Ciências
ULisboa

Faculdade
de Ciências
da Universidade
de Lisboa

DISCIPLINA MIEA 2018

Mobilidade Sustentável

What is sustainable mobility?

Comparing transport systems??

Sustainable mobility indicators

Indicators of sustainable Mobility

11 Indicators

1 DIMENSION

Emissions per year (per capita)

Environmental

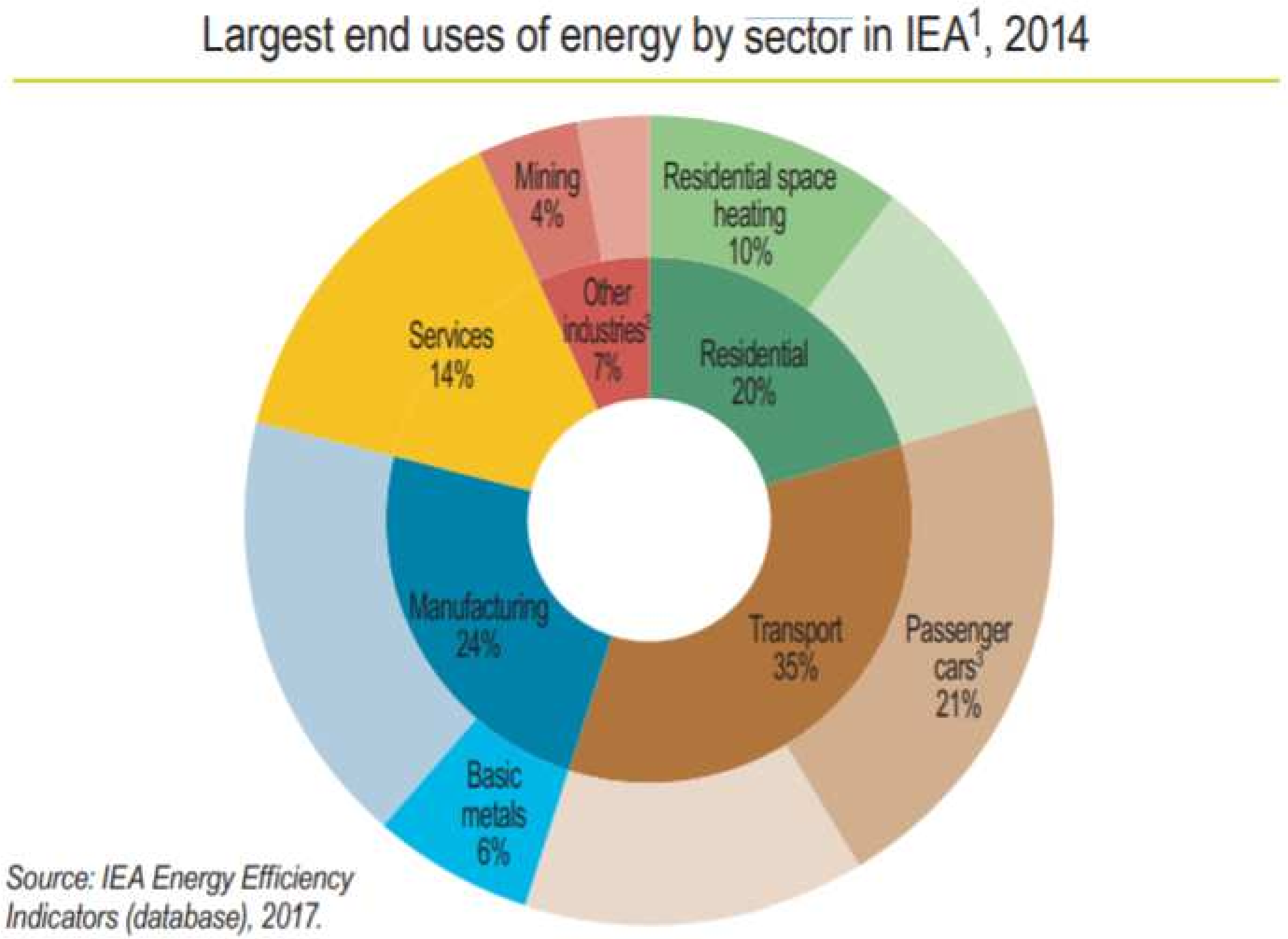
NOx (NO and NO_2)
VOCs
CO
PM10
PM2.5
SOx
O_3
CO_2
N_2O
CH_4

Ton or g/year

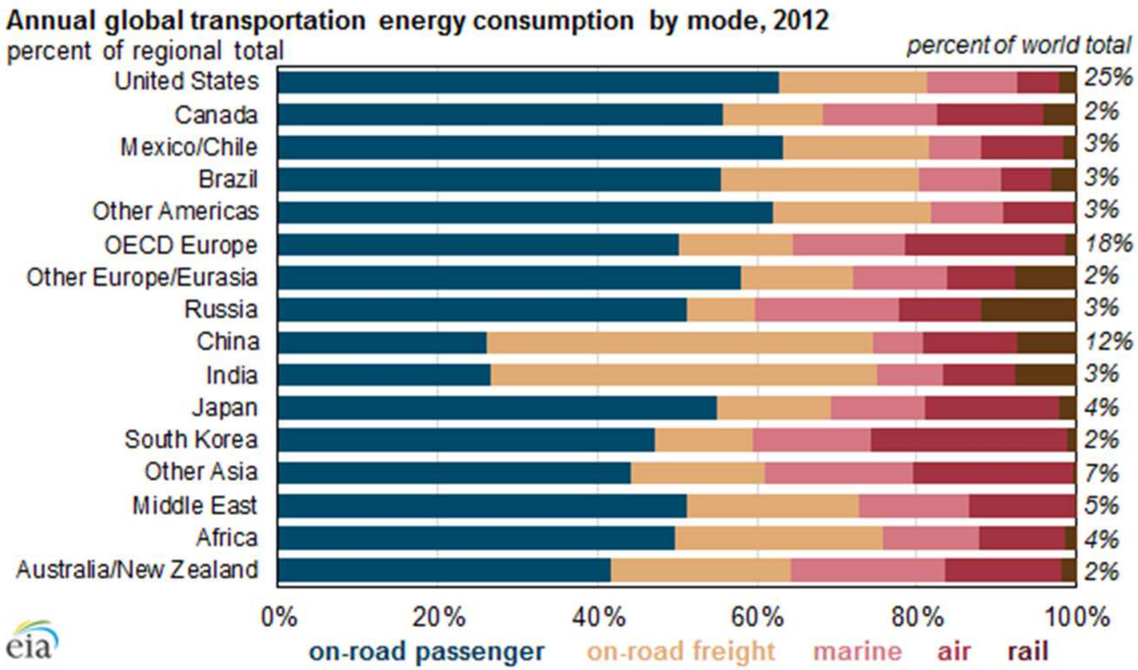
Energy consumption per year (per capita)

MJ or MJ/year

Transports share



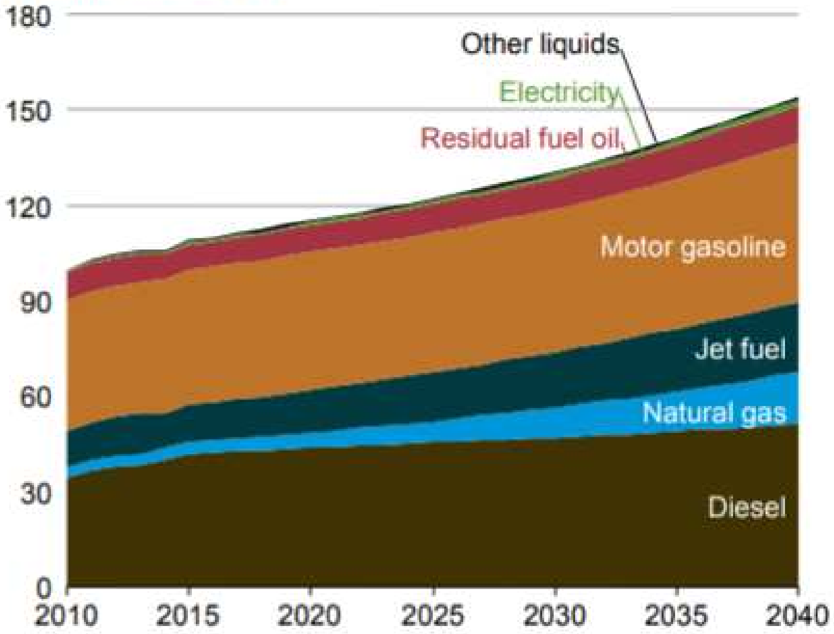
Transports mode share



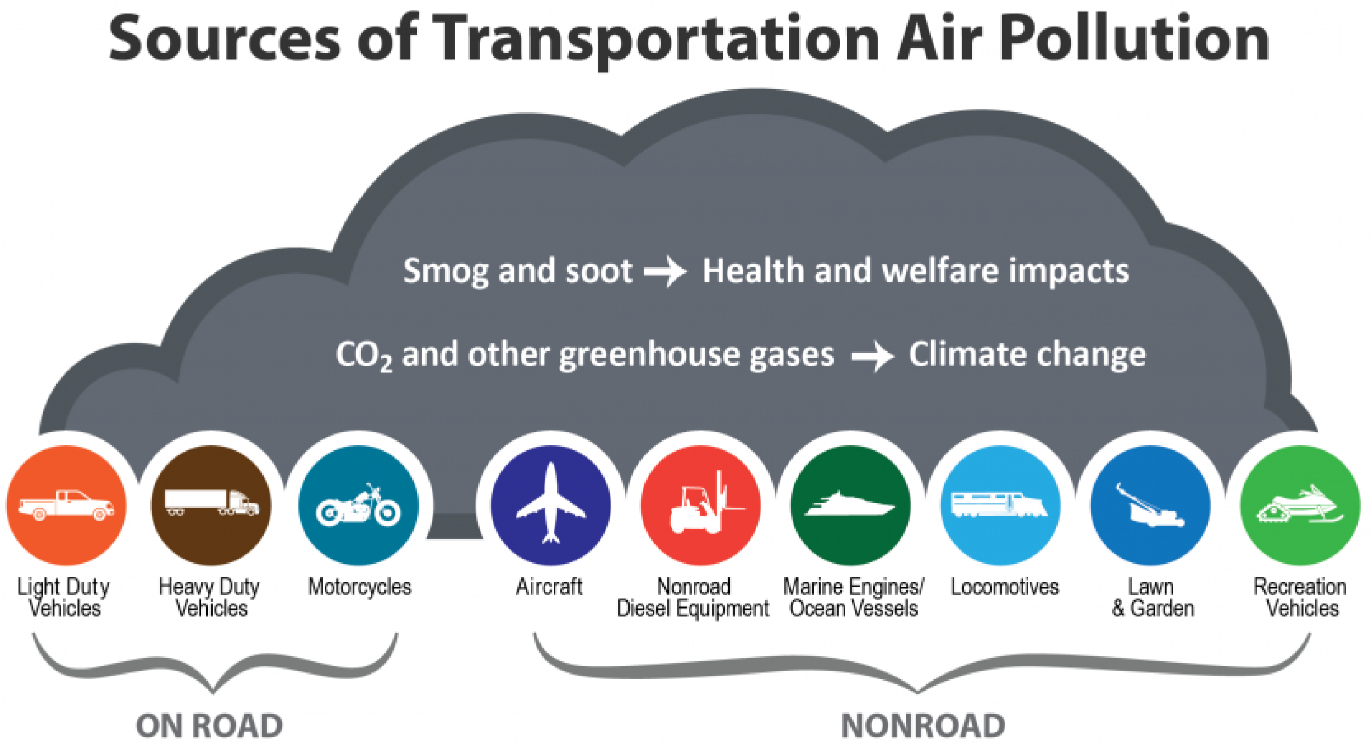
Source: EUROSTAT
http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Energy_consumption_of_transport_by_mode_EU-28.jpg

