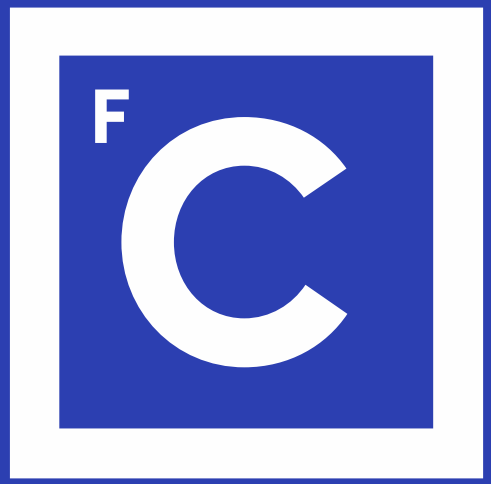


Ciências ULisboa

Faculdade
de Ciências
da Universidade
de Lisboa

DISCIPLINA MIEA 2018

Mobilidade Sustentável

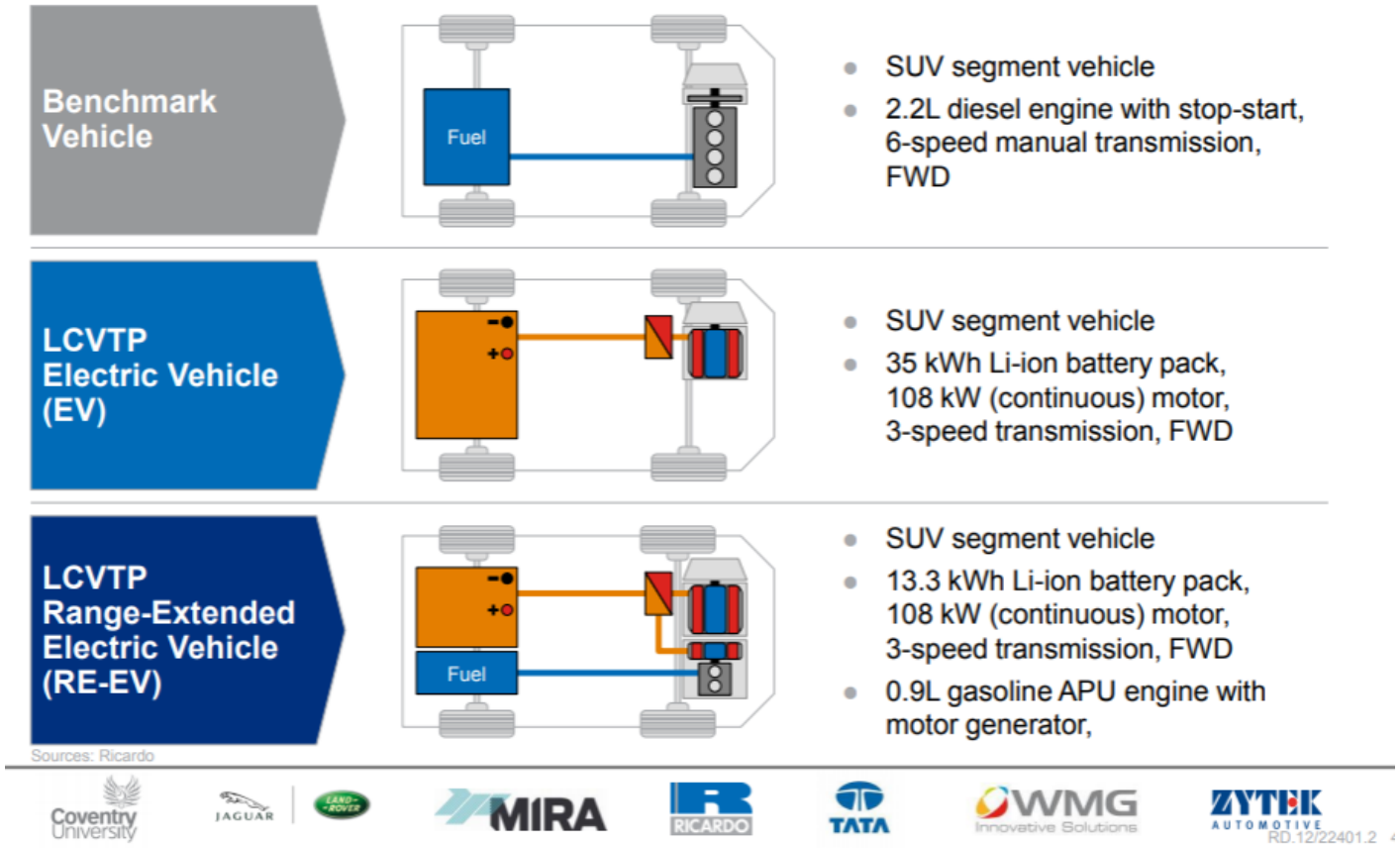
What is sustainable mobility?

