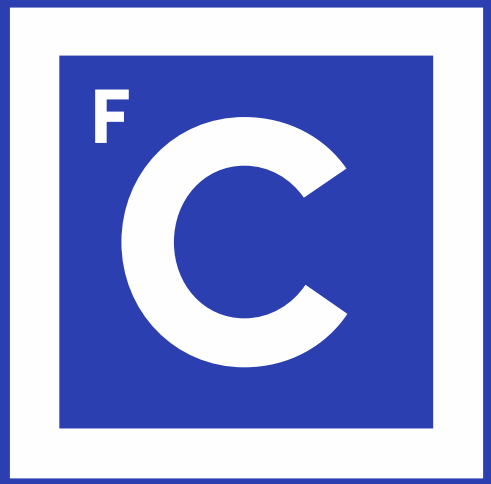


Ciências ULisboa

Faculdade
de Ciências
da Universidade
de Lisboa

DISCIPLINA MIEA 2017

Sustainable Mobility

Minimum energy and emissions

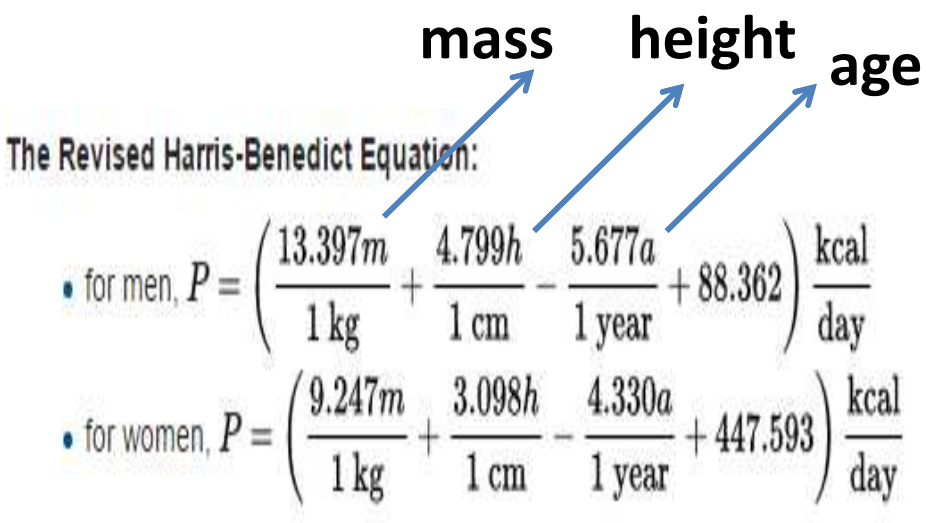
Home ⟺ Work

Home ⟺ University

on a regular basis

Commuting by motorized or soft modes

Minimum energy and emissions



Basal energy

Harris JA, Benedict FG (1918). "A Biometric Study of Human Basal Metabolism". Proceedings of the National Academy of Sciences of the United States of America. 4 (12): 370–3.

A Biometric Study of Basal Metabolism in Man. J. Arthur Harris and Francis G. Benedict. Washington, DC: Carnegie Institution, 1919.

Minimum energy and emissions

((-55.0969 + (0.6309 x **HR**) + (0.1988 x **W**) + (0.2017 x **A**))/4.184) x 60 x **T**

Activity energy **kcal**

((-20.4022 + (0.4472 x **HR**) - (0.1263 x **W**) + (0.074 x **A**))/4.184) x 60 x **T**

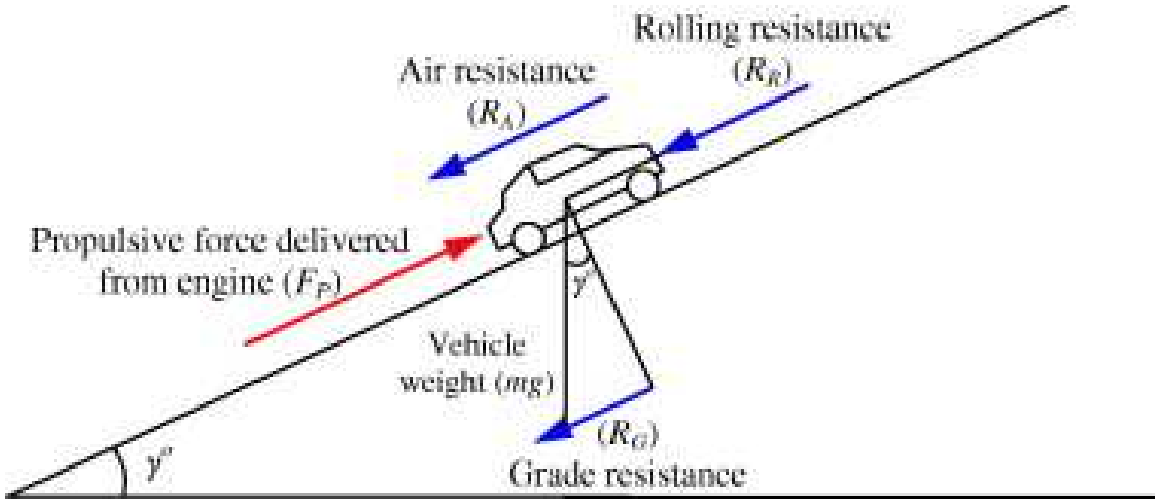
HR = Heart rate (in beats/minute)

W = Weight (in kilograms)

A = Age (in years)

T = Exercise duration time (in hours)

