Seed to Seat

AMERICAN HARDWOOD EXPORT COUNCIL

Life Cycle Assessment
The Blue Chair by Dokter & Misses

In designing The Blue Chair, Dokter & Misses set out to create a sustainable and carbon-conscious reimagining of their very first chair, originally designed in steel in 2007 and now adapted in tulipwood. The result is striking, both from a functional and environmental perspective. Thanks to tulipwood's light yet strong properties the designers kept the essence of the chair's original extreme geometric profile yet evolved the design into a softer, more ergonomic piece.

Nearly 98% of the entire mass of The Blue Chair comprises tulipwood which contributes to a strong environmental profile. Tulipwood is one of the most abundant American hardwoods accounting for 7% of the total U.S. resource. Every year, the volume of tulipwood in U.S. forests grows on average by 32 million cubic meters, of which only 13 million is harvested. This means the volume standing in U.S. hardwood forests expands by 19 million cubic meters every year. It takes only a fraction of a second for the wood harvested to make The Blue Chair to be replaced by regrowth in the U.S. forest.

The carbon footprint of The Blue Chair is extremely low for a furniture item likely to have a long life and replaced only occasionally. At 24 kg CO2 eq., the carbon footprint is the same as driving 159 km in a typical South African car and equal

Replacement time of harvested timber	Carbon footprint (Kg of CO_2 equivalent)	Equivalent distance in a family car (Km)	Equivalent carbon footprint for average South African
0.06 seconds	24 Kg	159 Km	1 day

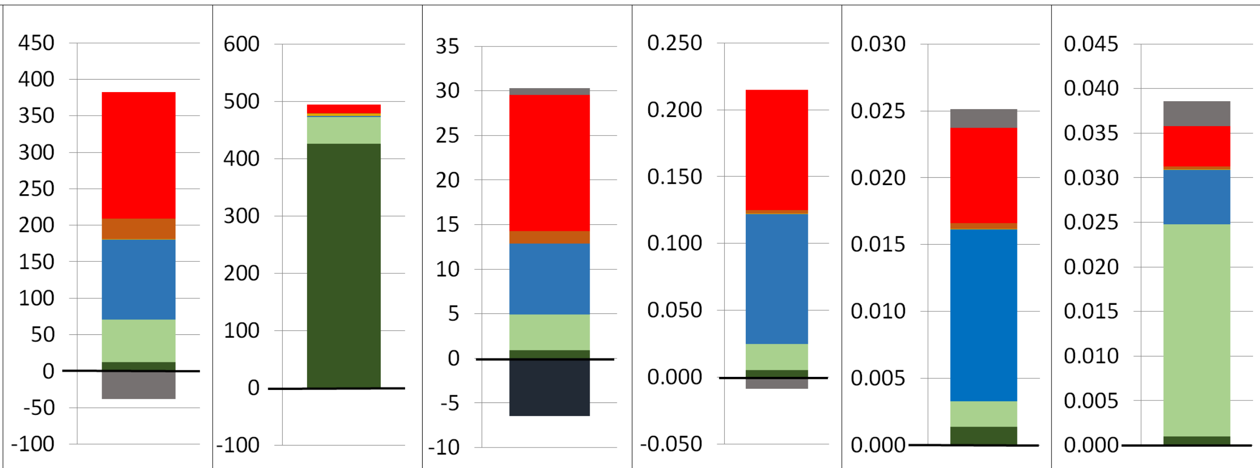
to the carbon emissions of the average South African over a 24-hour period. Emissions of 34.4 kg CO2 eq. during all processes to produce and transport the tulipwood from the U.S., to supply other materials, and to manufacture in South Africa, are offset by 6.5 kg CO2 eq. stored in the finished chair and another 4.1 kg CO2 eq. due to burning of wood offcuts at the factory in South Africa. Not only is tulipwood abundant in the American forest, but it is also relatively easy to work and quick to kiln dry, which reduces the need for energy during processing in the U.S. The high strength to weight ratio means that less tulipwood is required to produce furniture of required strength and durability. The light weight of the material also reduces environmental impacts due to bulk transport of lumber to South Africa.

Wood material efficiency of 28% for manufacturing the prototype is quite low, partly because available wood dimensions for the Seed to Seat project did not readily match the needs of the design.

However this did not add significantly to the environmental burden because the wood is non-toxic and biodegradable and may be used for energy production, offsetting use of fossil fuels

A large proportion of carbon emissions and other environmental impacts occur at the manufacturing stage in South Africa, primarily due to time on the CNC machine powered by electricity from the South African national grid which is 95% dependent on heavy coal. Emissions during manufacturing may be reduced for mass-production through investment in product-specific tooling or use of renewable energy.

