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Using life cycle thinking to analyze environmental labeling: the case of appearance wood products

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Abstract

Purpose Growing public concern about the current state of our planet led to the creation of numerous regulations, standards, and certifications for the protection of humans and the environment. Ecolabels were defined for products such as cleaning products, paints, and many others. Wood building products are no exception. The objective of this study is to analyze the existing ecolabelling programs for appearance wood products in nonresidential applications and to evaluate them relatively to their effective role in environment protection or reduction of environment footprint.

Methods The research was conducted on the most common International Organization for Standardization (ISO) type I ecolabels in North America, the European Union, and Japan. Certification schemes applicable to appearance wood products for nonresidential applications were considered. In a life cycle assessment perspective, certification criteria were compared regarding their ability to consider and integrate environment impacts.

Results and discussion A wide range of ecolabels can apply to appearance wood products, from indoor air quality to wood from sustainable forest management. Moreover, it has been found that among all certification schemes studied, those integrating the whole life cycle were the most relevant.

Conclusions The remaining limitation of ISO type I ecolabels is the lack of environmental information enabling the differentiation between products bearing the same ecolabel. This can be overcome by ISO type III environmental product declarations. Thus, allowing a better understanding of the implications related with the use of wood products compared to other materials in the nonresidential building sector.

Keywords Appearance wood products · ISO type I ecolabel · LCA · Nonresidential buildings

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1 Introduction

1.1 Evolution of societal environmental awareness

The most recent Intergovernmental Panel on Climate Change (IPCC) report states that it is extremely unlikely that the global warming pattern during the past half century could be explained without human-induced external forcing (Hegerl et al. 2007). Since the three major environmental crisis of the twentieth century, Bhopal (1984), Chernobyl (1986), and the oil spill in Alaska (1989), the need and will for environmentally friendly industries and practices have been only growing. More environmental disasters have been registered ever since, the Gulf of Mexico oil spill in 2010 and the nuclear disaster of Fukushima in 2011 to name some. Some studies quoted in the Fourth IPCC Assessment Report (Sathaye et al. 2007) bring out the role of nongovernmental and civil society actors in pushing forward the cause of climate change mitigation. From these concerns, environmental regulations, standards, and voluntary environmental labeling have been developing.

1.2 The building sector

1.2.1 Buildings ecological footprint

The building sector has a large environmental impact when looking at carbon dioxide emissions, energy consumption, and material extraction (Bribián et al. 2011; González and García Navarro 2006). According to Bribián et al. (2011), building construction and civil works use 60 % of the raw material extracted from the lithosphere and the building sector represents 24 %. According to Esin (2007), building materials have a significant role to play in building energy consumption over its life cycle. Thormark (2006) showed, in one of his studies, that the embodied energy of a building can be substantially changed through materials substitution. Furthermore, among all the main carbon dioxide-emitting activities, the building sector is one where practice improvement may have significant environment impact reduction, with minimum change in the western world lifestyle (Barker et al. 2007; Levine et al. 2007). This highlights the need for environmentally friendly materials in the building sector.

1.2.2 Nonresidential construction and appearance wood products

The Canadian government, in its 2009 budget (Béchard 2008), was willing to promote the use of wood in nonresidential buildings (commercial and institutional). In buildings, wood utilization is usually referred to as structural material. However, a broad range of wood building materials is used in the finishing construction steps. Among those, wood floor covering, wall paneling, ceiling tile, siding, and decorative wall paneling can be listed. Those materials have an aesthetical function and they are often used in large volumes.

A study was conducted by Fell and Lavoie (2009) about opportunities to increase appearance wood products utilization in nonresidential buildings in Canada. Results show that commercial offices, accounting for 410 million square feet in the country, are a priority sector since commercial spaces turn over and are often remodeled. In this type of building, the utilization of wood is quite spread out but not intensive even though respondents would like to see more wood in their working environment. Hotels are another type of construction possessing a medium to high priority for further wood use. Schools show a moderate potential. These express the need for a positive environment but for durability as well due to high frequentation rate. The same pattern is observed for hospitals, where the durability of materials is considered more important than the use of natural materials, because of cleaning requirements. The authors consider that durability is a key consideration for further wood use. At last, in recreation facilities, concrete and steel overwhelm largely the use of wood that is most likely to be part of a mixed material solution.

Several North American studies reveal that wood products are not well perceived by professionals in the building sector (O'Connor et al. 2003, 2004; Robichaud et al. 2009). Building professionals see in wood a lack of performance in structural applications, fire resistance, and durability when used in large scale buildings (O'Connor et al. 2003). Wood design is not seen as complex, but rather less desirable (Robichaud et al. 2009). The market share of wood products in nonresidential structures is of 4 %, compared to 71 % in residential construction over the same period (RISI Inc. 2008). In their research on wood use in nonresidential construction, Robichaud et al. (2009) point out that the only higher performance perceived by polled architects for wood was environmental friendliness when tested along with: contribution to a higher building value, durability, fire resistance, and structural performance. Steel was considered the most performing for structural application, while concrete was seen as the most performing in durability, fire resistance, and in adding value to a building. Finally, Robichaud (2010) argues that it is not only necessary to convince architects to use wood, but also to make it easier for them to find specific data they need and that is difficult for them to find such as: species properties, maintenance, durability, origins, cost, and more recently carbon footprint. Among professionals, green claims receive lukewarm responses because of a perception of greenwashing, which they consider useless to influence their choices.

1.3 Environmental benefits and issues from wood and wood products utilization

When considering environmentally friendly materials, there is a broad agreement around the virtues of using wood (Sathre and O'Connor 2010). Wood-made products show numerous environmental benefits, but they also face some environmental issues.

Wood is a renewable resource from the forests. Nevertheless, without proper forest management and harvesting methods, its usage can lead to soil deterioration, forest degradation, and deforestation (Gerwing 2002; Kilian 1998; Quine and Humphrey 2005; Shvidenko 2008). These are current environmental issues, mostly in the tropical rain forests whereas European and Northern American forests are generally considered to be managed in a sustainable manner (FAO 2010).

Wood, a naturally grown material, is constituted by the action of photosynthesis, using the sunlight to fix atmospheric carbon dioxide to grow. As a result, carbon dioxide is stored in the wood structure until the material burns or decays after the death of the tree, through the action of insects, fungi, and bacteria. When wood is processed to become a product, the carbon is still stocked until the product end of life. However, Buchanan and Bry Levine (1999) consider that carbon storage in wood products is *not a long-term solution* to CO_2 storage. Wood products have a finite life and their constant use may result in a steady-state level of carbon storage while cumulatively increasing the carbon emissions due to the fossil fuels utilization for their manufacturing.

Comparatively to other building materials, wood is a better choice when considering global carbon emissions because its manufacturing needs less energy and fossil fuels than for other building materials such as steel, concrete, etc. (Bribián et al. 2011; Buchanan and Bry Levine 1999; Nabuurs et al. 2007). In fact, the forest products industry has a high degree of self-sufficiency because over one half of all energy used in the primary forest products industry is self-generated. The combustion of mill residues provides the necessary energy for processing and space heating, but they can also be burned to create direct and indirect heat for wood drying (Bowyer et al. 2007). The balance in equivalent carbon dioxide emissions is almost neutral, due to the low level of industrial processing and can be negative, representing a net absorption of emissions, if the products are recycled or reused instead of landfilled at the end of their life (Bribián et al. 2011). In contrast, in the USA, landfilling of wood is considered as a carbon sink of anthropogenic origin considering is does not decay entirely and would not have been buried naturally (US EPA 2002). Overall, wood usage, substituting steel, concrete, or almost any other building materials, generates a clear greenhouse gas reduction benefit (Sathre and O'Connor 2010, Nabuurs et al. 2007).

In wood-based appearance products manufacturing (e.g. wood floor covering, wall paneling, ceiling tile, siding, and decorative wall paneling) adhesives, glues, coatings or paints, taints, and varnishes can contain volatile organic compounds (VOCs). Some adhesives are made of chemicals emitting VOCs, the most mentioned being formaldehyde and its derivatives, which are known to have negative effects on human health (An et al. 2010; Gminski et al. 2010; Irigaray et al. 2007; Mølhave et al. 1995). VOCs can react with ozone molecules, even at low concentration, inducing submicron particles and by-products, that may provoke harmful consequences on the health of some sensitive populations (US EPA 2000). Furthermore, additives like flame retardant (halogen based), fungicides, pesticides, and other biocides improve the material durability against mold, decay, or fire but can be a source of toxic exposure. All these additives are potentially detrimental to human health and the source of negative environmental impact. Consequently, depending on whether the manufacturing stage is involving a large quantity of these additives or not, and large quantity of energy or not, the resulting product is or is not a better environmental choice. Moreover, the relative environmental footprint of wood products must be compared with that of alternative materials if environmental impact is to be minimized.

Besides, considering the abundant literature on environmental attributes and properties of structural wood products, this exploratory study is focusing on appearance wood products in order to have a better understanding of ecolabelling practices of these lesser-known products and their environmental impact in nonresidential buildings.

