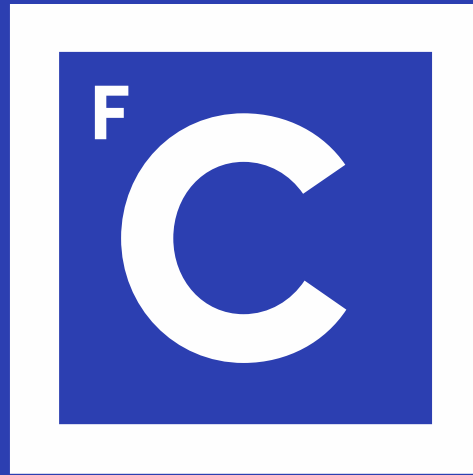




Ciências ULisboa

Faculdade
de Ciências
da Universidade
de Lisboa

DISCIPLINA MIEA 2018

move ► green



Mobilidade Sustentável

Home  Work/ University

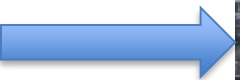
on a regular basis

Commuting by motorized or soft modes



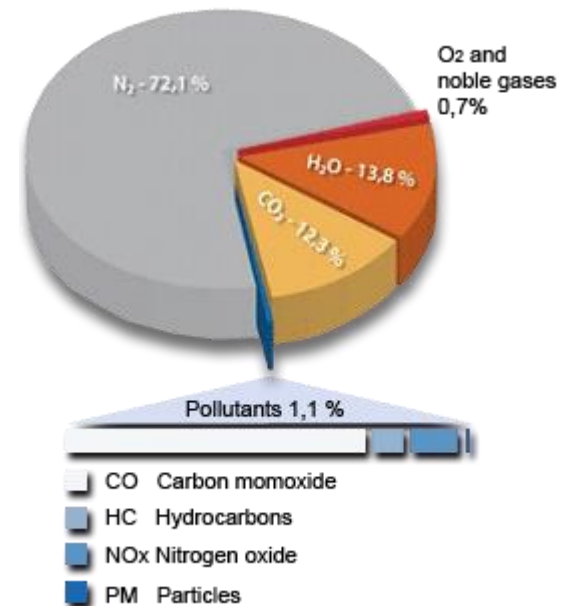
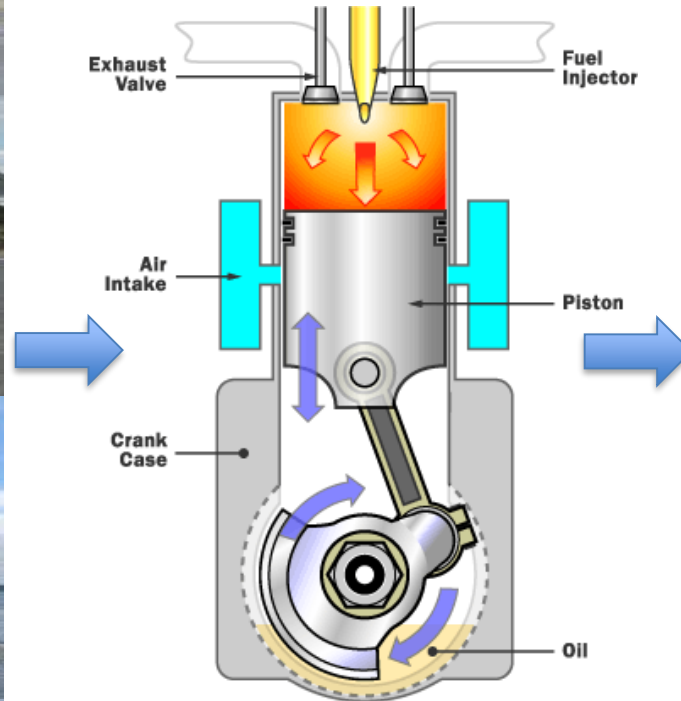
Emissions

Energy



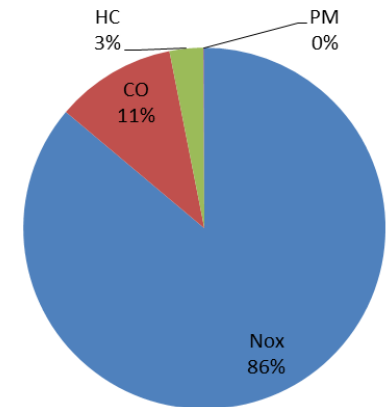
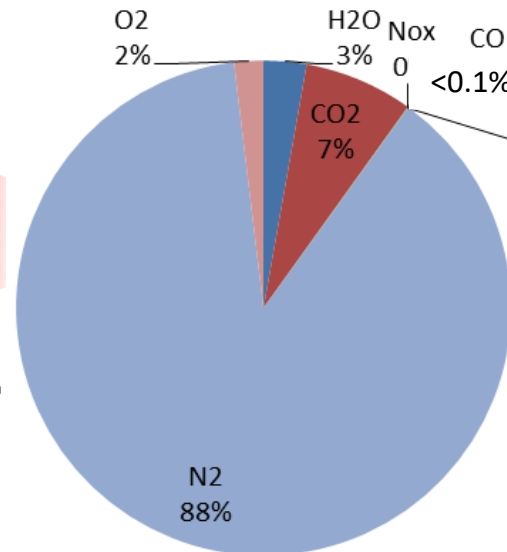
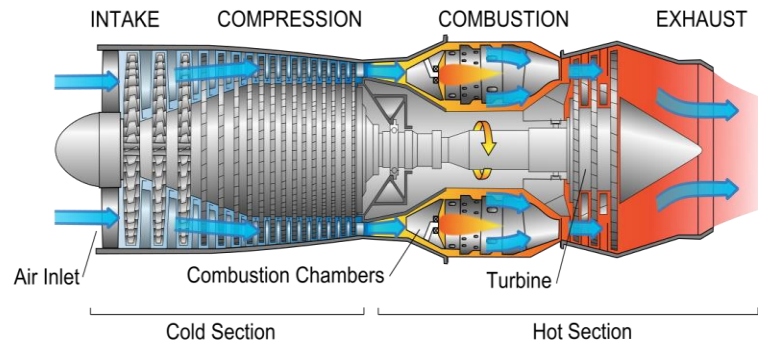


Why do we have emissions???



MOBILE COMBUSTION

Why do we have emissions???

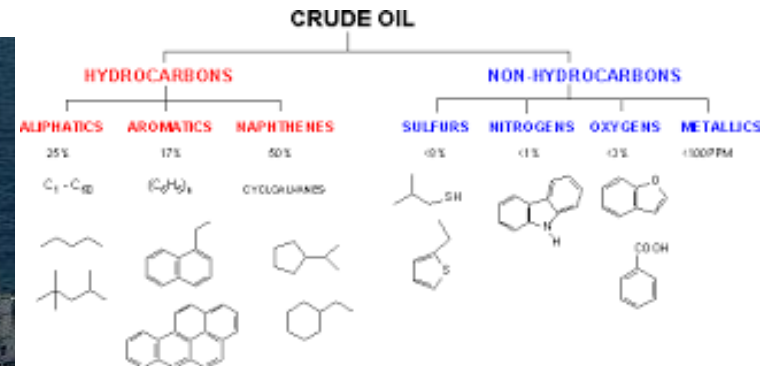


MOBILE COMBUSTION

1 toe = 41.868 GJ or 11.63 MWh

the amount of energy released by burning one tonne of crude oil

1 toe ~ 2.5 tCO₂



Carbon - 83 to 87%

Hydrogen - 10 to 14%

Nitrogen - 0.1 to 2%

Oxygen - 0.05 to 1.5%

Sulfur - 0.05 to 6.0%

Metals - < 0.1%

TABLE D.4
Data on fuel properties

Fuel	Formula (phase)	Molecular weight	Specific gravity: (density,† kg/dm³)	Heat of vaporization, kJ/kg†	Specific heat		Higher heating value, MJ/kg	Lower heating value, MJ/kg	LHV of stoich. mixture, MJ/kg	(A/F) _s	(F/A) _s	Fuel octane rating	
					Liquid, kJ/kg · K	Vapor c _p , kJ/kg · K						RON	MON
Practical fuels§													
Gasoline	C ₈ H _{11.87n} (l)	~110	0.72–0.78	350	2.4	~1.7	47.3	44.0	2.83	14.6	0.0685	91–99	82–89
Light diesel	C ₈ H _{11.8n} (l)	~170	0.78–0.84	270	2.2	~1.7	46.1	43.2	2.79	14.5	0.0690	—	—
Heavy diesel	C ₈ H _{11.7n} (l)	~200	0.82–0.88	230	1.9	~1.7	45.5	42.8	2.85	14.4	0.0697	—	—
Natural gas	C ₈ H _{3.8n} N _{0.1n} (g)	~18	(~0.79†)	—	—	~2	50	45	2.9	14.5	0.069	—	—
Pure hydrocarbons													
Methane	CH ₄ (g)	16.04	(0.72†)	509	0.63	2.2	55.5	50.0	2.72	17.23	0.0580	120	120
Propane	C ₃ H ₈ (g)	44.10	0.51 (2.0†)	426	2.5	1.6	50.4	46.4	2.75	15.67	0.0638	112	97
Isooctane	C ₈ H ₁₈ (l)	114.23	0.692	308	2.1	1.63	47.8	44.3	2.75	15.13	0.0661	100	100
Cetane	C ₁₆ H ₃₄ (l)	226.44	0.773	358	—	1.6	47.3	44.0	2.78	14.82	0.0675	—	—
Benzene	C ₆ H ₆ (l)	78.11	0.879	433	1.72	1.1	41.9	40.2	2.82	13.27	0.0753	—	115
Toluene	C ₇ H ₈ (l)	92.14	0.867	412	1.68	1.1	42.5	40.6	2.79	13.50	0.0741	120	109
Alcohols													
Methanol	CH ₄ O(l)	32.04	0.792	1103	2.6	1.72	22.7	20.0	2.68	6.47	0.155	106	92
Ethanol	C ₂ H ₆ O(l)	46.07	0.785	840	2.5	1.93	29.7	26.9	2.69	9.00	0.111	107	89
Other fuels													
Carbon	C(s)	12.01	~2§	—	—	—	33.8	33.8	2.70	11.51	0.0869	—	—
Carbon monoxide	CO(g)	28.01	(1.25†)	—	—	1.05	10.1	10.1	2.91	2.467	0.405	—	—
Hydrogen	H ₂ (g)	2.015	(0.090†)	—	—	1.44	142.0	120.0	3.40	34.3	0.0292	—	—

(l) liquid phase; (g) gaseous phase; (s) solid phase.

† Density in kg/m³ at 0°C and 1 atm.

‡ At 1 atm and 25°C for liquid fuels; at 1 atm and boiling temperature for gaseous fuels.

§ Typical values.

RON, research octane number; MON, motor octane number.

Sources:

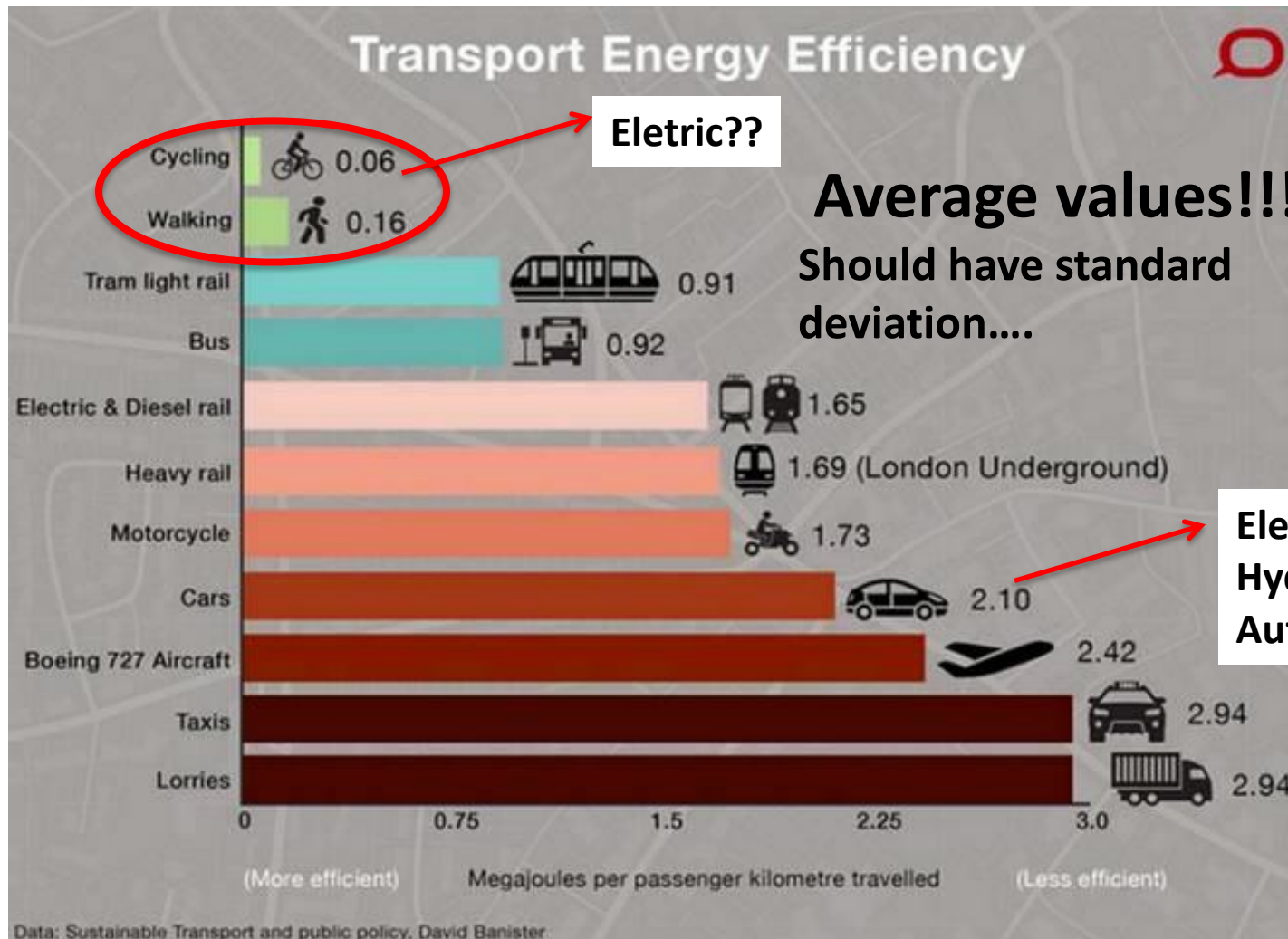
E. M. Goodger, *Hydrocarbon Fuels; Production, Properties and Performance of Liquids and Gases*, Macmillan, London, 1975.

E. F. Obert, *Internal Combustion Engines and Air Pollution*, Intext Educational Publishers, 1973 edition.

C. F. Taylor, *The Internal Combustion Engine in Theory and Practice*, vol. I, MIT Press, 1966.

J. W. Rose and J. R. Cooper (eds.), *Technical Data on Fuel*, 7th ed., British National Committee, World Energy Conference, London, 1977.

		Density at STP (kg/m ³)	Ratio of HHV to LHV energy content	Net Calorific Value / LHV (MJ/L) (MJ/kg)		Gross Calorific Value / HHV (MJ/L) (MJ/kg)		Carbon Intensity (g CO ₂ -eq / MJ LHV)
Crude Oil		856 ± 24	1.052 ± 0.001	36.84 ± 1.05	43.05 ± 1.40	38.76 ± 1.10	45.30 ± 1.47	73.5 ± 2.6
Petrol / Gasoline		741 ± 4	1.063 ± 0.015	32.70 ± 0.44	44.15 ± 0.74	34.77 ± 0.47	46.94 ± 0.70	70.8 ± 4.4
Diesel		837 ± 8	1.063 ± 0.011	35.94 ± 0.45	42.91 ± 0.46	38.19 ± 0.47	45.60 ± 0.49	74.3 ± 2.3
Fuel Oil		959 ± 17	1.058 ± 0.008	39.21 ± 1.09	40.87 ± 0.94	41.50 ± 1.15	43.26 ± 1.00	77.8 ± 2.1
LPG		533 ± 18	1.077 ± 0.008	24.67 ± 0.80	46.28 ± 0.74	26.57 ± 0.86	49.84 ± 0.80	63.9 ± 2.1
Kerosene		807 ± 6	1.053 ± 0.001	35.24 ± 0.41	43.69 ± 0.51	37.10 ± 0.43	45.99 ± 0.54	72.0 ± 1.8
Hydrogen	(35 MPa)	23.65 ± 0.09		2.837 ± 0.003		3.355 ± 0.004		
	(70 MPa)	39.69 ± 0.16	1.183 ± 0.001	4.761 ± 0.005	119.95 ± 0.13	5.631 ± 0.006	141.88 ± 0.16	0
	(liquid)	72.41 ± 0.72		8.685 ± 0.010		10.273 ± 0.011		
		(kg/m ³)	(HHV / LHV)	(MJ/kg)		(MJ/kg)		(g/MJ LHV)
Coal			1.050 ± 0.004	-	25.75 ± 2.64	-	27.05 ± 2.77	95.7 ± 7.0
		(kg/m ³)	(HHV / LHV)	(MJ/m ³)	(MJ/kg)	(MJ/m ³)	(MJ/kg)	(g/MJ LHV)
Natural Gas		0.768 ± 0.039	1.109 ± 0.003	35.22 ± 2.22	45.86 ± 3.95	39.05 ± 2.47	50.84 ± 4.38	56.9 ± 3.4
Hydrogen	(1 atm.)	0.0838 ± 0.0008	1.183 ± 0.001	10.05 ± 0.01	119.95 ± 0.13	11.88 ± 0.01	141.88 ± 0.16	0



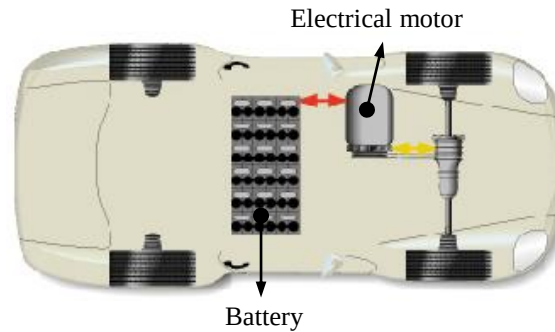
Average values!!!!

