Liquid Packaging Board – A Positive *Carbon Footprint*

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Abstract
Carbon footprint determination of products and services has been one of the most studied environmental impact categories in the world due to the climatic changes perceived in many regions of the planet. This article shows how the increase in technological efficiency achieved by the company Klabin over the past ten years has reduced the environmental impact of LPB - Liquid Packaging Board production. The scope of this study includes data and information relative to all inputs and products used in the various steps of the LPB manufacturing process, from the production of pine and eucalyptus seedlings in the forest up to the rolls of finished carton leaving the production line ready for shipment in the facility located in Telêmaco Borba (State of Paraná, Brazil). The evolution of the environmental profile of LPB paperboard was evaluated by comparing the data and information contained in the inventory commissioned by Klabin in 1998 with the data and information quantified and collected for the purpose of this project relative to the year 2008. Among the main results of this project, the reduction in greenhouse gas emissions was impressive. Based on a life cycle methodology, the CO_2 balance currently shows a surplus of 1594 kg CO_2 equiv. stored per metric ton of LPB paperboard produced, since photosynthesis stores a greater quantity of CO_2 in the wood than is released into the air through greenhouse gas emissions (in CO_2 equiv.) associated with the manufacturing process. The results show that LPB, differently from other packaging materials, does not add to the greenhouse effect. Cellulose packages are a form of temporary storage of CO_2 and, in addition, do not increase the global warming potential. This is very characteristic of cellulose materials.

Keywords
Cellulose, life cycle assessment, carbon sequestration, packaging, *cradle-to-gate*, efficiency.

1. Introduction

The decade of 2000-2010 may be identified in the future as the period when the environmental awareness of the worldwide population was at its greatest. This significant increase is due to climatic changes, which have already been foreseen for many years and are being “felt” by people around the world.

The 4th IPCC– Intergovernmental Panel on Climate Change Report provided scientific evidence that global warming is correlated with the increase in greenhouse gas emissions. The global temperature of the planet has shown a rising tendency throughout the past century. Measurements recorded up to now suggest that the average temperature of the Earth’s surface has risen about 0.74°C (IPCC, 2007a).

For the next two decades a warming of about 0.2°C per decade is anticipated according to the IPCC Special Report on Emission Scenarios (SRES). Also, increases in global average temperatures as associated with extreme climatic effects (floods, storms, hurricanes and droughts) and alterations in the variability of hydrologic phenonema (changes in rainfall patterns, advancing of the sea on rivers), jeopardizing life on Earth (a threat to biodiversity, agriculture, health and the well being of the human population) (IPCC, 2007b).

By mid-century, annual average river runoff and water availability are projected to increase by 10-40% at high latitudes and in some wet tropical areas, and decrease by 10-30% over some dry regions at mid-latitudes and in the dry tropics, some of which are presently water stressed areas. Approximately 20-30% of plant and animal species assessed so far are likely to be at increased risk of extinction if increases in global average temperature exceed 1.5-2.5°C (IPCC, 2007c).

Klabin has long been committed to running its business in a sustainable manner and is concerned with the *carbon footprint* of its products. Klabin is the biggest producer, exporter and recycler of paper in Brazil, with 17 industrial plants in Brazil and one in Argentina. Self-sufficient in wood, it has 224 thousand hectares of planted forests and 187 thousand hectares of preserved native woodlands and has been certified by the FSC - Forest Stewardship Council since 1998.

Liquid packaging board (LPB) represented 38% of total volume of products manufactured in 2008 in the Telêmaco Borba plant. LPB is mainly used to produce aseptic containers for beverage cartons. In general, it is combined with other materials such as polyethylene to provide waterproofing and aluminum to aggregate light and oxygen barriers.

2. Objective

The objective of the overall study was to conduct a *cradle-to-gate* life cycle assessment – in compliance with the requirements of the ISO 14040 standard series – of Liquid Packaging Board (LPB), with a special emphasis on *Carbon Footprint* determination, which is the focus of this particular article.

In addition, the project had the aim of measuring how the overall technological improvement carried out over the last ten years has affected the current environmental profile of LPB production.

3. Method

The present 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 and ISO, 2006b).

The general principles of theses methods are also discussed in the publication entitled "Life Cycle Assessment – Principles and Applications" (Mourad et al., 2002).

