Life Cycle Assessment as a Tool to Promote Sustainable Thermowood Boards: a Portuguese Case Study

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Keywords: EPD, LCA, PCR, Thermowood

ABSTRACT

The aim of the present work was to conduct a Life Cycle Assessment study of thermally-modified Atlanticwood® pine boards based on real data provided by the Santos & Santos Madeiras company. Atlanticwood® pine boards have several applications, but are mainly used for exterior decking and the cladding facades of buildings. The LCA study was conducted based on the ISO 14040/44 standard and PCR "Product Category Rules for preparing an environmental product declaration for Construction Products and Construction Services". Because the precise function of the product or scenarios at the building level is unknown the declared unit is used instead of the functional unit. The declared unit is applicable for an EPD that covers "cradle to gate" and in this case is 1 m^3 of Atlanticwood® pine boards. The inventory datasets for the products and processes included in the system boundaries were obtained from the company (specific data). Generic data were obtained and adapted as necessary from the Ecoinvent 3.1 database and from Franklin USA. The inventory analysis and, subsequently, the impact analysis was carried out using the SimaPro8.0.4 LCA software and associated databases and methods. The method chosen for the impact assessment was EPD (2013) V1.01. The results show that more than ¾ of "Acidification", "Eutrophication", "Global warming" and "Abiotic depletion" caused by 1 m^3 of Atlanticwood® pine boards production is due to energy consumption (electricity + gas + biomass). This was to be expected since the treatment is based on the production of heat and no chemicals are added during the heat treatment process.

INTRODUCTION

The environmental performance of products is a growing concern for most companies due to increasingly restrictive legislation and the greater awareness of consumers about environmental issues. Santos & Santos Madeiras (S&S) is a Portuguese company, certified by the FSC® (Forest Stewardship Council®), which has all its activity in the forestry sector, mainly in wood products processing. S&S decided to undertake Life Cycle Assessment (LCA) studies on their products in order to later carry out an Environmental Product Declaration (EPD).

Atlanticwood® is the registered trademark of the S&S thermally modified wood products manufactured using the Thermowood® method (ThermoWood 2003). Thermal treatment is a technologically advanced process involving the use of three variables only: heat, pressure and moisture. Wood is gradually heated to temperatures ranging from 160°C to 230°C, which changes its molecular structure making it more dimensionally stable and resistant to biodegradation and imbuing it with properties similar to those of tropical species. The thermal treatment turns the color of the wood darker and gives it a warmer hue. The process for the production of thermally modified wood uses no chemical compounds at all, thereby avoiding harmful effects to the environment and no substances whatsoever are added during the treatment. The total absence of chemical compounds preserves the natural beauty of the wood, ensuring it blends in perfectly with numerous decorative solutions and maintains an all-round uniform colour.

The thermal treatment used in S&S varies from medium to high intensity. Thermo I – intense treatment – is conducted at a higher temperature level. The resulting products feature a high degree of dimensional stability and durability, significantly increasing the service life of the item. The intensive treatment of the wood ensures that it can be used both indoors and outdoors. It is most commonly used for lining walls and cladding (indoors and outdoors), indoor floors and decking. Thermo S – soft treatment – is a medium-temperature treatment that increases the stability of the wood, giving it a bright shiny to a medium brown (honey) tone. The soft treatment is recommended for indoor use exclusively, such as in flooring, linings and other decor.

LCA is a technique for assessing the environmental aspects and potential impacts associated with a product (ISO 14040; ISO 2006a, ISO 14044; ISO 2006b) and has been used by industry in many situations (European Platform on LCA), for example to help reduce overall environmental burdens across the whole life cycle of goods and services, to improve the competitiveness of a company's products or to communicate with governmental bodies. It can also be used in decision making, as a tool to improve product design (for example the choice of materials), the selection of technologies, specific design criteria and when considering recycling, or in benchmarking of product system options, in purchasing decision making and technology investments, innovation systems, etc. The benefit of LCA is that it provides a single tool that is able to provide insights into the upstream and downstream trade-offs associated with environmental pressures, human health and the consumption of resources.

EPDs or Environmental Product Declaration Type III (ISO 14025; ISO 2006c) is a set of quantified environmental data consisting of pre-set categories of parameters based on Life Cycle Assessment according to the ISO 14040 series of standards, with at least a minimum set of parameters for each product group (Bogeskär *et al.* 2002). EPDs have to meet and comply with specific and strict methodological prerequisites to the product group, so-called, Product Category Rules (PCR). Product Category Rules for preparing an environmental product declaration for Construction Products and Construction Services are published by International EPD® System (PCR, 2014).

