Eco-Efficiency of Chair Design Concepts

using GaBi i-report

DRAFT numbers - final wood weights to be confirmed! Steaming missing - needs to be added --- no alder -- ash as first estimate, needs to be confirmed

Preseve chair

Lauren Davis

1 Introduction

Life cycle assessment (LCA) is a standardized scientific method for systematic analysis of flows (e.g. mass and energy) associated with the life cycle of a specified product, a technology, a service or manufacturing process systems (ISO 2006). The approach in principle aims at a holistic and comprehensive analysis of the above items including raw materials acquisition, manufacturing as well as use and End-of-life (EoL) management. According to the International Organization for Standardization (ISO) 14040/44 standards, an LCA study consists of four phases : (1) goal and scope (framework and objective of the study); (2) life cycle inventory (input/output analysis of mass and energy flows); (3) life cycle impact assessment (evaluation of environmental relevance, e.g. global warming potential); and (4) interpretation (e.g. optimization potential) (ISO 2006).

The goal and scope stage outlines the rationale of the study, the anticipated use of the results of the study, the boundary conditions, the data requirements and the assumptions to analyze the product system under consideration, and other similar technical specifications for the study. The goal of the study is to answer the specific questions which have been raised by the target audience and the stakeholders involved, while considering potential uses of the study's results. The scope of the study defines the systems' boundary in terms of technological, geographical, and temporal coverage of the study, attributes of the product system, and the level of detail and the complexity addressed by the study.

The life cycle inventory (LCI) stage qualitatively and quantitatively analyzes the materials and energy used (inputs) as well as the products and by-products generated, the environmental releases in terms of non-retained emissions to the environmental compartments and the wastes to be treated (outputs) for the product system being studied. The LCI data can be used on its own to: understand total emissions, wastes and resource-use associated with the material or the product being studied; improve production or product performance; or be further analyzed and interpreted to provide insights into the potential environmental impacts from the system (life cycle impact assessment and interpretation, LCIA).

2 Context

The American Hardwood Export Council teams up with the Royal College of Art to merge design with sustainability

The American Hardwood Export Council is collaborating with product design students at the Royal College of Art in London to produce and exhibit chairs during the London Design Festival.

Under the leadership of tutors Sebastian Wrong and Harry Richardson, using wood as a material and its Life Cycle impacts have been added to the Design Products curriculum and the students have been set the challenge of designing a functional chair or seat in an American hardwood of their choice. The designs will be developed in to working prototypes with the help of Benchmark, internationally renowned for its craftsmanship in wood and long-standing relationship with designer Terence Conran.

The American Hardwood Export Council (AHEC) is well known in the international design community for its creative promotion of hardwood, having worked with the likes of David Adjaye, Matteo Thun, Sou Fujimoto, Arup and Amanda Levete. But now its attention has turned to the potential stars of the future with a unique and groundbreaking project for students.

Education and research provides a unique element to the project because AHEC is using, for the first time, its ground-breaking Life Cycle Assessment (LCA) research to help the students produce detailed Life Cycle impacts for their designs.

Each chosen prototype will be environmentally profiled using this i-report developed for AHEC by sustainability experts, PE International.

The LCI profiles of American hardwood are based on a critically reviewed LCA study. In addition AHEC is in the process of producing the first-ever Environmental Product Declaration for American hardwood lumber and veneer; it is this data that will be used by the students to build a full “cradle-to-grave” impact for their designs.

3 Scope of the study

3.1 Choice of Impact Categories

A comprehensive set of environmental impact categories has been investigated. The choice of categories was made based on the recommendations of the ILCD Handbook (ILCD Handbook, 2010) and the choice of indicators was made based on the European EPD rules for construction products (EN 15804, 2012).

The study life cycle impact assessment includes the following inventory flows and environmental categories: primary energy demand (total and non-renewable sources), global warming potential, photochemical oxidant creation potential (smog formation), acidification potential, stratospheric ozone depletion and eutrophication potentials.

In the selected impact categories the CML indicators were calculated. The methods and indicators for each category were chosen based on the European EPD rules for construction products (EN 15804, 2012).

The details of each impact category and its indicator are shown in tthe following table.

Category Indicator	Impact category	Description	Unit	Reference
Energy Use	Primary Energy Demand (PE)	A measure of the total amount of primary energy extracted from the earth. PE is expressed in energy demand from non-renewable resources (e.g. petroleum, natural gas, uranium, etc.) and energy demand from renewable resources (e.g. hydropower, wind energy, solar, etc.). Efficiencies in energy conversion (e.g. power, heat, steam, etc.) are taken into account.	MJ	Guinée et al., 2001, factors updated in 2010