Transports share by energy source

Figure 8-2. World transportation sector delivered energy consumption by energy source, 2010–40 (quadrillion Btu)

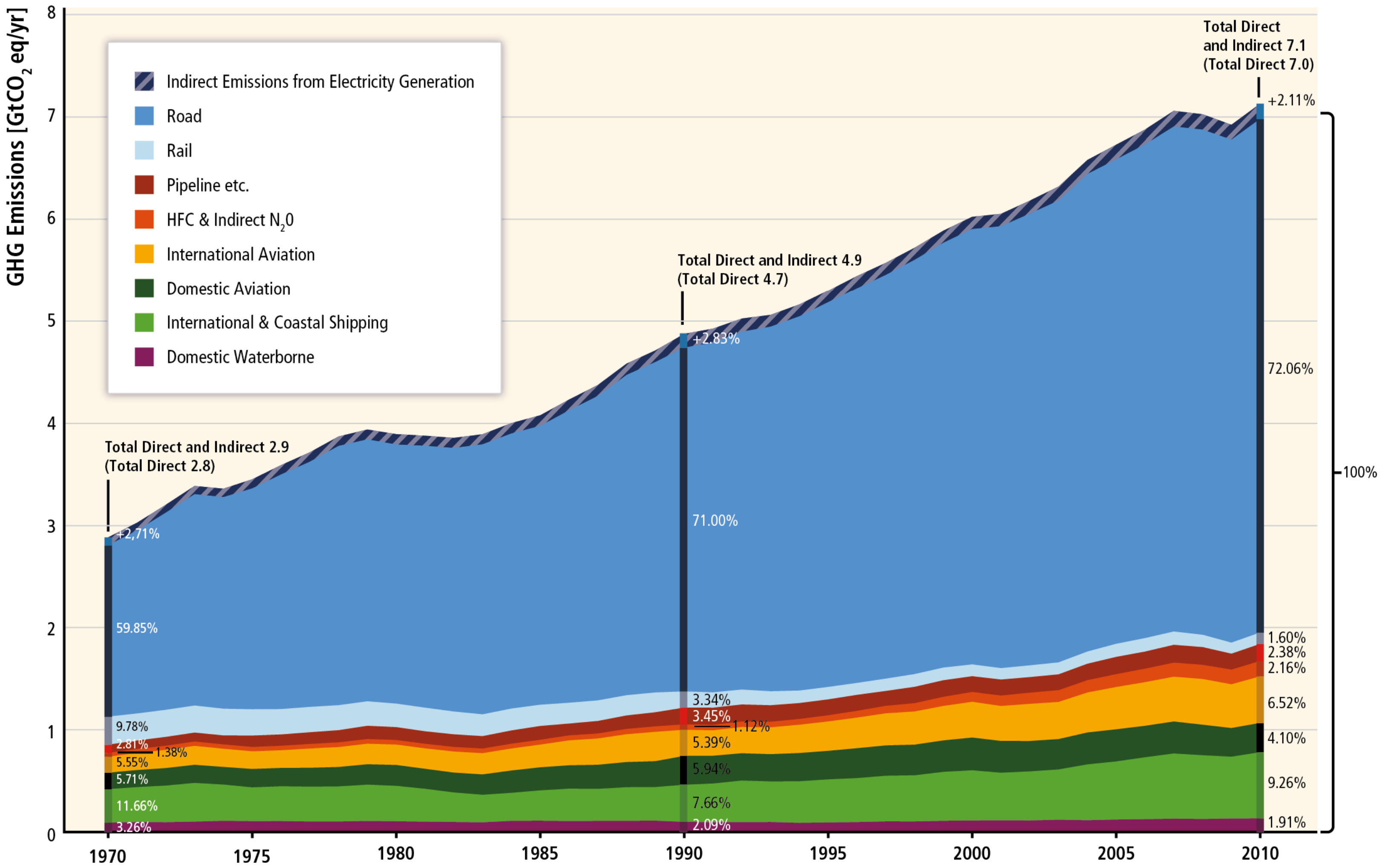


Transports share by energy source

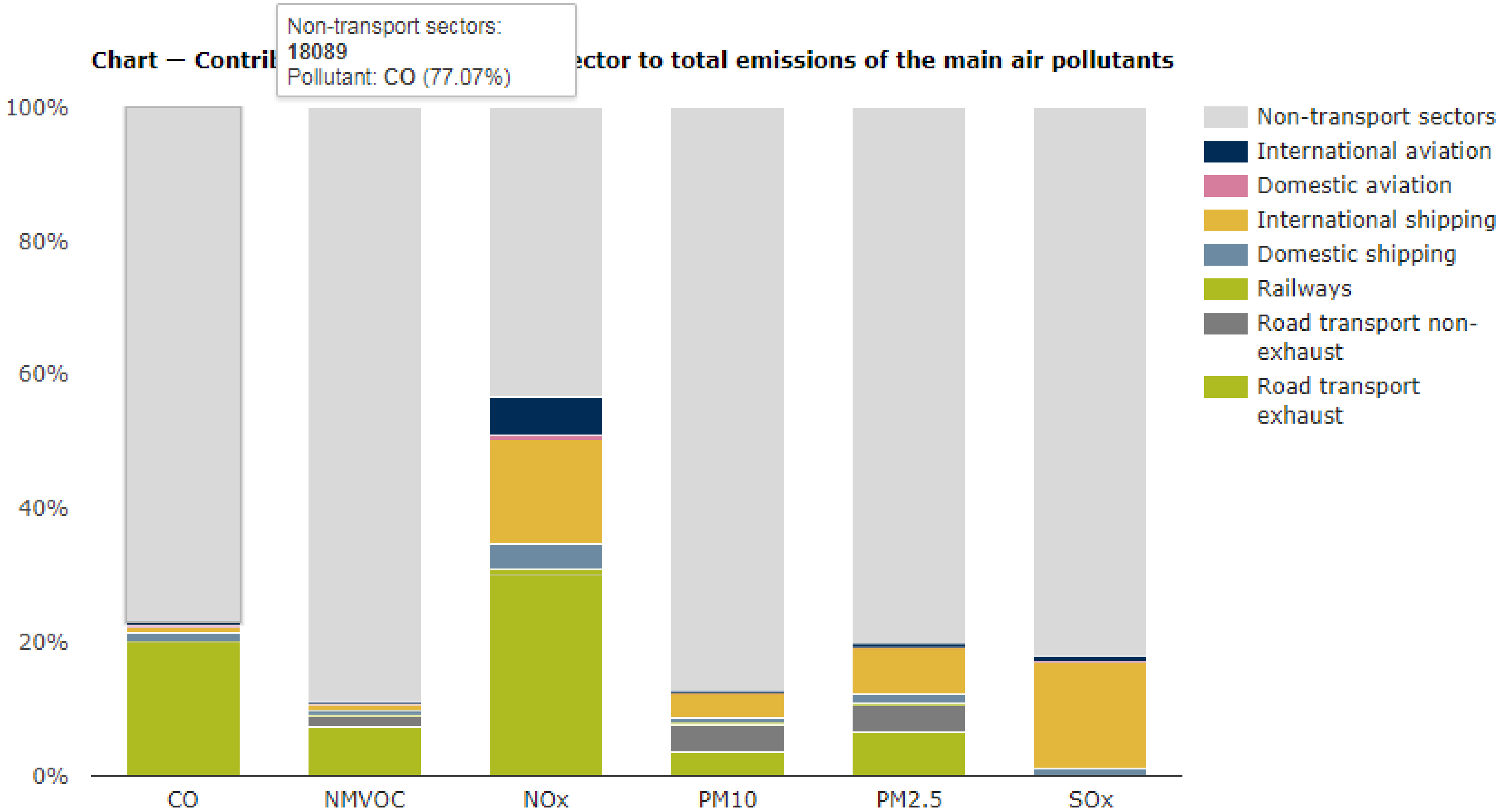


Transport share

IPCC (2014)



