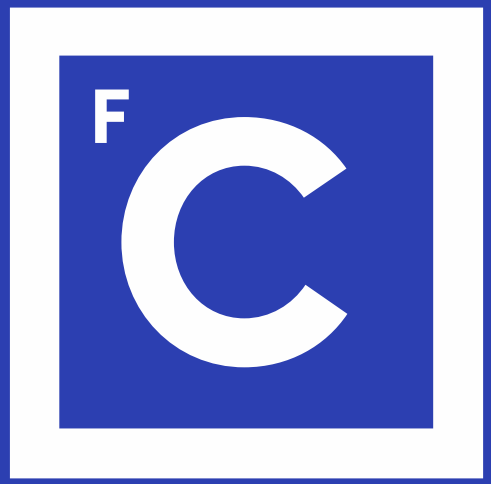


Ciências ULisboa

Faculdade
de Ciências
da Universidade
de Lisboa

DISCIPLINA MIEA 2018

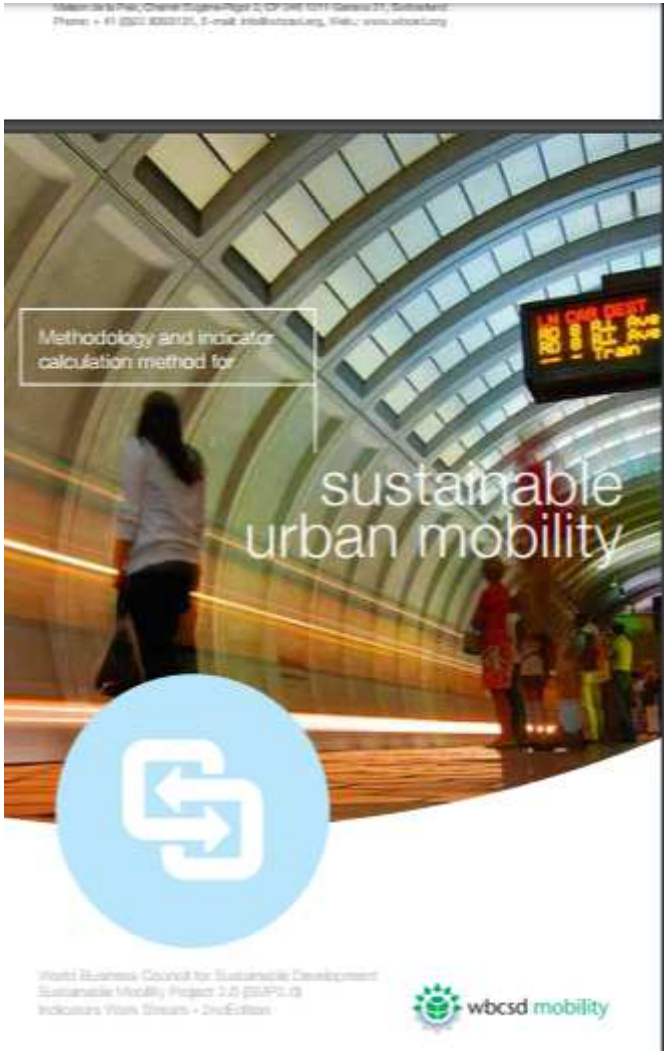
Mobilidade Sustentável

What is sustainable mobility?

Comparing transport systems??

Sustainable mobility indicators

What is sustainable mobility?



World Business Council for Sustainable Development

Sustainable Mobility Project 2.0 (SMP2.0) Indicators Work Stream - 2nd Edition

http://wbcsdpublications.org/wp-content/uploads/2016/01/SMP2.0_Sustainable-Mobility-Indicators_2ndEdition.pdf

What is sustainable mobility?

DIMENSIONS vs ***INDICATORS***

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

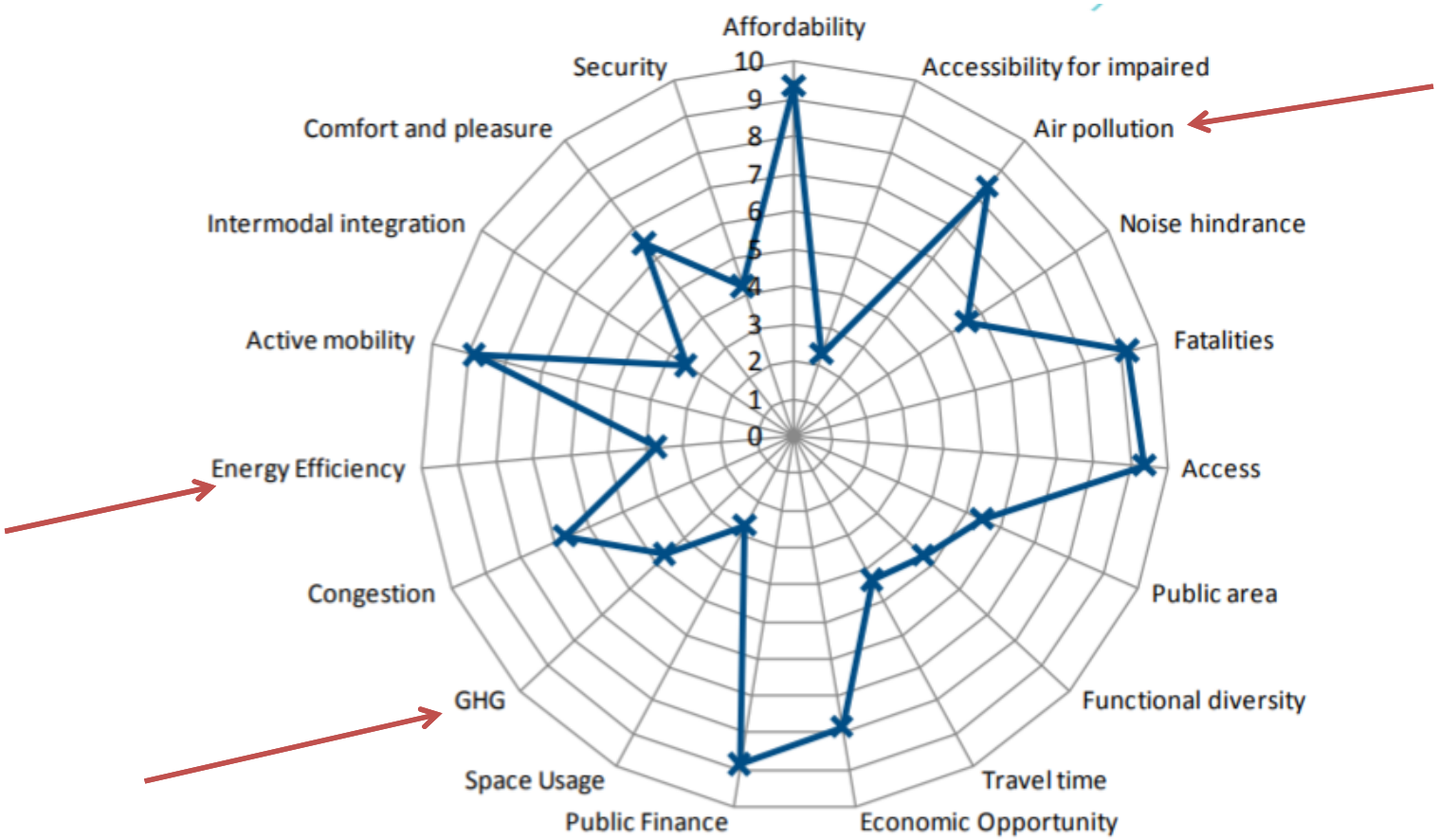
Three dimensions refer to the sustainability of the resource use and/or the impacts of mobility in the city:

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

4 dimensions- 19 Indicators

What is sustainable mobility?

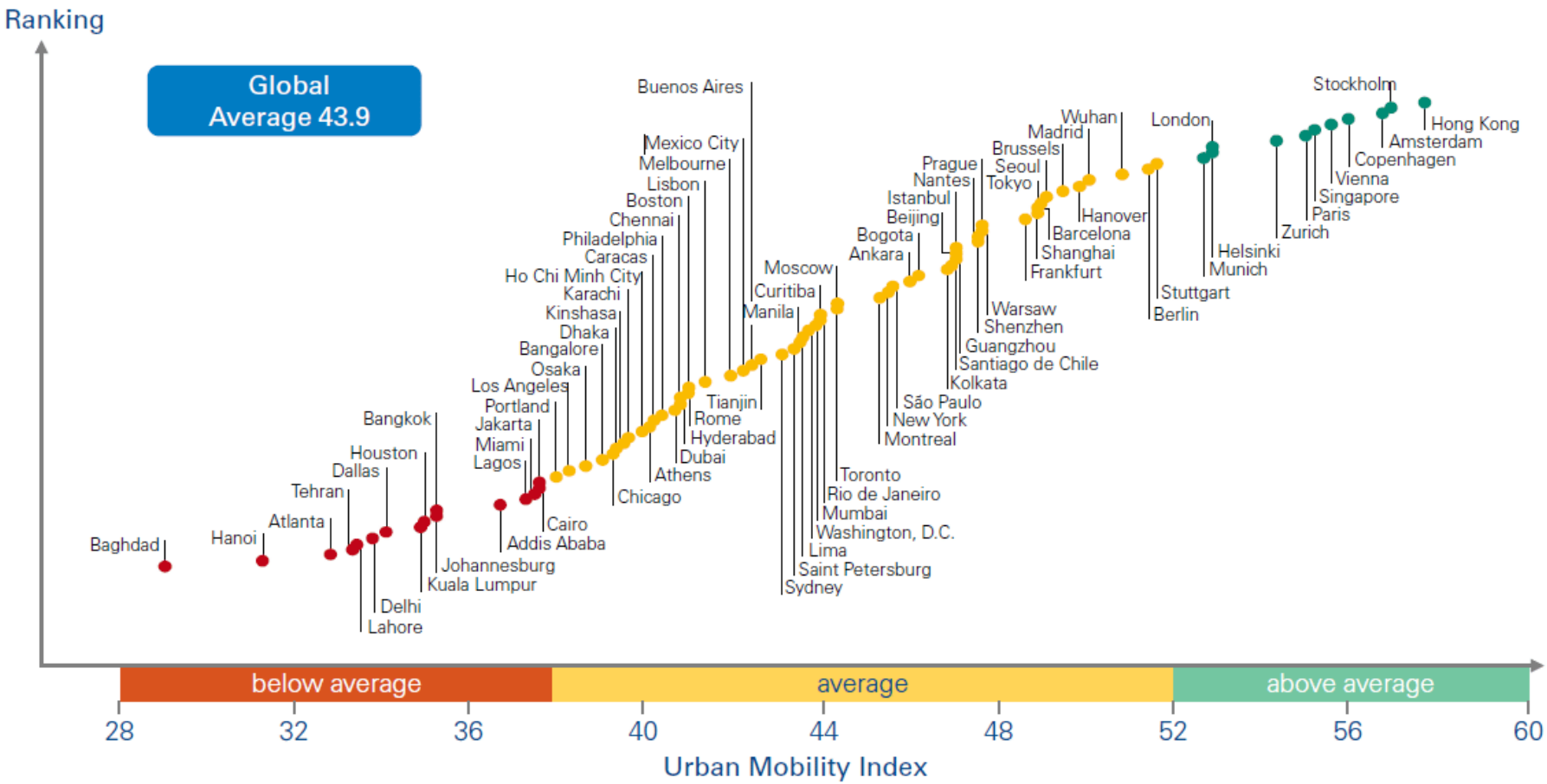
19 INDICATORS



What is sustainable mobility?