Category Indicator	Impact category	Description	Unit	Reference
Climate Change	Global Warming Potential** (GWP)	A measure of greenhouse gas emissions, such as CO_2 and methane. These emissions are causing an increase in the absorption of radiation emitted by the earth, magnifying the natural greenhouse effect.	kg CO_2 equivalent	IPCC, 2006, *100 year GWP is used*
Eutrophication	Eutrophication Potential (CML)	A measure of emissions that cause eutrophying effects to the environment. The eutrophication potential is a stoichiometric procedure, which identifies the equivalence between N and P for both terrestrial and aquatic systems	kg Phosphate equivalent	Guinée et al., 2001, factors updated in 2010
Acidification	Acidification Potential (CML)	A measure of emissions that cause acidifying effects to the environment. The acidification potential is assigned by relating the existing S-, N-, and halogen atoms to the molecular weight.	kg SO2 equivalent	Guinée et al., 2001, factors updated in 2010
Ozone creation in troposphere	Photochemical Ozone Creation Potential (POCP)	A measure of emissions of precursors that contribute to low level smog, produced by the reaction of nitrogen oxides and VOC's under the influence of UV light.	kg Ethene equivalent	Guinée et al., 2001, factors updated in 2010
Stratospheric Ozone Depletion	Stratospheric Ozone Depletion	Refers to the thinning of the stratospheric ozone layer as a result of emissions. This effect causes a greater fraction of solar UV-B radiation to reach the surface earths, with potentially harmful impacts to human and animal health, terrestrial and aquatic ecosystems etc. referring trichlorofluoromethane, also called freon-11 or CFC 11	Kg CFC-11 equivalent or trichlorofluoro methane, also called freon-11 or R11	Guinée et al., 2001, factors updated in 2010

3.2 Biogenic carbon

During growth, carbon is stored in the wood via photosynthesis. This biogenic carbon is stored in the lumber and its subsequent products. The carbon stored in biomass will - sooner or later- be released – at the end of the product's life cycle. The end of the product's life cycle is not included in this study. The potential benefits from carbon storage, delayed emissions or substituting effect could be fully excluded or accounted differently according to different standards. To enable study stakeholders to utilise the data for different applications, and to avoid the AHEC communication being perceived as “green washing”, the stored (biogenic) carbon will be clearly quantified in the inventory for transparent carbon balance, and treated as a separate element in the report whilst not being subtracted from the Global Warming impact of the product.

Stored carbon that does not end up in the final lumber product, e.g. carbon stored in forest leftover biomass (e.g. small branches) or saw-mill co-products (e.g. chips, dust) is not assigned to the lumber. It is assumed to be eventually converted back to CO2 and emitted. Carbon in the forest floor or forest soil is not assigned to the lumber. Only the carbon that is stored in the final lumber product is accounted as stored carbon.

Not enough data is available on the carbon content in different hardwood species and a conservative value 46.27% carbon in abs dry mass was modeled as carbon storage for all hardwood species. This is a minimum value reported for hardwoods (Lamlom, Savidge, 2003).

Besides the carbon stored in the final lumber product, removals from the atmosphere from biogenic sources are not modeled in this study. Therefore, Biogenic carbon dioxide emissions are modeled as carbon neutral (no impact of the GWP) as they are offset by the uptake in biomass.