Motor vehicle dynamics



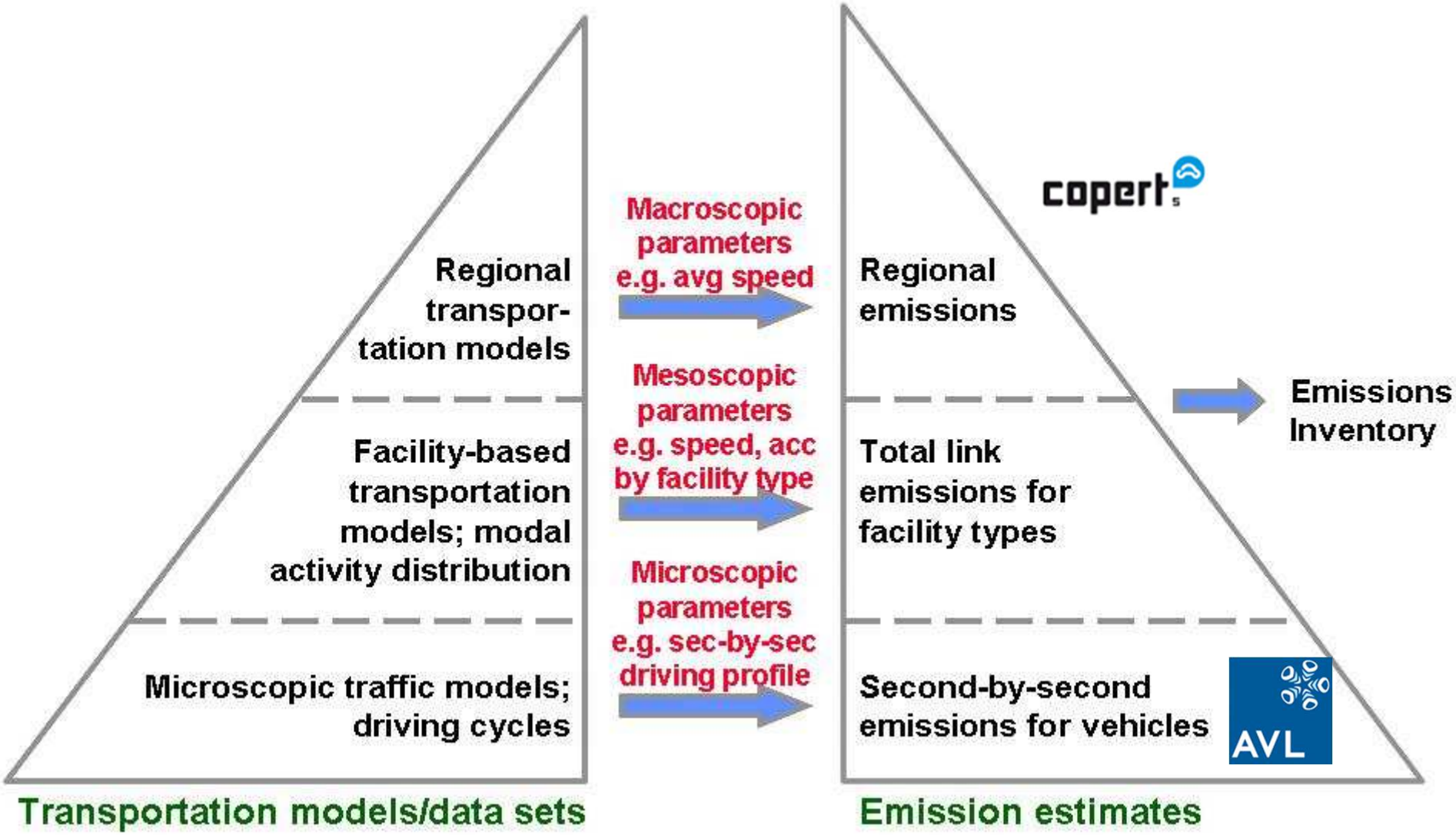
Roling $$Rr = k_r(m+m_p)g \bullet \cos\gamma$$

Road gradient $$Fw = (m+m_p)g \bullet sin\gamma$$

Aerodynamics $$Ra = 1/2 \bullet \rho C_d A_f v^2$$

Propultion $$Fp = (k_m \bullet m + m_p) \bullet dv/dt$$

Fleet impacts



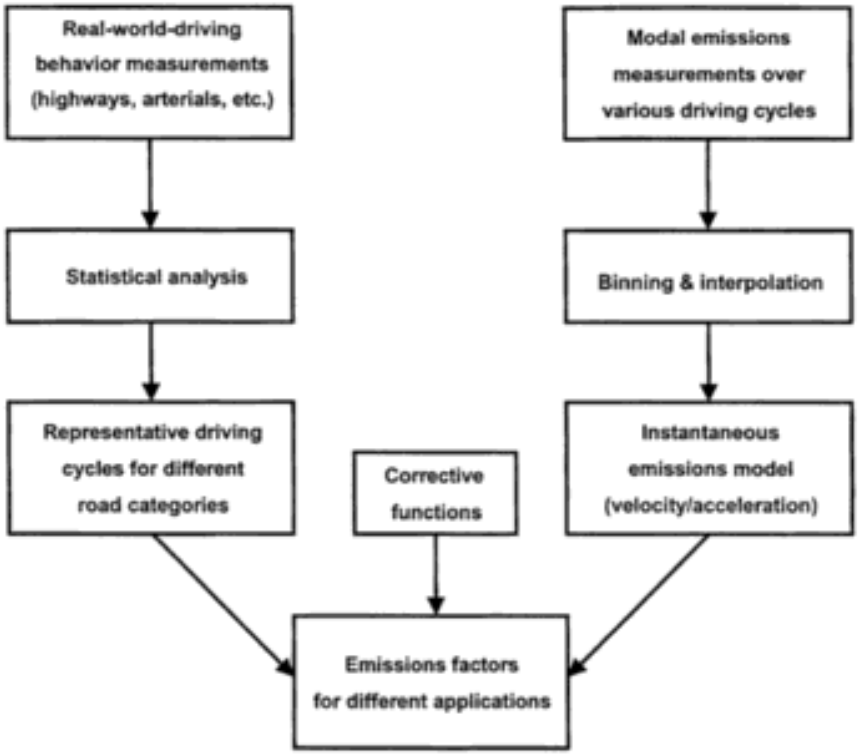


FIGURE 5-2 Database development for the Handbook of Emissions Factors. Source FRG-FEPA 1993.

