A Life Cycle Assessment of printed matter using EE-IO data: Opportunities and limitations of a combined approach

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In Belgium the Federal Public Planning Agency responsible for product policy is exploring the possibilities to introduce a carbon/environmental labeling initiative for consumer products. In that context VITO studied the environmental impact of printed matter (newspaper and periodical) using life cycle assessment.
An ISO-conform LCA study is performed, using specific data (from private partners in the life cycle chain) as well as generic data from publicly available LCA data sources. In Flanders EE-IO tables with high resolution (117x 117) have recently been developed. Since the sectors for "printed matter" have a strong base in Flanders and as such are well-defined in the Flemish IO-tables, the potential for using EE-IO data as input for the LCA study is explored. Part of the project was to compare the results from and efforts for performing an ISO-conform LCA versus a combined IO-LCA. For the case of printed matter this provided insights to the offset between accuracy of results and efforts needed for data inventory.

1. Introduction

This pilot project 'Life cycle assessment of printed matter' fits within the policy of the Federal Government to reduce the entire environmental impact in the complete chain of products (also for consumers) and to increase life cycle thinking. In this framework the Federal Government also wishes to investigate the possibilities of product labeling, especially given the recent developments in other countries and on an EU level.

The overall study has a twofold objective:

- **Research** questions:
  - What is the contribution of the different phases in the life cycle of printed matter in the total environmental impact? In other words what are the hot spots in the life cycle?
  - What is the impact of the different printing processes in the total environmental impact of the printed matter?
  - Which materials and processes are responsible for the environmental impact?
  - What is the added value of environmental Input Output modeling in the inventory phase, with regard to generic background data?
- The Federal Public Service, Health, Food Safety and Environment specifically raises questions with regard to the **feasibility** of life cycle assessment in policy.

The printing and publishing sector in Flanders which is the focus of this study, generates an environmental impact through its daily activities. The Flemish environmental input-output model creates the opportunity to assess the importance of the sector on a monetary level and its contribution to the total environmental impact of the Flemish economic sectors.
From an economic point of view, the economic output of the sector, related to the production of intermediate (for other sectors) as well as final products (for households, government, export,…), **contributes for 1,2%** to the total output of all Flemish economic sectors. This puts the printing and publish sector in the top 25.

Table 1: Positioning of the printing and publishing sector in relation to the Flemish economy

Economic sector	Output (million Euros)
1. Wholesale	25206 (7,4%)
2. Real estate	17974 (5,3%)
3. Retail	12650 (3,7%)
4. Motor vehicles	12326 (3,6%)
5. Health care	11559 (3,4%)
…	…
24. Printing & publishing	4025 (1,2%)

Coupling environmental information with monetary flows in the Flemish IO-model allows to calculate environmental impacts related to the sector's activities. For the printing and publishing sector, the climate change (ton CO_2-equivalents) caused by the sector was calculated as an example.

When looking at the impact caused by a sector we can look at the emissions generated by the sector itself (emissions at the stack) on one hand and the emissions generated by the delivering sectors of the printing and publishing sector on the other.
For the printing and publishing sector, the own emissions of CO_2, CH_4 and N_2O, which contribute to climate change, are almost negligible: the sector only contributes for 0,0004% to the total emission of these pollutants. When we take the product chain of the printed products into account (according to life cycle thinking), we include that part of emissions of delivering sectors that is related to the amount of inputs the printing and publishing sector uses. From this perspective, the printing and publishing sector accounts for about 0,31% tot the total contribution to climate change of the Flemish economy. A contribution analysis makes it possible to identify the source of CO_2-equivalents along the life cycle of a printed product, as is shown in Figure 1.

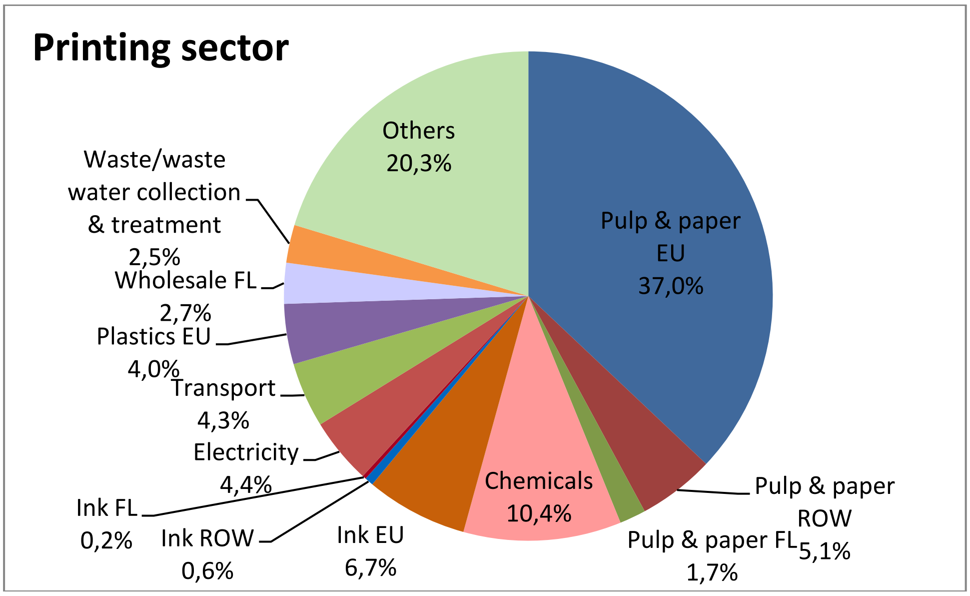

Figure 1: Sources of CO_2-equivalents caused by the production of printed products by the Flemish printing sector.

2. Goal and scope of the study

This project distinguishes 2 parts:

- An **ISO-conform life cycle assessment** (LCA) based on a combination of specific data (provided by the project partners) and generic data from LCA-databases;
- A **combined IO LCA**, based on specific data provided by the project partners and generic data from the Environmentally extended Flemish IO-model.

This pilot project is performed by VITO (life cycle assessment) in close collaboration with the private partners: Corelio Printing (a printing office), Agfa Graphics (producer of printing plates) and Febelgra (National Assocation of graphical industry).

We specifically focus on **printed matter** that is processed by two types of printing processes:

- Newspaper: printed with coldset process;
- Periodical: printed with heatset process.

The **functional unit** in this LCA is defined as: “the production, distribution and end of life treatment of 1 m^2 of printed newspaper/periodical”. This definition encompasses the production of the printed matter (in the printing office), but also the upstream processes such as production of printing plates, paper and ink, distribution to the consumers and end of life treatment (collection, recycling, incineration, …).

The life cycle of the printed matter will be analyzed from cradle-to-grave. The following figure shows the life cycle stages included.