Transport share



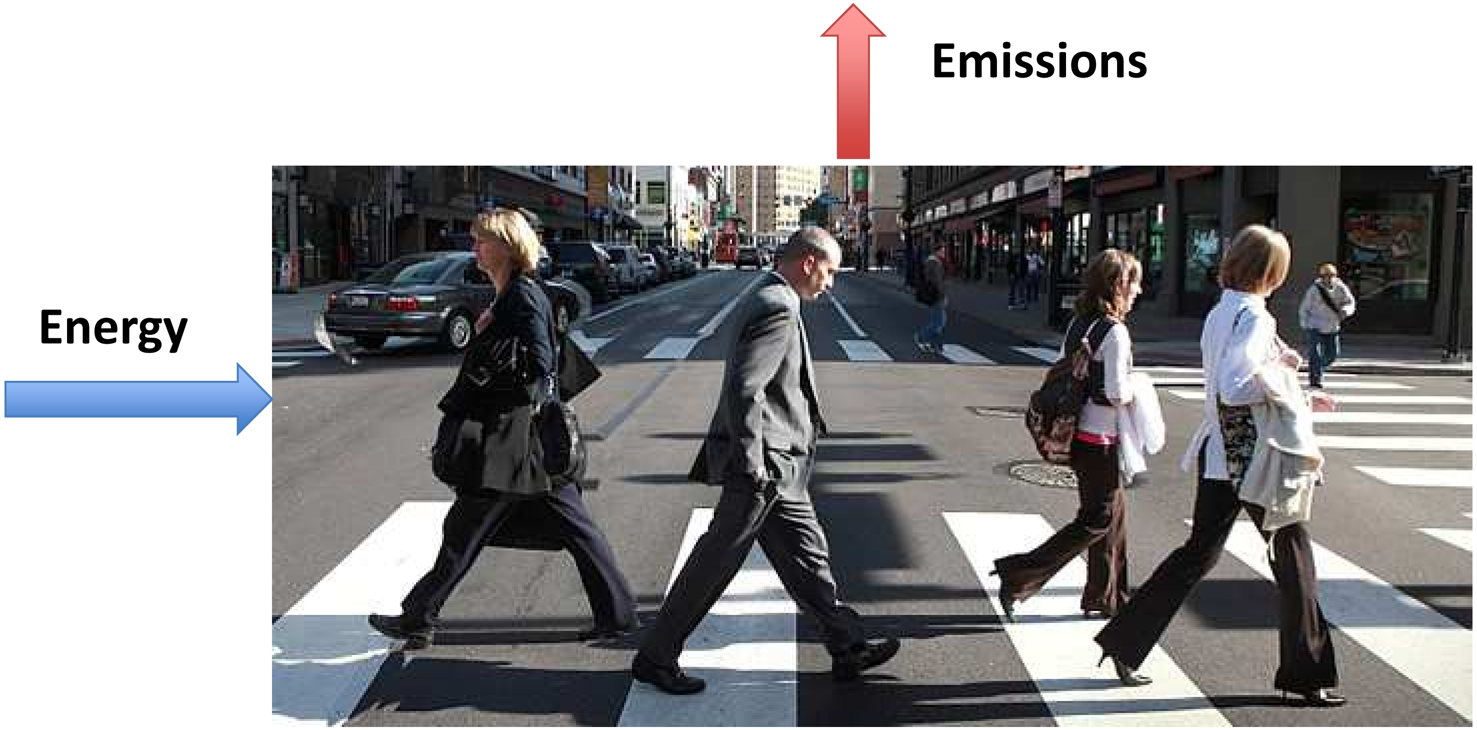
2017

European Environment Agency

Minimum energy and emissions

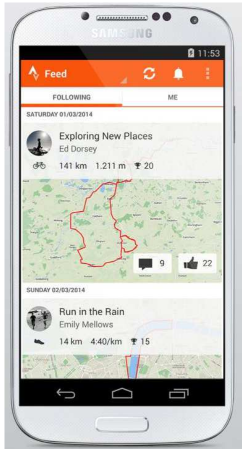
Emissions

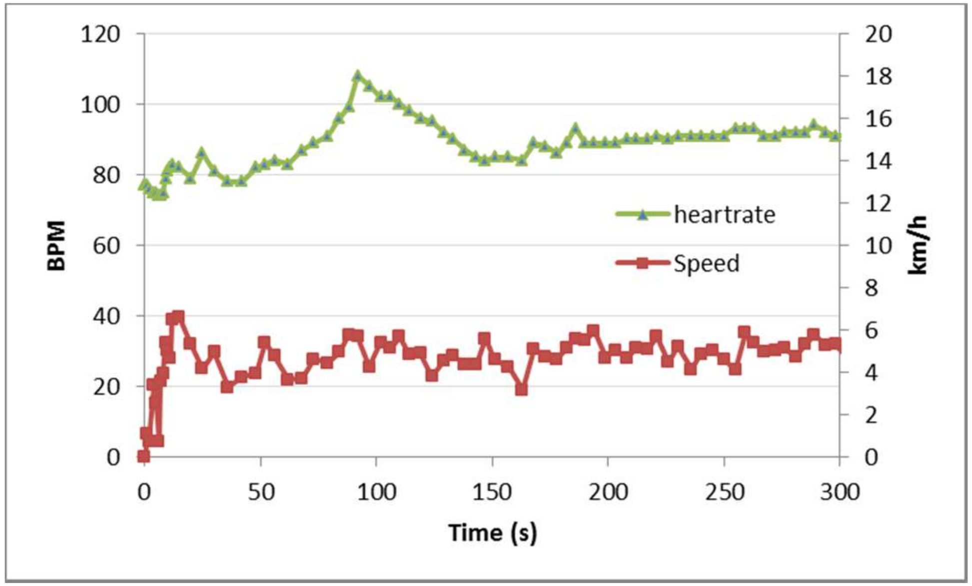
Energy



Measurements by ACTIVITY WATCH w/ GPS

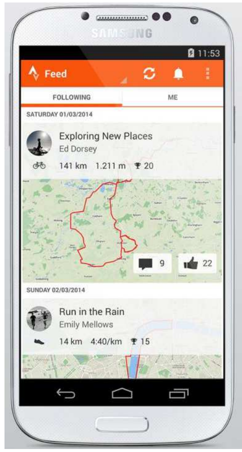
STRAVA™

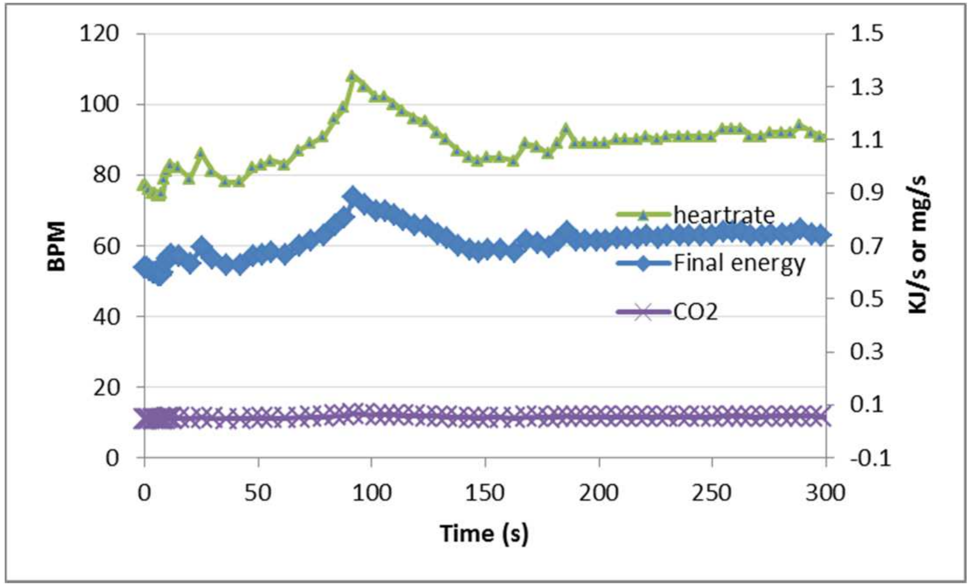




Measurements by ACTIVITY WATCH w/ GPS

STRAVA™





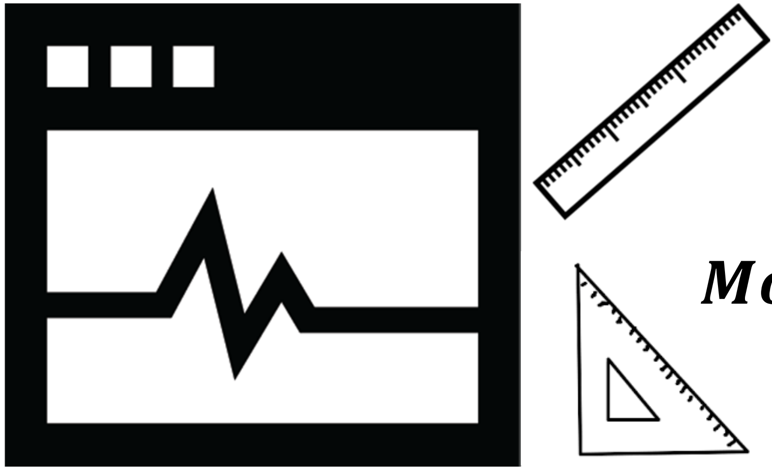
distance 0.8 km
bpm 89 bpm
time 644.64 seconds
Speed 4.5 km/h

Correlation #1 $\frac{Walk-Basal}{Distance}$ **0.14286** **0.010**

MJ/pkm g/pkm

Correlation #2 $\frac{Combined}{Distance}$ **0.170023** **0.012**

Measurements of sustainable Mobility



$$\boldsymbol{Mobility} = \text{Passengers x km}$$

$$\boldsymbol{Motorization\ index} = \frac{N^{er} vehicles}{1000\ inhabitants}$$

Potential of transferring car trips to public transport and soft modes
= $\%\ of\ trips\ by\ public\ transport\ and\ soft\ modes$

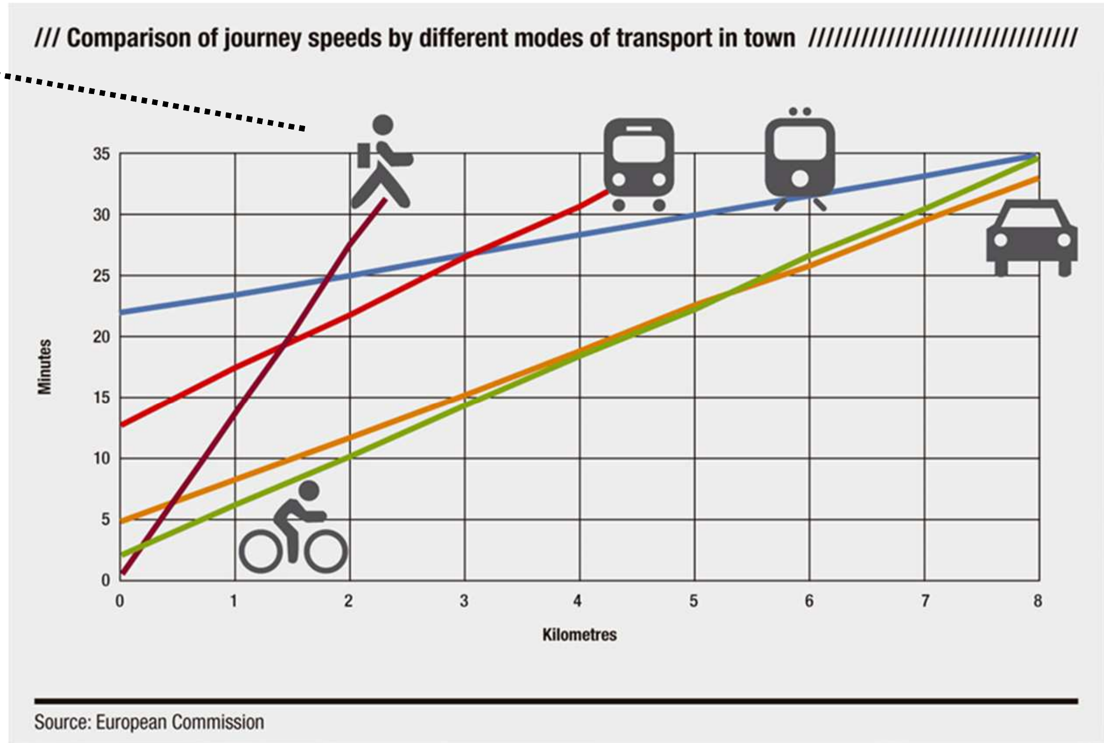
$$\textbf{\textit{Final energy}}\ \boldsymbol{Efficiency} = MJ/pkm$$

$$\boldsymbol{Local\ impact}\ HC, CO, NOx, PM2.5, PM10\ \boldsymbol{emissions} = g/pkm$$

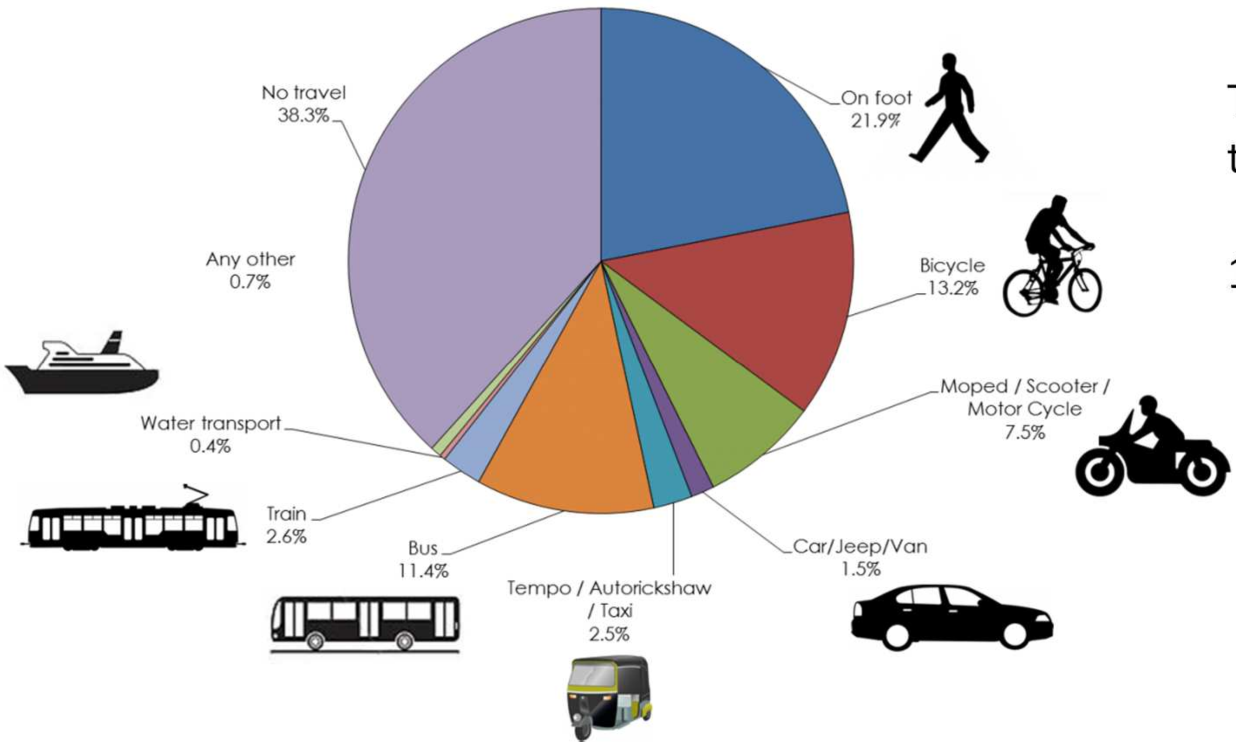
$$\boldsymbol{Global\ impact}\ CO_{2eq}\ \boldsymbol{emissions} = g/pkm$$

Total travel times

~ 4.5 km/h



Knowing how people move???



