American Forest & Paper Association

Printing & Writing Papers

Life-Cycle Assessment Summary Report

PRINTING & WRITING PAPERS LIFE-CYCLE ASSESSMENT

The American Forest & Paper Association (AF&PA) and the Forest Products Association of Canada (FPAC) initiated a life-cycle assessment (LCA) to evaluate the environmental impact of four North American grades of printing and writing (P&W) papers. The specific products examined are: 1) a ream of office paper made of uncoated freesheet; 2) a telephone directory made primarily of uncoated mechanical paper; 3) a catalog made primarily of coated freesheet; and 4) a magazine made primarily of coated mechanical paper.

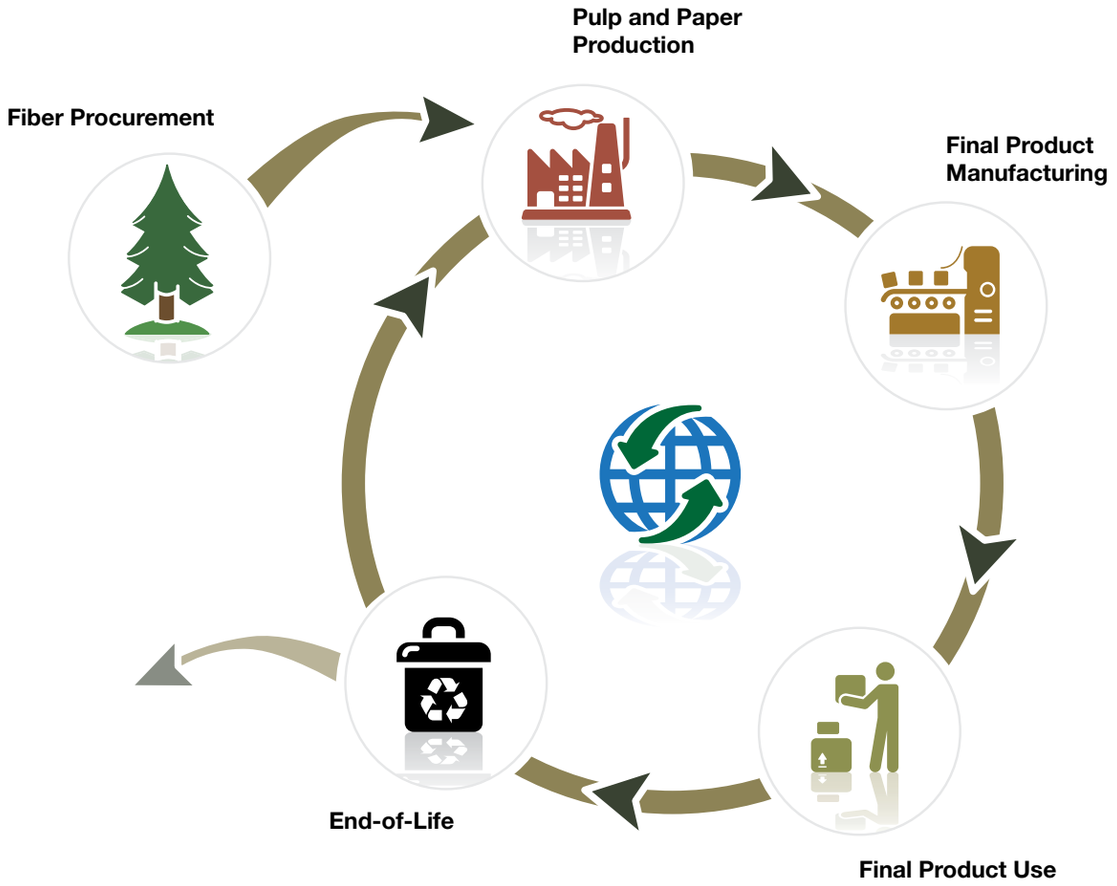
The study is the most comprehensive ever conducted for North American printing and writing papers. The data was collected from 72 mills in the U.S. and Canada, which produced 22.4 million short tons of printing and writing papers in 2006-07. This represents approximately 77 percent of all North American production within that time period. The LCA was conducted by the National Council for Air and Stream Improvement, Inc. (NCASI) — an independent, nonprofit research institute recognized as a leading resource of environmental topics of interest to the forest products industry.

Although this study analyzes impacts of entire product life cycles, cradle-to-gate inventory results for the four grades of paper also have been evaluated to facilitate studies of other products made from these grades. It is important to note that this study is not a comparative LCA; it does not provide product comparisons or compare impacts of various communication forms such as electronic, paper-based, or broadcast media. While this type of comparison may be important for future understanding of the choices to be made in communication vehicles and their environmental impacts, strategies and methods for conducting such comparative analysis are the subjects of future research and outside the scope of this study.

WHAT IS LCA?

Life-cycle assessment (LCA) is a comprehensive environmental accounting tool with well-established procedures and methods that are governed by specific rules and standards, most notably those developed by the International Organization for Standardization (ISO). LCA use continues to increase and there are now many experienced LCA practitioners worldwide who have successfully applied LCA across a broad range of industry sectors.

As illustrated in the diagram on Page 2, LCA is an approach that analyzes the flows associated with the entire life cycle of a product or a service, usually "from cradle-to-grave," i.e., from raw material extraction, to manufacturing, use, recovery, and end-of-life (EoL). Process steps are identified for each stage in the life cycle. The inputs (materials and energy) and outputs (releases to air, water, soil, etc.) are determined for each step. The inputs and outputs are then grouped into impact categories, which are evaluated for environmental impact potential, and summarized as the basis for drawing conclusions and improving future results.



An LCA study involves four phases:

1. Goal and Scope — defining the purpose and system boundaries of the study
2. Inventory — compiling the inputs and outputs of the product throughout its life cycle
3. Impact assessment — evaluating the significance of potential environmental impacts of the inventory results
4. Interpretation — summarizing results as the basis for drawing conclusions

GOAL

AF&PA and FPAC intend to provide credible research and transparency that will assist their respective members and stakeholders in making informed decisions regarding papers used for printing and writing communications.

LCA goals:

- Educate customers and stakeholders
- Understand environmental impacts of printing and writing paper products
- Identify which life-cycle stages contribute the greatest impacts
- Establish a baseline for performance improvements
- Create a platform for future comparative analysis

SCOPE

The scope of this study was a "cradle-to-grave" LCA of four 2006-07 North American industry-average paper products. The four products investigated in this study are detailed in Table 1. Scoping parameters specific to each paper grade studied are detailed as follows.

Table 1. Printing and Writing Products
Average P&W Paper Products Studied

Characteristics	PAPER PRODUCT			
	Ream of office paper	Catalog	Telephone directory	Magazine
Paper grade	Uncoated freesheet (UCF)	Coated freesheet (CF)	Uncoated mechanical paper	Coated mechanical paper
Basis weight	20 # (75 gsm)	45 # (68 gsm)	22 # (36 gsm)	38 # (57 gsm)
Number of pages	1,000 pages (500 sheets)	72 pages (36 sheets)	1,200 pages (600 sheets)	120 pages (60 sheets)
Format	8½" x 11"	8" x 10½"	8½" x 10½" x 2"	8" x 10½"
Cover pages/ packaging	Paper wrap	2 covers (CF), 60 # (90 gsm)	2 covers (bleached board), 123 # (200 gsm)	2 covers (CF), 60 # (90 gsm)
Printing*	Not included	64% offset, 36% rotogravure	Offset printing	64% offset, 36% rotogravure
Functional unit	The production in the U.S. and Canada, delivery to an average U.S. customer, use and final disposal or recovery of one standard ream of office paper	The production in the U.S. and Canada, delivery to an average U.S. customer, use and final disposal of standard catalog	The production in the U.S. and Canada, delivery to an average U.S. customer, use and final disposal of a standard telephone directory	The production in the U.S. and Canada, delivery to an average U.S. customer, use and final disposal of a standard magazine
Weight of paper (dry)	Uncoated freesheet: 2.15 kg (4.73 lb)	Coated freesheet: 0.135 kg (0.297 lb)	Uncoated mechanical: 1.18 kg (2.60 lb) Bleached board: 0.0244 kg (0.0538 lb)	Coated mechanical: 0.176 kg (0.388 lb) Coated freesheet: 0.0093 kg (0.0204 lb)
Recycled content	4%	5%	20%	2%
Recovery rate**	71.5%	32.7%	19.1%	38.6%

*Magazine Publishers of America 2008.
**EPA estimate

Detailed attributes and composition of four P&W products studied.

