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Swiss Competence Center for Energy Research
Efficient Technologies and Systems for Mobility
Supported by: Swiss Confederation, Innosuisse – Swiss Innovation Agency
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Advancements of environmental externality modelling of various modes of transportation

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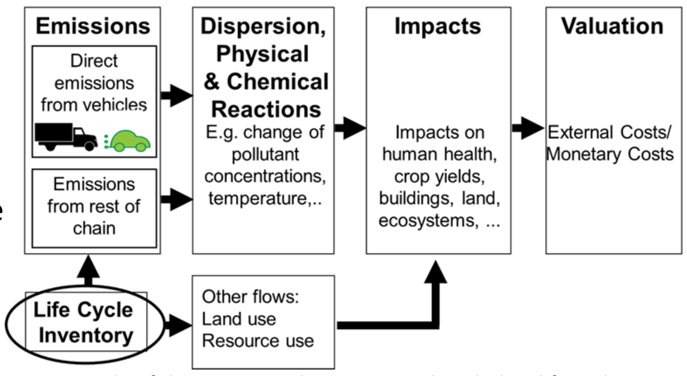
Environmental impacts and associated external costs are estimated for selected current and future technologies of passenger transport and freight transport. Apart from various types of fossil-fueled and electric cars, some technologies of public passenger transport are included for comparison with private motorized passenger transport. Freight transport options by various diesel trucks and electric trucks are compared to diesel trains and electric trains.

Methods

The environmental impact and external cost assessment employs the location-dependent impact pathway methodology [1,2] in combination with life cycle assessment as described by the "semi-regionalized approach" [3,4,5]. The major air quality model (EcoSense) applies a 50 km x 50 km grid covering the whole of Europe [1]. Impacts considered include human mortality and morbidity, crop yield changes, biodiversity losses, material damages, and climate change due to greenhouse gas emissions. External costs utilize European valuation based on VOLY (value of a life year) method [2,6,7]. Life cycle inventory data is from ecoinvent database [8].



Principle of the impact pathway approach including life cycles

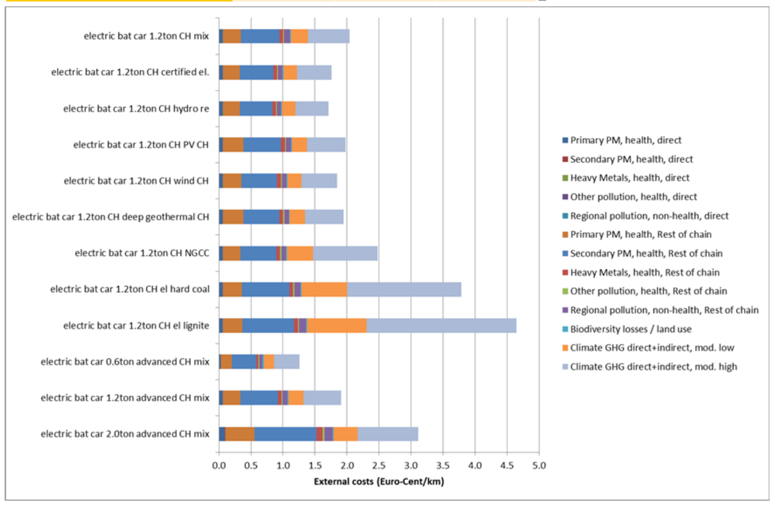
Passenger transport

Table1: Modelled direct non-exhaust air emissions kg/(vehicle*km) from tires, brakes, and road abrasion of battery electric passenger cars (incl. 80 kg load).

empty vehicle+bat. mass	0.6 ton	1.2 ton	2.0 ton
PM2.5	4.1E-06	7.5E-06	1.2E-05
PM, > 2.5 um, < 10um	2.9E-06	5.4E-06	8.8E-06
PM, > 10 um	5.2E-06	9.6E-06	1.6E-05
Elemental carbon	1.3E-06	2.5E-06	4.1E-06
Organic carbon	3.2E-06	6.0E-06	9.9E-06
Arsenic	1.2E-10	2.2E-10	3.6E-10
Cadmium	6.8E-11	1.3E-10	2.1E-10
Chromium	2.1E-10	3.9E-10	6.5E-10
Lead	9.1E-09	1.7E-08	2.8E-08
Nickel	6.7E-10	1.2E-09	2.0E-09
PAH	3.6E-11	6.6E-11	1.1E-10
Advanced battery cap. kWh	30	52	110
Adv. consumption kWh/km	0.1	0.14	2.0