3.1 Functional unit

The LPB investigated in this study were assessed by using a functional unit that consisted of 1000 kg of LPB, with 7.5% of moisture content.

3.2 Boundaries of the study

This Life Cycle Assessment – LCA starts with the production of pine and eucalyptus seedlings which will, at a later stage, be transplanted to the forest and covers the whole manufacturing cycle up to the moment when the LPB leave the Klabin manufacturing facility located in Telêmaco Borba (State of Paraná, Brazil).

The scope of this study includes data and information relative to all inputs and products used in the various steps of the manufacturing process, from the production of seedlings in nurseries up to the rolls of finished carton leaving the production line ready for shipment. Due to the large number of inputs used in the manufacturing of the board, a factor equal to 10% of the total weight or mass of board produced was set as criterion of exclusion from the boundaries. First, the inputs of the final inventory were arranged in ascending order. Then, they were summed and ranked accordingly.

3.3 LPB production system

The system was modeled considering all the steps discussed in the following text. Figures 1 depict the flowchart of the steps that were included. The system was modeled using the GABI 4.2 software program.

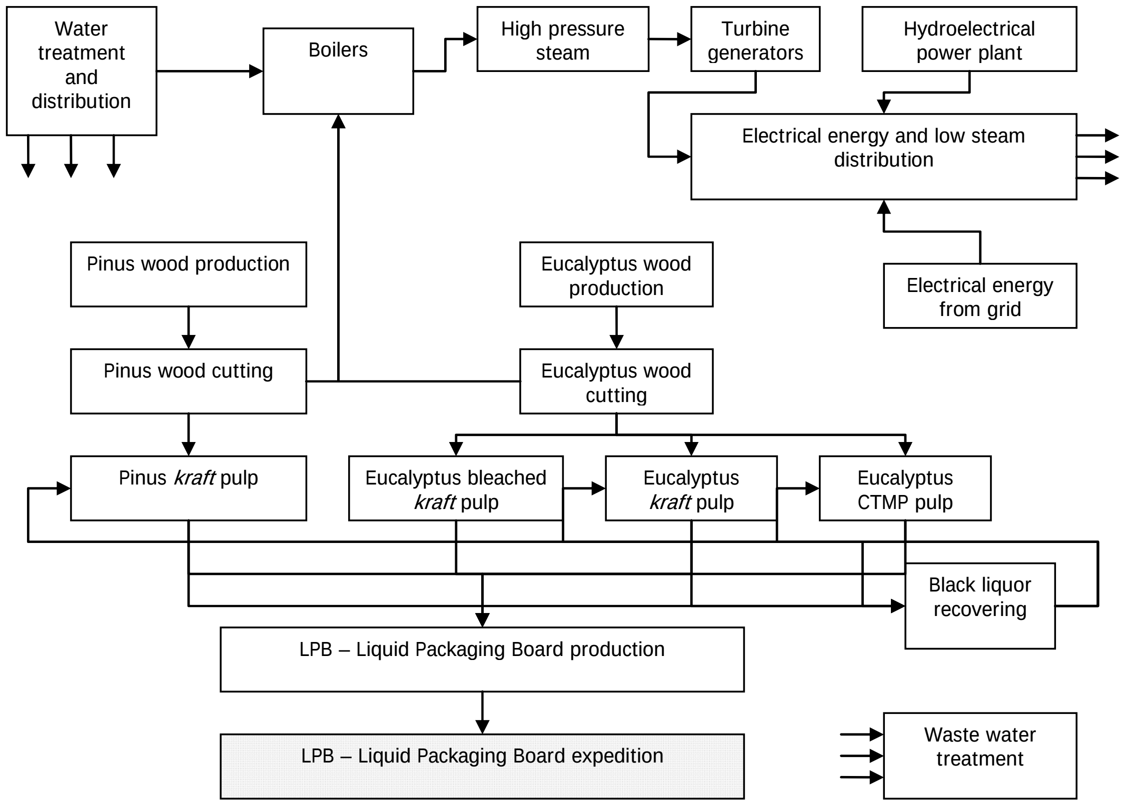

Figure 1. Flowchart for the modeling of the LPB paperboard production system – *Liquid Packaging Board*, relative to the year 2008.

