Transport and environment

The problem analysis for transportation sectors:

- Emission inventories and environmental effects

- Life cycle analysis of different transport means

Product strategies into increased design spaces:

- Role of the improvement and redesign of vehicles

- Alternative technologies and sustainable mobility

- The future of automotive technological systems ?

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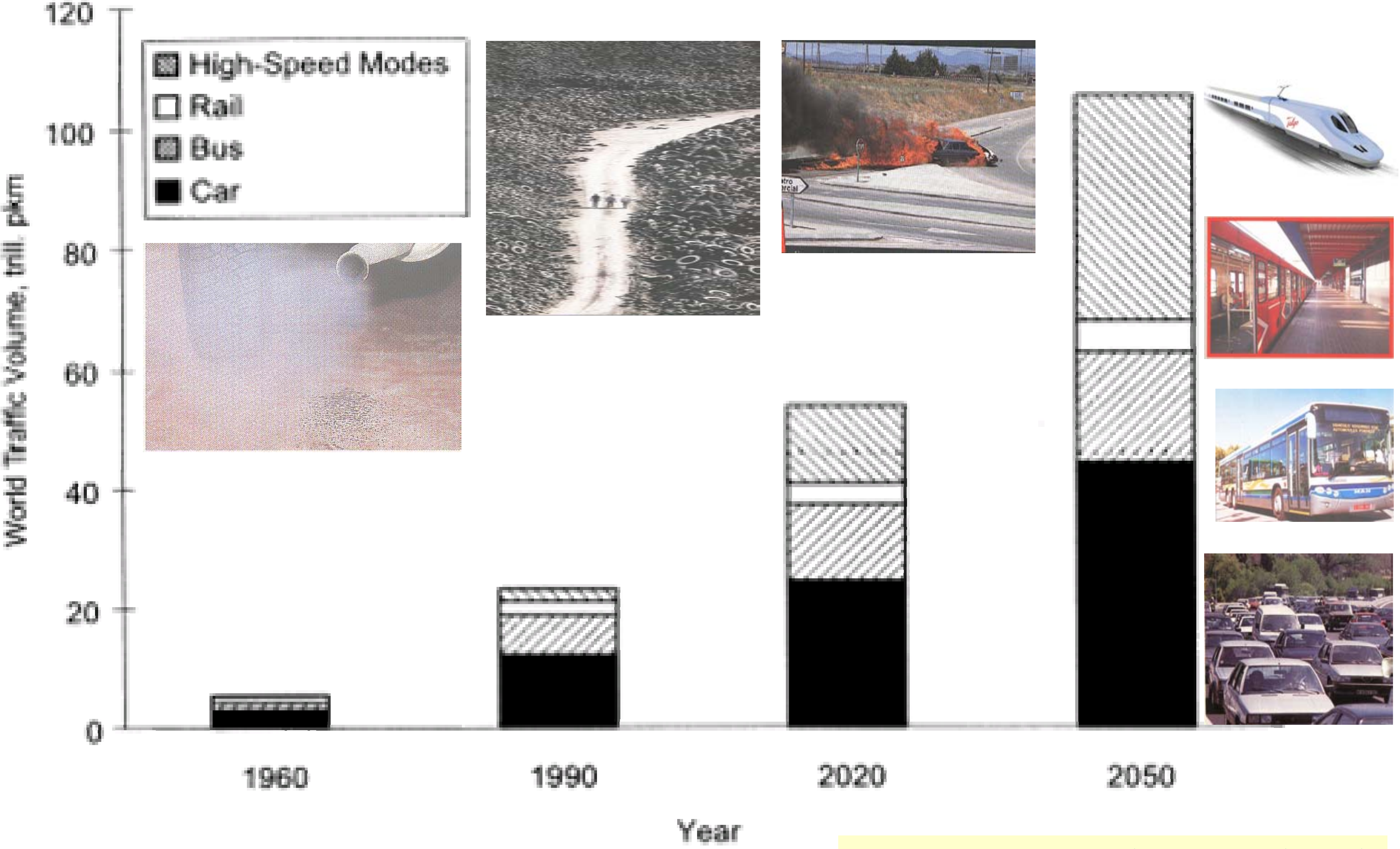
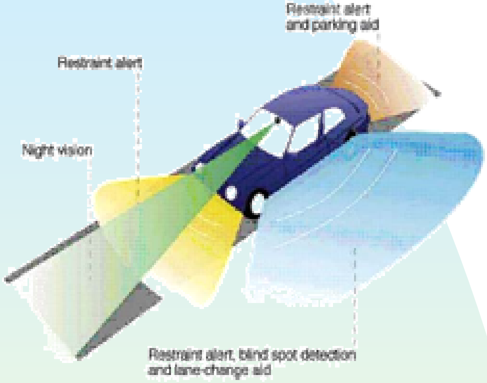
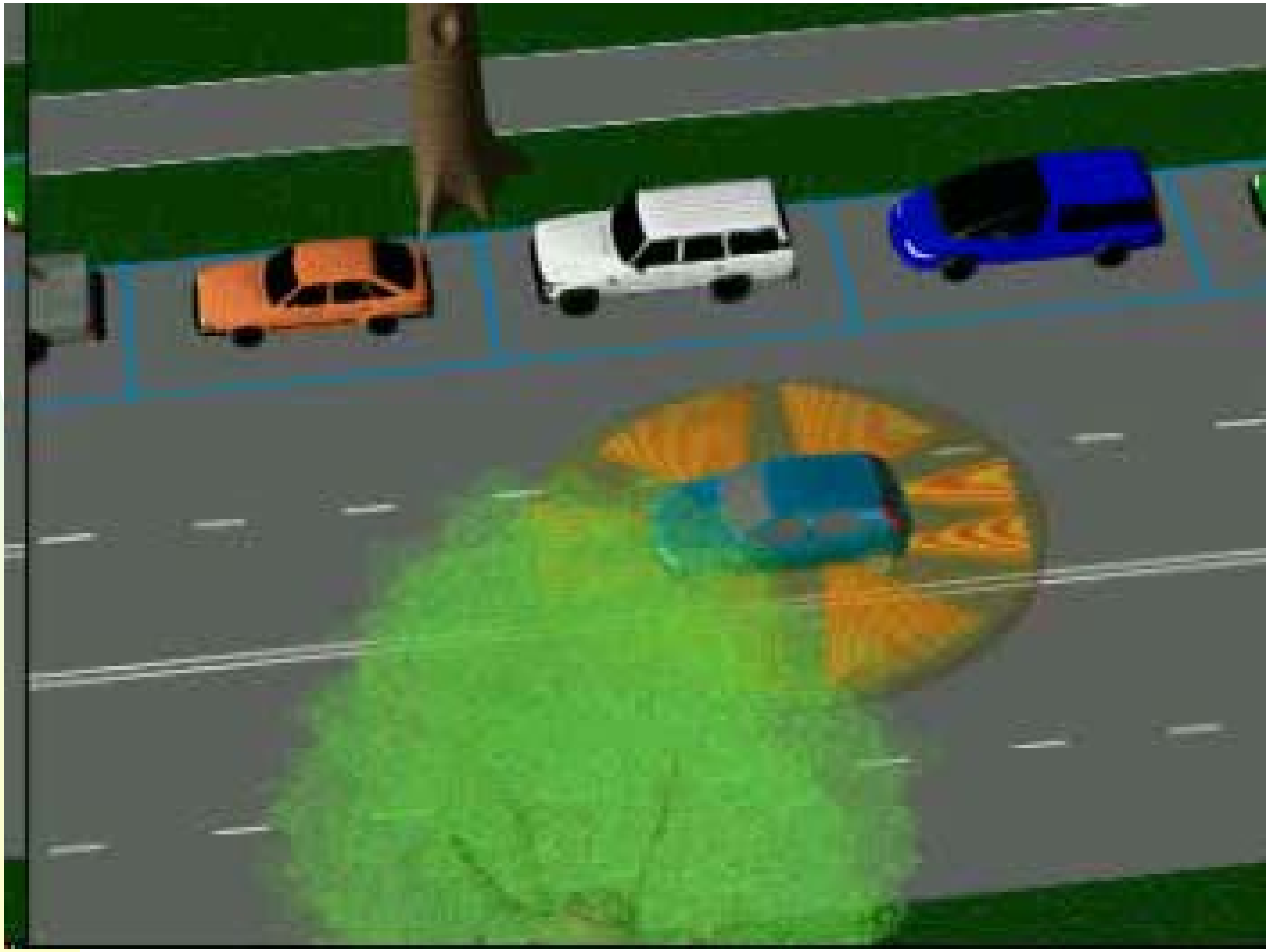
The problem analysis for transportation sectors



World terrestrial mobility by transport means (historical and estimated future values)

Safety: retention systems with vehicle sensors





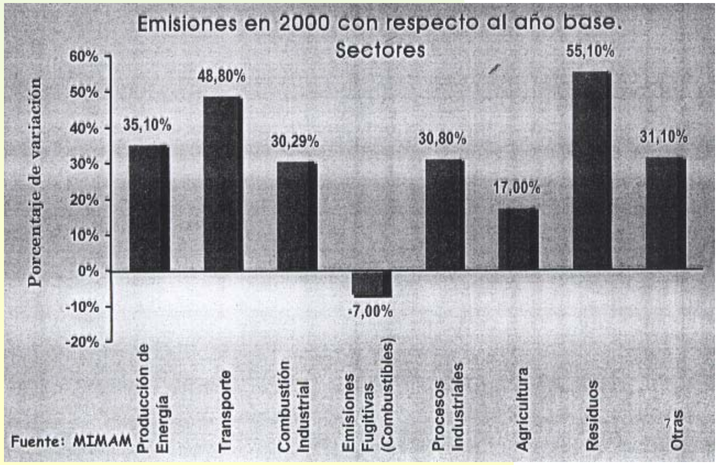
IMPROVEMENT OF CRASH COMPATIBILITY BETWEEN CARS

