Life cycle assessment and additives: state of knowledge

Larsen, Henrik Fred; van der Voet, Ester; Rydberg, Tomas

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SEVENTH FRAMEWORK PROGRAMME

RISKCYCLE

Life cycle assessment and additives: state of knowledge

Henrik Fred Larsen, QSA, DTU Management Engineering

Ester van der Voet, CML

Tomas Rydberg, IVL

DTU

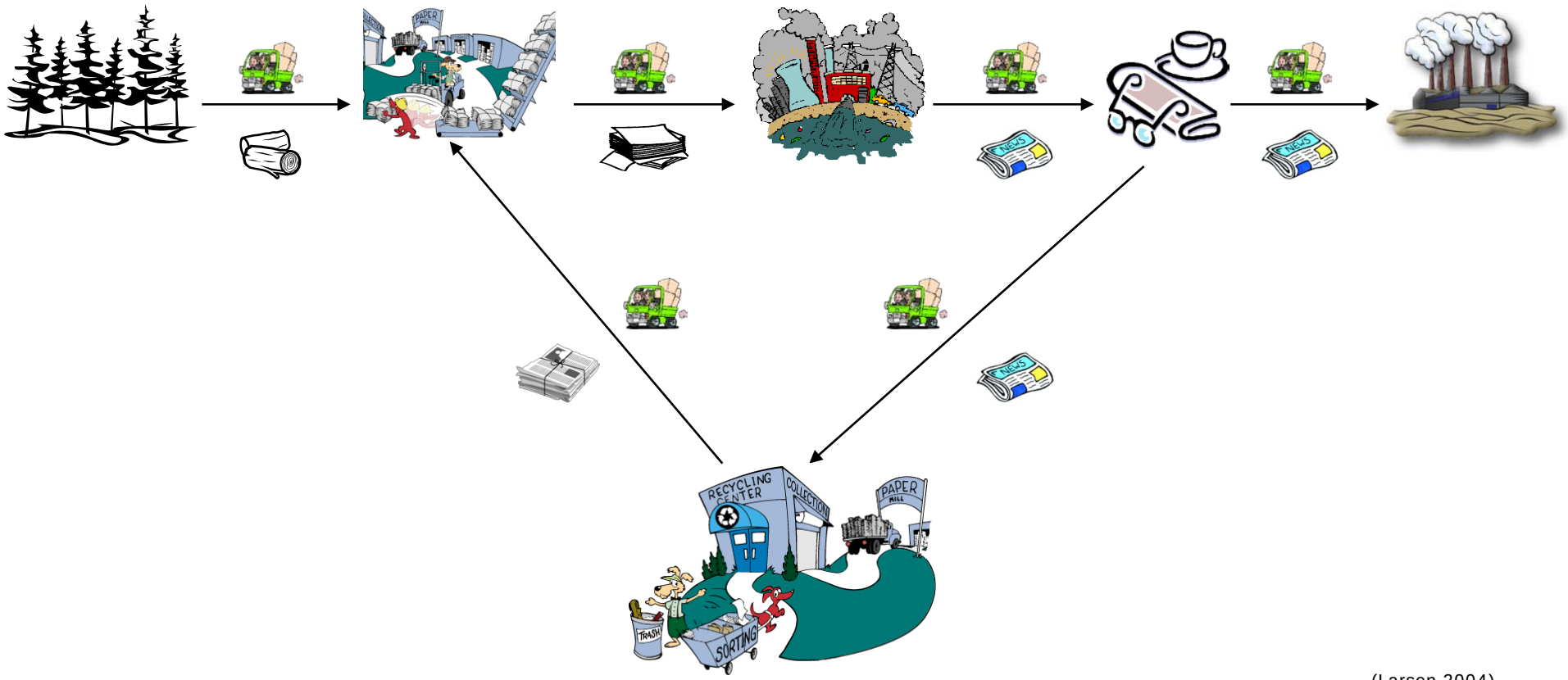
Outline

- Aims and status of RiskCycle WP6: Life cycle assessment (LCA) of additives
- What is LCA; example on printed matter/paper
- Life cycle inventory (LCI) on plastics and additives
- Outcomes of existing LCA studies on plastics and additives
- Life cycle impact assessment (LCIA) characterization factors for additives/impurities

