Life cycle assessment and additives: state of knowledge

Larsen, Henrik Fred; von der Voet, Ester; Van Oers L, Lauran; Yang, Gao; Rydberg, Tomas

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SEVENTH FRAMEWORK PROGRAMME

RISKCYCLE

Life cycle assessment and additives: state of knowledge

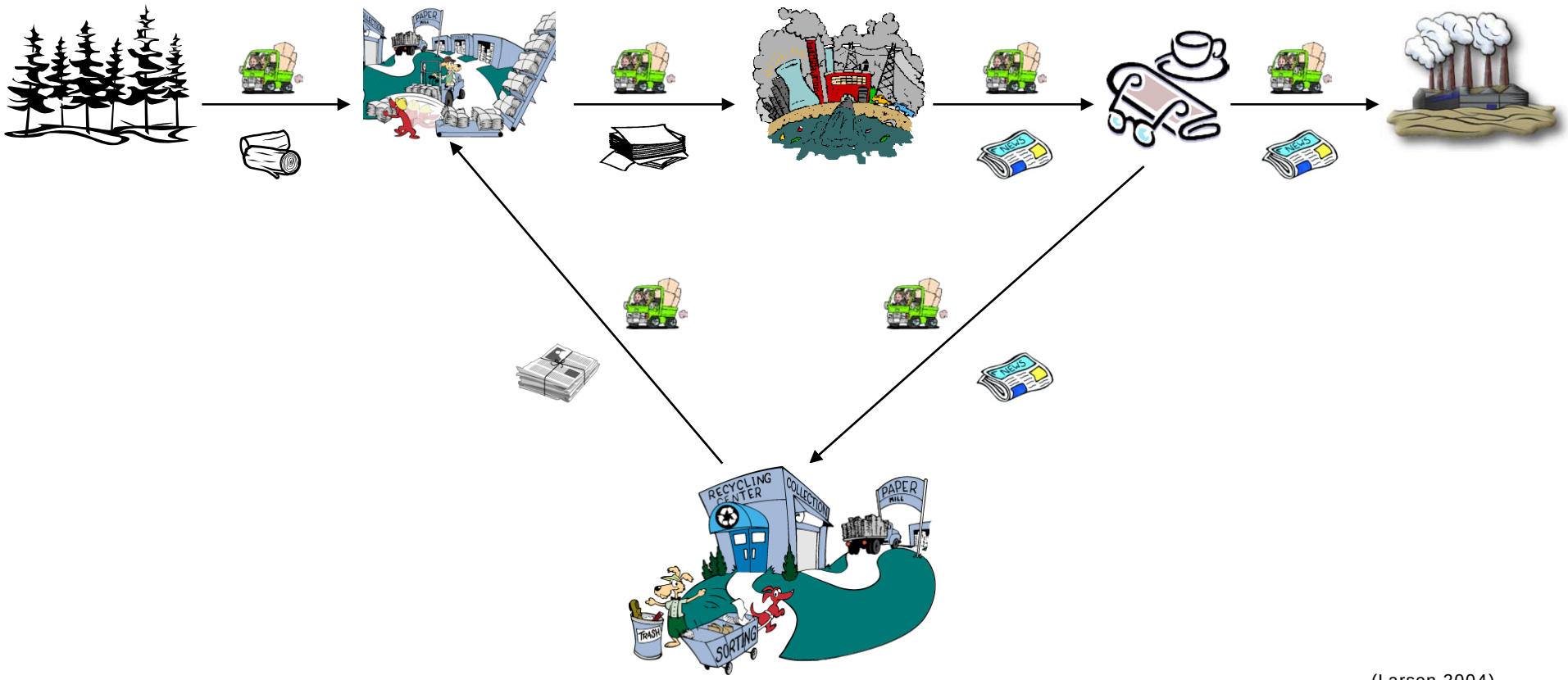
Henrik Fred Larsen and Gao Yang, QSA, DTU Management Engineering
Ester van der Voet and Lauran van Oers, CML
Tomas Rydberg, IVL

