Application of Life Cycle Assessment in the Zimbabwean Pulp and Paper industry

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Abstract
This paper discusses the Life Cycle Assessment of newsprint paper in Zimbabwe. The product system used for the study covers the production of raw materials, the pre- combustion effects of coal and of electricity production. The data from the production of newsprint at Mutare Board and Paper Mills, the largest paper mill in Zimbabwe, is used. Original inventory data was acquired from the company primary documents. Main emissions to air are a result of the burning of fossil fuel for the production of steam at the pulp mills and also during the production of electricity. The results of the LCI are used for mid-point impact assessment using SIMAPRO software.

Keywords
Energy, LCA, environment, pulp and paper

1. INTRODUCTION

The Zimbabwean pulp and paper industry is one of the most important economic activities in Zimbabwe and it is also adopting the concept of sustainable development. This is shown by several improvements and investments that have been undertaken by the pulp and paper industry in order to improve its environmental performance. The concept of sustainable development involves LCA of products, efficient resource utilization, energy conservation, limitation of wastes from households and industries. The pulp and paper industry is also seeking to embrace the benefits that come with sustainable development by striking a balance between economic, social and environmental aspects of development. The main purpose of carrying out the study was the identification and assessment of the environmental impacts that are a result of the production of newsprint in Zimbabwe. The objectives are:

- Identifying the most efficient and cost effective options for increasing the environmental performance of the production of writing and printing paper in Zimbabwe.
- Assessing the pulp and paper processes in order to identify opportunities for efficiency improvements, such as waste treatment fewer raw material use and energy saving.

Promoting green design and manufacturing in the Zimbabwean pulp and paper industry. This study found out that the pulp and paper industry in Zimbabwe is making some effort to optimise the use of energy in order to reduce their operating costs and also to reduce the amount consumed in line with protecting the environment. Coal and electricity are the main sources of energy in the Zimbabwean pulp and paper industry resulting in negative environmental impacts. The industry is also improving its environmental performance through improved waste treatment systems. Life Cycle Assessment (LCA) is thus an appropriate method to get a global overview of the pulp and paper industry in Zimbabwe and therefore be able to identify opportunities for raw material and energy optimisation as well as improving the efficiency of waste treatments systems. The LCA methodology was applied to the production of newsprint in Zimbabwe and this paper presents the major findings.

2. METHODOLOGY

The study was performed using the international organization for standardisation (ISO)'s four main standards on life cycle assessment, namely. ISO 14040, 1997- Principles and framework, ISO 14041, 1998 Goal and scope definition and inventory analysis, ISO 14042, 2000- Life cycle impact assessment and ISO 14043, 2000, Life cycle interpretation. The goal refers to the intended application and audience and the reasons for conducting the study, specifically stating the purpose of the study. Scope: the scope definition caters for the following items; description of the system, the functional unit, system boundaries, impact assessment methodologies, data quality requirements and assumptions [2]. The goal and scope definition determines the course of the study.

The product used for the study is newsprint paper that is produced in Zimbabwe. The newsprint is produced in the Eastern Highlands where the temperate climate is ideal for the growing of exotic pine trees that provide the basic raw materials for the paper- making. The system studied produces newsprint paper through mechanical pulping of virgin pinewood. The pulp produced is mixed with imported chemical pulp. The system boundary included the extraction of fossil fuels, production of electricity, transportation, pulping and paper-making. The system boundary excluded the maintenance of goods and machinery, chemical production, and the paper utilisation phase. The process flow diagram for the production of newsprint in Zimbabwe is shown in Fig 1. The functional unit for this study is 53gsm newsprint paper produced in Zimbabwe from the pulping of pinewood. The impact categories that were considered in the study are: acidification, eutrophication, ecotoxicity, human toxicity, global warming using the IPCC global warming potentials for 100 years, non-renewable resource depletion and ozone depletion. All these impact categories were assessed using the Eco-indicator 99 (H), Version 2.03 of the SimaPro software version 7.0. Non-renewable resource depletion (NRRD) was determined using the Cumulative Energy Demand, Version 1.03 of the SimaPro software.

