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# INTEGRATING ENVIRONMENTAL PRODUCT DECLARATION INTO ECOLABELING STANDARDS: THE CASE OF WOODEN ARCHITECTURAL COMPONENTS

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**ABSTRACT**

The path to sustainable development requires the involvement of consumers and producers of goods. Ecolabels have emerged as the primary avenue of communication between the main agents within production chains, enabling environmental impact reduction and serving as criteria for consumer choices. However, many labels are not easy to attain (mainly for small businesses), as they demand environmental and safety requirements. Moreover, actual labeling program structures are not practical for public educational institutions to implement, making it more difficult for universities to act as impartial analysts. This research aimed to discuss about the possibility of a new ecolabel, the "Environmental Priority Ecolabel Guarantee", based on criteria used by existing environmental labeling programs and Environmental Product Declaration rules from existing EPD programs. A Brazilian case study was developed involving a sound absorber, which was a wooden architectural product. Qualitative and quantitative descriptions were made based on ecodesign principles and Life Cycle Assessment (LCA), respectively. The case study demonstrated the feasibility of the ecolabels wherein LCA played a key role to guarantee better environmental performance and that is possible for an University to act promoting sustainable development in small and medium enterprises.



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## INTRODUCTION

Since 2002, researchers at the Federal University of Minas Gerais (UFMG) in Brazil have studied small enterprises in the wood and furniture industry to improve their sustainability. As a result, furniture and architectural components for environmental comfort (e.g., sound absorbers, sound diffusers and *brises-soleil*) have been produced out of eucalyptus wood from renewable forests, and some of these products have been licensed to small companies. Over this period, demand has risen for the quality certification of the studied companies' products (Paoliello and Carrasco, 2008). In response to new environmental demands, it has also become necessary to search for ways, such as ecolabeling, that would assure the environmental gains achieved by these new products, which were designed ecologically using proven methods. This demanding behavior for communicate environmental gains is trending worldwide.

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Although the increased relevance on the field of sustainable production and consumption (SPC), ecolabels are mainly a kind of voluntary efforts that one may direct to meet a set of standards. This is based on the assumption that such standards increase legitimacy among stakeholders (Mueller *et al*., 2009), from big to small enterprises in any economical sector. Thus, ecolabeling have become a vehicle that companies use to communicate with consumers, creating competitive advantages for manufacturers and expanding the gamut of user choice. Aligned with that, Delmas *et al*. (2013) affirms that ecolabels are being widely used as a policy tool to provide consumers with information. Consequently, traditional tariff barriers have been replaced by technical barriers to free trade due to the demand for certifications and/or environmental labels for the commercialization of products and services, and these new barriers are becoming a critical economic and trade competitiveness issue (Gottberg *et al*., 2006; Houe and Grabot, 2009; Teisl *et al*., 2002; Thai *et al*., 2010). In addition, more recently, ecolabels have become an important tool for Sustainable Public Procurement (UNEP, 2011 and 2012;

Uttam and Roos, 2014; Zackrisson *et al*., 2008) or to mitigate risk (Castka and Corbett, 2014). There is a wide variety of standards with different requirement levels (Mueller *et al*., 2009). Castka and Corbett (2014) corroborates in the statement that there are currently over 400 ecolabels, or ecolabeling schemes. Analogously with Mueller *et al*. (2009), Castka and Corbett (2014) point that the schemes can vary in different ways including who controls it, who verifies, who is accredited, what it covers, what it demands, among others. For instance, the Leadership in Energy & Environmental Design (LEED) is a certification applied to the building sector regarding to sustainable constructions, while the Forestry Stewardship Council (FSC) is related to forestry practices.

The growing interest and popularity of ecolabels has also been coupled with growing concerns about their credibility, in part because the standard-setting and conformity assessment practices that they adopt exhibit striking differences (Castka and Corbett, 2014), what can jeopardize the reputation of social and environmental standards among stakeholders and their long-term trust in these instruments (Mueller *et al*., 2009). Moreover, specific sectors may find difficulties trying to be framed in existing ecolabeling programs, mainly small companies.

One possible reason for the low number of companies that participate in label programs might be linked to the requirement for safety and use performance tests and the difficulty of maintaining the audit structure. The ISO 14024 – Type I Environmental Labeling standards (ISO, 1999) require that products that apply for the label must comply not only with environmental criteria but also with criteria linked to use and safety. In addition, another barrier may be that the interpretation of labeling schemes often requires expert help (Espinoza *et al*., 2012; Houe and Grabot, 2009), which is an impediment to the participation of small businesses (Clift, 1993). Other possible reason is the lack of credibility that turns out to inhibit investments. It has been proposed that this gap can be narrowed by the use of third-party independent assurance (Castka and Corbett, 2014), where governance plays a key role. In this sense, much have been discussed about credibility in ecolabel market and the means to turn possible its application to other industrial sectors, as small and medium enterprises (SMEs). Universities enjoy high credibility as it does not have, in thesis, commercial interests on private business, alongside retain advanced knowledge on methodological issues and measurement laboratories that can perform technical analysis and reports.

UFMG's prior experiences with the creation of a certification body (Saffar *et al*., 2004) demonstrated the limitations to the implementation of a diversified laboratory and auditing structure designed to meet the requirements of safety and use performance tests that involved an institutional structure that had to be inspected and authorized by a well-known institution of metrology. Given that an ecolabel can effectively communicate the environmental quality of a product, UFMG's research program thus arrived at a major question: how can a category of product (for example, architectural components) that is not included in the existing labeling programs be effectively labeled? In the Brazilian context (but also in other countries), the category of furniture products (including chairs, wood panels, steel furniture for indoor use and office furniture) presented by the ABNT Ecolabel program (ABNT, 2014) is the most similar to the products studied, i.e., wooden architectural components. The decision to instantiate a new label gave rise to other questions: what would the ecolabel criteria be and how could they be defined? Would life cycle assessment (LCA) be required as a criterion?

Research on this topic has been conducted at the UFMG since 2007 and has been aimed at the creation of the "Environmental Priority Ecolabel Guarantee" in an attempt to overcome the non-existence of labels geared toward the sector of wooden architectural components.

The creation of the "Environmental Priority Ecolabel Guarantee" (Fig. 1) is the result of UFMG's researches, developed in projects funded by the National Council for Scientific and Technological Development (CNPq) and the Minas Gerais State Research Foundation (FAPEMIG). These projects aimed to guarantee the environmental quality of products, especially those marketed by microenterprises and small businesses, in an attempt to raise awareness and understanding regarding the environmental aspects of a product, in turn influencing consumer choices.

**Figure 1. 'Environmental Priority Ecolabel Guarantee' seal - http://www.arq.ufmg.br/tau/ecoselo/.**

Initially, the criteria for the environmental assessment of the product and the granting of the Ecolabel were based on five main parameters of the product's life-cycle:

- Obtaining the raw material: renewability, recyclability, degradability, and transport;
- Production: energy consumption, industrial waste control, organization and reuse of waste;
- Use;
- Post-use: recyclability or degradability, adhesives, and varnishes;
- Socioeconomic aspects: valuing of identity, incentive for use of local resources, and valuing of the local workforce.

Some difficulties were encountered in the implementation of these criteria, especially regarding the definition of standards, given the absence of specific norms; the measures for renewability, recyclability, and degradability of specific materials and standards referent to the socioeconomic aspects of the system; as well as the definition of the limits for transport. Therefore, it was determined that the criteria and organization of the label should be in harmony with the ISO 14020 standards – Environmental Labels and Declarations (ISO, 2000). In addition, the adoption of Life Cycle Assessment (LCA) from the ISO 14040 standards (ISO, 2006b,c) was deemed necessary to quantitatively verify the environmental impacts caused as well as the validity of the qualitative decisions made regarding the product's ecodesign. Certainly, ecolabeling schemes have been based on the LCAs of typical products that have incorporated the consideration of:

a) the definition of product group; b) the identification of life cycle impact; c) the evaluation of ways to reduce impacts and; and d) the setting criteria (Clift, 1993). However, Type I Environmental Labeling programs do not generally require the impact of a product to be quantified by LCA; this is not "a compulsory part of the criteria development process in either of the programmes" (Bratt *et al*., 2011). Despite the difficulties encountered in applying LCA, such as the complexity of the data collection and the interaction of different stages of production, the method is accepted as the most important method used to integrate and analyze environmental aspects in product development (Chang *et al*., 2014; Sousa and Wallace, 2006). One possible way of standardizing LCA is to integrate a requirement for companies to make Environmental Product Declarations (EPDs), or Type III labeling stems by ISO 14025 (ISO, 2006a), into the ecolabeling scheme. This is in accordance with the European Commission, which has emphasized the importance of including EPDs in environmental labeling programs, standardizing forms of product information (Zackrisson *et al*., 2008).