DTU

Outline

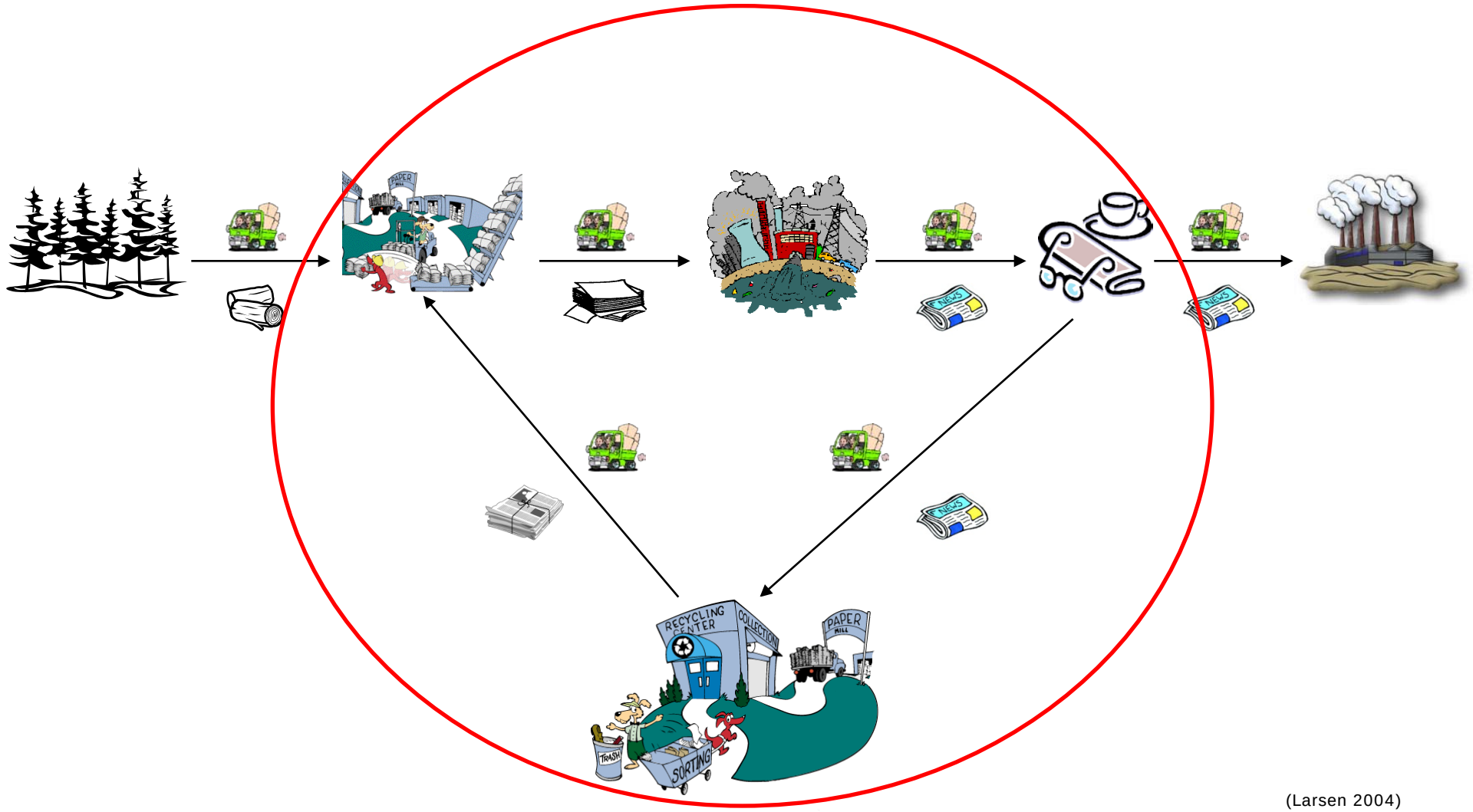
- What is LCA; example on printed matter/paper
- LCA impact profile on printed matter
  - Significant contributing chemical emissions
  - Data lack regarding additives, impurities etc.
  - Examples on potential “additives” in recycled paper
- Aims and status of RiskCycle WP6: Life cycle assessment (LCA) of additives
- Review on plastic LCAs
- Research needs on LCA and additives