Aims and status of WP6 on LCA of additives

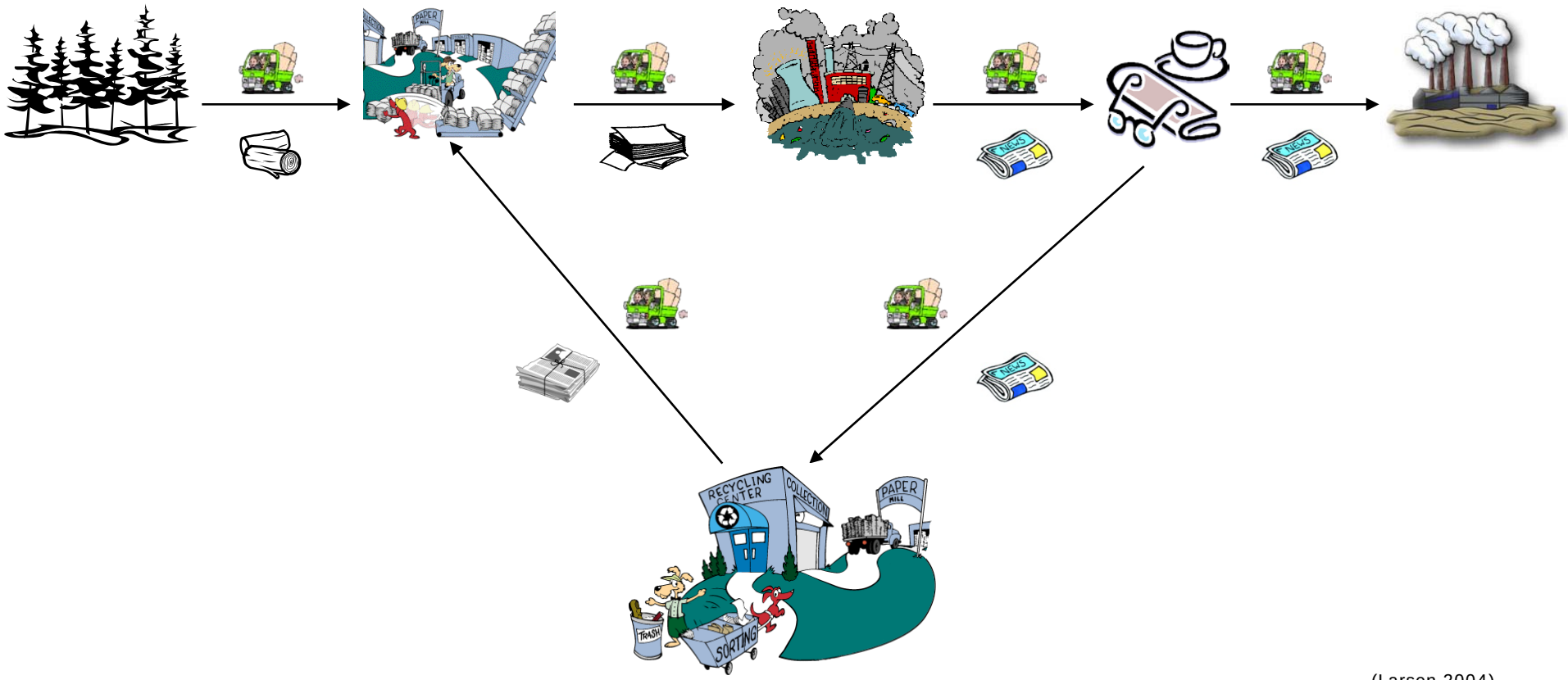
- Report state-of-the-art knowledge on LCA studies with relevance for additives: *Draft report on additives in plastics exists (D6.1)*
- Report on LCA framework for additives and their application: *In progress - An existing Swedish case study on plastic will be included in the coming Springer book "Global Risk-Based Management of Chemical Additives" (D6.2)*
- A database containing LCA (LCI and LCIA) data regarding selected additives: *In progress but problems with lack of data (D6.3)*
- Report on new illustrative LCA case studies. *Paper and plastic have been chosen. Not yet started up (D6.4)*