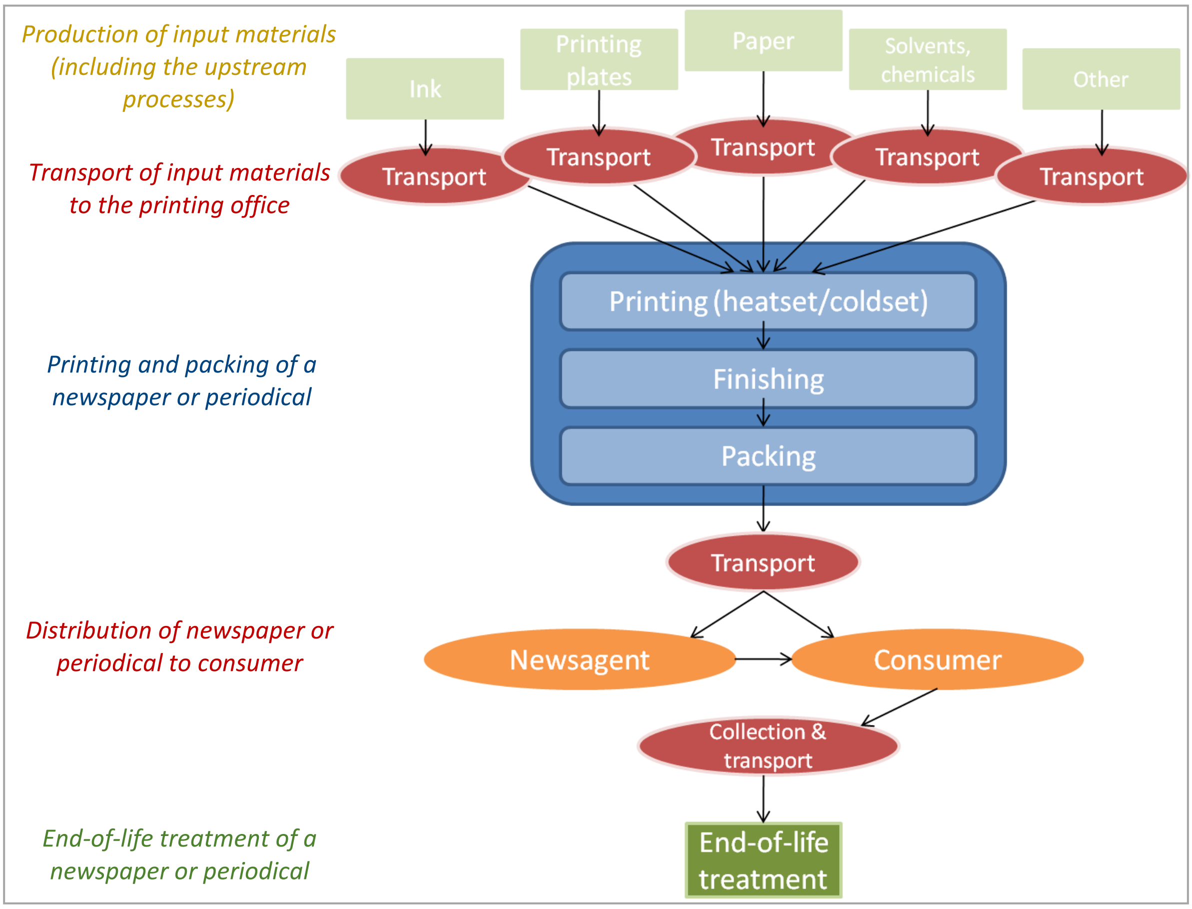

Figure 2: System boundaries of the LCA-study

Data represent all the input flows (material, energy,…) and all the output flows (emissions, waste, …) which are described and quantified, for all life cycle phases from cradle-to-grave. Waste is considered as part of the system under study, whether this waste is landfilled, incinerated or recycled. Avoided electricity production due to energy recovery of waste incineration is taken into account as well. For recycling of waste, the recycled content approach is used in the basic scenario, as shown in Figure 2.

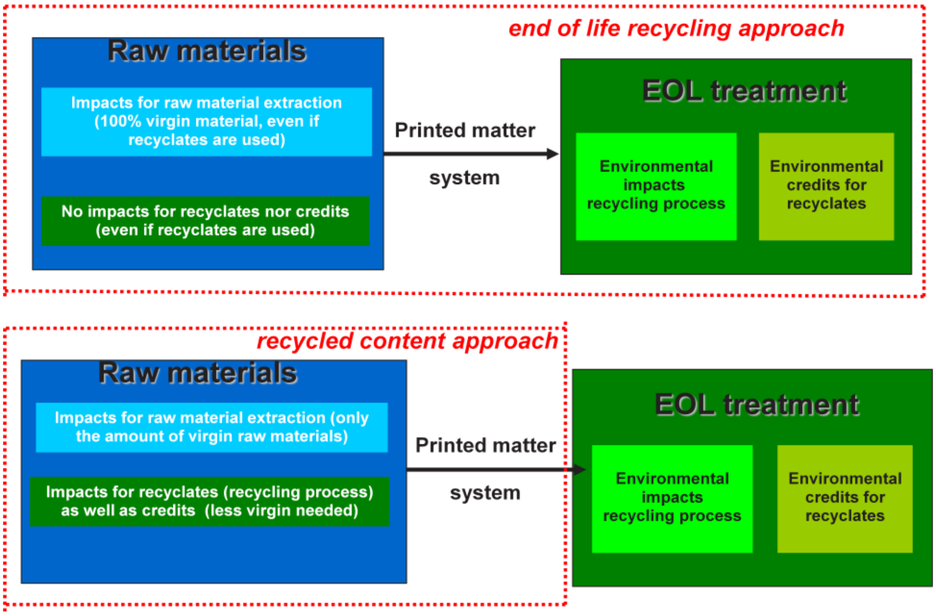

Figure 3: Approach for recycling of waste

3. Methodology

3.1 LCA methodology

The LCA is performed according to the ISO and ILCD recommendations.

According to these guidelines an LCA is performed in 4 steps:

- Goal and scope definition;
- Life Cycle Inventory Analysis (LCI);
- Life Cycle Impact Assessment (LCIA);
- Interpretation.

The relation between the different phases is illustrated in Figure 4.

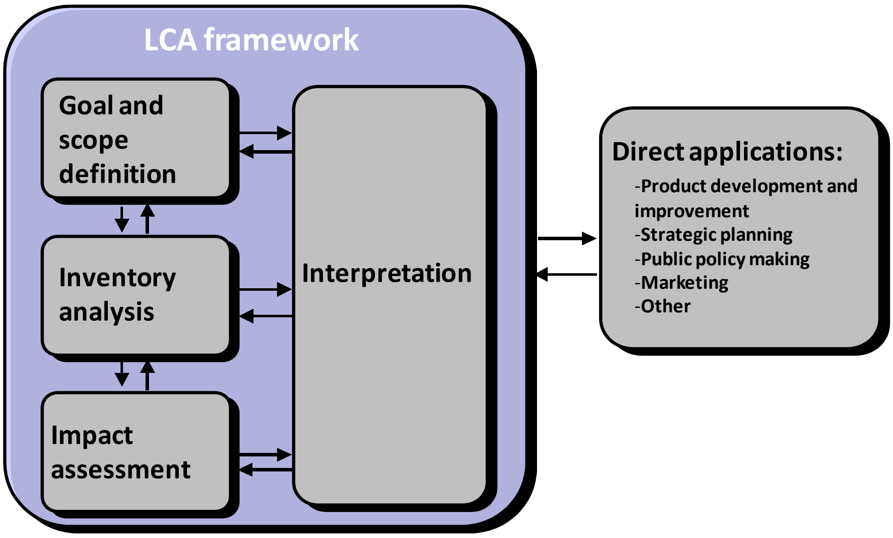

Figure 4: Methodological framework of an LCA (ISO, 2006)

The data inventory is as much as possible based on specific data that are supplied by the project partners. Background data are based on the Ecoinvent database. The life cycle impact assessment is done according to the Recipe midpoint method.

Table 2: Overview of the data used in the LCA

Life cycle phase	Data source	Life cycle phase	Data source
Chemicals	Ecoinvent/estimation	**Heat**	Ecoinvent
Ink	Ecoinvent	**Tap water**	IO model
Paper	Ecoinvent	**Printing factory**	Corelio printing
Printing plates	Agfa Graphics	**Transport**	Ecoinvent
Rubbers etc.	Ecoinvent	**EoL collection**	Ecoinvent
Electricity	Ecoinvent	**EoL treatment**	Ecoinvent

LCAs do not represent a complete picture of the environmental impact of a system. They represent a picture of those aspects that can be quantified. Any judgments that are based on the interpretation of LCI-data must bear in mind this limitation and, if necessary, obtain additional environmental information from other sources (hygienic aspects, risk assessment, etc.). The LCIA-results are relative expressions and do not predict impacts on category endpoints, exceedence of thresholds, safety margins or risks.