Comparing transport systems??

Sustainable mobility indicators, Life cycle

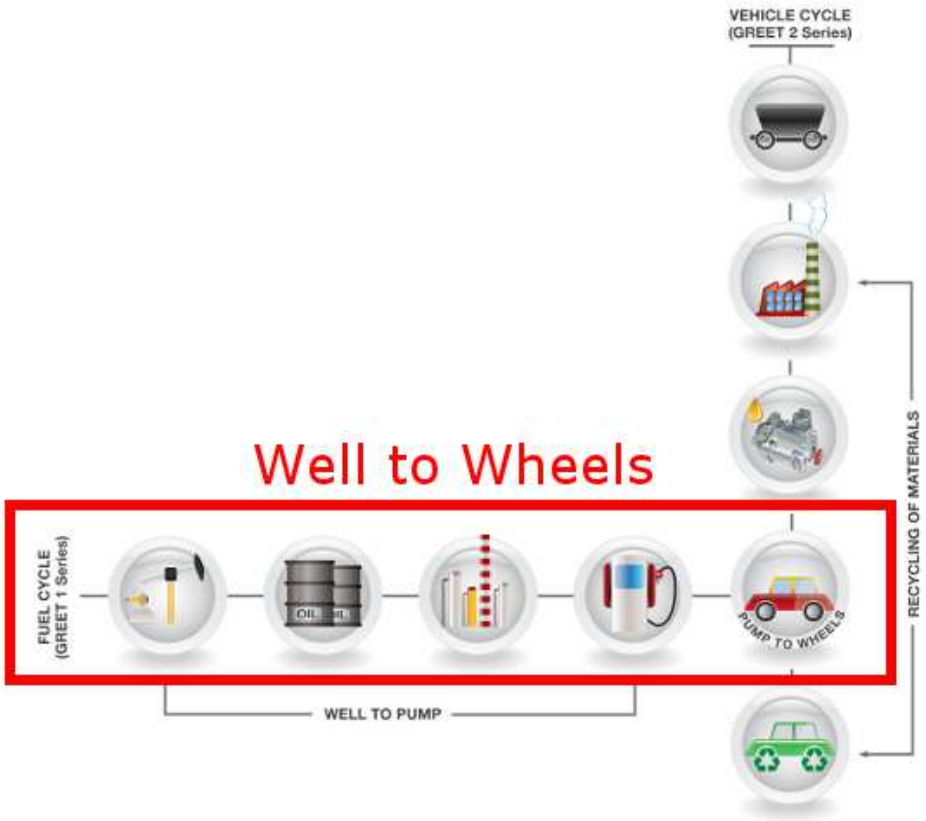
What is sustainable mobility?

