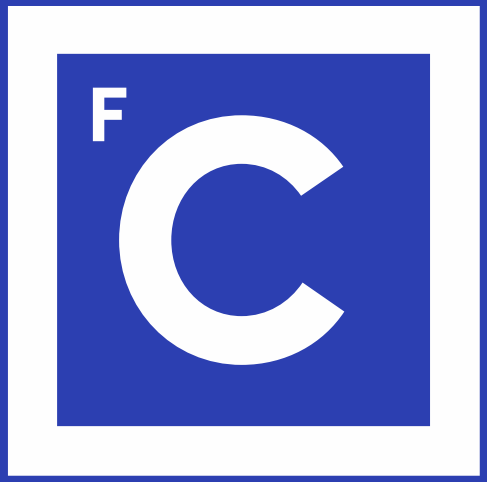


Ciências ULisboa

Faculdade
de Ciências
da Universidade
de Lisboa

Eng. Energy & Environment

Sustainable Mobility

Program

Topics	#	Contents
Basic concepts and definitions	1	Transportation system; Transports classification; historical evolution;
	2	Introduction to “sustainability and metrics”
	3	Energy conversions, primary energy, final energy, useful energy; Minimum energy and emissions in mobility,
	4	Propulsion technologies, internal combustion engines, electric motors, fuel cells, efficiencies
Characterization of mobility patterns	5	Surveys; Statistics; transport sector share energy & emissions;
Sustainability – Environmental dimension	6	Development of “sustainability and Metrics”
Air quality	7	World Health Organization, Directives, standards for emissions, air quality index
	8	Air quality networks and pollutants covered - local and global emissions
Emission inventories	9	Emission inventory models, micro to macro, motor vehicle dynamics
	10	COPERT 5 fleet model

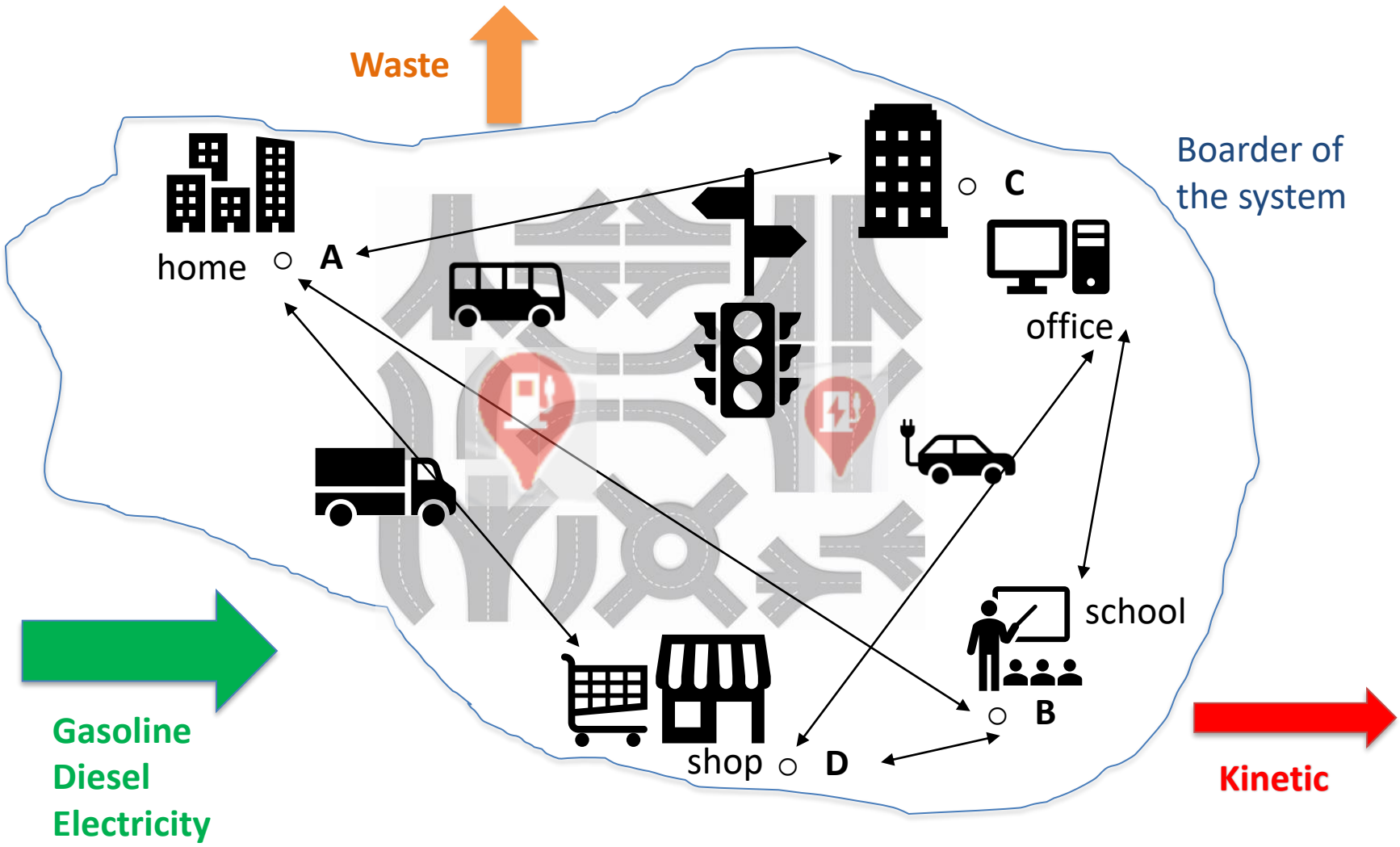
Program

Topics	#	Contents
Application of metrics of Sustainable mobility	11	Comparing Lisbon and Oporto mobility Screening mobility patterns in University campus
Life cycle analysis in transportation systems	12	Life cycle analysis
	13	Water, land use, resources scarcity and carbon footprint
	14	Carbon footprint in transport
	15	Carbon footprint applied to electric versus diesel technology
Disruptions & consequences	16	COVID19 impact overview

BASIC CONCEPTS

TOPIC #IV

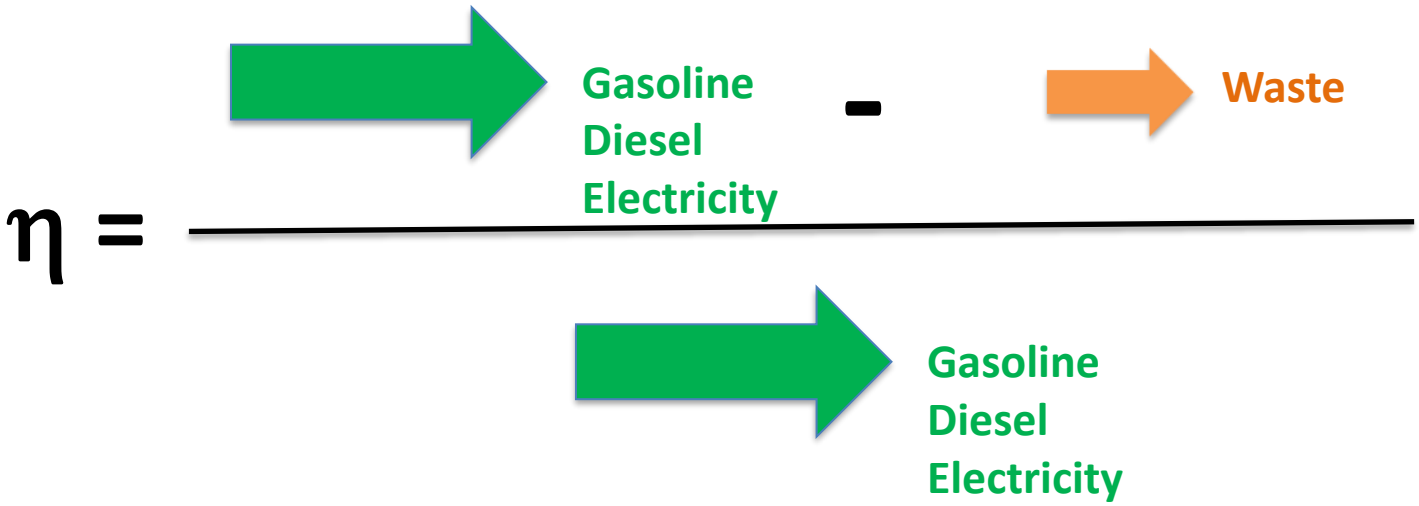
Energy Efficiency



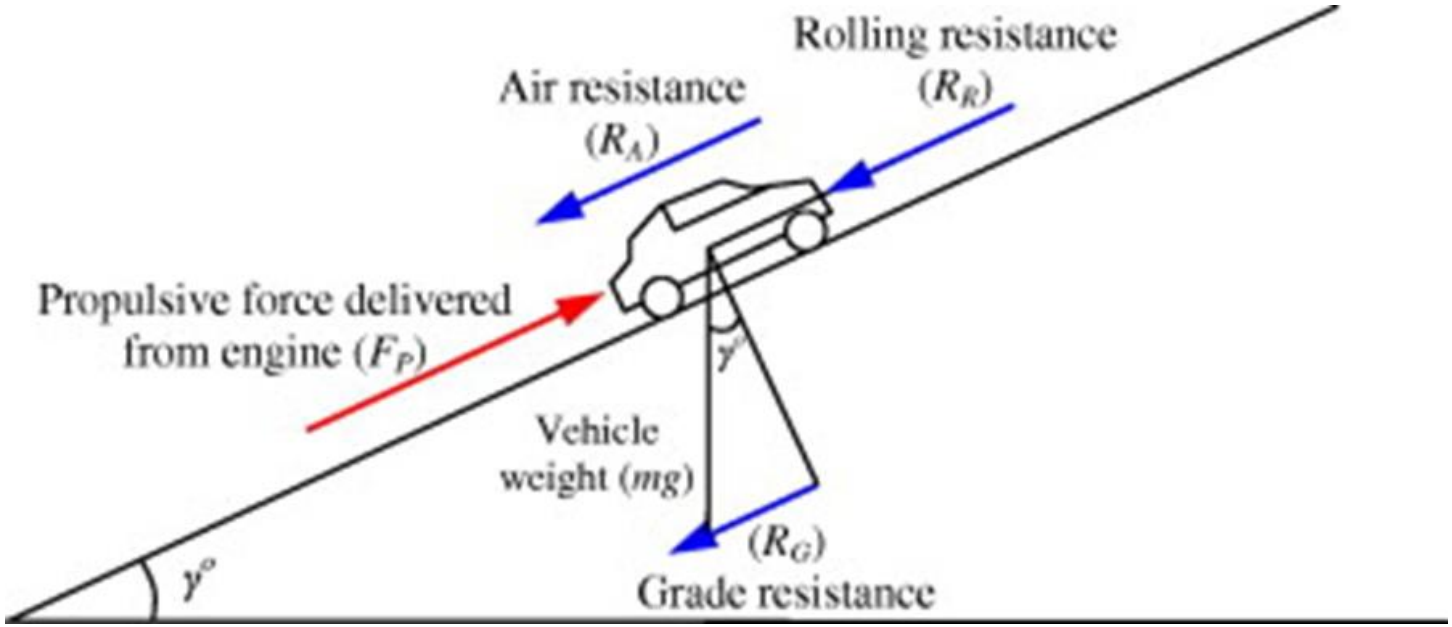
Energy Efficiency

$$\eta = \frac{\text{Kinetic}}{\text{Gasoline}\ \text{Diesel}\ \text{Electricity}}$$