Should have standard deviation....

Eletric??
Hydrogen??
Autonomous??



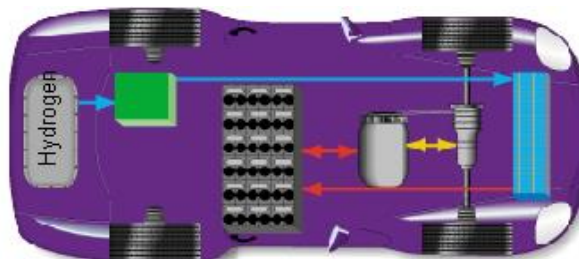
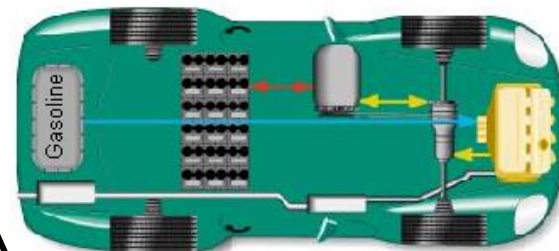
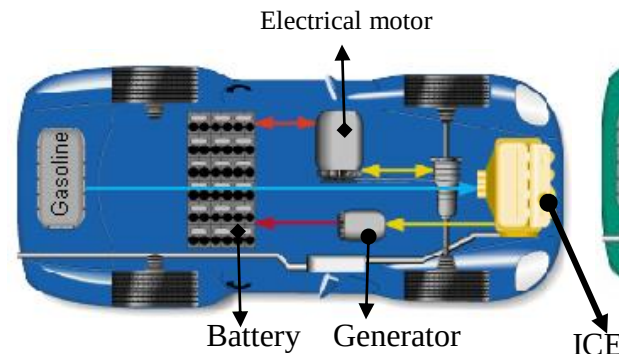
Plug-In



Final to useful energy....

Pure electric (efic. 60-70%)

Hybrids (efic. 20-30%)



Fuel cell (efic. 30-40%)

Most sold vehicle Portugal



0-100 km/h	14.5 s	
European test cycle l/100km	5.6	
1059 kg		

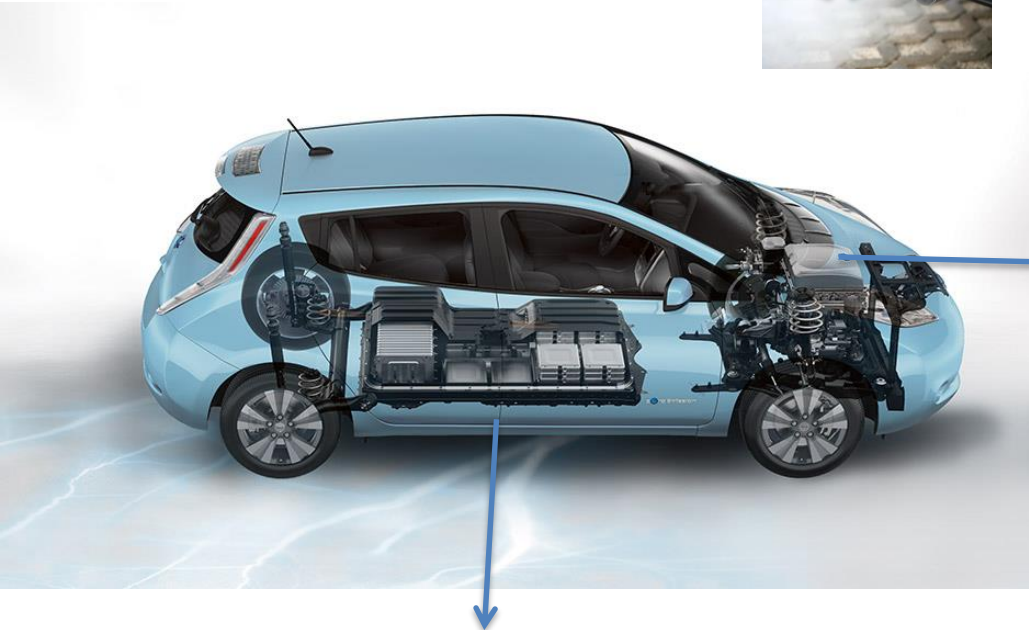
Gasoline Internal combustion engine

https://www.youtube.com/watch?v=DKF5dKo_r_Y

Leaf



No tailpipe emissions

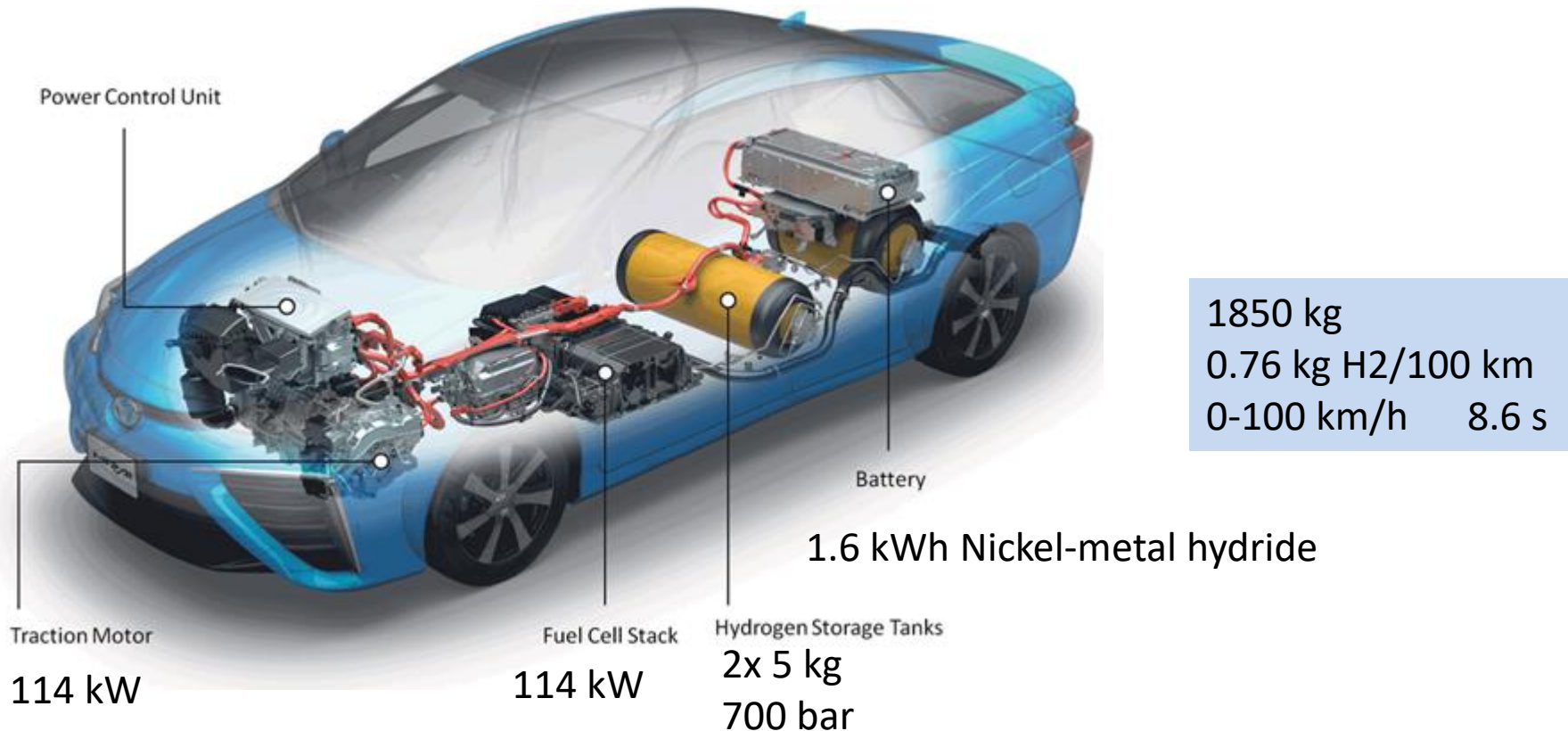


output power increased to over 110 kW (110 kW is peak power of electric motor – previously it was 80 kW)

- 192 cells (nickel manganese cobalt NMC instead lithium manganese oxide cells LMO)
- 24 modules (8 cells per module)
- 40 kWh capacity (32 kWh is available)

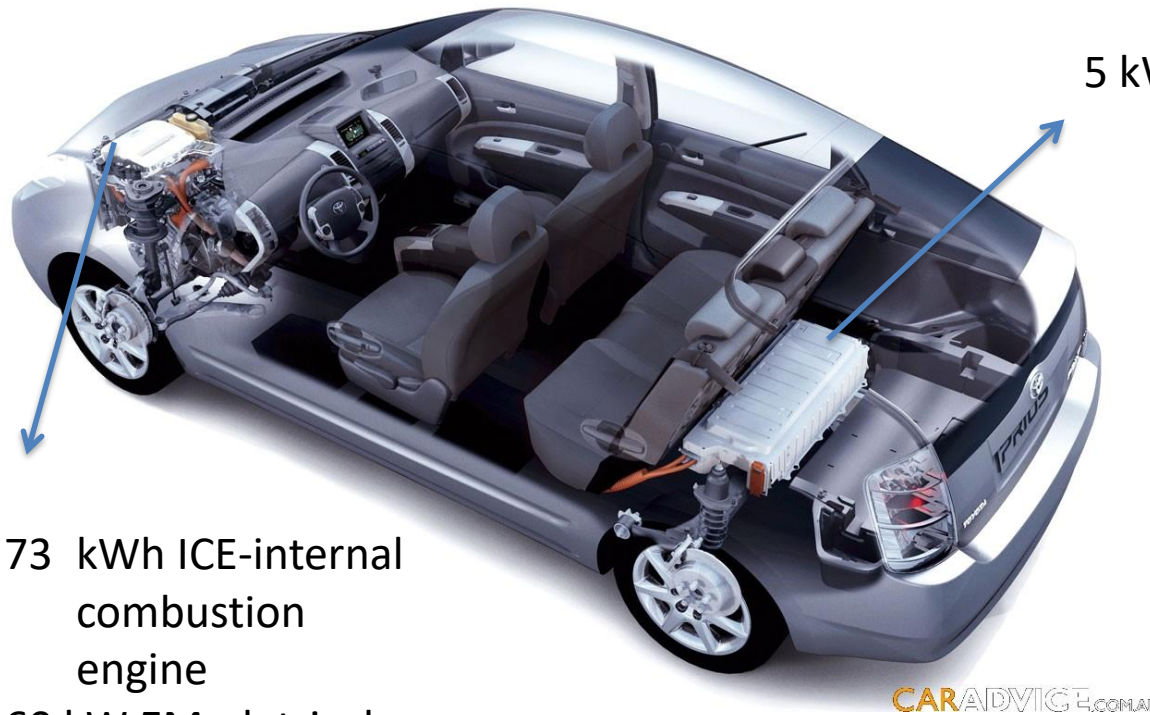
Curb weight (kg)	1570
(kWh/100km)	19.4
0-100km/h in 7.9 seconds	

Mirai



<https://www.youtube.com/watch?v=eybTbwOwkec>

Prius

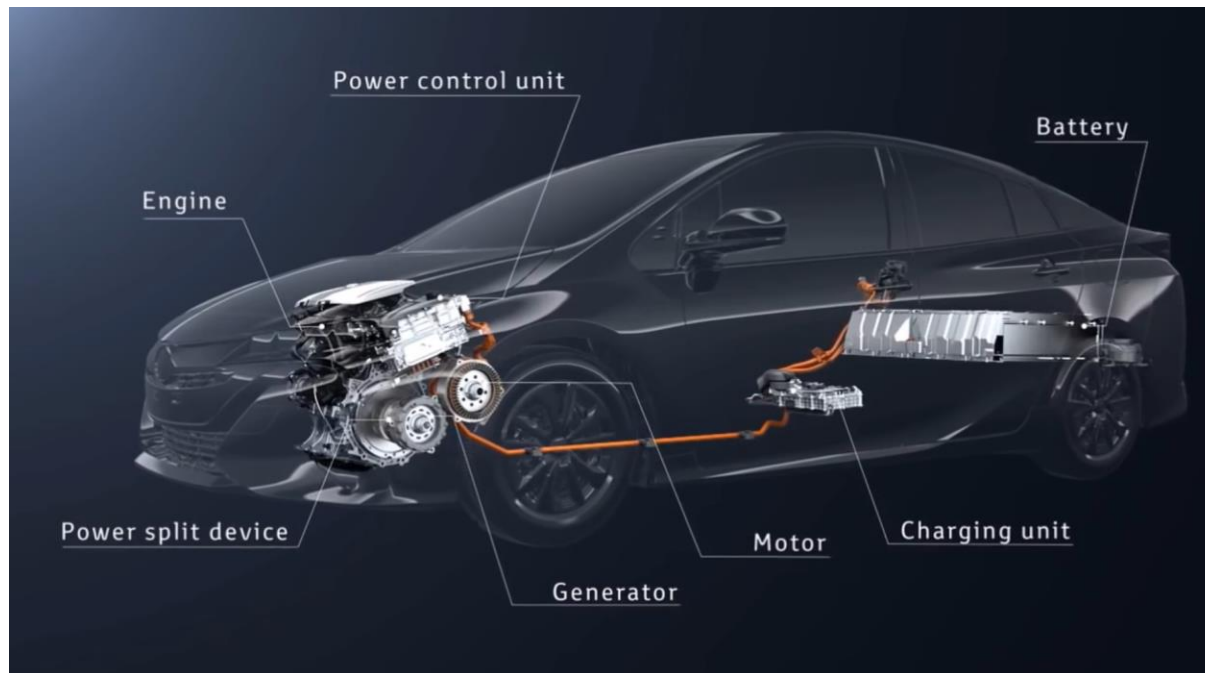


5 kWh Ni-MH

73 kWh ICE-internal
combustion
engine
60 kW EM-eletrical
motor

1475 kg
3 L/100 km
0-100 km/h 10.6 s

Prius plug-in



8.8 kWh Li-ion

1526 kg

1 L/100km

11 kWh/100km

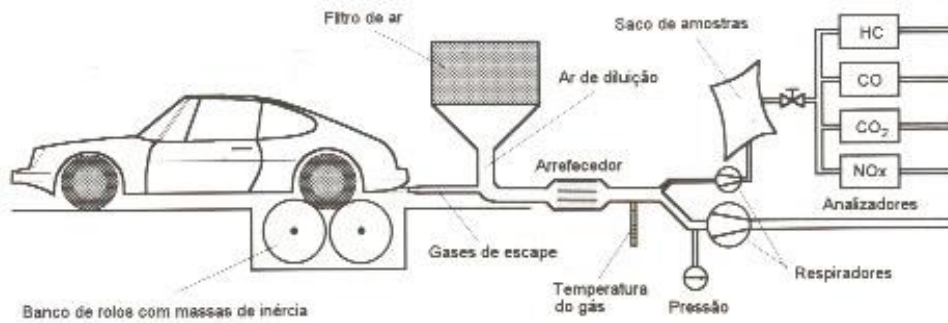
0-100 km/h 11.1 s

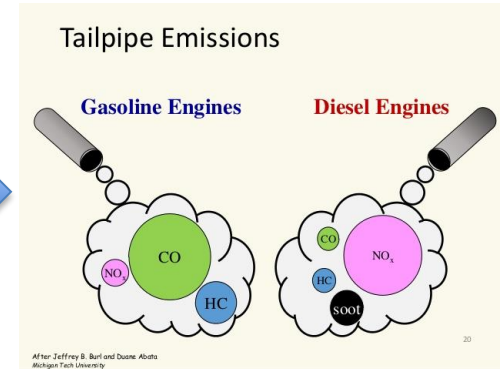
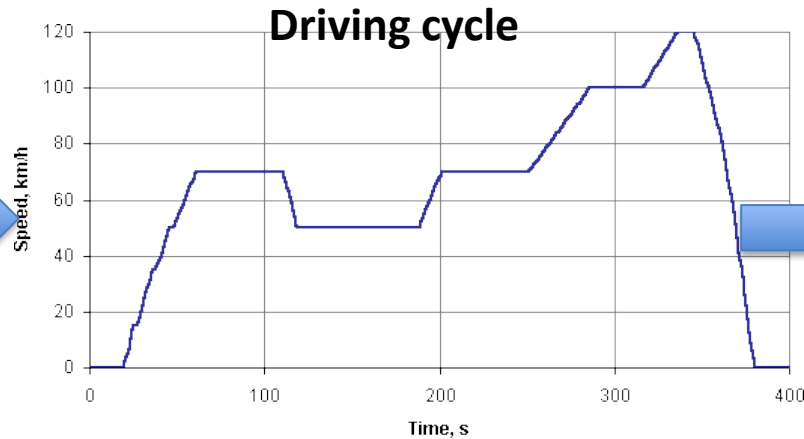
100 kW EM-eletrical motor

Car magazine info..... L/100km and gCO₂/km and Euro standard (CO, NMVOC, NO_x)



www.dieselnat.com



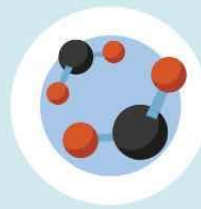


	UDC	EUDC	Artemis Urban	WLTC low*	WLTC
Duration [s]	780	400	993	589	1800
Length [km]	4.00	6.9	4.87	3.09	23.27
Average speed [km/h]	18.4	62.6	17.7	18.9	46.5
Max speed [km/h]	50	120	57.3	56.5	131.3
Idle time [%]	23.1	8.7	20.7	24.8	12.6
Cruising time [%]	25.1	49.2	9.7	15.8	25.3
Acceleration time [%]	27.2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

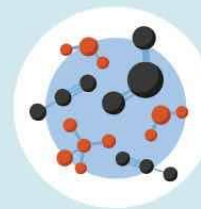
LABORATORY
TESTS FOR
PASSENGER
CARS MEASURE:



**FUEL
CONSUMPTION**



**CO2
EMISSIONS**
which are directly
related to fuel consumption



**POLLUTANT
EMISSIONS**



**ENERGY CONSUMPTION VALUES OF
ALTERNATIVE POWERTRAINS**
as well as the range of
electric vehicles

NEDC

New European Driving Cycle

- Designed in the **1980s**
- Based on **theoretical driving**
- Has become **outdated**



OLD TEST

NEW TEST

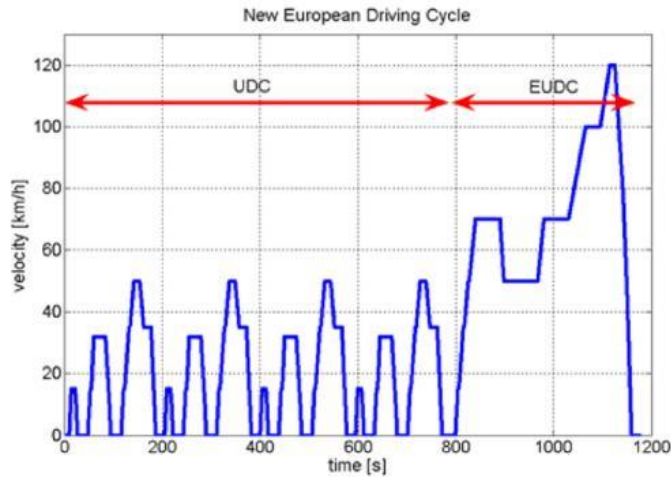
WLTP

Worldwide Harmonised Light
Vehicle Test Procedure

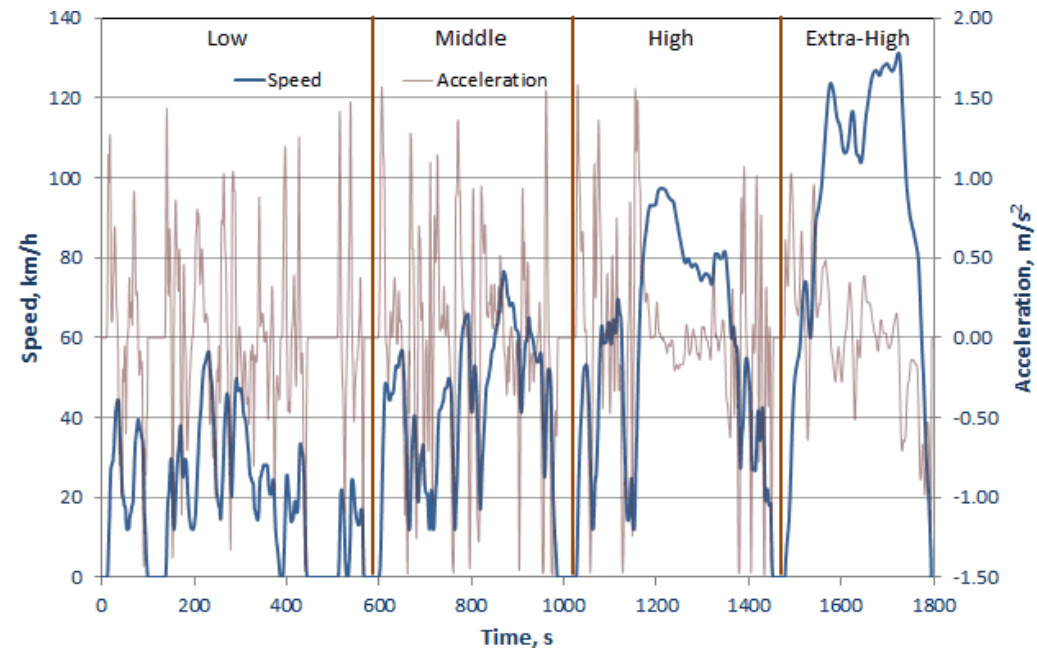
- Coming into force in **2017**
- Based on **real-driving data**
- Better matches **on-road performance**



- Europe – Light-duty



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



EU Emission Standards for Passenger Cars (Category M₁*)

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 N₁ 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

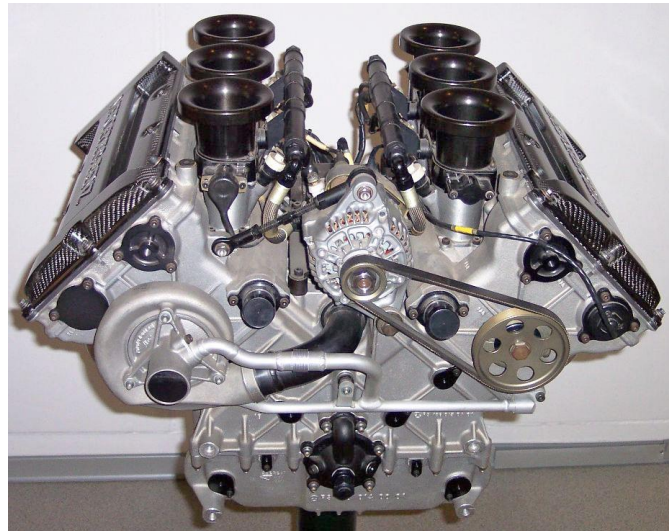
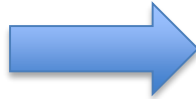
d. and NMHC = 0.068 g/km

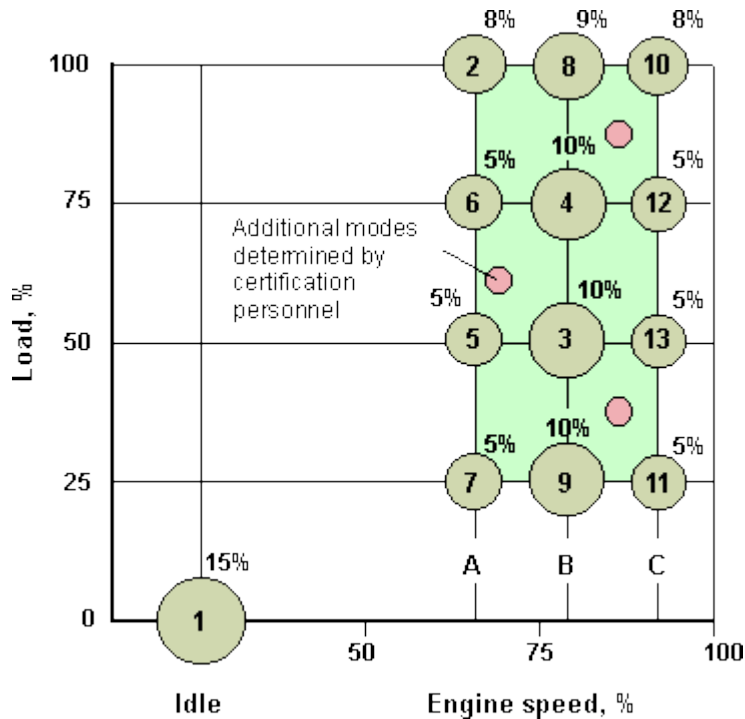
e. applicable only to vehicles using DI engines

f. 0.0045 g/km using the PMP measurement procedure

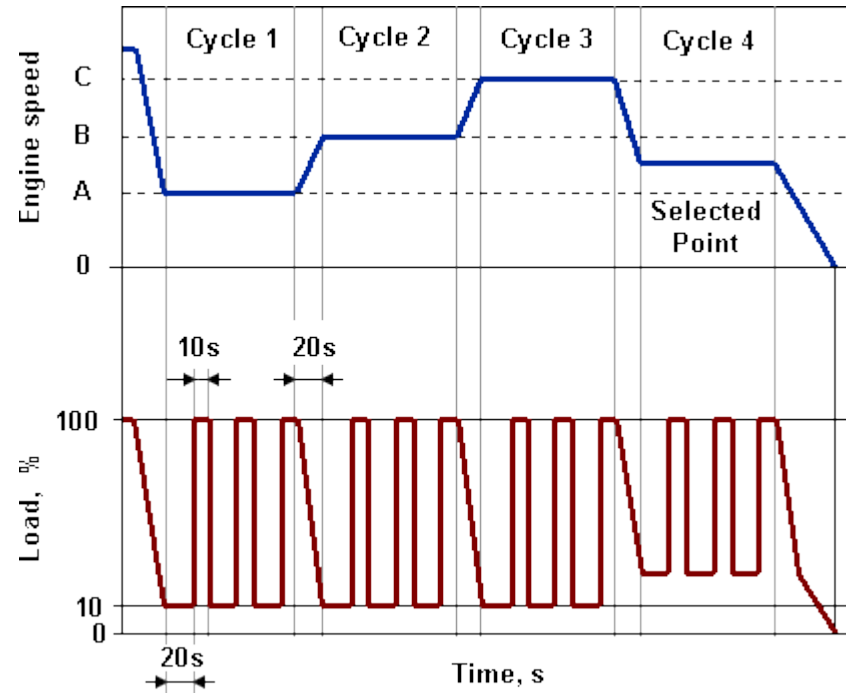
g. 6.0×10¹² 1/km within first three years from Euro 6 effective dates

Heavy-duty





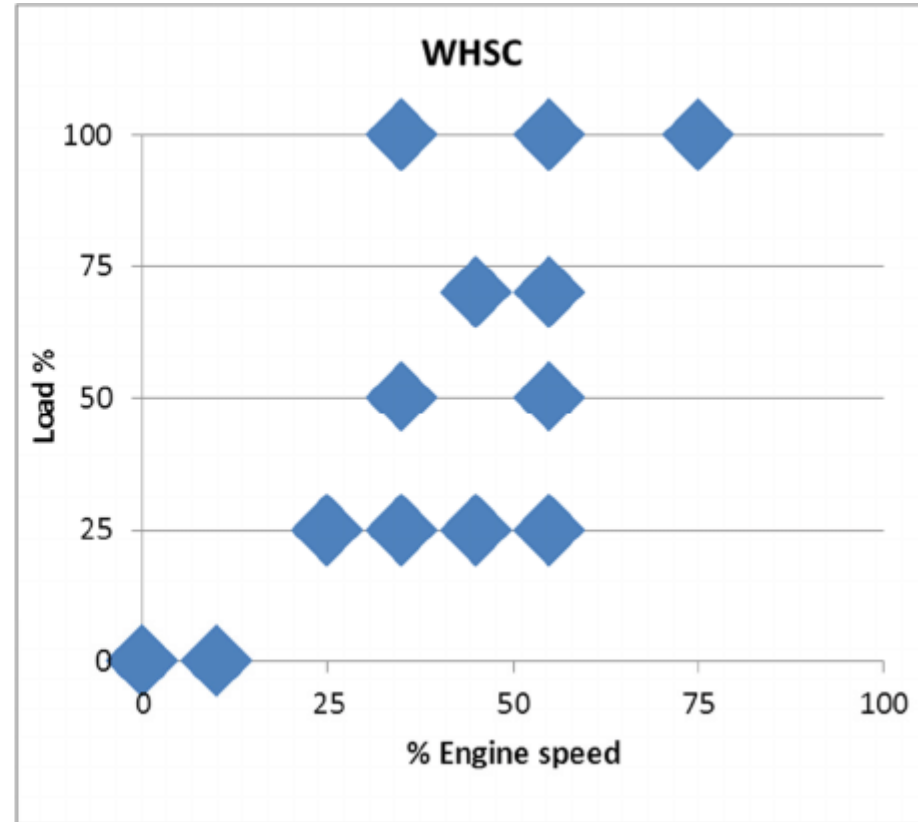
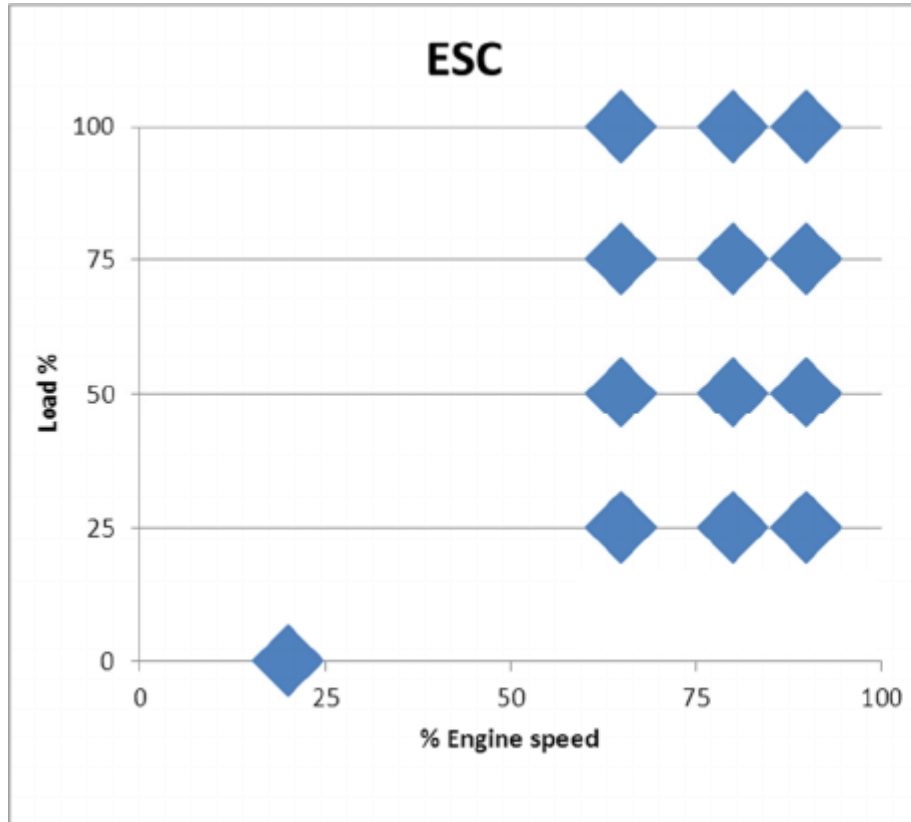
European Stationary Cycle (ESC)



European Load Response (ELR) engine test



World Harmonized Stationary Cycle (WHSC)



World Harmonized Stationary Cycle (WHSC)

- Europe Heavy-duty

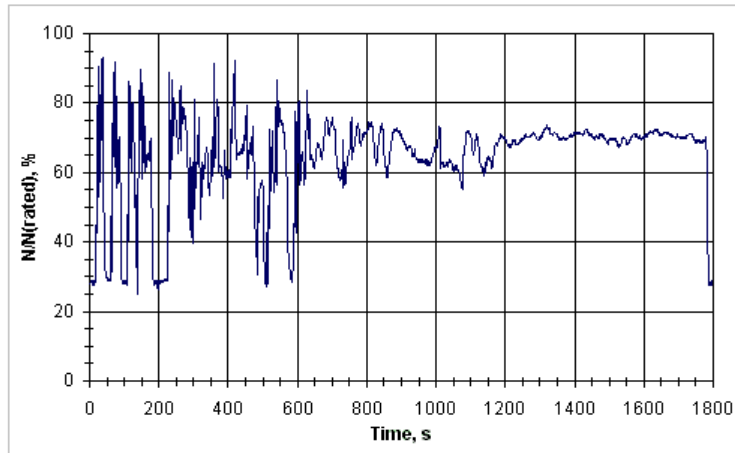
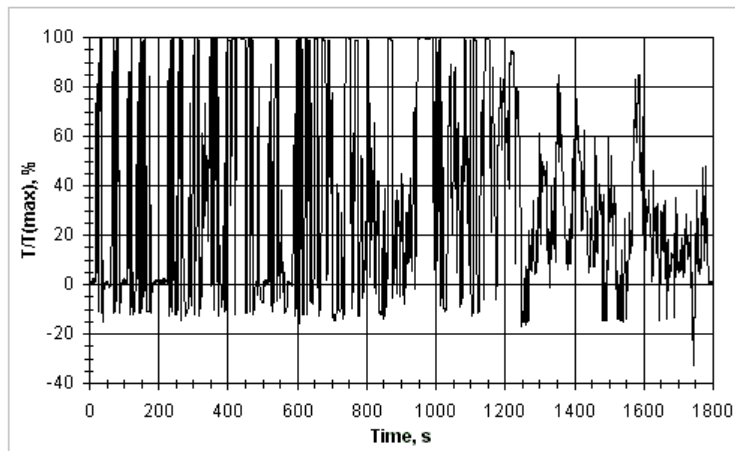
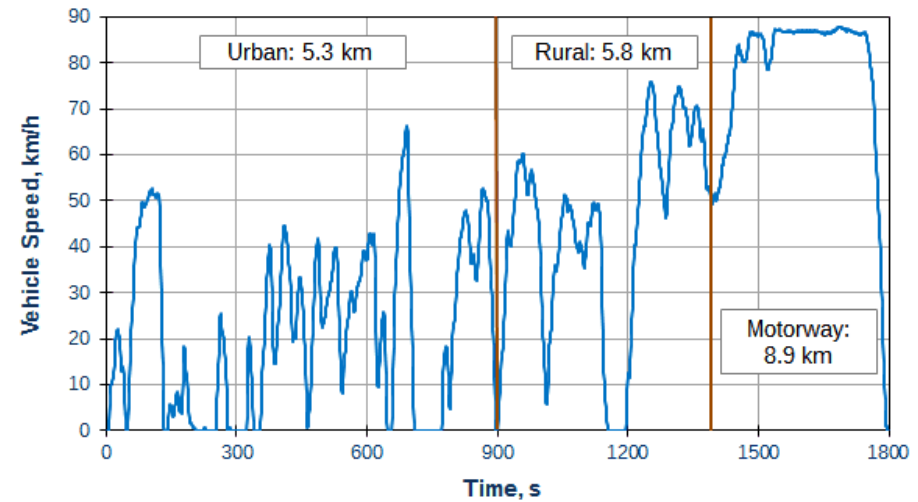