4 Results

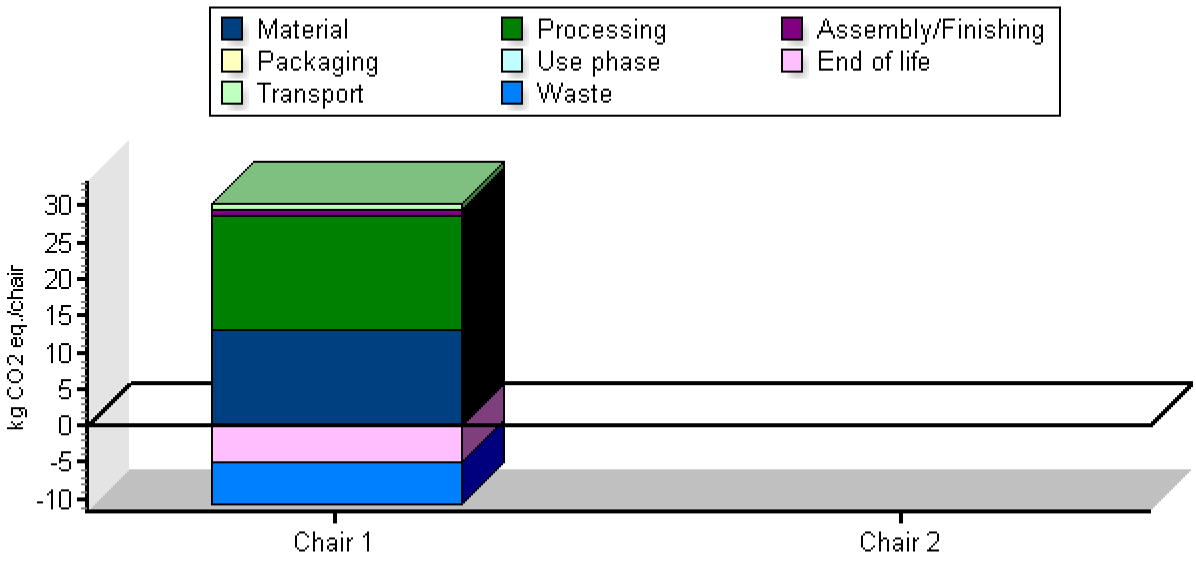
Overview Impact Assessment Chair1

	CML2001 - Nov. 2010, Acidification Potential (AP) [kg SO2-Equiv.]	CML2001 - Nov. 2010, Eutrophication Potential (EP) [kg Phosphate-Equiv.]	CML2001 - Nov. 2010, Global Warming Potential (GWP 100 years) [kg CO2-Equiv.]	CML2001 - Nov. 2010, Ozone Layer Depletion Potential (ODP, steady state) [kg R11-Equiv.]	CML2001 - Nov. 2010, Photochem. Ozone Creation Potential (POCP) [kg Ethene-Equiv.]	Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	Primary energy from resources (net cal. value) [MJ]
Assembly/Finishing	0,00	0,00	0,78	0,00	0,00	17,01	16,21
End of life	-0,01	0,00	-4,97	0,00	0,00	-83,04	-81,41
Material	0,10	0,01	13,14	0,00	0,03	736,13	186,30
Packaging							
Processing	0,05	0,00	15,48	0,00	0,00	253,53	241,75
Transport	0,00	0,00	0,77	0,00	0,00	11,02	10,61
Use phase	0,00	0,00	0,16	0,00	0,00	2,28	2,20
Waste	-0,01	0,00	-5,66	0,00	0,00	-94,11	-92,21

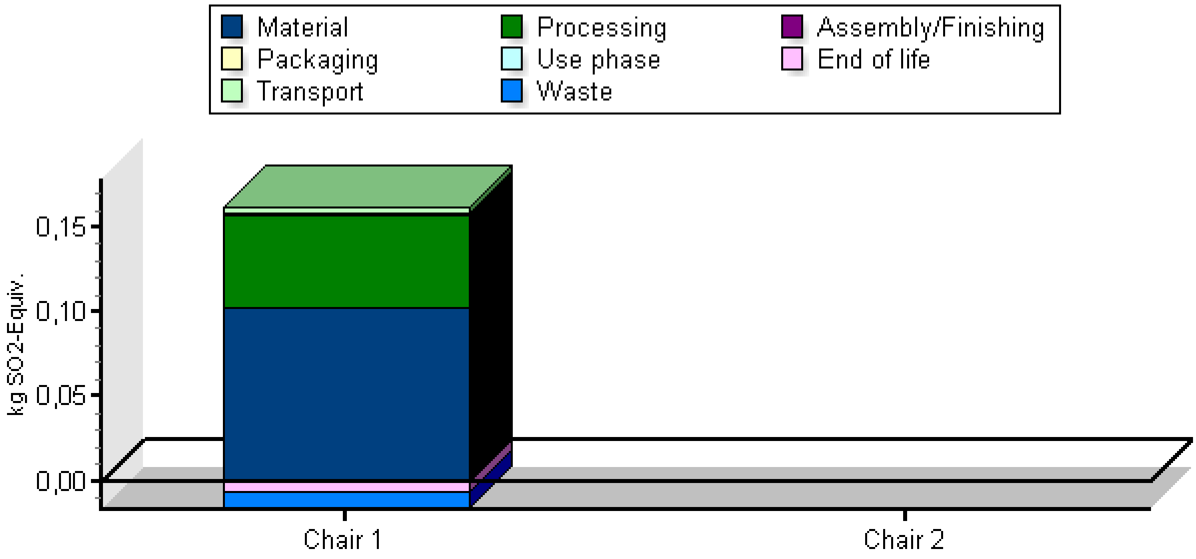
Overview Impact Assessment Chair2

	CML2001 - Nov. 2010, Acidification Potential (AP) [kg SO2-Equiv.]	CML2001 - Nov. 2010, Eutrophication Potential (EP) [kg Phosphate-Equiv.]	CML2001 - Nov. 2010, Global Warming Potential (GWP 100 years) [kg CO2-Equiv.]	CML2001 - Nov. 2010, Ozone Layer Depletion Potential (ODP, steady state) [kg R11-Equiv.]	CML2001 - Nov. 2010, Photochem. Ozone Creation Potential (POCP) [kg Ethene-Equiv.]	Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	Primary energy from resources (net cal. value) [MJ]
Assembly/Finishing							
End of life							
Material							
Packaging							
Processing							
Transport							
Use phase							
Waste							

