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ULisboa

Faculdade
de Ciências
da Universidade
de Lisboa

DISCIPLINA MIEA 2019

Sustainable Mobility

Energy and emissions

Home ⟷ **Work/ University**

on a regular basis

Commuting by motorized or soft modes

Emissions

Energy

What is sustainable mobility?

Comparing transport systems??

Sustainable mobility indicators

What is sustainable mobility?

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

?

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Global impacts

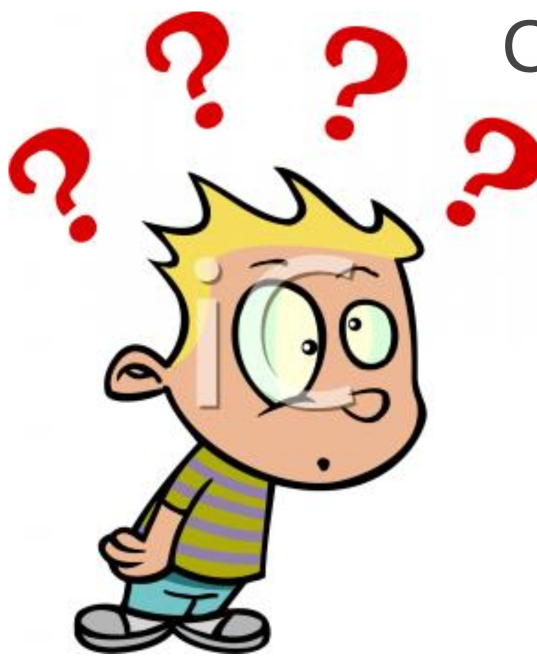
$$I_{\text{sust mob}} = I_{CO2} + I_{NOx} + I_{PM} + I_{Energy}$$

Carbon footprint

Global Warming potential
Impact category of LCA

WTW+CTG

Per capita.....