The life cycle of printed matter



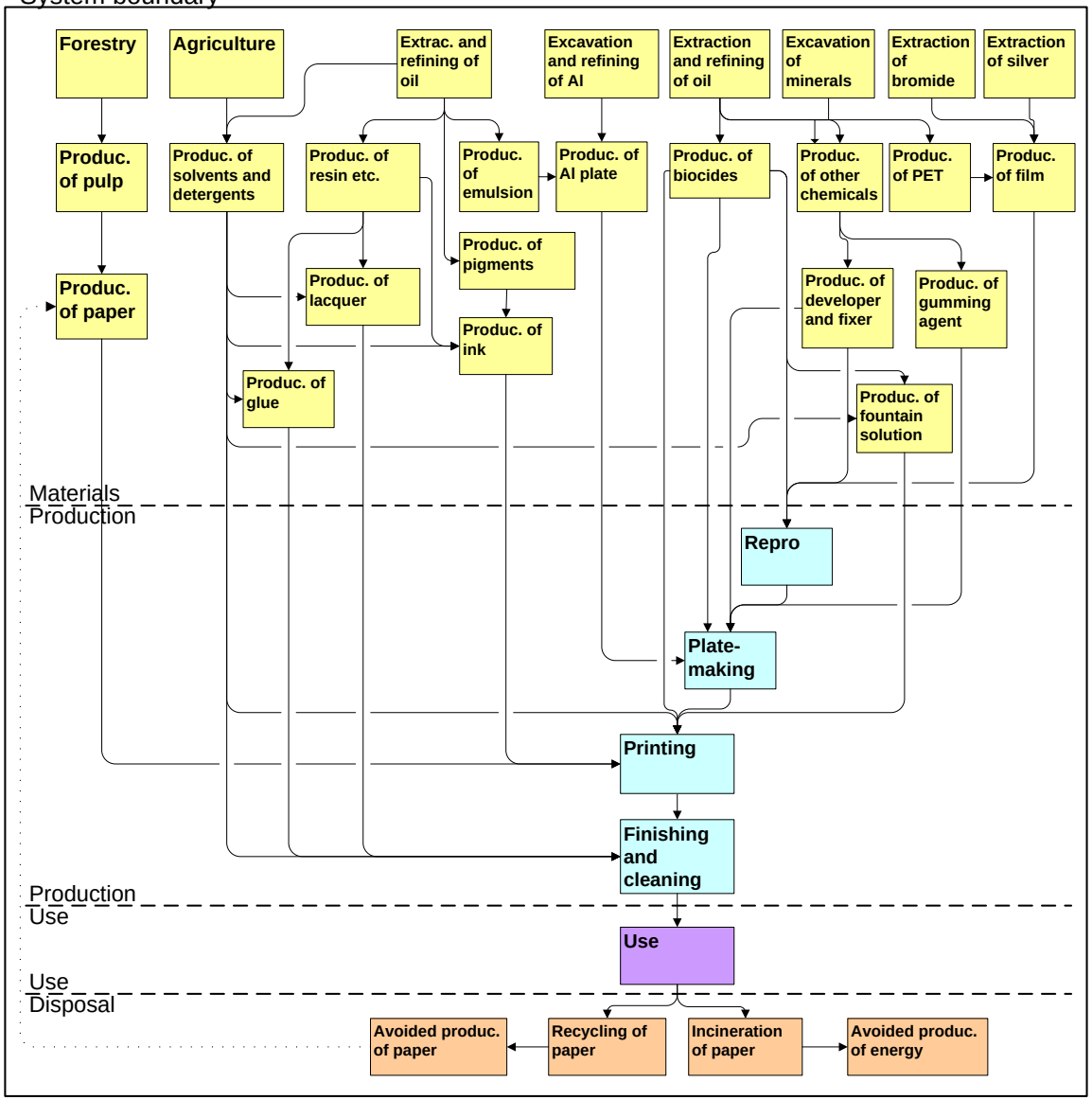
(Larsen 2004)