1.4 Environmental certification schemes

Most of the certification schemes end up in a labeling process on the product packaging or anything available for consumerism in order to communicate the approval to a larger audience (Boeglin 2007). Environmental labels are also known as ecolabels. On the one hand, ecolabels are mainly communication tools created for the consumers and are intended to serve an environment stewardship. On the other hand, companies of various sectors use ecolabels to communicate their environmental awareness and efforts to consumers.

Ecolabels can be applied to numerous products or services. Programs have been developed in almost every industrialized country and also in some developing countries. The Ecolabel Index website (Ecolabel Index 2011) lists over 424 ecolabels in 25 industrial sectors and 216 countries. This study focuses mainly on the applicability of these ecolabels to appearance wood products for nonresidential applications.

1.4.1 The three types of International Organization for Standardization (ISO) voluntary labels

According to the ISO 14020 series (ISO 2000), there are three types of environmental labels and declarations namely: types I, II, and III. Type I are environmental labels (ISO 14024, ISO 1999b) also known as ecolabels. They are multi-attributes, based on a set of criteria, and verified by a third party. One example could be the *Blue Angel* ecolabel. It was developed in Germany in 1978 and was the first type I ecolabelling program worldwide (Umweltbundesamt 2011).

Type II labels (ISO 14021, ISO 1999a) are self-declared environmental claims by manufacturers or retailers without independent verification. The claims may take the form of statements, symbols, or graphics on products or package labels. The possibility of misleading claims is a matter of concern because the nonverification requirement leads many existing labels to not fully satisfy the ISO 14021 (ISO 1999a) requirements (Fullana et al. 2008).

The third type of environmental labeling, type III (ISO 14025, ISO 2006), is applied to products under the name of Environmental Product Declaration (EPD). This label communicates product life cycle assessment (LCA) results, based on ISO 14040 series, verified by a third party. This is the most recent tool of the ISO 14020 series (ISO 2000). To be compared with each other, the results of LCA studies must have the same scope, system boundaries, and calculation rules and they must be presented in the same format (Fullana et al. 2008). In this study, the ecolabels defined as type I by ISO 14024 (ISO 1999b) were targeted for study.

1.4.2 Environmental certification programs for buildings

Green building certification programs are another category of environmental labeling that has been developed over the last two decades (Fullana et al. 2008). The oldest, the most globally recognized and the most comprehensive would be the British *Building Research Establishment Environmental Assessment Method* (*BREEAM*) that was first launched in 1990 (BRE Global Ltd 2011). In the USA, the *Leadership in Energy and Environmental Design* (*LEED*) is another widely recognized program (USGBC 2011). American programs like *Green Globes* (2005) and *Collaborative High Performance Schools* are also listed as sustainable construction standards (CHPS 2010). In Japan, green building standards have emerged with the *Comprehensive Assessment System for Building Environmental Efficiency* (*CASBEE*; JaGBC and JSBC 2008). In France, the *Haute Qualité Environnmentale* (High Environmental Quality in French; *HQE*) was developed (Certivéa and CSTB 2011). These programs were reviewed to assess their implication and demand for selected wood products bearing type I or type I-like ecolabels in sustainable buildings.

1.4.3 Carbon ecolabels

Carbon footprint labeling of products has been another type of environmental labeling tool for the past few years and it is currently undergoing rapid development. The main purpose of these ecolabels is to reduce greenhouse gas (GHG) emissions. The GHGs covered are the six gases mentioned by the Kyoto Protocol (carbon dioxide, methane, nitrous oxide, and the three F gases). The GHG emissions are calculated throughout the life cycle stages of a product or service (Rugrungruang et al. 2009; Schmidt 2009; Yang and Shen 2011).

Carbon labeling may be an opportunity to promote the carbon dioxide storage potential of wood products. Besides, as it has been said before, the manufacturing of wood products needs less energy than the traditional building materials (concrete, steel, etc.) and also other goods such as plastics as demonstrated by many authors (Sathre and O'Connor 2010). Therefore, carbon ecolabels occupy a place of choice in the environmental certification programs for wood products and this relationship is worth being studied in detail.

However, their labeling mainly lay on the type III EPD standard, ISO 14025 (ISO 2006; Schmidt 2009; Yang and Shen 2011). Consequently, since the present study only consider type I and type I-like ecolabels, these ecolabels have not been studied further.

1.5 Aim of the study

The aim of this paper is to analyze the potential for type I ecolabel applications (ISO 14024, ISO 1999b) for appearance wood products in nonresidential buildings. The relevance of each scheme in terms of environmental impact reduction is discussed.

2 Methodology

2.1 Qualitative research

To explore the subject, qualitative research was used. Qualitative research is more suitable when a problem is addressed in a hardly developed context and that a detailed comprehension of a phenomenon is needed (Flick 2006). This type of research provides a better perspective and was deemed appropriate for this study since there are very few papers about ecolabelling efficiency for appearance wood products. To develop our understanding about the subject under study and propose a conceptual framework, the research methodology has been based on grounded theory.

2.2 Ecolabel selection

The study has been conducted on the most largely recognized environmental labels within three geographical areas: North America (USA and Canada), European Union, and Japan. The certification schemes had to apply to appearance wood products in nonresidential buildings. The study covered specifically ISO 14024 (ISO 1999b) *type I* ecolabels, the third-party verified labels, not formally LCA based. The ISO framework for environmental labeling, being the most employed and recurrent in the literature on existing ecolabels, has been chosen for data gathering.

Nevertheless, single-attribute ecolabels like *Forest Stewardship Council* (*FSC*), *Programme for the Endorsement of Forest Certification* (*PEFC*) for forest products and ecolabels for indoor air quality (such as *Greenguard*) have been added to the ISO *type I* ecolabels by the authors. This type of ecolabels is not included in ISO 14024 (ISO 1999b) since it is not multi-attribute, but because those programs undergo third-party certification and cover key environmental issues for appearance wood products, they were considered in this study.

2.3 The grounded theory approach

The basic principle of the grounded theory methodology is to let the data guide the research process through constant gathering and analysis. The resulting theory is then said to be *grounded* in the data. Grounded theories, because they are drawn from data, are likely to offer insight, enhance understanding, and provide meaningful guide to action (Strauss and Corbin 1998). According to Charmaz (2006), grounded theory is a method of conducting qualitative research that focuses on creating conceptual frameworks or theories through building inductive analysis from the data. This method is different from others since it involves the researcher in data analysis while collecting data, the data analysis being used to inform and shape further data collection (Charmaz 2006).

The present study embraces the main components of grounded theory practice according to Glaser and Strauss (Glaser 1978; Glaser and Strauss 1967; Strauss 1987). During this research, the data collection and analysis have been simultaneously achieved. To help in the understanding and analytic process of the gathered data, analytic codes and categories have been implemented by the authors. Constant comparative method has been used and the development of our theory followed the flow of our analysis. A literature review about the subject has been done after developing the analysis to support our findings. Finally, Glaser and Strauss aimed to move qualitative inquiry beyond descriptive studies into the realm of explanatory theoretical frameworks, thereby providing abstract, conceptual understandings of the studied phenomena (Charmaz 2006).

Firstly, a content analysis of selected ecolabels was performed. It was meant to provide an insight of each environmental labeling using publicly available data. Basic information about the different programs is given (certification criteria, geographical origins, aim of the programs, and classification). The main data have been picked from the labeling organization websites and their online available literature, mainly certification guidelines and standards.

Secondly, led by the content analysis results, the authors decided that it would be interesting to carry on a critical analysis using a life cycle thinking (LCT) approach. The LCT concept was, in this study, interpreted with the coverage of life cycle stages and the coverage of environmental indicators (midpoint indicators). To that aim, the current ecolabelling programs were compared among each other, using data from primary sources (labeling organization). The midpoint environmental indicators (with related endpoints indicators) that resulted from the *Impact 2002+* impact assessment methodology, and the general structure have been chosen according to several references, that are, in order of importance: (1) Jolliet et al. (2004), Udo de Haes et al. (2002); (2) Bare and Gloria (2008); and (3) studies on LCA and environmental impacts of appearance wood products or their primary components, including wood floor coverings, hardwood panels, MDF, door frames, and particle board (Bribián et al. 2011; Frenette et al. 2010; Gonzalez-Garcia et al. 2009; Lipušček et al. 2010; Nebel et al. 2006; Rivela et al. 2006; Werner and Richter 2007).

The third and last step in our grounded theory methodology has been to search through the relevant literature to support the main findings and also gather additional data to enrich the later discussion. Thus, a literature review, on ecolabels ecological efficiency and their ability to promote environmental attributes of products, has been done.

3 Results

3.1 Content analysis

Environmental certification programs were classified in four categories. The different categories and their respective ecolabels are listed and described in Table 1. The four categories are: the forestry and forest products category (FO) certifying that products come from sustainably managed forests, the indoor air quality category (IA), the multi-attribute category (MA), and the life cycle-oriented category of certification. The last column of Table 1 indicates the geographical origins of each group. The FO and the MA category were observed to be coming from all selected geographic area (European Union, Japan, and North America), meaning that every area developed these types of program. However, the IA and life cycle (LC) category seem to exist only in North America.