Bratt *et al*. (2011) have shown that the "ecolabelling schemes are currently not as effective as they could be to contribute to sustainable production and consumption". They advocate for the expansion of the scope of ecolabeling schemes. Therefore, this work presents an alternative proposal for the drafting of criteria for the "Environmental Priority Ecolabel Guarantee". This idea stems from the presumption that satisfying the ISO 14020 standards is possible by combining the environmental precepts of Type I Labeling with the Environmental Product Declarations of Type III labeling, that is, removing the requirements for products to conform to use and safety regulations, and adding requirements for the presentation of LCA results. The main objective of the study was to create criteria for a new ecolabel allowing for the evaluation and certification of products not covered under the existing labeling programs and then to facilitate the implementation and encourage demand for the ecolabel, especially from microenterprises and small businesses[1]. The study sought to verify whether the establishment of criteria based both on product categories of existing Type I environmental labeling programs and on the presentation of EPDs to quantify impacts based on existing Type III programs is feasible. No previous study was found that compared the labels from ABNT Ecolabel, *NF Environnement*, and EU Ecolabel, nor any that compared the two EPD programs, which all possess criteria for products similar to the studied product. Moreover, defining an ecolabel applicable to small enterprises might be a vital step towards sustainable development, as industry practices will often converge onto practical certification requirements. The present report describes a case study of a wooden sound absorber. The qualitative and the quantitative aspects of this product were evaluated according to ecodesign principles and with LCA against the criteria proposed for the "Environmental Priority Ecolabel Guarantee".

**Conceptual basis – analysis of the iso 14020 series standards:** The requirements for the "environmental self-declarations" (or type II labeling), as defined by the ISO 14021 standards, are not applicable to the interests studied in this work.

### *Environmental labeling programs – ISO 14024 – Type I*

Environmental labeling programs (or type I) are defined by the ISO 14024 standards (ISO, 1999), which define principles and procedures so that the labeled products, when compared to others within the same category, can be identified as environmentally preferable. Type I labeled products must be adequate for the use and satisfaction of consumer needs concerning health, safety, and performance. This directly affects the design of experimental methods and procedures as well as the availability of laboratories, which must abide by well-known systems of standardization, accreditation and certification (Amstel *et al*., 2008). ABNT Ecolabel can assess product under 32 specific procedures (ABNT, 2014). Among these procedures, the criteria detailed in the reference documents "Ecolabel for Wooden Panels" (ABNT, 2013a) and "Ecolabel for Office Furniture" (ABNT, 2013b) are of interest to the present study. The *NF Environnement* label is coordinated by the French Association for Standardization (AFNOR) and sets forth criteria for 49 product categories (AFNOR, 2014), of which the present study focused on the *NF Environnement – Ameublement* label (AFNOR, 2012). The EU Ecolabel for wood furniture is based on regulations set forth by the European Community. Covered products must contain no less than 90% of solid wood or wood derivatives (EU, 2009), which makes this standard relevant for comparison to the architectural components of this study. Table A.1 (see Appendices) presents the basic elements involved in a labeling program, comparing these three labels, as they possess the criteria for products that are similar to the architectural components treated in this work.

### *Environmental Product Declaration – ISO 14025 – Type III*

EPDs (or type III declarations) and their related programs are defined by ISO 14025 standards (ISO, 2006a). These standards refer to business-to-business (B2B) communication but do not preclude a business-to-consumer (B2C) application under specifications. In contrast to Type I labeling, Type III declarations supply quantitative data in the form of predetermined and LCA-derived parameters as well as additional quantitative and qualitative environmental information when relevant. A program of environmental declaration must be based on Product Category Rules (PCRs). Table A.2 (see Appendices) shows the basic elements of environmental declarations and compares the following programs: the Norwegian EPD Norge and the Swedish International EPD® System (Environdec). These two programs present PCRs for many categories of products, among which two are similar to the architectural components treated in this work: the category of building materials – wood and wood-based products for use in construction works (EPD-NORGE, 2013) and the category of forestry, wood, and paper products: builders' joinery and carpentry of wood (ENVIRONDEC, 2011). The EPD Norge program is managed by the Norwegian EPD Foundation (EPD-NORGE, 2014). The International EPD® System is managed by the Swedish Environmental Management Council (ENVIRONDEC, 2014).

## MATERIAL AND METHODS

This research consisted of the study of a specific product: the sound absorber, an architectural component that is composed of more than 90% wood, similar to other products in its category.

[1] The State of Minas Gerais have approximately 20,000 industries registered. Only 15 companies have more than 3,000 employees and 1,000 more than 100 employees, i.e. the majority is microenterprises and small businesses (Costa, 2014)

The product was analyzed a) qualitatively according to ecodesign criteria, and b) quantitatively by performing an LCA on its life-cycle inventory, in preparation for an EPD. These analyses represented the foundation for the drafting of criteria for the "Environmental Priority Ecolabel Guarantee" presented in this article in the Results and Discussion section.

***Qualitative description of the sound absorber – Ecodesign***

The sound absorber (Fig. 2) is an architectural component designed to control the acoustics of built environments for environmental comfort. This product is composed of resonators forming a "wood fabric" made of eucalyptus (*Eucalyptus* sp.), pierced by sisal ropes and spaced by cork washers in such a way as to create a wave-shaped outline with one curved and one straight part. The use of sisal and cork is justified by the substitution of synthetic materials with renewable and more sustainable sourced ones (González-García *et al*., 2013; Mestre and Vogtlander, 2013; Rives *et al*., 2013; Rives *et al*., 2012). Studies have shown that the use of domestic Brazilian cork resources replaces imports from Portugal (Rios, 2007; Souza *et al*., 2013). The proposed format of the sound absorber consists of an air "mattress", which ensures the absorption of sound. The washers prevent the resonators from vibrating with sound waves and create spaces between them, which are responsible for the entrance of sound. The curved portion provides the total absorption of approximately 24 metric sabins and a straight portion of approximately 7 metric sabins. The lateral closure is made of curved wood covered by a bamboo straw braid made by local craftswomen. The models are attached to the wall using a wedge system, which can be arranged according to the space of the environment: in classrooms, party rooms, theaters, and so on. A wide range of visual effects can be achieved with this product, as the module can be mounted in any orientation.

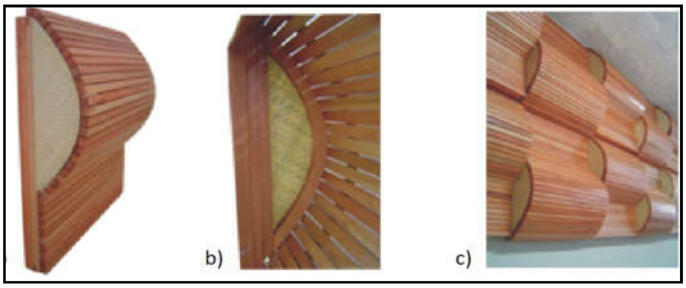


**Figure 2. Sound Absorber (patent pending at National Institute of Industrial Property - INPI); a) unit; b) internal detail; c) installation in a classroom of the School of Architecture / UFMG**

This product was originally designed in research projects at UFMG that sought to increase the competitiveness of microenterprises from the region of Vale do Jequitinhonha, Minas Gerais, Brazil (Pereira, 2013). It was developed according to the principles of ecodesign, in harmony with the principles suggested by the United Nations Environment Programme (UNEP, 2009), bearing in mind the acoustic comfort within the environment, physical and mechanical properties of wood, use functions and product esteem, symbolic values and the creation of identity, the productive process, the market, and the target public. The adopted qualitative criteria for ecodesign refer to: commercial standardization; modularity; ease of installation, use, and maintenance; flexibility; use of renewable and/or natural raw materials; use of water-based finishing products; and a sustainable production process (characterized by reduced inputs, reduced waste, care for worker health, and local development).

