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WOOD AND OTHER RENEWABLE RESOURCES

Life cycle assessment of cellulose packaging materials production: folding box board and *kraftliner* paper

Anna Lúcia Mourad · Henrique Luvison Gomes da Silva ·
Júlio César Batista Nogueira

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Abstract
Purpose Many companies around the world have been challenged to make their products in a more sustainable way in the last decade in order to minimize their environmental impacts. Klabin, the largest producer, exporter, and recycler of paper in Brazil, has made great efforts to exchange old for new and more efficient equipment to produce cellulose packaging materials. The objective of this study was to measure the benefits of modernization of its plant located in the southern region of the country for manufacturing carrier board/folding box board (CB/FBB) and *kraftliner* paper (KP).
Methods The goal established was analyzed through a *cradle-to-gate* life cycle assessment methodology.
Results and discussion The modernization carried out has led to several improvements such as the reductions measured by the functional units of 1,000 kg of CB/FBB and 1,000 kg of KP, respectively, of energy consumption (21 and 3 %), water (8.5 % for CB/FBB only), wood (6.6 and 7.2 %), and land use (6.9 and 7.1 %). The environmental impact categories (according to CML 2001) that have suffered greater reductions are human toxicity (68 and 69 %), abiotic depletion (59 and 28 %), and global warming potential (51 and 9 %) for the same reference units.
Conclusions The results achieved clearly show the importance of renewing industrial plant in order to achieve better environmental performance and also provide a historical inventory perspective for the company to establish future targets for improvement.

Keywords Cardboard · CTMP · Efficiency · Life cycle assessment · Paperboard

1 Introduction

The pulp and paper industry around the world, as well as other sectors of the economy, has focused efforts in recent years to reduce the environmental impact of its activities. Reduction of consumption of energy and water, emissions to air and water, as well as decreasing in the greenhouse gas emissions are among the most common results reported (Pro Carton 2013; Manda et al. 2012; AF&PA 2012; Cepi 2011; Fefco 2010; Francis et al. 2002). Substitution of more efficient fuels is also applied (Lopes et al. 2003). Due to this movement, it becomes even more and more important to report the results achieved by the various initiatives undertaken in order to share experiences and to establish historical levels of environmental performance achieved.

The recent effort of the cellulose industry to improve its environmental profile has transformed paper into an excellent modern packaging choice. Klabin, the biggest producer, exporter, and recycler of paper in Brazil with 17 industrial plants and one in Argentina, has been modernizing its manufacturing process over the last few years with the introduction of new more efficient equipment. The company is self-sufficient in wood having 224,000 hectares of planted forests and 187,000 hectares of preserved native woodlands and has been certified by the Forest Stewardship Council (FSC) since 1998.

Cellulose for packaging materials is traditionally obtained in Brazil and also in many other countries through a *kraft* digestion process which dissolves the most part of hemicellulose and lignin, thus resulting in a yield of around 50–75 %.

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A. L. Mourad (✉)
Packaging Technology Center, Institute of Food Technology – CETEA/ITAL, Av. Brasil, 2880, ZIP 13070-178 Campinas, SP, Brazil
e-mail: anna@ital.sp.gov.br

H. L. G. da Silva · J. C. B. Nogueira
Klabin S/A, Fazenda Monte Alegre, S/N, ZIP 84275-000 Telêmaco Borba, PR, Brazil

The chemi-thermomechanical pulp (CTMP) process solubilizes only part of these components and has a higher yield (~90 %) than *kraft* and less fiber damage. For such reasons, these processes have been combined for the development of cellulose packaging materials which results in less environmental impact and products with higher mechanical strength. The high-yield mechanical pulp has also been introduced in order to reduce the consumption of natural resources and the pressure of the land use. Sizable environmental benefits were found associating micro- and nano-TiO_2 coatings with CTMP pulp for production of printing and writing paper (Manda et al. 2012).

In the scientific literature, few cases discuss the basic processes for cellulose packaging production from a life cycle perspective, and in most studies, inventories obtained from external databases are used. As a result, this work differs from others because it is the fruit of a detailed survey on the largest manufacturer located in Latin America.

The aim was to evaluate the environmental improvement achieved as a consequence of a significant investment in the production process of the carrier board/folding box board (CB/FBB) and *kraftliner* paper (KP) through a life cycle assessment study in a *cradle-to-gate* approach.

Folding cartons are small to medium sized “cardboard boxes” made from cartonboard. They are referred to as folding cartons because they are usually delivered to the packer in a flat form, either as a side seam glued carton, which is folded flat, or as a flat piece of printed board cut around the perimeter to a carton profile.