3.1.1 Forest and forest products attribute ecolabels

According to the majority of selected ecolabel certification criteria, wood from sustainable forest management certification is the most commonly required attribute. The FO category aims at preventing forest land-use change and forest degradation, while fostering community involvement and economic development. In practice, different interpretations exist of sustainable forest management (SFM). In Table 1, the main features of FO ecolabels have been classified under six parameters as found in Hansen et al. (2006). However, as PEFC and Sustainable Green Ecosystem Council (SGEC) parameters were not presented in this study, the following sources were used to fill in the parameters description, respectively, ITS Global (2011) and SGEC (2003). Differences among the FO ecolabels criteria show that every program has its own interpretation of what should be SFM. For example, plantations are not controlled under every scheme that is presented in Table 1; FSC, PEFC, and

Table 1 Summary of ecolabels applicable to appearance wood products

Category/ecolabels	Main features	Geographic origins
FO—Forestry and forest products oriented[a] (Hansen et al. 2006; ITS Global 2011; SGEC 2003)		
FSC (chain of custody)	Plantations: information needed: representation on landscape, date of establishment and management blocks (species diversity, genetic foundation and stand structure) Chemicals: minimized use requirements; integrated pest management (IPM) approach; documentation requirement, strict monitoring and control; ban chemicals types 1a and 1b WHO	North America
	Clear cut: limitations in size and location (varies among national and regional standard)	
	GMO: prohibited	
	Exotics: permitted but not promoted. Require careful monitoring to avoid adverse environmental impacts	
	Reserves: conservation zones to protect rare, threatened and endangered species; representation samples of ecosystems on landscape mapped and protected. Require maintaining and enhancing attributes of high conservation value forests	
SFI (CoC)	Plantations: no specific policy. Plantations not defined or regulated Chemicals: require minimizing their use given management objectives; promote IPM where feasible	USA and Canada
	Clear cuts: average of 120 acres; exceptions for forest health emergencies and natural catastrophes	
	GMO: require adherence to government regulations and international protocols; utilization governed by scientifically sound methods	
	Exotics: minimize their use; if research documentation is available and indicates exotics pose minimal risk	
	Reserves: require identification and management of sites with ecological, geological, historical, or cultural significance. Manager has discretion on how best to manage these sites	
CSA Z809 (CoC)	Plantations: no specific policy. Plantations not defined or regulated. Chemicals: no specific policy beyond government regulations	Canada
	Clear cuts: no specific policy beyond following government regulations	
	GMO: guided to address their use through consultation with public advisory group	
	Exotics: no specific policy beyond following government regulations	
	Reserves: respect government-protected areas; determine existence of under protected ecosystems (at the landscape level) in defined forest area and ensure their protection.	
PEFC (CoC)	Plantations: ecologically important forest areas, containing significant concentrations shall primarily be addressed at the establishment stage of forest plantations and those areas shall form a part of buffer zones and set-aside areas, which are dedicated to environmental, ecological, cultural and social functions. Chemicals: require minimizing the use; integrated pest management (IPM) approach; require documentation, strict monitoring and control; ban chemicals types 1a and 1b WHO	EU
	Clear-cuts: not mentioned in standard	
	GMO: prohibited	
	Exotics: for reforestation/afforestation, native species and local provenances, well adapted to site conditions shall be preferred. Introduced species can be used if impacts on ecosystem and genetic integrity of native species have been evaluated and if negative impacts can be avoided or minimized.	
	Reserves: forest management planning, inventory and mapping of forest resources shall identify, protect and/or conserve ecologically important forest areas, containing significant concentrations.	
SGEC (CoC)	Plantations: If an artificial regeneration method is used, it should be done by the principle of *TEKICHI-TEKIBOKU* or "putting the right tree in the right place." Chemicals: The use of chemical substances (e.g. agricultural chemicals) should be subject to laws and limited to minimal use.	Japan
	Clear-cuts: Large-scale clear cutting should be avoided. If possible, non-clear cutting method is recommended. Harvest of forest products should be regulated so as to secure their sustainable use.	
	GMO: not mentioned	
	Exotics: If an artificial regeneration method is used, it should be done by the principle of *TEKICHI-TEKIBOKU* or "putting the right tree in the right place."	
	Reserves: Two levels of management policies should be recognized. Conservation plans for biodiversity should be built on a management policy developed for each landscape level. For main forest types, their management policies should be established for each forest stand level. Within certified forests under consideration, important elements for biodiversity (e.g., virgin forests, natural	

Table 1 (continued)

Category/ecolabels	Main features			Geographic origins
	forests, forests around local communities, grasslands, swamps, ponds and agricultural fields) should be identified on a map. Their management policies should be established. Threatened species defined under IUCN Red List Category and their habitats should be protected.			
IA—Indoor air quality oriented (GEI 2010; SCS 2007)				
Floorscore	For flooring products: formaldehyde concentration$\leq$16.5 μg/m^3; Acetaldehyde concentration$\leq$9 μg/m^3; All other organic chemicals with established Chronic Reference Exposure Levels (CRELs) – Less than or equal to one half the CREL as listed in the latest edition of the Cal/EPA OEHHA list of chemicals with noncancer CRELs. The current version of this list is accessible at http://www.oehha.ca.gov/air/chronic_rels/AllChrels.html			USA
Indoor advantage	For interior building materials, furnishings and finish systems.			USA
	Chemical/chemical group	Workstation systems (all configuration types)	Seating	
	TVOC (toluence)	<0.5 mg/m^3	<0.25 mg/m^3	
	Formaldehyde	<50 ppb	<25 ppb	
	Total Aldehydes	<100 ppb	<50 ppb	
	4-Phenylcyclohexane (4 pch)	<0.0065 mg/m^3	<0.00325 mg/m^3	
Indoor advantage gold	For interior building materials, furnishings and finish systems: same as *Indoor Advantage* with formaldehyde concentration$\leq$16.5 μg/m^3 and Acetaldehyde concentration in the product$\leq$9 μg/m^3; All other organic chemicals with established Chronic Reference Exposure Levels (CRELs)—less than or equal to one half the CREL as listed in the latest edition of the Cal/EPA OEHHA list of chemicals with noncancer CRELs. The current version of this list is accessible at http://www.oehha.ca.gov/air/chronic_rels/AllChrels.html			
Greenguard	For interior building materials, furnishings and finish systems: same numbers as *Indoor Advantage* but "Workstation systems" is replaced by "Full level" (building construction materials and finishes, wood finishes, countertops, casework, visual display products, and furniture workstation, case good systems, and movable walls) and "Seating" replaced by "Half Levels" (OEM materials, mattresses and bedding, seating, individual case goods, tables, workstation components, shelving, and children's furniture); Include individual VOCs (not listed VOC)$\leq$0.1 threshold limit value (TLV) industrial workplace standard (full and half levels); respirable particles $\leq$0.05 mg/m^3 (full levels) and $\leq$0.025 mg/m^3 (half levels) for particles applicable to fibrous, particle-releasing products with exposed surface area in air stream and for wood finishing (sanding) systems.			USA
MA—Multi-attributes (AFNOR Certification 2002; Eco Mark 2009, 2010; Environmental Choice Program 1996; EUEB 2009a, b; FCBA 2011; Nordic Ecolabelling 2003, 2010; RAL gGmbH 2010a, b; Terrachoice 2009)				
EcoMark Japan	Raw materials	Wooden part shall be 100 % made from reused or unused wood (thinned wood, waste wood, construction waste wood and less useful wood) and SFM certified; no preservative agents (+termite control agents, fungicides, or insect repellent, for wooden floor); for products using lumber from dismantled building, wood with preservatives, biocides, and pesticides shall be differentiated and eliminated; for solid wood, CoC certification is required		Japan
	Manufacture	Coatings shall conform to criteria for heavy metals and heavy metal compounds; adhesives used for indoor furniture manufacture shall not emit formaldehyde, be certified F**** or equivalents should be used; compliance with environmental laws for the last 5 years in the area; CFCs or HCFCs shall not be used; toluene and xylene should not be added; restricted amount of hexavalent chromium and arsenic		
	Transportation	Plastics used for packaging shall not contain halogens and organic halogenates		
	Use	Wooden materials should not emit formaldehyde, must be certified F**** or equivalent; products using paint, adhesive, or wooden material shall provide ventilation instruction; adhesives used for		

Table 1 (continued)