Comparing transport systems?? Different vehicle technologies in the fleet

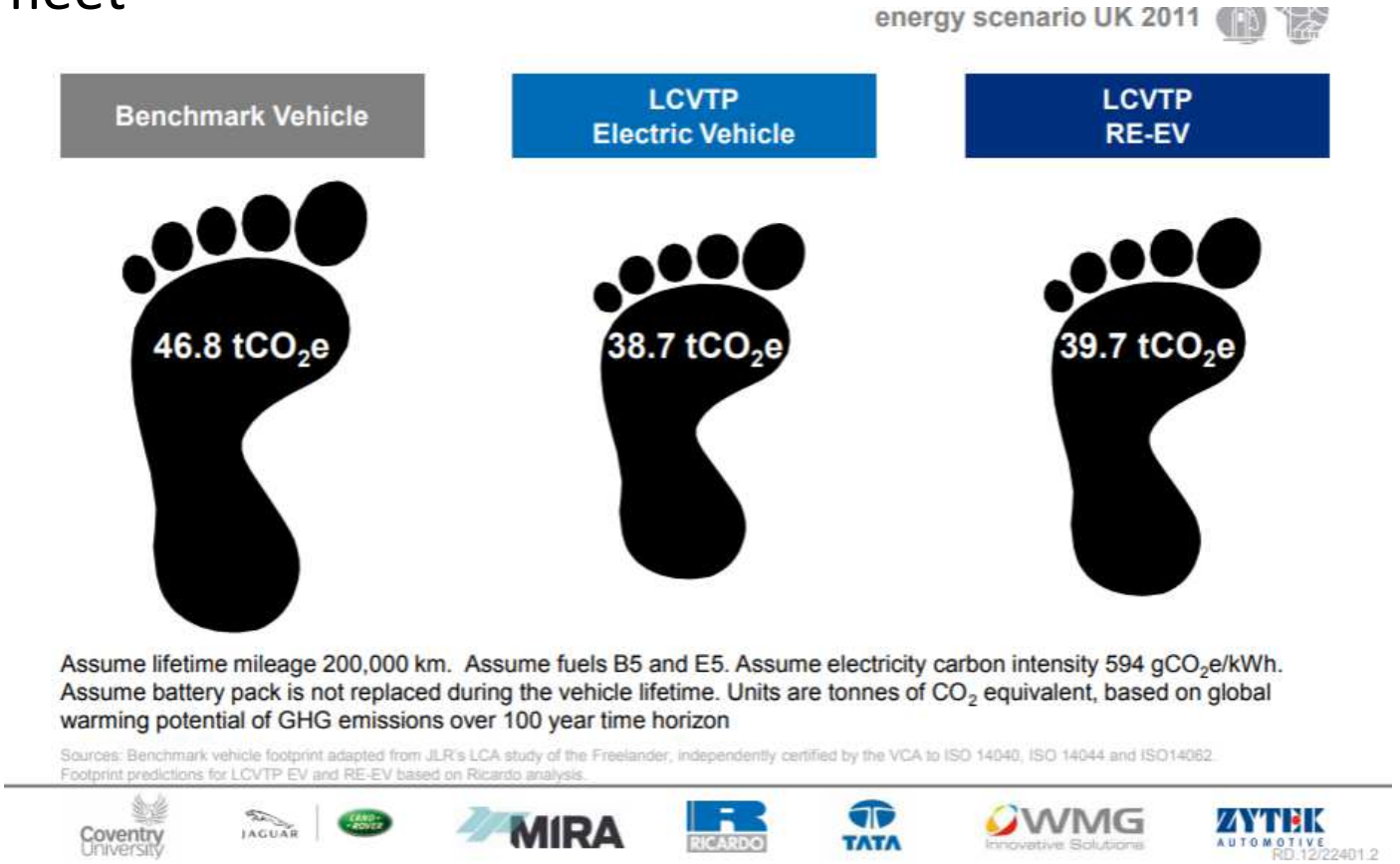


What is sustainable mobility?

Comparing transport systems?? Different vehicle technologies in the fleet- life cycle- global warming potential impact category



Comparing transport systems?? Different vehicle technologies in the fleet

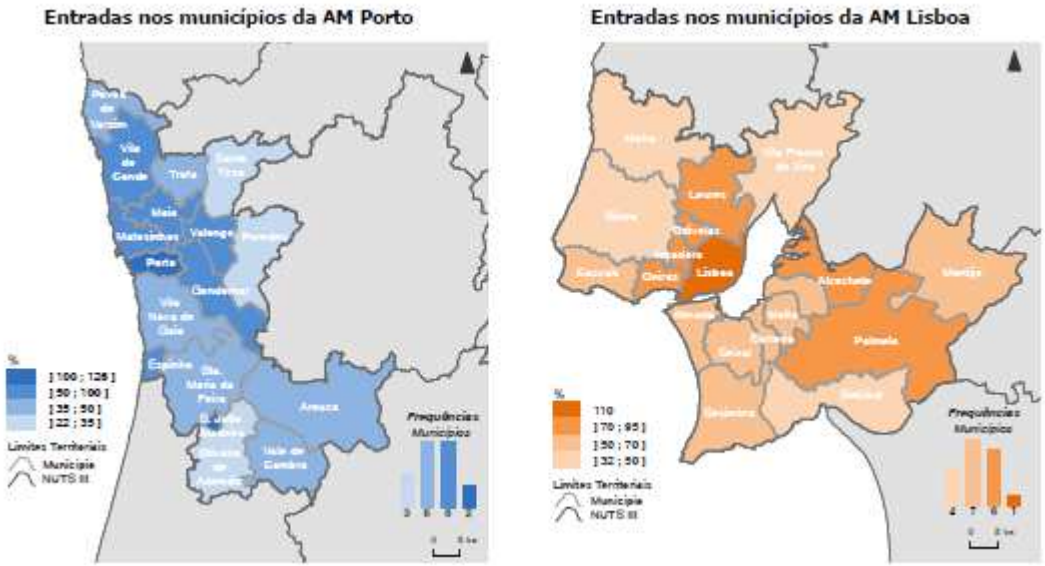


What is sustainable mobility?

Materials e.g. GREET (https://greet.es.anl.gov/)

Fuel WTT e.g. JRC (https://iet.jrc.ec.europa.eu/about-jec/sites/iet.jrc.ec.europa.eu.about-jec/files/documents/report_2014/wtt_appendix_4_v4a.pdf)

Lisbon versus Porto (metropolitan areas)



sustainable mobility????

