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ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Quality control in LCA

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Key points for good LCA practice

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1. Goal and system definition

1a. Screening approach

It is recommended to carry out the LCA in two steps:

- A first screening phase covering the whole LCA and assessing order of magnitude of emission inventory and impacts

- A detailed analysis to improve the assessment for most important impacts

1b . System function

LCA relates the environmental impacts to a product function. Products or systems can only be compared on the basis of a similar function.

1c Functional unit

The functional unit is in all scenarios the common unit representing the function of the system. In the inventory emission are calculated per functional unit. The reference flow provides for each scenario the basic product quantities needed per funtional unit.

Reference flows, product life time or number of reuse can be key parameters for environmental optimisation

1c System boundaries

System boundaries include all the necessary processes to assure the desired function.

Rule 1: System boundaries should cover the same reality in all scenarios
Rule 2: Only processes contributing to more than x% of the emissions are retained
Rule 3: Identical processes in different scenarios can only be excluded if the reference flows corresponding to these processes are strictly equal (total output of the system must also be identical).

2. Inventory
2a. Allocation

The methods can be applied only if they fulfill their respective condition of use (causality principle), in the following order of preference:

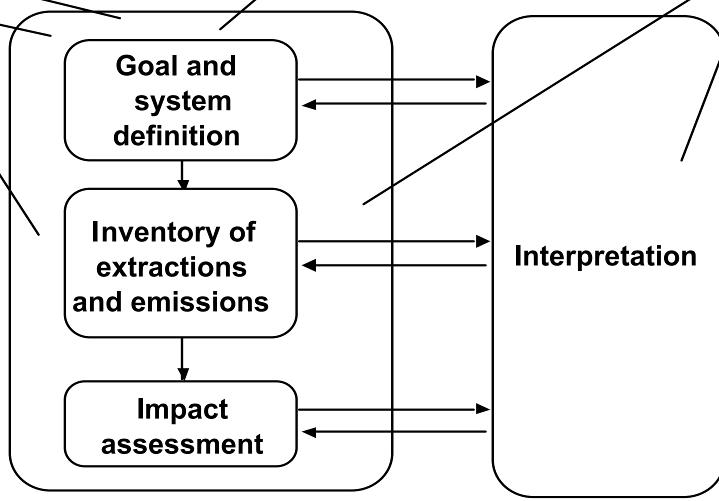
- To avoid allocation: Process separation, if it is possible to dissociate the different production systems; System extension, if the substituted product is fully defined

- Physical allocation only in case of physical causality. Allocation on the basis of mass or energy content is to be avoided without direct causality. Use marginal allocation, when it is possible to vary marginally the proportion between the co-product and the product

- Financial allocation in other cases as a measure of the incentive for production.

2b Data quality

Data quality depends on reliability, completeness, together with temporal, geographical and technical correlations



3 Impact assessment

Impact assessment methods should at least include main informations on effect (e.g intrisic toxicity) and fate (tranport, dilution and degradation).

In addition modifiers such as background concentration and spatial differentiation could be considered

So far: use several impact

4. Interpretation

The impact assessment aims to compare the contributions of the production phases, of the different pollutants and for each LCA steps.

Therefore, interpretation should be carried out at different levels, looking:
- At the contribution of each production step. Improvement should be carried out in priority for steps generating the largest impact and for those with the best cost efficiency (low cost)
- At the contribution of each pollutant
- At each phase of the life cycle assessment, after the inventory, the characterisation and the valuations steps.

Key points for good LCA practice
1a. Screening approach

1.Goal and system definition

1a. Screening approach

It is recommended to carry out the LCA in two steps:

- A first screening phase covering the whole LCA and assessing order of magnitude of emission inventory and impacts

- A detailed analysis to improve the assessment for most important impacts

1b.Function+functional unit

1.Goal and system definition

1b. System function

LCA : environmental impacts related to function. Comparison only on the basis of a similar (secundary ?) function.

1c Functional unit (FU)

Common unit representing the function of the system. Inventory emission are calculated per FU

The reference flow : basic inputs to obtain 1 functional unit. Difers between scenarios

Key parameters: product life time & number of reuse

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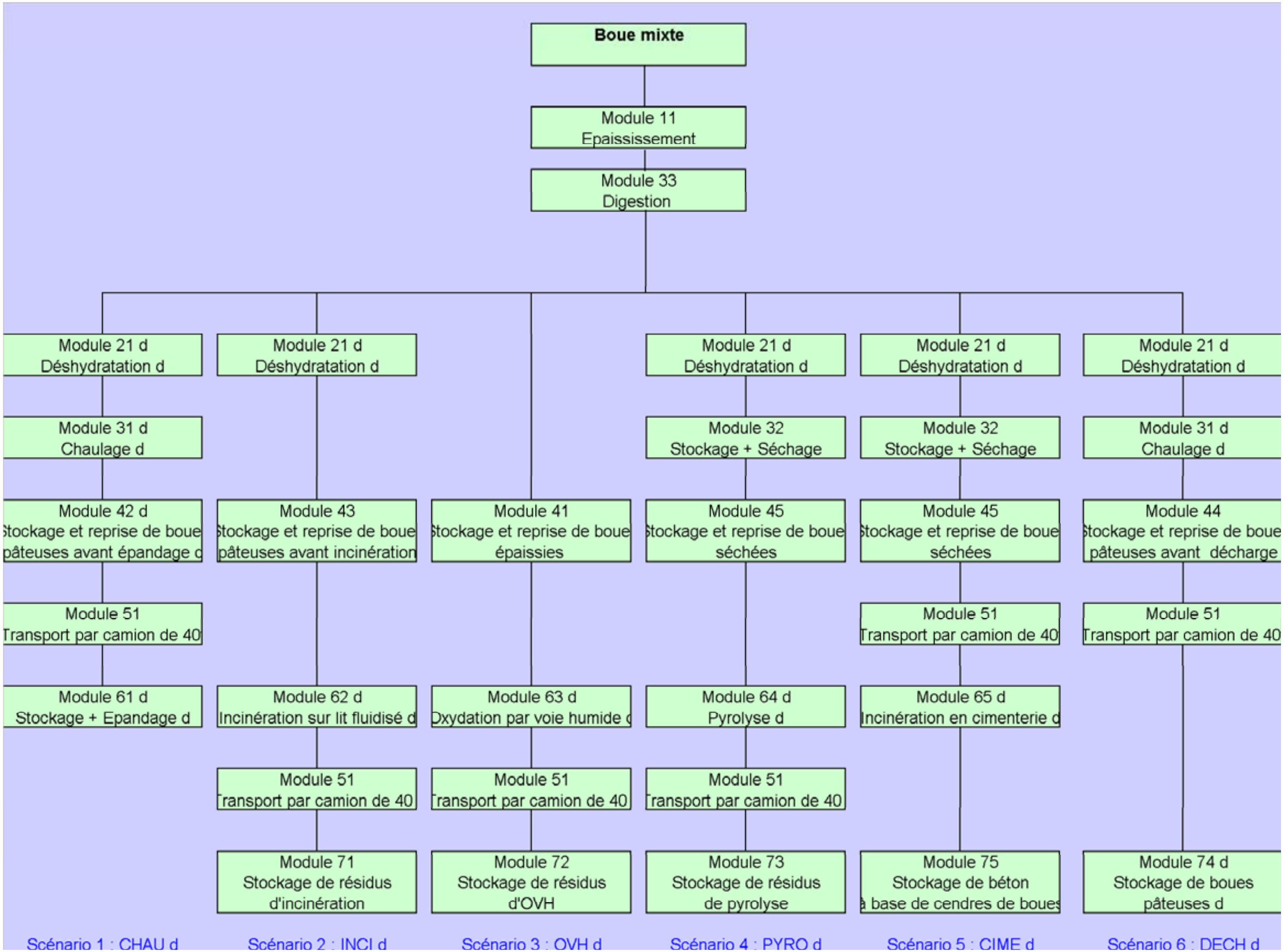
Process tree (with digestion)



Key points for good LCA practice
1c. System boundaries

1.Goal and system definition

1c System boundaries

All the necessary processes to assure the desired function.

