Seed to Seat

AMERICAN HARDWOOD EXPORT COUNCIL

Life Cycle Assessment
Flow Stool by Jacques Cronje

The high wood content of The Flow Stool contributes to a relatively strong environmental profile for a bespoke furniture item. Over 95% of the mass of The Flow Stool comprises red oak, the most abundant American hardwood with forest volume equivalent to around 2,500 million cubic meters, 18% of the total U.S. hardwood resource. Every year, the volume of red oak in U.S. forests grows on average by 55 million cubic meters, of which only 34 million is harvested. This means the volume standing in U.S. hardwood forests expands by 21 million cubic meters per year. It takes no more than a small fraction of a second for forest growth to replace the red oak used to manufacture The Flow Stool.

Low carbon footprint

The carbon footprint of The Flow Stool is extremely low for a high-end product likely to have a long life and to be replaced only occasionally. At 48 kg CO2 eq., the carbon footprint of the stool is the same as driving 316 km in a typical South African car and equal to the carbon emissions of the average South African over a two-day period. Emissions of 62.6 kg CO2 eq. during all processes to produce and transport the red oak from the U.S., to supply other materials, and to manufacture in South Africa, are offset by 6.6 kg CO2 eq. stored in the finished stool and another 8.5 kg CO2 eq. due to

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
0.04 seconds	48 Kg	316 Km	2 days

burning of wood offcuts at the factory in South Africa.

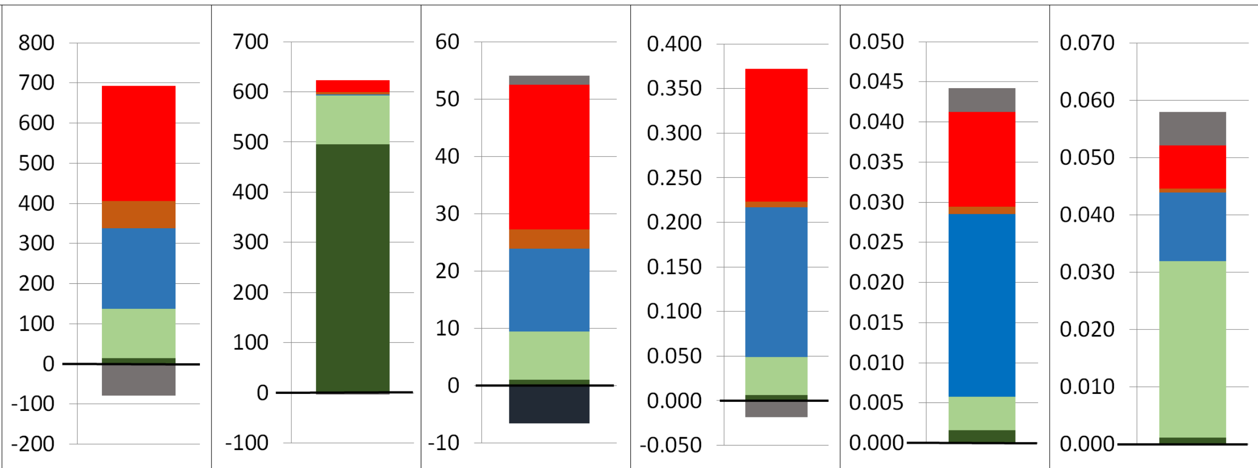
With low impacts at other life cycle stages, manufacturing in South Africa accounts for a relatively large share of the overall environmental impact. Impacts at this stage are mainly due to use of a CNC machine and extractor fan both powered by electricity from the South African national grid which has 95% dependency on heavy coal. Strategies to increase the share of renewables (such as solar energy) in the supply of electricity during manufacturing would significantly mitigate environmental impact.

There was a high level of wood wastage to manufacture the prototype, with only 16% of the sawn wood supplied in South Africa ending up in the finished item. The high level of wastage reduced the long-term carbon storage potential but did not add significantly to the environmental burden in other ways because the wood is non-toxic and biodegradable and may be used for energy production, offsetting use of fossil fuels.