3.3.1 Pinus and Eucaliptus wood production

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 life cycle of 14 and 7 years, respectively. Initially, seedlings are produced in nurseries where they remain until they are ready to be transplanted to the forest area. At this stage, the seedlings are transplanted to tubettes containing compost produced from a mixture of carbonized rice hull and fertilizers. They are watered by a sprinkler system. After having been transferred to the forest area, the seedlings are treated with herbicides, ant control agents, fertilizers and limestone.

3.3.2 Wood cutting

The wood is separated from the bark and chips that will be routed to the biomass boilers. Bark is removed by abrasion. After having passed through a log washer, the debarked logs are then fed into the chipping unit. Wood chips graded by size and thickness are sieved and moved to outside storage areas. The wood debris produced by the debarker machine is further reduced in size and transported by conveyor belt to the bark storage area prior to being burnt in the biomass boilers.

3.3.3 Pulping processes

The digestion processes of pine and eucalyptus woods are performed separately. Four types of pulp in various combinations are used to produce LPB paperboard: pine kraft pulp, eucalyptus CTMP (*chemithermomechanical pulp),* Eucalyptus kraft pulp and bleached eucalyptus kraft pulp

<u>*Kraft* digestion process</u>

Size-grade wood chips are impregnated with white liquor before being fed to a digester. The pulp is obtained by digestion with caustic soda, low pressure steam and white liquor recovered from black liquor. After refining, the pulp mass is screened to eliminate any reject fines and oversize particles produced during the process, including sand. After screening, the pulp mass then further goes through several washing stages, after which it is conveyed to the storage towers.

CTMP Digestion Process

Size-grade woods chips are washed and preheated in steam. Next, they are put through a conical press that crushes the chips. The crushed chips are treated with chemical agents and further refined. After refining, CTMP pulp is screened and the pulp mass then further goes through washing stages before being conveyed to the storage towers.

3.3.4 Bleaching process

The process starts with oxygen delignification. After the delignification stage, the actual bleaching process is initiated. The pulp is bleached using the so-called - *Elementary Chlorine Free* process (ECF) process, using a sequence of chlorine dioxide (ClO_2), hydrogen peroxide and chlorine dioxide. After reaction time, the pulp mass goes through the last washing stage and is then further conveyed to the storage towers.

3.3.5 Black liquor recovering

The black liquor produced during the wood digestion processes passes through a series of evaporators until it reaches a solids level of 80%. The concentrated black liquor is sprayed into the recovery boilers and burned, generating high-pressure steam. The solid mass remaining is recovered in many stages recreating the white liquor used in the wood-cooking process.

3.3.6 LPB sheet formation

LPB paperboard is produced on large paper machines. The first step in the manufacture of paper called the preparation of the mass, consists in refining the cellulosic pulps by dispersing the fibers as a dilute suspension in water with the aid of chemicals. The fibers are filtered from the suspension through a sieve or screen in a way as to make a uniform layer of drained pulp, that is, a wet sheet of paper. Next, this sheet is passed to the pressing section of the paper machine where it is placed in contact with a felt and pressed to remove excess water. Final drying is accomplished by evaporation of the water contained in the wet sheet by contact with high temperature steam rolls to reduce the moisture level to within specification. The sheet then passes onto the coater where *couchê* ink and starch are applied to the surface of the carton. At the end of the production process, the paperboard is rolled onto spools. The spools or rolls are cut to the width and diameter specified by the customer.

3.3.7 Steam and energy cogeneration

The process of steam generation consists in transforming fuels and water (demineralized) into high-pressure steam in power boilers. In this process, three fuels are used: a) biomass from bark and wood trimmings; b) black liquor from the wood-digestion process and c) fuel oil purchased from outside sources. The boilers operate at temperatures between 400 and 500°C and produce high-pressure steams of 46 and 100 bar (kgf/cm^2). In the turbine generators, these high-pressure steams are converted to low- and medium-pressure steam (12 and 4 bar) and electrical energy which are consumed in the cellulose production process and by the paper machines.

3.3.8 Effluent treatment

The effluents discharged from the facility pass through three basic treatment stages: primary, secondary and tertiary. The role of the primary treatment is to eliminate solid contaminants, neutralize and cool the effluent. Solids retention is accomplished through a series of degritting, screening, desanding and solids separation processes. The secondary treatment is a biological process that aerobically degrades organic substances using oxygen introduced through high-efficiency aeration grids of high chemical resistance and subsequently in aeration tanks. The sedimented sludge is removed and circulated through the system. Only the excess sludge generated in the treatment station is further dehydrated and reused as fertilizer in the forested areas.
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.