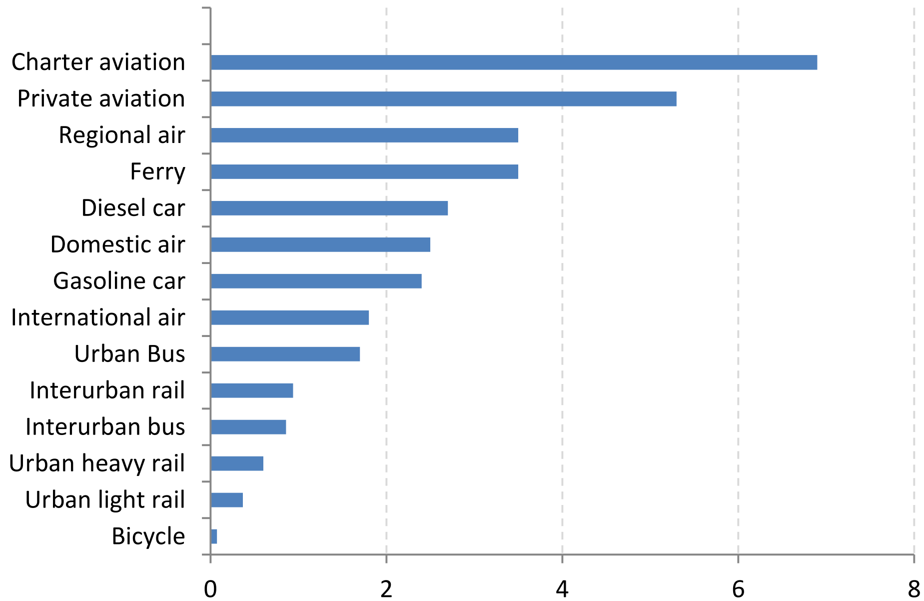
Global

CO_2 equivalent or GHG

Life cycle

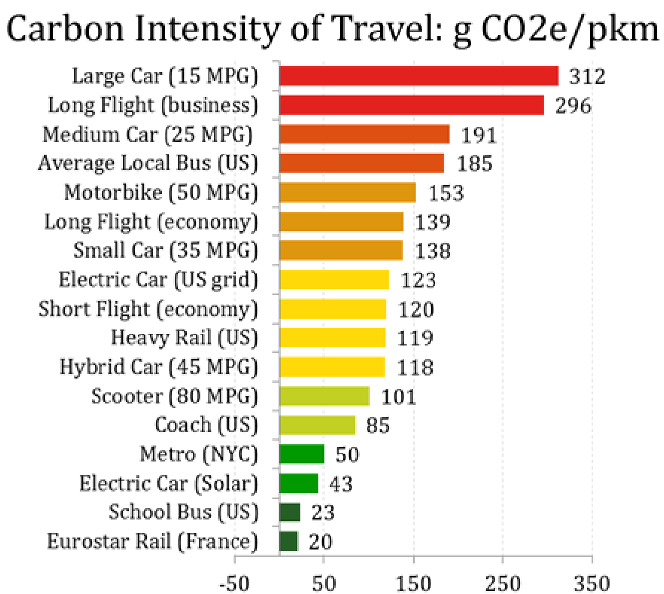
Typical energy consumption by mode

MJ/(p*km)



Australia, Lenz (1999)

Fuel use -TTW



US, 2005, http://shrinkthatfootprint.com/shrink-your-travel-footprint

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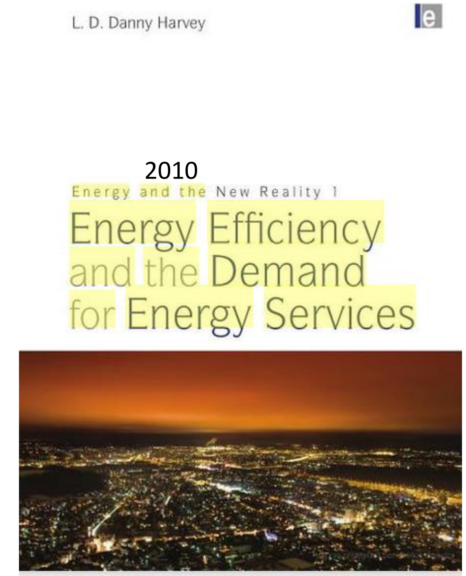
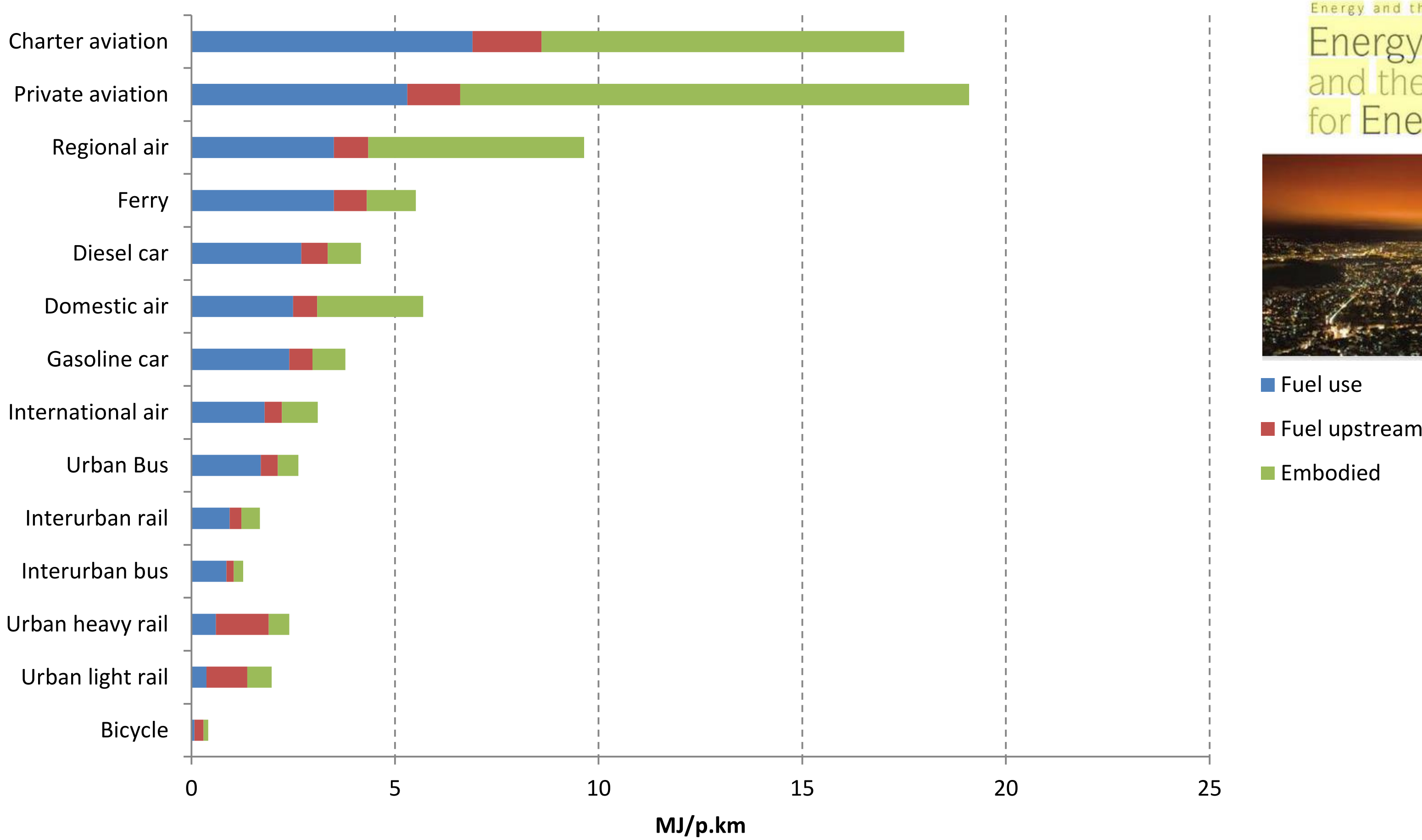
Life cycle