In Cradle-to-wheels

Indicators

Indicator	Weight	Definition
CO_{2eq}	5	**Life cycle emissions from commuting in kg/capita/year (non-biogenic; WTW & CTW-materials)**
PM2.5	10	Annual hourly arithmetic average
NOx	10	Annual hourly arithmetic average
O_3	10	Annual hourly arithmetic average
Energy	5	**% fossil WTW & CTW-materials**

Minimum and maximum values of indicator scale

PM10 150 -10 ($\mu g/m^3$)

CO_2 7.5 - 0 (ton/capita/year)

NO_x 200- 0 ($\mu g/m^3$)

O_3 240-0 ($\mu g/m^3$)

Energy 100-0 (%)

Surveys

Exercise. Recent mobility survey 2017 Porto and Lisbon. Calculate the sustainable mobility index for each city. What can you say?

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~people per mode

Quadro 9

Voltar ao Índice

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

km per trip

AM Porto

	Duração média (minutos)	Distância média (km)
AM Porto	**21.8**	**10.1**
Automóvel - condutor	18.0	11.4
Automóvel - passageiro	17.6	11.4
Motociclo/ciclomotor	13.5	7.4
Autocarro (transporte público)	40.6	9.8
Comboio	57.6	31.0
Metropolitano	37.6	9.4
Barco	12.5	0.7
Táxi	19.4	8.7
Transporte escolar / empresa	32.8	23.5
A pé	24.5	2.3
Bicicleta	35.9	9.5
Outro/desconhecido	38.2	34.8

Nota: Exclui as deslocações internacionais

Surveys

Quadro 6

Voltar ao Índice

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

AM Porto

Unidade:10^3

	Deslocações		
	Total semanal	Dias úteis	SDF a)
AM Porto	**23,987.4**	**17,098.6**	**6,888.8**
Transporte individual	**16,546.7**	**11,372.4**	**5,174.3**
Automóvel - condutor	12,162.1	8,454.0	3,708.1
Automóvel - passageiro	4,061.4	2,687.8	1,373.7
Motociclo/ciclomotor	323.1	230.6	92.5
Transporte público ou coletivo	**2,670.4**	**2,282.1**	**388.3**
Dos quais:			
Autocarro	1,628.5	1,384.7	243.9
Comboio	190.2	168.6	21.6
Metropolitano	473.9	390.6	83.3
Modos suaves (a pé e bicicleta)	**4,536.9**	**3,268.1**	**1,268.7**
Outro/desconhecido	**291.1**	**57.5**	**233.5**

a) SDF - Sábados, domingos e Feriados

Number trips Per mode

Lisbon

BUS

→ Data MJ/pkm from sustainability report 1.6 MJ/pkm

CAR

→ Most sold vehicle, VCA info

0-100 km/h 14.5 s
European test cycle l/100km 5.6
1059 kg (2 MJ/km)

TRAIN

→ Data MJ/pkm from sustainability report 0.3 MJ/pkm

SUBWAY

→ Data 16.9 MJ/pkm from sustainability report

Porto

BUS

Data MJ/pkm from sustainability report 0.7 MJ/pkm

CAR

Most sold vehicle, VCA info

0-100 km/h 14.5 s
European test cycle l/100km 5.6
1059 kg (2 MJ/km)

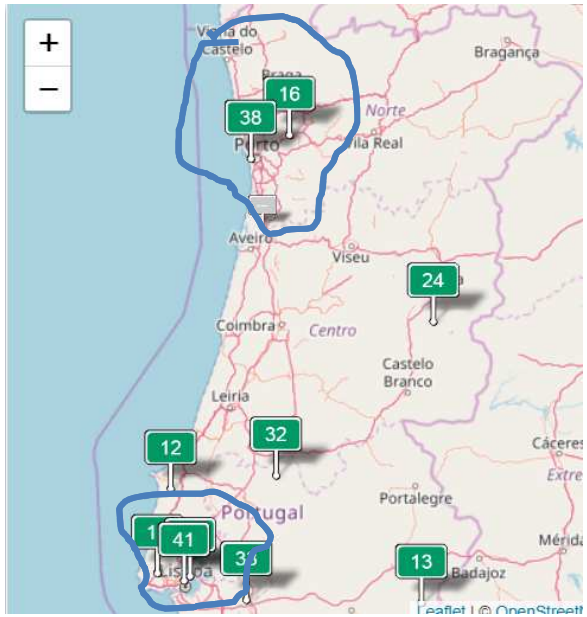
TRAIN

→ Data MJ/pkm from sustainability report 0.3 MJ/pkm

SUBWAY

→ Data 0.47 MJ/pkm from sustainability report (0.131 kWh/pkm)