The aim of the present work was to conduct a LCA (cradle to gate) study of Atlanticwood® pine boards (Thermo I) based on real data provided by S&S to help the company management reduce overall environmental burdens across the life cycle of the product.

EXPERIMENTAL

The LCA (cradle to gate) study of Atlanticwood® pine boards was performed on the basis of the ISO 14040/44 (2006) standard and PCR 2012:01 recommendations (PCR, 2014).

According to ISO 14040/44, the LCA is divided into four phases: 1) goal definition – which defines the aim and scope of the study as well as the functional unit (a measure of the function of the system studied); 2) inventory analysis – which lists emissions of pollutants into air, water and soil, solid wastes and the consumption of resources per functional unit; 3) impact assessment – which assesses the environmental impact of the pollutants emitted throughout the life cycle; and 4) interpretation of results.

According to PCR 2012:01 the environmental impact per declared unit for the following environmental impact categories shall be reported in the EPD, divided into core, upstream and downstream module and the stages A to C and D if relevant according to EN 15804 (2012): global warming, kg CO_2 equivalents (GWP100); biogenic carbon stored in products, kg CO_2 equivalents (optional); ozone depletion, kg CFC 11 equivalents; acidification of land and water, SO_2 equivalents; eutrophication, PO_4 - equivalents; photochemical ozone creation, C_2H_2 equivalents; depletion of abiotic resources (elements), kg Sb equivalents; depletion of abiotic resources (fossil), MJ net calorific value. In Europe, the characterization factors outlined in EN 15804 (CML baseline) shall be used.

Goal and scope of the study

Goal of the study

The main aim of this study was to conduct a LCA (cradle to gate) to assess the potential life cycle environmental impacts associated with Atlanticwood® pine boards (Thermo I) produced by the S&S company. The results of the study were to be communicated to the company decision makers who could assess the environmental profile of the products and indicate areas where opportunities exist to improve its overall environmental impacts. Another aim of this study was to prepare an environmental product declaration for Atlanticwood® pine boards.

Scope of the study

The study was based on Atlanticwood® pine boards (Thermo I) with a length of 0.6 - 2.6 m, width of 100 – 120 mm and thickness of 26 mm, to reach a durability level which complies with the requirements for durability class 3.2 according the EN335-2 (2006) standard and to be used in the construction of exterior decks or cladding.

Functional unit

The declared unit is used instead of the functional unit, because the precise function of the product or scenarios at the building level are unknown. The declared unit is applicable for an EPD that covers "cradle to gate" and in this case is 1 m^3 of Atlanticwood® pine boards.

System boundary

The system boundary for the product system is represented in a simplified way in Fig.1.

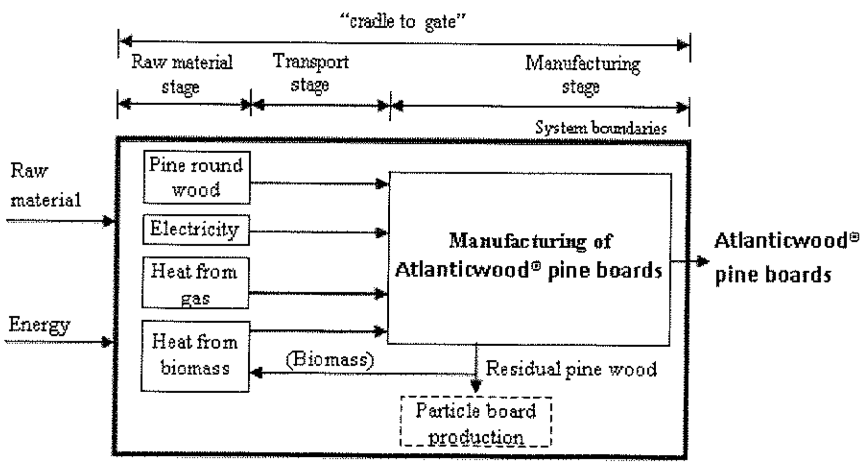

Figure 1: The system boundaries of the study

The product system delivers a secondary raw material (residual pine wood) that can be used as raw material for another product system (particleboard production). To solve this allocation problem the system boundaries were expanded to include particleboard production.
EPDs, "cradle to gate", correspond with the product stage and the modules to be included in the boundaries are the information modules A1-A3: A1- raw material extraction and processing, processing of secondary material input (e.g. recycling processes); A2- transport to the manufacturer; A3- manufacturing.

Inventory analysis

The inventory analysis and, subsequently, the impact analysis have been performed using the LCA software SimaPro 8.0.4 (PRé Consultants) and associated databases and methods.