1. OFFICE PAPER
(made from uncoated freesheet)

Almost all office paper included in this study is produced by U.S. mills using a variety of pulp sources. About 4 percent of the fiber needed to produce the office paper comes from recovered fiber,[1] primarily market deinked pulp (MDIP), with the balance being supplied by bleached kraft pulp. Most of the bleached kraft pulp used in uncoated freesheet is produced on-site, although bleached kraft market pulp (produced primarily in Canada and U.S.) also is used. No separate converting operations are included in the office paper system because the operations required to convert paper rolls to finished product (i.e., cutting and packaging) are included in the operations performed at the paper mill. Based on data from the U.S. Environmental Protection Agency (EPA) for "office-type papers," it has been assumed that, after use, 71.8 percent of used office paper is recovered for recycling, 5.2 percent is burned for energy and 23.0 percent is sent to landfills.

[1]The scope of the study addressed the average paper produced in North America, so the paper modeled in the LCA contains the average amounts of recovered fiber. The results would change if the average recovered fiber content changed.

2. CATALOG
(made from coated freesheet)

All coated freesheet included in this study is produced by U.S. mills using a variety of pulp sources. About 5 percent of the fiber needed to produce the catalog comes from recovered fiber,[1] primarily MDIP and old newspapers (ONP), with the balance being supplied by bleached kraft pulp. Most of the bleached kraft pulp is produced on-site, but market pulp (produced primarily in Canada and U.S.) also is used. Life-cycle environmental impacts pertaining to converting operations required to convert the coated freesheet into a catalog (primarily printing) are included in this study. Based on EPA data for "other commercial printing," it has been assumed that, after use, 32.7 percent of used catalogs is recovered for recycling, 12.5 percent is burned for energy and 54.8 percent is sent to landfills.

3. TELEPHONE DIRECTORY
(made from uncoated mechanical paper)

About 20 percent of North American uncoated mechanical paper is produced by U.S. mills, while 80 percent is produced in Canada. About 20 percent of the fiber needed to produce directory paper comes from recovered fiber[2] (a mix of MDIP, ONP, old magazines and mixed papers), with the balance being supplied by bleached mechanical pulp (produced and purchased) and some chemical pulp (produced on-site and/or purchased). According to the EPA, 19.1 percent of used directories is recovered for recycling, 15.0 percent is burned for energy and 65.9 percent is sent to landfills.

4. MAGAZINES
(made from coated mechanical paper)

About 80 percent of North American coated mechanical paper is produced by U.S. mills, while 20 percent is produced in Canada. About 2 percent of the fiber needed to produce uncoated mechanical paper comes from recovered fiber,[1] primarily ONP used to produce deinked pulp on-site, with the balance being supplied by bleached mechanical pulp and some kraft pulp (produced on-site and/or purchased). According to the EPA, 38.6 percent of used magazines is recovered for recycling, 11.4 percent is burned for energy and 50.0 percent is sent to landfills.

[1]The scope of the study addressed the average paper produced in North America, so the paper modeled in the LCA contains the average amounts of recovered fiber. The results would change if the average recovered fiber content changed.

[2]Ibid.

SYSTEM BOUNDARIES: LIFE-CYCLE STUDY DESIGN AND METHODS EMPLOYED

For each of the four product systems investigated in this study, system boundaries are set according to a cradle-to-grave approach (from raw material extraction to final disposal of paper products). Transport is also included. The data are from 2006-07,[3] or a date as close as possible to those years. The system boundary has been separated into five life-cycle stages:

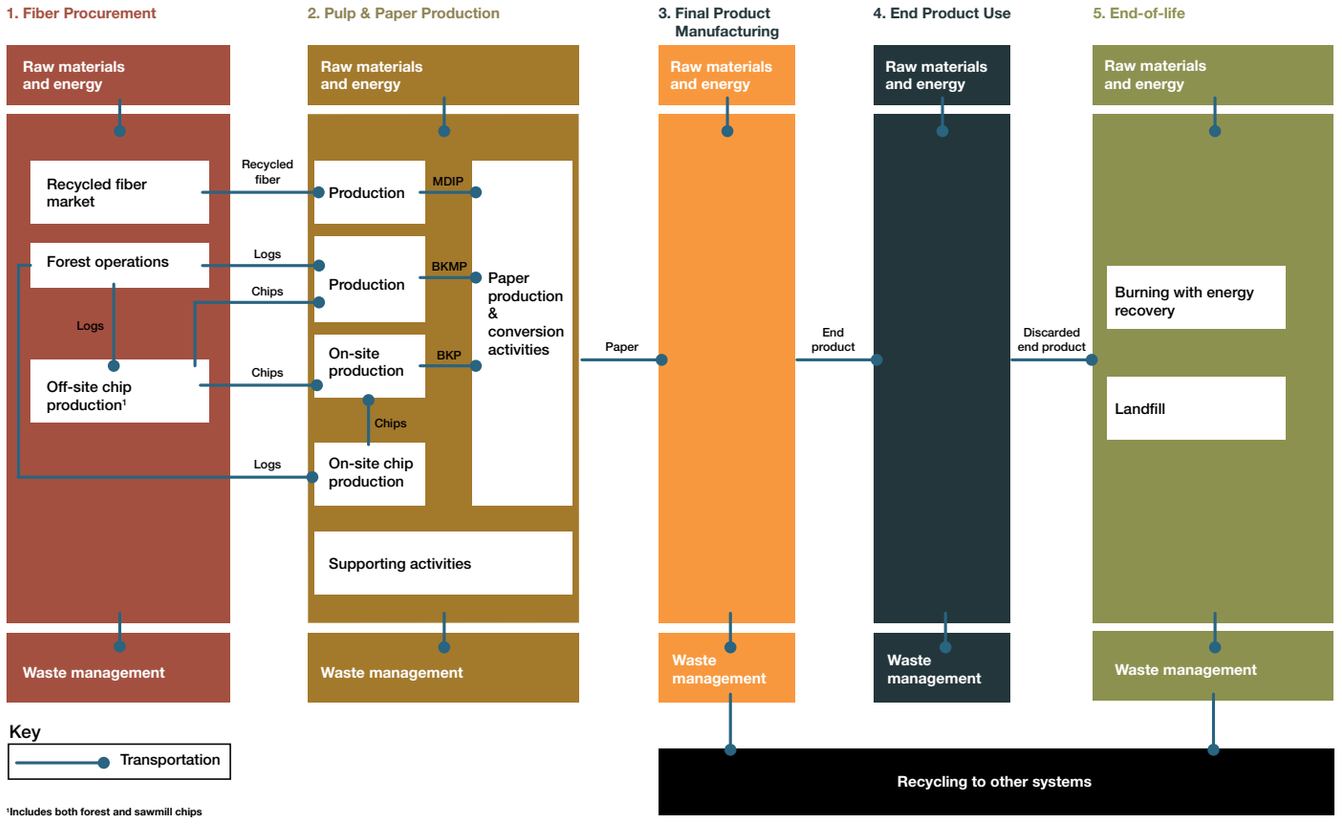
1. Fiber procurement: includes forest operations, off-site chip production, off-site recovery and processing of recycled fiber and transport of all fiber (wood, market pulp and recycled fiber) to pulp and paper mills.
2. Pulp and paper production: includes on-site production of chips, production of market pulps and on-site produced pulp, papermaking operations, converting of paper in rolls and reams,[4] packaging and supporting activities (on-site steam and power production, on-site chemical production, effluent treatment, on-site waste management, etc.).
3. Production of the final product: includes the activities involved in converting the paper into the specified paper product, such as printing, binding, etc.
   a. In the case of office paper, it is assumed that the ream produced at pulp and paper mill is the final product (i.e., no "production of the final product" life-cycle stage is included).
4. Use: includes transportation to the use phase.
5. End-of-life (EoL): includes EoL management of the paper product (landfilling, burning and energy recovery). Material that is recovered for recycling is assumed to leave the system boundaries.

[3] U.S. data from AF&PA are from 2006, while Canadian data from FPAC are from 2007.

[4] Assumed to occur at the same site as papermaking.

Each life-cycle stage comprises upstream raw material and energy production, downstream waste management (i.e., management of wastes produced during the life-cycle stage)[5] and transportation between related unit processes. Transportation between two life-cycle stages is included in the downstream stage, except for fiber procurement, which was defined to include transportation of the fiber to the pulp and paper mill.

Figure 1. System Boundary Example



[5]"Waste" burdens being tracked or acknowledged in the "use" phase are not paper wastes but other wastes that may be generated as a result of using the paper product.

LIFE-CYCLE INVENTORY AND IMPACT ASSESSMENT

The inventory phase of the LCA involves data collection and modeling of the product system. This encompasses the collection of thousands of input and output data points related to the processes that occur during the life cycle of the product (such as raw materials, energy, chemicals, air emissions, water emissions, etc.). This inventory data forms the basis for assessing the resulting environmental impacts for each impact indicator.

Impact indicator results were developed for global warming,[6] acidification, respiratory effects, eutrophication, stratospheric ozone depletion, smog and fossil fuel depletion.[7,8] These impact categories are defined in the box below. In addition, inventory results were developed for life-cycle energy demand, water use and solid waste generation.