Although partly due to the curvaceous design, the main reason for the relatively high level of process waste was that the wood supplied, which was donated rather than purchased for this project, was not in sizes that could be readily adapted to the design. If manufactured at scale, sawn timber would be procured in sizes closer to those required and much less raw material would be used per unit.

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	613	620	47.46	0.354	0.044	0.058
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)	14.22	122.31	202.06	0.00	67.44	286.32	-79.70	0.00	612.66
Primary energy demand (renewable)	[MJ]	PED (R)	495.97	96.18	2.58	0.00	4.24	24.47	-3.70	0.00	619.75
Global Warming Potential (ex. biogenic carbon)	[kg CO2-Equiv.]	GWP	1.05	8.36	14.51	0.00	3.37	25.19	1.60	-6.62	47.46
Acidification Potential	[kg SO2-Equiv.]	AP	0.0063	0.0424	0.1684	0.0000	0.0060	0.1492	-0.0184	0.0000	0.3539
Eutrophication Potential	[kg Phosphate-Equiv.]	EP	0.0016	0.0042	0.0227	0.0000	0.0009	0.0118	0.0029	0.0000	0.0442
Photochemical Ozone Creation Potential	[kg Ethene-Equiv.]	POCP	0.0011	0.0308	0.0119	0.0000	0.0008	0.0074	0.0058	0.0000	0.0579

Table 1: LCA Key Facts

Seat to Seat Designer: Jacques Cronje			
Functional Unit: 1 chair			
American hardwood delivered to factory gate			
Hardwood species: Red oak			
Quantity		m3	0.037
		kg	25.74
Replacement time [(1)]		seconds	0.04
Carbon footprint	Emissions	kg CO_2 eq	23.91
	Wood carbon store		-40.85
	Total		-16.94
Wood balance			
Wood delivered to factory		kg	25.7
Wood in product			4.2
Waste wood			21.6
Wood material efficiency		%	16
Completed Seed to Seat prototype for display at 100% Design 2017			
Quantity in product	Hardwood	kg	4.2
	Other material		0.3
	Total		4.5
Sawdust[(2)]		kg	2.2
Waste to incinerator[(2)]	Quantity	kg	6.5
	Energy generated	MJ	50.5
Waste to land fill[(2)]	Quantity	kg	12.9
	Energy generated	MJ	6.3
Carbon footprint	Emissions	kg CO_2 eq	62.6
	Biogenic carbon		-6.6
	Waste offset [(3)]		-8.5
	Total footprint		47.5
	Equivalent drive [(4)]	km	316

(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

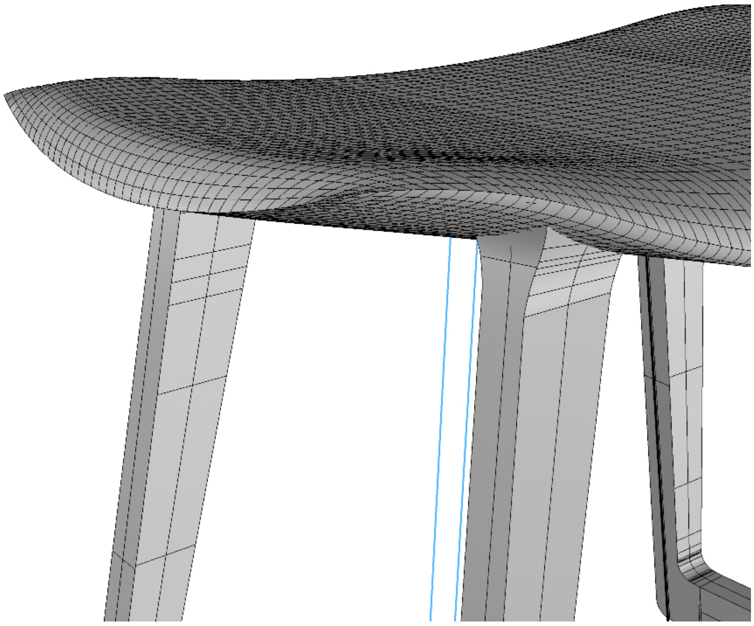


Table 2: Environmental Impact Categories

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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