3.3.9 Hydro-Electrical Plant
Klabin operates the Presidente Vargas – Mauá hydro-electrical plant, built 1942 and 1952. It is located downstream the facility, on the Tibagi river, at a distance of 43 km by road. The plant normally operates at full capacity of 23 MW, with a flow rate of approximately $80m^3$ water/second. The dam is 246 m wide and 20 meters high. In the period 2006 – 2008, plant supplied about 20% of the total electrical power consumed by the facility.

3.4 Global warming potential - GWP and Carbon Footprint – CF

The greenhouse effect gases quantified within the boundaries of this study (carbon dioxide, methane, nitrous oxide) and expressed in terms of the amount of carbon dioxide (CO_2) with equivalent greenhouse effect (kg CO_2 equiv.) over a specified timescale of 100 years generate the *Global Warming Potential* or GWP values, also known as the "*Carbon footprint*" of products. GWP estimates in this study were based on emission factors published in the 2001 IPCC Report according to CML 2001 methodology (Guinée et al., 2001).

According to PAS 2050 – Publicity Available Specification, the term "product *carbon footprint*" refers to the GHG emissions of a product across its life cycle, from raw materials through production. It includes the greenhouse gases carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), together with families of gases including hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) (PAS, 2008).

As LPB is an intermediate packaging material, the process map steps for carbon footprint calculation was performed by using a business-to-business (B2B) route, using a *cradle-to-gate* approach, as established by PAS 2050 (PAS, 2008).

4. Results and discussion

4.1 Carbon footprint of LPB - Liquid Packaging Board (*cradle-to-gate*)

Table 1 and Figure 2 show the *carbon footprint* balance of LPB disclosing the quantities absorbed during photosynthesis and emitted during the manufacturing process.

Table 1. *Carbon footprint* for the inventories (*cradle-to-gate*) of 1998 and 2008. Functional unit: 1000 kg LPB - *Liquid Packaging Board*.

Parameter	*Carbon footprint* (kg CO_2 equiv/1000 kg LPB)	
	1998	2008
Absorbed through photosynthesis	-5338	-3646
Emitted during LPB manufacture	7104	2052
Balance	1766	-1594

These results summarize 10 years of technological improvements which were introduced in this period:

- continued intensive research on genetic improvement of the species planted in the reforested areas significantly increased agricultural productivity. Between 1998 and 2008, the productivity of eucalyptus increased by 11% and reached 315 metric tons per hectare, while the productivity of pine increased by 3%, reaching 519 metric tons per hectare.

- the profile of the primary energy supply has substantially changed over the years, with increasing substitution of renewable energy sources for traditional fossil fuels. As a result, only 8% of that energy comes from fossil fuels, a fact that makes its primary energy supply predominantly renewable.

- the introduction of CTMP, which has a higher pulp yield than the *kraft* process, increased the overall efficiency of the manufacturing process.

- a significant part of the equipment was optimized or replaced by more efficient and modern equipment such as new digestors, refiners, boilers, turbine generators, paper machines, etc.

- the process controllers were completely automated in a central unit which permits interference and immediate intervention in all the manufacturing steps, reducing the general losses.