IMPACT CATEGORIES

- Global warming (GW): Potential change in the earth's climate caused by the buildup of greenhouse gases (GHGs) in the upper atmosphere that trap heat from the reflected sunlight that would have otherwise passed out of the earth's atmosphere.
- Eutrophication (EU): The increase of nutrients, such as phosphorus and nitrogen, discharged to water bodies, which negatively impacts water quality and disrupts ecosystems.
- Acidification (AC): Decrease in the acidity of rain and deposition of acidic particulates due to the release of gases, such as sulfur dioxide (SO_2) and nitrogen oxides (NOx).
- POCP/smog potential (SM): Formation of hazardous ground-level ozone by sunlight instigating the photochemical reaction of nitrogen oxides with hydrocarbons and volatile organic compounds (VOCs).
- Respiratory effects (RES): When inhaled, particulates and gases such as SO_2 and NOx cause respiratory effects.
- Stratospheric ozone depletion (OD): Pollutants that cause the destruction of the protective ozone layer in the upper atmosphere.
- Fossil fuel depletion (FF): Depletion of nonrenewable fuels, the measurement accounts for the increasing energy intensity required for extraction as reserves are more difficult to extract.

[6] In accordance with accepted greenhouse gas accounting practices, biomass carbon and biomass-derived CO_2 were tracked separately from fossil fuel-derived CO_2 and other greenhouse gases in the life-cycle impact assessment (LCIA). The effects of biomass carbon on the atmosphere were characterized by calculating the changes in the stocks of stored carbon through the life cycle of the product (globally, the net change in total stocks of stored biomass carbon is mathematically equal to the net flow of biomass carbon to/from the atmosphere).

[7] Name of all impact categories as defined in the EPA Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI) method.

[8] Results also were obtained for several toxicity-related indicators, but the results proved to be highly imprecise and of uncertain significance, so they are not discussed in the executive summary.

IMPACT ASSESSMENT – OFFICE PAPER
(UNCOATED FREESHEET)

The cradle-to-grave life-cycle impact assessment (LCIA) results shown in Table 2 indicate that the uncoated freesheet production life-cycle stage is the largest contributor to all impact categories except for eutrophication, for which the largest contributor is the EoL. *Note: In the case of office paper there is no life-cycle Step 3 (i.e., production activities such as printing).*

Table 2. LCIA Results
Ream of Office Paper

Impact category	Unit	Total (ream)	1. Fiber procurement	2. Uncoated freesheet production	4. Transport of UCF	5. End-of-life	Carbon storage†
Global warming	kg CO_2 eq.	4.25	8.8%	58.3%	1.4%	36.7%	-5.1%
Acidification	H^+ moles eq.	1.43	12.6%	83.5%	2.9%	0.9%	N/A
Respiratory effects	kg $PM_{2.5}$ eq.	0.00676	5.1%	93.6%	0.7%	0.6%	
Eutrophication	kg N eq.	0.00775	3.5%	38.8%	0.6%	57.2%	
Ozone depletion	kg CFC-11 eq.	2.60E-07	8%	77%	5%	11%	
Smog	kg NOx eq.	8.81E-03	26.2%	58.5%	10.9%	4.4%	
Fossil fuel depletion	MJ surplus	3.02	16.5%	78.7%	3.5%	1.2%	

†Carbon sequestration in use and landfill.

62%

Use of renewable resources in office paper:
In this study, the inventory results document that 62 percent (mass basis) of the total life-cycle resource requirements (excluding water)[9] for a ream of office paper is renewable (i.e., wood fiber).

[9]The data does not allow for characterizing water consumption; only water use numbers are available. Water use equals water consumed (e.g., released as steam or leaves with the product) plus water returned to the environment. Hence, water consumption was not included in the total resource consumption indicator.

Of the 160 kg (353 pounds) of water associated with the ream of office paper life cycle,

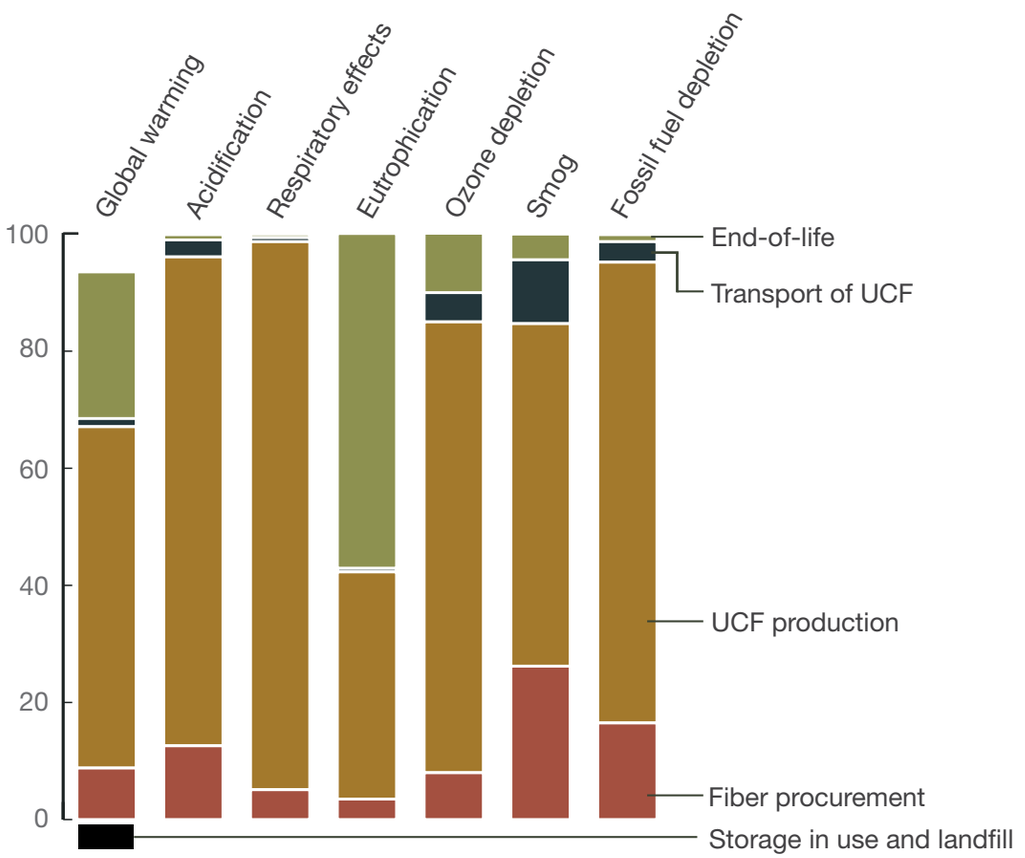
133 kg (293 pounds) are used at the mill to manufacture the paper. More than 90 percent of this water is returned to the environment.

Water use:
After fiber, water is the most important renewable raw material used in paper production. It is used in most stages of manufacturing and is recycled and reused throughout the process, and then is returned to the environment. Small amounts also evaporate or are retained in the final product.

INTERPRETATION

The study also examined the contributions of the different life-cycle stages to the impact categories (see Figure 2, adapted from Table 2). While uncoated freesheet production is the primary contributor to all impact categories except eutrophication, truck transportation of the fiber (fiber procurement life-cycle stage) is also a significant contributor to acidification. Fiber procurement (transportation and fuel usage) has a significant effect on smog potential and fossil fuel depletion.