Typical energy consumption by mode in book





To keep.....

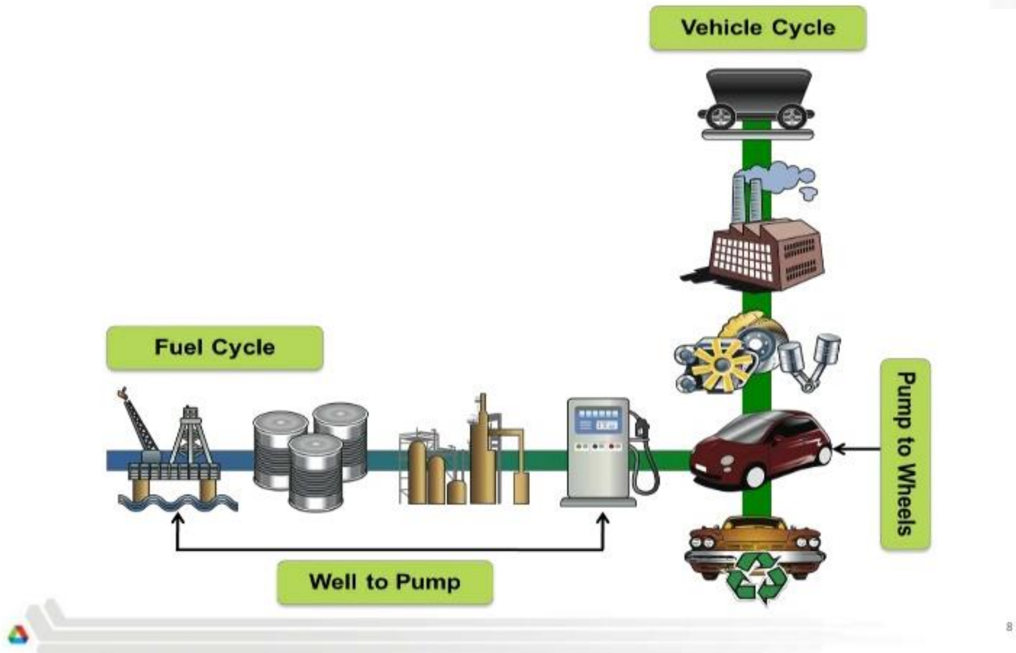
Fuel WTT

Diesel 1.2 MJ/MJ
15.4 g/MJ

J R C T E C H N I C A L R E P O R T S

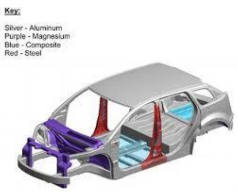
Production
Assembly
Dismantling
Recycling

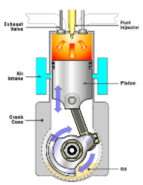
ICE car 75 GJ (0.5 MJ/km)
4.8 ton for 150000 km lifetime (32 g/km)

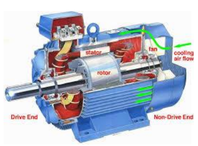


To keep.....LCA static

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)

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

Lifetime 720 000 km (12 years)

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)