Category/ecolabels	Main features		Geographic origins
		indoor furniture manufacture shall not emit formaldehyde, must be certified F**** or equivalents should be used	
	End of life	Repair systems available to users; product disassembly; product recyclable after use	
EU Ecolabel (European Ecolabel)	Raw materials	At least 60 % of any solid wood and 30 % of wood-based materials have to be either chain of custody (FSC, PEFC, SFI, CSA) or recycled materials; recycled wood or plant material should have re stricted amount of heavy metals and fluorine, chlorine, PCP and tar oils; no GMO wood	European Union
	Manufacture	No dangerous substances for the raw wood and plant treatment (Directive 67/548/EEC, directive 1999/45/EC); no dangerous substances in the coating and surface treatments (VOC, adhesives, formaldehyde less than 0.05 ppm, plasticizers, biocides) Directive 67/548/EEC; no impregnation for wooden flooring, no hazardous preservative substances; recovery of by-product; limited energy consumption	
	Transportation	Easily recyclable or from renewable resources or reusable packaging	
	Use	Formaldehyde release≤0.05 ppm; limitation in VOC emissions (ex: total VOC without LIC ≤0.05 mg/m^3 air); fitness for use	
	End of life	Consumer information	
NF Environment	Raw materials	No endangered wood species (CITES); Chain of custody (FSC, PEFC or equivalent): 70 % certified wood(volume or weight) if solid wood and 50 % if wood panels; no GMO wood; if the product is made with less than 40 wt% of wood, 30 wt% must be recycled materials	France
	Manufacture	No added substances from the Directive 67/548/EEC of 27 June 1967 on dangerous substances in the wooden product; only flame retardant chemically bonded or surface bonded with the matrix or material can be used in the product; restrictions concerning phthalates use (di-*n*-octyl phthalate, di-isononyl phthalate and di-isodecyl phthalate are prohibited); if nanomaterials are used, the producer have to explain the technological benefit from using nanomaterials and provide information about the toxicity and ecotoxicity of the nanoparticles and that there is no risk of leakage during the whole product life cycle	
	Transportation	Storage and transportation optimization; packaging made from recycled or easily recyclable materials, if not the packaging has to be reused several times	
	Use	≤50 % of E1 limit value for formaldehyde emission of panels; fitness for purpose; If lightning is incorporated, it has to facilitate the use of energy efficient light sources (LED, fluo-compact lamp…); information for user: maintenance, disposal…	
	End of life	Materials separability; labeling of plastic components for further reclamation; worn product collection	

Table 1 (continued)

Category/ecolabels	Main features		Geographic origins
	Extra criteria	Restricted values for the product embodied energy (ex: office desktop and legs, ≤1,000); calculate CO2 emissions of the product life cycle using ISO 14064	
EcoLogo environmental choice	Raw materials	Wood harvested or traded in accordance with the CITES where applicable	Canada
	Manufacture	Should not contain plastic foam formulated using CFCs or HCFCs; controlled storage of liquid surface coating; manufactured at a facility that has undergone solid waste audit/waste reduction plan/ track progress towards waste reduction and diversion from disposal	
	Transportation use	Indoor air concentration in VOC ≤0.5 mg/m^3; indoor air concentration in formaldehyde ≤0.5 mg/m^3	
	End of life	Instruction of recycling on major rigid molded plastic components; information for repairing/ replacing worn parts	
Nordic Ecolabel	Raw materials	*Renewable*: no biocides; indicate % of recycled/ reused wood and certified wood; no added substances from the Directive 67/548/EEC of 27 June 1967 on dangerous substances in the wooden product/directive 1999/45/EC; (floor coverings) bamboo not necessarily certified but has to come from sustainable sources *Non-renewable*: at least 30 % recycled/reused materials; limited amount of heavy metals (As, Pb, Cd, Hg, Cr)	Scandinavia
	Manufacture	*Chemicals*: no hazardous substances (very toxic, toxic, CMT4); no halogenated plastics for surface treatment; limited quantity of organic solvents g/m^2 and environmental harmful substances; (floor coverings) no nanoparticles should be added (nanometals, nanominerals, nanocarbon, nanofluorine) *Energy consumption*: indicate electricity and fuel for panels production (kWh/kg) *Emission*: evaluate air emissions CO^2 and SO^{2}kg/kg panel; water emissions COD/kg of product; dust amount	
	Transportation		
	Use	Formaldehyde restrictions; no radioactive substances	
	End of life	Production waste must be reused (nutrient, energy production or composting); no chlorine based packaging	
Blue Angel	Raw materials	Indicate % of certified wood and/or recycled wood; origin of wood if not certified	Germany
	Manufacture	Formaldehyde emission <0.05 ppm; detectable MDI monomer <0.1 µg/m^3; phenol-containing binding agent, phenol content <14 µg/m^3; no wood preservatives nor halogenated compound; no added substances from the Directive 67/548/EEC of 27 June 1967 on dangerous substances in the wooden product (very toxic, toxic, CMT); liquid coating systems (<250 g/L of VOC for 2D systems (doors, etc.) and <420 g/L VOC for 3D systems (furniture,	

Table 1 (continued)

Category/ecolabels	Main features		Geographic origins
		etc.)); no fungicides, insecticides, flame retardant, halogenated compounds, inorganic ammonium phosphates, boron compounds, dehydrating minerals	
	Transportation	Packaging must permit post manufacture outgassing of VOC	
	Use	IAQ: emission restrictions for formaldehydes; organic compounds boiling point 50–250 °C and >250 °C; and CMT substances. For 2D systems (panels) and 3D systems (structure).	
	End of life	Consumer info for disposal; functionally compatible replacement of wearing parts for at least 5 years; Recycling/Disposal	
LC—Life cycle oriented (BIFMA 2008, 2011; MBDC 2010; MTS 2006)			
Level; Total of 90 points; Level 1: 32–44 points, Level 2: 45–62 points, Level 3: 63–90 points			
	Materials	Certification prerequisite(s) (CP): Development of a *Design for Environment* program for the organization, the facility and the product—maximum points available for “Materials” criteria: 26 points	USA
	Energy and atmosphere	CP: Develop energy policy—maximum points available for “E&A” criteria: 25 points	
	Human and ecosystem health	CP: Demonstration of compliance with key chemicals, risk & EMS policies—maximum points available for “H&EH” criteria: 29 points	
	Social responsibility	CP: Employee health and safety, labor and human rights—maximum points available for “SR” criteria: 10 points	
SMaRT[b]; Total of 157 points; Sustainable: 28–40 points, Silver: 41–60 points, Gold: 61–89 points, Platinum: 90–157 points			
	Safe for public health and environment	CP: Feedstock inventory documentation; input Stockholm chemicals; output Stockholm chemicals—maximum points available for “SPH&E” criteria: 31 points	North America
	Renewable energy and energy reduction	CP: Energy inventory—maximum points available for “RE&ER” criteria: 36 points	
	Biobased or recycled materials	CP: biobased and recycled content materials inventory—maximum points available for “BRM” criteria: 30 points	
	Facility- or company-based criteria	CP: EMS environmental policy and targets; social indicator reporting for manufacturers; LCA process—maximum points available for “FC” criteria: 18 points	
	Reclamation, sustainable reuse and end of life management	CP: Setting up operational reclamation and/or sustainable reuse programs; performance durability—maximum points available for “RSR&EOL” criteria: 23 points	
	Innovation in manufacturing	No CP—maximum points available for “IM” criteria: 19 points	
Cradle2Cradle; Total of 25 criteria; Basic (6/25), Silver (10/25), Gold (17/25), Platinum (25/25)			
	Material health	CP: complete ingredient formulations for all materials used in the product—total number of criteria to fulfill: 8	USA
	Material reutilization	CP: Recycled content and weight of all materials used in the product—total number of criteria to fulfill: 6	

Table 1 (continued)

Category/ecolabels	Main features		Geographic origins
	Renewable energy use	CP: Annual energy required for manufacture of product and source(s) of that energy—total number of criteria to fulfill: 4	
	Water stewardship	CP: Water stewardship guidelines documents — total number of criteria to fulfill: 4	
	Social responsibility	CP: fair labor, corporate ethics guideline documents—total number of criteria to fulfill: 3	

A chain of custody (CoC) certification is the link between wood products and the origin of wood. Obtaining a CoC certificate implies to have a forestry management certificate issued by the same organization. For instance a *FSC* CoC certificate can be issued if the raw material comes from *FSC* certified forests and not from *other forest management certification schemes*

SFI Sustainable Forestry Initiative, *CSA Z809* Canadian Standards Association for sustainable forest management, *SGEC* Sustainable Green Ecosystem Council, *FSC* Forest Stewardship Council, *PEFC* Programme for the Endorsement of Forest Certification, *EMS* Environmental Management Systems, *SMaRT* Sustainable Materials Rating Technology, *CMT* substances stand for carcinogenic, mutagenic and teratogenic substances

SGEC seem to have specific requirements, while SFI and CSA Z809 do not. Compared to the others, PEFC may endorse nationally developed schemes if they conform to the criteria, indicators, and operational guidelines of the scheme; that is why in Canada, PEFC is represented by SFI and CSA (Gulbrandsen 2004; ITS Global 2011). As a general comment, it can be said that FO ecolabels have been important because they seem to succeed in making a change in the global forest regime where public governance did not (Gulbrandsen 2004).