Figure 2. Cradle-to-Grave Contribution Analysis
Office Paper



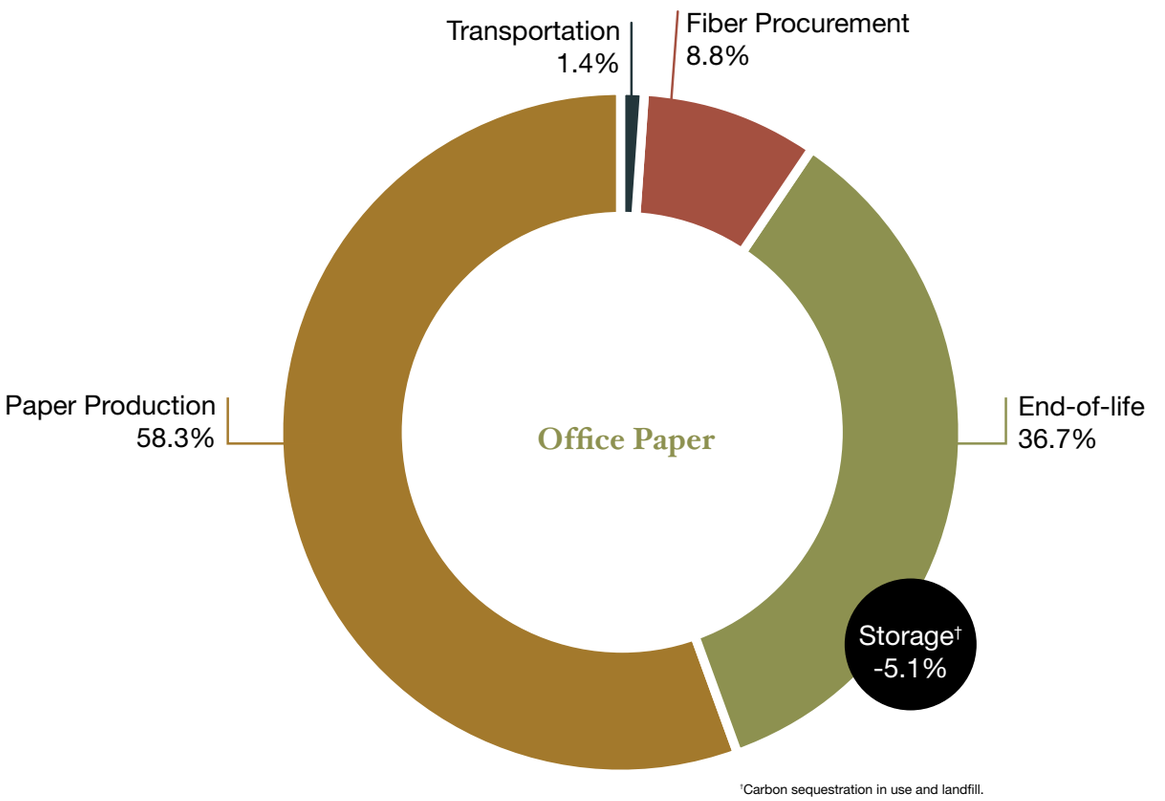
CLOSER LOOK AT SELECTED RESULTS

The impact indicator of primary interest to many stakeholders is the global warming (GW) potential, or amount of greenhouse gases (GHGs) produced through the life cycle. The carbon footprint is a measure of all GHGs produced and is measured in units of tons (or kg) of carbon dioxide equivalents.

Global warming: Significant contributors to the GW impact include production of uncoated freesheet (releases from fossil fuel combustion at pulp and paper mills, releases associated with electricity purchased by pulp and paper mills, and production of sodium chlorate); and EoL (methane generated and released when the office paper is disposed of in landfills). In the case of office paper, the carbon stored in products in use and in landfills has a small impact on global warming.

Paper production and EoL stages contribute most to office paper's carbon footprint. Increasing recovery rate from 72 percent to 85 percent decreases the carbon footprint by approximately 25 percent. By eliminating landfill and replacing with burning and energy recovery, this indicator is reduced by 40 percent.

Figure 3. Distribution of Carbon Footprint



†Carbon sequestration in use and landfill.

IMPACT ASSESSMENT – CATALOG
(COATED FREESHEET)

The cradle-to-grave LCIA results shown in Table 3 indicate that for catalogs, the paper and catalog production life-cycle stages are the largest contributors to all impact categories except for eutrophication, for which the largest contributor is the paper's EoL.

Table 3. LCIA Results
Catalog

Impact category	Unit	Total (catalog)	1. Fiber procurement	2. Paper production	3. Production of catalogs	4. Transport and use	5. End-of-life	Storage in use and landfill†
Global warming	kg CO_2 eq.	4.89E-01	5.4%	43.6%	15.7%	1.2%	37.7%	-3.4%
Acidification	H^+ moles eq.	1.67E-01	7.6%	67.4%	21.1%	1.1%	2.9%	N/A
Respiratory effects	kg $PM_{2.5}$ eq.	6.52E-04	3.5%	77.9%	15.6%	0.3%	2.6%	
Eutrophication	kg N eq.	8.85E-04	1.9%	19%	6.2%	0.2%	72.8%	
Ozone depletion	kg CFC-11 eq.	2.63E-08	6%	53%	31%	4%	7%	
Smog	kg NOx eq.	2.10E-03	7.7%	36.4%	48.7%	1.8%	5.3%	
Fossil fuel depletion	MJ surplus	3.94E-01	9.3%	52.4%	29.8%	2.6%	5.9%	

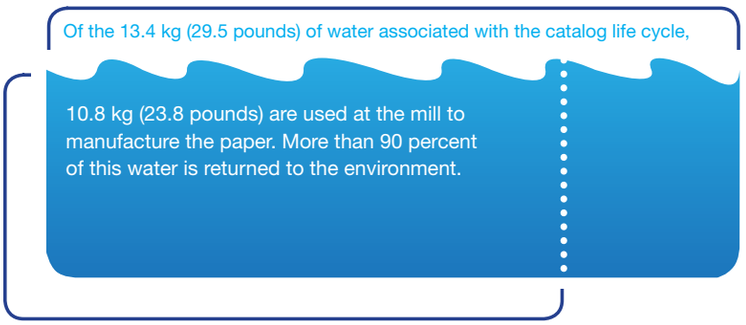
†Carbon sequestration in use and landfill.

Use of renewable resources in catalogs

45%

In this study, the inventory results document that 45 percent (mass basis) of the total life-cycle resource requirements (excluding water)[9] for a catalog is renewable (i.e., wood fiber). This value may seem lower than one would expect. This is because conversion of the coated freesheet into catalogs involves using a significant amount of nonrenewable resources, mainly due to electricity consumption.

[9]The data does not allow for characterizing water consumption; only water use numbers are available. Water use equals water consumed (e.g., released as steam or leaves with the product) plus water returned to the environment. Hence, water consumption was not included in the total resource consumption indicator.

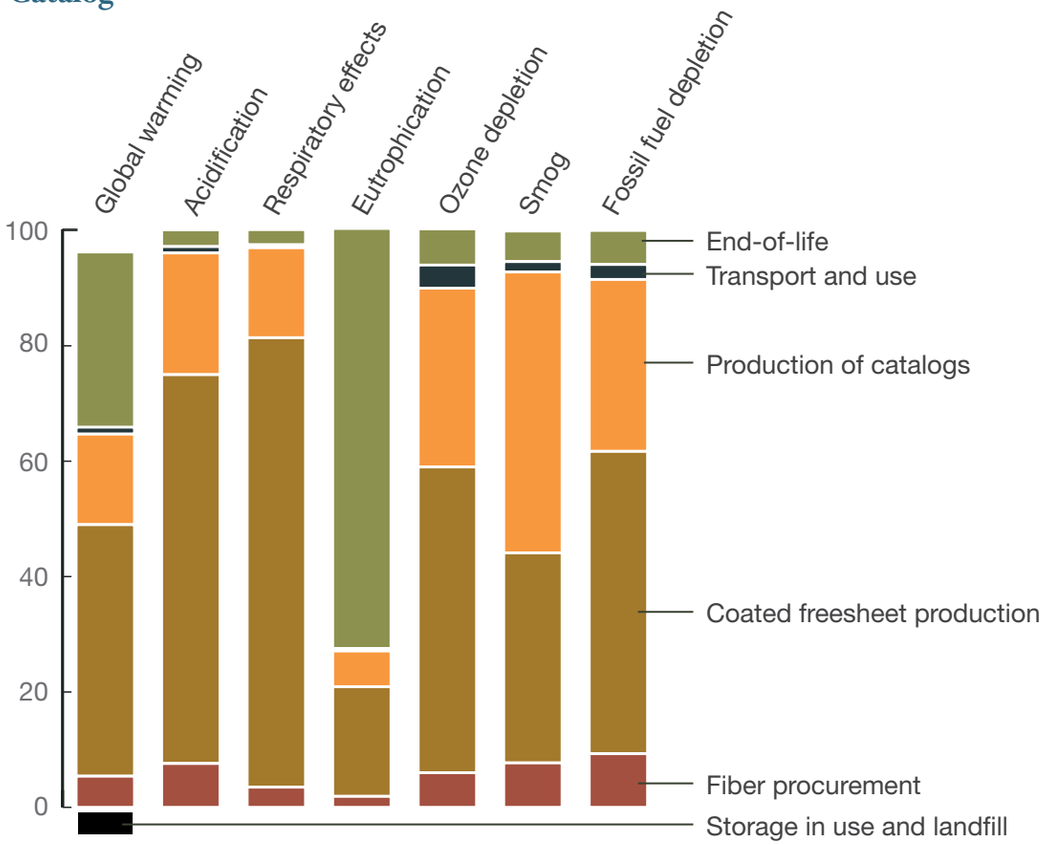


Water use:
After fiber, water is the most important renewable raw material used in paper production. It is used in most stages of manufacturing and is recycled and reused throughout the process, and then is returned to the environment. Small amounts also evaporate or are retained in the final product.