Figure 6: Arthur D. Little' Urban Mobility Index 2.0

19 INDICATORS



Source: Arthur D. Little Urban Mobility Index 2.0; UITP is independent of this index, which does not necessarily reflect its opinion; 100 index points for city that would achieve best performance on each criteria.

What is sustainable mobility?

2 DIMENSIONS (MATURITY & PERFORMANCE)

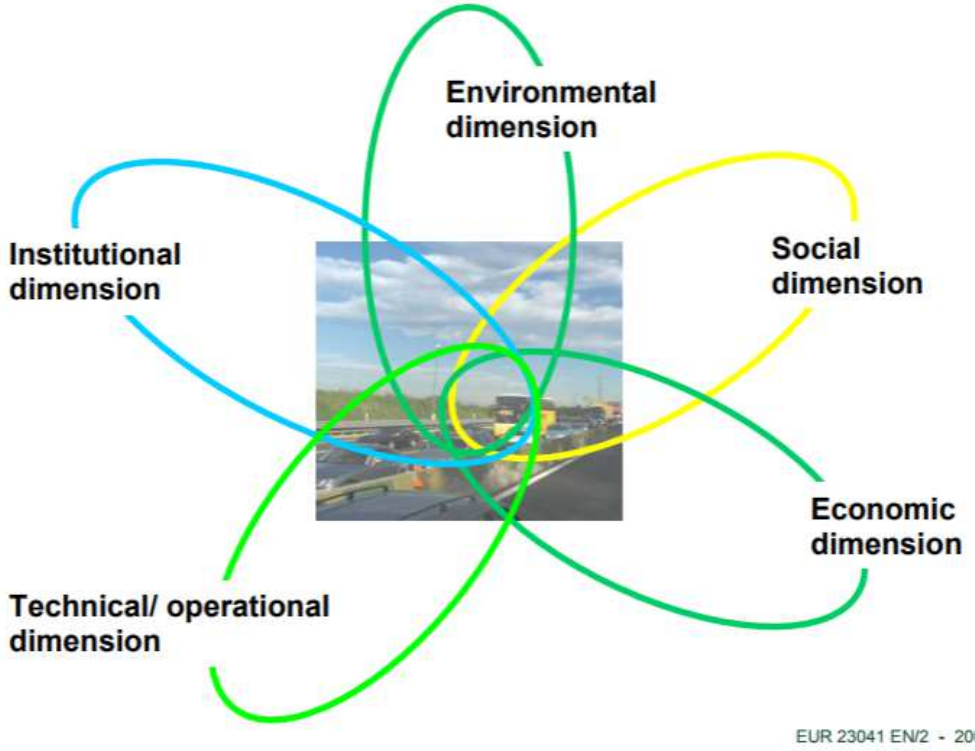
Figure 8: Top 11 cities with above average mobility score

		Maturity indicators											Performance indicators							
		Fin. attract. of PT (cost of 5 km PT/ cost of 5 km car)	Share of public transport in modal split [%]	Share of zero-emission modes in modal split [%]	Roads density (deviation from optimum) [km/km^2]	Cycle path network density [km/ths km^2]	Urban agglomeration density [citizens/km^2]	Smart card penetration [cards/capita]	Bike sharing performance [shared bikes/ million citizens]	Car sharing performance [shared cars/million citizens]	Density of vehicles registered [vehicles/capita]	Frequency of the busiest public transport line [times/ day]	Initiatives of public sector (0 to 10 scale)	Transport related CO_2 emissions [kg/capita]	Annual average NO_2 concentration [mcg/m^3]	Annual average PM_{10} concentration [mcg/m^3]	Traffic related fatalities per 1 million citizens	Dynamics of share public transport in modal split [%]	Dynamics zero-emission modes in modal split [%]	Mean travel time to work [minutes]	OVERALL SCORE
1	Hong Kong	1.7	55%	38%	2.0	187	6.5	3.1	0	0	0.07	324	10	776	50.0	50.0	16.2	+20%	0%	36.6	58.2
2	Stockholm	6.7	33%	34%	0.5	4,041	3.7	0.6	852	400	0.40	212	10	1,348	12.5	16.7	9.4	-7%	+89%	33.7	57.4
3	Amsterdam	3.0	8%	50%	1.7	3,502	3.2	0.7	527	1,219	0.32	130	10	844	30.0	24.7	19.5	+12%	+13%	35.5	57.2
4	Copenhagen	4.8	27%	33%	2.7	3,977	2.7	0.1	1,025	246	0.24	238	10	812	56.0	28.0	4.1	+123%	-15%	29.7	56.4
5	Vienna	3.9	39%	34%	0.6	2,948	3.8	0.0	692	415	0.39	277	10	1,111	21.7	21.5	16.1	+15%	+13%	29.3	56.0
6	Singapore	2.6	48%	23%	2.6	280	7.3	2.9	19	57	0.18	233	9	1,381	22.0	29.0	32.5	+17%	+64%	36.8	55.6
7	Paris	2.9	34%	50%	8.8	3,520	3.8	0.6	2,224	219	0.46	267	10	1,163	39.2	38.0	23.9	+7%	0%	38.6	55.4
8	Zurich	3.8	39%	31%	0.7	3,700	4.2	0.0	232	1,064	0.54	149	10	1,200	30.1	19.1	15.4	+15%	+3%	30.4	54.7
9	London	3.9	34%	26%	10.8	254	5.6	3.1	1,012	253	0.39	468	10	1,050	37.0	22.9	26.6	+10%	+4%	44.1	53.2
9	Helsinki	3.6	27%	40%	2.1	4,678	2.3	0.9	0	70	0.48	246	10	1,228	28.0	20.2	13.9	-16%	+8%	28.5	53.2
11	Munich	4.6	21%	42%	0.1	3,862	3.0	0.0	727	640	0.56	210	10	1,351	35.3	21.7	15.3	0%	+11%	30.1	53.0

Source: Arthur D. Little Urban Mobility Index 2.0

What is sustainable mobility?

DIMENSIONS vs ***INDICATORS***



JRC
EUROPEAN COMMISSION

5 dimensions- 55 Indicators

Indicators of sustainable Mobility

JRC EUROPEAN COMMISSION

55 Indicators– Joint Research Centre

Table 1. Indicator Framework for the Evaluation of Transport Sustainability Performance

DIMENSION	THEME	RELATED INDICATORS
ECONOMIC	*Transport Demand and Intensity*	1.Volume of transport relative to GDP (tonne-km; passenger-km)
		2. Road transport (passenger and freight; tonne-km and passenger -km)
		3. Railway transport (passenger and freight; tonne-km and passenger-km)
		4. Maritime transport for goods and passengers (tonne-km and passenger-km)
		5. Inland waterway transport (passenger and freight; tonne-km and passenger-km)
		6. Air transport (passenger and freight; tonne-km and passenger-km)
		7. Intermodal transport (tonne-km and passenger-km)
	Transport Costs and Prices	8. Total per capita transport expenditures (vehicle parking, roads and transit services)
		9. Motor vehicle fuel prices and taxes (for gasoline and gas/ diesel)
		10. Direct user cost by mode (passenger transport)
		11. External costs of transport activities (congestion, emission costs, safety costs) by transport mode (freight and passenger)
		12. Internalization of costs (implementation of economic policy tools with a direct link with the marginal external costs of the use of different transport modes)
		13. Subsidies to transport
		14. Taxation of vehicles and vehicle use
		15. % of GDP contributed by transport
		16. Investment in transport infrastructure (per capita by mode/ as share of GDP)
	Infrastructure	17. Road quality - paved roads, fair/ good condition
		18. Total length of roads in km by mode

http://publications.jrc.ec.europa.eu/repository/bitstream/JRC54971/sust_transp_ind_report_final.pdf

Indicators of sustainable Mobility

JRC EUROPEAN COMMISSION

		19. Density of infrastructure (km-km^2)
SOCIAL	***Accessibility and Mobility***	20. Average passenger journey time
		21. Average passenger journey length per mode
		22. Quality of transport for disadvantaged people (disabled, low incomes, children)
		23. Personal mobility (daily or annual person-km and trips by income group)
		24. Volume of passengers
	Risk and Safety	25. Persons killed in traffic accidents (number of fatalities - 1000 vehicle km; per million inhabitants)
		26. Traffic accidents involving personal injury (number of injuries – 1000 vehicle km; per million inhabitants)
	Health Impacts	27. Population exposed to and annoyed by traffic noise, by noise category and by mode associated with health and other effects
		28. Cases of chronic respiratory diseases, cancer, headaches. Respiratory restricted activity days and premature deaths due to motor vehicle pollution
	Affordability	29. Private car ownership
		30. Affordability (portion of households income devoted to transport)
	Employment	31. Contribution of transport sector (by mode) to employment growth

Indicators of sustainable Mobility

JRC EUROPEAN COMMISSION

ENVIRONMENTAL	***Transport Emissions***	32. NOx emissions (per capita)
		33. VOCs emissions (per capita)
		34. PM_{10} and $PM_{2.5}$ emissions (per capita)
		35. SOx emissions (per capita)
		36. O_3 concentration (per capita)
		37. CO_2 emissions (per capita)
		38. N_20 emissions (per capita)
		39. CH_4 emissions (per capita)
	Energy Efficiency	40. Energy consumption by transport mode (tonne-oil equivalent per vehicle km)
		41. Fuel consumption (vehicles-km by mode)
	Impacts on Environmental Resources	42. Habitat and ecosystem disruption
		43. Land take by transport infrastructure mode
	Environmental Risks and Damages	44. Polluting accidents (land, air, water)
		45. Hazardous materials transported by mode
	Renewables	46. Use of renewable energy sources (numbers of alternative-fuelled vehicles) - use of biofuels
TECHNICAL and OPERATIONAL	***Occupancy of Transportation***	47. Occupancy rate of passenger vehicles
		48. Load factors for freight transport (LDV, HDV)
	Technology Status	49. Average age of vehicle fleet
		50. Size of vehicle fleet (vehicle/ 1 mln. inhabitants)
		51. Proportion of vehicle fleet meeting certain air emission standards (Euro IV, Euro V etc.)
INSTITUTIONAL	***Measures to Improve Transport Sustainability***	52. R&D expenditure on "eco vehicles" and clean transport fuels
		53. Total expenditure on pollution prevention and clean-up
		54. Measures taken to improve public transport
	Institutional Development	55. Uptake of strategic environmental assessment in the transport sector