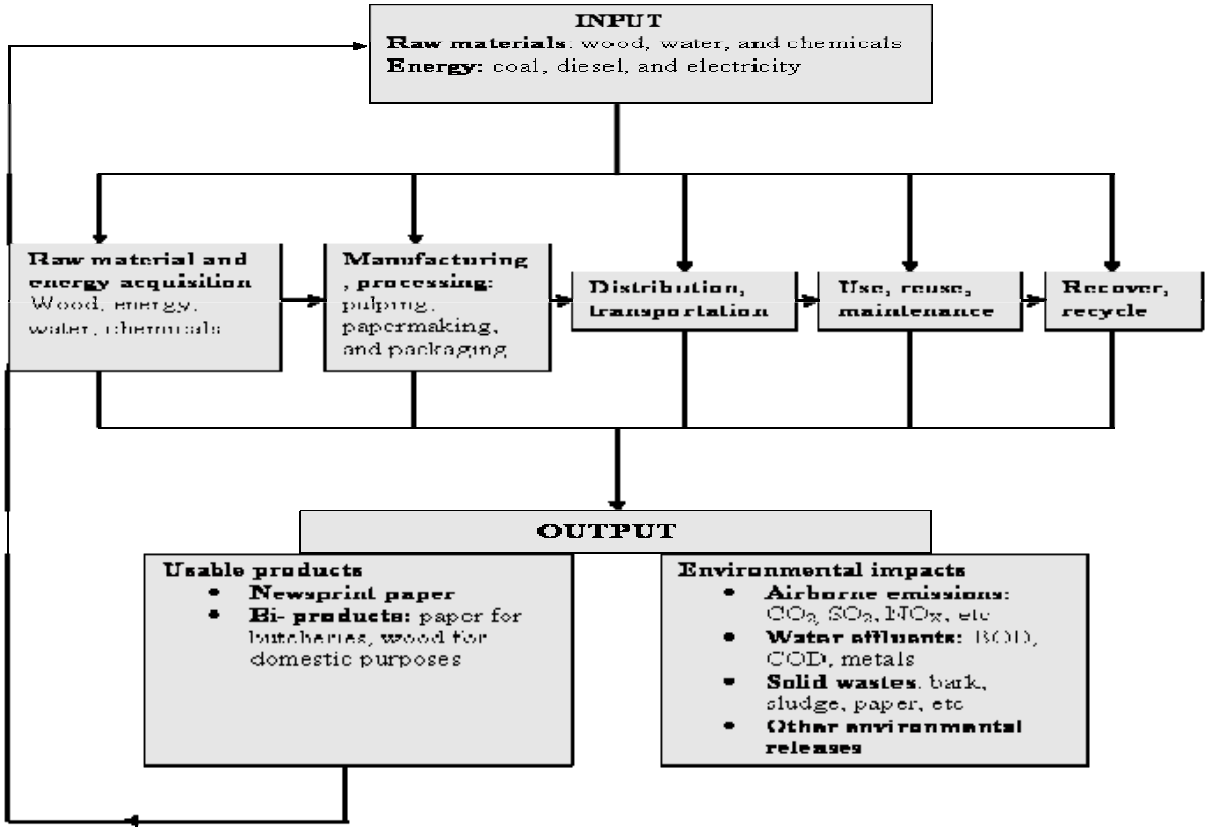

Fig 1 Process flow diagram

Inventory analysis involved data collection and calculation procedures to quantify relevant inputs and outputs of product system (Use of resources and emissions to air). Allocation procedures were used to deal with the system [4]. Calculation of energy flows included the different fuels and electricity sources used, the efficiency of conversion and distribution of energy flow as well as the inputs associated with the generation and use of that energy flow [5]. Inventory data collection was done for the processes that are relevant to the chosen LCA boundary. This data was made available by the pulp and paper industry in Zimbabwe. Some of the data was collected through the use of questionnaires, from literature and from databases. The system starts with pine tree production, which mainly involves forest installation, forest growth and wood harvesting. Only data for wood harvesting was included in this study. Wood harvesting involves felling, cutting and truck loading. Data was collected for the transportation of the pinewood to the pulp mills. Transportation of raw materials such as coal was also considered in the study.