3.2 Combined IO-LCA

The Flemish Environmental Input-Output model

The Flemish environmentally extended input-output model was developed from 2007 until 2010 in commission of the Flemish Public Waste Agency (OVAM), the Flemish Environment Agency (VMM) and the Environment, Nature and Energy department (LNE) (OVAM, 2010; Vercalsteren et al., 2008); Avonds en Vandille, 2008; Bilsen et al., 2008). The IO-model allows to relate economy with ecology, on a scientific base. It inventories all relevant economic and environmental data with regard to production and consumption. This makes it a powerful instrument to support decisions in sustainability policy making of a region. The IO-model can provide answers on questions such as “Which economic sectors en which consumption activities in Flanders create the largest environmental impact?”, “Is the environmental impact generated in Flanders, in the rest of Belgium or the world?”.

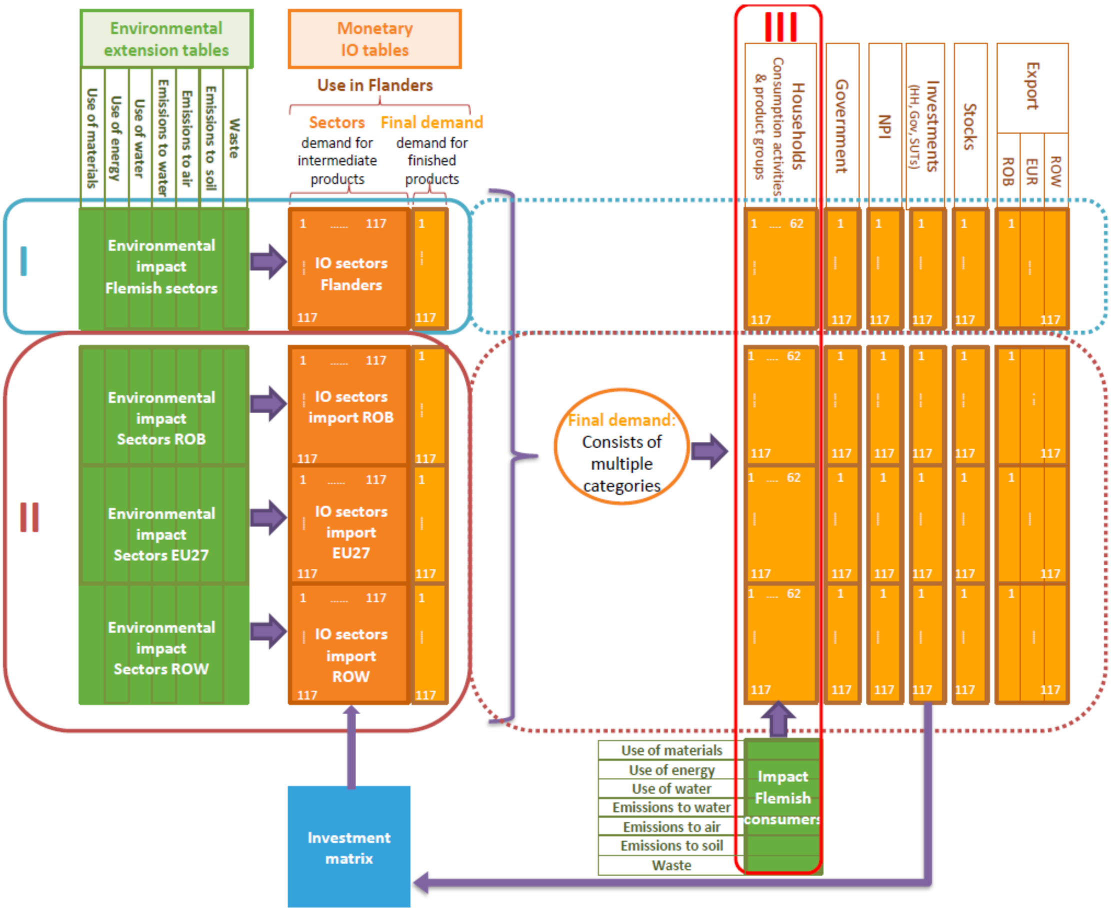

Figure 5: Structure of the Flemish environmentally extended Input Output model

The Flemish environmental input-output model consists of 3 building blocks, as shown in Figure 5

- I: The Flemish monetary input-output table and corresponding environmental extension tables;
- II: The monetary input-output table related to import and the corresponding environmental extension tables;
- III: The monetary consumption table and corresponding environmental extension table.

<u>Combined IO-LCA</u>

In the combined input-output life cycle assessment, part of the data used in the ISO conform LCA are now replaced with data from the Flemish environmental input-output model. The sectors in the life cycle of printed matter are well represented in the IO model, which enables one to do this hybrid assessment.

The motivation behind this hybrid approach to LCA is to see whether the use of generic IO data for the upstream or downstream steps in the life cycle can lead to similar results as an ISO conform LCA. If this is the case, it can simplify data collection when performing life cycle assessment. For this study specifically, this implies that IO data will be used for steps upstream of the printing office (Corelio) as well as the end-of-life collection and treatment.

The specific data provided by Corelio for the printing part of the life cycle of a newspaper or a magazine remains as a basis for the other data in the IO based LCA. Since the IO-model is based on monetary flows, monetary amounts of the different inputs to the printing activities from Corelio are needed. Prices per unit of input material were provided to allow the conversion of the data to monetary amounts.

Table 3 shows the data sources used for each of the steps in the life cycle of a printed product:

Table 3: Overview of the data used in the IO based LCA

Life cycle phase	Data source	IO sector	Life cycle phase	Data source	IO sector
Chemicals	IO model	24A1: Basic chemistry	**Heat**	Ecoinvent	/
Ink	IO model	24C1: Paint, ink, varnish…	**Tap water**	IO model	41A1: Drinking water & distribution
Paper	IO model	21A1: Pulp & paper	**Printing factory**	Corelio	/
Printing plates	IO model	28B1: Surface treatment	**Transport**	Ecoinvent	/
Rubbers etc.	IO model	25A1: Rubber products	**EoL collection**	Ecoinvent	/
Electricity	IO model	40A1: Electricity, gas, steam	**EoL treatment**	Ecoinvent	/

4. Results

The environmental profiles based on the ISO LCA are presented as a basis.
Figure 6 presents the environmental profile for **newspaper** from cradle to grave (expressed per functional unit). This environmental profile shows the contribution of the various steps in the life cycle, per environmental impact category. For each category, the total contribution is always set at 100% and the relative contributions of the various life cycle phases are visible. For those phases that result in an environmental credit (due to avoided material production in case of recycling or avoided energy production in case of incineration with energy recovery), this credit is presented as a negative impact in proportion to the total environmental impact.

