ENVIRONMENTAL LIFE - CYCLE ASSESSMENT

THE ROTUNDA SEROTINA

DESIGNED BY KOLMAN BOYE

MADE BY BENCHMARK IN AMERICAN CHERRY

KOLMAN × BOYE

BENCHMARK

AMERICAN HARDWOOD EXPORT COUNCIL

SUMMARY

The dominance of American cherry in the Rotunda and limited use of other more energy intensive materials contributes to a very strong environmental profile. Cherry is a highly desirable timber which is readily available in the U.S. forest but which has been underutilised in recent years. It takes less than a minute for new growth in the U.S. forest to replace the cherry logs harvested to manufacture the Rotunda. The Rotunda is carbon neutral on a cradle to grave basis. The carbon emissions associated with delivery of the wood and fabrication of the structure is more than offset by energy generated from offcuts and disposal at end of life. In addition around a tonne of CO_2 equivalent is sequestered in the main structure of the Rotunda and a further 295 kg in the trays.

WOOD RESOURCE

American black cherry, which grows extensively in Pennsylvania, New York, Virginia and West Virginia, is one of the world's fastest growing temperate hardwoods. It regenerates naturally and ages to a striking, rich reddish-brown colour. From a craftsman's point of view, cherry works and finishes well. And yet cherry is still being vastly underutilised. Cherry has become a victim of fashion which the forestry industry can ill afford given its 100-year planting and cropping plan. Establishing a balance between market demand and the dynamic of the forest is essential to achieve true sustainability.

U.S. forest inventory data[1] shows that cherry harvests could be greatly increased without undermining forest integrity or biodiversity. American cherry growing stock is 306 million m^3, 2.7% of total U.S. hardwood growing stock. American cherry is growing 8.6 million m^3 per year while the harvest is 3.5 million m^3 per year. After harvesting, an additional 5.1 million m^3 of cherry accumulate in U.S. forests every year. Growth exceeds harvest in all U.S. states.

It takes around 40 seconds for new growth in the U.S. forest to replace the cherry logs harvested to manufacture the Rotunda.

CARBON FOOTPRINT

The Rotunda is better than carbon neutral. The cradle-to-grave carbon footprint is -(minus) 231 kg of CO_2 equivalent. Emissions during all stages of material extraction and processing, manufacturing, and transport are 2742 kg of CO_2 equivalent. This is offset by 2973 kg of avoided emissions from energy recovery.

As a bespoke project with many individual elements, a high proportion of wood required to manufacture the Rotunda did not end up in the finished product. Wood was also required for the crates to transport the Rotunda from the UK to Milan (see Table).

TABLE 1 - KG OF MATERIAL INPUTS, OUTPUTS & FINISHED PRODUCT

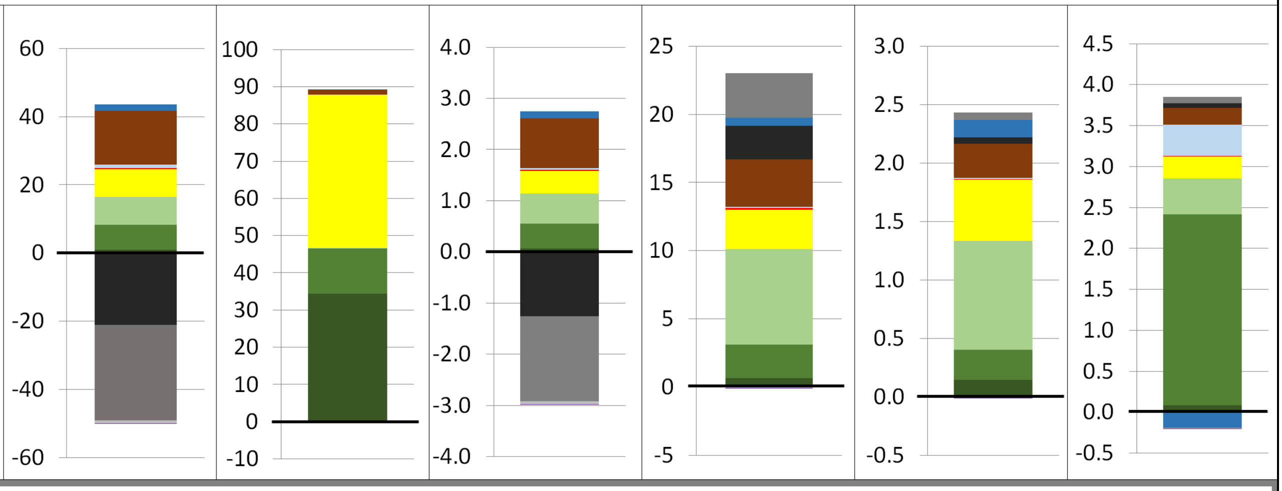
Element	Input materials		Waste wood		Finished product
	Wood	Other	Weight	% of input	
Structure	1626	2.26	1003	62%	625
Trays*	1054	7.00	506	48%	555
Crates	1833	5.50	601	33%	1237