Energy use data was also collected. The pulp and paper industry in Zimbabwe purchases electricity from the national grid and data was collected for the production of electricity from coal, which is the main fossil fuel, used for the production of electricity in Zimbabwe. The pre-combustion effects of the fuels used in the other paper life cycle stages were explored. The main fuel used is coal. Data was collected from the relevant bodies that are involved in fuel production. Mechanical pulp is produced from the pinewood. The data on the production of pulp was acquired from the pulp mills in Zimbabwe. In some instances assumptions and estimates were made here data was not readily available. The data also included the energy that is consumed in terms of both coal and electricity. The coal is used for the production of process steam.

The impact assessment phase of an LCA was aimed at evaluating the significance of potential environmental impacts using the results of the life cycle inventory analysis. Impact assessment also involves the assigning of inventory results to different impact categories [6]. This is known as characterization. The total potential contribution from all inputs and outputs to the different impact categories is calculated using weighting factors. The fourth stage involved the evaluation of opportunities for energy, materials inputs or environmental impacts along the life cycle. In this paper, the inventory analysis and impact assessment results in the Zimbabwean pulp and paper industry are discussed. Conclusions and recommendations that are in line with the objectives of the LCA were then made [5].

3. RESULTS

A first interpretation of the results at the inventory level can be done based on individual parameters [1]. The following parameters discussed from an environmental point of view are analysed: non-renewable and renewable energy consumption, carbon dioxide ($C0_2$), sulphur dioxide (SO_2), nitrogen oxides (NO_X), and chemical oxygen demand (COD). The carbon dioxide originated from non-renewable fuels was considered because it is assumed that the

carbon dioxide produced from renewable sources is balanced by carbon dioxide in the forest. In the figures and results, pulp and paper mills refer to the production of pulp and paper at the pulp mills, Hwange colliery coal represents the extraction of coal in Zimbabwe, ZESA power represents production of electricity according to Zimbabwean conditions, Cellulose sulphate BCC represents production of imported chemical pulp and Truck 28t B250 represents the transportation systems in the life cycle.

4.1 Energy consumption

The pulping processes and the paper making process at the mills are the most important consumer of non-renewable energy in the form of coal. This is followed by the production of electricity that is used in the production of the paper. The production of chemical pulp also consumes a significant amount of energy even though this is not derived Zimbabwe because the chemical pulp is imported. Transportation also accounts for a significant amount energy consumed in the life cycle

4.2 Water emissions

The pulping processes at the pulp mill are the most important contributor as far as the chemical oxygen demand is concerned. The generation of electricity and the extraction of coal are also significant contributors to the emissions to water systems.

4.3 Air emissions

The major source of carbon dioxide is onsite energy use at the pulp mills where pulping and papermaking is carried out. Transportation generates most of the NO_X during the transportation of wood from the forest to the pulp mill and also transportation of coal to the pulp and paper mills. Wood harvesting is also an important contributor to air emissions and the pulp mill also contributes significantly to air emissions. Sulphur dioxide is mainly produced during production processes at the pulp mills. The production of the electricity that is used at the mills is also an important contributor to air emissions.

4.4 Global warming

The results presented in Figure 2 show that the pulping and paper making process has about 72% contribution to the global warming potentials for 100 years. The extraction of coal accounts for close to 10% contribution to this impact category. Transportation and generation of electricity from coal have almost equal contributions of about 5% each to global warming.

4.5 Acidification

In the present scenario the production of pulp and the paper making at the factory is the greatest contributor to acidification with a contribution of about 42% and this is mainly a result of the sulphur dioxide that is emitted into the atmosphere during the combustion of coal for steam production. Transportation is the second in contribution at about 35%, due to the release of NO_X from transportation of wood and coal to the pulp mills. The production of chemical pulp at 22% is also an important contributor, but this pulp is imported. The different contribution levels are shown in Figure 3. The extraction of coal has a very low contribution to this impact category at about 2 %.

4.6 Human toxicity

The main contributors to this impact category are carcinogens that cause cancer, respiratory organic and respiratory inorganic substances. The production of the pulp and the paper at the pulp mills account for more than 50% contribution to this impact category. Pulp and paper mills production has a significant contribution to all the three components of this impact category that is carcinogens, respiratory in-organics and respiratory organics. Transportation is also an important contributor to due to the emission of gases such as carbon monoxide as a result of incomplete combustion.