Travel to work by modes of transport, 2011.

100% = 200.4 million.

Surveys….

Surveys

1st design
2nd test in a few people
3rd did you get the info you needed?

No

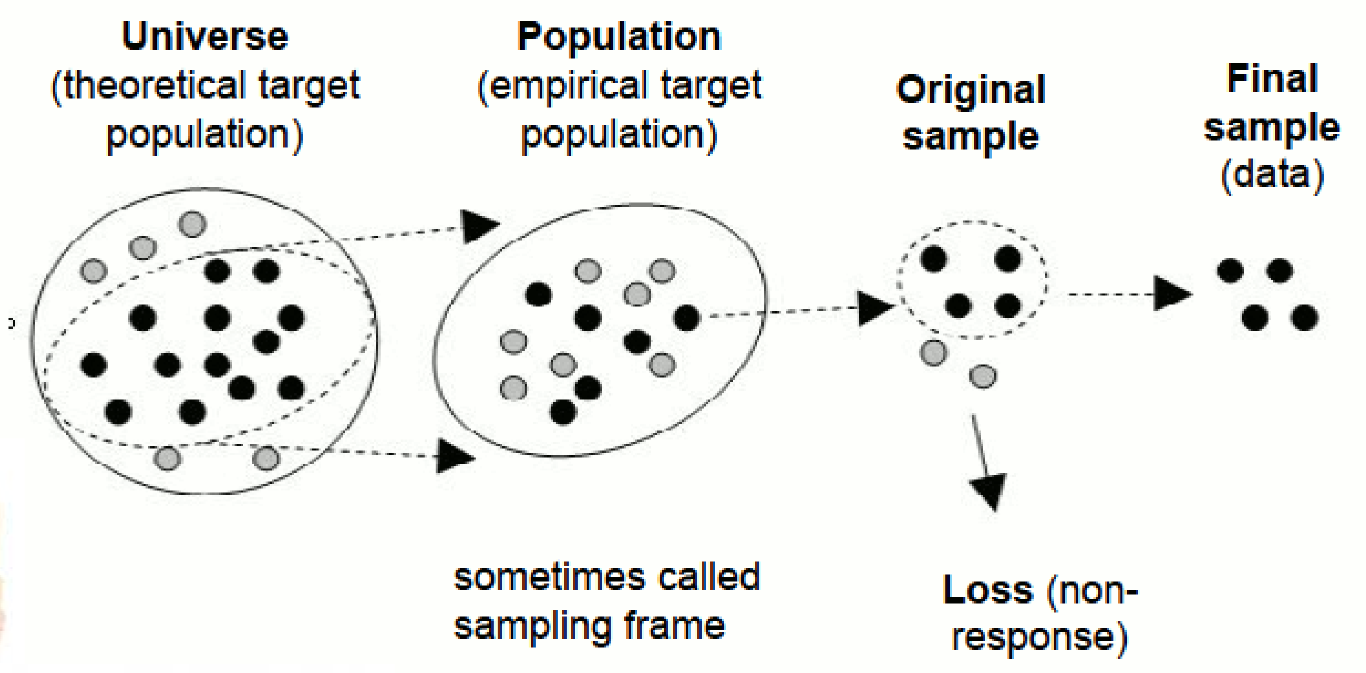
Yes!
Ready to go…

On-line

In person

Surveys

How people travel?



Surveys

How people travel? Origin –Destination

How many respondents?

$$Sample\ Size = \frac{\frac{z^2 \times p(1-p)}{e^2}}{1+\left(\frac{z^2 \times p(1-p)}{e^2 N}\right)}$$

N= total population (small size)
Z = confidence level (90%, 99%, 95%)
e = margin of error (e.g. 5% input 0.05)
p= 50% (estimative of answer, 0.5)

N > 100.000 individuals $\Rightarrow$ Sample size $\boxed{\frac{z^2 \times p(1-p)}{e^2}}$

Recent mobility survey 2017 Porto and Lisbon

Impact of people travel?

$$\Sigma_i(\text{Number trip}_i \text{ X km per trip}_i \text{ X } EC_i)$$

$_i$ mode of transport

EC_i final energy consumption by mode (MJ/pkm)

Energy and emissions

Home ⟷ **Work/ University**

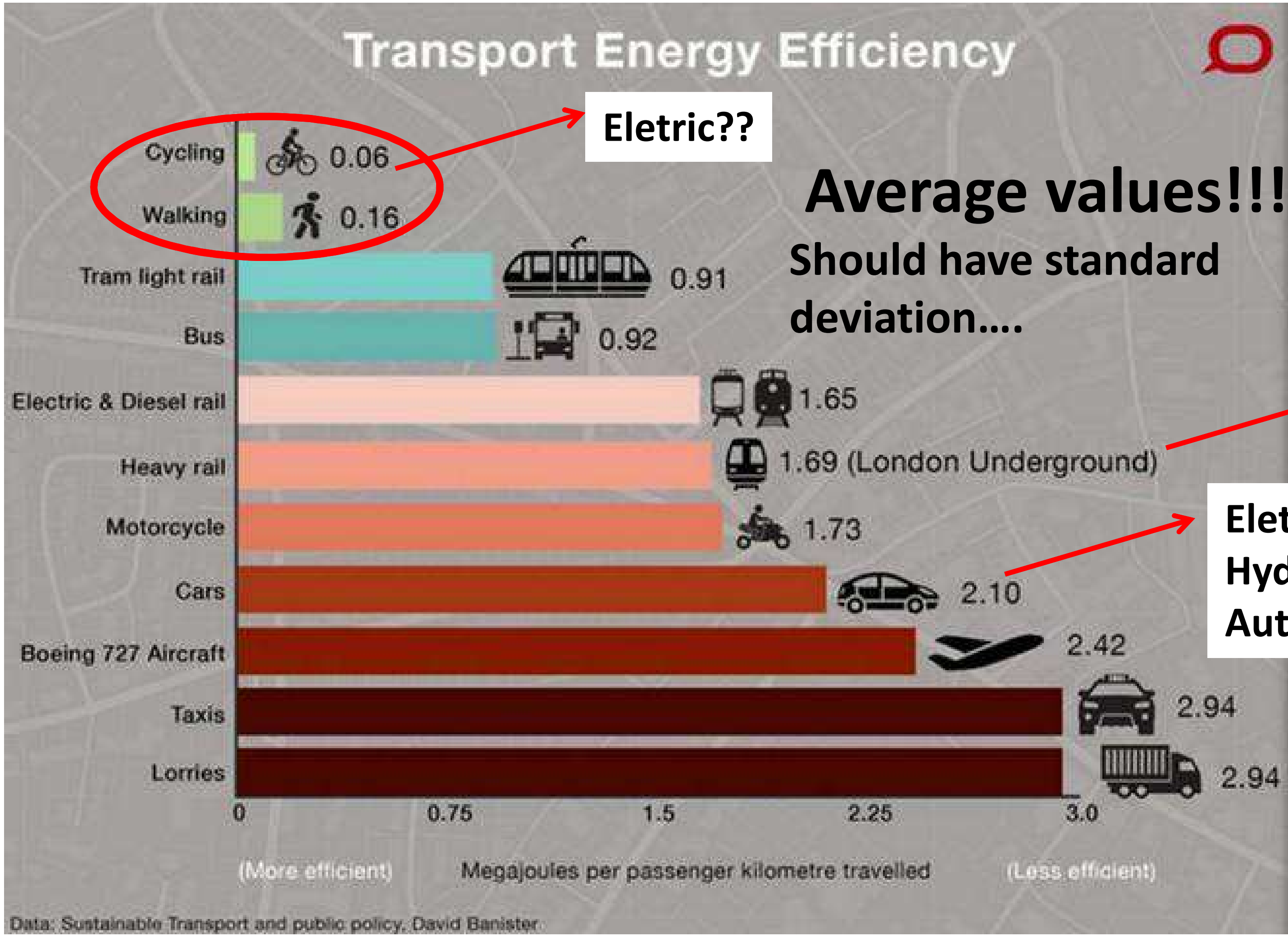
on a regular basis

Commuting by motorized or soft modes

Emissions

Energy

Final energy factors



Eletric??

Average values!!!!!

Should have standard deviation....

Eletric??
Hydrogen??
Autonomous??

Bike

emel

SIEMENS Ingenuity for life

ORBITA EST. 1971

Battery 1,12 kWh

Eletric motor 3 kW

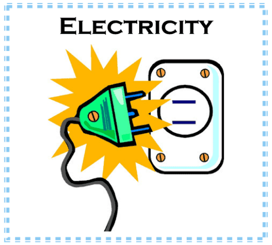
Top speed 24 km/h

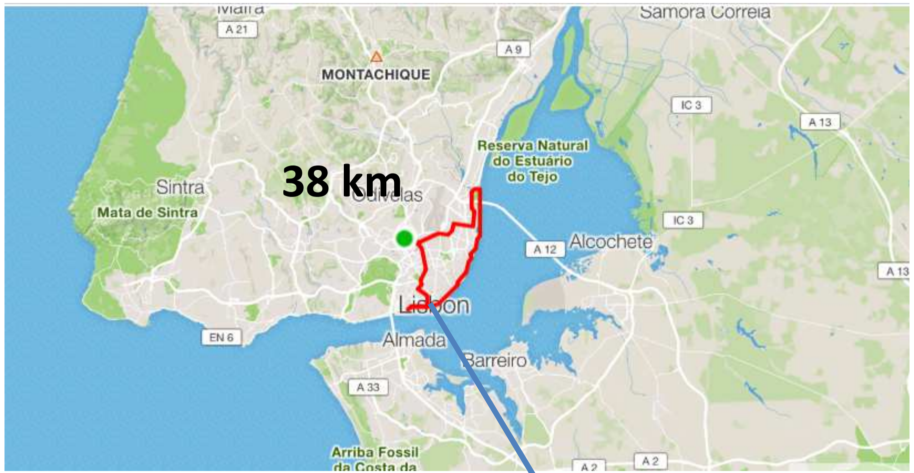
Final energy

MJ/pkm???

