LCA case studies: Textile and printed matter (paper)

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SEVENTH FRAMEWORK PROGRAMME

RISKCYCLE

LCA case studies
Textile and printed matter (paper)

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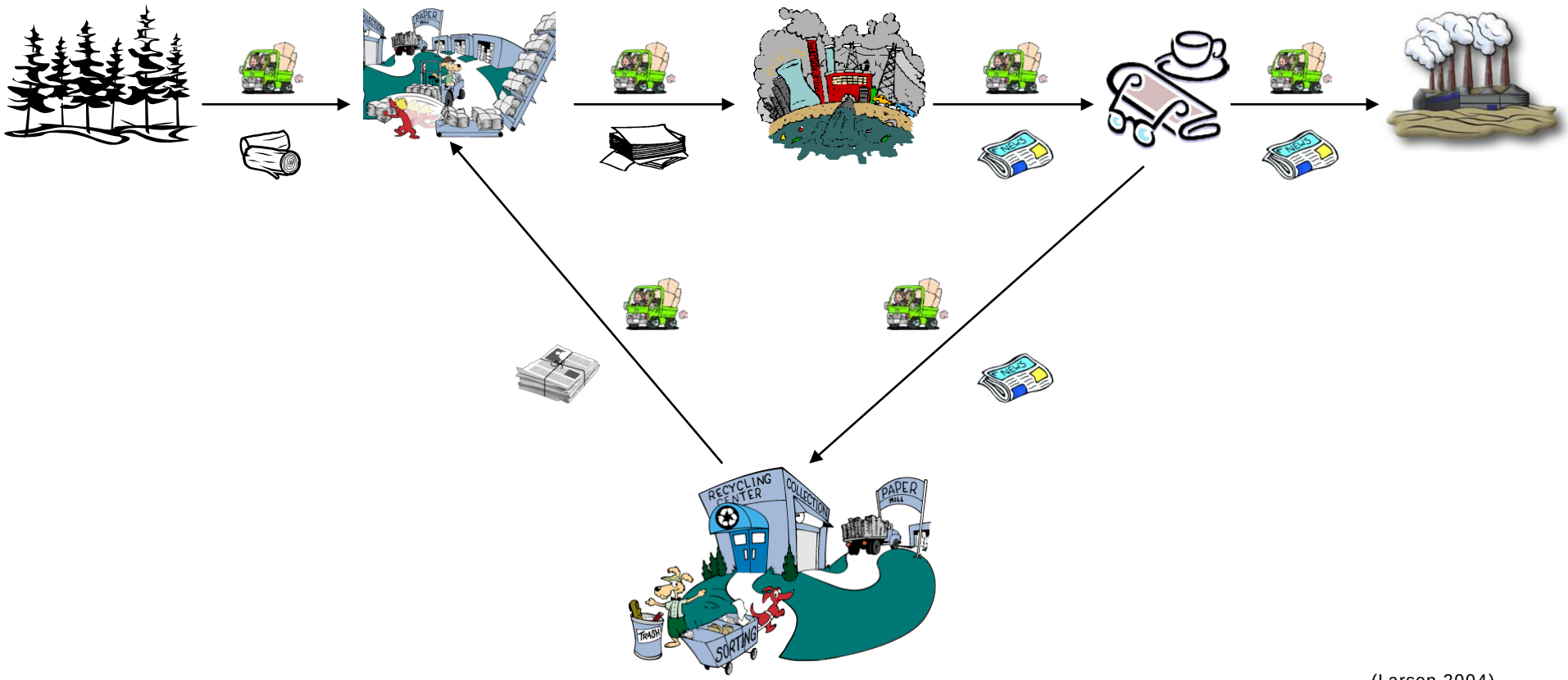
Outline