Figure 2. ETC Transient Cycle—Engine Speed



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



- Europe Heavy-duty

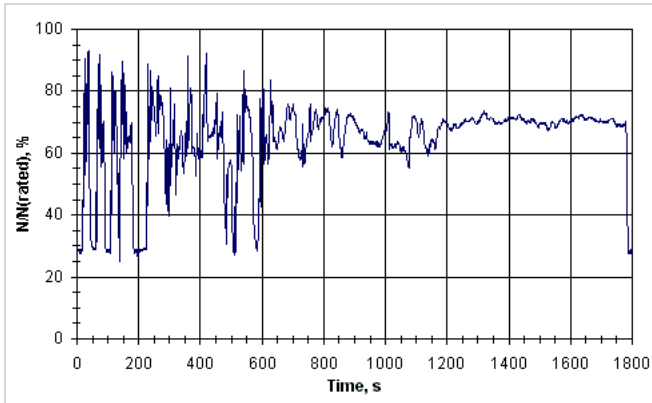


Figure 2. ETC Transient Cycle—Engine Speed

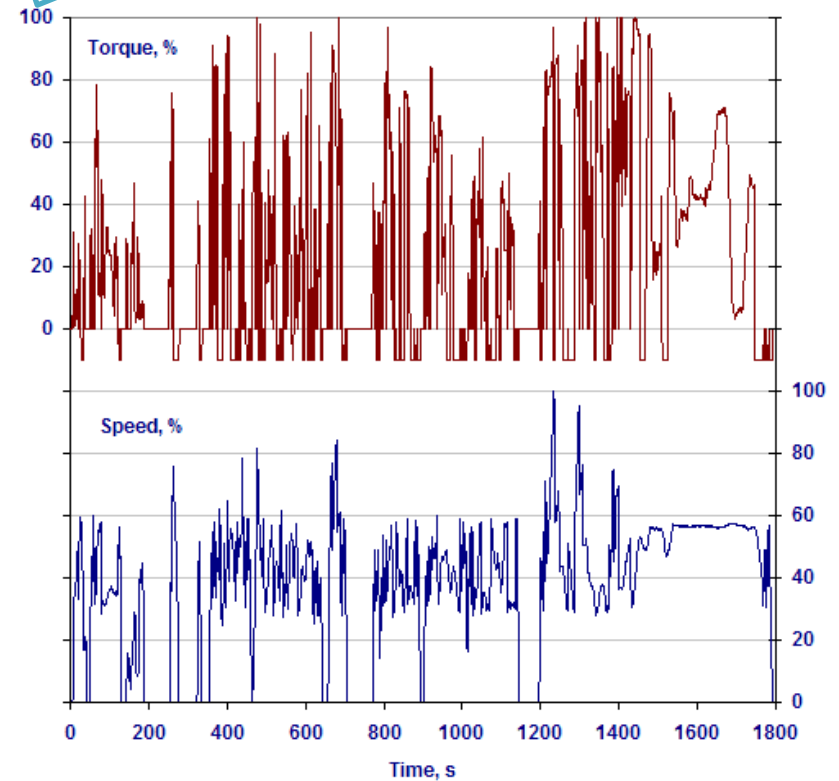
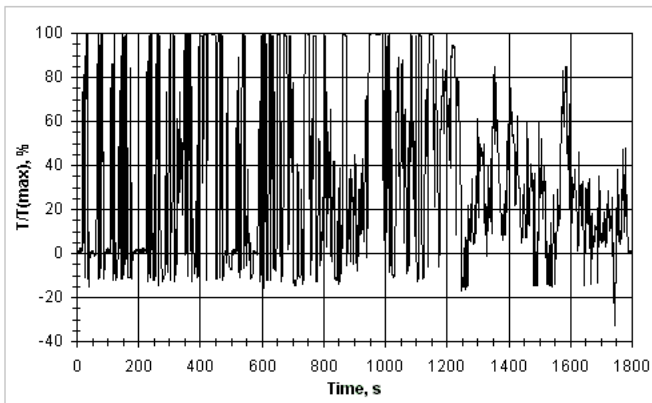


Figure 1. World Harmonized Transient Cycle (WHTC)

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 <i>EEV only</i>	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	

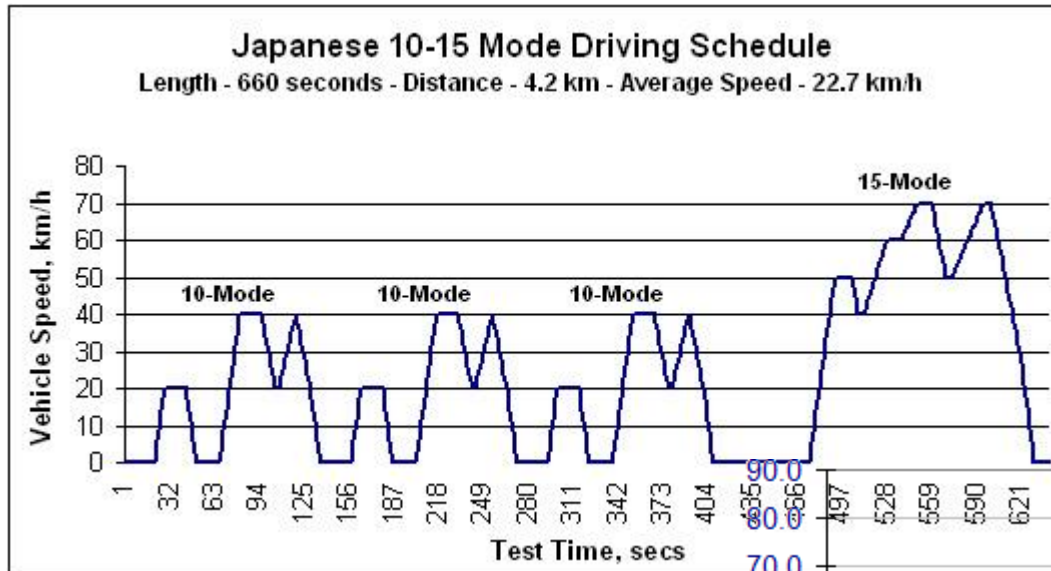
a - PM = 0.13 g/kWh for engines < 0.75 dm³ swept volume per cylinder and a rated power speed > 3000 min⁻¹

Table 2
EU Emission Standards for Heavy-Duty Diesel and Gas Engines: Transient Testing

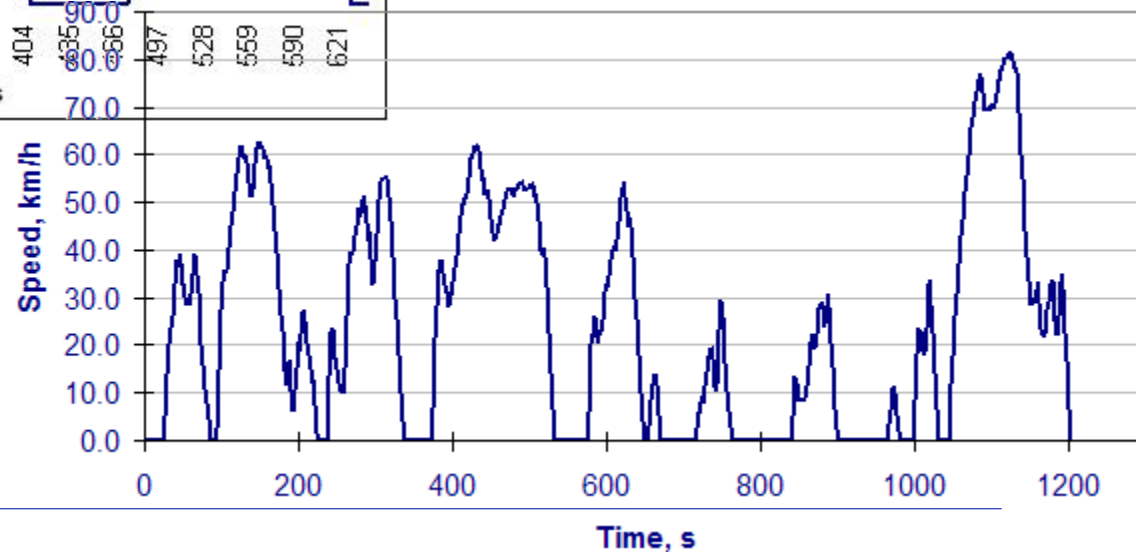
Stage	Date	Test	CO	NMHC	CH ₄ ^a	NOx	PM ^b	PN ^e
			g/kWh					1/kWh
Euro III	1999.10 <i>EEV only</i>	ETC	3.0	0.40	0.65	2.0	0.02	
	2000.10		5.45	0.78	1.6	5.0	0.16 ^c	
Euro IV	2005.10		4.0	0.55	1.1	3.5	0.03	
Euro V	2008.10		4.0	0.55	1.1	2.0	0.03	
Euro VI	2013.01	WHTC	4.0	0.16 ^d	0.5	0.46	0.01	6.0×10 ¹¹

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 dm³ 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

- Japan light-duty



JC08

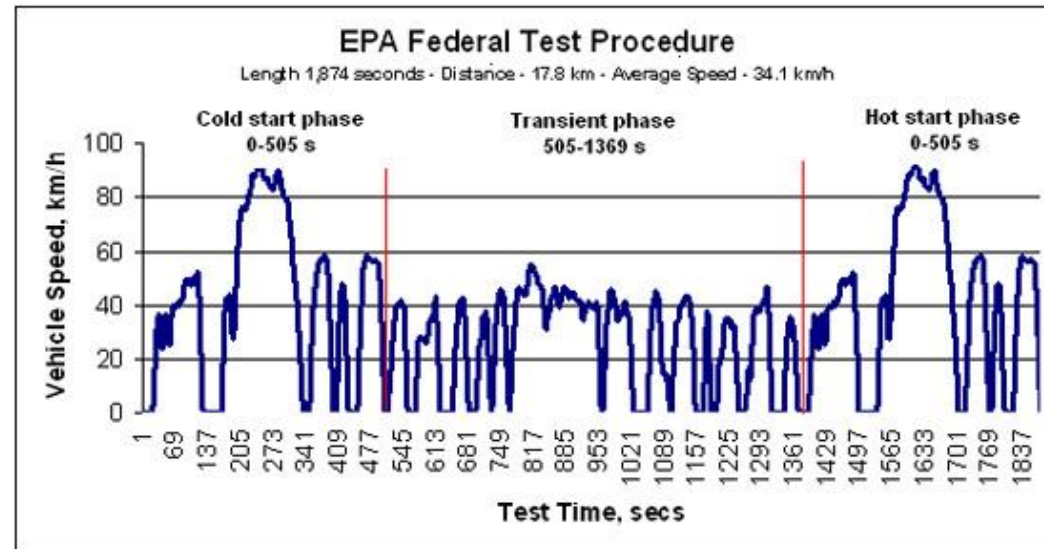


Japanese Emission Standards for Diesel Passenger Cars, g/km

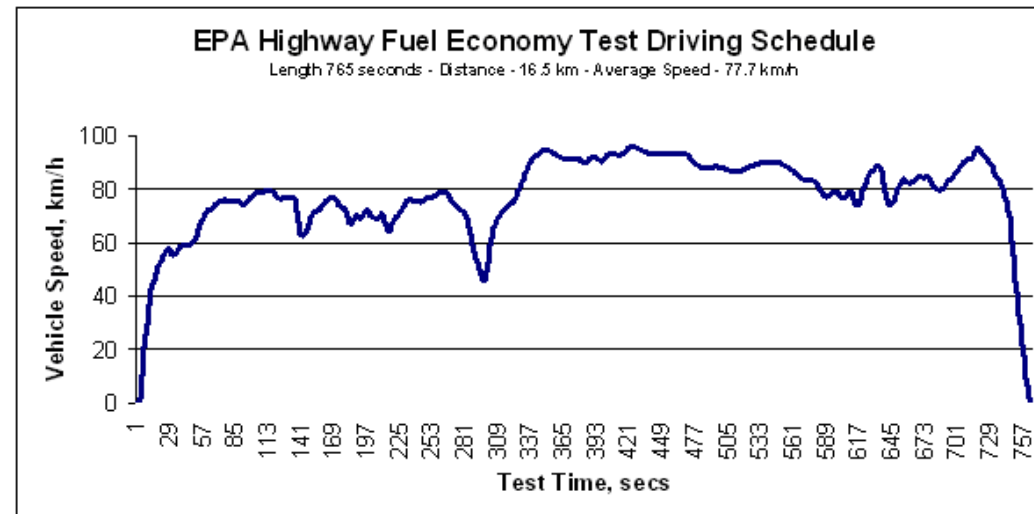
Vehicle Weight	Date	Test	CO	HC	NOx	PM
			mean (max)	mean (max)	mean (max)	mean (max)
< 1250 kg*	1986	10-15 mode	2.1 (2.7)	0.40 (0.62)	0.70 (0.98)	
	1990		2.1 (2.7)	0.40 (0.62)	0.50 (0.72)	
	1994		2.1 (2.7)	0.40 (0.62)	0.50 (0.72)	0.20 (0.34)
	1997		2.1 (2.7)	0.40 (0.62)	0.40 (0.55)	0.08 (0.14)
	2002 ^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						

- **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

EU Emission Standards for Passenger Cars (Category M₁*)

Category	50,000 miles/5 years					100,000 miles/5 years		g/km					
	NMOG ^a	CO	NOx	PM	HCHO	NMOG ^a	CO	CO	HC	HC+NOx	NOx	PM	PN
Passenger cars								2.72 (3.16)	-	0.97 (1.13)	-	0.14 (0.18)	-
Tier 1	0.25	3.4	0.4	0.08	-	0.31	4.2	1.0	-	0.7	-	0.08	-
TLEV	0.125	3.4	0.4	-	0.015	0.156	4.2	1.0	-	0.9	-	0.10	-
LEV	0.075	3.4	0.2	-	0.015	0.090	4.2	0.64	-	0.56	0.50	0.05	-
ULEV	0.040	1.7	0.2	-	0.008	0.055	2.1	0.50	-	0.30	0.25	0.025	-
								0.50	-	0.23	0.18	0.005 ^f	-
								0.50	-	0.23	0.18	0.005 ^f	6.0×10 ¹¹
								0.50	-	0.17	0.08	0.005 ^f	6.0×10 ¹¹
Euro 6 2014.09								Positive Ignition (Gasoline)					
Euro 1†								2.72 (3.16)	-	0.97 (1.13)	-	-	-
Euro 2								2.2	-	0.5	-	-	-
Euro 3								2.30	0.20	-	0.15	-	-
Euro 4								1.0	0.10	-	0.08	-	-
Euro 5								1.0	0.10 ^d	-	0.06	0.005 ^{e,f}	-
Euro 6								1.0	0.10 ^d	-	0.06	0.005 ^{e,f}	6.0×10 ¹¹ e,g

2.11 g/km
1.06 g/km

* At the Euro 1..4 stages, passenger vehicles > 2,500 kg were type approved as Category N₁ 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. 6.0×10¹² 1/km within first three years from Euro 6 effective dates

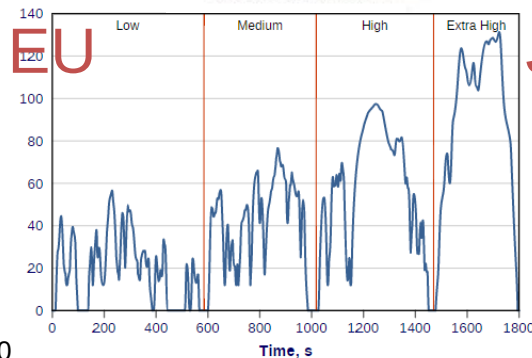
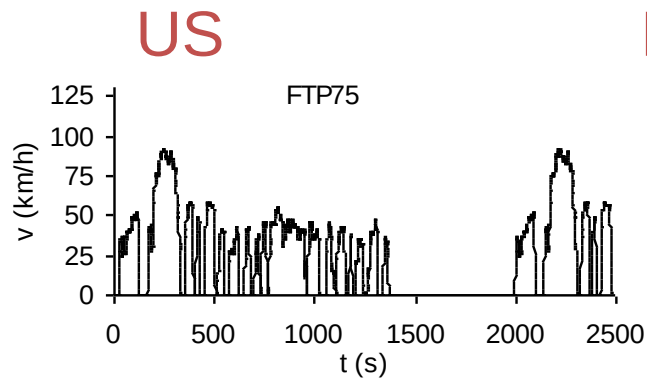
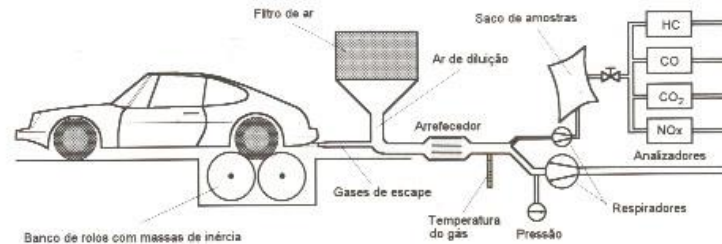
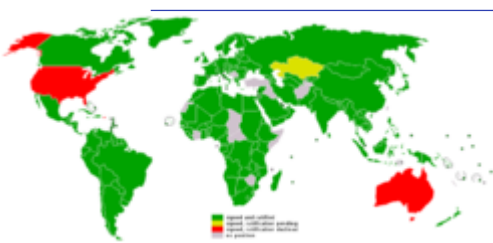


