The significance of boundary conditions and assumptions in the environmental life cycle assessment of paper and cardboard waste management strategies.

- an analytical review of existing studies

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  - review
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  - further data analysis

Literature search approach and outcome

The international literature search contained three main elements:

- A targeted approach to LCA institutions and experts worldwide and material institutions and waste institutions
- A broad search of the scientific literature
- An international Internet search via search engines and homepages of relevant institutions (mainly national Environmental Protection Agencies)

Evaluated and selected studies

Evaluated: 108 studies

Selected: 9 studies

No. of scenarios: 63

Criteria for final inclusion of studies in the review

1. The study was to be an LCA or LCA-like study complying with LCA quality standards

2. The material stream in question was analysed and reported on separately, that is, not as a part of a mixed waste stream

3. The study included a comparison of two or more scenarios for the end-of-life handling of the material stream in question.

OBS: In practice, all studies comprising a quantitative environmental comparison of waste management options also met the other two criteria and were included

Results and conclusions were held up against system delimitation issues

Raw materials / forestry	1	Alternative use of land/wood included?
	2	Saved wood used for energy?
	3	Wood marginal
Paper production		Virgin paper
	4	- Electricity marginal
	5	- Steam marginal
		Recovered paper
	6	- Electricity marginal
	7	- Steam marginal
	8	Energy export from virgin paper included?
Disposal / energy recovery	9	Which is the main alternative to recycling: incineration or landfilling?
	10	Emissions from landfill included?
	11	Energy from incineration substitutes heat?
	12	Energy from incineration substitutes electricity?
	13	Alternative use of incineration & landfilling capacity included?
	14	In which ratio does recycled paper substitute virgin paper? (1:1 or 1:0.8 or 1:0.5 or other)
	15	Handling of rejects and de-inking waste from paper recovery included?

Essential system delimiation issues identified

Waste management comparisons

Scenarios comparing:

- recycling to incineration
- recycling to landfill
- incineration to landfill

System boundary approaches:

A: Quantitative and relative presentation possible

B: Quantitative, but not relative presentation possible

Result presentation format

– example: energy

$$\frac{[\text{Impact from recycling}] - [\text{Impact from incineration}]}{[\text{Impact from incineration}]} \%$$

Result presentation format

– example: global warming potential

All impact categories

Recycling vs. Incineration

X.Y The LCA covers the entire life cycle, i.e. relative difference in percentage can be calculated

X.Y The LCA covers only waste management end-of-life. The quantification in percentage is, therefore, not possible, and the environmental preference is shown qualitatively, out of scale

X.Y Green = Newsprint, newspapers, magazines

X.Y Orange = Mixed paper, graphic paper, office paper

X.Y Yellow = corrugated board and other cardboard

X:Y → Means that this value lies outside of the scale.

All impact categories

Recycling vs. Landfill

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X.Y Yellow = corrugated board and other cardboard

All impact categories

Recycling vs. a mix of Incineration and Landfill

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X.Y Green = Newsprint, newspapers, magazines

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X.Y Yellow = corrugated board and other cardboard

All impact categories

Incineration vs. Landfill

X.Y The LCA covers the entire life cycle, i.e. relative difference in percentage can be calculated

X.Y Orange = Mixed paper, graphic paper, office paper

GWP quantitatively

GWP quantitatively

4 key issues divide the conclusions

1. The virgin pulp type – i.e. the energy split between electricity and thermal energy in production of the various virgin paper and cardboard types

2. The marginal electricity assumed for virgin paper/cardboard production

3. The potential utilisation of the extra incineration capacity created by recycling to reduce landfilling

4. The inclusion of an alternative use of saved wood for virgin paper/cardboard production

The virgin pulp type

Newsprint

Mixed paper

Cardboard

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The marginal electricity assumed for virgin paper/cardboard production

Newsprint

Mixed paper

Cardboard

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X.Y — Orange = Mixed paper, graphic paper, office paper

X.Y — Yellow = corrugated board and other cardboard

X.Y — Blue = Electricity for virgin paper/cardboard production assumed to be based partly or fully on wood

Utilisation of released incineration capacity

Newsprint

Mixed paper

Cardboard

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X:Y → Means that this value lies outside of the scale.

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X.Y Yellow = corrugated board and other cardboard

X.Y Blue = Released incineration capacity assumed used to reduce landfilling

The cascade effect

The inclusion of alternative use of saved wood

Newsprint

Relative difference: (Recycling - Incineration) / Incineration

Saved emission of greenhousegases in tonne of CO_2-eq. / tonne paper

Mixed paper

Relative difference: (Recycling - Incineration) / Incineration

Saved emission of greenhousegases in tonne of CO_2-eq. / tonne paper

Cardboard

Relative difference: (Recycling - Incineration) / Incineration

Saved emission of greenhousegases in tonne of CO_2-eq. / tonne paper

X.Y — The LCA covers the entire life cycle, i.e. relative difference in percentage can be calculated

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X:Y → Means that this value lies outside of the scale.

X.Y — Green = Newsprint, newspapers, magazines

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X.Y — Yellow = corrugated board and other cardboard

X.Y — Blue = Saved wood used for energy or wood marginal = fossil fuel

Conclusion (mainly on GWP)

- Paper and cardboard from TMP or CTMP (mainly newsprint):

  recycling > incineration > landfilling

  regardless of assumptions

- Other paper and cardboard (chemical pulp):
  - In case of cascade effect:

    recycling > incineration > landfilling

  - In case of biomass limitation (fossil fuel is the marginal fuel):

    recycling > incineration > landfilling

  - All other cases:

    incineration > recycling > landfilling