INTERPRETATION

In this section, the contributions of the different life-cycle stages to the impact categories are examined in greater detail (see Figure 4, adapted from Table 3). While coated freesheet production is the primary contributor to all impact categories except eutrophication and smog, the production of the catalogs (purchased electricity) also contributes significantly to acidification, respiratory effects, stratospheric ozone depletion, smog and fossil fuel depletion. For catalogs, fiber procurement (fiber transportation) is another important contributor to smog, and EoL (as indicated through chemical oxygen demand (COD) from the leachate of municipal paper landfill) is the life-cycle stage that contributes most to eutrophication.

Figure 4. Cradle-to-Grave Contribution Analysis
Catalog



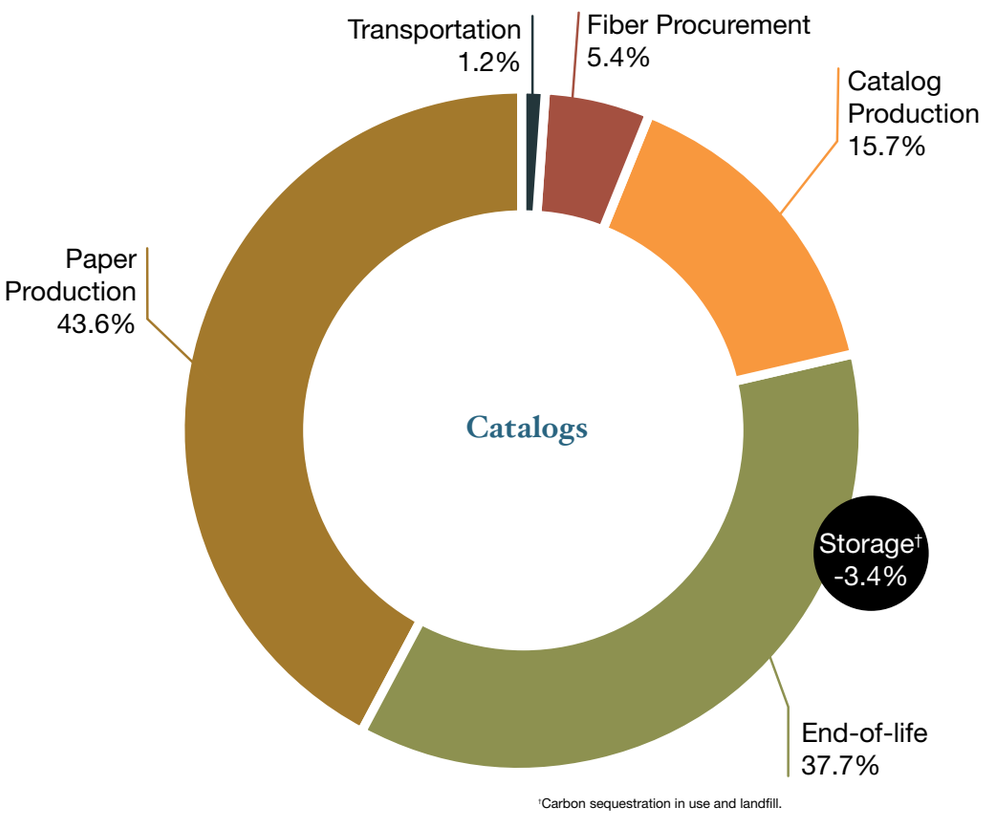
CLOSER LOOK AT SELECTED RESULTS

The impact indicator of primary interest to many stakeholders is the global warming (GW) potential, or amount of greenhouse gases (GHGs) produced through the life cycle. The carbon footprint is a measure of all GHGs produced and is measured in units of tons (or kg) of carbon dioxide equivalents.

Global warming: Significant contributors to global warming include the following life-cycle stages: production of the coated freesheet (fossil fuels burned at pulp and paper mills and purchased electricity); EoL (methane generated and released when the catalogs are disposed of in landfills); and the catalog production (purchased electricity[10]). In the case of catalogs made of coated freesheet, the impacts of carbon stored in products and landfills are not very significant because most of the carbon degrades.

Increasing recovery from 33 percent to 50 percent decreases the carbon footprint by approximately 15 percent. Replacing landfill by burning reduces the footprint by 40 percent.

Figure 5. Distribution of Carbon Footprint



†Carbon sequestration in use and landfill.

[10]Note that electricity production for printing operations was based on a European study.

IMPACT ASSESSMENT – TELEPHONE DIRECTORY (UNCOATED MECHANICAL)

The cradle-to-grave LCIA results shown in Table 4 indicate that production of the directories is a significant contributor to all impact categories except eutrophication and acidification. The paper production life-cycle stage is also an important contributor.

Table 4. LCIA Results
Telephone Directory

Impact category	Unit	Total (telephone directory)	1. Fiber procurement	2. Paper production	3. Production of the directory	4. Transport and use	5. End-of-life	Storage in use and landfill†
Global warming	kg CO_2 eq.	2.24	18.6%	64.7%	43.1%	2.1%	26.9%	-55.4%
Acidification	H^+ moles eq.	1.21	15.7%	42.2%	37%	1.3%	3.7%	N/A
Respiratory effects	kg $PM_{2.5}$ eq.	0.00427	13%	55.2%	27.5%	0.4%	3.8%	
Eutrophication	kg N eq.	0.00937	2.8%	14.2%	9.3%	0.2%	73.6%	
Ozone depletion	kg CFC-11 eq.	2.40E-07	8.1%	28.9%	52.8%	3.5%	6.7%	
Smog	kg NOx eq.	0.00427	13%	55.2%	27.5%	0.4%	3.8%	
Fossil fuel depletion	MJ surplus	3.85	12.5%	34.2%	45.7%	2.2%	5.4%	

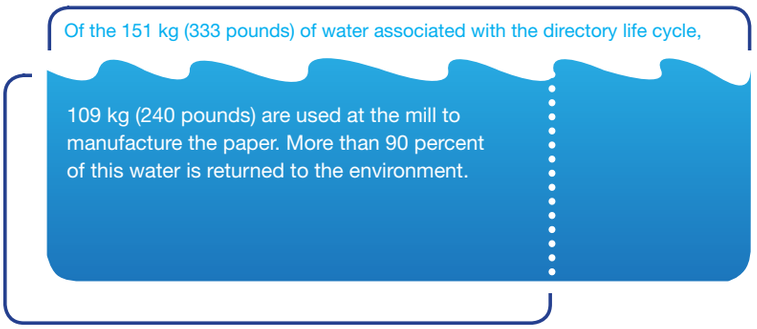
†Carbon sequestration in use and landfill.

52%

Telephone directory use of renewable resources

In this study, the inventory results document that 52 percent (mass basis) of the total life-cycle resource requirements (excluding water)[9] for a telephone directory is renewable (i.e., wood fiber). This value may seem lower than one would expect. This is because the conversion of the uncoated mechanical paper into directories involves using a significant amount of nonrenewable resources, mainly due to electricity consumption.

[9]The data does not allow for characterizing water consumption; only water use numbers are available. Water use equals water consumed (e.g., released as steam or leaves with the product) plus water returned to the environment. Hence, water consumption was not included in the total resource consumption indicator.