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Lisbon fleet 30 boats

Classe Damen – 8 navios

Catamarans com capacidade para 600 passageiros.
Idade média: 11 anos

Classe Austal – 2 navios

Catamarans com capacidade para 292 passageiros.
Idade média: 13 anos

Navio Fantasia

Catamaran com capacidade para 150 passageiros.
Idade média: 16 anos

Classe Algés – 7 navios

Catamarans com capacidade para 496 passageiros.
Idade média: 18 anos

Classe S. Jorge – 1 navio

Monocascos com capacidade para 1000 passageiros.
Idade média: 23 anos

Classe Cacilhense – 6 navios

Monocascos com capacidade para 476 passageiros.
Idade média: 34 anos

Classe Alemã – 1 navio

Monocasco com capacidade para 280 passageiros.
Idade média: 56 anos

Ferry catamaran – 2 navios

Ferries com capacidade para 360 passageiros e 29 veículos.
Idade média: 5 anos

Ferry monocasco - 2 navios

Ferries com capacidade para 346 passageiros e 24 veículos.
Idade média: 57 anos

To keep.....LCA static

https://www.archives-ouvertes.fr/hal-01302624/document
Aluminum Hull weight (kg) 10 855 Lifetime 60 years
140 ton CO2eq
18 m long/60 passenger

Transtejo SofLusa 30 catamarã fleet
https://web3.cmvm.pt/sdi/emitentes/docs/fsd440754.pdf
49 m long/600 passenger

Pkm/year = 106 702 107

Average Hull ~ 300 ton aluminum (300 000 kg*9.2 kg CO2eq/kg *30 catamarã/60 years)= 46 tonCO2eq/year

OR 0.43 gCO_{2eq}/PKM

DAMEN FAST FERRY 4212
https://products.damen.com/en/ranges/fast-ferry/damen-fast-ferry-4212
https://e-lass.eu/media/2016/08/Cost-and-energy-assessment-of-a-high-speed-ship.pdf

To keep…..LCA static

4 032 713 pkm in 2017

Lifetime 40 years

https://www.cp.pt/StaticFiles/Institucional/2_gestao_sustentavel/1_RelatoriosSustentabilidade/relatorio-de-sustentabilidade-2017.pdf

https://www.cp.pt/institucional/pt/cultura-ferroviaria/frota-material-circulante

152 317 kg (4 carriage); fleet 374 trains (42 in Lisbon)

https://www.alstom.com/sites/alstom.com/files/2018/07/14/m-csr-18-Environmental%20Product%20Declaration%20-%20Coradia%20Polyvalent.pdf?epslanguage=en-GB

To keep.....LCA static

4 032 713 000 pkm in 2017

1 270 474 000pkm in 2017 Lisbon

Lifetime 40 years

152 317 kg *42 trains*(0.53steel*4.93 kgCO2eq/kgsteel +
+0.11HDPE*3.71 kgcO2eq/kgHDPE+ 0.36aluminum*9.2 kgCO2eq/kgaluminum)/40/1270474
= 0.79 g CO2eq/pkm

To keep.....LCA static

Example motorbikes

Materials (extraction & production)

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

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

0.12 $\mathbf{MJ_{fossil}/pkm}$

To keep…..LCA static

Example motorbikes

Materials (extraction & production)

metal/steel	91.92 **kg***[4.93 k**g**$\mathbf{CO2_{eq}}$**/kg**]
aluminium	15 **kg** *[9.2 k**g**$\mathbf{CO2_{eq}}$**/kg**]
plastic (HDPE)	15.3 **kg** *[3.71 k**g**$\mathbf{CO2_{eq}}$**/kg**]

13 g$\mathbf{CO2_{eq}}$**/pkm** (1 driver, 50 000 km)