Indicators of sustainable Mobility

JRC EUROPEAN COMMISSION

ENVIRONMENTAL	*Transport Emissions*	32. NOx emissions (per capita)
		33. VOCs emissions (per capita)
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	Renewables	46. Use of renewable energy sources (numbers of alternative-fuelled vehicles) - use of biofuels

Indicators of sustainable Mobility

1 DIMENSION

11 Indicators

Environmental

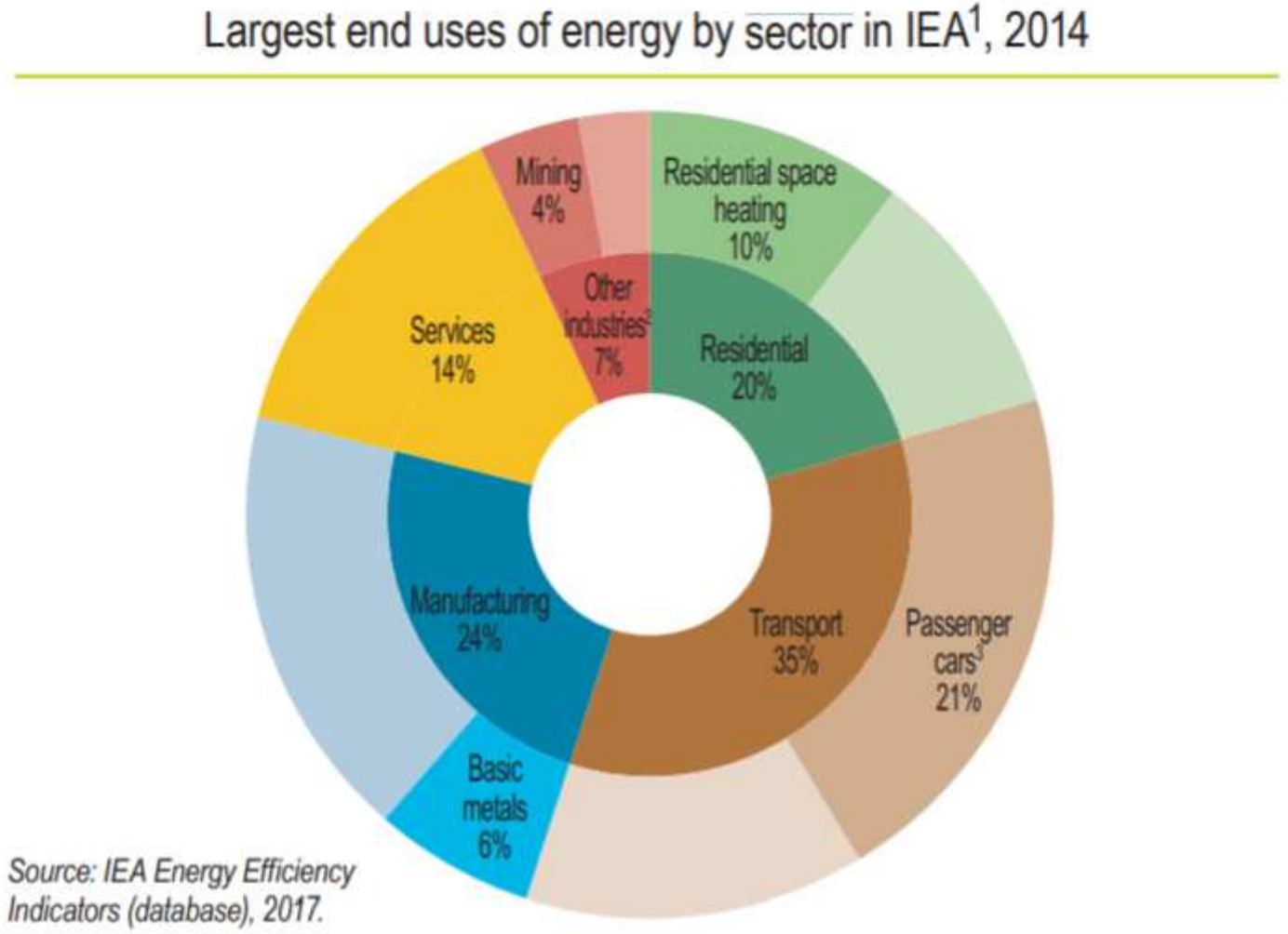
Emissions per year (per capita)

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

Ton or g/year

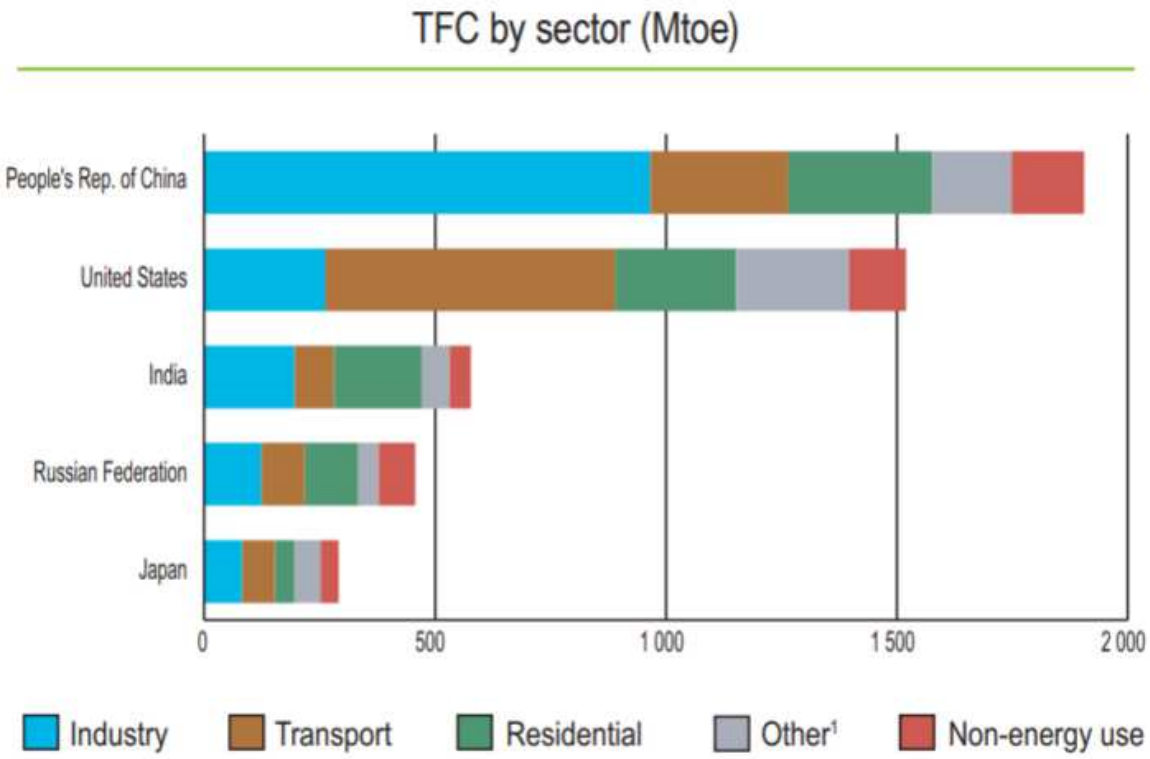
Energy consumption per year (per capita)