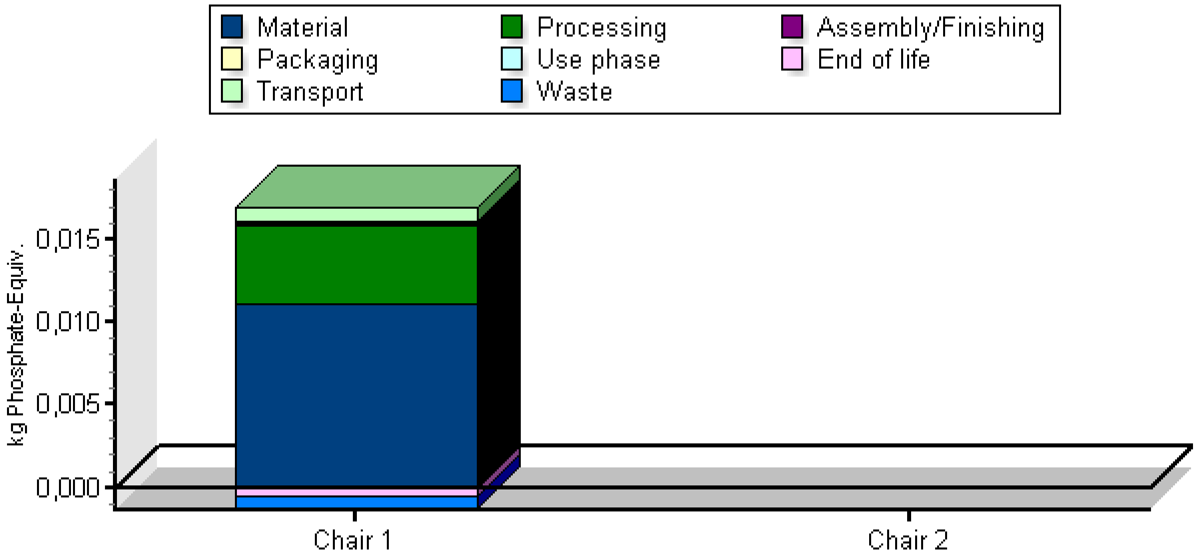
Comparison Global Warming Potential



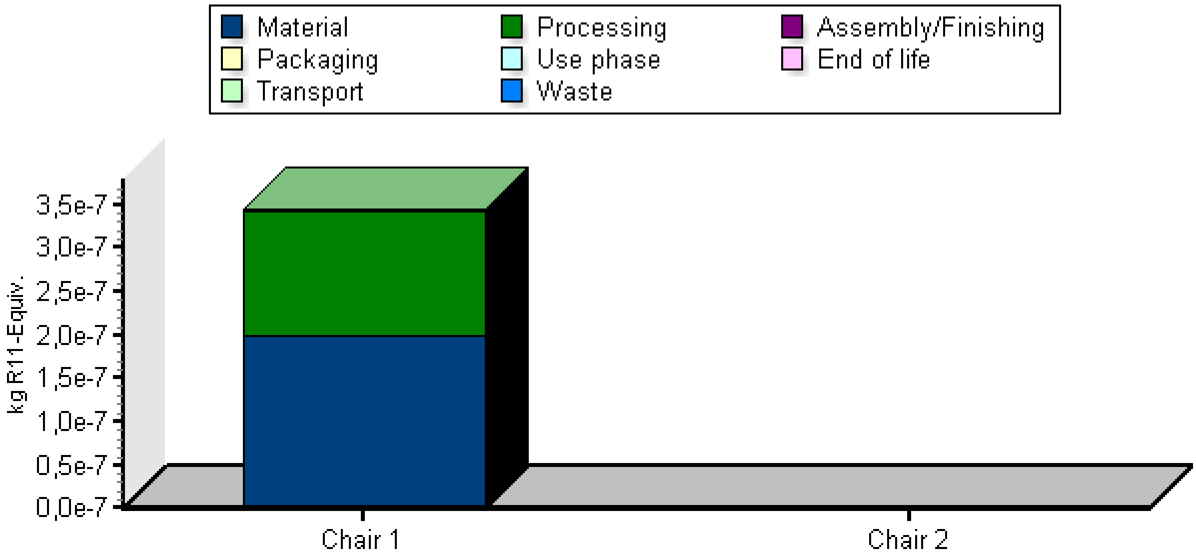
Comparison Acidification Potential



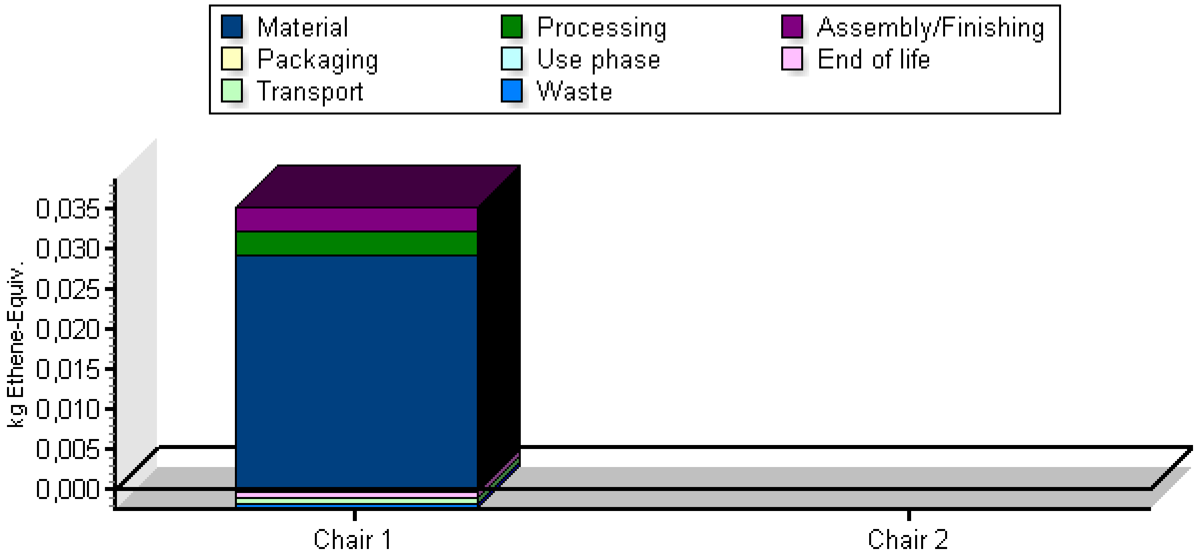
