Extented Abstract


The perception that human activities might have significant impact in the environment led, in the last decades, to the development of policies and methodologies to better understand and handle the subject. The United Nations Conference on Environment and Development (UNCED), also known as the Rio Summit or ECO-92, was a major event in that direction. More than one hundred heads of state gathered with other representatives from the society, industries and environmentalists to discuss about sustainable development and global warming (MCDONOUGH and BRAUNGART, 2002). One of the negotiation’s result was the definition of the eco-efficiency strategy, that guided the industry approach to the issue in the two past decades.

Reducing direct and indirect environmental impact in every possible opportunity became one of the main strategies to reach such eco-efficiency. To identify these possibilities, the product’s life cycle became focus of studies from researchers, companies and governments. The Law no. 12.305/2010, for example, defines life cycle as the series of stages related to the development of the product, the acquisition of raw material, the production process, consumption and final disposal.

In a similar way, the International Standards Organization (ISO) defines life cycle as consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal. 14000 series os norms, from ISO, is one of the main tools to provide inputs to this debate. More specific, 14020 and 14040 regulate environmental labels and life cycle assessment (LCA). While labels are essential to communicate to the market the characteristics of a product, LCA is one of the most complete tool to help decisions related to the development of products or services. It can be applied to the whole life cycle, from raw material extraction to disposal, or in specific stages, and allows for a comparison between two different solutions based in the same functional unit, or objective, making it easier to identify the least negative impact.

Cradle-to-cradle methodology (C2C) developed by MCDONOUGH and BRAUNGART (2002) takes a step further in the approach of the environmental impact reduction, suggesting that instead of reducing the negative impact, products and services should have a positive impact in the environment.

Although C2C shares some principles with ecodesign, and utilize LCA as a tool to support choices related to material and processes, it was chosen as guideline for this work given its more radical principles and the possibility of evaluation through an certification process developed by the authors. C2C framework describes a way of designing products with closed loop life cycles, suggesting that every product is part of a biological or technical cycle, depending on the nutrients in it. Biological nutrients are materials used by living organisms in the processes of cellular division, growing, and other complex functions. A product design to integrate this cycle should be able to go through composting process without contaminating the soil. Technical nutrients are materials extracted from the environment and processed for use in industrial processes. To be characterized as a technical nutrient according to C2C, its composition and use must allow them to be recycled without losing its high quality. Materials from different cycles should never be mixed in a permanent way, to avoid contamination from one to the other.

The methodology can be applied in different areas, and for this research the furniture industry was chosen, given its use of the forest as raw material – a central theme
of environmental discussion, especially in Brazil that has 4.2 million squared kilometers of Amazon biome, one of the richest ecosystems of the planet in biodiversity.

Wood processing is very labor intensive. The conversion of logs to boards, with different types of cut and techniques for drying the wood must be done in controlled environment to avoid splits and cracks that damage the boards. Its high resistance compared to its specific mass, and the easy workability (low energy, simple machines) made it the favorite material for the furniture industry (MENDES, 2005) and allowed for the development of a great variety of fittings. In the 20th century new technologies were developed to industrialize wood working. The large scale production of plywood allowed wood manufactures to have a better percentage of used material from the log, and furniture manufactures had a stable board always with the same dimensions, marking the beginning of industrial furniture production. The development of new technologies and the shortage of wood supply led to the development of other levels of wood industrialization, such as the particleboard and the medium density fiberboard (MDF). Both materials have a very good ratio of log use (around 1,35 m³ of log to 1 m³ of material) when compared to plywood (2,3 m³ of log to 1 m³ of material) and became standard for large scale furniture industry in Brazil. Along with the high productivity and the fact that is uses sustainable raw material, many times particleboard and MDF are marketed as sustainable products.

Both particleboard and MDF panels are composed by wood material and formaldehyde (a substance classified as carcinogenic by major global health agencies)-based resin. Although technology allows for the formaldehyde to be harmless during the production and use stages, it prevents that the panels have the same destination of wood when disposed.

In Chapter 3 the particleboard and MDF life cycle was described, based on site visits, literature review and interviews, so that, later, possibilities of suitability for the C2C could be evaluated.

A visit was made to a MDF production plant, in the south region of Brazil, and gave a very good notion of the proportion of that sector. In terms of inputs and outputs it was observed that all of the logs used come from forests planted with this purpose, and the MDF waste (from sanding and cutting) is used in internal process to generate energy. The process can be divided in two: turning the logs into fiber, and turning fibers into board.

The practices of the main furniture industries regarding installed equipment, safety measures, types of furniture and waste management were analyzed from literature review. Most of the large scale industries have very similar processes of production, but waste management differs a lot depending on the level of organization of local associations. By lack of information and under a mistaken argument of environmental benefit in various furniture centers sawdust has been used in lining grange, fertilizer for vegetables, or burned without emissions control for energy production (PEREIRA, 2003). Only in Arapongas, Paraná, it was found a waste treatment center (CETEC) maintained by the local furniture industries association. The center receives and treats each kind of waste (ink, solvents, plastic band, sandpaper, and others) according to federal and local legislation. The wood waste is turned into pellets for energy generation (LIMA, 2005).

In terms of use of the furniture it was observed that a piece of furniture can suffer a series of transformations to extend its lifetime such as restoration to its original form or new covering materials, and the reuse is very common, through selling or donating. A piece of furniture is only disposed, and reaches the municipal urban cleaning company when it has no conditions of being reused. In Rio de Janeiro no special treatment is given to wood waste, and the final destination are landfills.

At the end of the study, all of the aspects of C2C were applied to the life cycle of the MDF furniture, including the current solutions given to its waste. Creating composite plastics were not recommended since it can render impossible to recover the fibers, or the plastic, creating products that will loose quality each time they are recycled. Burning was not recommended too, since it generates dioxins, harmful to human health, need very
expensive filtering equipment, and does not represent a closed cycle of materials. Landfill disposal was the solution considered to be the safer, although it also does not configure a closed cycle since the materials are lost indefinitely.

Regarding the suitability of MDF to the biological or technical cycle, biological would be a logical choice since it's made with raw material from forests. As 91% of all produced MDF is covered with plastic, ink or varnish, the compost produced would be contaminated, therefore not compatible to C2C guidelines. It could be a solution for the uncoated 9% that becomes waste in the production plants, although wood degradation is slow and the composting plant would take a large area.

There are recent technologies that can recover fibers from used boards with the same quality, and such process represent a promising opportunity for evaluating the MDF as part of a closed technological cycle.

Even though the potential for closing both biological cycle or technical cycle is good, the use of harmful components in it composition and fragmentation of furniture discard configure big challenges that must be overcome.

To help solve that issue, design should be largely used by industries in order to conceive innovative products that would consider C2C principles from the start. The exploration of new materials such as colored MDF could reduce the need for coating. Combining traditional wood working fittings with modern equipment such as computer numerical control (CNC) machines could create pieces productive and easy to disassemble, making it easier to be collected to a fiber recovery factory, for example.

As final recommendations, it was found that there is a lack of precise data to feed a LCA study that could compare the use of virgin and recovered fibers; the use of formaldehyde should be avoided; coatings represent a threat in the process, so they should be avoided or new coating should be developed considering the C2C process; a transparent certification system should replace the current labels which are not clear; and legislation could compel industries to take a sustainable approach do the MDF lifecycle.

**Keywords**

Solid waste; life cycle; cradle-to-cradle, C2C; furniture, MDF, MDP.