Transports share

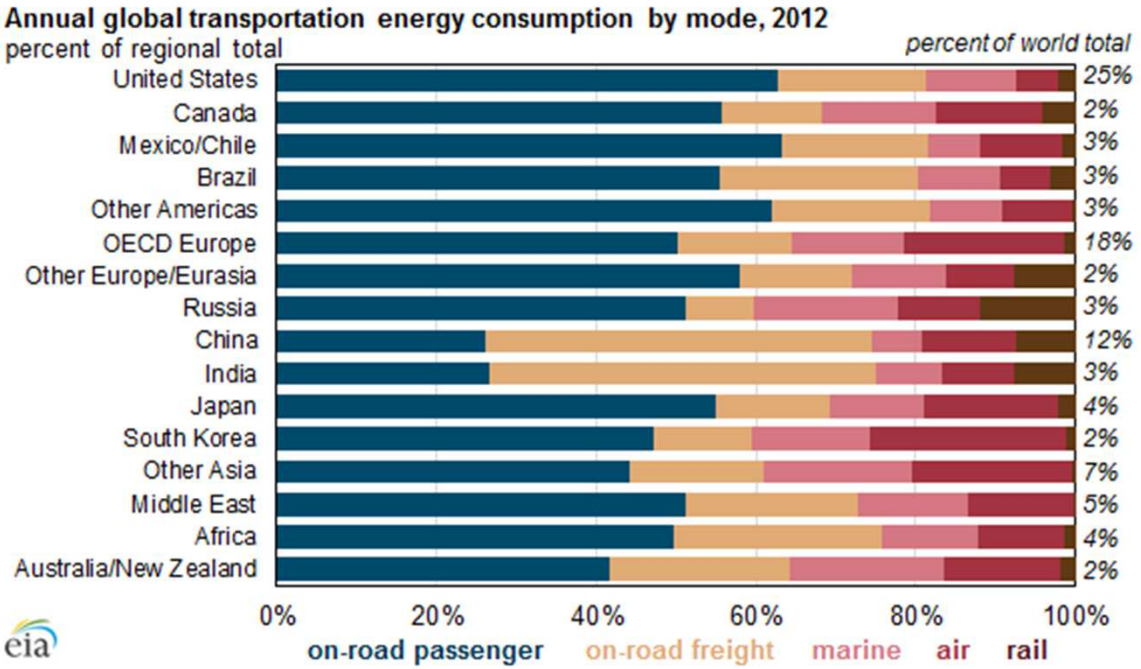


Transports share

Top five countries by total final consumption



Transports mode share

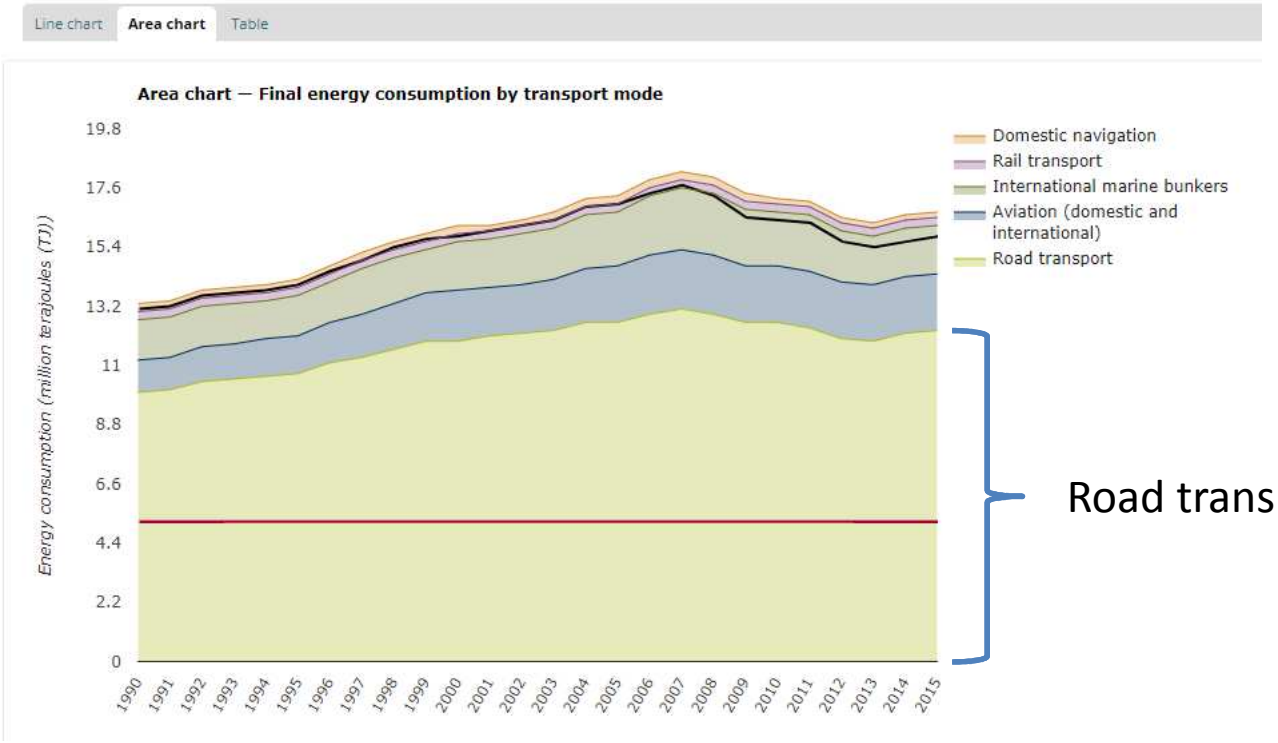


Source: EUROSTAT
http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Energy_consumption_of_transport_by_mode_EU-28.jpg

Transports mode share

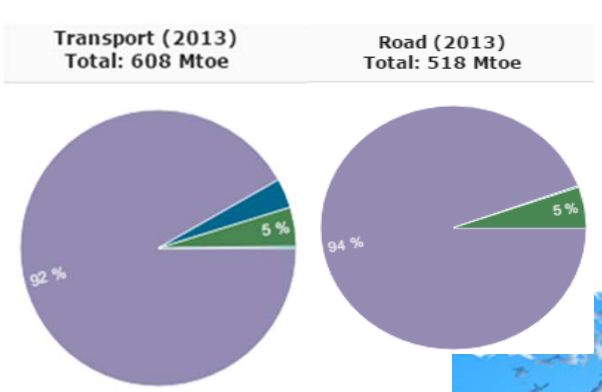
European Environment Agency

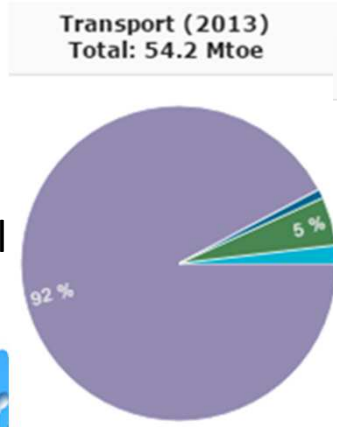
Fig. 1: Final energy consumption by transport mode