AQS – QUALAR data (downloads section)



Maia	D.Manuel II-Vermoim	Urban	Traffic
Matosinhos	João Gomes Laranjo-S.Hora	Urban	Traffic
Porto	Francisco Sá Carneiro-Campanha	Urban	Traffic

Lisboa	Entrecampos	Urban	Traffic
Lisboa	Avenida da Liberdade	Urban	Traffic
Lisboa	Santa Cruz de Benfica	Urban	Traffic
Odivelas	Odivelas-Ramada	Urban	Traffic

Fleet impacts

AQS – QUALAR data (downloads section)

Lisboa Entrecampos Urban Traffic

Data (Hora UTC)	Dióxido de Enxofre µg/m3	Partículas < 10 µm µg/m3	Ozono µg/m3	Dióxido de Azoto µg/m3	Óxidos de Azoto µg/m3	Monóxido de Carbono mg/m3	Benzeno µg/m3	Monóxido de Azoto µg/m3	Partículas < 2.5 µm µg/m3
01/10/2017 00:00	0,000		69,060	6,640	7,500	0,154	0,2	0,570	
01/10/2017 01:00	0,070		66,450	6,910	8,540	0,160	0,2	1,060	
01/10/2017 02:00	0,180		64,950	5,540	6,750	0,160	0,2	0,790	
01/10/2017 03:00	0,730		61,160	7,540	10,680	0,148	0,1	2,040	
01/10/2017 04:00	0,990		60,570	4,790	5,920	0,142	0,1	0,740	
01/10/2017 05:00	1,330		55,530	8,690	13,250	0,151	0,1	2,970	
01/10/2017 06:00	2,270		52,110	10,800	12,660	0,154	0,1	1,210	
01/10/2017 07:00	2,160		48,110	13,360	16,650	0,168	0,1	2,140	
01/10/2017 08:00	2,310		45,740	15,830	23,370	0,183	0,2	4,920	
01/10/2017 09:00	2,720		52,910	13,050	20,060	0,189	0,2	4,570	
01/10/2017 10:00	3,550		56,550	16,280	24,880	0,206	0,2	5,610	
01/10/2017 11:00	3,260		67,230	14,320	20,890	0,203	0,4	4,280	
01/10/2017 12:00	0,390		68,670	30,410	54,460	0,270	0,5	15,690	
01/10/2017 13:00	1,190		82,660	22,580	31,730	0,229	0,4	5,970	
01/10/2017 14:00	0,930		87,450	17,720	23,080	0,209	0,3	3,500	
01/10/2017 15:00	0,000		77,960	19,800	25,220	0,206	0,4	3,530	
01/10/2017 16:00	0,000		64,840	24,610	31,890	0,215	0,4	4,750	
01/10/2017 17:00	0,000		49,360	31,950	41,360	0,218	0,4	6,130	
01/10/2017 18:00	0,000		49,560	25,920	32,250	0,197	0,4	4,130	
01/10/2017 19:00	0,000		52,330	16,800	21,980	0,183	0,3	3,380	
01/10/2017 20:00	0,000		35,770	40,130	54,200	0,331	0,4	9,180	
01/10/2017 21:00	0,000		38,530	38,140	46,670	0,252	0,9	5,560	

Fleet impacts

AQS – QUALAR data (downloads section)

2017	µg/m3	PM10	O_3	NOx
Lisboa	Entrecampos	32.7	44	40.9
Lisboa	Avenida da Liberdade	33.5	NA	60.4
Lisboa	Santa Cruz de Benfica	36.4	NA	38.2
Odivelas	Odivelas-Ramada	24.2	NA	26.8
Average		**31.7**	**44**	**41.6**

Fleet impacts

AQS – QUALAR data (downloads section)

2017 µg/m3	PM10	O_3	NOx
Maia D.Manuel II-Vermoim	14.7	48.1*	17.9
Matosinhos João Gomes Laranjo-S.Hora	20.7	42.8*	30.8
Porto Francisco Sá Carneiro-Campanha	19	39.6*	54
Average	18.1	43.5*	34.2

