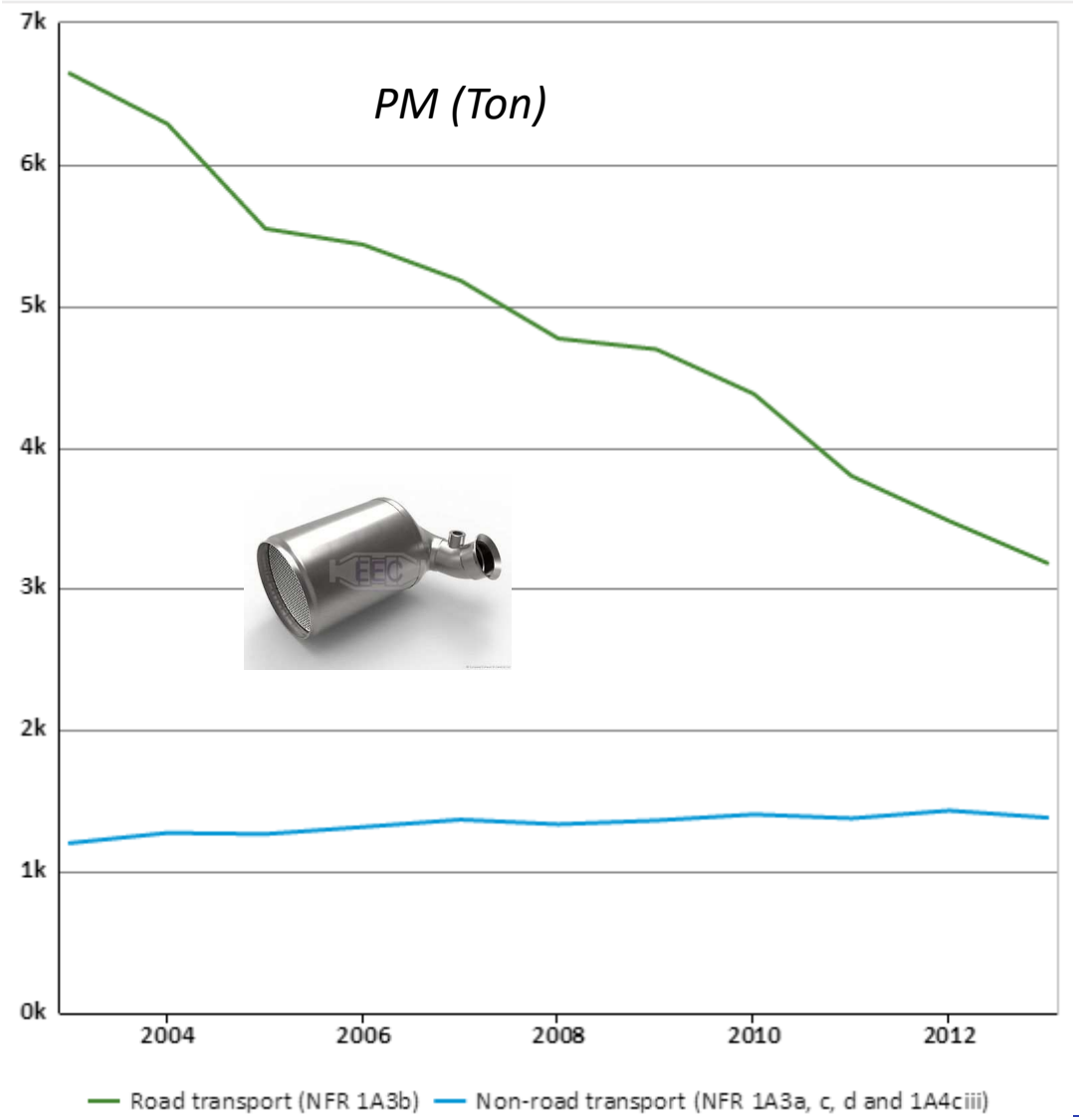
$$CO + H_2O \rightarrow CO_2 + H_2 \quad (\Delta H=-41.15\ kJ/molCO) \quad (2)$$

~ 70 000 ton H_2 production for transports in Portugal

Source:

- Life cycle inventory analysis of hydrogen production by the steam-reforming process: comparison between vegetable oils and fossil fuels as feedstock;
- Hydrogen Production via Natural Gas Reforming Process – A Life Cycle Assessment Approach

LOCAL EMISSIONS



Contribution to the total Portugal

@ 2012

30% NOx

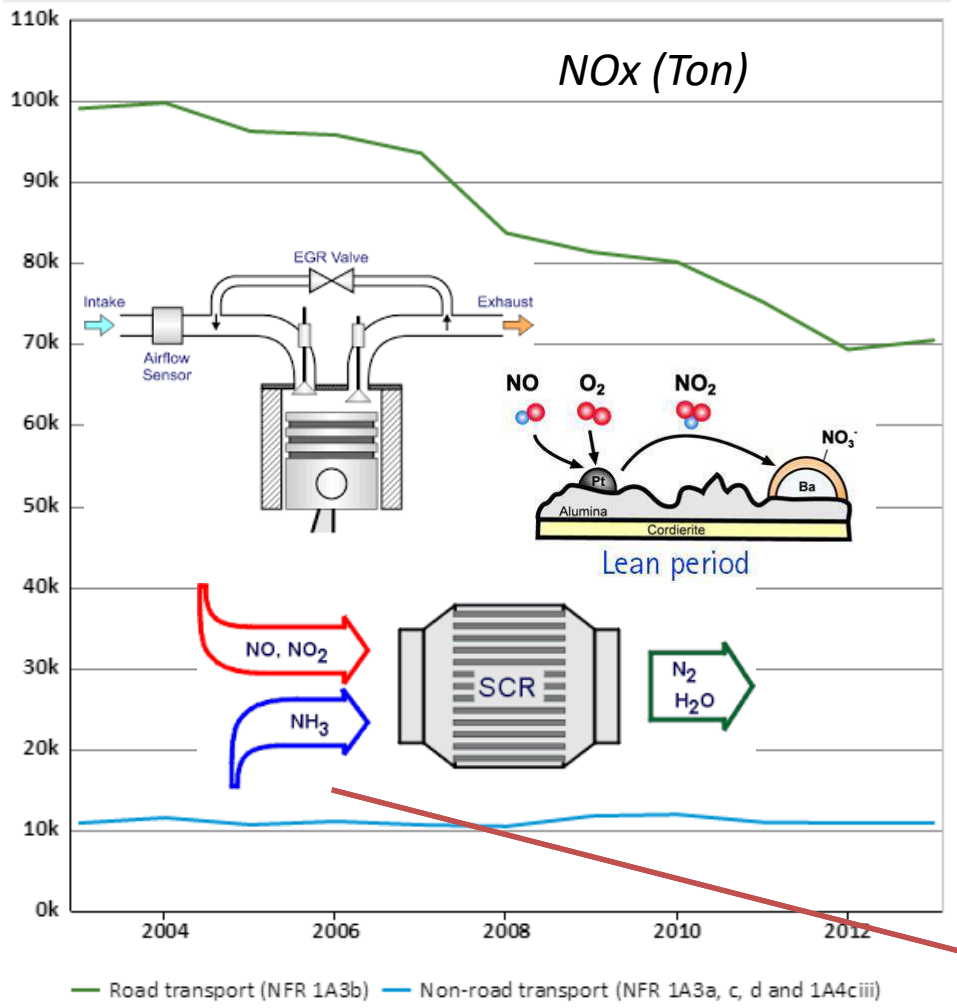
5% NMVOC

3.3% PM 2.5

3.1% PM 10

26% CO

LOCAL EMISSIONS

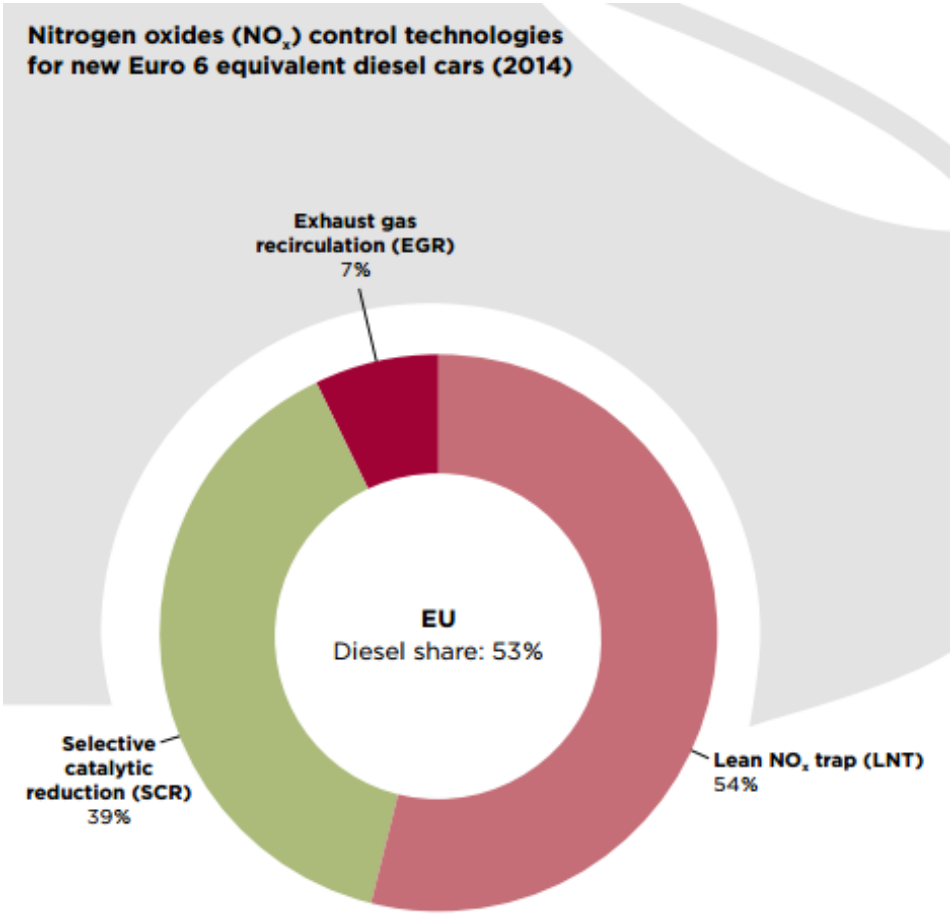


Contribution to the total Portugal

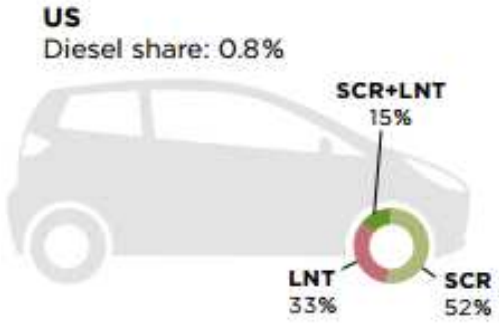