The life cycle of printed matter



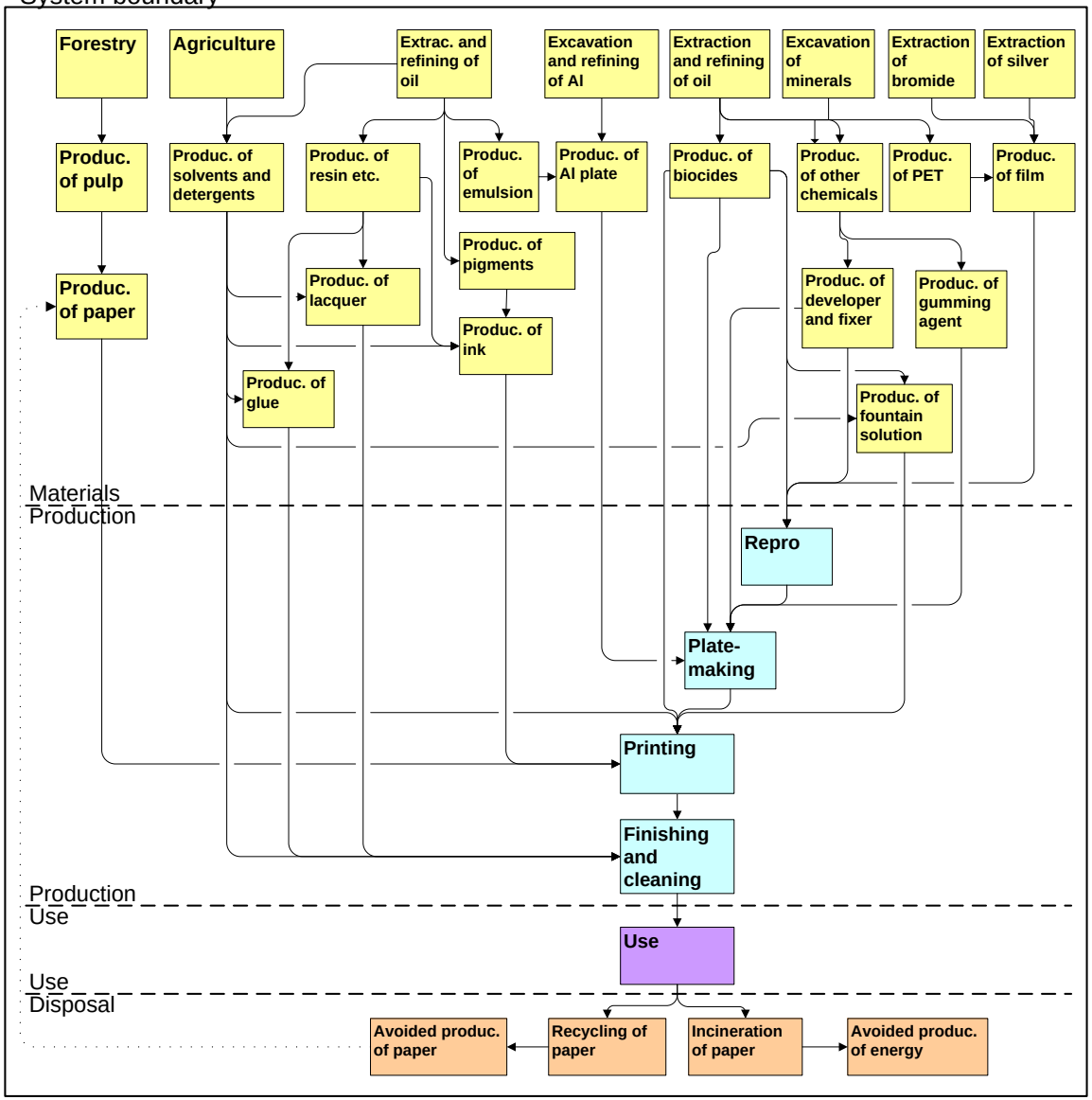
(Larsen 2004)

