THE INVISIBLE STORE OF HAPPINESS

MADE IN AMERICAN CHERRY AND SOFT MAPLE

ENVIRONMENTAL LIFE - CYCLE ASSESSMENT

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SUMMARY

The use of American cherry and maple in the Invisible Store of Happiness combined with strong craftsmanship emphasising efficient material and energy use contributes to a very strong environmental profile. Both cherry and maple are highly desirable timbers which are readily available in the U.S. forest but which have been underutilised in recent years. It takes less than 15 seconds for new growth in the U.S. forest to replace the hardwood logs harvested to manufacture the Invisible Store. The carbon footprint of the structure is 36 kg CO_2 equivalent on a cradle to grave basis, less than half that of an Apple iphone[1]. Much of the energy input into material production derives from renewables. The waste wood produced during manufacturing and at End Of Life can be used for energy production, thereby offsetting use of fossil fuels.

Of course it would be a shame for such workmanship to be sent to the incinerator too soon. Such an outcome seems unlikely – the structure is designed to be readily dismantled and transported elsewhere. This fact, together with the quality, beauty and durability of the design, suggest the Invisible Store will remain on display and act as a carbon store for many years. Around 825 kg CO_2 equivalent is sequestered in the Invisible Store of Happiness.

CARBON FOOTPRINT

The cradle-to-grave carbon footprint of the Invisible Store of Happiness is 36 kg of CO_2 equivalent. Emissions during all stages of material extraction and processing, manufacturing, and transport are 1157 kg of CO_2 equivalent. This is offset by 1121 kg of avoided emissions resulting from substitution of fossil fuels through incineration of wood waste.

As a bespoke project with many individual elements, a high proportion of wood required to manufacture the Invisible Store did not end up in the finished product (see Table). However many of the larger wood offcuts were given to students who helped on the Invisible Store project for use in their own university projects. Sebastian Cox's studio is also making Christmas decorations, bowls, and chopping boards from the offcuts. The remaining solid waste offcuts were bagged for firewood. Sawdust and chipping was pelletized for biomass. Both firewood and pellets were made available for use by the local community.

The spruce ply and softwood was used for the steam bending jigs and is not contained in the finished structure. The jigs were designed for disassembly and for re-use. Offcuts during manufacture of the jigs were