Energy and Emission factors

MJ/pkm and g/pkm

Fleet impacts

Vehicle activity x Occupation x Factor x days/year

km

e.g. 1.5 people/car

e.g. 256 days/year

Energy and Emission factors

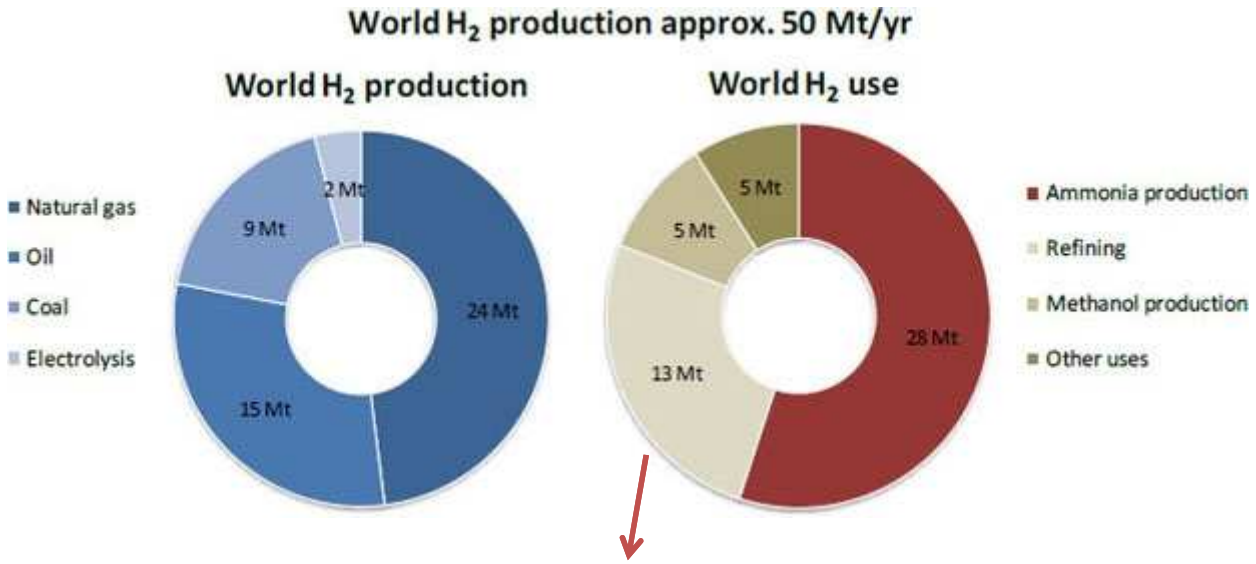
MJ/pkm and g/pkm

Fleet impacts

EXAMPLE:

HOW TO EVALUATE HYDROGEN IMPACT ON ROAD TRANSPORTATION?????

Hydrogen in today's transportation



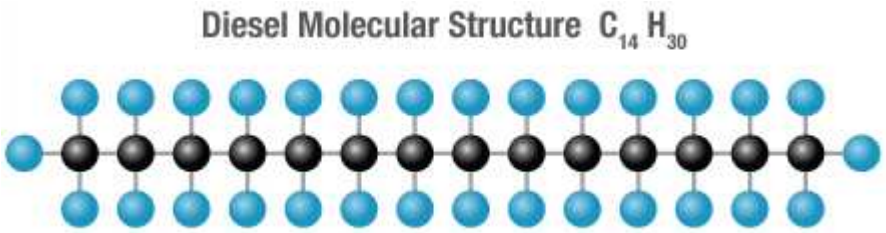
Desulfurization of transportation fuels

39 Mtoe to 1831 Mtoe of diesel & gasoline in transportation 2%.... (2012)

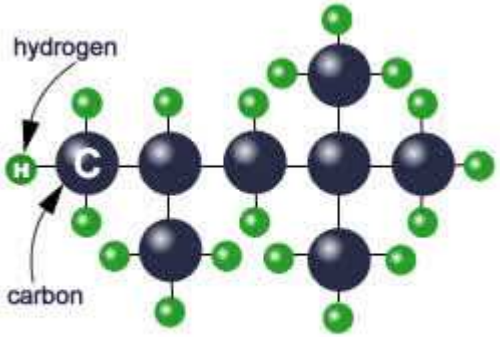
Steam methane reforming

~ 70 000 ton H_2 production for transports in Portugal

Commuting in Portugal



C:H ~ 1:2
40 MJ/kg



65%

35%

90% motorized road (50% of trips by car/motorcycle 40% by bus)

ACEA European Automobile Manufacturers Association

eurostat

What is sustainable mobility?