The life cycle of printed matter



(Larsen 2004)

System boundary



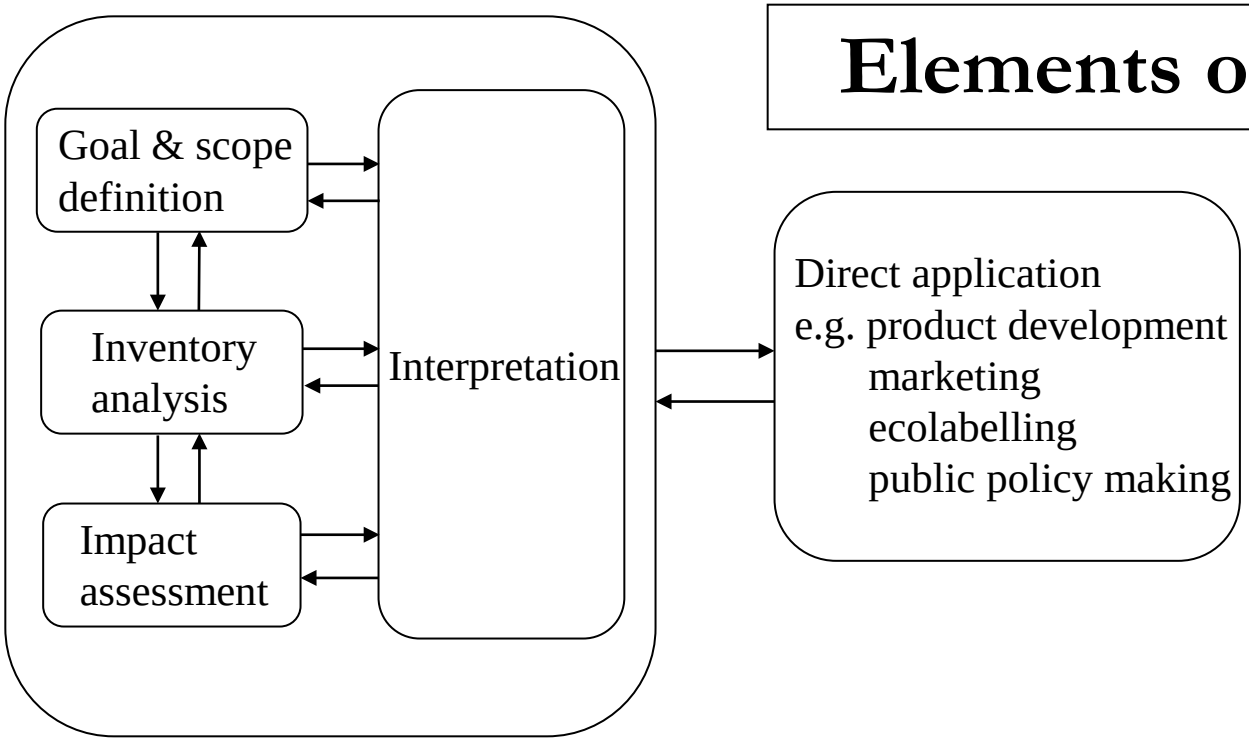
(Larsen et al. 2009)

What is Life Cycle Assessment, LCA?

Characteristic features of LCA:

- A decision supporting tool
- Focus on services typically represented by a product (the "functional unit") For example: 1 ton printed matter
- Comparative (relative statements). For example: Distribution of relative impacts from emissions and resource consumption during the life cycle
- Holistic perspective
  - life cycle from cradle to grave
  - all relevant environmental impacts, e.g. Global warming, acidification, ecotoxicity……..
  - resource consumption (biotic and abiotic), e.g. Kaolin, Al, Ag, coal….
- Aggregation over time and space
  - life cycle is global
  - life cycle may span over decades or even centuries

Elements of LCA (I)