The life cycle of printed matter



(Larsen 2004)

System boundary



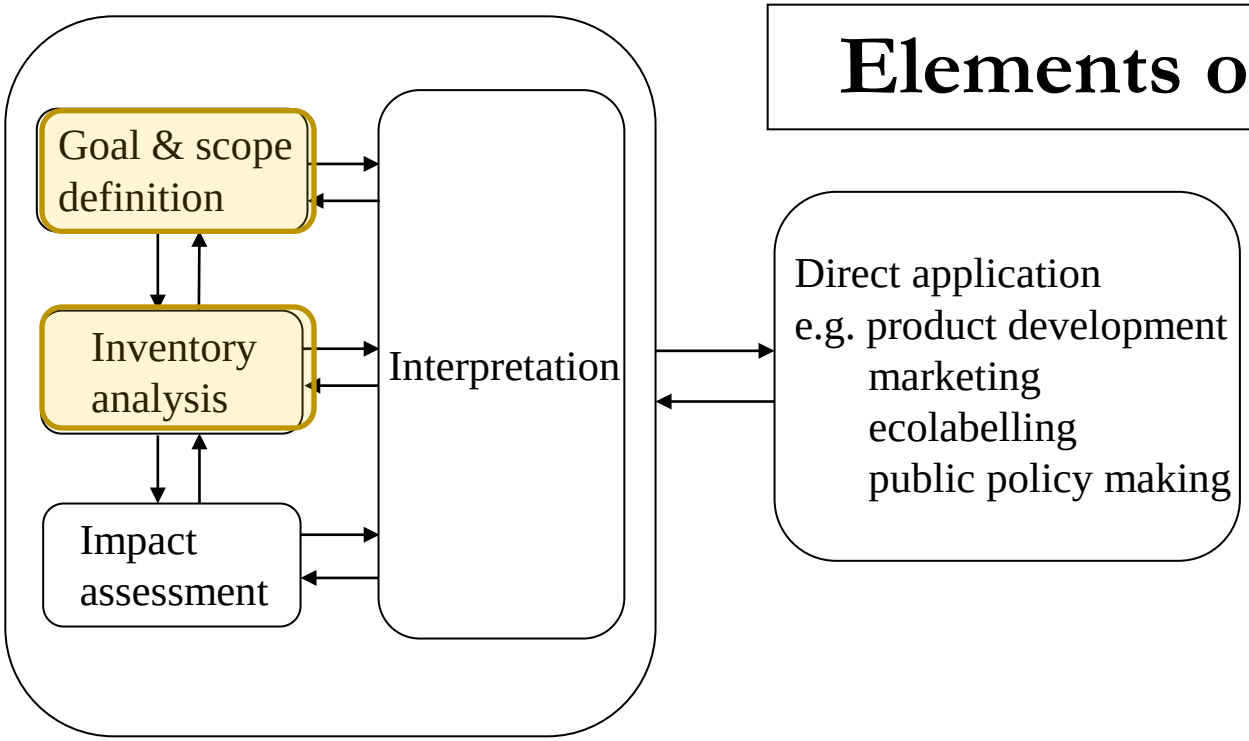
(Larsen et al. 2009)

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)