Comparison Eutrophication Potential



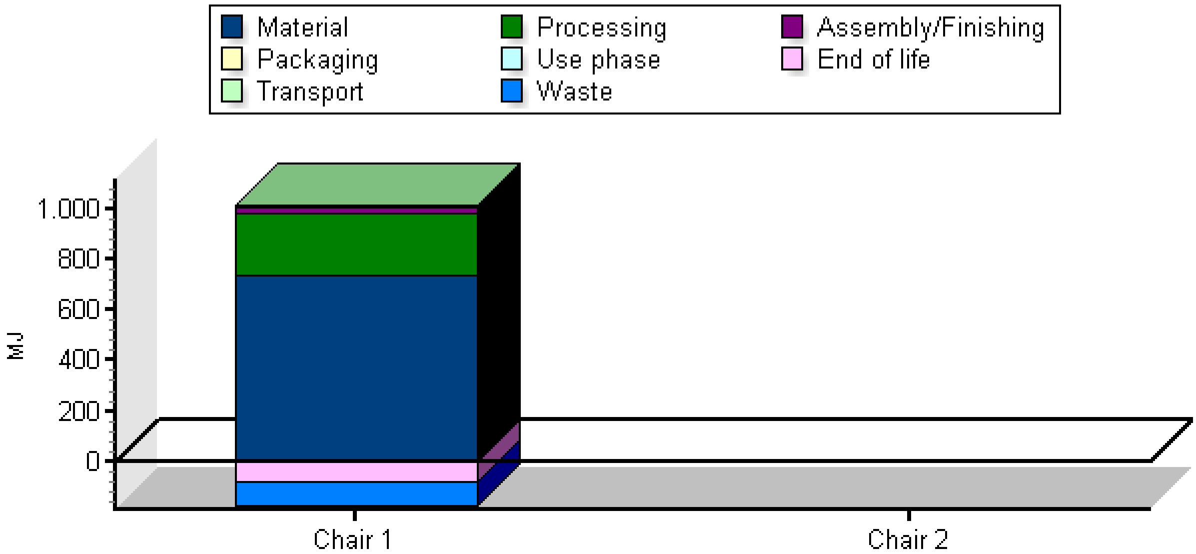
Comparison Ozone Depletion Potential



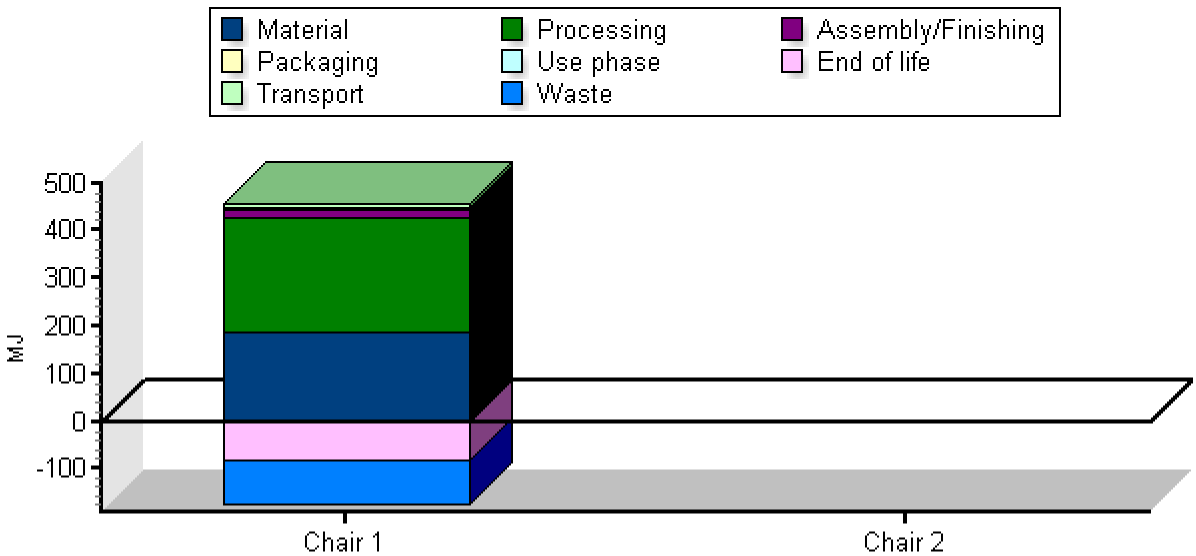
Comparison of Photochem. Ozone Creation Potential