model assumptions

Emission factors for conventional fossil-based vehicles were taken from ecoinvent as far as possible. Based on non-exhaust emission factors per km for conventional cars [9] and conventional trucks [8], non-exhaust emissions of electric vehicles were estimated. The emissions from tires, brakes and road abrasion are assumed to be proportional to the total vehicle mass (vehicle plus load). For electric vehicles, it was assumed that mechanical braking can be reduced by about 70% due to electric braking compared to conventional fossil-fueled vehicles. Emission factors from trolleybuses and motorcycles are from ecoinvent. Assumptions for long-distance passenger train: PM10: 34, PM2.5: 8 mg/pkm, urban train scaled according to electricity consumption PM10: 37, PM2.5: 9 mg/pkm, freight train non-exhaust PM10: 41, PM2.5: 10 mg/(ton*km), own estimate based on [10], and: [11], [12], [13], [14]. (pkm=person*km; PM=Particulate matter)



On the left: Estimated external costs of current and near future electric cars with different weight and electricity options.

Batteries assumed for electric cars:
Current 120 Wh/kg,
future (advanced) 200 Wh/kg.

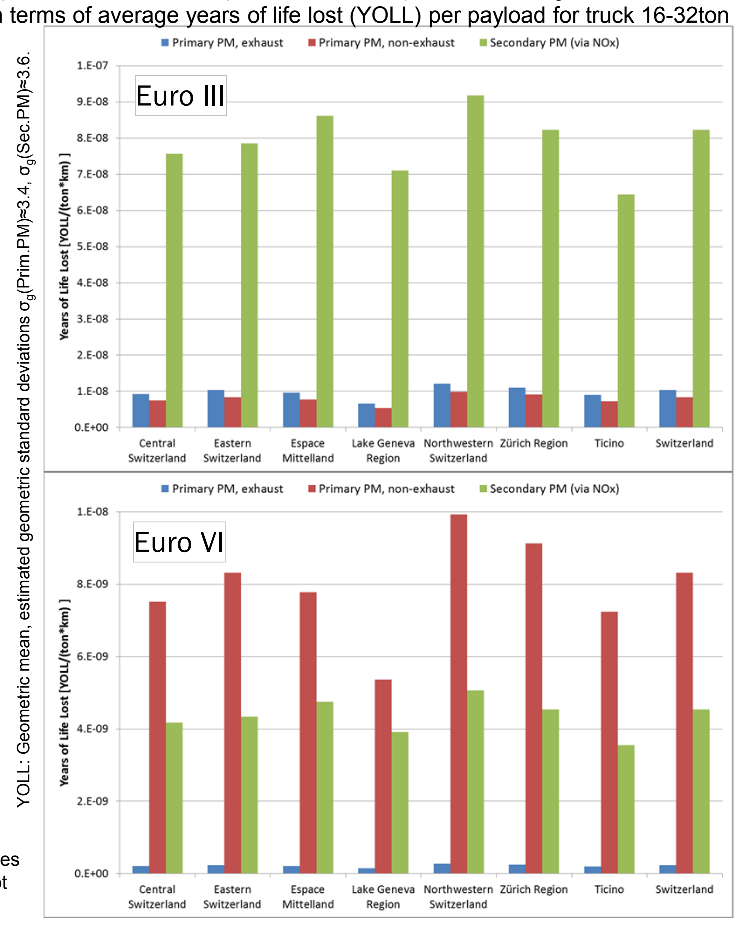
Model assumptions for battery electric truck (future)		
empty vehicle mass without battery	kg	7500
battery mass	kg	1500
payload mass	kg	3270
battery, specific energy	Wh/kg	200
electricity consumption	kWh/vkm	1.0

Uncertainties of impact and external cost estimates are high [1,2,6]. Secondary organic aerosols not included; All systems: accidents not included.