** Total for the 1650 trays manufactured for the Rotunda*

CRADLE TO GRAVE ENVIRONMENTAL IMPACT OF THE ROTUNDA

Impact category	Primary energy demand (non-renewable)	Primary energy demand (renewable)	Global Warming Potential	Acidification Potential	Eutrophication Potential	Photochemical Ozone Creation Potential
Unit	GJ	GJ	tonnes CO2-Equiv.	kg SO2-Equiv.	kg Phosphate-Equiv.	kg Ethene-Equiv.
Total	-6	89	-0.23	22.9	2.43	3.65

Data by process steps



Key: Hardwood forestry; Hardwood processing; Hardwood transport; Other wood; Steel fixings; Glues & Coatings; Benchmark processing; Process waste; Transport to exhibition; Hardwood EoL; MDF EoL; Steel EoL

The significant volume of waste wood diverted to energy production offsets use of fossil fuels in other industrial processes and is therefore recorded as a credit in the LCA. The downside of wood wastage is that the long-term carbon storage potential is reduced. Nevertheless, 1042 kg CO_2 equivalent remains sequestered in the main structure of the Rotunda and a further 295 kg in the 1650 trays manufactured for the Rotunda.

OTHER IMPACTS

The eutrophication potential (EP) of the Rotunda is 2.43 kg of phosphate equivalent, about the same as caused each year by conventional farming of 0.11 hectares of land for wheat in the EU[2]. Most EP of the Rotunda is due to nitrate emissions during burning of fuels for transport and material processing. Hardly any EP is linked to growth of U.S. hardwoods which thrive under natural conditions and rarely require fertilisers.

TABLE 2 - MATERIALS USED FOR THE ROTUNDA

Wood materials	Use	Volume (m^3)
American cherry sawn	Trays	1.88
American cherry sawn	Main structure	2.90
MDF	Main structure	0.11
Joinery grade redwood	Transport crates	1.24
Spruce plywood	Transport crates	2.43
Other materials	**Use**	**Weight (Kg)**
Food Safe Oil	Tray finishing	7.00
Glue - Titebond 3	Main structure fixing	2.12
1" Masking tape	Main structure fixing	0.13
Osmo matt oil	Main structure finishing	0.01
Screws	Transport crate fixing	1.00
Glue	Transport crate fixing	3.00
Staples	Transport crate fixing	1.50

The Rotunda's acidification potential (AP) of 22.9 kg of SO_2 equivalent is mainly caused by emissions during shipping of hardwoods from the U.S. to the EU and is due to the high sulphur content of marine fuels.

The Rotunda's Photochemical Ozone Creation Potential (POCP) is 3.65 kg of Ethene equivalent. Processing of U.S. hardwoods makes a significant contribution to POCP due to the presence of terpenes, naturally occurring VOCs, in wood resin. Although terpenes are released naturally as trees grow, processes in which wood is heated lead to more significant emissions.