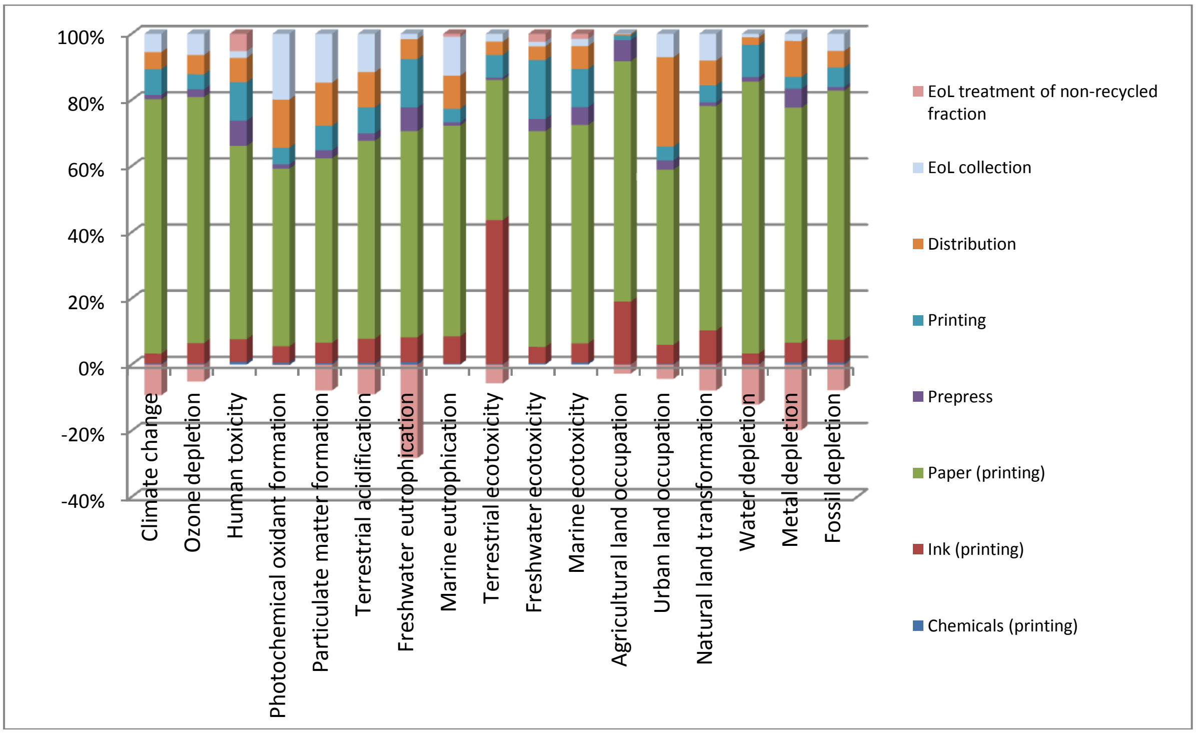

Figure 6: Environmental profile of 1 m² of newspaper printed in coldset from cradle to grave

The production of the paper is responsible for the major contribution to nearly all impact categories (between 40-80%). The other life cycle phases (production of ink, printing, distribution and EoL collection) have much lower contributions, with large variations depending on the impact category. Production of ink causes a significant impact to terrestrial ecotoxicity and to a lesser extent to agricultural land occupation. The contribution of the printing process is more important for freshwater eutrophication and freshwater ecotoxicity compared to the other impact categories. Transport-related phases (distribution and EoL collection) contribute significantly to photochemical oxidant formation, particulate matter formation, terrestrial acidification and urban land occupation. For most impact categories, the contribution of prepress and production of chemicals is negligible. The EoL treatment of newspapers scores for most impact categories a negative environmental impact (i.e. credit) due to the energy recovery during the incineration of the newspapers.

Figure 7 presents the normalized environmental profile for 1 m² newspaper from cradle to grave. In this context, normalization entails comparing the environmental profile of the newspaper to the annual contribution made by an average European to the various concerned environmental impact categories (reference year 2000). In concrete terms, this calculates the relationship between the environmental impact of 1m² newspaper from cradle-to-grave and the annual impact of an average European. For the following environmental impact categories the contribution caused by 1m² newspaper from cradle-to-grave is relevant compared to the contribution made by economic activity in Europe:

- Natural land transformation;
- Marine ecotoxicity;
- Freshwater eutrophication;
- Freshwater ecotoxicity;
- Human toxicity;
- Fossil depletion;
- Climate change.

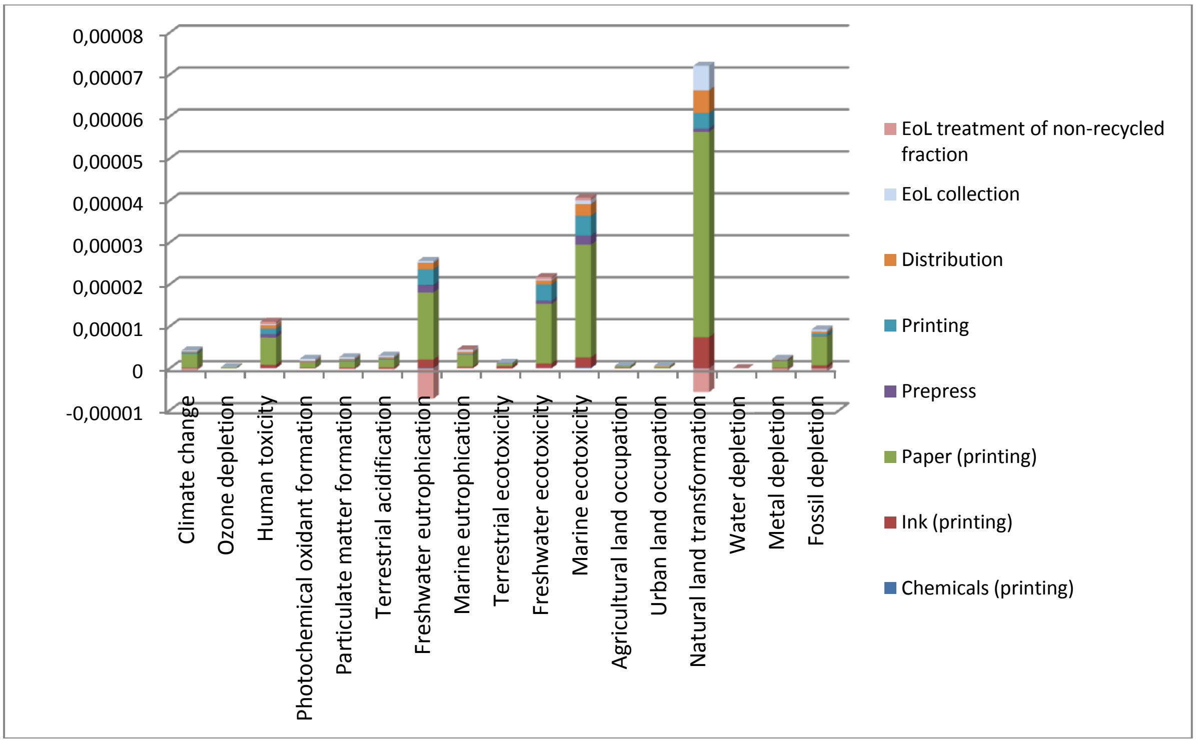

Figure 7: Normalized environmental profile of 1 m² newspaper printed in coldset (from cradle to grave)

Figure 8 presents the environmental profile of 1m² **periodical**. The environmental profile is dominated by the production of the paper (contribution between 80 and 99,5%). The contribution of the other life cycle phases (production of ink, printing, distribution and EoL collection) is much lower and nearly insignificant. Production of ink contributes mainly to terrestrial ecotoxicity and to a lesser extent to ozone layer depletion. The contribution of the printing process is rather low, and only significant for climate change, ozone layer depletion and fossil depletion. The contribution of the other phases is not significant. The EoL treatment of newspapers scores for most impact categories a negative environmental impact (i.e. credit) due to the energy recovery during the incineration of the newspapers.