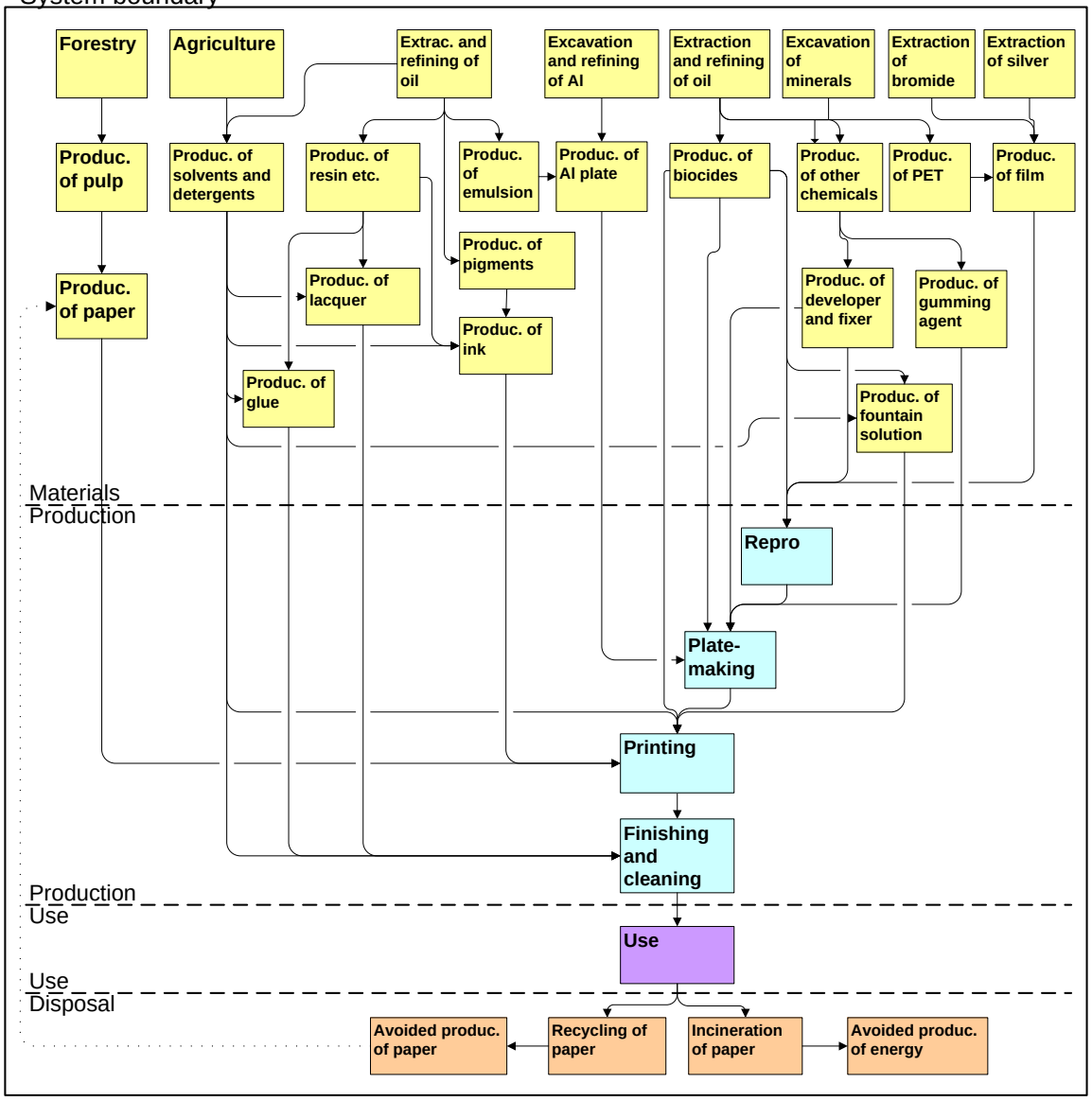
Goal and Scope definition

- defining goal: For example identify the distribution of potential impacts… defining scope: For example scoping the product system
- decisive for interpretation and use of results: For example identifying the importance of additives for the impact profile when recycling resources like paper and plastic

Inventory analysis (LCI)