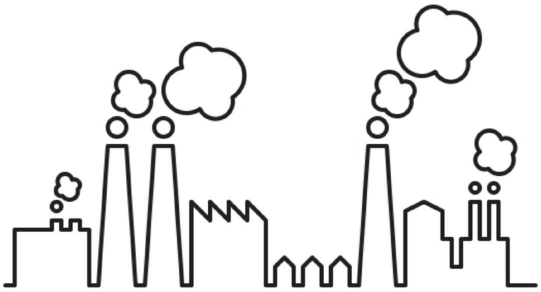
Renewable energy

Although 44 GJ of non-renewable (fossil fuel) energy was required during all life cycle stages to point of delivery in Milan, this is offset by 50 GJ of energy available from burning of wood offcuts during processing and waste wood at final disposal.

The 89 GJ input of renewable energy is due partly to the high proportion of thermal energy from burning of wood waste during processing of wood for the transport crates and the hardwood kiln drying process. At least 90% of all thermal energy used for kiln drying in the U.S. hardwood sector is derived from biomass.

The high proportion of renewable energy attributed to the forestry stage is a feature of life cycle inventory rules for wood products and has nothing to do with the energy for forestry operations. It is the solar energy absorbed by the tree during growth and converted into chemical energy within the wood itself. In other words it is the energy that would have been released if the wood were burnt immediately after harvest.

ENVIRONMENTAL IMPACT CATEGORIES

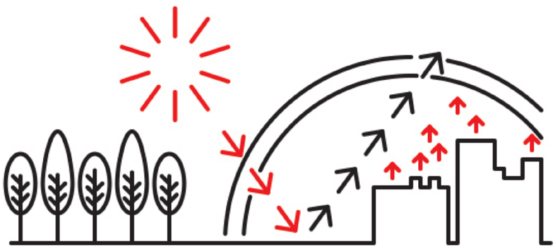


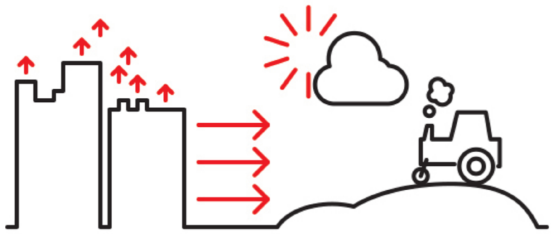
❶ PRIMARY ENERGY DEMAND (NON-RENEWABLE RESOURCES)

This is a measure of the total demand of primary energy that comes from non-renewable resources, such as oil and natural gas. Measured in gigajoules (GJ), the primary energy demand takes into account the conversion efficiencies from the primary energy to, for example, electricity. The generation of carbon dioxide from the production of energy is one of the major causes of global warming.

❷ PRIMARY ENERGY DEMAND (RENEWABLE RESOURCES)

Like the primary energy demand from non-renewable resources, this is a measure of the total amount of primary energy, but in this case, derived from renewable sources such as hydropower and wind energy. Again, it takes conversion efficiencies into account where appropriate. Total primary energy demand can be measured by adding the figures for energy from non-renewable and renewable resources



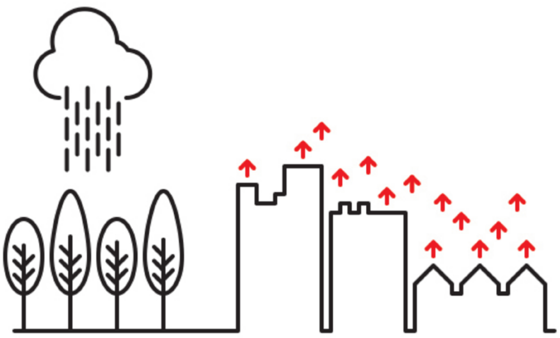


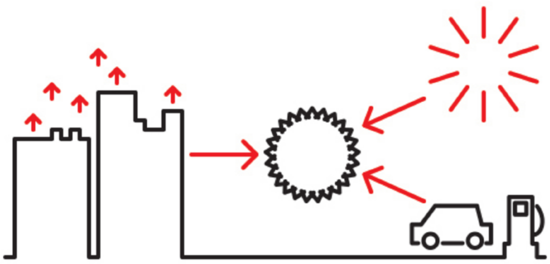
❸ GLOBAL WARMING POTENTIAL (GWP)

Global warming is usually regarded as one of the most significant environmental issues. Global Warming Potential, measured in kg CO2 equivalent, is also a good marker for other environmental impacts. It is calculated from the volumes of greenhouse gases, such as carbon dioxide and methane, emitted during a process.