***Quantitative description of the sound absorber – LCA***

The sound absorber is a modular product made mainly of eucalyptus wood (93.3%), together with other inputs, such as sisal rope (0.1%), cork washers (0.2%), and screws (0.2%), in addition to other substances used for surface coating (sealer: 1.6%; varnish: 5.2%), a minimal amount of glue, and bamboo braids for side finishing (Table 1)[2]. Environdec (2008) recommend that for EPDs not covering a full life cycle, e.g., for building products where their further fate and function are unknown, which is the case of the sound absorber, the concept of a functional unit (FU) should be translated into terms of so-called Declared Units (DU). A DU is defined as a quantity of a product for use as a reference unit for an environmental declaration based on an information module (ENVIRONDEC, 2013) wherein on architectural components are defined generally as a volume amount (e.g. 1 $m^3$). In this sense, the DU is 1 $m^3$ of sound absorber[3] (Table 1). For the sake of complementation on product system performance, this DU represents 53.3 product units and correspond to the filling of 25.57 $m^2$ for a total sound absorption of 1.65 metric sabins (which can be used as a FU in further studies, for comparative purposes). The system boundaries (Fig. 3) go from 'cradle to gate' and encompass the extraction phase (growth of the tree and obtaining of the log), log-sawing processes (production of sawn and dry timber), and manufacturing of the absorber (including the consumptions of raw materials, energy and fuel inherent to the manufacturing of the final product).

Multi-functionality in the wood manufacturing chain has been discussed worldwide (Dias and Arroja, 2012; Garcia and Freire, 2014; Jungmeier *et al*., 2002a; Jungmeier *et al*. 2002b), as co-products (i.e., wood chips, sawdust, shavings and barks) have other functions outside the system's boundaries (e.g., as fuel or for particle board production). Following Environdec (2008) statement - "the environmental impact connected to the processing of the waste into a resource for a subsequent user rests with the user of the resulting resource" - hence, despite of transportation (that were accounted to the system), those outputs shall be regarded as inputs to the "next" life cycle (Fig. 3). This approach, named Polluter-Pays (PP) by Environdec (2008) is also known as the "cut-off" allocation method (Baumann and Tillman 2004; Ekvall and Tillman 1997; NCASI 2012), and has previously been applied in LCA studies, as in Garcia and Freire, (2014), Gaudreault *et al*. (2009); Spielmann and Althaus (2007); Torrellas *et al*. (2012). The co-products of the log sawing process – wood chips, sawdust, and ground-up bark – and from manufacturing – wood chips, shavings, and sawdust – are not allocated, as they are considered to be processed in other system. The data covering the 'log-sawing' and 'manufacturing' processes were obtained from a primary source, while the data from the 'extraction' phase were obtained from the Ecoinvent database. The timber used to perform the calculations was from

[2]- The Aquaris YL 2140 sealer and the Aquaris YO30 1453 varnish, both water-based solutions commercialized by Syerlack, are applied to the product's final surface finishing. The composition of the sealer includes a solvent, 2-butoxietanol, zinc organic salt, while the varnish contains 2,2,4-trimethyl-1,3-pentanediol-monoisobutyrate, polyethylene wax, dipropyleneglycol, and paraffin, according to the Material Safety Data Sheets (MSDS) provided by Sayerlack. For absorber manufacturing, a small quantity of glue is used, (Casco-Rez® 2500 TN, Hexion), composed of polyvinyl acetate dispersed in water, which is disregarded in this study.

eucalyptus logs with bark (*Eucalyptus* spp. standing, under bark, u=50%, in plantation/TH U), and the model included the $CO_2$ flux associated with the plantation and occupation of the land. Wood forestry data from Ecoinvent presents a $CO_2$ assimilation model based on 49.4% of the carbon in the wood, including the bark (10%), being sequestered (Althaus, 2007).

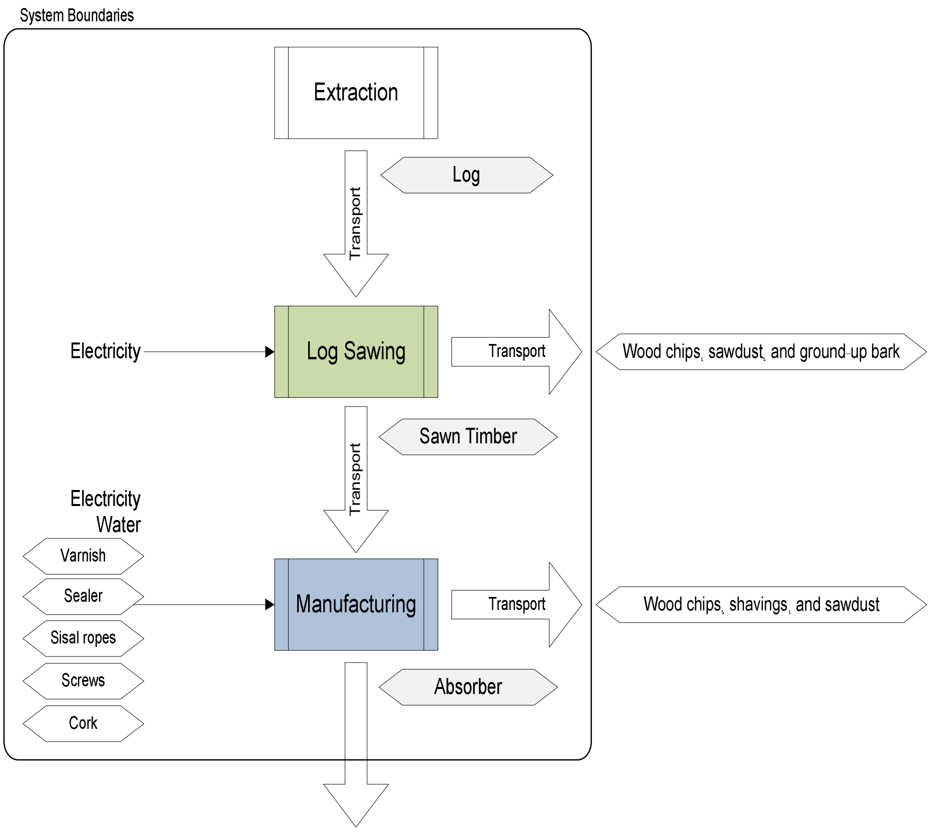


**Figure 3. System boundaries of the sound absorber**

**Table 1. Raw materials used in the sound absorber: suppliers and quantities**

| Raw material (RM) | Name of RM supplier | Location of RM supplier city/state | Quantity (kg RM/kg product) | Quantity (kg RM/declared unit) |
|---|---|---|---|---|
| Eucalyptus timber | Bahia Produtos de Madeira | Nova Viçosa, Bahia (BA) | 0.933 | 962.49 |
| Cork washers | - | BA | 0.002 | 1.76 |
| Sisal ropes | - | BA | 0.001 | 1.07 |
| Screws and nuts | - | São Paulo (SP) | 0.002 | 1.60 |
| Bamboo braid | Local craftswomen | Turmalina, Minas Gerais (MG) | disregarded | - |
| Casco-Rez® 2500 TN Glue | Hexion™ | Curitiba, Paraná (PR) | minimal | - |
| Aquaris YO30 1453 Varnish | Sayerlack | Cajamar, SP | 0.052 | 53.31 |
| Aquaris YL 2140 Sealer | Sayerlack | Cajamar, SP | 0.016 | 16.00 |