World Business Council for Sustainable Development

Accessibility for mobility impaired groups	Accessibility for impaired	S	Q
Air polluting emissions	Air pollution	Q	
Noise hindrance	Noise hindrance	Q	
Fatalities	Fatalities	Q	
Access to mobility services	Access	Q	
Quality of public area	Public area	Q	
Urban Functional diversity	Functional diversity	Q	E
Commuting travel time	Travel time	Q	E
Economic Opportunity	Economic Opportunity	Q	E
Net public finance	Public Finance	E	
Mobility space usage	Space Usage	G	E
Emissions of greenhouse gases (GHG)	GHG	G	
Congestion and delays	Congestion	G	S
Energy efficiency	Energy efficiency	G	S
Opportunity for active mobility	Active mobility	G	S
Intermodal integration	Intermodal integration	S	
Comfort and pleasure	Comfort and pleasure	S	Q
Security	Security	S	Q

Table.1: Overview of the 19 Sustainable Urban Mobility Indicators indicating the dimensions of the sustainability of the mobility system. Source: Oran Consulting for WBCSD SMP2.0, 2014

Three dimensions refer to the sustainability of the resource use and/or the impacts of mobility in the city:

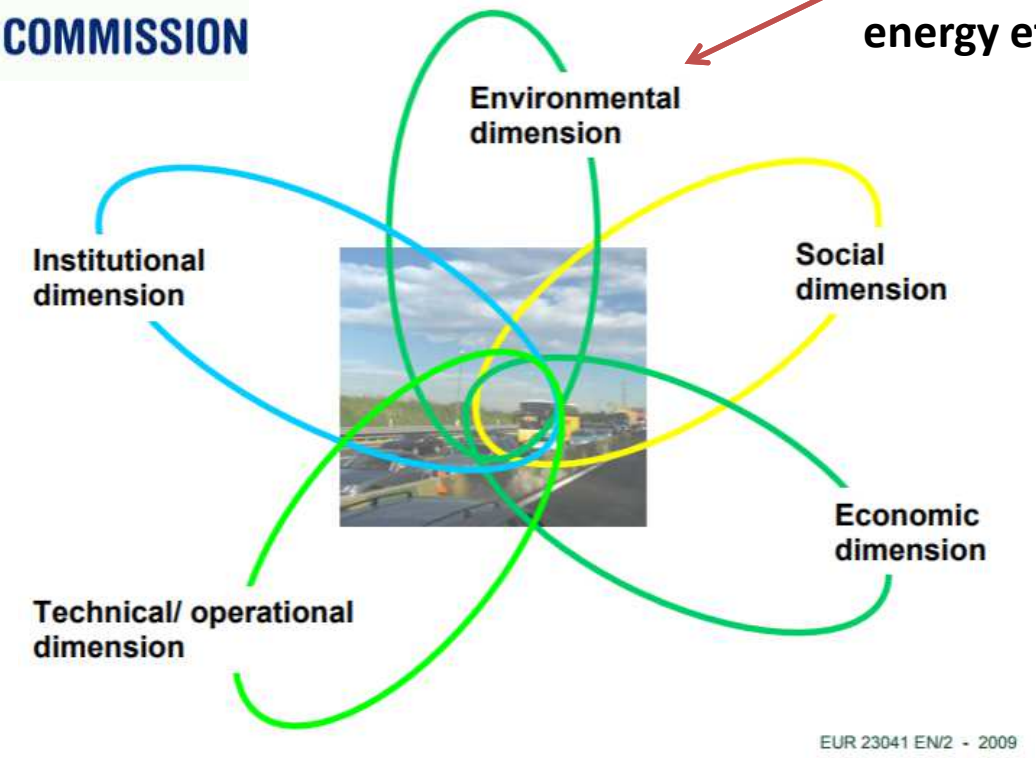
- G — Global environment
- Q — Quality of life
- E — Economic success
- S — Mobility system performance

4 dimensions- 19 Indicators

What is sustainable mobility?

JRC
EUROPEAN COMMISSION

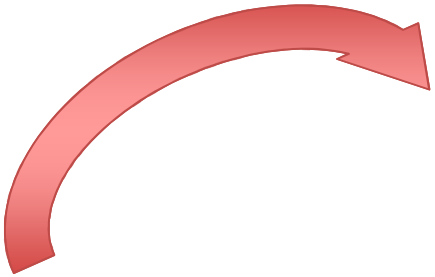
Transport emissions and energy efficiency