*nearest air quality monitoring station

Goal, scope and definition

Cradle-to-Wheels

Well-to-Wheels

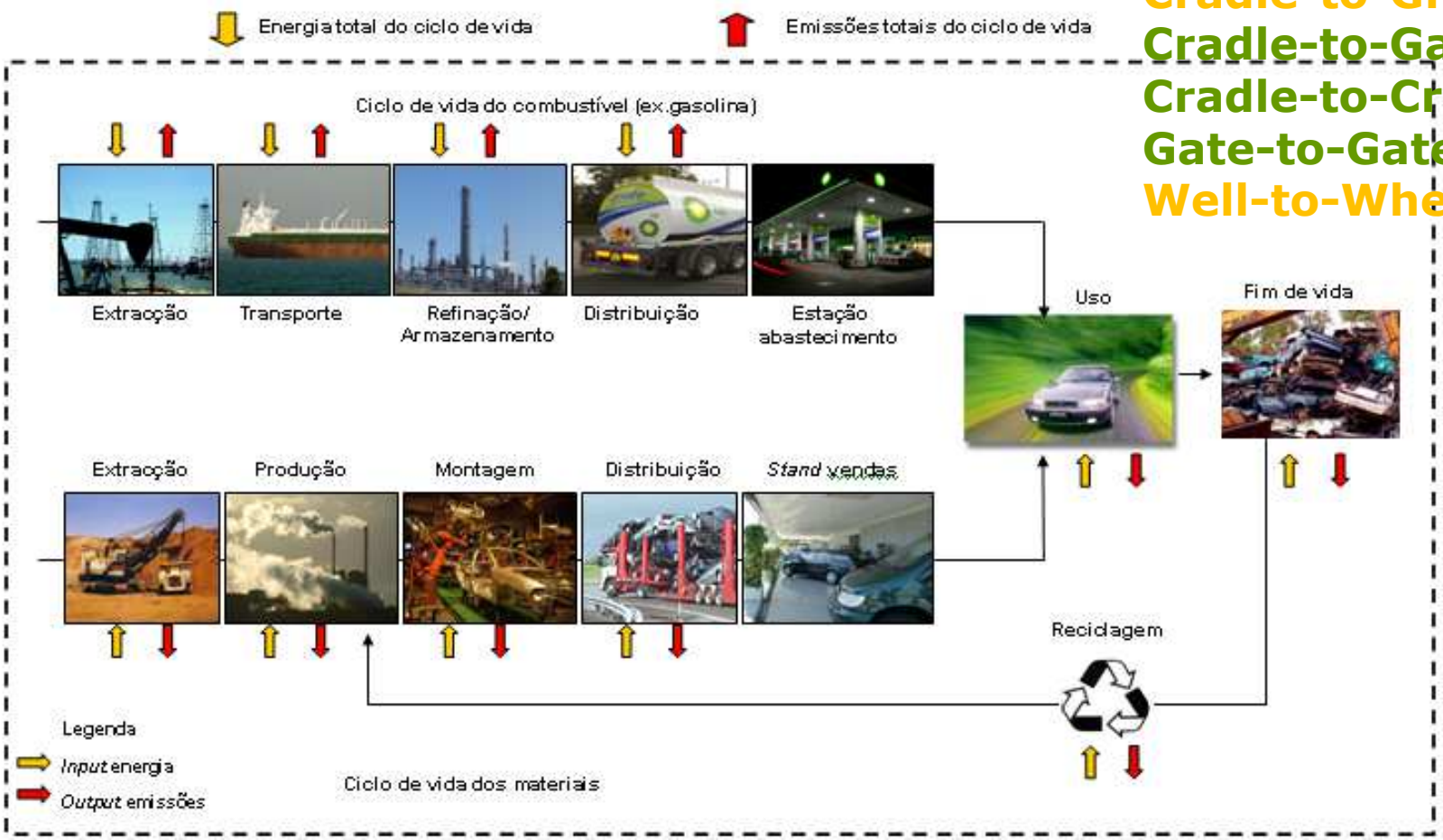
Cradle-to-Grave (CTG)

Cradle-to-Gate (CTG)

Cradle-to-Cradle (CTC)

Gate-to-Gate (GTG)

Well-to-Wheel (WTW)



To keep…..LCA static

WELL-TO-TANK Appendix 2 - Version 4a

European Commission

JRC TECHNICAL REPORTS

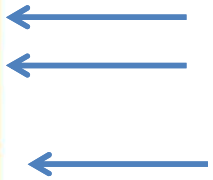
	MJ/MJ (% fossil)	gCO_2/MJ	gCH_4/MJ	gN_2O/MJ
gasoline	1.18 MJ/MJ (99% Fossil)	13.05	0.028	3.4E-5
diesel	1.2 MJ/MJ (99% Fossil)	14.62	0.0288	3.4E-5
electricity	3.07 MJ/MJ (EU average 2014, 85% fossil)	131.56	0.31	0.006