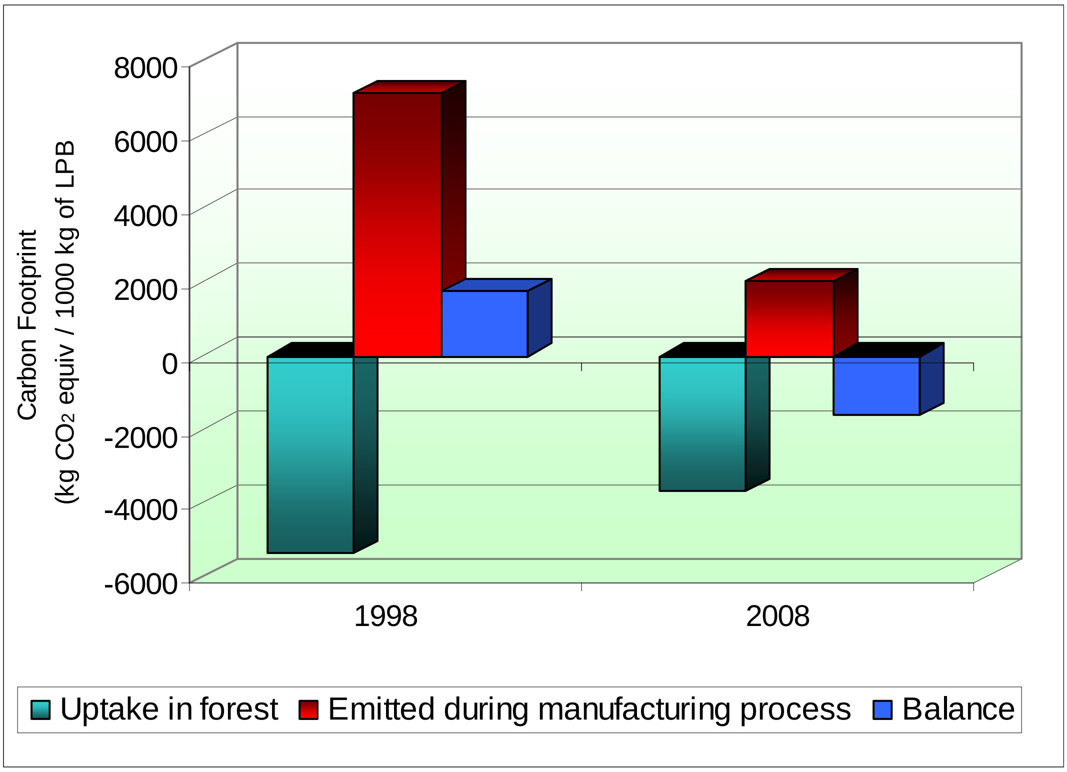

Figure 2. Evolution of the *carbon footprint* in the production of LPB, throughout its life cycle from the forest to the exit gate of the manufacturing facility.

In 2008, PRO CARTON – the European Association of Carton and Cartonboard Manufacturers published the study entitled *Carbon footprint for cartons*. Using actual production data provided by a large number of carton and cartonboard manufacturers across Europe, a *cradle-to-gate* study – from the forest to the exit gate of the manufacturing plants – in accordance with the standards and procedures laid down in the document PAS 2050 – *Publicity Available Specification* (PAS, 2008). This study also covered the companies that use recovered fibers.

This study revealed that, on average, these packages stored 1474 kg CO_2 equiv/t of carton, whereas during their production cycle only 1004 kg CO_2 equiv/t of carton are emitted, due to the burning of fossil fuels (PRO CARTON, 2008).

The surplus of 470 kg CO_2 equiv/t of carton of PRO CARTON is smaller than the surplus found in this study, but the European study includes the use of recycled fiber.

4.2 Temporary storage

This study was carried out up to the gate of the Klabin facility. In order to have a complete idea of the carbon cycle it is necessary to extend the calculations for a particular use of this material such as LPB to manufacture liquid cartons which are further converted to a product container as milk or juice, for example. Considering a time horizon of 100 years, the carbon temporarily stored will be released to the atmosphere again as carbon dioxide and/or methane, depending on the oxygen availability (Hunt, .

Even in this partial evaluation, the result shown up to the gate of the Klabin manufacturing unit is quite impressive and distinct from other packaging materials like plastic, metal or glass, which usually contribute with the increase of global warming potential and the *carbon footprin*t, when they are analyzed from a *cradle-to-gate* perspective.

5. Conclusion

Concerning environmental aspects, the cellulose industry can be placed among those sectors with have smaller impacts due to the renewability and reciclability of the cellulose fibers.

The results has found in this research show that these aspects can be additionally improved when the manufacturer has a very well established principles of sustainability, that have been clearly developed over many years.

The CO_2 balance currently shows a surplus of 1594 kg CO_2 equiv. stored per metric ton of LPB paperboard produced, since photosynthesis stores a greater quantity of CO_2 in the wood than is released into the air through greenhouse gas emissions (in CO_2 equiv.) associated with the manufacturing process. This value does not include carbon dioxide emissions that occur in subsequent stages of the life cycle of the paperboard, i.e., associated with the manufacture, use and final disposal of packages made using LPB paperboard as one of the raw materials.

The evolution of CF measured between 1998 and 2008 was achieved by a combination of several technological improvements such as agricultural productivity, replacement of fossil by renewable fuels and introduction of higher yield pulp – CTMP and more efficient equipment.

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