Folding box board is a grade typically made from layers of mechanical pulp sandwiched between layers of chemical pulp and up to three layers of coating on the top or printing surface. It is used in such markets as pharmaceuticals; frozen, chilled foods; confectionery; and others (Pro Carton 2013).

Kraft paper is known by its high mechanical resistance, and it is usually used as the outer layers of corrugated paperboard boxes. It can be produced with several fiber compositions to produce packaging with different mechanical resistances depending on its final usage such as lightweight bags (sugar, flour, and chocolates) or for heavy industrial sacks (cement, lime, and fertilizers).

In Brazil, cardboard and *kraft* represented 14 % of the total value of packaging materials consumed in 2010 (Datamark–Market Intelligence 2011).

2 Methods

A cradle-to-gate study was structured in accordance with the guidelines and requirements for conducting life cycle assessment studies set forth in ISO Standard 14040 “Environmental management – Life cycle assessment – Principles and framework” and ISO Standard 14044 “Environmental management – Life cycle assessment – Requirements and guidelines” (ISO 2006a, b).

2.1 Functional unit

The products investigated in this study were assessed by using the functional unit of 1,000 kg of carrier board/folding box board (CB/FBB) and 1,000 kg of *kraftliner* paper (KP), both with 7.5 % of moisture content.

2.2 Boundaries and data collection

The study begins with the planting of seedlings in nurseries and goes up to the production of paper and cardboard rolls that are shipped from the factory in Telêmaco Borba in Paraná state. It includes all inputs and products used at the various steps in the forestry and factory operations.

Data required were obtained through 22 questionnaires prepared by CETEA and answered by the heads of each sector of the factory. Primary data employed represent annual consumption or emission.

The data sent in to CETEA were analyzed, modeled, and discussed throughout the entire development of the project with the Klabin team for complete validation of the data. None allocation was employed. For data validation, it used a dry mass balance separated from the liquid balance for each unit process. It was possible to differentiate the inventories for each product through their average annual pulp composition, since all the production units have been modeled individually. The data of the individual products multiplied by their annual productions were compared with those of the overall factory. Deviations between modeling and actual consumption for energy and water were less than 6 %.

The system was modeled using the GABI 4.2 software program.

Since Klabin does not produce all the electrical power it consumes, the data relative to the portion of electrical energy purchased from outside sources were based on the CETEA inventory database. In Brazil, electric energy for public utility services is produced by an interconnected system of electric plants, mostly hydroelectric (Coltro et al. 2003).

The inventories of fuel oil (burned in the boilers) and diesel oil (used in harvesting operations and truck transportation) were also calculated based on the data contained in the CETEA database. These inventories include the main aspects (consumption and emissions) related to oil extraction and fossil fuel production (pre-combustion).

The emissions stemming from transportation of raw materials were calculated based on the distances between their point of origin and the Klabin facility located in Telêmaco Borba.

The life cycle inventories of coating ink and hydrogen peroxide used in the manufacture of the paperboard were also taken into account. The data relative to these input products encompass their entire production chain, from raw material extraction up to their final processing. These data were modeled by adapting international databases with data from the average total primary energy supply of their respective production sectors in Brazil.

2.3 CB/FBB and KP manufacturing

Klabin produces cellulose from pine (*Pinus taeda* and *Pinus elliottii*) and eucalyptus (*Eucalyptus grandis*, *Eucalyptus saligna*, and *Eucalyptus dunnii*) trees. Pine and eucalyptus trees for cellulose production have a rotation of 14 and 7 years, respectively. After harvesting the trees from the forest, the logs are transported to the mill.

The wood is separated from the bark, and the resulting chips are routed to the biomass boilers. Pine and eucalyptus wood digestion is performed separately. CB/FBB is composed of *kraft* pine pulp, eucalyptus chemi-thermomechanical pulp (CTMP), *kraft* eucalyptus pulp, and bleached eucalyptus *kraft* pulp. KP is a combination of pine and eucalyptus *kraft* pulps. The digestion process uses caustic soda, white liquor, and low-pressure steam. In CTMP digestion, the wood chips are preheated with steam and crushed. Following this, the chips are treated with chemical agents (caustic soda, hydrogen peroxide, sulfuric acid, and a chelating agent). Part of the eucalyptus pulp is bleached using the so-called elementary chlorine-free (ECF) process (which consumes oxygen, chlorine dioxide, and hydrogen peroxide). Cellulosic pulps are refined, screened, and washed in several stages. The black liquor produced during the wood digestion is recovered at many stages recreating the white liquor used in the wood-cooking process. Very diluted fiber suspensions combined with specific chemicals are deposited in felts that are pressed to remove excess water. The final stages of drying use heated cylinders that evaporate the remaining water. KP is practically ready at this stage. Couchê ink and starch are applied to the surface of CB/FBB.