To keep.....LCA static

Table 1. Studies on electric vehicle battery production emissions

Authors	Year	Battery production emissions (kg CO_2e/kWh)	Additional notes
Messagie[a]	2017	56	Assumes vehicle with 30 kWh battery constructed in the European Union, finding that BEVs will have lower life-cycle emissions than a comparable diesel vehicle when operated in any country in Europe.
Hao et al.[b]	2017	96-127	Uses China grid for battery manufacturing. Finds substantial differences between battery chemistries. Batteries produced in U.S. create 65% less GHGs.
Romare & Dahllöf[c]	2017	150-200	Reviews literature, concluding manufacturing energy contributes at least 50% of battery life-cycle emissions. Assumes battery manufacturing in Asia.
Wolfram & Wiedmann[d]	2017	106	Models life-cycle emissions of various powertrains in Australia. Manufacturing inventories come primarily from ecoinvent database.
Ambrose & Kendal[e]	2016	194-494	Uses top-down simulation to determine GHG emissions for electric vehicle manufacturing and use. Manufacturing process energy represents 80% of battery emissions. Assumes manufacturing grid representative of East Asia.
Dunn et al.[f]	2016	30-50	Uses bottom-up methodology, with U.S. electricity used for manufacturing.
Ellingsen, Singh, & Strømman[g]	2016	157	BEVs of all sizes are cleaner over a lifetime than conventional vehicles, although it may require up to 70,000 km to make up the manufacturing "debt."
Kim et al.[h]	2016	140	Study based on a Ford Focus BEV using real factory data. Total manufacturing of BEV creates 39% more GHGs than a comparable ICE car.
Peters et al.[i]	2016	110 (average)	Reveals significant variety in carbon intensities reported across literature based on methodology and chemistry.
Nealer, Reichmuth, & Anair[j]	2015	73	Finds that BEVs create 50% less GHGs on a per-mile basis than comparable ICEs, and manufacturing (in U.S.) is 8%-12% of life-cycle emissions.
Majeau-Bettez, Hawkins, & Strömman[k]	2011	200-250	Uses combined bottom-up and top-down approach. Different battery chemistries can have significantly different effects.