Many of the MA and LC certification programs refer to or require FO certification, at varying degrees. For example, the recognition of FO ecolabels is sometimes limited to the FSC program only while in other programs, all FO ecolabels are considered valid. As presented in Table 1, the FO ecolabels have been developed equally in the European Union, Japan, and the USA. Even though Japan has a national program for sustainable forestry, SGEC, it seems to be neither widely employed nationally nor internationally recognized within the environmental labeling field. For instance, even the Japanese MA ecolabel, *EcoMark*, does not mention it specifically.

3.1.2 Indoor air quality ecolabels

The second required attribute for appearance wood products specifies limitation in VOC emissions. The purpose of the IA ecolabel is to provide healthier products for the indoor environment. VOC emission is a common and specific issue for composite wood products or wood products with resins, adhesives, or coatings. From an air quality standpoint, it is generally recommended to limit the use of such chemicals in the manufacturing process and when possible, to eliminate them. The IA ecolabels listed in Table 1 are specific to indoor building materials. *Floorscore* is an ecolabel for flooring products while the three others are for all kind of interior building materials, furnishings and finish systems, such as, wood finishes, countertops, workstation systems, and more. Products are certified against their compliance to defined values presented in Table 1. It appears that those values are similar among the selected IA programs. *Greenguard* exhibits the same numbers as the others but has a different range of values, whether it is an environment for children or adults, since children are much sensitive to VOCs. The standard developed for children is *Greenguard for School and Children*. While *Greenguard* has created another standard for school and children, *Floorscore*, *Indoor Advantage* and *Indoor Advantage Gold* propose a school classroom scenario to calculate the emissions and/or concentration in VOCs. *Indoor Advantage Gold* is a level up the basic *Indoor Advantage* certification.

As for geographical preferences for IA ecolabels, it is mainly a North American (USA) phenomenon. It can be explain by the fact that in EU and Japan, the indoor air quality is managed by regulations. As for examples, grades from F** ($\leq$0.12 mg/m^{2}h) to F**** ($\leq$0.005 mg/m^{2}h) can be cited for formaldehyde*emitting building material according to Japanese Industrial and Agricultural Standards. The use of indoor finishing materials that emit more than 0.12 mg/m^{2}h of formaldehyde is prohibited; the use of F** and F*** materials is limited to certain areas; and no restriction of use is observed for F****-graded indoor finishing materials (MLIT 2003). In the EU, this level of emissions comes from E1 ($\leq$3.5 mg/m^{2}h) to E2 (3.5 mg/m^{2}h$<$release value$\leq$8 mg/m^{2}h) (CARB 2007; Dinwoodie et al. 2008). However, in North America, the state of California is an exception since it introduced the same type of VOCs regulation as for Japan and EU, under the name of CARB/ATCM 93120[1] in 2008 with two levels of formaldehyde

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[1] The California Air Resources Board has been created in 1967 and the Airborne Toxic Control Measure for composite wood products has been approved in April 2008.

emission called phase 1 (0.08 ppm for hardwood plywood, 0.18 ppm for PB, and 0.21 ppm for MDF) and phase 2 (0.05 ppm for hardwood plywood, 0.09 ppm for particleboard, and 0.11 ppm for MDF; CARB 2007).

3.1.3 Multi-attribute ecolabels

A wood product can also be certified regarding its environmental impact reduction for more than one life cycle stage. In fact, the MA-certified products have been assessed through recommendations made for different life cycle stages. The number of criteria at a life cycle stage and the coverage of life cycle stages depend on the program. The main goal of MA ecolabels is to ensure that a product is a better environmental choice in its category than the standard product already on the market. Those criteria are usually related to environmental issues faced by the basic product. The MA category has a fragmented vision of the product life cycle since it does not provide a holistic evaluation, but acts on different stages separately. Most of the time, the criteria are grouped as such, otherwise, there is no class specified, only a list of criteria. For more readability, the criteria have been grouped in Table 1 according to a common pattern in the category: grouped by life cycle stage. Among the most restrictive ecolabels, *NF Environnement* is standing out because of the number of requirements in each group of criteria: it has even extra criteria about the calculation of the product's embodied energy and the CO_2 emissions during the product life cycle. Alongside NF Environnement, stands the *Nordic Ecolabel* that has criteria such as energy consumption of manufacture and emissions to air and water. The less restrictive ecolabel seems to be *EcoLogo–Environmental Choice*: it has no precise requirement for wood sourcing, although it follows guidelines of CITES[2] where applicable; it has no instructions for preservative agents, etc.

The MA type of ecolabels has been mainly developed in the EU and Japan. Very few schemes have been developed in North America; we can cite the *EcoLogo* program in Canada.

3.1.4 Life cycle-oriented ecolabels

The LC category aims at certifying a product over its entire life cycle. This differs from the MA category because it aims at assessing the life cycle as a whole. The purpose of the LC ecolabels is to provide products that have a significantly good environmental performance. This is achieved by including the LCA methodology (as defined in ISO 14040) or at least a formal life cycle approach. The incentive to consider all criteria at all life cycle stages in the design phase is also what makes the LC category different from the MA category. From Table 1, it is easy to differentiate the MA and LC categories. All these programs are based on a rating system: while *Level* and *SMaRT* have points, *Cradle2Cradle* works with a definite number of criteria to fulfill in order to reach the different level of certification. The certification prerequisites (CP in Table 1) are requirements for starting the certification process, in that sense they must be fulfilled. These programs have a larger scope than MA ecolabels; in fact, they include higher dimensions like using a definite percentage of renewable energy, social ethic, Environmental Management Systems or even water stewardship for *Cradle2Cradle*.

The difference between this category of ecolabels and an EPD is the use of the LCA tool. In the context of EPD, LCA is used to assess the product over its entire life cycle and the results are presented under the form of environment impact results. It would be impossible to differentiate two products bearing the same LC ecolabel while they should show different EPD results. In the LC category, LCA is presented as a tool to assess the product over its entire life cycle except for the program *Cradle2Cradle* that does not mention the LCA methodology. In the *SMaRT* program, the LCA process is a certification prerequisite (see Table 1), while the *Level* program provides up to 3 points for a third-party-verified LCA process in the "Materials" group of criteria. LC ecolabels have all been developed in North America, especially in the USA.

3.1.5 Discussion of the ecolabel categories

Firstly, it can be said that the intrinsic environmental benefits of wood are not highlighted by the reviewed ecolabels. For example, carbon sequestration and benefits from the substitution of conventional materials by wood on the emission of GHGs are not included as *green* properties. EPDs would take better consideration of the singularity of wood since it communicates LCA results that integrate these dimensions.

Secondly, aside from certified wood, a common recommendation among environmental labeling programs (MA and even LC category) is the use of rapidly renewable materials. This term is used to refer to materials that have a natural growth rate of 10 years and less. For example, the *EcoLogo* criteria for flooring products concern bamboo flooring or flooring made with "other virgin wood substitute", such as scrap/waste wood or FSC (or INBAR) certified fast-growing material (Terrachoice 2009). The *EU ecolabel* and the *Nordic ecolabel* and the LC ecolabel, *Level*, also include bamboo flooring in their criteria (Nordic Ecolabelling 2010; BIFMA 2011). If recommendations about rapidly renewable materials are likely to be integrated in environmental certification along with wood, it cannot be clearly and readily identified as being sustainable. Short-rotation crops are likely to put a heavier strain on soils while longer rotations are more likely to allow for soil regeneration. It can be argued that forest management, carefully

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[2] The Convention on International Trade of Endangered Species of Wild Fauna and Flora, also known as, the Washington Convention (1975).

assessing allowable cut, is more sustainable than short rotation crops, existing ecolabels often do not recognize this.

Thirdly, as it has been explained earlier, FO ecolabels have been developed equally worldwide. The need for SFM is actually globally spread since forests and wood are important resources used by mankind everywhere. The fact that, IA ecolabels are mostly developed in USA, highlight a need for controlling VOC including formaldehyde emissions where regulations is lacking. MA ecolabels have been mostly found in the EU and Japan and little in North America, while LC ecolabels have been mainly developed in the USA. MA certification programs are older than LC certification programs, which means probably that LC programs in the USA have been developed to respond to an increasing demand for sustainable products.

Finally, from the primary approach to our data, it emerges that the most frequently requested environmental priorities for wood products are low VOC emissions and certified wood. According to their certification criteria and standards, it has been possible to classify the studied ecolabels in four categories (see Table 1). The FO and IA categories, being only focused on resolving particular environmental issues (sustainable forestry practices and indoor or air quality, respectively), give a narrower view of environmental impacts related to wood products than the MA and LC categories that take the entire life cycle into account. Moreover, the LC category has a holistic approach of the product life cycle and should then provide better information about the product environmental impacts.

3.2 Life Cycle Thinking

Life cycle thinking can be defined as minimizing negative impacts and highlighting positive impacts, while avoiding transferring issues from one life cycle step to another (CIRAIG 2005). The second part of the study aims at looking beyond the available data on ecolabels. To that purpose, all certification criteria were analyzed and then compared among each other in two steps: (1) considering the product life cycle and (2) considering midpoint and endpoint environmental impacts categories.