❹ ACIDIFICATION POTENTIAL (AP)

This is a measure of the emissions that cause acidifying effects to the environment, which can cause imbalances and the death of species. Emissions of sulphur dioxide and nitrous oxide result in acid rain which can fall some way from the place where the emissions occur. Acidification potential is measured in kg of sulphur dioxide equivalent.





❺ EUTROPHICATION POTENTIAL (EP)

Eutrophication is the process by which water receives an excessive amount of nutrients, particularly phosphates and nitrates. These nutrients, which typically come from run-off from fertilisers, lead to algal blooms which, in turn, deprive the water of oxygen and lead to imbalances and deaths in the aquatic populations. Eutrophication is measured in terms of kg of phosphate equivalent, and kg of nitrogen equivalent.

❻ PHOTOCHEMICAL OZONE CREATION POTENTIAL (POCP)

This is a measure of emissions or precursors that contribute to low-level smog. It is measured in kg of ethene equivalent. Ozone layer depletion potential (ODP) is also part of the i-report but is not included in the charts because the effect is negligible. There may seem to be a contradiction between these two impacts but, put simply, high-level ozone is good and should be protected, whereas ozone at ground level is a pollutant.

NOTES

1. Figures based on 2011/2012 data from the U.S. Forest Service Forest Inventory and Analysis (FIA) program at http://www.fia.fs.fed.us/
2. Based on Williams et al 2010 at Cranfield Natural Resources Management Institute who for 1 tonne of bread wheat from conventional farming in the UK assessed Eutrophication Potential of 3.1 kg of phosphate equivalent and average occupation of 0.14 hectares of Grade 3a agricultural land.

ENVIRONMENTAL LIFE-CYCLE ASSESSMENT

Environmental life-cycle 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 (see page 3). LCA may also provide qualitative assessment of other environmental impacts such as on biodiversity and land-use that are less easy to quantify.

The LCA of the Rotunda builds on a two-year study, commissioned by AHEC and undertaken by *thinkstep* (formerly PE International), to assess environmental impacts associated with delivery of US hardwood material into world markets[a]. This involved a wide-ranging independent assessment of hardwood forestry practices and a survey of the hundreds of US companies engaged in the processing and export of hardwood products.

Life cycle inventory data from the LCA of U.S. hardwoods was combined with data gathered during product manufacture at Benchmark in the UK. It was also combined with *thinkstep*'s existing life-cycle inventory database which covers an expanding range of non-wood materials and product groups. Using *thinkstep*'s Gabi software for LCA, the data was analysed to quantify environmental impacts.

To model the cradle-to-grave impact of the Rotunda, the following assumptions are made about waste disposal during manufacture at Benchmark and at the end of the product's life.

- Wood waste generated during manufacture of the structure, trays and crates is combusted in a biomass boiler substituting for natural gas.
- No credit or burden is given for waste wood that is reused.
- Hardwood and other solid wood in the structure, trays and crates are combusted at end of life in a biomass boiler substituting for natural gas.
- MDF is disposed of in a waste incinerator producing electricity and thermal energy that avoid the UK grid mix and thermal energy from natural gas.
- Stainless steel screws are considered to be too small to be separately recycled and are also considered to be put through the incinerator and ultimately landfilled with the bottom ash.

These assumptions are based on information gathered from Benchmark about its standard procedures for use of waste and from secondary sources about waste-disposal practices in the UK.

a. The thinkstep *LCA study of US sawn hardwood is available at http://www.americanhardwood.org/fileadmin/docs/sustainability/Final_LCA_Lumber_report.pdf*