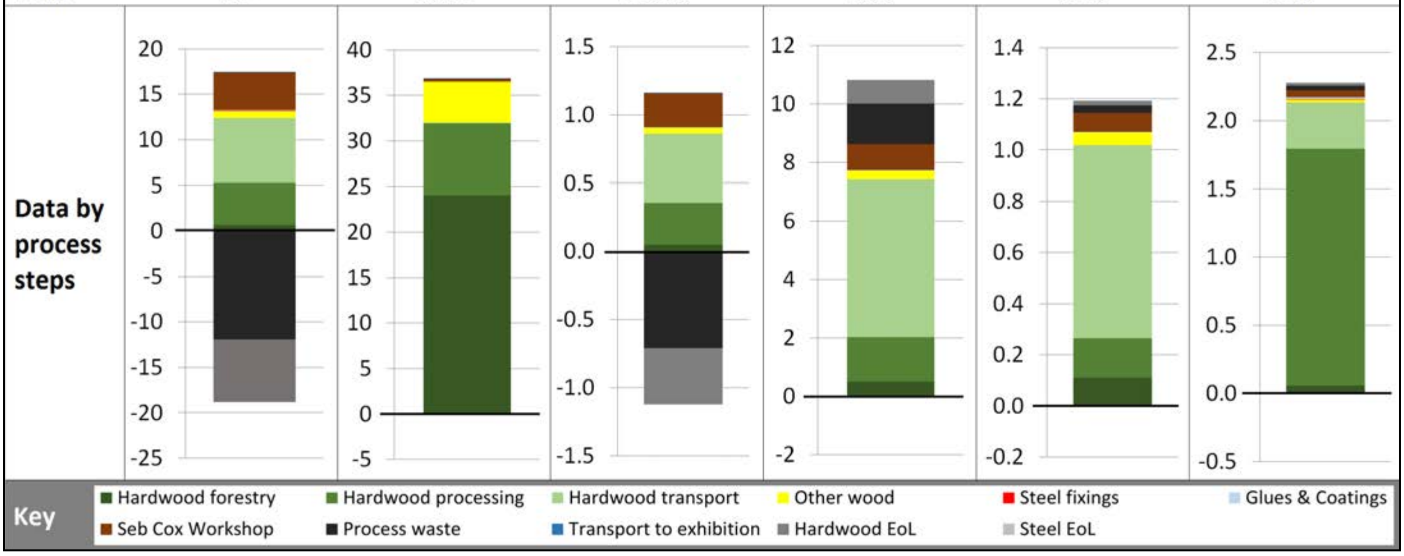
MATERIAL USE AND OUTPUTS FOR THE INVISIBLE STORE OF HAPPINESS

Material	Component	Quantity unit	Quantity used	In final structure		Waste for energy		Reused for other products	
				Quantity	Share	Quantity	Share	Quantity	Share
American Maple 1.25 inch	Structure	m^3	0.68	0.32	47%	0.24	35%	0.12	18%
American Cherry 1.5 inch	Structure	m^3	0.37	0.18	47%	0.13	35%	0.07	18%
American Cherry 2 inch	Structure	m^3	1.58	0.28	18%	1.02	64%*	0.28	18%
Spruce Ply sheets for jigs	Jig	m^3	0.25	0	0%	0	0%	0.25	100%
Spruce softwood for jigs	Jig	m^3	0.19	0	0%	0	0%	0.19	100%
Glue	Fixing	kg	0.70	0.70	100%	0	0%	0	0%
Steel (screws etc)	Fixing	kg	0.30	0.30	100%	0	0%	0	0%
Oil	Finishing	litre	0.25	0.25	100%	0	0%	0	0%

**This includes a significant volume of cherry wood wasted when trialing the manufacturing process in the early stages of the project.*

CRADLE TO GRAVE ENVIRONMENTAL IMPACT OF THE INVISIBLE STORE OF HAPPINESS

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	-1.4	36.8	0.036	10.8	1.19	2.27



also used as biomass.

The downside of wood wastage is that the long-term carbon storage potential is reduced. Nevertheless, 825 kg CO_2 equivalent remains sequestered in the Invisible Store and a further 357 kg CO_2 equivalent in the softwood and plywood jigs.

WOOD RESOURCE

American black cherry and American maple are some of the world's fastest growing temperate hardwoods. Both species regenerate naturally and are typically harvested through low intensity selection felling. Maple grows throughout the eastern United States, particularly concentrated in northern regions. Cherry grows extensively in Pennsylvania, New York, Virginia and West Virginia. Both cherry and maple are vastly underutilised. Both timbers have 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[2] shows that harvests of both maple and cherry could be greatly increased without undermining forest integrity or biodiversity. The volume of maple standing in U.S. forests grows at a rate of 49 million m^3 per year, while the harvest is only 20 million m^3 per year. After harvesting, 29 million m^3 of maple accumulate in U.S. forests every year. American cherry is growing 8.6 million m^3 per year while the harvest is 3.5 million m^3 per year. After harvesting, 5.1 million m^3 of cherry accumulate in U.S. forests every year. It takes around 13 seconds for new growth in the U.S. forest to replace the American hardwood logs harvested to manufacture the Invisible Store of Happiness.

OTHER IMPACTS

The eutrophication potential (EP) of the Invisible Store is 1.19 kg of phosphate equivalent, about the same as caused each year by conventional farming of 550 square meters of land for wheat in the UK[3]. Most EP of the Invisible Store 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.

The Invisible Store's acidification potential (AP) of 10.8 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.