4.7 Eutrophication

The largest contribution to eutrophication is from the pulp and paper mill as shown in Figure 3. This has a contribution of 42 % followed by transportation, which accounts for about 35% contribution. The reason for such a scenario is mainly due to the release of nitrates into the water from the mechanical pulping that takes place at the pulp mills.

4.8 Climate change

Climate change is another impact category that is mainly a result of the emissions from the pulp and paper mills. The pulp mills contribute more than 70% to this impact category. Extraction of coal (Hwange colliery coal) is the second largest contributor with close to 10% contribution. Transportation and the production of electricity have very little contribution to this parameter. This is clearly shown in the graph for characterization and damage assessment in Figure 3.

4.9 Ozone depletion

This impact category is mainly a result of transportation because it is the process that produces much of carbon monoxide that is responsible for depleting the ozone. Transportation accounts for approximately 50% contribution to this impact category. The chemical pulp, that is imported and mixed with mechanical pulp for the manufacture of newsprint is the second largest contributor after transportation. Chemical pulp contributes about 23% to this impact category. The production of electricity has a very low contribution, see Figure 3.

4.10 Ecotoxicity

The pulping and paper making processes (pulp and paper mills) are responsible for contributing much to the toxicity of the ecosystem. This is mainly due to the chemicals that are used during the production of pulp and these include defoamers, biocides and dyes. This stage accounts for slightly above 65% contribution to this impact category. Chemical pulp also contributes significantly to this impact category followed by transportation, which has a relatively low contribution to this impact category about 7%.