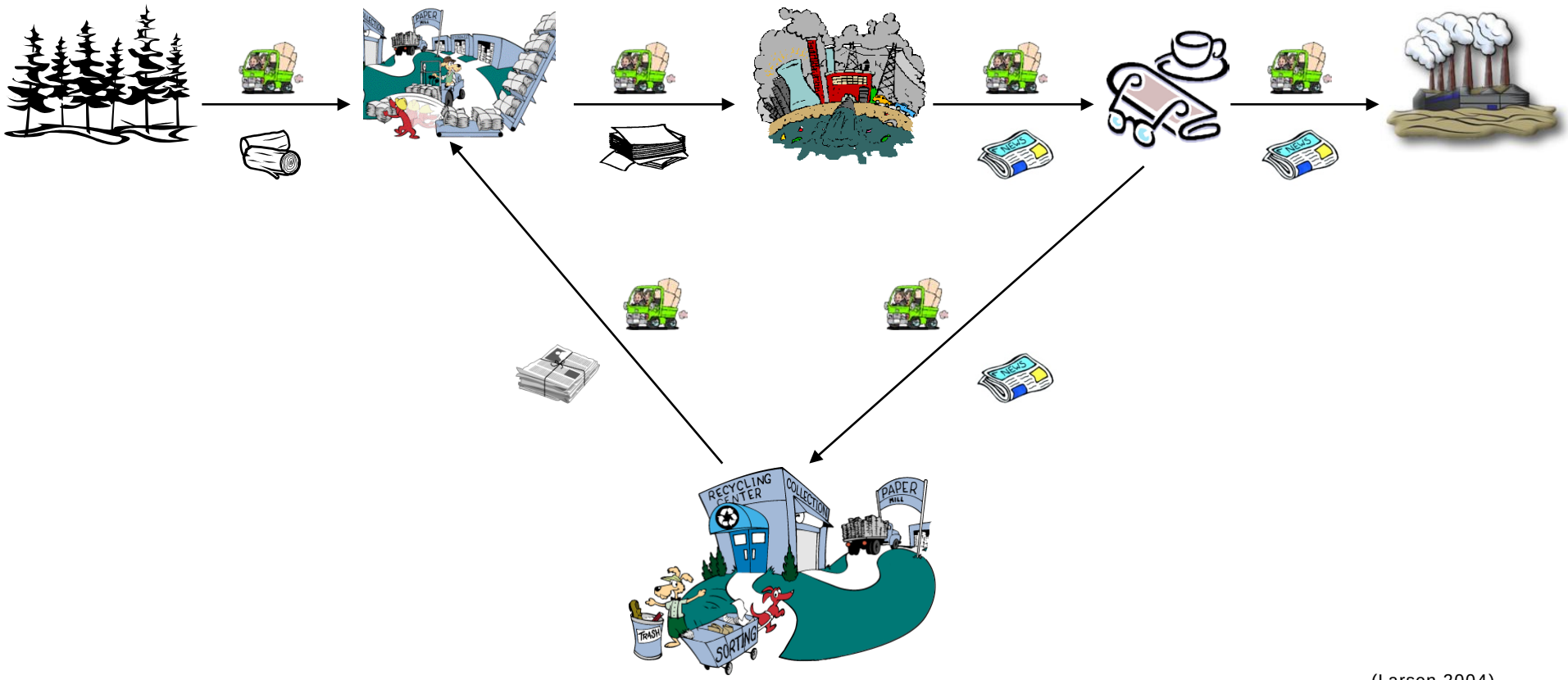
- What is LCA: characteristics, elements; goal and scope, inventory, life cycle impact assessment (LCIA)
- LCA impact profile on printed matter
  - Significant contributing chemical emissions
  - Data lack regarding additives, impurities etc.
- LCA impact profile on textile (T-shirt)
  - Significant contributing chemical emissions
- Examples on potential “additives” in recycled paper and textiles: Hazardous substances found in the Danish printing industry and in textiles on the Danish marked

The life cycle of printed matter



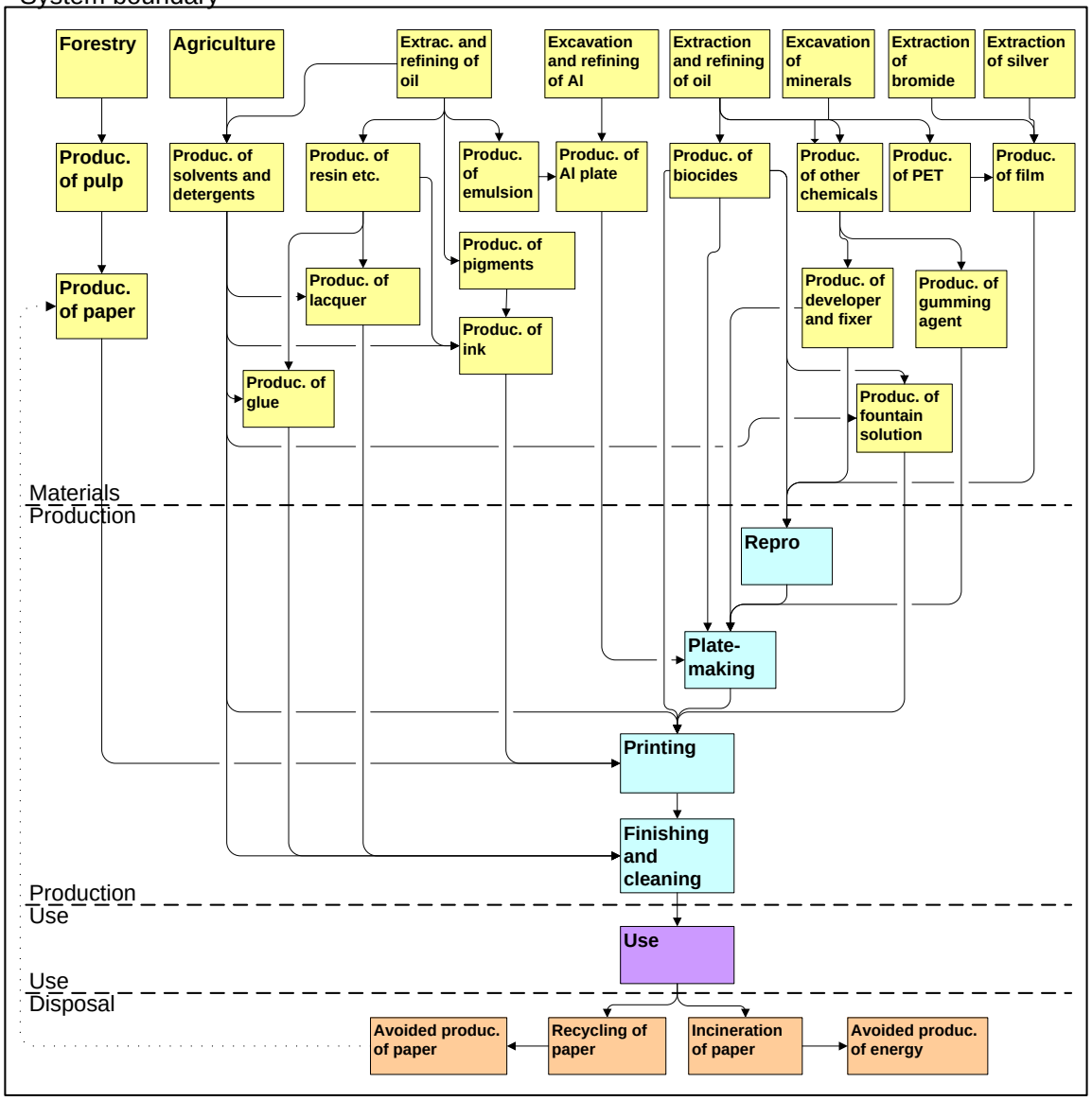
(Larsen 2004)