Figure 1. WLTC cycle for Class 3b vehicles

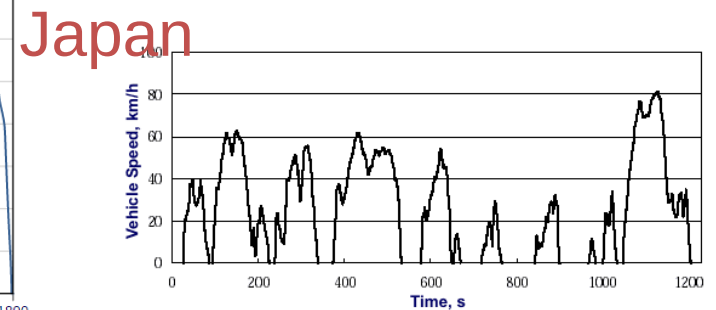
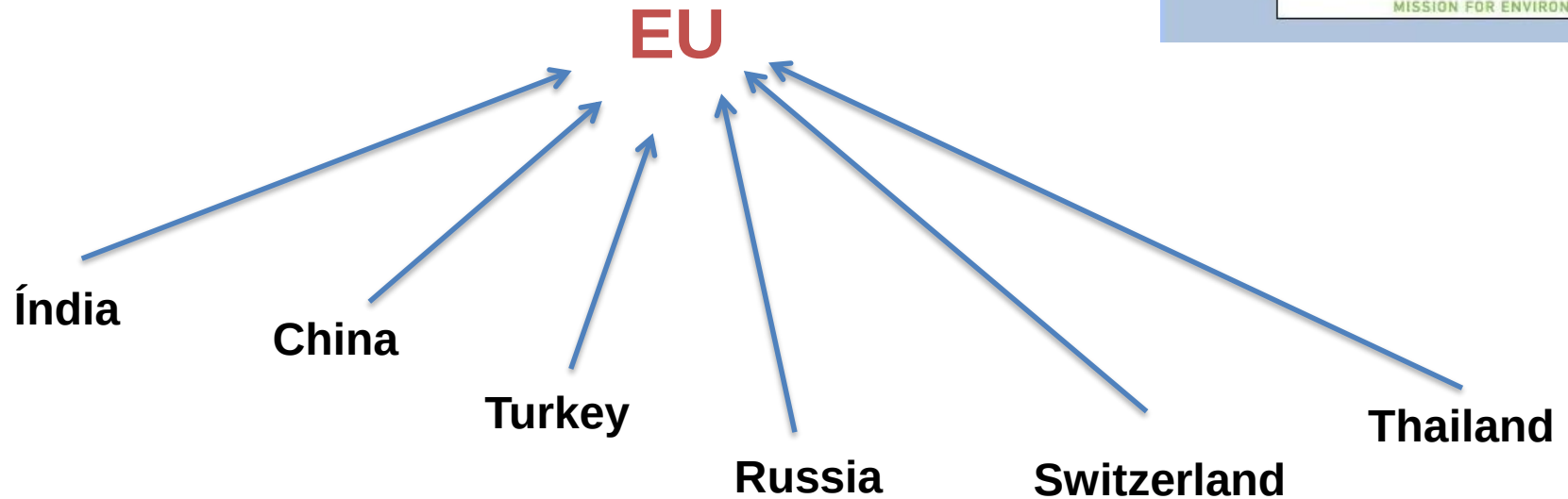
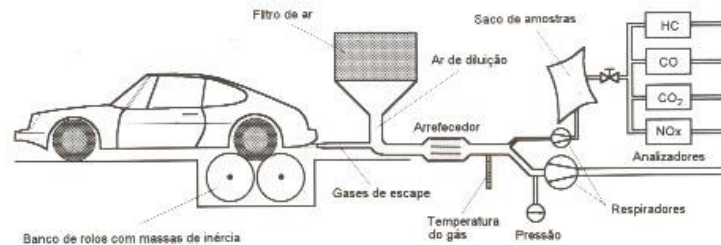
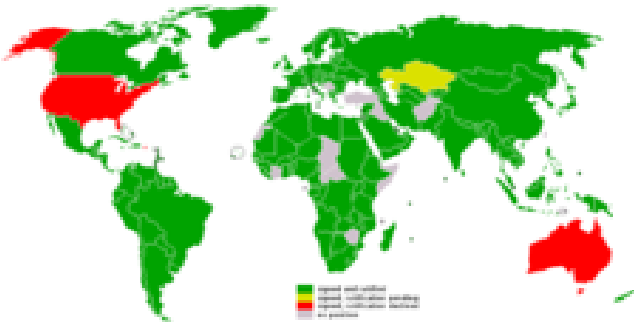


Figure 2. New Transient Mode for Vehicles < 3,500 kg GVW (proposed)

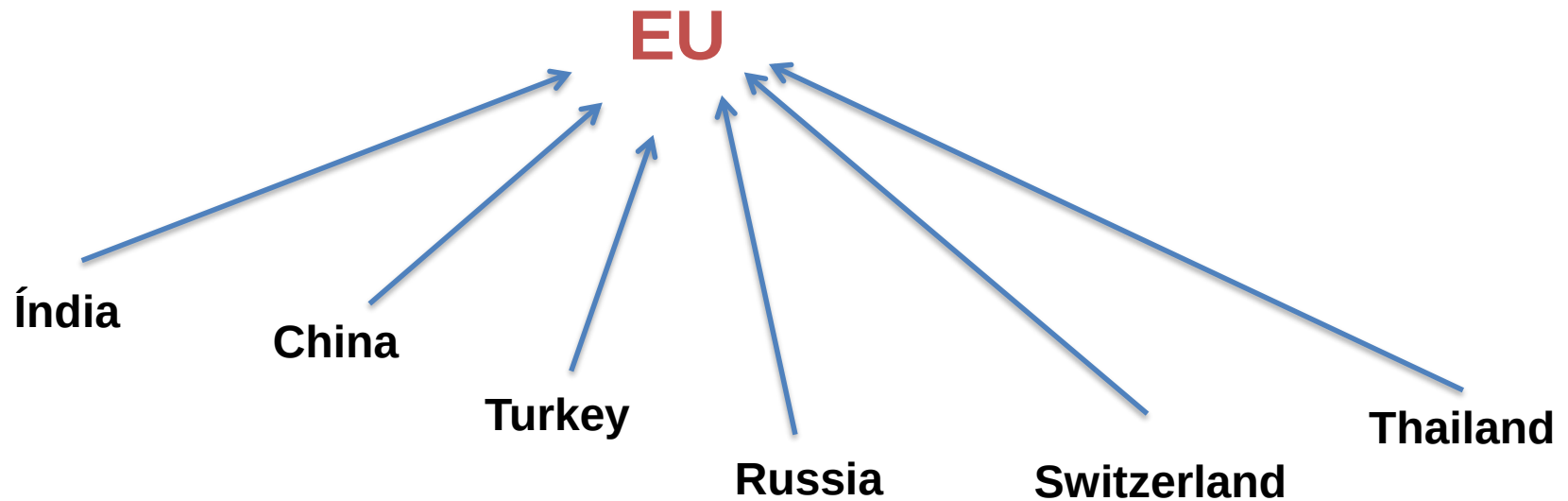
Driving cycle	FTP75	NEDC	10*15 mode
Maximum speed (km/h)	91.2	120	70
Average speed (km/h)	34.1	33.6	22.7
Distance (km)	17.8	11.05	4.16
Time (s/min.)	2479/ 41.3	1180/19.7	660/11
Maximum acceleration (m/s ²)	1.48	1.06	0.79
idle (s)	361	298	215



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



Worldwide Harmonized Light Vehicles Test Cycle (WLTC)

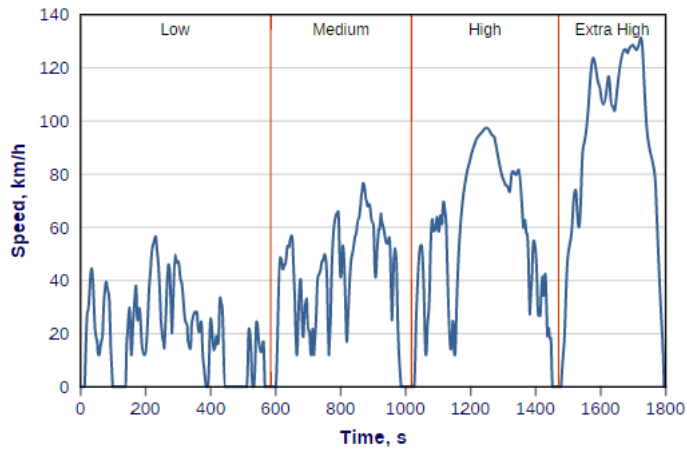


Figure 1. WLTC cycle for Class 3b vehicles

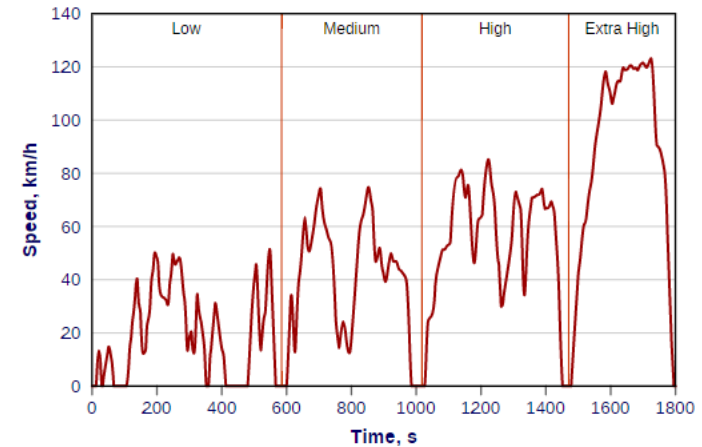


Figure 2. WLTC cycle for Class 2 vehicles

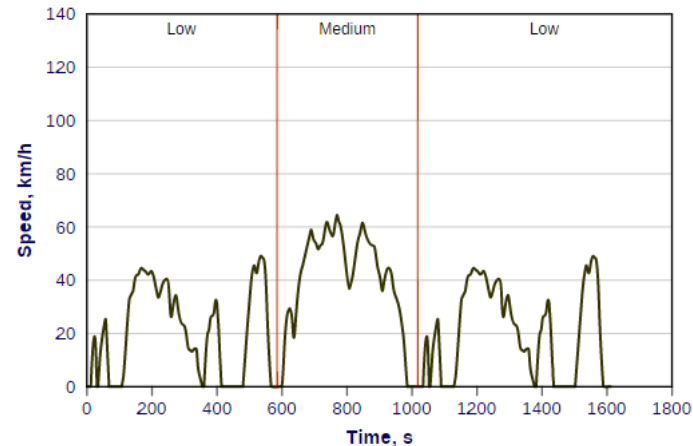
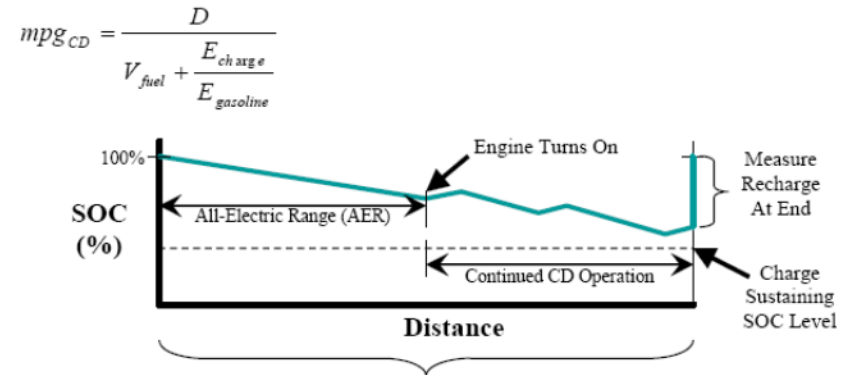


Figure 3. WLTC cycle for Class 1 vehicles

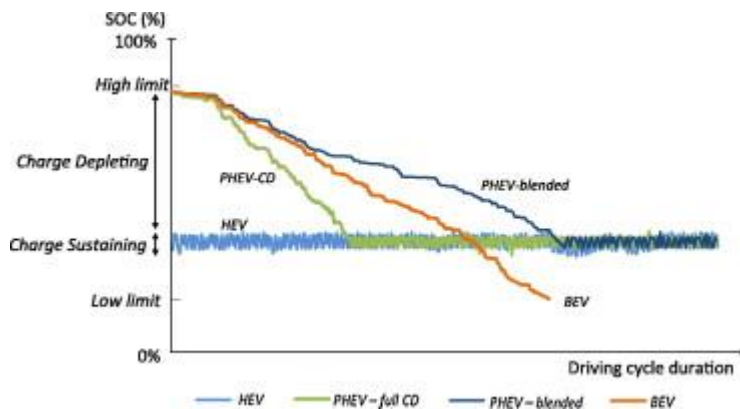
PHEV or off vehicle charging hybrid electric vehicle



D = Four UDSS or Three HWFET Cycles (~30 miles)
(if no engine on in first 30 miles continue to run cycles until it does turn on)

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

SOC - STATE OF CHARGE



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

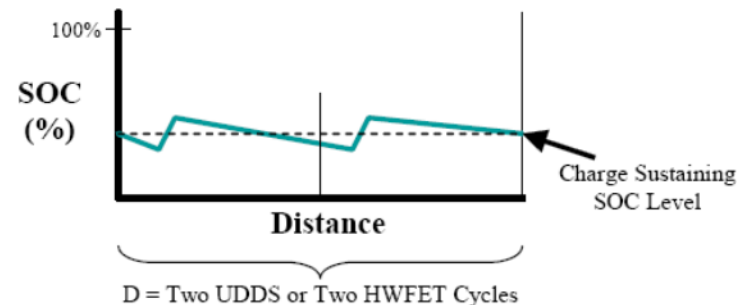


Figure 2: PCT to measure Charge-Sustaining (CS) vehicle fuel economy; illustrated with application to the UDSS or HWFET test cycles

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
		<i>Criteria Emissions, FC, CO₂, AER, EAER, R_{CDC}, R_{CDA}, E_{AC}</i>	<i>Criteria Emissions, FC, CO₂</i>	<i>AERcity, E_{AC}city</i>
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 + Extra High 3	Low 3 + Medium 3-2
NOVC-HEV	Class 3a	--	Low 3 + Medium 3-1 + High 3-1 + Extra High 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)

<https://carfueldata.vehicle-certificationagency.gov.uk/downloads/default.aspx>

TOYOTA	Prius Plug-in, MY2017,	1.8 VVT-i Auto	AT,	1798 cm3,	Electricity / Petrol
Euro Standard	Noise Level dB(A)	CO [mg/km]	THC [mg/km]	NOx [mg/km]	
6	67	67	17	1	
Electric energy consumption Wh/km	Maximum range (km)	Metric Combined (L/100km)	CO2 g/km		
72	63	1	22		



Vehicle Certification Agency

Worldwide Harmonized Light Vehicles Test Cycle (WLTC)



Vehicle Certification Agency

AUDI Q7 e-tron 3.0 TDI quattro (258PS) V6 8speed Tiptronic with 19" wheels QA8 2967 cm³
Electricity / Diesel

Euro Standard	Noise Level dB(A)	CO [mg/km]	THC [mg/km]	NOx [mg/km]	PM [mg/km]
6	70	53	6	22	0.34

Electric energy consumption Wh/km	Maximum range (km)	Metric Combined (L/100km)	CO ₂ g/km
181	56	1.8	48

Worldwide Harmonized Light Vehicles Test Cycle (WLTC)

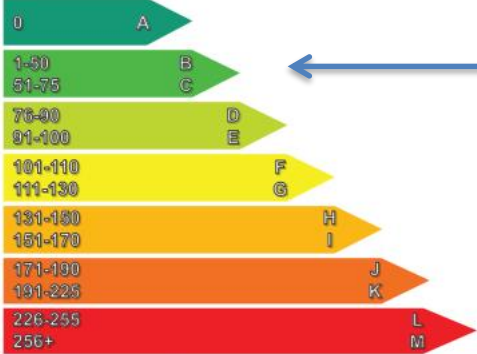
NISSAN Leaf, MY2016, 30 kWh Electricity

Euro Standard	Noise Level dB(A)	CO [mg/km]	THC [mg/km]	NOx [mg/km]
6	68	0	0	0

Electric energy consumption Wh/km	Maximum range (km)	Metric Combined (L/100km)	CO2 g/km
150	250	0	0

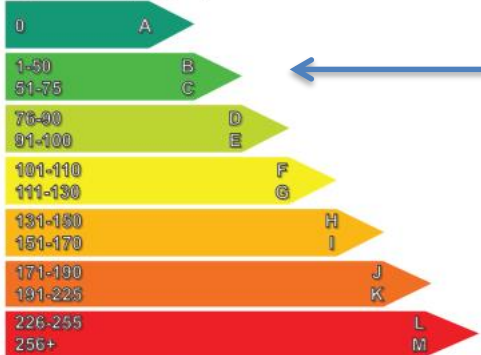


Vehicle Certification Agency

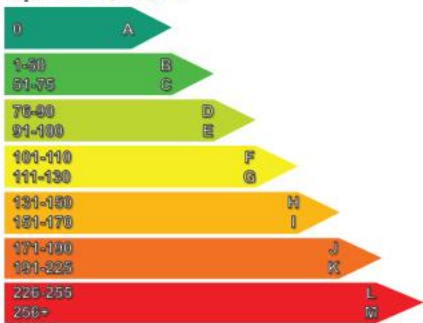
Fuel Economy		CO ₂ emissions		
CO ₂ emissions figure (g/km)				
				
Fuel and Electricity cost (estimated) for 12,000 miles A guide price for comparison purposes is calculated using the combined drive cycle (town centre and motorway) and average fuel and electricity price. Fuel consumption for plug-in hybrid vehicles is measured in two conditions, one with the battery freshly charged and another where it is significantly depleted. A weighted average of the two figures obtained is calculated based on an assumption that a vehicle is driven 16 miles (25km) beyond its maximum electric range, using the engine as required without recharging. Cost is recalculated annually. Unit Cost as at March 2018: petrol £1.19/litre, diesel £1.23/litre, electricity 15.9p/kWh.		Fuel £	Electricity £	Total (3) £
VED for 12 months Vehicle excise duty (VED) or road tax varies according to the CO ₂ emissions and fuel type of the vehicle.		1st year rate (1) £	Standard rate (2) £	
Air Quality Information Euro 6d(TEMP) includes an RDE (Real Driving Emissions) requirement to deliver greater on-road emissions reductions. Vehicles that already comply with the future requirements for RDE, Euro 6d, will be exempt from the diesel supplement. All new cars are Euro 6. Euro 6 cars meet current minimum standards for clean air zones.		Euro Standard		Diesel VED supplement
Energy consumption: Mpg and Miles/kWh (3)		Electric range: Miles (3)		
Environmental Information: A guide on fuel economy and CO₂ emissions which contains data for all new passenger car models is available at any point of sale free of charge. In addition to the fuel efficiency of a car, driving behaviour as well as other non-technical factors play a role in determining a car's fuel consumption and CO₂ emissions. CO₂ is the main greenhouse gas responsible for global warming.				
Make/Model:		Engine Capacity (cc):		
Fuel Type: (4)		Transmission: N/A		
Fuel Consumption: <i>Drive cycle</i>		Litres/100km		Mpg
Urban		N/A		N/A
Extra-urban		N/A		N/A
Weighted Combined		(3)		(3)
Carbon dioxide emissions (g/km) (weighted): Important note: Some specifications of this make/model may have lower CO ₂ emissions than this. Check with your dealer.				
(1) A new 1st year VED rate will be applied to cars registered for the first time (scheme effective from April 2010 and revised April 2017). (2) The standard 12 month VED rate for all registered cars in this band is shown for the purposes of comparison. Note, figures quoted reflect the current rate only, and may be subject to change in the future. Cars with a list price of over £40,000 when new pay an additional rate of £310 per year on top of the standard rate for five years.				