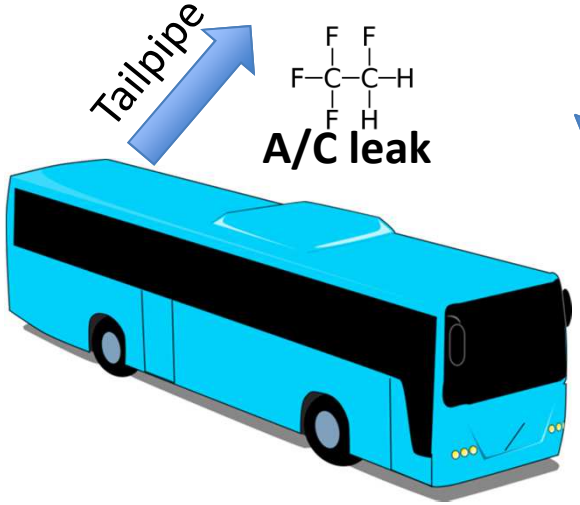
5 dimensions- 55 Indicators

Sources of carbon in transportation

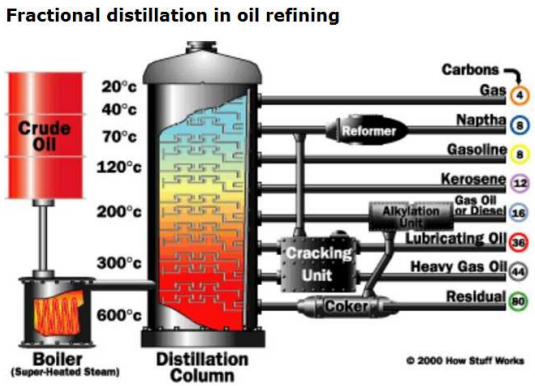
WTW Well-to-Wheels



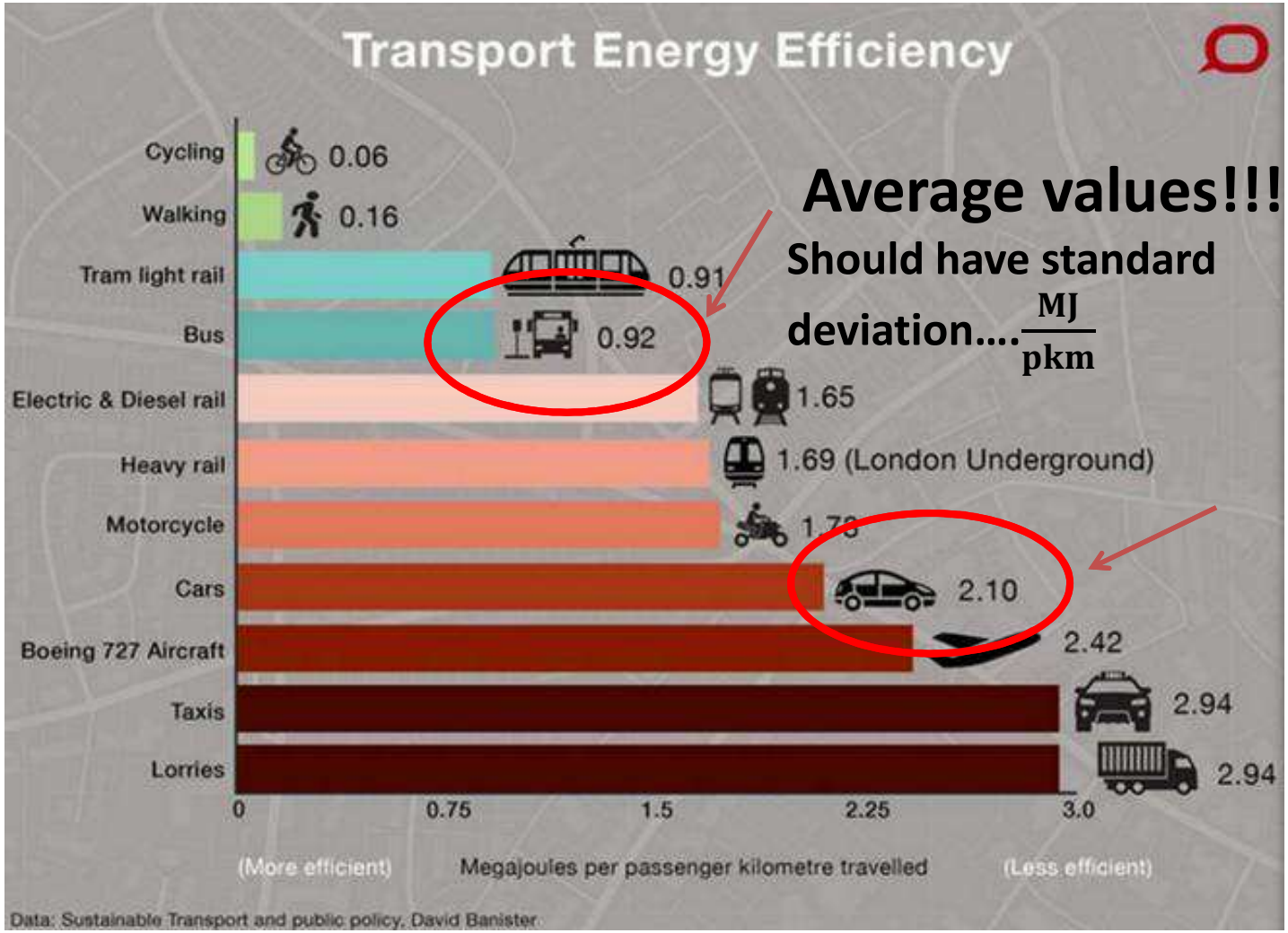
Manufacturing



Fuel and lube oil production

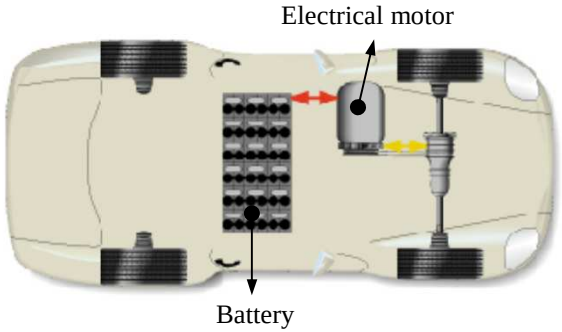


TTW energy efficiency



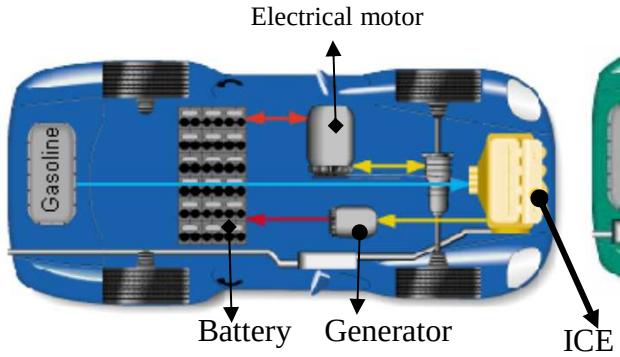
Vehicle technology

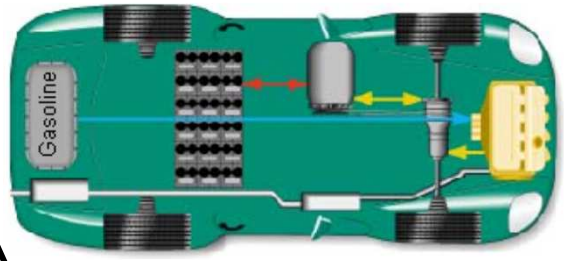
Plug-In

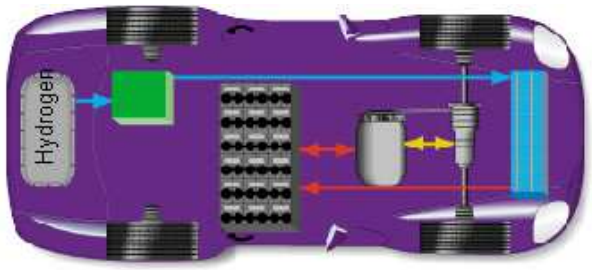


Pure electric (efic. 60-70%)

Hybrids (efic. 20-30%)







Fuel cell (efic. 30-40%)

Energy conversion…..