3.2.1 Ecolabels vs. product life cycle

The life cycle of a product consists in five different stages (CIRAIG 2005): (1) extraction of raw materials, (2) manufacturing, (3) transportation, (4) usage, and (5) end of life. The aim of this section is to identify which stages are taken into account in the selected environmental certification programs for appearance wood products. As mentioned earlier, this has been mostly conducted by reviewing and by processing the available data on the product life cycle (from each labeling organization) and then confronted to the five different stages of the life cycle. The results are presented in Fig. 1.

As can be noticed in Fig. 1, single-attribute ecolabels like the FO and IA categories cover mainly one stage of the wood product's life cycle. For the FO ecolabels, it is the raw materials extraction stage that is covered, while for the IA ecolabels, it is the usage stage.

Multi-attributes ecolabels tend to cover almost every stage of the product life cycle. The criteria are in general based on LCA results of the product. In this aim, environmental issues are highlighted and then transformed into criteria in order to improve the environmental performance at almost each stage of the life cycle. The relevance of the MA category may then come from the fact that it does not only focus on a single attribute of the product. Since they are not formally LCA based, the MA programs tend not to take into consideration some of the LCA steps such as the transportation stage or the end-of-life management.

When end-of-life is considered, the propositions may take into account to: facilitate the disassembly of the product; indicate clearly on the product, with a label, the possibility of recycling (for example for plastics); create a document, for the consumer, explaining procedures and contacts for the maintenance and end-of-life management of the product. In any case, what emerges from every MA ecolabels standards is the need for easy disassembly of the product, leading to better recycling scenarii. This latter affirmation is represented in Fig. 1c by the white arrow toward disposal, since the recommendations tend to avoid disposal as much as possible.

However, the LC ecolabels based on integrated life cycle analysis take into account the product life cycle as a whole and therefore may push further the environmental impact reduction of the product. The environmental certification schemes of the LC category are all based on a rating scale. Even if these can be classified under multi-attribute ecolabels regarding the ISO definition, they cannot be associated with the MA category. First of all, as can be seen in Table 1, the criteria are not classified according to the product life cycle stages but to several environmentally strategic topics, such as material health or energy management, and even social responsibility. Also, they all express the utilization of the LCA or LC thinking methodology in their certification criteria, thus judging the entire product life cycle in a holistic manner. In Fig. 1d, the arrow toward disposal is dashed because in this category of ecolabels, recycling and reutilization of the product are encouraged. In the *Cradle2Cradle* program, the manufacturer is even helped to go toward a closed loop life cycle for his product.

3.2.2 Ecolabels vs. environmental impacts

All ecolabels were confronted to specific environmental impacts for appearance wood products as was found in the LCA literature for these products. Thereby, it should reveal

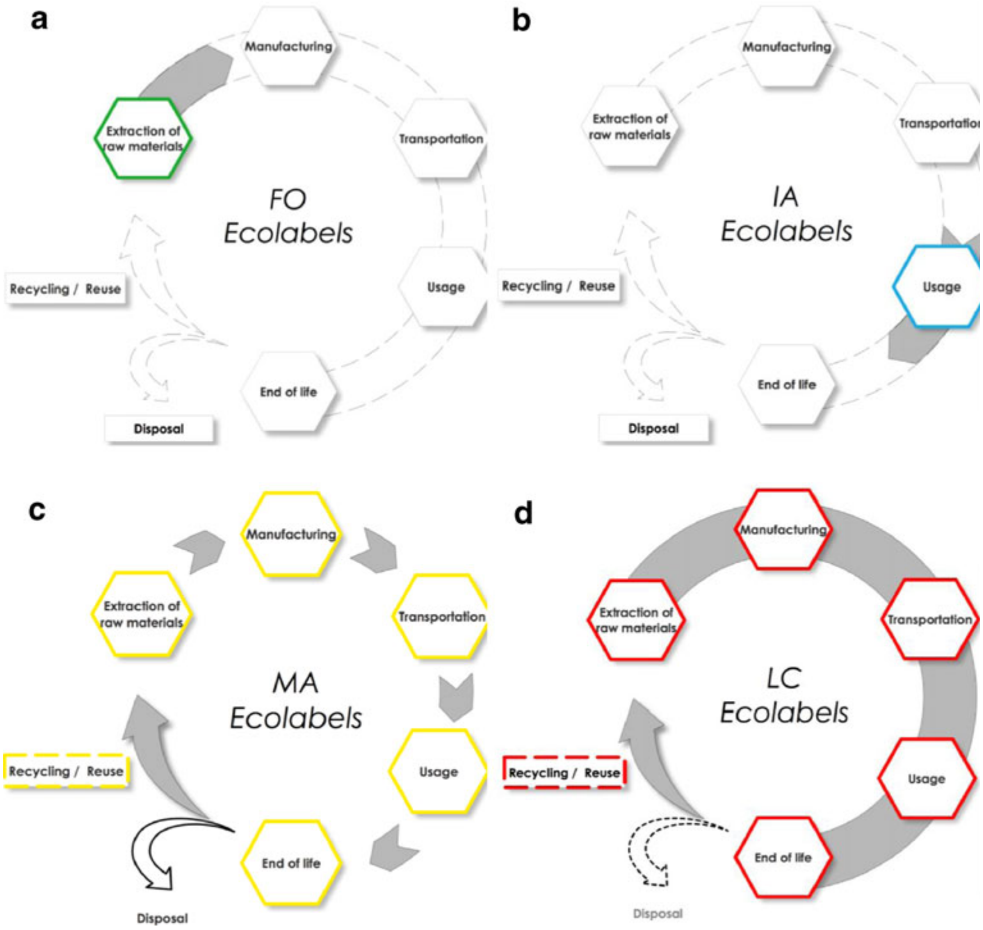

Fig. 1 Diagrams of the respective coverage of life cycle stages for the studied categories of ecolabels: **a** forestry- and forest products-oriented ecolabels, **b** indoor air quality-oriented ecolabels, **c** multi-attributes ecolabels, and **d** life cycle-oriented ecolabels

how much the selected programs theoretically cover the various impacts. Figure 2 presents to the left the different categories of ecolabels (from Table 1), to the center the midpoint impact factors and to the right, the endpoint damage categories.

According to the literature, the most common midpoint categories for wood products are: human toxicity (HT), photochemical oxidation, climate change (CC), acidification, eutrophication, ecotoxicity, abiotic resource depletion, biotic resource depletion (BR), and land-use impacts (LU). Their related damage categories are human health (HH), natural environment (NE), natural resources (NR), and the man-made environment (MM).

The IA category that concerns indoor air quality in buildings is related to only one midpoint and endpoint category, respectively, HT and HH. The aim of these ecolabels is to promote a healthier indoor environment in buildings such as schools, offices, etc. Hence they show very limited, although valuable, environment impact assessment value.

The FO category intends to prevent CC, BR, and LU. Ecolabels help the prevention on CC by a sustainable management of forests and thus avoiding deforestation, land degradation, and release of large quantities of carbon dioxide, the main gas involved in global warming. Sustainable management of forests also enables to prevent BR. The impacts of wood extraction are likely threats on ecosystems and biodiversity. Therefore, FO ecolabels cover NE, NR, and MM endpoints. Although still somehow limited in its environment impact coverage, FO ecolabels has a much broader coverage than the IA catergory.

The MA category covers a broader range of midpoint categories. HT is considered through required level of formaldehyde and other VOC emissions and also through the avoidance of hazardous chemicals that can be carcinogenic, mutagenic, and toxic to human beings (e.g., heavy metals, halogenated flame retardant, arsenic, cadmium, etc.). The majority of MA ecolabels takes into consideration sustainable forestry, thus FO ecolabels. As a result, MA ecolabels cover the same midpoint categories as FO ecolabels, namely CC, BR, and LU. On further examination, some MA programs cover other specific categories. Some impose quantitative levels on the global life cycle product specific energy or energy consumption. Some require information on greenhouse gas emissions or more specifically on CO_2 emissions throughout the product's life cycle. This leads to a full coverage of the endpoint categories (HH, NR, NE, and MM).