Rule 1: Cover the same reality in all scenarios

Rule 2: Only processes contributing to more than x% of the emissions/mass

Rule 3: Identical processes excluded only if reference flows are also identical.

Herbicides A et B treatment of 1 ha

Labour

20 l Diesel

↓

Application herbicides A

10kgA, 5 l Diesel

↓

Yield

Labour

20 l Diesel

↓

Application herbicides B

0.2kgB, 2 l Diesel

↓

Yield

Herbicides A et B treatment of 1 ha

Labour
20 l Diesel

↓

Application herbicides A
10kgA, 5 l Diesel

↓

Yield 5 t

Labour
20 l Diesel

↓

Application herbicides B
0.2kgB, 2 l Diesel

↓

Yield 4 t

Herbicides A et B treatment of 1 ha

Labour
20 l Diesel

per FU
4 l Diesel/t

Application herbicides A
10kgA, 5 l Diesel

2kgA/t,
1 l Diesel/t

Tot:
5 l Diesel/t

Yield 5 t

Labour
20 l Diesel

per FU
5 l Diesel/t

Application herbicides B
0.2kgB, 2 l Diesel

0.05kgB/t,
0.5 l Dies./t

Tot:
5.5 l Dies./t

Yield 4 t

Key points for good LCA practice
1c. System boundaries

1.Goal and system definition

1c System boundaries

All the necessary processes to assure the desired function.

Rule 1: Cover the same reality in all scenarios

Rule 2: Only processes contributing to more than x% of the emissions/mass

Rule 3: Identical processes excluded only if reference flows are also identical.

Pharma product system boundaries

Europe

Switzerland

Europe

World

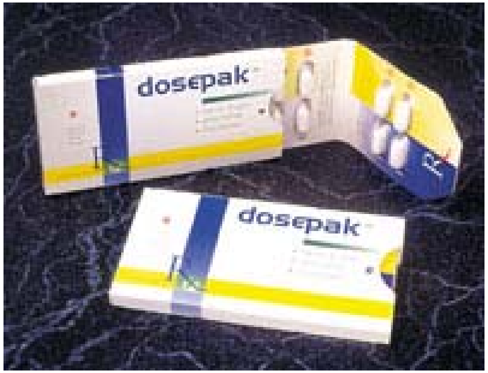
R&D

Chemical production

Pharmaceutical production

Production site

Packaging



Sales/ shipping unit

Pharma product system boundaries

Europe

R&D

Switzerland

Chemical production

↓

Pharmaceutical production

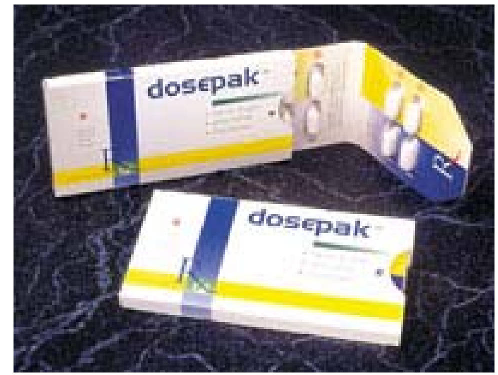
Production site

Sales/ shipping unit

Europe

Packaging

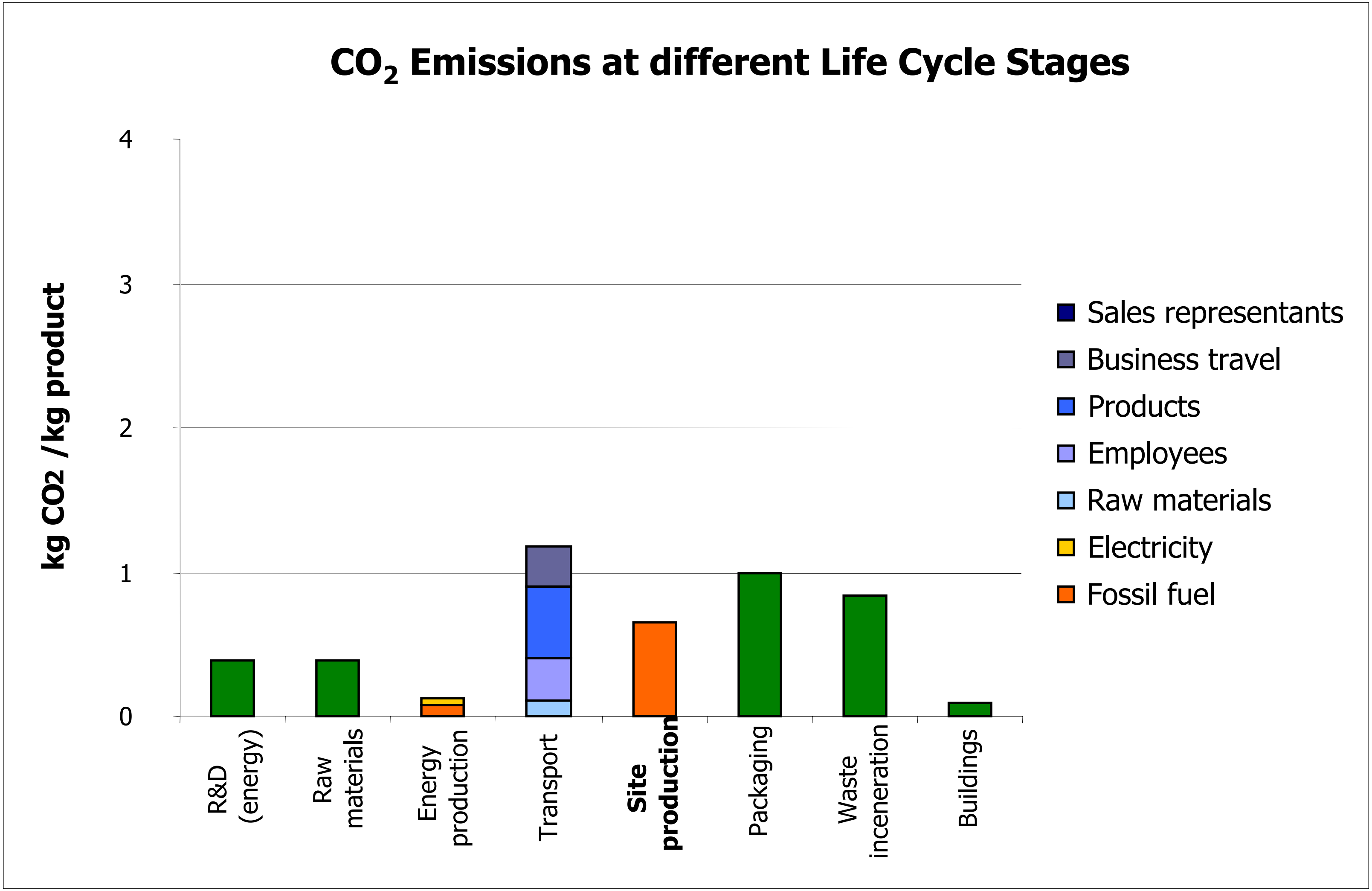
World



Secondary packaging
6 x the product mass
70 x the active substance mass

t

CO2 Emissions Pharma Industry



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Pharma product system boundaries