Energy Efficiency

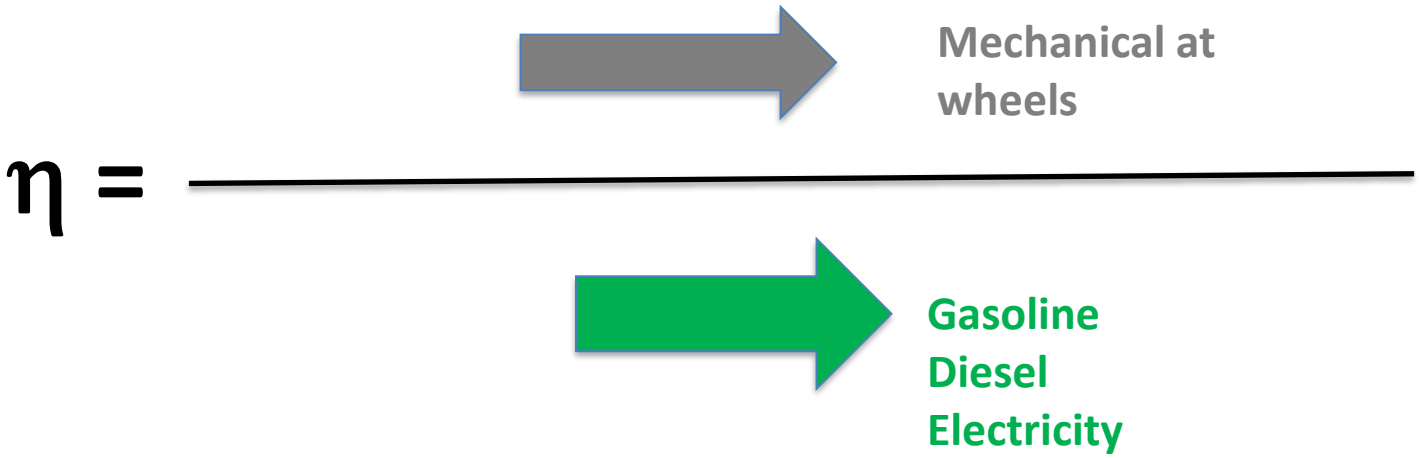


Energy efficiency



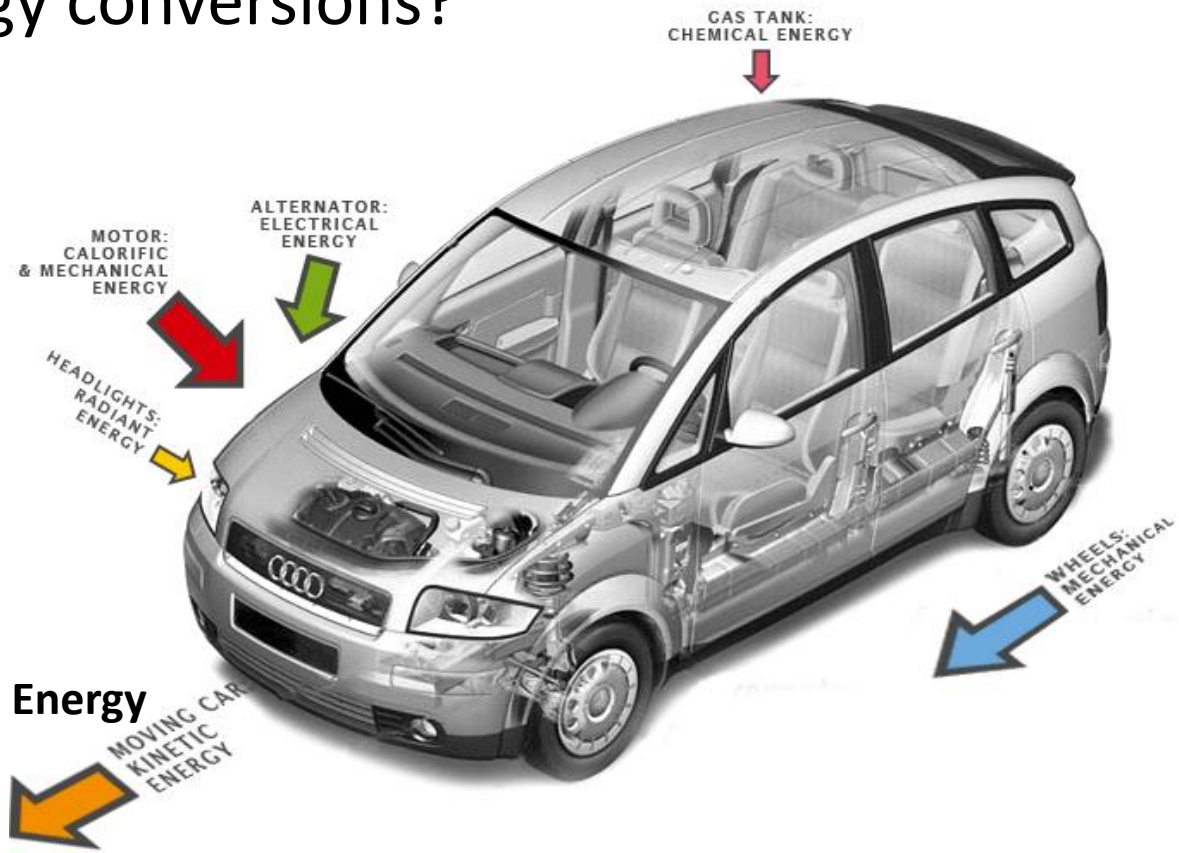
Useful Energy (traction, rolling resistance, aerodynamic drag, grade force)

Energy Efficiency



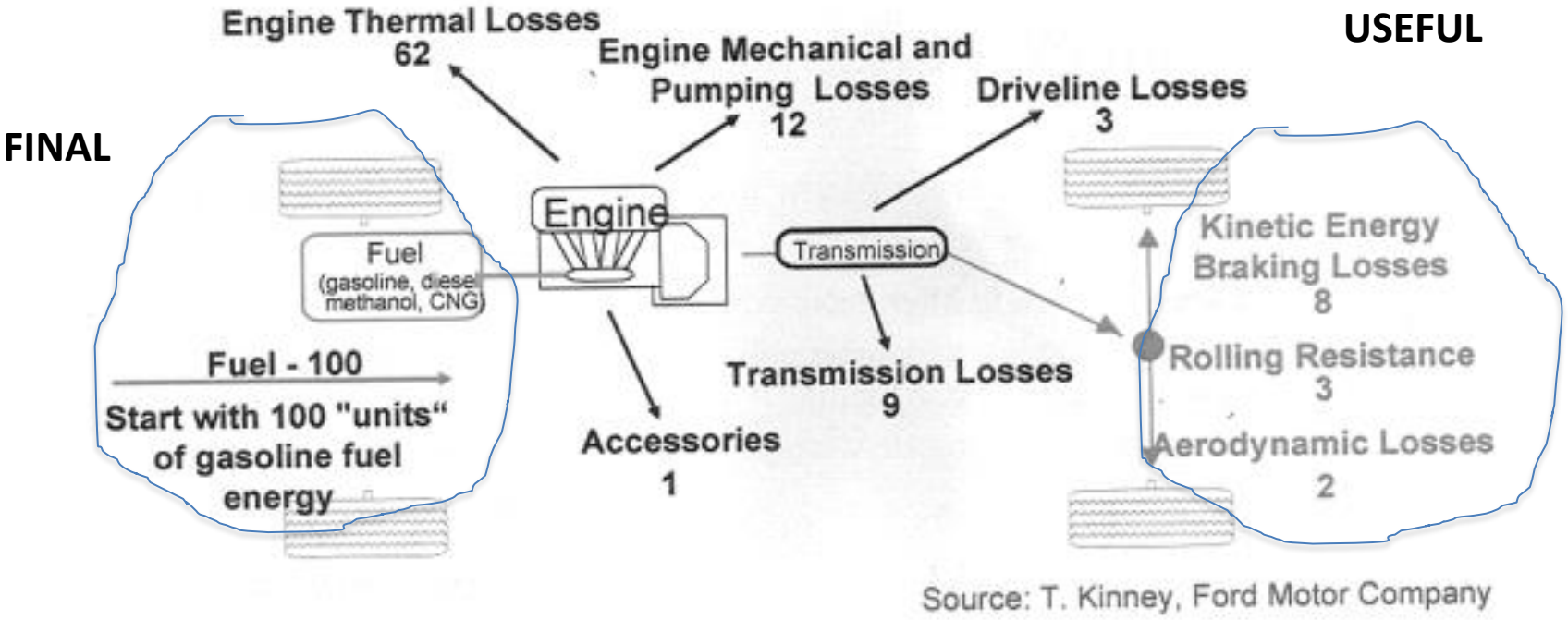
Energy efficiency

Energy conversions?



Useful Energy

Energy efficiency



Energy efficiency

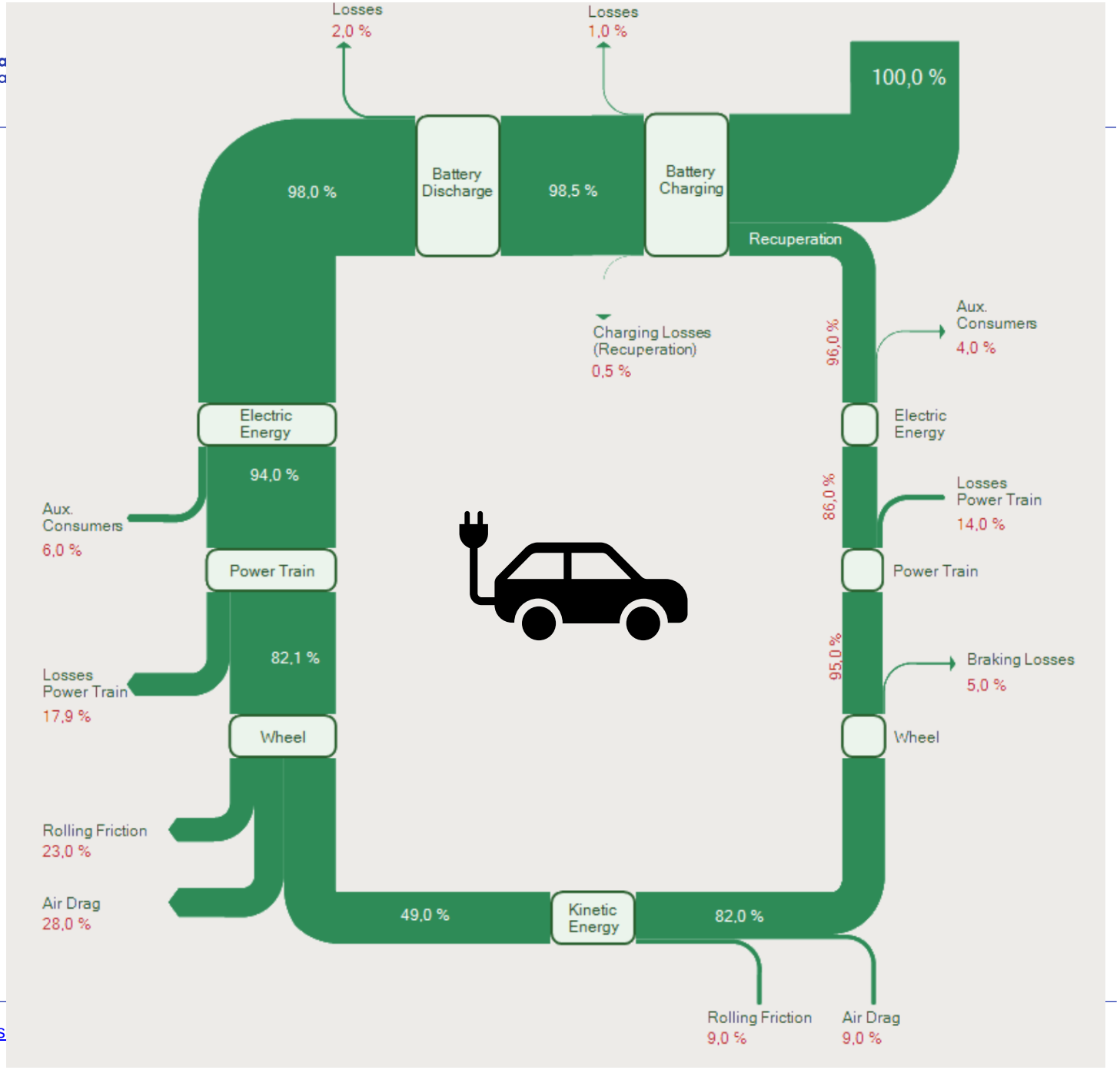
$$\eta = \frac{\text{Useful}}{\text{Final}}$$

$$\eta = (8+3+2)/100 = 13\%$$

Energy efficiency

$$\eta = \frac{\text{Kinetic}}{\text{Gasoline, Diesel, Electricity}}$$

$$\eta = 8/100 = 8\%$$


Losses
2,0 %
Losses
1,0 %
100,0 %
98,0 %
Battery
Discharge
98,5 %
Battery
Charging
Recuperation
Charging Losses
(Recuperation)
0,5 %
96,0 %
Aux.
Consumers
4,0 %
Electric
Energy
Electric
Energy
94,0 %
Aux.
Consumers
6,0 %
86,0 %
Losses
Power Train
14,0 %
Power Train
Power Train
82,1 %
Losses
Power Train
17,9 %
95,0 %
Braking Losses
5,0 %
Wheel
Wheel
Rolling Friction
23,0 %
Air Drag
28,0 %
49,0 %
Kinetic
Energy
82,0 %
Rolling Friction
9,0 %
Air Drag
9,0 %