Data type/data collection

The inventory datasets for the products and processes included in the system boundaries are presented in Table 1. They are the company's data and relate to the year 2014. Almost 100% of the wood comes from forests in the region where the S&S facilities are located. All the materials and energy used for the production of 1 m^3 of Atlanticwood® pine boards were accounted for, excluding packaging.

Table 1: Inventory datasets for 1 m^3 of Atlanticwood® pine boards manufacturing

Inputs		Outputs	
Pine round wood	4.587 m^3	Atlanticwood® pine boards	**1** m^3
Electricity	267.294 kWh	Residual pine wood for particle board production (out)	2.727 m^3
Heat from Gas (propane)	42.133 kg (542.392 kWh)	Residual pine wood for inside heat production (biomass)	0.860 m^3
Heat from biomass (residual pine wood)	0.860 m^3 (2024.482 kWh)	Water	0.229 m^3
Transport of pine round wood	156 t.km		
Water	0. 229 m^3		

The following assumptions were made for the inventory datasets:
- The pine round wood (4.587 m^3) with a moisture content of (u=70 %) and density of (d=680 kg/m^3) is transported from the forest to the company an average distance of 50 km.
- As the product system delivers a quantity of residual pine wood (2.727 m^3) for particle board production impacts from the same quantity of industrial wood production (at forest road) was considered to be avoided.
- The infrastructure for the production facilities of the thermally-modified pine board was not taken into account as it has been assumed that its contribution to the overall impact is negligible (Jungmeier et al. 2002).
The inventory datasets for the background system (such as electricity) were obtained and adapted as necessary from databases presented in SimaPro 8.0.4 software and other sources as recorded in Table 2.

Table 2: Inventory data for the background system

Process	Equivalent process	Source
Pine round wood	Round wood, softwood, under bark, u=70% at forest road/PT U	Ferreira and Domingos (2012)
Electricity	Electricity, low voltage, at grid/PT U	SimaPro 8.0.4 - Ecoinvent database (adapted according to electricity source of EDP 2014)
Heat from gas (propane)	Heat from LPG FAL	SimaPro 8.0.4 - Franklin USA 98 database
Heat from biomass (residual pine wood)	Wood chips, from industry, softwood, burned in furnace 1000kW/CH U-adapted	SimaPro 8.0.4 - Ecoinvent database
Residual pine wood for particle board (production out)	Industrial wood, softwood, under bark, u=102%, at forest road/PT U	Ferreira and Domingos (2012)
Transport of pine round wood	Transport, freight, lorry >32 metric ton, EURO5 {GLO}|market for| Conseq, U	SimaPro 8.0.4 - Ecoinvent database

Life cycle impact assessment (LCIA)

The method chosen for impact assessment was EPD (2013) V1.01 (SEMC, 2013) ready to use in SimaPro software. All impact categories are taken directly from CML-IA baseline method (eutrophication, global warming, photochemical oxidation, ozone layer depletion and abiotic depletion) and CML-IA non baseline method (acidification).

RESULTS AND INTERPRETATION

The following (Table 3 and Figure 2) show the unit process contributions from the production of 1 m^3 of Atlanticwood® pine boards (Thermo I) on the impact categories considered.

Table 3: Impact assessment (characterization)

Impact category	Unit	Total	Electricity	Heat from gas	Heat from biomass	Transport of pine round wood	Pine round wood	Residual pine wood for particle board
Acidification (fate not incl.)	kg SO2 eq	1.728	0.871	0.156	0.544	0.051	0.406	-0.300
Eutrophication	kg PO4--- eq	0.472	0.269	0.029	0.137	0.031	0.083	-0.077
Global warming (GWP100a)	kg CO2 eq	279.502	117.454	134.437	6.529	12.394	48.875	-40.187
Photochemical oxidation	kg C2H4 eq	0.124	0.032	0.009	0.014	0.002	0.124	-0.056
Ozone layer depletion (ODP) (optional)	kg CFC-11 eq	1.12E-05	4.86E-06	7.70E-08	8.7E-08	2.56E-06	8.7E-06	-5.19E-06
Abiotic depletion (optional)	kg Sb eq	1.36E-04	2.52E-04	4.06E-09	8.7E-06	9.73E-06	1.9E-05	-1.54E-04

Sending the pine wood residues resulting from the Atlanticwood® pine board production process the manufacture of "particleboard" allows a reduction (negative sign in Table 3 and Figure 2) in all categories of impact, with a 53% reduction in "Abiotic depletion", 31% in "Photochemical oxidation" and 32% in the "Ozone layer depletion (ODP)". The reduction in other indicators, although below the former, are still significant, representing 15% on acidification, 14% on eutrophication and 13% on global warming. It should be noted that the contribution of pine round wood transport is almost insignificant to all the environmental indicators (1%-6%) except for the ozone layer depletion (ODP) that contributes 16%.