Emissions from transport

	CO_2 (Gt_C, 1990)	Traffic	Estimate (Gt_C, 2020)
Light vehicles	0,6	+1,8 %/yr	0,59 – 0,99
Heavy vehicle	0,4	+2,3 %/yr	0,47 – 0,72
Aviation	0,15	+3,6 %/yr	0,19 – 0,31
Railway Waterway	0,07	0	0,07 – 0,08
TOTAL	1,2		1,3 – 2,1

Energy consumption in USA per sectors / Cuatrillions of BTU

Year	Industry	Transport	Residential/ commercial	Total
1950	50%	25%	25%	33,1
1991	35%	30%	35%	81,5
Δ	x 1,7	x 3,0	x 3,4	x 2,5

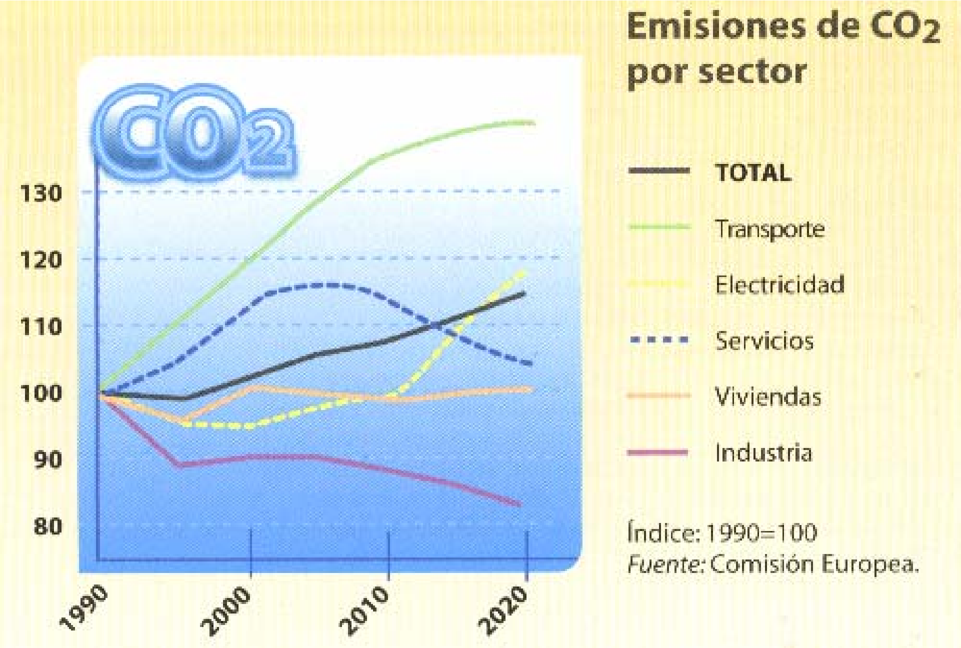


Emissions from transport (Spain, 2000)

Ing.Quím. nº437, pp.196-204 (2006)

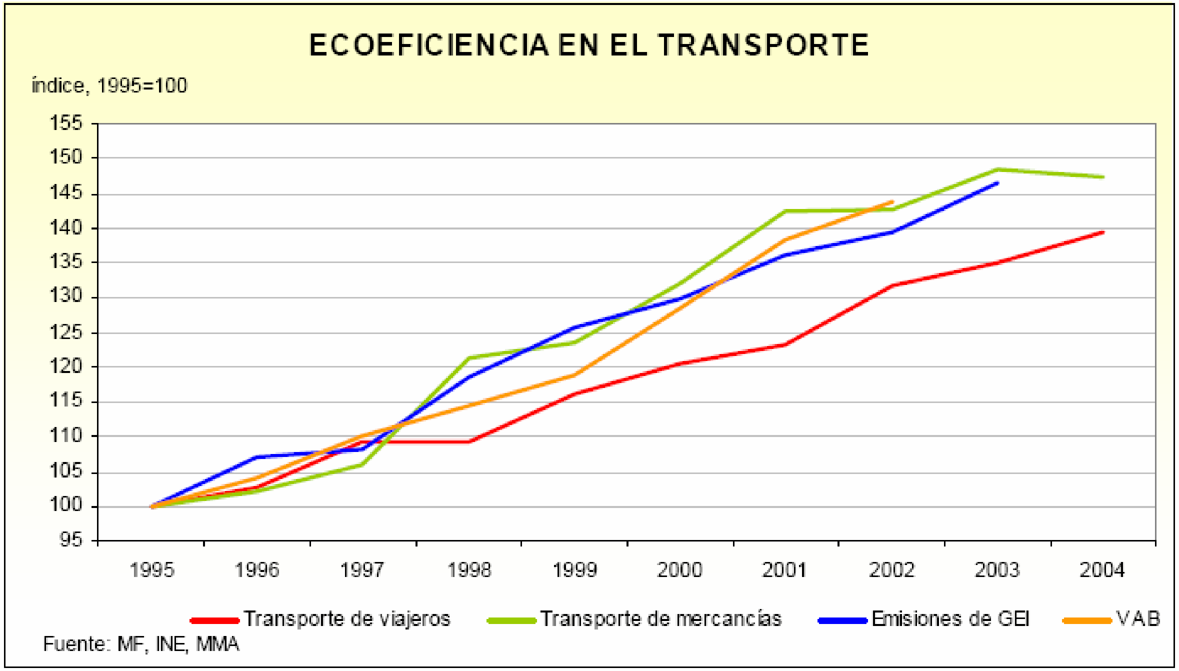
Mode	CO_2 (Mt_C)	CO (kt)[1]	CH_4 (kt)	N_2O (kt)	POCPs: NOx	NMVOC
Roadway	21,1 (LV-20% HV-30%)	1517	9,9	6,3	547	322
Airway	1,5 (red: -10%)	12,9	0.07	0,2	19,2	1,7
Railway	0,1	1,0	0,02	0,1	3,9	0,5
Waterway	0,3	1,1	0,09	0,1	39,5	1,8
Total	**23**	**1530**	**10,1**	**6,7**	**610**	**326**
Energy	28	20			342	8,9
Industry	16	270			206	18

[1] Indirect activity by absorption of $OH^·$ (sump of CH_4)



Emisiones de CO_2 por sector

Índice: 1990=100
Fuente: Comisión Europea.



ECOEFICIENCIA EN EL TRANSPORTE

Fuente: MF, INE, MMA

Emission inventories and environmental effects

- The 1st step is to identify sources of potential contaminants, and the 2nd is to inventory flows, concentrations and matrix characteristics (gas, liquids, solids), by means of balances, sampling or emission factors

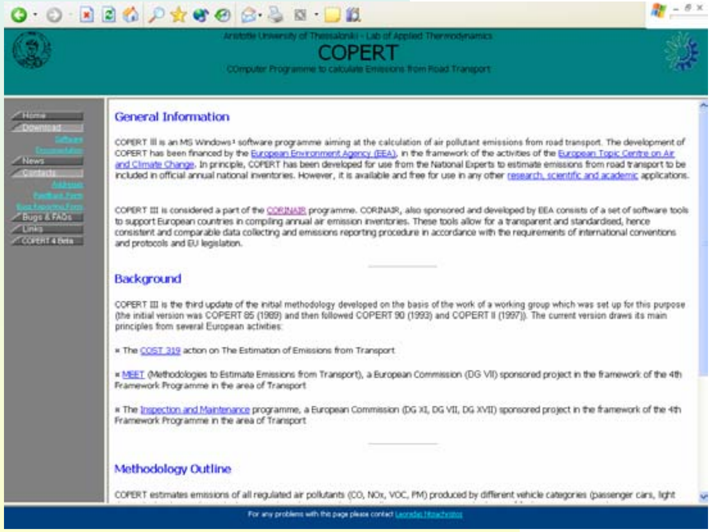
Vehicle Emission Laboratory (JRC, Ispra, Italy)

Emission factors for transport

	CO_2 (kg_C/kg_{fuel})		CH_4 (mg/MJ or km)	N_2O (mg/MJ)	Hydrocarbons & CO (autos)
Road	Gasoline	0,76	19 Light 60-260 Heavy 110-570 Cycles 150-420	5,4	Methane 170 ppm Ethane 160 Acetylene 120
	Diesel	0,85	3,8 Light 6- 60 Heavy 60-210	6,7	Formol 100 Aldehydes 53
Aviation	Petrol (kerosen) Gas	0,87	0,94	5 0	Toluene 55 Xilenes 50 CO: 8 g/km
Railway	Liquid (diesel) Gas	0,87	4,5	9	Propilene 49 Alquenes C_4 36
Marine & other	Liquid (fuel-oil) Gas	0,85	4,4 2,2	2 2	Alquenes C_5 35 hcs: Benzene 22 1,2 g/km

interactive web page: http://cfpub.epa.gov/oarweb/index.cfm?action=fire.main the creation of a complete road transport inventory is met when providing correct data for the following fields:

1. Country>Fuel
2. Country>Monthly Temperatures
3. Country>Reid Vapor Pressure
4. Country>Cold Start Parameters
5. Activity Data>Fleet Info
6. Activity Data>Circulation Info
7. Activity Data>Evaporation Share



Aristotle University of Thessaloniki - Lab of Applied Thermodynamics

COPERT

COmputer Programme to calculate Emissions from Road Transport

General Information

COPERT III is an MS Windows¹ software programme aiming at the calculation of air pollutant emissions from road transport. The development of COPERT has been financed by the European Environment Agency (EEA), in the framework of the activities of the European Topic Centre on Air and Climate Change. In principle, COPERT has been developed for use from the National Experts to estimate emissions from road transport to be included in official annual national inventories. However, it is available and free for use in any other research, scientific and academic applications.