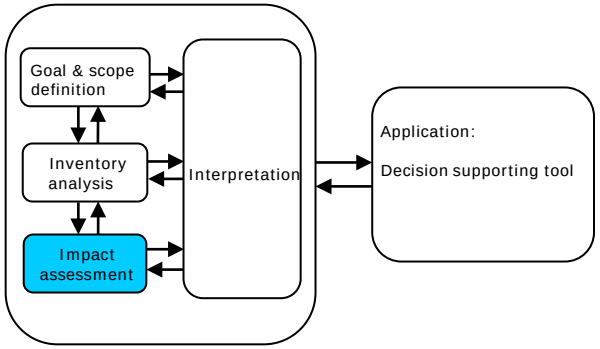
- collecting in- and output data for all processes

System boundary



(Larsen et al. 2009)

Life cycle impact assessment (LCIA)



Classification: *"What does this emission contribute to?"*

- Assignment of emissions to impact categories according to their potential effects
  - Global warming (e.g. CO_2, CH_4)
  - Acidification (e.g. NO_2, SO_3)
  - Ecotoxicity (e.g. phthalates, heavy metals)
  - Human toxicity (e.g. benzene, PAH's)
  - ……..

Characterisation: *"How much may it contribute?"*

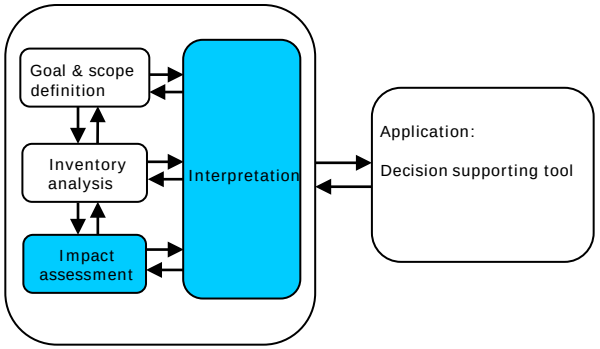
- Quantification of contributions to the different impact categories by estimating impact potentials, IPs (e.g. multiplying the characterisation factors (CFs) for each chemical by the emitted amount (Q) per functional unit (fu)):

$$IP = Q * CF$$

- Example (GWP):

Substance	Q (g/fu)	CF (g CO_2-eq/g)	IP (g CO_2-eq/fu)
Carbon dioxid (CO_2)	250	1	250
Methane (CH_4)	10	25	250
Total			500

Life cycle impact assessment (LCIA) and interpretation



Normalisation: *"Is that much?"*

- Expression of the impact potentials relative to a reference situation (person-equivalence, PE), e.g. normalisation reference (NR) for GWP: 8,700 kg CO_2-eq/pers/year. The normalised impact potential (nIP):

$$nIP = IP/NR$$

Impact category	NR (kg CO_2-eq/pers/year)	IP/fu (kg CO_2-eq/fu)	nIP (mPE/fu)
Global warming (GWP)	8700	0,5	0,057

Valuation: *"Is it important?"*

- Ranking, grouping or assignment of weights (weighting factors, WFs) to the different impact potentials (EDIP: political reduction targets), e.g. for global warming a targeted 10 years reduction of 20% => WF=1/(1-0.2) = 1.3. The weighted impact potential (wIP):