Energy sources for commuting w/o biogenic Well-to-pump

To keep…..LCA static

IPCC 5th report, GWP 100 years time horizon

Substance	AR1 (1990)	AR2 (1995)	AR3 (2001)	AR4 (2007)	AR5 (2013)
Carbon dioxide, fossil (CO_2)	1	1	1	1	1
Methane, fossil (CH_4)	21	21	23	25	28
Methane, biogenic (CH_4)	18.25	18.25	20.25	22.25	25.25
Dinitrogen monoxide (N_2O)	290	310	296	298	265
HCFC-141b	440	-	700	725	782
HFC-134a	1200	1300	1300	1430	1300
HCFC-22	1500	-	1700	1810	1760
HCFC-142b	1600	-	2400	2310	1980
CFC-11	3500	-	4600	4750	4660
CFC-12	7300	-	10600	10900	10200
Sulfur hexafluoride	-	23900	22200	22800	23500



To keep…..LCA static

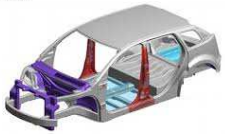
WELL-TO-TANK Appendix 2 - Version 4a

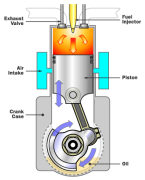
JRC TECHNICAL REPORTS

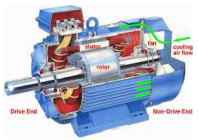
	gCO_{2eq}/MJ
gasoline	13.05+**28***0.028 + **265***3.4E-5 = 13.8
diesel	14.62+**28***0.0288 + **265***3.4E-5= 15.4
electricity	131.56+**28***0.31 + **265***0.006 = 141.8

IPCC 5th report, GWP 100 years time horizon

To keep…..LCA static







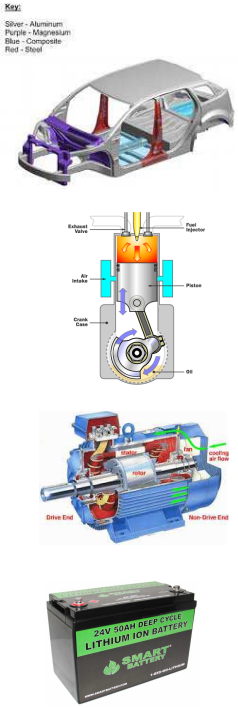
Main Materials extraction & production energy/CO_{2eq}

	MJ/kg - % fossil	$kgCO_2/kg$	$kgCH_4/kg$	kgN_2O/kg
metal/steel	39.4 – 95%	4.778825	0.005204	3.11518E-05
plastic (HDPE)	44.25 – 89%	3.538649	0.005872	4.28658E-05
aluminium	175.7- 78%	8.815898	0.012619	9.96822E-05

Argonne NATIONAL LABORATORY

To keep…..LCA static

Main Materials extraction & production energy/CO_{2eq}



	$kgCO_{2eq}/kg$
metal/steel	4.778825+**28***0.005204+**265***3.11518E-05=**4.93**
plastic (HDPE)	3.538649+**28***0.005872+**265***4.28658E-05=**3.71**
aluminium	8.815898+**28***0.012619+**265***9.96822E-05=**9.20**

Argonne NATIONAL LABORATORY

To keep…..LCA static

Materials	
metal/steel	7.5 kg
plastic (HDPE)	1 kg
aluminium	1.5 kg
Total	**10 kg**

Lifetime 15 000 km (20 years)

Materials	
metal/steel	6600 kg
plastic (HDPE)	1 kg
aluminium	2000 kg
Total	**9 000 kg**

Lifetime 720 000 km (12 years)

Materials	
metal/steel	44647 kg
plastic (HDPE)	9550 kg
aluminium	30805 kg
Total	**85 000 kg**

Lifetime 5 400 000 km (30 years)

To keep…..LCA static

metal/steel	91.92 kg
aluminium	15 kg
plastic (HDPE)	15.3 kg
Total	**130 kg**

Lifetime 50 000 km (14 years)

metal/steel	635 kg
aluminium	10 kg
plastic (HDPE)	116 kg
Total	**1059 kg**

Lifetime 150 000 km (14 years)

To keep…..LCA static

Example motorbikes

Well-to-Tank gasoline: 1.18 MJ/MJ_{final} = 1.17 MJ_{fossil}/MJ_{final} + 0.01 MJ_{ren}/MJ_{final}

Final energy consumption: 35 g/km*10^{-3}kg/g*(44 MJ/kg)= **1.54 MJ_{final}/pkm** (1 driver)

Tier 1 default

Lower heating value of the fuel

WTW = 1.54 MJ_{final}/pkm *1.17 MJ_{fossil}/MJ_{final} + 1.54 MJ_{final}/pkm * 0.01 MJ_{ren}/MJ_{final} = **1.81 MJ/pkm**

1.8 MJ_{fossil}/pkm

To keep…..LCA static

Example motorbikes

Well-to-Tank gasoline: 13.8 g/MJ_{final}

Final energy consumption: 35 g/km*10^{-3}kg/g*(44 MJ/kg)= **1.54 MJ_{final}/pkm** (1 driver)
TTW = 8*44/(8*12+18)* 35 g/km= 108 g/pkm