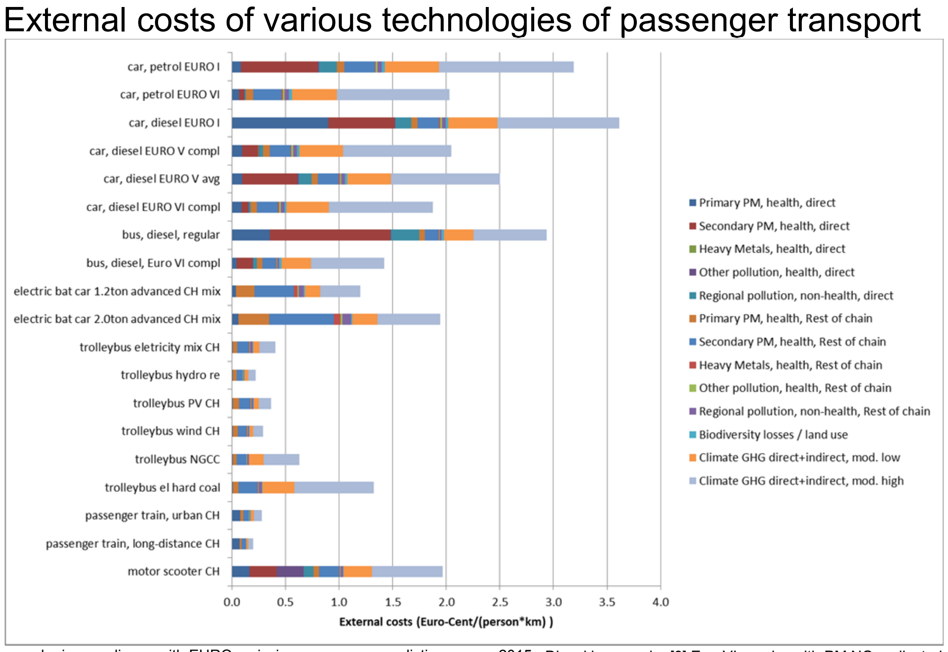
Freight transport

Health impacts – Years of Life Lost

Spatial variation of Europe-wide health impacts due to regional emissions in terms of average years of life lost (YOLL) per payload for truck 16-32ton

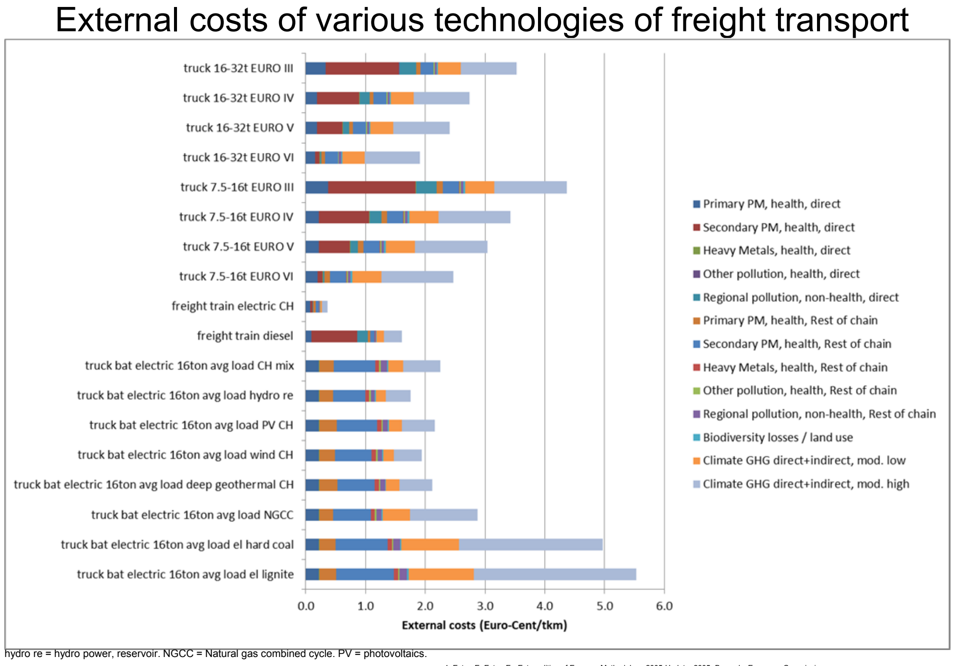


External costs of various technologies of passenger transport



compl = in compliance with EURO emission norm, avg = realistic average 2015. Diesel bus:regular:[8],EuroVI:regular with PM,NOx adjusted.

External costs of various technologies of freight transport



hydro re = hydro power, reservoir. NGCC = Natural gas combined cycle. PV = photovoltaics.

Conclusions

The environmental performance of transport depends significantly on vehicle mass, load factor, life cycle burdens, and (in case of electric vehicles) electricity supply. Evolving regulations have reduced exhaust emissions thereby making non-exhaust emissions from brakes, tires and road abrasion more important in relative terms. Non-exhaust emissions will remain an issue for land transport in future because they are also associated with electric vehicles (incl. cars, trains, buses, trucks,…).

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