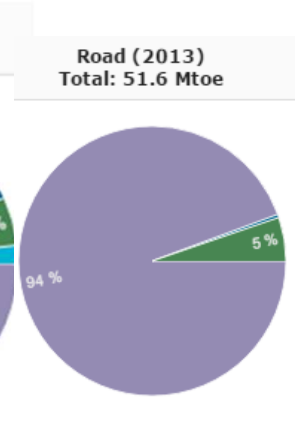


Road transport

Transports share by energy source



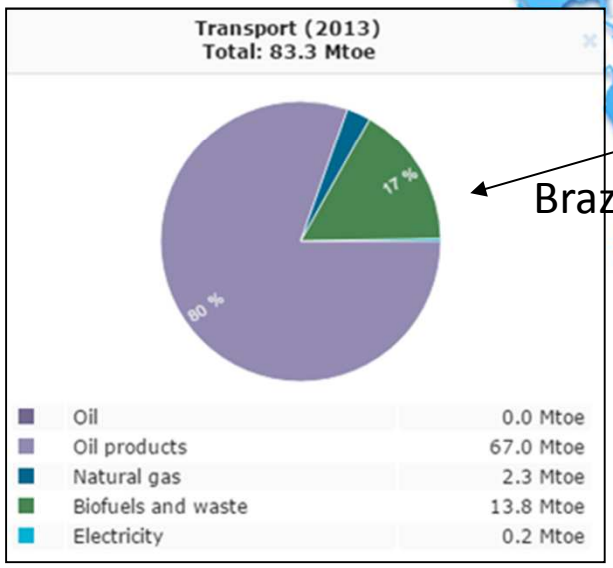




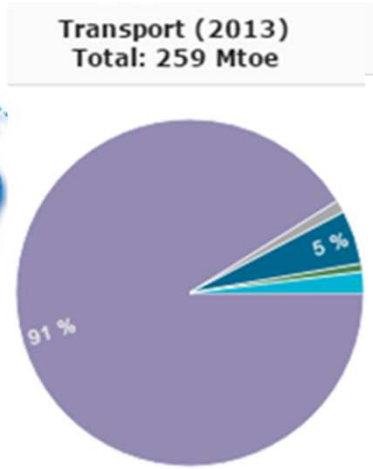
Germany: 53% Oil

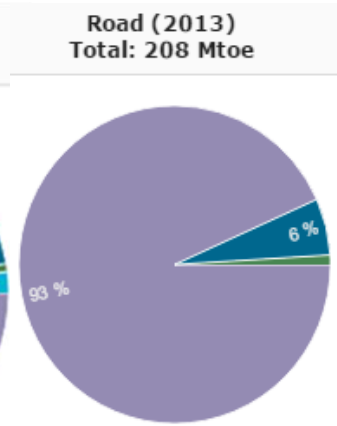
US:77% Oil

RPC:53% Oil



Brazil:67% Oil



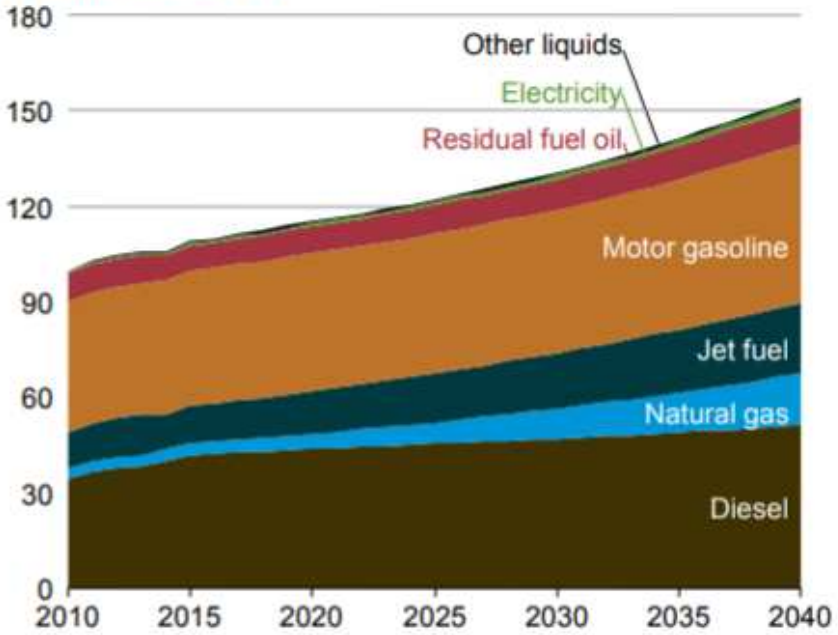


Source: IEA 2015

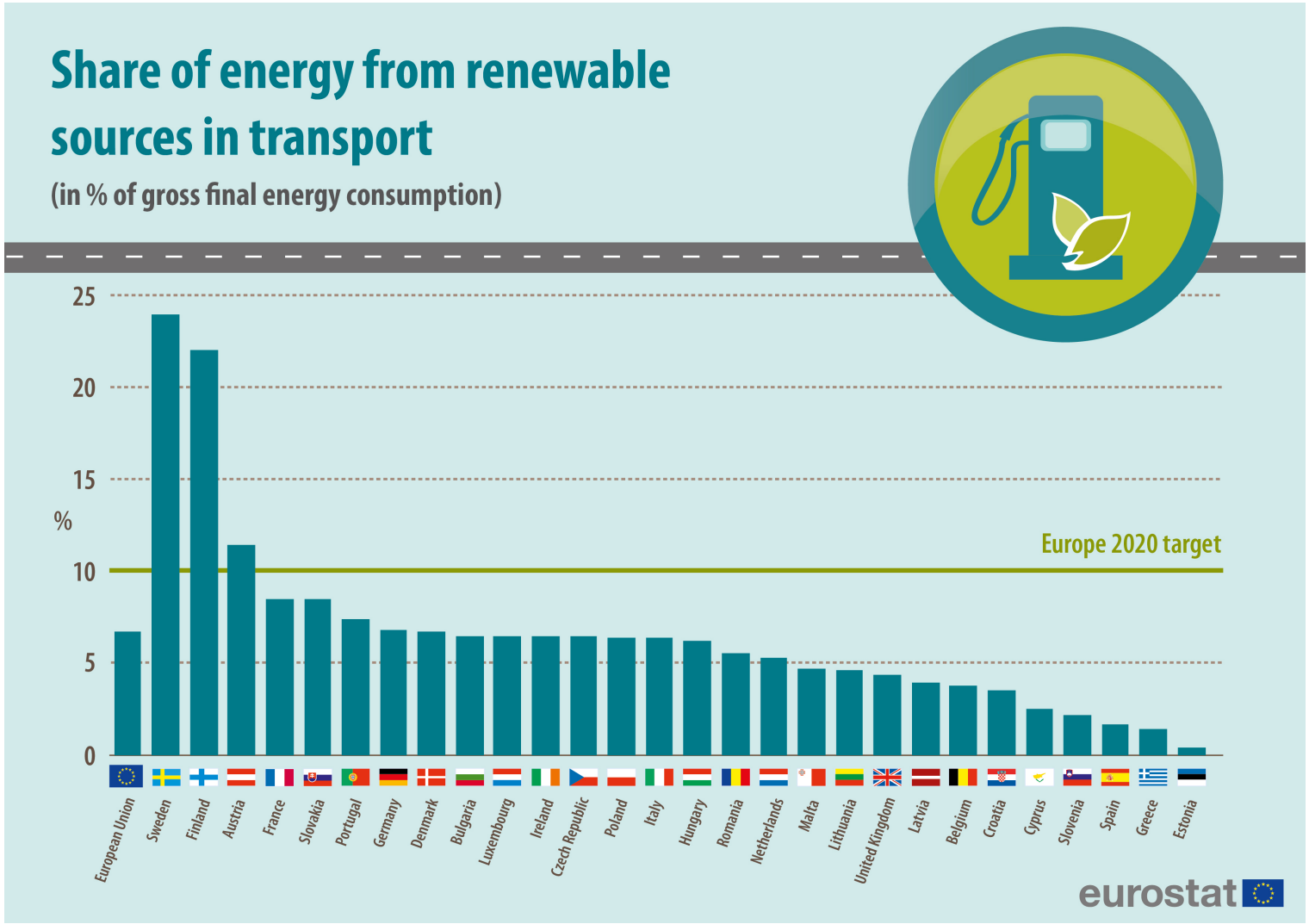
Transports share by energy source

eia

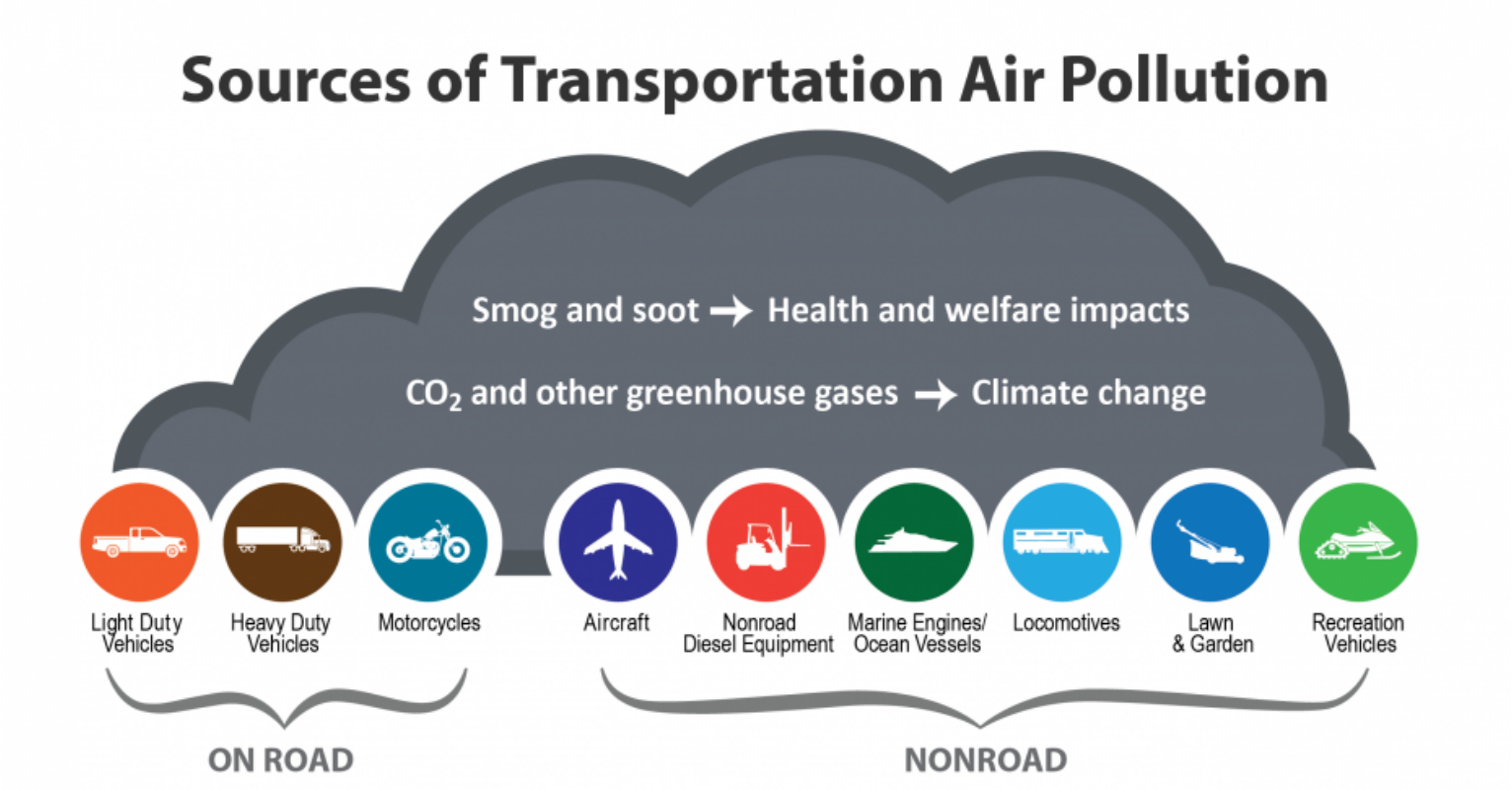
Figure 8-2. World transportation sector delivered energy consumption by energy source, 2010–40 (quadrillion Btu)