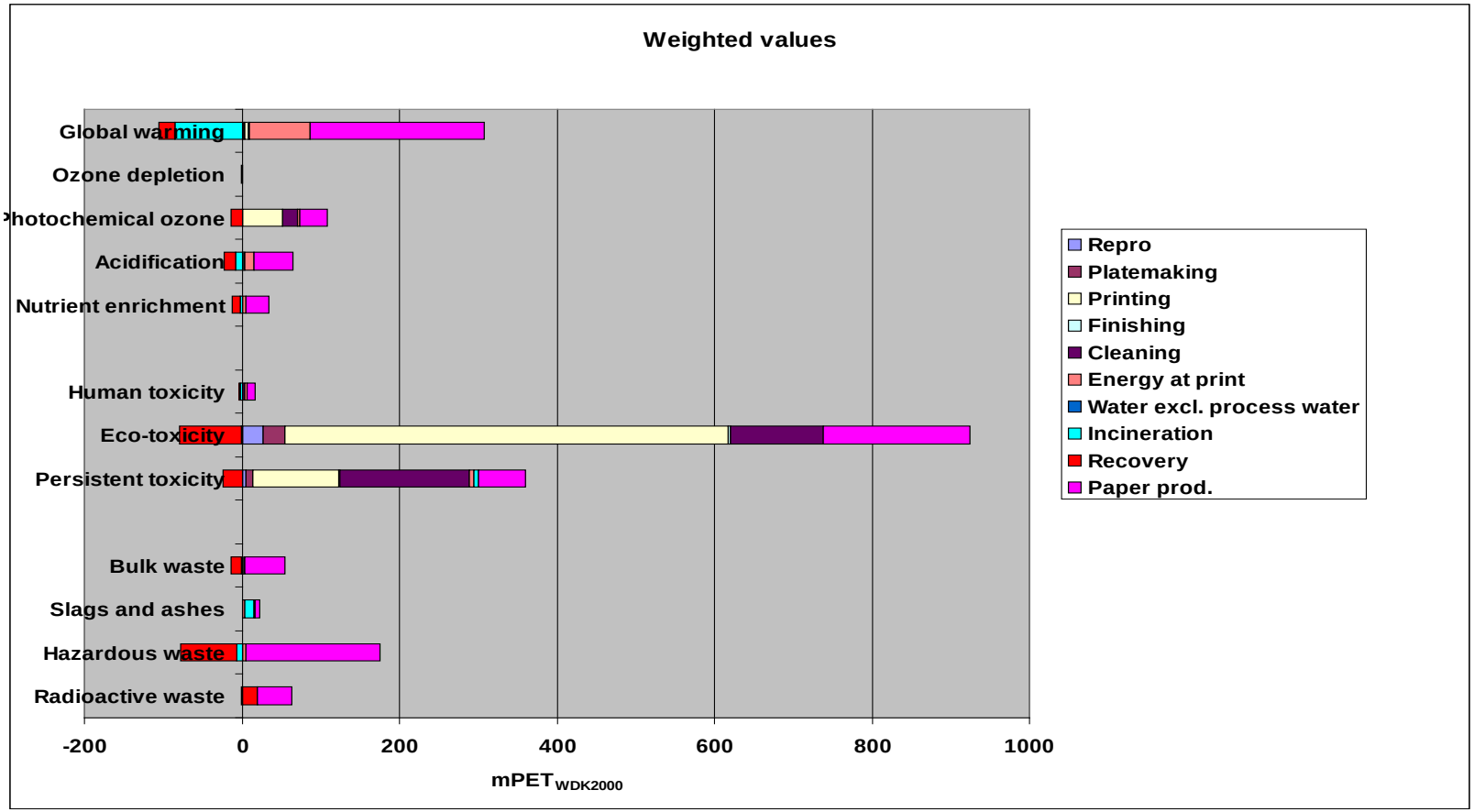
$$wIP = nIP*WF$$

Impact category	WF	nIP (mPE/fu)	wIP (mPET/fu)
Global warming (GWP)	1,3	0,057	0,074

Interpretation: *"Where is the hotspots in the life cycle and for what reason?"*

- Is paper production a hotspot for printed matter life cycle? Due to energy consumption?

Example: Impact profile on printed matter



(Larsen et al. 2006)

Significant contributing chemical emissions to the printed matter impact profile

- Emissions of ink residues (tetradecane) and cleaning agents (hexane, tetradecane) during the printing process and cleaning (35%)
- Emissions (dichlorobenzidine, chloroaniline, cuprous chloride) during pigment production (17-20%)
- Emissions of heavy metals and AOX (as dichloro benzene) during paper production (>3%)
- Emissions of fountain chemicals (i.e. isopropyl alcohol, IPA) during the printing process (6%)
- Emissions of biocides and hydroquinone from the repro- and plate making process (3%)

(Larsen et al. 2006)

Known additives/impurities/production emissions that might play an important role for the paper/printed matter LCA impact profile but for which knowledge/data is lacking