Considering LC ecolabels, the majority of programs include the whole LCA process in their structure. By doing a LCA, all selected midpoint and endpoint categories are should

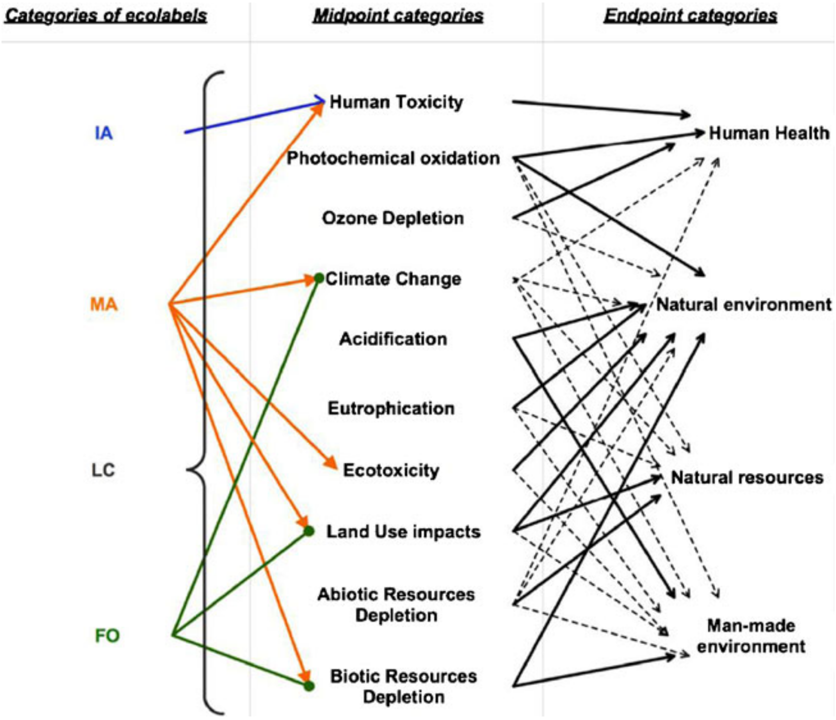

Fig. 2 Midpoint and endpoint categories covered by the different ecolabel categories. Between midpoint and endpoint categories only: *solid arrows* quantitative data, *dashed arrows* uncertain or qualitative data. The number and direction of the arrows linking the midpoint and endpoint categories are based on the work of Jolliet et al. (2004)

be covered. However, they are rating based and the LCA process is not always required, that is the case of *Cradle2-Cradle* and *Level*.

3.2.3 Discussion of life cycle thinking analysis

This second step in our analysis reveals how the studied ecolabels integrate LCT. It can be said that FO and IA ecolabels cover only one stage of wood products life cycle, extraction of raw material and utilization, respectively. In the case of the FO category, the first stage of a wood product life cycle covers multiple environmental impacts (land-use impacts, biotic resources depletion, and climate change). For the IA category, indoor air quality is only related to the human toxicity impact; hence, only one environmental impact is covered. MA ecolabels may cover every life cycle stages of a wood product but there are differences among the programs. In general, MA ecolabels target the same environmental impacts as FO and IA categories along with ecotoxicity. The coverage of the MA category is hence highly variable and it does not guarantee full coverage of environmental impact assessment. Finally, LC ecolabels have the maximum coverage of environmental impacts since they include or recommend in their procedure the explicit use of the LCA tool.

3.3 Literature review on environmental performance and benefits of ecolabelling programs

In most cases, the literature on ecolabelling programs compares and assesses the programs or instruments framework and criteria. In many reports, it is said that the complexity involved with such tools is partly responsible for the lack of information about results and feedbacks (Fullana et al. 2008).

According to the literature, multi-attribute ecolabels (MA category) was found to be a better approach than single attribute ecolabels (IA and FO categories) even if they are both not accurately representing overall environmental performance of a product (ANSI 2009; Grisel and Osset 2008).

In his paper on carbon footprint ecolabel, which is both single-attribute and single-indicator type, Schmidt (2009) expresses that a variety of LCA indicators are necessary for describing the environmental impacts of the product. Therefore, simplifying a complex reality into only one indicator, in his paper Global warming potential, essential information may be left out which might lead to completely wrong conclusions. In addition, Weidema et al. (2008) report that focusing on a single indicator alone is a crude approach. It may give a misleading picture of the impacts in certain cases as opposed to the multiple-indicator approach in LCA. Weidema et al. (2008) give as an example the case of biofuels that may be seen as ecofriendly when looking at their low carbon footprint. Biofuels have nonetheless negative land-use impacts because of pressure put on rainforests and other rich habitats. Thus, it appears that single indicator and single-attribute ecolabels, like the IA category, is not the right approach to judge the product ecofriendliness. Besides, concerning coverage of life cycle stages, Schmidt (2009) considers that all life cycle stages of a product system have to be taken into account and modeled. The author estimates that this is the only way for tailored handling and impact reduction measures to be taken. Actually, the FO category only covers the first life cycle stage, but covers three indicators (CC, LU, and BR); the IA category covers the usage stage of the life cycle and only one indicator (HT). From what has been said, the FO and IA ecolabels may not be the way to go to obtain overall low environmental impact wood products.

Despite many reservations on the use of single-attribute and single-indicator ecolabels, they still have their usefulness to resolve specific environmental issues (ANSI 2009). Then obviously, using one environmental indicator is still better than using none at all (Weidema et al. 2008).

LCA seems to be the most suitable approach to assess all environmental impacts of a product as an ecolabelling support tool, but this is also the most difficult and fastidious tool (CIRAIG 2005). Compared to a single-attribute ecolabel, the LCA tool appears to facilitate the overall environmental optimization of product systems (Schmidt 2009). From this perspective, LCA-based ecolabels appear to be better than MA ecolabels but they tend to be harder to implement. Moreover, a shortage that should be mentioned about the LCA is the integration of human indoor air pollutant exposure. In their paper, Hellweg et al. (2009) bring the fact that health effects from indoor pollutant emissions and exposure are often neglected in LCA, which can in turn have a negative impact on the optimized product. This implies that LC ecolabels may be coupled with IA ecolabels to fill the gap.

The topic of FO ecolabels appears to be fairly controversial in the literature, while the various FO ecolabels are often competing in the same jurisdictions on different territories (Cashore et al. 2005; Roberge et al. 2010). Other comparative studies have demonstrated many variations among the main FO studied schemes, as much as the number and nature of the requirements (quantitative criteria, the use of modal verbs like *shall* or *will*, etc.) or their position towards existing government policies (reinforcement, *status quo*…) (Mcdermott et al. 2008; Ozinga and Krul 2004; Tikina et al. 2012; Wingate and McFarlane 2005). Gulbrandsen (2004) explores five dimensions of forest certification such as inclusion of a broad range of stakeholders, strength of environmental and social standards, quality of auditing, producer participation, and market penetration. He explains that even though FSC, PEFC, SFI, and CSA were formally private and voluntary nonprofit organizations, they were controlled or owned by different interests. For example, while ecological, economic, and social interests have an equal say in the FSC, all the competitors that are SFI, CSA, PEFC are setup by the forest industry for the forest industry. Although the participation and powers of ecological and social interest varies among SFI, CSA, and PEFC, they are all industry dominated; CSA and PEFC being more opened to greater stakeholder participation. On the strength of standards, Gulbrandsen (2004) remarks that many industry-dominated schemes have responded to FSC competition and criticism by changing upward and FSC have become more flexible for the need of business but being still a more stringent environmental and social standards than the others. In addition, the quality of audits and also the stringency and rigor of a scheme standard are what promote progress towards sustainable forestry practices. According to Gulbrandsen (2004), the level of participation in a certification scheme influences in a way forestry practices. As for example, the large number of certified monocultures plantations, the little trouble to sell uncertified or even illegally sourced timber and the fact that only small volumes of certified wood originating from natural-grown forests in developing countries enter international trade, make it not simple to halt the rate of deforestation, forest degradation, and loss of biodiversity; another example presented by the author is the fact that the FSC is considered costly, rigorous, intrusive and lacking of legitimacy, motivated forest industries and forest owners to setup schemes that pay less attention to environmental and social criteria for sustainable forestry, and more to economic criteria. Finally, concerning market penetration, Gulbrandsen (2004) comments that the greater the market support for a certification scheme, the greater its chances of influencing forestry practices in the direction envisaged by the scheme. Finally, unless markets are prepared to pay a significant premium for strong ecolabels, producers will, not surprisingly, tend to prefer labels under schemes with weaker and more flexible standards (Gulbrandsen 2004). To finish, it is important to mention that only 9 % of forestry worldwide is certified under voluntary certification systems and that a little 1 % concerns developing countries, where obviously the need for SFM is far greater than in developed countries (Gulbrandsen 2004; ITS Global 2011).

In general, for a given product, the ecolabel quality is dependent on the preliminary work quality itself. This means the accuracy of the environmental verification, objectivity, and precision, but also the clarity and relevance of the product environmental strategy are of importance (Grisel and Osset 2008).

To conclude on this literature insight, it has been found that single-attribute ecolabels are good tools but not representative of the overall environmental performance of a product. In that sense, MA and LC ecolabels are better, but the LC ecolabels are standing above all the categories since they have the best coverage of life cycle stages and environmental impacts because of the integration of the LCA methodology.