At the end of the production process, the paper and board are cut to each customer's specifications. Figure 1 shows the flowchart of CB/FBB and KP production highlighting the technological differences after modernization.

2.4 Energy and steam supply

The bark and wood trimmings, the black liquor from the wood digestion process, and fuel oil are burned inside five different boilers that generate steam at high pressure. The new boiler #5, manufactured in 2008, has a fluidized bed, less heavy oil consumption, higher maximum continuous vaporization (250 t/h), and a higher pressure in the outlet of the superheater (100 kg/cm^{2}g) than the other boilers, built between 1966 and 1976 and subsequently modernized. Fluidized bed boilers are considered one of the best available technologies for steam generation in pulp and paper industries (European commission 2013).

The high pressure steam is converted into low-pressure steam in four turbine generators which cogenerates electrical energy. In the turbine generators, steam at 46 and 100 bar pressure is converted to low- and medium-pressure steam (12 and 4 bar). Low-pressure steam and electrical power are produced by counterpressure, counterpressure+extraction, and counterpressure+condensation turbine generators.

Klabin also operates its own hydroelectric plant, the Presidente Vargas–Mauá hydroelectric plant, built between 1942 and 1952. It is located downstream of the facility, on the Tibagi river, at a distance of 43 km by road from the manufacturing site. The plant normally operates at full capacity of 23 MW, with a flow rate of approximately 80 m^3 water/s. The dam is 246 m wide and 20 m high. The hydroelectric plant supplies about 20 % of the total electrical power consumed by the facility. The remaining electrical energy is bought from the Brazilian grid.

2.5 Effluent treatment

The effluents discharged from the facility pass through three treatment stages. The role of the primary treatment is to eliminate solid contaminants and neutralize and cool the effluent. Solids retention is accomplished through a series of solids separation processes: degritting, screening, and desanding. The secondary treatment is a biological process that aerobically degrades organic substances. Oxygen is initially introduced through high-efficiency aeration grids of high chemical resistance and subsequently in aeration tanks. Next, the effluent is pumped to the secondary sedimentation tanks or basins. Part of the clarified effluent is discharged into the Tibagi river, and the other part flows to the tertiary treatment. In the tertiary treatment, sedimentable solids are retained by a membrane as part of an ultrafiltration process, which also reduces the chemical oxygen demand (COD). The ultrafiltration unit began to operate in 2008. Ultrafiltration is also included among the best technologies available by the European Commission.

2.6 Sensitivity analysis and environmental impacts

The final inventories obtained for the production of CB/FBB and KP were evaluated using the midpoint methodology CML 2001 (updated in December 2007), developed by the Centre of Environmental Science at Leiden University (Guinée et al. 2002). The following categories of environmental impact were analyzed: abiotic depletion (ADP), global warming potential (GWP), acidification (AP), eutrophication (EP), human