Energy efficiency

$$\eta = \frac{\text{Useful}}{\text{Final}}$$

$$\eta_{\text{discharging}} = 0.99*0.98*0.94*0.821 = 75\%$$

Energy efficiency

$$\eta = \frac{\text{Kinetic}}{\text{Gasoline, Diesel, Electricity}}$$

$$\eta_{\text{discharging}} =$$

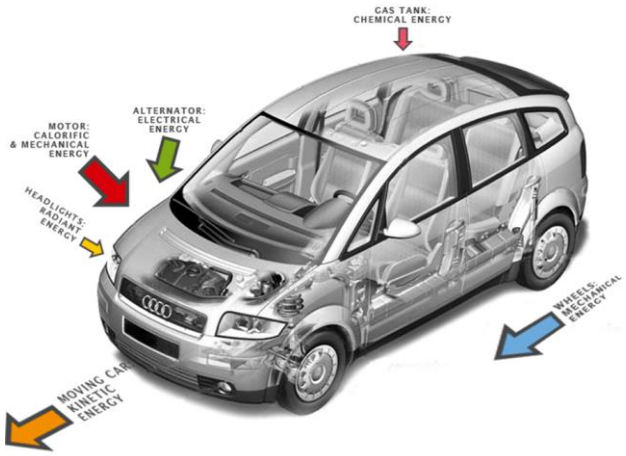
$$0.99*0.98*0.94*0.821*0.49 = 37\%$$

Energy efficiency

$$\eta = \frac{\text{recovered}}{\text{Kinetic}}$$

$$\eta_{\text{charging}} = 0.82*0.95*0.86*0.96*0.95 = 61\%$$

Vehicle technologies – TTW energy efficiency



Final to useful energy….

ICEV – Internal combustion engine vehicle

(efic. 10-25 %)

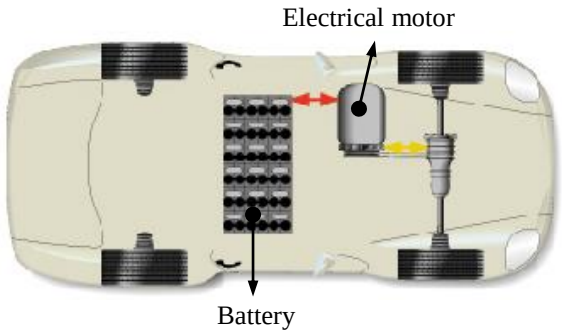
Hybrid Cars Now, Fuel Cell Cars Later
Nurettin Demirdöven1, John Deutch2,*
Science 13 Aug 2004:
Vol. 305, Issue 5686, pp. 974-976
DOI: 10.1126/science.1093965

https://www.fueleconomy.gov/feg/atv.shtml

Vehicle technologies

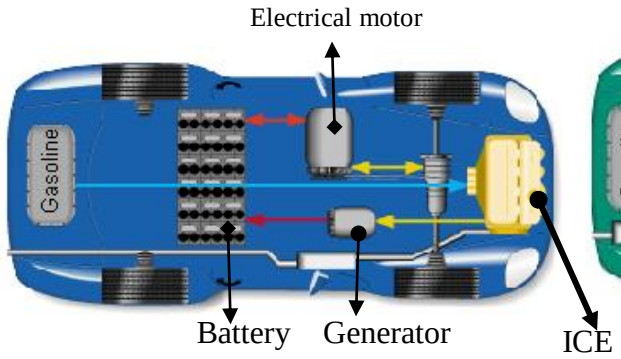
Final to useful energy….

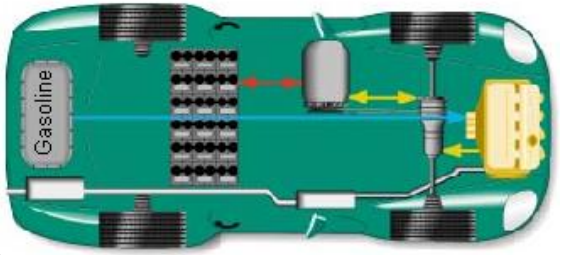
Plug-In

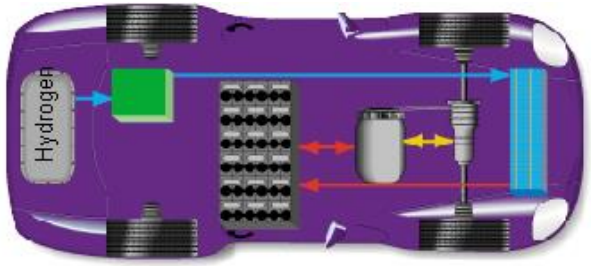


Pure electric (efic. 65-75%)

Hybrids (efic. 25-35%)

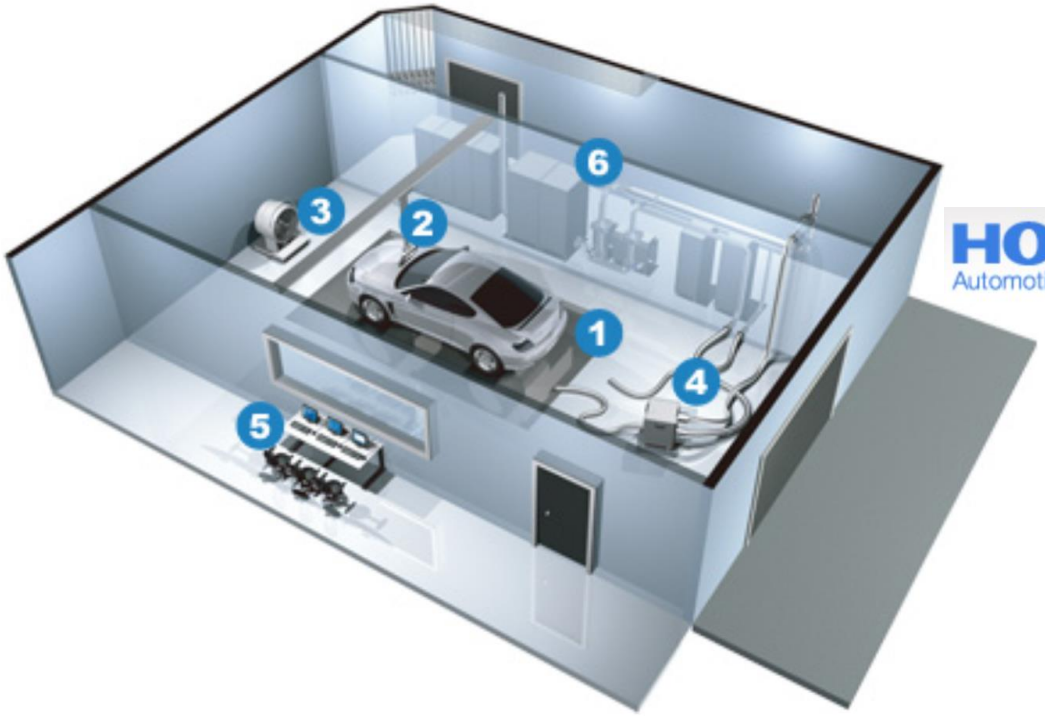






Fuel cell (efic. 30-40%)

Standard Fuel figures

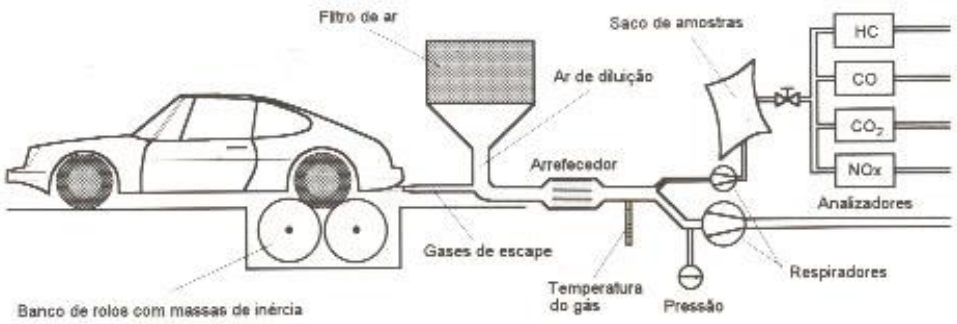


1. 4WD chassis dyno
2. Drivers aid monitor
3. Air speed fan
4. Remote mix-T, RMT
5. Control room with VETS
6. Emission analysis equipment

Roller bench/ chassis dynamometer

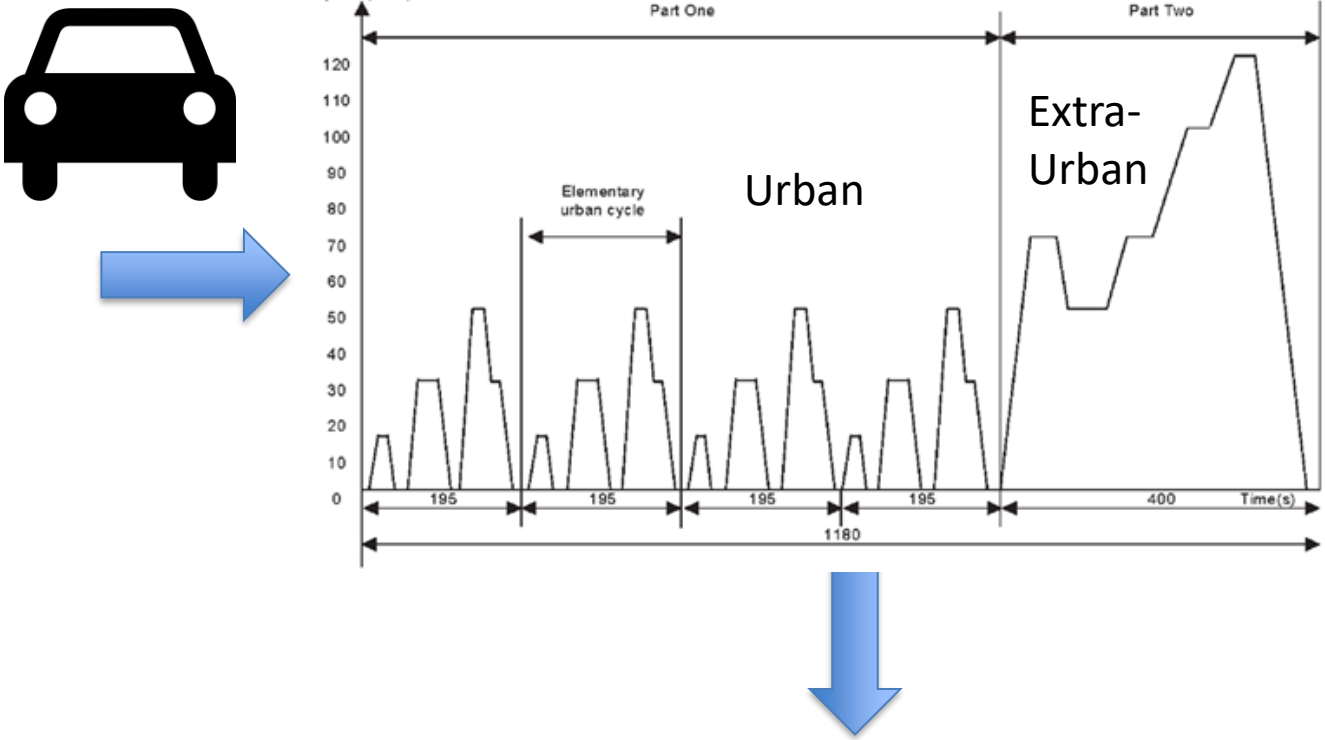
Standard Fuel figures

www.dieselnet.com



Standard Fuel figures

OLD European Driving cycle



Urban

Extra-Urban

Combined

L/100 km or kWh/km

Standard Fuel figures

Worldwide Harmonized Light Vehicles Test Cycle (WLTC)