- Ink components (and their precursors) production: siccatives, antioxidants, pigments, dyes etc.
- Water emissions from paper production: softeners (BPA), other phenolic compounds (NPE, APE), other surfactants (LAS), biocides (benzothiazoler, dibromo-compounds), wood extractions (terpenoids, resin acids) and more
- Recycling of paper: Fate of paper chemicals, ink chemicals, glue chemicals etc.
- Treatment of chemical waste: Fate of (hazardous) waste from printing (ink waste, used cleaning agents, used rinsing water etc.) and from recycling of paper (sludge from repulping

Plastic: LCI data on plastics and additives

Review of standard LCI databases

- Overview of JRC-IES
- Overview of UNEP-SETAC Life-Cycle Initiative

Data on plastics:

- Most LCI databases use PlasticsEurope data for plastics production
- Aggregate data, do not include additives, although this is not obvious
- No data on use
- no data on recycling, data on incineration not specific for additives

Data on additives production:

- Hardly available, only metals and in 1 instance DEHP (Oers and Voet 2010)

LCA studies on plastics and additives I

Literature review: 110 documents of plastics LCAs

- only 25 of those mention additives

- many publications on (plastics) waste management
- additives not included in emissions list
- additives mentioned as problem for recycling, but no numbers

- in product LCAs additives are never mentioned as important

- a few articles on LCIA include additives.

(Oers and Voet 2010)

LCA studies on plastics and additives II

Why are additives not identified as important contributors to environmental problems?

- We don‘t know but we can speculate
- Many LCAs do not include toxicity as an impact category
- Many LCAs are limited to energy/fossil fuel related issues
- Most LCAs do not include additives at all, possibly even unintentionally
- additives may in fact be unimportant....?

- In view of the absence of data and systematic treatment of additives, no conclusions can be drawn!

(Oers and Voet 2010)

LCA studies on plastics and additives III

How to proceed?

- LCI databases need to be supplemented with additives data
  - production of additives
  - production of plastics should include additives
  - additive emissions in the use phase
  - additive emissions in waste treatment: recycling / landfill
- This is time consuming, so for Riskcycle case studies another approach is needed
  - based on Material Flow Analysis and emission factors

(Oers and Voet 2010)

Proposed additives/impurities to be included in RiskCycle
-USEtox LCIA characterisation factors (CFs)

Sector	Chemical group	Substance/synonym	CAS No.	CF (fresh water ecotox – emission to fresh water) (PAF*m3*day/kg)¤	Quality
Lubricants	Perfluoro octane sulfonate	PFOS	2795-39-3	-	-
	Perfluoro octanic acid	PFOA	335-67-1	-	-
	Nonyl phenoxy acetic acid	NPAA	3115-49-9	-	-
Textiles	Hexabromo cyclododecane	HBCDD	25637-99-4	6,4E+04	Preliminary*
	5-Chloro-2-(2,4-dichloro-phenoxy)-phenol (biocide)	Triclosan	3380-34-5	9,9E+04	Preliminary*
Plastics	Di-(2-ethylhexyl)-phthalate	DEHP	117-81-7	3,2E+02	Recommended #
	Lead	Pb(II)	7439-92-1	3,7E+02	Preliminary*
	Organotins				
Electronics	Pentabromodiphenylethers	2,2',4,4',5-Pentabromo-diphenyl ether (BDE 99)	60348-60-9	-	-
		2,2',4,4',6-Pentabromo-diphenyl ether (BDE 100)	189084-64-8	-	-
	Decabromodiphenylether	Decabromodiphenylether	1163-19-5	-	-
	Triphenylphosphate	TPP	115-86-6	2,2E+04	
	Mercury	Hg(II)		2,2E+04	Preliminary*
Leather; paper	Nonylphenol	NPE	25154-52-3	1,5E+04	Recommended #
	Bisphenol A	BPA	80-05-7	5,2E+03	Recommended #
	Isothiazolinones (biocides)	5-chloro-2-methyl-isothiazolin-3-one (CMI)	26172-55-4	5,4E+04	Recommended #
		2-methyl-2-isothiazolin-3-one (MI)	2682-20-4	1,8E+05	Recommended #

* Interim according to USEtox team # Recommended by USEtox team ¤ www.usetox.org

- LCI: For most of these, production inventory data does not exist

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