The life cycle of printed matter



(Larsen 2004)

System boundary



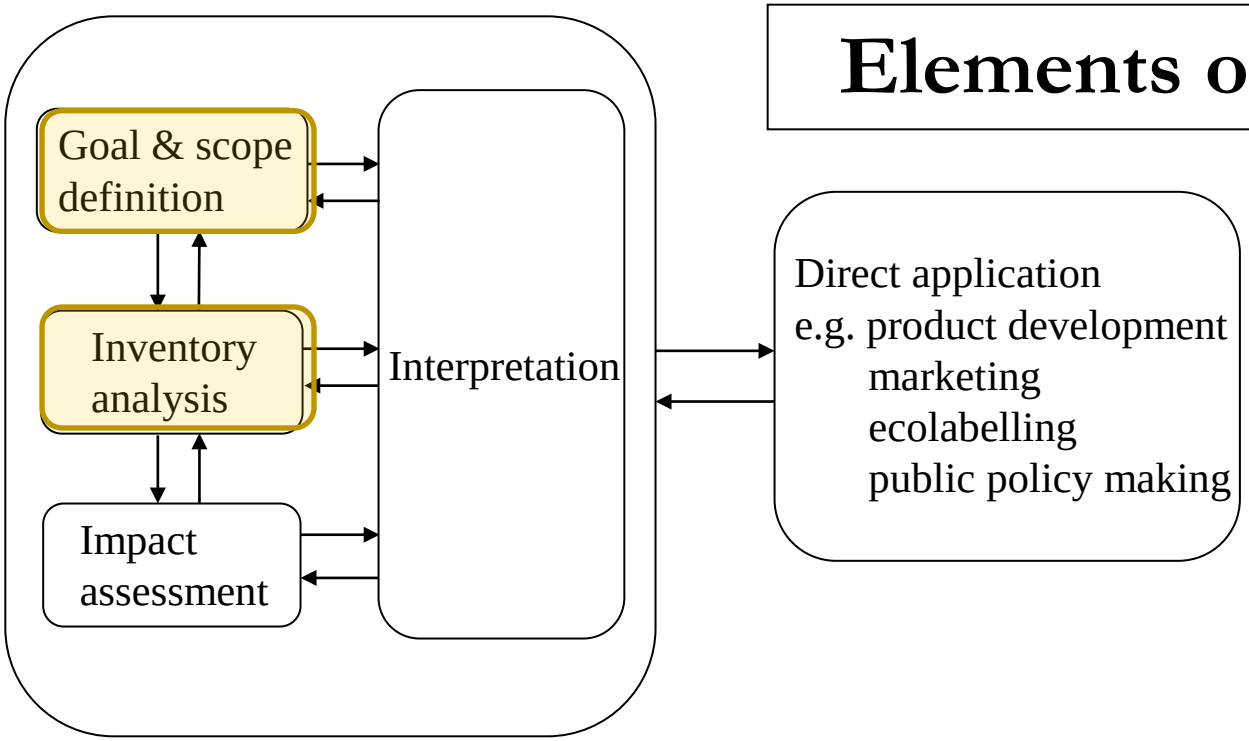
(Larsen et al. 2009)