**Table 2. Production logistics**

| Material | Location of supplier or receiver of waste city/state/country | Transport (type, capacity, age of truck, cargo in tons.) | Distance traveled (km) | Distance traveled (t.km) |
|---|---|---|---|---|
| Eucalyptus log | Nova Viçosa, BA | Transport lorry, 36t, 2000 to 2010, 27t | 87 | 152.16 |
| Eucalyptus timber | Nova Viçosa, BA | Transport lorry, 16t, 2000 to 2010, 10t | 420 | 404.24 |
| Varnish and sealer | Cajamar, SP | - | 1,100 | 76.24 |
| Log sawing waste | Nova Viçosa, BA | Transport lorry, 7.5 t, 2000 to 2010, 3.7t | 3 | 0.94 |
| Manufacturing waste | Turmalina, MG | Transport lorry, 7.5 t, 2000 to 2010, 3.7t | 3 | 2.36 |

In the specific case of forestry activity, carbon dioxide sequestration during vegetative growth can be considered (ENVIRONDEC, 2011); furthermore, when forest wood is used to make durable goods, carbon is sequestered for even longer (Arzoumanidis *et al*., 2014; González-García *et al*., 2013, PAS 2050, 2011) as in Iritani *et al*. (2014). Although some authors indicate that the carbon stored in these products might eventually be released back into the atmosphere at their end of life (Arzoumanidis *et al*., 2014; Vogtländer *et al*., 2014), that step is not within the system boundaries studied. The inventory survey refers to the quantification of the inputs and outputs from the product system, respecting the mass balance within the established boundaries[3]. The absorbers are manufactured in the city of Turmalina, Minas Gerais, Brazil, using wood produced by the company, Bahia Produtos de Madeira, located in the city of Nova Viçosa in the southern

[3] - The density of sawn timber (*Eucalyptus urograndis*) is 650kg/m$^3$, according to the manufacturer (Bahia Produtos de Madeira, 2014a). For green timber (log), the adopted density was 515 kg/m$^3$, referring to the average between the *E. grandis* and *E. urophila* species, according to Oliveira et al. (2005).

**Table 3. Waste from log sawing and manufacturing processes**

| Material | Destination | Name of waste receiver | Quantity (kg/kg product) | Quantity (kg/functional unit) |
|---|---|---|---|---|
| Wood chips, sawdust, and ground-up bark | Energy generation | Diverse | 0.45 | 787.46 |
| Wood chips, shavings, and sawdust | Energy generation | Brick Manufacturers in Turmalina, MG | 0.32 | 312.14 |

**Table 4. Criteria for 'Environmental Priority Ecolabel Guarantee' and its application**

| Proposed Criteria | Reference | Sound absorber (application) |
|---|---|---|
| Criterion 1: Product Description<br>The product must be made of at least 90% solid wood or a wood-based material; easily replaceable glass and installation materials can be excluded from the calculation; the weight for each of the other materials may not exceed 3% of the product's weight. | Data presented in the EPD. | Presentation of EPD (below in Table 7):<br>- The sound absorber is made of at least 93.3% Eucalyptus wood. |
| Criterion 2: Hazardous substances<br>a) Product may not contain hazardous substances in any of the following risk (R)-phrases: R23, R24, R25, R26, R27, R28, R39, R40, R42, R43, R45, R46, R48, R49, R50, R51, R52, R53, R60, R61, R62, R63, R68;<br>b) Product may not contain halogenated organic bindings, azidirins, polyaridirins, or pigments or additives containing lead, cadmium, chrome, mercury, arsenic, boron, copper or organostannic compounds;<br>c) Only flame retarders that are chemically linked to the material or on the surface (reactive retarders) may be used, and the product may not contain substances in any of the following R-phrases: R40, R45, R46, R49, R50, R51, R52, R53, R60, R61, R62, R63, R68. | R-phrases: European Guidelines 67/548/EEC and 1999/45/CE.<br><br>ABNT/NBR 14725 Standards- Chemical products–Information on safety, health, and environment: Part 1: Terminology, Part 3: Labelling, Part 4: Material Safety Data Sheets - MSDS<br><br>Environmental operating permits – according to Resolution 237/1997 (National Council for the Environment - CONAMA) and relevant state laws.<br><br>Hazardous Waste:<br>Brazilian Decree 4.581/2003: Basel Convention.<br>Resolution 313/2002: National Inventory of Solid Industrial Waste (CONAMA).<br>- ABNT/NBR 10004 Standards- Solid Waste– Classification. | Presentation of MSDS – ABNT/NBR 14725:<br>Water-based acrylic varnish:<br>- 2,2,4-trimetil-1,3-pentanodiol-monoisobutyrate, CAS: 25265-77-4, R-Phrases: N.a. (Not available)<br>- polyethylene wax, CAS: 9002-88-4, R-Phrases: N.a.<br>- dipropyleneglycol, CAS: 25265-71-8, R-Phrases: N.a.<br>- paraffin, CAS: 8002-74-2, R-Phrases: N.a.<br>Water-based acrylic sealer:<br>- 2-butoxyethanol, CAS: 111-76-2,<br>R-Phrases: R20/21/22; R37<br>- zinc organic salt, CAS: 557-05-01, R-Phrases: N.a.<br><br>Presentation of Environmental License and Environmental Operating Permit, according to Decree 44.844/2008 (Minas Gerais, Brazil), Normative Deliberation 74/2004, (State Council for Environmental Policy - COPAM-MG, Brazil) and State Law 13.796/2000 (Minas Gerais, Brazil). |
| Criterion 3: Requirements regarding wood and wood-based materials<br>a) Sustainable forest management;<br>b) Use of waste, wood chips, or wood fibers in the production of wood-based materials according to the limit of chemical contamination (EPF Standard);<br>c) Product must not be treated with impregnating chemicals or preservatives, and the wood must not be treated with hazardous products (Criterion 2);<br>d) Wood panels must not contain hazardous products (Criterion 2);<br>e) Formaldehyde emissions must be controlled;<br>f) Product may not contain genetically modified wood. | Brazilian National Forest Certification Program – CERFLOR<br>Forest Stewardship Council (FSC, Certification<br>EPF Standard for delivery conditions of recycled wood.<br>ABNT/NBR 14810-2 –Particle panels of medium density - Part 2: Requirements and laboratory test methods (MDP).<br>ABNT/NBR 15316-3 –fiberboards of medium density - Part 3 - laboratory test methods (MDF)<br>ABNT/NBR ISO 12466-1 -Plywood – high quality glue - Part 1: laboratory test methods.<br>ABNT/NBR 10024 –Hardwood fiberboards – Requirements and laboratory test methods. | Presentation of Cerflor of the origin of the wood in Chain of Custody Certification, according to: ABNT/NBR 14790 –Sustainable forest management — Chain of Custody.<br>This process uses hardwood Eucalyptus *urograndis*, a hybrid of the *E. grandis* and *E. urophyla* species. This mixture is performed by a natural process (pollination, grafting, cuttings, etc.) to obtain a final product that is appropriate for use. |
| Criterion 4: Surface treatment and finishing<br>a) Surface treatment with plastics or metals may not exceed 2% of the product weight;<br>b) Other treatments are limited to 5% volatile organic compounds (VOC); the quantity of substances that are toxic to the environment (painting and varnish) must be limited to 14 $g/m^2$ of the covered surface and 35 $g/m^2$ for VOCs;<br>c) The formaldehyde emissions must be limited to 0.05 ppm;<br>d) If there are plasticizers, the phthalates must be considered hazardous products. DNOP (di-*n*-octylphthalate), DINP (diisononyl phthalate), and DIDP (diisodecylphthalate) may not be used;<br>e) Biocides must be used with restrictions. | ABNT/NBR 14535 –wood furniture – requirements and laboratory test for painted surfaces.<br>ABNT/NBR 16256 –Determination of theoretical calculation of VOCs in adhesives and sealers – LEED Method.<br>ABNT/NBR 16257 –<br>Determination of the theoretical calculation of the VOC in adhesives and sealers – MIR method.<br>ABNT/NBR 11702 –Corrected Version: 2011 –Paints for construction works – Paints for non-industrial buildings – Classification. | Presentation of MSDS according to ABNT/NBR 14725 (see above).<br><br>The treatment and finishing of product surfaces are performed with water-based acrylic sealer and acrylic varnish, respectively. |
| Criterion 5: Product assembly<br>a) Adhesives and glues must not contain hazardous products (Criterion 2);<br>b) The VOC content of adhesives and glues must not surpass 5% (p/p). | Idem: ABNT/NBR 16256.<br>Idem: ABNT/NBR 16257. | Used a small amount of adhesive (Casco-Rez® 2500 TN, Hexion), composed of polyvinyl acetate dispersed in water. |