E-Bike Example

Real use Final energy MJ/pkm???biogenic vs eletric

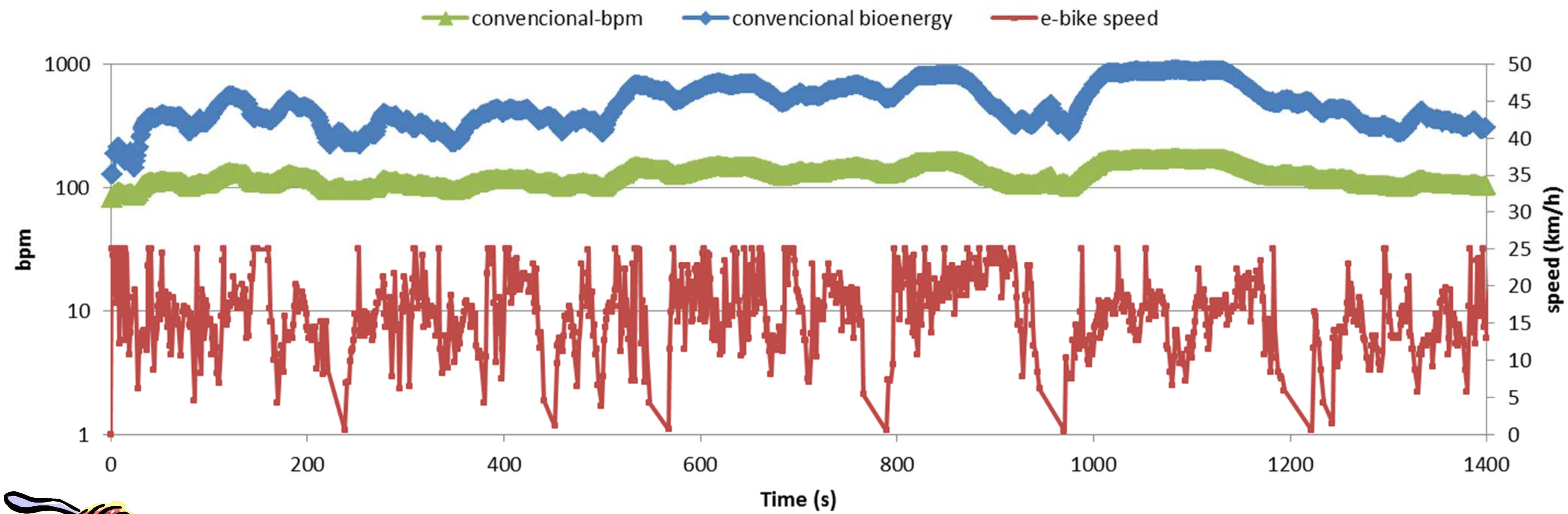




E-bike swap

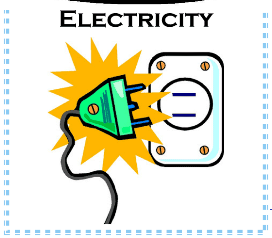
E-Bike Example

Representation first 5 km



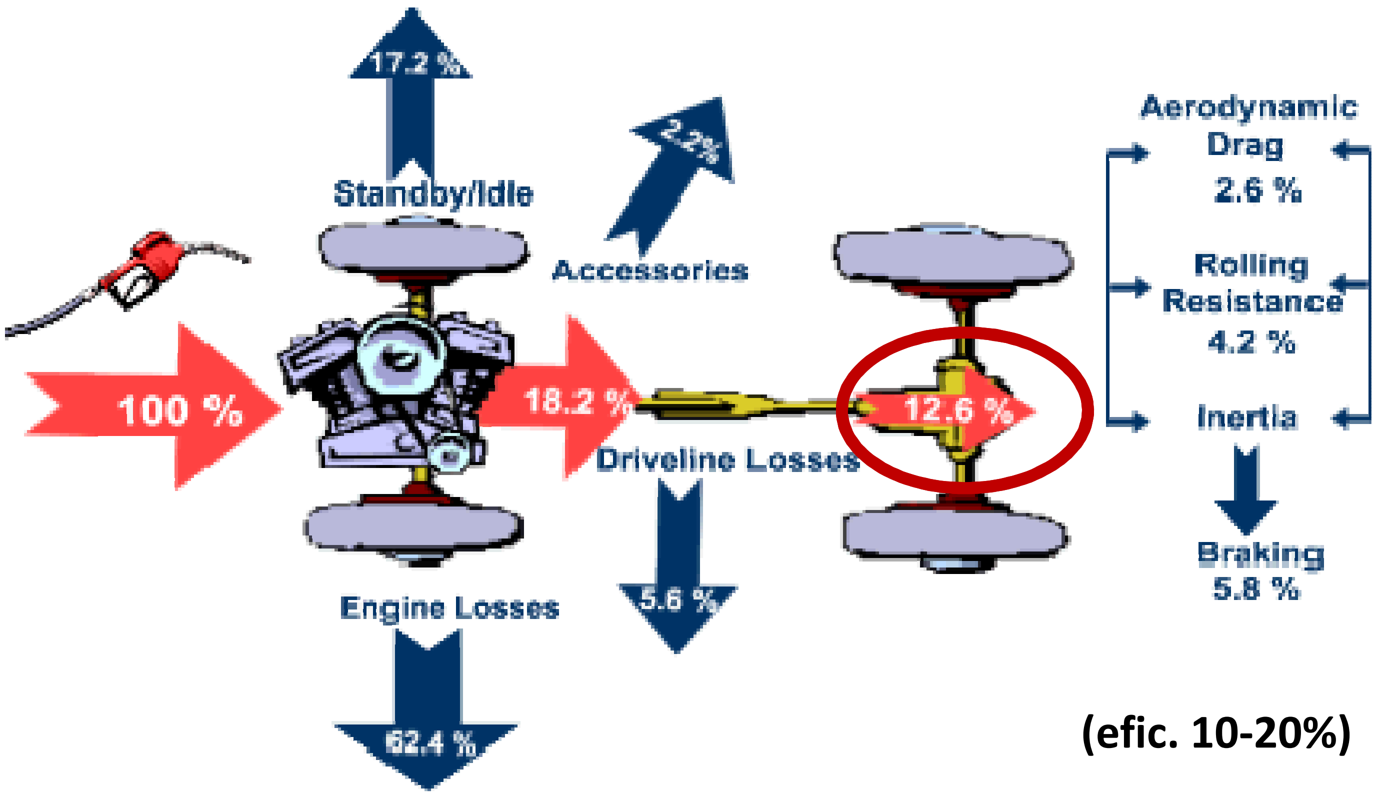
~ 0.14 MJ/pkm

Overall 500 m elevation gain……



Real range: 30 km spent 1.12 kWh → 1.12/30 * 3.6 = **0.13 MJ/pkm final energy electricity**

Final to useful energy
e.g. Conventional Internal Combustion Engine Car

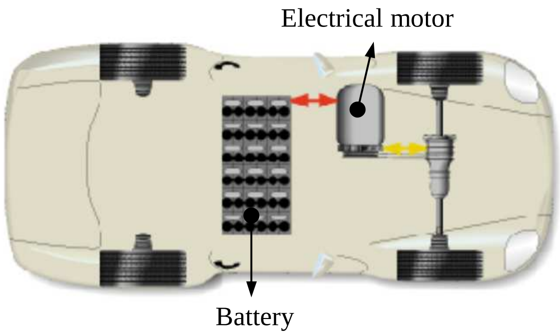


(efic. 10-20%)

Vehicle technologies

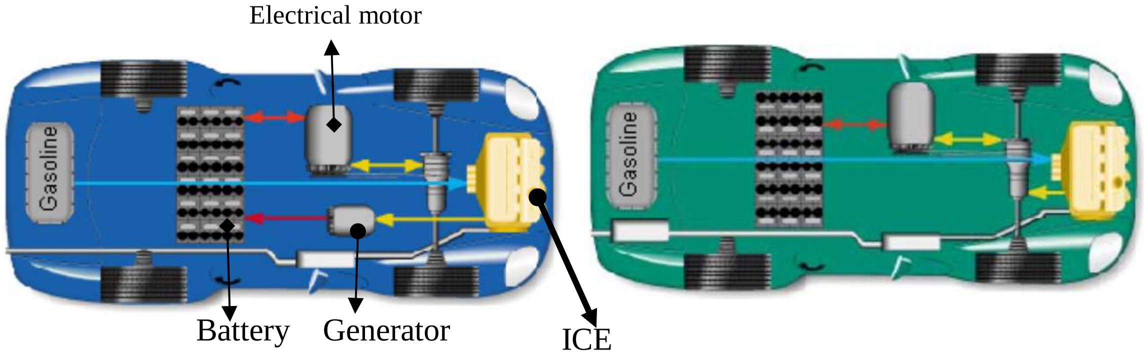
Plug-In

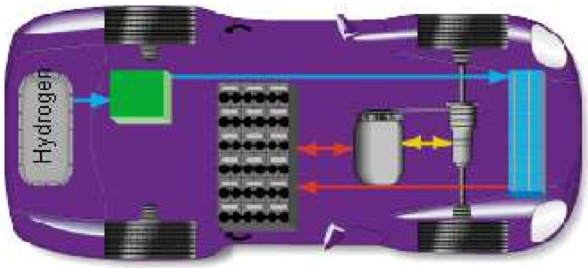
Final to useful energy….



Pure electric (efic. 60-70%)

Hybrids (efic. 20-30%)





Fuel cell (efic. 30-40%)

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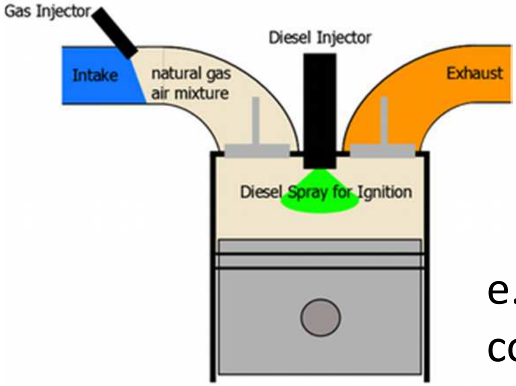
Transport….. energy

1 tank different fuels-1 engine with a mixture or 1

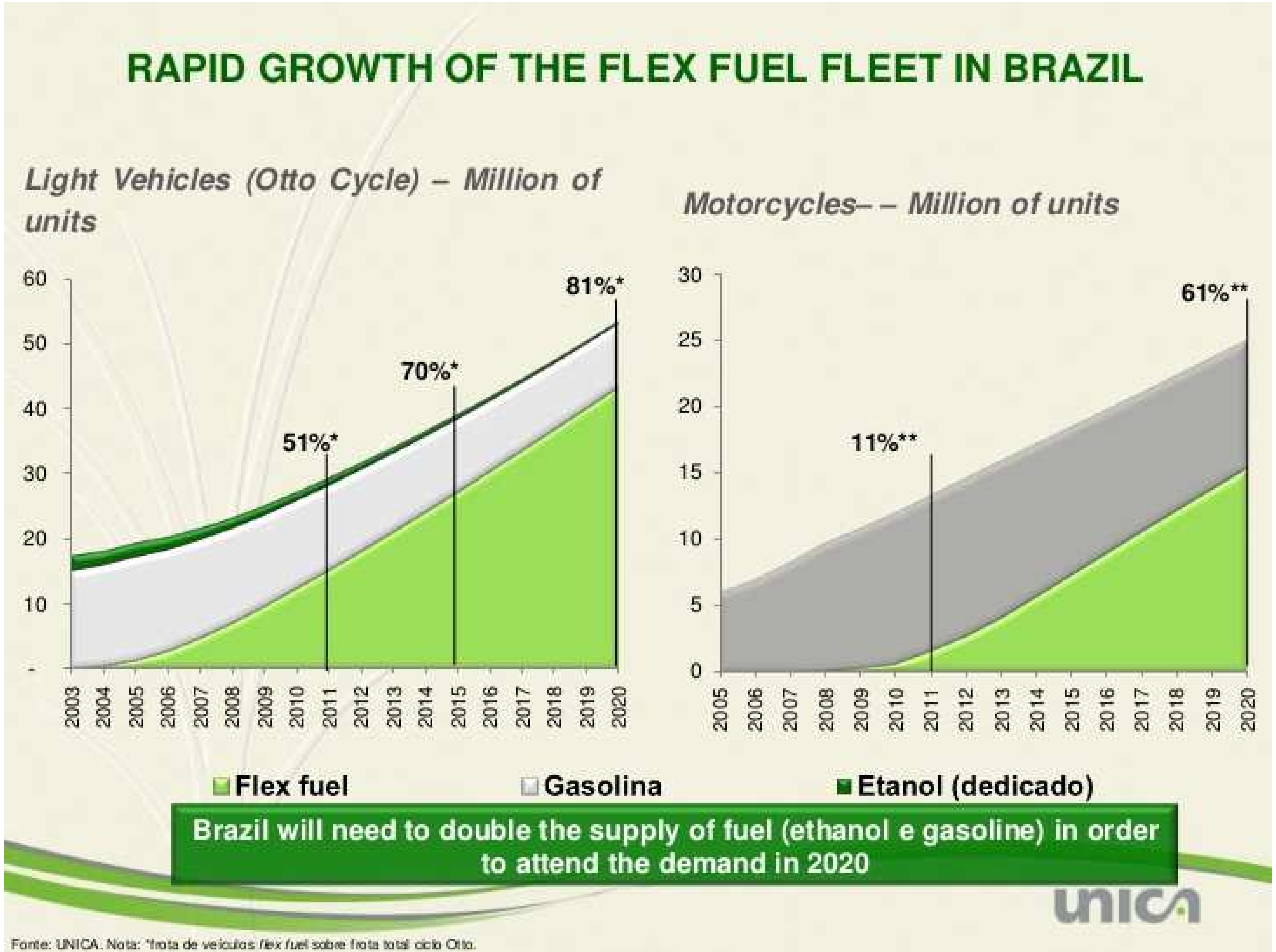
- **Flex-fuel**
- **Bi-fuel**
- **Dual-fuel**

2 tanks different fuels-1 engine operating with 1

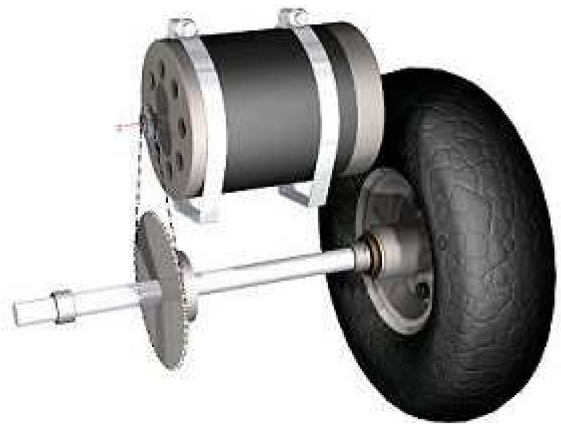
2 tanks different fuels-1 engine operating with a mixture usually for start-up



e.g. natural gas-diesel combustion


RAPID GROWTH OF THE FLEX FUEL FLEET IN BRAZIL
Light Vehicles (Otto Cycle) – Million of units
Motorcycles– – Million of units
81%*
70%*
51%*
61%**
11%**
Flex fuel
Gasolina
Etanol (dedicado)
Brazil will need to double the supply of fuel (ethanol e gasoline) in order to attend the demand in 2020
unica
Fonte: UNICA. Nota: *frota de veículos flex fuel sobre frota total ciclo Otto.