Primary energy demand from ren. and non ren. resources



Primary energy from non-renewable resources



4.1 Impact Assessment of Material input

Acidification Potential (AP) [kg SO2-Equiv.]

	Chair 1	Chair 2
American Hardwood Lumber 1	0,03	
American Hardwood Lumber 2	0,04	
American Hardwood Lumber 3	0,01	
American Hardwood Lumber 4	0,01	
American Hardwood Lumber 5	0,02	
PP reinforced plastic		
Coating (solvent based)		
Coating (water based)	0,00	
Epoxy glue		
Nuts and bolds		
Leather		
Plywood		
PE (HD)		
PU		
PVA glue	0,00	
PU synthetic leather		
PVC synthetic leather		
Stainless steel sheet		
Steel sheet		
Wax		
Steel		
Plant based oil	0,00	
Aluminium sheet		
Brass		
Cotton fabric		
Polyamid 6.6 (PA 6.6) fabric		
Polyester (PET) fabric		
Polypropylene (PP)		

Eutrophication Potential (EP) [kg Phosphate-Equiv.]

	Chair 1	Chair 2
American Hardwood Lumber 1	0,00	
American Hardwood Lumber 2	0,00	
American Hardwood Lumber 3	0,00	
American Hardwood Lumber 4	0,00	
American Hardwood Lumber 5	0,00	
PP reinforced plastic		
Coating (solvent based)		
Coating (water based)	0,00	
Epoxy glue		
Nuts and bolds		
Leather		
Plywood		
PE (HD)		
PU		
PVA glue	0,00	
PU synthetic leather		
PVC synthetic leather		
Stainless steel sheet		
Steel sheet		
Wax		
Steel		
Plant based oil	0,00	
Aluminium sheet		
Brass		
Cotton fabric		
Polyamid 6.6 (PA 6.6) fabric		
Polyester (PET) fabric		
Polypropylene (PP)		

Global Warming Potential (GWP 100 years) [kg CO2-Equiv.]

	Chair 1	Chair 2
American Hardwood Lumber 1	3,31	
American Hardwood Lumber 2	5,38	
American Hardwood Lumber 3	0,88	
American Hardwood Lumber 4	0,87	
American Hardwood Lumber 5	2,70	
PP reinforced plastic		
Coating (solvent based)		
Coating (water based)	0,20	
Epoxy glue		
Nuts and bolds		
Leather		
Plywood		
PE (HD)		
PU		
PVA glue	0,57	
PU synthetic leather		
PVC synthetic leather		
Stainless steel sheet		
Steel sheet		
Wax		
Steel		
Plant based oil	0,01	
Aluminium sheet		
Brass		
Cotton fabric		
Polyamid 6.6 (PA 6.6) fabric		
Polyester (PET) fabric		
Polypropylene (PP)		

Carbon uptake (biogenic Carbon dioxide)

As stated above (3.4) the stored (biogenic) carbon is quantified seperately here for transparent carbon balance, and not being subtracted from the Global Warming impact of the product.

	Chair 1	Chair 2
Product Hardwood lumber <e-ep>	-7,35	
Product Hardwood lumber <e-ep>	-10,45	
Product Hardwood lumber <e-ep>	-2,19	
Product Hardwood lumber <e-ep>	-2,48	
Product Hardwood lumber <e-ep>	-6,02	

	Chair 1	Chair 2
Leather		
Plant based oil	-0,05	
Cotton fabric		

Ozone Layer Depletion Potential (ODP, steady state) [kg R11-Equiv.]