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)



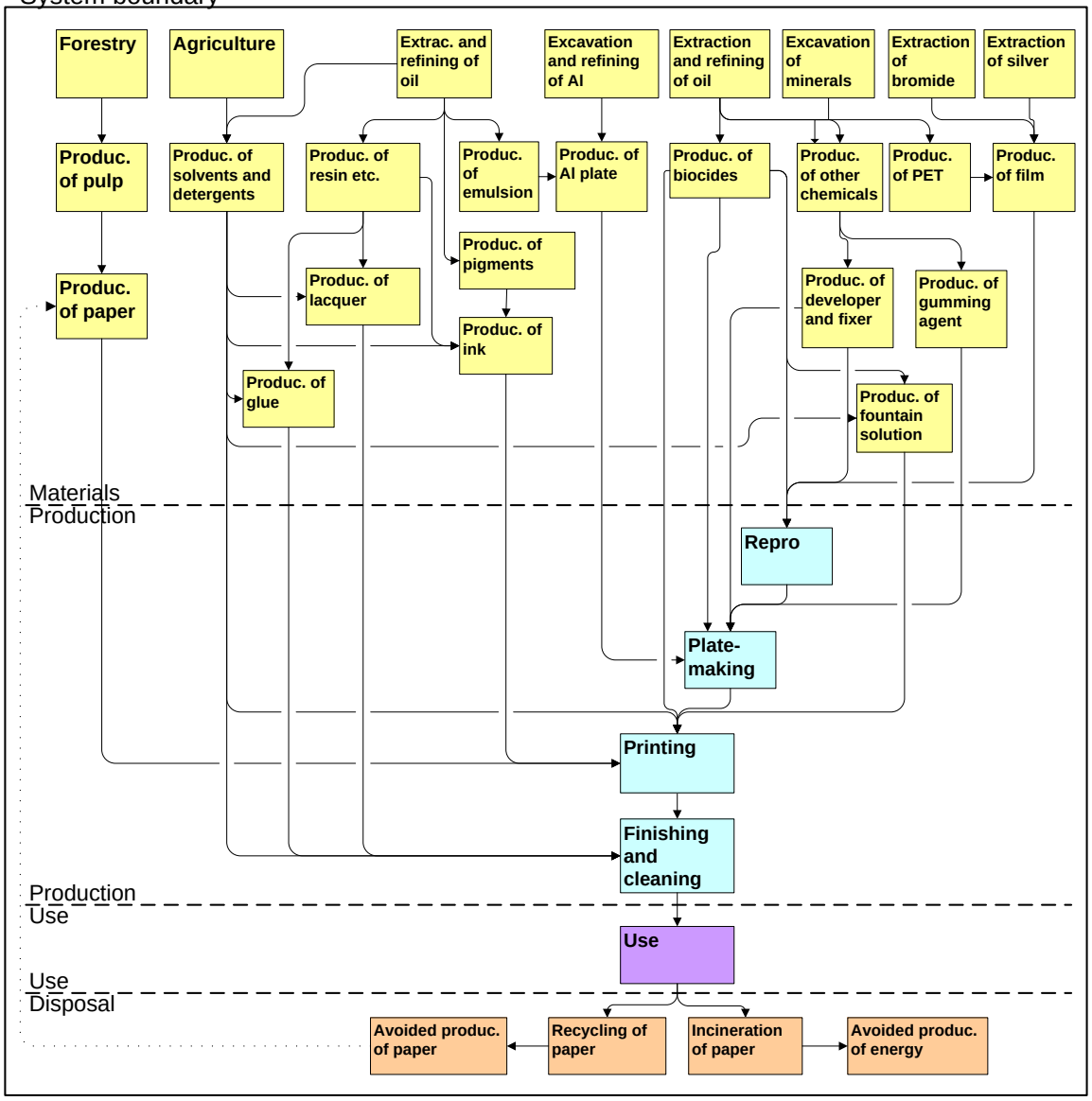
Goal and Scope definition

- 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

Inventory analysis (LCI)

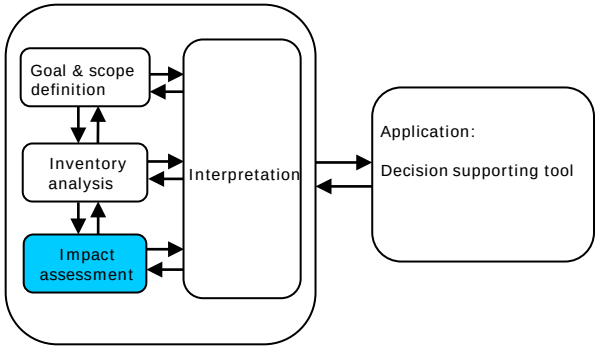
- collecting in- and output data for all processes