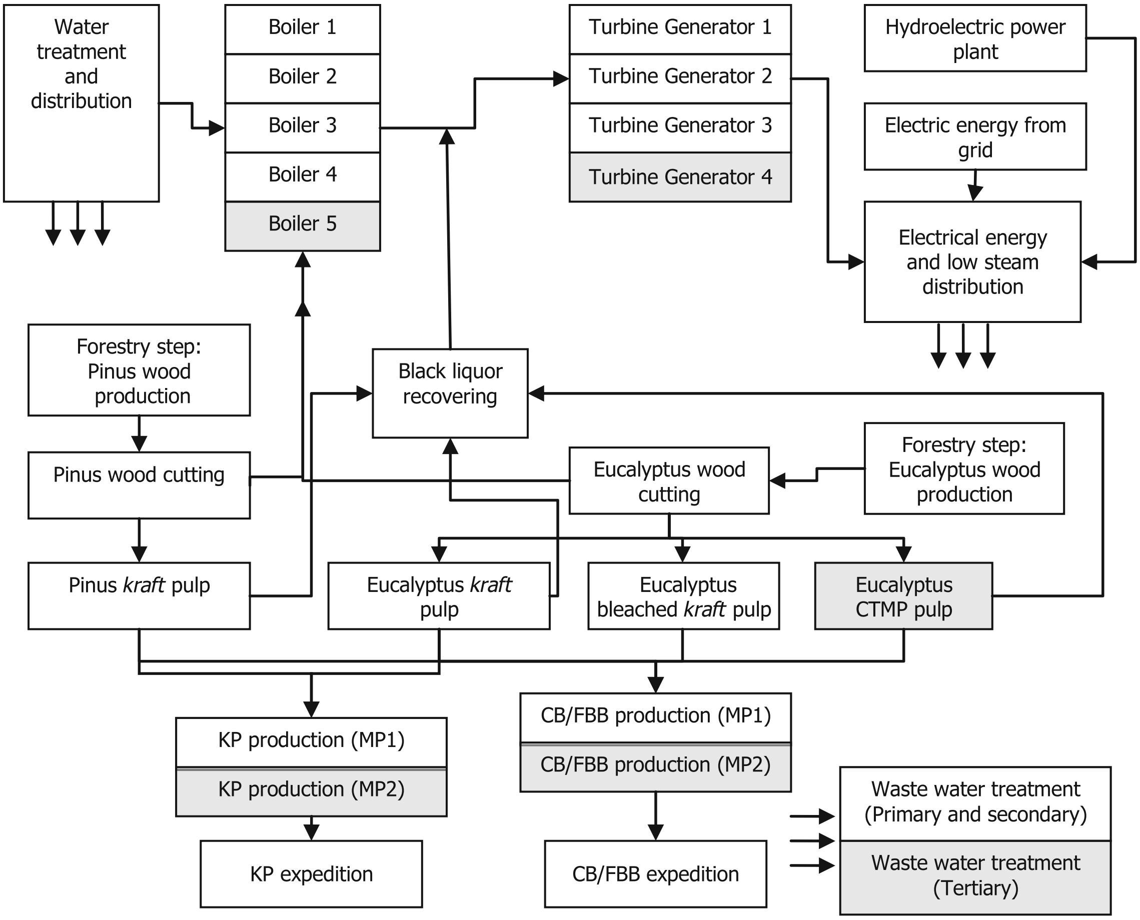


Fig. 1 Flowchart of CB/FBB and KP production system showing steps (*gray blocks*) introduced after factory modernization

toxicity (HTP), and photochemical ozone creation potentials (POCP). Although cellulose packaging material can be understood as a temporary carbon stock in a cradle-to-gate perspective, due to the uptake of carbon dioxide during photosynthesis phase, when considering a cradle-to-grave perspective, the previously stored renewable carbon dioxide is released to the atmosphere during final disposition. For this reason, only the carbon dioxide from fossil origin was considered for GWP calculation in this study to avoid any misunderstanding.

A sensitivity analysis was carried out between the two periods for the products evaluated in order to understand the contribution of each manufacturing stages for final impacts using the CML midpoint methodology.

The endpoint methodology Eco-indicator 99 was applied to turn the results of this study comparable with European ones, although none of the existing methods for evaluating local impacts had been developed considering Brazilian characteristics. The EI-99, a normalized damage oriented methodology, was applied selecting the hierarchist approach, which balances long and short time perspectives (Goedkoop and Spriensma 2001). The method considers three main damage categories: ecosystem quality, human health, and resources fossil fuel. The ecosystem quality is expressed in potentially disappeared fraction (pdf) times area times year (pdf.m^{2}a) and is composed by the following impact categories: acidification/eutrophication, ecotoxicity, land conversion, and land use. The human health is expressed in terms of disability adjusted life years (DALY) and is composed by carcinogenic effects, climate change, respiratory (inorganic), and respiratory (organic). The resource fossil fuel damage category is expressed in megajoules of surplus energy.

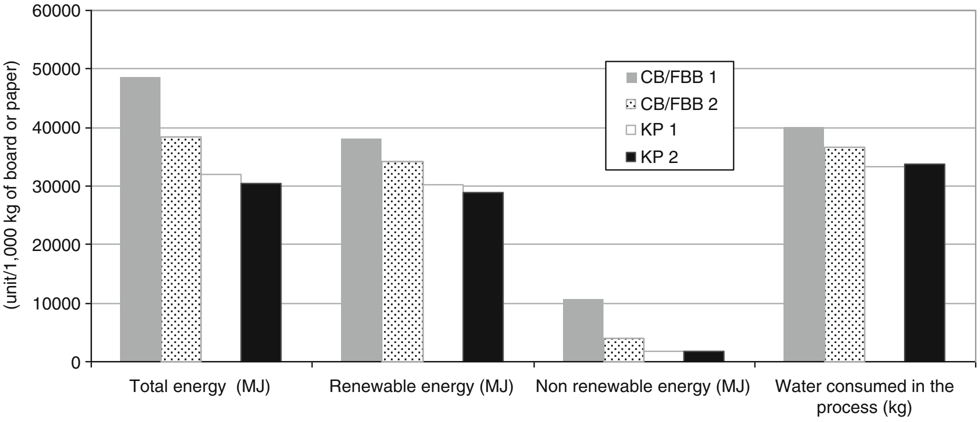
3 Results and discussion

3.1 Energy, water, wood, and land use consumption

Energy, water, wood, and land use consumption was selected as the main macro indicator of the life cycle inventories of products analyzed and shown in Figs. 2 and 3.