Refinery (distillation column)

Power plants (vapour cycle) renewables

Reforming

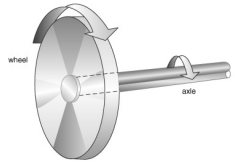
Transesterification

Fermentation

Flexibility…..

Fuel/technology	BEV	PHEV	HEV	ICEV
Electricity	✓	✓		
Hydrogen		✓	✓	✓
Gasoline		✓	✓	✓
Diesel		✓	✓	✓
Biodiesel		✓	✓	✓
Ethanol		✓	✓	✓

Efficiency…..



Primary energy

Final energy

Useful energy

H_2 production in Portugal …2050

Porto and Sines refinery

~ 9-12 kg CO2eq/kg H_2

Emissions

Energy

Steam methane reforming

~ 180 MJ/kg H_2

(efic. 68%)

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

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

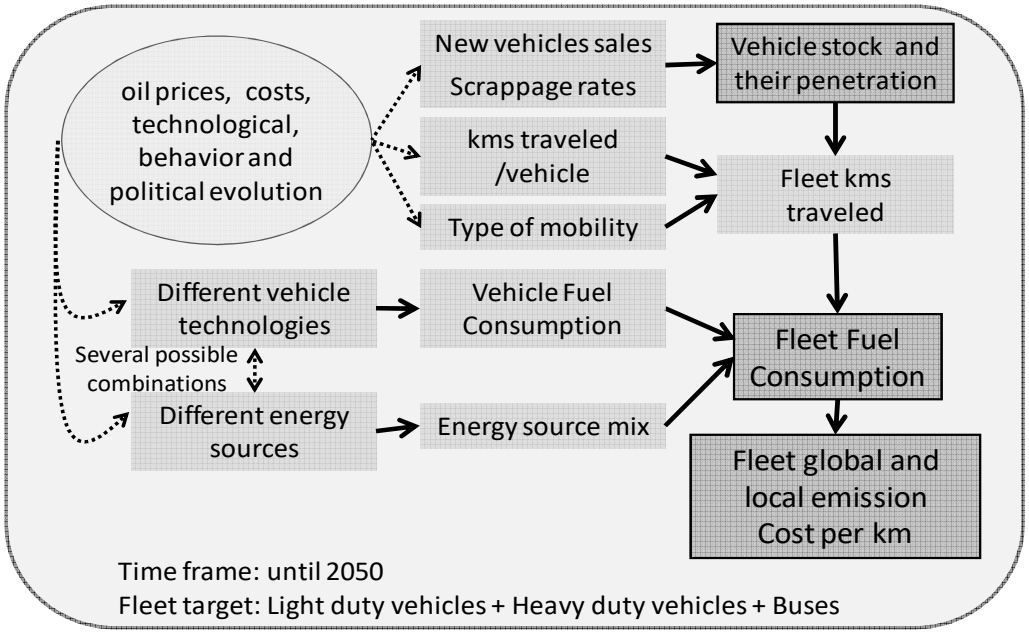
~ 70 000 ton H_2 production for transports in Portugal

Source:

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

Scenarios for Portugal – ”What if”

Excel spreadsheet model based on forecast scenarios that estimates the total fleet life cycle energy consumption, CO_2 emissions and air quality related impact



Baptista, Patrícia C., Patricia, **Silva, Carla M.,** Farias, Tiago L., Heywood, John B. (2012), **Energy and environmental impacts of alternative pathways for the Portuguese road transportation sector**, Energy Policy, 5(12):802–815.

Scenarious for Portugal

INSTITUTO NACIONAL DE ESTATÍSTICA
STATISTICS PORTUGAL

Evolution of the total number of vehicles per 1000 inhabitants along time.

Number of vehicles per 1000 inhabitants	LDV	HDV	Buses
2010	553.3	15.4	1.5
2020	573.9	15.5	1.6
2030	612.3	15.8	1.7
2050	615.1	15.8	2.2

2050

Visions	Scenarios	BUS		Total shift
		NG	FC HEV	
Liquid fuels	**1. Low**	2%	1%	**3%**
	2. Medium	9%	4%	**13%**
	3. High	20%	10%	**30%**
Diversified	**1. Low**	2%	1%	**3%**
	2. Medium	9%	4%	**13%**
	3. High	20%	10%	**30%**
Electricity	**1. Low**	2%	1%	**3%**
	2. Medium	9%	4%	**13%**
	3. High	20%	10%	**30%**
Hydrogen	**1. Low**	1%	2%	**3%**
	2. Medium	4%	9%	**13%**
	3. High	10%	20%	**30%**

~ 5 000 Bus

~ 50 000 km/bus.year

Scenarious for Portugal

M4 Hydrogen powered 1 435 000 (22%)

HyWays for Europe; modest policy & learning
Mckinsey for Europe;

Number of vehicles considered in each scenario

Year	LDV gasoline	LDV Diesel	HEV diesel	HEV gasoline	FCV PHEV	FCV HEV	PHEV gasoline	PHEV diesel	EV	NG
M2										
2010	3817	2046	0	33	0	0	0	0	0	0
2020	2463	3294	26	430	0	0	0	0	0	0
2030	1833	3631	304	622	0	0	107	23	135	16
2050	1442	2662	623	404	64	48	317	445	510	59
M4										
2010	3821	2057	0	18	0	0	0	0	0	0
2020	2547	3467	10	188	0	0	0	0	0	0
2030	2106	4152	122	275	0	0	0	0	0	16
2050	1631	3012	249	187	638	797	0	0	0	59
BAU										
2010	3804	2084	0	8	0	0	0	0	0	0
2020	2226	3857	2	128	0	0	0	0	0	0
2030	1359	4910	127	265	0	0	8	1	0	0
2050	1187	4651	386	177	0	0	52	119	0	0

R. Wurster, et al, "The European Hydrogen Roadmap," European Commission, Hyways-Hydrogen Energy in Europe, Luxembourg, 2008.