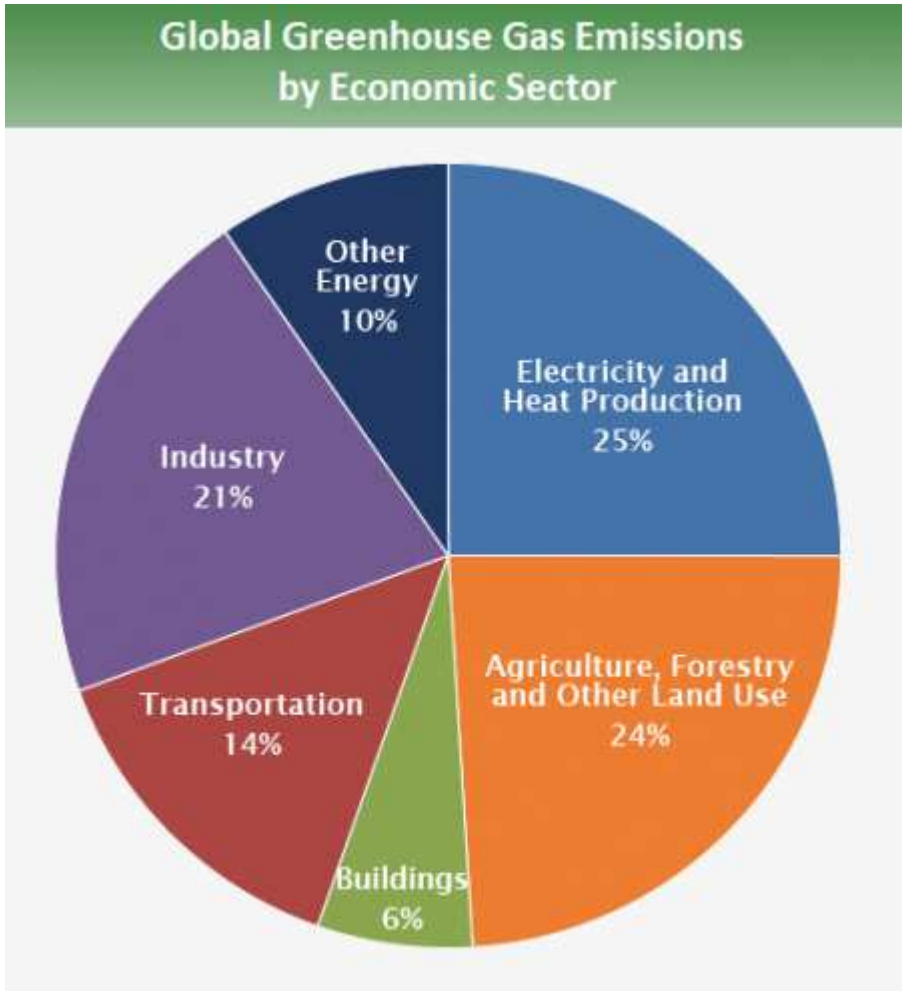
Transports share by energy source



Transports share by energy source



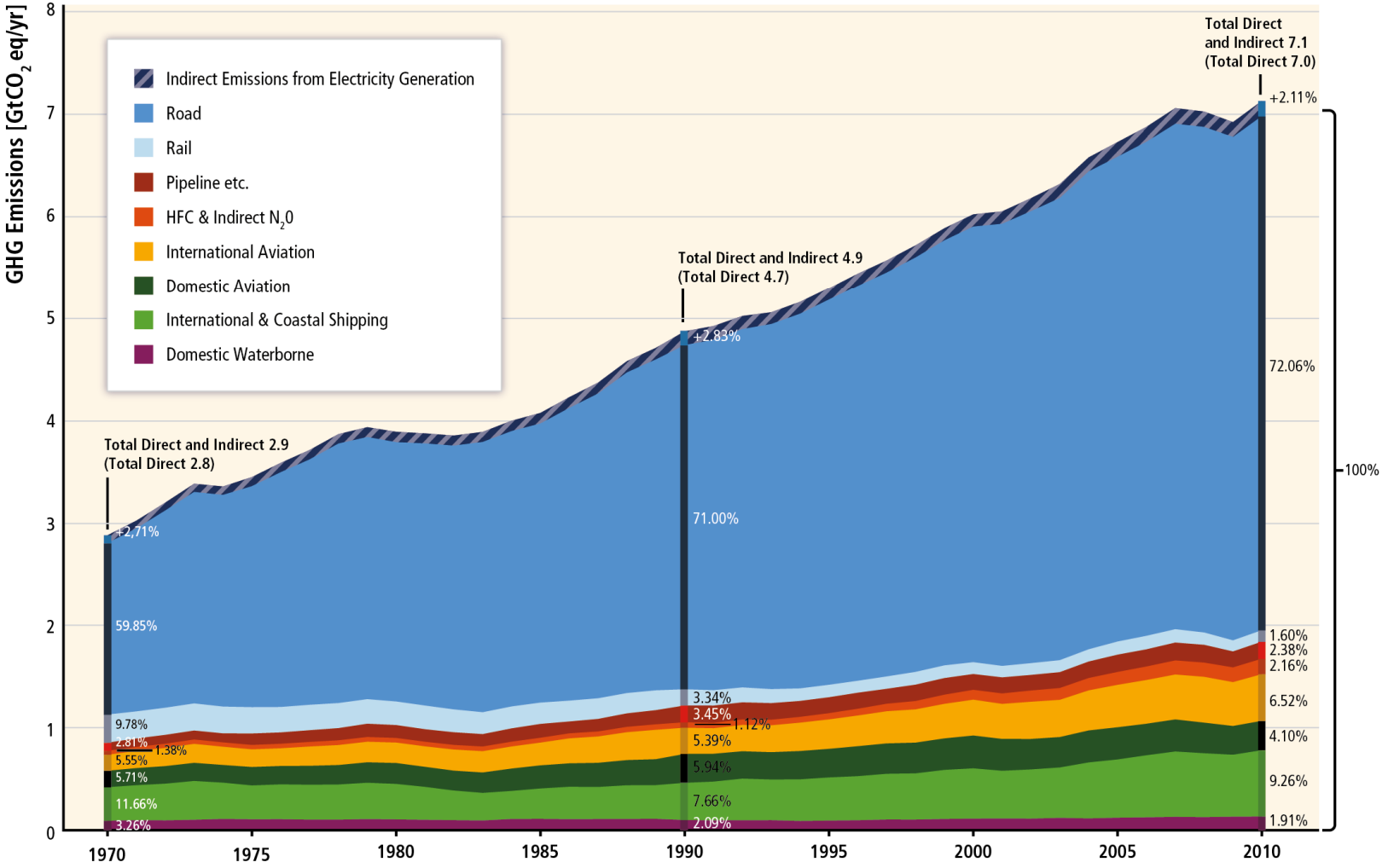
Transport share



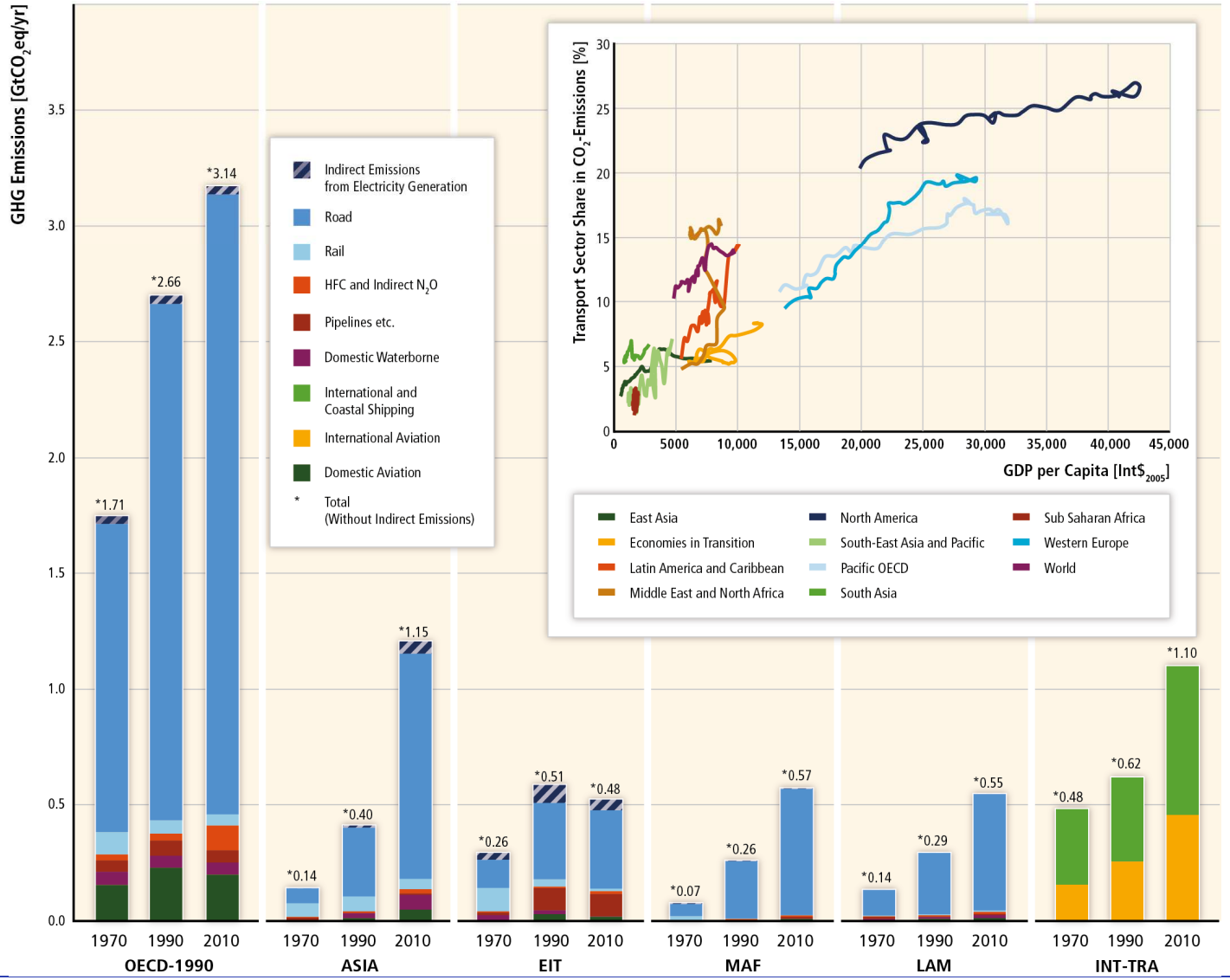
Source: IPCC (2014); EXIT based on global emissions from 2010. Details about the sources included in these estimates can be found in the Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

Transport share

IPCC (2014)

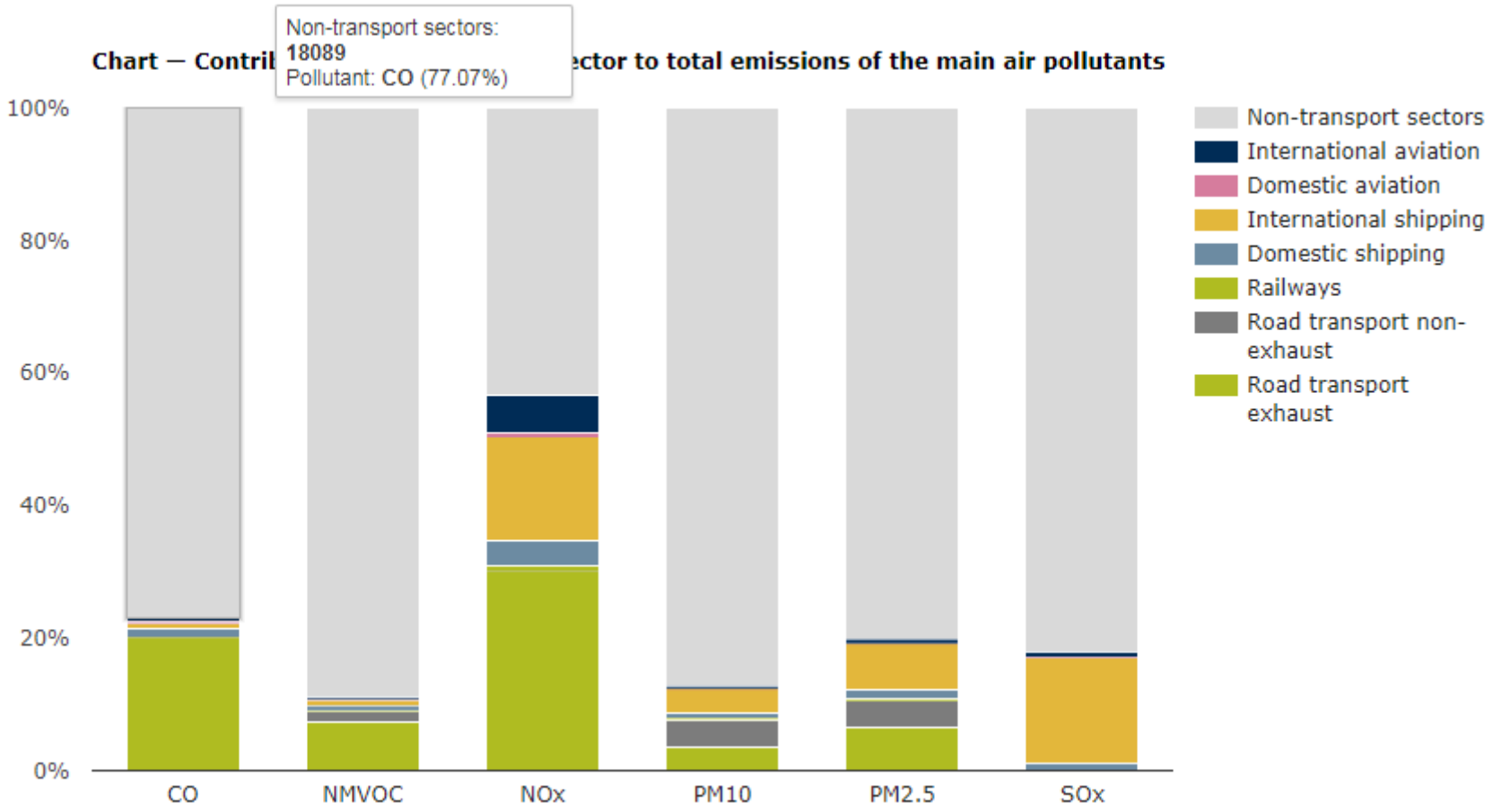


Transport share



IPCC (2014)

Transport share



2017

European Environment Agency

Transports share

LOCAL AIR QUALITY EMISSIONS (EUROPE)

					NON-TRANSPORT	
NOx	32.9%	0.9%	19.1%	4.5%	NOx	42.6%
CO	26.6%	0.2%	2.3%	0.7%	CO	70.2%
SOx	0.1%	0.0%	20.9%	0.5%	SOx	78.5%
VOLATILE ORGANIC COMPOUNDS	15.4%	0.14%	2.52%	0.40%	VOLATILE ORGANIC COMPOUNDS	81.54%
FINE PARTICLES (PM2.5)	14.2%	0.4%	11.4%	0.6%	FINE PARTICLES (PM2.5)	73.4%

In % of total emissions | source: European Environment Agency, 2013

THANKS TO IMPROVEMENTS IN AIRCRAFT TECHNOLOGY, THE IMPACT OF AIRCRAFT EMISSIONS ON LOCAL AIR QUALITY IS RELATIVELY LOW COMPARED TO OTHER SOURCES.