<https://carfueldata.vehicle-certification-agency.gov.uk/additional/labels/2018-Electric-Hybrid-Label-Blank.pdf>

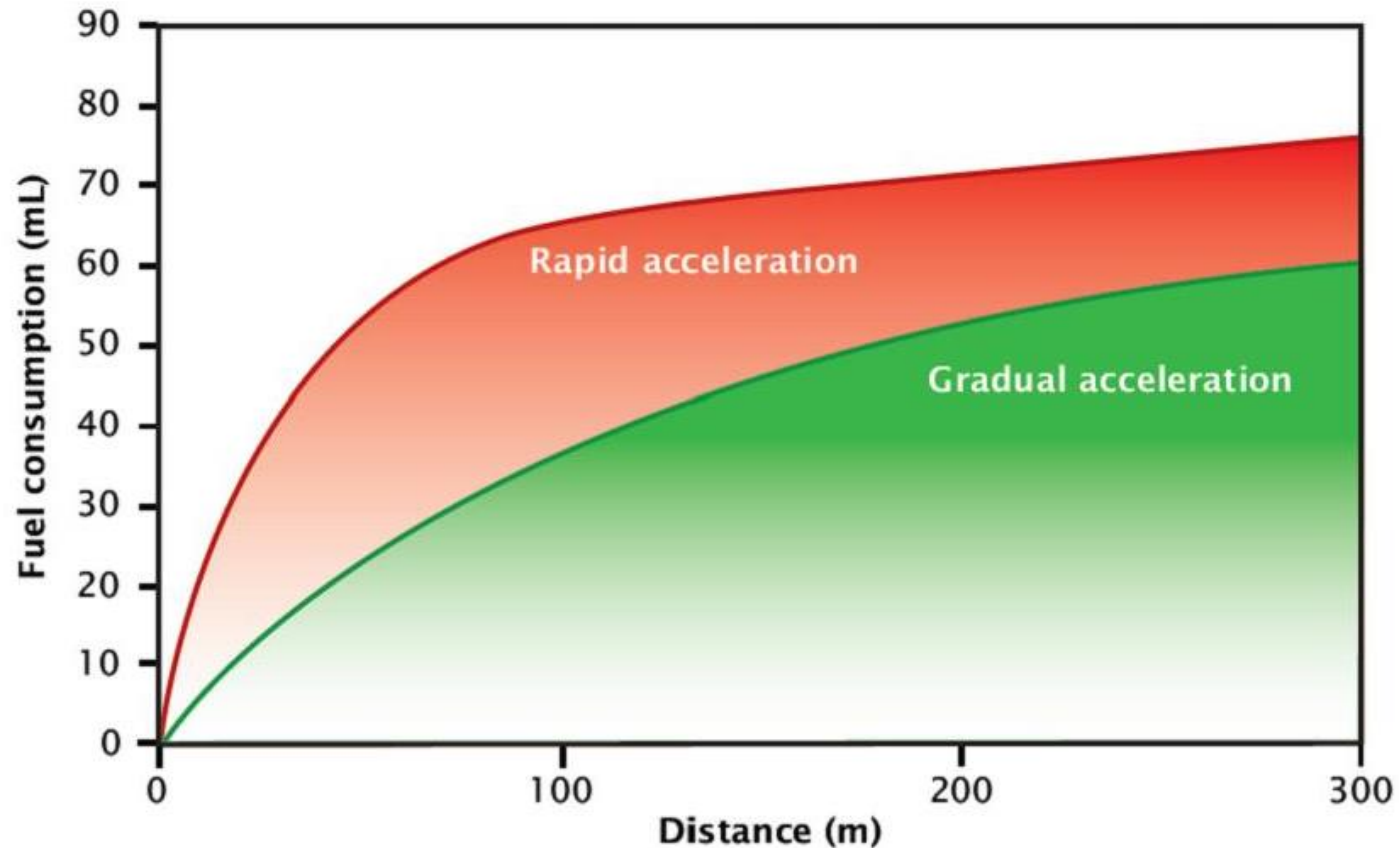
Fuel Economy		CO ₂ emissions		
CO ₂ emissions figure (g/km)				
				
Fuel and Electricity cost (estimated) for 12,000 miles A guide price for comparison purposes is calculated using the combined drive cycle (town centre and motorway) and average fuel and electricity price. Fuel consumption for plug-in hybrid vehicles is measured in two conditions, one with the battery freshly charged and another where it is significantly depleted. A weighted average of the two figures obtained is calculated based on an assumption that a vehicle is driven 16 miles (25km) beyond its maximum electric range, using the engine as required without recharging. Cost is recalculated annually. Unit Cost as at March 2018: petrol £1.19/litre, diesel £1.23/litre, electricity 15.9p/kWh.		Fuel £	Electricity £	Total £ ⁽³⁾
VED for 12 months Vehicle excise duty (VED) or road tax varies according to the CO₂ emissions and fuel type of the vehicle.		1st year rate ⁽¹⁾ £	Standard rate ⁽²⁾ £	
Air Quality Information Euro 6d(TEMP) includes an RDE (Real Driving Emissions) requirement to deliver greater on-road emissions reductions. Vehicles that already comply with the future requirements for RDE, Euro 6d, will be exempt from the diesel supplement. All new cars are Euro 6. Euro 6 cars meet current minimum standards for clean air zones.		Euro Standard		Diesel VED supplement
Energy consumption: Mpg and Miles/kWh ⁽³⁾		Electric range: Miles ⁽³⁾		
Environmental Information: A guide on fuel economy and CO₂ emissions which contains data for all new passenger car models is available at any point of sale free of charge. In addition to the fuel efficiency of a car, driving behaviour as well as other non-technical factors play a role in determining a car's fuel consumption and CO₂ emissions. CO₂ is the main greenhouse gas responsible for global warming.				
Make/Model:		Engine Capacity (cc):		
Fuel Type: ⁽⁴⁾		Transmission: N/A		
Fuel Consumption: <i>Drive cycle</i>		Litres/100km		Mpg
Urban		N/A		N/A
Extra-urban		N/A		N/A
Weighted Combined				⁽³⁾
Carbon dioxide emissions (g/km) (weighted): Important note: Some specifications of this make/model may have lower CO ₂ emissions than this. Check with your dealer.				
(1) A new 1st year VED rate will be applied to cars registered for the first time (scheme effective from April 2010 and revised April 2017). (2) The standard 12 month VED rate for all registered cars in this band is shown for the purposes of comparison. Note, figures quoted reflect the current rate only, and may be subject to change in the future. Cars with a list price of over £40,000 when new pay an additional rate of £310 per year on top of the standard rate for five years. (3) The standard 12 month VED rate for all registered cars in this band is shown for the purposes of comparison. Note, figures quoted reflect the current rate only, and may be subject to change in the future. Cars with a list price of over £40,000 when new pay an additional rate of £310 per year on top of the standard rate for five years. (4) The standard 12 month VED rate for all registered cars in this band is shown for the purposes of comparison. Note, figures quoted reflect the current rate only, and may be subject to change in the future. Cars with a list price of over £40,000 when new pay an additional rate of £310 per year on top of the standard rate for five years.				



Fuel Economy		CO ₂ emissions	
CO ₂ emissions figure (g/km)		0 g/km ⁽¹⁾	
			
		Annual energy cost ⁽²⁾	
		1st year rate	Standard rate
		£0 ⁽¹⁾	£0 ⁽²⁾
Electric energy consumption:	Miles/kWh ⁽³⁾	Electric range: Miles ⁽³⁾	
Environmental Information: A guide on fuel economy and CO₂ emissions which contains data for all new passenger car models is available at any point of sale free of charge. In addition to the fuel efficiency of a car, driving behaviour as well as other non-technical factors play a role in determining a car's fuel consumption and CO₂ emissions. CO₂ is the main greenhouse gas responsible for global warming.			
Make/Model:		Engine Capacity (cc):	N/A
Fuel Type: Electricity ⁽⁴⁾		Transmission:	N/A
Fuel Consumption:	Litres/100km⁽⁵⁾	Mpg⁽⁵⁾	
<i>Drive cycle</i>			
Urban	N/A	N/A	
Extra-urban	N/A	N/A	
Combined	N/A	N/A	
Carbon dioxide emissions (g/km): 0			
Important note: Some specifications of this make/model may have lower CO ₂ emissions than this. Check with your dealer.			
(1) A new 1st year VED rate will be applied to cars registered for the first time (scheme effective from April 2010 and revised April 2017). (2) The standard 12 month VED rate for all registered cars in this band is shown for the purposes of comparison. Note, figures quoted reflect the current rate only, and may be subject to change in the future. Cars with a list price of over £40,000 when new pay an additional rate of £310 per year on top of the standard rate for five years. (3) Please note that figures quoted are obtained under specific test conditions, they may not be achieved under 'real world' driving conditions. However, the figures serve as a means of comparing models of a similar type. (4) A list of electric vehicle charging points is available here: https://www.zap-map.com/live/ (5) Not available for electric cars			
 Department for Transport		 Vehicle Certification Agency	
Important note: The test used to establish the fuel consumption and CO₂ figures above is changing. To find out more about this and how it might affect your purchasing decision, please read the accompanying fact sheet.			



Effect of acceleration rate on fuel consumption of a Pontiac G5



Battery Range



Eco drive style, no HVAC



Eco drive style, with HVAC



Sporty drive style, with HVAC



Sporty drive style, with HVAC
at extreme ambient temperatures



Vehicle activity x N^{er} Trips x Factor x days/year

Km/week/
mode/trip

trips/mode

e.g. 48
weeks/year

Energy and Emission factors

MJ/pkm and g/pkm

MJ/year and g/year

Control point Fuel sales

Fuel sales for consumption

Indicator

Lead-free petrol 98 ▼

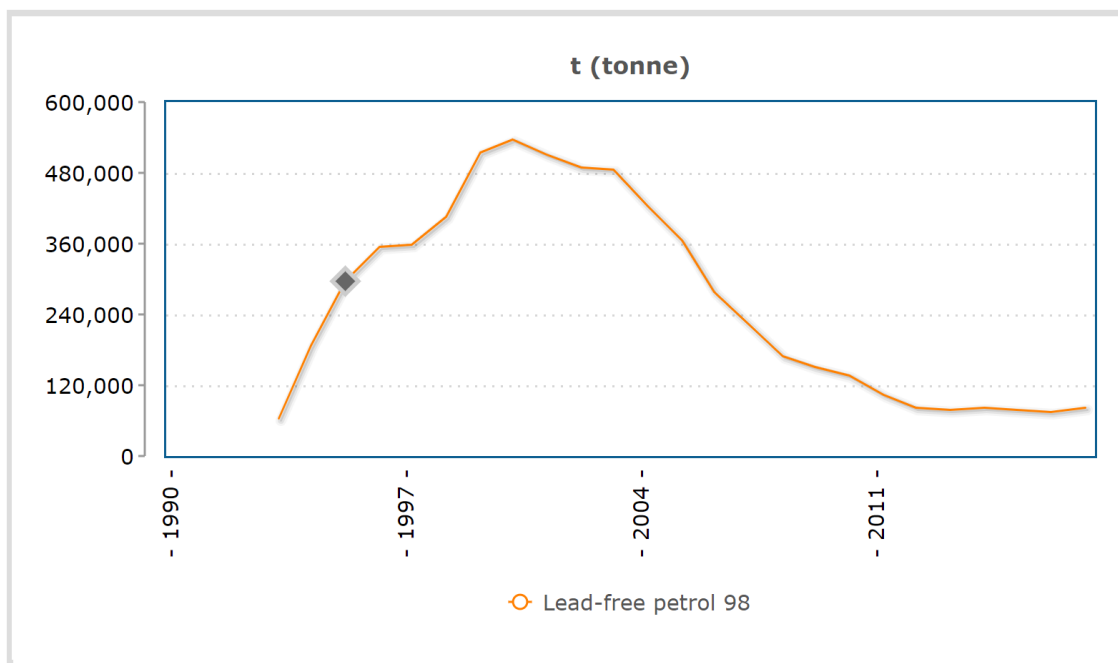
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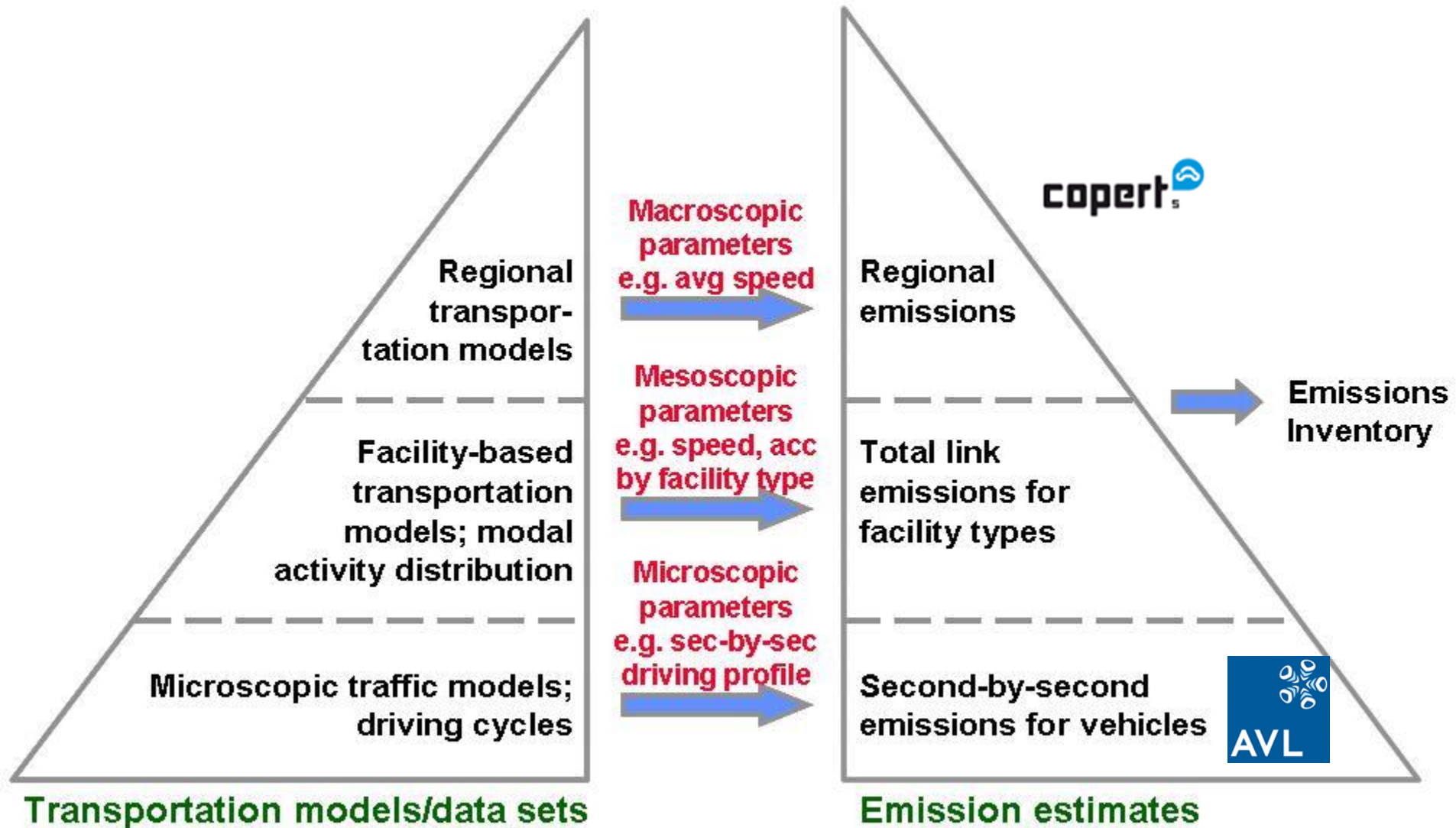
1993

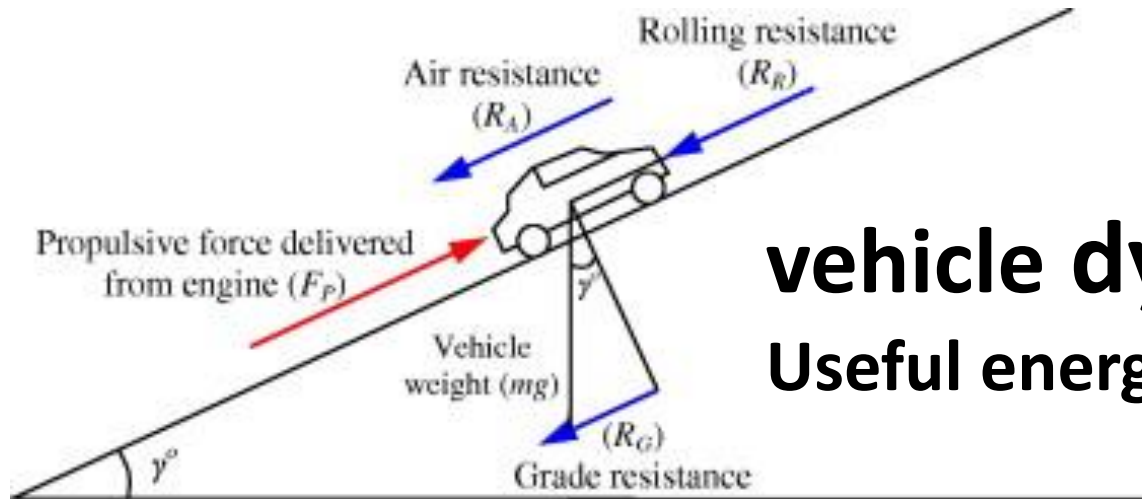
63,741
t (tonnes)