**Table 5. Environmental Product Declaration – EPD**

| PCR | Sound Absorber | | | | |
|---|---|---|---|---|---|
| Company description | *EcopoloJequitinhonha*, consortium consisting of five microenterprises from Turmalina, Vale do Jequitinhonha, MG, Brazil. | | | | |
| Product Characteristics | Dimension: 690x690x220 mm; Eucalyptus wood (Lyptus); weight: 12.2; environmental sound absorption. Its production aims to enhance local development. | | | | |
| Composition | Eucalyptus wood | 93.3% | | | |
| | Cork washers | 0.2% | | | |
| | Sisal ropes | 0.1% | | | |
| | Screws and nuts | 0.2% | | | |
| | Bamboo braids | - | | | |
| | Casco-Rez® 2500 TN Glue | - | | | |
| | Aquaris YO30 1453 Varnish | 5.2% | CAS: 25265-77-4, R-Phrases: N.a.<br>CAS: 9002-88-4, R-Phrases: N.a.<br>CAS: 25265-71-8, R-Phrases: N.a.<br>CAS: 8002-74-2, R-Phrases: N.a. | | |
| | Aquaris YL 2140Sealer | 1.6% | CAS: 111-76-2, R20/21/22; R37<br>CAS: 557-05-01, R-Phrases: N.a. | | |
| Methodology | LCA: ISO (2006b) 14040 and 14044 (2006c); CML-IA, 2013 (PRéConsultants, 2013); Supporting annexes for EPDs. The International EPD Cooperation (ENVIRONDEC, 2008); Potential; PCR for "builders' joinery and carpentry of wood (including cellular wood panels, assembled parquet panels, shingles, and shakes)" (ENVIRONDEC, 2011). | | | | |
| Functional unit | 25.57 m² for a total sound absorption of 1.65 metric sabins | | | | |
| Declared unit | 1m³ (ENVIRONDEC, 2011) | | | | |
| System limits | Upstream module, which includes the "cradle to gate" processes (mainly from the data of supply-chain); the Core module, which includes the "gate to gate" processes (from the manufacturing phase data). | | | | |
| Data Quality | Upstream processes:<br>- Data collected on site: log extraction process and wood transformation into board (*Eucalyptus*spp., standing, under bark, u=50%, in plantation/THA U)<br>- Data from the contractor, elements: cork (Cork, raw {GLO} \| Market for \| Allocdef, U), wire sisal (Yarn, jute {GLO} \| Market for \| Allocdef, U), screw (Steel, low-alloyed, at plant/RER U), varnish (Paraffin, at plant/RER U; Dipropylene glycol monomethyl ether, at plant/RER U, Water, river/BR and general organic chemical for data were lacking) and sealer (Water, river/BR; and general organic chemical for data were lacking).<br>- Transport of main parts and elements along the supply-chain included.<br>- Due to a lack of data, sealer and two elements of varnish (2,2,4-trimethyl-1,3-pentanediol monoisobutyrate and polyethylene wax) were considered to be general organic chemicals (organic chemical, at plant/GLO. U).<br>Core Processes:<br>- Goods: Site-specific data collected for manufacturing process.<br>- Services: secondary data from Ecoinvent database used for: electricity (Electricity, medium voltage, production, at grid/BR U) and diesel consumption (Diesel, at regional storage/RER U).<br>- Transport is based on the actual transport mode, distance from the supplier and vehicle cargo load (Transport Lorry, 3.5-7.5t, EURO 3/RER U; Transport Lorry, 7.5-16t, EURO 3/RER U; Transport Lorry, >32t, EURO 3/RER U). | | | | |
| Impact potential (Declared unit) | | | Upstream | Core | Total |
| | Gross Energy Demand | MJ eq. | 5.52E+04 | 4.94E+03 | 9.01E+04 |
| | Global warming (GWP 100) | ton. $CO_2$ eq | -5.45 | 0.23 | -5.22 |
| | Ozone layer depletion (ODP) | kg CFC $11^-$ eq | 1.07E-05 | 3.02E-05 | 4,09E-05 |
| | Photochemical oxidation | kg $C_2H_4$ eq | 0.032 | 0.045 | 0.077 |
| | Eutrophication | kg $PO_4$ eq | 0.096 | 0.207 | 0.302 |
| | Acidification | kg $SO_2^{3-}$ eq | 0.26 | 0.75 | 1.00 |
| Use of resources, waste, other indicators | Majority use of renewable resources: wood from planted forest, sisal, cork, and bamboo. Water-based finishing products. Waste reused for energy generation and the substitution of charcoal. | | | | |
| Further information | Product manufacturing seeks to increase the competitiveness of microenterprises. Buys from local handcraft industries, enhancing the possibility of social gains. | | | | |

region of the state of Bahia, 420 km from Turmalina (Table 2). Regarding production flows, to reach the final weight of an absorber unit (12.2 kg), 32.82 kg of wood is consumed. In the process of log-sawing to obtain sawn timber, a loss of 14.77 kg (45%) occurs, while in the manufacturing process, there is a loss of 5.85 kg (32.4%). That comes to a total loss about approximately 62.8%. These losses were calculated according to primary data obtained in the manufacturing processes, as well as from data reported in prior literature (Vieira, 2006; Lima and Silva, 2005; Brito, 1995). On a DU basis, to produce 1 $m^3$ of absorbers (650.34 kg), 962.49 kg and 1,749 kg of timber and log are necessary in the processes of sawing and extraction, respectively. The logistics, including distances and main flows, are described in Table 2. Regarding manufacturing processes (core), 360.3 kW.h is consumed for log processing and 395.9 kW.h during the operation of sliding table saw, regular saw, electric planer, drill and sander, and finishing spray guns. The dilution of the sealer and varnish also consumes water (10.26 liters). Fig. 3. The losses incurred during the log-sawing and manufacturing processes are considered waste (Table 3).

In the log-sawing process, the waste is generally used for energy generation (Bahia Produtos de Madeira, 2014b). In the manufacturing process, the waste is sent and/or donated to brick manufacturers of the region, also for energy generation, according to information provided by the manufacturer. To achieve a quantitative understanding of the environmental impacts, the LCA method was applied, using the SimaPro 8.0 software, employing the CML-IA method of life cycle impact assessment (PRé Consultants, 2013), with the insertion of the single issue category of Cumulative Energy Demand and with characterization methods modified according to those set forth by Environdec (2008) for the categories of global warming, acidification, eutrophication, depletion of the ozone layer, photochemical oxidation, and energy demand itself. The results of the calculation of the balance of the impacts will be presented later in this text (item 4.2) within the EPD.

## RESULTS AND DISCUSSION

The justification for the proposal presented below is based on the aforementioned studies, according to which it is possible to affirm the feasibility of the combination of environmental criteria defined according to the Labeling Programs Type I (ISO 14024), together with the adoption of the EPD Type III (ISO 14025), given the following:

1) Fully meeting the ISO 14024 standards renders the proposal unfeasible, given the requirements for products to conform to use and safety regulations, as well as the need for a large, inspected, and authorized laboratory structure;
2) The quantitative assessment of the impacts presented by LCA results, even the LCAs do not present standards of limits to be achieved, is important for a more complete analysis of the system. Cobut *et al*., (2013) attested to the importance of LCA in ecolabeling processes, where companies' interest in presenting environmental declarations about their products has been growing, spurred on by the expansion of ISO 14025 standards in recent years. This indicates a possible standardization of LCA results for comparisons in the near future.

