Life Cycle Assessment
Seed Chair by Christoph Karl

The wood content of the Seed Chair is the major determinant of environmental impact. Very few non-wood materials are used and the relative simplicity of the design allows the wood to speak for itself and avoids the need for elaborate processing and finishing.
Over 97% of the entire mass of the Seed Chair comprises tulipwood, one of the most abundant American hardwoods with forest volume of over 1000 million cubic meters, 7% of the total U.S. hardwood resource.

Tulipwood replaced in a fraction of a second
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 Seed Chair to be replaced by regrowth in in the U.S. forest.
The carbon footprint of the Seed Chair is extremely low for a furniture item which is likely to have a long life and be replaced only occasionally. At 15 kg CO2 eq., the carbon footprint of the chair is the same as driving 100 km in a typical car on sale in South Africa and

	CO2	Kms	CO2
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
0.03 seconds	15 Kg	100 Km	15 hours

equal to the carbon emissions of the average South African over a 15-hour period. Emissions of 23.9 kg CO_2 eq. during all processes to produce and transport the American tulipwood, to supply other materials, and to manufacture in South Africa, are offset by 7.3 kg CO_2 eq. stored in the finished chair and another 1.5 kg CO_2 eq. due to burning of wood offcuts at the factory in South Africa (which substituted for fossil fuel).

Efficient use of wood

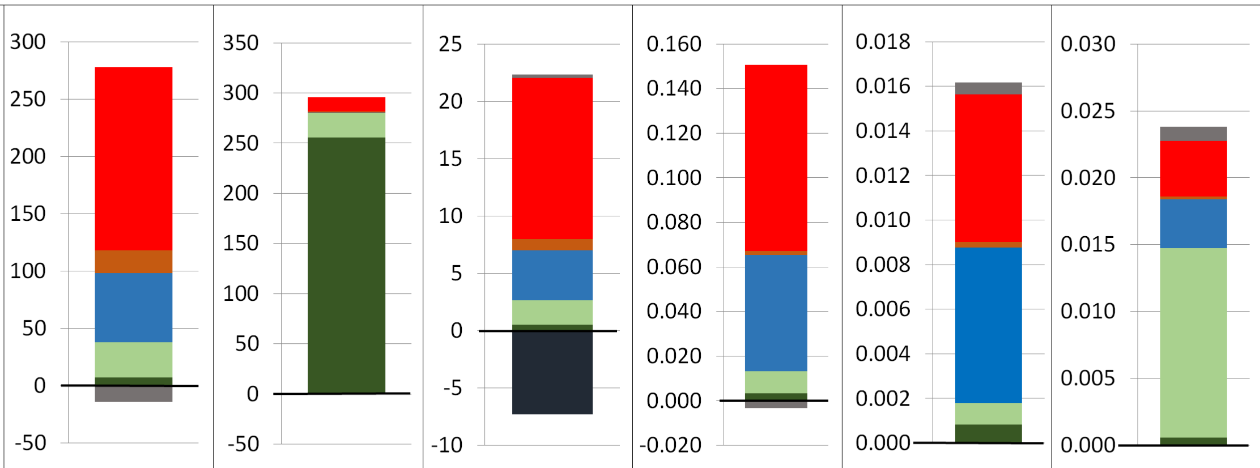
Not only is tulipwood abundant in the American forest, but it is also relatively easy to work and quick to kiln dry, which reduces the need for energy during processing in the U.S. It has a high strength to weight ratio so that less material is required to produce furniture of required strength and durability. Wood material efficiency is also quite high with 54% of wood supplied ending up in the finished prototype, a tribute to the relative simplicity and timeless nature of the design. Efficient use of material reduces environmental impacts associated with bulk transport of lumber to the factory and with waste disposal.

Impacts during manufacturing

A large proportion of carbon emissions and other environmental impacts occur at the manufacturing stage in South Africa, primarily due to nearly one hour spent on the CNC machine. Emissions during the manufacturing stage could be reduced significantly for mass-production through investment in product-specific tooling or use of solar or other renewable energy instead of grid electricity.