FIGURE 1: CRADLE TO FACTORY GATE ENVIRONMENTAL IMPACT

Impact category	Primary energy demand (non-renewable)	Primary energy demand (renewable)	Global Warming Potential	Acidification Potential	Eutrophication Potential	Photochemical Ozone Creation Potential
Unit	MJ	MJ	kg CO2-Equiv.	kg SO2-Equiv.	kg Phosphate-Equiv.	kg Ethene-Equiv.
Total	344	493	23.84	0.206	0.025	0.039
Data by process steps						

Key: Hardwood forestry; Hardwood processing; Hardwood transport; Fixings & furnishing; Glues & coatings; Manufacturing; Process waste; Biogenic carbon

Impact Category	Unit		Hardwood forestry	Hardwood processing	Hardwood transport	Fixings & furnishing	Glues & coatings	Manu-facturing	Process waste	Biogenic carbon	Total
Primary energy demand (non-renewable)	[MJ]	PED (NR)	12.22	58.84	109.54	0.66	28.07	173.04	-38.16	0.00	344.21
Primary energy demand (renewable)	[MJ]	PED (R)	426.17	46.47	1.56	3.85	1.71	14.79	-1.77	0.00	492.79
Global Warming Potential (ex. biogenic carbon)	[kg CO2-Equiv.]	GWP	0.90	4.03	7.92	0.05	1.40	15.22	0.77	-6.45	23.84
Acidification Potential	[kg SO2-Equiv.]	AP	0.0054	0.0195	0.0970	0.0003	0.0025	0.0902	-0.0088	0.0000	0.2061
Eutrophication Potential	[kg Phosphate-Equiv.]	EP	0.0014	0.0019	0.0129	0.0000	0.0004	0.0071	0.0014	0.0000	0.0251
Photochemical Ozone Creation Potential	[kg Ethene-Equiv.]	POCP	0.0010	0.0238	0.0061	0.0001	0.0003	0.0045	0.0028	0.0000	0.0386

Table 1: LCA Key Facts			
Seat to Seat Designer: Dokter & Misses			
Functional Unit: 1 chair			
American hardwood delivered to factory gate			
Hardwood species: Tulipwood			
Quantity		m3	0.030
		kg	14.27
Replacement time (1)		seconds	0.06
Carbon footprint	Emissions	$kg\ CO_2$ eq	13.00
	Wood carbon store		-22.64
	Total		-9.64
Wood balance			
Wood delivered to factory		kg	14.4
Wood in product			4.1
Waste wood			10.3
Wood material efficiency		%	28
Completed Seed to Seat prototype for display at 100% Design 2017			
Quantity in product	Hardwood	kg	4.1
	Other material		0.1
	Total		4.2
Sawdust(2)		kg	1.0
Waste to incinerator(2)	Quantity	kg	3.1
	Energy generated	MJ	24.2
Waste to land fill(2)	Quantity	kg	6.2
	Energy generated	MJ	3.0
Carbon footprint	Emissions	$kg\ CO_2$ eq	34.4
	Biogenic carbon		-6.5
	Waste offset (3)		-4.1
	Total footprint		23.8
	Equivalent drive (4)	km	159

(1) The time required for new growth in the U.S. hardwood forest to replace the wood harvested for the design.
(2) For wood waste, assumed that 10% is saw dust emitted to the air or otherwise lost to the local environment, 30% is incinerated for energy production and 60% is sent for landfill.
(3) The offset due to production of energy from incineration of wood offcuts and (a much smaller amount) from landfill gas which replaces for use of fossil fuels.
(4) Estimate of equivalent driving distance based on 155g CO_2/km average emissions of cars sold in South Africa from Journal of Energy in Southern Africa, Vol.27 No.4 Nov 2016

Table 2: Environmental Impact Categories

Primary Energy Demand from Resources

Use of fossil fuels in mega-joules. The impact category has limited application on its own because it does not differentiate between energy sources (e.g. oil or coal). Nor does it represent "embodied energy". However it is an important driver of other environmental impacts including global warming, acidification, eutrophication, and resource depletion.

Primary Energy Demand from Renewables

Use of energy derived from renewable raw materials in mega-joules.

Global Warming Potential

Often termed "carbon footprint". Expressed in kg of carbon dioxide equivalent. The sum of the warming potential of all gases emitted (including CO2, methane and water vapour) which influence the energy balance of the atmosphere leading to increased average temperatures.