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?"*

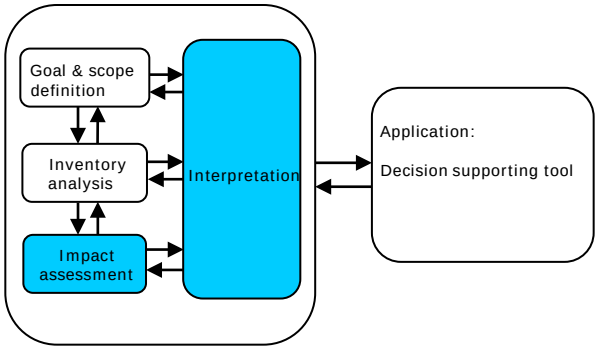
- Quantification of contributions to the different impact categories by estimating impact potentials, IPs (e.g. multiplying the characterisation factors (CFs) for each chemical by the emitted amount (Q) per functional unit (fu)):

$$IP = Q*CF$$

- 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):

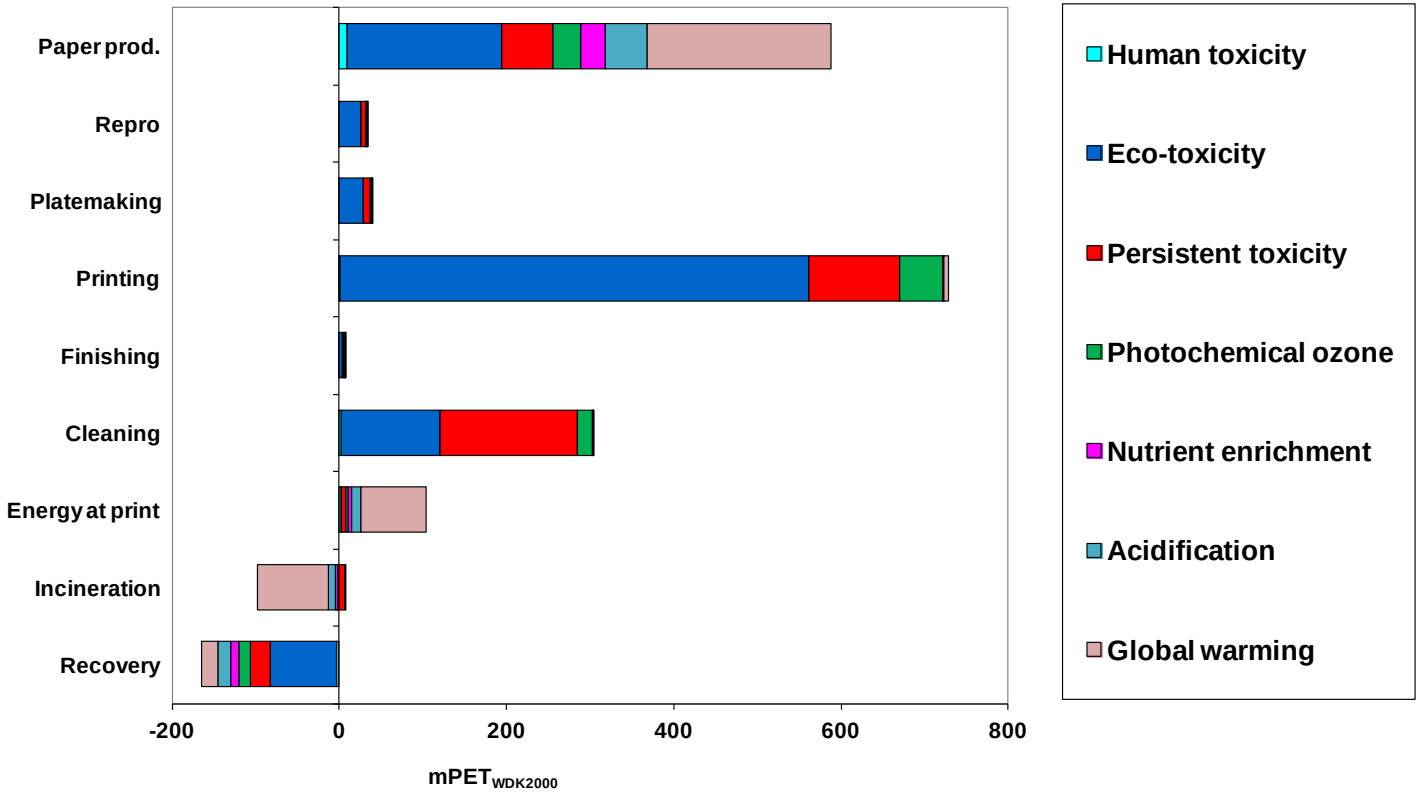
$$wIP = nIP*WF$$

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?

