



UNIVERSITY OF THE  
WITWATERSRAND,  
JOHANNESBURG

## **Life Cycle Assessment of Coated White-Lined Chipboard**

*Prepared by*

**Edwin Ephraim Botha**

**(1600069)**

*Submitted to*

School of Chemical and Metallurgical Engineering, Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg, in fulfilment of the requirements for the degree of Master of Science in Engineering

**Supervisor: Kevin Harding**

03/02/2023

## DECLARATION

I declare that this dissertation is my own, unaided work. It is being submitted for the Degree of Master of Science at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.

A handwritten signature in black ink, consisting of stylized, overlapping loops and a final dot.

---

(Signature of candidate)

\_\_\_\_03\_\_\_\_day of \_\_\_\_\_February\_\_\_\_2023

## Executive Summary

South Africa is working towards creating a more sustainable and circular economy. As part of this goal, South Africa released the extended producer's responsibility to improve the effective management of products in the final waste streams by reducing the number of raw materials used in the product, minimizing waste and reducing the toxicity of the product in the final waste stream. This legislation applies to industries that produce products such as paper, plastic, biodegradable and compostable materials, glass, metal, and single-use packaging. According to the EPR legislation, white-lined chipboard (WLC) is considered a kraft/corrugated case product and is part of the paper and paper packaging class. The South African EPR requires an LCA for the products, however, South Africa does not have datasets for the pulp and paper industry that can be used to conduct the LCA. As a result, local LCAs have been conducted using international data. The results generated from these do not represent South Africa, its processes, infrastructure or its technologies and can therefore misinform industries, shareholders or management of the true impact of a process.

The objective of this work was to perform a cradle-to-gate LCA on WLC manufacturing in which the process of forestry, pulping, recycling and manufacturing was included. Data from local industries were used to conduct the LCA, thereby using data that only represent South Africa and eliminating the use of international data as much as possible. As part of the objective to create the South African LCA and South African datasets, process improvements, comparisons between international data and local data, and comparisons of life cycle impact methods were studied as well.

The life cycle assessment included a cradle-to-gate approach in which the environmental impact to produce a "1 kg coated white-lined chipboard" was studied. The LCA was conducted using SimaPro v9.3.0.3 simulation software and the impacts were determined using the ReCiPe 2016 v1.1 (H) impact method. The LCA included forestry and forestry operations, recycling, pulping and bleaching of virgin eucalyptus wood fibre, and WLC manufacturing. The LCA did not include the converting, use, or end-of-life phase. Data was collected from local industries, and most of the data was comprised of primary data, however, due to some data gaps, mass balances, energy balances and secondary data were used to calculate the missing values. The data collected was compiled into inventory lists for forestry, pulping and WLC manufacturing.

The environmental impact assessment of WLC production was conducted considering the following impact categories: global warming, freshwater ecotoxicity, terrestrial acidification, freshwater eutrophication, ozone formation and ozone depletion. The results indicated that the mill's use of electricity and energy (steam production) were the major contributors in all impact categories. The results indicated that it was because of South Africa's and the mill's reliance on fossil fuels, particularly coal, to produce electricity and energy.

A comparative LCA was conducted in which the South African WLC data was compared to a European dataset and a South African – European hybrid dataset. Due to South Africa's reliance on coal for most of its electricity and energy requirements, the South African datasets had a much higher impact in all the impact categories compared to the European dataset. The comparison to the hybrid dataset indicated that the hybrid dataset had a more accurate representation of the South African process. However, there was still variability in the results. It was expected that the environmental scores from the hybrid data analysis would be in between the South African and European scores, and for 4 out of the 6 categories it was. The comparisons favoured the use of South African data as it was more accurate and representative of the South African process and therefore more reliable, but the use of hybrid data could be beneficial if a quick LCA study needs to be conducted to obtain a general idea of the impact of a process or product comparison.

The uncertainty test was conducted using the Monte Carlo analysis with a 1000-interval run and a 95 % confidence interval. The uncertainty test conducted indicated that the use of different models could significantly change the outcome of the impact scores. Three factors could affect the outcome of the impact assessment, namely the uncertainty of the data in the inventory list, the inventory list of the impact methods and the characterisation factors used by the impact methods. To ensure that the uncertainty from the Monte Carlo analysis was because of the data in the inventory and not because of the impact method. The Monte Carlo analysis was conducted for three methods, the ReCiPe 2016, EF 3.0 and the TRACI 2.0 method. The error for global warming, acidification and ozone formation was small for all three impact categories, indicating that the uncertainty for the data was little. The error for freshwater ecotoxicity and ozone depletion was large for ReCiPe 2016, but small for EF 3.0 and TRACI 2.0, indicating that the uncertainty came from the ReCiPe method and not the data. Lastly, for freshwater eutrophication, the error for all three methods was large,

indicating that the uncertainty came from the data used and therefore the data was less reliable.

As part of the LCA, possible process improvements were studied using comparative LCA. The first alternative studied was the use of alternative fuel sources for the boiler process. From the use of natural gas, coal and biomass it was found that both natural gas and biomass had an overall reduction in environmental impacts for all impact categories. Of the three fuels, biomass was the best alternative for global warming, but other than global warming, the environmental impact of both biomass and natural gas were similar. Although both options were more environmentally sustainable, limitations such as the capital required for boiler conversion/replacement, increased transport and transport costs (biomass), biomass availability, fluctuating currencies (imported natural gas) and the need to reduce fossil fuel reliance (natural gas), both alternatives could not yet be fully implemented.

Replacing electricity can only be achieved by considering alternative renewable electricity sources such as photovoltaic solar power (PV) and concentrated solar power (CSP). Of the two, PV solar power is the most accessible since it uses unusable space (rooftop) and is produced and installed by local companies. Sufficient roof space is available at the mill to substitute 11.6 % of the mill's electricity with PV solar electricity. The installation and purchasing of the panels would cost around ZAR 121 million (excluding storage systems). Based on the municipal electricity cost savings, the capital could be recovered in about 5 years. Running the comparative LCA with the PV solar system included, five of the six impact categories experienced a reduction, with global warming experiencing the lowest reduction of 5 % and ozone depletion experiencing the highest reduction of 7.8 %. The only impact category that worsened was freshwater ecotoxicity by 1.5 %, but this was due to the additional water required for PV maintenance and cleaning.

The last improvement studied was changing the production of the WLC, which consists of about 75 % recycled fibre and 25 % virgin fibre, to fully recycled fibre. A discussion with a food safety specialist indicated that doing the transition would require a completely new product development since a significant number of variables would change. These include mechanical properties; food safety requirements; changes in chemical requirements; increases in transport and energy; and changes to the production process as equipment would have to be altered or replaced. Conducting a theoretical comparative LCA, the fully recycled WLC had an overall lower environmental footprint compared to the original WLC. The largest

difference was for ozone depletion at 6.4 % and the smallest was for global warming at 0.44 %. However, more research is required to accurately compare the two on a realistic basis as opposed to a theoretical basis.