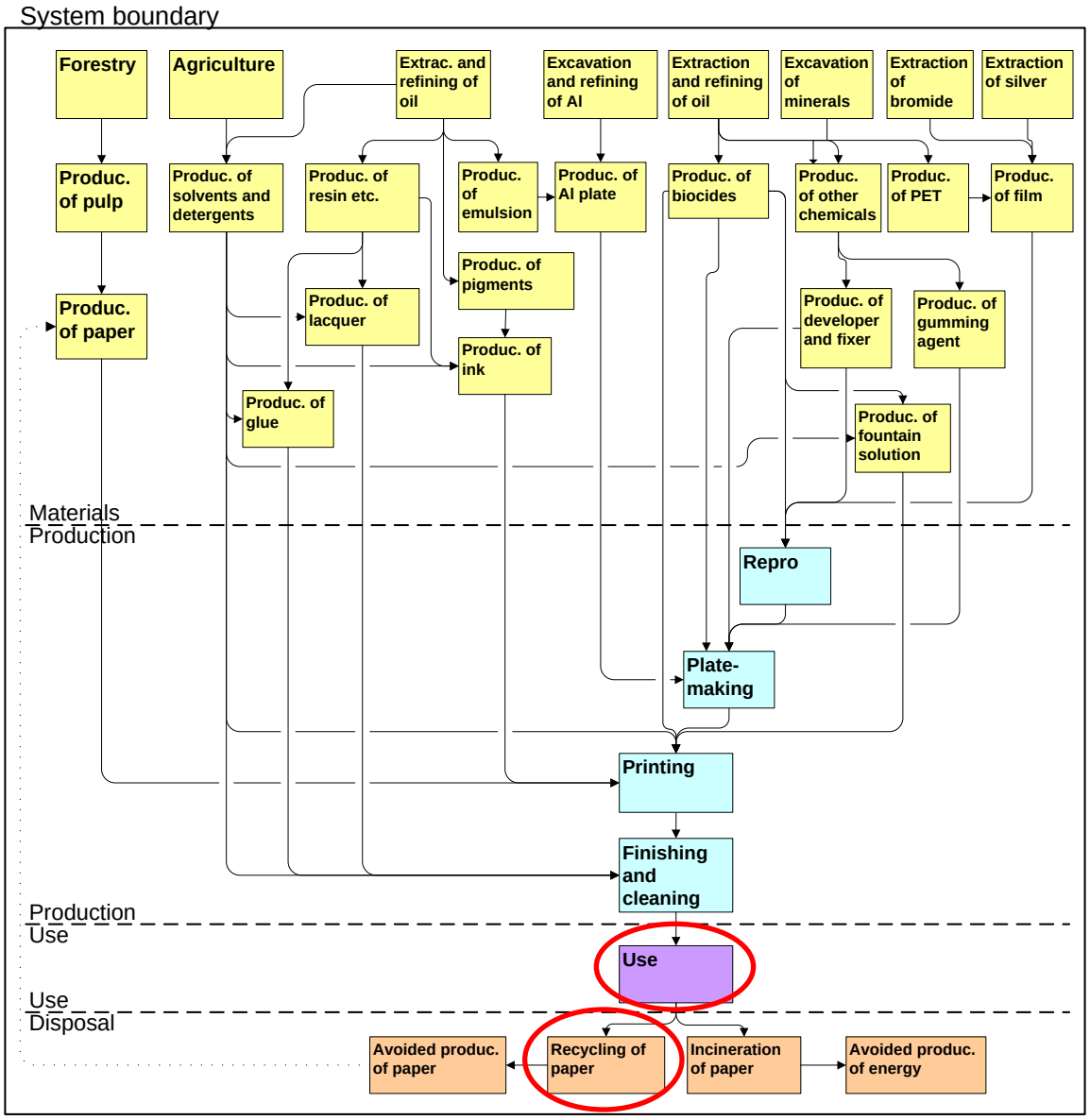


Goal and Scope definition

- 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

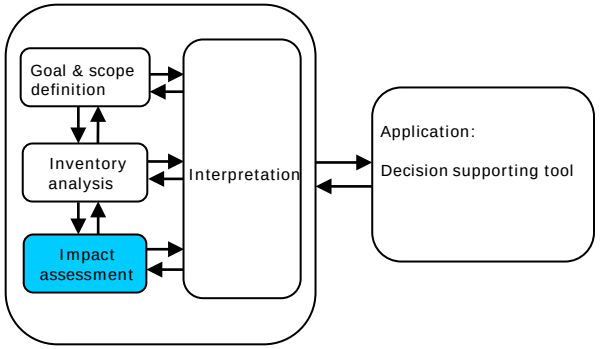
Inventory analysis (LCI)