Tier 1 default

Lower heating value of the fuel

WTW = 1.54 MJ_{final}/pkm *13.8 g/MJ_{final} +108 g/pkm = 129 **g$CO2_{eq}$ /pkm**

To keep…..LCA static

Example motorbikes

Materials (extraction & production)

metal/steel	91.92 **kg***[39.4*0.95 **MJ_{Fossil}/kg** + 39.4*0.05 **MJ_{ren}/kg**]
aluminium	15 **kg** *[175.7*0.78 **MJ_{Fossil}/kg** + 175.7*0.22 **MJ_{ren}/kg**]
plastic (HDPE)	15.3 **kg** *[44.25*0.89 **MJ_{Fossil}/kg** + 44.25* 0.11 **MJ_{ren}/kg**]

0.14 **MJ/pkm** (1 driver, 50 000 km)

0.12 **MJ_{fossil}/pkm**

To keep…..LCA static

Example motorbikes

Materials (extraction & production)

metal/steel	91.92 **kg***[4.93 k**gCO2$_{eq}$/kg**]
aluminium	15 **kg** *[9.2 k**gCO2$_{eq}$/kg**]
plastic (HDPE)	15.3 **kg** *[3.71 k**gCO2$_{eq}$/kg**]

13 gCO2$_{eq}$/pkm (1 driver, 50 000 km)

To keep…..LCA static

Example motorbikes

Overall CO2eq/capita/year?

(Well-to-Tank) + (Tank-to-Wheels) + Materials (extraction & production)

pkm year(from survey)*(**21 $gCO2_{eq}$/pkm**+**108 $gCO2_{eq}$/pkm**+0.0**13 $gCO2_{eq}$/pkm**)/capita

Lisbon

pkm motorbike = 11.7 km*270.9 p/week*48 week= 152 137 pkm/year

Capita = 2.57 Million people

To keep…..LCA static

Example motorbikes

% fossil energy

(Well-to-Wheels) + Materials (extraction & production)

$$\frac{1.8\ MJ_{fossil}/pkm + 0.12\ MJ_{fossil}/pkm}{1.81\ MJ/pkm + 0.14\ MJ/pkm} * 100\% = 98\%$$

P#3

Calculate and compare the ranking of Lisbon commuting with Porto commuting according to the new defined sustainable mobility indicator (follow example from motorbike and add all other transport modes).
What can you say about which has the most sustainable mobility??

Deliver excel until 14 December.

Indicators

Indicator	Weight	Definition
CO_{2eq}	5	**Life cycle emissions from commuting in kg/capita/year (non-biogenic; WTW & CTW-materials)**
PM2.5	10	Annual hourly arithmetic average
NOx	10	Annual hourly arithmetic average
O_3	10	Annual hourly arithmetic average
Energy	5	**% fossil WTW**

Minimum and maximum values of indicator scale

PM10 150 -10 ($\mu g/m^3$)

CO_2 7.5 - 0 (ton/capita/year)

NO_x 200- 0 ($\mu g/m^3$)

O_3 240-0 ($\mu g/m^3$)

Energy 100-0 (%)

What is sustainable mobility?

$$I_{sust\ mob} = I_{CO2} + I_{NOx} + I_{O3} + I_{Energy}$$

I_{CO2}

I_{NOx}

I_{O3}

I_{Energy}

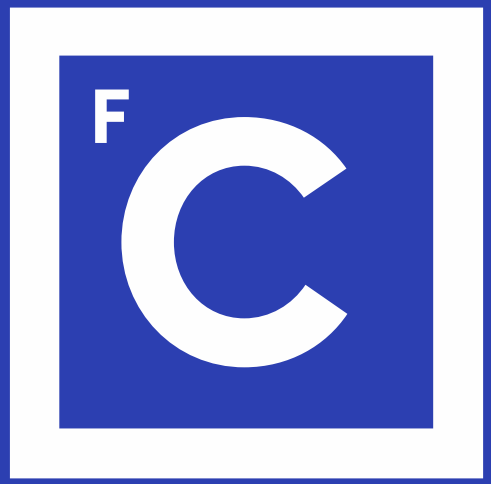
Previous

Lisboa	CO2	4.597679
	PM10	8.45
	NOx	7.92
	O3	8.166667
	Energy	1.205949
	Total	**30.34029**
Porto	CO2	4.597978
	PM10	9.419048
	NOx	8.288333
	O3	8.1875
	Energy	0.8997
	Total	**31.39256**

WTW Well-to-Wheels?
Materials cradle-to-gate?

How stays the new ranking??

Obrigado



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