COPERT III is considered a part of the CORINAIR programme. CORINAIR, also sponsored and developed by EEA consists of a set of software tools to support European countries in compiling annual air emission inventories. These tools allow for a transparent and standardised, hence consistent and comparable data collecting and emissions reporting procedure in accordance with the requirements of international conventions and protocols and EU legislation.

Background

COPERT III is the third update of the initial methodology developed on the basis of the work of a working group which was set up for this purpose (the initial version was COPERT 85 (1989) and then followed COPERT 90 (1993) and COPERT II (1997)). The current version draws its main principles from several European activities:

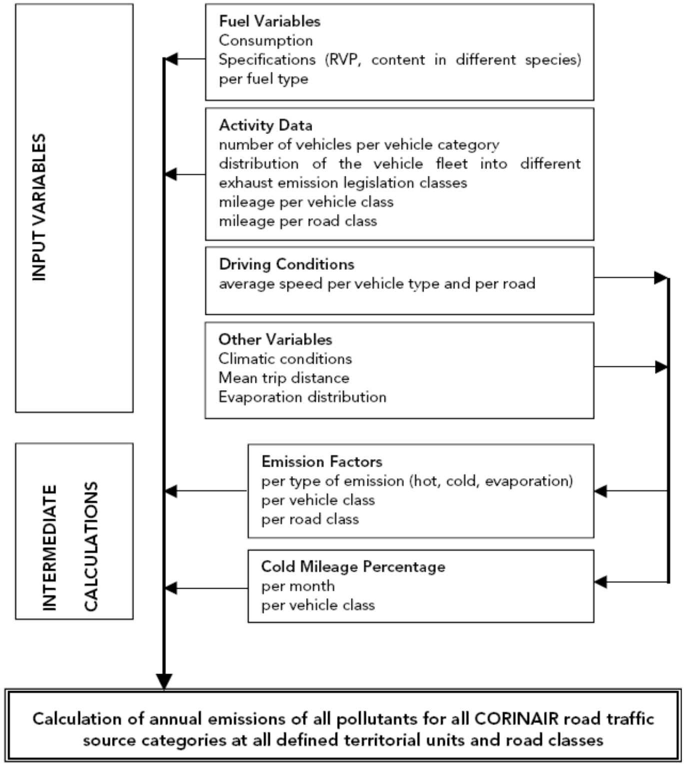
- The COST 319 action on The Estimation of Emissions from Transport
- MEET (Methodologies to Estimate Emissions from Transport), a European Commission (DG VII) sponsored project in the framework of the 4th Framework Programme in the area of Transport
- The Inspection and Maintenance programme, a European Commission (DG XI, DG VII, DG XVII) sponsored project in the framework of the 4th Framework Programme in the area of Transport

Methodology Outline

COPERT estimates emissions of all regulated air pollutants (CO, NOx, VOC, PM) produced by different vehicle categories (passenger cars, light

For any problems with this page please contact Leonidas Ntziachristos

Emission factors (road transport):
http://lat.eng.auth.gr/copert/



INPUT VARIABLES

Fuel Variables
Consumption
Specifications (RVP, content in different species) per fuel type

Activity Data
number of vehicles per vehicle category
distribution of the vehicle fleet into different exhaust emission legislation classes
mileage per vehicle class
mileage per road class

Driving Conditions
average speed per vehicle type and per road

Other Variables
Climatic conditions
Mean trip distance
Evaporation distribution

INTERMEDIATE CALCULATIONS

Emission Factors
per type of emission (hot, cold, evaporation)
per vehicle class
per road class

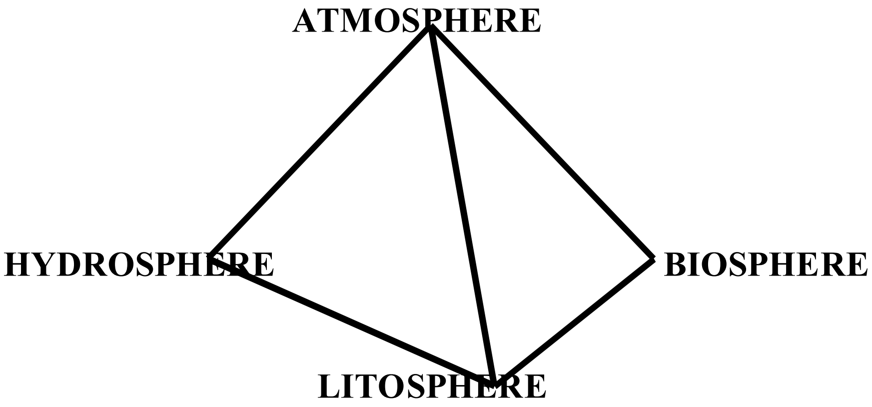
Cold Mileage Percentage
per month
per vehicle class

Calculation of annual emissions of all pollutants for all CORINAIR road traffic source categories at all defined territorial units and road classes

Ecological risk assessment: from defining the sources to estimating effects

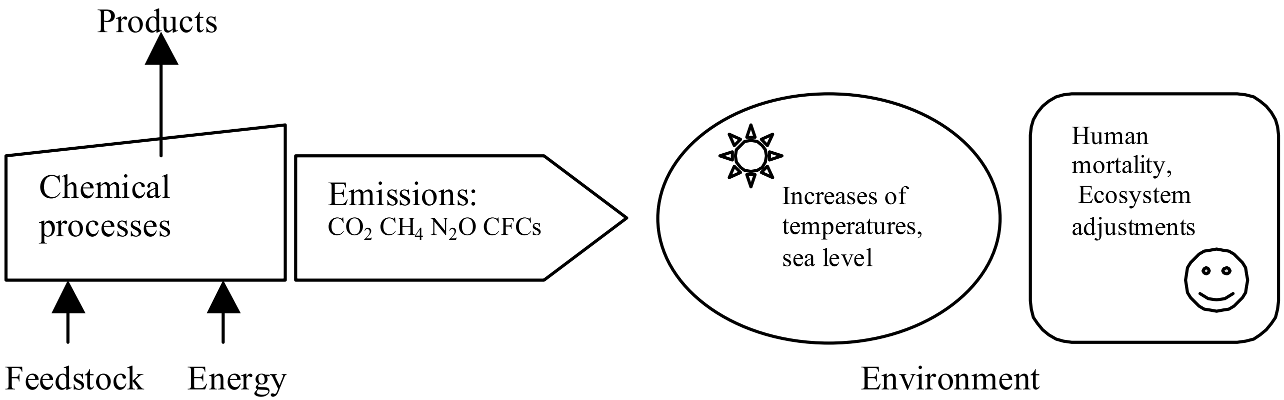
MEDIUM	Urban	Regional	Global
Atmosphere	**photo-chemical** and **acidification** (CO,VOCs,NOx,SOx,NH_3)		**radiative effects** (CO_2,CH_4,N_2O, CFCs)
Hydrosphere	**wastewaters** and **eutrophication** (organics, ions NP)		**water resources, raw materials and energy** (consumption); **toxics** to air, water, soil (AH, pesticides, metals)
Litosphere	**landfills, incineration** (solid wastes)	**soil & groundwater** (diffuse pollution)	

Impact scales and environmental compartments



Multimedia pollution tetrahedron

Global impacts: the climate change



Products

Chemical processes

Emissions:
CO_2 CH_4 N_2O CFCs

Increases of temperatures, sea level

Human mortality, Ecosystem adjustments

Feedstock

Energy

Environment

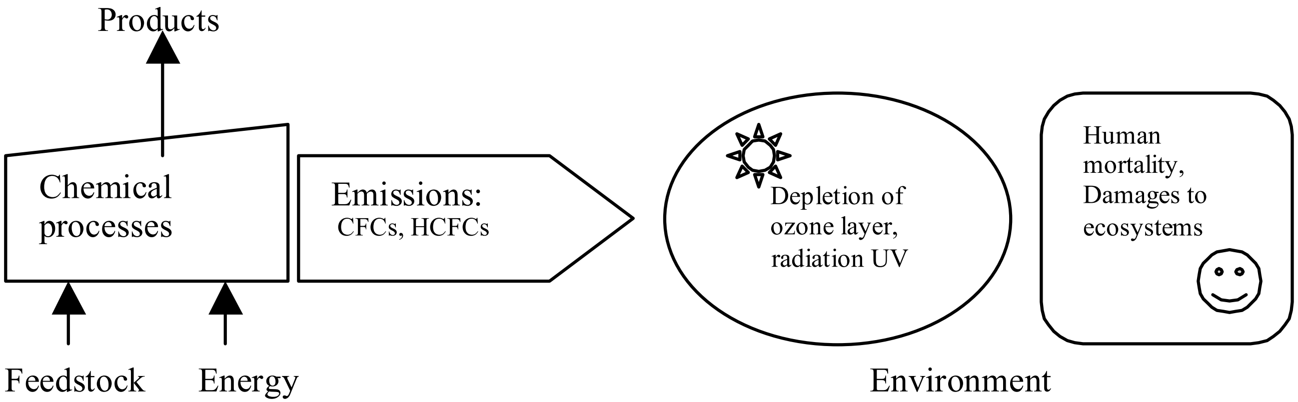
Greenhouse emissions (cause and effects chain)