- collecting in- and output data for all processes



(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?"*

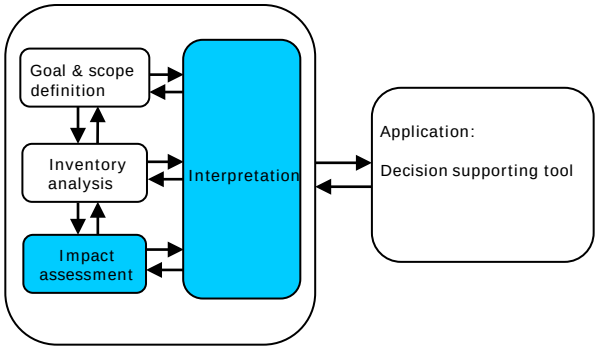
- Quantification of contributions to the different impact categories by estimating impact potentials, IPs (e.g. multiplying the characterisation factors (CFs) for each chemical by the emitted amount (Q) per functional unit (fu)):

$$IP = Q*CF$$

- 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):

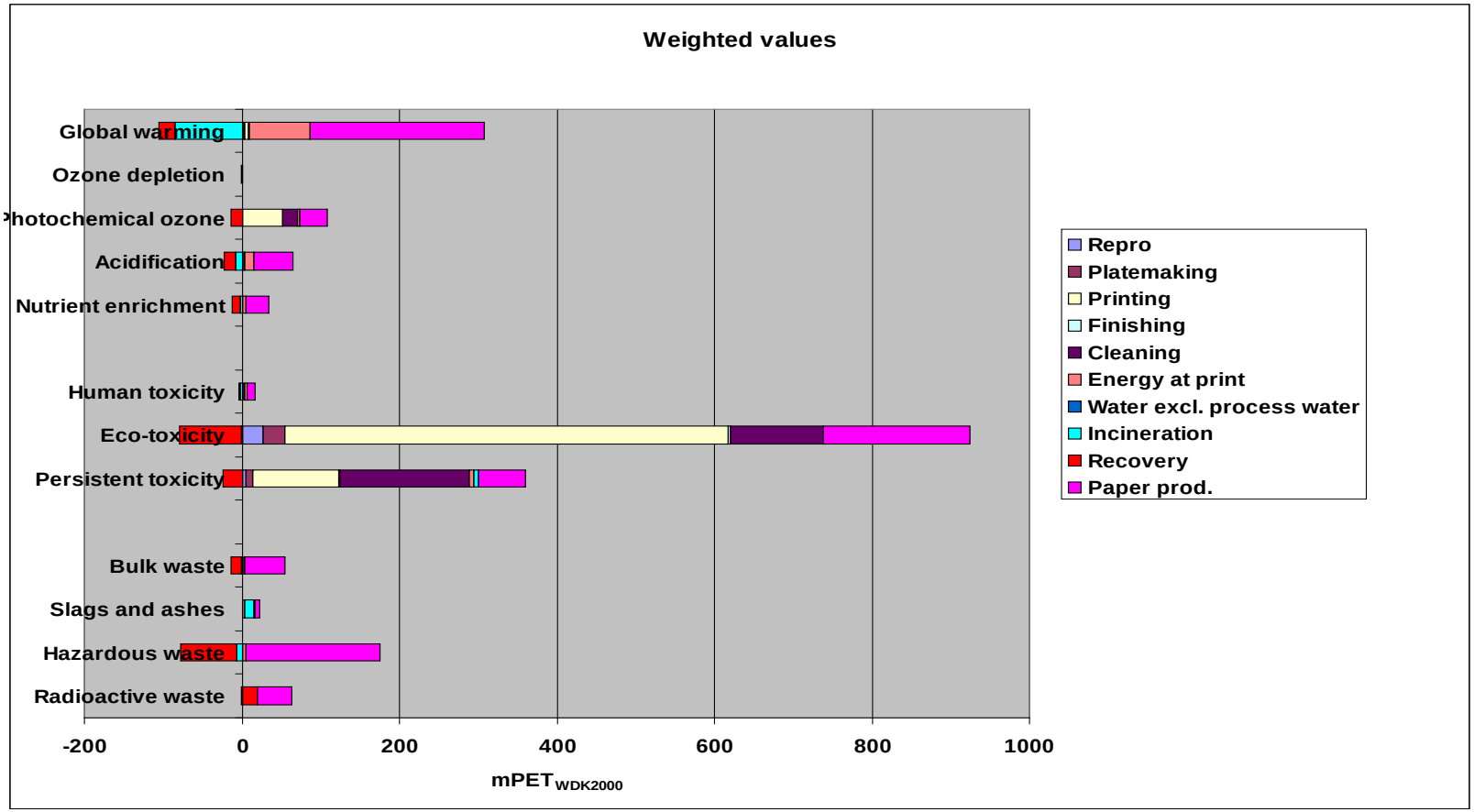
$$wIP = nIP*WF$$

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 accumulation of additives/impurities in recycled paper or recycled plastic a hotspot?

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 and more
- Water emissions from paper production: softeners (BPA), other phenolic compounds (NPE, APE), other surfactants (LAS), biocides (benzothiazoler, dibromo-compounds), wood extractions (terpenoids, resin acids), fluorescent whitening agents and more
- Recycling of paper: Fate of paper chemicals (wet strength agents, biocides, dyes), ink chemicals (phthalates, hydrocarbons), glue chemicals and more
- 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)

(Ginebreda et al. 2011, Larsen et al. 2006 and more)

Substances of very high concern (SVHC) appearing on the recently updated EU REACH Annex XIV candidate list and found in the Danish printing industry

Name	CAS No.	Annex XIV criteria	Use
Chromtrioxide	1333-82-0	Carc 1, mut 2	Chrome plating (gravure)
Trichloroethylene	79-01-6	Carc 2	Inks
Cobalt-siccatives *	(10124-43-3)	(Carc 2)	Inks (off-set, screen printing)
Acrylamide	79-06-1	Carc 2, mut 2	Unknown (impurity?)
Pigment Yellow 34 (lead-chromate)	1344-37-2	Rep 1	Inks (screen printing)
Pigment Red 104 (lead-chromate)	12656-85-8	Rep 1	Inks (screen printing)
2-Methoxy ethanol	109-86-4	Rep 2	Photochemistry
Di(2-ethylhexyl)phthalate, DEHP	117-81-7	Rep 2, EDS-list	Inks
Dibutylphthalate, DBT	84-74-2	Rep 2, EDS-list	Inks (screen printing, flexo)
Benzylbutylphthalate, BBT	85-68-7	Rep 2, EDS-list	Inks
Boric acid and borax	10043-35-3 and 1301-96-4	Rep 2	Photochemistry