Electricity in road transport



Plug-in…. or not

- **hybrid electric vehicles (HEV),**
- **battery electric vehicles (BEV), and**
- **fuel cell electric vehicles (FCEV)**

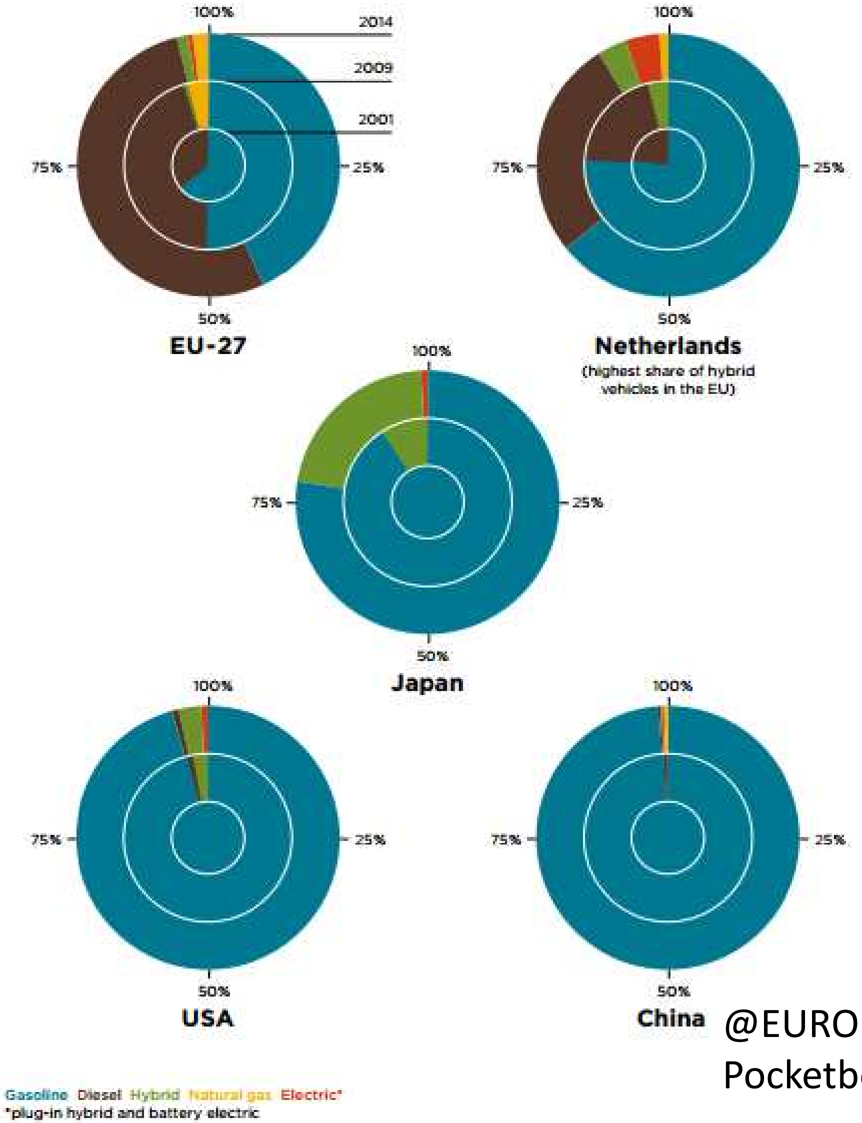
Electricity in road transport

Motor-wheel

- **hybrid electric vehicles (HEV)**

2 sources:
Food and electricity to propel

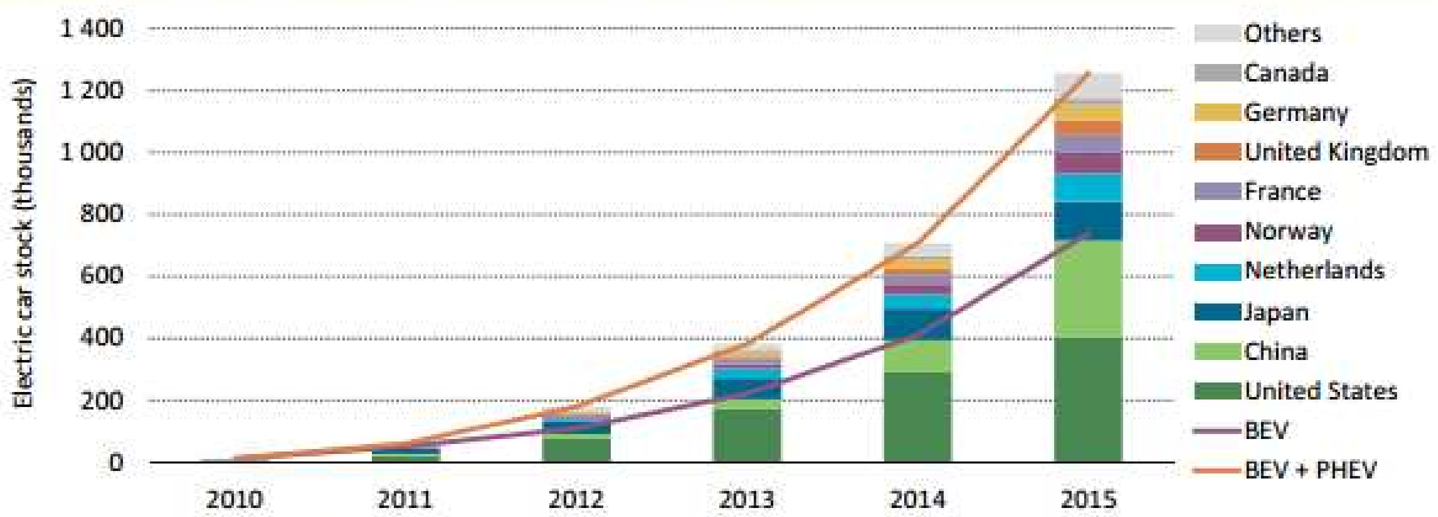
Evolution….. energy



@EUROPEAN VEHICLE MARKET STATISTICS Pocketbook 2015/16

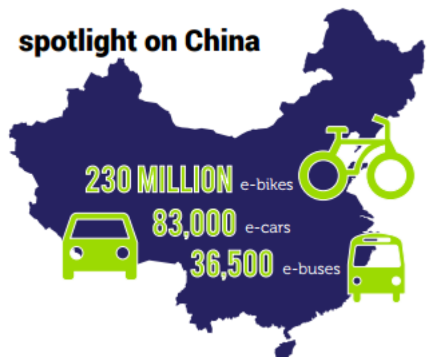
Evolution….. energy

Figure 1 • Evolution of the global electric car stock, 2010-15



Note: the EV stock shown here is primarily estimated on the basis of cumulative sales since 2005.

Sources: IEA analysis based on EVI country submissions, complemented by EAFO (2016), IHS Polk (2014), MarkLines (20 (2016a), EEA (2015) and IA-HEV (2015).



@https://www.fuelseurope.eu/uploads/Modules/Resources/fuelseurope-statistical-report-2015.pdf

IEA: Global EV Outlook 2015

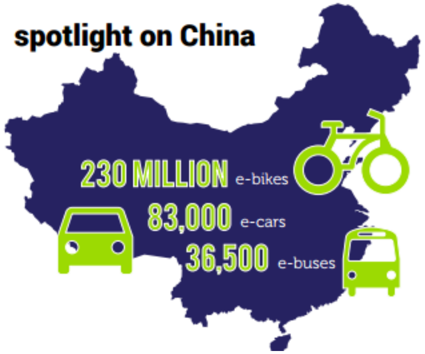
Evolution….. energy

Registered e-vehicles/1000 inhabitants

CHINA 83000/ 1 379 000 = 0.06

US 1.5

GERMANY 0.9



IEA: Global EV Outlook 2015

Vehicle technologies

Most sold vehicle Portugal

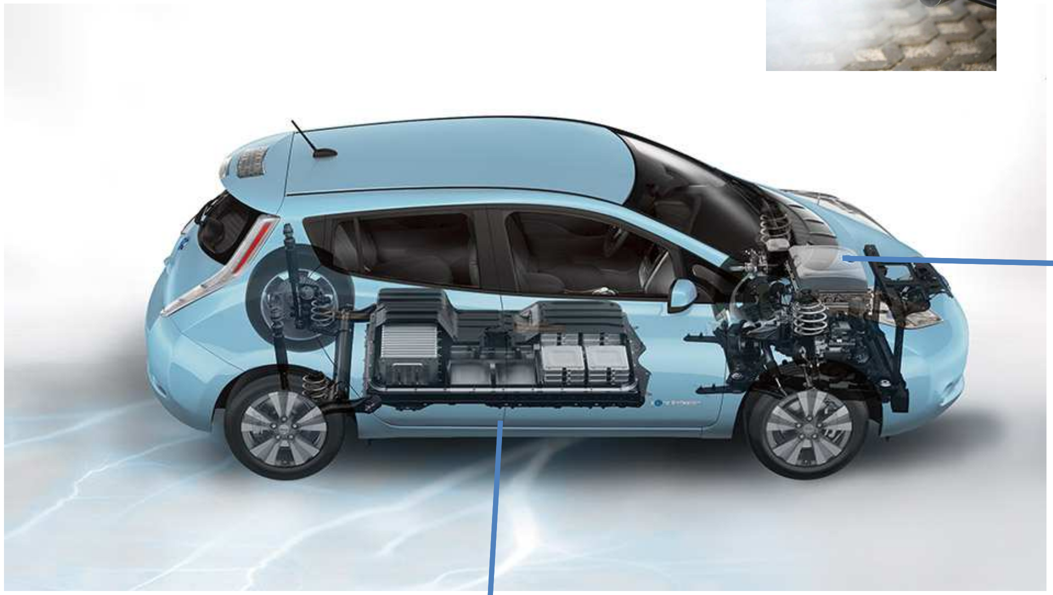
0-100 km/h 14.5 s
European test cycle l/100km 5.6
1059 kg