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	264	295	15.02	0.147	0.016	0.024
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)	7.33	30.58	60.54	0.00	19.48	159.99	-14.25	0.00	263.67
Primary energy demand (renewable)	[MJ]	PED (R)	255.70	24.19	0.76	0.00	1.17	13.67	-0.66	0.00	294.84
Global Warming Potential (ex. biogenic carbon)	[kg CO2-Equiv.]	GWP	0.54	2.10	4.36	0.00	0.97	14.08	0.29	-7.31	15.02
Acidification Potential	[kg SO2-Equiv.]	AP	0.0033	0.0100	0.0522	0.0000	0.0018	0.0834	-0.0033	0.0000	0.1473
Eutrophication Potential	[kg Phosphate-Equiv.]	EP	0.0008	0.0010	0.0070	0.0000	0.0003	0.0066	0.0005	0.0000	0.0162
Photochemical Ozone Creation Potential	[kg Ethene-Equiv.]	POCP	0.0006	0.0141	0.0037	0.0000	0.0002	0.0042	0.0010	0.0000	0.0238

Table 1: LCA Key Facts			
Seat to Seat Designer: Christoph Karl			
Functional Unit: 1 chair			
American hardwood delivered to factory gate			
Hardwood species: Tulipwood			
Quantity		m3	0.018
		kg	8.46
Replacement time (1)		seconds	0.03
Carbon footprint	Emissions	$kg\ CO_2$ eq	6.99
	Wood carbon store		-13.43
	Total		-6.43
Wood balance			
Wood delivered to factory		kg	8.5
Wood in product			4.6
Waste wood			3.9
Wood material efficiency		%	54
Completed Seed to Seat prototype for display at 100% Design 2017			
Quantity in product	Hardwood	kg	4.6
	Other material		0.1
	Total		4.7
Sawdust(2)		kg	0.4
Waste to incinerator(2)	Quantity	kg	1.2
	Energy generated	MJ	9.0
Waste to land fill(2)	Quantity	kg	2.3
	Energy generated	MJ	1.1
Carbon footprint	Emissions	$kg\ CO_2$ eq	23.9
	Biogenic carbon		-7.3
	Waste offset (3)		-1.5
	Total footprint		15.0
	Equivalent drive (4)	km	100

(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

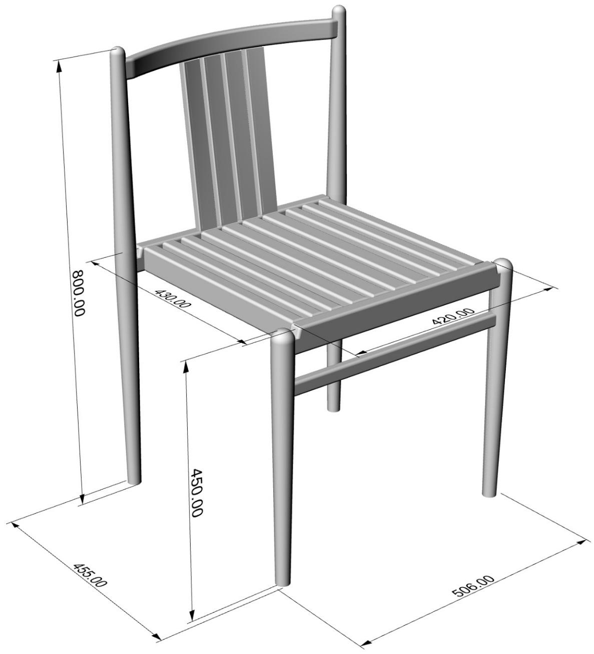


Table 2: Environmental Impact Categories
Primary Energy Demand from Resources
Use of fossil fuels in mega-joules. The impact category has limited application on its own because it does not differentiate between energy sources (e.g. oil or coal). Nor does it represent “embodied energy”. However it is 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)

Seed to Seat

AMERICAN HARDWOOD EXPORT COUNCIL