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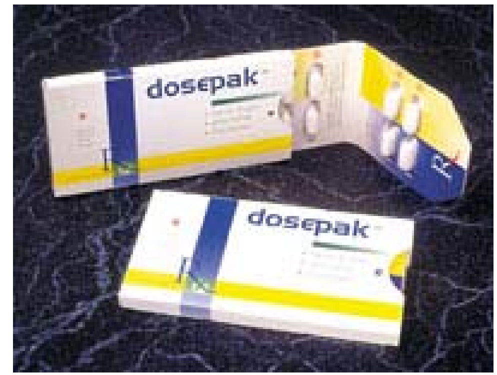
Europe	Switzerland	Europe	World
R&D	**Chemical production** → **Pharmaceutical production** (Production site)	**Packaging**	



Sales/ shipping unit

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Pharma product system boundaries

Europe

R&D

Switzerland

Chemical production

Pharmaceutical production

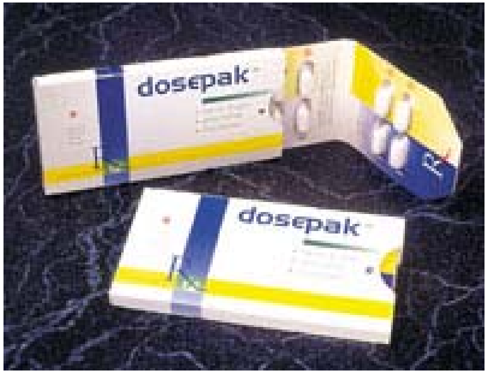
Production site

Sales/ shipping unit

Europe

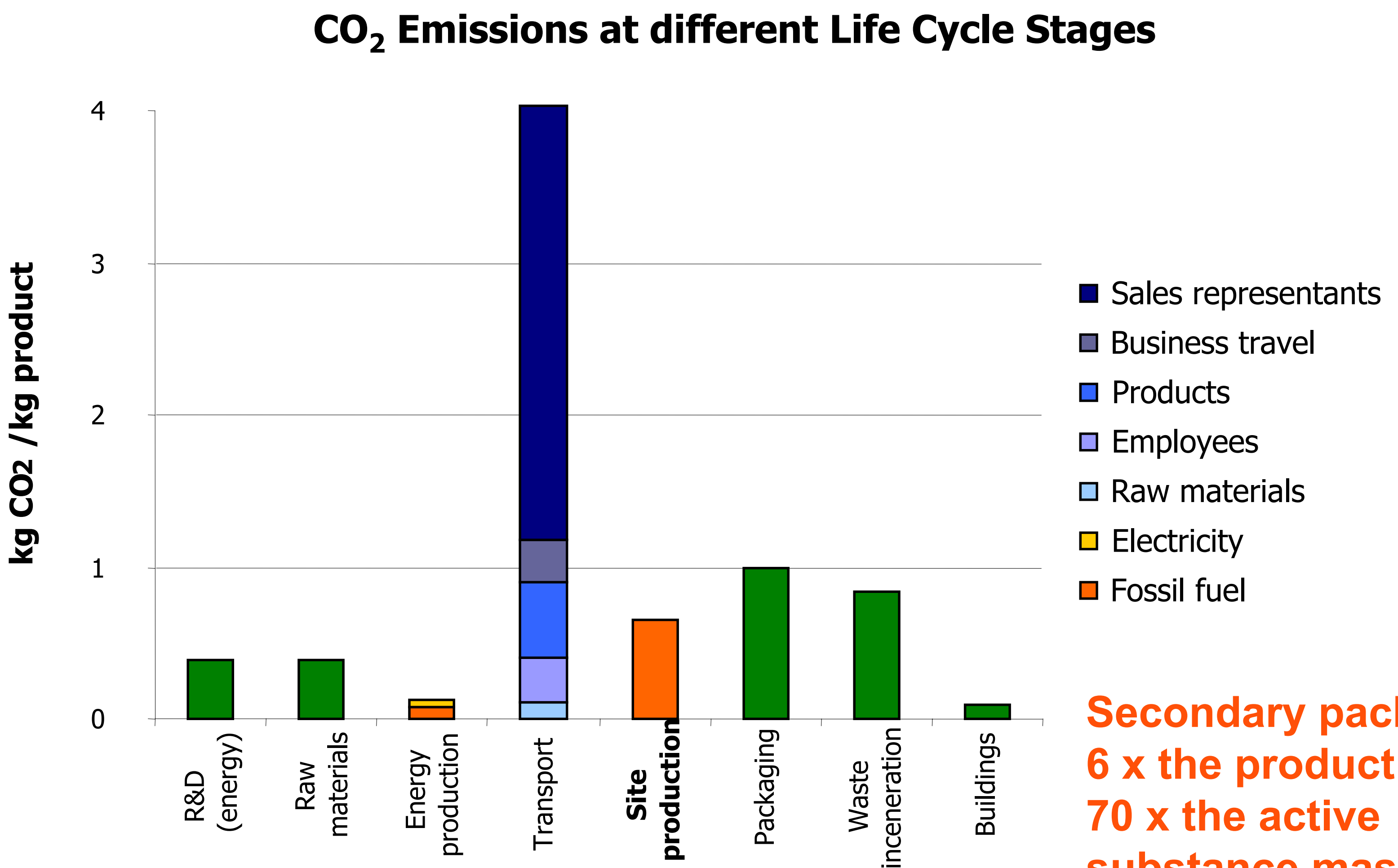
Packaging

World



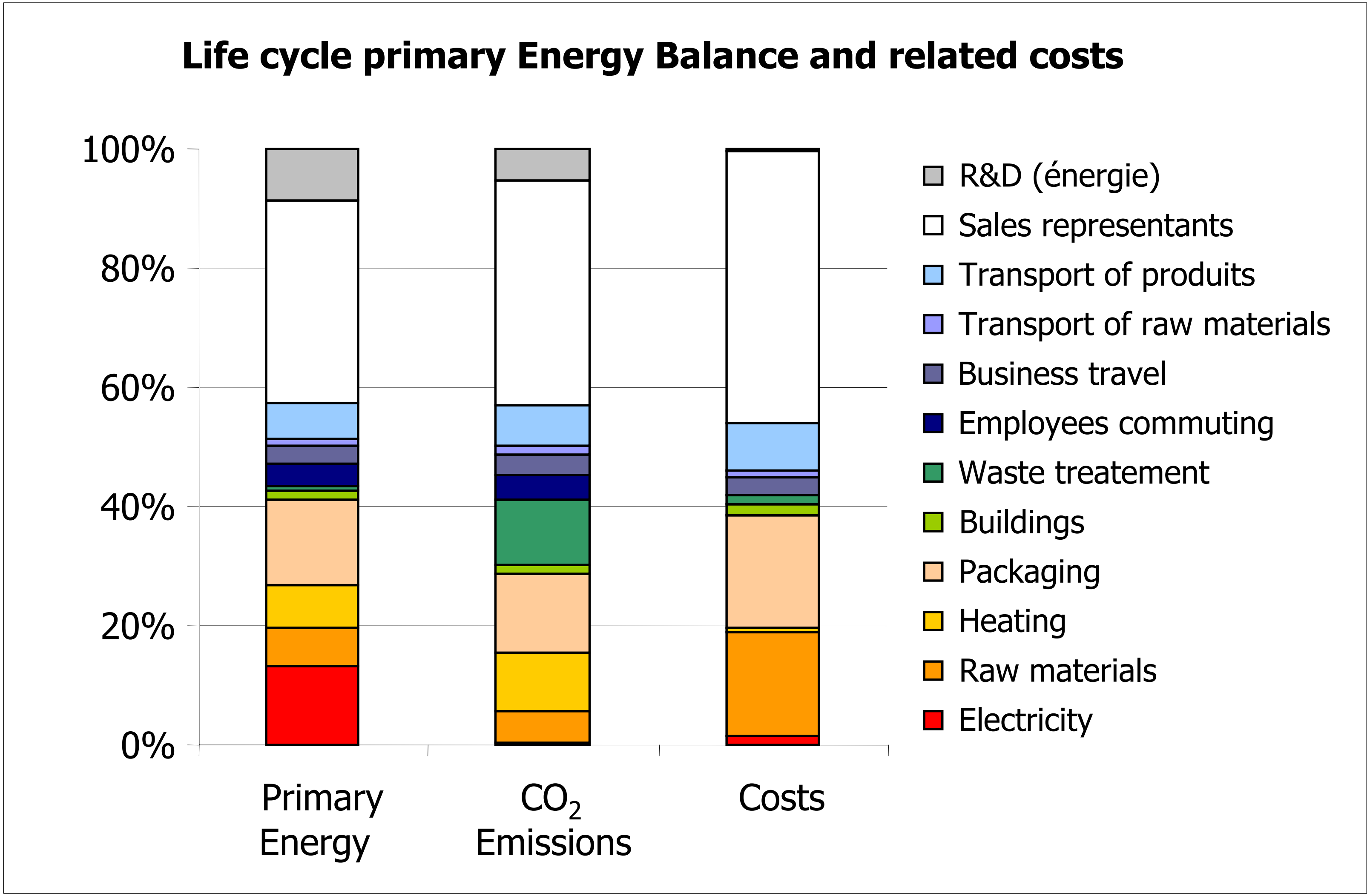
Worldwide sales (representants)

CO2 Emissions Pharma Industry



Secondary packaging 6 x the product mass 70 x the active substance mass

LC Environment vs. cost



Key points for good LCA practice
1c. System boundaries

1.Goal and system definition

Look at cost structure to avoid forgetting main impacts:

→ Check if all steps representing main costs have been considered

→ Conduct screenings with Input/Output LCA

Key points for good LCA practice
2a. Allocation

2.Inventory

2a. Allocation

Only if causality principle), in the following order of preference:

- To avoid allocation by:

Process separation, if possible to dissociat

System extension, if the substituted produ is fully defined