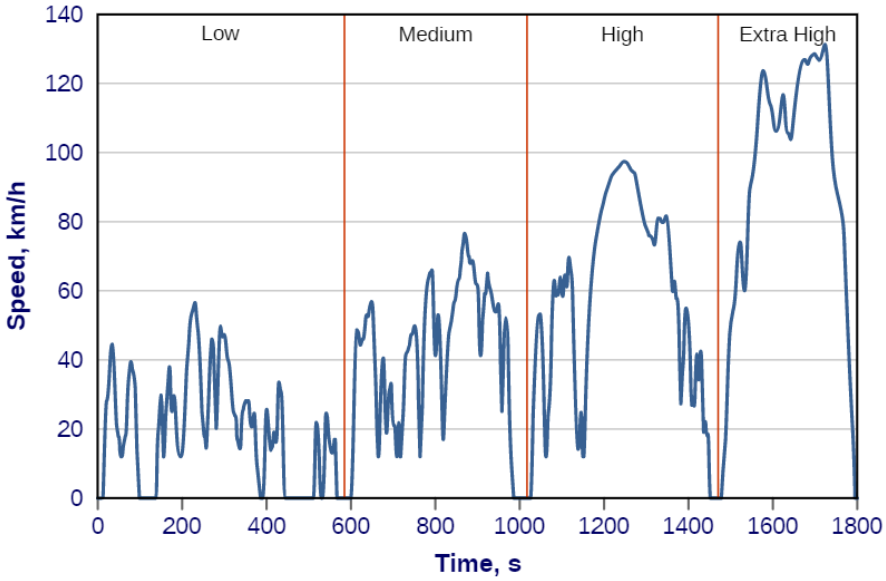


Figure 1. WLTC cycle for Class 3b vehicles

Class 3 is representative of vehicles driven in Europe and Japan

Standard Fuel figures

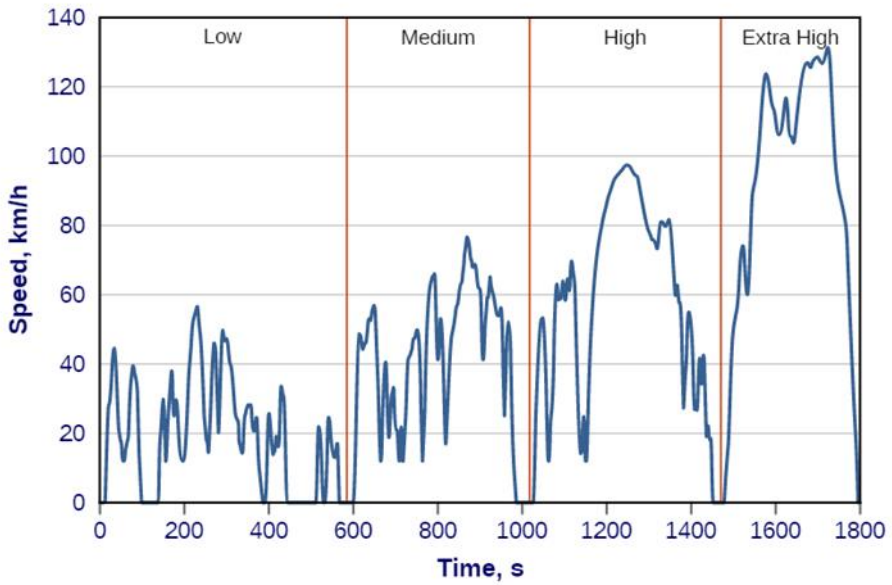


Figure 1. WLTC cycle for Class 3b vehicles

Combined 5.4 L/100km

Standard Fuel figures

Worldwide Harmonized Light Vehicles Test Cycle (WLTC)

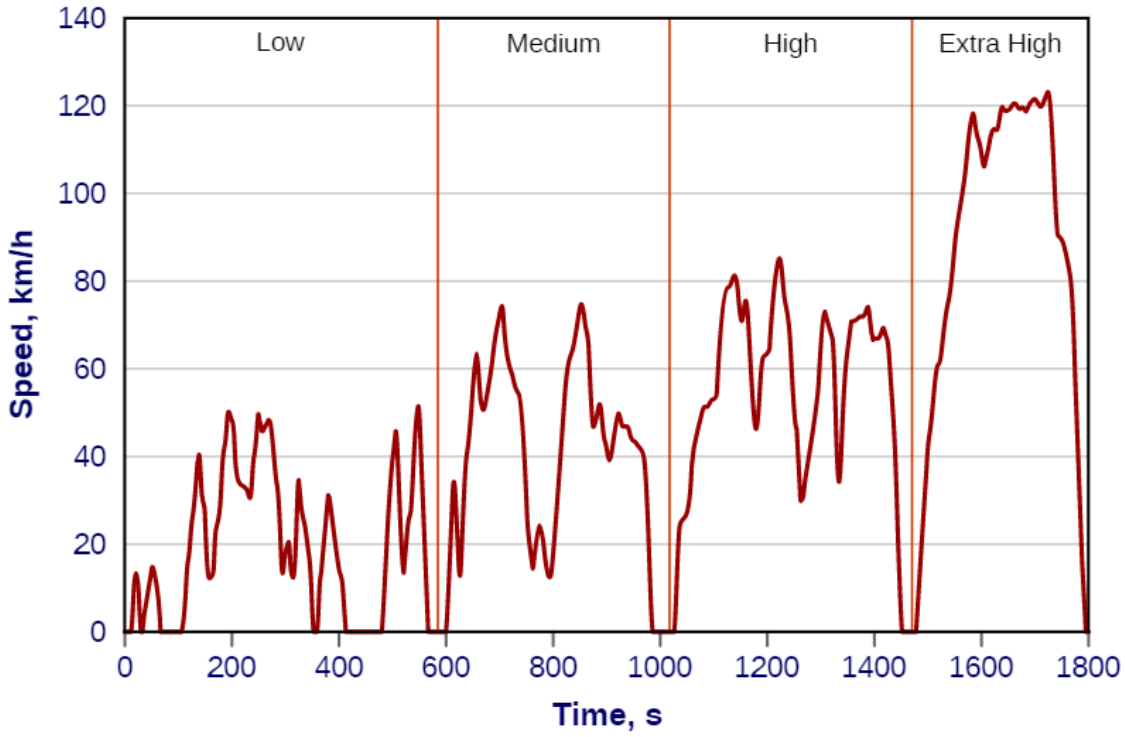
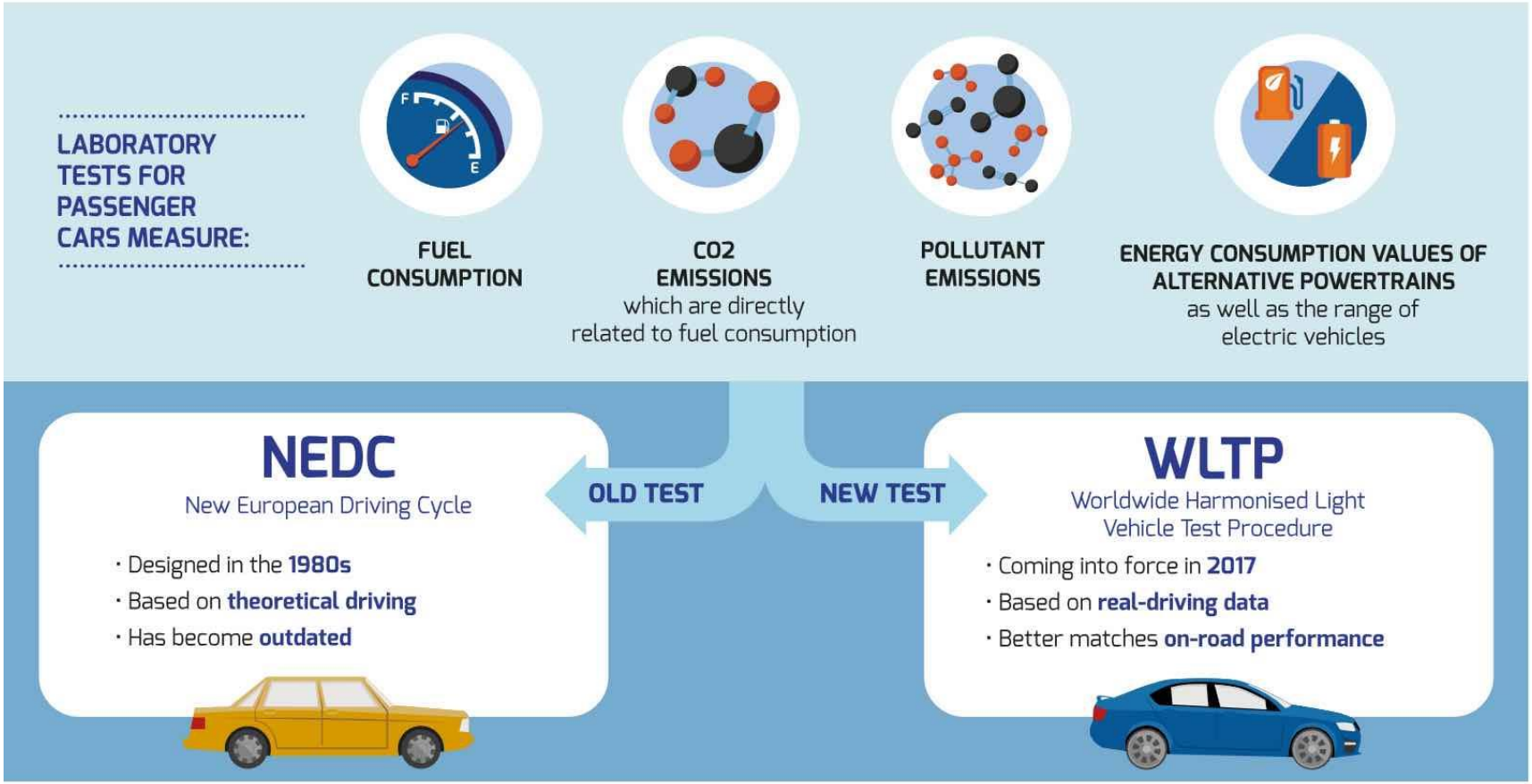


Figure 2. WLTC cycle for Class 2 vehicles

Class 2 is representative of vehicles driven in India and of low power vehicles driven in Japan and Europe

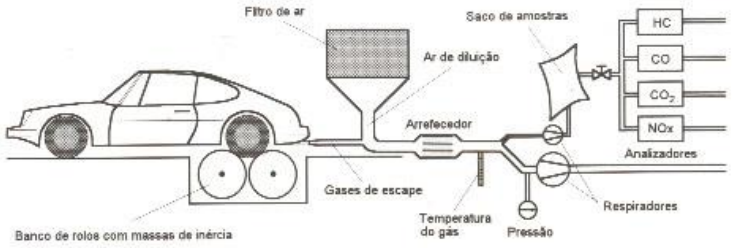
Regulations - standards



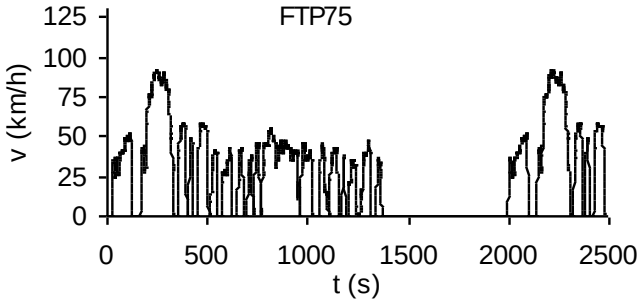
Standard Fuel figures

	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

World scenario/Legislation



US



EU

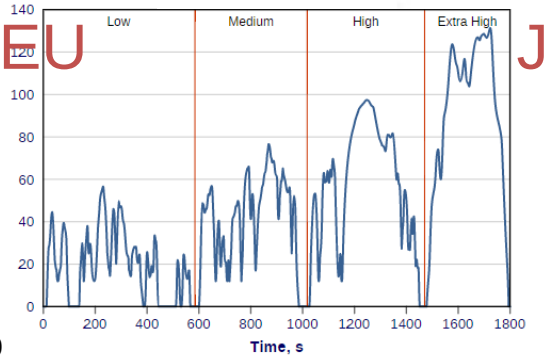


Figure 1. WLTC cycle for Class 3b vehicles

Japan

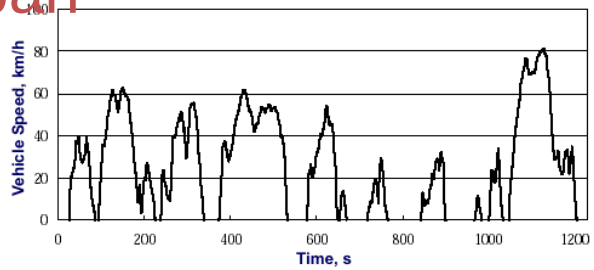
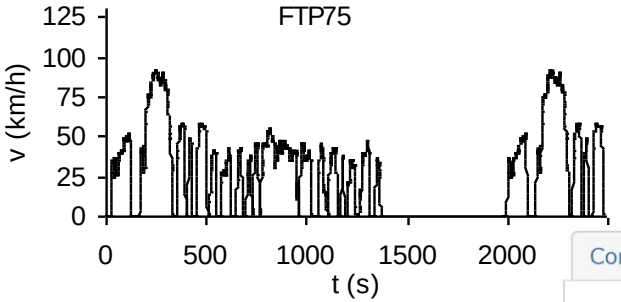