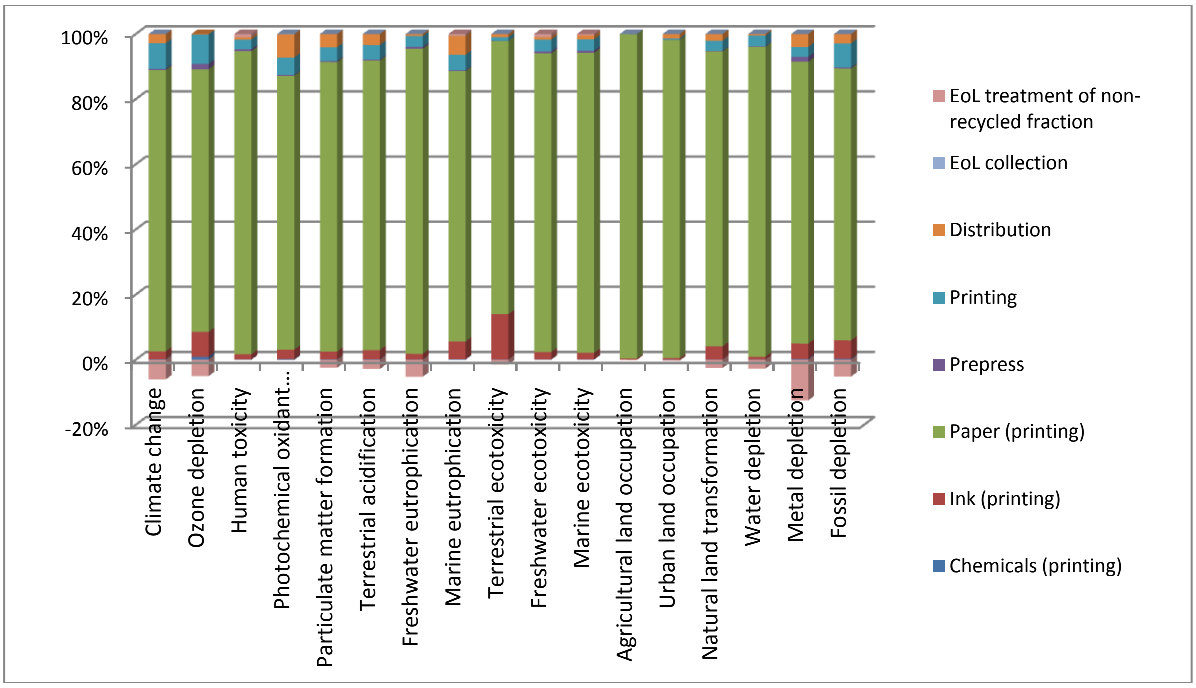

Figure 8: Environmental profile of 1 m² periodical printed in heatset (cradle to grave)

As for newspaper the environmental profile of the periodical is normalized to the annual contribution made by an average European (reference year 2000). Figure 9 presents the normalized environmental profile for 1 m² periodical from cradle to grave. For the following environmental impact categories the contribution caused by 1m² periodical from cradle-to-grave is relevant compared to the contribution made by economic activity in Europe:

- Natural land transformation;
- Marine ecotoxicity;
- Freshwater eutrophication;
- Freshwater ecotoxicity;
- Human toxicity;
- Fossil depletion.

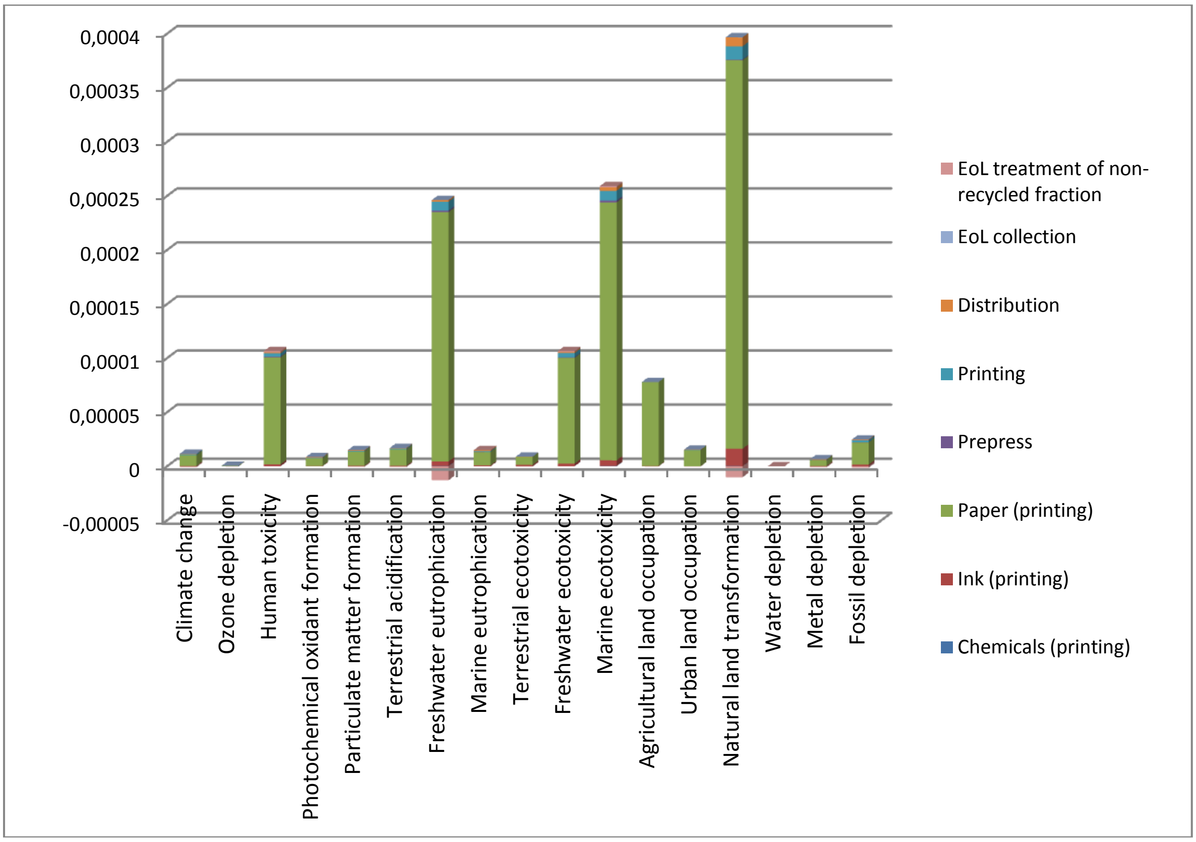

Figure 9: Normalized environmental profile for 1 m² periodical printed in heatset (cradle to grave)

A **comparison** between the environmental profile of a newspaper and a periodical was not the objective of this study. However comparing the environmental impacts of both paper products leads to additional insights in the causes of the different environmental impacts and the share of the different life cycle phases in the total. The comparative environmental profile is presented in Figure 10. Per impact category the product with the highest total contribution is set at 100%, the impact of the other product is presented relative to this.