- Physical allocation only if proved causalit Avoid mass or x without direct causality.

- Financial allocation as incentive for production

Key points for good LCA practice
2b. Check for errors

2.Inventory

2b Data quality: depends on reliability, completeness, temporal, geographical and technical correlations

1st rule: never trust a software !

a) Perform a primary energy and CO_2 hand calculated inventory

looking at
- reference flows and
- emission factors MJ/unit or kgCO_2/unit

b) Check gCO_2/MJ

c) Check the Carbon balance

Screening - first order of magnitude: primary energy balance

Energy consumption during use phase

1 kWh electricity (Europe)	11.8 MJ non renewable primary energy
1 kWh electricity (CH-Switzerland)	7.3 MJ
1 kg oil (42.5 MJ final)	50 MJ
1 l gasoline	43 MJ
1 m3 water	7- 20 MJ

Transport

1000 km kg Transport lorry CH	5.1 MJ
1000 km kg Transport plane	17 MJ
1 pers km Train	0.5 MJ
1 pers km Car/plane	3.2 MJ

Materials (per kg !!!)

1 kg Aluminium	184 MJ
1 kg Recycled aluminium	18.5 MJ
1 kg Copper	106 MJ
1 kg Steel	30-100 MJ
1 kg Plastics	80-110 MJ
1 kg Paper	20 MJ
1 kg Glass	14 MJ
1 kg Concrete	0.6 MJ
1 kg PC-control unit	210-1000 MJ

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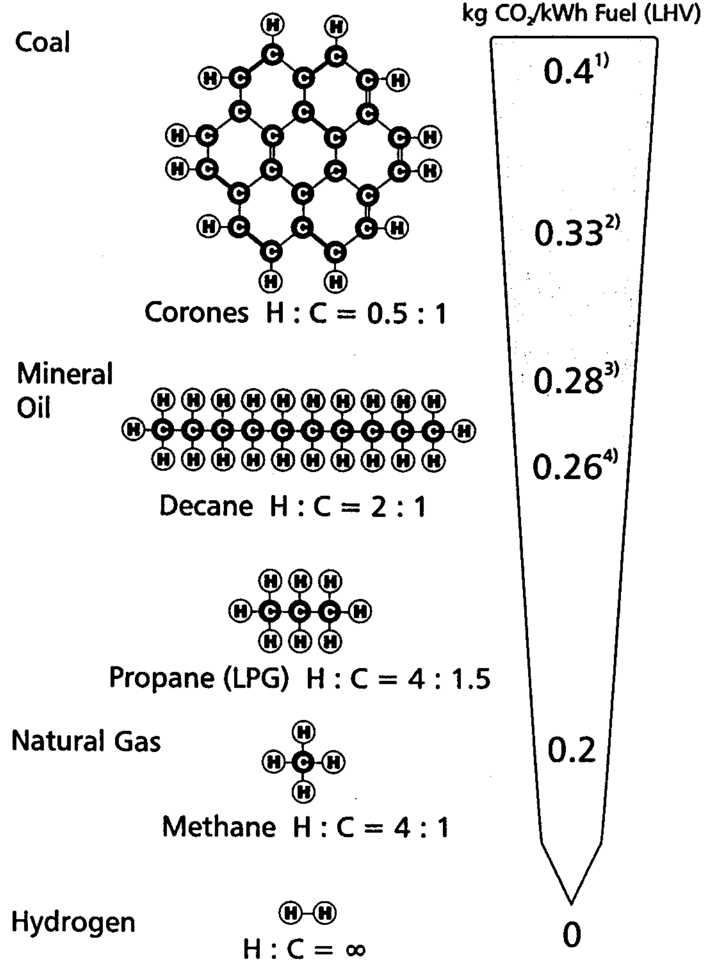
Reference flows for unit processes