Minimum energy and emissions

Home ⟷ **Work (or university)**

Commuting

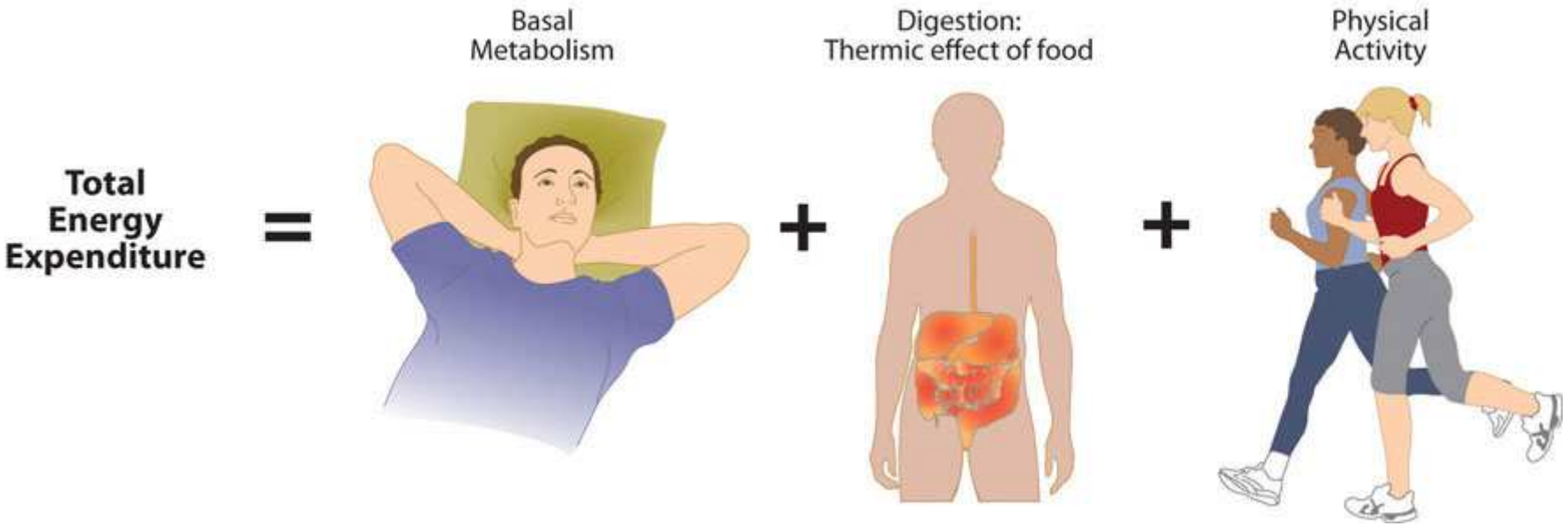
Minimum energy and emissions

Emissions

Energy

Mobility baseline

Walking….always….speed? Energy????Emissions???



Mobility baseline

Walking….always….speed? Energy????

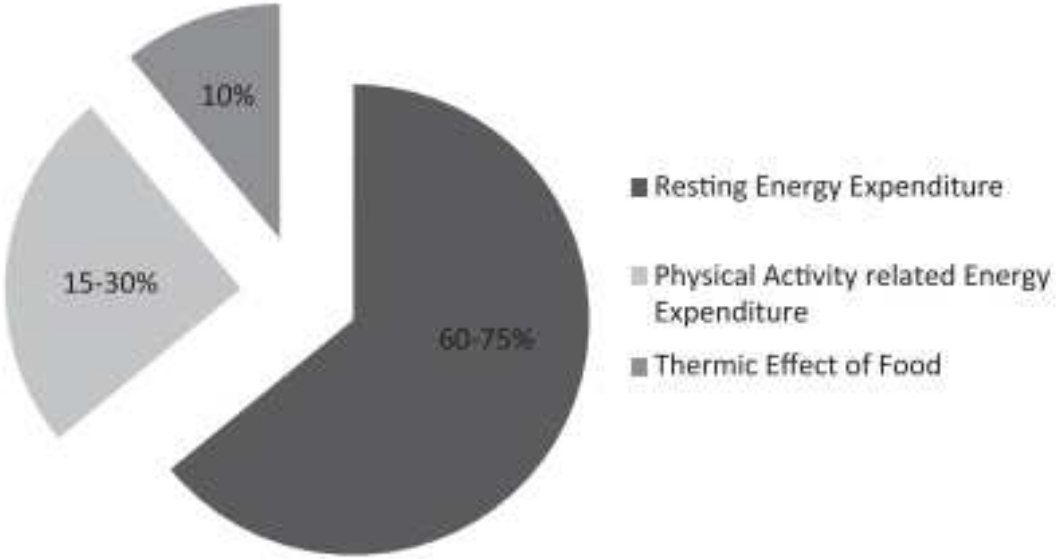


Figure 1. Components of typical total daily energy expenditure. Resting energy expenditure indicates the energy needed to maintain vital life functions during basal and sleeping conditions; physical activity–related energy expenditure, the energy needed to maintain movement demand above that of resting conditions; and thermic effect of food, the energy required for purposes of digestion and the breakdown of food stuff. Modified from McArdle et al.[21]

History…..and…future

Walking….always….speed? Energy????Emissions???

The Revised Harris-Benedict Equation:

- for men, $P = \left(\frac{13.397m}{1\,\text{kg}} + \frac{4.799h}{1\,\text{cm}} - \frac{5.677a}{1\,\text{year}} + 88.362 \right) \frac{\text{kcal}}{\text{day}}$
- for women, $P = \left(\frac{9.247m}{1\,\text{kg}} + \frac{3.098h}{1\,\text{cm}} - \frac{4.330a}{1\,\text{year}} + 447.593 \right) \frac{\text{kcal}}{\text{day}}$

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)

Baseline Emissions?

Metabolic Work Rate (Watts or J/s)

MWR = - 1967 + 8.58 HR + 25.1 HT + 4.50 A – 7.47 RHR + 67.8 G

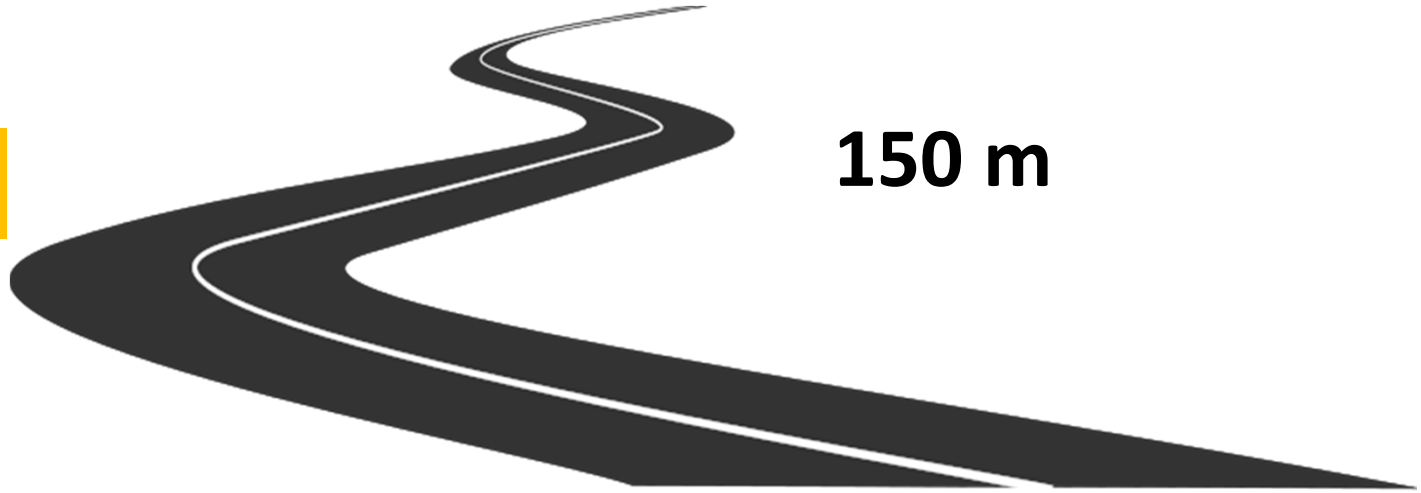
Where,
HR is heart rate (bpm)
HT is height (in.)
A is age (yr),
RHR is resting heart rate (bpm)
G is gender (M=0, F=1).

@ Predictive Models for Estimating Metabolic Workload based on Heart Rate and Physical Characteristics

Minimum energy and emissions

Example: P#1

Active modes



150 m

	Height (cm)	W (kg)	BPM basal	BPM walking	A	Sex	T (s)
Margarida	161	63	76	88	17	F	137
Catarina	161	54	76	84	16	F	133
Mariana	164	60	80	160	16	F	43
Joana	158	47.5	64	84	16	F	126.6
Mariana	178	60	76	92	16	F	126.6

Minimum energy and emissions

1 kcal = 0.0041868 MJ

MJ/day/((24h*3600s/h)/day)*time_exercise

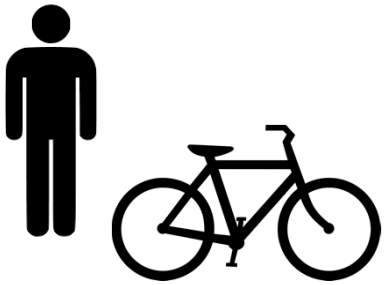
1 kcal = 0.0041868 MJ;

Basal (kcal/dia)	Basal (MJ/dia)	Basal (MJ)	Walking (kcal)	Walking (MJ)
1455.322	6.09314215	0.00966158	6.686553936	0.018333684
1376.429	5.762832937	0.008871028	6.106641173	0.016696258
1441.205	6.034037094	0.003003051	7.666106597	0.029093404

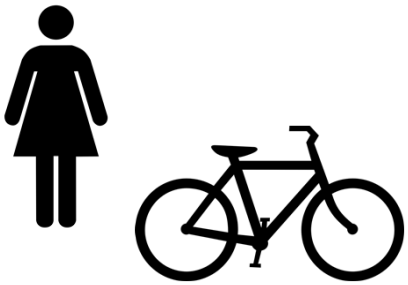
(Walking-Basal)/distance

0.12 MJ/pkm
0.11 MJ/pkm
0.19 MJ/pkm
0.12 MJ/pkm
0.14 MJ/pkm

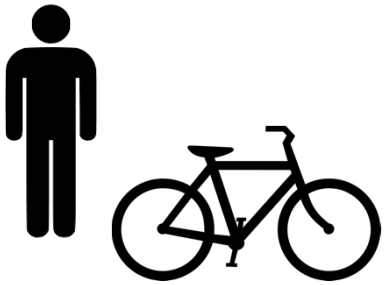
Minimum energy and emissions



Height (cm)	Weight (kg)	BPM basal	BPM exercise	Age	Sex	
171	53	68	128	17	M	Luis
165	55	56	108	17	F	Joana
183	62	89	160	15	M	João
174	67	68	116	17	M	Francisco
183	73	76	104	17	M	João