The drop in energy consumption is mainly due to the introduction of CTMP for paperboard production. The total energy saving for CB/FBB and *kraftliner* was 10.2 GJ/t with an energy consumption of 38.3 GJ/1,000 kg (21 % of reduction) and 1.5 GJ/t with an energy consumption of 30.5 GJ/1,000 kg (5 % of reduction), respectively.

Fig. 2 Comparison of energy and water consumption before (*1*) and after (*2*) new equipment introduction



On the one hand, the production of these materials can be classified as energy intensive; on the other hand, the energy matrix is mostly renewable. Only 9 and 5 % of the energy consumed for the production of CB/FBB and KP, respectively, come from fossil fuels. Besides that, the process is gradually moving toward energy self-sustainability. Of the total energy consumed, 10 and 6 % for the production of CB/FBB and KP, respectively, come from external energy sources.

Water consumption was reduced by 8.5 %, reaching a level of 36.5 m^3 water per metric ton of CB/FBB produced and was about 33.7 m^3 water per metric ton of paper produced.

The introduction of CTMP, which has a higher pulp yield than the *kraft* process, increased the overall efficiency of wood use, which, along with all the other improvements incorporated into the process, reduced the consumption of wood by 6.6 % for CB/FBB production. The improvements introduced in production processes, particularly the placing into operation of a new boiler and a new turbine generator—more efficient in generating steam and electrical power—reduced wood consumption by 7.1 % in the 3-year period for KP production.

The introduction of CTMP pulp made it possible to reduce the use of wood and, consequently, that of land, resulting in a reduction in continued land use of 6.8 % for CB/FBB output. Increased efficiency in wood use in this 3-year period, such as the introduction of boiler #5 and turbine generator #4, diminished, consequently, the land use, resulting in a reduction of 7 % of continued land use for KP production.

3.2 Midpoint environmental impacts analysis

The environmental impact assessment was carried out using methodology CML 2001 (Guinée et al. 2002), updated in 2007. The results are shown in Table 1.

Table 1 clearly shows the improvements obtained with the modernization of the factory.

The first major reduction was measured in human toxicity potential by the decrease of 68 and 70 % per 1,000 kg of cardboard and paper, respectively. This reduction was mainly achieved as a result of improvements in the effluent treatment step with the implementation of the ultrafiltration unit in 2008.

The second greater reduction was the depletion of abiotic resources: 59 and 28 % for cardboard and paper, respectively, mainly due to reduced consumption of oil and natural gas.

The third most significant reduction was achieved by reducing the global warming potential, which is a major goal of the company to the mitigation of climate change: The result

Fig. 3 Comparison of wood consumption and land use before (*1*) and after (*2*) new equipment introduction

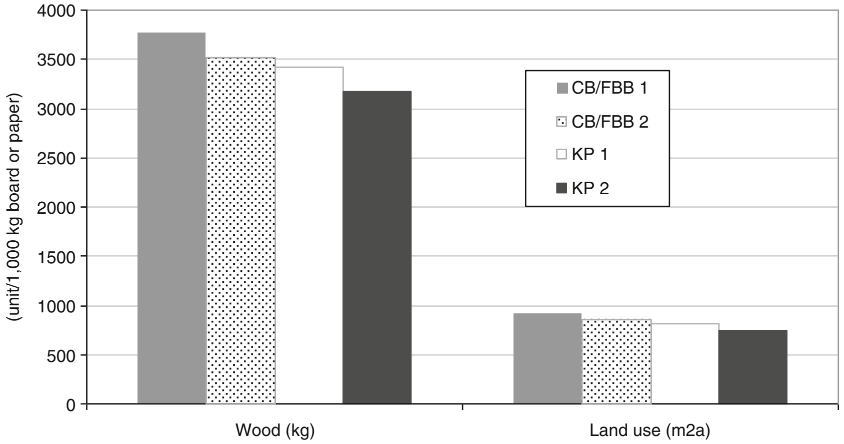


Table 1 Environmental impact categories of *cradle-to-gate* life cycle inventories of systems evaluated according to CML 2001(updated to 2007)

Environmental impact indicator	CB/FBB			KP		
	Before (1)	After (2)	Reduction (%)	Before (1)	After (2)	Reduction (%)
Abiotic resource depletion (ADP) (kg Sb equiv)	5.8	2.4	59	1.9	1. 4	28
Global warming potential (GWP) (kg CO_2 fossil equiv)	936	461	51	287	261	9
Acidification potential (AP) (kg SO_2 equiv)	9.0	6.3	31	4.1	3.9	5
Eutrophication potential (EP) (kg phosphate equiv)	1.13	0.71	37	0.58	0.44	24
Human toxicity potential (HTP) (kg de DCB equiv)	24.8	7.9	68	17.0	5.2	70
Photochem. ozone creation pot. (POCP) (kg ethylene equiv)	0.67	0.48	27	0.34	0.33	4

Functional units: 1,000 kg of board or paper

showed a fall of 51 and 9 % in GWP for manufacturing of cardboard and paper, respectively.