Figure 2. New Transient Mode for Vehicles < 3,500 kg GVW (proposed)

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

World scenario/Legislation

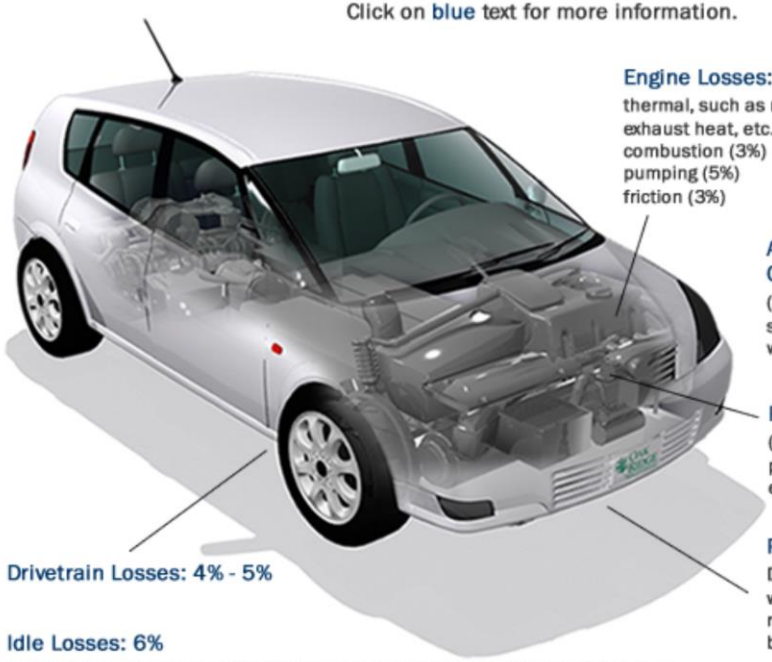


US

Combined | City | Highway

Energy Requirements for City (Stop and Go) Driving

Click on blue text for more information.



Engine Losses: 71% - 75%
thermal, such as radiator, exhaust heat, etc. (60% - 64%)
combustion (3%)
pumping (5%)
friction (3%)

Auxiliary Electrical Losses: 0% - 2%
(e.g., climate control fans, seat and steering wheel warmers, headlights, etc.)

Parasitic Losses: 5% - 7%
(e.g., water, fuel and oil pumps, ignition system, engine control system, etc.)

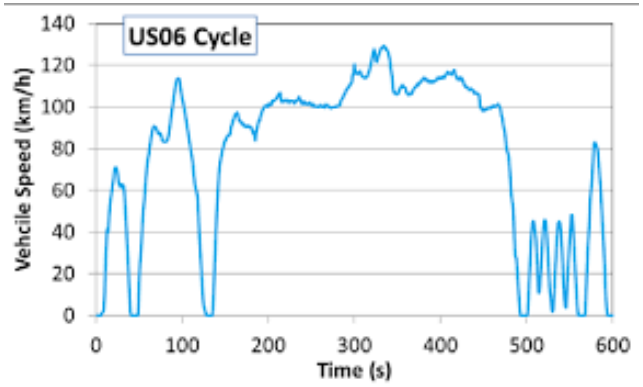
Power to Wheels: 12% - 20%
Dissipated as
wind resistance: (3% - 5%)
rolling resistance (3% - 5%)
braking (6% - 10%)

Drivetrain Losses: 4% - 5%

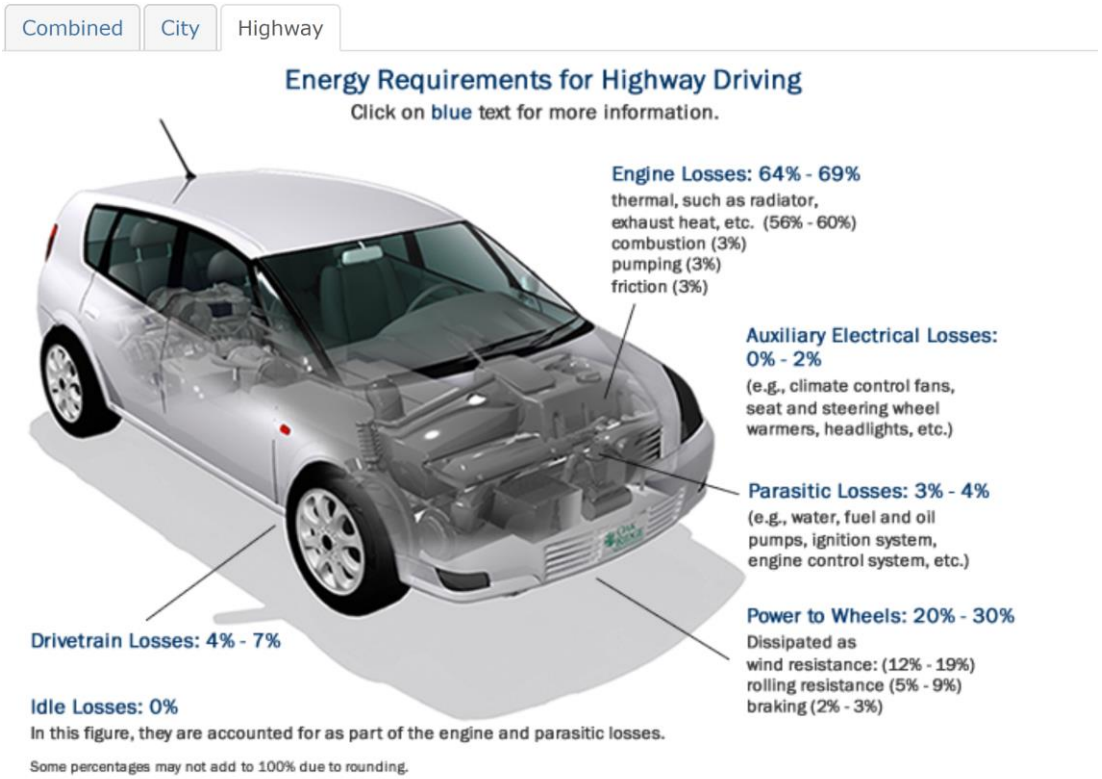
Idle Losses: 6%
In this figure, they are accounted for as part of the engine and parasitic losses.

Some percentages may not add to 100% due to rounding.

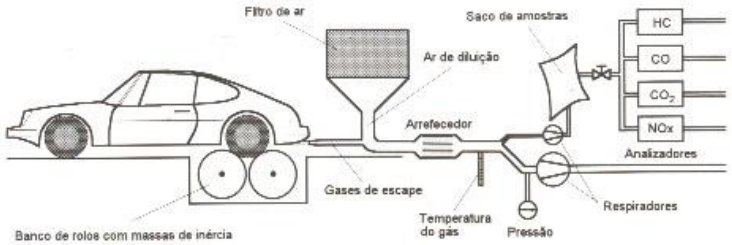
World scenario/Legislation



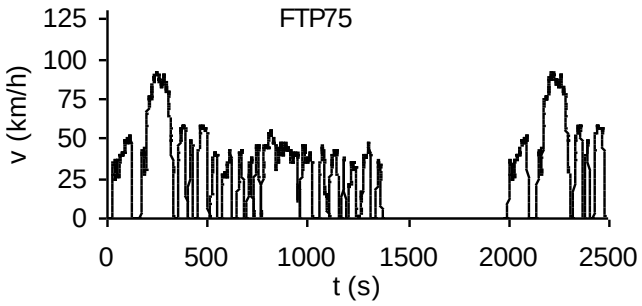
US



World scenario/Legislation



US



EU

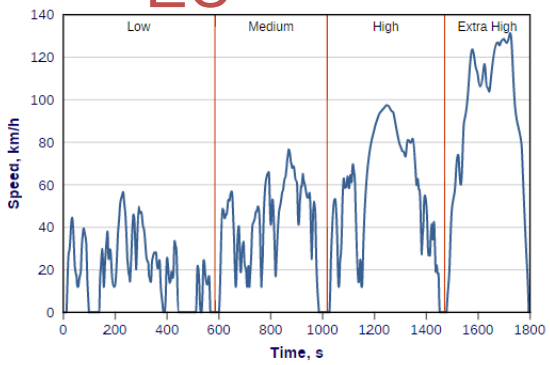


Figure 1. WLTC cycle for Class 3b vehicles

Japan

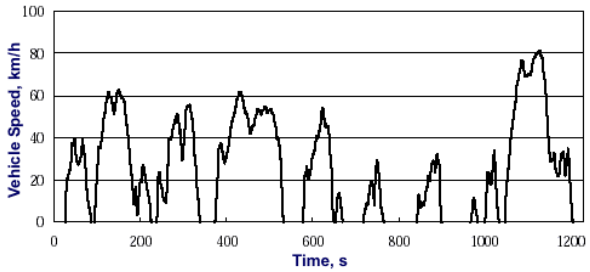


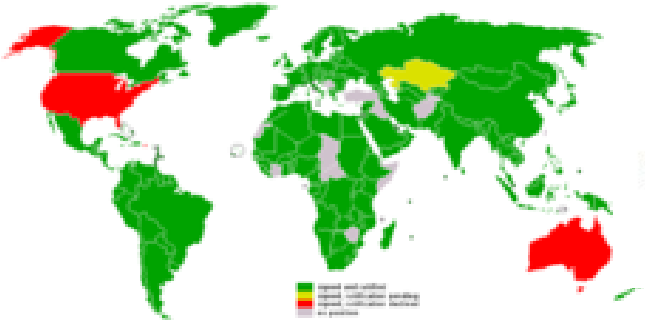
Figure 2. New Transient Mode for Vehicles < 3,500 kg GVW (proposed)

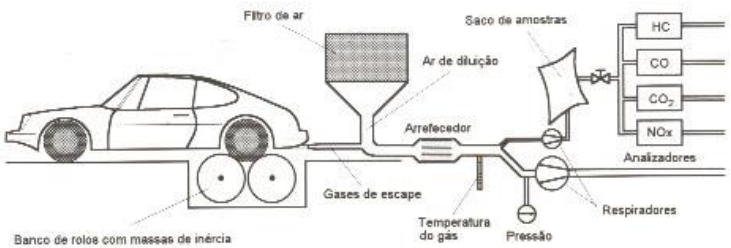
mpg – miles your car can do burning 1 gallon of fuel