Case 1: Impact profile on printed matter



Functional unit:
1 ton sheet fed offset 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%)

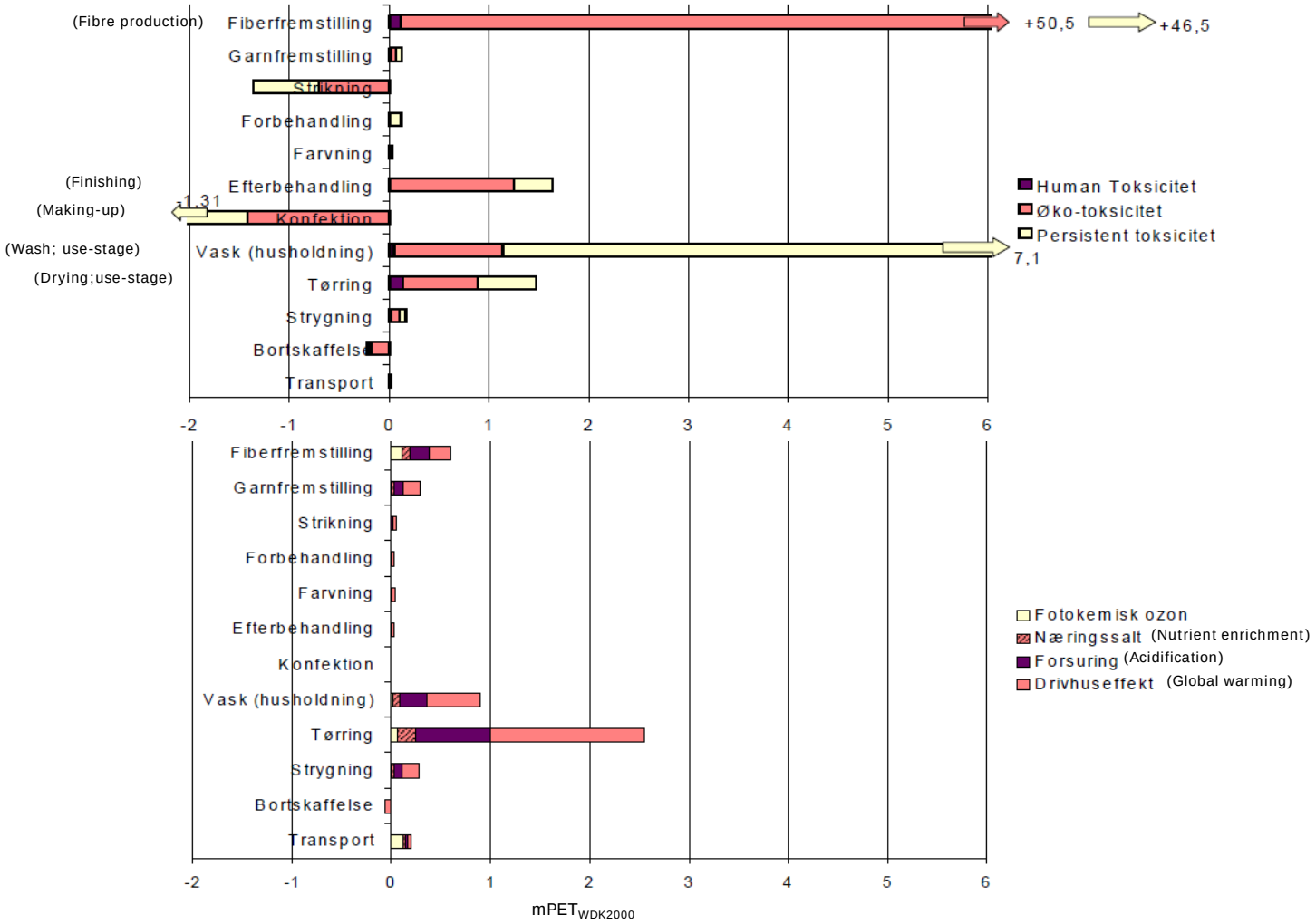
(Larsen et al. 2006)

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)

Case 2: Impact profile on textile (T-shirt)



Functional unit:
One cotton T-shirt (250 g)