Acidification

The main source of this indicator is electricity consumption at approximately 43%. Another 27% applies to heat from biomass and 20% to pine round wood at the forest road. Heat from gas only accounts for 8%.

Eutrophication

The eutrophication is similar to the acidification in terms of its distribution.

Global warming (GWP100a)

Approximately 42% of the indicator value applies to heat from gas, 37% to electricity consumption and 15% to pine round wood at the forest road. The indicator for the transport of pine round wood is a mere 2%.

Photochemical oxidation

The main source of this indicator is pine round wood at the forest road with 69%. Another 18% applies to electricity consumption. Heat from biomass only accounts for 8% and heat from gas 5%.

Ozone layer depletion (ODP)

54% of the indicator value applies to pine round wood at the forest road, 30% to electricity consumption and 16% to the transport of pine round wood. Heat from biomass only accounts for 1%.

Abiotic depletion

Electricity consumption is the main source of this indicator at 87%. Pine round wood at the forest road is responsible for 7% of this indicator. Transport of pine round wood and heat from biomass each contribute 3%.

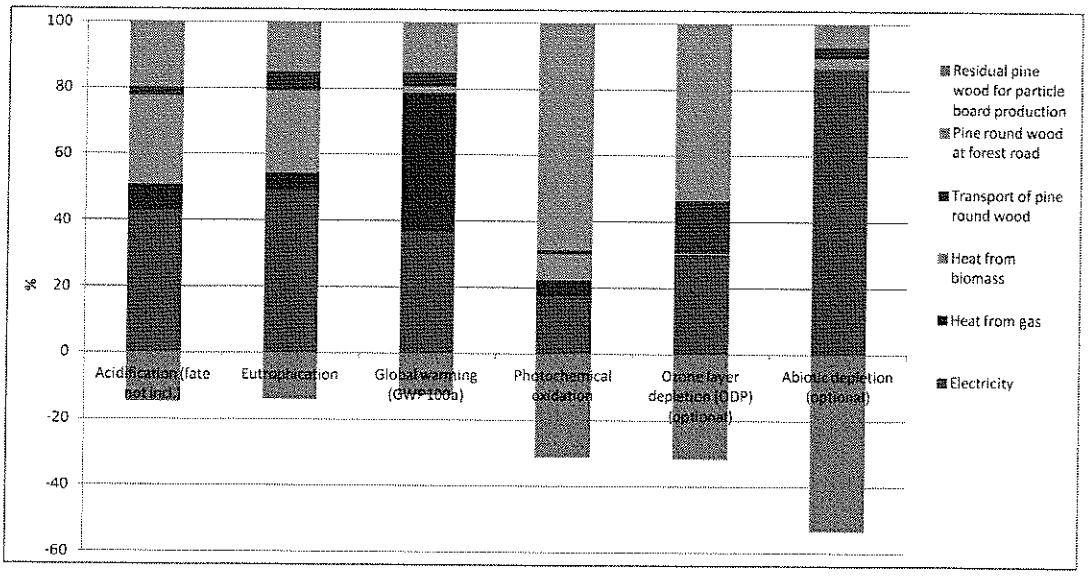

Figure 2: Environmental profile of 1 m^3 Atlanticwood® pine boards. Method: EPD (2013) V1.01 / Characterization

CONCLUSIONS

The results show that more than ¾ of "Acidification", "Eutrophication", "Global warming" and "Abiotic depletion" caused by 1 m^3 of Atlanticwood® pine boards production is due to energy consumption (electricity + gas + biomass). Pine round wood production is the process that contributes most to the other impact categories "Photochemical oxidation" and "Ozone layer depletion (ODP)".
This was to be expected since the treatment is based on heat production and no chemical are added during the heat treatment process. The amount of energy necessary for the treatment is much higher than used in wood processing activities.

ACKNOWLEDGEMENTS

The authors would like to thank the the Center for Studies in Education, Technologies and Health (CI&DETS) of Polytecnic Institute of Viseu and the Portuguese Foundation for Science and Technology (FCT).

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The Eighth European
Conference on
Wood Modification

ECWM8

Proceedings of the Eighth European Conference on Wood Modification

In association with:
COST FP1303 Performance of bio-based building materials

Edited by:
Mark Hughes, Lauri Rautkari, Tuuli Uimonen,
Holger Militz and Brigitte Junge

Paasitorni
Helsinki, Finland
26th and 27th of October
2015

Aalto University
School of Chemical
Technology