- $GWP_i = \int \varepsilon_i C_i dt / \int \varepsilon_{CO2} C_{CO2} dt$

Greenhouse gases and contributions to global warming

Gas	Source	Emission ant	Conc. prind	Conc. prst	Rsd. time	Ef.radiative	Cont.global
CO_2	Fossil fuels, deforestation	6000 Mt/yr	280 ppm	360 ppm	50-200 yrs	1	50%
CH_4	Anaerobiosis, mining, gas	300 Mt/yr	800 ppb	1700 ppb	10 yrs	58	12-19%
N_2O	Agriculture, Industry	5 Mt/yr	285 ppb	310 ppb	140-190 yrs	206	4-6%
CFCs	refrigerants, solvent, aerosols	1 Mt/yr	0	0,7 ppb	65-110 yrs	4860	17-21%
O_3	photochemicals transport & ind.			22 ppb	hours-days	2000	8%

depletion of stratospheric ozone



Products

Chemical processes

Feedstock

Energy

Emissions:
CFCs, HCFCs

Depletion of ozone layer, radiation UV

Human mortality, Damages to ecosystems

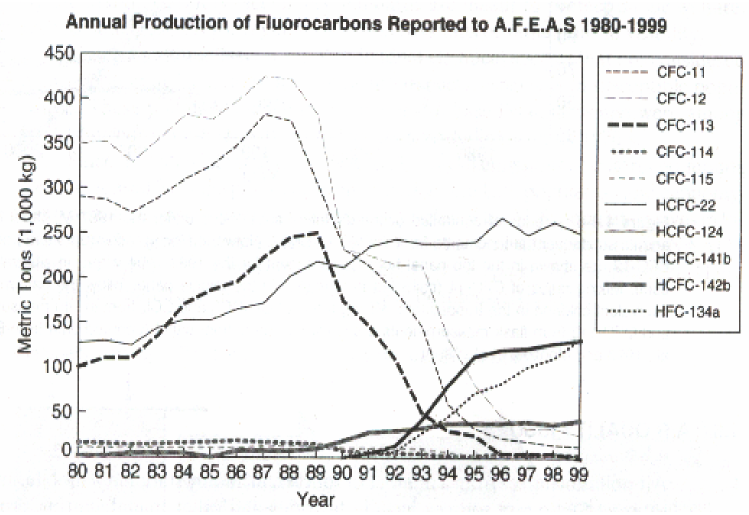
Environment

Emissions destructive of ozone (cause and effects chain)

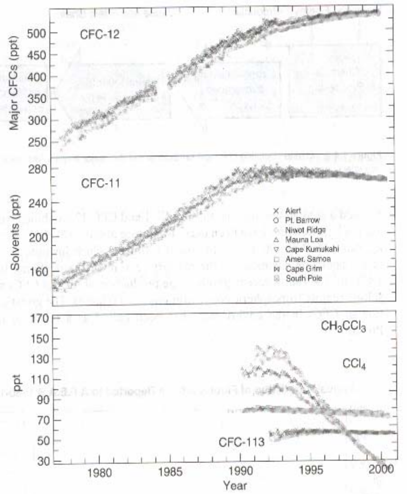
$$Cl + O_3 \rightarrow ClO + O_2$$

$$\underline{ClO + O \rightarrow Cl + O_2}$$

$$O_3 + O \rightarrow 2\,O_2$$



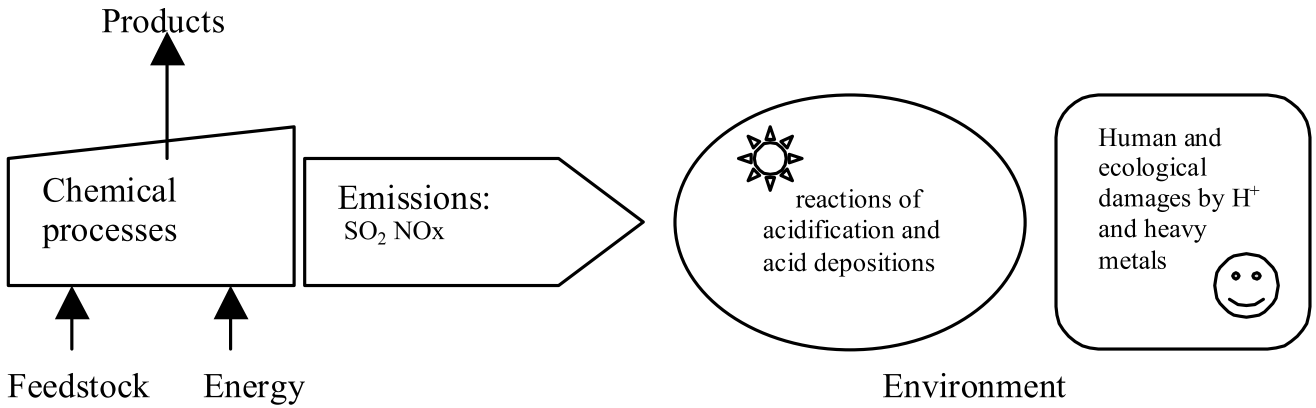
Annual Production of Fluorocarbons Reported to A.F.E.A.S 1980-1999



$$ODP_i = \delta(O_3)_i \,/\, \delta(O_3)_{CFC11}$$

δ: f(persistence, Cl atoms, rate constants)

Transboundary effects: the acid rain



Products

Chemical processes

Emissions:
SO_2 NOx

reactions of acidification and acid depositions

Human and ecological damages by H^+ and heavy metals

Feedstock

Energy

Environment

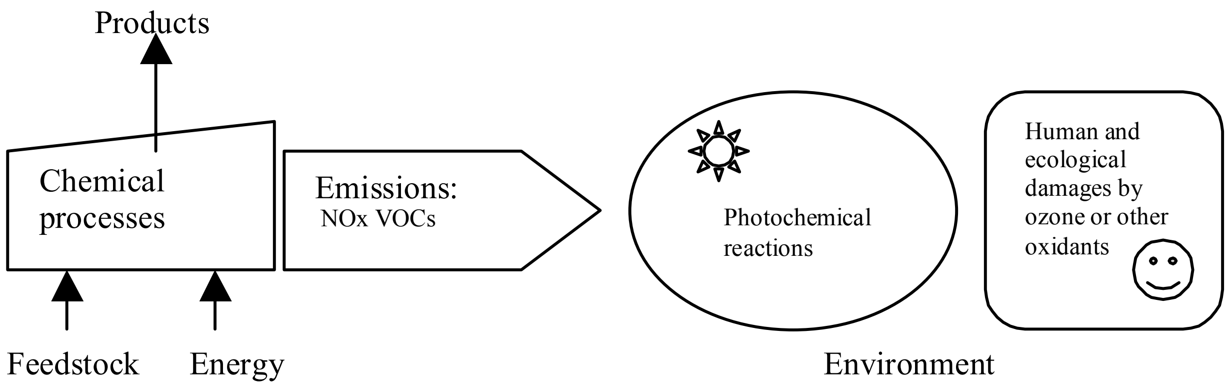
Acidification (cause and effects chain)

- $X_i + \cdots \rightarrow \alpha_i H^+ + \cdots$

$$AP_i = (\alpha_i/M_i)/(\alpha_{SO2}/M_{SO2})$$

X_i	α_i	M_i	AP_i
SO_2	2	64	1,0
NO_2	1	46	0,7
HCl	1	36	0,9

Air quality: trophospheric ozone



Products

Chemical processes

Emissions:
NOx VOCs

Photochemical reactions

Human and ecological damages by ozone or other oxidants

Feedstock

Energy

Environment

Photochemical smog formation (cause and effects chain)

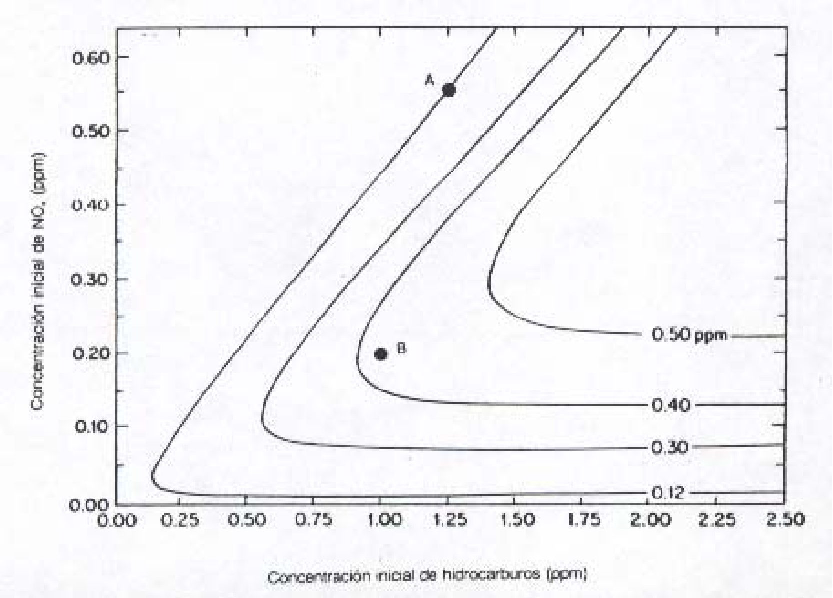
$$NO_2 \xrightarrow{h\nu} NO + O \xrightarrow{O_2} O_3$$