The factory modernization also brought benefits to the other impact categories evaluated such as EU, AP, and POCP, with reductions reaching 37, 31, and 27 %, respectively, for CB/FBB and 24, 5, and 4 %, respectively, for KP.

3.3 Contribution and sensitivity analysis

As shown in Figs. 4, 5, and 6, the contribution and sensitivity analysis was done considering the three highest environmental impact reductions in order to understand the influence of each stage for the results obtained after the modernization of the manufacturing process.

Figure 4 shows clearly that the new wastewater treatment was the stage responsible for the highest reductions in the human toxicity potential, mainly due the reduction in the emission of heavy metals to water, which was reduced by 42 and 33 %, reaching a level of 6.6 and 6.1 g per ton of CB/FBB and KP, respectively.

The reduction of consumption of hydrogen peroxide (and consequently the consumption of natural gas and heavy fuel oil) by changing the sequence of bleaching process was the main factor for the reduction of abiotic resource depletion in CB/FBB manufacturing process as shown in Fig. 5.

The reductions found for GWP reduction are mainly due two stages: the bleaching pulp process and the steam generation by boilers. Although the wood preparation also has a significant contribution to the emission of greenhouse gasses, the modernization of the facility did not alter in a great extension the generation of these gasses in this step. In the bleaching process, the reduction of hydrogen peroxide reduced the emissions associated with its use. The introduction of the more efficient boiler #5, which burns mainly bark and eucalyptus chips, reduced the share of steam from heavy fuel oil boilers. After modernization, the main greenhouse gasses by functional units were as follows: 426 and 245 kg of fossil carbon dioxide, 4.9 and 2.8 kg of nitrogen oxides, and 2.4 and 1.1 kg of methane by the production of 1,000 kg of CB/FBB and KP, respectively.

The reduction of improvements found for CB/FBB was greater than that for KP, since CTMP pulp is not used for KP and also because the content of cellulose in the paper formulation is higher than that in the cardboard.

3.4 Endpoint environmental impact analysis

The Eco-indicator 99 method was selected to evaluate the results obtained for an endpoint perspective, normalized through a hierarchist approach. Figures 7 and 8 show the contribution of each stage for the total damage impact.

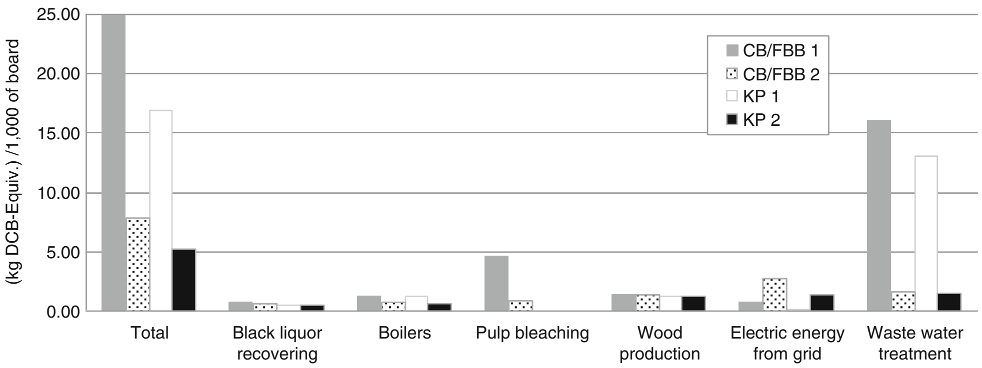


Fig. 4 The contribution analysis of human toxicity potential for production of CB/FBB and KP before (*1*) and after (*2*) factory modernization