Internal combustion engine

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

Leaf

No tailpipe emissions



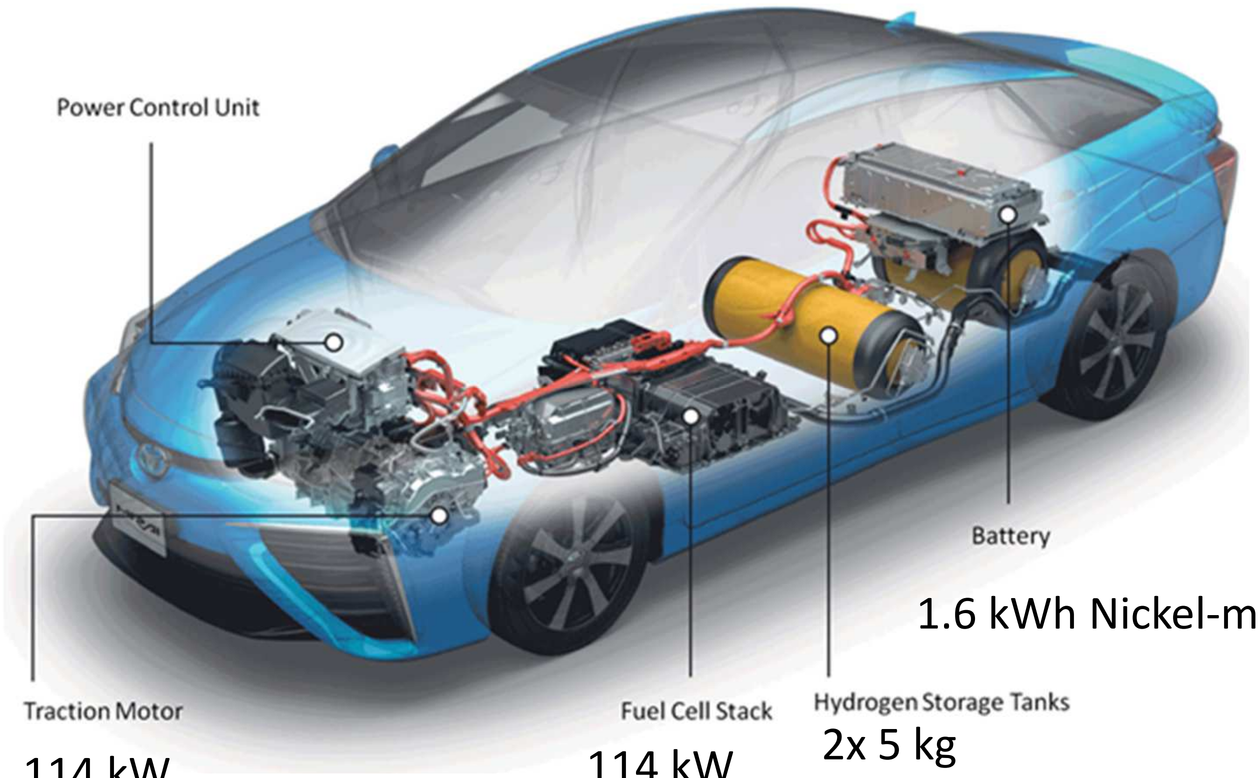
output power increased to over 110 kW (110 kW is peak power of electric motor – previously it was 80 kW)

- 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

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

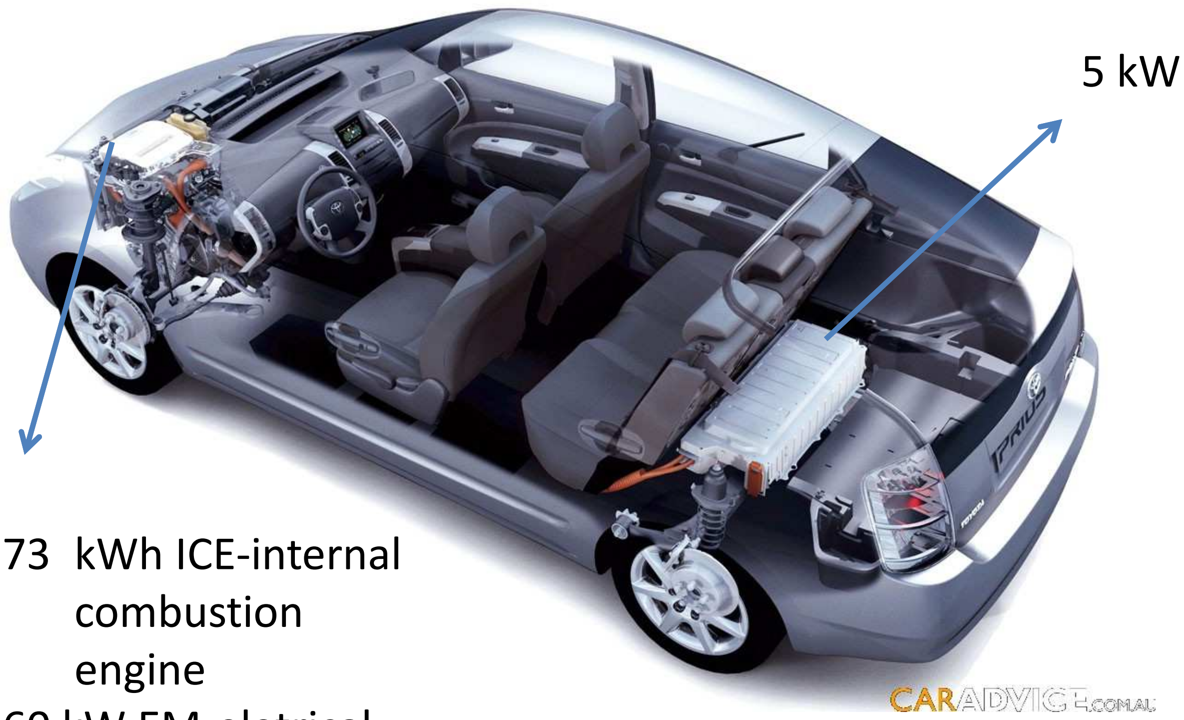
114 kW

2x 5 kg
700 bar

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

Vehicle technologies

Prius



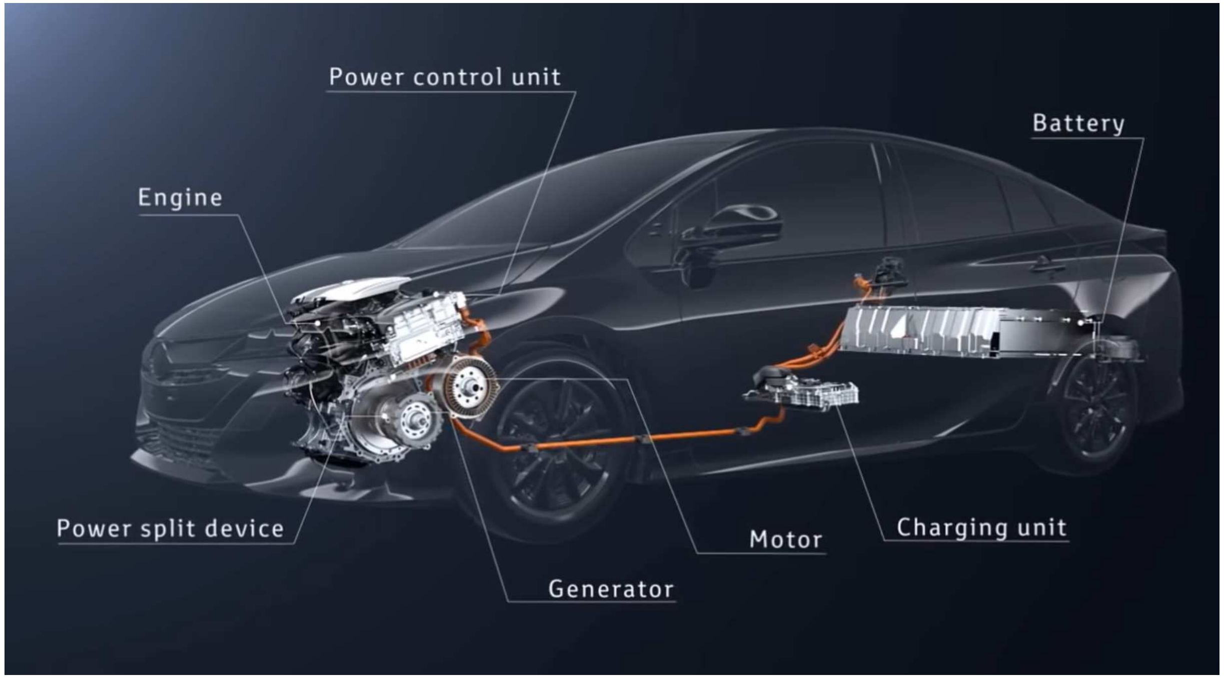
5 kWh Ni-MH

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

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

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 technologies

Flex fuel   Sweden 1952 bioethanol filling pumps

0-100 km/h:12,0 s
city consumption: 13,6 l/100km
82 kW
1282 kg

85%ethanol
15%gasoline by volume

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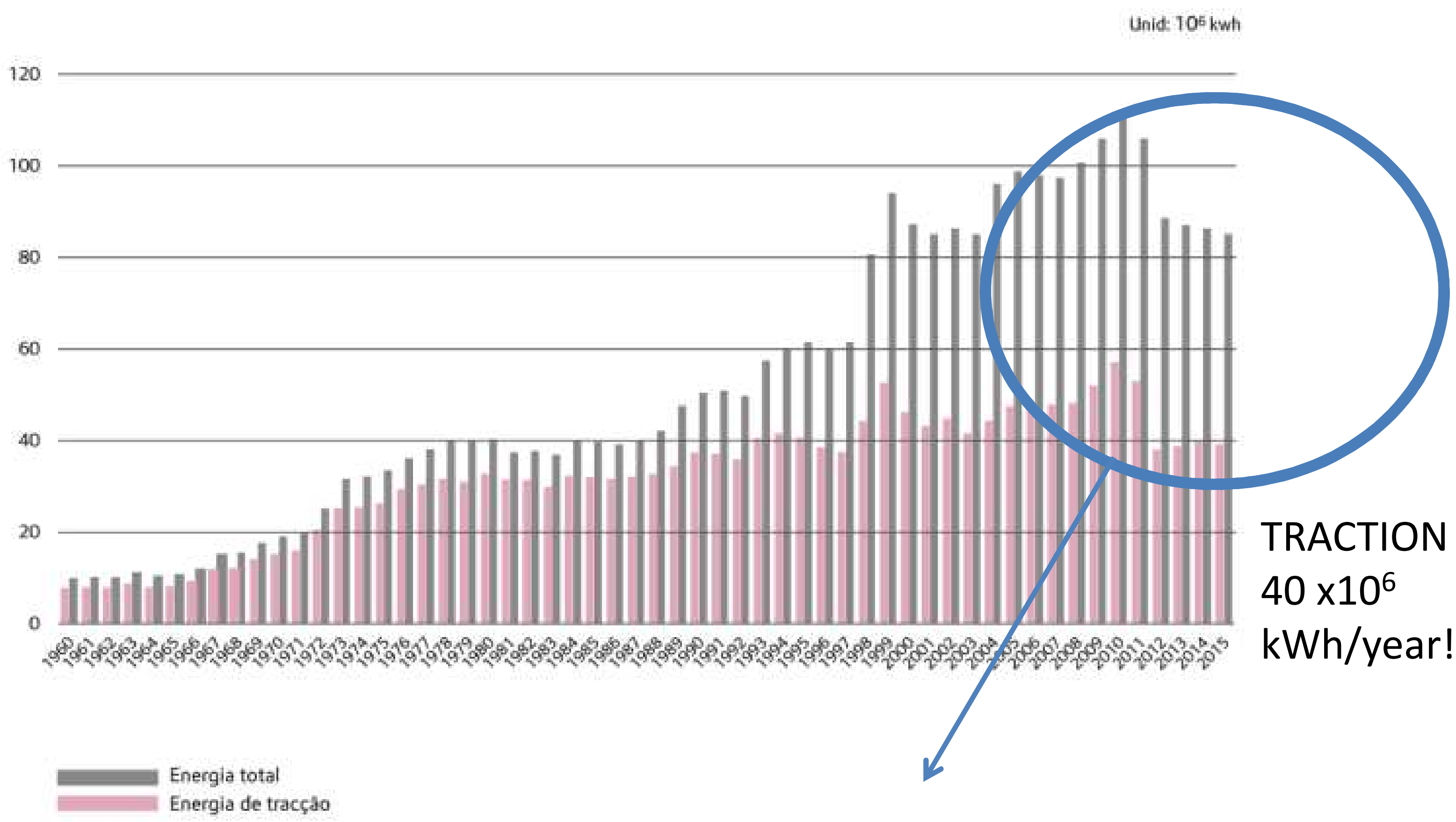
Vehicle technologies

L/100km x MJ/L =MJ/pkm
1 person (the driver)

Fuel	MJ/L	Research octane number
Methanol	17.9	108.7
Ethanol	21.2	108.6
E85 (85% ethanol+ 15% gasoline)	25.2	105
Gasohol (90% gasoline + 10% ethanol)	33.7	93/94
Regular gasoline/petrol	34.8	min. 91
Premium gasoline/petrol		max. 104
Diesel	38.6	25

Energy consumption....MJ/pkm

Energy consumption….MJ/pkm



TRACTION
40 x10^6
kWh/year!