To keep…..LCA static

Nissan Leaf 40 kWh…..150 000 km

……. 40 kWh * (max table) = 8 g/km

……. 40 kwh * (min table) = 132 g/km

To keep.....LCA static

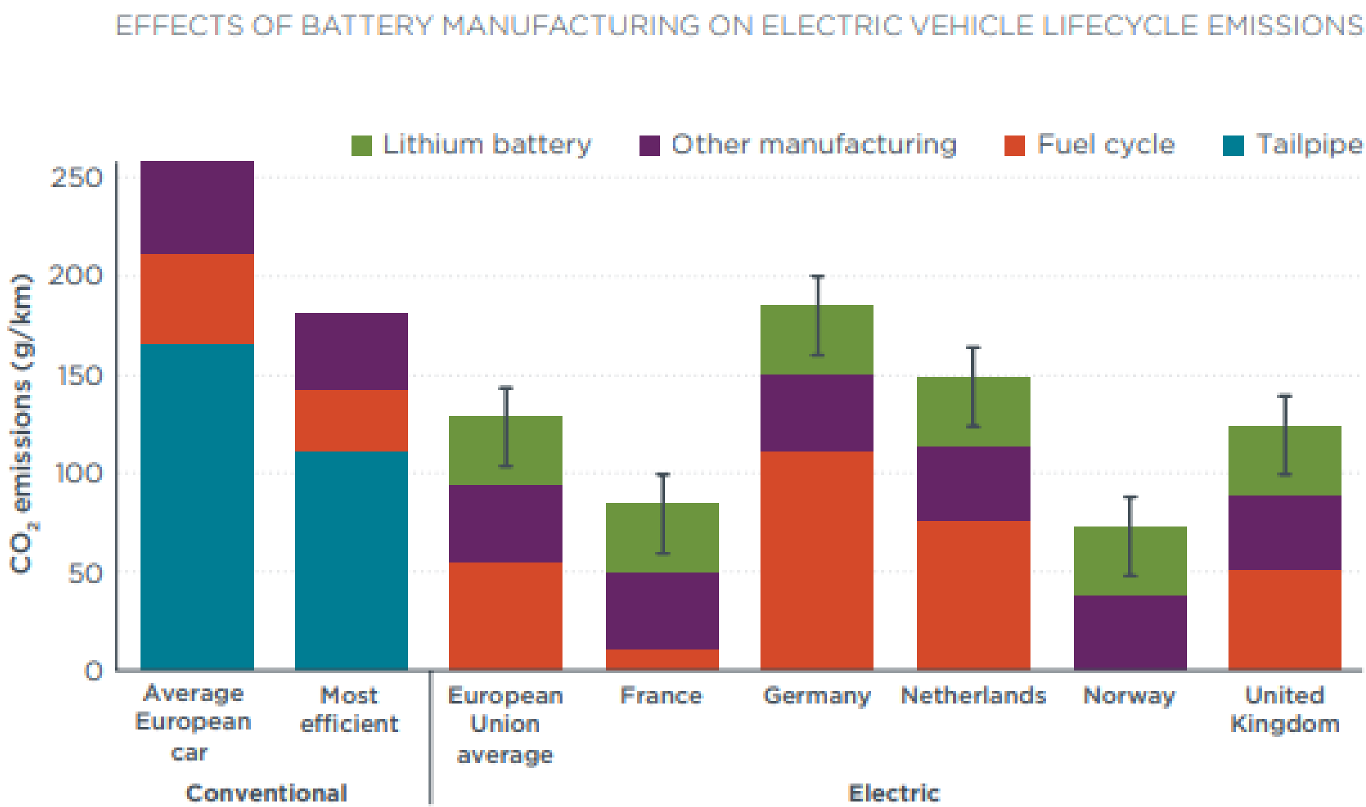
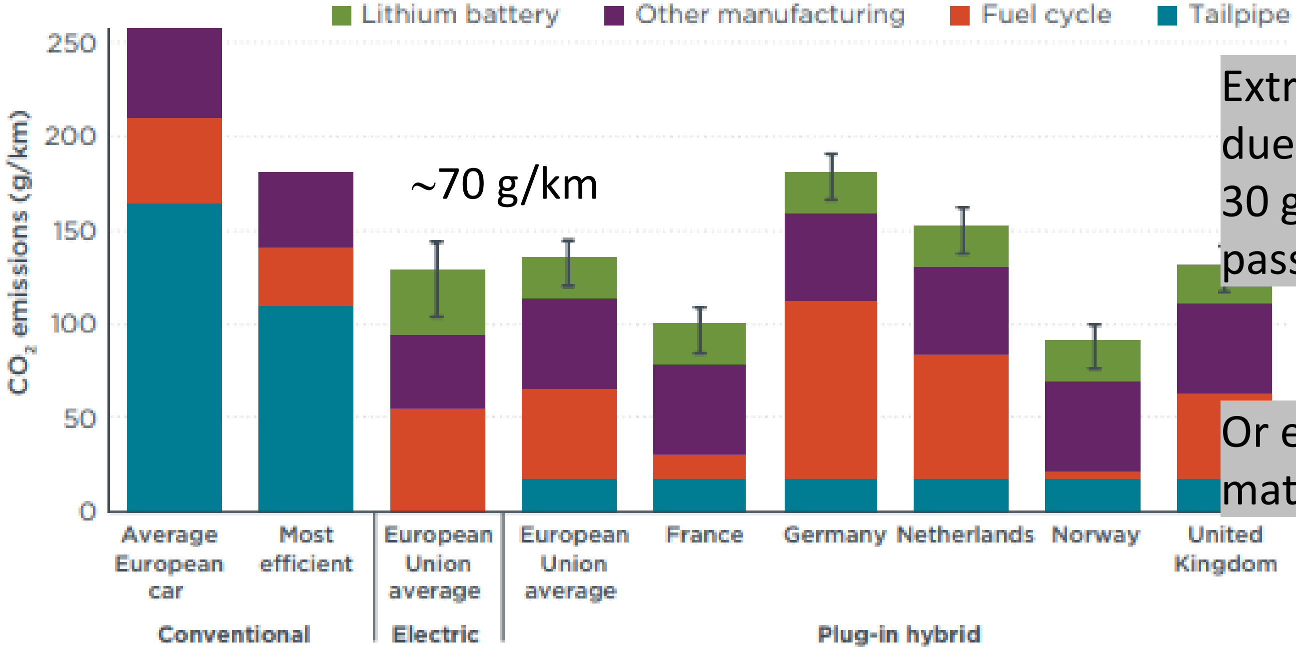


Figure 1. Life-cycle emissions (over 150,000 km) of electric and conventional vehicles in Europe in 2015.

https://theicct.org/sites/default/files/publications/EV-life-cycle-GHG_ICCT-Briefing_09022018_vF.pdf

To keep…..LCA static

~40 g/km



~70 g/km

Extra CO_2 emissions due to manufacturing 30 g/km for passenger car

Or extra in 75% in materials e-bus

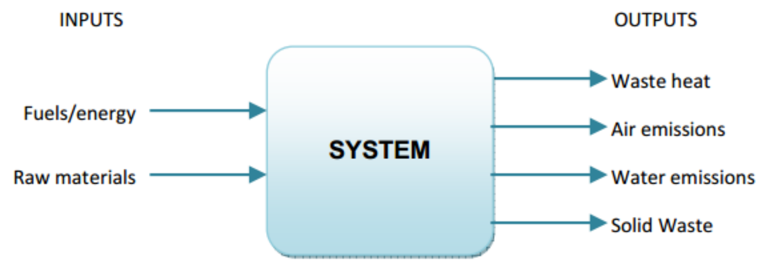
Figure 2. Comparison of life-cycle greenhouse gas emissions in conventional, electric, and plug-in hybrid vehicles in various European markets.

https://theicct.org/sites/default/files/publications/EV-life-cycle-GHG_ICCT-Briefing_09022018_vF.pdf

Inventory

For car materials…..e.g.