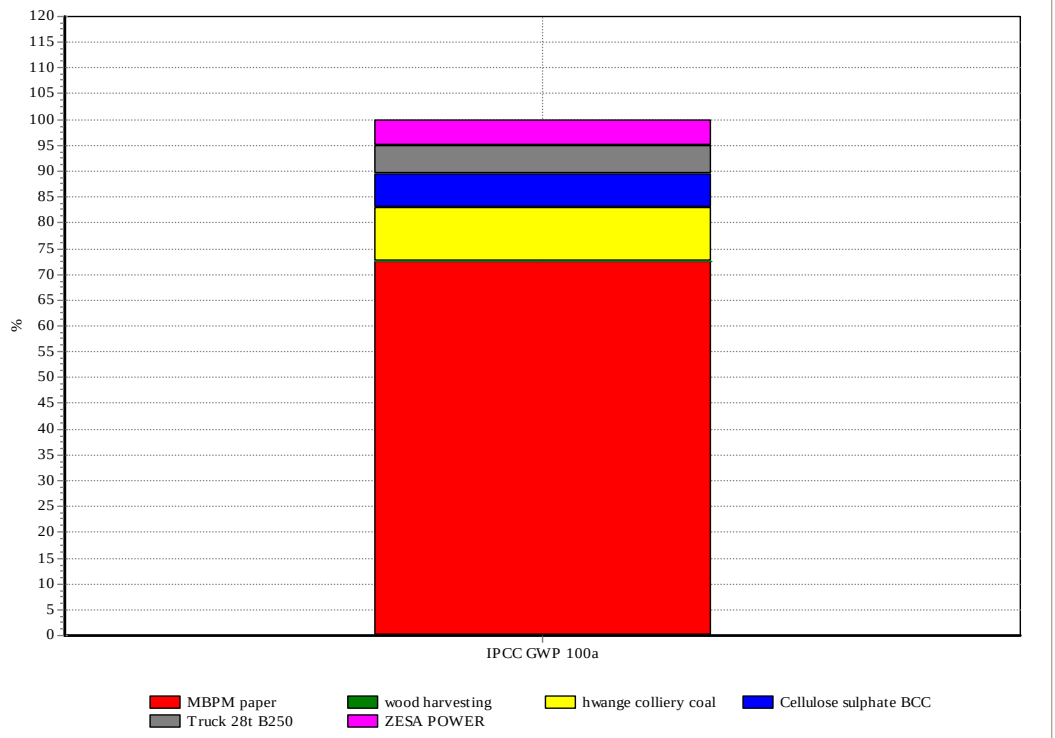

Fig 2 IPCC global warming potentials for 100 years

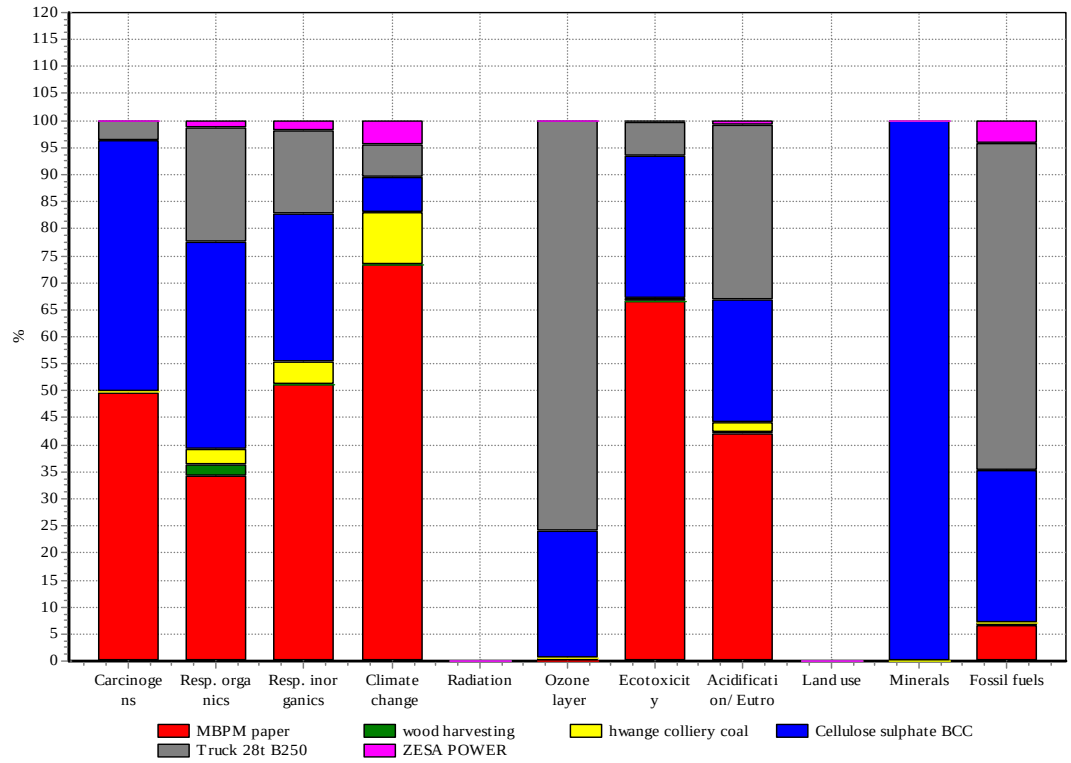

Fig 3 Results of characterisation and damage assessment

4.11 Cumulative energy demand

The pulp and paper processes, as shown in Figure 4, are responsible for the highest consumption of non-renewable fossil energy at about 35%. The production of electricity is also a significant consumer of non-renewable fossil energy and this is due to the coal that is used for the production of 70% of the electricity in Zimbabwe. This has a 22% contribution to this impact category. Non-renewable nuclear is only attributable to chemical pulp (cellulose sulphate BCC) because it is imported and it is produced in those countries where nuclear energy is in use. As for renewable energy from water the greatest contributor is chemical pulp and the pulping and paper making processes also have a significant contribution of close to 15%. The production of electricity (ZESA power) also has a relatively low contribution to this impact category

5. Conclusion

The following conclusions can be drawn based on the inventory and impact assessment results.