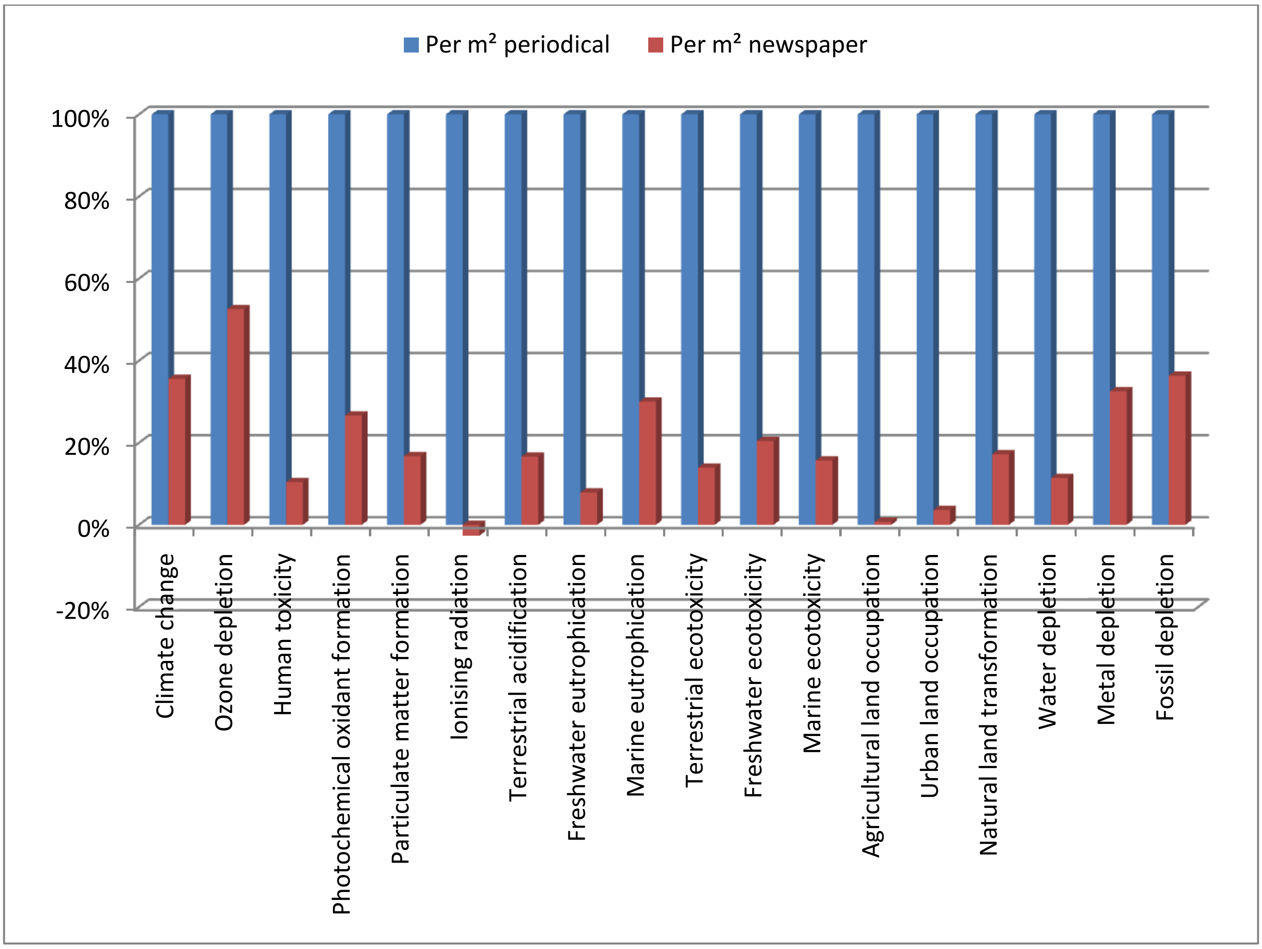

Figure 10: Comparison of the environmental impact of newspaper and periodical (from cradle to grave)

It is important to bear in mind that the environmental profile compares 1m² of newspaper with 1m² of periodical, and not one newspaper with one periodical. The comparison shows clearly that 1m² newspaper from cradle to grave has a significantly lower impact than 1m² of periodical from cradle to grave, and this accounts for all environmental impacts. The difference is mainly due to the larger impact of 2 life cycle phases:

- paper production: which is for newspaper 100% recycled and for periodical almost 100% virgin paper. But more important, per m² of newspaper less paper is needed (45g versus 80g);
- printing: newspapers are printed with coldset, which requires much less energy than heatset that is used to print periodicals.

The **combined input-output life cycle assessment** leads to the environmental profiles as presented below.

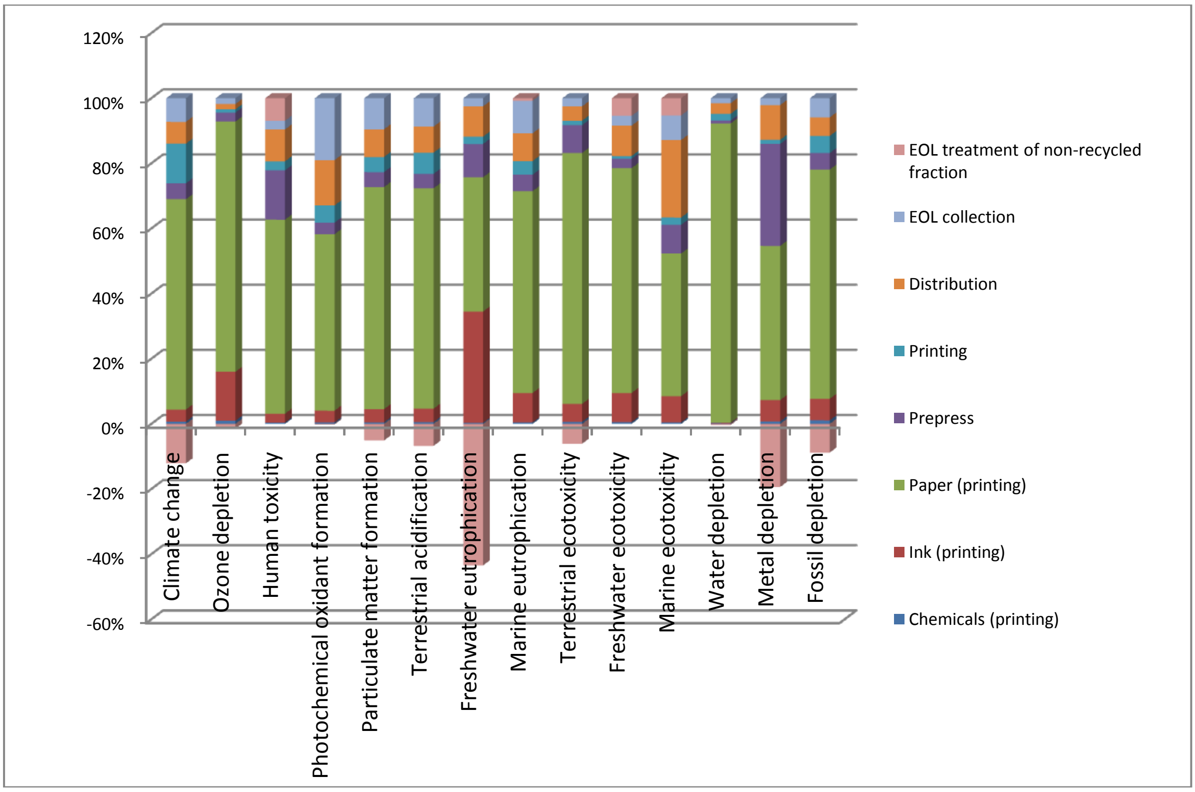

Figure 11: Environmental profile of 1 m² of newspaper calculated in the combined IO-LCA

As for the contribution of the different life cycle phases, the environmental profile shows more or less the same results as the ISO conform profile. A normalized profile is made as well to show the most important impact categories.

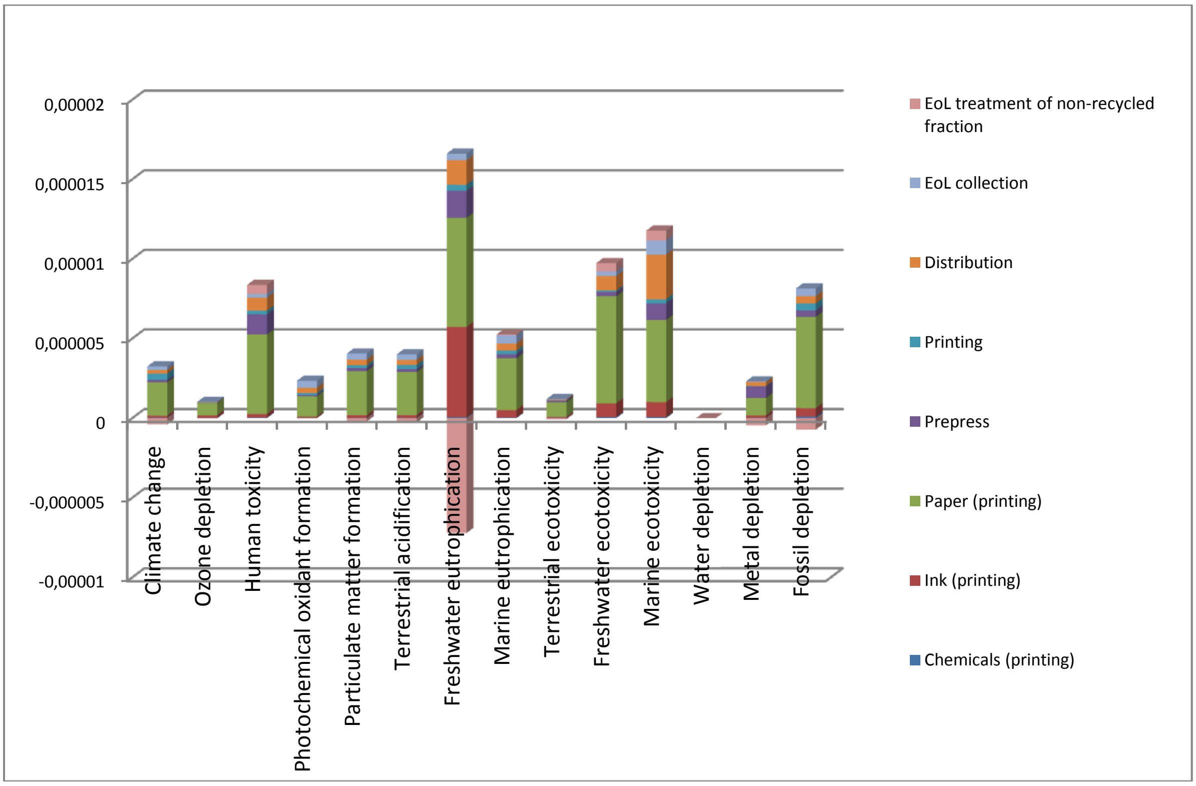

Figure 12: Normalized environmental profile of 1 m² of newspaper as calculated with the combined IO-LCA