$$O_3 \xrightarrow{NO} NO_2 + O_2$$

$$VOC + NO \longrightarrow \text{oxidation products}$$

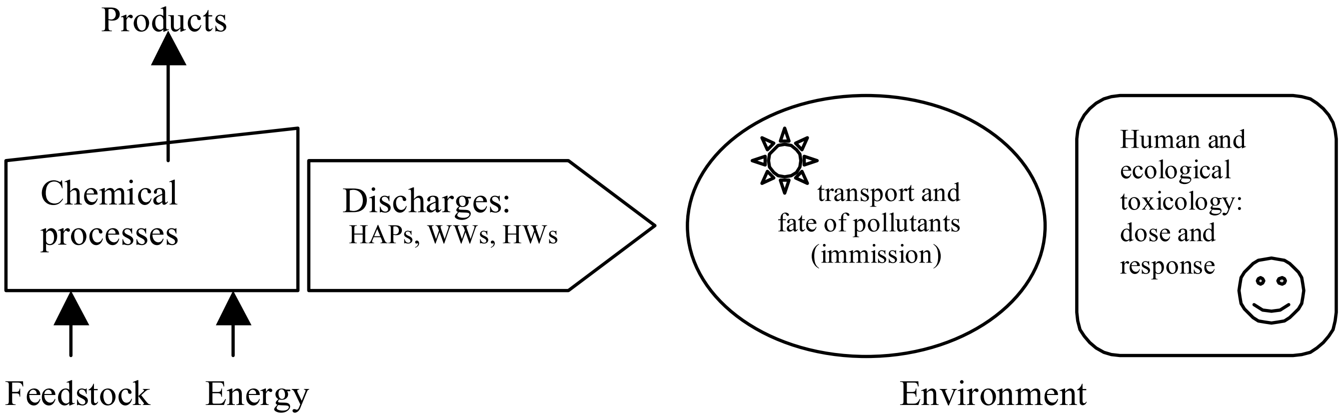
$$POCP_i = MIR_i/MIR_{ROG}$$

- MIR: maximum incremental reactivity of organic gases



Environmental assessment of chemicals

- Characterization of risks include information on discharges, environmental fate, the human exposures and its biological response: **Chemical risk = f (hazard, exposure)**

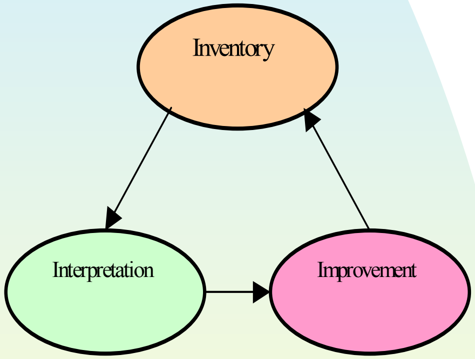


Toxic releases (air emissions, water effluents, solid wastes) and chain of effects

- Risk indexes can be expressed as the product of inherent potentials (IP) and exposure (EP), relative to one compound (r):
  - $I_i = (EP \cdot IP)_i / (EP \cdot IP)_r$ $\quad I = \Sigma\, m_i \cdot I_i$

Life cycle concepts

- Life cycle assessment (LCA) is a method for evaluating the environmental consequences of a product system or activity holistically across its entire life (from cradle to grave)
- The *improvement analysis*, should respond to the results of the evaluation (*inventory and impact assessment*) by designing strategies to reduce the identified burdens

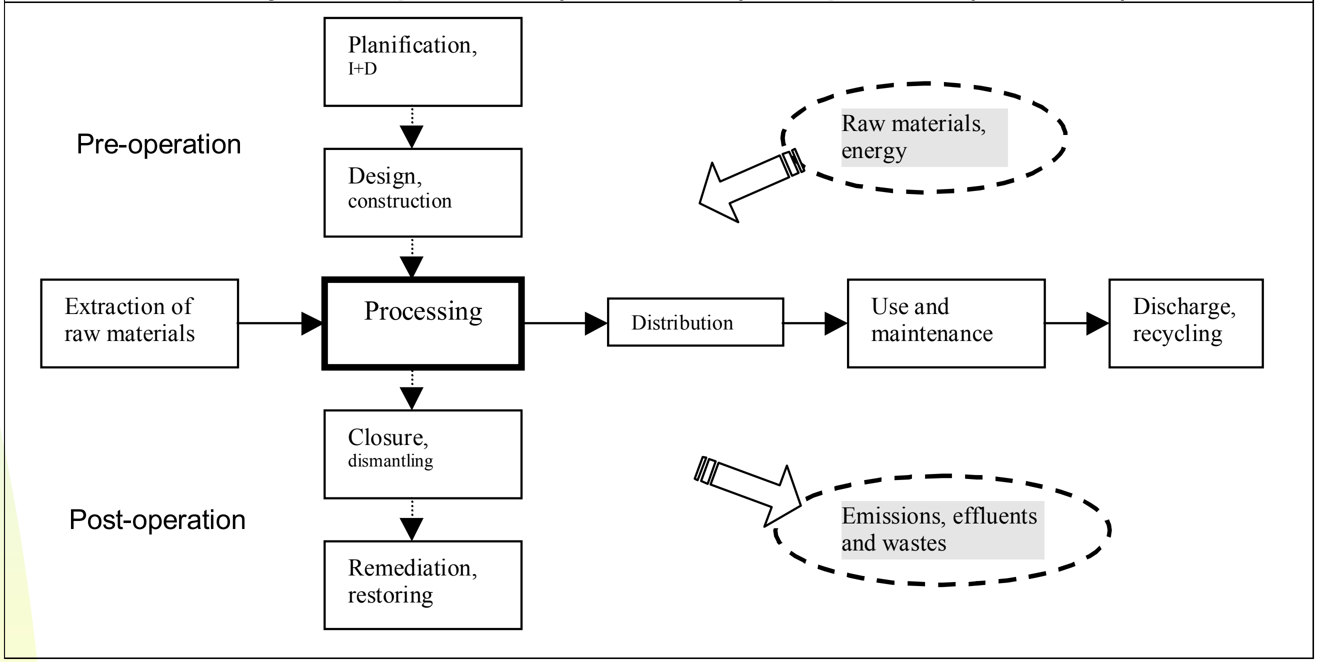


Inventory

Interpretation

Improvement

Life cycles of processes (vertical axis) and products (horizontal)



Pre-operation

Planification, I+D

Design, construction

Raw materials, energy

Extraction of raw materials

Processing

Distribution

Use and maintenance

Discharge, recycling

Closure, dismantling

Remediation, restoring

Post-operation

Emissions, effluents and wastes

- LCA methodology is a useful and powerful tool for assessment and mitigation of impacts from the human activities, as these must be holistically approached; they can be used for different purposes, like products comparison, strategic planning, eco-labeling and design of the systems (process development and product stewardship)

- Goal and scope
  - Objective, system limits and functional unit (equivalent products)

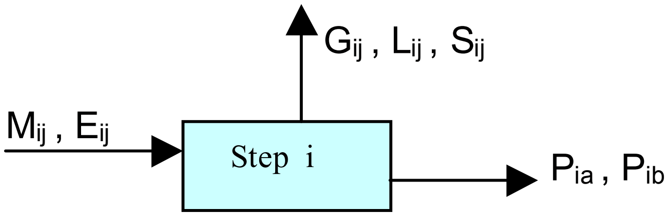
- Life cycle inventories (**LCI**)
  - include all relevant data on interchanges with the environment: resource inputs, products, emissions, effluents and wastes

Table for life cycle inventory (mass/energy balances)

Categories (units) (**interchanges**)	**Life cycle stages**			
	1	2	... i ...	n
Raw materials (kg) (minerals and water)	M_{1j}	M_{2j}	M_{ij}	M_{nj}
Energy (MJ) (coal,oil,gas,hydro,nuclear,etc)	E_{1j}	E_{2j}	E_{ij}	E_{nj}
Gas emissions (g) (COx, SOx, NOx, HX, COVs, dust, metals)	G_{1j}	G_{2j}	G_{ij}	G_{nj}
Liquid effluents (g) (DQO, DBO, TSD, SS, H^+, Cl^-, organics, nitrogen, metals)	L_{1j}	L_{2j}	L_{ij}	L_{nj}
Solid wastes (g) (industrial, mineral, hazardous)	S_{1j}	S_{2j}	S_{ij}	S_{nj}
Products	P_{1j}	P_{2j}	P_{ij}	P_{nj}

data treatment (total interchanges by functional unit)

E.g.: various interchanges (I_j) and two co-products (P_j)



partitioning: $\mathbf{I_{Pia}} = a_l \cdot I_{ij}$ $\mathbf{I_{Pib}} = b_l \cdot I_{ij}$ $(a_l + b_l = 1)$

normalizing: $\mathbf{I_{ij} / P_{ij}}$

aggregating: $\Sigma_i \, \mathbf{I'_{ij}}$

LCAccess

- **Impact assessment**: that converts the inventory data (interchanges) in environmental effects (impact estimates on human heath or ecosystems)
  - **Classification** of inputs and outputs by known impact problems
  - **Characterization** of the potential effects with \`equivalent factors´
    - this quantify impacts by integrating the inventory values and their potential factors, to obtain **effect indicators by problem category**

Problems generally considered in LCA for characterizing the environmental impacts