Lead-free petrol 98



Click the chart to amplify it





vehicle dynamics

Useful energy consumption

Roling	$R_r = k_r(m+m_p)g \cdot \cos \gamma$
Road gradient	$F_w = (m+m_p)g \cdot \sin \gamma$
Aerodynamics	$R_a = 1/2 \cdot \rho C_d A_f v^2$
Propultion	$F_p = (k_m \cdot m + m_p) \cdot dv/dt$

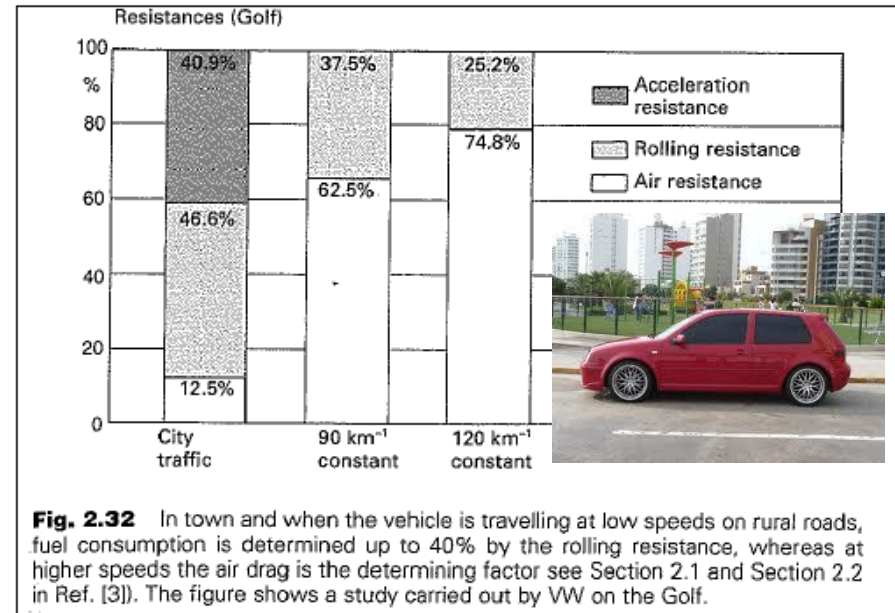
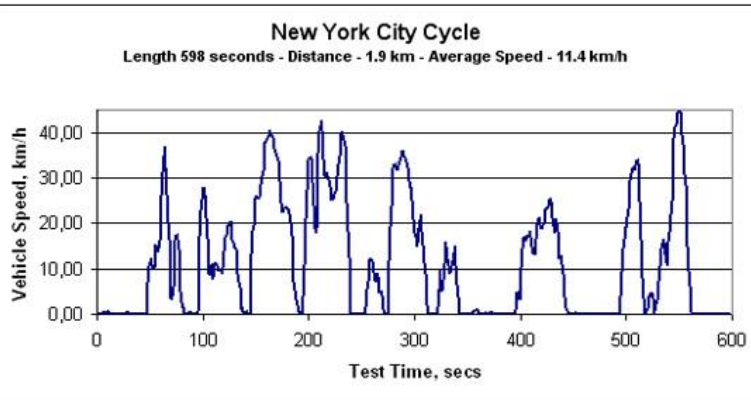
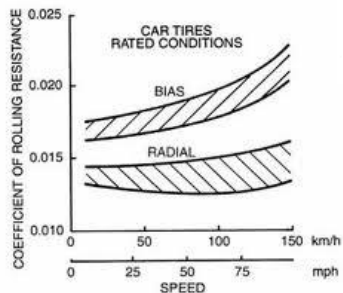
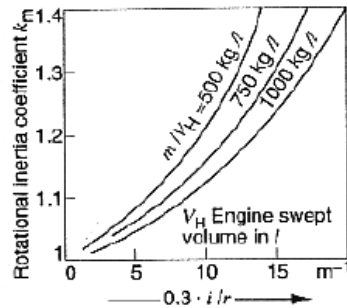
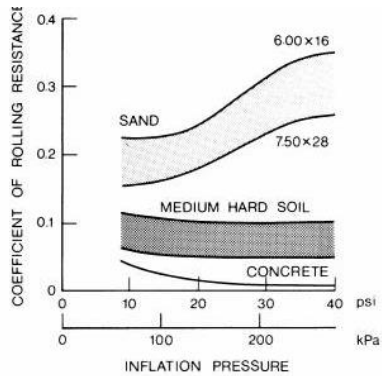


Fig. 2.32 In town and when the vehicle is travelling at low speeds on rural roads, fuel consumption is determined up to 40% by the rolling resistance, whereas at higher speeds the air drag is the determining factor see Section 2.1 and Section 2.2 in Ref. [3]). The figure shows a study carried out by VW on the Golf.

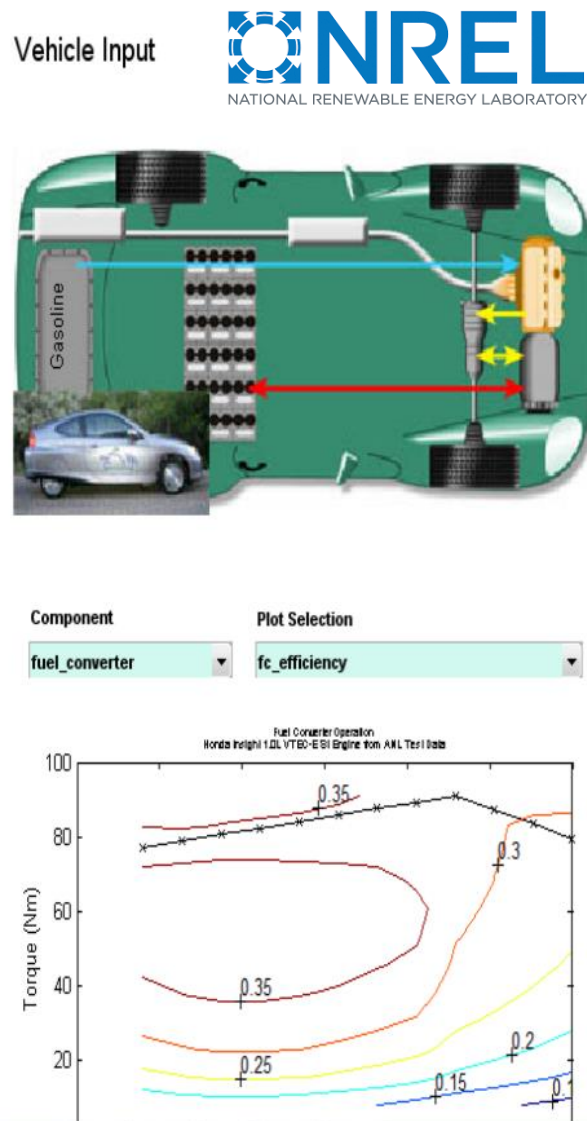
Contribution of Tire Rolling Resistance to Vehicle Fuel Economy Versus Speed
(Reprinted with permission from the Automotive Chassis: Engineering Principles, 2nd Edition, Reed Educational and Professional Publishing Ltd., 2001)

Rolling k_r
Aerodynamics $C_d A_f$
Propulsion k_m



@Bosch Automotive Handbook: 8th Edition

Roling	k_r	0.013	0.01
Aerodynamics	$C_d A_f$	0.35x1.91m ²	0.6x7m ²
Propulsion	k_m	1.1	1.13



Load File: **INSIGHT_defaults_in**

Drivetrain Config: **insight**

	version	type		max pwr (kW)	peak eff	mass (kg)
☒ Vehicle	?	VEH_INSIGHT				520
☒ Fuel Converter	ic	si	FC_INSIGHT	50	0.4	130
☒ Exhaust Aftertreat	?	EX_SI_CC		#of mod	V nom	5
☒ Energy Storage	rint	nimh	ESS_NIMH6	20	154	20
☐ Energy Storage 2	?	ess 2 options				
☒ Motor	?	MC_INSIGHT_draft		10	0.96	60
Motor 2	?	motor 2 options				
Starter	?	starter options				
☐ Generator	?	gc options				
☒ Transmission	man	man	TX_SSPD_SI_INSIGHT		1	91
Transmission 2	?	trans 2 options				
Clutch/Torq. Conv.	?	clutch/torque converter options				
☒ Torque Coupling	?	TC_INSIGHT			1	
☒ Wheel/Axle	Crr	Crr	WH_INSIGHT			0
☒ Accessory	Const	Const	ACC_INSIGHT			
Acc Electrical	?	acc elec options				
☒ Powertrain Control	insight	man	PTC_INSIGHT			

front wheel drive ☒ rear wheel drive ☐ four wheel drive ☐

View Block Diagram **BD_INSIGHT**

Cargo Mass: **136**

Calculated Mass: **962**

☒ override mass: **1000**

Variable List:

Save Help

EMEP/EEA air pollutant emission inventory guidebook

EEA Report | No 21/2016

EMEP/EEA air pollutant emission inventory guidebook 2016

Technical guidance to prepare national emission inventories

ISSN 1977-8449



EMEP/EEA air pollutant emission inventory guidebook

- Part B: sectoral guidance chapters

- 1. Energy

- ▲ 1.A Combustion

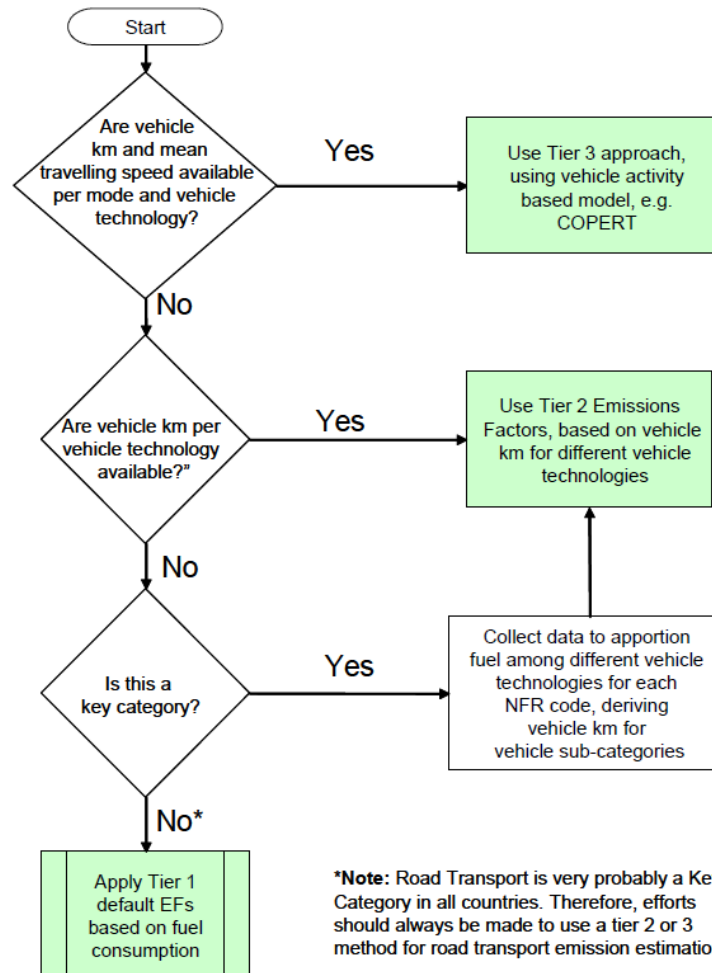
- 1.A.1 Energy industries [2.4 MB]
 - 1.A.2 Manufacturing industries and construction [893.2 KB]
 - 1.A.3.a Aviation 2016 [1.5 MB]
 - 1.A.3.b.i-iv Road transport 2016 [3.3 MB]
 - 1.A.3.b.i-iv Road transport Annex HDVs 2016 [3.0 MB]
 - 1.A.3.b.v Gasoline evaporation 2016 [861.2 KB]
 - 1.A.3.b.vi-vii Road 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!

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



First estimation (high uncertainty) emissions proportional to fuel consumption

$$E_x = \sum_y (\sum_m (FC_{y,m} \times EF_{x,y,m})) \quad (Eq. 1)$$

Where:

E_x = emission of pollutant x [g],

$FC_{y,m}$ = fuel consumption of vehicle category y using fuel m [kg],

$EF_{x,y,m}$ = fuel consumption-specific emission factor of pollutant x for vehicle category y

and fuel m [g/kg]

First estimation (high uncertainty) emissions proportional to fuel consumption

Table 3.15: Tier 1 — Typical fuel consumption figures, per km, by category of vehicle

Vehicle category (j)	Fuel	Typical fuel consumption (g/km)
Passenger cars	Petrol	70
	Diesel	60
	LPG	57.5
	E85	86.5
	CNG	62.6
LCV	Petrol	100
	Diesel	80
HDV	Diesel	240
	CNG (buses)	500
Two-wheel vehicles	Petrol	35

First estimation (high uncertainty) emissions proportional to fuel consumption

Table 3.5: Tier 1 emission factors for CO and NMVOCs

Category	Fuel	CO			NMVOC		
		(g/kg fuel)			(g/kg fuel)		
		Mean	Min	Max	Mean	Min	Max
PC	Petrol	84.7	49.0	269.5	10.05	5.55	34.42
	Diesel	3.33	2.05	8.19	0.70	0.41	1.88
	LPG	84.7	38.7	117.0	13.64	6.10	25.66
LCV	Petrol	152.3	68.7	238.3	14.59	3.91	26.08
	Diesel	7.40	6.37	11.71	1.54	1.29	1.96
HDV	Diesel	7.58	5.73	10.57	1.92	1.33	3.77
	CNG (Buses)	5.70	2.20	15.00	0.26	0.10	0.67
Two-wheel	Petrol	497.7	331.2	664.5	131.4	30.0	364.8

First estimation (high uncertainty) emissions proportional to fuel consumption

Table 3.6: Tier 1 emission factors for NO_x and PM

Category	Fuel	NO _x			PM		
		(g/kg fuel)			(g/kg fuel)		
		Mean	Min	Max	Mean	Min	Max
PC	Petrol	8.73	4.48	29.89	0.03	0.02	0.04
	Diesel	12.96	11.20	13.88	1.10	0.80	2.64
	LPG	15.20	4.18	34.30	0.00	0.00	0.00
LCV	Petrol	13.22	3.24	25.46	0.02	0.02	0.03
	Diesel	14.91	13.36	18.43	1.52	1.10	2.99
HDV	Diesel	33.37	28.34	38.29	0.94	0.61	1.57
	CNG (Buses)	13.00	5.50	30.00	0.02	0.01	0.04
Two-wheel	Petrol	6.64	1.99	10.73	2.20	0.55	6.02

Surveys, energy & emissions

Exercise3: Take the exercise 2 community of 10 people (they get richer...). They now prefer car. What would be the yearly impact in biogenic and non-biogenic final energy consumption and CO₂, NO_x and PM if:

One-way trip

Weekday: 20% walk 2 km; 20% bus 2 km; 60% car 2 km

- i) Conventional ICE technology
- ii) Electric based technology
- iii) Hydrogen based technology

Surveys, energy & emissions

BUS



→ Data MJ/pkm from sustainability report or Tier 1 EEA?

CAR



→ Most sold vehicle, VCA info
Or Tier 1 EEA?

Try euro limits.....to get to a conclusion.....