Using GREET



1) Summary of Energy Consumption and Emissions: GJ or grams per-vehicle lifetime
1.1) ICEV: Conventional Material

300 000 km

	GJ or grams per vehicle lifetime					Percentage of each stage			
	Components	ADR	Batteries	Fluids	Total	Components	ADR	Batteries	Fluids
Total energy	69.278	11.015	3.691	12.211	96.196	72.0%	11.5%	3.8%	12.7%
Fossil fuels	62.345	8.367	2.590	12.064	85.366	73.0%	9.8%	3.0%	14.1%
Coal	17.908	2.669	1.302	0.308	22.188	80.7%	12.0%	5.9%	1.4%
Natural gas	32.907	5.118	1.005	2.163	41.192	79.9%	12.4%	2.4%	5.3%
Petroleum	11.530	0.580	0.283	9.593	21.987	52.4%	2.6%	1.3%	43.6%
CO2	4,507,794	752,357	195,092	701,563	6,156,806	73.2%	12.2%	3.2%	11.4%
CH4	8803.870	1210.898	367.990	1143.375	11526.133	76.4%	10.5%	3.2%	9.9%
N2O	59.009	12.609	4.118	5.466	81.201	72.7%	15.5%	5.1%	6.7%
GHGs	4,727,750	783,940	204,774	729,479	6,445,943	73.3%	12.2%	3.2%	11.3%

gCO2eq per 1 diesel car 4.8 ton (32 g/km) 150 000 km

gCO2eq per 1 eletric car 7.2 ton (47.8 g/km) 150 000 km

Extra 50%

Example

Exercise 5: Take the exercise 2 community of 10 people (they get richer…). They now prefer car. What would be the yearly impact of materials CO_{2eq} if:

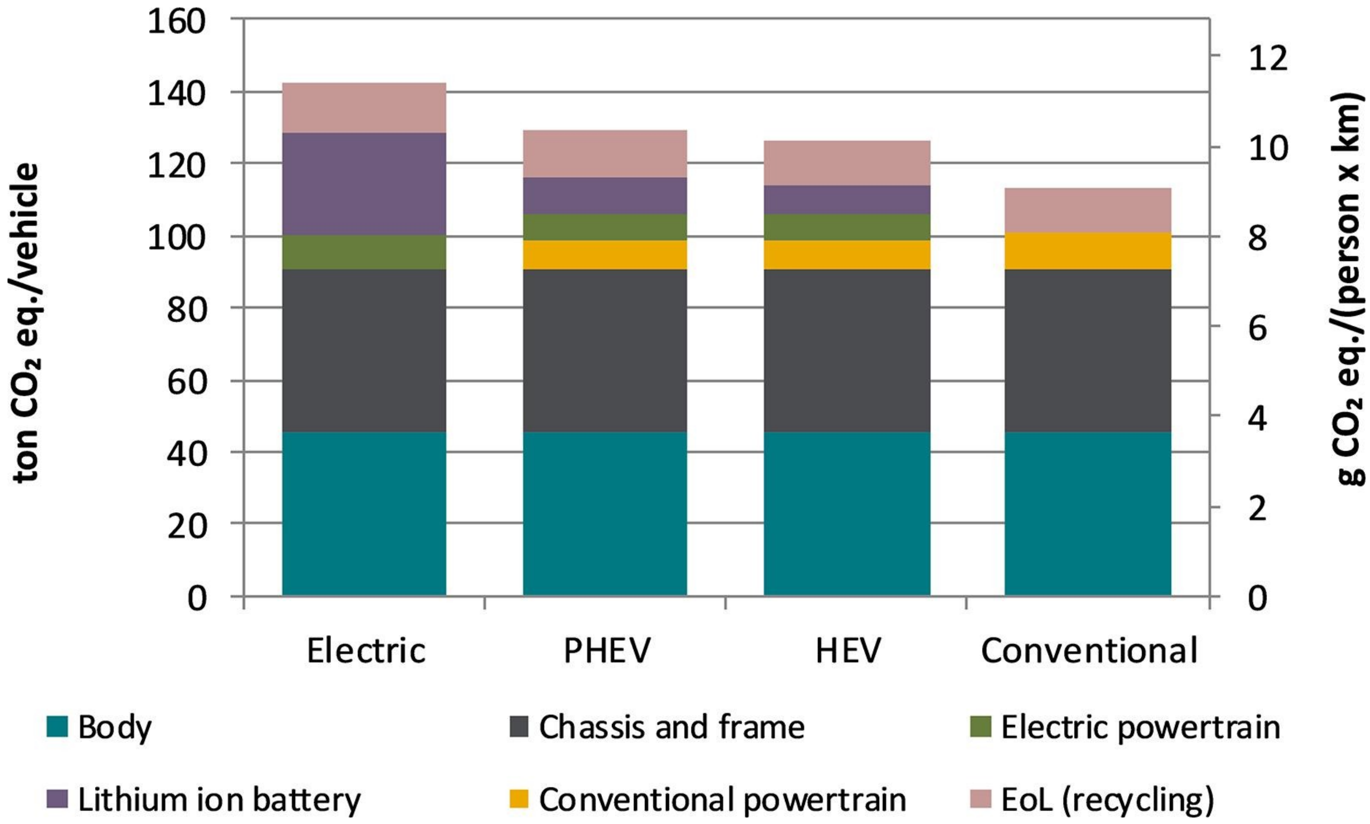
Weekday One-way trip: 20% walk 2 km; 20% bus 2 km; 60% car 2 km