	Chair 1	Chair 2
American Hardwood Lumber 1	0,00	
American Hardwood Lumber 2	0,00	
American Hardwood Lumber 3	0,00	
American Hardwood Lumber 4	0,00	
American Hardwood Lumber 5	0,00	
PP reinforced plastic		
Coating (solvent based)		
Coating (water based)	0,00	
Epoxy glue		
Nuts and bolds		
Leather		
Plywood		
PE (HD)		
PU		
PVA glue	0,00	
PU synthetic leather		
PVC synthetic leather		
Stainless steel sheet		
Steel sheet		
Wax		
Steel		
Plant based oil	0,00	
Aluminium sheet		
Brass		
Cotton fabric		
Polyamid 6.6 (PA 6.6) fabric		
Polyester (PET) fabric		
Polypropylene (PP)		

Photochem. Ozone Creation Potential (POCP) [kg Ethene-Equiv.]

	Chair 1	Chair 2
American Hardwood Lumber 1	0,01	
American Hardwood Lumber 2	0,01	
American Hardwood Lumber 3	0,00	
American Hardwood Lumber 4	0,00	
American Hardwood Lumber 5	0,01	
PP reinforced plastic		
Coating (solvent based)		
Coating (water based)	0,00	
Epoxy glue		
Nuts and bolds		
Leather		
Plywood		
PE (HD)		
PU		
PVA glue	0,00	
PU synthetic leather		
PVC synthetic leather		
Stainless steel sheet		
Steel sheet		
Wax		
Steel		
Plant based oil	0,00	
Aluminium sheet		
Brass		
Cotton fabric		
Polyamid 6.6 (PA 6.6) fabric		
Polyester (PET) fabric		
Polypropylene (PP)		

Primary energy demand from fossil sources (non renewable resources) [MJ]

	Chair 1	Chair 2
American Hardwood Lumber 1	47,03	
American Hardwood Lumber 2	76,88	
American Hardwood Lumber 3	12,36	
American Hardwood Lumber 4	12,08	
American Hardwood Lumber 5	37,94	
PP reinforced plastic		
Coating (solvent based)		
Coating (water based)	4,04	
Epoxy glue		
Nuts and bolds		
Leather		
Plywood		
PE (HD)		
PU		
PVA glue	12,12	
PU synthetic leather		
PVC synthetic leather		
Stainless steel sheet		
Steel sheet		
Wax		
Steel		
Plant based oil	0,05	
Aluminium sheet		
Brass		
Cotton fabric		
Polyamid 6.6 (PA 6.6) fabric		
Polyester (PET) fabric		
Polypropylene (PP)		

Primary energy demand from renewable and fossil sources (non renwable) [MJ]

	Chair 1	Chair 2
American Hardwood Lumber 1	201,48	
American Hardwood Lumber 2	270,17	
American Hardwood Lumber 3	49,97	
American Hardwood Lumber 4	48,99	
American Hardwood Lumber 5	165,52	
PP reinforced plastic		
Coating (solvent based)		
Coating (water based)	4,21	
Epoxy glue		
Nuts and bolds		
Leather		
Plywood		
PE (HD)		
PU		
PVA glue	12,24	
PU synthetic leather		
PVC synthetic leather		
Stainless steel sheet		
Steel sheet		
Wax		
Steel		
Plant based oil	0,57	
Aluminium sheet		
Brass		
Cotton fabric		
Polyamid 6.6 (PA 6.6) fabric		
Polyester (PET) fabric		
Polypropylene (PP)		

5 Parameters

The following table illustrates the parameters for the chair designed by Lauren Davis

Szenario-Parameter			
	Chair 1	Chair 2	
Materials			
Wood			
Hardwood lumber 1			
Mass	4,33	0	[kg; material use, total input] Wood use
Species	Walnut	Ash	specify hardwood species
Thickness	2	1	[inch] please choose the value between 0-5 inch
loss	2,27	0	[kg; material loss] Wood waste
Hardwood lumber 2			

Mass	6,16	0	[kg; material use, total input] Wood use
Species	RedOak	Basswood	
Thickness	2	1	[inch] please choose the value between 0-5 inch
loss	3,22	0	[kg; material loss] Wood waste
Hardwood lumber 3			
Mass	1,29	0	[kg; material use, total input] Wood use
Species	Ash	Birch	
Thickness	2	1	[inch] please choose the value between 0-5 inch
loss	0,68	0	[kg; material loss] Wood waste
Hardwood lumber 4			
Mass	1,46	0	[kg; material use, total input] Wood use
Species	SoftMaple	Cottonwood	
Thickness	2	1	[inch] please choose the value between 0-5 inch
loss	0,76	0	[kg; material loss] Wood waste
Hardwood lumber 5			
Mass	3,55	0	[kg; material use, total input] Wood use
Species	Cherry	HardMaple	
Thickness	2	1	[inch] please choose the value between 0-5 inch
loss	1,86	0	[kg; material loss] Wood waste
Plywood	0	0	[kg; material use, total input] Plywood use
Plywood loss	0	0	[kg; material loss] Plywood waste
Recycled Hardwood	0	0	[kg; material use, total input] Recycled hardwood use
Recycled Hardwood loss	0	0	[kg; material loss] Recycled hardwood waste
Metals			
Steel sheet	0	0	[kg; material use, total input] Steel use (sheet)
Steel sheet losses	0	0	[kg; material loss] Steel waste (sheet)
Steel	0	0	[kg; material use, total input] Steel use (wire)
Steel wire losses	0	0	[kg; material loss] Steel waste (wire)
Stainless steel	0	0	[kg; material use, total input] Steel use (stainless)