Numéro du module	Nom du module					
Consommation d'énergie						
11	Epaississement					
		Boues	1	tMS		
		Siccité	0.3%	%		
		Electricité	41.6	kWh/tMS	(Philippe Koller, STEP d'Aïre)	566
		Polymère	0.13	kg/tMS	(Philippe Koller, STEP d'Aïre)	5
21	Déshydratation					
		Boues	1	tMS		
		Siccité	6.8%	%		
		Electricité	69	kWh/tMS	[Blaize, 2000]	938
		Polymère	7	kg/tMS	[Bobin, 2000]	293
44	Stockage et reprise de boues pâteuses avant incinération					
		Boues	1	tMS		
		Siccité	25%	%		
		Electricité	29.3	kWh/tMS	Calcul	398
62	Incinération sur lit fluidisé					
		Boues	1	tMS		
		Siccité	25%	%		
		Electricité	260	kWh/tMS	(Jean Verguet, Degrémont)	3536
		Gaz naturel	65	Nm^3/tMS	(Jean Verguet, Degrémont)	2551
		Chaux	30	kg/tMS	(Jean Verguet, Degrémont)	84
		Charbon actif	2	kg/tMS	(Jean Verguet, Degrémont)	141
		Diesel	12.8	l/tMS	[Bobin, 2000]	
		Densité	0.84	kg/l	[Chassot, Candinas, 1997]	502
51	Transport des résidus par camion de 40 t					
		Cendres	408	kgMB	(Jean Verguet, Degrémont)	
		Résidus d'épuration	45	kgMB	(Jean Verguet, Degrémont)	
		Distance	100	km	Donnée de l'étude	
			45.3	tkm/tMS	Calcul	118
71	Stockage des résidus d'incinération					
	Stockage	Cendres	0.408	tMB/tMS	(Jean Verguet, Degrémont)	
		Résidus d'épuration	0.045	tMB/tMS	(Jean Verguet, Degrémont)	
		Diesel	2.1	kg/tMS	[BUWAL, 1998]	44
		Electricité	0.5	kWh/tMS	[BUWAL, 1998]	3
		Huile de chauffage	0.13	kg/tMS	[BUWAL, 1998]	3
Total						**9183**
Economie d'énergie						
121	Production et utilisation de gaz naturel pour la production d'eau chaude					
		Energie économisée	5198	MJ/tMS	(Jean Verguet, Degrémont)	
		PCI Gaz naturel	36	MJ/Nm^3	(Jean Verguet, Degrémont)	
		Rendement de la chaudière	0.8		(Didier Grouset, Ecole des Mines d'Albi)	
		Gaz économisé	180.5	Nm^3/tMS	Calcul (cf. Annexe 4)	7084
Total						**7084**
Bilan						**2099**

H:C ratio and CO2 emissions per MJ

The Atomic Hydrogen/Carbon Ratio



1) Brown Coal 2) Hard Coal

Comparaison - check gCO2 / MJ non renewable primary

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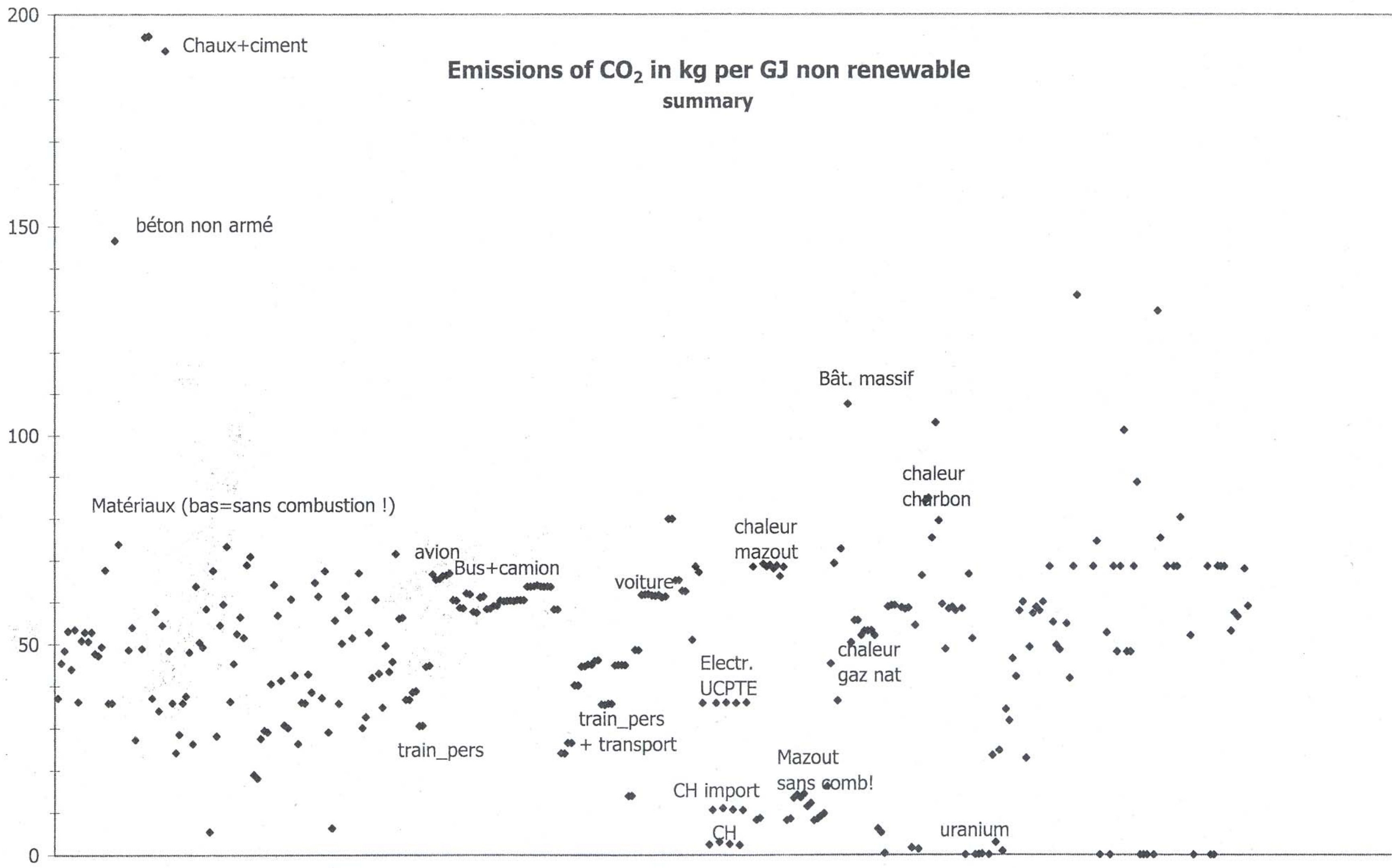


Contrôle: g CO2 par MJ primaire non renouvelable

Fossil fuels (transport + heat) :

oil, petrol, diesel, kerosene — 58 - 70 gCO_2/MJ (incl. 10g precombustion)

Natural Gas — 52 - 57 gCO_2/MJ

Coke — 75 - 103 gCO_2/MJ

Electricity (Europe) — 43 gCO_2/MJ

Electricity (CH supply) — 16 gCO_2/MJ

Electricity (CH production) — 3 gCO_2/MJ

Materials:

Fossil materials: plastics, etc. — 60 gCO_2/MJ env. (30g manufacturing, 30g elimination)

Metals: depends on % electricity and mix — Env. 50 gCO_2/MJ

Concrete — 148 gCO_2/MJ

Cement — 195 gCO_2/MJ

Wood, cardboard, renewable energy — Also about 65 gCO_2/MJ non renewable

Negative before EOL because fixation

Problem detection:

- If diesel, oil around 10 gCO_2/MJ: combustion is not considered
- If plastics around 30 gCO_2/MJ, EOL emissions have been neglected
- If renewable negative, EOL not considered, only fixation

Émissions de CO_2

Phase	Quantité par UF [Unité par UF]	Emissions par unité [kgCO2/Unité]	Emissions par UF [kg_{CO2}/UF]	Check [kg_{CO2}/GJ]
Materiaux Verre Cuivre	 0.12 [kg/UF] 0.09 [kg/UF]	 1 [kg_{CO2}/kg] 5.2 [kg_{CO2}/kg]	 0.12 0.47	 70 49
Fabrication	2.2 [MJ_{prim}/UF] (6 x 0.35 MJ_{prim}/amp)	2 [kg_{CO2}/ 1000 MJ_{prim}]	0.0044	2
Utilisation	360 [kWh_{fin}/UF] = 1296 [MJ_{fin}/UF]	0.01 [kg_{CO2}/ 1000MJ_{fin}]	12.96	4
Transport	270 [kg·km/UF]	0.3 [kg_{CO2}/ 1000kg·km]	0.081	58
Emballage	0.06 [kg/UF]	-1.09 [kg_{CO2}/kg] + [kg_{CO2}/kg]	-0.065	
Total			13.7	

Carbon balance for landspreading of sludges (kg C per t dry matter)

Carbon in kg C	Air	As CO_2	338.7	kg C
338.7				
	Water	MeS	7.0	
Thickening	Water	MeS	4.5	
	Water	MeS	20.3	
306.9				
Dehydration	Water	MeS	14.5	
292.4				
Transport				
292.4				
Storage	Water	MeS	0.003	
292.4				
Land spreading	Air	CH_4	10.5	
		CO_2	281.9	

Most common mistakes to be avoided in software tools

a) Unit check → good practice for Excel

An Excel formula shall never contain a figure. All data should be entered in separate cells, including conversion factors and units

→ one constant defined only in a single cell to enable consistant updates

Most common mistakes to be avoided in software tools

a) Unit check → good practice for Excel

b) Compare hand calculated and software results

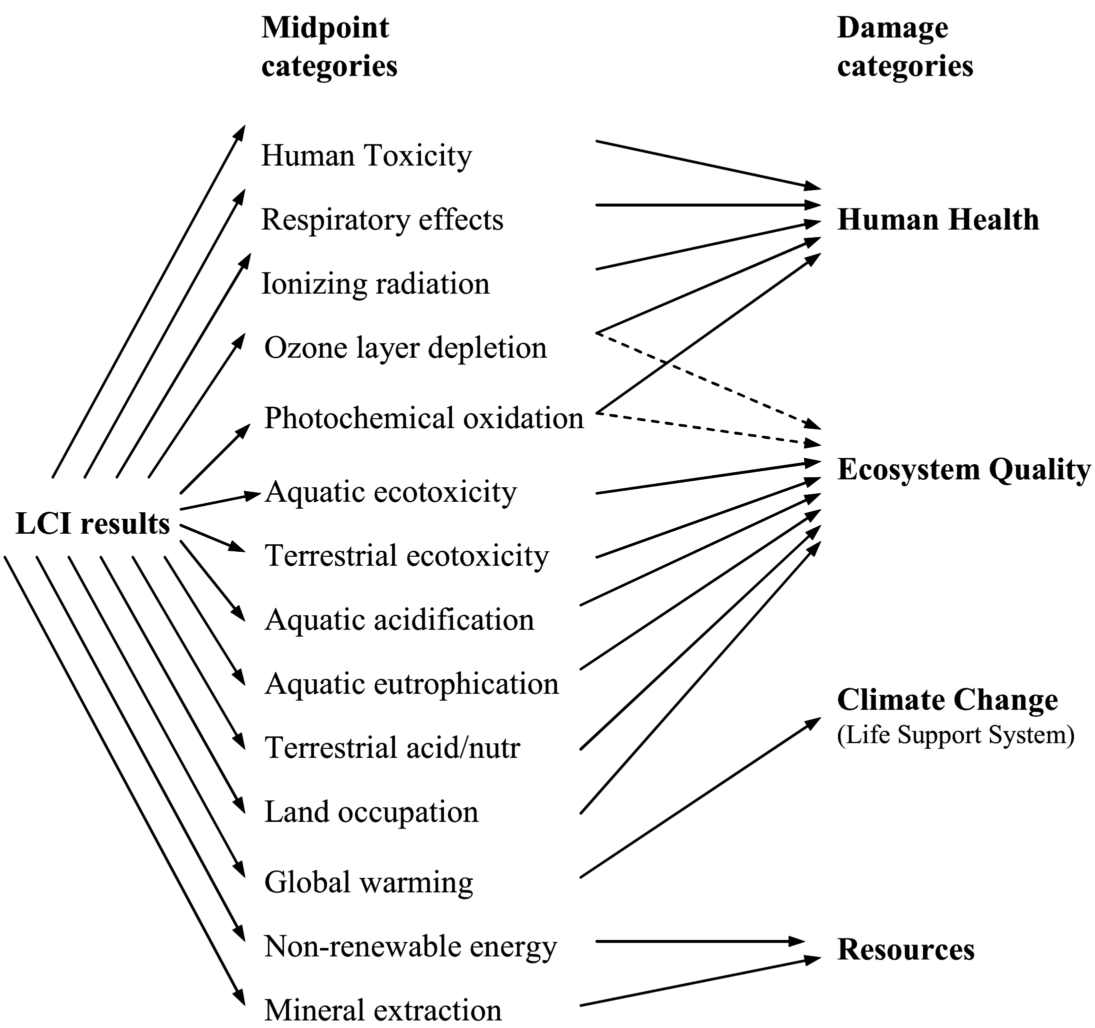
c) In LCA software: inconsistencies in substance identification

e.g. Non Methane Volatile Organic Compounds
NMVOC, HxCx, HC, COV, Hydrocarbons

Partikel, particles

→ systematically check the substances not considered in the impact assessment as displayed ...
or have CAS identification as e.g. in Simapro 6.

IMPACT 2002+


Midpoint
categories
Damage
categories
Human Toxicity
Respiratory effects
Ionizing radiation
Ozone layer depletion
Photochemical oxidation
Aquatic ecotoxicity
Terrestrial ecotoxicity
Aquatic acidification
Aquatic eutrophication
Terrestrial acid/nutr
Land occupation
Global warming
Non-renewable energy
Mineral extraction
LCI results
Human Health
Ecosystem Quality
Climate Change
(Life Support System)
Resources

Challenge

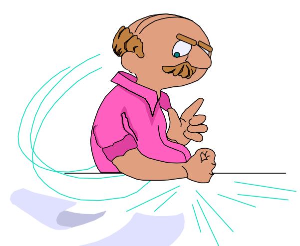
Tell me your results
I will tell who paid you !