The criteria presented in Table 4 concerning the "Environmental Priority Ecolabel Guarantee" illustrate their application in the category of wooden architectural components, examining the sound absorber as a case study.
Such criteria are based on the parameters adopted by the European Ecolabel for wood furniture (EU, 2009), the ABNT Ecolabel for Office Furniture (ABNT, 2013c), as well as PCRs defined by the International EPD® System (ENVIRONDEC, 2011) for builders' joinery and carpentry of wood. This proposal encompasses wooden architectural components, including components for environmental comfort (e.g., sound absorbers, *brises-soleil*), wood flooring, wall coatings, doors and window frames, stairwells, furniture, and other such finished products. The LCA results on a DU basis are shown in Table 5. Regarding each module's contribution to the overall impact, the core module (i.e., manufacturing processes) is responsible for most of the environmental impacts, as it generates 74% of the acidification impact, 68% of the eutrophication impact, offsets 4% of the carbon sequestered by upstream processes, emits 74% of the CFC equivalent to the ozone layer depletion impact category and is responsible for 59% of the photochemical oxidation. The exception is energy demand; the upstream module is responsible for 95% of the energy consumption.

The negative life-cycle Global Warming impact reflects that forest carbon has been sequestered from the atmosphere, which remains sequestered in the final product until it is discarded, whereupon it might be incinerated, returning the carbon to environment. Several LCAs of (architectural) wood products have shown similar behavior as in Iritani *et al*. (2014), Salazar and Meil (2009), and Vogtländer *et al*. (2014). Measures to decrease impacts should therefore be directed at core processes, as major impacts originated from product manufacturing. In this sense, reductions of electricity and fossil fuel consumption at all levels should be highly encouraged. Like other environmental labels based on LCA, this implementation begins by only requiring that the LCA system boundaries include the acquisition of raw materials and manufacturing processes (upstream and core, respectively). Additional simplifications are proposed, such as the cut-off approach to handle with the multi-functionality of products. These simple measures are designed to encourage businesses to begin the ecolabeling process, which will lead to the better environmental performance of products and processes. After initial implementation, the requirements should become more stringent and should include other life cycle steps, other impact categories, and other methodological procedures (e.g., sensibility and uncertainty analysis) to enhance the decision making process.

**Conclusions**

This article presents the proposed criteria for "Environmental Priority Ecolabel Guarantee" labeling, as a discuss about the possibility of a new ecolabel to be implemented at UFMG, a public university. The application of the proposed criteria to an actual product has been studied, underlining the limits of the criteria and the importance of the use of LCA. Further, when progressively implemented, the label standards will provide comparative results that indicate environmentally preferable choices on both the B2B and the B2C levels as well as provide data that are useful for mitigating the environmental impact of the production chains at small and medium size corporations. Within this perspective, Product Category Rules (PCR) play a key role to guarantee a comparative basis between LCAs. The managerial contribution of this research has been the development of procedures that can be reproduced in other product categories. The implementation of a labeling system that has main criteria that include principles from labeling programs (Type I) and from environmental declarations (Type III) is feasible for a public university, complies with its core mission and builds collaboration with industry by disseminating information about businesses' environmental practices, especially microenterprises and small businesses.

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## REFERENCES

ABNT, 2013a. Ecolabel for Wood Panel: PE-205.04 (in Portuguese). Associação Brasileira de Normas Técnicas. Rio de Janeiro. http://rotulo.abnt.org.br/index.php/criterio?option=com_content&view=category&id=191&Itemid=207&select_item=73_191 (accessed on February 2014).
ABNT, 2013b. Ecolabel for Office Furniture: PE-165.03 (in Portuguese). Associação Brasileira de Normas Técnicas. Rio de Janeiro. http://rotulo.abnt.org.br/index.php/criterio/239-uncategorised/categorias-criterio/produtos-mobiliarios/671-pe-165-03 (accessed on February 2014).
ABNT, 2014. Ecolabel ABNT - recognition and transparency / Criteria. Associação Brasileira de Normas Técnicas. Rio de Janeiro. http://www.abnt.org.br/rotulo/en/ (accessed on February 2014).
AFNOR, 2012. NF Environment Furniture – NF 217 (in French). Association Française de Normalisation. Paris. (accessed on February 2014).
AFNOR, 2014. NF Environment /categories of products or services certified (in French). Association Française de Normalisation. Paris. http://www.ecolabels.fr/fr/recherche-avancee/categories-de-produits-ou-services-certifies (accessed on February 2014).

Arzoumanidis, I., Fullana-i-Palmer, P., Raggi, A., Gazulla, C., Raugei, M., Benveniste, G., Anglada, M. 2014. Unresolved issues in the accounting of biogenic carbon exchanges in the wine sector. Journal of Cleaner Production 82, 16–22.

Authaus, H.J. 2007. Life Cycle Inventories of Renewable Materials. Data v.2.0. Ecoinvent Report No. 21. 127 p.

Bahia Produtos de Madeira, 2014a. Guide of Lyptus products (in Portuguese). http://www.lyptus.com.br/Guia_Produtos_Lyptus_v19.pdf (accessed on February 2014).

Bahia Produtos de Madeira, 2014b. By-product (in Portuguese). http://www.lyptus.com.br/subprodutos.php (accessed on February 2014).

Baumann, H. Tillman, A.M. 2004. The Hitch Hiker's Guide to LCA. Studentlitteratur AB – Lund - Sweden. 543 p.

Bratt, C., Hallstedt, S., Robèrt, K.-H., Broman, G., Oldmark, J. 2011. Assessment of ecolabelling criteria development from a strategic sustainability perspective. Journal of Cleaner Production 19, 1631-1638. http://dx.doi.org/10.1016/j.jclepro.2011.05.012

Brito, E. O., 1995. Estimation of waste production in the Brazilian industry sawmill and wood lamination (in Portuguese). Revista da Madeira, Curitiba, ano IV, n. 26, p. 34–39.

BSI, British Standards Institution. 2011. PAS 2050: 2011 Specification for the assessment of the life cycle greenhouse gas emissions of goods and services. BSI, London.

Castka, P; Corbett, C.J. 2014. Governance of EcoLabels: Expert Opinion and Media Coverage. J Bus Ethics, 2014.

Chang, D., Lee, C.K.M., Chen, C-H. 2014. Review of life cycle assessment towards sustainable product development. *Journal of Cleaner Production,* 83, 48-60. http://dx.doi.org/ 10.1016/j.jclepro.2014.07.050

Clift, R. 1993. Life cycle assessment and ecolabelling. *Journal of Cleaner Production.* 1 (3-4), 155–159.

Cobut, A., Beauregard, R., Blanchet, P. 2013. Using life cycle thinking to analyze environmental labeling: the case of appearance wood products. *International Journal of Life Cycle Assessment,* 18-3:722–742. http://dx.doi.org/10.1007/s11367-012-0505-9

Costa, W. 2014. Seminar about Sustainable Consumption and Production in 3rd December 2014 in Belo Horizonte, MG (personnal communication).

Delmas, M.A; Nairn-Birch, N; Balzarova, M. Choosing the Right EcoLabel for Your Product. Magazine: Summer 2013. Research Highlight June 18, 2013.

Dias, A.C; Arroja, L. 2012. Environmental impacts of eucalypt and maritime pine wood production in Portugal. Journal of Cleaner Production 37, 368–376.

Ekvall, T; Tillman, A.M. 1997. Open-Loop Recycling: Criteria for Allocation Procedures. *International Journal of LCA* - 2 (3), 155–162.

EN, 2012. EN15804 – Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products. European Standard.

ENVIRONDEC, 2008. Supporting annexes for Environmental Product Declarations – EPD. The International EPD Cooperation. http://www.environdec.com/Documents/GPI/EPD_annexes_080229.pdf (accessed on April 2014).

ENVIRONDEC, 2011. Builders' joinery and carpentry of wood (including cellular wood panels, assembled parquet panels, shingles and shakes). http://environdec.com/en/PCR/Detail/?Pcr=8112#.UwdkBWJdU2A (accessed on February 2014).

ENVIRONDEC, 2013. General Programme Instructions for the International EPD® System 2.01. http://www.environdec.com/Documents/GPI/General_programme_instructions_2_01_20130918.pdf (accessed on May 2014).