Mckinsey & Company, "A portfolio of power-trains for Europe: a fact based analysis; The roel of Battery Electric Vehicles, Plug-in Hybrids and Fuel Cell Electric Vehicles," 2011.

~ 12 000 km/car.year

Scenarious for Portugal

Energy consumption and TTW emission factors

Vehicle technology	Energy source	TTW					
		Energy (MJ/km)	CO_2 (g/km)	HC (g/km)	CO (g/km)	PM (g/km)	NO_x (g/km)
ICEV gasoline	Gasoline	2.12	154	0.10	1.12	0.005	0.05
ICEV diesel	Diesel	1.96	146	0.05	0.50	0.02	0.21
ICEV E100	Ethanol	2.12	0 (a)	(b)			
ICEV B100	Biodiesel	1.86		(c)			
HEV gasoline	Gasoline	1.67	59	=ICEV gasoline			
HEV diesel	Diesel	1.54	76	=ICEV diesel			
PHEV gasoline	Gasoline	1.80	122	=ICEV gasoline			
	Electricity	1.12	0	0	0	0	0
PHEV diesel	Diesel	1.66	116	=ICEV diesel			
	Electricity	1.04	0	0	0	0	0
EV	Electricity	0.60	0	0	0	0	0
FC-HEV	Hydrogen	1.08	0	0	0	0	
FC-PHEV	Hydrogen	0.67	0	0	0	0	
	Electricity	0.42	0	0	0	0	0
NG	natural gas	2.04	116	0.24	0.40	–	0.08
HDV	Diesel	8.89	662	1.12	10.76	0.10	6.18
Bus	Diesel	10.72	798	=HDV			
Bus NG	Natural gas	13.72	1022	=HDV			
Bus H_2	Hydrogen	14.47	0	0	0	0	0