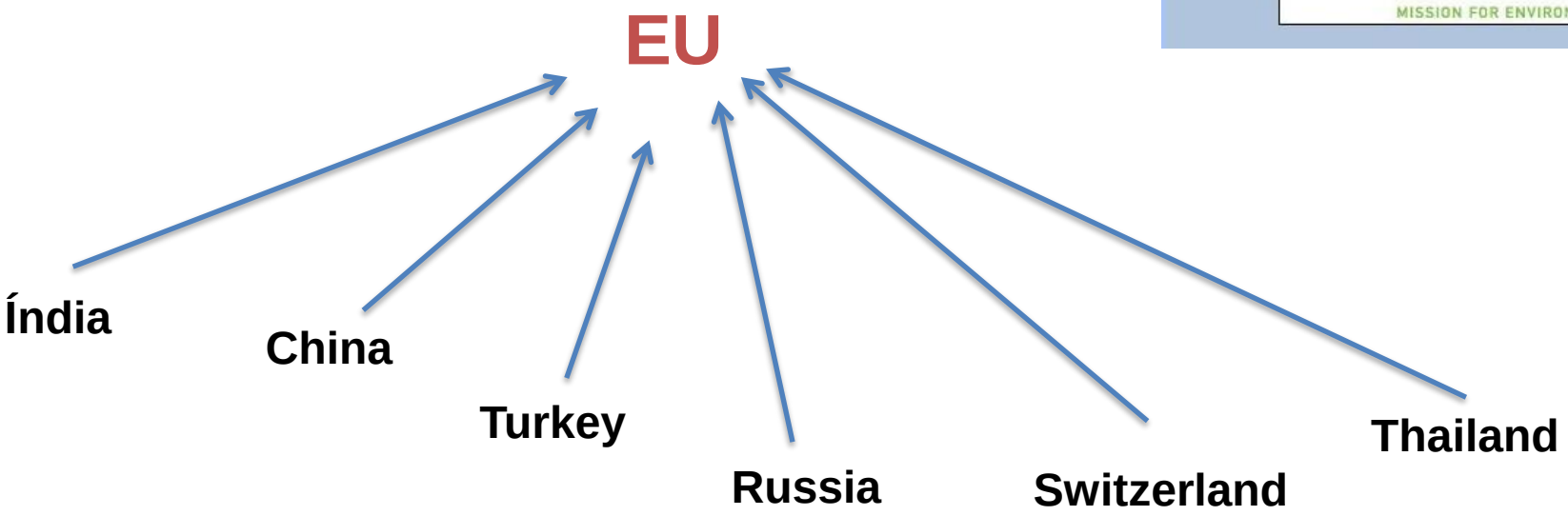
L/100km – how many liters you have to burn to make 100 km

km/L – how many km you can do by burning 1 L of fuel

World scenario/Legislation







Vehicle technologies

Car makers technical specifications…… Based on LABORATORY measurements

Vehicle technologies

Most sold vehicle Portugal

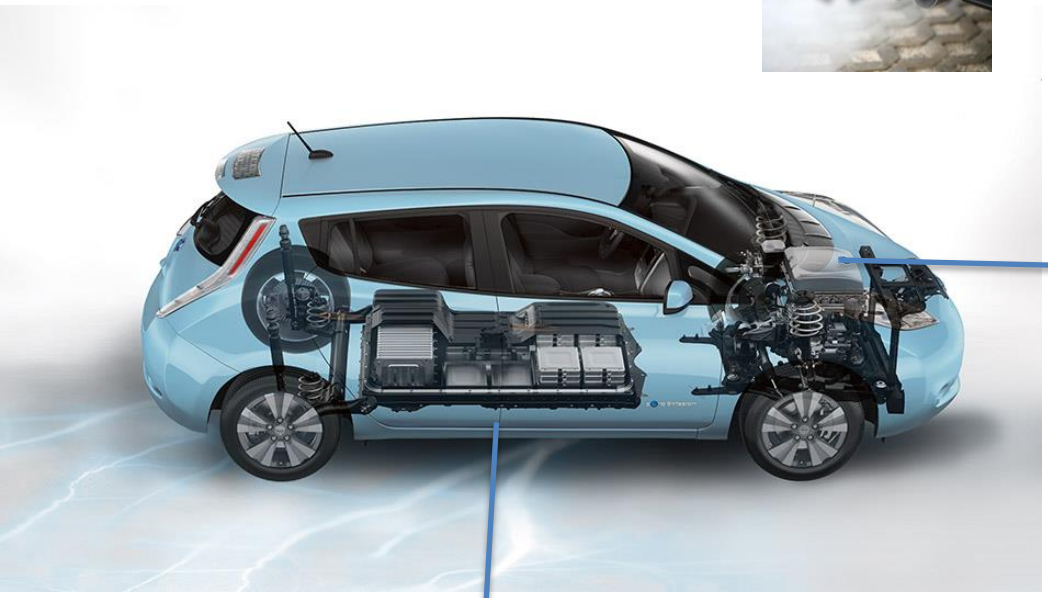
0-100 km/h	14.5 s
European test cycle l/100km	5.6
1059 kg	

Internal combustion engine

Evolution….. energy

Leaf

No tailpipe emissions



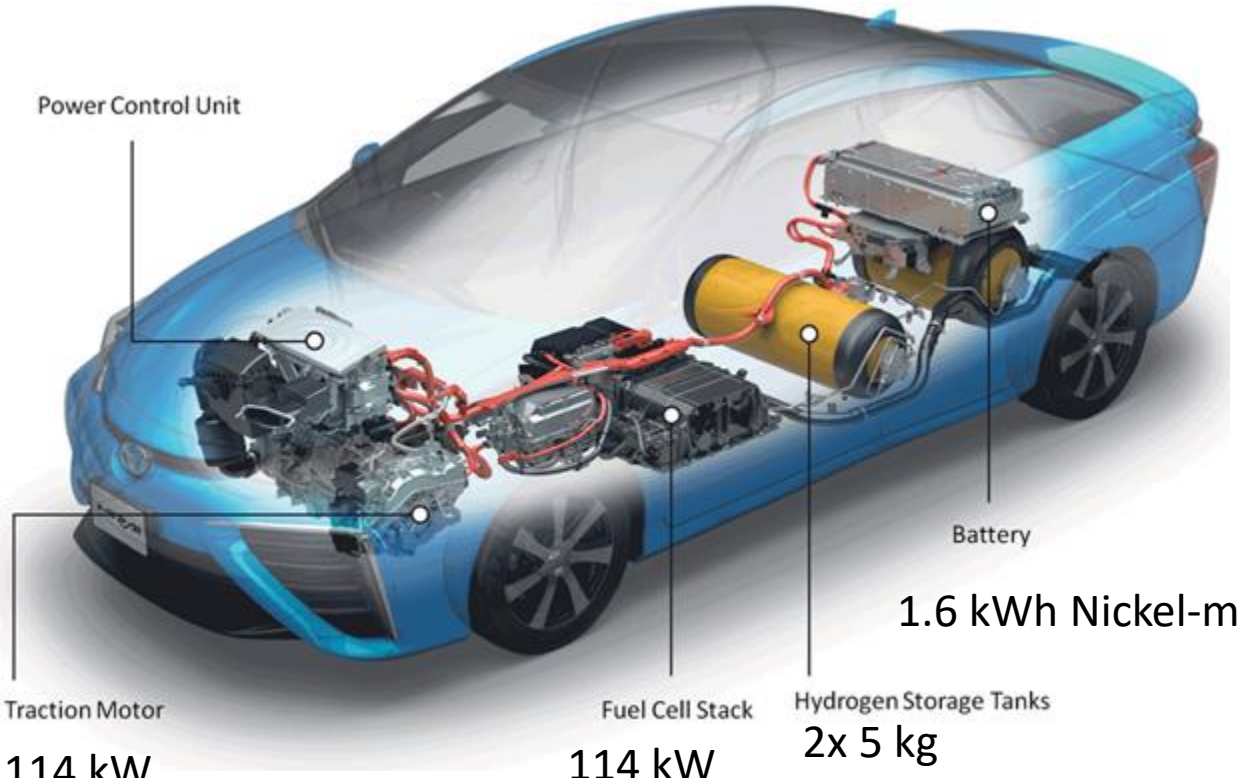
output power increased to over 110 kW (110 kW is peak power of electric motor – previously it was 80 kW)

- 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	

Vehicle technologies

Mirai



1850 kg
0.76 kg H2/100 km
0-100 km/h 8.6 s

1.6 kWh Nickel-metal hydride

114 kW

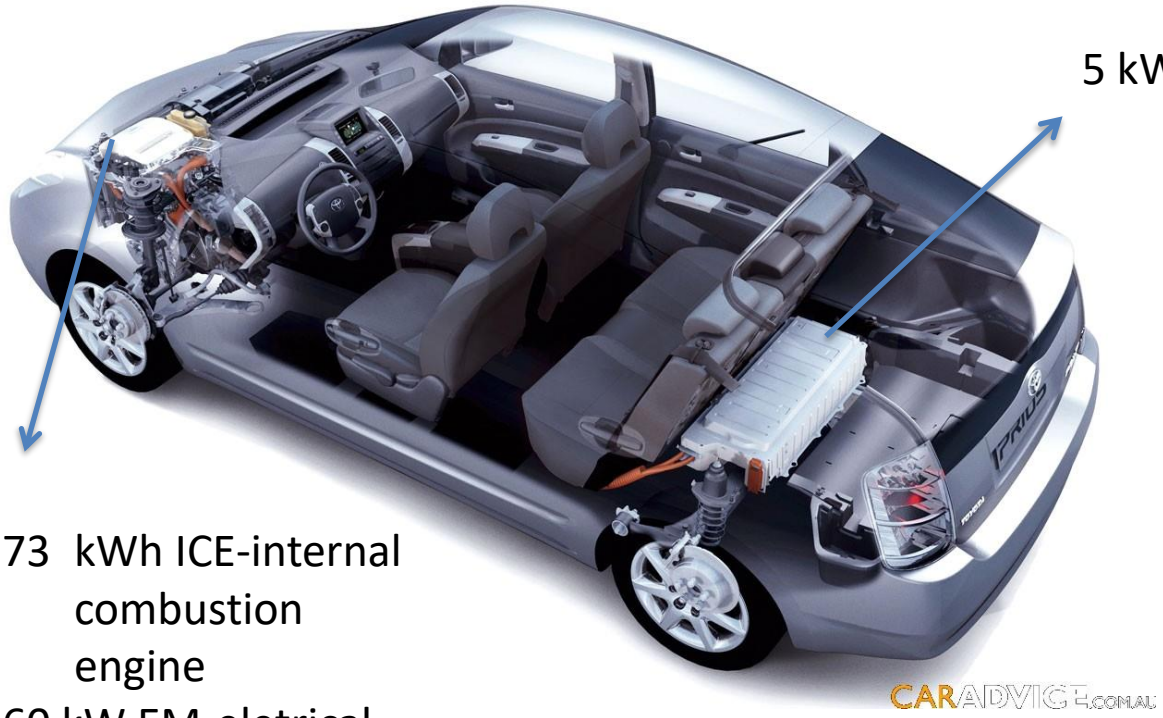
114 kW

2x 5 kg
700 bar

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

Vehicle technologies

Prius



5 kWh Ni-MH

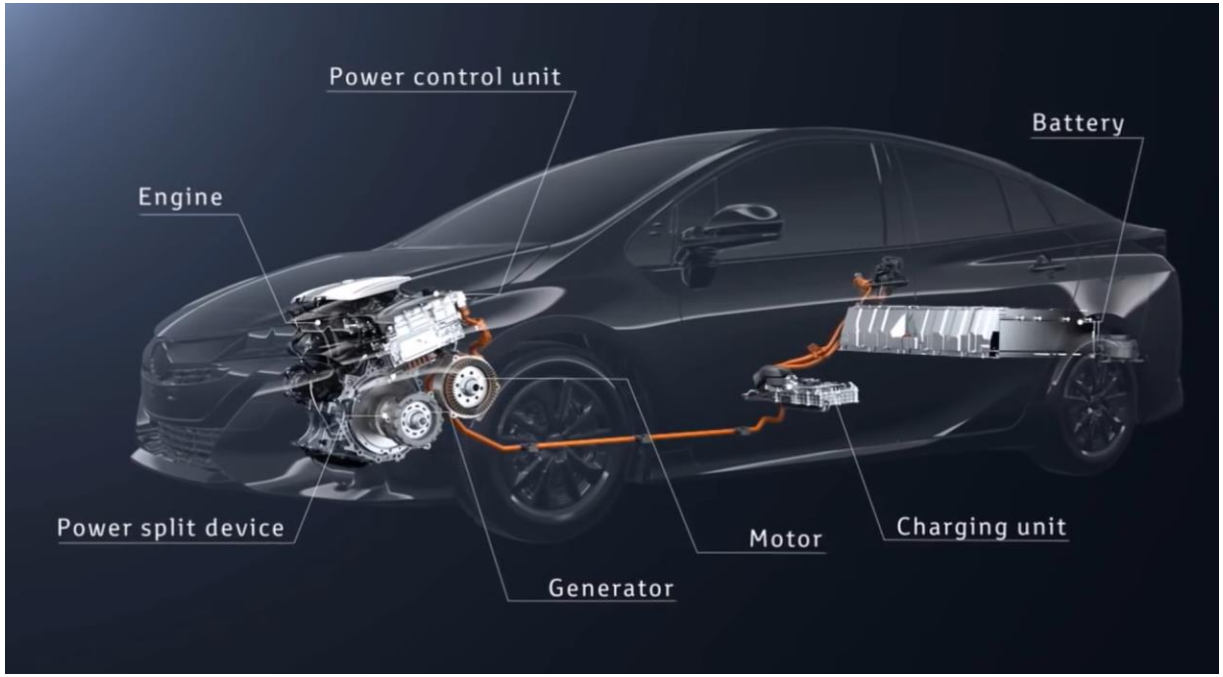
73 kWh ICE-internal combustion engine

60 kW EM-eletrical motor

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

Vehicle technologies

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

Vehicle final energy consumption database

Vehicle Certification Agency

Car fuel data, CO2 and vehicle tax tools

Select a search

Use these tools to find out information on the following:

Find fuel consumption and emissions information on a new or used car
Search for car details including fuel consumption, CO2 and other emissions, by make and model.
Find fuel consumption and emissions information on a new or used car

Find vehicle tax information on a new or used car
Search for car details by make, model and registration date, or view the current tax tables.
Find vehicle tax information on a new or used car

Find the cost of tax for all vehicle types
Search for the amount of tax payable on cars, motorcycles, lorries, coaches and all other vehicle types.
Find the cost of vehicle tax

Find new cars by fuel economy
Search for new cars by fuel consumption figures.
Find new cars by fuel economy

Find new cars and show fuel running costs
Search for new cars by the annual cost of fuel.
Find new cars and show their fuel running costs

Find new cars using alternative fuel types
Search for new cars using Liquefied Petroleum Gas (LPG)/Compressed Natural Gas (CNG) and petrol electric.
Find new cars using alternative fuel types

Download car fuel and emissions information
Find data on fuel consumption and emissions on individual cars. A sample of the environmental label can also be downloaded here.
Download car fuel and emissions information

Return to home page

https://carfueldata.vehicle-certification-agency.gov.uk/

World scenario/Legislation

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

World scenario/Legislation

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)	CO2 g/km
181	**56**	**1.8**	**48**

World scenario/Legislation

Worldwide Harmonized Light Vehicles Test Cycle (WLTC)

NISSAN Leaf, MY2016, 30 kWh Electricity

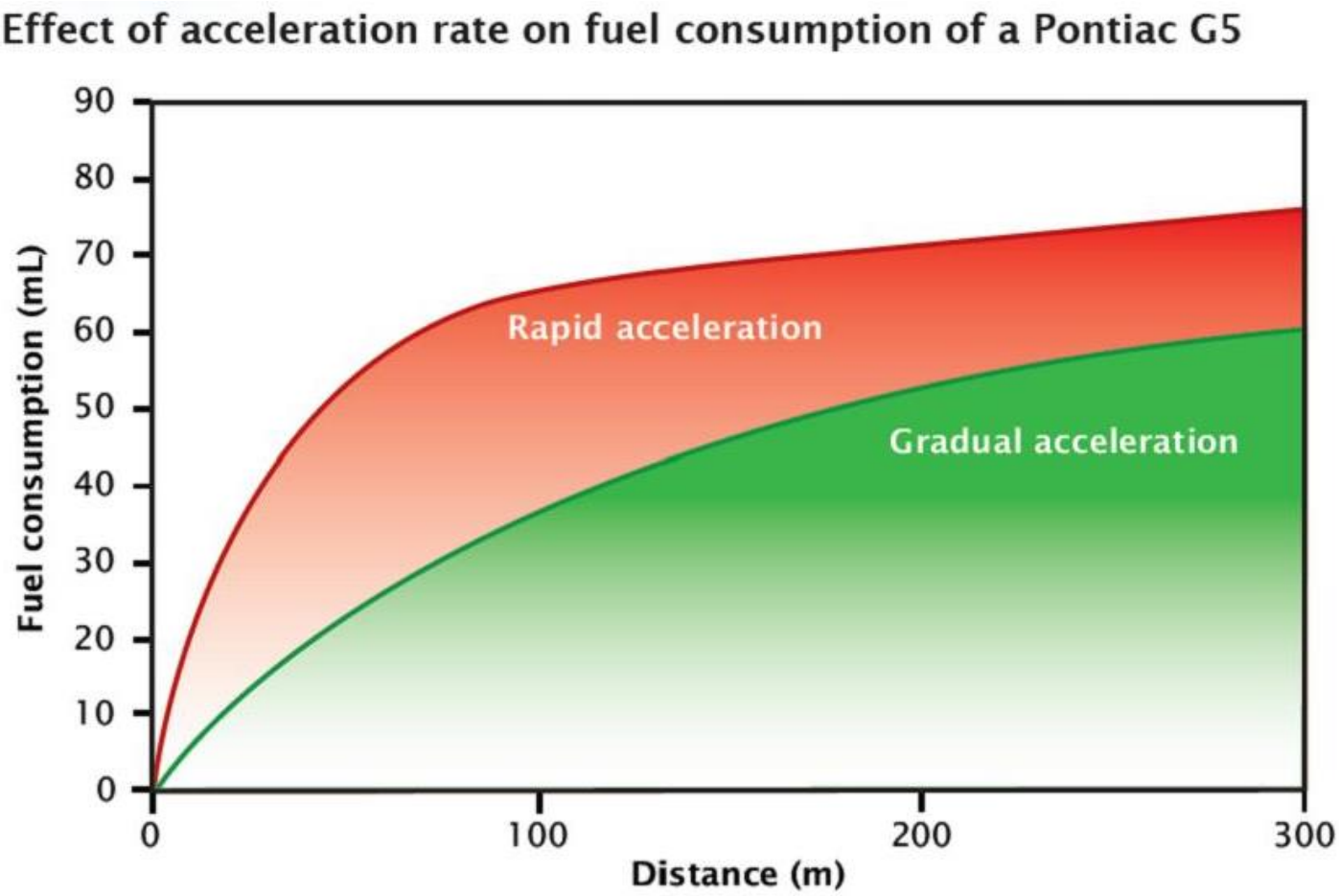
Euro Standard	Noise Level dB(A)	CO [mg/km]	THC [mg/km]	NOx [mg/km]
6	**68**	**0**	**0**	**0**

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

Vehicle Certification Agency

Standard driving cycles

Reality - Driver behaviour



Reality - Driver behaviour

Variation in real world-fuel consumption

Preparation for collection and monitoring of real-world fuel consumption data for light and heavy duty vehicles

Final report

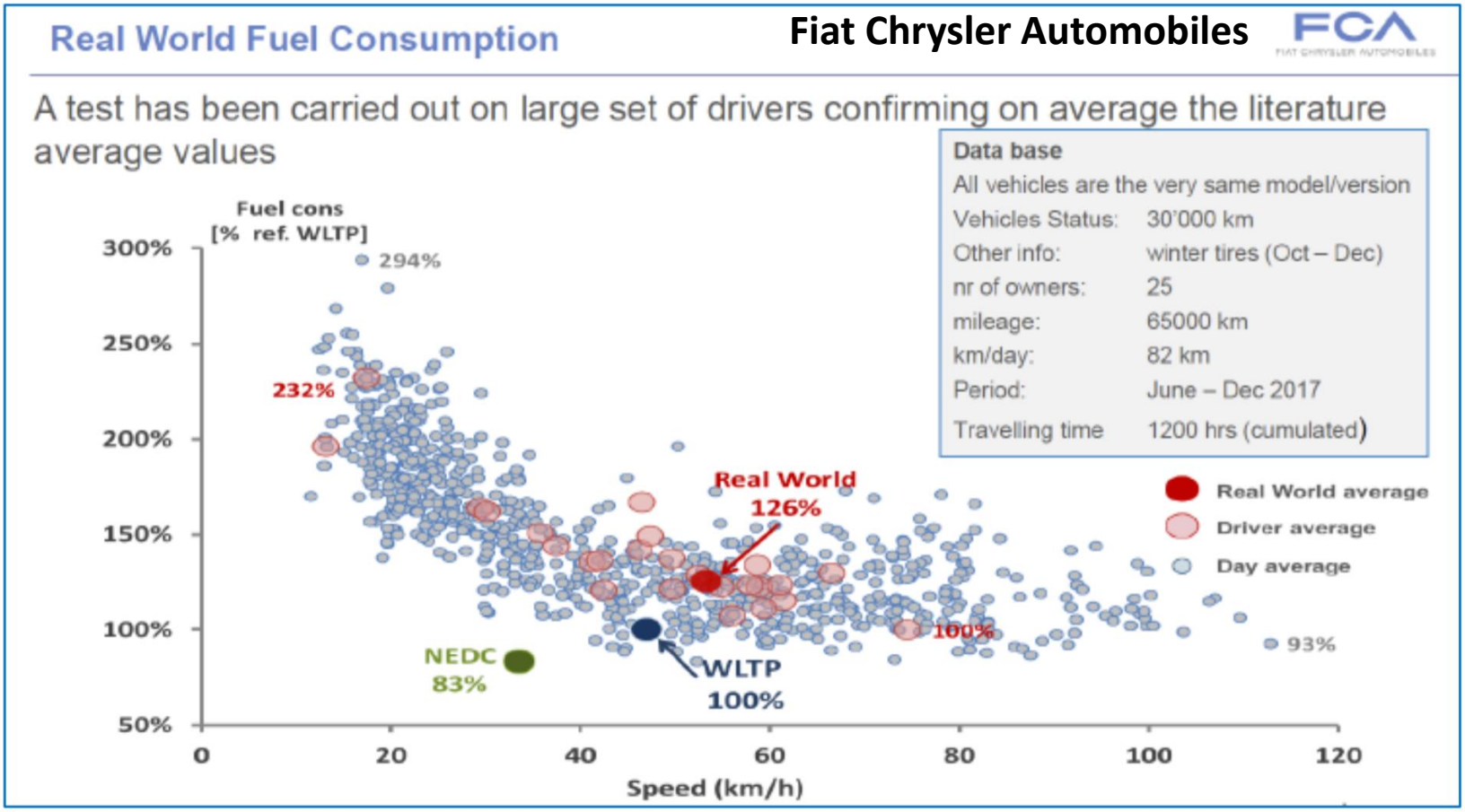
Report for European Commission – DG Climate Action

340201/2018/7878749/SER/CLIMA.C.4

ED 11840 | Issue Number 5 | Date 29/08/2019

Variation in real world-fuel consumption

Figure 5-1: Variation in real world fuel consumption data for nominally identical vehicles, driven by 25 different drivers each carrying out multiple trips (source: FCA, 2018)



Variation in real world-fuel consumption

Real trip daily variations….
93% to 294% of the WLTP reference value (100%)

- The use of auxiliary systems fitted to the vehicle
- Vehicle maintenance and ageing

- External factors (e.g. climate, weather, altitude, road conditions and traffic conditions)

- Driver factors (e.g. driving style)

- Trip characteristics (e.g. vehicle speed, trip length and grade)

Variation in real world-fuel consumption

WHITE PAPER NOVEMBER 2017

FROM LABORATORY TO ROAD
INTERNATIONAL

A COMPARISON OF OFFICIAL AND REAL-WORLD FUEL CONSUMPTION AND CO_2 VALUES FOR PASSENGER CARS IN EUROPE, THE UNITED STATES, CHINA, AND JAPAN

Uwe Tietge, Sonsoles Díaz, Zifei Yang, Peter Mock

icct
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

www.theicct.org
communications@theicct.org

Variation in real world-fuel consumption

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

www.fueleconomy.gov

the official U.S. government source for fuel economy information

Tracking Your MPG Just Got Easier

Now you can enter "My MPG" data at the pump from your mobile device at fueleconomy.gov/m!