Urgent need for recognised and consistent impact assessment methods

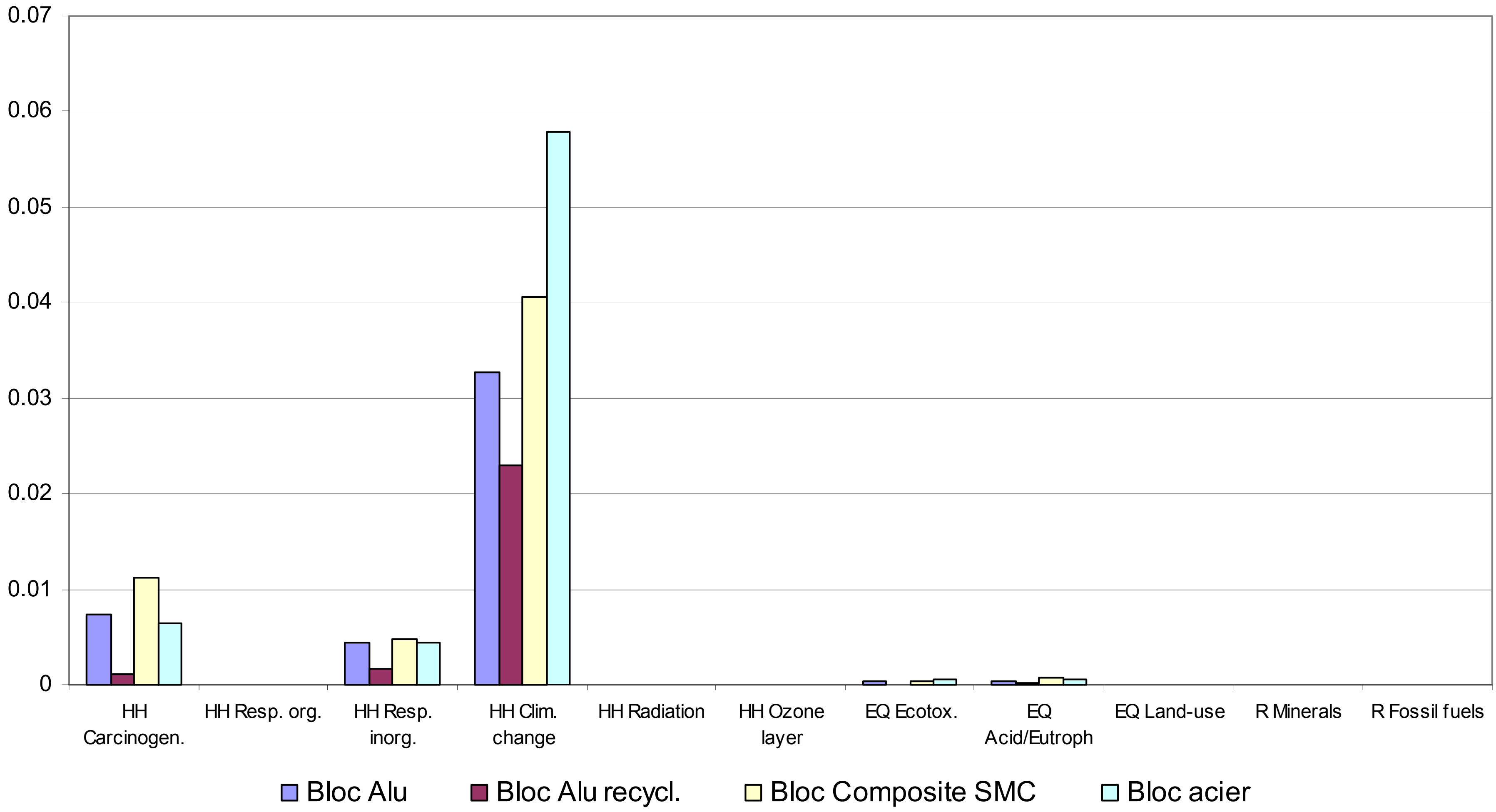
+ address ISO 14042 requirements (scientifically valid + environmentally relevant)

--> needs for a general framework for toxicity assessment.

No assessment means an implicit assessment !



Aggregate=make comparable
EcoIndicator 99 - Normalised damages



Front end panel

Key points for good LCA practice
3. Impact assessment

3.Impact assessment

At least include main informations on effect (e.g intrisic toxicity) and fate (tranport, dilution and degradation).

So far: use several impact assessment methods in parallel

Keep information separate

→ check orders of magnitude, for toxicity all substances contributing to more than 1‰ of the impact could be significant

Key points for good LCA practice
4. Interpretation

Interprete !

4. Compare the contributions at different levels, looking:

- At the contribution of each life cycle step (raw material, production, use, waste): Improvement in priority for steps generating largest impact and low cost