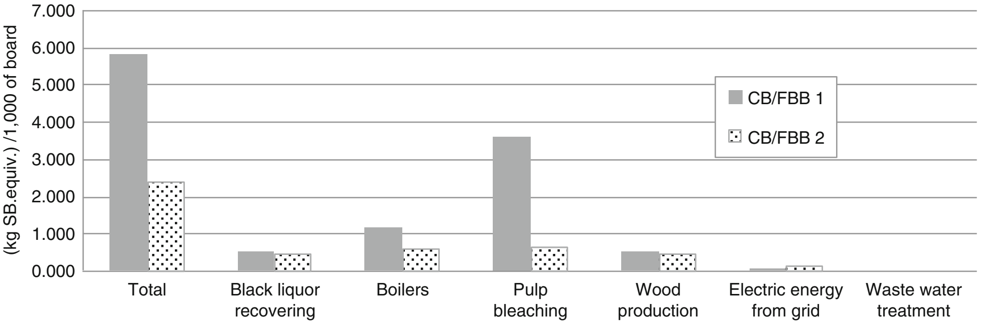


Fig. 5 The contribution analysis of abiotic depletion potential for production of CB/FBB before (*1*) and after (*2*) factory modernization

The total calculated damage impact for the production of CB/FBB and KP is 0.34 and 0.31 endpoints, respectively, according to EI-99.

The analysis of these figures shows a predominance of damage to human health, followed by quality and damage to the ecosystem quality and to the resource fossil fuel with the following percentage, respectively, of 46, 32, and 26 % for the production of CB/FBB and 64, 23, and 13 % for the production of KP. Production stages that have higher contribution to these damages are as follows: the generation of thermal energy by boilers, wood production, bleaching process, black liquor recovery, and energy from the grid.

3.5 Greenhouse gas emissions for similar studies

Recent IPCC reports have scientifically demonstrated the correlation between climate change and increased anthropogenic emissions of greenhouse gasses from the statistical analysis of many studies carried out around the world (IPCC 2007). Therefore, the reduction in the emission of these gasses is currently one of the main sustainability goals of most companies, which set reduction targets for the future.

As the concern with climate change is a general goal, it is important not only to quantify own emissions but also to compare them with similar processes.

The production of beverage cardboard liquid packaging board (LPB) in the same factory (Mourad et al. 2012) emits 512 kg of fossil CO_2 equiv. per metric ton. The formulation of LPB is slightly different from CB/FBB, a card for general use, to achieve the requirement levels of whiteness, moisture resistance, and stiffness.

These emissions were quantified by Environ (2012) in a recent work done to calculate the displacement of virgin pulp which occurs when it replaced by recycled pulp for magazine production. Considering the emissions from forest up to virgin pulp production, composed by 50 % of *kraft* and 50 % of mechanical, they found 1,630 kg fossil CO_2 equiv by ton of paper.

Pro Carton—Association of European Cartonboard and Carton Manufacturers—has been measuring its carbon footprint since 2005 and has achieved increasingly reductions. Data collected in 2011 representing 69 % of the production capacity in Europe (cartonboard mills and carton plants together) showed an average emission of 915 fossil CO_2 equiv per ton of cardboard using similar approach from *cradle-to-gate* (Pro Carton 2012) and the recommendations of PAS2050 (BSI 2011).

The American Forest & Paper Association reports a reduction of 10.8 % from baseline year 2005: greenhouse gas emissions of 0.74 tons CO_2 equiv per ton of production in 2010 compared to 0.83 tons CO_2 equiv per ton in 2005 (AF&PA 2012).

A life cycle assessment was carried out for a coated white board in China (Cui et al. 2011). As this plant does not make complete recovery of black liquor to obtain heat and energy, it

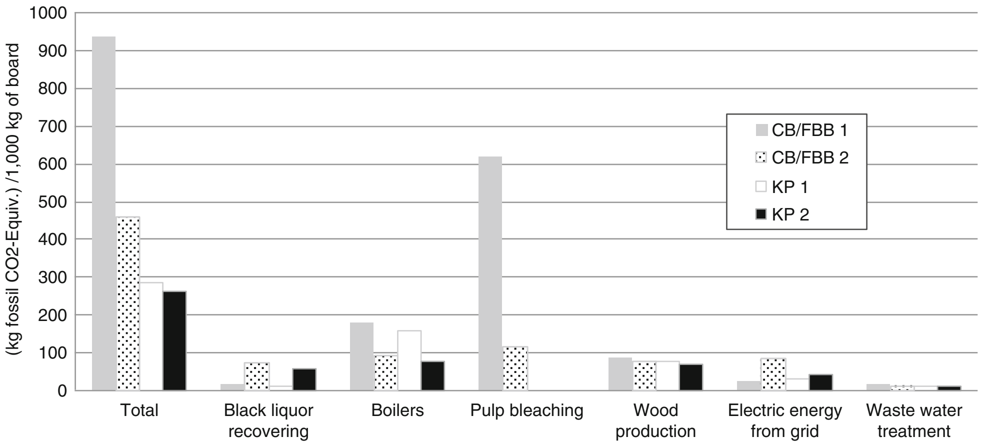


Fig. 6 The contribution analysis of global warming potential for production of CB/FBB and KP before (*1*) and after (*2*) factory modernization

Fig. 7 The contribution of each manufacture stage in the CB/FBB production (after factory modernization) for the damage categories of the method Eco-indicator 99 (normalized hierarchist approach)

consumes more fossil fuels than the previous processes evaluated and emits 2,300 kg CO_2 equiv by ton of cardboard.