Variation in real world-fuel consumption

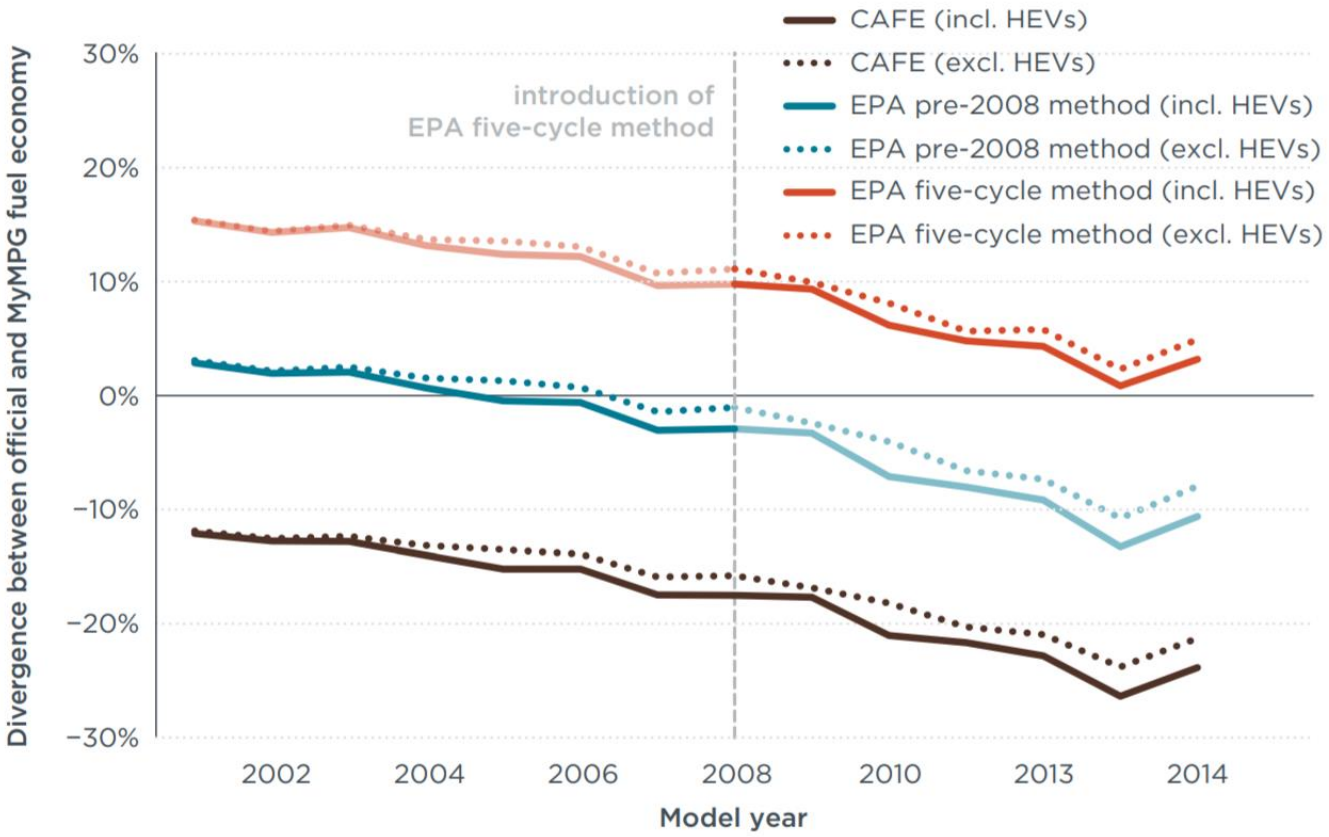
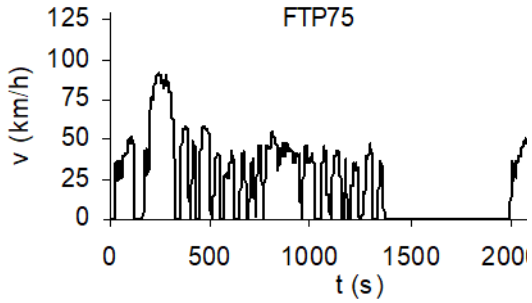


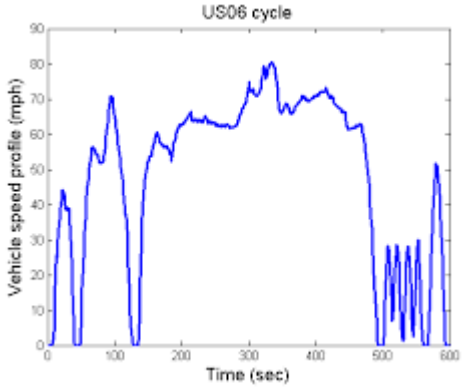
Figure 32. Divergence of MyMPG from official fuel economy values by powertrain. Official fuel economy values include CAFE figures and EPA label values.

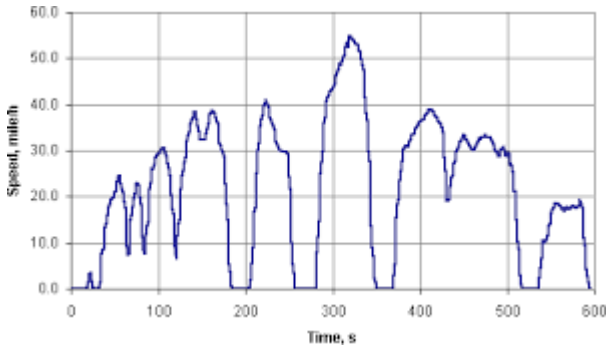
Variation in real world-fuel consumption

Test	*Driving*	*Ambient temperature*	*Engine condition at start*	*Accessories*
FTP	Low speed	24°C (75°F)	Cold and hot	None
HWFET	Mid-speed	24°C (75°F)	Hot	None
US06	Aggressive; low and high speed	24°C (75°F)	Hot	None
SC03	Low speed	35°C (95°F)	Hot	A/C on
Cold FTP	Low speed	–6.7°C (20°F)	Cold and hot	None

Source: US EPA (2006, p.34)







City | Highway | High Speed | Air Conditioning | Cold Temperature | Test Details

Vehicle technologies

Car magazine info…… LAB and “REAL”….

Variation in real world-fuel consumption

Consumo **standard**

Cidade/Urbano	7,2 lt/100km
Estrada/Rodovia	4,7 lt/100km
Combinado	5,6 lt/100km

real

Consumo de Teste Estimado

Combinado	9,5 lt/100km
Custo	12,46 €/100km (12,46 €/100km)
Preço	Portugal

+69%

Consumo real diário

Como é calculado?

motoreu

Average statistics provide by users and professional tests

Variation in real world-fuel consumption

Measuring real-world fuel consumption is a key:

- To MONITOR efficacy of CO_2 and fuel consumption targets (policy makers)
- To access realistic fuel consumption values and make informed vehicle purchasing decisions (consumers)

Variation in real world-fuel consumption

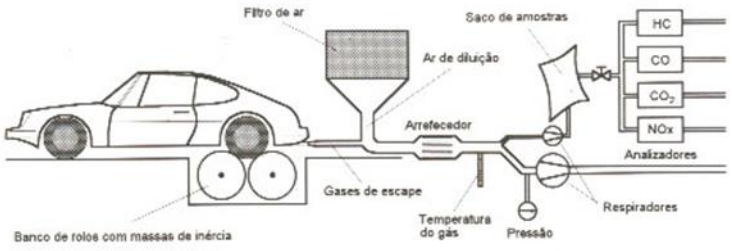
But LAB tests are also important to

COMPARE

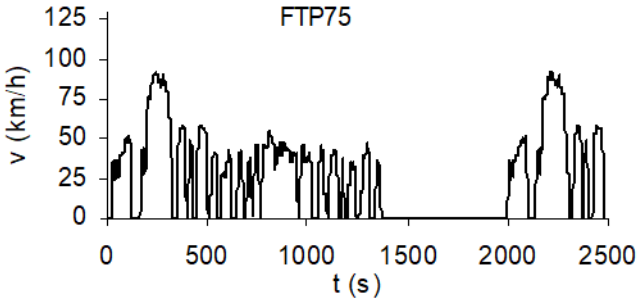
Cars in the exact same conditions!!!!

Variation in real world-fuel consumption

NOT comparable between different countries…..



US



EU

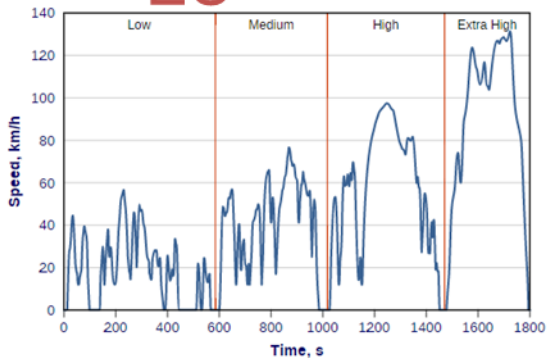


Figure 1. WLTC cycle for Class 3b vehicles

Japan

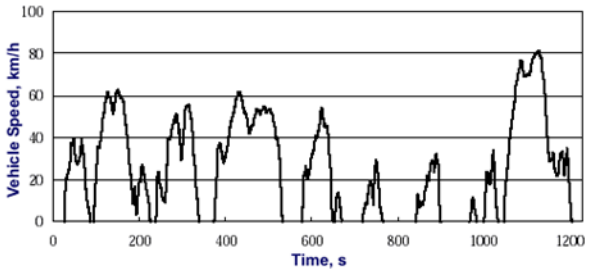
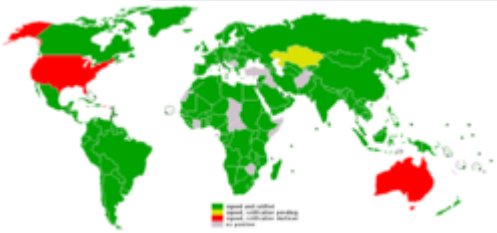
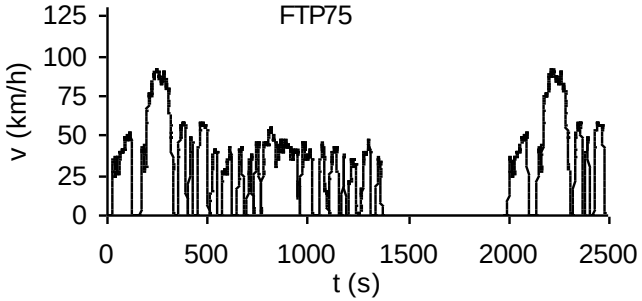


Figure 2. New Transient Mode for Vehicles < 3,500 kg GVW (proposed)

World scenario/Legislation



US



EU

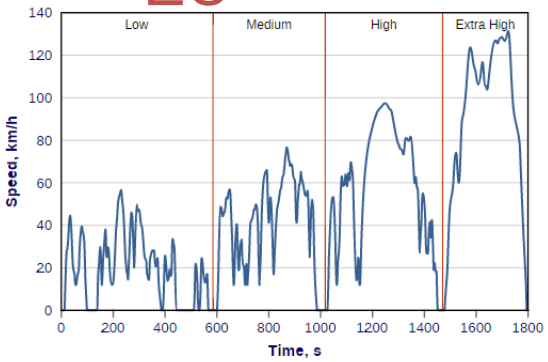


Figure 1. WLTC cycle for Class 3b vehicles

Japan

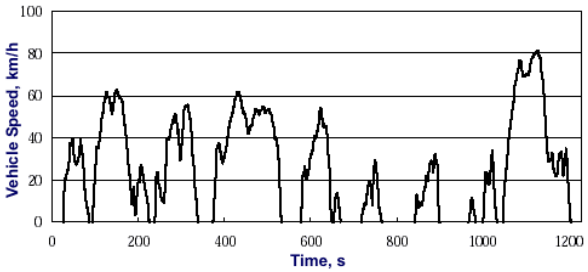


Figure 2. New Transient Mode for Vehicles < 3,500 kg GVW (proposed)

mpg – miles your car can do burning 1 gallon of fuel

L/100km – how many liters you have to burn to make 100 km

km/L – how many km you can do by burning 1 L of fuel

Open question

Imagine you buy a Toyota Prius car (HEV) in US, Europe or Japan. The technical specifications of the car related to fuel consumption are:

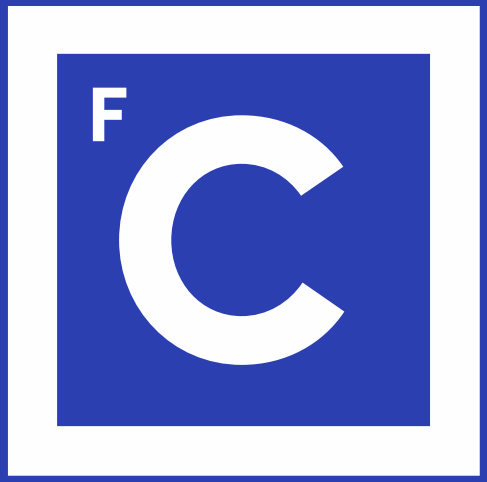
52 mpg

4.5 L/100km

40 km/L

You “real” fuel consumption will be different if you drive in New York, Lisbon or Tokyo??? Why?

Thanks



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