The lighting system dominates the energy consumption (37%); Illuminated advertising signs (14%) and ventilation (14%) are also major consumers @A breakdown of energy consumption in an underground station

Energy consumption….MJ/pkm

Lisbon underground

Indicadores chave

Indicadores		2009	2010	2011	2012	2013	Var. % 2013/ 2012
Procura							
Passageiros com título pago	10^3	165 191	170 858	164 845	141 382	125 153	-11,48
Passageiros transportados	10^3	176 726	182 642	178 774	154 005	135 712	-11,88
Passageiros x km	10^3	829 068	865 521	857 101	745 589	655 705	-12,06
Oferta							
Carruagens x km	10^3	25 274	27 649	26 467	21 339	21 498	0,75
Lugares x km	10^6	4 271	3 511	3 361	2 730	2 752	0,81

40 000 MWh/655705 pkm = 16.9 MJ/pkm!!!!!!!!!

NEED MORE PASSENGERS!!!

1 kWh is 3.6 MJ

Vehicle technologies

train

https://www.cp.pt/StaticFiles/Institucional/2_gestao_sustentavel/1_RelatoriosSustentabilidade/relatorio2014.pdf

Relativamente ao consumo total de energia por passageiro-quilómetro, os valores mantiveram-se estáveis:

Energia	Unidade	2012	2013	2014
Total de Energia Consumida	Gj	991.569,8	1.031.901,9	1.041.014,1
Consumo de Energia / Pk	Gj	0,00029	0,00031	0,00030

0.3 MJ/pkm

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Vehicle technologies

Bus

http://www.carris.pt/pt/relatorios-de-sustentabilidade/

Intensidade energética		
Instalações	2,72 gep/PK	2,82 gep/PK
Atividade de Transporte		
Autocarros	35,02 gep/PK	36,08 gep/PK
Modo elétrico	36,23 gep/PK	35,91 gep/PK
Total	**35,10 gep/PK**	**36,07 gep/PK**
Global CARRIS	**37,82 gep/PK**	**38,89 gep/PK**

Gep = grams equivalent oil = 0.042 MJ

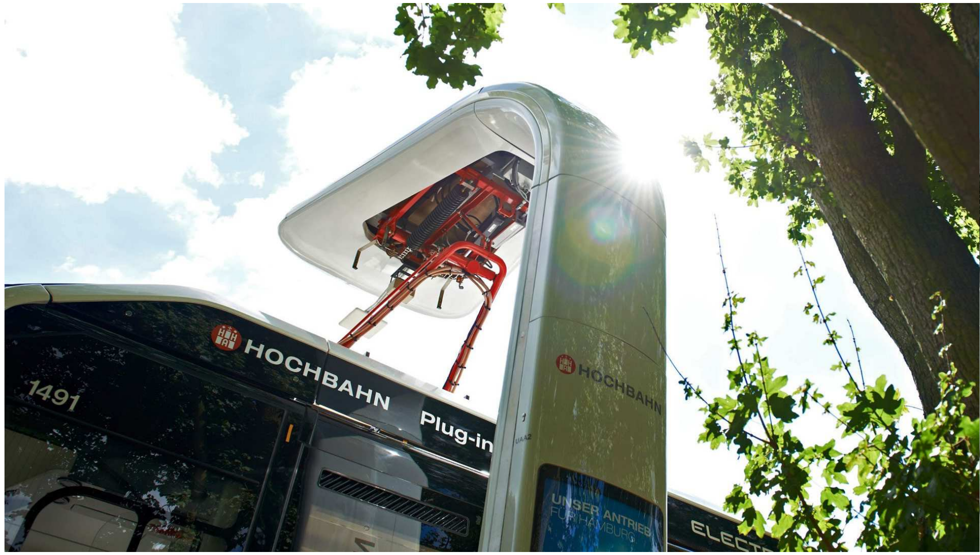
38gep/pkm =38*0.042= **1.6 MJ/pkm**

Vehicle technologies

Hydrogen bus

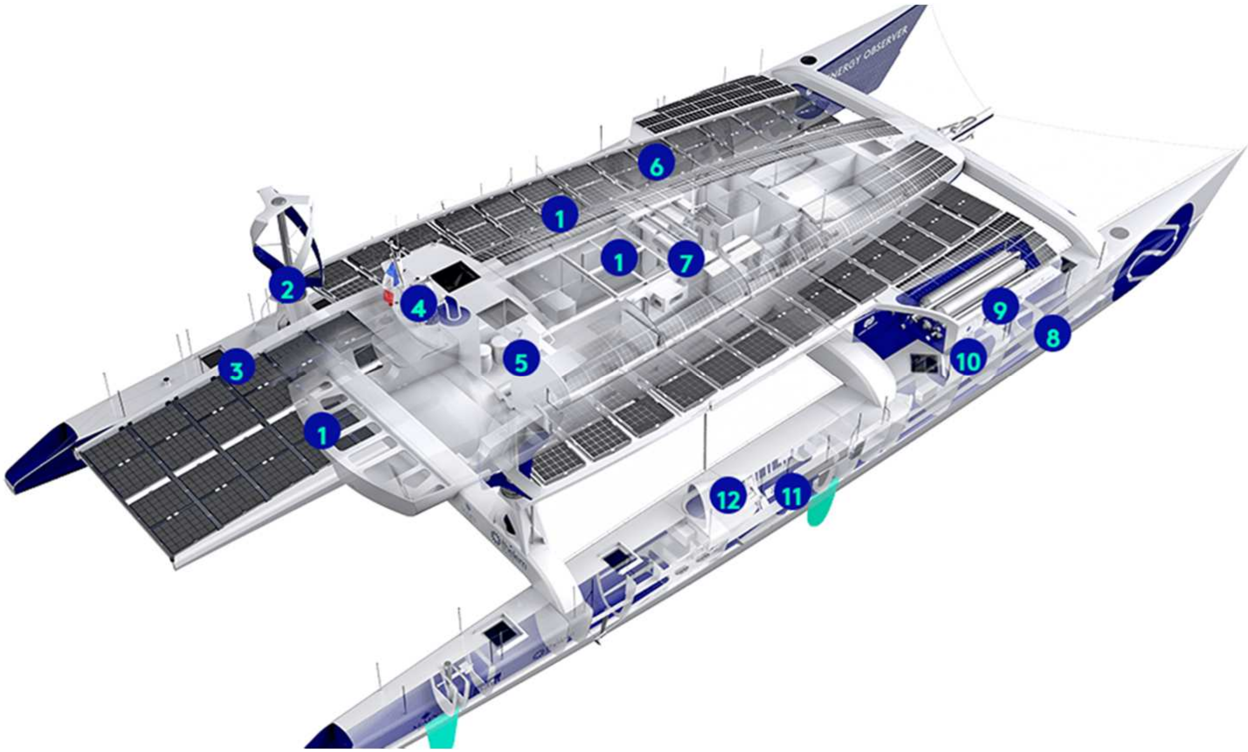
Vehicle technologies

Siemens eletric bus/ e-BRT system



Vehicle technologies

Energy observer



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

Vehicle technologies

Energy observer

1. PHOTOVOLTAIC PANELS
130 m2 of photovoltaic panels combining 3 different technologies: conformable, bifacial, and with a non-slip coating
21KWc

9. HYDROGEN STORAGE
Hydrogen tanks for long-term energy storage
2 x 4 322L tanks, or 62kg of H_2

10. FUEL CELL
To generate electricity from the stored hydrogen which acts as a range extender for the vessel, coupled with an absorption machine for air-conditioning
22 KW

8. ELECTROLYSER
To break down the H_2O molecule into oxygen (O_2) and dihydrogen (H_2). While the oxygen will be released into the atmosphere, the hydrogen will be stored in gaseous form in order to conserve the excess energy
4 Nm3/h at 30 bars

11. 400V POWER BATTERIES
Li-ion batteries for short-term energy storage and power demands' management of 106 Kwh for the motorisation, electrolysis, compression, and 220V and 24V power

Lisbon AML case study

P#2 AML – Metropolitan area of Lisbon. From the AML survey results shown below estimate the final energy consumption on a week and do a pie chart by mode.

First pie reference ; second e-bike e-cars e-bus; all H_2

Assuming a year with 48 weeks (except holidays) what would be the overall mobility related final energy consumption (biogenic and non biogenic)? What scenario would you advise? A more electrified one or a more hydrogen based one?

Surveys

Recent mobility survey 2017 Porto and Lisbon

Impact of people travel?

Quadro 9

Tempo e distância por deslocação, segundo o principal meio de transporte das deslocações

AM Lisboa

km per trip

		Duração média (minutos)	Distância média (km)
	AM Lisboa	**24.3**	**10.3**
car	Automóvel - condutor	21.7	12.7
	Automóvel - passageiro	20.8	13.3
motorbike	Motociclo/ciclomotor	18.0	11.7
bus	Autocarro (transporte público)	45.7	12.1
train	Comboio	53.4	19.1
subway	Metropolitano	39.7	8.5
boat	Barco	58.1	19.5
	Táxi	19.6	6.4
van	Transporte escolar / empresa	32.6	17.2
walk	A pé	17.0	1.5
bike	Bicicleta	36.2	8.8
	Outro/desconhecido	31.7	24.2

Nota: Exclui as deslocações internacionais

Surveys

Recent mobility survey 2017 Porto and Lisbon

Impact of people travel?

Quadro 6

Voltar ao Índice

Deslocações por tipo de dia e meio de transporte principal da deslocação

AM Lisboa

Unidade:10^3

		Deslocações		
		Total semanal	Dias úteis	SDF a)
	AM Lisboa	**37,697.1**	**27,439.7**	**10,257.4**
	Transporte individual	**22,542.4**	**15,715.5**	**6,826.9**
car	Automóvel - condutor	17,326.3	12,334.4	4,992.0
	Automóvel - passageiro	4,884.7	3,110.2	1,774.5
motorbike	Motociclo/ciclomotor	331.3	270.9	60.4
	Transporte público ou coletivo	**5,939.5**	**5,056.6**	**882.9**
	Dos quais:			
bus	Autocarro	2,945.9	2,476.0	469.9
train	Comboio	1,215.7	1,032.0	183.7
subway	Metropolitano	1,167.8	1,014.6	153.2
Walk and bike	**Modos suaves** (a pé e bicicleta)	**8,857.7**	**6,404.3**	**2,453.4**
	Outro/desconhecido	**357.4**	**263.4**	**94.1**

a) SDF - Sábados, domingos e Feriados

Number trips
Per mode

Fleet impacts

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

You learned….

- Technology portfolio for bike, car, bus and boat;
- Final to useful energy efficiency;
- Final energy consumption factors, first approach.

Obrigado

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