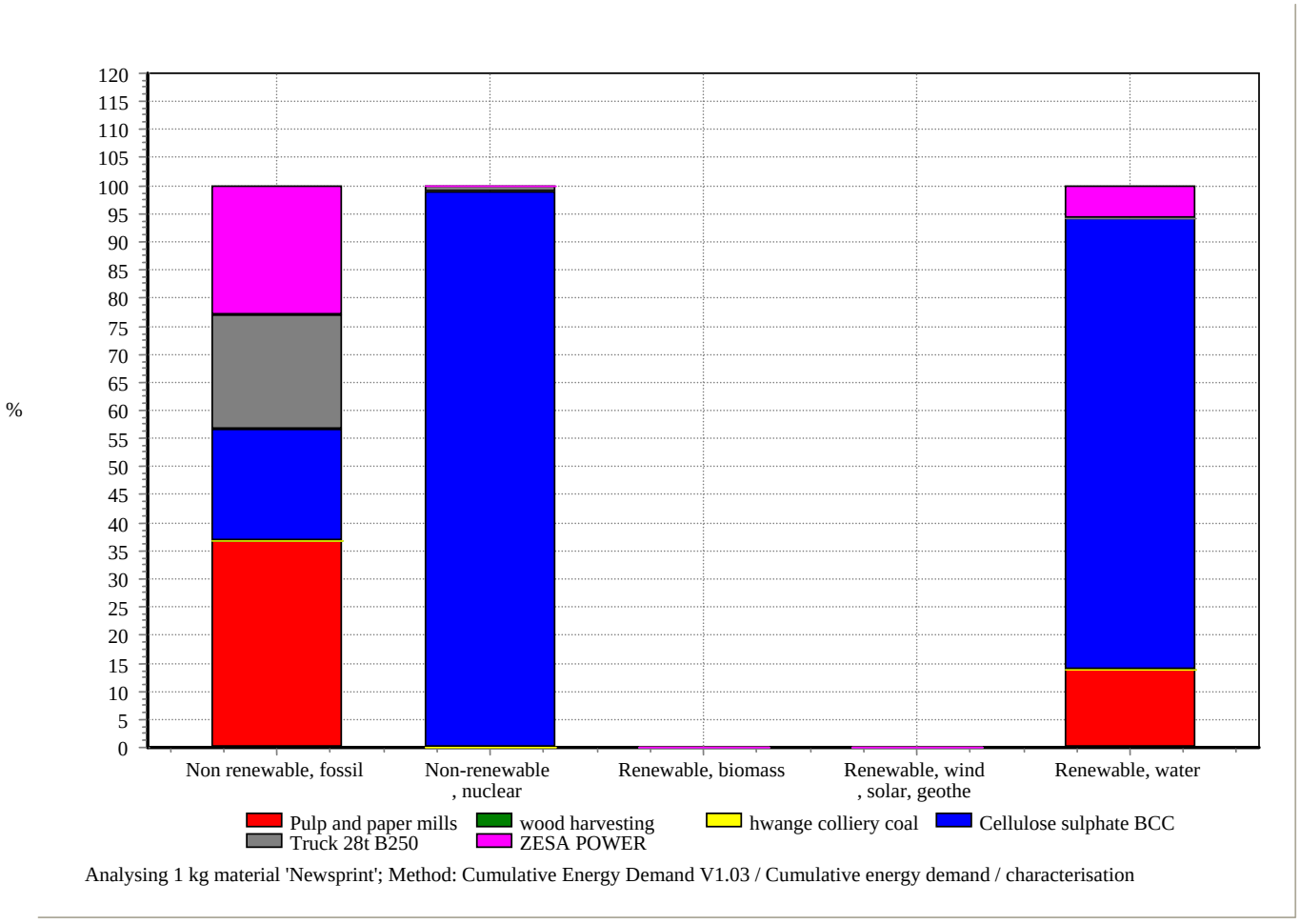

Fig 4 Results for cumulative energy demand

- The pulping processes assume a predominant role in global warming impact category as a result of carbon dioxide emissions.
- Transportation is the main contributor to the eutrophication and contributes significantly to the acidification impact categories.
- The contribution of the disposal stage of the life cycle of the paper to environmental impacts needs to be explored. In this case it was not included mainly due to

- The greatest contributor to carbon dioxide emission is the pulping and paper making processes due to the combustion of coal in the boilers. This results in a major contribution to the overall global warming potential. The pulping and papermaking are also the most significant contributors to the acidification impact category. It is also the main consumer of non-renewable energy and, as result; it is responsible for the most important share of the global system potential concerning non-renewable resource depletion.
- The pulping processes assume a predominant role in global warming impact category as a result of carbon dioxide emissions.

lack of data to describe the disposal processes.

These results reflect the data that was used based on the operations in Zimbabwe. Life cycle assessments done elsewhere might have similar results, but the percentage contribution to each impact category would differ, depending on the type of energy used, the electricity mix, the sources of raw materials and the type of technology used in the pulp and paper industry in a target country of study. However this work presents findings from an African perspective and demonstrates the use of SIMAPRO software and Eco-indicator 99 in life cycle assessment.

6. ACKNOWLEGDEMENTS

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