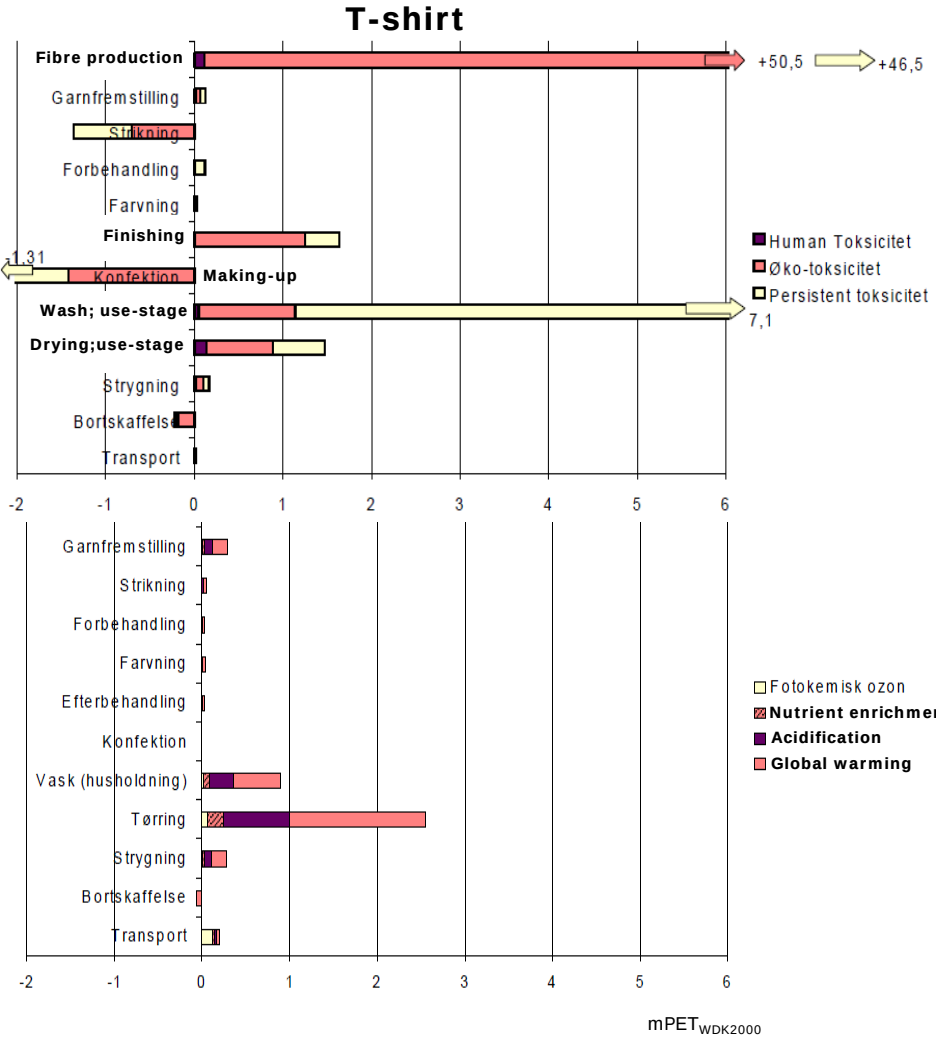
(Laursen et al. 2007)

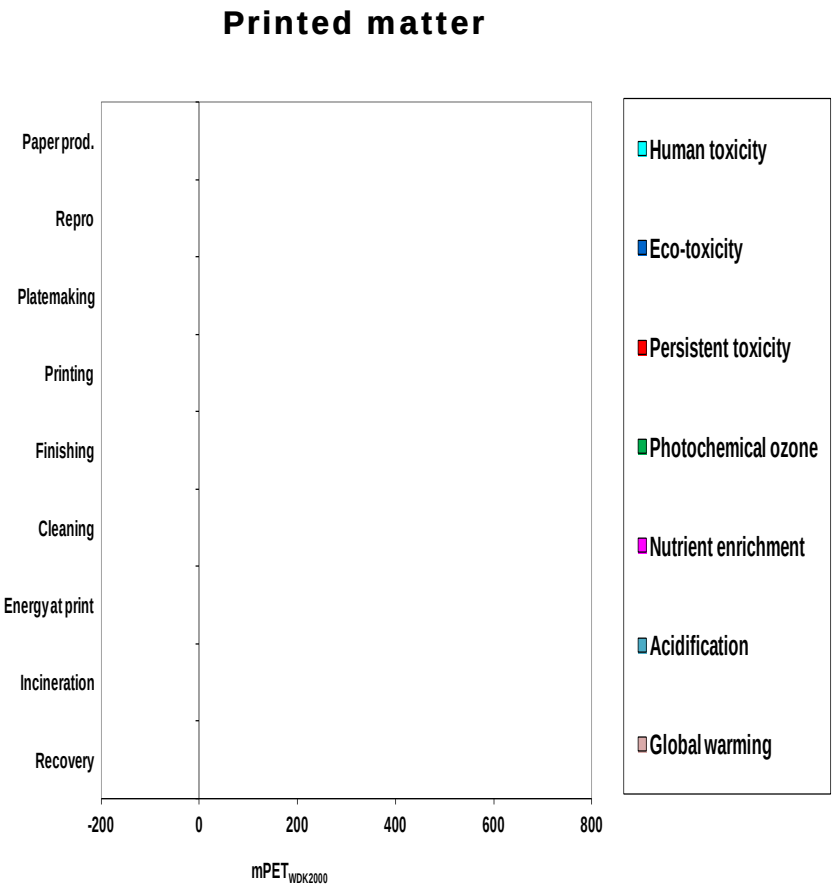
Significant contributing chemical emissions to the cotton T-shirt impact profile

- Pesticide emissions from cotton cultivation (Fiber production)
- Minor contribution from emissions of reactive dyes, like Reactive Black 5 (Dying)
- Emissions of softening agents, e.g. cationic tensides (Finishing)
- Washing agent emissions, e.g. LAS (Use stage)
- Case less comprehensive on chemical emissions than case 1 on printed matter