@ 2012
30% NOx
5% NMVOC
3.3% PM 2.5
3.1% PM 10
26% CO

NH_3 from H_2….

EMISSIONS



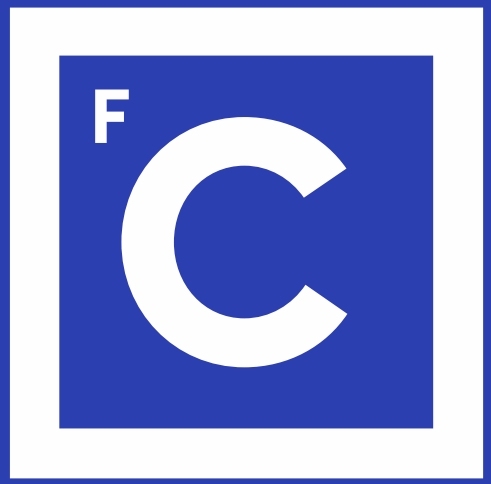
NOx control



So far you learned…..

- Calculation energy soft/active modes MJ/pkm;
- Calculation energy motorized modes MJ/pkm
- Primary, final and useful energy efficiency;
- Fuel and technology matrices;
- Calculation of emissions g/pkm (Tier 1, Tier 2 and Tier 3);
- **Standards for Road vehicles (used in COPERT)**.

Thanks



Ciências ULisboa

Faculdade
de Ciências
da Universidade
de Lisboa