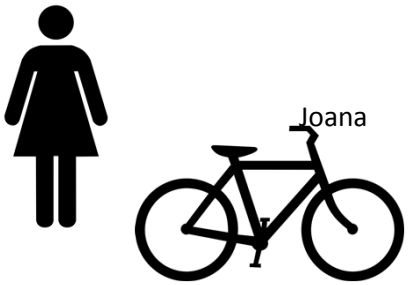


Minimum energy and emissions



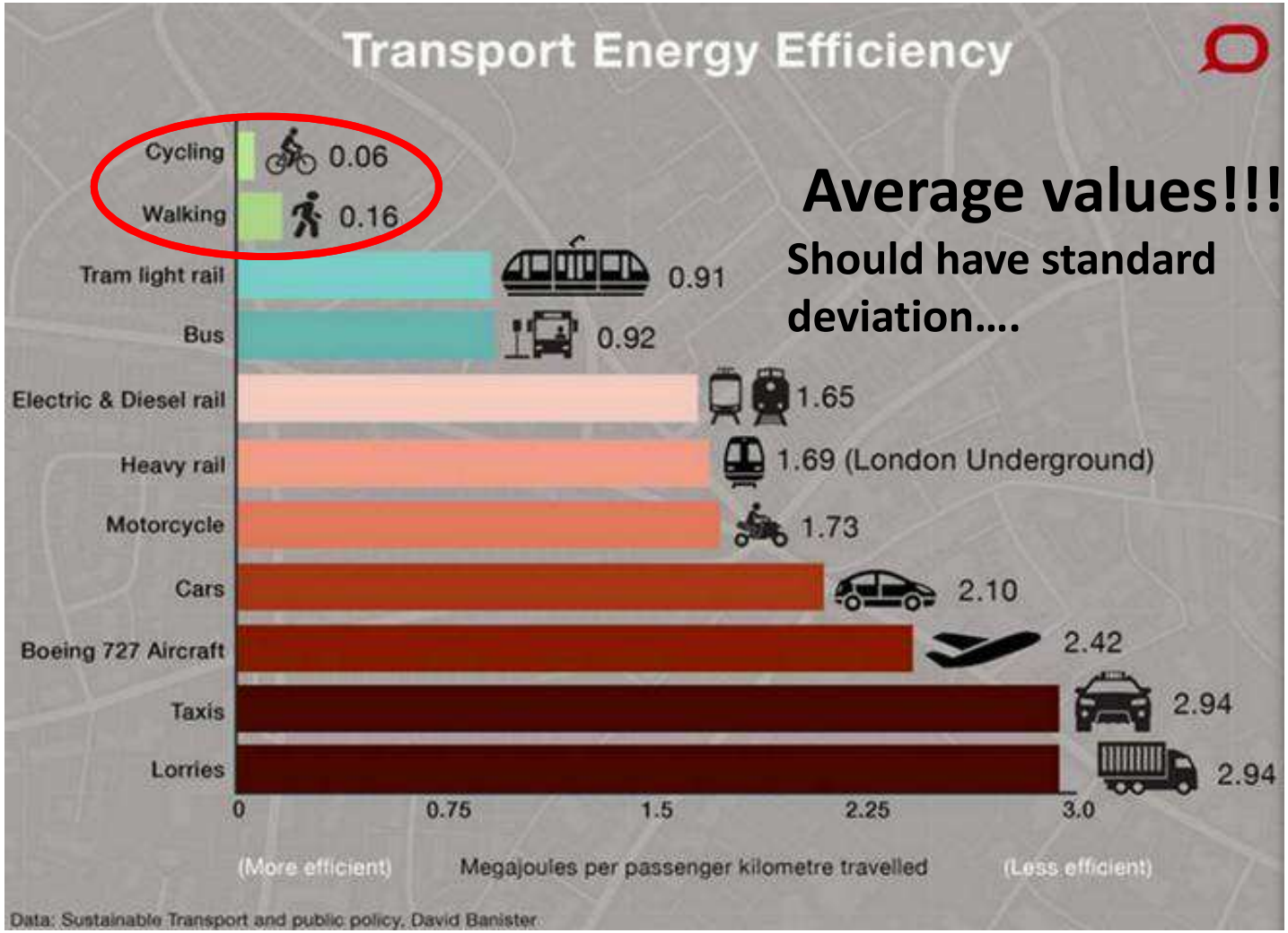
	Tempo (s)	Energia basal (kcal/dia)	Energia basal (MJ/dia)	**Energia basal (MJ)**	Energia (kcal)	**Energia (MJ)**
Luis	32	1522.523	6.374499296	0.00236093	8.93665233	0.03505505
João	37	1712.038	7.167960698	0.00306961	10.4489281	0.040677959
Francisco	41	1724.478	7.22004449	0.003426179	5.689435946	0.020394352
João	42	1848.051	7.737419927	0.003761246	4.761137667	0.016172685

0.23	**MJ/pkm**
0.07	**MJ/pkm**
0.14	**MJ/pkm**
0.11	**MJ/pkm**
0.27	**MJ/pkm**



Joana	34	1393.738	5.835302258	0.0022963	3.00762667	0.010296032

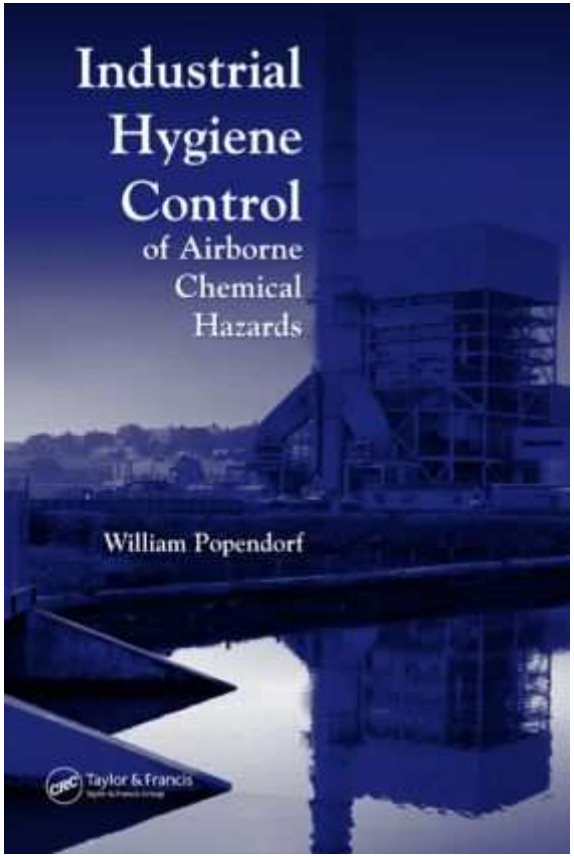
UK transport energy efficiency



Average values!!!!!

Should have standard deviation….

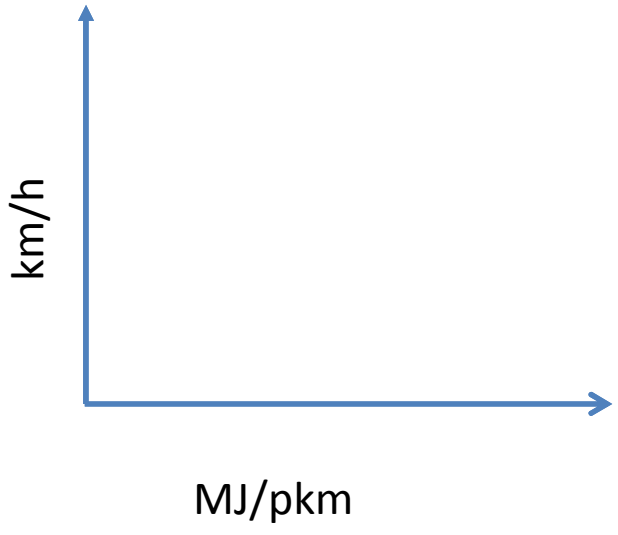
Biogenic CO_2

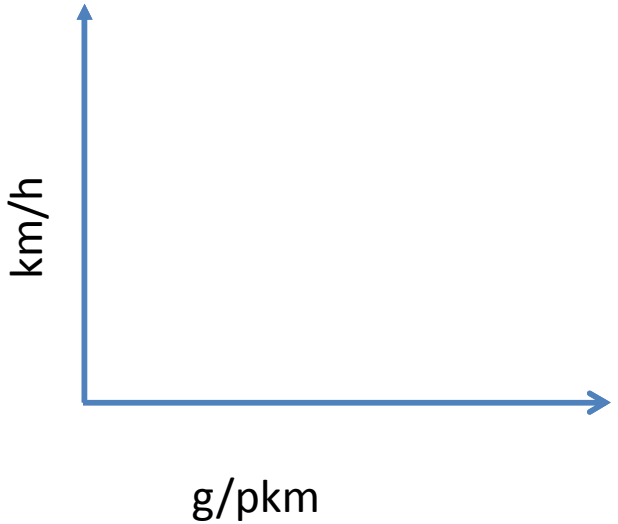


0.075 gCO2/MJ

Estimate your energy for regular walking (at least 3 repetitions of the measurements), in MJ/pkm, and speed (km/h). What would be your graph?

Excel file by e-mail

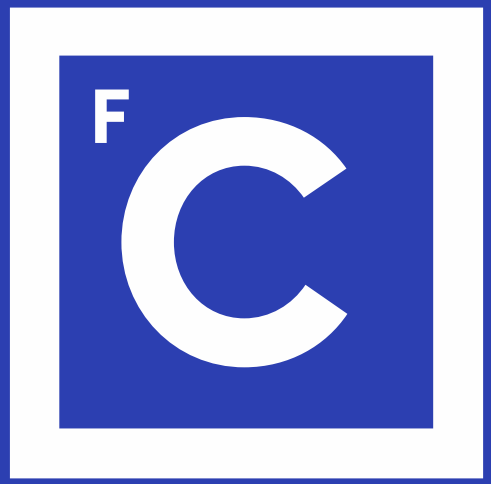




You learned….

- Share in final energy and emissions;
- Calculating energy baseline for mobility-walking;
- Biogenic emissions.

Obrigado



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