(Laursen et al. 2007)

Comparison: Case 1 and case 2





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)

Substances meeting Annex XIV candidate list criteria and found in the Danish printing industry (not listed on the REACH Annex XIV candidate list but potential candidates that may be listed in the future)

Name	CAS No.	Annex XIV criteria	Use
Benzene	71-43-2	Carc 1, mut 2	Inks, cleaning agents
Epichlorohydrin	106-89-8	Carc 2	Unknown (impurity?)
2-Methylaziridine	75-55-8	Carc 2	Inks (flexo)
Aziridine	151-56-4	Carc 2, mut 2	Inks (flexo, screen printing)
Propylenoxide	75-56-9	Carc 2, mut 2	Inks, cleaning agents
2-Methoxy propylacetate	70657-70-4	Rep 2	Inks (screen printing)
Triethylene glycol dimethylether	112-49-2	Rep 2	Brake fluid
2-Methoxypropan-1-ol	1589-47-5	Rep 2	Unknown
Alkylphenolethoxylates	(25154-52-3)	EDS-list	Inks, cleaning agents
Chloroalkanes, C14-17	85535-85-9	Possible PBT/vPvB-substance	Chain oil
Octamethylcyclotetrasiloxane (polydimethylsiloxane)	556-67-2 (9016-00-6)	Possible PBT/vPvB-substance	Inks
Bisphenol A	80-05-7	EDS-list	Inks, thermal paper
Resorcinol	108-46-3	EDS-list	Glue
Styrene	100-42-5	EDS-list	Inks, glue
Decamethyl-cyclopentasiloxane	541-02-6	Possible PBT/vPvB-substance	Inks
Stoddard solvent	8052-41-3	Carc 2	Unknown
Solventnaphtha (crude oil), hydrogen treated light naphthen- (benzene >= 0.1%)	92062-15-2	Carc 2	Cleaning agent

(Larsen 2011)

Substances found in textiles on the Danish market and assessed to pose a risk to consumer health and/or the aquatic environment

(22 textiles analyzed)

Name	CAS No.	Use
2,6-Dichloro-4-nitroaniline	99-30-9	Impurity in dye/pigment
2-Chloro-4-nitroaniline	121-87-9	Impurity in dye/pigment
6-Methyl-3-nitroaniline	119-32-4	Impurity in dye/pigment
p-Chloroaniline	106-47-8	Impurity in dye/pigment
p-Nitroanilie	100-01-6	Impurity in dye/pigment
Diphenylamine	122-39-4	Impurity in dye/pigment
Acridine	260-94-6	Impurity in dye/pigment
Nitrobenzene	98-95-3	Impurity in dye/pigment
Toluene diisocyanate	584-84-9	Impurity in polyurethane
DEHP	117-81-7	Softener/fixer
Alkyl benzenes	95-63-6 and more	Carrier for use in textile dying, spinning oils and more
Nicotine	54-11-5/65-30-5	Biocide/impurity in dye
Tetrachloroethylene	127-18-4	Carrier for use in textile dying
Nonylphenol ethoxylates	9016-45-9	Dispersing agent in dying/detergent in post treatment
Chromium	7440-47-3	Impurity in or part of dye/pigment
Zinc	7440-66-6	Catalyst in dying, post treatment: anti-curl agents
Lead	7439-92-1	Impurity in or part of dye/pigment
Cadmium	7440-43-9	Impurity in dye/pigment, PVC stabilizer

(Larsen et al. 2000)

Substances found in textiles on the Danish market and assessed to pose a risk to consumer health and/or the aquatic environment

(22 textiles analyzed)

Chemical	Amount in textile (mg/kg)	% washed out in first wash at consumer
2,6-Dichloro-4-nitroaniline	2 - 9	< 0,5
2-Chloro-4-nitroaniline	0,5 - 3	< 0,5 - 16
6-Methyl-3-nitroaniline	7 - 64	15 - 41
p-Chloroaniline	4 - 18	4
p-Nitroanilie	1 - 110	< 1
Diphenylamine	36	62
Acridine	5	8
Nitrobenzene	2	< 0,4
Toluene diisocyanate	1 - 48	0,3 - < 1,6
DEHP	4 - 1000	0,02 - 80
Alkyl benzenes	70 - 110	<0,01 - <0,02
Nicotine	0,5 - 16	< 2 - 62
Tetrachloroethylene	55	0,03
Nonylphenol ethoxylates	>26 - >85	< 1 - 100
Chromium	0,5 - 250 (1140)	0,3 – 48 (2)
Zinc	2 - 910	11 - 100
Lead	0,3 – 90	0,3 - 100 (PVC; 1)
Cadmium	0,1 - 18	(60) (PVC; 2)

(Larsen et al. 2000)

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Thank you for your attention