ENVIRONDEC, 2014. The International EPD® System. http://www.environdec.com/en/The-International-EPD-System/#.UwdSNWJdU2A (accessed on February 2014).

EPD-NORGE, 2013. Wood and wood-based products for use in construction. http://www.epd-norge.no/getfile.php/PDF/PCR/NPCR%20015%20Wood%20and%20wood-based%20products%20for%20use%20in%20construction.pdf (accessed on February 2014).

EPD-NORGE, 2014. EPD Norway. http://www.epd-norge.no/category.php?categoryID=578 (accessed on February 2014).

Espinoza, O., Buehlmann, U., Smith, B. 2012. Forest certification and green building standards: overview and use in the U.S. hardwood industry. *Journal of Cleaner Production* 33, 30–41. http://dx.doi.org/10.1016/j.jclepro.2012.05.004

EU Ecolabel, 2014. The EU Ecolabel. http://ec.europa.eu/environment/ecolabel/ (accessed on February 2014).

EU, 2009. Application pack for the ecolabel - Application form for wooden furniture. European Union. http://ec.europa.eu/environment/ecolabel/documents/applicationpack_furniture.pdf (accessed on February 2014).

Gaudreault, C; Samson, R; Stuart, P. 2009. Implications of choices and interpretation in LCA for multi-criteria process design: de-inked pulp capacity and cogeneration at a paper mill case study. *Journal of Cleaner Production* 17, 1535–546.

González-García, S., Dias, A.C. and Arroja, L., 2013. Life-cycle assessment of typical Portuguese cork oak woodlands. *Science of the Total Environment* 452–453, 355–364. http://dx.doi.org/10.1016/j.scitotenv.2013.02.053

González-García, S., Krowas, I., Becker, G., Feijoo, G., Moreira, M.T. 2013. Cradle-to-gate life cycle inventory and environmental performance of Douglas-fir roundwood production in Germany. *Journal of Cleaner Production* 54,24–252.

Gottberg, A., Morris, J., Pollard, S., Mark-Herbert, C., Cook, M., 2006. Producer responsibility, waste minimization and the WEE Directive: case studies in ecodesign from the European lighting sector. *Science of the Total Environment* 359, 38–56. http://dx.doi.org/10.1016/j.scitotenv.2005.07.001

Houe, R., Grabot, B. 2009. Assessing the compliance of a product with an ecolabel: From standards to constraints. *International Journal of Production Economics* 121, 21–38. http://dx.doi.org/10.1016/j.ijpe.2008.03.014

Iritani, D.R., Silva, D.A.L., Saavedra, Y.M.D., Grael, P.F.F., Ometto, A.R., 2014. Sustainable strategies analysis through Life Cycle Assessment: a case study in a furniture industry. *Journal of Cleaner Production* (article in press), 1–11.

ISO, 1999. ISO 14024: Environmental labels and declarations – Type I environmental labeling –Principles and procedures. International Organization for Standardization.

ISO, 2000. ISO 14020: Environmental labels and declarations – General principles. *International Organization for Standardization.*

ISO, 2006a. ISO 14025: Environmental labels and declarations – Type III environmental declarations principles and procedures. *International Organization for Standardization.*

ISO, 2006b. ISO 14040: Environmental Management – Life Cycle Assessment – Principles and framework. International Organization for Standardization.

ISO, 2006c. ISO 14044: Environmental management – Life cycle assessment - Requirements and guidelines. International Organization for Standardization.

ISO, 2007. ISO 21930: Provides the principles and requirements for type III environmental declarations (EPD) of building products. International Organization for Standardization.

Jungmeier, G., Werner, F., Jarnehammar, A.C., 2002a. Allocation in LCA of wood- based products, experiences of cost action E9, Part I. Methodology. *Int. J. Life Cycle Assess.* 7 (5), 290–294.

Jungmeier, G., Werner, F., Jarnehammar, A.C., Hohenthal, C., Richter, K., 2002b. Allocation in LCA of wood-based products, experiences of cost action E9, Part II. Examples. *Int. J. Life Cycle Assess.* 7 (6), 369–375.

Lima, E.G., Silva, D. A., 2005. Generated waste wood furniture industries located in the furniture center of Arapongas-PR (in Portuguese). *Revista Floresta. Curitiba*: v. 35, n. 01.

Mestre, A., Vogtlander, J., 2013. Eco-efficient value creation of cork products: an LCA-based method for design intervention. *Journal of Cleaner Production* 57, 101–114. http://dx.doi.org/10.1016/j.jclepro.2013.04.023

Mueller, M; dos Santos, V.G; Seuring, S. 2009. The Contribution of Environmental and Social Standards Towards Ensuring Legitimacy in Supply Chain Governance. *Journal of Business Ethics* (2009) 89: 509–523.

NCASI. 2012. Methods for Open-Loop Recycling Allocation in Life Cycle Assessment and Carbon Footprint Studies of Paper Products. Technical Bulletin No. 1003. Research Triangle Park, N.C.: National Council for Air and Stream Improvement, Inc. 106 p.

Oliveira, J.T. da S.; Hellmeister, J. C.; Tomazello Filho, M., 2005. Variation of the moisture content and specific gravity in the wood of seven eucalypt species (in Portuguese). Revista Árvore, Viçosa-MG, 29 (1), 115–127.

Paoliello, C., Carrasco, E.V.M., 2008. Chair load analysis during daily sitting activities. *Forest Products Journal*, 58, 28–31.

Pereira, A.F., 2013. Ecodesign, sustainability and action research: valuing the use of eucalyptus timber at Jequitinhonha Valley (MG - Brazil). *Journal of Design Research,* 11, 91–106. http://dx.doi.org/10.1504/JDR.2013.054070

PRé Consultants, 2013. SimaPro database manual: Methods library. Report version 2.5 [online] http://www.pre-sustainability.com/download/DatabaseManualMethods-oct2013.pdf (accessed on December 2013).

Rios, P.D'A., 2007. Technological characterization and production of cork panels *Kielmeyera coriácea* (pau-santo) (in Portuguese). Thesis, Universidade Federal de Lavras.

Rives, J., Fernandez-Rodriguez, I., Rieradevall, J. and Gabarrell, X., 2012. Environmental analysis of raw cork extraction in cork oak forests in southern Europe (Catalonia e Spain). *Journal of Environmental Management* 110, 236–245. http://dx.doi.org/10.1016/j.jenvman.2012.06.024.

Rives, J., Fernandez-Rodriguez, I., Rieradevall, J. and Gabarrell, X., 2013. Integrated environmental analysis of the main cork products in southern Europe (Catalonia e Spain). *Journal of Cleaner Production* 51, 289–298. http://dx.doi.org/10.1016/j.jclepro.2013.01.015

Saffar, J. M. E.; Carrasco, E. V. M.; Pereira, A. F.; França, L. R.G.; Sommer, R. M.R.; Oliveira, A. L. C.; Brescia, E. A., 2004. Social inclusion through product certification: structuring Xilon Institute Foundation (in Portuguese). Congresso ABIPIT 2004, Belo Horizonte.

Salazar, J., Meil, J. 2009. Prospects for carbon-neutral housing: the influence of greater wood use on the carbon footprint of a single-family residence. *Journal of Cleaner Production* 17,1563–1571.

Sousa, I., Wallace, D. 2006. Product classification to support approximate life-cycle assessment of design concepts. *Technological Forecasting and Social Change*, 73 (3), 228-249.

Souza, E.R.B., Naves, R.V., Oliveira, M.F., 2013. Start of production of fruits cagaiteira (*Eugenia dysenterica* DC) in Goiânia, Goiás (in Portuguese). Revista Brasileira de Fruticultura, Jaboticabal - SP, 35 (3), 906–909.

Spielmann, M; Althaus, H.J. 2007. Can a prolonged use of a passenger car reduce environmental burdens? Life Cycle analysis of Swiss passenger cars. *Journal of Cleaner Production* 15, 1122–1134.