Impact category	Equivalent factors	Spatial scale	Temporal scale
Resource depletion	**C/R (fossil fuels, minerals, renewable)**	global	decades-centuries
Global warming	**GWP (CO_2,CH_4,N_2O,O_3,CFCs,...)**		decades-centuries
Stratospheric ozone	**ODP (halogenated hydrocarbons)**		decades
Acidification	**AP (SOx, NOx, NH_3, HCl, HF)**	regional	years
Aquatic toxicity	**ETA (diverse toxic agents)**		hours-decades
Eutrophycation	**EP (phosphorus, nitrogen, carbon)**		years
Habitat destruction	**Area/time (media displacements)**		years-decades
Tropospheric ozone	**POCP (hydrocarbons, oxygenates)**	local	hours-days
Terrestrial toxicity	**ETS (diverse toxic agents)**		hours-decades
Human carcinogens	**TPH (diverse toxic agents)**		hours-decades

  - **Valuation** of environmental index by means of \`weighting factors´
    - this counterbalance effects by using some criteria of importance, which can be derived from the relative distance of the current situation in regard of the goals set out in policy documents (e.g. reduction objectives, legal limitations, etc)

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while the first steps are based in objective scientific data or models, the last is inherently subjective and depends on social preferences (i.e. the single index is always relative to the choice of weight factors, and if priorities change the score will change too)

Measuring the personal environmental space

The targeted person equivalent has properties which makes it suitable as a yard stick for industry´s environmental performace:

- It is centrally determined, and derived from actual emissions and political targets (is common to all)
- Reflects society´s piorities and the probable developments and estimates in environmental impacts
- It is suitable as a yardstick in green accounting, system optimization and product documentation

The European person equivalent (PE) is a quantification of the environmental impact caused anually by the activities of an average european (from global to local as well as consumption of resources); similarly, the targeted PET are the corresponding quantifications in the near future according to the current political sets (it expresses the societal priorities in pollution reduction and the expected environmental space available to all of us). The ratio PE/PET is a measure of the ambitions of current environmental policy for each of the environmental problem areas (a relevant expression of its environmental importance). The size of the environmental policy target latitude will gradually approach the existing latitude as the environmental policy approach the targets for sustainability.

Both concepts have been developed for use in LCA to help comparations across different environmental impact categories, in a pedagogic form. By expressing these impacts in PE, they are expresed at a common scale and their relative size is displayed on the background load from society (enlighting on the true relative size of the impacts). And, when they are expressed in PET, the priorities of the current policy are introduced as values into the comparation (as an expression of the relative mportance of the diferent environmental problems); it is thus permisible to compare the impacts directly across categories (valuation).

Impact category	Unit/ person-yr	European PE (1994)	European PET (2004)	Reduction for 2004	Estimate for sustainability
Global warming	kg CO_2 eq	8200	7900	4%	65%
Ozone depletion	g CFC11 eq	0,081	0	100%	<100%
Photochemicals	kg CH_4 eq	25	20	20%	50%
Acidification	kg SO_2 eq	74	49	34%	90%
Nutrification	kg NO_3^- eq	120	85	29%	90%
Ecotoxicity	m^3 water	350.000	290.000	17%	85%
Human toxicity . via	m^3 water	52.000	35.000		
	m^3 air	$3{,}1\cdot10^9$	$2{,}9\cdot10^9$		

Wenzel H, Hauschild M and Alting L; Environmental Assessment of Products, Vol.1 (2000) & Vol.2 (1998), Kluwer Academic Publishers.

Interpretation and improvement analysis

- Last is to obtain conclusions from previous steps, with the objective to identify the most relevant environmental aspects and priorize options:
  - recommending a product (comparative type cases); there are many studies on products performing the same function, though they are controversial and distract attention on others which focus on systems improvements
  - modification of design or processes (specific case studies); these permit to check the processes, ingredients or operations with more impact, as well as comparing changes to optimize systems, which constitute perhaps the most interesting applications of LCA
    - E.g. PE inventory show that more than 75% of energy is consumed as raw material, i.e. efforts might be in reducing the weight of products (polymers)
    - with polyester clothes, more than 80% of energy during life cycles is due to the use phase, i.e. alternative is designing fibers easier to clean and dry
    - computers reveal major energy consumption in monitor use, while hazardous wastes and raw materials dominate in the semiconductor manufacture
    - in other study, the daily transport of product represents 30% of the energy, meaning that the supply mode -usually negligible- plays here a key role
  - Other applications include: strategic planning of products, where LCA helps to internalize business impacts (regulations); and development of long time public policies (procurement, laws and eco-labeling)

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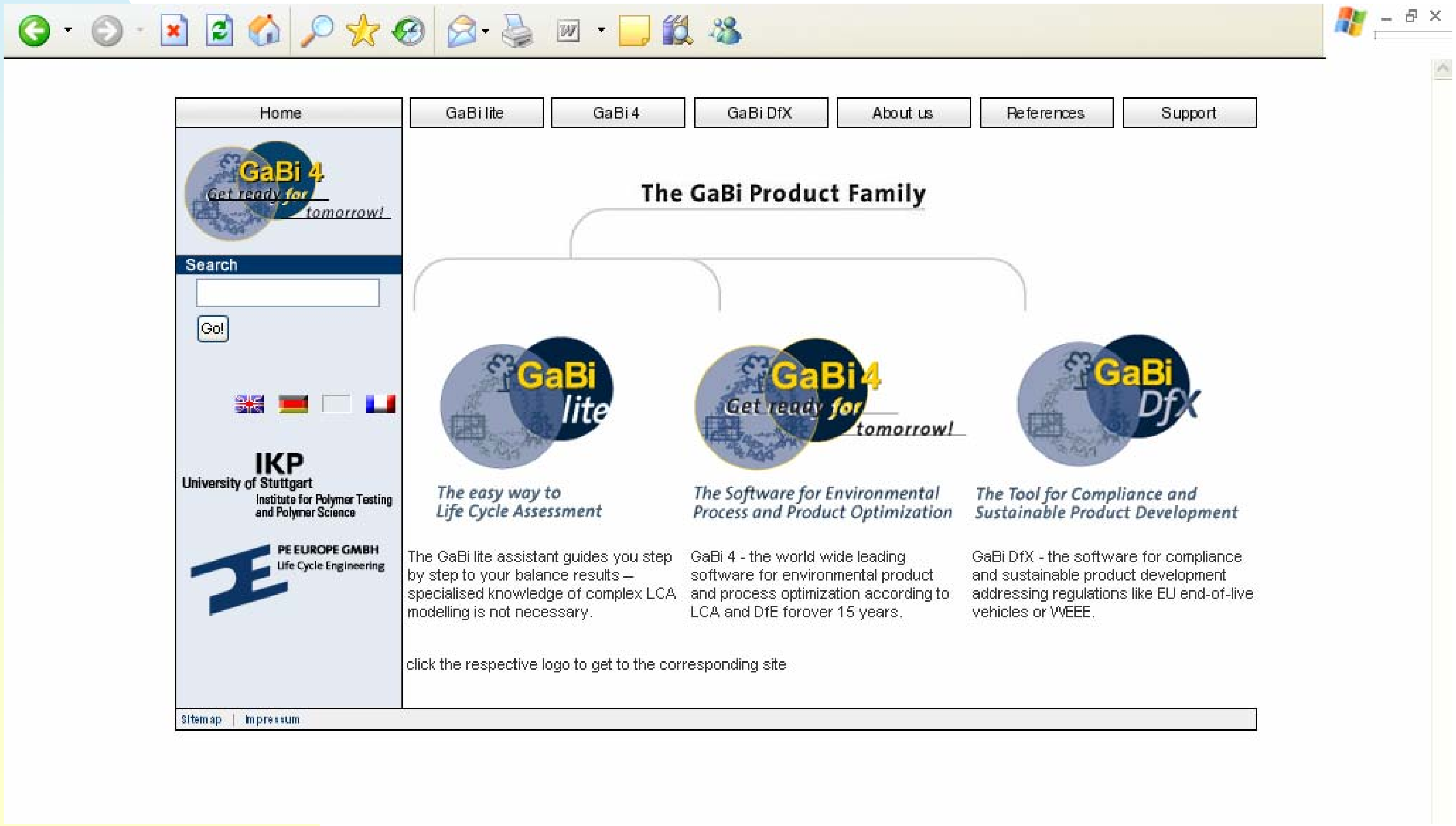
Software and databases for Life Cycle Engineering (v. Edu, Profesional, DfX, etc)

webpage & demo downloads: http://www.gabi-software.com/



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IKP
University of Stuttgart
Institute for Polymer Testing and Polymer Science