* Possible content of soluble cobalt(II)salts. Cobalt(II)sulphate, cobalt dichloride, cobalt(II)rbonate, cobalt(II)dinitrate and cobalt(II)diacetate all appears on the recently updated REACH Annex XIV candidate list [25]. IARC classify all soluble cobalt(II)salts as possible carcinogenic, i.e. group 2B (http://monographs.iarc.fr/ENG/Monographs/vol86/mono86.pdf)

(Larsen 2011)

Aims and status of WP6 on LCA of additives

- Report state-of-the-art knowledge on LCA studies with relevance for additives: *Report on additives in plastics exists (D6.1)*
- Report on LCA framework for additives and their application: *In progress* – Inventory relevant data from a *Swedish case study on plastic and a Danish on printed matter submitted to Springer (two chapters in 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. In progress (D6.4)*

Plastic: LCI data on plastic and additives

Review of 33 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 plastic and additives

Literature review: 110 documents of plastic 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)

Proposed additives/impurities to be included in RiskCycle RA

-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 *

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

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

LCA studies on plastic / paper and additives

Why are additives typically not identified as important contributors to environmental impacts in LCA

- We don‘t know but we can speculate
- Many LCAs do not include (eco)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!

Conclusion leading to three main research needs

- LCI databases (on plastic and paper) need to be supplemented with data on emissions of additives
  - production of plastic/paper should include additives
  - additive emissions in the use phase
  - additive emissions in waste treatment: recycling / landfill / incineration
- LCI databases (on plastic and paper) need to be supplemented with data on additive production
- LCIA characterization factors on additives need to be calculated/estimated

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