i) Conventional ICE technology

ii) Electric based technology

Example

https://www.sciencedirect.com/science/article/pii/S1361920919302792



Example

32 passenger in capacity 105 passenger (16 p/km)

Route 7.6 km each way

average speed of 18 km/h, for 65 000 km per year

12 years means (65000*12= 780 000 km lifetime and 780 000*16 =12.5 million person-km)

110 kWh/100 km

https://www.sciencedirect.com/science/article/pii/S1361920919302792

Example

Materials Conventional ICE technology

8 gCO_{2eq}/pkm

35 gCO_{2eq}/pkm

Example

8 gCO_{2eq}/pkm*2p*2km*2*5day/week*48week/year = 15 360 g CO2eq/year (15.4 kg CO2eq in a year due to embodied materials)

40 gCO_{2eq}/pkm 6p*2km*2*5day/week*48week/year = 230 400 g CO2eq/year (230.4 kg due to embodied materials)

Example

- **TTW direct fuel combustion (fuel consumption from reports)**

1.4 MJ/pkm*74 gCO_2/MJ*2*2*2*5*48 = 198 912 gCO_2/year

1.6 MJ/pkm*73 gCO_2/MJ *6*2*2*5*48 = 672 768 gCO_2/year

- **WTT emissions of producing and transporting fuel**

15.2 gCO2eq/MJ*1.4* 2*2*2*5*48 = 40 857

14 gCO2eq/MJ*1.6* 6*2*2*5*48 = 129 024

Example

Materials e- technology

E-bus

10.5 gCO_{2eq}/pkm*2p*2km*2*5day/week*48week/year = 20 160 g CO2eq/year (20.2 kg CO2eq in a year due to embodied materials)

E-car

60 gCO_{2eq}/pkm 6p*2km*2*5day/week*48week/year = 345 600 g CO2eq/year (345.6 kg due to embodied materials)

Example

e- technology

- **TTW direct fuel combustion**

Zero emission vehicle

- **WTT emissions of producing and transporting fuel**

205 gCO2eq/kWh* 0.04 kWh/pkm * 2*2*2*5*48 = 157 44

205 gCO2eq/kWh* 0.14kWh/pkm * 6*2*2*5*48 = 165 312

Example

kg CO_{2eq} Non-biogenic

TTW	872	0
WTT	169	181
Embodied materials	245	366


1 bus 6 car


E-bus E-car

Example

Overall kg CO_{2eq} Non-biogenic

1286

547

1 bus 6 car

E-bus E-car

Only looking to GWP or CO_{2eq} we can say that e-vehicles have positive impact
And, also, air quality ZEV-Zero emission vehicle

……739 kg CO_{2eq} less

Example

Alternative…….Car pooling

Difference: 50% materials in car or **130 kg CO2eq/year** less

1 bus 6 car 1 bus 2 car




Example

Not accounting infrastructure of chargins versus gas stations….

You learned....

- Embodied materials impact on CO2eq
- Example

Obrigado

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