PE EUROPE GMBH
Life Cycle Engineering

LCA of different transport means

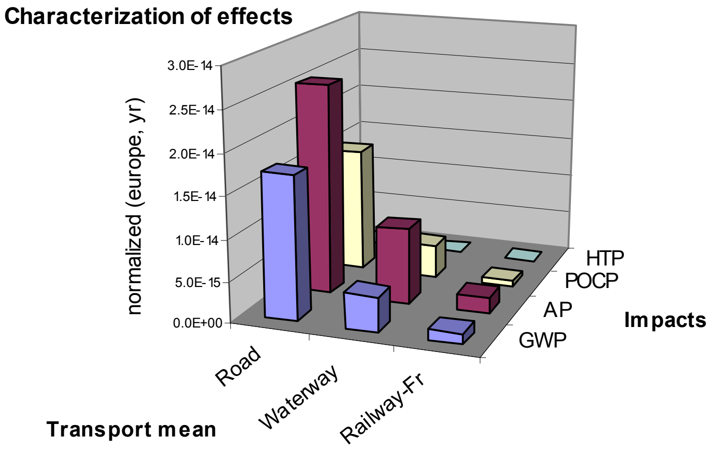
TRANSPORT **Cargo (per ton·km)**		Average truck/13t payload/local	Average ship/1228t payload/canal	Rail transport-goods (average)	Airplane jet - cargo (average)
Diesel	kg	2.98E-2	7.24E-3	9.75E-4	-
Electric power	MJ_{nhv}	-	-	1.38E-1	-
Kerosene		-	-	-	2.68E-1
Carbon dioxide	kg	9.37E-2	2.30E-2	3.10E-3	8.46E-1
Carb monoxide	kg	3.11E-4	8.68E-5	1.76E-5	2.74E-4
Methane	kg	5.25E-6	3.62E-6	1.95E-8	7.60E-7
Nitrogen oxides	kg	1.15E-3	4.34E-4	5.36E-5	4.38E-3
NMVOC	kg	1.56E-4	3.50E-5	6.04E-6	2.26E-5
Sulphur dioxide	kg	8.95E-5	2.17E-5	2.93E-6	1.34E-5

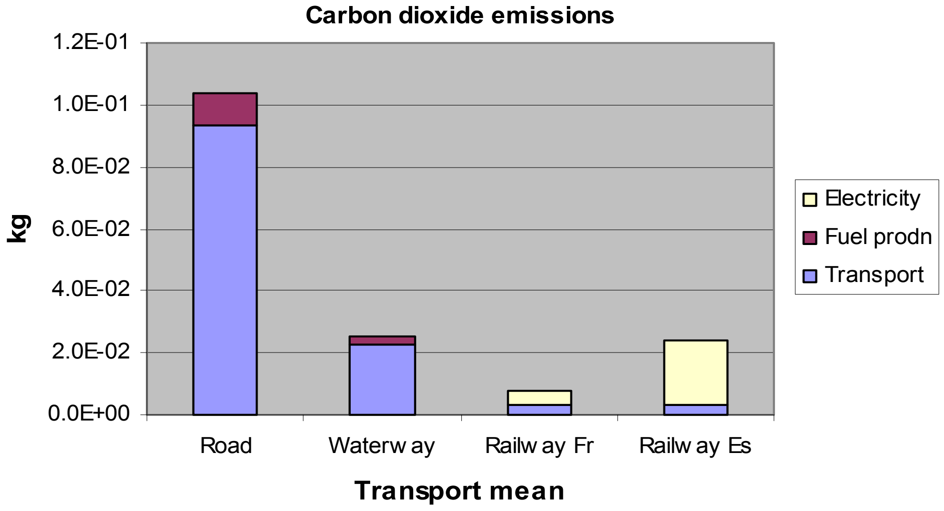
ENERGY CONVERSION		Diesel free refinery	Kerosene free refinery	Power grid mix ES (1998)	Power grid mix FR (1998)
Unit		1 kg	1 kg	1 MJ_{NHV}	1 MJ_{NHV}
Carbon dioxide	kg	3.45E-1	3.17E-1	1.47E-1	3.09E-2
Carb monoxide	kg	6.46E-4	6.36E-4	2.18E-5	6.26E-6
Methane	kg	3.01E-3	3.01E-3	4.05E-4	1.03E-4
Nitrogen oxides	kg	1.92E-3	1.89E-3	3.27E-4	7.50E-5
NMVOC	kg	7.40E-3	7.37E-3	6.65E-5	1.73E-5
Sulphur dioxide	kg	8.37E-4	7.77E-4	7.70E-4	1.49E-4

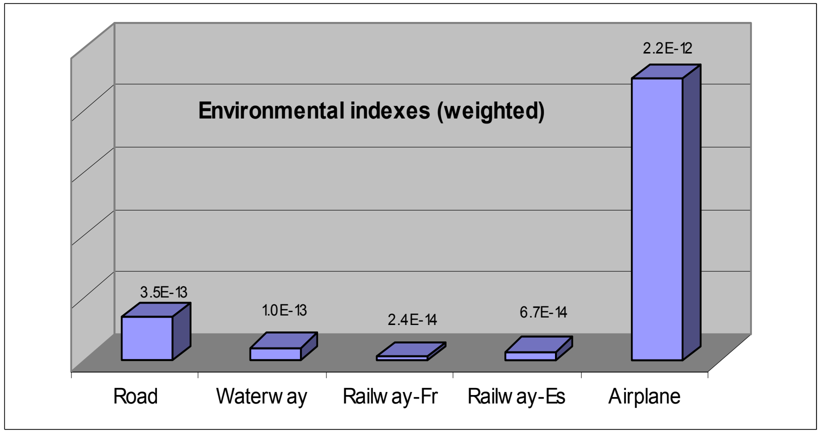
Life Cycle Inventory aggregation: $E_i = E_t + E_e \cdot m_{et}$		Road vehicle	Waterway	Railway		Air transport
				Fr	Es	
Carbon dioxide	kg	1.04E-01	2.55E-02	7.70E-03	2.37E-02	9.31E-01
Carb monoxide	kg	3.30E-04	9.15E-05	1.91E-05	2.12E-05	4.44E-04
Methane	kg	9.49E-05	2.54E-05	1.72E-05	5.88E-05	8.07E-04
Nitrogen oxides	kg	1.21E-03	4.48E-04	6.58E-05	1.01E-04	4.89E-03
NMVOC	kg	3.77E-04	8.86E-05	1.56E-05	2.24E-05	2.00E-03
Sulphur dioxide	kg	1.14E-04	2.78E-05	2.43E-05	1.10E-04	2.22E-04

Classification and characterization CML2001		GWP 100 yr Kg $CO_{2,\ eq}$	AP Kg $SO_{2,\ eq}$	POCP Kg $C_2H_{4,\ eq}$	HTP kg DCB_{eq}
Carbon dioxide	(CO_2)	1			
Carb monoxide	(CO)				
Methane	(CH_4)	23			
Nitrogen oxides	(NO_x)		0.7	0.028	1.2
NMVOC	(VOC)	16.1		0.364	0.0585
Sulphur dioxide	(SO_2)		1		
Normalization (Europe, kg_{eq} / yr)		6.45E12	3.73E10	1.12E10	1.03E13
Weighting, CML96 Experts		10	5	3	8

Total: $\Sigma E_i \cdot P_i$	Road vehicle	Waterway	Railway-Fr	Railway-Es	Air transport
GWP	1.12E-01	2.75E-02	8.35E-03	2.54E-02	9.82E-01
AP	9.59E-04	3.41E-04	7.04E-05	1.80E-04	3.64E-03
POCP	1.71E-04	4.48E-05	7.54E-06	1.10E-05	8.64E-04
HTP	1.47E-03	5.43E-04	7.99E-05	1.22E-04	5.98E-03
Environmental index	3.50E-13	1.01E-13	2.45E-14	6.67E-14	2.25E-12


Characterization of effects


Carbon dioxide emissions


Environmental indexes (weighted)

Performance of different passenger and freight transport modes in terms of average transport work, based on US 2002 data

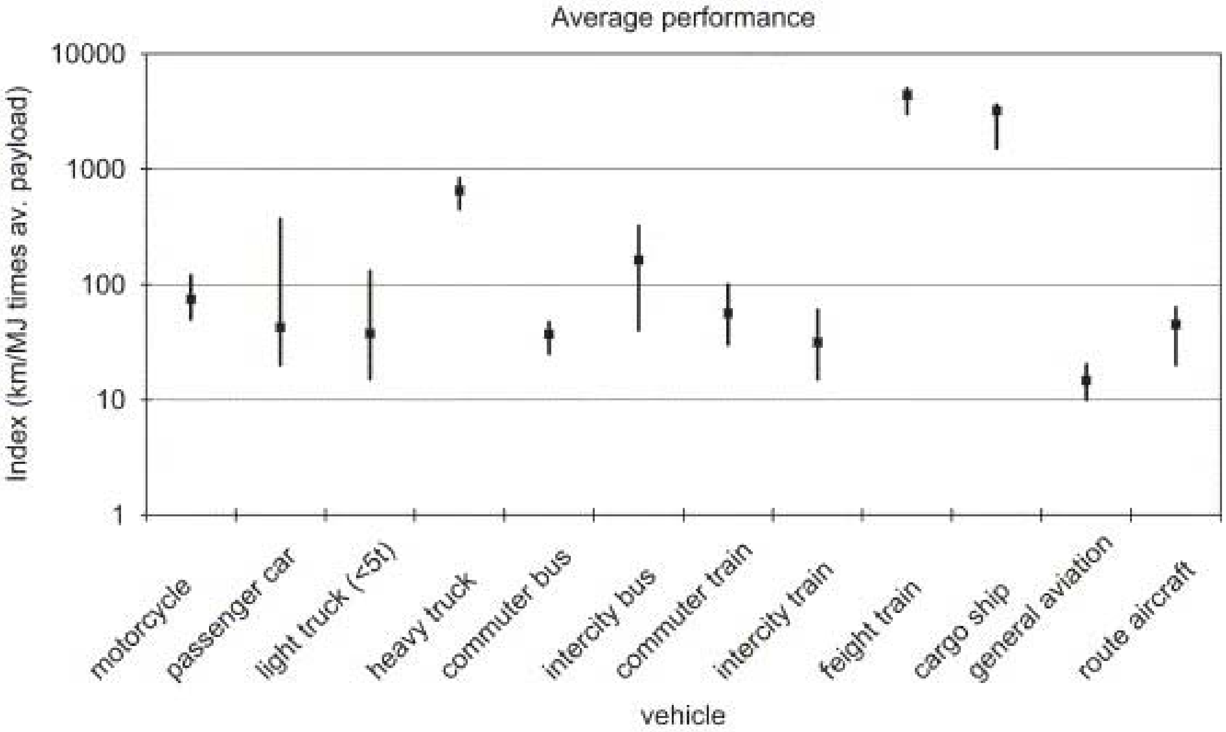


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Fig. 1. Official 2005 performance data (based on European driving cycle and licensing procedures) for selected passenger cars as function of payload