Stainless steel losses	0	0	[kg; material loss] Steel waste (stainless)
Aluminum	0	0	[kg; material use, total input] Aluminum use
Aluminum losses	0	0	[kg; material loss] Aluminum waste
Brass	0	0	[kg; material use, total input] Brass use
Brass losses	0	0	[kg; material loss] Brass waste
Plastic			
Polyethylene	0	0	[kg; material use, total input] Use of plastic (Polyethylene, high density)
Polyethylene losses	0	0	[kg; material loss] waste of plastic (Polyethylene, high density)
Polyurethan foam/pad	0	0	[kg; material use, total input] Use of foam/pad (Polyurethane)
Polyurethan foam/pad losses	0	0	[kg; material loss] waste of foam/pad (Polyurethane)
Polypropylen	0	0	[kg; material use, total input] Use of plastic (Polypropylen)
Polypropylen losses	0	0	[kg; material loss] waste of plastic (Polypropylen)
Reinforced Polymer	0	0	[kg; material use, total input] Use of plastic (reinforced polymer)
Reinforced Polymer losses	0	0	[kg; material loss] waste of plastic (reinforced polymer)
Bio Resin	0	0	[kg; material use, total input] Bio Resin
Bio Resin loss	0	0	[kg; material loss] Bio Resin
Textiles			
Cotton fibre	0	0	[kg; material loss] Fabric (Cotton)
Cotton fibre losses	0	0	[kg; material use, total input] Fabric (Cotton)
Leather	0	0	[kg; material use, total input] Leather
Leather losses	0	0	[kg; material loss] leather waste
PUR synthetic leather	0	0	[kg; material use, total input] PUR synthetic leather
PUR synthetic leather losses	0	0	[kg; material loss] PUR synthetic leather waste
PVC sythetic leather	0	0	[kg; material use, total input] Fabric (synthetic leather)
PVC sythetic leather losses	0	0	[kg; material loss] Fabric (synthetic leather)

Polyamid fabric	0	0	[kg; material use, total input] Fabric (Polyamid)
Polyamid fabric losses	0	0	[kg; material loss] Fabric (Polyamid)
Polyester fabric	0	0	[kg; material use, total input] Fabric (Polyester)
Polyester fabric losses	0	0	[kg; material loss] Fabric (Polyester)
Machinery			
Machinery Use			
Cross cut saw	60	0	[min] Time cross cut saw is used
Straight line edger	0	0	[min] Time straight line edger is used
Four side planer	0	0	[min] Time four side planer is used
CNC	0	0	[min] Time CNC is used
Morticer	0	0	[min] Time morticer is used
Through feed sander	0	0	[min] Time through feed speed sander is used
Press	0	0	[min] Time press is used
Linisher	0	0	[min] Time through linisher is used
Machinery Capacity			
Cross cut saw	26,43	0	[kW] Energy requirement cross cut saw
Straight line edger	0	0	[kW] Energy requirement straight line edger
Four side planer	0	0	[kW] Energy requirement four sided planer
CNC	0	0	[kW] Energy requirement CNC
Morticer	0	0	[kW] Energy requirement morticer
Through feed sander	0	0	[kW] Energy requirement through feed speed sander
Press	0	0	[kW] Energy requirement press
Linisher	0	0	[kW] Energy requirement linisher
Assembly/Finishing			
Fixing Materials (nails, screws, bolts)	0	0	[kg] use of fixing materials (Screws, mails, bolts)
Glue (Epoxy resin)	0	0	[kg] use of Epoxy resin glue
PVA Glue	0,06	0	[kg] use of PVA glue
Paint/Laquer (water based)	0,06	0	[kg] use of water-based paint/laquer
Paint/Laquer (solvent based)	0	0	[kg] use of solvent-based paint/laquer
Plant based oil	0,01	0	[kg] use of plant based oil

Wax	0	0	[kg] use of Wax
Packaging			
Packaging foil	0	0	[kg; material use, total input] PP foil use for packaging
Cardboard	0	0	[kg; material use, total input] Cardboard for packaging
Use Phase			
Shipping to customer by rail	0	0	[km] distance start - end, default = 100 km
Shipping to customer by ship	0	0	[km] Distance seaborne transport (default=100km)
Shipping to customer by truck	100	0	[km] distance start - end, default = 100 km
Life span			
Durableness	1	0	[years] lifetime of chair (1= impact over complete lifespan; if >1 impact assessment per year of lifetime)