3.6 Suggestions for improvement of the environmental performance

Considering the results found in the previous sections, using the midpoint and endpoint views, authors identify the following actions for future programs to improve the general environmental profile and also to reduce the global warming potential of these products:

- Increasing the share of biomass burning, thereby reducing that of fuel oil
- Use of fuel from renewable sources in agricultural equipment
- Replacing fuel oil with natural gas, which has a lower carbon dioxide emission per unit of energy supplied
- Discussion with the supplier of the bleaching agent (hydrogen peroxide) for it to provide data from its local production since the addition in the process has a significant impact. In the current study, the LCI of this input was extracted from an external database; the real impact can be greater or less than measured.
- Reducing the dependence on electricity from the grid, increasing its capacity to generate electricity through its own hydroelectric and steam cogeneration

4 Final conclusions

The modernization of the cellulose packaging material productive process employed by Klabin at its Telêmaco Borba plant has resulted in several improvements in the environmental performance of these products. The study revealed that the following alterations were responsible for most of the environmental impact reductions: the introduction of the ultrafiltration plant (a tertiary effluent treatment), the introduction of a new more efficient biomass boiler with a fluidized bed, and the change of the bleaching sequence. Based on the CML 2001 model updated in December 2007, the following improvements were noted after these actions:

- Energy consumption was reduced by 21 % (CB/FBB) and 5 % (KP), reaching the value of 38.3 MJ/kg of CB/FBB and 30.5 MJ/kg of KP. As a result, the next challenge includes the minimization of fossil energy sources that currently account for 9 % of the total consumed in the production of the board.
- Water consumption was reduced by 8.5 %, reaching a level of 36.5 m^3 water per metric ton of CB/FBB. There was no significant change in this indicator for the KP production that remained in 34 m^3 water per metric ton of paper produced.
- Wood consumption and land use accounted for reductions around 7 % for both products due to the introduction

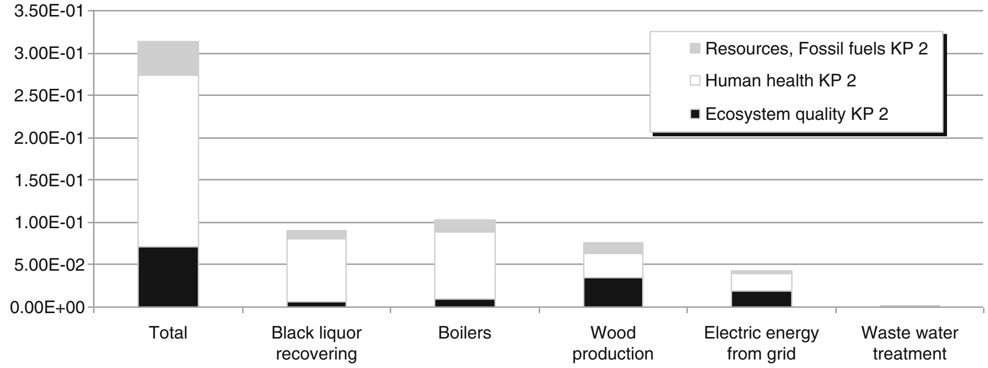


Fig. 8 The contribution of each manufacture stage in the KP production (after factory modernization) for the damage categories of the method Eco-indicator 99 (normalized hierarchist approach)

of CTMP pulp (for CB/FBB) and the introduction of the newly more efficient biomass boilers and turbine generator equipment.

- Significant reductions were observed in all environmental impact categories evaluated, the most being significant reductions in the production of CB/KP and FBB, which, respectively, were 68 and 69 % for human toxicity, 59 and 28 % for abiotic depletion, and 51 and 9 % for GWP.
- Carbon dioxide fossil equivalent emissions have been employed as an excellent indicator to evaluate the performance of processes regarding the growing concern about climate change. Emissions of 461 kg CO_2 fossil equiv per metric ton CB/FBB and 261 kg CO_2 fossil equiv per metric ton KP demonstrate that these processes can be considered among the most efficient in the literature available.

According to Eco-indicator 99, the products evaluated impact with 0.34 and 0.31 endpoints for the production of 1,000 kg of CB/FBB and KP, respectively, with a slight predominance of damage to the human health.

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