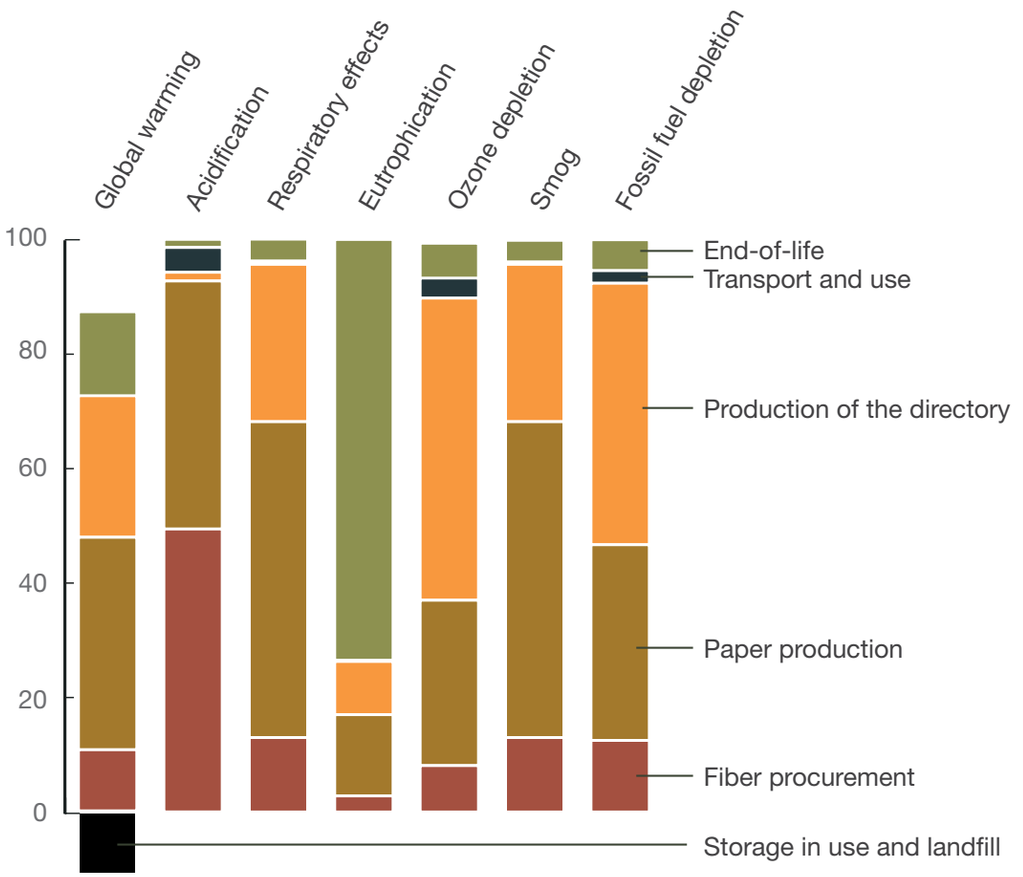


Water use:
After fiber, water is the most important renewable raw material used in paper production. It is used in most stages of manufacturing and is recycled and reused throughout the process, and then is returned to the environment. Small amounts also evaporate or are retained in the final product.

INTERPRETATION

In this section, the contributions of the different life-cycle stages to the impact categories are examined in greater detail (see Figure 6, adapted from Table 4). While production of the directories is a significant contributor to all impact categories except eutrophication and acidification, paper production also contributes to acidification, smog, ozone depletion, fossil fuel depletion and respiratory effects. The EoL is the main contributor to the eutrophication indicator.

Figure 6. Cradle-to-Grave Contribution Analysis
Telephone Directory



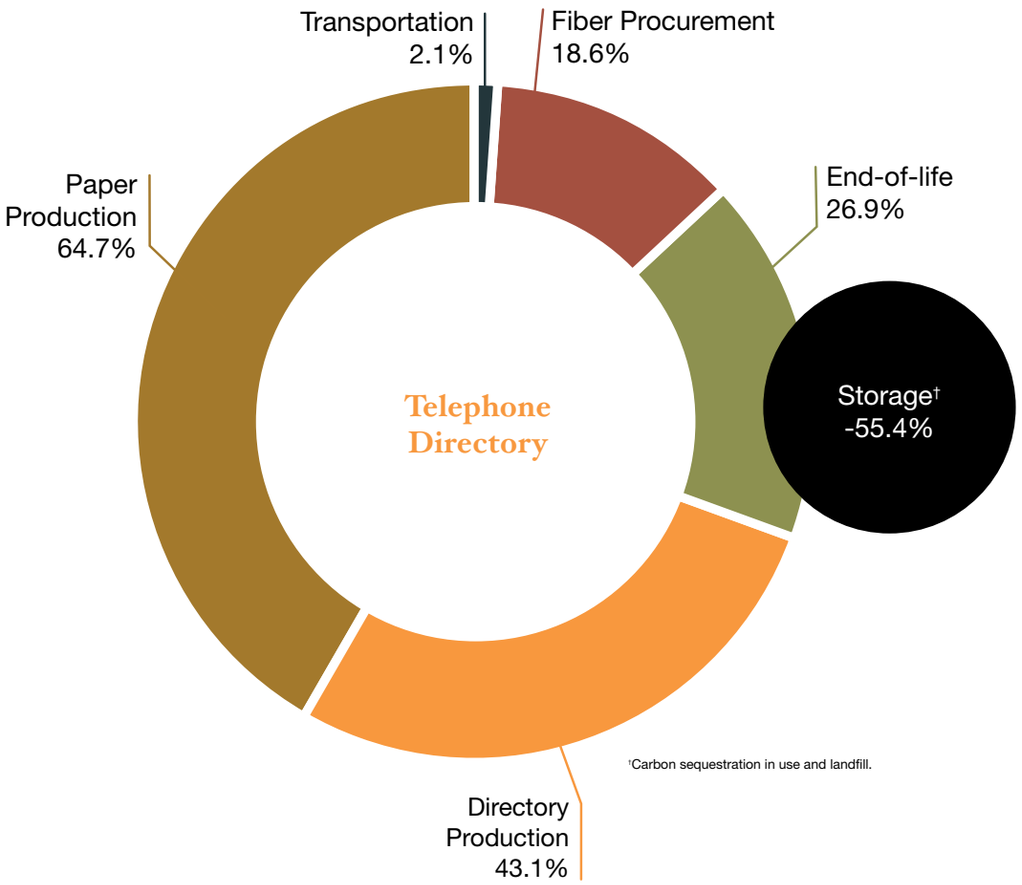
CLOSER LOOK AT SELECTED RESULTS

The impact indicator of primary interest to many stakeholders is the global warming (GW) potential, or amount of greenhouse gases (GHGs) produced through the life cycle. The carbon footprint is a measure of all GHGs produced and is measured in units of tons (or kg) of carbon dioxide equivalents.

Global warming: Significant contributors to global warming include the following life-cycle stages: paper production (usage of fossil fuels and purchased electricity) and telephone directory manufacturing (purchased electricity[10]). In the case of uncoated mechanical paper, the carbon stored in the product in use and in landfills more than compensates for the methane from landfills at EoL (-55 percent for storage versus 27 percent for landfills).

Significant contributors are paper production and directory production. Increase in recovery has almost no effect on carbon footprint because the benefits from exporting the burden to subsequent uses and burning with energy recovery are largely compensated by less carbon stored in the system boundary.

Figure 7. Distribution of Carbon Footprint



[10]Note that electricity production for printing operations was based on a European study.

IMPACT ASSESSMENT – MAGAZINES
(COATED MECHANICAL)

The cradle-to-grave LCIA results shown in Table 5 indicate that production of paper is the life-cycle stage contributing most to all impact categories for magazines except eutrophication and smog. The production of magazines is also an important contributor.

Table 5. LCIA Results
Magazines

Impact category	Unit	Total magazine	1. Fiber procurement	2. Paper production	3. Production of the magazine	4. Transport and use of magazine	5. End-of-life	Storage in use and landfill†
Global warming	kg CO_2 eq.	0.459	5.8%	66.3%	27.3%	0.5%	19%	-18.8%
Acidification	H^+ moles eq.	0.184	6.9%	58.1%	31.2%	0.4%	3.5%	N/A
Respiratory effects	kg $PM_{2.5}$ eq.	7.11E-04	3.1%	70.2%	23.3%	0.1%	3.2%	
Eutrophication	kg N eq.	1.11E-03	1.4%	17.4%	8%	0.1%	73.1%	
Ozone depletion	kg CFC-11 eq.	3.85E-08	4%	55%	31.8%	2.8%	6.3%	
Smog	kg NOx eq.	2.84E-03	6%	30.2%	58.7%	0.5%	4.6%	
Fossil fuel depletion	MJ surplus	0.590	6.2%	55.3%	32.5%	0.6%	5.3%	

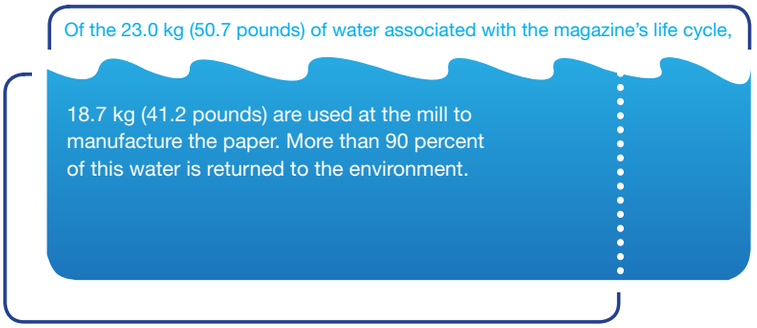
†Carbon sequestration in use and landfill.

39%

Use of renewable resources in magazines

In this study, the inventory results document that about 39 percent (mass basis) of the total life-cycle resource requirements (excluding water)[9] for a magazine made of coated mechanical paper is renewable (i.e., wood fiber). This value may seem lower than one would expect. This is because the conversion of the coated mechanical paper into magazines involves the usage of a significant amount of nonrenewable resources, mainly due to electricity consumption.

[9]The data does not allow for characterizing water consumption; only water use numbers are available. Water use equals water consumed (e.g., released as steam or leaves with the product) plus water returned to the environment. Hence, water consumption was not included in the total resource consumption indicator.