~ 6 l/100km

~ 2 l/100km

~ 0.8 kg H_2/100km

~ 0.6 kg/100km

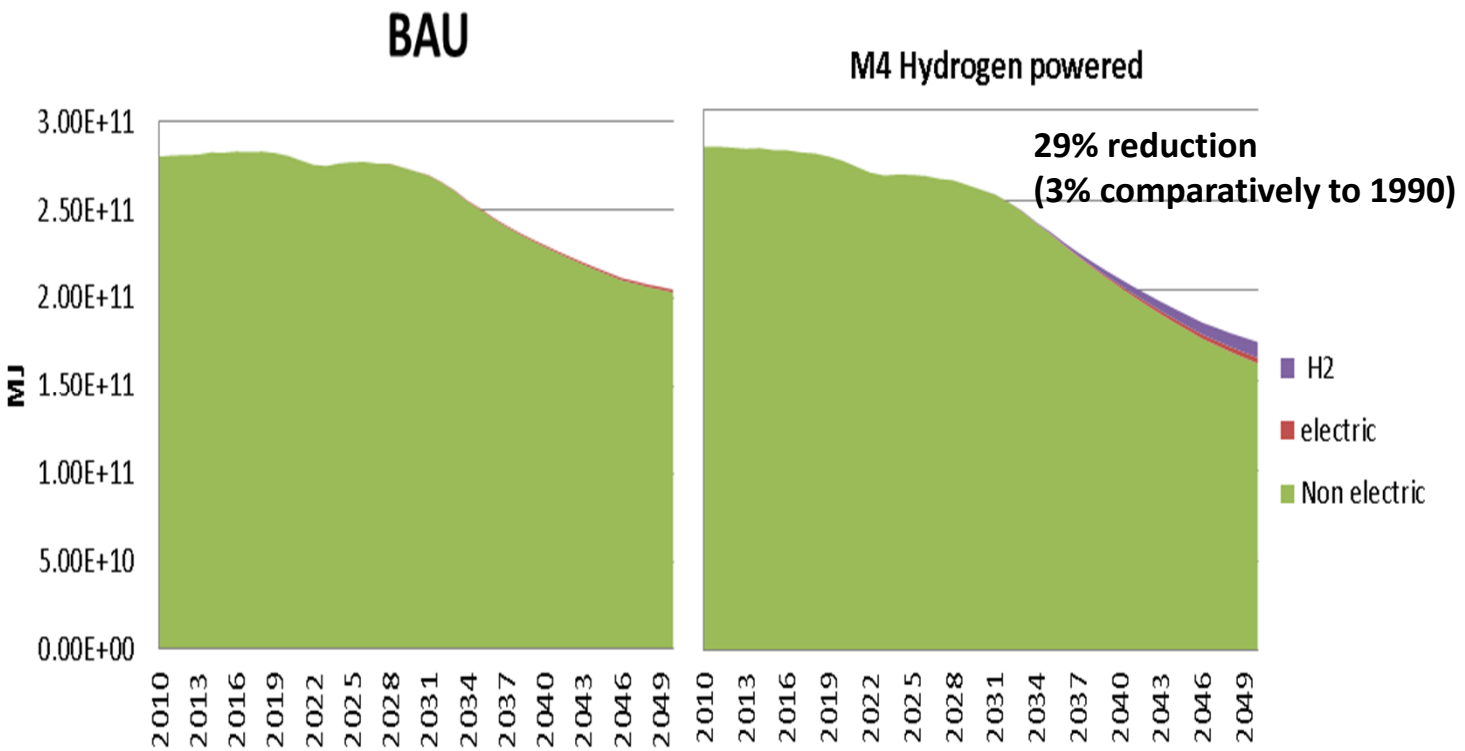
~ 12 kg H_2/100km

~ 10 kg H_2/100km

Vehicle technology	Year		
	2010	2020	2050
ICEV diesel	1	0.90	0.63
ICEV gasoline	1	0.90	0.64
HEV gasoline	1	0.91	0.65
NG		0.97	0.90
HDV	1	0.95	0.80
BUS	1	0.97	0.90
EV	1	0.93	0.75
PHEV gasoline	1	0.93	0.74
PHEV diesel	1	0.93	0.74
HEV diesel	1	0.92	0.72
FCV HEV	1	0.94	0.77
FCV PHEV	1	0.94	0.77

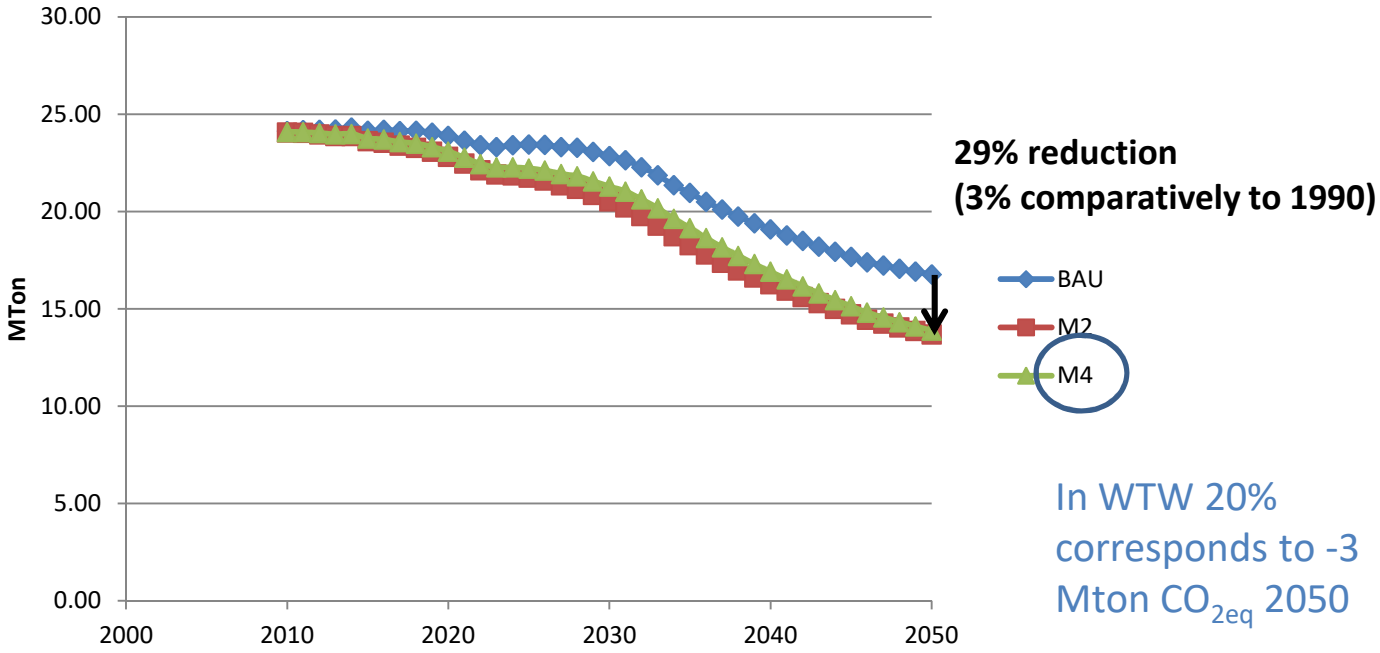
Scenarious for Portugal

Final energy consumption



Scenarious for Portugal

CO_{2eq} TTW



In WTW 20% corresponds to -3 Mton CO_{2eq} 2050

~ 100 000 ton H_2 production for transports in Portugal

Scenarious for Portugal

HYDROGEN in Portugal sustainable????

INDICATORS

Transport emissions and energy efficiency

Bus rapid transit systems in Equador

Influence of eletrification and increased biofuel/H_2 share

Electricity

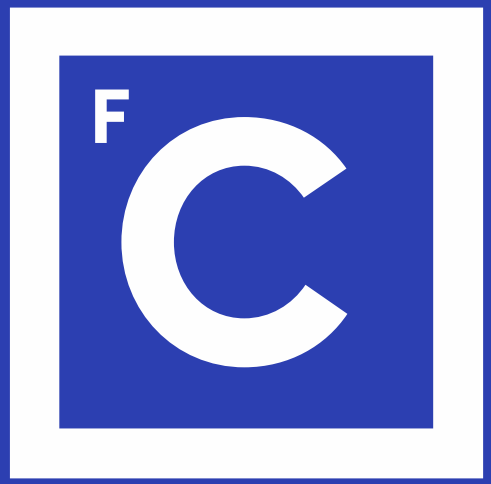
Biofuels/H2

CO_2;
NOx;
PM2.5;
NH_3
NMVOC
CH_4

- On going **Biofuel Reforming**

✓ EEA, *tier 3* aproach (COPERT);
✓ AVL-Cruise;
✓ AVL-Boost.

Thanks



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