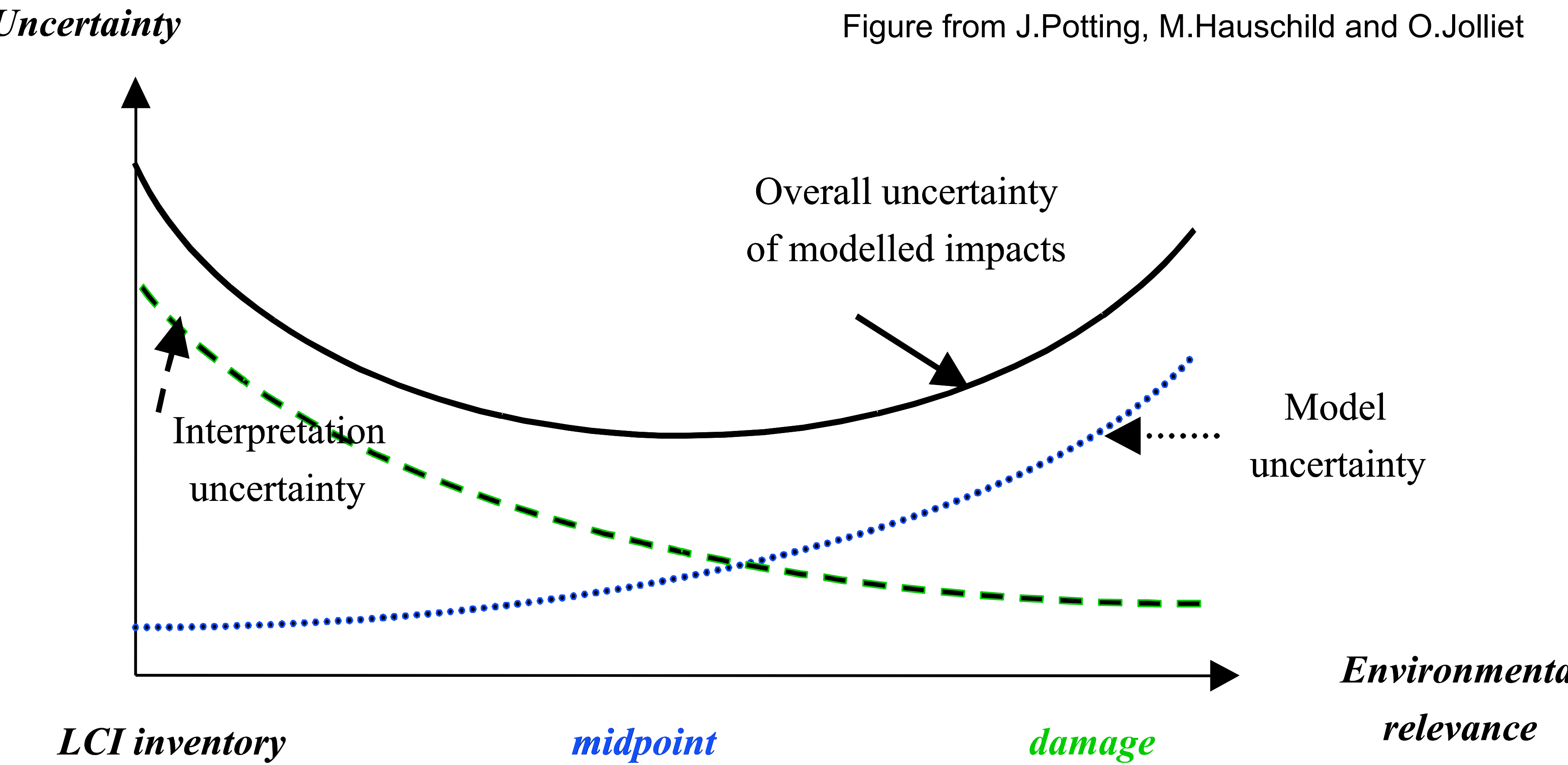
- At the contribution of each pollutant

- At each LCA phase, after the inventory, the characterisation and the valuations steps.

More time on interpretation !

Towards a combination of midpoint-endpoint

Figure from J.Potting, M.Hauschild and O.Jolliet



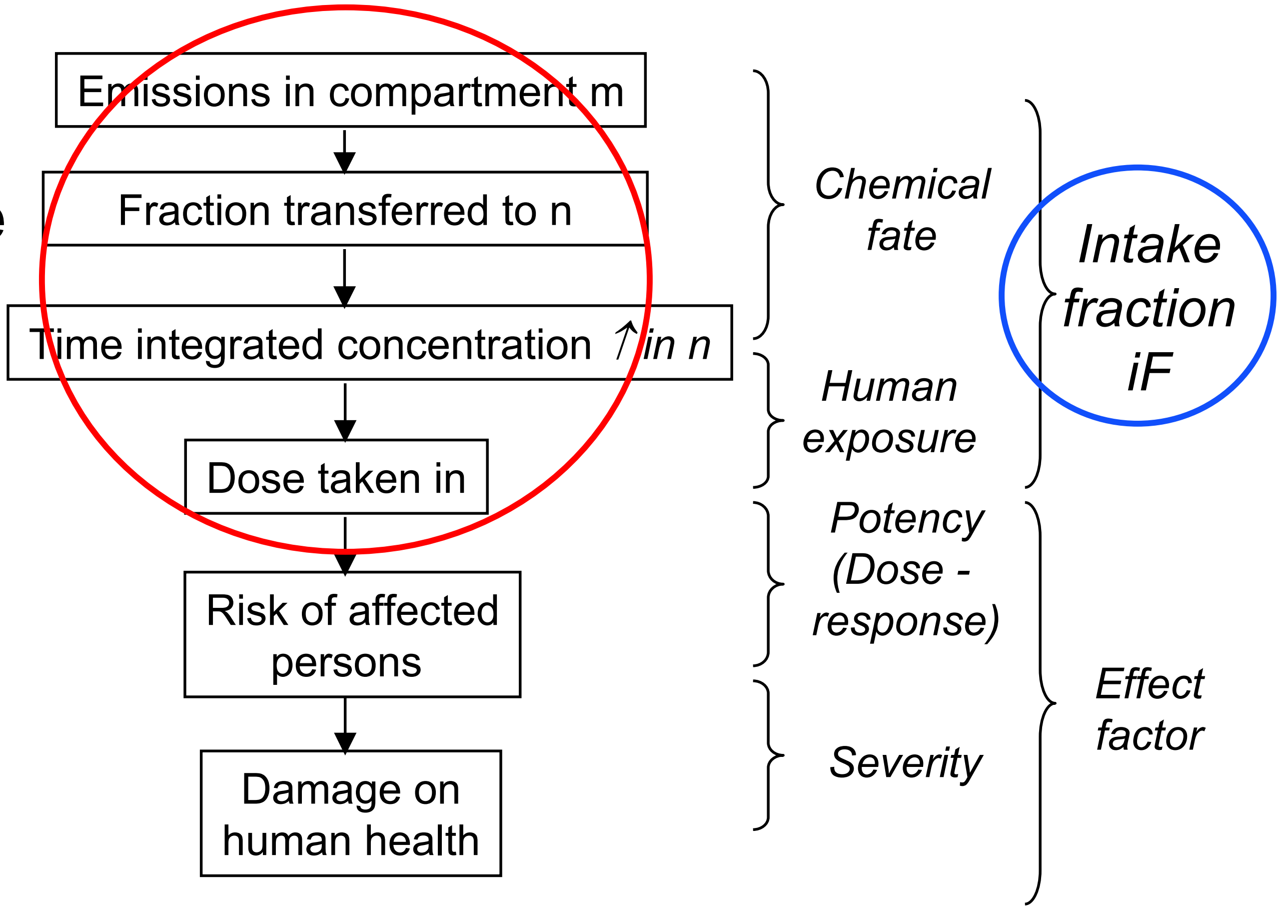
Stop when increase in model uncertainty > increase in relevance !

IMPACT 2002+

Midpoint categories	Damage factors	Units
Carcinogens	1.45E-06	DALY/kg chloroethylene
Non-carcinogens	1.45E-06	DALY/kg chloroethylene
Respiratory inorganics	7.00E-04	DALY/kg PM2.5
Ozone layer	1.05E-03	DALY/kg CFC-11
Radiation	2.10E-10	DALY/Bq carbon-14
Respiratory organics	2.13E-06	DALY/kg ethylene
Aquatic ecotoxicity	8.86E-05	PDF.m^2.yr/kg triethylene glycol
Terrestrial ecotoxicity	8.86E-05	PDF.m^2.yr/kg triethylene glycol
Terrestrial acidification/nutr.	1.04	PDF.m^2.yr/kg $SO_{2\$}$
Land occupation	1.09	PDF.m^2.yr/m^2 organic arable land.yr
Global Warming	1	kg CO_2/kg CO_2
Mineral extraction	5.10E-02	MJ/kg iron
Non-renewable energy	45.6	MJ/kg crude oil

Emission to damage

Fate side



$$iF = \frac{\sum_{\text{people, time}} \text{intake of pollutant by an individual } (mass)}{\text{mass released into the environment } (\text{mass})}$$

(ES&T, 2002)

Energy balance

Phase	Quantity per FU [Unit perUF]	Energy per unit [MJ/Unit]	Energy per FU [MJ/FU]
Materials			
Manufactu-ring			
Use			
Transport			
Packing			
Total			

CO2 emissions

Phase	Quantity per FU [Unit perUF]	Emission per unit [kgCO2/Unit]	Emission per FU [kgCO2/FU]
Materials	Like energy		
Manufactu-ring			
Use			
Transport			
Packing			
Total			