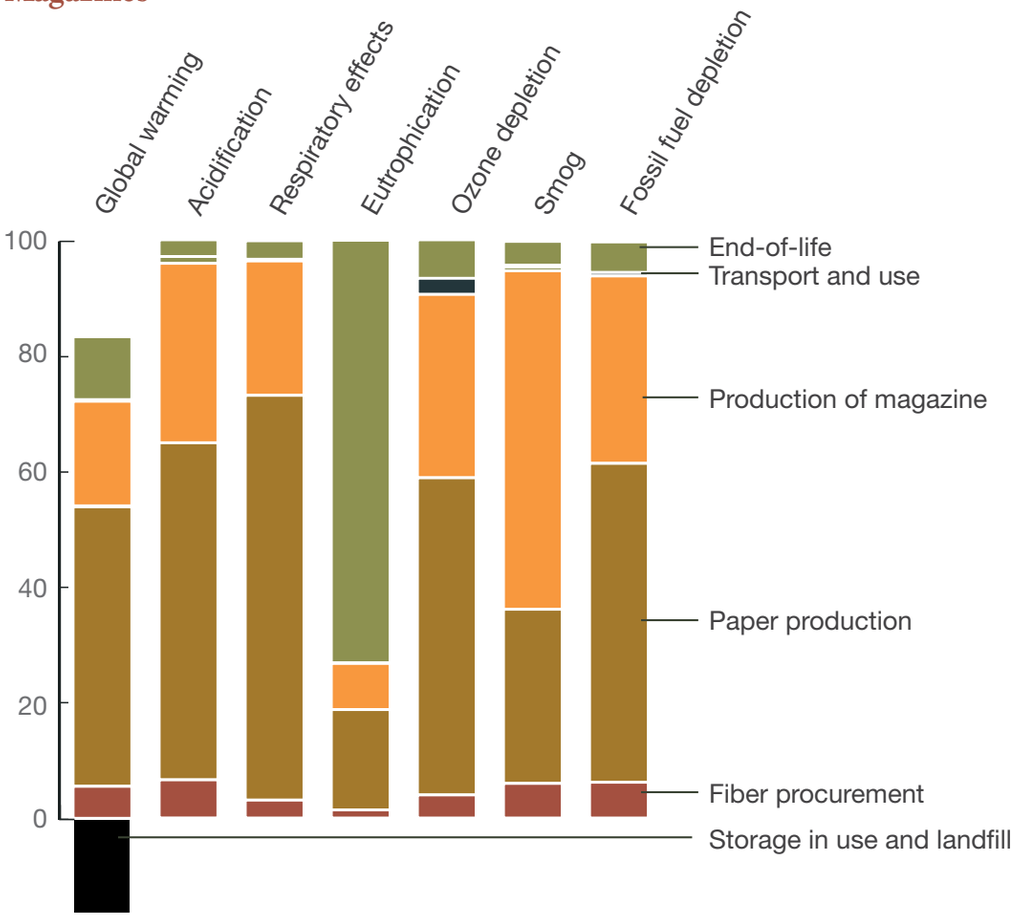


Water use:
After fiber, water is the most important renewable raw material used in paper production. It is used in most stages of manufacturing and is recycled and reused throughout the process, and then is returned to the environment. Small amounts also evaporate or are retained in the final product.

INTERPRETATION

In this section, the contributions of the different life-cycle stages to the impact categories are examined in greater detail (see Figure 8, adapted from Table 5). In addition to the primary contributions made by paper production and production of magazines, end-of-life (as indicated through COD from the leachate of municipal paper landfill) is the life-cycle stage that contributes most to eutrophication.

Figure 8. Cradle-to-Grave Contribution Analysis
Magazines



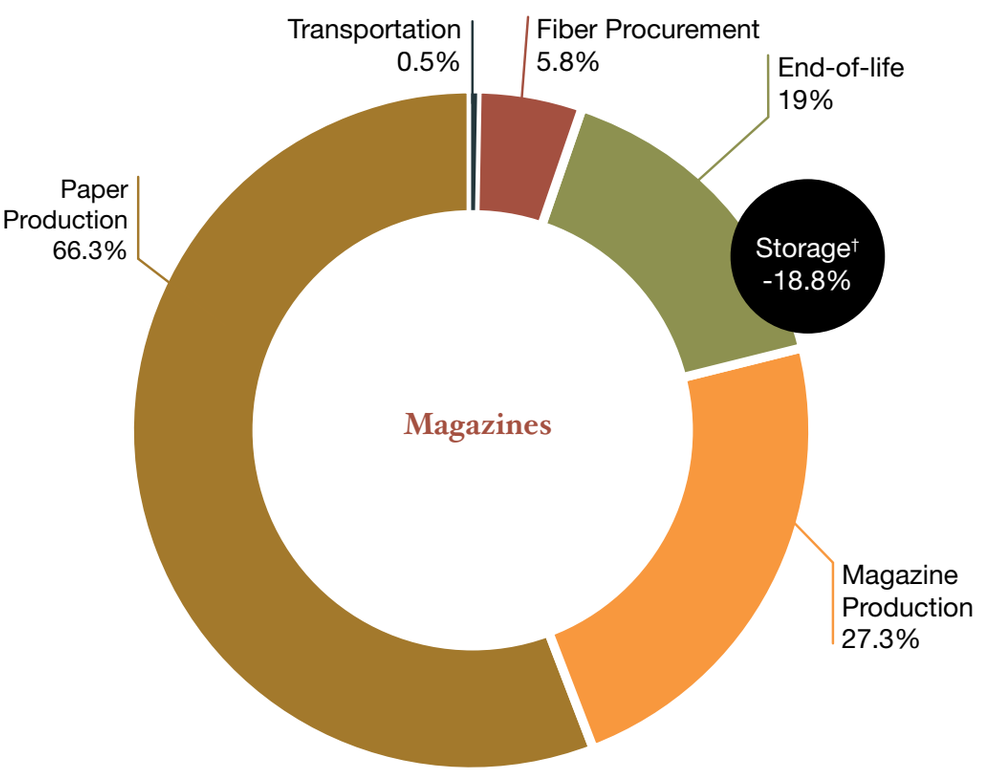
CLOSER LOOK AT SELECTED RESULTS

The impact indicator of primary interest to many stakeholders is the global warming (GW) potential, or amount of greenhouse gases (GHGs) produced through the life cycle. The carbon footprint is a measure of all GHGs produced and is measured in units of tons (or kg) of carbon dioxide equivalents.

Global warming: The primary contributors to the GW indicator include the following life-cycle stages: paper production and magazine manufacturing (releases associated with purchased electricity and fuels burned during those stages). In the case of coated mechanical paper, the carbon stored in the product in use and in landfill compensates for global warming due to methane from landfills at EoL (-19 percent for storage versus 19 percent for landfills).

Paper production and magazine production are the largest contributors to the magazines's carbon footprint. Recovery rate increases have almost no effect on carbon footprint because the benefits of exporting the burden are compensated by less carbon stored within the boundary.

Figure 9. Distribution of Carbon Footprint



†Carbon sequestration in use and landfill.

THE KEY FINDINGS OF THE LCA STUDY

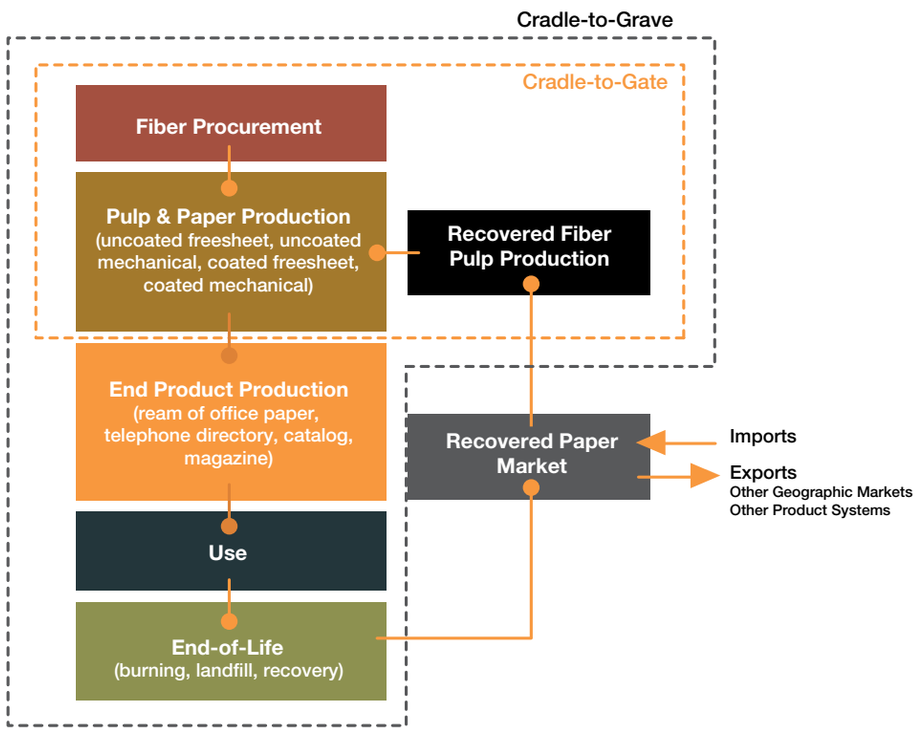
Overall:
The LCA study concluded that the most significant life-cycle impacts for printing and writing papers results from the production of the paper and disposal of used paper at the end-of-life.