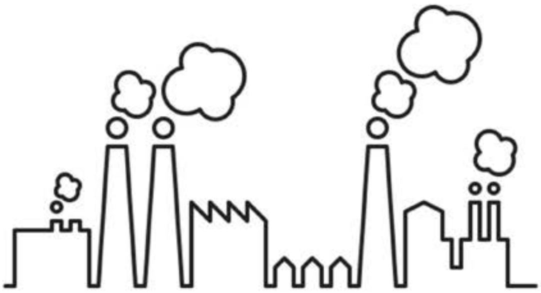
The Invisible Store's Photochemical Ozone Creation Potential (POCP) is 2.27 kg of Ethene equivalent. Processing of U.S. hardwoods makes a significant contribution to POCP due to the presence of terpenes, naturally occurring VOCs, in wood resin. Although terpenes are released naturally as trees grow, processes in which wood is heated lead to more significant emissions.

Renewable energy

Although 17.4 GJ of non-renewable (fossil fuel) energy was required during all life cycle stages to point of installation at Clerkenwell, this is offset by 18.8 GJ of energy available from burning of wood offcuts during processing and waste wood at final disposal.

The 37 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 jigs 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.

ENVIRONMENTAL IMPACT CATEGORIES

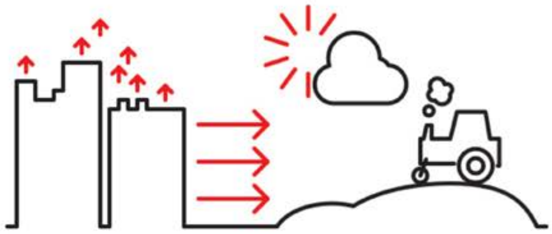


❶ PRIMARY ENERGY DEMAND (NON-RENEWABLE RESOURCES)

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

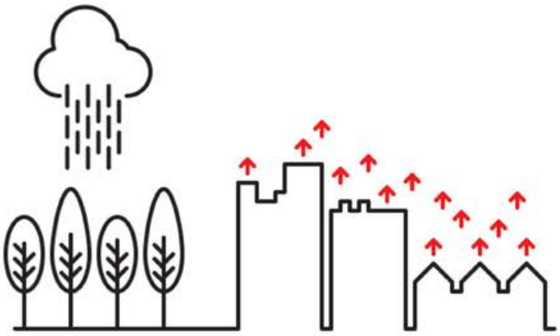


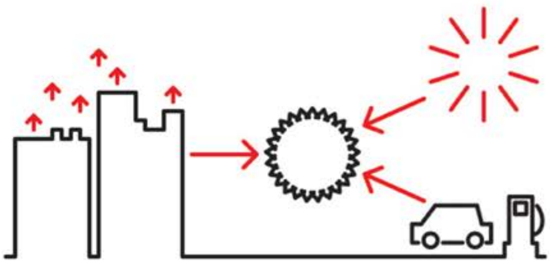
❸ GLOBAL WARMING POTENTIAL (GWP)

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. The carbon footprint of an Apple iphone 6 is 95 kg CO_2 equivalent according to the Apple Product Environmental Report available at http://www.apple.com/environment/reports/
2. 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/
3. 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 Invisible Store of Happiness 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 Sebastian Cox's studio 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 Invisible Store, the following assumptions are made:

- Of total wood input of 1.95 m^3 of cherry and 0.68 m^3 of soft maple, 0.35 m^3 (18%) and 0.12 m^3 (18%) respectively are allocated to co-products and not assigned to the Invisible Store of Happiness.
- Mass allocation is used to assign impacts between the main product and offcuts that are reused for other projects.
- Wood waste generated during manufacture of the structure is combusted in a biomass boiler substituting for natural gas.
- Hardwood in the structure is combusted at end of life in a biomass boiler substituting for natural gas.
- No credit is given in the carbon footprint for delayed carbon emissions due to storage in the structure or the jigs.
- 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.
- Data on transport of non-hardwood raw materials to the manufacturing site are modelled as being 100 km by road as robust data are lacking.

These assumptions are based on information gathered from Sebastian Cox about 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