4 Discussion

It has been perceived that single-criteria approach of the FO and IA ecolabels was not suitable to express overall environmental performance, and further in the study, it has been confirmed that a relevant assessment of environmental performance of a product should not be based on only few impact indicators and/or life cycle stages. Strong convergence was observed along the idea that the holistic approach of the LC category was better than the fragmented approach of the MA category to support the development of environmentally friendly product. As found in the literature, considering the entire life cycle of a product is a prerequisite for successful environmental analysis. However, notwithstanding the observations made through the analysis, LC ecolabels appear to be more difficult to implement due to the necessities and complexities of the LCA methodology and the deep implications related to such certification programs. As a final comment, in EPDs context, LCA is used to provide quantitative product environmental impact, it makes ISO type III environmental declarations even more relevant than ISO type I LC ecolabels. LCA is not systematic in LC ecolabelling programs (Table 1), some require a LCA process and some do not.

4.1 Implications for nonresidential buildings

In many sustainable building programs worldwide (LEED, CASBEE, HQE, BREEAM, etc.), certified wood is one of the features in certification criteria (BRE Global Ltd 2010; Certivéa and CSTB 2011; JaGBC and JSBC 2008; USGBC 2009). This particular need for certified wood products in such projects can be fulfilled with ecolabels from the FO category.

In addition, a healthy indoor environment is a feature of upmost importance in buildings, especially for institutional buildings, since children are more sensitive to indoor sources of VOCs. North American green building programs (LEED, GreenGlobes, or Collaborative High Performance Schools) usually refer to or recognize the use of IA ecolabels when choosing interior wood products. In sustainable building programs from the European Union and Japan, IA ecolabels are not considered since these issues are dealt through regulations. However, when the need for low-emitting wood products is expressed, MA-ecolabelled products are chosen because they have already been tested for limited VOCs emissions during the certification process. This approach allows to simultaneously meet low VOC indoor environment and low environment impact.

In contrast to the findings, ecolabels from the FO and IA categories are the most often found in green construction. As mentioned in the literature, they both respond to specific environmental issues like the indoor air pollution and unsustainable management of wood and there is demand for this kind of specific response. Nonetheless, although single-attribute ecolabels might be useful, they are not the right answers where overall environmental performance is to be assessed. As an example, an IA-ecolabelled wood product can have a low VOCs emission and being made from wood that comes from unsustainable forestry practices.

The integration of MA-ecolabelled wood products in green buildings is good step further since they are used mostly for their low-emitting properties. Actually, HQE and CASBEE require the use of their respective MA ecolabel, NF Environnement, and *EcoMark*, to fulfill the need for low-emitting building materials (Certivéa and CSTB 2011; JaGBC and JSBC 2008).

LC ecolabels are better vehicles for closer-to-reality environmental performance; hence LC-ecolabelled wood products should contribute in a higher level of sustainability of nonresidential buildings. Considering the fact that minimizing indoor air pollutant, such as VOCs including formaldehyde, in the product is not in the basic requirements of LC ecolabels (cf. Table 1), IA ecolabels could be proposed to partly complete this weakness if not already applied. The low establishment of LC-ecolabelled products, not only in green building programs but also in the range of green products, is probably related to the complexity of such certification process since it requires complex and tedious gathering data, compared to the three others categories of ecolabels. Another reason for this low interest in such environmental labels may be the rise of recommendation for EPD from international organization, which is expected to provide a step further toward harmonization of environmental properties of products, and that is more specifically based on rigorous and comparable methodology across products, with a higher degree of transparency.

For certified appearance wood products to have a greater impact in sustainable construction in general, building certification programs should increase their efforts to recognize such product ecolabels. FO and IA ecolabels are already integrated at different scale, respectively: FO-ecolabelled wood products are widely demanded but IA-ecolabelled products are more specific to North America, especially the US (except California state) since indoor air quality regulations are lacking compared to the California state, the EU, and Japan. More environmentally efficient ecolabels such as MA and LC ecolabels are not well represented and integrated in green building programs, despite the fact that they can contribute in a non-negligible manner to the overall sustainability of a building. The concept of materials selection to minimize environment impact should not be restricted to the building structure. In fact, materials used in the envelope as well as in interior and exterior cladding also have their environmental impacts and contribute to the overall environmental burden of the building in the environment. This is even more true as the inside environment is more often replaced.

4.2 Implications for specifiers and nonresidential building owners

Somehow it happens that building professionals like architects, designers, or specifiers are reluctant toward the utilization of wood products due to a lack of knowledge about the material. However, it is agreed globally that wood gives a unique feeling when employed in construction as an exterior or interior product. Moreover, as it has been said in "Section 1.3", wood exhibits good environmental features and is becoming the material of choice in this era of environmental consciousness. Similarly, environmental certification of appearance wood products combined with the inherent properties of wood should increase their utilization in sustainable building projects.

Then, to be successful products in the era of green consumerism, certified appearance wood products should demonstrate clear environmental benefits with equal performances to avoid confusion or even ignorance among consumer, regarding the array of product quality offered throughout the market (Thompson et al. 2010; Akerlof 1970). This ties up with what observed Robichaud (2010) in his study: professionals such as architects seemed to seek information that was not necessarily available to help them choose wood products that they consider more environmentally friendly over other conventional materials that have already owned their place in the nonresidential sector. Alongside, the abundance of ecolabels, environmental claims and possibilities of green washing make them more reserved (Robichaud 2010).

Moreover in type I certification process, every successful products get the same *mark*. Aside from the fact that most building professionals are aware of the ecolabel signification, it does not provide much information for comparison between products. In that sense, EPDs could be an answer, allowing them to compare products with a quantitative knowledge of their environmental impacts, which in the long run could lead to a stronger awareness, thus fulfilling the need for ecofriendly products among the public audience. EPDs may also permit an easier integration of certified appearance wood products in sustainable building projects. Nevertheless, the use of complex methodologies that are not harmonized, and heavy data acquisition requirements are limitations that will have to be overcome in the future to provide better environmental impact information to the customers such as specifiers in nonresidential project or nonresidential building owners. In summary, providing to specifiers or architects a better communication and more information about certified appearance wood products may lead to an increase of specification for this type of product in nonresidential projects and more importantly in green nonresidential projects. Nevertheless, this dynamic depends also on the environmental strategy and policy applied by the client that in turn affects the choices made by a specifier, architect, or designer.

5 Conclusions

The aim of this paper was to describe existing ISO type I ecolabels applicable to appearance wood products and to evaluate them according to their relevance toward reducing the environmental footprint of the nonresidential building sector.

By a primary approach with the analysis of ecolabel content, it was possible to identify major environmental issues such as sustainable forest management and low volatile organic compound emissions that are the main purposes of the *Forest product* oriented and *Indoor Air* quality category, respectively. The *Multi-Attributes* and *Life Cycle* oriented categories assess the product over its entire life cycle but major differences exist among them. The multi-attributes category has a fragmented approach (criteria for each life cycle stage) while the life cycle oriented category has a holistic approach aiming at evaluating all aspects of environmental impact over the whole life cycle of products. Besides, it can be said that ecolabel development tends to lag behind the quick evolution of science. An example of this is the lack of full recognition of the carbon benefits of wood as a building material that, since the latest IPCC report in 2007, has been strongly established, but is broadly lacking recognition in most ecolabels, except those that are starting to include the calculation of greenhouse gas emissions from the product manufacture.

By assessing the selected categories against a life cycle thinking approach, it was found that single attribute ecolabels such as the forest products oriented and indoor air quality categories are limited to very limited, respectively, in respect to their environmental impact assessment. Multi-Attributes ecolabels however, have a broader coverage of the environmental impacts of appearance wood products. The LC-oriented category is the one with the best coverage of environmental impacts. Despite their low coverage of environmental impacts, single-attribute ecolabels can still be considered useful and important, as a tool to solve specific environment problems, such as deforestation, land degradation, or unhealthy indoor environment.

By reviewing the literature on ecolabels and their environmental relevance, LC-oriented ecolabels were observed to be better than indoor air quality, forest products oriented and multi-attributes categories because of their broader spectrum of environment impact coverage over the whole life cycle of products. Many authors agree on the fact that the use of the LCA tool results in more effective and on appropriate environmental improvement of products. Finally LCA, to assess environmental burden of products, is becoming more widespread and tends to impose itself for ecolabel legitimacy. Among potential issue of ecolabels not using the LCA methodology is the lack of quantifiable data establishing a link between environmental criteria and the real environmental impacts of the product. It is interesting to see that the literature review brought a non-negligible support to our conceptual framework.

From the grounded theory, methodology has emerged the observation that the life cycle-oriented category of ecolabels to be more representative of the actual environmental performance of appearance wood products. However, life cycle-oriented ecolabels are hardly mentioned globally contrarily to forestry and forest products-oriented ecolabels like the FSC or PEFC. Thus, it was observed that life cycle-oriented ecolabels are seldom included in sustainable building programs while FSC is the first required criteria for wood products. The lack of information or education about wood and available ecolabels for wood products and their signification seems to be responsible for this situation.

One limitation of LCA-based category, belonging to ISO type I description, is the lack of differentiation between products bearing the same ecolabels. This can be overcome by ISO type III environmental product declarations, which can be assimilated to nutrition labels. These allow the quantitative differentiation between labeled products and a better understanding of the implications related with the use of wood products compared to other materials in the nonresidential building sector.

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