Key Conclusions:

- The environmental impacts of paper production are largely driven by the use of fossil fuels in the pulp and paper manufacturing process.
- Increasing the use of bio-based energy sources at paper mills would reduce climate change impacts.
- Increasing the recovery rate of all papers, particularly of products that decompose readily in the anaerobic environment in a landfill (e.g., freesheet papers) would have a significant positive effect on global warming impacts.
- Avoiding landfilling of nonrecoverable paper fiber by burning with energy recovery would have a very significant impact on results, particularly for products that decompose readily in the anaerobic environment in a landfill.
- Transportation is not very significant in overall life-cycle impacts.

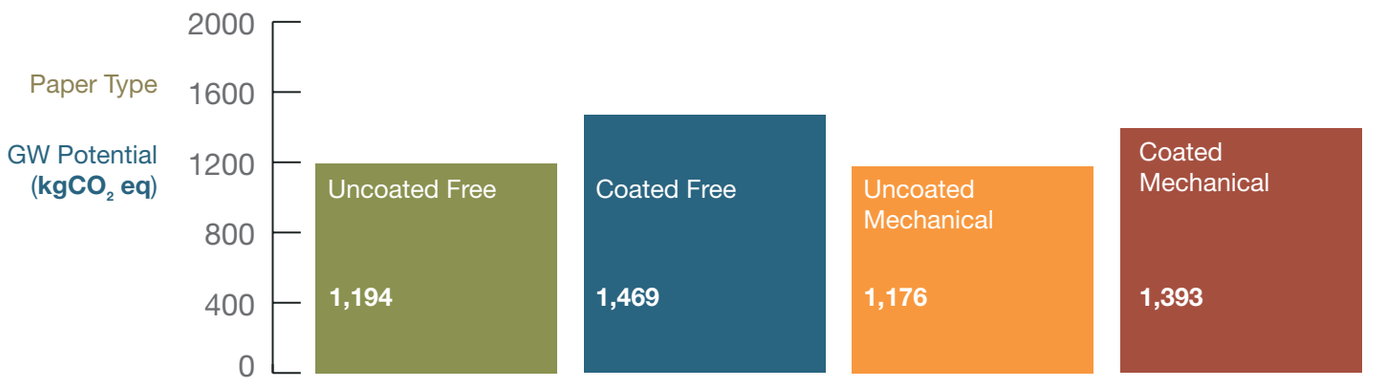
CRADLE-TO-GATE RESULTS CALCULATIONS

While the entire life-cycle impacts for printing and writing papers are captured in the **cradle-to-grave** boundary system (raw material extraction through final disposal), the LCA study also calculated **cradle-to-gate** results. The cradle-to-gate boundary includes all steps up to and including paper production, but not end product production, use or end-of-life (see figure below).



For stakeholders wishing to determine the global warming (GW) impact (carbon footprint) for the paper component of a specific printing project, the cradle-to-gate industry average values per short ton for the four major printing paper grade types studied are shown below.

Figure 10. Cradle-to-Gate Results
Results are per bone-dry short ton.



Note: These values are calculated as cradle-to-gate emissions of all greenhouse gases, not including CO_2 originating from biomass. To use these values to calculate cradle-to-grave values, add any subsequent gate-to-grave emissions, not including CO_2 originating from biomass and subtract net additions of carbon to the amounts stored in products-in-use and product-in-landfills. The values shown were developed using the ISO 14049 "number of subsequent uses" approach for allocating open loop recycling, so the complete footprint also will reflect this application of this allocation method.

IMPACT OF INCREASING RECYCLED CONTENT

Both recycled fiber and fresh fiber from sustainably managed forests provide environmental benefits as well as potential impacts.

The paper fiber cycle depends both on fresh fiber from well-managed forests and recycled fiber from a strong recovery network. Recycled fiber alone cannot meet all the fiber supply needs since recycled fiber breaks down with each use and about 15 percent of paper products, such as tissues and documents stored for extended periods of time, cannot be recycled. Fresh fiber and recycled fiber both have potential impacts. For recycled fiber, impacts to measure include whether recovered fiber has to be transported long distances, what kind of energy is being used, and how much processing is required to achieve the end-product specifications.

The LCA study included assumptions about recycled fiber content based on industry averages for each of the products analyzed. On the whole, the manufacturing systems for these products in North America are consistent enough that results can be considered as representative of the industry. However, for the specific case of increasing the recycled content in printing papers, it is not feasible to make industry-wide representative conclusions. Results are highly dependent on the individual production and logistic circumstances at each facility using the recovered fiber.

In LCA work, there are several methodologies that can be applied for systems with recycled content. In this study, the burden of virgin fiber manufacturing is allocated to recycled fiber based on the fact that the majority of virgin fiber is used subsequently outside of the boundary of the system (i.e., recycled printing and writing grades get used in other products like containerboard and tissue). As such, when paper recovery rates are increased, the manufacturing footprint is decreased because the burden of manufacturing gets shifted to the recovered fiber. This type of approach is based on the inherent value system that it is important to increase the recovery of materials at their end-of-life. An alternative approach would be to place 100 percent of the burden on virgin materials, which, as a result, would reduce the burden (or impact) when using recycled fiber.

COMPARISON TO E-MEDIA

This study was conducted specifically to identify the environmental impacts of four specific paper-based communication products, and does not compare impacts of other communication forms such as electronic media. Strategies and methods for conducting such comparative evaluations could be the subjects of future research, which would be able to leverage the data from this LCA.

No matter which communication vehicle is chosen, buyers wanting to make sustainable choices should:

- Ask questions of suppliers to ensure they meet their sustainability criteria
- Make responsible choices about product design and use to minimize potential environmental impacts (e.g., by minimizing waste and energy use).
- Make responsible choices at end-of-life to maximize recovery and reuse, keep useful resources out of landfills and manage toxic impacts

OPPORTUNITIES FOR FUTURE LCA STUDY IMPROVEMENTS

In this study, printing activities were modeled using a European study (see full report for complete citation). It has been shown that electricity consumption and VOC releases associated with printing have important impacts on the results for several indicators. Electricity consumption was refined to use the information from one large representative U.S. printer. There is an opportunity to improve the quality of the study by collecting specific information for VOCs and industry-average information for both parameters. Other processes that were modeled using generic information, and for which there is an opportunity to improve the results by collecting specific information, include the production of sodium chlorate.

It is important to understand that, while the results of this study are valid for the average product investigated, the mill-to-mill differences can be very important — in some cases important enough to result in mill-specific conclusions based on specific mills that are opposite from the conclusions obtained in this study.

DATA SOURCES AND METHODOLOGY

The study is the most comprehensive ever conducted for North American printing and writing papers. The data was collected from 72 mills in the U.S. and Canada, which produced 22.4 million short tons of printing and writing papers in 2006-07. This represents approximately 77 percent of all North American production within that time period. Results represent a North American industry average; it must be noted that mill-to-mill differences can be significant, and individual mill data analysis can, therefore, yield vastly different results from those found in this study.

The LCA was conducted by the National Council for Air and Stream Improvement, Inc. (NCASI) — an independent, nonprofit research institute recognized as a leading resource of environmental topics of interest to the forest products industry.

- Most mill-level environmental and energy data for pulp and paper manufacturing came from biennial surveys by AF&PA and FPAC. Some data came from government databases.
- Data on types and amounts of material inputs and outputs at pulp and paper mills came from Fisher International's database.
- Printing data came from a European study.
- Data and models for other life-cycle aspects (landfill, for example) came from government sources, public LCI databases and public studies.
- For open-loop recycling of recovered fiber, the "number of subsequent uses" allocation method was used (illustrated in ISO 14049).
- Life-cycle modeling and calculations were done in the SimaPro™ LCA software.
- Potential environmental impacts were characterized using the TRACI impact assessment method developed by the EPA, with the CML[1] (2001) method used in a sensitivity analysis.

PEER REVIEW PANEL

The study and final report have been reviewed by an external peer review panel, which ensures that the study, among other requirements, was conducted according to the provisions of the ISO standards. The panel consisted of the following individuals:

- Martha Stevenson, chairperson — private consultant
- Pascal Lesage — life-cycle assessment consultant, associate professor at École Polytechnique de Montréal
- Dale Phenicie, Environmental Affairs Consulting

[1]The scope of the study addressed the average paper produced in North America, so the paper modeled in the LCA contains the average amounts of recovered fiber. The results would change if the average recovered fiber content changed.

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