Teisl, M.F., Rubin, J., Noblet, C.L. 2008. Non-dirty dancing? Interaction between ecolabels and consumers. Journal of Economic Psychology, 29 (2), 140–159. http://dx.doi.org/10.1016/j.joep.2007.04.002

Thai V.N., Morioka, T., Tokai, A., Yamamoto, Y., Matsui, T. 2010. Selection of product categories for a national ecolabelling scheme in developing countries: a case study of Vietnamese manufacturing sub-sectors. *Journal of Cleaner Production* 18 (2010) 1446–1457. http://dx.doi.org/10.1016/j.jclepro.2010.05.013

Torrellas, M; Antón, A; Ruijs, M; Victoria, N.G; Stanghellini, C; Montero, J.I. 2012. Environmental and economic assessment of protected crops in four European scenarios. *Journal of Cleaner Production* 28, 45–55.

UNEP, 2009. Design for Sustainability: A step-by-step approach. United Nations Environment Programme and Delft University of Technology.

UNEP. 2011. Paving the way for sustainable consumption and production: the Marrakech Process progress report: towards a 10-Year Framework of Programmes on Sustainable Consumption and Production. Paris: United Nations Environment Programme.

UNEP. 2012. Sustainable public procurement implementation guidelines: introducing UNEP's approach. Paris: United Nations Environment Programme.

Uttam, K. and Roos, C.L.L. 2014. Competitive dialogue procedure for sustainable public procurement. Journal of Cleaner Production. http://dx.doi.org/10.1016/j.jclepro.2014.08.031

Vieira, R.S., 2006. Small Objects of Eucalyptus Wood: possibility of use of waste. (Dissertation) (in Portuguese). Mestrado em Engenharia Florestal, Universidade Federal de Lavras.

Vogtländer, J.G., Van der Velden, N.M., Van der Lugt, P. 2014. Carbon sequestration in LCA, a proposal for a new approach based on the global carbon cycle; cases on wood and on bamboo. *International Journal of Life Cycle Assessment,* 19: 13–23

Zackrisson, M., Rocha, C., Christiansen, K., Jarnehammar, A. 2008. Stepwise environmental product declarations: ten SME case studies. *Journal of Cleaner Production* 16, 1872–1886. http://dx.doi.org/10.1016/j.jclepro.2008.01.001

## Appendices

**Table A.1. Basic elements for the Labeling Program, ISO 14024 standards: comparison of the ABNT Environmental Quality, NF Environnement, and EU Ecolabel labels**

| Stage | ABNT Environmental Quality | NF Environnement | EU Ecolabel |
|---|---|---|---|
| Product description | Office furniture | Home or professional furniture | Inside and outside home furniture and commercial furniture |
| Solicitation procedures | Signing of proposal and contract, analysis of the documentation, technical visit. | Forwarding of documentation. Must have quality management system. | Forwarding of documentation, including declarations: use of materials by producers and suppliers, and Laboratory Test Reports. |
| Meeting the criteria | Adequacy to the use;<br>Raw material: wood derivatives, hazardous substances, formaldehyde content, use of fabric;<br>Manufacture process;<br>Packaging;<br>Final destination;<br>Distribution;<br>Energy and water;<br>Environmental legislation;<br>Labor, anti-discriminatory, and safety regulations. | Adequacy to the use;<br>Use of wood species;<br>Origin and traceability of the wood;<br>Non-use of genetically modified wood;<br>Formaldehyde emission by wood fiberboard;<br>Percentage of recycled material;<br>Acquisition of textiles;<br>Use of flame retardants;<br>Phthalates;<br>Nanomaterials;<br>Packaging;<br>Volume optimization: transport and storage;<br>Product use attitude;<br>Energy economy integrated to product;<br>User information;<br>Consumer services;<br>Materials separation;<br>Recommendation for the recycling of plastic;<br>End-of-life Furniture collection;<br>Specific energy limitations;<br>Assessment of $CO_2$ emissions. | Product composition: 90% wood or wood derivative;<br>Hazardous substances;<br>Wood and wood-based materials;<br>Surface finishing;<br>Product assembly, including adhesives;<br>End-of-life: durability, safety, maintenance, recycling and waste, information provided to the consumer, finished product packaging, information on the packaging, information on the label. |
| Laboratory tests | ABNT is responsible for the selection of laboratories. Laboratories authorized by Inmetro (National Institute of Meteorology, Quality, and Technology) need not be assessed. | Laboratory Test Reports must be carried out per independent laboratory with authorization from AFNOR. | Laboratory tests and analyses carried out by laboratories authorized according to ISO 17025 standards. Other laboratories must be analyzed. |
| Audit inspections | Pre-inspections are optional; Certification inspection: assessment of products and meeting of technical criteria and legal requirements, sample collection, and laboratory tests; Initial quality assessment. | Initial inspection: assessment of conformity to the required criteria and processes. In the case of outsourcing, it may require an inspection of the quality system of the third party. Complementary control may also occur. | Visits are scheduled on a case by case basis. |
| Concession of the label | Approval or denial with corrective actions for the granting of permission to use the company logo on the product.<br>Maintenance inspections with annual periodicity. | Approval or denial. Corrective actions may be required. Certificate issued is valid for three years. After, monitoring inspections are carried out annually. Renewal may be free if the company has the ISO 14001. | Approval or denial.<br>Upon analysis, complementary documentation may be requested. Requirements are checked at regular intervals according to the assessment procedures. |

**Table A.2. Basic elements for Environmental Product Declarations: comparison between EPD Norge Programs and the International EPD® System**

| Item | EPD Norge | Environdec |
|---|---|---|
| Product category | Building materials: wood and wood-based products for use in construction works | Forestry, wood, and paper products: builders' joinery and carpentry of wood (including cellular wood panels, assembled parquet panels, shingles, and shakes). |
| Product description | Declared unit, scope of analysis, impacted market. Product and material description.<br>Composition specifications of the final product: quantity, unit. Hazardous substance information. | Information about the company, installations involved environmental management system.<br>Product and material description. Composition specifications of the final product: quantity, unit. Hazardous substance information. Declared unit. |
| System limits and type of declaration | EPD 1: Cradle to gate for all products<br>EPD 2: Cradle to gate with options<br>EPD 3: Cradle to grave | Upstream module (cradle-to-gate)<br>Core module (Manufacturing processes) (gate-to-gate)<br>Downstream module (gate-to-grave) |
| Method | Indication of functional unit, declared unit, system limits. Presentation of manufacturing scenarios, use, end-of-life, and transport. Allocation rules as set forth by EN (2012) 15804 standards. | Indication of functional unit, declared unit, system limits. Quality of data. Allocation rules. |
| Environmental impacts | EN (2012) 15804 standards:<br>- Global warming potential (kg $CO_2$equivalents, 100 years)<br>- Depletion potential of the stratospheric ozone layer(kg CFC 11-eq., 20 years)<br>- Acidification potential of land and water (kg $SO_2$ eq.)<br>- Eutrophication potential (kg$PO_4^{3-}$ eq.)<br>- Formation potential of tropospheric ozone photochemical oxidants (kg $C_2H_4$ eq.)<br>- Abiotic depletion potential for non-fossil resources (kg Sb-eq.)<br>- Abiotic depletion potential for fossil resources(MJ, net calorific value) | - Gross Calorific Values (MJ eq.)<br>- Greenhouse gases (kg $CO_2$ equivalents, 100 years).<br>- Ozone-depleting gases (kg CFC 11-eq., 20 years)<br>- Acidifying gases (kg $SO_2$eq.)<br>- Substances to water contributing to oxygen depletion (kg $PO_4^{3-}$ eq.)<br>- Gases that contribute to the creation of ground-level ozone (kg $C_2H_4$ eq.) |
| Life-cycle data | Energy and resources in the phases of production, use, and end-of-life, including transport. | Use of resources, energy, water, and generated waste. |
| Additional information | Quality of the air within the environment, toxic impacts on soil and water. Others. | Information about biogenic $CO_2$ emissions.<br>Waterfootprint calculated by means of the WF network protocol. Others, such as consumer questions, etc. |
| Verification and validation | Verification according to ISO (2006a) 14025 and ISO (2007) 21930 standards. Valid for 5 years. | If changes in the impacts are above 5%, it must be updated annually. Reviewed every 3 years. |

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