The normalization shows the following environmental impact categories to be the most relevant:

- Freshwater eutrophication;
- Marine ecotoxicity;
- Freshwater ecotoxicity;
- Human toxicity;
- Fossil depletion.

Climate change is only the 9^{th} most important category.

It is clear that the general picture (most significant life cycle phases, most significant environmental impact categories, …) remains more or less the same, whether using ISO conform LCA or combined IO-LCA. The same can be said for the results for a periodical.

To see the difference in absolute value between the results of the ISO conform LCA and the hybrid, IO-based LCA, each of the impact categories is compared in absolute values.

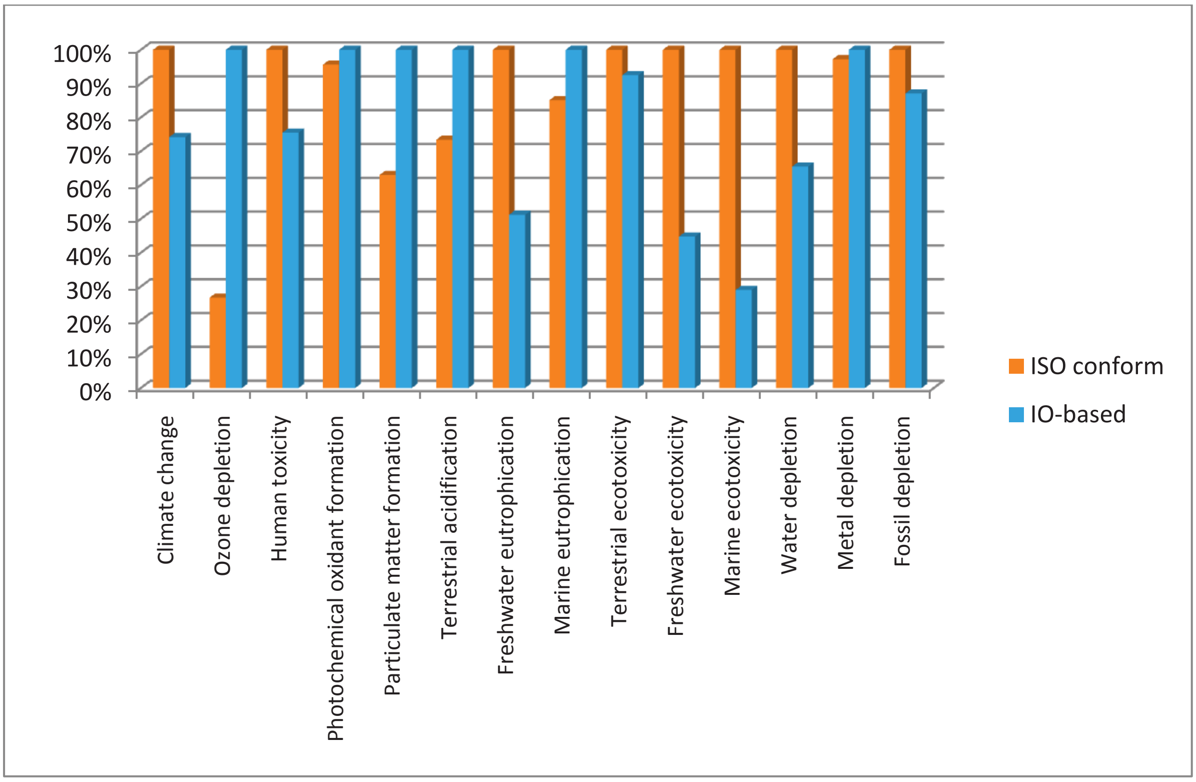

Figure 13: Comparison between the environmental profile of 1 m² of newspaper calculated in the ISO conform LCA versus the combined IO-LCA

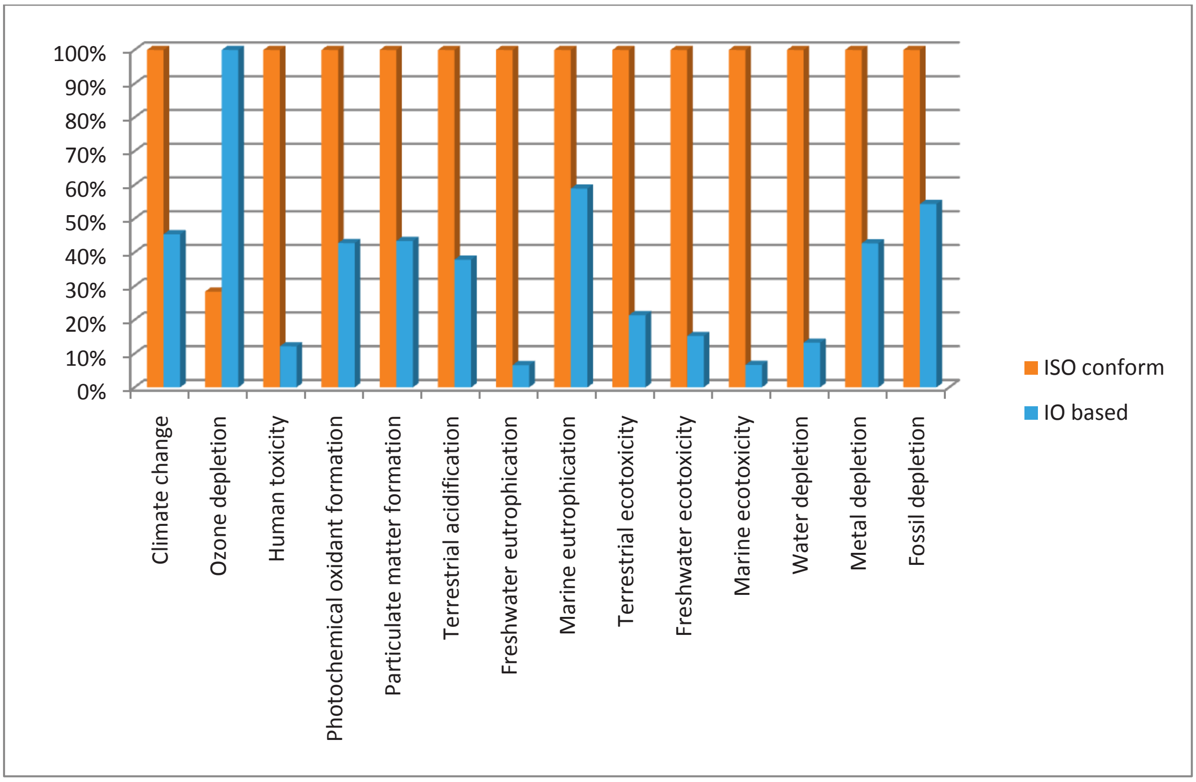

Figure 14: Comparison between the environmental profile of a periodical as calculated with the ISO conform LCA versus the combined IO-LCA

When comparing the results of the IO-based LCA and the ISO conform LCA, it is clear that the absolute values differ significantly for most impact categories and this for newspapers as well as periodicals. The relative importance (contribution) of the different life cycle phases remains mostly the same and at least identifies the production of paper as the most important phase.