Acidification Potential

Potential for acidification of soil and damage to plant health resulting from emissions to air, water and land of acidifying compounds such as sulphur dioxide (SO2) and nitrogen oxides (NOX). Expressed in kg of sulphur dioxide equivalent.

Eutrophication Potential

Nutrient enrichment of water by release of phosphorous or nitrogen compounds (such as fertilisers) and organic matter (e.g. in effluents). This causes excess growth of plant matter and depletion of oxygen levels in rivers, lakes and seas. Expressed in kg of phosphate equivalent.

Photochemical Ozone Creation Potential

Often referred to as "photochemical smog". Increased levels of ozone at ground level arise through the reaction of volatile organic compounds, for example ethene, with oxygen compounds or oxides of nitrogen in air and under the influence of sunlight. The problem afflicts modern cities and impacts human health and reduces vegetative production. Expressed in kg of kg ethene equivalent.

WHAT IS LCA?

Life-cycle environmental assessment (LCA) involves the collection and evaluation of quantitative data on all the inputs and outputs of material, energy and waste flows associated with a product over its entire life cycle so that the environmental impacts can be determined. LCA quantifies environmental effects against a range of impact categories. LCA may also provide qualitative assessment of other environmental impacts, such as on biodiversity and land-use, that are less easy to quantify.

WHAT IS INCLUDED IN THE LCA?

The LCA of the Seed to Seat designs covers all processes from extraction of wood and other raw materials, transport of these materials to processing location, all processing steps (notably sawing and kilning in the case of wood), transport of processed products to the factory in South Africa, and manufacture of the finished design. Due to lack of information on durability, maintenance and disposal at end-of-life, the LCA is not a full "cradle-to-grave" assessment, and instead determines the environmental impact of the design when delivered to the customer.

WHO PREPARED THE LCA?

The LCA is commissioned by the American Hardwood Export Council (AHEC) and prepared by Rupert Oliver, Director of Forest Industries Intelligence Ltd, a U.K. based consultant with over 25 years experience of sustainability issues in the forest products sector.

HOW IS THE LCA CARRIED OUT?

The LCA draws on a two-year study, commissioned by AHEC and undertaken by PE International (now Thinkstep), to assess environmental impacts linked to delivery of U.S hardwood into world markets[a]. This involved independent assessment of hardwood forestry practices and a survey of the hundreds of U.S. companies engaged in the processing and export of hardwood products. Information from the LCA of U.S. hardwoods is combined with the latest U.S. government forest inventory data[b] and data gathered during manufacturing in South Africa. It is also combined with Thinkstep's existing life-cycle inventory database which covers an expanding range of non-wood materials and products.

WHAT ASSUMPTIONS ARE MADE?

In any LCA there will be data gaps and various assumptions have to be made. The analysis errs on the side of caution and aims to over-estimate rather than to under-estimate environmental impact, for example:

- U.S. hardwood is assumed to be delivered to South Africa by a relatively long route: by truck from central harvest point to an East Coast port in the U.S. and by container ship to South Africa. For delivery to Cape Town, wood is assumed to be landed at Cape Town and an additional 100 km is allowed to the factory gate. For delivery to Johannesburg, wood is assumed to be landed at Durban and then transported by truck for 650 km to Johannesburg.
- Due to lack of detailed LCA data on non-wood materials sourced in South Africa (such as steel screws, glues, and coatings), data is used for the closest surrogates available in the Thinkstep database and transport in each case is assumed to be from typical countries of origin for each product.
- Due to lack of detailed data on waste utilisation during manufacturing, it is assumed that 60% of wood waste is sent for landfill and 40% is incinerated for energy production.
- Sulphur content of marine fuels is assumed to be 2.7% compared to estimated international average of 2.4%.

HOW DOES THIS BEING A PROTOTYPE, NOT A PRODUCTION MODEL, AFFECT ENVIRONMENTAL IMPACT?

The environmental impacts of prototypes tend to be high per unit of production due to trial and error during fabrication. When producing finished designs at scale, manufacturers are able to adjust material procurement and production techniques to significantly increase efficiency and reduce waste.

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a. The Thinkstep LCA study of U.S. sawn hardwood is available at http://www.forestindustries.info/images/Final_LCA_Lumber_report.pdf

b. Latest U.S. forest inventory data is drawn from the U.S. Forest Service Forest Inventory and Analysis (FIA) database at http://apps.fs.fed.us/fia/fido/index.html (last accessed in January 2016 and using 2014 data for most U.S. states)

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