Surveys, energy & emissions

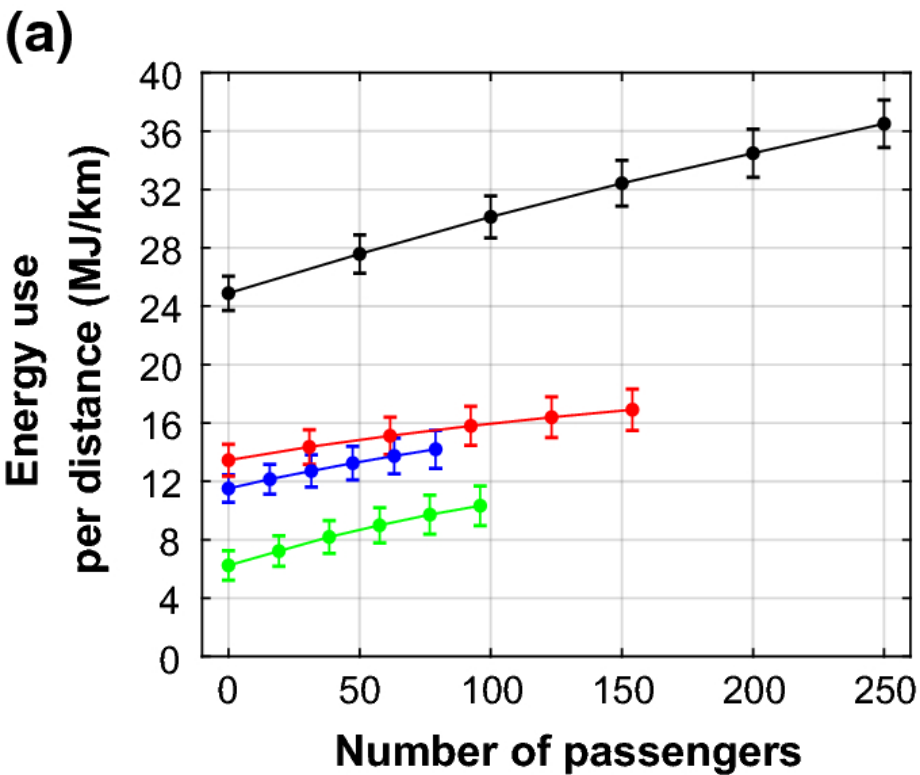


August 2017

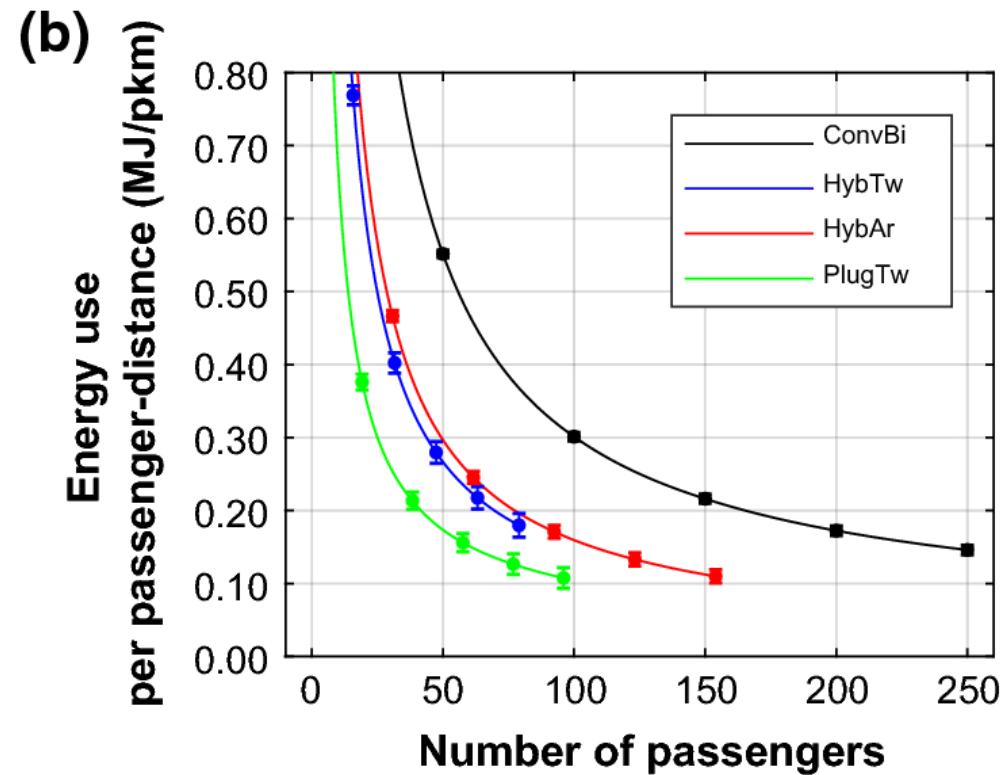
Manufa	Model	Description	Trans	Engine	Fuel	Metric	Metric	Metric	CO2	Emissions	Emissions	THC + NOx	Particulates
cturer			missio	Capacit	Type	Urban	Extra-	Combin	g/k	CO	NOx	Emissions	[No.]
RENAU			n	y	Dies	(Cold)	Urban	ed	m	[mg/km]	[mg/km]	[mg/km]	[mg/km]
LT	Clio Euro6, 2015	dCi 110 S/S	M6	1461	el	3.8	3.3	3.5	90	354	18	60	0.08
RENAU		Energy dCi 90			Dies								
LT	Clio Euro6, 2015	S/S	M5	1461	el	3.5	3.1	3.3	85	158	33	60	0.08
RENAU		Energy dCi 90			Dies								
LT	Clio Euro6, 2015	S/S ECO	M5	1461	el	3.3	3.1	3.2	82	158	33	60	0.08
RENAU	Clio Sport Tourer				Dies								
LT	Euro6, 2015	dCi 90 S/S	M5	1461	el	3.5	3.1	3.3	85	158	33	60	0.08
RENAU	Clio Sport Tourer	Energy dCi 90			Dies								
LT	Euro6, 2015	S/S ECO	M5	1461	el	3.4	3.1	3.2	84	158	33	60	0.08
RENAUL		Energy TCe 90											
T	Clio Euro6, 2015	S/S	M5	898	Petrol	5.7	4.1	4.7	105	327	28		
RENAUL	Clio Sport Tourer	Energy TCe 90											
T	Euro6, 2015	S/S	M5	898	Petrol	5.7	4	4.6	104	327	28		

Worldwide Harmonized Light Vehicles Test Cycle (WLTC)

Surveys, energy & emissions



FC linear with weight

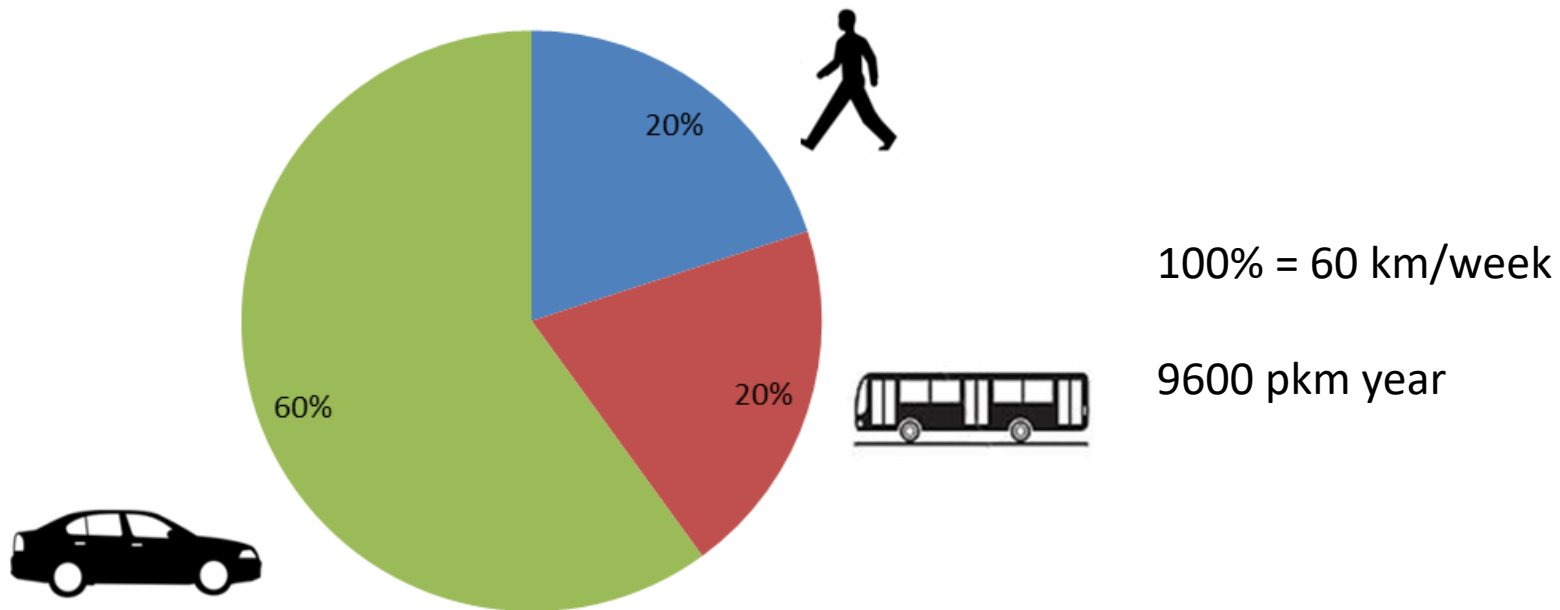


See excel resolution

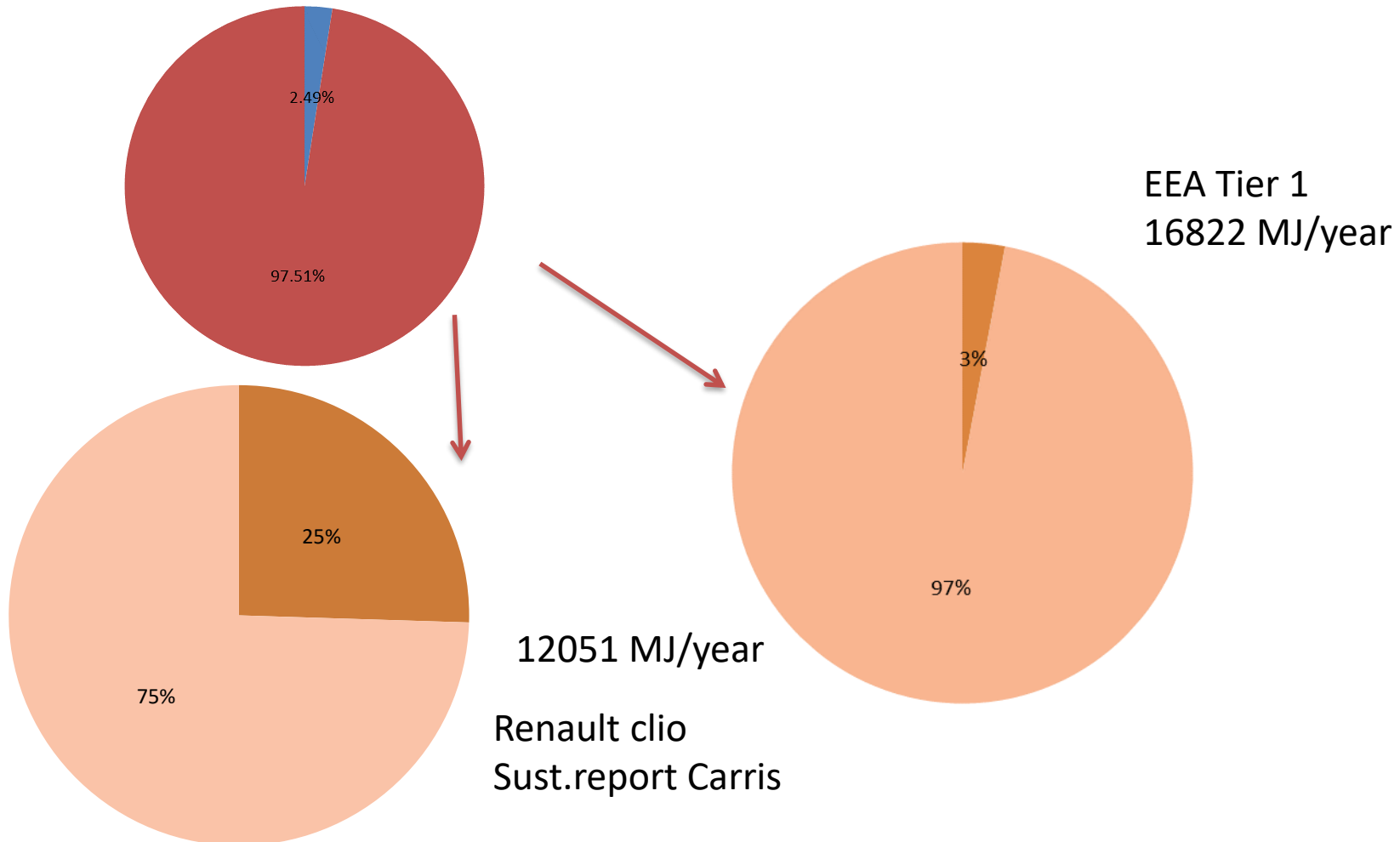
Bus Car	1.6 (MJ/pkm) carris sust.report					EEA Tier 1				
	4.5 (L/100km) most sold vehicle	1.55898	MJ/pkm			240 g/km		10.368 MJ/km	80 Lugares	0.2592 MJ/pkm
						65 g/km	🟢	2.834 MJ/km	5 Lugares	2.834 MJ/pkm
								gCO2/gfuel	gNOx/kgfuel	gPM/kgfuel
						bus		3.2	33.37	0.94
						car		3.2	10.845	0.565
						g/MJ				
Final energy	MJ/year	Ton CO2		NOx	PM	MJ/year	bus	74.07407407	0.772453704	0.022381
bus	3072	0.227555556	g/kWh	0.4	0.01	497.664	car	73.4006734	0.248738532	0.013452
			Ton/year	0.0003413	2.494E-05	16323.84	ton/year			
car	8979.7248	0.391516001	g/km	0.0305	0.00008	16821.5	bus	0.227555556	0.002372978	6.88E-05
Total (MJ/year)	12051.7248	0.619071557	Ton/year	0.0001757	4.608E-07		car	0.659117847	0.002233604	0.000121
		Total (Ton/year)		0.000517	2.54E-05		Total (Ton/year)	0.886673403	0.004606581	0.00019

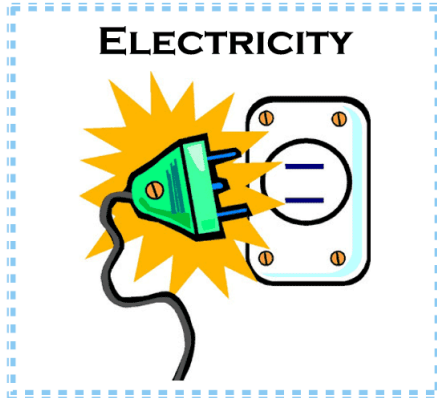
Surveys, energ. & emissions

Travel to work by transport mode (km basis)



MJ/year, mostly from combustion





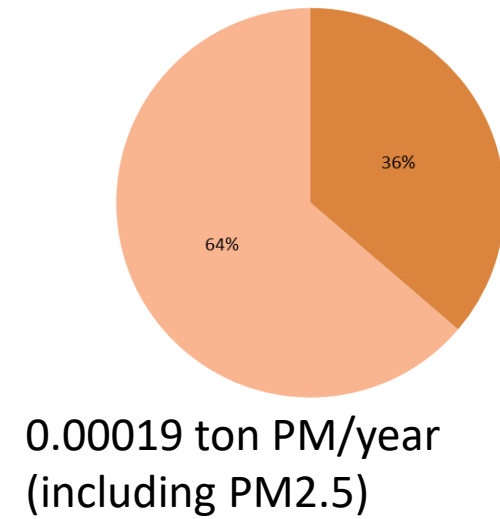
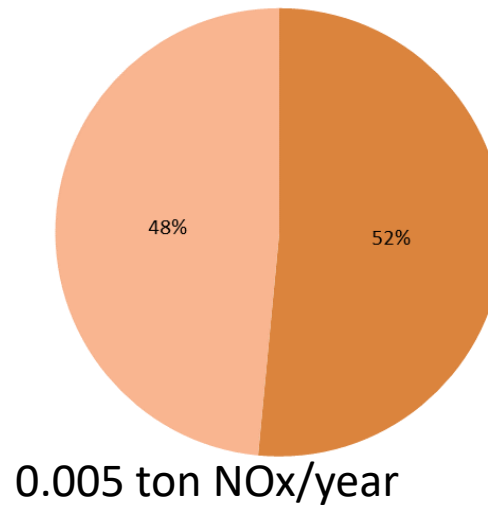
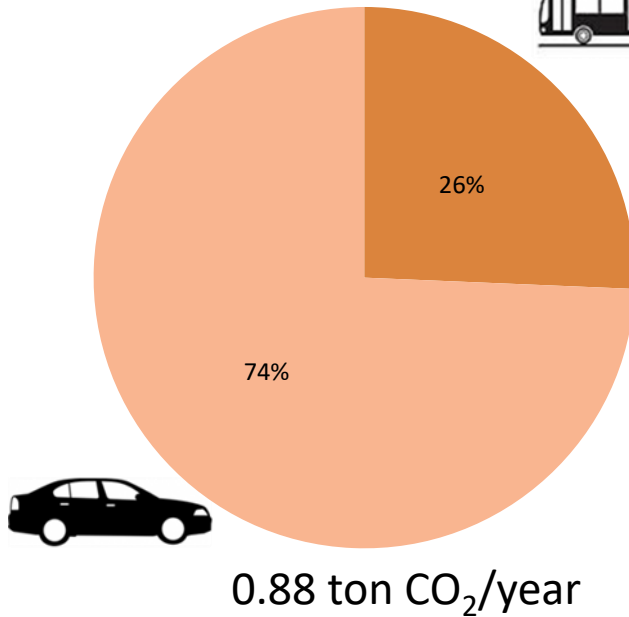
$$12051 * 0.2 / 0.7 = 3443 \text{ MJ/year}$$



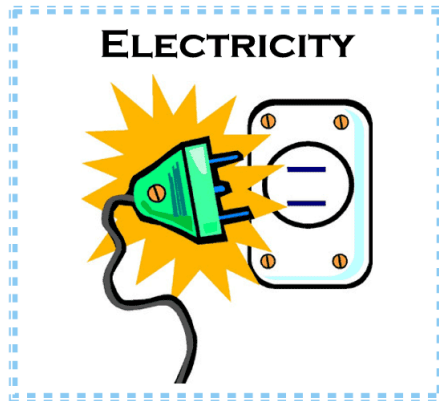
Using final to useful efficiencies.....
or choose
Nissan Leaf and Mirai data but for
bus.....

$$12051 * 0.2 / 0.4 = 6026 \text{ MJ/year}$$

CO₂, NO_x and PM_{2.5} (ton/year)



CO₂, NO_x and PM_{2.5} (ton/year)



0 ton CO₂/year



0 ton NO_x/year

0 ton PM/year
(including PM_{2.5})

Air quality related NO_x and PM_{2.5} = 0 ton/year



0.005 ton NO_x/year



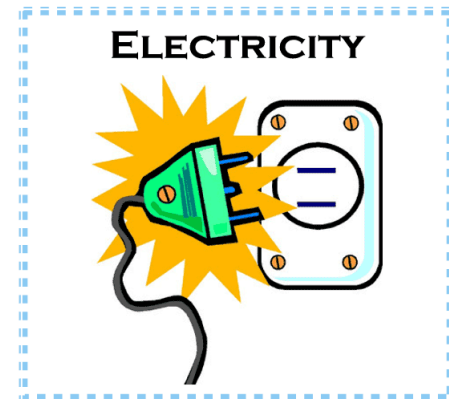
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shutterstock.com • 140323552

0.00019 ton PM/year
(including PM_{2.5})

Air quality related NOx and PM2.5 = 0 ton/year



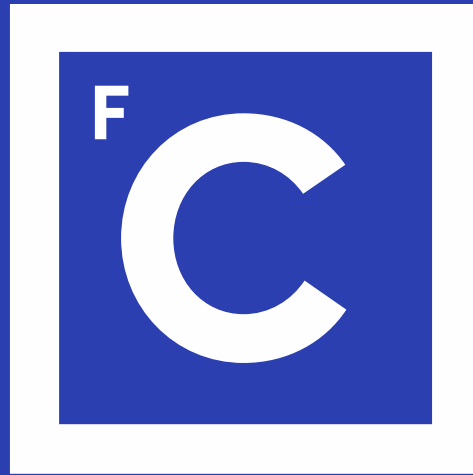
Global emission CO₂ Well-to-wheels??



?

- Final energy consumption factors, first approach;
- Emission modelling, macro to micro scale;
- European Environmental Agency Tier 1 approach;
- Fuel sales as a control point.

Obrigado



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de Ciências
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de Lisboa