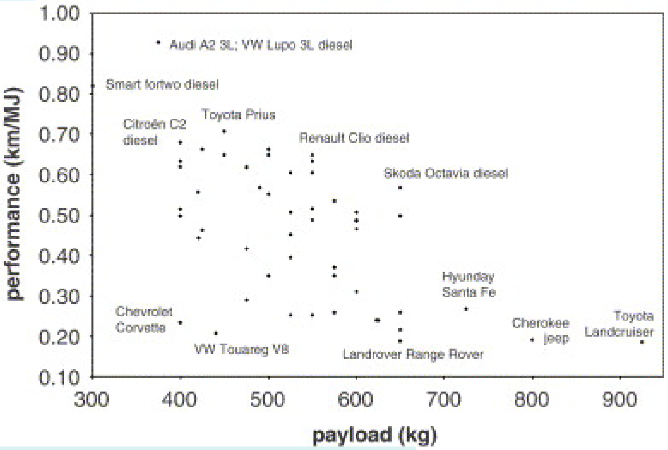
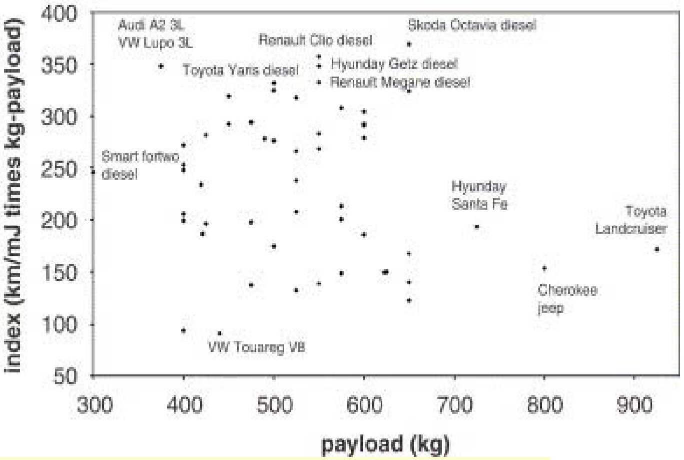


Fig. 2. Calculation of the transport work efficiency index based upon performance data for passenger cars as function of maximum permitted payload



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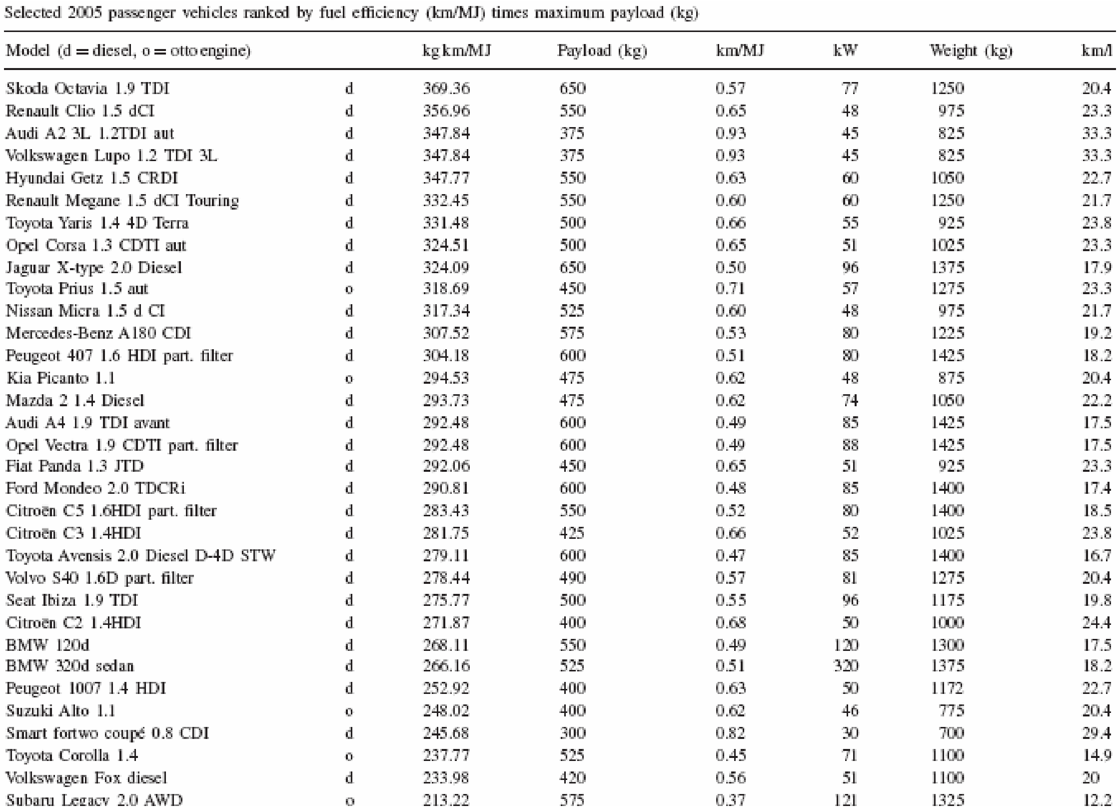
Selected 2005 passenger vehicles ranked by fuel efficiency (km/MJ) times maximum payload (kg)

Model (d = diesel, o = otto engine)		kg km/MJ	Payload (kg)	km/MJ	kW	Weight (kg)	km/l
Skoda Octavia 1.9 TDI	d	369.36	650	0.57	77	1250	20.4
Renault Clio 1.5 dCI	d	356.96	550	0.65	48	975	23.3
Audi A2 3L 1.2TDI aut	d	347.84	375	0.93	45	825	33.3
Volkswagen Lupo 1.2 TDI 3L	d	347.84	375	0.93	45	825	33.3
Hyundai Getz 1.5 CRDI	d	347.77	550	0.63	60	1050	22.7
Renault Megane 1.5 dCI Touring	d	332.45	550	0.60	60	1250	21.7
Toyota Yaris 1.4 4D Terra	d	331.48	500	0.66	55	925	23.8
Opel Corsa 1.3 CDTI aut	d	324.51	500	0.65	51	1025	23.3
Jaguar X-type 2.0 Diesel	d	324.09	650	0.50	96	1375	17.9
Toyota Prius 1.5 aut	o	318.69	450	0.71	57	1275	23.3
Nissan Micra 1.5 d CI	d	317.34	525	0.60	48	975	21.7
Mercedes-Benz A180 CDI	d	307.52	575	0.53	80	1225	19.2
Peugeot 407 1.6 HDI part. filter	d	304.18	600	0.51	80	1425	18.2
Kia Picanto 1.1	o	294.53	475	0.62	48	875	20.4
Mazda 2 1.4 Diesel	d	293.73	475	0.62	74	1050	22.2
Audi A4 1.9 TDI avant	d	292.48	600	0.49	85	1425	17.5
Opel Vectra 1.9 CDTI part. filter	d	292.48	600	0.49	88	1425	17.5
Fiat Panda 1.3 JTD	d	292.06	450	0.65	51	925	23.3
Ford Mondeo 2.0 TDCRi	d	290.81	600	0.48	85	1400	17.4
Citroën C5 1.6HDI part. filter	d	283.43	550	0.52	80	1400	18.5
Citroën C3 1.4HDI	d	281.75	425	0.66	52	1025	23.8
Toyota Avensis 2.0 Diesel D-4D STW	d	279.11	600	0.47	85	1400	16.7
Volvo S40 1.6D part. filter	d	278.44	490	0.57	81	1275	20.4
Seat Ibiza 1.9 TDI	d	275.77	500	0.55	96	1175	19.8
Citroën C2 1.4HDI	d	271.87	400	0.68	50	1000	24.4
BMW 120d	d	268.11	550	0.49	120	1300	17.5
BMW 320d sedan	d	266.16	525	0.51	320	1375	18.2
Peugeot 1007 1.4 HDI	d	252.92	400	0.63	50	1172	22.7
Suzuki Alto 1.1	o	248.02	400	0.62	46	775	20.4
Smart fortwo coupé 0.8 CDI	d	245.68	300	0.82	30	700	29.4
Toyota Corolla 1.4	o	237.77	525	0.45	71	1100	14.9
Volkswagen Fox diesel	d	233.98	420	0.56	51	1100	20
Subaru Legacy 2.0 AWD	o	213.22	575	0.37	121	1325	12.2

In general, one would like to compare the advantages, such as those of **high efficiency** or **low pollution** propulsion systems, with the cost associated with each feature.

In the case of efficiency, there is hardly any cost penalty: the common rail, computer controlled compression ignition `diesel cars´ coming on the market cost the same as the less than half as efficient average car.

Some people are willing to spend more money on inefficient cars than on the most efficient ones offered in the marketplace, for reasons of biased advertising and the archaic notions that less efficient cars rank higher as `status symbols´. These market imperfections are difficult to meaningfully include in a scientific context.