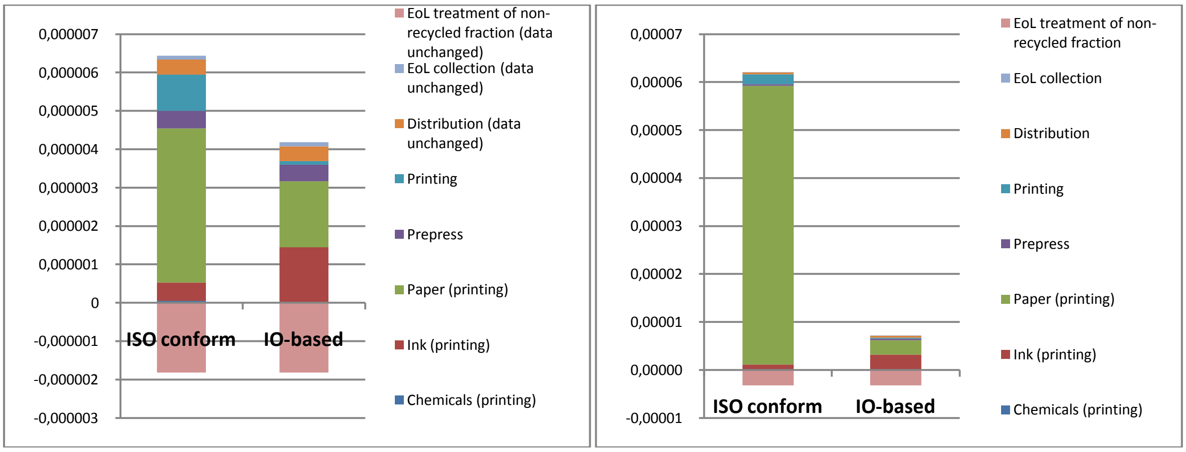

Figure 15: Comparison for freshwater eutrophication (kg P-equivalents) calculated in both methods, for newspaper (left) and periodical (right)

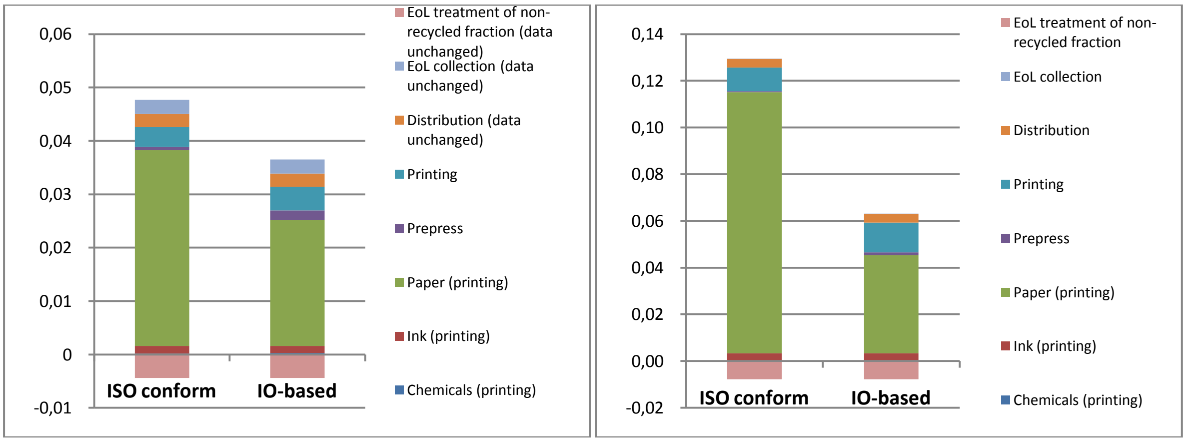

Figure 16: Comparison for climate change (kg CO_2-equivalents) calculated in both methods, for newspaper (left) and periodical (right)

Both for newspapers and periodicals, the impact of the printing phase is of less importance in the IO-based results, with the exception of climate change. Then again, the impact caused by prepress is often more important in the IO-based results compared to the ISO conform LCA. The explanation for this kind of differences is most likely to be found in the data behind these processes. For printing, the specific information reported by Corelio was maintained, but coupled to data from the EcoInvent database in the ISO conform LCA and to data from the Flemish input-output model in the hybrid IO-based LCA. A big difference between these data is *the number and kind of pollutants* which are included. Another issue is that, in IO-based LCA, one works with *generic, sector average values* which of course eliminate all the detailed impacts related to, e.g. the type of paper or waste treatment. This is what causes a major difference when looking at the calculated profiles for periodicals with both LCA methods. The paper used in the production of a periodical has a higher environmental burden than that used for the production of a newspaper (see Annex A). From the results of the IO-based LCA it seems that the (average) environmental data for the paper producing sector are more representative for the newspaper case than for the periodicals. Through the use of such generic data from IO, the correctness of the results can be severely influenced as can be seen from the results in this study, especially for a periodical.

5. Conclusions

To **conclude**, it stands to reason that the paper production is responsible for a large share of the environmental impact since paper is the main raw material and substrate of the printed matter and represents most of the weight of the final product.
The use of purchased energy plays an important role in the environmental impact of both printed matter products (for nearly all environmental impact categories). This is reflected in all LCIA and carbon footprint results and related to both printed matter products.

Normalization of both environmental profiles shows that climate change is not the most relevant environmental impact when it concerns printed matter products. In this regard it is also important to mention that toxicity and ecotoxicity assessment in the LCIA framework is still under development. At this moment major uncertainties are related to the LCIA-methods with regard to (eco)toxicity. Leaving out the (eco)toxicity impacts, eutrophication, fossil depletion and climate change are of most relevance.

Both LCA and combined IO-LCA cover all life cycle phases. LCA is a bottom-up methodology that provides much more detail than the IO based LCA. Combined IO-LCA provides less detail (depending on the number of sectors/product groups where data is available) but can be less time consuming. The end-of-life phase is elaborated more in the ISO conform LCA where the end-of-life phase is currently more limited in IO due to availability of economic data. This is no methodological issue but one of data availability.
LCA and combined IO-LCA can be used with the same environmental categories.
For the IO-based LCA, environmental categories such as agricultural land occupation, urban land occupation and natural land transformation can not be calculated, since land use is not included as such in the environmental data in the Flemish input-output model. Other environmental categories as calculated in the Recipe-method are possible, but results will be largely influenced by the number and type of pollutants included in the model and their translation into the impact categories.
LCA follows a bottom-up approach and is therefore very specific for any product category or material. In IO-based LCA, the data used are averages for all product categories and materials that are produced by a certain sector. This is why certain differences related to the specific characteristics of products or materials are no longer visible. Of course, the sectoral split up in the model is another very important factor for the applicability of the IO-model: if the sectors in the model can not represent the different life cycle phases, the use of data from the model will only create a larger error. For this case, with the impacts of a printed product, the economic sectors present in the life cycle are well described in the model which allows application of the data in an IO-based LCA.
In this pilot study LCA data are available on several qualities of paper used for newspaper and periodicals, which differ widely. In the IO-based LCA the paper sector is one sector only, having an average performance that applies for all kinds of paper. This leads to the recommendation that whenever more detailed LCA data are available it is better to use those and to use IO-data for completion of data gaps or for orientation by detecting main significantly contributing sectors. Data collection efforts should focus on those contributions.

It is fair to conclude that the hot spot identification for printed matter is more or less independent of the methodology or the environmental impact categories included. The inclusion of different environmental impact categories though, leads to more transparent, balanced and detailed results. Experience with other projects learns that this depends largely on the type of product. Results and conclusions often differ a lot when a full LCA is performed versus a carbon footprint analysis.